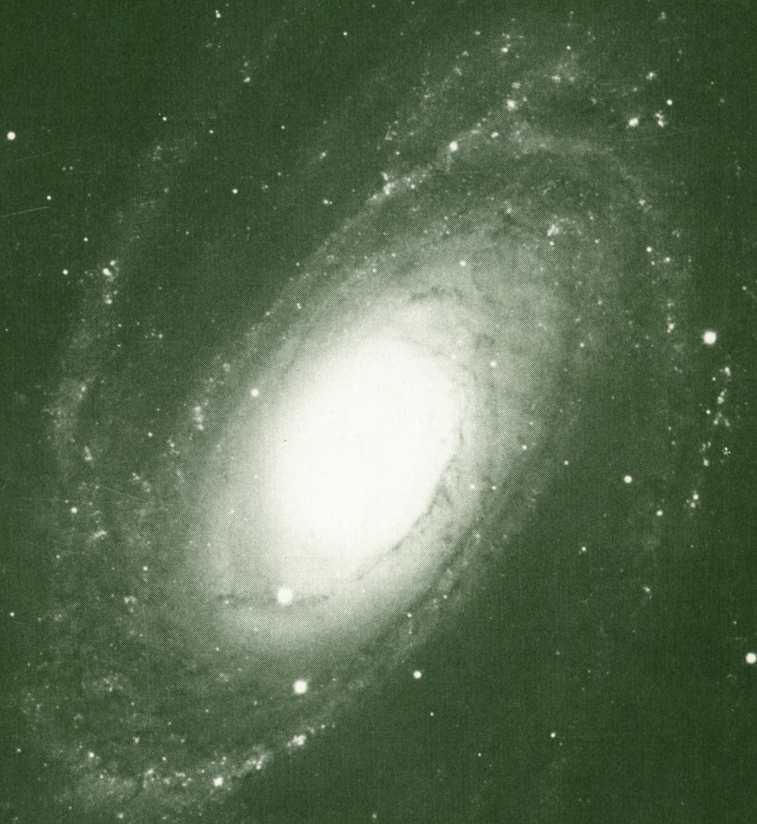
OBSERVER'S HANDBOOK



1984

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THE ROYAL ASTRONOMICAL SOCIETY OF CANADA

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OBSERVER'S HANDBOOK 1984

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THE ORIGINS OF THE ROYAL ASTRONOMICAL SOCIETY OF CANADA

In the mid-nineteenth century, in the bustling Lake Ontario port city of Toronto, there were no professional astronomers. However, many inhabitants of the city were keenly interested in sciences and current developments in them. King's College, which grew into the University of Toronto, had been started in 1842. In 1849 it had 36 undergraduates attending, and had graduated a total of 55 students in the three faculties of arts, law and medicine. The Toronto Magnetic Observatory had been established in 1840. Its early directors and observers were officers and soldiers in garrison. Some of them, such as Captain J. F. Lefroy, contributed much to the cultural life of the city. Out of this body of interest came the Canadian Institute established in 1849 "to promote those pursuits which are calculated to refine and exalt a people".

Besides holding weekly meetings, the Canadian Institute accumulated an outstanding library. There many hours were spent in study by Andrew Elvins who had come to Canada from Cornwall in 1844. In 1860 he moved to Toronto, with a population then of 44 000, and became chief cutter in a well known clothing store on King Street. While the Canadian Institute held discussion meetings of all sciences, Elvins wished to concentrate on astronomy. For this purpose he gathered together a few like-minded friends.

On December 1, 1868 The Toronto Astronomical Club met for the first time, at the Elvins' home, "having for its object the aiding of each other in the pursuit of astronomical knowledge". The thousands of meteor sightings of the Leonid showers made in Toronto in November 1867 and 1868 had doubtless encouraged the project. In May, 1869 the word "Club" was changed to "Society". Written records were kept for the first year, until the secretary moved away. After that, the group met only sporadically, but by the distribution of materials Elvins kept interest alive.

As the century wore on, Elvins, who lived till 1918, acquired more kindred spirits, some of them influential and prominent. As a result, on March 10, 1890 the organization was incorporated as The Astronomical and Astrophysical Society of Toronto. In May, 1900 chiefly through the efforts of one of the important early members George E. Lumsden, the name was changed to The Toronto Astronomical Society. On March 3, 1903 through legal application the name took on its current form, The Royal Astronomical Society of Canada. For many years the Society had its offices and library in the Canadian Institute buildings, and held meetings there.

Early in the 1890's, Dr. Clarence A. Chant of the University of Toronto became deeply interested in the Society. The impetus which he gave to it until his death in 1956 still lingers. During its first fifteen years the Society published annually volumes containing its Transactions and Annual Report. In 1907 Dr. Chant started The Journal of the Royal Astronomical Society of Canada, and this Handbook, called then "The Canadian Astronomical Handbook". It is a remarkable fact that at the time of his death Dr. Chant had been the Editor of both the Journal and the Handbook for exactly 50 years. During this period he received generous assistance from many of the Society's members. At times the Journal was published monthly, but currently it is bi-monthly.

The change of name in 1903 led immediately to the concept that the Society should not be limited to Toronto, but should become national in scope. The second Centre to be established was that of Ottawa in 1906, where the Dominion Observatory was being established. Now the Society has 20 Centres from sea to sea across Canada, as listed elsewhere in this Handbook. The growth in membership to nearly 3000 also shows its flourishing state.

HELEN SAWYER HOGG

EDITOR'S COMMENTS

On behalf of The Royal Astronomical Society of Canada, I wish to thank the contributors to the 1984 OBSERVER'S HANDBOOK (see the inside front cover). In particular I wish to welcome Fred Espenak (Eclipses), Robert Garrison (The Brightest Stars), and William Herbst (Galactic Nebulae) as new contributors. The latter two replace Donald MacRae (David Dunlap Observatory) and René Racine (Canada-France-Hawaii Telescope) respectively, both of whom have provided valuable support to the HANDBOOK over several years.

Several revisions and additions have been made for 1984. The table of physical elements of the solar system has been updated using the IAU (1976) system of astronomical constants (U.S. Naval Observatory Circular #163). Joseph Veverka has expanded the table on planetary satellites. The section on time has been revised, partly in response to the introduction of *Terrestrial Dynamical Time* in 1984. Thanks to the initiative of Fred Espenak, the section on eclipses has been considerably expanded. The magnitude limit for *total* lunar occultation predictions has again been changed (from 6.0 to 5.0) in recognition of the availability of more extensive predictions for experienced observers from other sources, and to give more emphasis to lunar graze events. Blyth Robertson has revised the section on meteorite impact sites. Janet Mattei has again provided new material for the variable stars section; this year it includes a description of the photoelectric photometry observing program of the AAVSO. Anthony Moffat has included some information on stellar associations in the star clusters section. William Herbst has revised the list of galactic nebulae to include more objects in the southern sky.

In addition to the regular contributors, several other individuals have provided ideas and support. I particularly want to thank Randall Brooks (St. Mary's University) for providing twilight times, information on an occultation by Neptune, and the base map for the path of Pluto. Leo Enright (Sharbot Lake, Ont.) provided input on the accuracy of the sidereal time equation.

The OBSERVER'S HANDBOOK could not exist without the strong, voluntary support of its twenty-four contributors and the provision of pre-publication material from *The Astronomical Almanac* by both the Nautical Almanac Office of the U.S. Naval Observatory and Her Majesty's Nautical Almanac Office of the Royal Greenwich Observatory. Additional support is provided by Rosemary Freeman, Executive-Secretary of The Royal Astronomical Society of Canada, and by the Department of Physics, Acadia University, Nova Scotia. In the latter instance, I especially wish to acknowledge the careful preparation of the lunar occultation tables, in both this and the previous two editions, by Julia Melzer.

Comments and suggestions should be directed to the Editor (address on the inside front cover). Good observing *quo ducit Urania*!

ROY L. BISHOP, EDITOR

COVER PHOTOGRAPH

The galaxy M81 (NGC 3031), taken with the Canada-France-Hawaii Telescope (IIaO emulsion, GG385 filter, 45 minute exposure), courtesy of Dr. René Racine, Executive Director. Discovered by J. E. Bode in Berlin in 1774, M81 is a fine example of a large, Sb-type spiral galaxy. It is the main member of a small group of galaxies near our own Local Group. At 12 million light years from us, we see M81 as it was at the beginning of the Pliocene epoch, when the primate stock ancestral to man appeared on the African savannahs.

REPORTING OF SIGNIFICANT ASTRONOMICAL DISCOVERIES

Professional and amateur astronomers who wish to report a possible discovery (e.g. a new comet, nova, or supernova) should send their report to Dr. Brian Marsden of the International Astronomical Union Central Bureau for Astronomical Telegrams, 60 Garden St., Cambridge, MA 02138, U.S.A. TWX/telex/telegraphic communication is preferred (TWX number: 710-320-6842 ASTROGRAM CAM), although 30 second messages will be recorded by telephone (1-617-864-5758). Messages are accepted at any time. Inexperienced observers are advised to have their observation checked, if at all possible, before contacting the Central Bureau. For an account of the history of the Bureau and its work today, see "Life in the Hot Seat", *Sky and Telescope*, August 1980, p. 92.

AN INVITATION FOR MEMBERSHIP IN THE ROYAL ASTRONOMICAL SOCIETY OF CANADA

The history of The Royal Astronomical Society of Canada goes back to the middle of the nineteenth century. The Society was incorporated within the province of Ontario in 1890, received its Royal Charter in 1903, and was federally incorporated in 1968. The National Office of the Society is located at 136 Dupont Street, Toronto, Ontario M5R 1V2, telephone (416) 924 7973. The business office and library are housed there.

The Society is devoted to the advancement of astronomy and allied sciences, and has members in many countries and from all walks of life. Any serious user of this HANDBOOK would benefit from membership. An applicant may affiliate with one of the twenty Centres across Canada, or may join the Society directly as an unattached member. Centres are located in Newfoundland (St. John's), Nova Scotia (Halifax), Quebec (Montreal (2), and Quebec), Ontario (Ottawa, Kingston, Toronto, Hamilton, Niagara Falls, Kitchener-Waterloo, London, Windsor, and Sarnia), Manitoba (Winnipeg), Saskatchewan (Saskatoon), Alberta (Edmonton and Calgary), and British Columbia (Vancouver and Victoria). Contact the National Office for the address of any of the Centres.

Members receive the publications of the Society free of charge: the OBSERVER'S HANDBOOK (published annually in November), and the bimonthly JOURNAL and NATIONAL NEWSLETTER which contain articles on many aspects of astronomy. The membership year begins October 1, and members receive the publications of the Society for the following calendar year. Annual fees are currently $20, and $12.50 for persons under 18 years. Life membership is $300. (To cover higher mailing costs, these fees are to be read as U.S. dollars for members outside of Canada. Also, persons wishing to affiliate with one of the Centres are advised that some Centres levy a small surcharge.)

SUGGESTIONS FOR FURTHER READING

The OBSERVER'S HANDBOOK is an annual guide to astronomical phenomena and data. The following is a brief list of publications which may be useful as an introduction to astronomy, as a companion to the HANDBOOK, or for advanced work. Star atlases are mentioned near the bottom of page 169.

Burnham, Robert. *Burnham's Celestial Handbook, Volumes 1, 2 and 3*. Dover Publications, Inc., New York, 1978. A detailed, well-presented, observer's guide to the universe beyond the solar system.

Harrison, E. R. *Cosmology*. Cambridge University Press, Cambridge, 1981. An elegant, stimulating introduction to the structure of the universe.

Hogg, Helen S. *The Stars Belong To Everyone*. Doubleday Canada Ltd., Toronto, 1976. Superb introduction to the sky.

Newton, Jack, and Teece, Philip. *The Cambridge Deep Sky Album*. Cambridge University Press, Cambridge, 1983. A photographic introduction to the Universe beyond the Solar System through a small telescope.

Peltier, L. C. *Guideposts To The Stars*. Collier-Macmillan Canada, Ltd., Ontario. Macmillan Publishing Co., New York, 1972. An enjoyable introduction to the stars by a man who loved the night.

Rükl, A. *Moon, Mars and Venus*. Hamlyn Publishing Group Ltd., Toronto and New York, 1976. A compact, detailed, lunar atlas.

Sherrod, P. C. *A Complete Manual of Amateur Astronomy*. Prentice-Hall, New Jersey, 1981. A comprehensive guide to observational astronomy for amateurs.

Sky and Telescope. Sky Publishing Corp., 49 Bay State Road, Cambridge, MA 02238. A monthly magazine containing articles on all aspects of astronomy.

Texereau, J. *How To Make A Telescope*. Doubleday and Co., New York, 1963. The best guide to making a Newtonian telescope.

VISITING HOURS AT SOME CANADIAN OBSERVATORIES AND PLANETARIA

COMPILED BY MARIE FIDLER

OBSERVATORIES

Algonquin Radio Observatory, Lake Traverse, Ontario K0A 2L0.
Tours by appointment only. Telephone (613) 735-0141.

Burke-Gaffney Observatory, Saint Mary's University, Halifax, Nova Scotia B3H 3C3.
October-April: Saturday evenings, 7:00 p.m.
May-September: Saturday evenings, 9:00 p.m.
Monday evening or daytime tours by arrangement. Phone 429-9780, ext. 184.

Canada-France-Hawaii Telescope, Mauna Kea, Hawaii, U.S.A. 96743.
R.A.S.C. members visiting "Big Island" are welcome to day-time visits of the CFHT installations. For appointment please phone (808) 885-7944.

David Dunlap Observatory, Richmond Hill, Ontario L4C 4Y6.
Tuesday mornings throughout the year, 10:00 a.m.
Saturday evenings, April through October, by reservation. Telephone (416) 884-2112.

Dominion Astrophysical Observatory, Victoria, B.C. V8X 3X3.
May-August: Daily, 9:15 a.m.–4:15 p.m.
September-April: Monday to Friday, 9:15 a.m.–4:15 p.m.
Public observing, Saturday evenings, April-October inclusive.

Dominion Radio Astrophysical Observatory, Penticton, B.C. V2A 6K3.
Conducted Tours: Sundays, July and August only, 2:00–5:00 p.m.
Visitors' Centre: Open year round during daylight hours.
For information please phone (604) 497-5321.

Hume Cronyn Observatory, University of Western Ontario, London, ON, N6A 3K7.
For tour and program information please phone (519) 679-3184.

National Museum of Science and Technology, 1867 St. Laurent Blvd., Ottawa, Ontario. K1A 0M8.
Evening tours, by appointment only. Telephone (613) 998-9520.
September-June: Group tours: Mon. through Thurs. Public visits, Fri.
July-August: Public visits: Tues., Wed., Thurs.

Observatoire astronomique du mont Mégantic, Notre-Dame-des-Bois, P.Q. J0B 2E0.
Telephone (819) 888-2822 for information on summer programs.

Gordon MacMillan Southam Observatory, 1100 Chestnut St., Vancouver, BC, V6J 3J9.
Open clear weekends and holidays (noon through 10:30 p.m.), and open 6 days per week during July and August (closed on non-holiday Mondays). Free admission. For information call (604) 738-2855.

University of British Columbia Observatory, 2219 Main Mall, Vancouver, B.C. V6T 1W5.
Free public observing, Saturday evenings: phone (604) 228-6186. Tours: phone (604) 228–2802.

PLANETARIA

Alberta Natural Resources Science Centre, Mobile Planetarium, P.O. Box 3182, Sherwood Park, Alberta T8A 2A6.

This planetarium travels throughout Alberta with public shows given Monday, Tuesday, and Thursday evenings. For locations and times, telephone (403) 427-9490, 9491 or 9492.

Calgary Centennial Planetarium, 701–11 Street S.W., P.O. Box 2100, Calgary, Alberta T2P 2M5.

For program information, telephone (403) 264-4060 or 264-2030.

Doran Planetarium, Laurentian University, Ramsey Lake Road, Sudbury, Ontario P3E 2C6.

Phone (705) 675-1151, ext. 381 for information.

Dow Planetarium, 1000 St. Jacques Street W., Montreal, P.Q. H3C 1G7.

Live shows in French and in English every open day except Monday. Closed 3 weeks in September after Labour Day. For general information telephone (514) 872-4530.

Edmonton Space Sciences Centre, Coronation Park, 142 St. and 111 Ave., Edmonton, Alberta.

Opening July 1, 1984. Features planetarium Star Theatre, IMAX film theatre, and exhibit galleries. Phone 452-9100 for program information.

The Halifax Planetarium, The Education Section of Nova Scotia Museum, Summer Street, Halifax, N.S. B3H 3A6.

Free public shows take place on some evenings at 8:00 p.m. and group shows can be arranged. For information, telephone (902) 429-4610.

The Lockhart Planetarium, 394 University College, 500 Dysart Road, The University of Manitoba, Winnipeg, Manitoba R3T 2M8.

For group reservations, telephone (204) 474-9785.

H.R. MacMillan Planetarium, 1100 Chestnut Street, Vancouver, B.C. V6J 3J9.

Public shows daily except Monday.
For show information telephone (604) 736-3656.

Manitoba Planetarium, 190 Rupert Avenue at Main Street, Winnipeg, Manitoba R3B 0N2.

For information call (204) 943-3142.

McLaughlin Planetarium, 100 Queen's Park, Toronto, Ontario M5S 2C6.

Public shows Tues.–Fri. 3:00 and 7:45. Additional shows on weekends and during summer. School shows and evening courses. Sky information (416) 978-5399. For show times and information call (416) 978-8550.

Ontario Science Centre, 770 Don Mills Road, Don Mills, Ontario M3C 1T3.

Open daily except Christmas Day from 10:00 a.m. to 6:00 p.m. Telephone (416) 429-4100.

University of Prince Edward Island Planetarium, Charlottetown, P.E.I. C1A 4P3

For show information telephone (902) 892-4121.

Queen Elizabeth Planetarium, Coronation Park, 139 St. & 114 Ave., Edmonton, Alberta T5J 0K1.

Phone 455-0119 for program information. Will close in 1984 when new Space Sciences Centre opens.

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SYMBOLS

SUN, MOON, AND PLANETS

☉ The Sun	☾ The Moon generally	♃ Jupiter
🌑 New Moon	☿ Mercury	♄ Saturn
🌕 Full Moon	♀ Venus	♅ Uranus
☽ First Quarter	⊕ Earth	♆ Neptune
☾ Last Quarter	♂ Mars	♇ Pluto

SIGNS OF THE ZODIAC

♈ Aries . . . . 0°	♌ Leo . . . . 120°	♐ Sagittarius . . . 240°
♉ Taurus . . . . . . 30°	♍ Virgo . . . . . . 150°	♑ Capricornus . . 270°
♊ Gemini . . . . . . 60°	♎ Libra . . . . 180°	♒ Aquarius . . . . 300°
♋ Cancer . . . . . . 90°	♏ Scorpius . . . . 210°	♓ Pisces . . . . 330°

THE GREEK ALPHABET

Α, α	Alpha	Ι, ι	Iota	Ρ, ρ	Rho
Β, β	Beta	Κ, κ	Kappa	Σ, σ	Sigma
Γ, γ	Gamma	Λ, λ	Lambda	Τ, τ	Tau
Δ, δ	Delta	Μ, μ	Mu	Υ, υ	Upsilon
Ε, ε	Epsilon	Ν, ν	Nu	Φ, φ	Phi
Ζ, ζ	Zeta	Ξ, ξ	Xi	Χ, χ	Chi
Η, η	Eta	Ο, ο	Omicron	Ψ, ψ	Psi
Θ, θ, ϑ	Theta	Π, π	Pi	Ω, ω	Omega

CO-ORDINATE SYSTEMS AND TERMINOLOGY

Astronomical positions are usually measured in a system based on the *celestial poles* and *celestial equator,* the intersections of Earth's rotation axis and equatorial plane, respectively, and the infinite sphere of the sky. *Right ascension* (R.A. or α) is measured in hours (h), minutes (m) and seconds (s) of time, eastward along the celestial equator from the *vernal equinox. Declination* (Dec. or δ) is measured in degrees (°), minutes (′) and seconds (″) of arc, northward (N or +) or southward (S or −) from the celestial equator toward the N or S celestial pole.

Positions can also be measured in a system based on the *ecliptic,* the intersection of Earth's orbit plane and the infinite sphere of the sky. The Sun appears to move eastward along the ecliptic during the year. *Longitude* is measured eastward along the ecliptic from the vernal equinox; *latitude* is measured at right angles to the ecliptic, northward or southward toward the N or S ecliptic pole. The *vernal equinox* is one of the two intersections of the ecliptic and the celestial equator; it is the one at which the Sun crosses the celestial equator moving from south to north.

Objects are *in conjunction* if they have the same longitude or R.A., and are *in opposition* if they have longitudes or R.A.'s which differ by 180°. If the second object is not specified, it is assumed to be the Sun. For instance, if a planet is "in conjunction", it has the same longitude as the Sun. At *superior conjunction,* the planet is more distant than the Sun; at *inferior conjunction,* it is nearer. (See the diagram on page 92.)

If an object crosses the ecliptic moving northward, it is at the *ascending node* of its orbit; if it crosses the ecliptic moving southward, it is at the *descending node.*

Elongation is the difference in longitude between an object and a second object (usually the Sun). At conjunction, the elongation of a planet is thus zero.

BASIC DATA

PRINCIPAL ELEMENTS OF THE SOLAR SYSTEM

MEAN ORBITAL ELEMENTS

Planet	Mean Distance from Sun		Period of Revolution		Eccentricity (e)	Inclination (i)	Long. of Node (☊)	Long. of Perihelion (π)	Mean Long. at Epoch (L)
	A	millions of km	Sidereal (P)	Synodic					
				days		°	°	°	°
Mercury	0.387	57.9	88.0d.	116	0.206	7.0	47.9	76.8	222.6
Venus	0.723	108.1	224.7	584	0.007	3.4	76.3	131.0	174.3
Earth	1.000	149.5	365.26	...	0.017	0.0	0.0	102.3	100.2
Mars	1.524	227.8	687.0	780	0.093	1.8	49.2	335.3	258.8
Jupiter	5.203	778.	11.86a	399	0.048	1.3	100.0	13.7	259.8
Saturn	9.539	1427.	29.46	378	0.056	2.5	113.3	92.3	280.7
Uranus	19.18	2869.	84.01	370	0.047	0.8	73.8	170.0	141.3
Neptune	30.06	4497.	164.8	367	0.009	1.8	131.3	44.3	216.9
Pluto	39.44	5900.	247.7	367	0.250	17.2	109.9	224.2	181.6

These elements, for epoch 1960 Jan. 1.5 E.T., are taken from the *Explanatory Supplement to the American Ephemeris and Nautical Almanac.*

PHYSICAL ELEMENTS

Object	Equat. Diam. km	Oblateness	Mass** ⊕ = 1	Density g/cm^3	Gravity ⊕ = 1	Esc. Speed km/s	Rotn. Period d	Incl. °	Albedo
☉ Sun	1 392 000	0	332 946.0	1.41	27.9	617.5	25–35*		—
☾ Moon	3 476	0	0.012300	3.34	0.17	2.4	27.3217	6.7	0.12
☿ Mercury	4 878	0	0.055274	5.43	0.38	4.3	58.65	0.0	0.106
♀ Venus	12 104	0	0.814998	5.24	0.90	10.4	243.0	177.4	0.65
⊕ Earth	12 756	1/298	1.000000	5.52	1.00	11.2	0.9973	23.4	0.36
♂ Mars	6 794	1/164	0.107447	3.93	0.38	5.0	1.0260	25.2	0.15
♃ Jupiter	142 800	1/16	317.892	1.33	2.53	59.6	0.410	3.1	0.52
♄ Saturn	120 000	1/9	95.168	0.71	1.07	35.6	0.427	26.7	0.47
⛢ Uranus	50 800	1/30	14.559	1.31	0.92	21.4	0.45†	97.9	0.50
♆ Neptune	48 600	1/30	17.239	1.77	1.19	23.8	0.67†	29.6	0.41
♇ Pluto	3 000?	?	0.0026?	1.1?	0.05?	1.2?	6.3867	118?	0.5?

The table gives the *mean* density, the gravity and escape speed *at the pole* and the inclination of equator *to orbit*. Evidence in 1977 suggests that the equatorial diameter of Uranus may be 55,800 km and that its oblateness may be 1/120.

*depending on latitude

†There is some evidence that the rotation periods of Uranus and Neptune are 1.0 and 0.76 day, respectively; these values are larger than those given in the table.

**For the planets other than Earth, these masses include the contribution from satellites.

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SATELLITES OF THE SOLAR SYSTEM

By Joseph Veverka

Name	Diam. (km)	Mass (10^{20} kg) Density (t/m^3)	Mean Dist. from Planet (10^3 km/″) Rev. Period (D)	Eccentricity Orbit Incl (°)	Vis. Mag. Vis. Albedo	Discovery
Satellite of Earth						
Moon	3476	734.9 ± 0.7 3.34	384.5/ — 27.322	0.0549 18–29	−12.7 0.11	
Satellites of Mars						
I Phobos	21	(1.3 ± 0.2) × 10^{-4} ~2	9.4/ 25 0.319	0.015 1.1	11.6 0.07	A. Hall, 1877
II Deimos	12	(1.8 ± 0.2) × 10^{-5} ~2	23.5/ 63 1.263	0.0005 1.8v	12.7 0.07	A. Hall, 1877
Satellites of Jupiter						
XVI Metis	(40)	— —	128/ 42 0.294	0 —	17.5 (0.05)	S. Synnott, 1979
XIV Adrastea	(25)	— —	129/ 42 0.297	0 —	18.7 (0.05)	D. Jewitt, 1979
V Amalthea	170	— —	180/ 59 0.498	0.003 0.4	14.1 0.05	E. Barnard, 1892
XV Thebe	(80)	— —	222/ 73 0.674	0.013 —	16.0 (0.05)	S. Synnott, 1979
I Io	3630	892 ± 4 3.55	422/138 1.769	0 0	5.0 0.6	Galileo, 1610
II Europa	3140	487 ± 5 3.04	671/220 3.551	0 0.5	5.3 0.6	Galileo, 1610
III Ganymede	5260	1 490 ± 6 1.93	1 070/351 7.155	0.001 0.2	4.6 0.4	Galileo, 1610

Apparent magnitude and mean distance from planet are at mean opposition distance. The inclination of the orbit is referred to the planet's equator; a value greater than 90° indicates retrograde motion.

Values in parentheses are uncertain.

Note: Pronunciations of the names of the planetary satellites are given on p. 93.

Name	Diam. (km)	Mass (10^{20} kg) Density (t/m³)	Mean Dist. from Planet (10^3 km/″) Rev. Period (D)	Eccen-tricity Orbit Incl (°)	Vis. Mag. Vis. Albedo	Discovery
IV Callisto	4800	1075 ± 4 1.83	1 885/ 618 16.689	0.007 0.2	5.6 0.2	Galileo, 1610
XIII Leda	(15)	— —	11 110/3640 240	0.147 26.7	20 —	C. Kowal, 1974
VI Himalia	185	— —	11 470/3760 251	0.158 27.6	14.8 0.03	C. Perrine, 1904
X Lysithea	(35)	— —	11 710/3840 260	0.130 29.0	18.4 —	S. Nicholson, 1938
VII Elara	75	— —	11 740/3850 260	0.207 24.8	16.8 0.03	C. Perrine, 1905
XII Ananke	(30)	— —	20 700/6790 617	0.17 147	18.9 —	S. Nicholson, 1951
XI Carme	(40)	— —	22 350/7330 692	0.21 164	18.0 —	S. Nicholson, 1938
VIII Pasiphae	(50)	— —	23 330/7650 735	0.38 145	17.1 —	P. Melotte, 1908
IX Sinope	(35)	— —	23 370/7660 758	0.28 153	18.3 —	S. Nicholson, 1914
SATELLITES OF SATURN						
XVII Atlas	30	— —	137/ 23 0.601	0.002 0.3	(18) 0.4	Voyager Team, 1980
XVI 1980S27	100	— —	139/ 23 0.613	0.004 0.0	(13.5) 0.6	Voyager Team, 1980
XV 1980S26	90	— —	142/ 24 0.628	0.004 0.1	(14) 0.5	Voyager Team, 1980
X Janus	190	— —	151/ 25 0.695*	0.009 0.3	(14) 0.6	Dollfus, Fountain, Larson, 1966
XI Epimetheus	120	— —	151/ 25 0.695*	0.007 0.1	(14.5) 0.5	Fountain, Larson, Dollfus, 1966
I Mimas	390	0.38 ± 0.01 1.2	187/ 30 0.942	0.020 1.5	12.5 0.7	W. Herschel, 1789
II Enceladus	500	0.8 ± 0.3 1.1	238/ 38 1.370	0.004 0.02	11.8 1.0	W. Herschel, 1789

*Co-orbital satellites.

Name	Diam. (km)	Mass (10^{20} kg) Density (t/m^3)	Mean Dist. from Planet (10^3 km/″) Rev. Period (D)	Eccentricity Orbit Incl (°)	Vis. Mag. Vis. Albedo	Discovery
III Tethys	1060	7.6 ± 0.9 1.2	295/ 48 1.888	0.000 1.1	10.3 0.8	G. Cassini, 1684
XIII Telesto	25	— —	295/ 48 1.888[a]	— —	(18) 1.0	1980*
XIV Calypso	25	— —	295/ 48 1.888[b]	— —	(18) 0.7	1980*
IV Dione	1120	10.5 ± 0.3 1.4	378/ 61 2.737	0.002 0.02	10.4 0.6	G. Cassini, 1684
1980S6	30	— —	378/ 61 2.737[c]	0.005 —	(17.5) 0.6	1980*
V Rhea	1530	24.9 ± 1.5 1.3	526/ 85 4.517	0.001 0.4	9.7 0.6	G. Cassini, 1672
VI Titan	5550†	1345.7 ± 0.3 1.88	1 221/ 197 15.945	0.029 0.3	8.4 0.2	C. Huygens, 1655
VII Hyperion	255	— —	1 481/ 239 21.276	0.104 0.4	14.2 0.3	G. Bond, W. Lassell, 1848
VIII Iapetus	1460	18.8 ± 1.2 1.2	3 561/ 575 79.331	0.028 14.7	11.0v 0.08 −0.4	G. Cassini, 1671
IX Phoebe	220	— —	12 960/2096 550.46	0.163 150	16.5 0.05	W. Pickering, 1898
Satellites of Uranus						
V Miranda	(300)	— —	130/ 9 1.414	0.017 3.4	16.5 —	G. Kuiper, 1948
I Ariel	1350	(17) 1.3 ± 0.5	192/ 14 2.520	0.0028 0	14.0 0.3	W. Lassell, 1851
II Umbriel	1100	(10) 1.4 ± 0.5	267/ 20 4.144	0.0035 0	14.9 0.2	W. Lassell, 1851

*Observed both from Earth and by Voyager spacecraft. Priority of discovery is under consideration by the International Astronomical Union.

[a]Librates about trailing (L_5) Lagrangian point of Tethys' orbit.

[b]Librates about leading (L_4) Lagrangian point of Tethys' orbit.

[c]Librates about leading (L_4) Lagrangian point of Dione's orbit with a period of ~790 D.

†Cloud-top diameter. Solid-body diameter equals 5150 km.

Name	Diam. (km)	Mass (10^{20} kg) Density (t/m^3)	Mean Dist. from Planet (10^3 km/″) Rev. Period (D)	Eccentricity Orbit Incl (°)	Vis. Mag. Vis. Albedo	Discovery
III Titania	1600	(58) 2.7 ± 0.6	438/ 33 8.706	0.0024 0	13.9 0.2	W. Herschel, 1787
IV Oberon	1650	(61) 2.6 ± 0.6	587/ 44 13.463	0.0007 0	14.1 0.2	W. Herschel, 1787
SATELLITES OF NEPTUNE						
I Triton	(3500)	1300? ?	354/ 17 5.877	<0.0005 160.0	13.6 (0.4)	W. Lassell, 1846
II Nereid	(300)	— —	5 600/264 365.21	0.75 27.6	18.7 —	G. Kuiper, 1949
SATELLITE OF PLUTO						
I Charon	(1300)	— —	20.0/0.9 6.387	0 0	17 —	J. Christy, 1978

TELESCOPE PARAMETERS

(where D = diameter of aperture in millimetres)

Limiting Visual Magnitude $m_l \simeq 2.7 + 5 \log D$, assuming transparent, dark-sky conditions and magnification ⩾ 1D. (See article by R. Sinnott, *Sky and Telescope*, *45*, 401, 1973)

Smallest Resolvable Angle $\theta \simeq 120/D$ seconds of arc. However, atmospheric conditions seldom permit values less than 0″.5.

Useful Magnification Range ≃ 0.2D to 2D. The lower limit may be a little less, but depends upon the maximum diameter of the entrance pupil of the individual observer's eye. Also, 0.2D provides better contrast than a lower value. The upper limit is determined by the wave nature of light and the optical limitations of the eye, although atmospheric turbulence usually limits the maximum magnification to 500x or less. For examination of double stars, magnifications up to 4D are sometimes useful. Note that the reciprocal of the coefficient to D is the diameter (in mm) of the telescope's exit pupil.

Values for some common apertures are:

D (mm)	60	75	100	125	150	200	350	400
m_l	11.6	12.1	12.7	13.2	13.6	14.2	15.4	15.7
θ (″)	2.0	1.6	1.2	1.0	0.80	0.60	0.34	0.30
0.2D	12x	15x	20x	25x	30x	40x	70x	80x
2D	120x	150x	200x	250x	300x	400x	700x	800x

SOME ASTRONOMICAL AND PHYSICAL DATA

D

LENGTH

1 astronomical unit (A)	= 1.495 978 70 × 10^{11} m = 499.004 782 light seconds
1 light year (ly)	= 9.460 536 × 10^{15} m (based on average Gregorian year)
	= 63 239.8 AU
1 parsec (pc)	= 3.085 678 × 10^{16} m
	= 206 264.8 AU = 3.261 631 light years
1 mile	≡ 1.609 344 km
1 Angstrom	≡ 0.1 nm

TIME

Day:	Mean sidereal (equinox to equinox)	= 86 164.094 s
	Mean rotation (fixed star to fixed star)	= 86 164.102 s
	Day (D)	≡ 86 400. s
	Mean solar	= 86 400.003 s
Month:	Draconic (node to node)	= 27.212 22 D
	Tropical (equinox to equinox)	= 27.321 58 D
	Sidereal (fixed star to fixed star)	= 27.321 66 D
	Anomalistic (perigee to perigee)	= 27.554 55 D
	Synodic (New Moon to New Moon)	= 29.530 59 D
Year:	Eclipse (lunar node to lunar node)	= 346.6201 D
	Tropical (equinox to equinox)	= 365.2422 D
	Average Gregorian	= 365.2425 D
	Average Julian	= 365.2500 D
	Sidereal (fixed star to fixed star)	= 365.2564 D
	Anomalistic (perihelion to perihelion)	= 365.2596 D

EARTH

Mass = 5.974 × 10^{24} kg
Radius: Equatorial, a = 6378.140 km; Polar, b = 6356.755 km;
Mean, $\sqrt[3]{a^2b}$ = 6371.004 km
1° of latitude = 111.133 − 0.559 cos 2ϕ km (at latitude ϕ)
1° of longitude = 111.413 cos ϕ − 0.094 cos 3ϕ km
Distance of sea horizon for eye h metres above sea-level ~3.9$\sqrt{h}$ km (refraction inc.)
Standard atmospheric pressure = 101.325 kPa (~1 kg above 1 cm^2)
Speed of sound in standard atmosphere = 331 m s^{-1}
Magnetic field at surface ~5 × 10^{-5} T
Magnetic poles: 76°N, 101°W; 66°S, 140°E
Surface gravity at latitude 45°, g = 9.806 m s^{-2}
Age ~4.6 Ga
Meteoric flux ~1 × 10^{-15} kg m^{-2} s^{-1}
Escape speed from Earth = 11.2 km s^{-1}
Solar parallax = 8″.794 148
Constant of aberration = 20″.495 52
Obliquity of ecliptic = 23°.4414 (1984.0)
Annual general precession = 50″.26; Precession period = 25 800 a
Orbital speed = 29.8 km s^{-1}
Escape speed at 1 AU from Sun = 42.1 km s^{-1}

SUN

Mass ≡ 1S = 1.9891 × 10^{30} kg; Radius = 696 265 km; Eff. temperature = 5770 K
Output: Power = 3.83 × 10^{26} W; M_{bol} = 4.75
Luminous intensity = 2.84 × 10^{27} cd; M_V = 4.84
At 1 AU, outside Earth's atmosphere:
Energy flux = 1.36 kW m^{-2}; m_{bol} = −26.82
Illuminance = 1.27 × 10^5 lx; m_V = −26.74

Solar wind speed near Earth ~450 km s^{-1} (travel time, Sun to Earth ~5 D)
Solar velocity = 19.75 km s^{-1} toward α = 18.07 h, δ = +30° (solar apex)

MILKY WAY GALAXY

Mass ~10^{12} solar masses
Centre: α = 17 h 42.5 min, δ = −28° 59′ (1950)
Distance to centre ~9 kpc, diameter ~100 kpc
North pole: α = 12 h 49 min, δ = 27° 24′ (1950)
Rotational speed (at Sun) ~250 km s^{-1}
Rotational period (at Sun) ~220 Ma
Velocity relative to the 3 K background ~600 km s^{-1} toward $\alpha \sim$ 10 h, $\delta \sim -20°$

MISCELLANEOUS CONSTANTS

Speed of light, c = 299 792 458. m s^{-1}
Planck's constant, h = 6.6262×10^{-34} J s
Gravitational constant, G = 6.672×10^{-11} N m^2 kg^{-2}
Elementary charge, e = 1.6022×10^{-19} C
Electron rest mass = 9.1095×10^{-31} kg
Proton rest mass = 1.6726×10^{-27} kg
Avogadro constant, $N_A = 6.022 \times 10^{26}$ $kmol^{-1}$
Atomic mass unit, u = 1.6606×10^{-27} kg = N_A^{-1} = 931.50 MeV
Boltzmann constant, k = 1.381×10^{-23} J K^{-1} = 8.62×10^{-5} eV K^{-1} ~1 eV/10^4 K
Stefan-Boltzmann constant, $\sigma = 5.67 \times 10^{-8}$ W m^{-2} K^{-4}
Wien's law, $\lambda_m T = 2.898 \times 10^{-3}$ m K (per dλ)
Hubble constant, H ~ 50 to 75 km s^{-1} Mpc^{-1} (depending on method of determination)
Thermochemical calorie (cal) = 4.184 J
Electron-volt (eV) = 1.6022×10^{-19} J
1 eV per event = 23 060. cal mol^{-1}
1 W = 10^7 ergs s^{-1}
$\pi = 3.141\,592\,654 \simeq (113 \div 355)^{-1}$
1″ = 4.8481×10^{-6} rad
Number of square degrees on a sphere = 41 253.

MISCELLANEOUS INFORMATION

Relations between sidereal time t, right ascension α, hour angle h, declination δ, azimuth A (measured east of north), altitude a, and latitude ϕ:

$h = t - \alpha$
$\sin a = \sin \delta \sin \phi + \cos h \cos \delta \cos \phi$
$\cos \delta \sin h = -\cos a \sin A$
$\sin \delta = \sin a \sin \phi + \cos a \cos A \cos \phi$

Annual precession in α = 3.0730 + 1.3362 $\sin \alpha \tan \delta$ seconds
Annual precession in δ = 20″.043 $\cos \alpha$
Log of light intensity ratio = 0.4 times magnitude difference
$4\,^1H \rightarrow\,^4He$ + 26.73 MeV
Stable particles: γ, e^-, e^+, p, $\bar{p}$, neutrinos(?)
Some SI symbols and prefixes:

m	metre	N	newton (kg m s^{-2})	n	nano	10^{-9}
kg	kilogram	J	joule (N m)	μ	micro	10^{-6}
s	second	W	watt (J s^{-1})	m	milli	10^{-3}
min	minute	Pa	pascal (N m^{-2})	c	centi	10^{-2}
h	hour	t	tonne (10^3 kg)	k	kilo	10^3
d	day	Hz	Hertz (s^{-1})	M	mega	10^6
a	year	C	coulomb (A s)	G	giga	10^9

Relation between rest mass (m), linear momentum (p), total energy (E), kinetic energy (KE), and $\gamma = (1 - v^2/c^2)^{-0.5}$:

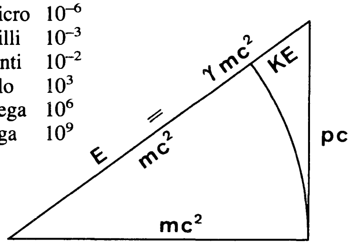


TABLE OF PRECESSION FOR 50 YEARS

If declination is positive, use inner R.A. scale; if declination is *negative*, use *outer* R.A. scale, and *reverse the sign of the precession in declination*

R.A. for Dec. −	R.A. for Dec. +	Prec. in Dec.	Precession in right ascension											Prec. in Dec.	R.A. for Dec. +	R.A. for Dec. −
			δ = 85°	80°	75°	70°	60°	50°	40°	30°	20°	10°	0°			
h m	h m	′	m	m	m	m	m	m	m	m	m	m	m	′	h m	h m
12 00	0 00	+16.7	+ 2.56	+2.56	+2.56	+2.56	+2.56	+2.56	+2.56	+2.56	+2.56	+2.56	+2.56	−16.7	12 00	*24 00*
12 30	0 30	+16.6	4.22	3.39	3.10	2.96	2.81	2.73	2.68	2.64	2.61	2.59	2.56	−16.6	11 30	*23 30*
13 00	1 00	+16.1	5.85	4.20	3.64	3.35	3.06	2.90	2.80	2.73	2.67	2.61	2.56	−16.1	11 00	*23 00*
13 30	1 30	+15.4	7.43	4.98	4.15	3.73	3.30	3.07	2.92	2.81	2.72	2.64	2.56	−15.4	10 30	*22 30*
14 00	2 00	+14.5	8.92	5.72	4.64	4.09	3.53	3.22	3.03	2.88	2.76	2.66	2.56	−14.5	10 00	*22 00*
14 30	2 30	+13.3	10.31	6.41	5.09	4.42	3.73	3.37	3.13	2.95	2.81	2.68	2.56	−13.3	9 30	*21 30*
15 00	3 00	+11.8	11.56	7.03	5.50	4.72	3.92	3.50	3.22	3.02	2.85	2.70	2.56	−11.8	9 00	*21 00*
15 30	3 30	+10.2	12.66	7.57	5.86	4.99	4.09	3.61	3.30	3.07	2.88	2.72	2.56	−10.2	8 30	*20 30*
16 00	4 00	+ 8.4	13.58	8.03	6.16	5.21	4.23	3.71	3.37	3.12	2.91	2.73	2.56	− 8.4	8 00	*20 00*
16 30	4 30	+ 6.4	14.32	8.40	6.40	5.39	4.34	3.79	3.42	3.15	2.94	2.74	2.56	− 6.4	7 30	*19 30*
17 00	5 00	+ 4.3	14.85	8.66	6.57	5.52	4.42	3.84	3.46	3.18	2.95	2.75	2.56	− 4.3	7 00	*19 00*
17 30	5 30	+ 2.2	15.18	8.82	6.68	5.59	4.47	3.88	3.49	3.20	2.96	2.76	2.56	− 2.2	6 30	*18 30*
18 00	6 00	0.0	15.29	8.88	6.72	5.62	4.49	3.89	3.50	3.20	2.97	2.76	2.56	0.0	6 00	*18 00*
0 00	12 00	−16.7	2.56	2.56	2.56	2.56	2.56	2.56	2.56	2.56	2.56	2.56	2.56	+16.7	24 00	*12 00*
0 30	12 30	−16.6	+ 0.90	1.74	2.02	2.16	2.31	2.39	2.44	2.48	2.51	2.54	2.56	+16.6	23 30	*11 30*
1 00	13 00	−16.1	− 0.73	0.93	1.49	1.77	2.06	2.22	2.32	2.39	2.46	2.51	2.56	+16.1	23 00	*11 00*
1 30	13 30	−15.4	− 2.31	+0.14	0.97	1.39	1.82	2.05	2.20	2.31	2.41	2.49	2.56	+15.4	22 30	*10 30*
2 00	14 00	−14.5	− 3.80	−0.60	0.48	1.03	1.60	1.90	2.09	2.24	2.36	2.46	2.56	+14.5	22 00	*10 00*
2 30	14 30	−13.3	− 5.19	−1.28	+0.03	0.70	1.39	1.75	1.99	2.17	2.31	2.44	2.56	+13.3	21 30	*9 30*
3 00	15 00	−11.8	− 6.44	−1.90	−0.38	0.40	1.20	1.62	1.90	2.11	2.27	2.42	2.56	+11.8	21 00	*9 00*
3 30	15 30	−10.2	− 7.54	−2.45	−0.74	+0.13	1.03	1.51	1.82	2.05	2.24	2.41	2.56	+10.2	20 30	*8 30*
4 00	16 00	− 8.4	− 8.46	−2.91	−1.04	−0.09	0.89	1.41	1.75	2.00	2.21	2.39	2.56	+ 8.4	20 00	*8 00*
4 30	16 30	− 6.4	− 9.20	−3.27	−1.28	−0.27	0.78	1.33	1.70	1.97	2.19	2.38	2.56	+ 6.4	19 30	*7 30*
5 00	17 00	− 4.3	− 9.73	−3.54	−1.45	−0.39	0.70	1.28	1.66	1.94	2.17	2.37	2.56	+ 4.3	19 00	*7 00*
5 30	17 30	− 2.2	−10.06	−3.70	−1.56	−0.47	0.65	1.25	1.63	1.92	2.16	2.37	2.56	+ 2.2	18 30	*6 30*
6 00	18 00	0.0	−10.17	−3.75	−1.59	−0.50	0.63	1.23	1.63	1.92	2.16	2.36	2.56	0.0	18 00	*6 00*

To avoid interpolation in this table, which becomes increasingly inaccurate for large |δ|, precession formulae may be used (see p. 15).

TIME

Time has been said to be nature's way of keeping everything from happening at once. For astronomical purposes the concern is not with defining time, but with its measurement. For this, units of time and time scales must be established and clocks devised.

There are three obvious, natural, periodic time intervals on Earth: the seasonal cycle (year); the cycle of lunar phases (month); and the day-night cycle (day). The problem of accurately subdividing these natural intervals to make time locally available at any moment was satisfactorily solved in 1657 by Christiaan Huygens who invented the first practical pendulum clock. Through successive refinements the pendulum clock reigned supreme for nearly three centuries, until it was surpassed in precision by the quartz oscillator in the 1940's. Within another 20 years the quartz clock was, in turn, superseded by the cesium atomic clock which today has a precision near one part in 10^{13} (one second in 300 000 years).

The cycle of the seasons is called the *tropical year* and contains 365.2422 days. The cycle of lunar phases is known as the *synodic month* and equals 29.53059 days. The average day-night (diurnal) cycle is the *mean solar day* and contains approximately 86 400.003 s. Other types of year, month and day have been defined and are listed along with brief definitions and durations on p. 14.

Today the second is the basic unit of time. For many decades a second meant 1/86400 of the mean solar day. However, Earth's rotation on its axis is not perfectly uniform: tidal friction causes a secular slowing of about one part in 10^{12} per day; shifts of Earth's crust relative to the axis of rotation (polar wobble) produce a small quasi-periodic variation; meteorological factors cause a small periodic seasonal change; and there are random variations of a few parts in 10^8 possibly associated with core-mantle interactions. Atoms display a permanence and stability that planets cannot, thus the second now has an atomic definition: 9 192 631 770 periods of the radiation corresponding to the transition between the two hyperfine levels of the ground state of the cesium 133 atom. This is known as the SI (for Système International) second (abbreviation s).

Although Earth's axial rotation is not sufficiently predictable to serve as a precise clock, the orbital motions of the planets and of our Moon are predictable to high accuracy. Through the dynamical equations describing these motions, a uniform time scale can be derived. This scale, known as *Ephemeris Time* (ET), was for many years the basis of astronomical ephemerides. Also, the definition of the SI second, mentioned above, was chosen so that it was identical to the ephemeris second to within the precision of measurement. Because atomic clocks are readily available and because of their proven precision, as of 1984 Ephemeris Time has been abandoned in favor of *Terrestrial Dynamical Time* (TDT). The unit of TDT is the SI second and its scale has been chosen to agree with the current ET scale.

Other time scales are in use. *International Atomic Time* (TAI), like TDT, runs at the SI rate but, for historical reasons, lags TDT by exactly 32.184 seconds. Another is *Universal Time* (UT1, or often simply UT) which is mean solar time at the Greenwich (England) meridian, corrected for polar wobble. In practice UT1 is defined in terms of *Greenwich Mean Sidereal Time* (GMST), the latter being defined in terms of Earth's rotation relative to the mean vernal equinox of date (see p. 8). The adjective *mean* is used here to denote that small, periodic variations due to the nutation of Earth's axis have been averaged out, the mean equinox being affected only by the precession of the axis. GMST is the hour angle of this equinox. i.e. GMST equals the right ascension of a star (corrected for nutation) at the Greenwich meridian.

Closely related to UT1 is *Coordinated Universal Time* (UTC). UTC runs at the SI rate and is offset an integral number of seconds from TAI so that it approximates UT1. Because Earth's rotation is being slowed by tidal friction, UT1 now loses about one second per year relative to UTC. "Leap seconds" are inserted into UTC on June

30 or December 31 so that the difference UT1-UTC ≡ ΔUT1 does not exceed ± 0.7 s. UTC lags TAI, and as of July 1, 1983 TAI-UTC ≡ ΔAT = 22 s (i.e. TDT − UTC = 22 s + 32.184 s = 54.184 s exactly).

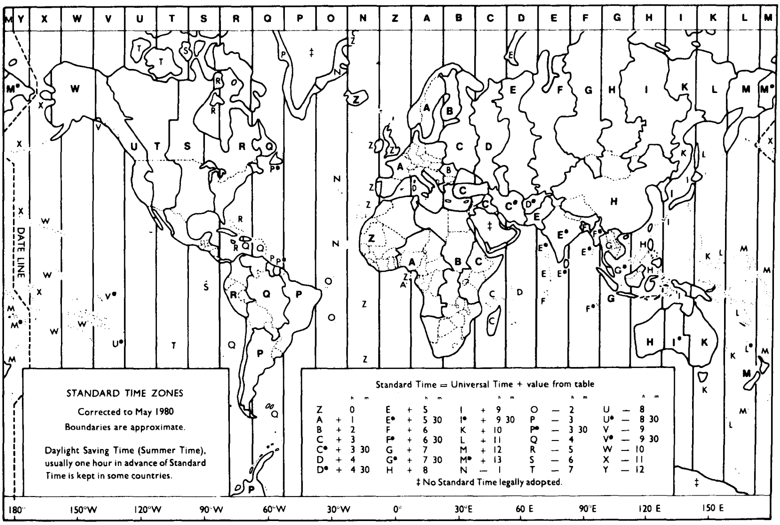
The world system of civil time is based on UT1. To keep clocks at various longitudes reasonably in phase with the day-night cycle and yet to avoid the inconvenience to travellers of a local time that varies continuously with longitude, a century ago Earth was divided into about 24 *standard time* zones, adjacent zones generally differing by one hour and each ideally 15 degrees wide (see the maps on pages 18 and 19). The zero zone is centred on the Greenwich meridian. All clocks within the same time zone read the same time. Some countries observe "daylight saving time" during the summer months. In Canada and the United States, clocks are generally set one hour ahead of standard time on the last Sunday in April and return to standard time on the last Sunday in October.

A sundial indicates *apparent solar time* at the observer's meridian. Not only is this, in general, different from standard time, but it is far from uniform because of Earth's elliptical orbit and the inclination of the ecliptic to the celestial equator. If the Sun is replaced by a fictitious mean sun moving uniformly along the equator, this defines *Local Mean (Solar) Time* (LMT). Apparent solar time can differ by up to 16 minutes from LMT depending upon the time of year (see p. 50). Also, depending upon the observer's location within his standard time zone, his standard time may differ by up to an hour or so from LMT (see p. 54).

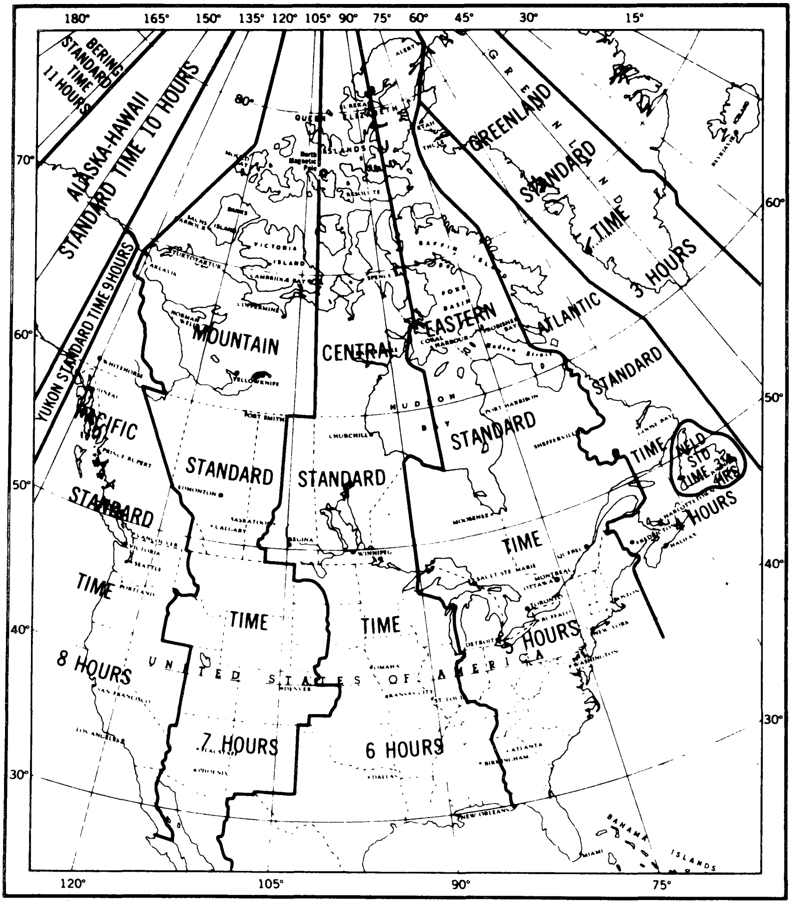
In the same manner that GMST is defined, a *Local Mean Sidereal Time* (LMST) is defined for each observer's meridian. Because Earth makes one more rotation with respect to the other stars than it does with respect to the Sun during a year, sidereal time gains relative to standard time, LMT, UT1, TAI or TDT by about 3^m56^s per day or 2^h per month. Also, because of precession, the mean sidereal day is about 8 ms shorter than Earth's period of rotation (see p. 14). LMST may be used to set a telescope on an object of known right ascension. The hour angle of the object equals the sidereal time less the right ascension. LMST may be available from a sidereal clock, or it can be calculated as explained on p. 20.

WORLD MAP OF TIME ZONES

Taken from *Astronomical Phenomena for the Year* 1984 (Washington: U.S. Government Printing Office, and London: Her Majesty's Stationery Office)



MAP OF STANDARD TIME ZONES



PRODUCED BY THE SURVEYS AND MAPPING BRANCH, DEPARTMENT OF ENERGY, MINES AND RESOURCES, OTTAWA, CANADA, 1973.

MAP OF STANDARD TIME ZONES

The map shows the number of hours by which each time zone is *slower* than Greenwich, that is, the number of hours which must be *added* to the zone's standard time to give Universal Time.

Note: Since the preparation of the above map, the standard time zones have been changed so that all parts of the Yukon Territory now observe Pacific Standard Time. The Yukon Standard Time Zone still includes a small part of Alaska, as shown on the above map. Also, the part of Texas west of longitude 105° is in the Mountain Time Zone.

RADIO TIME SIGNALS

National time services distribute Coordinated Universal Time (UTC). UTC is coordinated through the Bureau International de l'Heure in Paris so that most time services are synchronized to a tenth of a millisecond. Radio time signals available in North America include:

CHU Ottawa, Ontario	3.330, 7.335, 14.670 MHz
WWV Fort Collins, Colorado	2.5, 5, 10, 15, 20 MHz

The difference $\Delta UT1 = UT1 - UTC$ to the nearest tenth of a second is coded in the signals. If UT1 is ahead of UTC, second markers beginning at the 1 second mark of each minute are doubled, the number of doubled markers indicating the number of tenths of a second UT1 is ahead of UTC. If UT1 is behind UTC, the doubled markers begin at the 9 second point.

MEAN SIDEREAL TIME 1984

The following is the Greenwich Mean Sidereal Time (GMST) on day 0 at 0^h UT of each month:

Jan. 0	$06^{h}.5906$	Apr. 0	$12^{h}.5702$	July 0	$18^{h}.5498$	Oct. 0	$00^{h}.5951$
Feb. 0	08.6276	May 0	14.5415	Aug. 0	20.5868	Nov. 0	02.6321
Mar. 0	10.5332	June 0	16.5785	Sep. 0	22.6238	Dec. 0	04.6034

GMST at hour t UT on day d of the month

$$= \text{GMST at } 0^h\text{UT on day } 0 + 0^{h}.065710d + 1^{h}.002738t$$

Local Mean Sidereal Time (LMST) = GMST − west longitude
(or + east longitude)

LMST calculated by this method will be accurate to ± 0.2s provided t is stated to ± 0.1s or better and the observer's longitude is known to $\pm 1''$. (Note that t must be expressed in decimal hours UT. Also, to achieve ± 0.1s accuracy in t, the correction ΔUT1 must be applied to UTC. See the above section on radio time signals.)

JULIAN DATE, 1984

The Julian date is commonly used by astronomers to refer to the time of astronomical events, because it avoids some of the annoying complexities of the civil calendar. The Julian day corresponding to a given date is the number of days which have elapsed since January 1, 4713 B.C. For an account of the origin of the Julian system see: "The Julian Period", by C. H. Cleminshaw in the *Griffith Observer*, April 1975; "The Origin of the Julian Day System", by G. Moyer in *Sky and Telescope*, April 1981.

The Julian day commences at noon (12^h) UT. To find the Julian date at any time during 1984, determine the day of the month and time at the Greenwich meridian, convert this to a decimal day, and add it to one of the following numbers according to the month. (These numbers are the Julian dates for 0^hUT on the "0th" day of each month.):

Jan.	244 5699.5	Apr.	244 5790.5	July	244 5881.5	Oct.	244 5973.5
Feb.	244 5730.5	May	244 5820.5	Aug.	244 5912.5	Nov.	244 6004.5
Mar.	244 5759.5	June	244 5851.5	Sep.	244 5943.5	Dec.	244 6034.5

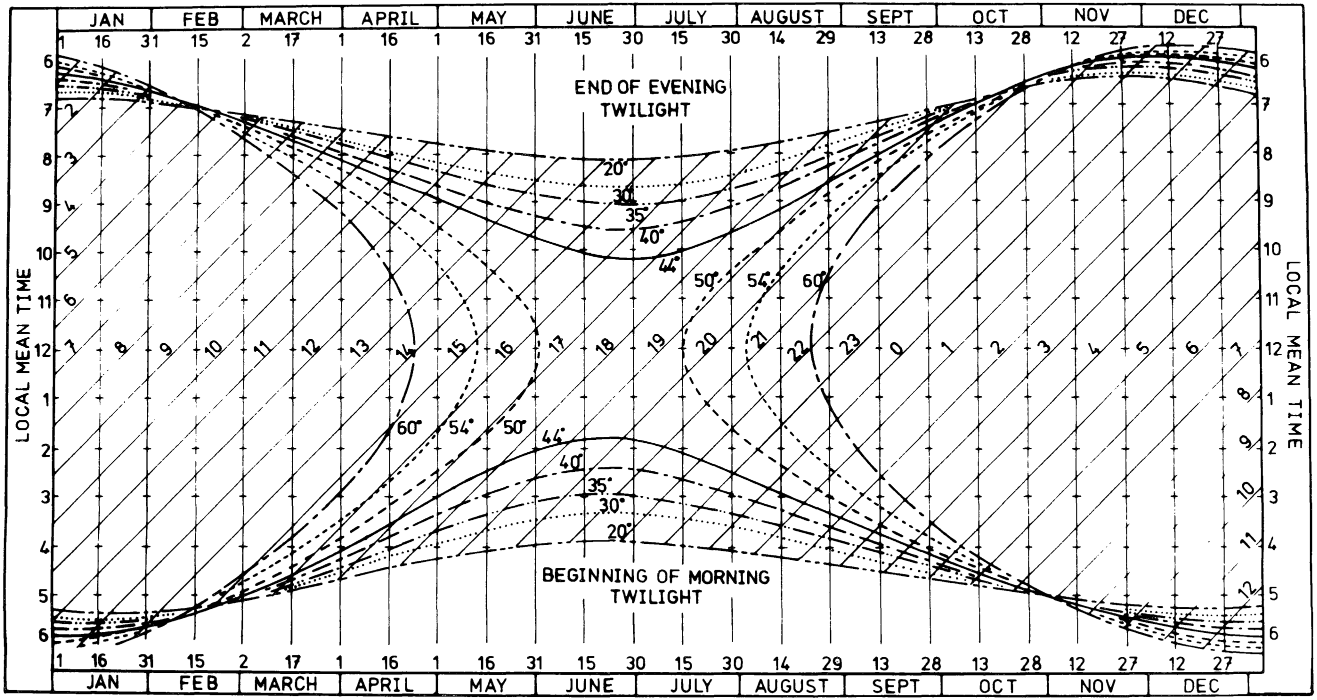
e.g. 21:36 EDT on May 18 = 01:36 UT on May 19 = May 19.07 UT = 244 5820.5 + 19.07 = JD 244 5839.57

The Julian dates for 0 UT January 0 for several previous years are 244 0000.5 plus (for years indicated): 951(1971), 1316(1972), 1682(1973), 2047(1974), 2412(1975), 2777(1976), 3143(1977), 3508(1978), 3873(1979), 4238(1980), 4604(1981), 4969(1982), 5334(1983), 5699(1984).

Note: Anniversary and festival dates for 1984 appear on p. 23.

ASTRONOMICAL TWILIGHT AND SIDEREAL TIME

The diagram gives (i) the local mean time (LMT) of the beginning and end of astronomical twilight (curved lines) at a given latitude on a given date and (ii) the local mean sidereal time (LMST, diagonal lines) at a given LMT on a given date. The LMST is also the right ascension of an object on the observer's celestial meridian. To use the diagram, draw a line downward from the given date; the line cuts the curved lines at the LMT of beginning and end of twilight, and cuts each diagonal line at the LMT corresponding to the LMST marked on the line. See pages 17 and 58 for definitions of LMT, LMST and astronomical twilight. (Diagram prepared by Randall Brooks.)



THE SKY MONTH BY MONTH

BY JOHN R. PERCY

Introduction—In the monthly descriptions of the sky on the following pages, positions of the Sun and planets are given for 0 h Dynamical Time, which differs only slightly from Standard Time on the Greenwich meridian (see p. 17). Estimates of altitude are for an observer in latitude 45°N. Unless noted otherwise, the descriptive comments about the planets apply to the middle of the month.

The Sun—The values of the equation of time are for 0^h Dynamical Time ("equation of time" ≡ apparent solar time − local mean time). For times of sunrise and sunset and for changes in the length of the day, see pp. 54–57. See also p. 50.

The Moon—Its phases, perigee and apogee times and distances (rounded to the nearest 100 km), and its conjunctions with the planets are given in the monthly tables.

M

For times of moonrise and moonset, see pp. 62–75.

Elongation, Age and Phase of the Moon—The *elongation* is the angular distance of the Moon from the Sun in degrees, counted eastward around the sky. Thus, elongations of 0°, 90°, 180°, and 270° correspond to new, first quarter, full, and last quarter moon. The *age* of the Moon is the time since the new moon phase. Because the Moon's orbital motion is not uniform, the age of the Moon does not accurately specify its phase. The Moon's elongation increases on the average by 12.2° per day, first quarter, full and last quarter phases corresponding approximately to 7.4, 14.8 and 22.1 days respectively.

The Sun's selenographic colongitude is essentially a convenient way of indicating the position of the sunrise terminator as it moves across the face of the Moon. It provides an accurate method of recording the exact conditions of illumination (angle of illumination), and makes it possible to observe the Moon under exactly the same lighting conditions at a later date. The Sun's selenographic colongitude is numerically equal to the selenographic longitude of the sunrise terminator reckoned eastward from the mean centre of the disk. Its value increases at the rate of nearly 12.2° per day or about $\frac{1}{2}$° per hour; it is approximately 270°, 0°, 90° and 180° at New Moon, First Quarter, Full Moon and Last Quarter respectively. Values of the Sun's selenographic colongitude are given on the following pages for the first day of each month.

Sunrise will occur at a given point *east* of the central meridian of the Moon when the Sun's selenographic colongitude is equal to the eastern selenographic longitude of the point; at a point *west* of the central meridian when the Sun's selenographic colongitude is equal to 360° minus the western selenographic longitude of the point. The longitude of the sunset terminator differs by 180° from that of the sunrise terminator.

Libration is the shifting, or rather apparent shifting, of the visible disk of the Moon. Sometimes the observer sees features farther around the eastern or the western limb (libration in longitude), or the northern or southern limb (libration in latitude). When the libration in longitude is positive, the mean central point of the disk of the Moon is displaced eastward on the celestial sphere, exposing to view a region on the west limb. When the libration in latitude is positive, the mean central point of the disk of the Moon is displaced towards the south, and a region on the north limb is exposed to view.

The dates of the greatest positive and negative values of the libration in longitude and latitude are given in the following pages.

The Moon's Orbit. In 1984, the ascending node of the Moon's orbit regresses from longitude 75° to 55° (all within Taurus).

The Planets—Further information in regard to the planets, including Pluto, is found on pp. 91–107. For the configurations of Jupiter's four Galilean satellites, see the monthly tables. In these diagrams, the central vertical band represents the equatorial diameter of the disk of Jupiter. Time is shown by the vertical scale, each horizontal line denoting 0^h Universal Time. (Be sure to convert to U.T. before using these diagrams.) The relative positions of the satellites at any time with respect to the disk of Jupiter are given by the four labelled curves (I, II, III, IV) (see p. 10 for the key to these Roman numerals). In constructing these diagrams, the positions of the satellites in the direction perpendicular to the equator of Jupiter are necessarily neglected. Note that the orientation is for an inverting telescope. For the various transits, occultations, and eclipses of these satellites, see p. 108.

Minima of Algol—The times of mid-eclipse are given in the monthly tables and are calculated from the ephemeris

$$\text{heliocentric minimum} = 2440953.4657 + 2.8673075\,E$$

and are rounded off to the nearest ten minutes. (The first number in the equation is the Julian date corresponding to 1971 Jan. 1.9657, an Algol minimum. The second number is the period of Algol in days, and E is an integer.)

Occultations of Stars and Planets—For information about occultations of stars and planets visible in North America, see pp. 81–90 and 121.

ANNIVERSARIES AND FESTIVALS 1984

New Year's Day	Sun.	Jan.	1
Epiphany	Fri.	Jan.	6
Lincoln's Birthday (U.S.)	Sun.	Feb.	12
Washington's Birthday (U.S.)	Mon.	Feb.	20
St. David (Wales)	Thu.	Mar.	1
Ash Wednesday		Mar.	7
St. Patrick (Ireland)	Sat.	Mar.	17
Palm Sunday		Apr.	15
First Day of Passover	Tue.	Apr.	17
Good Friday		Apr.	20
Birthday of Queen Elizabeth II (1926)	Sat.	Apr.	21
Easter Sunday		Apr.	22
St. George (England)	Mon.	Apr.	23
Victoria Day	Mon.	May	21
Memorial Day (U.S.)	Mon.	May	28
Ascension Day	Thu.	May	31
First Day of Ramadan	Thu.	May	31
Shebuoth	Wed.	June	6
Pentecost (Whit Sunday)		June	10
Trinity Sunday		June	17
Canada Day	Sun.	July	1
Independence Day (U.S.)	Wed.	July	4
Civic Holiday	Mon.	Aug.	6
Labour Day	Mon.	Sep.	3
Rosh Hashanah	Thu.	Sep.	27
Islamic New Year	Thu.	Sep.	27
Yom Kippur	Sat.	Oct.	6
Thanksgiving (Can.)	Mon.	Oct.	8
Columbus Day (U.S.)	Mon.	Oct.	8
Succoth	Thu.	Oct.	11
Election Day (U.S.)	Tue.	Nov.	6
Remembrance Day	Sun.	Nov.	11
Veterans' Day (U.S.)	Sun.	Nov.	11
Thanksgiving (U.S.)	Thu.	Nov.	22
St. Andrew (Scotland)	Fri.	Nov.	30
First Sunday in Advent		Dec.	2
Christmas	Tue.	Dec.	25

Note: 1984 and 1985 calendars are on the inside back cover.

THE SKY FOR JANUARY 1984

The Sun—During January, the sun's R.A. increases from 18 h 42 m to 20 h 55 m and its Decl. changes from −23°05′ to −20°55′. The equation of time changes from −3 m 03 s to −13 m 29 s. On Jan. 3, Earth is at perihelion, 147 096 000km from the sun.

The Moon—On Jan. 1.0 U.T., the age of the moon is 27.5 d. The sun's selenographic colongitude is 239.06° and increases by 12.2° each day thereafter. The libration in longitude is maximum (west limb exposed) on Jan. 26 (7°) and minimum (east limb exposed) on Jan. 14 (7°). The libration in latitude is maximum (north limb exposed) on Jan. 8 (7°) and minimum (south limb exposed) on Jan. 21 (7°). The new moon at the beginning of the month will provide a good opportunity for the viewing of the Quadrantid meteors.

Mercury on the 1st is in R.A. 18 h 35 m, Decl. −20°32′, and on the 15th is in R.A. 18 h 06 m, Decl. −20°59′. Early in the month, it is not visible, but by Jan 22, it is at greatest elongation west (24°). At that time, it rises about $1\frac{1}{2}$ h before the sun, and can be seen with difficulty, low in the east, just before sunrise.

M

Venus on the 1st is in R.A. 15 h 53 m, Decl. −18°01′, and on the 15th it is in R.A. 17 h 04 m, Decl. −21°07′, mag. −3.5, and transits at 9 h 29 m. It can be seen very low in the south south-east, just before sunrise. This is a very poor year for observing Venus. Superior conjunction falls half way through the year and, both before and after this, the orientation of the ecliptic conspires to place the planet inconveniently low in the sky (at least for the northern hemisphere observer). See also *Jupiter*, *Uranus* and *Neptune* below.

Mars on the 15th is in R.A. 14 h 02 m, Decl. −10°46′, mag. +1.2, and transits at 6 h 26 m. Toward the end of the month, it moves from Virgo into Libra, where it remains until late summer. In January, it rises in the late evening, and is west of the meridian by sunrise.

Jupiter on the 15th is in R.A. 17 h 56 m, Decl. −23°08′, mag. −1.4, and transits at 10 h 20 m. Throughout the year, it is in Sagittarius; watch its motion relative to the many bright stars in this constellation. This month, it rises about $1\frac{1}{2}$ h before the sun, and can be seen with difficulty, low in the east, just before sunrise. It is 0.8° south of Venus on Jan. 27. See also *Neptune* below.

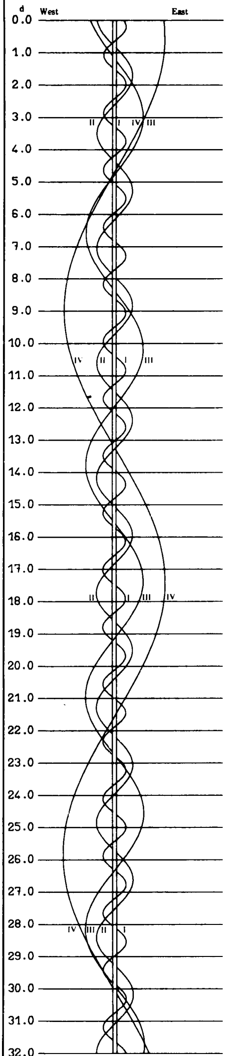
Saturn on the 15th is in R.A. 14 h 53 m, Decl. −14°07′, mag. +0.8, and transits at 7 h 17 m. It rises at about midnight, and is near the meridian by sunrise. Throughout the year, it is in the relatively faint constellation Libra, near the α star Zubenelgenubi.

Uranus on the 15th is in R.A. 16 h 42 m, Decl. −22°10′, mag. +6.0, and transits at 9 h 06 m. In January and throughout 1984, Uranus is in Ophiuchus. Venus passes 1.8° north of Uranus on Jan. 10.

Neptune on the 15th is in R.A. 17 h 59 m, Decl. −22°17′, mag. +7.8, and transits at 10 h 23 m. In January and throughout 1984, Neptune is in Sagittarius, near M8, M20 and M21. On Jan. 19, Jupiter is 0.9° south of Neptune and on Jan. 25, Venus is 0.03° north of Neptune: a good opportunity and excuse to look for Neptune with binoculars or a small telescope.

Shortly before sunrise, around the middle of the month, it would be possible, in principle, to see all eight planets at once. Their elongations west of the sun are as follows: Mercury (24°), Venus (36°), Mars (85°), Jupiter (30°), Saturn (75°), Uranus (48°), Neptune (30°) and Pluto (88°). As mentioned above, some of these planets could be seen only with great difficulty.

1984			JANUARY UNIVERSAL TIME	Min. of Algol	Config. of Jupiter's Satellites
	d	h m		h m	
Sun.	1				
Mon.	2			5 20	
Tues.	3	05 16	● New Moon		
		22	Earth at perihelion		
Wed.	4	02	Quadrantid meteors		
Thur.	5			2 10	
Fri.	6				
Sat.	7		Mercury at greatest hel. lat. N.	23 00	
		20	Moon at apogee (405 600 km)		
Sun.	8	03	Venus 7° N. of Antares		
Mon.	9				
Tues.	10	13	Venus 1.8° N. of Uranus	19 50	
Wed.	11	01	Mercury stationary		
		09 48	☽ First Quarter		
Thur.	12				
Fri.	13			16 40	
Sat.	14				
Sun.	15				
Mon.	16			13 30	
Tues.	17				
Wed.	18	14 05	○ Full Moon		
Thur.	19	18	Jupiter 0.9° S. of Neptune	10 20	
		22	Moon at perigee (359 500 km)		
Fri.	20				
Sat.	21				
Sun.	22	05	Mercury at greatest elong. W. (24°)	7 10	
Mon.	23				
Tues.	24				
Wed.	25	04 48	☾ Last Quarter	4 00	
		09	Mars 1.6° S. of Moon		
		23	Venus 0.03° N. of Neptune		
Thur.	26	01	Saturn 0.2° S. of Moon; occultation[1]		
Fri.	27	02	Venus 0.8° N. of Jupiter		
Sat.	28	03	Uranus 0.2° S. of Moon; occultation[2]	0 50	
Sun.	29	13	Neptune 3° N. of Moon		
		16	Jupiter 1.8° N. of Moon		
		22	Venus 3° N. of Moon		
Mon.	30		Mercury at descending node	21 30	
		21	Mercury 3° N. of Moon		
Tues.	31	18	Vesta stationary		



[1]Visible from Saudi Arabia, India, East Indies and Australia
[2]Visible from Saudi Arabia and N.E. Africa

THE SKY FOR FEBRUARY 1984

The Sun—During February, the sun's R.A. increases from 20 h 55 m to 22 h 48 m and its Decl. changes from −17°23′ to −7°36′. The equation of time changes from −13 m 29 s to −12 m 27 s, reaching a minimum of −14 m 18 s on Feb. 12.

The Moon—On Feb. 1.0 U.T., the age of the moon is 28.8 d. The sun's selenographic colongitude is 256.01° and increases by 12.2° each day thereafter. The libration in longitude is maximum (west limb exposed) on Feb. 23 (8°) and minimum (east limb exposed) on Feb. 11 (8°). The libration in latitude is maximum (north limb exposed) on Feb. 4 (7°) and minimum (south limb exposed) on Feb. 18 (7°). Note that the full moon occurs when the moon is near perigee, whereas in September the full moon will occur when the moon is near apogee. This should produce an easily-measurable change in the angular diameter of the full moon. Can you devise a simple method for making this measurement? This makes a good project for students.

Mercury on the 1st is in R.A. 19 h 21 m, Decl. −22°21′, and on the 15th is in R.A. 20 h 47 m, Decl. −19°39′. During the month, it moves slowly in toward superior conjunction, and is not easily visible.

Venus on the 1st is in R.A. 18 h 33 m, Decl. −22°20′, and on the 15th it is in R.A. 19 h 47 m, Decl. −20°59′, mag. −3.4, and transits at 10 h 11 m. Venus also moves slowly in toward superior conjunction but on account of its greater brilliance and elongation, it can still be seen low in the south-east, just before sunrise.

Mars on the 15th is in R.A. 14 h 57 m, Decl. −15°07′, mag. +0.6, and transits at 5 h 20 m. In Libra, it rises in mid-evening and is low in the south-west by sunrise. Early in the month, it passes 2° north of Zubenelgenubi. On Feb. 15, it passes 0.8° south of Saturn. At this time, Mars and Saturn are comparable in brightness, but Mars is noticeably redder.

Jupiter on the 15th is in R.A. 18 h 23 m, Decl. −23°04′, mag. −1.5, and transits at 8 h 45 m. In Sagittarius north of the Teapot, it rises shortly before the sun and is very low in the south south-east at sunrise. The four giant planets – Jupiter, Saturn, Uranus and Neptune – are all far south of the equator this year. Thus they are favourably placed for southern hemisphere observers, but not for northern hemisphere observers.

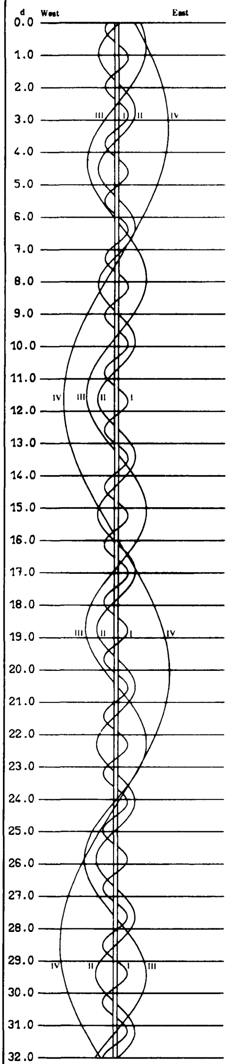
Saturn on the 15th is in R.A. 14 h 58 m, Decl. −14°23′, mag. +0.7, and transits at 5 h 21 m. In Libra just east of Zubenelgenubi, it rises in mid-evening and is low in the south-west by sunrise. On Feb. 25 it is stationary, then commences retrograde motion as it approaches opposition. See also *Mars* above.

Uranus on the 15th is in R.A. 16 h 47 m, Decl. −22°19′, mag. +6.0, and transits at 7 h 09 m. Note that the magnitudes of Uranus and Neptune remain almost constant during the year. This is because their distances from Earth and the sun do not vary much, and they do not show any significant phase effects.

Neptune on the 15th is in R.A. 18 h 03 m, Decl. −22°16′, mag. +7.8, and transits at 8 h 25 m.

1984			FEBRUARY UNIVERSAL TIME	Min. of Algol
	d	h m		h m
Wed.	1	23 46	● New Moon	
Thur.	2			18 20
Fri.	3			
Sat.	4	09	Moon at apogee (406 400 km)	
Sun.	5			15 10
Mon.	6	09	Pallas in conjunction	
Tues.	7			
Wed.	8			12 00
Thur.	9		Mercury at aphelion	
		19	Pluto stationary	
Fri.	10	04 00	☽ First Quarter	
Sat.	11			8 50
Sun.	12			
Mon.	13			
Tues.	14			5 40
Wed.	15	13	Mars 0.8° S. of Saturn	
Thur.	16			
Fri.	17	00 41	○ Full Moon	2 30
		09	Moon at perigee (356 700 km)	
Sat.	18		Venus at descending node	
Sun.	19			23 20
Mon.	20			
Tues.	21			
Wed.	22	09	Saturn 0.3° N. of Moon; occultation[1]	20 10
		14	Mars 0.3° S. of Moon; occultation[2]	
Thur.	23	17 12	☾ Last Quarter	
Fri.	24	10	Uranus 0.2° N. of Moon; occultation[3]	
Sat.	25	06	Saturn stationary	17 00
		20	Neptune 3° N. of Moon	
Sun.	26	08	Jupiter 2° N. of Moon	
Mon.	27			
Tues.	28			13 50
Wed.	29	03	Venus 4° N. of Moon	

Config. of Jupiter's Satellites



[1]Visible from S. Pacific, S. and W. of S. America, S. Atlantic
[2]Visible from N. and central Pacific, N.W. of S. America
[3]Visible from S. Pacific, W. of S. America

THE SKY FOR MARCH 1984

The Sun—During March, the sun's R.A. increases from 22 h 48 m to 0 h 42 m and its Decl. changes from −7°36′ to +4°32′. The equation of time changes from −12 m 27 s to −3 m 59 s. On Mar. 20 at 10:25 U.T., the sun reaches the vernal equinox, and spring begins in the northern hemisphere. Since 1984 is a leap year, spring appears to begin a day "early" this year.

The Moon—On Mar. 1.0 U.T., the age of the moon is 28.0 d. The sun's selenographic colongitude is 248.82° and increases by 12.2° each day thereafter. The libration in longitude is maximum (west limb exposed) on Mar. 22 (8°) and minimum (east limb exposed) on Mar. 10 (8°). The libration in latitude is maximum (north limb exposed) on Mar. 2 (7°) and 29 (7°) and minimum (south limb exposed) on Mar. 16 (7°). Note that the magnitude of the libration is particularly large this month.

Mercury on the 1st is in R.A. 22 h 27 m, Decl. −12°00′, and on the 15th is in R.A. 0 h 04 m, Decl. −0°34′. Throughout the month, it is too close to the sun to be seen. It passes through superior conjunction on Mar. 8.

Venus on the 1st is in R.A. 21 h 04 m, Decl. −17°20′, and on the 15th it is in R.A. 22 h 12 m, Decl. −12°15′, mag. −3.3, and transits at 10 h 41 m. It can be seen with difficulty, very low in the south-east, just before sunrise.

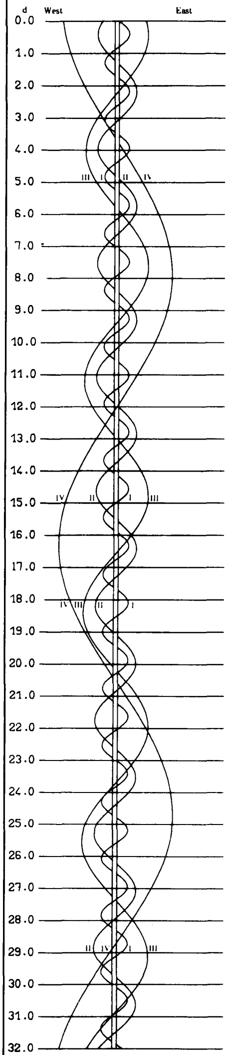
Mars on the 15th is in R.A. 15 h 35 m, Decl. −17°44′, mag. −0.1, and transits at 4 h 04 m. In Libra, it rises in mid-evening and is low in the south-west by sunrise. During the month, it brightens by nearly a magnitude, as its distance from Earth decreases. The phase of the planet also changes slowly, from gibbous to full. We often forget that Mars, as well as Venus and Mercury, shows phases (but not the full set).

Jupiter on the 15th is in R.A. 18 h 43 m, Decl. −22°50′, mag. −1.7, and transits at 7 h 11 m. In Sagittarius north of the Teapot, it rises about $3\frac{1}{2}$ h before the sun and is low in the south at sunrise.

Saturn on the 15th is in R.A. 14 h 57 m, Decl. −14°13′, mag. +0.6, and transits at 3 h 26 m. In Libra just east of Zubenelgenubi, it rises in mid-evening and is low in the south-west by sunrise. On Mar. 25 there is an occultation of SAO 158913 by Saturn and its rings. This is a rare event. The only other star brighter than magnitude 9 to be occulted by Saturn during this decade is 28 Sgr ($5^{m}.8$) on July 3, 1989. See p. 121 for more information on this year's event.

Uranus on the 15th is in R.A. 16 h 49 m, Decl. −22°23′, mag. +5.9, and transits at 5 h 17 m.

Neptune on the 15th is in R.A. 18 h 06 m, Decl. −22°15′, mag. +7.8, and transits at 6 h 34 m.

1984	d	h m	MARCH UNIVERSAL TIME	Min. of Algol	Config. of Jupiter's Satellites
	d	h m		h m	
Thur.	1		Mercury at greatest hel. lat. S.		
Fri.	2	11	Moon at apogee (406 700 km)	10 40	
		18 31	New Moon		
Sat.	3				
Sun.	4				
Mon.	5			7 30	
Tues.	6				
Wed.	7				
Thur.	8	17	Mercury in superior conjunction	4 20	
Fri.	9				
Sat.	10	14	Vesta 1.1° S. of Moon; occultation		
		18 27	☽ First Quarter		
Sun.	11			1 00	
Mon.	12				
Tues.	13			21 50	
Wed.	14				
Thur.	15				
Fri.	16	21	Moon at perigee (357 200 km)	18 40	
Sat.	17	10 10	Full Moon		
Sun.	18	06	Uranus stationary		
Mon.	19			15 30	
Tues.	20		Mercury at ascending node		
		10 25	Vernal equinox; spring begins		
		18	Saturn 0.6° N. of Moon; occultation[1]		
Wed.	21	13	Mars 0.4° N. of Moon; occultation[2]		
Thur.	22	18	Uranus 0.5° N. of Moon; occultation[1]	12 20	
		20	Ceres in conjunction		
Fri.	23				
Sat.	24		Mercury at perihelion		
			Venus at aphelion		
		03	Neptune 3° N. of Moon		
		07 58	☾ Last Quarter		
		21	Jupiter 3° N. of Moon		
Sun.	25	06 +	Occultation of SAO 158913 by Saturn[3]	9 10	
Mon.	26				
Tues.	27				
Wed.	28			6 00	
Thur.	29	16	Moon at apogee (406 400 km)		
Fri.	30	12	Venus 4° N. of Moon		
Sat.	31			2 50	

[1]Visible from Indian Ocean, Indonesia, Australia, New Zealand
[2]Visible from S. Pacific, extreme N. New Zealand, S. of S. America
[3]See p. 121 for further information

THE SKY FOR APRIL 1984

The Sun—During April, the sun's R.A. increases from 0 h 42 m to 2 h 34 m and its Decl. changes from +4°32′ to +15°04′. The equation of time changes from −3 m 59 s to +2 m 53 s, being zero on Apr. 15.

The Moon—On Apr. 1.0 U.T., the age of the moon is 29.2 d. The sun's selenographic colongitude is 266.46° and increases by 12.2° each day thereafter. The libration in longitude is maximum (west limb exposed) on Apr. 19 (7°) and minimum (east limb exposed) on Apr. 7 (7°). The libration in latitude is maximum (north limb exposed) on Apr. 25 (7°) and minimum (south limb exposed) on Apr. 12 (7°).

Mercury on the 1st is in R.A. 1 h 49 m, Decl. +13°41′, and on the 15th is in R.A. 2 h 12 m, Decl. +16°17′. Early in the month, it can be seen very low in the west, just after sunset: greatest elongation east (19°) occurs on Apr. 3. Such elongations are normally very favourable in the (northern) spring, in the sense that the planet appears well above the horizon. In this case, however, the maximum elongation is only 19°, because the planet is so close to perihelion. The planet is not visible during the second half of the month; it passes inferior conjunction on Apr. 22.

Venus on the 1st is in R.A. 23 h 31 m, Decl. −4°40′, and on the 15th it is in R.A. 0 h 35 m, Decl. +2°06′, mag. −3.3, and transits at 11 h 02 m. It is too close to the sun to be easily seen.

Mars on the 15th is in R.A. 15 h 43 m, Decl. −18°46′, mag. −1.0, and transits at 2 h 09 m. It rises early in the evening, and is very low in the south-west by sunrise. It has moved eastward through Libra almost to the boundary of Scorpius. Then on Apr. 5 it is stationary, and begins retrograde motion. During the mouth, it brightens by yet another magnitude.

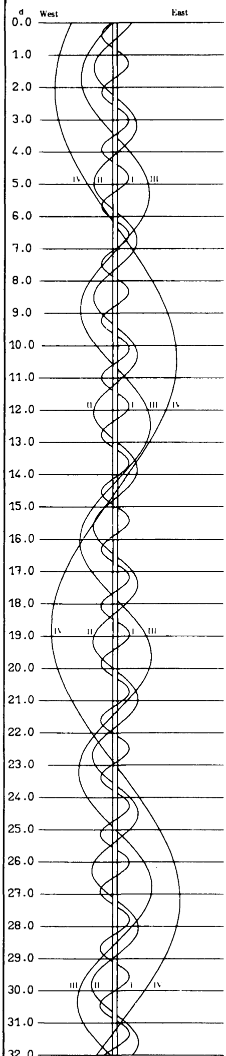
Jupiter on the 15th is in R.A. 18 h 55 m, Decl. −22°38′, mag. −1.9, and transits at 5 h 21 m. In Sagittarius, it rises about 4 h before the sun and is low in the south at sunrise. On Apr. 29 it is stationary, and begins retrograde motion.

Saturn on the 15th is in R.A. 14 h 51 m, Decl. −13°41′, mag. +0.4, and transits at 1 h 17 m. In Libra, it rises at about sunset and sets at about sunrise. Late in the month, it passes about 2° north of Zubenelgenubi.

Uranus on the 15th is in R.A. 16 h 47 m, Decl. −22°21′, mag. +5.9, and transits at 3 h 13 m.

Neptune on the 15th is in R.A. 18 h 06 m, Decl. −22°14′, mag. +7.7, and transits at 4 h 32 m.

1984			APRIL UNIVERSAL TIME	Min. of Algol	Config. of Jupiter's Satellites
	d	h m		h m	
Sun.	1	12 10	🌑 New Moon		
Mon.	2	14	Neptune stationary	23 40	
Tues.	3	00	Mercury 6° N. of Moon		
		03	Mercury at greatest elong. E. (19°)		
Wed.	4		Mercury at greatest hel. lat. N.		
Thur.	5	02	Mars stationary	20 30	
Fri.	6				
Sat.	7	11	Vesta 1.2° S of Moon; occultation		
Sun.	8			17 20	
Mon.	9	04 51	☽ First Quarter		
Tues.	10				
Wed.	11			14 10	
Thur.	12	00	Mercury stationary		
Fri.	13				
Sat.	14	06	Moon at perigee (360 500 km)	11 00	
Sun.	15		Venus at greatest hel. lat. S.		
		19 11	🌕 Full Moon		
Mon.	16				
Tues.	17	01	Saturn 0.6° N. of Moon; occultation[1]	7 40	
		23	Mars 0.04° S. of Moon; occultation[2]		
Wed.	18				
Thur.	19	03	Uranus 0.6° N. of Moon; occultation[1]		
Fri.	20	12	Neptune 3° N. of Moon	4 30	
		16	Pluto at opposition		
Sat.	21	09	Jupiter 3° N. of Moon		
Sun.	22	04	Lyrid meteors		
		05	Mercury in inferior conjunction		
Mon.	23	00 26	☾ Last Quarter	1 20	
Tues.	24				
Wed.	25			22 10	
Thur.	26	07	Moon at apogee (405 400 km)		
Fri.	27		Mercury at descending node		
Sat.	28			19 00	
Sun.	29	20	Jupiter stationary		
Mon.	30	00	Mercury 0.7° N. of Venus		



[1]Visible from S. America, S. Atlantic, Antarctica
[2]Visible from Africa, Madagascar, Indian Ocean, Indonesia, W. Australia

THE SKY FOR MAY 1984

The Sun—During May, the sun's R.A. increases from 2 h 34 m to 4 h 36 m and its Decl. changes from +15°04′ to +22°03′. The equation of time changes from +2 m 53 s to +2 m 16 s, reaching a maximum of 3 m 42 s on May 14. On May 30, there is an annular eclipse of the sun, the path of annularity extending through Mexico and the south-eastern U.S.A. The eclipse is visible as a partial eclipse in all of North America except the extreme north-western and arctic regions. See p. 76 and 79.

The Moon—On May 1.0 U.T., the age of the moon is 29.5 d. The sun's selenographic colongitude is 272.41° and increases by 12.2° each day thereafter. The libration in longitude is maximum (west limb exposed) on May 17 (6°) and minimum (east limb exposed) on May 4 (6°) and 31 (5°). The libration in latitude is maximum (north limb exposed) on May 23 (7°) and minimum (south limb exposed) on May 9 (7°). On May 14–15, there is a penumbral eclipse of the moon, visible from North America. On May 18, there is an occultation of Mercury by the moon, visible (with difficulty) from northern Canada.

Mercury on the 1st is in R.A. 1 h 42 m, Decl. +9°32′, and on the 15th is in R.A. 1 h 55 m, Decl. +8°17′. Greatest elongation west (26°) occurs on May 19, but this is not a favourable elongation, especially as the planet is 5° south of the ecliptic at the time. As a result, the planet will be too low in the sky to be easily seen. At elongation west, Mercury is always brighter *after* greatest elongation. Why? See also *The Moon* above.

Venus on the 1st is in R.A. 1 h 48 m, Decl. +9°42′, and on the 15th it is in R.A. 2 h 54 m, Decl. +15°37′, mag. −3.4, and transits at 11 h 23 m. It is not visible in May.

Mars on the 15th is in R.A. 15 h 08 m, Decl. −17°55′, mag. −1.7, and transits at 23 h 31 m. At magnitude −1.7, it dominates the constellation Libra. It rises at about sunset and sets at about sunrise. On May 11 it is at opposition. On May 19, it is closest to Earth: 0.5315 A or 79 500 000 km. At a particularly favourable opposition (of which this is not one), Mars can be as close as 55 000 000 km.

Jupiter on the 15th is in R.A. 18 h 55 m, Decl. −22°41′, mag. −2.1, and transits at 3 h 23 m. In Sagittarius, it rises about 5 h before the sun and is west of the meridian by sunrise.

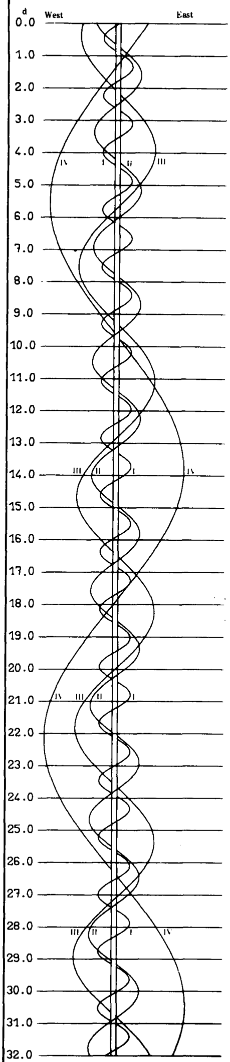
Saturn on the 15th is in R.A. 14 h 42 m, Decl. −13°02′, mag. +0.3, and transits at 23 h 07 m. In Libra, slightly west of Zubenelgenubi, it rises at about sunset and sets at about sunrise. On May 3 it is at opposition, at a distance of 8.853 A or 1 323 000 000 km.

Uranus on the 15th is in R.A. 16 h 43 m, Decl. −22°14′, mag. +5.8, and transits at 1 h 11 m.

Neptune on the 15th is in R.A. 18 h 04 m, Decl. −22°14′, mag. +7.7, and transits at 2 h 32 m.

1984			MAY UNIVERSAL TIME	Min. of Algol
	d	h m		h m
Tues.	1	03 45	● New Moon	15 50
Wed.	2			
Thur.	3	08	Saturn at opposition	
Fri.	4	07	η Aquarid meteors	12 40
		13	Mercury stationary	
Sat.	5			
Sun.	6			
Mon.	7		Mercury at aphelion	9 30
Tues.	8		Mars at descending node	
		11 50	☽ First Quarter	
Wed.	9			
Thur.	10			6 20
Fri.	11	09	Mars at opposition	
Sat.	12	03	Moon at perigee (365 600 km)	
Sun.	13			3 10
Mon.	14	08	Saturn 0.5° N. of Moon; occultation[1]	
		19	Mars 2° S. of Moon	
Tues.	15	04 29	○ Full Moon; eclipse of Moon, p. 76	23 50
Wed.	16	11	Uranus 0.6° N. of Moon; occultation[2]	
Thur.	17	20	Neptune 3° N. of Moon	
Fri.	18	17	Jupiter 3° N. of Moon	20 40
Sat.	19	11	Mars closest approach to Earth (79 500 000 km)	
		20	Mercury at greatest elong. W. (26°)	
Sun.	20			
Mon.	21			17 30
Tues.	22	17 45	☾ Last Quarter	
Wed.	23			
Thur.	24	01	Moon at apogee (404 500 km)	14 20
Fri.	25			
Sat.	26			
Sun.	27			11 10
Mon.	28		Mercury at greatest hel. lat. S.	
		18	Mercury 1.0° S. of Moon; occultation[3]	
Tues.	29			
Wed.	30	16 48	● New Moon; eclipse of Sun, p. 76	8 00
Thur.	31			

Config. of Jupiter's Satellites



[1]Visible from central and S. Pacific, S. of S. America, Antarctica
[2]Visible from New Guinea, Australia, New Zealand, Antarctica
[3]Visible from N. Pacific, Alaska, N. Canada, Arctic, N. Greenland

THE SKY FOR JUNE 1984

The Sun—During June, the sun's R.A. increases from 4 h 36 m to 6 h 41 m and its Decl. changes from +22°03′ to +23°07′. The equation of time changes from +2 m 16 s to −3 m 44 s, being zero June 13. On June 21 at 5:02 U.T., the sun reaches the summer solstice, and summer begins in the northern hemisphere.

The Moon—On June 1.0 U.T., the age of the moon is 1.3 d. The sun's selenographic colongitude is 291.05° and increases by 12.2° each day thereafter. The libration in longitude is maximum (west limb exposed) on June 14 (5°) and minimum (east limb exposed) on June 27 (6°). The libration in latitude is maximum (north limb exposed) on June 19 (7°) and minimum (south limb exposed) on June 6 (7°). On June 13, there is a penumbral eclipse of the moon, not visible from North America.

Mercury on the 1st is in R.A. 3 h 09 m, Decl. +14°59′, and on the 15th is in R.A. 4 h 52 m, Decl. +22°19′. It is not visible this month: after the rather unfavourable elongation discussed last month, it closes rapidly in on the sun, passing through superior conjunction on June 23.

Venus on the 1st is in R.A. 4 h 19 m, Decl. +21°02′, and on the 15th it is in R.A. 5 h 33 m, Decl. +23°28′, mag. −3.5, and transits at 12 h 00 m. It is not visible this month; it passes through superior conjunction on June 15.

Mars on the 15th is in R.A. 14 h 36 m, Decl. −16°54′, mag. −1.2, and transits at 20 h 58 m. In Libra, it is approaching the meridian at sunset, and sets shortly after midnight. Its retrograde motion has carried it westward almost as far as Saturn (which is 4° further north), but on June 20 it is stationary, then resumes its direct (eastward) motion relative to the background stars.

Jupiter on the 15th is in R.A. 18 h 43 m, Decl. −22°59′, mag. −2.2, and transits at 1 h 09 m. In Sagittarius, it rises at about sunset and sets at about sunrise. On June 29 it is at opposition, at a distance of 4.205 A or 629 000 000 km.

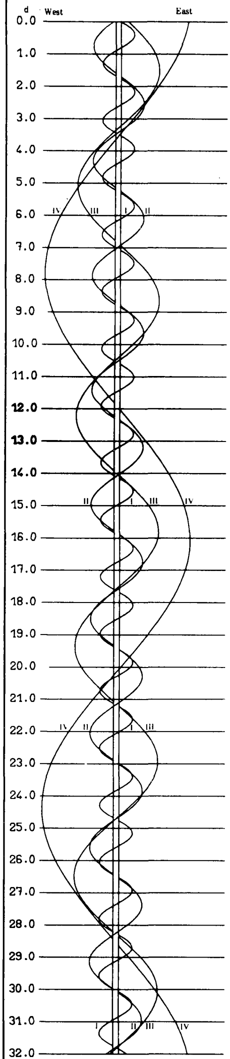
Saturn on the 15th is in R.A. 14 h 35 m, Decl. −12°32′, mag. +0.6, and transits at 20 h 57 m. In Libra, it is approaching the meridian at sunset and sets shortly after midnight. See also *Mars* above.

Uranus on the 15th is in R.A. 16 h 38 m, Decl. −22°04′, mag. +5.8, and transits at 23 h 00 m. On June 1 it is at opposition, at a distance of 18.00 A or 2 690 000 000 km.

Neptune on the 15th is in R.A. 18 h 01 m, Decl. −22°14′, mag. +7.7, and transits at 0 h 27 m. On June 21 it is at opposition, at a distance of 29.25 A or 4 370 000 000 km.

1984			JUNE UNIVERSAL TIME	Min. of Algol
	d	h m		h m
Fri.	1	22	Uranus at opposition	
Sat.	2			4 50
Sun.	3			
Mon.	4			
Tues.	5			1 40
Wed.	6	16 42	☽ First Quarter	
Thur.	7	11	Moon at perigee (369 500 km)	22 30
Fri.	8			
Sat.	9			
Sun.	10		Venus at ascending node	19 10
		13	Saturn 0.2° N. of Moon; occultation[1]	
		14	Mars 4° S. of Moon	
Mon.	11			
Tues.	12	18	Uranus 0.5° N. of Moon; occultation[2]	
Wed.	13	01	Mercury 5° N. of Aldebaran	16 00
		14 42	○ Full Moon; eclipse of Moon, p. 76	
Thur.	14	04	Neptune 3° N. of Moon	
		22	Jupiter 3° N. of Moon	
Fri.	15	23	Venus in superior conjunction	
Sat.	16		Mercury at ascending node	12 50
Sun.	17			
Mon.	18			
Tues.	19			9 40
Wed.	20		Mercury at perihelion	
		10	Mars stationary	
		20	Moon at apogee (404 200 km)	
Thur.	21	05 02	Summer solstice; summer begins	
		06	Neptune at opposition	
		11 10	☾ Last Quarter	
Fri.	22			6 30
Sat.	23	02	Mercury in superior conjunction	
Sun.	24			
Mon.	25			3 20
Tues.	26			
Wed.	27			
Thur.	28			0 10
Fri.	29	03 18	● New Moon	
		16	Jupiter at opposition	
Sat.	30		Mercury at greatest hel. lat. N.	21 00

Config. of Jupiter's Satellites



[1]Visible from India, S.E. Asia, Australia

[2]Visible from S. Africa, Madagascar, Indian Ocean, Antarctica, S. Australia, New Zealand

THE SKY FOR JULY 1984

The Sun—During July, the sun's R.A. increases from 6 h 41 m to 8 h 45 m and its Decl. changes from +23°07′ to +18°02′. The equation of time changes from −3 m 44 s to −6 m 17 s, reaching a minimum of −6 m 27 s on July 26. On July 3, Earth is at aphelion, 152 105 000 km from the sun. If you compare this distance with aphelion distances in previous years, you will notice that the distance is not constant, because the orbit of Earth is affected by the pull of the moon and planets as well as the pull of the sun.

The Moon—On July 1.0 U.T., the age of the moon is 1.9 d. The sun's selenographic colongitude is 297.70° and increases by 12.2° each day thereafter. The libration in longitude is maximum (west limb exposed) on July 10 (5°) and minimum (east limb exposed) on July 24 (7°). The libration in latitude is maximum (north limb exposed) on July 16 (7°) and minimum (south limb exposed) on July 3 (7°) and 30 (7°).

M

Mercury on the 1st is in R.A. 7 h 22 m, Decl. +23°57′, and on the 15th is in R.A. 9 h 08 m, Decl. +17°48′. During the month, it moves steadily east of the sun, reaching greatest elongation (27°) on Aug. 1. Although the size of the elongation is unusually large (because the planet is near aphelion), the geometry is rather unfavourable, and the planet is no more than 10° above the western horizon at sunset. It passes 0.8° south of Regulus on July 26.

Venus on the 1st is in R.A. 6 h 59 m, Decl. +23°31′, and on the 15th it is in R.A. 8 h 13 m, Decl. +21°09′, mag. −3.4, and transits at 12 h 41 m. It is not visible this month, as it is no more than 13° east of the sun.

Mars on the 15th is in R.A. 14 h 50 m, Decl. −18°37′, mag. −0.6, and transits at 19 h 16 m. In Libra, it is low in the south at sunset and sets about 4 h later. As a consequence of its eastward motion, its elongation decreases rather slowly during the rest of the year, but it fades in brightness by 2 magnitudes.

Jupiter on the 15th is in R.A. 18 h 27 m, Decl. −23°16′, mag. −2.2, and transits at 22 h 51 m. In Sagittarius, it rises at about sunset and sets at about sunrise.

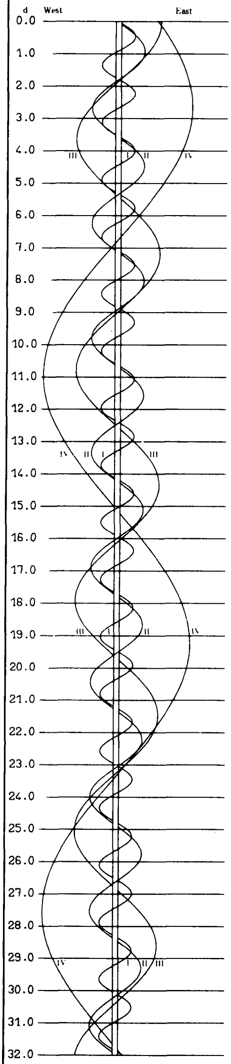
Saturn on the 15th is in R.A. 14 h 32 m, Decl. −12°27′, mag. +0.7, and transits at 18 h 57 m. In Libra, it is west of the meridian at sunset and sets about 4 h later. On July 14 it is stationary, then resumes its direct (eastward) motion relative to the stars.

Uranus on the 15th is in R.A. 16 h 33 m, Decl. −21°56′, mag. +5.8, and transits at 20 h 58 m.

Neptune on the 15th is in R.A. 17 h 58 m, Decl. −22°14′, mag. +7.7, and transits at 22 h 22 m. On July 22 Neptune occults the 8.7 magnitude star SAO 186001. The occultation lasts 28 minutes at Cerro Tololo, Chile; 4 minutes at Mauna Kea, Hawaii, but will be an appulse for most of North America. See p. 121 for more information.

1984			JULY UNIVERSAL TIME	Min. of Algol
	d	h m		h m
Sun.	1			
Mon.	2	23	Moon at perigee (367 300 km)	
Tues.	3	07	Earth at aphelion	17 40
		14	Mercury 5° S. of Pollux	
Wed.	4			
Thur.	5	21 04	☽ First Quarter	
Fri.	6			14 30
Sat.	7	17	Saturn 0.1° N. of Moon; occultation[1]	
		22	Mars 4° S. of Moon	
Sun.	8			
Mon.	9	23	Uranus 0.4° N. of Moon; occultation[2]	11 20
Tues.	10			
Wed.	11	11	Neptune 3° N. of Moon	
		20	Pallas stationary	
		23	Jupiter 3° N. of Moon	
Thur.	12			8 10
Fri.	13	02 20	☺ Full Moon	
Sat.	14		Venus at perihelion	
		04	Saturn stationary	
Sun.	15			5 00
Mon.	16	02	Pluto stationary	
Tues.	17			
Wed.	18	14	Moon at apogee (404 800 km)	1 50
Thur.	19			
Fri.	20			22 40
Sat.	21	04 01	☾ Last Quarter	
Sun.	22		Occultation of SAO 186001 by Neptune[3]	
Mon.	23			19 20
Tues.	24		Mercury at descending node	
Wed.	25			
Thur.	26	05	Mercury 0.8° S. of Regulus	16 10
Fri.	27		Jupiter at descending node	
Sat.	28	10	South δ Aquarid meteors	
		11 51	● New Moon	
Sun.	29			13 00
Mon.	30	07	Mercury 7° S. of Moon	
		12	Moon at perigee (362 400 km)	
Tues.	31			

Config. of Jupiter's Satellites



[1]Visible from Africa, Madagascar and the Indian Ocean
[2]Visible from S. America, S. Atlantic, S. Africa and Madagascar
[3]See p. 121 for more information

THE SKY FOR AUGUST 1984

The Sun—During August, the sun's R.A. increases from 8 h 45 m to 10 h 41 m and its Decl. changes from +18°02′ to +8°18′. The equation of time changes from −6 m 17 s to −0 m 03 s.

The Moon—On Aug. 1.0 U.T., the age of the moon is 3.5 d. The sun's selenographic colongitude is 304.37° and increases by 12.2° each day thereafter. The libration in longitude is maximum (west limb exposed) on Aug. 6 (6°) and minimum (east limb exposed) on Aug. 21 (7°). The libration in latitude is maximum (north limb exposed) on Aug. 12 (7°) and minimum (south limb exposed) on Aug. 26 (7°). Although the full moon interferes with observation of the Perseid meteors, there are several planets which are well placed for observation this month.

Mercury on the 1st is in R.A. 10 h 30 m, Decl. +7°59′, and on the 15th is in R.A. 10 h 53 m, Decl. +2°50′. During the month, it moves from greatest elongation east (27°) on Aug. 1 to inferior conjunction on Aug. 28, but as discussed last month, this is not a favourable elongation, and the planet stands no more than 10° above the western horizon at sunset.

Venus on the 1st is in R.A. 9 h 38 m, Decl. +15°40′, and on the 15th it is in R.A. 10 h 44 m, Decl. +9°36′, mag. −3.3, and transits at 13 h 10 m. Although the planet is moving eastward relative to the sun, the angle of the ecliptic to the horizon is such that it is too low in the sky to be visible.

Mars on the 15th is in R.A. 15 h 43 m, Decl. −22°08′, mag. −0.1, and transits at 18 h 07 m. It is west of the meridian at sunset and sets about 3 h later. It moves from Libra through Scorpius, and is approaching Antares by the end of the month. Mars and Antares are similar in colour, but Mars is somewhat brighter.

Jupiter on the 15th is in R.A. 18 h 15 m, Decl. −23°26′, mag. −2.1, and transits at 20 h 37 m. In Sagittarius, it is east of the meridian at sunset and sets at about midnight. On Aug. 29 it is stationary, then resumes its direct (eastward) motion relative to the stars.

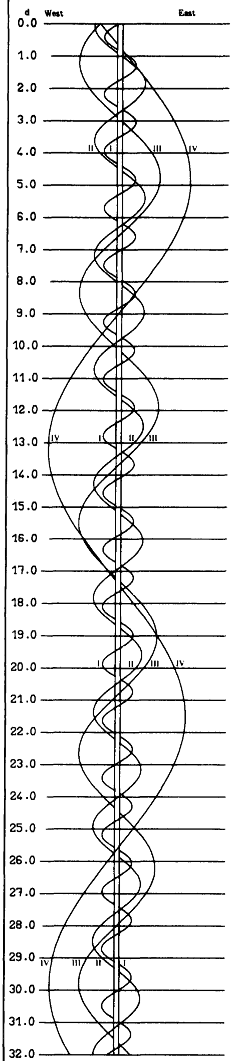
Saturn on the 15th is in R.A. 14 h 35 m, Decl. −12°51′, mag. +0.8, and transits at 16 h 58 m. In Libra, it is low in the south-west at sunset and sets about 3 h later.

Uranus on the 15th is in R.A. 16 h 31 m, Decl. −21°52′, mag. +5.8, and transits at 18 h 54 m.

Neptune on the 15th is in R.A. 17 h 55 m, Decl. −22°15′, mag. +7.7, and transits at 20 h 17 m.

1984	d	h m	AUGUST UNIVERSAL TIME	Min. of Algol h m
Wed.	1	00	Mercury at greatest elong. E. (27°)	9 50
Thur.	2			
Fri.	3		Mercury at aphelion	
Sat.	4	00	Saturn 0.3° N. of Moon; occultation[1]	6 40
		02 33	☽ First Quarter	
		22	Mars 3° S. of Moon	
Sun.	5		Venus at greatest hel. lat. N.	
Mon.	6	04	Uranus 0.5° N. of Moon; occultation[2]	
Tues.	7	05	Venus 1.1° N. of Regulus	3 30
		15	Neptune 3° N. of Moon	
		15	Juno in conjunction	
Wed.	8	01	Jupiter 2° N. of Moon	
Thur.	9			
Fri.	10	02	Vesta in conjunction	0 20
Sat.	11	15 43	○ Full Moon	
Sun.	12	01	Perseid meteors	21 00
Mon.	13			
Tues.	14	01	Mercury stationary	
Wed.	15	05	Moon at apogee (405 800 km)	17 50
Thur.	16	16	Mercury 6° S. of Venus	
Fri.	17			
Sat.	18	06	Uranus stationary	14 40
Sun.	19	19 40	☾ Last Quarter	
Mon.	20			
Tues.	21			11 30
Wed.	22			
Thur.	23			
Fri.	24		Mercury at greatest hel. lat. S.	8 20
Sat.	25			
Sun.	26	19 25	● New Moon	
Mon.	27	17	Moon at perigee (358 500 km)	5 10
Tues.	28	03	Venus 4° S. of Moon	
		15	Mercury in inferior conjunction	
Wed.	29	23	Jupiter stationary	
Thur.	30			2 00
Fri.	31	09	Saturn 0.5° N. of Moon; occultation[3]	

Config. of Jupiter's Satellites



[1]Visible from the Pacific, and the S. of S. America
[2]Visible from the S. Pacific, Antarctica, and the S. of S. America
[3]Visible from E. Africa, Madagascar, S.W. Australia, Tasmania, New Zealand

THE SKY FOR SEPTEMBER 1984

The Sun—During September, the sun's R.A. increases from 10 h 41 m to 12 h 29 m and its Decl. changes from +8°18′ to −3°10′. The equation of time changes from −0 m 03 s to +10 m 16 s, being zero on Sept. 1. On Sept 22 at 20:33 U.T., the sun reaches the autumnal equinox, and autumn begins in the northern hemisphere.

The Moon—On Sept. 1.0 U.T., the age of the moon is 5.2 d. The sun's selenographic colongitude is 335.28° and increases by 12.2° each day thereafter. The libration in longitude is maximum (west limb exposed) on Sept. 2 (7°) and minimum (east limb exposed) on Sept. 19 (8°). The libration in latitude is maximum (north limb exposed) on Sept. 8 (7°) and minimum (south limb exposed) on Sept. 22 (7°). The Harvest Moon (which is the full moon closest in time to the autumnal equinox) occurs on Sept. 10. Around this time, the moon rises at about the same time each evening (as you can see from the tables of moonrise elsewhere in this *Handbook*).

M *Mercury* on the 1st is in R.A. 10 h 13 m, Decl. +7°27′, and on the 15th is in R.A. 10 h 26 m, Decl. +10°31′. It is at greatest elongation west (18°) on Sept. 14, so around the middle of the month, it can be seen very low in the east at sunrise. The unusually small value of the greatest elongation (18°) results from the fact that the planet is at perihelion on Sept. 16. It passes 3° south of Regulus on Sept. 4 (moving westward), is stationary on Sept. 6, then passes 1.6° south of Regulus again on Sept. 8 (moving eastward).

Venus on the 1st is in R.A. 12 h 01 m, Decl. +1°09′, and on the 15th it is in R.A. 13 h 03 m, Decl. −6°02′, mag. −3.3, and transits at 13 h 27 m. Despite the slowly-increasing elongation, it is still too low in the sky to be seen with ease. It passes 3° north of Spica on Sept. 19.

Mars on the 15th is in R.A. 17 h 01 m, Decl. −25°02′, mag. +0.3, and transits at 17 h 23 m. It is west of the meridian at sunset and sets about 3 h later. During the month, it moves rapidly eastward along the lower boundary of Ophiuchus, passing 2° north of Antares on Sept. 3. On Sept. 4 it passes 2° south of Uranus, providing a good excuse and opportunity to look for Uranus with binoculars or a small telescope.

Jupiter on the 15th is in R.A. 18 h 15 m, Decl. −23°30′, mag. −1.9, and transits at 18 h 36 m. In Sagittarius, east of Mars, it is low in the south at sunset and sets about 4 h later.

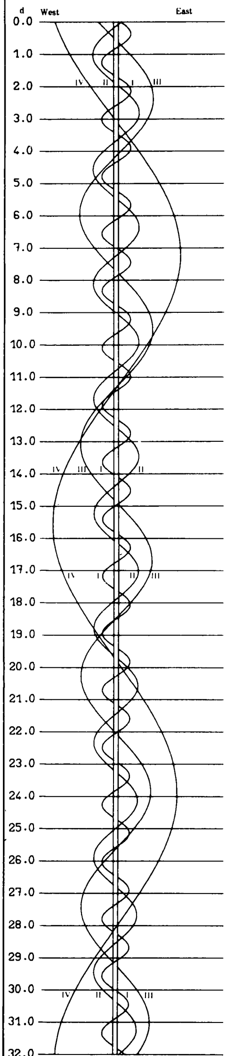
Saturn on the 15th is in R.A. 14 h 44 m, Decl. −13°38′, mag. +0.9, and transits at 15 h 05 m. In Libra, it is very low in the south-west at sunset and sets shortly afterward. Late in the month, it passes 2° north of Zubenelgenubi.

Uranus on the 15th is in R.A. 16 h 33 m, Decl. −21°56′, mag. +5.9, and transits at 16 h 54 m. See also *Mars* above.

Neptune on the 15th is in R.A. 17 h 54 m, Decl. −22°16′, mag. +7.7, and transits at 18 h 15 m.

1984	d	h m	SEPTEMBER UNIVERSAL TIME	Min. of Algol h m
Sat.	1			22 40
Sun.	2	07	Mars 1.7° S. of Moon	
		10 30	☽ First Quarter	
		10	Uranus 0.8° N. of Moon; occultation[1]	
Mon.	3	03	Mars 2° N. of Antares	
		20	Neptune 4° N. of Moon	
Tues.	4	03	Mercury 3° S. of Regulus	19 30
		05	Jupiter 3° N. of Moon	
		11	Mars 2° S. of Uranus	
Wed.	5			
Thur.	6	08	Mercury stationary	
		09	Pallas at opposition	
Fri.	7			16 20
Sat.	8	12	Mercury 1.6° S. of Regulus	
Sun.	9	23	Neptune stationary	
Mon.	10	07 01	○ Full Moon; Harvest Moon	13 10
Tues.	11	13	Moon at apogee (406 400 km)	
Wed.	12		Mercury at ascending node	
Thur.	13			10 00
Fri.	14	01	Mercury at greatest elong. W. (18°)	
Sat.	15			
Sun.	16		Mercury at perihelion	6 50
Mon.	17			
Tues.	18	09 31	☾ Last Quarter	
Wed.	19	15	Venus 3° N. of Spica	3 40
Thur.	20			
Fri.	21			
Sat.	22	01	Ceres stationary	0 20
		20 33	Autumnal equinox, autumn begins	
Sun.	23			
Mon.	24			21 10
Tues.	25	03 11	● New Moon	
		03	Moon at perigee (357 000 km)	
Wed.	26		Mercury at greatest hel. lat. N.	
Thur.	27	00	Venus 2° S. of Moon	18 00
		22	Saturn 0.9° N. of Moon; occultation[2]	
Fri.	28			
Sat.	29	19	Uranus 1.1° N. of Moon; occultation[1]	
Sun.	30		Venus at descending node	14 50

Config. of Jupiter's Satellites



[1]Visible from Antarctica

[2]Visible from New Zealand, S. Pacific and Antarctica

THE SKY FOR OCTOBER 1984

The Sun—During October, the sun's R.A. increases from 12 h 29 m to 14 h 25 m and its Decl. changes from −3°10′ to −14°25′. The equation of time changes from +10 m 16 s to +16 m 24 s.

The Moon—On Oct 1.0 U.T., the age of the moon is 5.9 d. The sun's selenographic colongitude is 341.32° and increases by 12.2° each day thereafter. The libration in longitude is maximum (west limb exposed) on Oct. 1 (8°) and 29 (7°) and minimum (east limb exposed) on Oct. 17 (7°). The libration in latitude is maximum (north limb exposed) on Oct. 5 (7°) and minimum (south limb exposed) on Oct. 20 (7°). The Hunters' Moon occurs on Oct. 9. This is the full moon following the Harvest Moon, and has rather similar properties: the moon rises at about the same time for several days in succession, providing useful light for evening activities at that time.

M

Mercury on the 1st is in R.A. 12 h 04 m, Decl. +1°30′, and on the 15th is in R.A. 13 h 33 m, Decl. −9°03′. It passes through superior conjunction on Oct. 10, and is not visible this month.

Venus on the 1st is in R.A. 14 h 17 m, Decl. −13°44′, and on the 15th it is in R.A. 15 h 24 m, Decl. −19°23′, mag. −3.4, and transits at 13 h 50 m. Throughout the month, it continues to move slowly eastward relative to the sun, but it is still very low in the sky at sunset, and can only be seen with difficulty. It passes 3° south of Saturn on Oct. 8, 3° north of Antares on Oct. 27 and 1.5° south of Uranus on Oct. 30.

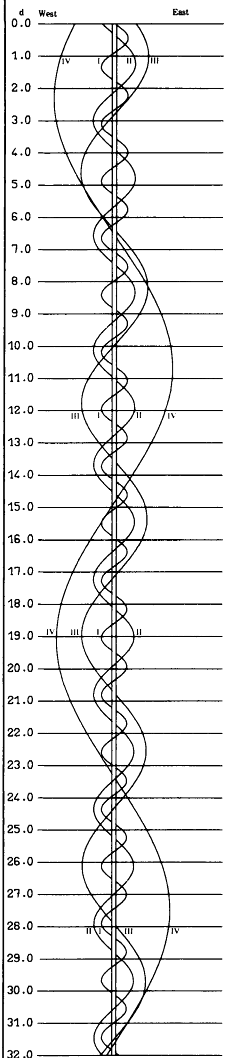
Mars on the 15th is in R.A. 18 h 30 m, Decl. −25°18′, mag. +0.6, and transits at 16 h 55 m. Early in the month, Mars moves from Ophiuchus into Sagittarius, passing 1.9° south of Jupiter (on Oct. 13) in its rapid motion eastward across the constellation. At sunset, the two planets can be seen very low in the southern sky and they set about 4 h later. See also *Neptune* below.

Jupiter on the 15th is in R.A. 18 h 27 m, Decl. −23°26′, mag. −1.7, and transits at 16 h 50 m. In Sagittarius (as mentioned above), it is very low in the southern sky at sunset and sets about 4 h later.

Saturn on the 15th is in R.A. 14 h 56 m, Decl. −14°36′, mag. +0.8, and transits at 13 h 19 m. In Libra, it is closing in rapidly on the sun; under good conditions, it might possibly be visible early in the month, very low in the south-west, just after sunset. See also *Venus* above.

Uranus on the 15th is in R.A. 16 h 37 m, Decl. −22°04′, mag. +5.9, and transits at 15 h 00 m. On Oct. 30, Venus passes 1.5° south of Uranus.

Neptune on the 15th is in R.A. 17 h 56 m, Decl. −22°18′, mag. +7.8, and transits at 16 h 18 m. On Oct. 3, Mars passes 3° south of Neptune.

1984			OCTOBER UNIVERSAL TIME	Min. of Algol	Config. of Jupiter's Satellites
	d	h m		h m	
Mon.	1	00	Mars 0.3° N. of Moon; occultation[1]		
		03	Neptune 4° N. of Moon		
		14	Jupiter 3° N. of Moon		
		21 52	☽ First Quarter		
Tues.	2				
Wed.	3	14	Mars 3° S. of Neptune	11 40	
Thur.	4				
Fri.	5				
Sat.	6			8 30	
Sun.	7				
Mon.	8	15	Moon at apogee (406 300 km)		
		17	Venus 3° S. of Saturn		
Tues.	9	23 58	☺ Full Moon; Hunters' Moon	5 20	
Wed.	10	18	Mercury in superior conjunction		
Thur.	11				
Fri.	12		Mars at greatest hel. lat. S.	2 00	
Sat.	13	23	Mars 1.9° S. of Jupiter		
Sun.	14			22 50	
Mon.	15				
Tues.	16				
Wed.	17	21 14	☾ Last Quarter	19 40	
Thur.	18				
Fri.	19				
Sat.	20		Mercury at descending node	16 30	
Sun.	21	05	Orionid meteors		
		20	Vesta 0.4° S. of Moon; occultation		
Mon.	22				
Tues.	23	14	Moon at perigee (358 500 km)	13 20	
Wed.	24	12 08	● New Moon		
Thur.	25	08	Pluto in conjunction		
Fri.	26	15	Pallas stationary	10 10	
Sat.	27	00	Venus 0.3° S. of Moon; occultation[2]		
		06	Uranus 1.3° N. of Moon		
		16	Venus 3° N. of Antares		
Sun.	28	13	Neptune 4° N. of Moon		
Mon.	29	05	Jupiter 3° N. of Moon	7 00	
		20	Mercury 3° S. of Saturn		
		21	Mars 2° N. of Moon		
Tues.	30		Mercury at aphelion		
		00	Venus 1.5° S. of Uranus		
Wed.	31	13 07	☽ First Quarter		

[1]Visible from S. Pacific, S. of S. America
[2]Visible from Japan, Pacific, Central America

THE SKY FOR NOVEMBER 1984

The Sun—During November, the sun's R.A. increases from 14 h 25 m to 16 h 29 m and its Decl. changes from −14°25′ to −21°48′. The equation of time changes from +16 m 24 s to +11 m 02 s, reaching a maximum of +16 m 26 s on Nov. 3. On Nov. 22–23, there is a total eclipse of the sun, visible along a path extending from Indonesia eastward across the South Pacific. The partial phases of the eclipse are not visible from North America. The path of totality is rather similar to that for the June 11, 1983 eclipse. Note that the moon is near perigee, as is usually the case when there is a total eclipse of the sun. Why?

The Moon—On Nov. 1.0 U.T., the age of the moon is 7.5 d. The sun's selenographic colongitude is 359.04° and increases by 12.2° each day thereafter. The libration in longitude is maximum (west limb exposed) on Nov. 26 (6°) and minimum (east limb exposed) on Nov. 13 (6°). The libration in latitude is maximum (north limb exposed) on Nov. 2 (7°) and 29 (7°) and minimum (south limb exposed) on Nov. 16 (7°). On Nov. 8, there is a penumbral eclipse of the moon, not visible from North America except from the most extreme northern parts.

Mercury on the 1st is in R.A. 15 h 16 m, Decl. −19°27′, and on the 15th is in R.A. 16 h 41 m, Decl. −24°37′. Towards the end of the month, it may be visible very low in the south-west, just after sunset. It reaches greatest elongation east (22°) on Nov. 25. This is not a particularly favourable elongation, however, especially as the planet is well south of the ecliptic. On Nov. 12, it passes 2° north of Antares.

Venus on the 1st is in R.A. 16 h 51 m, Decl. −24°02′, and on the 15th it is in R.A. 18 h 05 m, Decl. −25°28′, mag. −3.5, and transits at 14 h 29 m. Moving eastward through Sagittarius, it may be seen with difficulty, very low in the south south-west, just after sunset. It passes 3° south of Neptune on Nov. 13 and 2° south of Jupiter on Nov. 24. On Nov. 19 Venus occults the star λ Sagittarii, an event visible from parts of the west coast of N. America (see p. 121).

Mars on the 15th is in R.A. 20 h 08 m, Decl. −21°54′, mag. +0.8, and transits at 16 h 30 m. Moving from Sagittarius into Capricornus, it is very low in the southern sky at sunset and sets about 4½ h later.

Jupiter on the 15th is in R.A. 18 h 49 m, Decl. −23°09′, mag. −1.5, and transits at 15 h 10 m. In Sagittarius, it may be seen with difficulty, low in the south south-west at sunset, and it sets shortly thereafter. See also *Venus* above.

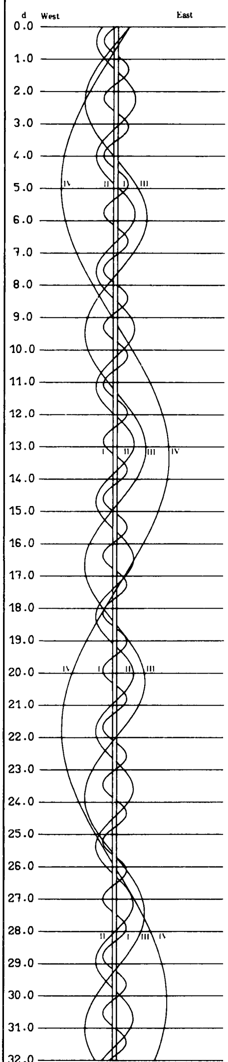
Saturn on the 15th is in R.A. 15 h 11 m, Decl. −15°39′, mag. +0.7, and transits at 11 h 32 m. It is in conjunction with the sun on Nov. 11 and is not visible this month.

Uranus on the 15th is in R.A. 16 h 44 m, Decl. −22°18′, mag. +6.0, and transits at 13 h 05 m.

Neptune on the 15th is in R.A. 17 h 59 m, Decl. −22°19′, mag. +7.8, and transits at 14 h 20 m.

1984			NOVEMBER UNIVERSAL TIME	Min. of Algol
	d	h m		h m
Thur.	1			3 50
Fri.	2			
Sat.	3		South Taurid meteors	
			Venus at aphelion	
Sun.	4	23	Moon at apogee (405 700 km)	0 30
Mon.	5			
Tues.	6			21 20
Wed.	7		Mars at perihelion	
Thur.	8	17 43	○ Full Moon; eclipse of Moon, p. 76	
Fri.	9			18 10
Sat.	10	12	Ceres at opposition	
Sun.	11	07	Saturn in conjunction	
Mon.	12	22	Mercury 2° N. of Antares	15 00
Tues.	13	19	Venus 3° S. of Neptune	
Wed.	14			
Thur.	15	14	Mercury 2° S. of Uranus	11 50
Fri.	16	06 59	☽ Last Quarter	
Sat.	17	12	Leonid meteors	
Sun.	18			8 40
Mon.	19		Mercury at greatest hel. lat. S.	
		01 35	Occultation of λ Sgr by Venus[1]	
		03	Vesta 1.1° N. of Moon; occultation	
Tues.	20	21	Moon at perigee (362 800 km)	
Wed.	21			5 30
Thur.	22	22 57	● New Moon; eclipse of Sun, p. 76	
Fri.	23			
Sat.	24	14	Mercury 0.1° S. of Moon; occultation[2]	2 20
		21	Venus 2° S. of Jupiter	
Sun.	25	00	Neptune 4° N. of Moon	
		18	Mercury at greatest elong. E. (22°)	
		23	Jupiter 4° N. of Moon	
Mon.	26		Venus at greatest hel. lat. S.	23 10
		01	Venus 1.6° N. of Moon	
Tues.	27	21	Mars 4° N. of Moon	
Wed.	28			
Thur.	29			19 50
Fri.	30	08 00	☽ First Quarter	

Config. of Jupiter's Satellites



[1]See p. 121 for further information
[2]Visible from N. of S. America, S. Atlantic, central and S. Africa, Madagascar

THE SKY FOR DECEMBER 1984

The Sun—During December, the sun's R.A. increases from 16 h 29 m to 18 h 46 m and its Decl. changes from −21°48′ to −23°02′. The equation of time changes from +11 m 02 s to −3 m 24 s, being zero on Dec. 25. On Dec. 21, at 16:23 U.T., the sun reaches the winter solstice, and winter begins in the northern hemisphere.

The Moon—On Dec. 1.0 U.T., the age of the moon is 8.0 d. The sun's selenographic colongitude is 4.13° and increases by 12.2° each day thereafter. The libration in longitude is maximum (west limb exposed) on Dec. 24 (5°) and minimum (east limb exposed) on Dec. 10 (5°). The libration in latitude is maximum (north limb exposed) on Dec. 26 (7°) and minimum (south limb exposed) on Dec. 13 (7°).

M

Mercury on the 1st is in R.A. 17 h 58 m, Decl. −25°21′, and on the 15th is in R.A. 17 h 27 m, Decl. −21°17′. During the month, it passes rapidly through inferior conjunction and, by the end of the month it can be seen very low in the south-east, just before sunrise. Why does it pass so unusually quickly through inferior conjunction? Because it also passes through perihelion at that time, and its orbital velocity is greater than average at that time.

Venus on the 1st is in R.A. 19 h 30 m, Decl. −24°11′, and on the 15th it is in R.A. 20 h 39 m, Decl. −20°42′, mag. −3.7, and transits at 15 h 05 m. It can be seen very low in the south south-west, just after sunset and it sets about 3 h later.

Mars on the 15th is in R.A. 21 h 40 m, Decl. −15°17′, mag. +1.0, and transits at 16 h 04 m. Moving from Capricornus into Aquarius, it is low in the south at sunset and sets about $4\frac{1}{2}$ h later.

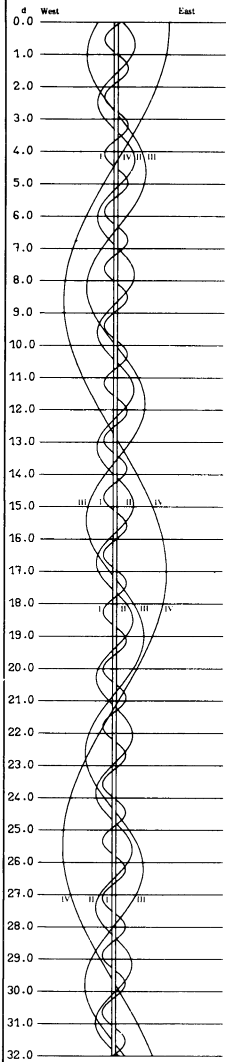
Jupiter on the 15th is in R.A. 19 h 16 m, Decl. −22°31′, mag. −1.5, and transits at 13 h 39 m. In Sagittarius, it may be seen with great difficulty, very low in the south-west at sunset.

Saturn on the 15th is in R.A. 15 h 25 m, Decl. −16°32′, mag. +0.8, and transits at 9 h 48 m. In Libra, it moves rapidly west of the sun, and by the end of the month, it rises about 3 h before the sun and can be seen low in the south-east just before sunrise.

Uranus on the 15th is in R.A. 16 h 52 m, Decl. −22°31′, mag. +6.0, and transits at 11 h 15 m. On Dec. 5, it is in conjunction with the sun.

Neptune on the 15th is in R.A. 18 h 04 m, Decl. −22°19′, mag. +7.8, and transits at 12 h 26 m. On Dec. 23, it is in conjunction with the sun.

1984			DECEMBER UNIVERSAL TIME	Min. of Algol	Config. of Jupiter's Satellites
	d	h m		h m	
Sat.	1				
Sun.	2	15	Moon at apogee (404 800 km)	16 40	
		15	Mercury 3° S. of Neptune		
Mon.	3				
Tues.	4	21	Mercury stationary		
Wed.	5	18	Uranus in conjunction	13 30	
Thur.	6	15	Mercury 1.8° S. of Neptune		
Fri.	7				
Sat.	8	10 53	☺ Full Moon	10 20	
Sun.	9		Mercury at ascending node		
Mon.	10				
Tues.	11			7 10	
Wed.	12				
Thur.	13		Mercury at perihelion		
Fri.	14	00	Geminid meteors	4 00	
		14	Mercury in inferior conjunction		
Sat.	15	15 25	☾ Last Quarter		
Sun.	16				
Mon.	17			0 50	
Tues.	18	10	Moon at perigee (368 400 km)		
Wed.	19	21	Saturn 1.8° N. of Moon	21 40	
Thur.	20				
Fri.	21		Uranus at descending node		
		16 23	Winter solstice; winter begins		
Sat.	22	06	Ursid meteors	18 30	
		11 47	● New Moon		
		19	Neptune in conjunction		
Sun.	23		Mercury at greatest hel. lat. N.		
		20	Jupiter 4° N. of Moon		
		22	Mercury 3° N. of Uranus		
Mon.	24	17	Mercury stationary		
Tues.	25			15 20	
Wed.	26	02	Venus 3° N. of Moon		
		07	Mercury 3° N. of Uranus		
Thur.	27	00	Mars 4° N. of Moon		
		23	Pallas 1.2° N. of Moon; occultation		
Fri.	28			12 10	
Sat.	29				
Sun.	30	05 27	☽ First Quarter		
		12	Moon at apogee (404 300 km)		
Mon.	31			9 00	



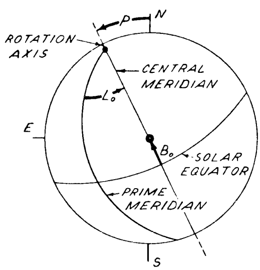
SUN
EPHEMERIS

⊙

Date 0^hUT	Apparent 1984 RA	Apparent 1984 Dec	Transit at Greenwich UT	Orientation P	Orientation B_0	Orientation L_0
	h m	° ′	h m s	°	°	°
Jan 1	18 42.4	-23 05	12 03 17	+ 2.4	-3.0	101.8
6	19 04.4	-22 37	12 05 36	- 0.0	-3.5	35.9
11	19 26.3	-21 58	12 07 43	- 2.4	-4.1	330.1
16	19 47.9	-21 08	12 09 35	- 4.8	-4.6	264.2
21	20 09.2	-20 08	12 11 10	- 7.1	-5.1	198.4
26	20 30.3	-18 58	12 12 27	- 9.3	-5.5	132.6
31	20 51.0	-17 40	12 13 24	-11.5	-5.9	66.8
Feb 5	21 11.3	-16 14	12 14 01	-13.5	-6.2	0.9
10	21 31.3	-14 41	12 14 17	-15.4	-6.6	295.1
15	21 51.0	-13 02	12 14 13	-17.2	-6.8	229.2
20	22 10.4	-11 17	12 13 51	-18.8	-7.0	163.4
25	22 29.5	- 9 28	12 13 13	-20.3	-7.1	97.6
Mar 1	22 48.4	- 7 36	12 12 21	-21.6	-7.2	31.7
6	23 07.0	- 5 40	12 11 16	-22.8	-7.2	325.8
11	23 25.5	- 3 43	12 10 00	-23.8	-7.2	259.9
16	23 43.8	- 1 45	12 08 37	-24.6	-7.1	194.0
21	0 02.1	+ 0 13	12 07 08	-25.3	-7.0	128.1
26	0 20.3	+ 2 12	12 05 38	-25.8	-6.8	62.2
31	0 38.5	+ 4 09	12 04 07	-26.2	-6.6	356.2
Apr 5	0 56.7	+ 6 04	12 02 39	-26.3	-6.3	290.3
10	1 15.0	+ 7 56	12 01 16	-26.3	-5.9	224.3
15	1 33.4	+ 9 45	11 59 59	-26.0	-5.6	158.3
20	1 52.0	+11 30	11 58 51	-25.6	-5.2	92.2
25	2 10.8	+13 11	11 57 54	-25.1	-4.7	26.2
30	2 29.7	+14 46	11 57 10	-24.3	-4.2	320.1
May 5	2 48.9	+16 15	11 56 39	-23.4	-3.7	254.0
10	3 08.3	+17 37	11 56 22	-22.2	-3.2	187.9
15	3 27.9	+18 52	11 56 18	-20.9	-2.6	121.8
20	3 47.8	+19 58	11 56 29	-19.5	-2.0	55.7
25	4 07.9	+20 57	11 56 53	-17.9	-1.4	349.5
30	4 28.2	+21 46	11 57 30	-16.1	-0.8	283.4
Jun 4	4 48.7	+22 26	11 58 18	-14.2	-0.2	217.2
9	5 09.3	+22 56	11 59 13	-12.2	+0.4	151.0
14	5 30.0	+23 16	12 00 14	-10.2	+1.0	84.8
19	5 50.8	+23 26	12 01 19	- 8.0	+1.5	18.6
24	6 11.6	+23 25	12 02 24	- 5.8	+2.1	312.5
29	6 32.4	+23 14	12 03 26	- 3.5	+2.7	246.3
Jul 4	6 53.0	+22 53	12 04 23	- 1.2	+3.2	180.1
9	7 13.6	+22 22	12 05 12	+ 1.0	+3.8	113.9
14	7 33.9	+21 41	12 05 49	+ 3.3	+4.3	47.8
19	7 54.1	+20 51	12 06 14	+ 5.5	+4.7	341.6
24	8 14.0	+19 53	12 06 26	+ 7.6	+5.2	275.4
29	8 33.7	+18 46	12 06 24	+ 9.7	+5.6	209.3

Date 0^hUT	Apparent 1984 RA	Apparent 1984 Dec	Transit at Greenwich UT	Orientation P	Orientation B_0	Orientation L_0
	h m	° ′	h m s	°	°	°
Aug 3	8 53.2	+17 31	12 06 06	+11.7	+5.9	143.2
8	9 12.4	+16 09	12 05 33	+13.6	+6.3	77.1
13	9 31.3	+14 41	12 04 45	+15.4	+6.6	11.0
18	9 50.0	+13 07	12 03 44	+17.1	+6.8	304.9
23	10 08.5	+11 28	12 02 30	+18.6	+7.0	238.8
28	10 26.8	+ 9 44	12 01 07	+20.1	+7.1	172.7
Sep 2	10 45.0	+ 7 56	11 59 34	+21.4	+7.2	106.7
7	11 03.1	+ 6 05	11 57 54	+22.6	+7.2	40.6
12	11 21.0	+ 4 12	11 56 09	+23.6	+7.2	334.6
17	11 39.0	+ 2 16	11 54 22	+24.4	+7.2	268.6
22	11 56.9	+ 0 20	11 52 36	+25.2	+7.0	202.6
27	12 14.9	- 1 37	11 50 53	+25.7	+6.9	136.6
Oct 2	12 33.0	- 3 34	11 49 15	+26.1	+6.6	70.6
7	12 51.2	- 5 29	11 47 45	+26.3	+6.4	4.7
12	13 09.5	- 7 23	11 46 24	+26.3	+6.0	298.7
17	13 28.1	- 9 14	11 45 17	+26.1	+5.7	232.7
22	13 46.9	-11 02	11 44 26	+25.8	+5.3	166.8
27	14 06.0	-12 46	11 43 51	+25.2	+4.8	100.8
Nov 1	14 25.5	-14 25	11 43 35	+24.5	+4.3	34.9
6	14 45.2	-15 58	11 43 39	+23.6	+3.8	329.0
11	15 05.3	-17 25	11 44 03	+22.4	+3.2	263.1
16	15 25.7	-18 44	11 44 49	+21.1	+2.7	197.2
21	15 46.5	-19 54	11 45 56	+19.6	+2.1	131.2
26	16 07.6	-20 56	11 47 23	+17.9	+1.5	65.4
Dec 1	16 29.1	-21 48	11 49 08	+16.0	+0.8	359.4
6	16 50.8	-22 29	11 51 09	+14.0	+0.2	293.6
11	17 12.7	-23 00	11 53 22	+11.9	-0.4	227.7
16	17 34.8	-23 19	11 55 45	+ 9.7	-1.1	161.8
21	17 57.0	-23 26	11 58 14	+ 7.3	-1.7	95.9
26	18 19.2	-23 22	12 00 44	+ 5.0	-2.3	30.1
31	18 41.3	-23 06	12 03 10	+ 2.5	-2.9	324.2

P is the position angle of the axis of rotation, measured eastward from the north point on the disk. B_0 is the heliographic latitude of the centre of the disk, and L_0 is the heliographic longitude of the centre of the disk, from Carrington's solar meridian, measured in the direction of rotation (see diagram). The rotation period of the Sun depends on latitude. The *sidereal* period of rotation at the equator is 25.38^d.



SUNDIAL CORRECTION

The "Transit at Greenwich" time (pages 48 and 49) may be used to calculate the sundial correction at the observer's position. e.g. To find the correction at Winnipeg on August 15, 1984: At Greenwich the Sun transits at $12^h04^m45^s$ on August 13 and at $12^h03^m44^s$ on August 18. Thus, to the nearest minute, on August 15 at both Greenwich and Winnipeg the Sun will transit at 12^h04^m mean solar time, or 12^h33^m CST, since Winnipeg has a longitude correction of $+29^m$ (See page 54). Thus a 4^m correction must be added to the reading of a simple sundial to obtain mean solar time.

A figure accurate to a second or two can be obtained by interpolating for longitude. The interpolated transit time at Greenwich for August 15 is $12^h04^m21^s$, the daily change in the time being $-12\overset{s}{.}2$. Adjusting this for the longitude of Winnipeg: $12^h04^m21^s - (12\overset{s}{.}2 \times 6^h29^m \div 24^h) = 12^h04^m18^s$. Thus the sundial correction is 4^m18^s. To find the standard time of the Sun's transit to the nearest second or two, the observer's longitude must be known to $10''$ or better. e.g. Suppose an observer in Winnipeg is at longitude $97°13'50''$ W, or $6^h28^m55^s$ W of Greenwich. The time of transit will be $12^h04^m18^s + 28^m55^s = 12^h33^m13^s$ CST ($13^h33^m13^s$ CDT).

SOLAR ROTATION (SYNODIC)

DATES OF COMMENCEMENT (UT, $L_o = 0°$)
OF NUMBERED SYNODIC ROTATIONS

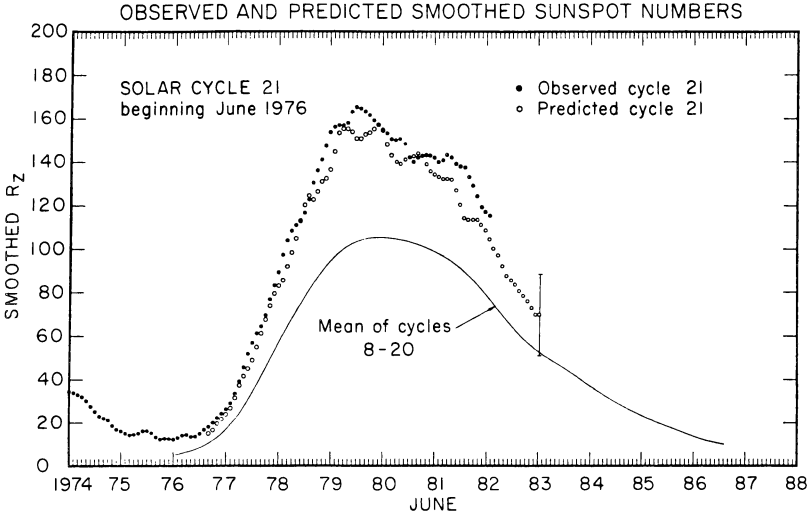
No.	Commences	No.	Commences	No.	Commences
1744	Jan 8.73	1749	May 24.21	1754	Oct 7.35
1745	Feb 5.07	1750	Jun 20.41	1755	Nov 3.65
1746	Mar 3.40	1751	Jul 17.61	1756	Nov 30.96
1747	Mar 30.71	1752	Aug 13.83	1757	Dec 28.28
1748	Apr 26.98	1753	Sep 10.08	1758	1985 Jan 24.62

SOLAR ACTIVITY

SUNSPOTS, FLARES, AND AURORAE

BY V. GAIZAUSKAS

The present sunspot cycle (21) is compared with the mean of cycles 8 to 20 in the diagram adapted from "Solar-Geophysical Data" (U.S. Dept. of Commerce, Boulder, Colorado). The data plotted in the graph are monthly smoothed relative sunspot numbers from Zürich. The vertical bar defines the interval in which the most recent value in the graph can be predicted with a confidence of 90%. These *smoothed* data indicate that the maximum of the cycle occurred in the interval December 1979–January 1980. Another measure of solar activity is the 10 cm microwave flux which has been monitored daily since 1947 by the National Research Council of Canada (Covington, A.E. 1967, *J. Roy. Astron. Soc. Can.*, *61*, 314). The 10 cm flux correlates closely with sunspot number and has the advantage of being reproducible without subjective bias by an observer.



The present trend of solar activity is steadily downward as episodes of high activity (e.g. June and December 1982, early May 1983) occur less frequently. The first evidence for the beginning of the next sunspot cycle (22) was announced in late April 1983 when several small bipolar regions appeared at high (>30°) northern heliographic latitudes. Although spots did not form, the preceding and following magnetic polarities in these regions had the signs appropriate to a new solar cycle. Sunspot minimum is not expected until 1987.

Successive eleven-year peaks of sunspot activity follow long-term trends which can in extreme cases result in prolonged periods of very low activity (Eddy, J.A. 1976, *Science*, *192*, 1189; 1977, *Scientific Am.*, *236*, 80). We are at an opposite extreme; Cycle 21 has the second highest peak of this century, exceeded only by Cycle 19 (maximum at 1957.9).

Occasional outbursts of intense solar activity will probably still occur in 1984. Amateurs who observe sunspots* may still find it worthwhile to keep a watch for

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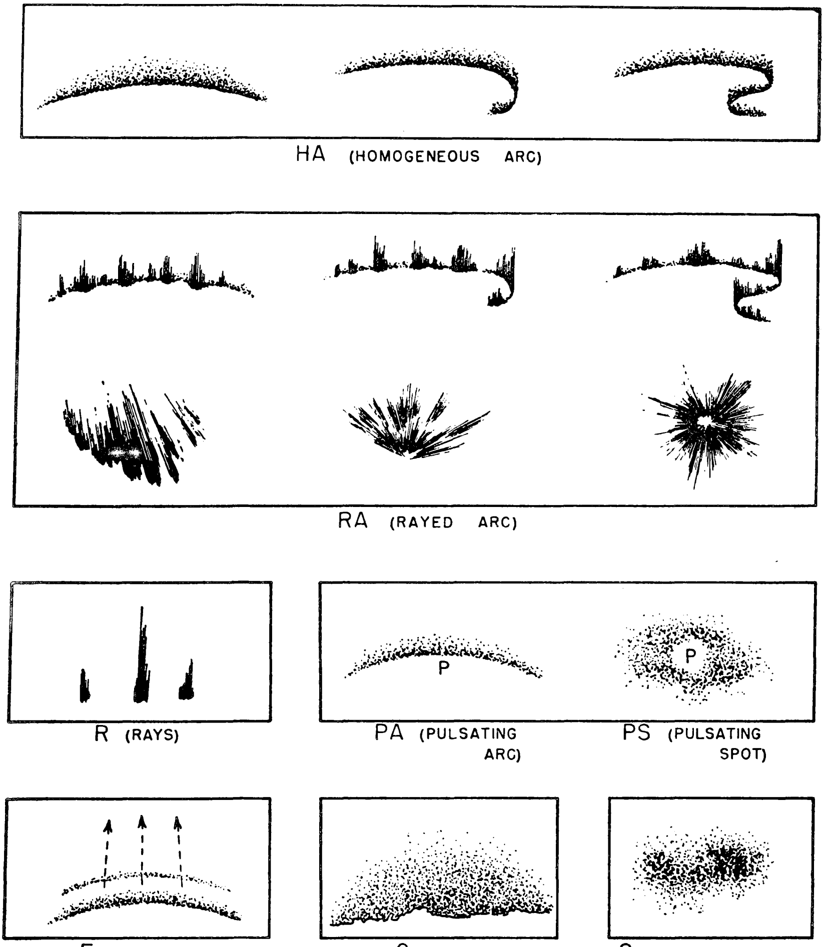
**Editor's Note*: Some of the hazards in viewing the sun and some effective safety precautions are discussed by B. Ralph Chou (*J. Roy. Astron. Soc. Can.*, *75*, 36, 1981; *Sky and Telescope*, *62*, 119, 1981).

white light flares (Pike, R. 1974, *J. Roy. Astron. Soc. Can.*, *68*, 330). Five or six white light flares are estimated to occur each year during a few years around peak sunspot activity. These rare events are visible in the solar photosphere for a few minutes at most and are not to be confused with long-enduring "light bridges" or bright facular patches adjacent to sunspots. White light flares erupt as one or more intensely bright and compact structures (a few arc-sec or less) during the explosive phase of highly energetic flares. They are most likely to occur in complex, rapidly-evolving sunspot groups with many closely-packed umbrae enclosed by a single penumbra. Forewarning of such energetic events may be given for several hours by a realignment of penumbral filaments or a major increase in penumbral size.

Some intense auroral displays may yet be observed in 1984 in the southern, populous parts of Canada. Aurorae ("Northern Lights") are caused by the precipitation into the ionosphere of energetic charged particles from a vast reservoir enveloping Earth, the *magnetosphere*. Seen from above (e.g. from the Canadian ISIS satellites) aurorae are concentrated in elliptical bands called *auroral ovals* that ring Earth's magnetic poles. When the Sun is calm, the ovals shrink to nearly circular rings centred close to the geomagnetic poles. As the Sun grows more active, the ovals advance towards lower latitudes (e.g. in Canada to Churchill, Man. and to Yellowknife, N.W.T.) and become more eccentric with respect to the geomagnetic poles. During periods of very intense solar activity, the ovals shift closer still towards the Equator (e.g. down to the Southern United States for the northern oval). For an observer at the ground, the shifting patterns of the aurora over the night sky reflect the
⊙ changes in the magnetic and electric fields along the paths of electrons streaming toward Earth.

The magnetospheric reservoir of particles is created by a complicated interaction between Earth's magnetic field and the *solar wind*, a magnetized plasma that flows continuously from the Sun even in the absence of solar activity. The solar wind has considerable structure; the highest speed streams originate in *coronal holes*, extended regions of low density and temperature in the solar corona. Near sunspot maximum, coronal holes are nearly absent except in small areas near the Sun's poles. But during the declining phase of the cycle, holes form rapidly and live longer (e.g. up to 10 solar rotations). They should reach their maximum extent by 1984–5 when single long-lived holes may extend from either of the Sun's poles to its equator and into the adjacent hemisphere. They are firmly associated with recurrent 27-day geomagnetic disturbances. The normal balance between the solar wind and the magnetosphere can be suddenly upset (e.g. by changes in the magnitude and direction of the magnetic field 'blown' towards Earth by the solar wind, by changes in the wind's speed, or by a major solar flare) and can lead to an *auroral sub-storm*. But universal agreement is still lacking on the exact mechanism which triggers sub-storms.

The atoms and molecules, mostly those of oxygen and nitrogen, that radiate the shimmering light of the aurora are terrestrial in origin. They become luminous at heights between 100 and 400 km through collisions with energetic particles that have leaked out of the magnetosphere during a sub-storm. A faint auroral display may not exceed the brightness threshold of colour perception for the eye; it will be sensed as white. Most aurorae appear green or blue-green with occasional faint patches of pink or red. The green colour is due to excited atoms of oxygen radiating at a wavelength of 558 nm; the blue is produced by ionized nitrogen molecules radiating in a group of spectral bands between 391 and 470 nm. The green and blue emissions are concentrated near an altitude of 110 km. Rare, all-red auroras have been measured to occur between 200 and 400 km; the red colour is due to the 630 and 636 nm lines of atomic oxygen, and is normally faint (because of the low concentration of oxygen at that altitude) unless the influx of particles is very great. Red emission also occurs at lower altitudes, near 90 km, where the spectrum can be dominated by emission in a series of bands between 650 and 680 nm.



Illustrative sketches of standard auroral forms. This simplified classification was devised for visual observers during the International Geophysical Year (IGY), nearly three decades ago. The sketches emphasize the fundamental features of auroral patterns and minimize variations which depend on the location of the observer.

TIMES OF SUNRISE AND SUNSET

The tables on pages 55 to 57 give the times of sunrise and sunset at four day intervals for places ranging from 20° to 60° north latitude. "Rise" and "set" correspond to the upper limb of the Sun appearing at the horizon for an observer at sea level. The values are in UT and are for the Greenwich meridian, although for North American observers the stated values may be read as standard time at the standard meridians (60°, 75°, *etc.*) without significant error. The values may be interpolated linearly for both non-tabular latitudes and dates. Also, it is possible to extrapolate the table beyond the 20° and 60° latitude limits a few degrees without significant loss of accuracy.

The standard time of an event at a particular location must take account of the observer's longitude relative to his or her standard meridian. The table below lists the latitude and the longitude correction (in minutes of time) for a number of cities and towns. e.g. To find the time of sunrise at Toronto on February 16, 1984: The latitude is 44°, and from the table the time of sunrise at 0° longitude is 06:59 UT. Thus at the Eastern time zone (E) meridian (75° west), the time of sunrise will be approximately 06:59 EST. The correction for Toronto is + 18 minutes, so sunrise will occur at 07:17 EST on that date. Corrections for places not listed below may be found by converting the difference between the longitude of the place and that of its standard meridian to time (15° = 1 h), the correction being positive if the place is west of its standard meridian, negative if east. Finally, it should be emphasized that the observed time will often differ up to several minutes from the predicted time because of a difference in height between the observer and the actual horizon.

CANADIAN CITIES AND TOWNS						AMERICAN CITIES		
	Lat.	Corr.		Lat.	Corr.		Lat.	Corr.
Baker Lake	64°	+24C	Peterborough	44°	+13E	Atlanta	34°	+37E
Brandon	50	+40C	Prince Albert	53	+63C	Baltimore	39	+06E
Calgary	51	+36M	Prince George	54	+11P	Birmingham	33	−13C
Charlottetown	46	+12A	Prince Rupert	54	+41P	Boston	42	−16E
Chicoutimi	48	−16E	Quebec	47	−15E	Buffalo	43	+15E
Churchill	59	+17C	Regina	50	+58C	Chicago	42	−10C
Corner Brook	49	+22N	Resolute	75	+20C	Cincinnati	39	+38E
Cornwall	45	−01E	Rimouski	48	−26E	Cleveland	42	+26E
Edmonton	54	+34M	St. Catharines	43	+17E	Dallas	33	+27C
Fredericton	46	+27A	St. Hyacinthe	46	−08E	Denver	40	00M
Gander	49	+08N	St. John, N.B.	45	+24A	Fairbanks	65	−10A
Goose Bay	53	+02A	St. John's, Nfld.	48	+01N	Flagstaff	35	+27M
Granby	45	−09E	Sarnia	43	+29E	Indianapolis	40	−15C
Halifax	45	+14A	Saskatoon	52	+67C	Juneau	58	+58P
Hamilton	43	+20E	Sault Ste. Marie	47	+37E	Kansas City	39	+18C
Kapuskasing	49	+30E	Sept Iles	50	−35E	Los Angeles	34	−07P
Kenora	50	+18C	Sherbrooke	45	−12E	Louisville	38	−17C
Kingston	44	+06E	Sudbury	47	+24E	Memphis	35	00C
Kitchener	43	+22E	Sydney	46	+01A	Miami	26	+21E
Lethbridge	50	+31M	The Pas	54	+45C	Milwaukee	43	−09C
London	43	+25E	Thunder Bay	48	+57E	Minneapolis	45	+13C
Medicine Hat	50	+23M	Timmins	48	+26E	New Orleans	30	00C
Moncton	46	+19A	Toronto	44	+18E	New York	41	−04E
Montreal	46	−06E	Trail	49	−09P	Omaha	41	+24C
Moosonee	51	+23E	Trois Rivieres	46	−10E	Philadelphia	40	+01E
Moose Jaw	50	+62C	Vancouver	49	+12P	Phoenix	33	+28M
Niagara Falls	43	+16E	Victoria	48	+13P	Pittsburgh	40	+20E
North Bay	46	+18E	Whitehorse	61	00Y	St. Louis	39	+01C
Ottawa	45	+03E	Windsor, Ont.	42	+32E	San Francisco	38	+10P
Owen Sound	45	+24E	Winnipeg	50	+29C	Seattle	48	+09P
Pangnirtung	66	+23A	Yarmouth	44	+24A	Tucson	32	+24M
Penticton	49	−02P	Yellowknife	62	+38M	Washington	39	+08E

LAT.	+20°		+30°		+35°		+40°		+44°		+50°		+54°		+60°	
EVENT	RISE	SET	RISE	SET	RISE	SET	RISE	SET	RISE	SET	RISE	SET	RISE	SET	RISE	SET
	h m	h m	h m	h m	h m	h m	h m	h m	h m	h m	h m	h m	h m	h m	h m	h m
Jan. −1	6 34	17 30	6 55	17 10	7 07	16 57	7 21	16 43	7 35	16 30	7 59	16 06	8 19	15 46	9 03	15 01
3	6 36	17 33	6 56	17 12	7 08	17 00	7 22	16 47	7 35	16 34	7 59	16 10	8 19	15 50	9 02	15 07
7	6 37	17 35	6 57	17 15	7 09	17 04	7 22	16 50	7 35	16 38	7 58	16 15	8 17	15 55	8 59	15 14
11	6 37	17 38	6 57	17 19	7 09	17 07	7 22	16 54	7 34	16 42	7 56	16 20	8 15	16 01	8 54	15 21
15	6 38	17 41	6 57	17 22	7 08	17 11	7 20	16 58	7 32	16 47	7 53	16 25	8 11	16 07	8 49	15 30
19	6 38	17 43	6 56	17 25	7 07	17 15	7 19	17 03	7 30	16 52	7 50	16 32	8 07	16 14	8 43	15 39
23	6 38	17 46	6 55	17 29	7 05	17 19	7 16	17 07	7 27	16 57	7 46	16 38	8 02	16 22	8 35	15 49
27	6 37	17 48	6 53	17 32	7 03	17 23	7 14	17 12	7 24	17 02	7 41	16 44	7 57	16 29	8 27	15 59
31	6 36	17 51	6 51	17 36	7 00	17 27	7 10	17 17	7 20	17 08	7 36	16 51	7 50	16 37	8 18	16 09
Feb. 4	6 35	17 53	6 49	17 39	6 57	17 31	7 07	17 22	7 15	17 13	7 30	16 58	7 43	16 45	8 09	16 20
8	6 33	17 55	6 46	17 42	6 54	17 35	7 02	17 27	7 10	17 19	7 24	17 05	7 36	16 53	7 59	16 31
12	6 31	17 57	6 43	17 46	6 50	17 39	6 58	17 31	7 05	17 24	7 17	17 12	7 28	17 01	7 48	16 41
16	6 29	17 59	6 40	17 49	6 46	17 43	6 53	17 36	6 59	17 30	7 10	17 19	7 20	17 10	7 38	16 52
20	6 27	18 01	6 36	17 52	6 42	17 47	6 48	17 41	6 53	17 35	7 03	17 26	7 11	17 18	7 27	17 02
24	6 24	18 03	6 32	17 55	6 37	17 50	6 42	17 45	6 47	17 41	6 55	17 32	7 02	17 26	7 15	17 12
28	6 21	18 04	6 28	17 58	6 32	17 54	6 36	17 50	6 40	17 46	6 47	17 39	6 53	17 33	7 04	17 23
Mar. 3	6 18	18 06	6 24	18 01	6 27	17 58	6 30	17 54	6 33	17 51	6 39	17 46	6 44	17 41	6 52	17 33
7	6 15	18 07	6 19	18 03	6 22	18 01	6 24	17 59	6 27	17 56	6 31	17 52	6 34	17 49	6 40	17 43
11	6 12	18 09	6 15	18 06	6 16	18 04	6 18	18 03	6 19	18 01	6 22	17 59	6 24	17 57	6 29	17 53
15	6 08	18 10	6 10	18 08	6 11	18 08	6 11	18 07	6 12	18 06	6 14	18 05	6 15	18 04	6 16	18 03
19	6 05	18 11	6 05	18 11	6 05	18 11	6 05	18 11	6 05	18 11	6 05	18 12	6 05	18 12	6 04	18 12
23	6 01	18 12	6 00	18 13	5 59	18 14	5 59	18 15	5 58	18 16	5 56	18 18	5 55	18 19	5 52	18 22
27	5 58	18 13	5 55	18 16	5 54	18 17	5 52	18 19	5 50	18 21	5 47	18 24	5 45	18 27	5 40	18 32
31	5 54	18 14	5 51	18 18	5 48	18 21	5 46	18 23	5 43	18 26	5 39	18 31	5 35	18 34	5 28	18 42
Apr. 4	5 51	18 15	5 46	18 21	5 43	18 24	5 39	18 27	5 36	18 31	5 30	18 37	5 25	18 42	5 16	18 52
8	5 48	18 16	5 41	18 23	5 37	18 27	5 33	18 31	5 29	18 36	5 22	18 43	5 16	18 49	5 04	19 01
12	5 44	18 17	5 36	18 25	5 32	18 30	5 27	18 36	5 22	18 40	5 13	18 49	5 06	18 57	4 52	19 11
16	5 41	18 19	5 32	18 28	5 27	18 33	5 21	18 40	5 15	18 45	5 05	18 56	4 57	19 04	4 40	19 21
20	5 38	18 20	5 28	18 30	5 22	18 37	5 15	18 44	5 08	18 50	4 57	19 02	4 47	19 12	4 29	19 31
24	5 35	18 21	5 24	18 33	5 17	18 40	5 09	18 48	5 02	18 55	4 49	19 08	4 38	19 19	4 17	19 41
28	5 33	18 23	5 20	18 35	5 12	18 43	5 04	18 52	4 56	19 00	4 42	19 14	4 30	19 26	4 06	19 51

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LAT.	+20°		+30°		+35°		+40°		+44°		+50°		+54°		+60°	
EVENT	RISE	SET	RISE	SET	RISE	SET	RISE	SET	RISE	SET	RISE	SET	RISE	SET	RISE	SET
	h m	h m	h m	h m	h m	h m	h m	h m	h m	h m	h m	h m	h m	h m	h m	h m
May 2	5 30	18 24	5 16	18 38	5 08	18 46	4 59	18 56	4 50	19 05	4 34	19 20	4 21	19 34	3 55	20 01
6	5 28	18 25	5 13	18 41	5 04	18 50	4 54	19 00	4 45	19 09	4 28	19 26	4 13	19 41	3 44	20 11
10	5 26	18 27	5 10	18 43	5 00	18 53	4 50	19 04	4 40	19 14	4 21	19 32	4 06	19 48	3 34	20 20
14	5 24	18 29	5 07	18 46	4 57	18 56	4 46	19 08	4 35	19 18	4 15	19 38	3 59	19 55	3 24	20 30
18	5 23	18 30	5 05	18 48	4 54	18 59	4 42	19 11	4 31	19 23	4 10	19 44	3 52	20 02	3 15	20 39
22	5 22	18 32	5 03	18 51	4 52	19 02	4 39	19 15	4 27	19 27	4 05	19 49	3 46	20 08	3 07	20 48
26	5 21	18 33	5 01	18 53	4 50	19 05	4 36	19 18	4 24	19 31	4 01	19 54	3 41	20 14	2 59	20 57
30	5 20	18 35	5 00	18 55	4 48	19 07	4 34	19 21	4 21	19 34	3 57	19 58	3 37	20 19	2 52	21 04
June 3	5 20	18 37	4 59	18 58	4 47	19 10	4 32	19 24	4 19	19 38	3 54	20 02	3 33	20 24	2 46	21 11
7	5 20	18 38	4 58	18 59	4 46	19 12	4 31	19 27	4 18	19 40	3 52	20 06	3 30	20 28	2 42	21 17
11	5 20	18 39	4 58	19 01	4 45	19 14	4 31	19 29	4 17	19 43	3 51	20 09	3 28	20 32	2 38	21 22
15	5 20	18 41	4 58	19 03	4 45	19 16	4 30	19 31	4 16	19 45	3 50	20 11	3 27	20 34	2 36	21 25
19	5 21	18 42	4 59	19 04	4 46	19 17	4 31	19 32	4 17	19 46	3 50	20 12	3 27	20 36	2 35	21 27
23	5 22	18 42	5 00	19 05	4 47	19 18	4 32	19 33	4 18	19 47	3 51	20 13	3 28	20 36	2 36	21 28
27	5 23	18 43	5 01	19 05	4 48	19 18	4 33	19 33	4 19	19 47	3 53	20 13	3 30	20 36	2 38	21 27
July 1	5 24	18 43	5 02	19 05	4 50	19 18	4 35	19 33	4 21	19 47	3 55	20 12	3 32	20 35	2 42	21 25
5	5 25	18 44	5 04	19 05	4 52	19 17	4 37	19 32	4 23	19 46	3 58	20 11	3 36	20 33	2 47	21 21
9	5 27	18 43	5 06	19 04	4 54	19 16	4 39	19 31	4 26	19 44	4 01	20 09	3 40	20 30	2 53	21 16
13	5 28	18 43	5 08	19 03	4 56	19 15	4 42	19 29	4 29	19 42	4 05	20 05	3 45	20 26	3 00	21 10
17	5 30	18 42	5 10	19 02	4 59	19 13	4 45	19 27	4 33	19 39	4 10	20 02	3 50	20 21	3 08	21 03
21	5 31	18 41	5 12	19 00	5 01	19 11	4 49	19 24	4 37	19 36	4 15	19 57	3 56	20 16	3 16	20 55
25	5 33	18 40	5 15	18 58	5 04	19 08	4 52	19 20	4 41	19 32	4 20	19 52	4 02	20 10	3 25	20 47
29	5 34	18 38	5 17	18 55	5 07	19 05	4 56	19 17	4 45	19 27	4 25	19 47	4 08	20 03	3 34	20 37
Aug. 2	5 36	18 36	5 20	18 52	5 10	19 02	4 59	19 13	4 49	19 22	4 31	19 41	4 15	19 56	3 43	20 28
6	5 37	18 34	5 22	18 49	5 13	18 58	5 03	19 08	4 54	19 17	4 36	19 34	4 22	19 48	3 53	20 17
10	5 38	18 32	5 24	18 46	5 16	18 54	5 07	19 03	4 58	19 12	4 42	19 27	4 29	19 40	4 02	20 07
14	5 40	18 29	5 27	18 42	5 19	18 49	5 11	18 58	5 03	19 06	4 48	19 20	4 36	19 32	4 12	19 56
18	5 41	18 26	5 29	18 38	5 22	18 45	5 14	18 52	5 07	18 59	4 54	19 12	4 43	19 23	4 22	19 44
22	5 42	18 23	5 31	18 34	5 25	18 40	5 18	18 47	5 12	18 53	5 00	19 04	4 50	19 14	4 31	19 33
26	5 43	18 20	5 34	18 29	5 28	18 35	5 22	18 41	5 16	18 46	5 06	18 56	4 58	19 05	4 41	19 21
30	5 44	18 17	5 36	18 25	5 31	18 29	5 26	18 35	5 21	18 39	5 12	18 48	5 05	18 55	4 50	19 09

LAT.	+20°		+30°		+35°		+40°		+44°		+50°		+54°		+60°	
EVENT	RISE	SET	RISE	SET	RISE	SET	RISE	SET	RISE	SET	RISE	SET	RISE	SET	RISE	SET
	h m	h m	h m	h m	h m	h m	h m	h m	h m	h m	h m	h m	h m	h m	h m	h m
Sep. 3	5 45	18 13	5 38	18 20	5 34	18 24	5 30	18 28	5 25	18 32	5 18	18 39	5 12	18 45	5 00	18 57
7	5 46	18 10	5 40	18 15	5 37	18 18	5 33	18 22	5 30	18 25	5 24	18 31	5 19	18 36	5 09	18 45
11	5 46	18 06	5 42	18 10	5 40	18 13	5 37	18 15	5 35	18 18	5 30	18 22	5 26	18 26	5 19	18 33
15	5 47	18 03	5 44	18 05	5 43	18 07	5 41	18 09	5 39	18 10	5 36	18 13	5 33	18 16	5 28	18 21
19	5 48	17 59	5 47	18 00	5 46	18 01	5 45	18 02	5 44	18 03	5 42	18 05	5 40	18 06	5 37	18 09
23	5 49	17 55	5 49	17 55	5 49	17 55	5 48	17 55	5 48	17 55	5 48	17 56	5 47	17 56	5 47	17 56
27	5 50	17 52	5 51	17 50	5 52	17 50	5 52	17 49	5 53	17 48	5 54	17 47	5 55	17 46	5 56	17 44
Oct. 1	5 51	17 48	5 53	17 45	5 55	17 44	5 56	17 42	5 58	17 41	6 00	17 38	6 02	17 36	6 06	17 32
5	5 52	17 45	5 56	17 41	5 58	17 38	6 00	17 36	6 02	17 34	6 06	17 30	6 09	17 26	6 15	17 20
9	5 53	17 41	5 58	17 36	6 01	17 33	6 04	17 29	6 07	17 26	6 12	17 21	6 17	17 17	6 25	17 08
13	5 54	17 38	6 01	17 31	6 04	17 28	6 08	17 23	6 12	17 20	6 19	17 13	6 24	17 07	6 35	16 57
17	5 55	17 35	6 03	17 27	6 08	17 22	6 13	17 17	6 17	17 13	6 25	17 05	6 32	16 58	6 45	16 45
21	5 57	17 32	6 06	17 23	6 11	17 18	6 17	17 12	6 22	17 06	6 32	16 57	6 39	16 49	6 55	16 34
25	5 58	17 29	6 09	17 19	6 15	17 13	6 21	17 06	6 27	17 00	6 38	16 49	6 47	16 40	7 05	16 22
29	6 00	17 27	6 12	17 15	6 18	17 09	6 26	17 01	6 33	16 54	6 45	16 42	6 55	16 32	7 15	16 12
Nov. 2	6 02	17 25	6 15	17 12	6 22	17 05	6 30	16 56	6 38	16 49	6 52	16 35	7 03	16 24	7 25	16 01
6	6 04	17 23	6 18	17 09	6 26	17 01	6 35	16 52	6 43	16 44	6 58	16 28	7 11	16 16	7 35	15 51
10	6 06	17 22	6 21	17 07	6 30	16 58	6 39	16 48	6 48	16 39	7 05	16 22	7 18	16 09	7 46	15 41
14	6 08	17 20	6 24	17 04	6 34	16 55	6 44	16 44	6 54	16 35	7 11	16 17	7 26	16 02	7 56	15 32
18	6 11	17 20	6 28	17 03	6 37	16 53	6 49	16 41	6 59	16 31	7 18	16 12	7 34	15 56	8 06	15 24
22	6 13	17 19	6 31	17 01	6 41	16 51	6 53	16 39	7 04	16 28	7 24	16 08	7 41	15 51	8 15	15 16
26	6 16	17 19	6 34	17 00	6 45	16 49	6 58	16 37	7 09	16 25	7 30	16 04	7 48	15 47	8 25	15 10
30	6 18	17 19	6 38	17 00	6 49	16 49	7 02	16 36	7 14	16 24	7 36	16 02	7 54	15 43	8 33	15 04
Dec. 4	6 21	17 20	6 41	17 00	6 52	16 48	7 06	16 35	7 18	16 22	7 41	16 00	8 00	15 40	8 41	14 59
8	6 23	17 21	6 44	17 00	6 56	16 48	7 09	16 35	7 22	16 22	7 45	15 58	8 06	15 38	8 48	14 56
12	6 26	17 22	6 46	17 01	6 59	16 49	7 13	16 35	7 26	16 22	7 49	15 58	8 10	15 37	8 54	14 54
16	6 28	17 24	6 49	17 02	7 01	16 50	7 15	16 36	7 29	16 23	7 53	15 59	8 14	15 38	8 58	14 53
20	6 30	17 25	6 51	17 04	7 04	16 52	7 18	16 38	7 31	16 24	7 56	16 00	8 17	15 39	9 02	14 54
24	6 32	17 27	6 53	17 06	7 06	16 54	7 20	16 40	7 33	16 27	7 57	16 02	8 18	15 41	9 03	14 56
28	6 34	17 30	6 55	17 09	7 07	16 56	7 21	16 42	7 34	16 29	7 58	16 05	8 19	15 44	9 04	15 00
32	6 35	17 32	6 56	17 11	7 08	16 59	7 22	16 45	7 35	16 33	7 59	16 09	8 19	15 48	9 02	15 05

TWILIGHT

This table gives the beginning of morning and ending of evening astronomical twilight (Sun 18° below the horizon) in UT at the Greenwich meridian. For observers in North America, the times may be treated in the same way as those of sunrise and sunset (see p. 54).

LAT.	+20°		+30°		+35°		+40°		+44°		+50°		+54°		+60°	
M-E	MORN.	EVE.	MORN.	EVE.	MORN.	EVE.	MORN.	EVE.	MORN.	EVE.	MORN.	EVE.	MORN.	EVE.	MORN.	EVE.
	h m	h m	h m	h m	h m	h m	h m	h m	h m	h m	h m	h m	h m	h m	h m	h m
Jan. 0	5 16	18 50	5 30	18 36	5 37	18 29	5 44	18 21	5 50	18 15	6 00	18 06	6 06	17 59	6 18	17 48
10	5 19	18 55	5 32	18 42	5 39	18 36	5 45	18 29	5 51	18 24	5 59	18 16	6 05	18 10	6 15	18 00
20	5 21	19 01	5 32	18 50	5 38	18 44	5 43	18 39	5 48	18 34	5 54	18 28	5 59	18 23	6 07	18 16
30	5 20	19 06	5 30	18 57	5 34	18 53	5 38	18 49	5 41	18 46	5 45	18 42	5 48	18 39	5 52	18 35
Feb. 9	5 18	19 11	5 24	19 04	5 27	19 02	5 30	18 59	5 31	18 58	5 33	18 56	5 33	18 56	5 33	18 56
19	5 13	19 15	5 17	19 11	5 18	19 10	5 18	19 10	5 18	19 11	5 17	19 12	5 15	19 14	5 10	19 20
29	5 07	19 18	5 08	19 18	5 07	19 19	5 05	19 21	5 03	19 23	4 58	19 28	4 53	19 33	4 42	19 44
Mar. 10	5 00	19 21	4 56	19 25	4 54	19 28	4 50	19 32	4 45	19 36	4 37	19 45	4 29	19 53	4 11	20 11
20	4 51	19 24	4 44	19 31	4 39	19 36	4 33	19 43	4 26	19 50	4 13	20 03	4 01	20 15	3 36	20 41
30	4 42	19 28	4 31	19 38	4 24	19 46	4 15	19 55	4 05	20 05	3 48	20 22	3 32	20 39	2 56	21 16
Apr. 9	4 32	19 31	4 18	19 46	4 08	19 56	3 57	20 08	3 44	20 20	3 21	20 44	2 59	21 06	2 07	22 00
19	4 23	19 36	4 05	19 54	3 53	20 06	3 38	20 21	3 23	20 37	2 53	21 07	2 24	21 38	0 54	23 16
29	4 15	19 40	3 53	20 03	3 38	20 17	3 20	20 36	3 02	20 55	2 23	21 34	1 42	22 17	.. ..	.. ..
May 9	4 07	19 46	3 42	20 12	3 25	20 29	3 03	20 50	2 41	21 14	1 52	22 04	0 42	23 21	.. ..	.. ..
19	4 02	19 52	3 33	20 21	3 13	20 40	2 49	21 05	2 22	21 33	1 17	22 39	.. ..	.. ..	.. ..	.. ..
29	3 58	19 57	3 26	20 29	3 05	20 50	2 37	21 18	2 05	21 51	0 31	23 31	.. ..	.. ..	.. ..	.. ..
June 8	3 56	20 02	3 23	20 36	3 00	20 59	2 30	21 29	1 54	22 05	.. ..	.. ..	.. ..	.. ..	.. ..	.. ..
18	3 57	20 05	3 22	20 40	2 59	21 04	2 27	21 35	1 49	22 13	.. ..	.. ..	.. ..	.. ..	.. ..	.. ..
28	3 59	20 07	3 25	20 41	3 02	21 05	2 31	21 36	1 53	22 14	.. ..	.. ..	.. ..	.. ..	.. ..	.. ..
July 8	4 03	20 07	3 30	20 39	3 08	21 02	2 39	21 31	2 04	22 05	.. ..	.. ..	.. ..	.. ..	.. ..	.. ..
18	4 08	20 04	3 38	20 34	3 17	20 55	2 50	21 21	2 20	21 51	0 59	23 09	.. ..	.. ..	.. ..	.. ..
28	4 14	19 59	3 46	20 26	3 27	20 45	3 04	21 08	2 38	21 34	1 40	22 30	.. ..	.. ..	.. ..	.. ..
Aug. 7	4 19	19 52	3 54	20 16	3 38	20 32	3 18	20 52	2 56	21 13	2 12	21 57	1 16	22 50	.. ..	.. ..
17	4 24	19 44	4 03	20 04	3 49	20 18	3 32	20 34	3 14	20 52	2 40	21 26	2 03	22 02	.. ..	.. ..
27	4 28	19 35	4 11	19 51	4 00	20 02	3 46	20 16	3 32	20 30	3 04	20 57	2 37	21 23	1 24	22 32
Sep. 6	4 31	19 25	4 18	19 38	4 09	19 46	3 58	19 57	3 47	20 08	3 26	20 29	3 06	20 49	2 19	21 34
16	4 34	19 15	4 25	19 24	4 18	19 31	4 10	19 39	4 01	19 47	3 45	20 03	3 31	20 17	2 58	20 49
26	4 37	19 06	4 31	19 11	4 27	19 15	4 21	19 21	4 15	19 27	4 03	19 38	3 53	19 48	3 30	20 11
Oct. 6	4 39	18 57	4 37	18 59	4 35	19 01	4 31	19 04	4 28	19 08	4 20	19 15	4 13	19 22	3 57	19 37
16	4 42	18 49	4 43	18 48	4 43	18 48	4 41	18 49	4 39	18 51	4 36	18 54	4 32	18 58	4 23	19 07
26	4 45	18 43	4 49	18 39	4 51	18 37	4 51	18 36	4 52	18 35	4 51	18 36	4 50	18 37	4 46	18 40
Nov. 5	4 48	18 39	4 56	18 31	4 59	18 28	5 01	18 25	5 03	18 23	5 06	18 21	5 07	18 19	5 08	18 18
15	4 53	18 37	5 02	18 27	5 07	18 22	5 11	18 17	5 15	18 14	5 20	18 09	5 23	18 05	5 28	18 00
25	4 58	18 36	5 10	18 24	5 15	18 19	5 21	18 13	5 26	18 08	5 33	18 01	5 38	17 56	5 46	17 47
Dec. 5	5 03	18 38	5 17	18 25	5 23	18 18	5 30	18 11	5 36	18 06	5 44	17 57	5 50	17 51	6 01	17 40
15	5 09	18 42	5 23	18 28	5 30	18 21	5 37	18 13	5 43	18 07	5 53	17 58	6 00	17 51	6 12	17 39
25	5 14	18 47	5 28	18 32	5 35	18 25	5 43	18 18	5 49	18 12	5 58	18 02	6 05	17 55	6 18	17 43
Jan. 4	5 18	18 52	5 32	18 39	5 38	18 32	5 45	18 25	5 51	18 19	6 00	18 10	6 06	18 04	6 18	17 53

MOON

KEY TO THE MAP OF THE MOON

CRATERS

21—Albategnius
22—Alphonsus
23—Arago
24—Archimedes
25—Aristarchus
26—Aristillus
27—Aristoteles
28—Arzachel
29—Atlas
31—Autolycus
32—Bessel
33—Bullialdus
34—Cassini
35—Catharina
36—Clavius
37—Cleomedes
38—Cook
39—Copernicus
41—Cyrillus
42—Delambre
43—Endymion
44—Eratosthenes
45—Eudoxus
46—Fracastorius
47—Furnerius
48—Gassendi
49—Grimaldi
51—Halley
52—Hercules
53—Herschel
54—Hevelius
55—Hipparchus
56—Julius Caesar
57—Kepler
58—Langrenus
59—Lansberg
61—Longomontanus
62—Macrobius
63—Maginus
64—Manilius
65—Maskelyne
66—Maurolycus
67—Mersenius
68—Newcomb
69—Petavius
71—Piccolomini
72—Plato
73—Plinius
74—Posidonius
75—Ptolemaeus
76—Reinhold
77—Ross
78—Schickard
79—Schiller
81—Snellius
82—Stevinus
83—Taruntius
84—Theophilus
85—Timocharis
86—Tycho
87—Wilhelm

MOUNTAINS

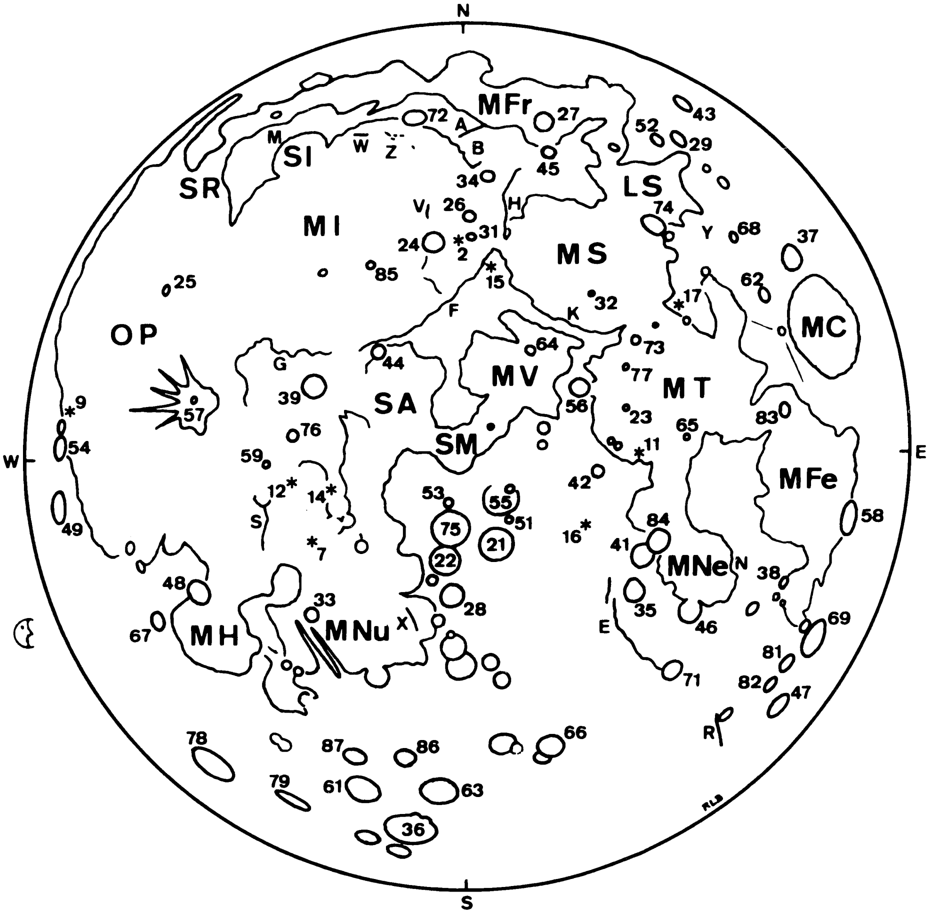
A —Alpine Valley
B —Alps Mts.
E —Altai Mts.
F —Apennine Mts.
G —Carpathian Mts.
H —Caucasus Mts.
K —Haemus Mts.
M—Jura Mts.
N —Pyrenees Mts.
R —Rheita Valley
S —Riphaeus Mts.
V —Spitzbergen
W—Straight Range
X —Straight Wall
Y —Taurus Mts.
Z —Teneriffe Mts.

MARIA

LS —Lacus Somniorum (Lake of Dreams)
MC —Mare Crisium (Sea of Crises)
MFe —Mare Fecunditatis (Sea of Fertility)
MFr —Mare Frigoris (Sea of Cold)
MH —Mare Humorum (Sea of Moisture)
MI —Mare Imbrium (Sea of Rains)
MNe—Mare Nectaris (Sea of Nectar)
MNu—Mare Nubium (Sea of Clouds)
MS —Mare Serenitatis (Sea of Serenity)
MT —Mare Tranquillitatis (Sea of Tranquillity)
MV —Mare Vaporum (Sea of Vapors)
OP —Oceanus Procellarum (Ocean of Storms)
SA —Sinus Aestuum (Seething Bay)
SI —Sinus Iridum (Bay of Rainbows)
SM —Sinus Medii (Central Bay)
SR —Sinus Roris (Bay of Dew)

LUNAR PROBES

2—Luna 2, First to reach Moon (1959·9·13)
7—Ranger 7, First close pictures (1964·7·31)
9—Luna 9, First soft landing (1966·2·3)
11—Apollo 11, First men on Moon (1969·7·20)
12—Apollo 12 (1969·11·19)
14—Apollo 14 (1971·2·5)
15—Apollo 15 (1971·7·30)
16—Apollo 16 (1972·4·21)
17—Apollo 17 (1972·12·11)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MAP OF

THE MOON

FULL MOON DATES

(UT)

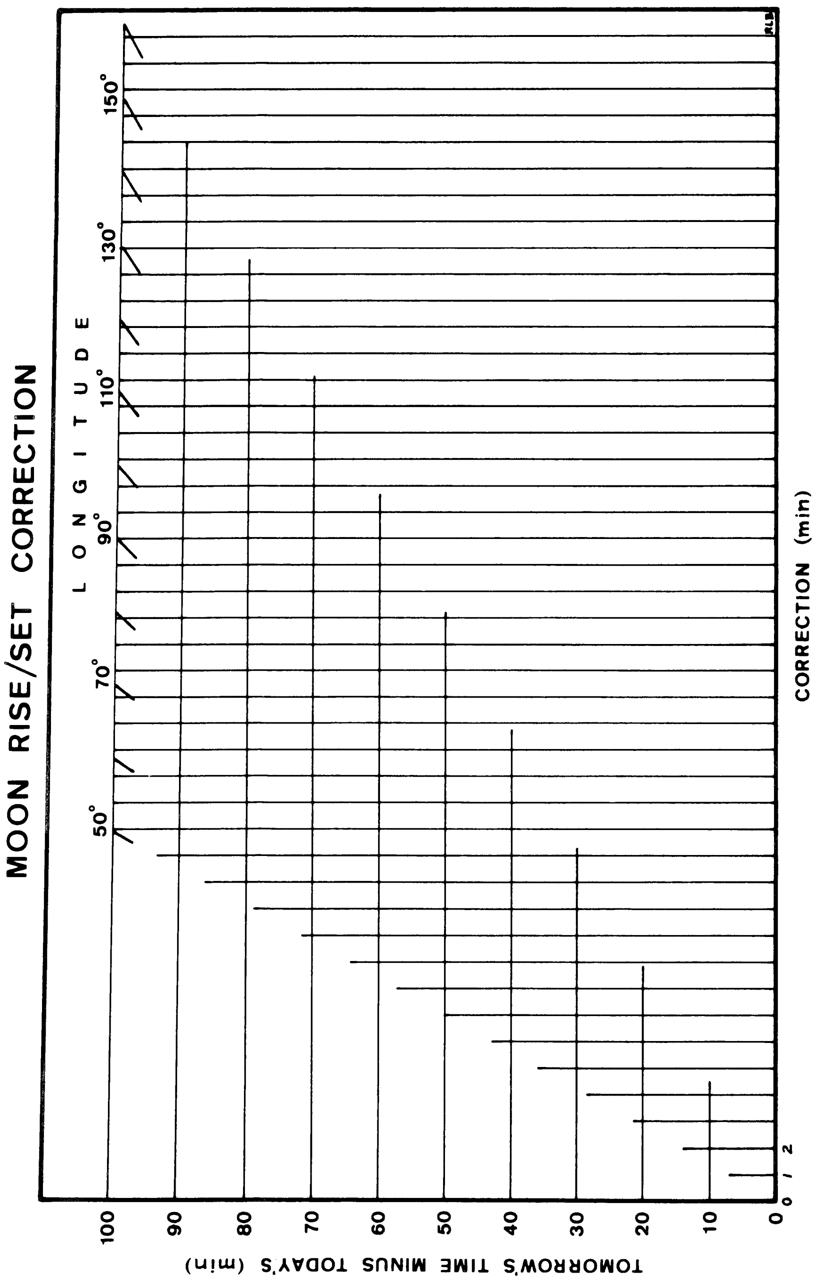
1984		1985	
Jan. 18	Jul. 13	Jan. 7	Jul. 2
Feb. 17	Aug. 11	Feb. 5	Jul. 31
Mar. 17	Sep. 10	Mar. 7	Aug. 30
Apr. 15	Oct. 9	Apr. 5	Sep. 29
May 15	Nov. 8	May 4	Oct. 28
Jun. 13	Dec. 8	Jun. 3	Nov. 27
			Dec. 27

TIMES OF MOONRISE AND MOONSET

The tables on pages 64 to 75 give the times of moonrise and moonset for each day of the year for places ranging from 20° to 60° north latitude. The tables may be interpolated linearly for non-tabular latitudes, and can be extrapolated beyond the 20° and 60° latitude limits a few degrees without significant loss of accuracy. "Rise" and "set" correspond to the upper limb of the Moon appearing at the horizon for an observer at sea level. The times are in UT and are for the Greenwich meridian. Because of the relatively rapid eastward motion of the Moon, unlike the sunrise and sunset tables, the times *cannot* be read directly as standard times at the various standard meridians in North America. The table must be interpolated according to the observer's longitude. Also, the observer's longitude correction relative to his standard meridian must, of course, be applied (see p. 54). The graph on the opposite page enables the sum of these two corrections to be determined easily in one step. However, the graph must be set for your longitude.

To prepare the Moon Rise/Set Correction graph, first locate your longitude on the longitude scale. Using a straight-edge, draw a line from the origin (0,0 point) to your position on the longitude scale (a *red* pen is recommended to make this line stand out). Next, the CORRECTION axis must be labeled. As a guide, the first three divisions have been tentatively labeled 0, 1, 2; *but*, to these numbers must be added your longitude correction relative to your standard meridian (p. 54). e.g. For Toronto the correction is +18 minutes, thus an observer in Toronto would label this axis: 18, 19, 20, 21, ... 62, 63. An observer in Rimouski (longitude correction: −26) would label the axis: −26, −25, −24, ... 18, 19.

The graph is now ready for use on any day from your position. From the table obtain tomorrow's time and today's time for the event (moonrise, or moonset), enter the difference on the ordinate, and run horizontally across to meet the diagonal line. The correction, to the nearest minute, can then be read directly below off the abscissa. This correction is applied to "today's time" in the table. (Note that, due to a difference in height between the observer and the actual horizon, the observed time may differ by up to several minutes from the predicted time.)


MOON RISE/SET CORRECTION
LONGITUDE
50°
70°
90°
110°
130°
150°
CORRECTION (min)
0
1
2
TOMORROW'S TIME MINUS TODAY'S (min)
100
90
80
70
60
50
40
30
20
10
0
RLB

LAT.	+20°		+30°		+35°		+40°		+44°		+50°		+54°		+60°	
EVENT	RISE	SET	RISE	SET	RISE	SET	RISE	SET	RISE	SET	RISE	SET	RISE	SET	RISE	SET
	h m	h m	h m	h m	h m	h m	h m	h m	h m	h m	h m	h m	h m	h m	h m	h m
Jan. 1	4 58	16 08	5 20	15 45	5 33	15 32	5 48	15 17	6 02	15 02	6 28	14 35	6 51	14 12	7 40	13 21
2	5 54	16 59	6 18	16 35	6 32	16 20	6 49	16 04	7 04	15 48	7 33	15 19	7 59	14 53	8 57	13 55
● 3	6 48	17 52	7 13	17 28	7 27	17 14	7 44	16 57	7 59	16 41	8 29	16 12	8 55	15 46	9 54	14 47
4	7 38	18 46	8 02	18 23	8 16	18 10	8 31	17 54	8 46	17 40	9 14	17 13	9 38	16 49	10 31	15 57
5	8 24	19 39	8 45	19 19	8 58	19 08	9 12	18 54	9 25	18 42	9 49	18 19	10 10	17 59	10 53	17 17
6	9 06	20 31	9 24	20 15	9 34	20 05	9 46	19 54	9 57	19 44	10 16	19 26	10 33	19 10	11 07	18 39
7	9 44	21 21	9 58	21 09	10 06	21 02	10 15	20 54	10 23	20 47	10 38	20 33	10 51	20 22	11 15	20 00
8	10 19	22 10	10 29	22 02	10 35	21 58	10 41	21 53	10 47	21 48	10 57	21 40	11 05	21 33	11 21	21 19
9	10 53	22 58	10 58	22 55	11 01	22 53	11 04	22 51	11 08	22 50	11 13	22 46	11 18	22 43	11 26	22 38
10	11 26	23 47	11 26	23 48	11 27	23 49	11 27	23 50	11 28	23 51	11 28	23 53	11 29	23 54	11 30	23 57
◑ 11	11 59	.. ..	11 55	.. ..	11 53	.. ..	11 50	.. ..	11 48	.. ..	11 44	.. ..	11 41	.. ..	11 34	.. ..
12	12 34	0 37	12 25	0 43	12 20	0 47	12 15	0 51	12 10	0 55	12 01	1 01	11 54	1 07	11 39	1 18
13	13 12	1 29	12 59	1 40	12 51	1 46	12 42	1 53	12 35	2 00	12 21	2 12	12 09	2 23	11 46	2 43
14	13 54	2 24	13 37	2 40	13 27	2 49	13 15	2 59	13 04	3 09	12 45	3 27	12 29	3 42	11 56	4 12
15	14 43	3 23	14 21	3 43	14 09	3 54	13 55	4 08	13 42	4 20	13 17	4 44	12 57	5 03	12 13	5 46
16	15 38	4 25	15 14	4 48	15 00	5 02	14 44	5 18	14 29	5 32	14 01	6 00	13 36	6 24	12 42	7 17
17	16 40	5 29	16 16	5 54	16 01	6 08	15 44	6 25	15 29	6 40	14 59	7 10	14 34	7 36	13 35	8 34
○ 18	17 47	6 32	17 24	6 55	17 10	7 09	16 55	7 25	16 40	7 40	16 13	8 08	15 49	8 33	14 56	9 26
19	18 55	7 30	18 35	7 51	18 24	8 03	18 11	8 17	17 59	8 30	17 37	8 54	17 18	9 14	16 37	9 56
20	20 01	8 24	19 47	8 40	19 39	8 50	19 29	9 00	19 20	9 10	19 04	9 28	18 51	9 43	18 23	10 13
21	21 05	9 11	20 57	9 23	20 51	9 29	20 46	9 36	20 40	9 43	20 31	9 55	20 23	10 05	20 07	10 24
22	22 06	9 55	22 03	10 01	22 02	10 04	22 00	10 08	21 58	10 11	21 54	10 17	21 52	10 22	21 46	10 31
23	23 05	10 36	23 08	10 36	23 09	10 36	23 11	10 36	23 12	10 36	23 15	10 37	23 17	10 37	23 22	10 37
24	.. ..	11 15	.. ..	11 10	.. ..	11 07	.. ..	11 04	.. ..	10 01	.. ..	10 55	.. ..	10 51	.. ..	10 43
◐ 25	0 03	11 55	0 10	11 45	0 15	11 39	0 20	11 32	0 25	11 26	0 34	11 15	0 41	11 06	0 55	10 49
26	0 59	12 36	1 12	12 21	1 20	12 12	1 29	12 02	1 37	11 53	1 51	11 37	2 03	11 23	2 28	10 57
27	1 56	13 19	2 14	13 00	2 24	12 49	2 36	12 36	2 47	12 24	3 07	12 03	3 24	11 45	3 59	11 08
28	2 53	14 05	3 14	13 43	3 27	13 30	3 41	13 15	3 54	13 01	4 19	12 35	4 41	12 13	5 28	11 25
29	3 49	14 55	4 13	14 30	4 26	14 16	4 43	14 00	4 58	13 44	5 26	13 16	5 51	12 50	6 47	11 54
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	7	16 46	4 53	16 36	5 01	16 31	5 05	16 25	5 10	16 19	5 14	16 09	5 22	16 01	5 29	15 45	5 42
○	8	17 21	5 43	17 07	5 56	16 59	6 03	16 50	6 11	16 41	6 18	16 26	6 32	16 13	6 43	15 48	7 06
	9	18 00	6 36	17 42	6 52	17 31	7 02	17 19	7 13	17 07	7 24	16 47	7 43	16 29	7 59	15 54	8 33
	10	18 43	7 30	18 21	7 51	18 08	8 03	17 53	8 17	17 39	8 31	17 14	8 55	16 51	9 17	16 04	10 03
	11	19 32	8 26	19 07	8 51	18 52	9 05	18 35	9 21	18 19	9 37	17 50	10 06	17 23	10 32	16 23	11 31
	12	20 26	9 24	20 00	9 50	19 44	10 05	19 26	10 23	19 09	10 39	18 37	11 11	18 09	11 40	17 01	12 47
	13	21 23	10 20	20 58	10 46	20 43	11 01	20 26	11 19	20 09	11 35	19 38	12 07	19 11	12 35	18 06	13 40
	14	22 24	11 13	22 01	11 37	21 48	11 51	21 32	12 07	21 18	12 22	20 50	12 51	20 27	13 15	19 34	14 09
	15	23 25	12 03	23 06	12 23	22 55	12 35	22 43	12 49	22 31	13 01	22 10	13 24	21 51	13 44	21 13	14 24
☾	16	.. ..	12 49	.. ..	13 04	.. ..	13 13	23 56	13 24	23 47	13 33	23 32	13 50	23 19	14 05	22 54	14 33
	17	0 26	13 31	0 12	13 42	0 05	13 48	.. ..	13 54	.. ..	14 01	.. ..	14 12	.. ..	14 21	.. ..	14 38
	18	1 26	14 12	1 18	14 17	1 14	14 19	1 09	14 22	1 04	14 25	0 55	14 30	0 48	14 34	0 34	14 42
	19	2 26	14 52	2 25	14 51	2 23	14 50	2 22	14 49	2 21	14 49	2 19	14 47	2 17	14 46	2 14	14 45
	20	3 27	15 32	3 31	15 25	3 34	15 21	3 37	15 17	3 39	15 13	3 44	15 05	3 48	14 59	3 55	14 48
	21	4 29	16 15	4 39	16 03	4 45	15 55	4 52	15 47	4 59	15 39	5 10	15 25	5 20	15 14	5 39	14 52
●	22	5 33	17 02	5 49	16 44	5 59	16 33	6 09	16 21	6 19	16 10	6 38	15 50	6 53	15 33	7 25	14 58
	23	6 38	17 53	7 00	17 31	7 12	17 17	7 26	17 02	7 40	16 48	8 05	16 22	8 27	15 59	9 14	15 10
	24	7 44	18 49	8 08	18 23	8 23	18 08	8 40	17 51	8 56	17 34	9 26	17 03	9 53	16 36	10 55	15 33
	25	8 46	19 47	9 13	19 21	9 28	19 05	9 46	18 47	10 03	18 30	10 36	17 58	11 05	17 28	12 16	16 18
	26	9 44	20 47	10 10	20 22	10 25	20 07	10 43	19 50	10 59	19 33	11 30	19 03	11 58	18 35	13 03	17 31
	27	10 36	21 45	10 59	21 23	11 13	21 10	11 29	20 55	11 43	20 40	12 11	20 14	12 35	19 51	13 27	19 00
	28	11 21	22 40	11 41	22 22	11 52	22 11	12 06	21 59	12 18	21 48	12 40	21 27	12 59	21 09	13 38	20 32
	29	12 01	23 33	12 17	23 19	12 26	23 11	12 36	23 02	12 45	22 54	13 02	22 38	13 16	22 25	13 45	22 00
☽	30	12 37	.. ..	12 48	.. ..	12 54	.. ..	13 01	.. ..	13 08	23 57	13 20	23 48	13 29	23 39	13 48	23 23

LAT.	+20°		+30°		+35°		+40°		+44°		+50°		+54°		+60°	
EVENT	RISE	SET	RISE	SET	RISE	SET	RISE	SET	RISE	SET	RISE	SET	RISE	SET	RISE	SET
	h m	h m	h m	h m	h m	h m	h m	h m	h m	h m	h m	h m	h m	h m	h m	h m
Dec. 1	13 10	0 23	13 16	0 14	13 20	0 09	13 24	0 03	13 28	.. ..	13 35	.. ..	13 40	.. ..	13 51	.. ..
2	13 42	1 11	13 43	1 07	13 44	1 05	13 45	1 02	13 46	0 59	13 48	0 55	13 50	0 51	13 52	0 44
3	14 13	1 59	14 10	2 00	14 08	2 00	14 06	2 00	14 04	2 01	14 01	2 02	13 59	2 02	13 54	2 03
4	14 45	2 47	14 37	2 52	14 33	2 56	14 28	2 59	14 23	3 03	14 15	3 09	14 09	3 14	13 56	3 23
5	15 20	3 36	15 07	3 47	15 00	3 53	14 52	3 59	14 45	4 06	14 31	4 17	14 20	4 27	13 59	4 45
6	15 57	4 28	15 40	4 43	15 31	4 52	15 19	5 02	15 09	5 11	14 51	5 28	14 35	5 42	14 04	6 11
7	16 39	5 22	16 18	5 41	16 06	5 53	15 52	6 06	15 39	6 18	15 15	6 41	14 55	7 00	14 12	7 41
○ 8	17 27	6 18	17 03	6 41	16 48	6 55	16 32	7 11	16 17	7 26	15 48	7 53	15 23	8 18	14 28	9 12
9	18 20	7 16	17 54	7 42	17 38	7 57	17 21	8 14	17 04	8 31	16 32	9 02	16 04	9 30	14 58	10 35
10	19 17	8 14	18 51	8 40	18 36	8 56	18 18	9 13	18 02	9 30	17 30	10 02	17 02	10 30	15 55	11 38
11	20 18	9 09	19 54	9 34	19 40	9 49	19 24	10 05	19 09	10 21	18 40	10 50	18 15	11 16	17 18	12 14
12	21 19	10 01	20 59	10 22	20 48	10 35	20 34	10 49	20 22	11 03	19 58	11 27	19 38	11 48	18 56	12 33
13	22 20	10 48	22 05	11 05	21 56	11 15	21 46	11 26	21 37	11 37	21 20	11 55	21 06	12 11	20 36	12 43
14	23 20	11 31	23 10	11 43	23 05	11 50	22 58	11 58	22 52	12 05	22 42	12 18	22 33	12 28	22 16	12 49
☾ 15	.. ..	12 11	.. ..	12 18	.. ..	12 21	.. ..	12 26	.. ..	12 30	.. ..	12 36	.. ..	12 42	23 53	12 53
16	0 19	12 50	0 15	12 51	0 12	12 51	0 10	12 52	0 07	12 52	0 03	12 53	0 00	12 54	.. ..	12 56
17	1 17	13 29	1 19	13 24	1 20	13 21	1 21	13 18	1 23	13 15	1 25	13 10	1 27	13 06	1 30	12 58
18	2 16	14 09	2 24	13 59	2 29	13 53	2 34	13 46	2 39	13 40	2 47	13 29	2 55	13 19	3 09	13 02
19	3 17	14 53	3 31	14 37	3 39	14 28	3 48	14 17	3 56	14 07	4 12	13 50	4 24	13 36	4 51	13 07
20	4 20	15 40	4 39	15 20	4 50	15 08	5 03	14 54	5 15	14 41	5 37	14 17	5 56	13 57	6 35	13 16
21	5 24	16 33	5 47	16 09	6 01	15 54	6 17	15 38	6 32	15 22	7 00	14 54	7 24	14 28	8 19	13 32
● 22	6 28	17 30	6 54	17 04	7 09	16 48	7 27	16 30	7 43	16 14	8 15	15 41	8 43	15 13	9 51	14 05
23	7 28	18 30	7 55	18 04	8 10	17 48	8 28	17 31	8 45	17 14	9 17	16 42	9 46	16 13	10 55	15 05
24	8 23	19 29	8 48	19 06	9 03	18 52	9 19	18 36	9 35	18 20	10 04	17 52	10 30	17 27	11 28	16 30
25	9 12	20 27	9 34	20 07	9 46	19 55	10 01	19 42	10 14	19 29	10 39	19 06	11 00	18 46	11 45	18 03
26	9 55	21 22	10 13	21 06	10 23	20 57	10 34	20 47	10 45	20 37	11 04	20 20	11 20	20 05	11 53	19 34
27	10 34	22 14	10 46	22 03	10 54	21 57	11 02	21 50	11 10	21 43	11 24	21 31	11 35	21 21	11 58	21 01
28	11 08	23 03	11 16	22 57	11 21	22 54	11 26	22 50	11 31	22 46	11 40	22 40	11 47	22 34	12 01	22 23
29	11 40	23 51	11 44	23 50	11 46	23 50	11 48	23 49	11 50	23 48	11 54	23 47	11 57	23 46	12 03	23 43
☽ 30	12 12	.. ..	12 11	.. ..	12 10	.. ..	12 09	.. ..	12 08	.. ..	12 07	.. ..	12 06	.. ..	12 04	.. ..
31	12 43	0 39	12 38	0 43	12 34	0 45	12 30	0 47	12 27	0 49	12 21	0 53	12 16	0 57	12 06	1 03

ECLIPSES DURING 1984

By Fred Espenak

Five eclipses will occur during 1984. Two of these are solar eclipses (one annular and one total) and the remaining three are lunar eclipses (all penumbral).

1. *May 14–15: Penumbral Eclipse of the Moon*
   This event will be visible from all of North and South America except for Alaska and territory north of the Arctic Circle. Maximum eclipse occurs at 4:40 UT when the penumbral magnitude is 0.8332. At this time, a subtle to moderate shading of the Moon's southern limb will be visible.

2. *May 30: Annular Eclipse of the Sun*
   North Americans will witness this rather unusual eclipse during the mid to late morning hours. The visibility of the annular phase is limited to a narrow belt which begins in the Pacific Ocean at 14:57 UT, runs through central Mexico and the southeastern United States, across the North Atlantic and terminates in North Africa at 18:33 UT. Among the cities which lie in or near the path of annularity are Guadalajara, Mexico; New Orleans, Louisiana; Atlanta, Georgia; Greenville, South Carolina; Greensboro, North Carolina; and Richmond, Virginia. A partial eclipse will be widely visible from most of North America (excluding Alaska), the northern tip of South America, western Europe and North Africa.
   As is characteristic of all annular eclipses, the Sun will appear larger than the Moon and a ring or annulus of sunlight will surround the Moon at maximum eclipse. The most remarkable feature of the May 30 event is that the Sun's apparent diameter exceeds the Moon's by only 4 arc-seconds. As a result, the annular phase will last a mere 10 to 20 seconds along much of a 15 000 kilometre long path which is only 10 kilometres wide!

3. *June 12–13: Penumbral Eclipse of the Moon*
   This event will occur while the Moon is above the horizon from Asia, Australia and the South Pacific. However, the penumbral magnitude is so small (0.0908) that it's very doubtful that the eclipse will be detected visually.

4. *November 8: Penumbral Eclipse of the Moon*
   The last lunar eclipse of 1984 will be visible primarily from the Eastern Hemisphere. However, observers in the Yukon and Alaska may see the first half of the event just before sunrise on the morning of November 8. Maximum eclipse occurs at 17:55 UT when the penumbral magnitude is 0.9262.

5. *November 22–23: Total Eclipse of the Sun*
   The path of totality begins at 21:13 UT (22 Nov) off the coast of the Indonesian island of Halmahera and sweeps over New Guinea. Continuing out across the Coral Sea, it passes 96 km south of New Caledonia and 435 km north of New Zealand. The path crosses the South Pacific where it ends 1600 km west of Chile at 00:34 UT (23 Nov). Maximum eclipse occurs northeast of New Zealand where totality will last just under 2 minutes. A partial eclipse will be seen from Australia, New Zealand, Antarctica, the South Pacific and southern Chile.

SOLAR ECLIPSE MAPS

For each solar eclipse, an orthographic projection map of Earth shows the path of partial and total (or annular) eclipse. The maps are oriented with the point of greatest eclipse at the center. This point is marked by an "*" and an observer here would see an eclipse with the greatest possible magnitude from anywhere in the path. Neglecting Earth's oblateness, it also corresponds to the moment when the axis of the Moon's shadow passes closest to the center of Earth. Along the path of totality (or annularity) is the position of the Moon's umbral shadow at each hour (UT) during the eclipse. The much larger outline of the penumbral shadow is also shown at each hour (UT) and appears as a dotted curve. The limits of the penumbra delineate the region of visibility of the partial solar eclipse. Loops at the western and eastern extremes of the penumbra's path identify the areas where the eclipse is in progress at sunrise and sunset, respectively.

Data pertinent to the eclipse appear with each map. In the upper left corner are the times of greatest eclipse and conjunction of the Moon and Sun in right ascension, the minimum distance of the Moon's shadow axis from Earth's center in Earth radii (Gamma) and the geocentric ratio of diameters of the Moon and the Sun. To the upper right are contact times of the Moon's shadow with Earth. P1 and P4 are the first and last contacts of the penumbra, while U1 and U4 are the first and last contacts of the umbra. Below each map are the geocentric coordinates of the Sun and Moon at the instant of greatest eclipse. They include the right ascension (RA), declination (DEC), apparent semi-diameter (SD) and horizontal parallax (HP). The Saros series for the eclipse is listed along with the Julian Date at greatest eclipse and delta T or the difference between Dynamical and Universal Time. Finally, the geodetic co-ordinates of the point of greatest eclipse are given, as well as the local circumstances there. In particular, the Sun's altitude (ALT) and azimuth (AZ) are listed along with the duration of totality (or annularity) and the width of the path.

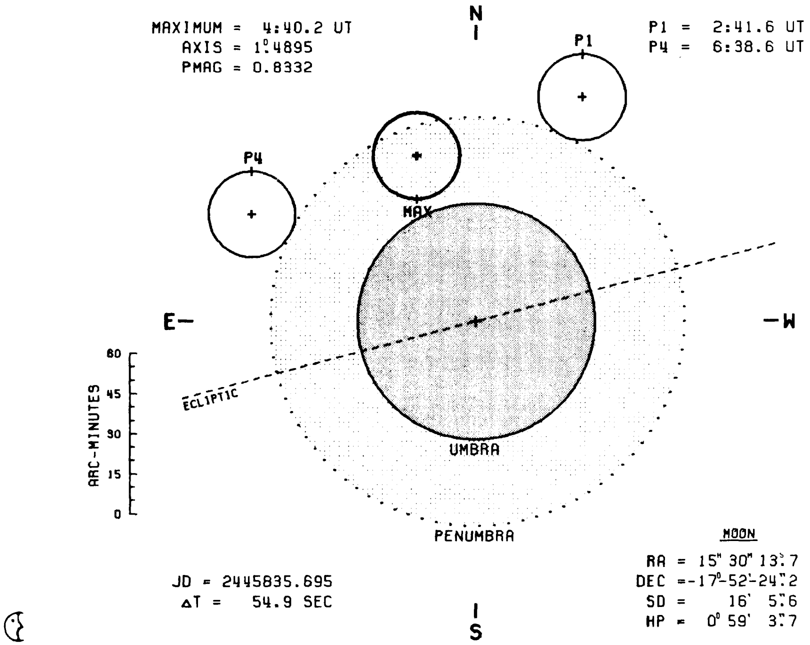
LUNAR ECLIPSE MAP

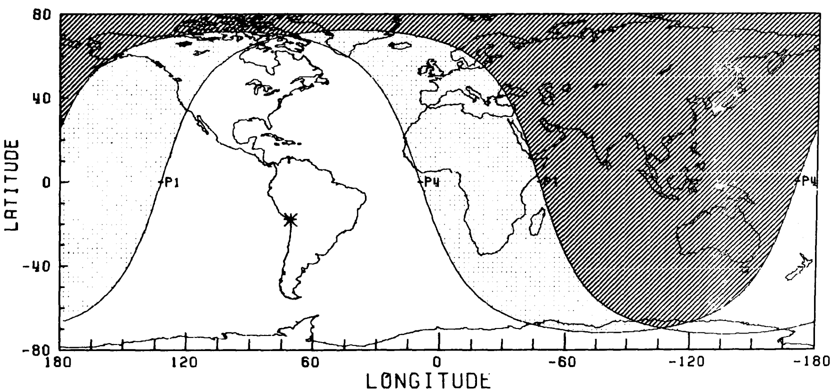
The May 15 lunar eclipse has two diagrams associated with it. The top one shows the path of the Moon with respect to Earth's penumbral and umbral shadows. Above it and to the left is the time of maximum eclipse, the angle subtended between the Moon and the shadow axis at that instant, followed by the penumbral magnitude of the eclipse. The penumbral magnitude is the fraction of the Moon's disk obscured by the penumbra at maximum eclipse and measured along a common diameter. To the upper right are the contact times of the eclipse. P1 and P4 are the first and last contacts of the penumbra; they are the instants when the penumbral eclipse begins and ends. In the lower left corner are the Julian Date at maximum eclipse and delta T or the difference between Dynamical and Universal Time. The Moon's geocentric coordinates at greatest eclipse are given in the lower right corner. They include the right ascension (RA), declination (DEC), apparent semi-diameter (SD) and horizontal parallax (HP).

The bottom map is a cylindrical equidistant projection of Earth which shows the regions of visibility for each stage of the eclipse. In particular, the moonrise/moonset terminator is plotted for each contact and is labeled accordingly. The point where the Moon is in the zenith at maximum eclipse is indicated by an "*". The region which is completely unshaded will observe the entire eclipse while the area marked by solid diagonal lines will not witness any of the event. The remaining shaded areas will experience moonrise or moonset while the eclipse is in progress. The shaded zone east of "*" will witness moonset before the eclipse ends while the shaded zone west of "*" will witness moonrise after the eclipse has begun.

Additional information about eclipses is published annually in the *Astronomical Almanac*. Special circulars on up-coming solar eclipses are usually published twelve months in advance of an event. They contain many pages of detailed predictions and are highly recommended. They can be obtained by writing to the Almanac Office, U.S. Naval Observatory, Washington, DC 20390, U.S.A.

PENUMBRAL LUNAR ECLIPSE - 15 MAY 1984

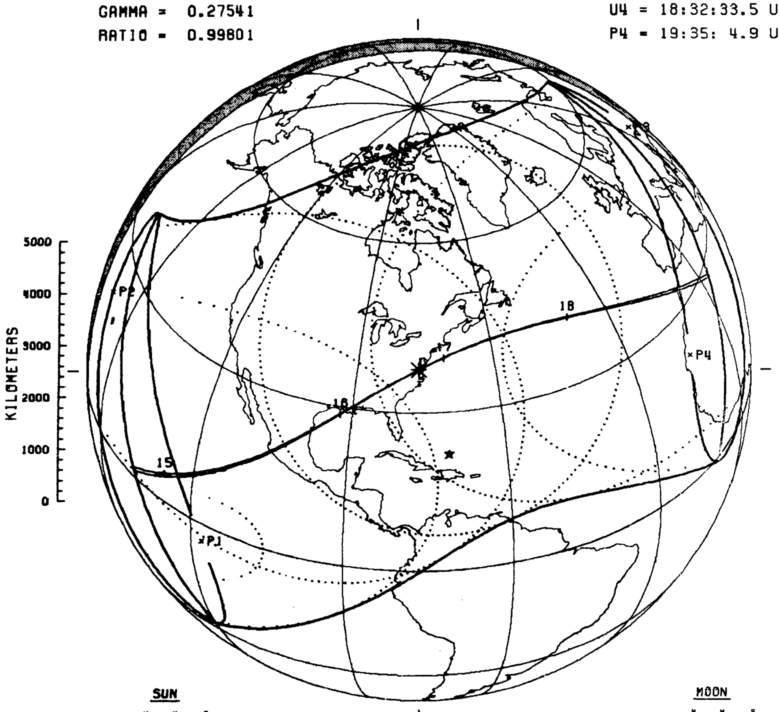




ANNULAR SOLAR ECLIPSE - 30 MAY 1984

GREATEST = 16:44:47.4 UT
CONJUNCTION = 16:52:38.6 UT
GAMMA = 0.27541
RATIO = 0.99801

P1 = 13:54:20.2 UT
U1 = 14:56:52.5 UT
U4 = 18:32:33.5 UT
P4 = 19:35: 4.9 UT



SUN

RA = 4ʰ31ᵐ 2ˢ.1
DEC = 21°52' 5".5
SD = 15' 47".9
HP = 0° 0' 8".7

MOON

RA = 4ʰ30ᵐ45ˢ.4
DEC = 22° 7' 14".7
SD = 15' 30".3
HP = 0°56' 54".1

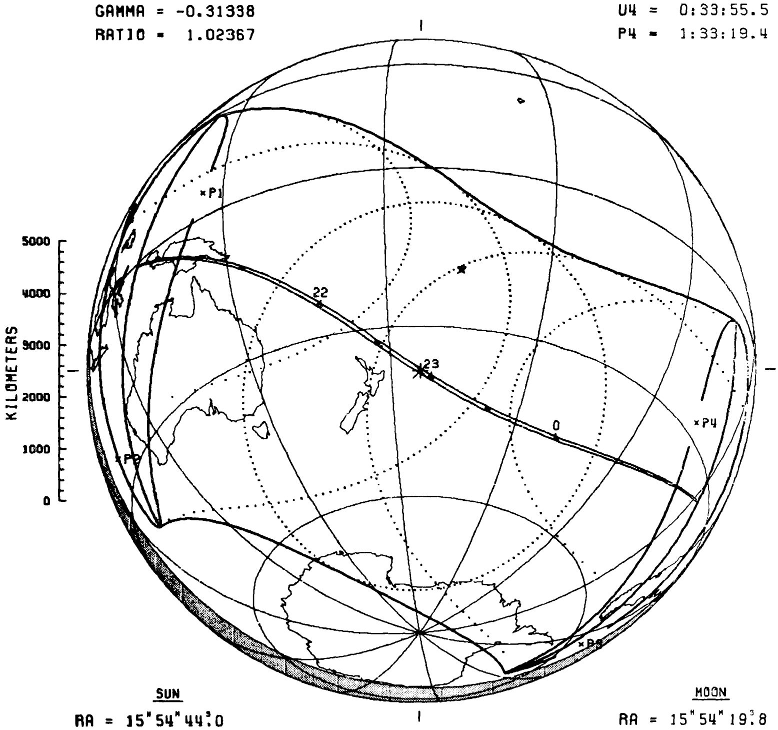
SAROS 137 JD = 2445851.198 ΔT = 53.6 SEC

GREATEST	LAT = 37° 29'.0N	ALT = 73°.7	DURATION = 11.4 SEC
ECLIPSE :	LONG = 76° 44'.4W	AZ = 164°.1	WIDTH = 7.2 KM

TOTAL SOLAR ECLIPSE - 22 NOV 1984

GREATEST = 22:53:22.0 UT
CONJUNCTION = 23: 3:53.6 UT
GAMMA = -0.31338
RATIO = 1.02367

P1 = 20:13:25.0 UT
U1 = 21:12:40.1 UT
U4 = 0:33:55.5 UT
P4 = 1:33:19.4 UT



SUN

RA = $15^{h}54^{m}44^{s}.0$
DEC = $-20^{\circ}19'37''.1$
SD = $16'13''.4$
HP = $0^{\circ}0'8''.9$

MOON

RA = $15^{h}54^{m}19^{s}.8$
DEC = $-20^{\circ}37'27''.1$
SD = $16'19''.2$
HP = $0^{\circ}59'53''.7$

SAROS 142 JD = 2446027.454 ΔT = 54.1 SEC

GREATEST	LAT = $37^{\circ}47'.7$S	ALT = $71^{\circ}.5$	DURATION = 119.5 SEC
ECLIPSE :	LONG = $173^{\circ}38'.9$W	AZ = $20^{\circ}.2$	WIDTH = 84.8 KM

OCCULTATIONS BY THE MOON

PREDICTIONS BY THE
INTERNATIONAL LUNAR OCCULTATION CENTRE
TOKYO, JAPAN

The Moon often passes between Earth and a star, an event called an occultation. During an occultation a star suddenly disappears as the east limb of the Moon crosses the line between the star and observer. The star reappears from behind the west limb some time later. Because the Moon moves through an angle about equal to its own diameter every hour, the longest time for an occultation is about an hour. The time is shorter if the occultation is not central. Occultations are equivalent to total solar eclipses, except they are eclipses of stars other than the Sun.

Since observing occultations is rather easy, provided the weather is suitable and equipment is available, amateur astronomers are encouraged to try this activity. The slow, majestic drift of the Moon in its orbit is an interesting part of such observations, and the disappearance or reappearance of a star at the Moon's limb is a remarkable sight, particularly when it occurs as a *graze* near the Moon's northern or southern edge. In the latter case the star may disappear and reappear several times in succession as mountains and valleys in the Moon's polar regions pass by it. On rarer occasions the moon occults a planet. A memorable event observed by the editor a few years ago was a graze involving Saturn. At one point only a portion of Saturn's rings were visible over a lunar valley, resembling a pale rainbow above that stark landscape.

Lunar occultation and graze observations are used to refine our knowledge of the Moon's orbit, the shape of the lunar profile, and the fundamental star coordinate system. These observations complement those made by other techniques, such as laser-ranging and photographs. Improved knowledge of the lunar profile is useful in determinations of the Sun's diameter from solar eclipse records. Occultation observations are also useful for detecting double stars and measuring their separations. Binaries with separations as small as 0″.01 have been discovered visually during grazes. Doubles with separations in this range are useful for filling the gap between doubles which can be directly resolved visually and those whose duplicity has been discovered spectroscopically.

Analysis of lunar occultation observations is currently being done at the U.S. Naval Observatory and the International Lunar Occultation Centre (ILOC). The latter organization is the world clearing house for such observations. Readers who are interested in pursuing a systematic program of lunar occultation observations should write to the ILOC (address on the inside front cover under "Kubo") for their booklet: *Guide to Lunar Occultation Observations*.

Observers in North America should also contact the International Occultation Timing Association (IOTA), P.O. Box 3392, Columbus, OH 43210-0392, U.S.A. IOTA provides predictions and coordination services for occultation observers. Detailed predictions for any grazing occultation are available ($1.50 U.S. each); instructions concerning the use of predictions are also available ($2.50 U.S.). Annual membership in IOTA is $11.00 U.S. in North America, $16.00 U.S. overseas. Membership includes free graze predictions, descriptive materials, and a subscription to *Occultation Newsletter* (available separately for $5.50 U.S.).

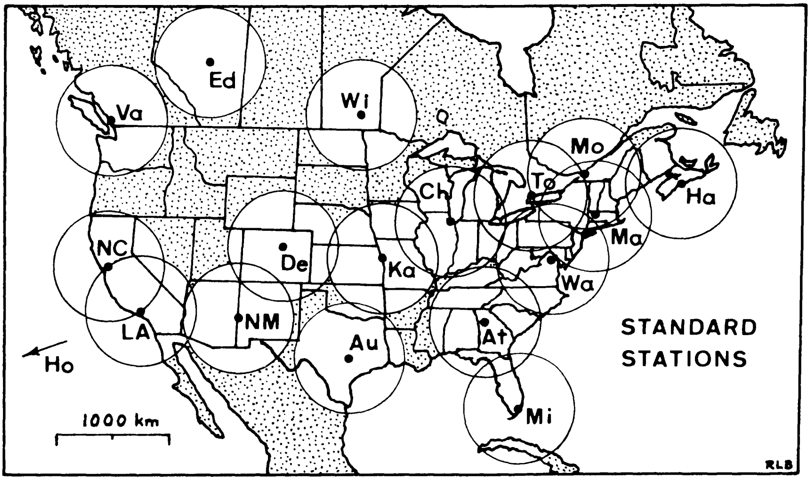
The main information required in a lunar occultation observation is the time of the event and the observer's location. Supplementary information includes the seeing conditions, size of telescope used, timing method used, estimate of the observer's reaction time and the accuracy of the timing, and whether or not the reaction time correction has been applied. The timing should be as accurate as possible, preferably to 0.5s or better. (A shortwave radio time signal and cassette tape recorder provide a simple, permanent time record). The observer's geodetic latitude, longitude, and altitude should be known to at least the nearest second of arc and 20 metres respectively. These can be determined from a suitable topographical map. For

Canada these are available from the Canada Map Office, 615 Booth Street, Ottawa, ON, K1A 0E9. In the United States east of the Mississippi write to: U.S. Geological Survey, 1200 S. Eads St., Arlington, VA 22202; west of the Mississippi the address is: U.S. Geological Survey, Denver Federal Centre, Bldg. 41, Denver, CO 80225.

The following pages give tables of predictions, and a table and maps of northern or southern limits for many cases where grazing occultations may be seen.

1. TOTAL OCCULTATION PREDICTIONS

The total occultation predictions are for the 18 standard stations identified on the map below; the coordinates of these stations are given in the table headings.



The tables are generally limited to stars of magnitude 5.0 or brighter. The first five columns give for each occultation the date, the Zodiacal Catalogue number of the star, its magnitude, the phenomenon (DD or DB = disappearance at dark limb or bright limb, respectively; RD or RB = reappearance at dark limb or bright limb, respectively), and the elongation of the Moon from the Sun in degrees (see page 22). Under each station are given the universal time of the event, factors *a* and *b* (see below), and the position angle (from the north point, eastward around the Moon's limb to the point of occurrence of the phenomenon). In certain cases, predictions have been omitted due to the Moon being too near or below the horizon, no occultation, interference of sunlight, or other difficulties. If *a* and *b* are insignificant, they are omitted.

The terms *a* and *b* are for determining corrections to the times of the phenomena for stations within 500 km of the standard stations. Thus if λ_o, ϕ_o, be the longitude and latitude of the standard station and λ, ϕ, the longitude and latitude of the observer, then for the observer we have: UT of phenomenon = UT of phenomenon at the standard station $+ a(\lambda - \lambda_o) + b(\phi - \phi_o)$ where $\lambda - \lambda_o$ and $\phi - \phi_o$ are expressed in degrees and *a* and *b* are in minutes of time per degree. Due regard must be paid to the algebraic signs of the terms. Also, to convert UT to the standard time of the observer, see page 17.

As an example, consider the occultation of ZC 1702 on Jan. 22, 1984 as seen from Ottawa. For Ottawa, $\lambda = 75.72°$ and $\phi = 45.40°$. The nearest standard station is Montreal, for which $\lambda_o = 73.60°$ and $\phi_o = 45.50°$. Therefore, the UT of the reappearance at the dark limb ("RD") is $8^h1^m.2 - 1^m.4(75.72 - 73.60) - 0^m.8(45.40 - 45.50) = 7^h58^m.3$. Note that almost the same result is obtained by using Toronto as the standard station. The elongation of the Moon is 233° which means that the Moon is in the waning gibbous phase (between full and last quarter). The position angle of reappearance is about 300°.

The total lunar occultation predictions below, being limited to stars of magnitude 5.0 or brighter, are only the more spectacular events and are presented in order to introduce observers to this type of work. The number of events observable at any location increases *rapidly* as predictions are extended to fainter and fainter stars. Observers who wish to pursue this work can obtain more extensive lists from Walter V. Morgan, 10961 Morgan Territory Rd., Livermore, CA 94550, U.S.A., by providing accurate geographical coordinates and a long, self-addressed envelope (with postage). Experienced observers who regularly measure 60 or more events per year may obtain even more detailed predictions computed for their location by contacting: Occultation Project, Nautical Almanac Office, U.S. Naval Observatory, 34th and Massachusetts Ave., NW, Washington, D.C. 20390, U.S.A.

LUNAR OCCULTATIONS 1984

					Ha HALIFAX, NS W 63°6, N 44°6				Mo MONTREAL, PQ W 73°6, N 45°5				To TORONTO, ON W 79°4, N 43°7			
DATE	ZC	MAG	PH	ELG	UT	a	b	PA	UT	a	b	PA	UT	a	b	PA
				°	h m	m/°	m/°	°	h m	m/°	m/°	°	h m	m/°	m/°	°
Jan 7	3349	4.2	DD	52	22 15.8	-1.1	-0.1	59	22 5.0	-1.0	0.6	42				
22	1702	4.2	RD	233	8 15.1	-1.2	-1.5	316	8 1.2	-1.4	-0.8	304	7 53.6	-1.6	-0.2	291
24	1941	4.8	RD	260	9 9.5			232								
27	2307	4.1	RD	296	8 49.2	-1.9	2.4	245								
Mar 12	1030	3.2	DD	108	5 45.5	-0.7	0.1	40	5 38.6	-0.7	-0.4	55	5 35.8	-0.7	-0.8	68
13	1170	3.7	DD	121	5 2.8	-1.4	0.1	47	4 49.4	-1.3	-0.4	63	4 42.8	-1.3	-0.7	77
19	1941	4.8	RD	204	3 19.2	-1.0	0.3	296	3 10.4	-0.8	0.7	287	3 3.9	-0.8	1.2	275
23	2500	3.4	RD	258	7 50.1	-1.5	0.5	286	7 37.0	-1.3	1.0	276	7 27.4	-1.3	1.4	264
Jun 21	3536	4.7	RD	268	6 16.8	-0.8	1.9	246	6 11.9	-0.5	1.9	249				
21	5	4.7	RD	269					8 18.7	-0.9	2.2	215	8 9.4	-0.9	2.2	218
Aug 13	3349	4.2	RD	199	7 30.5	-0.9	0.5	220	7 19.1	-1.4	0.3	238	7 9.3	-1.7	0.4	244
Sep 17	709	4.3	RD	257	7 42.1	-1.8	0.9	264	7 25.5	-1.7	0.7	281	7 14.5	-1.7	0.7	286
27	2118	2.9	DD	40					23 20.8	-0.8	-1.5	99	23 18.5	-1.0	-1.4	101
Oct 14	656	4.4	RD	227	6 7.0	-2.1	0.2	277	5 44.5	-2.4	-0.4	298	5 30.6			305
Nov 3	3349	4.2	DD	118	1 5.2	-0.9	1.1	30	0 59.4	-0.4	2.0	10	0 53.6	-0.1	2.6	1
12	900	4.9	RD	219	3 50.7	-1.7	0.2	295	3 32.8			318	3 22.3			327
18	1702	4.2	RD	297	8 28.5	-0.6	-1.2	336	8 22.3	-0.5	-1.0	335	8 21.1	-0.4	-0.6	327
26	2910	4.8	DD	51	22 59.0			138	22 35.3	-1.9	-1.6	113	22 26.1	-2.1	-1.2	108

					Wi WINNIPEG, MB W 97°2, N 49°9				Ed EDMONTON, AB W 113°4, N 53°6				Va VANCOUVER, BC W 123°1, N 49°2			
DATE	ZC	MAG	PH	ELG	UT	a	b	PA	UT	a	b	PA	UT	a	b	PA
				°	h m	m/°	m/°	°	h m	m/°	m/°	°	h m	m/°	m/°	°
Jan 22	1702	4.2	RD	232	7 30.8	-1.0	0.4	291	7 19.8	-0.6	0.7	295	7 10.4	-0.4	1.2	278
Feb 26	2750	2.1	DB	305					17 41.8	-1.4	-0.9	99	17 29.4	-1.8	-0.5	98
26	2750	2.1	RD	305									18 49.3	-1.2	-0.7	251
Mar 12	1030	3.2	DD	108	5 15.3	-1.1	-0.8	72	4 53.6	-1.3	-0.4	75	4 42.3	-1.5	-0.7	94
13	1170	3.7	DD	121	4 13.4	-1.5	-0.3	79	3 49.0	-1.5	0.6	76	3 32.4	-1.5	0.4	93
Jun 21	5	4.7	RD	269	8 9.6	-0.5	2.1	233								
Aug 13	3349	4.2	RD	199	6 37.0	-2.0	0.6	279	6 11.1	-1.5	1.1	299	5 54.0	-1.0	1.1	299
Sep 27	2118	2.9	DD	40	22 49.5	-1.3	-1.1	101	22 25.0	-1.3	-0.5	111	22 15.0	-1.2	-0.5	128
27	2118	2.9	RB	40	23 56.5	-1.0	-1.6	308	23 34.6	-1.1	-1.1	304	23 26.6	-1.4	-0.7	292
Nov 10	656	4.4	RD	201					13 16.6	-0.4	-2.0	283	13 18.5	-0.8	-1.3	264
16	1484	3.6	RD	273					13 1.4	-1.2	-0.8	307	12 50.1	-1.4	0.2	286
26	2914	5.0	DD	52	23 40.6	-1.6	-1.0	100								
Dec 16	1821	2.9	DB	285	18 42.9	-0.2	-1.9	138	18 30.8	-0.4	-1.9	141	18 34.8	-0.5	-2.0	151
16	1821	2.9	RD	285					19 26.7	-0.3	-1.7	277	19 29.3	-0.6	-1.6	270

DATE	ZC	MAG	PH	ELG	Ma MASSACHUSETTS W 72°5, N 42°5 UT	a	b	PA	Wa WASHINGTON, DC W 77°0, N 38°9 UT	a	b	PA	Ch CHICAGO, IL W 87°7, N 41°9 UT	a	b	PA
				°	h m	m/°	m/°	°	h m	m/°	m/°	°	h m	m/°	m/°	°
Jan 7	3349	4.2	DD	52	22 4.8	-1.3	0.4	50								
22	1702	4.2	RD	233	8 5.2	-1.6	-0.7	298	7 58.6	-2.0	-0.0	280	7 39.4	-1.7	0.7	274
Mar 12	1030	3.2	DD	108	5 40.8	-0.5	-0.6	61	5 41.2	-0.5	-0.9	77	5 31.7	-0.7	-1.1	84
13	1170	3.7	DD	121	4 52.3	-1.2	-0.6	71	4 50.0	-1.2	-1.0	87	4 33.2	-1.4	-1.0	93
19	1941	4.8	RD	204	3 8.8	-1.0	1.0	278	2 59.2	-1.2	1.9	258	2 55.2	-0.7	1.8	259
23	2500	3.4	RD	258	7 35.5	-1.5	1.0	271	7 23.9	-1.7	1.6	255				
Jun 21	3536	4.7	RD	268	6 6.8	-0.5	1.9	246								
21	5	4.7	RD	269	8 13.0	-0.9	2.3	210	8 0.3	-0.9	2.5	209	7 58.6	-0.7	2.3	221
Aug 13	3349	4.2	RD	199	7 19.4	-1.4	0.6	230	7 10.3	-1.6	0.8	230	6 52.4	-2.1	0.6	253
Sep 17	709	4.3	RD	257	7 24.8	-1.6	1.0	271	7 13.9	-1.5	1.1	269	6 59.9	-1.6	0.4	298
27	2118	2.9	DD	40	23 26.2	-0.8	-1.5	103	23 27.9	-0.9	-1.5	108	23 11.8	-1.3	-1.4	105
28	2118	2.9	RB	40									0 18.9	-0.8	-1.7	300
Oct 14	656	4.4	RD	227	5 47.1	-2.2	0.3	285	5 36.0	-2.1	0.5	283				
Nov 3	3349	4.2	DD	118	0 54.4	-0.8	1.8	18	0 43.6	-0.9	2.2	17	0 53.1			338
12	900	4.9	RD	219	3 35.8	-1.6	0.1	303	3 28.5	-1.4	0.2	300				
18	1702	4.2	RD	297	8 25.1	-0.6	-0.6	323	8 23.7	-0.5	-0.1	309	8 19.0	-0.3	-0.3	320
26	2910	4.8	DD	51	22 43.0	-2.3	-2.1	123	22 39.3	-2.7	-2.1	124				
27	2914	5.0	DD	52									0 14.2			137

DATE	ZC	MAG	PH	ELG	Mi MIAMI, FL W 80°3, N 25°8 UT	a	b	PA	At ATLANTA, GA W 84°3, N 33°8 UT	a	b	PA	Au AUSTIN, TX W 97°8, N 30°2 UT	a	b	PA
				°	h m	m/°	m/°	°	h m	m/°	m/°	°	h m	m/°	m/°	°
Jan 17	1030	3.2	DD	164									10 3.2			26
22	1702	4.2	RD	232					7 35.7	-3.1	2.8	245				
Mar 12	1030	3.2	DD	108	5 55.7	0.0	-1.5	117	5 43.5	-0.4	-1.3	101	5 44.2	-0.4	-2.3	131
13	1170	3.7	DD	121	5 6.4	-0.6	-2.0	129	4 48.4	-1.1	-1.6	112	4 41.4	-1.0	-3.1	145
23	2500	3.4	DD	258					6 43.0			194				
23	2500	3.4	RD	258					6 50.1			206				
Apr 21	2750	2.1	DB	250	6 12.0	-1.5	1.8	66	6 24.2	-2.0	3.1	44				
21	2750	2.1	RD	250	7 15.2	-0.8	-0.7	314	7 5.5	0.2	-1.5	334				
May 9	1484	3.6	DD	99									4 34.8	-2.2	-0.1	71
Jun 21	5	4.7	RD	268	7 17.9			180	7 41.4	-0.7	2.7	206	7 24.0	-0.4	2.8	201
Aug 13	3349	4.2	RD	199	6 45.5	-1.4	2.2	208	6 52.1	-1.9	1.2	233	6 17.9	-2.3	1.4	248
Sep 17	709	4.3	RD	257	6 50.8	-0.9	1.7	242	6 58.0	-1.2	1.1	269	6 40.7	-0.9	0.6	284
27	2118	2.9	DD	40	23 46.6	-1.1	-1.9	133	23 28.0	-1.2	-1.6	116	23 14.5	-1.6	-1.7	128
28	2118	2.9	RB	41					0 34.5	-0.7	-1.4	286	0 26.3	-1.3	-1.2	281
Oct 1	2721	3.3	DD	91	23 48.4	-2.5	1.7	44	24 3.0			8				
14	656	4.4	RD	227	5 16.6	-1.4	1.4	253	5 18.6	-1.8	0.6	283	4 53.7	-1.9	-0.5	305
Nov 3	3349	4.2	DD	117	0 10.1	-1.8	2.2	38	0 24.2	-1.0	2.8	14	0 1.2			358
12	900	4.9	RD	219	3 16.6	-0.7	1.0	267	3 18.3	-1.1	0.2	298	3 5.6	-1.0	-0.7	315
18	1702	4.2	RD	297	8 14.1	-0.5	1.5	258	8 19.4	-0.4	0.4	290				

DATE	ZC	MAG	PH	ELG	Ka KANSAS CITY, MO W 94°5, N 39°0 UT	a	b	PA	De DENVER, CO W 105°0, N 39°8 UT	a	b	PA	NM NEW MEXICO, AZ W 109°0, N 34°0 UT	a	b	PA
				°	h m	m/°	m/°	°	h m	m/°	m/°	°	h m	m/°	m/°	°
Jan 17	1030	3.2	DD	164									9 44.4			37
22	1702	4.2	RD	232	7 23.3	-1.9	2.1	253	7 8.0	-1.4	2.8	245				
Feb 26	2750	2.1	DB	305					18 17.9	-2.4	-2.6	132	18 25.3			146
26	2750	2.1	RD	306					19 5.0	0.1	0.9	207	18 56.7			192
Mar 12	1030	3.2	DD	108	5 30.1	-0.8	-1.4	100	5 19.2	-1.1	-1.7	110	5 27.9	-0.8	-2.8	135
13	1170	3.7	DD	121	4 27.0	-1.5	-1.5	110	4 9.2	-1.7	-1.5	118	4 15.3	-1.5	-3.1	145
May 9	1484	3.6	DD	99					4 19.3			54	4 9.0	-2.2	-0.6	86
Jun 21	5	4.7	RD	268	7 47.6	-0.6	2.3	219								
Aug 13	3349	4.2	RD	199	6 35.4	-2.3	0.9	259	6 12.9	-2.1	1.0	273	5 58.6	-1.9	1.2	267
Sep 17	709	4.3	DD	257									6 17.1			348
17	709	4.3	RD	257	6 48.3	-1.6	0.1	304					6 25.8			330
27	2118	2.9	DD	40	23 6.4	-1.5	-1.4	112	22 48.9	-1.6	-1.2	119	22 50.0	-1.6	-1.5	133
28	2118	2.9	RB	40	0 17.3	-1.1	-1.6	296	0 3.3	-1.4	-1.5	295	0 5.0	-1.7	-1.2	284
Oct 27	2359	4.8	DD	35					0 52.6	-0.9	-1.0	82	0 54.7	-1.1	-1.1	91
Nov 16	1484	3.6	RD	273									13 6.9	-3.5	2.5	243
27	2914	5.0	DD	52	0 2.8	-2.9	-2.6	129								
Dec 16	1821	2.9	DB	285					19 1.8	-0.2	-2.2	152	19 14.6	-0.2	-2.6	165

DATE	ZC	MAG	PH	ELG	LA LOS ANGELES, CA W 118°3, N 34°1 UT	a	b	PA	NC N. CALIFORNIA W 122°0, N 38°0 UT	a	b	PA	Ho HONOLULU, HI W 157°9, N 21°3 UT	a	b	PA
				°	h m	m/°	m/°	°	h m	m/°	m/°	°	h m	m/°	m/°	°
Jan 17	1030	3.2	DD	163	9 24.1	-2.1	0.9	54	9 21.2	-2.4	2.0	41	7 52.1	-2.6	-0.6	110
20	1484	3.6	RD	209									14 48.9	-0.1	-3.3	348
22	1702	4.2	RD	232					6 44.5			221				
Feb 11	628	4.8	DD	105									9 26.4	-1.0	-1.5	106
21	2033	4.3	RD	242									10 57.7	-1.2	0.5	277
22	MARS	0.5	DB	255									12 12.2	-0.8	-0.7	130
22	MARS	0.5	RD	256									13 28.8	-1.6	-0.6	300
23	2307	4.1	RD	269									15 32.8	-2.5	-0.5	288
23	2310	4.6	RD	269									16 2.8	-3.4	0.5	262
26	2750	2.1	DB	305	17 56.0	-2.9	-2.0	127	17 40.2	-2.5	-1.1	115				
26	2750	2.1	RD	305	18 56.4	-0.7	1.0	214	18 54.8	-1.2	0.1	230				
Mar 12	1030	3.2	DD	108	5 19.5	-0.9	-4.0	148	5 1.8	-1.5	-2.8	134				
13	1170	3.7	DD	120	3 59.4	-1.8	-4.0	153	3 41.1	-2.0	-1.9	134				
29	3349	4.2	RD	328									15 48.8	-0.6	1.2	257
Apr 18	2307	4.1	RD	214									8 31.1	-0.2	-0.6	312
18	2310	4.6	RD	215									8 57.2	-0.8	0.1	288
May 9	1484	3.6	DD	99	3 49.5	-2.0	-1.0	104	3 38.7	-2.1	-0.7	100				
18	2750	2.1	DB	225									18 13.1	-0.5	-0.3	75
Jun 7	1702	4.2	DD	97									5 27.2	-0.9	-2.9	162
9	1941	4.8	DD	124									6 49.0	-1.8	-1.6	134
Jul 12	2750	2.1	DD	172	11 7.1			14								
Aug 5	2241	5.0	DD	105	6 46.9	-0.5	0.2	51	6 49.0			30	5 26.2	-2.7	-0.7	106
13	3349	4.2	RD	198	5 43.2	-1.4	1.2	272	5 42.9	-1.2	1.1	280				
Sep 4	2650	4.7	DD	112					6 53.1	-2.4	-3.3	143	6 3.8			168
27	2118	2.9	DD	40	22 35.9	-1.3	-1.6	147	22 25.7	-1.2	-1.3	145				
27	2118	2.9	RB	40	23 47.3	-2.1	-0.8	275	23 36.8	-2.0	-0.7	278				
Nov 10	656	4.4	RD	201	13 26.3	-1.4	1.5	213	13 25.1	-1.2	0.5	226				
10	660	4.4	RD	201									13 29.3	-2.6	0.1	259
16	1484	3.6	RD	273					12 38.9	-2.4	3.0	242				
Dec 15	1702	4.2	RD	270									15 24.6	-2.2	-1.0	298
16	1821	2.9	DB	285	19 12.2	-0.2	-2.8	172	19 0.7	-0.3	-2.6	166				
16	1821	2.9	RD	286	19 50.4	-0.6	-0.6	248	19 44.9	-0.7	-1.0	255				
31	URAN	6.0	DD	107									16 25.4	-0.4	-0.4	125

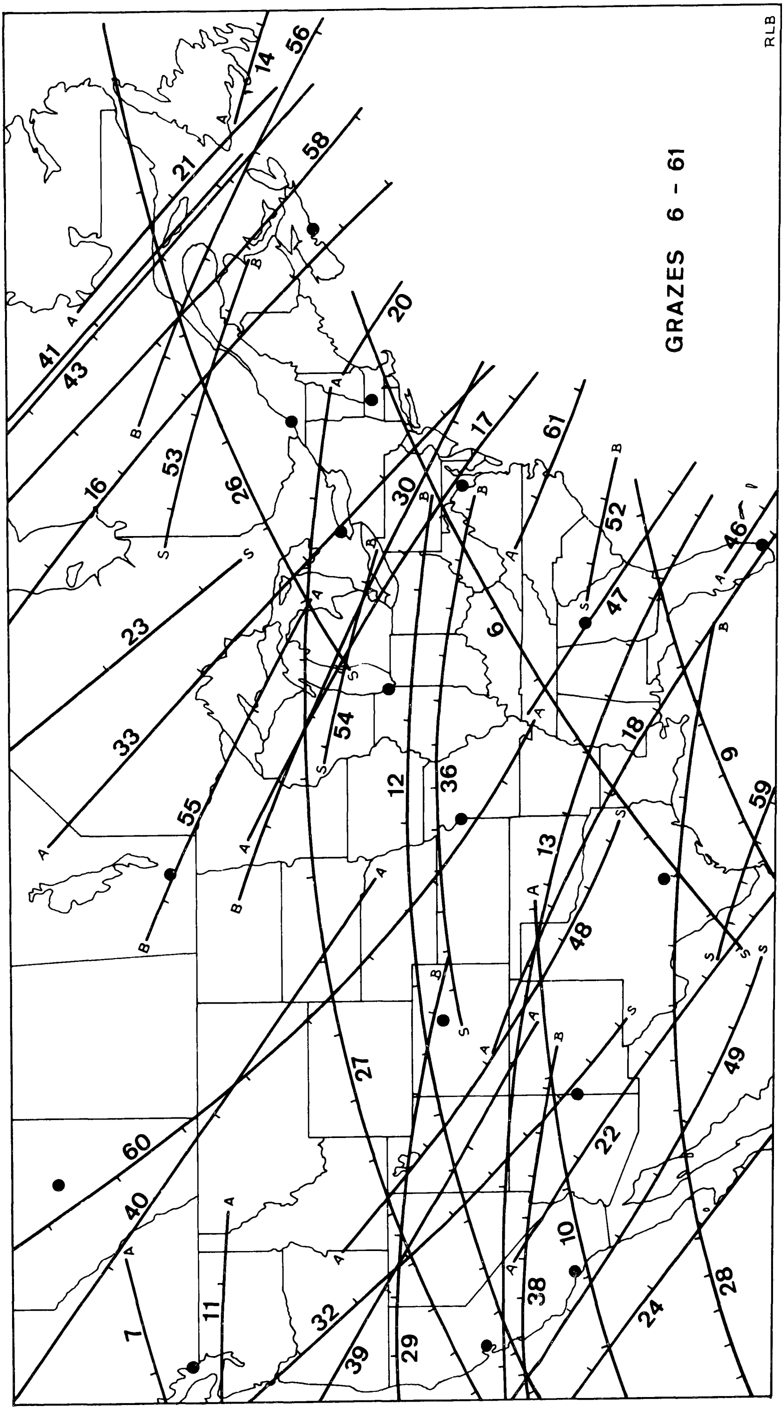
2. GRAZE PREDICTIONS

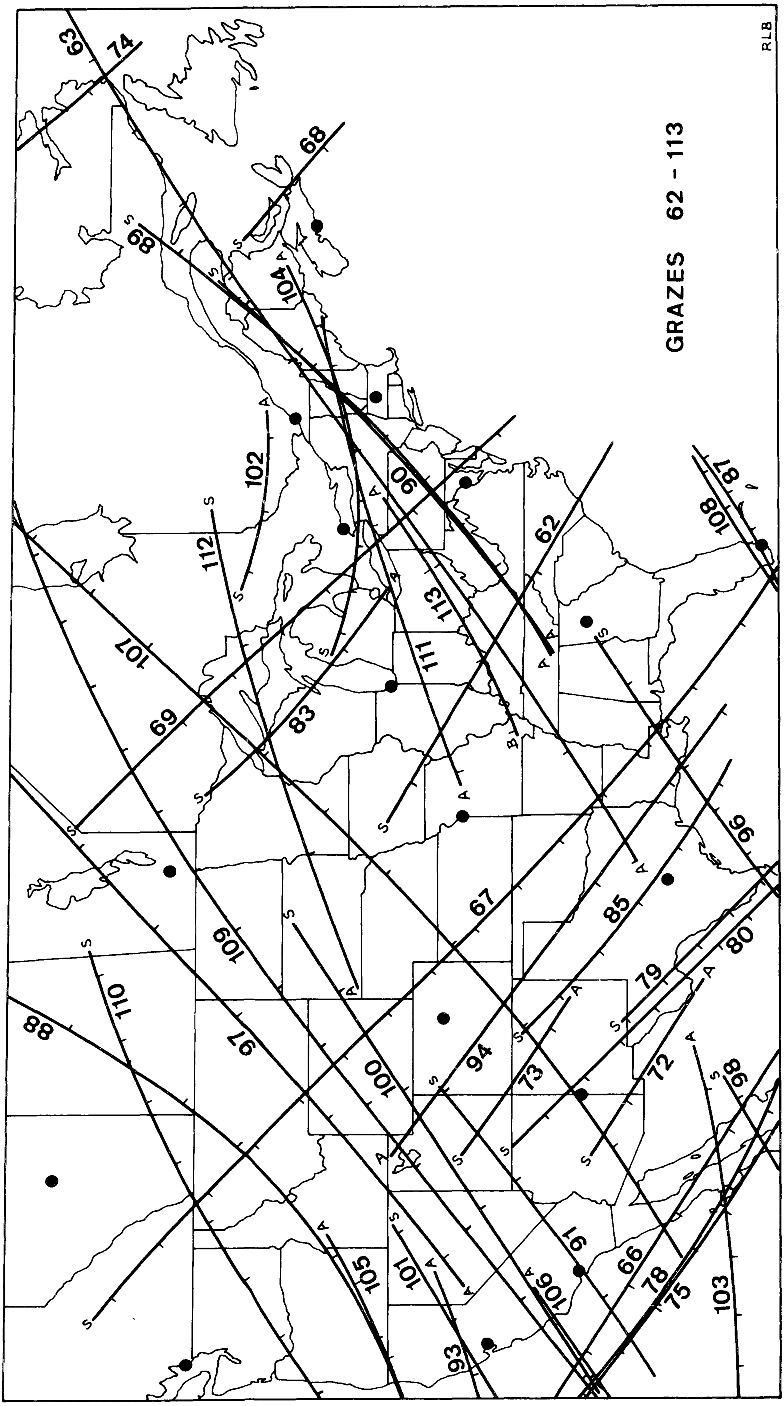
The table on the next page lists lunar graze predictions for much of North America for 1984. The events are limited to stars of magnitude 7.5 or brighter which will graze the limb of the Moon when it is at a favourable elongation from the Sun and at least 10° above the observer's horizon (5° in the case of stars brighter than $5^{m}.5$ and 2° for those brighter than $3^{m}.5$). For each is given: a chronological sequential number, the Zodiacal Catalogue number and magnitude of the star, the time of the beginning of each graze track (the west end of the track), the percent of the Moon sunlit (a minus sign indicates a waning Moon), and whether the track is the northern (N) or southern (S) limit of the occultation.

The maps show the predicted graze tracks. Each track is keyed to the sequential number in the table. Several tracks begin and/or end with a letter *A*, *B*, or *S* indicated. *A* denotes that the Moon is at a low altitude, *B* that the bright limb interferes, and *S* that daylight interferes. The tick marks along the tracks indicate multiples of 5 minutes of every hour. e.g. If the time for the west end of a track is $3^h16^m11^s$, the tick marks proceeding eastward correspond to $3^h20^m00^s$, $3^h25^m00^s$, *etc*. Also, the tick marks are located on the side of each line that the star is occulted. The locations of the North American *standard stations* for lunar total occultation predictions are indicated by dots on the graze maps (as on the map on page 82, where the names are indicated by symbols).

Detailed predictions for any graze are available from the International Occultation Timing Association (see page 81).

No	ZC	m_v	UT at Start of Track in West	h	m	s	%	L
6	3484	6.8	Jan. 9	0	34	46	28	S
7	60	7.0	10	5	39	10	38	S
9	165	6.7	11	2	37	39	47	S
10	178	6.8	11	5	21	1	48	S
11	298	7.2	12	7	47	1	58	S
12	404	5.2	13	4	48	57	67	S
13	1702	4.2	22	6	34	20	-80	S
14	1924	5.8	24	4	27	56	-60	S
16	1941	4.8	24	8	32	26	-59	S
17	2060	6.3	25	8	25	8	-48	S
18	2064	6.5	25	8	45	50	-47	S
20	2307	4.1	27	8	22	30	-27	S
21	2310	4.6	27	8	57	40	-27	S
22	2330	6.3	27	11	46	41	-26	S
23	2327	6.7	27	12	11	24	-26	S
24	2337	6.4	27	13	3	34	-26	S
26	106	6.8	Feb. 6	23	34	15	20	S
27	354	5.5	9	2	38	54	39	S
28	469	7.3	10	3	31	44	50	S
29	614	5.7	11	5	30	51	60	S
30	761	6.7	12	6	11	13	71	N
32	2160	6.6	22	12	25	51	-62	S
33	2267	5.1	23	8	50	49	-53	S
36	839	5.3	Mar.11	1	15	17	53	S
38	853	7.0	11	3	21	45	54	S
39	880	7.2	11	7	39	57	55	N
40	882	5.0	11	7	54	33	55	N
41	1030	3.2	12	5	45	42	65	N
43	1170	3.7	13	4	58	18	75	N
46	2499	6.6	23	6	33	5	-60	S
47	2500	3.4	23	6	45	18	-60	S
48	2669	6.2	24	11	20	37	-48	S
49	2676	6.5	24	11	45	25	-48	S
52	642	6.9	Apr. 6	0	21	53	18	S
53	646	6.1	6	0	32	46	18	S
54	651	5.9	6	1	8	48	18	S
55	665	5.7	6	3	23	43	19	N
56	789	6.9	7	0	46	13	27	N
58	1117	5.1	9	4	0	43	49	N
59	1251	5.9	10	1	35	1	60	N
60	1544	5.7	12	8	17	29	83	N
61	3032	7.2	23	8	18	19	-46	S
62	918	7.0	May 5	1	52	39	15	N
63	1030	3.2	5	15	19	1	21	S
66	1085	7.0	6	4	6	4	25	N
67	1484	3.6	9	3	58	0	58	N
68	1586	7.5	10	0	15	19	67	N
69	1598	6.4	10	2	44	53	68	N
72	1046	6.9	June 2	3	2	56	7	N
73	1049	6.6	2	3	20	58	7	N
74	1180	7.1	3	1	32	34	13	N
75	1334	7.0	4	4	58	52	23	N
78	1702	4.2	7	6	24	19	56	N
79	1921	5.9	9	2	34	39	77	N
80	1924	5.8	9	3	16	6	77	N
83	1544	5.7	July 3	3	0	53	20	N
85	1659	6.8	4	2	55	33	30	N
87	66	6.8	19	6	23	40	-67	N
88	192	5.3	20	8	17	14	-58	N
89	517	6.4	Jul.23	7	11	30	-29	N
90	665	5.7	24	7	50	6	-20	N
91	835	6.9	25	11	22	42	-11	N
93	2241	5.0	Aug. 5	6	53	58	63	N
94	2500	3.4	6	23	40	3	80	N
96	767	5.5	21	10	25	13	-33	N
97	918	7.0	22	9	24	18	-24	N
98	932	7.4	22	12	13	12	-23	N
100	1085	7.0	23	10	59	46	-15	N
101	1094	6.9	23	12	21	9	-14	N
102	2182	6.3	Sep. 1	0	43	28	35	N
103	2192	6.2	1	3	46	28	36	N
104	2459	7.2	3	0	47	18	56	N
105	2483	7.1	3	4	51	38	58	N
106	2650	4.7	4	7	12	58	69	S
107	709	4.3	17	6	17	19	-61	N
108	716	6.2	17	8	43	14	-60	N
109	867	6.9	18	9	3	53	-50	N
110	877	6.6	18	11	14	35	-49	N
111	1435	6.7	22	9	39	50	-11	N
112	1436	6.9	22	10	17	56	-10	N
113	2558	6.2	Oct. 1	0	59	35	41	S
114	2721	3.3	1	23	1	36	51	N
115	2723	6.7	2	0	24	20	51	S
117	3018	6.3	4	1	28	54	71	N
118	634	5.3	14	1	59	0	-85	N
119	656	4.4	14	4	29	4	-84	N
120	657	5.4	14	4	34	4	-84	N
122	932	7.4	16	2	53	52	-68	N
123	1131	7.2	17	10	49	21	-54	N
124	1251	5.9	18	8	11	11	-44	N
125	1270	6.1	18	11	24	27	-43	N
128	2848	5.6	30	2	43	45	35	S
133	1211	6.2	Nov.14	5	58	41	-71	N
134	1484	3.6	16	12	10	20	-47	S
135	1586	7.5	17	8	33	44	-37	N
136	1598	6.4	17	11	0	43	-36	S
137	1702	4.2	18	7	59	38	-27	N
138	1951	7.1	20	11	28	22	-8	S
139	2721	3.3	25	16	26	5	10	N
140	2910	4.8	26	22	52	57	19	S
141	2914	5.0	27	0	10	23	19	S
142	2925	7.5	27	2	0	1	20	S
143	3052	6.2	27	23	20	14	27	S
144	3458	6.5	Dec. 1	7	0	7	58	S
146	25	7.5	2	8	8	57	68	S
147	1544	5.7	14	4	27	0	-66	S
148	1569	6.8	14	11	24	37	-63	S
150	1821	2.9	16	19	36	49	-37	S
151	1920	6.7	17	12	23	59	-29	S
152	2036	6.9	18	11	21	47	-19	S
153	2173	7.0	19	13	34	45	-10	S
154	2181	7.1	19	14	44	20	-10	S
155	3141	6.0	26	0	57	55	13	S
156	3276	7.4	27	2	13	30	21	S
157	66	6.8	30	0	45	58	48	S
158	83	6.9	30	6	11	45	50	S
159	202	7.0	31	7	7	6	59	S


GRAZES 6 - 61
RLB


GRAZES 62 - 113
RLB
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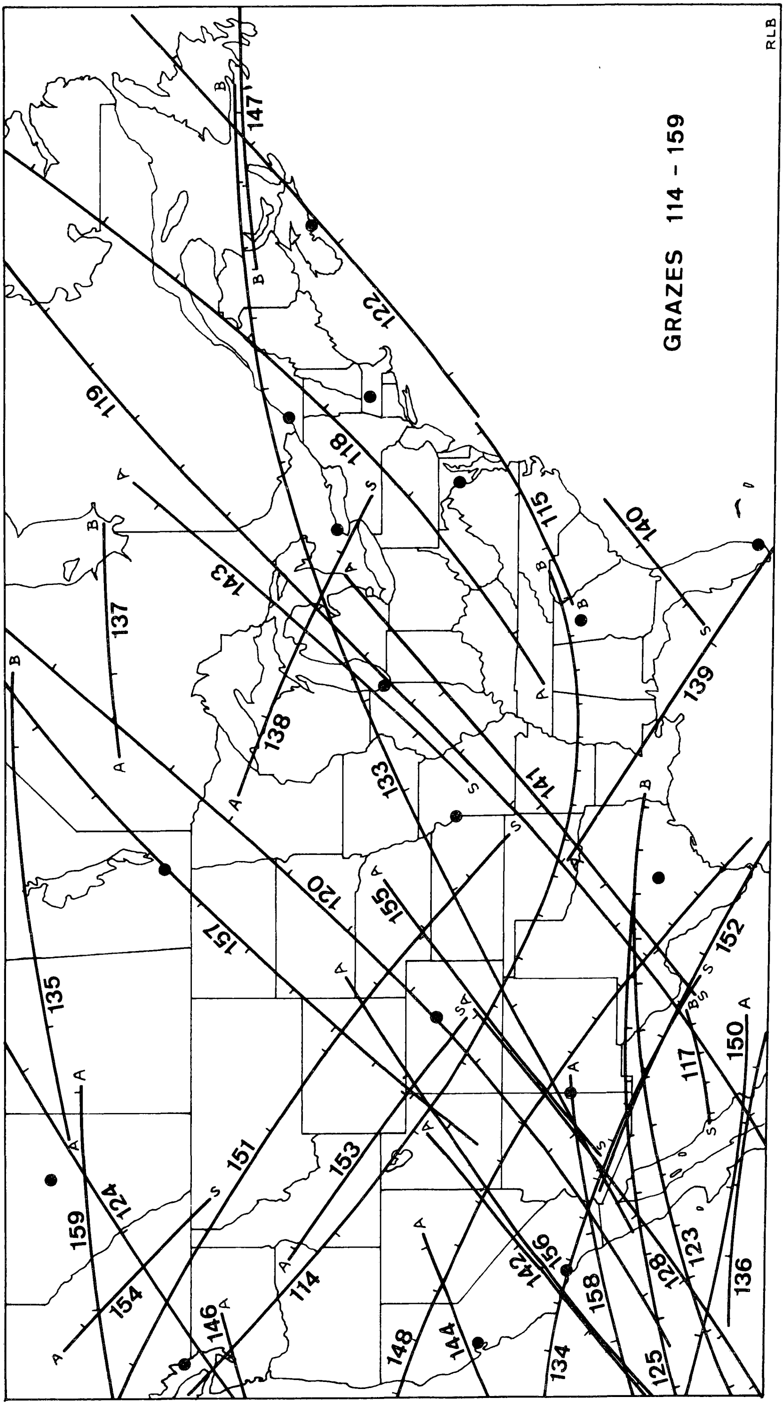
GRAZES 114 - 159
RLB
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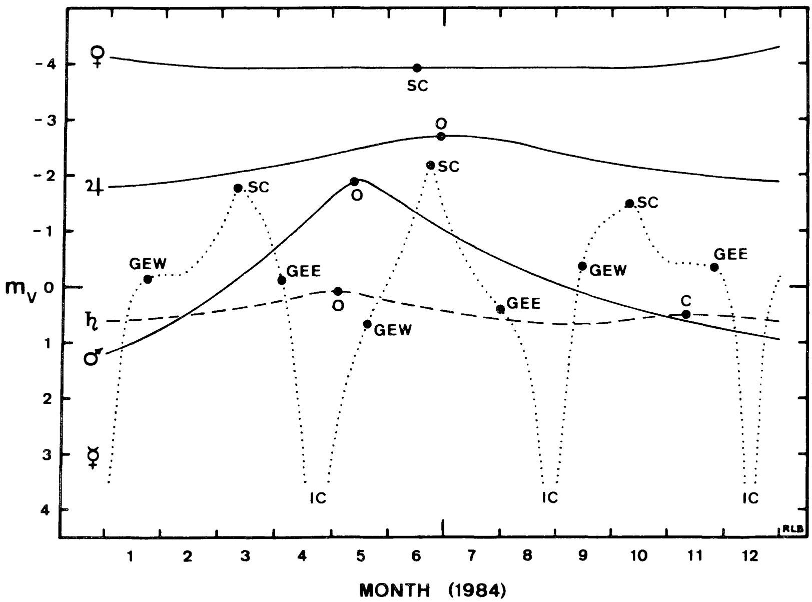
PLANETS, SATELLITES, AND ASTEROIDS

PLANETARY HELIOCENTRIC LONGITUDES 1984

Date UT	Planet					
	M	V	E	M	J	S
Jan. 1.0	103°	179°	100°	170°	263°	219°
Feb. 1.0	233	229	131	183	266	220
Mar. 1.0	318	275	161	197	268	221
Apr. 1.0	121	324	191	211	271	222
May 1.0	238	11	221	226	273	223
June 1.0	333	61	251	241	276	224
July 1.0	138	109	279	258	278	225
Aug. 1.0	250	160	309	275	281	226
Sep. 1.0	350	210	339	294	283	227
Oct. 1.0	158	258	8	312	286	228
Nov. 1.0	261	307	39	332	288	229
Dec. 1.0	4	354	69	351	291	230
Jan. 1.0	176	44	100	10	294	231

The heliocentric longitude is the angle between the vernal equinox and the planet, as seen from the Sun. It is measured in the ecliptic plane, in the direction of the orbital motion of the planets (counterclockwise as viewed from the north side of the ecliptic plane). Knowing the heliocentric longitudes, and the approximate distances of the planets from the Sun (page 9), the reader can construct the orientation of the Sun and planets on any date.

The heliocentric longitude of Uranus increases from 250° to 254° during the year; that of Neptune from 269° to 271°, and that of Pluto from 210° to 213°.



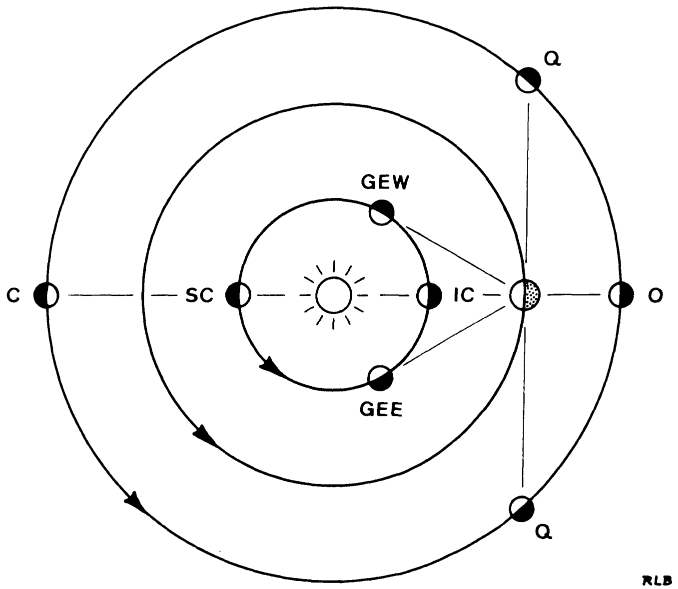
The magnitudes of the five, classical (naked eye) planets in 1984. Oppositions (O), conjunctions (C), inferior and superior conjunctions (IC, SC), and greatest elongations east and west (GEE, GEW) are indicated. (Note the diagram explaining these terms on page 92. For planetary symbols see page 8.)

PRONUNCIATION OF PLANET NAMES

Mercury	mûr'kyoo-rē
Venus	vē'nŭs
Earth	ûrth
Mars	mȧrs
Jupiter	jo͞o'pĭ-tẽr
Saturn	sȧt'ûrn
Uranus	yoor'ȧ-nŭs
Neptune	nĕp'to͞on
Pluto	plo͞o'tō

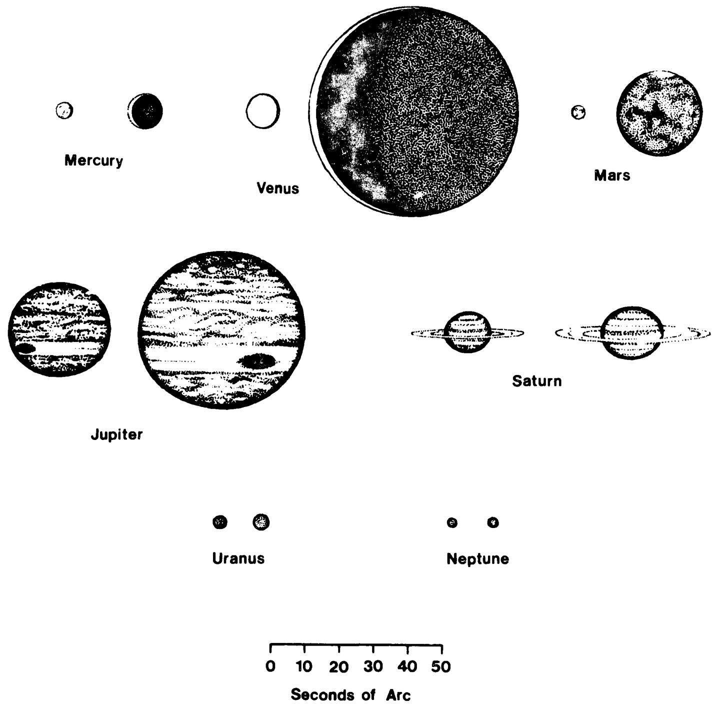
ā dāte; ă tăp; â câre; ȧ ȧsk; ē wē; ĕ mĕt; ẽ makẽr; ī īce; ĭ bĭt; ō gō; ŏ hŏt; ô ôrb; oo book; o͞o mo͞on; ū ūnite; ŭ ŭp; û ûrn.

P



This diagram is a simplified view of the Solar System, from the north side. Earth is shown (middle orbit) together with an "inferior" planet (e.g. Venus) and a "superior" planet (e.g. Mars). Four special configurations of the inferior planet relative to Earth are shown (in counterclockwise chronological sequence): inferior conjunction (IC), greatest elongation west (GEW), superior conjunction (SC), greatest elongation east (GEE). Four special configurations of the superior planet relative to Earth are also shown (in clockwise chronological sequence): opposition (O), quadrature (Q), conjunction (C), quadrature (Q).

PLANETS: APPARENT SIZES



The apparent maximum and minimum observable size of seven planets is illustrated along with characteristic telescopic appearance. The large satellites of Jupiter (not shown) appear smaller than Neptune.

PRONUNCIATION OF SATELLITE NAMES

Adrastea	ȧ-drăs'tē-ȧ	Europa	yoo-rō'pȧ	Nereid	nēr'ē-ĭd
Amalthea	ăm''l-thē'ȧ	Ganymede	găn'ĕ-mēd'	Oberon	ō'bȧ-rŏn'
Ananke	ȧ'năn-kē	Himalia	hĭm'ȧ-lĭ-ȧ	Pasiphae	pȧ-sĭf'ȧ ē'
Ariel	âr'ē-ĕl	Hyperion	hī-pēr'ī-ĕn	Phobos	fō'bŏs
Callisto	kȧ-lĭs'tō	Iapetus	ī-ăp'ŭ-tŭs	Phoebe	fē'bē
Carme	kȧr'mē	Io	ī'ō	Rhea	rē'ȧ
Charon	kâr'ĕn	Leda	lē'dȧ	Sinope	sĭ-nō'pē
Deimos	dī'mŏs	Lysithea	lĭs'ĭ-thē'-ȧ	Tethys	tē'thĭs
Dione	dī-ŏ'nē	Mimas	mī'măs	Titan	tī't'n
Elara	ē'lȧr-ȧ	Miranda	mĭ-răn'dȧ	Titania	tī-tā'nē-ȧ
Enceladus	ĕn-sĕl'ȧ-dŭs	Moon	mo͞on	Triton	trī't'n
				Umbriel	ŭm'brē-ĕl'

ā dāte; ă tăp; â câre; ȧ ȧsk; ē wē; ĕ mĕt; ē makēr; ī īce; ĭ bĭt; ō gō; ŏ hŏt; ô ôrb; oo book; o͞o mo͞on; ū ūnite; ŭ ŭp; û ûrn.

THE PLANETS FOR 1984

BY TERENCE DICKINSON

MERCURY

At just over one-third Earth's distance from the Sun, Mercury is the solar system's innermost planet and the only one known to be almost entirely without an atmosphere. Mercury is a small world only 6% as large as Earth by volume—barely larger than our moon.

Until the advent of interplanetary probes, virtually nothing was known about the surface of Mercury. Only the vaguest smudges have been seen through Earth-based telescopes. In 1974 the U.S. spacecraft Mariner 10 photographed one hemisphere of Mercury revealing it to be extremely heavily cratered, in many respects identical in appearance to the far side of Earth's moon. There is no interplanetary mission planned to photograph the other hemisphere.

Mercury's orbit is the most elliptical of any planet except Pluto's. Once each orbit Mercury approaches to within 0.31 A of the Sun and then half an orbit (44 days) later it is out to 0.47 A. This amounts to a 24 million km range in distance from the Sun, making the Sun in Mercury's sky vary from about four times the area we see it to more than ten times its apparent area from Earth. Mercury's sidereal rotation period of 59 days combines with the 88 day orbital period of the planet to produce a solar day (one sunrise to the next) of 176 days—the longest of any planet.

Of the five planets visible to the unaided eye Mercury is by far the most difficult to observe and is seldom conveniently located for either unaided eye or telescopic observation. The problem for observers is Mercury's tight orbit which constrains the planet to a small zone on either side of the Sun as viewed from Earth. When Mercury is east of the Sun we may see it as an evening star low in the west just after sunset. When it is west of the Sun we might view Mercury as a morning star in the east before sunrise. But due to celestial geometry involving the tilt of Earth's axis and Mercury's orbit we get much better views of Mercury at certain times of the year.

The best time to see the planet in the evening is in the spring, and in the morning in the fall (from the northern hemisphere). Binoculars are of great assistance in searching for the planet about 40 minutes to an hour after sunset or before sunrise during the periods when it is visible. Mercury generally appears about the same colour and brightness as the planet Saturn.

Telescopic observers will find the rapidly changing phases of Mercury of interest. The planet appears to zip from gibbous to crescent phase in about three weeks during each of its elongations. In the table below data concerning the six greatest elongations of Mercury during 1984 are presented.

GREATEST ELONGATIONS OF MERCURY IN 1984

Date, UT	Elongation	Magnitude	Angular Diameter
Jan 22	24° W	-0.1	6.″7
Apr 3	19 E	0.0	7.5
May 19	26 W	+0.6	8.3
Aug 1	27 E	+0.4	7.7
Sep 14	18 W	-0.2	7.2
Nov 25	22 E	-0.3	6.5

MERCURY
TELESCOPIC OBSERVING DATA FOR FAVOURABLE EASTERN (EVENING) ELONGATION 1984

Date 0h UT	Magnitude	Angular Diameter	% of Disk Illuminated	Distance From Sun	RA	Dec
Mar 21	-1.3	5.″6	88	12°	$0^h 45^m$	+5° 03′
Mar 26	-0.9	6.1	73	16	1 18	9 28
Mar 31	-0.4	7.0	53	19	1 45	13 06
Apr 5	+0.4	8.0	34	19	2 03	15 34
Apr 10	+1.4	9.3	18	16	2 12	16 39

Mercury's phases have been glimpsed with telescopes of 75 mm aperture or less, but generally a 100 mm or larger telescope is required to distinguish them. In larger instruments under conditions of excellent seeing (usually when Mercury is viewed in the daytime) dusky features have been glimpsed by experienced observers. Thorough analysis has shown only a fair correlation between these visually observed features and the surface of the planet as photographed by Mariner 10.

VENUS

Venus is the only planet in the solar system that closely resembles Earth in size and mass. It also comes nearer to Earth than any other planet, at times approaching as close as 41 million km. Despite the fundamental similarity, Earth and Venus differ greatly according to findings of recent spacecraft missions to the planet.

We now know that Venus is infernally hot over its entire surface, ranging little from a mean of +455°C. The high temperature is due to the dense carbon dioxide atmosphere of Venus which, when combined with small quantities of water vapour and other gases known to be present, has the special property of allowing sunlight to penetrate to the planet's surface but not permitting the resulting heat to escape. In much the same way as the glass cover of a greenhouse keeps plants warm, an atmosphere of carbon dioxide can heat up a planetary surface to a higher temperature than would be achieved in an airless environment.

Venus' atmosphere has a surface pressure 91 times Earth's sea-level atmospheric pressure. A haze layer extends down from about 65 km above the surface to about 50 km, where a dense two- to three-km-thick cloud deck occurs. The haze continues to within about 30 km from the surface where the atmosphere clears. The Soviet Venera 9 and 10 spacecraft which landed on Venus in 1975 and photographed the planet's surface showed that sunlight similar to that received on Earth on a heavily overcast day does penetrate down to the surface. The clouds and haze that cloak the planet, consisting chiefly of droplets of sulphuric acid, are highly reflective, making Venus brilliant in the nighttime sky. However, telescopically, the planet is virtually a featureless orb.

In 1978 Soviet and American landing devices detected what appears to be evidence of periods of continuous lightning in the atmosphere and of a glow at night near Venus' surface. The source of the glow and the mechanism that produces the lightning in Venus' atmosphere are unknown. Recent findings also show that below the clouds Venus' atmosphere is remarkably uniform in temperature and pressure at all latitudes and in both day and night hemispheres. Winds at the surface range from 2 to 10 km/h.

Based on extensive radar data returned from the Pioneer Orbiter, nearly the entire planet has been mapped. Sixty percent of Venus' surface is relatively flat, rolling plains varying in height by only about 1 km between high and low points. Only 16 percent of the surface could be described as lowlands (perhaps comparable to ocean basins on Earth). Only eight percent is true highland, ranging to a maximum altitude of 10.6 km above the rolling plains. Venus' crust appears to be thicker than Earth's—thick enough to choke off plate tectonics. Apparently, Venus' crust is one huge tectonic plate. There is no evidence of features like Earth's midocean ridges.

Despite the differences between Venus and Earth, there is growing evidence from analysis of the Pioneer readings that about four billion years ago, Venus probably had a global ocean of water almost identical to Earth's for several hundred million years. At that time the Sun was only two-thirds of its present brightness, but as solar radiation slowly increased toward present levels, the Venus ocean was doomed. Evaporation fuelled a massive buildup of atmospheric carbon dioxide, which ultimately led to the greenhouse situation seen today.

Venus is the brightest natural celestial object in the nighttime sky apart from the Moon and whenever it is visible is readily recognized. Because its orbit is within that of Earth, Venus is never separated from the Sun by an angle greater than 47 degrees. However, this is more than sufficient for the dazzling object to dominate the morning or evening sky.

Like Mercury, Venus exhibits phases although they are much easier to distinguish because of Venus' greater size. When it is far from us (near the other side of its orbit) we see the planet nearly fully illuminated, but because of its distance it appears small—about 10 seconds of arc in diameter. As Venus moves closer to Earth the phase decreases (we see less of the illuminated portion of the planet) but the diameter increases until it is a thin slice nearly a minute of arc in diameter. It takes Venus several months to run through from one of these extremes to the other compared to just a few weeks for Mercury.

Venus will not display its usual prominence in evening and morning skies in 1984. Indeed, with superior conjunction occurring in mid-year, this is the most unfavourable year for observing the planet in several decades. Nonetheless, as 1984 opens, the planet is still quite prominent in the morning sky before sunrise. As the year advances, the planet becomes progressively more difficult to detect, and from March through to late September, it is buried in the solar glare. Only for the last few weeks of the year does Venus emerge as a dazzling object gracing the western evening sky.

On January 1, Venus is 1.10 A from Earth. That distance increases to 1.74 A by superior conjunction on June 15, then reduces to 0.85 A by the end of the year. The planet's apparent diameter on these three dates is 15.2″, 9.6″ and 19.6″ respectively. Throughout 1984, Venus never appears less than 60% illuminated.

P

When Venus is about a 20% crescent even rigidly-held, good quality binoculars can be used to distinguish that the planet is not spherical or a point source. A 60 mm refractor should be capable of revealing all but the gibbous and full phases of Venus. Experienced observers prefer to observe Venus during the daytime, and indeed the planet is bright enough to be seen with the unaided eye if one knows where to look.

Venus appears to most observers to be featureless no matter what type of telescope is used or what the planet's phase. However, over the past century some observers using medium or large size telescopes have reported dusky, patchy markings usually described as slightly less brilliant than the dazzling white of the rest of the planet. We now know that there are many subtle variations in the intensity of the clouds of Venus as photographed in ultraviolet by spacecraft and Earth-based telescopes. But when the ultraviolet photos are compared to drawings of the patchy markings seen by visual observers the correlation is fair at best.

When Venus is less than 10% illuminated the cusps (the points at the ends of the crescent) can sometimes be seen to extend into the night side of the planet. This is an actual observation of solar illumination being scattered by the atmosphere of Venus. When Venus is a thin sliver of a crescent the extended cusps may be seen to ring the entire planet.

MARS

Mars is the planet that has long captivated the imagination of mankind as a possible abode of life. One of the major objectives of the Viking spacecraft which landed on Mars in 1976 was the quest for Martian microorganisms. The Viking biology experiments completed the search in 1977 and, although the results are somewhat ambiguous, there is no convincing evidence of life we are familiar with.

The landscapes photographed by the Viking landers were basically desert vistas strewn with rocks ranging up to several metres wide. Judging by their texture and colour, and chemistry analysis by Viking, the rocks are fragments of lava flows. The soil composition resembles that of basaltic lavas on Earth and our Moon. About 1% of the soil is water, chemically bound in the crystal structure of the rock and soil particles. Some planetary scientists speculate that water in the form of permafrost exists a few metres below the surface. However, Viking and its predecessors have shown that water was once abundant enough on Mars to leave major structures on the planet resembling riverbeds. Analysis of high resolution Viking Orbiter photographs of these structures has led most investigators to conclude that they were likely carved during the planet's early history.

The red planet's thin atmosphere has an average surface pressure only 0.7% of Earth's and consists of 95% carbon dioxide, 2.7% nitrogen, 1.6% argon, 0.6% carbon monoxide, 0.15% oxygen and 0.03% water vapour. Winds in the Martian atmosphere reach speeds exceeding 300 km/h and in so doing raise vast amounts of dust that can envelop the planet for weeks at a time. The dust storms were thought to occur with seasonal regularity shortly after Mars passed the perihelion point of its elliptical orbit, but the Viking observations revealed more complex weather patterns.

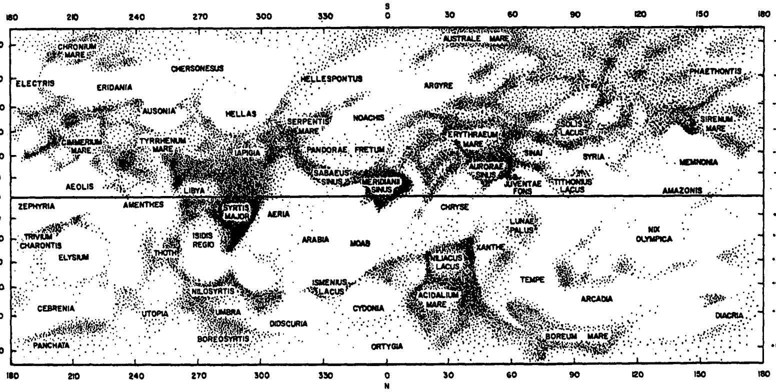
In many ways Mars is the most interesting planet to observe with the unaided eye. It moves rapidly among the stars—its motion can usually be detected after an interval of less than a week—and it varies in brightness over a far greater range than any other planet. Mars may be distinguished by its orange-red colour, a hue that originates with rust-coloured dust that covers much of the planet.

Telescopically Mars is usually a disappointingly small featureless ochre disk except within a few months of opposition when its distance from Earth is then near minimum. If Mars is at perihelion at these times the separation can be as little as 56 million km. Such close approaches occur at intervals of 15 to 17 years; the most recent was in 1971. At a perihelion opposition the telescopic disk of Mars is 25 seconds of arc in diameter and much detail on the planet can be distinguished with telescopes of 100 mm aperture or greater. At oppositions other than when Mars is at perihelion, the disk is correspondingly smaller.

As 1984 opens, Mars is seen after midnight near the Virgo-Libra border, not far to the west of Saturn. The two planets are in conjunction on February 15 when they are less than a degree apart and almost identical in brightness. Mars continues its eastward motion, then retrogrades, spending the spring and summer in Libra. Throughout this time, it is an extremely prominent reddish-orange object, peaking at magnitude −1.9 in mid-May. Opposition is May 11 when Mars rises at sunset and is visible in the southern sky throughout the night. Mars is on the move again in late summer, crossing into Scorpius in late August, Ophiuchus in September, Sagittarius in October and on to Capricornus and Aquarius by the end of the year.

This is an excellent year for telescopic observation of the red planet. Mars is greater than 10 seconds of arc in diameter from March 9 to August 20, reaching a maximum size of 17.6″ on May 19, the date of closest approach to Earth. At that time, Mars will be 0.531 A (79.5 million km) from Earth, closer than it has been since 1973. Telescopically, Mars will then be about the same size as the disk of Saturn. Detail on the Martian globe is expected to be more contrasty prior to closest approach, rather than after, because Mars is entering its summer season when global dust storms most often occur. As in recent years, the north polar region will again be tipped Earthward throughout the prime observing period. The north polar cap should be visible as a white button on the ochre disk.

MAP OF MARS



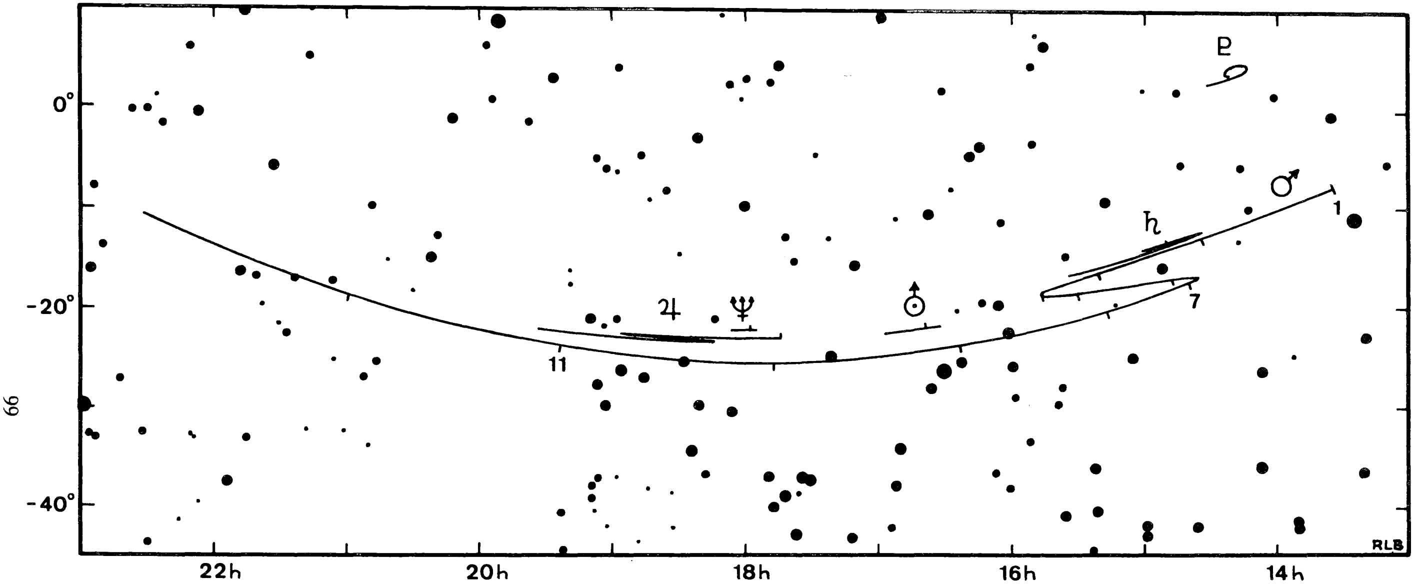
Latitude is plotted on the vertical axis (south at the top); longitude is plotted on the horizontal axis.

MARS: EPHEMERIS FOR PHYSICAL OBSERVATIONS 1984

Date UT	Dist. A	Mag.	Eq. Diam.	Ill. %	Pos. Ang.	Incl.	L(1)	Δ
Jan 1.0	1.615	+1.2	5″8	91	36°	21°	319°84	9°59
Feb 1.0	1.301	+0.7	7.2	90	38	16	22.49	9.47
Mar 1.0	1.009	+0.1	9.3	91	38	12	107.79	9.35
Mar 17.0	0.860	-0.3	10.9	92	38	10	318.27	9.22
Apr 2.0	0.727	-0.8	12.9	95	37	10	170.80	9.10
Apr 10.0	0.670	-1.0	14.0	96	37	10	98.02	9.01
Apr 18.0	0.622	-1.3	15.1	98	37	10	25.94	8.92
Apr 26.0	0.582	-1.5	16.1	99	38	11	314.56	8.85
May 4.0	0.553	-1.7	16.9	100	38	13	243.80	8.80
May 8.0	0.543	-1.8	17.2	100	38	13	208.59	8.79
May 12.0	0.537	-1.9	17.4	100	39	14	173.44	8.78
May 16.0	0.533	-1.9	17.6	100	39	15	138.31	8.79
May 20.0	0.531	-1.8	17.6	100	39	16	103.16	8.80
May 24.0	0.533	-1.8	17.6	99	39	16	67.95	8.83
May 28.0	0.538	-1.7	17.4	98	39	17	32.63	8.86
Jun 1.0	0.545	-1.6	17.2	98	39	17	357.18	8.93
Jun 9.0	0.566	-1.5	16.5	96	39	18	285.71	9.04
Jun 17.0	0.594	-1.3	15.7	94	39	19	213.42	9.14
Jun 25.0	0.629	-1.1	14.9	92	39	19	140.28	9.24
Jul 3.0	0.667	-1.0	14.0	90	39	19	66.33	9.37
Jul 19.0	0.752	-0.7	12.4	88	39	17	276.38	9.50
Aug 4.0	0.842	-0.4	11.1	86	39	15	124.40	9.61
Sep 1.0	1.003	0.0	9.3	85	36	9	215.42	9.69
Oct 1.0	1.174	+0.3	8.0	85	28	0	284.73	9.76
Nov 1.0	1.352	+0.5	6.9	87	16	-10	342.27	9.83
Dec 1.0	1.529	+0.7	6.1	89	2	-19	47.27	9.92

RLB

For selected dates, this table gives the distance of Mars from Earth, its magnitude, equatorial angular diameter, fraction of the disk illuminated, position angle of the rotation axis (measured counterclockwise from north, i.e. toward the east), inclination of the rotation axis to the plane of the sky (positive if the north pole is tipped toward Earth), and two quantities L(1) and Δ which can be used to calculate the longitude L of the central meridian of the geometric disk. For a given date and time (UT) of observation, L is equal to L(1) for the nearest preceding date in the table less *Δ times the number of complete days elapsed since that date. To the result,* add *14°.6 multiplied by the time in hours elapsed since 0h UT. If the result is less than 0°,* add *360°; if the result is greater than 360°,* subtract *360°. The answer is accurate to better than 1°. The value of L can then be compared with the above map.*



The paths of Mars, Jupiter, Saturn, Uranus, Neptune and Pluto during 1984. (The coordinates are for 1984. For planetary symbols see page 8.) In all cases except for Pluto, a single tick on the north side of each path indicates the planet's position at the beginning of the year. At the end of the year all planets are at the east (left) end of their paths. For the path of Mars, tick marks on the south side indicate the position of Mars at the beginning of each month. (To aid identification, the marks for January, July and November are numbered 1, 7 and 11 respectively.) Mars passes 0.8° south of Saturn on February 15. Later in the year, Mars passes near three bright stars: 24′ south of δ Sco on August 22, 24′ south of θ Oph on September 22, and 6′ north of λ Sgr on October 13. Jupiter makes three passes less than 1° north of the large globular cluster M22: on March 3, June 29, and October 27. (Larger scale maps for Uranus, Neptune and Pluto appear a few pages ahead.)

JUPITER

Jupiter, the solar system's largest planet, is a colossal ball of hydrogen and helium without any solid surface comparable to land masses on Earth. In many respects Jupiter is more like a star than a planet. Jupiter likely has a small rocky core encased in a thick mantle of metallic hydrogen which is enveloped by a massive atmospheric cloak topped by a quilt of multi-coloured clouds.

The windswept visible surface of Jupiter is constantly changing. Vast dark belts merge with one another or sometimes fade to insignificance. Brighter zones—actually smeared bands of ammonia clouds—vary in intensity and frequently are carved up with dark rifts or loops called festoons. The equatorial region of Jupiter's clouds rotates five minutes faster than the rest of the planet: 9 hours 50 minutes compared to 9 hours 55 minutes. This means constant interaction as one region slips by the other at about 400 km/h. It also means that there are basically two rotational systems from the viewpoint of week-to-week telescopic observation.

In the table below the two quantities L(1) and Δ can be used to calculate the longitude L of the central meridian of the illuminated disk of Jupiter. System I is the most rapidly rotating region between the middle of the North Equatorial Belt and the middle of the South Equatorial Belt. System II applies to the rest of the planet. For a given date and time (U.T.) of observation, L is equal to L(1) for the month in question *plus* Δ times the number of complete days elapsed since 0 h U.T. on the first of the month *plus* either 36.58° (for system I) or 36.26° (for system II) times the number of hours elapsed since 0 h U.T. The result will usually exceed 360°; if so, divide the result by 360 and then multiply the decimal portion of the quotient by 360°. This procedure, which is accurate to 1°, is readily computed using a modest calculator.

Jupiter's rapid rotation also makes the great globe markedly oval so that it appears about 7% "squashed" at the poles. Jupiter's apparent equatorial diameter ranges from 47″ at opposition on June 29 to a minimum of 32″ at conjunction on January 16, 1985.

JUPITER: EPHEMERIS FOR PHYSICAL OBSERVATIONS 1984

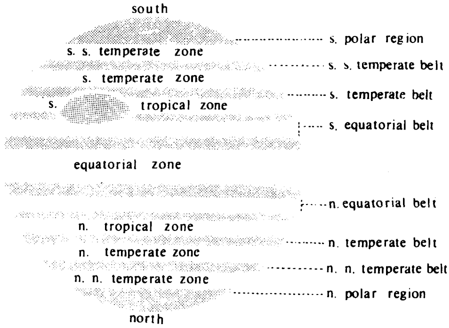
P

Date UT	Mag.	App. Equat. Diam.	System I		System II	
			L(1)	Δ	L(1)	Δ
Jan 1.0	-1.3	31″.6	141°.0	157°.72	71°.0	150°.09
Feb 1.0	-1.4	32.8	350.4	157.78	43.9	150.15
Mar 1.0	-1.5	34.9	246.1	157.85	78.3	150.22
Apr 1.0	-1.7	38.1	99.6	157.94	55.2	150.30
May 1.0	-1.9	41.9	157.6	158.01	244.4	150.38
Jun 1.0	-2.1	45.4	16.0	158.04	226.2	150.41
Jul 1.0	-2.2	46.8	77.1	157.99	58.4	150.36
Aug 1.0	-2.1	45.3	294.8	157.88	39.6	150.25
Sep 1.0	-1.9	41.9	149.2	157.77	17.4	150.14
Oct 1.0	-1.7	38.2	202.3	157.69	201.7	150.07
Nov 1.0	-1.5	35.2	50.8	157.65	173.7	150.02
Dec 1.0	-1.4	33.1	100.4	157.65	354.4	150.02
Jan 1.0	-1.4	32.2				

RLB

JUPITER'S BELTS AND ZONES

Viewed through a telescope of 150 mm aperture or greater, Jupiter exhibits a variety of changing detail and colour in its cloudy atmosphere. Some features are of long duration, others are short-lived. The standard nomenclature of the belts and zones is given in the figure.



The Great Red Spot, a salmon-coloured oval vortex whose hue may possibly be due to organic-like compounds that are constantly spewed from some heated atmospheric source below, is the longest-lived structure on the visible surface of Jupiter. The spot and the changing cloud structures that stripe the planet can be easily observed in small telescopes because the apparent size of the visible surface of Jupiter is far greater than that of any other planet. Occasionally (1981–83 for example) the Red Spot loses its prominence, becoming difficult to detect in smaller telescopes, only to return to its normal state a few years later.

Two Voyager spacecraft swung through the Jovian system in 1979 and transmitted to Earth superbly detailed photographs of the planet and its five inner moons. Among the most surprising finds was a ring of dust-size particles around the giant planet's equator. The ring apparently extends from the Jovian clouds out to 59 000 km.

The smallest of telescopes will reveal Jupiter's four large moons, each of which is equal to or larger than Earth's satellite. The moons provide a never-ending fascination for amateur astronomers. Sometimes the satellites are paired on either side of the belted planet; frequently one is missing—either behind Jupiter or in the planet's shadow. Even more interesting are the occasions when one of the moons casts its shadow on the disk of the planet. The tiny black shadow of one of the moons can be particularly evident if it is cast on one of the bright zones of Jupiter. According to some observers this phenomenon is evident in a good 60 mm refractor. Both the satellite positions and the times of their interaction with the Jovian disk are given elsewhere in the HANDBOOK. Jupiter's other satellites are photographic objects for large instruments.

As 1984 opens, Jupiter, in Sagittarius, is difficult to observe, low in the southeast dawn twilight. By April it becomes visible in the late evening sky and is ideally placed for telescopic viewing for the next six months. Despite the fact that it is five times Earth's distance from the Sun, Jupiter's giant size and reflective clouds make it a celestial beacon which is unmistakable, particularly around opposition.

Opposition this year occurs on June 29, when the giant planet is 629 million km (4.21 A) from Earth. Minimum possible distance between the two planets is 590 million km.

SATURN

Saturn is the telescopic showpiece of the night sky. The chilling beauty of the small pale orb floating in a field of velvet is something no photographs or descriptions can adequately duplicate. According to recent Voyager spacecraft findings, the rings consist of billions of particles that range in size from microscopic specks to flying mountains kilometres across. The reason "rings" is plural and not singular is that gaps and brightness differences define hundreds of distinct rings. However, from Earth only the three most prominent components—known simply as rings A, B, and C—can be distinguished. (See the diagram on p. 103.)

Cassini's Division, a gap between rings A and B discovered in 1675, is visible in small telescopes when the ring system is well inclined to our view. The Voyager spacecraft revealed Cassini's Division as a region less densely populated with ring particles than adjacent rings. Ring B, the brightest, overpowers ring C to such an extent that ring C, also known as the crepe ring, is seen only with difficulty in small telescopes. Other ring structures beyond these three are not visible in amateur telescopes.

In addition to the rings, Saturn has a family of at least twenty satellites. Titan, the largest, is easily seen in any telescope as an eighth-magnitude object orbiting Saturn in about 16 days. At east and west elongation Titan appears about five ring diameters from the planet. Titan is the only satellite in the solar system with a substantial atmosphere, now known to be primarily nitrogen and 4.6 times as massive as Earth's, with a surface pressure of 1.6 Earth atmospheres.

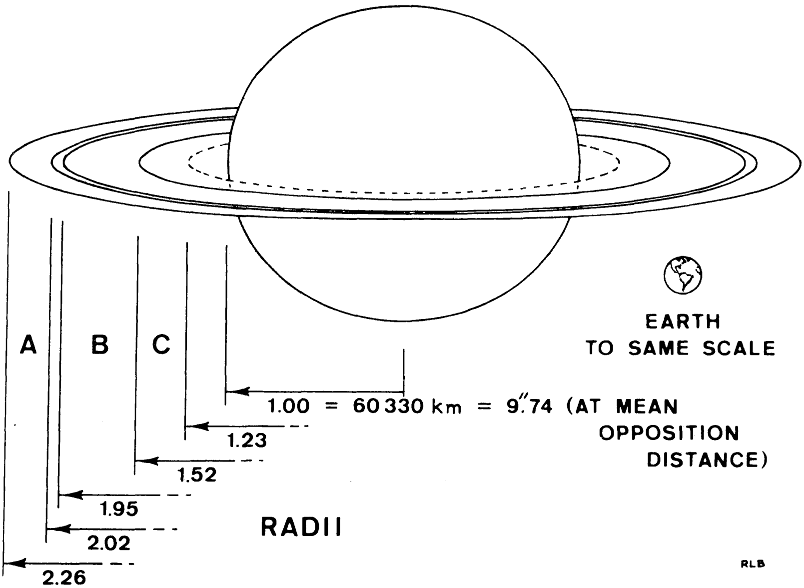
Telescopes over 60 mm aperture should reveal Rhea at 10th magnitude less than two ring-diameters from Saturn. The satellite Iapetus has the peculiar property of being five times brighter at western elongation ($10^{\mathrm{m}}.1$) than at eastern elongation ($11^{\mathrm{m}}.9$). One side of the moon has the reflectivity of snow while the other resembles dark rock. The reason for this is unknown. When brightest, Iapetus is located about 12 ring-diameters west of its parent planet. Of the remaining moons Tethys and Dione may be glimpsed in a 150 mm telescope but the others require larger apertures or photographic techniques. (See page 117 for an ephemeris for the five brightest satellites of Saturn.)

The disk of Saturn appears about 1/6 the area Jupiter appears through the same telescope with the same magnification. In telescopes less than 100 mm aperture probably no features will ever be seen on the surface of the planet other than the shadow cast by the rings. As the size of the telescope is increased the pale equatorial region, a dusky equatorial band, and the darker polar regions become evident. Basically, Saturn has a belt system like Jupiter's but it is much less active and the contrast is reduced. Seldom in telescopes less than 200 mm aperture do more than one or two belts come into view. In 1980, the planet's rotation period was established at 10 hours, 40 minutes, four percent longer than previous estimates. Very rarely a spot among the Saturnian clouds will appear unexpectedly, but less than a dozen notable spots have been recorded since telescopic observation of Saturn commenced in the 17th century.

From year to year the rings of Saturn take on different appearances. The planet's orbit is an immense 29.5 year circuit about the Sun, so in the course of an observing season the planet moves relatively little in its orbit (and thus appears to remain in about the same general area of the sky) and maintains an essentially static orientation toward Earth. In 1973 the rings were presented to their fullest extent (27°) as viewed from Earth, with the southern face being visible. The north face will be seen similarly displayed in 1987. In apparent width the rings are equal to the equatorial diameter of Jupiter.

SATURN

MAIN RING FEATURES VISIBLE FROM EARTH



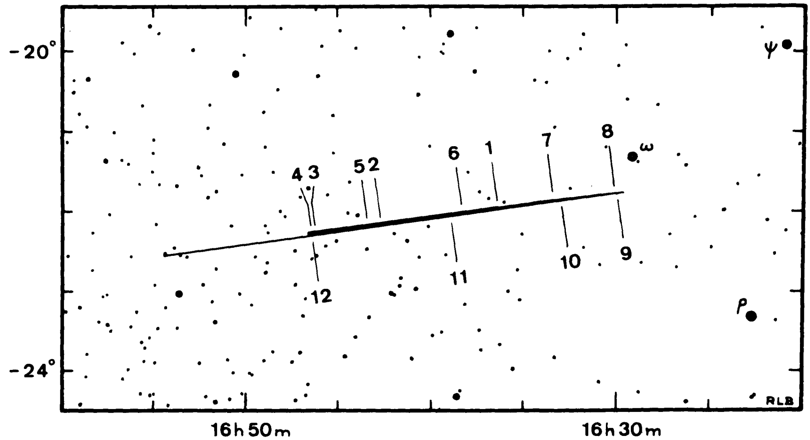
As 1984 opens, the rings are tilted 20.4° with respect to Earth, with the northern face being visible. The tilt remains near this value until May, when it decreases slightly, reaching 19.0° in June. From then until October, when Saturn is too close to the Sun for observation, the ring inclination slowly increases to near 22°. By December 31, when Saturn is visible in the morning sky, the rings have opened to 23.3°.

Saturn is in Libra and rises about four hours before the Sun as 1984 begins. Opposition is on May 3, when the planet is 1.32 billion km (8.85 A) from Earth. At that time Saturn is 18.″7 in equatorial diameter, and the rings are 42.″4 in width. Saturn will remain in Libra for all of 1984 and much of 1985.

URANUS

Although Uranus can be seen with the unaided eye under a clear, dark sky it was apparently unknown until 1781 when it was accidentally discovered by William Herschel with a 150 mm reflecting telescope. It can be easily seen with binoculars, and a telescope will reveal its small, greenish, featureless disk.

Jupiter, Saturn, Uranus and Neptune are rather similar in the sense that their interiors consist mainly of hydrogen and helium and their atmospheres consist of these same elements and simple compounds of hydrogen. Unlike the three other giant planets, the axis of Uranus is tipped almost parallel to the plane of the solar system. This means that we can view Uranus nearly pole-on at certain points in its 84 year orbit of the Sun. The northern hemisphere of Uranus is now directed toward Earth and we will be viewing the planet almost exactly toward its north pole in 1985. Uranus has five satellites, all smaller than Earth's moon, none of which can be detected in small or moderate sized telescopes.



The path of Uranus in southwestern Ophiuchus, 1984. The right end of the path is about 4° north of Antares (See the chart on page 99). The position of Uranus is marked for the first day of each month, where 1 = January, 2 = February, etc. The faintest stars shown are of magnitude 9. The magnitude of Uranus is about 6. The coordinates are for 1950.

The 1977 discovery of at least five rings encircling Uranus is regarded as one of the major planetary finds in recent years. Their detection emerged during a relatively routine occultation observation from an airborne observatory—an experiment initially intended to provide a more accurate measure of the diameter of Uranus. Refinement of the observations and results from another occultation in 1978 indicates there is evidence for eight (possibly nine) rings relatively evenly spaced from 16 000 to 24 000 km above the cloudy surface of Uranus. The outer ring is about 100 km wide but curiously eccentric. The others are estimated to be between 5 and 10 km across.

These dimensions are markedly different from Saturn's three major rings, each of which is thousands of kilometres wide. The rings are not as dense as Saturn's major ring since the occulted star did not completely disappear during passage behind them. Also, the albedo of the individual particles is believed to be low suggesting a dark substance compared to Saturn's brilliantly reflective ring material. The Uranian rings are invisible by direct visual observation from Earth because of their small dimensions and the enormous distance that separates us from Uranus.

Estimates of Uranus' diameter made over the last half century range from 46 000 to 56 000 km depending on the technique employed. Some recent work supports the high end of this range. If this proves to be correct then Uranus, like Saturn, has an average density less than that of water. The long-quoted rotation period of Uranus (about 11 hours) has come into question recently and may be in error by a factor of at least 2, since several recent studies have yielded values in the 12 to 24 hour range. Uranus' nearly pole-on aspect in recent years is the primary impediment to obtaining an accurate value for the planet's spin.

Uranus is in Ophiuchus during 1984, close to Omega Ophiuchi. Opposition is on June 1, when the planet is 2.69 billion km (18.00 A) from Earth. At this time its magnitude is +5.5 and its apparent diameter is 3.9 seconds of arc.

NEPTUNE

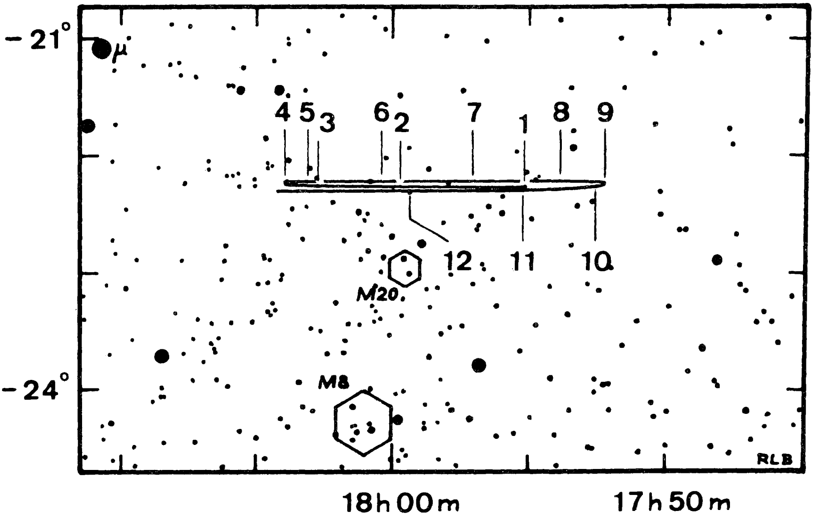
The discovery of Neptune in 1846, after its existence in the sky had been predicted from independent calculations by Leverrier in France and Adams in England, was regarded as the crowning achievement of Newton's theory of universal gravitation. Actually Neptune had been seen—but mistaken for a star—several times before its "discovery".

Telescopically, the planet appears as a 2.3 second of arc, featureless, bluish-green disk. Neptune's large moon Triton can be seen by an experienced observer using a 300 mm telescope. Recent measurements from NASA's Infrared Facility on Mauna Kea (Hawaii) suggest that Triton is smaller than Earth's moon, thus effectively eliminating the possibility that it is the largest satellite in the solar system. Spectral studies in 1982 indicate that the surface of Triton may be rocky, with methane glaciers and a shallow sea of liquid nitrogen. However, these results are tentative. Triton varies from 8 to 17 seconds of arc from Neptune during its 5.9-day orbit. An unconfirmed third moon of Neptune was reported in 1981. This object may prove to be one of a large number of smaller as-yet-undetected bodies in orbit around the planet.

Since the discovery of Uranus' rings in 1977, numerous searches for a Neptunian ring system have failed to reveal one. However, recent analysis of decade-old records of an occultation by Neptune suggests there may indeed be a tenuous ring about 3000 to 7000 km above the planet's equator. Other occultation records are being scanned to confirm the suspected dimming of starlight near Neptune. Neptune's diameter was determined with high precision from occultation observations in 1969.

Uncertainties in the rotation period of Neptune may have narrowed in 1981 with the results from over 300 infrared observations of the planet made with a 1.3-metre telescope at Kitt Peak. Astronomers Michael Belton, Lloyd Wallace and Sethanne Howard conclude that Neptune's rotation period is 18.2 hours, with an uncertainty of plus or minus 24 minutes.

In 1984 Neptune is buried in the Milky Way in western Sagittarius just north of the Trifid Nebula (M20) (see the chart). At opposition on June 21 Neptune is magnitude +7.9 and 4.38 billion km (29.25 A) distant from Earth.



The path of Neptune during 1984. Moving through the central Milky Way, Neptune is almost lost against the star clouds of Sagittarius. Its position is marked for the first day of each month, where 1 = January, 2 = February, etc. The faintest stars shown are of 9th magnitude, somewhat dimmer than 7.9 magnitude Neptune. South of the path is the Trifid Nebula (M20) and the Lagoon Nebula (M8). The coordinates are for 1950.

PLUTO

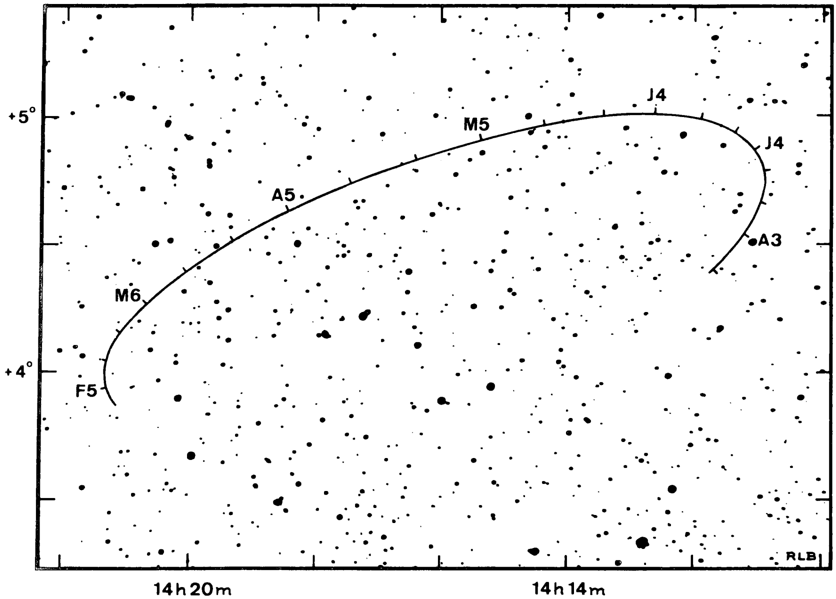
Pluto, the most distant known planet, was discovered at the Lowell Observatory in 1930 as a result of an extensive search started two decades earlier by Percival Lowell. The faint star-like image was first detected by Clyde Tombaugh by comparing photographs taken on different dates.

The most important advance in our knowledge of Pluto since its discovery came in 1978 as a result of routine examinations of photographs of the planet taken at the U.S. Naval Observatory, Flagstaff, Arizona. James W. Christy detected an elongation of Pluto's image on some of the photos which has been confirmed as a large satellite revolving once every 6.3867 days—identical to the planet's rotation period. This means that the moon is visible only from one hemisphere of Pluto. Calculations made some years ago suggest that this is the only stable orbit a satellite could have with Pluto's slow rotation rate. The moon too would likely have one side constantly turned to Pluto. The name Charon has been proposed for the new-found object.

Recent speckle-interferometry observations by D. Bonneau and R. Foy using the Canada-France-Hawaii Telescope reveal Pluto and Charon as a unique double planet, 4000 and 2000 km in diameter respectively, orbiting 22 000 km apart. This amounts to an apparent separation of 1.02 seconds of arc at Pluto's present distance. The derived mass for Pluto is one-quarter the mass of Earth's moon. Charon is about one-tenth as massive. The albedo of both objects is about 20%. These values yield a density of 0.5 that of water, definitely indicating Pluto and Charon are fluffy balls of ice, most likely water, methane, and ammonia. This conclusion is supported by recent observations of a tenuous methane atmosphere on Pluto. However, since Pluto's surface gravity is too feeble to retain a primordial methane atmosphere it is probable that as the planet nears perihelion, the Sun is evaporating its frosty surface.

Besides being the solar system's smallest planet, Pluto is different from the other eight in almost every respect. Its unique characteristics include its orbit which is relatively higher inclined and so elliptical that the planet will be closer to the Sun than Neptune from 1980 to 1999. Just where such a freak fits into the solar system's origin and evolution is unknown. Perhaps Pluto is the largest member of a group of small, icy, comet-like structures beyond Neptune.

At opposition on April 20, Pluto's astrometric position is R.A. (2000) 14^h $19^m\!.28^s$, Dec. (2000) $+4° 33' 44''$ and its distance from Earth will be 4.32 billion km (28.87 A). With an apparent magnitude of +13.7, Pluto is a difficult target in moderate-sized amateur telescopes.

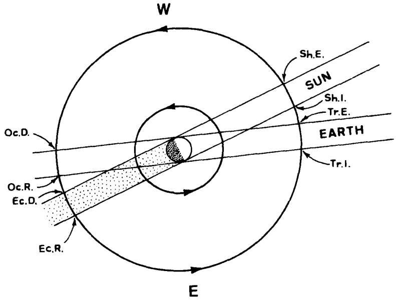


The path of Pluto in eastern Virgo, 1984. Its position is marked at 10-day intervals, beginning at February 5 (F5). The brightest stars in the field shown here are about magnitude 7, and the faintest are magnitude 14. The centre of Pluto's retrograde loop lies 5° northeast (position angle ~60°) of the star τ Virginis (see the chart on page 99). Pluto reaches opposition on April 20 at magnitude 13.7. The chart is based on Vehrenberg's Atlas Stellarum 1950.0, *and the coordinates are for that epoch.*

JUPITER

PHENOMENA OF THE GALILEAN SATELLITES

The following tables give the various transits, occultations, and eclipses of the four great satellites of Jupiter. All such phenomena are given except when Jupiter is within a few weeks of conjunction (Dec. 14, 1983 and Jan. 16, 1985). Since the phenomena are not instantaneous but require up to several minutes, the predicted times are for the middle of each event. The abbreviations are: I = Io, II = Europa, III = Ganymede, IV = Callisto; Ec = eclipse, Oc = occultation, Tr = transit of the satellite, Sh = transit of the shadow, I = ingress, E = egress, D = disappearance, R = reappearance.



The general motions of the satellites, and the successive phenomena are shown in the diagram at right. Satellites move from east to west across the face of the planet, and from west to east behind it. Before opposition, shadows fall to the west, and after opposition, to the east (as in the diagram). The sequence of phenomena in the diagram, beginning at the lower right, is: transit ingress (Tr.I.), transit egress (Tr.E.), shadow ingress (Sh.I.), shadow egress (Sh.E.), occultation disappearance (Oc.D.), occultation reappearance (Oc.R.), eclipse disappearance (Ec.D.) and eclipse reappearance (Ec.R.), but this sequence will depend on the actual Sun-Jupiter-Earth angle.

Over half the phenomena listed will not be visible from any one locality because they occur when Jupiter is below the horizon or when daylight interferes. To determine which phenomena are visible from a given locality (latitude ϕ) on a certain date, note the local time that Jupiter transits and its declination δ (see The Sky Month By Month section). Jupiter will be above the horizon for a time of $(1/15)\cos^{-1}(-\tan\phi\tan\delta)$ hours on either side of the time of transit. A second time interval corresponding to nighttime can be determined from the Twilight table. The region of overlap of these two time intervals will correspond to Jupiter being both above the horizon and in a dark sky. Those phenomena in the table which fall within this time "window" will be visible.

In practice, the observer usually knows when Jupiter will be conveniently placed in the night sky, and the table can simply be scanned to select those events which occur near these times. For example, an active observer in Victoria, British Columbia, on July 5 would know that Jupiter is well placed in the late evening sky. If he planned to observe from 10 pm to 2 am PDT (7 h behind UT), he could scan the table for events in the interval July 6, 5 h to 9 h UT. He would find two events, at 2313 and 2323 PDT, both involving the satellite Io.

SATELLITES OF JUPITER, 1984

UNIVERSAL TIME OF GEOCENTRIC PHENOMENA

MARCH

d	h	m	
1	3	29	II. Ec.D.
	8	20	II. Oc.R.
	15	20	I. Ec.D.
	18	42	I. Oc.R.
	23	33	III. Sh.I.
2	2	23	III. Sh.E.
	4	08	III. Tr.I.
	7	04	III. Tr.E.
	12	28	I. Sh.I.
	13	36	I. Tr.I.
	14	41	I. Sh.E.
	15	49	I. Tr.E.
	22	40	II. Sh.I.
3	0	57	II. Tr.I.
	1	11	II. Sh.E.
	3	30	II. Tr.E.
	9	48	I. Ec.D.
	13	12	I. Oc.R.
4	6	57	I. Sh.I.
	8	05	I. Tr.I.
	9	09	I. Sh.E.
	10	18	I. Tr.E.
	16	47	II. Ec.D.
	21	41	II. Oc.R.
5	4	17	I. Ec.D.
	7	41	I. Oc.R.
	13	30	III. Ec.D.
	16	22	III. Ec.R.
	18	12	III. Oc.D.
	21	11	III. Oc.R.
6	1	25	I. Sh.I.
	2	35	I. Tr.I.
	3	38	I. Sh.E.
	4	48	I. Tr.E.
	11	58	II. Sh.I.
	14	18	II. Tr.I.
	14	28	II. Sh.E.
	16	51	II. Tr.E.
	22	45	I. Ec.D.
7	2	10	I. Oc.R.
	19	54	I. Sh.I.
	21	04	I. Tr.I.
	22	06	I. Sh.E.
	23	17	I. Tr.E.
8	6	04	II. Ec.D.
	11	02	II. Oc.R.
	17	13	I. Ec.D.
	20	39	I. Oc.R.
9	3	31	III. Sh.I.
	6	22	III. Sh.E.
	8	20	III. Tr.I.
9	11	17	III. Tr.E.
	14	22	I. Sh.I.
	15	33	I. Tr.I.
	16	34	I. Sh.E.
	17	46	I. Tr.E.
10	1	15	II. Sh.I.
	3	38	II. Tr.I.
	3	46	II. Sh.E.
	6	11	II. Tr.E.
	11	42	I. Ec.D.
	15	08	I. Oc.R.
11	8	50	I. Sh.I.
	10	02	I. Tr.I.
	11	03	I. Sh.E.
	12	15	I. Tr.E.
	19	21	II. Ec.D.
12	0	23	II. Oc.R.
	0	58	IV. Tr.I.
	1	17	IV. Tr.E.
	6	10	I. Ec.D.
	9	37	I. Oc.R.
	17	28	III. Ec.D.
	20	21	III. Ec.R.
	22	22	III. Oc.D.
13	1	22	III. Oc.R.
	3	19	I. Sh.I.
	4	31	I. Tr.I.
	5	31	I. Sh.E.
	6	44	I. Tr.E.
	14	32	II. Sh.I.
	16	58	II. Tr.I.
	17	03	II. Sh.E.
	19	31	II. Tr.E.
14	0	38	I. Ec.D.
	4	06	I. Oc.R.
	21	47	I. Sh.I.
	23	00	I. Tr.I.
	23	59	I. Sh.E.
15	1	13	I. Tr.E.
	8	38	II. Ec.D.
	13	43	II. Oc.R.
	19	07	I. Ec.D.
	22	35	I. Oc.R.
16	7	29	III. Sh.I.
	10	21	III. Sh.E.
	12	28	III. Tr.I.
	15	27	III. Tr.E.
	16	15	I. Sh.I.
	17	29	I. Tr.I.
	18	28	I. Sh.E.
	19	42	I. Tr.E.
17	3	50	II. Sh.I.
	6	17	II. Tr.I.
	6	20	II. Sh.E.
	8	51	II. Tr.E.
	13	35	I. Ec.D.
	17	04	I. Oc.R.
18	10	44	I. Sh.I.
	11	58	I. Tr.I.
	12	56	I. Sh.E.
	14	11	I. Tr.E.
	21	56	II. Ec.D.
19	3	03	II. Oc.R.
	8	03	I. Ec.D.
	11	33	I. Oc.R.
	21	25	III. Ec.D.
20	0	19	III. Ec.R.
	2	29	III. Oc.D.
	5	12	I. Sh.I.
	5	30	III. Oc.R.
	6	27	I. Tr.I.
	7	25	I. Sh.E.
	8	40	I. Tr.E.
	11	41	IV. Oc.D.
	12	49	IV. Oc.R.
	17	07	II. Sh.I.
	19	36	II. Tr.I.
	19	38	II. Sh.E.
	22	10	II. Tr.E.
21	2	32	I. Ec.D.
	6	02	I. Oc.R.
	23	40	I. Sh.I.
22	0	55	I. Tr.I.
	1	53	I. Sh.E.
	3	09	I. Tr.E.
	11	13	II. Ec.D.
	16	22	II. Oc.R.
	21	00	I. Ec.D.
23	0	30	I. Oc.R.
	11	28	III. Sh.I.
	14	20	III. Sh.E.
	16	34	III. Tr.I.
	18	09	I. Sh.I.
	19	24	I. Tr.I.
	19	33	III. Tr.E.
	20	21	I. Sh.E.
	21	37	I. Tr.E.
24	6	24	II. Sh.I.
	8	55	II. Tr.I.
	8	55	II. Sh.E.
	11	28	II. Tr.E.
	15	28	I. Ec.D.
	18	59	I. Oc.R.
25	12	37	I. Sh.I.
	13	53	I. Tr.I.
	14	50	I. Sh.E.
	16	06	I. Tr.E.
26	0	31	II. Ec.D.
	3	04	II. Ec.R.
	3	05	II. Oc.D.
	5	41	II. Oc.R.
	9	57	I. Ec.D.
	13	28	I. Oc.R.
27	1	22	III. Ec.D.
	4	17	III. Ec.R.
	6	32	III. Oc.D.
	7	05	I. Sh.I.
	8	21	I. Tr.I.
	9	18	I. Sh.E.
	9	33	III. Oc.R.
	10	35	I. Tr.E.
	19	41	II. Sh.I.
	22	12	II. Sh.E.
	22	13	II. Tr.I.
28	0	46	II. Tr.E.
	4	25	I. Ec.D.
	7	56	I. Oc.R.
	19	13	IV. Tr.I.
	20	22	IV. Tr.E.
29	1	34	I. Sh.I.
	2	50	I. Tr.I.
	3	46	I. Sh.E.
	5	03	I. Tr.E.
	13	48	II. Ec.D.
	16	21	II. Ec.R.
	16	23	II. Oc.D.
	19	00	II. Oc.R.
	22	53	I. Ec.D.
30	2	24	I. Oc.R.
	15	26	III. Sh.I.
	18	19	III. Sh.E.
	20	02	I. Sh.I.
	20	36	III. Tr.I.
	21	18	I. Tr.I.
	22	15	I. Sh.E.
	23	32	I. Tr.E.
	23	35	III. Tr.E.
31	8	58	II. Sh.I.
	11	29	II. Sh.E.
	11	30	II. Tr.I.
	14	04	II. Tr.E.
	17	21	I. Ec.D.
	20	53	I. Oc.R.

UNIVERSAL TIME OF GEOCENTRIC PHENOMENA

APRIL

d	h	m	Phenomenon
1	14	30	I. Sh.I.
	15	47	I. Tr.I.
	16	43	I. Sh.E.
	18	00	I. Tr.E.
2	3	05	II. Ec.D.
	5	39	II. Ec.R.
	5	41	II. Oc.D.
	8	18	II. Oc.R.
	11	50	I. Ec.D.
	15	21	I. Oc.R.
3	5	20	III. Ec.D.
	8	16	III. Ec.R.
	8	59	I. Sh.I.
	10	15	I. Tr.I.
	10	31	III. Oc.D.
	11	12	I. Sh.E.
	12	29	I. Tr.E.
	13	34	III. Oc.R.
	22	15	II. Sh.I.
4	0	46	II. Sh.E.
	0	47	II. Tr.I.
	3	21	II. Tr.E.
	6	18	I. Ec.D.
	9	49	I. Oc.R.
5	3	27	I. Sh.I.
	4	43	I. Tr.I.
	5	40	I. Sh.E.
	6	57	I. Tr.E.
	16	23	II. Ec.D.
	18	57	II. Ec.R.
	18	58	II. Oc.D.
	21	35	II. Oc.R.
6	0	46	I. Ec.D.
	4	18	I. Oc.R.
	5	43	IV. Oc.D.
	7	16	IV. Oc.R.
	19	24	III. Sh.I.
	21	56	I. Sh.I.
	22	18	III. Sh.E.
	23	12	I. Tr.I.
7	0	08	I. Sh.E.
	0	33	III. Tr.I.
	1	25	I. Tr.E.
	3	33	III. Tr.E.
	11	32	II. Sh.I.
	14	04	II. Sh.E.
	14	04	II. Tr.I.
	16	38	II. Tr.E.
	19	15	I. Ec.D.
	22	46	I. Oc.R.
8	16	24	I. Sh.I.
	17	40	I. Tr.I.
	18	37	I. Sh.E.
	19	53	I. Tr.E.
9	5	41	II. Ec.D.
	8	15	II. Ec.R.
	8	16	II. Oc.D.
	10	53	II. Oc.R.
	13	43	I. Ec.D.
	17	14	I. Oc.R.
10	9	18	III. Ec.D.
	10	52	I. Sh.I.
	12	08	I. Tr.I.
	12	15	III. Ec.R.
	13	05	I. Sh.E.
	14	22	I. Tr.E.
	14	26	III. Oc.D.
	17	30	III. Oc.R.
11	0	49	II. Sh.I.
	3	19	II. Tr.I.
	3	21	II. Sh.E.
	5	54	II. Tr.E.
	8	11	I. Ec.D.
	11	42	I. Oc.R.
12	5	21	I. Sh.I.
	6	36	I. Tr.I.
	7	33	I. Sh.E.
	8	50	I. Tr.E.
	18	58	II. Ec.D.
13	0	09	II. Oc.R.
	2	40	I. Ec.D.
	6	10	I. Oc.R.
	23	21	III. Sh.I.
	23	49	I. Sh.I.
14	1	04	I. Tr.I.
	2	02	I. Sh.E.
	2	16	III. Sh.E.
	3	18	I. Tr.E.
	4	26	III. Tr.I.
	7	27	III. Tr.E.
	12	52	IV. Tr.I.
	14	06	II. Sh.I.
	14	23	IV. Tr.E.
	16	35	II. Tr.I.
	16	38	II. Sh.E.
	19	09	II. Tr.E.
	21	08	I. Ec.D.
15	0	38	I. Oc.R.
	18	17	I. Sh.I.
	19	32	I. Tr.I.
	20	30	I. Sh.E.
	21	46	I. Tr.E.
16	8	16	II. Ec.D.
	13	26	II. Oc.R.
	15	36	I. Ec.D.
	19	06	I. Oc.R.
17	12	46	I. Sh.I.
	13	16	III. Ec.D.
	14	00	I. Tr.I.
	14	59	I. Sh.E.
	16	14	I. Tr.E.
	16	14	III. Ec.R.
	18	18	III. Oc.D.
	21	22	III. Oc.R.
18	3	23	II. Sh.I.
	5	50	II. Tr.I.
	5	55	II. Sh.E.
	8	24	II. Tr.E.
	10	04	I. Ec.D.
	13	33	I. Oc.R.
19	7	14	I. Sh.I.
	8	28	I. Tr.I.
	9	27	I. Sh.E.
	10	41	I. Tr.E.
	21	33	II. Ec.D.
20	2	41	II. Oc.R.
	4	33	I. Ec.D.
	8	01	I. Oc.R.
21	1	42	I. Sh.I.
	2	55	I. Tr.I.
	3	19	III. Sh.I.
	3	56	I. Sh.E.
	5	09	I. Tr.E.
	6	15	III. Sh.E.
	8	15	III. Tr.I.
	11	17	III. Tr.E.
	16	40	II. Sh.I.
	19	04	II. Tr.I.
	19	12	II. Sh.E.
	21	38	II. Tr.E.
	23	01	I. Ec.D.
22	2	29	I. Oc.R.
	20	11	I. Sh.I.
	21	23	I. Tr.I.
	22	24	I. Sh.E.
	22	58	IV. Oc.D.
	23	37	I. Tr.E.
23	0	45	IV. Oc.R.
	10	51	II. Ec.D.
	15	56	II. Oc.R.
	17	29	I. Ec.D.
	20	56	I. Oc.R.
24	14	39	I. Sh.I.
	15	51	I. Tr.I.
	16	52	I. Sh.E.
	17	14	III. Ec.D.
	18	05	I. Tr.E.
	20	13	III. Ec.R.
	22	05	III. Oc.D.
25	1	09	III. Oc.R.
	5	56	II. Sh.I.
	8	17	II. Tr.I.
	8	29	II. Sh.E.
	10	52	II. Tr.E.
	11	58	I. Ec.D.
	15	24	I. Oc.R
26	9	08	I. Sh.I.
	10	18	I. Tr.I.
	11	21	I. Sh.E.
	12	32	I. Tr.E.
27	0	09	II. Ec.D.
	5	11	II. Oc.R.
	6	26	I. Ec.D.
	9	51	I. Oc.R.
28	3	36	I. Sh.I.
	4	46	I. Tr.I.
	5	49	I. Sh.E.
	7	00	I. Tr.E.
	7	17	III. Sh.I.
	10	14	III. Sh.E.
	12	00	III. Tr.I.
	15	02	III. Tr.E.
	19	13	II. Sh.I.
	21	31	II. Tr.I.
	21	46	II. Sh.E.
29	0	05	II. Tr.E.
	0	54	I. Ec.D.
	4	18	I. Oc.R.
	22	04	I. Sh.I.
	23	13	I. Tr.I.
30	0	18	I. Sh.E.
	1	27	I. Tr.E.
	13	27	II. Ec.D.
	18	25	II. Oc.R.
	19	23	I. Ec.D.
	22	46	I. Oc.R.

SATELLITES OF JUPITER, 1984

UNIVERSAL TIME OF GEOCENTRIC PHENOMENA

MAY

d	h	m	Phenomenon
1	5	40	IV. Tr.I.
	7	24	IV. Tr.E.
	16	33	I. Sh.I.
	17	41	I. Tr.I.
	18	46	I. Sh.E.
	19	55	I. Tr.E.
	21	12	III. Ec.D.
2	0	11	III. Ec.R.
	1	47	III. Oc.D.
	4	51	III. Oc.R.
	8	30	II. Sh.I.
	10	43	II. Tr.I.
	11	03	II. Sh.E.
	13	18	II. Tr.E.
	13	51	I. Ec.D.
	17	13	I. Oc.R.
3	11	01	I. Sh.I.
	12	08	I. Tr.I.
	13	15	I. Sh.E.
	14	22	I. Tr.E.
4	2	44	II. Ec.D.
	7	38	II. Oc.R.
	8	19	I. Ec.D.
	11	40	I. Oc.R.
5	5	29	I. Sh.I.
	6	35	I. Tr.I.
	7	43	I. Sh.E.
	8	49	I. Tr.E.
	11	15	III. Sh.I.
	14	13	III. Sh.E.
	15	40	III. Tr.I.
	18	43	III. Tr.E.
	21	47	II. Sh.I.
	23	55	II. Tr.I.
6	0	19	II. Sh.E.
	2	30	II. Tr.E.
	2	48	I. Ec.D.
	6	07	I. Oc.R.
	23	58	I. Sh.I.
7	1	02	I. Tr.I.
	2	11	I. Sh.E.
	3	16	I. Tr.E.
	16	02	II. Ec.D.
	20	51	II. Oc.R.
	21	16	I. Ec.D.
8	0	34	I. Oc.R.
	18	26	I. Sh.I.
	19	29	I. Tr.I.
	20	40	I. Sh.E.
	21	44	I. Tr.E.
9	1	10	III. Ec.D.
9	4	10	III. Ec.R.
	5	24	III. Oc.D.
	5	59	IV. Ec.D.
	6	44	IV. Ec.R.
	8	29	III. Oc.R.
	11	03	II. Sh.I.
	13	07	II. Tr.I.
	13	36	II. Sh.E.
	15	19	IV. Oc.D.
	15	41	II. Tr.E.
	15	44	I. Ec.D.
	17	14	IV. Oc.R.
	19	01	I. Oc.R.
10	12	55	I. Sh.I.
	13	56	I. Tr.I.
	15	08	I. Sh.E.
	16	11	I. Tr.E.
11	5	20	II. Ec.D.
	10	03	II. Oc.R.
	10	12	I. Ec.D.
	13	28	I. Oc.R.
12	7	23	I. Sh.I.
	8	23	I. Tr.I.
	9	37	I. Sh.E.
	10	38	I. Tr.E.
	15	14	III. Sh.I.
	18	13	III. Sh.E.
	19	16	III. Tr.I.
	22	19	III. Tr.E.
13	0	20	II. Sh.I.
	2	18	II. Tr.I.
	2	53	II. Sh.E.
	4	41	I. Ec.D.
	4	52	II. Tr.E.
	7	55	I. Oc.R.
14	1	51	I. Sh.I.
	2	50	I. Tr.I.
	4	05	I. Sh.E.
	5	05	I. Tr.E.
	18	38	II. Ec.D.
	23	09	I. Ec.D.
	23	15	II. Oc.R.
15	2	21	I. Oc.R.
	20	20	I. Sh.I.
	21	17	I. Tr.I.
	22	34	I. Sh.E.
	23	32	I. Tr.E.
16	5	07	III. Ec.D.
	8	08	III. Ec.R.
	8	57	III. Oc.D.
	12	02	III. Oc.R.
	13	37	II. Sh.I.
16	15	28	II. Tr.I.
	16	10	II. Sh.E.
	17	37	I. Ec.D.
	18	03	II. Tr.E.
	20	48	I. Oc.R.
17	13	10	IV. Sh.I.
	14	02	IV. Sh.E.
	14	48	I. Sh.I.
	15	44	I. Tr.I.
	17	02	I. Sh.E.
	17	58	I. Tr.E.
	21	33	IV. Tr.I.
	23	23	IV. Tr.E.
18	7	56	II. Ec.D.
	12	06	I. Ec.D.
	12	26	II. Oc.R.
	15	15	I. Oc.R.
19	9	17	I. Sh.I.
	10	11	I. Tr.I.
	11	31	I. Sh.E.
	12	25	I. Tr.E.
	19	12	III. Sh.I.
	22	12	III. Sh.E.
	22	48	III. Tr.I.
20	1	51	III. Tr.E.
	2	53	II. Sh.I.
	4	38	II. Tr.I.
	5	27	II. Sh.E.
	6	34	I. Ec.D.
	7	13	II. Tr.E.
	9	41	I. Oc.R.
21	3	45	I. Sh.I.
	4	37	I. Tr.I.
	5	59	I. Sh.E.
	6	52	I. Tr.E.
	21	15	II. Ec.D.
22	1	02	I. Ec.D.
	1	38	II. Oc.R.
	4	08	I. Oc.R.
	22	14	I. Sh.I.
	23	04	I. Tr.I.
23	0	28	I. Sh.E.
	1	19	I. Tr.E.
	9	05	III. Ec.D.
	12	07	III. Ec.R.
	12	26	III. Oc.D.
	15	31	III. Oc.R.
	16	10	II. Sh.I.
	17	47	II. Tr.I.
	18	44	II. Sh.E.
	19	31	I. Ec.D.
	20	22	II. Tr.E.
23	22	34	I. Oc.R.
24	16	42	I. Sh.I.
	17	31	I. Tr.I.
	18	56	I. Sh.E.
	19	45	I. Tr.E.
25	10	32	II. Ec.D.
	13	59	I. Ec.D.
	14	48	II. Oc.R.
	17	01	I. Oc.R.
	23	43	IV. Ec.D.
26	1	03	IV. Ec.R.
	6	46	IV. Oc.D.
	8	45	IV. Oc.R.
	11	11	I. Sh.I.
	11	57	I. Tr.I.
	13	25	I. Sh.E.
	14	12	I. Tr.E.
	23	10	III. Sh.I.
27	2	11	III. Sh.E.
	2	15	III. Tr.I.
	5	19	III. Tr. E.
	5	27	II. Sh.I.
	6	56	II. Tr.I.
	8	01	II. Sh.E.
	8	28	I. Ec.D.
	9	31	II. Tr.E.
	11	27	I. Oc.R.
28	5	39	I. Sh.I.
	6	23	I. Tr.I.
	7	53	I. Sh.E.
	8	38	I. Tr.E.
	23	51	II. Ec.D.
29	2	56	I. Ec.D.
	3	58	II. Oc.R.
	5	53	I. Oc.R.
30	0	08	I. Sh.I.
	0	50	I. Tr.I.
	2	22	I. Sh.E.
	3	05	I. Tr.E.
	13	04	III. Ec.D.
	18	44	II. Sh.I.
	18	57	III. Oc.R.
	20	05	II. Tr.I.
	21	18	II. Sh.E.
	21	24	I. Ec.D.
	22	40	II. Tr.E.
31	0	20	I. Oc.R.
	18	36	I. Sh.I.
	19	16	I. Tr.I.
	20	51	I. Sh.E.
	21	31	I. Tr.E.

SATELLITES OF JUPITER, 1984

UNIVERSAL TIME OF GEOCENTRIC PHENOMENA

JUNE

d	h	m	
1	13	09	II. Ec.D.
	15	53	I. Ec.D.
	17	07	II. Oc.R.
	18	46	I. Oc.R.
2	13	05	I. Sh.I.
	13	43	I. Tr.I.
	15	19	I. Sh.E.
	15	57	I. Tr.E.
3	3	08	III. Sh.I.
	5	38	III. Tr.I.
	6	11	III. Sh.E.
	6	58	IV. Sh.I.
	8	00	II. Sh.I.
	8	21	IV. Sh.E.
	8	43	III. Tr.E.
	9	13	II. Tr.I.
	10	21	I. Ec.D.
	10	35	II. Sh.E.
	11	48	II. Tr.E.
	12	36	IV. Tr.I.
	13	12	I. Oc.R.
	14	28	IV. Tr.E.
4	7	33	I. Sh.I.
	8	09	I. Tr.I.
	9	48	I. Sh.E.
	10	24	I. Tr.E.
5	2	27	II. Ec.D.
	4	49	I. Ec.D.
	6	17	II. Oc.R.
	7	38	I. Oc.R.
6	2	02	I. Sh.I.
	2	35	I. Tr.I.
	4	16	I. Sh.E.
	4	50	I. Tr.E.
	17	03	III. Ec.D.
	21	17	II. Sh.I.
	22	19	III. Oc.R.
	22	21	II. Tr.I.
	23	18	I. Ec.D.
	23	52	II. Sh.E.
7	0	56	II. Tr.E.
	2	04	I. Oc.R.
	20	30	I. Sh.I.
	21	01	I. Tr.I.
	22	45	I. Sh.E.
	23	16	I. Tr.E.
8	15	45	II. Ec.D.
	17	46	I. Ec.D.
8	19	25	II. Oc.R.
	20	30	I. Oc.R.
9	14	59	I. Sh.I.
	15	28	I. Tr.I.
	17	13	I. Sh.E.
	17	42	I. Tr.E.
10	7	06	III. Sh.I.
	8	59	III. Tr.I.
	10	10	III. Sh.E.
	10	34	II. Sh.I.
	11	28	II. Tr.I.
	12	03	III. Tr.E.
	12	15	I. Ec.D.
	13	09	II. Sh.E.
	14	04	II. Tr.E.
	14	56	I. Oc.R.
11	9	27	I. Sh.I.
	9	54	I. Tr.I.
	11	42	I. Sh.E.
	12	09	I. Tr.E.
	17	34	IV. Ec.D.
	19	17	IV. Ec.R.
	21	29	IV. Oc.D.
	23	28	IV. Oc.R.
12	5	04	II. Ec.D.
	6	43	I. Ec.D.
	8	34	II. Oc.R.
	9	22	I. Oc.R.
13	3	56	I. Sh.I.
	4	20	I Tr.I.
	6	11	I. Sh.E.
	6	35	I. Tr.E.
	21	01	III. Ec.D.
	23	50	II. Sh.I.
14	0	35	II. Tr.I.
	1	11	I. Ec.D.
	1	39	III. Oc.R.
	2	26	II. Sh.E.
	3	11	II. Tr.E.
	3	48	I. Oc.R.
	22	24	I. Sh.I.
	22	46	I. Tr.I.
15	0	39	I. Sh.E.
	1	01	I. Tr.E.
	18	22	II. Ec.D.
	19	40	I. Ec.D.
	21	42	II. Oc.R.
	22	14	I. Oc.R.
16	16	53	I. Sh.I.
	17	12	I. Tr.I.
	19	08	I. Sh.E.
	19	27	I. Tr.E.
17	11	05	III. Sh.I.
	12	18	III. Tr.I.
	13	07	II. Sh.I.
	13	42	II. Tr.I.
	14	08	I. Ec.D.
	14	10	III. Sh.E.
	15	22	III. Tr.E.
	15	43	II. Sh.E.
	16	18	II. Tr.E.
	16	40	I. Oc.R.
18	11	21	I. Sh.I.
	11	38	I. Tr.I.
	13	36	I. Sh.E.
	13	53	I. Tr.E.
19	7	41	II. Ec.D.
	8	37	I. Ec.D.
	10	50	II. Oc.R.
	11	06	I. Oc.R.
20	0	50	IV. Sh.I.
	2	36	IV. Sh.E.
	3	01	IV. Tr.I.
	4	53	IV. Tr.E.
	5	50	I. Sh.I.
	6	04	I. Tr.I.
	8	05	I. Sh.E.
	8	19	I. Tr.E.
21	0	59	III. Ec.D.
	2	24	II. Sh.I.
	2	49	II. Tr.I.
	3	05	I. Ec.D.
	4	56	III. Oc.R.
	5	00	II. Sh.E.
	5	25	II. Tr.E.
	5	32	I. Oc.R.
22	0	19	I. Sh.I.
	0	30	I. Tr.I.
	2	34	I. Sh.E.
	2	45	I. Tr.E.
	20	59	II. Ec.D.
	21	34	I. Ec.D.
	23	57	II. Oc.R.
	23	58	I. Oc.R.
23	18	47	I. Sh.I.
	18	56	I. Tr.I.
23	21	02	I. Sh.E.
	21	11	I. Tr.E.
24	15	04	III. Sh.I.
	15	35	III. Tr.I.
	15	41	II. Sh.I.
	15	56	II. Tr.I.
	16	02	I. Ec.D.
	18	10	III. Sh.E.
	18	17	II. Sh.E.
	18	24	I. Oc.R.
	18	31	II. Tr.E.
	18	39	III. Tr.E.
25	13	16	I. Sh.I.
	13	22	I. Tr.I.
	15	31	I. Sh.E.
	15	37	I. Tr.E.
26	10	18	II. Ec.D.
	10	31	I. Ec.D.
	12	50	I. Oc.R.
	13	06	II. Oc.R.
27	7	45	I. Sh.I.
	7	48	I. Tr.I.
	10	00	I. Sh.E.
	10	03	I. Tr.E.
28	4	58	III. Ec.D.
	4	58	II. Sh.I.
	4	59	I. Ec.D.
	5	02	II. Tr.I.
	7	16	I. Oc.R.
	7	34	II. Sh.E.
	7	38	II. Tr.E.
	8	12	III. Oc.R.
	11	28	IV. Ec.D.
	13	45	IV. Oc.R.
29	2	13	I. Sh.I.
	2	14	I. Tr.I.
	4	28	I. Sh.E.
	4	29	I. Tr.E.
	23	27	I. Oc.D
	23	35	II. Oc.D
30	1	42	I. Ec.R.
	2	14	II. Ec.R.
	20	40	I. Tr.I.
	20	42	I. Sh.I.
	22	55	I. Tr.E.
	22	57	I. Sh.E.

SATELLITES OF JUPITER, 1984

UNIVERSAL TIME OF GEOCENTRIC PHENOMENA

JULY

d	h	m	Phenomenon
1	17	53	I. Oc.D.
	18	09	II. Tr.I.
	18	15	II. Sh.I.
	18	52	III. Tr.I.
	19	04	III. Sh.I.
	20	11	I. Ec.R.
	20	45	II. Tr.E.
	20	51	II. Sh.E.
	21	57	III. Tr.E.
	22	10	III. Sh.E.
2	15	06	I. Tr.I.
	15	10	I. Sh.I.
	17	21	I. Tr.E.
	17	26	I. Sh.E.
3	12	19	I. Oc.D.
	12	43	II. Oc.D.
	14	39	I. Ec.R.
	15	33	II. Ec.R.
4	9	32	I. Tr.I.
	9	39	I. Sh.I.
	11	47	I. Tr.E.
	11	55	I. Sh.E.
5	6	45	I. Oc.D.
	7	16	II. Tr.I.
	7	32	II. Sh.I.
	8	23	III. Oc.D.
	9	08	I. Ec.R.
	9	51	II. Tr.E.
	10	08	II. Sh.E.
	12	03	III. Ec.R.
6	3	58	I. Tr.I.
	4	08	I. Sh.I.
	6	13	I. Tr.E.
	6	23	I. Sh.E.
	17	11	IV. Tr.I.
	18	45	IV. Sh.I.
	19	03	IV. Tr.E.
	20	50	IV. Sh.E.
7	1	11	I. Oc.D.
	1	51	II. Oc.D.
	3	36	I. Ec.R.
	4	52	II. Ec.R.
	22	24	I. Tr.I.
	22	37	I. Sh.I.
8	0	39	I. Tr.E.
	0	52	I. Sh.E.
	19	37	I. Oc.D.
	20	23	II. Tr.I.
	20	49	II. Sh.I.
	22	05	I. Ec.R.
	22	09	III. Tr.I.
8	22	58	II. Tr.E.
	23	04	III. Sh.I.
	23	26	II. Sh.E.
9	1	14	III. Tr.E.
	2	11	III. Sh.E.
	16	50	I. Tr.I.
	17	05	I. Sh.I.
	19	05	I. Tr.E.
	19	21	I. Sh.E.
10	14	03	I. Oc.D.
	14	59	II. Oc.D.
	16	33	I. Ec.R.
	18	11	II. Ec.R.
11	11	17	I. Tr.I.
	11	34	I. Sh.I.
	13	32	I. Tr.E.
	13	49	I. Sh.E.
12	8	29	I. Oc.D.
	9	30	II. Tr.I.
	10	06	II. Sh.I.
	11	02	I. Ec.R.
	11	40	III. Oc.D.
	12	05	II. Tr.E.
	12	43	II. Sh.E.
	16	03	III. Ec.R.
13	5	43	I. Tr.I.
	6	03	I. Sh.I.
	7	58	I. Tr.E.
	8	18	I. Sh.E.
14	2	55	I. Oc.D.
	4	07	II. Oc.D.
	5	30	I. Ec.R.
	7	29	II. Ec.R.
15	0	09	I. Tr.I.
	0	31	I. Sh.I.
	2	00	IV. Oc.D.
	2	24	I. Tr.E.
	2	47	I. Sh.E.
	4	00	IV. Oc.R.
	5	24	IV. Ec.D.
	7	42	IV. Ec.R.
	21	21	I. Oc.D.
	22	37	II. Tr.I.
	23	23	II. Sh.I.
	23	59	I. Ec.R.
16	1	12	II. Tr.E.
	1	27	III. Tr.I.
	2	00	II. Sh.E.
	3	03	III. Sh.I.
	4	32	III. Tr.E.
16	6	11	III. Sh.E.
	18	35	I. Tr.I.
	19	00	I. Sh.I.
	20	50	I. Tr.E.
	21	15	I. Sh.E.
17	15	47	I. Oc.D.
	17	16	II. Oc.D.
	18	28	I. Ec.R.
	20	49	II. Ec.R.
18	13	01	I. Tr.I.
	13	29	I. Sh.I.
	15	16	I. Tr.E.
	15	44	I. Sh.E.
19	10	13	I. Oc.D.
	11	44	II. Tr.I.
	12	40	II. Sh.I.
	12	56	I. Ec.R.
	14	20	II. Tr.E.
	14	59	III. Oc.D.
	15	17	II. Sh.E.
	20	03	III. Ec.R.
20	7	28	I. Tr.I.
	7	58	I. Sh.I.
	9	43	I. Tr.E.
	10	13	I. Sh.E.
21	4	39	I. Oc.D.
	6	24	II. Oc.D.
	7	25	I. Ec.R.
	10	07	II. Ec.R.
22	1	54	I. Tr.I.
	2	26	I. Sh.I.
	4	09	I. Tr.E.
	4	42	I. Sh.E.
	23	06	I. Oc.D.
23	0	52	II. Tr.I.
	1	53	I. Ec.R.
	1	58	II. Sh.I.
	3	28	II. Tr.E.
	4	35	II. Sh.E.
	4	47	III. Tr.I.
	7	02	III. Sh.I.
	7	33	IV. Tr.I.
	7	52	III. Tr.E.
	9	27	IV. Tr.E.
	10	11	III. Sh.E.
	12	43	IV. Sh.I.
	15	04	IV. Sh.E.
	20	21	I. Tr.I.
	20	55	I. Sh.I.
	22	35	I. Tr.E.
	23	10	I. Sh.E.
24	17	32	I. Oc.D.
	19	34	II. Oc.D.
	20	22	I. Ec.R.
	23	26	II. Ec.R.
25	14	47	I. Tr.I.
	15	24	I. Sh.I.
	17	02	I. Tr.E.
	17	39	I. Sh.E.
26	11	58	I. Oc.D.
	14	01	II. Tr.I.
	14	51	I. Ec.R.
	15	15	II. Sh.I.
	16	36	II. Tr.E.
	17	52	II. Sh.E.
	18	21	III. Oc.D.
27	0	04	III. Ec.R.
	9	14	I. Tr.I.
	9	53	I. Sh.I.
	11	28	I. Tr.E.
	12	08	I. Sh.E.
28	6	25	I. Oc.D.
	8	43	II. Oc.D.
	9	19	I. Ec.R.
	12	45	II. Ec.R.
29	3	40	I. Tr.I.
	4	21	I. Sh.I.
	5	55	I. Tr.E.
	6	37	I. Sh.E.
30	0	51	I. Oc.D.
	3	09	II. Tr.I.
	3	48	I. Ec.R.
	4	32	II. Sh.I.
	5	45	II. Tr.E.
	7	09	II. Sh.E.
	8	10	III. Tr.I.
	11	02	III. Sh.I.
	11	15	III. Tr.E.
	14	11	III. Sh.E.
	22	07	I. Tr.I.
	22	50	I. Sh.I.
31	0	22	I. Tr.E.
	1	05	I. Sh.E.
	16	38	IV. Oc.D.
	18	40	IV. Oc.R.
	19	18	I. Oc.D.
	21	53	II. Oc.D.
	22	17	I. Ec.R.
	23	21	IV. Ec.D.

SATELLITES OF JUPITER, 1984

UNIVERSAL TIME OF GEOCENTRIC PHENOMENA

AUGUST

d	h	m	Phenomenon
1	1	54	IV. Ec.R.
	2	04	II. Ec.R.
	16	34	I. Tr.I.
	17	19	I. Sh.I.
	18	48	I. Tr.E.
	19	34	I. Sh.E.
2	13	44	I. Oc.D.
	16	18	II. Tr.I.
	16	45	I. Ec.R.
	17	50	II. Sh.I.
	18	54	II. Tr.E.
	20	27	II. Sh.E.
	21	45	III. Oc.D.
3	0	52	III. Oc.R.
	0	54	III. Ec.D.
	4	04	III. Ec.R.
	11	00	I. Tr.I.
	11	48	I. Sh.I.
	13	15	I. Tr.E.
	14	03	I. Sh.E.
4	8	11	I. Oc.D.
	11	03	II. Oc.D.
	11	14	I. Ec.R.
	15	22	II. Ec.R.
5	5	27	I. Tr.I.
	6	17	I. Sh.I.
	7	42	I. Tr.E.
	8	32	I. Sh.E.
6	2	38	I. Oc.D.
	5	28	II. Tr.I.
	5	43	I. Ec.R.
	7	07	II. Sh.I.
	8	03	II. Tr.E.
	9	44	II. Sh.E.
	11	37	III. Tr.I.
	14	42	III. Tr.E.
	15	02	III. Sh.I.
	18	11	III. Sh.E.
	23	54	I. Tr.I.
7	0	45	I. Sh.I.
	2	09	I. Tr.E.
	3	00	I. Sh.E.
	21	04	I. Oc.D.
8	0	11	I. Ec.R.
	0	15	II. Oc.D.
	4	42	II. Ec.R.
	18	21	I. Tr.I.
	19	14	I. Sh.I.
	20	36	I. Tr.E.
	21	29	I. Sh.E.
	22	28	IV. Tr.I.
9	0	27	IV. Tr.E.

d	h	m	Phenomenon
9	6	42	IV. Sh.I.
	9	17	IV. Sh.E.
	15	31	I. Oc.D.
	18	38	II. Tr.I.
	18	40	I. Ec.R.
	20	24	II. Sh.I.
	21	13	II. Tr.E.
	23	02	II. Sh.E.
10	1	14	III. Oc.D.
	4	20	III. Oc.R.
	4	53	III. Ec.D.
	8	05	III. Ec.R.
	12	48	I. Tr.I.
	13	43	I. Sh.I.
	15	03	I. Tr.E.
	15	58	I. Sh.E.
11	9	58	I. Oc.D.
	13	09	I. Ec.R.
	13	26	II. Oc.D.
	18	00	II. Ec.R.
12	7	15	I. Tr.I.
	8	12	I. Sh.I.
	9	30	I. Tr.E.
	10	27	I. Sh.E.
13	4	25	I. Oc.D.
	7	37	I. Ec.R.
	7	49	II. Tr.I.
	9	42	II. Sh.I.
	10	24	II. Tr.E.
	12	19	II. Sh.E.
	15	08	III. Tr.I.
	18	13	III. Tr.E.
	19	02	III. Sh.I.
	22	12	III. Sh.E.
14	1	42	I. Tr.I.
	2	41	I. Sh.I.
	3	57	I. Tr.E.
	4	56	I. Sh.E.
	22	52	I. Oc.D.
15	2	06	I. Ec.R.
	2	38	II. Oc.D.
	7	19	II. Ec.R.
	20	10	I. Tr.I.
	21	10	I. Sh.I.
	22	24	I. Tr.E.
	23	24	I. Sh.E.
16	17	19	I. Oc.D.
	20	35	I. Ec.R.
	21	00	II. Tr.I.
	22	59	II. Sh.I.
	23	35	II. Tr.E.
17	1	37	II. Sh.E.

d	h	m	Phenomenon
17	4	46	III. Oc.D.
	7	53	III. Oc.R.
	7	58	IV. Oc.D.
	8	52	III. Ec.D.
	10	07	IV. Oc.R.
	12	05	III. Ec.R.
	14	37	I. Tr.I.
	15	38	I. Sh.I.
	16	51	I. Tr.E.
	17	20	IV. Ec.D.
	17	53	I. Sh.E.
	20	06	IV. Ec.R.
18	11	46	I. Oc.D.
	15	04	I. Ec.R.
	15	50	II. Oc.D.
	20	38	II. Ec.R.
19	9	04	I. Tr.I.
	10	07	I. Sh.I.
	11	19	I. Tr.E.
	12	22	I. Sh.E.
20	6	14	I. Oc.D.
	9	32	I. Ec.R.
	10	12	II. Tr.I.
	12	17	II. Sh.I.
	12	47	II. Tr.E.
	14	55	II. Sh.E.
	18	44	III. Tr.I.
	21	49	III. Tr.E.
	23	02	III. Sh.I.
21	2	13	III. Sh.E.
	3	32	I. Tr.I.
	4	36	I. Sh,I.
	5	46	I. Tr.E.
	6	51	I. Sh.E.
22	0	41	I. Oc.D.
	4	01	I. Ec.R.
	5	03	II. Oc.D.
	9	57	II. Ec.R.
	21	59	I. Tr.I.
	23	05	I. Sh.I.
23	0	14	I. Tr.E.
	1	20	I. Sh.E.
	19	08	I. Oc.D.
	22	30	I. Ec.R.
	23	24	II. Tr.I.
24	1	34	II. Sh.I.
	1	59	II. Tr.E.
	4	13	II. Sh.E.
	8	22	III. Oc.D.
	11	30	III. Oc.R.
	12	52	III. Ec.D.
	16	05	III. Ec.R.
	16	27	I. Tr.I.

d	h	m	Phenomenon
24	17	34	I. Sh.I.
	18	41	I. Tr.E.
	19	48	I. Sh.E.
25	13	36	I. Oc.D.
	14	14	IV. Tr.I.
	16	21	IV. Tr.E.
	16	59	I. Ec.R.
	18	17	II. Oc.D.
	23	16	II. Ec.R.
26	0	43	IV. Sh.I.
	3	30	IV. Sh.E.
	10	55	I. Tr.I.
	12	03	I. Sh.I.
	13	09	I. Tr.E.
	14	17	I. Sh.E.
27	8	03	I. Oc.D.
	11	27	I. Ec.R.
	12	37	II. Tr.I.
	14	52	II. Sh.I.
	15	12	II. Tr.E.
	17	30	II. Sh.E.
	22	23	III. Tr.I.
28	1	29	III. Tr.E.
	3	02	III. Sh.I.
	5	22	I. Tr.I.
	6	14	III. Sh.E.
	6	31	I. Sh.I.
	7	37	I. Tr.E.
	8	46	I. Sh.E.
29	2	31	I. Oc.D.
	5	56	I. Ec.R.
	7	31	II. Oc.D.
	12	35	II. Ec.R.
	23	50	I. Tr.I.
30	1	00	I. Sh.I.
	2	04	I. Tr.E.
	3	15	I. Sh.E.
	20	59	I. Oc.D.
31	0	25	I. Ec.R.
	1	50	II. Tr.I.
	4	10	II. Sh.I.
	4	26	II. Tr.E.
	6	48	II. Sh.E.
	12	04	III. Oc.D.
	15	13	III. Oc.R.
	16	52	III. Ec.D.
	18	18	I. Tr.I.
	19	29	I. Sh.I.
	20	06	III. Ec.R.
	20	32	I. Tr.E.
	21	44	I. Sh.E.

SATELLITES OF JUPITER, 1984

UNIVERSAL TIME OF GEOCENTRIC PHENOMENA

SEPTEMBER

d	h	m	
1	15	26	I. Oc.D.
	18	54	I. Ec.R.
	20	46	II. Oc.D.
2	1	53	II. Ec.R.
	12	46	I. Tr.I.
	13	58	I. Sh.I.
	15	00	I. Tr.E.
	16	13	I. Sh.E.
3	0	13	IV. Oc.D.
	2	30	IV. Oc.R.
	9	54	I. Oc.D.
	11	21	IV. Ec.D.
	13	22	I. Ec.R.
	14	18	IV. Ec.R.
	15	04	II. Tr.I.
	17	28	II. Sh.I.
	17	40	II. Tr.E.
	20	06	II. Sh.E.
4	2	08	III. Tr.I.
	5	14	III. Tr.E.
	7	02	III. Sh.I.
	7	14	I. Tr.I.
	8	27	I. Sh.I.
	9	28	I. Tr.E.
	10	14	III. Sh.E.
	10	41	I. Sh.E.
5	4	22	I. Oc.D.
	7	51	I. Ec.R.
	10	01	II. Oc.D.
	15	12	II. Ec.R.
6	1	42	I. Tr.I.
	2	56	I. Sh.I.
	3	56	I. Tr.E.
	5	10	I. Sh.E.
	22	50	I. Oc.D.
7	2	20	I. Ec.R.
	4	19	II. Tr.I.
	6	45	II. Sh.I.
	6	55	II. Tr.E.
	9	24	II. Sh.E.
	15	51	III. Oc.D.
	19	00	III. Oc.R.
	20	10	I. Tr.I.
	20	52	III. Ec.D.
	21	24	I. Sh.I.
	22	24	I. Tr.E.
	23	39	I. Sh.E.
8	0	06	III. Ec.R.
	17	18	I. Oc.D.
	20	49	I. Ec.R.
	23	17	II. Oc.D.

d	h	m	
9	4	31	II. Ec.R.
	14	39	I. Tr.I.
	15	53	I. Sh.I.
	16	53	I. Tr.E.
	18	08	I. Sh.E.
10	11	46	I. Oc.D.
	15	17	I. Ec.R.
	17	34	II. Tr.I.
	20	03	II. Sh.I.
	20	10	II. Tr.E.
	22	42	II. Sh.E.
11	5	56	III. Tr.I.
	6	58	IV. Tr.I.
	9	03	III. Tr.E.
	9	07	I. Tr.I.
	9	14	IV. Tr.E.
	10	22	I. Sh.I.
	11	02	III. Sh.I.
	11	21	I. Tr.E.
	12	37	I. Sh.E.
	14	15	III. Sh.E.
	18	45	IV. Sh.I.
	21	43	IV. Sh.E.
12	6	15	I. Oc.D.
	9	46	I. Ec.R.
	12	34	II. Oc.D.
	17	50	II. Ec.R.
13	3	35	I. Tr.I.
	4	51	I. Sh.I.
	5	49	I. Tr.E.
	7	06	I. Sh.E.
14	0	43	I. Oc.D.
	4	15	I. Ec.R.
	6	50	II. Tr.I.
	9	21	II. Sh.I.
	9	26	II. Tr.E.
	12	00	II. Sh.E.
	19	42	III. Oc.D.
	22	04	I. Tr.I.
	22	52	III. Oc.R.
	23	20	I. Sh.I.
15	0	18	I. Tr.E.
	0	52	III. Ec.D.
	1	35	I. Sh.E.
	4	08	III. Ec.R.
	19	11	I. Oc.D.
	22	44	I. Ec.R.
16	1	50	II. Oc.D.
	7	08	II. Ec.R.
	16	32	I. Tr.I.
	17	49	I. Sh.I.

d	h	m	
16	18	46	I. Tr.E.
	20	03	I. Sh.E.
17	13	40	I. Oc.D.
	17	13	I. Ec.R.
	20	06	II. Tr.I.
	22	39	II. Sh.I.
	22	43	II. Tr.E.
18	1	18	II. Sh.E.
	9	50	III. Tr.I.
	11	01	I. Tr.I.
	12	18	I. Sh.I.
	12	57	III. Tr.E.
	13	15	I. Tr.E.
	14	32	I. Sh.E.
	15	02	III. Sh.I.
	18	15	III. Sh.E.
19	8	08	I. Oc.D.
	11	42	I. Ec.R.
	15	08	II. Oc.D.
	17	26	IV. Oc.D.
	19	53	IV. Oc.R.
	20	27	II. Ec.R.
20	5	22	IV. Ec.D.
	5	29	I. Tr.I.
	6	46	I. Sh.I.
	7	43	I. Tr.E.
	8	30	IV. Ec.R.
	9	01	I. Sh.E.
21	2	37	I. Oc.D.
	6	10	I. Ec.R.
	9	23	II. Tr.I.
	11	57	II. Sh.I.
	12	00	II. Tr.E.
	14	36	II. Sh.E.
	23	37	III. Oc.D.
	23	58	I. Tr.I.
22	1	15	I. Sh.I.
	2	12	I. Tr.E.
	2	48	III. Oc.R.
	3	30	I. Sh.E.
	4	53	III. Ec.D.
	8	09	III. Ec.R.
	21	05	I. Oc.D.
23	0	39	I. Ec.R.
	4	25	II. Oc.D.
	9	46	II. Ec.R.
	18	27	I. Tr.I.
	19	44	I. Sh.I.
	20	41	I. Tr.E.
	21	59	I. Sh.E.

d	h	m	
24	15	34	I. Oc.D.
	19	08	I. Ec.R.
	22	41	II. Tr.I.
25	1	15	II. Sh.I.
	1	17	II. Tr.E.
	3	55	II. Sh.E.
	12	55	I. Tr.I.
	13	47	III. Tr.I.
	14	13	I. Sh.I.
	15	10	I. Tr.E.
	16	28	I. Sh.E.
	16	56	III. Tr.E.
	19	02	III. Sh.I.
	22	16	III. Sh.E.
26	10	03	I. Oc.D.
	13	37	I. Ec.R.
	17	44	II. Oc.D.
	23	04	II. Ec.R.
27	7	24	I. Tr.I.
	8	42	I. Sh.I.
	9	38	I. Tr.E.
	10	57	I. Sh.E.
28	0	38	IV. Tr.I.
	3	06	IV. Tr.E.
	4	32	I. Oc.D.
	8	06	I. Ec.R.
	11	59	II. Tr.I.
	12	47	IV. Sh.I.
	14	33	II. Sh.I.
	14	35	II. Tr.E.
	15	57	IV. Sh.E.
	17	13	II. Sh.E.
29	1	53	I. Tr.I.
	3	11	I. Sh.I.
	3	37	III. Oc.D.
	4	07	I. Tr.E.
	5	25	I. Sh.E.
	6	48	III. Oc.R.
	8	53	III. Ec.D.
	12	09	III. Ec.R.
	23	00	I. Oc.D.
30	2	34	I. Ec.R.
	7	03	II. Oc.D.
	12	23	II. Ec.R.
	20	22	I. Tr.I.
	21	40	I. Sh.I.
	22	36	I. Tr.E.
	23	54	I. Sh.E.

SATELLITES OF JUPITER, 1984

UNIVERSAL TIME OF GEOCENTRIC PHENOMENA

OCTOBER

d	h	m	Phenomenon
1	17	29	I. Oc.D.
	21	03	I. Ec.R.
2	1	17	II. Tr.I.
	3	51	II. Sh.I.
	3	54	II. Tr.E.
	6	31	II. Sh.E.
	14	51	I. Tr.I.
	16	08	I. Sh.I.
	17	05	I. Tr.E.
	17	49	III. Tr.I.
	18	23	I. Sh.E.
	20	58	III. Tr.E.
	23	03	III. Sh.I.
3	2	18	III. Sh.E.
	11	58	I. Oc.D.
	15	32	I. Ec.R.
	20	22	II. Oc.D.
4	1	41	II. Ec.R.
	9	20	I. Tr.I.
	10	37	I. Sh.I.
	11	35	I. Tr.E.
	12	52	I. Sh.E.
5	6	27	I. Oc.D.
	10	01	I. Ec.R.
	14	36	II. Tr.I.
	17	09	II. Sh.I.
	17	13	II. Tr.E.
	19	49	II. Sh.E.
6	3	50	I. Tr.I.
	5	06	I. Sh.I.
	6	04	I. Tr.E.
	7	21	I. Sh.E.
	7	40	III. Oc.D.
	10	52	III. Oc.R.
	11	32	IV. Oc.D.
	12	52	III. Ec.D.
	14	11	IV. Oc.R.
	16	10	III. Ec.R.
	23	24	IV. Ec.D.
7	0	57	I. Oc.D.
	2	42	IV. Ec.R.
	4	30	I. Ec.R.
	9	42	II. Oc.D.
	15	00	II. Ec.R.
	22	19	I. Tr.I.
	23	35	I. Sh.I.
8	0	33	I. Tr.E.
	1	50	I. Sh.E.
	19	26	I. Oc.D.
	22	59	I. Ec.R.
9	3	55	II. Tr.I.
9	6	27	II. Sh.I.
	6	33	II. Tr.E.
	9	08	II. Sh.E.
	16	48	I. Tr.I.
	18	04	I. Sh.I.
	19	02	I. Tr.E.
	20	18	I. Sh.E.
	21	56	III. Tr.I.
10	1	05	III. Tr.E.
	3	04	III. Sh.I.
	6	19	III. Sh.E.
	13	55	I. Oc.D.
	17	27	I. Ec.R.
	23	02	II. Oc.D.
11	4	18	II. Ec.R.
	11	17	I. Tr.I.
	12	33	I. Sh.I.
	13	31	I. Tr.E.
	14	47	I. Sh.E.
12	8	24	I. Oc.D.
	11	56	I. Ec.R.
	17	15	II. Tr.I.
	19	45	II. Sh.I.
	19	53	II. Tr.E.
	22	26	II. Sh.E.
13	5	47	I. Tr.I.
	7	01	I. Sh.I.
	8	01	I. Tr.E.
	9	16	I. Sh.E.
	11	47	III. Oc.D.
	15	00	III. Oc.R.
	16	52	III. Ec.D.
	20	11	III. Ec.R.
14	2	54	I. Oc.D.
	6	25	I. Ec.R.
	12	23	II. Oc.D.
	17	37	II. Ec.R.
	19	10	IV. Tr.I.
	21	50	IV. Tr.E.
15	0	16	I. Tr.I.
	1	30	I. Sh.I.
	2	30	I. Tr.E.
	3	45	I. Sh.E.
	6	51	IV. Sh.I.
	10	10	IV. Sh.E.
	21	23	I. Oc.D.
16	0	54	I. Ec.R.
	6	36	II. Tr.I.
	9	04	II. Sh.I.
	9	14	II. Tr.E.
	11	45	II. Sh.E.
	18	45	I. Tr.I.
16	19	59	I. Sh.I.
	21	00	I. Tr.E.
	22	14	I. Sh.E.
17	2	05	III. Tr.I.
	5	15	III. Tr.E.
	7	04	III. Sh.I.
	10	20	III. Sh.E.
	15	52	I. Oc.D.
	19	23	I. Ec.R.
18	1	44	II. Oc.D.
	6	55	II. Ec.R.
	13	15	I. Tr.I.
	14	28	I. Sh.I.
	15	29	I. Tr.E.
	16	43	I. Sh.E.
19	10	22	I. Oc.D.
	13	52	I. Ec.R.
	19	56	II. Tr.I.
	22	22	II. Sh.I.
	22	35	II. Tr.E.
20	1	03	II. Sh.E.
	7	44	I. Tr.I.
	8	57	I. Sh.I.
	9	59	I. Tr.E.
	11	11	I. Sh.E.
	15	58	III. Oc.D.
	19	12	III. Oc.R.
	20	53	III. Ec.D.
21	0	12	III. Ec.R.
	4	51	I. Oc.D.
	8	21	I. Ec.R.
	15	05	II. Oc.D.
	20	13	II. Ec.R.
22	2	14	I. Tr.I.
	3	26	I. Sh.I.
	4	28	I. Tr.E.
	5	40	I. Sh.E.
	23	21	I. Oc.D.
23	2	49	I. Ec.R.
	6	25	IV. Oc.D.
	9	17	IV. Oc.R.
	9	18	II. Tr.I.
	11	40	II. Sh.I.
	11	57	II. Tr.E.
	14	22	II. Sh.E.
	17	26	IV. Ec.D.
	20	44	I. Tr.I.
	20	53	IV. Ec.R.
	21	54	I. Sh.I.
	22	58	I. Tr.E.
24	0	09	I. Sh.E.
24	6	17	III. Tr.I.
	9	29	III. Tr.E.
	11	04	III. Sh.I.
	14	21	III. Sh.E.
	17	51	I. Oc.D.
	21	18	I. Ec.R.
25	4	27	II. Oc.D.
	9	32	II. Ec.R.
	15	13	I. Tr.I.
	16	23	I. Sh.I.
	17	28	I. Tr.E.
	18	38	I. Sh.E.
26	12	20	I. Oc.D.
	15	47	I. Ec.R.
	22	39	II. Tr.I.
27	0	58	II. Sh.I.
	1	18	II. Tr.E.
	3	41	II. Sh.E.
	9	43	I. Tr.I.
	10	52	I. Sh.I.
	11	57	I. Tr.E.
	13	07	I. Sh.E.
	20	12	III. Oc.D.
	23	27	III. Oc.R.
28	0	53	III. Ec.D.
	4	13	III. Ec.R.
	6	50	I. Oc.D.
	10	16	I. Ec.R.
	17	49	II. Oc.D.
	22	50	II. Ec.R.
29	4	13	I. Tr.I.
	5	21	I. Sh.I.
	6	27	I. Tr.E.
	7	36	I. Sh.E.
30	1	20	I. Oc.D.
	4	45	I. Ec.R.
	12	01	II. Tr.I.
	14	17	II. Sh.I.
	14	41	II. Tr.E.
	16	59	II. Sh.E.
	22	42	I. Tr.I.
	23	49	I. Sh.I.
31	0	57	I. Tr.E.
	2	04	I. Sh.E.
	10	32	III. Tr.I.
	13	45	III. Tr.E.
	14	25	IV. Tr.I.
	15	04	III. Sh.I.
	17	20	IV. Tr.E.
	18	22	III. Sh.E.
	19	50	I. Oc.D.
	23	14	I. Ec.R.

SATURN

EPHEMERIS FOR THE BRIGHTER SATELLITES

The table below may be used to determine the orbital position of each of the five brightest satellites of Saturn at any time in 1984. The northern side of the rings and orbital planes of the five satellites now face Earth, being tilted approximately 19° from edge-on during the part of the year when Saturn is conveniently placed in the night sky (The orbit of Iapetus deviates most from this figure since it is itself tilted 15° to the ring plane). Hence the satellites pass (east to west) in front of and south of the centre of Saturn, and (west to east) behind and north of the centre of Saturn.

For each satellite, the table gives the visual magnitude, orbital period,* distance from the centre of Saturn in units of the radius of Saturn's *rings* (the outer radius of ring A), and time (UT) of the first *eastern* elongation in each month. For example, to find the position of Rhea on May 19, 1984 at 22 h EDT (May 20, 2 h UT): The first eastern elongation in May occurs on May 2 at 11.8 h. May 20, 2 h is 17.592 d or 17.592 ÷ 4.517 = 3.895 periods later. Thus Rhea will be 0.895 × 360° = 322° from eastern elongation. Hence it will be behind Saturn, 3.9 × cos 322° = 3.1 ring radii east of the centre of Saturn, and somewhat north.

**Note*: Sidereal periods rather than synodic periods are listed since, due to Earth's orbital motion, the sidereal period yields less error in predictions during the months near opposition. Predictions based on this table are accurate to within a couple of degrees.

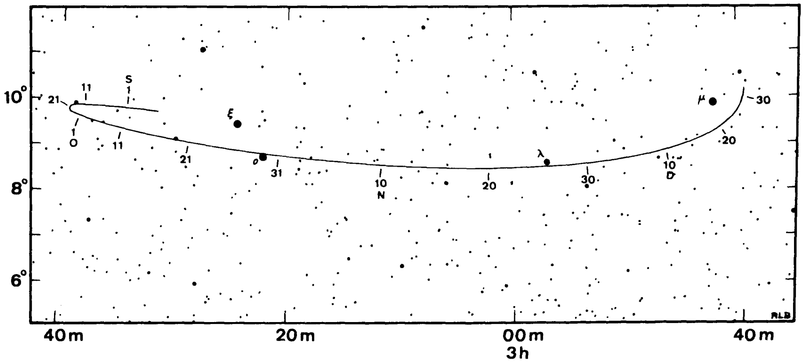
	Tethys	Dione	Rhea	Titan	Iapetus
m_v	10.3	10.4	9.7	8.4	~11
P	1.888^d	2.737^d	4.517^d	15.945^d	79.331^d
r	2.2	2.8	3.9	9.0	26.1
Jan.	$0^d 21^h.6$	$2^d 06^h.8$	$1^d 12^h.9$	$1^d 08^h.1$	
Feb.	2 00.0	1 09.6	2 04.4	2 07.5	
Mar.	1 07.6	2 12.2	4 19.4	5 05.2	$16^d 16^h.0$
Apr.	2 09.6	1 14.5	5 09.9	6 01.3	
May	2 14.3	1 16.6	2 11.8	7 20.3	
June	1 18.9	3 12.4	3 02.1	8 15.6	2 21.2
July	1 23.7	3 14.8	4 16.7	10 12.0	
Aug.	1 04.7	2 17.5	5 07.8	11 10.1	21 04.9
Sep.	2 07.3	1 20.4	1 10.8	12 09.7	
Oct.	2 12.6	1 23.5	3 02.7	14 10.5	
Nov.	1 18.0	1 02.7	3 18.8	15 11.8	10 07.5
Dec.	1 23.3	1 05.9	5 10.9	1 12.5	

EPHEMERIDES FOR THE BRIGHTEST ASTEROIDS 1984

PROVIDED BY BRIAN G. MARSDEN

The following are the ephemerides for the brightest asteroids in 1984: those asteroids which will be brighter than photographic magnitude 11.0 and more than 90° from the Sun. The tables give the number and name of the asteroid, the date at 0^h E.T. (which differs only slightly from U.T.), the right ascension and declination for the epoch 1950 (for convenience in plotting on commonly-used star charts) and the *photographic* magnitude (which is normally about $0^{m}.7$ *fainter* than the visual magnitude). These data were derived from current osculating elements, and were generously calculated and provided by Dr. Brian G. Marsden of the Smithsonian Astrophysical Observatory.

A map is provided for Ceres, the brightest asteroid during 1984. The map is based on the *A.A.V.S.O. Variable Star Atlas* and shows the predicted path of the asteroid during a four month interval around opposition. The coordinates are for 1950. Readers can make maps for other asteroids by using the ephemerides and an appropriate star atlas.



The path of Ceres near the Taurus-Cetus border, 1984. Its position is marked at 10-day intervals, beginning with September 1 (S1). The faintest stars shown are of magnitude 9, and the coordinates are for 1950.0. Ceres is at magnitude 8.7 on September 1, but brightens to 7.7 when at opposition on November 12, 1.826 A from Earth. By the end of the year it has faded to magnitude 8.4. It is curious that Ceres is asteroid number 1 (it was the 1st asteroid to be discovered—on the 1st day of the 1st month of the 1st year of the last century), is 1st in order of size among the asteroids (it has a diameter of 1 Mm), and is 1st in brightness of all the asteroids during 1984.

(1) Ceres

Date 0h E.T.	R.A.(1950)	Dec.(1950)	Mag.
Aug. 28	$3^h32^m.1$	+ 9°49′	8.8
Sept. 7	3 36.7	+ 9 54	
17	3 39.1	+ 9 52	8.5
27	3 39.1	+ 9 44	
Oct. 7	3 36.5	+ 9 31	8.2
17	3 31.5	+ 9 16	
27	3 24.2	+ 8 59	7.8
Nov. 6	3 15.4	+ 8 45	
16	3 05.9	+ 8 37	7.7
26	2 56.8	+ 8 37	
Dec. 6	2 49.0	+ 8 48	8.0
16	2 43.3	+ 9 11	
26	2 40.1	+ 9 45	8.3

(2) Pallas

Date 0h E.T.	R.A.(1950)	Dec.(1950)	Mag.
June 29	$23^h10^m.1$	+ 9°41′	10.5
July 9	23 11.5	+ 9 33	
19	23 11.1	+ 9 08	10.2
29	23 08.8	+ 8 23	
Aug. 8	23 04.7	+ 7 16	9.9
18	22 59.0	+ 5 47	
28	22 52.0	+ 3 58	9.5
Sept. 7	22 44.5	+ 1 53	
17	22 37.1	- 0 19	9.5
27	22 30.6	- 2 30	
Oct. 7	22 25.6	- 4 33	9.8
17	22 22.5	- 6 23	
27	22 21.5	- 7 54	10.0
Nov. 6	22 22.6	- 9 07	
16	22 25.8	-10 01	10.2
26	22 30.9	-10 37	

(3) Juno

Date 0h E.T.	R.A.(1950)	Dec.(1950)	Mag.
Jan. 1	$2^h07^m.9$	- 4°42′	9.3
11	2 17.5	- 3 06	
21	2 29.2	- 1 20	9.7
31	2 42.7	+ 0 32	

(4) Vesta

Date 0h E.T.	R.A.(1950)	Dec.(1950)	Mag.
Jan. 1	$4^h59^m.9$	+19°04′	7.6
11	4 52.1	+19 25	
21	4 47.1	+19 50	8.0
31	4 45.3	+20 18	
Feb. 10	4 46.6	+20 49	8.3
20	4 50.8	+21 22	
Mar. 1	4 57.5	+21 56	8.6
11	5 06.5	+22 30	

(6) Hebe

Date 0h E.T.	R.A.(1950)	Dec.(1950)	Mag.
Oct. 7	$6^h29^m.7$	+ 6°20′	10.1
17	6 39.0	+ 5 30	
27	6 45.6	+ 4 42	9.9
Nov. 6	6 49.1	+ 4 01	
16	6 49.1	+ 3 31	9.6
26	6 45.7	+ 3 18	
Dec. 6	6 39.0	+ 3 27	9.3
16	6 29.9	+ 4 01	
26	6 19.5	+ 5 00	9.1

(7) Iris

Date 0h E.T.	R.A.(1950)	Dec.(1950)	Mag.
Sept.17	$5^h04^m.1$	+26°53′	9.7
27	5 20.1	+26 58	
Oct. 7	5 33.5	+26 53	9.3
17	5 43.7	+26 38	
27	5 50.2	+26 14	8.9
Nov. 6	5 52.3	+25 43	
16	5 50.1	+25 05	8.5
26	5 43.7	+24 19	
Dec. 6	5 34.4	+23 27	8.1
16	5 23.9	+22 32	
26	5 14.3	+21 37	8.3

(8) Flora

Date 0h E.T.	R.A.(1950)	Dec.(1950)	Mag.
July 19	$1^h10^m.4$	+ 0°43′	10.6
29	1 23.3	+ 1 13	
Aug. 8	1 34.4	+ 1 28	10.2
18	1 43.2	+ 1 24	
28	1 49.3	+ 1 00	9.7
Sept. 7	1 52.2	+ 0 18	
17	1 51.5	- 0 40	9.2
27	1 47.4	- 1 49	
Oct. 7	1 40.3	- 2 58	8.8
17	1 31.5	- 3 56	
27	1 22.6	- 4 31	8.9
Nov. 6	1 15.3	- 4 36	
16	1 10.8	- 4 11	9.3
26	1 09.7	- 3 17	
Dec. 6	1 12.2	- 1 59	9.8
16	1 17.9	- 0 24	
26	1 26.4	+ 1 24	10.2

(9) Metis

Date 0h E.T.	R.A.(1950)	Dec.(1950)	Mag.
Jan. 1	$12^h18^m.5$	+ 5°07′	11.2
11	12 26.2	+ 4 46	
21	12 31.5	+ 4 41	10.9
31	12 34.0	+ 4 53	
Feb. 10	12 33.7	+ 5 23	10.6
20	12 30.3	+ 6 08	
Mar. 1	12 24.1	+ 7 04	10.3
11	12 15.7	+ 8 05	
21	12 06.2	+ 9 00	10.0
31	11 56.7	+ 9 44	
Apr. 10	11 48.4	+10 10	10.4
20	11 42.2	+10 15	
30	11 38.6	+10 01	10.8
May 10	11 37.7	+ 9 30	

(10) Hygiea

Date 0h E.T.	R.A.(1950)	Dec.(1950)	Mag.
June 29	$21^h09^m.6$	-14°25′	10.8
July 9	21 04.6	-14 32	
19	20 57.8	-14 46	10.5
29	20 50.0	-15 05	
Aug. 8	20 42.0	-15 26	10.3
18	20 34.5	-15 47	
28	20 28.3	-16 05	10.8
Sept. 7	20 24.1	-16 17	

(11) Parthenope

Date 0h E.T.	R.A.(1950)	Dec.(1950)	Mag.
Mar. 21	$12^h20^m.4$	+ 4°35′	10.9
31	12 11.6	+ 5 42	

(13) Egeria

Date 0h E.T.	R.A.(1950)	Dec.(1950)	Mag.
Jan. 1	$9^h02^m.8$	+43°27′	11.0
11	8 54.6	+45 05	
21	8 43.4	+46 21	10.9
31	8 30.7	+47 03	
Feb. 10	8 18.8	+47 07	11.0
20	8 09.4	+46 35	

(14) Irene

Date 0h E.T.	R.A.(1950)	Dec.(1950)	Mag.
Jan. 21	$13^h39^m.7$	$+1^\circ21'$	11.0
31	13 50.6	+ 1 03	
Feb. 10	13 59.4	+ 1 01	10.7
20	14 05.7	+ 1 15	
Mar. 1	14 09.0	+ 1 42	10.3
11	14 09.2	+ 2 22	
21	14 06.1	+ 3 08	9.9
31	14 00.2	+ 3 55	
Apr. 10	13 52.2	+ 4 33	9.7
20	13 43.2	+ 4 56	
30	13 34.6	+ 4 57	9.8
May 10	13 27.6	+ 4 34	
20	13 23.0	+ 3 49	10.2
30	13 21.2	+ 2 45	
June 9	13 22.1	+ 1 25	10.6
19	13 25.7	- 0 06	
29	13 31.6	- 1 45	11.0
July 9	13 39.6	- 3 30	

(15) Eunomia

Date 0h E.T.	R.A.(1950)	Dec.(1950)	Mag.
Apr. 10	$17^h32^m.8$	$-33^\circ53'$	11.0
20	17 33.3	-34 09	
30	17 31.1	-34 19	10.7
May 10	17 26.0	-34 22	
20	17 18.4	-34 14	10.4
30	17 08.8	-33 54	
June 9	16 58.2	-33 20	10.1
19	16 47.8	-32 33	
29	16 38.6	-31 37	10.3
July 9	16 31.6	-30 37	
19	16 27.1	-29 38	10.5
29	16 25.5	-28 44	
Aug. 8	16 26.6	-27 58	10.8
18	16 30.3	-27 19	
28	16 36.4	-26 48	11.0
Sept. 7	16 44.5	-26 23	

(16) Psyche

Date 0h E.T.	R.A.(1950)	Dec.(1950)	Mag.
June 29	$21^h15^m.8$	$-13^\circ48'$	10.8
July 9	21 12.0	-14 10	
19	21 06.1	-14 43	10.5
29	20 58.7	-15 24	
Aug. 8	20 50.5	-16 08	10.1
18	20 42.7	-16 52	
28	20 36.0	-17 31	10.5
Sept. 7	20 31.3	-18 02	
17	20 29.1	-18 23	10.8
27	20 29.5	-18 34	

P

(18) Melpomene

Date 0h E.T.	R.A.(1950)	Dec.(1950)	Mag.
May 20	$17^h00^m.4$	$-6^\circ20'$	11.0
30	16 50.9	- 5 50	
June 9	16 40.6	- 5 34	10.8
19	16 30.7	- 5 36	
29	16 22.3	- 5 56	11.0
July 9	16 16.1	- 6 32	

(20) Massalia

Date 0h E.T.	R.A.(1950)	Dec.(1950)	Mag.
Jan. 1	$1^h16^m.3$	$+7^\circ44'$	11.0
11	1 25.9	+ 8 40	

(23) Thalia

Date 0h E.T.	R.A.(1950)	Dec.(1950)	Mag.
Nov. 16	$2^h49^m.7$	$+10^\circ17'$	10.9
26	2 39.6	+10 26	

(27) Euterpe

Date 0h E.T.	R.A.(1950)	Dec.(1950)	Mag.
Mar. 1	$11^h24^m.8$	$+6^\circ46'$	10.7
11	11 15.2	+ 7 50	
21	11 06.1	+ 8 46	11.0
31	10 58.8	+ 9 26	

(29) Amphitrite

Date 0h E.T.	R.A.(1950)	Dec.(1950)	Mag.
Jan. 1	$8^h51^m.0$	$+26^\circ21'$	10.4
11	8 42.5	+26 53	
21	8 32.2	+27 21	10.1
31	8 21.2	+27 37	
Feb. 10	8 11.1	+27 40	10.4
20	8 03.1	+27 28	
Mar. 1	7 58.1	+27 04	10.8
11	7 56.4	+26 30	

(37) Fides

Date 0h E.T.	R.A.(1950)	Dec.(1950)	Mag.
Oct. 7	$1^h38^m.8$	$+11^\circ40'$	11.0
17	1 30.0	+11 09	
27	1 20.9	+10 32	10.9
Nov. 6	1 12.9	+ 9 59	

(39) Laetitia

Date 0h E.T.	R.A.(1950)	Dec.(1950)	Mag.
Jan. 1	$4^h38^m.2$	$+6^\circ46'$	11.0
11	4 33.4	+ 7 24	

(63) Ausonia

Date 0h E.T.	R.A.(1950)	Dec.(1950)	Mag.
Apr. 30	$18^h18^m.1$	$-32^\circ20'$	11.0
May 10	18 20.4	-32 53	
20	18 18.8	-33 23	10.6
30	18 13.3	-33 47	
June 9	18 04.7	-34 00	10.2
19	17 54.1	-33 56	
29	17 43.4	-33 34	10.1
July 9	17 34.3	-32 56	
19	17 28.2	-32 09	10.5
29	17 25.7	-31 19	
Aug. 8	17 27.1	-30 31	10.9
18	17 32.0	-29 46	

(89) Julia

Date 0h E.T.	R.A.(1950)	Dec.(1950)	Mag.
June 29	$18^h46^m.7$	$-38^\circ27'$	10.9
July 9	18 34.0	-37 32	
19	18 22.5	-36 14	11.0
29	18 13.5	-34 42	

(97) Klotho

Date 0h E.T.	R.A.(1950)	Dec.(1950)	Mag.
Oct. 7	$3^h11^m.5$	$+0^\circ49'$	11.0
17	3 08.9	- 1 02	
27	3 03.6	- 2 49	10.6
Nov. 6	2 56.6	- 4 17	
16	2 49.2	- 5 17	10.6
26	2 42.9	- 5 41	
Dec. 6	2 38.8	- 5 27	10.9
16	2 37.5	- 4 41	

(144) Vibilia

Date 0h E.T.	R.A.(1950)	Dec.(1950)	Mag.
Oct. 27	$2^h54^m.4$	$+10^\circ56'$	10.9
Nov. 6	2 45.1	+10 42	

PLANETARY APPULSES AND OCCULTATIONS

PROVIDED BY GORDON E. TAYLOR

A *planetary appulse* is a close approach of a star and a planet, minor planet (asteroid), or satellite (moon) as seen from Earth. At certain locations on Earth the appulse may be seen as an *occultation*, a "solar eclipse", but usually of a star other than our Sun. Careful observations of these events can provide valuable information on the position, size, and shape of the occulting body, and indicate the possible presence of satellites and/or atmosphere surrounding the body. In the case of asteroids, information of this sort is not currently obtainable in any other way. In addition, through a stepwise drop in the light of the occulted star or a gradual dimming, an occultation can reveal the binary nature of some stars or their diameter.

Gordon Taylor has issued a list of 60 possible occultations of stars by asteroids for 1984. Nine of these may be visible from North America (including Hawaii). In addition there are three occultations by planets during the year: by Saturn, Neptune, and Venus. The data on the Saturn and Venus events were supplied by Mr. Taylor, while the Neptune event is taken from a list by Mink, Klemola and Elliot (*Astronomical Journal*, *86*, 135, 1981). Unfortunately the Saturn event will be rather difficult to observe visually because of the relative faintness of the star, while Venus will be only 6° from the horizon. All predictions are listed on the next page. In the first table, the month (M), day (D), hour, and minute range of each event are given along with data on the occulted star. In the second table, Δm_v is the change in visual magnitude which will accompany the occultation, and Δt is the predicted maximum duration in seconds.

Improved predictions may be available closer to the time of the various events. Within a few days of each event, observers may obtain recorded telephone messages at 312-259-2376 (Chicago, Ill.). Observers of events which may cross parts of Canada (January 20, March 13, September 2, September 16 and October 21) should call 613-996-9345 (Dr. Ian Halliday, Herzberg Institute of Astrophysics, Ottawa, Ont.) to obtain possible last-minute updates.

Serious observers of occultations pay careful attention to: the determination of their geographical latitude, longitude, and altitude (which should be known to the nearest second of arc and 20 m, respectively); identification of the star; accurate timing of the events (considerable care is needed to attain an accuracy of 0.5 s or better: a shortwave radio time signal and cassette tape recorder are recommended); monitoring the star for several minutes surrounding the time of closest approach in order to time the possible occultation and/or any secondary extinctions of the star; the provision of independent observers a kilometre or more apart for both confirmation and improved "resolution" of the eclipse shadow. High speed photoelectric recordings are very desirable when possible. When reporting timings, state the aperture of the telescope used, describe the timing method, estimate your reaction time and the accuracy of the timing, and state whether or not the reaction time correction has been applied. Reaction times vary from about 0.2 s to 1.0 s or more depending on the observer and the magnitude of the star.

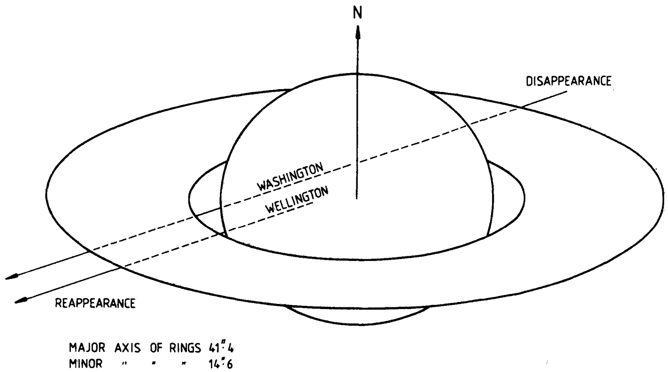
Observations of these events are coordinated in North America by the International Occultation Timing Association (IOTA). Dr. Dunham of the IOTA intends to publish an article on planetary occultations for 1984 in the January issue of *Sky and Telescope*. (See page 81 of this *Handbook* for more information on the IOTA.) Observations of planetary occultations, *including* negative observations, should be sent to H.M. Nautical Almanac Office, Royal Greenwich Observatory, Herstmonceux Castle, Hailsham, East Sussex, England BN27 1RP (the world clearing house for such observations), and to Dr. Dunham at P.O. Box 7488, Silver Spring, MD 20907, U.S.A. for publication by the IOTA. (Note that observations of *lunar* occultations should be sent to Japan. See page 81.)

Key	Time (UT)				Star			
	M	D	h	min	Name	m_v	α (1950)	δ
P1	1	20	7	5± 6	AGK3 + 3°1203	9.2	$8^h44^m37^s$	+ 3°45′04″
E	3	13	5	58± 6	AGK3 + 8°1465	9.8	11 13 01	+ 8 03 27
S	3	25	6	00*	SAO 158913	8.8		
L	5	16	9	48± 8	SAO 158714	9.1	14 37 16	−12 21 49
N	7	22	6	37**	SAO 186001	8.7	17 54 43	−22 13 45
K	8	25	9	7±11	SAO 185260	9.1	17 15 57	−25 40 13
W	9	2	10	13± 1	AGK3 + 5°0640	10.3	5 32 38	+ 5 01 46
A	9	16	2	19± 5	SAO 146599	8.7	23 13 22	− 7 09 37
C	10	6	3	20±13	SAO 145486	8.6	21 31 01	− 6 35 47
M	10	21	4	13±12	AGK3 +36°0536	8.4	5 16 19	+36 52 57
P2	11	8	5	25± 6	AGK3 +24°0011	10.2	0 07 19	+24 25 51
V	11	19	1	35	λ Sgr	2.9		

*Approx. time of start of occultation, which lasts ~4.2h
**Time of closest approach. For most of N. America Neptune will pass S. of the star.

Key	Asteroid/Planet		Occult.		Possible Area of Visibility*
	Name	m_v	Δm_v	Δt	
P1	194 Prokne	12.5	3.4	12	U.S.A.
E	27 Euterpe	9.9	0.8	12	N. Canada
S	Saturn	0.3	0.0		Americas, Pacific, New Zealand
L	21 Lutetia	10.8	1.9	11	Mexico, N. Pacific
N	Neptune	7.9	0.4		S. America, Hawaii
K	104 Klymene	14.3	5.2	24	E. Indies, Hawaii?
W	747 Winchester	11.7	1.7	7	U.S.A.
A	47 Aglaja	11.3	2.7	14	Canada
C	365 Corduba	13.3	4.7	16	Pacific (near California)
M	545 Messalina	14.3	5.9	18	N. Africa, Europe, N. Canada
P2	790 Pretoria	13.2	3.1	15	Bermuda, Florida, Cent. America
V	Venus	−4.1	0.0	~50	Coastal area British Columbia and NW Washington State

*For occultations by asteroids, see the preceding page for directions to obtain updates.



OCCULTATION OF SAO 158913 BY SATURN ON 1984 MARCH 25

METEORS, COMETS, AND DUST

METEORS, FIREBALLS, AND METEORITES

BY PETER M. MILLMAN

Meteoroids are small solid particles moving in orbits about the Sun. On entering the Earth's atmosphere they become luminous and appear as meteors or fireballs, and in rare cases, if large enough to avoid complete fragmentation and vaporization, they may fall to the Earth as meteorites.

Meteors are visible on any night of the year. At certain times of the year the Earth encounters larger numbers of meteoroids all moving together along the same orbit. Such a group is known as a meteor stream and the visible phenomenon is called a meteor shower. The orbits followed by these meteor streams are very similar to those of short-period comets, and in many cases can be identified with the orbits of specific comets.

The radiant is the position among the stars from which the meteors of a given shower seem to radiate. This is an effect of perspective commonly observed for any group of parallel lines. Some showers, notably the Quadrantids, Perseids, and Geminids, are very regular in their return each year and do not vary greatly in the numbers of meteors seen at the time of maximum. Other showers, like the Leonids, are very unpredictable and may arrive in great numbers or fail to appear at all in any given year. The δ Aquarids and the Taurids are spread out over a fairly extended period of time without a sharp maximum.

For more information concerning meteor showers, see the paper by A. F. Cook in "Evolutionary and Physical Properties of Meteoroids", NASA SP-319, pp. 183–191, 1973.

The light of meteors is produced by a mixture of atoms and molecules, originating from both the meteoroid and the Earth's atmosphere. i.e. The light of a meteor is primarily from a glowing gas, and not from the solid meteoroid itself. The collision, at a very high speed, of the material from the meteoroid with the Earth's atmosphere

MAJOR VISUAL METEOR SHOWERS FOR 1984

Shower	Shower Maximum			Radiant				Single Observer Hourly Rate	Speed of Encounter with Earth	Normal Duration to ¼ Strength of Max.
	Date	U.T.	Moon	Position at Max. R.A.	Dec.	Daily Motion R.A.	Dec.			
		h		h m	°	m	°		km/s	days
Quadrantids	Jan. 4	02	NM	15 28	+50	—	—	40	41	1.1
Lyrids	Apr. 22	04	LQ	18 16	+34	+4.4	0.0	15	48	2
η Aquarids	May 4	07	NM	22 24	00	+3.6	+0.4	20	65	3
S. δ Aquarids	July 28	10	NM	22 36	−17	+3.4	+0.17	20	41	7
Perseids	Aug. 12	01	FM	03 04	+58	+5.4	+0.12	50	60	4.6
Orionids	Oct. 21	05	NM	06 20	+15	+4.9	+0.13	25	66	2
S. Taurids	Nov. 3	—	FQ	03 32	+14	+2.7	+0.13	15	28	—
Leonids	Nov. 17	12	LQ	10 08	+22	+2.8	−0.42	15	71	—
Geminids	Dec. 14	00	LQ	07 32	+32	+4.2	−0.07	50	35	2.6
Ursids	Dec. 22	06	NM	14 28	+76	—	—	15	34	2
Quadrantids	(1985) Jan. 3	08	FM	15 28	+50	—	—	40	41	1.1

excites the involved atoms and molecules to shine, each with its own characteristic wavelength (colour). In addition to the light of oxygen and nitrogen, prominent in the luminosity of meteors, we find the orange-yellow of sodium, the brilliant green of magnesium, and various other wavelengths of light produced by iron, calcium, and some dozen, less-common elements. For a general survey of the light of meteors see *Smithsonian Contributions to Astrophysics*, 7, p. 119–127, 1963.

An observer located away from city lights, and with perfect sky conditions on a moonless night, will see an overall average of seven sporadic meteors per hour apart from the shower meteors. These have been included in the hourly rates listed in the table. Slight haze or nearby lighting will greatly reduce the number of meteors seen. More meteors appear in the early morning hours than in the evening, and more during the last half of the year than during the first half.

When a meteor has a luminosity greater than the brightest stars and planets it is generally termed a fireball. The visible trails of most meteors occur high in the atmosphere from 60 to 110 kilometres altitude. Only the rare, very bright fireballs survive down to the lower levels of Earth's atmosphere, and, in general, these are not associated with meteor showers. The occurrence of such an object should be reported immediately to the nearest astronomical group or other organization concerned with the collection of such information. Where no local organization exists, reports should be sent to Meteor Centre, Herzberg Institute of Astrophysics, National Research Council of Canada, Ottawa, Ontario, K1A 0R6. If sounds are heard accompanying a bright fireball there is a possibility that a meteorite may have fallen. Astronomers must rely on observations made by the general public to track down such an object.

For 1984 the comet associated with the Perseid meteor shower, 1862 III Swift-Tuttle, may be in the inner part of the solar system and a better than average shower in August is a possibility. The two showers associated with Halley's Comet, due in 1986, are the η Aquarids and the Orionids and these showers should be given priority in meteor observations for the next few years.

A SELECTION OF MINOR VISUAL METEOR SHOWERS

Shower	Dates	Date of Max.	Speed
			km/s
δ Leonids	Feb. 5–Mar. 19	Feb. 26	23
σ Leonids	Mar. 21–May 13	Apr. 17	20
τ Herculids	May 19–June 14	June 3	15
N. δ Aquarids	July 14–Aug. 25	Aug. 12	42
α Capricornids	July 15–Aug. 10	July 30	23
S. ι Aquarids	July 15–Aug. 25	Aug. 5	34
N. ι Aquarids	July 15–Sept. 20	Aug. 20	31
κ Cygnids	Aug. 9–Oct. 6	Aug. 18	25
S. Piscids	Aug. 31–Nov. 2	Sept. 20	26
N. Piscids	Sept. 25–Oct. 19	Oct. 12	29
N. Taurids	Sept. 19–Dec. 1	Nov. 13	29
Annual Andromedids	Sept. 25–Nov. 12	Oct. 3	18–23
Coma Berenicids	Dec. 12–Jan. 23	—	65

NORTH AMERICAN METEORITE IMPACT SITES

By P. Blyth Robertson

The realization that our Earth is truly part of the solar system, and not a planet in isolation, has been dramatically demonstrated by the past two decades of space exploration. Bodies such as Phobos, Callisto, Mimas, which were once solely part of the astronomer's realm, are now familiar terrain to planetary geologists, and an insight into the age and history of their surfaces can be derived from a knowledge of, and comparison with geological processes on Earth. In particular, as the only common feature apparent on all bodies from Mercury outward to the moons of Saturn is the abundance of meteorite craters, studies of the terrestrial equivalents may lead to better understanding of the evolution of planetary crusts.

Although all the planets are heavily cratered, the source of the impacting bodies is not the same throughout the solar system, nor has the rate been constant with time. The densely-cratered lunar highlands reveal a period of intense bombardment between 4.6 and 3.9 billion years ago, whereas the crater populations on the younger mare surfaces indicate a subsequent, considerably reduced rate that may have fluctuated somewhat over the past 3 billion years. It is believed that the cratering history of Earth is like that of the Moon, but all vestiges of the early bombardment, and a large percentage of the craters from the later period have been obliterated by various geologic processes on the 'active' Earth. A significant number of the larger, younger craters have been preserved, however, and their ages determined through radiometric age-dating techniques, to permit a calculation of the recent cratering rate. This rate, for the past 120 million years, is 5.4×10^{-15} per square kilometre of Earth per year, for craters 20 kilometres or larger in diameter. In other words, an event of this magnitude may occur every 7.6 million years in North America.

An impact crater results from a combination of excavation of the shattered target rocks and further expansion of the cavity by outward and downward movements of highly fractured material. Craters larger than 4 or 5 km undergo further modification through rebound and uplift of the crater floor, and downward faulting and displacement of large blocks in a broad annulus surrounding the crater. These movements result in a comparatively shallow impact structure whose outer dimension is approximately 40% larger than that of the initial crater.

The magnitude of the impact event is proportional to the kinetic energy of the meteorite, and therefore depends on its size, composition and speed. A 20 km impact structure on Earth would result from an impact yielding the equivalent of approximately 64 000 megatons of TNT, and could be produced by a stony meteorite (density 3.4 g/cm^3), 900 m in diameter, travelling at a typical speed of 20 km/s. Thus the diameter of the impact structure is many times that of the impacting body. (The kinetic energy of a typical meteor is about 100 times the explosive energy of the same mass of TNT.—Ed.)

In impacts, where craters greater than approximately 1.5 km are created, extreme shock pressures and temperatures vaporize and melt the meteorite. It subsequently becomes thoroughly mixed with the melted target rocks and is no longer recognizable in its original form, although chemical traces have been discovered. Of the 37 North American impact structures listed, which account for roughly 40% of the world's recognized total, meteorite fragments are preserved at only 3. The remainder are identified by the presence of characteristic deformation features in the target rocks; features that are uniquely produced by extreme shock pressures generated in nature only by hypervelocity, meteorite impact. In addition to these sites there are twenty or more structures in Canada and the United States whose impact origin seems highly probable, but where distinctive shock deformation has not been found.

In the table, sites accessible by road or boat are marked "A" or "B" respectively and those sites where data have been obtained through diamond-drilling or geophysical surveys are signified by "D" and "G", respectively.

Name	Lat. °	Lat. ′	Long. °	Long. ′	Diam. (km)	Age ($\times 10^6$ a)	Surface Expression	Visible Geologic Features			
Barringer, Meteor Crater, Ariz.	35	02	111	01	1.2	.05	rimmed polygonal crater	fragments of meteorite, highly shocked sandstone	A	D	G
Bee Bluff, Texas	29	02	099	51	2.4	40±10	shallow circ. depress'n.; rim remnants	breccia	A		
Brent, Ont.	46	05	078	29	3.8	450±30	sediment-filled shallow depression	fracturing	A	D	G
Carswell, Sask.	58	27	109	30	37	485±50	discontinuous circular ridge	shatter cones, breccia			G
Charlevoix, Que.	47	32	070	18	46	360±25	semi-circular trough, central elevation	breccia, shatter cones, impact melt	A		G
Clearwater Lake East, Que.	56	05	074	07	22	290±20	circular lake	sedimentary float		D	G
Clearwater Lake West, Que.	56	13	074	30	32	290±20	island ring in circular lake	impact melt		D	G
Crooked Creek, Missouri	37	50	091	23	5.6	320±80	oval area of disturbed rocks, shallow marginal depression	breccia, shatter cones	A		
Decaturville, Missouri	37	54	092	43	6	<300	slight oval depression	breccia, shatter cones	A	D	
Deep Bay, Sask.	56	24	102	59	12	100±50	circular bay	sedimentary float		D	G
Flynn Creek, Tenn.	36	16	085	37	3.8	360±20	sediment-filled shallow depression with slight central elevation	breccia, shatter cones, disturbed rocks	A	D	G
Gow Lake, Sask.	56	27	104	29	5	<250	lake and central island	breccia			G
Haviland, Kansas	37	35	099	10	0.0011	<0.001	excavated depression	fragments of meteorite	A		
Haughton, NWT	75	22	089	40	20	<20	shallow circular depression	shatter cones, breccia			G
Holleford, Ont.	44	28	076	38	2	550±100	sediment-filled shallow depression	sedimentary fill	A	D	G
Ile Rouleau, Que.	50	41	073	53	4	<300	island is central uplift of submerged structure	shatter cones, breccia dikes			
Kentland, Ind.	40	45	087	24	13	300	central uplift exposed in quarries, rest buried	breccia, shatter cones, disturbed rocks	A		
Lac Couture, Que.	60	08	075	18	8	430	circular lake	breccia float			
Lac la Moinerie, Que.	57	26	066	36	8	400	lake-filled, partly circular	breccia float			G
Lake St. Martin, Man.	51	47	098	33	23	225±40	none, buried and eroded	impact melt	A	D	G
Lake Wanapitei, Ont.	46	44	080	44	8.5	37±2	lake-filled, partly circular	breccia float	A		G
Manicouagan, Que.	51	23	068	42	100	210±4	circumferal lake, central elevation	impact melt, breccia	B		G
Manson, Iowa	42	35	094	31	32	<100	none, central elevation buried to 30 m	none	A	D	G
Middlesboro, Ky.	36	37	083	44	6	300	circular depression	disturbed rocks	A		
Mistastin Lake, Labr.	55	53	063	18	28	38±4	elliptical lake and central island	breccia, impact melt			
New Quebec Crater, Que.	61	17	073	40	3.2	<5	rimmed, circular lake	raised rim			G
Nicholson Lake, NWT	62	40	102	41	12.5	<400	irregular lake with islands	breccia			G
Odessa, Tex.	31	48	102	30	0.17	0.03	sediment-filled depression with very slight rim, 4 others buried and smaller	fragments of meteorite	A	D	G
Pilot Lake, NWT	60	17	111	01	6	<440	circular lake	fracturing, breccia float			
Redwing Creek, N. Dak.	47	40	102	30	9	200	none, buried	none	A	D	G
Serpent Mound, Ohio	39	02	083	24	6.4	300	circular area of disturbed rock, slight central elevation	breccia, shatter cones	A		G
Sierra Madera, Tex.	30	36	102	55	13	100	central hills, annular depression, outer ring of hills	breccia, shatter cones	A	D	G
Slate Islands, Ont.	48	40	087	00	30	350	islands are central uplift of submerged structure	shatter cones, breccia dikes	B		G
Steen River, Alta.	59	31	117	38	25	95±7	none, buried to 200 metres	none		D	G
Sudbury, Ont.	46	36	081	11	140	1840±150	elliptical basin	breccia, impact melt, shatter cones	A	D	G
Wells Creek, Tenn.	36	23	087	40	14	200±100	basin with cenral hill, inner and outer annular, valleys and ridges	breccia, shatter cones	A	D	G
West Hawk Lake, Man.	49	46	095	11	2.7	100±50	circular lake	none	A	D	G

COMETS IN 1984

By Brian G. Marsden

The following periodic comets are expected at perihelion during 1984:

Comet	Perihelion Date	Perihelion Dist.	Period
		A	a
Taylor	Jan. 7	1.96	7.0
Crommelin	Feb. 20	0.73	27
Smirnova-Chernykh	Feb. 21	3.56	8.5
Tritton	Mar. 3	1.44	6.4
Encke	Mar. 27	0.34	3.3
Clark	May 29	1.55	5.5
Wolf	May 31	2.42	8.2
Faye	July 9	1.59	7.3
Tuttle-Giacobini-Kresák	July 28	1.12	5.6
Wild 2	Aug. 20	1.49	6.2
Wolf-Harrington	Sept. 22	1.62	6.5
Neujmin 1	Oct. 8	1.55	18
Arend-Rigaux	Dec. 1	1.45	6.8
Schaumasse	Dec. 7	1.21	8.3
Haneda-Campos	Dec. 26	1.22	6.3

The return of P/Encke is rather favourable, and P/Crommelin should be moderately bright right at perihelion. P/Arend-Rigaux and P/Neujmin 1 are very favourably placed (although the latter is far south); these comets are unusual in that they are generally very stellar in appearance, but they will probably show some cometary attributes at their 1984 returns. P/Schaumasse has not been observed since 1960, but the present return is quite favourable. Ephemerides for the five comets are given on the next page.

P/Smirnova-Chernykh, which has been observable all round its orbit, is at perihelion in 1984. P/Clark will be well placed, P/Faye and P/Wolf-Harrington moderately so. P/Taylor, lost from its discovery apparition in 1916 (when two components were in fact observed) until 1977, will be comparably placed again in 1984. P/Wolf will be faint, P/Tuttle-Giacobini-Kresák very faint (unless it has an outburst, as it did in 1973). P/Wild 2, making its first predicted appearance, will not be particularly favourably placed; P/Haneda-Campos and P/Tritton, likewise, will be very faint, the prediction for the latter being very uncertain also. P/Halley, due at perihelion on 1986 Feb. 9, was recovered in 1982 Oct. (possibly when it experienced a small outburst) but is not expected to be brighter than magnitude 20-21 by the end of 1984.

COMET CROMMELIN

Date 0h E.T.	R.A. (1950)	Dec. (1950)	Mag.
Feb. 10	$0^h07^m.5$	$+2°58'$	9.8
20	0 59.7	+ 0 17	
Mar. 1	1 56.5	- 3 36	9.3
11	2 57.2	- 8 11	
21	4 01.3	-12 41	10.8

COMET ENCKE

Date 0h E.T.	R.A. (1950)	Dec. (1950)	Mag.
Feb. 20	$0^h13^m.9$	$+9°15'$	11.1
25	0 24.6	+10 08	
Mar. 1	0 36.0	+11 00	10.0
6	0 48.0	+11 48	
11	1 00.2	+12 23	8.8
16	1 11.4	+12 30	
21	1 18.6	+11 33	7.7
Apr. 10	0 07.1	- 8 45	9.3
15	23 49.7	-12 08	
20	23 38.3	-14 12	11.3

COMET NEUJMIN 1

Date 0h E.T.	R.A. (1950)	Dec. (1950)	Mag.
Aug. 28	$18^h19^m.6$	$-40°14'$	11.4
Sept. 7	18 36.5	-37 05	
17	18 56.9	-33 43	11.3
27	19 19.9	-30 11	
Oct. 7	19 44.7	-26 28	11.4

COMET SCHAUMASSE

Date 0h E.T.	R.A. (1950)	Dec. (1950)	Mag.
Oct. 27	$9^h52^m.7$	$+17°13'$	11.4
Nov. 6	10 34.7	+15 08	
16	11 16.8	+12 40	10.8
26	11 57.9	+ 9 57	
Dec. 6	12 37.4	+ 7 07	10.6
16	13 14.5	+ 4 22	
26	13 49.0	+ 1 48	10.7

COMET AREND-RIGAUX

Date 0h E.T.	R.A. (1950)	Dec. (1950)	Mag.
Dec. 6	$8^h29^m.5$	$+0°11'$	11.5
16	8 43.7	+ 2 46	
26	8 54.2	+ 6 28	11.3

Editor's Note: Although Halley's comet will not be visible in small telescopes before the summer of 1985, observing plans are well-advanced. Ground-based observations will be coordinated by the *International Halley Watch* (IHW), an organization approved by the International Astronomical Union. The IHW Western Hemisphere Lead Centre is at the Jet Propulsion Laboratory of the California Institute of Technology (4800 Oak Grove Drive, Pasadena, CA 91109, U.S.A.). Stephen J. Edberg of the IHW is Coordinator for Amateur Observations, and has produced a two-part manual entitled: *International Halley Watch Amateur Observer's Manual for Scientific Comet Studies*. Part I gives detailed instructions for observation projects valuable to the IHW in six areas of study: (1) visual observations, (2) photography, (3) astrometry, (4) spectroscopic observations, (5) photoelectric photometry, and (6) meteor observations. Part II includes an ephemeris for Comet Halley for the period 1985–1987 and star charts showing its position from November 1985 through May 1986. This manual is being published by the U.S. Government Printing Office (Washington, D.C. 20402, U.S.A.) and also possibly by private publishers (e.g. Sky Publishing Corp., 49 Bay State Road, Cambridge, MA 02238-1290, U.S.A.).

Some additional information is contained in *The Comet Halley Handbook* by Donald K. Yeomans, also available from the U.S. Government Printing Office. A short article with diagrams is found on page 500 of the June 1981 issue of *Sky and Telescope*. A more comprehensive article on Halley's comet appears in the April 1983 issue of *The Journal of The Royal Astronomical Society of Canada*, by Dr. Ian Halliday.

INTERPLANETARY DUST

Outside of the astronomical community it is not generally realized that the inner solar system contains a vast cloud of dust. The particles in this cloud are concentrated near the plane of the ecliptic and toward the Sun, their spatial particle density in the ecliptic falling off somewhat more rapidly than the reciprocal of their distance from the Sun. Measurements from spacecraft indicate that the cloud extends well beyond the orbit of Mars, but that it is negligible in the vicinity of Jupiter's orbit and beyond. Aside from this overall structure, the cloud is quite uniform both spatially and temporally.

The particles composing the cloud have a continuum of sizes, from pebble-sized clumps down to specks with diameters comparable to the wavelength of visible light and smaller. The smaller particles are the more numerous, although the mass distribution appears to peak near 10^{-8} kg, corresponding to a particle diameter of a few tenths of a millimetre. The total mass of the cloud is small, amounting to perhaps 10^{-14} of the mass of the solar system. It is as if the moons of Mars had been pulverized and spread throughout the inner solar system.

Like the planetary system, the interplanetary dust cloud is not static. Its particles generally move in orbits about the Sun. In addition, the particles undergo continual fragmentation due to collisions, sputtering associated with bombardment by the solar wind, electrostatic bursting, and sublimation. This progression toward smaller and smaller sizes is of crucial significance for the cloud, since particles with diameters appreciably less than a tenth of a millimetre have a sufficiently large surface-to-volume ratio that the pressure of the Sun's radiation has a significant effect upon their motion. Their orbits become non-Keplerian and many particles are lost as they spiral inward toward the Sun (the Poynting-Robertson effect). For the smallest particles, radiation pressure and interactions with the solar wind dominate, with the result that these particles are blown out of the solar system. The estimated mean life of a cloud particle is about 10^5 years. Since this is much less than the age of the solar system, it is obvious that the cloud must be in a dynamic equilibrium. Part of the tail of a bright comet is due to significant quantities of dust ejected from its nucleus, and it is generally assumed that comets provide the main supply of new dust to the cloud. Since comet nuclei are believed to consist of the undifferentiated matter from which the solar system formed, the dust of the interplanetary cloud is most likely composed of this same low-density, fragile, primitive material.

To an observer on Earth the most noticeable aspect of the dust cloud is meteors – larger particles of the cloud which encounter Earth and vaporize in its upper atmosphere. In addition, sunlight scattered by the dust cloud appears as a faint glow in the vicinity of the ecliptic. This glow is brightest toward the Sun, is due primarily to particles having diameters between a few micrometres and a millimetre, and is referred to as the *zodiacal light*. A slight brightening in the sky opposite the Sun, called the *Gegenschein* (German for "counter-glow"), is due to a phase effect (analogous to the full moon), and also possibly to a concentration of dust at the L3 Lagrangian point of the Earth-Sun system. As astronomical objects, the zodiacal light and Gegenschein are unusual in that they can be seen only with the unaided eye. Both are invisible in binoculars or a telescope.

The Zodiacal Light

Nearly a millenium ago the Persian astronomer-poet Omar Khayyam referred to the zodiacal light in the second quatrain of his *Rubaiyat.* As translated by the poet Edward FitzGerald, we have the haunting lines: "Dreaming when Dawn's Left Hand was in the Sky", and "Before the phantom of False morning died".

When conditions are favorable, the zodiacal light is indeed a mysterious and beautiful sight. It is best seen after the end of evening twilight and before the beginning of morning twilight (see page 58). Because the zodiacal light is brightest nearest the Sun, it is best seen when the ecliptic is at a steep angle relative to the horizon. In the tropics this is always the case and the short duration of twilight is an added advantage. At mid-northern latitudes the optimum geometry occurs in the evening western sky in February and March, and in the morning eastern sky in October. The zodiacal light appears as a huge, softly radiant pyramid of white light with its base near the horizon and its axis centered on the zodiac. In its brightest parts it exceeds the luminance of the central Milky Way.

Despite its brightness, many people have not seen the zodiacal light. As mentioned above, certain times of night and times of year are more favorable than others. In addition, moonlight, haze, or light pollution rule out any chance of seeing this phenomenon. Even with a dark, transparent sky the inexperienced observer may confuse the zodiacal light with twilight and thus ignore it, or he may not notice it because he is expecting a much smaller object.

The Gegenschein

Photometric measurements indicate that the zodiacal light extends all around the zodiac with a shallow minimum in brightness some 120° to 150° from the Sun; nevertheless, this "zodiacal band" or "light bridge" is exceedingly faint and hence rarely visible. However, the slight brightening in the vicinity of the anti-solar point can be seen under the right conditions.

The Gegenschein is very faint. The slightest haze, moonlight, bright nearby stars, planets, or light pollution will hide it completely. Most observers, including experienced ones, have not seen it. It is a ghostly apparition best seen near midnight and, in mid-northern latitudes, in the fall or winter when the anti-solar point is nearest the zenith. To avoid interference from bright stars or the Milky Way, observations should be restricted to the periods late September to early November, and late January to early February when the Gegenschein is in Pisces and Cancer respectively. It appears as a faint yet distinct, somewhat elliptical glow perhaps 10° in diameter. The luminance of the Gegenschein is about 10^{-4} cd/m^2, some ten orders of magnitude dimmer than the brightest light the human eye can tolerate.

STARS

CONSTELLATIONS

Nominative & Pronunciation	Genitive	Abbr.	Meaning
Andromeda, ăn-drŏm'ē-dȧ	Andromedae	And	Daughter of Cassiopeia
Antlia, ănt'lĭ-ȧ	Antliae	Ant	The Air Pump
Apus, ā'pŭs	Apodis	Aps	Bird of Paradise
Aquarius, ȧ-kwâr'ĭ-ŭs	Aquarii	Aqr	The Water-bearer
Aquila, ăk'wĭ-lȧ	Aquilae	Aql	The Eagle
Ara, ā'rȧ	Arae	Ara	The Altar
Aries, ā'rĭ-ēz	Arietis	Ari	The Ram
Auriga, ô-rī'gȧ	Aurigae	Aur	The Charioteer
Bootes, bō-ō'tēz	Bootis	Boo	The Herdsman
Caelum, sē'lŭm	Caeli	Cae	The Chisel
Camelopardalis kȧ-mĕl'ō-pȧr'dȧ-lĭs	Camelopardalis	Cam	The Giraffe
Cancer, kăn'sẽr	Cancri	Cnc	The Crab
Canes Venatici kā'nēz vē-năt'ĭ-sī	Canum Venaticorum	CVn	The Hunting Dogs
Canis Major, kā'nĭs mā'jẽr	Canis Majoris	CMa	The Big Dog
Canis Minor, kā'nĭs mī'nẽr	Canis Minoris	CMi	The Little Dog
Capricornus, kăp'rĭ-kôr'nŭs	Capricorni	Cap	The Horned Goat
Carina, kȧ-rī'nȧ	Carinae	Car	The Keel
Cassiopeia, kăs'ĭ-ō-pē'yȧ	Cassiopeiae	Cas	The Queen
Centaurus, sĕn-tô'rŭs	Centauri	Cen	The Centaur
Cepheus, sē'fūs	Cephei	Cep	The King
Cetus, sē'tŭs	Ceti	Cet	The Whale
Chamaeleon, kȧ-mē'lē-ŭn	Chamaeleontis	Cha	The Chameleon
Circinus, sûr'sĭ-nŭs	Circini	Cir	The Compasses
Columba, kō-lŭm'bȧ	Columbae	Col	The Dove
Coma Berenices kō'mȧ bĕr'ē-nī'sēz	Comae Berenices	Com	Berenice's Hair
Corona Australis kō-rō'nȧ ôs-trā'lĭs	Coronae Australis	CrA	The Southern Crown
Corona Borealis kō-rō'nȧ bō'rē-ā'lĭs	Coronae Borealis	CrB	The Northern Crown
Corvus, kôr'vŭs	Corvi	Crv	The Crow
Crater, krā'tẽr	Crateris	Crt	The Cup
Crux, krŭks	Crucis	Cru	The Cross
Cygnus, sĭg'nŭs	Cygni	Cyg	The Swan
Delphinus, dĕl-fī'nŭs	Delphini	Del	The Dolphin
Dorado, dō-rȧ'dō	Doradus	Dor	The Goldfish
Draco, drā'kō	Draconis	Dra	The Dragon
Equuleus, ē-kwo͞o'lē-ŭs	Equulei	Equ	The Little Horse
Eridanus, ē-rĭd'ȧ-nŭs	Eridani	Eri	A River
Fornax, fôr'năks	Fornacis	For	The Furnace
Gemini, jĕm'ĭ-nī	Geminorum	Gem	The Twins
Grus, grŭs	Gruis	Gru	The Crane (bird)
Hercules, hûr'kū-lēz	Herculis	Her	The Son of Zeus
Horologium, hŏr'ō-lō'jĭ-ŭm	Horologii	Hor	The Clock
Hydra, hī'drȧ	Hydrae	Hya	The Water Snake (♀)
Hydrus, hī'drŭs	Hydri	Hyi	The Water Snake (♂)

Nominative & Pronunciation	Genitive	Abbr.	Meaning
Indus, ĭn'dŭs	Indi	Ind	The Indian
Lacerta, lȧ-sûr'tȧ	Lacertae	Lac	The Lizard
Leo, lē'ō	Leonis	Leo	The Lion
Leo Minor, lē'ō mī'nẽr	Leonis Minoris	LMi	The Little Lion
Lepus, lē'pŭs	Leporis	Lep	The Hare
Libra, lī'brȧ	Librae	Lib	The Balance
Lupus, lū'pŭs	Lupi	Lup	The Wolf
Lynx, lĭnks	Lyncis	Lyn	The Lynx
Lyra, lī'rȧ	Lyrae	Lyr	The Lyre
Mensa, mĕn'sȧ	Mensae	Men	Table Mountain
Microscopium mī'krō-skō'pĭ-ŭm	Microscopii	Mic	The Microscope
Monoceros, mō-nŏs'ẽr-ŏs	Monocerotis	Mon	The Unicorn
Musca, mŭs'kȧ	Muscae	Mus	The Fly
Norma, nôr'mȧ	Normae	Nor	The Square
Octans, ŏk'tănz	Octantis	Oct	The Octant
Ophiuchus, ŏf'ĭ-ū'kŭs	Ophiuchi	Oph	The Serpent-bearer
Orion, ō-rī'ŏn	Orionis	Ori	The Hunter
Pavo, pā'vō	Pavonis	Pav	The Peacock
Pegasus, pĕg'ȧ-sŭs	Pegasi	Peg	The Winged Horse
Perseus, pûr'sūs	Persei	Per	Rescuer of Andromeda
Phoenix, fē'nĭks	Phoenicis	Phe	The Phoenix
Pictor, pĭk'tẽr	Pictoris	Pic	The Painter
Pisces, pĭs'ēz	Piscium	Psc	The Fishes
Piscis Austrinus pĭs'ĭs ôs-trī'nŭs	Piscis Austrini	PsA	The Southern Fish
Puppis, pŭp'ĭs	Puppis	Pup	The Stern
Pyxis, pĭk'sĭs	Pyxidis	Pyx	The Compass
Reticulum, rē-tĭk'ū-lŭm	Reticuli	Ret	The Reticle
Sagitta, sȧ-jĭt'ȧ	Sagittae	Sge	The Arrow
Sagittarius, săj'ĭ-tā'rĭ-ŭs	Sagittarii	Sgr	The Archer
Scorpius, skôr'pĭ-ŭs	Scorpii	Sco	The Scorpion
Sculptor, skŭlp'tẽr	Sculptoris	Scl	The Sculptor
Scutum, skū'tŭm	Scuti	Sct	The Shield
Serpens, sûr'pĕnz	Serpentis	Ser	The Serpent
Sextans, sĕks'tănz	Sextantis	Sex	The Sextant
Taurus, tô'rŭs	Tauri	Tau	The Bull
Telescopium tĕl'ē-skō'pĭ-ŭm	Telescopii	Tel	The Telescope
Triangulum, trī-ăng'gū-lŭm	Trianguli	Tri	The Triangle
Triangulum Australe trī-ăng'gū-lŭm ôs-trā'lē	Trianguli Australis	TrA	The Southern Triangle
Tucana, tū-kā'nȧ	Tucanae	Tuc	The Toucan
Ursa Major, ûr'sȧ mā'jẽr	Ursae Majoris	UMa	The Great Bear
Ursa Minor, ûr'sȧ mī'nẽr	Ursae Minoris	UMi	The Little Bear
Vela, vē'lȧ	Velorum	Vel	The Sails
Virgo, vûr'gō	Virginis	Vir	The Maiden
Volans, vō'lănz	Volantis	Vol	The Flying Fish
Vulpecula, vŭl-pĕk'ū-lȧ	Vulpeculae	Vul	The Fox

ā dāte; ă tăp; â câre; ȧ ȧsk; ē wē; ĕ mĕt; ẽ makẽr; ī īce; ĭ bĭt; ō gō; ŏ hŏt; ô ôrb; o͞o mo͞on; ū ūnite; ŭ ŭp; û ûrn.

FINDING LIST OF SOME NAMED STARS

Name	Con.	R.A.	Name	Con.	R.A.
Acamar, ā'kȧ-mȧr	θ Eri	02	Gienah, jē'nȧ	γ Crv	12
Achernar, ā'kĕr-nȧr	α Eri	01	Hadar, hăd'ȧr	β Cen	14
Acrux, ā'krŭks	α Cru	12	Hamal, hăm'ăl	α Ari	02
Adara, ȧ-dā'rȧ	ε CMa	06	Kaus Australis,	ε Sgr	18
Al Na'ir, ăl-nâr'	α Gru	22	kôs ôs-trā'lĭs		
Albireo, ăl-bĭr'ē-ō	β Cyg	19	Kochab, kō'kăb	β UMi	14
Alcor, ăl-kôr'	80 UMa	13	Markab, mȧr'kăb	α Peg	23
Alcyone, ăl-sī'ō-nē	η Tau	03	Megrez, mē'grĕz	δ UMa	12
Aldebaran,	α Tau	04	Menkar, mĕn'kȧr	α Cet	03
ăl-dĕb'ȧ-rȧn			Menkent, mĕn'kĕnt	θ Cen	14
Alderamin,	α Cep	21	Merak, mē'răk	β UMa	11
ăl-dĕr'ȧ-mĭn			Merope, mĕr'ō-pē	23 Tau	03
Algeiba, ăl-jē'bȧ	γ Leo	10	Miaplacidus,	β Car	09
Algenib, ăl-jē'nĭb	γ Peg	00	mī'ȧ-plăs'ĭ-dŭs		
Algol, ăl'gŏl	β Per	03	Mintaka, mĭn-tȧ'kȧ	δ Ori	05
Alioth, ăl'ĭ-ŏth	ε UMa	12	Mira, mī'rȧ	o Cet	02
Alkaid, ăl-kād'	η UMa	13	Mirach, mī'răk	β And	01
Almach, ăl'măk	γ And	02	Mirfak, mĭr'făk	α Per	03
Alnilam, ăl-nī'lăm	ε Ori	05	Mizar, mī'zȧr	ζ UMa	13
Alphard, ăl'fȧrd	α Hya	09	Nunki, nŭn'kē	σ Sgr	18
Alphecca, ăl-fĕk'ȧ	α CrB	15	Peacock, pē'kŏk'	α Pav	20
Alpheratz, ăl-fē'răts	α And	00	Phecda, fĕk'dȧ	γ UMa	11
Altair, ăl-târ'	α Aql	19	Polaris, pō-lâr'ĭs	α UMi	02
Ankaa, ăn'kȧ	α Phe	00	Pollux, pŏl'ŭks	β Gem	07
Antares, ăn-tā'rēs	α Sco	16	Procyon, prō'sĭ-ŏn	α CMi	07
Arcturus, ȧrk-tū'rŭs	α Boo	14	Pulcherrima,	ε Boo	14
Atria, ā'trĭ-ȧ	α TrA	16	pŭl-kĕr'ĭmȧ		
Avior, ă-vĭ-ôr'	ε Car	08	Ras-Algethi,	α Her	17
Bellatrix, bĕ-lā'trĭks	γ Ori	05	rȧs'ăl-jē'thē		
Betelgeuse, bĕt'ĕl-jūz	α Ori	05	Rasalhague,	α Oph	17
			rȧs'ăl-hā'gwē		
Canopus, kȧ-nō'pŭs	αCar	06	Regulus, rĕg'ū-lŭs	α Leo	10
Capella, kȧ-pĕl'ȧ	α Aur	05	Rigel, rī'jĕl	β Ori	05
Caph, kăf	β Cas	00	Rigil Kentaurus,	α Cen	14
Castor, kȧs'tĕr	α Gem	07	rī'jĭl kĕn-tô'rŭs		
Cor Caroli, kôr kăr'ŏ-lī	α CVn	12	Sabik, sā'bĭk	η Oph	17
Deneb, dĕn'ĕb	α Cyg	20	Scheat, shē'ăt	β Peg	23
Denebola, dĕ-nĕb'ō-lȧ	β Leo	11	Schedar, shĕd'ȧr	α Cas	00
Diphda, dĭf'dȧ	β Cet	00	Shaula, shô'lȧ	λ Sco	17
Dubhe, dŭb'ē	α UMa	11	Sirius, sĭr'ĭ-ŭs	α CMa	06
Elnath, ĕl'năth	β Tau	05	Spica, spī'kȧ	α Vir	13
Eltanin, ĕl-tā'nĭn	γ Dra	17	Suhail, sŭ-hāl'	λ Vel	09
Enif, ĕn'ĭf	ε Peg	21	Thuban, thōō'bȧn	α Dra	14
Fomalhaut, fō'măl-ôt	α PsA	22	Vega, vē'gȧ	α Lyr	18
Gacrux, gȧ'krŭks	γ Cru	12	Zubenelgenubi,	α Lib	14
Gemma, jĕm'ȧ	α CrB	15	zōō-bĕn'ĕl-jĕ-nū'bē		

Key to pronunciation on p. 132.

THE BRIGHTEST STARS

By Robert F. Garrison

The 286 stars brighter than apparent magnitude 3.55.

Star. If the star is a visual double the letter *A* indicates that the data are for the brighter component. The brightness and separation of the second component *B* are given in the last column. Sometimes the double is too close to be conveniently resolved and the data refer to the combined light, *AB*; in interpreting such data the magnitudes of the two components must be considered.

Visual Magnitude (*V*). These magnitudes are based on *photoelectric observations*, with a few exceptions, which have been adjusted to match the yellow colour-sensitivity of the eye. The photometric system is that of Johnson and Morgan in *Ap. J.*, vol. 117, p. 313, 1953. It is as likely as not that the true magnitude is within 0.03 mag. of the quoted figure, on the average. Variable stars are indicated with a "v". The type of variability, range, *R*, in magnitudes, and period in days are given.

Colour index ($B-V$). The blue magnitude, *B*, is the brightness of a star as observed photoelectrically through a blue filter. The difference $B-V$ is therefore a measure of the colour of a star. The table reveals a close relation between $B-V$ and spectral type. Some of the stars are slightly reddened by interstellar dust. The probable error of a value of $B-V$ is only 0.01 or 0.02 mag.

Type. The customary spectral (temperature) classification is given first. The Roman numerals are indicators of *luminosity class*. They are to be interpreted as follows: Ia—most luminous supergiants; Ib—less luminous supergiants; II—bright giants; III—normal giants; IV—subgiants; V—main sequence stars. Intermediate classes are sometimes used, e.g. Iab. Approximate absolute magnitudes can be assigned to the various spectral and luminosity class combinations. Other symbols used in this column are: p—a peculiarity; e—emission lines; v—the spectrum is variable; m—lines due to metallic elements are abnormally strong; f—the O-type spectrum has several broad emission lines; n or nn—unusually wide or diffuse lines. A composite spectrum, e.g. M1 Ib+B, shows up when a star is composed of two nearly equal but unresolved components. The table now includes accurate spectral and luminosity classes for all stars in the southern sky. All other types were very kindly provided especially for this table by Dr. W. W. Morgan, Yerkes Observatory.

Parallax (π). From "General Catalogue of Trigonometric Stellar Parallaxes" by Louise F. Jenkins, Yale Univ. Obs., 1952.

Absolute visual magnitude (M_V), and *distance in light-years* (D). If π is greater than 0.030″ the distance corresponds to this trigonometric parallax and the absolute magnitude was computed from the formula $M_V = V + 5 + 5 \log \pi$. Otherwise a generally more accurate absolute magnitude was obtained from the luminosity class. In this case the formula was used to *compute* π and the distance corresponds to this "spectroscopic" parallax. The formula is an expression of the inverse square law for decrease in light intensity with increasing distance. The effect of absorption of light by interstellar dust was neglected, except for three stars, ζ Per, σ Sco and ζ Oph, which are significantly reddened and would therefore be about a magnitude brighter if they were in the clear.

Annual proper motion (μ), and *radial velocity* (R). From "General Catalogue of Stellar Radial Velocities" by R. E. Wilson, Carnegie Inst. Pub. 601, 1953. The information on radial velocities was brought up-to-date in 1975 by Dr. C. T. Bolton of the Dunlap Observatory. Italics indicate an average value of a variable radial velocity.

The star names are given for all the officially designated navigation stars and a few others. Throughout the table, a *colon* (:) indicates an uncertainty.

	Right Ascension	Declination	Visual Magnitude	Colour Index	Spectral Classification		Parallax	Absolute Magnitude	Distance light-years	Proper Motion	Radial Velocity		
Star	R.A. 1980	Dec.	V	$B–V$	Type		π	M_V	D	μ	R		
	h m	° ′					″		l.y.	″	km/s		
Sun			-26.73	+0.63	G2	V		+4.84					***Sun***
α And	00 07.3	+28 58	2.06	−0.08	B9p		0.024	−0.1	90	0.209	*−11.7*	Manganese star	*Alpheratz*
β Cas	08.1	+59 02	2.26v	+0.34	F2	IV	0.072	+1.6	45	0.555	+11.8	Var. *R* $0^m.08$, 0.10^d	*Caph*
γ Peg	12.2	+15 04	2.84v	−0.23	B2	IV	−.004	−3.4	570	0.010	+04.1	β CMa type, *R* in *V* 2.83–2.85, 0.15^d	
β Hyi	24.6	−77 22	2.78	+0.62	G1	IV	0.153	+3.7	21	2.255	+22.8		γ Peg = *Algenib*
α Phe	25.3	−42 25	2.39	+1.08	K0	IIIb	0.035	+0.1	93	0.442	*+74.6*		*Ankaa*
δ And *A*	38.2	+30 45	3.25:	+1.26	K3	III	0.024	−0.2	160	0.161	−07.3	*B* 12^m 28″	
α Cas	39.4	+56 25	2.22	+1.18	K0	II–III	0.009	−1.1	150	0.058	−03.8	Var.?	*Schedar*
β Cet	42.6	−18 06	2.02	+1.03	K1	III	0.057	+0.8	57	0.234	+13.1		*Diphda*
η Cas *A*	47.9	+57 42	3.47	+0.56	G0	V	0.182	+4.8	18	1.221	+09.4	*B* 7.26^m 12″	
γ Cas *A*	55.5	+60 36	2.5v	−0.16v	B0	IV:pe	0.034	−0.3:	96:	0.026	−06.8	Var. *B* 8.18^m 2″	
β Phe *AB*	01 05.1	−46 50	3.30	+0.88	G8	III	0.017	+0.3	190	0.035	−01.1	*A* 4.1^m *B* 4.1^m 1″	
η Cet	07.6	−10 17	3.44	+1.16	K3	III	0.032	+1.0	102	0.250	+11.5		
β And	08.6	+35 31	2.02	+1.57	M0	III	0.043	+0.2	76	0.211	+00.3		*Mirach*
δ Cas	24.4	+60 08	2.67	+0.13	A5	V	0.029	+2.1	43	0.301	+06.7	Ecl.? *R* 0.08^m 759^d	*Ruchbah*
γ Phe	27.5	−43 25	3.40	+1.56	K5	IIb–III	−.003	−4.6	1300	0.209	*+25.7*		
α Eri	37.0	−57 20	0.51	−0.16	B3	Vp	0.023	−2.3	118	0.098	+19		***Achernar***
τ Cet	43.2	−16 03	3.50	+0.72	G8	Vp	0.275	+5.70	12	1.921	−16.2		

Star	R.A. 1980	Dec.	V	$B-V$	Type	π	M_V	D	μ	R		
	h m	° ′				″		l.y.	″	km/s		
α Tri	01 52.0	+29 29	3.42	+0.50	F6 IV	0.050	+2.0	65	0.230	*−12.6*		
ε Cas	52.9	+63 34	3.37	−0.15	B3 IV:p	0.007	−2.7	520	0.038	−08.1		
β Ari	53.6	+20 43	2.65	+0.14	A5 V	0.063	+1.7	52	0.147	*−04.0*		*Sheratan*
α Hyi	58.1	−61 40	2.84	+0.28	F0 V		+2.9	31	0.265	+07		
γ And *A*	02 02.7	+42 14	2.14:	+1.16:	K3 II	0.005	−2.4	260	0.068	−11.7	*B* 5.4^{m} *C* 6.2^{m} *A–BC* 10″ *B–C* 0.6″	γ And = *Almach*
α Ari	06.1	+23 22	2.00	+1.15	K2 III	0.043	+0.2	76	0.241	−14.3		*Hamal*
β Tri	08.4	+34 54	3.00	+0.13	A5 III	0.012	−0.1	140	0.156	*+15.2*		
α UMi *A*	12.5	+89 11	1.99v	+0.60v	F8 Ib	0.003	−4.6	680	0.046	*−17.4*	Cep., *R* 0.11^{m} 4.0^{d}, *B* 8.9^{m} 18″	*Polaris*
o Cet *A*	18.3	−03 04	2.0v		M5.5e–M9e	0.013	−0.5	103	0.232	+63.8	LP, *R* 2.0–10.1, 332^{d}, *B* 10^{m} 1″	*Mira*
γ Cet *AB*	42.2	+03 10	3.48	+0.11	A2 V	0.048	+2.0	68	0.203	−05.1	*A* 3.57^{m} *B* 6.23^{m} 3″	
θ Eri *AB*	57.5	−40 23	2.92	+0.13	A3 III	0.028	+1.7	65	0.061	*+11.9*	*A* 3.25^{m} *B* 4.36^{m} 8″	*Acamar*
α Cet	03 01.2	+04 00	2.54	+1.63	M2 III	0.003	−0.5	130	0.075	−25.9		*Menkar*
γ Per	03.3	+53 25	2.91:	+0.72:	G8III + A5V	0.011	+0.3	113	0.004	*+02.5*		
ρ Per	03.7	+38 45	3.5v		M4 II–III	0.008	−1.0	260	0.172	+28.2	Irr. *R* 3.2–3.8	
β Per	06.6	+40 52	2.06v	−0.07	B8 V	0.031	−0.5	105	0.006	*+06.0*	Ecl. *R* 2.06–3.28, 2.87^{d}	*Algol*
α Per	22.9	+49 47	1.80	+0.48	F5 Ib	0.029	−4.4	570	0.035	−02.4		*Mirfak*
δ Per	41.5	+47 44	3.03	−0.14	B5 III	0.007	−3.3	590	0.046	+02.8		
η Tau	46.3	+24 03	2.86	−0.09	B7 III	0.005	−3.2	541	0.050	+10.1	in Pleiades	*Alcyone*
γ Hyi	47.5	−74 18	3.30	+1.61	M2 III	−.001	−1.5	300	0.125	+16.0		
ζ Per *A*	52.7	+31 50	2.83	+0.13	B1 Ib	0.007	−6.1	1000	0.015	+20.6	*B* 9.36^{m} 13″	
ε Per *A*	56.5	+39 57	2.88	−0.17	B0.5 V	−.001	−3.7	680	0.036	*−01*	*B* 7.99^{m} 9″	
γ Eri	57.1	−13 34	2.96	+1.58	M0 III	0.003	−0.5	160	0.126	+61.7		
α Ret *A*	04 14.1	−62 32	3.33	+0.91	G9 III	0.008	−2.1	390	0.064	+35.6	*B* 12^{m} 49″	
ε Tau	27.5	+19 08	3.54	+1.02	K0 III	0.018	+0.1	160	0.118	+38.6		
θ^{2} Tau	27.5	+15 49	3.42	+0.17	A7 III	0.025	+0.2	140	0.108	*+39.5*		
α Dor	33.5	−55 05	3.28	−0.08	A0 IIIp	0.011	−1.2	260	0.051	+25.6	Silicon star	
α Tau *A*	34.8	+16 28	0.86v	+1.52	K5 III	0.048	−0.7	68	0.202	+54.1	Irr.? *R* 0.78–0.93, *B* 13^{m} 31″	***Aldebaran***
π^{3} Ori	48.3	+06 56	3.17	+0.45	F6 V	0.125	+3.65	26	0.468	+24.3		
ι Aur	55.7	+33 08	2.68:	+1.49	K3 II	0.015	−2.4	330	0.021	+17.5		

Star	R.A. 1980	Dec.	V	$B–V$	Type	π	M_V	D	μ	R		
	h m	° ′				″		l.y.	″	km/s		
ε Aur	05 00.5	+43 48	3.0v	+0.50:	F0 Iap	0.004	−7.1	3400	0.008	*−01.4*	Ecl. *R* 0.81^m 9886^d	
ε Lep	04.6	−22 24	3.21	+1.46	K5 III	0.006	−0.4	170	0.077	+01.0		
η Aur	05.1	+41 13	3.17	−0.18	B3 V	0.013	−2.1	370	0.077	+07.4		
β Eri	06.9	−05 06	2.79	+0.13	A3 III	0.042	+0.9	78	0.122	−08		
μ Lep	12.1	−16 13	3.29	−0.09	B9 IIIp	0.018	−2.1	390	0.049	+27.7	Manganese star	
β Ori *A*	13.6	−08 13	0.14v	−0.04	B8 Ia	−.003	−7.1	900	0.001	*+20.7*	Irr.? *R* 0.08–0.20, *B* 6.65^m 9″	***Rigel***
α Aur	15.2	+45 59	0.05	+0.80	G8 III: +F	0.073	−0.6	45	0.435	*+30.2*		***Capella***
η Ori *AB*	23.5	−02 24	3.32v	−0.18	B0.5 V	0.004	−3.7	940	0.008	*+19.8*	Ecl. *R* 3.32–3.50, 8.0^d, *A* 3.59^m *B* 4.98^m 1″	
γ Ori	24.0	+06 20	1.64	−0.23	B2 III	0.026	−4.2	470	0.015	+18.2		*Bellatrix*
β Tau	25.0	+28 36	1.65	−0.13	B7 III	0.018	−3.2	300	0.178	+08.0		*Elnath*
β Lep *A*	27.4	−20 47	2.81	+0.82	G5 III	0.014	+0.1	113	0.090	−13.5	*B* 9.4^m 3″	
δ Ori *A*	31.0	−00 19	2.20v	−0.20	O9.5 II	0.004	−6.1	1500	0.002	*+22.0*	Ecl. *R* 2.20–2.35 5.7^d, B 6.74^m 53″	
α Lep	31.8	−17 51	2.58	+0.22	F0 Ib	0.002	−4.6	900	0.006	+24.7		
λ Ori *AB*	34.1	+09 55	3.40	−0.18	O8 III	0.006	−5.1	1800	0.006	+33.5	*A* 3.56^m *B* 5.54^m 4″ *C* 10.92^m 29″	
ι Ori *AB*	34.5	−05 56	2.76	−0.24	O9 III	0.021	−6.1	2000	0.005	*+27.6*	*A* 2.78^m *B* 7.31^m 11″	
ε Ori	35.2	−01 13	1.70	−0.19	B0 Ia	−.007	−6.8	1600	0.000	+26.1		*Alnilam*
ζ Tau	36.5	+21 08	3.07:	−0.13:	B2 III:p	−.002	−4.2	940	0.023	*+22.8*	Shell star	
α Col *A*	39.0	−34 05	2.64	−0.11	B7 IV	−.005	−0.6	140	0.026	+35	*B* 12^m 12″	*Phact*
ζ Ori *AB*	39.7	−01 57	1.79	−0.22	O9.5 Ib	0.022	−6.6	1600	0.004	+18.1	*A* 1.91^m *B* 4.05^m 3″	*Alnitak*
κ Ori	46.8	−09 41	2.06	−0.17	B0.5 Ia	0.009	−6.9	2100	0.004	+20.6		
β Col	50.2	−35 47	3.12	+1.16	K1.5 III	0.023	+0.0	140	0.402	+89.4		
α Ori	54.0	+07 24	0.41v	+1.87:	M2 Iab	0.005	−5.6	520	0.028	*+21.0*	Irr.? *R* 0.06:–0.75:^{m}	***Betelgeuse***
β Aur	58.0	+44 57	1.86	+0.06	A2 V	0.037	−0.3	88	0.051	*−18.2*		*Menkalinan*
θ Aur *AB*	58.4	+37 13	2.65v	−0.07	B9.5pv	0.018	+0.1	108	0.097	+29.3	Silicon star *A* 2.67^m *B* 7.14^m 3″, var., 1.4^d	
η Gem *A*	06 13.7	+22 31	3.33v	+1.58	M3 III	0.013	−0.6	200	0.066	*+19.0*	*R* 0.27^m, *B* 6.70^m 1″	
ζ CMa	19.6	−30 03	3.04	−0.18	B2.5 V	−.003	−2.4	390	0.004	*+32.2*		
μ Gem	21.7	+22 32	2.92v	+1.63	M3 III	0.021	−0.6	160	0.129	+54.8	*R* 0.14^m	
β CMa	21.8	−17 56	1.96v	−0.24	B1 II–III	0.014	−4.8	750	0.004	*+33.7*	β CMa type variable, 0.25^d	
α Car	23.5	−52 41	−0.72	+0.16	F0 Ib–II	0.018	−3.1	98	0.025	+20.5		***Canopus***
γ Gem	36.6	+16 25	1.93	0.00	A0 IV	0.031	−0.6	105	0.066	*−12.5*		*Alhena*

Star	R.A. 1980	Dec.	V	$B–V$	Type	π	M_V	D	μ	R		
	h m	° ′				″		l.y.	″	km/s		
ν Pup	06 37.1	−43 11	3.19	−0.10	B8 III		−3.2	620	0.010	+28.2		
ε Gem	42.7	+25 09	3.00	+1.39	G8 Ib	0.009	−4.6	1080	0.016	+09.9		
ξ Gem	44.2	+12 55	3.38	+0.43	F5 IV	0.051	+1.9	64	0.224	+25.3		
α CMa *A*	44.2	−16 42	−1.47	+0.01	A1 V	0.375	+1.45	8.7	1.324	*−07.6*	*B* 8.66^m 1980.0: 10.0″, P.A. 46°	***Sirius***
α Pic	48.2	−61 55	3.27	+0.21	A7 Vn		+2.1	57	0.272	+20.6		
τ Pup	49.5	−50 36	2.92	+1.21	K1 III		+0.1	124	0.079	*+36.4*		
ε CMa *A*	57.8	−28 57	1.48:	−0.18:	B2 II		−5.1	680	0.004	+27.4	*B* 7.5^m 8″	***Adhara***
o² CMa	07 02.2	−23 48	3.02	−0.09	B3 Ia		−7.1	3400	0.000	+48.4		
δ CMa	07.6	−26 22	1.85	+0.65	F8 Ia	−.018	−7.1	2100	0.005	+34.3		
L_2 Pup	12.9	−44.37			M5e–M6e	0.016	−3.1	650	0.342	+53.0	LP, *R* 3.4–6.2, 141^d	
π Pup	16.5	−37 04	2.70:	+1.63:	K3 Ib	0.023	−0.3	140	0.008	+15.8		
η CMa	23.3	−29 15	2.46	−0.08	B5 Ia		−7.1	2700	0.008	+41.1		
β CMi	26.2	+08 20	2.91	−0.09	B7 V	0.020	−1.1	210	0.065	+22		
σ Pup *A*	28.6	−43 15	3.24	+1.49	K5 III	0.013	−0.4	180	0.195	*+88.1*	*B* 9.4^m 22″	
α Gem *A*	33.3	+31 56	1.97	+0.00:	A1 V	0.072	+1.3	45	0.199	+06.0	} 2″, *B–V* +0.02, *C* 9.08v^m 73″	***Castor***
α Gem *B*	33.3	+31 56	2.95	+0.07:	A5m	0.072	+2.3	45	0.199	*−01.2*		
α CMi *A*	38.2	+05 17	0.37	+0.41	F5 IV–V	0.288	+2.7	11.3	1.250	*−03.2*	*B* 10.7^m 4″	***Procyon***
β Gem	44.1	+28 05	1.16	+1.02	K0 III	0.093	+1.0	35	0.625	+03.3		***Pollux***
ξ Pup	48.4	−24 50	3.34	+1.23	G3 Ib	−.003	−4.6	1240	0.005	*+02.7*		
χ Car	56.2	−52 56	3.48	−0.18	B3 IVp		−2.1	430	0.039	+19.1		
ζ Pup	08 02.9	−39.57	2.23	−0.26	O5 Iaf		−7.1	2400	0.033	−24		
ρ Pup	06.7	−24 15	2.80v	+0.42	F6 IIp	0.031	+0.3:	105:	0.098	+46.6	Var. *R* 2.72–2.87, 0.14^d	
γ Vel *A*	08.9	−47 18	1.83	−0.26	WC8		−4.1	520	0.011	+35	*B* 4.31^m 41″	
ε Car	22.1	−59 26	1.90:	+1.30:	K3:III+B2:V		−3.1:	340	0.030	+11.5		***Avior***
o UMa *A*	28.6	+60 47	3.37	+0.83	G5 III	0.004	+0.1	150	0.171	+19.8	*B* 15^m 7″	
δ Vel *AB*	44.2	−54 38	1.95	+0.05	A2 V	0.043	+0.2	76	0.086	+02.2	*A* 2.0^m *B* 5.1^m 3″ *CD* 10^m 69″	
ε Hya *ABC*	45.7	+06 30	3.39	+0.68	G0:IV comp.	0.010	+0.6	140	0.198	*+36.4*	*A* 3.7^m *B* 5.2^m 0.2″ 15^y, *C* 6.8^m 3″ *D* 12^m 20″	
ζ Hya	54.3	+06 02	3.11	+1.00	K0 II–III	0.029	−1.1	220	0.101	+22.8		
ι UMa *A*	57.9	+48 07	3.12	+0.19	A7 V	0.066	+2.2	49	0.505	+12.2	*BC* 10.8^m 4″	

Star	R.A. 1980	Dec.	V	$B–V$	Type	π	M_V	D	μ	R		
	h m	° ′				″		l.y.	″	km/s		
λ Vel	09 07.3	−43 21	2.24	+1.64:	K4 Ib–IIa	0.015	−4.6	750	0.026	+18.4		*Suhail*
a Car	10.5	−58 52	3.43	−0.17	B2 IV–V		−2.9	590	0.028	*+23.3*		
β Car	13.0	−69 38	1.67	+0.01	A1 III	0.038	−0.4	86	0.183	−05		*Miaplacidus*
ι Car	16.6	−59 11	2.25	+0.17	A9 Ib		−4.6	750	0.019	+13.3		
α Lyn	19.9	+34 29	3.17	+1.54	M0 III	0.021	−0.5	180	0.217	+37.6		
κ Vel	21.5	−54 56	2.49	−0.20	B2 IV–V	0.007	−3.4	470	0.012	*+21.9*		
α Hya	26.6	−08 35	1.98	+1.44	K4 III	0.017	−0.3	94	0.034	−04.3		*Alphard*
N Vel	30.6	−56 57	3.19	+1.56	K5 III	0.015	−0.4	170	0.036	−13.9		
θ UMa *A*	31.5	+51 46	3.12	+0.46	F6 IV	0.052	+1.8	63	1.094	+15.4	*B* 14^m 5″	
ε Leo	44.7	+23 51	2.99	+0.81	G0 II	0.002	−2.1	340	0.048	+05.0		
l Car	44.7	−62 26	4.1		G8 Ia	0.019	−5.5	2700	0.016	*+04.0*	Cep. max. 3.4^m min. 4.8^m, 35.52^d	
υ Car *AB*	46.6	−64 59	2.95	+0.26	A8 Ib	0.020	−2.1	340	0.012	+13.6	*A* 3.02^m *B* 6.03^m 5″	
α Leo *A*	10 07.3	+12 04	1.36	−0.11	B7 V	0.039	−0.7	84	0.248	+03.5	*B* 8.1^m 177″	***Regulus***
ω Car	13.2	−69 56	3.33	−0.08	B8 III		−1.5	300	0.029	*+04*		
ζ Leo	15.7	+23 31	3.46	+0.30	F0 III	0.009	+0.5	130	0.023	−15.0		
λ UMa	15.9	+43 01	3.45	+0.03	A2 IV	−.010	+0.1	150	0.170	+18.3		
q Car	16.4	−61 14	3.41v	+1.55	K3 Ib–II	0.018	−4.6	1300	0.023	+08.6	Var. *R* 3.38–3.44	
γ Leo *AB*	18.8	+19 57	1.99	+1.13	K0 IIIp	0.019	+0.1	90	0.350	−36.6	*A* 2.29^m *B* 3.54^m 4″	
μ UMa	21.1	+41 36	3.05	+1.55	M0 III	0.031	+0.5	105	0.086	*−20.5*		
p Car	31.4	−61 35	3.30v	−0.11	B4 Vne		−2.3	430	0.021	+26.0	Var. *R* 3.22–3.39	
θ Car	42.2	−64 17	2.74	−0.22	B0.5 Vp		−4.0	710	0.018	+24		
μ Vel *AB*	45.9	−49 19	2.67	+0.89	G5 IIIa		+0.1	108	0.085	+06.9	*A* 2.7^m *B* 7.2^m 1″	
ν Hya	48.6	−16 05	3.12	+1.25	K3 III	0.022	−0.2	150	0.221	−01.0		
β UMa	11 00.6	+56 30	2.37	−0.03	A1 V	0.042	+0.5	78	0.087	−12.0		*Merak*
α UMa *AB*	02.5	+61 52	1.81	+1.06	K0 III	0.031	−0.7	105	0.138	−08.9	*A* 1.88^m *B* 4.82^m 1″	*Dubhe*
ψ UMa	08.6	+44 36	3.00	+1.14	K1 III		+0.0	130	0.072	−03.8		
δ Leo	13.0	+20 38	2.57	+0.13	A4 V	0.040	+0.6	82	0.201	−20.6		
θ Leo	13.2	+15 33	3.34	0.00	A2 V	0.019	+1.1	90	0.104	+07.8		
λ Cen	34.9	−62 54	3.15	−0.05	B9 III		−2.1	370	0.039	*−01*		
β Leo	48.0	+14 41	2.14	+0.09	A3 V	0.076	+1.5	43	0.511	−01		*Denebola*

Star	R.A. 1980	Dec.	V	B–V	Type	π	M_V	D	μ	R		
	h m	° ′				″		l.y.	″	km/s		
γ UMa	11 52.7	+53 49	2.44	0.00	A0 V	0.020	+0.2	90	0.094	−12.9		*Phecda*
δ Cen	12 07.3	−50 36	2.59v	−0.11:	B2 IVne		−2.7	370	0.042	+09	Var. *R* 2.56–2.62	
ε Crv	09.1	−22 30	3.00	+1.33	K3 III		−0.2	140	0.069	+04.9		
δ Cru	14.1	−58 38	2.81v	−0.23	B2 IV		−3.4	570	0.041	+26.4	Var *R* 2.78–2.84	
δ UMa	14.4	+57 09	3.30	+0.07	A3 V	0.052	+1.9	63	0.106	−12.9		*Megrez*
γ Crv	14.8	−17 25	2.59	−0.10	B8 III		−3.1	450	0.163	−04.2		*Gienah*
α Cru *A*	25.4	−62 59	1.39	−0.25	B0.5 IV		−3.9	370	0.042	*−11.2*		
α Cru *B*	25.4	−62 59	1.86	−0.25	B1 V		−3.4	370	0.042	*−00.6*	} 5″, *C* 4.90^m 89″	***Acrux***
δ Crv *A*	28.8	−16 24	2.97	−0.04	B9.5 V	0.018	+0.1	124	0.255	+09	*B* 8.26^m 24″	
γ Cru	30.1	−57 00	1.69	+1.55	M4 III		−2.5	220	0.274	+21.3		*Gacrux*
β Crv	33.3	−23 17	2.66	+0.89	G5 III	0.027	+0.1	108	0.059	−07.7		
α Mus	36.0	−69 01	2.70v	−0.20	B2 IV–V		−2.9	430	0.037	*+10*	Var. *R* 2.66–2.73	
γ Cen *AB*	40.5	−48 51	2.17	+0.00	A0 IV	0.006	−0.5	160	0.197	−07.5	*A* 2.9^m *B* 2.9^m 2″	
γ Vir *AB*	40.6	−01 20	2.76	+0.34	F0 V	0.101	+3.5	32	0.567	−19.7	*A* 3.50^m *B* 3.52^m 4″	
β Mus *AB*	45.0	−68 00	3.06	−0.17:	B2 V		−2.1	470	0.041	+42	*A* 3.7^m *B* 4.0^m 1″	
β Cru	46.6	−59 35	1.28v	−0.25	B0.5 III		−4.6	490	0.049	+20.0	β CMa var., 0.25^d:	***Beta Crucis***
ε UMa	53.2	+56 04	1.79v	−0.03	A0pv	0.008	+0.2	68	0.113	−09.3	Chromium-europium star	*Alioth*
α CVn *A*	55.1	+38 26	2.90v	−0.10	B9.5pv	0.023	+0.1	118	0.238	*−03.3*	Silicon-europium star. *B* 5.61^m 20″	*Cor Caroli*
ε Vir	13 01.2	+11 05	2.83	+0.93	G9 II–III	0.036	+0.6	90	0.274	−14.0		
γ Hya	17.8	−23 04	2.98	+0.92	G8 III	0.021	+0.3	113	0.086	−05.4		
ι Cen	19.5	−36 36	2.76	+0.05	A2 V	0.046	+1.1	71	0.351	+00.1		
ζ UMa *A*	23.1	+55 02	2.26	+0.02	A2 V	0.037	+0.1	88	0.127	*−05.6*	*B* 3.94^m 14″ (Alcor, 708″)	*Mizar*
α Vir	24.1	−11 03	0.91v	−0.24	B1 V	0.021	−3.3	220	0.054	*+01.0*	Ecl. *R* 0.91–1.01, 4.0^d, β CMa var.,	***Spica***
ζ Vir	33.7	−00 30	3.37	+0.10	A3 Vn	0.035	+1.1	93	0.287	−13.2		
ε Cen	38.6	−53 22	2.33v	−0.23	B1 III		−3.9	570	0.033	+05.6	β CMa var., 0.17^d	
η UMa	46.8	+49 25	1.87	−0.20	B3 V	0.004	−2.1	210	0.123	−10.9		*Alkaid*
ν Cen	48.3	−41 35	3.42	−0.22	B2 IV		−3.4	750	0.037	*+09.0*		
μ Cen	48.4	−42 23	3.12v	−0.13:	B2 V:pne		−2.7	470	0.032	+12.6	Var. *R* 3.08–3.17	
η Boo	53.8	+18 30	2.69	+0.59	G0 IV	0.102	+2.7	32	0.370	*+01.0*		
ζ Cen	54.3	−47 12	2.56	−0.23:	B2.5 IV		−3.4	520	0.076	*+06.5*		

Star	R.A. 1980	Dec.	V	$B-V$	Type		π	M_V	D	μ	R		
	h m	° ′					″		l.y.	″	km/s		
β Cen *AB*	14 02.4	−60 16	0.63v	−0.23:	B1	III	0.016	−5.2	490	0.035	*−12*	*A* 0.7ᵐ *B* 3.9ᵐ 1″, β CMa var.	***Hadar***
π Hya	05.3	−26 35	3.25	+1.13	K2	III	0.039	+1.2	84	0.156	+27.2		
θ Cen	05.5	−36 17	2.04	+1.03	K0	IIIb	0.059	+0.9	55	0.738	+01.3		*Menkent*
α Boo	14.8	+19 17	−0.06	+1.23	K2	IIIp	0.090	−0.3	36	2.284	−05.2		***Arcturus***
γ Boo	31.3	+38 24	3.05	+0.19	A7	III	0.016	+0.2	118	0.186	−35.5		
η Cen	34.2	−42 04	2.39v	−0.21	B1.5	V:ne		−3.0	390	0.049	−00.2	Var, *R* 2.33–2.45	
α Cen *A*	38.4	−60 46	0.01	+0.68	G2	V	.751	+4.39	4.3	3.676	−24.6	22″	***Rigil Kentaurus***
α Cen *B*	38.4	−60 46	1.40:	+0.73:	K4	V		+5.8	4.3		−20.7		
α Lup	40.7	−47 19	2.32v	−0.22	B1	V		−3.3	430	0.033	*+07.3*	β CMa var., 0.26ᵈ	
α Cir *AB*	40.9	−64 53	3.18	+0.25	A8p		0.049	+1.6	66	0.308	+07.4	Strontium star. *A* 3.19ᵐ *B* 8.61ᵐ 16″	
ε Boo *AB*	44.1	+27 09	2.37	+0.96	K1:	III:+A	0.013	+0.0	103	0.051	−16.5	*A* 2.47ᵐ *B* 5.04ᵐ 3″	
α Lib *A*	49.8	−15 54	2.76	+0.15	A3m		0.049	+1.2	66	0.130	−10	*B* 5.15ᵐ 231″	*Zubenelgenubi*
β UMi	50.8	+74 14	2.07	+1.47	K4	III	0.031	−0.5	105	0.033	+16.9		*Kochab*
β Lup	57.3	−43 03	2.69	−0.23	B2	IV		−3.4	540	0.066	−00.3		
κ Cen	57.8	−42 01	3.15	−0.21	B2	V		−2.7	470	0.033	+09.1		
β Boo	15 01.2	+40 28	3.48	+0.95	G8	III	0.022	+0.3	140	0.059	−19.9		
σ Lib	02.9	−25 12	3.31	+1.65	M4	III	0.056	+2.0:	58:	0.089	−04.3		
ζ Lup *A*	10.8	−52 01	3.42	+0.90:	G8	III	0.036	+1.2	90	0.135	−09.7	*B* 7.8ᵐ 71″	
δ Boo *A*	14.7	+33 24	3.47	+0.95	G8	III	0.028	+0.3	140	0.148	−12.2	*B* 7.84ᵐ 105″	
β Lib	15.9	−09 18	2.61	−0.11	B8	V	−.012	−0.6	140	0.101	−35.2		
γ TrA	17.1	−68 36	2.89	+0.01	A0	IV	0.005	+0.2	113	0.067	−06	Europium star	
δ Lup	20.1	−40 34	3.21v	−0.23	B2	IV		−3.4	680	0.032	+02	β CMa var., 0.165ᵈ	
γ UMi	20.8	+71 54	3.04	+0.06	A3	II–III	−.005	−1.5	270	0.026	*−03.9*		
ι Dra	24.5	+59 02	3.28	+1.18	K2	III	0.032	+0.8	102	0.012	−11.0		
γ Lup *AB*	33.8	−41 06	2.80	−0.22	B2	Vn		−2.7	570	0.037	*+06*	*A* 3.5ᵐ *B* 3.7ᵐ 1″	
α CrB	33.8	+26 47	2.23v	−0.02	A0	V	0.043	+0.4	76	0.154	*+01.7*	Ecl. *R* 0.11ᵐ, 17.4ᵈ	*Alphecca*
α Ser	43.3	+06 29	2.65	+1.17	K2	III	0.046	+1.0	71	0.139	+02.9		
β TrA	53.4	−63 22	2.84	+0.28:	F0	IV	0.078	+2.3	42	0.448	−00.3		
π Sco	57.6	−26 04	2.92	−0.19	B1	V	0.005	−3.3	570	0.034	*−03*		
η Lup *AB*	58.8	−38 21	3.40	−0.23	B2.5	IV		−2.7	570	0.042	+07	*A* 3.47ᵐ *B* 7.70ᵐ 15″	
δ Sco	59.2	−22 34	2.34	−0.13	B0	V		−4.0	590	0.032	−14		*Dschubba*

Star	R.A. 1980	Dec.	V	$B-V$	Type	π	M_V	D	μ	R		
	h m	° ′				″		l.y.	″	km/s		
β Sco *AB*	16 04.3	−19 45	2.65	−0.09	B0.5 V	0.004	−3.7	650	0.027	*−01.0*	*A* 2.78ᵐ *B* 5.04ᵐ 1″, *C* 4.93ᵐ 14″	
δ Oph	13.3	−03 37	2.72	+1.59	M1 III	0.029	−0.5	140	0.156	−19.9		
ε Oph	17.2	−04 39	3.22	+0.97	G9 III	0.036	+1.0	90	0.089	−10.3		
σ Sco *A*	20.0	−25 32	2.86v	+0.14	B1 III		−4.4	570	0.030	*+02.5*	β CMa *R* 2.82–2.90, 0.25ᵈ, *B* 8.49ᵐ 20″	
η Dra *A*	23.7	+61 33	2.71	+0.92	G8 III	0.043	+0.9	76	0.062	−14.3	*B* 8.7ᵐ 6″	
α Sco *A*	28.2	−26 23	0.92v	+1.84	M1.5Iab +B2.5V	0.019	−5.1	520	0.029	−03.2	*A* 0.86ᵐ–1.02ᵐ *B* 5.07ᵐ 3″	***Antares***
β Her	29.3	+21 32	2.78	+0.92	G8 III	0.017	+0.3	103	0.105	*−25.5*		
τ Sco	34.6	−28 10	2.85	−0.25	B0 V		−4.0	750	0.030	−00.7		
ζ Oph	36.1	−10 31	2.57	+0.00	O9.5 V	−.007	−4.3	520	0.022	*−19*		
ζ Her *AB*	40.6	+31 38	2.81	+0.64	G0 IV	0.110	+3.1	30	0.608	*−69.9*	*A* 2.91ᵐ *B* 5.46ᵐ 1″	
η Her	42.2	+38 58	3.46	+0.92	G7 III–IV	0.053	+2.1	62	0.097	+08.3		
α TrA	46.5	−68 60	1.93	+1.43	K2 Ib	0.024	−0.1	82	0.044	−03.6		*Atria*
ε Sco	48.8	−34 16	2.28	+1.16	K2 IIIb	0.049	+0.7	66	0.664	−02.5		
μ¹ Sco	50.5	−38 01	2.99v	−0.20	B1.5 IV+B		−3.0	520	0.033	*−25*	Ecl. *R* 2.99–3.09, 1.4ᵈ	
κ Oph	56.8	+09 25	3.18	+1.15	K2 III	0.026	−0.1	150	0.293	−55.6		
ζ Ara	56.9	−55 57	3.12	+1.61	K4 III	0.036	+0.9	90	0.042	−06.0		
ζ Dra	17 08.7	+65 44	3.20	−0.12	B6 III	0.017	−3.2	620	0.026	−14.1		
η Oph *AB*	09.3	−15 42	2.43	+0.06	A2.5 V	0.047	+1.4	69	0.097	−00.9	*A* 3.0ᵐ *B* 3.4ᵐ 1″	*Sabik*
η Sco	10.7	−43 13	3.33	+0.38	F2 III	0.063	+2.3	52	0.293	−28.4		
α Her *AB*	13.8	+14 24	3.10v	+1.41	M5 II	−.007	−2.3	410	0.032	−33.1	*A* 3.2ᵐ ± 0.3 *B* 5.4ᵐ 5″	*Ras-Algethi*
δ Her	14.2	+24 51	3.14	+0.09	A3 IV	0.034	+0.8	96	0.164	−41		
π Her	14.3	+36 49	3.13	+1.43	K3 II	0.020	−2.4	410	0.029	−25.7		
θ Oph	20.8	−24 59	3.29v	−0.22	B2 IV		−3.4	710	0.025	*−03.6*	β CMa var., 0.14ᵈ	
β Ara	23.6	−55 31	2.90:	+1.45:	K1.5 Ib	0.026	−4.6	1030	0.035	−00.4		
γ Ara *A*	23.8	−56 22	3.32	−0.16:	B1 Ib		−3.3	680	0.017	−04	*B* 10ᵐ 18″	
υ Sco	29.4	−37 16	2.71	−0.22	B2 IV		−3.4	540	0.039	*+07*		
β Dra *A*	29.9	+52 20	2.77	+0.96	G2 II	0.009	−2.1	310	0.019	−20.0	*B* 11.49ᵐ 4″	
α Ara	30.3	−49 52	2.95	−0.18:	B2.5 V		−2.4	390	0.083	*−02*		
λ Sco	32.3	−37 05	1.60v	−0.24	B1.5 IV		−3.3	310	0.031	00	β CMa var., 0.21ᵈ	*Shaula*
α Oph	34.0	+12 35	2.09	+0.16	A5 III	0.056	+0.8	58	0.260	+12.7		*Rasalhague*
θ Sco	35.9	−42 59	1.86	+0.39	F0 II	0.020	−4.6	650	0.012	+01.4		

Star	R.A. 1980	Dec.	V	$B–V$	Type	π	M_V	D	μ	R	
	h m	° ′				″		l.y.	″	km/s	
κ Sco	17 41.1	−39 01	2.39v	−0.21	B1.5 III		−3.4	470	0.031	*−10*	β CMa var., 0.20[d]
β Oph	42.5	+04 35	2.77	+1.16	K2 III	0.023	−0.1	124	0.160	−12.0	
μ Her *A*	45.7	+27 45	3.42	+0.75	G5 IV	0.108	+3.6	30	0.811	−15.6	*BC* 9.78[m] 33″
$ι^1$ Sco	46.2	−40 06	3.02	+0.49	F2 Ia	0.013	−7.1	3400	0.004	*−27.6*	
G Sco	48.4	−37 02	3.21	+1.18	K2 III	0.032	+0.7	102	0.064	+24.7	
γ Dra	56.1	+51 29	2.21	+1.52	K5 III	0.017	−0.4	108	0.026	−27.6	*Eltanin*
ν Oph	58.0	−09 47	3.32	+1.00	G9 III	0.015	+0.2	140	0.118	+12.4	
γ Sgr	18 04.5	−30 26	2.97	+1.00	K0 III	0.018	+0.1	124	0.200	*+22.1*	
η Sgr *A*	16.3	−36 47	3.12	+1.55	M3 III	0.038	+1.1:	86:	0.218	+00.5	*B* 10[m] 4″
δ Sgr	19.7	−29 50	2.71	+1.39	K2.5 IIIa	0.039	+0.7	84	0.050	−20.0	
η Ser	20.2	−02 54	3.23	+0.94	K0 III–IV	0.054	+1.9	60	0.894	+08.9	
ε Sgr	22.9	−34 24	1.81	−0.02	B9.5 III	0.015	−1.1	124	0.135	−11	*Kaus Australis*
λ Sgr	26.7	−25 27	2.80	+1.05	K1 III	0.046	+1.1	71	0.194	−43.3	
α Lyr	36.2	+38 46	0.04	0.00	A0 V	0.123	+0.5	26.5	0.345	−13.9	***Vega***
φ Sgr	44.4	−27 01	3.20	−0.11	B8.5 II–III		−3.1	590	0.052	+21.5	
β Lyr *A*	49.4	+33 21	3.38v	−0.05:	B5pe shell+A	−.011	−4.6	1300	0.007	*−17.8*	Ecl. *R* 3.38–4.36, 12.9[d], *B* 7.8[m] 46″
σ Sgr	54.0	−26 19	2.12:	−0.21	B2.5 V		−2.7	300	0.059	−11	*Nunki*
$ξ^2$ Sgr	56.5	−21 07	3.51	+1.18:	K1 III	0.006	+0.0	160	0.035	−19.9	
γ Lyr	58.2	+32 40	3.25	−0.05	B9 III	0.011	−2.1	370	0.007	−21.5	
ζ Sgr *AB*	19 01.3	−29 54	2.61	+0.08	A3 IV	0.020	+0.1	140	0.020	+22	*A* 3.3[m] *B* 3.5[m] < 1″
ζ Aql *A*	04.5	+13 50	2.99	+0.01	A0 V:nn	0.036	+0.8	90	0.101	−26.3	*B* 12[m] 5″
λ Aql	05.2	−04 55	3.44	−0.10	B9 V:n	0.025	−0.1	160	0.092	−14	
τ Sgr	05.7	−27 42	3.30	+1.18	K1.5 III	0.038	+1.2	86	0.261	*+45.4*	
π Sgr *ABC*	08.6	−21 03	2.89	+0.35	F2 II–III	0.016	−0.7	250	0.040	−09.8	*A* 3.7[m] *B* 3.8[m] *C* 6.0[m] < 1″
δ Dra	12.5	+67 38	3.06	+1.00	G9 III	0.028	+0.2	124	0.130	+24.8	
δ Aql	24.5	+03 04	3.38	+0.31	F0 IV	0.062	+2.3	53	0.267	*−29.9*	
β Cyg *A*	29.9	+27 55	3.07	+1.12	K3 II:+B:	0.004	−2.4	410	0.009	−24.0	*B* 5.11[m] 35″ *Albireo*
δ Cyg *AB*	44.3	+45 05	2.87	−0.03	B9.5 III	0.021	−1.7	270	0.060	−21	*A* 2.91[m] *B* 6.44[m] 2″
γ Aql	45.3	+10 33	2.72	+1.52	K3 II	0.006	−2.4	340	0.012	−02.1	
α Aql	49.8	+08 49	0.77	+0.22	A7 IV–V	0.198	+2.2	16.5	0.658	−26.3	***Altair***

Star	R.A. 1980	Dec.	V	$B-V$	Type	π	M_V	D	μ	R	
	h m	° ′				″		l.y.	″	km/s	
θ Aql	20 10.3	−00 52	3.24	−0.07	B9.5 III	0.008	−1.7	330	0.034	*−27.3*	
β Cap *A*	19.9	−14 51	3.06	+0.76	K2III+A5:V	0.005	+0.1	130	0.039	−18.9	Type gK0: + late B; *B* 5.97ᵐ 205″
γ Cyg	21.5	+40 11	2.22	+0.66	F8 Ib	−.006	−4.6	750	0.001	−07.5	
α Pav	24.1	−56 48	1.95	−0.20	B2.5 V		−2.9	310	0.087	*+02.0*	*Peacock*
α Ind	36.2	−47 21	3.11	+1.00	K0 III CN-1	0.039	+1.1	84	0.082	−01.1	
α Cyg	40.7	+45 12	1.26	+0.09	A2 Ia	−.013	−7.1	1600	0.003	*−04.6*	***Deneb***
β Pav	43.2	−66 17	3.45	+0.16	A7 III	0.026	−0.1	160	0.046	+09.8	
η Cep	44.9	+61 45	3.41	+0.92	K0 IV	0.071	+2.7	46	0.825	−87.3	
ε Cyg	45.4	+33 53	2.46	+1.03	K0 III	0.044	+0.7	74	0.481	*−10.3*	
ζ Cyg	21 12.1	+30 08	3.19	+1.00	G8 II	0.021	−2.2	390	0.056	+17.4	
α Cep	18.2	+62 31	2.44	+0.24	A7 IV–V	0.063	+1.4	52	0.156	−10	*Alderamin*
β Cep	28.4	+70 28	3.15v	−0.22v	B2 III	0.005	−4.2	980	0.014	*−03.1*	β CMa *R* 3.14–3.16, 0.19ᵈ
β Aqr	30.5	−05 40	2.86	+0.82	G0 Ib	0.000	−4.6	1030	0.017	+06.5	
ε Peg *A*	43.2	+09 48	2.38	+1.55	K2 Ib	−.005	−4.6	780	0.025	+04.7	*B* 11ᵐ 82″ *Enif*
δ Cap	45.9	−16 13	2.92v	+0.29	A6m	0.065	+2.0	50	0.392	*−00.2*	Var. *R* 2.88–2.95
γ Gru	52.7	−37 27	3.00	−0.10	B8 III	0.008	−3.1	540	0.102	−02.1	
α Aqr	22 04.7	−00 25	2.93	+0.96	G2 Ib	0.003	−4.6	1080	0.016	+07.5	
α Gru	06.9	−47 04	1.76	−0.14	B7 IV	0.051	+0.3:	64:	0.194	+11.8	*Al Na'ir*
ζ Cep	10.1	+58 06	3.36	+1.59	K1 Ib	0.019	−4.6	1240	0.015	*−18.4*	
α Tuc	17.1	−60 21	2.87	+1.40	K4 III	0.019	+1.5	62	0.079	*+42.2*	
δ Cep *A*	28.5	+58 19	3.96v	+0.66v	F5–G2 Ib	0.005	−4.0	1300	0.012	*−16.8*	Cep. *R* 3.51–4.42, 5.4ᵈ, *B* 6.19ᵐ 41″
ζ Peg	40.5	+10 44	3.40	−0.08:	B8 V	−.004	−0.6	210	0.077	+07	
β Gru	41.5	−46 59	2.17v	+1.59	M5 III	0.003	−2.5	280	0.134	+01.6	Var. *R* 2.11–2.23
η Peg	42.1	+30 07	2.95	+0.85	G8 II: + F?	−.002	−2.2	360	0.027	*+04.3*	
δ Aqr	53.6	−15 56	3.28	+0.08	A3 V	0.039	+1.2	84	0.047	+18.0	
α PsA	56.5	−29 44	1.15	+0.10	A3 V	0.144	+2.0	22.6	0.367	+06.5	***Fomalhaut***
β Peg	23 02.8	+27 58	2.5 v	+1.67	M2 II–III	0.015	−1.5	210	0.234	+08.7	Var. *R* 2.4–2.7 *Scheat*
α Peg	03.8	+15 05	2.50	−0.03	B9.5 III	0.030	−0.1	109	0.071	−03.5	*Markab*
γ Cep	38.5	+77 30	3.20	+1.02	K1 IV	0.064	+2.2	51	0.168	−42.4	

THE NEAREST STARS

By Alan H. Batten

The accompanying table lists all the stars known to be within a distance of just over 5 parsecs (or 17 light-years) from the Sun. The table is based on the list published by Prof. P. van de Kamp in the 1971 edition of *Annual Reviews of Astronomy and Astrophysics*, but has been further revised at his suggestion. There are five systems in this Table not listed by van de Kamp: two (L725-32 and B.D. 44°2051) have been included for several years now, the other three (G51-15, G208-44 and 45, and G9-38A and B) are all objects for which parallaxes have recently been determined with the 155 cm astrometric reflector of the U.S. Naval Observatory in Flagstaff, Arizona. One disadvantage of updating the list in this way is that it loses some of the homogeneity of van de Kamp's original. As more refined values of the parallaxes become available, the order of some of the stars in the list is likely to be changed, and some now included may be excluded. In particular, the last system in the list, G9-38, is just beyond the limit of 17 light-years. It has been included because it is an interesting system and an example of some of the surprises that may still be in store for us as faint nearby stars are examined with the powerful astrometric reflector. Moreover, its right to inclusion is no more in doubt than those of some other systems, notably Stein 2051 and B.D. 44°2051, above it in the list.

Successive columns of the table give the name of each star, its position for 1980, its annual parallax π, its distance in light years, its spectral type, its proper motion in seconds of arc per year (that is its apparent motion across the sky—nearby stars usually have large proper motions), its total space velocity W in km/s when known, its apparent magnitude V, and its absolute visual magnitude M_V. Spectral types have not yet been determined for the newest stars in the list: all of those stars are very red and they will probably be found to be of type M. Luminosity classes have not been given because all the stars are dwarfs or fainter. An *e* after the spectral type indicates that emission lines are visible in the spectrum; the prefix *wd* indicates a white dwarf or analogous object. Apparent magnitudes given to two decimals are photoelectric V magnitudes. Those given to one decimal are the best available visual magnitudes. The magnitudes of stars known to be variable are bracketed. A major change from earlier versions of the table is the substitution of the stars' absolute visual magnitudes for their luminosities relative to the Sun. To convert the new quantities to the old, one would have to take into account the bolometric corrections—poorly determined for very red stars—and convert the magnitudes to intensity ratios. The brightest star in the list, Sirius A, is about 23 times the Sun's luminosity, and the faintest, Wolf 359, is about 50,000 times less luminous than the Sun. Data like proper motion and space velocity are not given separately for the components of multiple systems, unless each component has a somewhat different motion. The space velocities and many of the magnitudes have been taken from Gliese's *Catalogue of Nearby Stars*.

Measuring the distances of stars is one of the most difficult and important jobs of an observational astronomer. As the Earth travels around the Sun each year, the positions of the nearer stars, against the background of the more distant ones, changes very slightly. This change is called *annual parallax*, and even for the nearest star to the Sun it is less than the apparent size of a penny at about 4 km distance. Ultimately all our knowledge of distances in the universe depends on our being able to measure these tiny apparent displacements accurately, for a relatively small sample of nearby stars. A graphic way of conveying the immense distances of stars is to express them in *light-years*. One light-year, about ten million million km, is the distance light travels in one year. The more useful technical unit is a *parsec*—the distance at which a star would have an annual parallax of one second of arc. One parsec is equal to about 3.26 light years. The distance of a star in parsecs is simply the reciprocal of its annual parallax expressed (as in the table) in seconds of arc.

The list contains 68 stars. Of these, 34 are single (including the Sun, whose planets are not counted); 28 are found in 14 double systems (including the pair G208-44 and 45), and 6 are found in 2 triple systems. In addition, there is evidence for unseen companions, that might be intermediate in mass between stars and planets, associated with seven of these stars. Note how nearly all the stars in the list are very faint cool stars of low mass. Highly luminous stars are very rare, and no giants or very hot massive stars are to be found in the solar neighbourhood.

Name	1980 α	1980 δ	π	D	Sp.	μ	W	V	M_v
	h m	° ′	″	l.y.		″	km/s		
Sun					G2			−26.72	+4.85
α Cen A	14 38	−60 46	0.760	4.3	G2	3.68	32	−0.01	4.39
B					K4			1.33	5.73
C	14 28	−62 36			M5e	3.85	29	11.05	15.45
Barnard's*	17 56	+04 36	.552	5.9	M5	10.61	140	9.54	13.25
Wolf 359	10 56	+07 10	.431	7.6	M8e	4.71	54	13.53	16.70
BD+36°2147*	11 03	+36 07	.402	8.1	M2e	4.78	102	7.50	10.52
Sirius A	6 44	−16 42	.377	8.6	A1	1.33	19	−1.46	1.42
B					*wd*A			8.7	11.6
Luy 726−8A	1 37	−18 04	.365	8.9	M5e	3.36	52	12.5	15.3
B					M5e		54	(13.0)	(15.8)
Ross 154	18 49	−23 50	.345	9.4	M5e	0.72	11	10.6	13.3
Ross 248	23 40	+44 04	.317	10.3	M6e	1.58	84	12.29	14.80
ε Eri	3 32	−09 32	.305	10.7	K2e	0.98	23	3.73	6.15
Luy 789−6	22 38	−15 28	.302	10.8	M7e	3.26	79	12.18	14.58
Ross 128	11 47	+00 58	.301	10.8	M5	1.37	25	11.10	13.49
61 Cyg A	21 06	+38 38	.292	11.2	K5e	5.22	105	5.22	7.55
B*					K7e			6.03	8.36
ε Ind	22 03	−56 52	.291	11.2	K8e	4.69	86	4.68	7.00
Procyon A	7 39	+05 17	.287	11.4	F5	1.25	21	0.37	2.66
B					*wd*F			10.7	12.99
Σ 2398 A	18 42	+59 36	.284	11.5	M4	2.28	39	8.90	11.17
B					M5			9.69	11.96
BD+43°44A	0 18	+43 54	.282	11.6	M1e	2.89	50	8.07	10.32
B					M6e		53	11.04	13.29
CD−36°15693	23 05	−35 59	.279	11.7	M2e	6.90	118	7.36	9.59
τ Ceti	1 43	−16 03	.273	11.9	G8p	1.92	36	3.50	5.68
G51−15	8 29	+26 51	.273	12.0		0.42		14.81	16.99
BD+5°1668*	7 27	+05 27	.266	12.2	M5	3.73	71	9.82	11.94
Luy 725−32	1 11	−17 06	.262	12.5	M5e	1.31	52	11.6	13.7
CD−39°14192	21 16	−38 58	.260	12.6	M0e	3.46	67	6.67	8.75
Kapteyn's	5 11	−44 59	.256	12.7	M0	8.89	293	8.81	10.85
Krüger 60A	22 27	+57 36	.254	12.8	M3	0.86	30	9.85	11.87
B					M4.5e			(11.3)	(13.3)
Ross 614A	6 28	−02 48	.249	13.1	M7e	0.99	30	11.07	13.05
B								14.8	16.8
BD−12°4523	16 30	−12 36	.249	13.1	M5	1.18	26	10.12	12.10
van Maanen's	0 48	+05 19	.234	13.9	*wd*G	2.95	59	12.37	14.22
Wolf 424A	12 33	+09 09	.229	14.2	M6e	1.75	37	13.16	14.96
B					M6e			13.4	15.2
G158−27	0 06	−07 38	.226	14.4		2.06		13.73	15.50
CD−37°15492	0 04	−37 27	.225	14.5	M4	6.08	130	8.63	10.39
BD+50°1725	10 10	+49 33	.217	15.0	K7e	1.45	40	6.59	8.27
CD−46°11540	17 28	−46 53	.216	15.1	M4	1.13		9.36	11.03
CD−49°13515	21 32	−49 11	.214	15.2	M1	0.81	20	8.67	10.32
CD−44°11909*	17 37	−44 17	.213	15.3	M5	1.16		11.2	12.8
G208−44	19 53	+44 21	.213	15.3		0.75		13.41	15.05
Luy 1159−16	1 59	+13 00	.212	15.4	M8e	2.08		12.27	13.90
BD+15°2620	13 44	+15 01	.208	15.7	M4e	2.30	56	8.50	10.09
G208−45	19 53	+44 21	.207	15.8	M5	0.63		13.99	15.57
BD+68°946	17 37	+68 22	.207	15.8	M4	1.33	36	9.15	10.73
Luy 145−141	11 44	−64 42	.206	15.9	*wd*	2.68		11.44	13.01
BD−15°6290	22 52	−14 22	.206	15.9	M5	1.16	28	10.17	11.74
o^2 Eri A	4 14	−07 41	.205	15.9	K1e	4.08	104	4.43	5.99
B					*wd*A			9.53	11.09
C					M4e			11.17	12.73
BD+20°2465*	10 19	+19 58	.202	16.1	M4e	0.49	16	9.43	10.96
BD+44°2051A	11 05	+43 36	.199	16.4	M2e	4.40	132	8.77	10.26
B					M8e			(14.5)	(16.0)
Altair*	19 49	+08 49	.196	16.6	A7	0.66	31	0.76	2.22
70 Oph A	18 05	+02 31	.195	16.7	K0e	1.13	28	4.22	5.67
B					K5e			6.0	7.5
AC+79°3888	11 46	+78 47	.194	16.8	M4	0.89	121	10.9	12.3
BD+43°4305*	22 46	+44 14	.193	16.9	M5e	0.83	20	10.2	11.6
Stein 2051A	4 30	+58 57	.192	17.0	M4	2.37		11.09	12.51
B					*wd*			12.44	13.86
G9−38A	8 57	+19 51	.190	17.2		0.89		14.06	15.45
B						0.79		14.92	16.31

*Suspected unseen companion.

DOUBLE AND MULTIPLE STARS

By Charles E. Worley

Many stars can be separated into two or more components by use of a telescope. The larger the aperture of the telescope, the closer the stars which can be separated under good seeing conditions. With telescopes of moderate size and good optical quality, and for stars which are not unduly faint or of large magnitude difference, the minimum angular separation in seconds of arc is given by 120/D, where D is the diameter of the telescope's objective in millimetres.

The following lists contain some interesting examples of double stars. The first list presents pairs whose orbital motions are very slow. Consequently, their angular separations remain relatively fixed and these pairs are suitable for testing the performance of small telescopes. In the second list are pairs of more general interest, including a number of binaries of short period for which the position angles and separations are changing rapidly.

In both lists the columns give, successively: the star designation in two forms; its right ascension and declination for 1980; the combined visual magnitude of the pair and the individual magnitudes; the apparent separation and position angle for 1984.0; and the period, if known. (The position angle is the angular direction of the fainter star from the brighter, measured counterclockwise from north.)

Many of the components are themselves very close visual or spectroscopic binaries. (Other double stars appear in the tables of Nearest Stars and Brightest Stars. For more information about observing these stars, see the articles by: J. Ashbrook in *Sky and Telescope*, **60**, 379 (1980); J. Meeus in *Sky and Telescope*, **41**, 21 and 89 (1971); and by C. E. Worley in *Sky and Telescope*, **22**, 73, 140 and 261 (1961). The latter two articles have been reprinted by Sky Publishing Corp., 49 Bay State Road, Cambridge, Mass. 02238 under the titles *Some Bright Visual Binary Stars* and *Visual Observing of Double Stars*, each $1.95 U.S.—Ed.)

Star		A.D.S.	R.A. 1980.0 h	m	Dec. 1980.0 °	′	Magnitudes comb.	A	B	P.A. 1984.0 °	Sep. 1984.0 ″	P (app.) years
λ	Cas	434	00	30.7	+54	26	4.9	5.5	5.8	184	0.6	640
α	Psc	1615	02	01.0	+02	40	4.0	4.3	5.3	278	1.7	720
33	Ori	4123	05	30.2	+03	16	5.7	6.0	7.3	27	1.8	—
OΣ	156	5447	06	46.3	+18	13	6.1	6.8	7.0	238	0.5	1100
Σ	1338	7307	09	19.7	+38	17	5.8	6.5	6.7	261	1.1	400
35	Com	8695	12	52.3	+21	21	5.1*	5.2	7.4	167	1.1	500
Σ	2054	10052	16	23.6	+61	44	5.6	6.0	7.2	355	1.1	—
ϵ^1	Lyr†	11635	18	43.7	+39	38	5.1	5.4	6.5	354	2.7	1200
ϵ^2	Lyr†	11635	18	43.7	+39	38	4.4	5.1	5.3	82	2.4	600
π	Aql	12962	19	47.7	+11	45	5.6	6.0	6.8	110	1.4	—
61	Cyg	14636	21	05.5	+38	34	4.8	5.2	6.0	147	29.5	722
OΣ	500	16877	23	36.5	+44	20	5.9	6.4	7.1	355	0.5	—
η	Cas	671	00	47.7	+57	44	3.5*	3.5	7.2	309	12.2	480
Σ	186	1538	01	54.8	+01	45	6.0	6.8	6.8	55	1.3	170
γ	And AB	1630	02	02.4	+42	16	2.1*	2.1	5.1	64	9.8	—
γ	And BC	1630	02	02.4	+42	16	5.1	5.5	6.3	107	0.6	61
OΣ	65	2799	03	49.2	+25	32	5.2	5.8	6.2	208	0.5	62
α	CMa	5423	06	44.3	−16	40	−1.4	−1.4	8.5	38	8.7	50
α	Gem	6175	07	33.3	+31	55	1.6	2.0	2.8	85	2.5	420
ζ	Cnc AB	6650	08	11.1	+17	43	5.0	5.6	5.9	249	0.7	60
ζ	Cnc AC	6650	08	11.1	+17	43	5.2	5.4	7.3	79	5.9	1150
σ^2	UMa	7203	09	08.6	+67	13	4.8*	4.8	8.2	0	3.4	1100
γ	Leo	7724	10	18.9	+19	57	1.8	2.1	3.4	124	4.3	620
ξ	UMa	8119	11	17.1	+31	39	3.8	4.3	4.8	94	2.5	60
γ	Vir	8630	12	40.7	−01	21	2.8	3.5	3.5	294	3.6	170
ζ	Boo	9343	14	40.1	+13	49	3.8	4.5	4.5	304	1.0	125
ξ	Boo	9413	14	50.4	+19	12	4.5	4.7	6.8	330	7.2	150
ζ	Her	10157	16	40.6	+31	38	2.8	2.9	5.5	116	1.4	35
τ	Oph	11005	18	01.9	−08	11	4.7	5.2	5.9	278	1.8	280
70	Oph	11046	18	04.5	+02	32	4.0	4.2	6.0	295	2.2	88
δ	Cyg	12880	19	44.4	+45	04	2.9*	2.9	6.3	231	2.4	830
4	Aqr	14360	20	50.4	−05	53	6.0	6.4	7.2	12	0.9	150
τ	Cyg	14787	21	13.9	+37	57	3.7	3.8	6.4	114	0.6	50
μ	Cyg	15270	21	43.2	+28	39	4.5	4.8	6.1	301	1.7	500
ζ	Aqr	15971	22	27.8	−00	08	3.6	4.3	4.5	218	1.8	850
Σ	3050	17149	23	58.5	+33	37	5.8	6.5	6.7	315	1.6	350

*There is a marked colour difference between the components.
†The separation of the two pairs of ε Lyr is 208″.

VARIABLE STARS

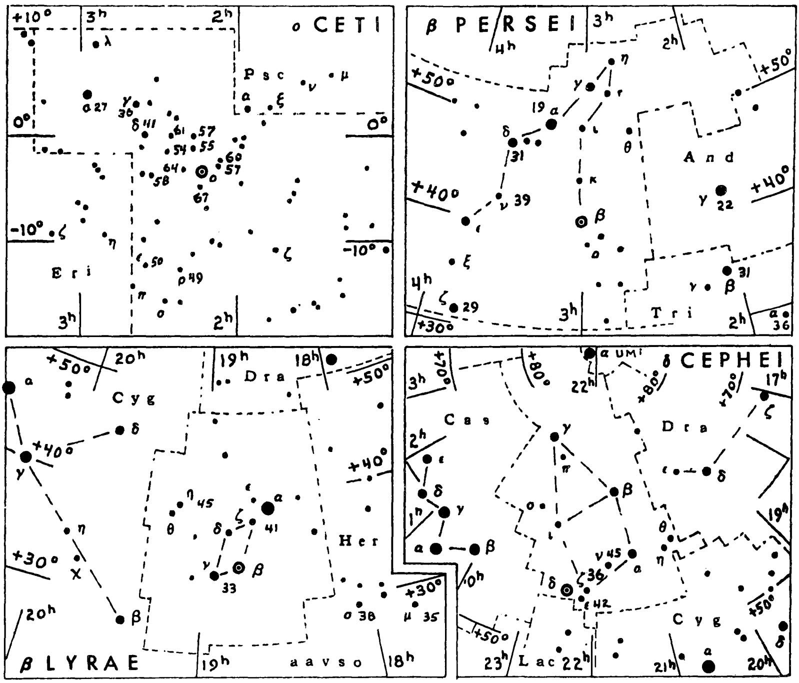
By Janet A. Mattei

Variable stars provide information about many stellar properties. Depending upon their type, variables can tell the mass, radius, temperature, luminosity, internal and external structure, composition, and evolution of stars. The systematic observation of variable stars is an area in which an amateur astronomer can make a valuable contribution to astronomy.

For beginning observers, charts of the fields of four different types of bright variable stars are printed below. On each chart, the magnitudes (with decimal point omitted) of several suitable comparison stars are shown. A brightness estimate of the variable is made using two comparison stars, one brighter, one fainter than the variable. The magnitude, date, and time of each observation are recorded. When a number of observations have been made, a graph of magnitude versus date may be plotted. The shape of this "light curve" depends on the type of variable. Further information about variable star observing may be obtained from the American Association of Variable Star Observers, 187 Concord Ave., Cambridge, Massachusetts 02138, U.S.A.

The first table on the next page is a list of long-period variables, brighter than magnitude 8.0 at maximum, and north of $-20°$. The first column (the Harvard designation of the star) gives the position for the year 1900: the first four figures give the hours and minutes of right ascension, the last two figures the declination in degrees (italicised for southern declinations). The column headed "Max." gives the mean maximum magnitude. The "Period" is in days. The "Epoch" gives the predicted date of the earliest maximum occurring this year; by adding multiples of the period to this epoch the dates of subsequent maxima may be found. These variables may reach maximum two or three weeks before or after the epoch and may remain at maximum for several weeks. This table is prepared using the observations of the American Association of Variable Star Observers.

The second table contains stars which are representative of some other types of variables. The data for the preparation of the predicted epoch of maximum and minimum are taken from *The General Catalog of Variable Stars*, 3rd ed., and its *Second Supplement*; for the eclipsing binaries (except β Lyr) and RR Lyrae variables from *Rocznik Astronomiczny Obserwatorium Krakowskiego 1983, International Supplement*; for β Lyr from *Acta Astronomica* 29, 393, 1979.



LONG-PERIOD VARIABLE STARS

Variable	Max. m_v	Per d	Epoch 1984	Variable	Max. m_v	Per d	Epoch 1984
001755 T Cas	7.8	445	Sept. 10	142539 V Boo	7.9	258	May 10
001838 R And	7.0	409	Nov. 28	143227 R Boo	7.2	223	June 7
021143 W And	7.4	397	July 15	151731 S CrB	7.3	361	Jan. 15
0214*03* o Cet	3.4	332	May 19	154639 V CrB	7.5	358	July 26
0228*13* U Cet	7.5	235	July 18	154615 R Ser	6.9	357	June 18
023133 R Tri	6.2	266	Feb. 14	160625 RU Her	8.0	484	June 16
043065 T Cam	8.0	374	Dec. 18	162119 U Her	7.5	406	Apr. 29
0455*14* R Lep	6.8	432	Sept. 26	1621*12* V Oph	7.5	298	Oct. 4
050953 R Aur	7.7	459	May 20	163266 R Dra	7.6	245	Feb. 29
054920 U Ori	6.3	372	Oct. 30	164715 S Her	7.6	307	Oct. 10
0617*02* V Mon	7.0	335	Sept. 29	1702*15* R Oph	7.9	302	May 8
065355 R Lyn	7.9	379	Aug. 11	171723 RS Her	7.9	219	May 22
070122aR Gem	7.1	370	Aug. 19	180531 T Her	8.0	165	Apr. 9
070310 R CMi	8.0	338	Jan. 16	181136 W Lyr	7.9	196	June 20
072708 S CMi	7.5	332	Aug. 6	183308 X Oph	6.8	334	Feb. 9
081112 R Cnc	6.8	362	Dec. 9	190108 R Aql	6.1	300	Jan. 30
081617 V Cnc	7.9	272	Aug. 14	1910*17* T Sgr	8.0	392	Dec. 29
084803 S Hya	7.8	257	May 13	1910*19* R Sgr	7.3	269	Mar. 19
0850*08* T Hya	7.8	288	Apr. 14	193449 R Cyg	7.5	426	Aug. 2
093934 R LMi	7.1	372	May 24	194048 RT Cyg	7.3	190	Jan. 21
094211 R Leo	5.8	313	Feb. 2	194632 χ Cyg	5.2	407	May 19
103769 R UMa	7.5	302	July 17	201647 U Cyg	7.2	465	Sept. 10
1214*18* R Crv	7.5	317	Aug. 25	2044*05* T Aqr	7.7	202	Mar. 11
122001 SS Vir	6.8	355	Jan. 15	210868 T Cep	6.0	390	Feb. 17
123160 T UMa	7.7	257	June 23	213753 RU Cyg	8.0	234	June 24
123307 R Vir	6.9	146	Jan. 14	230110 R Peg	7.8	378	Mar. 25
123961 S UMa	7.8	226	Mar. 13	230759 V Cas	7.9	228	Feb. 20
131546 V CVn	6.8	192	June 4	231508 S Peg	8.0	319	Sept. 6
1327*06* S Vir	7.0	378	May 7	2338*15* R Aqr	6.5	387	May 12
134440 R CVn	7.7	328	June 27	235350 R Cas	7.0	431	Feb. 28
142584 R Cam	7.9	270	May 20	2357*15* W Cet	7.6	351	Oct. 13

OTHER TYPES OF VARIABLE STARS

Variable	Max. m_v	Min. m_v	Type	Sp. Cl.	Period d	Epoch 1984 U.T.
005381 U Cep	6.7	9.8	Ecl.	B8+gG2	2.49307	Jan. 1.38*
025838 ρ Per	3.3	4.0	Semi R	M4	33–55, 1100	—
030140 β Per	2.1	3.3	Ecl.	B8+G	2.86731	—
035512 λ Tau	3.5	4.0	Ecl.	B3	3.952952	Jan. 3.37*
060822 η Gem	3.1	3.9	Semi R	M3	233.4	—
061907 T Mon	5.6	6.6	δ Cep	F7–K1	27.0205	Jan. 2.85
065820 ζ Gem	3.6	4.2	δ Cep	F7–G3	10.15082	Jan. 4.84
154428 R Cr B	5.8	14.8	R Cr B	cFpep		—
171014 α Her	3.0	4.0	Semi R	M5	50–130, 6 yrs.	—
1842*05* R Sct	5.0	7.0	RVTau	G0e-K0p	144	—
184633 β Lyr	3.4	4.3	Ecl.	B8	12.93599†	Jan. 5.09*
192242 RR Lyr	6.9	8.0	RR Lyr	A2–F1	0.566867	Jan. 1.56
194700 η Aql	3.5	4.3	δ Cep	F6–G4	7.176641	Jan. 1.86
222557 δ Cep	3.5	4.4	δ Cep	F5–G2	5.366341	Jan. 3.16

*Minimum.
†Changing period.

BRIEF DESCRIPTION OF VARIABLE TYPES

Variable stars are divided into four main classes: Pulsating and eruptive variables where variability is intrinsic due to physical changes in the star or stellar system; eclipsing binary and rotating stars where variability is extrinsic due to an eclipse of one star by another or the effect of stellar rotation. A brief and general description about the major types in each class is given below.

I. *Pulsating Variables*

Cepheids: Variables that pulsate with periods from 1 to 70 days. They have high luminosity and the amplitude of light variation ranges from 0.1 to 2 magnitudes. The prototypes of the group are located in open clusters and obey the well known period-luminosity relation. They are of F spectral class at maximum and G to K at minimum. The later the spectral class of a Cepheid the longer is its period. Typical representative: δ Cephei.

RR Lyrae Type: Pulsating, giant variables with periods ranging from 0.05 to 1.2 days with amplitude of light variation between 1 and 2 magnitudes. They are usually of A spectral class. Typical representative: RR Lyrae.

RV Tauri Type: Supergiant variables with characteristic light curve of alternating deep and shallow minima. The periods, defined as the interval between two deep minima, range from 30 to 150 days. The amplitude of light variation may be as much as 3 magnitudes. Many show long term cyclic variation of 500 to 9000 days. Generally the spectral classes range from G to K. Typical representative: R Scuti.

Long period—Mira Ceti variables: Giant variables that vary with amplitudes from 2.5 to 5 magnitudes or more. They have well defined periodicity, ranging from 80 to 1000 days. They show characteristic emission spectra of late spectral classes of M, C, and S. Typical representative: o Ceti (Mira).

Semiregular Variables: Giants and supergiants showing appreciable periodicity accompanied by intervals of irregularities of light variation.The periods range from 30 to 1000 days with amplitudes not more than 1 to 2 magnitudes in general. Typical representative: R Ursae Minoris.

Irregular Variables: Stars that at times show only a trace of periodicity or none at all. Typical representative: RX Leporis.

II. *Eruptive Variables*

Novae: Close binary systems consisting of a normal star and a white dwarf that increase 7 to 16 magnitudes in brightness in a matter of 1 to several hundreds of days. After the outburst, the star fades slowly until the initial brightness is reached in several years or decades. Near maximum brightness, the spectrum is generally similar to A or F giants. Typical representative: CP Puppis (Nova 1942).

Supernovae: Brightness increases 20 or more magnitudes due to a gigantic stellar explosion. The general appearance of the light curve is similar to novae. Typical representative: CM Tauri (Supernova of A.D. 1054 and the central star of the Crab Nebula).

R Coronae Borealis Type: Highly luminous variables that have non-periodic drops in brightness from 1 to 9 magnitudes, due to the formation of "carbon soot" in the stars' atmosphere. The duration of minima varies from a few months to years. Members of this group have F to K and R spectral class. Typical representative: R Coronae Borealis.

U Geminorum Type: Dwarf novae that have long intervals of quiescence at minimum with sudden rises to maximum. Depending upon the star, the amplitude of eruptions range from 2 to 6 magnitudes, and the duration between outbursts ten to thousands of days. Most of these stars are spectroscopic binaries with periods of few hours. Typical representative: SS Cygni.

Z Camelopardalis Type: Variables similar to U Gem stars in their physical and spectroscopic properties. They show cyclic variations interrupted by intervals of constant brightness (stillstands) lasting for several cycles, approximately one third of the way from maximum to minimum. Typical representative: Z Camelopardalis.

III. *Eclipsing Binaries*

Binary system of stars with the orbital plane lying near the line of sight of the observer. The components periodically eclipse each other, causing decrease in light in the apparent brightness of the system, as is seen and recorded by the observer. The period of the eclipses coincides with the period of the orbital motion of the components. Typical representative: β Persei (Algol).

IV. *Rotating Variables*

Rapidly rotating stars, usually close binary systems, which undergo small amplitude changes in light that may be due to dark or bright spots on their stellar surface. Eclipses may also be present in such systems. Typical representative: R Canum Venaticorum.

PHOTOELECTRIC PHOTOMETRY OBSERVING PROGRAM

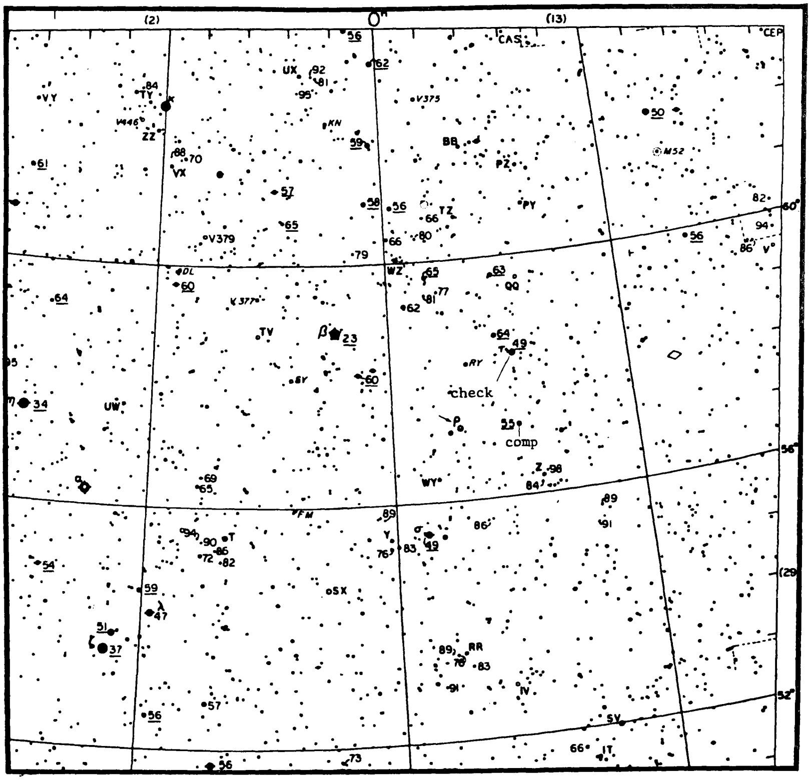
In recent years, advances in electronics and the availability of moderately priced photometers have made it possible for many observers to include photoelectric photometry in their programs. Valuable contributions can be made by systematic long-term (over months and years) photometric monitoring of variable stars, particularly stars with less than one magnitude of range of variation.

The American Association of Variable Star Observers (AAVSO) recently developed a photoelectric photometry observing program, to better monitor those stars with small amplitude. This program includes variable stars of all types – semiregular, irregular, symbiotic, eclipsing binary, RS Canum Venaticorum, R Coronae Borealis, RV Tauri, etc. – for the varied interest of the photometrists. The majority of the stars are bright, red variables with small amplitude, suitable for observing with 150 to 300 mm telescopes. Specially prepared charts with the variable and two carefully selected comparison stars marked are provided for each variable. The AAVSO has also prepared special instructions and forms for reporting photoelectric data. The observations received can be reduced for the observers by the AAVSO, and can be stored at the AAVSO headquarters on magnetic tape for future reference and use.

For this year's HANDBOOK, bright, circumpolar variable rho Cas has been selected from this program as a good candidate for beginner photometrists. This interesting variable, generally varying between visual magnitude 4.1 and 5.1, had a minimum from 1945 to 1947 when it faded to magnitude 6.2. Due to this one "known" minimum it has been classified as a possible R Coronae Borealis type of variable. Its optical and spectroscopic behavior, however, does not substantiate this classification and suggests a semiregular or irregular type of variability. Rho Cas needs photometric monitoring to determine its type of variability and to resolve its small amplitude, short-term variations. A chart of the field, with comparison and check stars identified, is printed on the next page. This variable does not have a significant extinction or gain setting problem and because of its position, it is observable all year by observers with good northern horizons.

Photoelectric photometry should be an enjoyable, challenging, and satisfying experience. Observers with small telescopes and non-ideal sites can still make valuable contributions monitoring bright, and relatively long period variables. Interested observers are invited to participate in the AAVSO Photoelectric Observing Program. Further information on the program, copies of the *AAVSO Photoelectric Photometry Chart Catalog* which lists stars in the program ($1.00 U.S.), and individual charts ($0.25 U.S.) may be obtained from the AAVSO at 187 Concord Avenue, Cambridge, Massachusetts 02138, U.S.A.

STAR	COORDINATES - EPOCH 1900		TYPE	MAX - MIN	SPECTRUM	S.A.O. #
	h m s	° '		m m		
rho Cas 234956	23 49 23	56 56	RCB?	4.1 - 6.2	F8p-K5p	035879
Comparsion	23 42 08	56 54		5.64V	KO	035761
Check	23 42 10	58 06		4.87V	KO	035763



FROM: AAVSO Variable Star Atlas (1950 Coordinates)

AAVSO CHART

REVISED 3-83 SKP/JRP

STAR CLUSTERS

BY ANTHONY MOFFAT

The study of star clusters is crucial for the understanding of stellar structure and evolution. It is generally believed that the stars seen in a given cluster formed nearly simultaneously from the same parent cloud of gas and dust; thus, the basic factor which distinguishes one star from another is the quantity of matter each contains. Comparing one cluster with another, it is essentially only the age and the chemical composition of their stars that differ. But what makes one cluster *appear* different from another in the sky is mainly the degree of concentration and regularity, the spread in magnitude and colour of the member stars, all of which vary mainly with age, and the total number of stars. Extremely young clusters are often irregular in shape with clumps of newly formed stars, pervaded by lanes of obscuring dust and bright nebulosity (e.g. the Orion Nebula around the Trapezium Cluster), while the oldest clusters, if they were fortunate enough not to have already dissipated or been torn apart by external forces, tend to be symmetric in shape, with only the slower-burning, low-mass stars remaining visible; the massive stars will have spent their nuclear fuel and passed to the degenerate graveyard of white dwarfs, neutron stars, or black holes depending on their original mass.

The star clusters in the lists below were selected as the most conspicuous. Two types can be recognized: *open* and *globular*. Open clusters often appear as irregular aggregates of tens to thousands of stars, sometimes barely distinguishable from random fluctuations of the general field; they are concentrated toward the Galactic disk and generally contain stars of chemical abundance like the Sun. They range in age from very young to very old.

Sometimes we observe loose, extended groups of very young stars. When precise methods of photometry, spectroscopy and kinematics are applied, we see that these stars often have a common, but not necessarily strictly coeval, origin. Such loose concentrations of stars are referred to as *associations*. Dynamically, they are generally unbound over time scales of the order of ten million years, being subject to the strong tidal forces of passing clouds and the background Galaxy. Often, they contain sub-concentrations of young open clusters (e.g. the double cluster h and χ Persei of slightly different ages despite their proximity, in the association Per OB1, which stretches over some 6° on the sky), with a strong gradient in age as the star formation process rips through them from one edge to another. In view of their sparse nature, we do not consider it appropriate here to list any of the over 100-odd catalogued associations in the Galaxy.

Globular clusters on the other hand are highly symmetric, extremely old agglomerations of up to several million stars, distributed throughout the Galactic halo but concentrated toward the centre of the Galaxy. Compared to the Sun and other disk stars, they tend to be much less abundant in elements heavier than hydrogen and helium.

The first table includes all well-defined Galactic open clusters with diameters greater than 40′ and/or integrated magnitudes brighter than 5.0, as well as the richest clusters and some of special interest. The apparent integrated photographic magnitude is from Collinder, the angular diameter is generally from Trumpler, and the photographic magnitude of the fifth-brightest star, m_5, is from Shapley, except where in italics, which are new data. The distance is mainly from Becker and Fenkart (*Astr. Astrophys. Suppl.* **4**, 241 (1971)). The earliest spectral type of cluster stars, Sp, is a measure of the age as follows: expressed in millions of years, 05 = 2, B0 = 8, B5 = 70, A0 = 400, A5 = 1000, F0 = 3000 and F5 = 10000.

NGC or other†	R.A. 1980 h m	Dec. 1980 ° ′	Int. m_{pg}	Diam. ′	m_5	Dist. 1000 l.y.	Sp	Remarks
188	00 42.0	+85 14	9.3	14	14.6	5.0	F2	Oldest known
752	01 56.6	+37 35	6.6	45	9.6	1.2	A5	
869	02 17.6	+57 04	4.3	30	9.5	7.0	B1	h Per
884	02 21.0	+57 02	4.4	30	9.5	8.1	B0	χ Per, M supergiants
Perseus	03 21	+48 32	2.3	240	5	0.6	B1	Moving cl.; α Per
Pleiades	03 45.9	+24 04	1.6	120	4.2	0.41	B6	M45, best known
Hyades	04 19	+15 35	0.8	400	*1.5*	0.13	A2	Moving cl.**, in Taurus
1912	05 27.3	+35 49	7.0	18	9.7	4.6	B5	M38
1976/80	05 34.4	−05 24	2.5	50	*5.5*	1.3	O5	Trapezium, very young
2099	05 51.1	+32 32	6.2	24	9.7	4.2	B8	M37
2168	06 07.6	+24 21	5.6	29	9.0	2.8	B5	M35
2232	06 25.5	−04 44	4.1	*20*	*7*	1.6	B1	
2244	06 31.3	+04 53	5.2	27	*8.0*	5.3	O5	Rosette, very young
2264	06 39.9	+09 54	4.1	30	*8.0*	2.4	O8	S Mon
2287	06 46.2	−20 43	5.0	32	*8.8*	2.2	B4	M41
2362	07 18.0	−24 54	3.8	7	9.4	5.4	O9	τ CMa
2422	07 34.7	−14 27	4.3	30	9.8	1.6	B3	
2437	07 40.9	−14 46	6.6	27	10.8	5.4	B8	M46
2451	07 44.7	−37 55	3.7	37	6	1.0	B5	
2516	07 58.0	−60 51	3.3	50	10.1	1.2	B8	
2546	08 11.8	−37 35	5.0	45	7	2.7	B0	
2632	08 39.0	+20 04	3.9	90	7.5	0.59	A0	Praesepe, M44
IC2391	08 39.7	−52 59	2.6	45	3.5	0.5	B4	
IC2395	08 40.4	−48 07	4.6	20	10.1	2.9	B2	
2682	08 49.3	+11 54	7.4	18	10.8	2.7	F2	M67, very old
3114	10 02.0	−60 01	4.5	37	7	2.8	B5	
IC2602	10 42.6	−64 17	1.6	65	6	0.5	B1	θ Car
Tr 16	10 44.4	−59 36	6.7	10	10	9.6	O3	η Car and Nebula
3532	11 05.5	−58 33	3.4	55	8.1	1.4	B8	
3766	11 35.2	−61 30	4.4	12	8.1	5.8	B1	
Coma	12 24.1	+26 13	2.9	300	5.5	0.3	A1	Very sparse
4755	12 52.4	−60 13	5.2	12	7	6.8	B3	κ Cru, "jewel box"
6067	16 11.7	−54 10	6.5	16	10.9	4.7	B3	G, K supergiants
6231	16 52.6	−41 46	8.5	16	7.5	5.8	O9	O supergiants, WR stars
Tr 24	16 55.6	−40 38	8.5	60	*7.3*	5.2	O5	
6405	17 38.8	−32 12	4.6	26	8.3	1.5	B4	M6
IC4665	17 45.7	+05 44	5.4	50	7	1.1	B8	
6475	17 52.6	−34 48	3.3	50	7.4	0.8	B5	M7
6494	17 55.7	−19 01	5.9	27	10.2	1.4	B8	M23
6523	18 01.9	−24 23	5.2	45	*7*	5.1	O5	M8, Lagoon Neb.
6611	18 17.8	−13 48	6.6	8	10.6	5.5	O7	M16, nebula
IC4725	18 30.5	−19 16	6.2	35	9.3	2.0	B3	M25, Cepheid U Sgr
IC4756	18 38.3	+05 26	5.4	50	8.5	1.4	A3	
6705	18 50.0	−06 18	6.8	12.5	12	5.6	B8	M11, very rich
Mel 227	20 08.2	−79 23	5.2	60	*9*	0.8	B9	
IC1396	21 38.3	+57 25	5.1	60	*8.5*	2.3	O6	Tr 37
7790	23 57.4	+61 06	7.1	4.5	11.7	10.3	B1	Cepheids CEa, CEb and CF Cas

†IC = Index Catalogue; Tr = Trumpler; Mel = Melotte.
**basic for distance determination.

The table below includes all globular clusters with a total apparent photographic magnitude brighter than about 7.5. The data are taken from a compilation by Arp (*Galactic Structure*, ed. Blaauw and Schmidt, U. Chicago 1965), supplemented by H. S. Hogg's Bibliography (*Publ. David Dunlap Obs.* **2**, No. 12, 1963). The apparent diameter given contains 90% of the stars, except values in italics which are from miscellaneous sources. The concentration class is such that I is the most compact, XII is least. The integrated spectral type varies mainly with the abundances, and m(25) refers to the mean blue magnitude of the 25 brightest stars excluding the 5 brightest, which are liable to fluctuate more. The number of variables known in the cluster is also given.

Globular Clusters

NGC	M or other	R.A. 1980 h m	Dec. 1980 ° ′	Int. m_{pg}	Diam. ′	Conc.	Int. Sp. T.	m(25)	No. Var.	Dist. 1000 l.y.
104	47 Tuc	00 23.1	−72 11	4.35	*44*	III	G3	13.54	11	16
1851*		05 13.3	−40 02	7.72	*11.5*	II	F7		3	46
2808		09 11.5	−64 42	7.4	*18.8*	I	F8	15.09	4	30
5139	ω Cen	13 25.6	−47 12	4.5	*65.4*	VIII	F7	13.01	165	17
5272	3	13 41.3	+28 29	6.86	9.3	VI	F7	14.35	189	35
5904	5	15 17.5	+02 10	6.69	10.7	V	F6	14.07	97	26
6121	4	16 22.4	−26 28	7.05	22.6	IX	*G0*	13.21	43	14
6205	13	16 41.0	+36 30	6.43	12.9	V	F6	13.85	10	21
6218	12	16 46.1	−01 55	7.58	21.5	IX	F8	14.07	1	24
6254	10	16 56.0	−04 05	7.26	16.2	VII	G1	14.17	3	20
6341*	92	17 16.5	+43 10	6.94	12.3	IV	F1	13.96	16	26
6397		17 39.2	−53 40	6.9	*19*	IX	F5	12.71	3	9
6541		18 06.5	−43 45	7.5	*23.2*	III	F6	13.45	1	13
6656	22	18 35.1	−23 56	6.15	26.2	VII	F7	13.73	24	10
6723		18 58.3	−36 39	7.37	11.7	VII	G4	14.32	19	24
6752		19 09.1	−60 01	6.8	*41.9*	VI	F6	13.36	1	17
6809	55	19 38.8	−30 59	6.72	21.1	XI	F5	13.68	6	20
7078*	15	21 29.1	+12 05	6.96	9.4	IV	F2	14.44	103	34
7089	2	21 32.4	−00 55	6.94	6.8	II	F4	14.77	22	40

*Compact X-ray sources were discovered in these clusters in 1975.

NEBULAE

GALACTIC NEBULAE

By William Herbst

The following objects were selected from the brightest and largest of the various classes to illustrate the different types of interactions between stars and interstellar matter in our galaxy. *Emission regions* (HII) are excited by the strong ultraviolet flux of young, hot stars and are characterized by the lines of hydrogen in their spectra. *Reflection nebulae* (Ref) result from the diffusion of starlight by clouds of interstellar dust. At certain stages of their evolution stars become unstable and explode, shedding their outer layers into what becomes a *planetary nebula* (Pl) or a *supernova remnant* (SN). Protostellar nebulae (PrS) are objects still poorly understood; they are somewhat similar to the reflection nebulae, but their associated stars, often variable, are very luminous infrared stars which may be in the earliest stages of stellar evolution. Also included in the selection are three *extended complexes* (Comp) of special interest for their rich population of dark and bright nebulosities of various types. In the table S is the optical surface brightness in magnitude per square second of arc of representative regions of the nebula, and m* is the magnitude of the associated star.

NGC	M	Con	α 1980 δ h m	° ′	Type	Size ′	S mag. sq″	m *	Dist. 10^3 l.y.	Remarks
1435		Tau	03 46.3	+24 01	Ref	15	20	4	0.4	Merope nebula
1535		Eri	04 13.3	−12 48	Pl	0.5	17	12		
1952	1	Tau	05 33.3	+22 05	SN	5	19	16v	4	"Crab" + pulsar
1976	42	Ori	05 34.3	−05 25	HII	30	18	4	1.5	Orion nebula
2070		Dor	05 38.7	−69 06	HII	20	—	13	200	Tarantula Neb.
ζOri		Ori	05 39.8	−01 57	Comp	2°			1.5	Incl. "Horsehead"
2068	78	Ori	05 45.8	+00 02	Ref	5	20		1.5	
IC443		Gem	06 16.4	+22 36	SN	40			2	
2244		Mon	06 31.3	+04 53	HII	50	21	7	3	Rosette neb.
2261		Mon	06 38.0	+08 44	PrS	2		12v	4	Hubble's var. neb.
2392		Gem	07 28.0	+20 57	Pl	0.3	18	10	10	Clown face neb.
2626		Vel	08 34.9	−40 34	Ref	2	—	10	3	
3132		Vel	10 06.2	−40 19	Pl	1	17	10	—	Eight-Burst
3324		Car	10 36.7	−58 32	HII	15	—	8	9	
3372		Car	10 44.3	−59 35	HII	80	—	6v	9	Carina Neb.
3503		Car	11 00.5	−60 37	Ref	3	—	11	9	
3587	97	UMa	11 13.6	+55 08	Pl	3	21	13	12	Owl nebula
—		Cru	12 50	−63	Dark	6°	—	—	0.5	Coal Sack
5189		Mus	13 32.4	−65 54	HII	150	—	10	—	
ρOph		Oph	16 24.4	−23 24	Comp	4°			0.5	Bright + dark neb.
6514	20	Sgr	18 01.2	−23 02	HII	15	19		3.5	Trifid nebula
6523	8	Sgr	18 02.4	−24 23	HII	40	18		4.5	Lagoon nebula
6543		Dra	17 58.6	+66 37	Pl	0.4	15	11	3.5	
6618	17	Sgr	18 19.7	−16 12	HII	20	19		3	Horseshoe neb.
6720	57	Lyr	18 52.9	+33 01	Pl	1.2	18	15	5	Ring nebula
6726		CrA	19 00.4	−36 56	PrS	5	—	7	0.5	
6853	27	Vul	19 58.6	+22 40	Pl	7	20	13	3.5	Dumb-bell neb.
6888		Cyg	20 11.6	+38 21	HII	15				
γCyg		Cyg	20 21.5	+40 12	Comp	6°				HII + dark neb.
6960/95		Cyg	20 44.8	+30 38	SN	150			2.5	Cygnus loop
7000		Cyg	20 58.2	+44 14	HII	100	22		3.5	N. America neb.
7009		Aqr	21 03.0	−11 28	Pl	0.5	16	12	3	Saturn nebula
7027		Cyg	21 06.4	+42 09	Pl	0.2	15	13		
7129		Cep	21 42.5	+65 00	Ref	3	21	10	2.5	Small cluster
7293		Aqr	22 28.5	−20 54	Pl	13	22	13		Helix nebula

THE MESSIER CATALOGUE

By Alan Dyer

The Messier Catalogue, with its modern additions, represents a listing of many of the brightest and best deep-sky wonders. The following table lists the Messier objects by season for the *evening observer*, grouping the objects within their respective constellations, with the constellations themselves listed roughly in order of increasing right ascension, i.e., constellations further to the east and which rise later in the night are further down the list.

The columns contain: Messier's number (M); the constellation; the object's New General Catalogue (NGC) number; the type of object (OC = open cluster, GC = globular cluster, PN = planetary nebula, EN = emission nebula, RN = reflection nebula, SNR = supernova remnant, G = galaxy (with the type of galaxy also listed); the 1980 co-ordinates; the visual magnitude (unless marked with a "p" which indicates a photographic magnitude). The "Remarks" column contains comments on the object's appearance and observability. The final column, marked "Seen", is for the observer to use in checking off those objects which he or she has located. An asterisk in the "Type" column indicates that additional information about the object may be found elsewhere in the HANDBOOK, in the appropriate table. Most data are from the Skalnate Pleso *Atlas of the Heavens* catalogue; occasionally from other sources.

All these objects can be seen in a small telescope (60 mm refractor, for instance), with M74 and M83 generally considered to be the most difficult. The most southerly M-objects are M6 and M7 in Scorpius, with M54, M55, M69, and M70 in Sagittarius almost as far south. Notice how different classes of objects dominate the skies of the various seasons: open clusters dominate the winter sky; galaxies by the hundreds abound in the spring sky; the summer sky contains many globular clusters and nebulae; while the autumn sky is a mixture of clusters and galaxies. This effect is due to the presence (or absence) of the Milky Way in any particular season, and whether or not we are looking toward the centre of the Galaxy (as in summer) or away from the centre (as in winter).

M	Con	NGC	Type	R.A. (1980)	Dec.	m_v	Remarks	Seen
The Winter Sky				h m	° ′			
1	Tau	1952	SNR*	5 33.3	+22 01	8.4	Crab Neb.; supernova remnant	
45	Tau	—	OC*	3 46.3	+24 03	1.4	Pleiades; RFT object	
36	Aur	1960	OC	5 35.0	+34 05	6.3	best at low magnification	
37	Aur	2099	OC*	5 51.5	+32 33	6.2	finest of 3 Aur. clusters	
38	Aur	1912	OC	5 27.3	+35 48	7.4	large, scattered group	
42	Ori	1976	EN*	5 34.4	−05 24	—	Orion Nebula	
43	Ori	1982	EN	5 34.6	−05 18	—	detached part of Orion Neb.	
78	Ori	2068	RN	5 45.8	+00 02	—	featureless reflection neb.	
79	Lep	1904	GC	5 23.3	−24 32	8.4	20 cm scope needed to resolve	
35	Gem	2168	OC*	6 07.6	+24 21	5.3	superb open cluster	
41	CMa	2287	OC*	6 46.2	−20 43	5.0	4°S. of Sirius; use low mag.	
50	Mon	2323	OC	7 02.0	−08 19	6.9	between Sirius and Procyon	
46	Pup	2437	OC*	7 40.9	−14 46	6.0	rich cl.; contains PN NGC 2438	
47	Pup	2422	OC	7 35.6	−14 27	4.5	coarse cl.; 1.5°W. of M46	
93	Pup	2447	OC	7 43.6	−23 49	6.0	smaller, brighter than M46	
48	Hya	2548	OC	8 12.5	−05 43	5.3	former "lost" Messier object	
The Spring Sky								
44	Cnc	2632	OC*	8 38.8	+20 04	3.7	Beehive Cl.; RFT object	
67	Cnc	2682	OC*	8 50.0	+11 54	6.1	"ancient" star cluster	
40	UMa	—	—	12 34.4	+58 20	9.0	two stars; sep. 50″	
81	UMa	3031	G-Sb*	9 54.2	+69 09	7.9	very bright spiral	
82	UMa	3034	G-Pec*	9 54.4	+69 47	8.8	the "exploding" galaxy	
97	UMa	3587	PN*	11 13.7	+55 08	12.0	Owl Nebula	

M	Con	NGC	Type	R.A. (1980) Dec.	m$_v$	Remarks	Seen
101	UMa	5457	G-Sc*	14 02.5 +54 27	9.6	large, faint, face-on spiral	
108	UMa	3556	G-Sc	11 10.5 +55 47	10.7	nearly edge-on; near M97	
109	UMa	3992	G-Sb	11 56.6 +53 29	10.8	barred spiral; near γ UMa	
65	Leo	3623	G-Sb	11 17.8 +13 13	9.3	bright elongated spiral	
66	Leo	3627	G-Sb	11 19.1 +13 07	8.4	M65 in same field	
95	Leo	3351	G-SBb	10 42.8 +11 49	10.4	bright barred spiral	
96	Leo	3368	G-Sbp	10 45.6 +11 56	9.1	M95 in same field	
105	Leo	3379	G-E1	10 46.8 +12 42	9.2	very near M95 and M96	
53	Com	5024	GC	13 12.0 +18 17	7.6	15 cm scope needed to resolve	
64	Com	4826	G-Sb*	12 55.7 +21 48	8.8	Black Eye Galaxy	
85	Com	4382	G-SO	12 24.3 +18 18	9.3	bright elliptical shape	
88	Com	4501	G-Sb	12 30.9 +14 32	10.2	bright multiple-arm spiral	
91	Com	4548	G-SBb	12 34.4 +14 36	10.8	not the same as M58	
98	Com	4192	G-Sb	12 12.7 +15 01	10.7	nearly edge-on spiral	
99	Com	4254	G-Sc	12 17.8 +14 32	10.1	nearly face-on spiral	
100	Com	4321	G-Sc	12 21.9 +15 56	10.6	face-on spiral; star-like nuc.	
49	Vir	4472	G-E4*	12 28.8 +08 07	8.6	very bright elliptical	
58	Vir	4579	G-SB	12 36.7 +11 56	9.2	bright barred spiral	
59	Vir	4621	G-E3	12 41.0 +11 47	9.6	bright elliptical near M58	
60	Vir	4649	G-E1	12 42.6 +11 41	8.9	bright elliptical near M59	
61	Vir	4303	G-Sc	12 20.8 +04 36	10.1	face-on barred spiral	
84	Vir	4374	G-E1	12 24.1 +13 00	9.3	bright elliptical	
86	Vir	4406	G-E3	12 25.1 +13 03	9.7	M84 in same field	
87	Vir	4486	G-E1	12 29.7 +12 30	9.2	nearly spherical galaxy	
89	Vir	4552	G-E0	12 34.6 +12 40	9.5	resembles M87; smaller	
90	Vir	4569	G-Sb	12 35.8 +13 16	10.0	bright spiral; near M89	
104	Vir	4594	G-Sb*	12 38.8 −11 31	8.7	Sombrero Galaxy	
3	CVn	5272	GC*	13 41.3 +28 29	6.4	contains many variables	
51	CVn	5194	G-Sc*	13 29.0 +47 18	8.1	Whirlpool Galaxy	
63	CVn	5055	G-Sb*	13 14.8 +42 08	9.5	Sunflower Galaxy	
94	CVn	4736	G-Sbp*	12 50.1 +41 14	7.9	very bright and comet-like	
106	CVn	4258	G-Sbp*	12 18.0 +47 25	8.6	large, bright spiral	
68	Hya	4590	GC	12 38.3 −26 38	8.2	15 cm scope needed to resolve	
83	Hya	5236	G-Sc*	13 35.9 −29 46	10.1	very faint and diffuse	
102	Dra	5866	G-E6p	15 05.9 +55 50	10.8	small, edge-on galaxy	
5	Ser	5904	GC*	15 17.5 +02 11	6.2	one of the finest globulars	
The Summer Sky							
13	Her	6205	GC*	16 41.0 +36 30	5.7	spectacular globular cl.	
92	Her	6341	GC*	17 16.5 +43 10	6.1	9°NE. of M13; bright	
9	Oph	6333	GC	17 18.1 −18 30	7.3	smallest of Oph. globulars	
10	Oph	6254	GC*	16 56.0 −04 05	6.7	rich cl.; M12 3.4° away	
12	Oph	6218	GC*	16 46.1 −01 55	6.6	loose globular	
14	Oph	6402	GC	17 36.5 −03 14	7.7	20 cm scope needed to resolve	
19	Oph	6273	GC	17 01.3 −26 14	6.6	oblate globular	
62	Oph	6266	GC	16 59.9 −30 05	6.6	unsymmetrical; in rich field	
107	Oph	6171	GC	16 31.3 −13 02	9.2	small, faint globular	
4	Sco	6121	GC*	16 22.4 −26 27	6.4	bright globular near Antares	
6	Sco	6405	OC*	17 38.9 −32 11	5.3	best at low magnification	
7	Sco	6475	OC*	17 52.6 −34 48	3.2	excellent in binoculars	
80	Sco	6093	GC	16 15.8 −22 56	7.7	very compressed globular	
16	Ser	6611	EN*	18 17.8 −13 48	—	Star-Queen Neb. w/ open cl.	
8	Sgr	6523	EN*	18 02.4 −24 23	—	Lagoon Neb. w/cl. NGC 6530	
17	Sgr	6618	EN*	18 19.7 −16 12	—	Swan or Omega Nebula	
18	Sgr	6613	OC	18 18.8 −17 09	7.5	sparse cluster; 1°S. of M17	
20	Sgr	6514	EN*	18 01.2 −23 02	—	Trifid Nebula	
21	Sgr	6531	OC	18 03.4 −22 30	6.5	0.7°NE. of M20	
22	Sgr	6656	GC*	18 35.2 −23 55	5.9	low altitude dims beauty	
23	Sgr	6494	OC*	17 55.7 −19 00	6.9	bright, loose cluster	
24	Sgr	—	—	18 17 −18 27	4.6	Milky Way patch; binoc. obj.	
25	Sgr	I4725	OC*	18 30.5 −19 16	6.5	bright but sparse cluster	
28	Sgr	6626	GC	18 23.2 −24 52	7.3	compact globular near M22	
54	Sgr	6715	GC	18 53.8 −30 30	8.7p	not easily resolved	

M	Con	NGC	Type	R.A. (1980) Dec.	m_v	Remarks	Seen
55	Sgr	6809	GC*	19 38.7 −31 00	7.1p	bright, loose globular	
69	Sgr	6637	GC	18 30.1 −32 23	8.9	small, poor globular	
70	Sgr	6681	GC	18 42.0 −32 18	9.6	small globular; 2°E. of M69	
75	Sgr	6864	GC	20 04.9 −21 59	8.0	small, remote globular	
11	Sct	6705	OC*	18 50.0 −06 18	6.3	superb open cluster	
26	Sct	6694	OC	18 44.1 −09 25	9.3	bright, coarse cluster	
56	Lyr	6779	GC	19 15.8 +30 08	8.2	within rich field	
57	Lyr	6720	PN*	18 52.9 +33 01	9.3	Ring Nebula	
71	Sge	6838	GC	19 52.8 +18 44	9.0	loose globular cl.	
27	Vul	6853	PN*	19 58.8 +22 40	7.6	Dumbbell Nebula	
29	Cyg	6913	OC	20 23.3 +38 27	7.1	small, poor open cl.	
39	Cyg	7092	OC	21 31.5 +48 21	5.2	very sparse cluster	
The Autumn Sky							
2	Aqr	7089	GC*	21 32.4 −00 54	6.3	20 cm scope needed to resolve	
72	Aqr	6981	GC	20 52.3 −12 39	9.8	near NGC 7009 (Saturn Neb.)	
73	Aqr	6994	OC	20 57.8 −12 44	11.0	group of 4 stars only	
15	Peg	7078	GC*	21 29.1 +12 05	6.0	rich, compact globular	
30	Cap	7099	GC	21 39.2 −23 15	8.4	noticeable elliptical shape	
52	Cas	7654	OC	23 23.3 +61 29	7.3	young, rich cluster	
103	Cas	581	OC	01 31.9 +60 35	7.4	3 NGC clusters nearby	
31	And	224	G-Sb*	00 41.6 +41 09	4.8	Andromeda Gal.; large	
32	And	221	G-E2*	00 41.6 +40 45	8.7	companion gal. to M31	
110	And	205	G-E6*	00 39.1 +41 35	9.4	companion gal. to M31	
33	Tri	598	G-Sc*	01 32.8 +30 33	6.7	large, diffuse spiral	
74	Psc	628	G-Sc	01 35.6 +15 41	10.2	faint, elusive spiral	
77	Cet	1068	G-Sbp	02 41.6 +00 04	8.9	Seyfert gal.; star-like nuc.	
34	Per	1039	OC	02 40.7 +42 43	5.5	best at very low mag.	
76	Per	650	PN*	01 40.9 +51 28	12.2	Little Dumbbell Neb.	

NUMERICAL LISTING OF MESSIER OBJECTS

M	Sky	Con	M	Sky	Con	M	Sky	Con	M	Sky	Con	M	Sky	Con
1	Wi	Tau	23	Su	Sgr	45	Wi	Tau	67	Sp	Cnc	89	Sp	Vir
2	Au	Aqr	24	Su	Sgr	46	Wi	Pup	68	Sp	Hya	90	Sp	Vir
3	Sp	CVn	25	Su	Sgr	47	Wi	Pup	69	Su	Sgr	91	Sp	Com
4	Su	Sco	26	Su	Sct	48	Wi	Hya	70	Su	Sgr	92	Su	Her
5	Sp	Ser	27	Su	Vul	49	Sp	Vir	71	Su	Sge	93	Wi	Pup
6	Su	Sco	28	Su	Sgr	50	Wi	Mon	72	Au	Aqr	94	Sp	CVn
7	Su	Sco	29	Su	Cyg	51	Sp	CVn	73	Au	Aqr	95	Sp	Leo
8	Su	Sgr	30	Au	Cap	52	Au	Cas	74	Au	Psc	96	Sp	Leo
9	Su	Oph	31	Au	And	53	Sp	Com	75	Su	Sgr	97	Sp	UMa
10	Su	Oph	32	Au	And	54	Su	Sgr	76	Au	Per	98	Sp	Com
11	Su	Sct	33	Au	Tri	55	Su	Sgr	77	Au	Cet	99	Sp	Com
12	Su	Oph	34	Au	Per	56	Su	Lyr	78	Wi	Ori	100	Sp	Com
13	Su	Her	35	Wi	Gem	57	Su	Lyr	79	Wi	Lep	101	Sp	UMa
14	Su	Oph	36	Wi	Aur	58	Sp	Vir	80	Su	Sco	102	Sp	Dra
15	Au	Peg	37	Wi	Aur	59	Sp	Vir	81	Sp	UMa	103	Au	Cas
16	Su	Ser	38	Wi	Aur	60	Sp	Vir	82	Sp	UMa	104	Sp	Vir
17	Su	Sgr	39	Su	Cyg	61	Sp	Vir	83	Sp	Hya	105	Sp	Leo
18	Su	Sgr	40	Sp	UMa	62	Su	Oph	84	Sp	Vir	106	Sp	CVn
19	Su	Oph	41	Wi	CMa	63	Sp	CVn	85	Sp	Com	107	Su	Oph
20	Su	Sgr	42	Wi	Ori	64	Sp	Com	86	Sp	Vir	108	Sp	UMa
21	Su	Sgr	43	Wi	Ori	65	Sp	Leo	87	Sp	Vir	109	Sp	UMa
22	Su	Sgr	44	Sp	Cnc	66	Sp	Leo	88	Sp	Com	110	Au	And

The abbreviations are: Wi, winter; Sp, spring; Su, summer; Au, autumn.

Footnote to Messier Catalogue: The identifications of M91 and M102 are controversial; some believe that these two objects are duplicate observations of M58 and M101 respectively. Also, objects M104 to M110 are not always included in the standard version of the Messier Catalogue. Like many other objects in the catalogue, they were discovered by Mechain and reported to Messier for verification and inclusion in the catalogue.

THE FINEST N.G.C. OBJECTS + 20

BY ALAN DYER

The New General Catalogue of deep-sky objects was originally published by J. L. E. Dreyer in 1888. Supplementary Index Catalogues were published in 1895 and 1908. Together, they contain descriptions and positions of 13,226 galaxies, clusters and nebulae. Many of these are well within reach of amateur telescopes. Indeed, the brightness and size of many NGC objects rival those of the better known deep-sky targets of the Messier Catalogue (almost all of which are also in the NGC catalogue). However, most NGC objects are more challenging to locate and observe than the Messiers.

The first four sections of the following list contain 110 of the finest NGC objects that are visible from mid-northern latitudes. The arrangement is similar to that used in the preceding Messier Catalogue. A telescope of at least 15 cm aperture will likely be required to locate all these objects. The last section is for those wishing to begin to extend their deep-sky observing program beyond the basic catalogue of Charles Messier or the brightest objects of the New General Catalogue. It is a selected list of 20 "challenging" objects, and is arranged in order of right ascension.

The *Wil Tirion Sky Atlas 2000.0*, the sets of index card finder charts called *AstroCards*, or the *AAVSO Variable Star Atlas* will be indispensible in locating the objects on this list. For more information about them, and many other deep-sky objects, see *Burnham's Celestial Handbook* (Vol. 1, 2, 3), and the *Webb Society Deep-Sky Observer's Handbooks*.

Abbreviations used: OC = open cluster, GC = globular cluster, PN = planetary nebula, EN = emission nebula, RN = reflection nebula, E/RN = combination emission and reflection nebula, DN = dark nebula, SNR = supernova remnant, G = galaxy (the Hubble classification is also listed with each galaxy). Magnitudes are visual; exceptions are marked with a "p" indicating a photographic magnitude. Sizes of each object are in minutes of arc, with the exception of planetary nebulae which are given in seconds of arc. The number of stars (*) and, where space permits, the Shapley classification is also given for star clusters in the Remarks column.

No.	NGC	Con	Type	R.A. (1950)	Dec.	m_v	Size	Remarks
The Autumn Sky				h m	° ′			
1	7009	Aqr	PN	21 01.4	−11 34	9.1	44″ × 26″	Saturn Nebula; bright oval planetary
2	7293	Aqr	PN	22 27.0	−21 06	6.5	900″ × 720″	Helix Nebula; very large and diffuse
3	7331	Peg	G-Sb	22 34.8	+34 10	9.7	10.0 × 2.3	large, very bright spiral galaxy
4	7789	Cas	OC	23 54.5	+56 26	9.6	30	200*; faint but very rich cluster
5	185	Cas	G-EO	00 36.1	+48 04	11.7	2.2 × 2.2	companion to M31; quite bright
6	281	Cas	EN	00 50.4	+56 19	—	22 × 27	large, faint nebulosity near γ Cas.
7	457	Cas	OC	01 15.9	+58 04	7.5	10	100*; Type e—intermediate rich
8	663	Cas	OC	01 42.6	+61 01	7.1	11	80*; NGC 654 and 659 nearby
9	7662	And	PN	23 23.5	+42 14	9.2	32″ × 28″	star-like at low mag.; annular, bluish
10	891	And	G-Sb	02 19.3	+42 07	10.9p	11.8 × 1.1	faint, classic edge-on with dust lane
11	253	Scl	G-Scp	00 45.1	−25 34	8.9	24.6 × 4.5	very large and bright but at low alt.
12	772	Ari	G-Sb	01 56.6	+18 46	10.9	5.0 × 3.0	diffuse spiral galaxy
13	936	Cet	G-SBa	02 25.1	−01 22	10.7	3.3 × 2.5	near M77; NGC 941 in same field
14a	869	Per	OC	02 15.5	+56 55	4.4	36	Double Cluster; superb!
14b	884	Per	OC	02 18.9	+56 53	4.7	36	Double Cluster; superb!
15	1023	Per	G-E7p	02 37.2	+38 52	10.5p	4.0 × 1.2	bright, lens-shaped galaxy; near M34
16	1491	Per	EN	03 59.5	+51 10	—	3 × 3	small, fairly bright emission nebula
17	1501	Cam	PN	04 02.6	+60 47	12.0	56″ × 58″	faint, distinctive oval; darker centre
18	1232	Eri	G-Sc	03 07.5	−20 46	10.7	7.0 × 5.5	fairly bright, large face-on spiral
19	1300	Eri	G-SBb	03 17.5	−19 35	11.3	5.7 × 3.5	large barred spiral near NGC 1232
20	1535	Eri	PN	04 12.1	−12 52	10.4	20″ × 17″	blue-grey disk

No.	NGC	Con	Type	R.A. (1950)	Dec.	m_v	Size	Remarks
The Winter Sky				h m	° ′			
21	1907	Aur	OC	05 24.7	+35 17	9.9	5	40*; nice contrast with nearby M38
22	1931	Aur	EN	05 28.1	+34 13	—	3 × 3	haze surrounding 4 stars
23	1788	Ori	E/RN	05 04.5	−03 24	—	8 × 5	fairly bright but diffuse E/R neb.
24	1973+	Ori	E/RN	05 32.9	−04 48	—	40 × 25	near M42 and M43; often neglected
25	2022	Ori	PN	05 39.3	+09 03	12.4	28″ × 27″	small, faint but distinct; annular
26	2194	Ori	OC	06 11.0	+12 50	9.2	8	100*; Type e; faint but rich
27	2158	Gem	OC	06 04.3	+24 06	12.5	4	40*; same field as M35; nice contrast
28	2392	Gem	PN	07 26.2	+21 01	8.3	47″ × 43″	Clown-Face Nebula; very bright
29	2244	Mon	OC	06 29.7	+04 54	6.2	40	16*; in centre of Rosette Nebula
30	2261	Mon	E/RN	06 36.4	+08 46	var.	5 × 3	Hubble's Variable Nebula
31	2359	CMa	EN	07 15.4	−13 07	—	8 × 6	fairly bright; NGC's 2360 & 2362 nearby
32	2438	Pup	PN	07 39.6	−14 36	11.8	68″	within M46 open cluster
33	2440	Pup	PN	07 39.9	−18 05	10.3	54″ × 20″	almost starlike; irregular at high mag.
34	2539	Pup	OC	08 08.4	−12 41	8.2	21	150*; Type f—fairly rich
35	2403	Cam	G-Sc	07 32.0	+65 43	8.9	17 × 10	bright, very large; visible in binocs.
36	2655	Cam	G-S	08 49.4	+78 25	10.7	5.0 × 2.4	bright ellipse w/ star-like nucleus
The Spring Sky								
37	2683	Lyn	G-Sb	08 49.6	+33 38	9.6	8.0 × 1.3	nearly edge-on spiral; very bright
38	2841	UMa	G-Sb	09 18.6	+51 12	9.3	6.4 × 2.4	classic elongated spiral; very bright
39	2985	UMa	G-Sb	09 46.0	+72 31	10.6	5.5 × 5.0	near M81 and M82
40	3077	UMa	G-E2p	09 59.4	+68 58	10.9	2.3 × 1.9	small elliptical; companion to M81/82
41	3079	UMa	G-Sb	09 58.6	+55 57	11.2	8.0 × 1.0	edge-on spiral, NGC 2950 nearby
42	3184	UMa	G-Sc	10 15.2	+41 40	9.6	5.6 × 5.6	large, diffuse face-on spiral
43	3675	UMa	G-Sb	11 23.5	+43 52	10.6	4.0 × 1.7	elongated spiral; same field as 56 UMa
44	3877	UMa	G-Sb	11 43.5	+47 46	10.9	4.4 × 0.8	edge-on; same field as Chi UMa
45	3941	UMa	G-Sa	11 50.3	+37 16	9.8	1.8 × 1.2	small, bright, elliptical shape
46	4026	UMa	G-E8	11 56.9	+51 12	10.7	3.6 × 0.7	lens-shaped edge-on; near γ UMa
47	4088	UMa	G-Sc	12 03.0	+50 49	10.9	4.5 × 1.4	nearly edge-on; 4085 in same field
48	4111	UMa	G-S0	12 04.5	+43 21	9.7	3.3 × 0.6	bright, lens-shaped, edge-on spiral
49	4157	UMa	G-Sb	12 08.6	+50 46	11.9	6.5 × 0.8	edge-on, a thin sliver; 4026+4088 nearby
50	4605	UMa	G-Scp	12 37.8	+61 53	9.6	5.0 × 1.2	bright, distinct, edge-on spiral
51	3115	Sex	G-E6	10 02.8	−07 28	9.3	4.0 × 1.2	"Spindle Galaxy"; bright, elongated
52	3242	Hya	PN	10 22.4	−18 23	9.1	40″ × 35″	"Ghost of Jupiter" planetary
53	3344	LMi	G-Sc	10 40.7	+25 11	10.4	7.6 × 6.2	diffuse, face-on spiral
54	3432	LMi	G-Sc	10 49.7	+36 54	11.4	5.8 × 0.8	nearly edge-on; faint flat streak
55	2903	Leo	G-Sb	09 29.3	+21 44	9.1	11.0 × 4.6	very bright, large elongated spiral
56	3384	Leo	G-E7	10 45.7	+12 54	10.2	4.4 × 1.4	same field as M105 and NGC 3389
57	3521	Leo	G-Sc	11 03.2	+00 14	9.5	7.0 × 4.0	very bright, large spiral
58	3607	Leo	G-E1	11 14.3	+18 20	9.6	1.7 × 1.5	NGC 3605 and 3608 in same field
59	3628	Leo	G-Sb	11 17.7	+13 53	10.9	12.0 × 1.5	large, edge-on; same field as M65/M66
60	4214	CVn	G-irr	12 13.1	+36 36	10.3	6.6 × 5.8	large irregular galaxy
61	4244	CVn	G-S	12 15.0	+38 05	11.9	14.5 × 1.0	large, distinct, edge-on spiral
62	4449	CVn	G-irr	12 25.8	+44 22	9.2	4.1 × 3.4	bright rectangular shape
63	4490	CVn	G-Sc	12 28.3	+41 55	9.7	5.6 × 2.1	bright spiral; 4485 in same field
64	4631	CVn	G-Sc	12 39.8	+32 49	9.3	12.6 × 1.4	very large, bright, edge-on; no dust lane
65	4656	CVn	G-Sc	12 41.6	+32 26	11.2	19.5 × 2.0	same field as 4631; fainter, smaller
66	5005	CVn	G-Sb	13 08.5	+37 19	9.8	4.4 × 1.7	bright elongated spiral; near α CVn
67	5033	CVn	G-Sb	13 11.2	+36 51	10.3	9.9 × 4.8	large, bright spiral near NGC 5005
68	4274	Com	G-Sb	12 17.4	+29 53	10.8	6.7 × 1.3	NGC 4278 in same field
69	4494	Com	G-E1	12 28.9	+26 03	9.6	1.3 × 1.2	small, bright elliptical
70	4414	Com	G-Sc	12 24.0	+31 30	9.7	3.2 × 1.5	bright spiral; star-like nucleus
71	4559	Com	G-Sc	12 33.5	+28 14	10.6	11.0 × 4.5	large spiral; coarse structure
72	4565	Com	G-Sb	12 33.9	+26 16	10.2	14.4 × 1.2	superb edge-on spiral with dust lane
73	4725	Com	G-Sb	12 48.1	+25 46	8.9	10.0 × 5.5	very bright, large spiral
74	4361	Crv	PN	12 21.9	−18 29	11.4	18″	$12^{\mathrm{m}}.8$ central star

No.	NGC	Con	Type	R.A. (1950)	Dec.	m_v	Size	Remarks
75	4216	Vir	G-Sb	12 13.4	+13 25	10.4	7.4 × 0.9	nearly edge-on; two others in field
76	4388	Vir	G-Sb	12 23.3	+12 56	11.7p	5.0 × 0.9	edge-on; near M84 and M86
77	4438	Vir	G-S	12 25.3	+13 17	10.8	8.0 × 3.0	paired with NGC 4435
78	4473	Vir	G-E4	12 27.3	+13 42	10.1	1.6 × 0.9	NGC 4477 in same field
79	4517	Vir	G-Sc	12 29.0	+00 21	12.0	8.9 × 0.8	faint edge-on spiral
80	4526	Vir	G-E7	12 31.6	+07 58	10.9	3.3 × 1.0	between two 7^{m}0 stars
81	4535	Vir	G-Sc	12 31.8	+08 28	10.4p	6.0 × 4.0	near M49
82	4697	Vir	G-E4	12 46.0	−05 32	9.6	2.2 × 1.4	small, bright elliptical
83	4699	Vir	G-Sa	12 46.5	−08 24	9.3	3.0 × 2.0	small, bright elliptical shape
84	4762	Vir	G-Sa	12 50.4	+11 31	11.0	3.7 × 0.4	flattest galaxy; 4754 in same field
85	5746	Vir	G-Sb	14 42.3	+02 10	10.1	6.3 × 0.8	fine, edge-on spiral near 109 Virginis
86	5907	Dra	G-Sb	15 14.6	+56 31	11.3	11.1 × 0.7	fine, edge-on spiral with dust lane
87	6503	Dra	G-Sb	16 49.9	+70 10	9.6	4.5 × 1.0	bright spiral
88	6543	Dra	PN	17 58.8	+66 38	8.7	22″	luminous blue-green disk
The Summer Sky								
89	6207	Her	G-Sc	16 41.3	+36 56	11.3	2.0 × 1.1	same field as M13 cluster
90	6210	Her	PN	16 42.5	+23 53	9.2	20″ × 13″	very star-like blue planetary
91	6369	Oph	PN	17 26.3	−23 44	9.9	28″	greenish, annular, and circular
92	6572	Oph	PN	18 09.7	+06 50	8.9	16″ × 13″	tiny oval; bright blue
93	6633	Oph	OC	18 25.1	+06 32	4.9	20	wide-field cluster; IC4756 nearby
94	6712	Sct	GC	18 50.3	−08 47	8.9	2.1	small globular near M26
95	6819	Cyg	OC	19 39.6	+40 06	10.1	6	150*; faint but rich cluster
96	6826	Cyg	PN	19 43.4	+50 24	9.4	27″ × 24″	Blinking Planetary Nebula
97	6960	Cyg	SNR	20 43.6	+30 32	—	70 × 6	Veil Nebula (west component)
98	6992–5	Cyg	SNR	20 54.3	+31 30	—	78 × 8	Veil Nebula (east component)
99	7000	Cyg	EN	20 57.0	+44 08	—	120 × 100	North America Neb.; binoc. obj.
100	7027	Cyg	EN	21 05.1	+42 02	10.4	18″ × 11″	very star-like H II region
101	6445	Sgr	PN	17 47.8	−20 00	11.8	38″ × 29″	small, bright and annular; near M23
102	6818	Sgr	PN	19 41.1	−14 17	9.9	22″ × 15″	"Little Gem"; annular; 6822 nearby
103	6802	Vul	OC	19 28.4	+20 10	11.0	3.5	60*; small, faint but rich
104	6940	Vul	OC	20 32.5	+28 08	8.2	20	100*; Type e; rich cluster
105	6939	Cep	OC	20 30.4	+60 28	10.0	5	80*; very rich; 6946 in same field
106	6946	Cep	G-Sc	20 33.9	+59 58	9.7p	9.0 × 7.5	faint, diffuse, face-on spiral
107	7129	Cep	RN	21 42.0	+65 52	—	7 × 7	small faint RN; several stars inv.
108	40	Cep	PN	00 10.2	+72 15	10.5	60″ × 38″	small circular glow; 11^{m}5 central star
109	7209	Lac	OC	22 03.2	+46 15	7.6	20	50*; Type d; within Milky Way
110	7243	Lac	OC	22 13.2	+49 38	7.4	20	40*; Type d; within Milky Way
Challenge Objects								
1	246	Cet	PN	00 44.6	−12 09	8.5	240″ × 210″	large and diffuse; deceptively difficult
2	1275	Per	G	03 16.4	+41 20	12.7	0.7 × 0.6	small and faint; exploding gal.; Perseus A
3	1432/35	Tau	RN	03 43.3	+23 42	—	30 × 30	Pleiades nebl'y; brightest around Merope
4	1499	Per	EN	04 00.1	+36 17	—	145 × 40	California Neb.; very large and faint
5	IC434/35/ B33/2023	Ori	E/R/DN	05 38.6	−02 26	—	60/3/10	complex of nebl'y S. of zeta Ori., B33 is famous dark Horsehead Neb.; difficult
6	IC431/32/ NGC 2024	Ori	E/RN	05 39.4	−01 52	—	4/6/30	complex of nebl'y N. of zeta Ori., NGC2024 is easy but masked by glow from zeta.
7	IC 443	Gem	SNR	06 13.9	+22 48	—	27 × 5	v. faint supernova remnant NE. of η Gem.
8	J 900	Gem	PN	06 23.0	+17 49	12.2	12″ × 10″	bright but starlike; oval at high mag.
9	2237/46	Mon	EN	06 29.6	+04 40	—	60	Rosette Neb.; very large; incl. NGC2244
10	2419	Lyn	GC	07 34.8	+39 00	11.5	1.7	most distant known Milky Way GC (2×10^5 l.y.)
11	5897	Lib	GC	15 14.5	−20 50	10.9	7.3	large, but faint and loose globular cl.
12	B 72	Oph	DN	17 21.0	−23 35	—	30	Barnard's dark S-Nebula; RFT needed
13	6781	Aql	PN	19 16.0	+06 26	11.8	106″	pale version of M97; large, fairly bright
14	6791	Lyr	OC	19 19.0	+37 40	11	13	large, faint but very rich cl.; 100+*
15	M1-92	Cyg	RN	19 34.3	+29 27	11	0.2 × 0.1	Footprint Neb.; bright but starlike; double
16	6822	Sgr	G-irr	19 42.1	−14 53	11.0	16.2 × 11.2	Barnard's Gal.; member Local Grp.; faint
17	6888	Cyg	SNR?	20 10.7	+38 16	—	18 × 12	Crescent Neb.; small faint arc near γ Cyg.
18	IC 5146	Cyg	RN	21 51.3	+47 02	—	12 × 12	Cocoon Neb.; faint; at end of long dark neb.
19	7317–20	Peg	G's	22 33.7	+33 42	14–15	—	Stephan's Quintet; $\frac{1}{2}$°SSW. of NGC 7331
20	7635	Cas	EN	23 18.5	+60 54	—	4 × 3	Bubble Neb.; v. faint; $\frac{1}{2}$°SW. of M52

GALAXIES

BY BARRY F. MADORE

External galaxies are generally of such low surface brightness that they often prove disappointing objects for the amateur observer. However it must be remembered that many of these galaxies were discovered with very small telescopes and that the enjoyment of their discovery can be recaptured. In addition the central concentration of light varies from galaxy to galaxy making a visual classification of the types possible at the telescope. Indeed the type of galaxy as listed in the first table is in part based on the fraction of light coming from the central bulge of the galaxy as compared to the contribution from a disk component. Disk galaxies with dominant bulges are classified as Sa; as the nuclear contribution declines, types of Sb, Sc, and Sd are assigned until the nucleus is absent at type Sm. Often the disks of these galaxies show spiral symmetry, the coherence and strength of which is denoted by Roman numerals I through V, smaller numbers indicating well-formed global spiral patterns. Those spirals with central bars are designated SB while those with only a hint of a disk embedded in the bulge are called S0. A separate class of galaxies which possess no disk component are called ellipticals and can only be further classified numerically by their apparent flattening: E0 being apparently round, E7 being the most flattened.

The following table presents the 40 brightest galaxies taken from the Revised Shapley-Ames Catalog. As well as their designations, positions, and types, the table lists the total blue magnitudes, major and minor axis lengths (to the nearest minute of arc), one modern estimate of their distances in thousands of parsecs, and finally their radial velocities corrected for the motion of our Sun about the galactic centre.

THE 40 OPTICALLY BRIGHTEST SHAPLEY-AMES GALAXIES

NGC/IC (Other)	α/δ (1983)	Type	B_T ma × mi	Distance Corrected Radial Vel.
55	00ʰ14ᵐ04ˢ −39°17.1′	Sc	8.22 mag 25 × 3 arc min	3 100 kpc +115 km/s
205	00 39 27 +41 35.7	S0/E5pec	8.83 8 × 3	730 +49
221 M32	00 41 49 +40 46.3	E2	9.01 3 × 3	730 +86
224 M31	00 41 49 +41 10.5	Sb I–II	4.38 160 × 40	730 −10
247	00 46 19 −20 51.2	Sc III–IV	9.51 18 × 5	3 100 +604
253	00 46 46 −25 23.0	Sc	8.13 22 × 6	4 200 +504
SMC	00 52 10 −72 55.3	Im IV–V	2.79 216 × 216	60 +359
300	00 54.05 −37 46.7	Sc III	8.70 20 × 10	2 400 +625
598 M33	01 32 55 +30 34.0	Sc II–III	6.26 60 × 40	900 +506
628 M74	01 35 49 +15 41.6	Sc I	9.77 8 × 8	17 000 +507
1068 M77	02 41 49 −00 05.2	Sb II	9.55 3 × 2	25 000 +510
1291	03 16 42 −41 11.3	SBa	9.42 5 × 2	15 000 +512
1313	03 18 04 −66 33.6	SBc III–IV	9.37 5 × 3	5 200 +261
1316 Fornax A	03 22 03 −37 16.1	Sa (pec)	9.60 4 × 3	30 000 +1713
LMC	05 23 45 −69 46.3	SBm III	0.63 432 × 432	50 +34
2403	07 35 13 +65 38.2	Sc III	8.89 16 × 10	3 600 +299
2903	09 31 02 +21 34.4	Sc I–III	9.50 11 × 5	9 400 +472
3031 M81	09 54 11 +69 08.9	Sb I–II	7.86 16 × 10	3 600 +124
3034 M82	09 54 24 +69 45.5	Amor- phous	9.28 7 × 2	3 600 +409
3521	11 04 57 +00 03.5	Sb II–III	9.64 7 × 2	13 000 +627

NGC/IC (Other)	α/δ (1983)	Type	B_T ma × mi	Distance Corrected Radial Vel.
3627 M66	11 19 22 +13 05.0	Sb II	9.74 8 × 3	12 000 +593
4258 M106	12 18 07 +47 24.1	Sb II	8.95 20 × 6	10 000 +520
4449	12 27 24 +44 11.4	Sm IV	9.85 5 × 3	5 000 +250
4472 M49	12 28 55 +08 05.8	E1/S0	9.32 5 × 4	22 000 +822
4486 M87	12 29 58 +12 29.2	E0	9.62 3 × 3	22 000 +1136
4594 M104	12 39 07 −11 31.8	Sa/b	9.28 7 × 2	17 000 +873
4631	12 41 18 +32 38.0	Sc	9.84 12 × 1	12 000 +606
4649 M60	12 42 49 +11 38.7	S0	9.83 4 × 3	22 000 +1142
4736 M94	12 50 06 +41 12.9	Sab	8.92 5 × 4	6 900 +345
4826 M64	12 55 55 +21 46.5	Sab II	9.37 8 × 4	7 000 +350
4945	13 04 28 −49 22.5	Sc	9.60 12 × 2	7 000 +275
5055 M63	13 15 04 +42 07.4	Sbc II–III	9.33 8 × 3	11 000 +550
5128 Cen A	13 24 29 −42 35.7	S0 (pec)	7.89 10 × 3	6 900 +251
5194 M51	13 29 10 +47 17.2	Sbc I–II	8.57 12 × 6	11 000 +541
5236 M83	13 36 02 −29 46.8	SBc II	8.51 10 × 8	6 900 +275
5457 M101	14 02 39 +54 26.4	Sc I	8.18 22 × 22	7 600 +372
6744	19 08 09 −63 53.0	Sbc II	9.24 9 × 9	13 000 +663
6822	19 43 59 −14 50.8	Im IV–V	9.35 20 × 10	680 +15
6946	20 34 30 +60 05.9	Sc II	9.68 13 × 9	6 700 +336
7793	23 56 57 −32 41.1	Sd IV	9.65 6 × 4	4 200 +241

The following table contains the positions and catalogue designations of all those galaxies known to have proper names which usually honour the discoverer (Object McLeish), identify the constellation in which the galaxy is found (Fornax A) or describe the galaxy in some easily remembered way (Whirlpool galaxy).

GALAXIES WITH PROPER NAMES

Name/Other	α/δ (1950)	Name/Other	α/δ (1950)
Andromeda Galaxy = M31 = NGC 224	$00^h40^m\!.0$ +41°00′	Holmberg III	$09^h09^m\!.6$ +74°26′
Andromeda I	00 43.0 +37 44	Holmberg IV = DDO 185	13 52.8 +54 09
Andromeda II	01 13.5 +33 09	Holmberg V	13 38.8 +54 35
Andromeda III	00 32.6 +36 14	Holmberg VI = NGC 1325 A	03 22.6 −21 31
Andromeda IV	00 39.8 +40 18	Holmberg VII = DDO 137	12 33.2 +06 35
Antennae = NGC 4038/39	11 59.3 −18 35	Holmberg VIII = DDO 166	13 11.0 +36 29
Barnard's Galaxy = NGC 6822	19 42.1 −14 53	Holmberg IX = DDO 66	09 53.5 +69 17
BL Lac	22 01.9 +42 11	Hydra A	09 15.7 −11 53
Capricorn Dwarf = Pal 13	21 44.0 −21 29	Keenan's System = NGC 5216/18 = Arp 104	13 31.1 +62 52
Caraffe Galaxy	04 26.6 −48 01	Large Magellanic Cloud	05 24.0 −69 48
Carina Dwarf	06 45.1 −51 00	Leo I = Harrington-Wilson #1 = Regulus Dwarf = DDO 74	10 05.8 +12 33
Cartwheel Galaxy	00 35.0 −34 01	Leo II = Harrington-Wilson #2 = Leo B = DDO 93	11 10.8 +22 26
Centaurus A = NGC 5128 = Arp 153	13 22.5 −42 46	Leo A = Leo III = DDO 69	09 56.5 +30 59
Circinus Galaxy	14 09.3 −65 06	Lindsay-Shapley Ring	06 44.4 −74 11
Copeland Septet = NGC 3745/54 = Arp 370	11 35.1 +22 18	McLeish's Object	20 05.0 −66 22
Cygnus A	19 57.7 +40 36	Maffei I	02 32.6 +59 26
Draco Dwarf = DDO 208	17 19.2 +57 58	Maffei II	02 38.1 +59 23
Fath 703	15 11.0 −15 17	Mayall's Object = Arp 148 = VV32	11 01.1 +41 07
Fornax A = NGC 1316	03 20.8 −37 23	Mice = NGC 4676 = Arp 242	12 44.7 +30 54
Fornax Dwarf	02 37.8 −34 44	Pegasus Dwarf = DDO 216	23 26.0 +14 28
Fourçade-Figueroa Object	13 32.4 −33 38	Perseus A = NGC 1275	03 16.5 +41 20
GR8 (Gibson Reaves) = DDO 155	12 56.2 +14 29	Pinwheel Galaxy = M101 = NGC 5457	14 01.5 +54 36
Hardcastle Nebula	13 10.2 −32 26	Regulus Dwarf = Leo I = DDO 74	10 05.8 +12 33
Hercules A	16 48.7 +05 06	Reticulum Dwarf	04 35.4 −58 56
Holmberg I = DDO 63	09 36.0 +71 25	Reinmuth 80 = NGC 4517 A	00 57.6 −33 58
Holmberg II = DDO 50 = Arp 268	08 13.7 +70 52	Seashell Galaxy	13 44.5 −30 10

Name/Other	α/δ (1950)	Name/Other	α/δ (1950)
Serpens Dwarf	$15^{h}13^{m}.5$ +00°03′	Triangulum Galaxy = M33 = NGC 598	$01^{h}31^{m}.0$ +30°24′
Seyfert's Sextet = NGC 6027 A–D	15 57.0 +20 54	Ursa Minor Dwarf = DDO 199	15 08.2 +67 23
Sextans A = DDO 75	10 08.6 −04 28	Virgo A = M87 = NGC 4486 = Arp 152	12 28.3 +12 40
Sextans B = DDO 70	09 57.4 +05 34	Whirlpool Galaxy = M51 = NGC 5194	13 27.8 +47 27
Sextans C	10 03.0 +00 19	Wild's Triplet = Arp 248	11 44.2 −03 33
Small Magellanic Cloud	00 51.0 −73 06	Wolf-Lundmark-Melotte = DDO 221	23 59.4 −15 44
Sombrero Galaxy = M104 = NGC 4594	12 37.6 −11 21	Zwicky No. 2 = DDO 105	11 55.9 +38 21
Spindle Galaxy = NGC 3115	10 02.8 −07 28	Zwicky's Triplet = Arp 103	16 48.0 +45 33
Stephans Quintet = NGC 7317-20 = Arp 319	22 33.7 +33 42		

The nearest galaxies listed below form what is known as our Local Group of galaxies. Many of the distances are still quite uncertain.

THE NEAR-BY GALAXIES: OUR LOCAL GROUP

Name	α (1983.0)	δ	B_T	Type	Distance (kpc)
M31 = NGC 224	$00^{h}41^{m}.8$	+41°11′	4.38	Sb I–II	730
Galaxy	—	—	—	Sb/c	—
M33 = NGC 598	01 32.9	+30 34	6.26	Sc II–III	900
LMC	05 23.8	−69 46	0.63	SBm III	50
SMC	00 52.2	−72 55	2.79	Im IV–V	60
NGC 6822	19 44.0	−14 51	9.35	Im IV–V	520
IC 1613	01 03.9	+02 02	10.00	Im V	740
NGC 205	00 39.5	+41 36	8.83	S0/E5 pec	730
M32 = NGC 221	00 41.8	+40 46	9.01	E2	730
NGC 185	00 38.0	+48 15	10.13	dE3 pec	730
NGC 147	00 32.3	+48 25	10.36	dE5	730
Fornax	02 39.2	−34 36	9.1	dE	130
Sculptor	00 59.0	−33 47	10.5	dE	85
Leo I	10 07.6	+12 24	11.27	dE	230
Leo II	11 12.6	+22 15	12.85	dE	230
Draco	17 19.8	+57 56	—	dE	80
Ursa Minor	15 08.6	+67 16	—	dE	75
Carina	06 47.2	−50 59	—	dE	170
And I	00 44.6	+37 57	13.5	dE	730
And II	01 15.5	+33 21	13.5	dE	730
And III	00 34.5	+36 25	13.5	dE	730
LGS 3	01 02.9	+21 48	—	?	730

RADIO SOURCES

BY JOHN GALT

Although several thousand radio sources have been catalogued, most of them are observable only with the largest radio telescopes. This list contains the few strong sources which could be detected with amateur radio telescopes as well as representative examples of astronomical objects which emit radio waves.

Name	α (1980) h	m	δ °	′	Remarks
Tycho's s'nova	00	24.6	+64	01	Remnant of supernova of 1572
Andromeda gal.	00	41.5	+41	09	Closest normal spiral galaxy
IC 1795, W3	02	23.9	+62	01	Multiple HII region, OH emission
Algol	03	06.6	+40	52	Star emits high freq. radio waves
NGC 1275, 3C 84	03	18.5	+41	26	Seyfert galaxy, radio variable
CP 0328	03	31.3	+54	29	Pulsar, period = 0.7145 s, H abs'n.
Crab neb, M1*	05	33.2	+22	00	Remnant of supernova of 1054
NP 0532	05	33.2	+22	00	Radio, optical & X-ray pulsar
V 371 Orionis	05	32.7	+01	54	Red dwarf, radio & optical flare star
Orion neb, M42	05	34.3	−05	24	HII region, OH emission, IR source
IC 443	06	16.1	+22	36	Supernova remnant (date unknown)
Rosette neb	06	30.9	+04	53	HII region
YV CMa	07	22.2	−20	42	Optical var. IR source, OH, H_2O emission
3C 273	12	28.0	+02	10	Nearest, strongest quasar
Virgo A, M87*	12	29.8	+12	30	EO galaxy with jet
Centaurus A	13	24.2	−42	55	NGC 5128 peculiar galaxy
3C 295	14	10.7	+52	18	21st mag, galaxy, 4.5×10^9 light years
OQ 172	14	44.3	+10	04	Quasar, very large redshift z = 3.53
Scorpio X-1	16	18.8	−15	35	X-ray, radio, and optical variable
Kepler's s'nova	17	27.6	−21	16	Remnant of supernova of 1604
Galactic nucleus	17	44.3	−28	56	Complex region OH, NH_3 em., H_2CO abs'n.
Omega neb, M17	18	19.3	−16	10	HII region, double structure
SS433	19	10.9	+04	56	Star with high velocity jets
CP 1919	19	20.8	+21	50	First pulsar discovered, P = 1.337 s
Cygnus A*	19	58.7	+40	41	Strong radio galaxy, double source
Cygnus X	20	21.9	+40	19	Complex region
NML Cygnus	20	45.8	+40	02	Infrared source, OH emission
Cygnus loop	20	51.4	+29	36	S'nova remnant (Network nebula)
N. America	20	54.4	+43	59	Radio shape resembles photographs
BL Lac	22	01.9	+42	11	Radio and optical variable
3C 446	22	24.7	−05	04	Quasar, optical mag. & spectrum var.
Cassiopeia A*	23	22.5	+58	42	Strongest source, s'nova remnant
Sun*					Continuous emission & bursts
Moon					Thermal source only
Jupiter*					Radio bursts controlled by Io

Source marked * could be detected with amateur radio telescopes. Radio maps of the broad structure of the sky can be found in *Sky and Telescope*, 1982, March, p. 230. (For more information about amateur radio astronomy, see *Astronomy*, **5**, no. 12, 50 (1977), a series of articles in *J. Roy. Ast. Soc. Canada*, **72**, L5, L22, L38 . . . (1978) and a series of articles in *Sky and Telescope*, **55**, 385 and 475 and **56**, 28 and 114 (1978)—*Ed.*)

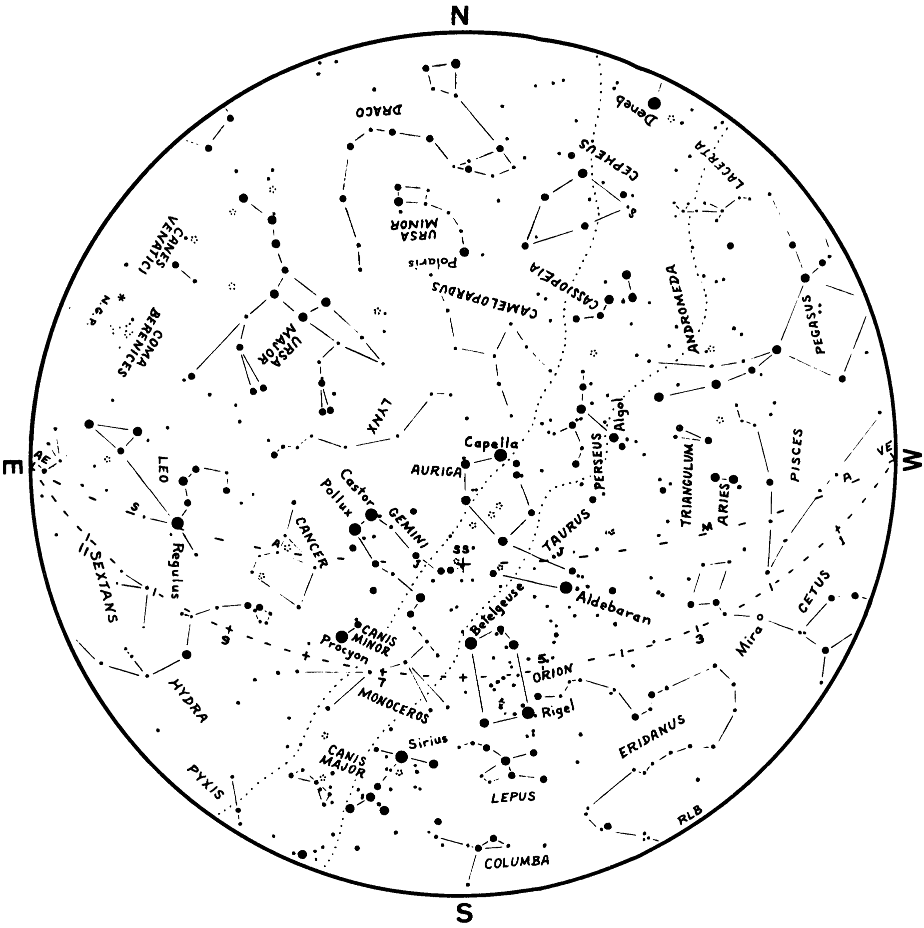
MAPS OF THE NIGHT SKY

The maps on the next six pages depict the night sky as it appears at various times of the year. The maps are drawn for latitude 45° N, but are useful for latitudes several degrees north or south of this. Because the aspect of the night sky changes continuously with both longitude and time, while time zones change discontinuously with both longitude and time of year, it is not possible to state simply when, in general, a particular observer will find that his or her sky fits exactly one of the six maps. The month indicated on each map is the time of year when the map will match the "late evening" sky. On any particular night, successive maps will represent the sky as it appears every four hours later. For example, at 2 or 3 am on a March night, the May map should be used. Just after dinner on a January night, the November map will be appropriate.

The maps show stars down to a magnitude of 4.5 or 5, i.e. those which are readily apparent to the unaided eye on a reasonably dark night. The center of each map is the zenith, the point directly overhead; the circumference is the horizon. To identify the stars, hold the map in front of you so that the part of the horizon which you are facing (west, for instance) is downward. (The four letters around the periphery of each map indicate compass directions.) Stars forming the usual constellation patterns are linked by straight lines, constellation names being given in upper case letters. The names in lower case are those of first magnitude stars, except Algol and Mira which are famous variable stars, and Polaris which is near the north celestial pole. Small clusters of dots indicate the positions of bright star clusters, nebulae, or galaxies. Although a few of these are just visible to the naked eye, and most can be located in binoculars, a telescope is needed for good views of these objects.

The pair of wavy, dotted lines indicates roughly the borders of the Milky Way, while small asterisks locate the directions of the galactic center (G.C.), north galactic pole (N.G.P.) and south galactic pole (S.G.P.). Two dashed lines appear on each map. The one with more dashes is the celestial equator. Tick marks along this indicate hours of right ascension, the odd hours being labeled. The line with fewer dashes is the ecliptic, the apparent annual path of the Sun across the heavens. Letters along this line indicate the approximate position of the Sun at the beginning of each month. Also located along the ecliptic are the vernal equinox (VE), summer solstice (SS), autumnal equinox (AE), and winter solstice (WS). The Moon and the other eight planets are found near the ecliptic, but since their motions are not related in a simple way to our year, it is not feasible to show them on a general set of star maps.

Star maps providing more detail than possible in the six, all-sky maps presented here are available. For example: *Norton's Star Atlas* (8700 stars to magnitude 6.3); *Tirion's Sky Atlas 2000.0* (43 000 stars to magnitude 8.0); *AAVSO Variable Star Atlas* (260 000 stars to magnitude 9.5) (Sky Publishing Corporation, 49 Bay State Road, Cambridge, MA 02238). Norton's is a classic and should be in the library of anyone who has a keen interest in the night sky. Both Tirion's atlas and the AAVSO atlas will be invaluable to the advanced observer. For information on the mythology of the night sky, *Star Names, Their Lore and Meaning* by R. H. Allen is a standard reference (Dover Publications, Inc., 180 Varick St., New York, NY 10014).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CEPHEUS
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LACERTA
URSA MINOR
Polaris
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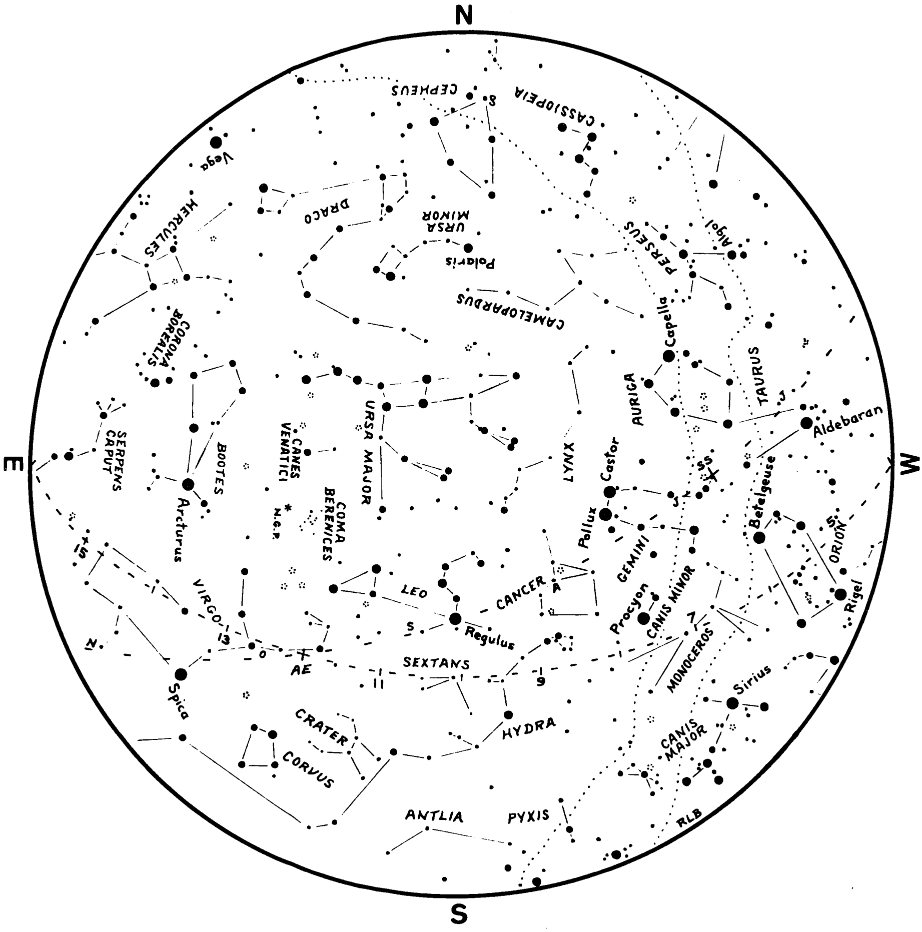
CASSIOPEIA
ANDROMEDA
PEGASUS
CANES VENATICI
URSA MAJOR
COMA BERENICES
N.G.P.
LYNX
Capella
AURIGA
Algol
PERSEUS
TRIANGULUM
ARIES
PISCES
LEO
Castor
Pollux
GEMINI
CANCER
TAURUS
Regulus
SEXTANS
Aldebaran
CETUS
Mira
Betelgeuse
CANIS MINOR
Procyon
ORION
Rigel
HYDRA
MONOCEROS
ERIDANUS
CANIS MAJOR
Sirius
LEPUS
PYXIS
RLB
COLUMBA

JANUARY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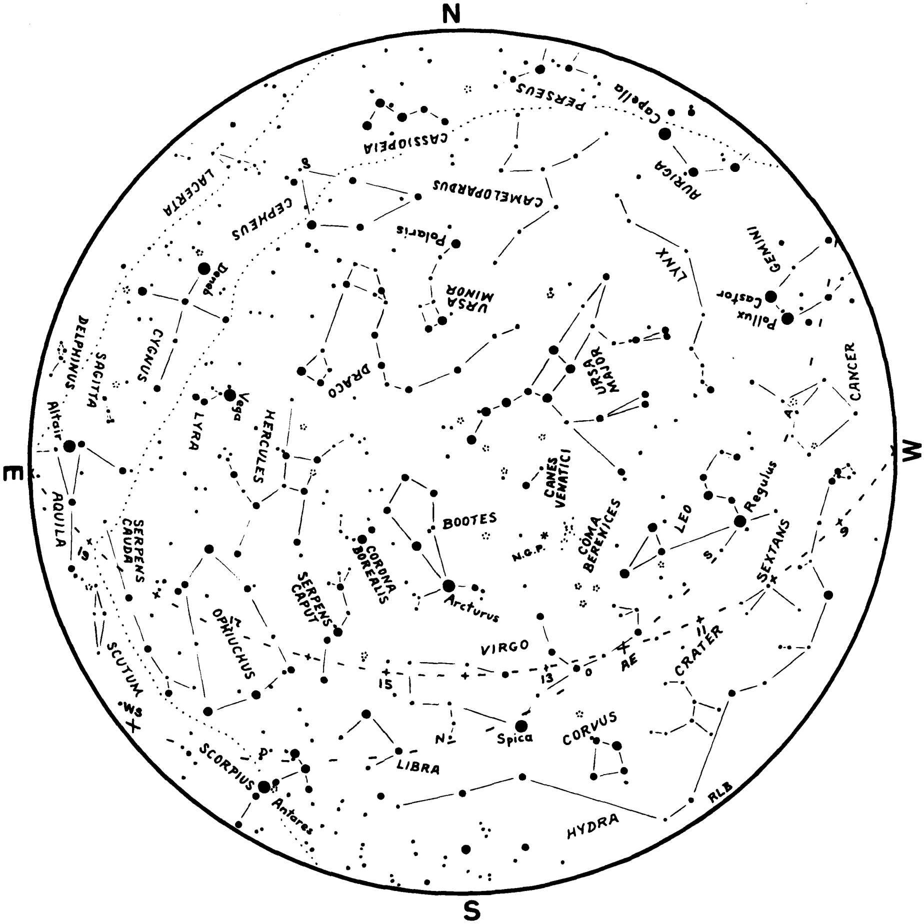
CEPHEUS
CASSIOPEIA
Vega
HERCULES
DRACO
URSA MINOR
Polaris
PERSEUS
Algol
CAMELOPARDUS
CORONA BOREALIS
Capella
TAURUS
AURIGA
Aldebaran
URSA MAJOR
CANES VENATICI
SERPENS CAPUT
BOOTES
LYNX
Castor
Arcturus
COMA BERENICES
N.G.P.
Pollux
Betelgeuse
ORION
GEMINI
VIRGO
LEO
CANCER
CANIS MINOR
Procyon
Rigel
Regulus
MONOCEROS
AE
SEXTANS
Spica
Sirius
CRATER
HYDRA
CORVUS
CANIS MAJOR
ANTLIA
PYXIS
RLB

MARCH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Capella
CASSIOPEIA
AURIGA
CAMELOPARDUS
LACERTA
CEPHEUS
Polaris
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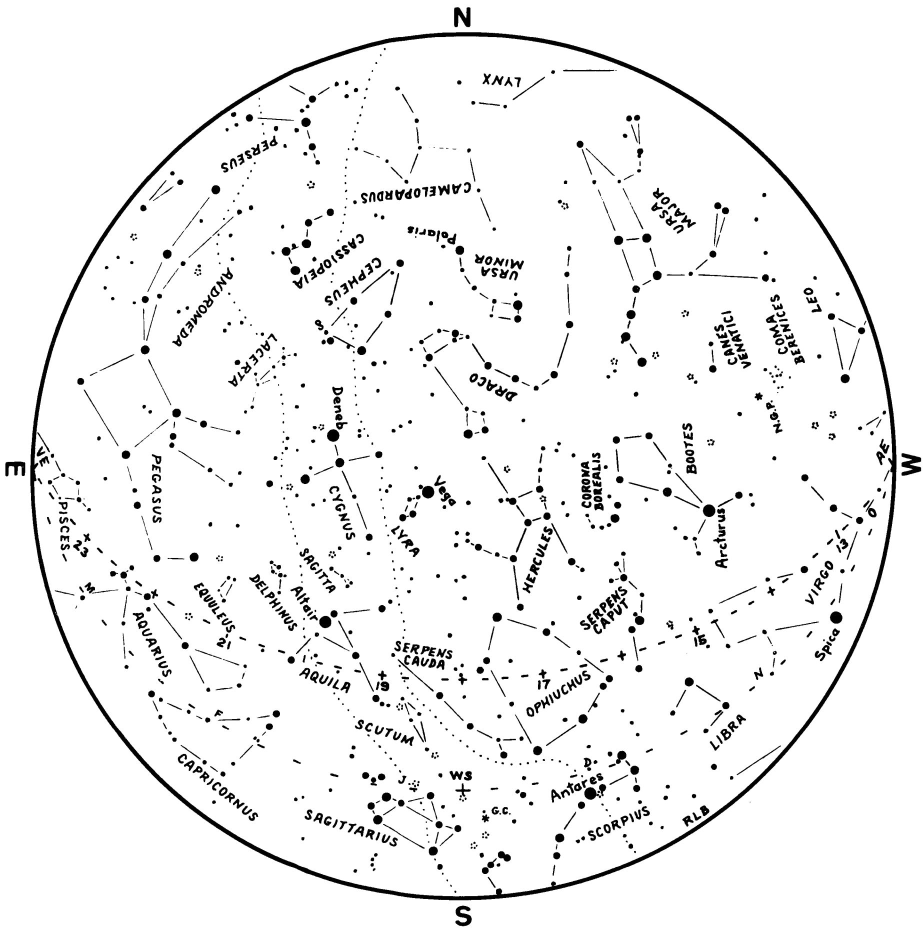
Deneb
URSA MINOR
Castor
Pollux
DELPHINUS
SAGITTA
CYGNUS
DRACO
URSA MAJOR
CANCER
Vega
LYRA
HERCULES
Altair
CANES VENATICI
AQUILA
BOOTES
COMA BERENICES
LEO
Regulus
SERPENS CAUDA
CORONA BOREALIS
N.G.P.
SEXTANS
SERPENS CAPUT
OPHIUCHUS
Arcturus
VIRGO
AE
CRATER
SCUTUM
CORVUS
Spica
SCORPIUS
LIBRA
Antares
HYDRA
RLB

MAY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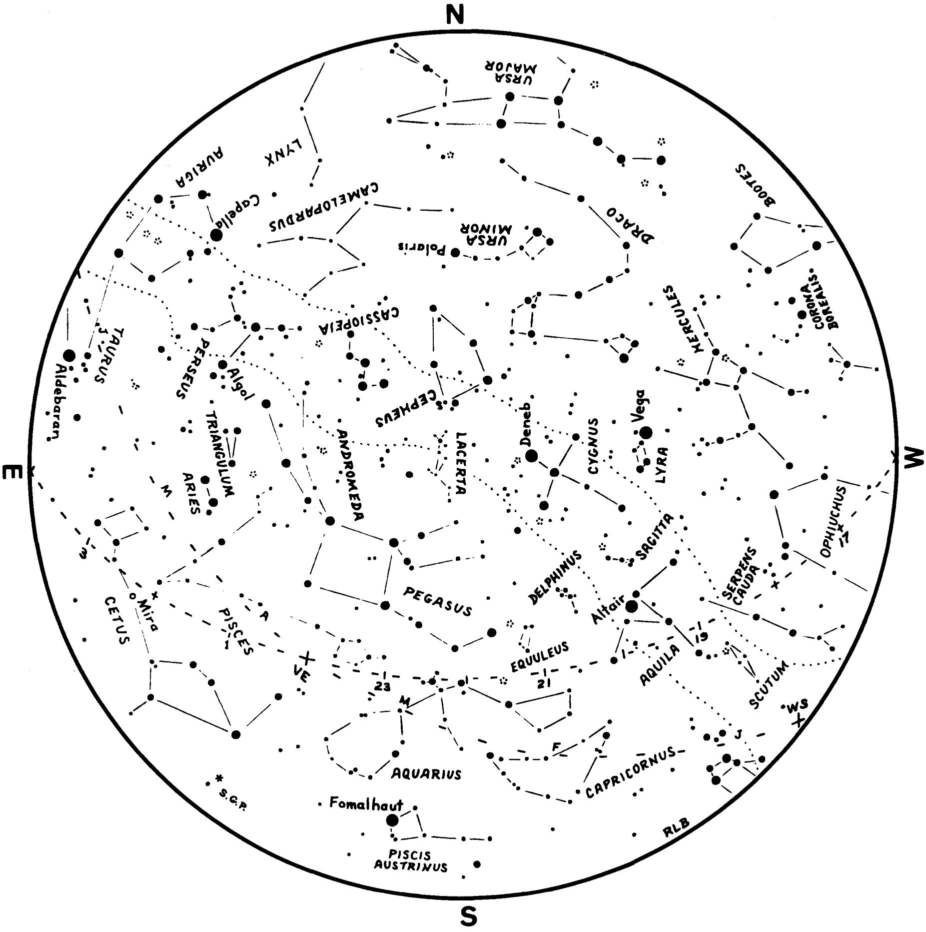
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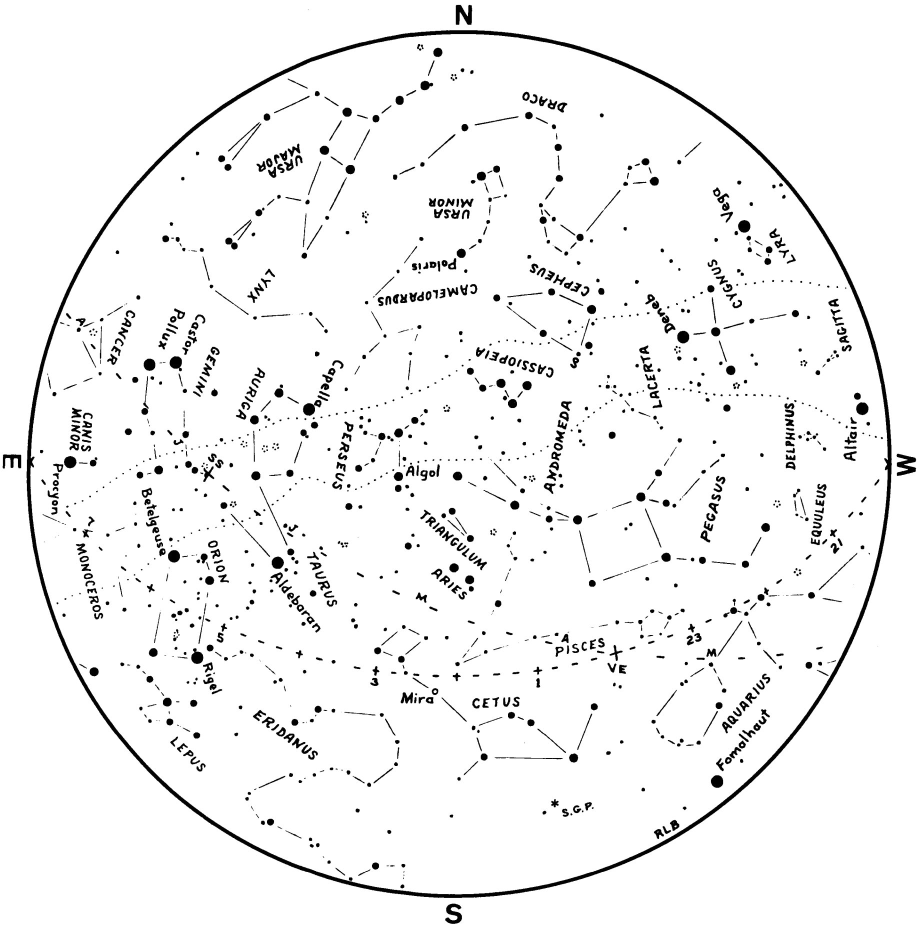
SEPTEMBER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ARIES
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Rigel
Mira
CETUS
ERIDANUS
LEPUS
AQUARIUS
Fomalhaut
S.G.P.
RLB

NOVEMBER

KEY TO LEFT-HAND MARGIN SYMBOLS

D BASIC DATA

t TIME

M THE SKY MONTH BY MONTH

⊙ SUN

☾ MOON

P PLANETS, SATELLITES, AND ASTEROIDS

╲. METEORS, COMETS, AND DUST

✸ STARS

⁘ NEBULAE

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CALENDAR 1984

January

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