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Journal

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PROMOTING
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Société Royale d'Astronomie du Canada

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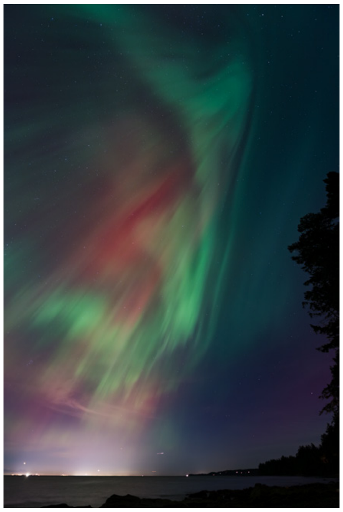

The aurora borealis once again lit up the skies across Canada, and much of the world. This time the display occurred on the night of Oct. 10-11 and was visible even in heavily light-polluted Toronto. Martin Gisborne photographed them from Bells Landing, on Gabriola Island, in British Columbia. He took the 8-second photograph at roughly 9:30 p.m. using a Nikon D850, with a 14-24 mm ƒ/2.8 lens at 15 mm, and ISO 400. The skyglow of Vancouver can be seen in the distance.

Journal

The *Journal* is a bi-monthly publication of The Royal Astronomical Society of Canada and is devoted to the advancement of astronomy and allied sciences. It contains articles on Canadian astronomers and current activities of the RASC and its Centres, research and review papers by professional and amateur astronomers, and articles of a historical, biographical, or educational nature of general interest to the astronomical community. All contributions are welcome, but the editors reserve the right to edit material prior to publication. Research papers are reviewed prior to publication, and professional astronomers with institutional affiliations are asked to pay publication charges of $100 per page. Such charges are waived for RASC members who do not have access to professional funds as well as for solicited articles. Manuscripts and other submitted material may be in English or French, and should be sent to the Editor-in-Chief.

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President's Corner

1984 – A Story of Two Solar Eclipses

by Michael Watson, President
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This is a story about two solar eclipses that occurred 40 years ago this year. To tell this story I have to start with a setup—a review of the basics of solar eclipses.

The Setup

When people become interested in astronomy, they learn early on that there must be at least two solar eclipses visible from some part of planet Earth every year, and—very rarely—there can be up to seven. Both solar and lunar eclipses occur during so-called "eclipse seasons," which are approximately six months apart and regress around the calendar such that one eclipse season follows the previous one by 173 days. Eclipse seasons last for about 35 days, during which both lunar and solar eclipses occur, and in each succeeding year they take place about 20 days earlier than in the previous year.

Newly minted astronomers also learn that, broadly speaking, there are two types of solar eclipses: central eclipses, in which the Moon passes centrally across the Sun as seen from a narrow path somewhere on Earth; and non-central or partial eclipses, in which only a portion of the Sun is obscured by the Moon, and the Moon passes across either the northern or southern hemisphere of the Sun, so that from no place on Earth can the Moon be seen to pass centrally across the Sun's disk.

Central solar eclipses are of two types: total and annular, owing to the fact that the Moon's orbit around Earth is an ellipse and not a circle. Once a month, at or near apogee, the Moon lies further from Earth and appears smaller in the sky than average; half a month later it is at or close to perigee, when it is closer and appears larger in the sky than average. When the Moon is at or near apogee at the time of a central solar eclipse, its disk is too small to cover the surface of the Sun completely. At mid-eclipse there is a thin ring, or "annulus" of uncovered Sun around the black disk of the Moon. This type of eclipse, during which the solar corona cannot be seen owing to the brilliance of the uneclipsed ring of sunlight, is therefore called an "annular" eclipse. The most recent example of annular eclipse was 14 months ago, in October 2023, which I drove to Texas to observe.

Where, however, a central solar eclipse occurs when the Moon is at or near perigee, the Moon's disk as seen from Earth is large enough to cover the entire brilliant photosphere of the

Sun, and a total eclipse occurs. Then the Sun's corona appears, and pink-coloured prominences appear on the limb of the Sun. Dedicated eclipse chasers travel half-way around the globe time and time again to witness the breathtaking beauty of a total solar eclipse.

There are two other closely related types of central eclipse, however, that are rare and that few people get to see in their lifetimes: (i) the hybrid eclipse; and (ii) the beaded annular eclipse. A hybrid central eclipse takes place at the point of the month when the Moon is halfway between the apogee and perigee points of its orbit. At the point of maximum eclipse along the path for a hybrid eclipse, the Moon is just barely large enough to cover the Sun's surface, and for just a few seconds the eclipse is total and the solar corona springs into view. Both earlier and later in the eclipse path, however, on either side (west or east) of the point where the eclipse appears total, the Moon is further away from the surface of Earth across which its shadow is racing. From these points the Moon appears smaller in the sky, and the result is a very brief annular eclipse at both the beginning and the end of the eclipse path, generally of only a few seconds in length.

A "beaded annular" eclipse occurs when the Moon is almost but not quite large enough to cover the Sun's surface completely. At these points on the eclipse path, which is only a few kilometres wide, at the moment of maximum eclipse, brilliant beads of sunlight can be seen bursting through valleys on the edge (or limb) of the Moon, while mountains on the Moon's limb break up the razor-thin annulus of sunlight. At this moment the dark disk of the Moon is surrounded, 360°, by a dozen or more beads of sunlight, in one of the briefest but most amazing spectacles that can be seen in nature.

There are two last points about central solar eclipses that are crucial to understand this story that I'm about to tell: (1) Two successive solar eclipses cannot be total. If in one eclipse season there is a total eclipse visible from some location on Earth, at the next eclipse season the single eclipse must be either annular, beaded annular, or partial, and if there are two eclipses in the next eclipse season, they must both be partial. The result? It is common wisdom that at no two successive eclipses of the Sun can the solar corona been seen.

(2) Eclipses occur in a cycle called the "Saros," which is a period of 18.04 years, after which one solar eclipse is replicated almost exactly in type and duration. The main difference between two successive eclipses in one Saros cycle is that the second one can be seen almost exactly one-third of the way around the globe to the west.

The Story

And now we get to the tale of the two solar eclipses in 1984.

In that year—my 13th year as an RASC member—the eclipse seasons occurred in the months of May and November. Up to that point I had been in the paths of totality of three total eclipses, in 1972 and 1979 in Canada, and in 1983 in Java, Indonesia.

The eclipse of 1984 May 30, was one of the rare beaded annular eclipses, in which 99.8 percent of the Sun's diameter was to be covered by the Moon. Astronomers in North America were excited, because the path of the annular eclipse, only a few kilometres wide, would cross the southeastern United States from Louisiana northeastward across Georgia, North Carolina, and Virginia, and the point of maximum eclipse would be a few dozen kilometres east of Richmond, Virginia, near the Atlantic coast. At that point, the path of the annular eclipse would be only 7 kilometres wide, and the predicted duration of the annular phase was 11.5 seconds.

Even though this would be an annular eclipse, the Moon would be so large that it would almost cover the Sun, and the predictions were that it would actually be a beaded annular eclipse of the type described above. I thought there was also a decent chance that, through a telescope, an astute observer looking at exactly the right time might be able to catch a glimpse of the solar corona. I read the post-eclipse coverage in Sky & Telescope magazine for accounts of the previous annular eclipse in the series, which had taken place on 1966 May 20, and for which the best observing location was in Greece. That eclipse was even larger in magnitude, with 99.91% of the Sun's diameter covered at mid-eclipse. But although the stories said that observers tried to see the corona, no one reported having been successful. I read, however, that they all had tried to spot the corona at the moment of mid-eclipse, when there were tiny beads of sunlight all around the dark lunar disk. From my experience at the 1983 eclipse, that seemed to me to be the wrong time to look. I thought that in the seconds before mid-eclipse, when there would be a razor-thin crescent of sunlight on the eastern limb of the eclipsed Sun, an observer should be looking at the opposite limb, where no beads of sunlight were yet shining through, to spot the inner corona. And in the seconds after mid-eclipse, when the Moon had moved further across the solar disk and a thin crescent of Sun would be emerging on the western limb, the observer should then shift the telescope slightly to the east and look at the eastern limb. This, I thought, would be an interesting experiment!

So the Toronto Centre organized a two-day bus trip to Virginia, our plan being to observe the eclipse from Petersburg, Virginia, where the annular phase was predicted to last 12.3 seconds. On the morning of the big day, however, the weather was terrible; cloud and pelting rain. So we quickly changed plans and had our drivers take our busload of enthusiasts as fast as possible 390 km further southwest along the eclipse path to the small town of Cleveland, North Carolina, where the forecast was for a clear front to have moved in by eclipse time. The partial eclipse was already underway when we arrived at the local high school, ran into the school to speak to the principal, and got permission to set up our scopes and watch the eclipse from the school's playing field. At 12.34.41 the annular phase started, but a few seconds before that Randy Attwood and I looked through the viewfinders of our cameras at the western limb of the eclipse Sun and saw wisps of the inner corona! About 20 seconds later, we shifted our scopes a little to the west to the opposite limb and saw corona there too.

Needless to say, there was an explosion of cheers from all of us, realizing how lucky were had been to see this once-in-a-lifetime event.

But that's only half the story. Long before 1984, I knew that there would be a second solar eclipse that year; a total eclipse that would be seen in about as distant and hard-to-get-to location as one could imagine: Papua New Guinea, a short distance north of Australia in the Coral Sea. From the little town of Hula, a 120 km drive from the capital, Port Moresby, 10° south of the equator, the total eclipse would last just 53 seconds, 105 minutes after sunrise, with the Sun just 24° above the eastern horizon.

A few minutes after we had seen the corona at the May eclipse, Randy, his now wife Betty Robinson (both of them current members of the Board of Directors of the Society) and I looked at each other and decided that we had to be in Papua New Guinea the following November 22. Why? To try to become—most likely—the first and only people ever to have seen the solar corona at two successive eclipses.

The story of that eclipse trip could take many pages, with all of the adventures, camping with our tents and sleeping bags in the schoolyard beneath tall palm trees, showing the young school children the Sun through eclipse safety glasses the day before the eclipse; on and on. There are two related images that are still fresh in our minds' eye 40 years later: When we awoke on the morning of the eclipse and peered out of the tent, we saw a semi-circle of very quiet young children sitting cross-legged, intently staring at the tents, waiting for us to get up. The little bag of refuse that we had left outside one of the tents was gone; they had taken it away for us. A few minutes later, one of the older boys scrambled up the trunk of one of the palms and cut down coconuts for our breakfast.

And then the Sun rose in a clear sky over the Coral Sea, in which we had swum the day before. The partial phase of the eclipse started with the Sun not quite 10° above the horizon and progressed over the next 95 minutes until the Moon's umbral shadow swept over us at 7:22 local time. The corona sprang into view, with a few pink prominences around the solar disk. Fifty-three seconds later it was all over. All, that is, except for the cheering, a celebratory bottle of (quite warm) Champagne, and the realization that we had accomplished what had seemed months earlier to be a very challenging goal! ✶

News Notes / En manchette

Compiled by Jay Anderson

More ice inside Ceres than thought

Since the first sighting of the first-discovered and largest asteroid in our Solar System was made in 1801 by Giuseppe Piazzi, astronomers and planetary scientists have pondered the make-up of this dwarf planet. Ceres's heavily battered and dimpled surface is covered in impact craters. Scientists have long argued that visible craters on the surface meant that it could not be very icy, as craters would not be able persist for any length of time on a plastic ice-world surface.

Researchers at Purdue University and NASA's Jet Propulsion Lab (JPL) now believe Ceres is a very icy object that possibly was once a muddy ocean world. This discovery that Ceres has a dirty ice crust was led by Ian Pamerleau, Ph.D. student, and Mike Sori, assistant professor in Purdue's Department of Earth, Atmospheric, and Planetary Sciences, who published their findings in *Nature Astronomy*. The duo along with Jennifer Scully, research scientist with JPL, used computer simulations of how craters on Ceres deform over billions of years.

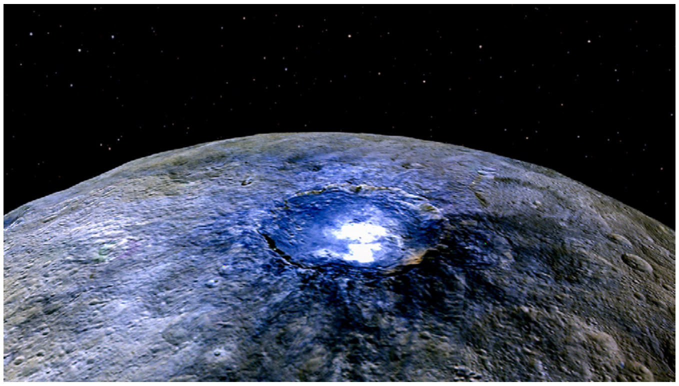
Figure 1 — A close-up image of Ceres showing Occator crater with its ice-spewing cryovolcano. NASA/JPL-CALTECH/UCLA/MPS/DLR/IDA

"We think that there's lots of water-ice near Ceres' surface, and that it gets gradually less icy as you go deeper and deeper," Sori said. "People used to think that if Ceres was very icy, the craters would deform quickly over time, like glaciers flowing on Earth, or like gooey flowing honey. However, we've shown through our simulations that ice can be much stronger in conditions on Ceres than previously predicted if you mix in just a little bit of solid rock."

The team's discovery is contradictory to the previous belief that Ceres was relatively dry. The common assumption was that Ceres was less than 40 percent ice with silicates, salts, organic matter, and clathrates, a light but strong material formed when gas is trapped in an ice lattice, completing the mix. Sori's team now believes the surface is more like 90 percent ice.

"Our interpretation of all this is that Ceres used to be an 'ocean world' like Europa (one of Jupiter's moons), but with a dirty, muddy ocean," Sori said. "As that muddy ocean froze over time, it created an icy crust with a little bit of rocky material trapped in it."

Pamerleau explained how they used computer simulations to model how relaxation occurs for craters on Ceres over billions of years.

"Even solids will flow over long timescales, and ice flows more readily than rock. Craters have deep bowls which produce high stresses that then relax to a lower stress state, resulting in a shallower bowl via solid state flow," he said. "So the conclusion after NASA's *Dawn* mission was that due to the lack of relaxed, shallow craters, the crust could not be that icy.

"Our computer simulations account for a new way that ice can flow with only a little bit of non-ice impurities mixed in, which would allow for a very ice-rich crust to barely flow even over billions of years. Therefore, we could get an ice-rich Ceres that still matches the observed lack of crater relaxation. We tested different crustal structures in these simulations and found that a gradational crust with a high ice content near the surface that grades down to lower ice with depth was the best way to limit relaxation of Cerean craters."

The modelling results indicated that a simple 12-km-diameter crater at the warm equator in a crust that is uniformly 90 percent ice relaxes 5 percent after 1 Gyr as long as impurities were ≥ 6 percent. At other latitudes, the small-crater relaxation was even less. At higher latitudes, larger, complex craters showed minimal deformation on billion-year timescales, but those at the equator experience substantial relaxation in the same time frame. In effect, the impurities in the ice mixture stiffen the regolith and preserve its characteristics over long time periods.

"Ceres is the largest object in the asteroid belt, and a dwarf planet. I think sometimes people think of small, lumpy things as asteroids (and most of them are!), but Ceres really looks more like a planet," Sori said. "It is a big sphere, diameter 950 kilometres or so, and has surface features like craters, volcanoes, and landslides."

On 2007 September 27, NASA launched the *Dawn* mission. This mission was the first and only spacecraft to orbit two extraterrestrial destinations—the protoplanet Vesta and Ceres. Launched in 2007, *Dawn* reached Ceres in 2015 and orbited the dwarf planet until 2018.

"We used multiple observations made with *Dawn* data as motivation for finding an ice-rich crust that resisted crater relaxation on Ceres. Different surface features (e.g. pits, domes, and landslides, etc.) suggest the near subsurface of Ceres contains a lot of ice," Pamerleau said. "Spectrographic data also shows that there should be ice beneath the regolith on the dwarf planet and gravity data yields a density value very near that of ice ($1{,}287\ \mathrm{kg\,m^{-3}}$), specifically impure ice. We also took a topographic profile of an actual complex crater on Ceres and used it to construct the geometry for some of our simulations."

Sori says that because Ceres is the largest asteroid there was suspicion that it could have been an icy object based on some estimates of its mass made from the Earth. Those factors made it a great choice for a spacecraft visit.

"To me the exciting part of all this, if we're right, is that we have a frozen ocean world pretty close to Earth. Ceres may be a valuable point of comparison for the ocean-hosting icy moons of the outer Solar System, like Jupiter's moon Europa and Saturn's moon Enceladus," Sori said. "Ceres, we think, is therefore the most accessible icy world in the Universe. That makes it a great target for future spacecraft missions. Some of the bright features we see at Ceres's surface are the remnants of Ceres's muddy ocean, now mostly or entirely frozen, erupted onto the surface. So we have a place to collect samples from the ocean of an ancient ocean world that is not too difficult to send a spacecraft to."

Compiled in part with material provided by Purdue University

Another measure of the Hubble Constant

Measuring the Hubble constant, the rate at which the Universe is expanding, is an active area of research among astronomers around the world who analyze data from both ground- and space-based observatories. NASA's *James Webb Space Telescope* has already contributed to this ongoing discussion. Earlier this year, astronomers used Webb data containing Cepheid variables and Type Ia supernovae, reliable distance markers to measure the Universe's expansion rate, in order to confirm NASA's *Hubble Space Telescope*'s previous measurements. Now, researchers are using an independent method of measurement to further improve the precision of the Hubble constant: gravitationally lensed supernovae. Brenda Frye from the University of Arizona, along with a team of many researchers from different institutions around the world, is leading this effort after Webb's discovery of three points of light in the direction of a distant and densely populated cluster of galaxies.

Dr. Frye explained what the team has nicknamed Supernova H0pe and how gravitational lensing effects are providing insights into the Hubble constant:

"It all started with one question by the team: 'What are those three dots that weren't there before? Could that be a supernova?'" she said. "The points of light, not visible in 2015 Hubble imaging of the same cluster, were obvious when the images of PLCK G165.7+67.0 arrived on Earth from Webb's Guaranteed Time Observations of the Prime Extragalactic Areas for Reionization and Lensing Science (PEARLS) "Cluster" program. The team notes the question was the first to pop to mind for good reason: 'The field of G165 was selected for this program due to its high rate of star formation of more than 300 solar masses per year, an attribute that correlates with higher supernova rates.'

"Initial analyses confirmed that these dots corresponded to an exploding star, one with rare qualities. First, it's a Type Ia supernova, an explosion of a white dwarf star. This type of supernova is generally called a 'standard candle,' meaning that the supernova had a known intrinsic brightness. Second, it is gravitationally lensed.

"Gravitational lensing is important to this experiment. The lens, consisting of a cluster of galaxies that is situated between the supernova and us, bends the supernova's light into multiple images. This is similar to how a trifold vanity mirror presents three different images of a person sitting in front of it. In the Webb image, this was demonstrated right before our eyes in that the middle image was flipped relative to the other two images, a 'lensing' effect predicted by theory.

"To achieve three images, the light travelled along three different paths. Since each path had a different length, and light travelled at the same speed, the supernova was imaged in this Webb observation at three different times during its explosion. In the trifold mirror analogy, a time-delay ensued in which the right-hand mirror depicted a person lifting a comb, the left-hand mirror showed hair being combed, and the middle mirror displayed the person putting down the comb.

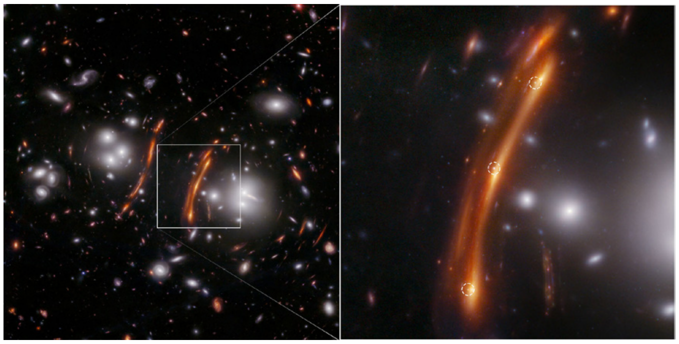

Figure 2 — NASA's James Webb Space Telescope*'s NIRCam (Near-Infrared Camera) image of the galaxy cluster PLCK G165.7+67.0, also known as G165, on the left shows the magnifying effect a foreground cluster can have on the distant Universe beyond. The zoomed region on the right shows supernova H0pe triply imaged (labelled with white dashed circles) due to gravitational lensing. Credit: NASA, ESA, CSA, STScI, B. Frye (University of Arizona), R. Windhorst (Arizona State University), S. Cohen (Arizona State University), J. D'Silva (University of Western Australia, Perth), A. Koekemoer (Space Telescope Science Institute), J. Summers (Arizona State University).*

"Trifold supernova images are special: The time delays, supernova distance, and gravitational-lensing properties yield a value for the Hubble constant or H0 (pronounced H-naught). The supernova was named SN H0pe since it gives astronomers hope to better understand the Universe's changing expansion rate.

"In an effort to explore SN H0pe further, the PEARLS-Clusters team wrote a Webb Director's Discretionary Time (DDT) proposal that was evaluated by science experts in a dual-anonymous review and recommended by the Webb Science Policies Group for DDT observations. In parallel, data was acquired at the MMT, a 6.5-metre telescope on Mt. Hopkins, and the Large Binocular Telescope on Mt. Graham, both in Arizona. In analyzing both observations, our team was able to confirm that SN H0pe is anchored to a background galaxy, well behind the cluster, that existed 3.5 billion years after the Big Bang.

"SN H0pe is one of the most distant Type Ia supernovae observed to date [at z=1.78]. A different team member made another time-delay measurement by analyzing its spectrum from Webb, confirming the Type Ia nature of SN H0pe.

"Seven subgroups contributed lens models describing the 2-D matter distribution of the galaxy cluster. Since the Type Ia supernova is a standard candle, each lens model was 'graded' by its ability to predict the time delays and supernova brightnesses relative to the true measured values.

"To prevent biases, the results were blinded from these independent groups and revealed to each other on the announced day and time of a 'live unblinding.' The team reports the value for the Hubble constant as 75.4 kilometres per second per megaparsec, plus 8.1 or minus 5.5. (One parsec is equivalent to 3.26 light-years of distance.) This is only the second measurement of the Hubble constant by this method, and the first time using a standard candle. The PEARLS program lead investigator remarked, 'This is one of the great Webb discoveries, and is leading to a better understanding of this fundamental parameter of our Universe.'

"Our team's results are impactful: The Hubble constant value matches other measurements in the local Universe, and is somewhat in tension with values obtained when the Universe was young. Webb observations in Cycle 3 will improve on the uncertainties, allowing more sensitive constraints on H0."

Barnard's star serves a goodie

Using the European Southern Observatory's Very Large Telescope (ESO's VLT), astronomers have discovered an exoplanet orbiting Barnard's star, the closest single star to our Sun. On this newly discovered exoplanet, which has at least half the mass of Venus, a year lasts just over three Earth days. The team's observations also hint at the existence of three more exoplanet candidates, in various orbits around the star.

Located just 5.96 light-years away, Barnard's star is the second-closest stellar system—after Alpha Centauri's three-star group—and the closest individual star to us. The star is a small red-dwarf in Ophiuchus with a mass about 1/6th of the Sun and a visual magnitude of +9.5. The star has the distinction of the highest proper motion across the sky. Owing to its proximity, it is a primary target in the search for Earth-like exoplanets. Despite a promising detection back in 2018, no planet orbiting Barnard's star had been confirmed until now.

The discovery of this new exoplanet—announced in a paper published in the journal *Astronomy & Astrophysics*—is the result of observations made over the last five years with ESO's VLT, located at Paranal Observatory in Chile. "Even if it took a long time, we were always confident that we could find something," says Jonay González Hernández, a researcher at the Instituto de Astrofísica de Canarias in Spain, and lead author of the paper.

The team were looking for signals from possible exoplanets within the habitable or temperate zone of Barnard's star—the range where liquid water can exist on the planet's surface. Red dwarfs like Barnard's star are often targeted by astronomers since low-mass rocky planets are easier to detect there than around larger Sun-like stars.

Barnard b, as the newly discovered exoplanet is called, is 20 times closer to Barnard's star than Mercury is to the Sun. It orbits its star in 3.15 Earth days and has a surface temperature around 125 °C.

"Barnard b is one of the lowest-mass exoplanets known and one of the few known with a mass less than that of Earth. But the planet is too close to the host star, closer than the habitable zone," explains González Hernández. "Even if the star is about 2500 degrees cooler than our Sun, it is too hot there to maintain liquid water on the surface."

For their observations, the team used ESPRESSO, a highly precise instrument designed to measure the wobble of a star caused by the gravitational pull of one or more orbiting planets. The results obtained from these observations were confirmed by data from other instruments that also specialized in exoplanet hunting: HARPS at ESO's La Silla Observatory, HARPS-N and CARMENES. The new data do not, however, support the existence of the exoplanet reported in 2018.

In addition to the confirmed planet, the international team also found hints of three more exoplanet candidates orbiting the same star with orbital periods between 2 and 6 days and with equilibrium temperatures between 440K for the inner planet to 310K for the outer. These candidates, however, will require additional observations with ESPRESSO to be confirmed.

"We now need to continue observing this star to confirm the other candidate signals," says Alejandro Suárez Mascareño, a researcher also at the Instituto de Astrofísica de Canarias and co-author of the study. "But the discovery of this planet, along with other previous discoveries such as Proxima b and d, shows that our cosmic backyard is full of low-mass planets."

ESO's Extremely Large Telescope (ELT), currently under construction, is set to transform the field of exoplanet research. The ELT's ANDES instrument will allow researchers to detect more of these small, rocky planets in the temperate zone around nearby stars, beyond the reach of current telescopes, and enable them to study the composition of their atmospheres.

Composed with material provided by the ESO.

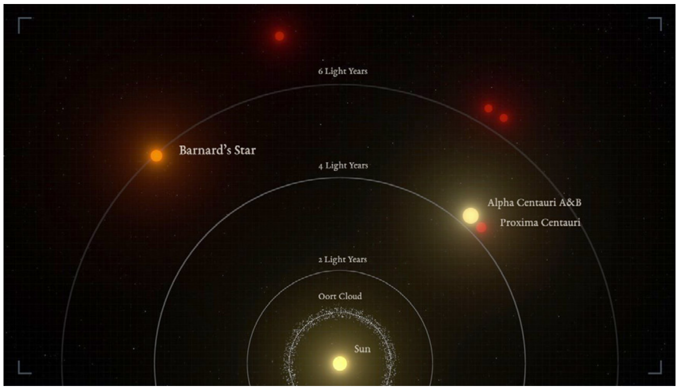

Figure 3 — Graphic representation of the relative distances between the nearest stars and the Sun. Barnard's star is the second-closest star system to the Sun, and the nearest single star to us. Image: IEEC/Science-Wave – Guillem Ramisa

Aging *Voyager 2* loses a sensor

After travelling more than 20.5 billion kilometres from Earth over nearly 50 years, the *Voyager 2* spacecraft is running short of power. On September 25, mission engineers at NASA turned off the plasma science instrument aboard the *Voyager 2* spacecraft due to the probe's gradually shrinking electrical power supply. Voyager continues to use four other science instruments to study the region outside our heliosphere, the protective bubble of particles and magnetic fields created by the Sun. The probe has enough power to continue exploring this region with at least one operational science instrument into the 2030s.

Mission engineers have taken steps to avoid turning off a science instrument for as long as possible because the science data collected by *Voyager 2* and its twin is unique. No other human-made spacecraft has operated in interstellar space, the region outside the heliosphere. The plasma science instrument measures the amount of plasma (electrically charged atoms) and the direction it is flowing. It has collected limited data in recent years due to its orientation relative to the direction that plasma is flowing in interstellar space.

Both spacecraft are powered by decaying plutonium and lose about four watts of power each year. After the twin Voyagers completed their exploration of the giant planets in the 1980s, the mission team turned off several science instruments that would not be used in the study of interstellar space. That gave the spacecraft plenty of extra power until a few years ago.

Since then, the team has turned off all onboard systems not essential for keeping the probes working, including some heaters. In order to postpone having to shut off another science instrument, they also adjusted how *Voyager 2*'s voltage is monitored.

The command to turn off the plasma science instrument was sent by NASA's Deep Space Network. It took 19 hours to reach *Voyager 2*, and the return signal took another 19 hours to reach Earth.

Mission engineers always carefully monitor changes being made to the 47-year-old spacecraft's operations to ensure they don't generate any unwanted secondary effects. The team has confirmed that the switch-off command was executed without incident and the probe is operating normally.

The plasma science instrument measures the flow and constitution of the solar wind, and in 2018, the instrument proved critical in determining that *Voyager 2* left the heliosphere and emerged into interstellar space. The boundary between the heliosphere and interstellar space is demarcated by changes in the atoms, particles, and magnetic fields that instruments on the Voyagers can detect. The instrument was also able to investigate the characteristics of charged particles in planetary atmospheres as it passed the outer planets on its way to the outer Solar System and beyond.

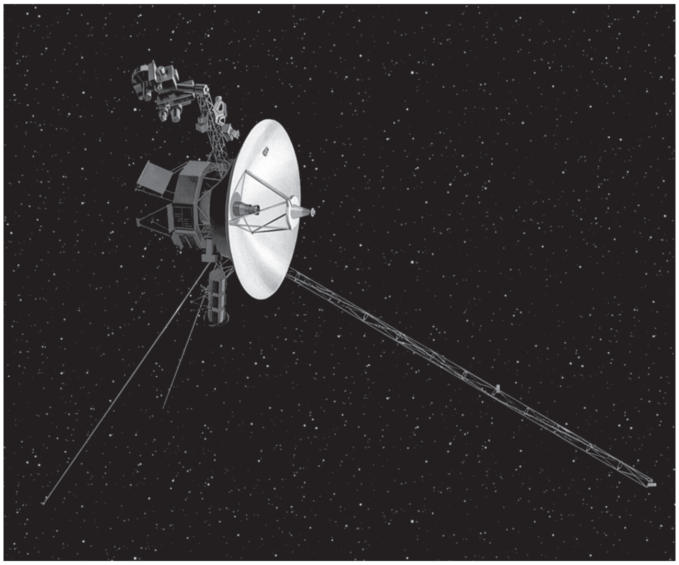

Figure 4 — Voyager 2. *Image: NASA*

Inside the heliosphere, particles from the Sun flow outward, away from our nearest star. The heliosphere is moving through interstellar space, so at *Voyager 2*'s position near the front of the solar bubble, the plasma flows in almost the opposite direction of the solar particles.

The plasma science instrument consists of four "cups." Three cups point in the direction of the Sun and observe the solar wind while inside the heliosphere. A fourth points at a right angle to the direction of the other three and observes the plasma in planetary magnetospheres, the heliosphere, and now, interstellar space.

When *Voyager 2* exited the heliosphere, the flow of plasma into the three cups facing the Sun dropped off dramatically. The most useful data from the fourth cup comes only once every three months, when the spacecraft does a 360-degree turn on the axis pointed toward the Sun. This factored into the mission's decision to turn this instrument off before others.

Remaining instruments will continue to measure galactic cosmic rays, magnetic fields, and plasma waves. The available power decreases about 4 watts per year as the plutonium that powers the spacecraft decays. Running until the mid-2030s will be a challenge.

The plasma science instrument on *Voyager 1* stopped working in 1980 and was turned off in 2007 to save power. Another instrument aboard *Voyager 2*, called the plasma wave subsystem, can estimate the plasma density when eruptions from the Sun drive shocks through the interstellar medium, producing plasma waves.

The Voyager team continues to monitor the health of the spacecraft and its available resources to make engineering decisions that maximize the mission's science output.

Composed with material provided by NASA.

Feature Article /
Article de fond

The 1860 eclipse expedition to Labrador: Context and Contacts

by Peter Broughton
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Abstract

The solar eclipse of July 1860 is reviewed here, emphasizing the contributions to the U.S. expedition to Labrador by Edward Ashe of the Québec Observatory. Early eclipse photography is summarized, especially the 1860 work of Peter Duchochois in Labrador and his mentor, Lewis Rutherfurd, in New York. Examples of sunspot sizes are compared from drawings, photographs, and timings made during the eclipse. Some long-lasting scientific and cultural spin-offs of the eclipse and the expedition are briefly considered.

Introduction

The solar eclipse of 1860 July 18 can be considered as a convenient marker of the transition of astronomy from its traditional positional roots to the new astrophysics. This came about partly because of the new wet collodion process in photography. The year 1860 also seems to be the first occasion that a Canadian government provided financial support for participation in an astronomical expedition (Public Accounts 1860?). The beneficiary was Edward D. Ashe (1814–95). Though English-born and a lieutenant in the Royal Navy, he was sent to Canada to direct the newly established Québec Observatory in 1850. He married in Québec, had nine children and died in Sherbrooke, so we might consider him Canadian long before there was such a thing as Canadian citizenship. The government grant of $500 enabled Ashe to join the U.S. Coast Survey on their expedition to northern Labrador for the eclipse of 1860 July 18. His own narrative of the expedition (Ashe 1861) gives the expedition a personal flavour.

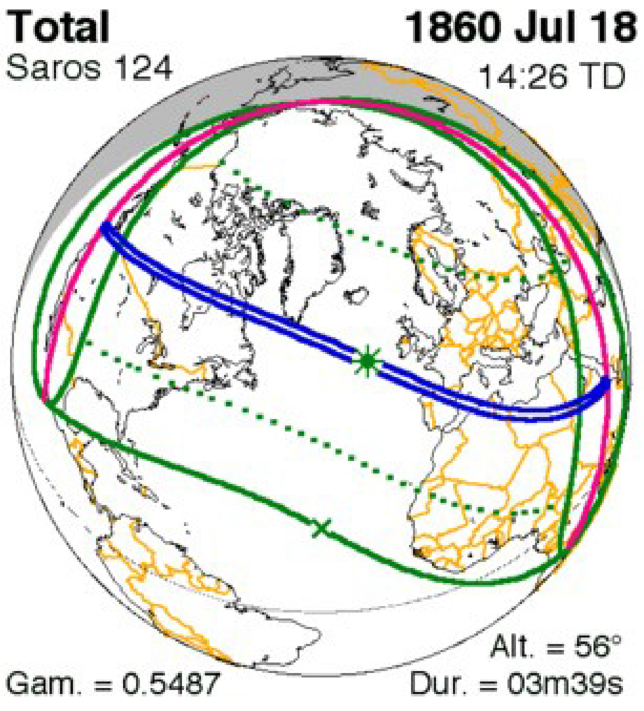
Figure 1 shows the geographic visibility of the eclipse including the path of totality, which spanned North America and the Atlantic Ocean. The eclipse, therefore, had the potential to improve transatlantic longitudes, a primary aim of its detailed study according to the Report of the United States Coast Survey (1861), p.23. (Page numbers from this report will appear in square brackets throughout this article.) A resolution [229] signed into law by President Buchanan on 1860 June 15, authorized and directed the Superintendent of the Coast Survey to furnish a vessel and provisions.

Other U.S. government expeditions in 1860

The Coast Survey also sent an expedition, under J.M. Gilliss, to Washington territory; that team successfully observed the eclipse at sunrise [275–292]. The extent and detail of Gilliss's visual observations during less than two minutes of totality is breathtaking. Perhaps the advent of photography has dulled our senses of quick observation! Here is a small part of his report:

> *At the moment of totality beads of golden and ruby-colored light flashed almost entirely around the moon. They were not constant in dimensions or color at one point, even for a second, but fitfully flickering, as reflections from rippled water, and as mutable in the respective places of color. I do not think this band could have been more than 10″ or 12″ broad. It was generally separated from the sharp lunar disc by a delicate line of white light, which disappeared as the changes of form or color took place. It broke up suddenly at 4h. 47m. 36s.5, and then for the first time protuberances were noted beyond the following limb of the moon. The position of the largest one was S 75° or 78° W., and its general form that of a flattened cone or pyramid of cumulus cloud, which, when first observed, was perhaps 2′ broad at the base and 1′ high. … As the moon moved onward it was certainly broader at the base and brighter at the summit than when first recognized, though I cannot say that its apparent altitude was increased thereby [285-6].*

Returning to the telescope after a few seconds away, he noted "a totally different picture had been substituted … [The dark



Five Millennium Canon of Solar Eclipses (Espenak & Meeus)

Figure 1 — Solar eclipse map from Five Millennium Canon of Solar Eclipses *(Espenak & Meeus)*

disc of the moon] was thrown in bold relief upon a ground of virgin white, traceable in every direction for the distance of quite a semidiameter." Clearly, Gilliss had witnessed the corona in all its glory. Gilliss's assistant, W.B. McMurtrie, a draughtsman with the Hydrographic Department, made two colourful sketches of totality based on Gilliss's description and rough sketches, but I have not reproduced them here as his rainbow-like arcs that appeared to cross the dark lunar disc are, to me, incomprehensible.

Another U.S. expedition to view the 1860 eclipse is probably the best known but certainly the least successful. The U.S. Navy sent two of its employees in the Nautical Almanac Office, William Ferrel and Nova Scotia-born Simon Newcomb, to territory controlled by the Hudson's Bay Company, near Cumberland House (Saskatchewan) (Ferrel 1861). The exceedingly difficult journey from St. Paul, Minnesota, and return, required three months. It aroused general interest but, with only some glimpses of the partial eclipse through heavy cloud, their only results were the latitude of the site and the times of third and fourth contact as well as the time of last contact with a large sunspot. Kennedy (1972, 1976, 1996) has described aspects of that expedition in the pages of this *Journal* and Levy (2021) has written an informative blog. Neither the Washington nor the Saskatchewan team was equipped to take photographs but, as will be seen later, they were an important aspect of the Labrador expedition.

Some Canadian observations of the 1860 eclipse outside the path of totality

Charles Smallwood (1860) of Montréal made visual observations of the eclipse and encouraged photographer William Notman to try to capture the partial phases—a project in which he succeeded, though troubled with passing clouds (Figure 2). What appears to be a sunspot near the eastern limb of the Sun in the second image, taken at 7:30, is likely an artifact since it does not appear in any of the other photos. Though meteorology was Smallwood's main concern, he did observe the solar spectrum during the eclipse and saw no changes. He reported that "the sun's disc presented several spots, one of a large size, which had been visible for some days" which, he said, was "well shown" on Notman's ambrotypes.

Meanwhile in Fredericton, Professor W.B. Jack (1860) and some students used the college's 7-foot telescope (stopped down to 3-inch aperture) to make a sketch of the Sun (Figure 6d). It showed several spots, and he recorded the times of occultation of seven of them.

Eclipse photography leading up to 1860

In an article primarily about the renowned expedition of 1860 to Spain and Warren De La Rue's success there in photographing the total eclipse, Hingley (2001) noted that there were earlier eclipse photos. On 1842 July 8 in Milan, Gian Alessandro Majocchi apparently succeeded in getting daguerreotypes of the Sun during the partial phases of a total

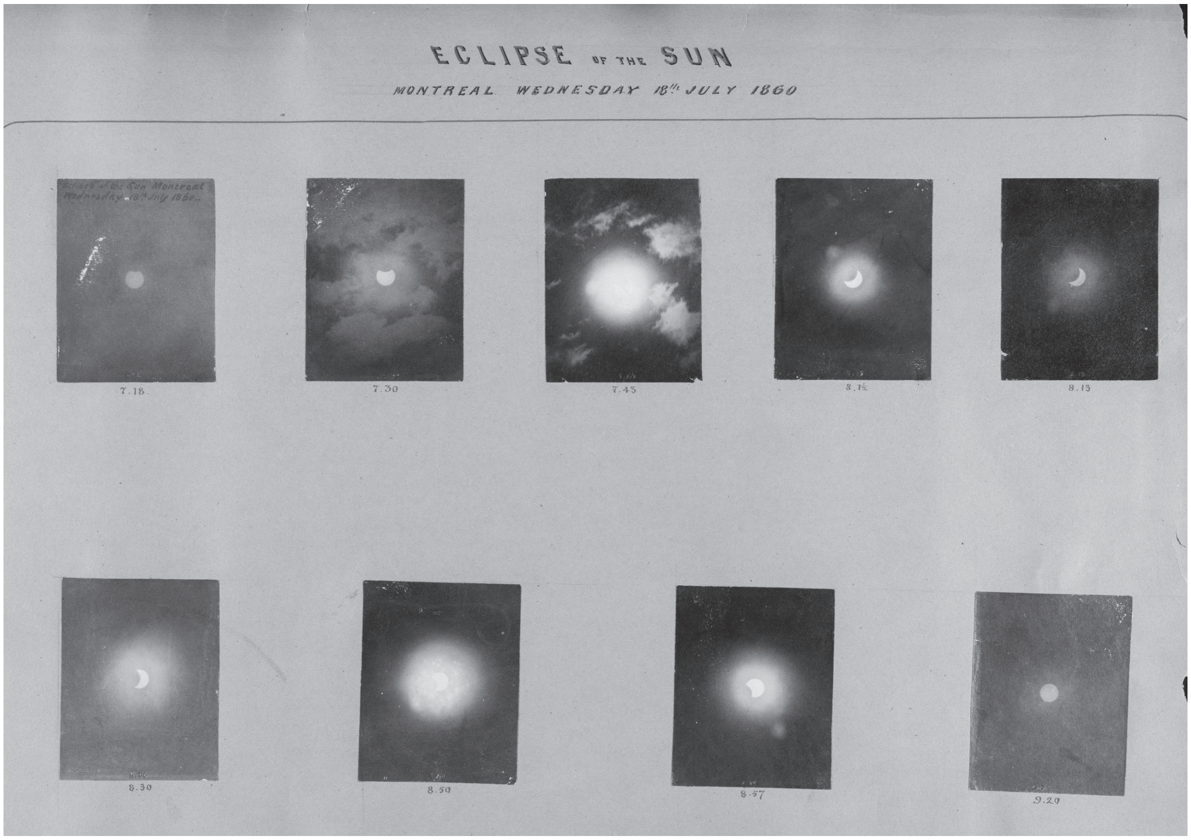


Figure 2 — William Notman's ambrotypes of the eclipse, Thomas E. Blackwell album, p. 176. The fourth image, taken at 8:13 (presumably mean local time) was just two minutes before the maximum at Montréal. (Library and Archives Canada)

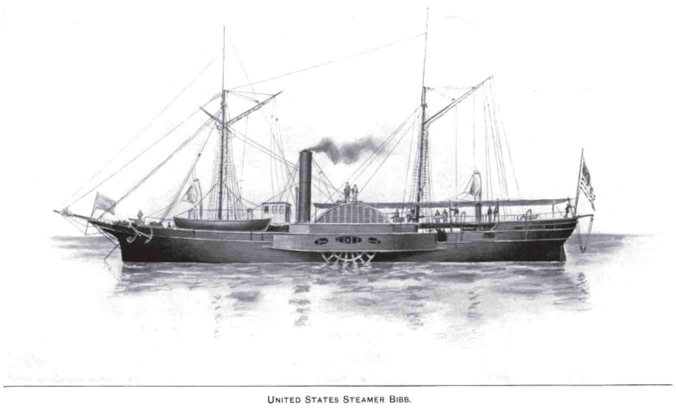


Figure 3 — The ship of the expedition to Labrador. (Official Records of the Union and Confederate Navies in the War of the Rebellion." *Series 1, Volume 22)*

eclipse, but his photos no longer survive. The next convenient opportunity for Europeans came in 1851. On July 28, Berkowski at Königsberg, Prussia, captured the corona during the total eclipse in a daguerreotype believed to be the earliest such image still extant (Schielicke and Wittmann 2005).

An annular eclipse of 1854 May 26 was widely observed in Canada and the U.S. Several Americans made daguerreotypes of it both outside and within the central path. The most remarkable were recorded at Ogdensburg, on the American side of the St. Lawrence River—five daguerreotypes, all during the four minutes of annularity, by Professor Stephen Alexander of the College of New Jersey (later Princeton University). These, and small images of the partial phases taken by William and Frederick Langenheim, are now at the Metropolitan Museum of Art in New York City. Both sets of photos can be seen on Wikipedia en.wikipedia.org/wiki/Solar_eclipse_of_May_26,_1854. Apparently, there are no Canadian photos of the 1854 eclipse or of a solar eclipse of any type until 1860.

The most famous photographs of the 1860 solar eclipse were taken at Rivabellosa, Spain, by Warren De La Rue. It took two years before the images he captured became widely available. De La Rue (1861) wrote:

> *Some further delay will take place before copies of the two totality pictures can be printed off for circulation. In order to show the details of the protuberances it is necessary to enlarge the copies to about 9 inches in diameter, and from these to make a sufficient number of negatives to print the paper copies it is proposed to publish.*

De La Rue (1862) not only secured the best eclipse photographs that had ever been taken up to that date but provided a very detailed diagram showing the lunar profile, the positions of the solar prominences, and sunspots (Figure 6a). All subsequent photos and drawings reproduced here will be related to this diagram.

De La Rue was motivated to photograph the eclipse, in part, by the 1851 daguerreotype taken at Königsberg, referred to above, but decided against using that process in favour of the new, much more sensitive, wet collodion method. The British navy provided a large ship, HMS Himalaya, for the use of the expedition, but De La Rue stated that the photographic aspect of the expedition still cost more than £450 of which the government paid only £150. (It would seem that the Canadian government's grant of $500 = £100 to Ashe was in line, considering that Ashe only had a modest amount of equipment to transport.)

Hingley (2001) provided some additional details about the processes that would have been used to copy and enlarge photos. He reproduced the better of the two original images—rather less spectacular than the two touched-up lithographs that are widely reproduced. As Ranyard (1879, p. 578) noted, De La Rue took "two photographs ... during totality, each with an exposure of about 60 seconds, but only slight traces of the corona were obtained. The photoheliograph seems to have been slightly shifted during the exposure of the second photograph, and three images of the brighter prominences were obtained."

The Expedition to Labrador

As required by the U.S. government resolution, Superintendent A.D. Bache organized the expedition to Labrador, putting Stephen Alexander in charge. [His report is found on p. 229–75.] As we have seen, Alexander was an experienced eclipse observer and was assisted by four astronomers, three associated with American colleges and the fourth being Ashe. In addition, a geologist, a magnetician, and meteorologists all presented formal accounts contained in Bache's overall report.

Bache must have laid his plans well in advance of the presidential approval granted on June 15. As a representative of a government intruding on foreign territory, he had to request permission for the official expedition. Sir Alexander

Figure 4 — Sketch by Oscar M. Lieber, geologist on the Labrador eclipse expedition. The Bibb at anchor is truly dwarfed by the vast and rugged landscape. (From Figure 38, on a foldout sheet at the end of the Report of the United States Coast Survey for 1860.)

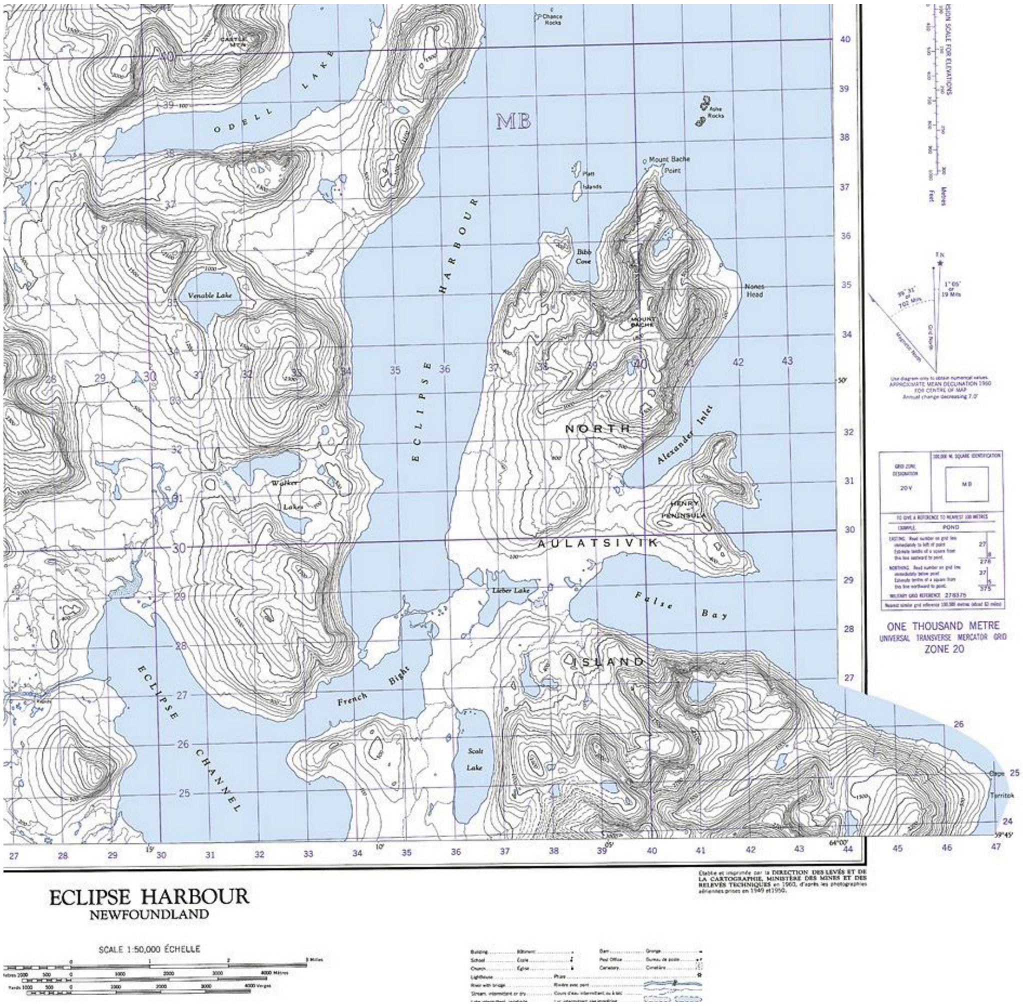
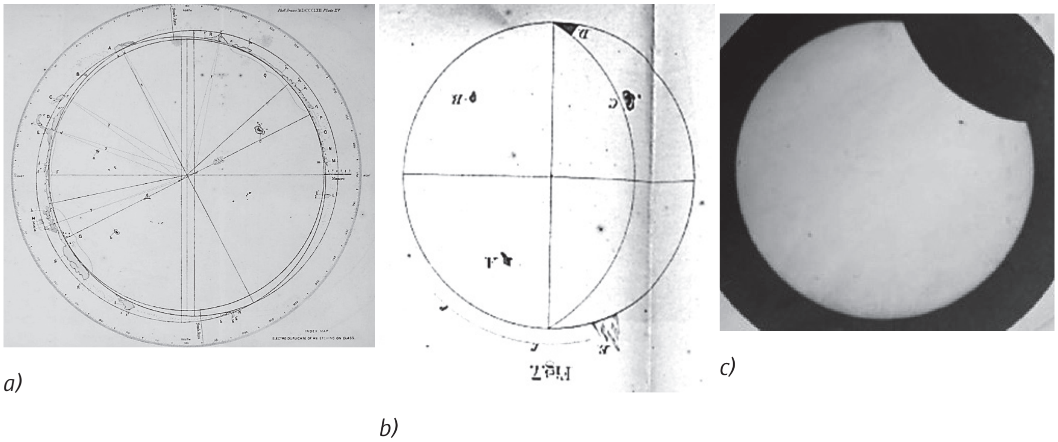


Figure 5 — The southeast corner of this Canadian topographic map 024P16 has coordinates 64°W, 59°45′N. The main observing site was apparently just to the west of the first "A" in Aulatsivik, one of the few Inuktitut names in the region. As well as "Eclipse Channel" and "Eclipse Bay" (where the Bibb rode at anchor), "Bibb Cove" commemorates the ship, while the names of many on the expedition are shown: Alexander Inlet, Ashe Rocks, Lieber Lake, Murray Head, Venable Lakes. Mount Bache (and Point), and Henry Peninsula likely commemorate A.D. Bache and Joseph Henry, who headed Coast Survey and the Smithsonian Institution respectively.

Bannerman, governor of Newfoundland and Sir George Simpson of the Hudson's Bay Company provided such credentials "as would have secured, in case of need, the sympathy and assistance of the officials connected with their respective departments on the coast of Labrador. The friendly letter of the governor … expresse[d] good wishes that must have been prompted by a full appreciation of the importance of the object in view"[25].

The expedition was able to set out from New York on June 28 in the Coast Survey's 150-foot-long side-wheeler Bibb (Figure 3), under the command of Lieutenant Murray, USN. After stopping for extra coal at North Sydney, Nova Scotia, they proceeded through the Gulf of St. Lawrence, the Strait of Belle Isle, and up the Labrador coast. Good use was made of the time on the voyage in discussing and assigning the various duties anticipated for eclipse day. As they made their way north, Stephen Alexander made the discouraging observation that "the mountains of this bold coast were themselves partially covered with snow, and all along the bases of those mountains reposed a quiet, well-defined belt of mist" [229]. By the time they reached their destination, Aulezavik Island [Aulatsivik, to use their spelling], well within the path of totality, they had completed a trip of over 3,000 km in 15 days. Murray later expressed his gratitude to Lt. Ashe "who, on all occasions, was ready with aid which was invaluable to us in navigating the coast of Labrador" [401]. A harbour entered from the north side of the island offered a good anchorage and shelter from the ocean mists. Less than five full days remained to land all the equipment, to reconnoitre the best observing site and set everything up to prepare for the big event. Oscar Lieber, the American geologist on the expedition, made a splendid sketch of the view from the site chosen by the astronomers (Figure 4). On a terrace 110 feet (33 m) above the sea, Ashe erected a small prefabricated observatory to house the transit instrument. With this and their Dent chronometer, Alexander, Ashe, and Smith found the latitude to be 59° 47′ 49″ N and longitude 4h 16m 29s (64° 07′ 15″) west of Greenwich [230]. Judging from the presumed location on a modern topographic map (Figure 5), the latitude was 21″ too low, and the longitude was 9″ too high. In other words, they knew their location within a few hundred metres. However, the day before the eclipse:

> *Ashe met with so many obstacles from the interference of daylight, great fickleness of the weather, and almost continual clouds at night, and sometimes also from storms, to say nothing of unexpected mechanical difficulties and obstacles, that, after a persevering and faithful trial, he was compelled to abandon the hope of any result from the transit instrument, and we were obliged to trust to our sextants only [232].*

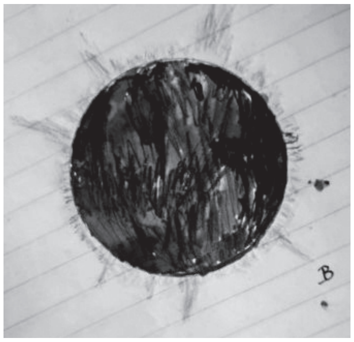


a)

b)

c)

d)



e)

Figure 6 — Five views of the 1860 solar eclipse, scaled to approximately the same size and oriented so that north is up, east to the left: (a) De La Rue (1862) "Index Map," Plate XV (b) Ashe's diagram from Report (1861) (c) Rutherfurd photo (([U.S.] National Archives RG23, PI 105/15, Box 311, Coastal Survey, Solar Eclipse, July 18', 1860, p. 400 (d) Sketch of the sun by W. B. Jack (1860) (e) A drawing by Collins and verified by other Bibb crew members shows the corona and a large "beam", labelled B. The blobs above and below B are probably just ink blots. ([U.S.] National Archives RG23, PI 105/15, Box 311, Coastal Survey, Solar Eclipse, July 18th, 1860, back of p.263)

Once the eclipse began, the astronomers, aided by everyone from officers to seamen, were to look out for no less than 32 different phenomena [232–33].

Photographers on the Labrador expedition

Peter Constant Duchochois (1826–1909) volunteered to go as photographer, having had some second-hand experience in solar imaging. He, along with his friend Victor Prevost, had a business partnership in New York City on Broadway between Bleeker and Houston Streets in 1853–55 (Newhall 2013). During their association, Prevost took 19 photographs of the partial phases of the solar eclipse of 1854 at West Point, New York (Bartlett 1854). By 1859, Duchochois had moved to 207 Canal Street. A half-hour walk away was the home of lawyer-turned-astrophotographer, Lewis M. Rutherfurd (Hannavy 2008). Rutherfurd (consistently misspelled as Rutherford), in preparation for the 1860 eclipse, gave Duchochois the benefits of his experience and loaned Duchochois photographic apparatus and instruments for the expedition [23]. Duchochois provided fascinating particulars about the telescope (five-foot, equatorially mounted), the camera, and the photographic process [262–3]. Warner (1971) added the interesting detail that the telescope that went to Labrador was a visual achromatic refractor made by Alvan Clark & Sons, but adapted by Rutherfurd to photographic needs by inserting a ring spacer between the crown and flint elements of the objective lens.

Duchochois, assisted by A.W. Thompson of the Coast Survey, did succeed in obtaining several photos of partial phases of the eclipse but not totality. According to the Coast Survey Report [25], "Thirteen photographs of the eclipse, and thirty-six stereoscopic views of the coast of Labrador and of the doings of the party, were made by Mr. Duchochois, and are deposited in the archives of the Coast Survey." A careful search did not locate them in the Coast Survey fonds at the National Archives and Records Administration (NARA) or in their Still Pictures Division, but 12 of his eclipse photos (Figure 7) do exist in the New York Public Library (Duchochois 1860). Only the first exposure shows what might be a sunspot. Paper copies of the photos were also sent by Alexander to the Astronomer Royal (Ranyard, p. 733). As for the other views taken on the expedition, only four glass stereographs showing expedition members outside their tent have been located at the Smithsonian Institution's National Museum

Figure 7 — A snapshot of the 12 photos of the eclipse taken by P.C. Duchochois in Labrador. Since the Moon moves from west to east (left to right), the images are all inverted. Sadly, clouds obscured totality. (Courtesy of the New York Public Library)

of American History, and two of them are reproduced here (Figure 8). Strangely, in the fonds of the US Coast Survey at NARA, there are nine images of the 1860 solar eclipse labelled "Labrador" but closer examination reveals that they were taken by L.M. Rutherfurd in New York City. His initials appear beneath each photo and the coordinates of his home are provided beside one of the images (Figure 6c).

Visual Observations from Labrador

In total, the astronomers and their assistants who went to Labrador had seven telescopes [238]. Most were about the same size as the one used by Ashe—a 42-inch Dollond achromatic refractor with an aperture of 3.5 inches equipped with a 40× ocular. It was mounted equatorially so that the Sun could be kept centred by moving the telescope in only one direction [252]. Murray, the commander of the expedition, had the largest telescope—a 7.5-inch Fitz refractor of focal length 5 feet. The astronomers were arranged in a circle with Alexander and the timekeeper, who called out the seconds, in the centre. During the observations, various coloured filters or "screens" were used. One can only surmise that they provided sufficient protection that no serious eye-damage ensued.

Because of fleeting clouds, Ashe seems to have been the only one to record the instant of emersion when the Sun first began to reappear. He also was the only astronomer to witness even part of the Sun's corona, though the seamen on board the Bibb, three-quarters of a mile (1.2 km) to the southwest, were successful. Ashe's report [252–54]:

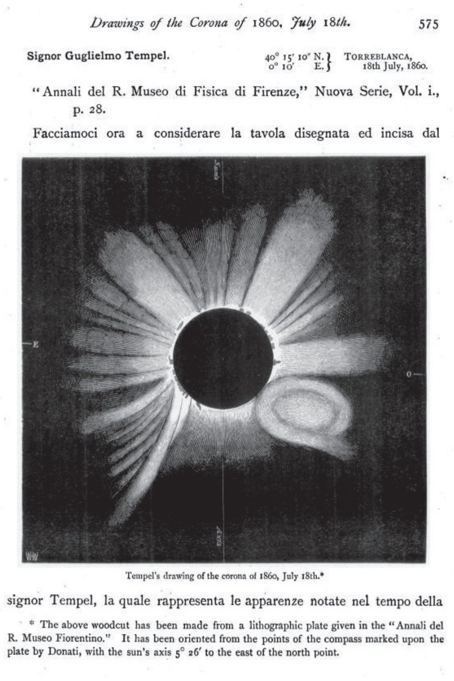
> *About eight minutes before the total eclipse, I removed the coloured screen [light orange filter] from the eyepiece, and as there was a light thin cloud over the sun, I could look steadily on the bright part without protection to the eye. … When the bright crescent was reduced to a thin line of light, it was beautiful object to behold, extending about 130 degrees around the edge of the moon. Shortly afterwards, it broke up into fragments [Baily's beads], which appeared to swim from the centre towards the cusps. At 2h. 5m. 32s. the last speck of light vanished, and a bright halo surrounded the part of the moon that I was looking at, and about 20 degrees in the second quadrant I saw a white flame shooting up to a considerable distance. [Later he explained, "I have spoken of the phenomena as seen through an inverting telescope, and a vertical and horizontal line supposed to be drawn on the surface of the sun."] A dense cloud now passed over the sun, preventing further observations being made until the emersion.*

Ashe's use of the words "vertical" and "horizontal" seems to be at odds with his diagram [Figure 1 in the Report] that shows "S" (for south) at the top with the flame about 20° to the left (west). This depiction has been assumed to be correct and has been used, after rotating through 180°, in Figure 6b. The crew on board the Bibb (mainly Mr. Collins, the purser's steward) viewed the eclipsed Sun without telescopes and produced a sketch of the corona shown in Figure 6e, rotated through 27° counterclockwise so that north is up. The beam marked B, it was afterwards noted, coincided nicely with Ashe's "white flame."

It is possible that the flame and protuberance were manifestations of a rapidly evolving feature in the Sun's corona. European observers saw a huge coronal loop in the southwest quadrant a couple of hours later (figure 9).

Figure 8a — This image represents two aspects of stereoscopy—the binoculars held by an unknown observer and the stereo camera used by P.C. Duchochois to take the original photos at Eclipse Harbor in July 1860. There was no mention of binoculars among the equipment used on the expedition. (Part of a glass plate stereograph, National Museum of American History AHB2024q003850)

Figure 8b — Part of another stereograph by P.C. Duchochois taken in July 1860 at Eclipse Harbor, Labrador. The man, unidentified in the original photo, closely resembles Prof. Stephen Alexander. The instrument, also unidentified, may be a 10" sextant made by Pistor & Martins. (National Museum of American History, AHB2024q003854)



Drawings of the Corona of 1860, *July 18th.* 575

Signor Guglielmo Tempel. 40° 15′ 10″ N. 0° 10′ E. TORREBLANCA, 18th July, 1860.

"Annali del R. Museo di Fisica di Firenze," Nuova Serie, Vol. i., p. 28.

Facciamoci ora a considerare la tavola disegnata ed incisa dal

Tempel's drawing of the corona of 1860, July 18th.*

signor Tempel, la quale rappresenta le apparenze notate nel tempo della

* The above woodcut has been made from a lithographic plate given in the "Annali del R. Museo Fiorentino." It has been oriented from the points of the compass marked upon the plate by Donati, with the sun's axis 5° 26′ to the east of the north point.

Figure 9 — Illustration of coronal loop observed by Wilhelm Tempel in eastern Spain (Ranyard 1879, page 575)

Ashe's description of a "bright halo" around the Moon during totality may indicate that he saw the corona, and the "white flame" could be a coronal mass ejection (CME)—a feature that "shows an observable change in coronal structure that occurs on a time scale of a few minutes to several hours and involves the appearance (and outward motion) of a new, discrete, bright, white-light feature in the corona" (Hundhausen et al. 1984). Eddy (1974) wrote, "[Ashe's] tantalizing observation, made under poor conditions, is of course of very limited value; still, it may be a real record of the early phase of coronal disturbance which developed as the shadow swept across the north Atlantic."

How big were the sunspots?

This is an important question to ask since the areas of sunspots lead to a better measure of solar activity than a simple count of the number of sunspots. Simultaneous drawings and photographs of the solar surface provide evidence that sunspots, if they appear at all on the photographs, are proportionally much smaller than when recorded visually in sketches. This effect is well known to scientists studying historic solar activity using sunspot area (Uneme et al. 2022). Primitive photographic emulsions may degrade over the years, while in drawings made shortly after viewing through a telescope, memory plays tricks, apparently exaggerating the perceived size of the spots.

Times of immersion or emersion of sunspots as the eclipse progressed have the potential to provide a calibration of the size of a spot but discordant descriptions, apparently referring to the same spot, prove difficult to reconcile. For example, Alexander [242] recorded the time when the Moon touched the penumbra of a large spot (8h 21m 09s) and when it completely covered the spot (8h 21m 28s), in other words 19 seconds later. Since, between first and second contact of the total eclipse, the Moon moved across the diameter of the Sun's disc—1888 seconds of arc in 3914 seconds of time, the distance across the entire spot, parallel to the Moon's motion, was 9.2 arc-seconds. If the Sun's image, either drawn or photographed, was 10 cm, for example, the spot's diameter, including penumbra, would be less than 0.5 mm. Meanwhile, Jack, in Fredericton, found that 44 seconds elapsed between "contact with umbra of large spot A" and "contact with nucleus of large spot A." Taking this to represent just half of the spot, 88 seconds of time corresponds to 42 seconds of arc. Hubbard (1860), at New Haven, Connecticut, found 63 seconds elapsed between "1st and 2nd contact" at the emersion of the large spot. These few examples illustrate the difficulty inherent in the timing method.

Figure 10 — Not an early Lawren Harris painting but a watercolor sketch made on the Labrador coast by O.M. Lieber ([U.S.] National Archives RG23, PI 105/15, Box 311, Coastal Survey, Solar Eclipse, July 18th, 1860, p. 549). In the engraved version accompanying the Report (1861), figure 38, the caption reads "S. Entr. To Aulezavik Sound … View of Crater shaped Mt. E. Side of Aulezavik Island."

Figure 11 — Watercolour by Henry Acland showing the Ariadne during the gloom of the eclipse (Library and Archives Canada)

[First Paper.]

[To F. S. Knowlton, of Portsmouth, New Hampshire, the writer is greatly indebted for admirable photographic views of coast and interior landscapes. They are believed to be the only photographs of Labrador scenery ever taken.]

FROM the storm-brewing Gulf of St. Lawrence to where Cape Chudleigh breaks the vast ice-floes that sweep down from the Arctic

Entered according to Act of Congress, in the year 1861, by Harper and Brothers, in the Clerk's Office of the District Court for the Southern District of New York.

Vol. XXII.—No. 131.—Oo

Figure 12 — Illustration from Hallock (1861), 577

Oscar Lieber and the Inuit

Lieber, in addition to his formal report [402–08] and map of the geology of the Labrador coast, kept a diary and made some delightful sketches of people and scenes. Now, these are mostly at the institution where he taught, the University of South Carolina, but one that was uncovered at NARA is shown in Figure 10. Lieber's hopes to publish his unique account were never realized due to death, in 1862, from injuries in the U.S. Civil War, but his descriptions of Inuit life have found lasting resonance (Loring 1998; Procter 2023). The latter author quoted a passage from Lieber's journal illustrating the knowledge of eclipses by one indigenous woman at Spotted Island who spoke both English and Inuttitut:

> *She wanted to know something about our object in traveling so long. I told her we had done so for the purpose of seeing the eclipse. 'That we call 'suchunik ivunga tallinga mucktok' she said. I remarked that where we had been it was all dark and here could only have been partial. 'Oh' she said, 'when it's all dark we call it 'suchunick illunane tallinga lucktok. What I told you just now means half dark.' 'Suchiniulp' she observed, means the sun, 'but when we talk of it that way we say 'suchunik'.*

This unnamed woman may have picked up some of her knowledge of eclipses from the Moravian missionaries who had long-established outposts on the Labrador coast, but nonetheless she seemed to have witnessed solar eclipses firsthand. Indeed, there had been several in the previous decade that could have been seen as partial from Labrador, sometimes near sunrise or sunset: 1851 July 28, 1854 May 26, 1858 March 15, and 1859 July 29 (Espenak 2017).

Figure 13 — Cover of Jules Verne's novel, later translated into English as "The Fur Country."

Once the eclipse was over, … the Bibb sailed back to the States, stopping on August 7 at Newport, Rhode Island, where the American Association for the Advancement of Science (AAAS) was holding its annual meeting [24]. The astronomers were given a hearty welcome, and Alexander, as past president of the organization, provided his admiring audience with an up-to-the-minute account of the expedition. Ashe had already been dropped off in Sydney, Nova Scotia, whence he returned home to Québec, just in time for the celebrations surrounding the visit of the Prince of Wales—a first "Royal Tour" for Canada and a very ambitious itinerary including the northeastern U.S.

An interesting sidelight to Prince Edward's trip occurred while he was still crossing the Atlantic. The log of his ship, HMS Hero, was included in a journal by Gardner Engleheart (1860?), Private Secretary to the Duke of Newcastle (Secretary of State for the Colonies) both of whom were part of the entourage. The log entry for July 18 read, "Wind still foul; fog. Eclipse of sun shortly after 11 A.M. At a little before noon seven-eighths eclipsed; seen through fog with naked eye. Weather threatening." Engleheart himself wrote that "The eclipse relieved the monotony of our voyage. It was visible to the naked eye through the fog (Lat. 50.31, Long, 31.1) and lasted for nearly three hours, two-thirds of the sun being obscured at the maximum eclipse. The atmosphere assumed its usual inky hue, but the fog prevented any just appreciation of the effect of loss of sun-light." The general appearance was well-captured by Sir Henry Acland in a water colour of the accompanying ship, HMS Ariadne, reproduced in Figure 11. Acland, professor of medicine at Oxford, was the prince's physician during the trip. (See https://janerupert.ca/ for more fascinating details.)

Writers inspired by the eclipse

A lengthy two-part article in Harper's Magazine (Hallock 1861) may be the only remnant of an unofficial and unsuccessful expedition that also went to Labrador, mainly for fishing and hunting (Figure 12). The style of this piece, in which the author calls himself Quilldriver and gives fanciful names and conversation to other characters like Captain Squid, seems to imply it is all a spoof. However, the excellent illustrations of Labrador, apparently based on photographs by F.S. Knowlton of Portsmouth, New Hampshire [later of Woburn, Mass.], leave the impression that it was at least partially based on the truth. As explained by Crovisier (2009), the eclipse of 1860 was also a central theme of Jules Verne's (1873) adventure novel, The Fur Country (Figure 13). While it is probably human nature to prefer reading well-told tales of fiction over factual accounts, in the author's opinion the excitement and satisfaction in tracking down elusive real details eclipses any made-up story. ✶

Acknowledgements

I am grateful to many archivists for their assistance, to Peggy Ann Brown for her research at NARA, to Joan Schwartz for alerting me to Notman's photos of the 1860 eclipse, to Clark Muir for pointing out the Acland illustration, and to Hisashi Hayakawa for his interest and help.

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Research Article /
Article de Recherche

A Foundation for the "Explosion Model" of the Big Bang

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Abstract:

The explosion hypothesis of the Big Bang is compared against observational cosmology and the concordance model of Lambda cold dark matter (LCDM). If we assume we are within a flat Friedmann–Lemaitre–Robertson–Walker (FLRW) Universe whose changing scale factor $\dot{a}$ is so small at our "local" Big Bang scales that we can approximate it as a static and Euclidean space, the conceptualization of the explosion model becomes straightforward from a physical perspective. With this presupposition established, the pillars of observational cosmology are considered in the explosion model context: Hubble's law becomes a relative velocity in a radial vector field $\mathcal{U}(\boldsymbol{r},t)$, cosmological redshift becomes a special relativistic interpretation of peculiar velocities within that vector field space (a necessity since we're assuming negligeable spacetime expansion), and the CMB's temperature dipole is argued to be at least partially due to the energy dispersion inherent to the inverse square law of a localized explosion in spacetime.

Introduction to the "explosion" model

It's called the "localized" Big Bang model, or the "explosion" model, or the "naive misconceptions of the Big Bang" model because it's the first image that comes to mind whenever someone thinks of the Big Bang: something that went *bang* and expelled matter outward like a bomb or a supernova. This imagery is often visualized in popular science videos with an explosion in space so, for better or worse, it's become cemented into the public's imagination when we think of the beginning of the Universe.

Unfortunately, the name Big Bang is misleading since there was not an expansion of energy moving through space like we'd expect from an explosion, but rather general relativity predicts it is in fact the spacetime itself that expands outward in every direction, taking with it all the matter and energy of the Universe along for the ride. And since general relativity has been enormously successful, few have paid much attention to that initial image that comes to mind when a layperson thinks of the words "Big Bang".

It turns out this neglect of the explosion model is so thorough, there isn't even an agreed upon name for it, nor has anyone really attempted to apply a basic theoretical framework to the idea, apparently. What warrants the neglect that this model receives is hard to say for sure, but that doesn't change the remarkable fact that we would sooner consider incredibly complex and exotic models of the Big Bang such as the holographic Universe or M-brane cyclic cosmology before humouring the simplest one.

Should we not give this explosion hypothesis a fair trial before digging its grave? Why not play the devil's advocate? Let's take a step back and think once more about that image in the mind of a person who has just discovered the theory of the Big Bang: a radial expulsion of energy within spacetime. Let's, for a moment, consider what this Universe would look like and how the physics would have to be written in order for it to match with the observations we know to be true in our actual Universe. Surely any model that's so widely ignored would have to do cosmic acrobatics in order for it to fit with the data… right?

Hubble's law

Proving that the most fundamental cosmological fact of all, Hubble's law, is compatible with this local model should be the first priority. And indeed, one could instantly visualize Hubble's law being satisfied by an observer at the very centre of where the Big Bang happened: objects would extend away from us in all directions at speeds proportional to their distance, which is precisely the relationship which Edwin Hubble discovered in 1929. That, however, is a very convenient place to have been placed by mere chance. So unlikely, in fact, that it breaks the spirit of the Copernican principle many times over because humans have a tendency to put ourselves at the centre of the Universe and this idea keeps getting proven wrong. Therefore, a local Big Bang model will not be taken seriously if only a single reference frame is applicable with Hubble's law.

There must be some velocity field which can demonstrate Hubble's law no matter the coordinates within that vector field, so it's of interest to find the mathematical description for that vector field, if it exists. The visualization of a velocity field with a diagram is probably a good place to start, so let's begin in a flat Friedmann–Lemaître–Robertson–Walker (FLRW) Universe, but whose scale factor derivative $\dot{a}$ is so small at our "local" Big Bang scales that it can be approximated as a static Euclidean space. Its components are within the real numbers $\mathbf{R}^2$ and its vectors are constrained to eleven world lines of equal radial velocity and linearly increasing distance

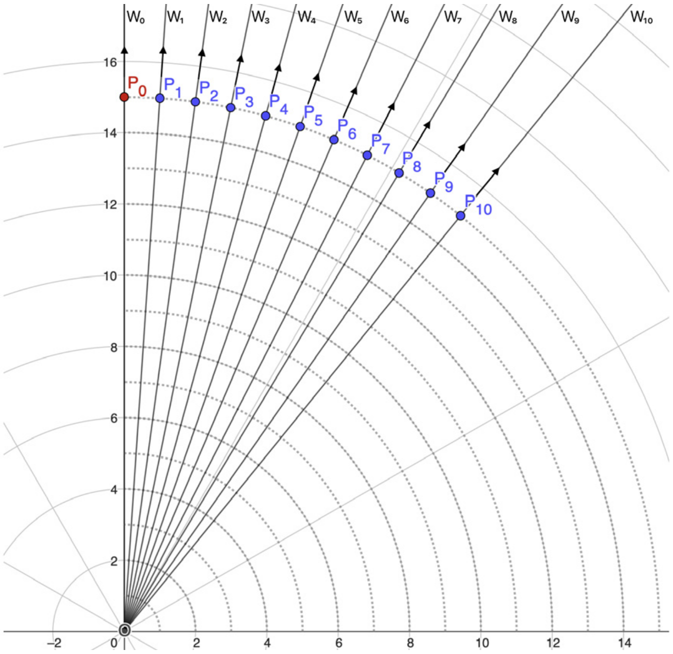


Figure 1 – Eleven objects travel 1.0m/s away from the origin, each black ray representing their past and future trajectory, or world lines. They arrive at their visualized location after 15 seconds, denoted by P_i.

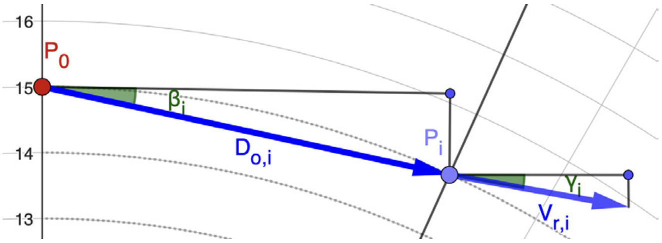


Figure 2 – How P_0 observes objects on the i'th world line at P_i. $D_{o,i}$ is the distance to the i'th world line at the present time t = 15. $V_{r,i}$ is the relative velocity of a world line. β_i and γ_i are the angles between the plane orthogonal to W_0 and the distance and relative velocity vectors, respectively.

	θ_i	β_i	γ_i	$\mathcal{V}_{(r=15)}$	$\mathcal{V}_i - \mathcal{V}_0 = V_{r,i}$	$D_{o,i}$
W0 (us)	90.00	0.00	0.00	1.00	0.00	0.00
W1	86.18	1.91	1.91	1.00	0.07	1.00
W2	82.36	3.82	3.82	1.00	0.13	2.00
W3	78.52	5.74	5.74	1.00	0.20	3.00
W4	74.84	7.66	7.66	1.00	0.27	4.00
W5	70.81	9.59	9.59	1.00	0.33	5.00
W6	66.93	11.54	11.54	1.00	0.40	6.00
W7	62.99	13.49	13.49	1.00	0.47	7.00
W8	59.09	15.47	15.47	1.00	0.53	8.00
W9	55.10	17.46	17.46	1.00	0.60	9.00
W10	51.06	19.47	19.47	1.00	0.67	10.00

Table 1 — Data from Figures 1 and 2. θ is the angle between the x-axis and the i'th world line. $V_{r,i}$ is the relative velocity from W_0 and the other variables are described in Figure 2.

from world line 0, which is the world line that moves upward along the y-axis (world line 0 is our world line, let's say). In other words the radial vector ***r*** is the progression of cosmic time as well as the absolute velocity of each world line. The points P_i are the location of objects on their respective world lines at $t = 15$ seconds and $r = 15$ meters, where $i \in \{1,2,\ldots 10\}$, so they are travelling at one metre per second and their position vector magnitudes from world line 0 are $P_o \rightarrow P_i = i = D_{o,i}$. This is shown in the diagram of Figure 1 in polar coordinates, while the world lines' trajectories are shown as the rays extending from the origin (from here on out we'll refer to "world line 10" as "W_{10}", "world line 9" as "W_9", etc.).

With that in mind, we should ask what qualities would an astronomer living on P_0 observe about the objects at P_i, and do they align with Hubble's law? Notwithstanding the astronomer's unlikely ability to know where the origin of his Big Bang is, and, not to mention, the angle to various world lines he is observing, let's carry on with the analysis and imagine he measures all the objects, P_1 through P_{10}, in order to begin constructing his Universe model. If the speed of light is instantaneous in this diagram (we'll get to that later), and if we assume the effect of gravity is negligible for now, the snapshot of information contained in the astronomer's telescope of P_1 through P_{10} would be calculated straightforwardly like the Figure 2 and Table 1 show.

What may seem like a trivial exercise of elementary geometry is actually revealing something quite important if we look a bit closer. The relative velocity of P_{10}, from our perspective at P_0, has increased from the relative velocity of P_9, which has increased from the relative velocity of P_8, and so on until P_1, which means, writing it out explicitly in Equations 2.0 and 2.1:

$$\| \mathbf{P}_i \| < \| \mathbf{P}_{i+1} \| \,, \tag{2.0}$$

$$\frac{d}{dt} \| \mathbf{P}_i \| < \frac{d}{dt} \| \mathbf{P}_{i+1} \| \,. \tag{2.1}$$

And even more importantly, the angle between the plane orthogonal to W_0 and the position vector towards P_i which we've called β_i, is equal to the angle between that same perpendicular plane and the relative velocity vector of P_i, we'll call γ_i, so the relative velocity vector $V_{r,i}$ points directly away from P_0 in every case:

$$\beta_i = \gamma_i \tag{2.2}$$

If the astronomer were to discover 10 more objects for every radial interval ($r = 14,13,12,\ldots 1$) it turns out these relationships hold true at different radii too, so long as the change in an object's radial position ***r*** corresponds to a proportional change in the absolute velocity of the object: $d\mathcal{V}(\boldsymbol{r},t) \propto k d\boldsymbol{r}$, where $\mathcal{V}(\boldsymbol{r},t)$ is the absolute velocity, and k is a constant; $k \neq 0, \mathbf{R}^-$. For instance, when P_0 is at $r = 15$, objects at $r = 14$ would have a radial velocity of $14/15 m/s$, objects at $r = 13$ would be travelling $13/15 m/s$, and so on.

That's good, since this is the general manner in which matter is supposed to explode from a point; objects furthest from the origin are going the fastest and objects nearest the origin of the expansion are going slowest. Now we know there are at least two reference frames which could appreciate Hubble's law in a local Universe model, yet it's still hard to argue that this is sufficient. Maybe we just got lucky? Going through each of the infinite amount of reference frames would be the most thorough proof, but it seems more economical to summarize the information we've gathered so far into a general form: a vector field like Equation 2.3, 2.4, (while removing the former constraints):

$$\mathcal{U}(\mathbf{r},t) = \frac{d\mathbf{r}}{dt} - \nabla\Phi(\mathbf{r})t, \tag{2.3}$$

$$= \mathscr{V}(\mathbf{r},t) + \mathbf{g}t, \tag{2.4}$$

$$= \text{absolute velocity - gravity component},$$

$\mathcal{U}$ is our absolute, or universal velocity field which is written in script form so as to not be confused with U, potential energy; ∇ is the differential operator nabla; $\Phi(\boldsymbol{r})$ is the gravitational scalar field; $\boldsymbol{g}$ is the Newtonian force of gravity $-Gm/r^2$, and t is cosmic time or the proper time of a world line. $\mathcal{U}$ is constrained by two radii of arbitrary magnitude $r_1 < \mathcal{U} < r_2$ just to give us the desired annulus shape; a spherical "shell" of energy.

From here it's just a matter of subtracting any reference frame $P(\boldsymbol{r},t)$ from $\mathcal{U}(\boldsymbol{r},t)$ to get the resulting vector field from the perspective of whichever coordinates we choose. *Hypothesis 1* (Figure 3) shows the absolute velocity field $\mathcal{U}(\boldsymbol{r},t)$ in the top left corner as well as three examples of $\mathcal{U}(\boldsymbol{r},t)$ transformed to arbitrary positions: $A = (8,8)$, $B = (3,3)$ and $C = (-5,2)$. We have once again assumed the gravity component is small and has a negligeable effect on the vector lengths.

Clearly, after looking at these vector field maps, it does not matter whether the observer is at the centre of the Big Bang or anywhere else: celestial objects would be seen receding from us everywhere in the sky with velocities increasing proportionally to their distance away from us. As a result of this visual confirmation, there is now reasonable leverage to claim that an absolute, linearly increasing velocity expansion (ALIVE) case of the local Universe model can satisfy the following conditions of Hubble's law:

1. the relative velocity of all objects increases proportionally to distance in every reference frame (Eq. 2.0, 2.1),
2. the position vector and the relative velocity vector of all objects from all reference frames are directionally equal (Eq. 2.2),
3. that direction is *exactly anti-parallel* the reference frame in question,
4. and therefore Hubble's law, in the explosion Universe model, is a relative velocity function which decreases in conjunction with cosmic time because absolute velocity $\mathcal{V}$ is constant;

$$H = \frac{\| \mathscr{V}_i \| - \| \mathscr{V}_0 \|}{D}, \qquad (2.5)$$

= relative velocity / proper distance.

While this is a good start for anyone rooting for the local Universe model, it's well known that this velocity-distance ratio does not hold at cosmological scales since the redshift increase accelerates relative the distance increase. There's still work to do to.

Also, anyone who's already aware of the "raisins in a rising dough" or "dots on an inflating balloon" analogies—often used to visualize the increasing scale factor *a(t)* in the FLRW metric— will have surely thought to themselves that we've attempted to reinvent the wheel here, but there's a crucial difference between Lambda cold dark matter (LCDM) and ALIVE expansion hypotheses: it's not spacetime expanding that causes the recession velocities in our local Big Bang model (the "dough"), but the energy itself which has an absolute, positive radial velocity (the "raisins"). To help clarify this visually, a graphic in *Hypothesis 2* (Figure 4) shows how the velocity field would look when applied to various scales of the real Universe.

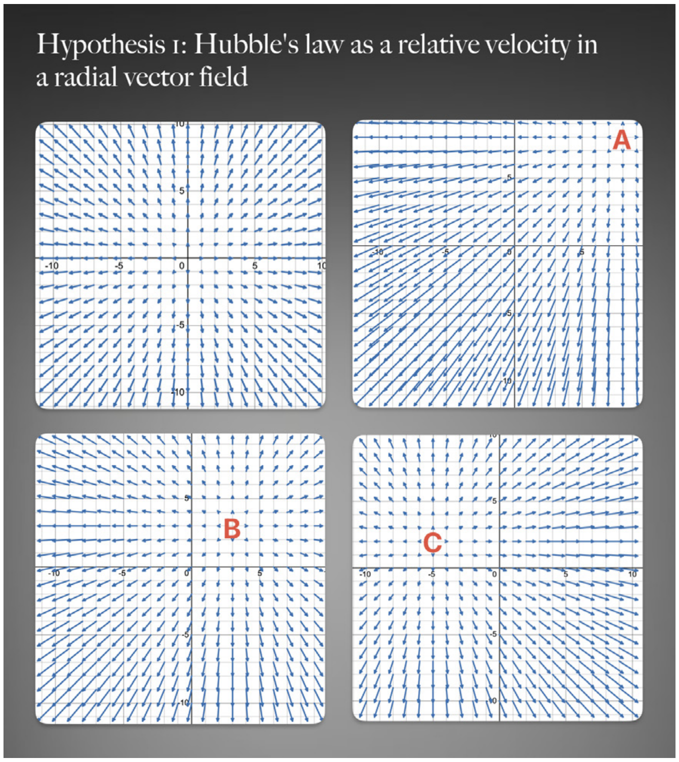


Figure 3 – The vector field of $\mathcal{U}$ in the top left corner would be equivalent to the absolute reference frame of an explosion model. The other vector fields are the same $\mathcal{U}$ but transformed to position A, B, and C.

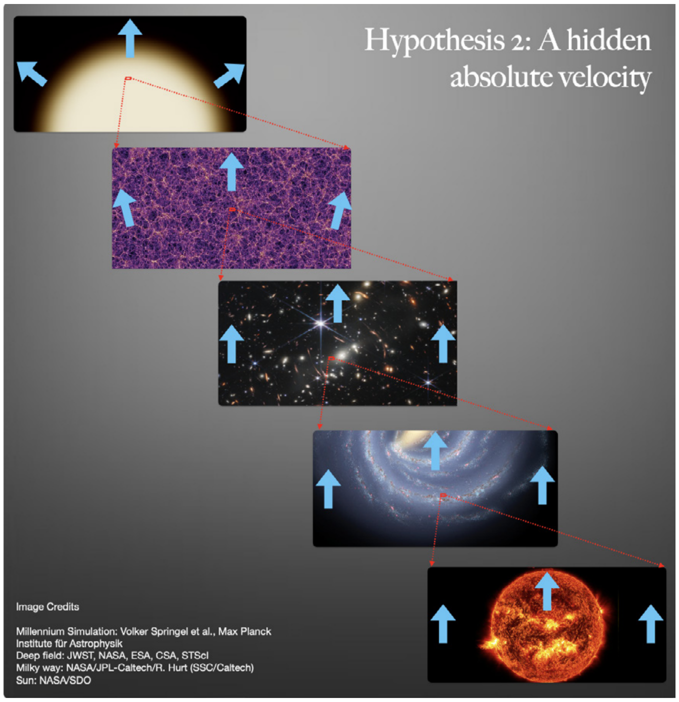


Image Credits

Millennium Simulation: Volker Springel et al., Max Planck Institute für Astrophysik
Deep field: JWST, NASA, ESA, CSA, STScI
Milky way: NASA/JPL-Caltech/R. Hurt (SSC/Caltech)
Sun: NASA/SDO

Figure 4 – What the absolute velocity would imply in the actual Universe, where the top left frame is the hypothetical view of half of our "local" Big Bang shooting outward.

Redshift-distance relation

Now, let there be light. Redshifted photons from receding celestial objects inform nearly every aspect of the cosmological parameters that we use to build models of the Big Bang. A correct interpretation of this redshift and its relationship with distance in particular—known as the redshift-distance relation—is a key piece of the Jenga puzzle without which the whole thing comes tumbling down.

As spacetime expands it carries the matter with it, creating a quasi-velocity that makes it appear all objects are receding from us at speeds that are proportional to how far away they are. But nothing is really moving! Space is just "stretching". Electromagnetic radiation does not shift its wavelength at the moment of emission from the source in the standard cosmological model, but rather on the journey through spacetime because spacetime is what's causing the increase of the wavelength (where that energy goes, we do not know). When light reaches us, although it appears to be a Doppler shift effect, and although we calculate it with the Doppler shift formula at small scales ($v<<c$), its redshift is called cosmological redshift and it is not the same as redshift from a peculiar velocity.

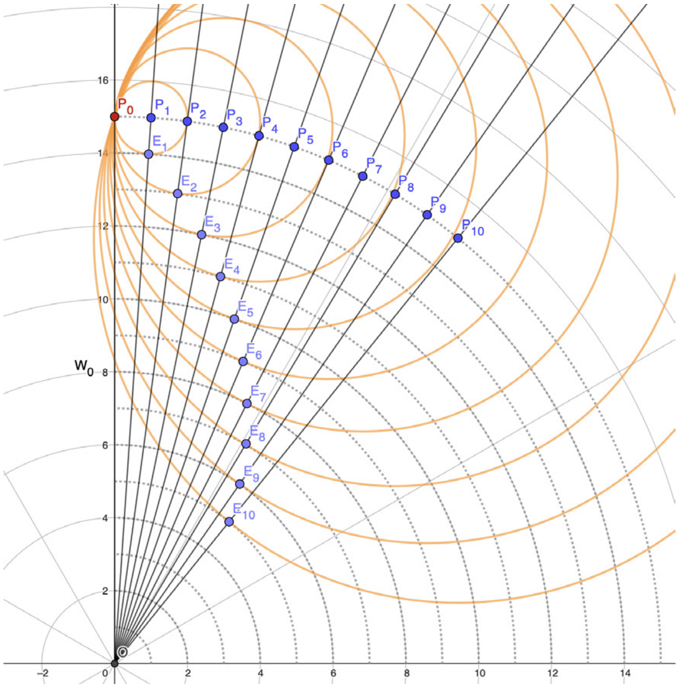
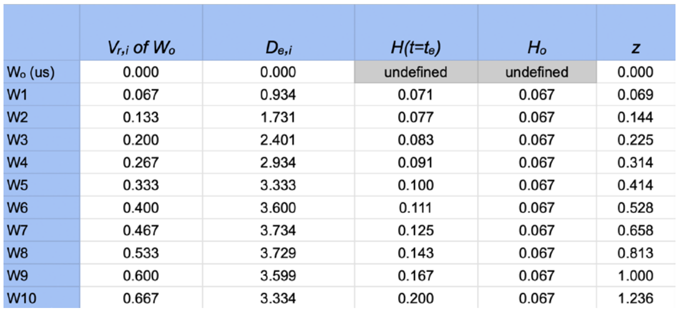


Figure 5 – A 2-D light-cone diagram which illustrates the point of light emission E_i*, and the point of observation* P_0 *for each world line. Yellow circles are emission "ripples" travelling at light speed and are for illustrative purposes only.*



	$V_{r,i}$ of W_o	$D_{e,i}$	$H(t=t_e)$	H_o	z
W_o (us)	0.000	0.000	undefined	undefined	0.000
W1	0.067	0.934	0.071	0.067	0.069
W2	0.133	1.731	0.077	0.067	0.144
W3	0.200	2.401	0.083	0.067	0.225
W4	0.267	2.934	0.091	0.067	0.314
W5	0.333	3.333	0.100	0.067	0.414
W6	0.400	3.600	0.111	0.067	0.528
W7	0.467	3.734	0.125	0.067	0.658
W8	0.533	3.729	0.143	0.067	0.813
W9	0.600	3.599	0.167	0.067	1.000
W10	0.667	3.334	0.200	0.067	1.236

Table 2 – Data from the light cone diagram of Figure 5. $V_{r,i}$ *is the relative velocity of the i'th world line from* P_0*'s frame.* $D_{e,i}$ *is the distance between the i'th world line and* W_0 *at the time when light was emitted.* $H(t=t_e)$ *is the Hubble value at time* t_e*, and z is redshift calculated with the longitudinal Doppler shift formula.*

That distinction, or lack of distinction, is quite important here because we must eschew the general relativistic interpretation of redshift as a result of spacetime expansion in favour of a literal velocity field described by special relativity; things really *are* moving in this model. So the interpretation of redshift of the explosion model neatly aligns with the equation that we use to calculate it: the relativistic Doppler effect.

We get into a tricky theoretical position though, because it seems almost *too* simple. And yet simplicity isn't the primary issue with applying special relativity to cosmology because evidently this has been attempted before and, as one can imagine, it didn't go so well. In an oft cited paper by Tamara M. Davis and Charles H. Lineweaver from 2004, for instance, they made an attempt to apply special relativity to the data and found it disagreed with the magnitude-redshift relation from type 1a supernovae by 23σ! In other words, applying special relativity to cosmology is not just gauche, but wrong to the point of absurdity. Clearly we have our work cut out for us.

Be that as it may, we still need to build our model's framework before we can tear it down. Returning to our diagram from §2, let's see what happens to our model when light speed is no longer instantaneous and behaves as it should in a special relativistic context. Figure 5 is a 2-D light cone diagram of our local Big Bang model and demonstrates how inhabitants on P_0 would measure recession velocities in the Universe around them; the following image of Table 2 has the measurements of the system. The speed of light in this diagram is one metre per second, and the absolute velocity of each of these world lines is the same as light: 1.0*m/s*. Figure 5's light ripples are for illustrative purposes only and do not represent physical reality since spacetime is famously anathema to absolute reference frames. Additionally the diagram seems to suggest we are reintroducing Newtonian relativity to light which may be an uncomfortable necessity of this model, however for our purposes we will focus only on relative velocities observed by our worldline.

At $t = 15$, P_0 receives light from all 10 other world lines at the same time, as illustrated by the yellow circles. Their hyperspatial position of the present is marked by "present time" P_i where $i \in \{1, 2, \ldots 10\}$. Which is to say, if the speed of light were instantaneous we would see these points at position P_i of the diagram just like in the previous diagram of Figure 1. Once again the world lines have been arranged so that each position P_i increases linearly from us by one unit of light speed per unit time. The time when light was emitted, which P_0 is now receiving at $t = 15$, is shown as "time emitted" E_j and $j \in \{1, 2, \ldots 10\}$, where redshift is encoded into the light at the time the light was emitted, not during the journey through space.

Imagine our astronomer on P_0 measures the distance and redshift of local celestial objects such as those at P_1 in order to obtain a Hubble value from this data. At $t = 15$, he would observe the light from P_1 as it was at $t = 14$, and come up with about 0.071 Hubble units, or *m/s per metre*. Now imagine, soon afterwards, he begins measuring late-time celestial objects from the most distant sources such as at P_{10} and applies this Hubble value onto the data. What would he measure?

After measuring the recession velocity of P_{10} to be 0.67*m/s* and inputting the Hubble value 0.071*m/s per metre* that was obtained from P_1 into the Hubble formula, he would calculate a proper distance at time emitted using the velocity-distance relation to be $D = v / H = 9.33m$, which is considerably more than the expected value if he knew the actual distance at emission $D_{e,10}$ to be 3.33*m*. A third of what was measured from the redshift-distance calculation! If the astronomer thought that Hubble's law is constant throughout space and time, he would take the redshift-distance relation at face value and over-calculate the distance to E_{10} by 6.00*m*. This theoretical calculation would eventually contradict observation when, say, galaxies were seen to be more developed than they should be. So what's going on here?

Although the hyperspatial Hubble value of P_{10} relative P_0 is exactly the same as all other P_i's along the θ-plane of constant radius (0.067*m/s per metre*), due to the time taken by light to reach us at P_0, we would observe information of a recession velocity as it was at the time when the light of W_{10} was emitted; in this case at E_{10} when $t = 5$.

Continues on page 260

Pen & Pixel

Figure 1 – Comet C/2023 A3 (Tsuchinshan-ATLAS) put on quite the show in September and October. Shelley Jackson was able to capture the Milky Way with its many treats, including M20, M8, M16, M17, and M18, along with Venus at the horizon, and the comet. "The tail of the comet is fading into the out-stretched arm of the Milky Way as if the Milky Way itself is reaching to grab the comet by the tail just to keep it with us a little longer," Shelley said. She used a Nikon D5500, a wide-field Rokinon lens (14mm ƒ2.8). This is a stack of 15, 8-second exposures shot at ISO 1600. She used Sequator for stacking, aligning stars and freezing the ground and PixInsight for stretching the raw data and for colour and detail enhancements.

Figure 2 – David Trahair captured the full moon and the CN Tower from Toronto on 2024 September 17. He used a Nikon Z6ii and a 70-200mm Nikkor with a 2x teleconverter.

Continues on page 259

What's Up in the Sky?

December/January 2024/25

Compiled by James Edgar

December Skies

The Moon is new on December 1. By the 4th, the Moon's thin sliver in the west is joined by Venus, just 2 degrees to the north. On the 8th, Saturn is a mere 0.3 degrees south of our first-quarter satellite, occulted for viewers in the Southern Hemisphere. The Moon is at perigee (closest to Earth) on the 12th at 365,361 km. On the 13th, with the waxing gibbous Moon among the stars of the Pleiades, Uranus is 4 degrees south. Jupiter is 5 degrees south of the Moon on the 15th, which will be full on the 16th. Might be a good time for a photo opportunity. The 18th sees the Moon occulting Mars for observers in the extreme north of Canada–otherwise a close conjunction of less than an degree. On the 24th, the Moon is at apogee (farthest from Earth) at a distance of 404,485 km. That evening sees Spica hugging Luna at only 0.2 degrees away. Spica is the bright star in Virgo, The Maiden. The 28th has the red star Antares just 0.09 degrees north of the Moon, an occultation in the Southern Hemisphere. And, finally, 29 days later, the Moon is new again on the 30th.

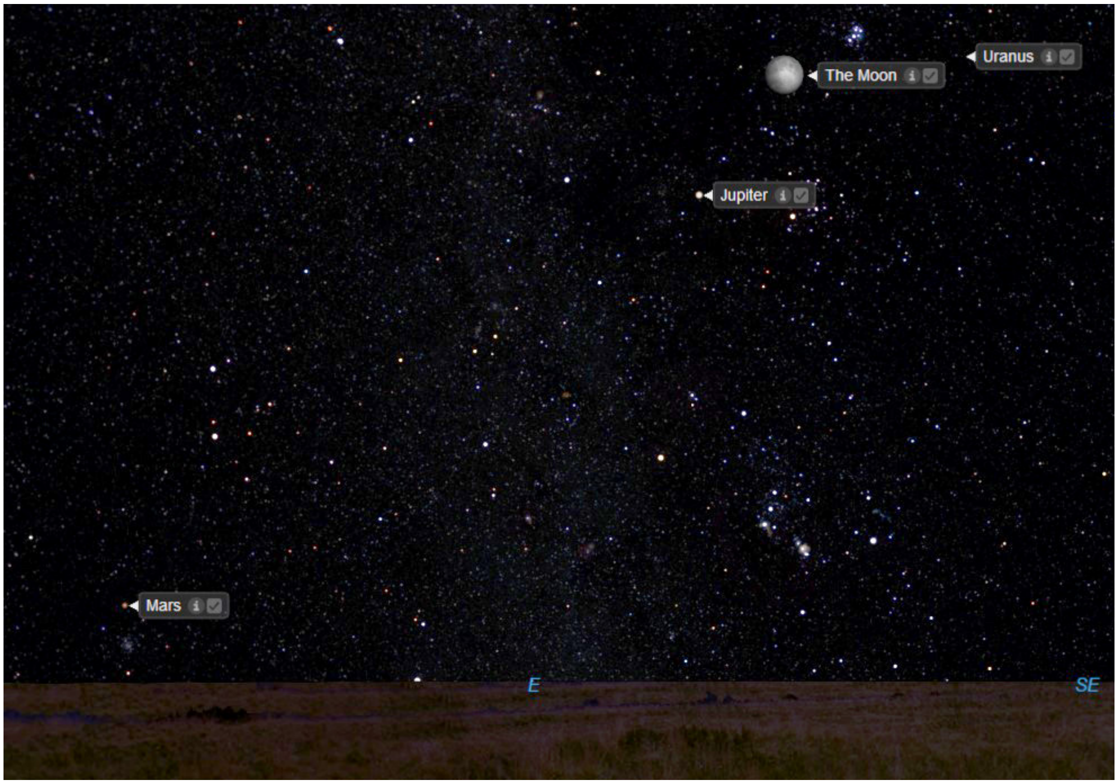


Figure 1 — On late evening of December 4, Mars rises in the east among the stars of Cancer, the Crab, while Jupiter, the Moon, and Uranus gather in Taurus.

Mercury is too close to the Sun for safe viewing during the first half of December. It rises in the early morning eastern sky, skirting north of Antares on the 22nd.

Venus is prominent in the western evening twilight, and joined by the Moon on the 4th. Each passing day sees the brightest planet rise higher and higher.

Mars is among the stars of Cancer, The Crab, rising just a half hour after Orion to the west. The Red Planet begins retrograde motion on the 7th, seemingly moving westward (but it's the Earth moving faster that causes this strange behaviour). The planet is well placed for evening viewing, with Pollux and Castor a bit north, Orion to the west, and Jupiter high above.

Jupiter is well placed for evening viewing among the stars of Taurus, The Bull. The Moon is 5 degrees north on the 15th.

Saturn rises in early afternoon, making an appearance at sundown, a little to the northeast of Venus. The Ringed Planet is approaching a ring crossing in March 2025, so the rings gradually become edge-on. Unfortunately, the ring crossing occurs when Saturn is hidden by the Sun, so a non-event.

Uranus rises in the late afternoon, ahead of Jupiter. The Pleiades are easy to spot just to the northwest of Jupiter, so the blue-green Uranus may be picked out of the starry background. It's the spot that doesn't twinkle.

Neptune, the elusive planet. It's so far away that it looks impossibly small. You'd have to use powerful binoculars or a medium powered telescope to see it, and even then, it's a tiny spot. The blue planet is among the stars of Pisces, The Fish.

Winter solstice is on the early morning of December 21.

The **Geminid meteors** peak on the evening of the 13th.

The **Ursid meteors** peak on the morning of the 22nd.

Continues on page 258

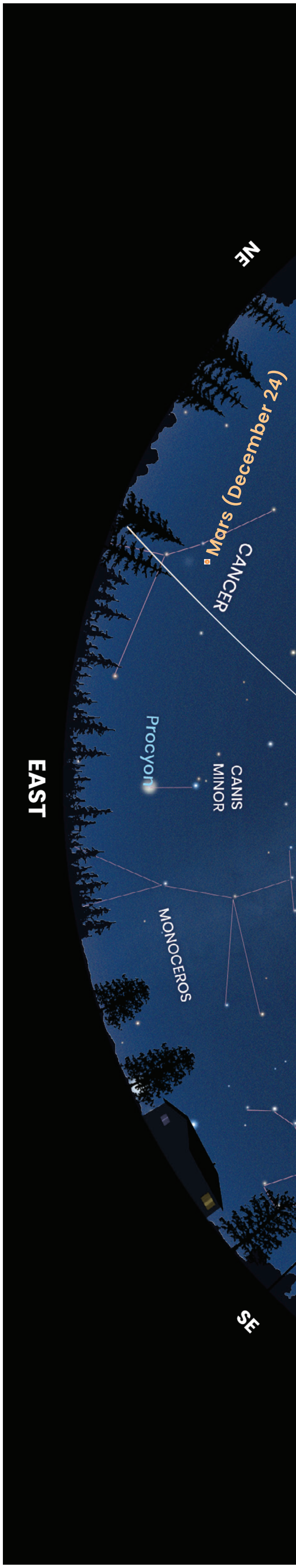
The Sky December 2024/January 2025

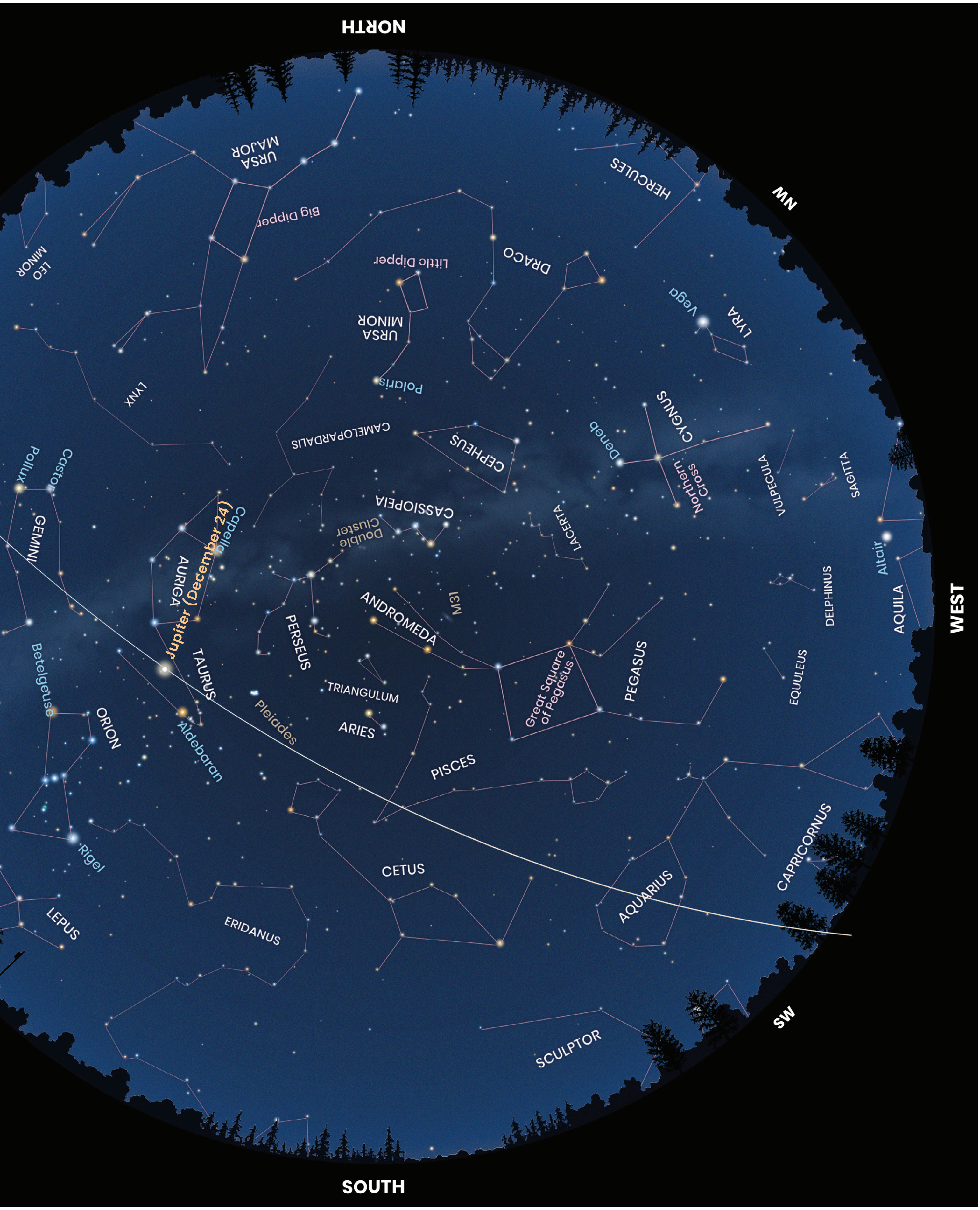
Compiled by James Edgar with cartography by Glenn LeDrew

Celestial Calendar
(bold=impressive or rare)

Dec. 1	new Moon at 6:21 a.m. EST (lunation 1261)
Dec. 4	**Venus 2° north of thin crescent Moon**
Dec. 7	Jupiter at opposition
Dec. 8	Moon at first quarter
Dec. 9	Neptune 0.8° south of first-quarter Moon
Dec. 12	Moon at perigee (365,361 km)
Dec. 13	Uranus 4° south of Moon
Dec. 13	**Geminid meteors peak at 8:00 p.m. EST**
Dec. 14	Jupiter 5° south of waxing gibbous Moon
Dec. 15	full Moon at 4:02 a.m. EST
Dec. 18	**Mars 0.9° south of Moon, occultation**
Dec. 21	Winter solstice at 4:21 a.m. EST
Dec. 22	Ursid meteors peak at 5:00 a.m. EST
Dec. 22	Moon at last quarter
Dec. 23	**double shadows on Jupiter**
Dec. 24	Moon at apogee (404,485 km)
Dec. 24	Spica 0.2° south of waning crescent Moon
Dec. 28	**Antares 0.09° north of thin crescent waning Moon**
Dec. 30	**double shadows on Jupiter**
Dec. 30	new Moon at 5:27 p.m. EST (lunation 1262)
Jan. 3	**Venus 1.4° north of Moon**
Jan. 4	Quadrantid meteors peak at 10 a.m. EST
Jan. 4	Earth at perihelion (147,103,686 km)
Jan. 4	**Saturn 0.7° south of waxing crescent Moon**
Jan. 5	Neptune 1.1° south of waxing crescent Moon
Jan. 6	Moon at first quarter
Jan. 7	Moon at perigee (370,171 km)
Jan. 9	Uranus 4° south of waxing gibbous Moon
Jan. 9	**Moon in Pleiades (M45)**
Jan. 10	Venus at greatest elongation east (47°)
Jan. 10	Jupiter 5° south of nearly full Moon
Jan. 12	Mars at closest approach
Jan. 13	full Moon at 5:27 p.m. EST
Jan. 13	**Mars occulted by full Moon**
Jan. 20	**Venus 3° north of Saturn**
Jan. 21	**Spica occulted by last-quarter Moon**
Jan. 21	Moon at apogee (404,298 km)
Jan. 18	**Mars 2° south of Pollux**
Jan. 21	Moon at last quarter
Jan. 24	**Antares 0.3° north of Moon**
Jan. 29	new Moon at 7:36 a.m. EST (lunation 1263)

	DATE	MAGNITUDE	DIAMETER (″)	CONSTELLATION	VISIBILITY
Mercury	Dec. 1	—	9.4	Ophiuchus	—
	Jan. 1	−0.3	5.9	Ophiuchus	Dawn
	Oct. 1	−3.9	12.2	Libra	Evening
Venus	Dec. 1	−4.2	17.1	Sagittarius	Evening
	Jan. 1	−4.5	22.2	Aquarius	Evening
	Nov. 1	0.1	9.2	Cancer	Evening
Mars	Dec. 1	−0.5	11.6	Cancer	Evening
	Jan. 1	−1.2	14.3	Cancer	Evening
	Oct. 1	0.6	19.0	Aquarius	Evening
Jupiter	Dec. 1	−2.8	48.1	Taurus	Evening
	Jan. 1	−2.7	47.0	Taurus	Evening
	Nov. 1	5.6	3.8	Taurus	Evening
Saturn	Dec. 1	0.9	17.5	Aquarius	Evening
	Jan. 1	1.1	16.6	Aquarius	Evening
Uranus	Dec. 1	5.6	3.8	Taurus	Evening
	Jan. 1	5.7	3.7	Aries	Evening
Neptune	Dec. 1	7.9	2.3	Pisces	Evening
	Jan. 1	7.9	2.3	Pisces	Evening




NORTH
NW
WEST
SW
SOUTH
URSA MAJOR
Big Dipper
HERCULES
LEO MINOR
Little Dipper
DRACO
URSA MINOR
Vega
LYRA
LYNX
Polaris
CYGNUS
Deneb
CAMELOPARDALIS
CEPHEUS
Northern Cross
VULPECULA
SAGITTA
Pollux
Castor
GEMINI
Capella
Jupiter (December 24)
AURIGA
CASSIOPEIA
Double Cluster
LACERTA
Altair
AQUILA
DELPHINUS
M31
ANDROMEDA
PERSEUS
TAURUS
Betelgeuse
ORION
Aldebaran
Pleiades
TRIANGULUM
ARIES
Great Square of Pegasus
PEGASUS
EQUULEUS
PISCES
Rigel
CETUS
CAPRICORNUS
AQUARIUS
LEPUS
ERIDANUS
SCULPTOR

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January Skies

The Moon is just past new phase as January opens. The 3rd sees Venus 1.4 degrees north of a very slender crescent. On the following day, Saturn is 0.7 degrees south of the Moon, an occultation for some parts of the world, but not the northern part of North America. On the 5th, Neptune is 1.1 degrees south, another occultation, but in the Eastern Hemisphere. The Moon is at first quarter on the 6th, and reaches perigee on the 7th at 370,171 km from Earth. By the 9th, Luna is 4 degrees north of Uranus, both objects among the stars of the Pleiades. Jupiter, not far away, is 5 degrees south of the Moon on the 10th. Full Moon is on the 13th, with Mars a scant 0.2 degrees away–this is an occultation for North American viewers, so might be an event to mark on calendars. Uranus is joined by the Moon on January 8/9. The 22nd finds Spica 0.1 degrees north of the last-quarter Moon, which is also at apogee of 404,298 km from Earth. Antares is 0.3 degrees north of the Moon, an occultation in the Southern Hemisphere. New Moon is on the 29th.

Mercury is well placed in the dawn sky, becoming ever more gibbous as the month progresses. By month-end, the speedy planet is too near the Sun to be seen.

Venus puts on a great show in the first half of 2025, prominently placed in the western evening sky. The thin crescent Moon is nearby on January 3, and Saturn is in conjunction on the 20th, among the stars of Aquarius.

Mars is retrograding in Cancer, moving westward to Gemini by the 12th, and occulted by the full Moon on the 13th. The Red Planet also reaches closest approach to Earth on the 12th. On the following day, the full Moon occults Mars. By the 21st, Mars has moved to within 2 degrees of Pollux.

Jupiter is retrograding in Taurus, well overhead throughout the night. The giant gas planet is a great one to watch, noting the constant motions of the four Galilean satellites–the ones first observed with a telescope by Galileo in 1610. The waxing gibbous Moon passes by on the 10th.

Saturn shares the early evening sky with Venus and the waxing crescent Moon on the 4th. The rings will be of great interest, as a ring-crossing event occurs in March. Unfortunately, the planet is too close to the Sun then to see the actual crossing. An interesting bit is that we'll only see the southern side of the rings until 2039. Venus slowly climbs the ecliptic to be in conjunction with Saturn on the 20th.

Uranus, retrograding in Aries near the Taurus border, is joined by the waxing gibbous Moon on the 18th. Try to spot the distant planet without visual aid–it's tiny but the blue-green disk is quite distinct. A telling feature is the steady appearance–stars twinkle; planets don't.

Neptune needs visual aid, usually a telescope, to be seen. The icy blue planet can be found among the stars of Pisces, The Fish, in the southwest after sunset.

The **Quadrantid meteors peak** on January 3 at 15:00 UT (9 a.m. CST).

Earth is at perihelion on January 4, at 147,103,686 km from the Sun. ✶

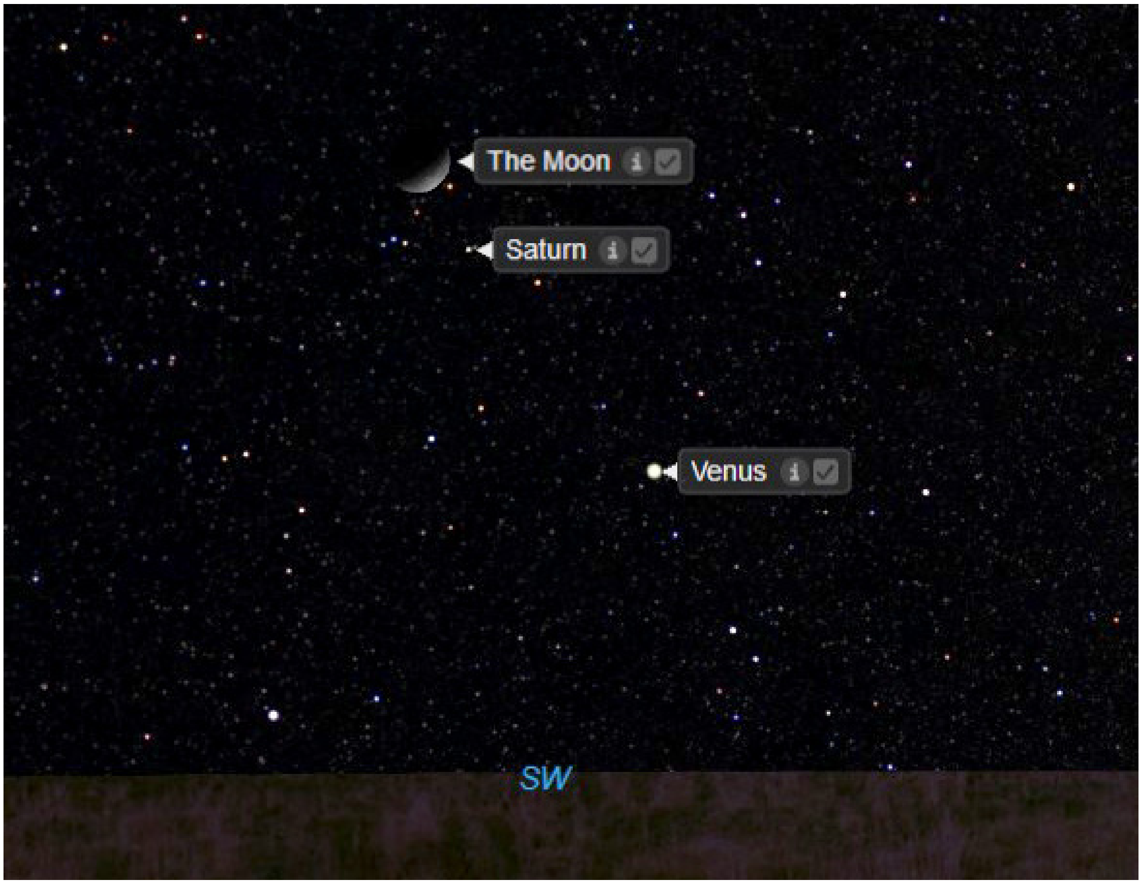

Figure 2 — On the evening of January 4, shortly after sunset, the Moon, Saturn, and Venus are nicely positioned for a photo op among the stars of Aquarius.

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Figure 3 – The tendrils of the Crescent Nebula (NGC 6888) are shown in incredible detail in this image by Kimberly Sibbald. She imaged using PlaneWave CDK14 at 2,563mm, a Mesu Mark II friction drive mount with a QHY268M camera and SHO 3.0nm filters. Total integration was 31 hours and 30 minutes, with Hα subs 37x1200 seconds, OIII subs 37x1200 seconds, and SII subs 16x 1200 seconds and RGB for stars at a total of 1 hour 30 minutes.

Figure 4 – Katelyn Beecroft imaged C/2023 A3 (Tsuchinshan-ATLAS) and its anti-tail from her home just south of London, Ontario, with a Rokinon 135mm ƒ/2 lens and her Canon Rebel T6i. This is a stack of 25 6-second images stacked and processed in Photoshop.

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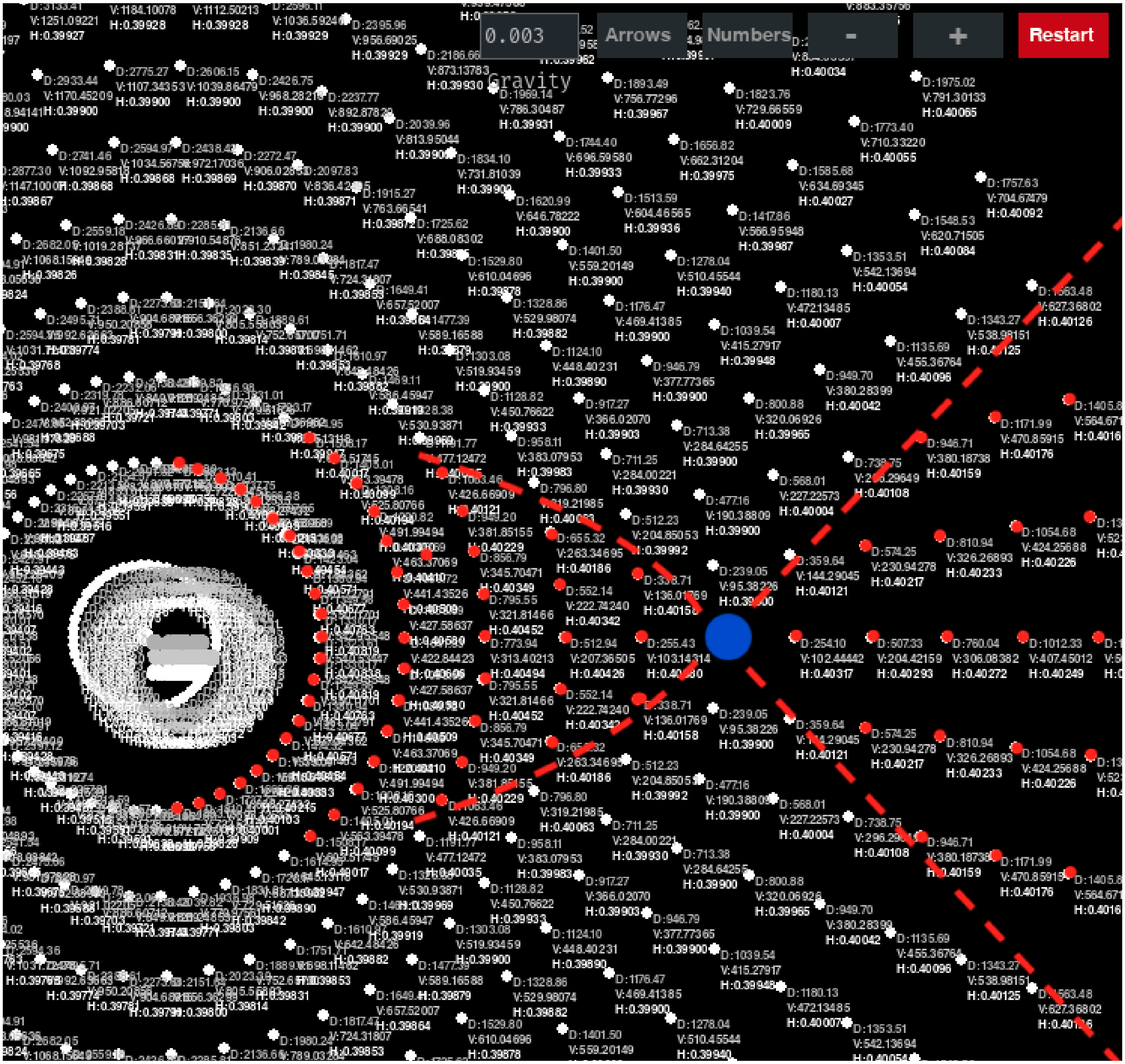

Figure 7 – A radial velocity field simulation with relative velocities from the perspective of the blue dot. Gravity with an arbitrary strength was added to the Python simulation to roughly emulate the ALIVE model's velocity field properties.

And since the absolute velocity of all energy in the ALIVE Universe model is constant while distance is increasing, the Hubble value of everything falls in tandem with the progression of cosmic time in this way: $H = 1/t$. Anything in the past will have a greater velocity-distance ratio than it does in the present and for that reason the Hubble value the astronomer measures from objects of E_1 will be much less than the one measured from E_{10} (even when using the correct distance at time of emission), which is 0.20*m/s per meter*. That's where the error came in: he applied a Hubble constant that isn't constant.

The residents on P_0 would eventually discover the redshift of objects doesn't just increase but actually accelerates relative the distance increase because Hubble's law is not static but dynamic in this Universe; a function that asymptotes to zero with positive cosmic time, $t \rightarrow \infty$, $H \rightarrow 0$.

Accounting for this new discovery, the astronomer adjusts the previous Hubble law of Eq. 2.5 so that the distance at time emitted uses the appropriate Hubble function:

$$H(t = t_e) = \frac{\| \mathscr{V}_i \| - \| \mathscr{V}_0 \|}{D_e}, \tag{3.0}$$

where $H(t{=}t_e)$ is the Hubble value at the time light was emitted and D_e is the proper distance at the time emitted. The Hubble function

$H(t)$ is related to $H(t=t_e)$ by the inverse of the cosmic time at which the object emitted light:

$$H(t=t_e)=\frac{1}{t_e}. \tag{3.1}$$

So in both LCDM and the ALIVE model we have a dynamic Hubble law but for different reasons. There is a changing Hubble value in the LCDM model as a result of shifting ratios of energy density throughout cosmic time, where omega Ω denotes the percentage of each energy density relative to one another and some density ratios make spacetime expansion go faster or slower than others, hence a changing Hubble value. The changing Hubble law in LCDM changes only in time, however, and not in space, so it should be the same no matter where we look in the sky as long as it has the same look-back time. Today, dark energy is by far the most dominant energy in the Universe (~70%) but it had a negligeable presence in the early days soon after the Big Bang.

The ALIVE model's Hubble law is dynamic due to the geometric properties of the radial vector field $\mathcal{U}$ combined with a finite speed of light that has redshift-distance information from an earlier point in history baked in. This explosion model's feature is what we will assume is responsible for what LCDM interprets as dark energy. A compilation of each Hubble value at each era of cosmic history, shown below in the graph of *Hypothesis 3* (Figure 6), demonstrates an exponential trajectory of $H(t)$ towards infinity when looking backward in time which is what we'd expect as distance approaches zero while absolute velocity remains constant.

But unlike LCDM, the explosion model predicts a dynamic value of Hubble's law throughout both time *and* space: we should expect a peculiar velocity field that's shaped like an hourglass. After inputting the vector field $\mathcal{U}$ into a particle simulation and observing the dynamic relative velocity of each of the "galaxies" under the influence of gravity, it seems the increase or decrease in the relative velocity of stellar objects corresponds to what's technically called a hyperboloid, where the axis through the centre of it is parallel with $\mathcal{V}$, our absolute velocity's radial axis ($\mathcal{V}$ is pointing to the right of Figure 7 in this case).

Objects within the red hourglass of Figure 7 have accelerating recession velocities over cosmic time, with maximum acceleration observed at the axis of absolute motion in both directions; galaxies outside this shape are decelerating, and with maximum deceleration seen perpendicular our absolute motion. The exact volume and shape of the hourglass seems to depend on the amount of mass density in the particle simulation (gravity's strength was adjustable in the simulation). So if these velocity fields are observed in reality, they could provide good observational evidence for this model, while the exact shape of the hyperboloid should confirm how much total mass there is in our localized Big Bang.

Up until now we've seen relative velocity formulas without invoking the key aspect of observational cosmology that provides these velocities: the ratio between the observed wavelength of light and its wavelength at the time of emission. Redshift. It's what tells us how much relative velocity there is, which means our equations aren't of much practical use without bringing z into them since that's what we can actually measure.

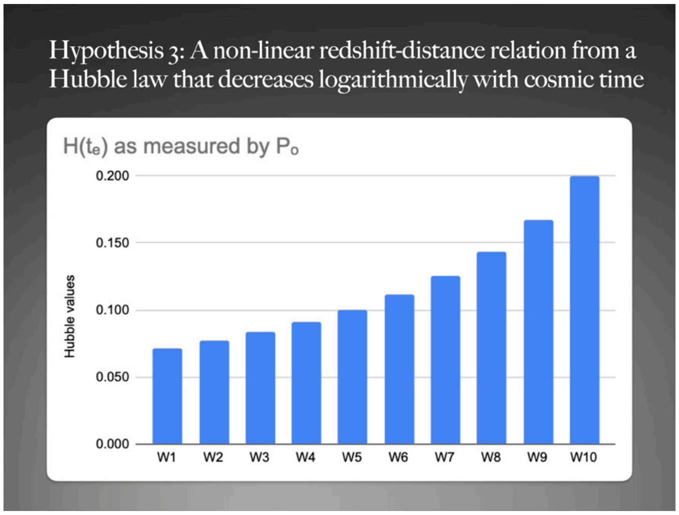

Figure 6 – A dynamic Hubble law viewed by the astronomer on W_0. Hubble's law decreases at a rate of inverse cosmic time and so the redshift-distance relation increases exponentially the farther back in time we look as well.

The simplest redshift formula is $cz = v$, and it's sufficient for most astronomy in the local celestial arena when $z << 1$. It is not compatible with cosmological measurements since there are many objects whose redshifts are well beyond $z = 1$ which would suggest they are travelling faster than light. Evidently the first point of order for a distance-redshift relation in this model is to make sure nothing is moving faster than the messenger of information which indicates something is there to begin with. The equation for a longitudinal relativistic Doppler shift in terms of velocity is:

$$v=c\,\frac{(1+z)^2-1}{(1+z)^2+1}, \tag{3.2}$$

which does exactly that. And then returning to the Davis and Lineweaver paper from 2004, they go on to add the Hubble relation $H = v/D$ into that equation above by assuming the velocity in both are equivalent. They get the following formula, where c is the speed of light and H is Hubble's parameter, in terms of the proper distance $D(z)$:

$$D(z)=\frac{c}{H(t)}\,\frac{(1+z)^2-1}{(1+z)^2+1}. \tag{3.3}$$

Soon after this point in their paper they say to the reader that this is a potentially careless method of derivation in the context of spacetime expansion, stating on page 104:

> "*However, since SR does not provide a technique for incorporating acceleration into our calculations for the expansion of the Universe, the best we can do is assume that the recession velocity, and thus Hubble's constant, are approximately the same at the time of emission as they are now.*"

Gratefully, acceleration is not a factor in our explosion model, so neither is a changing recession velocity. For that reason their method of deriving proper distance in a special relativistic manner, despite their trepidation, seems to be valid for our purposes of creating a localized Big Bang model. The only issue with calculating $D(z)$ in this way is that we need to know the Hubble value of the Universe as it is today, right now. Therefor any distance calculation we make using the generally accepted $H = 70$ *km/s per Mpc* must be a lower bound because Hubble's value has decreased in the time it took light to reach us from the redshifted object we're using to measure that value.

With proper distance now in hand, we are able to convert this into the luminosity distance like so: $D_L(z) = D(z)(1+z)$. And finally we can use $D_L(z)$ in a distance modulus formula to apply our model to the real world data like the standard candles of SN1a. We are deviating slightly from the Davis and Lineweaver method here by using the vanilla distance modulus rather than the one they borrowed from another paper by Perlmutter from 1999. The former equation being:

$$m - M = 5\log_{10}\left(\frac{D_L(z)}{10\text{pc}}\right). \tag{3.4}$$

This should be all the tools we need to incorporate special relativity and, more broadly, light, into our explosion model. Although there's still an elephant in the room named 23 sigma from that 2004 paper, we will tolerate that awkwardness for now and come back to it later when we start applying our toy model to the real Universe in §5.

Energy density distribution

Energy density of the Universe and its distribution around space is what seals the destiny of the cosmos, no matter the model we happen to be using. After Hubble's law, arguably the second most important fact of cosmology is this energy distribution which, in the standard cosmological model, goes by the name of the "cosmological principle": the presumption that all the dark and baryonic matter in the Universe is, on average, distributed evenly at cosmic scales (generally beyond 100 *mega-parsecs*) like an ideal fluid. From this principle comes the homogeneity and isotropy of our Universe's energy distribution, and Einstein's field equations simplify into the more palatable Friedmann equations.

Our explosion hypothesis obviously has a very different interpretation of matter within its Universe: the Friedmann equations aren't applicable because we assume energy density has a minor or undetectable impact on spacetime expansion since recession velocities are interpreted as literal velocities and not cosmological redshift. Recalling our velocity field $\mathcal{U}$ from Equation 2.4, it's clear that the energy density distribution of the ALIVE Universe dilutes from the source exponentially and has the same distribution properties as gravity and electric charge: that of the inverse square law $1/(4\pi r^2)$. From that simple function of radius we can ascertain a good bit of information about the local Big Bang model as long as we adhere to its corollaries:

1. We should expect an energy density dipole in the sky both in terms of the matter distribution in the form of galaxies, but also a distinct temperature dipole in the radiation left over from the decoupling event (basically a transition from plasma to matter) around 380,000 years after the Big Bang.

2. From that universal energy density asymmetry would come a universal gravity well towards the source of the energy distribution; in this case that means there would be a force of gravity pulling everything towards the origin of the Big Bang from whence we came. Meaning, we should notice bulk galaxy flows towards that spot across the observable Universe.

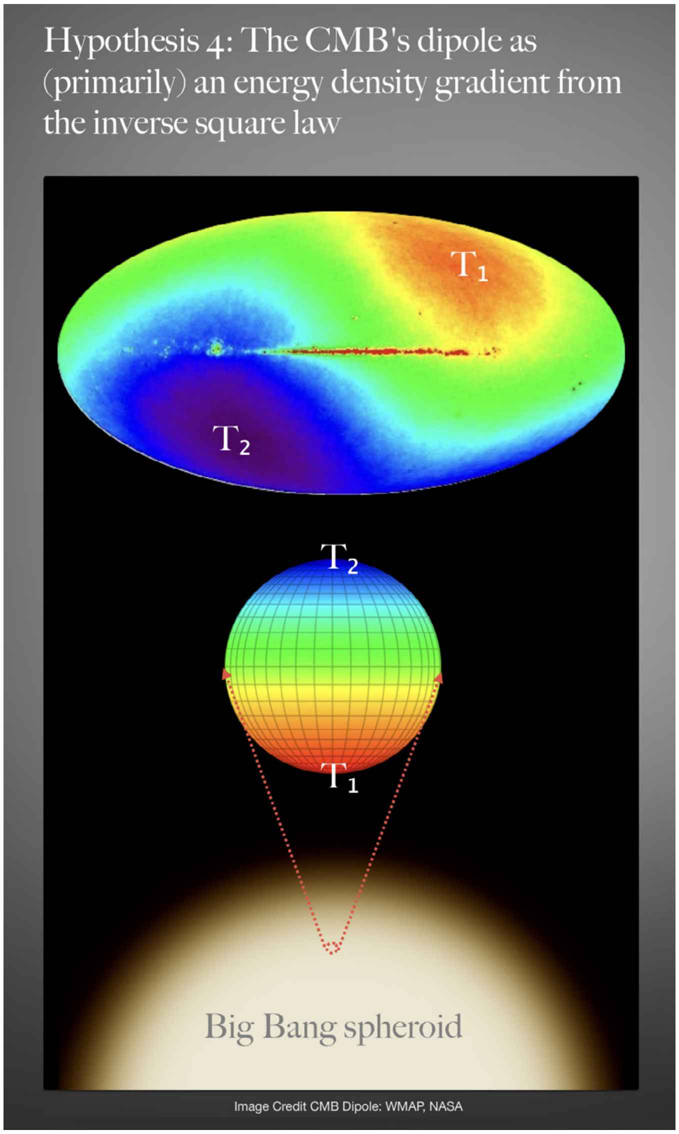

Image Credit CMB Dipole: WMAP, NASA

Figure 8 – The temperature dipole of the CMB were it to be a density gradient from an explosion model. The hot spot is T_1 and the cold spot is T_2. Both an "internal" and "external" view of the dipole is shown as well as its orientation relative the Big Bang.

3. Presumably our localized Big Bang's shape is not a perfect sphere so we would think it likely for there to exist density anisotropies perpendicular to the axis of our absolute velocity which correspond to our being in an expanding spheroid of energy. That density variance should also be seen as hot patches and cold patches in the Cosmic Microwave Background (CMB) like the dipole.

But we don't see any of that! At this point an explosion Big Bang model seems to break down because we observe very high uniformity of energy across the sky both in terms of galaxy density as well as the CMB's temperature. If the inverse square law is indeed the function of the explosion hypothesis' energy distribution then where is the evidence for this in observational cosmology? This is not just a valid point, it's actually the main reason why Alan Guth, the man behind inflation theory, says the Big Bang explosion model gets ignored by the experts:

"*If there were a localized explosion that occurred in some particular direction in the sky […] then one would expect that this direction would be clearly visible as a hot spot in the background radiation. The idea of a localized explosion would work only if we happened to be living right at the center of the explosion. Since it seems very unlikely that we should be so close to the center, the possibility of a localized explosion is not given much serious consideration.*" (p. 74, 1997)

In a paper titled "In the realm of the Hubble tension—a review of solutions" from 2021, the researchers made a summary of the many dozens of alternatives to the standard cosmological model that are being theorized upon which aim to patch some of the growing issues with LCDM such as the Hubble tension. Their research is 110 pages long while containing over 1,000 references, and because it has exactly zero footnotes or mentions of an explosion hypothesis of the Big Bang anywhere in the text, it corroborates Alan Guth's claim: everyone thinks this idea is silly. And they're probably correct.

But as it happens, very recently there have been cracks forming in the principle of isotropy and homogeneity of the Universe with new tensions becoming prominent as we resolve data ever more precisely and see that these incongruities with the cosmological principle are not going away. Even more peculiar is the fact that many of these unexplained and seemingly unrelated energy density phenomena appear to be pointing towards the same direction in the sky; a spot that somehow also aligns with the peak of the CMB's kinematic dipole; the "hot spot" at (*l*) 264.0°, (*b*) 48.3° in galactic coordinates.

It started with an obscure paper from 1984 by G.F.R. Baldwin and J.E. Ellis that provided a test for whether the kinematic dipole of the CMB is indeed caused by our Milky Way galaxy's motion relative the CMB. They concluded that, if the temperature dipole of the CMB is really caused by the relativistic Doppler effect, then the magnitude of the CMB's dipole should match the magnitude of other cosmologically distant sources such as the quasar background. Subsequent research in the following decades used newly acquired quasar and radio galaxy data with the astrophysics from this 1984 paper to determine that, actually no, they do not match! And yet, despite the implications of this discovery, it appears it wasn't until a conference was held by the *Royal Astronomical Society* in April of 2024, titled "Challenging the standard cosmological model," that this new tension was taken seriously.

When some or all of the CMB temperature dipole is not caused by the relativistic Doppler effect—which seems to be the case—this implies that one half of the sky is inherently warmer than the other half of the sky (by up to 0.007 *degrees Kelvin*), which contradicts the cosmological principle and, more importantly in the context of this article, the notion that the CMB is highly uniform. That may be a remarkable turning point in this story since the principle reason why Alan Guth (and ostensibly the professional community) ignores the explosion hypothesis is no longer valid. Moreover, this non-uniformity "may be interpreted as an intrinsic over-density of galaxies and quasars on very large scales" as well. (Secrest et al. 2022; one of the many papers that found this discrepancy between the CMB dipole and the radio galaxy and quasar dipole magnitudes.)

What happens when there's an over-density of matter in one half of the Universe? A universal gravity well happens. To believe the CMB's temperature hotspot is aligned with this galaxy over-density by chance is not impossible, though when we consider how the bulk flow of the Local Group of galaxies is roughly towards the same direction in the sky, and how convergence of that bulk movement to the CMB rest frame is still not found out to about 400*Mpc*, it gets harder to claim these phenomena aren't physically related somehow; especially when we further recall how the controversial "dark flow" discovery from 2008 by Kashlinsky et al. suggested nearly all of the galaxy clusters in the observable Universe have a peculiar velocity towards the CMB's hotspot as well. And then let's not forget the "axis of evil" (or the preferred axis) whose name encapsulates the bizarre set of minor, though statistically significant, differences between the same two halves of the sky.

So it seems we *do* have reasonable observational evidence to satisfy the first two corollaries of the ALIVE Big Bang model after all, which in and of itself is a curiosity. The moment when this curiosity becomes a profundity is when the third corollary is found in the CMB's temperature signature as well. There are two multipoles in the CMB that align perpendicularly with the axis of the dipole: the quadrupole and the octopole. These temperature fluctuations are very discrete (much less than the dipole's ±0.0035° difference from the mean of the CMB) but nevertheless detectable and without any real explanation in the standard cosmological model. In the explosion model, the quadrupole and octopole are energy density fluctuations inherent to an expanding spheroid.

Hypothesis 4 illustrates the CMB's density gradient interpretation in Figure 8, where our "internal" view of the CMB is juxtaposed with an "external" spherical view to help demonstrate our orientation relative the Big Bang. Armed with a relationship between radius and flux density, our astronomer living on W_0 draws a diagram (Figure 9). He compares the ratio between galaxy densities at two opposite points along his absolute axis of motion with the distance ratio between their radii (from the origin of the Big Bang) by using the other manifestation of the inverse square law: $(R_2/R_1)^2 = \rho_1/\rho_2$. If one end of the flux measurement that's closest to the origin is the first radius R_1, and the second radius is R_1 plus two radii of distance r, so $R_2 = R_1+2r$, then we are left with a single unknown variable in the inverse square equation which can be solved after rearranging like so:

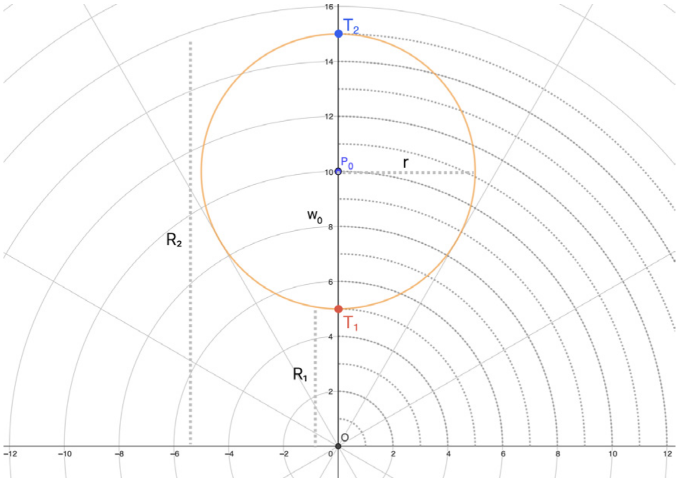

Figure 9 – Density gradient schematic of the local Big Bang Universe. Here ρ_1 and ρ_2 are at the same points as T_1 and T_2 respectively.

$$R_1 = \frac{2r}{\sqrt{\frac{\rho_1}{\rho_2}} - 1}. \tag{4.0}$$

Equation 4.0 is just a snapshot at one moment in time however, so we need to incorporate the light delay of that information into the relationship. We can find r in terms of redshift z using a one-dimensional kinematic equation where the total distance light travelled to a receding observer is $ct = r + vt$, then inserting the longitudinal relativistic Doppler shift of Eq. 3.2 into the velocity variable of the kinematic formula in this way:

$$r = \left[c\left(1 - \frac{(z+1)^2 - 1}{(z+1)^2 + 1}\right) \right] t, \tag{4.1}$$

we get r at the time light was emitted. There's been a slight change in notation here since r now represents a radius from the observer's frame, and R is the universal radius from the Big Bang's origin out to a point. The distance from the Big Bang's origin to the coordinate of the astronomer R_0 when he was at $R = 10$ is just $R_1 + r = R_0$ so now he can figure out the radius of his Big Bang both at $t = 10$ and today at $t = 15$ by extrapolating the information he's gained from the Equation 4.0.

Should we not have galactic density measurement capacity for some reason, then an alternative but equally valid derivation is possible when we recall that the Stephan-Boltzmann formula contains a relationship between the inverse square law and the temperature of a black body. The ratio of two radii within a black body would look like the following Equation 4.2, with ε for emissivity (the proportion of light that can enter or leave an object and not be reflected away) which is approximately equal to 1; σ being the Stephan-Boltzmann constant, P being power and T is temperature:

$$\frac{P}{P} = \frac{4\pi R_1^2 \sigma T_1^4}{4\pi R_2^2 \sigma T_2^4}. \tag{4.2}$$

It's an eyesore at first glance though gratefully many things cancel out. After once again substituting $R_2 = R_1 + 2r$, and solving for R_1, we get the same equation as 4.0 except expressed with radiation temperature, where T_1 and T_2 are the radiation temperatures at radii R_1 and R_2, respectively:

$$R_1 = \frac{2r}{\left(\frac{T_1}{T_2}\right)^2 - 1}. \tag{4.3}$$

It turns out this will be the more useful equation when we start applying these relationships to the real world since the CMB's temperature data can be accessed quite easily and it's conveniently assumed to be a blackbody with emissivity ≈ 1. So the Equation 4.3 should be valid if we know where our real world axis of motion is as well as the temperature difference of the CMB's radiation at two points along that axis (and we know the distance between those two points at the time the light was emitted).

But first let's use this newly found radius to find an approximation of the total mass of the Universe by integrating a density function $\rho(r)$ out to the outer surface of the Big Bang's spheroid (that we'll approximate as a sphere); which is to say, to the outer surface demarcated by our location at present cosmic time. Of course the true border of the local Big Bang's energy distribution will be much larger so this estimate will be a lower bound calculation, especially since the radius estimation is also a lower bound approximation because we've assumed at $t = 0$, $R = 0$, which is unlikely to be the case. $R \geq 0$ at $t = 0$ is more probable.

When density of an object like a sphere is not constant, we approximate its density distribution with a function—in this case the inverse square law—then integrate this function $\rho(r)$ to get mass like so (using b as a constant):

$$M = \int_V \rho(r)dV$$

$$= \int^R \frac{b}{r^2}(4\pi r^2)dr$$

$$= 4\pi bR$$

Then substituting $\rho(r)r^2 = b$ back into the equation, we get a function for the total mass of the local Big Bang if we know the average density of our observable Universe:

$$M = \rho(r)4\pi R^3 \tag{4.4}$$

In summary of this section, possibly the most satisfying implication of the energy density distribution of the ALIVE Universe is that it *does* have an intuitive answer for the most common question about the Big Bang from a layperson: "where is the centre of the Universe?" The direction to the centre of the Big Bang is towards the peak of the CMB's hot spot, (*l*) 264.0°, (*b*) 48.3° in galactic coordinates, which is towards the Hydra constellation. It's a completely unremarkable spot to the naked eye so it's useful to illustrate that coordinate with an arrow relative the Milky Way in *Hypothesis 5* (Figure 10).

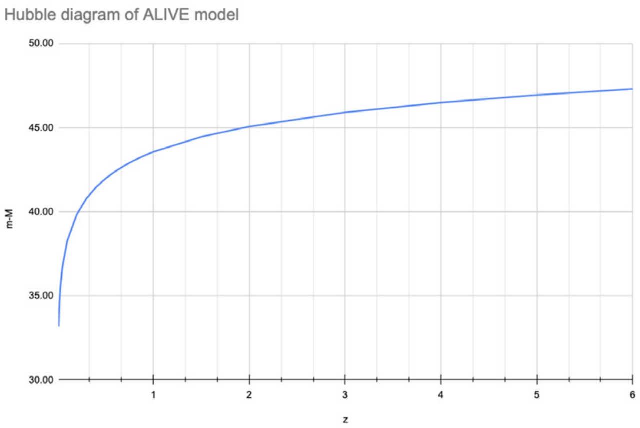

Figure 11 – The μ(z) to z curve predicted through special relativistic derivation, which would be applicable to the local Big Bang model.

Applying the model to our Universe

It appears we have what we need for the foundation of our explosion model. But it's still only a basic foundation. The question now is whether this framework will allow us to construct a sturdy theory on top without it tumbling down under the weight of actual cosmological data. Have we been humouring this explosion model a little too much? Or does it actually have some legs. We've arrived at the *coup de résistance.*

There were a few uncomfortable assumptions we had to make in §2, but the first major qualm we encountered with this model is in §3: applying special relativity to cosmology. Although we live in a general relativistic world, we've removed ourselves from a feature of it, spacetime expansion, in favour of a velocity field from the vector space $\mathcal{U}$. Doing so requires us to apply the method we adapted from the Davis and Lineweaver paper described in §3, which is as follows: recalling Equation 3.3, we start by inputting varying redshifts into it up to some arbitrary number, let's say $z = 6$, for reasons that will be clear in a moment. Speed of light c in a vacuum is 299,800 *km/s,* and Hubble's value H is 70*km/s per Mpc,* which gives us our proper distances $D(z)$. We convert $D(z)$ into luminosity distance—again that's $D_L(z) = D(z)(1+z)$—and then use those values to get our distance modulus $\mu(z)$ from Equation 3.4, leaving us with the following set of values in Table 3, and further illustrated with a Hubble diagram in Figure 11.

There are plenty of papers whose Hubble diagrams we could borrow to compare this data against, such as the original dark energy research articles by Schmidt, Perlmutter, and Riess from 1998, but it makes better sense to use more modern conflations of data that include not only SN1a but also quasars, for instance, because that will allow us to extend the Hubble diagram well beyond $z = 1$ and into deep time. A well cited paper published in *Nature Astronomy* from 2019 titled "Cosmological constraints from the Hubble diagram of quasars at high redshifts" by G. Risaliti and E. Lusso seems as good as any so we'll use theirs.

Figure 12 (from their Figure 2) is their Hubble diagram that goes out to $z = 5$ and is extrapolated to $z = 6$. It illustrates the SN1a data from the JLA survey as cyan points for redshifts out to about $z = 1.5$, and superimposes quasar data "from the cross-correlation of the *XMM-Newton* Serendipitous Source Catalogue Data Release 7 with the *Sloan Digital Sky Survey* (SDSS) quasar catalogues from Data Releases 7 and 12"—using yellow points with their respective error bars. The red points represent the mean but that average is only for the quasars (a black line is used to show the best fit curve). Dark blue stars in the $z > 3$ range are quasars from the observatory *XMM- Newton*, "significantly increasing the reliability of our cosmological analysis."

The dashed purple line is what is predicted by a flat LCDM model where $\Omega m = 0.31 \pm 0.05$. It agrees well with the data out to about $z = 1.0$—which is why LCDM is the concordance model—but then, as the researchers note in the article, something interesting happens: the best fit quasar curve begins to diverge from the LCDM prediction and increasingly so at higher redshifts. Risaliti and Lusso suggest this may be a result of an evolving Λ, which could be true. However, if we turn our attention to the green curve, the ALIVE model's distance modulus curve, this divergence of LCDM's prediction from the best fit curve presents an opportunity to give the explosion model some

Hypothesis 5: The Big Bang's centre is towards *(l) 264.0° (b) 48.3°*

Image Credit Milky Way: ESO/S. Brunier

Figure 10 – The direction toward the centre of the Big Bang, according to the ALIVE model, is (l) 264.0°, (b) 48.3° in galactic coordinates.

unexpected credit; in the *XMM-Newton* data, the quasars are *better fit* to its distance modulus to redshift relation than LCDM, which is remarkable.

The ALIVE model's $\mu(z)$ to redshift curve is certainly not a perfect fit nor does it represent the data better than LCDM, but it's clearly not as bad as the 23 sigma that was found by Davis and Lineweaver[1]; in fact it seems to deviate from the quasar standard candles about as much as LCDM. And let's not forget, since we're using $H = 70$ *km/s per Mpc*, this distance modulus to redshift curve is a lower bound calculation because the ALIVE model's Hubble value will have decreased in the time it took light to reach us; Hubble's value today will be smaller, so in actuality its distance modulus to redshift curve will be higher and closer to the black best-fit curve.

Any proponents of the localized Big Bang model might be relieved know that its biggest obstacle is not so insurmountable after all. Now that we know it wasn't a complete waste of our time developing this explosion model, we can do some of the more exciting calculations from our other derivations in the previous sections.

The age of the Universe in this model is simply the Hubble time, plus the amount of time between the true Big Bang event in which we inherited our absolute motion and the transition from the density "singularity" traditionally at $t = 0$ to the density we can calculate afterwards (which is probably a negligeable addition to cosmic time):

$$1/H_0 \approx 14 \textit{ billion years.}$$

We can calculate our absolute velocity through spacetime by presuming that the CMB's temperature dipole ratio that we observe today is approximately the same as it was at the time of recombination despite the large decrease in temperature. We also presume any effects of gravitational redshift or blueshift from the universal energy density gradient inherent to this model are negligeable.

Thankfully the CMB's temperature is extremely well studied and we know its hot spot peak is 3.35mK higher than the CMB mean average of 2.726K and 3.35mK lower than this average at the peak of the cold spot. We can find r using Equation 4.1 once we've inputed $z = 1100$ for the redshift of the CMB radiation and 14 billion years for the total time light travelled t. This gives us r as it was at the time of recombination about 380,000 years after the Big Bang: 23,100 *light years*. Then, inputting the CMB temperature ratio into Eq. 4.3, we get $R_1 = 406r$ and therefor the radial distance from us to the origin of the Big Bang is $R_0 = R_1 + r = 407r$. This means, at the time of recombination, R_0 was $9.4\text{x}10^6$ *ly* in magnitude.

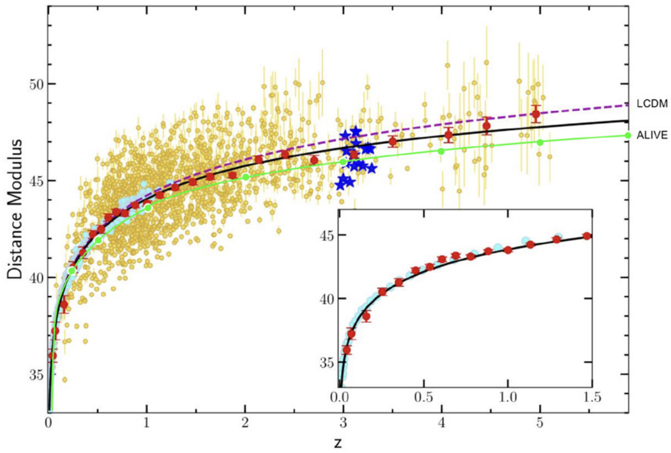

Figure 12 – Hubble diagram of SN1a and quasars from G. Risaliti and E. Lusso (2019) with the distance modulus to redshift curve of the ALIVE model predicted by special relativity superimposed. This ALIVE distance modulus to redshift curve is a lower bound estimate.

z	0.1	0.5	1	1.5	2	3	4	5	6
m-M (H=70)	38.26	41.97	43.56	44.45	45.06	45.90	46.48	46.93	47.30

Table 3 – Distance modulus data of the ALIVE model.

Knowing R_0 at the time of last scattering, and knowing the cosmic time at which that recombination happened, it's safe to estimate our absolute velocity $\mathcal{V}_0$ because it's presumably the same today. The radial axis of absolute motion goes through the CMB's hotspot peak and the CMB's cold spot peak, so our absolute velocity vector is in the direction of the cold spot peak at (l) 84°, (b) -48°, in galactic coordinates, with a magnitude of:

$$\mathcal{V}_0 \approx 24.7 \text{ times the } \textit{speed of light}.$$

Today, every 14 billion light-years the incremental change of the absolute velocity along our absolute axis of motion is ± c (which is ±70k*m/s per Mpc*), with increasing absolute velocity with increasing radius from the origin, and vice versa.

The idea we are travelling through spacetime many times the speed of light is probably unpalatable to most readers and it's easy to sympathize with this for obvious reasons. A saving grace might be to compare this result with galactic objects in LCDM whose recession velocities are sometimes much greater than light speed because spacetime expansion is happening superluminally beyond the Hubble horizon. This isn't a violation of special relativity because the motion isn't in any observer's inertial frame. In other words, general relativity allows for superluminal speeds.

Using this absolute velocity $\mathcal{V}_0 = 24.7c$ and multiplying it by the age of the Universe we get an approximate radius of the entirety of the Big Bang out to our location, right now. In reality it is much larger than this but it's difficult to say how much farther the Big Bang spheroid goes so we'll have to accept our anthropic bias:

$$\text{Radius of Universe to Milky Way} \approx 346 \textit{ billion lightyears.}$$

The mass of this Universe is trickier because we shouldn't use LCDM estimates for the average energy density of the Universe, about $3\text{x}10^{-27} kg/m^3$, since those estimates are calculated relative the critical density which is not applicable in this model. Yet it's hard to know how to calculate this value manually without writing another chapter so we will have to use that estimate regardless. Inputting values into Equation 4.4, we get about:

$$\text{Lower bound mass of the Big Bang} \approx 3.4\text{x}10^{60} kg,$$

which is indeed a pretty low number by cosmology standards, though it will suffice as a lower bound estimate.

Summary

We've come to the end of our little excursion through the naive Big Bang model. Although it is generally undesirable to many because it doesn't fit well with the data, it's been demonstrated there are qualities of a local Universe—that I've described collectively as the absolute linearly increasing velocity expansion (ALIVE) case of the explosion model—which could allow for this hypothesis to be competitive with the concordance model if the interpretations of various phenomena like galactic redshift and the CMB's dipole are flexible. Hopefully that doesn't sound like an opinion I'm expressing but rather a conclusion that follows naturally from the arguments that have been laid out in this text.

Impartiality is fundamental to scientific inquiry and transparency of that impartiality is just as important. I have made efforts to frame this article in such a way that is neither for or against this explosion model to the best of my abilities, however I will admit I admire the simplicity of this explosion hypothesis especially relative the complexity of other cosmology models that sometimes verge on the absurd. Like it was stated previously, I find it quite incredible how we have not given any attention to the most straightforward cosmology model before disproving it and then continuing our exploration of the more advanced ideas. That's usually how the process of elimination is supposed to work isn't it?

In summary I would like to provide a revealing quote from an authority figure in cosmology that I think is supportive of this explosion hypothesis. Georges Lemaître is largely credited as a founding father of spacetime expansion models alongside its co-discoverers: Alexander Friedmann, Howard P. Robertson, and Arthur G. Walker. Lemaître was the first to provide a theoretical approximation for the Hubble constant and although his initial estimate was way off, it was nevertheless a remarkable prediction that ended up being reinforced by Edwin Hubble's discovery of Hubble's law in 1929. From that point on we have assumed the expansion of the fabric of spacetime is what's causing the redshift of photons from receding galaxies in every direction. But there was a dissenter.

According to the first-hand account of Lemaître, when he travelled to Brussels to attend the (now famous) fifth Solvay Conference from October 24 to 29 in 1927, he was strolling down the avenues of Leopold park discussing his paper on the spacetime expansion of the Universe. Lemaître recalled this reaction to his idea in a memoir he wrote thirty years later: "He spoke to me about an article regarding the expansion of the Universe, passed almost unnoticed, which I had written the previous year and a friend had him read. After some favourable technical observations he concluded by saying that, from the point of view of physics, it seemed to him absolutely abominable."

I'm sure you can guess who *he* was. ✶

Endnotes

[1] When using their special relativistic method but not converting D(z) into $D_L(z)$, we get the SR distance modulus to redshift curve shown in their Hubble diagram (their Figure 5) which is 23 sigma from the best fit curve. I submitted this error to the journal *Publications of the Astronomical Society of Australia* (PASA) and the two authors.

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John Percy's Universe

Finding our Place in the Universe

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Back in June 2024, a colleague at Heritage Toronto gifted me an astronomy book that had recently crossed her desk. Frankly, I don't often read astronomy books nowadays—technical or popular. But the topic of this one—cosmography—piqued my interest and curiosity. It's not a topic that I am very familiar with. There was a strong human-interest component, too: the book follows the career of French astrophysicist Hélène Courtois from lowly graduate student to professor and vice-president of her university (and wife, and mother of three). It describes the challenges of observational astronomy: the competitive quest for funding and telescope time (and clear sky), and the role and limitations of technology in the progress of research. It accurately describes the life of an astronomer: the travel, the ups and downs of collaboration, and the exhilaration of discovery. So, first of all, this column is a shout-out for this award-winning book *Finding our Place in the Universe*, by Professor Hélène Courtois, translated from the French by Nikki Kopelman, published by The MIT Press (2019). Yes, it's a few years old, but it's still fresh. The price is listed as $33.95 at Indigo, and you can search your local library for copies.

Courtois is a cosmographer. She makes maps of the cosmos, showing where we are in the Universe. Four centuries ago, the Copernican revolution showed that we lived on a small planet, orbiting a star—the Sun. A century ago, Harlow Shapley and others showed that the Sun was situated in the outskirts of a spiral galaxy of hundreds of billions of other stars—the Milky Way. At the same time, Edwin Hubble and others showed that there are a multitude of other galaxies besides our own. Our galaxy belonged to a small group, prosaically called The Local Group. There were clusters, and superclusters. And this whole system is expanding! Courtois and her colleagues are extending this picture to reveal an even bigger, more majestic picture.

It is relatively easy to make 2-D maps of the sky: just take an image. But to make 3-D maps, with depth, requires us to know the distance of each galaxy in the map. Over the past century, astronomers have developed several tools to estimate the distance of a galaxy from its luminosity—or the luminosity of something in it. Then, by combining this luminosity with the observed magnitude, the distance can be calculated from the inverse-square law of brightness.

The observed periods of Cepheid pulsating variable stars are related to their luminosity. Refining and applying this relation was a key project of the *Hubble Space Telescope*, led by Canadian-American astronomer, Wendy Freedman. This book includes sidebar biographies of Wendy and several other women astronomers who have contributed significantly to cosmography, including Henrietta Leavitt who discovered the Cepheid period-luminosity relation. It was subsequently named after her.

The Faber-Jackson relation, developed by Sandra Faber and Robert Jackson, relates the dispersion of the velocities of stars in the central bulges of elliptical galaxies, as measured by spectroscopy, to the galaxies' luminosities.

The Tully-Fisher relation, developed by Brent Tully (a Canadian) and Richard Fisher, relates the rotational velocity of a spiral galaxy (corrected for its inclination) to its luminosity.

The peak luminosity of a Type Ia supernova is approximately uniform, and small variations from uniformity can be corrected for from the observed rate of the supernova's fading.

Even better than a 3-D map is a 3-D dynamic map, one that shows the motions of the galaxies—the cosmic flow. 2-D motions of galaxies across the line of sight are too small to measure. Motions of approach or recession along the line of sight can be measured from the spectrum of the galaxy by the Doppler effect. However, they are complicated by the recessional motion of the expansion of the Universe. These dynamical motions are astrophysically important, because they are caused by the gravitational force of the matter in the clusters and superclusters around us, so they can help to map this matter. And one of the great mysteries of modern cosmology is the so-called dark matter that makes up 90 percent of the matter in the Universe. What is it?

Courtois's graduate work began with compiling a homogenized database of galaxies, with the idea of improving both the quantity and quality of the data in the sample. Her research later took her to Australia, to the Parkes radio dish, and the Siding Springs Observatory, where she painstakingly installed a multi-fibre optic spectrograph on the UK Schmidt telescope, to measure the velocities of dozens of galaxies at once. This and other observations led to her 1995 Ph.D. thesis, *Structure et cinématique de l'univers local*, based on a dynamic 3-D map of 1376 galaxies.

After a postdoc in Heidelberg, she landed her present position at the University of Lyon 1 (also called Université Claude Bernard Lyon), where she has quickly risen through the ranks to professor and vice-president (international relations), created a comprehensive program of university studies in the sciences of the Universe, done outreach to people of all ages, and signed on as a patron of the local Vaulx-en-Velin planetarium. Her many honours include, in 2020, Chevalier of the Legion of Honour—the equivalent of a knighthood.

Her research has expanded equally rapidly in the last two decades, as she extends her studies of the distribution and motion of the millions of galaxies in our cosmic neighbourhood. She gradually built a research team and acquired a diverse set of collaborators from around the world,

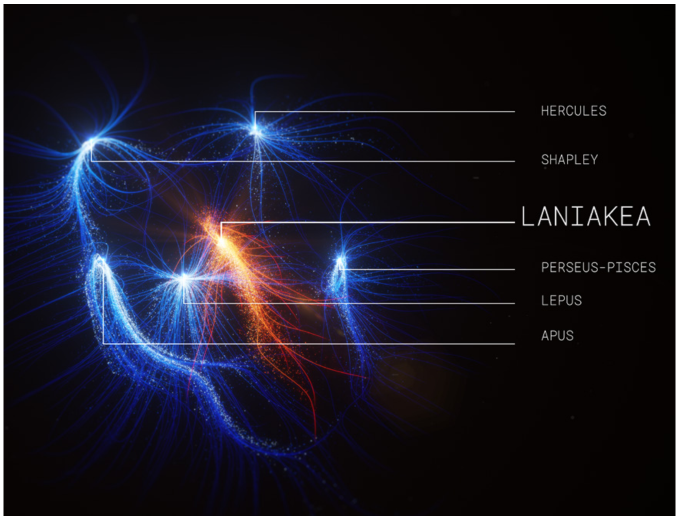

Figure 1 — Our cosmic neighbourhood, showing "our" supercluster Laniakea*, as determined from the* CosmicFlow 4 *project. The scale is about 1 giga-light-year. Source: Professor H. Courtois.*

who contributed their special skills—and their data—for a series of increasingly complex international projects. Her work took her to optical and radio telescopes in Hawaii, and to the Green Bank radio telescope in West Virginia, refining and applying the Tully-Fisher relation, in collaboration with Tully.

In 2011, her research program developed another branch—numerical modelling of the positions and motions of millions of galaxies in the nearby Universe of superclusters and voids (which are as interesting and important as the superclusters). This entailed new skills, new collaborators, and new tools—supercomputers. It allowed her to trace the cosmic flows forward and backward in time. It showed, for instance, that large structures—superclusters and voids—developed only a few billion years after the Big Bang—relatively early in time.

These were—and still are—exciting times for cosmology, including the study of the dark matter and dark energy that make up the vast majority of the "stuff" in the Universe. Cosmography can help solve some of these mysteries. She was part of the team that, by detecting the acceleration of the expansion of the Universe, provided the evidence for dark energy in the first place.

Locally, there were intriguing questions about large-scale structures in our cosmic neighbourhood, such as a large concentration of matter dubbed "The Great Attractor," a Holy Grail for cosmographers, but inconveniently hidden behind the plane of our Milky Way. Courtois took leadership roles in large projects, notably *CosmicFlow 1*, *2*, *3*, and *4*, which produced and interpreted dynamical 3-D maps of 1,800, 8,000, 18,000, and 55,877 galaxies, respectively, revealing more superclusters, with voids between them (e.g. Dupuy and Courtois 2023). Her core collaborators were Yehuda Hoffman, Daniel Pomarède, and Brent Tully. The last two images in the book show Courtois with this core group, and with her large astronomical "family." This reminds us, once again, of the collaborative and human aspects of astronomy.

Currently, she is part of the European Space Agency's *Euclid* satellite mission, which is designed to help understand dark matter and dark energy by studying billions of galaxies. There is even a *Euclid* citizen science project in which you can help! We hear too little about *Euclid*, and other ESA projects on this side of the ocean.

Beyond just the content in this book, I enjoyed it for the exemplary way in which it is organized and written. It's a story, and the story flows smoothly and naturally. Basic astronomy principles are contained in sidebars. You will learn a lot of basic astronomy from these! And even if you do not understand every detail, you will get the general idea. There are clear, simple diagrams, numerous images from observations and computer simulations and visualizations, and colour plates of the most important ones. A short "bibliography/webography" includes links to useful videos, as well as books and a few key research papers. The book is a refreshing change from the usual gee-whiz books. It respects the reader's intelligence. Maybe it's a cultural Old-World-versus-New-World thing.

So, what's the final answer? What is our place in the Universe? Our galaxy is on the edge of a supercluster—one of the largest structures known in the Universe. It and its neighbours are undergoing complex flows, as a result of the gravity of other superclusters around it, and the non-gravity of voids. It includes a hundred thousand large galaxies, and a million small ones—a hundred times bigger than the well-known Virgo Cluster with its 1,300 galaxies. As far as we know, our little corner of the Universe is representative of the Universe as a whole. Courtois and her team have named "our" supercluster *Laniakea*—which means "immense heaven" in Hawaiian (Tully et al. 2014). That's very appropriate, considering the important role of astronomy in Hawaii today, and its deep roots in Hawaiian Indigenous culture.

Acknowledgement

I thank Professor Courtois for providing Figure 1, and permission to use it. ✶

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CFHT Chronicles

45 Years at the Top of the World

by Mary Beth Laychak, Director
of Strategic Communications,
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(mary@cfht.hawaii.edu)

At 2 a.m. on 1979 August 7, the Canada-France-Hawaii Telescope (CFHT) saw its first light. A few days later on August 11, the first image was taken and then debuted at the IAU general assembly in Montréal. The official inauguration of the CFHT was held on September 28. As we exit 2024, CFHT's 45th year of world-class observations, let us take a look back on our early years.

Figure 1 — The dedication of CFHT on 1979 September 28

As a note, I have heavily borrowed from my 2019 column on our 40th anniversary, CFHT annual reports for this article, and the University of Hawaii Institute for Astronomy's website on the origins of astronomy in Hawaii (www.ifa.hawaii.edu/users/steiger/epilog.htm). Reports from 2004 to current are available on our website, but 1974–2003 are in our archives. By no means is this article a complete history of CFHT or even a complete history of the early years, I have 2000 words give or take. For those deeply interested in the early years of CFHT, I recommend the CFHT Oral History "Gathering the Forgotten Voices," created by our retired librarian Liz Bryson.

When talking about the story of CFHT, we do not start in 1979, but rather a decade earlier. Both Canada and France decided to undertake parallel projects for four-metre telescopes: the Queen Elizabeth II telescope and the telescope project of the fifth and sixth Government Plans. I will leave it up to the reader to figure out which was the Canadian project. Neither project advanced past the technical studies and the purchase of primary mirror blanks.

According to the 1974 CFHT annual report, economic difficulties of the late 1960s caused the agencies responsible for the two telescope projects to consider joining forces in a telescope venture constructing a single large telescope in a first-rate site. The two countries, with the provision that new partners would be entertained if the selected site was outside Canada or France, would share the "new" telescope.

Meanwhile in Hawaii…

In the early 1960s, Gerard Kuiper was on the hunt for a site for a new telescope for the Lunar and Planetary Laboratory in Tucson. He and master optician Alika Herring conducted site surveys on Haleakala, the highest peak on Maui. The seeing on Haleakala is extraordinary, but the mountain is only 10,000 feet (3,048 m) in elevation, slightly above the inversion layer at 8,000 feet (2,400 m). The close proximity to the top of the inversion layer leads to Haleakala being susceptible to fog. As the story goes, Kuiper and Herring could see the peak of Maunakea rising above the clouds from across the channel separating Maui and Hawaii Island even when the fog was rolling in on Haleakala. They wondered if Maunakea was the site they were looking for.

The Hawaii Chamber of Commerce invited Kuiper to consider Maunakea as the site for his observatory. Kuiper brought Herring with him to survey the site after the governor of Hawaii, John A. Burns, released funds to create the Maunakea Access Road. Today, the summit access road is named after Gov. Burns. Herring set up his telescope and a small dome on Pu'u Poliahu and began his survey. Herring described the seeing on Maunakea as perfect at times.

(The story of Alika Herring and his mirror-making abilities is incredible. I highly encourage interested readers to read up on his work.)

According to the Institute for Astronomy (IFA) page on the subject, Kuiper submitted a proposal to NASA to build a telescope on the mountain. NASA opened the door to other proposals, explicitly inviting Harvard and the University of Hawaii (UH) to submit their own proposals. An upstart UH received the funding for the 88″ telescope, and the rest is history…

In 1973, UH began preliminary discussions with Canada and France to join their 4-metre telescope project, which now would be located on the summit of Maunakea at 4,200 metres. In May 1973, the Canadian government announced their participation in the project. By July of that year, the CFHT project office opened its doors on the grounds of the Meudon Observatory and work continued on the memorandum of understanding, which ultimately morphed into the Tripartite Agreement signed on 1974 February 22.

The first CFHT annual report lists the personnel of the corporation and project office as of 1974 December 31. The staff of CFHT was small, 5 staff members and 18 in the project office. The executive director and associate executive directors of CFHT in 1974, Roger Cayrel and Graham Odgers, remained with the project and wrote the 1979 annual report as director and associate director.

Jumping ahead to 1979...

The annual report describes the night of first light and some of the subsequent activities in the weeks following. According to the report:

"The first image was obtained on 7 August at 2 a.m. The seeing, which was rather bad at that time, prevented an assessment of the telescope's optical quality from being made.

"The first photographs were taken without corrector on 11 August, just before the general assembly of the International Astronomical Union in Montréal.

"The following weeks were devoted to the mounting of the ultraviolet corrector and to remedying a problem with the opening of the mirror cover.

"The ultraviolet corrector was in place in September, and the first photographs with the corrector were taken at the end of the month, before the dedication of the telescope."

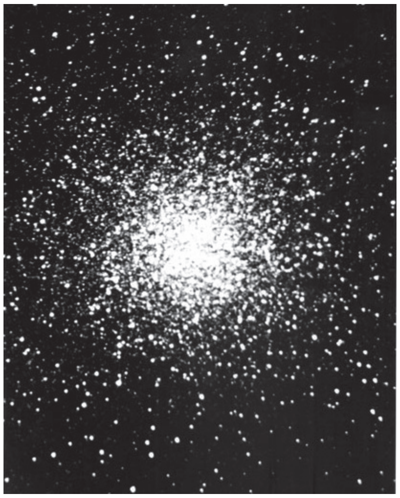

Figure 2 — The first CFHT image taken on 1979 August 11

The dedication ceremony is similarly described in the annual report. More than 160 people attended, many from Canada, France. and the U.S. mainland. They were driven by 4-wheel-drive vehicles and accompanied by a detachment of the Hawaii National Guard to the summit. "The day was warm and sunny with little wind and the large audience experienced very little discomfort, although the ceremonies were kept as brief as possible."

Under an open dome, the event kicked off with the playing of all the anthems, "O Canada," "La Marseillaise," "Hawaii Pono'i" (the state song of Hawaii), and the "Star Spangled Banner." Speeches were made by Roch LaSalle, the Minister of Supply and Services of Canada, Pierre Aigrain, Secretary of State for Research of France, and George Ariyoshi, Governor of Hawaii. As seen in the first photo of this article, the telescope was draped with three maile and orchid leis. At the completion of the speeches, the three dignitaries untied the leis. The telescope then slewed to an almost horizontal position, giving the crowd a view of the primary mirror.

As I read the description of the dedication ceremony, I thought about the people in the audience. I give lots of tours, for high school students, for grad students, to community members, VIPs...the list is endless. If a CFHT staff member runs into a tourist visiting from Canada or France while on their way to the lunch shack at the summit, they often offer to show the person around. (Please do not take this as an invitation to fly to Hawaii and just hang around the dome until someone opens the door.) In every tour I give, people gasp at two points. The first—when the telescope silently begins to move. It is astonishing to see a telescope the size of CFHT move, but not hear any sound. I imagine the people at the dedication ceremony felt that same sense of awe of engineering as our visitors 45 years later. The second gasp is the view from our catwalk, four stories above the ground with the single best view on the mountain.

The dedication ceremony moved to the lower altitude of Waimea, where everyone enjoyed "an excellent lunch of the best Hawaiian beef and Bordeaux wine." Clearly, the CFHT love of a good party was ingrained into our DNA from day one. Nobel Laureate Dr. Gerhard Herzberg delivered an address to the audience before everyone in attendance watched a film chronicling the main phases of CFHT's construction.

The 1979 annual report contains the full text of Herzberg's address. He mentions CFHT is the largest telescope at such a high altitude and the first major telescope "built by the collaboration of the old and the new world, that is France on the one hand and Canada and Hawai'i on the other." Today, multinational collaboration is the norm in astronomy projects. The old and new worlds combine with nations across Asia, Africa, and Oceania to fund projects that are redefining our knowledge of the cosmos.

Herzberg specified two questions in astronomy he foresaw CFHT answering. First, he suggests using the "new and promising" radial-velocity method to detect planets around nearby stars. Herzberg said it's "a sobering thought to realize that there is as yet no unambiguous proof for the existence of a

Figure 4 — (L to R) Dr. Cayrel, Dr. Locke, Senator Abercrombie, Professor Herzberg toast at the post dedication lunch in Waimea.

Figure 3 — View from the CFHT catwalk.

single planetary system similar to our own." The unambiguous proof of exoplanets would arrive years later, but as regular readers of our column know, answering that question is one of the science cases for our infrared spectragraph/spectropolimeter SPIRou. The astronomers behind that instrument hope to discover an Earth-like planet, the next step in answering the question that lies at the heart of Herzberg's prediction—are we alone in the Universe?

The second question Herzberg saw CFHT working on is the shape of the Universe. Do we live in an open or closed Universe? As it turns out, data from WMAP, *Planck*, and a number of other ground- and balloon-based experiments show that the Universe is flat with a 0.4% margin of error. While open vs closed vs flat may be resolved (or as resolved as anything in astronomy ever gets), astronomers are exploring the curvature of space and the global Universe structure.

As we move into our 46th year on Maunakea, astronomers using CFHT are still studying both of Herzberg's questions, plus probing countless other hypotheses to aid in our understanding of the Universe. I will end this look back with Herzberg's final words in the dedication speech: "To me, however, the overriding point is the support of intellectual endeavours that try to understand the structure of the Universe and the nature and role of man in it." ✶

Mary Beth Laychak has loved astronomy and space since following the missions of Star Trek's Enterprise. *She is the Canada-France-Hawaii Telescope Director of Strategic Communications; the CFHT is located on the summit of Maunakea on the Big Island of Hawaii.*

Dish on the Cosmos

Gravity Leaves its Mark

by Erik Rosolowsky, University of Alberta (rosolowsky@ualberta.ca)

Spiral galaxies are some of the most striking phenomena in astronomy. These whirling patterns of a galaxy give an immediate visual impression that the galaxy is spinning like a storm system on Earth. These spiral arms are the hallmark of gravitation playing an important role in shaping the disk of a galaxy. Recently, Canadian astronomers at the University of Victoria have used the Atacama Large Millimetre/submillimetre Array (ALMA) to find spiral arms in a new place: the disks of forming stars. These spiral arms provide a possible answer to big questions about how planets form.

Figure 1 compares two ALMA maps of gas emission from disks, showing the gas disk around the young star AB Aurigae and the spiral galaxy M100. These images are both false-colour maps with bright colours indicating more emission from the molecule. Both systems display obvious spiral-arm features. In terms of physics, these arms indicate that there is sufficient mass in the disk to prompt a gravitational instability.

Despite the visible similarities, galaxies and forming stars have notable differences in how their spiral arms arise. While both types of systems consist of a rotating disk, the main difference is in how massive the central object is compared to the disk. For a stellar system, the star at the centre typically has most of the mass. Our Sun is >99% of the mass in the Solar System, all packed into a cosmically small region. As a result, all the material in stellar system-orbits primarily feels the gravitational attraction of the star and follows orbits around it. These types of systems are called Keplerian because of the orbital patterns that Johannes Kepler deduced from our own Solar System. In a Keplerian system, objects closer to the central object have higher orbital speeds and shorter orbital periods compared to objects farther out.

In contrast, spiral galaxies have their mass spread throughout their disk of stars and dark matter. While there is frequently a supermassive black hole at the centre of galaxies, this black hole is typically a tiny fraction of the entire galaxy's mass. In our Milky Way, the central black hole is only 0.05% of the mass of the galaxy's visible matter (and an even tinier fraction of the entire mass, once dark matter is included). The orbits of spiral galaxies—like our own Milky Way—are controlled by the mutual gravitation of all the stars with each other. The orbits are distinctly not Keplerian, where most stars in a spiral galaxy are orbiting around the centre at about the same speed. Because stars at the outskirts of the galaxy have a longer distance to travel, the orbital periods of these outer stars are

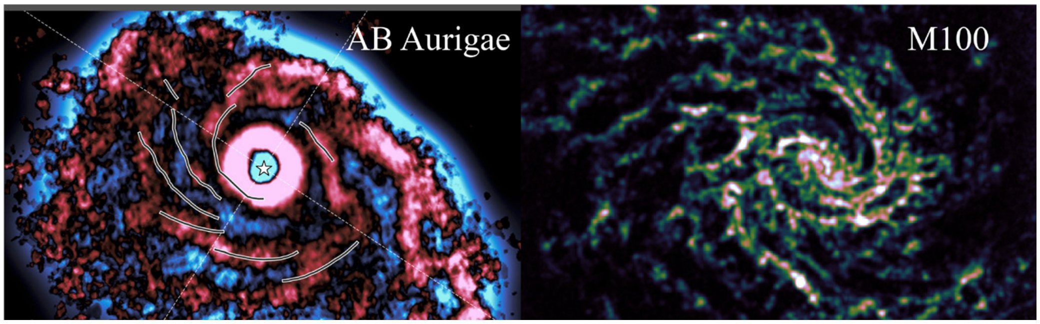

Figure 1 — ALMA maps of the carbon monoxide emission from two astronomical systems: the young star AB Aurigae and the spiral galaxy M100. Both systems show spiral arms, a feature of gravitational attraction shaping the material of a disk. The arms of AB Aurigae are indicated with curved lines. Credit: ALMA (ESO/NAOJ/NSF NRAO), Speedie et al.; PHANGS Collaboration

still longer, but not as long as would be expected in a Keplerian system.

Spiral arms are an indication that gravity is starting to pull material together. Gravity, by nature, is a destabilizing force. All matter feels a mutual gravitational attraction, and closer objects will feel a stronger gravitational force. The general tendency of gravity is to pull things closer, where they will feel stronger attraction, get pulled closer, etc. This gravitational instability needs to be counteracted by something. In the case of a planetary system, it is the orbital motions of the planets and other bodies in the system. The planets are all moving around in elliptical orbits, so while they are pulled toward the central star, their lateral motion keeps them from falling into the central star. In a galaxy, the material wouldn't be attracted toward the centre but rather to other parts of the disk, causing the material to clump up. Since the different parts of a galaxy disk are moving at different speeds, the clumps get pulled back apart by the orbital motions in a process called shear. Spiral arms form in parts of the galaxy disk where there is enough matter that the gravitational attraction can start to overcome these shearing motions. The common physics of shear balancing gravitation leads to the characteristic spiral structure seen in the disks of galaxies. In galaxies, this process is self-limiting. The mass of gas in any single region is not so large that it destabilizes the whole disk, nor do the arms contract into single objects.

In forming a stellar system, the presence of spiral arms indicates a large amount of gas in a disk around the star. This so-called accretion disk is the channel by which gravity is moving material into the star. Since the lateral orbital motions in stellar systems keep the material from falling directly onto the star, the accretion disk dissipates these lateral motions so that the forming star can build up mass. An accretion disk in a Keplerian system is strongly shearing, especially when compared to galaxy disks. This strong shear has been thought to suppress the formation of spiral structure. However, if there is a large enough amount of mass found in the accretion disk, the gravitational attraction can overcome the shearing motions and spiral structure will emerge. These spiral arms will tend to be relatively high mass, and in the context of the forming disk, can prompt the formation of planets.

The presence of spiral arms and the implied gravitational instability of the accretion disk helps answer some mysteries about planet formation. Since the material in interstellar space is small—gas molecules and small grains of dust—how does this material come together in a forming planetary system to make a planet, especially a massive gas giant like Jupiter? The dust grains and gas will freeze and stick together over time, but this process is relatively slow. Stars and their planetary systems show good evidence of coming together quickly in only about a million years. The slow buildup process is thought to take at least 10 times as long. Finding spiral arms indicates that the accretion disk is pushing gas together to higher densities than expected by the slow buildup model. Gravity boosts the process along, accelerating the process so that planetary systems can form rapidly.

These new discoveries were enabled by ongoing developments at the ALMA facility, which is now more than 10 years old. This column also represents 10 years of me writing for JRASC, but it will be my last contribution to JRASC for a while. I have been elected to leadership roles in the Canadian Astronomical Society, and I'll be focusing on that for some time. In the past 10 years, there have been vast, transformational discoveries driven by radio astronomy. Likely the most notable was the first images of black holes from the Event Horizon Telescope network, but there were also mysteries like fast radio bursts and growing challenges like the proliferation of telecommunication signals as invisible light pollution. The next 10 years will see further discoveries driven by the construction of the Square Kilometre Array, an overhaul of the ALMA telescope and potentially the construction of an upgraded version of the Very Large Array in New Mexico. I look forward to getting over my own mountain of work to get back and share these new ideas with you.

Read more about spiral arms in accretion disks: https://arxiv.org/abs/2409.02196 ✶

Erik Rosolowsky is a professor of physics at the University of Alberta where he researches how star formation influences nearby galaxies. He completes this work using radio and millimetre-wave telescopes, computer simulations, and dangerous amounts of coffee.

Skyward

What's a Heaven For? and Palomar Mountain

by David Levy, Kingston & Montréal Centre

> Morello's outline there is wrongly traced,
> His hue mistaken; what of that? or else,
> Rightly traced and well ordered; what of that?
> Speak as they please, what does the mountain care?
> Ah, but a man's reach should exceed his grasp,
> Or what's a heaven for?
> —Robert Browning, *Andrea del Sarto,* 1855.

Decades ago, during the fall of a year that I recall might have been 1972, I attended Yom Kippur services at our family synagogue in Montréal, Congregation Shaar Hashomayim. The Congregation had instituted a new feature that year, a Yom Kippur teach-in. I decided to give it a try. The topics were completely open that year, and the audience applauded every comment. I was a trifle nervous about saying anything, but I stood up and made a comment about God, and how our concepts of God are as different as each of us might be. I ended my comment with these two lines from Robert Browning's famous Andrea del Sarto:

> Ah, but a man's reach should exceed his grasp,
> Or what's a heaven for?

My comment did get a smattering of applause. Afterward my life went on, and on, until a few days ago, when writing a book featuring poetry about the night sky, I chanced upon Browning's poem again.

This Browning poem is surely one of his most famous and insightful. The poet suggests that Mount Morello, in Italy near Florence, is "wrongly traced." He then supposes that the mountain itself, if it has consciousness, wouldn't care if its outline was correct or not: "what does the mountain care?" In the final two lines of this section the poet transcends geographically from Morello to infinity, from Earthly cares to the outermost reaches of space and time—"Or what's a heaven for?"

It is not often that someone can compare the reading of a great and fabulous poem with a sporting event, but here I try.

I like to compare these lines of "Andrea del Sarto" with watching a baseball game. In my experience, a typical baseball game consists of lengthy stretches of strike-outs, some walks, breaks between innings, and other trivia. But these breaks are interspersed with exciting base hits, doubles, triples, and home runs. These events often happen without warning, and a large crowd in the stands can be electrified instantaneously, rising to its feet as the ball heads off the field, into the stands. It does seem odd to compare a work of English literature to a baseball game, but in this case, it works.

Writing about ball games, I have missed a football game to see a deep partial eclipse of the Moon. On 1961 August 26, there was an eclipse in which 99.2 percent of the Moon was embedded in the Earth's umbral shadow. In this way, the stadium offers us yet another way to enjoy the night sky and to remember that even during sporting events, we can enjoy the night sky by looking at it briefly from our stadium chairs. When we do that during the most important game of all, we are truly winners.

Palomar Mountain Observatory

Last month I drove all the way from my Vail, Arizona, home to Palomar Mountain Observatory. As most of this column's readers know, I have visited this place many dozens of times from my first encounter in March of 1974, and regularly from the late summer of 1989 to the late spring of 1996. I have always loved this magical place. Each visit, as I would drive in, I would pass the expansive dome of the mighty 200-inch Hale Telescope. As I drove by, I felt the telescope waving at me. We are the same age. The telescope was officially inaugurated on

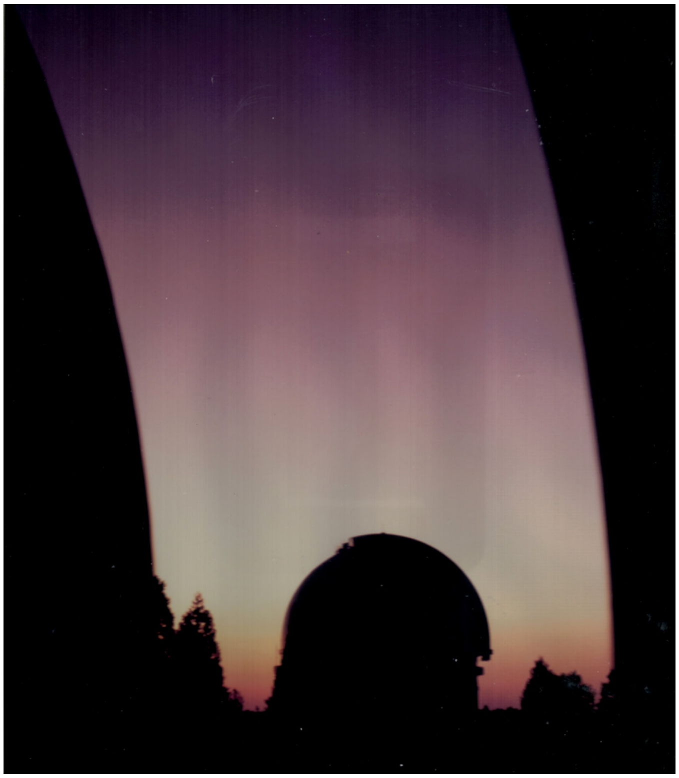

Figure 1 — The monstrous dome of the Hale 200-inch telescope on Palomar Mountain, as seen through the opened slit of the 18-inch Schmidt camera dome at twilight.

Figure 2 — Comet Tsuchinshan-ATLAS, 2024 October 19.

1948 June 3, just 12 days after my birth on May 22 that year. We are both 76. (I was probably too young to give a speech, with a poetic quotation, at that event.)

The purpose of this visit was to watch the September 17 partial eclipse of the Moon with my close friend Jean Mueller. I have known Jean for decades—she operated telescopes at Palomar, mostly the 48-inch Samuel Oschin Schmidt telescope that opened just before the giant 200-inch. While there, she exposed many photographic plates for the second POSS (Palomar Observatory Sky Survey) survey. Mueller would scan the plates for stars that appeared in and around galaxies and mark a galaxy. She would then compare that galaxy with a picture from earlier to see if the star had newly appeared. If it had, she would measure the position of the star, and then an astronomer would confirm her discovery on the 200-inch. This meticulous work enabled Mueller to discover 107 supernovae in addition to 15 comets and 15 now-numbered asteroids. Jean Mueller is a prime, absolutely first-rate astronomer and observer of the night sky, and she is admired and highly respected around the world.

It has been 30 years since I last visited Palomar, and I was overdue for a return. I cruised by the colossal dome housing the 200-inch Hale telescope—at one time the largest in the world. This was not my reason for visiting Palomar all those years ago. Instead, I drove some metres on to see the 18-inch Schmidt camera telescope. This beautiful instrument was the first, and is the oldest telescope on this mountain, and its record of discovery is dazzling. It helped Fritz Zwicky discover 121 exploding stars, or supernovae, in distant galaxies. It has a historic record of discovery of asteroids and comets, by far the most important of which is Comet Shoemaker-Levy 9 on 1993 March 23. In July 1994, the pieces of this shattered comet slammed into Jupiter. Colliding at a velocity of 60 kilometres per second, each fragment left a very bright flash and a large brownish cloud that persisted for months.

During my September, visit I learned how the 18-inch was moved to the observatory museum where it has become a lovely exhibit. When I saw my old friend again, I almost cried. I then visited the outside of the dome that was our home for so long, and while there, the treasured memories of working with Gene and Carolyn flooded back like an incoming ocean tide. This time I could not hold back the tears of joy.

With the possible exception of our discovery of Comet Shoemaker-Levy 9, this was by far the most emotive visit I've ever had to Palomar. For the first time in my long association, the overwhelming history of the place really struck me. I felt I was standing next to Russell Porter as he drew a sketch of the telescope, even before its mirror was installed, pointed toward the north. He even flashed me his legendary grin. Porter became famous long before he helped design the 200-inch. In the November 1925 issue of *Scientific American*, he published its lead article "The Heavens Declare the Glory of God." That piece of writing also marked the opening of Stellafane, the telescope-makers' conference still held every year atop Breezy Hill in Vermont. Last year Stellafane celebrated 100 years of its legendary pink clubhouse.

On that incredible evening of September 17, we watched a wonderful partial lunar eclipse. Only seven percent of the Moon was covered in the Earth's central or umbral shadow, but the outer penumbra shadow dimmed much of the rest of the Moon. And just five weeks later, mighty Comet Tsuchinshan-ATLAS painted its rosy picture across the evening sky. May these haunting events add to our joy in the night sky that shall be remembered forever. ✶

David H. Levy is arguably one of the most enthusiastic and famous amateur astronomers of our time. Although he has never taken a class in astronomy, he has written more than three dozen books, has written for three astronomy magazines, and has appeared on television programs featured on the Discovery *and* Science *channels. Among David's accomplishments are 23 comet discoveries, the most famous being Shoemaker–Levy 9 that collided with Jupiter in 1994, a few hundred shared asteroid discoveries, an Emmy for the documentary* Three Minutes to Impact, *five honorary doctorates in science, and a Ph.D. that combines astronomy and English Literature. Currently, he is the editor of the web magazine* Sky's Up!, *has a monthly column, "Skyward," in the local* Vail Voice *paper and in other publications. David continues to hunt for comets and asteroids, and he lectures worldwide. David was President of the National Sharing the Sky Foundation, which tries to inspire people young and old to enjoy the night sky.*

Blast from the Past!

Compiled by James Edgar
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ASTRONOMICAL NOTES

[This article first appeared in the 1909 Journal, *Vol. 3, p. 477.]*

The Systematic Motions of the Stars. F.W. Dyson, F.R.S.

A systematic character in the proper motions of the stars was discovered by Herschel, and attributed to the motion of the Solar System. Different methods gave very different results for the direction of this motion. Thus Airy and Argelander placed the apex in declination + 35°, Bessel in –5°. In 1895 Dr. Kobold called attention to these discrepancies, which seemed to point to an error in the fundamental hypothesis that the peculiar motions of the stars have no preference for any particular directions. In 1906 Kapteyn, from the proper motions of 2,400 stars given in Auwers-Bradley, showed that the proper motions relative to the Sun exhibited preference for two special directions, and that when the solar motion was subtracted the stars were moving in two streams in opposite directions relative to their centre of gravity. These relative motions were directed towards, and away from, the star Orionis (R.A. 91°, declination + 13°). Eddington, discussing the proper motions of 4,500 stars in the Groombridge Catalogue determined by Dyson and Thackeray, also found that the stars formed two drifts in good agreement with Kapteyn's results. Confirmation was obtained from 1,200 stars within 10° of the North Pole, and from 2,000 zodiacal stars. Schwarzschild showed that the Greenwich-Groombridge proper motions might be satisfactorily explained by supposing that the peculiar motions of the stars did not obey Maxwell's law for haphazard distribution, but that the resolved parts in one direction were all increased in a definite ratio. Beljawski applied this to the stars of large proper motion in Porter's catalogues. Prof. Dyson determined the favoured directions from all proper motions greater than 20″ a century. Of 1,800 stars examined it was possible to assign 1,100 to one drift and 600 to the other, 100 showing no systematic motion. All these results are in close accord, since all agree in showing an increase of the peculiar velocities in one direction and the opposite, this direction being nearly the same in all cases. This direction is in the plane of the Milky Way, but it is too early to offer any explanation of the motions. (*Nature*, November 4).

With the range between freezing point and boiling point less than half as great as on the Earth, the range of temperature within which water will remain in the liquid state is much reduced, whilst with the atmospheric pressure so slight at the surface of the planet, the diurnal range of temperature will be much increased. The form of water that we on the Earth regard as normal is the liquid state. But that cannot be the normal form for Mars. For that planet, water must most frequently show itself as ice or the related forms of snow or hoar frost, and when either of these forms under the influence of the Sun's heat is melted, the intermediate state, that of the liquid, will be easily and quickly passed through much more quickly than on the Earth. On the Earth aqueous circulation is carried both by ocean currents and by the transportation of water vapour in the atmosphere. There is nothing on Mars to correspond to the vast ocean surfaces of the Earth, and from the ease with which water will pass into vapour it is clear that we must look to the atmospheric circulation as the chief means for the transference of moisture from one region to another.

And, indeed, this is readily enough admitted by all writers on Martian meteorology, so far as it relates to the transfer of moisture towards the pole; it is only when the question of the movement in the opposite direction arises that it is assumed to be impossible that the moisture should travel in the form of vapour, and it is found imperative to cover Mars with a Titanic system of irrigation works fitted with mammoth pumping stations at short intervals. Yet the atmospheric circulation of Mars cannot be always in one and the same direction. If anything, one would suppose that the winds blowing in summer time from the melting pole cap would be more heavily laden with vapour than those blowing in winter towards the freezing cap.

Yet a further point. If we have water currents conducted along carefully constructed canals in order to convey water from the melting pole cap towards the equator, their flow cannot be uninterrupted. The polar regions are, indeed, enjoying perpetual sunlight, and melting and evaporation will go on fast and furiously; but as the water approaches the tropics, it will be exposed through ever-lengthening nights to rapid radiation, and soon a point will be reached whereat night after night the canals would be frozen solid.

It will be remembered that even for the equator of Mars we found a climate resembling that suggested by places on the Earth like Archangel. In other words, that the mean temperature was definitely below freezing point. This would mean that even great expanses of water were frozen to the bottom at night, and that the daily melting could be only superficial. It would be only shallow masses of water that could be completely thawed in the course of a 12-hour day. There would be every degree of melting from the equator to the poles, but it would be near the poles alone that a complete liquefaction could take place.

E.W. MAUNDER, *Journal British Astronomical Association*, November, 1909.

Generalising from a representative example, we might consider all parts of the Martian surface which show evidence of change to be covered by vegetation, and all those which remain fairly constant during the course of ages to represent either large sheets of water, or even desolate plains, like those of our satellite.

No one ever saw a single artificial canal on Mars, and it is the opinion of Mr. A. Stanley Williams that the Mendon observations have disproved "for ever the existence of the systems of hard, geometrically patterned lines with which some observers have so elaborately endowed the planet." And the minor details or "canals" in perfect harmony with Mr. Maunder's theory, have assumed a more irregular, knotted, disconnected, and, to put it plainly, a more natural-looking appearance. We thus see in the so-called "canals" a work of Nature, not of Intellect; the spots relieving the gloom of a wilderness, and not the titanic productions of supernatural beings. To account for their various phenomena, we need only invoke the natural agencies of vegetation, water, cloud, and inevitable differences of colour in a desert region. Some of them are mere isolated dusky features; the majority are knotted bands; others look like rivers with their tributaries; while a few would seem to lie in pairs, like the irregular streaks radiating out of the more important walled plains of the Moon.

Such was the doom of that geometrical network, and such our gropings as to the physical condition of Mars. There is hardly any more fascinating sight in the universe than this little planet—the only living and probably still inhabited world showing us the intricate details of its very surface. And should it·be objected that the views here chosen have assumed too geomorphic, or even too selenomorphic a character, the excuse would be that, in framing physical theories, the scientific imagination cannot transcend the world of fact and experience.

E.M. ANTONIADI, *Journal British Astronomical Association*, November, 1909.

The plane of the comet's orbit makes an angle of 18° with the Earth's orbit plane. The comet's orbit therefore passes "through" the planetary orbits like the two adjacent links of a chain. The comet will approach within fifty-six million miles of the Sun, and then recede during thirty-eight years until it is far beyond Neptune's path. In perihelion it must travel thirty-four miles per second, but at the outer turning its speed will be less than one mile a second.

Since the coming of photography and the accurate recording of details of comet structure utterly invisible to the eye, it has been possible to measure these motions. Comparisons of photographs of the same comet made two or three hours apart have shown that condensations and other structural forms have moved rapidly outward during the interval; only a few miles per second at first, but faster and faster as the distance out in the tail increased. Some observed speeds have been nearly fifty miles per second. Fifty miles per second is more than four million miles per day. If such motions exist, the constituents of the tail on one night are not the constituents of the tail of the following nights. Half a century ago the great physicist, Clerk-Maxwell, in developing the electromagnetic theory of light, deduced mathematically that the so-called light and heat-waves, in striking upon any object, exert a pressure upon that object, very much as ocean waves falling upon the cliffs press against the obstructing rocks. The pressure due to light and heat-waves, called radiation pressure, is extremely slight; so slight, in fact, that skilled experimenters were unable to detect its existence for many years. At last, about the year 1900, a Russian physicist, Lebedew, was able to observe this effect; and a few months later two American physicists, Nichols and Hull, were even more successful, for their accurate observations showed a satisfactory agreement with the demands of Maxwell's theory.

All the materials of a comet are necessarily attracted by the Sun, according to the law of gravitation. There can be no doubt that they are also acted upon by radiation pressure. The former seeks to draw all into the Sun, the latter to drive them into outer space. These are opposing forces. On the more massive parts of a comet, comprising the nucleus, radiation pressure is ineffective; and the nucleus moves along in its prescribed curve with remarkable precision. Not so with the finely divided materials of the coma and tail. Gravity acts as a function of a particle's mass, whereas radiation pressure's action is dependent upon the surface-area of a particle in relation to its mass. As particles become smaller and smaller a size will be reached such that these opposing forces will be precisely balanced. Particles larger than these will be drawn nearer to the Sun. Particles smaller will recede from the Sun.

Astronomers will welcome the coming of Halley's Comet, full of hope that the photo-dry-plate, the spectroscope, and other ways and means of attack invented since its last visit in 1835 will enable them to remove something of the mystery of comets, the most mysterious of all celestial bodies.

PROF. W. W. CAMPBELL, Publications Astronomical Society of the Pacific, No. 128.

J.R.C. ✶

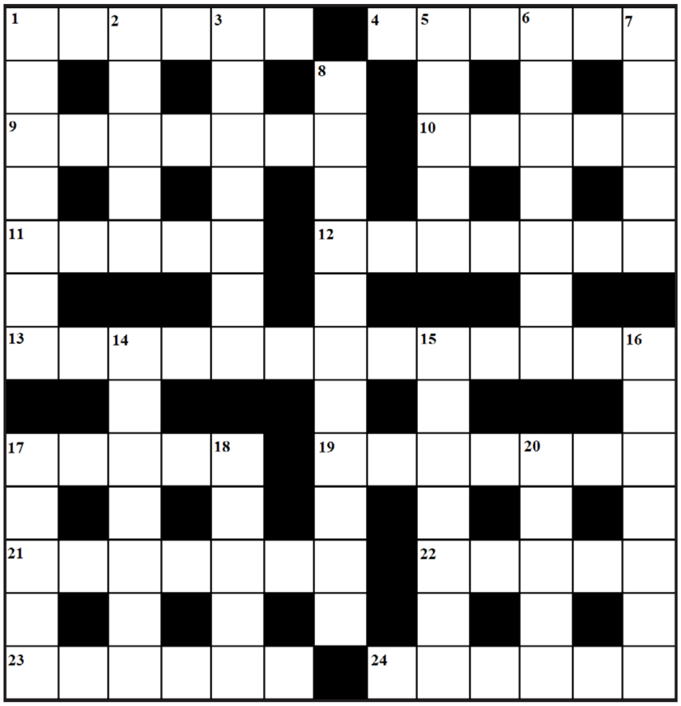
J.R. Collins was Society Secretary, one of the signatories in 1903 requesting from King Edward VII the privilege of prefixing the word Royal to the name Astronomical Society of Canada.

The February 2025 *Journal* deadline
for submissions is 2024 December 1.

See the published schedule at
rasc.ca/sites/default/files/jrascschedule2024.pdf

Astrocryptic

by Curt Nason



ACROSS

1. Though Trojan, she's in the main belt when he's in the Caribbean (6)
4. Turncoats around northern instrument in the southern sky (6)
9. Do these eyepieces have a 57°apparent field of view (7)
10. Go all around the sky in search of a variable (5)
11. Like Hydra; exotic but lost head, turned poisonous (5)
12. Macs are rotated as imaging equipment (7)
13. We learned about Saturn and Titan from scribes in soap sculpture (7,6)
17. Scariest constellation held the first point of astrology (5)
19. Southern denizen of Wonderland has a cone impacted (7)
21. Is this star on the mane sequence? (7)
22. Follow the clues to a coronal explorer (5)
23. Harris went back to a former time of Alpheratz (6)
24. Old city with an American planet (6)

DOWN

1. Bruno was burnt as one thereabout, I see, I hear (7)
2. Medic returned with former Mayan star charts in Dresden (5)
3. Cosmology of a non-isotropic universe in Arabian-Chinese coalition (7)
5. The allure of particle physics (5)
6. Inconvenient truth-sayer almost led sailor to the crow's nest (7)
7. The Sun is shining on a Martian lake (5)
8. Purple Mountain's majestic discovery has odder chins than us (11)
14. Shaula has a painful place in the sky (7)
15. Unusual creator of energy in a stellar core (7)
16. Flip a coin around Ophiuchus. It's heads or tails. (7)
17. He missed out on Neptune but rings it anyway (5)
18. New galaxy atlas credited in sea change for astronomy (5)
20. Teach people what meteors leave behind (5)

Answers to previous puzzle

Across: **1** PROXIMA (hid); **5** HYDRA (anag); **8** RUBIN (ru(b)in); **9** TEBBUTT (rev+butt); **10** YARKOVSKY (anag); **11** LYR (2 def); **12** EXPOSE (hom); **13** EPACTS (e-pacts); **16** TYR (2 def); **17** OWL NEBULA (owl+anag); **19** NODDING (2 def); **20** OUTRE (hid); **21** NIXON (Nix+on); **22** THEOREM (anag+e)

Down: **1** PERCY (hid); **2** OLBER'S PARADOX (def+hom); **3** IGNEOUS (anag+o); **4** AL-TUSI (Al+anag); **5** HOBBY (2 def); **6** DOUBLE CLUSTER (anag+e); **7** ANTARES (anag); **12** ELTANIN (anag+n); **14** PLEIONE (anag); **15** FLIGHT (hom or F+light) **17** ORION (scorpion-scp); **18** ABEAM (2 def)

The Royal Astronomical Society of Canada

Vision

To be Canada's premier organization of amateur and professional astronomers, promoting astronomy to all.

Mission

To enhance understanding of and inspire curiosity about the Universe, through public outreach, education, and support for astronomical research.

Values

- Sharing knowledge and experience
- Collaboration and fellowship
- Enrichment of our community through diversity
- Discovery through the scientific method

Obituary

Alan H. Batten 1933–2024

by Christopher Gainor

Allan Henry Batten, whose life as an astronomer at the Dominion Astrophysical Observatory in Victoria included distinguished service to the RASC as President and as Editor of this *Journal*, passed away in Victoria on July 30 at age 91.

Dr. Batten's career at the DAO focused on radial velocities and binary stars, and he published widely on those topics. His work was honoured with a D.Sc. from St. Andrew's University in Scotland in 1974 and election to the Royal Society of Canada three years later.

He born in Whitstable, Kent, England, on 1933 January 21, and earned a B.Sc. at St. Andrew's and a Ph.D. at the University of Manchester. In 1959, he came to Victoria as a post-doctoral fellow at the DAO. After joining the permanent staff two years later, he spent the rest of his career there, retiring in 1991 and continuing as a guest researcher there until 2011.

Dr. Batten joined the Victoria Centre in 1962 and served the Centre in many capacities, including as President in 1970–72.

He then got involved in the national Society, serving as National President in 1976–78, and as JRASC Editor 1980–88. He received the RASC Service Award in 1988, was honorary president from 1993–97, and was named a Fellow of the RASC in 2016.

In his book *Looking Up: A History of the RASC,* Peter Broughton wrote that: "During his term as President, he visited all 18 Centres, speaking in French when appropriate and always delighting his audience with his talent as a raconteur." He spoke many times to the Victoria Centre and elsewhere throughout his life and was a major contributor to *JRASC*, where he wrote many pieces about famous astronomers, and the *Observer's Handbook*, where he contributed the Nearest Stars section for many years.

His service to astronomy also extended to CASCA, where he served as its second President in 1972–74, following Dr. Helen Sawyer Hogg in that post. He also served the International Astronomical Union, where he was Vice-President from 1985 to 1991, taught at the University of Victoria, and held visiting appointments in many places, including the Vatican Observatory.

He and his first wife Lois Eleanor (Dewis) had a son, Michael, and a daughter, Margaret. After Eleanor's passing, Dr. Batten married Erica Cruikshank Dodd, who survives him, along with his children and grandchildren.

Over time, Dr. Batten became more interested in the history of astronomy and in philosophical reflections on science and society, and later in his life, he lectured and wrote widely on these topics. He was active in the Anglican Church of Canada and at the Centre for Studies in Religion and Society.

This aspect of his life was raised during his funeral service at Christ Church Cathedral in Victoria. There his son Michael, an Anglican priest, said of Dr. Batten: "He believed that science and religion were related fields of endeavour which at least partially overlapped, and he would not draw an impermeable boundary between the two."

One of his favourite pastimes was serving as a bellringer at the cathedral, and those who attended his funeral were greeted by the sounds of the bells ringing in his honour. ✶

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THE ROYAL ASTRONOMICAL SOCIETY OF CANADA

Board of Directors and appointed officers for 2024/2025 | Conseil d'administration et membres attitrés pour 2024/2025

Great Images

by Shraddha Pai

Shraddha Pai imaged the Milky Way from Costa Rica in 2022. "We had just arrived in Costa Rica the previous night and were staying in an (extremely) 'rustic' Airbnb on the Pacific side in the town of Esterillos Oestes. Jetlagged, I awoke at 4 a.m. local time at went out to look at the sky (as one does). To my amazement, the galactic core was high overhead!" she says. "I ran back in and got my tripod and camera (as one also does). To get the framing right, I had to set up the camera straddling two stairs descending to the backyard and get used to the sound of iguanas rustling about in the nearby leaves. (There were MANY iguanas all over the property, and even on the roof). It was a real welcome gift from Costa Rican skies." Shraddha used an Olympus EM1-III DSLR, with a 12mm ƒ/2.8 lens at ISO 800 for 15 seconds. Edited in Lightroom Classic with Topaz Denoise.

Journal

Mark Germani imaged the Cygnus Wall found in the North America Nebula (NGC 7000). The final image is an integration of 9 hours of Hα, OIII and RGB data over 5 nights in September 2024. He used an Astro-Tech AT92, a ZWO ASI533MC Pro camera on an iOptron CEM26.