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RASNZ NEWSLETTER

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Featured this month

Auckland Astronomical Society

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Professor P. W. Burbidge was the person most responsible for the founding of the modern Auckland Astronomical Society. “

AUCKLAND ASTRONOMICAL SOCIETY

Mt. John Observatory. Credit: Bernard Spragg

President's Desk

Following a very busy and productive 2022, we start 2023 with the exciting news that a further 1.4% of New Zealand's natural night sky has been protected for us and future generations to enjoy. This is the result of a long journey and committed work by the dark sky community in south Wairarapa with support from numerous parties including a strong letter of support from Prime Minister Jacinta Ardern. It has led to Wairarapa International Dark Sky Reserve being accredited by the *International Dark-Sky Association* (IDA) as the 2nd in New Zealand joining Aoraki Mackenzie International Dark Sky Reserve and only the 21st in the world. This is described in detail in this Newsletter by RASNZ member Dr. Tom Love who led this exercise to completion.

RASNZ has commenced 2023 supporting two specific initiatives. First is the *Globe at Night* 'Citizen Science Campaign' to measure the night sky brightness from whatever location you are in. In addition to the information and videos provided in this Newsletter, a Facebook live event with RASNZ Secretary Emily Barraclough is planned for Friday, 17 February 2023, to show you how to observe and record. And second is a 'Petition' to the New Zealand Parliament by RASNZ Councillor Professor John Hearnshaw to introduce national legislation to reduce light pollution. Details on both initiatives are available in this Newsletter and on the RASNZ website and it should only take 15 minutes and 2 minutes respectively to complete. We would very much appreciate it if you could undertake these small tasks and thereby add your weight to initiatives that have extremely beneficial goals. Both in their own way aim to minimise the impacts on light pollution on the ecological-biological systems adversely affecting biodiversity and health, as well as protecting our culturally, historically, astronomically and scientifically important night skies.

The other welcome news is our government's recognition in the New Year's Honours of Professor Rangi Matamua as an Officer of the New Zealand Order of Merit for his services to Māori astronomy which is covered in more detail in this Newsletter. Recognition of Māori astronomy has emerged strongly in recent years, with Matariki becoming a public holiday, an initiative spearheaded and led by Professor Matamua, giving it a boost and leading to a better understanding of Māori astronomy by the general public. RASNZ of course continues with its efforts to further support this aspect of astronomy.

Further to the work we undertook last year, the *Ministry of Business, Innovation and Employment* (MBIE) has advised that it has integrated as appropriate the inputs provided by RASNZ on the 'New Zealand Space Policy Review' and on 'Developing the Aotearoa New Zealand Aerospace Strategy'.

President's Desk (cont'd)

Concerning some of the activities that RASNZ is currently focusing on, these include:

- ★ Supporting the *Globe at Night* 'Citizen Science Campaign' set for 12-21 February 2023.
- ★ Organising a 'Meteorite Search' in partnership with Northland Astronomical Society, in a designated area of Northland on one day of the weekend of 11/12 February 2023.
- ★ Supporting the 'Amateur Research Survey' which had 98 responses and which the survey team is now working on, undertaking analysis, commentary and supplementary information gathering prior to arriving at potential ways in which RASNZ can support amateur research activity in astronomy in NZ.
- ★ Supporting the 'Petition' to New Zealand Parliament closing on 20 April 2023.
- ★ Organising the RASNZ annual conference on 2-4 June 2023 which will be hosted by Auckland Astronomical Society, which is also featured in this Newsletter.

Astronomy continues its move into the mainstream with increased interest in New Zealand the result of many factors including: the growth of our space industry ever since the *New Zealand Space Agency* was set-up in 2016; a significant growth in Māori astronomy following the recognition of Matariki as a public holiday; and increasing coverage in local and international media most recently highlighting the success of the JWST (James Webb Space Telescope) and DART (Double Asteroid Redirection Test) missions during the year.

Operated and managed entirely by volunteers when it was founded way back in 1920, as it was then so it is today. But since that time RASNZ has evolved into a multi-layered entity with a multi-faceted mission seeking to support the ever-increasing professional, amateur and public interest in astronomy in New Zealand. This has been achieved and can only continue to be delivered upon in 2023 and beyond through your generous support as members, volunteers, collaborators and donors, and for this we continue to say, '*Thank you!*'

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RASNZ Membership system

A reminder to ensure you have paid your subscriptions for the 2022 year.
Payments can be made at https://www.rasnz.org.nz/rasnz/payments-and-donations

Featured this Month

The Auckland Astronomical Society

The Society was founded on June 21st, 1923 and later that year became a section of the Auckland Institute and Museum. Professor P. W. Burbidge was the person most responsible for the founding of the modern Auckland Astronomical Society. In 1920 he was appointed to the Chair of Physics at the University of Auckland. He served as President of the Society from 1925 until 1940 and continued as Curator of Instruments until 1950. Burbidge worked tirelessly, promoting the concept of an astronomical observatory for Auckland, lobbying the Auckland City Council and many other bodies for support. In recognition of his dedication to the Society he was elected an Honorary Member in 1954. He died in 1984. Today the Society has about 600 members (counting family memberships as two members).

The Society is celebrating its 100th anniversary on 21st June 2023 and intend to publish a commemorative history to mark the occasion. We will also be hosting the 2023 RASNZ conference (further information below).

Meetings

The Society hold meetings on the first four Mondays of each month, except for January, when there are no meetings and just the first three Mondays for December. Each Monday has a particular theme, with the current programme having the first Monday an informal introduction to Astronomy course. The second Monday has two meetings starting with the Young Astronomers Group and followed by our main Monthly meeting usually featuring a guest speaker. The third Monday also features two meetings starting with a specialist astrophotography group meeting followed by Practical Astronomy. The later concerning astronomical equipment and learning the Night Sky. Finally we use the fourth Monday as a film Night featuring one or more documentaries on astronomical topics. The Society also have a small library of astronomical books and periodicals, which are available for loan to members.

Society Outreach

The main outreach activity involves providing speakers and telescopes for public events related to the Matariki season but we also help out with various organisations on request.

Kumeu Observatory

The Society operate an Observatory in a semi-rural area, located about six km from the town of Kumeu to the North West of the main Auckland urban area. The site is owned by a member but can be used by members wishing to observe in somewhat darker skies than provided by the suburbs of Auckland City. The Society own a 400mm GSO Ritchey–Chrétien telescope supplied by Astronz. The telescope is mounted on a Software Bisque Paramount, which has been upgraded with new electronics identical to the upgraded Zeiss mount and newer Paramount in the second dome at the Stardome. A team of members carry out various research and imaging projects using a QHY 600M camera equipped with a computer controlled filter wheel.

Kumeu Observatory

The Auckland Astronomical Society (cont'd)

Burbidge Dinner

The AAS hold an annual dinner held in honour of Prof Percy Burbidge. We invite an international guest speaker to deliver an after dinner presentation known as the Burbidge Lecture. This is the main social event for Society members.

NZ Astrophotography competition for the Harry Williams Trophy

The Society established a competition in honour of the late Harry Williams, who was a pioneer of amateur astrophotography in the society and a prolific amateur telescope maker. The competition was eventually merged with the RASNZ run NZ Astrophotography Competition. The combined competition was initially run with AAS member Jonathan Green as convenor and Director of the RASNZ Astrophotography Section, a role that has now been taken up by Amit Ashok Kamble. Jonathan built up the competition over a number of years, with a steady increase in the number and quality of entries and that trend has continued with Amit in charge. The results of the competition are announced each year at the AAS annual Burbidge Dinner.

Kumeu Observatory

Burbidge Dinner (left),
Group photo at the Northern Star Party (below).

Northern Star Party

The AAS hold an annual or sometimes bi-annual observing weekend, normally held at the Waharau regional park. The sky conditions are reasonably dark, with the Hunua hills blocking most of the Auckland City light dome. This event is open to the general public as well as members, but we apply a limit to the number of people who can attend due to the parking and available facilities. Places are assigned on a first come first served basis.

The Auckland Astronomical Society (cont'd)

Astronz

The AAS established Astronomy NZ Ltd now trading as Astronz in the year 2000. Astronz was originally set up to import astronomical equipment to make this more affordable for Amateur Astronomers in New Zealand. Over time the annual turnover of Astronz has increased substantially and now employs some contract staff. Astronz became a registered charity in 2018 and undertakes a more formal charitable giving programme since then.

Although Astronz remains 100% owned by the AAS, it is run as an independent entity with the following goals:

- ★ *Promote and foster the science of astronomy in New Zealand,*
- ★ *to encourage and arrange the association of people interested in astronomy for their mutual help and organisation of astronomical work,*
- ★ *to cooperate with other bodies having similar objectives to the Auckland Astronomical Society.*

Charitable Giving Programme

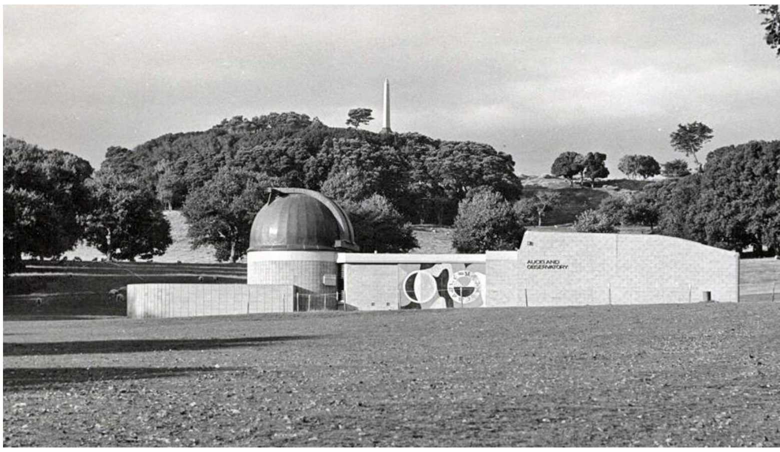
Astronz's grant programme is funded with the profits from the activities of the shop. The grant programme promotes astronomy by:

- ★ *Furthering astronomy and science education and outreach, and*
- ★ *Supporting eligible astronomical and dark sky society activities.*

Auckland Observatory Trust

The history of the Auckland Observatory (now known as Stardome Observatory and Planetarium). began in 1948 when the Auckland Astronomical Society began fundraising for a public observatory in Auckland. By 1956 the Society had significant funds, including a substantial bequest from Mrs Edith Winstone-Blackwell, for the purchase of a telescope for public use. The Society formed the Auckland Observatory Trust Board to build on these funds and provide for the construction and management of a new observatory.

In 1960 One Tree Hill Borough Council provided a 21-year lease, which has been subsequently extended, for a site in One Tree Hill Domain (which Stardome still occupies), and in March 1967 the Observatory opened.



Auckland Observatory featuring the copper-clad wooden Zeiss dome

The Auckland Astronomical Society (cont'd)

The observatory is currently closed to carry out a full replacement of the roof, new foyer, shop rearrangement and new displays. The process is expected to take about five months. In the mean time, the AAS will be holding meetings at temporary premises.

The principal instrument of the Observatory is a 0.5 meter Classical Cassegrain reflector, with an effective focal length of 6.65 meters, designed and manufactured by the Carl Zeiss facility in Jena. The telescope is mounted on an offset German Equatorial system, also supplied by Zeiss, as is the observatory dome. The mount was equipped with a sidereal tracking drive but pointing the Telescope to a particular object was completely manual. This process was aided by large setting circles and a co-mounted 115mm refractor "finder scope". A second dome that was added as one of the building upgrades features a 400mm Meade ACF, mounted on a Software Bisque Paramount ME II. This telescope is used for research activities involving digital photometry and astrometry.

When approaching the 50th anniversary of the observatory, Dr Grant Christie, proposed that the Trust Board approve the funding of an upgrade to the mount to provide full automation. The Board approved this proposal and Dr Christie led a project team to carry out the upgrade, which was successfully completed. A presentation of how the upgrade was done can be viewed via the AAS youtube channel here.

AAS member Marc Bos preparing to remove the Zeiss telescope main mirror prior to the mount upgrade (above)
The observatory with second dome, planetarium and additional rooms (below).

The Auckland Astronomical Society (cont'd)

Planetarium

Originally the Auckland Museum operated a Planetarium which had been donated by the Farmers Trading Company in 1958. The Planetarium at the Museum closed in 1989, allowing Stardome the opportunity to build a replacement Planetarium. Fundraising was undertaken with a clear vision to provide the country with the best facility possible.

Major funding from the Lotteries Commission, the ASB Community Trust, a loan from the Auckland City Council and donations from the Auckland public raised nearly $3 million for the project. The new planetarium and associated facilities opened in February 1997 and remains the largest and most advanced in New Zealand.

Stardome now provides the Auckland region and New Zealand with leading-edge planetarium technology coupled with expert personalised assistance from their team of astronomy educators and presenters.

AAS website.

RASNZ conference 2023

As part of the celebration of the AAS 100th anniversary, the AAS are hosting the 2023 RASNZ conference at the Waipuna Conference Center in Auckland. For further information, see the conference website.

AUCKLAND ASTRONOMICAL SOCIETY

Cosmology at a crossroads

by David Wiltshire

David Wiltshire is a professor of theoretical physics at the University of Canterbury. His research interests broadly cover general relativity, cosmology and quantum gravity. He obtained his PhD in the 1980s in the group of Stephen Hawking at the University of Cambridge, UK, and after a variety of research and teaching appointments in Italy, UK and Australia returned home to Christchurch in 2001

Since the mid-2000s his particular interest has been the challenge to theoretical cosmology posed by the apparently accelerated expansion of the Universe, or so-called "dark energy". While revisiting old assumptions about cosmological observations and the way the mass distribution in the Universe is averaged, he posits that "dark energy" may in fact be a misidentification of "quasi-local gravitational energy", an aspect of Einstein's theory that we have yet to fully understand. His approach is called "timescape cosmology" and may lead to a reinterpretation of "dark energy" and also possibly of "dark matter" as a modified geometrical theory of gravity on the largest scales in the Universe.

What is the Universe made of?

Cosmology today stands at a unique point in its history. Astronomical observations of ever increasing variety and detail have revealed a vast cosmic web of large complex structures. Yet the theoretical model by which we extract the Universe's expansion history from such data is increasingly challenged as observational precision improves. Estimates of the present expansion rate of the Universe, the Hubble constant, H_0, are now discrepant by up to 5 standard deviations ("5 sigma") – the gold standard for a discovery in particle physics. Along with other tensions in measures of the expansion history, there are anomalies in the spectrum of tiny ripples in the Cosmic Microwave Background (CMB) – the relic radiation of the Big Bang. Furthermore, images from the James Webb Space Telescope now reveal a Universe with an abundance of galaxies that formed much earlier than expected.

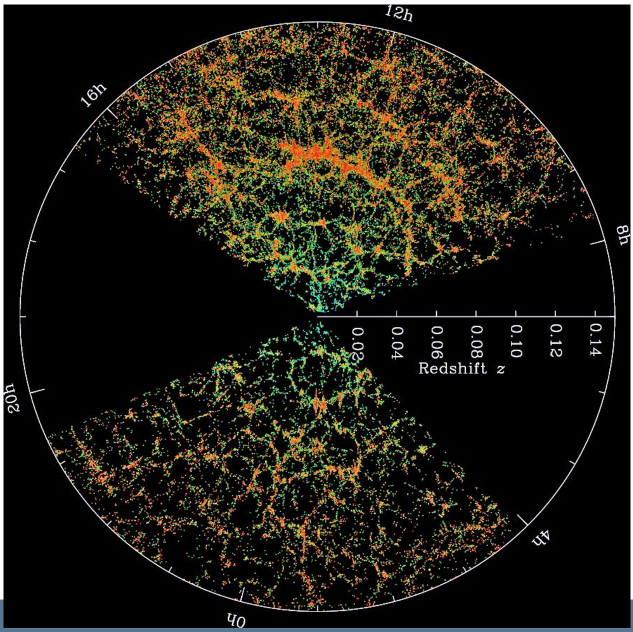


Fig 1. Cosmic web showing the late epoch Universe: voids are surrounded by sheets and threaded by thin filaments of galaxy clusters. Each point represents a galaxy. [Image credit: Sloan Digital Sky Survey]

These expectations are all built on the standard ΛCDM cosmology which – despite the cracks mentioned above – has passed numerous independent observational tests. The standard cosmology does, however, contain two fundamental mysteries at its core:

I. 25% Cold Dark Matter (CDM) which cannot be ordinary `baryonic' matter of which atoms are made, which does not interact electromagnetically, has not been directly detected and is only inferred via indirect gravitational effects as missing mass; and
II. 70% dark energy – a mysterious pressure in the vacuum of space, as exemplified by a cosmological constant, Λ. This is needed to counter the attractive force of gravity, thereby allowing cosmic expansion to accelerate at late epochs, explaining supernova observations.

What 95% of the present epoch Universe is made of still eludes physical explanation.

There is a bigger elephant in the room, however: a 100-year old simplifying assumption put into Einstein's equations – that the Universe expands on average exactly as if all the cosmic structures of Fig. 1 are smoothed into a featureless fluid. At any instant of time the fluid is assumed to be identical everywhere in space – *homogeneous* – and in all directions – *isotropic*. The CMB reveals that the Universe was indeed very smooth when it was 380,000 years old. However, at the present epoch evidence for an average isotropic expansion law is only found on scales larger than 450 million light years, three times the diameter of the most typical voids.

Inhomogeneous cosmology, backreaction and the Timescape

General Relativity (GR) is directly tested in *few-body systems* from the Solar System to supermassive black holes. GR is based on Einstein's tensor field equations in which the curved spacetime geometry is proportional to the energy-momentum generated by matter fields. As John Wheeler said: *Matter tells space how to curve, space tell matter how to move*. In few-body systems the energy-momentum is obtained by an average or coarse-graining of non-gravitational forces only, by well understood procedures: we do not need to worry about equations describing the composition of the Earth or Sun to treat one as a point particle moving in the gravitational field of the other. However, moving from a few bodies to an average geometry for the whole Universe involves fitting one geometry inside another in a complex hierarchy of structures: from stars to galaxies, to galaxy clusters, to filaments and voids, to the Universe.

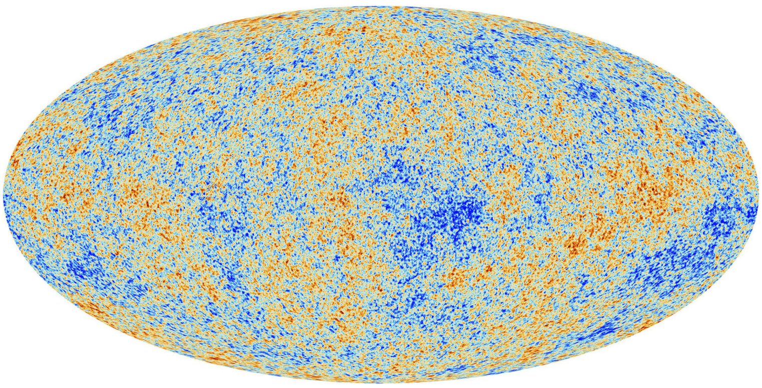


***Fig 2**. Tiny ripples in the cosmic microwave background of a few parts in 100,000 of the average temperature. These remain after subtracting the 100 times larger dipole anisotropy (Fig 5), and galactic and point source foregrounds. The temperature fluctuations arise from density fluctuations from which all structures (stars, galaxies, clusters, voids...) grew via gravitational instability.*
[Image credit: ESA, Planck collaboration]

Cosmology at a crossroads (cont'd)

Since Einstein's equations are nonlinear we cannot separate the coarse-graining of geometry from the coarse-graining of matter. The *fitting problem* for general relativistic cosmology is hard and unsolved. However, the basic principles of GR must be part of the solution. Since Einstein's equations directly relate matter and curvature on small scales, limited by the finite speeds of propagation of light and sound, there is no reason to expect the Universe to evolve on average exactly as if curvature is the same everywhere in space. Yet that is exactly the simplifying assumption built into the 100-year old spatially homogeneous and isotropic Friedmann-Lemaître-Robertson-Walker (FLRW) geometries of the standard cosmology.

In the early 2000s Thomas Buchert introduced a pioneering formalism for the cosmological fitting problem in GR. He showed that small scale inhomogeneities may grow to significantly affect average cosmic expansion, giving differences from FLRW evolution – called backreaction. In this setting, cosmic acceleration may actually be a misinterpretation of observations, explaining a coincidence that acceleration appears to begin only at epochs when vast structures come to dominate the cosmic web. In other words, dark energy may be an illusion. Unsurprisingly, backreaction has been much debated. The debate is muddied by the fact that some theorists consider alternative averaging schemes to Buchert's which automatically guarantee backreaction to be insignificant.

Buchert's mathematical formalism can be interpreted in many different ways, and in itself it offers no explanation as to why the Universe should have a close to average isotropic expansion despite observed inhomogeneities.

This fact, which the standard cosmology assumes rather than explains, demands an explanation. I offered one in 2007 by revisiting the first principles of General Relativity in extending Einstein's classic 1907 thought experiments to the case of expanding space. The result is an extension of Einstein's Strong Equivalence Principle to cosmological averages which I call the Cosmological Equivalence Principle, and an observationally viable cosmology without dark energy, the Timescape.

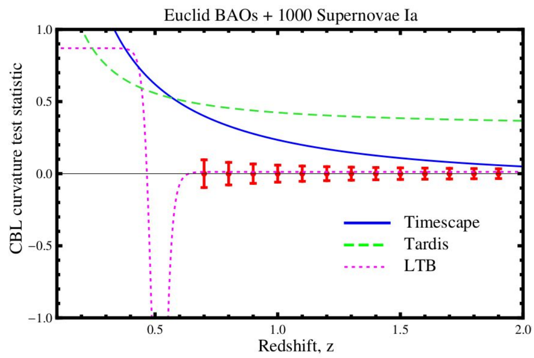


Fig. 3. FLRW curvature null test. Simulated ΛCDM data (red points) for the Euclid satellite compared to 2 falsifiable backreaction model predictions – Timescape, Tardis – and an unfalsifiable inhomogeneous Lemaître-Tolman-Bondi (LTB) model. [Image credit: D Sapone et al, 2014]

In the presence of spatially varying curvature generated by growing density gradients at late epochs, I claim there are choices of regional rulers and clocks that nonetheless maintain an average isotropic expansion. The concepts of elapsed time, and age of the Universe, vary between observers in bound structures and the statistical volume average. This is the notion of a Timescape. The Timescape cosmology has passed many of the same key tests that the standard ΛCDM cosmology does. Since ΛCDM is empirically a good fit in many tests, any successful model will inevitably have differences that are small; for Timescape the differences in the average expansion compared to ΛCDM models are 1-3% at any given distance.

Cosmology at a crossroads (cont'd)

ESA's Euclid satellite will have the precision to test these differences over the next 6 years. It will determine the angular size of a cosmic standard ruler, the *Baryon Acoustic Oscillation* (BAO) scale: the echo of the peak density of sound waves in the primordial plasma, as reflected in numbers of galaxies that grew from that initial excess density. Looking back in time over many epochs of cosmic history, Euclid will determine how this angular scale evolved as structures grew. It will have the precision to directly test whether average curvature is spatially constant as in the FLRW models, or not as in backreaction scenarios including the Timescape and Tardis models (Fig. 3).

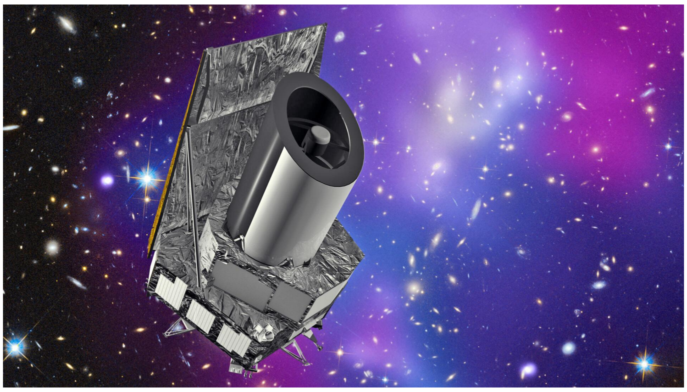


***Fig. 4**. ESA's Euclid satellite was originally set to launch in 2022 on a Soyuz rocket, but due to world events will now be launched on a Falcon 9 rocket by SpaceX in 2023. [Image credit: ESA, Euclid Consortium]*

While Euclid will enable precision measurements of the expansion history that definitively test the FLRW assumption, if the standard FLRW model is incorrect then there should be other definitive signatures of inhomogeneous cosmology. Indeed, there is such an anomalous signature, recognised as a 2 to 3 sigma tension for over a decade, which new observations have pushed over the crucial 5 sigma threshold last year.

Motion versus expansion: the anomalous radio galaxy and quasar dipole

The standard cosmology accounts for inhomogeneities by small perturbations of the average FLRW solution, and their nonlinear evolution using large N-body computer simulations, almost exclusively with only Newtonian gravity. It is assumed that all spatial variations of cosmic expansion can be reduced to uniform FLRW expansion in a *cosmic rest frame*, plus relative local peculiar motions, so-called *boosts*, of all galaxies. Local boosts are calculated purely in special relativity, and do not require full GR. Einstein's Strong Equivalence Principle guarantees that in GR we can always perform arbitrary boosts at a source and observer. What is not required by GR, however, is that after subtracting the boosts the average propagation of light from source to observer should follow paths predicted by a FLRW solution. That is the 100-year old ad hoc assumption that backreaction models challenge.

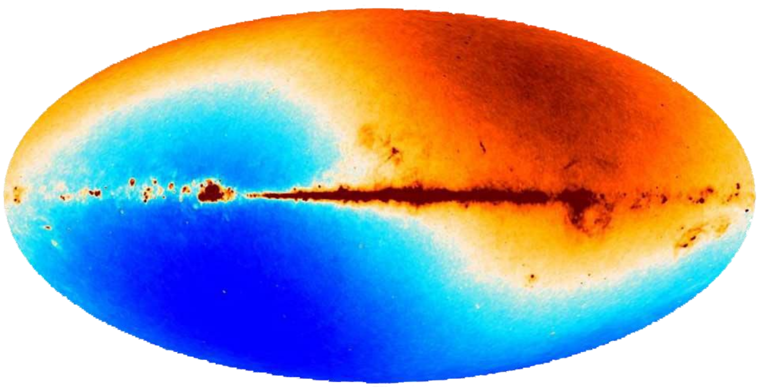


***Fig. 5**. Dipole anisotropy of the cosmic microwave background, conventionally interpreted as purely due to our motion towards the hotspot. The horizontal dark stripe is emission from our Galaxy. [Image credit: ESA, Planck collaboration]*

Cosmology at a crossroads (cont'd)

The remarkable isotropy of the CMB is conventionally taken as evidence for a cosmic rest frame. The CMB radiation has an ideal black body spectrum peaked at microwave frequencies with a temperature of 2.725 Kelvin, with the same value anywhere on our sky up to parts of one in a thousand. Furthermore, the milli-Kelvin fluctuations have the characteristic form of a dipole, just as the special relativistic Doppler effect would predict if our motion with respect to the cosmic rest frame is 371 km/s in the direction of the constellation Leo. This must include components of motion within the largest structure to which we are gravitationally bound: the Local Group of galaxies. Space does not expand within the Local Group. By vector addition, once we have subtracted the motion of the Sun within the Milky Way, and of the Milky Way within the Local Group, we find that the Local Group of galaxies must be moving at 635 km/s in the direction of the constellation Hydra. Such putative Local Group motion is on a scale on which the Universe is expanding.

A catch in GR is that differential cosmic expansion on small cosmological scales (less than 400 million light years) combined with our known motion within the Local Group, can also produce a leading CMB dipole anisotropy very much like the one observed. For realistic models differences between a non-kinematic anisotropy and a purely kinematic anisotropy only show up at the level of a few percent of the dipole, on large angular scales. But this is precisely the amplitude of the primordial fluctuations seen in Fig. 2. Furthermore, the CMB quadrupole and other large angle multipoles have puzzling anomalies whose statistical significance increased with increasing observational precision, culminating in the results of the Planck collaboration.

Ten years ago we found in an analysis of 4534 galaxies that average "local" cosmic expansion is actually significantly more uniform in the rest frame of the Local Group rather than in the putative rest frame of the CMB.

The kinematic nature of the CMB dipole, or indeed of any isotropic background of very distant sources, can be directly tested via the predictions of special relativistic aberration and modulation. For the CMB the direction of the dipole determined by the Planck team in 2013 using this method was found to be consistent with the observed dipole when the analysis was confined to angles less than 1 degree across. However, the aberration dipole direction moves across the sky to point along an axis associated with the known anomalies when only large angles are considered.

An equivalent test on the distribution of distant radio galaxies and quasars has now reached a very high sensitivity with an analysis of 1.36 million quasars and 0.5 million radio galaxies, in a study led by Nathan Secrest of the US Naval Observatory. These reveal dipoles of amplitudes 2 and 3 times larger than the kinematic expectations, pointing 26° and 45° away from the CMB dipole direction. The two results combined give a 5.1 sigma disagreement from the expectation of the standard cosmology. Published last October in *Astrophysical Journal Letters* under the title *"A Challenge to the Standard Cosmological Model"* this is perhaps the strongest evidence yet of the need for a paradigm shift.

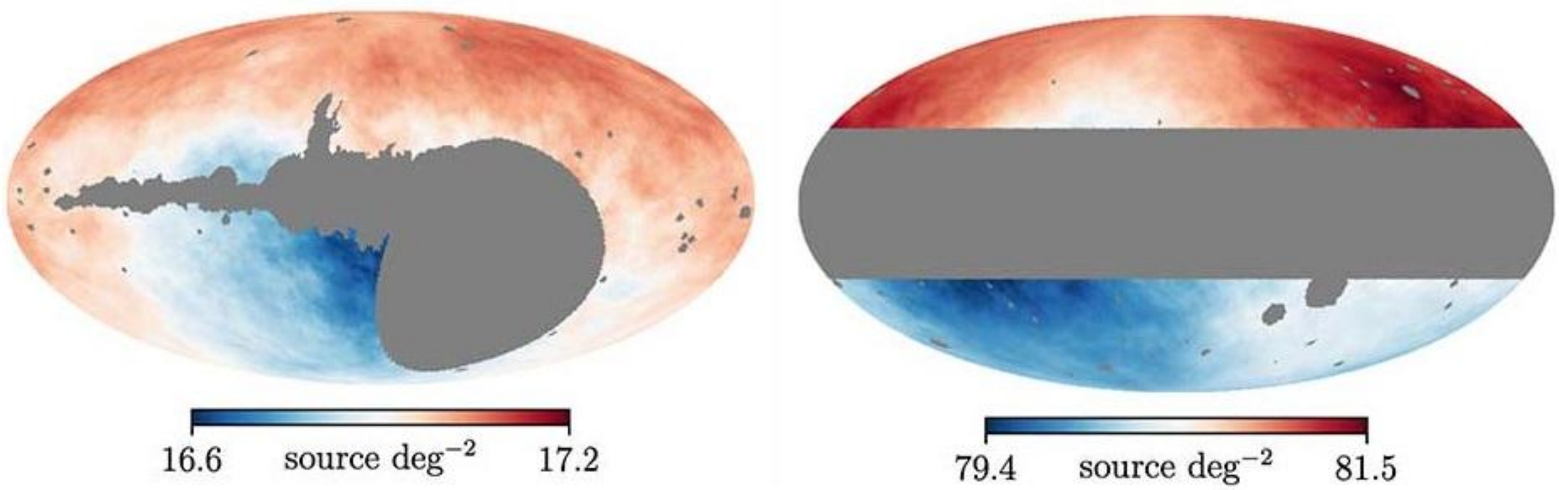


Fig. 6. The smoothed sky map of NVSS radio sources (left) and WISE quasars (right) exhibiting the characteristic dipole anisotropy due to aberration which is expected due to our local motion. The amplitude and direction relative to the CMB dipole are anomalous, however. Some parts of the sky have been masked to ensure uniformity of the source counts and to block out foregrounds. [Image credit: N Secrest et al, 2022]

The statistical significance of this result is naturally being debated. In astrophysics there can always be unaccounted for systematic biases. All we actually observe are wavelengths and intensities of radiation, their time series and angles on the sky. There are always statistical selection biases arising from the limitations of our telescopes. Furthermore, the light was produced by processes that are often impossible to recreate in any terrestrial laboratory. It then travels to us across the vastest distances in the Universe through a heap of mess in between. When presented with a puzzle, a conservative observer will naturally seek an explanation in an unaccounted observational bias, as that is so often the cause.

As a conservative theorist, however, I am deeply aware that Einstein did not provide final foundational answers in applying his theory to cosmology. The FLRW assumption is an ad hoc one theoretically, and a non-kinematic dipole is the natural result of any cosmology that breaks this assumption.

Computational cosmology with numerical General Relativity

While backreaction models can make predictions about average expansion (Fig 3) and while a non-kinematic anisotropy is expected in such models, calculations of the precise amplitude and direction of a feature such as Fig 6 require numerical simulations using full GR.

Large numerical simulations have been undertaken in the standard cosmology since the 1990s. While sophisticated in treating matter these simulations still use Newton's gravity theory, rather than GR, with cosmic expansion scaled by the FLRW solutions. Although Einstein's field equations are 107 years old, it took 90 years to fully implement them numerically. Computational challenges due to the complex nonlinearities of the field equations are compounded by intrinsic physical ambiguities about how we split space and time. The 2-body problem was only solved in the mid-2000s. Cosmology in GR was computationally too hard until very recently, even with the largest supercomputers.

Cosmology at a crossroads (cont'd)

Cosmology poses new challenges for numerical relativity over and above those of few-body systems. It is only in the last 7 years that new techniques implementing the full Einstein equations in cosmological simulations have been pioneered by a handful of researchers worldwide. One of these pioneers, Hayley Macpherson, was awarded the Charlene Heisler Prize by the Astronomical Society of Australia for her PhD thesis from Monash University in 2020. Now a NASA Einstein Fellow at the University of Chicago, Macpherson is a co-supervisor (by distance) of my PhD student Michael Williams at the University of Canterbury. He is currently investigating the self-consistency of the standard ΛCDM cosmology within GR. There are still many open questions as to whether structure grows in the same way in the standard cosmology when we go beyond Newtonian gravity.

Such questions need to be understood before we can begin to tackle the larger challenges posed by a complete paradigm shift.

Simulations begin with an initial spectrum of density fluctuations consistent with the CMB anisotropies (Fig 2) which are then evolved forward in time by Einstein's equations (Fig 7). Once we have resolved a slew of technical questions concerning simulations with standard model initial conditions, our ultimate aim is to change the initial conditions. Removing dark energy while including an initial very small amount backreaction at the CMB epoch, will allow us to validate or refute the Timescape scenario and to directly tackle questions such as those posed by the anomalous dipole in the radio galaxies and quasars.

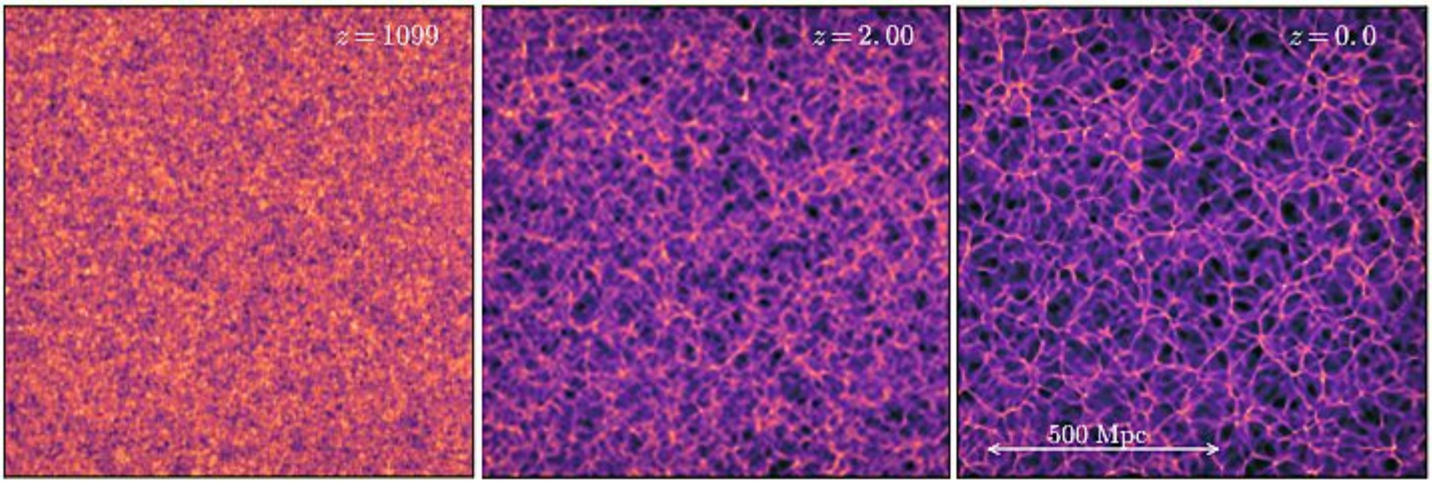


Fig. 7. Emergence of a cosmic web in a cosmological simulation using General Relativity. Panels show a 2--dimensional slice of the simulated evolving density distribution: from left, 300,000 years after the Big Bang to right, a universe similar to ours today. Dark regions are void of matter, and lighter purple regions are more dense. [Image credit: H J Macpherson et al, 2019]

The outlook

Changing the foundations of a cosmological model on which many decades of research and thousands of careers are built is not easy when it comes to securing funding, even with a proposal which seeks a deeper understanding of unsolved open questions in our best theory of gravity, General Relativity. To actually shift the paradigm requires convincing many more theorists to take up these difficult questions. Unfortunately, many theorists find it easier to either invent new matter fields that have never been observed, or to even modify Einstein's gravity in ad hoc ways, while keeping the FLRW assumption because it is simple. If observational tensions and anomalies continue to grow, there is likely to be a tipping point. If my assessment is correct, that tipping point will come within the next decade.

What would a new paradigm look like? As with any foundational revolution in science, much of that is beyond our present imagination. One thing is clear, however. A non-kinematic differential expansion affecting the CMB dipole (Fig. 5) at the level of 1% would require us to redraw the CMB sky map (Fig. 2) since the primordial fluctuations are of the same order. Differences would only occur on the very largest angles subtended on our sky by nearby voids, sheets and filaments in our cosmic "back yard" (less than 400 million light years away). CMB temperature differences on angles less than 1 degree apart would still be the same statistically, with little effect on many parameters that are important for modelling the formation of the first stars and galaxies. However, to the eye the biggest blobs in Fig 2 could well be in different places! This sky map is sometimes referred to as the "baby photo of the Universe". Consequently, we can reasonably expect that a new paradigm would change the face of the Universe in quite a literal sense.

Fo further information see:
http://www2.phys.canterbury.ac.nz/~dlw24/

Wairarapa International Dark Sky Reserve

Another IDA accredited International Dark Sky Place in New Zealand

by Dr. Tom Love

The Reserve

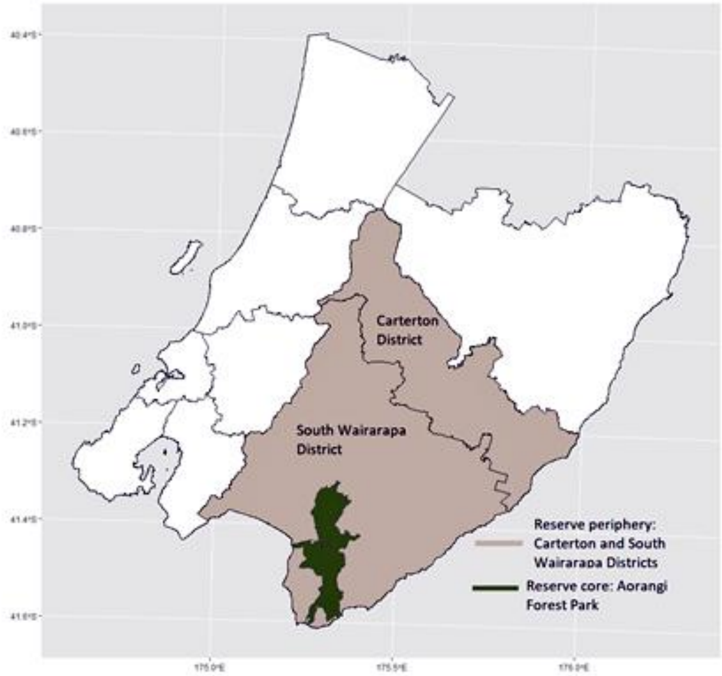
The newly certified Wairarapa International Dark Sky Reserve covers the areas of Carterton District and South Wairarapa District. The dark core of the reserve is formed by DOC's Aorangi Forest Park, shown in the map below. The intention is to work to add Masterton District to the reserve periphery in due course. Amenities in the core include the Pinnacles (a geological formation of Badlands); the Aorangi Crossing walking and cycling track from the Pinnacles to Cape Palliser, four tramping huts, a campsite at the entrance to the Pinnacles, and two lodges. DOC estimates that around 4,000 people overnight in the park lodges and campsite each year. There are no permanent residents in the core.

The area of the core Aorangi Forest Park is 194 square kilometres. The area of the full reserve (Carterton and South Wairarapa Districts) is 3,665 square kilometres, with a population of about 21,400 at the last census. In the future, Masterton District will add a further 2,322 square kilometres to the reserve.

Wairarapa's historic relationship with starlight

The name Wairarapa refers to the glistening waters of the Lake Wairarapa, reflecting the light from the stars above. The region has a long historical relationship to the skies, with connections to the navigators Kupe and Captain Cook, as a centre for indigenous agriculture governed by the calendar, as well as an early example of an observatory built by the customs officer Stephen Carkeek in the 1860s. The area is strongly associated with the 19th century local representative Charles Rooking Carter for whom the town of Carterton was named and who bequeathed funding for Carter Observatory, for many years New Zealand's National Observatory.

Modern day Wairarapa is a magnet for photographers who wish to record the spectacular nightscapes and views of the Milky Way that can be captured here, and is the home of a number of organisations that provide education and night sky experiences, including Milky-Way Kiwi, Under the Stars, and Stonehenge Aotearoa. The Phoenix Astronomical Society, Wellington Astronomical Society and Wairarapa Astronomical Society are all active in the region, providing access to astronomical equipment under dark skies for their members.



Conservation and Dark Skies

Light pollution has adverse impacts on New Zealand's native fauna, much of which is naturally nocturnal. Reducing light pollution in the Wairarapa supports the conservation goals of the Aorangi Forest Restoration Trust, the Department Of Conservation and other conservation organisations.

IDA accreditation

From the International Dark Sky Association (IDA):

> *An IDA International Dark Sky Reserve is a public or private land possessing an exceptional or distinguished quality of starry nights and nocturnal environment that is specifically protected for its scientific, natural, educational, cultural, heritage and/or public enjoyment. Reserves consist of a core area meeting minimum criteria for sky quality and natural darkness, and a peripheral area that supports dark sky preservation in the core.*

To achieve certification, the Wairarapa Dark Sky Association (WDSA):

1. Worked closely with the District Councils to incorporate appropriate lighting regulations into the District Plan. This involved working with planning consultants and lighting experts to develop rules requiring that new external light fittings in the Districts should not scatter light upwards, should be a suitably warm (and therefore non-scattering) colour, and have controls such as timers where appropriate. These changes were proposed, underwent public consultation through the plan change process, and were formally adopted by the Councils.

2. Took measurements showing the darkness of the sky in the core, and monitoring the darkness of the sky across the whole reserve area. We used special meters to take handheld measurements in the Aorangi Forest Park, and demonstrated that it is a genuinely dark place at new moon. We placed automatic meters across the towns and settlements in the reserve periphery, to show that even in our urban areas the impact of light pollution is kept to moderate levels.

3. Measured and described public outdoor lights across the whole reserve – this involved taking photographs and using a special meter to measure the brightness and colour of existing lights, including streetlights, and lights on public buildings such as town halls, stations, parks and playgrounds. This serves as a baseline against which to compare future levels of artificial light at night across the region.

4. Conducted public events and communication activities to promote awareness of light pollution and good practice actions to reduce light pollution, including demonstration projects such as improving outdoor lighting at Mitre 10 in Martinborough.

5. Worked with the Department Of Conservation to modify lights on lodges in Aorangi Forest Park to be compliant with lighting rules.

6. Prepared a comprehensive application document for scrutiny by the IDA.

The WDSA website
WDSA Facebook page
International Dark Sky Association website

Globe at Night Citizen Science Campaign

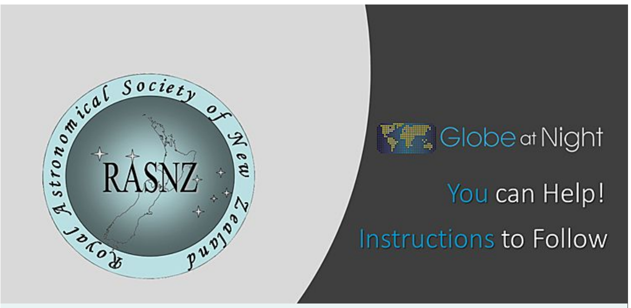
The Royal Astronomical Society of New Zealand welcomes you to join us on the Globe at Night campaign and help us map the impact of light pollution in New Zealand which will help us understand and manage the issue of light pollution both in New Zealand and globally.

All you need is a smartphone (tablet or computer) to measure and submit night sky brightness observations from wherever you are.

Readings from locations experiencing light pollution are particularly encouraged.

Your contribution plays an important role in the fight against light pollution providing scientists with much larger and more diverse data sets that might have otherwise been unachievable.

For New Zealand, we'd like to focus on February (12th-21st using the Orion constellation) and
June (9th – 18th using the Southern Cross constellation).



RASNZ Contacts:
[Antony Gomez]
[Steve Butler]
[Emily Barraclough]

Globe at Night [website]
More detailed instructions [here].

How to Participate:

During the campaign dates, go outside on a clear night more than an hour after sunset and let your eyes adjust to the dark (at least 10 minutes).

Find the constellation you are reporting on – Orion and Southern Cross are the two best known and easy to identify constellations in New Zealand. Many smartphone apps or programs can help you locate it if you are unsure where it is.

The 3-minute video below will show you how to go to the Globe at Night report page (making sure you are in nighttime mode), choose the star chart that most closely matches what you see in the sky, Select the amount of cloud cover at the time of your observation and submit your data

https://vimeo.com/user154165690/gan-rasnz
Password: GAN

Why we collect this data

Another 3-minute video explains why we collect this data and how valuable your contribution is.

https://vimeo.com/user154165690/whycollectdata
Password: GAN

Join us on Facebook live for an event featuring the Globe at Night Citizen Science Program. We will show you how to observe and record light pollution levels in your area. Not only will you learn about the impact of light pollution on our environment, but you'll also have the opportunity to contribute to vital scientific research. Mark your calendars and tune in to our [Facebook page] on Friday 17th February 9:30 pm (raincheck date 19th February) for our first live Citizen Science event.
See you there!

Petition to New Zealand Parliament on light pollution and the need for dark skies

by John Hearnshaw

I have submitted a petition to the New Zealand Parliament proposing that legislation is introduced to reduce light pollution and promote dark skies. If this is done on a nationwide basis, then the process of getting accreditation for dark sky places in this country will be so much simpler, as the whole country will have a uniform light pollution abatement law, and this will greatly reduce the efforts required from individual district and city councils.

The petition can be read and signed here.

Anyone can support this petition by signing it on-line, and the more people that do so will strengthen the message to Parliament.

I would be delighted if many RASNZ members take a few minutes to support the petition by signing.

In addition, I would be grateful if you forward the link to any ecologically-minded friends and colleagues who may be interested in giving their support.

The petition will be open for supporting signatures until 20 April 2023, after which it will go to the Petitions Select Committee before being presented to the House.

Thanks for your support.

Photo credit: Antony Gomez

Number of signatures at date of publishing:

463

Closing date 20 April 2023.

Surely New Zealand can do better!

NASA's SOFIA 747SP Last Flight

by Nicholas A. Veronico

NASA's airborne telescope, the Stratospheric Observatory for Infrared Astronomy known as SOFIA, N747NA, landed at Davis-Monthan AFB, Ariz., on 13 December 2022 in the first step of its retirement. The observatory's final home will be the [Pima Air & Space Museum](), located adjacent to the Air Force Base. The observatory's last flight departed Palmdale, Calif., at 8:31 a.m., local time, made passes at both Palmdale and the nearby Armstrong Flight Research Center, before heading east, arriving at Davis-Monthan AFB, at 11:33 a.m. local time. Flying the observatory was James L. Less (former USAF test pilot), Elizabeth "Liz" Ruth (former Air Force and United Airlines pilot), and flight engineer Tim Sandon (chief flight engineer, NASA Armstrong Flight Research Center). On the science deck was Mission Director Charlie Kaminski, Flight Mechanic/Safety Technician Chad Hutchison, along with Holger Jakob and Oliver Zeile, from the German SOFIA Institute (DSI) at the University of Stuttgart, who monitored the telescope systems during the flight. Kaminski holds the distinction of flying the most missions on SOFIA – 369 – and Less will transition from SOFIA to serve as a project pilot for the NASA X-59 Quiet Supersonic Technology (QueSST) aircraft.

SOFIA will sit at Davis-Monthan AFB until mid-January when she will be towed out the gate and over to the Pima Air & Space Museum. Once at the museum, NASA technicians will complete a "save list" of items that will be repurposed. The observatory is expected to go on public view at the museum in mid-April 2023.

The final SOFIA flight crew, from left: Flight Engineer Tim Sandon, Pilots Liz Ruth and Jim Less, Telescope engineers Oliver Zeile and Holger Jakob, Flight Mechanic/Safety Technician Chad Hutchison, and Mission Director Charlie Kaminski after deplaning at Davis-Monthan AFB. (Courtesy Charlie Kaminski)

The SOFIA Mission

SOFIA was an international astrophysics collaboration between NASA and the German Aerospace Center (DLR), and carried a telescope with a 106-inch (2.7-meter) diameter telescope.

Using a suite of six instruments, the observatory studied the universe at mid- and far-infrared wavelengths from 0.36 to 612 microns. Observations were focused on planets, planetary nebulae, astrochemistry, comets, supernovae, star formation, as well as the galactic centre. Science missions lasted 10 hours and were flown at altitudes between 39,000 and 45,000 feet. The observatory flew 732 science missions during its operational life.

NASA's SOFIA 747SP Last Flight (cont'd)

NASA's airborne observatory became fully operational in 2014, and at its retirement still had more than a decade of useful life remaining. The decision to terminate the program was controversial as no other observatory, in use today or on the drawing board, can study the far-infrared at the wavelengths seen by SOFIA. Today's newest telescope, the James Webb Space Telescope is only capable of viewing objects out to 28.3 microns and cannot see wavelengths where star formation and other astrophysical processes occur.

An Historic Airframe

SOFIA is a highly modified Boeing 747SP, one of only 45 of the type constructed. The SP was built to fly long-range routes, such as New York to Johannesburg, or New York to the Middle East, before engine technology changed in the mid-1980s that enable greater range with twin-engines. The SP could carry 232 passengers and a dozen crew over a range of 6,625 miles. SOFIA began life as Pan Am's *Clipper Lindbergh*, (N536PA, msn 21441) making her first flight on April 25, 1977. She was delivered to the carrier on May 6 of that year. Charles Lindbergh's widow, Anne Morrow Lindbergh, christened the jetliner on May 20, 1977, the 50th anniversary of her late husband's solo flight across the Atlantic Ocean.

In 1986, United Air Lines acquired Pan Am's Pacific fleet, which included *Clipper Lindbergh*. The jetliner's registration was changed to N145UA, and flew until parked at Las Vegas when phased out of service in 1995. NASA acquired the SP on Oct. 27, 1997, and the SOFIA program got underway. Modifications to the jetliner, now N747NA, were accomplished at Waco, Texas, and SOFIA made her first post-modification flight on April 26, 2007.

On May 20, 2007, Lindbergh's grandson, Erik, re-christened NASA's airborne telescope *Clipper Lindbergh*. Additional modifications were completed at NASA Armstrong Flight Research Center's Flight Facility at Air Force Plant 42 at Palmdale, Calif. This location would also serve as the observatory's operating base, while the science staff was located at the SOFIA Science Center at NASA Ames Research Center adjacent to the former NAS Moffett Field, near San Jose, Calif. SOFIA's first 100-percent open door test flight occurred on Dec. 18, 2009, and her "first light flight" – the first test of the entire telescope system – was on the night of May 25/26, 2010. The observatory's first science flight was flown on Dec. 1, 2010. She reached full operational capability in 2014.

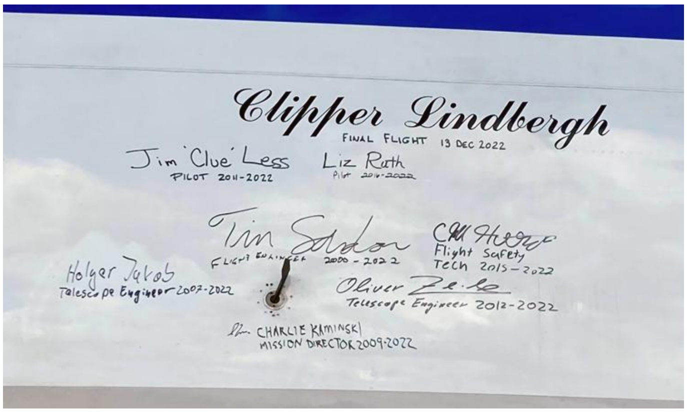
On May 21, 2007, Erik Lindbergh, grandson of Charles A. Lindbergh, christens NASA's 747 Clipper Lindbergh with a special commemorative concoction representing local, NASA, and industry partners. (NASA/Tom Tschida).

NASA's SOFIA 747SP Last Flight (cont'd)

World-Class Science

SOFIA had the unique ability to study occultations. An occultation occurs when a planet passes between Earth and a distant star and casts a shadow that travels across Earth's surface. Ground-based observatories cannot be picked up and moved to a location within the shadow's path of travel, however, SOFIA could fly to any location on the globe to make such observations.

As the planet blocks out the light from the star, the star's light illuminates the planet showing whether the planet has an atmosphere, the composition of the atmosphere, and if there are winds circulating within the atmosphere. SOFIA's first occultation observation took plane on June 23, 2011, when Pluto passed between the Earth and a distant star. Information from this occultation contributed to the body of knowledge of the former planet.



In the long-held tradition of crews flying an aircraft to its final destination, the last flight crew of SOFIA signed the fuselage of Clipper Lindbergh. (Photo by Charlie Kaminski).

One of the most impressive occultation observations was made on July 10, 2017, when SOFIA departed Christchurch, New Zealand, and flew north into the South Pacific Ocean to catch a glimpse of a Kuiper Belt object known as 2014 MU69, estimated to be 12-25 miles across. Scientists from NASA's New Horizons Spacecraft team wanted to know if there was debris floating around MU69 as an impact would be detrimental for the spacecraft. MU69 is the most distant object ever studied by a spacecraft as in 2017, it was 4.1 billion miles from Earth. MU69's shadow was passing over the Earth at 55,000 mph, and the team had to navigate to a point in the exact centre of the shadow to collect two seconds of data. There was no margin for error. The team successfully imaged the small object and data from the SOFIA observations was combined with subsequent studies to determine if it was safe for the New Horizons spacecraft to pass close-by.

SOFIA is also noted for its discovery of helium hydride, thought to be the first type of molecule to from after the Big Bang; that the nearby planetary system surrounding the star Epsilon Eridani is very similar to our solar system; as well as the role magnetic fields play in the behaviour of Black Holes.

A top 10 list of SOFIA's most influential discoveries is here.

This article was earlier published in Warbird News.

The Year 2022 in Physics

by Natalie Wolchover, Quanta Magazine

The year began right as the James Webb Space Telescope was unfurling its sunshield — the giant, nail-bitingly thin and delicate blanket that, once open, would plunge the observatory into frigid shade and open up its view of the infrared universe. Within hours of the ball dropping here in New York City, the sunshield could have caught on a snag, ruining the new telescope and tossing billions of dollars and decades of work into the void. Instead, the sunshield opened perfectly, getting the new year in physics off to an excellent start.

JWST soon started to glimpse gorgeous new faces of the cosmos. On July 11, President Biden unveiled the telescope's first public image — a panoramic view of thousands of galaxies various distances away in space and time. Four more instantly iconic images were released the next day. Since then, the telescope's data has been distributed among hundreds of astronomers and cosmologists, and cosmic discoveries and papers are pouring forth.

Astronomy is swimming in fresh data of all kinds. In May, for instance, the Event Horizon Telescope released the first-ever photo of the supermassive black hole in the heart of our galaxy — one of several recent observations that are helping astrophysicists figure out how galaxies operate. Other telescopes are mapping the locations of millions of galaxies, an effort that recently yielded surprising evidence of an asymmetry in galaxy distribution.

Breakthroughs are coming fast in condensed matter physics, too. An experiment published in September all but proved the origin of high-temperature superconductivity, which could help in the field's perennial quest for an even warmer version of the phenomenon that could work at room temperature. That's also a goal of research on two-dimensional materials. This year, a kind of flat crystal that once helped lubricate skis has emerged as a powerful platform for exotic, potentially useful quantum phenomena.

Particle physicists, who seek new fundamental ingredients of the universe, have been less lucky. They've continued to unravel features of particles we already know of — including the proton, the subject of a wonderful visual project we published this fall. But theorists have few if any concrete clues about how to go beyond the Standard Model of particle physics, the stiflingly comprehensive set of equations for the quantum world that's been the theory to beat for half a century. Hope is a virtue, though, and at least one possible crack in the Standard Model did open up this year.

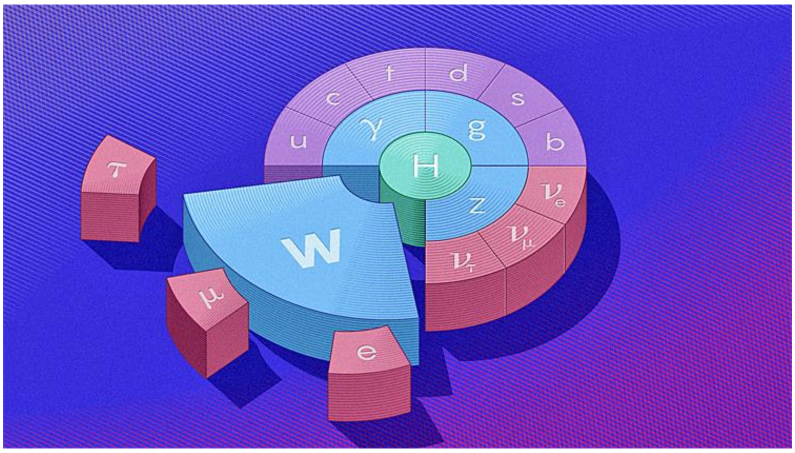
Let's start the 2022 greatest-hits list there.

A Tantalizingly Heavy Boson

The Tevatron collider in Illinois smashed its last protons a decade ago, but its handlers have continued to analyze its detections of W bosons — particles that mediate the weak force. They announced in April that, by painstakingly tracking down and eliminating sources of error in the data, they'd measured the mass of the W boson more precisely than ever before and found the particle significantly heavier than predicted by the Standard Model of particle physics.

A true discrepancy with the Standard Model would be a monumental discovery, pointing to new particles or effects beyond the theory's purview. But hold the applause. Other experiments weighing the W — most notably the ATLAS experiment at Europe's Large Hadron Collider — measured a mass much closer to the Standard Model prediction. The new Tevatron measurement purports to be more precise, but one or both groups might have missed some subtle source of error.

The ATLAS experiment aims to resolve the matter. As Guillaume Unal, a member of ATLAS, said, "The W boson has to be the same on both sides of the Atlantic."



The curious heaviness of the W boson, one of 17 known elementary particles, may point to unknown particles or forces.
Credit: Quanta Magazine

Rethinking Naturalness

All that buzz about a tenuous hint of a problem with the Standard Model reflects the troubled situation particle physicists find themselves in. The 17 elementary particles known to exist — the ones described by the Standard Model — don't solve all the mysteries of the universe. Yet the Large Hadron Collider hasn't turned up an 18th.

For years, theorists have struggled with how to proceed. But recently, a new direction has opened up.

Theorists are rethinking a long-held assumption known as naturalness — a way of reasoning about what's natural or expected in the laws of nature.

The idea is closely connected to nature's reductionist, nesting-doll structure, where big stuff is explained by smaller stuff. Now theorists wonder if profound naturalness problems like the lack of new particles from the Large Hadron Collider might mean the laws of nature aren't structured in such a simple bottom-up way after all. In a spate of new papers, they're exploring how gravity might dramatically change the picture.

"Some people call it a crisis," said the theoretical particle physicist Isabel Garcia Garcia, referring to the current moment in the field. But that's too pessimistic, in her view: "It's a time where I feel like we are onto something profound."

(Incidentally, as well as rethinking naturalness, Garcia Garcia also studies the physics of nothing — the subject of a rollicking explainer published in August.)

2D Physics Unlocked

Thousands of condensed matter physicists have studied graphene, a crystal sheet made of carbon atoms that has special properties. But lately a new family of flat crystals has hit the scene: transition metal dichalcogenides, or TMDs. Stacking different TMDs gives rise to bespoke materials with different quantum properties and behaviors.

The near-magical properties of these materials are known largely thanks to Jie Shan and Kin Fai Mak, a married couple who co-run a lab at Cornell University.

Quanta's profile of Shan and Mak, published this past summer, tells the story of 2D materials against the backdrop of condensed matter physics, while also unpacking a slew of exciting new breakthroughs spilling out of Shan and Mak's lab, from artificial atoms to long-lived excitons. A short documentary about the duo and their discoveries also appeared on *Quanta*'s YouTube channel.

A Holographic Wormhole

In November, physicists announced a first-of-its-kind "quantum gravity experiment on a chip," in the words of team leader Maria Spiropulu of the California Institute of Technology. They ran a "wormhole teleportation protocol" on Google's Sycamore quantum computer, manipulating the flow of quantum information in the computer in such a way that it was mathematically equivalent, or dual, to information passing through a wormhole between two points in space-time.

To be clear, the wormhole isn't part of the space-time we inhabit. It's a sort of simulation or hologram — though not one of the kinds we're used to — and it has a different space-time geometry than the real, positively curved, 4D space-time we live in. The point of the experiment was to demonstrate holographic duality, a major theoretical discovery of the last 25 years which states that certain quantum systems of particles can be interpreted as a bendy, gravitating space-time continuum. (The space-time can loosely be thought of as a hologram that emerges from the lower-dimensional quantum system.) In more advanced quantum computer experiments in the coming years, researchers hope to explore the mechanics of holographic duality, with the ultimate goal of unraveling whether "gravity in our universe is emergent from some quantum [bits] in the same way that this little baby one-dimensional wormhole is emergent" from the Sycamore chip, said Daniel Jafferis of Harvard University, who developed the wormhole teleportation protocol.

The holographic wormhole spawned endless opinions among physicists and lay readers alike. Some physicists thought the quantum simulation was too pared down compared to the theoretical model it was based on to have a holographic dual description as a wormhole. Many felt that the physicists behind the work, and we, the journalists who covered it, should have better emphasized that this was not an actual wormhole that could transport people to Andromeda. Indeed, to open up a wormhole in real space-time, you'd need negative-energy material, and that doesn't seem to exist.

JWST Is Revolutionizing Astronomy

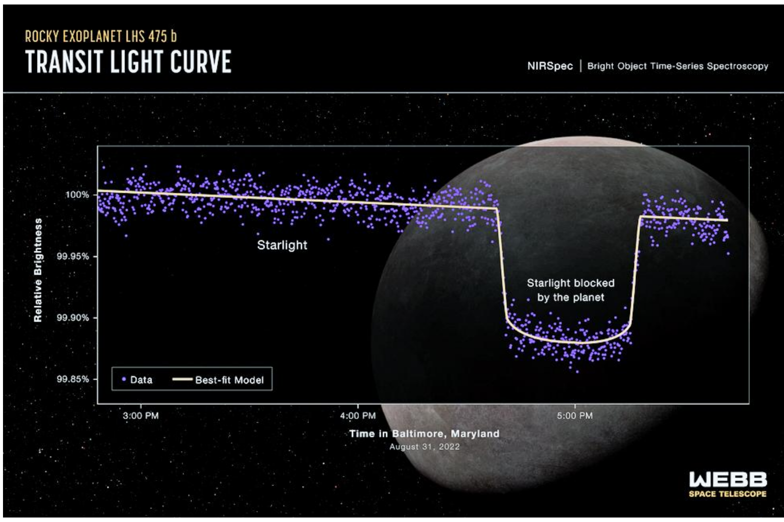
The biggest thing in physics this year is floating a million miles away, at a spot in space called Lagrange Point 2, where its sunshield can simultaneously block out the Earth, moon and sun. JWST's images have made hearts stand still. Its data is already reshaping our understanding of the cosmos.

When Biden unveiled JWST's first image, researchers immediately began spotting interesting galaxies in the vast tableau. Scientific papers appeared online within days. Two weeks later, *Quanta* reported that JWST data had already yielded new discoveries about galaxies, stars, exoplanets and even Jupiter. One of the most exciting early findings was that galaxies seem to have assembled surprisingly early in cosmic history — perhaps even earlier than cosmological models can easily explain. Expect to hear more about this in 2023.

We'll also have to wait patiently for JWST's much-anticipated studies of the rocky planets in a nearby star system called TRAPPIST-1. A key JWST specialty is to dissect the starlight that pierces the atmosphere of a distant planet as the planet moves across the face of its star. This reveals what the planet's atmosphere is made of, including possible evidence of "biosignature" gases that might signify alien biology. The telescope has produced excellent exoplanet spectra already. But potentially habitable worlds, like the TRAPPIST-1 planets, are so small that they'll need to transit in front of their suns a few times over the next few years before atmospheric features will show up.

Seeing clear-cut biosignatures in their skies might be unlikely. Still, some astronomers have waited their whole careers for the search to begin. Lisa Kaltenegger, director of the Carl Sagan Institute at Cornell University and one of the leading computer modelers of potentially habitable worlds, came of age just as the first exoplanets were discovered. She joined a cadre of dreamers who started thinking about how to find life on one. Our profile of Kaltenegger describes how she and her generation of exoplanet astronomers have planned for this era for decades, setting the stage for an epochal detection. More on that in the coming years.

Natalie Wolchover is Senior Editor at Quanta Magazine.



A light curve from NASA's James Webb Space Telescope's Near-Infrared Spectrograph (NIRSpec) shows the change in brightness from the LHS 475 star system over time as the planet transited the star on August 31, 2022. LHS 475 b is a rocky, Earth-sized exoplanet that orbits a red dwarf star roughly 41 light-years away, in the constellation Octans. Credits: Illustration: NASA, ESA, CSA, L. Hustak (STScI); Science: K. Stevenson, J. Lustig- Yaeger, E. May (Johns Hopkins University Applied Physics Laboratory), G. Fu (Johns Hopkins University), and S. Moran (University of Arizona)

NASA's InSight Lander Detects Stunning Meteoroid Impact on Mars

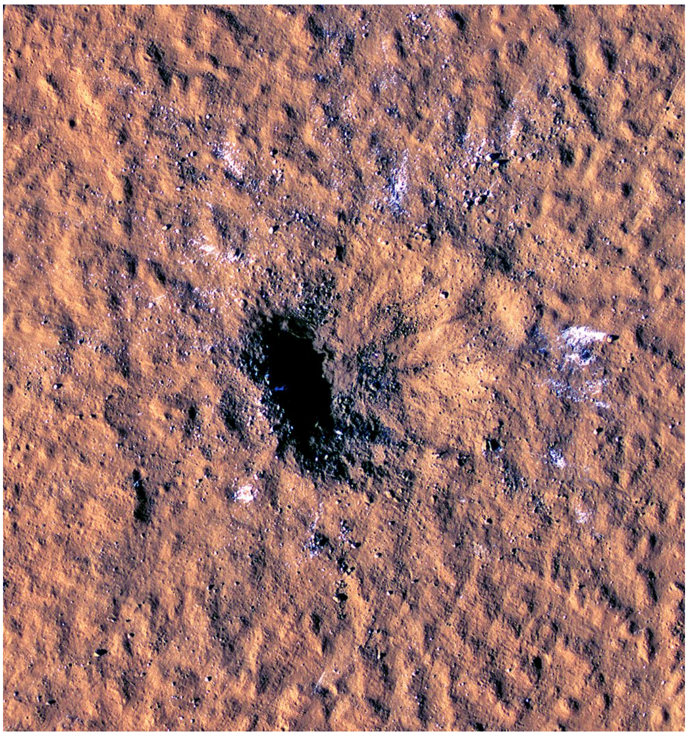
by JPL

The agency's lander felt the ground shake during the impact while cameras aboard the Mars Reconnaissance Orbiter spotted the yawning new crater from space. NASA's InSight lander recorded a magnitude 4 marsquake Dec. 24 2021, but scientists learned only later the cause of that quake: a meteoroid strike estimated to be one of the biggest seen on Mars since NASA began exploring the cosmos. What's more, the meteoroid excavated boulder size chunks of ice buried closer to the Martian equator than ever found before – a discovery with implications for NASA's future plans to send astronauts to the Red Planet.

Scientists determined the quake resulted from a meteoroid impact when they looked at before-and-after images from NASA's Mars Reconnaissance Orbiter (MRO) and spotted a new, yawning crater. Offering a rare opportunity to see how a large impact shook the ground on Mars, the event and its effects are detailed in two papers published Thursday, Oct. 27 2022, in the journal Science.

The meteoroid is estimated to have spanned 16 to 39 feet (5 to 12 meters) – small enough that it would have burned up in Earth's atmosphere, but not in Mars' thin atmosphere, which is just 1% as dense as our planet's. The impact, in a region called Amazonis Planitia, blasted a crater roughly 492 feet (150 meters) across and 70 feet (21 meters) deep. Some of the ejecta thrown by the impact flew as far as 23 miles (37 kilometers) away.
With images and seismic data documenting the event, this is believed to be one of the largest craters ever witnessed forming any place in the solar system. Many larger craters exist on the Red Planet, but they are significantly older and predate any Mars mission.

"It's unprecedented to find a fresh impact of this size," said Ingrid Daubar of Brown University, who leads InSight's Impact Science Working Group. "It's an exciting moment in geologic history, and we got to witness it."



Boulder-size blocks of water ice can be seen around the rim of an impact crater on Mars, as viewed by the high-resolution imaging science experiment (HiRISE camera) abourd NASA's Mars reconnaissance Orbiter. The crater was ormed on 24 December 2021 by a meteoroid strike in the Amazonis Planitia region. Credit: NASA/JPL-Catech/University of Arizona.

InSight, NASA's Mars lander that studied the planet's interior

by the Planetary Society

Highlights

- Mars and Earth both had conditions suitable for life for some periods of time 3 to 4 billion years ago, until Mars lost its atmosphere and became a cold, dry desert.
- NASA's InSight spacecraft studied Mars' interior and Marsquakes to learn how other worlds, including Earth-like exoplanets around other stars, evolve.
- InSight was operational on Mars from November 2018 until December 2022.

What was InSight?

Space exploration missions to Mars have taught us that for at least some periods of time 3 to 4 billion years ago, Mars had conditions that could have supported life as we know it. Then, Mars lost its magnetic field and the Sun stripped away its atmosphere. Why did this happen on Mars but not Earth? To learn why our planet took such a different evolutionary path and what the possibilities are for other worlds including Earth-like exoplanets, we need to learn about Mars' interior.

NASA's InSight spacecraft, an acronym for *Interior Exploration using Seismic Investigations, Geodesy and Heat Transport*, launched to Mars in May 2018 and landed later that year in November. Its mission was to learn more about how Mars' interior is layered so scientists could compare Mars with what we know about other planets and Earth.

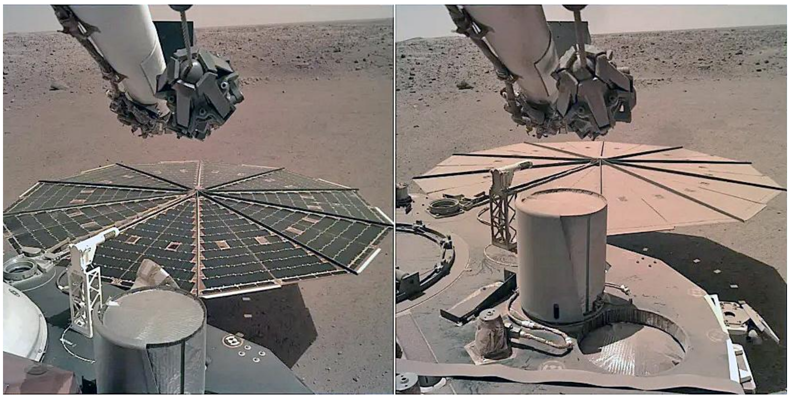
InSight had two main science experiments: a seismometer called SEIS to measure Marsquakes and a heat-flow probe called HP3 designed to burrow up to 5 meters beneath the surface to collect temperature readings. InSight used its robotic arm to place both on the surface shortly after arrival.

The largest Marsquake recorded by SEIS was a magnitude 4.7. The waves from Marsquakes are different than those seen on Earth and the Moon, indicating Mars' uppermost layers may be heavily fractured or that the quakes come from deep within the planet.

The soil at InSight's landing site was different than any seen before on Mars, and did not provide enough friction for the HP3 temperature probe known as the mole to burrow beneath the surface. After nearly two years of efforts with InSight's robotic arm to help the mole dig, NASA formally called off the effort in January 2020.

Mission complete

On Dec. 21, 2022 NASA officially declared InSight's mission over. The space agency had tried to make contact with the lander but said its solar-powered batteries appeared to have run out of energy.



A solar array on the InSight lander in December 2018 (left) and June 2021 (right). NASA/JPL-Caltech

NASA Telescope Takes 12-Year Time-Lapse Movie of Entire Sky

Pictures of the sky can show us cosmic wonders; movies can bring them to life. Movies from NASA's **NEOWISE** space telescope are revealing motion and change across the sky.

Every six months, NASA's Near-Earth Object Wide Field Infrared Survey Explorer, or NEOWISE spacecraft completes one trip halfway around the Sun, taking images in all directions. Stitched together, those images form an "all-sky" map showing the location and brightness of hundreds of millions of objects. Using 18 all-sky maps produced by the spacecraft (with the 19th and 20th to be released in March 2023), scientists have created what is essentially a time-lapse movie of the sky, revealing changes that span a decade.
Each map is a tremendous resource for astronomers, but when viewed in sequence as a time-lapse, they serve as an even stronger resource for trying to better understand the universe. Comparing the maps can reveal distant objects that have changed position or brightness over time, what's known as time-domain astronomy.

Watch the video (2:14) here.

Full article here.

Credit: NASA/JPL-Caltech

NASA's Perseverance Rover Deposits First Sample on Mars Surface

A titanium tube containing a rock sample is resting on the Red Planet's surface after being placed there on Dec. 21 by NASA's Perseverance Mars rover. Over the next two months, the rover will deposit a total of 10 tubes at the location, called "Three Forks," building humanity's first sample depot on another planet. The depot marks a historic early step in the Mars Sample Return campaign. The depot will serve as a backup if Perseverance can't deliver its samples. In that case, a pair of Sample Recovery Helicopters would be called upon to finish the job.

The first sample to drop was a chalk-size core of igneous rock informally named "Malay," which was collected on Jan. 31, 2022, in a region of Mars' Jezero Crater called "South Séítah." Perseverance's complex Sampling and Caching System took almost an hour to retrieve the metal tube from inside the rover's belly, view it one last time with its internal CacheCam, and drop the sample roughly 3 feet (89 centimeters) onto a carefully selected patch of Martian surface.

Full article here.

Credit: NASA/JPL-Catech/MSSS.

Hipparchus's map of the stars may finally have been found

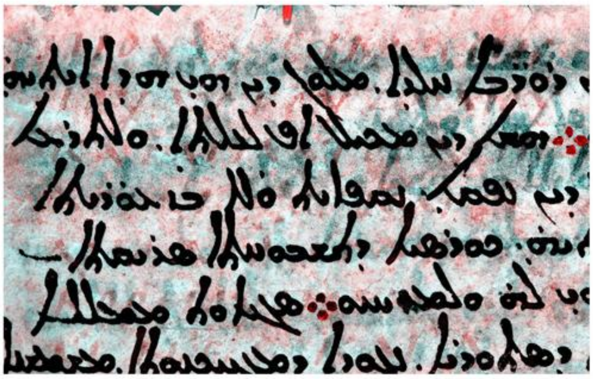
Source: Bob Yirka , Phys.org.

A trio of researchers from CNRS, UMR, Tyndale House and Sorbonne Université, respectively, have found what might be the famous Hipparchus's map of the stars. In their paper published in *Journal for the History of Astronomy*, Victor Gysembergh, Peter Williams and Emanuel Zingg describe a palimpsest manuscript that was found at the Greek Orthodox St Catherine's Monastery on the Sinai Peninsula, and what they believe it describes.

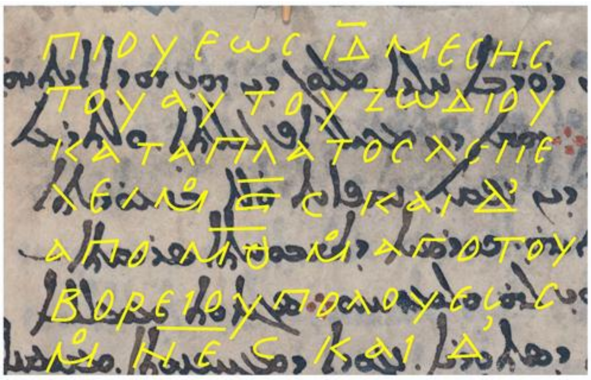
Historians have long believed that a catalogue of the stars was created long ago by early Greek astronomer Hipparchus—his catalogue was believed to represent the earliest map of the stars. But lack of physical evidence of such a map has left the record for creation of the earliest star map to Ptolemy. In this new effort, the researchers believe they have found part of the catalogue that Hipparchus created sometime between 162 and 127 BCE.

The work began with study of a palimpsest manuscript that was originally found at the Greek Orthodox St Catherine's Monastery and is now owned by the Museum of the Bible in Washington, D.C. The team noted that the material on which the text had been printed was written over text that had been scraped away, allowing for reuse—a common practice during the period. Intrigued, one of the team members asked a group of students to see if they could make out any of the prior text. One of them, Jamie Klair, found what appeared to be a line of text that had previously been seen in work by Eratosthenes, an astronomer.

Next, convinced that the subtext may have importance, the manuscript was sent to Early Manuscripts Electronic Library, where it was scanned using a variety of lighting techniques. The researchers were able to recover most of what had been erased. The overwritten text described the positions of several constellations and other star positions. By using precession (the amount of Earth's wobble), the team was able to ascertain not only the precision of the star coordinates but the dates that the measurements had been taken. They found the coordinates to be quite precise—more so than the work by Ptolemy. And the date that the mapping had taken place was 129 BCE. The researchers conclude that their evaluation of the manuscript very strongly suggests it was created by Hipparchus and that it represents the oldest star map known to exist.



(above) The enhanced Greek undertext appears in red below the Syriac overtext in black.
(below) Yellow tracings based on full set of multispectral images.
Credit: Journal for the History of Astronomy (2022).



The Evening Sky in February 2023

By Alan Gilmore

Venus and **Jupiter** are the 'evening stars', both low in the west. Brilliant Venus sets 70 minutes after the Sun through the month. Golden Jupiter sets more than two hours after the Sun at the beginning of the month but sinks steadily lower night to night. At the end of February Jupiter will be near Venus. The thin crescent Moon will be beside Venus on the 22nd and above Jupiter on the 23rd.

We are moving to the far side of the Sun from Jupiter, hence its steady fall in the west. It is 840 million km away mid-month. Venus, on the inside track, is slowly catching up with us. As it does so it will move higher in the evening sky till June. After that it will fall lower as it passes between us and the Sun.

Mars is a bright orange-red 'star' low in the sky a little west of due north. Above it are the orange stars Aldebaran, fainter than Mars, and Betelgeuse, similar in brightness to Mars. We are leaving Mars behind so it is fading. At mid-month it is 150 million km away. The Moon will be near Mars on the 28th.

Sirius and **Canopus** are the brightest true stars. Sirius, the brightest of all the stars, is north of overhead. Canopus, the second brightest star, is a bit south of overhead. Both stars are white in colour.

Sirius, 'the Dog Star', marks the head of **Canis Major** the big dog. A group of stars above and right of it make the dog's hindquarters and tail, upside down.

Procyon, in the northeast below Sirius, marks the smaller of the two dogs that follow Orion the hunter across the sky. Sirius is 8.6 light years* away.

Below and left of Sirius are bluish **Rigel** and orange **Betelgeuse**, the brightest stars in **Orion**. Between them is a line of three stars: Orion's belt. To southern hemisphere star watchers, the line of three makes the bottom of 'The Pot'. The handle of The Pot is Orion's sword, a fainter line of stars above the bright three. At its centre is the Orion Nebula; a glowing gas cloud around 1300 light years away.

Orion's belt points down and left to the orange star **Aldebaran**. Continuing the line finds the **Pleiades** or **Matariki** star cluster, well to the left of Mars. Aldebaran makes one eye of Taurus the bull. It is on one tip of an upside-down V of stars making the face of **Taurus**. These constellation pictures were thought up by northern hemisphere folk so are upside down to us.

The V-shaped group is called the Hyades cluster. It is 130 light years away. Aldebaran is not a member of the cluster but merely on the line of sight, 65 light years from us. It is a red-giant star 145 times brighter than the sun. The Pleiades/Matariki star cluster is also known as the Seven Sisters and Subaru among many names. The cluster is 440 light years from us. From northern Aotearoa the bright star **Capella** is on the north skyline. It is 90,000 times brighter than the sun and 3300 light years away.

Crux, the Southern Cross, is in the southeast. Below it are Beta and **Alpha Centauri,** often called 'The Pointers'. Alpha Centauri is the closest naked-eye star, 4.3 light years away.

The Evening Sky in February 2023

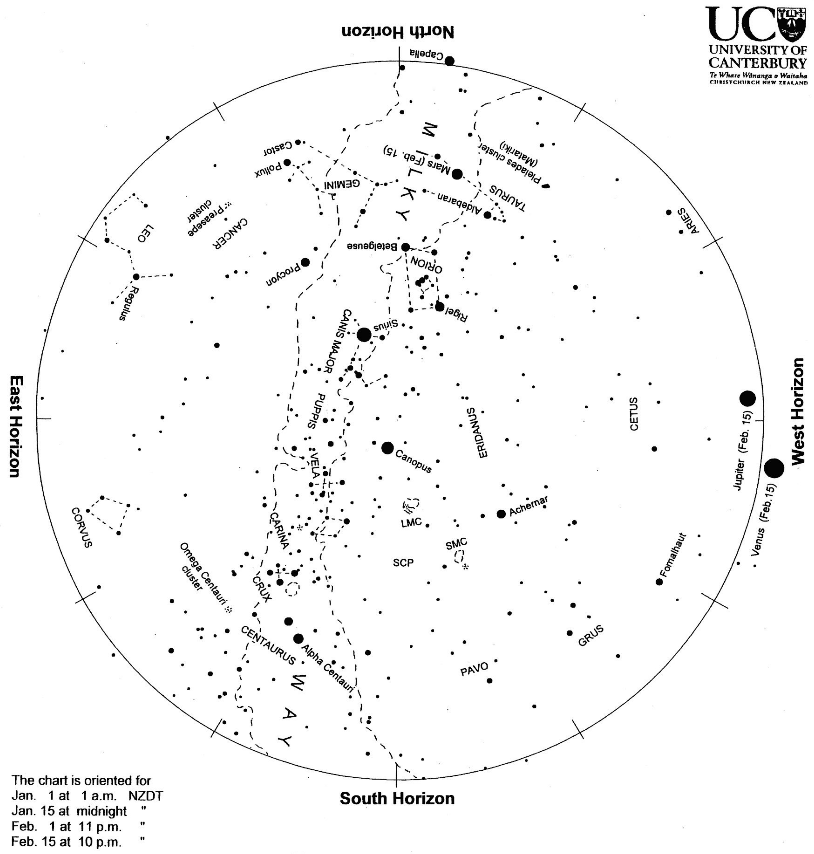
Beta Centauri is a blue-giant star hundreds of light years away, as are most of the stars in Crux. **Canopus** is also a very luminous distant star; 13 000 times brighter than the sun and 300 light years away.

The **Milky Way** is brightest in the southeast toward Crux. It can be traced up the sky, fading where it is nearly overhead. It becomes very faint east, or right, of Orion. The Milky Way is our edgewise view of the galaxy, the pancake of billions of stars of which the sun is just one.

The Clouds of Magellan, **LMC** and **SMC** are high in the south sky, easily seen by eye on a dark moonless night. They are two small galaxies about 160 000 and 200 000 light years away.

Mercury is in the morning sky, rising in the southeast around 4:30 a.m. at the beginning of the month. It is a lone bright 'star' in an empty region of sky. The thin crescent Moon will be above Mercury on the morning of the 19th

Find all (large) charts [here](#).



Evening sky in February 2023

To use the chart, hold it up to the sky. Turn the chart so the direction you are looking is at the bottom of the chart. If you are looking to the south then have 'South horizon' at the lower edge. As the earth turns the sky appears to rotate clockwise around the south celestial pole (SCP on the chart). Stars rise in the east and set in the west, just like the sun. The sky makes a small extra westward shift each night as we orbit the sun.

Venus and Jupiter are the 'evening stars', low in the west and setting early. Mars is a medium-bright orange-red 'star' low in the north. Sirius, the brightest true star, appears north of overhead at dusk. Canopus, the second brightest star, is south of the zenith. Orion, containing 'The Pot', is midway up the north sky. Below and left of Orion are Taurus and the Pleiades/Matariki star cluster, well left of Mars. The Southern Cross and Pointers are midway up the southeast sky. The Clouds of Magellan, LMC and SMC, two nearby galaxies, are high in the south sky.

Chart produced by Guide 8 software; www.projectpluto.com. Labels and text added by Alan Gilmore, Mt John Observatory of the University of Canterbury, P.O. Box 56, Lake Tekapo 7945, New Zealand .www.canterbury.ac.nz

Rangi Matamua - Officer of the New Zealand Order of Merit

For services to Māori astronomy

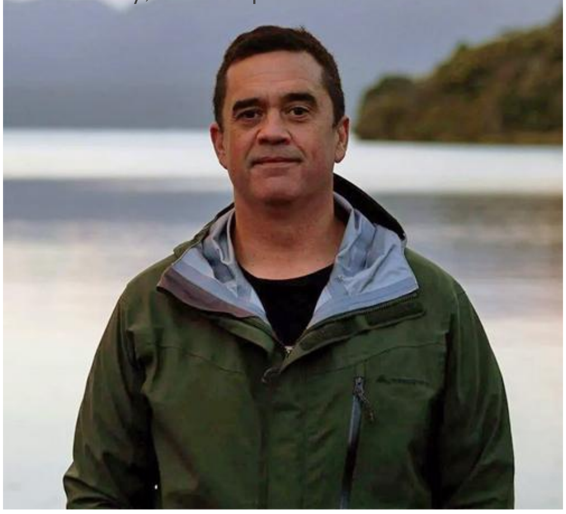
Professor Rangi Matamua (Tūhoe) is regarded as one of New Zealand's foremost Māori scholars for his contribution to Māori astronomy, star lore and Māori culture.

Professor Matamua has widely written on Matariki, identifying the nine stars Māori perceived in the cluster, in contrast to the seven associated with the Pleiades in European tradition. He has spent two decades researching Māori knowledge and tradition passed down from generations in a range of anthologies.

He is a professor at Massey University's School of Māori Knowledge, and has undertaken significant research in the areas of Māori language revitalisation, Māori culture, and astronomy. He is a board member of Society for Māori Astronomy Research and Traditions. He was the first Māori to win the Prime Minister's Science Prize in 2019 and is a Fellow of the Royal Society Te Apārangi. He was appointed the Government's Chief Advisor Mātauranga Matariki in 2022. He uses his social media platform to engage with a range of audiences, speaking in te Reo Māori and English, educating on astronomy, with more than one million views on his web-series. He gives regular presentations around New Zealand and internationally. Professor Matamua was presented with the Te Apārangi Callaghan Medal in 2020 by the Royal Society of New Zealand.

Living by the Stars

Professor Rangi Matamua (Tūhoe) is a pioneering Māori scholar who has revolutionised understandings of Māori astronomy, and in particular Matariki.



He is renowned for his role communicating his research in an accessible and engaging way and reaching both academic and non-academic audiences. Rangi is both the author of the bestselling book *Matariki: The Star of the Year* (published both in English and te reo editions), presenter of the award winning te reo Māori web series *Living by the Stars* and has an extensive social media following on Living by the Stars page.

He has challenged widespread misconceptions about Māori astronomy and has enhanced our understandings of a Māori world view of the stars. His research is situated at the interface between mātauranga Māori and Western science, and he is helping to reconnect people with maramataka – the Māori lunar calendar – and the environment. Rangi is also part of a wider movement, reclaiming Indigenous astronomy as part of a continued process of decolonisation.

Website.

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Later this year

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Enrolment is already open.

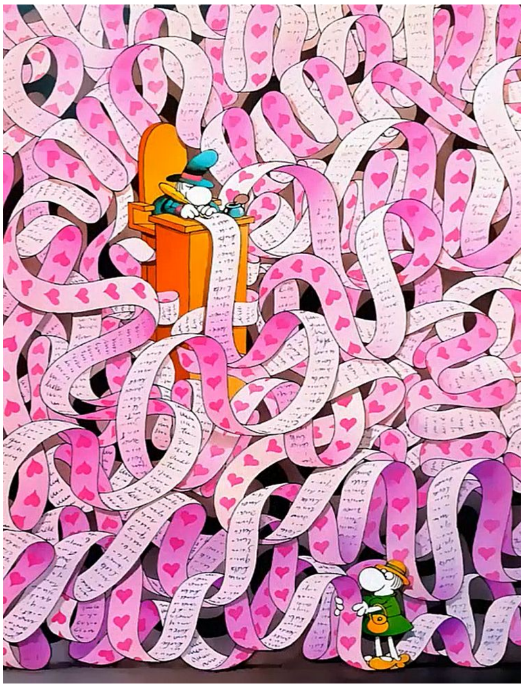
Short URL’s

We have replaced the ridiculously long Google addresses to our newsletters and pdf’s with a short URL that is easy to remember.

For all new style issues the address is and will be:

tinyurl.com/rasnz-enews### (animated)
tinyurl.com/rasnz-pnews### (pdf)
(### is the issue number)

This starts with the August issue 259.



Quotes of the Month

“An open mind leaves a chance for someone to drop a worthwhile thought in it”. Mark Twain.

“So remember to look up at the stars and not down on your feet. Try to make sense of what you see and wonder about what makes a Universe exist. Be curious. And however difficult life may seem, there is always something you can do and succeed at. It matters that you don’t just give up”. Stephen Hawking.

“The “Dopeler Effect”: The tendency of stupid ideas to seem smarter when they come at you rapidly”. Raccoon TV.

How to Join the RASNZ

RASNZ membership is open to all individuals with an interest in astronomy in New Zealand. Information about the society and its objects can be found at http://rasnz.org.nz/rasnz/membership-benefits

For membership complete the online application form found at Membership Application

Basic membership for the 2022 year starts at $40 for an ordinary member, which includes an email subscription to our journal 'Southern Stars'.

Until next Issue

Contributions must be in by the 15th of the month.

Archive

You can now find links to all new style issues in the archive here.

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