Massive stars are defined to be those that explode in core-collapse supernovae and are therefore important sources for energy and new elements in galaxies. I'll begin discussing the lives of stars by talking about the evidence we have for which type of stars explode as which type of supernovae. From this point I'll work backwards through a star’s evolution to their births. Finally I'll explain how its becoming apparent that most massive stars are born in a binary systems and so their evolution is changed as the stars “get in each others way”.

Dr John Eldridge obtained his PhD from Institute of Astronomy, University of Cambridge, UK in 2005. Since then he has had post-doctoral appointments in Institut d'Astrophysics de Paris (France), Queen’s University Belfast (Northern Ireland) and Institute of Astronomy, UK. He joined University of Auckland in 2011 and is now lecturing the 107 class (Introductory Astronomy). He has published multiple papers on the evolution of massive stars and the progenitors of supernovae.
## Calendar of Events for 2013

### March 2013 Programme

<table>
<thead>
<tr>
<th>Day</th>
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<tr>
<td>Fri</td>
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<td>7:30pm</td>
<td>Young astronomers with Margaret Arthur</td>
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<tr>
<td>Mon</td>
<td>4</td>
<td>8:00pm</td>
<td>Introduction to Astronomy with Bernie Brenner and Peter Felhofer</td>
</tr>
<tr>
<td>Mon</td>
<td>11</td>
<td>8:00pm</td>
<td>Society Meeting.</td>
</tr>
<tr>
<td>Sat</td>
<td>16</td>
<td>8:00pm</td>
<td>The Autumn night sky in an informal location. See notice below.</td>
</tr>
<tr>
<td>Mon</td>
<td>18</td>
<td>8:00pm</td>
<td>Autumn sky night Starting in the planetarium &amp; viewing outside as weather</td>
</tr>
<tr>
<td>Wed</td>
<td>20</td>
<td>7:30pm</td>
<td>Council Meeting</td>
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<tr>
<td>Mon</td>
<td>25</td>
<td>8:00pm</td>
<td>Film night with Gavin Logan</td>
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### April 2013 Programme

<table>
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<tbody>
<tr>
<td>Mon</td>
<td>1</td>
<td>8:00pm</td>
<td>Introduction to Astronomy with Bernie Brenner and Peter Felhofer</td>
</tr>
<tr>
<td>Fri</td>
<td>5</td>
<td>7:30pm</td>
<td>Young astronomers with Margaret Arthur</td>
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<tr>
<td>Mon</td>
<td>8</td>
<td>8:00pm</td>
<td>Society Meeting</td>
</tr>
<tr>
<td>Sat</td>
<td>13</td>
<td>8:00pm</td>
<td>Practical Astronomy Dark Sky Observing Night at the Arataki Visitor’s Centre</td>
</tr>
<tr>
<td>Mon</td>
<td>15</td>
<td>8:00pm</td>
<td>Practical astronomy with Bill Thomas</td>
</tr>
<tr>
<td>Wed</td>
<td>17</td>
<td>7:30pm</td>
<td>Council Meeting</td>
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<tr>
<td>Mon</td>
<td>22</td>
<td>8:00pm</td>
<td>Society AGM followed by Film night with Gavin Logan. See notice</td>
</tr>
<tr>
<td>Mon</td>
<td>29</td>
<td>8:00pm</td>
<td>Film night with Gavin Logan</td>
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### Autumn Dark Sky Night. Saturday 16th March

A chance to observe the Autumn sky in an informal setting with a dark sky.
Dave Wyers has agreed to host us again and you will have a fantastic opportunity to explore the sky. Bring your telescope. There will be a number of Society telescopes to use.
Viewing will be preceded by a BBQ. Bring your dinner supplies.

**Location:** 490 White Hills Rd, Wainui (near Silverdale)
- Solar viewing from 4pm
- BBQ at approx. 6pm
- Night sky viewing from dusk.

See the Society website for details

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### Film Night Monday 25 March 8:00pm With Gavin Logan

Ride the Comet is a documentary that gives an insight into the composition and characteristics of comets. It explains the matter from which comets are made and also the reason for the sudden disappearance of a comet. The documentary tells about the different types of comets and provides a detailed analysis of what these comets can cause if they enter the Earth’s atmosphere.

It is 44 minutes long and will be followed by a February 2013 Sky at Night show with Dr Chris Lintott and Dr Lucie Green entitled “the Sun King”. It is a very informative show about solar activity and how to safely observe the Sun (28 minutes long).

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### Welcome to New members

- Zinnia Manchanda (family)
- Duncan Bell (ordinary)
- Sarah Basheer (ordinary)
- Anthony Ellis (ordinary)
- Yap-Su Ong (family)
Notice of Annual General Meeting

The Annual General Meeting of the Auckland Astronomical Society Inc. will be held in the Sun Room of the Stardome Observatory, One Tree Hill Domain on Monday 22nd April 2012 starting at 8:00pm.

All society members are encouraged to attend and help with the future of the Society.

The agenda and a copy of the reports will be posted on the member’s area of the society website (www.astronomy.org.nz) at least one week before the meeting. Printed copies will also be distributed at the meeting.

Nominations are open for all council positions; President, Vice President, Treasurer, Secretary, Librarian, Curator of Instruments, Editor and three to five council members.

Nominations must be received by the Secretary by Monday 1st April 2013 and must be made using the form below. Note nominees, nominators and seconders must be current financial members.

Any questions or enquires can be directed to Grant Christie (President) by email to info@astronomy.org.nz or phone 09 636 3437.

Nomination for Auckland Astronomical Society Council

To be completed by the nominator & a seconder. Both must be a current financial member.

I .............................................................. nominate ..............................................................

for the position of ..............................................................

signed: .............................................................. dated: ..............................................................

I .............................................................. second the nomination of ..............................................................

for the position of ..............................................................

signed: .............................................................. dated: ..............................................................

To be completed by the nominee. The nominee must be a current financial member and have been so for at least one year.

I .............................................................. accept nomination for ..............................................................

signed: .............................................................. dated: ..............................................................

Send form to: The Secretary, Auckland Astronomical Society
PO Box 24187, Royal Oak, Auckland 1345

Must be received by 1st April 2013.
Universe or Multiverse

Film Night Report by Gavin Logan

The first film night of 2013 was a documentary featuring well-known physicist Brian Greene who went through the latest thinking about whether The Universe we see is the only one or whether there are multiple universes. The audience at this well attended evening were shown interviews with leading scientists who were both for and against the idea of multiple universes.

The Multiverse theory suggests that there could be several copies of everything in existence and that there are extra dimensions. It also suggests that not all universes are the same and that in some galaxies and stars and matter as we know it may not have formed. Dark energy is discussed in the film, focusing on the difference between what the theory of dark energy predicts and what level of dark energy is required for the current rate of expansion of The Universe. Brian Greene believes that Dark Energy can be neatly explained using a multi-verse theory.

This film was followed by the December 2012 Sky at Night show. It was the last one made while Patrick Moore was alive and featured the latest information and photos about the planet Mercury from the messenger spacecraft results.

Next month’s film night is on Monday 25th March at the Star Dome and features a film called “Ride the Comet”. Ride the Comet is a documentary that gives an insight into the composition and characteristics of comets. It explains the matter from which comets are made and also the reason for their sudden. The documentary discusses the different types of comets and provides a detailed analysis of what might happen if a comet were to enter the Earth’s atmosphere.

It is 44 minutes long and will be followed by the “February 2013 Sky at Night” show with Dr Chris Lintott and Dr Lucie Green entitled “the Sun King”. It is a very informative show about solar activity and how to safely observe the Sun (28 minutes long).

Explanation: A meteoroid fell to Earth on February 15, streaking some 20 to 30 kilometres above the city of Chelyabinsk, Russia at 9:20am local time. Initially travelling at about 20 kilometres per second, its explosive deceleration after impact with the lower atmosphere created a flash brighter than the Sun. This picture of the brilliant bolide (and others of its persistent trail) was captured by photographer Marat Ametvaleev, surprised during his morning sunrise session creating panoramic images of the nearby frosty landscape. An estimated 500 kilotons of energy was released by the explosion of the 17 meter wide space rock with a mass of 7,000 to 10,000 tons. Actually expected to occur on average once every 100 years, the magnitude of the Chelyabinsk event is the largest known since the Tunguska impact in 1908.
Russian Fireball Largest Ever Detected by Comprehensive Nuclear-Test-Ban Treaty Organization's Infrasound Sensors

From Science Daily

Infrasonic waves from the meteor that broke up over Russia's Ural mountains last week were the largest ever recorded by the CTBTO's International Monitoring System. Infrasound is low frequency sound with a range of less than 10 Hz. The blast was detected by 17 infrasound stations in the CTBTO's network, which tracks atomic blasts across the planet. The furthest station to record the sub-audible sound was 15,000km away in Antarctica.

The origin of the low frequency sound waves from the blast was estimated at 03:22 GMT on 15 February 2013. People cannot hear the low frequency waves that were emitted but they were recorded by the CTBTO's network of sensors as they travelled across continents.

"We saw straight away that the event would be huge, in the same order as the Sulawesi event from 2009. The observations are some of the largest that CTBTO's infrasound stations have detected," CTBTO acoustic scientist, Pierrick Mialle said.

Until last week, the bolide explosion above Sulawesi, Indonesia, in October 2009 was the largest infrasound event registered by 15 stations in the CTBTO's network.

Infrasound has been used as part of the CTBTO's tools to detect atomic blasts since April 2001 when the first station came online in Germany. Data from the stations is sent in near real time to Vienna, Austria, for analysis at the CTBTO's headquarters. Both the raw and analysed data are provided to all Member States.

"We know it’s not a fixed explosion because we can see the change in direction as the meteorite moves towards Earth. It’s not a single explosion, it’s burning, travelling faster than the speed of sound. That’s how we distinguish it from mining blasts or volcanic eruptions.

"Scientists all around the world will be using the CTBTO's data in the next months and year to come, to better understand this phenomena and to learn more about the altitude, energy released and how the meteor broke up," Mialle said.

The infrasound station at Qaanaaq, Greenland was among those that recorded the meteor explosion in Russia. There are currently 45 infrasound stations in the CTBTO's network that measure micro pressure changes in the atmosphere generated by infrasonic waves. Like meteor blasts, atomic explosions produce their own distinctive, low frequency sound waves that can travel across continents.

Infrasound is one of four technologies (including seismic, hydro acoustic and radionuclide) the CTBTO uses to monitor the globe for violations of the Comprehensive Nuclear-Test-Ban Treaty that bans all nuclear explosions.

Seismic signals from the meteor were also detected at several Kazakh stations close to the explosion and impact area. Listen to the audio files of the infrasound recording after it has been filtered and the signal accelerated.

Days before the meteor on 12 February 2013, the CTBTO's seismic network detected an unusual seismic event in the Democratic People's Republic of Korea (DPRK), which measured 4.9 in magnitude. Later that morning, the DPRK announced that it had conducted a nuclear test. The event was registered by 94 seismic stations and two infrasound stations in the CTBTO's network. The data processing and analysis are designed to weed out natural events and focus on those events that might be explosions, including nuclear explosions.
Comet Lemon brightened five magnitudes from its earlier predicted brightness. In recent days it has been an easy binocular object near the Small Cloud of Magellan. The waxing Moon will make it harder to see over the coming week. The ephemeris, right, is from the Minor Planet Center and is based on elements from Minor Planet Electronic Circular 2013-C52. The comet’s positions are given for 10 p.m. NZDT.

The total brightness, m1, listed has been increased by five magnitudes from the ephemeris provided by the Minor Planet Center. There is no guarantee that the comet will keep to this level of brightness. The comet will be very low in the evening twilight from March 19 onward; elongation (angle from the Sun) is less than 30 degrees. C/2012 F6 passes 0.731246 AU (110 million km) from the Sun on March 24.5 UT on the far side from Earth. It remains close to the Sun from our viewpoint after perihelion then gradually moves into the northern hemisphere dawn sky.
Comet PANSTARSS (C/2011 L4)

By Alan Gilmore

The ephemeris, on right, is from the Minor Planet Center and is based on elements from Minor Planet Electronic Circular 2013-C52. At the end of February the comet will be south of the Sun possibly allowing it to be seen at both dawn and dusk. The ephemerides give positions for both times. In March it moves into the evening sky.

The comet is just 16 degrees from the Sun on March 8, making it difficult to see in the bright twilight. It passes 0.30154 AU (45 million km) from the Sun on March 10. After perihelion it moves into the northern hemisphere sky.

Ephemeris data for March

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<tr>
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<td>23 28 27</td>
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<td>08</td>
<td>00 15 12</td>
<td>-09 50</td>
<td>0.6</td>
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The projected brightness curve of comet PanSTARRS.

NASA Releases Radar Movie of Asteroid 2012 DA14

From Science daily

An initial sequence of radar images of asteroid 2012 DA14 was obtained on the night of Feb. 15/16, 2013, by NASA scientists using the 230-foot (70-meter) Deep Space Network antenna at Goldstone, Calif. Each of the 72 frames required 320 seconds of data collection by the Goldstone radar.

The observations were made as the asteroid was moving away from Earth. The asteroid’s distance from the radar dish increased from 74,000 miles (120,000 kilometres) to 195,000 miles (314,000 kilometres). The resolution is 13 feet (four meters) per pixel. The images span close to eight hours and clearly show an elongated object undergoing roughly one full rotation. The images suggest that the asteroid has a long axis of about 130 feet (40 meters). The radar observations were led by scientists Lance Benner and Marina Brozovic of NASA’s Jet Propulsion Laboratory, Pasadena, Calif. Additional Goldstone radar observations are scheduled on February 18, 19 and 20.

Radar is a powerful technique for studying an asteroid’s size, shape, rotation state, surface features and surface roughness, and for improving calculations of its orbit. Radar measurements of asteroid distances and velocities often enable computation of asteroid orbits much further into the future than if radar observations weren’t available.

NASA detects, tracks and characterizes asteroids and comets passing close to Earth using both ground- and space-based telescopes. The Near-Earth Object Observations Program, commonly called “Spaceguard,” discovers these objects, characterizes a subset of them, and plots their orbits to determine if any could be potentially hazardous to our planet.
Kepler Discovers a System of Tiny Planets

NASA’s Kepler mission scientists have discovered a new planetary system that is home to the smallest planet yet found around a star similar to our Sun

From Science Daily

A Tiny Planet

NASA’s Kepler mission has discovered a new planetary system that is home to the smallest planet yet found around a star similar to our Sun, approximately 210 light-years away in the constellation Lyra.

The artist’s concept depicts the new planet dubbed Kepler-37b. The planet is slightly larger than our Moon, measuring about one-third the size of Earth. Kepler-37b orbits its host star every 13 days at less than one-third the distance Mercury is to the Sun. The estimated surface temperature of this smouldering planet, at more than 800 degrees Fahrenheit (700 degrees Kelvin), would melt the zinc in a penny.

Astronomers don’t think the tiny planet has an atmosphere or could support life as we know it, but the Moon-size world is almost certainly rocky in composition. Image credit: NASA/Ames/JPL-Caltech

The planets are located in a system called Kepler-37, about 210 light-years from Earth in the constellation Lyra. The smallest planet, Kepler-37b, is slightly larger than our Moon, measuring about one-third the size of Earth. It is smaller than Mercury, which made its detection a challenge.

The Moon-size planet and its two companion planets were found by scientists with NASA’s Kepler mission to find Earth-sized planets in or near the "habitable zone," the region in a planetary system where liquid water might exist on the surface of an orbiting planet. However, while the star in Kepler-37 may be similar to our Sun, the system appears quite unlike the solar system in which we live.

Astronomers think Kepler-37b does not have an atmosphere and cannot support life as we know it. The tiny planet almost certainly is rocky in composition. Kepler-37c, the closer neighbouring planet, is slightly smaller than Venus, measuring almost three-quarters the size of Earth. Kepler-37d, the farther planet, is twice the size of Earth.

The first exoplanets found to orbit a normal star were giants. As technologies have advanced, smaller and smaller planets have been found, and Kepler has shown even Earth-size exoplanets are common.

"Even Kepler can only detect such a tiny world around the brightest stars it observes," said Jack Lissauer, a planetary scientist at NASA’s Ames Research Center in Moffett Field, Calif. "The fact we’ve discovered tiny Kepler-37b suggests such little planets are common, and more planetary wonders await as we continue to gather and analyse additional data."

Kepler-37’s host star belongs to the same class as our Sun, although it is slightly cooler and smaller. All three planets orbit the star at less than the distance Mercury is to the Sun, suggesting they are very hot, inhospitable worlds. Kepler-37b orbits every 13 days at less than one-third Mercury’s distance from the Sun. The estimated surface temperature of this smouldering planet, at more than 800 degrees Fahrenheit (700 degrees Kelvin), would be hot enough to melt the zinc in a penny. Kepler-37c and Kepler-37d, orbit every 21 days and 40 days, respectively.

"We uncovered a planet smaller than any in our solar system orbiting one of the few stars that is both bright and quiet, where signal detection was possible," said Thomas Barclay, Kepler scientist at the Bay Area Environmental Research Institute in Sonoma, Calif., and lead author of the new study published in the journal Nature. "This discovery shows close-in planets can
be smaller, as well as much larger, than planets orbiting our Sun.*

The research team used data from NASA’s Kepler space telescope, which simultaneously and continuously measures the brightness of more than 150,000 stars every 30 minutes. When a planet candidate transits, or passes, in front of the star from the spacecraft’s vantage point, a percentage of light from the star is blocked. This causes a dip in the brightness of the starlight that reveals the transiting planet’s size relative to its star.

The size of the star must be known in order to measure the planet’s size accurately. To learn more about the properties of the star Kepler-37, scientists examined sound waves generated by the boiling motion beneath the surface of the star. They probed the interior structure of Kepler-37’s star just as geologists use seismic waves generated by earthquakes to probe the interior structure of Earth. The science is called asteroseismology.

The sound waves travel into the star and bring information back up to the surface. The waves cause oscillations that Kepler observes as a rapid flickering of the star’s brightness. Like bells in a steeple, small stars ring at high tones while larger stars boom in lower tones. The barely discernible, high-frequency oscillations in the brightness of small stars are the most difficult to measure. This is why most objects previously subjected to asteroseismic analysis are larger than the Sun.

With the very high precision of the Kepler instrument, astronomers have reached a new milestone. The star Kepler-37, with a radius just three-quarters of the Sun, now is the smallest bell in the asteroseismology steeple. The radius of the star is known to 3 percent accuracy, which translates to exceptional accuracy in the planet’s size.

Are Super-Earths Actually Mini-Neptunes?

From Science Daily

I

n the last two decades astronomers have found hundreds of planets in orbit around other stars. One type of these so-called ‘exoplanets’ is the super-Earths that are thought to have a high proportion of rock but at the same time are significantly bigger than our own world. Now a new study led by Helmut Lammer of the Space Research Institute (IWF) of the Austrian Academy of Sciences suggests that these planets are actually surrounded by extended hydrogen-rich envelopes and that they are unlikely to ever become Earth-like. Rather than being super-Earths, these worlds are more like mini-Neptunes.

The scientists publish their work in the journal Monthly Notices of the Royal Astronomical Society.

‘Super-Earths’ follow a different evolutionary track to the planets found in our Solar system but an open question is whether they can evolve to become rocky bodies like the ‘terrestrial planets’ Mercury, Venus, Earth and Mars. To try to answer this, Dr Lammer and his team looked at the impact of radiation on the upper atmospheres of super-Earths orbiting the stars Kepler-11, Giese 1214 and 55 Cancri.

This group of planets are all a few times more massive and slightly larger than Earth. They orbit very close to their respective stars. The way in which the mass of planets scales with their sizes suggests that they have solid cores surrounded by hydrogen or hydrogen-rich atmospheres, probably captured from the clouds of gas and dust (nebulae) from which the planets formed.

The new model suggests that the short wavelength extreme ultraviolet light (much ‘bluer’ than the blue light we see with our eyes) of the host stars heats up the gaseous envelopes of these worlds, so that they expand up to several times the radius of each planet and gas escapes from them fairly quickly. Nonetheless most of the atmosphere remains in place over the whole lifetime of the stars they orbit.

*Our results indicate that, although material in the atmosphere of these planets escapes at a high rate, unlike lower mass Earth-like planets many of these super-Earths may not get rid of their nebula-captured hydrogen-rich atmospheres," says Dr Lammer.

Rather than becoming more like Earth, the super-Earths may more closely resemble Neptune, which together with Uranus, is a smaller ‘gas giant’ in our Solar system. If the scientists’ results are right, then super-Earths further out from their stars in the ‘habitable zone’, where the temperature would allow liquid water to exist, would hold on to their atmospheres even more effectively. If that happens, they would be much less likely to be habitable.

The team’s findings will be put to the test in 2017 when the European Space Agency launches the CHaracterising ExOPlanets Satellite (CHEOPS). This will study super-Earths in more detail and should be able to tell whether some of these exotic worlds could one day be more like our own.
A new paradigm for understanding the earliest eras in the history of The Universe has been developed by scientists at Penn State University. Using techniques from an area of modern physics called loop quantum cosmology, developed at Penn State, the scientists now have extended analyses that include quantum physics farther back in time than ever before -- all the way to the beginning. The new paradigm of loop quantum origins shows, for the first time, that the large-scale structures we now see in The Universe evolved from fundamental fluctuations in the essential quantum nature of “space-time,” which existed even at the very beginning of The Universe over 14 billion years ago. The achievement also provides new opportunities for testing competing theories of modern cosmology against breakthrough observations expected from next-generation telescopes.

The research will be published on 11 December 2012 as an “Editor’s Suggestion” paper in the scientific journal Physical Review Letters.

“We humans always have yearned to understand more about the origin and evolution of our universe,” said Abhay Ashtekar, the senior author of the paper. “So it is an exciting time in our group right now, as we begin using our new paradigm to understand, in more detail, the dynamics that matter and geometry experienced during the earliest eras of The Universe, including at the very beginning.” Ashtekar is the Holder of the Eberly Family Chair in Physics at Penn State and the director of the university’s Institute for Gravitation and the Cosmos. Co-authors of the paper, along with Ashtekar, are postdoctoral fellows Ivan Agullo and William Nelson.

The new paradigm provides a conceptual and mathematical framework for describing the exotic “quantum-mechanical geometry of space-time” in the very early universe. The paradigm shows that, during this early era, The Universe was compressed to such unimaginable densities that its behaviour was ruled not by the classical physics of Einstein’s general theory of relativity, but by an even more fundamental theory that also incorporates the strange dynamics of quantum mechanics. The density of matter was huge then -- 1094 grams per cubic centimetre, as compared with the density of an atomic nucleus today, which is only 1014 grams.

In this bizarre quantum-mechanical environment -- where one can speak only of probabilities of events rather than certainties -- physical properties naturally would be vastly different from the way we experience them today. Among these differences, Ashtekar said, are the concept of “time,” as well as the changing dynamics of various systems over time as they experience the fabric of quantum geometry itself.

No space observatories have been able to detect anything as long ago and far away as the very early eras of The Universe described by the new paradigm. But a few observatories have come close. Cosmic background radiation has been detected in an era when The Universe was only 380-thousand years old. By that time, after a period of rapid expansion called “inflation,” The Universe had burst out into a much-diluted version of its earlier super-compressed self. At the beginning of inflation, the density of The Universe was a trillion times less than during its infancy, so quantum factors now are much less important in ruling the large-scale dynamics of matter and geometry.

Observations of the cosmic background radiation show that The Universe had a predominantly uniform consistency after inflation, except for a light sprinkling of some regions that were more dense and others that were less dense. The standard inflationary paradigm for describing the early universe, which uses the classical-physics equations of Einstein, treats space-time as a smooth continuum. “The inflationary paradigm enjoys remarkable success in explaining the observed features of the cosmic background radiation. Yet this model is incomplete. It retains the idea that The Universe burst forth from nothing in a Big Bang, which naturally results from the inability of the paradigm’s general-relativity physics to describe extreme quantum-mechanical situations,” Agullo said. “One needs a quantum theory of gravity, like loop quantum cosmology, to go beyond Einstein in order to capture the true physics near the origin of The Universe.”

Earlier work with loop quantum cosmology in Ashtekar’s group had updated the concept of the Big Bang with the intriguing concept of a Big Bounce, which allows the possibility that our universe emerged not from nothing but from a super-compressed mass of matter that previously may have had a history of its own.

Even though the quantum-mechanical conditions at the beginning of The Universe were vastly different from the classical-physics conditions after inflation, the new achievement by the Penn State physicists reveals a surprising connection between the two different paradigms that describe these eras. When scientists use the inflation paradigm together with Einstein’s equations to model the evolution of the seed-like areas sprinkled throughout the cosmic background radiation, they find that the irregularities serve as seeds that evolve over time into the galaxy clusters and other large-scale structures that we see in The Universe today. Amazingly, when the Penn State scientists used their new loop-quantum-origins paradigm with its quantum-cosmology equations, they found that fundamental fluctuations in the very nature of space at the moment of the Big Bounce evolve to become the seed-like structures seen in the cosmic microwave background.

“Our new work shows that the initial conditions at the very beginning of The Universe naturally lead to the large-scale structure of The Universe that we observe today,” Ashtekar said. “In human terms, it is like taking a snapshot of a baby right at birth and then being able to project from it an accurate profile
of how that person will be at age 100."

"This paper pushes back the genesis of the cosmic structure of our universe from the inflationary epoch all the way to the Big Bounce, covering some 11 orders of magnitude in the density of matter and the curvature of space-time," Nelson said. "We now have narrowed down the initial conditions that could exist at the Big Bounce, plus we find that the evolution of those initial conditions agrees with observations of the cosmic background radiation."

The team’s results also identify a narrower range of parameters for which the new paradigm predicts novel effects, distinguishing it from standard inflation. Ashtekar said, "It is exciting that we soon may be able to test different predictions from these two theories against future discoveries with next-generation observational missions. Such experiments will help us to continue gaining a deeper understanding of the very, very early universe."

The research was supported by the National Science Foundation.

This image is a plot of the power spectra in the cosmic microwave background (CMB) predicted in Loop Quantum Cosmology and in the Standard Inflationary Scenario. The two different spectra are contrasted in this plot, which shows their ratio as a function of k, the inverse of wave length, of fluctuations in the cosmic microwave background. For many of the parameters, observable wave numbers k are greater than 9 and the two predictions are indistinguishable. For a narrow window of parameters, observable k can be smaller than 9. Then the two predictions differ. Both are in agreement with currently available data, but future observations should be able to distinguish between them. (Credit: Image courtesy of Penn State)
**Chondrule Formation**

*From CosmoSparks*

The origin of chondrules—the material from which they formed and their melting histories—has intrigued Cosmo-chemists for decades and continues as an active research theme. Recent work by Devin Schrader (formerly at the University of Arizona and now at the University of Hawaii) and colleagues from Arizona, New York, and Hawaii’s, aims to constrain the formation conditions of the two main chondrule groups, designated type-I and type-II, to answer whether or how their origins are related. Schrader and co-authors have studied the oxygen-isotopic compositions and oxidation states of olivine in type-I and type-II chondrules from three Renazzo-like carbonaceous (CR) chondrites. The meteorite samples (GRA 95229, GRA 06100, and QUE 99177; collected by the U.S. Antarctic Search for Meteorites program), span a wide range of whole rock oxygen-isotopic compositions. Their detailed analyses of the major-and minor-element abundances and in situ oxygen-isotopic compositions of 21 chondrule olivines yielded interesting results, including:

A relationship between the oxygen-isotopic composition and oxidation state (expressed as oxygen fugacity) of chondrule olivines suggests the processes that controlled them are linked. Schrader and co-authors found that as the oxygen-isotopic composition increases to heavier values, a chondrule’s apparent oxygen fugacity increases.

The abundance of ice or the amount of reduced carbon that accreted with the material from which a chondrule formed may have created microenvironments (oxidizing or reducing) that led to a distinct oxygen fugacity for that chondrule during its formation. That is, more ice led to a more oxidizing environment, whereas more reduced carbon (because it bonds to oxygen) led to a reducing environment. Schrader and colleagues suggest the precursors of type-I chondrules contained more reduced carbon than type-II chondrules.

A relationship between chondrule petrology and oxygen-isotopic composition is due to the degree of melting and exchange with 16O-poor gas during melting. Schrader and colleagues found the partially melted, relict-grain bearing type-II chondrules are oxygen-isotope heterogeneous, while the relict-free type-II chondrules are oxygen-isotope homogeneous, and all are similarly 16O-poor.

The oxygen-isotopic composition of the gas that exchanged with chondrules in CR chondrites is distinct from the extremely-16O-poor primordial water of the Solar System inferred from oxygen-isotopic data from the carbonaceous chondrite Acfer 094 by Naoya Sakamoto (Hokkaido University, Sapporo) and colleagues.

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**The Last Big Bump Before a Supernova Explodes**

*From Science daily*

A formal supernova hunt is shedding new light on the death sequence of massive stars—specifically, the kind that self-destruct in Type IIn supernova explosions.

Digging through the Palomar Transient Factory (PTF) data archive housed at the Department of Energy’s National Energy Research Scientific Computing Center (NERSC) at Lawrence Berkeley National Laboratory (Berkeley Lab), astronomers have found the first causal evidence that these massive stars shed huge amounts of material in a “penultimate outburst” before final detonation as supernovae.

A focused search for Type IIn SN precursor bursts, conducted by Eran Ofek of Israel’s Weizmann Institute and the PTF team, led to this finding. Their results were published in the February 7, 2013 issue of Nature. PTF is an international collaboration that brings together researchers, universities, observatories and Berkeley Lab to hunt for supernovae and other astronomical objects.

**The Causal Link**

Massive stars -- somewhere between eight and 100 times the mass of our Sun -- spend much of their lives fusing hydrogen...
(the lightest element) into increasingly heavier elements, like helium, oxygen, carbon and so on. In the end, there is almost nothing left but an iron core. Eventually, that core collapses, releasing a tremendous amount of energy as neutrinos, magnetic fields and shock waves and destroying the star in the process. From Earth, this explosive event is observed as a supernova. If astronomers detect hydrogen, the event is classified as a Type II supernova. And if the hydrogen-emission line is narrow, the event is classified as a Type IIn (for “narrow”).

In the case of Type IIn events, scientists suspected that the narrow emission line occurs as light from the event passes through a thin sphere of hydrogen that was already surrounding the star before it went supernova. Some believed that the dying star might have shed this shell of material before it self-destructed, but until recently there was no evidence to link such an outburst to an actual supernova.

That’s where PTF comes in. For almost four years, the PTF team has relied on a robotic telescope mounted on the Palomar Observatory’s Samuel Oschin Telescope in Southern California to scan the sky nightly. As soon as observations were taken, the data travelled more than 400 miles to NERSC -- via the National Science Foundation’s High Performance Wireless Research and Education Network and the Department of Energy’s Energy Sciences Network (ESnet) -- where computers running software called the Real-Time Transient Detection Pipeline screened the data and identified events for astronomers to follow up on. NERSC also archived this data and allowed collaborators to access it over the Internet through a web-based science gateway, called DeepSky.

On August 25, 2010 the PTF pipeline detected a Type IIn supernova half a billion light years away in the constellation Hercules. Shortly after, Ofek led a search of previous PTF scans of the same stellar neighbourhood -- using a high-quality pipeline developed by Mark Sullivan, of the University of Southampton -- and found the supernova’s likely precursor, a massive variable star that had shed a huge amount of mass only 40 days before the supernova was detected. They labelled the event, SN 2010mc.

"After NERSC tools found SN 2010mc, we went back through the archives and found evidence of a previous outburst in the same location and knew that it blew some material out of the star before the final supernova," says Brad Cenko, a UC Berkeley postdoctoral researcher and co-author of the paper. "We’ve seen evidence of this happening before, but there have been only one or two cases where we’ve been able to conclusively say when the previous outburst happened."

Ofek and the PTF team developed a scenario and tested it against competing theoretical ideas, using evidence from several sky surveys that were triggered to observe SN 2010mc once it was detected by the NERSC pipeline. They concluded that the "penultimate outburst" had blown off a hundredth of a solar mass in a shell expanding 2,000 kilometres per second, already 7 billion kilometres away from the supernova when it exploded. Earlier ejecta were detected 10 billion kilometres away, having slowed to a hundred kilometres per second.

After the supernova explosion, high-velocity ejecta passing through shells of earlier debris left a record of varying brightness and spectral features. The observations pointed to the most likely theoretical model of what happened: turbulence-excited gravity waves drove successive episodes of mass loss, finally culminating in the collapse and explosion of the core. Because the stellar outburst occurred very shortly before the supernova, the astronomers suspected that the events were causally linked. Cenko notes that this could have important implications for what processes trigger a supernova.

"I think it is a very interesting object we found, and the way we do our survey and the search at NERSC made it something we were in the unique position to find," says Peter Nugent, a Berkeley Lab senior staff scientist and member of the PTF collaboration.

The Future

Once the team found SN 2010mc’s precursor, the team used Sullivan’s pipeline to sift through stellar neighbourhoods in the PTF archival data where other Type IIn supernovae had previously been detected. According to Nugent, this exercise helped the team identify several other similar cases.

"Although the PTF project is no longer collecting data every night, we are still relying on NERSC resources to sift through our archival data," says Nugent. "This recent discovery shows us that there is still a lot that we can learn from the archival data at NERSC, and gives us some insights into how we may design..."
Students and scholars of astronomy need little introduction to the life and work of the German-born English astronomer William Herschel (1738-1822). A true polymath, Herschel was a pioneer of the study of binary stars and nebulae, the discoverer of infrared radiation in sunlight, a skilled mathematician, optical lens grinder and telescope maker, a ground-breaking naturalist and a prolific classical composer. His discovery of the planet Uranus in 1781, as well as two of its moons and two more moons of Saturn, garnered him fame, acclaim and a place in astronomical history. However, not all of Herschel’s scientific work was equally well received, and not all his discoveries are as well known today.

One of Herschel’s key areas of study, and a subject of great fascination for him, was those stars that seemed to change their brightness: what we now call variable stars; and he was responsible for much of the progress made in the understanding of these distant suns. His son John Frederick W. Herschel wrote in the 1833 A Treatise on Astronomy that, thanks to his father’s catalogue of brightness of the stars in each constellation, ‘amateurs of the science with only good eyes, or moderate equipment, might employ their time to excellent advantage.’

In today’s science, we know why variable stars vary in brightness. But in Herschel’s time, this was still a source of some mystery. As he sought to understand why these stars appeared to change, he attempted to correlate the phenomenon with another that he had studied extensively, namely the existence of sunspots on our own planet’s nearest star. Herschel posed the hypothesis that these more distant suns might also possess spots, which perhaps were the cause of their vacillation from brightness to dimness. Just two centuries after Galileo had proposed that sunspots were dark clouds floating about in the solar atmosphere, Herschel shared the contemporary scientific view that the greater the number of spots on the Sun, the more these would block out the light energy radiated to earth: hence, the ‘spottier’ a variable star, the less bright it would appear from Earth.

Spurred on by the fact that he had perfected a telescope that gave him a view of the Sun whose clarity was unprecedented at the time, Herschel deepened his study of sunspots, and this led him to form a new and radical notion: the possibility of a correlation between the number of sunspots and Earth’s climate.

He had noticed that, between July 1795 and February 1800, there had been a number of days when there had been no sunspot activity at all. Then, they had suddenly returned in abundance. He wrote: ‘It appears to me . . . that our Sun has for some time past been labouring under a disposition, from which it is now in a fair way of recovering’. In 1801 he presented a paper to the Royal Society entitled ‘The Nature of the Sun’, in which he wrote: ‘I am now much inclined to believe that openings [sunspots] with great shallows, ridges, nodules and corrugations, instead of small indentation, may lead us to expect a copious emission of heat, and therefore mild seasons . . . A constant observation of the Sun with this view, and a proper information respecting the general mildness or severity of the seasons, in all parts of the world, may bring this theory to perfection or refute it if it be not well founded.’

But how was Herschel to back up his hypothesis? Hampered by the lack of precise meteorological records by which to test his theory, he persevered by lateral thinking. Given the effects of lesser or greater quantities of sunshine on vegetation, it struck him that records of good or bad harvests might provide him with the data he needed. Any correlation between these and periods of many or few sunspots would theoretically support his argument. Using Adam Smith’s The Wealth of Nations as his source, he was able to single out five periods when, due to poor harvests, the price of wheat in England had been particularly high. Comparing these records to those of sunspot activity during those periods, he discovered to his surprise a clear correlation between poorer wheat harvests and...
a relative lack of sunspot activity. Contrary to what had been thought until then, the presence of sunspots did not reduce the amount of heat from the Sun, the opposite was true: greater sunspot activity corresponded to good weather and lower wheat prices, while a lack of sunspots corresponded to high wheat prices, which implied less favourable weather. ‘It seems probable,’ he wrote, ‘that some temporary scarcity or defect of the vegetation has taken place when the Sun has been without those appearances which we surmise to be the symptoms of a copious emission of light and heat’. As we now know, the sun emits greater ultraviolet radiation, causing more heating of the Earth’s atmosphere, during periods of greater sunspot activity, or solar maximum. But in Herschel’s time this was a revolutionary idea – and the apparent correlation with Earth’s climate made it more revolutionary still.

Excited by his findings, Herschel urged his scientific colleagues to examine solar activity in more detail. Sadly, far from praising his discovery, his peers responded with scepticism and even ridicule. A piece in The Edinburgh Review lambasted his ‘erroneous theory concerning the influence of the solar spots and the price of grain’ as a ‘grand absurdity’. Clearly, the world was not ready to accept such stuff. For once in his illustrious career, the great William Herschel had fallen flat and his attempt to wake the scientific community to his radical idea had failed.

And even to this day, the prevailing views remain largely unchanged. While nobody would now dispute the correlation between solar activity and geometric disturbances on Earth – one only has to think of the SOHO Satellite and the data it sends back, containing potential warnings of increases in solar activity which could have a detrimental effect on such things as telecommunications systems – scientists have generally remained deeply sceptical of claims that there may be a correlation between solar activity and weather on Earth. One respected meteorologist in the 1960s warned that climate researchers risked branding themselves as cranks if they entertained any notion of Sun-weather relationships. And in the modern era of sensitive political debate over climate change and global warming, pointing at possible links between earthly weather and cycles of solar activity has become more charged and contentious than ever.

But the time may come when scientists will be forced to revise the orthodox view. Two hundred years after William Herschel urged the Fellows of the Royal Society to investigate the links between sunspots and Earth’s climate, Israeli scientists Dr Lev A Pustilnik and Dr Gregory Yom Din used modern statistical methods to re-examine Herschel’s ideas and concluded that the great astronomer had been right after all. The modern findings confirmed that wheat prices in England during that period did indeed fluctuate in line with solar activity, being higher at solar minimum than at solar maximum, suggesting that the crop was more difficult to grow when sunspot activity was at its lowest.

The implications of this finding go far deeper. In August 2012, scientists studying climate patterns in Central Europe, specifically the winter freezing patterns of the Rhine, revealed a striking correlation between unusually cold Central European winters and periods of low solar activity. The studies, headed by Frank Sirocko, Professor of Sedimentology and Paleoclimatology at the Institute of Geosciences of Johannes Gutenberg University, Mainz, Germany, suggest that the extremely cold European winters of 2010/11 were the result of the North Atlantic Oscillation which Sirocko and his team now link to the low solar activity during that time. Furthermore, the researchers found that out of fourteen episodes between 1780 and 1963 when, according to historical records, the Rhine is known to have frozen over, ten corresponded to periods of minimal sunspot activity – establishing for the first time a possible common link between very cold European winters of the last 230 years. The known 11-year cycle of solar activity makes it possible, according to these results, to predict to some degree how the number of sunspots at any given period could affect our climate on Earth. What first drew Professor Sirocko’s attention to this possibility was the fact that the 125-mile skating race he once attended in the Netherlands can only be held every 11 years, when the rivers freeze up. ‘There must be a reason for this,’ Sirocko remembers thinking, ‘and it turns out there is.”
Library Corner

By Tony Reynolds

The Usborne Book of Astronomy and Space
Lisa Miles, Alastair Smith

Just added to our youth section, this book is a fascinating yet practical beginner’s guide with an abundance of amazing photographs and realistic illustrations. It includes clearly explained activities, experiments, projects and internet links.

Catalogue section: Youth

 Featured Section – Youth

Our youth section is a wonderful store of books aimed at the younger reader, though the age group by no means constrains the subject matter. There is plenty in there to fascinate and educate everyone from the earliest readers (and even before if Dad does the reading) through to those ready to tackle more advance topics. It is also a good starting point for anyone beginning in astronomy as the books are well written, covering a wide array of topics and always fabulously illustrated.

Located in the lower left-hand shelf of the library.

New Acquisitions

The Planets
Dava Sobel

A signed copy following Dava’s recent visit to New Zealand.

This book traces the ‘lives’ of each member of our solar family, from myth and history, astrology and science fiction, to the latest data from the modern era’s robotic space probes. In lyrical prose interspersed with poems by Tennyson, Blake and others, ‘The Planets’ gives a breathtaking, intimate view of these heavenly bodies.

Catalogue section: QB601

Testing Einstein’s Famous Equation $E=mc^2$ in Outer Space

From Science Daily

University of Arizona physicist Andrei Lebed has stirred the physics community with an intriguing idea yet to be tested experimentally: The world’s most iconic equation, Albert Einstein’s $E=mc^2$, may be correct or not depending on where you are in space.

With the first explosions of atomic bombs, the world became witness to one of the most important and consequential principles in physics: Energy and mass, fundamentally speaking, are the same thing and can, in fact, be converted into each other.

This was first demonstrated by Albert Einstein’s Theory of Special Relativity and famously expressed in his iconic equation, $E=mc^2$, where $E$ stands for energy, $m$ for mass and $c$ for the speed of light (squared).

Although physicists have since validated Einstein’s equation in countless experiments and calculations, and many technologies including mobile phones and GPS navigation depend on it, University of Arizona physics professor Andrei Lebed has stirred the physics community by suggesting that $E=mc^2$ may not hold up in certain circumstances.

The key to Lebed’s argument lies in the very concept of mass itself. According to accepted paradigm, there is no difference between the mass of a moving object that can be defined in terms of its inertia, and the mass bestowed on that object by a gravitational field. In simple terms, the former, also called inertial mass, is what causes a car’s fender to bend upon impact of another vehicle, while the latter, called gravitational mass, is commonly referred to as “weight.”

This equivalence principle between the inertial and gravitational masses, introduced in classical physics by Galileo Galilei and in modern physics by Albert Einstein, has been confirmed with a very high level of accuracy. “But my calculations show that beyond a...
If one measures the weight of quantum objects, such as a hydrogen atom, often enough, the result will be the same in the vast majority of cases, but a tiny portion of those measurements give a different reading, in apparent violation of E=mc^2. This has physicists puzzled, but it could be explained if gravitational mass was not the same as inertial mass, which is a paradigm in physics.

"Most physicists disagree with this because they believe that gravitational mass exactly equals inertial mass," Lebed said. "But my point is that gravitational mass may not be equal to inertial mass due to some quantum effects in General Relativity, which is Einstein's theory of gravitation. To the best of my knowledge, nobody has ever proposed this before."

Lebed presented his calculations and their ramifications at the Marcel Grossmann Meeting in Stockholm last summer, where the community greeted them with equal amounts of scepticism and curiosity. Held every three years and attended by about 1,000 scientists from around the world, the conference focuses on the theoretical and experimental General Relativity, astrophysics and relativistic field theories. Lebed's results will be published in the conference proceedings in February.

In the meantime, Lebed has invited his peers to evaluate his calculations and suggested an experiment to test his conclusions, which he published in the world's largest collection of preprints at Cornell University Library (see Extra Info).

"The most important problem in physics is the Unifying Theory of Everything -- a theory that can describe all forces observed in nature," said Lebed. "The main problem toward such a theory is how to unite relativistic quantum mechanics and gravity. I try to make a connection between quantum objects and General Relativity."

The key to understand Lebed's reasoning is gravitation. On paper at least, he showed that while E=mc^2 always holds true for inertial mass, it doesn't always for gravitational mass.

"What this probably means is that gravitational mass is not the same as inertial," he said.

According to Einstein, gravitation is a result of a curvature in space itself. Think of a mattress on which several objects have been laid out, say, a ping pong ball, a baseball and a bowling ball. The ping pong ball will make no visible dent, the baseball will make a very small one and the bowling ball will sink into the foam. Stars and planets do the same thing to space. The larger an object's mass, the larger of a dent it will make into the fabric of space.

In other words, the more mass, the stronger the gravitational pull. In this conceptual model of gravitation, it is easy to see how a small object, like an asteroid wandering through space, eventually would get caught in the depression of a planet, trapped in its gravitational field.

"Space has a curvature," Lebed said. "And when you move a mass in space, this curvature disturbs this motion."

According to the UA physicist, the curvature of space is what makes gravitational mass different from inertial mass.

Lebed suggested to test his idea by measuring the weight of the simplest quantum object: a single hydrogen atom, which only consists of a nucleus, a single proton and a lone electron orbiting the nucleus. Because he expects the effect to be extremely small, lots of hydrogen atoms would be needed.

Here is the idea:

On a rare occasion, the electron whizzing around the atom's nucleus jumps to a higher energy level, which can roughly be thought of as a wider orbit. Within a short time, the electron falls back onto its previous energy level. According to E=mc^2, the hydrogen atom's mass will change along with the change in energy level.

So far, so good. But what would happen if we moved that same atom away from Earth, where space is no longer curved, but flat? You guessed it: The electron could not jump to higher energy levels because in flat space it would be confined to its primary energy level. There is no jumping around in flat space.

"In this case, the electron can occupy only the first level of the hydrogen atom," Lebed explained. "It doesn't feel the curvature of gravitation."

"Then we move it close to Earth's gravitational field, and because of the curvature of space, there is a probability of that electron jumping from the first level to the second. And now the mass will be different."

"People have done calculations of energy levels here on Earth, but that gives you nothing because the curvature stays the same, so there is no perturbation," Lebed said. "But what they didn't take into account before that opportunity of that electron to jump from the first to the second level because the curvature disturbs the atom."

"Instead of measuring weight directly, we would detect these energy switching events, which would make themselves known as emitted photons -- essentially, light," he explained.

Lebed suggested the following experiment to test his hypothesis: Send a small spacecraft with a tank of hydrogen and a sensitive photo detector onto a journey into space.

In outer space, the relationship between mass and energy is the same for the atom, but only because the flat space doesn't permit the electron to change energy levels.

"When we're close to Earth, the curvature of space disturbs the atom, and there is a probability for the electron to jump, thereby emitting a photon that is registered by the detector," he said.

Depending on the energy level, the relationship between mass and energy is no longer fixed under the influence of a gravitational field.

Lebed said the spacecraft would not have to go very far.

"We'd have to send the probe out two or three times the radius of Earth, and it will work."

According to Lebed, his work is the first proposition to test the combination of quantum mechanics and Einstein's theory of gravity in the solar system.

"There are no direct tests on the marriage of those two theories," he said. "It is important not only from the point of view that gravitational mass is not equal to inertial mass, but also because many see this marriage as some kind of monster. I would like to test this marriage. I want to see whether it works or not."
Observing Notes March 2013

By Alan Gilmore

Jupiter is the 'evening star', appearing in the northwest soon after sunset and setting around 11 pm mid month. Jupiter slips steadily lower as we move to the far side of the Sun from it. Jupiter shows a disk with its four bright 'Galilean' moons lined up on either side. Jupiter is 800 million km from us in March.

Saturn is in the east at dusk, on the opposite side of the sky to Jupiter. Saturn looks like a bright star in an empty region of sky. Above and left of it is Spica the brightest star in Virgo. A telescope magnifying 20x shows Saturn's rings. Its largest moon, Titan, is four ring-diameters from the planet. Large telescopes will show fainter moons, mostly closer to Saturn than Titan. Saturn is 1360 million km away in mid March.

Sirius is the brightest star in the sky though fainter than Jupiter. It appears at dusk, northwest of overhead. It is quickly followed by Canopus, southwest of the zenith. Below Sirius are Rigel and 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'. Orion's belt points down and left to a V-shaped pattern of stars above Jupiter. These make the face of Taurus the Bull. Aldebaran is the orange star above Jupiter. Its name is Arabic for the eye of the bull. Below Jupiter, low in the northeast, is the Pleiades or Matariki star cluster, setting early.

Sirius is the brightest star in the sky both because it is relatively close, nine light years* away, and 23 times brighter than the Sun. Rigel, above and left of Orion's belt, is a bluish supergiant star, 40 000 times brighter than the Sun and much hotter. It is 800 light years away. Orange Betelgeuse, below and right of the line of three, is a red-giant star, cooler than the Sun but much bigger and 9000 times brighter. It is 400 light years from us. The handle of "The Pot", or Orion's sword, has the Orion Nebula at its centre; a glowing gas cloud many light-years across and 1300 light years away.

Near the north skyline are Pollux and Castor marking the heads of Gemini the twins. Right of them and higher is the star cluster Praesepe, marking the shell of Cancer the crab. Praesepe is also called the Beehive cluster, the reason obvious when it is viewed in binoculars. It is 500 light years away. Young clusters, like the Pleiades/Matariki cluster have bright stars in them. The bright stars burn out after 100 million years or so. Old clusters like Praesepe have no bright stars.

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. Beta Centauri, like most of the stars in Crux, is a blue-giant star hundreds of light years away. 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 becomes broader lower in the southeast toward Scorpius. Above Crux the Milky Way can be traced to nearly overhead where it fades. It becomes very faint in the north, 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 begins its best morning sky appearance of the year during March. At the middle of the month it rises due east at dawn. It looks like a moderately bright star. It remains in the morning sky through April. Mercury is a tiny object in a telescope. It looks like a crescent Moon in March, waxing toward full in April. Venus and Mars are on the other side of the Sun so hidden this month.

*A light year (l.y.) is the distance that light travels in one year: nearly 10 million million km or 10^{13} km. Sunlight takes eight minutes to get here; moonlight about one second. Sunlight reaches Neptune, the outermost major planet, in four hours. It takes four years to reach the nearest star, Alpha Centauri.

*A light year (l.y.) is the distance that light travels in one year: nearly 10 million million km. Sunlight takes eight minutes to get here; moonlight about one second. Sunlight reaches Neptune, the outermost major planet, in four hours. It takes sunlight four years to reach the nearest star, Alpha Centauri.
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.

Jupiter is the ‘evening star’, appearing in the northwest at dusk and setting around 11 pm. Medium-bright Saturn appears on the horizon opposite to Jupiter. Sirius is the brightest true star, northwest of overhead. Canopus, the second brightest star, is southwest of overhead. Orion, containing ‘The Pot’, is below Sirius in the northwest sky. Above Jupiter is the V of stars making the face of Taurus the bull. Below Jupiter is the Pleiades/Matariki star cluster, setting early. The Southern Cross and the Pointers are midway up the southeast sky. Nearby galaxies the Clouds of Magellan, LMC and SMC, are high in the south sky. The Scorpion rises in the southeast later.
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