ScienceWise

SCIENCE MAGAZINE OF THE AUSTRALIAN NATIONAL UNIVERSITY

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Astronomy Special Edition

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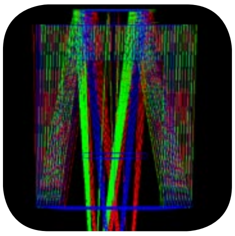

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Cover Image
The Andromeda galaxy by Adam Block/NOAO/AURA/NSF

The Editor's corner

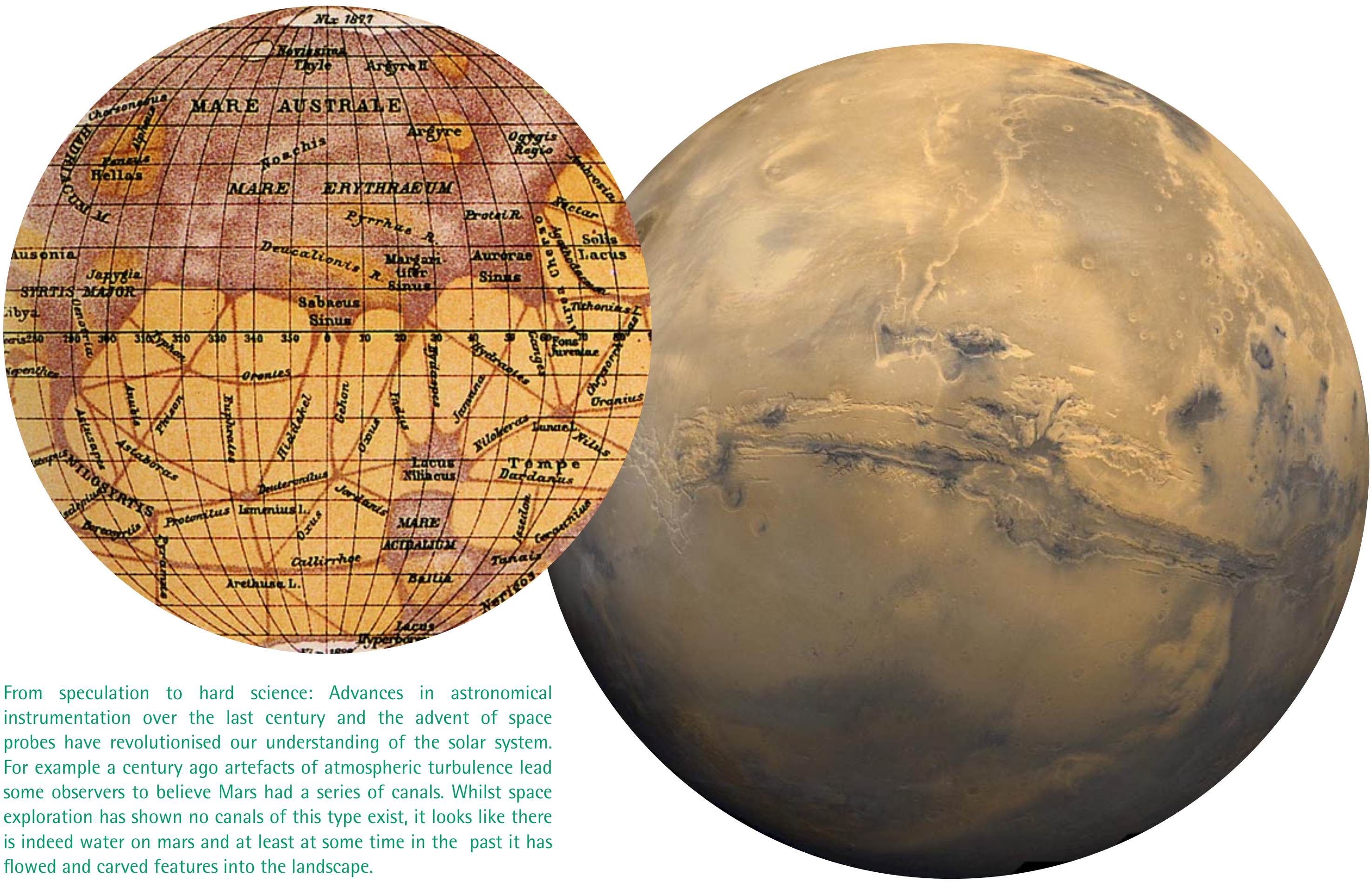
Welcome to the Astronomy Special

Dr Tim Wetherell

The beginning of the twenty first century is probably one of the most exciting times there has ever been in the history of astronomy. The power and optical finesse of modern research telescopes is enabling scientists to gather data in sufficient quantity and quality to build and test detailed models of cosmology and the processes of star and planet formation. Radio, x-ray and optical astronomy are combining to create images of astronomical objects in unprecedented detail. At the same time data from space probes is expanding our knowledge of our own solar system to a degree that would have been unimaginable a century ago.

Back then, the surfaces of other planets and their satellites were known only as vague drawings that inspired intense debate amongst astronomers over martian canals and the solid surface of Jupiter. Now we have topological maps with resolutions of a few metres. We have spectroscopic data yielding information about the chemical composition of atmospheres and surfaces throughout the solar system. That's in no way to belittle astronomers of the past. The data they extracted from limited instruments and the science they deduced from it were truly remarkable. The efforts of Edwin Hubble, Clyde Tombaugh, Henrietta Swan Leavitt and many others lay the foundations of modern astronomy. But inevitably the better the data you have, the more science you can do with it. To the prospective research student in astronomy today, there are a wealth of potential projects offering opportunities to be involved at the start of numerous rapidly expanding fields.

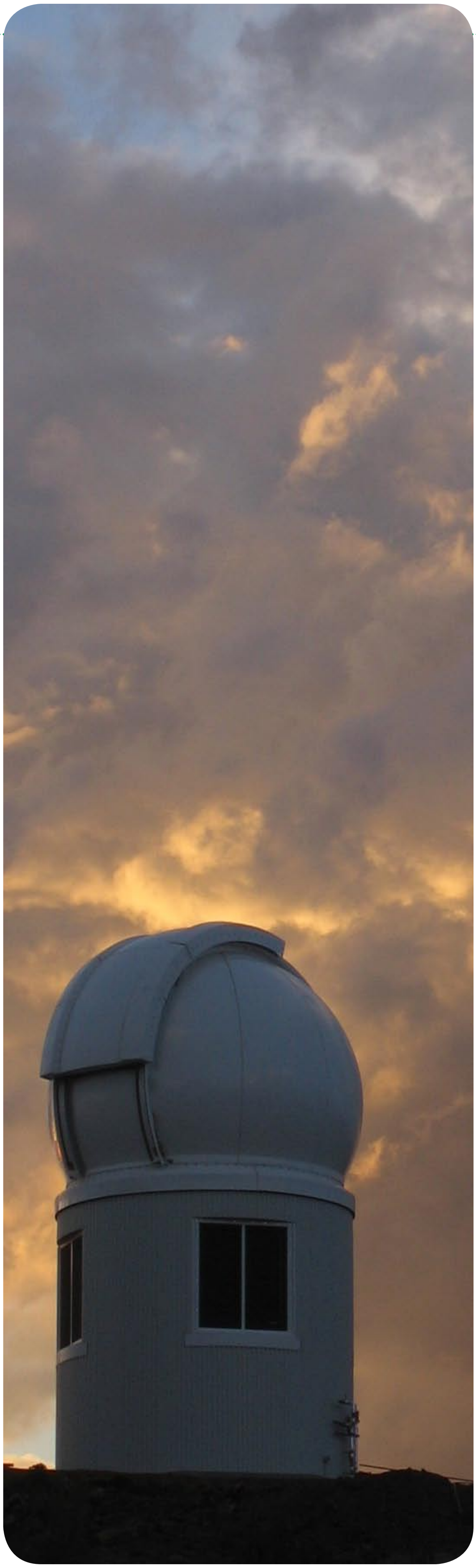
In this magazine we look at just a few of the exciting astronomy research projects currently underway at The Australian National University and its partner organisations.



From speculation to hard science: Advances in astronomical instrumentation over the last century and the advent of space probes have revolutionised our understanding of the solar system. For example a century ago artefacts of atmospheric turbulence lead some observers to believe Mars had a series of canals. Whilst space exploration has shown no canals of this type exist, it looks like there is indeed water on mars and at least at some time in the past it has flowed and carved features into the landscape.

SkyMapper

State-of-the-art Facility Begins Survey of the Southern Sky



Mount Stromlo Observatory had just refitted the historic Great Melbourne Telescope as an automated sky survey instrument when the 2003 Canberra bushfires swept through the area. These devastating fires destroyed the Great Melbourne Telescope along with many other instruments. Although a research setback, this also presented an opportunity to design a state-of-the-art replacement survey telescope - SkyMapper. Growing light pollution in Canberra and improvements in communications technologies led to the decision to site SkyMapper under the pristine skies of Siding Spring Observatory near Coonabarabran.

Skymapper represents the state of the art both in terms of the 1.35m diameter f4.79 modified Cassegrain optics and the 268 megapixel detector designed and built at The Australian National University. The instrument also has the advantage of being designed as a stand alone automated survey instrument from the outset. So the design isn't compromised by requirements to perform other kinds of astronomy.

The aspheric mirrors, and a sophisticated mirror alignment system give the telescope a wide field of view free of distortions, such as coma and spherical aberration that would normally render such a fast optical system useless. "Normally when a telescope looks at the sky, it looks at a narrow patch which is about a hundredth the size of a full moon," Project leader Professor Brian Schmidt explains. "SkyMapper will look at a piece of sky 40 times larger than the full moon. In addition, there will be huge digital cameras behind them that are 100 times more sensitive than normal cameras."

Data will be transmitted at a rate of 100 Megabytes a second to The ANU supercomputer facility for processing. The telescope will be fully automated, with the astronomers working from the Mount Stromlo Observatory.

SkyMapper's main task will be to conduct the first ever systematic survey of the entire southern sky to produce a detailed digital map.

Since SkyMapper will be sensitive enough to pick up some of the most distant and faintest objects, the chart will have a deep time dimension. Because of the time it takes light waves to reach Earth, the Southern Sky Survey will enable astronomers to look back to the time soon after the Big Bang when the first stars' nuclear fusion reactions set the primeval universe ablaze. This was the time when stars were beginning to manufacture the heavy elements from hydrogen, including iron and the element that billions of years later would form the basis of life on Earth.

As well as information on brightness, position and shape of celestial objects, SkyMapper's survey will also record the spectral types of stars. To achieve this, a series of six glass filters each about 300mm square will be automatically inserted in sequence during each exposure. The filters isolate various wavelength bands from ultra-violet to the near infra-red. Of course design of this system is more complex that it at first sounds because each filter must have superb uniformity in order for images recorded at different times and orientations to be meaningfully compared. "This wavelength discrimination facility will enable scientists to pinpoint stars with low concentrations of heavy elements," says ANU astronomer Stefan Keller. "Successive generations of stars return heavy elements to the interstellar gas and this is incorporated in future stars, SkyMapper will search for stars with the lowest proportion of heavy elements to find the oldest stars. These will give us insight into the way the universe was first lit up by stars and how galaxies form. This is the real niche of SkyMapper. These stars are very rare – about 100 in a billion."

Another project will centre on objects almost on our doorstep – lumps of rock heavier than Pluto and variously catalogued as planetoids, trans-Neptunian objects and dwarf planets.

"Most observations of our solar system so far have focused on the orbital plane of the planets," says Stefan Keller. "Skymapper will look far beyond that and has the potential to detect the biggest planetoids."

A manageable distilled version of the Southern Sky Survey will provide a publicly available set of images of all the stars, galaxies, and nebulae in our celestial hemisphere, as well as a database containing the accurate colour, position, brightness, variability, and shape of every one of the billions of objects in the southern sky.

Unpacking the primary mirror on site

Dr. Stefan Keller of the Research School of Astronomy and Astrophysics inside the Skymapper dome

The SkyMapper survey will be used by astronomers across Australia and around the world to undertake a multitude of projects including:

• Uncovering the most distant objects known in the universe – the first quasars that we think formed when the universe was 3% of its current age.

• Discovering large dwarf planets like Pluto in the outer solar system.

• Obtaining a comprehensive map census of the stars in our Galaxy, providing the temperature, composition, and size of more than a billion objects.

• Providing our best map of the invisible material (known as dark matter) which makes up the majority of our galaxy using samples of very rare stars uncovered in the survey.

• Pinpointing the first stars that formed in our galaxy 13 billion years ago by their chemical composition.

Sticking to the Stars

The Complex Processes Creating Accretion Discs

Artist's impression of an accretion disk forming a protostar and planets

Modern astronomers believe that stars are born in the dense cores of molecular clouds, essentially regions of space with relatively high density gas and dust, such as those in the famous Orion nebula. Within such nebulae, the interplay between turbulent flow, magnetic fields and shock waves from nearby supernovae explosions may result in the formation of a region with slightly higher density than the surrounding medium. This dense region then begins to gravitationally draw material from the cloud in a process astronomers call accretion.

However the process is far more complex than it might at first sight, appear. The individual particles in the cloud are all moving and the cloud generally has a net angular momentum. The laws of physics dictate that this angular momentum must be conserved which means that as material is drawn towards the forming protostar, it spins faster and faster like water flowing down a plug hole. It also means that the inflow occurs preferentially in the direction perpendicular to the plane of rotation, so the inwardly spiralling material forms a flattened disk with the protostar at the centre. However, there comes a point where the speed of rotation within the disk is so fast that centrifugal force prevents any further inward motion and the disc becomes rotationally supported. This is exactly the situation with all bodies in stable orbits including our own planet. The Earth is unable to move closer to the sun without shedding some of its angular momentum and fortunately for us, it has no way to do this. But it is exactly this kind of orbital stability that nature has to overcome if stars such as the sun are to form in the first place. How this is possible within physics of accretion disks is a question of special interest to Dr Raquel Salmeron of the ANU Research School of Astronomy and Astrophysics and Research School of Earth Sciences. Dr Salmeron is developing a novel theoretical model of accretion that incorporates a more comprehensive range of processes than has previously been used. Dr Salmeron explains that angular momentum lies at the core of disk dynamics and in order to understand angular momentum transport, it is essential to look closely at the microphysics, in other words, at the detailed dynamical processes in the gas and the interaction of the gas with the magnetic field.

A very small number of the atoms in the accretion disk surrounding a protostar are ionised by interstellar cosmic rays or radiation from the central object and/or a nearby star. The motion of these charged particles (ions and electrons) leads to the generation of magnetic fields which in turn influence the paths of the charged particles themselves. The process is immensely complex and far from well understood, but astronomers know the disc to be weakly magnetised. Furthermore, collisions between ions and neutral atoms also cause indirect linkage between neutral atoms and the magnetic field. Dr Salmeron believes that understanding and accurately modelling these interactions is the key to answering fundamental questions about the physics of accretion.

Depending on the density of the gas and the number of charged particles within it, there are different kinds of diffusion processes (essentially the `slippage' between the neutral gas and the magnetic field) that can occur. Two of them, in particular, have formed the basis for existing theoretical models. In very low density regions the charged ions and electrons can move with the magnetic field lines without much interaction with the surrounding neutral atoms because they hardly ever run into them - the so called ambipolar diffusion process. On the contrary, when the gas density is very high, they collide with neutrals so frequently that this process dominates their behaviour - the Ohmic diffusion limit.

Dr Salmeron's own research focuses on incorporating a third and largely neglected diffusion process, Hall diffusion. This occurs at intermediate densities where the small, fast electrons are able to follow field lines relatively freely whilst the much larger ions experience multiple collisions with neutrals. It's rather like the way an army of ants can move through a heard of elephants without bumping into too many of them, where as two herds of elephants simply can't cross paths without mayhem resulting. According to Dr Salmeron all three diffusion processes are often at work in different regions within a stellar accretion disk, and that it is the interplay of these processes, driven by the magnetic field, that dictates the overall behaviour of the system.

The complex picture that emerges is of a swirling disk of matter surrounding a protostar, gradually offloading a large proportion of its angular momentum through complex ion/magnetic field interactions and collisions with neutral atoms. This leads to a small amount of disk matter moving outwards and carrying away the excess angular momentum, so that most of the mass can slow down and spiral inwards towards the forming star. Depending on the magnetic field strength, the matter can move radially out, like water spun out of washing, or can be ejected vertically in what is known as disk wind. One interesting feature of disk wind is that the ejected material often forms what are known as jets - intense energetic flows of matter at right angles to the system.

Astronomers can observe such disks and jets in some nearby forming stars but with current technology telescopes, resolving the details of the process is tantalisingly out of reach. Dr Salmeron hopes that completion of new generation instruments such as the Atacama Large Millimetre Array under construction in Chile may provide the observational data required to test and refine current accretion theories.

The accretion process underlies all star and planet formation in the universe and determines how matter enters black holes such as those believed to lie at the centre of many galaxies. Consequently, understanding accretion is one of the fundamental topics in astronomy today.

Dr Raquel Salmeron

Hubble Space Telescope view of the great nebula in Orion, a region of stellar formation - Image NASA

By the Light of Exploding Stars

How Supernova Data Suggest the Expansion of the Universe is Accelerating

On casually glancing into the night sky, one might imagine that the brightest stars are the closest and dimmer ones are more remote. However the inherent brightness of stars varies by a factor of many millions, depending on their age, mass and other characteristics. The closest star to the Earth (other than the Sun) is Proxima Centauri – a dim dwarf completely invisible to the naked eye, yet the second brightest star in the entire sky, Canopus, is almost a hundred times more distant than Proxima.

For these reasons, establishing the scale of the universe is a far from simple task and the first accurate measurements of stellar distances were not made until the nineteenth century. These used a method called parallax, based on the 300 million kilometre difference in the Earth's position as it orbits the Sun. This changing viewpoint causes stars that are fairly close to the Earth to appear to shift slightly against the background of far more distant stars. The shift is tiny, but measurable. The nice thing about parallax is that it is a simple and therefore reliable geometric measurement but it only works for relatively close objects. For greater distances, astronomers must rely on what are known as 'standard candles' – that is objects whose inherent brightness is known, or at least believed to be known. If you know how bright something really is and you can measure how bright it appears, you can work out the distance by the inverse square law.

One useful set of standard candles are Cepheid variable stars. In the late nineteenth century, Henrietta Swan Leavitt studied Cepheids that form part of the Large Magellanic Cloud – a small satellite galaxy of the Milky Way. Because they were all in one galaxy and therefore all at essentially the same distance, she was able to accurately estimate their absolute brightness relative to each other. She noticed that there is a direct relationship between how intrinsically bright a Cepheid is and its period. This means that by measuring the apparent brightness and periods of Cepheids, astronomers can determine their distance far beyond the range of parallax. However, even the most distant Cephieds observable are not that far away in cosmic terms. For huge distances, astronomers have to use brighter and more distant standard candles such as entire galaxies, though the absolute brightness of such objects is not known with nearly the same certainty as that of Cepheids.

Hubble Space Telescope-Image of a type Ia Supernova SN1994D (bright star at lower left) in galaxy NGC 4526. For a brief period, this single star outshone the rest of its galaxy.

In the early twentieth century, with the advent of spectroscopy, astronomers were able to measure both the distance and the relative velocity of objects by observing how far their light was red shifted by the Doppler effect. By combining the distance and velocity information astronomers concluded that almost everything in the universe is receding from us. Edwin Hubble, after whom the famous space telescope is named, noticed that the greater the distance of an object, the faster the object seems to be moving away.

Knowing the velocities and distances of stars and galaxies, one can extrapolate back to the big bang and in this way, estimate an age for the universe. Having done this, a natural question to ask would be what will happen in the future? Will the combined gravity of all the matter in the universe eventually slow the expansion enough to collapse everything back to a big crunch, or will the universe expand forever?

This is a question that fascinates Professor Brian Schmidt of the ANU Research School of Astronomy and Astrophysics. To answer it, Professor Schmidt's research group have been measuring the velocities and distances of objects at far greater distances than that at which Cepheid variables could be observed. Entire galaxies can be used as standard candles and can be seen at great distances but it's hard to be sure about their inherent brightness, which in turn makes estimating their distance unreliable. To get around this, the group focused their attention on what are known as type Ia supernovae.

A type Ia supernova can occur in stars similar to the Sun. These are not massive enough to enable gravity to compress and heat the core past the point of burning its nuclear fuel to carbon and oxygen. Since iron is the lowest point in nuclear potential, such stars still contain massive amounts of nuclear fuel when the reactions stop. However, if the star is part of a binary pair, it can continue to siphon material off its companion once its own reactions cease, growing in mass until a critical point is reached where gravitational contraction enables carbon and oxygen to begin to fuse into heavier elements. Once this process begins to happen, it happens all at once, like in a nuclear bomb - liberating a huge amount of energy in a short time.

The special thing about type Ia supernovae is that they only occur in stars within quite narrow mass ranges which in turn means that they are all of similar brightness when they explode. This, coupled with their huge brightness, make them ideal as standard candles for extreme distances.

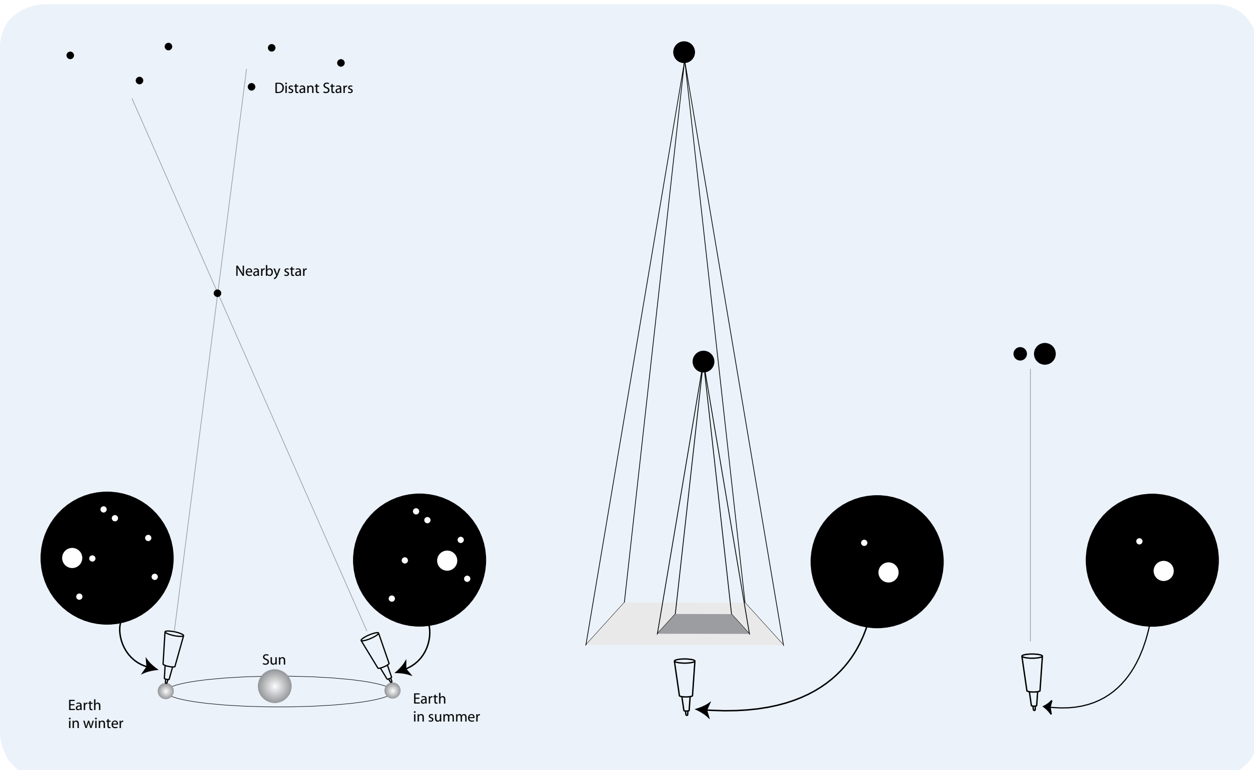
The group have been studying these supernovae for several years and having analysed their data, have come to the surprising conclusion that far from slowing down, the rate of expansion of the universe is actually speeding up. This counter intuitive scenario would have seemed almost inconceivable a few years ago. Professor Schmidt explains that our observations may really mean one of three things:

• The Exciting: the Universe is accelerating. The Universe is accelerated by some unknown type of matter that is spread throughout the Cosmos.

• The Heretical: General Relativity is as sacred as anything in Physics, but it may be wrong. Since our work is comparing the predictions of General Relativity with observations, if General Relativity is wrong, so are our conclusions.

• The Mundane (at least from our point of view): We are simply wrong and have been fooled by supernovae into believing the Universe is accelerating. Maybe supernovae are fainter in the past, and therefore look further away.

"We hope and believe it's the first alternative, but we have to work hard and test to see if it isn't the second or third. Checking these two other alternatives is a major focus of our current work".



Parallax distance measurements are based on the tiny shift seen in the position of nearby stars as the Earth orbits the Sun. Because this is a simple geometric measurement, it is highly reliable - The difficulty is that it only works for nearby stars because at large distances the shift becomes too small to measure.

Light spreads out according to the inverse square law so the light of a star becomes dimmer as it's distance increases. If a star's absolute brightness is known its distance can be calculated from its apparent brightness. This only works for a small number of star types whose absolute brightness can be calculated from their other physical properties. The method doesn't work with just any star because a dim and bright star at the same distance will look exactly the same through a telescope as two identical stars at different distances.

Watching the Skies

The Search for Potentially Hazardous Asteroids

In 1980, Luis and Walter Alvarez presented geological evidence that an asteroid about 10 km in diameter hit the Earth 65 million years ago, and wiped out the dinosaurs. Could such an event happen again, this time wiping out civilisation as we know it? Evidently planets get hit regularly by space rocks, for only 14 years later, in 1994, astronomers all over the world watched as fragments of comet Shoemaker-Levy-9 ploughed into Jupiter, producing huge fire-balls and long-lived disturbances in the Jovian atmosphere as large as the Earth.

Shortly after the Jovian impacts, the US Congress concluded that while such events may not happen very often, when they do the consequences are quite unacceptable! NASA was mandated to carry out a survey to find and determine the orbits of essentially all asteroids and comets that might someday hit the Earth with catastrophic effect. That survey is now nearing completion, having found an estimated 90% of all such potentially hazardous objects.

ANU's Research School of Astronomy and Astrophysics joined NASA's effort early in the survey. We teamed up with the University of Arizona in Tucson to provide both northern and southern sky coverage. Our project has used a 0.4m Schmidt telescope at Mt Bigelow near Tucson, together with the ANU's 0.5m Uppsala Schmidt telescope at Siding Spring near Coonabarabran. Both telescopes have been outfitted with identical CCD detectors and data handling software. Every clear, dark night, the two instruments have searched the skies for faint, rapidly moving, stellar-like images that betray a space rock moving past the Earth. Discoveries are relayed to the Minor Planet Center in Cambridge, Massachusetts, which sends the initial observational information to observers around the world for confirmation and for orbit calculation, so one can quickly determine whether the objects really do pose a danger to the Earth. The observed brightness and distance, together with an assumption about the reflectivity (albedo) of the object, give an idea of how large it may be.

How large is dangerous? The orbit tells us how fast it is moving, and therefore how much energy it might release upon impact onto the surface of the Earth. Sixty years of nuclear bomb research has also taught us a lot about the consequences of depositing large amounts of energy in a very short period of time at the Earth's surface. Indeed, that is essentially the basis of the conclusion that a 10km asteroid could have caused the demise of the dinosaurs.

How much smaller could a typical space rock be and still cause catastrophic damage? An asteroid or cometary nucleus about one kilometre in diameter is likely throw up enough material at impact that the Earth would enter a period of darkness long enough to cause global scale crop failure! Our survey has therefore been focused on detecting space rocks one kilometre and larger in diameter.

Astronomer Rob McNaught leads the asteroid survey project at Siding Spring. He is shown here standing next to the survey instrument, ANU's Uppsala Schmidt telescope.

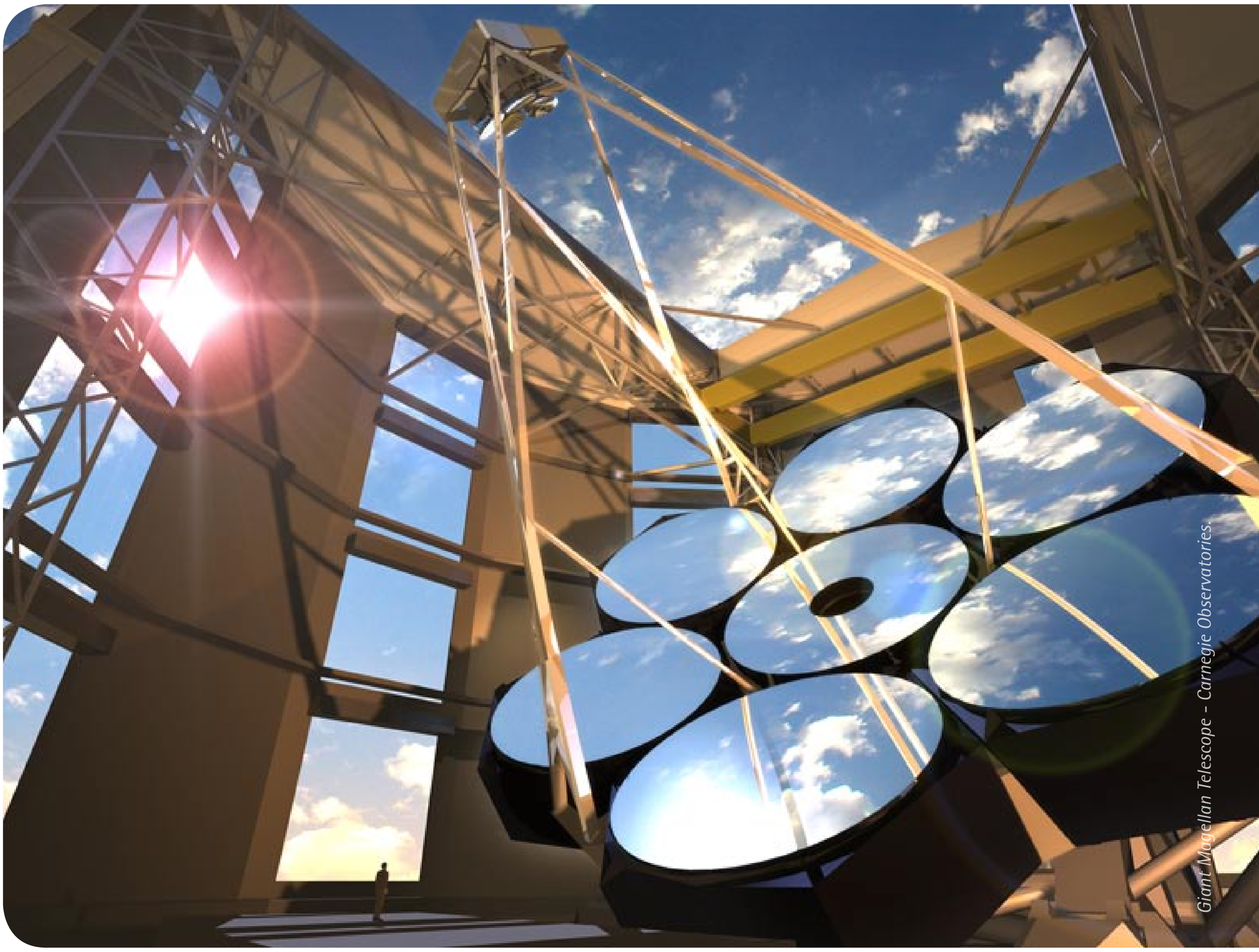
How many such rocks are there that could hit the Earth? All told, more than 5000 objects have been found that regularly come closer than twenty times the distance to the Moon. Such objects have orbits that in principle might be disturbed by the Earth, Moon or other planets, causing their orbit to veer close to the Earth. About 1000 of the 5000 have diameters of a kilometre or larger.

How often could we expect one of the latter to impact the Earth? On statistical grounds one estimates a serious impact every few hundred thousand years. But statistics aren't very interesting in this case. More important is the result of our survey, that none (thank goodness!) is expected to hit the Earth any time soon!

There are many more small space rocks than large ones, and the smaller the size the more often the collisions. Last year, our Arizona teammates discovered a 2 metre sized object, dubbed 2008 TC3, and we provided confirmation showing that it would indeed hit the Earth. Some 20 hours after its discovery it was observed to fall to Earth in the Sudan, making it the first space rock (meteorite) to be discovered before impact. The 26 March 2009 issue of Nature (p. 485) presents a detailed study of its entry into the atmosphere and an analysis of the meteoritic fragments.

New Window on the Universe

Creating the World's Most Powerful Telescope



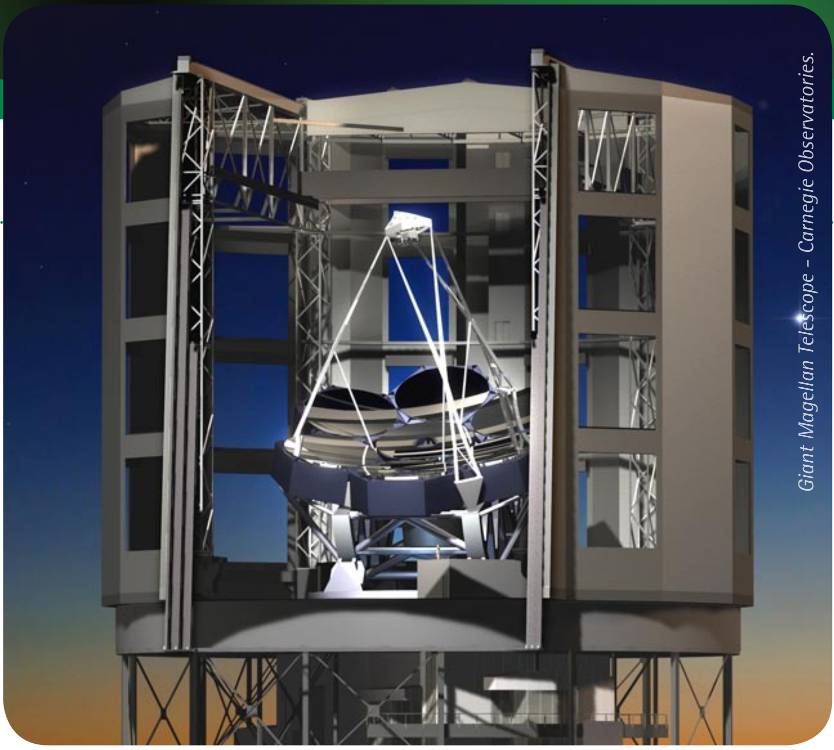
The Giant Magellan Telescope will be built by a consortium of The Australian National University, Carnegie Institution of Washington, Harvard University, Smithsonian Astrophysical Observatory, Texas A&M University, University of Arizona, The University of Texas at Austin.

Following the destruction of the Mt Stromlo observatory in the 2003 bushfires the then Director, Professor Penny Sackett was faced with a difficult decision; what was the best way forward?

Her solution was bold and innovative. Rather than rebuild facilities on the increasingly light polluted site at Stromlo, she opted for two major new telescopes. The Skymapper, to be built under the pristine skys of the University's Siding Spring Observatory – this instrument will complete a survey of the entire southern sky in unprecedented detail. And second to enter into a partnership with a consortium of other leading institutions to create what will be the most powerful telescope the world has yet seen; the GMT or Giant Magellan Telescope.

The advanced capabilities of the GMT will come from its enormous aperture. Seven 8.4 metre diameter mirrors will be used in combination to create a single gigantic 24.5 metre optic. Large size is important because the power of a telescope is dictated by the aperture of its primary mirror. The bigger the mirror the more light it collects and therefore, the fainter the objects it can see. But a large mirror also has another less obvious advantage. The laws of physics limit the maximum resolution of any

Professor Penny Sackett

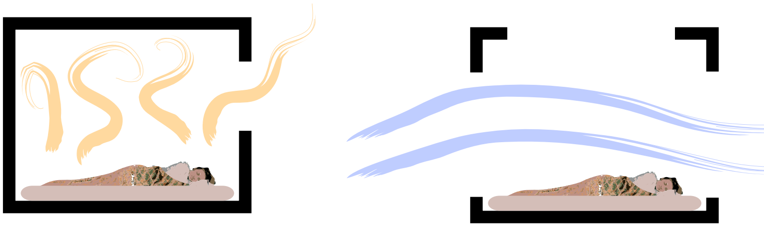


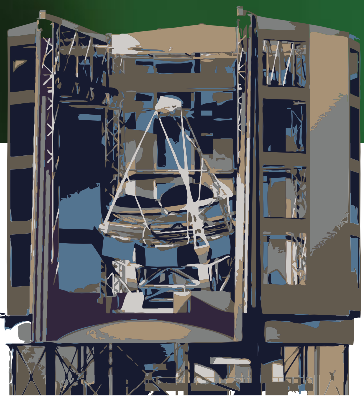
Giant Magellan Telescope - Carnegie Observatories.

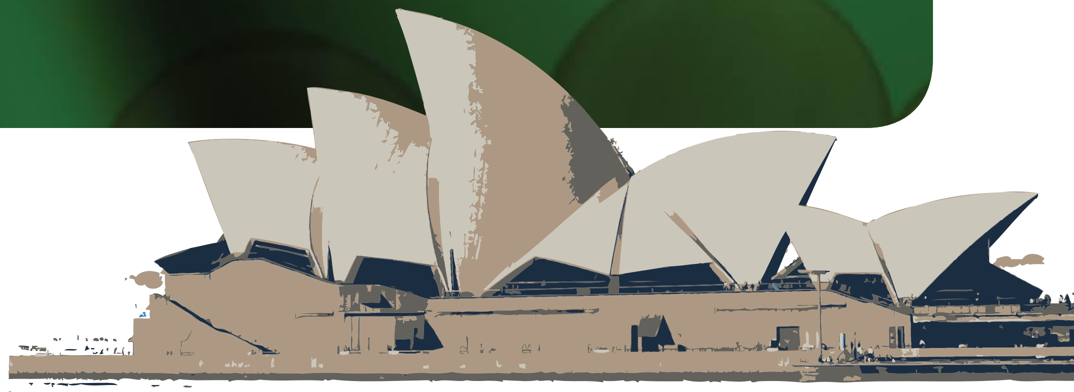
optical device. Diffraction from the edge of the aperture defines the smallest spot that can be focussed at any given wavelength – the so called Airy Disc. For a typical amateur telescope with a 200mm aperture this limit is roughly half an arcsecond, or 1/7200th of a degree. This means that the telescope can just resolve two stars separated by this amount (or see planetary features of this size). The Hubble Space telescope has ten times this aperture and hence ten times this resolution. That might not sound like a huge improvement, but because the finer resolution is along both x and y axis, the result is squared. In fact it's the same difference in imaging capability as that between a 5 mega pixel digital camera and a 50k web cam. The GMT has the potential to achieve ten times more resolution than Hubble, but to do this, the problems introduced by the Earth's atmosphere have to be overcome.

Air is almost totally transparent at optical wavelengths but its refractive index varies with temperature and pressure. Since the atmosphere is a seething mass of turbulence and winds, the effect is to distort incoming starlight. It's as though we are looking up from the bottom of a swimming pool. We see outside but the image is rippling and moving constantly. Astronomers call this natural seeing, and for a typical location, it limits the resolving power of any telescope to about one arcsecond. If left unchecked this would mean that the largest professional telescope would have no better resolution that the average amateur scope. However in the past couple of decades, scientists have been developing adaptive optics that cancel out these atmospheric distortions.

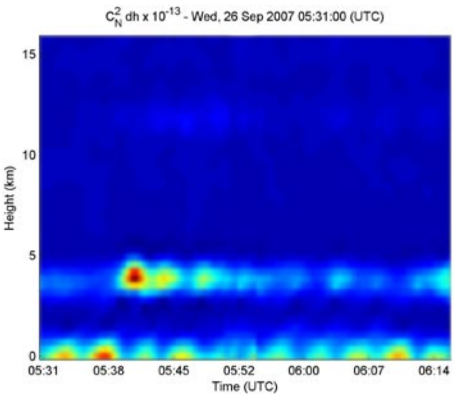
Conventional observatory domes tend to trap warm air which creates turbulent eddy currents in their apertures. This warm turbulent air degrades a telescopes ability to resolve fine detail. Open structures take less time to come to equilibrium and often offer superior views. It's a bit like sleeping with your bedroom window open on a hot night verses sleeping on the open verandah.







Imagine a structure as big as the Sydney Opera House, but one that can rotate and point a thousand ton telescope to any point in the sky with a precision of a millionth of a degree.



Before an adaptive optics system can be designed, it's important to know what the local atmospheric conditions are like. Dr Charles Jenkins from the Mt Stromlo Observatory has developed a system for measuring the extent of turbulence at different heights. The image of a closely separated double star such as Alpha Centauri is monitored in real time whilst an aperture mask blocks part of the incoming light. By the use of trigonometry, and monitoring which parts of the image of the two stars move in synch and which do not, it is possible to determine the altitude of the turbulence. The plot above shows data from the Las Campanas site. There is a narrow band of ground turbulence then for most of the time, very little distortion from the remainder of the atmosphere.

The basic principle of adaptive optics is to monitor the light coming from a star close to the object one is observing. In the absence of the atmosphere, the image should be an almost stationary, infinitesimally small point of light. However turbulence and distortion smears this out into a dancing blob. By using multiple actuators to distort the surface of a flexible optical element in the telescope and intelligent computer control, it is possible to cancel out most of the distortion. Of course as with all corrective systems, the better the material you begin with, the better the outcome. For this reason the GMT will be sited at Las Campanas Observatory in Chile. This site has high elevation, and very steady skies with a natural seeing often approaching 0.4 arcseconds – some of the best in the world.

Professor Sackett explains, "The GMT offers some very exciting research possibilities because of both its enormous light grasp and its resolution".

Although galaxies can be seen at enormous distances, individual stars can only be detected relatively close by with existing telescopes. The GMT's greatly increased light collecting area will enable it to observe individual stars up to almost twice the range presently possible which equates to an eight fold increase in the volume of space and hence number of stars observable. This is important in refining our models of the initial mass function – the proportion of stars formed with each particular mass.

Being able to probe further and deeper into the universe is also valuable to study the process of galaxy assembly and better understand the phenomena of dark matter and dark energy (the force that appears to be causing the expansion of the universe to accelerate).

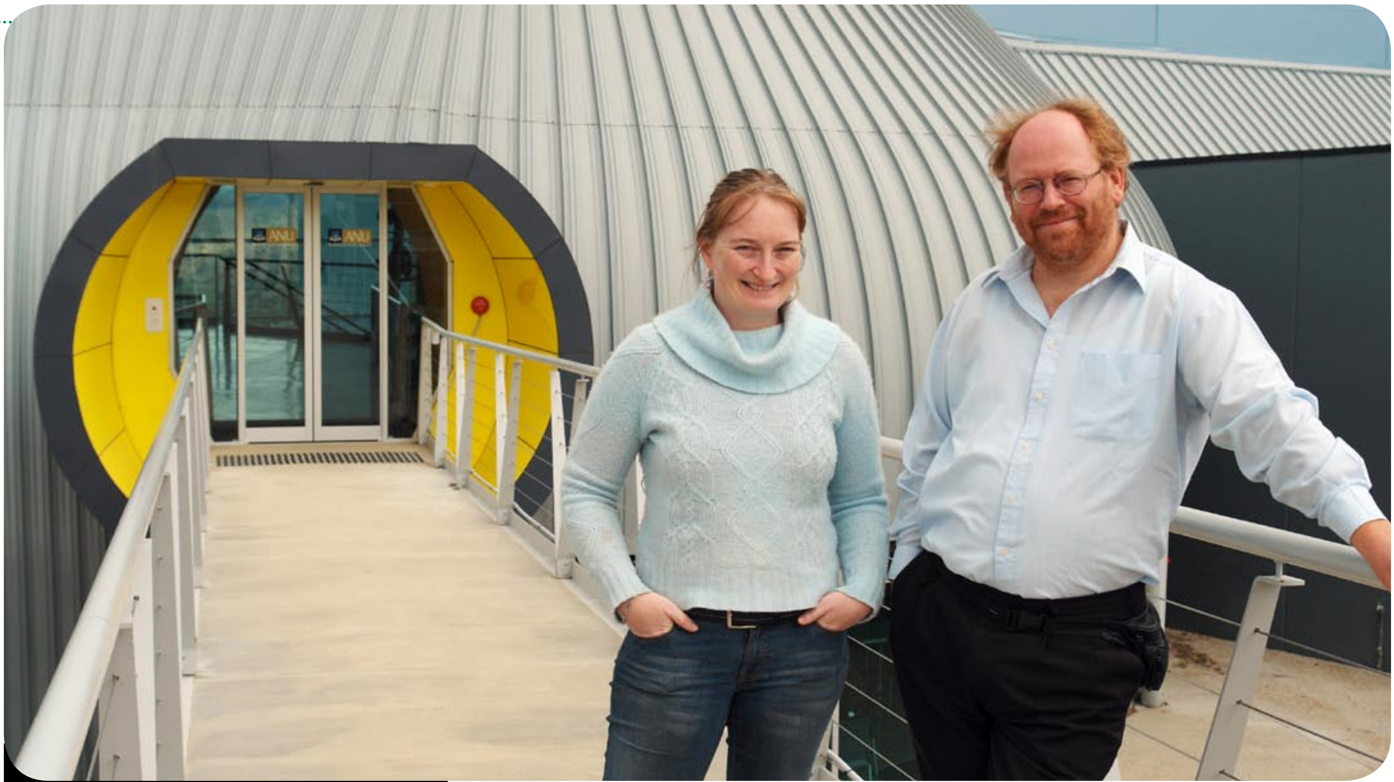
Once the adaptive optics are installed and working properly, the phenomenal resolution of the GMT should also enable it to resolve some planets beyond the solar system. Although astronomers have detected the presence of many such planets, to date it has not been possible to see them directly.

Application of the GMT won't be restricted to extra-solar planets. With ten times the resolution of Hubble, it will be able to make contributions to solar system science too, producing images comparable to some of those gathered by space probes.

New generation telescopes like the GMT make the early twenty first century an exciting time to be involved in astronomy.

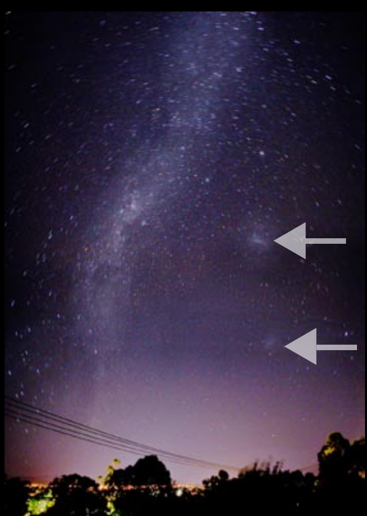
Small but Special

Astronomers Discover Galactic Building Block



Viewing your local Dwarf Galaxy

Next time you happen to be out on a clear night, you should be easily able to see our closest dwarf galaxies, the Magellanic Clouds. In the early evening of autumn, the larger of the two can be seen by looking roughly half way between the main band of the milky way directly overhead and the southern horizon. It looks just like a small faint patch of cloud.



When the Portuguese explorer Ferdinand Magellan sailed into the southern oceans in the early sixteenth century, he and his crew noticed that alongside the familiar hazy band of faint light extending across the sky were two strange cloud like objects which are known to this day as the large and small Magellanic Clouds.

Modern astronomers know these to be dwarf galaxies in orbit around our own galaxy, the Milky Way. The term "dwarf galaxy" conjures up an image of something small and perhaps rather insignificant, but in terms of modern cosmology, nothing could be further from the truth. Astronomers believe that such dwarf galaxies are the fundamental building blocks of the larger spiral and elliptical galaxies that house most of the stars in the universe, including our own sun. Dr Helmut Jerjen of the Research School of Astronomy and Astrophysics, a world authority on dwarf galaxies, describes them as "the bricks that build larger galaxies" and considers them amongst the most intriguing objects in the sky.

Scientists believe that in the early universe space was filled with irregular granular clumps of dark matter interspersed with great quantities of gas and dust. Where the dark matter was densest, it tended to gravitationally draw in the gas and dust, which in turn slowly condensed into many individual stars. Collectively these stars and the dark matter associated with them formed enormous numbers of dwarf galaxies. Over billions of years, these numerous dwarves conglomerated together under gravitational attraction to form the spiral, elliptical and lenticular galaxies that we see today.

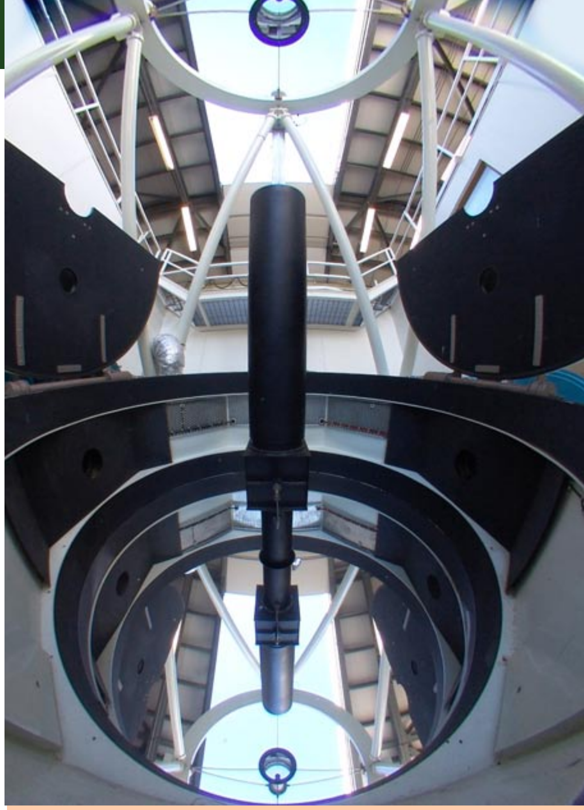
Although dwarf galaxies are of such importance to understanding the formation of the universe, there are actually a very limited number of them available to study. Partly because most of them have long since been absorbed into larger galaxies and partly because due to their small size and predominance of dark matter they are relatively dim stellar systems. This means that even the world's largest telescopes can only detect those that are quite close to us. However whilst observing with the ANU 2.3m telescope at Siding Spring, Dr Jerjen recently made a very surprising discovery. At the edge of his field of view were two galaxies long included in catalogues as large distant objects. To Dr Jerjen's expert eye, something looked a little odd about one of them. It had a granular transparent appearance more characteristic of a close dwarf than a distant elliptical.

Previously published red shift data showed that the two galaxies were receding from us at roughly 3200kms-1, implying a distance of about 60 million light years for both. Nevertheless, Dr Jerjen was having difficulty reconciling this with the appearance of the second object.

When a colleague at the European Southern Observatory (ESO) also became interested, the two decided to investigate further and using the 3.6m large European Southern Telescope (EST) in Chile with its ultra sensitive spectrograph to re measure the red shift of NGC 5011C. Because the spectrograph was able to align its slit along both galaxies simultaneously, the two spectra could be clearly detected and compared with no possibility of confusion or light contamination between them. As Dr Jerjen had suspected, the re measured shift of NGC 5011C was only 650kms-1, reducing it's distance to 12 million light years, a relative stone's throw on the universal scale.

As a final confirmation, Dr Jerjen was able to apply a technique that he himself has been instrumental in developing for dwarf galaxies called the surface brightness fluctuation method. In a nutshell, this is a mathematically rigorous and non subjective way to measure how granular or speckled a galaxy looks. Although you can't resolve individual stars with ground based telescopes, nearby galaxies that are partially resolved appear "lumpier" than distant ones. By quantifying this, it is possible to attach distances to such objects to compliment those obtained by red shift data. When this analysis was applied to NGC 5011C, it confirmed the new spectroscopy data. NGC 5011C was indeed one of those much sought after nearby dwarves.

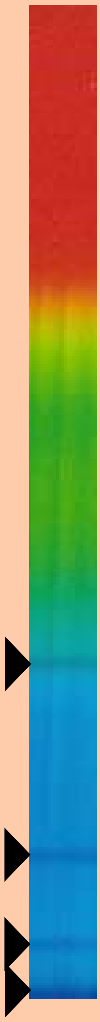
Astronomers now plan to employ a software package called SAPAC: (Surface brightness fluctuations Analysis Package for the Astronomical Community) created by Dr Jerjen and his PhD student Laura Dunn to analyse 25 Terabytes of imaging data from the new ANU SkyMapper telescope in order to search for hundreds of missing dwarf galaxies that are predicted by Cold Dark Matter cosmology.

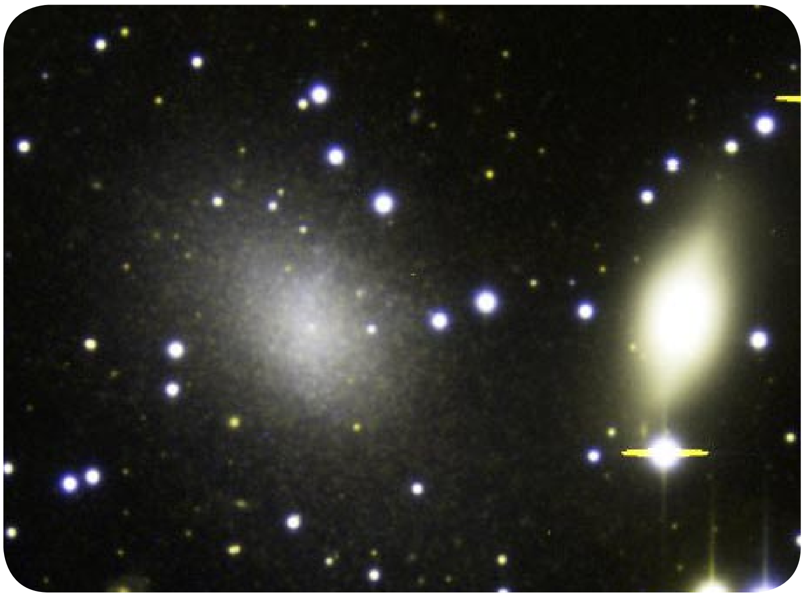


Above: The ANU 2.3m telescope at Siding Spring, used to discover the new dwarf galaxy.

Red Shift

The universe is expanding and as a general rule, the further away an object is the faster it is receding from us. This recession velocity Doppler shifts the wavelength of star light towards the red end of the spectrum. Most of a star's light is emitted over a broad wavelength range just like an incandescent light bulb, and detecting a tiny shift in such a broad emission would be neigh impossible. However, superimposed on this broad spectrum are very narrow dark absorption lines due atoms and molecules in the star's outer atmosphere. It is these dark lines Astronomers use to measure the red shift of objects and from this, determine their distance. The spectrum on the right is of the bright star Sirius, showing the characteristic hydrogen Balmer lines of hot stars.





Left: NGC 5011C (left), was originally thought to be the gigantic next door neighbour of the big, bright NGC 5011B (right)

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