The SkyMapper facility at dawn. The 1.3-metre telescope contained within will provide the world's first digital map of the southern sky.
Photo: S. Keller RSAA, ANU

New Window on Southern Skies

BY STEFAN KELLER

SkyMapper, an all-Australian designed and built telescope, will capture more than a billion stars and galaxies that are up to a million times fainter than is visible to the unaided eye.

The edge of our understanding of the Universe is tangible in the night sky. "What's that line across the sky made of?" asked my 5-year old son. "Stars. Lots of stars," I replied. "How did they get there, all those stars?" In quick time we had reached an unanswered question that is the work of astronomers around the world and the genesis for the next generation of large telescopes.

The short answer is gravity, since gravity causes matter to coalesce into clouds of gas and then to stars. But how did this process occur to produce the Milky Way? Was the bulk of our galaxy formed from the collapse of a giant cloud of hydrogen and helium left over from the Big Bang, or did the stars form in a series of smaller clumps and then fall into one another? What role did the dark matter that constitutes 90% of the mass of our galaxy play? The Australian National University's new SkyMapper telescope is designed to address these questions and many others.

The SkyMapper telescope is a $13 million investment by the Australian National University's Research School of Astronomy and Astrophysics. It rose from the ashes of the 2003 Canberra bushfires that devastated Mt Stromlo Observatory and destroyed our research telescopes there. The loss of those telescopes presented us with the opportunity to develop SkyMapper, which incorporates cutting-edge detector technology and electronics.

The telescope, designed and constructed by Electro Optics Systems in Canberra, is sited under the dark skies of our Siding Spring Observatory near Coonabarabran in central NSW. The telescope's mission is to create the world's first digital map of the southern sky. This map will record the position, brightness, colour and shape of more than one billion stars and galaxies to a depth one million times fainter than is accessible to the human eye.

At the heart of SkyMapper lies a massive digital camera designed and constructed in-house by ANU technicians led by Anthony Oates and Peter Conroy. The $2.5 million camera uses 268 million pixels to capture a region of sky 40 times larger than the full Moon every minute. The result: a complete digital map of the southern sky as seen through six coloured filters. In order to look for changes, each part of the sky will be targeted 36 times over a 5-year period.

The facility will operate autonomously with no necessity for human intervention on site. The dome will open in evening twilight and images will be taken during the night as warranted by the prevailing conditions until dawn.

An automated approach is not only efficient but also responsive. We can adapt the schedule of the telescope to capture images of, for instance, new supernovae and similar short-lived phenomena.

A large component of our program has been to design the software to keep pace with the rate of data acquisition, with SkyMapper delivering 100 megabytes of information about celestial objects every second. This is deposited 700 km away at the ANU node of the

Australian Partnership for Advanced Computing supercomputer via a dedicated internet link. The data is then processed to record object information. In total, over 5 years we expect to produce 474 terabytes of data (or the equivalent of the information stored on 110,000 DVDs). A 30 terabyte "distilled" version will be accessible via the internet. This will enable both professional and amateur astronomers here and abroad to use our data for a multitude of studies.

Wired World of Internet Observatories

Dedicated survey telescopes, such as SkyMapper, are leading a revolution in how astronomers work. More mundane observations can be avoided, replaced by data available from massive online databases.

The mediator between the globally distributed datasets and the astronomer is the so-called "Virtual Observatory" project. This is a global effort by astronomers and computer scientists to draw together disparate datasets into a cohesive whole that can be explored in unprecedented ways.

We enter uncharted discovery space as we match surveys across the electromagnetic spectrum from gamma rays to the radio – a range of wavelengths from ~0.01 nm to 100 metres). This exploration has serendipitous results. An example is the realisation that gamma-ray bursts, first detected by US defence satellites looking for nuclear weapons testing in the 1960s, are due to a new type of explosion at vast distances – the record stands at 12.8 billion light years from Earth. This finding was only possible when the first optical views of the rapidly fading embers of these explosions were viewed in the past decade.

With SkyMapper we will be able to respond within 30 seconds to the detection of a gamma-ray burst by a satellite and catch these elusive objects at their brightest. Project scientist, Prof Brian Schmidt, hopes to shed light on their formation.

It is currently thought that a gamma-ray burst is due to the collapse of a massive and rapidly rotating star into a black hole. With theories of their formation it is then possible to use the number of such explosions within a region of space to measure how many massive stars are formed at extremely early times after the Big Bang.

SkyMapper's vast coverage of the southern sky will enable us to search for those needles in the haystack – objects few in number but of great astronomical importance. For instance quasars – highly luminous galaxies powered by massive central black holes – tell us about the physical conditions when the Universe was only 550 million years old, or 4% of its current age.

This is an important phase in the life of the Universe, at the end of the cosmic "dark age". Prior to this time, the space between galaxies was opaque to light due to pervasive cool hydrogen gas. The electrons within this gas were so numerous they were able to absorb all photons of light, and the energy was then released into the infra-red. The first stars then started to shine and deposited sufficient energy into the Universe to remove the electrons from the hydrogen gas blanket around them. This made the Universe transparent.

There are a number of unanswered questions about this epoch. When did the first stars form? Did they form in a Universe-wide burst of activity or were there cosmic backwaters that did not take part? How long did the first stars take to make the Universe transparent? Was there a first generation of super-massive stars? SkyMapper will be able to dramatically increase the number of distant quasars we know about and increase our understanding of when the first stars formed and how massive they were.

Characterising Stars

Stars are characterised by three key param-

The Southern Cross and Pointers seen in their Milky Way backdrop of star clusters and clouds of glowing hydrogen gas. This view will be covered by about 50 SkyMapper frames. Of the estimated 100 billion stars in the Milky Way about 500 million will be accessible to SkyMapper, the remainder being exceedingly faint, distant and obscured by gas and dust. Photo: M. Bessell, RSAA, ANU

eters: their temperature, density and the amount of material such as carbon and iron they contain. Measuring these is SkyMapper's special niche in global astronomy. For SkyMapper we have designed a unique set of glass filters to select colours of light that optimally resolve the three key parameters. Such properties tell us a star's age and mass, and also about the previous generations of stars that have preceded it.

As successive generations of stars are born and die, they return to the Universe material enriched in the products of nuclear fusion. This is a one-way process – the amount of, say, iron is constantly increasing. This enables us to use the concentration of iron seen in a star as a clock. The older a star is, the lower is its iron concentration.

SkyMapper will search for stars with the lowest iron abundance to find the Universe's oldest stars. These stars are time capsules of the Universe as it was over 13 billion years ago. They bring this distant epoch within reach of scientific understanding.

However, such stars are exceedingly rare; we expect there to be only one in 10 million. It is only SkyMapper's wide coverage and unique filter design that make this study possible.

Mapping Dark Matter

Mysterious dark matter pervades our galaxy. The rate at which the outskirts of the Milky Way rotate tells us that the amount of matter contained within it is roughly 10 times more than is accounted for in a census of the stars and gas. Astronomers now feel confident that very little of this additional mass is in the form of ordinary matter such as dead stars or planets. We may not know what dark matter is but its gravity is evident and imprinted upon the motion of objects in and around the galaxy.

More than three billion years ago the Sagittarius dwarf galaxy strayed too close to the Milky Way and is now being torn apart. The effects of "tides" induced by the massive gravitational pull of our galaxy have stripped stars from the tiny dwarf galaxy into streams that wrap around the night sky. The extent and shape of these streams are related to the amount and distribution of matter, including dark matter in the Milky Way. With SkyMapper we will use such streams of stars to build up a map of dark matter in the Milky Way.

More Plutos?

Closer to home, SkyMapper will scan the southern sky for solar system objects, lumps of rock and ice outside the orbit of Neptune. A growing number of such objects have been found recently, including some more massive than Pluto, the best-known member of this family of objects termed Kuiper Belt objects.

Most observations of our solar system have so far focused on the northern sky and on the orbital plane of the planets. Kuiper Belt objects do not appear confined to this plane, however. Are there a number of Pluto-sized objects hidden in the southern sky? SkyMapper will soon tell.

The SkyMapper telescope, to be operational later this year, represents a new vehicle for scientific discovery and will serve as an iconic reference for the southern sky for decades to come. It will provide the future target stars and galaxies for the next generation of extremely large telescopes with mirrors 20–40 metres in diameter that are planned for the 2020s. Yet it represents one step on the timeline that started 400 years ago, when Galileo first applied the telescope to the night sky.

The bounds of our knowledge are apparent on a dark night, as my son pointed out. In this International Year of Astronomy, there is no better time to see how long it takes you to reach the edge of our understanding under the southern sky.

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