Australian Institute of Physics NSW Branch (June News)

The June meeting of the NSW branch of the AIP was held at the University of Sydney on Tuesday 23 June 2009 and featured a public talk by Professor Bryan Gaensler. Bryan Gaensler is a Professor of Physics at The University of Sydney, and is a Federation Fellow of the Australian Research Council. Prof. Gaensler was awarded his PhD in Physics from The University of Sydney in 1999, and subsequently held positions at the Massachusetts Institute of Technology, the Smithsonian Institution and Harvard University, before returning to Australia in 2006.

Prof. Gaensler's current research interests focus on Cosmic Magnetism. A remarkable discovery made by 20th century astronomers was that the Universe is magnetic. These cosmic magnetic fields play a vital role in controlling how stars and galaxies form and evolve. This naturally occurring magnetism also regulates solar activity, protects the Earth from harmful particles, and is vital for the navigation of birds and other species. His currently working to open the window to this "Magnetic Universe" by exploiting an effect called "Faraday rotation", in which light from a background object is subtly changed when it passes through a cloud of magnetised gas. Prof Gaensler and his team are carrying out detailed measurements using radio telescopes in Australia and in the USA. With these measurements, they can detect magnetic fields throughout the Universe! The observations that they are carrying out are resulting in three-dimensional maps of cosmic magnetism, which are revealing what these magnets look like and what role they have played in the evolving Universe.

The discovery that interstellar space is magnetic was unexpected and remarkable. But is this just a piece of cosmic trivia, or is magnetism an important part of the big picture? It turns out that many previously unsolved problems in astronomy suddenly make sense once one includes the effects of interstellar magnetism. As far as life on Earth is concerned, probably the most crucial role that magnets play in space is in the formation of new stars. The Sun and our solar system formed five billion years ago in a dark cloud of interstellar gas, which gradually became hotter and denser as it collapsed under its own gravity. But under the influence of gravity alone, such clouds would collapse too rapidly to form stars like the Sun. However, we now realise that the strong magnetic fields present in these clouds resist the force of gravity, and slow down the collapse enough so that stars can form in the way we expect. If it were not for cosmic magnetism, our Sun and its planets would never have come into existence. A similar problem applies to the entire Milky Way. Viewed from the side, the stars and gas in our galaxy form a circular disk that is about 100,000 light years across, and a few thousand light years thick. If we calculate the gravity of all the material in this disk, we find that the disk should collapse down on itself until it is paper-thin. However, this doesn't happen – something is holding up the gas and keeping it floating thousands of light years above the centre.

His talk gave us an insight into the Earth's magnetic field is not just a curiosity or a handy navigation aid, but is vital for the existence of life. The Sun continually generates a stream of high energy charged particles that flow out in all directions as part of the solar wind. Exposure to this particle stream can cause serious damage to living tissue; any humans who one day travel to Mars will need heavy shielding around their spacecraft to protect them from this onslaught. Just in the past 10 years a new class of stars, "magnetars", has been discovered. These bizarre beasts are only about 25 km across, and appear to be the most magnetic objects in the Universe, with magnetic fields up to a quadrillion (1,000,000,000,000,000) times stronger than the Earth's! In comparison, the most powerful magnet ever constructed in the laboratory produces a field that is amere million times stronger than the Earth's.

The sky seems full of magnets. Where does this magnetism come from? Although the rotation of a star can amplify an existing magnetic field in the object's interior, this can only work if one starts with some weak initial magnetism. This presumably was present when the star first formed. Since we know that stars form out of collapsing gas clouds, this means that the gas in interstellar space must be magnetic also. Starlight, like most naturally occurring light sources, should be unpolarised, meaning that each parcel of light has a random orientation. It is remarkable that magnetism is so pervasive in the Universe. If you drop a fridge magnet on the floor a few times, it quickly loses its magnetism. Similarly, all the dramatic explosions and collisions that galaxies experience as they evolve should serve to quickly tangle and destroy their magnetism before it can accumulate appreciably. And yet galaxies like the Milky Way are clearly magnetic. What is going on?

The first thing to examine is whether violent episodes indeed destroy a galaxy's magnetism. We set out to test this by looking for magnetism in the Large Magellanic Cloud (LMC), a small galaxy in orbit around our Milky Way, at a distance from Earth of about 170,000 light years. Faraday discovered that, under certain conditions, polarized light will have its angle of polarization rotated as it passes through a region in which magnetism is present. And the stronger the magnetic field, the more rotation is produced. To study the magnetism of the LMC, we took this phenomenon to its extreme: we found about 300 very distant galaxies behind the LMC and measured the polarization and Faraday rotation of each. This allowed us to map out what magnetism might be present in this nearby galaxy. There is clearly something fundamental that we are not understanding about where magnetism comes from and how it evolves as galaxies evolve. The problem in making further progress is that measuring these weak magnetic fields is difficult and time-consuming – the 300 measurements of Faraday rotation that we carried out through the LMC took about 1000 hours of observations with one of the world's most powerful radio telescopes. Thus, for any galaxy at all, in any direction and at any distance, we will always be able to measure the effects of Faraday rotation as this background polarized light passes through it. This will give us a spectacular census of magnetism in galaxies of all types and of all ages, with which we hope we can finally determine how magnetic fields emerge, evolve and perhaps are also destroyed. While we eagerly await the results of the SKA, it is important to realise that the great leaps forward in the study of magnetism will not come simply from collecting magnetic galaxies like stamps in an album. We know from studying the magnetic field of the Earth and the Sun that when viewed in detail, magnetism can be unbelievably complicated and dynamic.

Photo: From left to right, Dr Fred Osman (AIP Branch Chair), Professor Bryan Gaensler and Dr Graeme Melville (AIP Branch Secretary).

In conclusion, Prof Gaensler summarised that the following new discoveries will undoubtedly provide the answers to many long-standing problems, but at the same time they will raise a new set of magnetic mysteries for the next generation of astronomers to puzzle over.

- Cosmic Magnetism is a vigorous and rapidly developing field;
- Unique capabilities of radio astronomy;
- RM GRIG: structure of Magnetic field in Milky way in nearby galaxies and in galaxy clusters;
- RM vs. Red shift: evolution of magnetic field in galaxies and intergalactic space over cosmic time;
- Cosmic web: direct imaging of intergalactic magnetic fields; probes origin of magnetism in Universe;
- 2008: polarised sky finally begins to be revealed by SKA pathfinder experiments;
- 2016: exploration of full Magnetic Universe with Square Kilometre Array;
- Addresses major topics in fundamental physics/astrophysics;
- Will almost certainly yield new and unanticipated results.

The talk was very well received and geared to scientists and members of the public alike with many discussions continuing later during dinner at a nearby Italian restaurant. The Australian Institute of Physics thanks Professor Gaensler for his outstanding lecture!

Dr Frederick Osman – AIP NSW Branch Chair