The Dirac Lecture

Thursday, 19 July 2012

The accelerating universe

Professor Brian Schmidt FRS FRSN, Nobel Laureate for Physics, 2011

Professor Brian Schmidt FRS FRSN delivering the 2012 Dirac Lecture.

In conjunction with the University of New South Wales and with the Australian Institute of Physics, at the Society proudly presented the 2012 Dirac Lecture on Thursday, 19 July 2012. This year's lecture was delivered by Professor Brian Schmidt, 2011 Nobel Laureate for Physics.

Professor Schmidt took us on a fascinating journey of astronomy and cosmology, describing the work that he and his colleagues have done over the last two decades and where it fits in our understanding of the nature of the universe.

To establish a reference framework, we were taken on a quick tour of the universe using the speed of light as a ruler (the Moon is less than two light seconds from us. The Sun is 8 light minutes away. The nearest star, Alpha Centauri, 4.3 is light years away. We are 30,000 light years from the centre of our galaxy, the Milky Way. The nearest galaxy, Andromeda, is 2 million light years from us. The cosmic ray background establishes that the age of the universe is about 13.7 billion years, with the Hubble telescope being able to detect objects 12 billion light years away).

Although astronomy is one of the oldest sciences, modern cosmology had its beginnings in the 19th and 20th centuries when techniques such as spectral analysis began to be applied to light from the skies. Of particular importance was the phenomenon known as Doppler effect – objects that are moving towards us have their light shifted towards the blue end of the spectrum, while objects moving away have their light shifted to towards red. By analysing the spectra of galaxies, in 1916, Vesto Slipher found that all galaxies he observed were shifted towards red and therefore were moving away from us. The conclusion from this was that the universe is expanding.

Einstein's special theory of relativity published in 1907 proposed that acceleration due to gravity and acceleration due to motion are equivalent. This led to his general theory of relativity and the notion that space is curved. The solution to Einstein's equations are dynamic, implying that the universe should be in motion. To avoid the conclusion that the universe was expanding, Einstein introduced a "fudge factor" called the cosmological constant (Einstein later referred to this as his greatest blunder!).

One conclusion from the concept of an expanding universe is that at one point must have been a big bang. Observations suggest that the age of the universe could be as young as 9 billion years if its expansion was slowing due to gravity but this is contrary to observations that the oldest stars appear to be at least 12 billion years old.

Not only was Brian Schmidt interested in solving this problem and determining the age of the universe but he wanted to understand what its eventual fate might be. In the 1990s, by observing faintness/brightness plotted against high/low red shift it had been found that supernovae appeared to have very constant brightness and therefore could be used as a standard "candle". (It was later found that this was not quite so but further work to better understand Type 1A supernovae allowed for corrections that gave a very good correlation.)

Improved digital detection technology and data processing capability in the 1990s set the stage for major advances in astronomy. Many more supernovae could be observed and this gave the team led by Brian (whose area of specialisation was data processing) to study many high-resolution images and by tracking these images and filtering out background noise, to find supernovae candidates for much more detailed analysis. Brian's team found that distant supernovae were outside the range expected for a universe whose expansion was slowing. Detailed analysis of their data suggested that the expansion of the universe was in fact accelerating. This was contrary to the mainstream view of physicists at the time and, indeed was contrary to the findings of another team using a different approach to analysing the data. Professor Schmidt's team published their work and in 2011 were awarded the Nobel Prize.

The notion of a universe whose expansion is accelerating poses some interesting questions for cosmologists, not the least of which is what could be pushing it apart? Einstein's theory allows for the concept of "dark energy". The data from analysis of Type 1A supernovae can be explained if the forces are assumed to be about 30% "pull" from gravity and about 70% "push" from dark energy. For the universe to be flat (and an analysis of the background radiation of the universe shows that indeed it is flat, that is, the universe is not closed and it is not open), 27% of the universe would need to be matter and 73% would need to be dark energy. But the problem is that this is much more matter than appears to exist. The solution to this currently most favoured by cosmologists is the comcept of "dark matter" – matter that we cannot see. And it is not a small ammount – less than 5% of all matter is thought to be observable.

Professor Schmidt concluded his lecture with some long-range forecasts for the future of the universe. In some places, gravity will win and matter will merge; in others, space will accelerate faster and light from those areas will never reach us. There could even be a "big rip". In this scenario, a few million years before the end, gravity would be too weak to hold the Milky Way and other galaxies together. Our solar system would become gravitationally unbound, the stars and planets would be torn apart and at the very end, individual atoms would be ripped apart.