Report of 12 September 2013 Meeting
Royal Society
Southern Highlands Branch

Speaker: **Dr Ken Freeman FAA FRS**
Duffield Professor of Astronomy
Australian National University

Topic: **Our Galaxy, the Milky Way, Dark Matter**

Dark matter is now thought to make up as much as 97% of the Milky Way and 84% of the universe overall. Ken Freeman was the first to calculate that the luminous, visible matter in galaxies is only a small fraction of their overall mass.

He began this lecture with the history of understanding of our place in the Milky Way, then progressed to a description of its most important features which have been gradually discovered, including its dark matter content. He then ended with some of the recent findings of the inner region of the Milky Way – its bulge and the massive central black hole.

A compelling piece of evidence that dark matter exists in large quantities comes from the study of the rate of approach to each other of the Andromeda Galaxy (M31) and the Milky Way Galaxy. The Milky Way and M31 are now approaching each other at 118 km/s. To acquire this rate of approach in the life of the universe means that the total mass of the Milky Way Galaxy is at least 120 x 10^10 M. The stellar mass is approximately 6 x 10^10 M, therefore the ratio of dark to stellar mass is of the order of 20. The dark halo extends out to at least 120 kpc, far beyond the visible galaxy disk of approximately 20kpc.

Freeman cited this example as a discovery which had come too early. Kahn and Woltier's result was presented in 1959. It was simple and correct, and no one argued with the result. It just did not fit into the framework of thinking at the time, and so was effectively ignored. Merging of galaxies is still happening now with the end product of the merger often being an elliptical galaxy. In a few Gyr, the Milky Way will probably merge with M31.

Further evidence that dark matter dominates the mass budget of the universe comes from the rate of formation of galaxies after the Big Bang. The Big Bang occurred 13.7 Gyr ago. Galaxies were already forming 0.5 Gyr after that. Without dark matter, this could not have happened – galaxies would have taken much longer to form.

Professor Freeman noted that most spiral galaxies, including the Milky Way, have in addition to their readily observed thin disk, a second thicker disk component or bulge. The Milky Way's thick disk is significant, being about three times the thickness of the thin disk, and was discovered via star counts at the South Galactic Pole. Its mass is about 10% of the mass of the thin disk, its stars are old (>12 Gyr) and have less metals than the thin disk. They are enriched in alpha-elements (Mg, Si, Ca) which come from exploding massive stars, so formation was rapid (1Gyr). Once the thick disk stars were formed, there was a pause in star formation, until the thin disk stars started to form about 10Gyr ago. Thin disk star formation has continued at a more-or-less constant rate up to the present time.

Professor Freeman's research is exciting and ongoing. He is using chemical element abundance patterns to probe the formation of the Galactic thick disk, in a process known as chemical tagging. It needs a huge number of stellar spectra, data which does not yet exist. With the advent of the HERMES project at the AAT however, all that will soon change. Professor Freeman is planning to have the chemical abundances of many elements determined for over one million stars, mostly in the thin and thick disks.

The 54 person audience responded enthusiastically when Dr Freeman agreed to present further talks to the Southern Highlands Branch as his new data came to hand.

Anne Wood