F. Staff research

This section describes the research activities of staff at the Anglo-Australian Observatory, where not already covered in Chapter 3. In addition to providing support for the Observatory, the scientific staff pursue their own research programs. Staff make extensive use of the Anglo-Australian Telescope (AAT) and UK Schmidt Telescope (UKST) facilities and also use many other international research facilities such as the radio telescopes operated by the Australia Telescope National Facility and the Hubble Space Telescope.

A search for solar-like oscillations in Beta Hydri

In June 2000, Bedding (Sydney), Baldry (AAO) and O'Toole (Sydney) continuously monitored Beta Hydri for five nights using UCLES on the AAT. A circumpolar star, Beta Hydri was tracked for the full night and a spectrum was taken roughly every two minutes. In total, about 1200 spectra were obtained. The aim of this project (or why did it require five nights to study a third magnitude star?) was to detect solar–like oscillations. Theory predicts that Beta Hydri has a number of oscillation modes with periods of around 17 minutes and amplitudes of less than 1 m/s. Detecting these modes would allow the study of the internal structure of this star, which would otherwise be impossible, through the seismic interpretation of the frequencies and amplitudes. This technique is known as astroseismology.

In order to detect such a small motion on such a distant object, a high–resolution spectrograph is used in combination with an iodine cell to obtain Doppler shift measurements. This technique is used regularly by Paul Butler (CIW) and Chris Tinney (AAO) for their planet search program, and they have already shown that for the most stable stars, 3 m/s precision per measurement can be obtained. This precision in 1200 individual spectra should allow detection of sinusoidal amplitudes as low as 0.5 m/s using Fourier techniques. If successful, these oscillations will be the smallest motions to have been detected on a star other than our sun.

Type Ic Supernovae

Supernovae with no strong hydrogen, helium or silicon lines in their spectra are known as Type Ic. There is still no agreement on the type of star which explodes to form a Ic supernova, or what makes this event different from other supernovae. SN 1998bw was apparently a Ic supernova which also emitted a gamma-ray burst — an extremely high energy outburst not previously associated with supernovae — which can be best explained by an asymmetric explosion. As a followup to an AAO/RSAA monitoring program of SN 1998bw, Stathakis (AAO) is comparing velocity profiles from the strongest emission lines in four other Ic SNe. Line profiles can be analysed to map the velocity structure of the ejected envelope and to provide limits on the asymmetry and composition. Most of the observed lines in all four supernovae have significantly more blueshifted emission than redshifted emission. This result suggests that either Ic SNe are preferentially asymmetric towards the observer, enhancing emission travelling towards us, or more likely, emission from the far side of the supernova is being hidden by dense gas or dust.

Peculiar X-ray binary Circinus X-1

Circinus X-1 is a peculiar X-ray binary star system, whose nature has for many years defied explanation. Johnston (AAO) with Fender (Amsterdam) and Wu (Sydney, RCfTA) obtained infrared and optical spectra of the system, and discovered asymmetric emission lines. Asymmetric emission has also been detected in archival AAT spectra stretching back over 20 years. A new model suggests that the system is in a highly eccentric orbit. This group, together with Tauris and van den Heuvel (Amsterdam), suggests that the binary must be the survivor of a highly asymmetric supernova, leaving it with both a high eccentricity and a high space velocity.

Faint X-ray sources and black holes

Globular clusters contain many low–luminosity X-ray sources, whose nature is the subject of debate, because various types of objects can emit X-rays at such luminosities. Verbunt (Utrecht) and Johnston (AAO) have analysed High–Resolution Imager (HRI) data from the Rosat X-ray satellite on several clusters known to contain multiple X-ray sources in their core. Long images enable us to greatly improve the accuracy of the measured positions of the sources, to detect new sources and to measure variability in the known sources. A total of seventeen sources is detected in three clusters, several of which are well outside the core and thus may not be associated with the cluster.

Wu (Sydney, RCfTA), Soria (Sydney, MSSL) and Johnston (AAO) have been carrying out spectroscopic observations of several southern black–hole candidate binary systems. Spectra of GX 339–4, GRO J1655–40 and RXT J1550–564 reveal that the morphology and properties of the emission lines observed in these objects are different at different X-ray spectral states. The emission lines are double–peaked when the soft X-ray flux is strong. A model for this system based on an X-ray illuminated disk is successful in reproducing many features seen in the optical spectra.

The nature and origin of high–velocity clouds

The Galactic Halo is believed to have been formed by lower mass structures which were accreted and merged with the Halo. This process should still be ongoing today at a low level, and simulations predict that the Halo should have many more satellites than are actually observed. Strong candidates for the missing accreting mass are high velocity HI clouds (HVCs). These are ionized hydrogen clouds with velocities that can't be explained by simple galactic rotation. Unfortunately their distances are unknown for all but a few sources, so astronomers have not been able to test if HVCs are likely to be associated with dark matter.

Indirect measures of the distances to HVCs have resulted in wildly differing figures. Bland-Hawthorn (AAO) and Maloney (Colorado) have developed a new method to measure distances based on the Hα flux from a cloud. Using this method, HVCs fall into two populations: bright, nearby clouds; and faint clouds in the Galactic Halo, or even at greater distances. The discovery of dense clouds beyond the Halo would demonstrate for the first time that self-gravitating primordial gas clouds survive to the present day. A comparison of Hα and virial distances will be used to infer the contribution of a dark matter 'mini–halo'. Bland-Hawthorn and Lewis (AAO) intend to test the possible association of HVCs with dark matter. They will search for 'twinkling' of the starlight from a background galaxy seen through the HVC due to dark matter made of compact dark objects.

The Sagittarius Dwarf Galaxy

Lewis (AAO), working with Ibata (Heidelberg), Irwin (IoA) and Totten (Keele) have investigated the demise of the Sagittarius Dwarf Galaxy as it is torn apart by the tidal forces of the Milky Way. This study has revealed the presence of tidal material torn from the dwarf, traced by giant carbon stars, that covers a great circle on the sky. The spatial and kinematic properties of the stream offer strong constraints on the shape of the dark matter halo of the Galaxy, indicating that it is almost spherical. Such a result is at odds with theoretical models of the form and nature of dark matter in the Halo. Recent results from the Sloan Digital Sky Survey have uncovered coherent structures in their maps of the Galactic Halo which agree with our predictions of the form of the tidal debris.

Gravitational Lensing

Lewis (AAO), working with Ibata (Heidelberg), has investigated how the cosmologically distributed dark matter, in the form of compact objects, distorts our view of the distant universe. If this population exists, it will induce an observable flickering into the surface brightness of galaxies. With Wyithe (Melbourne, Princeton), Lewis and Ibata have extended these ideas to search for compact dark matter in clusters of galaxies, demonstrating that similar flickering will be seen in the surface brightness of gaint luminous arcs.

Globular clusters in spiral and elliptical galaxies

Bridges (AAO), in collaboration with a team of American, British and Canadian astronomers, is involved in several projects using multi–object spectroscopy to study globular cluster kinematics, ages and chemical composition, and the dark matter content in spiral and elliptical galaxies. In the Virgo cluster giant elliptical galaxy NGC 4472 (M49), nearly 150 globular cluster velocities have been measured, revealing significant differences between the metal–poor and metal–rich clusters: the metal–poor clusters have both a higher spread in velocity and a higher rotation. While all the clusters are old and similar in age, there is a hint that the metal–rich clusters are 0.5–1.0 Gyr younger than the metal–poor clusters. All of these results seem most consistent with a merger origin for NGC 4472, with the metal–poor clusters coming from the original spirals, and a new population of more metal–rich clusters formed later during the merger. The observed spread in cluster velocities, when compared with ROSAT X-ray observations of the hot gas around NGC 4472, supports the existence of a dark matter halo.

Bridges is also working with astronomers at Queen's University, Lick Observatory, Cambridge, and Harvard, on a major multi–fibre spectroscopic study of globular clusters in the Local Group spiral galaxy M31. The goal is to learn more about the formation and chemical enrichment history of M31 and other galaxies, and to distinguish between models for the formation of their stars and globular clusters. Velocities precise to 10–15 km/s have been measured for ~ 200 M31 clusters, a huge improvement over previous work. Chemical abundances have been derived from absorption–line features in the blue part of the spectrum. Preliminary analysis again shows significant differences between the metal–poor and metal–rich clusters: the metal–rich clusters are more spatially concentrated and have a much higher rotation. Thus, it is finally possible to identify the different cluster populations belonging to the disk, bulge, and halo of M31. The globular cluster velocities will be combined with those of M31 planetary nebulae stars to determine the mass (ie. dark matter content) of M31, and how the mass varies with distance from the galaxy center.

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Circumnuclear star formation in barred galaxies

A significant fraction of barred spiral galaxies are actively forming stars in their centres, usually within a ring or tightly–wound spiral a kiloparsec or so across. Ryder (AAO), together with Knapen (ING) and Takamiya (Gemini), has used CGS4 on UKIRT to collect K-band spectra of the circumnuclear star–forming regions in NGC 4321 and NGC 2903. Using the equivalent widths of the Brγ emission and CO absorption features, they are able to date the age of the star–forming regions. The observed spread in ages suggests that star formation is triggered by the passage of a spiral density wave travelling sequentially through each region.

What fuels active galactic nuclei?

Many galaxies possess a highly luminous compact core known as an Active Galactic Nucleus (AGN) which is thought to consist of a massive black hole into which matter is falling or accreting. The host galaxies of AGN frequently show other forms of nuclear activity such as massive bursts of star formation and inner rings or bars. Corbett (AAO) is a member of the COLA Project (Compact Objects in Low–power AGN), a large multi-national collaboration which aims to determine whether these forms of activity are related to the presence of the AGN, for instance by transporting fuel to the AGN, or are purely coincidental. This should help to explain why some galaxies have AGN and others do not.

The COLA project will address this question by comparing multi–wavelength properties of galaxies with AGN to those of a matched sample of "non-active" galaxies. During the past 24 months the COLA collaboration has undertaken a major all–sky study of the multi–wavelength properties of 217 galaxies in order to identify a sample of AGN without biases such as orientation and redshift. This initial phase is close to completion and when complete, a matching control sample of non-active galaxies will be selected. The two samples will then be studied in great detail from optical to radio wavelengths and on scales ranging from a few parsecs to kiloparsecs.

Radio sources in the 2dFGRS

Powerful radio galaxies act as "beacons" which can be seen to enormous distances, so radio surveys play a key role in developing our understanding of galaxy evolution and the high–redshift universe. The limiting factor, however, has always been the difficulty of obtaining follow-up optical spectroscopy. A new generation of faint, large–area radio imaging surveys are just being completed, and 2dF on the AAT is the ideal instrument to rapidly obtain redshifts and optical spectra for these large samples of radio sources. Sadler (Sydney), Cannon (AAO), McIntyre (ATNF) and Jackson (RSAA) have undertaken a project to cross–identify galaxies in the 2dF Galaxy Redshift Survey (2dFGRS) and the radio surveys NRAO/VLA Sky Survey (NVSS) in the north and Sydney University Molonglo Sky Survey (SUMs) in the south.

As a first step in exploring the redshift distribution of the faint radio source population, galaxies in the first 20% of the 2dFGRS have been cross–identified with 1.4 GHz radio sources in the NVSS. About 1.5 – 2% of 2dFGRS galaxies are detected as radio sources in the NVSS — already a sample of over 900 candidate radio–galaxies have been identified — including both active galaxies (AGN) and star–forming galaxies. One early result is that the space density of radio–weak AGN is higher than previously measured. The completed project is expected to yield ~ 4000 radio–galaxy spectra. This sample will be a powerful tool for studying the distribution and evolution of both AGN and star–burst galaxies.

Unusual variable quasars

Kedziora–Chudczer (AAO) has been studying an unusual quasar PKS 0405–385 at the distance of 9 billion light years, which shows large and rapid changes in its radio flux density. Such variability is probably produced by scintillation which requires an extremely small and compact component of the radio source. The brightness temperature of this compact component, contained in a volume of a few Solar Systems, is higher than 10^{14} K. The presence of such a hot source in a relatively small volume questions our understanding of emission processes in active galactic nuclei. To address this question, the properties of the polarized emission from PKS 0405–385 at optical and radio wavelengths are being investigated, and its intensity is being monitored to determine the long–term evolution.

During the Australia Telescope Intraday Variability Survey of 118 extragalactic radio sources, another unusual intraday variable BL Lac object has been found — PKS 1519–273 — which shows high and variable circular polarization. Such high circular polarization cannot be produced by any obvious known process, either intrinsic to the source (synchrotron emission) or a propagation effect (the conversion of linear to circular polarization). At present Kedziora–Chudczer and collaborators are investigating the possibility of coherently–induced emission in this object.

The evolution of quasars

The QSO luminosity function measures the brightness distribution of quasars. Boyle (AAO), Shanks (Durham), Smith (RSAA), Croom (AAO), Miller and Loaring (Oxford) have analysed the first 5000 quasars identified in the 2dF QSO redshift survey by comparing the luminosity function at different redshifts. They find that the function shows strong luminosity evolution — quasars are intrinsically fainter in the present day than at large redshifts. The results indicate that the quasar luminosities evolved in the period bracketted by $0.35<z<2.3$ and $-23>M_B>-26$.

With Schade (DAO), Boyle has completed the analysis of 76 low redshift AGN/QSOs imaged with the Hubble Space Telescope. They find that 55% of these radio–quiet QSOs live in spheroid–dominant galaxies. Other than this bias towards early–type galaxies, the properties (luminosity and size) of the galaxies are consistent with a field galaxy population. Boyle and Schade find no evidence for mergers in any of the QSOs, casting doubt on the hypothesis that QSOs are largely fuelled by interactions.

Together with Londish (Sydney), Boyle and Schade have also shown that the luminosity function for these AGN/QSOs changes to a flatter slope for objects brighter than $M_B = -20$ — there are more intrinsically bright AGN/QSOs than previously thought. This has an important bearing on the evolution of the QSO luminosity function and for the local luminosity density of AGN.