Development of High Energy Astrophysics in the Research School of Astronomy & Astrophysics

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Development of High Energy Astrophysics in the Research School of Astronomy & Astrophysics

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Prof. M.A. Dopita (RSAA) Dr. J. Li (RSAA/Dept. of Maths)
Dr. R.S. Sutherland (RSAA)

Executive Summary

Over the last decade, High Energy Astrophysics (HEA) has developed as one of the major branches of astronomy in the USA and in Europe, receiving a major share of the total funding for astronomy. Because of the high costs involved, Australia has not built the space observatories required for HEA. However, RSAA astronomers have competed very successfully in both HEA theory and space-based observation establishing a significant track record in this field.

In the next decade, a number of NASA *Great Space Observatories* will be launched to further research in HEA. We propose to develop the RSAA group further, in order to strengthen its links with the international effort in this field. A special effort will be made to exploit the theory which connects HEA and radio astronomy – a traditional area of strength in Australia.

The HEA group at the RSAA are involved in research on the physics of black holes and neutron stars, on the energetic jet and wind-like outflows which these objects generate, and on the interaction of these outflows with the surrounding medium. These processes are relevant for many types of astrophysical objects, describing phenomena ranging from the kilometer sized inner accretion disc around stellar mass black holes within our galaxy, to mega light year scale jets associated with the largest radio galaxies at the edge of the observable Universe. The development of HEA research will have significant benefits for cosmology and other areas of research within the RSAA. Research will focus on the study of high-energy radiative processes, atomic physics, multi-dimensional radiative hydrodynamics, and the combinations of these required to model space and ground-based observations.

We propose to build upon the current base of expertise in High Energy Astrophysics by:

- The appointment of an observer who is capable of successfully applying for and using modern space and ground-based facilities for High Energy Astrophysics observations
- The appointment of a numerical hydrodynamicist in the field of High Energy Astrophysics.
- Travel funds to enable reciprocal local and international visits by High Energy observers and theoreticians thereby enabling access to, and effective use of, local and overseas facilities.

The total recurrent budget is estimated at $183,330 per annum.

Contents

1 High Energy Astrophysics – A Scientific Frontier

1.1 What is High Energy Astrophysics?

High Energy Astrophysics is the study of high temperature and relativistic astronomical phenomena which are observable across the electromagnetic spectrum from radio through to γ-rays. Many high energy phenomena lead to emission of very high energy photons which can only be studied from space observatories.

Since the 1960s X-ray detecting satellites of increasing sensitivity and spatial resolution have been placed in orbit above the Earth's atmosphere. Some of the most dramatic results have been obtained from NASA's *Einstein Observatory*, the German *ROSAT* (for Rontgen-Satellite) and the Japanese satellite *ASCA*. The energy coverage and spatial imaging capabilities of these satellites varies. Most imaging has been at a resolution of approximately 1.5 minutes of arc. The era of X-ray astronomy has opened an entire new window on the Universe enabling studies of the structure of the corona of the sun and other stars, emission from black holes and other compact objects (ranging in mass from a few solar masses to billions of solar masses), the atmospheres of elliptical galaxies (involving implications for dark matter) and the emission from clusters of galaxies with important implications for cosmology and the formation of galaxies.

The launch of the *Hubble Space Telescope* (HST), the first Great Observatory, provided RSAA astronomers the opportunity to make leading theoretical and observational contributions in HEA described in detail below.

The most recent development in high energy astrophysics has been the advent of γ-ray astronomy. NASA's second Great Observatory, the *Compton Gamma-Ray Observatory* (GRO), has extended the energy range from 10 keV to 1 GeV and the new generation of ground-based Cerenkov telescopes has extended this range even further to the 100 GeV–10 TeV spectral region. The Compton GRO has provided much important information on an enigmatic class of objects known as γ-ray bursters – the last throes of a collapse of a star to a black hole. Active Galactic Nuclei were also discovered to be emitting significant amounts of power in the form of γ-rays and this is believed to represent radiation from a relativistic electron-positron jet in the region close to a supermassive black hole. Another major discovery of GRO was the existence of hot thermal coronae above black hole accretion disks.

1.2 The Future of High Energy Astrophysics

The next decade will see a revolution in our capabilities for space-based observation thanks to the NASA *Great Observatories Program* and many smaller explorer missions, operating across the electromagnetic spectrum. Our strategic objective is to tap into these observational resources and to make fundamental theoretical contributions to their interpretation.

Future space observatories include:

- The *Advanced X-Ray Astrophysics Facility* (AXAF) to be launched during 1999 and will provide unprecedented spatial and spectral resolution and sensitivity, greatly extending our knowledge of those objects which emit X-rays.
- The *Space Infrared Telescope Facility* (SIRTF) to be launched in 2000, enabling us to probe the dusty accretion environments surrounding black holes.
- The *Far Ultraviolet Spectroscopic Explorer* (FUSE), expected launch date June 1999. This will be used to study high energy phenomena in the local Universe, in the 900-1200 A region of the spectrum.

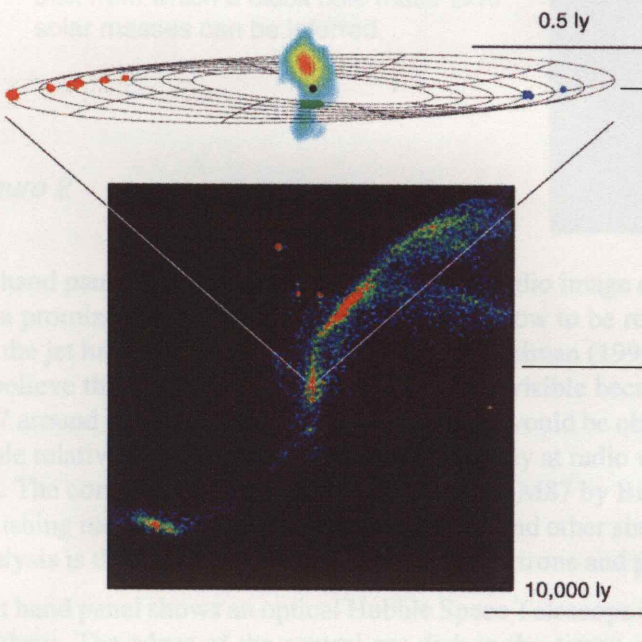
Important ground-based facilities include new technology Cerenkov arrays for detecting ultra high energy (TeV) γ-rays produced close to the event horizons of black holes. A significant Australian development here is the construction of the CANGAROO γ-ray observatory – a collaborative project between the University of Adelaide and the University of Tokyo.

In summary, High Energy Astrophysics involves a vast range of phenomena and incorporates the hot phase of the interstellar media of the Galaxy and external galaxies, the physics of ultrarelativistic particles in jet outflows from compact objects as well as the dynamics of such outflows and the physical environment of compact objects, such as black holes. It also addresses questions relating to dark matter in both individual galaxies and the Universe.

1.3 Examples of RSAA Research in High Energy Astrophysics

1.3.1 The Seyfert galaxy NGC 4258

The following figure typifies an astrophysical environment in which HEA observations and theory are important. The lower image is a 20cm (radio) image at ~1 arcsecond resolution of the active Seyfert galaxy NGC 4258 (de Pree, unpublished). This image shows two jets emerging in opposite directions from the nucleus. Both jets, in particular the Northern (upper) jet, interact with the interstellar medium of the galaxy, producing shock-excited X-ray emission. The upper part of the figure is based upon Very Long Baseline Interferometry (VLBI) observations at milliarcsecond resolution (Greenhill, Moran, Miyoshi and colleagues) which show the unresolved central jet, and spots of water vapour maser emission whose velocities indicate a central black hole mass of approximately 2×10^{7} solar masses. This galaxy is the target of AXAF observations by Dopita, Sutherland and colleagues.

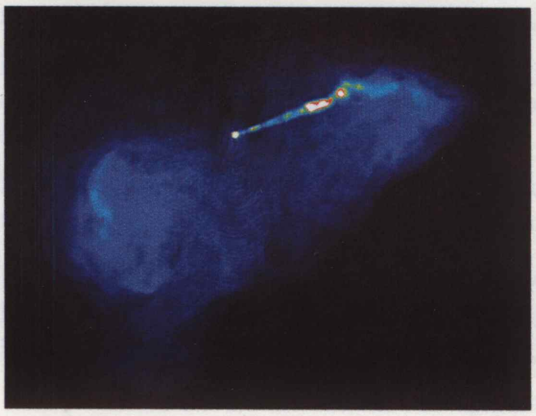


VLBI observations showing the central jet and maser spots, coloured red for receding and blue for approaching.
The wire frame shows the fit to a slightly warped rotating accretion disk model.

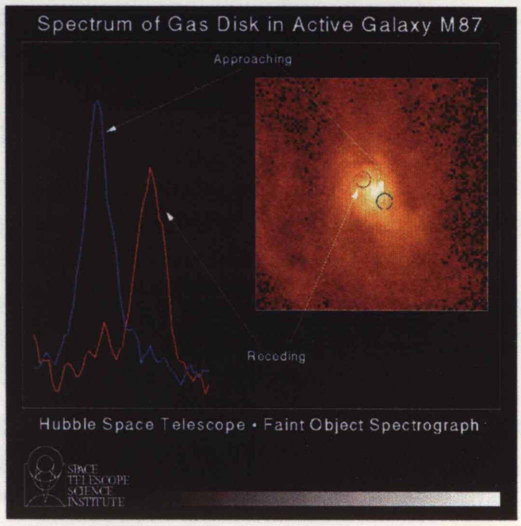
20 cm VLA image showing bent, bifurcated jets interacting with the interstellar medium of NGC 4258

Figure 1

1.3.2 The Radio Galaxy M87



2 cm radio image of the central part of the famous radio galaxy M87 (Biretta et al.)



An optical Hubble Space Telescope image (Ford et al.) of the central part of M87 showing the rotating gaseous accretion disk from which a black hole mass $2{\times}10^9$ solar masses can be inferred.

Figure 2

The left hand panel of Figure 2 shows a 2cm VLA radio image of the active radio galaxy M87. This galaxy has a prominent radio emitting jet which we know to be relativistic with a Lorentz factor > 5. The knots in the jet have been shown by Bicknell & Begelman (1996) to be relativistic shocks. Astronomers widely believe that there is a counterjet which is invisible because of relativistic beaming. If we could turn M87 around so that the jet points towards us, it would be observed as a blazar with intense and highly variable relativistically beamed emission – not only at radio wavelengths but also at X-ray and γ–ray energies. The comprehensive analysis of the data on M87 by Bicknell and Begelman is widely regarded as establishing most of the relevant physics for this and other similar galaxies. One important result from their analysis is that the M87 jet is composed of electrons and positrons.

The right hand panel shows an optical Hubble Space Telescope image of the central few hundred parsecs of the galaxy. The edges of the central gas disk in the centre of the galaxy are rotating with a relative speed of approximately 750 km/s indicative of a central black hole mass of $2{\times}10^9$ solar masses. A team of astronomers led by Dopita, have shown that the gas in the centre of this galaxy is shock-excited and have also revealed shock-related structures in the disk.

1.3.3 Theoretical Highlights

The investment of billions of dollars by the USA and European governments in high energy related space science underlines the scientific importance of this field. An important aspect of this proposal is the enabling of scientific links to these expensive facilities - links which are made possible by the presence in the RSAA of theoretical expertise which is held in high international regard. As evidence of this we cite the following scientific highlights:

- Theoretical hydrodynamic modelling of energetic phenomena such as jets in active galaxies and related radio observations [Bicknell] and high speed winds in quasars [de Kool & Begelman, 1995]
- Establishing the relationship between radio galaxies and BL-Lac objects [Bicknell, 1994].

- Modelling self-absorbed synchrotron sources as the origin of the far infrared continuum in radio quiet quasars [de Kool & Begelman, 1989]
- Use of X-ray data to constrain model atmospheres of elliptical galaxies containing radio sources and to constrain dark matter in elliptical galaxies [Bicknell and students]
- Recent work on magnetised accretion discs surrounding black holes and their relationship to high energy emission from accretion disc coronae [Bicknell and Kuncic (in preparation), de Kool (MNRAS, submitted)]
- Modelling the evaporation of X-ray irradiated accretion disks around black hole, with relevance to models of advection dominated accretion disks [de Kool & Wickramasinghe (1998)]
- Modelling and interpretation of time resolved X-ray and γ–ray data from X-ray satellites and the High Energy Gamma Ray Array (HEGRA) [Bicknell, in conjunction with ARC International Exchange Fellow, Wagner (Landessternwarte, Heidelberg), in preparation]
- The production of MAPPINGS, a comprehensive, sophisticated computer code for the calculation of spectra, including X-Ray spectra, of gas excited by either shock waves or photoionisation. [Sutherland (1992, 1998); Dopita and Sutherland (1995, 1996)]
- Modelling the radiative cooling of gas in the galaxy formation epoch of the early Universe [Sutherland & Dopita, in preparation].
- The first convincing and comprehensive papers that radiative shocks driven by jets can power emission line regions in active galaxies [Sutherland, Bicknell and Dopita (1993); Bicknell, Dopita & O'Dea (1997); Kuncic, Bicknell & Dopita (1998); Bicknell et al. (1998)]
- Successful proposals (against extremely strong competition) for two projects on NASA's Advanced X-ray Facility (AXAF) [Dopita, Sutherland in conjunction with Cecil (University of Carolina) and Wagner] and for observations, using the Italian Beppo Sax satellite, of the blazar Makarian 501 [Bicknell, Wagner and collaborators].
- The physics of relativistic pulsar winds; related work on accretion flows. [Li (1998); Li, Wickramasinghe & Rudiger (1996)]

2 Proposed research program in High Energy Astrophysics

With the development of high energy astrophysics in the RSAA, we would be well-placed to execute cutting edge research in the following areas:

- **Emission processes in blazars.** An overwhelming fraction of the total energy of many Active Galactic Nuclei, appears in γ-rays - from GeV to TeV energies. The relevant radiation mechanisms (specifically, the relative importance of Synchrotron Self Compton emission and External inverse Compton) and the composition of the relativistic jets (electron/positron or electron/proton) from where the emission originates are still uncertain. However, both of these questions impinge very directly on black hole physics - the environment of the black hole in active galactic nuclei and the origin of jets. Do jets originate, for example, in pair creation environments close to the black hole?
- **X-ray emission from the environment of black hole accretion discs.** According to standard theory, extragalactic black hole accretion discs have no right to emit X-rays since their temperature is expected to peak in the UV emitting region. However, they do emit a significant flux in X-rays and the most favoured model for this involves a hot ($T \sim 10^9$ K), magnetically heated, accretion disk corona. Theoretical work is being conducted on these in the RSAA at present and we seek the observational and theoretical resources to extend this work.
- **Shock-heated X-ray emitting gas.** As indicated above, shockwaves in AGN, driven, in part, by the nonthermal jets referred to above can produce significant X-ray emission. As a result of the work done at ANU in this area, this is now a hot topic in AGN physics with a number of international

groups successfully applying for time on the AXAF satellite to investigate the predicted spectra and luminosities of the shocked regions. This work also has a implications for the composition of the plasma ejected from the environs of black holes.

- **Production of jet outflows.** In active galactic nuclei, it is strongly suspected that processes very near a supermassive black hole are responsible for the production of jets and for the creation of pair-dominated plasma. Part of our theoretical program will relate to the idea that the "cleaning" of magnetic flux by the black hole is responsible for the production of kinetic energy in the pair-producing region close to the black hole. This involves a substantial program in the physics of black holes and their environments.
- **Production of fast quasar winds.** In the last few years it has become evident that most quasars contain fast (up to 0.2 times the speed of light) winds. The study of these winds is at present one of the most promising avenues towards further understanding of the accretion process in active galactic nuclei on scales of 0.01 to 1 parsec. De Kool is currently part of a collaboration with US astronomers to analyse data on quasar winds taken with instruments such as the Space Telescope, the ASCA X-ray satellite and the Keck telescope. These quasar winds wil be modelled using multidimensional radiative hydrodynamics.
- **Three dimensional radiative hydrodynamics.** Recently Sutherland and Bicknell have been developing computer codes for the purpose of realistically simulating plasmas which cool on a dynamical time scale. This work has numerous applications to the production of X-rays in shocks and to the physics of collisions between dense clouds and relativistic jets – such as occurs in high redshift radio galaxies, for example.

Underpinning all of the above programs is the need to be linked into contemporary observational programs in High Energy Astrophysics and the requirements for personnel to assist in developing the theoretical ideas which have originated in the RSAA.

3 Requested resources

A significant part of this proposal concerns the utilisation of facilities which are so expensive that Australia would be unable to fund them, but which impact significantly on our knowledge of areas to which Australian astronomers have made significant contributions through national optical and radio facilities. We propose to link into international High Energy Astrophysics in the following ways:

1. *Linkage to cutting edge observational programs through observational colleagues in the United States and Europe.* This involves international travel to and from Landessternwarte, Heidelberg (mainly involving our colleague, Dr Stefan Wagner) and high energy sites in the US (Goddard Space Flight Centre, and Harvard Smithsonian Center for Astrophysics). We have budgeted for eight return trips costed at $4,000 each.
2. *Utilisation of the CANGAROO project through the forging of links with the University of Adelaide.* The Adelaide group was originally involved with Cosmic Ray Physics which is a sub-field of High Energy Astrophysics and has more recently diversified in the direction of Active Galactic Nuclei. Their initiative in cooperating with Japanese physicists in developing CANGAROO is an important one and we look forward to a productive symbiosis between their group and ours. Indeed the response from that group to this initiative, has been positive. We have budgeted for four return trips between Adelaide and Canberra, costed at $1500 each.
3. *The appointment of a High Energy observer with a good record in X-ray and γ–ray astronomy.* It is one thing to be aware of developments in High Energy Astronomy; it is another matter to be confronted with the latest data from the newest technology observatories. This message was clearly brought home to us by Dr. Wagner's one year stay in the ANU as an ARC International Fellow. He provided us with the challenge of explaining the first time-resolved spectra of an X-ray and γ-ray

emitting blazar (Makarian 501, paper in preparation) and was an important consultant in successful time applications to AXAF. This appointment is a crucial one in thrusting our group into the mainstream of HEA, keeping us up to date with the very latest developments. We plan to make such an appointment at level C in order to attract an outstanding person in competition with USA and European institutions.

4. *The appointment of a numerical hydrodynamicist.* In addition to its importance to this proposal, such appointment is consistent with the RSAA's strategic plan to further develop theoretical astrophysics at the ANU. The latest data coming from space observatories is now so comprehensive that detailed modelling and simulation are mandatory. This person would be in a position to exploit ANU's outstanding supercomputing facilities. As with the observational position, we propose to make this appointment at level C, in order to attract good candidates in a competitive market.

4 Budget

Recurrent funding per annum

Item	Cost
High Energy Observer (level C + on costs)	$72,665
Numerical Hydrodynamicist (level C + on costs)	$72,665
Local travel	$ 6,000
International travel	$32,000
Total	**$183,330**

5 Relationship to Selection Criteria

5.1 Quality and importance of research

Current research in high energy astrophysics in the RSAA has been of a consistently high standard and has been responsible for the injection of significant new ideas and paradigms into mainstream astronomy. Given the track records of the proposers, success of the proposed research program is guaranteed.

5.2 Relationship to the Strategic Plan of the RSAA

Our strategic plan highlights two important subfields:

- How do accretion discs work?
- The physical environment of black holes

Moreover, HEA is also an important contributor to two other subfields, the quest for dark matter and the formation of structure in the Universe.

Another important component of our strategic plan is the development of Theoretical Astrophysics. This is a major component of our proposal.

5.3 Contribution to the Institute and ANU Strategic Plans

We note the following:

1. The area identified in this proposal is currently a strong one and would develop significantly with the requested additional funding.

2. Significant cooperation between the Institute and Faculties is involved since Bicknell and Li have joint appointments in the RSAA and the Dept. of Mathematics (Faculties).

5.4 Possible economic benefits to Australia

This proposal involves space science in a significant way. Currently, this is not a technology which is being actively pursued in Australia. However, at some stage, space science must develop a higher profile and scientific areas such as this can assist in providing impetus to such developments. This could occur, for example, through Australian groups bidding to build space instrumentation or through local experts providing experimental and/or theoretical input into major projects.

5.5 Generation of external funding.

Development of this area will enhance the prospect of successful, related ARC large grant applications. Bicknell and Sutherland have a good record here: Bicknell was successful in obtaining an ARC international fellowship for Wagner (a highly respected high energy observer); Bicknell (PI) and Sutherland (AI) have been successful in an ARC large program grant in a related area (numerical computation of three-dimensional radiative flows). Dopita also has an outstanding track record in securing external funds for space astronomy (e.g. the Hubble Space Telescope Fund for Australian astronomers). Developing collaborations with US based observers opens up excellent opportunities for NASA funded grants through consultancies with principal US investigators.

6 International Standing of Proposers

This section contains confidential information and has been omitted from this library copy.

7 Referees

1. Professor Rashid Sunyaev, Max Planck Institut fur Astrophysik, Karl-Schwarzschild Strasse 1, Postfach 1523, Garching 85740, Germany [email: sunyaev@MPA-Garching.MPG.DE]
2. Dr. Grzegorz M. Madejski, NASA/GSFC, Code 66, Greenbelt, MD 20771, USA [email:madejski@lheavx.gsfc.nasa.gov]
3. Professor Holland C. Ford, Dept. of Physics & Astronomy, Johns Hopkins University, 3400 Nth Charles St., Baltimore, MD 21218-2686, USA [email: ford@jhufos.pha.jhu.edu]

8 Relevant papers

The following is a list of papers which are either referred to in the main text or which are otherwise relevant to HEA. These references indicate a breadth of scientific knowledge and understanding which augur well for the success of this proposal.

Arav, N., Korista,K.T., de Kool, M., Junkkarinen, V.T., & Begelman, M.C. 1999, *HST observations of Broad absorption Line Quasar PG 0946+301*, ApJ, in press.

Bicknell G.V., 1994,*On the Relationship between BL Lacertae Objects and Fanaroff-Riley I Radio Galaxies*, ApJ, **422**, 542

Bicknell G.V., 1995,*Relativistic Jets and the Fanaroff-Riley Classification of Radio Galaxies*, ApJS, **101**, 29

Bicknell G.V. & Begelman M.C., 1996, *Understanding the kpc-scale Structure of M87*, ApJ, **467**, 597

Bicknell G.V., Dopita M.A. & O'Dea C.P., 1997,*Unification of the Radio and Optical Properties of Gigahertz Peak Spectrum and Compact Steep-Spectrum Radio Sources,* ApJ, **485**, 112

Bicknell G.V., Dopita M.A., Tsvetanov Z.I., & Sutherland R.S., 1998,*Are Seyfert Narrow-Line Regions Powered by Radio Jets?* ApJ, **495**, 680

Bicknell G.V. & Dopita M.A., 1998, *Relativistic Jets in FR1 and FR2 Radio Galaxies and Seyfert Galaxies*, in *Relativistic Jets in AGNs*, ed. M. Ostrowski, M. Sikora G. Madejski & M.C. Begelman (Poligrafia Inspektoratu Towarzystwa Salezjanskiego: Krakow), 1

De Kool, M., Begelman, M.C. & Sikora, M. 1989, *Self-absorbed synchrotron sources in AGN*, ApJ, **337**, 66

De Kool, M. & Begelman, M.C. 1991, *Outflows driven by cosmic ray pressure in BALQSOs*, ApJ **382**, 416

De Kool, M. & Meurs, E. 1994, *A BALQSO with low intrinsic X-ray absorption*, A&A **281**, 65

De Kool, M. & Begelman, M.C. 1995, *Radiation pressure Driven Magnetic Disc Winds in BALQSOs*, ApJ, **455**, 448

De Kool, M. 1997, *An overview of dynamical models for outflows in BALQSOs and Seyferts*, invited review for the workshop *Mass ejection from AGN*, OCIW, Pasadena.

De Kool, M. & Wickramasinghe, D.T. 1999, *Thermal Instability and Evaporation of Accretion disc Atmospheres*, MNRAS accepted.

Dopita, M.A., Koratkar, A. P., Allen, M.G., Tsvetanov, A., Ford, H.C., Bicknell, G.V., and Sutherland, R.S. 1997, *The LINER Nucleus of M87: A Shock-Excited Dissipative Accretion Disk,* ApJ **490**, 202

Dopita, M.A., & Sutherland R.S., 1995, *Spectral Signatures of Fast Shocks II: Optical Diagnostic Diagrams,* ApJ, **468**,195

Dopita, M.A., & Sutherland R.S., 1996, *Spectral Signatures of Fast Shocks 1: Low Density Model Grid,* ApJS, **102**,161

Kuncic Z., Bicknell G.V. & Dopita M.A., 1998, *Induced Compton Scattering in Gigahertz Peak Spectrum Radio Sources*, ApJ, **495**, L35

Li J., & Melrose D. B., 1994, Uniqueness of the Alfv'en Singularity in a relativistic pulsar wind, MNRAS, **270**, 687

Li J., 1998, On singularities of a cool relativistic pulsar wind, PASA, **15**(3), 328

Li J., Wickramasinghe D.T., & Rudiger G., 1996, *Magnetised Accretion and Funnel Flow*, ApJ, **469**, 765

Sutherland R.S., Dopita M.A., 1992, *Cooling Functions for Low Density Astrophysical Plasmas*, ApJS, **88**, 253

Sutherland R.S., Bicknell G.V., and Dopita M.A., 1993, *Shock Excitation of the Emission Line Filaments of Centaurus A,* ApJ, **414**, 510,

Sutherland R. S. 1998, *Accurate Free-Free Gaunt Factors for Astrophysical Plasmas,* MNRAS, **300**, 321

9 Curriculum Vitae of Proposers

9.1 Dr. Geoffrey V. Bicknell

Date of Birth: May 11, 1948
Employment
May 1995 appointed to tenurable position in RSAA/SMS.
Jan. 1980–May1995: Research fellow - Senior Fellow, RSAA (formerly MSSSO)
July 1978–Dec. 1979: Senior tutor, School of Mathematics, Monash University
Jan. 1977–June 1978: Postdoctoral fellow and research associate, Queens University, Kingston, Ontario, Canada
Education
1965-68 B.Sc. (First class Hons. in Applied Maths) University of Sydney
1969-70 M.Sc. in Applied Mathematics: *The Field Equations of General Relativity* (conferred 1971)
1970-75 Ph.D. *The Geometrisation of Physics*, 1976 (conferred, 1976)
Major research interests

- Relativistic jet dynamics
- High energy radiative phenomena in active galaxies
- Accretion discs in active galactic nuclei
- Computational fluid dynamics

Professional Societies
Astronomical Society of Australia, Australian Mathematical Society, American Astronomical Society, International Astronomical Union.
Awards
Visiting Scientist, National Radio Astronomy Observatory, Very Large Array, New Mexico, Mar 1986 - Sept. 1986
JILA visiting fellow, University of Colorado, Boulder Colorado, Oct. 1994 -Feb. 1995
Grants
1986 $US 10,000 for visiting scientist position at the VLA, New Mexico
1994 $US 12,000 for visiting scientist position at JILA, Univ. of Colorado
1996 (Sept.) Visiting scientist, Space Telescope Science Institute $2,100
1996 $21,000 (with Wickramasinghe and Ferrario) DIST grant for funding IAU Colloquium 163
1996 $US 24,700 (with Hawley, Univ. of Virginia and Ferrario, Dept. of Maths) for funding IAU Colloquium 163
1996 $4,100 DIST HST fund for travel to workshop at Univ. of Alabama and IAU symposium 175
1996 $US 2,100 from Univ. of Alabama for workshop there
1997 $8,000 grant to Dr. van Breugel from Anglo-Australian Observatory and Australia Telescope National Facility (intermediary)
1997 (Nov.) Visiting scientist, Space Telescope Science Institute $2,600
1998 (Mar-Apr.) DIST bilateral grant to visit JILA, University of Colorado and University of Victoria, British Columbia $4,100
1997 (Oct.) - 1998 (Oct.) ARC International Fellowship for Dr. S Wagner, $94,075
ARC Large grant (principal investigator) *Jet-Cloud Interactions in Active Galactic Nuclei,* $166,000 plus infrastructure, for level A postdoctoral fellow salary plus support.
Publications
56 papers in refereed journals; 27 conference papers; 2 edited books
12 invited papers at international conferences since 1984

9.2 Dr. Marthijn de Kool

Date of Birth: 24/8/57

Employment

Dec. 1997 – present Research School of Astronomy and AstrophysicsResearch Fellow (B)
Oct. 1996 – Nov. 1997 JILA, University of Colorado (USA) Senior Research Associate
Jan. 1991 – Step 1996Max-Planck Institut fur Astrophysik (Germany) Researchers (BAT IIa)
Step 1987 – Dec. 1990JILA, University of Colorado (USA) Research Associate

Degrees

June 1987 University of Amsterdam, (Netherlands) Ph.D.
Dec. 1982 University of Amsterdam (Netherlands) Drs.

Research Interests

Accretion physics, Active galactic Nuclei, Broad Absorption Line quasars, X-ray pulsars, interacting binary stars.

Publications in refereed journals

29 papers have appeared in print, 4 are accepted for publication

9.3 Prof. Michael A. Dopita FAA

Date and Place of Birth: 28 October 1946, Kraslice, Czechoslovakia

Education

1968 BA Honours in Natural Science, Wadham College, Oxford University.

1973 MA (Oxon), Ph.D. (Manchester).Advisor: Prof. J. Meaburn, Thesis: *The Temperature Structure of two High Density Galactic H II Regions*

Honours and Awards

1968 June Sir Maurice Bowra Essay Award.

1974 October RAS Young Scientist at the opening of the Anglo-Australian Telescope

1983 April Pawsey Medal of the Australian Academy of Sciences for outstanding research in the Natural Sciences by a researcher younger than 36.

1996 May Elected Fellow of the Australian Academy of Science (FAA).

Grants

1986 $64,700: from Australian Space Office for support of Lyman Science Working Group.

1989 $69,634: 3 year grant from DITAC International Science Science and Technology for *Space Science with the Hubble Space Telescope*

1992 $15,750: from DITAC International Science and Technology (Bilateral Science) for *The Extreme Ultraviolet Explorer Satellite*

1993 $241,666: 3 year grant from DITAC International Science Science and Technology for *Space Science with the Hubble Space Telescope*

1994 $30,220: 1 year grant from DITAC International Science Science and Technology for *The International Antarctic Balloon Observatory*

1995 $171,000: Contract from Australian Space Office (DIST) for the reduction of Endeavour data.

1996 $273,000: 3 year grant from DIST International Science Science and Technology for *Space Science with the Hubble Space Telescope*

1997 $225,000: with UNSW, Major National Research Facility Study:*A South Polar Infrared Telescope*

Membership of Editorial Boards

Member of the Board of Editors, Publications of the Astronomical Society of the Pacific 1990-1993.

Member of the Board of Editors, Astrophysics and Space Science 1994-1999.

Member of the Board of Editors, Publications of the Astronomical Society of Australia 1994-1997.

Professional Societies

International Astronomical Union, Astronomical Society of Australia,
American Astronomical Society, European-Asian Astronomical Society.

Current Membership of International Committees

President of International Astronomical Union Div VI: Interstellar Matter, 1997-2000.

Chair of the International Astronomical Union Executive Committee Working Group for the Development of Antarctic Astronomy.

Member, Science Oversight Committee for Wide Field Camera 3 of the Hubble Space Telescope

Member, Australian and SCAR Antarctic Astronomy Working Groups.

Publications

Co-editor of one book; Author or co-author of over 180 publications in refereed Journals
Invited speaker at 50 conferences; 90 contributions to conferences and other unrefereed publications.

9.4 Dr. Jianke Li

Date of Birth: October 23, 1957
Employment
Lecturer Department of Mathematics, and Research Fellow in the Research School for Astronomy and Astrophysics, ANU
Postdoctoral Fellow (7/92 -10/93): Research Centre for Theoretical Astrophysics, University of Sydney, Australia.
Postdoctoral Fellow (10/93-2/96): High Altitude Observatory, NCAR, Boulder, USA.
ARC Research Associate (3/96-12/96): The ANU Astrophysical Theory Centre, Canberra, Australia
Education
D.Phil in Astrophysics (10/88 -4/92), Astronomy Centre, University of Sussex, Brighton, England.
Research interests and achievements
Dr. Jianke Li has a major research interest in Astrophysical Magnetohydrodynamics, and his area of work ranges from stellar spin-down and internal rotation, star core-envelope magnetic coupling, stellar winds and magnetic braking theory, close binaries with compact stars, relativistic pulsar winds, planetary magnetosphere, star-disc interaction, and accretion discs, disc outflows and winds.
He has made fundamental contributions in three different areas:
Magnetic braking', Magnetic star-disc interactions and also Relativistic pulsar wind theory. His fundamental and other important results (e.g. in stellar spin-down) have been cited in international journals, and some of them have been quoted and adopted in the incoming book, *Stellar Magnetism*, by the internationally renowned theorist, Professor Leon Mestel.
Li led the research (with collaborators), Planets around white dwarfs, which has attracted the attention of the media, which led to reports in New Scientist (1/8/98), Sky \& Telescope (11/98) and also ANU News.
He has attracted *The Faculties New Starters Grants* of 1997 ($5000) and Small ARC grant' of 1998/99 (2 x $1300 with co-investigators).
Publications
Li has twenty-two publications in refereed journals.

9.5 Dr. Ralph S. Sutherland

Date and Place of Birth: 15th August 1964, Canberra Australia
Nationality: Australian
Marital Status: Married (Denise Louise, married 1985)
Children:Rodger James (1988) & Jennifer Ray (1991)
Academic Qualifications
1987 BSc Hons. (1st Class) Chemistry, Australian National University
1993 Ph.D. in Astrophysics, Mount Stromlo and Siding Spring Observatories, Australian National University
Main Research Interests
Theoretical Numerical Simulation Astrophysics in the areas of:

- Active Galaxies
- Interstellar Medium Physics
- Supernova Remnants
- Atomic Physics
- Accretion Phenomena in Compact Objects
- Massive Star Evolution and their ISM Interactions

Present Appointment
1996-97 Post-Doctoral Research Associate at the Astrophysical Theory Centre, Mount Stromlo & Siding Spring Observatories & School of Mathematical Sciences, The Australian National University
1997-98 Extended to 3rd year, and promoted to ANU Level B salary, retaining Postdoctoral position.
1999-present 3 Month Fixed term extension, Post-Doctoral Research Associate, Level B, at RSAA.
Postgraduate Career
1988Computer programmer, ANU Chemistry Department. Working on Fourier transforms and a chemical kinetics simulator.
1988Research assistant in surface and colloidal chemistry, ANU Applied Mathematics Department.
1989-1993 Postgraduate studies in astrophysics at Mount Stromlo & Siding Spring Observatories, Australian National University. Degree granted 1 Oct. 1993
1993-1995Post-Doctoral Research Associate at the Joint Institute for Laboratory Astrophysics, University of Colorado, Boulder, CO, USA
Academic Honours and Awards
1986 Royal Australian Chemical Institute Chemistry Prize for best final year chemistry student, Australian National University.
Grants
1997/8 DIST Bilateral Collaboration Grant - For travel to US to study massive stellar systems with Prof. M. Shull, University of Colorado. $3500
1998/9 ARC Large Research Grant with G. V. Bicknell, *Jet-Cloud Interactions in Active Galactic Nuclei* $166,000 over 1999, 2000, 2001 for a Level A Postdoctoral Position.
Management
1998-present Project Scientist for RSAA Antarctic Astronomy program
Affiliations
Member of Astronomical Society of Australia
Publications
20 papers in refereed journals; 16 conference papers