DEPARTMENT OF ASTROPHYSICS
UNIVERSITY OF OXFORD

(Director, Professor D.E.Blackwell)

(Report for the year ending 1973 December 31)

SOLAR RESEARCH

The 35-m solar telescope has been in continual use during the summer. Following the completion of his earlier investigation of photospheric currents, Professor Plaskett used the telescope during two months of 1973 to obtain supplementary data for this investigation. Dr Adam and Miss Jones used it to obtain further material for Miss Jones' study of the limb effect in the 5170 Å region: spectra for the determination of scattered light for this study were also obtained. Dr Adam also obtained some preliminary spectra for an investigation of the Fe I line at 5576 Å to be made by Dr A.B.Hart. Her own work on magnetic field direction determinations using lines in the region of 5250 Å has now been completed for 260 points over a large spot, and the reduction to heliographic co-ordinates and the interpretation of the results is in hand.

The Gornergrat solar station has now been closed. Over a period of several years a large amount of data has been obtained and recorded on punched tape, and this will be interpreted using data obtained with the departmental furnace during the next few years. One of the last items of equipment to be installed there was a magnetically suspended vibrating mirror, designed by Mr P.Craven, which was used by him for investigations of limb darkening by rapid scanning across the disk. Dr Adam spent ten days at the station in June, when she and Dr Ibbetson made some observations of the limb effect in the 6302 Å region with the low-noise spectrometer. Dr Ibbetson spent a year at the station as astronomer in charge.

Mrs Lamb spent several months in the department during the summer, when she completed her thesis on material motion in sunspots, which was accepted for the D.Phil. degree.

Dr Mallia has completed the reduction of all of the sunspot material that he obtained at the Gornergrat Observatory. He read an invited paper on 'Molecules in Stars' at the Third Colloquium on High Resolution Molecular Spectroscopy at Tours in September.
STEellar AND ExTRAGALACTIC RESEARCH

Professor Blackwell, Mr Ellis and Mr Willis made two visits to Israel during the year in order to test and use a spectrum scanner on the 40-in. telescope of the Florence and George Wise Observatory. The scanner had been made in the department to the design of Dr Ibbetson and Dr Petford. It was used in studies of the distribution of energy in the spectra of bright stars as part of an investigation of their surface gravities and atmospheric abundances. Spectra of some of these stars were obtained with the Isaac Newton telescope and the 30-in. telescope at the Royal Greenwich Observatory.

Dr Menzies has continued to work on the reduction of plate material on globular clusters that he has obtained at the Radcliffe Observatory, South Africa. Most of the reductions have now been completed for the clusters NGC 6352, 6723 and 288. In collaboration with Dr Mallia and Dr Selby’s group at Imperial College, he visited Tenerife on two occasions to use the 60-in. flux collector in order to carry out a programme of broad-band infrared observations of globular clusters.

Dr Peach together with Mr Austin, Miss Couper and Mr Godwin has been working on the properties of rich clusters of galaxies. Counts of galaxies in the field of nine rich clusters with \( z \) ranging from 0.13 to 0.20 have been made on \( V \) plates taken with the Palomar 48-in. Schmidt telescope. The surface density of galaxies as a function of distance from the cluster centre has been discussed in the context of three previously suggested approaches to a definition of angular size. Least-squares fits of the data to the projected isothermal gas sphere leads to a parameter \( \beta \) characterizing the radius of the cluster core. The mean distance of galaxies from the line of sight through the cluster centre, \( \gamma \), is a measure characterizing the size of the cluster as a whole. The use of secondary maxima in the density distribution has been considered and dismissed. \( R_\gamma \) and \( R_{3\delta} \), the intrinsic cluster and core radii in Mpc, were found to be related through the empirical equation

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R_\gamma = (0.31 \pm 0.02) R_{3\delta}^{-1} + (4.36 \pm 0.49 \times 10^{-3}) N_{SH} - (0.14 \pm 0.09)
\]

where \( N_{SH} \) is the cluster population. This equation was then used to define a new measure of angular radius \( \gamma_c \) by reducing the observed value of \( \gamma \) to that which would be observed for a cluster of standard radius on the assumption that \( R_{3\delta} \) and \( N_{SH} \) uniquely determine \( R_\gamma \). A plot of \( \gamma_c \) against \( z \) shows a standard deviation of the residuals of \( \gamma_c \) from a mean line with \( q_0 = +1 \) of only 18 per cent. It was suggested that the use of this parameter as a measure of angular size makes the angular diameter–redshift test using clusters of galaxies competitive with the apparent magnitude–redshift test using brightest cluster galaxies.

Magnitudes have been measured by photographic photometry for galaxies within 5 arcmin of the centre of the very rich cluster A1413.
The differential luminosity function shows a maximum at an absolute total $V$ magnitude of $-21.30$. The absolute magnitude difference between this and the brightest cluster member is $3.59$, which is closely consistent with the correlation of Bautz and Abell between this parameter and cluster richness and form type. The brightest cluster member shows an elliptical galaxy profile with a large scale length.

There is a significant difference between the distributions of the bright and faint galaxies; the former have a distribution consistent with spherical symmetry, while the fainter galaxies show a prolate distribution aligned with the major axis of the brightest cluster member. Counts in the field of the cluster show that this effect extends over most of the cluster volume.

The analysis of the peculiar southern star HD 101065 (Pryzbylski's star), which was undertaken by Dr Wegner and Dr Petford, has been finished. A quantitative atmospheric analysis of this star is exceedingly complicated, because of the great strength of rare earth lines in its spectrum. The star seems to be a cool Ap star of spectral class near Fo in which the iron-peak elements seem to have normal abundances, but the rare earths are overabundant in comparison with the Sun by five orders of magnitude.

During 1973 July-September, Dr Wegner visited the Radcliffe Observatory and the South African Astronomical Observatory. Observational data for four projects were obtained: (1) abundance in southern peculiar stars, (2) abundances in high-velocity metal-poor stars, (3) stars in Eggen's $\sigma$ Pup Group, and (4) spectra of southern hemisphere white dwarfs.

Dr Wegner is continuing investigations on white dwarfs. In collaboration with Dr Bues of Kiel University, atmospheric abundance analyses are being carried out on peculiar white dwarfs observed in the Southern Hemisphere. Recent results for the star EG 131 indicate that it has a hydrogen abundance intermediate between the DA and DB stars. Further observational studies are being carried out with the Isaac Newton telescope in order to obtain information on the gravitational redshifts of the white dwarfs. As part of this programme, Dr Wegner has obtained spectra of white dwarfs in common proper-motion binaries and galactic clusters, for which the radial velocities can be obtained directly.

**LABORATORY WORK**

Dr Smith and Mr O'Neill have used the furnace and photoelectric spectrometer to measure relative transition probabilities and collisional damping parameters for the $\lambda 6102, 6122$ and $6162$ Å lines of calcium. The line broadening and frequency shift produced by collisions with argon and neon have been determined for all three lines.
In September, Dr Smith spent three weeks at the Argonne National Laboratory, USA, where he used a large superconducting magnet to study the Zeeman effect in the Europium spectrum. Many new measurements of energy levels and Landé splitting factors were obtained, and these have been filed at the Atomic Data Centre of the National Bureau of Standards, USA, who partly sponsored the visit.

Dr Viggars has been working at AERE Harwell in collaboration with Dr T.W. Conlon studying nuclear reactions between carbon and oxygen ions at energies close to the Coulomb barrier. Such reactions are likely to occur in stars at temperatures of a few times $10^{9}$ K when a star in an oxygen régime undergoes a supernova explosion, and it is important to know the cross-sections for the various reaction channels to assess their influence on elemental abundances.

**THEORETICAL WORK**

Dr Bath has completed the development of a non-adiabatic hydrodynamic code to study mass transfer instabilities in semi-detached binary systems. Repetitive dynamical instabilities are found to occur with intervals between outbursts in the range of 2–100 days, using models with approximate properties of secondaries in dwarf novae systems. The interaction of the overflowing material with the compact accreting components has been studied as a model for the outbursts of such systems. In particular, the effect of inhomogeneities in the accretion disk has been examined and found to satisfactorily account for the periodicity phenomena observed in both dwarf novae and the binary X-ray sources.

Mr Evans has continued work on the problem of reflection heating in HZ Her and similar systems. Dr Bath and Mr Evans, in collaboration with Mr J.E.B. Pringle of the University of Cambridge, have studied an oblique rotator model to account for the 71 sec pulsations of the old nova DQ Her.

Dr Papaloizou has studied model envelopes of stars in Roche potentials and examined their stability from a linear point of view. Instabilities are found with similar properties to the hydrodynamic spherically symmetric models. A study of time-dependent accretion disks and surface nuclear burning on white dwarfs has been commenced.

Dr Sciama has studied astrophysical problems related to accretion by the Galaxy and to Mach's principle. In August, he gave an Invited Discourse at the 15th General Assembly of the IAU in Sydney on 'Early Stages of the Universe'. In November, he gave the first Young Persons' Lecture of the Royal Astronomical Society. This lecture, which was delivered at the University of St Andrews and was televised by the Open University, was entitled 'Not Seeing is Believing' (the Astronomy and Physics of Black Holes).
Dr Hunt has completed a study of the accretion of intergalactic gas by a realistic model of the Galaxy at rest with respect to the surrounding intergalactic medium. Solutions have been found for a range of initial temperatures for the gas \((10^8 - 3 \times 10^6 \, \text{K})\) and at each temperature for three values of the specific heat ratio, \(\gamma\), including adiabatic and isothermal accretions. The computed accretion rates are rather high (greater than \(5.6 \, M_\odot \, \text{yr}^{-1}\) in all cases), and in order to satisfy certain observational constraints it is perhaps necessary to assume that the accretion flow is impeded by pressure in the disk of the Galaxy. It is hoped to investigate this latter point more fully in the future.

Mr Anile has been studying radiation processes in cosmology. Some of this work is of immediate astrophysical interest, especially in connection with the effect of superclusters of galaxies on the intensity and polarization of the microwave background.

Mr Binney is working on the formation of galaxies, and the problem of the origin of their rotation. Mr Candelas is working on quantum problems in general relativity.

Mr Chaplin is studying singularities in general relativity. In view of Professor Penrose's arrival in 1973 October, it has been agreed that the more mathematical aspects of relativity theory should be based on the Mathematical Institute. Accordingly, Mr Chaplin has now been transferred to the Institute, and is working under Professor Penrose's supervision. Mr McNamara spent the year studying topological relativity in order to prepare for an attack on the singularity problem. He has also joined Professor Penrose, as have Mr Tod who is working on black holes, and Mr Hughson who is working on general relativity.

Mr Holmes has found a promising explanation for the recent observation that the ratio of primaries to secondaries in the cosmic rays is a decreasing function of energy. This involves the idea that higher-energy cosmic rays are confined in a thicker slab about the galactic plane, since they can only excite the plasma waves which confine them at greater heights, where the wave damping is less.

Mr Miller is studying gravitational collapse in general relativity. When Professor Chandrasekhar was with the department as a Senior Visiting Fellow, he worked with Mr Miller on this problem. They have written a joint paper on the quasi-static collapse of a slowly rotating homogeneous star, in which the calculations are carried out to the second order in the angular velocity. They are now investigating the more realistic, but much more difficult, problem of dynamical collapse, in which allowance must be made for the emission of gravitational radiation.

Mr Murray has worked on an experimental project at Harwell under Dr T.W. Conlon measuring the cross-section of \(\alpha\) transfer processes in
carbon and oxygen-induced reactions. He is currently studying the interaction of a supernova shockwave with the interstellar medium. Mr Wickett plans to perform extensive calculations on the joint hydrodynamic and nuclear processes that occur in the helium flash.

Dr Collins has continued his research on the nature of singularities in homogeneous cosmologies, Dr Brown on the theory of quantum gravity, and Dr Raine has worked with Mr Winlove on the problem of pair-production of particles in time-varying gravitational fields. Dr Duff has also worked on the theory of quantum gravitation, chiefly in collaboration with Dr Capper of Imperial College, London.

VISITORS

During their stay in the department, Professor Arnett advised on the nuclear-astrophysics programme and worked on his book ‘Thermonuclear Evolution of Stars and Galaxies’, Dr Ryan worked on black holes and singularities in cosmology, Drs Breuer, Hughes and Rudolph studied radiation problems in general relativity, and Dr Kuchar worked on the Hamiltonian formulation of general relativity. Professor Misner completed his work on gravitational synchrotron radiation, and also studied quantum effects in the early universe. Professor Sargent completed his studies of the local supercluster of galaxies, and tidal effects in small groups of galaxies. Dr Missana has studied the possible explanation of the solar redshift as being due to multiple Compton scattering in the solar chromosphere.

STAFF

Longer-term visitors to the Department during the year included Professor W.D. Arnett, Dr R. Breuer, Dr G. Calamai, Dr H.G. Hughes, Professor K. Kuchar, Dr F. Lund, Professor C.W. Misner, Dr M. Missana, Dr E. Rudolph, Dr M. P. Ryan, Professor G. C. Omer and Professor W. L. W. Sargent.


Professor H.H. Plaskett has continued his work in the Department during the year.

Colloquia and seminars were held regularly throughout the year. Speakers from outside the Department included Dr D. Acheson (Oxford), Dr D. Allen (RGO), Dr J.E. Beckman (QMC London), Dr R.G. Bingham (RGO), R.D. Blandford (Cambridge), Dr I. Bues (Sussex),
A. Burgess (Cambridge), Professor M. Cahen (Belgium), Dr R. D. Cannon (RGO), Dr P. E. Clegg (QMC London), Professor A. H. Cook (Cambridge), Professor B. S. de Witt (Texas), Dr W. G. Dixon (Cambridge), J. Emerson (London), Dr V. G. Endean (Oxford), Dr J. Faulkner (California), R. L. Forward (California), S. F. Gull (Cambridge), Dr E. R. Harrison (Sussex), Dr R. Henricson (Sussex), Dr H. G. Hughes (Maryland), Dr V. Icke (Sussex), Dr J. C. Jackson (RGO), Professor K. Kuchar (Princeton), Dr M. S. Longair (Cambridge), Professor C. W. Misner (Maryland), Dr P. Murdin (RGO), Dr C. A. Norman (RGO), Professor R. Penrose (Oxford), Professor M. J. Rees (Sussex), Professor P. H. Roberts (Newcastle), Dr P. W. Sandford (London), Dr W. Saslaw (Cambridge), Professor W. L. W. Sargent (California), Dr J. Sykes (OUP), Professor R. J. Tayler (Sussex), Dr M. Wallis (Oxford) and Dr N. O. Weiss (Cambridge).

The practical classes for the astronomy course in Honour Moderations have been supervised by Dr M. G. Adam with the assistance of Dr G. Wegner and Dr A. B. Sykes-Hart.

PUBLICATIONS


