Reports from Observatories, University Departments and Research Establishments

DEPARTMENT OF ASTROPHYSICS
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SOLAR RESEARCH

Dr Adam has completed her measurement of solar rotation using purely umbral lines in sunspot spectra and these results have now been published. Mr Waddington has made further observations of the shifts and shape of solar absorption lines at the disc centre. The small variations in peak intensity (of Fe I λ 6297.8 Å) as well as the wavelength shifts of the lines clearly show the five-minute oscillations of the solar surface. He has also investigated pressure shifts in laboratory furnace spectra for the correction of the line shift results. On the theoretical side he has made good progress with accounting for the shifts and profiles of the observed lines by using inhomogeneous models of the solar atmosphere. Professor Blackwell, Dr Shallis and Mr Simmons are using the precise measurement of the oscillator strength of Fe I lines (1.5, 2.2, 2.4 eV) and of Ti I lines (0.6 eV) reported elsewhere for the interpretation of the solar spectrum, deriving abundances and micro-turbulence values as a function of excitation potential. This analysis has also yielded separately the oscillator strengths of selected Fe II lines.

Dr Smith and Dr Petford have made further modifications to the North Tower solar spectrograph. A new grating table and a photoelectric scanning photometer, similar to the one used successfully at our Swiss outstation from 1968 to 1973, have been installed and are now ready for connection to a Nova minicomputer.

STELLAR PHYSICS AND PHYSICS OF THE GALAXY

Dr Mallia has continued his reductions of the high dispersion (10 Å mm⁻¹) spectra of giant stars in globular clusters that he obtained during two three-night allocations on the Anglo-Australian Telescope. The main body of data, which consists of spectra of stars in six southern clusters spanning the metallicity range, is now nearing publication stage. The principal results that have emerged are the following:

(i) In the clusters so far examined [Fe/H] ranges from −2.1 (NGC 6397) to −0.8 (47 Tuc). Most of the other elements show the same behaviour as Fe. However, [O/Fe] is consistently positive and [Ca/Fe] is frequently positive. On the other hand [C/Fe] is most frequently zero. In a few cases it is
positive and in a considerable number of cases (generally stars ascending the giant branch for the second time) it is less than zero.

(ii) The metal rich group of clusters are probably not so metal rich as had been previously thought. There appears to be a distinct gap in abundance between the oldest visible disc stars and open clusters and the globular clusters in the galactic nucleus. This conclusion needs to be reinforced by more observations. In 47 Tuc (and almost certainly in ω Cen as well) [N/Fe] is quite often negative.

(iii) In ω Cen there is a substantial variation in Fe abundance among stars on the giant branch. From one cut across the branch in the region of the brightest non-variable giants, a metal abundance variation of about a factor of 6 has been found between stars on the blue and red flanks of the giant branch. This abundance variation appears to lie at the root of the long-standing problem of the width of the giant branch of ω Cen in a V, B−V diagram.

Dr Chun supplemented an observing period at the AAT with 14 nights observing on the 20-inch and 40-inch telescopes at Mt Stromlo Observatory. His purpose was to make photometric observations of globular clusters using DDO filters in order to check for a radial abundance distribution for CN. However, virtually the whole of the observing period was cloudy. Reduction of the few observations made is now complete and the results indicate that NGC 2808, which shows a radial gradient of colour (in (B−V) and (U−B)), has a strong violet CN absorption in the central region which weakens by a factor × 2 towards the outer regions.

The ‘infrared flux method’ for determining accurate stellar angular diameters and effective temperatures has been further advanced during the year. A new exposition of the method has been published and flux tables have also been prepared to facilitate its easy and rapid use. The method has been applied to the temperature calibration of the spectral sequence, determination of the radii of main sequence stars, and to the determination of the radii and effective temperatures of Ap stars. As part of this program of work, Professor Blackwell, Dr Petford and Dr Shallis joined with Dr Selby of Imperial College in a new calibration of the infrared stellar flux at Tenerife. This work has been successful in the K-band. Dr Shallis attended the Workshop on ‘Ap stars in the infrared’ in Vienna where he discussed the application of the infrared flux method to Ap stars.

Dr Bath has continued his studies of classical and dwarf novae, and of other interacting binaries. He and Dr Ruggles have completed an investigation of the structure of steady-state optically-thick winds surrounding white dwarfs. Wind models are a powerful tool for investigating conditions in classical nova envelopes at outburst. The main conclusions from this study are that the photospheric luminosity must remain close to the Eddington luminosity during the optical decline, in agreement with observed behaviour in Nova Serpentis 1970 and Nova Cygni 1975, and that outflow must become supersonic close to the white dwarf surface. This work is being followed further by Mr Harkness, who has developed a model atmosphere program applicable to the extremely extended, high velocity envelopes that are
created. The continuum distribution has been determined for a range of mass loss rates in the case of an imposed temperature structure. The problem of determining the temperature structure self-consistently is now being examined.

Dr Bath has completed a study, in collaboration with Dr Pringle and Dr Whelan (Cambridge), of the ultraviolet and optical continuum distribution of three dwarf novae BV Cen, EX Hya and VW Hyi. Spectrophotometry in the wavelength region 1250–7500 Å shows that at quiescence BV Cen peaks at visible wavelengths where the spectrum of a late G-type star is evident. EX Hya was observed in quiescence and VW Hyi on decline from outburst. The continuum of both fit the predicted power law distribution of a steady optically thick disc. The fraction of disc luminosity emitted at visible wavelengths is only about 7 and 2 per cent respectively.

Dr Bath and Dr Pringle have developed a method for examining the evolution of time-dependent discs. The resulting computer code will allow examination of the cause of eruptive behaviour in discs, the rôle of viscosity and its effects on time-dependent behaviour, and the consequences of variability in the rate of mass transfer by the companion.

Dr Bath has suggested a binary model of Hubble–Sandage variables. These are the brightest stars in external galaxies. He argues that the spectral properties are those expected for high accretion rates on to main sequence stars and that accretion generates the bulk of the luminosity observed. He has also suggested that η Car may be a similar object in our own Galaxy.

Mr McMahon is continuing a study of the collapse of white dwarfs which accrete sufficient mass to lift them over the Chandrasekhar limit, and application to type I supernovae.

Mr Barnes has commenced a study of the s-process in intermediate mass stars and of the mixing processes that can occur in such stars. Mr Klapp is continuing his work on super-massive stars in the pre-galactic era and has been computing early evolutionary models of the low mass variety. Mr Olech has completed the necessary programming for calculating the stability of evolving low mass stars and is now entering a production run phase. Dr Edwards has investigated several topics. A suggestion has been made that a stochastic forced mixing may occur in certain stars external to sufficiently violent standard convection zones. A contribution has also been made to the study of the nature of active galactic nuclei. The applicability of the physics used to calculate nuclear reaction rates in stars has been considered with especial attention being given to the pp reaction. He is also working on unusual ways of producing deuterium. One rather interesting, albeit dubious, reaction has been found but an experimental limit on its rate does not exist. The work involving the calibration of photographic plates was successful and a paper has been submitted for publication. He has recently begun a collaboration with Dr Harris to study the nucleosynthesis of the elements due to explosive carbon burning.

Dr Wickett has been studying the structure and evolution of red giants with the joint aims of providing a clearer physical understanding of these stars and assisting the extension of his calculations on the helium flash. The red giant investigation uses a combination of analytic methods relying on
simplified physics, and full numerical solutions of the stellar evolution equations. The answer to the question 'why do shell burning stars with inert cores evolve in the way indicated by numerical calculations?' appears to be complicated and dependent on interactions between the various physical processes involved. But an improvement over the sketchy and sometimes inconsistent accounts to be found in textbooks is likely to be achieved. Results of the helium flash would include formulae for the conditions at the peak of the flash in terms of the initial conditions including the site of the flash treated as an arbitrary parameter. Also, some limits have been placed on the extremely uncertain theory of time-dependent convection by means of hydrodynamic calculations. He and Dr Miller and Professor Sciama have continued with the preparation of a review article on the late stages of stellar evolution.

Dr Hall is studying the implications that his model for the production of scattering inhomogeneities in the interstellar medium has for the problem of the variation of the decorrelation bandwidth of radio pulses with dispersion measure. Consideration of the decrease in the amplitude of the electron density fluctuations with distance from the central plane of the Galaxy shows that the decorrelation bandwidth should vary with dispersion measure in a manner that is not observed, unless the scale heights of the scattering irregularities and pulsars are similar. This result caused Dr Hall to re-examine the methods by which the scale heights of thermal electrons and pulsars in the Galaxy are determined, when he found that there are good reasons for believing the scale heights to be much less than the commonly accepted values.

EXTRAGALACTIC PHYSICS AND COSMOLOGY

Dr Godwin has completed photographic photometry of the condensed X-ray emitting cluster A1367; there is evidence that inhomogeneities in the distribution of galaxies have an important effect on the distribution of the intergalactic medium. Photometry of A1656 is continuing, and a study of selected regions near the South Galactic Pole, in collaboration with the Durham group and Dr Carter, is yielding comparisons with data obtained using the Edinburgh Cosmos facility. A technique for photographic stellar photometry has been developed, giving results which compare favourably with published electronographic photometry. Dr Godwin, in collaboration with Dr Strimpel, has used the projected distributions of galaxies in several clusters, with various models of three-dimensional cluster structure, to predict detailed maps of X-ray bremsstrahlung emission from the intergalactic medium; these are being compared with results from the HEAO-B satellite. Dr Godwin and Dr Peach have concluded that the distribution of magnitudes of first-ranked cluster galaxies in their photometric sample is consistent with statistical fluctuations about an underlying universal luminosity function together with minor variations due to interactions between the first-ranked and the other cluster members. Earlier conclusions to the contrary seem in their opinion to be misleading, arising from a physically unrealistic definition of galaxy magnitudes. Mr Kesterton has worked on models of first-ranked cluster galaxies and has contributed to the photometry of A1656. Mr Butchins has commenced studies of the statistics of cluster luminosity functions and
the evolution of the photometric properties of galaxies as a function of redshift.

With Dr Ellis and Dr Efstathiou (Durham) Dr Carter has used the AAT to search for minor axis rotation and other dynamical effects in three normal elliptical galaxies. Minor axis rotation was not detected in NGC 4472 and IC 4296; but in NGC 5813 there appears to be a peak rotation of about 15 km s\(^{-1}\). IC 4296, despite being a nearly round galaxy (E1), shows major axis rotation of at least 100 km s\(^{-1}\). Further observations of these two galaxies are planned. With Mr Metcalfe (vacation student) Dr Carter has completed an investigation into the morphology of clusters of galaxies. Clusters tend to be flatter than elliptical galaxies – and there is evidence for preferential alignment of cD galaxies with clusters. Dr Carter has also completed an investigation in four wavebands of a rich cluster of galaxies at position 0004-8-3450. The cluster shows a comparatively flat luminosity function, the colour–magnitude and two-colour diagram show that it consists almost entirely of E and S0 galaxies.

During three nights’ observing at the AAT in 1978 August Dr Chun, in collaboration with Professor Pagel (RGO) and Dr Edmunds (Cardiff) obtained spectra of six regions in the barred-spiral galaxy, NGC 1313, seven regions in the irregular galaxy, NGC 6822, and four regions in the normal spiral, NGC 7793. Dr Smith has now completed reduction of these spectra. In both NGC 1313 and 6822 the regions observed were predominantly of high excitation but measurements on the oxygen lines showed little evidence for a radial gradient of oxygen abundance as often found in late-type spiral galaxies. The abundance of nitrogen relative to oxygen in all three galaxies appeared to be independent of position. Two regions, one in NGC 1313 and the other in NGC 6822, had almost identical spectra suggesting similarity of abundances in these two galaxies.

During March Professor Sciama gave invited lectures at Einstein Centennial Symposia at the Institute for Advanced Study in Princeton, the New York Academy of Sciences, the University of Berne, and the Israel Academy of Sciences in Jerusalem. His lecture at the Institute for Advanced Study ‘Issues in Cosmology’ will be published.

Dr Holder has continued to study the problem of infall of intergalactic gas into the galaxy and improve the computer models for this process. In particular a simple frozen-in magnetic field has been incorporated into the equations of motion. This is to determine what halo magnetic field is compatible with high-velocity cloud formation by the mechanisms of thermal instabilities arising, due to radiative cooling, in the accreting gas. With a suitable variation of heavy element abundance with height above the galactic plane these instabilities form in the halo, whilst gas at infinity remains hot.

Dr Barrow has completed work on various aspects of cosmology and relativistic astrophysics including galaxy formation, the general solution to Einstein’s equations, and also grand unified gauge theories and their relevance to black hole physics and models of the early Universe. He has worked with Dr Matzner, during the latter’s visit to the department, on quantum-induced bounces in homogeneous cosmology and gauge theories.
During his visit, Dr Matzner has also studied post-post-Newtonian astronomy. In standard parametrized post-Newtonian formalism, the spatial part of the metric is carried to lower order than is the time part. However, for calculation of effects involving the propagation of radiation in the solar system, it is necessary to have the spatial components to the same accuracy as the time component. Although some post-post-Newtonian calculations to the required order for General Relativity have appeared, there has been no attempt at a parametrized form applicable to a range of models. Dr Matzner has made a start by giving a parametrization which is complete enough to include General Relativity. He has also been able to calculate a $\frac{1}{2}$ post-Newtonian effect, the differential deflection of starlight on the two sides of a rotating sun.

Dr Matzner has compared alternative explanations for the observed dipole fluctuations in the microwave and X-ray backgrounds. Cosmological models which are homogeneous as large scales are shown to provide viable explanations for the observations. Further observational results should allow the falsification of this class of models for the dipole anisotropies.

LABORATORY WORK

Professor Blackwell, Dr Petford, Dr Shallis and Mr Simmons have continued their measurements of the oscillator strengths of Fe I lines to high accuracy using the Oxford King furnace. Work on the 2.2 and 2.4 eV lines has now been completed to a relative accuracy of 1 per cent (degraded from 0.5 per cent in order to save energy). With Miss Leggett (vacation student) work on the 0 eV lines of Ti I has also been finished. These accurate oscillator strengths have been used for an interpretation of the solar spectrum, particularly for study of microturbulence in the solar atmosphere.

Dr Smith and Mr Raggett have continued their study of oscillator strengths and collisional damping constants in the neutral calcium spectrum. The Oxford furnace and spectrometer have been used to measure broadening by helium of a wide variety of transitions whose lower levels have excitation energy between 2.5 and 3.0 eV. In parallel with this investigation a calculation of the energy structure of the neutral calcium atom has been undertaken. Eigenvector compositions obtained from this calculation provide an explanation for discrepancies between measured oscillator strengths and those predicted using LS-coupling theory. Eigenvector compositions also correlate well with collisional damping measurements. A critical analysis of solar calcium lines using measured oscillator strengths and hydrogen damping constants predicted from measurements of broadening by helium has now commenced.

Preparations for the study of hyperfine structure in atomic spectra by Dr Petford, Dr Shallis and Mr Booth, in collaboration with Dr Wells (Imperial College) have continued.

RELATIVISTIC ASTROPHYSICS

The relativistic astrophysics group has been working on a range of problems using a variety of numerical techniques. Dr Miller assisted by Mr Murphy
has been continuing with the long-term project of computing in detail the gravitational collapse of rotating stars towards the black hole state. Dr Miller has implemented the flux corrected transport method in a general relativistic form. This method allows much more precise computations in regions containing discontinuities than is possible with artificial viscosity methods.

Dr Miller has continued his collaboration with Drs Anile and Motta of the University of Catania both of whom visited Oxford during the year. This work studies in detail the formation and damping of relativistic shocks using analytical and numerical techniques. A sophisticated computer program has been developed in which waves and shocks have been followed with velocity jumps up to 0.96c. Results from this program confirm Liang's suggestion that as the velocity jumps tend towards the speed of light, the characteristic damping timescale should begin to increase. The process of shock formation from specified initial waveforms is being studied in detail and some unexpected features have already emerged for cases where the velocity jump is large.

Mr Connors and Mr Stark continued their work concerning the transport of polarized radiation through a gaseous medium in cases where the effects of general relativity are important. The Monte Carlo computations which they have been carrying out in collaboration with Dr Piran, of the University of Texas at Austin, have now been completed.

Mr Stark has been studying temperature effects on the radiation transfer of polarization properties in gaseous electron scattering atmospheres which are so hot that significant changes from the zero temperature case occur. He has considered spontaneous and induced scattering effects and is applying his results to the cosmic microwave background as well as to plane atmospheric problems.

Mr Connors completed his work on applications of Regge calculus, and now the research programme which he started is being continued by Mr Porter. The aim is to apply this technique to detailed astrophysical problems. This is significantly more complicated than the study of comparatively simple situations which has been carried out hitherto but it is hoped that progress can be made with the use of large-scale computing techniques.

Mr Mann is applying ordinary finite element methods within the framework of general relativity as an alternative approach to the finite difference and Regge calculus methods being used by other members of the group.

QUANTUM GRAVITY

Professor Sciama has worked mainly in quantum gravity, paying particular attention to the consequences of introducing coupling between the modes of a quantum vacuum. Work continues on a book on 'Thermodynamics of Black Holes', and on an article on this subject to be written jointly with Dr P. Candelas and Dr Deutsch.

Mr Groves has been studying anisotropy dissipation arising from quantum fluctuations in the gravitational field of model cosmology.
Mr Najmi, in collaboration with Dr Deutsch and Mr Rouse has developed a general criterion for the definition of the vacuum in external gravitational fields. This work can be seen as a generalization of that of Brown & Dutton. It provides a general basis for the description of particle-production processes in the early Universe. In particular, the discussion of the Brown & Dutton work can now be extended to include anisotropic cosmological models. The details are shortly to be published.

Dr Brown has been studying renormalization theory as it is applied to the quantum theories mentioned above. From considerations of the scaling behaviour of these theories it is possible to infer much of the structure of the renormalized theories without having recourse to perturbation or weak field expansions. These results are currently being applied to the problems of black hole evaporation, anisotropy dissipation and the calculation of the quantum correction to Minkowski space from the inclusion of virtual graviton processes. Again the details are shortly to be published.

PUBLICATIONS

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