Newsletter

Quarterly Newsletter of the Indian Institute of Astrophysics

Volume 5 Number 2 April 1990

Coudé Echelle Spectroscopy with a CCD Detector

Aruna Goswami & Sunetra Giridhar

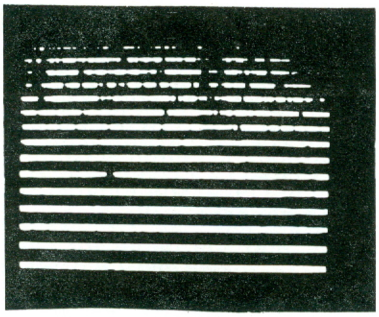


Figure 1. Echelle spectrum of Procyon in the wavelength range $\lambda\lambda$ 4500–6800.

The new CCD detector and data acquisition system from Photometric Inc. USA is being used, among other instruments (see Ram Sagar & Pati 1989) with the coudé echelle spectrograph of the 1-m Zeiss reflector at the VBO. The echelle spectrograph assembled locally has been in use for sometime with photographic emulsion as detector, with or without an image intensifier. It consists of a collimator mirror of 8 inch diameter and 56 inch focal length, an echelle grating of 79 grooves mm^{-1} blazed at 6746 Å in 33rd order interchangeable cross dispersor gratings of 300 and 150 l mm^{-1}, and a camera of 10 inch focal length. The spectrograph gives a linear dispersion of 8 Å mm^{-1} in this configuration. The CCD system uses a Thomson-CSF TH7882 chip sensitive up to 1 μm that is coated to improve its ultraviolet sensitivity. The format of CCD is 384×576 pixels of size 23 μm square. One pixel corresponds to 0.19 Å in the above configuration of the spectrograph.

The CCD chip is aligned such that the dispersion is along the rows of 384 pixels length. At the F/30 coudé focus the image scale is 6.4 arcsec mm^{-1}. With a reduction of 5.6 this corresponds to 36 arcsec mm^{-1} in the detector plane. In practice, one obtains a width of around 3–4 pixels in the detector plane corresponding to 2.5–3.5 arcsec inclusive of the size of seeing disc and guiding errors. A thorium-argon hollow cathode lamp is used for wavelength calibration and a xenon lamp is used for flatfield correction. We report in the following our results for measurements of equivalent widths.

We observed Arcturus (α Bootis) and Procyon (α Canis Minoris) since very high resolution photometric spectra are already available (Griffin 1968; Griffin & Griffin 1979 respectively). In addition, Mäckle *et al.* (1975) have published equivalent widths based on the data of Griffin (1968). Fig. 1 shows the image frame as displayed on the display monitor of the COMTAL VISION ONE/20 image processing unit at VBO.

The spectra were reduced using the RESPECT software (Prabhu, Anupama & Giridhar 1987) in its upgraded version (Prabhu & Anupama 1990). The extraction of the echelle spectrum follows the algorithm of Horne (1986) which can handle moderate geometric distortion of the spectrum inclusive of tilt. The extracted spectrum is a weighted sum of spectra in different rows, the weights being determined from a noise model. However, it assumes that the slit is aligned parallel to the columns. The loss in resolution due to this assumption is not significant due to the small width of the spectrum. Fig. 2 shows the spectra of Arcturus and Procyon in the Na I D region. The background level due to thermal noise and mean scattered light in the spectrograph is estimated using interorder counts after removing the effects of cosmic rays. Cosmic ray hits on the spectrum are not rejected since it is difficult to estimate the contamination as the spectrum is only a few pixels wide. The flat field corrections were made after removing a low order polynomial in each row. After extraction, the spectra were linearized in wavelength using a third degree polynomial for wavelength as a function of position. The wavelength identification is based on the atlas of D'Odorico *et al.* (1987). The standard error of the fit was 0.05 Å. The pseudocontinuum was determined using the highest points in each spectrum known to be free of stellar lines. The spectra were reduced to continuum by dividing by spline interpolated values between these points. The final spectra are shown in Fig. 2 as residual intensities against wavelength for the Na I D region.

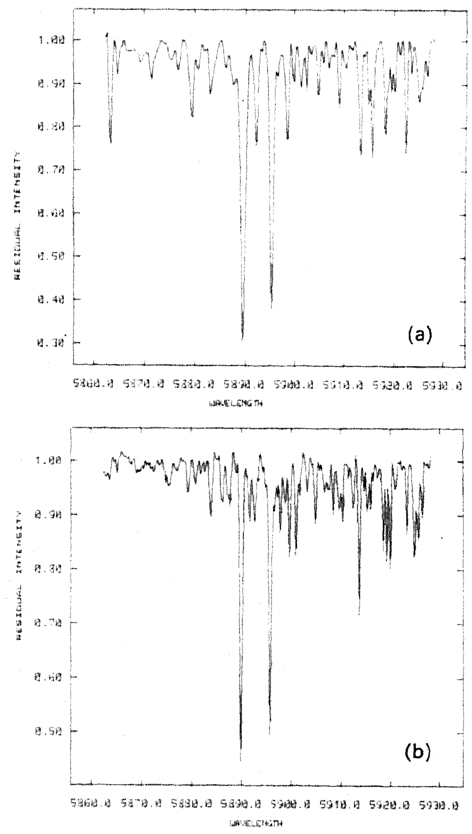


Figure 2. Spectra of (a) Arcturus and (b) Procyon in the region of Na I D. The signal to noise ratio is ~ 100.

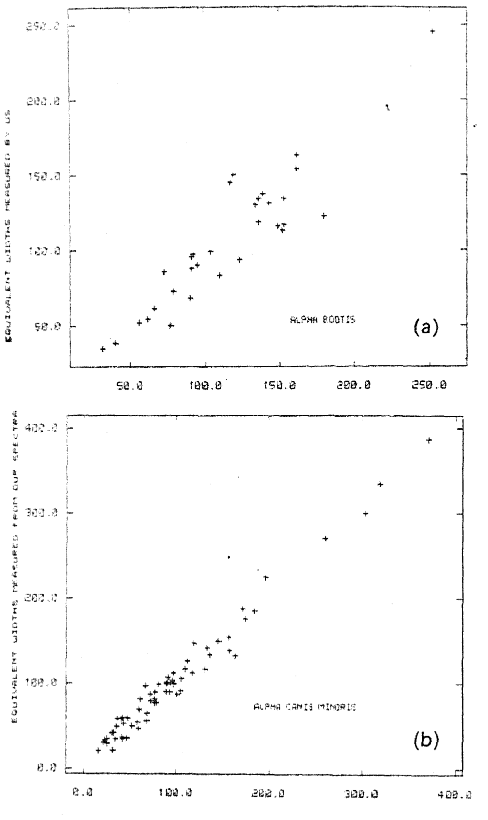


Figure 3. VBO equivalent widths are compared (a) with those of Mäckle *et al.* (1975) for Arcturus and (b) with those measured on Griffin & Griffin (1979) for Procyon.

We have measured 90 lines in the spectral region 4300–6600 Å. The measured equivalent widths are compared with Mäckle *et al.* (1975) for Arcturus, and with the one's measured on Griffin & Griffin (1979) for Procyon, as shown in Fig. 3. Our internal errors appear to be better than 15 per cent in the range of equivalent widths 50–150 mÅ, and still better for stronger lines. The errors are larger for weaker lines, reaching up to 40 per cent for 20 mÅ. The internal accuracies are independent of wavelength.

The telluric lines in the 6200 Å region, and also unblended lines in the comparison source have a full width at half maximum of 0.45 Å. This corresponds to about 2.5 pixels and represents the instrumental profile.

References

D'Odorico, S., Ghigo, M., Ponz, D. 1987, *An Atlas of Thorium-Argon Spectrum for the ESO Echelle Spectrograph in the λλ3400–9000Å Region*, ESO Sci. Rep. **6**.

Griffin, R. 1968, *A Photometric Atlas of the Spectrum of Arcturus*, Cambridge Philosophical Soc.

Griffin, R., Griffin, R. E. 1979, *A Photometric Atlas of the Spectrum of Procyon*, Cambridge Philosophical Soc.

Horne, K. 1986, *Publ. astr. Soc. Pacific*, **98**, 609.

Mäckle, R., Griffin, R., Griffin, R. E., Holweger, H. 1975, *Astr. Astrophys. Suppl. Ser.*, **19**, 303.

Prabhu, T. P., Anupama, G. C., Giridhar, S. 1987, *Bull. astr. Soc. India*, **15**, 98.

Prabhu, T. P., Anupama, G. C. 1990, Unpublished.

Sagar, R., Pati, A. K. 1989, *Bull astr. Soc. India*, **17**, 6.

N-Body Simulation of Interacting Galaxies

Most of the galaxies have regular shape and symmetry. A small fraction of them however show distorted structure and they are generally associated with close companions. Tidal interactions are often suspected when a galaxy shows distortion in its structure and is associated with a companion. Tidal disruption and merger are two important processes in the dynamical evolution of a binary stellar system. The merger time of two galaxies of comparable mass is shorter than the disruption time. On the other hand, a massive perturber is likely to cause considerable disruption of the satellite and in this case the disruption time could be shorter than the merger time.

As a small galaxy orbits around a giant companion, the time-dependent tidal field can have significant effects on their outer parts. For distant encounters the galaxies may pass around each other without causing much damage. In close encounters the tidal field removes orbital energy and transfers it to the internal energy of the galaxies. The tidal effects cause significant rearrangement of the structure of the galaxies on their outer parts in the form of bridges, tails and counterarms of various sizes and shapes. If the encounter is very close or even head-on, either considerable disruption of both systems results or the pair may merge to form a single system. The restricted three-body treatment has been found useful in studying the formation of various features on the outer parts of binary stellar systems.

The important parameters in the galaxy-galaxy collision are a) the distance of closest approach, b) the velocity of collision and c) the masses of the galaxies. Restricted three-body approach is employed to study the dependence of mass ratio on the formation of bridges and tails. A test galaxy consisting of massless particles distributed in a thin disk is perturbed by a point mass galaxy. A wide range of values for the mass ratio have been used ($0.001 \leqslant M_1/M \leqslant 10$, M_1, the mass of the perturber and M the mass of the test galaxy). The important results of this study are as follows.

1) The formation of bridges and tails are favoured when the mass ratio is of the order of unity. Tails last longer than bridges.

2) The tail is broad and long when the mass ratio is close to unity and becomes thinner and shorter as the mass ratio decreases.

3) The test galaxy remains unaffected if the perturber is much less massive than the test galaxy. Increasing the mass of the perturber leads to greater disruption of the test galaxy.

4) The formation of similar bridges and tails can be obtained by using the same collision parameter ν which is a function of the masses of the galaxies, their separation and eccentricity of the relative orbit. Well developed bridges and tails are formed for values of ν in the range $0.1 < \nu < 0.7$. If $\nu < 0.1$, essentially no damage is done to the test galaxy while for $\nu > 0.7$ the test galaxy suffers appreciable disruption.

The above study gives a qualitative picture of the tidal effects in binary galaxies. The tidal effects depend strongly on the separation and weakly on the ratio of the masses. If the perturber escapes after a collision, the victim galaxy will remain an isolated system showing tail structure without any visible companion.

In slow galactic encounters, the structure of the galaxy changes appreciably. Self-consistent N-body simulations are required to study the tidal effects in such encounters. Many earlier simulations dealt mainly with collisions of galaxies of comparable mass. They concentrated either on the merging aspect or on the tidal effects in slow hyperbolic encounters. In the present work, the tidal effects due to a massive perturber on a satellite galaxy have been studied using numerical simulations. The model consists of a spherical galaxy and a point-mass perturber and the encounter is non-penetrating. A wide range of density ratios and eccentricities of the orbit have been used. The integration of the orbits is performed using Aarseth's N-body 2 code.

Tidal damage is seen to occur after the perturber has passed the perigalactic point. The tendency to form bridges and tails is observed when the perturber is near the closest approach distance. The disruption of the satellite galaxy occurs when the numerical value of the fractional change in the internal energy is greater than two. In such cases the mass loss is seen to be greater than 40 per cent. This is in agreement with Miller's condition for disruption $F_T/F_I < 1/4$ (F_T is the maximum tidal stress and F_I is the internal force at median radius of the satellite). The ratio F_I/F_T is nearly equivalent to the density ratio ρ_h/ρ_R (ρ_h is the mean density within half-mass radius and ρ_R is the Roche density) and thus disruption occurs when $\rho_h/\rho_R < 4$. The variation of the fractional change in the energy $\Delta U/|U|$ and mass $\Delta M/M$ with time is shown in Figs 1 and 2 for several models. The energy change shows smooth vari-

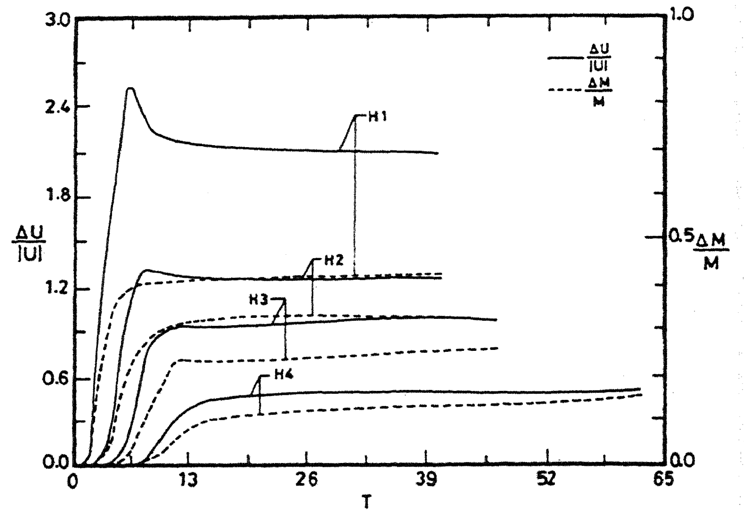


Figure 1. Fractional change in the energy and mass as a function of time for models in which the initial relative orbit of the perturber is hyperbolic.

ation in the case of unbound orbits and irregular variation in bound orbit cases. This is due to the fact that in the former case, the perturber is always on one side of the satellite as a result of which the satellite continuously gains energy whereas in the latter case the perturber is moving in closed orbits as a result of which the direction of the tidal acceleration gets partially reversed.

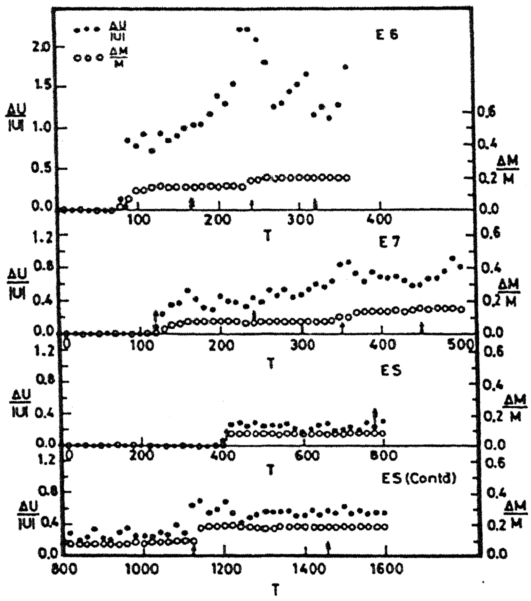


Figure 2. Same as figure 1 but for certain elliptic orbit encounters.

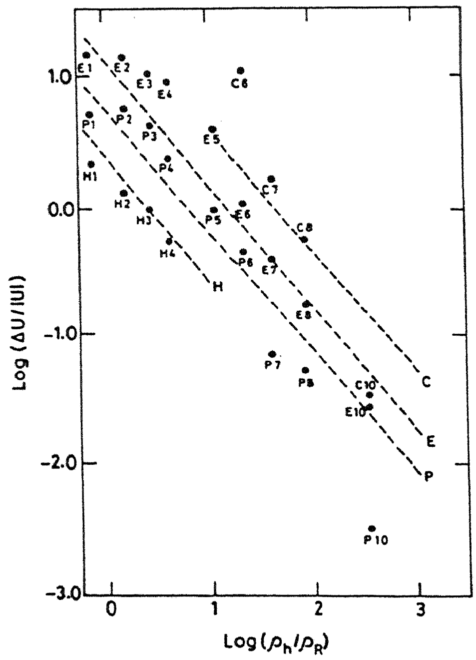


Figure 3. Variation of $\log(\Delta U/|U|)$ with $\log(\rho_h/\rho_R)$ for several models. The letters denote the type of orbit; H, hyperbolic; P, parabolic; E, elliptic and C, circular. The numbers following the letters denote decreasing mass ratio and increasing density ratio. The dashed lines show the results obtained from impulse approximation calculations.

A comparison of the numerical results with estimates of impulse approximation (IA) shows that the IA estimates of energy change agree within a factor of two with numerical results in the range $0.1 < \Delta U/|U| < 2$. Fig. 3 shows the agreement for various cases. When $\Delta U/|U| > 2$, the IA underestimates the tidal effects while for $\Delta U/|U| < 0.1$, it overestimates them. This is due to the fact that in the former case there is much loosening of the test galaxy which enhances the tidal effects whereas in the latter case the motion of the stars reduces the tidal effects and these factors are neglected in the IA.

Considerable amount of orbital angular momentum is imparted to the test galaxy especially in the case of bound orbit encounters. Even though the test galaxy gains angular momentum 90–99 per cent of it is carried away by the escaping particles leaving the remnant bound system with very little spin. As in the case of energy transfer the angular momentum shows smooth variation in the case of unbound orbits and irregular variation in bound orbit cases.

The process of decay of satellite orbit due to tidal friction is not significant for the type of models considered in the present work. The original spherical galaxy becomes elongated in the orbital plane and compressed in the direction perpendicular to it. The half-mass radius of the remnant bound system remains about the same as that of the initial galaxy within 20 per cent whereas the region containing 90–100 per cent of the mass shows considerable expansion which supports the fact that mild encounters produce distension in the victim's envelope.

The number of particles used to represent a stellar system is small in our simulations. Nevertheless a comparison of our numerical results with those obtained by earlier investigators shows good agreement. We, therefore, believe that many useful results can be obtained from numerical simulations using few particles and the discrepancies in the results are well within statistical fluctuations.

P. M. S. Namboodiri

(Synopsis of a thesis for which the Bangalore University has awarded a Ph.D. degree.)

A PC-XT Based 16 Channel Data Acquisition System

A PC-XT based 16 channel data acquisition system has been developed and integrated with the HF Doppler radar system operating at the Solar-Terrestial Research (STR) laboratory, Kodaikanal, for studies of ionospheric dynamics. This is intended to replace the existing analog recording system. The digital data acquisition system not only improves the sensitivity and temporal resolution of the ionospheric Doppler measurements but also facilitates faster off-line reductions of data.

The system digitizes, acquires and stores the data in 12 bit form, from a number of channels (maximum of 16) at required sampling rates. The sampling rates can be varied from 1 ms to about 50 ms.

Considering that the experiment involves acquiring data at fairly high rates from a number of channels and that too over a period of several hours, the data needs to be stored on secondary disk storage at regular intervals. However in order that no data samples are lost during the process of storage a double buffering scheme has been employed.

The program has been developed in a language called MODULA-2. The sampling interval is generated using the PC-XT timer 0. The normal interrupt service routine for the timer 0 is replaced by a user supplied one in which data acquisition from the analog to digital convertor is carried out at the desired instant.

The various features of the instrument are as under:

1) No. of channels: programmable—can be up to a maximum of 16.
2) Mode of scanning: sequential/random—generally random scan is used.
3) Sampling interval: programmable from 1 ms to 50 ms.
4) No. of data blocks to be acquired: programmable—however data acquisition can be stopped at any time by pressing ctrl scroll—lock key.
5) File identification: header details provided by user at run time.

The system is installed at the STR laboratory, Kodaikanal and has been operational for the past one year.

A. V. Ananth, A. V. V. Kutty & J. H. Sastri

Construction of Solar Vector Magnetograph

The proposal for construction of solar vector magnetograph to be employed at the solar tunnel telescope, Kodaikanal, has made considerable progress. The basic idea of the measurement is based on the doctoral work of K. S. Balasubramaniam, where estimates of vector magnetic fields on the sun were made by measuring polarization along the line wings of Zeeman-effect light (see *IIA Newsletter*, July 1989). The process of analysis was developed in detail by him and the present project is aimed at putting the practical measurement system at the solar tunnel telescope, where this measurement can be converted to magnetic vector and displayed.

The first step in this development is fabrication of the system where variable modulation on the Stoke vectors can be obtained. The polarimetric scheme has been finalized; it consist of a rotating polaroid and employing other polarizing elements so that the light from the sensitive line wings will be modulated by this unit. These variations extending over narrow rectangular size will be sensed by Peltier cooled CCD, which has been chosen and ordered and the resultant signals processed by a PC/AT system.

The mechanical mounting of the various optical components comprising the quarter wave plates, the polarizer and the filter is to begin shortly. The electronics for the movement of the polarizer has been tested and final fabrication will be undertaken soon.

The software for image acquisition from the asynchromous Peltier cooled CCD camera using the video frame grabber can be developed only after the availability of the necessary electronic hardware. However we hope to develop some preliminary version of the programs using the spare cards from VBT.

The program will be used to capture, store and integrate the pictures with orthogonal polarization at high rates to overcome the effects of atmospheric fluctuations.

The project also envisages some simple system which will be able to display the magnitudes of different Stokes parameters and possibly of the magnetic vector strength and orientation.

The project is financed under the SERC program of the Department of Science and Technology, and is for a period of 2 years from the date of release of funds. As there was delay in actual release of funds, some money from the Institute's contribution has been used to procure some minimal components necessary for the project. Rapid progress of the project may be expected when the DST funds become available.

J. C Bhattacharyya, P. Venkatakrishnan, A. V. Ananth & R. S. Narayanan

from the director

Activities of the Institute spread on many fronts during January–March. We had a rush of overseas visitors. Dr A. Ferro from Mexico and Dr F. H. Sahibov from USSR have been spending their extended stay utilising the telescopes at Vainu Bappu Observatory. An international team consisting of Dr M. C. E. Huber (ESA) and Prof. J. G. Timothy (Stanford Univ.) visited in connection with finalization of the design of the projected EUV solar imaging spectrograph, Prof. V. de Sabbata from Erice, Italy spent two weeks with us, delivered three lectures and held discussions with our scientists.

The Antarctic astronomical team which included two scientists from this Institute has returned after successfully completing their mission. We have taken up the analysis of the series of photographs brought by them. The Institute also participated in the discussions held in New Delhi for drawing up plans for the tenth Antarctic expedition.

Bangalore University has decided to start a course in Astrophysics in their Post Graduate Physics curriculum; our Institute, along with other sister organizations in the city, has extended its help and cooperation in this venture. We fervently hope that this unit should be a rich source of future scientific man-power for astronomical research in the country.

At the National Space Science Symposium at Nagpur, March 5–9, our scientists projected a programme of International Jupiter Watch to cover the spacecraft Galileo's visit to the planet in 1995. It was realised that many universities will be able to effectively contribute to the programme.

The Institute hosted in Bangalore the Optical Society of India's 18th Symposium on Optical Science & Engineering, during March 21–23, 1990. Besides presentation of some of the frontline problems in optical astronomy, the meeting resulted in very useful discussions between scientists of several institutions on matters concerning optical sciences.

All these activities ran in parallel with observational programmes at Kavalur and Kodaikanal, where very favourable observing conditions prevailed. Many bits of vital information could be gathered through these efforts.

Summary of Solar Observations at Kodiakanal Observatory during August 1989 to March 1990

	Days
Photoheliograms	180
H Alpha Spectroheliograms	161
Ca II K Spectroheliograms	160
Ca II K Prominence Spectroheliograms	92

newsline

The paper titled "Constraints on the Fundamental Properties of Gravity from SN 1987 A" by C. Sivaram was awarded honourable mention at the 1989 essay competition of the Gravity Research Foundation. C. Sivaram received the *Ettore Majorana* prize (1989) of the International School of Subnuclear Physics of the Majorana Centre, Italy, for outstanding participation in the course on challenging questions in particle physics. He also won the first prize for his paper on "Polarized Gamma Radiation from Supernovae" at the 21st International Cosmic Ray Conference, Adelaide, Australia.

* * *

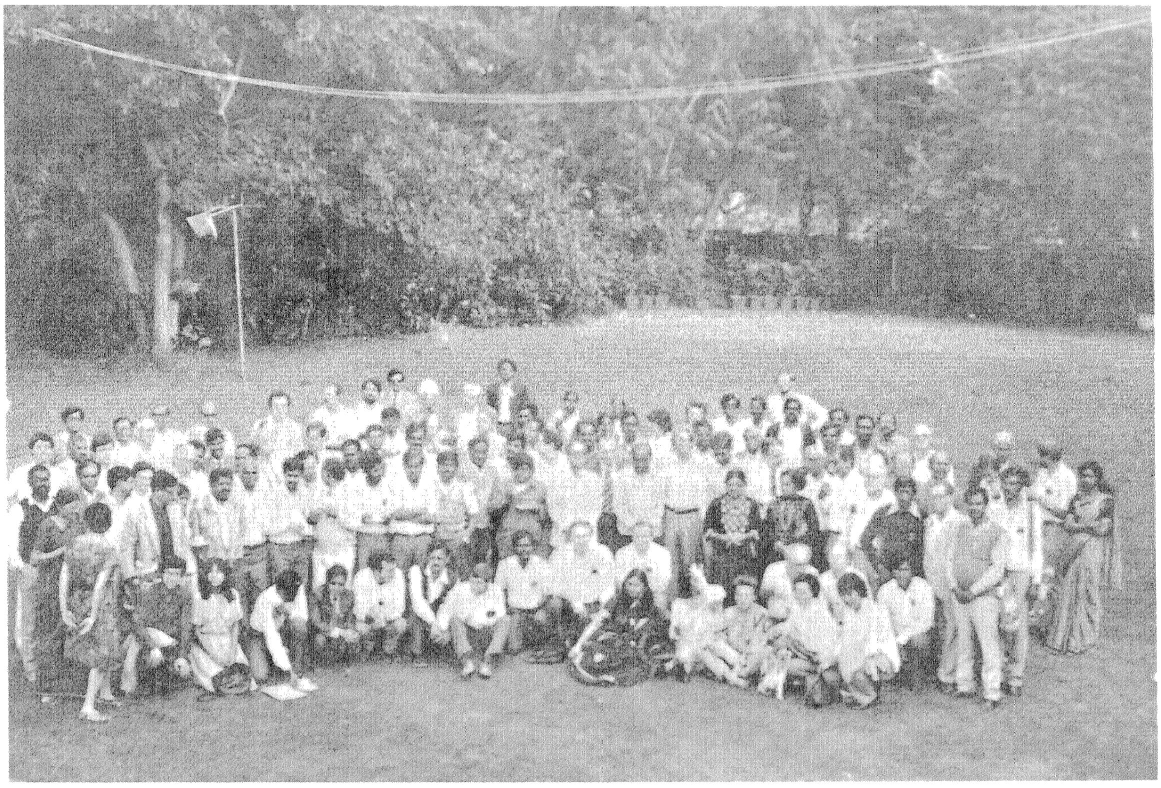
The Institute participated in the National Science Day celebrations by observing an "Open House Day" on 28 February 1990 on the occasion of the 62nd year of the discovery of the Raman Effect. Visits to the laboratories and video show of the films of the Institute's activities for scientists and students were organized.

* * *

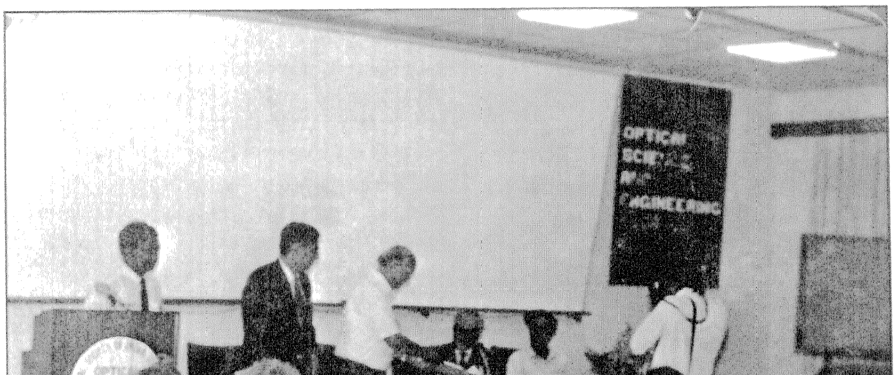
IIA also took part in the Science and Technology exhibition of the DST concurring with the 77th Science Congress at Cochin from 28 January–17 February 1990. The exhibition consisted of a display of the model of the 234 cm telescope, exhibits on the Institute's laboratories, the recent discovery of the asteroid Ramanujam and video shows of IIA films on the Institute and the Solar eclipse of 1980.

* * *

P. M. S. Namboodiri has been awarded a Ph.D. degree by the Bangalore University for his thesis on Studies in Interacting Galaxies.



Participants at the IAU Symposium 142 on *Basic Plasma Processes on the Sun* which was held at Bangalore during December 1–5, 1989.



Release of the souvenir at the 18th OSI Symposium on *Optical Science and Engineering* which was hosted by IIA, Bangalore, during March 21–23, 1990.

Goodbye, Charlie!

Alfred Charles Thomas has sought voluntary retirement commencing from April 2, 1990. Born in the year 1936 (April 16), Charles joined the Kodaikanal Observatory in 1960. He has devoted his three decades in service to the fabrication of astronomical instrumentation, in particular, for the 1-metre Zeiss reflector during the 1970s.

Charles, a mechanic by training, was fully involved in the installation of the 1-m reflector since 1971. When the telescope was bought, only photographic attachments were ordered with it. All the spectroscopic equipment were built in-house, with the collimators, and most of the camera optics made in the optic workshop. Charles handled the optical components dextrously and built several instruments: coudé spectrographs—conventional and echelle, Cassegrain nebular spectrograph, and spectrum scanner. He went on to build instruments for solar eclipse observations, and these were used at the eclipses of 1980 (India) and 1983 (Indonesia). He spent his last year in service on the design of a Cassegrain echelle spectrograph for the 1-m reflector.

Leaving all the family comforts at Kodaikanal, Charles has spent days that rolled on to years at Kavalur, dedicated to the development of this field station. Whenever there was any mechanical problem with the telescope or instrument, or with the designing of new adaptations such as image intensifier, it was to him that one turned to for a solution. He was a hard and conscientious worker and his mental adroitness was widely appreciated. Above all, he was a very good and jovial friend to everyone. We wish him a happy and healthy retired life.

out of context

Book Review
Patrick A. Wayman (ed.) Transactions of Internal Astronomical Union.

Celestial Mechanics (1984) **32.**

* * *

Dust in early type galaxies observed at the CFHT.

IAU Symp. 127, D. Reidel, Dordrecht, p. 405.

* * *

. . . following the classical model proposed by Faber (1973), these [gas depleted] galaxies . . . lost their external mass . . .

IAU Symp. 127, D. Reidel, Dordrecht, p. 99.

* * *

Editors: T. P. Prabhu & A. K. Pati
Editorial Assistant: Sandra Rajiva
Published by the Editors on behalf of the Director, Indian Institute of Astrophysics, Bangalore 560 034.

Newsletter
Quarterly Newsletter of the Indian Institute of Astrophysics
Vol. 5, No. 2, April 1990

To:

Indian Institute of Astrophysics
Bangalore 560 034.