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Training program

The Ooty summer training program 1990

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1. Introduction

The current development of major astronomical facilities within India, plus ready access to leading international instruments, provides unique challenges to Indian observational astronomy. However, for a number of reasons, the exploitation of these opportunities by staff and students of Indian educational establishments could be much greater than at present. Such reasons include a lack of exposure to experimental techniques and data reduction facilities, as well as a scarcity of information on the different areas of active research in astronomy and astrophysics.

Bearing these points in mind, and to meet the urgent need for a larger community to use the planned new radio facilities such as the Giant Metrewave Radio Telescope (GMRT) and the revitalised Ooty Radio Telescope (ORT), a radical approach to student training was tried out at the Radio Astronomy Centre (RAC), Ooty during May 1990. The program aimed at awakening enthusiasm in promising young people by involving them directly in observational radio astronomy through hands-on experience using the ORT. As the program was to culminate in a set of projects chosen to give the students a taste of real research, it began with a set of lectures and core experiments designed to provide the necessary background for coming to grips with this. We attempted to convey the thrill and demands of research in observational radio astronomy and to foster the culture of working as part of a team and contributing one's fraction to the project in hand.

The ORT is an equatorially-mounted cylindrical paraboloid of dimensions 530 × 30 m^2 and operated at 327 MHz. It has 12 contiguous simultaneously-available fan beams forming a north-south (NS) comb and can be used in the total-power mode, or with the signals from the north and south halves cross-correlated to form a short-spacing interferometer. The telescope feed line is divided in NS into twenty-two, 48-dipole phased modules, each of which can be independently switched in or out of the system (Swarup *et al.* 1971). In a unique move for a world-class instrument, the ORT was fully dedicated to the student program throughout May 1990.

2. Student selection

Twenty students (13 young men and seven women) participated in the summer program. They were selected from all over India, either on the basis of their grades and recommendations, or on the results of astronomy/physics quizzes held in Madurai and Bombay. Most were final-year B.Sc. or prefinal-year M.Sc./B.Tech. students. We also invited three fresh Ph.D. students working in related areas, anticipating that they might use the Ooty facilities in the course of their research.

3. The lecture series

During the first week of the activities, an intensive series of lectures was given to provide the students with the basic concepts needed to both understand and use radio telescopes and the associated equipment, and to be able to cope with astronomical problems and literature. The lecture series consisted of mini-courses in general astronomy, spherical astronomy, the radio sky, radio-astronomy techniques and data analysis. *In situ* demonstration lectures were also given on the ORT, computing and the observatory computing facilities. Over the remaining period of the program, seminars were held daily on selected topics in cosmology, galactic and extragalactic astronomy, interplanetary scintillations and the solar wind, radiation mechanisms and the Fourier transform. An afternoon visit was made to the nearby cosmic ray laboratory of TIFR.

Towards the end of the month, a special extended session was organised on the twin topics of Astronomy in India : today and tomorrow and on becoming and being an astronomer. The intention was to inform the students of the possibilities available for astronomical research within the country, to acquaint them with the diverse ways in which entry to an astronomical career can be achieved and to describe the nature of the graduate's life in astronomy. A number of informal evening get-togethers between staff and students were arranged at which impromptu discussions took place on such topics as, the relevance of astronomical research to society, the role of amateur astronomy clubs and the position of women in astronomy.

4. The core experiments

Concurrently with the first week's lectures, the students performed a set of six core experiments designed to provide familiarity with the ORT and to bring alive the lectures on radio-astronomy techniques. For this phase of the activities, the participants were broken into groups of five, each group performing all six experiments independently. Emphasis was placed on the individual involvement of the students at all levels. They were expected to position and point the telescope (under the watchful eye of the trained observer), set up the observing equipment, initiate the computer-controlled data acquisition, analyse and interpret the data and produce a short report in each case. The results from each of the groups were intercompared and discussed with the students in a general forum. The six core experiments are discussed briefly in this section.

(i) *ORT beam pattern for the central beam*

Measurement of the ORT beam pattern in both total-power and correlation modes for the central beam of the beam comb was the first core experiment. The pattern in hour angle was measured by allowing a strong point source to drift through the telescope beam. To obtain the declination pattern, the same source was tracked and the telescope stepped in intervals of 1 arcmin in declination until coverage of the main beam and first sidelobes was complete. In the case of the total-power mode, an off-source declination scan was also taken and subtracted from the on-source data to remove the small total-power steps which occur on changing the declination pointing. The mean half-power beamwidths (HPBW) from the results of the four groups were 2.1 deg × 4.2 arcmin for the correlation mode and 2.1 deg × 6.0 arcmin for the total-power mode, close to the generally-accepted values for the telescope.

(ii) *Declination patterns of the 12 correlated beams*

The previous experiment was extended in this, the longest experiment of the six. The students measured the declination patterns of all twelve correlated beams in the ORT beam comb. The HPBWs, calibration factors, detailed shapes and separations of the individual beams were derived. Next, 3-4 hr of high-latitude drift scan data were acquired for all twelve beams centred on a declination equal to the particular group number (*i.e.* dec. = 1°, 2°, 3° and 4°). The rms deviation of the data about its mean was computed for each beam. As the telescope is overwhelmingly confusion limited, this essentially represents the rms confusion level. For each beam, the rms value was turned into Jy/beam using the estimated calibration factors and the values were averaged to give the mean rms confusion in practical units.

The derived beam patterns agreed well between the separate groups, the mean HPBW for all the beams being 4.1 arcmin. The measured separations between adjacent beams agreed with values obtained by RAC staff six months earlier. The rms confusion level (1σ) averaged over the four groups came out to be 0.60 ± 0.06 Jy/beam.

(iii) *Measurement of system temperature*

The students were asked to measure the ORT system temperature both on sky adjacent to the radio galaxy, Hercules A, and pointing at the Galactic Centre. This was achieved by computing the dB rise on Her A and assuming an aperture efficiency of 26%. The average of the four groups gave T_{sys}(Her A) = 500K and T_{sys} (Galactic centre) = 990K. The students were also requested to estimate the signal-to-noise ratio for a one second integration on a 1 Jy source near Her A (average = 6.2) and the Galactic centre (average = 3.2).

(iv) *Interplanetary scintillations (IPS)*

This experiment illustrated the use of the method of interplanetary scintillations (IPS). Each group observed three strong extragalactic sources showing significant IPS. The scintillations were quantified via the scintillation index (m = rms scintillations/flux density). From prepared plots of m against solar elongation for sources of different sizes, the equivalent Gaussian sizes of the sources were estimated to be in the range of 0.1 to 0.6 arcsec. By fitting theoretical curves to the power spectra of the IPS, the students were able to estimate the solar-wind velocities near the points where the lines of sight to the sources were at closest solar approach (Manoharan and Ananthakrishnan 1990). The estimated velocities were in the range 300-650 km s^{-1}.

(v) *Radio interferometry*

A simple two-element interferometer can be produced from the ORT by switching off all but a separated pair of modules. Two experiments in radio interferometry were included, with alternate groups performing alternate experiments.

For the first experiment, a NS interferometer was produced by leaving on two modules symmetrically placed in the array, although the students were not told which pair of modules were involved. By scanning the modules in declination, the interferometer pattern was traced out, firstly with the outputs of the modules simply summed together (adding interferometer) and then with the outputs multiplied (correlation interferometer). From the fringe geometry, the students had to estimate which pair of modules were active.

In the second experiment, a number of pairs of ORT modules were used in succession to obtain the visibility of the Crab nebula as a function of interferometer baseline length. This was done by comparing the fringe amplitude for the Crab with that for the strong point source, 3C123. From the variation of visibility with baseline, the students derived the NS Gaussian half-width of the Crab nebula (6.3 arcmin).

(vi) *Measuring the flux densities of sources*

The final core experiment was to estimate the flux densities of a number of point sources, using a point source of known flux density for calibration. Before the peak deflection of each source was measured, the appropriate pointing offset was determined by off-setting the beam north and south of the source peak position such as to give equal deflections for the two positions. These offset declinations were averaged to give the optimum antenna pointing. A reference reading, effectively an off-source level, was obtained in the standard way for the ORT in correlation mode by randomising the phases of each dipole in the telescope feed line. In computing the calibration factor and the flux densities of the target sources, the fore-shortening of the ORT with declination was taken into consideration.

5. The main projects

RAC staff devised seven projects which, although limited in time, attempted to address topics of relevance to current research. In the selection, emphasis was laid upon projects which could produce a result within three weeks, and where the students could acquire at least part of the observational data themselves, analyse the data, become familiar with both the background of the project and the literature on the subject, and interpret the results in the light of their background studies. The students split into seven project groups, each having up to three members. The allocation of projects was based as closely as possible on the students' preferences, a method which seemed to be generally appreciated. The projects resulted in round the clock usage of the telescope.

On completion of their projects, all groups gave one-hour presentations, each group member concentrating on a different aspect of the investigation (*i.e.* the background and purpose of the experiment, the experimental method and data analysis, the results and interpretation). In addition, each project group submitted a written report based along the lines of a scientific paper. An assessment of the success of these projects in giving the students a feel for real research will be dealt with in section 6. Here, we give a brief description of each project and the results obtained by the students.

(i) *Measuring the Galactic background using the moon as a screen*

Accurate measurements of the brightness of the Galactic radio background are difficult to achieve because of the problems of absolute temperature standards, the unknown far-out sidelobe patterns of practical antennas and the large brightness differences in the sky. However, there is an alternative to traditional survey techniques allowing such estimates to be achieved for positions along the moon's path. The moon represents a disc emitter of essentially uniform, well-measured brightness temperature, $T_M = 225 \pm 1.3$ K at metre wavelengths (Stankevich, Wielebinski & Wilson 1970). When the moon occults an area of the background of brightness temperature T_B, this is replaced by the brightness temperature T_M. At 327 MHz, this can result in an apparent temperature excess or decrement, depending upon whether T_M is greater or less than T_B. In fact, if the area of the telescope beam intercepting the moon when pointing at its centre is Ω_W, the difference in brightness at a given position with the moon present and absent, expressed in flux density/beam, ΔS, is

$$\Delta S = (2k/\lambda^2)(T_M - T_B)\,\Omega_W,$$

where T_B is the beam-weighted brightness temperature of the sky blocked by the moon, k the Boltzmann's constant and λ the observing wavelength.

On the night of 1990 May 12-13, the moon passed over the Galactic plane close to the Galactic centre and was observed from rise to set, appearing as a strong dip in the sky brightness. Representative observations of the moon were also made for a few days before and after the night of May 12-13. For each position screened by the moon, a reobservation of the same position was made when the moon was far away. In all cases, reference regions at $\Delta RA = \pm 15^m$ were observed, and the bright point source Her A used for calibration. The moon appeared both as a flux excess and decrement at different stages of the experiment.

The observations were made in the correlation mode of the ORT to resolve out the distributed Galactic background, but only the central three north and three south modules were left active. This gave an NS beam pattern with $21/\cos\delta$ arcmin between the first nulls, meaning that for the declination of the moon on these days, most of the first negative sidelobes and all other sidelobes were off the moon. The NS beam pattern was measured accurately and using the standard ORT EW beam pattern, the value of Ω_W was estimated.

From the observations, values of T_B (327 MHz) were derived at the observed positions. To test the reasonableness of the results, the brightness temperatures at these positions at 408 MHz were estimated from the all-sky atlas of Haslam *et al.* (1982) and the values at the two frequencies plotted against each other (figure 1). The values are a good fit to the straight line that would be expected for a sky of constant spectral index, $\beta = 2.0$ ($T \propto \nu^{-\beta}$). Because of the closeness in frequency of 327 and 408 MHz, the errors in the estimated value of β are large ($\Delta\beta = \pm 0.5$), when considering the fitting error and a 10 per cent uncertainty in the 408-MHz temperature scale. Thus, it is not possible to distinguish between a thermal and nonthermal spectrum in this case. However, the power

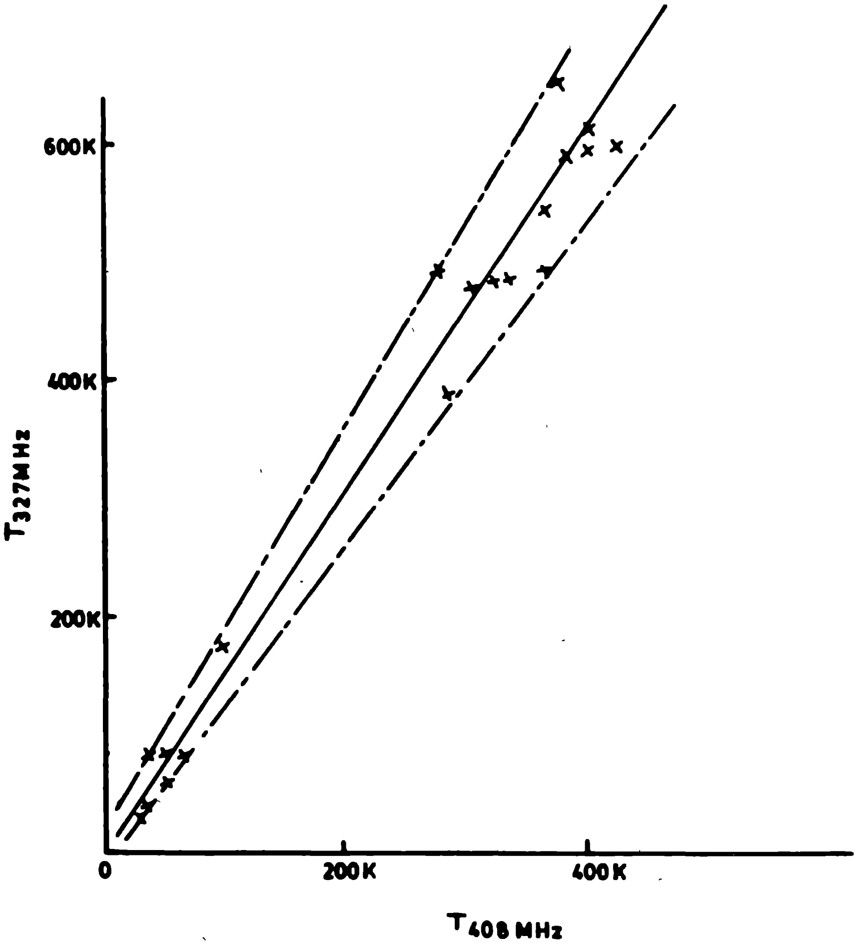

Figure 1. The Galactic background temperatures measured at 327 MHz using the moon screen technique are plotted against those estimated from the all-sky survey of Haslam *et al.* (1982) at 408 MHz. The continuous line has a slope of 2.0 while the dashed lines indicate the error of ± 0.5 in the slope of the fitted line.

of the method to provide sidelobe-free estimates of the background brightness is demonstrated.

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(ii) *Flux-density monitoring of SS433*

The peculiar radio star SS433 was monitored for 327-MHz flux density outbursts. The previously-lowest frequency at which such outbursts have been claimed is 408 MHz. The observations were begun on 1990 April 9 by RAC staff and continued by the students who analysed and interpreted data spanning the 44 days to May 22.

Every effort was made to obtain the most accurate possible measurements with a minimum of systematic errors. To this end, a new method of observing was employed. Two medium-strength radio sources were selected within 20 arcmin of the declination of SS433. One, 1810 + 046 (S_{327} ~ 6 Jy), was chosen as a reference source, while the other, 1719 + 047 (S_{327} ~ 3 Jy), has a similar flux density to SS433 and served as a control source. Because of their similar declinations, the pointing of the telescope was achieved by leaving the radio frequency (RF) phases set for SS433 and changing only the phases between the individual modules, which is performed at the intermediate frequency. As the HPBW of an individual module is 2.5°, all three sources are effectively observed at maximum gain. Also observed each day was the strong point source 3C317, to act as a flux-density calibrator. However, in this case the RF phases had also to be changed. Each night, the telescope declination-pointing offset was determined on the stronger sources 3C317 and 1810 + 046 and this value, accurate to ~ 5 arcsec, was used also for the two weaker sources. The observation order, 3C317, 1810 + 046, SS433, 1719 + 047 was retained throughout, so that any system drifts would affect the control source even more than SS433. NS beam patterns were taken on SS433 on a few occasions to check that the declination beam shape had not changed significantly. For each of the three program sources, pairs of reference regions were observed at $\Delta\mathrm{RA} \pm 10^m$ and at the same declination. For 3C317, the reference level was obtained by the more-usual ORT procedure of randomising the telescope phases.

Figure 2 presents the quantity, $\Delta = (x/\bar{x}) - 1$, where $x = S_x/S_{1810+046}$ and $\bar{x}$ is the mean value of x for data with either no, or only mild, ionospheric scintillations. The

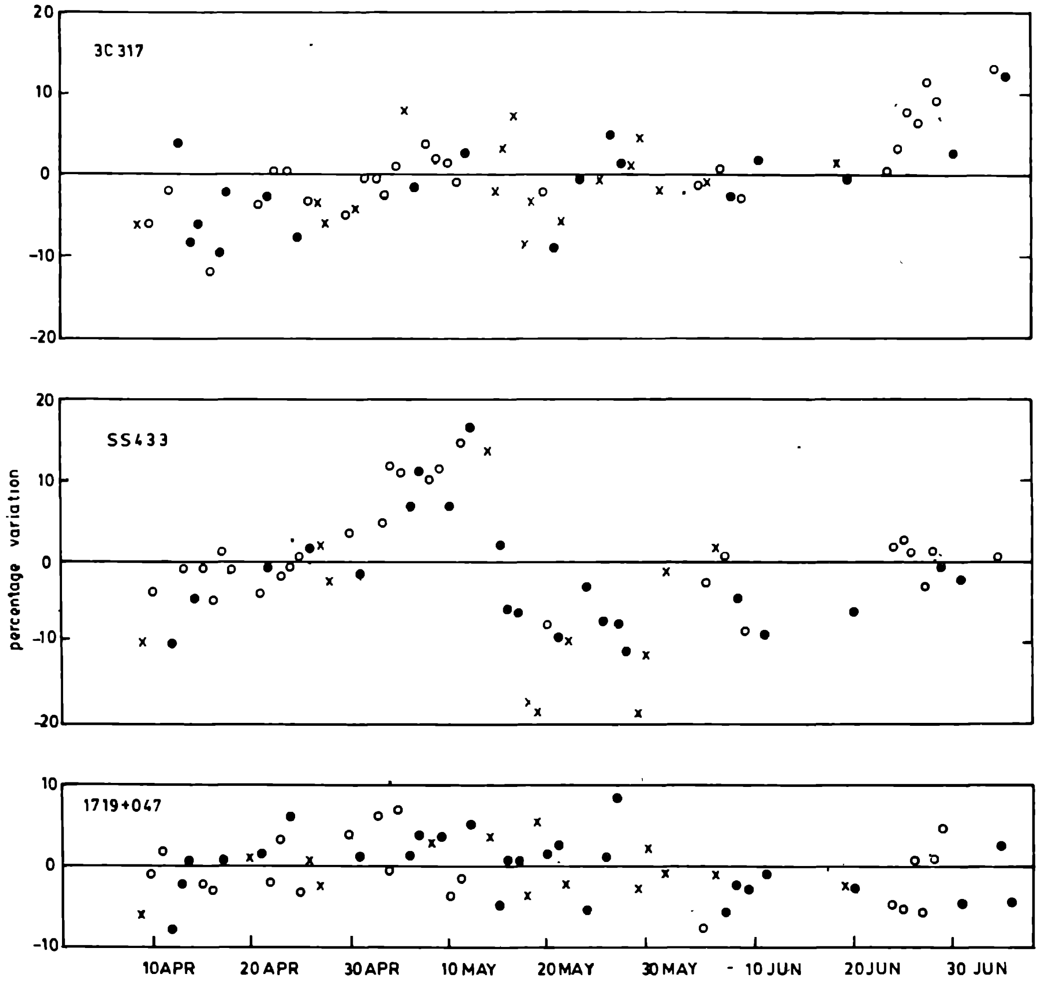

Figure 2. The percentage variations represented by Δ, as detailed in the text, are plotted against the date of observation. The open circles, filled circles and crosses denote data which were affected by no ionospheric scintillations, mild scintillations and heavy scintillations.

value of Δ is very steady for the control source 1719+047 ($\sigma = 3.7\%$). The values for 3C317 had $\sigma = 4.9\%$, the larger error possibly being due to the change of RF phases and the less exact reference measurements. For SS433, the rms was $\sigma = 8.6\%$, differing from that of 1719 + 047 by the significant value of 4.5-sigma. In fact, SS433 appeared to undergo flaring for about 12 days at the beginning of May (see figure 2). The apparent excess during this event amounted to $\Delta S \sim 0.6$ Jy. This event would be weaker than the bursts observed at 408 MHz by Bonsignori-Facondi *et al.* (1986) but the duration of the burst is consistent with their conclusion that the time scale of typical flares is some 17 days.

It would be of interest to compare these observations with simultaneous monitoring at a higher frequency to provide information on the spectrum of the burst and optical depth effects within the source. In respect of the latter property, it would be of value to monitor SS433 for an extended period at 327 MHz to compare the mean properties of flares at this frequency with the findings of Bonsignori-Facondi *et al.* at 408 MHz. (**S. Latha,** Presidency College, Madras; **S. Mala,** Department of Electrical Engineering, Indian Institute of Technology, Bombay; **V. Sankaranarayanan,** Madura College, Madurai)

(iii) *Interplanetary scintillation survey*

Interplanetary scintillations (IPS) provides sub-arcsec information on radio sources. While this information is not direct, as with VLBI, it has the advantage that it is quick and simple. This makes it especially adapted to statistical studies of large numbers of sources. In view of this, it was decided to make an IPS survey of a given region of sky to detect all scintillating sources within the area and to compare these and their parameters with the results from a total-intensity survey of the region.

To achieve this, the full 12-beam correlation system of the ORT was used. Before the experiment began, the students calibrated each beam in the beam comb and were careful to set the same attenuation for each, before each observing day. It was decided to survey two regions near the solar elongation giving maximum scintillation. These regions were centred at $\Delta\text{dec} \sim \pm 7.5°$ with respect to the declination of the sun, thus selecting regions where the sun is away from the principal axes of the telescope, where the sidelobe level is higher. The comb of beams covers 0.6° in declination and data were acquired at each setting for about 5 min before changing declination by 0.5°. For each right ascension, 10 declination settings were observed for each of the 2 regions ($\Delta\text{dec}^{tot} = 2 \times 5°$). On the next day, the procedure was repeated with the ORT moved to track a right ascension $+ 4^m$ higher. This gave optimum sampling of the region and also meant that the solar elongation from day to day was essentially the same. Data were acquired for 7 right ascensions, representing a coverage of about $2 \times 7° \times 5°$. The coordinates of the regions were

$$\text{(a) } 04^h\ 30^m \leq \text{RA(date)} \leq 04^h\ 54^m;\ +10° \leq \text{dec(date)} \leq +15°$$

$$\text{(b) } 04^h\ 30^m \leq \text{RA(date)} \leq 04^h\ 54^m;\ +25° \leq \text{dec(date)} \leq +30°.$$

Reduction of the data was achieved by splitting the 12-beam data into 12 pseudosingle beam data files and running each through the standard Ooty IPS analysis package. This included the editing out of interference and resulted in a set of 1680 power spectra, one for each sampling point of the survey. The students then scanned the spectra selecting those with the low-frequency excess characteristic of IPS.

The positions of all scintillators found in the survey were precessed to epoch 1950.0 and plotted on separate x-y graphs for each region. The Texas catalogue of radio sources is 90% complete to 0.25 Jy at 365 MHz and the positions of all Texas sources of flux density $\geqslant 0.5$ Jy were also plotted on the grids. Wherever a Texas source fell within the position-error box of a scintillator they were considered to be the same object. All the apparent scintillators associated with Texas sources were reobserved using the Texas positions to confirm the reality of the scintillations. Reobservations of the southern region were again made near the elongation of maximum scintillation ($\epsilon = 9^\circ$-16°), although the northern region could only be reobserved at larger elongations ($\epsilon = 16^\circ$-20°). The subsequent interpretation concentrated on the southern region.

Scintillations were detected for 42% of all Texas sources in the southern region with $S_{365} \geqslant 0.5$ Jy. The Texas catalogue contains a somewhat crude structural classification, which for the southern region was divided into five classes as follows, with the number in each category being shown within brackets:

(a) Point ($\theta \leqslant$ few arcsec) sources, ($n = 10$);
(b) Sources which could be either point or double, ($n = 15$);
(c) Double ($\theta \leqslant 20''$), ($n = 9$);
(d) Double ($20'' < \theta \leqslant 50''$), ($n = 12$);
(e) Double ($\theta > 50''$), ($n = 2$).

A histogram of the fraction in each class that were found to scintillate was prepared and the mean scintillation index (m = rms scintillations/total flux density) for the scintillators in each class was calculated (figure 3). It is seen that the fraction of scintillators was highest for the Texas point sources, which also had the highest mean scintillation index.

A number of positions showing scintillations in the survey did not correspond to any Texas source even down to 0.25 Jy. Four of these in the southern region, and two in the northern, had their scintillations confirmed in the follow-up observations. They could represent, (a) sources with $S_{365} > 0.25$ Jy but missed by the Texas catalogue (only one position had a scintillating flux density >0.25 Jy); (b) sources with $S_{365} > 0.25$ Jy at date to variability; (c) sources showing m $\sim$ 1, but whose flux density is somewhat below 0.25 Jy; (d) the effect of scintillation confusion, with two or more weaker sources present in the telescope beam combining to give a measurable scintillating flux density.
(**Mousumi Das**, Joint Astronomy Program, Department of Physics, Indian Institute of Science, Bangalore; **M. Deepa** and **Latha Sophia Rajamoni**, The American College, Madurai)

(iv) *IPS study of radio sources seen through the North Polar Spur*

The North Polar Spur (NPS) is a huge arc of radio emission rising from the Galactic plane near $l = 30^\circ$ and passing near the north Galactic pole. The most popular explanation of its nature is that it is a nearby supernova remnant. It has been demonstrated that a region with a statistically-significant lack of 81-MHz IPS sources occurs in a band some 20° outside the NPS (Rickard and Cronyn 1979). To investigate the situation for scintillators on and outside the spur at 327 MHz, complete samples down to 1.5 Jy at 408 MHz have been observed in IPS mode both on the NPS continuum ridge and in the region of scintillator deficiency of Rickard and Cronyn. These samples were observed in late 1989. Corresponding control samples for regions

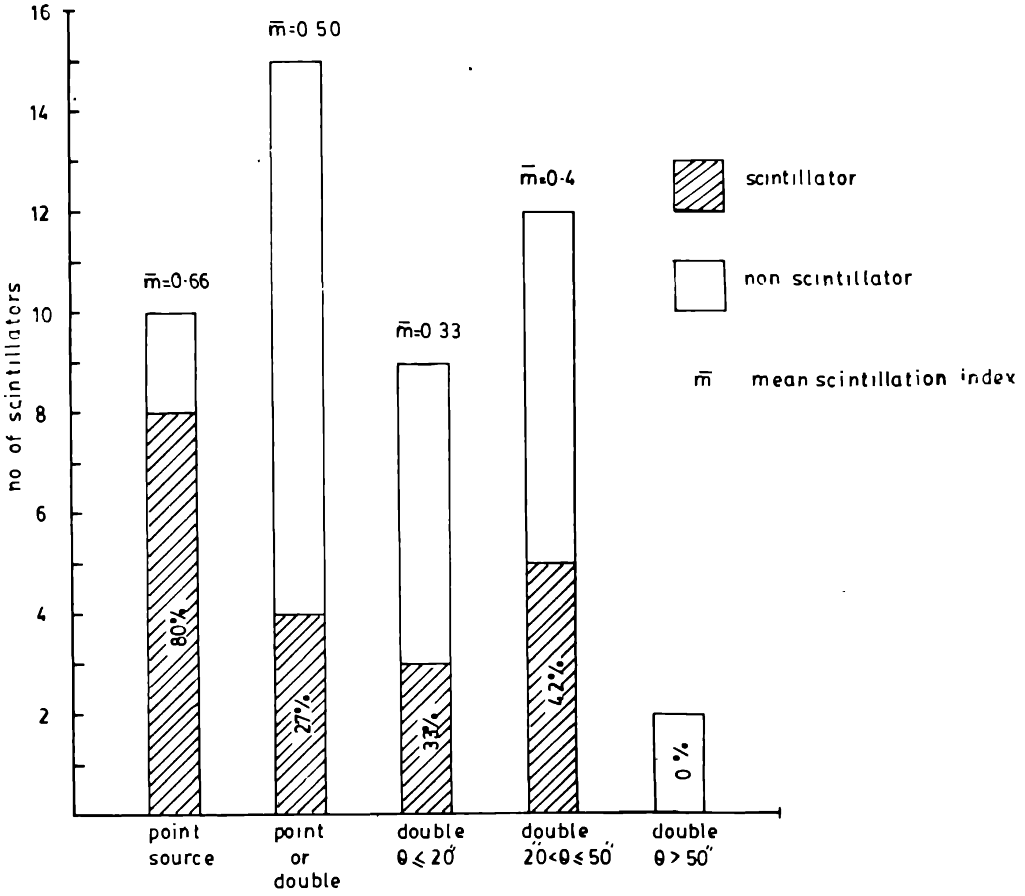

Figure 3. Results of the interplanetary-scintillation survey.

reflected about the celestial equator and at -12^h right ascension were observed 6 months later at similar solar elongation.

The students analysed a large subgroup of the NPS continuum ridge sources ($13^h \leq \mathrm{RA} \leq 16^h$) and observed and analysed the IPS records for the corresponding control region. For each source in the two regions they computed the compactness parameter, μ, defined by μ=(m measured at elongation ϵ)/(m expected for a point source at elongation ϵ). Histograms of μ were plotted for the NPS and control samples (figure 4). It is seen that the NPS sources appear to have a higher average value of μ than the control sources. For example, 19% of the control sample have $\mu > 0.4$, while the percentage for the NPS sources is 43%. A Kolmogorov-Smirnov test was performed on the cumulative distributions of μ and showed that the probability of the samples being drawn from the same population is < 0.05.

This result appears to demonstrate an excess of scintillators in the NPS sample. At this time it is not clear how to explain the result as there is no reason to expect scatter broadening of the sources in the control region by the interstellar medium, as might have been expected for lines of sight passing through the NPS. No significant difference is apparent in the selection of the sources. The simplest explanation would be a population of highly compact sources associated with the Spur itself, but Holden (1969) found no excess of discrete sources in the NPS for $S_{178} > 2$ Jy, a level similar to our flux density

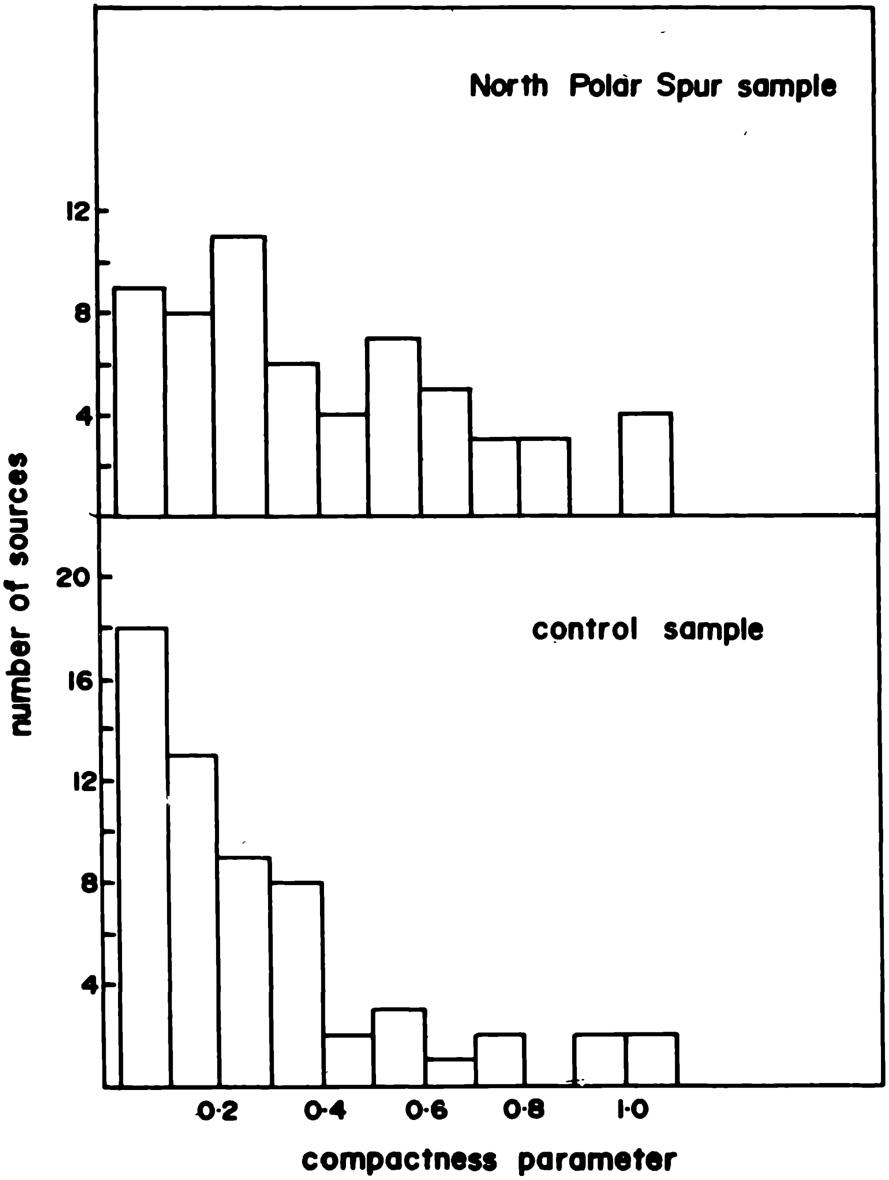

Figure 4. Histograms of the compactness parameter, μ, for the NPS and control samples.

cut-off, while Sofue & Reich (1979) arrived at a similar conclusion for sources of $S_{1420} > 0.25$ Jy. The situation will be clearer when the analysis is extended to the entire NPS region.

(**N. Andal,** The American College, Madurai; **Vijay Fafat** and **Sachin Nandgaonkar,** Department of Electrical Engineering, Indian Institute of Technology, Bombay)

(v) *Monitoring of the interplanetary medium*

Electron-density irregularities in the solar wind scatter radio waves reaching us from background sources and produce intensity fluctuations on the ground. A study of these scintillations can provide information on the properties of the solar-wind plasma, as well as on compact features in radio sources. For a power-law distribution of electron-density irregularities, the observed power spectrum of the intensity fluctuations can be modelled to derive the magnitude of the solar-wind velocity as well as the size of the scintillating component. This novel technique (Manoharan & Ananthakrishnan 1990) was used in this experiment to monitor the solar-wind plasma by measuring its velocity and the scintillation index, *m*, of the compact source 3C138.

This source was chosen because it is strong ($S_{327} = 18.6$ Jy). It is a well-known scintillator and during the course of the experiment (May 4 to 30) its solar elongation varied from 38° to 14° which is in the weak-scattering region. The source was monitored for about 8 hr on each of five days (May 7, 13, 18, 22 and 27) and for about 10 min on each of the other days.

By combining the IPS observations at different elongations, the source size of the scintillating component in 3C138 was estimated to be about 0.15 arcsec. On all days of extended monitoring, except May 13, the solar-wind velocity and scintillation index showed no significant variations over time scales of 5 to 8 hr. The solar-wind velocity was found to be between 300 and 350 km s^{-1}. On 13 May, the velocity increased from about 350 to 600 km s^{-1} over a time of 8 hr (figure 5). The scintillation index also showed a corresponding increase. This event, which is possibly due to a solar flare, was modelled by the students.

(**T. N. Chatterjee,** Institute of Radiophysics and Electronics, Calcutta; **L. R. Suresh Kumar,** Madura College, Madurai; **Vishwesh R. Muzumdar,** Saraswati Bhuwan College of Science, Aurangabad)

(vi) *Pulsar search*

A pulsar search was performed with the standard ORT system of 4-MHz band-width within the region $10^h \leq \mathrm{RA} \leq 12^h$; $-20° \geq \mathrm{dec} \geq -26°$. For the search, the full 12-beam system of the ORT was used. A Fast Fourier Transform approach was used in the search analysis. There was no previously known pulsar in the region. A number of candidates were reobserved but none confirmed, although pulsars with flux densities down to 25 mJy were detected in test observations.

(**Anoop Prasad,** St. Xavier's College, Bombay; **Umesh Navsariwala,** Indian Institute of Technology, Bombay; **Sadiqali Rangwala,** St. Xavier's College, Bombay)

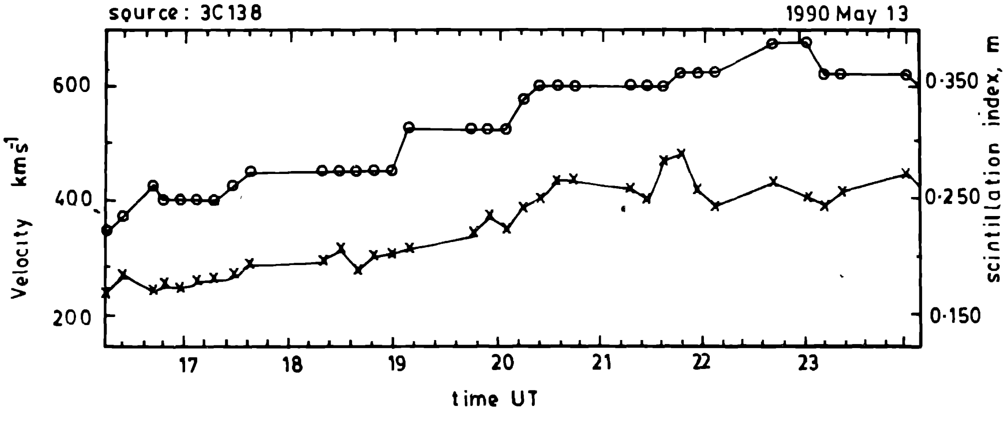

Figure 5. The event of May 13, in which the solar-wind velocity (circles) increased from 350 to 600 km s^{-1} over an 8-hr period, with a corresponding increase in the scintillation index (crosses).

(vii) *Low frequency variability*

Sixteen strong ($S_{327} > 3$ Jy), flat-spectrum sources were chosen from previous Ooty monitoring samples to look for variability on time scales of a few days. Eleven steep-spectrum sources distributed within the declination range ±35° were used as gain calibrators. Within the 10-day session, each source was observed 4-5 times, with the ORT being used in the correlation mode. Using all the calibrators observed on a single day, a mean gain factor was determined which was then applied to estimate flux densities for all sources, including the calibrators. It was found that $<\sigma_s/S> = 7\%$ for both the calibrators and the sample sources. Hence, no short-term variability $> 7\%$ was detected for these sources.

We have compared these ORT measurements with Ooty Synthesis Radio Telescope (OSRT) measurements made at the same frequency in 1987, and calculated the apparent fractional change, V, over 3 yr. For the calibrators, $< V > = 10\%$. For 7 sources, **0114 − 211, 1030 − 340, 1345 + 125, 1611 + 343, 1830 − 211, 2230 + 114 and** 2252 + 125, we detected $> 20\%$ difference in the flux densities. Most of these are well-known variables. The surprise was $V = 22\%$ for one of the steep-spectrum calibrators, 1030 − 340. The Texas catalogue classifies this source as a 17″ double. If this apparent variability were to be real, then the source may have a milliarcsec-sized component. (**S. Jeyakumar**, APSA College, Tirupathur; **Sidharth Misra**, Department of Physics, Delhi University, Delhi; **S. Ragothaman**, Madura College, Madurai)

6. Program questionnaire

A questionnaire was sent out following completion of the program and returned by 19 out of the 20 students. All were enthusiastic in their replies and appear to have thoroughly enjoyed the training. They found the core experiments and lectures useful and at the right level. All preferred a project-oriented summer training to one emphasising just lectures. Over half of the students remarked that they had been inclined towards a career in astronomy as a result of the summer training and most claimed to have obtained an idea of what actual research feels like. A majority felt that the program was too short and a further 10 days would have allowed more justice to have been done to most of the research projects. Almost all expressed a desire to return to Ooty next summer for similar training.

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