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A Microprocessor-based Star-Pointing Device for Optical Telescopes

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Introduction

A digital star-changing device has been developed in the laboratories of IIA in order to accurately point the telescope to stars differentially with respect to each other. Data acquisition is incremental with 1 pulse corresponding to 1 arcsec. Though the theoretical accuracy of the system is $\pm$ 1 arcsec, the practical accuracy is limited to $\pm$ 10 arcsec, by backlash of the gears and by overshooting, after the drives stop. A built-in microprocessor provides flexibility to select upto 42 program object coordinate pairs. The control commands are implemented through a user-friendly dialogue on the CRT monitor.

Hardware description

Configuration

The basic system comprises of (1) 8085 microprocessor, (2) 4×2K byte EPROM, (3) one 2K byte RAM, (4) one 8253 Timer/Counter, (5) one 8155 for 24 I/O lines as shown in Fig. 1. The SID, SOD lines are used through an RS-232C to interface to CRT monitor.

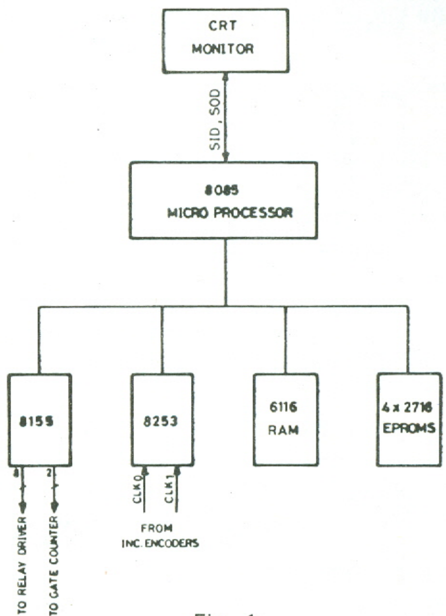


Fig. 1

Basic system configuration

Coordinate storage

The object's RA and DEC coordinate values are programmed as 5-digit BCD values in units of arcsec with sign information. Counter-0 of 8253 holds 4 digits of RA, and a memory extension byte is used for the fifth digit and the sign information. Counter-1 along with a memory extension byte holds DEC values. Thus one coordinate pair requiries a six-byte memory storage. In order to handle 42 program steps, 252-byte storage is provided from memory location 3E00 to 3EBB (Hex).

Principle of operation

The desired RA and DEC movement values are stored in units of arcsec. The corresponding encoder pulses from the respective incremental encoders count-down the stored value to zero. Meanwhile an output port sets a relay for the corresponding axis movement. Depending on the value of displacement, two speeds of motion are selected from the program. The slow motion corresponds to 10 arcmin/min while the fast motion sets 3°/min speed. For minimum overshoot, a displacement of at least 1900 arcsec is required to select fast motion. In case displacement is less than 1900 arcsec, slow motion is selected for the entire movement. For larger displacements (>1900 arcsec) in order to meet the ramp-up and ramp-down motions, the initial 100 steps and the final 200 steps select slow motion.

Sensor description

The incremental encoder is based on an IR LED detector pair generating pulses during the slot portions in a rotating disc, geared to the telescope axis. A line driver, Signetics 8T-13 has been used to drive the encoder pulses through a cable length of 40 metres. Fig. 2 shows the circuit diagram of the sensor assembly.

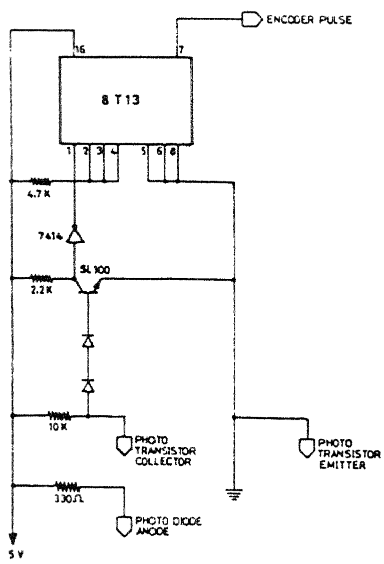


Fig. 2

Sensor circuit and line-driver

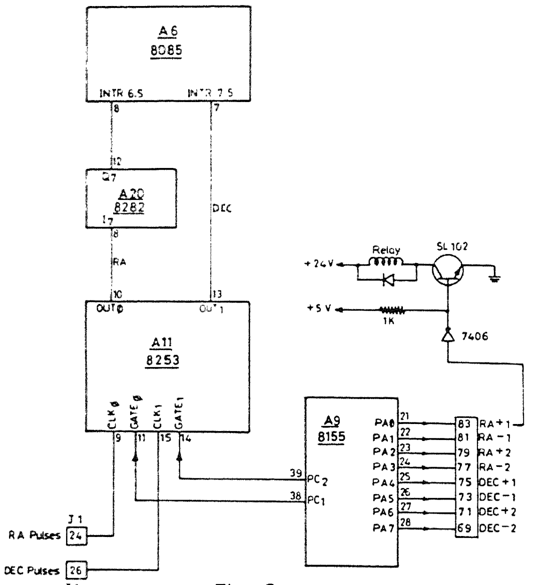


Fig. 3

Interface arrangement to the telescope

Output relay-drivers

The digital star-changing device operates in parallel to the RA-declination motion control manual push-buttons of the telescope. A set of 24V, one change-over electromechanical relays are employed for energizing the telescope movement. Four relays select RA slow-plus, RA slow-minus, RA fast-plus and RA fast-minus motions. Another set of 4 relays select similarly DEC axis movements. Fig. 3 shows the eight output lines from 8155 used for driving the relays.

Software routines

Fig. 4 shows the main program flow and Fig. 5 describes the various interrupt routines. The main program commences by initialising the two program locations X1 and X2 to zero. The two locations X1 and X2 hold the status for program completion in RA and DEC axes. The coordinate values are compared with 1900 units to decide the fast motion selection. The RA and DEC counters are initialized to program values. The corresponding extension memory holds the fifth digit and sign information. Gate 0 and gate 1 high transitions initiate count-down of counter-0 and counter-1.

The clock pulses are generated from the respective incremental encoders. The eight output lines of 8155 select the proper direction of motion and the speeds. On completion of RA and DEC motions, the X1 and X2 bits are set to logic-1 and the output ports are disabled, to switch off the motion relays. While the telescope is moving, the CRT monitor displays the RA and DEC decremented values.

Dialogue with the user

An interactive user-friendly menu-driven program through the CRT monitor has been implemented for the

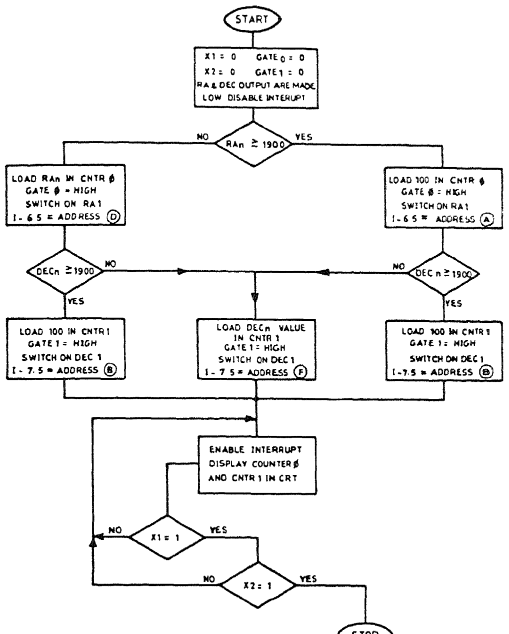


Fig. 4

Main program flow

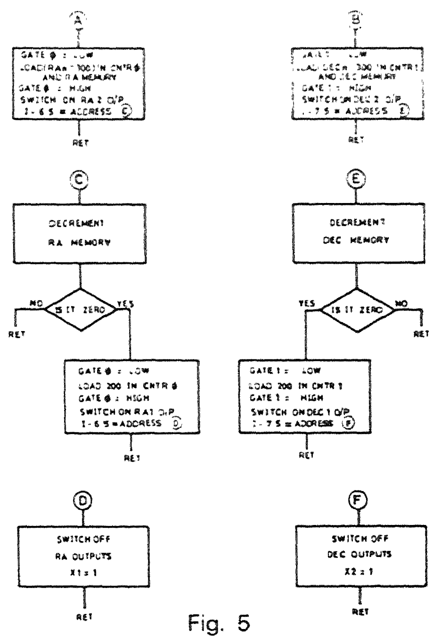


Fig. 5

Interrupt routines

telescope motion. The number of steps are programmable and the skip option provides a branching capability for pointing to different celestial objects.

Testing procedure

The star-changing device has been tested with the 1 metre optical telescope at Vainu Bappu Observatory, Kavalur. A set of bright objects were chosen and their relative displacements were worked out in units of arcsec pairs, based on their Ephemeris values. The error in pointing, based on the displacement at the cross-hair of the field viewing eyepiece has been found to be within ± 10 arcsec. In further field trials it is hoped to optimize the ramp-up and ramp-down durations so as to improve the pointing accuracy to better than ± 5 arcsec.

Use of SCD in Optical Astronomy

The star-changing device is quite a useful unit in optical telescopes, for programmed pointing to celestial objects. The instrument is particularly useful in the recording of lunar occultation light curves during emersion, and in photometry of extended objects.

from the director

On February twenty-third, we just completed a year of sighting a naked-eye supernova, after a long wait of almost four full centuries. We are lucky to have this rare celestial phenomenon just visible over the southern horizon from the Vainu Bappu Observatory, Kavalur, where an array of optical telescopes could be employed to record the rapidly changing signals conveying information about this rare phenomenon of nature. On twenty-fourth and twenty-fifth of February this year, we arranged for a meeting of scientists engaged in collection and analysis of various types of data about the supernova 1987a. The meeting gave us glimpses of many strange happenings in the cataclysmic process and its aftermath.

The supernova has lost a large part of its brightness. In order to record its fading light curve, a two-man expedition team with a portable 14-inch telescope and a photometer was sent to the island of Mauritius. Help of the India Meteorological Department for sparing the equipment and part of manpower needed for the observations is gratefully acknowledged. Due to bad weather, only limited amount of data could be gathered on fluxes in Hα and [OI] lines, and in *V* and *R* bands.

Major advances in our instrumentation programme could be achieved over the last two months when three CCD systems could be employed at the focal planes of two telescopes at the Vainu Bappu Observatory, Kavalur. Recording of stellar images upto the Palomar Sky Survey limits could be obtained with a few minutes' exposures. Further experiments for providing photometric calibrations and some essential image processing steps for these observations are on at this moment.

J. C. Bhattacharyya

Infrared photometer system for astronomical observations

An IR photometer system was developed in the Indian Institute of Astrophysics, Bangalore in collaboration with NRL, Washington, for wide-band photometry of astronomical sources in JHKLM bands (λ = 1 to 5 micron). The 0.5 mm diameter photovoltaic InSb detector used in the photometer is of low noise and is mounted on a cold deck at 77 K, of a standard 5 inch liquid nitrogen cooled dewar provided by Infrared Laboratories, USA. The photometer has 5 circular apertures of 0.5 mm, 1.0 mm, 1.5 mm, 2 mm and 3 mm diameter, apart from a blank aperture provided to determine the noise characteristics of the system at zero background. The photometer also has a two sector band circular variable interference filters for rapid continuous scan of the spectrum from 1.4 to 2.5 micron and 2.5 to 4.7 micron. Imaging lenses used in the system are designed for optimum results with a f/13 optical beam.

A low-noise current mode pre-amplifier with unit gain optimised for high impedance has as its first stage matched JFET transistors located near the detector and is operated at 77 K. The detector output is coupled through an operational amplifier. The lock-in phase amplifier synchronously rectifies the AC signal from the pre-amplifier with gains of 1, 10 and 100 and is coupled to a DC amplifier with gain settings of 3 and 10 with a variable DC off-set. During the early trial runs of the photometer at the 1-m telescope at Kavalur, recording of the output was in DC mode using a strip chart recorder.

Now we have added a Micro-processor based Lock-in Amplifier Model 510 which is remotely programmable via RS 232 and GP1B interfaces. It can be operated using a PC or simply with a terminal. All front panel features may be controlled and read via the computer interfaces. The high gain of 10^{10} of the amplifier makes it possible to get 10 volt output for a 1 nano-volt input signal. Using the SR565 lock-in Data Acquisition Software Package, it is possible to acquire, display and manipulate data from the lock-in amplifier directly on the PC and also to get/its printout.

The photometer was first tried out at the cassegrain focus of the 1-m telescope at Kavalur. To avoid reimaging and the resultant loss of signal and also to reach objects close to the horizon the photometer is mounted at an angle of 45 with respect to the optical axis of the telescope. This photometer was used for studying Comet Halley during its 1986 apparition and is now being used for the study of other celestial sources.

K. K. Scaria, R. M. Nair & K. R. Sivaraman

New Evidence for Sun's Long period Global Oscillation and their Role in Solar Cycle

The just concluded spherical-harmonic Fourier analysis of sunspot activity from 50795 positions and epochs of sunspot groups during 1902–1954 reveals that the eleven-year sunspot cycle is essentially a superposition of several symmetric (l = even, $m = 0$) modes of sun's global oscillations of the same periodicity. The relative amplitudes and the relative phases of these oscillations are found to be fairly constant from one sunspot cycle to another. The absolute phases of all the modes undergo roughly equal shifts of positive signs during the odd cycles and negative signs during the even cycles.

Phases relative to $l = 0$:

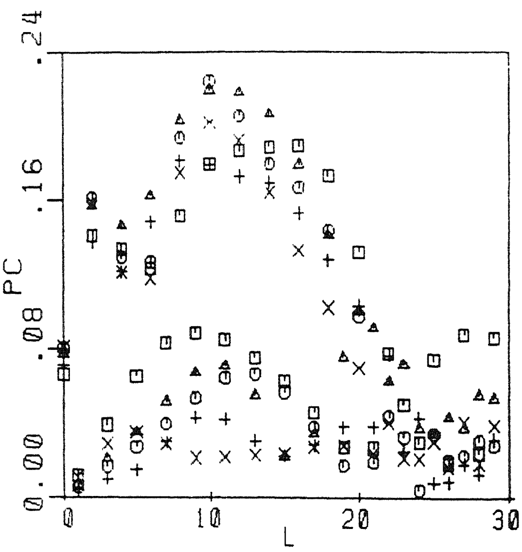
$l = 2$: 173 $\pm$5 , $l = 4$: −38 $\pm$11 , $l = 6$: 86 $\pm$17 ,
$l = 8$: −141 $\pm$7 , $l = 10$: 22 $\pm$8 , $l = 12$: −184 $\pm$12 .

Phase shifts, averaged over all modes, during successive cycles:

−39 $\pm$10 , 31 $\pm$9 , −27 $\pm$5 , +38 $\pm$8

The results support the models of solar cycle based on sun's hydromagnetic oscillations and provides evidence for several modes of the postulated oscillations. It also suggests that the basic mechanism of solar activity cycle may be related to the phase-shifts of the oscillations.

M. H. Gokhale



Relative amplitudes as functions of l during the five sunspot cycles shown by five different symbols.

IIA Bicentennial Commemorative Lecture—2

The second of the IIA bicentennial commemorative public lectures was delivered on 29 January 1988 by Dr. A. P. Mitra, Director General of Council of Scientific and Industrial Research (CSIR), at Indian Institute of Science, Faculty Hall. Dr. Mitra spoke on *Aeronomy Research in India.*

Dr. Mitra opined that research in aeronomy in India is important because (a) over the last few decades the traditional boundary of the lower and the upper atmosphere has virtually disappeared and we are increasingly recognizing the coupling between the sun, the magnetosphere, the ionosphere, the middle atmosphere and the lower atmosphere as one united system; (b) damage of the atmosphere due to human activities; (c) India had and continues to have a very distinguished record of research in aeronomy.

Tracing the history of aeronomy research in India, Dr. Mitra pointed out that this activity began here with the publication of the book *The Upper Atmosphere* by S. K. Mitra in 1947. It was gratifying to note that at the time of launching of Sputnik-I in 1957, the Soviet scientists found that the only reasonable model of the atmosphere they could use for predicting the lifetimes of satellities were those given in this book.

The International Geophysical Year (IGY), started on 1 July 1957, and continuing in an extended capacity through International Geophysical Cooperation (IGC) till 1 December 1959, marked a watershed in Indian research of the study of our planet and sun. It brought in a kind of revolution in Indian science in areas like atmospheric physics, cosmic rays, geomagnetism, solar physics, and earth sciences. Dr. Mitra felt that the achievements in the IGY were truly phenomenal with so little investment.

Dr. Mitra said that at present the single most important programme is the IMAP (India Middle Atmosphere Programme). Started in 1982 as a part of the international middle atmosphere programme, some of its important aims are (a) to examine the possibilities of damage to the middle atmosphere from man's activities; (b) study the role played by the middle atmosphere in determining climate and climatic changes; and (c) to examine the processes by which the sun acting through the middle atmosphere may be able to affect weather. This region of the atmosphere, stretching from about 10 km to 90 km, has attracted considerable attention in the recent past because of its possible role in providing coupling between the variable solar UV flux and the lower atmosphere. The single most important component is ozone which provides an important screen to biological species against the hazardous ultraviolet radiation. Several sophisticated instruments like LIDARS, and laser heterodyne were developed by Indian scientists, as a part of this programme. IMAP has provided very useful insight into the chemistry of the atmosphere.

Elaborating on the future of research in aeronomy, Dr. Mitra said that (a) for the lower atmosphere the main question concerns greenhouse gases: their nature, sources, and sinks; (b) in the middle atmosphere the main problem is ozone, which assumed new dimensions of importance with the discovery of the antarctic ozone hole in 1985; (c) in the upper atmosphere the two main questions include the matter of artificial modification of the ionosphere and the upper atmosphere as a processing laboratory of mass and energy flow between the sun and the magnetosphere on one side and the lower atmosphere on the other side. Besides, the questions of sun-weather relationships and global changes also need persistent attention. Big strides have been made in understanding many of these issues, informed Dr. Mitra.

In the concluding part of the lecture, Dr. Mitra discussed the future of aeronomy research in India. The international aeronomers' community has three special programmes: the World Ionospheric Thermospheric Study (WITS), Solar-Terrestrial Energy Programme (STEP), and the International Geosphere-Biosphere Programme (IGBP). The WITS programme which is shortly to begin will cover heights from 100 to 1000 km and in some ways supplements the MAP concerned with the heights below 100 km. STEP would trace the flow of energy from the sun to the various layers of the atmosphere and the coupling between some of these regions. The IGBP envisages interactive studies of the sun, the atmosphere, oceans, lithosphere and biosphere covering the biogeochemical cycles, hydrological cycles, and climatic processes. Indian scientists plan to participate actively in these international programmes, in addition to continuing with their own local programmes. They are already working on the fabrication of two major facilities—MST radar (Mesospheric Stratospheric Tropospheric radar) and SROSS-3 satellite—to strengthen their capability in this regard. Dr. Mitra informed that these are joint efforts between many scientists from a number of universities and national laboratories. The SROSS-3 satellite is expected to be launched in early 1989.

Dr. Mitra is confident that with the availability of world class facilities and heritage of distinguished records of work, aeronomy research in India holds an exciting future. He called upon the younger generation to take active interest in the study of our atmosphere which concerns us today and our survival tomorrow.

Earlier Prof. R. K. Kochhar, Chairman of the IIA Bicentennial Committee, outlined the history of the Indian Institute of Astrophysics. Prof. J. C. Bhattacharyya, Director, introduced the speaker.

S. K. Jain

A Matter of Quarks

The physicist's concept of what constitutes the basic building blocks of matter has undergone continual change as the domain of study has focussed on smaller and smaller dimensions. First it was thought to be the molecule; then it was the atom and later still, the nucleus and nucleons (*i.e.*, neutrons and protons). Today, with technology to probe into the structure of nucleons, it has become evident that all sub-atomic 'elementary' particles are composites of more elementary entities called quarks, and that a fundamental description of all matter should be in terms of various quarks and point-like light particles such as electrons and neutrinos, collectively called leptons.

The quark model has become a credible theory because of its remarkable success in explaining a variety of experimentally observed phenomena in sub-atomic physics. Individual, isolated quarks have not been seen in the usual laboratory conditions. The theory of quarks says that the binding energy beween a pair of quarks will rise very rapidly as their separation is increased. Nevertheless, one can envisage situations of matter in a state of extreme tight-squeeze wherein, due to pressure 'ionization', individual quarks will spill out of their parent particles such as nucleons, and form a uniform sea of quarks. For example, such a situation may be possible in the interiors of neutron stars (where core densities can be ten times the density at the centre of heavy nuclei such as uranium) and in the collisions of heavy ions in high energy accelerators. Another likely scenario is the universe in its earliest epochs of expansion. Therefore, in recent times, an important question has focussed on whether there are any 'good' signatures or signals that would give us evidence for the production or existence of quark matter in high density systems. In pursuit of this theme, at the European Centre for Nuclear Research (CERN) near Geneva, several groups have been actively engaged for the past two years in accelerating oxygen and sulphur ions and smashing them against a target of uranium nuclei at enormous energies (about 200 GeV per nucleon). This smash-up or mini-bang, akin to the hot big-bang state of the early universe, is expected to create a brief setting for quarks to come out of their confined states till such time when the temperature drops below a critical value.

The theory of quark plasma, its signals and the likely astrophysical ramifications were the subject matter of discussion in the recently concluded International Conference on the *Physics and Astrophysics of Quark Gluon Plasma* held during 8–12 February 1988 at Tata Institute of Fundamental Research in Bombay, with Indian Institute of Astrophysics as one of the sponsors. About 240 delegates from various Institutes in India and abroad participated, with roughly equal numbers of experimentalists and theorists. The highlight of the conference was the presentation by the NA 38 experimental group from CERN. Their results reported a suppression of the so-called J/psi resonance in the di-muon spectra from sulphur-uranium collisions producing large transverse energy—an effect predicted as indicator of formation of quark plasma. If quarks exist in neutron star cores, they will undergo beta decay, enhancing the neutrino emissivity and hence also the cooling rate of the star.

B. Datta

First year of SN 1987a

A workshop was arranged at IIA on 24 and 25 February 1988 to discuss the observational and theoretical efforts made during the last one year towards understanding SN 1987a.

The discussion was initiated by J. C. Bhattacharyya and began with an introduction to the supernova phenomenon by V. Krishan. Following this, S. Ramadurai (JAP) summarized the proceedings of the workshop on SN 1987a held recently at Aspen. He emphasized the early detection of gamma rays which suggests that the core is clumpy and the gamma rays diffuse out from in between the clumps.

T. P. Prabhu described the photometric behaviour of the supernova in *UBVRIJHKL* bands. He explained how the photometric information can lead to the estimates of bolometric luminosity and photospheric temperatures and radii as a function of time. This information can, in turn, be used to constrain the hydrodynamical models of the supernova explosion.

N. Kameswara Rao described the spectroscopic development of SN 1987a in the ultraviolet and optical regions. Preliminary studies based on VBO data in the optical region lead to the following inferences. First, the late-time spectrum ($\sim$250 d from maximum) shows that O/H ratio is much higher than solar. Secondly, the emission-line intensities, compared with the model calculations of C. Fransson & R. A. Chevalier (1987, *Astrophys. J.* **322**, L15–20) are consistent with a progenitor mass of 17–18 $M_{\odot}$ on the Zero-Age Main Sequence. Kameswara Rao also showed a UK-Schmidt objective-prism spectrum of the progenitor star, Sanduleak -69° 202, which exhibited stronger lines of He I and N II than in normal B-type supergiants.

A review was prepared by H. C. Bhatt on infrared observations of SN 1987a, and was read by S. Giridhar. Polarimetric observations made from VBO were described by M. R. Deshpande (PRL). D. Bhattacharya (RRI) summarized the X-ray observations obtained by

Ginga satellite, Mir-Kvant Observatory and the SMM. The emergence of X-rays much earlier than expected implies the mixing of Co^{56}. Bhattacharya also pointed out discrepancies in different observations. T. M. K. Marar (ISRO), on the following day, showed that SMM observations are uncertain since the detector was observing the supernova at a large angle. Marar also summarized the Indian Space missions planned for X-ray and gamma-ray astronomy. Unfortunately the possibility of observation of SN 1987a by Indian missions is rather remote.

R. Nityananda (RRI) described the speckle interferometric observations, the discovery of a secondary source, and the theoretical models advanced for explaining the observations.

C. Sivaram summarized the astrophysical aspects of the observed neutrinos from SN 1987a. He explained that the observations are consistent with a single event of core-collapse in a 15–20 $M_{\odot}$ star, and that there is no possibility of the formation of a black hole. M.V.N. Murthy (Matscience) discussed the particle physics aspects of the neutrino observations and concluded that no definitive limits can be placed on the neutrino mass.

Alak Ray (TIFR) reviewed the models of the supernova event. S. Ramadurai (JAP) reviewed the evolutionary models leading to the event. In order to explain the high CNO abundance in the ejecta, he proposed a model in which rotation induces CNO mixing in the core by meridional circulation. This model explains the CNO overabundance without requiring the star to have undergone a red supergiant phase.

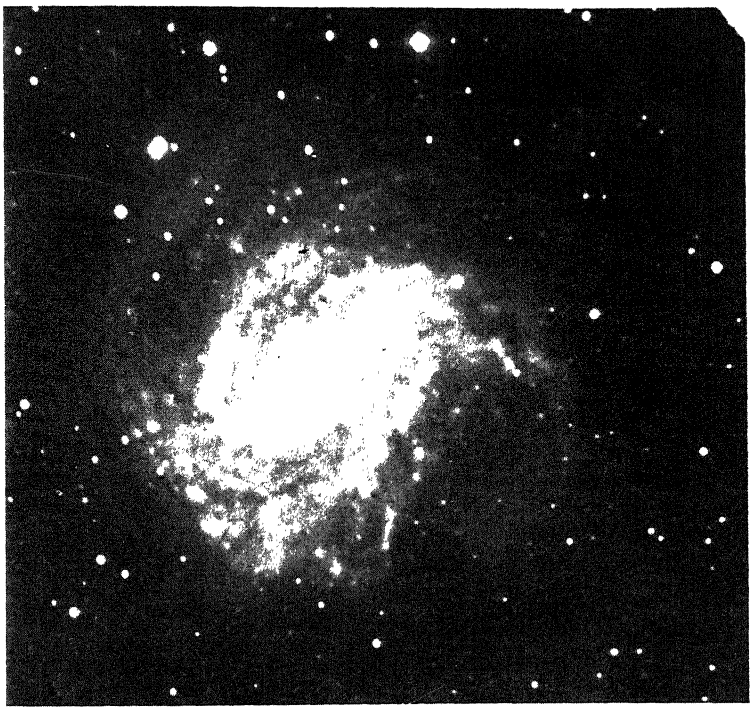
B. Datta reviewed the equation of state of hot dense matter, and G. Thejappa reviewed the theory of shocks in a supernova explosion. C. Shukre (RRI) discussed the prospects of finding a pulsar remnant of SN 1987a and concluded that there is no clear signature of a pulsar as yet.

T. Velusamy (RAC) described the high-resolution radio observations of supernova remnants in LMC and compared them with the remnants in our Galaxy. It appears that most supernova remnants in LMC are expanding freely.

C. Sivaram discussed the gravitational-wave generation in SN 1987a and concluded that they could not have been detected by the existing detectors. T. P. Prabhu summarized the current state of supernova statistics. He concluded that a much larger sample of supernovae with classification into types Ia, b, II P, L, and also a better understanding of differences in individual type II events are necessary before any further progress can be made with supernova statistics.

V. Radhakrishnan (RRI) summarized the ideas that emerged out of discussions during the workshop. He suggested that the binary models should not be ignored, as they do explain several observations closely related to the supernova phenomenon.

N. Kameswara Rao & T. P. Prabhu



A face-on spiral galaxy M83 photographed by K. K. Scaria and M. J. Rosario with the 2.3-m Vainu Bappu Telescope. Emulsion: 098-02; exposure time: 100 minutes.

of human elements

Baking the Cosmic Bread

I was amused when one day he [H.J. Bhabha] casually asked for instruction on how to use a Geiger counter; he was to travel to India by boat next week and wanted to measure the variation of cosmic rays with latitude. I told him the story of the boy who wanted to be a baker and was told he would have to serve a three years' apprenticeship: one year to run errands for the baker's wife; one to clean out the oven, and the last to learn how to bake bread. He smiled and got my point. Years later he became the head of the Atomic Energy Commission in India.

What Little I Remember
Otto R. Frisch
Cambridge University Press, 1979, p. 55.

out of context

. . . and is useful for comparing theoretical treatments of galaxy merging with observational data.

Mon. Not. R. astr. Soc. (1979) **189**, *831*

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Within the next ten years, . . . of IBM visualises . . .

The Computer Revolution (1971)
Thames and Hudson, London

* *

The author of nearly 300 scientific papers and over 20 books, we shall confine ourselves to those available in English . . .

Science and Society (1966)
Holden-Day

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