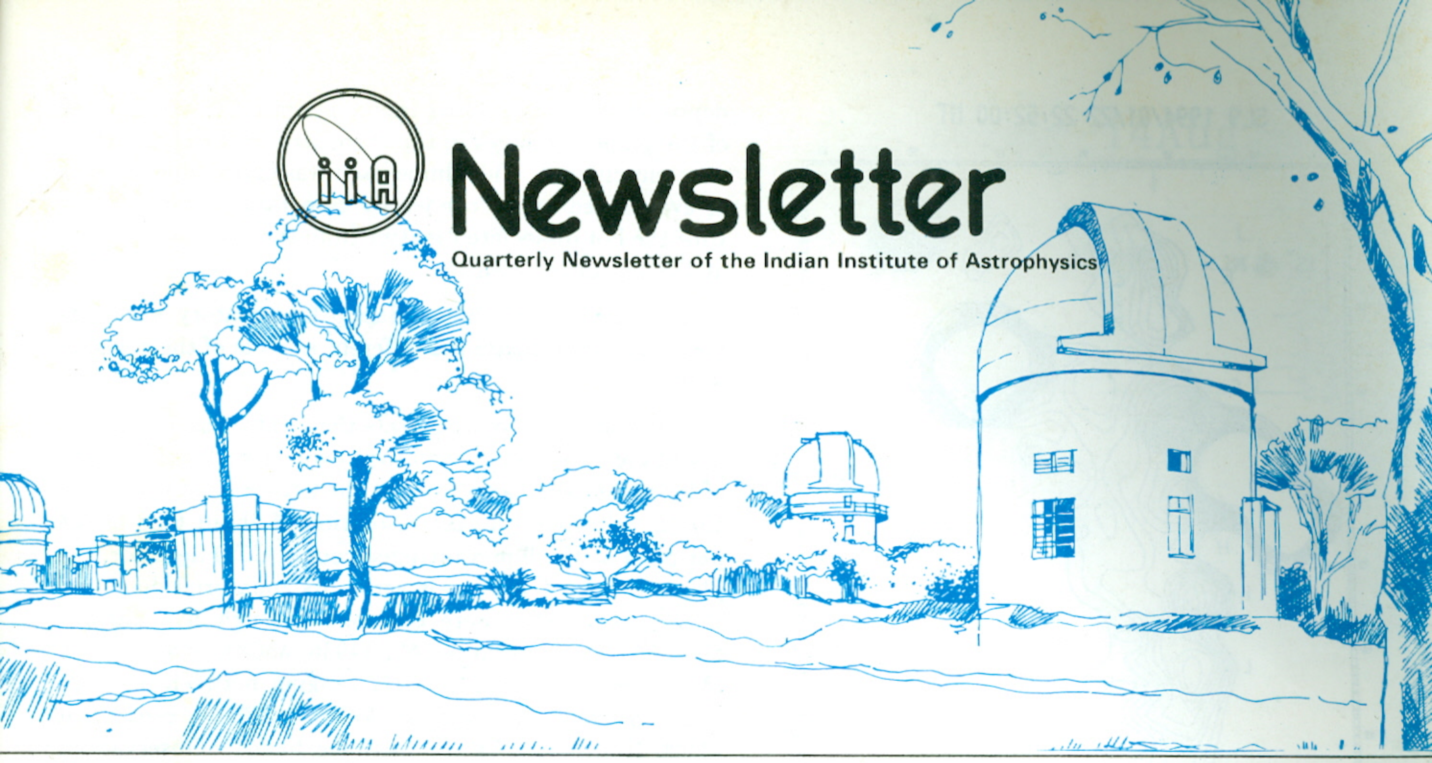

Newsletter

Quarterly Newsletter of the Indian Institute of Astrophysics

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Close Encounter of a Rare Kind : Pre- and Post-encounter observations of Comet Shoemaker-Levy with Jupiter

Comet Shoemaker-Levy 9 (SL 9) was discovered in 1993 by the Shoemakers and Levy (Shoemaker et al. 1993, IAUC 5752). Its proximity to planet Jupiter and the multicomponent train-like appearance, implied beyond doubt that a tidal disruption of this object had taken place in the near past. Marsden (IAUC 5906) and Yeomans & Chodas(IAUC 5909; BAAS 25, 1042) computed the orbit for the comet. Backward extrapolation of the orbit indicated that on 1992 July 8, the comet passed within 1.6 Jupiter radii north of the planet's centre, and underwent tidal disruption. Prior to the close encounter SL 9 was in a highly eccentric orbit around the planet. The orbit extrapolations by Marsden and independently by Yeomans & Chodas indicated another close approach in a course of 5 days centred around 1994 July 21. The impact parameter during this close approach was predicted to be 45000 km. The planet's radius being 71000 km, during the next perijove approach the fragments were to dive into the planet's atmosphere exploding at distances depending on their sizes. As the splitting of a comet by a planet and its subsequent crash onto that planet is an extremely rare event, much interest was generated in the observations of the comet itself during the pre-crash months and the planet itself during and after the collisions.

Pre-crash Observations: Soon after its discovery, an observational program of imaging of the field around SL9 was initiated at VBO using the 2.34 m telescope (VBT) with a CCD detector at its prime focus. The individual nuclei were identified in the images and their coordinates were determined by using the positions of the field stars in the HST Guide Star Catalogue. These positions were communicated to the Minor Planet Circular (MPC Feb.& July, 1994) for use by the international orbit computers to determine the final course of the fragments and the crash timings. Significant changes in the morphology of the dust envelope were evident over the course of our observations spanning 10.5 months. The cocoon of dust around the fragments and the whispy tails on the leading and trailing directions of the main train of the fragments seen in 1993 May are absent in the subsequent images. Much of the dust appears to have been swept away while passing in the vicinity of the apojove around 1994 July. Evolution of the orbits of the individual fragments and the dust grains caused gradual but steady increase in their mutual separation. The original train of about 50 arcsec at the time of discovery increased to 4.5 arcmin in April. With the thinning of the dusty envelope around SL9, the tails from individual fragments became noticeable. The length of these tails in the January – April images is in the order of 1 arcmin and do not appear to have changed over these months. This points towards very small relative velocities of the dust grains with respect to the corresponding fragment. Considering negative results of presence of OH^- and other cometary gases (Weaver, Feldman& A'Hearn 1994, Science 263, 787; Cochran 1993, IAUC 5732) this does not come as a surprise. A contour plot of the image obtained on 1994 January 22 is shown in Fig. 1.

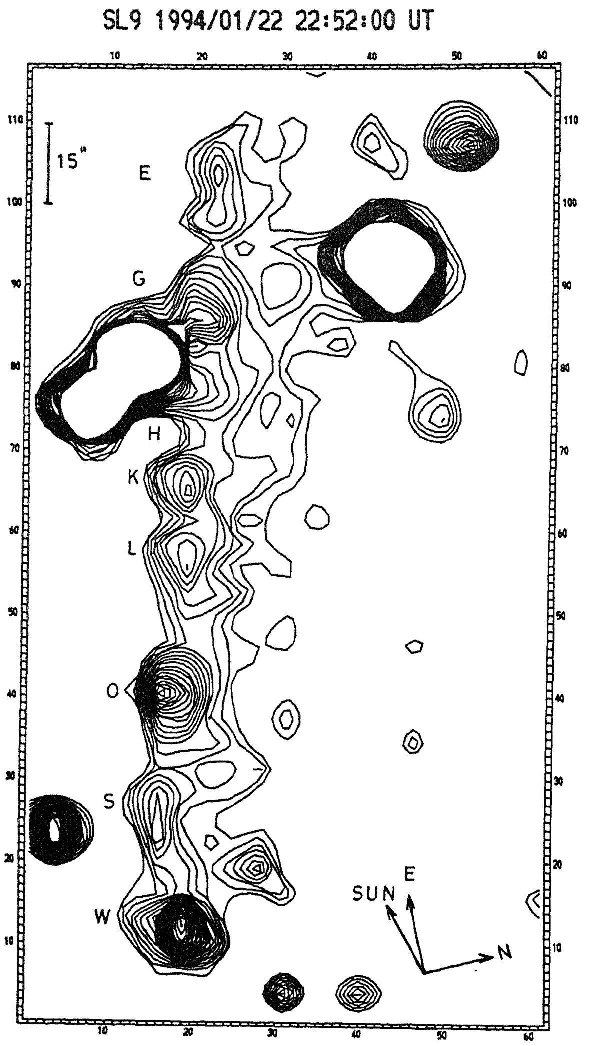


Fig. 1. A contour plot of the image of Comet Shoemaker-Levy taken on 1994 January 22 using the 48 inch telescope at JRO by R. Rajamohan, G. Som Sunder*, P. Vivekananda Rao*, R. Swaminathan* & B. Lokanadham*). Thirty contours are plotted between 19.80 mag arcsec^{-2} and 19.75 mag arcsec^{-2} to bring out the faint structures in the tails.

Post-crash Observations: The fate of the cometary fragments diving onto Jupiter at speeds of 60 km s^{-1} were investigated theoretically by Sekanina (1993, Science 262), Ahrens, Takata & O'Keefe (1994, Geophys. Res. Let. 21, 1087), and Zahnle & MacLow (1994, Icarus 108, 1). The theories predicted eruption of plumes rising to heights of about 2000–3000 km folowing explosions at depths depending on the mass of the fragments. Although the impacts were to take place on the night side of the planet, the impact sites were fortunately close to the morning terminator, so that rotation of the planet was expected to bring the top of the plume into view for a terrestrial observer within minutes of its eruption. The flashes due to explosions at the far side of the planet were predicted to be seen by reflection off the surface of the favourably located satellite. Considering the large amount of energy deposited by the colliding fragments into the atmosphere of the planet, changes in the chemistry of the atmosphere were anticipated. The plume itself was expected to consist of evaporated and recondensed cometary material along with the hot dissociated matter from the deep atmosphere at the site of the collision.

Observations at the Vainu Bappu Observatory were carried out to investigate the different aspects of the collision events.

Direct Imaging: To investigate the location and morphology of the impact spots and their evolution, direct imaging of the planet was carried out at the Cassegrain focus of the 1.02 m telescope. At the resolution of about 0.38 arcsec per pixel at the liquid nitrogen cooled CCD detector, the planet occupied 104 pixels across its equatorial diameter. Images of Jupiter were obtained through five narrow-band filters centred at λ4862, λ4935, λ5083, λ6581, λ8930 (Methane band) with FWHM ranging between 50 - 100 λ and a broad one with a FWHM of 300 λ centred at λ8900 (continuum at the methane band). Observations were carried out between July 18–22 and again on Aug 13–14 through λ4862 and λ8930 filters. The exposures ranged from a few seconds to a few minutes depending on the sky conditions. Fig.2 shows an image taken through the methane band. Continuous monitoring allowed follow up of these impact spots from the morning to the evening limb on Jupiter. The spots appeared bright in the λ8930 methane band and dark in other bands. This suggests that the clouds of material comprising of the evaporated and condensed cometary matter are at large heights from the visible cloud tops. Other regions appear darker in this band as the light is scattered by the aerosols in the presence of methane and ammonia vapours. The colour dependence of the scattered light from the crash sites will be investigated using the series of images. Persistance of the dark spots indicate their link with lower atmosphere.

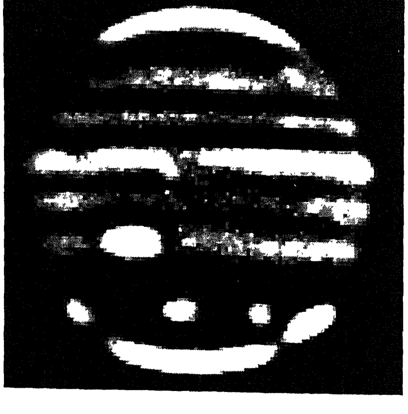


Fig. 2. Jupiter through the methane band after the completion of the collision series at 15:35 UT on 1994 July 22 from VBO. The feature at the eastern limb is E. The two spots towards west are due to H and Q impacts respectively. The elongated feature at the extreme west are due to D,G,S and R impacts.

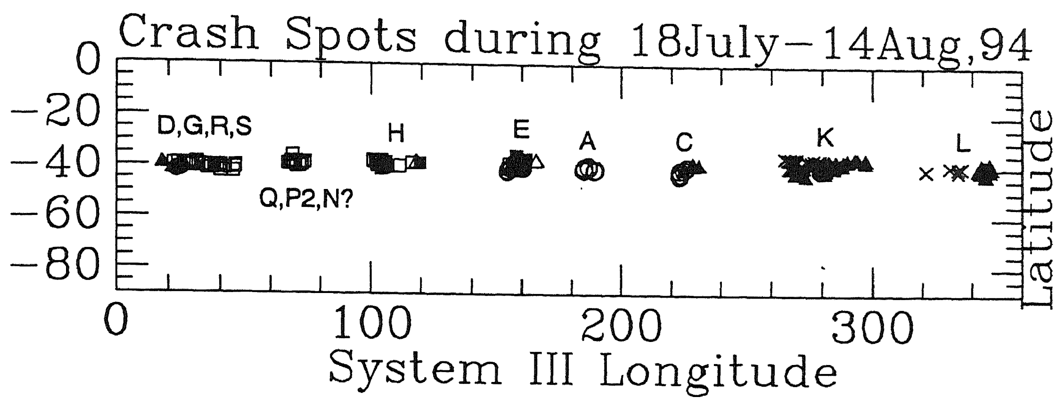


Fig. 3. Latitude and system III longitude of the crash spots in the methane band images taken between 1994 July 18 and August 13–14.

The images were reduced and were rotated so that the spin axis of the planet is vertical. The centre of the planet was obtained by using the ELLIPSE routine of STSDAS * under the IRAF **. The measured pixel positions with respect to the planet's centre were then used to calculate the planeto-centric positions of the spots. The system III positions of the spots measured from July 18 through August 14 are plotted in Fig. 3.

Jupiter was also imaged using a speckle camera at the Nasmyth focus of the 48-inch telescope at the Japal - Rangapur Observatory (JRO), Hyderabad. The images of Jupiter were enlarged by a factor of 3 by a barlow lens and images were obtained in three different filters with exposure times of about 100 ms. Two filters centred on λ5500 Å and 6110 Å with FW HM of 300 Å and 99 Å and an RG9 a filter with a lower wavelength cut off at 8000 Å were used. About 550 images were obtained through these three filters on 1994 July 17 and 80 images on 1994 July 24. A water cooled 1024 × 1024 pixels CCD was used as the detector. A liquid nitrogen cooled 512 × 512 pixels CCD of Osmania University was used for observations on July 22; due to poor sky conditions, only a few images could be obtained. These images, especially the ones obtained on the 17th and the 24th are being analysed by S.K. Saha using image processing algorithms to see disturbances in the cloud structure and fine scale vortex structures if any at the impact sites. It should be possible to see details to about 0.3 arcsec resolution as the images were obtained with 0.1 arcsec per pixel resolution. The reconstructed image will have a resolution similar to those obtained by the Hubble Space Telescope.

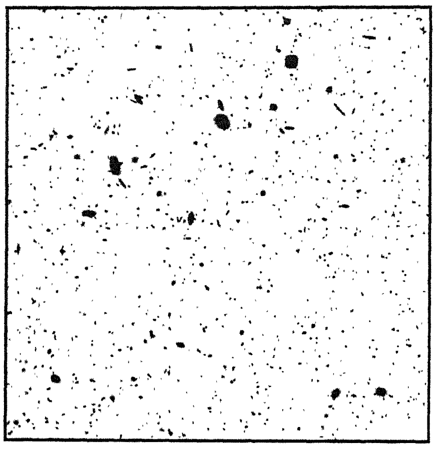
* The Space Telescope Science Data Analysis System

** IRAF is distribured by the National Optical Astronomy Observatories which is operated by the Association of Universities Inc.(AURA) under cooperative agreement with the National Science Foundation

Spectroscopic Investigations of the Crash Events: A series of low resolution spectra of the spots were obtained using the Boller & Chivens Spectrograph at the Cassegrain focus of the 2.34 m telescope. The long slit of the spectrograph was placed parallel to the equator at the crash latitude of 42-45° S. This arrangement permitted spectra of several crash spots in a single run. On July 18 and 19 the spectra were obtained at a resolution of 4.2 Å pixel^{-1} on the CCD detector covering a range of 4830-7400 Å. The light from the planet is mainly due to that scattered from the aerosols which form the visible cloud top. The presence of vapours of ammonia and methane leave their absorption signatures. Changes in the atmospheric chemistry and physical conditions will result in the changes of the concentrations of these vapours which might be detectable from a detailed study of the spectra at the crash zones. Therefore the aim of the spectroscopic observations was to investigate the changes in the equivalent widths of ammonia bands relative to the methane bands. In the region between 4830 – 7400 Å the spectra recorded two close pairs of these bands: CH4/NH3 at 5520/5430 and CH4/NH3 at 6190/6475. Spectroscopic observations were made on July 20, 21 and 22 in the wavelength region 8300 – 9200 Å with a resolution of 1.2 Å pixel^{-1}. The near continuous series of spectra will be analysed to investigate the differences in the equivalent width of the methane band at 8860 Å at the crash spots and the surrounding regions. The Jovian spectrum also contains absorption features of the sun light. To remove the solar features, spectra of a region on the Moon at the 'Mare Serenitatis' were obtained with the same grating settings on each night.

R. Vasundhara, Pavan Chakraborty, K.K. Ghosh, & K. Jayakumar

Simulating Model Universes



Monte Carlo simulations of galaxies distributed in small fields and extending to high redshifts are carried out for two choices of cosmological models defined by omega = 0, 1 for a fixed Ho = 50. The simulations are based on the local observed properties of galaxies and are extended to higher redshifts using spectral synthesis models of galaxy evolution and the pre-defined behaviour of space time geometry which determines its volume, age and distance behaviours at different redshifts. Conservation of galaxy number density is assumed throughout and no AGN or starburst activity is included. Within such a 'minimilistic' model, where the only evolutionary behaviour is of the previous generations of stars in galaxies, all the observed optical and infrared photometric and spectroscopic behaviours are roughly reproduced for a formation redshift of about 5. For further details see Chokshi et al. 1994, Ap J **424**, 578.

Arati Chokshi

colloquia

The following lectures were given at IIA between 1994 April 15 – 1995 March 31:

1. Evolution of the Sun's poloidal magnetic field (M. Dikpati, JAP, IISc., Bangalore)
2. OB associations in Galaxies (P. Battinelli, Observatorio Astronomico di Rome, Italy)
3. The initial evolution of open clusters (R. Capuzzo- Dolcetta, Instituto Astronomico, Roma, Italy)
4. Two-phase model of accretion disks in active galactic nuclei(J. Poutanen, Observatory and Astrophysics Laboratory, University of Helsinki, Finland)
5. Coherence in chaos (Bimla Buti, NPL, New Delhi)
6. Galaxies : shapes, cores and dust (Ajit Kembhavi, IUCAA, Pune)
7. Magnetic shear changes before and after solar flares (Ashok Ambastha, Udaipur Solar Observatory, (PRL) Udaipur)
8. Initial mass function and its relevance to dark matter (T. Richtler, Sternwarte der Universitat, Bonn, Germany)
9. Nucleosynthesis by the s process in red giants – The neutron density (D. Lambert, University of Texas, Austin, USA)
10. Emission-line variability in Active Galactic Nuclei (P.J. Wiita, Georgia State University, USA)
11. Hubble Space Telescope observations of H_2, C_2, and CO molecules in diffuse clouds towards σ Ophiuchi (D. Lambert, University of Texas, Austin, USA)
12. Microsecond Universe (B. Sinha, SINP and VECC, Calcutta)
13. Imaging polarimetry (A.K. Sen, IUCAA, Pune)
14. Chemical composition of RV Tauri variable IW Carinae (S. Giridhar, IIA, Bangalore)
15. Simulations of high redshift galaxies (A. Chokshi, IIA, Bangalore)
16. The puzzle of the highest-energy cosmic ray events (P. Bhattacharjee, IIA, Bangalore)
17. Continuum millimeter observations of high redshift radio quiet QSOs (A.Omont, Institute de Astrophysique, Paris)
18. What IRAF was, is and will be (F. Valdes, National Optical Astronomy Observatories, Tucson, Arizona)
19. Stellar populations in nearby dwarf galaxies (A. Saha, Space Telescope Science Institute, Baltimore)
20. Active spectrographs (Rajiv Bhatia, University of Padov, Italy)
21. Chromospheric structure and dynamics (W. Kalkofen, Harvard Smithsonian Centre for Astrophysics, Cambridge, USA)
22. Soap films (A. Mackay, Birkbeck college, London)
23. Global structure of discs around black holes (J. Artemova, Theoretical Astrphysics Centre, Copenhagen, Denmark)
24. Discovering the Alchemist Nagarjuna (D. Wujastyk, Welcome Institute for the History of Medicine, London)
25. Constraints on galaxy formation from the Lyman-alpha absorbers in front of quasars (K. Subramanian, GMRT, Pune)

Surendra Kumar Jain (1951–1994)

In the early hours of 1994 November 17, the cruel hand of death snatched away a young and promising scientist from our midst, when Dr Surendra Kumar Jain died of complications related to adenocarcinoma of the lung, after a courageous year-long fight with the disease. Dr Jain, Surendra to his numerous friends and colleagues, was a physicist by training who then turned his attention to the field of observational astrophysics and was one of our leading experts in the field of instrument development for astronomical research, in addition to being a research scientist. His interest spanned a wide range from solar physics to the physics of stellar envelopes and interstellar matter. In his early death a void has been created that will be difficult to fill.

Surendra Kumar Jain was born on January 11, 1951 in Dehra Dun, U.P. and had his early schooling and college education in Dehra Dun. He obtained a Bachelor's degree in 1969 and then an M.Sc. in Physics in 1971 from D.A.V. College, Dehra Dun, which was affiliated to Meerut University. He enrolled himself as a graduate student in Physics in Panjab University, Chandigarh and worked for his Ph.D. in the area of Cosmic Rays. He showed great independence already as the better part of the work was done while his guide was away on sabbatical leave from the University. Towards the end of his graduate tenure, Surendra spent a considerable amount of time working in the Cosmic Ray Laboratories of the Tata Institute of Fundamental Research, Bombay. The noted cosmic ray physicist Professor Yash Pal was effectively his thesis advisor at that stage.

Soon after submitting his thesis in early 1978 Surendra came down to Bangalore and started work as a Research Associate in the Department of Physics, Indian Institute of Science. He worked with Professor M.A. Viswamitra on the development of a novel probe, using soft x-rays, for the examination of morphological structures of chromosomes and chromatin. In 1981 January Surendra left the Indian Institute of Science when he was hired by the Indian Institute of Astrophysics as a Fellow. His most productive years followed in this Institute. He was promoted as a Reader in 1988.

It took Surendra Jain little time to adjust to the demands of the new discipline of astronomy and astrophysics and he embarked on his activities in this area with characteristic zeal and dedication. At the outset, the then Director of IIA, Professor Vainu Bappu wanted Surendra to develop a Fourier Transform Spectrometer for use in Kavalur. Surendra spent the initial years in this Institute trying to fulfil this requirement. As a first step he was able to rig up a laboratory model with a commercially available Michelson interferometer. Interferograms of various laboratory sources were recorded on magnetic tape and subsequently digitized and transformed in the Fourier domain on a hybrid computer. Some years later he, along with Dr M.J. Smyth of the Royal Observatory, Edinburgh, partly developed and assembled an infrared FTS and successfully tested it at the Cassegrain focus of the 102-cm Zeiss telescope in Kavalur. A new interface to mount the FTS at the Cassegrain focus of VBT was under development and left unfinished at the time of his death.

A second and much more successful instrument built by him is the stellar polarimeter which went into operation in its crudest version in 1985. In the subsequent years, Surendra continued to improve the design and performance of this instrument which ultimately led to the present *Star-and-Sky Chopping Polarimeter*, a state-of-the-art instrument which forms a part of our permanent treasure of focal plane instruments at the Vainu Bappu Observatory, Kavalur. The instrument brought in rich returns and Surendra collaborated with several colleagues from IIA and elsewhere to carry out important observational studies of close binaries, Herbig Ae/Be stars, post-AGB objects and protoplanetary nebulae, molecular clouds and young stellar associations. Several papers on the results of these investigations have already appeared and a few more are in the pipeline. Surendra also participated in an observational programme to study the internal kinematics of Galactic planetary nebulae using Fabry-Perot spectrometers built and operated by the Physical Research Laboratory, Ahmedabad. The results of these studies are also in print.

As a scientist with a rather wide spectrum of interests Surendra, along with his colleagues Jagdev Singh and P. Venkatakrishnan, undertook a study of the spatiotemporal behaviour of the He I 10830 Å line in the sun. From a time series spectra obtained of this line at the Vacuum Tower Telescope at the Kitt Peak National Observatory, USA, the authors were able to study the fluctuations in the line parameters which then prompted them to look deeper for the causes of these fluctuations. This investigation eventually motivated Surendra to participate in the *EUV Spectroheliometer Payload Project* where four different institutions from as many different countries are joint collaborators.

The EUV project was started in 1990 January with the aim of understanding, through high resolution studies of the sun, the interplay between the time-dependent geometry of the magnetic field structure and the associated flow of mass and energy in the various layers of the solar atmosphere. The last few years of his brief though productive scientific career Surendra devoted to this project. With his colleagues Ajay Saxena and J.C. Bhattacharyya, he took up the assigned task of designing and fabricating a 450 mm Gregorian telescope complete with optics and mechanical structure. The optics was fully designed and fabricated at the Optics Workshop of the Institute under Saxena's supervision. Design of the mechanical structure with its very special requirements posed quite a challenge and Surendra took this up with delight and enthusiasm. His experience in experimental physics and technical skill in building instruments measured up to the task on hand. He also displayed considerable managerial skills in coordinating the different aspects of the work until the structure was satisfactorily completed and delivered to Stanford University, USA. He did not live to see the completion of this project, nor the launch of the payload, which has been delayed beyond the original target date of 1994 August. Nor will Surendra be available to discuss and analyse the scientific data when it becomes available. But surely will he be remembered by the international consortium of colleagues participating in the project for the contribution he had made to it.

His scientific output was not prolific but he was one of the very few individuals in this Institute who chose and followed the difficult path of building an instrument with a purpose in mind and then used it successfully to produce science. He had his share of frustrations in bureaucratic delays and shortage of funds or lack of proper infrastructural facilities but he was always patient and displayed a kind of dogged persistence that ultimately helped in getting things done. He was thorough with his science and seldom balked a difficult task. In addition to his scientific activities he contributed substantially to improving the communication channels of the Institute. He was instrumental in starting the e-mail facility and he was responsible for maintaining it. He did this job efficiently and was always available to rectify a problem when it appeared. During the brief period he and the late Dr K.K. Scaria were placed in charge of the maintenance of the 102-cm telescope at VBO, he helped effect several small but important changes.

His large circle of friends will remember Surendra for his eminently sociable qualities. He was unpretentious, gentle and helpful. It was easy to make friends with him. His house was ever a popular meeting place for many of his colleagues who were attracted by the congenial atmosphere and the warm hospitality of his and his wife's. Everyone was always welcome, no hour of the day was a wrong one to visit.

Meticulous in his habits, unostentatious in his life style he imbibed the true spirit of Jainism in his dealings with the world. He would not hurt in words or action anybody, not even a flea. Life was not always kind to him but he bore his pains with a certain amount of stoicism. Struck with the killer disease, Surendra showed great courage during the year of his illness, fought valiantly with the much stronger adversary and had kept alive his hope till the end. Posterity will perhaps make a kinder appraisal of the man and his work. Surendra is survived by his wife Promila, sons Ayush and Nimish and an aged mother.

D.C.V. Mallik

R. S. Narayanan (1959–1994)

The friends and colleagues of R.S. Narayanan were shocked by his untimely death in an automobile accident on 12 August 1994.

Ramaswamy Soumya Narayanan was born on 27 January 1959 to R. Jayalakshmi and N. Ramaswamy in T. Nagar, Madras. He had his early schooling at Bombay where his father worked in the administrative wing of the Bhabha Atomic Research Centre. Watching bright young scientists, including Homi Bhabha, at close quarters made Ramaswamy wish for a scientific profession for his only child. He spurred his son towards that end, culminating in a Ph.D. for Narayanan at the Indian Institute of Technology, Delhi in 1984.

Narayanan then joined the Indian Institute of Astrophysics at Kodaikanal in May 1985. Being a stranger to astronomy did not stop him from plunging into the excitement of observations right from the beginning. He started by helping the team of observers of Comet Halley, as well as learning the rudiments of solar observations. His zeal for organising things was recognized when he was made the resident scientist for the field station of the Indian Institute of Astrophysics at Kodaikanal. Subsequently, he was also inducted into the team for making a solar vector magnetograph.

His vigorous liasing with various sections of the Institute as well as with DST officials helped in accelerating the pace of the vector magnetograph project. He also lent an able helping hand in the laboratories at Bangalore as well as at the observing floor at Kodaikanal during the testing/validation phase of the instrument.

His sense of adventure made him volunteer to be on the team that went to the Himalayas in search of a site for a new optical telescope. His stories about the Himalayan adventure were quite interesting.

The accident occured when he was bringing back some equipment from Kodaikanal that was used for trying to catch the encounters of the fragments of comet Shoemaker with Jupiter. In fact, that was the last scientific observation in which he participated. It is significant that his first and last encounters were related to observational aspects of Astronomy .

Narayanan had friends in all walks of life and in all sections of the Institute. His sudden demise under such tragic circumstances has left a deep sense of loss. The greatest loss is to his aged parents, who were seeing the burgeoning of their own dreams in him, which have been cruelly shattered.

P. Venkatakrishnan

Thomas

Thomas who was working as Mechanic A since 1993 April 1 at the Mechanical Workshop at IIA, Bangalore died in the same automobile accident as Narayanan on 1994 August 12 while returning from Kodaikanal. He was working in the Institute since 1986. To his colleagues and friends at the Institute his untimely demise came as a shock. He leaves behind his wife and a daughter.

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