IIA Newsletter

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Kodai School on 'Synthesis of Elements in Stars'

The year 2007 marked the fiftieth anniversary of the appearance of two pioneering papers on stellar nucleosynthesis – *'Synthesis of the Elements in Stars'* by E. M. Burbidge, G. R. Burbidge, W. A. Fowler and F. Hoyle (1957, Rev. Mod. Phys. 29, 547) and *'Stellar Evolution, Nuclear Astrophysics and Nucleogenesis'* by A. G. W. Cameron (1957, Chalk River Report CRL - 41). These papers laid the foundation for research in several aspects of theoretical and experimental nuclear physics, stellar modelling, and studies on the chemical composition of stars that showed distinct evidence of the processes of element synthesis suggested by these authors. Over the past half a century or so there have been significant progress in many of these fields, although there are still many outstanding problems waiting to be solved.

The Kodai School on 'Synthesis of elements in Stars' was held at the Kodaikanal Solar Observatory of the Indian Institute of Astrophysics from April 29 to May 13, 2008. It was organised to provide a glimpse of this exciting area of astrophysics to astrophysicists of tomorrow and to motivate young students. The 110-year old Kodaikanal Solar Observatory, with a history of significant scientific achievements, provided an ideal and inspiring setting for the school. The student participants, numbering a total of thirty four, were from different universities and research organisations all across the country. There were three international students – two from Brazil and one from Germany. Apart from the regular classroom lectures, students had ample time for informal discussions among themselves and with the school faculty.

The school drew strength from considerable in-house expertise at IIA in a number of critical areas. A highlight of the school, however, was the faculty participation by a number of leading astrophysicists from different parts of the world. Apart from the scientists from IIA, the school faculty included Marcel Arnould (Director, Institut d'Astronomie et d'Astrophysique, Université Libre de Bruxelles, Belgium), David L Lambert (Director, McDonald Observatory, University of Texas at Austin, USA), Bruce Fegley and Katharina Lodders (Washington University, St Louis, USA), Simon Jeffery (Armagh

Observatory, UK), Amanda Karakas (Mount Stromlo Observatory, Australia), Alak Ray (TIFR, Mumbai) and Kamales Kar (SINP, Kolkata).

Following a traditional and inspiring invocation from the Upanishad and a brief inaugural function, the school was opened to technical sessions. David Lambert set the tone of the scientific sessions with the lead talk on *'Synthesis of elements in stars: an overview'*. In two subsequent lectures, he also discussed *'The elements beyond the iron peak'*. The basic properties of nuclei were explained by Arun Mangalam (IIA) in a series of lectures and hands-on sessions which included solving problems. Cosmological nucleosynthesis of light elements was discussed by C Sivaram (IIA). These lectures provided the background for the series of lectures by other speakers that followed.

Massive stars, their evolution and nuclear reaction rates were discussed by Ray. He also discussed core-collapse in massive stars and supernovae in brief. In a series of lectures, Lodders gave a vivid picture of the present understanding of *'Elemental abundances: solar, meteoritic and outside the solar system'*. Estimation of condensation temperatures, a property of the chemical elements which is of great astrophysical importance, was explained by Fegley during his lectures on *'Cosmo-chemistry of the major elements'*.

A number of classes were devoted to the studies on stellar evolution: basic equations, elementary solutions and numerical methods. These classes were conducted by Jeffery. The students were introduced to a tool called 'Window to the Stars', an interactive visualisation tool for running stellar evolution models. Students actively participated in this programme learning the uses of this tool. AGB nucleosynthesis, that plays a significant role in the understanding of C, N, O abundances in ISM and the production and distribution of s-process elements, was discussed by Karakas. Starting with a broad overview of the evolution of low- and intermediate-mass stars, Karakas discussed in depth nucleosynthesis prior to the AGB phase, evolution and nucleosynthesis during the AGB phase, and evolution after the AGB phase and super-AGB stars. She also discussed in brief *'Low-metallicity evolution and nucleosynthesis'*.

Chemical composition of stars determined from high-resolution stellar spectra provide important observational constraints for theoretical studies of stellar nucleosynthesis and chemical evolution of the Galaxy, its origin and structure. Aruna Goswami (IIA) discussed some current issues in the understanding of the Galactic chemical evolution. Gajendra Pandey (IIA) explained how stellar spectra can be analysed using the 'Curve of growth technique'. Kameswara Rao (IIA) talked about the high-resolution echelle spectrograph at VBO, the only high resolution spectrograph currently available in India that can be used to acquire spectra of stars at a resolution of $\lambda/\Delta\lambda \sim 60{,}000$. He also discussed some results obtained from the analysis of data acquired using this instrument at the Vainu Bappu Telescope in Kavalur. Some concepts and techniques of stellar classification, including automated classification and stellar parametrization were introduced by Sunetra Giridhar (IIA).

The importance of weak-interaction rates for stellar evolution, supernovae and r-process nucleosynthesis was discussed by Kar. He also discussed weak interaction processes during the proton-proton cycles and the solar neutrino problem. In a series of talks titled *'The evolution of massive stars and the concomitant non-explosive and explosive nucleosynthesis'*, Arnould gave a comprehensive picture of the present understanding of explosive nucleosynthesis. His lectures covered a number of important problems that are yet unresolved but are crucial for our understanding of stellar nucleosynthesis. The scientific sessions ended with his talk on p-process nucleosynthesis to which the production of proton-rich elements is attributed, a topic of great importance but less explored as yet. It was evident from the feedback received from the participants that periodic organisation of such an event will go a long way in motivating students to choose astrophysics as their career. Aruna Goswami, Eswar Reddy and Gajendra Pandey coordinated the school.

— Aruna Goswami

Solar Coronal X-ray Bright Points from Hinode / XRT Observations

Solar coronal X-ray bright points (XBPs) have been an enigma since their discovery in the late 1960s. XBPs have been studied in great detail using Skylab and Yohkoh X-ray images. Their correspondence with small bipolar magnetic regions was discovered by combining ground-based magnetic field measurements with simultaneous space-borne X-ray imaging observations. The daily number of XBPs found on the Sun varies from several hundreds up to a few thousands. It is known that the observed XBP number is anti-correlated with the solar cycle, but this is an observational bias and the number density of XBPs is nearly independent of the 11-yr solar activity cycle. It is found that the diameters of the XBPs are around 10 - 20 arc sec and their lifetimes range from 2 hours to 2 days. Studies have indicated the temperatures to be fairly low, $T = 2 \times 10^6$ K, and electron densities, $n_e = 5 \times 10^9$ cm^{-3}, although cooler XBPs exist. XBPs are also useful as tracers of coronal rotation and contribute to the solar X-ray irradiance variability (DeLuca & Saar; Kariyappa & DeLuca, in preparation). Assuming that almost all XBPs represent new magnetic flux emerging at the solar surface, their overall contribution to the solar magnetic flux would exceed that of the active regions. Since a statistical interaction of the magnetic field is associated with the production of XBPs, the variation of the XBP number on the Sun will be a measure of the magnetic activity responsible for its origin.

Bright points are also observed in the chromosphere using high-resolution Ca II H and K spectroheliograms and filtergrams. Extensive studies have been conducted to determine their dynamical evolution, the contribution to chromospheric oscillations and heating, and to UV irradiance variability. Oscillations of the bright points at the higher chromosphere have been investigated using SOHO/SUMER Lyman series observations. It is known from these studies that the chromospheric bright points are associated with 3-min periods in their intensity variations. The study of the spatial and temporal relationship between the solar coronal XBPs and the photospheric and chromospheric magnetic features is an important issue in the physics of the Sun.

The Hinode/XRT observations provide an opportunity to investigate and understand more deeply the dynamical evolution and nature of XBPs than has been possible to date and to determine their relation to the large-scale magnetic features. Such high-resolution observations and investigations would be helpful in understanding the role of oscillations and

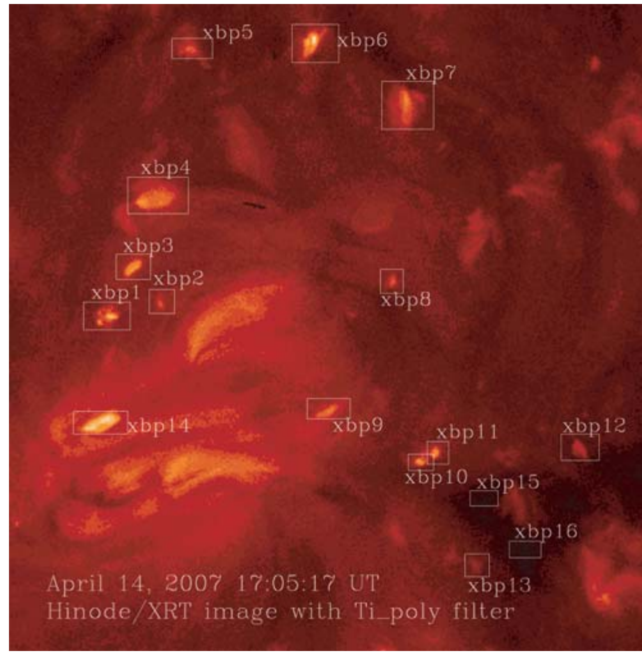

Figure 1. A sample image from the time series obtained by Hinode/XRT on April 14, 2007 at 17:05:17 UT. xbp1, xbp2,...,xbp14 are the XBPs and xbp15 and xbp16 are the background coronal regions selected for the analysis.

the nature of the waves associated with XBPs to heat the corona.

A 7-hour time sequence of soft X-ray images obtained on April 14, 2007 from the X-Ray Telescope (XRT) on board the Hinode Mission has been analysed. From the images, 14 XBPs (xbp1, xbp2,..., xbp14) and 2 background regions (xbp15 and xbp16) have been identified in a quiet region near the centre of the solar disk for analysis. The images have been calibrated using the routine *xrt_prep.pro* in IDL under SSW. This routine performs many corrections.On the calibrated images, the rectangular boxes covering the selected XBPs have been placed and the cumulative intensity values of the XBPs derived by adding all the pixel intensity values. After correcting for background coronal emission, the light curves of all the XBPs have been derived for further analysis. For the first time, a power spectrum analysis on XBP data has been used to determine the periods of intensity oscillations.

The XRT data show that XBPs tend to produce small and large time-scale fluctuations in their intensity and some periods of intensity oscillation are similar in all the XBPs. The periods observed with XRT data range from a few minutes to hours and these findings are in good agreement with the results derived from the analysis of full-disk images obtained by the Yohkoh/SXT experiment. Although at first sight the light curves of 14 XBPs seem to be very diverse

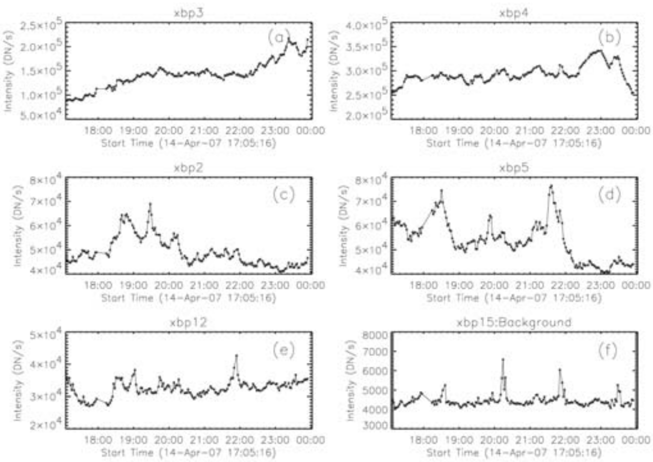

Figure 2. Time series of XBPs and a background coronal region (xbp2, xbp3, xbp4, xbp5, xbp12 & xbp15 as shown in Fig.1, where (a) xbp3 & (b) xbp4: class I; (c) xbp2 & (d) xbp5: class II and (e) xbp12: class III and (f) xbp15: background coronal region.

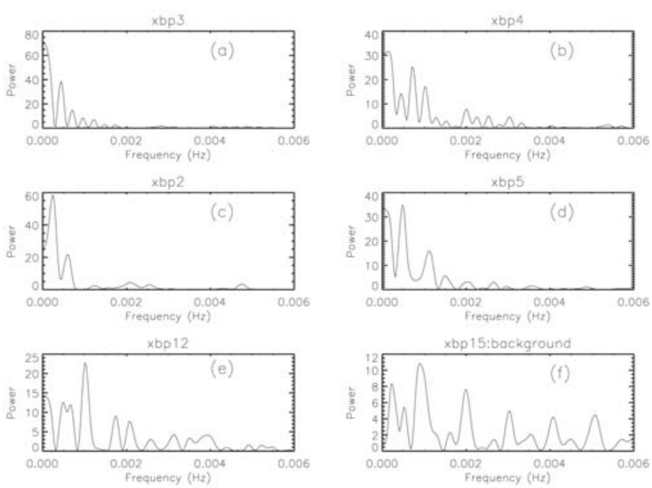

Figure 3. Power spectra derived for the time series of XBPs and a background coronal region (xbp2, xbp3, xbp4, xbp5, xbp12 & xbp15:background as shown in Fig.2).

in their pattern during evolution, the XBPs can broadly be grouped into three classes depending on their emission level. The class I XBPs show a very large intensity enhancement, whereas the class II XBPs show moderate brightness enhancement and the class III XBPs show only a marginal intensity enhancement during their dynamical evolution. Since the periods of intensity oscillation in all the three cases of XBPs seem to be similar, this can be taken as an evidence that heating mechanisms in the three cases of XBPs are similar. XBPs exhibit a wide variety of time-scales ranging from a few minutes to hours in their intensity variations and the periods are almost similar in all the cases of XBPs and thus seem to be independent of the differences in the brightness enhancement. The XBPs are the sites where intense brightness enhancement is seen, and the brightness oscillates with different periods. It suggests that the regions of intense vertical magnetic field strength coincide with regions that are bright, indicating non-radiative heating, irrespective of the sizes of these structures. A comparison between the XBPs and underlying photospheric magnetic features has suggested that the horizontal component of the magnetic field may be playing an important role in driving the brightening of an XBP. Therefore the explanation of the existence of different classes of XBPs with similar periods among all the XBPs may be related to the different strengths of the magnetic field with which they have been associated. A full description of the work may be found in Kariyappa and Varghese 2008, A&A, **485**, 289.

- R. Kariyappa

Be Phenomenon in Open Clusters: Results from a Survey of Emission-line Stars in Young Open Clusters

Introduction :

Open clusters are dynamically associated systems of stars which are found to be formed from giant molecular clouds through bursts of star formation. Apart from the coeval nature of the stars, they are assumed to be at the same distance and to have the same chemical composition. Hence an open cluster is a perfect place to study emission-line stars, since we do not have a hold on the ages and distances of emission-line stars from studies of such stars in the field. Since the emission-line stars are found to undergo evolution over a timescale of less than 100 Myr, young open clusters are the ones found to contain them. In this work, emission-line stars in young open clusters are identified to study their properties, as a function of age, spectral type and evolutionary state.

Early type emission-line stars are broadly classified as Classical Be (CBe) stars and Herbig Be (HBe) stars. Herbig Ae/Be (HAeBe) stars are intermediate mass pre-main sequence (PMS) stars, found to possess a natal accretion disk which is a remnant of star formation (Hillenbrand et.al 1992). CBe stars are fast rotators whose circumstellar disk is formed through decretion mechanism (wind/outflow) (Porter & Rivinius 2003). The formation of disk in CBe stars, i.e., the Be phenomenon, is still a puzzle. Certain studies indicate the possibility of disk formation during the core contraction phase (Fabregat & Torrejon 2000). We have performed a systematic survey of young open clusters in the northern sky, in order to study the properties of emission-line stars in clusters and to understand the Be phenomenon in CBe stars. We carried out this survey during the period 2003 - 2007 with the Himalayan Chandra Telescope, using the method of slitless spectroscopy. The cluster region was observed in the slitless spectral mode with a grism as the dispersing element using the HFOSC instrument in order to identify stars which show H_α in emission. The broad band R filter (7100Å, BW=2200Å) and Grism 5 (5200-10300Å, low resolution) of the HFOSC CCD system were used in combination without any slit. This mode of observation using the HFOSC yields an image where the stars are replaced by their spectra. A sample spectral image of the cluster NGC 7419 is shown in Figure 1.

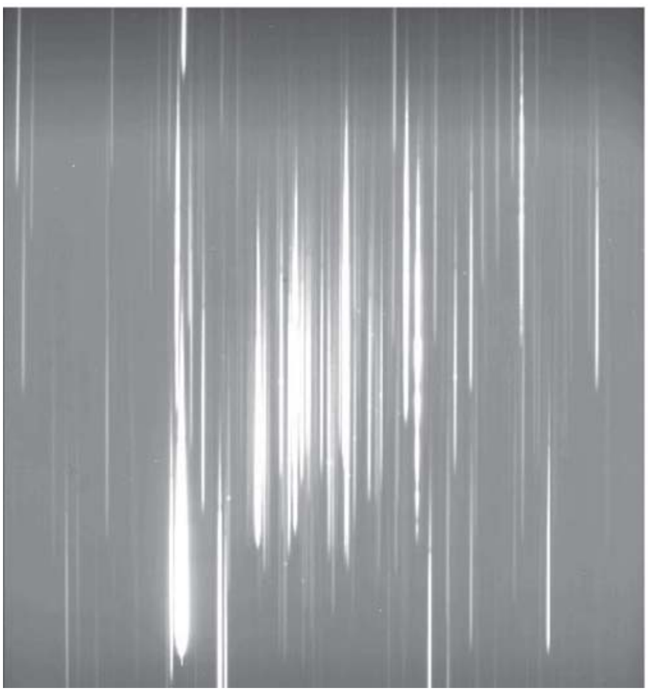

Figure 1. The slitless spectral image of NGC 7419.

In order to study the identified emission-line stars as well as the hosting cluster in detail, we have taken the photometric data from the references listed in WEBDA, a website devoted to the study of open clusters. We have constructed the M_v versus $(B - V)_0$ Colour Magnitude Diagrams (CMD) for them. A representative CMD for the cluster IC 1590 is shown in Figure 2.

The optical data was combined with Near-Infrared (NIR) photometry to look for NIR excess in emission-line stars. The NIR photometric magnitudes in J, H, K_s bands for all the candidate stars were taken from the 2MASS database. The NIR $(J - H)_0$ versus $(H - K)_0$ colour-colour diagrams (NIR CCDm) were plotted for the clusters to classify the emission-line stars based on their infrared excess. The NIR CCDm of

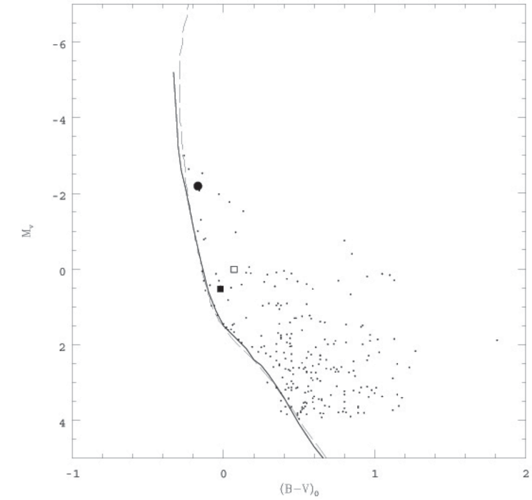

Figure 2. The M_v versus $(B-V)_0$ plot of the cluster IC 1590 is shown with an HBe star as an open square, an HAe star as a filled square and a CBe star as a filled circle. The data points are fitted with ZAMS which is shown as a solid line while the post-MS isochrone of 4 Myr is shown as a dashed line.

the cluster IC 1590 is displayed in Figure 3 as a representative of the surveyed clusters.

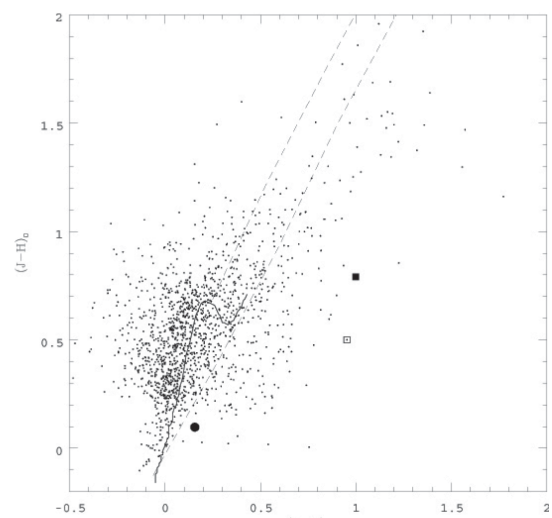

Figure 3. The NIR CCDm of the cluster IC 1590. Symbols have the same meaning as in Figure 2. The main sequence is shown in bold while the reddening vectors are shown as dashed lines.

Among the surveyed clusters which contain emission-line stars, we have studied in detail NGC 7419 (Subramaniam et al, 2006), NGC 146 (Subramaniam et al, 2005) and 4 clusters (Berkeley 86, Berkeley 87, IC 4996, NGC 6910) in the Cygnus region (Bhavya et al, 2007).

Results and Discussion :

1. We searched for emission-line stars in 207 clusters out of which 42 have been found to have at least one. This can be a lower limit, considering the variability of emission-line stars and the detection limit of the instrument.

2. A total of 157 emission-line stars have been identified. We have found 54 new emission-line stars in 24 open clusters, out of which 19 clusters are found to house emission-line stars for the first time.

3. The fraction of clusters housing emission-line stars is maximum in both the 0-10 and 20-30 Myr age bins (~ 40% each) while in the other age bins up to 80 Myr, this fraction ranges between 10% - 25% (Figure 4).

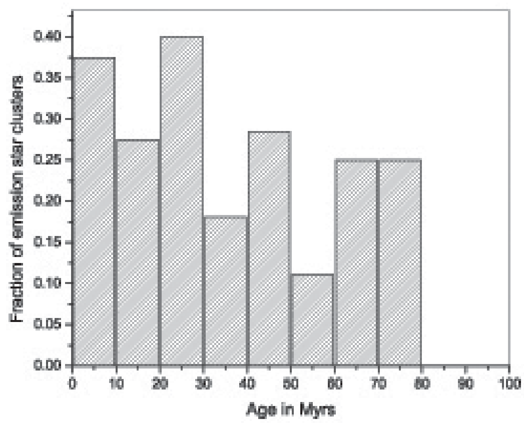

Figure 4. Fraction of clusters with emission-line stars with respect to the total number of clusters surveyed as a function of the cluster age.

4. Most of the emission-line stars in our survey belong to the CBe class (~ 92%) while a few are HBe stars (~ 6%) and HAe stars (~ 2%).

5. The youngest clusters that have CBe stars are IC 1590, NGC 637 and NGC 1624 (all 4 Myr old) while NGC 6756 (125 - 150 Myr) is the oldest cluster to have CBe stars.

6. The CBe stars are located all along the main sequence (MS) in the optical CMDs of clusters of all ages, which indicates that the Be phenomenon is unlikely due to core contraction near the turn-off.

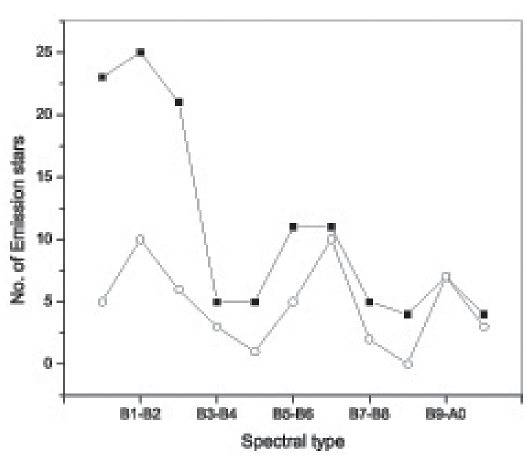

Figure 5. Distribution of the emission-line stars with respect to the spectral type. Solid squares display the total number of candidates while the open circles show the number of candidates after removing the contribution from 5 rich clusters.

7. The distribution of CBe stars as a function of spectral type shows peaks at B1-B2 and B6-B7. Rich clusters like NGC 7419 (25 e-stars), NGC 2345 (12), NGC 663 (22) and h+χ Persei (12) are found to favour the formation of early-type Be stars (Figure 5).

8. Among the 37 surveyed clusters, 29 are found to have Be star fraction, N(Be)/N(B+Be), less than 10%, while rich clusters like NGC 2345 with 26% and NGC 6649 with 17.9% have a Be star fraction more than 15%.

9. The CBe phenomenon is very common in clusters younger than 10 Myr, but there is an indication that these clusters lack CBe stars of spectral types earlier than B1. The fraction of clusters with CBe stars shows an enhancement in the 20-30 Myr age bin, which indicates that this could be due to evolution of some B stars to CBe stars, while they are on the MS. The above two findings suggest that there could be two mechanisms responsible for the CBe phenomenon. The first mechanism is one where some stars are born CBe stars. Our results mildly suggest that this happens mainly for spectral types later than B1. The second mechanism is one where the B stars turn into CBe stars, perhaps due to evolution within the MS, enhancement of rotation or structural changes. This is likely to happen in early B spectral types.

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– Blesson Mathew, Annapurni Subramaniam, Bhuwan Chandra Bhatt

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H I 21-cm Line Emission from Evolved Stars: GMRT Observations of Variable Carbon Star Y CVn

Evolution in the asymptotic giant branch (AGB) phase of low- and intermediate-mass stars (1 - 6 $M_{\odot}$) is dictated mainly by two processes – intense massloss by cool stellar winds and the advancement of the nuclear burning shells of hydrogen and helium. Thus the estimation of the rate of massloss and its variation with time during the AGB phase (steady winds or sporadic ejections) are of critical importance. Whether massloss also depends on the surface chemical composition, i.e., an oxygen-rich or a carbon-rich environment, is not quite clear. AGB stars are also sites for nucleosynthetic production of some heavy elements (e.g., s-process, fluorine etc). The atmosphere of these stars is enriched by these heavy elements because of mixing of the processed nuclear material from the interior. Estimation of massloss is also important for studying the chemical enrichment of the interstellar medium (ISM).

The spectroscopic features that have often been used for estimating the massloss in these cool high-luminosity stars are the resonance lines of neutral metals (e.g. Na I, K I), rotational lines of molecules like CO, and the infrared continum due to dust – features that arise mostly from trace elements (minor constitutents of the wind) whereas the bulk of the wind consists of neutral and molecular hydrogen gas. It has been suggested from the modeling of the atmospheric structure of these cool giants that for objects with T_{eff} > 2500 K the main constituent of the atmosphere is neutral hydrogen (Glassgold & Huggins 1983). Although the physical conditions in the wind could alter the amount of H I by molecule formation (and dissociation as well in chromospheric regions or shocks), the bulk of the gas is still expected to be in the atomic form. Obviously better estimates of massloss would result if the amount of the H I gas and its kinematics in the circumstellar regions of the evolved stars could be studied. The only line of H I that would be useful for such studies in these cool giants is the 21-cm line. The complications that arise in observing this line are the following: generally the line is weak and also can get contaminated by the Galactic H I emission in the lines-of-sight to the stars. However, the radial velocity differences between the stars and the ISM would help in isolating the circumstellar H I emission.

We have plans to systematically study the massloss phenomenon around carbon AGB stars from the observations of 21-cm emission using GMRT (the Giant Metre-wave Radio Telescope). GMRT provides not only the capability of large flux collection but also of sufficient angular and velocity resolution to map the circumstellar emission from the ejecta. Y Canum Venaticorum (Y CVn), a carbon SRb variable is one of the first objects we have observed with GMRT in this programme. The 21-cm emission around Y CVn was earlier detected with the Nancay telescope (Le Bertre & Gérard 2004; Libert et al 2007). However, the angular resolution of this single-dish telescope was 4'(RA) x 22'(DEC) which is too large a beamsize as the CO (1-0) line maps show extensions of only 13" in diameter.

Y CVn is a J type carbon star with $^{12}C/^{13}C$ of 3.5 (Lambert et al 1986). The distance derived from the recent Hipparcos parallax (3.12 ± 0.34 mas) is 321 pc which leads to a luminosity estimate of 1.34 X 10^4 $L_{\odot}$ thus placing the star on the thermally pulsing AGB track. The effective temperature is estimated as 2760 K (Bergeat et al 2001) suggesting atomic hydrogen dominates the atmosphere of the star. Several radio molecular line emissions due to CO, HCN, CN have been detected in the circumstellar envelope within a diameter of 13" as seen in the CO (1-0) line. However, the far infrared continuum emission (due to circumstellar dust) in 60, 90 and 100 μm show quasi-circular detached shells extending between 2.8' and 5.5' (Young et al 1993 and Izumiura et al 1996). The detached IR emission suggests either interaction of the ejected material from the star with ISM or an intense massloss episode in the past. Izumiura et al estimate that this episode lasted for 2 x 10^4 years and stopped about 10^4 years ago. Close to the star there seems to be asymmetric distribution of gas as suggested by molecular line emission. Particularly the CN lines show double peaked velocity profiles with a separation of 10 km/s centred on the stellar velocity (Lindquist et al 2000) suggesting a resolved shell with a diameter of 5.9", whereas the ^{12}CO (2-1) emission is extended with a diameter of 9" with some asymmetry, and the ^{12}CO (1-0) has a diameter of 13" with an expansion velocity of 7.8 km/s. The Nancay observations of H I 21-cm show a two-component profile – the main one with a full width at half maximum of 3 km/s and a weak broad one with a width of 15.6 km/s, both centred on the star of V_{lsr} = 21.1 km/s. The main component is claimed to be associated with the detached dust shell. Although the Nancay observations claim that the H I shell extends to 8' in east-west and may be 11' in north-south, a map of the spatial distribution of H I is lacking.The resolution was not adequate to really show the shape and distribution of H I gas. Thus GMRT observations become crucial.

Y CVn was observed by us with GMRT for 8 hours continuously on August 7, 2007 with a velocity resolution of 0.8 km/s. Observations were carried out in the experimental high-resolution mode with 256 channels over a 1.0 MHz band centred at the stellar velocity (V_{lsr}) of 20 km/s. 3C 286 was observed to set the flux density scale and a nearby VLA calibrator

J1227+365 was used for phase calibration. We used another experimental feature of the GMRT to switch the RF by 5 MHz below and above the observing band for bandpass calibration scans on 3C 286. We also used data from both the polarization states. Analysis of the data was carried out using AIPS.

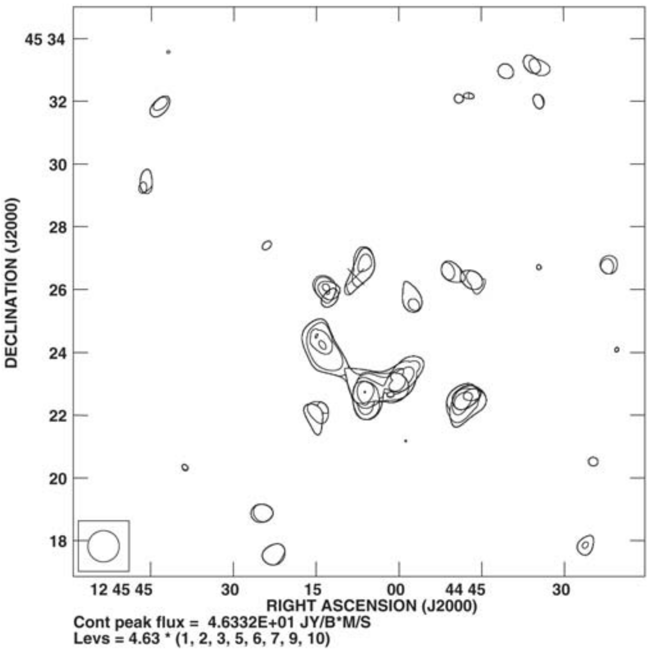

Figure 1. H I total intensity maps of the region around Y CVn derived from the data over the velocity 15 km/s < V(lsr) < 25 km/s. Spatial resolution of the map is 60"(dia) and contour levels are (1,2,4,6,8,9,10) x 4.63 jy/ beam m/s.

Figure 1 illustrates the distribution of H I 21 cm emission around Y CVn (marked by a cross) which appears to be in the form of discrete clouds distributed around the star, very much unlike the 90 μm infrared emission (the figure is smoothed to a synthesised beam of 1' diameter). The clouds occur predominantly on the southern side of the star within the infrared dust shell. A couple of fainter clouds do exist close to the star. The most intense emission comes from clouds (located about 4' to the south of the star) - which looks like an arc. Not surprisingly it occurs on the edge of the 90 μm infrared shell (See Figure 2).

The radial velocity maps (channel maps - Figure 3) show that most of the emission occurs between V_{lsr} = 18.4 and 20.0 km/s, at or slightly blueward of the stellar V_{lsr}. Most of the clouds are seen at V_{lsr}=19.2 km/s. A fainter cloud close to the star is seen even at 17.5 km/s. The predominant occurrence of the clouds to one side of the star and their slightly blueshifted radial velocity (by -1.8 km/s) suggest a very asymmetrical ejection from the star. The background H I emission from ISM in this velocity range of ± 5 km/s centred on the star is low and has been discussed by Le Bertre and Gérard (2004).

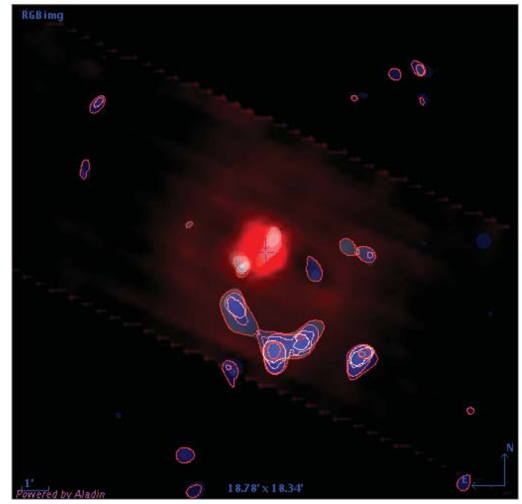

Figure 2. Same as figure 1 but in colour coded. The 90 micron infrared detached shell is shown in red. Note most of the clouds occur at the outer edge of the IR shell and to one side only.

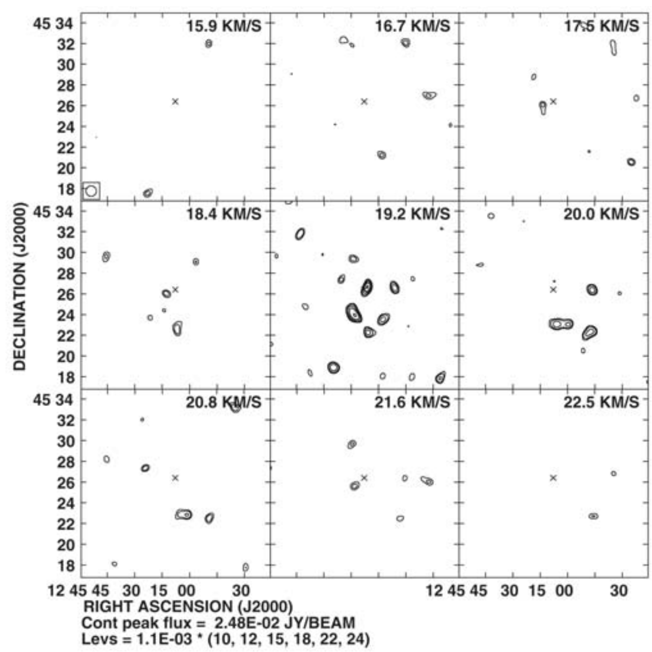

Figure 3. H I channel maps (radial velocity) of the region around Y CVn (shown as cross). The systemic velocity of the star derived from CO is 21.1 km/s.The velocity range 22.5 km/s to 15.9 km/s is shown. Countour levels are (10, 12, 15, 18, 22, 24) x 1.1 mJy/beam.

All the H I emission seen by GMRT corresponds to the component 1 of Nancay observations. Obviously the H I emission around Y CVn is asymmetric and occurs in clumps. Most interesting is the arc-like structure of the clouds. The gas might be moving at 2 km/s away from the star (towards us). The model favoured by Young et al (1993) in interpreting the infrared emission and Libert et al (2007) in interpreting the H I emission is that the circumstellar matter is moving away from the star and gets slowed down by the sweeping of the interstellar matter in front and the outer boundary of the infrared shell (an H I shell is also suggested to be associated with it) is the interaction zone between the circumstellar matter and ISM. The head-tail structure of the cloud and its occurrence at the outer edge of the infrared shell seem to support such a model although spherical symmetry around the star is not maintained. Similar clouds have been shown to be present around EP Aqr from 21-cm emission observed with VLA by Matthews and Reid (2007), although the earlier Nancay observations suggested it to be an extended detached shell (Le Bertre and Gérard 2004).

Detailed analysis is in progress. The first detection with GMRT of the circumstellar ejecta from Y CVn in the H I 21-cm emission does open up the possibility of studying stellar massloss in AGB stars from the most dominant component of the gas. Observations of other AGB stars with GMRT are being continued.

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- N. Kameswara Rao, Rekesh Mohan and David Lambert (McDonald Observatory)

Black Hole Mass: Key to the Quasar Radio Loudness Dichotomy

The discovery of quasars ("Quasi-Stellar Radio Sources") in 1962 was an early stunning outcome of the collaboration between radio and optical astronomers. Identification of the bright radio source 3C 273 with a star-like optical object and its subsequent optical spectroscopy, which placed it at a distance of about a billion light years, implied that the radiative output of an entire massive galaxy comprising a hundred billion stars is produced within this single star-like object, 3C 273. This immediately called for a far more efficient energy source, such as a supermassive black hole (SMBH) with 1-1000 million solar masses, which provides almost 50 times greater efficiency of the conversion of rest mass to energy than nuclear fusion, which sustains stars like our sun or operates in the hydrogen bomb. Hence the discovery of quasars gave birth to the subject of "relativistic astrophysics", unraveling a new facet of our Universe.

One already known intriguing aspect of the first quasar was the jet-like feature emitting both optical light and radio waves, which was seen to emerge from the star-like object. Such radiating jets are now known to be a fairly common attribute of quasars; they are believed to be collimated streams of magnetized relativistic plasma emanating from the vicinity of a supermassive black-hole and flowing outward at nearly the speed of light, eventually forming radio *lobes* that can extend up to millions of light years. One astonishing revelation, which came just within a year of the discovery of the first quasar, was that such jets of radio emission are only ejected by a small minority of quasars (about 1/6). Thus, whereas some quasars are *radio-loud*, the majority of them are in fact extremely weak radio emitters i.e., *radio-quiet*.

The origin of this *radio dichotomy* of quasars has remained an unresolved puzzle for the past four decades. According to one popular explanation, the jets are powered by spinning supermassive black holes

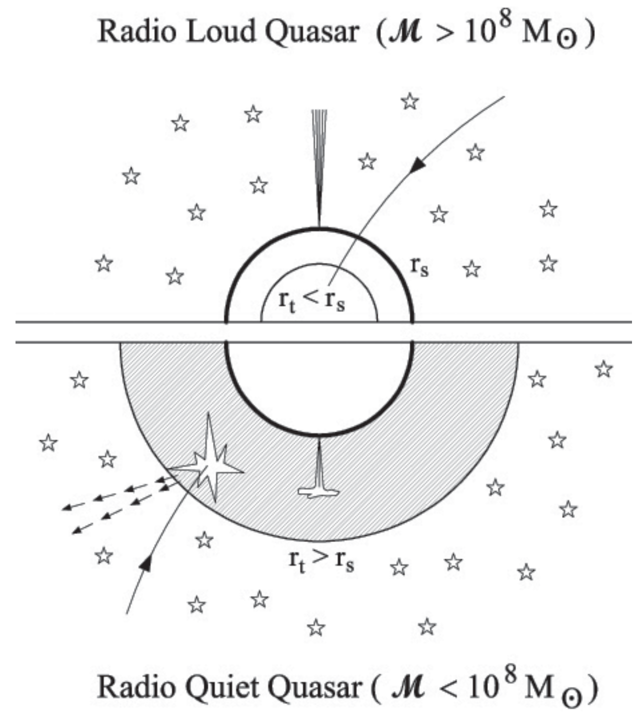

Figure 1. Schematic of tidal disruption of the incoming stars by the SMBH of mass ($\mathcal{M}$). The tidal sphere is depicted for the two cases, at the top for $\mathcal{M} > \mathcal{M}_c$, the critical mass (~ 10^8 solar masses), where the tidal sphere ($r=r_t$) lies inside the black hole's event horizon (thick line, $r=r_s$), and the bottom for $\mathcal{M} < \mathcal{M}_c$, hence $r_t>r_s$. In the former case, the stars are swallowed whole, producing no debris and hence the relativistic jet emerges from the ergosphere without resistance, i.e., as a radio-loud quasar. In the latter case, star disruption at the tidal radius occurs outside the event horizon, filling the region with stellar debris (shaded), which quenches the nascent jet, yielding a radio-quiet quasar. Roughly half the debris is ejected at speeds of ~ 10^4 km/s, which probably manifests itself as broad absorption lines in the quasar's ultra-violet/optical spectrum.

(Kerr SMBH), whereas in most quasars the SMBH are not spinning and hence they are radio-quiet[1]. In yet another scenario, radio-loudness is attained intermittently whenever a strong collimation is externally imposed on the jet by the outflowing hydromagnetic wind from the accretion disk of the SMBH[2,3]. A potential challenge to this proposal comes from the non-detection of long lasting radio lobes (produced by the erstwhile jet) in radio-quiet quasars.

During recent years, an interesting observational handle has emerged as a byproduct of the development of efficient and fairly reliable methods of estimating the masses of SMBH in galactic nuclei. These methods employ imaging photometry and high-resolution spectroscopy of the central stellar bulge of galaxies, done, for example, with the Hubble Space Telescope. A remarkable fact emerging from these data is that the SMBH in radio-loud quasars are always more massive than ~ $10^8\ M_\odot$ whereas the SMBH in radio-quiet quasars are *systematically* about 2 times less massive[4,5,6]. This systematic difference is indeed puzzling as it cannot be explained within the framework of any of the schemes proposed hitherto. At the same time, if the quasar dichotomy did hinge on this mass difference, it would require the existence of jets to be very sensitively dependent on the mass of SMBH.

One conspicuous effect of an SMBH (of mass $\mathcal{M}$) on the surrounding stars is the disruption of those stars that happen to approach within a certain radius (called the tidal radius, r_t) at which the tidal force (~ $G\ \mathcal{M}\ r_* /\ r_t^3$) exerted by the SMBH on the star (of mass m_* and radius r_*) becomes comparable to the self-gravity of the star (Gm_*/r_*^2). This sets the tidal radius to scale with the black hole mass as proportional to $\mathcal{M}^{1/3}$. On the other hand, the black hole event horizon, or the deepest surface from which distant observer can receive a signal, occurs at a radius known as the Schwarzschild radius($r_s \sim 2G\mathcal{M}/c^2$), which a scales linearly with the black hole mass. The two radii coincide for a critical SMBH mass of about $\mathcal{M}_c = 2 \times 10^8\ M_\odot$ for typical stars. Interestingly, this critical mass is tantalizingly close to the lower limit of the black hole's mass found in radio-loud quasars[7].

This naturally leads to two possibilities: (i) the star is swallowed whole by the black hole (for $r_t < r_s$), or (ii) the star is shredded outside the event horizon, as it approaches the tidal radius (for $r_t > r_s$). We have recently argued that the second case can have drastic observational implications, particularly for the issue of the radio dichotomy of quasars[8].

Guided by prior numerical hydrodynamic simulations[9], roughly half of the resulting tidal debris is expected to be expelled from the core region at speeds of ~10^4 km/s which, interestingly, is of the same order as the speeds of the so called broad-absorption-line (BAL) clouds detected in a subset of quasars. Also, the remaining stellar debris configured by the initial orbital angular momentum of the stars, forms a disk that would accrete on the SMBH on viscous time scales ($t_v = 10^3$ yrs) which is much longer than the typical expected time intervals (t_i=100 yrs) between arrivals of stars into the tidal sphere. Since the planes of stellar orbits are isotropic we expect a quasi-spherical cloud of the tidal debris to envelope the ergosphere of the black hole, from where jets of relativistic plasma emanate. A natural consequence of the interaction of this relativistic plasma of very low mass density with the surrounding, much denser, tidally stripped gas can result in a rapid jet deceleration and disruption through severe mass loading. For fiducial values of parameters like the number density of stars, their velocity dispersion, the black hole mass, the opening angle, the bulk velocity and the kinetic power of the jets, we estimate that the mass loading would disrupt the nascent jet within the inner light year scale. This situation characterizes a radio-quiet quasar. In contrast, for the rarer black hole with masses exceeding the critical mass ($\mathcal{M} > \mathcal{M}_c = 10^8\ M_\odot$), the stars are swallowed whole by the SMBH leaving no tidal debris to impede the jets which can thus successfully emerge to form a radio-loud quasar. Furthermore, few BAL signatures are expected in this situation, again consistent with the observations[10].

The tidal disruptions of stars have earlier been invoked to explain the flashes of ultra-violet and X-ray emission[11,12] from the cores of several quiescent elliptical galaxies and this has been suggested as evidence for supermassive black holes even in inactive nuclei. We argue that the tidal disruption rate is in fact sufficient to quench typical quasar jets. Also, in the context of our picture, the radio-loudness of certain ellipticals thought to be formed by mergers, can be explained by the enhancement of the black hole mass to above the critical value through the merger. The earlier explanation invoking an enhanced SMBH spin is inconsistent both with theoretical expectations[13] and with the systematic excess of black hole mass found in radio-loud quasars.

We are grateful to V. K. Subramanian for drawing the cartoon.

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– Arun Mangalam

A Non Accelerator Probe of New Physics

Motion reversal is known in physics parlance as time-reversal, as it can be realised mathematically by changing time, t to – t. The origin of time-reversal violation is one of the least understood of all the profound issues in physics. The observation of an electric dipole moment (EDM) of any fundamental particle or of a composite system like an atom or a molecule is a direct signature of the violation of time-reversal symmetry in Nature.

Open-shell atoms will have two dominant sources of intrinsic electric dipole moments; one due to the intrinsic EDM of its constituent electrons and the other due to a time-reversal violating interaction between the electrons and the nucleus mediated by spin zero particles. Despite the relentless experimental search for EDMs in elementary particles as well as in composite systems for more than five decades no conclusive result has been obtained. However, many on-going high precision atomic EDM experiments are aiming to achieve better detection limits, a few orders of magnitude lower than the current experimental limits.

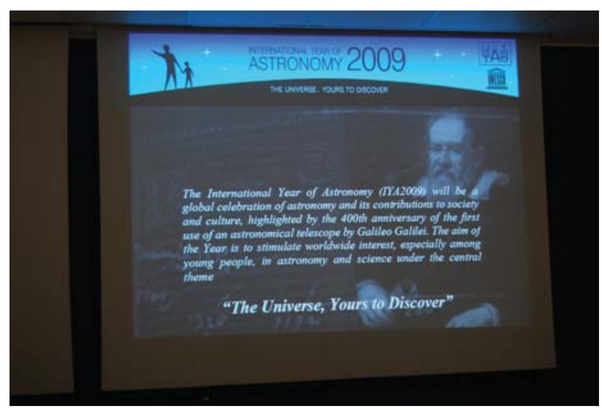
In order to obtain a limit for the electron EDM, one needs both the enhancement factors (ratios of the atomic to the electron EDMs) and the experimental atomic EDMs to a high precision. A rigorous relativistic quantum mechanical calculation has been carried out to predict the EDM enhancement factors for Rubidium (Rb) and Cesium (Cs) with a sub 1% accuracy for the first time. One of the unique features of this work is that it deals with the interplay of two very different interactions — the long-range Coulomb interaction and the short-range time-reversal violating interaction. The new results for the enhancement factors combined with those of the proposed non-accelerator EDM experiments on Rb and Cs, when they achieve their desired sensitivities, could open up a novel direction for finding new physics beyond the much celebrated model of particle physics, the Standard Model, which is indeed quite significant in the era of the Large Hadron Collider. This could also serve as a stringent test of many unification models, including Super-symmetry, and provide insights into one of the most important but unresolved questions in cosmology: the matter-antimatter asymmetry in the Universe to which we owe our existence today.

The full text of the paper authored by H. S. Nataraj, B. K. Sahoo, B. P. Das and D. Mukherjee has been accepted for publication in The Physical Review Letters (arXiv source: http://arxiv.org/abs/0804.0998) and will appear in print in July.

– H. S. Nataraj

Universalizing the Universe

As a preparation for the forthcoming International Year of Astronomy in 2009 (IYA), the Indian Institute of Astrophysics organised a one-day seminar on April 4, 2008, titled, "Universalizing the Universe". It brought together on a single platform, scientists, teachers, students, social scientists, science popularisers and cultural activists to deliberate on IYA's central theme, that the 400th anniversary of Galileo's epoch-making adventure to look into the sky with a telescope, gives an important opportunity to present science as a medium of international cooperation for peace, progress and global understanding.



Emphasising the above aim, first announced by the IAU and then endorsed by the UN General Assembly, Professor V. K. Gaur (IIA) in his inaugural address said, " the sky is a universal laboratory, from where one can learn mechanics, electromagnetism, relativity that makes one progress from the realm of wonder to that of knowledge." Concerning the democratic nature of this experience, Professor S. S. Hasan, Director, IIA, said that in the spirit of IYA's objectives, large mass of people must be drawn into the process and "larger the mobilisation, larger is the impact". He observed that as Galileo's life exemplifies, this event could be considered as a step to challenge obscurantism by scientific rationality.

A series of talks on the theme 'The sky as the universal laboratory' was presented with practical examples from naked eye astronomy (H.D. Ramachandra Rao, formerly, Christ College), astronomy with the sun (Jagdev Singh, IIA), night-sky observations with inexpensive 2"-12" telescopes (T. P. Prabhu, IIA), and pictures obtained from space (Jayant Murthy, IIA). It was noted that while a small 2" telescope (to be called Galileoscope, as suggested by the IAU) could act as the first instrument to initiate the uninitiated, larger telescopes in the country should be made accessible to the experienced amateur and the data from space can act as a resource that students and amateurs can exploit.

Science writing forms an important part of science popularisation. P. R. Vishwanath (IIA) and Biman Nath (RRI) noted that a scientist is placed with a great social responsibility and science writing gives the scientist a method to discharge this commitment. Vijay Padaki, of the Bangalore Little Theatre recorded that science can form an important theme for drama as science gives a new window to understand the history of ideas.

B. S. Shylaja (Nehru Planetarium, Bangalore) noted that though astronomy is included in the school and college syllabus, there is no introduction to practical observations. She narrated her experiences in introducing observational astronomy to several groups of students, using inexpensive equipment and simple mathematical analyses. A. Hemvathi (Pondicherry Science Forum) recalled that many a popular science organisation had emerged in response to the popular demand for mass viewing of the Halley's comet. He recalled that large numbers do come out, surmounting social obscurantism for viewing solar eclipses, transit of Venus. K.Pappootty, of the Kerala Shastra Sahithya Parishat, observed that the question of astrology crops up in many a popular talk on astronomy. He noted that history of astronomy and astrology forms an important starting point in any dialogue on scientific temper. M. Blesson, a Ph.D. student from IIA, showed how modern audiovisual techniques can help popularise astronomy, and related the efforts in making a short film on the occasion of the International Year of Physics. Ajith Padmanabhan, an M.Sc. student form the Loyola College, Chennai shared the experiences of a group of students in popularising astronomy to slum children and said that an inexpensive "Galileoscope" would be of great benefit towards this effort.

Democracy and equality being inseparable from scientific rationality, the IAU has declared "She is an astronomer" as a cornerstone activity for the IYA 2009. In a panel discussion with the same title, speakers (Prajval Shastri, Vasundhara Raju, Neeharika Verma, Ramya S., B.R.Prasad, Prasad Subramanian, Firoza K Sutaria) observed that gender inequity does continue in scientific institutions since natural scientists refuse to look at the society and are resistant to change. They

noted that this operates with subtlety which makes the phenomenon often inconspicuous. In their childhood, girls are not encouraged to take up science and "low expectations lead to low results." Even in academia, they agreed, it is not often recognised that women take science for their passion for it and it is the woman who moves out of science to keep the family intact. While this phenomenon operates at all levels, the panelists felt, science popularisation can help to change the social mindset, and structural changes like removal of the age restriction at recruitment and filling up vacancies at all levels are urgently needed.

The meet discussed in its last session, the steps to "link the unlinked" (Vivek Monteiro, Nav Nirmiti and T. V. Venkateswaran, Vigyan Prasar) by which scientific institutions and popular science organisations can work together for IYA. They felt that with a viable programme it would be possible to reach a million people. It was suggested that a long-term project like "a terra lab on every terrace" can be a proposal that can begin as a part of IYA 2009 and continue even afterwards.

The sessions were chaired by B. V. Subbarayappa, H. C. Bhatt, Devaki Jain, K. Vasu and V. K. Gaur. Six posters from different groups were on display. S. Chatterjee welcomed the gathering and gave the final remarks, while C. Muthumariappan proposed the vote of thanks. The participants expressed the urge to work towards IYA's motto, "Astronomy for All" and it was decided that various groups would hold workshops throughout the year.

– S. Chatterjee

VBO Summer School in Astronomy & Astrophysics

A summer school in astronomy and astrophysics was organised at the Vainu Bappu Observatory in Kavalur betweeen May 15 and 22, 2008. There were twenty participants, all post-graduate students from the universities and IITs, selected on the basis of their applications. The school was inaugurated by Dr A K Saxena, Dean (E), on May 15, 2008 at the new lecture hall in Lab B on the Kavalur campus. Saxena spoke on the motivation to do astronomy and recalled his early years spent at the observatory with Dr Vainu Bappu, the founder-director of IIA. His talk was followed by Dr G C Anupama's on 'An overview of the observational facilities at IIA'.

The school covered a broad range of topics in observational and theoretical astronomy starting with the basics of co-ordinate systems, optical telescopes and their designs, elements of photometry and spectrosocopy with applications, to the structure and evolution of stars, the variable stars, structure of the Galaxy and the astrophysics of galaxies. There were two talks on Solar System Objects. In the evening of May 21 there was a special lecture by Arun Mangalam on Black Holes which was much appreciated.

There were nine speakers drawn from the IIA faculty in Bangalore. In addition, scientists in Kavalur and two senior graduate students from Bangalore, Bharat Kumar Yerra and S Ramya, spoke on observational aspects and organised sessions on observations at the two major telescopes at VBO - the VBT and the Zeiss Telescope. C Muthumariappan (Resident scientist, VBO) organised the practical work and he was ably assisted by K Jayakumar, K Kuppuswamy, and M J Rosario.

The students had an opportunity to take stellar as well as calibration spectra with the UAGS instrument at the Zeiss Telescope. They were given spectra obtained with the echelle spectrograph at VBT and were taught how to reduce and analyse echelle data using the IRAF software.

Bharat and Ramya explained the operations at the 2-m telescope in Hanle with the HFOSC instrument and displayed low-resolution spectra obtained with that instrument. The students were given lessons on the reduction and analysis of the data using IRAF. Some imaging data obtained at the prime focus of VBT were also used for lessons in hands-on experiments with such data. Some of the students are continuing with the summer projects in IIA, Bangalore. It is hoped that the school succeeds to the extent that a few of the students at least will consider seriously a professional career in astronomy.

\- D. C. V. Mallik

Public Outreach Activities

Dr. C. Sivaram visited BEL Udyogigala Vijnana Vedike in Jalahalli, Bangalore on March 7, 2008 and spoke to school children on *Sun, Stars and the Universe*. The lecture generated a great deal of interest among the young audience and was followed by an interaction session in which the children participated with great fervor. Dr. Sivaram's visit and the talk were much appreciated by the organisers.

A group of twelve amateur astronomers from the Association of Friends of Astronomy (Goa), Margao Chapter, visited IIA on May 19 & 20, 2008. A two-day programme was organised for them. On the 19th, Dr R Ramesh spoke to the group on Radioastronomy and its application to the study of the Sun and Space Weather using the Gauribidanur Radioheliograph. This was followed by a talk by Dr Ashok Pati on Optical Telescopes and Imaging with CCDs. The group visited the Photonics Laboratory. On the 20th, the group was taken to CREST where Dr B C Bhatt gave an overview of the Indian Astronomical Observatory in Hanle, its prime instrument the Himalayan Chandra Telescope and its future plans. The direct satellite link with Hanle was established and the group could see the telescope and the technicians at work inside the dome but the actual demonstration of the telescope operation was hampered due to bad weather as it was snowing in Hanle and the dome had to stay closed. The visitors were briefed about the kind of telescopes they should procure to pursue their serious interest in variable star photometry and other projects.

Vintage Maps in IIA Archives

The Indian Institute of Astrophysics has valuable antique maps in its archives. These original maps were published under the supervision of the Society for the Diffusion of Useful Knowledge (SDUK). SDUK was formed by a small group of energetic, able and dedicated men devoted to the cause of adult education and the utilitarian ideal of 'knowledge is power'. SDUK initiated an extensive non-profit publication programme with the aim of providing cheap but authoritative printed material to a mass readership (Cain, M. T. 1994). The result was the production of a highly valued set of maps at a very reasonable price.

SDUK published 209 maps of various cities, towns and countries and out of these 110 were published between 1829 – 1844. Among the 209 maps, 51 were maps of various cities in the world. Many of these are accompanied by panoramic views of the cities depicting the architecture of their famous buildings (See the map of Bordeaux). There are a total of 41 maps in the IIA Archives, of which 25 are of important cities in Europe, 8 of various regions in India, 4 of British territories, 2 maps of ancient Britain, and 2 maps from the Asian Region - a map of the Empire of Japan and one of the Eastern Islands of Malay archipelago. The size of each map is 12" x 16".

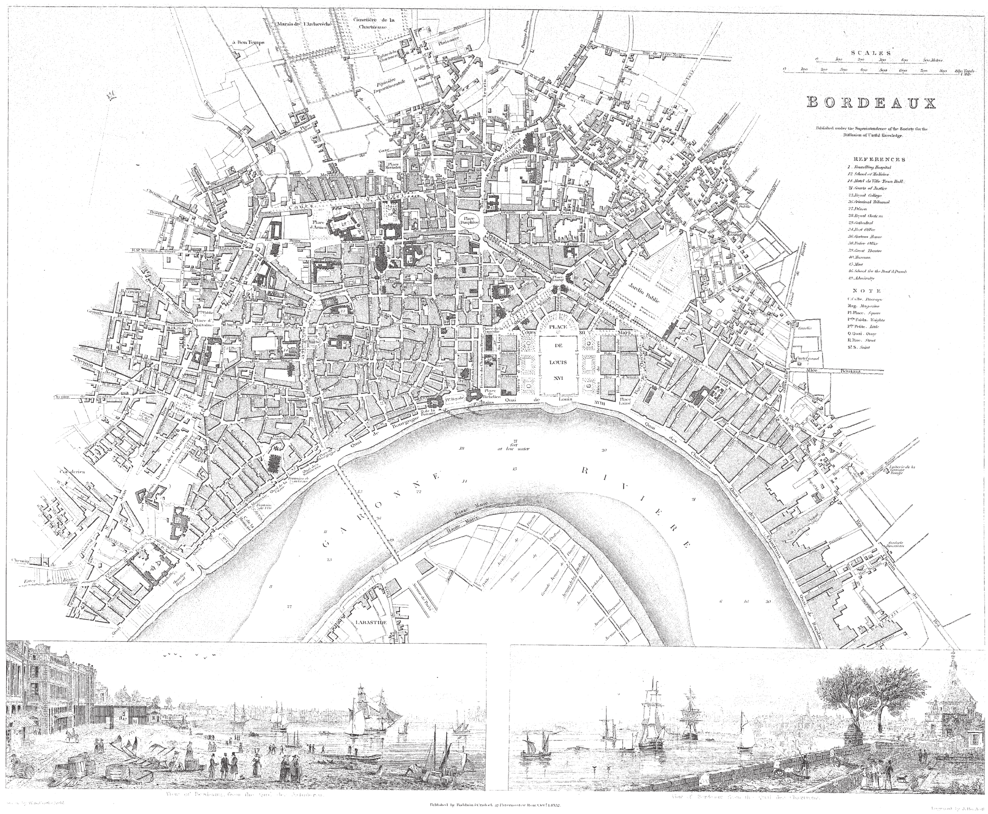
Out of 13 maps printed of various regions of India, IIA archives have 8 of them which are in very good condition. These maps have been preserved well due to the proper care taken. They are as follows:

1832	India III	Bombay, Presidency and Hyderabad
1832	India IV	Circars and Mouths of the Godavery
1833	India V	Sinde to Gujarat
1833	India VI	Bundelcand to Khandeish and Berar
1832	India VII	Allahabad to Bay of Bengal
1833	India IX	Delhi to Bundelcand
1834	India X	Oude to Allahabad
1834	India XI	The Panjab and Gurhwal

(Note: The original spelling are retained.)

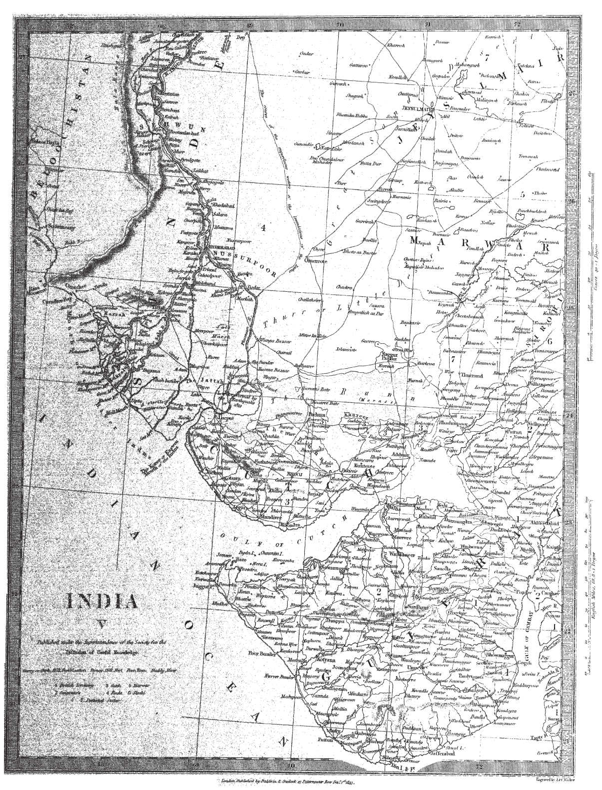
India featured prominently in the map project of SDUK. The maps were inexpensive and affordable to average Indians, in contrast to the maps produced by others, which were expensive.

The authenticity of the India maps relies on the fact that they were engraved by John Walker from the Survey of India. The India maps were modelled after the 'Atlas of India' produced by the East India Company. Also these maps of SDUK were arranged and numbered according to a grid established by lines of latitude and longitude as in the 'Atlas of India'. All the India maps were published between 1831 and 1835.



Bordeaux 1832

City map of Bordeaux, the wine city in France. At the bottom of the map, two scenic pictures are produced; the view of Bordeaux from the Quai des Salinieres and from the Quai des Chartrons.



Sinde to Gujarat 1833

A sample map of the region from Sind to Gujarat. The British occupied territories are designated '1', and '2' to 7' are local kingdoms and other European Colonies in the map.

India was one of the ten countries, which was fully covered by this map project. Hence the India sheets may be regarded as a crucial component of the Society's map publication project. (Barrow, I. J. 2004)

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- Christina Birdie, A Vagiswari

John Evershed
(1864 - 1956)

Magnetic Coupling between the Interior and the Atmosphere of the Sun

"Centenary Commemoration of the discovery of the Evershed Effect"

Venue & Date : Indian Institute of Astrophysics, Bangalore December 2 - 5, 2008

Magnetic fields of various scales in the Sun govern the dynamic phenomena that drive solar activity and variability. The Sun possesses a magnetic field of a complex geometry which extends far out into the interplanetary medium. The aim of the meeting is to focus on the critical issues pertaining to solar magnetism with particular emphasis on the various MHD processes that are at work in the solar atmosphere. The meeting will review the current status of magnetic field measurements and their implications in the light of the recent physical theories and numerical modeling that address the fundamental scales and processes in the highly magnetized turbulent plasma. The role of the magnetic fields as the agent, coupling the interior with the atmosphere and thereby provide the channels for the upward transport of energy and momentum from the interior and as progenitors of explosive events will be examined. Discussions on the new results that emerge from the space missions such as STEREO and Solar-B with special reference to the Hinode vector magnetic field measurements both from SOLAR-B and from ground-based telescopes will be one of the highlights of the meeting.

Another motivation for this meeting is the commemoration of the Centenary of the discovery of the Evershed effect at Kodaikanal, India in 1909.The Proceedings of the meeting will be published by Springer, and space will be allotted for review talks, oral and poster contributions.

Topics:

Magnetic field generation and transport mechanisms
Magnetic field measurements
Sunspot and active regions
Magnetic coupling through the atmosphere
Eruptive phenomena
Solar-stellar connections

Important Dates:

15^{th} Aug 2008: Abstract submission closes
15^{th} Aug 2008: Last date of application for financial support
1^{st} Sep 2008: Early Registration Closes
15^{th} Sep 2008: Acceptance of Abstract
1^{st} Oct 2008: Second Announcement with detailed Scientific Programme

Retirements and Appointments:

N Kameswara Rao, Senior Professor, retired from service on April 30, 2008 at the age of sixty two after a two-year extension. He is continuing as a Visiting Senior Professor in the institute.

S S Gupta, Professor, retired from service on May 31, 2008 at the age of sixty two after a two-year extension. He is continuing in IIA, Kodaikanal as a Visiting Professor.

Ravinder Kumar Banyal, an experimental physicist, and **S P Rajaguru**, a solar physicist, have recently been appointed Scientist C and Reader respectively. They are posted in IIA, Bangalore.

N D Hari Dass, Honorary Director, Poornaprajna Institute of Scientific Research and **Arnab Rai Choudhuri**, Professor, Department of Physics, Indian Institute of Science, have been offered Adjunct Professorships in IIA.

Prasad Subramanian, Scientist D, resigned from IIA in May, 2008 and joined IISER, Pune as a faculty member in the Department of Physics.

Honours and Awards:

Professor S S Hasan has been invited to serve on the prestigious International Committee of the Royal Astronomical Society.

Professor C Sivaram has received 'Honourable Mention' in the essay competition of Gravity Research Foundation (Massacusetts, USA) for the year 2008, for his essay titled 'OJ 287: New Testing Ground for General Relativity and Beyond.

Dr Savita Mathur (Ph.D., CEA Saclay, France) has been awarded the prestigious Chandrasekhar Post-Doctoral Fellowship of IIA. She is expected to join duty in September 2008.

Founder's Day Lecture

The Founder's Day Lecture for the year 2008 will be delivered by Professor C N R Rao, FRS, Linus Pauling Research Professor and Honorary President of the Jawaharlal Nehru Centre for Advanced Scientific Research, Bangalore on August 11.

Professor Rao will speak on
Doing Science in India: Personal Reflections
Time : 11.00 AM
Venue : IIA Auditorium

Editors: D. Banerjee, D.C.V. Mallik, B. A. Varghese
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