

NCRA • TIFR

**National Centre for Radio Astrophysics**

TATA INSTITUTE OF FUNDAMENTAL RESEARCH

**Annual Report  
2005–06**

*April 1, 2005 – March 31, 2006*



**A giant jet of synchrotron radio emission:**  
 GMRT radio photograph of a serendipitously found, giant radio jet emanating from a massive elliptical galaxy CGCG 049-033 situated 200 megaparsecs away. The jet of synchrotron radiation is shown in red colour, while the host elliptical galaxy made of old stars is in white colour. The enormous size of this 450 kiloparsec (~1.5 million light years) long jet makes it **the largest known radio jet** seen to extend all the way from the host galaxy to the terminal radio hotspot. The inset shows the details of the radio lobe. The jet bears a striking resemblance to the (7 times shorter) jet of the famous quasar 3C273, which is the first quasar discovered and still remains the most enigmatic one, due to its unique one-sided radio morphology. This radio image was made at 1.3 GHz using GMRT. [J. Bagchi (IUCAA), Gopal-Krishna, M. Krause (MPIfR, Germany) and S. Joshi (IUCAA)].

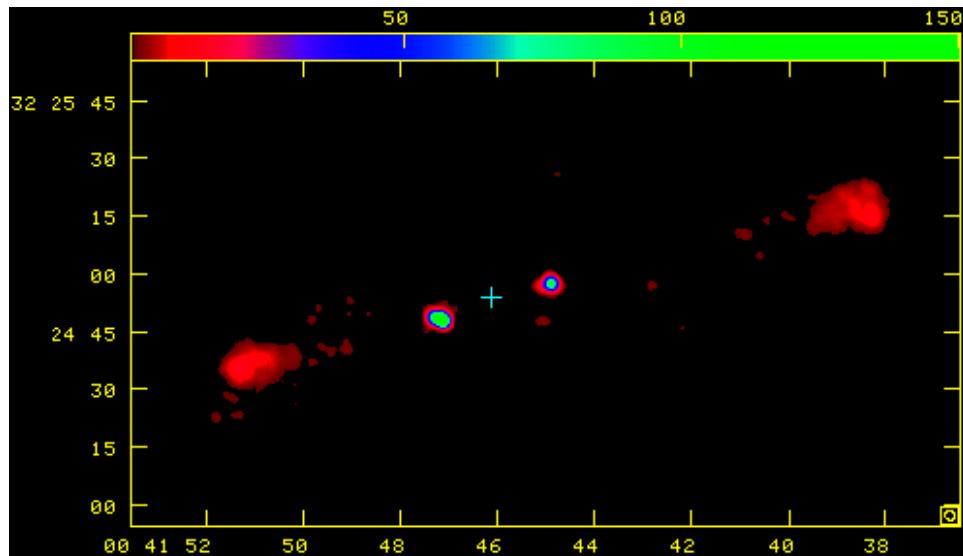


Image of the double-double radio galaxy J0041+3224 at 1280 MHz discovered with the GMRT. The cross marks the position of the optical object. [D.J. Saikia, C. Konar and V.K. Kulkarni]

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# Highlights

A new double-double radio galaxy which is a signature of episodic activity in galaxies was discovered using the GMRT. [*D.J. Saikia, et al.*]

HI absorption towards the core of a high-luminosity radio galaxy with features which show evidence of jet-cloud interaction was discovered using the GMRT. [*D.J. Saikia, et al.*]

A 61.86 millisecond pulsar was detected using GMRT in the supernova remnant G21.5-0.9. A characteristic age of  $\sim 4900$  years was inferred for this pulsar, which is not incompatible with the estimated age of the supernova remnant. It was found that this pulsar has a spin-down luminosity that is the second highest, after the Crab pulsar. [*Y. Gupta et al.*].

# Research Contributions

## Sun and Solar Wind

### **Evolution of Coronal Mass Ejections (CME) in the Inner Heliosphere:**

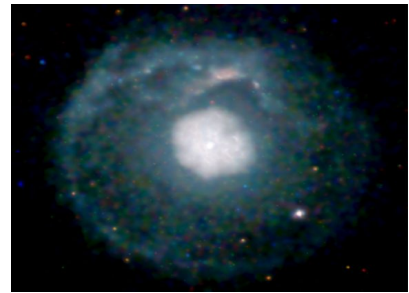
The radial evolution of 30 large CMEs between the Sun and the Earth was investigated using white-light images from LASCO coronagraphs and interplanetary scintillation (IPS) images obtained from the Ooty Radio Telescope. These CMEs covered an order of magnitude range of initial speeds of about 260–2600 km/s. It was found that: (1) the speed profile of the CME is dependent on its initial speed; (2) propagation of the CME undergoes continuous change, depending on its encounter with the solar wind; (3) the radial-speed profiles obtained by combining the LASCO and IPS images yield a factual view of the propagation of CMEs in the inner heliosphere. The transit times and speeds at 1 AU, computed from these profiles, are in good agreement with the actual measurements; (4) the mean travel time curve for different initial speeds and the shape of the radial speed profiles suggest that up to a distance of about  $80 R_{\odot}$ , the internal energy of the CME (or the expansion of the CME) dominates, however, at larger distances, the CME's interaction with the solar wind controls its propagation; (5) most of the CMEs tend to attain the speed of the ambient flow at 1 AU or beyond the Earth's orbit. [P.K. Manoharan].

**Long-lived Geomagnetic Storms:** Thirty seven long-lived geomagnetic storm (LLGMS) events with  $Dst < -100$  nT and the associated CMEs, which occurred during 1998–2002, were studied. It was found that LLGMS events were caused by (1) successive CMEs, accounting for ~65%; (2) single CMEs, accounting for ~22%; and (3) high-speed streams (HSS) in co-rotating interaction regions (CIRs) with no related CME, accounting for ~13%. The long duration of the LLGMS events was found to be due to successive CMEs and HSS events; the high intensity of the LLGMS events was related to the interaction of CMEs with other CMEs and HSS events. The duration of LLGMS was found to be well correlated with the number of participating

CMEs (correlation coefficient  $r = 0.78$ ). It was also inferred that the intensity of LLGMS has a good correlation ( $r=0.67$ ) with the degree of interaction (the number of CMEs interacting with a HSS event or with themselves). The role of preconditioning in LLGMS events, where the development occurred in multiple steps in the main and recovery phases, was investigated and it was found that the preconditioning does not affect the main phase of the LLGMS events, though it plays an important role during the recovery phase of the LLGMS events [P.K.Manoharan with H. Xie (*Ins. Theoretical Chemistry, Chongchun, China*), N. Gopalswamy (*Catholic Univ. USA*)].

**An X-class flare and its associated CME:** The multi-wavelength observations of an X-class flare that occurred on November 3, 2003 in the active region NOAA 10488, were investigated. The  $H\alpha$  measurements taken from the Solar Tower Telescope at ARIES, Nainital, showed two flare kernels connected by clear loops. Brightening of the loop-top near the flare maximum, and reorganization of the loop system were observed. A fairly wide, bright loop-front CME associated with this flare has been imaged by SOHO/LASCO. The propagation characteristics of the CME outside the LASCO field-of-view were studied by the remote sensing interplanetary scintillation measurements with the Ooty Radio Telescope. The light curves in the energy range 3-300 keV obtained from Ramaty High Energy Spectroscopic Imager (RHESSI) showed two peaks associated with the event. These investigations have been compared with multi-frequency radio measurements over wide frequency range and EIT images from SOHO, to infer the magnetic field morphology associated with the flare. It was inferred that a sequence of higher altitude magnetic reconnections and reconnections at the flare site among short non-potential loops, cause the outward expansion of the flux rope, initiation of the flare, and acceleration of particles to high energy [P.K.Manoharan with Bhuwan Joshi and P. Pant (ARIES)].

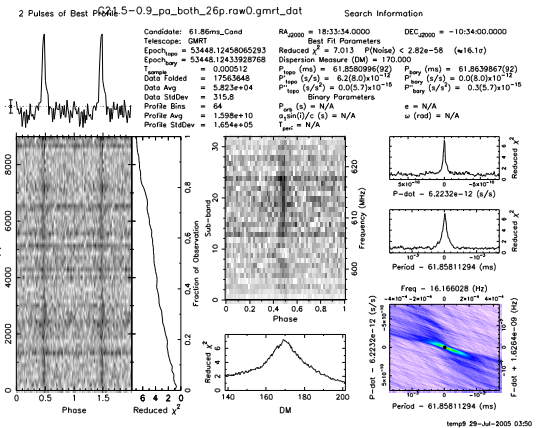
**Periodicities in sunspot activity during solar cycle No. 23:** Highly significant periodicities of  $\sim 175$  days and  $\sim 133$  days were found in the sunspot data for the northern hemisphere, consistent with the results known for the solar cycles 12-21. However, the southern hemisphere showed a strong  $\sim 85$ -day periodicity in the sunspot activity. In contrast, the analysis of solar flare index data over the same time interval did not show any significant peak. The different periodic behaviors of the sunspot and flare activities during cycle 23 can be understood in the light of periodic emergence of magnetic flux which partly takes place away from developed sunspot groups and hence may not necessarily increase the magnetic complexity of sunspot groups that leads to the flares [P.K. Manoharan with B. Joshi, P. Pant (ARIES)].



## Our Galaxy

### Pulsars

**Search for pulsars in supernova remnants:** During March-April 2005, a search for pulsars in selected supernova remnant targets, was carried out using the GMRT in the phased array mode at 610 MHz. Analysis of these data resulted in a new detection: a 61.86 millisecond pulsar in the supernova remnant G21.5-0.9. A characteristic age of  $\sim 4900$  years was inferred for this pulsar, which is not incompatible with the estimated age of the supernova remnant. It was found that this pulsar has a spin-down luminosity that is the second highest, after the Crab pulsar. [Y. Gupta and D. Mitra with D. Green, (MRAO, Cambridge, UK) and A. Acharyya (NIT, Durgapur)].



The GMRT has recently discovered a new pulsar (J1833-1024, shown in the bottom panel) in the supernova remnant G21.5-0.9, whose image taken with the Chandra X-ray telescope is shown in the top panel — the pulsar is thought to be located very close to the centre of this remnant



**Tracking pulsar dispersion measures with the GMRT:** A program to accurately determine the dispersion measures (DMs) of selected pulsars was initiated using the simultaneous dual-frequency capability of the GMRT. In the first paper the feasibility of estimating DMs with an accuracy of 1 part in 10000, or better, at individual epochs, was demonstrated using this novel technique. It was thus found that the mean DM values obtained for some of the pulsars show significant deviations from the values available in the literature. For most of the pulsars studied, significant fluctuations in the DM values were found over time scales of week to months. For some pulsars, like B2217+47, a large-scale DM gradient over 1-year period was found, which is modelled as being caused due to a plasma blob of enhanced electron density crossing the line of sight. For some pulsars, interestingly, the DM values obtained from different pairs of frequencies were found to be slightly different. Detailed investigation of some of these aspects using numerical simulations is in progress. [*Y. Gupta and D. Mitra with A.L. Ahuja and A.K. Kembhavi, (IUCAA)*]

**The GMRT long-period pulsar Survey:** Using GMRT, two new pulsars with periods of 932 ms and 1 second, and distances of 3.4 and 5.4 kpc, have been confirmed this year in the follow-up observations for this 610-MHz survey covering about 40 square degree of the sky near the Galactic plane. The survey aims to discover new long-period pulsars or pulsars with periods longer than 1 second and is the first such blind survey conducted with GMRT. Together with a new pulsar discovered last year (PSR J0026+6320), this survey has revealed three new pulsars so far. Follow-up observations are continuing with GMRT and the Jodrell Bank telescope to determine the timing solution for these pulsars. [*B.C. Joshi, with A.G. Lyne O. Hewitt, M. McLaughlin, A. Faulkner, M. Kramer, D. Lorimer (Jodrell Bank Observatory, UK)*]

**The Parkes High-latitude Survey:** The Parkes high-latitude pulsar survey covers a region of the sky enclosed by Galactic longitudes  $220^\circ < l < 260^\circ$  and Galactic latitudes  $|b| < 60^\circ$ . The observations were performed using the 1.4 GHz multibeam receiver on the Parkes 64-m radio telescope. Data were taken at a total of 6456 pointings of 265 s each. The system provided a sensitivity limit of 0.5 mJy, for long-period pulsars with 5 per cent

duty cycle. Data analysis resulted in the detection of 42 pulsars, of which 18 were previously unknown. Four of these belong to the class of the millisecond – or recycled – pulsars; of which, three are in binary systems including the first double pulsar system J0737–3039. Rotational, positional, and when available, orbital parameters have been derived for 17 of the objects. The discovery rate of millisecond to long period pulsars in the high latitude survey is twice that of the pulsars previously known in the same area and six times greater than that for the total pulsar population. [*B. C. Joshi with M. Burgay, N. D'Amico, A. Possenti (OAC, Italy), A. G. Lyne, M. A. McLaughlin, M. Kramer, (Jodrell Bank Obs. UK), R. N. Manchester (ATNF, Australia), F. Camilo (Columbia Univ, USA), P. C. C. Freire (NAIC, USA)*]

### **Galactic Novae**

**The evolving radio spectrum of the remnant of nova GK Persei:** By combining the GMRT and archival VLA observation of the nova GK Persei, a significant evolution of the nova remnant over the past two decades was found. The evolution involves a secular flux decrease of 2.1% per year and a spectral index of  $-0.7$  above 1.4 GHz. In contrast, the spectrum below 1.4 GHz, was found to evolve from a flat spectrum to a spectral index of  $-0.85$ . Estimating synchrotron loss and acceleration timescales, it was found that the acceleration slightly dominates over losses, for energies higher than the critical energy, while the losses dominate at lower electron energies. This led to a limit on the diffusion coefficient. [*N.G. Kantharia, with G. C. Anupama (IIA), Prasad Subramanian, (IUCAA)*]

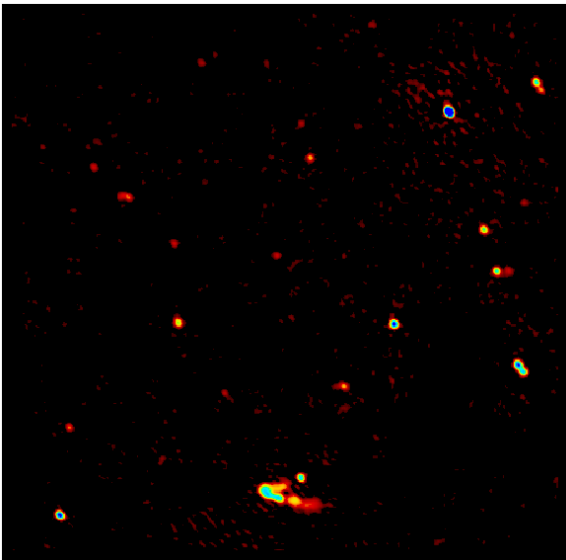
**The outburst of the nova RS Ophiuchi:** Following its outburst in February 2006, the nova RS Ophiuchi was monitored in the optical using the Himalayan Chandra Telescope (HCT) and in the radio band using the GMRT. The outburst was thus detected at 1.28 GHz, 1.06 GHz and, for the first time even below 1 GHz. A slow evolution of the nova in the present phase was found at 0.61 GHz and 0.33 GHz. The nova is also being monitored at much higher radio frequencies, in collaboration with a team from UK. [*N.G. Kantharia, with G.C. Anupama (IIA)*]

## Interstellar Medium within our galaxy

The data obtained from GMRT and the Leiden-Dwingeloo HI survey were used to determine the temperature (spin temperature of atomic hydrogen) of cold diffuse neutral interstellar medium and to compare it with the temperature of the molecular hydrogen (ortho-para temperature) derived from ultraviolet data for close lines-of-sight. A good match was found between these two temperatures for the lines-of-sight with molecular hydrogen column density exceeding a threshold value. This result is consistent with the theory that in cold neutral medium the spin temperature tracks the kinetic temperature due to collisions and that the ortho-para temperature is driven towards the kinetic temperature by proton exchange reactions. [N. Roy, J. N. Chengalur, with R. Srianand (IUCAA)]

## Galactic Micro-quasars

As part of an ongoing project to observe galactic micro-quasars at low



Full synthesis, wide-field GMRT image of the region J0916+6348, at 150 MHz. A dynamic range of 2000 and a rms noise of 1.5 mJy/beam with detection threshold of 12 mJy was achieved near the field centre. The resolution is 20 arcsec [Ishwara-Chandra and Nimisha Kantharia].

frequencies, extensive monitoring of GRS1915+105 was carried out with GMRT at 0.235, 0.61 and 1.28 GHz. A good correlation between the radio and X-ray emission was thus observed. The multi-frequency monitoring showed a steepening of the radio spectrum during the low/hard X-ray state. This is consistent with the scenario of extended jet ejection during this state. In a related program, as part of M. Pandey's PhD project, GMRT was used to survey 40 hard X-ray / Gamma-ray sources discovered by the INTEGRAL satellite. Thus, four

new microquasar candidates were found [M. Pandey (Mumbai Univ.), A.P.

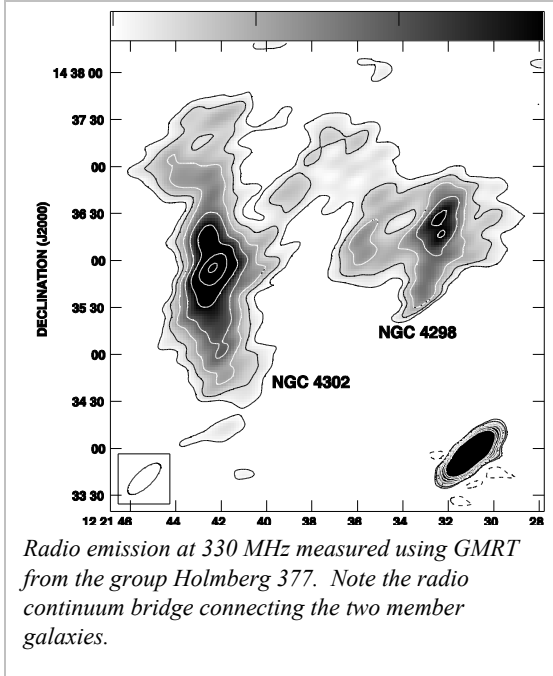
Rao, C.H. Ishwara-Chandra, Ph. Durouchoux (CNRS, France), R.K. Manchanda (TIFR)].

## Nearby galaxies

**The nearby galaxy NGC4438 and its environment:** GMRT and VLA were used to make a detailed study of NGC4438, a highly-disturbed active galaxy in the Virgo cluster. Observations of the central 1 kpc with the VLA at 4860 and 8460 MHz have revealed an inverted-spectrum radio nucleus located between two highly asymmetric lobes of radio continuum emission. The lobes which are also seen in H $\alpha$  and x-ray wavelengths and are located at  $\sim$ 230 and 730 pc from the nucleus, thus arise due to an AGN and not from a nuclear starburst. At lower frequencies, GMRT detected diffuse radio continuum emission on the western side of the galaxy, whose spectral index is flatter at higher frequencies, suggesting a mixture of thermal and non-thermal radiation.

The H $\text{I}$  observations detected an elongated structure of size  $\sim$ 9.8 kpc and H $\text{I}$  mass of  $1.8 \times 10^8 M_{\odot}$   $\sim$ 4.1 kpc offset to the western side of NGC4438 and undergoing systematic rotation. These observations also showed H $\text{I}$  emission from the disk of the galaxy as well as off-planar H $\text{I}$  gas located primarily on the western side of the galaxy and rotating about a velocity of  $\sim$ 110 km s $^{-1}$ , which is significantly higher than the systemic velocity of 71 km s $^{-1}$  for the galaxy. From these H $\text{I}$  spectral data, evidence was found for dynamical interaction of the rotating off-planar gas with the hot intracluster medium and with the companion galaxy NGC 4355. A kinematical scenario was developed for these structures, as well as the faint H $\text{I}$  tail detected towards the north of NGC 4438 which also has an associated optical emission. [Ananda Hota and D.J. Saikia, with Judith A. Irwin (Queen's University, Canada)].

**Detection of a radio continuum bridge in Holmberg 377:** Using GMRT a bridge of radio continuum emission with an ultra-steep spectral index of about -1.4 was discovered between two bright spiral galaxies NGC4302 and NGC 4298, which are separated by  $\sim$ 15 kpc. To study the dynamical interaction, H $\text{I}$  observations are being made with GMRT. [N.G. Kantharia, S. Anantha-krishnan]



**Radio emission from the Low Surface Brightness (LSB) galaxy 1300+0144:** Multi-frequency radio continuum and HI 21cm line observations of the giant LSB galaxy 1300+0144 were made with the GMRT. It was found that the HI disk extends well beyond the optical radius and the radio continuum arises in

the central active nucleus and is extended in the form of lobes. Such features have not been noticed in LSBs previously. [N.G. Kantharia, with Mousumi Das (RRI, Bangalore), Stacy McGaugh (UMD, USA), Stuart Vogel (UMD, USA)]

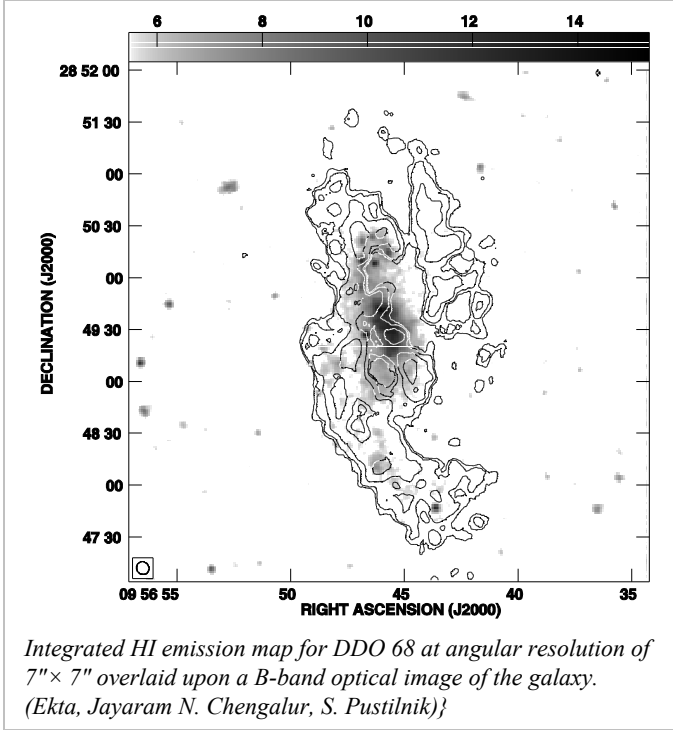
### Dwarf Galaxies

The gas distribution, kinematics and current star formation in a sample of 10 very faint ( $-13.37 < M_B < -9.55$ ) dwarf galaxies were compared. For all the galaxies we constructed maps of the HI column density at a constant linear resolution of  $\sim 300$  pc; this forms an excellent data set to check for the presence of a threshold column density for star formation. It was found that while current star formation (as traced by  $H\alpha$  emission) is confined to regions with relatively large ( $N_{HI} > (0.4 - 1.7) \times 10^{21} \text{ cm}^{-2}$ ) HI column density, the morphology of the  $H\alpha$  emission is, in general, not correlated with that of the high HI column density gas. Thus, while high column density gas may be necessary for star formation, in this sample at least, it is not sufficient to ensure that star formation does in fact occur. The line profiles of the HI emission were examined, but no simple relation was found between regions with complex line profiles and those with on-going star formation. Finally, the very fine scale ( $\sim 20-100$  pc) distribution of the HI gas was examined, and it was found that at these scales the emission exhibits a variety of shell like, clumpy and filamentary features. In summary, the interplay between star formation and gas density in these galaxies does not seem to show the simple large scale patterns observed in brighter galaxies [Ayesha Begum, Jayaram N.

*Chengalur, with Igor D. Karachentsev, S. S. Kaisin & M. Sharina (Special Astrophysical Observatory, Russia)]*

A study based on high sensitivity and high velocity resolution ( $\sim 1.6$  km/s) HI 21 cm line observations of a sample of extremely faint ( $M_B > -13.5$ ) dwarf galaxies was made using GMRT. All the sample galaxies show systematic large scale velocity gradients; earlier, less sensitive observations had found chaotic velocity fields in faint galaxies. For some of the galaxies, the velocity fields are completely consistent with ordered rotation, though often the peak circular velocities are comparable to the velocity dispersion. NGC 3741, one of the sample galaxies has what is probably the most extended known HI disk – the rotation curve was measured out to  $\sim 38$  optical disk scale lengths. This galaxy provides a unique opportunity to trace the extended distribution of dark matter around faint galaxies. Observations were made to investigate the dark matter distribution in the individual galaxies, as well as to search for systematic trends (such as those predicted from hierarchical structure formation models) in the dark halo parameters of galaxies of different sizes, and to compare the Tully-Fisher relationship for these faint galaxies with that of brighter galaxies. The hybrid configuration of the GMRT allows one to make images at a variety of spatial resolutions. Thus, data cubes for all the galaxies were constructed at a constant linear resolution of  $\sim 300$  pc. This provided a unique data set to check for the existence of a threshold HI column density for star formation (as has been often posited in brighter dwarf galaxies). In this regard, the sample is also interesting in that it has a very low average metallicity ( $12 + \log[\text{O}/\text{H}] \sim 7.45$ ), as compared to previous samples. Finally, a visibility based formalism (as well as the required software) was developed for determining the power spectrum of the HI intensity fluctuations in faint dwarf galaxies, where the expected signal is very weak. We compared the power spectra in our faint, largely quiescent galaxies, with those observed in much brighter galaxies. [*Ayesha Begum, J.N. Chengalur*].

## HI in the Galaxies with Low Metallicity: The HI distribution and



kinematics in the galaxies with low metallicity have been studied so that we can understand the mechanism by which the star-formation that was subdued in these galaxies for long, got triggered. This can provide important clues about the process of galaxy formation and evolution. From the HI data for four metal-poor galaxies, taken previously with GMRT, clear signs of interaction with a neighbour were found in all the four galaxies. One of the galaxies is DDO 68, a dwarf gas-rich galaxy and the nearest very metal poor galaxy located just 6.5

Mpc away. Its absolute blue magnitude is  $M_B \sim -14.3$  and its oxygen abundance is given by  $12 + \log(\text{O}/\text{H}) = 7.21$ . Spectral cubes were generated for DDO 68 at various resolutions. Channel maps and integrated HI emission maps show two tails emanating from the central body and their kinematics was modeled using the GMRT data [Ekta, J.N. Chengalur]

## Radio Galaxies, Quasars and Clusters of Galaxies

**A new double-double radio galaxy (DDRG):** The discovery of a double-double radio galaxy (DDRG), J0041+3224 of size 970 kpc, with the GMRT and its subsequent high-frequency observations with the VLA were modeled and the time scale of interruption of jet activity was estimated to be  $\sim 20$  Myr. A sample of known DDRGs was compiled and it was found that, statistically, the inner doubles appear more asymmetric relative to the nucleus, in both arm length and flux density ratios, as compared with the outer doubles. [D.J. Saikia, C. Konar and V.K. Kulkarni].

**Spectral ageing in the DDRG J1453+3308:** New radio observations at frequencies ranging from 240 to 4860 MHz of the well-known, double-double radio galaxy

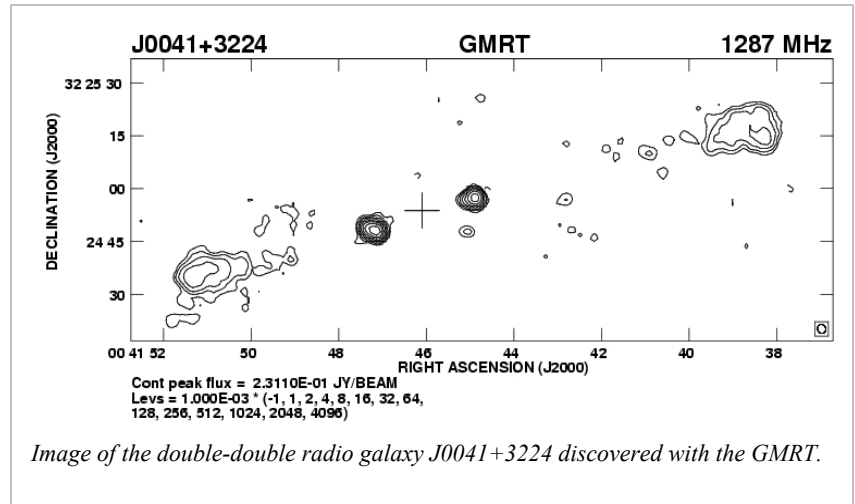


Image of the double-double radio galaxy J0041+3224 discovered with the GMRT.

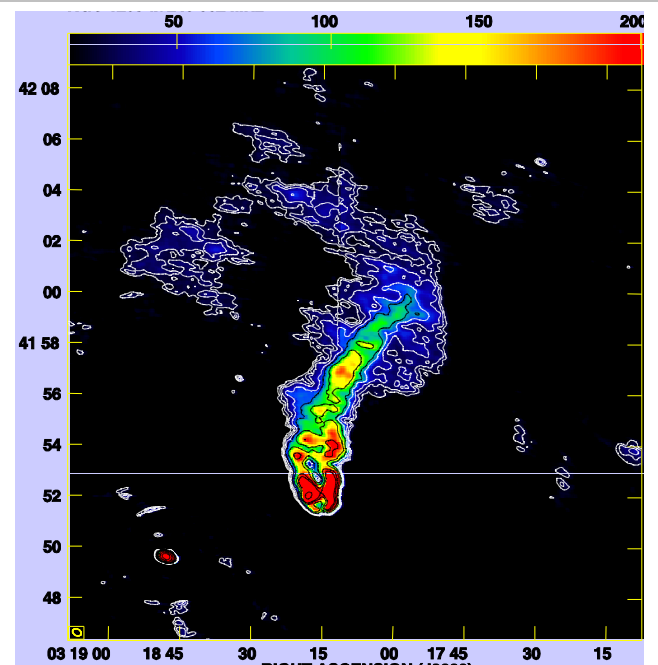
(DDRG), J1453+3308 were carried out, using the GMRT and VLA. From the spectral analysis it was estimated that the lobes of the inner double source are advancing at a speed of  $\sim 0.4c$ , which is  $\sim 10$  times faster than the estimated speed of the outer radio lobes. [C. Konar and D.J. Saikia, with M. Jamrozny and J. Machalski (Jagiellonian University Astronomical Observatory, Poland)].

**The highly asymmetric quasar 3C254:** Multifrequency, high-resolution radio observations of the highly asymmetric quasar 3C254 were made using MERLIN. The much smaller and less polarized eastern radio lobe is inferred to be approaching us and interacting with a dense intergalactic cloud. [D.J. Saikia, with Peter Thomasson and T.W.B. Muxlow (Jodrell Bank Observatory, UK)].

**A giant radio jet in a nearby massive elliptical galaxy:** A serendipitous discovery of a long radio jet emanating from a massive elliptical galaxy, CGCG 049-033, was followed up with multi-frequency imaging with the GMRT, VLA and the 100m Effelsberg radio telescope. The jet was thus found to remain well collimated and extending all the way from the parent galaxy to the terminal hotspot. Its enormous size of about 1.5 million light-years makes it **the largest known radio jet**. The morphology of this jet-hotspot system bears a striking resemblance to the ( $\sim 7$  times smaller) jet of the famous quasar, 3C273, which is the first quasar discovered and continues to be the most enigmatic one for its unique one-sided radio morphology. A model of this giant jet, based on the radio and optical observations (made with the 2-m IUCAA telescope), is being developed [Gopal-Krishna, with J. Bagchi & S. Joshi (IUCAA) and M. Krause (MPIfR, Germany)].



**Bulk speed of quasar jets:** Two key parameters of nuclear jets of quasars, namely, the bulk Lorentz factor and viewing angle, are usually determined by combining the radio flux variability with the measured proper motion of the VLBI knots. A generalized version of this method was developed by considering a *conical* geometry for the nuclear jets. It was thus shown



GMRT observations of NGC1265 at 240 MHz.  
[A. Pramesh Rao with D.V. Lal]

that the canonical method can grossly underestimate the jet's Lorentz factor and also its viewing angle (corresponding to an implausibly low probability of detection). The idea of conical ultra-relativistic jets was also shown to reconcile the extremely high Lorentz factors inferred from TeV flux variability of blazars ( $\Gamma \geq 20$ ) and the frequently observed mildly superluminal or even subluminal motions of their VLBI knots. [Gopal-Krishna, with Paul J. Wiita (GSU, USA) and S. Dhurde (IUCAA)].

**Origin of gaps between the lobes of radio galaxies:** There is now a growing realization that the ejection of relativistic plasma jets in quasars is preceded by a lengthy phase of thermal wind outflow from the nucleus. Its consequences for the morphology of radio galaxies were examined, for the first time and a dynamical interaction of the wind with the radio lobes was shown to explain, quantitatively, the radio emission gaps of up to 0.5 Mpc, that are observed between the two lobes of radio galaxies. This model can also explain the intriguing cases where the host galaxy is located extremely asymmetrically relative to the radio emission gap [Gopal-Krishna, with Paul J. Wiita (GSU, USA) and S. Joshi (IUCAA)].

“Head-Tail” or “tadpole shaped” radio sources mostly occur in clusters of galaxies and their radio morphology consists of a compact head coinciding with the optical host galaxy and two trails sweeping back from the head, probably due to the dynamic pressure of the intracluster gas. Two prominent head-tail sources, viz., NGC 1265, IC 310, are members of the nearby rich cluster of galaxies in Perseus (Abell 426). GMRT was used at 240 MHz to map the central radio galaxy 3C84 (NGC1275) of this rich cluster. The GMRT map shows a twin-tailed morphology at 240 MHz, with the tails detected upto 24' from the unresolved radio nucleus. A detailed comparison was made with the available WSRT map made at the higher frequency of 610 MHz. [A.P. Rao, with D.V. Lal (ASIAA, Taiwan)]

**Ram pressure stripping in Abell 1367:** Three irregular galaxies, namely CGCG 09787 (UGC 06697), 09779 and 09773, in the rich cluster of galaxies, A1367 were observed with the GMRT and VLA. These have 50–75 kpc long tails of radio continuum and H $\alpha$  emission, due to motion towards the main cluster core. Chandra observations of UGC 06697 also show an x-ray tail. In this galaxy a 21-cm H $\text{I}$  tail was found, with most of the H $\text{I}$  gas being stripped and red-shifted, due to the ram pressure of the intra cluster medium. In CGCG 09779 too, the H $\text{I}$  gas appears redshifted relative to the systemic velocity, with the peak being offset to the down-stream side by  $\sim 6$  kpc from the main stellar disk. The third galaxy CGCG 09773 shows H $\text{I}$  emission from the disk of the galaxy, with a much sharper gradient on the northern side, which is on the opposite side of the optical arc seen in the H $\alpha$  and B-band images. Radio continuum tails of all the three galaxies were detected using GMRT. [Ananda Hota and D.J. Saikia].

### **Radio spectroscopy of quasar and radio galaxies**

**Probing radio source environments via H $\text{I}$  and OH absorption:** The Arecibo 305-m telescope and the GMRT were used to search for associated H $\text{I}$  absorption in 27 extragalactic radio sources. In this sample, one new H $\text{I}$

absorption system was found (towards the radio galaxy 3C258), while five previously known H<sub>I</sub> absorption systems, and one galaxy detected in emission, were studied with improved frequency resolution and/or sensitivity. The sample included 17 gigahertz peaked spectrum (GPS) and compact steep spectrum (CSS) sources, of which four exhibit H<sub>I</sub> absorption. This detection rate of ~25% compares with the rate of ~40% obtained by Vermeulen et al. for similar sources. Neither OH emission, nor absorption was detected towards any of the sources that were observed at Arecibo. For

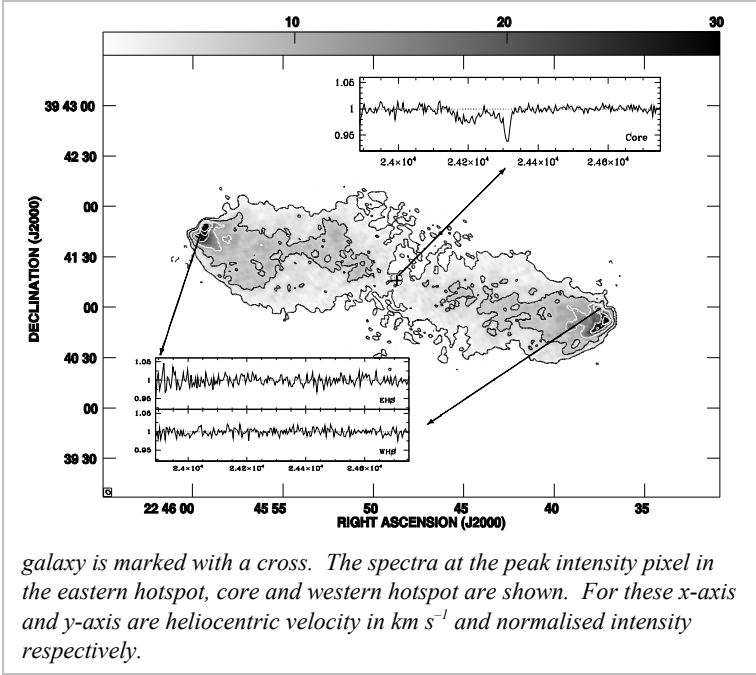
3C258, a limit on the abundance ratio of  $\frac{N(HI)}{N(OH)} \geq 4 \times 10^6$  was obtained.

The results were combined with those from other available H<sub>I</sub> searches, to build a sample of 96 radio sources consisting of 27 GPS, 35 CSS, 13 compact flat spectrum (CFS) and 21 large radio sources (LRGs). The H<sub>I</sub> absorption detection rate is the highest (~45%) for the compact GPS sources and the lowest for the LRGs. The H<sub>I</sub> column density was found to anticorrelate with radio source size, as also reported earlier by Pihlström et al., and in accord with the results of optical spectroscopy. Since no dependence of the H<sub>I</sub> column density on either redshift or luminosity was found, the environments of radio sources on GPS/CSS scales are probably similar at different redshifts. Further, consistent with the unification scheme, the GPS/CSS galaxies have an H<sub>I</sub> detection rate of ~40% which is significantly higher than the detection rate (~20%) found towards the GPS/CSS quasars. Finally, the principal (strongest) absorption component detected towards GPS sources appears blue-shifted in two-thirds of the cases, reinforcing the important role of jet-cloud interactions in determining the ionization and kinematical properties of the ambient gas. [*Neeraj Gupta and D.J. Saikia, with C.J. Salter and T. Ghosh (Arecibo Observatory, NAIC, USA) and S. Jeyakumar (Instituto de Geofisica, UNAM, Mexico)*].

### Discovery of associated H<sub>I</sub> absorption towards the radio galaxy 3C452:

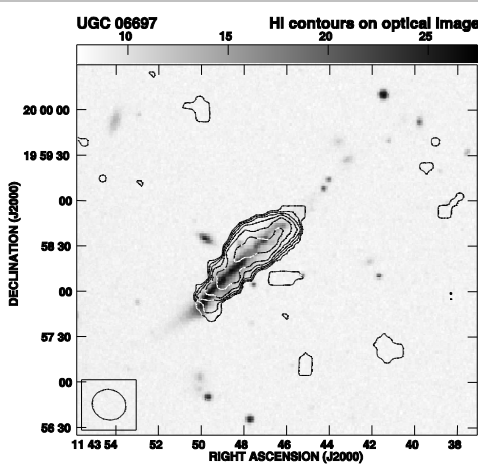
The 21-cm H<sub>I</sub> absorption profile detected using the GMRT towards the core of the Fanaroff-Riley II radio galaxy 3C452 (J2245+3941), was found to have three components. The strongest and narrowest of these component coincides

in velocity with the [O III] emission lines, while the other two components are blue-shifted with respect to it by  $\sim 30$  and  $115 \text{ km s}^{-1}$ . If the systemic velocity of the host galaxy is determined from low-ionization lines, which are red-shifted with respect to the [O III] doublet by about  $\sim 200 \text{ km s}^{-1}$ , then both the [O III] emission and 21-cm absorption lines are associated with outflowing material. [Neeraj Gupta and D.J. Saikia]



### Unification scheme and the distribution of neutral gas:

The consistency of H<sub>I</sub> properties with the unification scheme for radio galaxies and quasars, and any correlation with the symmetry parameters were examined for a sample of CSS and GPS radio sources, where the galaxies and quasars have similar redshift and luminosity distributions. In the sample, 15 out of 23 galaxies exhibit 21-cm H<sub>I</sub> absorption as against 1 out of 9 quasars, which is broadly consistent with the unification scheme. Also, there is a tendency for the detection rate as well as the H<sub>I</sub> column density for galaxies to increase with the radio core prominence,  $f_c$ , a statistical indicator of the degree of alignment of the jet axis to the line of sight. This can be understood in a scenario where the double radio source is larger than the scale of the circumnuclear H<sub>I</sub> disk, so that the lines of sight to the two lobes at very large inclinations do not intersect the disk. The sources in our sample also exhibit the known anti-correlation between H<sub>I</sub> column density and source size. This suggests that small linear size, along with an intermediate value of core



*HI total-intensity contours super-imposed on an optical image of the galaxy UGC 06697 in the cluster Abell 1367. The HI gas is stripped by ram pressure as the galaxy moves towards the south-east.*

prominence, is a good recipe for detecting 21-cm absorption in CSS and GPS objects. Some of the absorption could also be arising from clouds that have interacted with the radio jet. The HI column density and velocity shift of the primary absorption component, however, show no dependence on the degree of jet misalignment and the separation ratio of the twin radio lobes. [Neeraj Gupta and D.J. Saikia]

### Extragalactic radio sources towards the Galactic Centre Region

Fifty nine extragalactic radio sources were identified and the Faraday Rotation Measure of the polarised sources in the sample within  $-6^\circ < l < 6^\circ$ ,  $-2^\circ < b < 2.5^\circ$  region was determined. This increases by almost an order of magnitude the number of known extragalactic sources in this region towards the galactic centre. [A. Pramesh Rao, with S. Roy (ASTRON, The Netherlands)]

# Instrumentation and Facilities

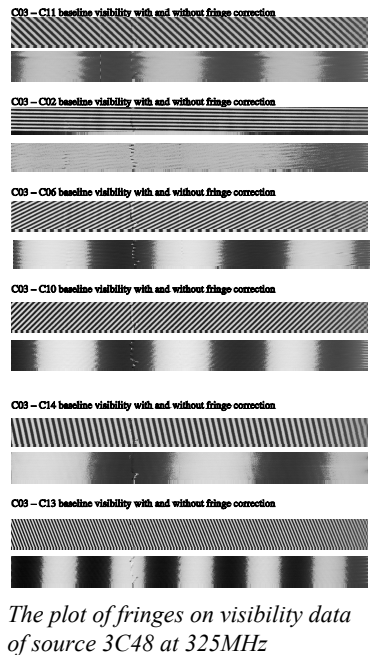
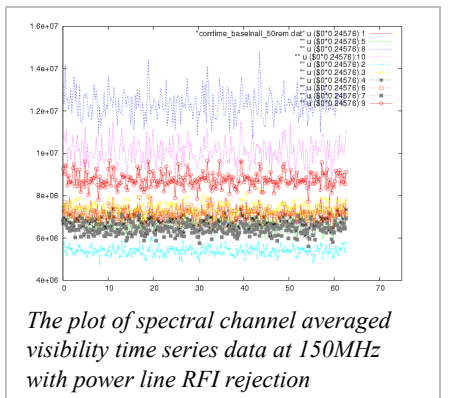
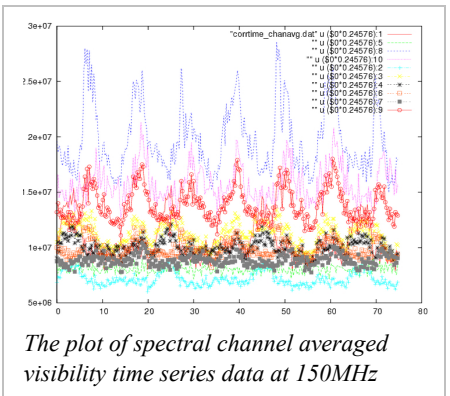
## Giant Metrewave Radio Telescope

### Eight Station prototype software correlator for the GMRT: An 8 antenna

prototype Software Correlator for the GMRT was built at NCRA. In the existing hardware Correlator, there is a constraint of acquiring high time resolution raw voltage

data and of changing the mode of operation with a new set of parameters. With the aid of flexible algorithms, in the Software Correlator it is easier to alter the code to reach new regions of the parameter space. The performance study of this Software Correlator has been done under various signal processing algorithms. The

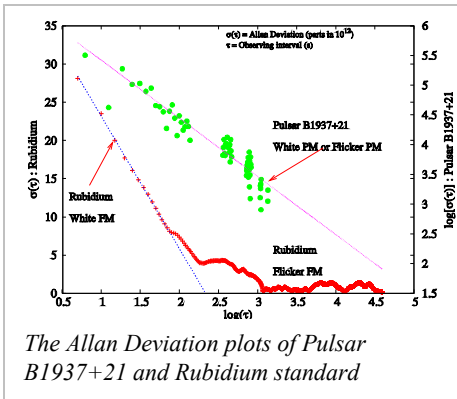
current 8 antenna Software Correlator consists of two identical nodes. Each node can take four 16 MHz or 32 MHz bandwidth analog signals with 8 bit or 4 bit resolution respectively. The fringes on the astronomical sources were observed using this two node Linux cluster. The figure on the left panel shows the fringes in correlated visibility time series over spectral channels for different baselines on source 3C48 at 325MHz. Several algorithmic features have already been implemented in the Software Correlator, like the routine for automatic gain calibration, the routine for filtering out the radio frequency interference (RFI) signals from the astronomical data, the routine for fringe correction of the incoming data. The RFI rejection algorithms were worked well for reducing the power line



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interference and giving the mean/rms ratio typically at the level of the expected thermal noise. The results are shown in figure on the top right panel. [J. Roy and Y. Gupta with Ue-Li Pen, Canadian Institute of Theoretical Astrophysics, Canada, Jeff Peterson, Carnegie Mellon University, USA]

**Evaluation of frequency standard using inter-comparison techniques and pulsar data:** A study was made of time domain stability of the



The Allan Deviation plots of Pulsar B1937+21 and Rubidium standard

observatory's frequency standard, which is a GPS disciplined Rubidium (Rb) atomic clock. The clocks were disciplined with the GPS 1 PPS signal in order to optimize long time stability while retaining the inherent short time stability. These experiments were carried out for estimation of Allan Variance (AV) of the clock errors and the identification of different kind of noise processes perturbing the timing

data. The noise processes were studied using the simulation of the power-law clock noises generated from the pseudo-random sequences having specified Power Spectral Density (PSD). The experimental results show that, on short-time scale, disciplined Rb follows the inherent stability of Rb only. The stability reaches the level of  $1 \times 10^{-12}$  on the averaging of 1000 seconds. The absolute frequency of the atomic clock was measured in an independent manner by using pulse Time of Arrival (TOA) data of millisecond pulsar PSR B1937+21. The work indicates that such observations of PSR B1937+21 can provide an accurate figure for frequency offset of 10 MHz Rb clock over a duration of 300 s ( $5.25 \times 10^{-15}$ ). The derived AV from these residuals is  $1 \times 10^{-9}$ , on 1000 s averaging. [J. Roy, B.C.Joshi and T.L.Venkatsubramani]

**Pulsar Software Baseband Receiver (PSBR) for GMRT:** A variety of pulsar studies, such as high precision astrometry, studies of narrow, highly polarized Giant Pulses and tests of theories of gravity, require high time resolution data. Few such observations at more than two frequencies below 1 GHz are available. GMRT has the unique capability to provide such multi-frequency pulsar data at low frequencies, but the quality and time resolution of pulsar radio signals is degraded due to dispersion in the inter-stellar

medium at these frequencies. PSBR is a new software based flexible and easily upgradeable pulsar receiver using a cluster of 4 commercially off-the-shelf available Pentium PCs and a high speed data acquisition card, which is capable of acquiring 16 MHz dual polarization data available at GMRT array combiner at a rate of 64 Mbytes per second. This receiver has recently been commissioned at GMRT. The receiver can be configured to record the baseband data up to a maximum bandwidth of 4 MHz to disk with a sampling time of 250 ns for offline coherent de-dispersion. The receiver was tested with high time resolution observations of several pulsars. The figure shows a high time resolution coherently dedispersed profile of PSR B1937+21 (a 1.5 ms pulsar) obtained at 610 and 235 MHz, respectively. The latter profile has been obtained for the first time, indicating a scattering timescale of about 300  $\mu$ s. High time resolution observations of Giant pulses from the Crab pulsar and pulsar microstructure along with timing observations of PSR B1937+21 were carried out with expected results, thus demonstrating the usefulness of the instrument. It is proposed to extend this instrument for the second sideband of GMRT and make it available for routine pulsar observations in the near future. [B C Joshi with Sunil Ramkrishna (I<sup>2</sup>IT), R. Balasuramianam]

### **Radio Frequency Interference (RFI)**

Radio telescope sites require regular surveys of terrestrial radio information, viz. spectrum, flux density and radio direction. Terrestrial wireless radio sources may interfere in the radio telescope signals. Such signals received through wide band antennas in the VHF/UHF bands are amplified, integrated and spectrum-frame averaged. The radio direction of these sources can be resolved if they are steady over the time of observation, unique in frequency and if the system consists of two or more stationary antennas possessing low side-lobe levels. Supporting experimental results were obtained from a fully functional multi-antenna system with omnidirectional coverage in the horizontal polarization. [Shubhendu Joardar with Asit Baran Bhattacharya (Kalyani University)]

A new innovative ultra wide band antenna/feed for usage in the VHF/UHF/microwave communication links, spectrum monitoring, radio



astronomy etc. was designed. The basic structure is a planar log periodic antenna. Instead of the conventional cavity back structure, a new type of reflecting structure has been introduced. The reflector structure has been named as step-lane reflector. The property of the step-lane reflector has been found to be log periodic. This has enabled more flexibility in the choice of bandwidth, better gain and relatively uniform characteristics over the frequency band as compared to the cavity backed type. Ultra wide band dual polarized feed designs are now possible with this technology. The basic theory and mathematical design relationships are presented. As an example, an actual design of an ultra wide band dual polarized feed in the UHF range has been presented together with some theoretical and experimental results. *[Shubhendu Joardar with Asit Baran Bhattacharya (Kalyani Univesity)]*

Terrestrial spectrum monitoring is done for the study of radio environment over time, especially radio astronomy, wave propagation, EMI/EMC, frequency allocation, out of band/spurious emissions, monitoring the growth of transmitters etc. The raw linear spectrum data appears to be narrow band tall vertical lines and stretches standing over a gradually varying wide band base level across the frequency band and time. An algorithm has been developed to separate these features and generate their spectral statistics. Spectral statistics are generated from these. Results of some real data are produced. *[Shubhendu Joardar with Asit Baran Bhattacharya (Kalyani University)]*

## **GMRT Time Allocation Committee Report**

From the beginning of 2002, the GMRT has run as a full fledged international observational facility for radio astronomy below 1.4 GHz and completed 9 observation cycles, approximately 6 months each. GMRT Control Centre (GCC) makes sure that at least 27 antennas are available for observations. Weekly maintenance downtime is approximately 1.5 days per week and annual maintenance shutdown is 2 months per year. Cycle 8 ran from June 2005 to October 2005 and Cycle 9 ran from November 2005 to April 2006. On the average, each cycle has been getting 50-55 proposals which are

screened by GMRT Time Allocation Committee (GTAC) and scheduled based on their recommendations.

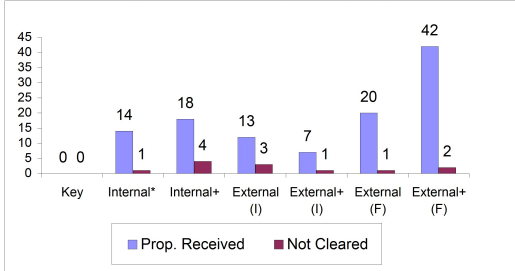
Several Target of Opportunity (ToO) proposals sent to Centre Director are approved and scheduled and interesting results have been emerging. Observing in the 150 MHz band has been started by experienced users and GTAC is receiving proposals for this band. New correlator modes namely polar & high resolution have also been enabled & released on experimental basis. RFI continues to be a problem but in spite of it, results are emerging. 6 research students from NCRA are presently using GMRT data for their thesis work and about 127 papers (including 37 publications during 2005–2006) have been published using GMRT data.

### Statistics of proposals - Cycle 1 to 9

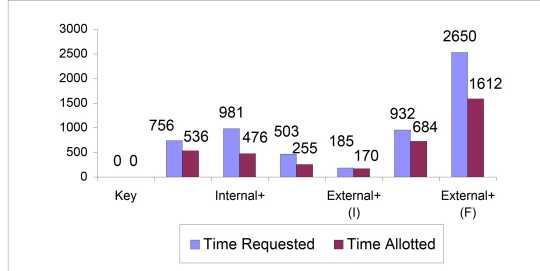
Categories	Proposals Received	Proposals Not Cleared	Time Requested	Time Allotted
	(Nos)	(Nos)	(Hours)	(Hours)
Key	22	3	5163	1193
Internal	87	6	4347	2603
Internal+	91	9	5268.5	2718
External (I)	54	15	2471	1163
External+ (I)	50	10	1747	1171
External (F)	84	6	4625	2399
External+ (F)	132	9	6955	4175
Total	520	58	30576.5	15422
<b>Legends</b>				
Key:	Key proposals			
Internal:	PI and Co-Is from TIFR			
Internal+:	PI from TIFR, Co-I non-TIFR			
External (I):	PI & Co-Is not from TIFR, but from other Indian Institutions			
External+ (I):	PI non-TIFR, with at least one Co-I from TIFR			
External (F):	PI & Co-Is from abroad.			
External+ (F)	PI from abroad, with at least one Co-I from India			

Streamlining and automating various procedures is under way. The statistics from 8<sup>th</sup> & 9<sup>th</sup> cycles are given below. As can be seen from the statistics, more than half the proposals had a foreign PI. This is different from the statistics of cycles 1 to 7 where more than 50% had Indian PIs. There continue to be an oversubscription by a factor of 2 in terms of observing time.

**GMRT Proposals Statistics (in nos.) - Cycle 8 to 9**



**GMRT Time statistics (in hrs)- Cycle 8 to 9**



**Categories**

- Key: Key proposals
- Internal: PI and Co-Is from TIFR
- Internal+: PI from TIFR, Co-I non-TIFR
- External (I): PI & Co-Is not from TIFR, but from other Indian Institutions
- External+ (I): PI non-TIFR, with atleast one Co-I from TIFR
- External (F): PI & Co-Is from abroad.
- External+ (F): PI from abroad, with atleast one Co-I from India

**Time allocation (in hrs)**

Cycle No.	Cycle 8	Cycle 9
Time requested	2413	3593
Time allotted	1945	1791

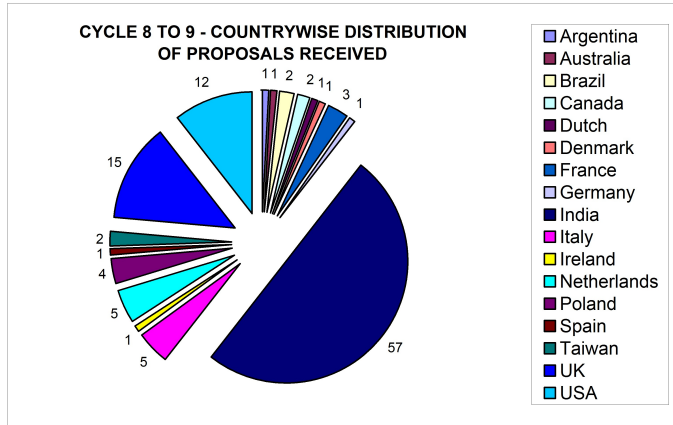
**Proposals received (in nos.)**

Category	Cycle 8	Cycle 9
PI from NCRA/TIFR	13	12
PI from India *	10	22
PI from abroad	31	26
All proposals	54	60

**COUNTRYWISE PROPOSALS RECEIVED**

Country	Nos
Argentina	1
Australia	1
Brazil	2
Canada	2
Dutch	1
Denmark	1
France	3
Germany	1
India	57
Italy	5
Ireland	1
Netherlands	5
Poland	4
Spain	1
Taiwan	2
UK	15
USA	12
<b>Total</b>	<b>114</b>

**CYCLE 8 TO 9 - COUNTRYWISE DISTRIBUTION OF PROPOSALS RECEIVED**



\* other than NCRA/TIFR

**Ooty Radio Telescope**

**ORT performance measurements at high declinations:** The declination coverage of ORT was increased to  $\pm 60$  degrees some time back. And many scientists wanted to know the actual performance of the array at higher declinations. To establish this many sources at all declinations were observed and an internal report was prepared on this measurements. [A.J. Selvanayagam and D. Nandagopal]

**Solar observing facility**

For CALLISTO (solar spectrograph for IHY program) setup, the Radio Astronomy Centre, Ooty, has been identified as a station in India. For this setup two log periodic antennas for both polarizations usable from 50 to

1000 MHz with about 6 to 8dB gain were made. Since the spectrograph receiver is expected to arrive shortly, regular monitoring is done using these set of antennas. [A.J. Selvanayagam and D. Nandagopal]

## Computing Facilities

Many high end PCs were installed for offline analysis of GMRT data. Adequate redundancy is built into offline data analysis network to enable trouble free operation. This enables astronomers and engineers to analyse data in a reasonable time. NCRA-TIFR link is upgraded to 256Kbps. This link along with the existing link of 1024Kbps internet link via VSNL is used by astronomers and engineers to access internet resources at high speed.

**Internet connectivity to RAC:** RAC had been using dialup internet connection till mid 2005. Now a 64 Kbps dedicated line with fixed ip internet connectivity is established.

## Library

Approximately 300 books were added to the collection at NCRA, Pune and GMRT observatory library during the financial year 2005-2006. The library subscribed to approximately 110 journals; this year three more journals were added to the GMRT library entitled IETE Technical Review, IETE Journal of Education and IETE Journal of Research.

The NCRA library initiated digitization efforts to scan material available in the library which had an archival value, with the help of a flatbed scanner available in the library. This is an ongoing activity and we plan to digitize more collections in near future. After scanning it was necessary to organize these collections and make them available to the library users online. The following collections are currently made available to the library users through library web page: © ASP Slides (contains around 600 slides) © CD-ROM's collection (contains around 650 records) © GMRT Publications (contains around 130 papers) © NCRA Technical Reports (contains around 200 technical reports) © ORT Publications (contains around 100 papers)

For maintaining these databases open source software tools such as MySQL relational database and PHP scripting language were used. These web based services have been found very useful to the library users all over the world. All these databases can be accessed from <http://www.ncra.tifr.res.in/~library> with different search options.

**Institutional Repository Initiative:** During last year library initiated an institutional repository of the digital collections available in the library. The repository is implemented through DSpace Open Source Digital Library software. Dspace is an open source digital repository software system for research institutions which helps to organize digital collections available in the library. The software is jointly developed by MIT libraries and Hewlett-Packard Labs. Academic members at NCRA can submit their preprints, published papers, working papers, lecture notes, technical reports etc. in DSpace@NCRA repository.

Currently the DSpace@NCRA repository includes collections such as newspaper clippings, preprints, graduate school reports, NCRA theses, talks & presentations of members of the group, lecture notes and GMRT images. More details about this repository can be found at <http://ncralib.ncra.tifr.res.in/dspace> [S.A. Barve, S.N. Dongare]

## National and International Involvement

### **S. Ananthakrishnan**

Vice Chairman, Commission J (Radio Astronomy), URSI, (2005-2008)

Member, EMT and Site Selection Committee, Square Kilometer Array

### **Gopal Krishna**

Member, SOC, 4<sup>th</sup> Korean Astrophysical Workshop (Daejong, S. Korea)

Member, SOC, 3<sup>rd</sup> ASTROSAT Workshop, held in Udaipur (Dec, 2005)

Convenor, GMRT Time Allocation Committee (GTAC) (until Jan, 2006)

Adjunct Professor, ARIES

### **A.W. Joshi**

Chief Advisor, NCERT Class XI/XII Physics books.

Chairman, Physics Group, SET (Maharashtra)

Member, Course Design Committee for revised version of Course Optics  
(PHE-09), IGNOU, New Delhi

Chairman, HSC Physics books, NCERT, Delhi

### **B.C. Joshi**

Member, Parkes Multibeam high latitude pulsar survey team

### **P.K. Manoharan**

Convenor, Solar Terrestrial Session (ST01), Asia Oceania Geosciences Society  
(AOGS) Conference, Singapore, June 20 - 24, 2005.

Member, Scientific Organizing Committee, International Solar Workshop on  
Transient Phenomena on the Sun and Interplanetary medium, ARIES,  
Nainital, April 5 - 8, 2005.

Secretary, Heliospheric Physics, Solar Terrestrial Section, Asia Oceania  
Geosciences Society.

Chairman, National Advisory Committee for the International Heliophysical  
Year India Program

Member, ADCOS Science Panel (ASP) of ISRO on Space Weather - Science  
and Applications

Chief convenor, General Session on 'Sun and Heliospheric Physics', Asia  
Oceania Geosciences Society (AOGS), 3rd meeting

Convenor of session on Space Weather Research: Theory, Modeling and  
Prediction (SH04), Western Pacific Geophysics meeting by American  
Geophysical Union, Beijing, China.

**Rajaram Nityananda**

Editor, Journal of Astronomy and Astrophysics

Member, Steering Committee, Australia Telescope National Facility,  
Australia.

**A. Pramesh Rao**

Member, International SKA Steering Committee.

**Nirupam Roy**

Member, LOC, 9th Young Astronomers' Meet 2005

**D.J. Saikia**

Associate Editor of the Bulletin of the Astronomical Society of India;

Member of the advisory committee for the Space Physics Centre, Kolkata.

Guest Editor of the Proceedings of the 23<sup>rd</sup> Meeting of the Astronomical  
Society of India.

## Visits

### **Ayesha Begum**

International Union of Radio Sciences (URSI) meeting  
New-Delhi, India, 23–29 October, 2005

ASTRON, Dwingeloo  
The Netherland, 21–23 December, 2005

Max Planck Institut fur Astronomie  
Heidelberg, Germany, 4–7 January, 2006

Leiden Observatory, Leiden  
The Netherland, 8–9 January, 2006

Kapteyn Astronomical Institute  
Groningen, The Netherland, 10–11 January, 2006

Argelander-Institut der Universitat Bonn, Radioastronomie,  
12–14 January, 2006

### **Ekta**

28th General Assembly of the URSI  
New Delhi, October 23 – 29, 2005.

### **Y. Gupta**

Preliminary Design Review Meeting for the EVLA Correlator Project  
DRAO, Penticton,  
July 10 -- 15, 2005.

XXVIII URSI General Assembly  
New Delhi, October 23 -- 28, 2005.

### **B.C. Joshi**

XXVIII General Assembly of Radio Science (URSI)  
New Delhi, India, October 23 - 29, 2005



CDAC and CERN Collaborative Workshop on GRID and High-Speed  
Networking  
Pune, February 24, 2006

**N.G. Kantharia**

SKA meeting  
NCRA-TIFR, Pune  
October 31–November 3, 2005.

28th General Assembly of the URSI  
New Delhi, October 23 – 29, 2005.

29th meeting of the ICRC  
TIFR Pune  
August 3–10, 2005.

**D.J. Saikia**

Raman Research Institute  
June 2005

Jodrell Bank Observatory, University of Manchester; the Astrophysics  
Research Institute, Liverpool John Moores University, Birkenhead and  
Department of Physics and Astronomy, University of Hertfordshire,  
Hertfordshire  
February–March 2006.

**Chiranjib Konar**

Jagiellonian University Astronomical Observatory, Poland, and Dwingeloo  
Observatory, The Netherlands,  
May–July 2006.

**Awards and Distinctions**

**Ayesha Begum**

Young Scientist Award, International Union of Radio Sciences (URSI)

## **A.W. Joshi**

II<sup>nd</sup> prize, Hindi popular book HAMARA SAURPARIVAR (हमारा सौरपरीवार),  
Rajbhasha Directorate of DRDO, New Delhi, August 2005

## **Invited Talks**

### **S. Ananthakrishnan**

The Square kilometer Array - A global project in Radio Astronomy,  
ASET Forum Colloquium, TIFR, Mumbai  
June 10, 2005

The Giant Metrewave Radio Telescope (GMRT) - Salient Features and Recent  
Results  
29th International Cosmic Ray Conference (ICRC 2005), NCRA,  
University of Pune  
August 4, 2005

Chandrayaan I - The Indian Moon Mission  
61st year of Jyotir Vignan Parisanstha, Fergusson College, Pune  
August 21, 2005

Chandrayaan I - The Indian Moon Mission  
St. Joseph's College, Nainital,  
August 31, 2005

J.C. Bose and growth of radio astronomy in India  
URSI GA pre-symposium, New Delhi  
October 2, 2005

J.C. Bose and his contribution to radio science,  
Institute of radio Physics and Electronics, Calcutta University, Kolkata  
January 27, 2006

Einstein's relativity and its radio astronomy connection  
Einstein Symposium, Dept. of Physics, Viswa-Bharati, Santiniketan, India,  
January 28-29, 2006

## Sun and the near space environment

a series of 3 talks to Indian Airforce Officers, Space Science Dept., Pune University

February 1-3, 2006

## Solar radio astronomy with GMRT,

'International Living With the Star' (ILWS) conference, Goa, India

February 13-18, 2006

## Antennas

Lecture course for MSc (Electronics), Pune University

January 15 - February 10, 2006

## GMRT and Solar radio astronomy

Air Force Research Lab., Boston, USA

April 18-20, 2006

## Murray and his interactions with the Indian IPS'ers

Dr. Murray Dryer's 80th birthday celebrations, Boulder, Colorado, USA,

April 28, 2006

## **Ayesha Begum**

### A study of HI in faint dwarf galaxies

ASTRON, Postdoctoral Interview talk

Dwingeloo, The Netherland, December 21, 2005,

### Radio astronomy with the GMRT

Young Astronomers' Meeting (YAM)

IUCAA, India, November 29, 2005,

## **Gopal Krishna**

### Intranight variability of blazars

Science from HCT, IIA, Bangalore

January, 21-22, 2006

AGN and Unification,

two lectures, 3rd ASTROSAT Workshop, M.L. Sukhadia University,  
Udaipur

December, 2005.

**Y. Gupta**

Data Transport and Signal Processing at the GMRT

XXVIII URSI General Assembly

New Delhi, October 23 -- 28, 2005.

**B.C. Joshi**

A software baseband receiver for pulsar astronomy at GMRT

XXVIII General Assembly of Radio Science (URSI)

New Delhi, India, October 27, 2005

**P.K. Manoharan**

Solar wind density turbulence caused by coronal mass ejection,

International Solar Workshop on Transient Phenomena on the Sun and  
Interplanetary medium,

ARIES, Nainital, April 5 - 7, 2005.

International Heliophysical Year (IHY) Program in India

Asia Oceania Geosciences Society (AOGS), 2nd Annual Meeting,

June 20-24, 2005, Singapore.

Scintillation and white-light measurements of coronal mass ejections between  
Sun and 1 AU'

Indo-Chinese workshop on Recent Advances in Solar Physics

Indian Institute of Astrophysics, Bangalore, November 7-11, 2005.

Radio scintillation imaging of coronal mass ejection from sun to earth  
distance'

General Assembly of International Union of Radio Science (URSI),

New Delhi, October 23-29, 2005.

International heliophysical year program in India

UN/ESA/NASA/UAE Workshop on the IHY 2007

Abu-Dhabi, United Arab Emirates, November 20-23, 2005.

Current trends and future prospective of the physics of the interplanetary medium pertaining to space weather'

National Space Science Symposium

Visakhapatnam, February 9-12, 2006.

The International Heliophysical Year (IHY) Program in India,

International Living With a Star Workshop on Solar Influence on the Heliosphere and Earth's Environment

Goa, February 19-24, 2006.

IPS Imaging of quiet and transient solar wind in the Sun-Earth distance,

International Living With a Star Workshop on Solar Influence on the Heliosphere and Earth's Environment

Goa, February 19-24, 2006.

Space weather program in India,

International Living With a Star Workshop on Solar Influence on the Heliosphere and Earth's Environment

Goa, February 19-24, 2006.

Recent Developments in Science

Key note address at the 2nd National Level Science Symposium 2006

Christ College, Rajkot, January 7, 2006.

### **D.J. Saikia**

Active Galactic Nuclei (two lectures),

Refresher course and VSP/VSRP programme,

IUCAA, Pune, June 2005

Starburst galaxies and AGN connection,

Third Astrosat workshop on Active Galactic Nuclei,

Udaipur, December 2006

## Conference Organised



The 9th Young Astronomers' Meet 2005 was jointly organised by NCRA, IUCAA and DST. A total of 81 research scholars from various institutes and university students across the country participated in the meet. Other than special evening colloquia, talks and poster presentations, a trip to the GMRT Observatory and IUCAA Girawali Optical Telescope was also arranged. [Nirupam Roy]

**International Cosmic Ray Conference:** NCRA was the venue for the International Cosmic Ray Conference hosted by TIFR, Mumbai. All the administrative support for holding the conference such as catering, transport, were made by NCRA. A visit to GMRT was also arranged. [K.P. Balakrishnan]

**Square Kilometer Array International Meeting 2005:** Over the period October 31 to November 5 more than one hundred radio astronomers and engineers from around the world met in Pune to discuss the scientific plans and engineering specifications for the Square Kilometer Array. The meeting was one of a regular annual planning exercise for what will be the most complex telescope ever built. The meeting resulted in an update of the key science projects that the SKA will address. At presentations made in Pune astronomers emphasized the unique role that SKA will play in addressing some of the fundamental physics questions of our time.

The design and construction of this giant telescope, which will stretch across the continent on which it is built, is a massive engineering challenge. There were a series of



*Delegates of the SKA 2005 meeting at the Giant Metrewave Radio Telescope.*

meetings on all engineering aspects, from the individual sub-systems to the complex software required to control the array and process the data. There were also highly productive joint discussions between the astronomers and the engineering working groups.

The meeting culminated in a 2-day session of the International SKA Steering Committee; this body controls the overall direction of the project and consists of representatives from 13 countries, including India. The Steering Committee discussed, among other things, the process of selecting a site for the SKA and the selection of a reference design for the array. It approved a budget for the international project office for 2006 and developed plans for an extensive outreach programme.

All those involved in the meetings in Pune thoroughly enjoyed the discussions and interactions with their Indian colleagues, especially those from the Indian industry. One of the highlights of the trip was a visit to the GMRT, one of the largest telescopes in the world. One of the great benefits of involvement in international projects is the knowledge that we can do far more together than we could ever do as individual nations. [A. Pramesh Rao]

## **Non DAE Research Projects**

The following electronic sub-systems for Brazilian Decametric Array have been designed and handed over to Prof. H.S. Sawant, INPE, Brazil. (a) 10 MHz to 3 GHz bandwidth solar attenuator with switchable attenuation values of 0 dB, 10 dB, 20 dB, 30 dB and termination. (b) 10 MHz to 3 GHz bandwidth 0-31 dB attenuator, variable in steps of 1 dB. (A. Praveenkumar, Anil N. Raut, Vilas Bhalerao)

## **Publications**

### **In Journals**

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Tracking pulsar dispersion measures using the Giant Metrewave Radio Telescope

*MNRAS*, **357**, 1023 (2005).

- G. C. Anupama & N. G. Kantharia  
RS Ophiuchi  
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Gas distribution, kinematics and star formation in faint dwarf galaxies,  
*MNRAS*, **365**, 1220 (2006)
- Ayesha Begum & Jayaram N. Chengalur,  
A search for HI in some peculiar faint dwarf galaxies  
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Filling Factors and scale heights of the DIG in the Milky Way  
*AN*, **327**, 81, (2006)
- M. Burgay, B.C. Joshi, N. D'Amico, A. Possenti, A.G. Lyne, R.N. Manchester,  
M.A. McLaughlin, M. Kramer, F. Camilo, P.C.C. Freire  
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*MNRAS*, **368**, 283, (2006)
- M. Burgay, A. Possenti, R.N. Manchester, M. Kramer, M.A. McLaughlin,  
D.R. Lorimer, I.H. Stairs, B.C. Joshi, A.G. Lyne, F. Camilo, N. D'Amico,  
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Neeraj Gupta, D.J. Saikia

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Neeraj Gupta, C.J. Salter, D.J. Saikia, T. Ghosh, S. Jeyakumar

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Outflowing material in the compact steep-spectrum source quasar 3C 48: evidence of jet-cloud interaction?

*MNRAS*, **361**, 451, (2005)

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Associated 21-cm H<sub>I</sub> absorption towards the radio galaxy 3C452 (J2245+3941).

*MNRAS*, in press (astro-ph/0605428), (2006)

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The Discovery of PSR J1833-1034: the pulsar associated with the supernova remnant G21.5-0.9

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Shubhendu Joardar

RFI Monitoring System of GMRT and Radio Interference Analysis on  
Various Radio-Astronomy Bands

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Shubhendu Joardar and Asit Baran Bhattacharya

New Design for Extremely Broad Band VHF/UHF/Microwave Dual  
Polarized Antenna Feeds

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New Designs of Ultra Wideband Dual Polarized Antenna Feeds for  
Broadband and Ultra Broadband Satellite and Microwave Links

*Proc. National Conference on Broadband Communication Systems,  
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August 3 - 10, 2005.

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## In Books

- Gopal-Krishna and P. J. Wiita  
Asymmetries in Powerful Extragalactic Radio Sources: *Invited Review*  
In "21st Century Astrophysics" (eds: S. K. Saha & V. K. Rastogi)  
Anita Publications, New Delhi (2005)

## Books/Book Reviews

- A W Joshi and Suresh Chandra,  
The Solar System for Pedestrians  
NCERT, Delhi, May 2006

## Technical Reports/Internal Reports

- S. Ananthkrishnan and Gopal Krishna  
"Science with GMRT", a booklet prepared for the URSI meeting, New  
Delhi, October, 2005
- A. Praveen Kumar, Anil N. Raut, Vilas Bhalerao  
Dynamic Range of the L-Band Front-End Receiver.
- A. Praveen Kumar, Anil N. Raut  
Developments in Low Noise Receiver Technologies,
- A. Praveen Kumar, Anil N. Raut, Vilas Bhalerao  
35 - 200 MHz Front-End for GMRT,
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Ranga Rao  
Feasibility Study for Conducting Wind Profiler Experiment with GMRT  
Antenna,
- S. Suresh Kumar, A. Praveen Kumar, Vinod Pacharne, M. Gopinathan  
Broadband Distributed Feedback Laser Based Analog Fiber-Optic Link



## Lectures at NCRA

### Astronomy and Instrumentation Seminar

**Govind Swarup:** Frontiers in Radio Astronomy in Science and Engineering  
May 23, 2005

**Neeraj Gupta:** Outflowing material in the CSS quasar 3C48  
May 27, 2005

**Aniket Sule,** *Univ. of Potsdam, Germany:* Formation and Stability of the Solar  
Tachocline  
July 1, 2005

**Nazirah Jetha,** *Univ. of Birmingham, UK:* AGN Interactions in Galaxy Groups  
and Clusters  
July 8, 2005

**Jeremy Lim,** *ASIAA, Taiwan:* Testing Fragmentation Models for Forming  
Binary/Multiple Protostars  
July 19, 2005

**Paul J. Wiita,** *Georgia State Univ., Atlanta, USA:* Accretion disks, jets and  
blazars  
August 5, 2005

**Simon Johnston,** *ATNF, CSIRO, Australia:* Evidence for alignment between  
the spin and velocity vectors in pulsars  
November 4, 2005

**Ramesh Bhat,** *Swinburne University:* Galactic pulsar census with ALFA:  
Progress and highlights  
November 10, 2005

**S. Sarala:** Software Development for Pulsar Search Data Analysis  
December 5, 2005

**Ayesha Begum:** The GMRT HI study extremely faint Dwarf Galaxies (Ph.D Thesis Seminar)  
December 12, 2005

**Sergio Mendoza,** *Instituto de Astronomia, Mexico:* Possible hydrodynamical relations in astrophysical jets and internal shock waves inside relativistic jets with time-dependent velocities  
December 16, 2005

**S. Sirothia:** Radio Continuum survey of the sky (-54 deg. to 90 deg.) At MHz using GMRT Single Dish: Status Report II  
December 22, 2005

**Avinash A. Deshpande,** *RRI, Bangalore:* Further evidence for collimated particle beams from pulsars  
December 23, 2005

**Mark Whittle,** *Univ. of Virginia, USA:* Seyfert jets: weak, slow and heavy  
January 12, 2006

**Andrew Fletcher,** *Univ. of Newcastle:* Radio Polarization observations of the Whirlpool galaxy: magnetic fields, cosmic rays and spiral structure in M51  
January 13, 2006

**Tracy Clarke,** *NRL, USA:* Radio and X-ray Observations of Cooling Core Clusters  
February 8, 2006

**B C Joshi:** A software based base band Receiver for Pulsar Astronomy with GMRT - PSBR  
February 17, 2006

### **Student Seminar**

**Ayesha Begum:** (*Ph.D. Synopsis Seminar*) An HI study of extremely faint dwarf galaxies  
May 20, 2005

**Smriti Mishra**, *Univ. of Chicago*: Minimizing Mean Square Facet Error for a 12 Meter Telescope  
September 1, 2005

**Informal Discussion Group (with IUCAA)**

**Neeraj Gupta**: Galactic Wind Shells and High Redshift Radio Galaxies: On the Nature of Radio Absorbers(Based on:astro-ph/0503322)  
April 1, 2005

**Manoj Puravankara**, *IUCAA*: Direct detection of thermal emission from extrasolar planets by Spitzer Space Telescope  
April 1, 2005

**Nimisha Kantharia**: Dense Cloud Ablation and Ram Pressure Stripping of the Virgo Spiral NGC 4402, by Hugh H.Crowl, Jeffrey D.P. Kenney, J.H.van Gorkom and Bernd Vollmer, astro-ph/0503422  
April 15, 2005

**Arman Shafieloo**, *IUCAA*: Uncorrelated Measurements of the Cosmic Expansion History and Dark Energy from Supernovae, by Yun Wang and Max Tegmark, astro-ph/0501351  
April 15, 2005

**Naresh Dadhich**, *IUCAA*: Detecting extra dimensions with gravity wave spectroscopy: the black string brane-world By Sanjeev Seahra, Chris, Clarkson & Roy Maartens, Phys. Rev. Letters, 40 (2005) 121302.  
April 29, 2005

**Naresh Dadhich**, *IUCAA*: Black holes in Gauss-Bonnet Gravity (Reference:Torii and H Maeda, Phy.Rev. D71 (2005) 124002, hep-th/0504127, /0504141)  
April 29, 2005

**B.C.Joshi**: A new(?) type of radio gun in the center of our Galaxy Based on Hyman et al. 2005, Nature, 434, 50  
April 29, 2005

**Jayaram Chengalur:** The star formation rate of the Universe at  $z = 6$  from the Hubble Ultra-Deep Field<sup>'''</sup> Based on Bunker et al. MNRAS vol.355, pp 374, (2004).

May 6, 2005

**Prasad Subramanian, IUCAA:** The Sun as a MHD generator: a new heating mechanism for coronal loops and closed magnetic field structures? By David Tsiklauri, 2005, submitted to A & A, astro-ph/0503702

May 6, 2005

**Ayesha Begum:** A giant flare from the magnetar SGR 1806-20 and the radio afterglow Based on the papers by Gaensler et al. Nature 434 (2005), 1104 & Palmer et al. Nature 434 (2005), 1107

May 20, 2005

**Atul Deep, IUCAA:** New constraints on MOND from galaxy clusters by Pointecouteau E. and Silk J. astro-ph 0505017

May 20, 2005

**Nirupam Roy:** An Observational Pursuit for Population III Stars in a Ly-alpha Emitter at  $z=6.33$  through H $\alpha$  Emission Based on astro-ph/0508443.

August 26, 2005

**S. Ananthakrishnan:** Detection and imaging of atmospheric radio flashes from cosmic ray air showers

September 9, 2005

**Asim Mahmood, IUCAA:** Financial markets and the Physicists perspective: Black-Scholes & beyond

September 9, 2005

**Bhaswati Bhattacharyya:** The geometry of the double-pulsar J0737-3039 from systematic variations (2004, Nature,428,919)

September 23, 2005

**Saumyadip Samui, IUCAA:** Global star formation rate of the Universe

September 23, 2005

- Ananda Hota:** Abnormal tails of normal galaxies (Oosterloo & van Gorkom 2005, *A & A*, 437, L19 Gavazzi et al. 2001, *ApJ*, 563, L23)  
October 7, 2005
- Gaurang Y. Mahajan,** *IUCAA*: Three new 'directions' could explain astronomical puzzle (astro-ph/0508572)  
October 7, 2005
- V K Kulkarni:** Direct evidence of the receding 'torus' around central nuclei of powerful radio sources ( T.G. Arshakian published in *A & A*, 436, 817 (2005)  
October 14, 2005
- Ranjeev Misra,** *IUCAA*: A dark jet dominates the power output of the stellar black hole Cygnus X-1 (Gallo et al.2005, *Nature*, 436, 8190)  
October 14, 2005
- Gopal Krishna:** Discovery of a bright quasar without a massive host galaxy (P.Magain et al. *Nature*, 437, 381 (2005)  
November 11, 2005
- Suryadeep Ray,** *IUCAA*: Towards Optimal Parallel N-Body Codes: PMFAST (Hugh Merz, Ue-Li Pen and Hy Trac *New Astronomy* 10 (2005), 393-407)  
November 11, 2005
- Dipanjan Mitra:** The Magnetic Field of the Large Magellanic Cloud Revealed Through Faraday Rotation (Gaensler et al. *Science* 11 March 2005: Vol.307.no.5715, pp. 1610 - 1612)  
November 25, 2005
- Arman Shafieloo,** *IUCAA*: Comparison of the Legacy and Gold SNIa Dataset Constraints on Dark Energy Models (S. Nesseris, L. Perivolaropoulos astro-ph/0511040)  
November 25, 2005

**Yashwant Gupta:** A Pulsar Bonanza in Terzan 5 (Ransom et al. Science, Vol 307, 11 Feb 2005)  
December 9, 2005

**R. Srianand, IUCAA:** Implications for the Cosmic Reionization from the Optical Afterglow Spectrum of the Gamma-Ray Burst 050904 at  $z = 6.3$  (Totani et al. astro-ph/0512154 and Kawai et al. astro-ph/0512052)  
December 9, 2005

**C.H. Ishwara Chandra:** GRB AT  $Z = 6.296$  (Based on, two papers appeared in Nature, March 9, 2006)  
March 17, 2006

**Kandaswamy Subramanian, IUCAA:** Significant Primordial Star Formation At Redshifts  $Z = 3 - 4$  ( Based of, Raul Jimenez and Zoltan Haiman, astro-ph/0602450)  
March 17, 2006

**Susmita Chakravorty, IUCAA:** The Afterglows and host Galaxies of Short GRBs (Based on, Edo Berger, 2006, astro-ph/0602004)  
March 31, 2006

**Dipanjan Mitra:** A Neutron Star with a Massive Progenitor in Westerlund 1 (Based on, Muno, et al., 2006, Apj, 636, L41)  
March 31, 2006

## Lectures / Lecture Courses Given Elsewhere

### Sunita Barve

Open Source Digital Library Software  
Management of Libraries in Digital Environment, YASHADA, Pune  
January 20, 2006.

### Neeraj Gupta

Probing radio source environments via absorption lines  
Young Astronomers' Meeting, IUCAA  
November 2005

**Y. Gupta**

The GMRT: Current Status and Future Plans

SKA 2005 Conference

Pune

October 31 - November 4, 2005.

**Ananda Hota**

Gas loss processes in gas-rich galaxies

Young Astronomers' Meeting, IUCAA

November 2005.

**A.W. Joshi**

Two lectures to participants of Navodaya Vidyalaya Samiti HSC Physics

Teachers

IGNOU, New Delhi,

October 26, 2005

Five sessions in Coaching Workshop on NET/SET Preparation in Physics

SRTM University, Nanded,

January 10-12, 2006

Conducted a Workshop of HSC physics teachers belonging to Jawahar

Navodaya Vidyalayas, sponsored by IGNOU/NVS, gave lectures and

clarified pedagogic points, showed experiments and demos

May 25-26, 2006

**N.G. Kantharia**

GMRT Time Scheduling: Present and Future

Academy-Industry Interaction, one day meeting held at NCRA to discuss possible joint projects with TCS and TRDDC engineers

February 3, 2006.

GMRT Observations of the group Holmberg 124 + Preliminary results on the groups Holmberg 377 and Holmberg 565  
28th General Assembly of the URSI, Delhi  
October 23 to 29, 2005.

Galactic Astronomy  
VSRP and Radio Astronomy School,  
May 25, 2005.

### **Chiranjib Konar**

Giant radio sources  
XXVIIIth General Assembly of URSI, New Delhi  
October 2005.

A study of giant radio galaxies  
NFRA, Dwingeloo, The Netherlands  
July 2005.

### **P.K. Manoharan**

Solar Magnetism  
Physics Department, Bharathiyar University, Coimbatore  
July 28, 2005.

Current Trends in Solar Physics  
Physics Department, Saurashtra University, Rajkot  
January 9, 2006.

### **J. Roy**

GMRT: A technological and scientific milestone in Indian science  
YAM2005, IUCAA, Pune  
November 29 - December 2, 2005

Evaluation of Frequency Standard using Inter-Comparison Techniques and Pulsar Data  
URSI2005, New Delhi.  
October 2005.



## **D.J. Saikia**

Outflows in nearby galaxies

Raman Research Institute, Bangalore  
June 2005

GMRT and radio studies of nearby active galaxies

Astrophysics Research Institute, Liverpool John Moores University,  
Birkenhead, England  
March 2006.

Episodic activity in radio galaxies

Astrophysics Research Institute, Liverpool John Moores University,  
Birkenhead, England  
March 2006.

A new double-double radio galaxy

Jodrell Bank Observatory, England  
March 2006.

H<sub>I</sub> absorption studies in radio sources

Jodrell Bank Observatory, England  
March 2006.

Double-double radio galaxies

School of Physics, University of Hertfordshire, England  
March 2006.

Testing AGN unification schemes using H<sub>I</sub> absorption

School of Physics, University of Hertfordshire, England  
March 2006.

## **Lectures**

### **K. Kalyanasundaram**

K. Kalyana Sundaram

PC and GPS based ORT remote display system  
RAC Ooty, October 7, 2005.

G. Swarup, NCRA, Pune  
History of ORT  
RAC, Ooty, April 20, 2005

A.K. Sudheer, PRL, Ahmedabad:  
Atmospheric Aerosols  
RAC Ooty, February 2, 2006.

## Graduate Courses

### Gopal Krishna

Introduction to Astronomy and Astrophysics (1<sup>st</sup> semester)

Extragalactic Astronomy II (4<sup>th</sup> semester)

### A.W. Joshi

Quantum Mechanics

Statistical Mechanics

### D.J. Saikia

Interstellar medium

## Ph.D. Theses / M.Sc. Theses

Sayali Avachat, Department of Physics, Pune University:  
Radio interferometry and a study of radio galaxies, *M.Sc. project*.  
(Guides: D.J. Saikia and Vasant Kulkarni)

Ayesha Begum:  
A GMRT HI study of extremely faint dwarf galaxies, *Ph.D. thesis*  
(Guide: J.N. Chaganlur)

Jitendra Kodilkar, GMRT Observatory, Khodad:  
Multi-frequency Radio Continuum Observations of Nearby Spiral  
Galaxies: NGC 2997 and NGC 4565'  
M.Sc thesis, Pune University,  
(Guide: S. Ananthkrishnan; Co-Guide: N.G. Kantharia)

N. Roy:

A Multi-wavelength Investigation of the Temperature of the Cold Neutral ISM

M.Sc. Thesis, TIFR

(Guide: J.N. Chengalur)

### **VSRP Projects / Training of College Students**

Syed Arif and Gangadhar Rao, ME Students, VNIT, Nagpur:

Interface and data acquisition aspects of the different pulsar receivers used at the GMRT.

(Guide: Y. Gupta)

Vibhor Deshmukh, N.S. Ratnveel, Archana Shinde, M.Tech Students, IIT, Pune:

Signal Processing Algorithms for Software Correlator.

(Guide: J. Roy, Y. Gupta)

Dhanya, Indian Academy of Sciences, Bangalore:

Radio Study of UGC11909

(Guide: S. Ananthkrishnan; Co-Guide: N.G. Kantharia)

Ajay C. Lakade, Hemant D. Chaudhari, Ratnakar A. Ghodeswar,

Department of E&TC Engg., Dr. Babasaheb Ambedkar Technological University, Lonere, Dist. - Raigad:

200 - 450 MHz Quadrature Hybrid Using Lange Coupler

Guide: A. Praveenkumar

A. Sumathi, Alagappa University, Karaikudi:

Study of coronal mass ejections and geo-magnetic storms, M.Phil.

(Physics).

Guide: P.K. Manoharan

V. Ponni Pavai, Bannari Amman Institute of Technology (Anna University):

Astronomical Ray Detection using Digital Signal Processing, B.E. Project.

Guide: P.K. Manoharan

A. Nagarajan, Sri Ramakrishna Mission Vidyalaya College of Arts and Science, Bharathiyar University:  
Initiation of coronal mass ejections, M.Sc. (Physics) project.  
Guide: P.K. Manoharan

S.K. Kandhimathy Swarnam and A.S. Nisha, St.Xavier's Catholic College of Engineering, Anna University:  
High resolution measurements techniques in radio astronomy, B.E. project.  
Guide: P.K. Manoharan

P.V. Kavith and V. Antony Jesu Suhima, St.Xavier's Catholic College of Engineering, Anna University  
Lunar Occultation of radio sources, B.E. project.  
Guide: P.K. Manoharan

Tarak Thakore, Physics Dept, Pune University:  
A study of dark matter distribution in faint dwarf galaxies  
Guide: Ayesha Begum

Data analysis demonstration in tutorials by Ekta  
Radio Astronomy School  
NCRA, Pune May-June, 2005.

Eighty two students [B.E., M.Sc. (Physics), B.Sc.(Physics)] from various engineering and science colleges all over Tamil Nadu attended the in-plant training programme conducted at RAC, during June 2005.

About 135 batches (each batch of about 50 to 60 students and teachers), students of engineering and science departments visited RAC, Ooty.

## **Popular Science Articles / Lectures**

### **P.K. Manoharan**

Unit of Science

Popular lecture at the Providence College, Coonoor  
July 29, 2005.

Sub-atomic Particle to Universe

Public talk at the Aruvankadu Public School, Nilgiri District  
November 18, 2005.

A training programme for the Post Graduate Physics Teachers of Higher  
Secondary Schools, Nilgiri District, Tamil Nadu, was conducted at the  
Radio Astronomy Centre, on October 7, 2005. About 40 teachers  
participated and benefited in this training programme.

**N. Roy**

Music of the Spheres

Popular Astronomy talk on Solar system, Fergusson College, Pune,  
January 17, 2005