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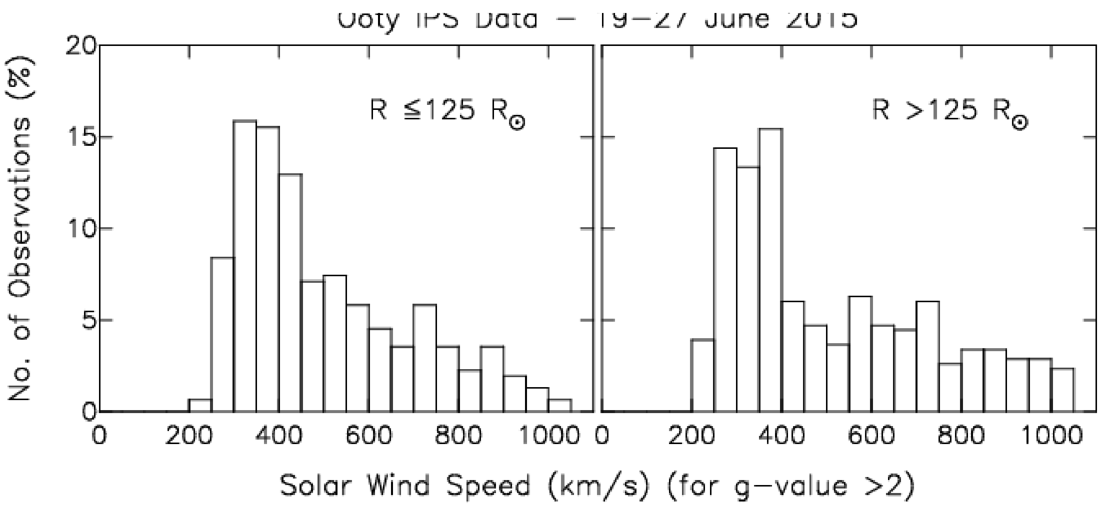
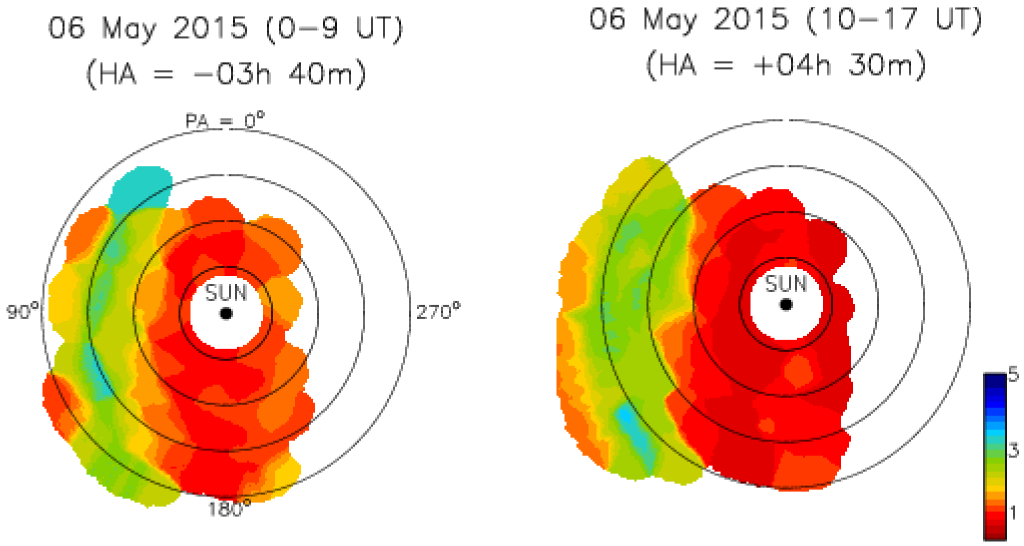
# Sun and Heliosphere

**Interplanetary Consequences of Coronal Mass Ejection Events occurred during 18–25 June 2015:** In this paper, we review the preliminary results on the propagation effects and interplanetary consequences of fast and wide coronal mass ejection (CME) events, occurred during 18–25 June 2015, in the Sun-Earth distance range. The interplanetary scintillation (IPS) images reveal that the large-scale structures of CME-driven disturbances filled nearly the entire inner heliosphere with a range of speeds, ∼300–1000 km/s. The comparison of speed data sets, from IPS technique results in the inner heliosphere and *in-situ* measurements at 1 AU, indicates that the drag force imposed by the low-speed wind dominated heliosphere on the propagation of CMEs may not be effective (refer to Figure 1). The arrival of shocks at 1 AU suggests that a shock can be driven in the interplanetary medium by the central part of the moving CME and also by a different part away from its centre. The increased flux of proton at energies  10 MeV is consistent with the acceleration of particles by the shock ahead of the CME. [*[P.K. Manoharan (NCRA), D. Maia (University of Porto, Portugal), A.  Johri (NCRA), and M.S. Induja [NCRA)*]




Histograms of solar wind speed estimates obtained from the Ooty IPS measurements at distances, respectively, ≤125 Rsun (left plot) and >125 Rsun (right plot). The y–axis marks the percentage of number of observations in each speed bin normalized by the total number of observations considered. These plots include speed data from sources for which the measured g-values are ≥2 and this criterion would allow only the enhanced level of scintillation caused by the propagating CME disturbances to be taken into account. It is evident in these plots that during the passage of CMEs, the interplanetary medium is filled with a range of speeds, ∼300–1000 km/s. However, as seen in the above plots, the evolution of high-speed wind (i.e., >500 km/s) between these two regions of the inner heliosphere (i.e., with respect to the midway between the Sun and Earth) is not significant.

**An Intense Flare–CME Event in 2015: Propagation and Interaction Effects Between the Sun and Earth's Orbit:** We report the interplanetary effects of a fast coronal mass ejection (CME) associated with the intense X2.7 flare that occurred on 05 May 2015. The near-Sun signatures of the CME at low-coronal heights [<2 Rsun] are obtained from the




Interplanetary-scintillation images observed with the ORT on 06 May 2015. In these "position angle–distance" diagrams, Sun is at the centre and concentric circles are of radii 50, 100, 150, 200 Rsun. The colour scale shows the normalised scintillation index. Time increases from the right-hand side of the image to the left-hand side of the image. The indicated hour angle [HA] positions correspond to the ORT pointing directions. The position angles [PAs] 0°, 90°, 180°, and 270°, respectively, correspond to North, East, South, and West of the Sun. The disturbance associated with the CME has expanded considerably in the IPS field of view and the comparison between these images clearly shows the propagation of the CME in the eastern direction with respect to the Sun

EUV images at 171 Å and metric radio observations. The intensity and duration of the CME-driven radio bursts in the near-Sun and interplanetary medium indicate this CME event to be an energetic one. The interplanetary-scintillation data, along with the low-frequency radio spectrum, played a crucial role in understanding the radial evolution of the speed and expansion of the CME in the inner heliosphere as well as its interaction with a preceding slow CME. Ooty IPS images are shown in Figure 2. The estimation of the speed of the CME at several points along the Sun to 1 AU trajectory shows that: i) the CME went through a rapid acceleration as well as expansion up to a height of ≈ 6 R , and ii) the CME continued to propagate at speed ≥800 km/s between the Sun and 1 AU. These results show that the CME likely overcame the drag exerted by the ambient/background solar wind with the support of its internal magnetic energy. When the CME interacted with a slow, preceding CME, the turbulence level associated with the CME-driven disturbance increased significantly. [*A. Johri and P.K Manoharan, NCRA*]

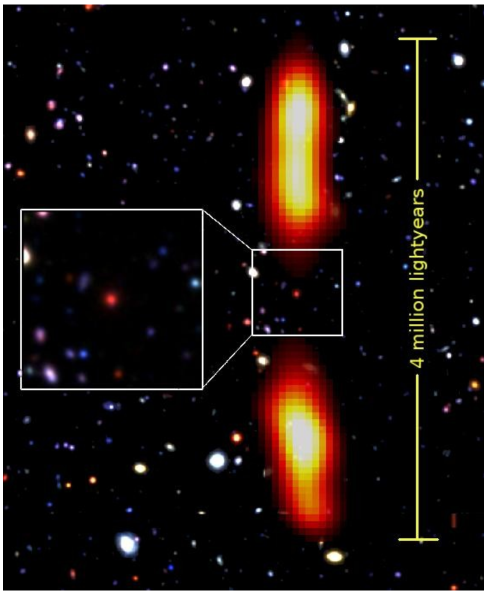
**Murchison Widefield Array Observations of Anomalous Variability: A Serendipitous Night-time Detection of Interplanetary Scintillation** : This study presents observations of high-amplitude rapid (2s) variability toward two bright, compact extragalactic radio sources out of several hundred of the brightest radio sources in one of the 30° x 30° Murchison Widefield Array (MWA) Epoch of Reionization fields using the MWA at 155 MHz. After rejecting intrinsic, instrumental, and ionospheric origins we consider the most likely explanation for this variability to be interplanetary scintillation (IPS), likely the result of a large coronal mass ejection propagating from the Sun. This is confirmed by roughly contemporaneous observations with the Ooty Radio Telescope. We see evidence for structure on spatial scales ranging from $<10^3$ to $10^6$ km. The serendipitous night-time nature of these detections illustrates the new regime that the MWA has opened for IPS studies with sensitive night-time, wide-field, low-frequency observations. This regime complements traditional dedicated strategies for observing IPS and can be utilized in real-time to facilitate dedicated follow-up observations. At the same time, it allows large-scale surveys for compact (arcsec) structures in low-frequency radio sources despite the 2' resolution of the array *[D.L. Kaplan (University of Wisconsin-Milwaukee), S.J. Tingay (Curtin University of Technology, Australia), P.K Manoharan (NCRA), et al.*]

**Low Frequency Radio Experiment (LORE) - A Baseline Design Study** : In this paper, we present a case study of Low Frequency Radio Experiment (LORE) payload to probe the corona and the solar disturbances at solar offsets greater than 2 solar radii, i.e., at frequencies below 30 MHz. The LORE can be complimentary to the planned Indian solar mission, "Aditya-L1" and its other payloads as well as synergistic to ground-based interplanetary scintillation (IPS) observations, which are routinely carried out by the Ooty Radio Telescope. We discuss the baseline design and technical details of the proposed LORE and its particular suitability for providing measurements on the detailed time and frequency structure of fast drifting type-III and slow drifting type-II radio bursts with unprecedented time and frequency resolutions. We also brief the gonio-polarimetry, which is possible with better-designed antennas and state-of-the-art electronics, employing FPGAs and an intelligent data management system. These would enable us to make a wide range of studies, such as nonlinear plasma processes in the Sun-Earth distance, *in-situ* radio emission from coronal mass ejections (CMEs), interplanetary CME driven shocks, nature of ICMEs driving decelerating IP shocks and space weather effects of solar wind interaction regions. [*P.K. Manoharan (NCRA), A. Naidu (NCRA), B.C. Joshi (NCRA), Jayashree Roy (NCRA), G. Kate, K. Pethe (College of Engineering, Pune), S. Galande (College of Engineering, Pune), S. Jamadar (College of Engineering, Pune), S.P. Mahajan (College of Engineering, Pune), and R.A. Patil (College of Engineering, Pune)* ]

**Satellite Mission Concepts Developed at the Alpbach 2013 Summer School on Space Weather** : This journal volume (Space Weather and Space Climate vol. 5, 2015) was edited by P.K. Manoharan. It contains articles on four mission concepts. A brief background: Sixty young, highly qualified European science and engineering students converge annually for stimulating 10 days of work in the Austrian Alps. In the above summer school, four teams were formed, each of which designed a space mission and was then judged by a jury of experts. Students learned how to approach the design of a satellite mission and explored new and startling ideas supported by experts. The Summer School Alpbach enjoys more than 30 years of tradition in providing in-depth teaching on different topics of space science and space technology, featuring lectures and concentrated working sessions on mission studies in self-organised working groups. The Summer School is organised by the Austrian Research Promotion Agency (FFG) and co-sponsored by the European Space Agency (ESA), the International Space Science Institute (ISSI), and the national space authorities of its member and cooperating states. [*P.K. Manoharan, NCRA*]

# Our Galaxy

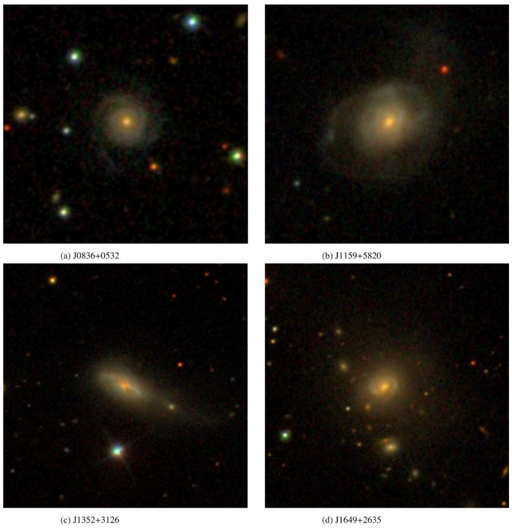
**Radio-Far-infrared Correlation in "Blue Cloud" Galaxies with 0 < z < 1.2:** We studied the radio-far-infrared (FIR) correlation in "blue cloud" galaxies chosen from the PRism MUltiobject Survey up to redshift (z) of 1.2 in the XMM-LSS field. We used rest-frame emission at 1.4 GHz in the radio and both monochromatic (at 70 µm) and bolometric (between 8 and 1000 µm) emission in the FIR. To probe the nature of the correlation up to z ~ 1.2, where direct detection of blue star-forming galaxies is impossible with current technology, we employ the technique of image stacking at 0.325 and 1.4 GHz in the radio and in six infrared bands, 24, 70, 160, 250, 350, and 500 µm. The stacking analysis allows us to probe the radio-FIR correlation for galaxies that are up to two orders of magnitude fainter than the ones detected directly. The k correction in the infrared wavebands is obtained by fitting the observed spectral energy distribution with a composite mid-IR power law and a single temperature graybody model. We find that the radio luminosity at 1.4 GHz is strongly correlated with monochromatic FIR luminosity at 70 µm having slope 1.09 ± 0.05 and with bolometric luminosity having slope 1.11 ± 0.04. Within the uncertainties of our measurement and the limitations of our flux-limited and color-selected sample, we do not find any evolution of the radio-FIR correlation with redshift.[*Yogesh Wadadekar with Aritra Basu (MPIfR, Germany), Alexandre Beelen (IAS, France), Veeresh Singh (UKZN, South Africa), K. N Archana (M. G. University).; Sandeep Sirothia, C. H. Ishwara-Chandra*]




This is an optical image with radio lobes (in yellow-red). The supermassive black hole in the red galaxy at the centre (zoomed in inset) has led to the formation of the giant radio lobes.

**A dying, giant radio galaxy in the distant Universe**: We have discovered a relic Giant Radio Galaxy (GRG) J021659-044920 at redshift z ~ 1.3 that exhibits large-scale extended, nearly co-spatial, radio and X-ray emission from radio lobes, but no detection of Active Galactic Nuclei core, jets and hotspots. The total angular extent of the GRG at the observed frame 0.325 GHz, using Giant Metrewave Radio Telescope observations is found to be ~2.4 arcmin, that corresponds to a total projected linear size of ~1.2 Mpc. The integrated radio spectrum between 0.240 and 1.4 GHz shows high spectral curvature with sharp steepening above 0.325 GHz, consistent with relic radio emission that is ˜8 X 10^6 yr old. The extended X-ray emission favours inverse-Compton scattering of the Cosmic Microwave Background (ICCMB) photons as the plausible origin. Using both X-ray and radio fluxes under the assumption of ICCMB we estimate the magnetic field in the lobes to be 3.3 µG. The magnetic field estimate based on energy equipartition is ~3.5 µG. Our work presents a extremely rare example of a GRG caught in dying phase in the distant Universe[*Yogesh Wadadekar with Prathamesh Tamhane (IISER-Pune), Aritra Basu (MPIfR, Germany),* *Veeresh Singh (UKZN, South Africa), C. H. Ishwara-Chandra, Alexandre Beelen (IAS, France), Sandeep Sirothia*]

**Discovery of rare double-lobe radio galaxies hosted in spiral galaxies:** Double-lobe radio galaxies in the local Universe have traditionally been found to be hosted in elliptical or lenticular galaxies. We have discovered four spiral-host double-lobe radio galaxies (J0836+0532, J1159+5820, J1352+3126, and J1649+2635) by cross-matching a large sample of ~187000 spiral galaxies from SDSS DR7 (Sloan Digital Sky Survey Data Release 7) to the full catalogues of FIRST (Faint Images of the Radio Sky at Twenty-cm) and NVSS (NRAO VLA Sky Survey). The host galaxies are forming stars at an average rate of 1.7-10 solar masses per year and possess supermassive black holes (SMBHs) with masses of a few times 10^8 solar masses. Their radio morphologies are similar to Fanaroff-Riley type II radio galaxies with total projected linear sizes ranging from 86 to 420 kpc. We proposed that the formation of spiral-host double-lobe radio galaxies can be attributed to more than one factor, such as the occurrence of strong interactions, mergers, and the presence of unusually massive SMBHs, such that the spiral structures are not destroyed. [*Yogesh Wadadekar with Veeresh Singh (UKZN, South Africa), C. H. Ishwara-Chandra, Jonathan Sievers (UKZN), Matt Hilton (UKZN), Alexandre Beelen (IAS, France)*]



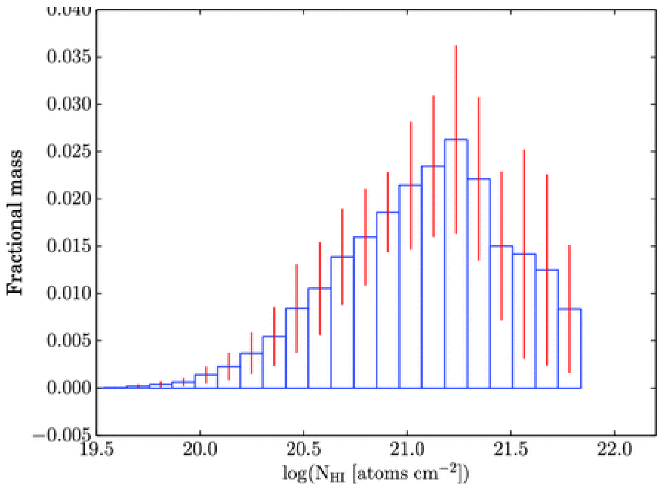

Optical images of the 4 newly discovered and extremely rare spiral galaxies, each of which hosts a large, double-lobed radio galaxy. From the 187,000 spiral galaxies searched, only these 4 galaxies were found to host FR-II type AGN

**Cosmic reionization after Planck:** Cosmic reionization holds the key to understand structure formation in the Universe, and can inform us about the properties of the first sources. By combining the recent release of Planck electron scattering optical depth data with observations of high-redshift quasar absorption spectra, we obtained strong constraints on viable reionization histories. We show that inclusion of Planck data favours a reionization scenario with a single stellar population. The mean neutral fraction drops from 0.8 at z = 10.6 to 0.0001 at z = 5.8, which indicates a significant reduction in contributions to reionization from high-redshift sources. We were able to put independent constraints on the escape fraction of ionizing photons by incorporating the high-redshift galaxy luminosity function data into our analysis. We obtained a non-evolving escape fraction of about 0.1 at $6<z<9$. [*Sourav Mitra (University of the Western Cape, South Africa), T. Roy Choudhury (NCRA), Andrea Ferrara (SNS, Pisa, Italy)*]

**Photon number conserving models of ionized bubbles during reionization**: Traditional excursion set based models of ionized bubble growth during the epoch of reionization are known to violate photon number conservation, in the sense that the mass fraction in ionized bubbles in these models does not equal the ratio of the number of ionizing photons produced by sources and the number of hydrogen atoms in the intergalactic medium. We demonstrated that this problem arises from a fundamental conceptual shortcoming of the excursion set approach which only tracks average mass fractions instead of the exact, stochastic source counts. With this insight, we built an approximately photon number conserving Monte Carlo model of bubble growth based on partitioning regions of dark matter into halos. Our model shows dramatic improvements in photon number conservation, as well as substantial differences in the bubble size distribution, as compared to traditional models. Along the way, we clarified some misconceptions regarding this problem that have appeared in the literature [*Aseem Paranjape (IUCAA, Pune), T. Roy Choudhury (NCRA), Hamsa Padmanabhan (IUCAA, Pune)*]

**Modelling the cosmic neutral hydrogen from DLAs and 21 cm observations:** There exist different analytical prescriptions in the literature to model the 21-cm (emission line surveys/intensity mapping experiments) and Damped Lyman-Alpha (DLA) observations of neutral hydrogen (HI) in the post-reionization universe. We attempted to reconcile the approaches towards a consistent model of the distribution and evolution of HI across redshifts. We found that a physically motivated prescription provides a good fit to the majority of the available data, but predicts a bias parameter for the DLAs which is in tension with the recent estimates from the clustering of DLA systems at $z \sim 2.3$. Our findings have significant consequences for the characteristic host halo masses of the DLAs and the power spectrum of 21-cm intensity fluctuations [*Hamsa Padmanabhan (IUCAA, Pune), T. Roy Choudhury (NCRA), A. Refregier (ETH, Zurich, Switzerland)*]

**The extremely gas rich Dwarf Galaxy And IV:** HST and GMRT observations are of the isolated dwarf irregular galaxy And IV allowed us to determine the galaxy distance of 7.17{??}0.31 Mpc using the Tip of Red Giant Branch method and show that the galaxy is extremely gas rich. The galaxy has a total blue absolute magnitude of -12.81 mag, linear Holmberg diameter of 1.88 kpc, and an HI-disk extending to 8.4 times the optical Holmberg radius. The HI mass-to-blue luminosity ratio for And IV amounts 12.9 in solar units. From the GMRT data we derived the rotation curve for the HI and fit it with different mass models. We found that the data are significantly




The fractional HI mass in the cold phase of the atomic ISM as a function of to HI column density. Above log( NHI) ??? 21.8 cold HI fraction drops to zero, consistent with the expected threshold column density for conversion of low metallicity (Z??? 0.1???Z???) gas into the molecular phase. From Patra et al., MNRAS,456,2467 (2016).

better fit with an iso-thermal dark matter halo, than by an NFW halo. We also found that the MOND rotation curve provides a very poor fit to the data. The fact that the iso-thermal dark matter halo provides the best fit to the data supports models in which star formation feedback results in the formation of a dark matter core in dwarf galaxies. The total mass-to-blue luminosity ratio of 162 (in solar units) makes And IV among the darkest dIrr galaxies known. However, its baryonic-to-dark mass ratio is close to the average cosmic baryon fraction [*Karachentsev, I. D.; Chengalur, J. N.; Tully, R. B.; Makarova, L. N.; Sharina, M. E.; Begum, A.; Rizzi, L.*]

**Cold Gas in Faint Dwarf Galaxies:** We presented the results of a study of the amount and distribution of cold atomic gas, as well its correlation with recent star formation in a sample of extremely faint dwarf irregular galaxies. Our sample was drawn from the Faint Irregular Galaxy GMRT Survey (FIGGS) and its extension, FIGGS2. We used two different methods to identify cold atomic gas. In the first method, HI spectra were decomposed into multiple Gaussian components and narrow Gaussian components were identified as cold HI. In the second method, the brightness temperature (TB ) is used as a tracer of cold HI. We find that the amount of cold gas identified using the TB method is significantly larger than the amount of gas identified using Gaussian decomposition. We found that the star formation rate density has a power-law dependence on the cold HI column density, but that the slope of this power law is significantly flatter than that of the canonical Kennicutt-Schmidt relation [*Patra, Narendra Nath; Chengalur, Jayaram N.; Karachentsev, Igor D.; Kaisin, Serafim S.; Begum, Ayesha* ]

**The GMRT High Resolution Southern Sky Survey [GHRSS]:** We conducted a survey for pulsars and transients using the GMRT viz., the GMRT High Resolution Southern Sky (GHRSS) survey. With 35% of the survey completed we reported the discovery of 10 pulsars, 1 of which is a millisecond pulsar (MSP), which is among the highest pulsar per square degree discovery rates for any off-Galactic plane survey. We re-detected 23 known in-beam pulsars. Utilising the imaging capability of the GMRT, we also localised four of the GHRSS pulsars (including the MSP) in the gated image plane within ??10???. We demonstrated rapid convergence in pulsar timing with a more precise position than is possible with single-dish discoveries. We also showed that we can localise the brightest transient sources with simultaneously obtained lower time resolution imaging data, demonstrating a technique that may have applications in the Square Kilometre Array [*Bhattacharyya, B.; Cooper, S.; Malenta, M.; Roy, J.; Chengalur, J.; Keith, M.; Kudale, S.; McLaughlin, M.; Ransom, S. M.; Ray, P. S.; Stappers, B. W.* ]

**HI Emission from a low redshift sub-DLA:** We presented HI 21 cm emission observations of the z ~ 0.00632 subdamped Lyman-?? absorber (sub-DLA) towards PG 1216+069 made using the Arecibo Telescope and the Very Large Array (VLA). The Arecibo HI 21cm spectrum corresponds to an H I mass of ~ 3.2 ?? $10^{\wedge 7}$ Msun, two orders of magnitude smaller than that of a typical spiral galaxy. This is surprising since in the local Universe the cross-section for absorption at high H I column densities is expected to be dominated by spirals. The HI 21cm emission detected in the VLA spectral cube has a low signal-to-noise ratio, and represents only half the total flux seen at Arecibo. Emission from three other sources is detected in the VLA observations, with only one of these sources having an optical counterpart. This group of HI sources appears to be part of complex `W', believed to lie in the background of the Virgo cluster. While several HI cloud complexes have been found in and around the Virgo cluster, it is unclear whether the ram pressure and galaxy harassment processes that are believed to be responsible for the creation of such clouds in a cluster environment are relevant at the location of this cloud complex. The extremely low metallicity of the gas, ~1/40 solar, also makes it unlikely that the sub-DLA consists of material that has been stripped from a galaxy. Thus, while our results have significantly improved our understanding of the host of this sub-DLA, the origin of the gas cloud remains a mystery [*Chengalur, Jayaram N.; Ghosh, T.; Salter, C. J.; Kanekar, N.; Momjian, E.; Keeney, B. A.; Stocke, J. T.* ]

**The spatially resolved K-S relation in atomic gas dominated regions:** We studied the Kennicutt-Schmidt (K-S) relation between average star formation rate (SFR) and average cold gas surface density in the HI-dominated ISM of nearby spiral and dwarf irregular galaxies. We divided galaxies into grid cells varying from sub-kpc to tens of kpc in size. Grid-cell measurements of low SFRs using H?? emission can be biased and scatter may be introduced because of non-uniform sampling of the IMF or because of stochastically varying star formation. In to alleviate these issues, we use far-ultraviolet emission to trace SFR, and we summed up the fluxes from different bins with the same gas surface density to calculate the average ??SFR at a given value of ??gas. We studied the resulting Kennicutt-Schmidt relation in 400 pc, 1 kpc and 10 kpc scale grids in nearby massive spirals and in 400 pc scale grids in nearby faint dwarf irregulars. We found a relation with a power-law slope of 1.5 in the HI-dominated regions for both kinds of galaxies. The relation is offset towards longer gas consumption time-scales compared to the molecular-hydrogen dominated centres of spirals, but the offset is an order of magnitude less than that quoted by earlier studies. Our results lead to the surprising conclusion that conversion of gas to stars is independent of metallicity in the HI-dominated regions of star-forming galaxies. Our observed relations are better fit by a model of star formation based on thermal and hydrostatic equilibrium in the ISM, in which stellar heating and supernova feedback set the thermal and turbulent pressure [*Roychowdhury, Sambit; Huang, Mei-Ling; Kauffmann, Guinevere; Wang, Jing; Chengalur, Jayaram N.* ]

**Merging gas rich void galaxies:** We presented a detailed study of the extremely isolated Sdm galaxy UGC 4722 (MB = -17.4) located in the nearby Lynx-Cancer void. UGC 4722 is a member of the Catalogue of Isolated Galaxies, and has also been identified as one of the most isolated galaxies in the Local Supercluster. Optical images of the galaxy however showed that it has a peculiar morphology with an elongated ??14 kpc-long plume. New observations with the Russian 6-m telescope (BTA) and the GMRT of the ionised and neutral gas in UGC 4722 revealed the second component responsible for the disturbed morphology of the system. This is a small, almost completely destroyed, very gas-rich dwarf. We estimated the oxygen abundance for both galaxies to be two to three times lower than what is expected from the luminosity-metallicityrelation for similar galaxies in denser environments. The colours of the plume stars were found to be consistent with a simple stellar population with a post starburst age of 0.45-0.5 Gyr. This system hence appears to be the first known case of a minor merger with a prominent tidal feature consisting of a young stellar population [*Chengalur, J. N.; Pustilnik, S. A.; Makarov, D. I.; Perepelitsyna, Y. A.; Safonova, E. S.; Karachentsev, I. D.* ]

**Orbital and super-orbital variability of LS I +61 303 at low radio frequencies with GMRT and LOFAR:** LS I +61 303 is a gamma-ray binary that exhibits an outburst at GHz frequencies each orbital cycle of 26.5 d and a super-orbital modulation with a period of 4.6 yr. We have performed a detailed study of the low-frequency radio emission of LS I +61 303 by analysing all the archival Giant Metrewave Radio Telescope data at 150, 235 and 610 MHz, and conducting regular LOw Frequency ARray observations at 150 MHz. We have detected the source for the first time at 150 MHz, which is also the first detection of a gamma-ray binary at such a low frequency. We have obtained the light curves of the source at 150, 235 and 610 MHz, all of them showing orbital modulation and the light curves at 235 and 610 MHz also show the existence of super-orbital variability. A comparison with contemporaneous 15-GHz data shows remarkable differences with these light curves. The light curve at 235 MHz seems to be anti-correlated with the one at 610 MHz, implying a shift of about 0.5 orbital phases in the maxima. We model the shifts between the maxima at different frequencies as due to the expansion of a one-zone emitting region assuming either free-free absorption or synchrotron self-absorption with two different magnetic field dependencies [*B. Marcote, M. Ribo, J. M. Paredes, C. H. Ishwara-Chandra and 22 authors]*

**Discovery of rare double-lobe radio galaxies hosted in spiral galaxies:** Double-lobe radio galaxies in the local Universe have traditionally been found to be hosted in elliptical or lenticular galaxies. We report the discovery of four spiral-host double-lobe radio galaxies that are discovered by cross-matching a large sample of 187 005 spiral galaxies from SDSS DR7 (Sloan Digital Sky Survey Data Release 7) to the full catalogues of FIRST (Faint Images of the Radio Sky at Twenty-cm) and NVSS (NRAO VLA Sky Survey). The host galaxies are forming stars at an average rate of 1.7-10 Msun/yr and possess supermassive black holes (SMBHs) with masses of a few times $10^{8}$ Msun. Their radio morphologies are similar to Fanaroff-Riley type II radio galaxies with total projected linear sizes ranging from 86 to 420 kpc, but their total 1.4-GHz radio luminosities are only in the range $10^{24}$-$10^{25}$ W/Hz. We propose that the formation of spiral-host double-lobe radio galaxies can be attributed to more than one factor, such as the occurrence of strong interactions, mergers, and the presence of unusually massive SMBHs, such that the spiral structures are not destroyed. Only one of our sources (J1649+2635) is found in a cluster environment, indicating that processes other than accretion through cooling flows e.g. galaxy-galaxy mergers or interactions could be plausible scenarios for triggering radio-loud active galactic nuclei activity in spiral galaxies [*Singh, V., Ishwara-Chandra, C. H., Sievers, J., Wadadekar, Y., Hilton, M., Beelen, A*.]

**Deep radio surveys at 325 MHz of legacy fields with GMRT: Search for High-redshift Radio Galaxies revisited :** We have carried out deep radio survey of legacy deep fields like DEEP2, VIMOS4, VLACOSMOS and LBDS at 325 MHz with GMRT. The primary aim of these observations are to search for steep spectrum radio sources, which are strong candidates for high-redshift radio galaxies. We have catalogued about 1000 sources with flux density > 1 mJy at 325 MHz, from one of the fields. The GMRT 325 MHz sources were matched with FIRST, NVSS, SDSS and DEEP2 optica l data. In this field, about 120 sources have spectral index steeper than 1 and majority remain un-identified with SDSS. The steep spectrum radio sources without optical counterparts are strong candidates for HzRGs and will be followed up in optical and IR for redshift estimates. One of the steep spectrum source, un-identified in SDSS, show clear FRII morphology in FIRST. Using FRI/FRII break luminosity, its redshift is expected to be > 2. This deep radio data at 325 MHz will also be used to study evolution of low power radio sources, along with available deep multi-band data. (Ishwara-Chandra C.H)

**J1216+0709: A Radio Galaxy with Three Episodes of AGN Jet Activity :** We report the discovery of a “triple-double radio galaxy,” J1216+0709, detected in deep low-frequency Giant Metrewave Radio Telescope (GMRT) observations. J1216+0709 is only the third radio galaxy, after B0925+420 and Speca, with three pairs of lobes resulting from three different episodes of active galactic nucleus (AGN) jet activity. The 610 MHz GMRT image clearly displays an inner pair of lobes, a nearly coaxial middle pair of lobes, and a pair of outer lobes that is bent with respect to the axis of the inner pair of lobes. The total end-to-end projected sizes of the inner, middle, and outer lobes are 40″ (~95 kpc), 1.□65 (~235 kpc), and 5.7 (~814 kpc), respectively. The host galaxy is a bright elliptical with blackhole mass of 4X10^9 Msun and a star formation rate of 4.66 Msun/yr. The host galaxy resides in a small group of three galaxies and is possibly going through an interaction with faint dwarf galaxies in the neighborhood, which may have triggered the recent episodes of AGN activity [*Singh, V., Ishwara-Chandra, C. H., Kharb, Preeti, Srivastava, Shweta, Janardhan, P.*]

# Pulsar

**Fermi millisecond pulsars (MSPs)** : From the timing follow-up of the Fermi millisecond pulsars (MSPs) discovered with the GMRT, we got detections of gamma-ray pulsations for three of these pulsars. Sensitive Pass 8 spectral analysis for PSR J0248+4230, J1207-5050 and J1536-4948 using the radio timing ephemerides derived from the GMRT observations, gave significant LAT detections. PSR J1536-4948 is found to be a bright LAT source allowing detailed study of radio-gamma-ray profile for probing the pulsar emission geometry [*Bhaswati Bhattacharyya (University of Manchester), Jayanta Roy (University of Manchester, NCRA), Paul Ray (Naval Research Laboratory), Yashwant Gupta (NCRA), Dipankar Bhattacharya (IUCAA) and members of Fermi Pulsar Search Consortium*]

**Supernovae and supernovae remnants:** We have discovered a shell type TeV supernova remnant SNR G353.6-0.7 in the GMRT 325 MHz band. The SNR shows the shell structure, however the maximum radio emission site is opposite to the TeV emission site. We are further studying this source. We carried out GMRT observations of three core collapse supernovae to look for their circumstellar interaction. In none of the cases, we found significant interaction. However, one of the cases is extreme absorption case which we are following with other telescopes in multiwaveband [*Poonam Chandra with A. J. Nayana (NCRA), Subhashis Roy (NCRA), Alexandre Marcowith & Matthieu Renaud (Laboratoire de Physique Theorique et Astroparticules, Universite Montpellier 2, CNRS, France), Marianne Lemoine-Goumard (Chemin du Solarium, CS 10120, 33170 GRADIGNAN CEDEX, France), Tatischeff Vincent (Centre de Spectrométrie Nucléaire et de Spectrométrie de Masse, IN2P3/CNRS and Univ Paris-Sud, 91405 Orsay, France ), Sanjay Bhatnagar (NRAO, Socorro, USA)* ]

**Magnetism in massive stars:** We observed and analysed 36 hours of VLA data for 18 magnetic stars above 8 solar masses to look for radio emission from these. We detected four stars. Two of them are O stars and 2 of them are B stars. Three stars seem to have non-thermal radio emission, which may arise due to magnetic field of binary interactions. We are carrying out a detailed study of these stars [*Poonam Chandra with Sushma Kurapati (NCRA), Gregg Wade (RMC, Kingston, Canada), Jason Grunhut (ESO, Garching bei München), Divya Oberoi* (NCRA), Asif ud-Doula (Penn State Worthington Scranton 120 Ridge View DriveDunmore, PA ), Mary Oksala (Astronomical Institute ASCR, Czech *Republic), Veronique Petit (Florida Institute of Technology. Melbourne, FL)* ]

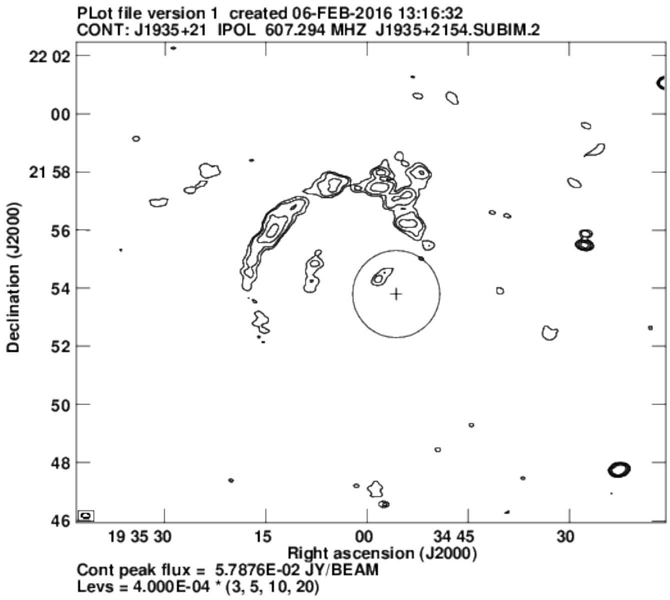
**Fast Radio Bursts with the GMRT:** We carried out study of four FRBs with the GMRT, which were detected with Parkes. In of of the FRB 150418, a potential afterglow has been found. The afterglow associates it with z=0.49 redshift galaxy. More work is being done to confirm or reject this association [*Poonam Chadnra with Ramesh Bhat and Shivani Bhandari andEmily Petroff (Centre for /Astrophysics/ & Supercomputing Swinburne University of Technology Hawthorn, Victoria 3122, Australia), Evan Keane (Jodrell Bank Centre for Astrophysics, Alan Turing Building, Oxford Road, Manchester, M13 9PL, United Kingdom) et al.* ]

**Search for pulsed radio emission from SWIFT J174540.7-290015:** To probe the possible magnetar nature of the transient X-ray source SWIFT J174540.7-290015, we conducted radio observations at 1390 MHz and 327 MHz, using the GMRT and the ORT, respectively. The source was observed at the two frequencies for 2.7 and 3.5 hours respectively. SWIFT J174540.7-290015 was detected as a transient X-ray source on February 6, 2016 (ATEL #8649). We observed the source using the ORT on February 10, 2016 at 327 MHz with 4 ms sampling time and 1024 frequency channels across the 16 MHz bandwidth. Our search for any periodic or transient emission from the source in the DM range of 0--3000 pc/cc did not result in any significant detection. The 5-sigma flux density upper limits for the periodic and transient radio signals from the source at 327 MHz are 4.5 mJy and 15 Jy, respectively. For computing these limits, we have assumed 10 percent pulse duty cycle for the periodic signal, and a pulse-width of 10 ms for the transient signal. Observations at 1390 MHz were conducted on February 15, 2016, using 15 dishes of the GMRT in phased-array mode, with a time resolution of 0.12 ms and 512 channels across a bandwidth of 33 MHz. Search for any periodic or transient signals in the DM range 0--3000 pc/cc from these data also did not result in any significant detection. Using these data, we constrain the 5-sigma periodic and transient flux densities of the source at 1390 MHz to 70 uJy and 0.2 Jy, respectively. Our radio observations suggests a "radio quiet" magnetar with high magnetic field (Rea et al. 2012). Our observations do not rule out a transient accreting neutron star [*Yogesh Maan, Mayuresh Surnis, M.A. Krishnakumar, Bhal Chandra Joshi, P K Manoharan*]

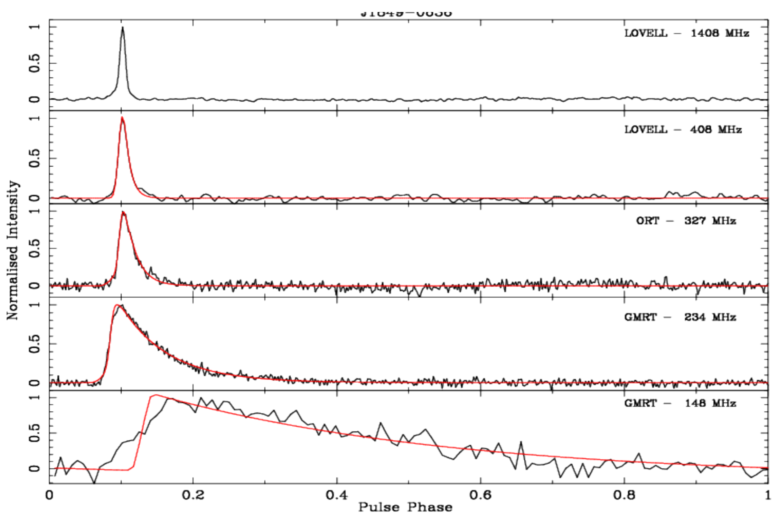
**Upper limits on the pulsed radio emission from SGR candidate SGR 0755-2933:** SGR J0755-2933 was discovered through a sharp, soft burst on March 16, 2016 at 22:41:24 UT by the Swift Burst Alert Telescope (BAT) instrument. While the X-ray flux has been reported to decline by a factor of 16 in subsequent Swift observations, no X-ray pulsations were detected (ATEL #8868). We performed radio observations with the ORT at 327 MHz and the GMRT at 1390 MHz. The observations at the ORT were performed on March 17, 2016 with 8 ms sampling over a band of 16 MHz, spread over 1024 channels. The observations at the GMRT were performed on March 25, 2016, wherein, the data were recorded simultaneously in imaging and phased array mode, over a bandwidth of 33 MHz, spread over 512 channels. The GMRT PA and ORT data were searched for periodic and transient signals over a dispersion measure range of 0--2000 pc/cc. We did not detect any significant pulsation with 8-sigma upper limits on flux density of 0.89 mJy and 0.12 mJy (assuming a 10 percent duty cycle) for periodic signals at 327 and 1390 MHz, respectively. The 8-sigma upper flux density limits for any transient signal are 2.8 Jy and 220 mJy (assuming 10 ms burst duration) at 327 and 1390 MHz, respectively. The 3-sigma upper limit on the continuum flux density from the imaging data at 1390 MHz is 0.3 mJy. [*Mayuresh Surnis, Yogesh Maan, Bhal Chandra Joshi, P K Manoharan*]

**Radio Pulsation Search and Imaging Study of SGR J1935+2154:** The Swift burst alert telescope (BAT) detected an X-ray burst of SGR J1935+2154 on July 5, 2014. The duration of the burst was ~0.1 s with a double peaked structure (Cummings et al. 2014). Following the trigger given by the above BAT detection, the Swift X-ray telescope (XRT) observations localized the source, which lies very close to the geometric center of the supernova remnant (SNR) G57.2+0.8. Subsequent Chandra and XMM-Newton observations revealed coherent pulsations from this source with a period of 3.2 s and confirmed its magnetar nature with a diffuse X-ray emission extending upto 1' around the magnetar, which could be a dust scattered halo or pulsar wind nebula (PWN).

We carried out imaging observations and search for radio pulsations with the GMRT and the ORT towards the magnetar SGR J1935+2154 immediately after the burst was reported. Imaging observations, with the GMRT on July 14, 2014 at 610 MHz with 33 MHz band spread across 512 channels, resulted in the first high resolution radio image (Figure 1) of the positionally associated SNR G57.2+0.8. A pulsational search was carried out on time-series data taken with the GMRT and the ORT. We did not detect significant periodic radio pulsations from the magnetar, with 8 sigma upper limits on its flux density of 0.4, and 0.2 mJy at 326.5, and 610 MHz, respectively, for an assumed duty cycle of 10 percent. The corresponding 6 sigma upper limits at the two frequencies for any burst emission with an assumed width of 10 ms are 0.5 Jy, and 63 mJy, respectively. No continuum radio point source was detected at the position of SGR J1935+2154 with a 3 sigma upper limit of 1.2 mJy. We also did not detect significant diffuse radio emission in a radius of 70 arc seconds in coincidence with the diffuse X-ray emission reported recently, with a 3 sigma upper limit of 4.5 mJy. Using the archival HI spectra, we estimated a more reliable distance of SNR G57.2+0.8 to be 11.7(3) kpc. Based on measured HI column density along this line of sight, we argue that the magnetar could be physically associated with SNR G57.2+0.8. Based on present data, we can not rule out




High resolution GMRT Image of SNR G57.2+0.8 at 610 MHz. The RMS noise in the map is 0.4 mJy. The contour levels are at 3, 5, 10, and 20 Σ. The cross indicates the position of SGR J1935+2154 with the size of the cross indicating 10 Σ position uncertainty. The solid circle represents the extent of diffuse X-ray emission reported by Israel et al. 2016

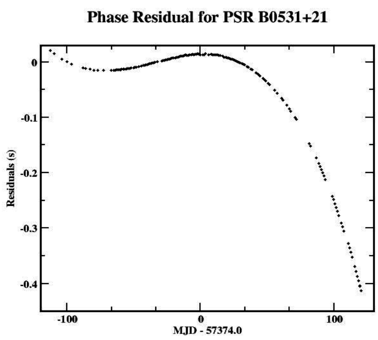



The plot shows the frequency evolution of pulse scatter broadening as a function of observing frequency for PSR J1849-0636. The profiles at 1420 and 408 MHz were taken from archival data (Gould and Lyne 1998) whereas those at 327, 234 and 148 MHz were obtained from our observations. The black curves represent the observed profile and the red curves show the best fit model from which an estimate of \tau_sc is obtained.

either a pulsar wind nebula or a dust scattering halo origin for the diffuse X-ray emission seen around the magnetar [*Mayuresh. P. Surnis, Bhal Chandra Joshi, Yogesh Maan, M. A. Krishnakumar, P. K. Manoharan, Arun Naidu*]

**Multi-Frequency observations for measuring scatter-broadening parameters of pulsars with GMRT:** Motivated by pulse scatter-broadening measurements of 124 pulsars with the ORT two years back, we conducted low frequency follow up observations at 148, 234 and 610 MHz using the GMRT last year with a view to significantly enhance the currently known sample (about 60) of measurements of frequency scaling index α for pulsars in our ORT study. Observations of 45 pulsars were carried out using the GMRT between July 9 to August 1, 2015 with a phased array of at least 15 antennas. We used 256 spectral channels across 16 MHz bandwidth at 148 and 234 MHz and across 32 MHz at 610 MHz. Evolution of pulse scatter-broadening as a function of frequency for PSR J1849-0636, observed using the GMRT and the ORT is shown in Figure 2. The analysis of these data has yielded 26, 42 and 5 new measurements at 148, 234 and 610 MHz respectively. Using all available data at multiple frequencies, this has enabled us to determine 40 measurements of the frequency scaling index α, 33 of which are new, significantly increasing the sample of such measurements. Further analysis and interpretation of these measurements is in progress [*M.A. Krishnakumar, B.C. Joshi and P.K. Manoharan*]

**A Pilot Pulsar Timing Array experiment with the ORT and the GMRT:** Pulsar Timing arrays use an ensemble of pulsars to detect small time varying changes in the proper separation between two points in space-time caused by a passing gravitational wave, which introduces a shift in frequency of their pulsed radiation. Last year, we started an experiment utilizing simultaneous observations with the ORT at 326.5 MHz and with the GMRT at 1300 MHz of a sample of 9 millisecond pulsars, currently being monitored by International Pulsar Timing Array experiments. The main objectives of the experiment is to build timing solutions for these pulsars, characterize the precision of pulse time of arrivals and measure variation in the dispersion measures of these pulsars, thereby contributing to the international efforts. Observations were carried out for 10 observing epochs so far using coherent dedispersion to achieve pulse time of arrivals with micro-second precision and preliminary results indicate dispersion measure variations in at least two of these pulsars. These observations are continuing [*Bhal Chandra Joshi, A. Gopakumar, Manjari Bagchi, P K Manoharan, M.A. Krishnakumar, Yogesh Maan, Arun Naidu*]




The plot shows the phase connected timing residuals for PSR B0531+21 using the observations with the ORT between October 2015 and March 2016. The residuals were obtained after subtracting a timing model, obtained from a fit to pulse arrival times. The timing model was calculated for December 18, 2015. The wander of the pulse period, called timing noise, is evident from the residuals.

**Simultaneous Observations of Crab pulsar with the GMRT, the ORT and the ASTROSAT:** Soon after the launch of Astrosat last year, observations of Crab Pulsar (PSR B0531+21) were carried out using the GMRT at 1280 MHz, the ORT at 326.5 MHz and ASTROSAT using its CZT instrument on board. The main objective of these observations was to calibrate the relative as well as absolute timing offset of time series data from these instruments upto 10 us precision with a view to validate capability for future radio high energy co-observations. The radio data has been used to obtain latest timing solution maintaining phase continuity over the last six months and to provide upto date ephemeris for folding high energy data, obtained with the CZT, every 15 days. Figure 3 shows a phase connected solution for the pulsar, which is known for its large timing noise. The random variation in its pulse period due to the timing noise, evident in Figure 3, makes accurate prediction of its period at an epoch for folding high energy data challenging and our 15 day ephemeris is useful for this. In addition, these data are currently being used to calibrate relative offsets between high energy and radio data. The radio data also consists of a statistical complete sample of giant pulses and work is in progress to examine its correlation with high energy emission [*Sachindra Naik, A. R. Rao, Dipankar Bhattacharya, Biswajit Paul, Santosh Vadawale, Bhal Chandra Joshi*]

# Extra Galactic Astronomy and Cosmology

**A study of Seyfert galaxies with strong Forbidden High-Ionization Lines:** We studied the radio properties at 1.4 GHz of Seyfert galaxies with strong forbidden high-ionization lines, selected from the Sloan Digital Sky Survey - a large-sized sample containing nearly equal proportion of diverse range of Seyfert galaxies showing similar redshift distributions

using the Very Large Array survey images. The radio detection rate is low, 49%, which is lower than the detection rate of several other known Seyfert galaxy samples. These galaxies show low star formation rates and the radio emission is dominated by the active nucleus with < 10% contribution from thermal emission, and possibly, none show evidence for relativistic beaming. The radio detection rate, distributions of radio power, and correlations between radio power and line luminosities or X-ray luminosity for NLS1, Seyfert 1 and Seyfert 2 galaxies are consistent with the predictions of the unified scheme hypothesis. Using correlation between radio and [O III] 5000 Angstrom luminosities, we show that ~8% sample sources are radio-intermediate and the remaining are radio-quiet. There is possibly an ionization stratification associated with clouds on scales of 0.1-1.0 kpc, which have large optical depths at 1.4 GHz, and it seems these clouds are responsible for free-free absorption of radio emission from the core; hence, leading to low radio detection rate for these FHIL-emitting Seyfert galaxies[*Dharam V. Lal*]

**Atacama Large Millimeter Array (ALMA) detections of CO emission in intermediate-redshift damped Lyman-alpha absorbers:** We have used the Atacama Large Millimeter Array (ALMA) to detect CO emission from five damped Lyman-alpha systems (DLAs) at z ~ 0.1-0.8, the first ever detections of molecular gas in DLAs. The inferred molecular gas masses are far larger than in typical spiral galaxies, with the molecular gas mass in one of the DLAs (at z=0.101) more than two times larger than the upper limit on its atomic gas HI mass. We have used the CO data on the latter DLA to obtain its rotation curve, and find that the damped absorption is likely to arise from the circumgalactic medium, and not from the host galaxy itself. For another DLA, at z=0.7156 towards J1323-0021, we also used the Very Large Telescope to detect H-alpha and OII emission, measuring its star formation rate, and thus allowing us to infer its star formation efficiency [*Kanekar N, with J. X. Prochaska (University of California, Santa Cruz, USA), M. Neeleman (University of California, Santa Cruz, USA), M. Zwaan (European Southern Observatory, Germany), P. MOLLER (European Southern Observatory, Germany), L. Christensen (Dark Cosmology Centre, Denmark)]*

**ALMA detection of ionized carbon emission in high-redshift damped Lyman-alpha absorbers:** We have used ALMA to detect ionized carbon CII-158micron emission from two DLAs at z~4, allowing us to identify the host galaxy of the two DLAs. These are the highest redshifts at which any line emission has been detected from a DLA host. They are also the first detections of CII-158micron emission from DLAs, opening a new window to probe the nature of the host galaxies. Our ALMA data also detected rest-frame 160-GHz continuum emission from the two DLAs, allowing an estimate of their star formation rates (SFRs); we obtain SFRs of 25-110 solar masses per year, far higher than typical of high-z DLAs. The CII-158micron line luminosities are also far higher than expected from the measured SFRs and the local correlation between line luminosity and SFR. Clear signatures of rotation were found in both DLAs, implying that these are massive rotating disks at high redshifts [*Kanekar N, with J. X. Prochaska (University of California, Santa Cruz, USA), M. Neeleman (University of California, Santa Cruz, USA), M. Rafelski (NASA-Goddard Space Flight Center, Maryland, USA)]*

**The gas mass and star formation rate of DLAs, and the neutral gas content of the Universe:** We have completed a Hubble Space Telescope (HST) archival survey for low-redshift DLAs and find that the neutral gas content of the Universe at z~1 is significantly lower than obtained from earlier, biased estimates. We also used the Arecibo telescope to carry out a search for redshifted HI-21cm emission from the HST sample of DLAs, and detected HI-21cm emission in seven systems, significantly increasing the number of systems with gas mass measurements. We obtained low atomic gas masses in all DLAs towards quasars, consistent with their low gas-phase metallicities, while one of the DLAs detected towards a bright galaxy was found to have a high atomic gas mass. Finally, we have used the Giant Metrewave Radio Telescope (GMRT) to map the HI-21cm emission from three of the DLAs detected with the Arecibo telescope, measuring the size of the DLA host galaxy and its rotation curve. We have also used the Canada-France-Hawaii Telescope (CFHT) to detect H-alpha emission from two of the DLAs detected in HI-21cm emission with the Arecibo telescope, and have used these data to determine their SFRs and hence the star formation efficiency [*Kanekar N . with J. X. Prochaska (University of California, Santa Cruz, USA), M. Neeleman (University of California, Santa Cruz, USA), J. Ribaudo (Utica College, New York, USA), Chengalur, Jayaram N. (NCRA-TIFR, Pune, India), W-H. Wang (Academia Sinica Institute of Astronomy and Astrophysics, Taiwan), and Tapasi Ghosh (Arecibo Observatory, USA)*]

**Neutral gas associated with active galactic nuclei:** We have continued a large project searching for ``associated'' HI-21cm absorption from a sample of compact flat spectrum radio sources at z=0.3-3.6 with the Giant Metrewave Radio Telescope (GMRT). The data on all sources have been analysed and HI-21cm absorption has so far been detected in five of them. We find statistically-significant evidence of redshift evolution in the HI-21cm optical depths of neutral gas associated with active galactic nuclei (AGNs) in this uniformly-selected sample, with lower detection rates of absorption as well as lower HI-21cm optical depths at high redshifts, z>0.76. However, the data are also consistent with an alternative hypothesis, that the decline in the strength of HI-21cm absorption at high redshifts is because the AGNs in the high-z sample have higher ultraviolet luminosities. We have also obtained the first detection of redshifted HI-21cm absorption in an AGN with a high ultraviolet luminosity, demonstrating that a literature model arguing that neutral gas cannot survive in the presence of an ultraluminous AGN is incorrect. We have also obtained the first two high-z detections of redshifted HI-21cm absorption in gigahertz-peaked-spectrum sources, at z~1.2. [*Kanekar N. with J.N.H.S. Aditya (NCRA-TIFR, Pune, India) and S. Kurapati (NCRA-TIFR, Pune, India)*]

**A blind millimetre-wave survey for high-redshift molecular absorption:** We have carried out a large ``blind'' survey for redshifted molecular absorption at redshifts z>0.85 towards 188 sources using the 30-50 GHz receiver of the Australia Telescope Compact Array (ATCA). When combined with our earlier Very Large Array survey, this will yield by far the largest-ever survey for redshifted molecular absorption, with a redshift path of ~230, nearly ten times larger than the best earlier such survey. The ATCA data have now been analysed and we have obtained 27 candidate detections of redshifted radio molecular absorption, which will be followed up with deeper ATCA observations to confirm these tentative detections. There is not a single known radio molecular absorber at $z>0.9$, so confirming even a few of these detections would have huge implications for studies of molecular gas and fundamental constant evolution at high redshifts [*Kanekar N. with A. J. Nayana (NCRA-TIFR, Pune, India), C. L. Carilli (NRAO-Socorro, USA), and K. M.Menten (Max-Planck-Institut fur Radioastronomie, Bonn, Germany)*]

# Square Kilometer Array

**NCRA leads Indian participation in the international SKA project :**

The Square Kilometre Array (SKA) is the most ambitious international radio astronomy project attempted to date. It aims to build a telescope with 1 million square metres of collecting area, covering a large frequency range from about 50 MHz to 10 GHz, in a radio quiet region of the globe. This will result in an instrument that is 50 times more sensitive than the best today, capable of cutting edge science in several aspects of astronomy and astrophysics. As of today, eleven of the major radio astronomy practicing nations are collaborating in this project, which entered the design phase from November 2013 onwards, expected to last till end of 2017. Construction of the telescope will then begin in 2018, with early science expected by 2021-22.

India (represented by NCRA) is now an active participant in the SKA, with NCRA having become a Full Member of the SKA Organisation in August 2014. This was transferred to a Full Membership of India, with a formal signing ceremony with the SKA Organisation, held at the Offices of the Department of Atomic Energy in Mumbai on the 5th of October 2015. The SKA India Steering Committee, a high level committee to provide guidance and monitoring of the overall SKA activities in India, was set-up in July 2015 by the Department of Atomic Energy, and had its first meeting on 7th September 2015 at TIFR, Mumbai. The SKA India Consortium (SKAIC), created in February 2015, to bring together under one umbrella all organisations in India interested in SKA activities and coordinate the SKA related activities across the country, has started functioning regularly. In addition to the main Executive Council of the SKAIC, two sub-committees have been formed by the SKAIC : one to coordinate all the science related activities and another to coordinate all the technical activities.

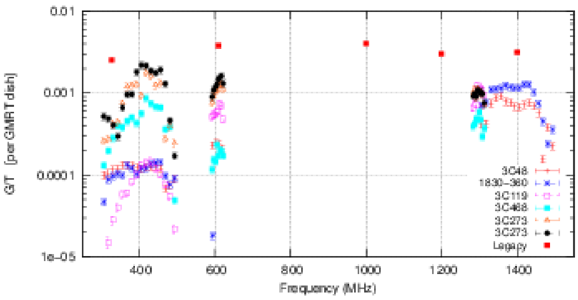
Meanwhile, Indian involvement in the design phase activities of the SKA continued, with NCRA leading a collaboration of members from 7 different SKA member countries for the work on the design of the Telescope Manager – a sophisticated monitor & control system for the SKA, which will be like the brain and central nervous system of the observatory. The Telescope Manager consortium has successfully completed the Preliminary Design Review phase of the work, and is now well into the Detailed Design phase that will lead to the Critical Design Review by middle of 2017. NCRA also continues to be involved to a smaller extent in the Central Signal Processing and Signal & Data Transport work packages. Many of these SKA activities are being carried out in active collaboration with partners from Indian industry.

Alongwith the above, science activities related to the SKA continue to gain momentum in India. SKA India Science Working Groups, formed in March 2014, have been working on developing the science case and the potential user base within the country. Their activities include carrying out theoretical studies and modelling, as well as using the existing facilities like the GMRT to conduct research and investigations that will prepare the scientific community to make the best use of the SKA when it is ready. Many of these science working groups have been meeting regularly and working on science case documents, in addition to increasing their participation in the International Science Working Groups of the SKA [*Yashwant Gupta, Y. Wadadekar, N.M. Ramanujam, T. R. Choudhury, Chengalur, Jayaram N., S.K. Ghosh, J.P. Kodilkar and B. Ajithkumar, (NCRA-TIFR) working with partners from TRDDC, TCS, PSL and NVIDIA in India, and with colleagues from many other Indian institutions as well as from SKA members in South Africa, U.K., Australia, Canada, Italy and Portugal*]

# Instrument and Facilities

**GMRT Servo system Upgrades :** The major upgrade of the GMRT servo system consists of the mass commissioning of new Brush-less DC (BLDC) motors and drives to replace the aging Permanent Magnet DC motors and mass commissioning of PC/104 based digital position loop controller to replace obsolete 8086-based controller. The mass commissioning of PC/104 based digital position loop controller was completed in all 30 antennas last year, which was a major milestone. These controller remove obsolescence and impart greater flexibility for implementing new control algorithms to improve tracking accuracy of the system. The mass commissioning of BLDC systems is also nearing completion with 25 antennas having been retrofitted with these systems. This has considerably brought down the antenna down time as the motors do not need to be serviced every 6 months as was the case earlier. Such service required a two day antenna downtime apart from the cost of service. The new system is also more reliable, which has resulted in number of intermittent problems having reduced significantly. It is expected to complete this mass commissioning in all antenna by October 2016. Another component being upgraded from last year is is the feed positioning system. New backlash free gearboxes were tried both in the laboratory and the antennas and their performance was found to be repeatable. Commissioning these gearboxes on all antenna is likely to reduce the extra time required for determining the elevation offsets. As a next step, work is underway to design a new feed position controller for tryout next year. If found suitable, a mass commissioning is planned in the subsequent years [*Suresh Sabhapathy, Shailendra Bagade, Amit Kumar, B. Thiygaraj, T Haokip, Samir Gadekar, Abhishek Pawar, Priyanka Desai, Sandeep Malu, and B C Joshi with BARC reactor control division*]

**Multi-frequency multi subarray observations using the upgarded-GMRT:** Recent upgrade of GMRT included a new GMRT Wideband backend (GWB), which allows observations with 400 MHz bandwidth using several combination of spectral channels. GWB also provides two beam output for time-series observations, which are useful for pulsar studies. Together with legacy GMRT Software Backend (GSB), this provides a capability for simultaneous 4 frequency pulsar observations. GWB can be used with the recently commissioned wide-band feeds (250-500 MHz and 1000-1400 MHz). These two new features of GMRT provide a unique capability to the GMRT to simultaneously observe pulsars from 150 to 1400 MHz, which would be very important for investigations into spectra of pulsars as well as a variety of propagation effects in the Inter-stellar medium, such as pulse scatter broadening and dispersion. In response to a call for proposal for a shared risk release of this backend, we put a proposal to test and validate this multi-frequency multi subarray




--- G/T_sys measurements as a function of frequency, using the sources 3C48, 3C119, 3C468.1, 1830$-$360 and 3C273 (2 measurements), along with theearlier measurements available from the GMRT website (marked as ``Legacy'' in the list of legends) are shown together.

capability of uGMRT as well as open up GWB for wideband pulsar observations. A total of 3 observing sessions were conducted in December and January 2015, with each of the sessions utilizing 24 (out of 30) GMRT dishes divided into 4 subarrays. The 4 subarrays were used at 150 MHz (once in legacy mode with 16 or 32 MHz bandwidth, and twice with the wideband system), 300--500 MHz (i.e. the wideband system), 610 MHz (in legacy mode with 33 MHz bandwidth), and L-band (once with the 200 MHz wideband system, and twice in legacy mode with 33 MHz bandwidth). The wideband observations utilized a bandwidth of 200 MHz with 4096 channels, while the legacy system observations used 512 channels across the (typically) bandwidth of 33 MHz. We observed calibrator sources as well as a select group of pulsars to estimated values of G/T_sys (Figure 4). Our conclusion was that the G/T_sys from the calibrator source 3C273 are comparable with those from the legacy system, while they were marginally smaller for other calibrators, particularly at lower frequencies, possibly due to presence of radio frequency interference (RFI). Data from observations of 10 pulsars were analyzed to determine the typical percentage of RFI-free data one gets and these indicate that for the 300--500 MHz and 1300--1500 MHz bands, typical percentage of data contaminated by RFI is 5--10 percent. However, this fraction can reach to 30--40 percent during peak RFI times. Overall, we could validate the multi-frequency multi subarray mode of GWB and generate feedback to the observatory for improvement. Currently, the science data analysis is in progress [*Yogesh Maan and Bhal Chandra Joshi*]

**Upgrade of the GMRT Electronics Systems** : The GMRT is undergoing a major upgrade which includes broad band seamless frequency coverage from 50 to 1500 MHz with improved sensitivity and maximum instantaneous bandwidth of 400 MHz. This is accompanied by other upgrades such as a next generation monitor & control system, a modern antenna servo system, improvements to the mechanical systems of the antennas, enhancements in data storage and computing resources, alongwith matching improvements in infrastructure facilities relating to civil and electrical systems. The upgrade requires several improvements to the front-end and back-end electronics systems of the telescope, including the fibre-optic system that connects these two systems. Many of these upgrade activities have crossed important implementation milestones, leading to the first major release of the upgraded GMRT systems to the user community. Highlights of some these upgrade activities during this year are as follows :

**Upgrades of the GMRT front-end and fibre-optic systems:**

1. **GMRT front-end and fibre-optic systems** : The main changes being carried out to the front-end systems are the design and implementation of new, broadband feeds; matching RF front-end electronics systems with improved dynamic range; and associated improvements in the support electronics. For the fibre-optic system, there is a new scheme for transfer of broadband signals from each antenna to the central receiver room, while maintaining the availability of the existing system for transfer of narrow band signals with IF carriers.

**1.1 For the GMRT feeds and front-end receivers, the following has been achieved :**

(a) For the 130-260 MHz band, the dual Kildal ring feed designed and installed on 4 antennas, has been found to have very good performance around 150 MHz, but needs some improvement of performance at the 235 MHz end of the band. The final version of the new front-end system has passed prototyping and is ready for mass production. It has a wireline based quadrature hybrid, a significantly improved low noise amplifier and narrowly tuned notch filters to block interfering signals from commercial TV and wireless systems. [*Bhandari Hanumanth Rao, Ramesh S, Bhalerao Vilas B, Prajapati A, Vawhal A, Sureshkumar S*]

(b) For the 250-500 MHz band, the cone-dipole feed has been installed on 22 of the 30 antennas, and the remaining feeds are available for installation. This is now accompanied by the final version of the front-end system, which features an improved low noise amplifier with 20 Kelvin noise temperature, notch filters and meta-material based switched sub-band filters. [*Bhandari Hanumanth Rao, Ramesh S, Raut Anil N, Temkar Vishal B, Chaterjee, S, Parikh G P, Prajapati A*]

(c) For the 550-900 MHz range, the final design of feed plus low noise front-end electronics was arrived at : a cone-dipole feed with a special front-end box very close to it containing the polarizer, low noise amplifier and calibration noise injection circuitry. The system uses in house developed low cost switched sub-band filter and special notch filters for rejecting TV and Mobile signals. This is now in mass production phase, and 4 antennas have been equipped with this system [*Bhandari Hanumanth Rao, Ramesh S, Bhalerao V B, Khan I, Prajapati A, Kumbhar G C, Sureshkumar S*]

(d) An upgraded high dynamic range version of the common box electronics that comes after the front-end systems has been finalized and entered into mass production. It has a much better dynamic range (1 dB compression and IP3 points) and is better in handling broadband signals without saturation. [*Temkar Vishal B., Kumbhar Ganesh C.*]

**1.2. Highlights from the Signal Transport and Fiber-Optics Systems are as follows :**

The RF over fiber system using Dense Wavelength Division Multiplexing (DWDM) to bring back the wideband signals from the upgraded systems (while continuing to support the existing narrow-band IF systems) and including a 1 Gbe bi-directional ethernet link, has now been successfully installed in all the 30 antennas, and is working reliably. Furthermore, work on equipping the fiber optic system at the central electronics building with RF frontend signal monitoring and in-line optical power monitoring, reached an advanced stage and installation for 16 antennas was completed. [*Sureshkumar S., Raybole Pravin, Lokhande Satish, Rai Sanjeet, Prajapati Ankur, Gopinathan M.*]

**Upgrades of the GMRT back-end systems :**

2. **GMRT back-end systems** :

As part of the GMRT upgrade, new back-end systems are being implemented to achieve the specifications for the upgrade like increased bandwidth of 400 MHz, direct processing of RF signals, increased dynamic range, improved channel resolution in the digital back-ends etc. A significant feature of the new system is the reduction in electronics at the remote antenna sites and shifting of most of the complex signal processing operations to the Central Electronics Building (CEB) which will reduce the down time of antennas in case of problems. Some of the main developments in this year have been as follows.

### 2.1. Analog Back-end System :

The complete Analog Backend system for 30 antennas has been completed and released for use, and is functioning well. The released system has improved dynamic range, facility for variable gain, selectable signal bandwidth and individual LO signal for each antenna. Other features like power equalisation, signal monitoring and system health monitoring tools have been implemented and released during this year. All these new facilities are widely used and help in quickly setting up of the telescope for observations, as well as in quick trouble shooting of problems in the system.

An RF filter bank at the input of the Analog Backend system has been developed and prototype units tested successfully with the system. When completed for all 30 antennas, this will improve the signal to noise ratio at the output of the Analog Backend system. The team is in the advanced stages of implementing a Active Hydrogen Maser based Time and Frequeny standard at GMRT and RAC Ooty, which will help improve the VLBI capability to these Telescopes. [*Ajithkumar B., Shinde Navnath, Gupta Shweta, Nanaware D.K., Ganla Atul, Dhende Abhijeet, Phakatkar Sudhir, Hande P.J., Vishwakarma Ajay*]

### 2.2. Digital Back-end Systems :

A 16-antenna, dual polarization version of the GPU-based hybrid correlator and beamformer (with incoherent and coherent modes and a pulsar preprocessor) was completed, and released for user in September 2015. It has Atmel dual ADC boards for digitisation of the baseband signals, Casper FPGA boards for data packetisation & transfer to the computer nodes, which are high-end DELL machines having NVIDIA K20 GPUs, and 40 Gbit infiniband connectivity between the nodes for data transfer. This system can currently process 100/200/400 MHz bandwidth signals, with upto 16 K spectral channels, and includes support for a full Stokes mode. Currently work is in progress to develop the next version of this back-end system which will support upto 32 antennas, dual polarisation signals with 400 MHz bandwidth, 16 K frequency channels and wide range of integration times. [*Reddy S. Harshvardhan, Kudale Sanjay, Shelton G.J., Halagali I.M., Bhonde I.S., Ajithkumar B., Gupta Yashwant*]

A scheme for improving the cross talk performance of the receiver, using phase modulation of the RF signal at each antenna with different Walsh Patterns and matching demodulation in the back-end system, is being developed. The scheme for demodulation in the back-end has been implemented and tested, and the prototype has been demonstrated to be working satisfactorily. The final system and implementation for all antennas, will be taken up shortly, in the next version of the back-end. [*Sandeep C Chaudhari, Sweta Gupta, Ajithkumar B., Yashwant Gupta*]

A scheme for digitising the signals directly at the antenna site and bringing the digital data to CEB through optical fibre links, that could have some advantages over the current analog system, is being developed for trial implementation in 5 antennas, and initial work in this direction has started. [*Sandeep C. Chaudhari, Aniket Hendre, N.D. Shinde, Sweta Gupta, Ajithkumar B*]

A scheme for detection and filtering of Radio Frequency Interference (RFI) signals in the digital back-ends, based on statistical properties of the desired signal and RFI, has been developed and is in advanced stages of testing and implementation in different stages of the back-end receiver system. Schemes are being developed for both narrow band and broadband interfering signals, including for the beamformer data. [*Kaushal D Buch, Kishor D. Naik, Aditya Chowdhury, Yashwant Gupta*]

## New Monitor & Control System for the upgraded GMRT :

### 3. New Monitor & Control System :

To control and coordinate the upgraded GMRT systems for performing astronomical observations, efforts are on to develop a next generation Monitor and Control (M&C) system. This includes modern hardware and software architectural features compared to the existing GMRT control system, including futuristic developments that could be of relevance to next generation radio telescopes such as the SKA. Some of the highlights are as follows. [Kodilkar Jitendra, Uprade Raj, Kanade Charudatta, Bhor Rahul, Misal Mahadev, Sateesh C., Rajendran B., Katore Santaji, Bhong Deepak, Sherkar Sachin, Nayak S., Kantharia Nimisha, Gupta Yashwant]

### 3.1. New M&C modules :

New Monitor and Control Modules (MCM) developed based on Rabbit RCM 4300 micro-controller, which had completed mass production last year, underwent significant software and firmware developments to implement control of various GMRT sub-systems at antenna base and in the Central building. Installation and testing of these MCM cards was completed for the Sentinel, Optical Fiber and FPS sub-systems at antenna base. For simultaneously updating the firmware on multiple MCM cards over the Ethernet interface, a Remote Firmware Update application has been developed and tested. To update the firmware, a web-interface is provided. The application will be used to update/maintain the firmware running on rabbit MCMs for all 30 antennas

### 3.2. Next Generation M&C Software System :

NCRA is actively involved in the development of a next generation M&C system applicable for large systems (including radio telescopes like the GMRT and the SKA), in collaboration with the TRDDC research laboratory and partners from software industry. As a first step of this effort, a modern M&C system software is being developed for the GMRT, which can be used as a demonstrator for SKA and can help evaluate and test various kind of prototypes required in the SKA design. The development of Phase-1 of this system was completed, wherein the basic M&C operations for 3 remotely controlled GMRT antennas were tested successfully using Ethernet interface from the new Central M&C system. The core M&C system functionality consists of sending control commands to the Servo and receiver sub-systems at antenna base, receiving monitoring data, event/alarms from the sub-systems, python based scripting environment, user-friendly GUI and automatically archiving of the M&C system data. The software architecture of the new M&C system is based on the TANGO open source software framework, and supports features like data driven configuration, scalability, and facility to evolve. The software architecture of the new M&C system is thus more aligned with the requirements of the Telescope Manager functionality planned in SKA1, and is expected to have direct relevance and feedback into this SKA design work, that is led by India. The GMRT M&C system development work is being carried out by the GMRT Operations Group, in close collaboration with industry partners TCS Pune.

3.3. **Web-based Absentee Observing and Monitoring System for the GMRT :**

A new system has been developed and released to help astronomers using the GMRT for astronomical observations, and for GMRT engineers to monitor data and perform statistical tests on several parameters such as antenna pointing, temperature, wind speeds etc. This web-based system is designed so that radio astronomers can prepare their observing files before their observations, monitor antenna control data and astronomical data quality during their observations and download their data after observations. Basic statistical tools to allow a detailed study of several antenna parameters over time are also provided. The system consists of a combination of newly developed tools and existing desktop tools that have been made web-compatible, and will further facilitate absentee observing that is being supported at the GMRT since 2014. Users have begun to use this facility regularly now, and since the website (http://gmrt.ncra.tifr.res.in/~astrosupp/) was officially released on 15 June 2015, there have been about 8000 visitors.

**3.4. Security System for High Lift Platform (HLP) :**

An integrated security system for the special High Lift Platform vehicles used at the GMRT has been developed in house. It provides alarm and SMS alert facility on detection of over temperature, smoke and vehicle door lock status. Installation and testing has been completed on one HLP vehicle.

1. GMRT Servo system Upgrades

The commissioning of the new PC-104 based servo control computer was completed for all 30 antennas of the GMRT. The commissioning of new Brush-less DC (BLDC) motors and drives continued on more antennas of the GMRT and a total of 24 antennas were completed by the end of this year. This upgrade has significantly reduced the down time of the antennas due to servo system problems and routine motor maintenance. Work was also started on n improved design of the servo control for the feed positioning system for the GMRT antennas. [Sabhapathy Suresh, Bagade Shailendra, Kumar Amit, Thiyagaraj B., Haokip T, Pawar A., Joshi B. C.]

2. Release of the first phase of the upgraded GMRT

The good progress achieved in the upgrade activities described above resulted in the first phase of the upgraded GMRT (uGMRT) being released to the user community. In October 2015, a 16 antenna uGMRT system supporting wideband observations of upto 400 MHz bandwidth in 2 of the 4 uGMRT bands (Band 5 : 1000 to 1450 and Band 3 : 250-500) was released for internal use by NCRA members for early science verification experiments. This was followed by an announcement in December 2015 of a shared risk release of this system to the world-wide astronomy community, from GMRT observing cycle #30 that starts in April 2016 . This would mark the first formal release of the uGMRT, and is eagerly awaited by the global community.

# Square Kilometer Array

**NCRA leads Indian participation in the international SKA project :** The Square Kilometre Array (SKA) is the most ambitious international radio astronomy project attempted to date. It aims to build a telescope with 1 million square metres of collecting area, covering a large frequency range from about 50 MHz to 10 GHz, in a radio quiet region of the globe. This will result in an instrument that is 50 times more sensitive than the best today, capable of cutting edge science in several aspects of astronomy and astrophysics. As of today, eleven of the major radio astronomy practicing nations are collaborating in this project, which entered the design phase from November 2013 onwards, expected to last till end of 2017. Construction of the telescope will then begin in 2018, with early science expected by 2021-22.

India (represented by NCRA) is now an active participant in the SKA, with NCRA having become a Full Member of the SKA Organisation in August 2014. This was transferred to a Full Membership of India, with a formal signing ceremony with the SKA Organisation, held at the Offices of the Department of Atomic Energy in Mumbai on the 5th of October 2015. The SKA India Steering Committee, a high level committee to provide guidance and monitoring of the overall SKA activities in India, was set-up in July 2015 by the Department of Atomic Energy, and had its first meeting on 7th September 2015 at TIFR, Mumbai. The SKA India Consortium (SKAIC), created in February 2015, to bring together under one umbrella all organisations in India interested in SKA activities and coordinate the SKA related activities across the country, has started functioning regularly. In addition to the main Executive Council of the SKAIC, two sub-committees have been formed by the SKAIC : one to coordinate all the science related activities and another to coordinate all the technical activities.

Meanwhile, Indian involvement in the design phase activities of the SKA continued, with NCRA leading a collaboration of members from 7 different SKA member countries for the work on the design of the Telescope Manager – a sophisticated monitor & control system for the SKA, which will be like the brain and central nervous system of the observatory. The Telescope Manager consortium has successfully completed the Preliminary Design Review phase of the work, and is now well into the Detailed Design phase that will lead to the Critical Design Review by middle of 2017. NCRA also continues to be involved to a smaller extent in the Central Signal Processing and Signal & Data Transport work packages. Many of these SKA activities are being carried out in active collaboration with partners from Indian industry.

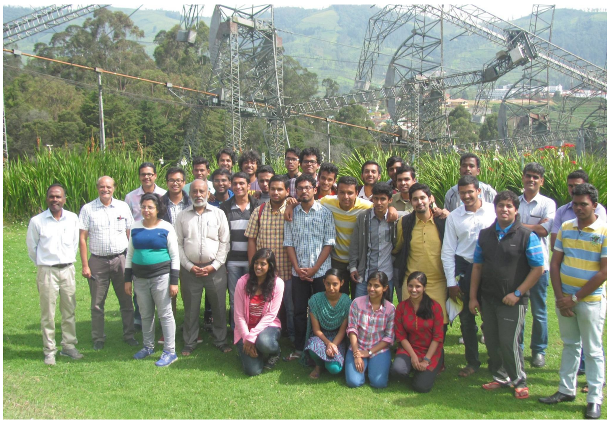
Alongwith the above, science activities related to the SKA continue to gain momentum in India. SKA India Science Working Groups, formed in March 2014, have been working on developing the science case and the potential user base within the country. Their activities include carrying out theoretical studies and modelling, as well as using the existing facilities like the GMRT to conduct research and investigations that will prepare the scientific community to make the best use of the SKA when it is ready. Many of these science working groups have been meeting regularly and working on science case documents, in addition to increasing their participation in the International Science Working

Groups of the SKA [*Yashwant Gupta, Y. Wadadekar, N.M. Ramanujam, T. R. Choudhury, J. N. Chengalur, S.K. Ghosh, J.P. Kodilkar and B. Ajithkumar, (NCRA-TIFR) working with partners from TRDDC, TCS, PSL and NVIDIA in India, and with colleagues from many other Indian institutions as well as from SKA members in South Africa, U.K., Australia, Canada, Italy and Portugal*]

**Prospects of detecting the 21-cm signature of the first sources with the SKA:** Several low-frequency experiments are being planned to study the nature of the first stars using the redshifted 21-cm signal from the cosmic dawn and epoch of reionization. We modelled the 21-cm signal pattern around these first sources using a one-dimensional radiative transfer simulation and worked out the detectability of these sources using a telescope like the SKA1-low. We found that, upon integrating the visibility around a typical source over all baselines and over a frequency interval of 16 MHz, it should be possible make a 9-sigma detection of the isolated sources at redshifts around 15 with the SKA1-low in 1000 hours. The exact value of the signal to noise ratio (SNR) will depend on the source properties. The predicted SNR decreases with increasing redshift. These calculations will be useful in planning 21-cm observations to detect the first sources [*Raghunath Ghara, T. Roy Choudhury (NCRA), Kanan Datta (Presidency University, Kolkata)*]

# Radio Physics Laboratory

**Activities of Radio Physics Laboratory:** The Radio Physics Laboratory (RPL) hosted the fourth ``Pulsar Observatory for students (POS)" program at Ooty Radio Telescope. The first leg of the program with lectures on pulsar astronomy was held between October 22-25, 2015, which was attended by 27 students, where they were exposed to details of pulsar astronomy (Figure 5). A new feature from this year was introduction to pulsar timing technique and its use in detection of gravitational waves. The students were also introduced to Fourier analysis and techniques to find new pulsars. The students then came in three batches till June 2016 to conduct live pulsar observations with ORT, where the participants were introduced to pulsar data analysis. At the end of the year, RPL hosted eighth radio astronomy winter school for College and University students (RAWSC-15) between December 15 to 24, 2015. The school was attended by 32 students drawn from all over India and seems to have become an exposure summer school of choice for the undergraduate science students(Figure 6). In this year's program, a new component of simple physics experiments was conducted in collaboration with IISER, Pune for two days apart from hands-on radio astronomy experiments and exposure lectures. RPL also put up a stall at the Annual Science day exposition at the GMRT and also participated in local astronomy outreach events. RPL also undertook an expansion of its facilities with procurement of laboratory equipment, antenna design software and radio astronomy receivers. A new experiment for two element interferometer was developed and a new 5-m antenna is currently being comissioned. Facilities at ORT were also upgraded by procurement of time standards and disks for POS archive and new pulsar analysis software was installed [*B. C. Joshi with Subhasis Roy, A. Gopakumar, J. Bagchi, N. Gupta K. Krishnakumar, P. K. Manoharan, A. Jesu Raja, T. R. Joshy, Ashok Kumar, D J Saikia, D Bhattacharya*]



Participants in Pulsar Observing for Student (POS-2015) workshop at RAC, Ooty

Participants in Radio Astronomy School for College students (RAWSC-2015) hosted by NCRA/IUCAA at Pune

# Radio Astronomy from Space

In the 12th plan, a new project to develop capability for radio astronomy from space was initiated. As part of this project, NCRA has undertaken the development of a solar radio astronomy payload called Low Frequency Radio Astronomy Experiment (LORE), which will be useful for observations of Type II and Type III bursts associated with solar energetic phenomena, such as Coronal Mass Ejections (CME) at 0 to 30 MHz, where ionosphere is opaque to radio waves necessitating space based astronomy. Last year, we developed an antenna system, consisting of three mutually orthogonal antennas after extensive simulations with antenna design software, CAD-FEKO. We also developed a preamplifier for these systems. A scaled version of these antennas at 70 MHz was validated in antenna radiation tests between Kollaripetta and Radio Astronomy Centre, Ooty last year. Implementation of signal processing in digital hardware was initiated last year and is currently in progress [*Bhal Chandra Joshi, P K Manoharan, Jayashree Roy, Gopinath Kate, Kaiwalya Pethe, Shridhar Galande, Sachin Jamadar*]

# GMRT Time Allocation Committee (GTAC)

# Staff List

**Pune**

(Academic) : Chandra P, Chengalur J. N., Ghosh S. K., Gupta Y, Ishwara Chandra C H, Joshi B. C., Kanekar N., Kantharia N. G., Lal D.V., Mitra D., Oberoi D, Roy Choudhury T, Roy J., Roy S, Saikia D. J., Sirothia S. K., Visweshwar Ram M.R., Wadadekar Y.G.,

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(Research Scholars): Aditya J. N. H. S., Atul Mohan, Bait Omkar S., Basu Avishek K., Bera Apurba, Chatterjee Atrideb, Chowdhury Aditya, Gaikwad Prakash S., Ghara Raghunath, Kurapati Sushma, Manna Souvik, Mishra Preetish K., Mondal Surajit, Naidu Arun Kumar, Nayana A J, Rahaman Minjahur S.K., Raut Dinesh V., Sebastian Biny, Sharma Rohit, Surnis Mayuresh

(Scientific): Ashok Kumar, Bollapragada N.R., Kate G. J., Meghe AA, Roy Jayashree, Gardasu B., Meshram S.G., Prasad A, Ramanujam N M, Venkatasubramani V., Banerjee R, Singh A.,

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(Administration): Adhikari S.S., Barve A. P., Bhujbal J. A., Ganeshan G., Gonde N.B., Jayasimha B. R., Joshi A., Khatavkar H. C., Khatkale S. J., Kulkarni M. M., Kulkarni S. M., Lokhande H. D., Mandhare J. D., Pandiselvan C., Patil S. V., Pawar D. V., Pawar K. R., Reena Shrikumar, Rohini Rajshekhar, Sabne M. M., Sangle B. S., Shetty S, Solanki J. K., Sonsale S.M., Verma V.K., Bandekar S. U., Gawas S.T, Patil P.S, Prajapati M.S, Revadkar S.D.

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**Khodad**

(Scientific): Gadekar S S, Ghalame A.B., Gokhale U.R, Hendre.A.S, Malu S.K., Naik K.D., Naik N.V., Parvathi S, Saurabh S., Ajith Kumar B., Amit Kumar, Ankur, Bagde S. K., Bhong D.B., Buch K.D., Chatterjee S, Chaudhari S C, Dongare S.N., Dubal S.S., Elipilli K A, Gnanaraj S.J., Goril S.K., Gupta S, Hanumanth B R, Joardar S., Kale H. S., Kamble J. R., Katore S. N., Khan I, Kodilkar J. P., Kudale S. S., Muley M.V., Nandi A.K., Nayak S., Padwal P.T., Parikh G.B., Patil M.S., Rai S.K., Raskar N.S., Raut A. N., Reddy H.S., Sabhapathy S, Samble M.S., Sherkar S S, Shinde N. D., Shinde N.J, Suresh Kumar S., Swami R. V., Thiyagarajan B., Umbarje M. S., Uprade R.R., Vasave R. J., Bhor R.D, Muley S.V.

(Technical): Jaiswar S.R., Salve S.M., Sankpal S.D., Bachal Shailendra J, Bhalerao V. B., Bhonde I. S., Bhumkar A.K, Burle S. M., Dhende A. T., Diwane A.A., Gaikwad K. R., Gaikwad P. S., Gaikwad Y.S., Ganla A.A., Gavit S.Z., Ghangale J. L., Ghorpade D.D., Halagali I, Hande P. J., Haokip T. S., Kamble U. S., Kanade C. P., Kasar P. N., Kedari H.V., Khande D.R., Kotawadekar A.P., Kumbhar G.C., Lokhande S. K., Lolap R.K., Mirajkar S.S., Misal M.B., Nalawade J. R., Nanaware D. K., Patil B. S., Patil S. D., Phakatkar S. V., Poonattu A. M., Rajendran B., Ramesh S., Raybole P. A., Sakthivel A., Satheesh C., Shirsath S.E., Somwanshi M. D., Temgire D. D., Temkar V.B., Thorat G M, Thorat G. G., Thorat R.B., Vawhal A.A, Vishwakarma A.M., Walunj D. V.

(Administration): Deshmukh N. S., Joglekar A.C., Jondhale A. B., Kanade D S, Kharmale V.S., Naik R. Y., Pokharkar D. B., Shaikh I G K, Ichake T.K, Kulkarni K D, Shaikh M.

(Auxiliary): Aher V. K., Bhalshankar S. L., Bhor A. G., Bhor S. G., Chaskar B.D., Dambale D. S., Dhumal P.T., Gaikwad B. S., Gawade S.N., Ghangale S. J., Ghorpade C. H., Ghorpade D. B., Gundgal D. K., Hande N. V., Karkud R. B., Khude K. R., Kuchik S. M., Mule N. D., Pingale R. Y., Sable B. C., Sake S. D., Shelake J. C., Thorat D. B., Vighe V.E., Wajge B. T., Yamgar L.B., Gadhave R.B, Gaikwad S. R., Ghangale H. K., Kotwal A. R., Shigwan R. B., Thorat K. T.

## Ooty

(Academic): Manoharan P. K., Krishnakumar M.A.

(Scientific): Kalyanasundaram K., Mittal Amit Kumar, Praveen P., Rajamohan S., Ravikumar D., Rodrigues I. E., Kavitha K., Uma Maheswari C,

(Technical): Alagupandiyaraja M, Chandrasekaran R., Chandrasekharan V., Nallasivam M., Raja K., Senthil Kumar S.J., Sivakumar. S, Venkatasubramani R., Jude N.R,

(Administration): Ghatal U.D., Lali Shantha Kumari N, Packiaraj V., Shyam V, Karpagam M, Mahendran R., Ravi Sankar R.

(Auxiliary): Aiyyappan S, Sankaran M., Thangakumar A.

# National and International Involvement

**Chandra, Poonam**

*Member*, International Astronomical Union (IAU)

**Chandra, Ishwara C. H**

*Councilor*, Executive Council, Astronomical Society of India, during 2013 to 2016
*Member*

Scientific Organizing Committee and Local Organising Committee, international meeting Extragalactic Relativistic Jets: Cause and Effect, ICTS, Bangalore during October 2015

**Chengalur, Jayaram N.**

*Member*

1. National Committee of the IAU
2. AIRIES Scientific Advisory Committee
3. SKA Science Working Group
4. JoAA editorial board
5. Sectional Committee of the Indian Academy of Science.

**Choudhury, T. R.**

*Member*

1. International Science Working Group on Cosmology for the SKA.
2. International Science Working Group on Cosmic Dawn / Epoch of Reinization for the SKA.

*Chair* Science Sub-Committee of the SKA-India Consortium

**Dharam V. Lal**

*Coordinator*

1. SKA India Continuum Survey Science Working Group

*Member*

1. SKA Extragalactic Continuum (galaxies/AGN, galaxy clusters) Science Working Group
2. SKA India Consortium

*Nominated*

1. Scientific Organising Committee of Science with uGMRT workshop

**Gupta, Y.**

*Member*

1. Steering Board of CASPER (Collaboration for Astronomy Signal Processing and Electronics Research, based out of University of California, Berkeley)
2. (Representing India) Board of the International Square Kilometre Array Organisation, from 2011 onwards
3. Governing Council of the Indian Institute of Astrophysics (IIA), Bengaluru, since January 2016.
4. Advisory Committee for the Shanti Swarup Bhatnagar Prize in Physical Sciences, 2015.
5. *Science Director* from India on the SKA Board, since 2014
6. *Leader,* Telescope Manager Consortium -- an international collaboration for work on the design of the Telescope Manager system for the SKA, led by NCRA, October 2013 onwards
7. *Chair* of the TMT-India Software Work Packages Monitoring Committee overseeing the overall development of software packages in India, for the Thirty Metre Telescope International Project; March 2015 onwards

**Joshi, B.C.**

*Member*

1. Panel on Education, COSPAR
2. RadioAstron International Science Committee

**Kanekar N.**

*Referee*

1. Journals Monthly Notices of the Royal Astronomical Society,
2. Astronomy and Astrophysics, and Astrophysical Journal,
3. for funding proposals to the European Research Council, and
4. for proposals for observing time on the Giant Metrewave Radio Telescope and the Shanghai-Tianma 65m telescope.

*Member*

1. Science Working Group ``Time Domain, Cosmology, and Physics" for the Very Large Array – 2020
2. Scientific Organizing Committee for the conference SKA in Seoul – 2015, South Korea, November 2015.

1. Co-organized the Radio Astronomy School, NCRA-TIFR, Pune, September 2015.

**Manoharan P.K.**

*Vice-President*

1. IAU Division E Commission 49 Interplanetary Plasma & Heliosphere

*Editor*

1. Solar and Terrestrial Sciences Section of *Geosciences Letters*, official journal of the Asia Oceania Geosciences Society (AOGS).
2. Journal of Space Weather and Space Climate
3. *National Coordinator*, International Space Weather Initiatives (ISWI) Programme in India
4. *Co-PI*, Aditya-L1 Space Solar Coronagraph Project, ISRO, India
5. *Membership* in International Union and Societies

*Member*

1. Nomination committee, Axford Medal of Asia Oceania Geosciences Society (AOGS)
2. Astronomical Society of India (ASI)
3. Asia Oceania Geosciences Society (AOGS)
4. International Astronomical Union (IAU)
5. Community of European Solar Radio Astronomers (CESRA)

# Visits

**Chandra, Poonam**

*Visited*

1. Bern, Switzerland, June 2015
2. Sweden, August 24-27, 2015
3. IISER Mohali, 2015 December 14-18, 2015
4. TIFR Mumbai, January, 2016

**Chandra, Ishwara C. H**

*Visited*

1. University of Barcelona, Spain, October 2015
2. INAF-Bologna, Italy, October 2015.

**Chengalur, Jayaram N.**

*Visited*

1. Seoul, South Korea, Nov 2-4, 2015.
2. KASI, South Korea, Nov 5-6, 2015.
3. Albuqurque, NM, USA, Dec 2-4, 2015.

**Dharam, V. Lal**

*Visited*

1. Kruger National Park in South Africa, July 1-3, 2015
2. Wenner-Gren Center, Stockholm, Sweden, August 24 - 27, 2015
3. ICTS-TIFR campus, Bangalore, October 12 to 20, 2015
4. TIFR, Mumbai, January 20 to 23, 2016

**Gupta, Y.**

*Visited*

1. SKA Consortium Work Package Leaders meeting, Jodrell Bank, UK , April 9-10, 2015
2. IIST, Trivandrum, April 9-10, 2015
3. CSP Consortium and the Work Package Leaders group meeting, Edingburgh, UK, April 9-10, 2015
4. Meeting for the constitution of the Inter-Governmental Organisation for future governance of the SKA project Rome, Italy, October 14-16, 2015
5. Pondicherry, ,PhD viva-voce examination, October 26-27, 2015
6. Annual SKA Engineering Meeting, Penticton, Canada, November 8-14, 2015
7. University of Toronto, Canada, Canadian Institute of Theoretical Astrophysics, November 16-17, 2015

8. SKA Board and the SKA Strategy Committee meeting, Jodrell Bank, UK, November 18-20, 2015
9. Science at Low Frequencies conference, Albuquerque, USA , December 2-4, 2015
10. 2nd meeting for the constitution of the Inter-Governmental Organisation for future governance of the SKA project Rome, Italy; January 26-29, 2016 :
11. Bologna, Italy, colloquium, January 26-29, 2016
12. Telescope Manager consortium of the SKA project meeting, Capetown, South Africa to February 1-5, 2016
13. IIA, Bangalore, February 8-9, 2016
14. IIT Indore, technical discussions and delivering an invited talk, March 28-29, 2016

**Joshi, B.C.**

*Visited*

1. Aryabhatta Research Institute of Observational Sciences, Nainital, India, May 6 - 8, 2015,
2. Radio Astron International Science Council, Max-Planck Institute for Radio Astronomy, Bonn, Germany, June 15 - 16, 2015,
3. Workshop on Young Rotation Powered Pulsars, Tata Institute of Fundamental Research, Mumbai, India, August 13, 2015,
4. SKA Key Science Workshop, Stockholm, Sweden, August 24 - 27, 2015,
5. 2nd URSI Regional Conference on Radio Science, Jawaharlal Nehru University, New Delhi, India, November 16 - 19, 2015
6. Neutron Star Pedagogic School, NCRA, Pune, India, January 6 - 13, 2016,
7. Neutron Star Workshop, NCRA, Pune, India, January 14 - 15, 2016,

**Kanekar, N.**

*Visited*

1. Arecibo Observatory, Puerto Rico, USA.; April 2015.
2. Columbia University, New York, USA.; April 2015.
3. University of California, Santa Cruz, USA.; April 2015.
4. The National Radio Astronomy Observatory, Socorro, New Mexico, USA; May 2015.
5. The National Central University, Taiwan; June 2015.
6. The Raman Research Institute, Bengaluru; June 2015.
7. The Korea Astronomy and Space Science Institute, Daejon, Korea; November 2015.
8. Esalen Institute, Big Sur, California, USA; February 2016.
9. University of California, Santa Cruz, USA.; February 2016.

**Manoharan, P.K.**

*Visited*

1. Solar-Terrestrial Environment Lab., Nagoya University, Japan, during March, 7–12 2015
2. Center for Geo-Space Science Research, Faculty of Sciences, University of Porto, Portugal, during October 09–16, 2015.

3. University of Mauritius, Mauritius, during September 25–26, 2015

**Wadadekar, Y.**

*Visited*

1. South African Astronomical Observatory, Cape Town, 4-18 July 2015

# Awards and Distinctions

**Chandra, Poonam C**.
*SwarnaJayanti Fellowship (2015)*

# Invited Talks in Conferences and Meetings

**Chandra, Poonam**

1. Gamma ray burst jets and their environments, Jet triggering Mechanisms, *TIFR Mumbai*, Jan 20-23, 2016
2. Evolution of explosions and their environments, NCRA Colloquium, *NCRA-TIFR, Pune*, Feb 26, 2016
3. Electromagnetic Counterparts of Gravitational Wave sources, International Conference on Gravitation and Cosmology , *IISER-Mohali*, December 14-18, 2015
4. Supernova SN 2010jl: An extraordinary evolution of the circumstellar interaction, Richard McCray Symposium, *Bern, Switzerland*, June 22-26, 2015

**Chengalur, Jayaram N.**

1. HI at intermediate Redshifts, SKA in Seoul Conference, *Seoul, South Korea*, Nov 2-4, 2015.
2. The Ooty Wide Field Array, Science at Low Frequencies II, *Albuquerque, NM, USA* Dec 2-4, 2015.
3. HI at intermediate and high Redshifts, Large Scale Structure Conference, *IUCAA*,*Pune,* Feb.1-12 , 2016.

**Choudhury T. Roy**

1. Reionization, Saha Theory Workshop: Cosmology, Interface, *Saha Institute of Nuclear Physics*, *Kolkata, India*, January 2015
2. Observational Constraints on Cosmological Reionization, Advanced Workshop on Cosmological Structures from Reionization to Galaxies: Combining efforts from analytical and numerical methods, *ICTP, Trieste, Italy*, May 2015
3. Invited Review, Observational Constraints on Reionization: Do we need 21 cm experiments?, National Workshop: Cosmology with the HI 21-cm Line, *Raman Research Institute, Bangalore, India*, June 2015.
4. Probing the Universe with Cosmic Neutral Hydrogen, Advances in Astroparticle Physics and Cosmology (AAPCOS), *Saha Institute of Nuclear Physics, Kolkata, India*, October 2015

**Joshi, B.C.**

1. Pulsars and their environments, Recent trends in study of compact objects (RETCO-II) Conference,*Nainital, India,* May 7, 2015

2. Radio emission from Young RPPS, Young Rotation Powered Pulsars workshop *TIFR, Mumbai, India,* August 13, 2015
3. (i) Pulsars and their environments, (ii) Radio Pulsars - Data Analysis techniques, Neutron Star Pedagogic School, *NCRA, Pune, India*, January 8 and 13, 2016
4. Pulsars science with SKA, Neutron Star Workshop, *NCRA, Pune, India,* January 15, 2016

**Kanekar, N.**

1. HI in High-Redshift Galaxies, workshop on 21cm Cosmology, *Bengaluru*, *India,* June 2015
2. The Gas Mass of Star-forming Galaxies at z~1.3", conference IMPS takes Esalen, *Esalen Institute, Big Sur, California, USA*; February 2016

**Manoharan, P.K.**

1. Current State of Reduced Solar Activity and Solar Wind Conditions, ST04-14-30 Session, Asia Oceania Geosciences Society (AOGS), 12th Annual Conference, *Singapore*, August 5, 2015
2. IPS Observations from Ooty Radio Telescope – Space Weather Studies", ST07-11 Session, Asia Oceania Geosciences Society (AOGS), 12th Annual Conference, *Singapore*, August 6, 2015
3. Invited presentations on
   (i) Radial evolution of coronal mass ejections in the inner heliosphere,
   (ii) Ooty studies on three-dimensional evolution of solar wind during solar cycles 22–24, Coimbra Solar Physics Meeting 2015: Ground-based Solar Observations in the Space Instrumentation Era, *Coimbra, Portugal*, October 05–09, 2015.
4. Colloquium, Ooty Radio Telescope – Space Weather Studies,*University of Mauritius, Mauritius*, September 25, 2015.

**Wadadekar, Y.**

1. A deep low frequency galaxy survey with the GMRT, SPARCS 2015, *Kruger National Park, South Africa*, 1 July 2015
2. The radio-FIR correlation in blue-cloud galaxies with z < 1, *University of Western Cape, South Africa,* 15 July 2015 and
3. The radio-FIR correlation in blue-cloud galaxies with z < 1, *ACRU University of Kwazulu-Natal, South Africa*, 23 July 2015
4. A dying, giant radio galaxy in the distant Universe" at the NCRA Academic Day, *NCRA-TIFR, Pune, India* 2015 on 26 November 2015

# Conference Organised by the School / Deptt. / Group

1. First "*Camp for Hands-on Experience in Radio Astronomy (CHERA)*" was held at RAC-NCRA-TIFR, during 1–14 July 2015. This decade has seen an unprecedented increase in the radio astronomy initiatives and related developmental activities across the world as well as in India. The CHERA was initiated to train the next generation of radio astronomers and instrumentation developers. The focus of the camp was to provide hands-on experience with instrumentation/ observation/ measurement/analysis, thus distinct from the other initiatives that were already in place. In addition to the hands-on component, the 2-week camp introduced under-graduate and masters students to radio astronomy, basic concepts and advance topics/techniques. The first camp included 11 students (3 from IITs, 2 from IISERs, 3 from Universities, 2 from other colleges, and 1 from IIST) plus 4 our own students and engineer trainees. The first CHERA at RAC was conducted in collaboration with the Raman Research Institute, Bangalore.

2. Organized a mini workshop at RAC, on "*Science with Upgraded ORT*" during 14–22 June 2015. In this workshop, 14 researchers/students from several institutions participated. I am happy to put in the record that the upgraded ORT has attracted more number of researchers, from different institutions within the country as well as from other countries, to make use of the ORT for challenging and advanced astrophysical research problems.

3. Fourth Workshop on *Pulsar Observatory for Students (POS)* was organized at RAC, during 22–25 October 2015. The POS workshop mainly aims to motivate undergraduate students to the methodology of pulsar astronomy in particular and radio astronomy in general. Each POS program consists of two legs: (1) a four-day workshop that introduces participants to basics of radio astronomy and pulsars (for the POS-2015, it took place during 22–25 October 2015); and (2) second leg of the program involves four-day live ORT observations of pulsars by the participants during their various academic breaks in the year. One observing session of POS-2015 was carried for the students during 27–30 December, 2015, and the second observing session will be held during 24–27 June 2016. In the POS-2015 programme nearly 25 students participated. For the POS programme the following members provide support in the organizational matters: Dr B.C.~Joshi (NCRA, TIFR) and Dr A. Gopakumar (DAA, TIFR). We have already started to see the fruits of the past-POS programmes. For example, some of the POS-trained students have joined the graduate school programmes of the NCRA and other astrophysical institutions.

4. One-week training programme at RAC for ~50 students of the first- and second-year bachelor science/engineering studnets. This programme includes lectures on astrophysical and engineering aspects of radio astronomy and visits to RAC facilities.

# Non DAE Research Projects

**P.K. Manoharan**

1. *Principle Investigator*
   Sun-Earth Connection and Space Weather Studies in the Three-dimensional Heliosphere, CAWSES-India Phase 2 Programme, ISRO Project (extended up to 2015).
2. *Co-Principle Investigator*
   Pulsar Monitoring observations program with the upgraded Ooty Radio Telescope, DST SERB, New Delhi

# Publications

## In Journals

Aditya,J. N. H. S.; Kanekar,N.; Kurapati, S.
A Giant Metrewave Radio Telescope search for associated HI 21 cm absorption in high-redshift flat-spectrum sources
*Monthly Notices of the Royal Astronomical Society*, 455, 4000 (2016)

Arabsalmani, M.; Roychowdhury, S.; Zwaan,M. A.; Kanekar,N.; Michalowski,M.
First measurement of HI 21 cm emission from a GRB host galaxy indicates a post-merger system
*Monthly Notices of the Royal Astronomical Society*,, 454, L51 (2015)

Arora, B. S.; Morgan, J.; Ord, S. M.; Tingay, S. J.; Hurley-Walker, N.; …. Oberoi, D.; Offringa, A. R.; Pindor, B.; Procopio, P.; Riding, J.; Staveley-Smith, L.; Wayth, R. B.; Wu, C.; Zheng, Q.; Bowman, J. D.; Cappallo, R. J.; Corey, B. E.; Emrich, D.; Goeke, R.; Greenhill, L. J.; Kaplan, D. L.; Kasper, J. C.; Kratzenberg, E.; Lonsdale, C. J.; Lynch, M. J.; McWhirter, S. R.; Morales, M. F.; Morgan, E.; Prabu, T.; Rogers, A. E. E.; Roshi, A.; Shankar, N. U.; Srivani, K. S.; Subrahmanyan, R.; Waterson, M.; Webster, R. L.; Whitney, A. R.; Williams, A.; Williams, C. L.
Ionospheric Modelling using GPS to Calibrate the MWA. I: Comparison of First Order Ionospheric Effects between GPS Models and MWA Observations
*Publications of the Astronomical Society of Australia*, **32, (**2015**)**

Basu, A.; Wadadekar, Y.; Beelen, A.; et al.
Radio-Far-infrared Correlation in Blue Cloud Galaxies with $0 < z < 1.2$
*The Astrophysical Journal*, **803**, 51, (2015)

Bhattacharyya B., Cooper S., Malenta M., Roy J., Chengalur J., Keith M., Kudale S., McLaughlin M., Ransom S. M., Ray P. S., Stappers B. W.
The GMRT High Resolution Southern Sky Survey for Pulsars and Transients. I. Survey Description and Initial Discoveries
*The Astrophysical Journal*, 817 ,130, 2016

Callingham, J. R.; Gaensler, B. M.; Ekers, R. D.; Tingay, S. J.; …. Oberoi, D.; Offringa, A. R.; Ord, S. M.; Pindor, B.; Prabu, T.; Procopio, P.; Riding, J.; Srivani, K. S.; Subrahmanyan, R.; Udaya Shankar, N.; Webster, R. L.; Williams, A.; Williams, C. L.
Broadband Spectral Modeling of the Extreme Gigahertz-peaked Spectrum Radio Source PKS B0008-421
*Astrophyiscal Journal*, **809**, 168 (2015)

Chandra, P.; Chevalier, R.; Chugai, N.; Fransson, C.; Soderberg, A.
X-Ray and Radio Emission from Type IIn Supernova SN 2010jl
*The Astrophysical Journal,* **810**, 32, (2015)

Chandra, P.; Wade, G. A.; Sundqvist, J. O.; Oberoi, D.; Grunhut, J. H.; ud-Doula, A.; Petit, V.; Cohen, D. H.; Oksala, M. E.; David-Uraz, A.
Detection of 610-MHz radio emission from hot magnetic stars
*Monthly Notices of the Royal Astronomical Society,* **452**, 1245, (2015)

Chakraborti, Sayan; Ray, Alak; Smith, Randall; Margutti, Raffaella; Pooley, David; Bose, Subhash; Sutaria, Firoza; Chandra, Poonam; et al.
Probing Final Stages of Stellar Evolution with X-Ray Observations of SN 2013ej
*The Astrophysical Journal*, **817**, 22, (2016)

Chengalur J. N., Ghosh T., Salter C. J., Kanekar N., Momjian E., Keeney B. A., Stocke J. T.
H I 21cm emission from the subdamped Lyman-alpha absorber at z = 0.0063 towards PG 1216+069
*Monthly Notices of the Royal Astronomical Society*, **453** ,3135, (2015)

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Lyman-α emitters gone missing: evidence for late reionization?
*Monthly Notices of the Royal Astronomical Society*, **452** 261 (2015),

Chengalur, J. N.; Ghosh,T.; Salter,C. J.; Kanekar, N.; Momjian,E.; Keeney,B. A.; Stocke, J. T.
HI 21cm emission from the sub-damped Lyman-alpha absorber at z=0.0063 towards PG 1216+069
*Monthly Notices of the Royal Astronomical Society*, **453**, 3135 (2015)

Chengalur J. N.; Pustilnik S. A.; Makarov D. I.; Perepelitsyna Y. A.; Safonova E. S.; Karachentsev I. D.
Study of the Lynx-Cancer void galaxies. - V. The extremely isolated galaxy UGC 4722
*Monthly Notices of the Royal Astronomical Society*, **448** ,1634, (2015)

De, K.; Gupta, Y.
A real-time coherent dedispersion pipeline for the Giant Metrewave Radio Telescope,
*Experimental Astronomy*, **41**, 67 (2016)

De Pasquale, Massimiliano; Kuin, N. P. M.; Oates, S.;.... Chandra, P.; et al.
The optical rebrightening of GRB100814A: an interplay of forward and reverse shocks?
*Monthly Notices of the Royal Astronomical Society,* **449**, 1024, (2015)

Dillon, J. S.; Neben, A. R.; Hewitt, J. N.; Tegmark, M.; …. Oberoi, D.; Ord, S. M.; Prabu, T.; Srivani, K. S.; Williams, A.; Williams, C. L.

Empirical covariance modeling for 21 cm power spectrum estimation: A method demonstration and new limits from early Murchison Widefield Array 128-tile data
*Physical Review D*, **91**, 123011 (2015)

Ghara, R.; Datta K. K.; Choudhury T. Roy
21 cm signal from cosmic dawn - II. Imprints of the light-cone effects
*Monthly Notices of the Royal Astronomical Society,* **453,** 3143 (2015),

George, L. T.; Dwarakanath, K. S.; Johnston-Hollitt, M.; ….. Oberoi, D.; Ord, S. M.; Prabu, T.; Rogers, A. E. E.; Roshi, A.; Shankar, N. U.; Srivani, K. S.; Subrahmanyan, R.; Waterson, M.; Webster, R. L.; Whitney, A. R.; Williams, A.; Williams, C. L.
An analysis of the halo and relic radio emission from Abell 3376 from Murchison Widefield Array observations
*Monthly Notices of the Royal Astronomical Society*, **451**,4207-4214 (2015)

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PSR B0329+54: Statistics of Substructure Discovered within the Scattering Disk on RadioAstron Baselines of up to 235,000 km
*The Astrophysical Journal*, **822**, 96. (2016)

Kaplan, D. L.; Tingay, S. J.; Manoharan, P. K.; ….. Oberoi, D.; Cairns, I. H.; Feng, L.; Kudryavtseva, N.; Bernardi, G.; Bowman, J. D.; Briggs, F.; Cappallo, R. J.; Deshpande, A. A.; Gaensler, B. M.; Greenhill, L. J.; Hurley Walker, N.; Hazelton, B. J.; Johnston Hollitt, M.; Lonsdale, C. J.; McWhirter, S. R.; Morales, M. F.; Morgan, E.; Ord, S. M.; Prabu, T.; Udaya Shankar, N.; Srivani, K. S.; Subrahmanyan, R.; Webster, R. L.; Williams, A.; Williams, C. L.,
Murchison Widefield Array Observations of Anomalous Variability: A Serendipitous Night-time Detection of Interplanetary Scintillation
*Astrophysical Journal*, L12 (2015)

Kanekar, N.; Meier,D.
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*The Astrophysical Journal Letters*, **811**, L23 (2015)

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*The Astrophysical Journal Letters* , **818**, L28 (2016)

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*Astronomische Nachrichten*, **337**, 306, (2016)

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*Nature*, **530**, 453, (2016)

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A GMRT study of Seyfert galaxies NGC 4235 and NGC 4594: evidence of episodic activity?
*Monthly Notices of the Royal Astronomical Society,* **459**, 1310-1326, (2016)

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Study of Milli-Jansky Seyfert Galaxies with Strong Forbidden High-Ionization Lines Using the Very Large Array Survey Images,
*Journal of the Korean Astronomical Society*, **48**, 399, (2015)

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*Geophysical Research Letters*, **42**, 3707-3714 (2015)

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*Radio Science*, 547-597 (2015)

Loi, S. T.; Murphy, T.; Bell, M. E.; Kaplan, D. L.; Lenc, E.;....... Oberoi, D.; Ord, S. M.; Prabu, T.; Rogers, A. E. E.; Roshi, A.; Shankar, N. U.; Srivani, K. S.; Subrahmanyan, R.; Tingay, S. J.; Waterson, M.; Wayth, R. B.; Webster, R. L.; Whitney, A. R.; Williams, A.; Williams, C. L.
Quantifying ionospheric effects on time-domain astrophysics with the Murchison Widefield Array
*Monthly Notices of the Royal Astronomical Society*, **453**, 2731-2746 (2015)

Macquart,J-P.; Kanekar, N.
On Detecting Millisecond Pulsars at the Galactic Center
*The Astrophysical Journal*, **805**, 172 (2015)

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*Monthly Notices of the Royal Astronomical Society,* **456**, 1791-1802, (2016)

Marcote, B., Rib'o, M.; Paredes, J.M.; Chandra,Ishwara, C.H.

Physical properties of the gamma-ray binary LS 5039 through low- and high frequency radio observations
*Monthly Notices of the Royal Astronomical Society,* **451**, 59-73, (2015)

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*Monthly Notices of the Royal Astronomical Society*, **454** L76 (2015)

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The HI Content of the Universe Over the Past 10 Gyrs
*The Astrophysical Journal*, 818, **113** (2016)

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*The Astrophysical Journal Letters*, **820**, L39 (2016)

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*Radio Science*, **50**, 614-629 (2015)

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*Astrophyiscal Journal*, **809**, 51 (2015)

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*Monthly Notices of the Royal Astronomical Society*, **450** L29 (2015),

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*Monthly Notices of the Royal Astronomical Society*, **451** 1692 (2015)

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*Monthly Notices of the Royal Astronomical Society*, **456** ,2467, (2016)

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*Monthly Notices of the Royal Astronomical Society,* **454**, 1556-1572 (2015)

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Chandra, Poonam; Nayana, A. J.
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Lal, Dharam V.
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Proceedings of the Korean Astronomical Society, 30, **423,** 2015

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## In Books

Manoharan, P.K.
Satellite mission concepts developed at the Alpbach 2013, Summer School on space weather
Journal of Space Weather and Space Climate, vol 5, March, 2015.

**Research Papers:**

P.K. Manoharan, A. Naidu, B.C. Joshi, Jayashree Roy, G. Kate, K. Pethe, S. Galande, S. Jamadar, S.P. Mahajan, R.A.Patil
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E. Aguilar-Rodriguez, J.C. Mejia-Ambriz, B.V. Jackson, A. Buffington, E. Romero-Hernandez, J.A. Gonzalez-Esparza, M. Rodriguez-Martinez, P. Hick, M. Tokumaru, P.K. Manoharan
Comparison of Solar Wind Speeds Using Wavelet Transform and Fourier Analysis in IPS Data, Solar Physics, 290, Issue 9, pp.2507-2518, 2015 (doi 10.1007/s11207-015-0758-0).

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Search for pulsed radio emission from SWIFT J174540.7-290015,
The Astronomer's Telegram, No. 8729, February 2016.

## Technical Reports/Internal Reports

Lal, Dharam Vir

Flux density measurements for CasA, Crab, Cygnus-A & Virgo-A calibrator sources from 50 to 1,450 MHz, 2301/617

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Expected ON–minus–OFF deflections with matched OFF positions for calibrator sources at 151, 235, 325, 610 and 1420 MHz, 2301/651 The Faint Irregular Galaxy GMRT Survey, Colloquium at KASI, South Korea,05/Nov/2015

# Lectures / Lecture Courses Given Elsewhere

**Chandra, Poonam C.**

1. Supernovae: shocked after violent death of stars, VSRP lectures, NCRA-TIFR, Pune, June 6, 2015
2. From birth to death: life cycle of stars, Radio Astronomy Winter School lecture, NCRA-TIFR, Pune, December 22, 2015
3. Converting an idea into a proposal, Radio Astronomy School lecture, NCRA-TIFR, Pune, September 2015
4. Sensitivity - In Radio Astronomy, Radio Astronomy School lecture, NCRA-TIFR, Pune, September 2015

**Chengalur, Jayaram N.**

1. The Faint Irregular Galaxy GMRT Survey, Colloquium at KASI, South Korea, Nov 5, 2015

**Choudhury T. Roy**

1. General Theory of Relativity(~25 Lectures), M.Sc. Course, SP Pune University, Pune, India, January - March 2016.

**Gupta, Y.**

1. Probing the Universe at Radio Wavelengths: From the GMRT to the SKA, (Colloquium) TIFR, Mumbai , September 16, 2015.
2. The upgraded GMRT : Current Status and Future Prospects,(Colloquium), CITA, Toronto, Canada November 17, 2015.
3. Science at Low Frequencies (Conference), Update from the GMRT : towards the next decade, Albuquerque, USA , December 2, 2015.
4. Probing the Universe at Radio Wavelengths : From the GMRT to the SKA,Tata Research Design and Development Centre, Pune, Januanry 18, 2016.
5. Update from India : the upgraded GMRT, (Colloquium), INAF, Bologna, Italy January 29, 2016.
6. The Universe at Radio Wavelengths, (Colloquium), IIT, Indore, March 28, 2016.
7. Pulsar Astronomy, Pedagogic School of the Neutron Star Workshop, NCRA, Pune, January 6 and 11, 2016.
8. Overview and Current Status of the SKA, Neutron Star Workshop NCRA, Pune, January 15, 2016
9. Telescope Manager Consortium, Annual SKA Engineering Meet, Penticton, Canada, November 11, 2015.

**Joshi, B.C.**

1. Introduction to Radio Astronomy Observing for Students (POS-2015) Radio Astronomy Centre, Ooty, India,October 22, 2015
2. Introduction to Data Analysis methodology, Pulsar Observing for Students (POS-2015), Radio Astronomy Centre, Ooty, India, October 23, 2015
3. Pulsar Timing Array and Square Kilometer Array,Pulsar Observing for Students (POS-2015), Radio Astronomy Centre, Ooty, India,October 25, 2015
4. Radio Astronomy with Single element radio telescope, Radio Astronomy School for College students (RAWSC-2015), NCRA, Pune, India, December 15, 2015
5. Pulsars and gravitational physics, Radio Astronomy School for College students (RAWSC-2015) NCRA, Pune, India December 19, 2015

**Kanekar, N.**

1. Modern Cosmology, Delta Corporation, Taiwan, June 2015
2. Modern Cosmology: Lecture at the Taichung High School, Taiwan, June 2015
3. High-redshift Galaxies, NCRA-TIFR Pune, June 2015
4. Interferometry and Radio Spectral Lines, Two lectures, Radio Astronomy School, NCRA-TIFR, Pune, September 2015
5. Do the Fundamental Constants Change with Time ?, (Colloquium) Arecibo Observatory, U.S.A. April 2015
6. Do the Fundamental Constants Change with Time ?, (Seminar) Columbia University, U.S.A.; April 2015
7. Stars and Gas in High-redshift Galaxies, (Seminar) National Astronomy Observatory, Socorro, U.S.A. May 2015
8. Do the Fundamental Constants Change with Time ?, (Colloquium) National Central University, Taiwan June 2015
9. Cold gas at high redshift ?, (Conference) SKA in Seoul, Seoul, South Korea, November 2015
10. The Nature of High-z Damped Lyman-alpha systems, (Colloquium),Korea Astronomy and Space Sciences Institute, Daejon, South Korea, November 2015

**Wadadekar Y.**

1. Galaxy formation, IUCAA Refresher Course, May 25, 2015
2. Variable Stars, Astronomy Olympiad Training cum Selection Camp HBCSE-TIFR, May 27, 2015
3. Digital Astronomy techniques, IUCAA workshop on Astronomy with Small Telescopes at SRTM University, Nanded, December 8, 2015.
4. Basics of telescopes, IUCAA workshop on Astronomy with Small Telescopes at SRTM University, Nanded, December 9, 2015.
5. EM Wave propogation Radio Astronomy Winter School 2015, NCRA, December 15, 2015

# Lectures by Visitors

## Colloquia

**Manoj Puravankara** (*TIFR, Mumbai*) Infrared spectroscopy of protostars with Herschel & Spitzer: Probing the earliest stages of stellar birth, April 20, 2015

**Dave Green** (*University of Cambridge, UK*) An updated Galactic supernova remnant catalogue -- 30 years old!, April 27, 2015

**Arnab Rai Choudhuri** (*Indian Institute of Science, Bengaluru*) Starspots, Stellar Cycles and Stellar Flares: Lessons from Solar Dynamo Models, August 24, 2015

**Vithal Tilvi** (*Arizona State University, USA*) Probing the Epoch of Reionization, December 22, 2015

**Prateek Sharma** (*Indian Institute of Science, Bengaluru*) Overlapping supernovae, the ISM, and galactic outflows, December 7, 2015

**Rishi Khatri** (*TIFR, Mumbai*) New constraints on CMB spectral distortions using Planck data, February 1, 2016

**Marek Jamrozy** (*Jagiellonian University, Poland*) Peculiar Radio Galaxies in Clusters of Galaxies , February 22, 2016

**Poonam Chandra** (*NCRA-TIFR,Pune*) Environments of massive stars and their explosions, February 26, 2016

**Ramit Bhattacharyya** (*Udaipur Solar Observatory, PRL, Udaipur*) A Tale of Two Scales: The Solar Corona, Feburary 5,2016

**Aritra Basu** (*Max-Planck-Institute for Radio Astronomy, Germany*) Magnetic fields: Near and far, January 8,2016

**Thushara Pillai (***Max-Planck Institute fur Radioastronomie, Germany*) Infrared Dark Clouds and High-Mass Star Formation, June 1, 2015

**Kate Clark** (*NVIDIA*) Exascale Radio Astronomy, June 15, 2015

**A. N. Ramaprakash** (*IUCAA*) The Thirty Metre Telescope project - status and Indian role, June 29, 2015

**Tarun Souradeep** (*IUCAA*) Planck's Cosmos , June 5, 2015

**Prasun Dutta** (*Indian Institute of Science Education and Research, Bhopal*) Characterising turbulence in the interstellar medium of galaxies , June 8, 2015

**Peter Kamphuis** (*NCRA-TIFR, Pune*) Modelling for Large Neutral Hydrogen Surveys, March 14, 2016

**Yashwant Gupta** (*NCRA-TIFR, Pune*) An MSP Potpourri, March 18, 2016

**T. P. Singh** (*TIFR, Mumbai*) Is quantum theory exact, or approximate?, March 21, 2016

**Girish Kulkarni** (*Institute of Astronomy, Cambridge, UK*) Small-scale Structure of the Intergalactic Medium, March 7,2016

**Jens Kauffmann** (*Max-Planck-Institute fur Radioastronomie, Germany*) Exploring Distant Star Formation with ALMA, May 25, 2015

**Sunder Sahayanathan** (*Bhabha Atomic Reseach Centre, Mumbai*) Blazars: The Unsolved Riddles, November 16, 2015

**Nick Kaiser** (*Institute for Astronomy, Hawaii, USA*) Gravitational Redshifts in Clusters of Galaxies, November 23, 2015

**Chanda Jog** (*Indian Institute of Science, Bengaluru*) Dynamical effect of dark matter halo on galactic disk instabilities, October 26, 2015

**Rajaram Nityananda** (*Azim Premji University, Bengaluru*) Irreversibility, Ignorance, and Inference: The many faces of Information, October, 9, 2015

**Subinoy Das** (*Indian Institute of Astrophysics, Bengaluru*) Possible astrophysical signatures of dark matter particle physics, September 21, 2015

# Seminars

**Nadeem Oozeer** (*SKA South Africa, Cape Town*) KAT 7 and MeerKAT, the SKA prescursors - a status update, April 24, 2015

**Kunal Mooley** (*Caltech, USA*) The 2015 Outburst of the Black Hole X-ray Binary, V404 Cyg, December 18, 2015

**Anshu Gupta** (*Australian National University, Australia*) Do galaxy clusters form via an inside-out model ?, December 21, 2015

**Anupreeta More** (*Kavli IPMU, Japan*) Mass distribution and concentration-mass relation in galaxy groups, February 15, 2016

**Shweta Srivastava** (*Physical Research Laboratory, Ahmedabad*) A multi-wavelength view of nearby Wolf-Rayet galaxies , July 14, 2015

**Archana Soam** (Aryabhatta Research Institute of Observational Sciences, Nainital) Magnetic fields in triggered and spontaneous star forming regions , July 7, 2015

**Sumana Nandi** (*KTH Royal Institute of Technology, Stockholm*) New insight on double-double radio galaxiess, March 11, 2016

**Aditya Chowdhury** (*NCRA-TIFR, Pune*) Radio Frequency Interference mitigation for pulsar data and the release of the GMRT Pulsar Tool, March 22, 2016

**Manasvita Joshi** (Boston University, USA) Multiwavelength Spectral Studies Of Blazars With MUZORF, November 3, 2015

**Sambit Roychowdhury** (*Max Planck Institute for Astrophysics, Garching, Germany*) Relating gas and star formation in the HI dominated regime, October 30, 2015

**Tejaswi Nerella** (*Caltech, USA*) The redshifted 21-cm line as a cosmological probe of magnetic fields and gravitational waves, September 22, 2015

# Graduate Courses

**Chandra, Poonam C.**

Electrodynamics and Radiative Processes I,
IUCAA-NCRA Graduate School, 2015-2016

**Choudhury, T. Roy**

General Theory of Relativity (M.Sc. - Part I)
Savitribai Phule Pune University, 2015 - 2016

**Oberoi, D.**

Astronomical Techniques II
IUCAA-NCRA Graduate School, 2015-2016

**Roy, S.**

Introduction to Astronomy and Astrophysics I
IUCAA-NCRA Graduate School, 2015-2016

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

**Chengalur, Jayaram N.**

N. Patra (NCRA) (Ph.D., September 2015)
The Interstellar Medium of Dwarf Galaxies
*Tata Institute of Fundamental Research, Mumbai*

**Choudhury T. Roy**

Prakash Gaikwad (NCRA), (M.Sc.Degree, 2015 )
Constraining temperature fluctuations in the intergalactic medium
*Tata Institute of Fundamental Research, Mumbai*

# Popular Science Articles / Lectures

**Wadadekar, Y.**

1. 25 years of the Hubble Space Telescope, Jyotitrvidya Parisanstha, Pune, April 26, 2015
2. Exploring our solar system, GHSS Nadukallur School, Tirunelveli,Tamilnadu, November 17, 2015
3. Observing Galaxies with radio light (in English and Marathi), IUCAA Second Saturday school program, January 9, 2016

**Choudhury T. Roy**

*Public Talk*

Square Kilometre Array: Exploring the Universe with the worlds largest radio telescope, Outreach Programme on Different Aspects of Astroparticle Physics and Cosmology, *Saha Institute of Nuclear Physics, Kolkata, India*, October 2015.

# Any other information

Public outreach programmes organized at RAC, Ooty:

1. **National Science Day 2015 at RAC:** As one of our public outreach activities, we organized the National Science Day at the RAC on 28 February 2015. This programme included several attractions, such as (i) demonstration of the Ooty Radio Telescope's mechanical, electrical, and electronics systems, (ii) watching the live observations of celestial objects using the ORT, (iii) observing the Sun and tracking its sunspots, (iv) demonstrations and exhibits on recent advances and developments in astronomy and astrophysics, (v) exhibits and demonstrations from other scientific and research organizations of the Nilgiri District, and (vi) Selected science models from schools and paintings made by students. In association with the RAC Science Day, science awareness events were also conducted at RAC for school students. Thousands of students and public benefited in this one-day long event. It was the 3nd science day programme organized at the RAC and was extremely successful.

2. **College Students' Visit to RAC:** During this period of the report, nearly about 10,000 to 15,000 students and faculty members of engineering/science colleges/universities (i.e., nearly 200 batches of students) from all over the country made educational visits to the RAC. For these students, we arranged the video on radio astronomy and one of the members of the institute explain the facilities at RAC.