Project Updates

Yashwant Gupta
National Centre for Radio Astrophysics NCRA-TIFR, Pune, India

GMRT upgrade: current status

Russ Taylor
University of Cape Town, South Africa

MeerKAT and MIGHTEE

Timothy Shimwell
Leiden Observatory, Leiden, The Netherlands

The LOFAR Two-metre Sky Survey

The LOFAR Two-metre Sky Survey (LoTSS) is a deep 120−168 MHz imaging survey that will eventually cover the entire Northern sky. Each of the 3170 pointings will be observed for 8 hrs, which, at most declinations, is sufficient to produce $\sim 5''$ resolution images with a sensitivity of $\sim$100 micro-Jy/beam and accomplish the main scientific aims of the survey which are to explore the formation and evolution of massive black holes, galaxies, clusters of galaxies and large-scale structure. Due to the compact core and long baselines of LOFAR, the images provide excellent sensitivity to both highly extended and compact emission. For legacy value, the data are archived at high spectral and time resolution to facilitate subarcsecond imaging and spectral line studies.

The first low-resolution data release has now been submitted for publication but LoTSS data at full resolution and sensitivity. In this talk I will outline status of the survey and discuss some preliminary results and future developments.

Joshua Marvil
CSIRO Astronomy & Space Science, Australia

ASKAP and EMU Updates

The Evolutionary Map of the Universe (EMU) is a large-area continuum survey with the Australian SKA Pathfinder (ASKAP). I will provide an overview of the ASKAP telescope and the EMU project, including an update oncommissioning progress andrecent preparations for the commencement of the survey. I will also discuss the planning of ∼800 hours of the ASKAP early science program which will begin in early 2017.

Bryan Gaensler
University of Toronto, Canada

An overview of the POSSUM polarisation survey on ASKAP

Sky Surveys

Minh Huynh
University of Western Australia, Australia

The ATCA XXL-S radio survey: First results and preliminary AGN luminosity functions

Minh Huynh (Andrew Butler, Vernesa Smolcic, Jacinta Delhaize)

The XXL is the largest survey ever with the XMM-Newton X-Ray telescope, comprising 6.9 MS spread over two 25 sq deg fields, the XMM-LSS field (XXL-N RA= 2:18, Dec= −5:17) and the BCS-XMM field (XXL-S at RA=23:30, Dec=−54:30). The main goals of the XXL project are to probe cosmology using galaxy clusters and to study galaxy evolution with a large sample of AGN. As part of the ongoing multiwavelength followup to achieve these science goals, radio observations at 2.1 GHz were obtained on the Australia Telescope Compact Array covering the full 25 sq deg of the XXL-S, reaching an rms noise of ∼40−50 microJy and a resolution of ∼5 arcsec. This is the largest radio survey ever at these flux density levels. We identify ∼6200 radio sources down to 5 sigma over 25 sq deg. We present the initial results and preliminary AGN radio luminosity functions from the ATCA XXL-S survey.

Huub Rottgering
University of Leiden, Leiden, The Netherlands

LOFAR, latest results on clusters, AGN and star bursting galaxies.

With the facet calibration technique LOFAR is now capable of almost routinely making images at 150 MHz down to noise levels of ∼100microJy from 8 hours of data. In this talk I will present the latest LOFAR results making use of this techniques. These results give insights into the physics of merging clusters clusters, AGN feedback and distant star bursting galaxies.

Roland Kothes
DRAO, Herzberg Programs in Astronomy and Astrophysics, Canada

First Results from the Observations of the SPARCS Northern Reference Field with the DRAO Synthesis Telescope

A major challenge for next-generation radio continuum surveys (ASKAP-EMU/POSSUM, Apertif-WODAN, LOFAR, etc.) will be to ensure uniformity between the surveys. This extends far beyond simply ensuring the flux calibration scales are the same, as subtle effects can cause inconsistencies between surveys which are difficult to detect unless the surveys themselves overlap, and a range of sources at all flux density scales are compared. To overcome this, SPARCS has initiated a series of observations of three fields at Declination -29, 0, and $+29$ degrees. Here I will report on the initiative to observe the Northern reference field with the synthesis telescope at the Dominion Radio Astrophysical Observatory (DRAO ST). The DRAO ST provides radio observations of atomic hydrogen and radio continuum emission, including the polarized signal, at four separate frequency bands with high spatial dynamic range and sub-arcminute resolution. Here, I will present preliminary results of the linear polarization characteristics and variability of compact sources.

Jack Radcliffe
Jodrell Bank Centre for Astrophysics, University of Manchester
and
Kapteyn Astronomical Institute, University of Groningen

Isolating AGN Using Deep Wide-field VLBI & e-MERLIN Observations

Previous, deep radio surveys have shown an upturn in the integrated source counts in sub-mJy regime. This is far in excess of those predicted by high luminosity radio galaxies and quasars that dominate at higher fluxes. Recent multi-wavelength studies and radio surveys (e.g. Padovani+ 2014), have shown that this upturn comprises of a mixture of active star-forming galaxies and faint AGN. Isolating these 'radio quiet' AGN is pivotal if we are to understand the interplay between star formation and AGN feedback around the peak star-forming era of the Universe. This can be achieved using ultra sensitive, wide-field, VLBI observations.

We present a new ultra-deep, wide-field VLBI survey covering a large, 180 arcmin^2, area to milliarcsec resolutions and microJy sensitivities. This survey utilises a recently developed VLBI calibration technique termed Multi-source Self-calibration (Radcliffe+ 16), which may be important in the advent of SKA-VLBI. Results are presented from the first (and possibly second) epoch of observations which reveal a substantial population of faint, microJy AGN. Combination imaging using the eMERGE (P.I. Muxlow) survey (a combination of JVLA + VLA + MERLIN + e-MERLIN) together with these new EVN data enables us to probe structure at multiple physical scales and allows us to separate contributions from star-formation and embedded AGN. When used in conjunction with 5GHz e-MERLIN and EVN observations, Chandra, Herschel and HST data, we are able to obtain a picture of AGN-starburst feedback mechanisms at high redshifts that the SKA will eventually solve.

Veeresh Singh
Physical Research Laboratory, Ahmedabad, India

Unveiling the nature of Infrared-faint Radio Sources in deep fields

Recent deep radio continuum surveys combined with auxiliary Infra-Red (IR) surveys have discovered a new population called 'Infrared-Faint Radio Sources' (IFRSs) that are relatively bright radio sources with faint or no counterparts in IR, optical wavelengths. Measuring the redshifts of IFRSs has been a challenge owing to the dearth of more sensitive optical and IR data and initial investigations have been limited only to radio wavelengths. Utilizing deep optical, IR data (from Subaru, VLT and Spitzer) we obtain redshifts of a significant fraction of IFRSs and found them to be high-redshift radio-loud Active Galactic Nuclei (AGN) lying at $z \sim 1.7 - 4.3$. Moreover, IFRSs exhibit diverse properties in terms of their radio luminosities, sizes and spectra, indicating them to be radio-loud AGN at different evolutionary phases. The discovery of IFRSs as a new population of high-z radio-loud AGN has important implication on the models of galaxy evolution and missing unresolved component of Cosmic X-ray Background. In this talk I shall also assess the role of upcoming radio continuum surveys from uGMRT and SKA in unveiling IFRSs at fainter flux limits.

Mattia Vaccari
University of the Western Cape, South Africa

HELP-ing Radio Continuum Surveys : The Herschel Extragalactic Legacy Project

Mattia Vaccari, Matt Jarvis, Russ Taylor & The HELP Consortium

The Herschel Extragalactic Legacy Project (HELP, http://herschel.sussex.ac.uk/) is a 4-year (2014-2017) 2.5 MEuro project funded by the EC FP7-SPACE programme whose aim is to produce homogeneous multi-wavelength value-added source catalogs spanning Herschel's wide-area extragalactic surveys for a total $\sim$1300 deg^2.

Building upon existing data reduction best practices at different wavelengths and developing new tools to identify the most likely sources of far-infrared emission in Herschel confused maps, HELP will bridge the gap between COSMOS and SDSS and produce a multi-wavelength database enabling galaxy evolution and AGN feedback studies of the distant Universe over the largest scales as a function of redshift and galaxy local environment. This will provide an accessible resource for the astronomical community to mine for decades to come, a lasting legacy of many thousands of hours on space telescopes as well as thousands of nights on ground based telescopes, building a solid foundation for future space missions and ground-based observatory projects.

In my talk I will introduce HELP, its main objectives and challenges, report on its status and finally outline how it will benefit radio continuum surveys by detailing a few ongoing studies ot faint radio source populations.

Active Galaxies

Joydeep Bagchi
Inter-University Centre for Astronomy and Astrophysics, Pune, India

Large Scale Relativistic Jets in Spiral Galaxies

All galaxies may contain a central massive black hole, but presently the majority are quiet and inactive. A fraction of these black holes however accrete so much matter that they outshine the combined light from all their stars. These active galaxies occasionally also launch powerful radio jets, which shoot out from the AGN upto Mpc distances, earning themselves the title of quasars and radio galaxies. However, powerful radio jets on ¿100 kpc scales are nearly always launched from the nuclei of elliptical galaxies and not spirals, and the typical radio luminosity of spiral galaxies is about $10^3 - 10^4$ times feebler than that of ellipticals, making them comparatively radio-quiet. The physical origin of this phenomenon and the mechanism by which relativistic jets are launched from accretion disks have long been the subject of investigations, yet the issue still remains mysterious despite a wealth of observations. Recent observations with GMRT or JVLA of a few rare spiral galaxies hosting ¿100 kpc scale jets have generated an intense renewed interest in this field. Highly sensitive observations with next generation radio telescopes such as SKA and LOFAR will bring far more focus and a paradigm shift in this field. I will present a comprehensive overview of this field highlighting the discoveries of a few exceptionally massive spiral galaxies ejecting record Mpc scale jets, that are challenging the conventional wisdom and providing a rare opportunity for probing the physics of relativistic jet formation and the co-evolution of host galaxies and their black hole properties − like mass and spin. These large relativistic jets are probably triggered via the so-called "Blandford-Znajek" mechanism, resulting from a high mass, and fast spin acquired by the central black hole, now accreting at low-Eddington rate. The estimated masses of these black holes are unusually high for a spiral host, while some of them even lack a central bulge. These ground breaking results point towards an unusual formation route which has assembled coevally, both the massive, spinning black holes and fast-rotating galactic disks over a cosmological time scale. Therefore these remarkable galactic systems are uniquely powerful laboratories for many future studies.

Prajval Shastri
Indian Institute of Astrophysics, India

Do z∼0 AGN Show Signatures of Black Hole Growth Feedback?

P. Shastri, J. Banfield, P. Kharb, and the S7 team

Scaling relationships for supermassive black holes are now well-established and persist to early cosmic epochs. They can be explained if star formation in the AGN host is regulated by feedback via mechanical and radiative energy from the accreting central supermassive black hole. We have undertaken a multi-wavelength investigation of about 140 southern AGN at redshifts<0.02, in order to search for signatures of such feedback. Our Siding Spring Southern Seyfert Spectroscopic Snapshot Survey (S7) using an integrated field unit (WiFeS) is being followed up by observations and compilation of data at radio (ATCA and GMRT) and other frequencies. We will present results for a few individual AGN and explore the implications of our results for SKA pathfinder science.

Ananda Hota
UM-DAE Centre for Excellence in Basic Sciences, India

Tracking galaxy evolution through merger and feedback using GMRT and citizen-science collaboratory RAD@home

Ananda Hota and Chiranjib Konar

We will present multi-wavelength observational results leading to understanding of the evolutionary history of some interesting galaxies in the process of transition. Telescopes like GMRT, VLA, SMA, Subaru, Chandra, XMM-Newton have been used in our study of target galaxies like NGC1482 (merger-remnant early-type with Superwind), NGC6764 (barred-spiral with radio bubble), NGC3801 (merger-remnant with shock-shells around sub-galactic radio lobes), Speca (Spiral-host episodic radio galaxy tracing cluster accretion) etc. Stellar population synthesis models and synchrotron spectral ageing have been used along with archival data in the UV, optical and IR to track back the history of various processes in these transitional galaxies caught-in-the-act. They serve as ideal labouratories for understanding the physical progress that drive evolution from spiral to elliptical through merger, star formation and AGN activities and feedback processes like starburst-driven superwind and AGN-jet driven outflows. Though AGN or quasar activity is extremely energetic, it is extremely short-lived. This justify focusing on transitional galaxies to find relic-evidences of the immediate past AGN-feedback which decide the future course of evolution of a galaxy. Relic radio lobes can be best detected in low frequency observations with the GMRT, LOFAR and in future SKA. Only in the year 2007, the very first relic-evidences of a past quasar activity ('Hanny's Voorwerp') was discovered by Galaxy Zoo citizen-scientists, in the optical bands. RAD@home (www.facebook.com/RADatHomeIndia/), the only Indian citizen-science research project in astronomy, analysing TGSS data and observing from the GMRT, was launched in April 2013. Unique, zero-infrastructure zero-funded design and findings from RAD@home will be presented in the meeting. These new findings include, radio bubbles in spiral galaxies, episodic radio galaxies, dead/relic lobe radio galaxies, diffuse relic/halo radio emissions in groups/clusters, possible shock fronts of cluster merger, radio-jet and companion galaxy interaction, radio galaxies bent by relative motion of the intra-filament medium in Mpc-scale galaxy filaments etc. Citizen-science has not only opened up a new way for astronomy research but also given us possibly the only promising way to extract maximum science out of the BIG DATA in the SKA-era. As our tag line Any BSc/BE Can Do research (#ABCDresearch) using GMRT sitting anywhere in India, RAD@home allow participation from all citizens with undergraduate science and engineering education in analysing data from GMRT (in particular TGSS survey data). Through one-week short-term trainings hosted in various research institutes and on-line e-class e-research discussion sessions a growing community of citizen-scientists or collaboratory of e-astronomers (current total 65) has been created. With such modifications, citizen-science can not only contribute to the knowledge creation in never-seen-before speed and approach but also give an equal opportunity of career growth in astronomy to people even in the under-developed regions where we always put our optical and radio telescopes.

Rubinur Khatun
Indian Institute of Astrophysics, India

Radio Observations of Candidate Dual Active Galactic Nuclei in Double Peaked Emission Line Galaxies

Rubinur Khatun and Mousumi Das

We present arcsecond scale radio observations with the Expanded Very large Array (EVLA) of eight galaxies that are classified as double peaked emission line active galactic nuclei (DPAGN) in optical surveys. Our main aim is to distinguish between dual AGN and jets or disks in these DPAGN. Dual or supermassive black hole (SMBH) binaries are expected to form during galaxy mergers and minor accretion events. When the SMBHs are accreting, they become dual AGN. Double peaked emission lines can indicate the presence of two AGN, but can also be due to powerful bipolar jets or outflows or rotating nuclear disks. High resolution radio observations are one of the best way to confirm the presence of binary AGNs. In our 6 GHz observation of the nuclei of eight DPAGN galaxies, we have detected two double core sources that appear to be dual AGN and four extended sources that are possibly radio jets associated with compact cores. The remaining two galaxies are single compact cores. We have used archival data at higher frequencies to do follow-up studies of one of the double core galaxies. Our results suggest that high resolution, multi-frequency radio observations are essential to detect dual SMBHs in our low redshift Universe.

Preeti Kharb
National Centre for Radio Astrophysics NCRA-TIFR, Pune, India

Low Frequency Observations of S7 Seyfert Galaxies

Preeti Kharb, S7 Team

A large fraction of Seyfert galaxies exhibit kiloparsec-scale radio structures (KSRs) in sensitive observations. While several pieces of evidence favour an AGN origin for KSRs, radio emission from nuclear star-forming regions can make a non-negligible contribution. We present results from our ongoing low-frequency GMRT survey of around 30 Seyfert/LINER galaxies belonging to the "Siding Spring Southern Seyfert Spectroscopic Snapshot Survey" (S7;Dopita et al. 2015). Spectral index images from 1390 and 610 MHz data are currently being analysed to separate the AGN and star-formation components. Furthermore, we are using these data to distinguish between the "roman candle" (young source) model and the "frustrated jet" (old source) model, as suggested in the work of Gallimore et al. (2006). We will briefly discuss the results of our study, and highlight the importance of future low frequency observations in understanding Seyfert outflows.

Techniques & Technical Issues and Surveys

Tessa Vernstrom
Dunlap Institute for A&A, University of Toronto, Canada

Clarifying Confusion

With the MWA, and other upcoming SKA Pathfinders, we will be reaching new survey depths. However due to the telescope resolutions source confusion will still be a (in some cases major) issue. Whether the goal is measuring source counts, the cosmic radio background, the Epoch of Reionisation signal, or the radio cosmic web it is important to not only understand confusion and its effects but also how it can be used as an analysis tool. Techniques like P(D) confusion analysis can be used for measuring source counts and diffusion emission below traditional levels. In this talk I will discuss the use of such techniques using results from previous radio data and simulations. I will also address the effects of things like non-constant instrumental noise, sidelobe contamination, and point source subtraction and how we might be able to apply this information to the MWA (and other pathfinders) data.

Srikrishna Sekhar
Indian Institute of Science Education and Research, Pune, India

Residual fringe subtraction to mitigate direction dependent errors

Srikrishna Sekhar and Ramana Athreya

We propose a new scheme to mitigate direction dependent errors by subtracting fringes from the residual visibilities. The sky as seen by the telescope varies with time and direction due to the ionosphere and the antenna primary beam. However, cleaning (deconvolution) assumes time-invariant sources. Therefore, the process of deconvolution leaves behind "uncleaned" fringes in the residual UV-plane which limits the dynamic range of the image. The strongest sources in the field are more liable to cause such errors resulting in poorer detection of the faintest objects.

The key issue here is that one is estimating the error for an individual baseline in an independent manner, unlike, for e.g in self-calibration where antenna-based corrections are determined for all baselines in one pass. This could result in an inadvertant modification of the target source structure.

We have developed a scheme by which the (strong) sources responsible for such residual fringes are identified and appropriate constraints imposed to limit the modifications to such (uninteresting) strong sources only. The scheme is of general applicability and can correct for the effect non-isoplanetic ionosphere and a variety of primary beam effects including azimuthal asymmetry, variation of size with bandwidth, and jitter. On the down side, the algorithm does not improve the dynamic range of the (offending) strong sources themselves.

Our results show reduction in the image noise by up to 30observations of the GMRT.

Huib Intema
Leiden Observatory, Leiden, The Netherlands

How to SPAM the 150 MHz sky

One of the relatively unexplored areas of astronomy is the low-frequency radio continuum sky at sub-arcminute resolution. The wide fields-of-view of current and future radio interferometers like LOFAR, MWA, JVLA low-band, GMRT, and SKA-low make them potentially powerful survey instruments, yet it comes at the cost of significantly increased complexity in the data processing. One major hurdle is to properly account for the direction-dependent distortions in the presence of large numbers of detectable cosmic sources within the field-of-view and beyond. One essential ingredient is having an accurate reference model of the sky at a similar frequency and resolution.

In this talk I will present methods and results of the fully automated processing of the 37,000 deg^2 archival 150 MHz GMRT sky survey (TGSS) data using the SPAM package. Covering about 90 percent of the radio sky at a median sensitivity of 3.5 mJy/beam, this $25''$ survey provides an excellent reference catalog for LOFAR and MWA, as well as a unique view on the relatively unexplored southern hemisphere sky, opening up many options to search for interesting objects.

Thomas Franzen
Curtin Institute of Radio Astronomy, Perth, Australia

Using GLEAM to unravel the nature of the low-frequency radio source population

Wide-field radio continuum surveys are important for understanding populations of extragalactic sources and their cosmic evolution. Low frequency surveys are particularly sensitive to sources with steep synchrotron spectra. They are unbiased by relativistic beaming effects and favour old emission originating from the extended lobes of radio galaxies rather than emission from the core. They therefore give a complementary view to ∼GHz surveys.

I will present the details of GLEAM, a new survey of the entire sky south of Dec +30 deg at 72−231 MHz, conducted with the MWA. Insights from this new low frequency data are already providing a more detailed view of the radio source populations. I will highlight some early science results from the GLEAM extragalactic catalogue (Hurley-Walker et al. 2016).

Kaushal Buch
National Centre for Radio Astrophysics NCRA-TIFR, Pune, India

Results from the Real-time RFI Excision System of uGMRT

Kaushal D. Buch, Yashwant Gupta and Ajithkumar B.

Real-time Radio Frequency Inteference (RFI) excision is being introduced as part of the GMRT wide-band digital backend (GWB). Compared to the offline techniques, real-time RFI mitigation techniques operate at a higher time-resolution resulting in lower loss of astronomical data. Here we describe the techniques used in this system followed by the results from the real-time RFI excision and quantitative analysis. After implementation of this system, tests carried out in presence of broadband and narrowband RFI show significant improvement (up to 12 dB) in the signal-to-noise ratio. We also describe the experiments and test conditions used to characterize performance of the system including its effects on the astronomical data.

Soumyajit Mandal
Leiden Observatory, Leiden, The Netherlands

Peering through the Lockman hole with LOFAR

The Low Frequency Array (LOFAR) is a powerful survey instrument and particularly sensitive to steep spectrum objects. LOFAR data processing is challenging due to the data volume and the ionosphere which, at low frequencies, needs to be calibrated as a function of time and location. In this talk, I will present our ongoing work on the ∼66 hours observation of the "Lockman hole" field, where we aim to make one of the deepest images ever at 150 MHz.

Cosmic Magnetism

Craig Anderson
CSIRO Astronomy and Space Science, Australia

Broadband, widefield radio polarimetry with ASKAP

Craig Anderson, George Heald, Bryan Gaensler, Ilana Feain, ASKAP ACES team

During its early science period, the ASKAP radio telescope will undertake a polarisation survey boasting an unprecedented combination of broad bandwidth and large sample size. I will discuss the ASKAP telescope from a polarimetric perspective, and detail progress towards initiating these early science observations. I will highlight the results of recent experiments that reveal the existence of complex broadband polarisation behaviour in cosmic radio sources, and explain how this reveals the existence and properties of complicated magnetised structures in our Milky Way's interstellar medium, as well as the inner regions of AGN themselves. I will discuss how these recent findings have motivated a robust and unique program of early science objectives for ASKAP and the POSSUM survey.

Jeroen Stil
Dept of Physics and Astronomy, University of Calgary, Canada

Magnetic fields in and around a nearby ionized intermediate-velocity filament

Faraday rotation of polarized extragalactic radio sources and polarization of diffuse synchrotron emission reveal the intriguing magnetic structure of a 35 degrees long structure with $V_LSR = -45$ km/s that stretches from b= 20 degr to b= 55 degr at l $\sim$78 degr. We use rotation measure and emission measure to derive a lower limit to the Alfven velocity in the plasma, and show that the plasma is magnetically dominated (plasma beta less than $0.1 - 1$). This argument can be applied more generally to situations where dispersion measures are unavailable, such as other high-latitude RM structures and clusters of galaxies. New observations from the GALFACTS survey show Faraday rotation of a diffuse glow of synchrotron emission discovered last year in Planck foreground studies. A preliminary analysis of structure functions of rotation measure of the diffuse polarized emission is presented.

Takuya Akahori
Kagoshima University, Japan

How many rotation measure grids do we need to study the intergalactic magnetic field?

The warm-hot intergalactic medium (WHIM) is expected to be more or less magnetized. This intergalactic magnetic field (IGMF) is thought to play crucial roles in diverse subjects of astrophysics and cosmology. Radio continuum observations of extragalactic polarized sources have provided a lot of clues about the WHIM and IGMF, though background/foreground contaminations have made the detection difficult. SKA precursors/pathfinders will provide us with dense rotation measure grids and fine Faraday spectra toward extragalactic sources such as galaxies, quasars, and fast radio bursts. These essentially contain three dimensional information of the WHIM and IGMF, so that would be helpful to detect them. In this presentation, we discuss ideal sources and their number we need in order to study IGMF, based on the numerical simulations and previous observations.

Bryan Gaensler
University of Toronto, Canada

Recent results on polarimetry of extragalactic sources.

Dharam Vir Lal
National Centre for Radio Astrophysics, TIFR, Pune, India
uGMRT test observations: Preliminary science results

The GMRT upgrade is nearing completion and has begun operations. The completed instrument will have new wide-band receivers and several upgrades in almost all aspects of the GMRT with the aim of significantly improving its capability and sensitivity. Hence, the improved facility will complement several other observatories as essential tool for discovery in several areas of astrophysics. Currently JVLA users are successfully demonstrating the capabilities of wide field, wide band imaging at GHz frequencies. For the low-frequencies, around several 100s of MHz, we still have to demonstrate this to fully exploit the scientific value of data. The ongoing upgrade of the GMRT serves as a testbed to demonstrate wide band, wide field-of-view imaging at these low frequencies. We conducted a few test studies using phase II release of the uGMRT, and focus on understanding data quality fidelity of new GMRT wide-band backend and challenges in uGMRT data reduction and analysis. These understandings from the test uGMRT observations will be presented.

Deepak Kumar Deo
National Centre for Radio Astrophysics NCRA-TIFR, Pune, India

Simulation of Imaging Extended Sources with The GMRT and uGMRT

Deepak Kumar Deo and Ruta Prabhakar Kale

Radio halos and relics are diffuse radio sources of Mpc sizes associated with the shocks and turbulence in the intra-cluster medium. Their angular sizes are in the range of a few to 10s of arcminutes which make them challenging targets for imaging with radio interferometers. Largest linear size of a source that can be sampled is limited by the shortest baseline whereas the differentiation of diffuse emission from the point source emissions is limited by the longest baseline of the interferometer. In pursuit of understanding the limitations in imaging of such large angular size diffuse sources through GMRT and its upgrade − uGMRT which has wider bandwidth and better sensitivity than the former, we have carried out a simulation study. We made a toy model of a radio halo of 1 Mpc linear size and simulated the corresponding visibilities as observed by GMRT and uGMRT using the CASA toolkit. The visibilities were imaged in CASA using the task 'clean' and the resulting image was compared with the model image. We studied the recovery of total flux density and morphology of the source when the source angular size, source strength, declination, observation duration and bandwidth were varied. Based on this study we provide recommendations for imaging strategies for extended sources with the present (GMRT and uGMRT) and upcoming radio telescopes such as the SKA.

Ruta Prabhakar Kale
National Centre for Radio Astrophysics NCRA-TIFR, Pune, India

From GMRT to uGMRT and beyond: Prospects for studying diffuse extended sources

The upgraded GMRT or the uGMRT is a SKA pathfinder telescope that will have wideband ($200 - 400$ MHz) receivers and backend over a frequency range of $125 - 1450$ MHz. The wide bandwidth significantly improves uv-coverage and hence the sensitivity to extended radio sources with structures on a wide range of angular scales. A quantitative comparison between uv-coverage of the GMRT and that of the uGMRT will be shown and prospects for the uGMRT will be highlighted. We will present results from observations with the 16 antenna uGMRT system towards galaxy cluster fields with extended radio sources and discuss strategies for future observations and analysis.

Francesco de Gasperin
University of Leiden, Leiden, The Netherlands

Challenges and solutions in upcoming low-frequency surveys: from LOFAR-LBA to uGMRT

Producing high-fidelity images in low-frequency radio surveys is quite complex for a number of reasons. In this talk I will explore some of the challenges we are facing in calibrating the LOFAR Low Band Antenna which work in the frequency range 30−80 MHz. I will show how to detect and correct for ionospheric first (delay), second (Faraday rotation) and third order effects. I will also present the problem of ionospheric scintillations. Finally, I will introduce two upcoming low-frequency surveys. The LoL-ss (LOFAR LBA sky survey; 42−66 MHz) that has already started, and the upcoming 400MUGS (400 MHz uGMRT survey; 300−500 MHz), whose pilot observations will start this cycle.

Biny Sebastian
National Centre for Radio Astrophysics NCRA-TIFR, Pune, India

A study of cometary shaped radio galaxies using legacy and upgraded GMRT systems.

Biny Sebastian and Dharam V. Lal

Cometary shaped radio galaxies or head tail radio galaxies are usually found in clusters and they are interesting because of their peculiar bent shape. We present the imaging results of several of the longest head-tail radio galaxies known in literature using GMRT observations. The test data was also acquired for one of the head-tail galaxies, 3C129 using the ongoing upgrade of the GMRT from the sample. Multi-frequency, multi-scale, wide-band data reduction techniques were used while imaging 3C129. Some interesting morphological features and the steepening of the spectra along the tail will be presented from this data.

Ishwara-Chandra C.H.
National Centre for Radio Astrophysics, TIFR, Pune, India

GMRT deep images of legacy fields and our new efforts using uGMRT.

High-redshift radio galaxies (HzRGs) trace most massive galaxies, hosting most massive blackholes, marking the locations of over-dense regions. Hence they are key to understand formation of galaxies hosting super-massive blackholes at high-redshifts. The known population of HzRGs represent only the tip-of-the-iceberg, and low-frequency instruments, e.g., GMRT can discover population of HzRGs, which is at least two orders of magnitude fainter. It has been shown that detecting steep spectrum radio sources is the most efficient method to discover HzRGs. Since steep spectrum radio sources are best detected at low radio frequencies, we have carried out deep low frequency radio observations of several extragalactic legacy fields with the GMRT at 325 MHz to search for HzRGs. The radio sources from these fields are cross matched with the VLA FIRST survey images at 1.4 GHz to obtain a catalog of sources with spectral index steeper than 1. Furthermore, with the upgraded GMRT would provide an improved sensitivity at least by a factor of 4. Here we present deep GMRT images at a sensitivity of 100 microJy and list HzRG candidates, and our preliminary efforts with the uGMRT.

GMRT – MIGHTEE collaboration

Observational Results

Jeremy Harwood
ASTRON, The Netherlands Institute for Radio Astronomy

FR II radio galaxies with SKA pathfinders: from MHz to GHz

The historical inability of radio interferometers to produce high sensitivity, large bandwidth observations with good uv coverage has meant that the detailed spectra of radio galaxies at low frequencies and on small spatial scales has remained a largely unexplored region of parameter space. However, the new generation of instruments such as the JVLA, LOFAR, MeerKAT and, ultimately, SKA mean that many of these limitations have now been removed.

In this talk, we present the latest results using LOFAR and the JVLA at frequencies between 50 and 460 MHz to investigate the dynamics, energetics and particle acceleration in FR II radio galaxies. For the first time, this allows us to undertake well resolved, detailed studies of FR IIs at low frequencies. We discuss how tighter constraints placed on the low-energy electron distribution, magnetic field strength and total energy content of the lobes impacts upon our understanding of the dynamics and energetics of nearby FR II radio galaxies and how an improved knowledge of their spectral structure on small spatial scales may have a significant impact on our understanding of particle acceleration in these sources. We go on to discuss how the upcoming MeerKAT surveys at GHz frequencies will help us further probe the underlying physics of radio galaxies, as well as to help answer long standing questions about their duty cycle, life expectancy and impact on their environment and galaxy evolution as a whole.

Pratik Dabhade
Inter-University Centre for Astronomy and Astrophysics, Pune, India

SAGAN :Search & Analysis of GRGs with Associated Nuclei

Pratik Dabhade, Joydeep Bagchi, Madhuri Gaikwad, Shishir Sankhyayan and Francoise Combes

In this talk I will present about Giant Radio Galaxies (GRGs) and highlight the importance of their studies and our efforts to solve major standing problems related to GRGs and their host AGN. The GRGs represent an extreme class of active galaxies which have linear sizes in the range of $\sim$0.5 Mpc to 5 Mpc which places them among the largest single astrophysical objects known to us. From the past four decades only $\sim$300 GRGs are known as oppose to thousands of normal sized radio galaxies ($> 450-500$ Kpc). It is unsettled if the large sizes of GRGs indicate the high efficiency of radio jets ejected from the central AGN, or they grow to huge sizes due to their location in sparser cluster environments.

In spite of various studies of GRGs, there is still not a single tested unified model which might explain the immense physical scale and other extreme properties of GRGs. Moreover, till now only a small fraction of these GRGs have been studied in sufficient detail in multiple wavebands for achieving a good understanding of their unusual nature. This puts a restriction on carrying out statistical studies of their properties. We under our project SAGAN (Search & Analysis of GRGs with Associated Nuclei) aim to firstly make a complete sample of all known GRGs with same cosmological parameters for uniformity, secondly find more GRGs from existing radio and optical surveys, thirdly study the hosts of GRGs in multiwavelength to understand the nature of accretion, feedback and their excitation types. Lastly we aim to study the environments of these GRGs and explore the effects of environment on morphology and other properties.

We have already discovered more than 100 GRGs (Dabhade et al-Submitted and Dabhade et al-in prep) from NVSS. These numerous GRGs were missed before due to their very low surface brightness features: they were just at the sensitivity limits of existing surveys like NVSS. I will describe the methods used and results of their analysis.

An all-sky radio continuum survey with SKA1 (low) will provide us a wealth of data having thousands of giants with low surface brightness features. We will also have sufficient high resolution and sensitivity at low frequencies to decipher and study their morphologies which extend over megaparsec scales. SKA1 will be able discover distant GRGs which are very faint to detect and difficult to resolve with current surveys and telescopes. The effect of inverse compton scattering on the ageing of the particles in radio lobes rapidly increases with redshift as the energy density of the microwave background increases as $(1 + z)^4$, thus acting as a hindrance in their growth. Therefore it is challenging and important to find high redshift GRGs as they could provide vital clue in the evolution of supermassive black holes. The discovery of large sample of GRGs in the distant universe with SKA will be boosted by synergy with other optical surveys like LSST, HETDEX, SDSS-eBOSS and DES.

Mousumi Das
Indian Institute of Astrophysics, Bangalore, India

GMRT Low Frequency Observations of Gas Around Void Galaxies

Mousumi Das, K.S. Dwarakanath and Preeti Kharb

Voids contain a sparse but significant population of galaxies that represent the remnants of the hierarchical galaxy formation process and their distribution may delineate a void substructure. A significant fraction of them show signatures of ongoing star formation and nuclear activity whichis similar to that found in normal galaxies in denser environments. It is not clear what triggers this star formation and nuclear activity; close interactions with companion galaxies or gas accretion along filaments are possible explanations. To understand what drives their evolution and whether it relates to an underlying substructure within the voids, we are investigating the large scale radio continuum emission around a sample of Bootes void galaxies using low frequency (610/150 MHz) GMRT observations. We present some early results of our radio study and discuss its implications for understanding galaxy evolution in isolated regions.

J.N.H.S. Aditya
National Centre for Radio Astrophysics (NCRA-TIFR), India

Cold Gas in High Redshift Galaxies

We have conducted a survey using Giant Metrewave Radio Telescope to search for "associated" redshifted HI 21 cm absorption from 74 active galactic nuclei (AGNs), selected from the Caltech-Jodrell Bank Flat-spectrum (CJF) sample. Out of 63 sources which have usable data 17 sources are at $0 < z < 0.5$, 39 are at $1.1 < z < 1.5$ and 7 are at $z \sim 3.5$. We have obtained detections of HI 21 cm absorption in 4 sources, out of which one is a tentative detection towards TXS 0604+728 at $z = 3.53$. If confirmed, this would be the highest redshift at which HI 21 cm absorption has been detected till date. Also, we obtained 3 new detections of associated H_I absorption at $z \approx 1.2$, in our survey. Including 29 CJF sources with searches for redshifted HI 21 cm absorption in the literature, mostly at $z < 1$, we construct a sample of 92 uniformly selected flat-spectrum sources. A Peto-Prentice test for censored data finds (at $\approx 3\sigma$ significance) that the strength of HI 21 cm absorption is weaker in the high-z sample than in the low$-$z sample; this is the first statistically significant evidence for redshift evolution in the strength of HI 21 cm absorption in a uniformly selected AGN sample (ref Aditya et al. 2016).

Upon adding 27 Gigahertz Peaked Spectrum (GPS) sources (7 sources observed by us using GMRT, and 20 from the literature) to the full sample of CJF sources, forming a sample of 119 compact AGNs, the null hypothesis that the low$-$z and high-z sub-samples of HI 21 cm optical depths are drawn from a similar distribution is rejected at $\approx 4.1\sigma$.

However, the two-sample test also finds that the HI 21 cm absorption strength is higher in AGNs with low ultraviolet or radio luminosities, at $\approx 3.4\sigma$. The fact that the higher-luminosity AGNs of the sample typically lie at high redshifts implies that it is currently not possible to break the degeneracy between AGN luminosity and redshift evolution as the primary cause of the low HI 21 cm opacities in high-redshift, high-luminosity active galactic nuclei. A sample at low redshifts, $z < 1$, with high AGN luminosities is critical to break this degeneracy. We have hence been using GBT to search for associated HI 21 cm absorption in a sample of 36 sources, at $0.4 < z < 1.0$, selected from the CJF sample.

Surajit Paul
Dept. of Physics, SP University of Pune, Pune, India

An SKA and uGMRT perspective of possible discovery of multiple shocks structures and filamentary inroads to massive galaxy clusters

Large scale structures (¿ few tens of Mpc) in the Universe comprise of complex filamentary network of matter surrounding large voids. They connect the massive Galaxy Clusters. Massive objects like galaxy groups and galaxy clusters display intriguing phenomena when in a merging state and become energetically active, and have been observed in radio extensively. But there are several interesting components that are yet to be detected in radio waves (e.g. filamentary connections). These vital components of cosmological structures are the main channels through which dark matter and baryons drain from voids and reach the nodes where Clusters are formed. As most of the matter is processed for the first time at the filamentary surfaces and the accretion zones of Galaxy Clusters, these regions contain a wealth of information about energetics of the cosmic structures. Due to baroclinic instability at the junction of filaments and Galaxy clusters, significant turbulence is generated and a high degree of magnetic fields are amplified. Charged particles are accelerated in these structures through shocks and turbulence that is driven by structure formation. As a result such objects then produce significant amounts of synchrotron radio emission due to the motion of accelerated charge particles in the enhanced magnetic field, which is crucial for tracing back the dynamical history of these structures.

In this work, we have simulated many high resolution (15 kpc) realisations of 128^3 Mpc h^{-1} cosmological volume using the ENZO hydrodynamic code. We then implemented Diffusive Shock Acceleration and Turbulent re-acceleration models to compute possible radio emission from galaxy clusters and their outskirts. Our theoretical predictions reveal possible multiple shock structures including multiple merger shocks and virial shocks. Though the virial shock is at the level of sub-Jy in the 1.4 GHz band, which is quite diffusecult to observe, an intermediate merger shock $2-3$ Mpc away from the centre has few 10s of Jy of radio power and the SKA may well detect such structures easily. The other striking result we have is the filamentary inroads. Long trails of parallel and linear radio structures can be seen in the deep potential of the filaments. Surprisingly, these structures, though far away from the centre (beyond the virial radius), have radio emission power only an order lower than the usual radio halos making it possible to detect with even uGMRT. This gives us the confidence that SKA will be able to detect several of these structures. These detections would not only reveal the actual extent of the galaxy clusters, they may also yield estimates of WHIM present in the filaments. We will present some early results of our predictions about SKA-1 observations both with mid and low arrays and possible upper-bounds from uGMRT.

Siddharth Malu and Abhirup Datta
Centre of Astronomy, Indian Institute of Technology, Indore, India

Disentangling the Sunyaev-Zeldovich Effect and Diffuse Emission sub-structure in galaxy clusters

Siddharth Malu, Abhirup Datta, Sergio Colafrancesco and Surajit Paul

Inverse Compton scattering of CMB photons off the thermal and non-thermal electrons in the atmospheres of galaxy clusters, usually referred to as Sunyaev-Zeldovich Effect (SZ effect), has been observed in many clusters in recent times (Bleem et al. (2015); Zwart et al. (2011)) though the SZ effect signal from cluster sub-structure has been detected only in a few clusters (Malu et al. (2011); Massardi et al. (2010)) in the Ku and K bands (12−24 GHz). Upper limits for the SZ effect signal from non-thermal electrons have also been derived (Colafrancesco et al. 2013). At the same time, in these clusters, both radio halos and radio relics have been observed at high frequencies, i.e. in the 12−24 GHz frequency range (Malu et al. (2010, 2011); Stroe et al. (2015)). This poses a unique challenge of separating positive and negative components in Ku, K-band images, and possibly also at higher frequency bands. Current observations (Malu et al. 2011) show that both diffuse emission and SZ effect features can be observed in the center of clusters. Spectra of diffuse emission − both radio halos and relics − are neither known, nor is there any firm predictions for them. Additionally, SZ sub-structure in clusters is expected to exist over a range of spatial scales. This is therefore a complex problem, which requires ultra deep, high-resolution observations of galaxy clusters in the range 12−24 GHz, and possibly beyond. The SKA1-mid is ideal for Ku band ($\sim$14 GHz) observations, provided the thermal SZ effect is either absent, or can be precisely modeled in the observed region, and we intend to produce a cluster survey using SKA1-mid. However, for completely disentangling the two effects, a higher frequency instrument may be needed. We present here results from 16−20 GHz observations of a southern mini-survey of galaxy clusters which show both diffuse emission as well as SZ effect − in one instance, in the same cluster. These results point to the need for an iterative approach which includes modeling the diffuse emission and SZ effect sub-structures, as well as a careful characterization of positive and negative features observed in high-frequency ($>$ 12 GHz) images of galaxy clusters. In this context, we will also discuss prospects for detection of SZ effect using SKA1-mid, at 14 GHz (Band-5).

Wendy L. Williams
Centre for Astrophysics Research, University of Hertfordshire, UK

LOFAR and Radio-Loud AGN

Radio observations provide a unique view of AGN. I will present a recent deep LOFAR image of the Bootes field at 150 MHz, made using new direction-dependent calibration techniques. This new image allows us to build statistically large samples of high power radio-loud AGN between 0.5 $<= z < 2$ which we use to study the evolution of their different accretion modes (high versus low excitation radio galaxies). We use the excellent multiwavelength coverage in this particular deep extragalacticfield to explore this evolution as a function of various properties of their host galaxies, including stellar masses and rest-frame colours. I will further discuss some recent progress towards furtherradio AGN science with the LOFAR Tier-1 survey.

Marek Jamrozy
Jagiellonian University, Krakow, Poland

Recurrent jet activity in radio galaxies

Maps of a sparse group of extragalactic radio sources show structures which differ significantly in brightness, spectral index and age. Various parts of these objects have been formed during different epochs of the central AGN activity, separated by inactive periods. The group of known radio sources to show indications of recurrent jet activity phases are still not numerous, however, the phenomenon has rapidly gained interest. Thus, for understanding the evolution of AGNs multifrequency radio data on their extended structures are of crucial importance. The planned modern all-sky multi-frequency radio surveys will provide ideal tools to search for and study AGN duty cycles.

Yogesh Wadadekar
National Centre for Radio Astrophysics NCRA-TIFR, Pune, India

A dying, giant radio galaxy in the distant Universe

Yogesh Wadadekar, P. Tamhane, A. Basu, V. Singh, C.H. Ishwara-Chandra, A. Beelen and S. Sirothia

We recently 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 without detection of Active Galactic Nuclei core, jets and hotspots in extremely deep multiband imaging. 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. This discovery was enabled by deep radio continuum observations supplemented by deep data in X-ray, optical, near and mid-infrared bands. The integrated radio spectrum for the lobes 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 8×10^6 yr old. The extended X-ray emission seen co-spatially with the radio lobes is characterized by an absorbed power law with photon index ∼ 1.86 which favours inverse-Compton scattering of the Cosmic Microwave Background (ICCMB) photons as the most plausible origin. Our work presents a case study of an extremely rare example of a GRG caught in the dying phase in the distant Universe. Strategies for discovering more such objects in upcoming deep continuum surveys with SKA precursors and the SKA Phase I, and the implications to the evolution of giant radio galaxies will be discussed.

Viral Parekh
Raman Research Institute, India

GMRT observations of diffuse radio sources

Radio observations have detected diffuse large scale emission from the intracluster medium (ICM), suggesting that non-thermal components, magnetic fields and relativistic particles, are co-existent with the hot ICM. One class of such diffuse radio sources is known as radio halos which are detected in about 1/3rd of galaxy clusters. Formation of radio halo is still an open debate. They are useful to probe large scale existence of relativistic particles, magnetic fields, and the whole cluster formation and evolution. In this work we show our current finding of radio halos in the MAssive Cluster Survey (MACS) catalogue. We used archival GMRT (150, 235 and 610 MHz) and EVLA (L band) data and made images at multiple radio frequencies of the following six clusters − MACSJ0417.5−1154, MACSJ1131.8−1955, MACSJ0308.9+2645, MACSJ2243.3−0935, MACSJ2228.5+2036 and MACSJ0358.8−2955. We detect diffuse radio emission (halo / relic) in the first four clusters. In the last two clusters we do not detect any diffuse radio emission but we estimate upper-limits on their radio powers. We also obtain archival Chandra X-ray data to carry out substructure analysis of these clusters. Based on X-ray data we find these MACS clusters to be disturbed and show substructures in their temperature maps. We found an ultra-steep spectrum radio halo in the MACSJ0417.5−1154 cluster whose rest-frame cut-off frequency is at ∼900 MHz and its radio power at 1.4 GHz is ∼11 times below that expected from the empirical relation between X-ray luminosities of clusters and the radio powers of halos in the clusters. GMRT, one of the precursor of SKA, is currently undergoing a major upgrade. This upgrade will improve its sensitivity by a factor of up to three with wide-band receiver having equivalent frequency coverage corresponding to that of SKA-LOW and some part of SKA1-MID. Wide bandwidth observations will provide high fidelity images of diffuse radio emission and spectral index distribution across the halos. Prior to the development of the upgraded-GMRT, spectra of radio halos and relics were often not well enough sampled to discern between competing physical models. A broadband observations of a large number of radio halos and relics will provide an unparalleled database of spectra. We will also discuss how this broadband spectral database will help us to investigate existing competing models of diffuse radio sources as well as how it will add valuable information to the next generation wide-band surveys to be conducted with ASKAP, MeerKAT and the SKA1-MID.

Source Detection and Classification

Zara Randriamanakoto
University of Cape Town, South Africa

Deep GMRT observations of the faint radio source population of the ELAIS-N1

Zara Randriamanakoto, Russ Taylor, Preshanth Jagannathan, Dharam Lal et al.

We report recent deep radio continuum observations of the ELAIS-N1 at 325 MHz with the GMRT. The extracted source catalogue contains more than 1500 sources detected above a 3-sigma level within a 3.2 square degree area of the field. Our differential source counts present a flattening at low flux densities, which are consistent with previous results in the literature. We also match the catalogue with recent GMRT data at 610 MHz to derive the spectral index distribution of the faint radio source population.

Marios Santos
University of the Western Cape, South Africa

Studying galaxies below the detection threshold using Bayesian statistical techniques

I will describe different statistical techniques we are developing, based on stacking and P(D) analysis, in order to extract information from noise dominated radio continuum maps, such as number counts and luminosity functions. I will describe the algorithms and some results with actual data.

Emmanuel Ocran
University of Cape Town, South Africa

The Nature of the μJy Radio Source Population

E. F. Ocran, A. R. Taylor, M. Vaccari

We present a multi-wavelength study into the nature of faint radio sources in a deep radio image at 610MHz covering 1.2 deg2 within the ELAIS N1 region with the Giant Metrewave Radio Telescope. We detect 2800 sources to a 5σ level of 50 μJy. At this depth we probe the radio source population at flux densities well below the regime dominated by classical Radio Galaxies and Active Galactic Nuclei (AGN). We match 85% of the radio population to Spitzer/IRAC counterparts and obtain a redshift estimate for 63% of the total sample, with 29% based on spectroscopy. Multi-wavelength diagnostics are used to identify AGN-dominated sources and classify them into radio-loud (RL) and radio-quiet (RQ) classes. For the sources with redshift estimates we implement a classification scheme based on radio luminosity, X-ray luminosity, BOSS/SDSS spectroscopy, IRAC colors, and MIPS 24m / Radio flux ratios. Our analysis shows that various diagnostics select different types of AGNs and we confirm that the MIPS 24m / Radio flux ratio criterion is an important parameter to identify RQ and RL AGNs. On the basis of this classification, we find that 10% of the sources with redshifts are RQ AGNs, with 4% being RL AGNs, and the remaining 86% are consistent with SFGs. We study the far-infrared radio correlation and measure a median q_IR value of 2:45 $\pm$0.01 for the SFGs and 2:47 $\pm$0.04 for objects with RQ AGNs.

Jon Zwart
University of Cape Town, South Africa

Bayesian approach for measurement of the polarization properties of sources below the noise

Niruj Ramanujam
National Centre for Radio Astrophysics NCRA-TIFR, Pune, India

Source Detection in the SKA Era − lessons from LOFAR

The expanded parameter space of modern low frequency radio surveys necessitate an automated and sophisticated source detection pipeline. The sky is populated by substantial diffuse emission along with a high density of point sources with non-linear spectral indices at these frequencies. Large fields of view and wide bandwidths of these instruments further complicate the analysis. In addition, the presence of large artifacts, and non-isoplanicity cannot be ignored.

PyBDSM, a source extraction software written for LOFAR, is now being used extensivley. We will describe its functionalities and the algorithms therein, including new analysis added in light of the recent LOFAR survey images. We will then describe further challenges that SKA 1 will pose for source extraction.