# Transformational Science with the SKA: Synergies with ALMA and other Contemporary Instruments.

17 – 21 February, 2014

*Stellenbosch, South Africa*

## Final Abstract Book

February 17, 2014

# The SKA: science, design and status'

## New instruments - TALK

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# Alma, its science and synergies with the SKA

## New instruments - TALK

Pierre Cox
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The Atacama Large Millimeter/sub-millimeter Array is transitioning from construction to operations. This connected element array currently operates from wavelengths of 3 mm to 350 microns with up to 66 array elements, 54 of 12-m diameter and 12 of 7-m diameter. While the antennas and most of the hardware for the receivers are on site, array capabilities are still expanding rapidly. In parallel with construction activities, early science observations have been going on since October 2011 with many exciting, fundamental results already obtained.
I will present the current status of the project and give an overview of the trailblazing science results obtained so far. The potential of the fully operational ALMA will be outlined as well as some of the development projects that are considered.
In summary, this talk will address the past, present and future of ALMA, describe the transformational science that is and will be produced with ALMA and, finally, outline synergies with the future SKA project.

# The Project of FAST

## New instruments - TALK

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Five-hundred-meter Aperture Spherical radio Telescope (FAST) is a Chinese megascience project to build the largest single dish radio telescope in the world. Its innovative engineering concept and design pave a new road to realize a huge single dish in the most effective way. It is an Arecibo-type antenna with

its own outstanding aspects. Being the most sensitive single dish radio telescope, FAST will enable astronomers to jump-start many science goals, such as surveying the neutral hydrogen in the Milky Way and other galaxies, detecting faint pulsars, looking for the first shining stars, hearing the possible signals from other civilizations, etc. We have planned the early science for FAST including pulsar searching in nearby galaxy (e.g. M31), OH mega-maser searching and low/mid-frequency spectra line detecting in Orion. The feasibility studies for FAST have been carried out for 14 years, supported by Chinese and world astronomical communities. Funding for FAST has been approved by the National Development and Reform Commission in July of 2007 with a capital budget $\approx$ 700 million RMB. The project time is 5.5 years from the commencement of work in March of 2011 and the first light is expected to be in 2016. Although we have run into many chanllenges in the last three years, the project is still moving forward on the schedule.

# MeerKAT - a progress update

## New instruments - TALK

Justin Jonas
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The MeerKAT radio telescope is currently under construction, with completion of the 64 dish array scheduled for 2016. This will be the largest centimetre wavelength telescope in the southern hemisphere, and one of the largest in the world. Construction of the first phase of the SKA is due to commence in about 2018 and the MeerKAT will be incorporated into SKA-mid, contributing about 25% of the total sensitivity for Phase 1. The science case, design and implementation of the MeerKAT will be discussed, with reference to its role as an SKA-mid precursor instrument.

# The Very Large Array after the upgrade

## New instruments - TALK

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The Jansky Very Large Array (JVLA) is the result of a comprehensive upgrade of the original VLA which arguably has resulted in a new instrument. This expanded VLA (EVLA) project has vastly improved a number of key aspects of the old VLA, some by orders of magnitude. In this presentation I intend to describe these improvements in some detail, summarize current capabilities, and describe plans for the future. I will also present a number of examples of the great new science this major upgrade of the VLA has enabled.

# The Murchison Widefield Array: Low Frequency Precursor for the SKA

## New instruments - TALK

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The Murchison Widefield Array (MWA) is a low frequency (80 - 300 MHz) precursor for the Square Kilometre Array (SKA), one of three SKA precursors in Australia and South Africa, and the first of the three to complete construction and commence full science operations. Operational since August 2013, the MWA is available under an "Open Skies" policy and is suited to a wide range of low frequency science, including: Epoch of Reionisation studies; transients and variable radio sources; solar and heliospheric science; and large-scale surveys (continuum and line). I will present an update on the operational status of the MWA and some of the early science highlights from the instrument. I will broadly discuss the critical role the MWA plays in the pre-construction phase of the SKA, particularly for the low frequency component of the SKA. The MWA is learning significant lessons for $SKA_{low}$ (science and technical), is an important platform for $SKA_{low}$ verification, and is the first entrant into the SKA world of Big Data in Australia. The MWA is exercising end-to-end infrastructure over 800 km, from CSIRO's Murchison Radioastronomy Observatory to the $80m Pawsey supercomputing centre in Perth, the same infrastructure that will support $SKA_{low}$.

# An overview of ALMA Science Verification

## New instruments - TALK

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The Atacama Large Millimeter/submillimeter Array (ALMA) is a unique and state-of-the-art international millimetre/submillimetre astronomical observatory just reaching the end of construction in the Atacama Desert of northern Chile at an altitude of 5000m above sea level. ALMA is an interferometer array of 66 12-m and 7-m diameter antennas, whose construction and operations are a partnership between Europe (ESO), North America (NRAO) and East Asia (NAOJ) and in cooperation with the Republic of Chile. ALMAs high-altitude site provides excellent atmospheric transmission over most of the wavelength range of 0.3 to 3 mm. At the shortest planned wavelength and most extended configuration ( 15 km diameter), the angular resolution of ALMA will be 5 milliarcseconds. ALMA is the only (sub)mm facility in the world able to provide this unprecedented combination of high angular resolution, high sensitivity and frequency coverage. Science Verification is the process by which we demonstrate that ALMA is capable of producing data of the quality required for scientific analysis, i.e. data good enough to be

included in the peer-reviewed literature, and by which we fully test all observing modes expected to be available during Early Science. This is achieved by making observations of a small number of selected astronomical objects. In this talk I will give an overview of ALMA Science Verification and its results.

# VLBI and the EVN in the years towards SKA and beyond

## New instruments - TALK

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The European VLVBI Network (EVN) is rapidly replacing its analog baseband converters with digital systems. Many EVN stations are now using the European-developed Digital Baseband Converters (DBBCs), while the KVAZAR network and the Chinese stations deploy the R1002 and CDAS systems. Likewise, the VLBA has retired all its legacy equipment and is now solely using the RDBE backends.
With it comes the opportunity to double and even quadruple the observing bandwidths, effectively doubling the sensitivity of the array. First tests, combining the VLBA at 2 Gbps with EVN stations at 1 and 2 Gbps, have shown that global observations using all these different digital systems can be accommodated. Last September, global 4 Gbps real-time e-VLBI was successfully demonstrated using EVN telescopes across Europe and South Africa.
Observing bandwidth will continue to increase in the coming years with the advent of the next version of the DBBC, currently under development. Geodetic VLBI and the Event Horizon Telescope will generate data streams of 16 and even 32 Gbps per telescope.
This higher sensitivity will come with an extended collaboration of networks, combining for example EVN and LBA telescopes to increase the number of long baselines and UV coverage at low and negative declinations, as well as allowing longer observations. More telescopes will join EVN observations, with the state-of-the-art 64 and 65 m telescopes in Sardinia and Shanghai providing an enormous boost in sensitivity. The Korean VLBI Network, which has recently joined the EVN as associate member, will further enhance the high-frequency capacity of the array.l
Very importantly, the development of an African VLBI Network will provide a host of opportunities for scientific collaborations between emerging radio astronomy institutes and the EVN, and the combination of the arrays will enable a tremendous improvement in UV coverage. MeerKAT will complement this with an unprecedented sensitivity on the longest N-S baselines.
In my presentation I will talk about these developments, and how the EVN, collaborating with networks around the world, at high frequencies and steadily increasing sensitivity, will continue to be a unique and important instrument, in the years leading up to and beyond the construction of the SKA.

## Cosmology with the SKA

### Cosmology, cosmic dawn and reionisation - TALK

Mario Santos
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The SKA provides an unique and unified way to probe the Universe at different stages of its evolution, allowing to constrain several cosmological parameters, from the nature of dark energy, to primordial non-Gaussianity, the curvature of the Universe or large-scale corrections from General Relativity. I will describe what can be achieved with different surveys, such as the high redshift HI survey using SKA-Low, the HI intensity mapping and galaxy survey at lower redshifts using SKA-Mid or a large continuum radio galaxy survey. I will address the possibilities offered by SKA Pathfinders and SKA Phase 1 as well as the more ambitious SKA Phase 2.

## Reionization and the Cosmic Dawn

### Cosmology, cosmic dawn and reionisation - TALK

Leon Koopmans
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Reionization and the Cosmic Dawn are the last and least explored phases in the history of the Universe. I will shortly review the current status of our theoretical and observational understanding of these phases, as well as how novel radio arrays aim to statistically discover and trace neutral hydrogen (HI) at redshifts beyond 6 in the coming years. I will end with a view on the discovery potential that SKA offers, in the decade(s) to come, to perform detailed tomographic studies of HI well beyond the capabilities of current arrays.

## Radio halos in galaxy clusters: A new cosmic probe for SKA and its pathfinders?

### Cosmology, cosmic dawn and reionisation - TALK

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Giant radio halos in galaxy clusters prove that ultra-relativistic particles (cosmic rays) and magnetic fields exist over Mpc scales, yet their origin remains poorly understood. We made the first demonstration

of a tight correlation between radio halo power and the cluster Sunyaev-Zel'dovich (SZ) effect signal to highlight a common underlying powering mechanism. Furthermore, we carried out an unbiased census of the radio halo population to show that these Mpc scale diffuse emissions may be much more numerous than previously thought. Whereas roughly 70% clusters selected from X-rays are in the radio halo "off state", the corresponding fraction in the SZ selected samples in only about 20%. This suggests a major upward revision of the radio halo count in the sky. We offer some qualitative understanding of this selection difference based on N-body hydrodynamic simulations of cluster mergers, and propose how the radio halo counts can be used to trace the cluster assembly history. I present some new results from our ongoing observational program using VLA and GMRT data, and conclude by discussing the prospects of radio halo cosmology with the next generation radio telescopes like ASKAP, MeerKAT and the SKA.

## Evolution of faint radio sources in the VIDEO-XMM3 field.

### Galaxy evolution - TALK

Kim McAlpine
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One of the primary goals of the SKA continuum surveys is to map the cosmic evolution of star-forming galaxies and AGN out to high redshift. Achieving these goals relies on multi-wavelength complementary datasets to separate the AGN and star-forming galaxy contributions to the faint radio population and to obtain photometric redshift estimates for a large fraction of the detected radio sources. In this talk I will present a new multi-wavelength investigation of the evolution of faint radio sources out to $z \approx 2.5$. This study combines a 1 square degree VLA radio survey, complete to a depth of $100\mu$ Jy, with accurate 10 band photometric redshifts from the VIDEO and CFHTLS surveys. The results indicate that the radio population experiences mild positive evolution out to $z \approx 1.2$ increasing their space density by a factor of $\approx 3$, consistent with results of several previous studies. Beyond $z = 1.2$ there is evidence of a slowing down of this evolution. Star-forming galaxies drive the more rapid evolution at low redshifts, $z < 1.2$, while more slowly evolving AGN populations dominate at higher redshifts resulting in a decline in the evolution of the radio luminosity function at $z > 1.2$. The evolution is best fit by pure luminosity evolution with star-forming galaxies evolving as $(1 + z)^{2.47\pm0.12}$ and AGN as $(1 + z)^{1.18\pm0.21}$.

## Three dimensional 'Intensity Mapping' of the Universe during the EoR

### Cosmology, cosmic dawn and reionisation - TALK

Marta Silva
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The high redshift Epoch of Reionization can be probed with several emission lines in order to obtain a complete picture of the reionization process. By using simulations in large sky fields of CII, Lyman alpha and 21cm lines emitted at redshifts of $z \approx 8$ to $z \approx 6$ we were able to predict the intensity and spatial fluctuations of these lines using observational data, galaxy properties from catalogs made with the Millennium and Millennium II simulations and an altered version of the Simfast21 code especially adapted to simulate these lines. In particular we found that there are good prospects for the detection of Lyman alpha emission and CII emission with expected average intensities of $1 \times 10^1$ Jy sr1 and $3.29 \times 10^2$ Jy sr1 respectively at redshift 7. The combined observation of these lines has the potential to establish a complete picture of the characteristics, spatial distribution and relative distribution of the gas in its several phases. Taking advantage of the intensity spatial fluctuations that can be detected with the intensity mapping technique we also consider the potential of cross correlation between the 21cm line with the CII line or the Lyman alpha line as a way to remove foregrounds.

# Studying the epoch of reionization with large-N radio arrays

## Cosmology, cosmic dawn and reionisation - TALK

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The epoch of reionization (EoR) and the formation of the very first luminous objects is the last thermal transition phase that our Universe underwent and it is still very poorly constrained observationally. Future deep optical/infrared/millimeter observations promise to reveal the galaxy population at redshift well within the epoch of reionization. Low frequency radio observations offer a complementary view on the redshifted 21cm line, sampling the evolution of the intergalactic medium potentially up to very high redshifts. Two large-N, low-frequency radio interferometers (PAPER and MWA) are deployed in the Southern Hemisphere and currently pursuing the detection of the EoR. I will present the current status of their EoR observations and their most recent results.

# 21 cm Cosmology

## HI in the early Universe - TALK

Tzu-Ching Chang
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# Insights in Galaxy Structure and Evolution from HI Imaging Surveys

## HI in the early Universe - TALK

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Kapteyn Astronomical Institute, University of Groningen , Netherlands

Imaging the distribution and kinematics of neutral Hydrogen in galaxies has uniquely revealed structures and physical processes on galaxy scales not seen by other observational means. While all-sky panchromatic imaging surveys have revolutionized our understanding of galaxy structure and evolution, to date, however, less than a thousand preselected galaxies have been targeted and imaged in HI, hampering an unbiased interpretation of results based on relatively small samples. In particular, understanding the role of a galaxy's cosmic environment on the properties of its HI content requires extensive and blind imaging surveys that will be initiated in the near future with SKA pathfinder and precursor facilities. This contribution will present a concise overview of current insights from HI imaging efforts and sketch some of the main themes to be addressed by the forthcoming HI surveys.

# The Wallaby HI survey

## HI in the early Universe - TALK

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I will give an update on the Australian SKA Pathfinder (ASKAP) and plans for ASKAP early science. Lots of activities are under way as part of the WALLABY project (and its sister project WNSHS), most of which are applicable to spectral line surveys in general. Examples are the development and testing of source finding and source characterisation algorithms (SOFIA, the Busy Fuction), the kinematic analysis pipeline, data archives, survey simulations and predictions of HI source catalogs, etc. In the meantime, we aim to carry out HI surveys of individual galkaxies, galaxy groups and cluster with the upgraded ATCA and look forward to KAT-7 and later Meerkat deep HI observations.

# The MeerKAT HI survey (Laduma)

## HI in the early Universe - TALK

Sarah Blyth
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University of Cape Town , South Africa

The LADUMA (Looking At the Distant Universe with the MeerKAT Array) survey has the aim to study galaxy evolution over cosmic time from the present back to when the Universe was less than half its current age (z 1.4). It will be the deepest survey of neutral hydrogen emission from galaxies prior to the SKA coming online. Neutral hydrogen plays a vital role in models of galaxy evolution and transformation, however the current deepest direct measurements of HI in galaxies are limited to the relatively nearby Universe (z 0.25). The survey will consist of 5000 hours of observations of a single pointing encompassing the Extended-Chandra Deep Field South. In combination with the wealth of multi-wavelength data already existing in this region, the LADUMA HI observations will allow many and varied studies of galaxies as a function of look-back time, environment, and other parameters. In this talk I will present an overview of the survey and the science goals we hope to achieve with it.

## Towards complete understanding of 21-cm signal from high redshifts

### HI in the early Universe - TALK

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Modeling of the 21-cm signal from the epoch of reionization and earlier is particularly challenging due to large-scale fluctuations in distribution of first stars, non-local effects of radiation emitted by stars etc. However, the ability to make precise theoretical predictions for the neutral hydrogen signal from high redshifts is essential in the SKA era. In my talk I will discuss the forcast for the 21-cm signal from z = 10-50 on $\approx$ 10-300 Mpc scales, which we make using a hybrid computational method. In our simulation we account for major physical phenomena that have a strong impact on the neutral hydrogen signal from high redshifts, such as ionization, negative radiative feedback to star formation, relative supersonic motion between baryons and dark matter, heating and Ly-alpha coupling.

## From Feast to Famine: Understanding Active Transformation in Galaxy Groups

### HI in the early Universe - TALK

Michelle Cluver
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HI is a key tracer of galaxy fuel, feeding the appetite of star formation, but it also acts as a signpost of tidal interactions. Gas stripped by tidal forces inhibits future star formation, but studies of compact

groups have revealed rapid evolution similar to that of the Coma Infall region, suggesting an additional mechanism within these much shallower gravitational potential wells. Spitzer spectroscopy has revealed shock-excited H2, most likely tracing collisions with tidally-stripped HI debris. These can be catastrophic, causing the rapid cessation of star formation. Combining the sophisticated group measures from the GAMA survey, optical IFU observations from SAMI, HI observations from KAT-7 and MeerKAT and mid-infrared data from WISE, we aim to address the feeding and feedback nature of neutral gas.

# CHILES: The COSMOS HI Large Extragalactic Survey

## HI in the early Universe - TALK

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With the newly upgraded Karl G. Jansky Very Large Array (VLA), the first direct detection of HI rich objects are now accessible over a continuous redshift range out to $z = 0.45$. The COSMOS HI Large Extragalactic Survey (CHILES) is a 1000 hour program on a single pointing centered in the COSMOS field, and we have just completed its first set of VLA observations during the recent B-configuration. CHILES serves as an important pathfinder for upcoming deep surveys with MeerKAT, ASKAP, and SKA for testing data reduction software, automating techniques for RFI flagging and source finding, and optimizing algorithms for data compression and imaging for data volumes which are still manageable using well established methods. Building on the results of our pilot survey, 50 hours of observing the same field out to $z = 0.2$, we find that the RFI environment improves beyond a redshift of 0.2. Our survey doubles the look-back time of existing HI measurements, making it possible to study evolution in the HI content of galaxies as a function of cosmic time, environment, galaxy properties, and morphology. The ability of resolve the HI morphology of galaxies at a redshift of $z = 0.45$ makes CHILES unique to all other SKA HI pathfinder surveys and will allow us quantify the changing impact of environment on galaxy evolution. I will summarize the findings from our pilot survey and present the lessons and recent results from the first stage of the full CHILES survey.

# Insights in galaxy formation from combined ALFALFA 21cm and SDSS survey data

## HI in the early Universe - TALK

Manolis Papastergis
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We use HI-line data from the ALFALFA 21cm survey and optical data from the SDSS, to measure the baryonic mass (stars+atomic gas) of several thousand galaxies in the local universe. This allows us to

directly measure the baryonic mass function of galaxies, and infer the average stellar and baryonic mass fractions of galaxies as a function of their host halo mass. We find that low mass halos are severely baryon depleted, even when their -often dominant- gas content is taken into account. We discuss the implications of this result for models of galaxy formation and evolution, with particular focus on the efficiency of baryonic feedback in low mass galaxies. Lastly, we complement the number density measurements of these galactic samples with measurements of their clustering properties (2-point correlation function). This allows us to probe further aspects of the connection between baryonic mass and host halo properties (such as scatter, etc.). This type of analysis will be crucial in the context of the next generation of radio surveys, where modeling the galaxy gas-halo connection in ever increasing detail is of central importance for cosmological studies.

# Rotation Measure Synthesis

## The role of magnetism - TALK

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An exciting new era of broadband radio polarimetry is now coming to pass through the rapid development of SKA Pathfinders and the promise of the SKA itself. With these new resources comes the possibility to harness new techniques to constrain the physical parameters in the magnetised Universe. I will give an overview of some of the new approaches that are being developed to tackle this challenge. I will focus on Rotation Measure (RM) Synthesis, an approach that was proposed nearly 50 years ago, but is only now coming into its own. Together with RM Synthesis, a host of other complementary approaches are now also being considered to explore a variety of complex phenomena. I will conclude with some thoughts on the prospects for using these new techniques to probe Cosmic Magnetism in the SKA era.

# Magnetic fields in the large-scale structure of the universe

## The role of magnetism - TALK

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Magnetic fields appear to be ubiquitous in astrophysical environments. The existence of magnetic fields in the large-scale structure of the universe has been established through observations of Faraday rotation and synchrotron emission, as well as through recent gamma-ray observations. Yet, the nature and origin of the magnetic fields remains controversial and largely unknown. In this talk, I briefly summarize recent developments in our understanding of the nature and origin of magnetic fields. I also describe a plausible scenario for the origin of the magnetic fields; seed fields were created in the early universe and

subsequently amplified during the formation of the large-scale structure of the universe. I then discuss the prospect of studies of magnetic fields in the large-scale structure of the universe with the SKA.

# Clusters: structure and magnetism

## The role of magnetism - TALK

Tiziana Venturi
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Cluster radio sources are essential tools to investigate magnetism on megaparsec scales and beyond. I will review our current knowledge both of the population of diffuse cluster radio sources, i.e. radio halos, relics and mini-halos, and of cluster radio galaxies, highlighting their properties and role in the study and understanding of cosmic magnetism. Finally I will summarize the impact of the SKA and its pathfinders on the cluster radio science.

# Magnetic science from SKA pathfinders

## The role of magnetism - TALK

Anna Scaife
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Understanding the Origin and Evolution of Cosmic Magnetism is a major science driver for the Square Kilometre Array. I will review the key aspects of this science as they are currently envisaged by the SKA Cosmic Magnetism Working Group and describe some of the programs currently being undertaken by the pathfinder instruments, which are expected to lead into SKA Phase I. I will touch on some of the technical challenges that these programs have encountered, as well as the progress being made and their current successes.

# Growth of Magnetic Field in the Large-Scale Structure of the Universe

## The role of magnetism - TALK

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Since turbulence can amplify a seed magnetic field very efficiently, turbulence plays important roles in the origin of cosmic magnetism. The seed magnetic field can be either spatially uniform or localized. If coherence length of a seed magnetic field is larger than the system size, we can treat it as a uniform seed field. It is well known that amplification of a uniform seed field is fast. Numerical simulations show that the saturation stage is reached in about 15 large-eddy turnover times (L/v), where L is the driving scale and v is the r.m.s. velocity. On the other hand, when a seed magnetic field is ejected from an astrophysical object, we expect that the seed field is highly localized in space. Our simulations show that growth of localized seed field is also very fast. Based on these results, we can construct a model for fast magnetization of the universe. Our model suggests that a localized seed magnetic field can fill the whole system in about $L_{sys}/L$ times the large-eddy turnover time and that growth of the magnetic field stops in about max(15, $L_{sys}/L$) times the large-eddy turnover time. Here $L_{sys}$ is the size of the whole system. Our finding implies that, regardless of the shape of the seed field, fast magnetization is possible in turbulent systems, such as large-scale structure of the universe or galaxies.

# Magnetic fields in intergalactic filaments

## The role of magnetism - TALK

Gabriele Giovannini
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I will present and discuss observational evidences on the presence of non-thermal diffuse emission in intergalactic filaments. The presence of radio emission on such a large scale allows to expand our knowledge of magnetic fields from clusters to filaments. This will be a foundamental step to understand the origin and properties of cosmological scale magnetic fields. In more detail I would like to present and discuss the peculiar filamentary structure connecting the A3411 and A3412 clusters of galaxies at the light of a new image of this region obtained with the KAT-7 radio telescope.

# Galaxy clusters with LOFAR and the SKA

## The role of magnetism - TALK

Marcus Bruggen
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Galaxy clusters form through a sequence of mergers of smaller clusters and groups. Shocks that occur during cluster mergers accelerate particles to relativistic energies, similar to what happens in supernova remnants. In the presence of magnetic fields, these particles emit synchrotron radiation and may form so-called radio relics. New observations show that diffusive shock acceleration operates on scales much larger than in supernova remnants and that shocks in galaxy clusters are capable of producing extremely energetic cosmic rays. However, recent observations of clusters with LOFAR and other instruments cast doubts on our understanding of the origin of cosmic rays and magnetic fields in the largest cosmological structures. Here we report on the progress of our LOFAR campaign on clusters and filaments and its implications for the SKA. The talk concludes with a review of the state of numerical simulations in this field.

# Radio halos in galaxy clusters: update and outlook for future radio surveys

## The role of magnetism - TALK

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Many galaxy clusters host Mpc-scale radio halos (RH), generated by ultrarelativistic electrons in the magnetized intra cluster medium (ICM). RH are always found in merging clusters, suggesting that they are complementary probes of the dissipation of the gravitational energy associated to the hierarchical growth of large scale structure. Still, the origin of RH is a puzzle. This is partially due to our limited knowledge of the statistical properties of RH, namely their formation rate in the Universe and their link with cluster evolution (mass, dynamics, redshift). I will present new results on the formation rate of RH in galaxy custers and on their connection with cluster mergers. Results are based on the analysis of the largest existing sample of mass-selected galaxy clusters with deep radio data, which is derived from the combintion of the "Planck SZ survey" with the "Extended GMRT RH Survey". Our study led to the discovery of the radio-SZ bimodality of clusters and represent a starting point for future studies in different redshift and cluster-mass ranges. I will show that these results have important implications on the expected statistical properties of RH (their formation rate with cluster mass and redshift, number counts, etc.) which could be tested by upcoming radio surveys (with LOFAR, ASKAP and Meerkat). I will also discuss expectations for future surveys with SKA and the importance of a synergy between low ($\approx$100 MHz) and high frequency ($\approx$1 GHz) observations to constrain the origin of these sources.

# AGN, Star Formation, and the Nano-Jy Sky

## Structure formation and the first galaxies - TALK

Paolo Padovani
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I present simple but robust estimates of the type of sources making up the faint, nano-Jy radio sky. These include star-forming galaxies, radio-quiet active galactic nuclei, low radio power ellipticals, and dwarf galaxies. I then estimate the X-ray, optical, and mid-infrared fluxes these objects are likely to have, which are very important for source identification and for the synergy between the SKA and its various pathfinders with future missions in other bands, including JWST, the ELTs, PAN-STARRS, LSST, SPICA, and Athena+.

# AGN and feedback

## Structure formation and the first galaxies - TALK

Raffaella Morganti
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The mechanism of energy feedback plays a key role in the modeling of structure formation and in reproducing the properties of local massive galaxies. The energy released by the active nucleus is one of the ways to generate such a feedback and gaseous outflows are one signature of such mechanism in action. Thus, the characterization of these outflows is, indirectly, an important step in testing our view of galaxy formation. These outflows can be radiatively driven or mechanically driven by the action of radio jets/lobes. I will review some of the recent results on the study of these AGN-driven outflows and, in particular, the role of radio jets in originating them. The results are reinforcing the conclusion that gas outflows have a complex and multiphase structure and that cold gas in different phases (atomic and molecular) represents a major component. High-spatial resolution observations have allowed, in a number of sources, to locate the region where the outflow originates as well as to derive more accurate estimates of the mass outflow rate and the associated energy. A possible link between the evolutionary stage of the radio source and the presence of outflows will also be discussed.
All these topics will be further investigated by a number of new radio telescopes. I will comment on what these instruments will do for us and I will present some initial results. As for many other topics, SKA will provide the major step forward and I will briefly comment on what the possibilities will be.

## Extreme starburst galaxies in the early universe

### Structure formation and the first galaxies - TALK

Kotaro Kohno
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Recent ALMA observations of ”extreme” starburst galaxies in the early universe will be presented.
(to be updated)

## The FR1- FR2 enigma

### Structure formation and the first galaxies - TALK

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tbc

## Deep Radio Continuum Surveys with the SKA and its precursors

### Structure formation and the first galaxies - TALK

Matt Jarvis
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I will give an overview of the key science that can be undertaken with the new deep and wide radio continuum surveys made possible by the increased survey speed of the SKA and its precursors and pathfinders. This includes tight constraints on the build-up of stellar mass in the Universe through measurement of the star-formation in galaxies, along with how AGN activity may impact on this process. I will also highlight how radio continuum surveys can be used as tracers of the large-scale structure in the Universe and hence how they can be used to pin down the cosmological model in a want that is complementary to wide-field surveys at other wavelengths.

# The value of wide radio surveys: Legacy and Serendipity

## Structure formation and the first galaxies - TALK

Ray Norris
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Wide radio surveys, such as the legendary NVSS and the planned EMU survey, have three distinct roles: (a) to answer the specific science questions for which they are designed, (b) to provide radio photometry and other radio data on objects being studied at other wavelengths, (c) to observe an unexplored region of observational phase space, with a high chance of making unexpected discoveries. While (a) is common to all well-designed observational science projects, (b) is rapidly changing because of technological advances. Nearly all sources in NVSS are radio-loud AGN, and thus interesting only to a minority of astronomers. In next-generation surveys being made by SKA and its pathfinders, the high sensitivity will enable the dust-free measurement of star formation rates of most galaxies studied at other wavelengths. As a result, next-generation SED templates for photometric redshifts are likely to include radio photometry as well as the conventional wavelengths. (c) is also radically changed by the technology. While many astronomical discoveries are the result of observing the Universe in a new way, the discoverers also relied on their great familiarity with the instrument, and their ability to distinguish discoveries from artefacts. While next generation radio surveys are certainly taking us into new areas of observational phase space, the instruments are so complex that no individual will truly understand them, and the petabyte databases will prevent any user from sifting through the data, looking for interesting curiosities. So it will be difficult to discover the unexpected with next generation radio telescopes. Or can we design algorithms that can mine the databases, searching for the unexpected? I describe the development of a project designed for the ASKAP-EMU project, but applicable to all other large radio surveys, which will mine the database searching for objects or phenomena that do not fit anything that we already know about, and instead are the ”unknown unknowns”.

# Radio emission mechanisms in the faint radio sky.

## Structure formation and the first galaxies - TALK

Margherita Bonzini
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The exploitation of the deepest radio observations currently available is important for paving the way for the future radio survey revealing their possible challenges and capabilities. Therefore, we investigated the physical properties of 900 radio sources detected in a deep VLA survey of the Extended Chandra Deep Field South detected down to a flux density limit of 32microJy. We separated AGNs from SFGs combining radio, mid-infrared and X-ray data to explore their relative contribution to the faint end of the radio population. Furthermore, we investigated the origin of radio emission in radio-quiet objects finding that the major contribution comes from star formation activity rather than accretion on the central black hole, as revealed by the comparison of the star formation rate derived from radio and far-infrared luminosity. This result implies that we have the remarkable opportunity of using the radio emission that

will be detected by the coming radio facilities to trace the star formation history up to high redshift even in the host galaxies of bright AGNs.

# Star formation at the edge of the Universe

## Structure formation and the first galaxies - TALK

Salomé Matos
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The most fundamental observational properties that need to be determined to obtain a comprehensive understanding of the physical processes of galaxy formation and evolution are the cosmic star formation history of the Universe and the volume-averaged star formation rate as a function of epoch. Previous studies have made considerable progress in recent years, but even so their measurements are aff ected by signi cant scatter and uncertainties due to the use of diff erent star-formation indicators, worsened by small area sampling and the e ffects of cosmic variance. We aim at overcoming these issues by using wide-field, sensitive un-biased surveys of star-forming galaxies at a range of redshifts across the peak epoch of cosmic star-formation. We present thefirst robust sample of star-forming galaxies at high redshifts (Lyman- emitter at $z > 7$) is obtained from a large area ( $12deg^2$) extragalactic survey within the epoch of reionisation and places strong constraints on the bright end of the Lyman- luminosity function.

# High Energy Physics of Blazars with SKA and Other Facilities Along the Spectrum

## Structure formation and the first galaxies - TALK

Ivan Agudo
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JIVE , Netherlands

Relativistic jets in AGN in general, and in blazars in particular, are among the most energetic and powerful astrophysical objects known so far. Their relativistic nature provides them the ability to emit profusely from large cosmological distances in all spectral ranges from radio wavelengths to gamma-rays, as well as abrupt variability in all time scales (from hours to years). Among the current challenges faced by high energy astrophysics are: the determination of the relativistic jet formation and collimation mechanisms and of the role played by the magnetic fields in such processes, the identification of the high energy emission site, and therefore of the involved emission mechanisms determination of the problems involving the mechanisms, and the jet plasma composition on the different scales of relativistic jets. Current deep and densely time sampled monitoring programs covering most of the available spectral ranges are starting to shed light for the case of some blazars. After a short review on the status of some of these problems, and of the special role played by radio and millimeter observations, I will present some of my latest results

on the location of the GeV emission in the jets of some blazars, at $> 10$ parsec from the central AGN engine. A discussion about the implications of these results about the gamma ray emission mechanisms involved will follow. I will finish with a perspective about how the synergy of SKA and ALMA, together with other facilities along the entire electromagnetic spectrum, will help to advance in the fundamental problems of the field in the near future.

# Wide field continuum surveys extragalactic radio sources and the SKA

## Structure formation and the first galaxies - TALK

Carole Jackson
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ICRAR - Curtin University , Australia

The SKA will offer significantly enhanced capability in both wide-field and deep survey capabilities, delivering sensitivity and resolution to be fully exploited along with data from the SKAs contemporaries. I will discuss how wide-field radio continuum surveys have laid the foundations of our overall understanding of the apparently disparate populations of extragalactic sources and their cosmic evolution. I will review current analyses from wide-field surveys and discuss how the SKA Precursor surveys, from MWA, ASKAP and MeerKAT, coupled with multi-wavelength data will further reveal the nature and evolution of the extragalactic sky en route to the SKA.

# AERAP - Information session

## Other - TALK

Declan Kirrane
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The core idea of this presentation is to provide an update on the African-European Radio Astronomy Platform (AERAP), its latest activities and visions for the near future. The presentation will brief the African audience on AERAP, while encouraging them to actively engage in global collaboration in the areas of human capital development and science capacity building, which would ultimately benefit the existing linkages in radio astronomy between Europe and Africa.

## A Fascinating View on Galaxy Rotations in the HI Window

### Galaxy evolution - TALK

Danail Obreschkow
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Large HI surveys by the SKA and its pathfinders will measure the projected rotation velocities of millions of late-type galaxies. Combined with optical inclination and size measurements, these data allow an approximate reconstruction of the angular momenta. The rotation velocities trace the distribution of dark matter, while angular momenta tackle the dynamics of cosmic tides and accretion flows. This talk highlights the exciting science of galaxy rotations and present cutting-edge results based on existing data. First, we discuss the consistency between the HIPASS/ALFALFA Velocity Function and CDM theory. Then, we present new high-precision measurements of the baryon angular momentum, contained in stars, atomic gas, and molecular gas, in late-type galaxies of the THINGS sample. A strong, irreducible correlation is found between mass, angular momentum and morphology. We discuss the origin of this relation and show how mass and angular momentum link to classical scaling relations, such as the fundamental plane for disk galaxies and the Tully-Fisher relation. Ultimately, this talk advocates the importance of galaxy rotations in the imminent era of combined wide-field radio/millimetre/optical surveys.

## Molecules at high red shift

### Galaxy evolution - TALK

Ian Heywood
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## Starburst Galaxies: Signatures and significance of extreme transformation

### Galaxy evolution - TALK

Thomas Jarrett
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Characterized by rapid consumption of their interstellar gas in the formation of massive stars, starburst galaxies exhibit one of the most extreme growth phases during their interminable evolution. Producing

copious mounts of UV radiation, starbursts are easily identified and studied through their powerful optical emission lines or through their dust-absorbed, reprocessed emission at infrared and sub-mm wavelengths. Because of these two outstanding features, namely, intense (massive) star formation and bright emission signatures, starbursts are ideal laboratories to study the often-complex (feedback) interaction between the formation of stars, their evolving environment and the physical mechanisms that energize the interstellar medium. In this presentation I will review the history and current state of studies in starburst galaxies, as well as discuss how the SKA-era will open new windows toward understanding the starburst phase of galaxy evolution.

## The COSMOS VLA Radio Survey : past. present and future

### Galaxy evolution - TALK

Paolo Ciliegi
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INAF - Bologna Observatory , Italy

Panchromatic cosmological surveys have critically advanced our understanding of the cosmic evolution of galaxies and AGN. The radio window offers a unique combination: a dust-unobscured star formation tracer at much higher angular resolution than achievable in the farIR and the ability to detect AGNs deemed crucial for massive galaxy formation. The power of large and deep radio surveys has been amply demonstrated during the last decade by several projects.
The Cosmological Evolution Survey (COSMOS) is an astronomical survey designed to probe the formation and evolution of galaxies as function of cosmic time. To date the field has been observed with most major space and ground based telescopes over nearly the full electromagnetic spectrum reaching high sensitivity.
Here I will review all the results obtained with the deep 20 cm data in the COSMOS field and I will present the results obtained with the recent 90 cm VLA observations and with new large project actually in progress with the Jansky Very Large Array (JVLA) radio telescope to observe the entire COSMOS field at 3 GHz down to a 5 sigma sensitivity of $10\mu$ Jy. The observations started in November 2012 and will end in 2014. This project (JVLA-COSMOS), reaching the faintest radio fluxes ever over a large field with superb multi-wavelength coverage, will open a range of new exploration windows in observational cosmology, and serve as the basis for next generation radio facilities, such as the Square Kilometre Array.

## Galaxy Evolution in the Virgo Cluster

### Galaxy evolution - NONE

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Galaxy evolution is influenced by environment. The properties in terms of morphology, color, gas content, star formation of galaxies residing in the field, groups, or clusters are markedly different. Environmental effects include gravitational interactions with other galaxies or the cluster potential and hydrodynamical effects as ram pressure stripping. For a significant number of Virgo galaxies UV (GALEX), optical, IR (Spitzer, Herschel), and radio (IRAM 30m, VLA) data, and detailed numerical simulations are available. I will review the insights on galaxy evolution in the Virgo cluster that we gained based on this dataset: establishment of a ram pressure stripping time sequence, dependence of the star formation efficiency on environment, the role of magnetic fields (polarized radio continuum emission), the local radio-FIR correlation, extraplanar star formation in Virgo galaxies, and the reaction of the multiphase ISM to external perturbations.

# New Frontiers: Cold Gas in Early-Type galaxies with ALMA and the SKA

### Galaxy evolution - TALK

Danielle Lucero
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University of Cape Town , South Africa

Recent observations of early-type galaxies (ETGs) from several volume limited surveys show that a significant fraction of these galaxies contain substantial reservoirs of both molecular (40%) and atomic gas (60%). This newly found population of star forming ETGs has been neglected by the large surveys aimed at determining universal star formation laws. This is mainly due to the fact that these type of studies require knowledge of the radial distribution of both cold gas components at sub-arcsecond resolution and precision measurements of the cold gas velocity dispersion. Obtaining sub-arcsecond resolution data at high spectral resolution is challenging for early-type galaxies, because they have (1) very compact CO disks, (2) low surface density neutral hydrogen, (3) are often much farther away than the nearby disk galaxies for which the these studies have already been done compounding the limitations of (1) and (2). Obtaining the necessary data on current instrumentation requires exorbitant amounts of time for each galaxy. Testing theoretical and empirical models of molecule formation and star formation for a representative sample of early-type galaxies will require ALMA and the SKA. In this talk I will outline what has been done with existing instrumentation and the limitations of that data.

# The ALMA and Jansky VLA view of massive galaxy formation at z=4.7

### Galaxy evolution - TALK

Jeff Wagg
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SKA Organisation , United Kingdom

With the commissioning of ALMA we begin a new era in sensitive, high resolution studies of obscured star-formation in the distant Universe. The quasar host galaxy, BR1202-0275, existing less than 1.5 billion years after the big bang, was one of the first high-redshift quasars shown to be luminous in the far-infared, suggesting an extreme burst of obscured star-formation. I will present ALMA commissioning observations of both thermal dust continuum and redshifted [CII] line emission, combined with recent VLA detections of rest-frame 250 GHz continuum and molecular CO line emission in both the quasar host galaxy and a second starburst galaxy located ≈25 kpc away. The data demonstrate the combined sensitivity of these new facilities for disentangling the star-formation properties of massive galaxies out to their epoch of formation.

# A candidate triple super-massive black hole system at intermediate redshift

## Galaxy evolution - TALK

Roger Deane
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University of Cape Town , South Africa

I will present the discovery of a candidate triple super-massive black hole system at z=0.4. The $10^8$ solar mass black holes have separations of ≈100 parsec and ≈7 kpc. The discovery of the 100 parsec binary is only possible with VLBI angular resolution and demonstrates the unique ability of VLBI arrays (including the future African VLBI Network) to find these exotic systems in large cosmological volumes. Larger sample sizes are required to constrain the impact binary (or more) black holes have on the inner density slope of their host galaxies; the black hole to bulge mass correlation; and the spectral shape of the gravitational wave background. I will therefore finish by describing our efforts to discover more binary super-massive black holes. This includes a deep ($<$ 10 micro-Jy/beam), wide-field VLBA survey of the CANDELS GOODS-North field which will generate approximately 5 Terabytes of uv-data and produce a final map with 0.5 Terapixels; and therefore falls into a regime that demands new calibration approaches.

# Constraining Radio Source Counts below the Survey Detection Threshold

## Cosmology, cosmic dawn and reionisation - TALK

Jonathan Zwart
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Somewhere between any survey's catalogue of significantly-detected sources and the faint confusion limit lies a population of undetected sources (1-5 times the noise). It is theoretically possible to constrain the radio number counts of such sources and exactly this method was recently applied to the COSMOS catalogue and FIRST data; because the sources are not detected at a high-enough significance level in the radio data, their position information must come from an auxiliary catalogue. The corresponding radio fluxes can then be binned and source-count models inferred.
I have assembled a sample of galaxies from the VIDEO survey, selected in the near-infrared K band, i.e. by mass. I will describe how we are applying existing algorithms to the VIDEO catalogue and 1.4-GHz VLA data that are in hand. I will show how we can measure and select between different 1.4-GHz source-count models using the bayesian evidence, as well as inferring star-formation rates and 1.4-GHz luminosity functions directly from the VIDEO-VLA data set by taking account of galaxies fitted spectral-energy distributions and photometric redshifts. This will be an excellent testing ground for the application of these novel bayesian algorithms to MeerKAT and SKA data.

# The Galactic Magnetic Field

## The Galaxy and the ISM - TALK

Marijke Haverkorn
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Although the magnetic field in the Milky Way is fairly well understood, we have very little information about the strength and structure of magnetic fields in the Milky Way gaseous halo (or thick disk). Knowledge about the magnetic halo of the Milky Way is important for studies of the Galactic ecosystem, Galactic cosmic ray propagation and dynamo theories. However, it also constitutes a foreground for e.g. Ultra-High Energy Cosmic Rays and Cosmic Microwave Background polarization.
In this talk, I will present recent work with SKA Pathfinders and others, on the Milky Way's magnetic field, focusing on the gaseous halo. I will also take a look in the future and describe new possibilities with the SKA.

# Interstellar chemistry and physics in the era of Herschel and ALMA

## The Galaxy and the ISM - TALK

John Black
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The recently completed mission of Herschel Space Observatory and the early science of the Atacama Large Millimeter/submillimeter Array (ALMA) define new challenges in the study of interstellar matter. For example, the Herschel key program "Probing InterStellar Matter with Absorption Spectroscopy"

(PRISMAS) has yielded important discoveries of reactive molecular ions. These ions (1) provide direct tests of the theory ion-driven interstellar chemistry, (2) serve as measures of the rate of ionization by cosmic rays, and (3) characterize a component of the cold neutral medium that has a small molecular fraction. ALMA and other mm-wave interferometers have extended sensitive absorption spectroscopy to galaxies at high redshift. Complementary information about cosmic-ray ionization and the so-called "dark molecular gas" has been coming from two other space missions: gamma-ray observations with the the Fermi satellite and analysis of foreground emission in Planck data. Prospects for SKA will be examined with reference to these recent developments. In particular, various possibilities for spectroscopy with SKA will be discussed.

# Star formation and circumstellar disks

## The Galaxy and the ISM - TALK

Andrea Isella
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The transformational imaging capabilities offered by ALMA, as well as future facilities such as CCAT and SKA, will open an unprecedented window on the formation of stars and planets. This will enables us to investigate how dense cores in molecular clouds collapse to form planetary systems by resolving the dust and gas emission on spatial scales that span from parsecs to astronomical units. Going from large to small spatial scales, I will first discuss how CCAT will study the formation of protostars by measuring the properties of the diffused atomic gas. I will then present ALMA observations that resolve single protostars on a spatial scale of a few AU and reveal planetary systems in the act of forming. Finally, I will discuss SKA capabilities in imaging the innermost regions of proto-planetary disks where Earth-like planets form and summarize the synergies between CCAT, ALMA, and SKA.

# Maser astrometry and Galactic structure

## The Galaxy and the ISM - TALK

Karl Menten
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About 100 trigonometric parallaxes and proper motions for masers found in high-mass star-forming regions have been measured with the BeSSeL Survey and the Japanese VERA project. These measurements provide strong evidence for the existence of spiral arms in the Milky Way, accurately locating many arm segments and yielding spiral pitch angles. Fitting the 6-dimensional position plus velocity data with axially symmetric models of the Milky Way, we find them consistent with a rotation curve that is nearly flat and obtain revised estimates of the distance to the center of the Galaxy and its circular rotation speed.

This contribution will summarize the present status of Galactic maser astrometry and will provide an outlook on spectral line Very Long Baseline Interferometry observations with the SKA.

## OH maser astrometry with the SKA

### The Galaxy and the ISM - TALK

Hiroshi Imai
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Astrometry with the core and remote stations of the Square Kilometre Array (SKA) has the high potential to expand the distance scale of study on the dynamics of the Milky Way on the basis of maser source trigonometry. At the same time, maser source proper motions measured with the SKA will enable us to explore the dynamics of the Local Group (LG) of galaxies. We have investigated feasibility of such astrometric scientific themes with the SKA and show here the latest considerations on these issues. Our attention is currently focused on OH masers, for which the astrometry at low frequency band is challenging but whose huge sample will be soon available from unbiased sky surveys currently conducted and planned .

## Radio and X-ray observations of TeV gamma-ray emitting supernova remnants

### The Galaxy and the ISM - TALK

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TeV gamma-ray emission from Supernova remnants (SNRs) has recently become of great interest with very high energy observations (e.g. HESS). The origin of the TeV emission is not yet well-known- it could be high energy electrons or high energy protons. In either case, TeV SNRs show great promise to increase our understanding of cosmic rays (CSs). We present radio and X-ray observations of several Galactic TeV SNRs. We analyze recent neutral hydrogen (HI) 21 cm line surveys of the Galactic plane to measure their kinematic distances based on updated knowledge of the Galactic disk structure. We use the CO line survey sensitive to molecular hydrogen clouds to validate these distance measurements and understand the ISM surrounding the TeV SNRs. In addition, we take advantage of current X-ray data to study the production of relativistic electrons in the TeV SNR and improve our understanding of the CSs' origin.

## Late stages of stellar evolution

### The Galaxy and the ISM - TALK

Albert Zijlstra
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Low and intermediate mass stars ($< 8M_{sun}$) account for 90% of all stellar death in the Universe. In their last phases, these stars eject most of their mass back into space through a superwind. This superwind plays a major role in the baryonic evolution of galaxies. Half of all elements heavier than iron come from these stars. The mass loss process is still poorly understood. I will discuss example projects with the SKA on this stellar mass loss, such as the enrichment of 3He, binary interactions, and the role of embedded magnetic fields

## Japanese activity for SKA: a status report of SKA-Japan consortium

### The Galaxy and the ISM - TALK

Toshihiro Handa
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In Japan about 120 voluntary scientists and engineers join to a consortium named SKA-jp. Our activity covers both astronomy and engineering. We have 6 science working groups for astronomy and 3 engineering working groups. In this talk we will present recent works done by them; for example Faraday tomography to address the intergalactic magnetic field, simulation of OH maser astrometry based on current research works with VLBI Exploration of Radio Astrometry (VERA), a prototype spectrometer, etc.

## Pulsar science with the SKA and its precursors - an overview

### Pulsars, transients and extreme physics - TALK

Michael Kramer
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Max-Planck-Institut fuer Radioastronomie , Germany

The science possible by studying radio pulsars is extremely broad. It ranges from detecting gravitational wave signals from early galaxy mergers to the study of extreme plasma and solid states physics, and from tests of fundamental laws of physics, including the possible variation of fundamental constants and tests of general relativity, to studies of the Galactic magnetic field and the Galactic centre region. All this is possible by ”only” registering and measuring the properties of the received pulses. The demands

on the telescope design are however often quite different from other modes of observing. But because pulsar studies have and will continue to pay off in expected and often unexpected ways, the SKA and its pathfinders will be able to observe pulsars. This talk summarises the stunning possibilities of pulsar science with the SKA and its precursors and sets the scene for the following talks.

# Nuclear Physics at Two Kiloparsecs with Millisecond Pulsars

## Pulsars, transients and extreme physics - TALK

Scott Ransom
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The central densities of neutron stars are the highest known in the Universe, so measurements probing the interiors of radio pulsars, or even just their masses and radii, can give us unique insights into the physics of matter at extreme densities. The discovery of several interesting new pulsars as well as improved instrumentation has finally allowed us to start measuring the masses of the rapidly spinning millisecond pulsars. High-precision radio timing measurements of relativistic parameters, like the Shapiro Delay, have yielded several neutron stars near 2 solar masses, while optical observations of some "black widow" radio pulsars have indicated potentially even more massive neutron stars. Such systems strongly constrain the equation of state of neutron star matter and a variety of other topics in physics/astrophysics. New radio telescopes like MeerKAT, FAST, and the SKA will provide many new pulsars and corresponding new mass measurements.

# Tests of theories of gravity with radio pulsars

## Pulsars, transients and extreme physics - TALK

Norbert Wex
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Max Planck Institute for Radio Astronomy , Germany

Before the 1970s, precision tests for gravity theories were constrained to the weak gravitational fields of the Solar system. Hence, only the weak-field slow-motion aspects of relativistic celestial mechanics could be investigated. Testing gravity beyond the first post-Newtonian contributions was for a long time out of reach.
The discovery of the first binary pulsar by Russell Hulse and Joseph Taylor in the summer of 1974 initiated a completely new field for testing relativistic gravity. For the first time the back reaction of gravitational wave emission on the binary motion could be studied, which gave the first evidence for the existence of gravitational waves as predicted by Einstein's general relativity. Furthermore, the Hulse-Taylor pulsar provided the first test bed for the gravitational interaction of strongly self-gravitating bodies.

To date there are a number of radio pulsars known, which can be utilized for precision test of gravity. Depending on their orbital properties and their companion, these pulsars provide tests for various different aspects of gravity.
I my talk I give an introduction to gravity tests with radio pulsars, and highlight some of the most important results. In addition, I give a brief outlook into the future of this exciting field of experimental gravity, in particular in view of the unprecedented capabilities of the SKA.

# LOTAAS: The LOFAR Tied-Array All-Sky Survey for Pulsars and Fast Transients

## Pulsars, transients and extreme physics - TALK

Jason Hessels
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ASTRON / University of Amsterdam , Netherlands

LOTAAS is an all-northern-sky survey for pulsars and fast transients using the LOFAR high-band antennas. LOTAAS takes advantage of LOFAR's unparalleled field-of-view and multi-beaming capabilities to perform the deepest all-sky survey ever undertaken for pulsars and other sub-second radio bursts. The survey is in many ways different from previous pulsar surveys (e.g., much longer dwell times and lower frequency) and the potential for the serendipitous discovery of new source classes and physical phenomena is high, especially because of the unprecedented total on-sky time the survey will achieve. In addition to its exciting scientific potential, LOTAAS is a path-finding survey for understanding how to use SKA-Low to discover a large fraction of the Galactic pulsar population. It may also show us that SKA-Low can indeed be a powerful machine for detecting fast transients in general. Here we present an overview of the novel survey approach and early results from the search processing.

# Magnetized nuclear matter and its influence on the behaviour of magnetars

## Pulsars, transients and extreme physics - TALK

Jacobus Diener
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National Institute for Theoretical Physics , South Africa

With the detection of radio-emission from highly magnetized neutron stars (known as magnetars) accurate timing of these objects with radio-telescopes are now possible. Similar to radio-pulsars magnetars also exhibit sudden increases in their rotational period, known as glitches. Detecting and monitoring these magnetar glitches will provide us with clues to the processes in the magnetar interior. Since these stars are very small (compared to normal stars), extremely massive as well as highly magnetized, any model of

the magnetar interior must be based on some description of dense and highly magnetized nuclear matter. However, since magnetars are much larger than normal nuclear matter systems (atomic nuclei), macroscopic effects have to be incorporated in the magnetar interior. Therefore, if the predictions of the model for the magnetar interior match the observed behaviour, insight is not only gained about highly magnetized compact objects, but the behaviour of matter under extreme conditions as well. This presentation will illustrate a simple description of highly magnetized nuclear matter, applied to the magnetar interior. It will show how changes in the magnetic field alter the angular velocity of the star. Furthermore, a possible (microscopic) origin of sudden changes in the magnetar magnetic field, which might lead to magnetar glitches, will also be discussed.

# Maximum pulsar mass and structure of neutron-star core

## Pulsars, transients and extreme physics - TALK

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Measured $2M_{sun}$ mass of two pulsars puts strong constraints on the equation of state (EOS) of neutron star (NS) core, through the condition that the theoretically calculated maximum allowable mass $M_{max}$ which is a functional of the EOS has to satisfy $M_{max}[EOS] > 2M_{sun}$. The true maximum mass of of NS is likely to be higher, so that the constraint on the EOS is likely to be even stronger. From the fundamental point of view, the NS core is built of quarks, either confined into the baryons (nucleons and hyperons) or forming a deconfined quark-gluon plasma. In both cases, we expect non-zero strangeness of the matter at density exceeding 2-3 nuclear densities (hyperon core or quark core). While quarks are point particles, the baryons have finite size. We show that including finite size of baryons using the (Lorentz invariant) excluded volume approximation applied to the relativistic mean field model (RMF) of dense matter leads to a solution of two problems. First, it allows for a reconciliation of existence of strange NS cores with $M_{max} > M_{obs}$ even if $M_{obs}$ exceeds $2M_{sun}$, avoiding an extreme fine tuning of the RMF parameters required for point baryons. Secondly, it eliminates the problem of "reconfinement" of quark gluon plasma at the center of the most massive NS, if strange NS cores are built of quark-gluon plasma. It is shown that the presence of sizable hyperon cores in $2M_{sun}$ NS implies radii for 1.2-1.5 $M_{sun}$ NS models which are typically 1-2 km larger than those for purely nucleon cores. This difference is explained in terms of the EOS at 2-3 nuclear densities, and perspectives of future resolution of the present controversy by observations is briefly mentioned.

# Black hole properties from radio astronomical observations

## Pulsars, transients and extreme physics - TALK

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TBA

# Transient Radio Sources

## Pulsars, transients and extreme physics - TALK

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ThunderKAT is the MeerKAT Large Survey Project (LSP) for incoherent (synchrotron) radio transients. Through a combination of pointed observations of selected targets (e.g. X-ray binaries, cataclysmic variables, supernovae, gamma-ray bursts) and commensal access to the transient radio sky via the other MeerKAT LSPs, ThunderKAT will identify and study transient radio sources at unprecedented depth and cadence. The MeerKAT 'transient' data spigot enables an efficient exploration of the unknown through fast real-time searches for new transients, as well as constrain the rates of known populations of radio transient sources at GHz frequencies, e.g. tidal disruption events and fast radio bursts. Our aim is to combine the real-time search for radio transient sources with a dedicated optical facility (MeerLICHT). MeerLICHT will exclusively and continuously track MeerKAT (during the night), providing a simultaneous optical/radio view of the transient sky. I will present early results from the ThunderKAT project from observations with the Karoo Array Telescope test array KAT-7.

# The Apertif Radio Transient System

## Pulsars, transients and extreme physics - TALK

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Apertif is a highly innovative receiver system that is currently being constructed for the Westerbork Synthesis Radio Telescope. Its factor 30 increase in field-of-view allows astronomers to survey the entire sky at 1.4 GHz with an unprecedented combination of sensitivity and speed. ARTS, the Apertif Radio Transient System, will extend this wide-field Apertif system to high time resolution, enabling unique searches for millisecond transients, as well as high-precision pulsar timing. ARTS also allows for a wholly new approach to Very Long Baseline Interferometry (VLBI) that produces sensitive, wide-area images at milliarcsecond angular resolution.
Searching for fast transients over the full element field of view will be a major challenge for the SKA. Exploiting the unique linear layout of Westerbork, ARTS will form full-sensitivity, full time resolution sampling of that entire 9 square degree field of view, showcasing techniques that will be essential for

SKA pulsar and fast-transient science. The powerful ARTS beam formers and transient detectors run in real-time and provide triggers to contemporary instruments ranging from radio to high-energy regimes, for follow up and localization of fast, enigmatic transients.

## Accessing Gamma Ray Bursts physics through SKA

### Pulsars, transients and extreme physics - TALK

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The properties of Gamma Ray Bursts afterglow emission in the radio and millimeter bands are still poorly explored despite the unique physical aspects of these sources that can be accessed in these bands. Radio calorimetry offer the opportunity to constrain the energetics of GRBs independently from their collimation and late time observations allow us derive constraints on the physical properties on the shock physics. I will present recent results of population studies that allow us to predict the detection rates and properties of GRBs radio afterglows accessible by present radio facilities, forthcoming SKA pathfinders and the final SKA. I will discuss the possibility to use radio detected GRBs as signpost of primordial Population III stars. I will present new results on the perspectives of detecting the large population of GRB orphan afterglows as slow transients in the radio and mm bands and the clues they can give on the properties (e.g. jet structure, luminosity function) of the population of GRBs as a whole.

## Probing Supermassive Black Hole Growth with SKA Pathfinders

### Pulsars, transients and extreme physics - TALK

Steve Croft
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A new generation of survey telescopes will change our understanding of how supermassive black holes grow. Whether by stupendous mergers that shake the fabric of space-time, by swallowing huge volumes of ten million degree gas, or by shredding stars that pass too close, growing black holes will make their presence known across the electromagnetic spectrum in wide-field time-domain surveys. I will focus particularly on the capabilities of the SKA and its pathfinders, which will provide radio variability information with cadences of days for samples of hundreds of thousands of active galactic nuclei, as well as constraining the statistics of stellar tidal disruption events and binary inspirals. I will present some of the current best limits on the transient rate in the radio from the Allen Telescope Array Pi GHz Sky Survey (PiGSS), and the relevance of these results for other pathfinders. I will also emphasize the importance of multi-wavelength data for understanding the populations of sources these surveys will see.

## Resonance effects around Black holes

### Pulsars, transients and extreme physics - TALK

Jeandrew Brink
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Resonances in the frequencies that characterize orbital motion around black-holes could result in several phenomenon that will be measurable with precision radio, X-ray and gravitational wave observatories in the next ten years. In this talk we introduce concepts associated with resonant orbits and explore the time and length scales typical of resonant phenomenon. We discuss astrophysical scenarios such as quasi-periodic oscillations, the formation of accretion structures akin to Saturn's rings and phase shifts in the gravitational wave and electromagnetic radiation emitted when a neutron star spirals into a black-hole.

## Diffuse Radio Emission from Cosmological Shocks

### Structure formation and the first galaxies - POSTER

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Gravitational clustering of nonlinear structures induces supersonic flow motions, which lead to the formation of cosmological shocks in the baryonic gas of the large scale structure. High energy particles are thought to be accelerated via diffusive shock acceleration at collisionless shocks in the tenuous, magnetized plasmas. In this talk, we review the properties of such shocks in the intracluster medium and their roles in the acceleration of nonthermal particles. We also discuss the implications on the observations of diffuse radio emission from galaxy clusters such as radio halos and radio relics, using SKA.

## 325-MHz Radio Luminosity Functions from GAMA/GMRT

### Galaxy evolution - POSTER

Matt Prescott
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We have matched observations from the Giant Metrewave Radio Telescope (GMRT) taken at 325-MHz,

with optical data from the Galaxy And Mass Assembly (GAMA) survey, using a likelihood ratio method. By doing so, we can assign reliable spectroscopic redshifts to radio sources, and produce radio luminosity functions out to z = 0.5, in order to probe the evolution of low-luminosity radio sources.

## Key Science with the Square Kilometre Array Phase 1

### Other - POSTER

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Key Science programs to be undertaken with Phase 1 of the Square Kilometre Array will be described, and the SKA Project Science Office and Science Working Groups will be introduced.

## Next-generation mock data sets for forthcoming SKA-precursor surveys

### New instruments - POSTER

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MeerKAT, ASKAP and ultimately the SKA will produce data sets the likes of which astronomers have never before encountered. HI line and continuum emission will be detected for hundreds of thousands of galaxies out to large redshifts. The challenge for astronomers will be to handle and analyse these data in the most efficient way in order to maximise their scientific impact.
To this end we have been producing realistic simulated data sets for various surveys to be carried out on MeerKAT and ASKAP. These are based on the results of state-of-the art semi-analytic simulations that predict the properties of galaxies. The predicted properties of each galaxy are used to generate a full 3-dimensional model of the system. These models each have unique HI distributions, rotation curves, disk inclinations and position angles, etc. The collection of 3-dimensional models are gathered together into a single large data cube ($\approx$ 1 TB for DINGO) spanning the entire survey volume. Adding realistic noise to this sky model and then convolving the result with a user-specified point-spread-function yields a very realistic mock data cube that can be used to test analysis pipelines, calibration techniques, source finding algorithms, issues related to cosmic variance, etc. All of this can be done before the telescopes become operational.
In my talk I will present the details involved with generating one of these cubes.

# Westerbork Northern Sky HI Survey

## New instruments - POSTER

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Apertif, the new receiver system of the Westerbork Synthesis Radio Telescope, will increase the instantaneous field of view of the instrument by a factor of 25 to 8 square degrees. On top of providing a preparational facility for radio surveys with the SKA, the WSRT/Apertif system will observe regions of the sky that the SKA or its precursor instruments cannot reach.
I will give an introduction to WNSHS - the Westerbork Northern Sky HI Survey. With WNSHS we propose to use Apertif to map the neutral hydrogen line above a declination of 27 degrees, out to a redshift of 0.26. Providing - spatially resolved - HI data of an unprecedented sample, WNSHS will enable research on the HI distrubution in the nearby universe, galaxy evolution and dynamics, and large-scale structure formation."

# Occurrence of Radio Halos in a mass-selected sample of galaxy clusters

## The role of magnetism - POSTER

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Many galaxy clusters host Mpc-scale radio halos (RH), generated by ultrarelativistic electrons in the magnetized intra cluster medium (ICM). RH are always found in merging clusters, suggesting that they are complementary probes of the dissipation of the gravitational energy associated to the hierarchical growth of large scale structure. Still, the origin of RH is a puzzle. The study of the statistical properties of RH is fundamental to discriminate among the possible models for their origin. In the framework of the turbulent re-acceleration scenario, RH should be found in massive/energetic merger events and thus they should become more rare in less massive systems and be absent in relaxed systems. To test this predictions and to constrain statistics of RH large mass selected samples of galaxy clusters with adequate radio and X-ray data are necessary. The recent advent of the Planck satellite allows to investigate the formation of RH in SZ-selected cluster samples. We select from the Plank SZ cluster catalog (PSZ) clusters with $M500 >\approx 6 \times 10^{14}$ solar masses and with $0.08 < z < 0.35$ and we cross checked our sample with the NVSS for low redshift clusters ($z <= 0.2$) and with the GMRT Radio Halo Survey for high redshift ones ($0.2 < z < 0.35$). In this poster we present preliminary results on the occurrence of RHs in this mass-selected sample of galaxy clusters and on their connection with the cluster dynamical status.

# The Low End of the Relativistic Electron Spectrum: Implications for X-ray Emission from Jets and Constraints on Acceleration Processes

## The role of magnetism - POSTER

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There are two problems related to the low end of the relativistic electron spectrum in extragalactic jets that can be addressed with low radio frequency observations with arcsec resolution. The first is a test of the inverse Compton (with beaming) model (IC/CMB) for the X-ray emission from quasar jets. Synchrotron emitting electrons with Lorentz factors of gamma in the range of 50-400 are those responsible for IC/CMB X-ray emission so it is generally necessary to make a blind extrapolation to very low radio frequencies from the arcsec resolution data predominantly obtained at cm wavelengths. The second issue relates to predictions of shock acceleration models that suggest there could be a low energy break in the electron distribution around gamma $\approx$2000, i.e. at an energy where the electron momentum is comparable to that of a proton. Intensities and spectral shapes near 100 MHz will significantly reduce the required extrapolation and provide evidence for or against the conflicting expectations: a single power law extending down to gamma $\approx$100 versus a break near gamma=2000.
In order to interpret the observations that will be forthcoming from LOFAR and eventually with SKA, it is necessary to understand the uncertainties associated with determining the magnetic field strength in the emitting region, the key factor in associating a frequency with gamma. In this contribution we examine the factors involved in computing the equipartition field and argue that invoking the parameter values that minimize $B_{eq}$ will provide a reasonable estimate of $B$. We briefly describe a LOFAR observation scheduled for May 2014 which will represent a first step in this endeavor.
This work was partially supported by NASA grant GO3-14106X.

# Variability of Class II Methanol Masers in Massive Star Forming Regions.

## Other - POSTER

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The two brightest Class II methanol masers (6.7 GHz and 12.2 GHz) are associated with massive star forming regions. Some of these class II methanol masers have been noted to show some variations when monitored over short or long term (e.g. Macleod & Gaylard, 1996). The most interesting ones were those showing periodic or quasi-periodic variations. It was first noted by Goedhart et al,. (2003) then more were reported by Goedhart et al., (2004), Goedhart et al., (2009), Araya et al., (2010) and Szymczak et al., (2011).
In total, nine class II methanol masers have been reported to show periodic or quasi-periodic variations. They show different waveforms and the sources of the observed periodicity is not confirmed yet. There

are few model to explain the vairiation. In general, these models use the background source to explain masers variability. Some of these models were proposed by the following people: Macleod & Gaylard (1996) used processing protostellar jets as the source of the observed irregularly variations, Sobolev et al., (2007) used variation of dust temperature in the background due the filaments formation in the accretion disk, van der Walt (2011) explained the periodicity in methanol masers to be due to colliding wind in a binary system (it could be protostars or a protostar with its companion) and Inyoshi et al., (2013), used protostellar pulsation mechanism due to rapid accretion rate as the reason of the observed periodicity.
The poster will show the time series of some of the periodic class II methanol masers. It will show how SKA and ALMA will help in understanding masers and their surroundings. Some of the thing which SKA will be useful in this field are: - Monitor periodic masers which are too faint for a single dish to follow properly. - The SKA phase two with its long baseline array could use annual parallax technique to determine the absolute distances to many more methanol masers and thus better define the structure of the southern Milky Way, where this opportunity has hardly been touch yet, and the AVN, as a precursor to the the SKA phase 2, could play a leading role in starting this. ALMA could detect the radio emission behind the class II methanol masers.

# A Sinusoidal Hough Transform to detect binary pulsars in Dynamic Power Spectra

## Pulsars, transients and extreme physics - POSTER

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Finding new binary pulsar is not a trivial task, most of the strong pulsars have already been found. To find the remaining weak pulsars we required to use longer observations. The as the length of the observation increase the power of the various form acceleration search drop. To detect weak compact binarys in these observations a new technique is needed. These pulsars leave a faint sinusoidal trail in a Dynamic Power Spectra. We use a Custom Sinusoidal Hough Transform to detect these faint trails. This transform is however a highly computationally intensive task as 4-dimensional parameter space needs to be explored. We have implemented a GPU accelerated Sinusoidal Hough Transform and used it to detect know pulsars in archival data. This transform has proven effective at re-detecting known pulsars, and is able to detect weak compact pulsars in observations where current search methods cannot.

# Improving the Southern Celestial Reference Frame ahead of the SKA

## Other - POSTER

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VLBI observations of any but the brightest sources and VLBI astrometry all rely on having reference sources, which are sources known to be compact, have strong VLBI detections at radio wavelengths and which have accurately known positions. Quasars being at great distances do not exhibit any measurable proper motion or parallax, making them ideal reference sources. VLBI observations in the southern celestial hemisphere have always been more difficult both because there are fewer radio telescopes in the south than in the north, and because the southern hemisphere very long baseline array is not well served with reference sources. Currently there is an expansion of radio astronomy capability at frequencies below 2 GHz in the southern hemisphere. In particular, both the Square-Kilometre Array (SKA) precursors, the South African MeerKAT and the Australian ASKAP, will operate at frequencies at or below L band ($\approx$1.4-1.7 GHz). Finally, the SKA itself will do much of its work at frequencies below 1.4 GHz. So far, however, the sky has been relatively little explored at high angular resolutions and frequencies $<$ 2 GHz, and even less so in the southern hemisphere, therefore the coming new VLBI stations, and long-baseline component of the SKA open up a significant window of discovery. However, for long baseline observations at low frequencies, reference sources will be needed. They are needed in particular for astrometric VLBI at L band, for example, obtaining trigonometric parallax distances to pulsars and circumstellar OH (1665 and 1667 MHz) masers. Southern very long baseline observations are planned at 1.6 GHz to improve the number of calibrator reference sources at low frequencies. In addition, dedicated astrometric observations to improve the southern celestial reference frame at 2.3/8.4 GHz are also currently underway, as well as observations to complete sky coverage at 22 GHz. At higher frequencies extra-galactic radio sources are not only expected to exhibit more compact source morphology but also a reduced core-shift. This reduction in astrophysical systematics should allow for a more well-defined and stable reference frame at 22 GHz, but also be advantageous in tying the VLBI reference frame to the future optical reference frames such as Gaia. Observations at 22 GHz would also be of much value in multi-wavelength studies of frequency dependent systematic errors due to the core-shift effect and to probe the sub-milliarcsecond structure of the most compact regions of emission in AGN. The coming African VLBI Network (AVN), will greatly facilitate observations of southern objects.