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Detecting HI 21 cm emission from the IGM in large scale filaments with current and future radio telescopes

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The cosmic web plays an important role in providing the environment for the formation and evolution of galaxies. Studying the role of local gas overdensities in the number density and general properties of galaxies requires observations of the large scale IGM structure. However, cosmic web filaments have only been observed indirectly through the positions of galaxies in large galaxy surveys or through absorption features in the spectra of high-redshift sources. We propose to directly detect intergalactic medium filaments through their emission in the HI 21 cm line. This signal depends on the density in the filaments and the strength of the UV/X-ray background. We use high-resolution cosmological simulations to estimate the intensity of this emission in low-redshift filaments and use it to make predictions for the direct detectability of specific filaments previously inferred from galaxy surveys, in particular SDSS.
Given the expected signal of these filaments, our study shows that HI emission from large filaments can be observed by current and next-generation radio telescopes. We estimate that gas in filaments of length l >15 Mpc/h with relatively small inclinations to the line of sight (<10 deg) can be observed in $\sim$ 40–100 h with telescopes such as GMRT or EVLA. The large field of view allows upcoming instruments such as Apertif and ASKAP to detect large filaments independently of their orientation and curvature, which opens up the possibility of stacking the emission from multiple filaments.
Furthermore, our estimates indicate that a more powerful future radio telescope like SKA can be used to completely map most of these filaments, which will allow them to be used as a strong cosmological probe.

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Probing diffuse radio emission in galaxy clusters with LOFAR

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Giant, low surface brightness, diffuse synchrotron sources with steep spectra have been observed in an increasing number of galaxy clusters. According to models, mergers can dissipate part of their energy in the (re)acceleration of relativistic particles and in the amplification of the intra-cluster medium (ICM) magnetic field, playing an important role in powering diffuse radio emission in the ICM. In particular, turbulence is believed to be responsible for the formation of the central and likely spherical sources called radio halos, while shocks are the origin of the elongated and polarized emissions found in cluster outskirts known as radio relics. Although this scenario seems supported by current observations, the processes that originate these synchrotron sources are still poorly constrained. In this respect, LOFAR gives the unique opportunity to study non-thermal phenomena in galaxy clusters with an unprecedented sensitivity and resolution at low frequency. I will present LOFAR observations at 150 MHz of two merging galaxy clusters, Abell 1758 and Abell 781, coming from two LOFAR Two-metre Sky Survey (LoTSS) Tier 1 pointings. Both clusters are in a complex dynamical state, as revealed by X-ray and optical observations, while previous radio observations at higher frequency already provided evidence of diffuse radio emission in the ICM. LOFAR allows to study with greater detail these steep spectrum sources recovering more (and new) diffuse emission in the clusters. I will discuss the implications of the new observations on the models of halos and relics formation.

3

BCGs radio analysis from a EGMRT and CLASH sample of galaxy clusters

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Brightest Cluster Galaxies (BCGs) are the most massive and luminous elliptical galaxies in the whole Universe. They inhabit the cores of galaxy clusters and their special position raises the question of the role of the environment in their evolution and in shaping their radio properties (Kale et al. 2015). Many BCGs show colors and light profiles similar to those of quiescent elliptical galaxies but a significant fraction of them exhibit star formation (Donahue et al. 2015). Their study is very important since they present very peculiar characteristics and since their evolution is strictly linked to the evolution of the host cluster. In my talk I will present a radio analysis of BCGs selected from a sample of ten galaxy clusters, in a redshift range $0.2 < z < 0.4$, mainly from CLASH and EGMRT surveys. From the dynamical point of view the clusters are either merging or cool core. I compared new GMRT data, both at 602 and 330 MHz with reprocessed VLA archival data at 1.4 GHz, exploiting also optical images already available. The main goal is to constrain the origin of BCGs radio emission, with the intent to enlarge the sample for a complete statistical analysis, but also, study the dynamical state of the central regions of clusters hosting a mini-halo, like the cool cores in our sample.

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An unbiased mass-selected sample of galaxy clusters: new statistical constraints

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Radio observations reveal the presence of diffuse Mpc-scale synchrotron emission in a fraction of galaxy clusters. These sources, known as radio halos, probe complex mechanisms operating within clusters that channel gravitational energy into particles and magnetic fields. In the current theoretical view, radio halos form via the acceleration of particles by turbulence injected in the ICM during merger events. This scenario has basic predictions about the statistical properties of radio halos that need large unbiased samples of galaxy clusters with adequate radio, SZ and X-ray data to be tested. We selected a sample of 75 galaxy clusters $M > 6 \times 10^{14} M_{\odot}$ and $z = 0.08 - 0.33$ from the Planck SZ catalogue and observed with the GMRT and JVLA the clusters of the sample without deep radio observations in order to complete the information about the presence/absence of radio halos. This is the largest mass-selected sample of galaxy clusters with deep radio data and X-ray observations available to date. The analysis of the new radio data led to the discovery of some interesting extended sources, as well as many clusters without radio halos for which we derived upper limits to the diffuse emission. I will discuss the distribution of the clusters of our sample (both radio halos and upper limits) in the radio power-mass diagram, updating and improving previous studies (Cassano et al. 2013). We found that a small percentage (15-20%) of clusters are underluminous with respect to the previous radio-mass correlation by Cassano et al. (2013), proving that the increase of the statistics allows to populate also the region below the correlation. Only few underluminous radio halos are know so far and they might shed light on the complex mechanisms of formation and evolution of radio halos. Based on a statistically sound sample, we can confirm that the fraction of clusters with radio halos increases with increasing the cluster mass, in agreement with the expectation of turbulent re-acceleration models.

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A combined JVLA and Chandra study of the Abell 2626 galaxy cluster

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We present the results of a new JVLA and Chandra study of the galaxy cluster Abell 2626. The radio emission of the cluster is characterized by the presence of a system of peculiar radio sources, the arcs, whose properties differ from the properties of the common cluster diffuse radio sources, as relics or mini-halos. In the past years, several models have been proposed to explain their origin. One of the most promising suggests that the arcs are trails of a pair of hot-spots that are moving, due to the precession of the jets of the central galaxy IC5338, that hosts a double optical core. By combining new radio and X-ray observations, we focus on the detailed study of the local properties of the thermal and non-thermal emission in the proximity of the radio arcs, in order to get more insights into their origin. The radio analysis, that we carried out by combining the new JVLA map at 3.0 GHZ with an archival VLA map at 1.4 GHz, allowed us to put a strong constraint on the time-scale of the jet precession of ˜10 Myr. On the other hand, the X-ray analysis led to the discovery of a cold front in the proximity of the radio arcs, whose discovery raises a new possibility for their origin. Therefore, we propose that the arcs are the brightest edges of a radio mini-halo, generated by turbulent re- acceleration in cold fronts originated by the sloshing of the gas. If this mechanism is inefficient, numerical simulations show that the radiation is generated with very steep spectrum and preferentially in the regions where magnetic fields and turbulence are stronger, which results in arc- like emissions tracing cold fronts.

6

Analysis of the rapid variability in the Q2237+0305 gravitationally lensed quasar

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Rapid variability has been observed for the first time in the Einstein Cross QSO 2237+0305, a radio quiet flat spectrum quasar at z∼1.7 that is quadruply lensed by a foreground galaxy at z∼0.04. The intrinsic variability of the Q2237+0305 quasar at the time scale of several days with the amplitudes of about 0.1-0.2 mag has been detected at the 95% confidence level. The Einstein Cross is known to have very short differential time delays, which, according to theoretical predictions, are of the order of several hours. The earlier determinations of the time delays made in the optical wavelengths (Vakulik et al. 2006, Koptelova et al. 2006) could not test these predictions properly because of very large errors resulted from the absence of distinct short-period features in the light curves. We have made use of the detected rapid flux variations to obtain the new more accurate estimates of the time delays in Q2237+0305, having applied our new method (Tsvetkova et al. 2016) that mitigates the effect of microlensing in measuring the time delays in gravitationally lensed quasars. Our results are consistent with the most recent theoretic predictions (e.g., Schmidt et al. 1998, Wertz & Surdej 2014). It is important to note that the time delays obtained from the light curves in the R and I spectral bands are well consistent with each other, while those from the V light curves differ noticeably. We assume this can be explained by the presence within the V spectral band of the broad emission line (BEL) C III] λ1909 redshifted to approximately 515 nm. Since the BEL region is presently believed to be much larger than that emitting the UV and visual light, the initial UV and optical signal from the inner regions of a quasar must undergo distortions in its successive re-emission (reverberation) as it propagates towards the BEL region. Such distortions will be different in different macroimages, depending on the phase of a microlensing event in each particular image. Therefore, observations in spectral bands free of the broad emission lines should be preferred for measurements of the time delays in gravitationally lensed quasars.

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Evidence for large scale toroidal magnetic field components in the jets of active galaxies

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The collimation mechanism for astrophysical jets, is a long standing question. Helical fields are generally accepted as the main magnetic field configuration for jet launching, it is still unclear what role they play (and if they survive) to the largest jet scales. A helical or toroidal B-field may contribute substantially to the collimation of the jet. The radio (synchrotron) emission from these jets can be highly linearly polarized. The observed polarization angle can be affected by Faraday rotation, which is the change in the observed polarization angle of an electromagnetic wave as it passes through a region with free electrons and magnetic field. This change is directly proportional to the wavelength squared and is also directly proportional to the line-of-sight magnetic field; therefore a monotonic gradient in the Faraday rotation measure (RM) transverse to the jet indicates a similar behaviour of the line-of-sight B-field component, implying a helical or toroidal magnetic field, this in turn implies an induced current along the jet. This type of analysis has mostly been done on parsec scales using VLBI observations at centimetre wavelengths, while relatively few studies have probed decaparsec to kiloparsec scales. The detection of statistically significant transverse RM gradients on such large scales can reliably show that a helical or toroidal field component persists to these distances from the centre of the AGN. We present results for 2 AGN on kiloparsec scales based on multiwavelength VLA observations which show significant transverse RM gradients. Furthermore, the inferred toroidal B-Field component on the sky gives evidence for a predominance of outward currents in the jets on kiloparsec scales, while an inward current is favoured on smaller scales making the system of electrical currents in the jet very similar to that of a coaxial cable.

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Phase-referencing measurements of positional shifts in ultra-compact AGN cores

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Accurate alignment of the optical reference frame with the VLBI based International Celestial Reference Frame (ICRF) requires good understanding of the positional discrepancies of the reference objects used for the alignment. The compactness of the ICRF objects requires relative astrometry for measuring the frequency-dependent core shifts, however, there are no established methods and approaches for such measurements. We have designed a project aimed at testing several potential methods for core shift measurements using relative astrometry For that purpose, we have used phase-referencing VLBA observations at 5 and 15 GHz in a sample of ten compact, high declination radio sources. These observations will provide crucial input for devising an optimal approach for the radio-optical reference frame aligment.

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Total and linearly polarized synchrotron emission from magnetized overpressured relativistic jets

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We present numerical simulations of overpressured magnetized relativistic jets which are characterized by their dominant type of energy, namely internal, kinetic, or magnetic. Each model is threaded by a helical magnetic field with a pitch angle of 45 deg and features a series of recollimation shocks produced by the initial pressure mismatch, and whose strength and number varies as a function of the dominant type of energy. We perform a full-Stokes parameters study of the polarization signatures from these models by integrating the radiative transfer equations for synchrotron radiation using as inputs the RMHD solutions. These simulations show a top-down emission asymmetry produced by the helical magnetic field and a roughly bimodal distribution of the EVPAs due to the axial symmetry. Small variations of the order of 15 deg are observed in the polarization of the stationary features associated with the recollimation shocks.

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Time Variability of the Core-Shift Effect in the Blazar 3C454.3

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In this work, we investigate the time variability of the core-shift effect in the very luminous blazar 3C454.3 (z=0.859). We employ multi-frequency (5,8,15,22,43 GHz) VLBA data of 19 epochs from 2005 until 2010. We perform core-shift measurements with frequency pairs via image plane cross-correlation and visibility plane model-fitting. These measurements will allow us to study the time variability of the core-shift in the blazar as well as the time evolution of the spectra. We will also compare our results and search for correlations in 37 GHz long-term light curve observations of 3C454.3 at the Metsähovi Radio Observatory. These results will allow us to examine how stable the core shift is over time if it varies due to outbursts or other processes. In addition,this study will give an important test for how reliable the core-shift measurements are.

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Multi-frequency polarimetry of a complete sample of PACO radio sources

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The high-frequency (> 20 GHz), bright flux density (> 200 mJy) radio population is dominated by blazars (BL Lacs and Flat Spectrum Radio Quasars), i.e. compact Doppler-boosted objects observed closely to the line of sight, whose emission at higher and higher frequency mostly arises from self-absorbed, knot-like synchrotron structures in the relativistic jet closer and closer to the active nucleus. Their polarization properties are still poorly constrained at high frequency, since spectra become steeper and the polarization fraction is typically few percents ($\sim 2.5\%$ at 20 GHz) of the total intensity flux density. Thus, observations requires sub-mJy sensitivities and results in literature are easily affected by spectral, detection and variability-related biases: most current estimates rely on extrapolations from low-frequency samples, which are affected by large uncertainties. Extending the characterization of polarization properties of radio sources to high frequencies provide invaluable information about magnetic fields and plasma in the inner and unresolved regions of relativistic jets: it has been argued that Faraday depolarization should be effective up to ~ 10 GHz and the ordering of magnetic fields should increase in such inner regions. Both these phenomena may result in an increasing trend of the polarization fraction with the frequency, but its determination is still debated.

From a cosmological point of view, extragalactic radio sources are an important contaminant to the microwave sky in total intensity and in polarization at scales smaller than 30 arcmin up to 100 GHz: an accurate determination of radio source emission is therefore crucial to extract the CMB angular power spectrum and, in particular, to study the primordial B-mode polarization that might be extremely weak for low values of the tensor to scalar perturbations ratio (r=T/S) associated with the stochastic background of gravitational waves, one of the most ambitious goal of current and future CMB projects.
We present the analysis of high sensitivity ($\sigma \sim 0.6$ mJy) multi-frequency polarimetric observations for a complete sample of 104 compact extragalactic radio sources drawn from the faint (> 200 mJy at 20 GHz in total intensity) Planck-ATCA Coeval Observations (PACO) catalogue, performed with the Australia Telescope Compact Array (ATCA) at 7 frequencies, over the $1.1 - 39$ GHz frequency range. An ALMA project observed in cycle 3 extends the analysis up to 100 GHz for a (complete) sub-sample of 32 objects. Polarization spectra of single sources cannot be simply inferred from total intensity ones, as different source components dominate the different emissions, despite total intensity spectra can be fitted by a double power law in over than 80% of the cases. On average, spectra steepen at frequencies > 30 GHz (both in total intensity and polarization). We distinguish three spectral categories in total intensity finding different behaviours in polarization fractions and polarization position angles (PPA) among them. We produce differential source counts for the sample observed. Multi-epoch variability analysis (from 1.5 up to 12 yr time lags) is also presented, taking into account past PACO and AT20G observations.
In addition, the observations provide useful informations both for better evaluating the statistical and systematic accuracies of PPA obtained with ALMA and for exploring the possibility of using ALMA measurements of bright and strongly polarized radio sources, in order to help in calibrating the PPA in CMB experiments. In fact, such calibration accuracy is becoming the limiting factor of several CMB polarization measurements.

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Measuring the Core Shift of Sgr A*

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Sagittarius A (*Sgr A*), the supermassive black hole (SMBH) in our Galactic Center, is one of the best laboratories to study the origin of mm/sub-mm emission from SMBHs because it is only ∼8 kpc away, resulting in a projected angular size of ∼10 μas corresponding to the Schwarzschild radius (r_{Sch}) of ∼0.1 AU (Genzel et al. 2010). At present, a variety of observation and theoretical models converge on the fact that the mm/sub-mm radiation is emitted from a region within several r_{Sch} of the black hole. This region is thought to be the jet base of *Sgr A* or a radiatively inefficient accretion flow (RIAF) (Falcke & Markoff 2000; Yuan et al. 2003) or a combination of both (Yuan et al. 2002). Revealing the origin of the (sub-)mm emission is important for understanding low-level accretion onto SMBHs which is presumably the dominant form of accretion in *Sgr A*.
Sgr A has an inverted synchrotron spectrum in the radio, that can only be explained by a stratified, self-absorbed geometry. However, it has not been understood well if the dominant geometry is an inflow or an outflow. In general, matter accretion onto a SMBH results in the launching of relativistic jets extending from sub-pc to Mpc scales in the most powerful cases. *Sgr A* also shows some evidence of the outflow at pc scale (Yusef-Zadeh et al. 2012; Li et al. 2013), but it has never been detected at sub-pc scale, where the jet launching region is thought to lie. However as the weakest known accreting black hole, with $L_{\rm bol} \approx 10^{-9} L_{\rm Edd}$, it has been shown that the expected small/faint jets would be challenging to detect with standard VLBA (Markoff, Bower & Falcke 2007).
In very long baseline interferometry (VLBI) observations, an optically thick surface (the photosphere) is shown as a radio core at a given observing frequency and moves toward the central SMBH with increasing frequency when the structure is elongated (e.g., conical jet), which is known as *core shift effect* (Blandford & Königl 1979; Lobanov 1998). Therefore this is an important tool to constrain the emission models.

However, only a few studies have tried to measure the core shift of Sgr A* (e.g., Bower et al. 2015). In general, astrometric studies are difficult at high frequencies because the non-dispersive effect on the phase by the Earth's atmosphere gets larger at higher frequencies. To overcome this problem, the frequency phase transfer (FPT) technique has been applied, which corrects the phase of target frequency using a lower frequency phase solution. Because the FPT removes the non-dispersive atmospheric phase errors which are rapidly varying, the coherence time is dramatically extended so that the phase referencing can be applied using a calibrator far from a target. Therefore, by applying the phase referencing with a combination of FPT, the so called source frequency phase referencing (SFPR), both non-dispersive and dispersive effects on the phase can be effectively calibrated (Rioja & Dodson, 2011). Once the severe phase errors have been corrected, the relative astrometric measurements can be recovered.
The Korean VLBI Network (KVN) is one of the best VLBI arrays to study the core shift, thanks to its quasi-optics system at four frequencies (i.e., 22 ,43, 86 and 129 GHz) so that it enables to apply the successful SFPR. We conducted several observations for *Sgr A* using KVN and found the positional shift of its center at different frequencies. We present our recent results of the *Sgr A* core shift measurements and discussions to remove the residual positional uncertainties.

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Radio galaxies with LOFAR: relic emission from opposites scales

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Divers in their age, scale and distance, the radio galaxies (RGs) are one of the imprints of the AGNs. One of the open questions regarding these objects is the phase of their activity. Because of their characteristic synchrotron emission, it is necessary to go to low frequencies in order to detect possible diffuse and extended emission. Indeed this emission would be the remaining of a previous activity, and, hence, show a steeper spectrum. New generation of radio telescopes such as LOFAR are thus extraordinary tools, which enable us to achieve our main goal and analyse different steps of RGs' evolution.
Here we present our current work, which is focusing on the study of individual objects belonging to the two extremes of the RGs, with the principal use of this European radio interferometer. On one end, 4C33.33 is a member of the family of the oldest and biggest objects, the Giant RGs. Because of this expected very extended and faint emission, its mapping is still a challenge not only for the science case but also for the automated processing and imaging of the data. It is also demonstrating the possibility for users to contribute in the development of the reduction tools, as simultaneously learning to master them. On the other end, the most compact and youngest of RGs (CSS/GPS - such as 1159+4645 shown here) require the use of LOFAR European baselines to resolve them and to observe the older emission. Thus this work is a part of the current exhilarating difficulty to solve within the frame of an international collaboration; the extension of the LOFAR pipelines to all its stations.

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The gaseous environment of radio galaxies

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The inter and circum galactic medium (IGM & CGM) play a crucial role in understanding galaxy formation and evolution. Unfortunately, little is known about the properties of this gas. It has recently become possible to observe the IGM adnd CGM via absorption spectroscopy from large spectroscopy surveys of quasars backlighting this medium. These quasar spectra provide large numbers of sightlines that show absorption at characteristic wavelengths when the quasar light along this sightline passes through, and is processed by, a dense cloud of gas associated with galaxies or other cosmic structures. One of the most common signatures found in quasar spectra is the strong Mg II absorption line doublet.
By cross correlating FIRST radio sources and MG II absorbers (from the MG catalogue from Zhu & Ménard 2013) we are able to determine relations between the Radio galaxy population source properties (such as radio loudness) and the absorber properties. This study describes a statistical analysis of FIRST sources around absorbers. Since the redshifts of the majority of the FIRST sources are unknown, we explore different background subtraction methods to analyse the relations between the absorbers and radio sources. We find an excess of absorbers from $10^1 - 10^2$ kpc from absorbers. This excess is strongest for intermediate radio sources, defined as those with a radio luminosity where $10^{23} > log(L) < 10^{25}$.

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The AGN fueling/feedback cycle: a multi-component study of a sample of local Radio Galaxies

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Galaxy formation theories struggle to explain the role of Black Hole accretion in shaping galaxies over cosmic time. Radio feedback, associated to radio jets, is accepted as a fundamental component of the lifecycle of the most massive radio loud early-type galaxies (Radio Loud ETGs, i.e. Radio Galaxies, RGs), at least in the late stages of cosmic evolution ($z < 1$). The many details of such process, however, still remain poorly understood (Heckman & Best 2014, for a review). It is generally accepted that High Excitation Radio Galaxies (HERGs) are triggered by cold gas transported to the center through merging or collisions with gas-rich galaxies, while accretion in Low Excitation Radio Galaxies (LERGs) may occur directly from the hot phase of the IGM. The most compelling evidence that cold gas can play a role in fuelling LERGs as well, is that in such systems dust and molecular gas are detected in larger quantities than in radio-quiet ETGs. This gas may cool from the hot phase, but could also come from stellar mass loss, interactions or mergers. Systematic high-resolution CO imaging of radio galaxies (in which radio jets are currently active) together with kinematic information on the stellar and ionized gas components, is fundamental to isolate the role played by radio-mode feedback in the overall formation and evolution of ETGs, allowing also to do a crucial comparison with existing studies of radio-quiet ETGs (e.g. ATLAS^{3D} sample, Alatalo et al. 2013). For this purpose, we have selected a complete volume-limited sample of eleven nearby ($z < 0.03$) RGs associated with elliptical galaxies, selected from the Southern Parkes 2.7 GHz survey (Ekers et al. 1989). All the selected galaxies have low-power ($P_{1.4GHz} \leq 10^{25}$ W Hz^{-1}), low accretion rate, and FRI type or (arcsec-scale) compact radio morphology. For all the sources, VLT/VIMOS IFS observations and ^{12}CO(2-1) integrated spectra with APEX are available (Warren et al. in prep; Prandoni et al. 2010; Laing et al. in prep), and an accurate re-imaging of the archival sub-arcsec/arcsec VLA data has been already done. Here we present the preliminary results obtained by reducing and analyzing ALMA Cycle 3 CO(2-1) observations of 9 targets, with resolutions ranging from 0.3 to 1 arcsec (Ruffa et al. in prep). The CO(2-1) line emission was detected in 7 out of 9 targets (detection significance from 8 to 35 sigma); CO(2-1) maps show regular rotating disk structures in the majority of the sources, but we have also peculiar cases in which the gas disk shows a disturbed morphology that seems to suggest an interaction with the radio jets; the analysis is still ongoing.

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Dying radio galaxies in the Lockman Hole

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Super massive black holes at the centre of galaxies can cycle through periods of activity (in this phase known as active galactic nuclei, AGN) and quiescence. The life-cycle of AGN is crucial for understanding the energetic impact they have on the host galaxy. In radio AGN this cycle can be followed using the characteristics of the radio spectrum and the morphology of the radio emission. In particular, the low radio frequencies can be used as fossil record to trace and characterise the active, inactive and restarted phases of radio galaxies. After the jets have switched off, radio galaxies undergo a fading phase which is often called the dying or remnant phase. It is poorly understood and very few sources in this phase are known. In this talk, I will present a sample of 23 candidate remnant radio galaxies that we selected in the Lockman Hole extragalactic field and first results of their optical identification. This sample was selected from deep images obtained with the LOw Freqeuncy ARray (LOFAR) on the basis of spectral criteria, such as ultra-steep spectral index and high spectral curvature, as well as low radio core prominence (CP) and relaxed shapes being used as morphological criteria. I will present the initial results of the optical identifications I performed in order to further investigate properties of these sources, such as deriving the redshift and radio power distribution as well as computing the size. The optical identifications of the remnant radio sources present in this sample were performed using the Sloan Digital Sky Survey Data Release 13 (SDSS DR13) and the Spitzer Extragalactic Representative Volume Survey (SERVS). The methods for optical identification developed for this project will be applied in the future on much bigger samples of remnant radio sources selected from the LOFAR 150-MHz survey.

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The flow of baryons through galaxies

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Studying the flow of baryons through galaxies is an important part of understanding the evolution of galaxies over time. We have exploited ALMA calibrator observations to perform a novel (sub)mm survey, ALMACAL. As part of this survey, we are searching for CO emission lines from the host galaxies of known Ly alpha absorbers. In the field of J0423-0127 we detect for the first-time multiple CO transitions from a galaxy associated with a Ly alpha absorber. Furthermore, we have optical IFU observations using MUSE revealing the optical counterpart of the CO emission and three additional emission line galaxies at the absorber redshift. Combining these datasets yields the information about cold and ionized gas and stars (metallicity and kinematics) for a group of galaxies. From this we can infer the interplay of galaxies and their circum galactic medium. Furthermore, the combination offers a census of the cool baryons at intermediate redshift.

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Sub-arcsecond LOFAR imaging of the nearby LIRG Arp299

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Low-frequency radio spectra of luminous and ultra-luminous infrared galaxies (LIRGs and ULIRGs, respectively) carry very relevant information by, e.g., tracing the free-free absorption, which constrains the thermal ionized gas component. While low-frequency turnovers in compact (U)LIRG galaxies are known to exist, the interpretation of such spectra is quite uncertain due to a lack of high-spatial information. LOFAR, armed with international baselines, is called to make breakthrough contributions to this field, as it is currently the only instrument that can provide sub-arcsecond, deep imaging at the relevant frequency range of 150 MHz.
Here, we present observations of the nearby LIRG Arp 299 obtained with the LOFAR telescope, complemented with e-MERLIN and VLA archival data from the Multi-Element Radio Linked Interferometer Network (MERLIN) and the Karl G. Jansky Very Large Array (VLA), spanning the frequency range from 150 MHz up to 36 GHz.
We model the radio emission of Arp 299 from 150 MHz to 36 GHz, with a typical angular resolution of ˜0.2", which allows us to spatially resolve the radio emission with unprecedented detail. Arp299 is the first LIRG (after the ULIRG Arp220) to be imaged with subarcsecond angular resolution at such low frequencies. By modelling the radio spectrum in such detail, we are able to (i) discern the mechanism(s) responsible for the low-frequency absorption; (ii) estimate the thermal and non-thermal emission from the relativistic electrons, and hence estimate the SFR in each of the two merging systems in Arp299. In addition, the modelling of the radio emission over two decades in frequency puts severe constraints on the ultra-relativistic electron energy distribution. Our observations open the avenue for similar studies of larger samples of LIRGs and ULIRGs, and shows what can be achieved with the SKA.

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Galaxy structure and dark matter in the KiDS survey

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Over the past years, there have been surveys dedicated to understanding processes that govern galaxy evolution; e.g. by tackling fundamental questions related to the morphology and size growth of galaxies, as well as the dark matter distribution at all scales. I will briefly report the work I will be involved within the Kilo Degree Survey (KiDS) at the VST telescope to automatically characterise the 2D surface brightness of galaxies in KiDS and how this can help with the search for faint arc-like features produced in lensing events. The methods and tools designed as part of our project will be optimised for future surveys with large data sets (e.g. LSST). We will also start testing tools to expand the strong lensing search in SKA data. In the SKA era, by combining the information from the optical/NIR (photo-z, stellar population and stellar mass) and radio (dark matter content), it will be possible to reconstruct the mass assembly of massive galaxies and cluster cores at z >1.5, constrain the Dark Matter density profile and presence of substructures, the IMF evolution, formation efficiency of these systems against the galaxy formation predictions at an unprecedented redshift range.

20

The energy distribution of electrons in radio jets

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Black-hole and neutron-star X-ray binaries exhibit compact radio jets, when they are in the so-called quiescent, hard, or hard intermediate states. The radio spectrum in these states is flat to slightly inverted, i.e., the spectral index alpha is typically in the range [0 – 0.5]. It is widely

accepted that the energy distribution of the electrons, in the rest frame of the jet, is a power law with index p in the approximate range [3 – 5]. A power-law energy distribution of the electrons in the jet is sufficient to explain the flat to slightly inverted spectrum emitted by the jet from radio to near infrared wavelengths, but is it necessary? Contrary to what our thinking was decades ago, now we know that the jets originate in the hot inner flow around black holes and neutron stars. Thus, we have investigated the spectrum that is emitted by a thermal jet with kT in the range [100 – 250 keV]. Under the assumption of a parabolic jet and flux freezing, we have computed the emitted spectrum from radio to near infrared using either a thermal distribution of electrons or a power-law one. We have found that parabolic jets with a thermal distribution of electrons give inverted spectra with alpha in the range [0 – 0.4], while jets with a power-law distribution of electrons give inverted spectra with alpha in the range [0 – 0.2]. The rest of the parameters are kept the same in the two cases. The break frequency, which marks the transition from optically thick to optically thin synchrotron emission, is comparable for the two electron energy distributions. Our conclusion is that, contrary to common belief, it is not necessary to invoke a power-law energy distribution of the electrons in a jet to explain its flat to slightly inverted radio spectrum. A relativistic Maxwellian produces similar spectra. Thus, the widely invoked "corona" around black holes in X-ray binaries may actually be the jet!

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The SCORPIO project: Stellar Radio emission in the SKA era

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Radio emission has been detected in a broad variety of stellar objects from all stages of stellar evolution. However, most of our knowledge originates from targeted observations of small samples, which are strongly biased to source which are peculiar at other wavelengths. In the absence of unbiased searches, it is very difficult to predict what will be found by SKA and its pathfinders, such as ASKAP, but we can be sure the new radio facilities are going to revolutionize our view of the Milky Way.
In such future perspective, we present the SCORPIO project, a ATCA deep survey at 2.1 GHz in the Galactic plane, aimed at reaching a flux limit of 40 μJy. We show the major scientific results of the analysis we conducted so far, with particular attention to the more than 80 extended sources ($>$ 30") and to the more than 2000 point sources that the SCORPIO field harbours. The main scientific output will be the production of catalogues of different populations of Galactic radio sources, from stars to SFRs and SNRs. Moreover, the SCORPIO project will guide the EMU design, the largest radio continuum survey ever obtained at the planned depth of 10 μJy/beam, to be conducted with ASKAP, in identifying issues arising from the complex continuum structure associated with the Galactic Plane and from the variable sources in the Galactic Plane. It will contribute in evaluating the most appropriate method for source finding and extraction for sources embedded in the diffuse emission expected at low Galactic latitude.

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Two special GPS pulsars: J1740+1000 and B1800-21

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Most of the pulsar radio spectra can be described by a simple power-law function. However, spectra of some pulsars show a different behaviour, among them are the so-called gigahertz-peaked spectra (GPS) characterized by a positive spectral index in the frequency range below one gigahertz (Kijak et al. 2017). The analysis of the spectral evolution of a binary pulsar PSR B1259-63 provided evidence that GPS have rather some environmental origin than an intrinsic one (Kijak et al 2011). Recently the model of the free-free thermal absorption was used in order to explain the turnover around one gigahertz in pulsars spectra by Lewandowski et al. (2015) and Rajwade et al. (2016). Such absorption may be caused by pulsars environments such as pulsar wind nebulae, dense filaments in supernovae remnants or cooler H II regions. In my talk I will focus on two unusual pulsars that show a turn-over around 1 GHz: J1740+1000 and B1800-21. In both cases the previous measurements have brought results that yield to intractable discrepancy between different interpretations of the nature of their spectra. For that reason both pulsars were observed at frequency range from 325 MHz to 5 GHz. I will present the results of our recent observations and discuss the shape of the newly acquired spectra. The first part of our observational project involved observations of the two pulsars J1740+1000 and B1800-21 using the Giant Meterwave Radio Telescope (GMRT) located near Pune in India. GMRT consist of 30 parabolic antennas spread in a Y shape over distances up to 25 km. Each of the antennas has 45 m dish diameter and is fully steerable. In the second part observations were made using the Green Bank Telescope that is a fully steerable single dish with 100-meter diameter collecting area and is located in Green Bank (West Virginia, USA).

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Radio emission in ultracool dwarfs: the nearby planetary system VHS 1256-1257

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Radio observations of ultracool stellar objects (late M, L and T objects) constitute a remarkable opportunity to investigate the magnetic activity of these objects and its influence on the formation of disks or planets.
The system VHS 1256-1257 is one of the candidates to improve the statistics of active cool objects. This young system (150-300 Myr) consists of a 0,1" equal-magnitude M7.5 brown dwarf binary and a planetary-mass L7 companion separated by 8". We observed this system with the Jansky Very Large Array and with the European VLBI Network at several frequency bands during 2015 and 2016.
We found weak but persistent radio emission spatially coincident with the main component of VHS 1256-1257. The spectral behaviour of the detected radio emission suggests that the acting radiation mechanism would be non-thermal, gyrosynchrotron emission. This implies the presence of magnetic fields of the order of kGauss. In addition, we set a strong upper bound to the flux density of the L7 planetary companion. Future observations with different radio interferometers to clarify the nature of VHS1256-1257 will be discussed.

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Dust evolution in HD163296: a path to planet formation

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Circumstellar disks of gas and dust, formed during the first stages of star formation as a result of the conservation of the angular momentum, set the initial conditions for the growth of larger bodies, and eventually planets, that occurs in the first few million years of the life of the star. Spatially resolved observations of circumstellar disks are key to understand the formation of planets as they provide a unique snapshot of the rapid transition from disks to planetary systems. In the last couple of years we witnessed an authentic revolution in our view of protoplanetary disks: thanks to ALMA long baselines we were able to observe a variety of features as rings, gaps and spirals in the dust continuum emission from several disks, as young as 1 Myr. The disk around Herbig Ae star HD163296 is one of the most bright and well studied in the solar vicinity: ALMA observations at 1.3mm revealed a clear ringed structure in the dust, and hydrodynamical simulations showed he dust and gas flux density profiles are compatible with a disk with embedded planets carving gaps in the surrounding material. Multi-wavelength studies allowed to measure the maximum grain size across the disk, suggesting that grains have grown to form larger aggregate than the typical sub-micron size of the ISM, and that dust is migrating towards the central star under the action of radial drift.

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Measuring RM variations with LOFAR: ISM vs ionosphere

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Magnetic fields play a crucial role in the magneto-hydrodynamic (MHD) heating of the interstellar medium (ISM) and the density fragmentation of cold molecular clouds, thus regulating the process of star formation. They are also known to be important in particle ray acceleration, which can provide the pressure to drive galactic outflows. However, many important characteristics of the magnetic fields, such as their origin and evolution, strength and structure, and their influence on Galactic dynamics remain unknown. Using the data from highly polarized pulsars observed with German LOFAR stations, we will investigate long-term Rotation Measure (RM) variations. Besides being sensitive to the astrophysical ISM effects due to LOFAR low-frequency range, our data are also susceptible to ionospheric effects. Using long pulsars' observations we can carefully investigate accuracy of the GPS ionospheric maps and independently estimate parameters of the noise, generated by imperfect ionospheric modeling. We will demonstrate the comparison of different ionospheric maps and discuss the pitfalls to expect while using them.

26

ALMA survey of astrochemical species around High mass protostars

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The birth of stars begins in the core of dense molecular clouds. The interaction of the gas with the dust grain surface in these dense cores together with the ionization by cosmic ray photons leads to the formation of complex molecules on the surface of the grains. Once stars form and heat the grains, these species are released into the gas. This presentation will describe a survey of a sample of 39 massive young stellar objects with ALMA with the aim to use these released species to probe the evolutionary stage of these objects. The data were taken in ALMA in cycle

3 and in Band 6 covering a frequency range around 227GHz (in the LSB) and 241GHz (USB). The spectral setup covers multiple transitions of a range of organic species including CH3OH, CH3CN, CH3CCH, CH3OCH3 as well as the J=2-1 transition of C17O and the 2-1 transition of CN with a velocity resolution of about 1km/s at a spectral resolution of about 1".

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On the reservoir of sulphur in dark clouds : chemistry and elemental abundance reconciled

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Sulphur-bearing species are often used to probe the physical structure of star forming regions of the interstellar medium, but the chemistry of sulphur in these regions is still poorly understood. In dark clouds, sulphur is supposed to be depleted under a form which is still unknown despite numerous observations and chemical modeling studies that have been performed. In order to improve the modeling of sulphur chemistry, we propose an enhancement of the sulphur chemical network using experimental and theoretical literature. We test the effect of the updated network on the outputs of a three phases gas-grain chemical model for dark cloud conditions using different elemental sulphur abundances. More particularly, we focus our study on the main sulphur reservoirs as well as on the agreement between model predictions and the abundances observed in the dark cloud TMC-1 (CP). Our results show that depending on the age of the observed cloud, the reservoir of sulphur could either be atomic sulphur in the gas-phase or HS and H_2S in icy grain bulks. We also report the first chemical model able to reproduce the abundances of observed S-bearing species in TMC-1 (CP) using as elemental abundance of sulphur its cosmic value.

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Nitrogen fractionation in high-mass star forming cores and its Galactic trend

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Nitrogen, the fifth most abundant element in the universe, exists in the form of two stable isotopes: ^{14}N, the main one, and the less abundant ^{15}N. Molecules found in comets and other pristine Solar system bodies are enriched in ^{15}N, because they show a lower ^{14}N/^{15}N ratio with respect to the value representative of the Proto-Solar Nebula (PSN), but the reasons of this enrichment cannot be explained by current chemical models. Also, the models are poorly constrained by the few observations obtained so far. To better understand the process of ^{15}N enrichment in star-forming regions, we have measured the ^{14}N/^{15}N ratio in a sample of 27 high-mass star forming cores, from observations of HCN(1-0) and HNC(1-0) (Colzi et al.˜2017a, submitted). These cores are believed to be the birthplaces of massive stars and rich clusters, the environment in which our Sun may have been formed. The observations were performed with the IRAM-30m Telescope, one of the best single-dish existing Radiotelescopes operating in the radio-millimeter regime. We have found values of the ^{14}N/^{15}N ratio that are distributed remarkably well around that of

the Protosolar Nebula (about 441). Moreover, these sources were divided into the three main evolutionary categories of the high-mass star formation process: 11 high-mass starless cores, 9 high-mass protostellar objects and 7 ultracompact H_{II} regions. This study shows that the isotopic ratio does not vary with time, which, therefore, does not seem to play a role in the fractionation of nitrogen. Afterwards we have decided to implement the sample by an even larger sample of this kind of sources (about 90 in total), observed with the IRAM 30-m as well. We have computed the $^{14}N/^{15}N$ ratios from the same molecules and we have confirmed that these ratios are concentrated in the range $\sim$ 270 (value measured for the terrestrial atmosphere) and $\sim$ 441 (Colzi et al.˜2017b, in prep). Thanks to the very large sample, and to the fact that these sources span a wide range of distances from the Galactic center, we have also found a Galactocentric gradient. This is the first $^{14}N/^{15}N$ gradient measured in the Milky way with a very robust statistics.

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Observations the eruptive filament in the range of 4-8 GHz at the Siberian Radioheliograph

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Regular observations of the Sun with multiwave Siberian Radioheliograph (SRH-48) in frequency range of 4-8 GHz were started at 2016. SRH-48 is 48-element T-shaped radiointerferometer. The images of the Sun are created via Fourier aperture synthesis. At 25 June 2016 the SRH-48 registered eruptive filament in the range of 4-8 GHz, which was observed in the eastern part of solar limb from 01:47 UT to 03:15 UT. According to orbital observatory SDO/AIA the filament was best of all observed in the channels 171, 304, 131,335 of 094 A. Also we compared the images with LASCO.

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Analysis of an interference affecting the data of the Siberian Radioheliograph

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The Siberian Solar Radio Telescope [Grechnev et al., 2003] is now being upgraded. The upgrading is aimed at providing the aperture synthesis imaging in the frequency range 4–8 GHz [Lesovoi et al., 2011, 2014] instead of the single-frequency direct imaging due to the Earth rotation. One type of radioheliograph data represents correlation plots [badary.iszf.irk.ru/srhCorrPlot.php]. In evaluating the covariation of two-level signals, these plots are sums of complex correlations, obtained for different antenna pairs. Bearing in mind that correlation of signals from an antenna pair is related to a spatial frequency, we can say that each value of the plot is an integral over a spatial spectrum. Limits of the integration are defined by the task. The radio heliograph data is influenced by radio frequency interference. The paper shows how to take into account the background radiation of the underlying surface, the radiation of geostationary satellites and airborne radars during the processing of the heliograph data.

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Study of the double plasma resonance instability generating solar radio zebras

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The double plasma resonance (DPR) instability plays a basic role in generation of solar radio zebras in type IV solar radio bursts. In the plasma, consisting the loss-cone type distribution of hot electrons and much denser and colder background plasma, this instability generates the upper-hybrid waves. They are transformed into the electromagnetic waves and observed as radio zebras. We computed not only the growth-rates of the double plasma resonance instability, but also saturation energies of the generated upper-hybrid waves in dependence on the ratio between the upper-hybrid ω_{UH} and electron-cyclotron ω_{ce} frequencies analytically and with a 3-dimensional electromagnetic particle-in-cell (3-D PIC) relativistic code. We varied temperatures of the both hot and background plasma components and studied the effects on the resulting growth rates and saturation energies.

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Unleashing the MeerKAT: early continuum L-Band imaging of the southern skies

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MeerKAT, a radio interferometer consisting of 64 13.5m offset Gregorian dish antennae, is currently under construction in the Great Karoo region of South Africa. I will discuss some of the challenges and early results of creating high dynamic range continuum maps with the array in its current 32 antennae state. I will also detail pipelining software and prototype pipelines under development in our group at SKA-SA.

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Receiver technology for radio astronomy and deep-space communications

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Radio astronomy and deep-space communication share many technical requirements, but also have technical conflicts. We attempt to solve some of these technological issues and provide a new design for a receiver system, where radio astronomy and communication applications can successfully share the same hardware and infrastructure. A collaboration between the Experimental Cosmology Group at Oxford University (ERC) and Goonhilly Earth Station Ltd. (GES) has been established, where ERC develops and provides the receiver hardware and GES provides the antenna and infrastructure to test the receiver system. We present a receiver system which covers the frequency ranges 4–8 GHz for radio astronomy applications, and 8.4 GHz for deep-space satellite communication at. Its architecture allows the receiver to be used in three different operational modes, interferometer mode, single dish mode, and deep-space communication mode.

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New technologies for the future radio telescope: SKA

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In recent years, for projects such as the SKA-low (Square Kilometre Array at low frequency) at MRO (Murchison Radio Observatory), the specifications do not affect only performance maximization: the system is vastly expanded and populated by hundreds of thousands antennas, so the cost factor becomes a key parameter. For this reason, the guidelines for implementing a system of this magnitude and size are looking for the best-performing technology that points to a push for mass production and at the same time the simplicity of deploy in remote places like the Australian desert. In this talk will be presented the contribution given by the Institute of Italian Radioastronomy for the design, construction and delpoy of AAVS1 (Aperture Array Verification System): an array of 400 antennas.