# Nearby Normal and Luminous Infrared Galaxies with the SKA

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## Abstract

The SKA will routinely provide $\mu$Jy sensitivity and sub-arcsecond angular resolutions at radio wavelengths. Planned SKA surveys will image vast numbers of nearby galaxies, which are expected to provide a cornerstone in our understanding of star-formation and accretion activity in the local Universe. Here, we outline some of the key continuum and molecular line studies of local galaxies, where the SKA will have a significant scientific impact and where the Spanish astrophysical community is particularly active.

## 1 Introduction

Star-formation (SF) and accretion onto a supermassive black hole are the two key processes in the evolution of galaxies in our Universe. Further, the SF history within individual galaxies still remains a crucial physical parameter that observations are only now beginning to accurately characterise. Radio observations provide by far some of the best diagnostics of these two processes, allowing a direct view of SF even in dusty environments, as well as the detection of AGN and the measurement of their accretion rate at bolometric luminosities far below anything detectable at higher energies. The high sensitivity, resolution and imaging fidelity capabilities of SKA, will ensure that the SKA will become a dominant instrument for the detailed study of nearby galaxies over the next decades. In this chapter, we outline the scientific motivation for undertaking large surveys and deep observations of galaxies in the local Universe across all available frequency bands of SKA, both continuum and spectral line studies.

## 2 Radio continuum as a star-forming tracer in nearby galaxies

—*Thermal and non-thermal radio emission as star-formation tracers*

Both continuum thermal free-free radio emission and synchrotron radio emission can be considered as SF tracers. Thus if the presence of an AGN can be excluded (or its contribution neglected), one could then obtain independent estimates of the SF rate, and thus check the linearity of the RC(thermal)–FIR and RC(sync)–FIR correlations. RC and FIR emission both depend on (recent) SF and will thus be correlated. Surprisingly, this RC–FIR relation of galaxies holds over 4 orders of magnitude in luminosity, irrespective of galaxy type [29, 18, 7] and has been observed to hold out to a redshift of about 3 [25, 3]. A well calibrated RC–FIR relation offers a powerful method to probe the cosmic SFR out to intermediate redshifts, initially with SKA pathfinders and precursors, and eventually with the SKA. For further details, we refer the reader to the chapter by Lisenfeld et al. (this book), which is exclusively devoted to discuss the RC–FIR correlation. However, we note that a well calibrated RC-FIR relation is an essential prerequisite for deep extragalactic surveys with the SKA.

An alternative to estimating SFR from the FIR, which at best provides modest angular resolution and relies on the availability of suitable satellites, one can use the RC to determine directly the current SFR in galaxies [16]. The thermal and non–thermal emission are the result of fundamentally different processes, with different RC–SFR relations expected for each component. The thermal RC, due to the ionized flux from massive stars, is expected to be directly proportional to the SFR. This makes it an ideal, virtually extinction–free proxy for SF [40]. The non–thermal RC depends on the magnetic field strength as well as the cosmic–ray energy density, unless one assumes an electron calorimeter which is unlikely, particularly for dwarf galaxies, or in general those galaxies with large–scale outflows. Usually one assumes energy equipartition between the CRe and the magnetic field, so that the RC–SFR relation is closely connected to a relation between the magnetic field and gas.

SKA1–MID will transform what can be achieved. Rather than an essentially monochromatic information, observations of about 1 hr per band will sample the entire radio continuum spectrum between 1.67 and 10 GHz (about 4 hr total per target), down to $\mu$Jy sensitivity. This will allow to put the above relations on a much more robust footing, as we will be able to separate off the thermal contribution, leaving just the non–thermal fraction. The spatially resolved spectral index distribution will come within reach, thus providing a lever on the propagation and aging of CRe as they diffuse from their sites of origin. At the $\mu$Jy level of sensitivity, we will be able to trace all star formation activity in local galaxies down to star formation rates as low as (see, e.g., equation 6 in [6])

$$SFR \lesssim 6.62 \times 10^{-4} \left(\frac{S_{1.4\mathrm{GHz}}}{\mu Jy}\right) \left(\frac{D}{100\,\mathrm{Mpc}}\right)^2 \mathrm{M}_\odot\,\mathrm{yr}^{-1}$$

—*The constituent parts of local galaxies*

Sensitive and critically high angular resolution radio images of nearby galaxies such as will be provided by the SKA1-MID ( $\lesssim 0''.22$) and by the complete SKA ( $\lesssim 0''.01$), provide one method by which observations can directly probe SF in a way which is independent of complex physical emission mechanisms. Whereas lower resolution radio observations of normal and star-forming galaxies trace the diffuse radio emission, sub-arcsecond angular resolution observations are required to systematically characterise the populations of individual compact SF products on a galaxy by galaxy basis by resolving away the diffuse emission. This population census can hence be used to directly infer the levels of SF.

Observed with $<0\farcs22$ angular resolution, each individual galaxy can be considered as a laboratory containing a large sample of discrete radio sources, all at essentially the same distance, which can be studied in a systematic way. At $\mu$Jy and sub-$\mu$Jy sensitivities and between frequencies of 1 and 7 GHz this source population, with the exception of accretion dominated objects and in particular AGN, will consist exclusively of sources related to various key phases of the stellar evolutionary sequence. This population will be a mixture of sources from the early stages of SF, such as compact HII regions, through SSCs, and stellar end-points like X-ray binaries, planetary nebulae, SNe [48] and their SNR.

By first detecting and then identifying the physical nature of these objects using a combination of radio morphologies and spectral indices, alongside extensive multi-wavelength ancillary data, high angular resolution radio observations will provide the first detailed extinction-free census of SF products within nearby galaxies. The majority of core-collapse SNe evolve to form long-lived radio SNR, hence this statistically well-constrained census combined with information regarding the sizes and hence canonical ages of SNR (for the nearest galaxies observed with sub-arcsecond resolution available in higher bands with SKA1–MID), can be used to directly infer levels of SF in individual galaxies. This will provide a further obscuration-independent SFR tracer and, because it detects massive stars which form CCSNe, will preferentially probe the top part of the IMF. When combined with other SFR measures such as IR/UV or global RC free-free and synchrotron emission (e.g., the case of the circumnuclear region of NGC 1614; see [30] and Fig.1), this will provide constraints on the universality of the IMF as a function of galaxy type, evolution and environment within the local volume.

Importantly, such a local galaxy radio survey will also identify populations of sources that trace earlier stages in stellar evolution, such as HII regions and SSCs, placing useful constraints on the levels of SF at various phases in the evolution of individual galaxies. When compared with other wavelength tracers, which probe different ranges of SF age and different spatial regions, these radio diagnostics will provide significant new insights.

Whilst this will be achievable on a galaxy-by-galaxy basis, the power and importance of an SKA survey of nearby galaxies arises from its large size and the available complementary multi-wavelength data-sets. By combining these direct radio tracers of SF products, with other multi-wavelength SF proxies (e.g. IR), significant constraints will be placed on their calibration and interpretation, with important implications across a wide range of observational astrophysics. Large-area SKA1 continuum surveys with both SKA-MID and SKA-SUR with sensitivities of $\sim 4\mu$Jy will be capable of detecting all local galaxies thus spanning a complete range of types and levels of both historical and ongoing SF, and allowing this census of SF products to be applied over the wide range of luminosity and environment parameter space inhabited by galaxies. Such a survey will provide the radio benchmark for studies of local galaxies with application to all observational astronomers.

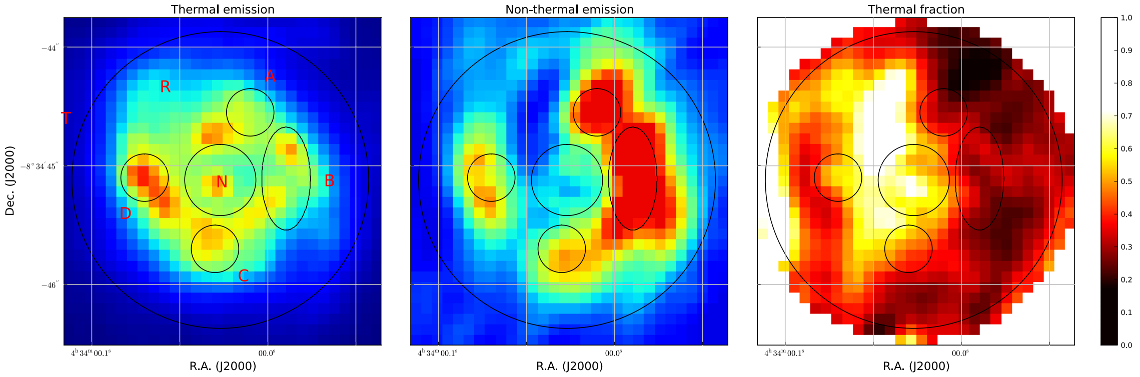

Figure 1: Decomposition of the 3.6 cm flux for the central kpc of the luminous infrared galaxy NGC 1614 into thermal (left) and non-thermal (middle) radio emission. The right panel shows the relative contribution of the thermal emission. Note that regions A and B are dominated by synchrotron non-thermal emission, in contrast with regions C and D. (Taken from [30].)

—*Resolving extragalactic star forming regions in clusters with the SKA*

A sizable fraction of the emission from young star forming clusters comes in the radio domain. This emission mainly arises in SNR of thermal or non-thermal nature and bresmtrahlung due to the cooling gas. In the extragalactic domain, the characterization of young star forming regions is difficult in the radio domain because of limited angular resolution and sensitivity, particularly at the lowest radio frequencies. However, the key advantage of studying starformation in radio is the transparency to dust, contrarily to the studies in the UV, optical and even in the near-IR where suitable angular resolutions are at reach but dust is the major drawback. Yet, with the present instrumentation, detecting these regions and spatially resolving them into their building blocks, the star clusters, are possibilities limited to the nearest, brightest starburst galaxies using facilities as the VLA in its larger configuration, e.g. NGC 253 (see Fig. 2 and [19]).

The large collective area and angular resolution of SKA will allow us to individually characterize these stellar building blocks not only in prototype objects like NGC 253, but also in most star forming regions in galaxies in the local Universe. Detailed mapping of extragalactic young star clusters is accessible today from the UV- to the optical- bands with the HST, in the near-IR band using Adaptive Optics in 8-10 m class telescopes, and in the millimetre/submillimetre with ALMA. The SKA will provide the complementary information in the cm range at comparable scales to those provided by all the above facilities. The ensemble of all these data will allow us to produce extremely well sampled spectral energy distributions. Modelling of these SEDs will deliver a more consistent picture of the onset and evolution of star formation in a wide range of environments within a given galaxy - e.g. star formation in the disk vs. that in the spiral arms - and between galaxies of different type and activity level (e.g. [41]).

—*From local U/LIRGs to high-redshift star-forming galaxies*

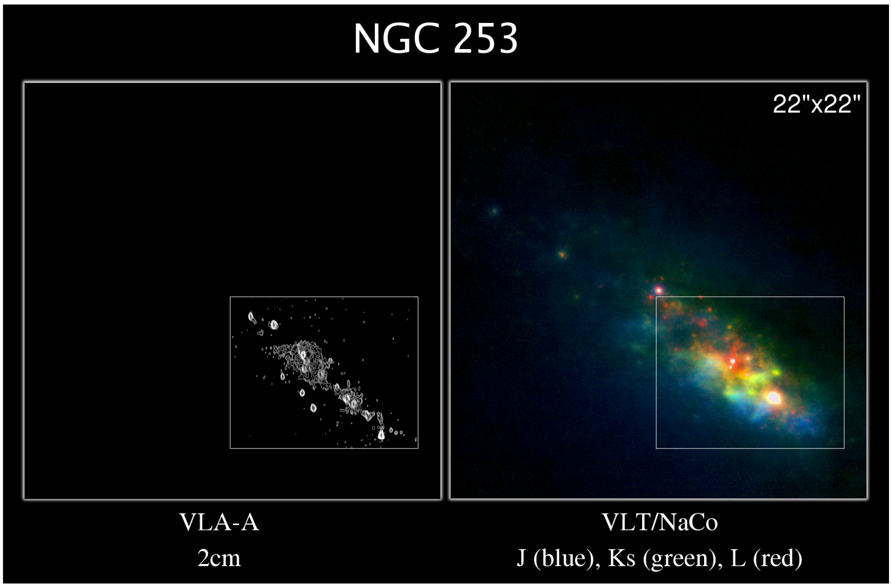

Figure 2: The central 150 pc of the nearest starburst NGC 253 (D=3.9 Mpc) spatially resolved into stellar clusters. The right panel shows a color composite VLT adaptive image taken at 1.2 $\mu$m, 2.2$\mu$m, and 4.6 $\mu$m. The inside square resolves into 37 young clusters, each with size of 3 pc (adapted from [19]). The left panel shows the same region at 2 cm collected with the VLA-A. Sensitivity limits restrict the detection to $\sim$15 clusters, all with a counterpart in the near-IR VLT image (adapted from [54].

Local ($z \lesssim 0.3$) Luminous Infrared Galaxies (LIRGs) are thought to be nearby scaled-down versions of high-z star-forming galaxies. Since a major science goal for the SKA and its pathfinders is the study of SF across cosmic time, it is crucial to i) have a detailed and accurate knowledge of local star-forming galaxies, and ii) test the radio-infrared (radio-IR) relation. Since radio emission is a dust-unbiased SF tracer, an accurate calibration of the radio-IR relation will be needed to determine the SFRs at high-z. Indeed, at $z \geq 1$, 1 arcsec corresponds to 8 kpc, so that disentangling AGN from star-forming activity is challenging, unless angular resolutions better than $\sim 0\farcs1$ are provided, so that one starts to separate a putative AGN from a compact starburst at essentially any redshift. This capability will be provided by the full SKA.

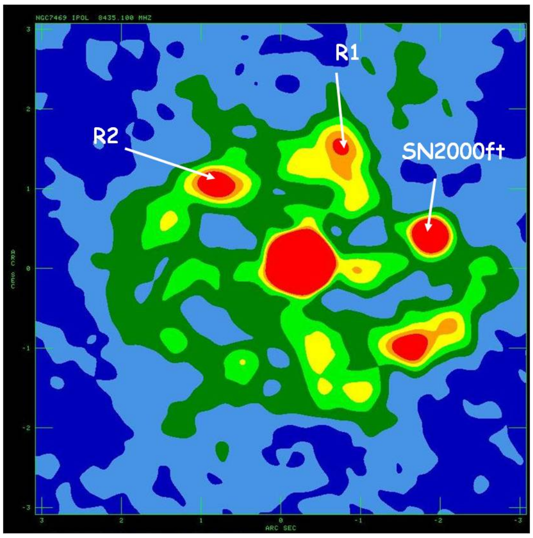

Figure 3: 8.4 GHz VLA image of SN 2000ft in the Luminous Infrared Galaxy NGC 7469, 70 Mpc away from us. The SN was discovered in 27 October 2000, about a few months after the explosion. The SN exploded at a deprojected distance of about 600 pc from the nucleus, whose radio emission is very prominent. Sub-arcsecond angular resolution radio observations are thus a very useful tool to detect extragalactic CCSNe. (Image taken from [1].)

A large fraction of massive SF at both low- and high-$z$ has taken place in (U)LIRGs. Their implied high SFRs are expected to result in CCSN rates a couple of orders of magnitude higher than in normal galaxies. Therefore, a powerful tracer for starburst activity in (U)LIRGs is the detection of CCSNe, since the SFR is directly related to the CCSN rate. However, most SNe occurring in ULIRGs are optically obscured by large amounts of dust in the nuclear starburst environment, and have therefore remained undiscovered by (optical) SN searches. Fortunately, it is possible to discover these CCSNe through high-resolution radio observations, as radio emission is free from extinction effects. Furthermore, CCSNe are expected (unlike thermonuclear SNe) to become strong radio emitters when the SN ejecta interact with the CSM that was ejected by the progenitor star before its explosion as a supernova. Therefore, if (U)LIRGs are starburst-dominated, bright radio SNe are expected to occur. Given their compactness and characteristic radio behavior of radio SNe they can be pinpointed with high-resolution, high-sensitivity radio observations (e.g., SN 2000ft in NGC 7469 [14, 1, 45], see Fig.3; or the supernova factories in Mrk 273 [11], Arp 299 [46, 12], or Arp 220 [43, 5]). However, since (U)LIRGs are likely to have an AGN contribution ([49, 2]) , high-sensitivity, high-resolution radio observations are required to disentangle the nuclear and stellar (mainly from young SNe) contributions to the radio emission, thus probing the mechanisms responsible for the heating of the dust in their (circum-)nuclear regions.

In view of the importance of (U)LIRGs in tracing the SF history across cosmic time, a targeted survey of local (U)LIRGs using SKA1–MID, up to a distance of 100 Mpc, will be essential. The sub-arcsecond angular resolution in band 2/3 will be well-matched to current (J)VLA-A images at higher frequencies, permitting the thermal and non-thermal contribution to be disentangled in the very centres of galaxies. Considering the continuum sensitivity provided by SKA1–MID, as little as 2 minutes per source would be sufficient to produce 1.7 GHz images of a similar depth to those currently provided by the JVLA at 8.4 GHz in 1 hour. A census of all local (U)LIRGs could be obtained in just a few hours with SKA1–MID. Even if the specifications deviate by as much as 30% in terms of sensitivity, this science will not be severely affected. However, baseline lengths of at least 200 km are required, to provide the necessary angular resolution. An SKA-MID survey providing an angular resolution of $0\farcs5$ corresponds to a physically interesting resolving linear scale of $\sim$250 pc at 100 Mpc.

Similarly, SKA1–MID will be a game–changer when it comes to providing a benchmark study for relating the CCSN rate to the SFR in both star-forming and normal spirals, and down to dwarf irregulars. With sensitivities of over an order of magnitude better than current instruments, and sub-arcsecond resolutions providing linear resolution scales of a few tens of pc within nearby galaxies, SKA1–MID will be well matched to spatially separate CCSNe from their surrounding diffuse emission, thus enabling a complete census of radio supernovae, provided the SKA1–MID survey is made of several visits of each field, so that the flux density and spectral variability of each individual source can be ascertained.

The full SKA will reach an angular resolution of about 10 mas at 1.67 GHz, i.e., a 20-fold increase with respect to SKA1. At this angular resolution, it will be possible to locate any individual core-collapse supernova (or supernova remnant) within the nuclear region of any local starburst galaxy, similarly to detailed studies in e.g., Arp 220 and Arp 299 (see Fig. 4, taken from [45, 47]), but with the potential of unveiling the much more numerous, fainter population of radio supernovae and supernova remnants. In turn, this will allow us to test scenarios of SN/CSM-ISM interaction, including estimates of the energy budgets in particles and magnetic fields, and determine the SNR luminosity vs. size relation for essentially all local (U)LIRGs. In addition, we will be able to extend the study described above to essentially all redshifts, as the 10 mas beam at 1.67 GHz will yield spatial resolutions of 80 pc, or better, at all redshifts. The limitation will be dictated by the sensitivity. In fact, even Type IIn supernovae will be realistically detected up to $z \lesssim 0.5$ (3-$\sigma$ detection after 1-hr with SKA1-MID against a source-free background). Even if lensing is taken into account, e.g., a factor of 5 increase, the maximum redshift to which we can expect a detection is $z \lesssim 1.2$. While exciting, the detection of such events will require specific, deep searches, rather than simply making a commensal use of the moderately deep surveys discussed here.

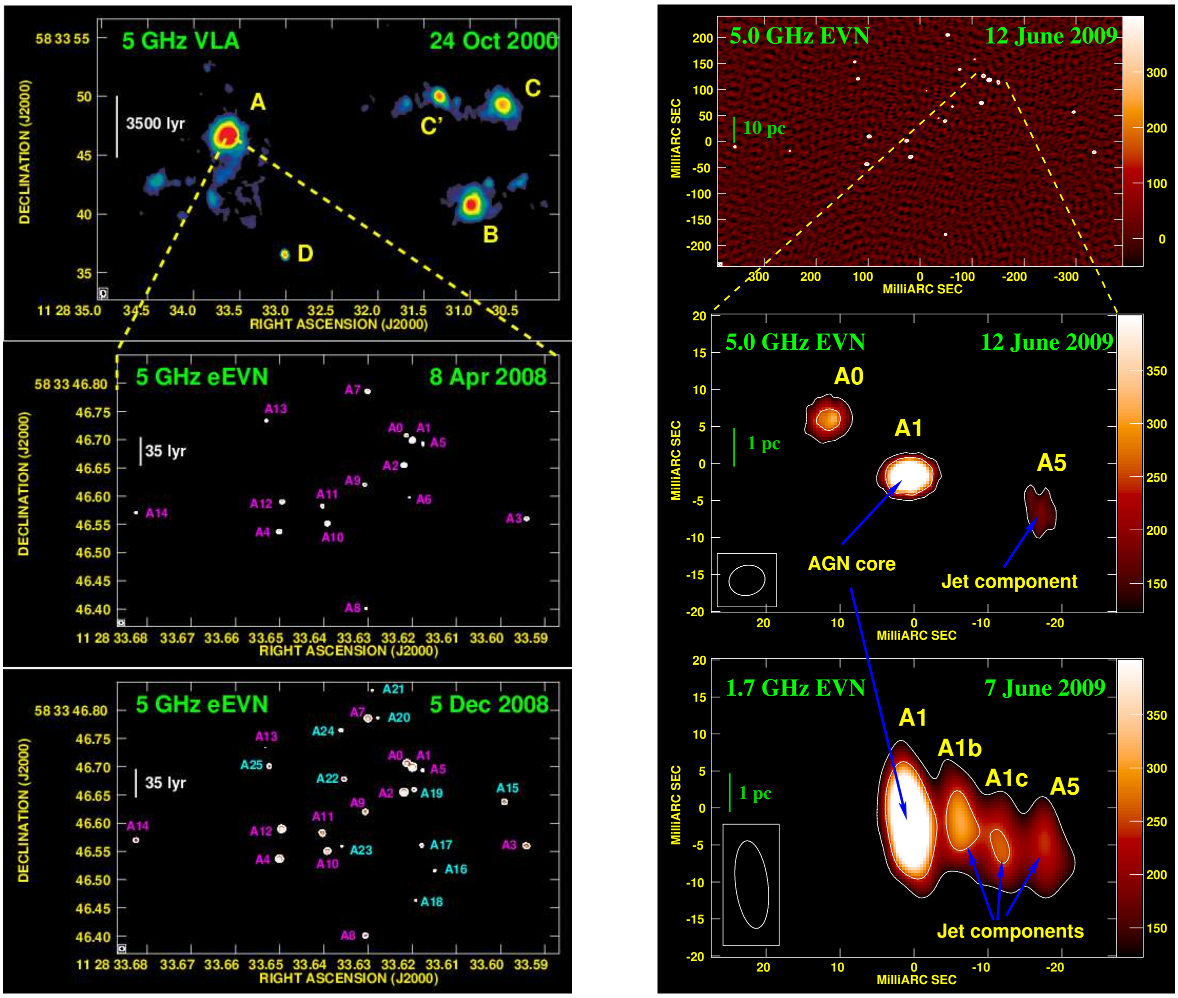

Figure 4: *Top left:* 5 GHz VLA archival observations of Arp 299 on 24 October 2000, displaying the five brightest knots of radio emission in this merging galaxy. *Middle and bottom left:* Contour maps drawn at five times the r.m.s. noise of our 5 GHz eEVN observations of the central 500 light years of the luminous infrared galaxy Arp 299-A on 8 April 2008 and 5 December 2008, revealing a large population of bright, compact, non-thermal emitting sources. To guide the reader's eye, we show in cyan the components detected only at the 5 December 2008 epoch. *Top right:* 5.0 GHz full EVN image of the central 150 parsec region of the luminous infrared galaxy Arp 299-A, displaying a large number of bright, compact, non-thermal emitting sources, mostly identified with young RSNe and SNRs. *Middle and bottom right:* Blow-ups of the inner 8 parsec of the nuclear region of Arp 299-A, as imaged with the full EVN at 1.7 and 5.0 GHz. The core-jet morphology, spectral index and luminosity of the A1–A5 region clearly revealed the location of the long-sought AGN in Arp 299A.

## 3 Molecular line probes of the fueling and feedback of activity

We list below a number of scientific questions in the study of the fueling and the feedback of activity in galaxies that can be addressed by using the capabilities of the SKA to probe the emission and absorption of a set of molecular lines in different environments:

—*Mega-masers:*

Extragalactic mega-masers can trace compact structures in the circumnuclear disks (CND) of active galaxies. They are the best probes of the molecular gas kinematics down to angular scales of $\mu$-arcseconds. Specifically, mega-masers trace gas within the narrow range of densities and temperatures at which the IR radiation is able to invert the population of the energy levels.

OH-lines at rest frequencies 1.6-1.7 GHz rank among the most important extragalactic mega or kilo-masers. They are up to 3 orders of magnitudes brighter than observed in Galactic regions of massive star formation. The OH luminosity tightly correlates with $L_{\rm IR}$ in the more than 100 ULIRGs where its emission has been detected (e.g.,[58]). This lends support to a picture where OH masers are favoured in merging systems, presumably thanks to the intense radiation from warmed-up dust ([34]). The OH-IR correlation opens the possibility of measuring the merger rate as a function of redshift. In a closer detail, high-spatial resolution observations of a dozen of nearby active galaxies have shown that OH mega-masers originate in compact rotating disks of up to a few hundred parsec size (see, e.g.,[4, 24, 39]). Therefore, further higher-quality observations with SKA could address two key questions of black-hole fueling mechanisms: whether these CND structures feed supermassive black holes and if nuclear star formation is also a coeval phenomenon. In addition, it has also been discussed if OH emission can trace AGN-feedback phenomena like the jet-ISM interaction at the CNDs ([24]). AGN-driven feedback might distort the dynamical status of the CNDs, which would explain the onset of nuclear warp instabilities or the existence of massive and energetically relevant outflows that are starting to be imaged by the Atacama Large Millimeter Array (ALMA) on similar spatial scales ([15, 22] and Fig. 5). The SKA in phase 1 has the high-spatial and spectral resolution capabilities required to image the emission of OH in different types of active galaxies at different redshift ranges. More specifically, resolving an OH megamaser disk of size ∼500 pc with SKA1-MID will be possible up to a distance of about ∼160 Mpc. With SKA, the maximum distance is not set by the resolution element, but rather by the sensitivity limit. Estimates indicate that a typical detection experiment for OH will require a few–to–20 hours per source for modest maser luminosities up to $z \sim 2$ ([8] and references therein).

The emission of extragalactic $H_2O$ mega-masers at 22 GHz, detected to date in more than 100 type-2 AGNs, is known to come from the inner pc or sub-pc regions around the putative tori of active galaxies. The gas kinematics inferred from these observations has provided the most accurate estimates of supermassive black hole masses in these sources. Combined with measurements of their proper motions, these observations, done in a statistically significant sample of galaxies at different redshift ranges, are the basis of the Mega-Maser Cosmology project, which aims at determining the Hubble constant (see [32] and references therein). As for OH masers, water mega-masers can probe the shocked jet-ISM interface in the CNDs of nearby AGNs (e.g., [44]). While the SKA in phase 1 will not have access to the 22 GHz range, making impossible the imaging of the $H_2O$ line in local galaxies, it is expected that the SKA will be sensitive enough to detect its emission at high redshift. The prospects of this type of project are good in view of the predicted higher occurrence of $H_2O$ masers in the early Universe ([31]).

—*Diffuse molecular gas:*

One of the main drivers of the SKA resides in its ability to detect the emission of the neutral hydrogen content of galaxies to cosmological distances. This goal can be reached thanks to the significant gain in sensitivity: the SKA will have a collecting area ∼two orders of magnitude larger than current radiotelecopes. With these sensitivity goals at hand, the SKA will be able to detect the emission of atomic hydrogen in Milky Way-like galaxies out to z∼1–1.5 and, also in the disks of large spiral galaxies like M 101 out to z∼2.5, after a typical integration time of 12 hours (see [55]). The detection of atomic and, also, molecular gas emission in the halos of isolated spirals, like the edge-on spiral NGC 891, is a representative example of the type of science that the SKA will routinely address in a large number of galaxies ([20, 42]). This neutral gas reservoir may be continuously falling onto the disks of galaxies and thus feed star formation activity on long time scales. The detection of massive atomic and molecular halos in a significant number of galaxies may provide an answer to the long-standing problem of the missing baryons.

It is expected that molecular gas at high galactic latitudes will be preferentially diffuse with typical densities $n(H_2) \sim 10^2 - 10^3$ cm$^{-3}$. This particular phase corresponds to the transition between the atomic medium, traced by the HI line at 21 cm, and the condensed molecular medium typically found in Giant Molecular Clouds (GMC) of galactic disks. While the CO (1–0) and (2–1) emission will be detected in the molecular thick disks and halo components with ALMA, the translation of line intensities into column densities is handicapped by the highly uncertain CO–to–$H_2$ conversion factor at these low densities ([35]). The emission of molecular species like CH, which has a micro-maser line at 3.3 GHz, is extremely useful in the low density phase ([26, 35, 33, 36, 37, 38]), which is expected to be prevalent in the halo gas components. First, the abundance of CH in diffuse molecular gas is high ($\sim 10^{-8}$). Furthermore, the typical densities required to excite the line are low $n(H_2) \sim 10^2 - 10^3$ cm$^{-3}$. Last, but not least, the conversion factor from CH–to–$H_2$ in the diffuse molecular gas medium is much more accurate than the corresponding factor for CO in diffuse gas, partly because the CH line is expected to be optically thin.

Extragalactic observations of the 3.3 GHz line have proved to be feasible in nearby galaxies like the LMC, NGC 253, NGC4945 and NGC 5128, though they are scarce due to the limited sensitivity of the first single-dish radio telescopes used in this experiment ([57, 13]). The improved capabilities of the SKA will make possible to map out the emission of CH in the disks but also in the halos of a significant sample of nearby galaxies in a few hours.

—*CO lines at high redshift:*

Current millimeter interferometers have been able to map the emission of carbon monoxide (CO) and that of other more complex molecular species (like HCN, $HCO^+$, CN or CS), and thus trace the content, distribution and kinematics of molecular gas in a growing

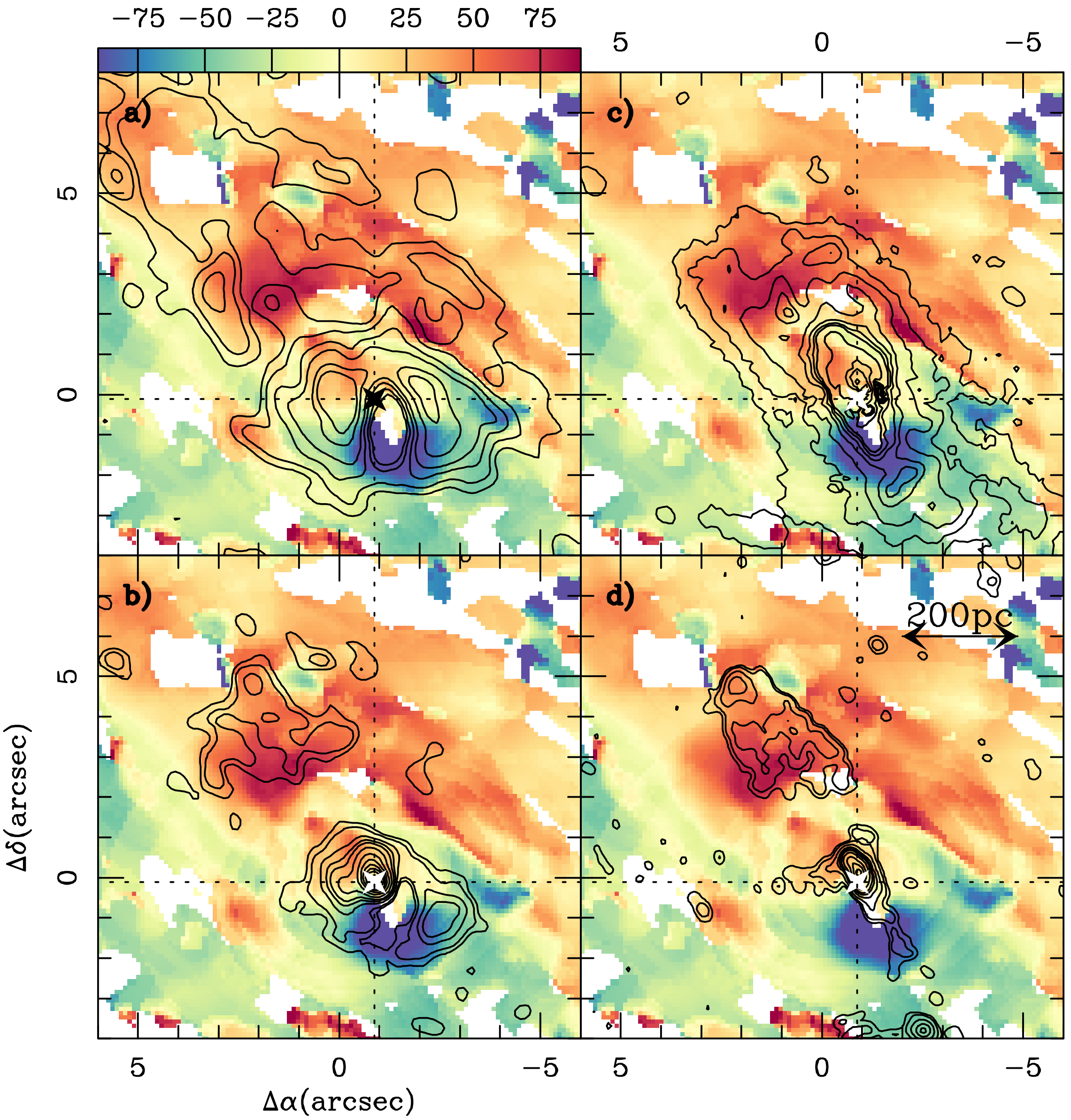

Figure 5: Overlay of the CO(3–2) velocities (in color scale) of the massive molecular outflow, as derived from the high-resolution observations done with ALMA in the CND of the Seyfert 2 galaxy NGC 1068 (adapted from [22]), with the contours representing: the integrated intensity of CO(3–2) (**a**) *upper left panel*; contours), the 349 GHz continuum emission (**b**) *lower left panel*; contours), the HST Pa$\alpha$ emission (**c**) *upper right panel* contours), and the 22 GHz VLA map of [23]) (**d**) *lower right panel*: contours).

number of galaxies. The study of CO emission in Local Universe targets has been crucial to studying star formation laws in galaxies ([9]). Furthermore, high-spatial resolution CO observations have been key in the study of AGN feeding mechanisms in the Local Universe ([21]). The high-sensitivity of current mm-interferometers have also allowed us to detect the emission of molecular gas in galaxies situated at redshifts beyond z∼1. This includes extreme starbursts/mergers outside the Main Sequence (like Sub-Millimeter Galaxies (SMGs)), but also QSOs, Lyman Break Galaxies(LBGs), and normal Star Forming Galaxies (SFGs) ([27, 56, 52, 17, 53]). It is worth noting the case of SDSS J1148+5251, the highest redshift quasar currently known detected in CO at z∼6.4 ([56]). Current models of galaxy formation and evolution require the observation of the *normal* population of SFGs at different redshift ranges.

Besides being a powerful HI radiotelescope, the SKA will also be able to probe the distribution of molecular hydrogen in galaxies to cosmological distances. As an illustration of the SKA capabilities, the cumulative number of CO(1–0)-detected galaxies at $\nu \sim$22 GHz would amount to $\sim 10^3$ per square degree only after one hour of integration time ([10]). In this context, it is worth noting that the SKA telescope may be a nice complement to the capabilities of ALMA. While ALMA will detect and image the emission from the high rotational lines of CO and other molecules in the high-redshift universe, the SKA will give information on the lower–J rotational lines of these species. The combination of SKA and ALMA observations is a prerequisite to characterize the spectral line energy distribution (SLED) of different molecular species in a statistically significant sample of galaxies and, also, for a wide range of redshifts. Modelling the SLEDs will allow us to derive the physical conditions and the chemical abundances in different extragalactic environments.

—*Other molecular species:*

Ongoing pilot studies carried out with Arecibo and the Jansky Very Large Array (JVLA) at the 1–10 GHz frequency range have revealed a surprising richness of strong molecular lines in the spectrum of the prototypical ULIRG Arp 220 ([51, 50]). The catalog of detected lines includes pre-biotic molecules, like methanimine ($CH_2NH$), in emission, three vibrationally excited $v_2 = 1$ direct l-type absorption lines of HCN and several line transitions of the OH radical seen in absorption against the continuum source. The high signal-to-noise ratio of the spectra opens the possibility of extending this type of survey with the SKA to a much larger sample of galaxies. In particular, it is expected that some of the molecules with lines in the 1-10 GHz range may also have strong maser transitions in the so far unexplored lower frequency range around 0.3 GHz in these sources.

## 4 Conclusions

The SKA will yield transformational science across a wide range of astrophysics for the next decades. In particular, the use of SKA for studies of the local Universe will enable an extremely wide range of science covering many areas of astrophysics, and will form the bridge between the detailed studies of objects in our own Galaxy and the distant high-redshift Universe. Deep and moderate-resolution (few arcsec) continuum and spectral line surveys of large numbers of nearby galaxies will be provided by projected SKA1 "all-sky" surveys at frequencies of ∼1-2 GHz. Such large area surveys will provide an essentially full radio atlas of the local Universe, and allow detailed studies of the non-thermal radio component of galaxies. Yet multiple, pointed observations covering a wide range of frequency bands, in particular higher band SKA1–MID (band 5), will be required to characterise the non-thermal components of local galaxies. This will allow us to obtain an independent measure of the SF within galaxies covering the full range of type and environments, which will be critical to our understanding of galaxy evolution and SF through cosmic time.

The use of both continuum and spectral line facilities of SKA will not only allow to study the physics of SF and extreme physics in accretion-dominated sources on an individual basis in nearby galaxies, but also allow statistical properties of these sources to be investigated, how they interact with the ISM and how they affect galaxy evolution.

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