Preparing for the World’s biggest radio telescope

Astronomers simulate physical processes in the interstellar medium of galaxies at “Cosmic Noon” for future SKAO observations

An international team of researchers has demonstrated that the Square Kilometre Array Observatory (SKAO) is capable of detecting radio emissions from normal spiral galaxies in the early universe. The SKAO, whose construction began this year, will soon be the largest radio telescope in the world. The astronomers, who are part of the SKAO's “Extragalactic Continuum” working group, are looking for a way to study a cosmic era in which star-forming activity suddenly decreased after an epoch known as “Cosmic Noon”. To this end, they simulated the physical properties of the interstellar medium of galaxies similar to the Triangulum Galaxy (M 33) and the Whirlpool Galaxy (M 51) in an early age of the Universe. The results show that potential surveys should be sensitive enough to detect galaxies already in SKAO’s first deployment phase.

During cosmic evolution, galaxies experienced a decline in star formation activity after a more active period about 10 billion years ago, called the “Cosmic Noon”. The transition from a golden epoch of star formation to a reduced rate of stars being born is still not fully understood. A drop in the amount of cool gas within galaxies, which serves as the fuel for star formation, is often considered the main reason. However, observations show that many galaxies still had sufficiently large gas reservoirs for star formation to happen.

“*Another possibility is that magnetic field pressure, high-energy particles, and turbulence increasingly stabilized the cool gas in galaxies,*” says Fatemeh Tabatabaei. She is a former researcher of the Max Planck Institute for Astronomy (MPIA) in Heidelberg, Germany, and a co-author of this study. She is now a faculty member at the Institute for Research in Fundamental Sciences (IPM) in Tehran, Iran. “*Understanding the importance of these factors requires energy balance studies as a function of redshift,*” she continues.

Redshift is the phenomenon whereby the spectra emitted by galaxies, for example, are shifted to longer wavelengths over time due to the expansion of the Universe. The redshift can be directly converted into a distance or age since the Big Bang.

To evaluate the prospect of the future Square Kilometer Array Observatory (SKAO) to help solve that puzzle, the astronomers have simulated the physical processes of the interstellar medium (ISM) of galaxies at varying redshifts. The ISM mainly consists of gas and microscopic solid particles astronomers call dust at different temperatures that pervade the space between the stars. The first part of this research is published in the Journal of *Monthly Notices of the Royal Astronomical Society* today.

Observations of the radio continuum emission are a powerful way to trace energetic processes in galaxies. This emission emerges mainly from the interaction of high-energy particles with magnetic fields, an energetic component of the ISM. Deep and spatially resolved observations at different radio frequencies with SKAO allow astronomers to map these processes in galaxies near and far. “*Such observations are the critical step toward understanding the energy balance and structure formation in galaxies over cosmic time and shedding light on the processes governing galaxy evolution and the* *reduction in star formation activity,*" explains Eva Schinnerer, a scientist at MPIA and co-author of this study.

"*Selecting the types of galaxies and cosmic distances needed to study these processes is an essential part of preparing for the actual SKAO data,*" says Mark Sargent from the International Space Science Institute in Bern, Switzerland, co-author of the study, and a former MPIA scientist.

"*As the first step, we were interested in simulating the radio continuum emission from the ISM of typical high-redshift galaxies, using normal present-day spiral galaxies such as M 51, NGC 6946, and M 33 as templates. Our simulation takes into account two different radiation mechanisms, the thermal free-free and the non-thermal synchrotron radiation,*" says Masoumeh Ghasemi-Nodehi, a postdoc at IPM and main author of the paper. "*We showed that the SKAO phase 1 MID radio frequency (SKA1-MID) surveys can map the synchrotron radiation in M51–like galaxies up to a redshift of 3 when the Universe had only 1/7 of its current age,*" she continues.

"*Both the relativistic particles and magnetic fields are expected to insert higher pressures into the interstellar medium at earlier times due to the higher level of star formation activity in these early galaxies. This expectation demonstrated by our studies needs to be further confirmed by the SKAO observations,*" says Fatemeh Tabatabaei.

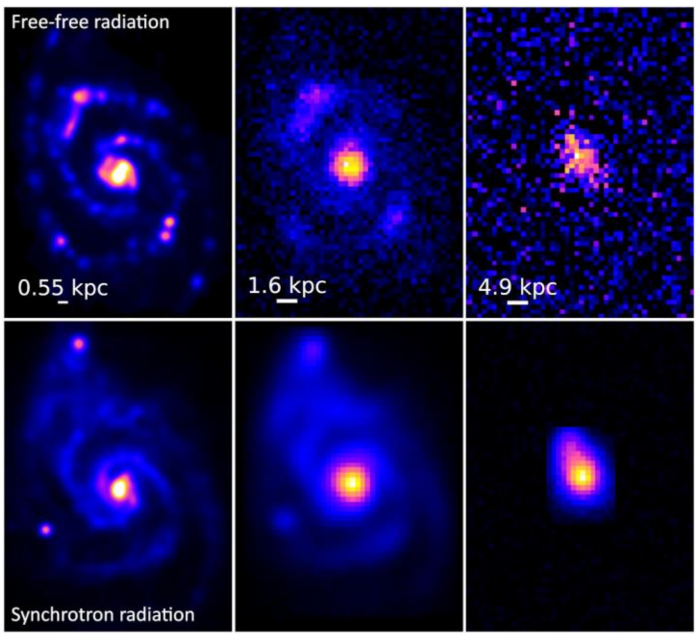
Thanks to SKAO's sensitivity and survey speed, this observatory will shed light on essential topics in astronomy and astrophysics. Its goals include investigating the formation of structures in the early universe, the formation of the first stars and galaxies, and galaxy evolution. In most cases, these phenomena will be studied through multi-wavelength surveys covering different sky areas in various deployment stages.

Additional information

This study is the result of an international collaboration whose members are: M. Ghasemi-Nodehi (Institute for Research in Fundamental Sciences, Tehran, Iran [IPM]), Fatemeh S. Tabatabaei (IPM, Instituto de Astrofísica de Canarias, Tenerife, Spain [IAC], and Max-Planck-Institut für Astronomie, Heidelberg, Germany [MPIA]), Mark Sargent (International Space Science Institute, Bern, Switzerland [ISSI] and University of Sussex, Brighton, United Kingdom), Eric J. Murphy (National Radio Astronomy Observatory, Charlottesville, USA), Habib Khosroshahi (IPM), Rob Beswick (Jodrell Bank Centre for Astrophysics/e-MERLIN, The University of Manchester, United Kingdom), Anna Bonaldi (SKA Organisation, Jodrell Bank, Macclesfield, United Kingdom), and Eva Schinnerer (MPIA)

Images

A composite image of the future SKA-Mid telescope, blending the existing precursor MeerKAT telescope dishes already on site with an artist's impression of the future SKA-Mid dishes. Credit: SKAO



Maps of the template galaxy M 51 seen in radio emission at an observed frequency of 1.4 GHz (wavelength of 21 cm). The top row shows the free-free radio component while the bottom row represents synchrotron radiation. From left to right: template images reconstructed from observations, simulated images at redshift 0.15 (1.9 billion years in the past) and 1.0 (7.8 billion years in the past). The white bars indicate the scales at the simulated distances, given in kiloparsecs (1 kpc = 3260 light-years). The simulations demonstrate that the SKAO will be able to detect the radio emission from this galaxy. Credit: Ghasemi-Nodehi et al. / MPIA

Paper

M. Ghasemi-Nodehi, Fatemeh S. Tabatabaei, Mark Sargent, Eric J. Murphy, Habib Khosroshahi, Rob Beswick, Anna Bonaldi, and Eva Schinnerer, "*Evolution of thermal and nonthermal radio continuum emission on kpc scales–Predictions for SKA*", Monthly Notices of the Royal Astronomical Society, Vol. 515, Issue 1, 1158 (2022). DOI: 10.1093/mnras/stac1393