THE CHALLENGES OF RADIOASTRONOMY IN THE ERA OF SKA

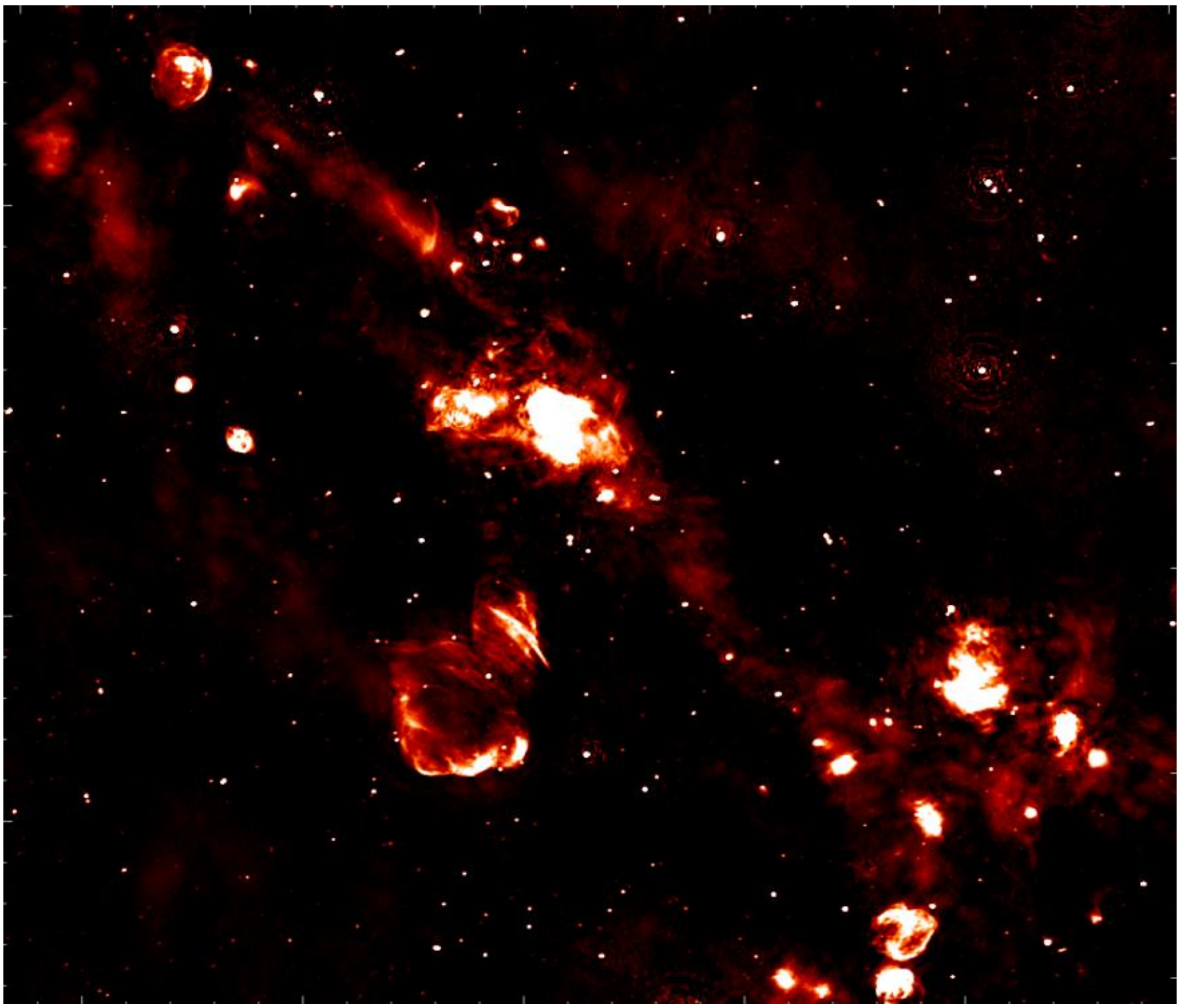
In the last decade, millimetric **radioastronomy has been the spearhead of multiple breakthrough discoveries** that have improved significantly our knowledge of the Universe, with instruments such as ALMA comparable to the best optical and infrared telescopes in terms of sensitivity and angular resolution. But we are on the edge of a new revolution. The **Square-Kilometre Array (SKA)**, an international collaborative project involving more than 100 scientific and technological partners from 20 countries, will become the largest radio interferometer ever built.

SKA will be distributed in two separate arrays in South Africa and Australia, comprising thousands of parabolic dishes and up to a million of low-frequency antennae that will cover the frequency range from 70 MHz to 10 GHz (and possibly beyond). The total collecting area, of about one square-kilometre (hence its name), will make of SKA **the most sensitive instrument to date,** to the point of being capable of sensing an airport radar on a planet tens of light years away. Definitely, SKA will be an authentic **game-changer**.

The MeerKAT array in South Africa, a SKA Precursor. (Credit: SARAO,2018)

At full operation, **SKA will survey the sky 10000 times faster than any other modern telescope, with a 50-fold increase in sensitivity**. It will provide astronomers with the ability to carry out extensive surveys of the entire sky in very short times, achieving an unprecedented level of detail and paving the way for thought-provoking discoveries. SKA is expected to revolutionise astrophysics, providing unique insights on the formation of the first stars, the evolution of galaxies, the nature of gravity and even the search for extraterrestrial life.

Furthermore, the advent of SKA -along with other next-generation instruments capable of all-sky surveys- will **change the way-of-working of the astrophysics community**. In a total paradigm-shift, multiwavelength all-sky surveys will in many cases replace traditional single-object observations, allowing astronomers to **simultaneously study multiple sources of the same type** (and their related phenomena) at the finest detail. Moreover, such surveys will be essential to perform far-reaching statistical studies of populations of interest, such as massive stars, pulsars, etc., unveiling previously unnoticed patterns and trends. This will result in a more comprehensive view of the different astrophysical sources that populate the Universe.



The SCORPIO field, a 40 squared degree patch of the Galactic Plane imaged by ASKAP, the Australian SKA Pathfinder (Credit: Umana et al. 2019, INAF)

But all this comes with an important downside: the amount of data produced by SKA will vastly **overwhelm the capabilities of the astrophysics community**. It is expected that, at full operation, SKA antennae will produce data rates largely **exceeding the global Internet traffic** (up to 16 Tb/sec!). Handling such a high data volume represents a true technological challenge, in terms of communications infrastructure, storage and computational power. In addition, this raw data needs to be further processed, converted into science-ready datasets, analysed and interpreted. Speaking of ‘final’ data products, we will easily enter **the exabyte realm**.

Astronomers will become literally overrun by this data deluge, unless we plan in advance how to deal with it. And we have the chance to do so thanks to the SKA precursors and pathfinders, such as MeerKAT (South Africa), ASKAP (Australia) and LOFAR (the Netherlands), to name a few. These are a series of facilities located either at future SKA construction sites (precursors) or spread all over the world (pathfinders), that participate in SKA-related technical and scientific studies, acting as test benchs for the development of crucial SKA technologies.

But, when it comes to exploiting scientific data, what can we do to face the incoming deluge? We need to build an ark. And that ark has a name: NEANIAS. **NEANIAS foreseen space research services are specifically designed to tackle the future needs of the astrophysics and planetary science communities.** In particular, they focus on the three critical fronts of the large-scale survey era: data visualization, map-making and source extraction and classification.

Data visualization services (NEANIAS S1) will deliver a set of functionalities to enable efficient **visual discovery** on large datasets from multiwavelength surveys, ensuring scalability and exploiting **innovative visualization techniques** such as augmented and virtual reality. On the other hand, mosaicking and map-making services (NEANIAS S2) will provide astronomers with tools to **produce large scale mosaics from multiwavelength surveys**. This will permit researchers to explore extended regions of the sky, **facilitating multiwavelength astronomy**, which is crucial to achieve a complete understanding of astrophysical phenomena across the whole electromagnetic spectrum. Finally, structure detection services (NEANIAS S3) will take advantage of **state-of-the-art machine learning techniques** and algorithms to support astronomers in the analysis of all-sky surveys. In particular, supervised and unsupervised learning algorithms will leverage the extraction, characterization and classification of both compact (e.g. stars, galaxies) and extended astronomical sources (e.g. circumstellar nebulae, supernovae remnants) in an automated way, further enhancing astronomers’ productivity. NEANIAS services will be **deployed on EOSC, the European Open Science Cloud,** facilitating access to researchers all around the world under FAIR principles (findability, accessibility, interoperability and reproducibility), and fostering scientific collaboration within a common ecosystem.

SKA is due to be completed by 2030. Once finished, it is expected to be operational for 50 years. Today, NEANIAS takes advantage of its precursors, along with data from existing infrared and radio surveys (MIPSGAL, AllWISE, THOR…), to develop and test its services, ensuring that all of them **reach the required technology readiness level before SKA sees its first light**.

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