

Status of the SKA project and the SKA Regional Centre Network.

Julián Garrido¹, Lourdes Verdes-Montenegro¹, and Susana Sánchez¹ and Julio Gallardo¹

¹ Instituto de Astrofísica de Andalucía (CSIC)

Abstract

The aim of this contribution is to present the status of the SKA (Square Kilometre Array) project and the SKA Regional Centre Network (SRCNet). The SKA project is an international effort to build two radio-interferometers that will be able to make revolutionary contributions to Astrophysics, Astrobiology, and Fundamental Physics. In January 2021, the SKA Observatory (SKAO) was established as the second intergovernmental organisation in astronomy (after the European Southern Observatory). For SKA1, the first phase of the telescopes, SKA-Low will consist of more than 130.000 low-frequency dipoles in Australia, and SKA-Mid will consist of 197 dishes in South Africa (including MeerKAT's 64 antennas). The construction commenced in July 2021 and the procurement for its contracts have already been initiated with 5 contracts pre-allocated to Spain. In addition, the SKAO is planning to start a development program for new instrumentation development.

The high data-rate and complexity of SKAO will necessarily transform how scientists access, analyse and share data from observations, being considered a Big Data machine. A network of SKA Regional Centres (SRCs) is being established to take the science data products that will emerge from the SKA telescopes to the final state required for science analysis.

1 Introduction

The SKA Observatory (SKAO) is an ESFRI (European Strategy Forum on Research Infrastructures) Landmark aimed to build two radio interferometers with the potential to make revolutionary contributions to astrophysics, astrobiology and fundamental physics. The unprecedented sensitivity of the Square Kilometre Array (SKA) telescopes pursues a number of scientific goals, like understanding the evolution of galaxies and how dark energy works or searching for complex molecules that are fundamental to the formation of life, among others. The Spanish scientific community has showed a strong interest in the project by drafting the Spanish SKA White Book [1], gathering the national scientific interest in SKA.

The two radio interferometers will complement each other over a wide range of the radio spectrum. In their first phase one will have 197 dish antennas with a maximum baseline of 150 km (SKA-mid, 350MHz - 15.4GHz) located in the Karoo Desert in South Africa, and the

other more than 131000 2-metre high dipole antennas located in Western Australia, grouped into 512 stations with maximum separation of 65 km (SKA-low, 50-350 MHz).

The SKA Regional Centres (SRCs) will receive data from the SKAO and will be responsible for maintaining its scientific archive. The SRCs will be distributed around the world, forming a global network to provide computational resources and collaborative tools to allow the international SKA community to take full advantage of the SKA telescopes. The SRC Network (SRCNet) will also provide scientific support in the use of the instruments and in the analysis of their data, being the SRCs the place where SKA science will take place.

In the following sections it is explained the overall summary of the international SKA journey so far (section 2) and the national scientific preparatory work (section 2.1), the design and construction activities (section 2.2) and the communications and outreach effort (section 2.3). The section 3 includes the activities related with the SRCNet (Section 3.1), the Spanish SRC prototype and the Open Science (section 3.2) and the SKA Data Challenges (Section 3.3). At the end, a section with the conclusions is also included (section 4).

2 The SKA Observatory journey

In 2008, the preparatory phase of the SKA (PREPSKA: A Preparatory phase proposal for the Square Kilometre Array, European Union FP7 2008-2012) officially started with the goal of preparing for the pre-construction activities. The SKA Organisation was established in 2011 as the entity in charge of the coordination of the pre-construction activities. The detailed design of the SKA telescopes were carried out by 12 international engineering consortia, formed in 2013, which were responsible for the fulfillment of the design requirements defined for the telescopes. The System Critical Design Review (CDR), a review of an independent external panel for the SKA telescopes' overall design, succeeded in December 2019.

A few months before the CDR, in March 2019, 7 countries signed the SKAO Convention with the aim to establish the Observatory as an intergovernmental organisation (IGO), which would tackle the construction and operations of the telescopes. This milestone started a transition phase from the SKA Organisation to the SKA Observatory, concluding in January 2021 with the ratification of the needed signatures to establish the SKAO. The first Council meeting was held a few days later and two high-level documents were approved: 1) the [Construction Proposal](#), the plan to build the SKA Phase 1 and 2) the [SKAO establishment and Delivery Plan](#), which establish the SKAO as a scientifically productive entity. They cover the first decade of SKAO's planning, from its establishment until two years after the end of the construction phase. More than 26 contracts with a total value of €216M have already been tendered and, once operational, a lifetime of more than 50 years is foreseen.

At the time of writing, eight countries¹ have joined the SKAO so far and another eight² are expected to join the IGO in the coming years. Spain became the 11th member of the SKA Organisation in June 2018 and the SKAO Council approved the Spanish membership in July 2021, being the accession process very advanced. While the process is on going, the

¹Australia, China, Italy, the Netherlands, Portugal, South Africa, Switzerland and the United Kingdom.

²Canada, France, Germany, India, Japan, South Korea, Spain and Sweden.

country has already started contributing to fund the SKAO.

Researchers from Spanish institutions have expressed their interest in the SKA since the 90's. From 2011 on, the *Instituto de Astrofísica de Andalucía* (IAA-CSIC) coordinates the national participation in the project, and receives direct economical support from the Spanish Science and Innovation Ministry (MCIN) since 2020. The coordination team gives support to academic groups, industry and MCIN in matters related to the project and interacts with the SKAO office. It also coordinates proposals and disseminates calls for funding and promotes the Spanish representation in SKAO committees, the scientific preparation and the participation in the SKAO construction. The group also coordinates communications and outreach at national level, being members of the SKA Communications and Outreach Network (SKACON) and its Steering Committee (SKACOSC).

2.1 Scientific preparatory work

The Spanish community participates in projects and observatories across the entire electromagnetic spectrum in synergy with SKA science. The participating in SKA precursors (telescopes located at future SKA sites) and pathfinders (telescopes using SKA preparatory technology) observation programmes (GASKAP, WALLABY, MIGHTEE, MHONGOOSE,...) is one of the major ongoing preparatory activities. Figure 1 shows two examples of the unprecedented science that SKA precursors are already delivering.

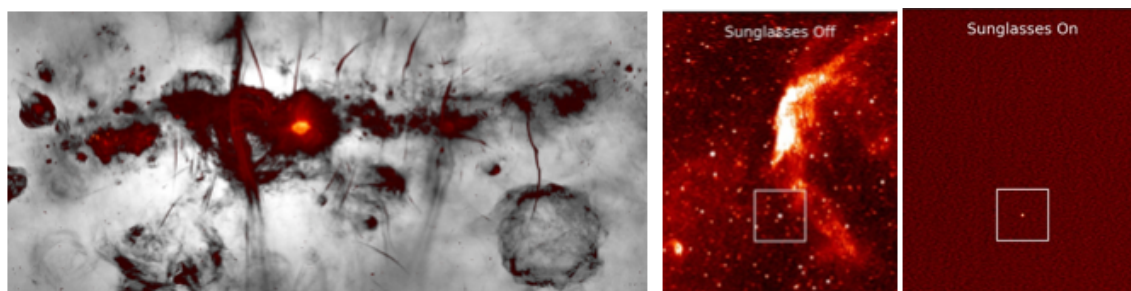


Figure 1: On the left, the deepest, most resolved image of the Milky Way centre (Heywood et al. [2], MeerKAT). On the right, the brightest ever pulsar found in the Magellanic Cloud (Wang et al. [3], ASKAP, Australian Square Kilometre Array Pathfinder)

The SKA-Mid and SKA-Low commissioning phase is expected to initiate in early 2024, with the finalisation of the construction of the first Array Assembly (AA - batch of antennas or stations), and science verification is scheduled to start by 2027. A series of SKA Data Challenges are being and will continue to be launched at the same time to help the community prepare for the analysis of the SKA data products that the SKA telescopes will deliver (sect. 3.3). Many astronomers from Spanish centres currently carry out research projects aligned with the SKA Science Drivers and have expressed a huge interest in SKA Science over the years specially by: 1) publishing the Spanish SKA White Book [1] in 2015 through the collaborative effort of 119 Spanish astronomers affiliated to 25 Spanish centres and 15 foreign ones; 2) organising and contributing in more than 10 SKA specific conferences in Spain; 3) being part

of 13 out of the 14 SKA Science Groups with the participation, at the time of writing, of 58 scientist from 18 Spanish research centres; and 4) establishing the Spanish SKA Network with national funds for national groups interested in the SKA project at scientific, technological and industrial levels to maintain contact and get involved in the initiative.

2.2 Design and Construction activities

In November 2011, the former MCIN funded a feasibility study for Spain's participation in SKA. As part of its results, the Spanish industry was interviewed to elaborate a Capability Map and identify stakeholders that could have relevant technological profiles for the SKA project. Two years later, eleven consortia were formed in order to carry out the design the specific elements of the telescopes between 2013 and 2019. At national level, more than 20 Spanish research centres and companies participated in 8 out of the 11 SKA design consortia.

The time period between the system CDR and the start of the telescopes' construction was defined as the 'bridging' phase, aimed at improving the design of different elements. Spain contributed to the Science Data Processor (IAA-CSIC and GMV through the project 'Supporting Open Science in the SKA by collecting Provenance from its Science Data processor') and to the Signal and Data Transport element ('White Rabbit Switch de alta fiabilidad de interoperabilidad 10G' project led by University of Granada and Seven Solutions).

Once the SKAO was established, its Council approved the start of the telescopes' construction in July 2021. This phase will last about 8 years and, in this period, the scientific community will begin to use part of the instrument to carry out the commissioning and verification of the instrument. As the MCIN has started the process to join the SKAO, Spain agreed with the SKAO on different technological areas for the Spanish industry to participate in i.e. synchronisation and distribution of signals, SKA-Mid dish antennas' sub-reflectors and different elements for the Band 1 (0.58–1.015GHz) and Band 5 (4.60–15.4GHz) receivers.

2.3 Communication and outreach

In 2022, the Spanish representatives at the SKACON and SKACOSC participated in the design of the SKAO Communication Strategy document, it covers the whole construction phase (2022-2029). In the same year, the [SKAO website](#) was published, including a page for [Spanish national information](#) about the SKA project.

Since last Spanish Society of Astronomy meeting, the SKA Spanish coordination team have been granted with funds from the International Astronomical Union (IAU) for two outreach projects. The IAU Office for Astronomy Outreach funded the 'From SKA to the World' project, aiming at developing online science communication and education products while targeting high school students. The 'Education for all' project, funded by the Office of Astronomy for Development, aimed to promote education in internally displaced communities in Burkina Faso. A collaboration has also been initiated in November 2022 during the Spanish Childhood day with the international Non-Governmental Organization, 'Aldeas Infantiles SOS' ('SOS Children Villages') with the intention to keep it growing.

3 SKA Regional Centre Activities

3.1 The SKA Regional Centre Network

In September 2016 the SKA organization established the SRC Coordination Group (SRCCG), with the mandate to define the requirements of the SRCNet. At that time, different international initiatives started contributing to the design of the SRCs, analyzing the requirements from a regional point of view, highlighting among them the European project “Advanced European Network of E-infrastructures for Astronomy with the SKA” (AENEAS). At the end of 2018, the SRC Steering Committee (SRCSC) took over from the SRCCG to take the SRCNet from design to implementation on a global basis. To this end, 7 working groups were established, focused on the following areas: SRCNet architecture, data logistics, operations, federated computing and data software services, SKA science archive, compute, and science user engagement. All these groups included a total of 12 Spanish members from 7 institutions. Among these groups the Science User Engagement Working Group was in charge to engage the community during the identification of requirements for the SRCNet

In early 2022, the SRCSC, with the support of the SRC Architect, defined nine international teams to carry out the SRCNet prototyping phase following an agile methodology. Five of these teams were focused on identifying and explore solutions in different areas (data management, science platform, Authentication and Authorisation, High Performance Computing (HPC) platforms and Visualisation). Two agile teams are in charge of building testbeds to provide feedback and a formal assessment of the technologies considered for the different SRC components. One of these teams is lead by the Spanish group in charge of the development of the Spanish SRC prototype (SPSRC). Two teams have not started their activity yet.

3.2 The Spanish SRC prototype and the Open Science

The IAA-CSIC is leading the development of the SPSRC as part of the program associated to its Severo Ochoa distinction. The SPSRC is providing support to scientific activities related to the SKA precursors and pathfinders, while promoting synergies and best practices on Open Science. The SPSRC initiative aims to build a transversal facility and uses Open Science as a tool to reach the whole astronomical community beyond that of radio astronomy.

As acknowledged by the United Nations Educational, Scientific and Cultural Organization (UNESCO), Open Science impacts on areas related to some of the Sustainable Development Goals (SDGs). The engagement of the SPSRC with Open Science is aligned with the position of SKA in this topic. SKAO is the first facility including reproducibility as a scientific metric of success. SKA project is aware of how Open Science impacts on areas related to some of the SDGs and the SKA’s foundational principles include the adoption of Open Science values.

3.3 The SKA Data Challenges

The SKA Data Challenges (SDCs) are exercises designed and published by the SKAO. They entail analysis of simulated SKA data products and their aim is to prepare the scientific

community for the analysis of the SKA data. The SDC1 was published in 2018, the SDC2 ran during the first part of 2021 and SDC3 will do in the first part of 2023. Since the SDC2 several international computing facilities provide support to the SDC participants, so the community get familiar to analyse the data using external platforms, in a similar way as when the SRCNet will be functioning. The SKAO offered reproducibility award for those SDC2 participants who demonstrated reusable methods and reproducible results.

4 Conclusions

The SKAO started the construction of the two telescopes in 2021 and Spain was allocated with 5 contracts in the areas of synchronisation and distribution of signals, SKA-Mid antennas' sub-reflectors and different elements for the bands 1 and 5. The SRCNet will be part of an end-to-end system composed by the SKAO and the SRCs. The SRCs will provide the community with access to data, computational resources and support to produce SKA science, as well as a platform for collaborative science. Spain is contributing to the development of the SRCNet and the SPSRC is supporting ongoing preparatory scientific activities.

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