España en el SKA

Lourdes Verdes-Montenegro (Coordinadora de la participación española en SKA)
Apoyo: Julián Garrido & Marina Fdez.-Peña Mollá
(IAA-CSIC)
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Open key questions in Astrophysics, Astrobiology and Fundamental Physics

- Formation of the 1st galaxies in a dark Universe dominated by atomic gas
- Evolution of the atomic gas and star formation till the current epoch
- Strong Field Tests of Gravity Using Pulsars and Black Holes
- Acceleration in the expansion of the Universe not understood yet
- Habitable extrasolar planets (proto-planetary disks, biomarkers)
THE SCIENCE DRIVING THE SKA

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Instrumentally:

- Ultrafaint radio signals (MHz to GHz, e.g. 21 cm HI line)
- Large collecting area
- High angular resolution: Interferometer
- High precision timing measurements
- High survey speed of large sky areas
**The Square Kilometre Array**

Total collecting area equivalent to 1 square kilometre

- Thousands of antennas with different technologies (frequency range)
- Separated by thousands of kilometres (finesse in details)
- Omnidirectional antennas and software pointing (surveys, transients)
- Technically == sensors network at continental scale

3 sites == 2 telescopes + HQ. 1 Observatory
SKA1-low = Australia
50 - 350 MHz
Baselines 65 km

SKA1-mid = South Africa
350 MHz - 14GHz
Baselines 150 km

Interferometer: allows phased development

131.000 dipoles

SKA1, 674 M€
Procurement 2020-2021
Construction 2021-2027
Early science 2026

133+64 dishes

Design Phase ~170M€

skatelescope.org
Advanced Instrumentation Program

~250 Dense aperture array stations
Frequency range: 200 - 500 MHz
500,000 dipoles + 2500 dishes

SKA2
2024 - 2030
Baselines up to 3500 km

Square Quad-Ridge Feed Horn for SKA-low
Phased array feeds (PAF)
Wide Band SPF
European Context and Organization

- High priority in ASTRONET roadmap (+EELT)
- Detached in the ERTRC report (European Radio Telescope Review Committee, Radio astronomy in Europe: Up to, and beyond, 2025)
- ESFRI landmark project
- > 1000 scientists and engineers from > 270 institutions > 20 countries.
  12 Member countries.
  
  Australia, Canada, China, France, Italy, New Zealand, South-Africa, Spain, Sweden, the Netherlands, UK and India, + Brasil, France, Japan, Malta, South Corea, Poland, Portugal, Russia, USA, Germany, Switzerland, Mexico, Irland, Russia
- Regularly invited to Board meetings: France, Spain, Portugal, Japan, USA, Germany
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Key dates
- End of pre-construction (CDR) = late 2019
- Procurement 2020-2021, construction 2021-2027
- Early science 2026

Need to be Member to lead KSPs and participate in construction
SKA Science

Advancing Astrophysics with the SKA. PoS 2015
New official SKA science book, 2000 pages
Comparison with other existing telescopes

SKA1-low $\times$ 135 LOFAR
SKA1-mid $\times$ 60 JVLA

SKA1-low $\times$ 8 LOFAR
SKA1-mid $\times$ 5 JVLA

c.f. R. Braun
Image Quality Comparison

- Single SKA1-Mid snap-shot compared to combination of snap-shots in each of VLA A +B+C+D
SKA precursor = MeerKAT, 64 antennas x 13.5m

The black hole at the centre of the Milky Way and filaments. (Image: (Credit: SARAO))
Notional package of Key Science Projects

- Outcome of well-documented SKA1 science prioritization process
- All objectives originated within the science community, reviewed by SRP, and SEAC
- Representative of high-impact science deliverables for 50/75% of the first 5 yrs of operations

<table>
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<th>SWG</th>
<th>Objective</th>
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<td>CD/EoR</td>
<td>Physics of the early universe IGM - I. Imaging</td>
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<td>CD/EoR</td>
<td>Physics of the early universe IGM - II. Power spectrum</td>
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<td>Pulsars</td>
<td>Reveal pulsar population and MSPs for gravity tests and Gravitational Wave detection</td>
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<td>Pulsars</td>
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<td>HI</td>
<td>Resolved HI kinematics and morphology of (^{10} \times 10^5 ) M(_{\odot}) mass galaxies out to (z \approx 0.8)</td>
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<td>HI</td>
<td>High spatial resolution studies of the ISM in the nearby Universe.</td>
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<td>HI</td>
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<tr>
<td>Transients</td>
<td>Solve missing baryon problem at (z \approx 2) and determine the Dark Energy Equation of State</td>
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<td>Cradle of Life</td>
<td>Map dust grain growth in the terrestrial planet forming zones at a distance of 100 pc</td>
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<td>Magnetism</td>
<td>The resolved all-Sky characterisation of the interstellar and intergalactic magnetic fields</td>
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<td>Cosmology</td>
<td>Constraints on primordial non-Gaussianity and tests of gravity on super-horizon scales.</td>
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<tr>
<td>Cosmology</td>
<td>Angular correlation functions to probe non-Gaussianity and the matter dipole</td>
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<tr>
<td>Continuum</td>
<td>Star formation history of the Universe (SFHU) – I + II. Non-thermal + Thermal processes</td>
</tr>
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Early science 2026

Star formation history of the Universe

L. Testi et al. 2014, PPVI, depicting grain growth in protoplanetary discs.

Optical light & 21 cm HI

Yun et al. 1994

Applied research challenges of the SKA

The construction of the SKA in the following years will be equivalent to building up a new 100 m radio telescope every 20 days.
**Instrumentally:**

- Ultrafaint radio signals (MHz to GHz, e.g. 21 cm HI line)
- Large collecting area → Massive production of antennas, receivers & chips
- High angular resolution: Interferometer
- High precision timing measurements
- High survey speed of large sky areas → Big data solutions required

Data transport and synchronization across thousand kms via optic fiber
SKA will be the greatest data research public project

- Massive data transport, storage and high speed computing
- Power challenge: central region = 100,000 inhab. city

The Challenge: Extraction of scientific knowledge

- Data products not in the final state for science analysis
- Direct delivery to end users is unfeasible
- International distributed scientific teams

SKA Regional Centres (SRCs), to be accredited by the SKA Observatory

SRCs will provide access to SKA community to data products they are authorised to, as well as the tools and processing power to generate and analyse advanced data products
SKA in Spain:
Organization

High-priority in MICINN Roadmap (2010)

MINECO-funded (2011-2014)

- May 2011: RIA meeting “Science and technical opportunities in the SKA era”
  Showed broad and strong scientific interest of Spanish researchers in SKA

- September 2011: MICINN applies for Spain to become SKA Observer

- Scientific Network (FIS2011-14593-E; IP. J. C. Guirado, U. Valencia)
  6 research institutions + 5 Universities

SKA related activities/reports regularly presented at the Red de Infraestructuras Astronómicas via the Radio Astronomy WG, G1
COORDINATION OF THE SPANISH PARTICIPATION IN THE SKA

• Feasibility study of the Spanish participation in the SKA (Led by IAA-CSIC; 75,000€, Dec 2011 - Jan 2014)
  
  Subprograma Infraestructuras Científicas Internacionales


CAB (INTA-CSIC), IFCA (CSIC), DICOM/UCAN, ICE-CSIC, IAC, OAN (IGN), Univ. Bna, Valencia, Pol. Cartagena, Granada, UCI

2008
Preparatory phase

2013
Detailed design, preconstruction

2020
SKA1 construction

• Diffusion and organisation of SKA activities in coordination with SKACON
  • Support to organization of meetings and conferences
  • Conferences in research centers
  • Outreach: talks, Spanish SKA Web, media, etc

• Support to academic groups, industry and MINECO
  • Interaction with design consortia, SKA Office
  • Diffusion of funding calls and coordination of proposals
  • Support to the incorporation in SKA committees/SWGs/KSP/design WPs

• Industry capacity map, preparation for procurement (collaboration with CDTI)
  • Joint discussions with international SKA related stakeholders
SCIENCE

• Publication in 2015 of the Spanish SKA White Book (120 researchers from 40 centers)

• (17% of those Spanish researchers were working out of Spain at the moment of writing the White book)

• 29 chapters


• Contribution to > 14 chapters of the SKA Science Book “Advancing Astrophysics with the SKA (2015)”

Download
http://spain.skatelescope.org/ska-science/libro-blanco-ska/
**Preparatory Work: Precursors and Pathfinders**

- Participation in preparatory works with the radio-interferometres pathfinders or precursors of SKA, e.g. POLAMI, GASKAP, Mhongoose, Mightee-Hi, …

27 researchers of 11 Spanish institutions participate in 9 out of the 11 SKA Science Working Groups/ 2 Focus groups

SKA Science meeting 8 – 12 April 2019
SKA HQ, Manchester
**CALIFA**: IFU data of 600 galaxies 

\(0.005 \leq z \leq 0.03\), 3.5 m@CAHA

**WEAVE-Apertif survey**

Spatial resolved derivation of the full SF history + properties of ionized gas mapped @ 2”

**SKA I-MID**: HI @ 3” in 10h

GMRT HI observations @ 20” (Scott et al 2014)

PREPARATORY WORK: IN SYNERGY WITH OTHER SPANISH PROJECTS

Calar Alto Obs.

WEAVE-Apertif survey

WHT

GMRT HI observations @ 20” (Scott et al 2014)

SKA I-MID: HI @ 3” in 10h
WORKSHOPS, CONFERENCES AND MEETINGS

• May 2012. SKAO visits Abengoa facilities. In 2016, PSA-CIEMAT.

• November 2012. Workshop
  “SKA: Strategic Position & Future Opportunities for Spanish Industry”
  Representatives of more than 50 companies and academic centres

• October 2014: Spanish SKA Day at IAA
  18 institutions +17 companies

• February 2016: SKA Industry Day
  organized by CDTI, SKAO, IAA
  > 80 participants, including SKA DG, and Consortia leaders

• November 2017
  - Physics opportunities with a new universe’s view: the SKA

• May 2018: VI Meeting on Fundamental Cosmology
  - 4 talks related to the SKA (J. Pritchard, D. Alonso, Á. de la Cruz Dombriz, L. Verdes-Montenegro).
SKA Power Supply Option Working group
  - Jesús Fernández (Solar Platform of Almería)

Spanish Liaison Industry Officer: Javier Echávarri (CDTI)

Boards of SKA design consortia
  - Dish: Eduardo Artal (U. Cantabria)
  - SaDT: Javier Díaz (UGR)
  - SDP: Lourdes Verdes-Montenegro (IAA) and Rosa M. Badia (BSC)

Dish consortia
  - Miguel A. Sánchez (IAA) invited to Dish Band2 Feed system CDR review panel.

SKA Regional Centre Coordination Group
  - Lourdes Verdes-Montenegro (External advisor)

SKA Communications Steering Committee (SKACOSC) and SKACON:
  - Marina Fernandez-Peña (IAA)

SKAO
  - Juan de Dios Santander Vela (System Engineer (SDP & TM))
  - Cristina Garcia-Miro (SKA VLBI Scientist)

SWG:
  - Currently, 27 researchers of 11 Spanish institutions participate in 9 out of the 11 SKA Science Working Groups. 2 co-Chair.
TECHNOLOGICAL DEVELOPMENTS FOR SKA DESIGN

- March-June 2013. Requests for proposals, evaluation
  - Each WP in pre-construction went to an International Consortium
2008
Preparatory phase

2013
Detailed design, preconstruction

2020
SKA1 construction

12 Spanish research centres and 12 companies participate in 8 SKA Pre-construction Consortia (~2 M€ Feb 2014)

- March-June 2013. Requests for proposals, evaluation
  - Each WP in pre-construction went to an International Consortium

TECHNOLOGICAL DEVELOPMENTS FOR SKA DESIGN

- WIDE BAND SINGLE PIXEL FEEDS
- TELESCOPE MANAGER
- CENTRAL SIGNAL PROCESSOR
- SIGNAL AND DATA TRANSPORT
- SCIENCE DATA PROCESSOR
- DISH
- MID-FREQUENCY APERTURE ARRAY
- PHASED ARRAY FEED
- LOW-FREQUENCY APERTURE ARRAY
- ASSEMBLY, INTEGRATION & VERIFICATION
- INFRASTRUCTURE AUSTRALIA
- INFRASTRUCTURE SOUTH AFRICA
• March-June 2013. Requests for proposals, evaluation
  - Each WP in pre-construction went to an International Consortium

11 Spanish research centres and 12 companies participate in 8 SKA Pre-construction Consortia (~2 M€ Feb 2014)

June 2017: IAA-CSIC and ICE (IEEC-CSIC) invited to join PAF
April 2013. VIA-SKA report
- “VIA-SKA: Feasibility study of the Spanish technological participation in the SKA”. Presented to MINECO, RIA
- Based on the capacity map for 40 companies

January - October 2017
- Revision of potential contracts for Spanish Industry in collaboration with CDTI
- Nomination of SKA ILO from CDTI
- CDTI survey to industry for construction contribution

May 2018
- Response to “SKA Construction Request for Information” CDTI in collab. IAA

Areas of expertise & SKA WPs of registered companies

"Estudio de viabilidad de la participación tecnológica española en el SKA" (J. Santander, L. Verdes-Montenegro - IAA-CSIC)
TECHNOLOGICAL DEVELOPMENTS FOR SKA DESIGN

- **Infra-SA & AUS:**
  - IAA-CSIC
  - PSA-CIEMAT
- **Dish:**
  - IFCA-CSIC
  - Univ. de Cantabria
  - OAN-IGN
  - UPN
- **Telescope Manager:**
  - GTD
- **iGrid-TD**
- **Arraela**
- **Aora Solar Spain**
- **CSP Sunless**
- **Torresol Energy**
- **TTI Norte**
- **Anteral**
- **Synchronization and Data Transport**
  - UGR, collab ROA
  - UPV
- **Central Signal Processor:**
  - UPM
- **Science Data Processor:**
  - IAA-CSIC
  - FCSCL
  - BSC
- **Phased Array Feeds (PAFs):**
  - IAA-CSIC
  - ICE (IEEC-CSIC)
- **Receivers**
- **Distribution of time**
- **Advanced analysis tools**
- **PAFs**
• **January 2012**: 9 VIA-SKA members in Work Breakdown Structure WGs

• **Since October 2013**: MINECO representative regularly invited to SKA Boards

• **November 2013 (G1- RIA) + January 2014 (RIA Board)**
  - Following VIA-SKA Feasibility study, RIA endorsed the recommendation on the interest of joining SKA

• **Feb 2014**: Spanish participation in SKA design valued in ~2M€ by SKA Board Chair after MINECO contact
• January 2012. 9 VIA-SKA members in Work Breakdown Structure WGs
• Since October 2013: MINECO representative regularly invited to SKA Boards
• November 2013 (G1- RIA) + January 2014 (RIA Board)
  - Following VIA-SKA Feasibility study, RIA endorsed the recommendation on the interest of joining SKA
• Feb 2014: Spanish participation in SKA design valued in ~2M€ by SKA Board Chair after MINECO contact
• December 2015. Letter from Secretary of State to SKA DG
  a dialog aiming at exploring scenarios for Spain to join SKA.
• 2016: SKA in the Spanish National budget
• June-July 2016
  - Report produced for the Evaluation of the participation of Spain in the SKA submitted to the Secretary of State: positive outcome.
  - Followed by on-going negotiations with SKA DG and Board
• **July 2017 - June 2019.** RED-SKA: Excellence network for the scientific and technological participation of Spain in the SKA - AYA2016-82017-REDT. Coordination: IAA-CSIC
  
  - Participants: CAB-CSIC, ICE-CSIC, IFCA/DICOM, Universidad de Valencia, BSC, UPM, UGR, IAC, CIEMAT-PSA.
• **July 2017 - June 2019.** RED-SKA: Excellence network for the scientific and technological participation of Spain in the SKA - AYA2016-82017-REDT. Coordination: IAA-CSIC
  - Participants: CAB-CSIC, ICE-CSIC, IFCA/DICOM, Universidad de Valencia, BSC, UPM, UGR, IAC, CIEMAT-PSA.

• **May 2018:** The Secretary of State sent to the SKA Organisation the *official request to become Member of the SKA project.*

• **Since 1st June Spain is the Member country of Organization**
SKA is an ESFRI Landmark project with potential for transformational science that will lead to a scientific revolution.

I+D+i in cutting edge technologies

The best scientists, engineers and managers are being attracted

Spain has developed a solid scientific community, strategically positioned within the project, working in close collaboration with engineers and industry, ready to:

• Play a major role in SKA1 KSPs

• Performing key contributions to the SKA design phase and construction, with impact in society