The renaissance of radio-astronomy with the Square Kilometre Array
La renaissance de la radio-astronomie avec le Square Kilometre Array

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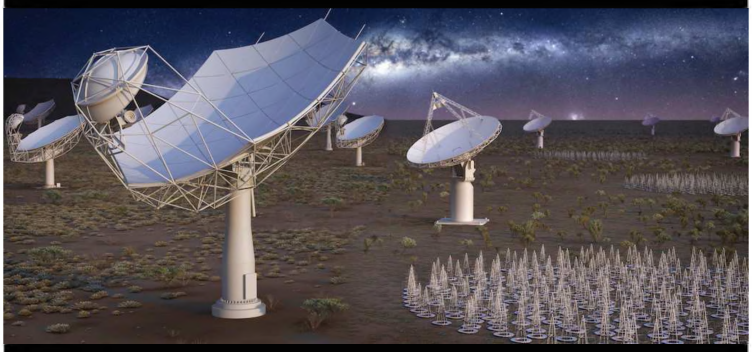
Mots-clefs: raio-télescope, astrophysique, cosmologie, big data

Abstract:
The Square Kilometre Array is an international collaboration whose goal is the construction of the world's largest low-frequency (0.50 to 25 GHz) radio telescope. SKA will conduct groundbreaking research that will transform our understanding of the Universe and fundamental physics. It also represents a huge technological challenge, being in particular one of the main world-wide future Big Data projects.
In this talk I will be giving an overview of the scientific objectives and technological challenges of the SKA and the rapidly increasing progress towards the beginning of construction. I will present some first results from the precursor telescopes designed to paved the way to the full SKA. Finally I will describe how the SKA project has brought the french community to innovate and create a new structure, the « Maison SKA-France », to coordinate the activities of the scientific, technological and industrial partners involved in SKA.

Résumé:
Le Square Kilometre Array est une collaboration internationale dont l'objectif est la construction du plus grand radio-télescope basses fréquences (0.5 à 25 GHz) au monde. SKA permettra des explorations scientifiques inédites qui devraient transformer notre compréhension de l'Univers et de la physique fondamentale. Ce projet représente un défis technologique de taille, tout particulièrement en étant le plus grand projet Big Data des années à venir.
Dans cette présentation je présenterai sommairement les objectifs scientifiques de SKA, les défis technologiques spécifiques à ce projet et je ferai un point sur l'état d'avancement de la construction. Je présenterai les premiers résultats scientifiques des télescopes précurseurs de SKA. Finalement je décrirai comment la France a innové en créant une structure, la maison SKA-France, qui permet de coordonner les activités scientifiques, technologiques et industriels des partenaires impliqués dans SKA.

The renaissance of radio-astronomy with the Square Kilometre Array



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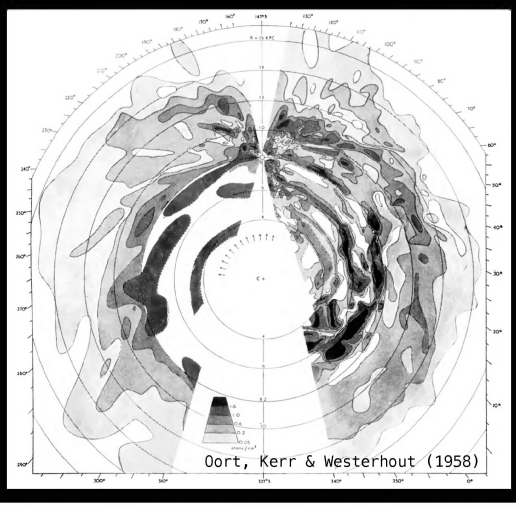
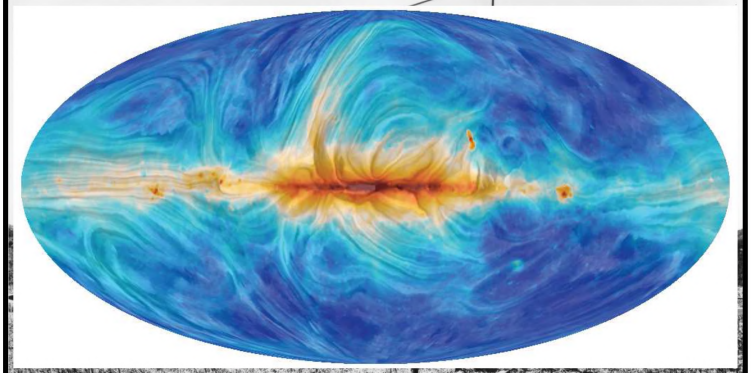
Laboratoire Astrophysique, Instrumentation, Modélisation
CEA-Saclay

Detection of the hydrogen 21cm line of the Milky Way



Accidental detection of radio-waves coming from space by Reber & Jansky in 1932 stronger in the direction of the Galactic plane

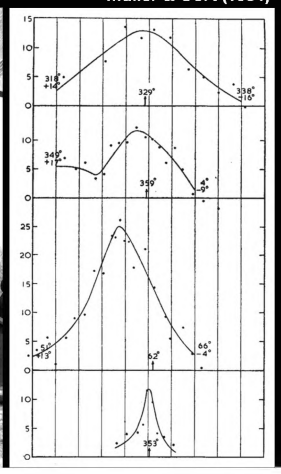


It was only in the 1950s that it was related to synchrotron emission, when the magnetic field of the Milky Way was detected (dust polarization)

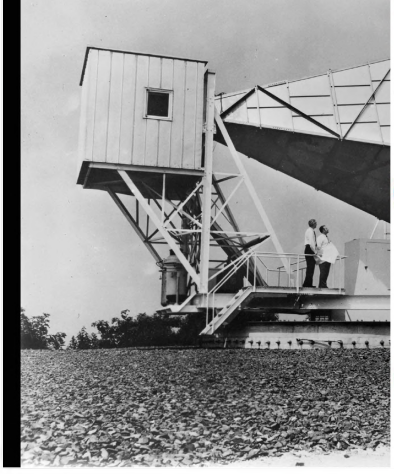
Detection of the hydrogen 21cm line of the Milky Way

Ewen & Purcell (1951)

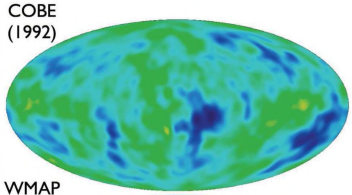
Muller & Oort (1951)



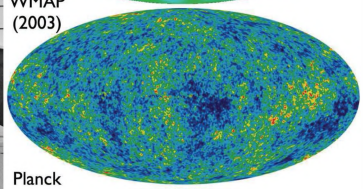
Detection of the Cosmic Microwave Bac



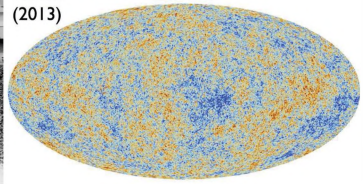
COBE (1992)



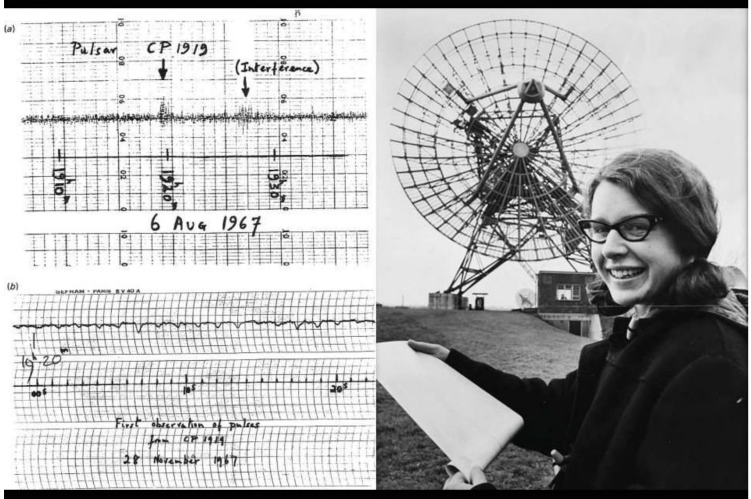
WMAP (2003)



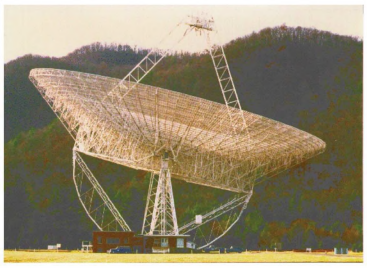
Planck (2013)

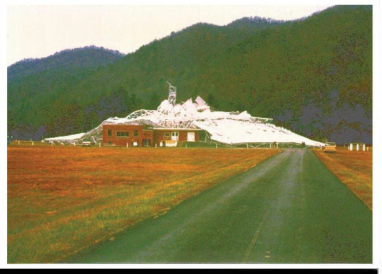


Discovery of pulsars in 1967 by Jocelyn Bell



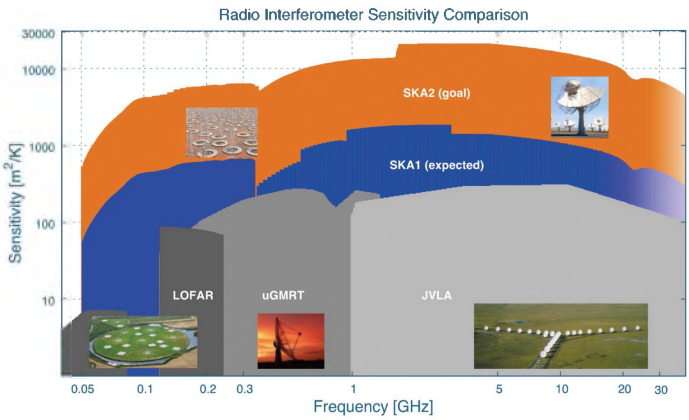
Then there was a slower period....





300 foot - Green Bank — November 15, 1988

Sensitivity Comparison



SKA Phase 1 - 2027

−50 MHz ——— 350 MHz ——— 15 (24) GHz →

Low radio contamination sites

SKA1-LOW (AUS)
130,000 antennas
65 km baseline

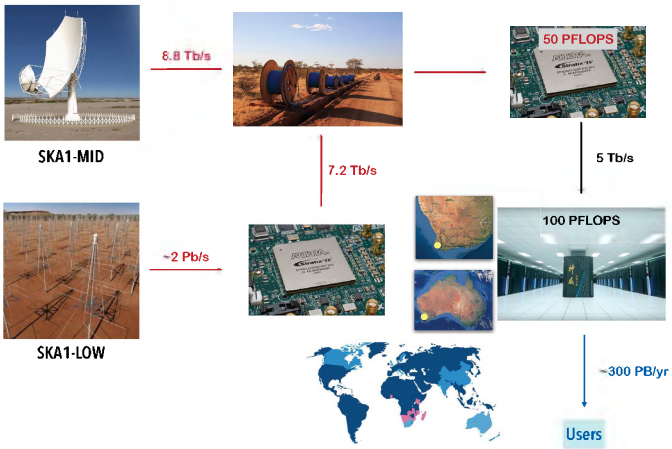
SKA2-LOW
Major expansion
across western-Aust.

SKA1-MID (SA)
200 dishes (15m)
120 km baseline

SKA2-MID
2000 dishes
3500 km baseline

SKA Organisation headquarter in Manchester (UK)

Data flow : a great challenge and a new way of working with the private sector



SKA– Key Science Drivers: The history of the Universe

Testing General Relativity (Strong Regime, Gravitational Waves)

Cosmic Dawn (First Stars and Galaxies)

Galaxy Evolution (Normal Galaxies z~2-3)

Cradle of Life (Planets, Molecules, SETI)

Cosmology (Dark Matter, Large Scale Structure)

Cosmic Magnetism (Origin, Evolution)

Exploration of the Unknown

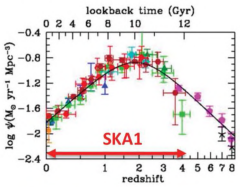
Broadest range of science of any facility, worldwide

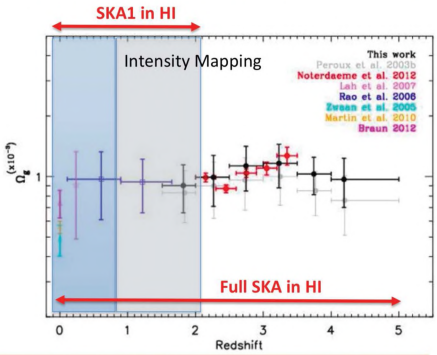
Galaxy Evolution & Star Formation

SKA1 for HI:
Resolved Emission to z~0.8
Intensity Mapping to z~2

Full SKA HI out to z~5

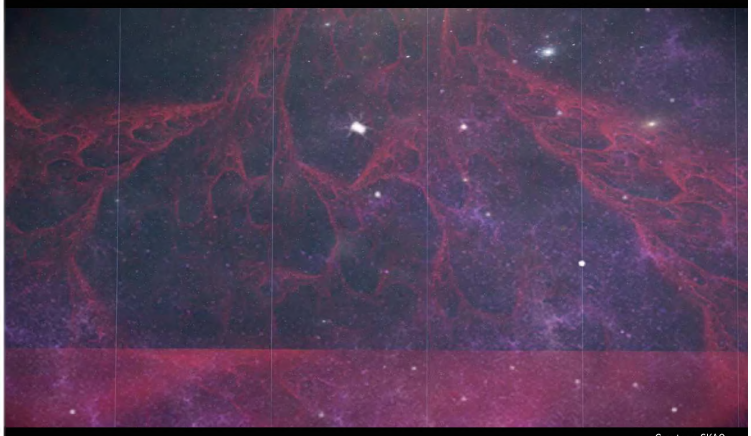
SKA1 continuum to z~4+





SKA sensitive to both ***indirect*** (non-thermal ~1 GHz) and ***direct*** (thermal ~10+ GHz) tracers of Star-Formation Rate, out to **z~4 ($10_{\odot}$/yr)**.
Multi-frequency telescope able to separate non-thermal and thermal components

Pulsar timing array

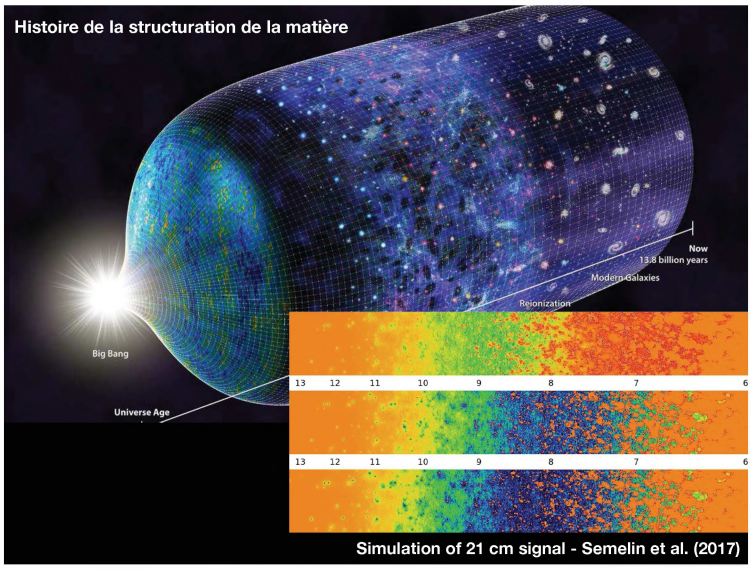


Courtesy: SKAO

The multi-phase nature of Galactic hydrogen

GALFA-HI survey - Arecibo radio-telescope - Peek et al. (2018)

Histoire de la structuration de la matière



Simulation of 21 cm signal - Semelin et al. (2017)

Grain Growth in Protoplanetary Disks

ALMA

Study the formation of planets

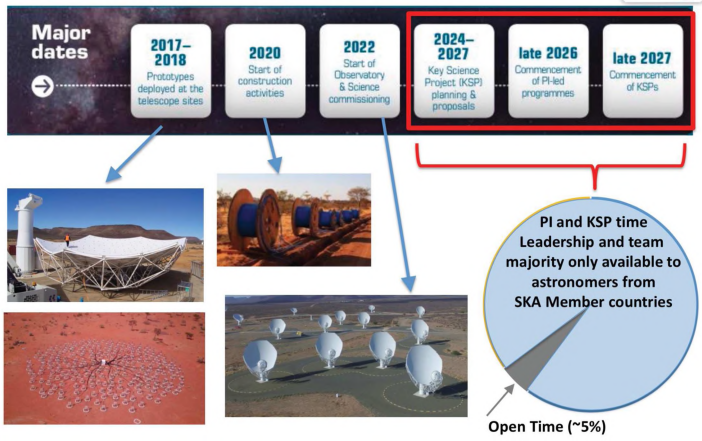
When/where do grains grow beyond pebbles to rocks?

Resolved disk observations allow for separation of free-free and thermal dust emission

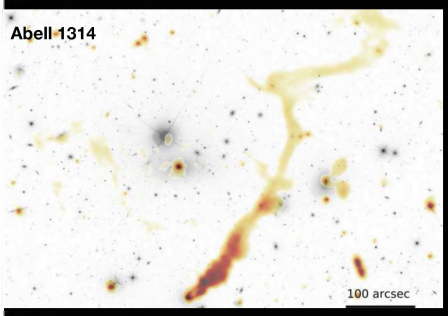
SKA1 at 15 GHz will have 4-5 AU resolution at nearest star-forming regions
Probing very large grains trapped in the terrestrial planet regime

→ SKA resolution and sensitivity at longer wavelengths sensitive to larger grain sizes

Timeline

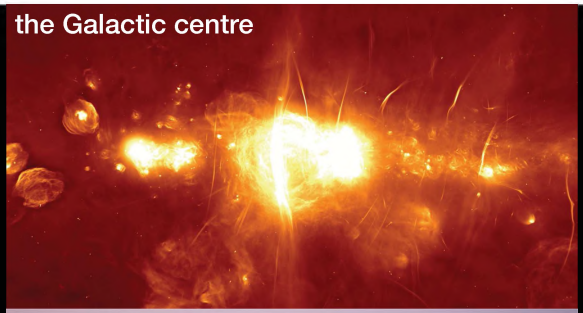


LOFAR



First release of public data in January 2019
424 square degrees at 6 arcsec resolution
326 000 sources, 30% with no optical counterpart
Synchrotron structures in galaxy clusters
See A&A special issue (2019/02)

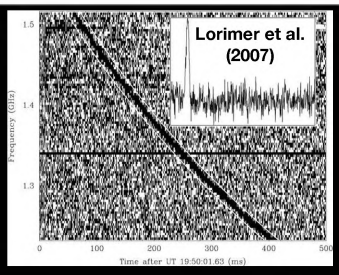
Low Band Antenna : 10-90MHz
High Band Antenna : 110-250 MHz
European network of stations
One station in France (Nançay)



2018/07

Fast radio burst

Milli-second pulse of radio emission
Unknown origin
Fast rotating neutron star / black holes ?
About 20 detected so far



Canadian Hydrogen Intensity Mapping Experiment

Second repeating FRB announced in 2019/01

The Small Magellanic Cloud

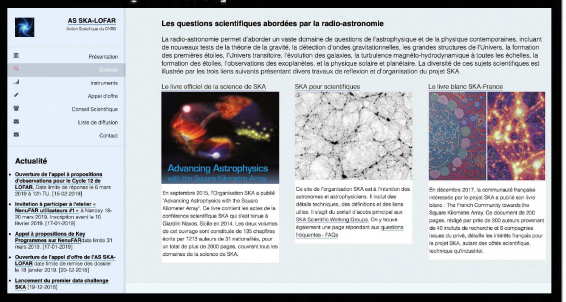
2018/10

The high potential for discoveries of the SKA

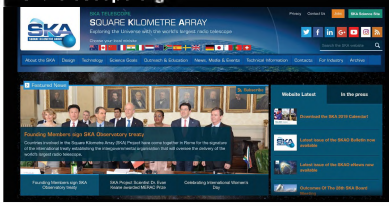
- Largest range of scales (LSS to planets)
- Largest range of time scales, from the firsts stars to now
- Large range of spectral diagnostics (21 cm, free-free synchrotron, RRL, molecular lines, Zeeman, Faraday rotation, dust emission)
- Increase of performance with time: with computing power and algorithms (hardware is cheap)
- New way to look at the sky (large field of view, high angular resolution (<arcsec), high mapping speed, evolution with time)
- Involved private sector: a new way of doing science

For more information

as-ska-lofar.fr [en francais]



skatelescope.org



ska-france.oca.eu