SKA, SKA-France and the PNHE

Philippe Zarka
LESIA & ORN, Observatoire de Paris, CNRS, PSL

https://ska-france.oca.eu/fr/accueil-ska
https://ska-france-2022.sciencesconf.org
https://www.skao.int
https://www.skao.int/en/science-users
https://as-ska-lofar.fr

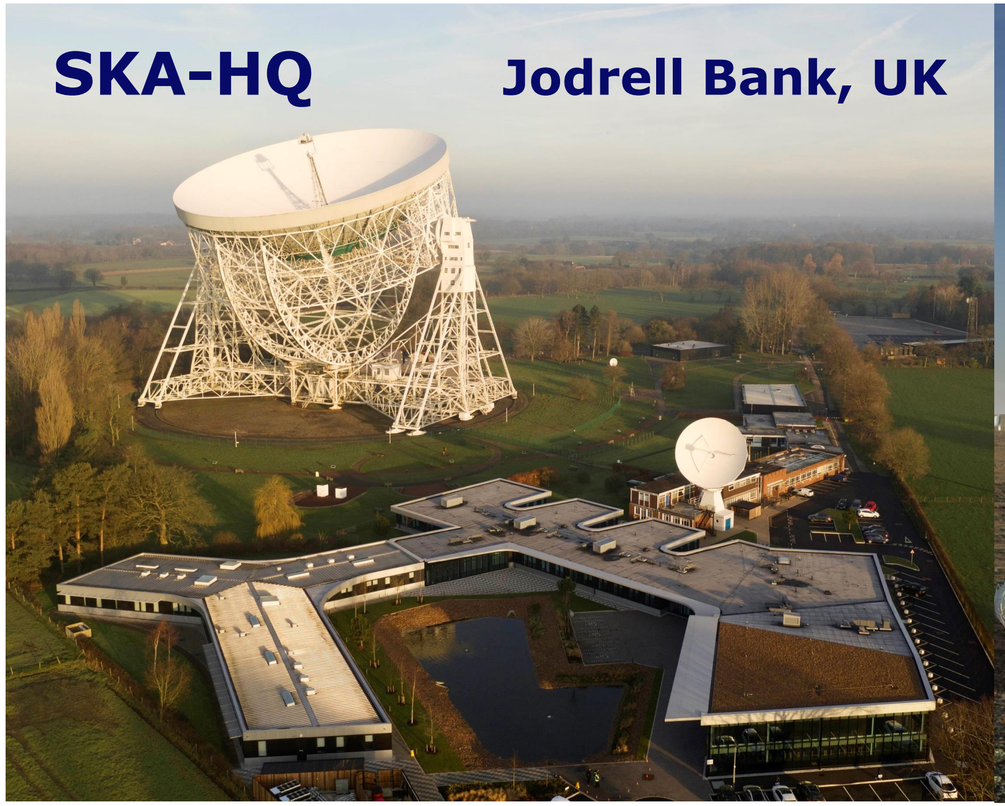
Thanks to: Chiara Ferrari, Catherine Césarsky, Marc-Antoine Miville-Deschênes, Françoise Combes

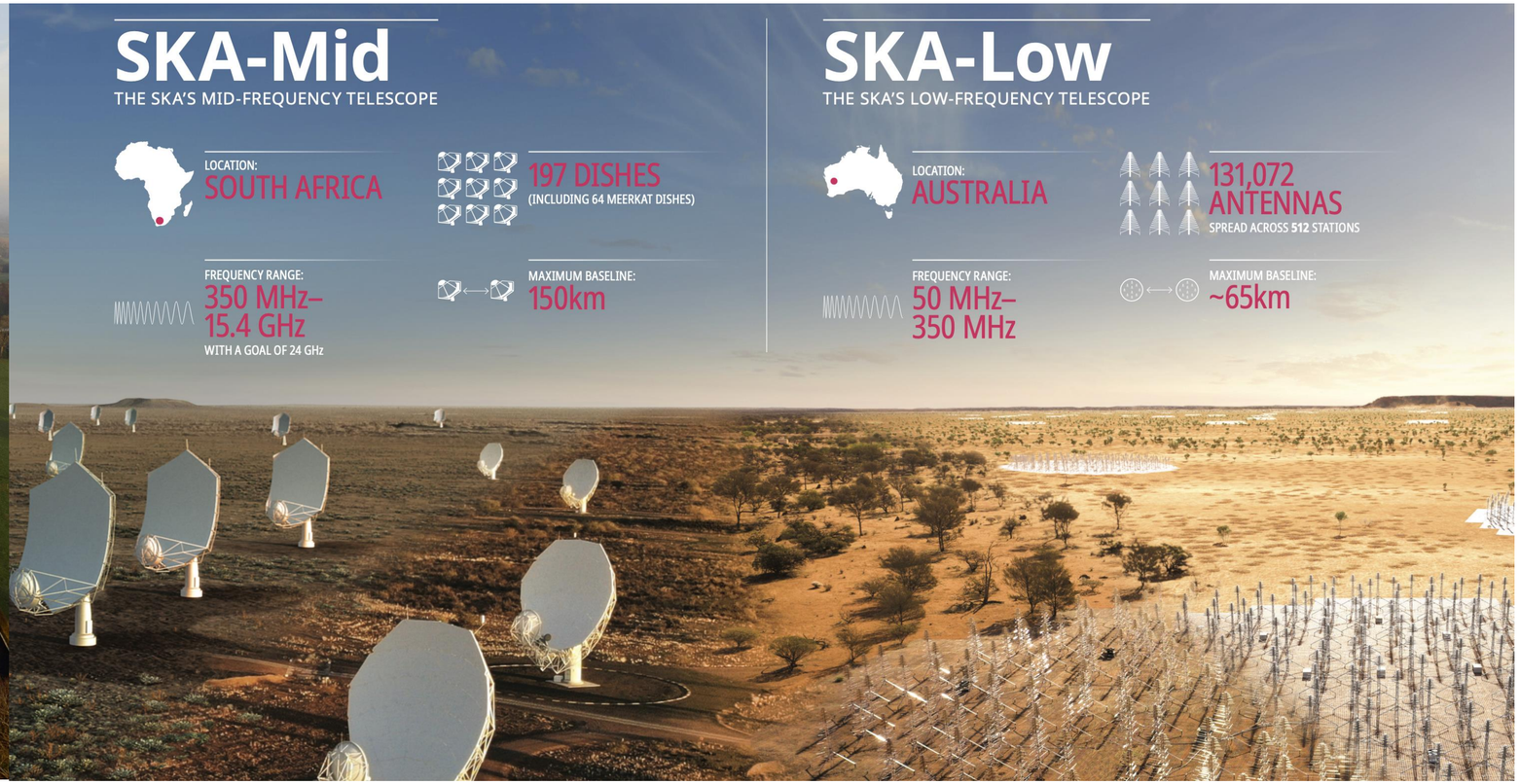
The SKAO: a new eye on the Universe

Catherine Cesarsky
Chairperson of SKAO Council

Journée SKA-France
November 2022

What are we building?
One Observatory, Two Telescopes, Three Sites



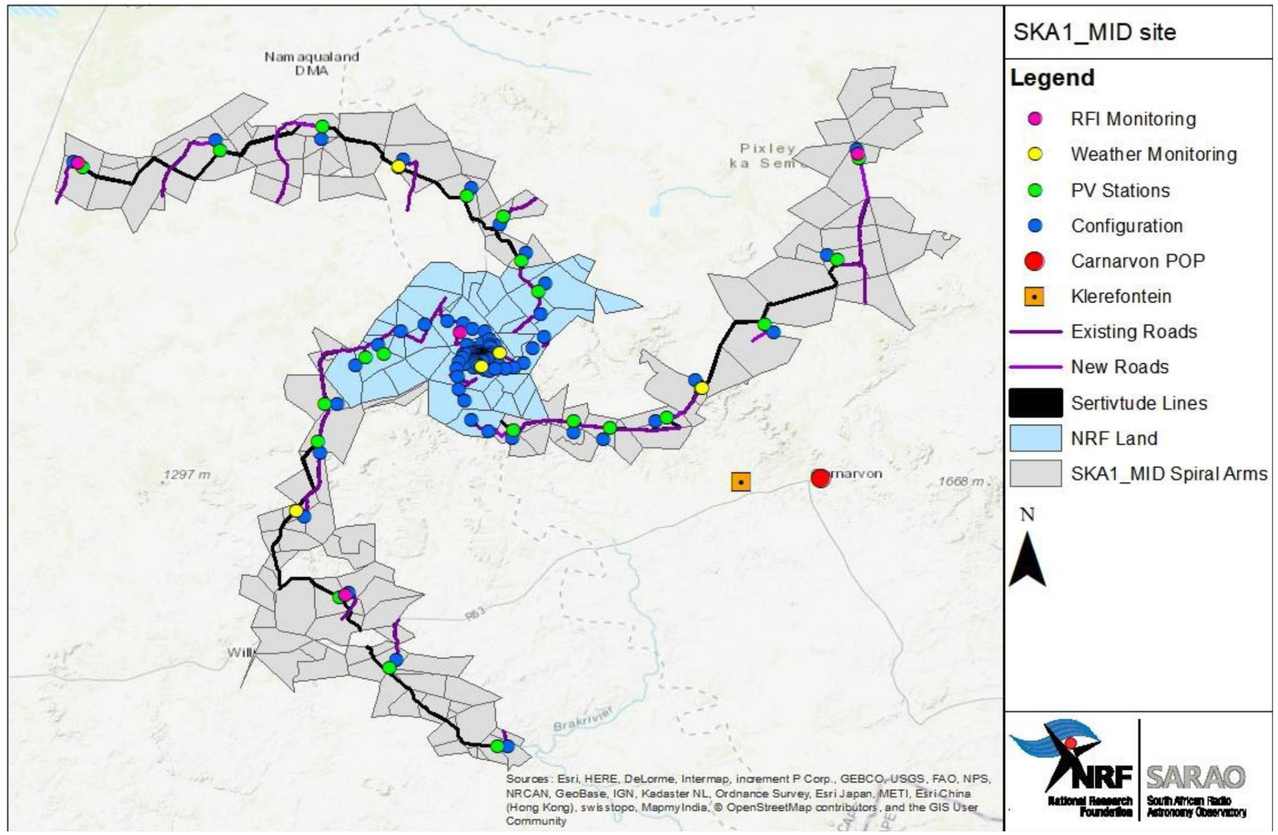


Sites selected for their radio quietness → low population density

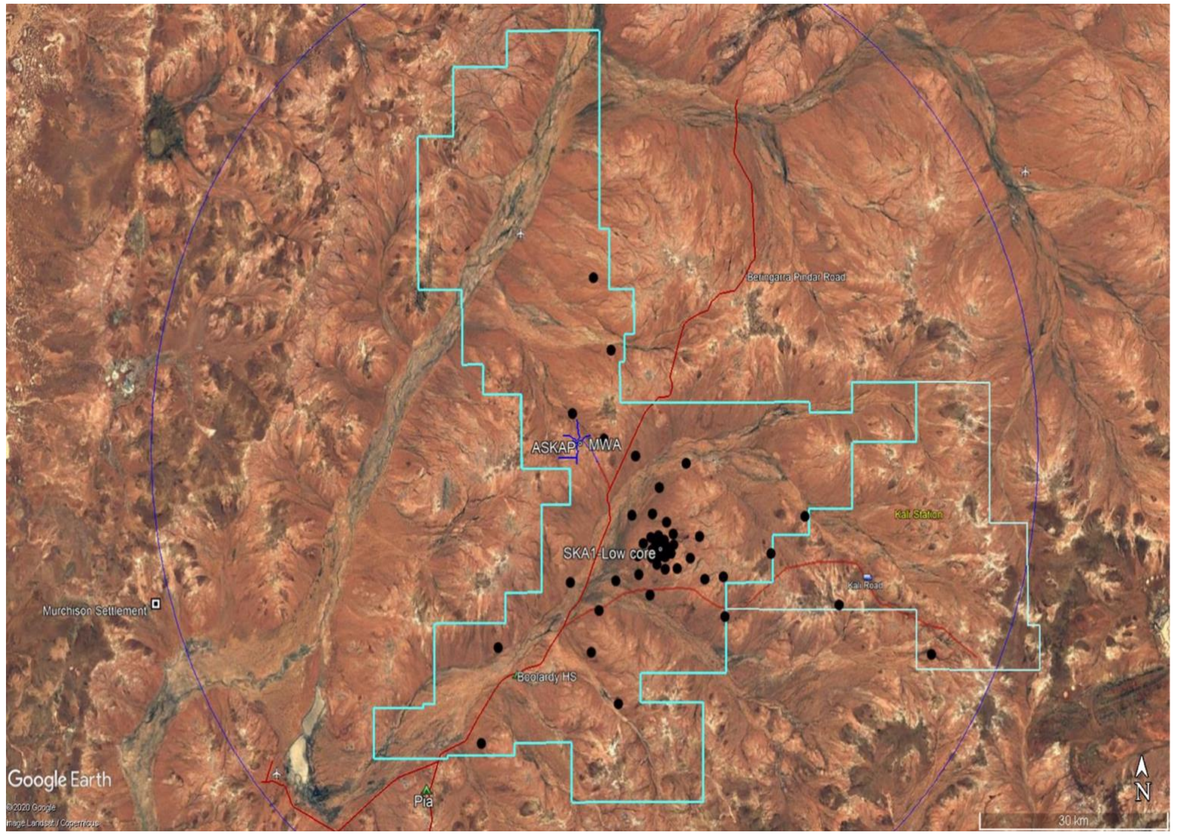
Total project cost: ~€2B; operational in 2029/2030

Array configurations in South Africa and Australia

150 km extent



74 km extent



The SKA project in numbers

€1.3 BILLION
CONSTRUCTION COST (2021 €)

131,072 ANTENNAS
IN WESTERN AUSTRALIA

710 PETABYTES
OF SCIENCE DATA DELIVERED TO SCIENCE USERS

€0.7 BILLION
FIRST 10 YEARS OF OPERATIONS COST (2021 €)

197 DISHES
IN SOUTH AFRICA (INCLUDING 64 MEERKAT DISHES)

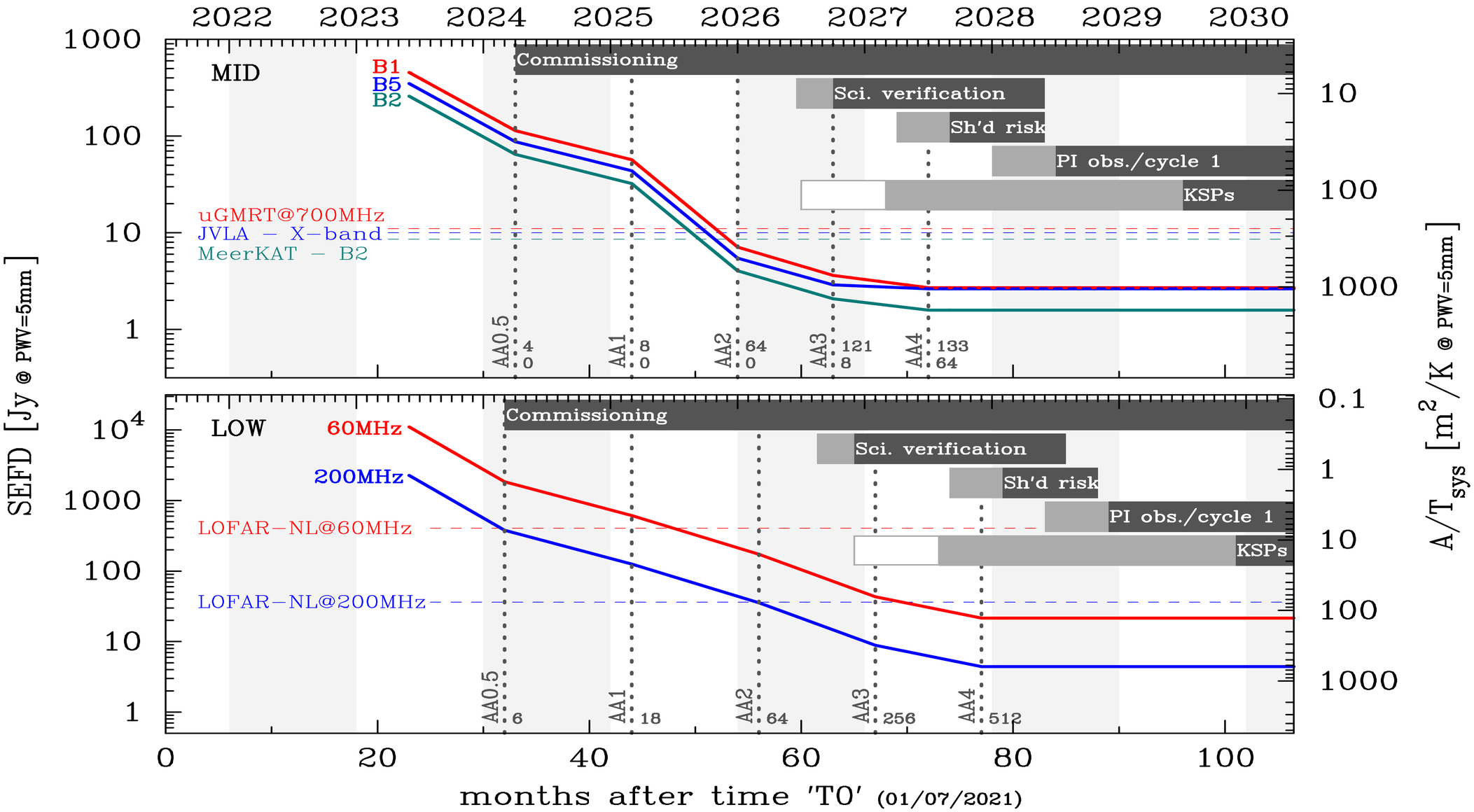
1 GLOBAL NETWORK
OF DATA CENTRES TO DELIVER SCIENCE-READY DATA PRODUCTS TO END-USERS

8 YEARS
TO CONSTRUCT

16 COUNTRIES
PARTICIPATING IN 2021

50+ YEARS
OF TRANSFORMATIONAL SCIENCE

The Evolution of Performance



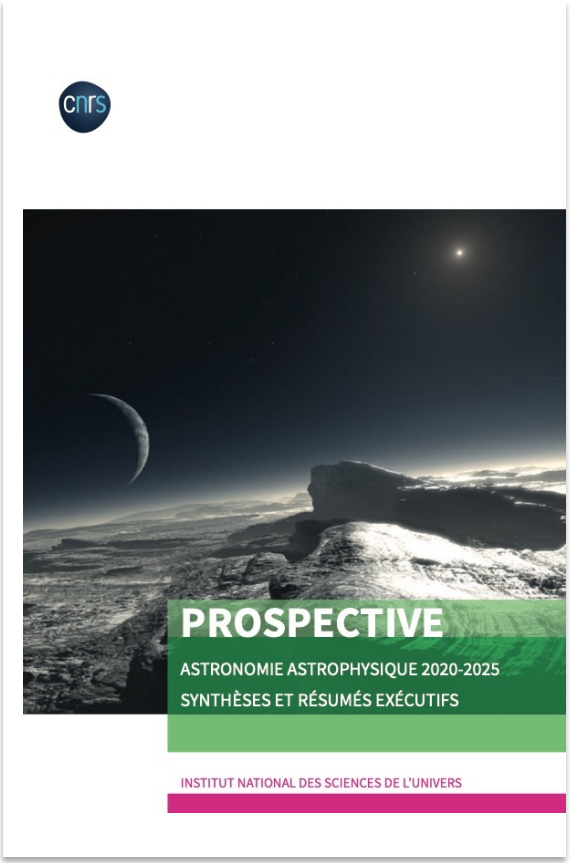
Anticipated Science Performance: https://arxiv.org/abs/1912.12699

Credit: Mark Sargent

The French path towards the SKAO

Chiara Ferrari
Astronomer @ OCA, SKA-France Director, Chair of European SKA Forum

"Prospective INSU AA" published in 2019



Priorité	Justification	Thématiques cibles	Missions spatiales engagées en synergie avec le moyen sol
INFRASTRUCTURES DE TYPE TGIR			
P0 : SKA	Apport d'un saut technologique (sensibilité, champ de vue instantané, multiplexage, etc.) permettant des avancées considérables sur un ensemble de thématiques très variées et d'intérêt majeur pour la communauté.	Aube cosmique, réionisation, évolution des galaxies et grandes structures, milieu interstellaire, disques protoplanétaires, formation stellaire, champs magnétiques, objets compacts, ciel transitoire, physique fondamentale, ondes gravitationnelles *via* les pulsars	JWST, Euclid, LISA, SVOM, Athena

Link to the full document

Milestones of SKA-France

November 2019

Two new partners of Maison SKA-France

& New INSU/AA Prospective

July 18, 2018

CNRS becomes member of SKA Organisation

May 17, 2018

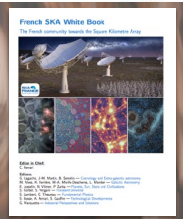
SKA inscribed as a project in the French Roadmap for Research Infrastructures published by MESRI

February 1st, 2018

Launch of Maison SKA-France

October 16, 2017

First SKA-France Day



July 1st, 2016

SKA-France Coordination

France & SKAO

April 11, 2022

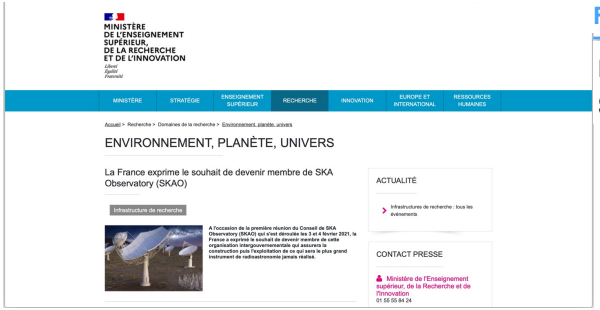
French government signs the accession agreement with the SKAO

March 7, 2022

Collaboration Agreement signed between SKAO and CNRS

May 28, 2021

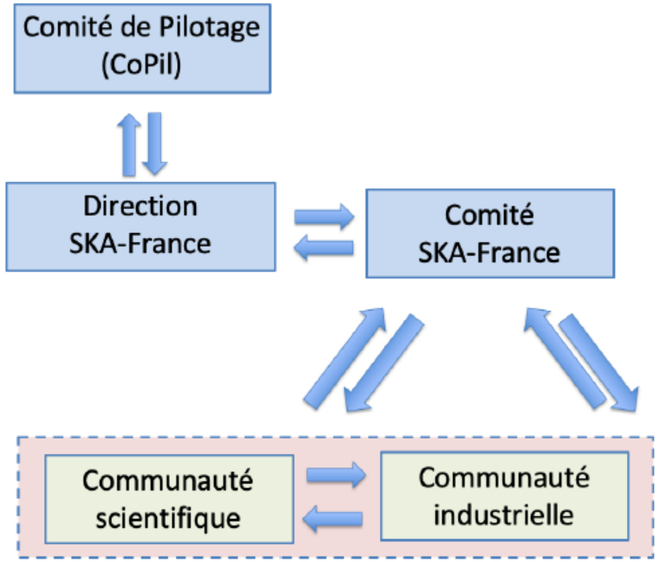
Announcement of France's accession to the SKA Observatory - after SKAO Council approval - made by the French President Emmanuel Macron



February 4, 2021

France expresses its wish to become a member of SKA Observatory

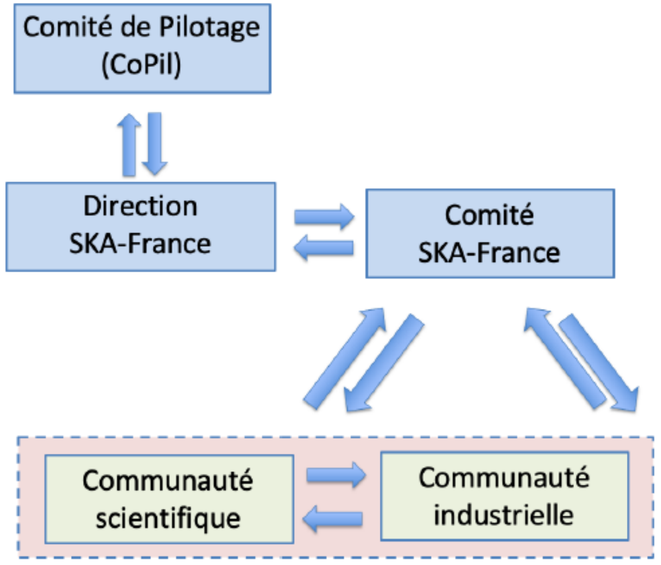
From “Maison SKA-France” …



Objective

Build a solid scientific, technological and industrial case for France joining SKAO

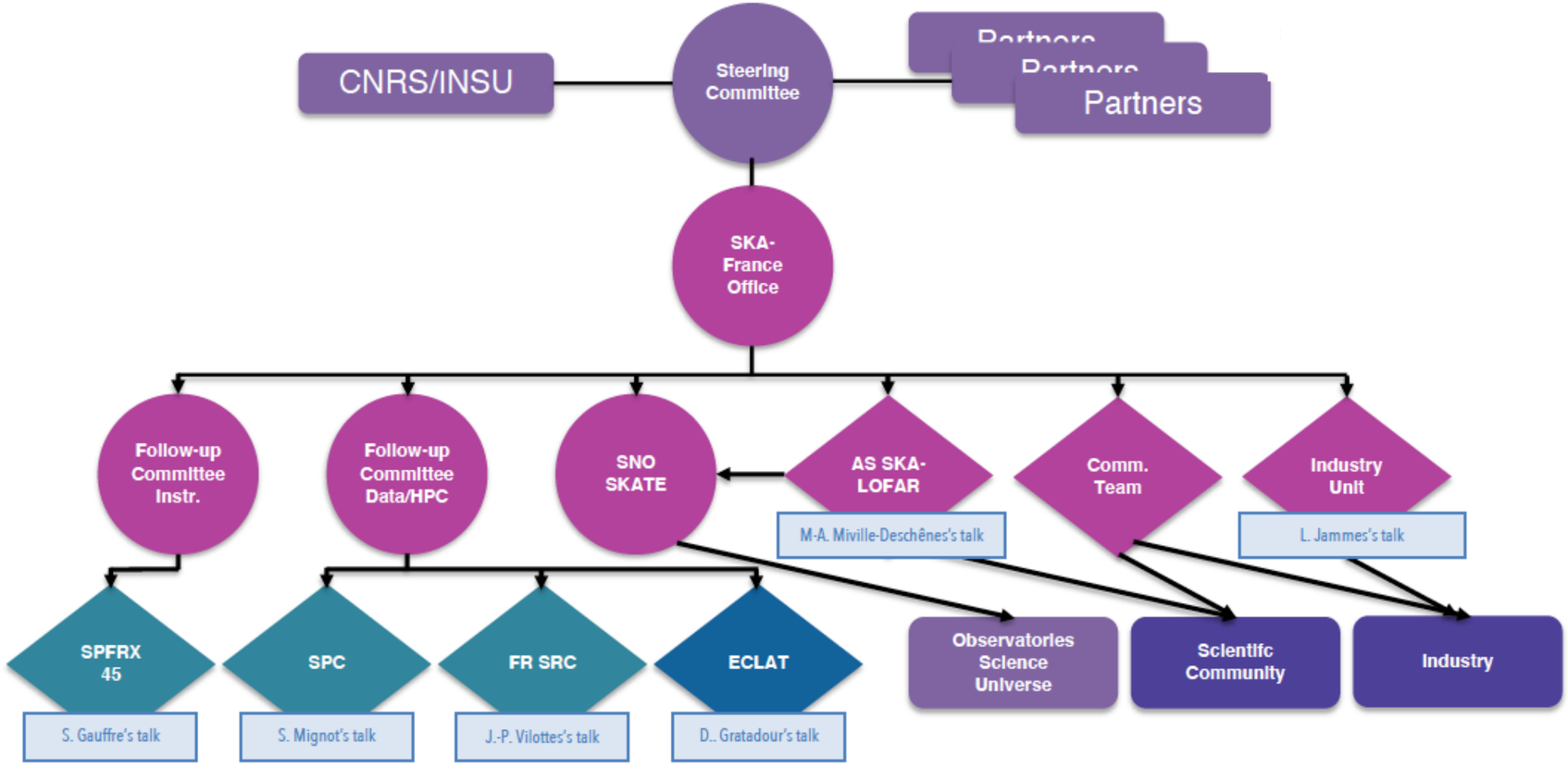
From "Maison SKA-France" …



Objective

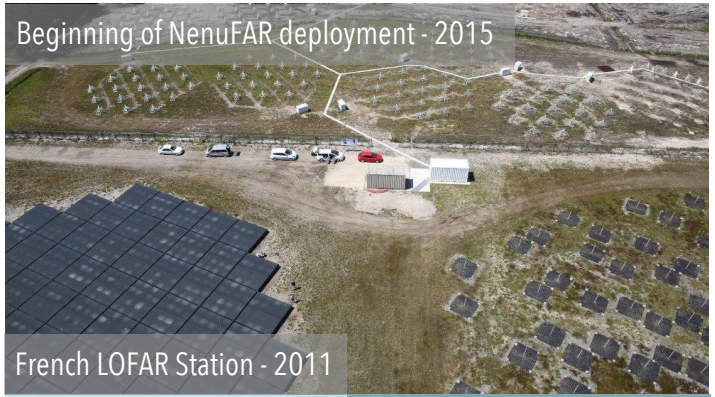
Build a solid scientific, technological and industrial case for France joining SKAO

…to "SKA-France 2.0"

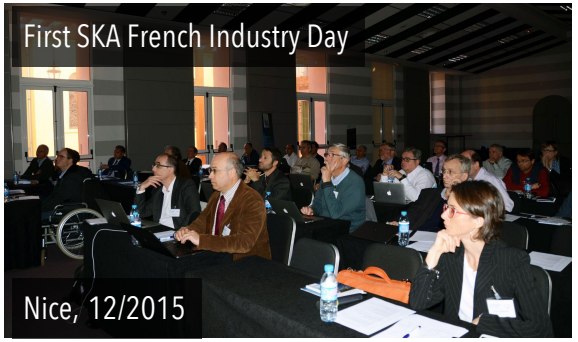


Why SKA-France ?

Challenges motivating French innovation



@ Nançay & Bordeaux

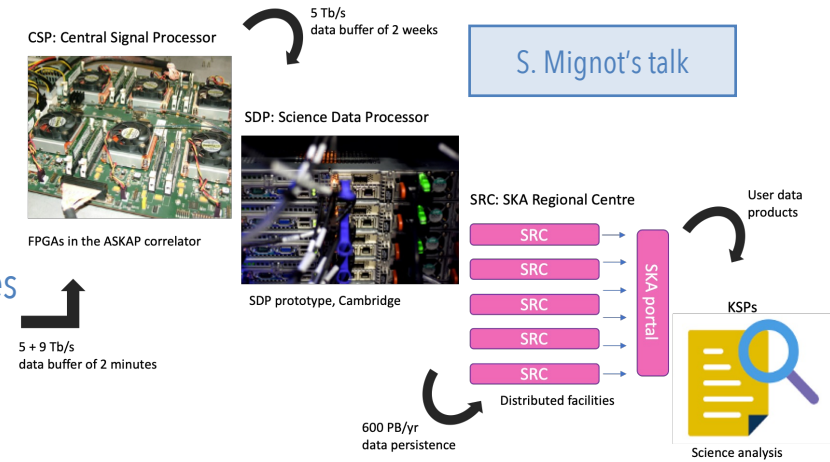


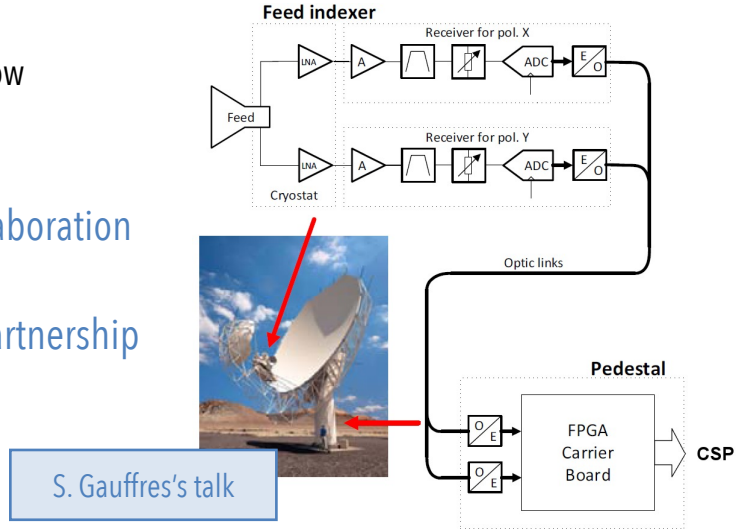
THALES · AIRBUS SAFRAN LAUNCHERS · IBM · fedd · ENGIE · NOKIA · Callisto · KALRAY · Alcatel·Lucent · DDN STORAGE · Schneider Electric · AEG · EDF · TOTAL · SAFT · NVIDIA · intel · BULL · AIR LIQUIDE · Alcatel·Lucent · Air Liquide

French participation in the SKAO

Construction & Operations

- Construction
  - Co-design & Equipment of the two sub-exascale computing centres of the Observatory
  - Supply of digital electronics for high-frequency receivers
- Strategic objectives for SKA-France
  - Environmental sustainability of the project
    - Efforts made by France in the design of future SKAO computing centres with low environmental impact
    - Study of energy solutions for SKA-MID funded in 2019
  - SKA: fundamental research as a driver for strategic innovation and collaboration between academia and industry
  - SKA Regional Centre Network (SRC-Net): a new model of End-to-End partnership
    - Governance
    - Design
    - Implementation





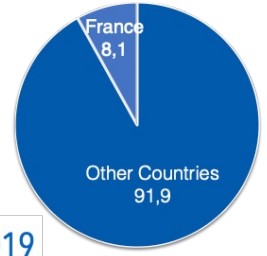
French participation in the SKAO

Science

- A continuously growing scientific community preparing for the start of SKAO observations
  - Active exploitation of SKA pathfinders and precursors (NenuFAR, LOFAR, MeerKAT, ASKAP, FAST, …)
  - Participation to all SKA Science Working Groups
  - Wide and recognised methodological expertise in data processing and analysis
  - The SKAO challenges interests a wider community of researchers, not only astronomers

2014

M-A. Miville-Deschênes's talk

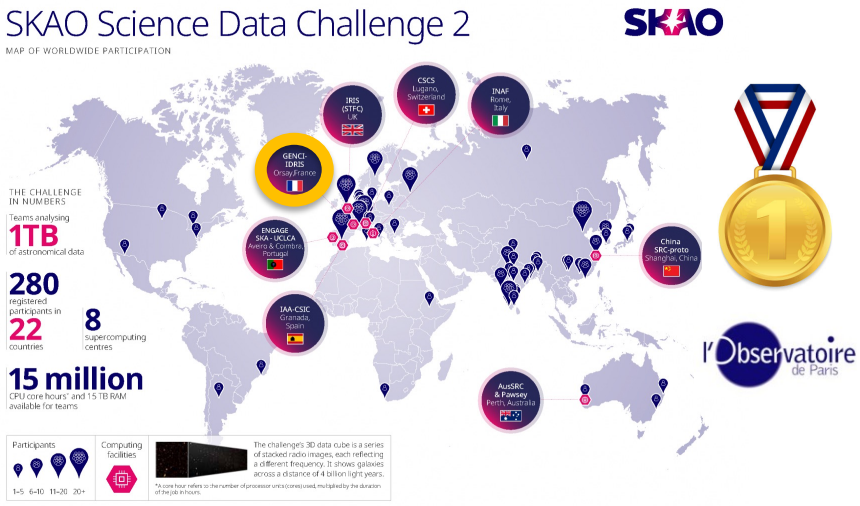


2019

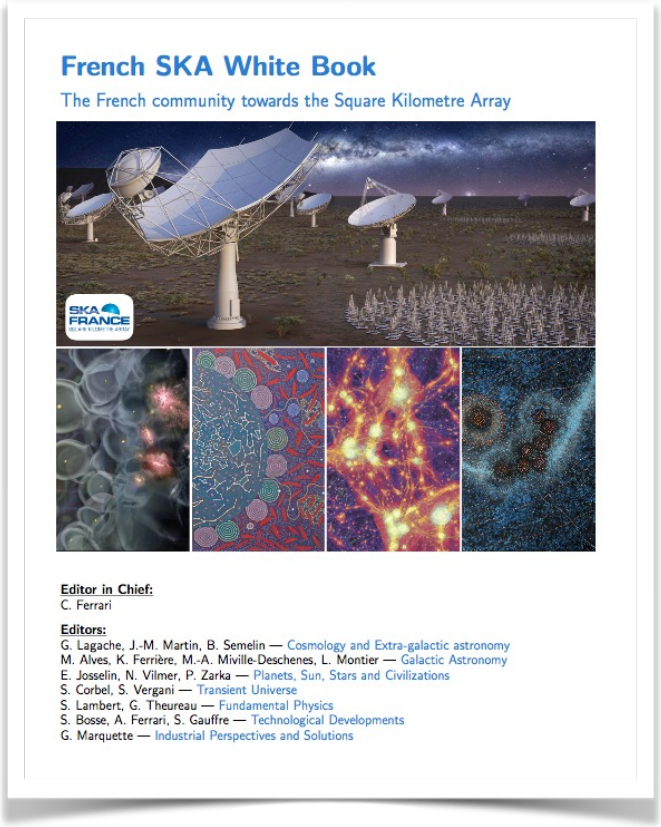
NumPex | Numérique Hautes Performances pour l'Exascale

- Pilot(s) institution(s) : CEA, CNRS, INRIA
- Scientific director(s) : Jean-Yves Berthou (INRIA), Jérôme Bobin (CEA), Michel Dayde (CNRS)
- FINANCEMENT ACCORDE 40,80 M€

D. Gratadour's & J.-P. Vilotte's talks



The French SKA White Book



176 authors from

* 40 French research institutes

* 6 private companies

14 SKA Science working groups

HI Galaxy Science

Epoch Of Reionization

Pulsars

Magnetism

Cradle of Life

Cosmology

Our Galaxy

Gravitational Waves

Extragalactic Spectral Line

Transients

VLBI

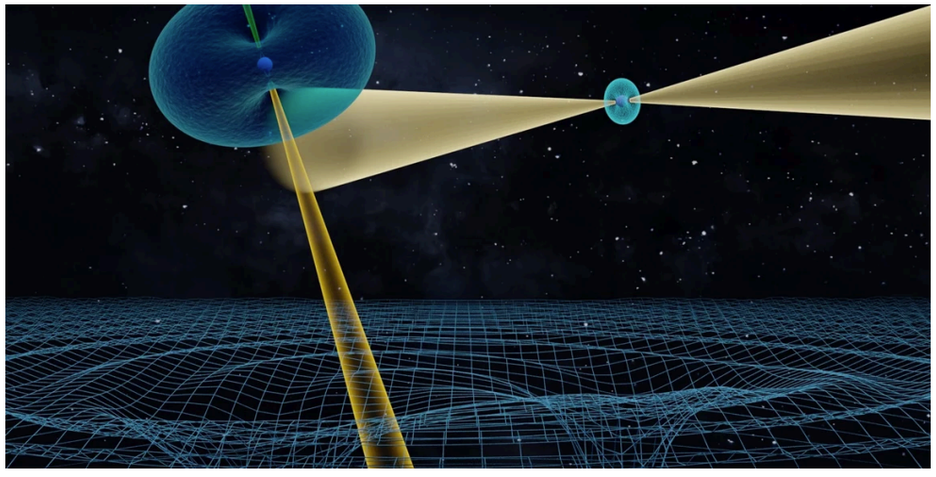
Solar, Heliospheric & Ionospheric Physics

Extragalactic Continuum

High Energy Cosmic Particles

Pulsars and gravitational waves

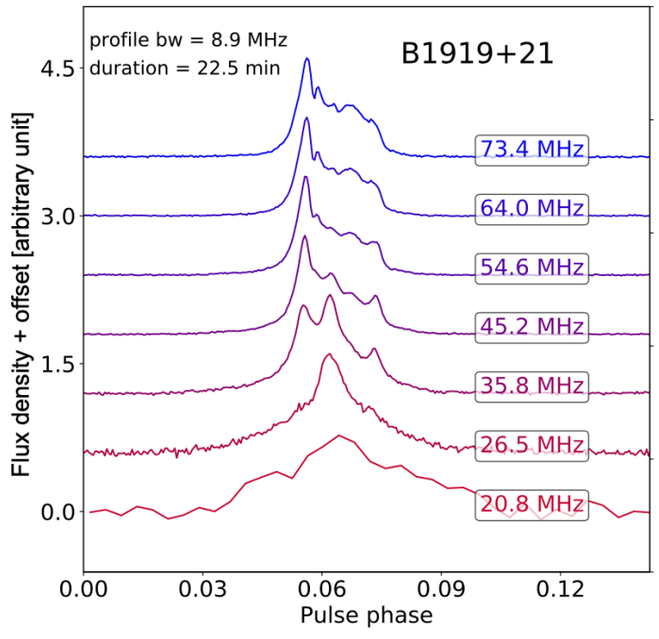
- Teams involved : LPC2E, USN, APC, LUTh, IRAP, AIM, LESIA
- Scientific topic : low frequency gravitational waves - PTA, test of gravity, physics of pulsars, fast radio bursts
- Expertise and leadership : instrumentation and pipeline for pulsar chronometry, PTA data analysis, test of gravitation with binary systems, FRB
- Contact : Gilles Theureau, Jean-Mathias Griessmeier, Baptiste Cecconi, Louis Bondonneau, Ismael Cognard, Lucas Guillemot, Guillaume Voisin, Cherry Ng



Kramer+(2021)
Gravity tests with a double pulsar

Voisin+(2020)
Test of general relativity with a pulsar in a triple star system

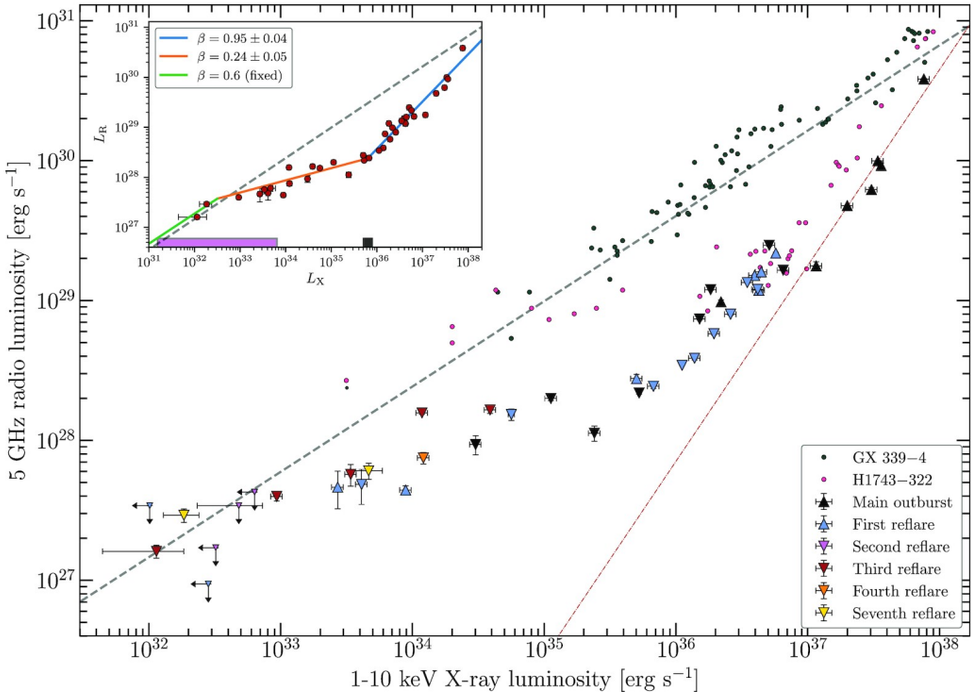
Implication in the International and European PTA
Antoniadis+(2022)
Chen+(2021)



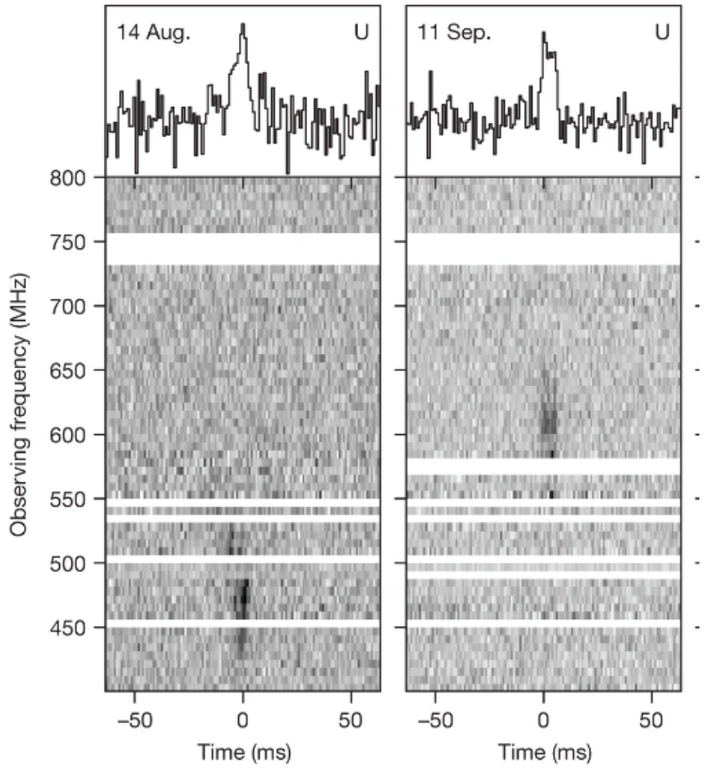
Pulsar with NenuFAR, LOFAR and MeerKAT
Bondonneau+(2021,2020)
Bailes+(2020)

Transients

- Teams involved : AIM, USN, LESIA, IRAP, LPC2E
- Scientific topic : Gamma-ray burst, kilonovae, accreting systems, jets, black holes, relativistic plasma, Fast Radio Bursts
- Expertise : theory, multi-wavelength observations of transients, multi messagers (EM - GW), signal reconstruction
- Contact : Stéphane Corbel, Mickael Coriat, Susanna Vergani, Cherry Ng



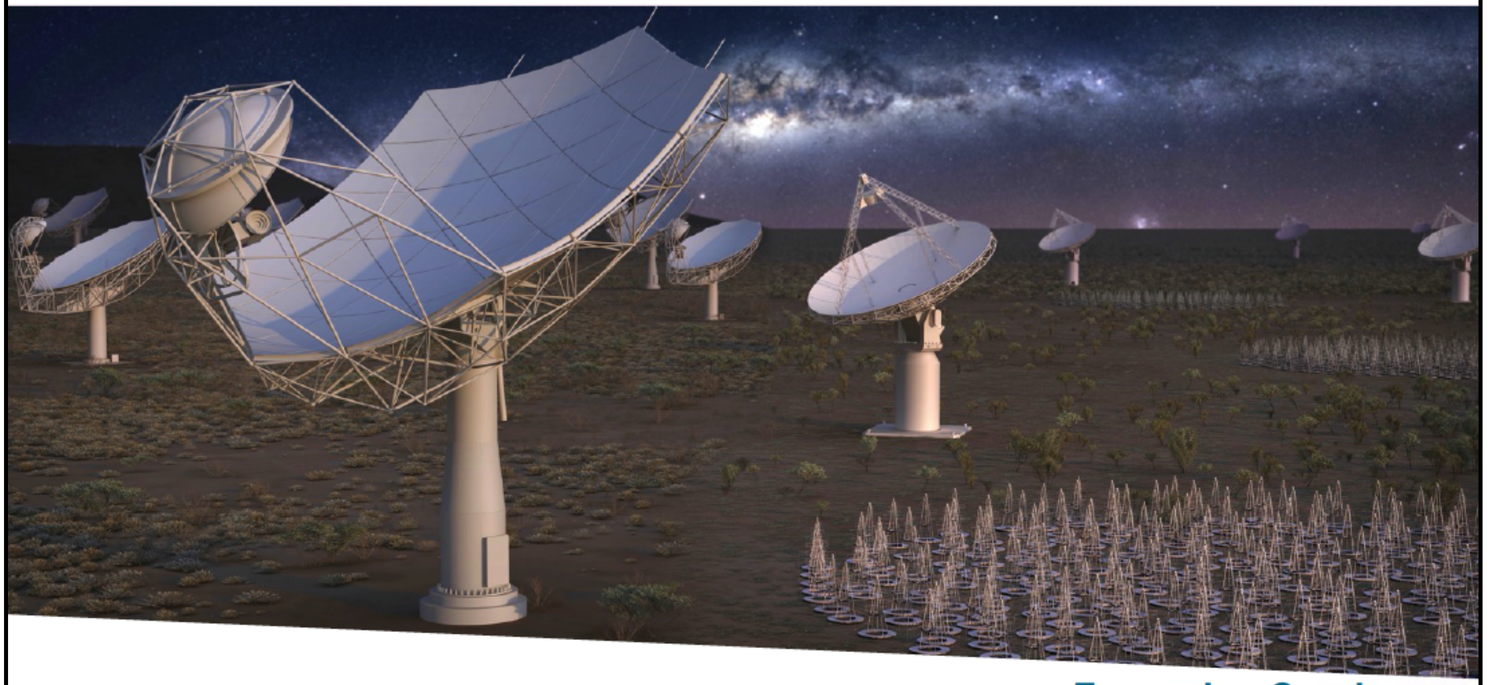
Carotenuto+(2021)
radio/X-ray correlation of a black hole transient



CHIME/FRB collaboration+(2019)
Ng, Cherry corresponding author
A second source of repeating fast radio bursts

ASTRONOMY in the NEXT DECADES with

SKAO



SQUARE KILOMETRE ARRAY

Exploring the Universe with the world's largest radio telescope

Françoise Combes
Observatoire de Paris

November 2022

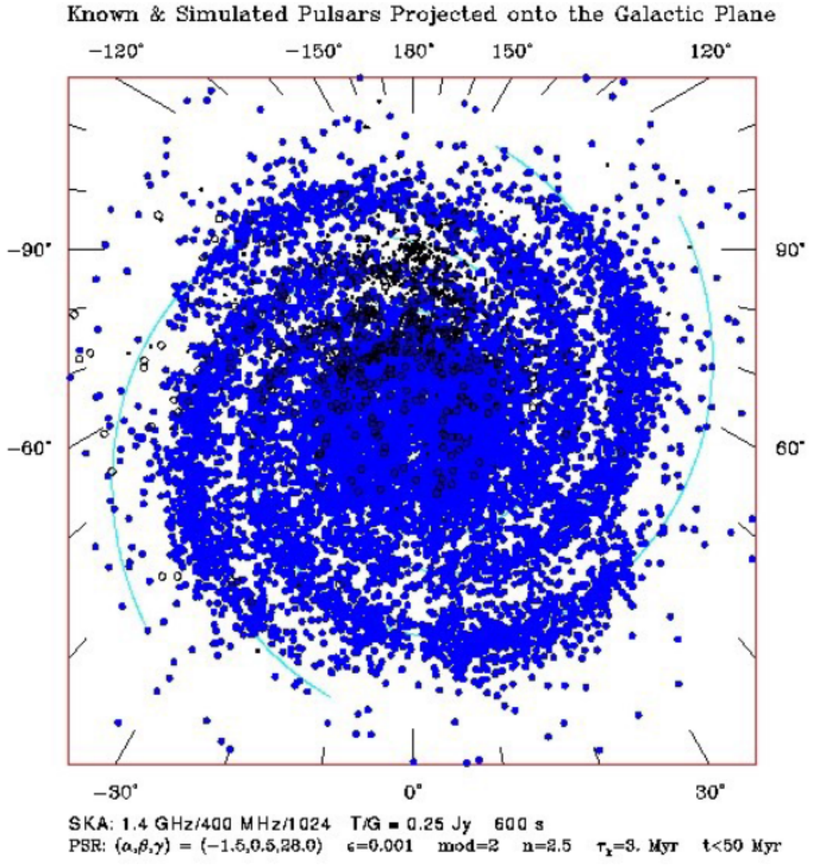
ASTRONOMY in the

SQUAR

Exploring the Un

Pulsars with SKA

J Cordes, 2004



MW: 30 000 PSR, 10^4 MSP
~20,000 potentially visible normal pulsars, MSPs and RRATs = **Rotating Radio Transients**
(irregular, nulling, might be more abundant?)

- SKA1 has the potential to find a large fraction (~50%?) of these pulsars

+ 7000 FRB/day in all sky

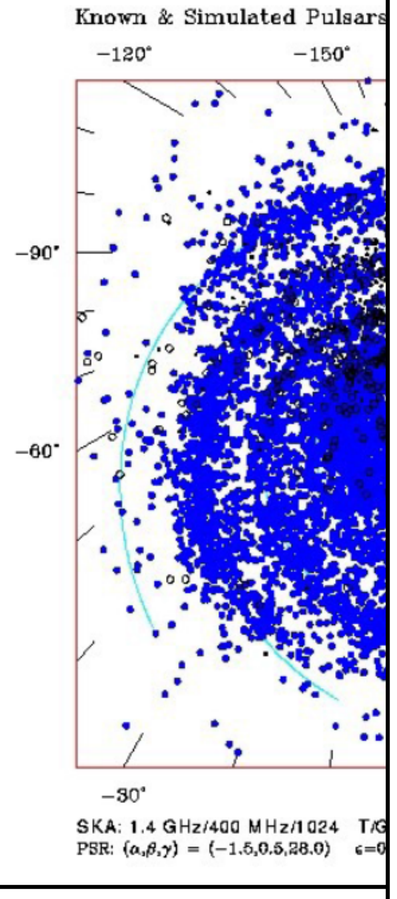
ASTRONOMY in the

SQUAR

Exploring the Un

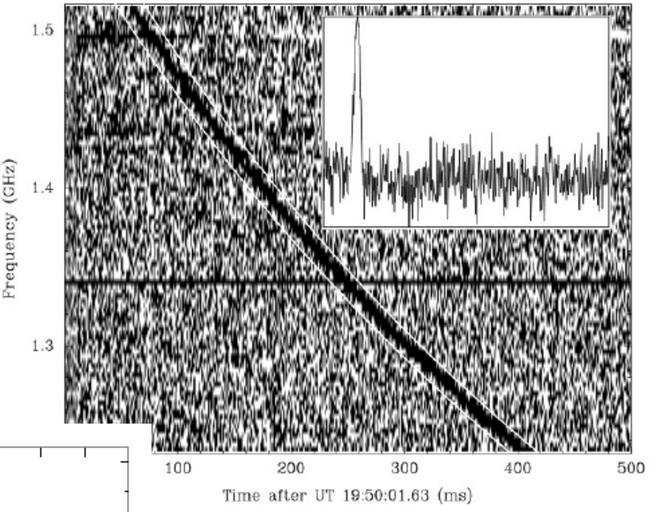
Pulsars with SKA

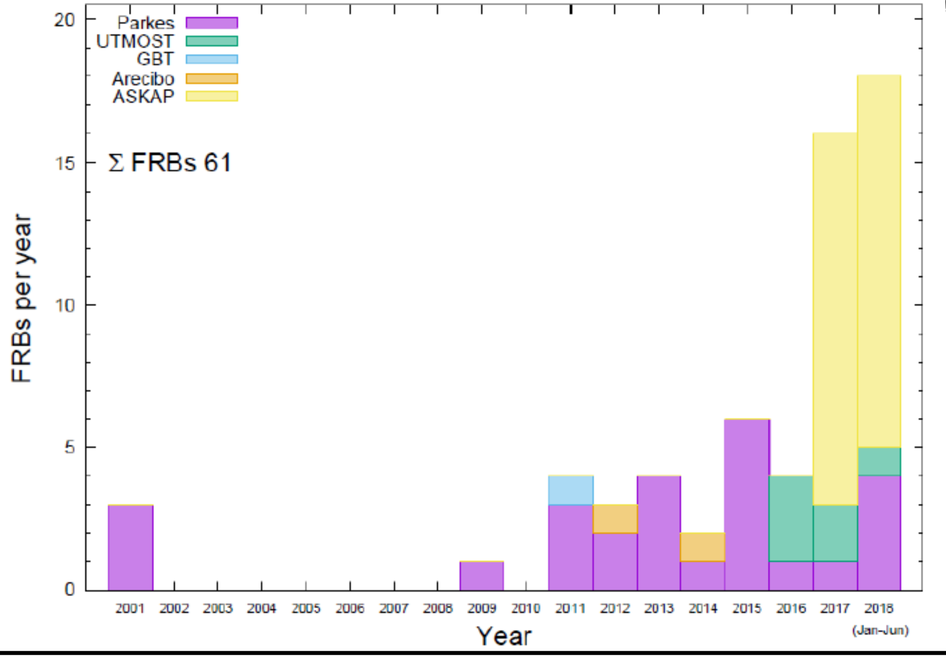
J Cordes, 2004



FRB: Fast Radio Bursts

With SKA-MID, 100 FRB/yr
with precise localisation
Detections by ASKAP, CHIME
➔540 detected (~800/day/sky)





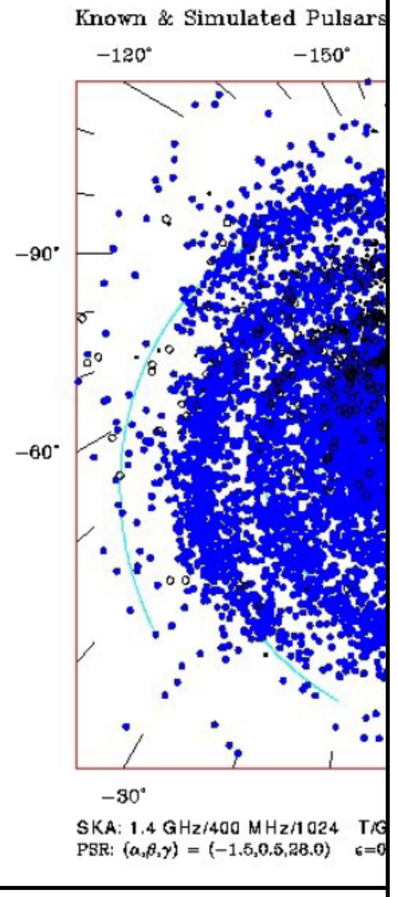
Lorimer et al 2007
Large DM==> far away
Powerful objects
In external galaxies
10μs variability
➔Compact objects
Strong B
➔ magnetars
Keane 2018

ASTRONOMY in the

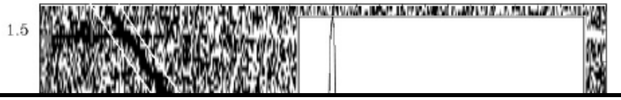
SQUAR
Exploring the Un

Pulsars with SKA

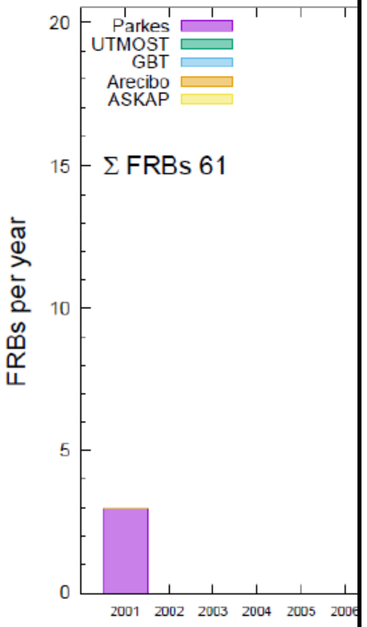
J Cordes, 2004



FRB: Fast Radio Bursts

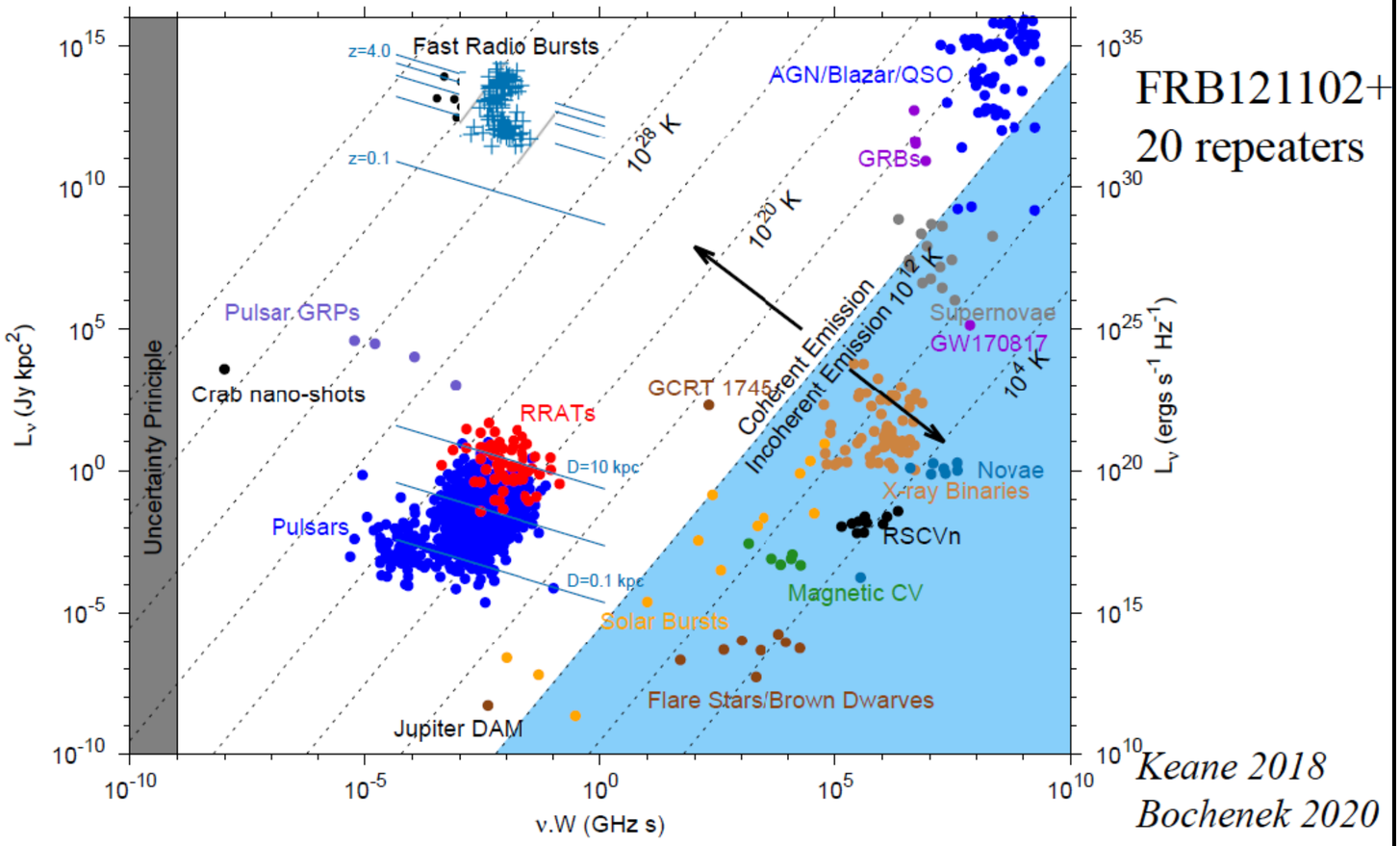


With SKA-MI
with precise lo
Detections by
➔540 detected



FRB in the transient diagram, L-νΔt

Could be use to trace the nature of Universe ➔ tomography



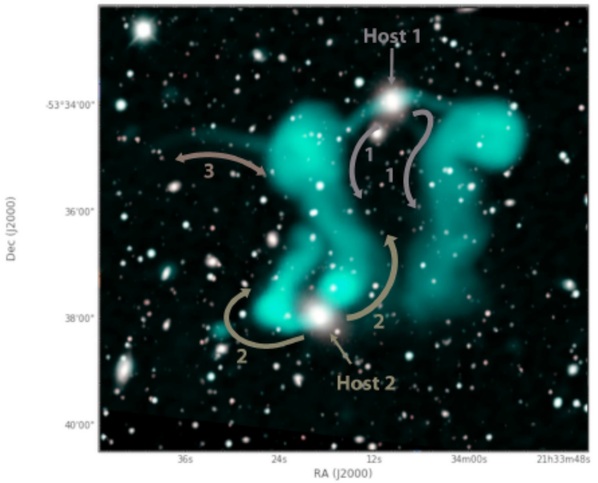
FRB121102+
20 repeaters

Keane 2018
Bochenek 2020

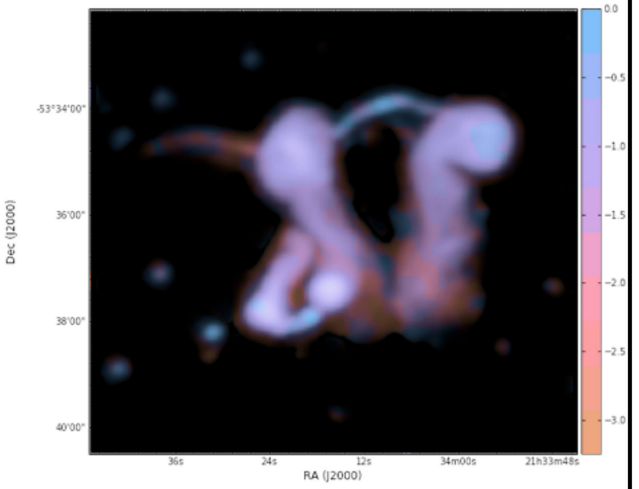
Probing Super-Massive Black Hole Evolution

- A pair of z = 0.08 SMBH-powered AGN, the "dancing ghosts" with angular separation of 360 kpc imaged with ASKAP

Norris et al. 2021PASA...38...46N



Radio/Optical Overlay



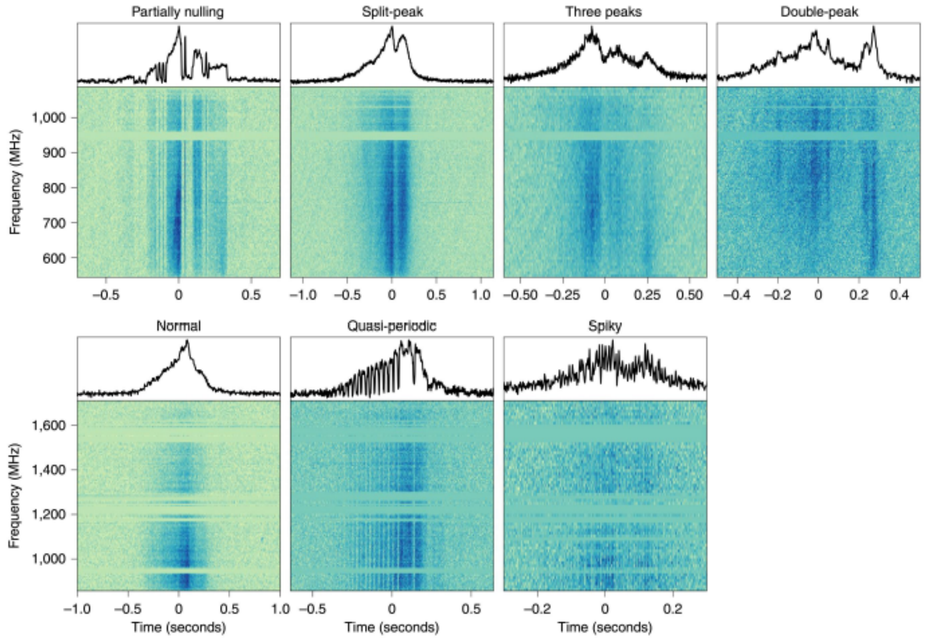
Radio Spectral Index

Probing Super-Massive Black Hole Evolution

- A pair of z = 0.08
  SMBH-p
  AGN,
  "dancing
  with ang
  separati
  kpc ima
  ASKAP

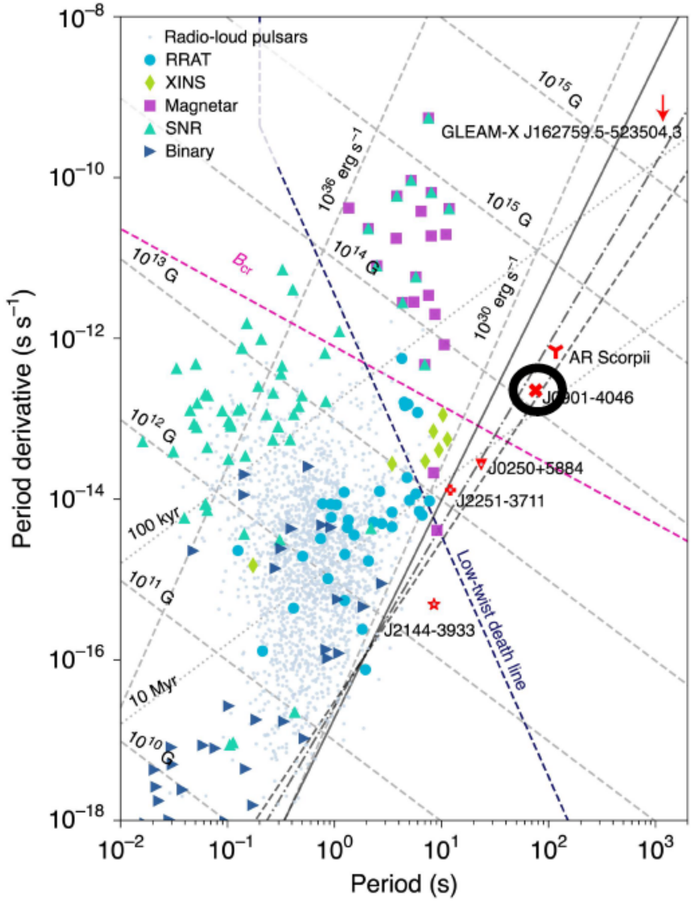
  Norris et a
  2021PASA

MeerKAT Discovery of ultra-long period Pulsar J0901-4046



- Discovery of 76 second period pulsar with unusual time varying properties: eg. quasi-periodic, partial nulling may provide new insights into pulse emission mechanism

Caleb et al, Nature Astronomy 6, 828–836 (2022)



Probing Super-Massive Black Hole Evolution

- A pair of z = 0.08
  SMBH-p
  AGN,
  "dancing
  with ang
  separati
  kpc ima
  ASKAP

  Norris et a
  2021PASA

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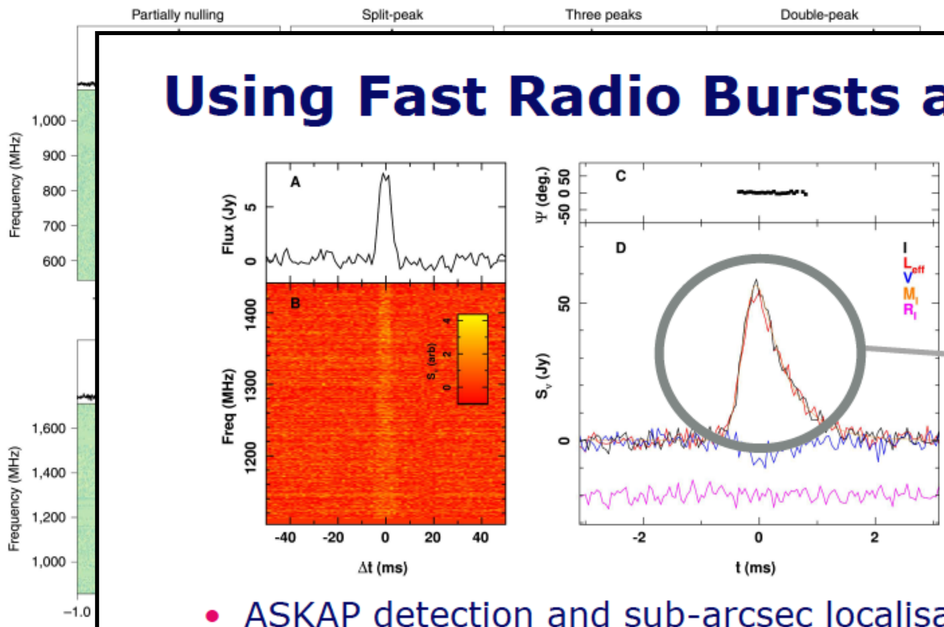
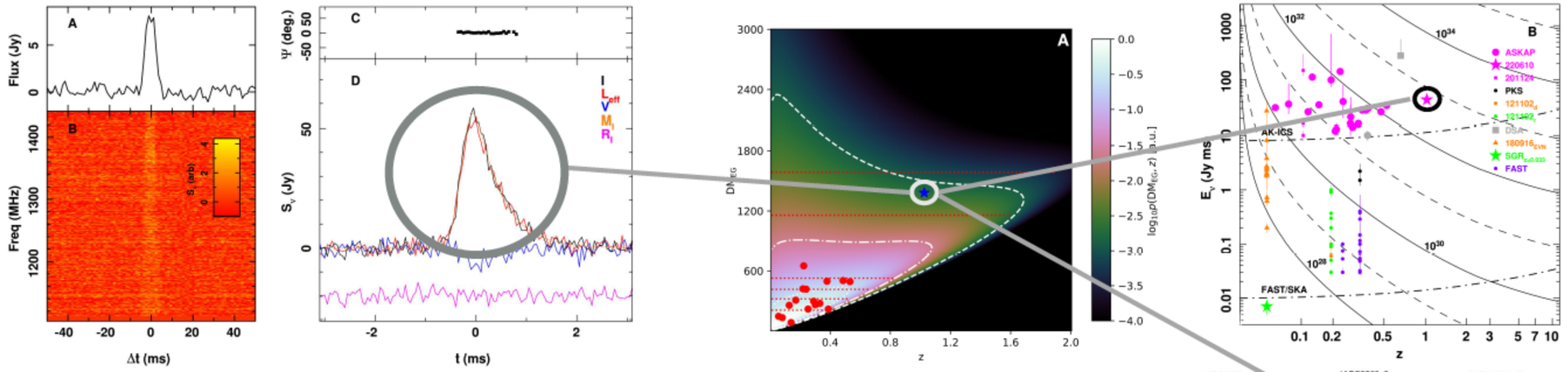
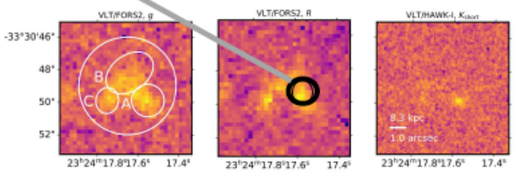
MeerKAT Discovery of ultra-long period Pulsar J0901-4046

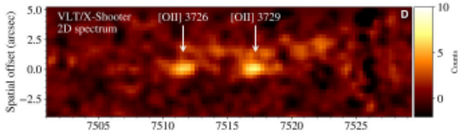


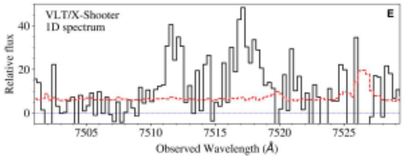
Using Fast Radio Bursts as Cosmological Probes



- ASKAP detection and sub-arcsec localisation of FRB20220610A
- Highest red-shift (z=1) and highest luminosity FRB yet discovered
- Pulse is 96% linearly polarised and RM = 215 rad m^{-2}
- Dispersion DM = 1376 pc cm^{-3} exceeds nominal IGM expectation by about 50%
- Host galaxy appears to be ongoing merger, with FRB near peak light of old stellar population
- SKA is 1000 times more sensitive; enables cosmology with FRB samples







Ryder et al 2022, Science, under review

How to get involved ?

- Register to one or more SKA Science Working Groups
  - https://www.skao.int/en/science-users
- Get in contact with the Action Spécifique SKA-LOFAR
  - as-ska-lofar.fr
  - register to the AS SKA-LOFAR newsletter

- https://ska-france.oca.eu/fr/accueil-ska
- https://ska-france-2022.sciencesconf.org
- https://www.skao.int
- https://www.skao.int/en/science-users
- https://as-ska-lofar.fr

https://nenufar.obs-nancay.fr/en/astronomer/

Cycle 3 ≤ 15/9/2023

Some of the big SKA Science questions

- **The Cradle of Life & Astrobiology**
  - *How do planets form? Are we alone?*
- **Strong-field Tests of Gravity with Pulsars and Black Holes**
  - *Was Einstein right with General Relativity?*
- **The Origin and Evolution of Cosmic Magnetism**
  - *What is the role of magnetism in galaxy evolution and the structure of the cosmic web?*
- **Galaxy Evolution probed by Neutral Hydrogen**
  - *How do normal galaxies form and grow?*
- **Galaxy Evolution probed in the Radio Continuum**
  - *What is the star-formation history of normal galaxies?*
- **Cosmic Dawn and the Epoch of Reionization**
  - *How and when did the first stars and galaxies form?*
- **Cosmology & Dark Energy**
  - *What is dark matter? What is the large-scale structure of the Universe?*
- **The Transient Radio Sky**
  - *What are Fast Radio Bursts and how can we best utilise them? What haven't we discovered?*