The Square Kilometre Array

Exploring the Universe with an ExaScale telescope

C. Ferrari

Astronomer

Director of Maison SKA-France

Observatoire de la CÔTE d'AZUR

SKA FRANCE
SQUARE KILOMETRE ARRAY

At the origin of the SKA concept (80's and 90's)
The "Hydrogen Array"

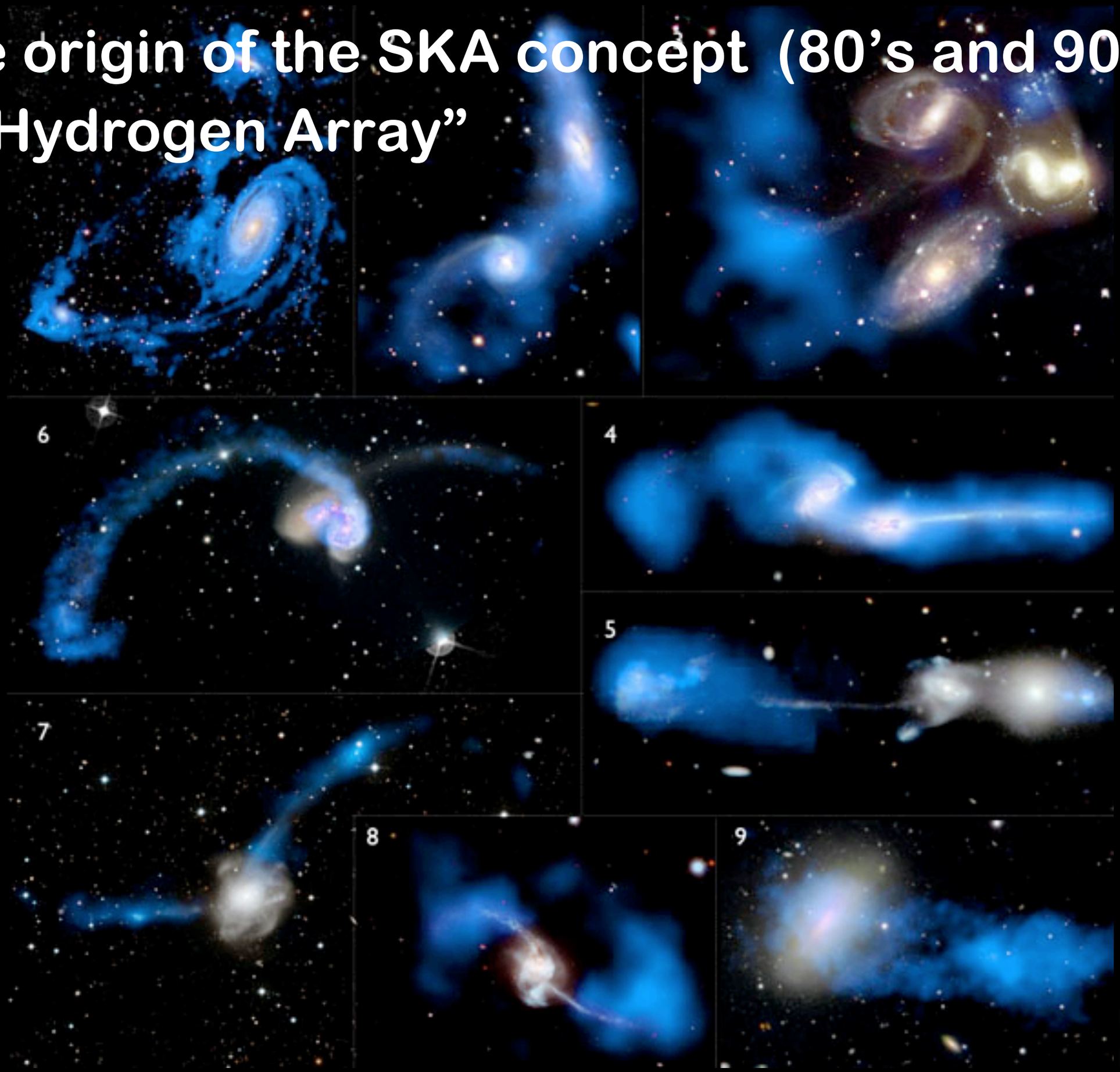


Image courtesy:
Duc & Renaud

A Golden Age for Radioastronomy

SKA Pathfinders

NenuFAR
France
10-85 MHz

LOFAR
Europe
30-80 MHz +
110-240 MHz

CHIME
Canada
400-800 MHz

APERTIF
The Netherlands
1 – 1.750 GHz

EVLA
USA
1- 50 GHz

And 10 more (in Europe, America, Japan, India, Australia)

SKA Precursors

MWA
Australia
80 - 300 MHz

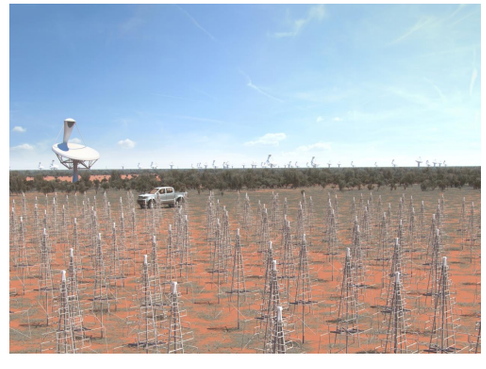
ASKAP
Australia
700 - 1800 MHz

HERA
South Africa
50 - 250 MHz

MeerKAT
South Africa
0.580 – 14 GHz

SKA

MID & LOW
South Africa &
Australia
50 MHz – 24 GHz



SKA FRANCE
SQUARE KILOMETRE ARRAY

A MeerKAT view of the Milky Way central region

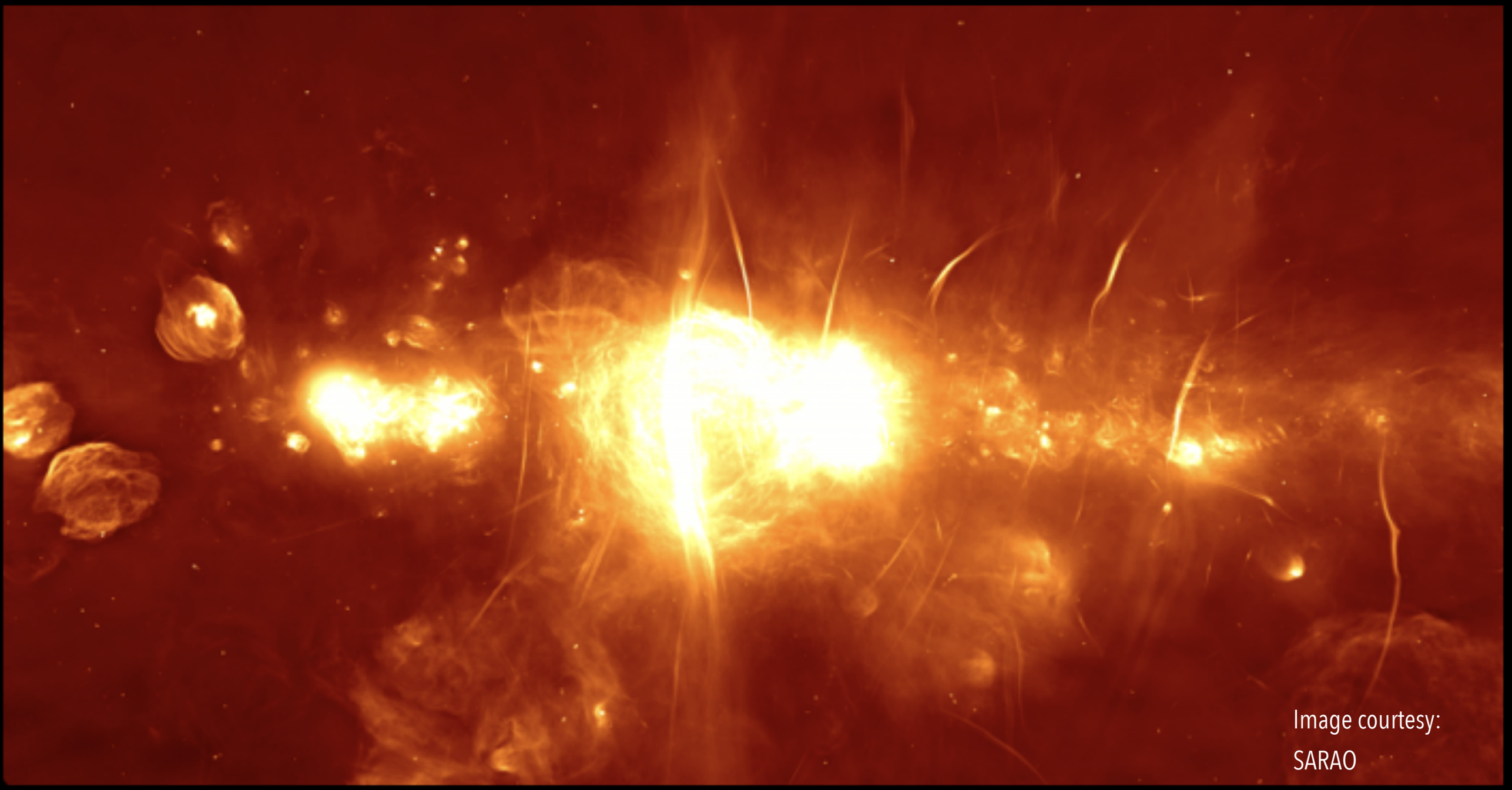
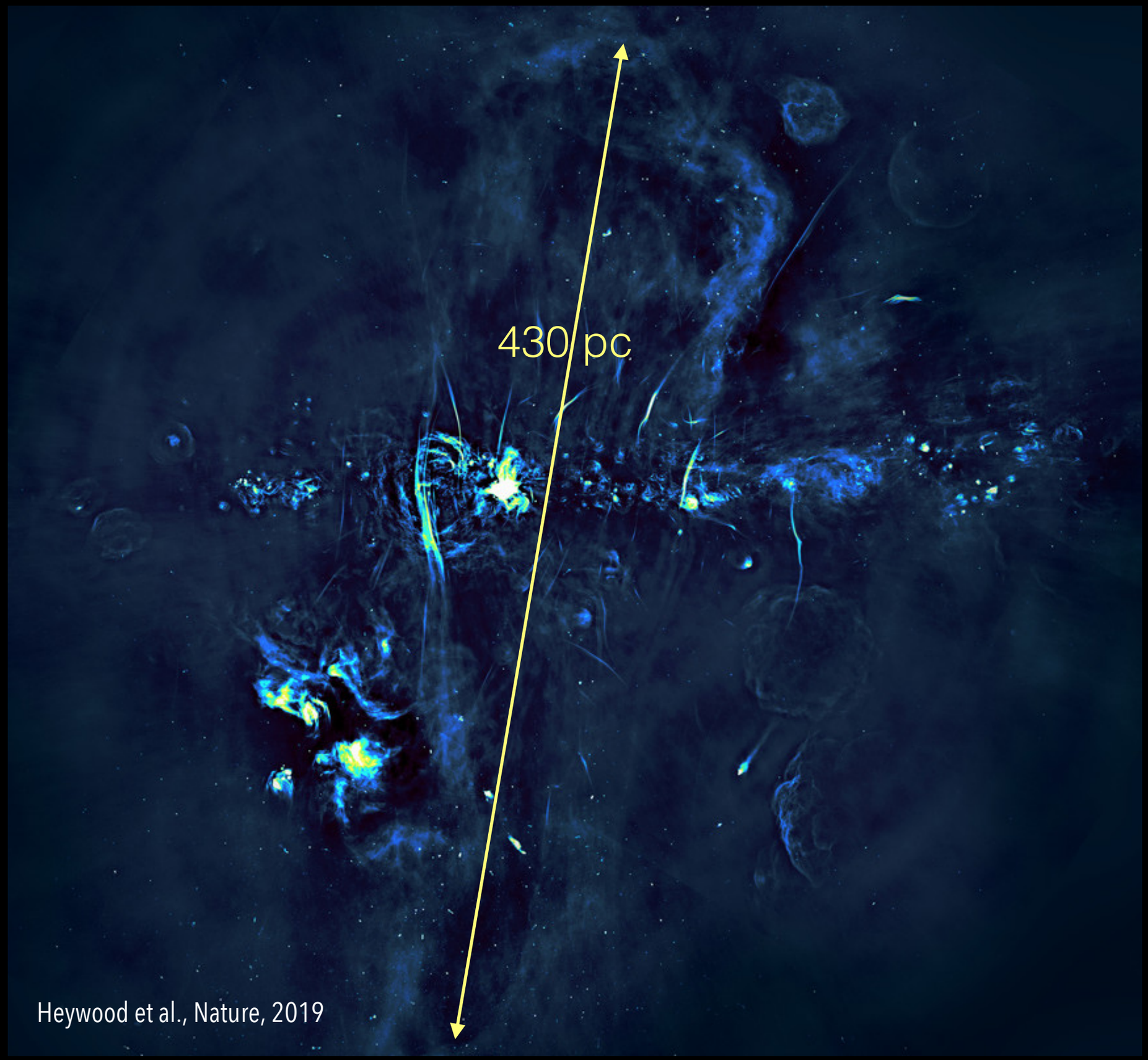


Image courtesy:
SARAO

A MeerKAT view of the Milky Way central region



Heywood et al., Nature, 2019

Changing our understanding of the Universe with the SKA

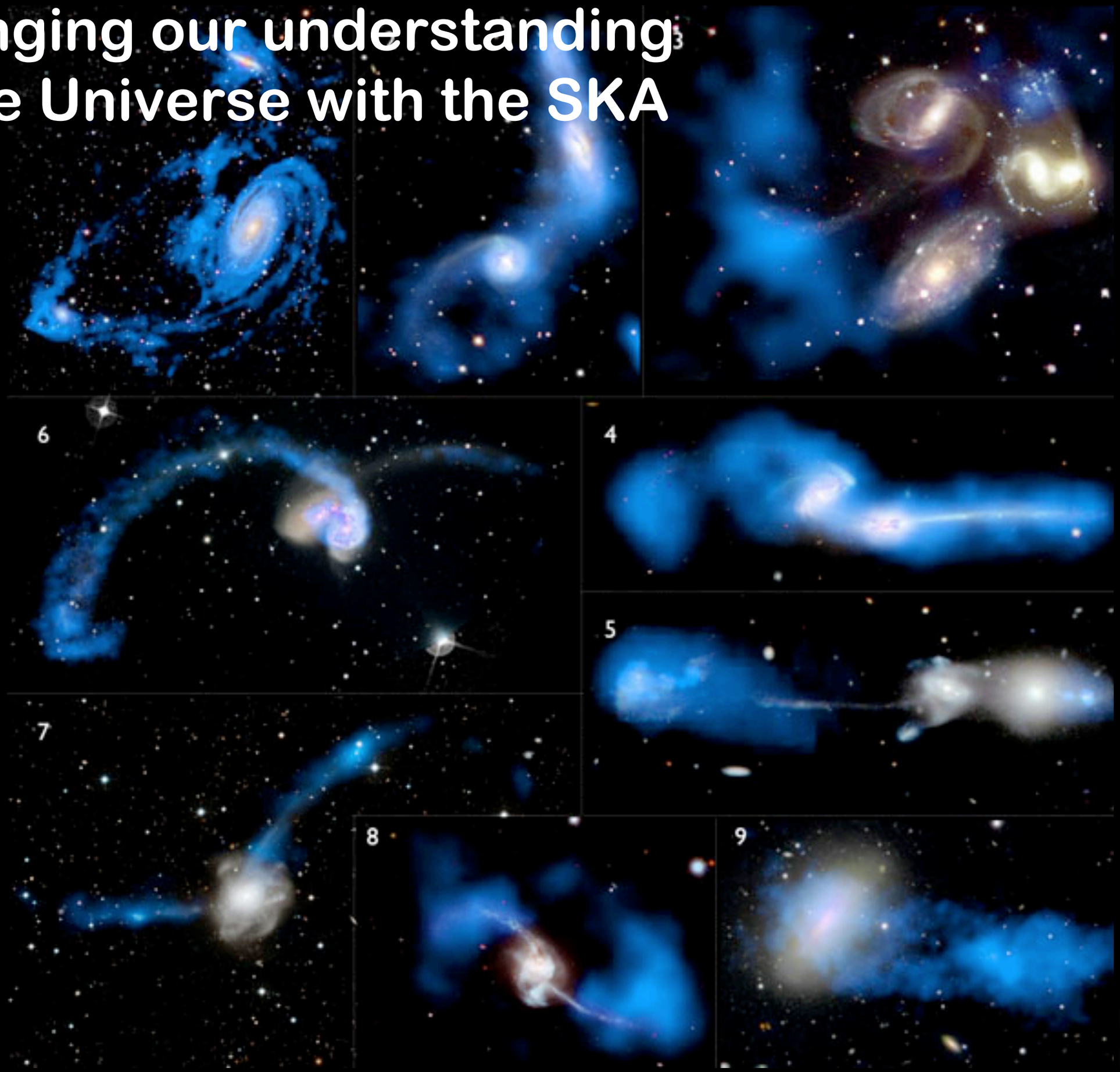
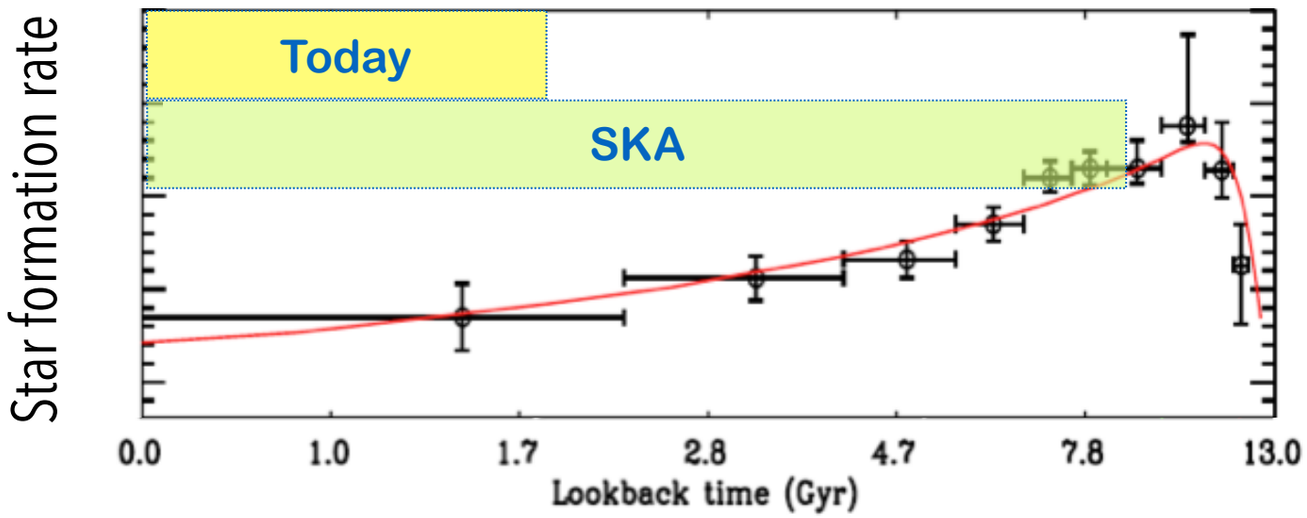
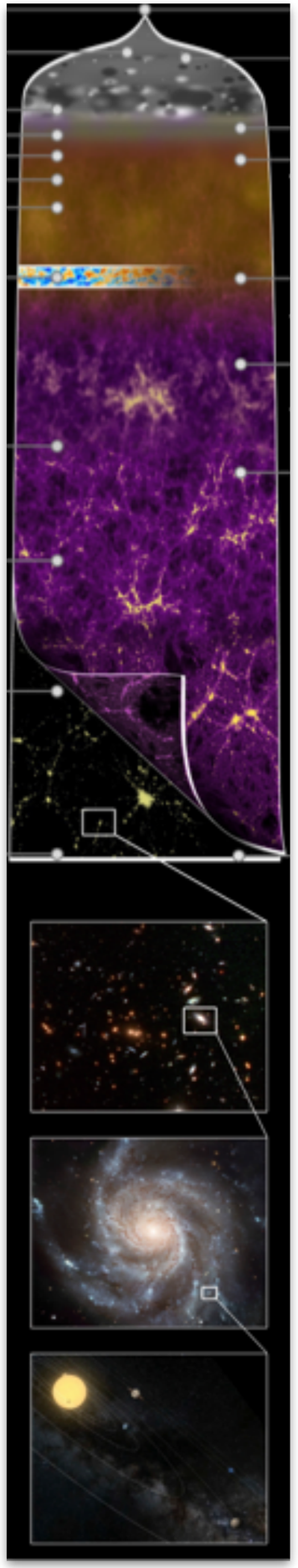


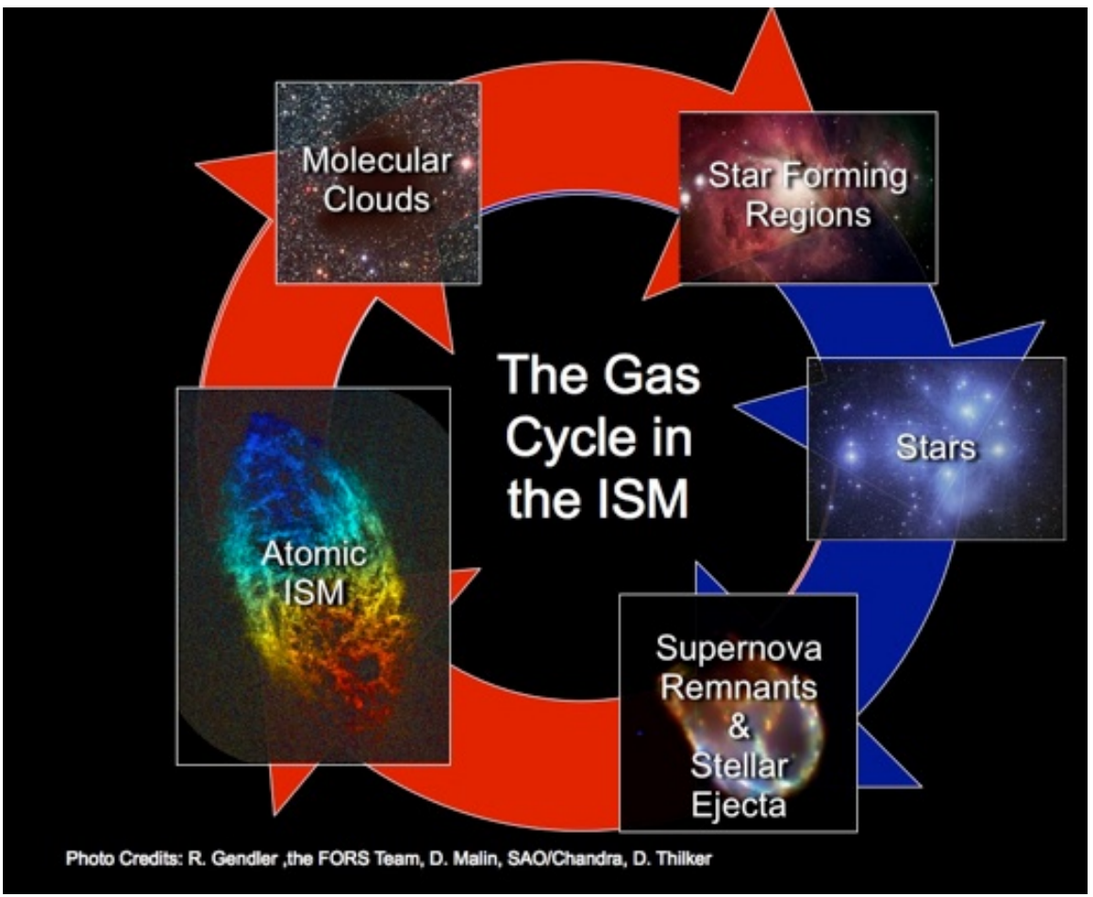
Image courtesy:
Duc & Renaud

Changing our understanding of the Universe with the SKA



Galaxy evolution





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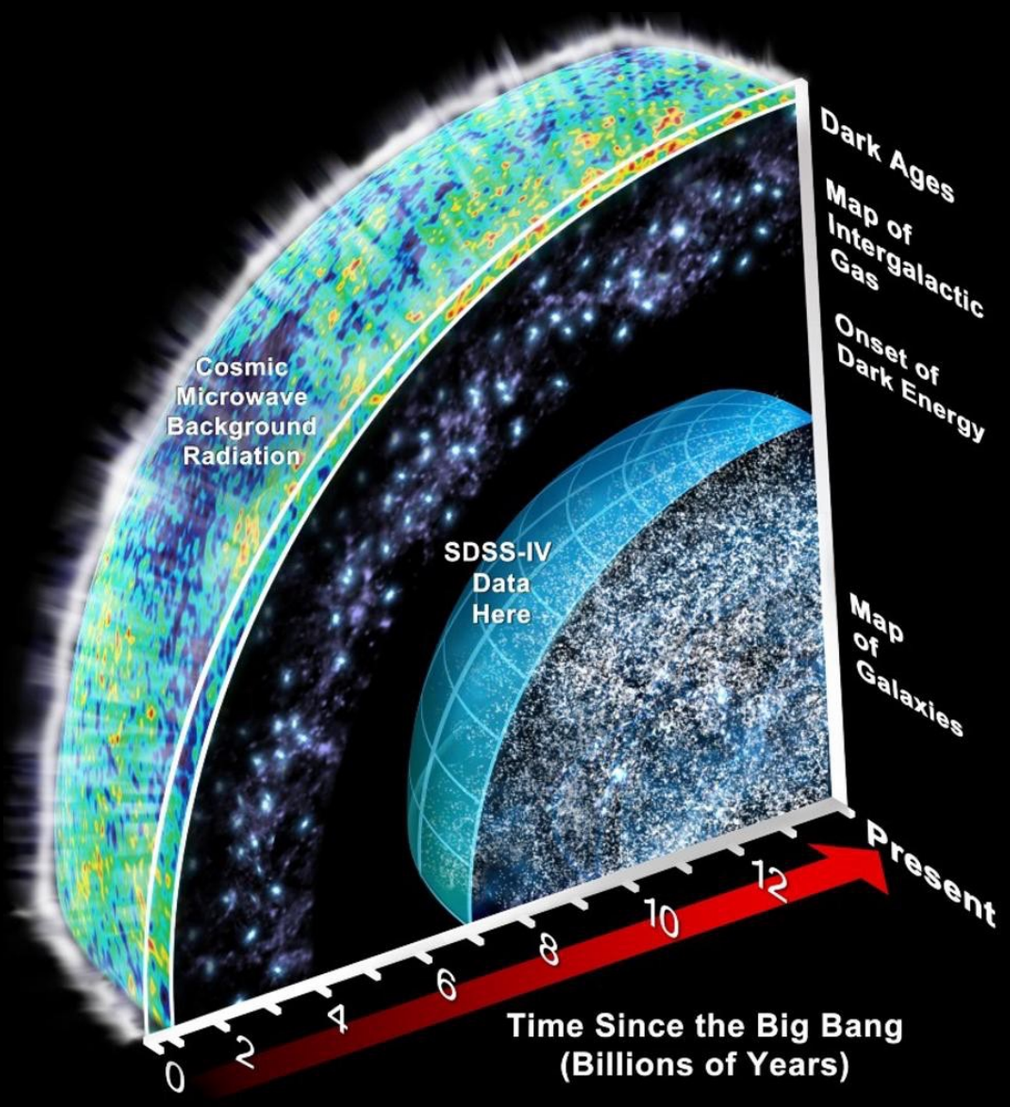
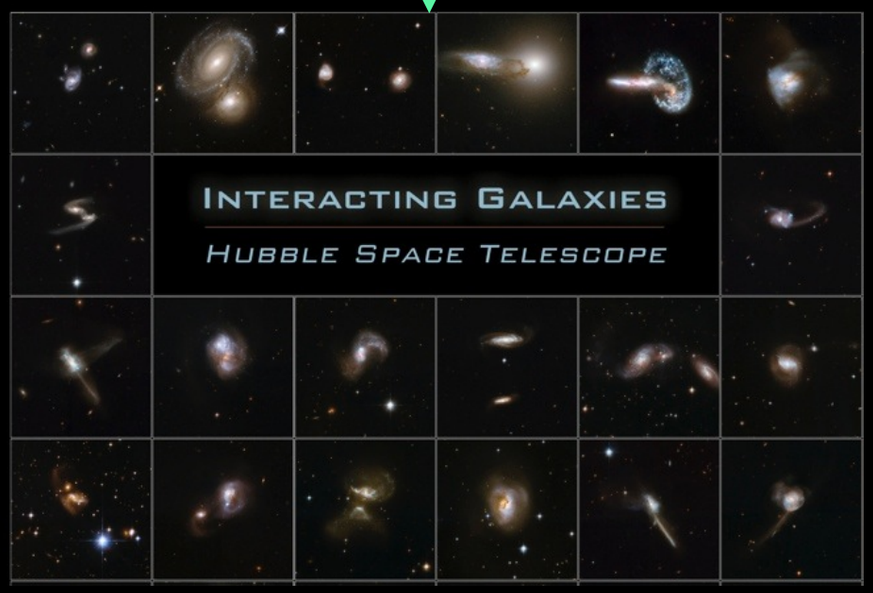
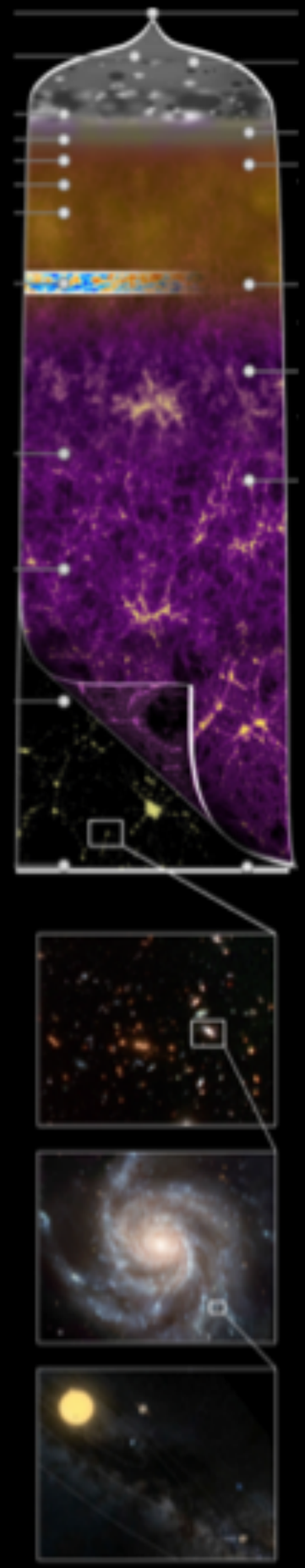
SQUARE KILOMETRE ARRAY

Changing our understanding of the Universe with the SKA







SKA FRANCE
SQUARE KILOMETRE ARRAY

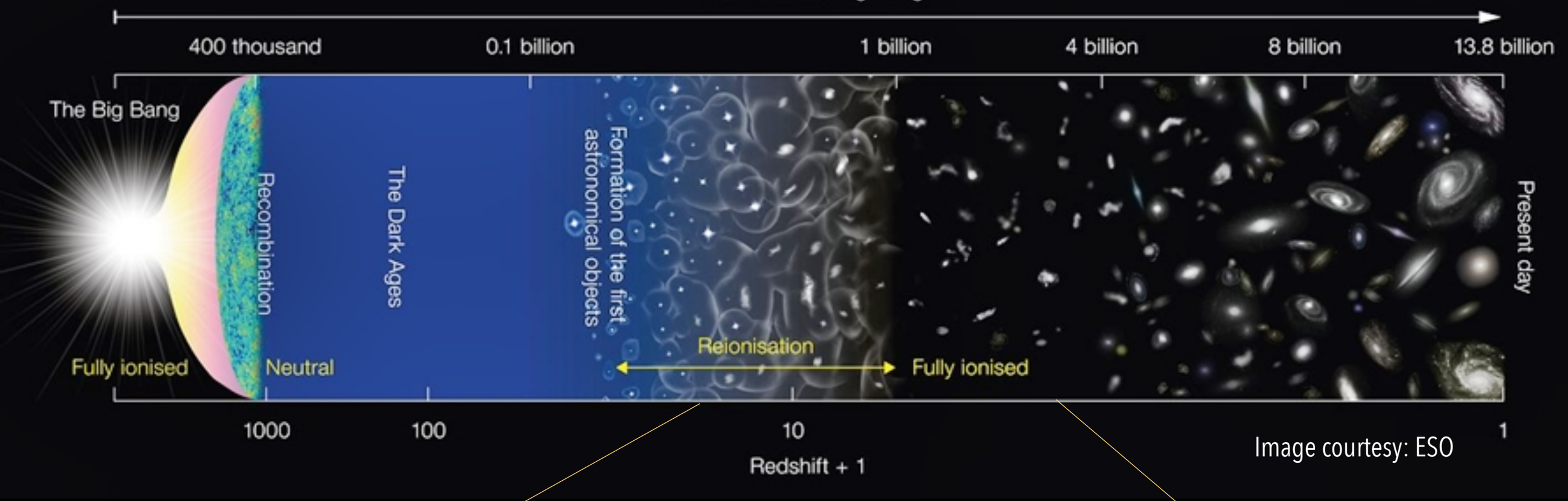


Image courtesy: ESO

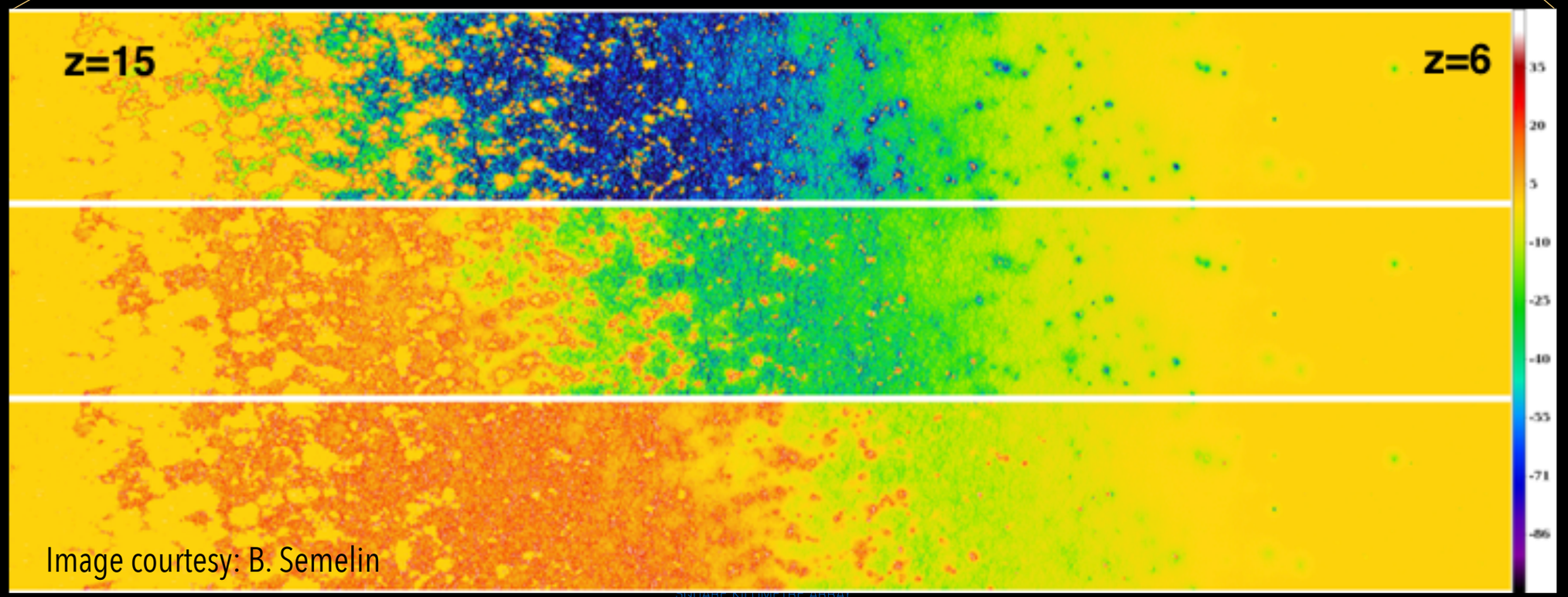
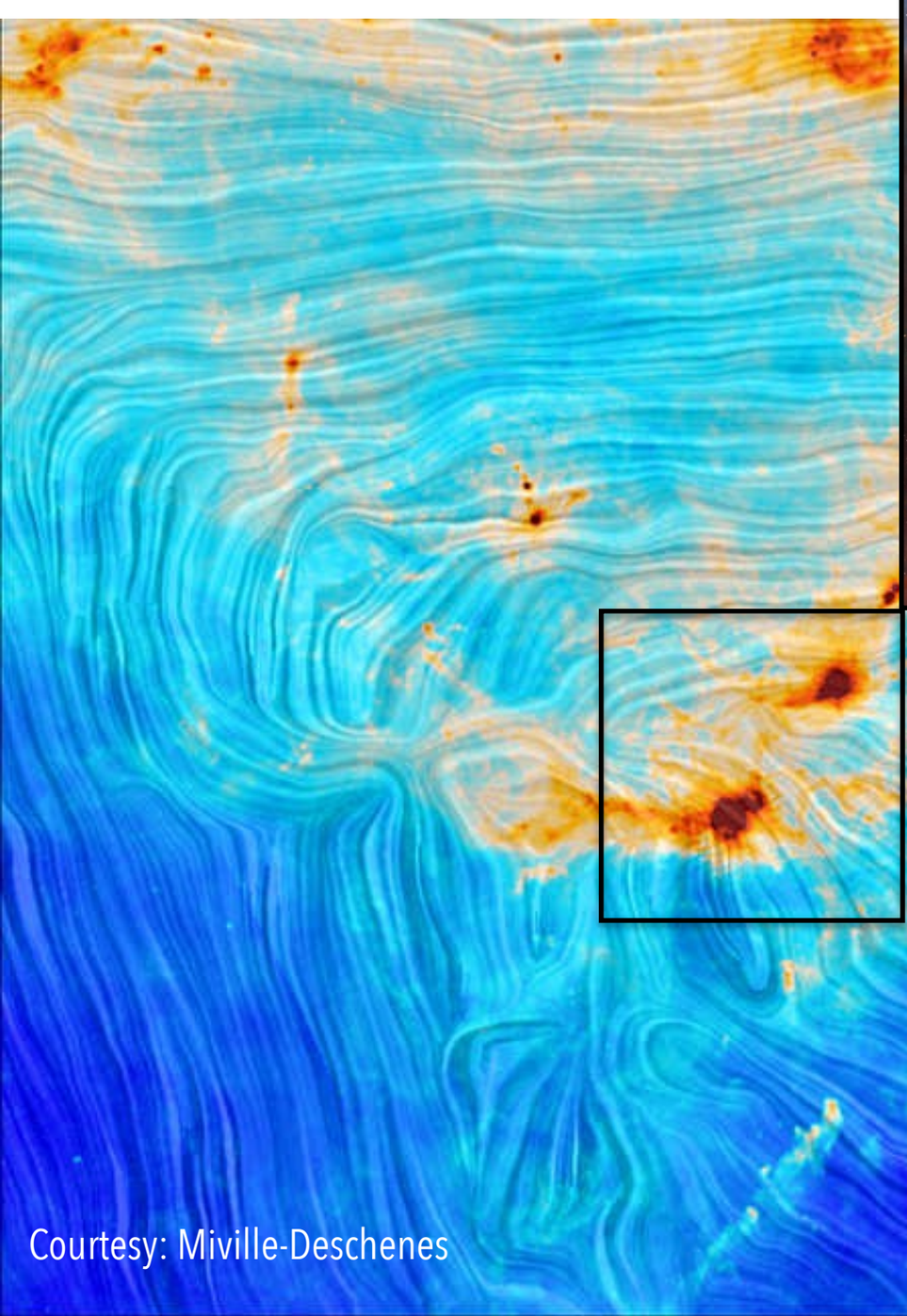


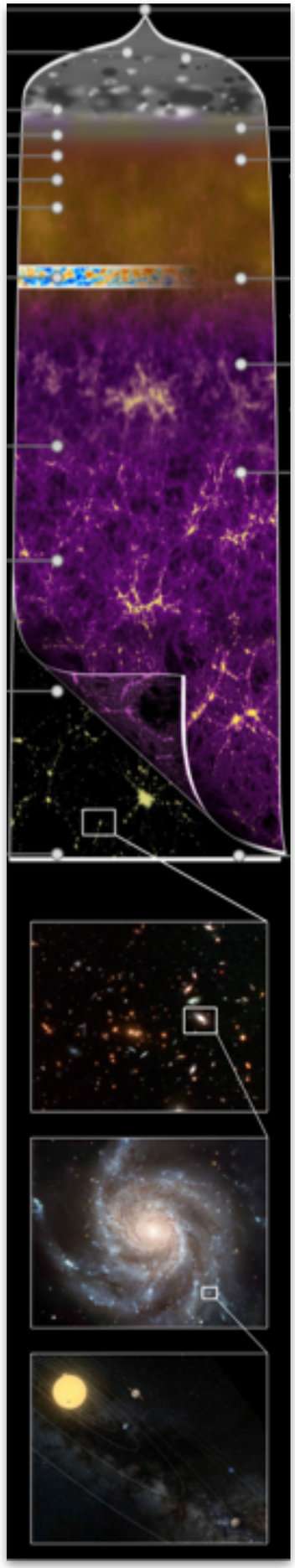
Image courtesy: B. Semelin

Changing our understanding of the Universe with the SKA



Courtesy: Miville-Deschenes

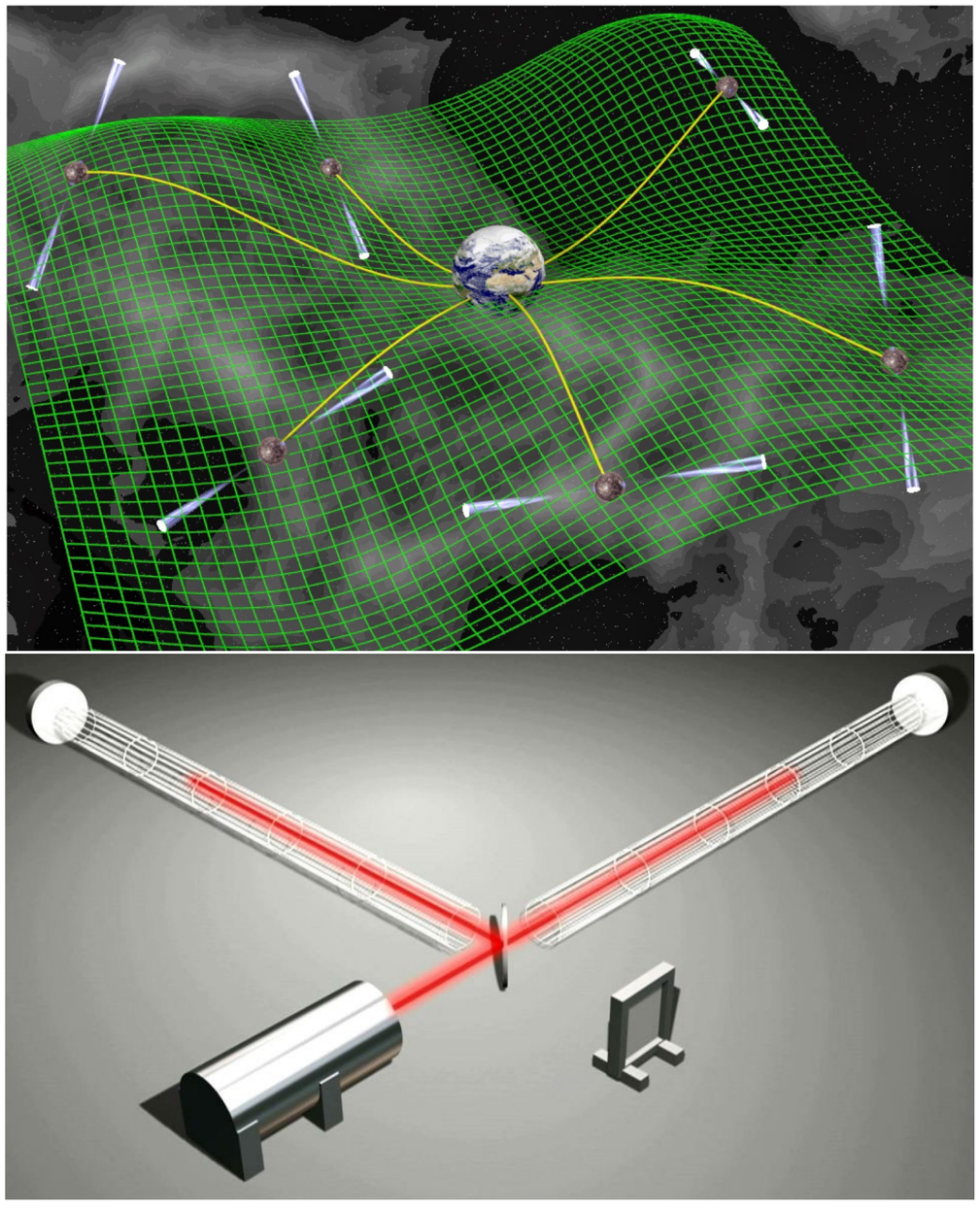
Cosmic magnetism



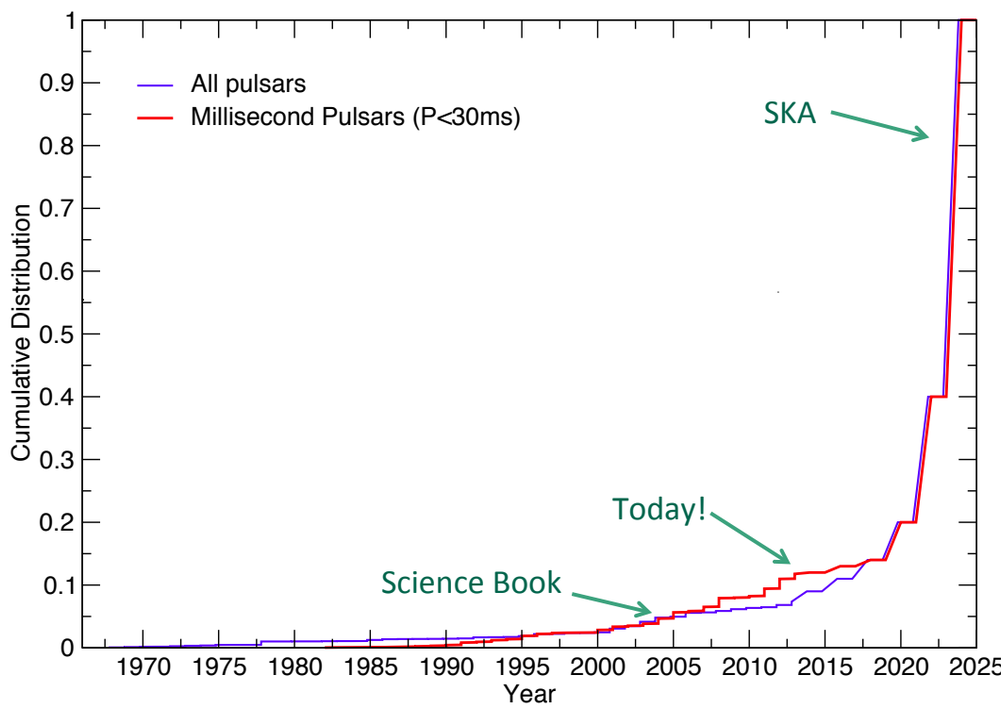
Changing our understanding of the Universe with the SKA

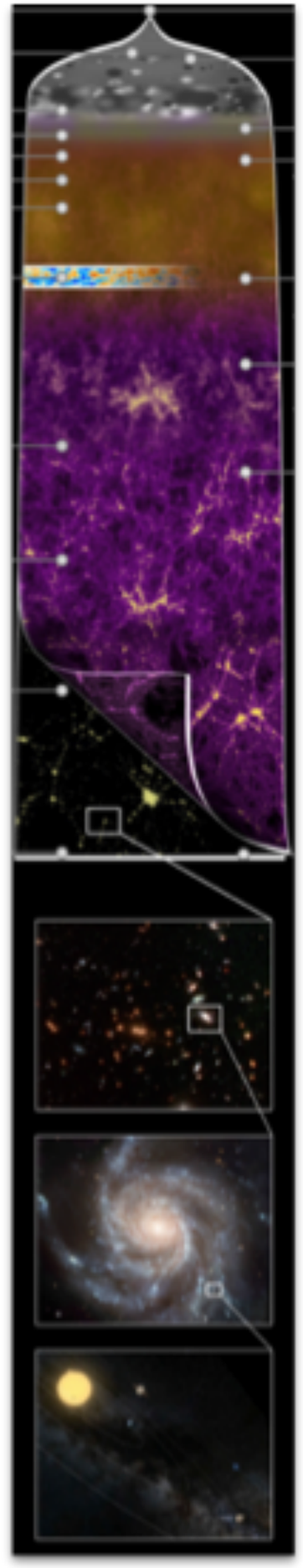
Courtesy: SKAO

Changing our understanding of the Universe with the SKA



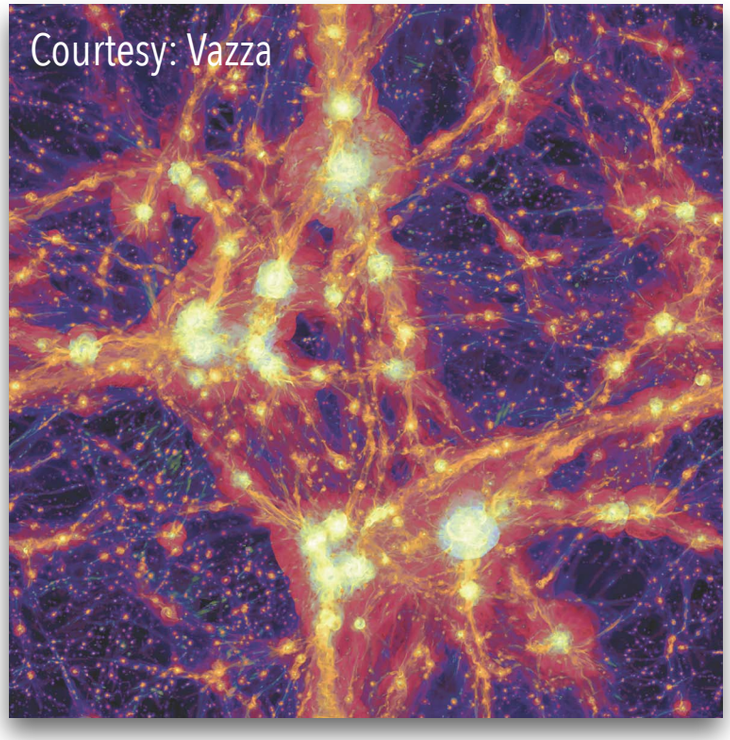
Kramer & Stappers 2015

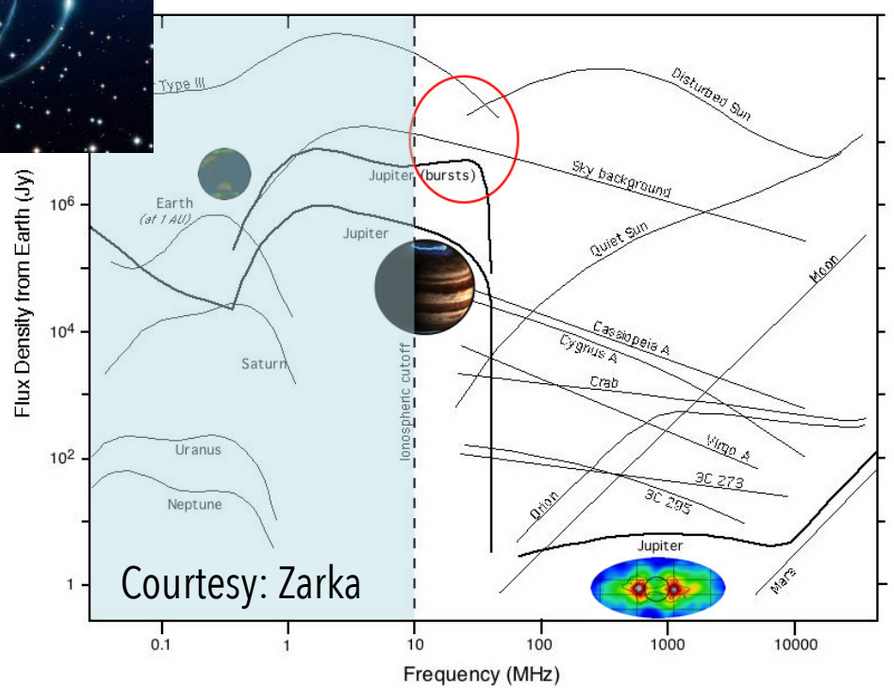




SKA FRANCE
SQUARE KILOMETRE ARRAY

Changing our understanding of the Universe with the SKA





Cosmic dawn & Epoch of Reionisation

Cosmology

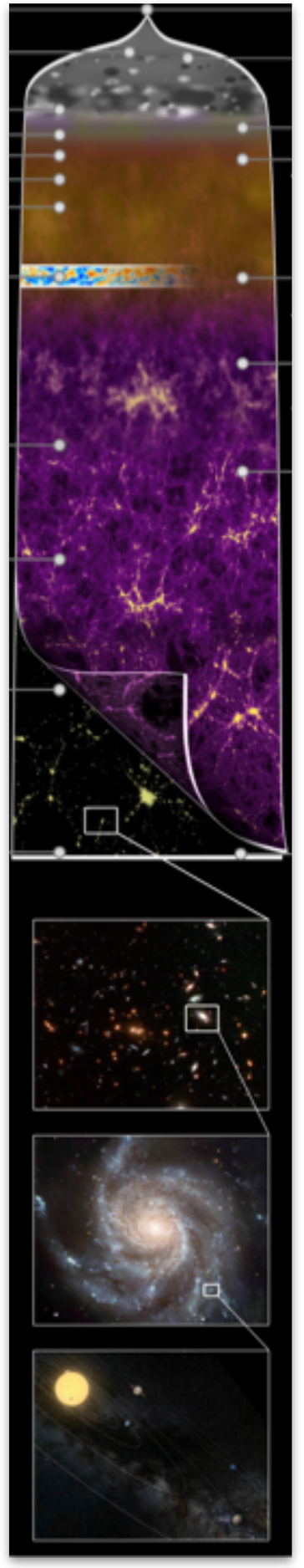
Galaxy evolution

Cosmic magnetism

Fundamental physics

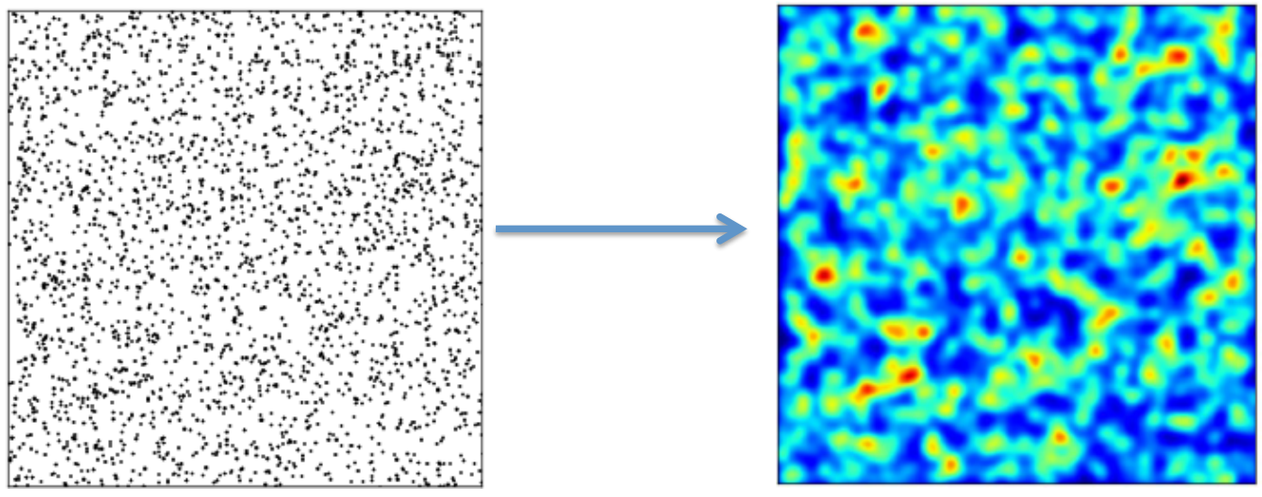
Transient sky

Cradle of life



Cosmology with the SKA

- **HI intensity mapping surveys**:
  - ~30,000 deg^2 out to z~3 in SKA1. Even though individual galaxies are not detected, the resolution is more than adequate to measure the fluctuations needed for BAO
- **Radio continuum surveys**:
  - ~30,000 deg^2 out to z~6, detecting ~10^8 galaxies in SKA1
  - ~10^9 galaxies in SKA2
- **HI galaxy redshift surveys**:
  - ~5,000 deg^2 out to z~0.7, detecting ~10^7 galaxies (SKA1)
  - ~30,000 deg^2 out to z~2, detecting ~10^9 galaxies (***SKA2 – the billion galaxy survey***)
- **Weak lensing surveys:**
  - ~5,000deg^2 survey on SKA1
  - ~30,000 deg^2 survey in SKA2



- Look at the total intensity for a given emission line in a large 3d pixel (angle and frequency)
- Pixel will have joint emission from multiple galaxies

Marteens+ 2015

Cosmology with the SKA

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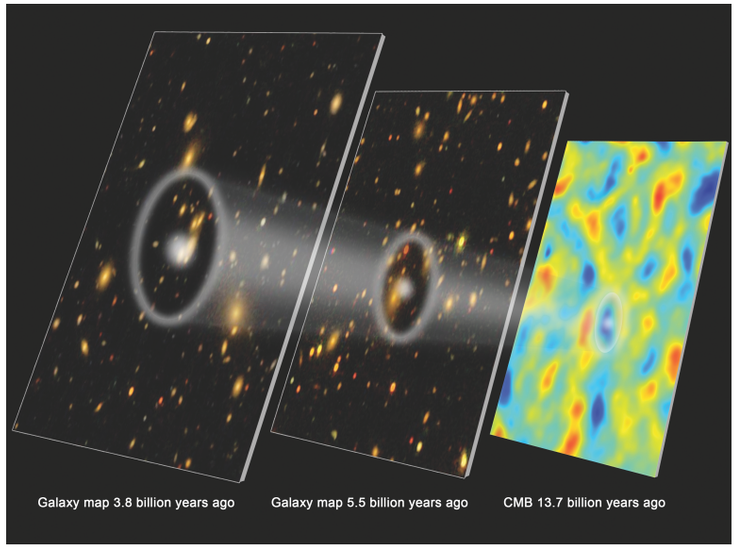
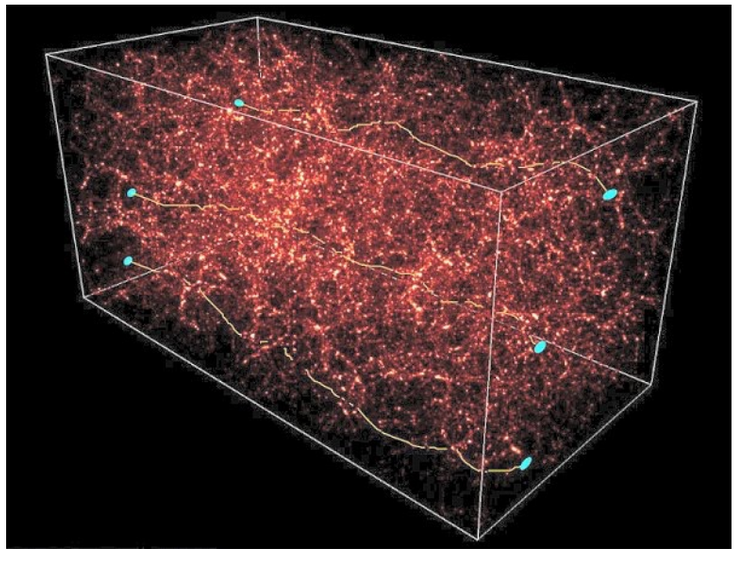
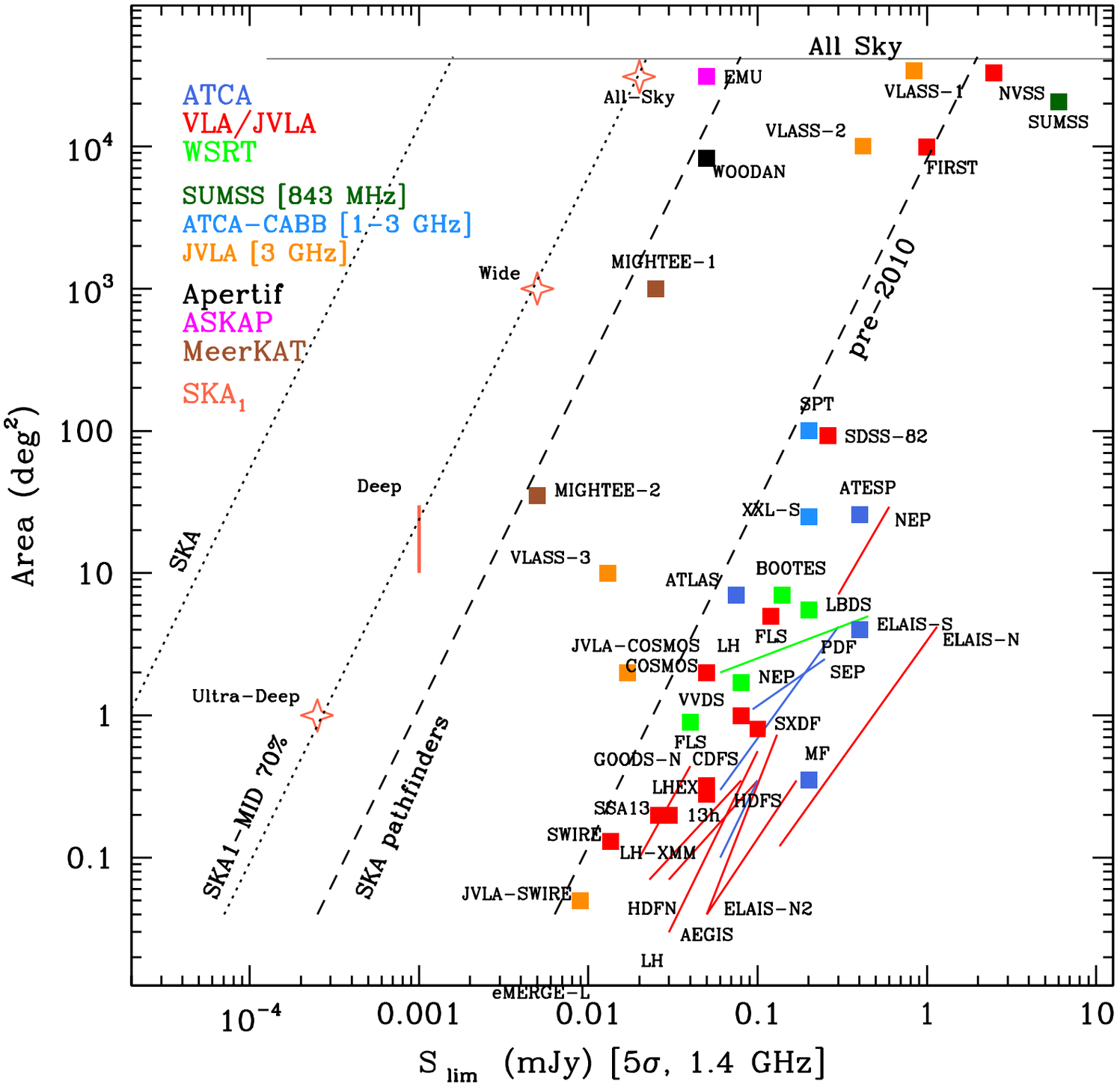


- the expansion history and geometry of the Universe
  - ➡ ‘standard ruler’ imprinted in the correlation function by the BAO
- the growth of structure
  - ➡ power spectrum of the observed density contrast
  - ➡ weak lensing survey



Marteens+ 2015

An exquisite instrument for surveying the sky



Prandoni & Seymour 2015

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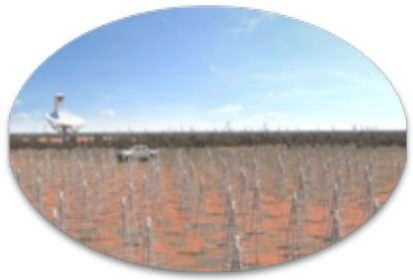
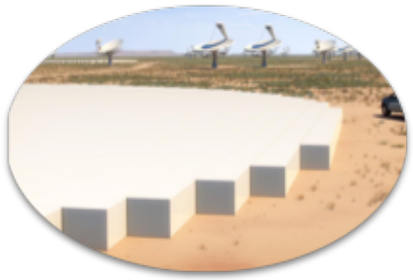
SQUARE KILOMETRE ARRAY

Why with the SKA

50 MHz ——— 25 GHz →



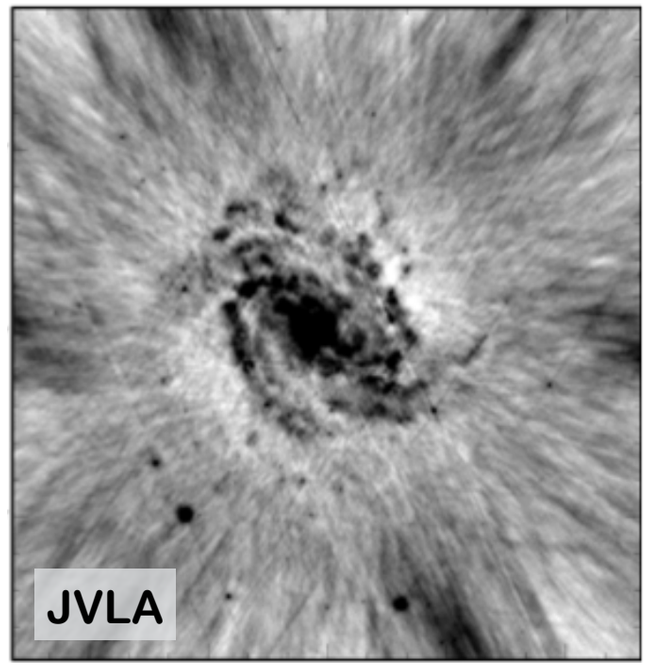
2-3 millions

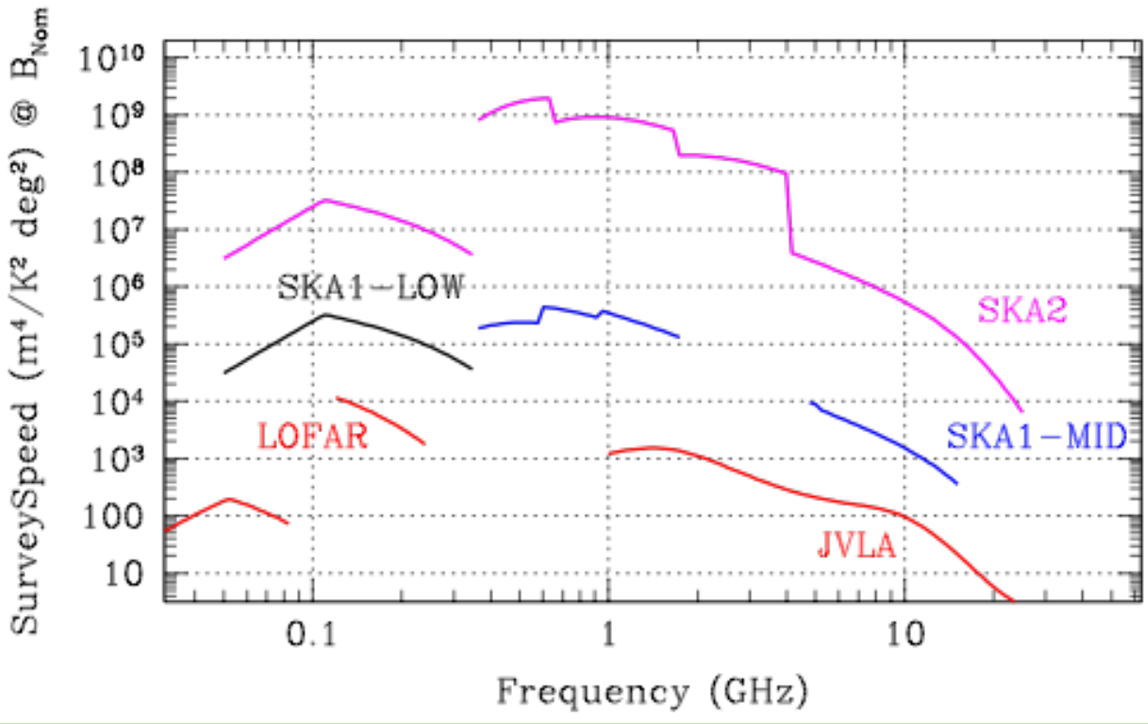


250 x 60 m

2500 x 15 m

+





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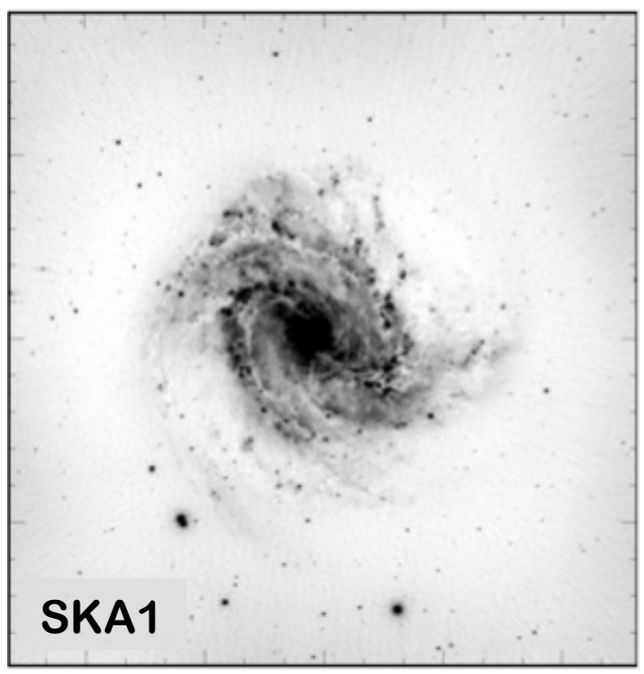


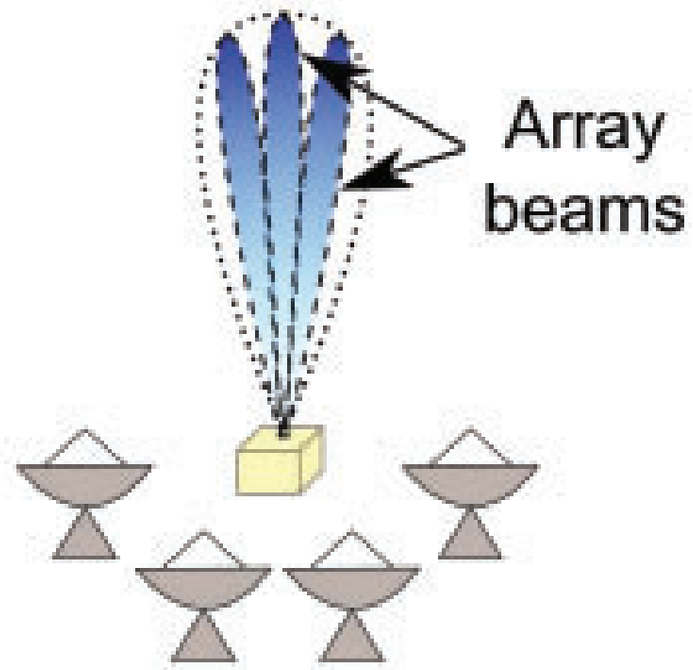
SKA FRANCE
SQUARE KILOMETRE ARRAY

Observing modes

Non-imaging (Tide Array Beams)

Pulsar Search & Timing

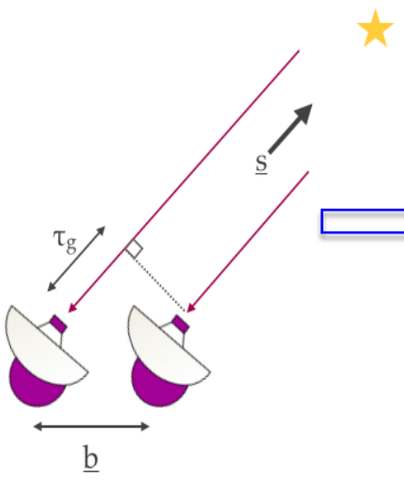
- Forms hundreds of beams within the dish/station beam
- Time resolution ~ 60-100 μs
- Data rate ~ 800 GB/s
- Archival ~ PB



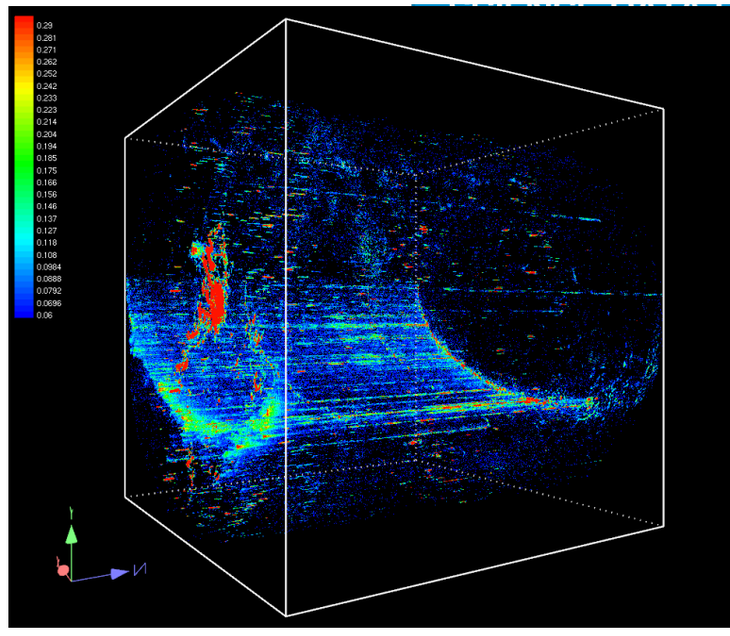
Imaging

Most of the other Key Science Topics

- 4D images (RA, Dec, Frequency, Polarization)
- Output image size ~ 1 PB
- Archival ~ 120 PB



$$T(x,y) = \int\int V(u,v) e^{-2\pi i(ux+vy)} dudv$$



SKA FRANCE
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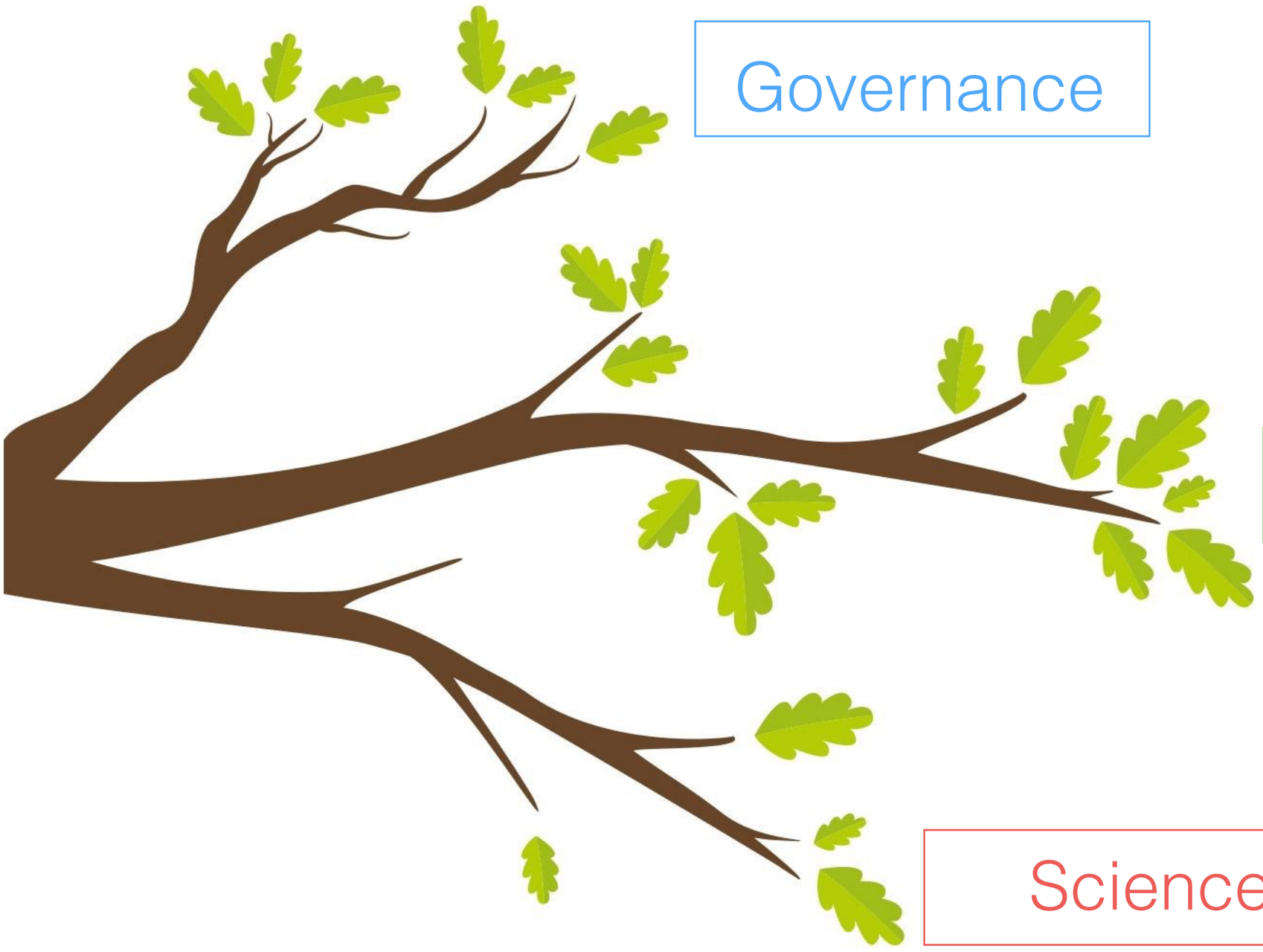
Development of the SKA project



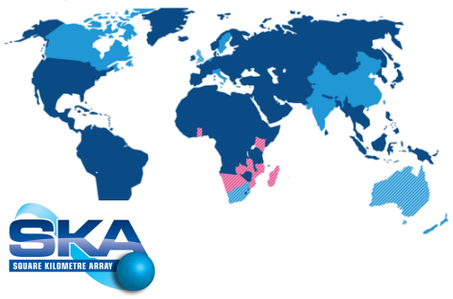
Governance

Technology

Science

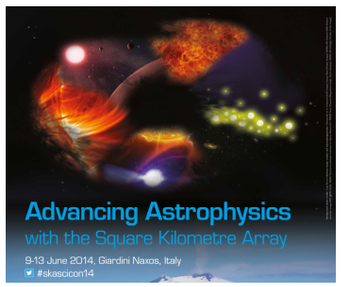
Development of the SKA project

2012



2013

2014



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SQUARE KILOMETRE ARRAY

Development of the SKA project

2012 — SKAO

2013 — Technical consortia

2014 - 2015 — SWG Meeting

2016

2017

	Design Baseline	Deployment Baseline
SKA1-Mid		
No. dishes	133 + 64*	130 + 64*
Max. Baseline	150 km	120 km
Band 1 Feeds	133	130
Band 2 Feeds	133	130
Band 5 Feeds	133	67
Pulsar Search (PSS)	500 nodes	375 nodes
SKA1-Low		
No. stations	512	476
Max. Baseline	65 km	40 km
Pulsar Search	167 nodes	125 nodes
Common		
Compute Power	260 PFLOPs	50 PFLOPs

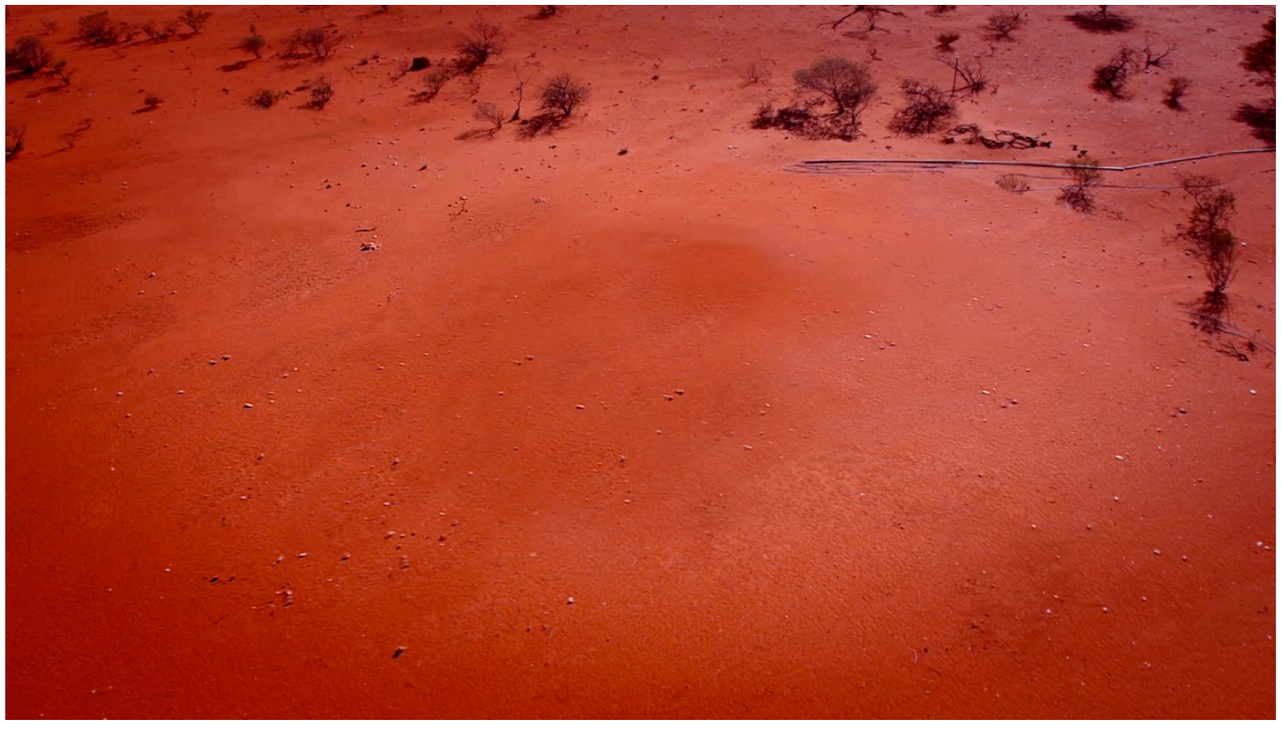
SKA FRANCE
SQUARE KILOMETRE ARRAY

SKA Phase 1 (SKA1)

SKA1-LOW (AUS)
130,000 log periodic antennas

SKA1-MID (SA)
197 dishes (15m)

50 MHz — **350 MHz** — **15 GHz** →



Development of the SKA project

2012 — SKAO

2013 — Technical consortia

2014 - 2015 — SWG Meeting; KSP

2016 — IGO negotiates start

2017 - 2018 — Deployment baseline

2019

SKA FRANCE
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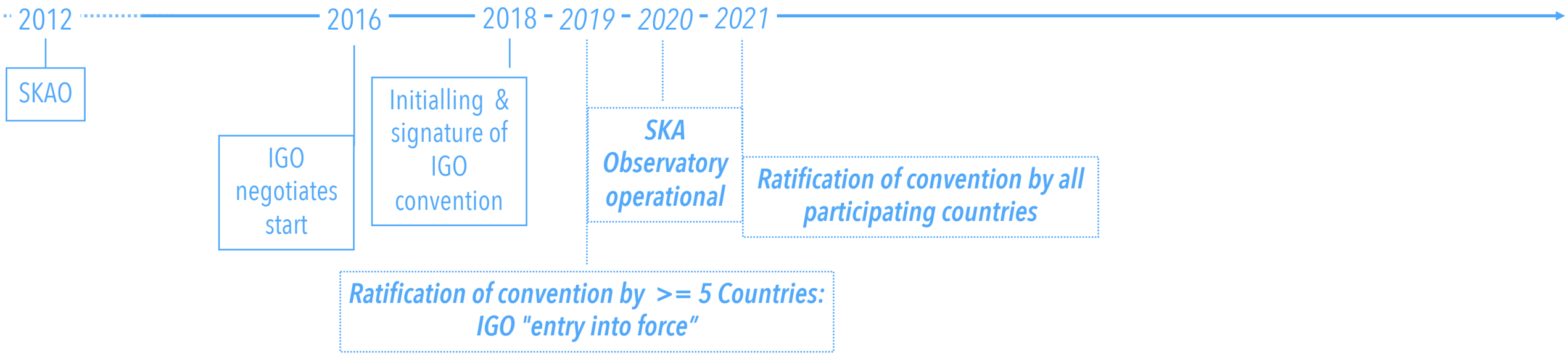
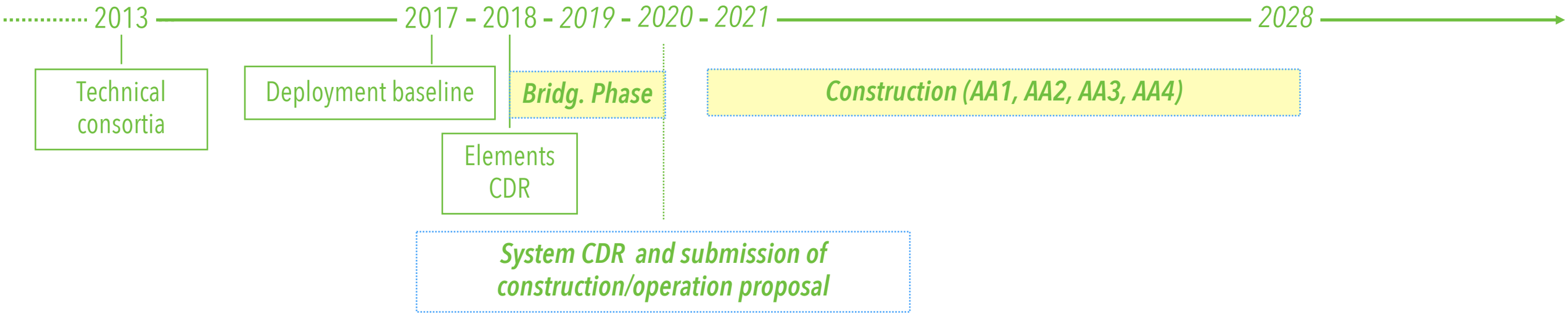
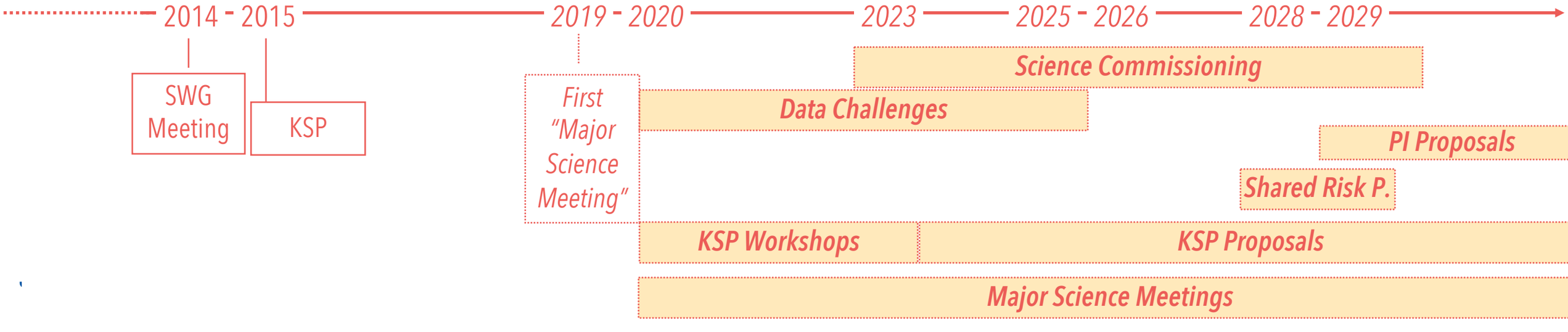
Development of the SKA project



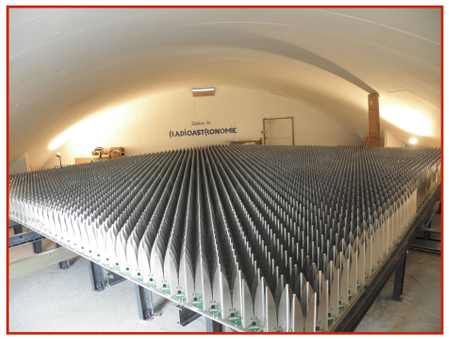




Timeline of the SKA project in France

2010 — 2011 — 2012 — 2015 — 2016 — 2017 — 2018 — 2020

Revision of the national roadmap

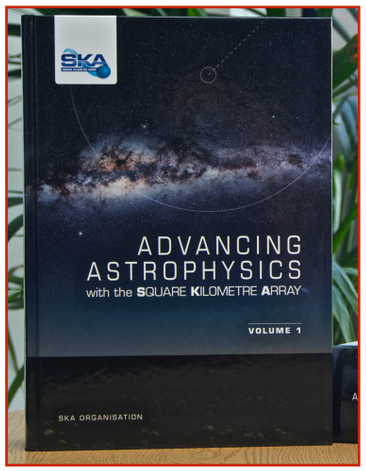


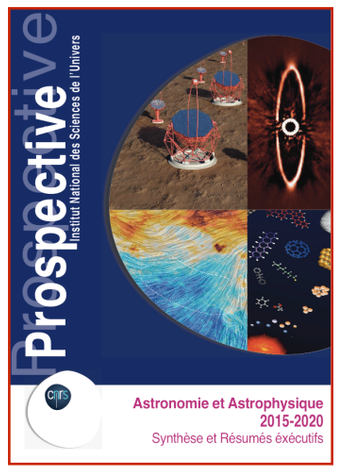
PrepSKA SQUARE KILOMETRE ARRAY

SKADS

SKA FRANCE SQUARE KILOMETRE ARRAY

cnrs — l'Observatoire de Paris — Observatoire de la CÔTE d'AZUR — université de BORDEAUX — UNIVERSITE D'ORLEANS





SKA FRANCE SQUARE KILOMETRE ARRAY

The French SKA White Book

178 authors from

* 40 French research institutes

* 6 private companies

SKA FRANCE
SQUARE KILOMETRE ARRAY

SKA: the radiotelescope of the XXIst century

SKA: a unique instrument

- French radio-astronomers are involved in the SKA scientific preparation
  - users of national et international radio-telescopes
  - all SKA Science Working Groups have French participants

SKA FRANCE
SQUARE KILOMETRE ARRAY

A wider and wider community

SKA: an interdisciplinary instrument

- The richest synergy chapter ever published about SKA vs. other projects, including:
  - instruments covering the whole electromagnetic spectrum
  - gravitational wave detectors

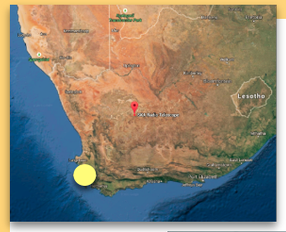
The SKA: an “exascale telescope”

SKA1-MID

8.8 Tb/s

7.2 Tb/s

Pulsar search & Correlation



2 x 5 Tb/s

SKA1-LOW

~2 Pb/s

Beam-forming

250 PFLOPS

Imaging & Science

350 PB/telescope/yr
(could be a lot, lot, lot more)

SKA Regional Centres

SKA FRANCE
SQUARE KILOMETRE ARRAY

February 2018: Maison SKA France

- A MoU between research organisations and their industry partners
- A science and technology roadmap
- A forum to develop fundamental research and R&D projects

May 2018: SKA as TGIR project within national roadmap

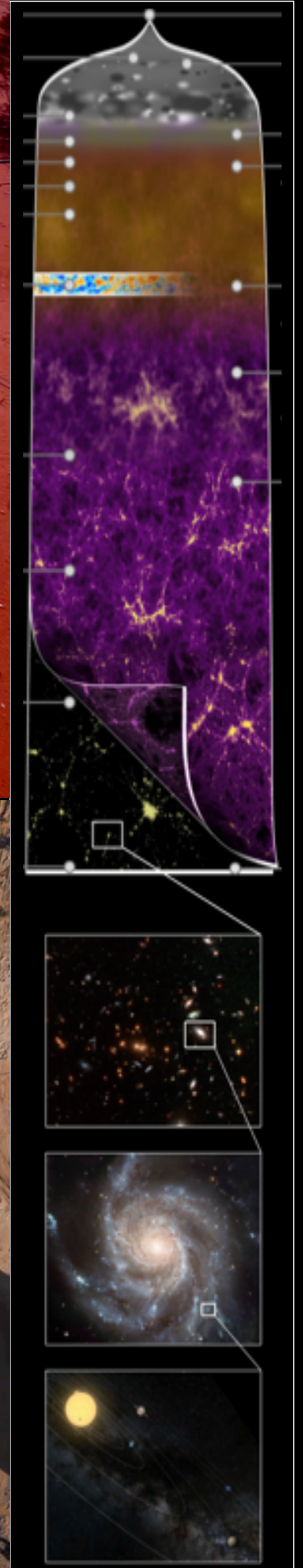
July 2018: CNRS new member of SKA Organisation

February 2018: Maison SKA France

- A MoU between research organisations and their industry partners
- A science and technology roadmap
- A forum to develop fundamental research and R&D projects

2020/2021: Next revision of the French roadmap

July 2018: CNRS new member of SKA Organisation



Thanks!

chiara.ferrari@oca.eu