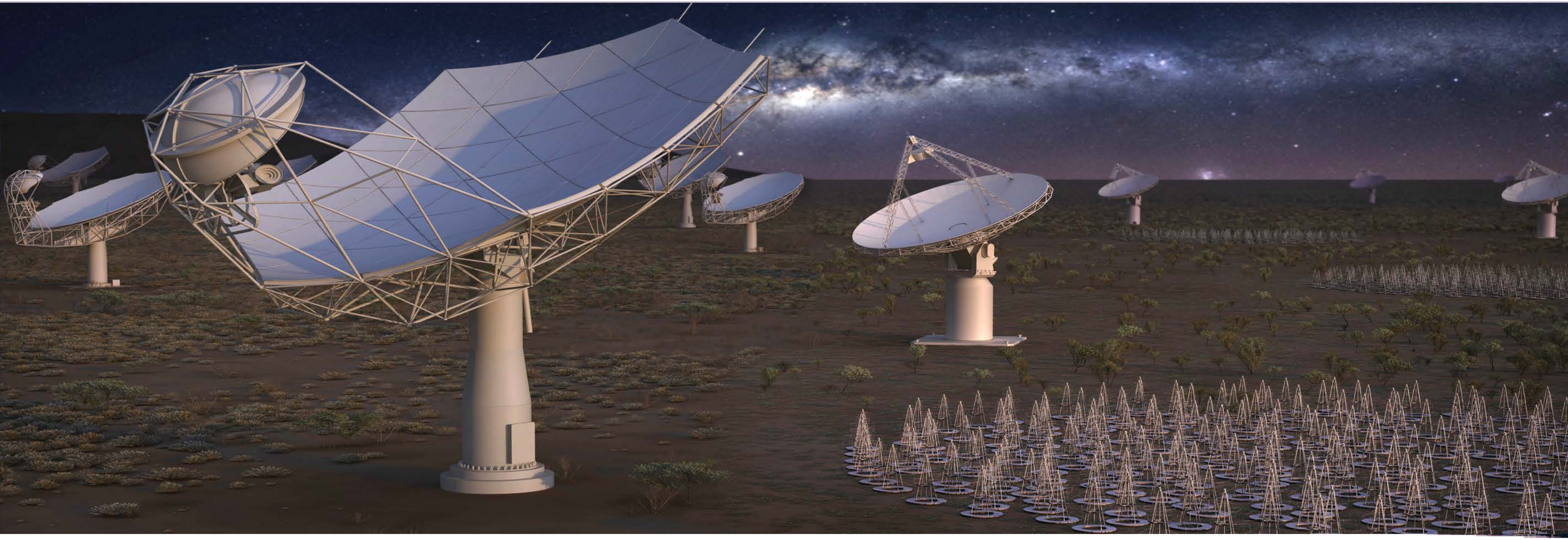
SKA Science and Coordination with Multi-messenger facilities

Groningen March 2019

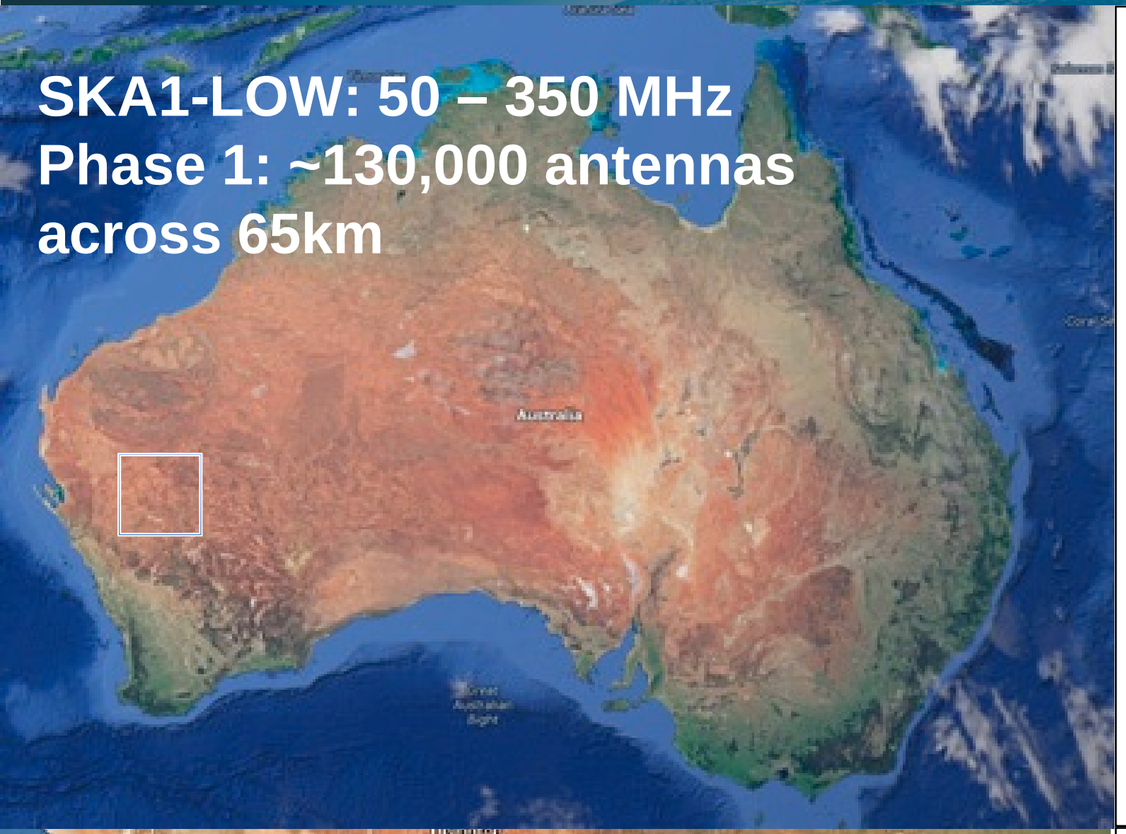


SQUARE KILOMETRE ARRAY

Exploring the Universe with the world's largest radio telescope

A. Bonaldi

Project scientist


SKA1-LOW: 50 – 350 MHz
Phase 1: ~130,000 antennas across 65km
Australia


SKA1-Mid: 350 MHz – 24 GHz
Phase 1: 200 15-m dishes across 150 km
Bloemfontein
Springbok
Lesotho
SKA Radio Telescope
Mthatha
East London
Graham's town
Oudtshoorn

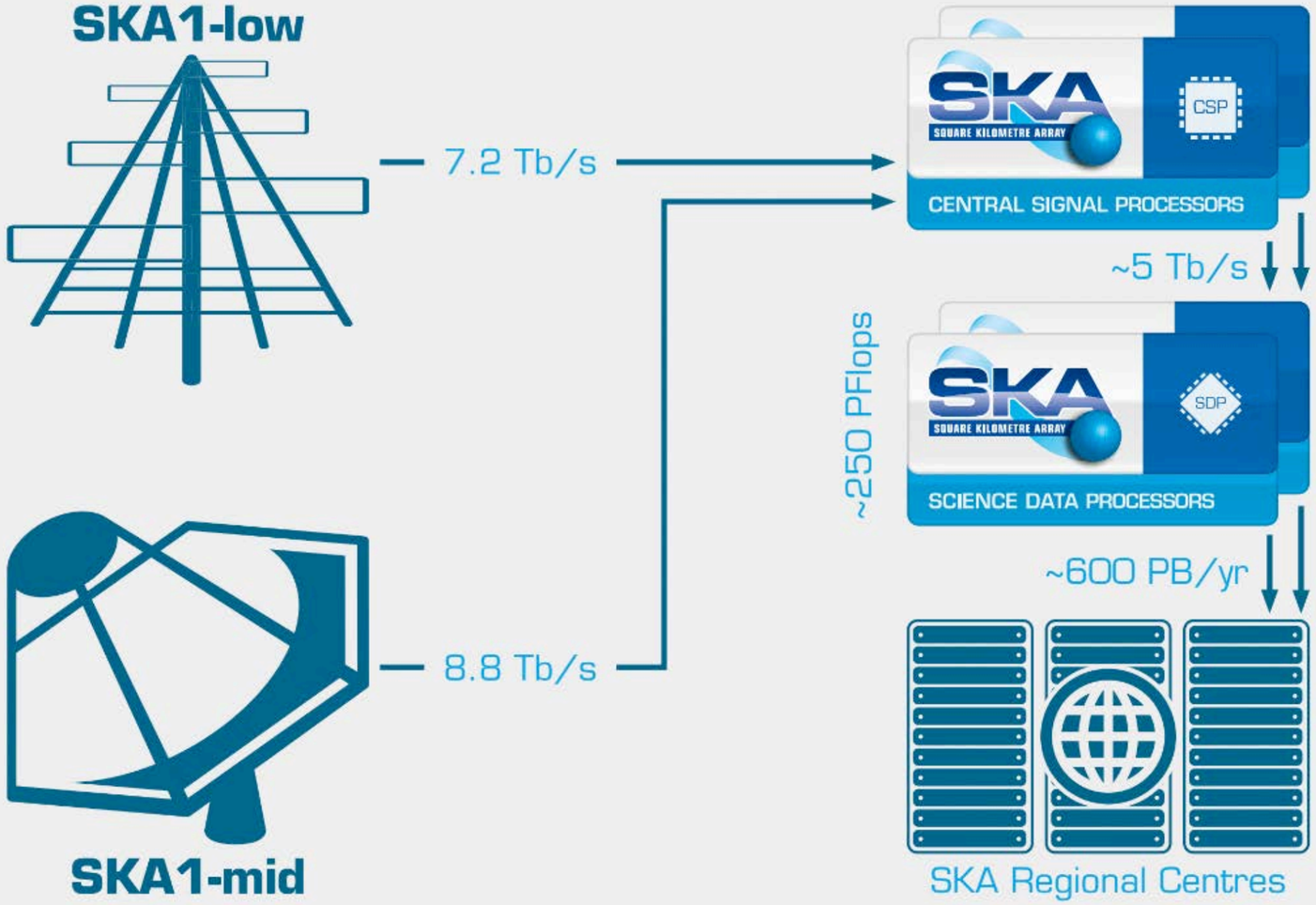
Members
Host Countries: Australia, South Africa, United Kingdom

African Partner Countries

This map is intended for reference only and is not meant to represent legal borders

SKA convention signing – 12 March 2019

Australia
South Africa
UK
Italy
Netherlands
China
Portugal



SKA1 OPERATIONAL CONCEPT DOCUMENT

Major dates

2017–2018
Prototypes deployed at the telescope sites

2020
Start of construction activities

2022
Start of Observatory & Science commissioning

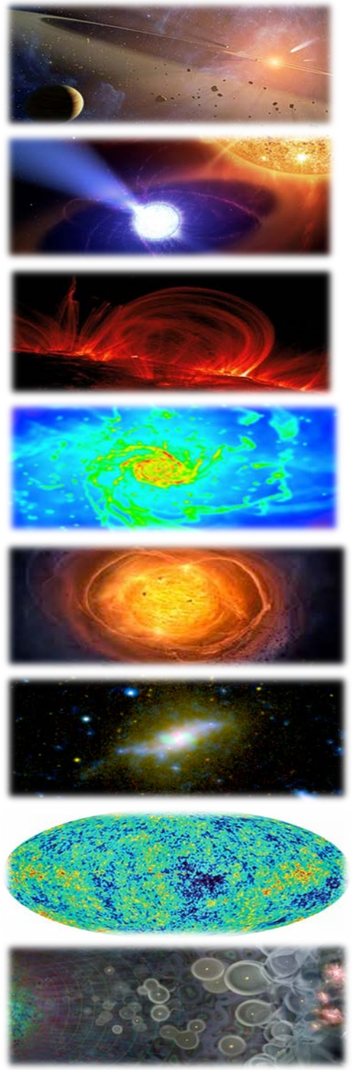
2024–2027
Key Science Project (KSP) planning & proposals

late 2026
Commencement of PI-led programmes

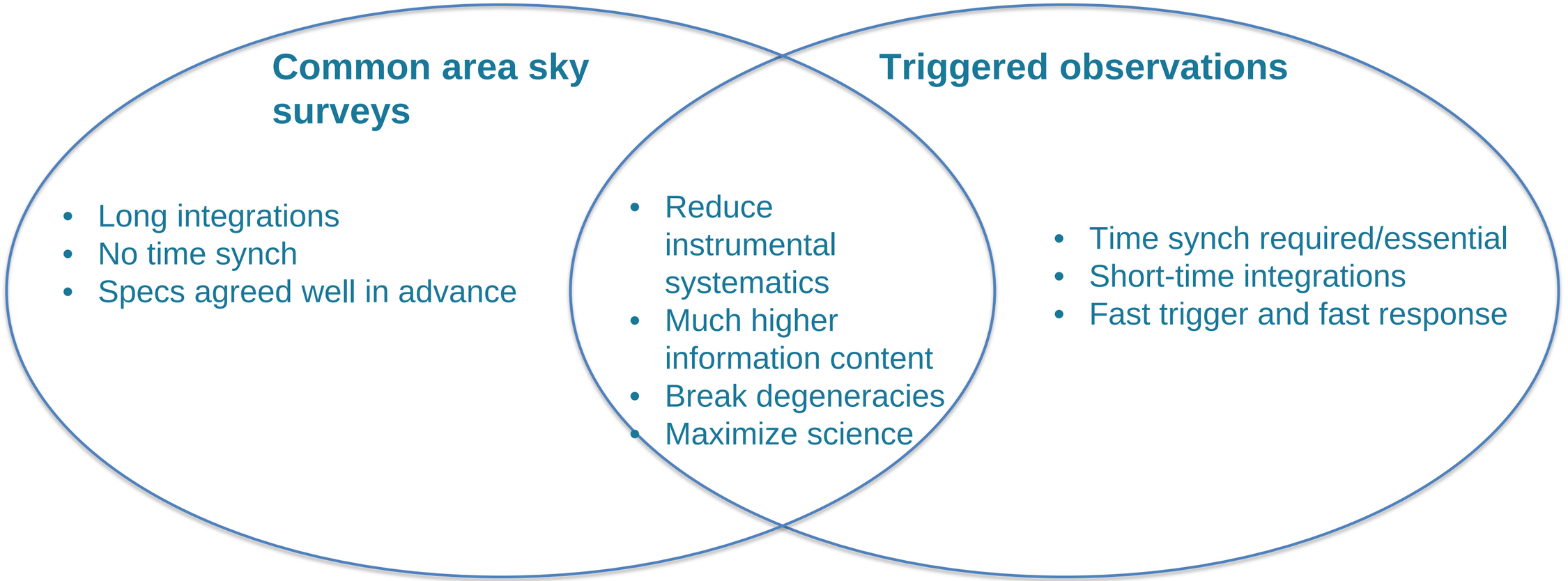
late 2027
Commencement of KSPs

SKA Big 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?*
- **The Transient Radio Sky**
  - *What are Fast Radio Bursts? What haven't we discovered?*
- **Galaxy Evolution probed in the Radio Continuum**
  - *What is the star-formation history of normal galaxies?*
- **Cosmology & Dark Energy**
  - *What is dark matter? What is the large-scale structure of the Universe?*
- **Cosmic Dawn and the Epoch of Reionization**
  - *How and when did the first stars and galaxies form?*



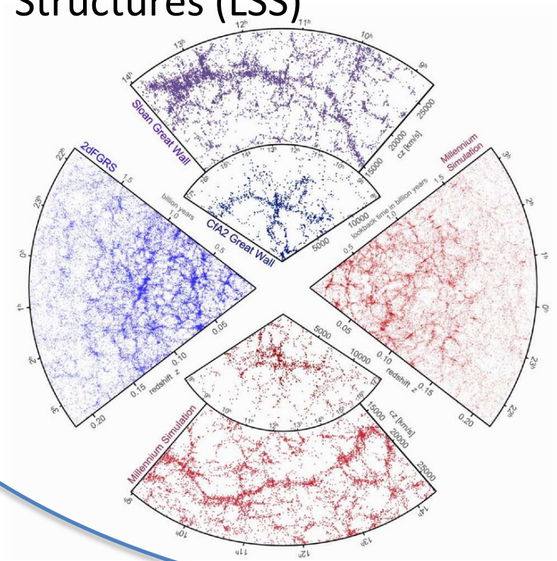
SKA MW/MM synergies



SKA MW/MM synergies

Common area sky survey

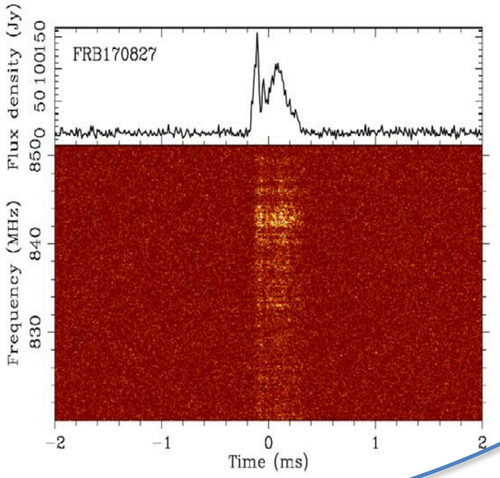
Cosmology with Large Scale Structures (LSS)



- Reduce instrumental systematics
- Much higher information content
- Break degeneracies
- Maximize science

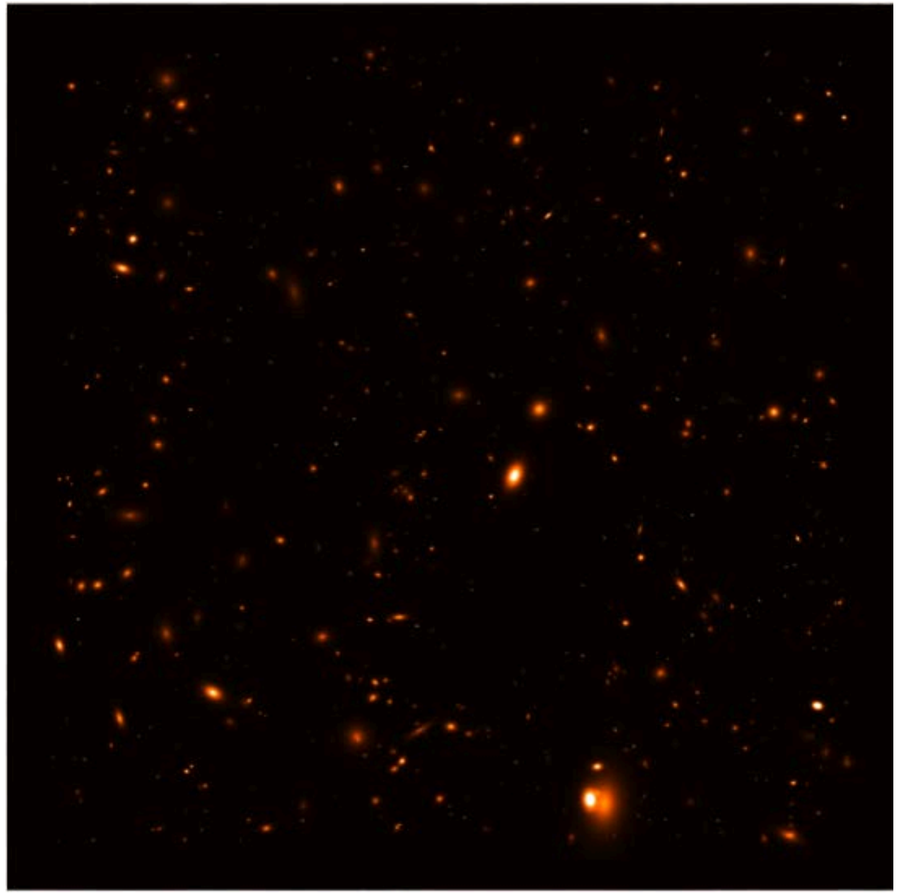
Triggered observations

Coordinated FRB localisation and characterisation



Measuring redshifts for SKA surveys

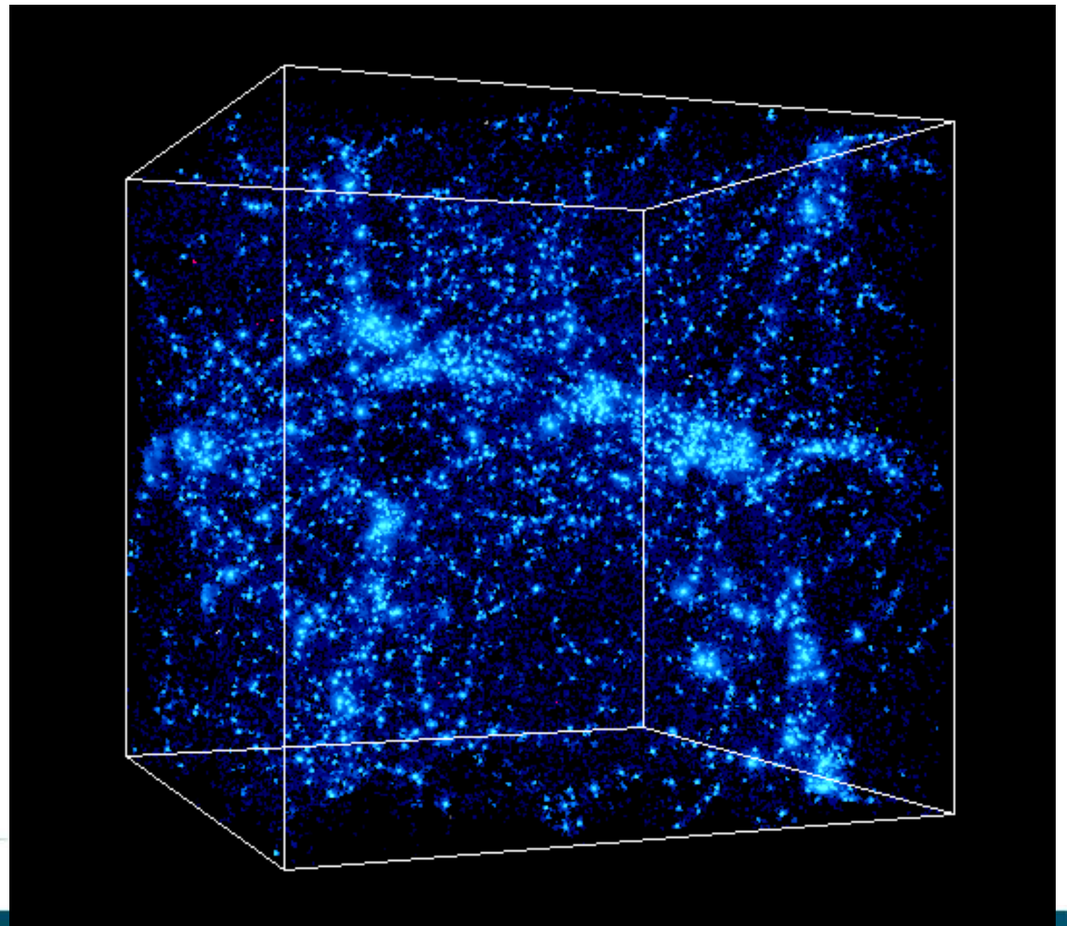
2D radio map



Optical/IR data:

photometric z , spectroscopic z

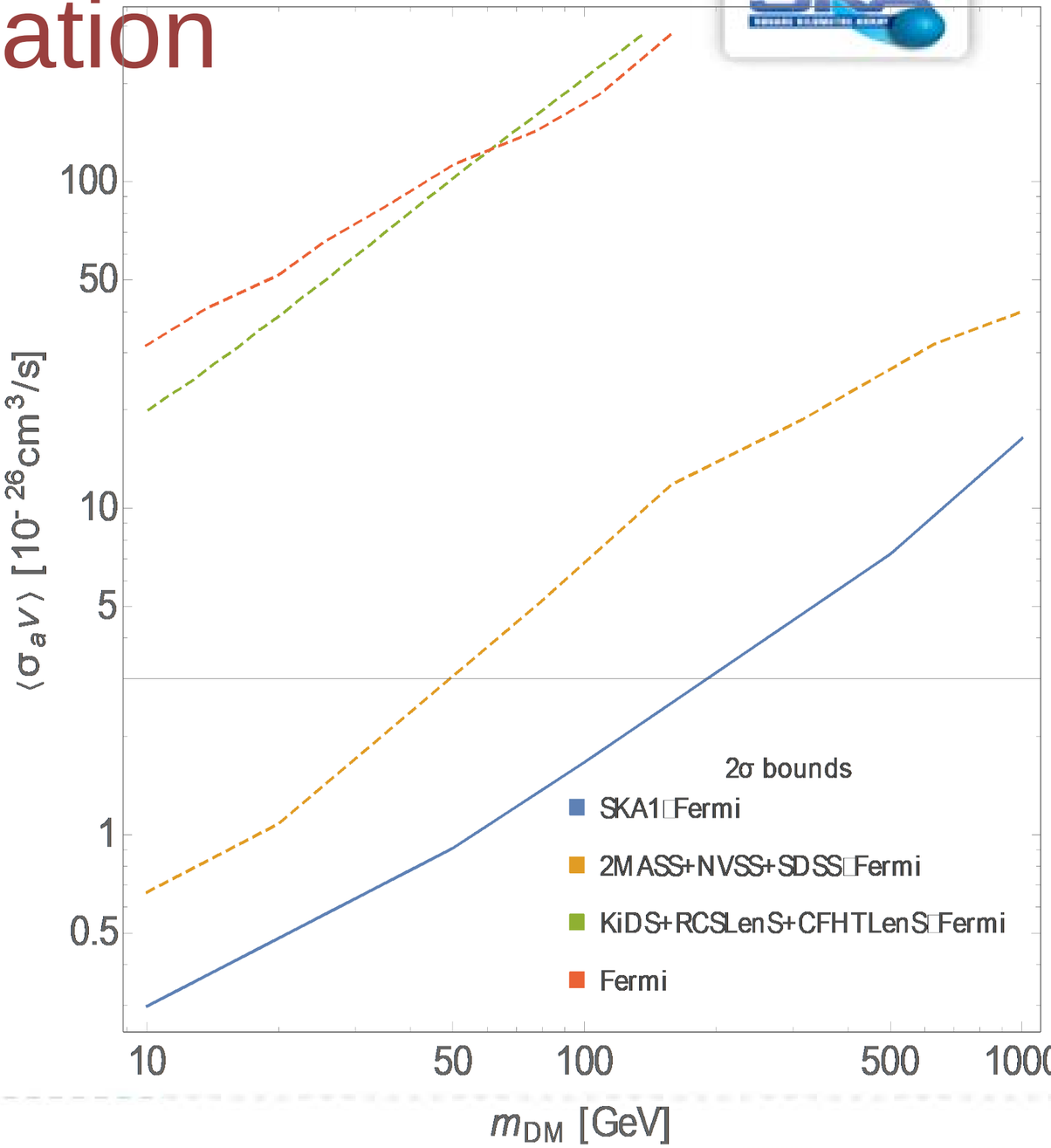
3D radio map + redshifts



Much better constraint on Dark Energy

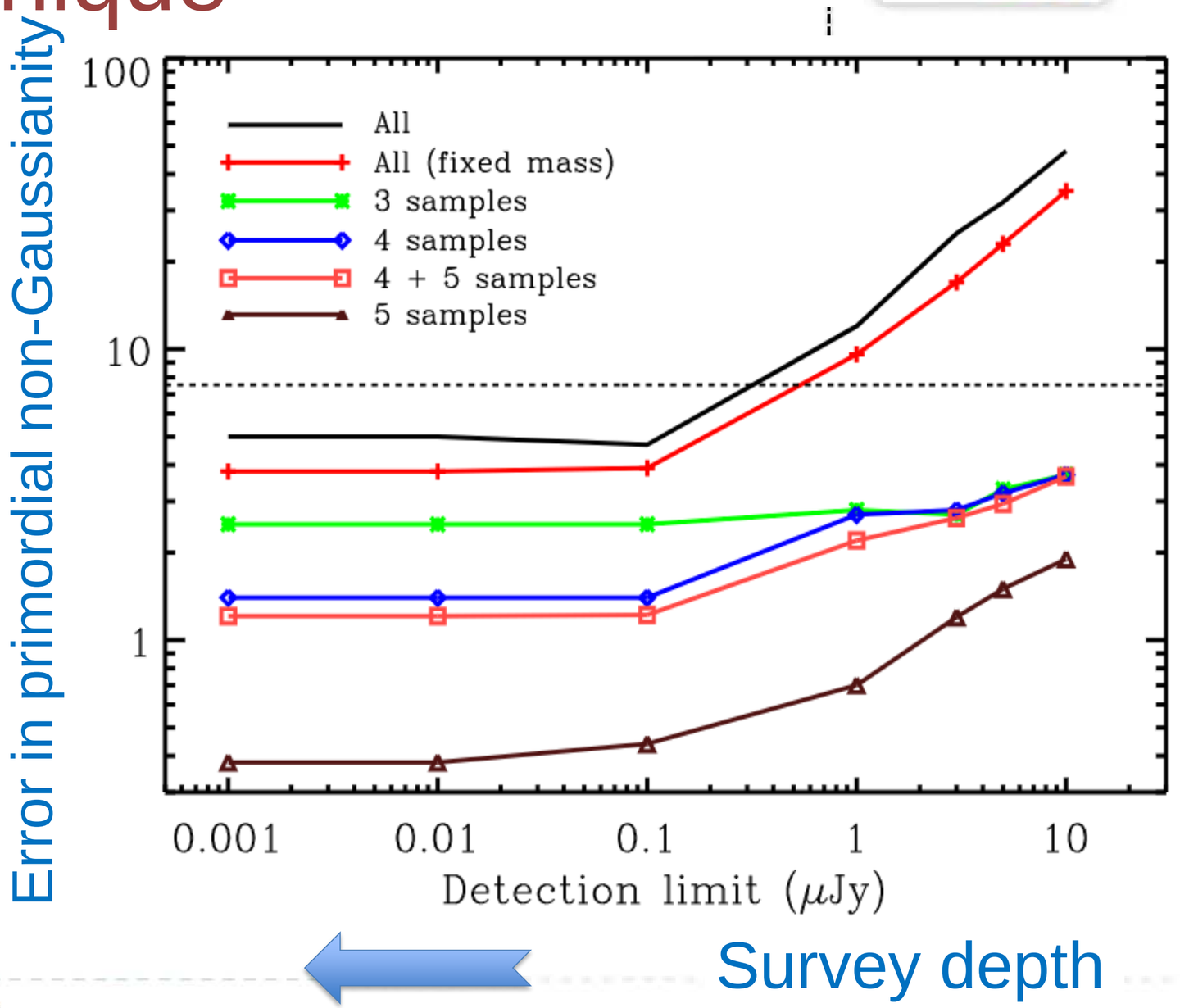
The power of cross-correlation

Constraints on Dark Matter particle models require radio (**SKA**), gamma ray (Fermi, **CTA**) and neutrino (**KM3NET**) data to separate the signal of DM annihilation from the astrophysical (e.g. blazars).



The multi-tracer technique

Radio+high energy radiation (X-ray, ©-ray, **CTA**) distinguishes between active and “normal” galaxies thus improving the constraining power of the survey



Coordinated FRB localisation and characterisation

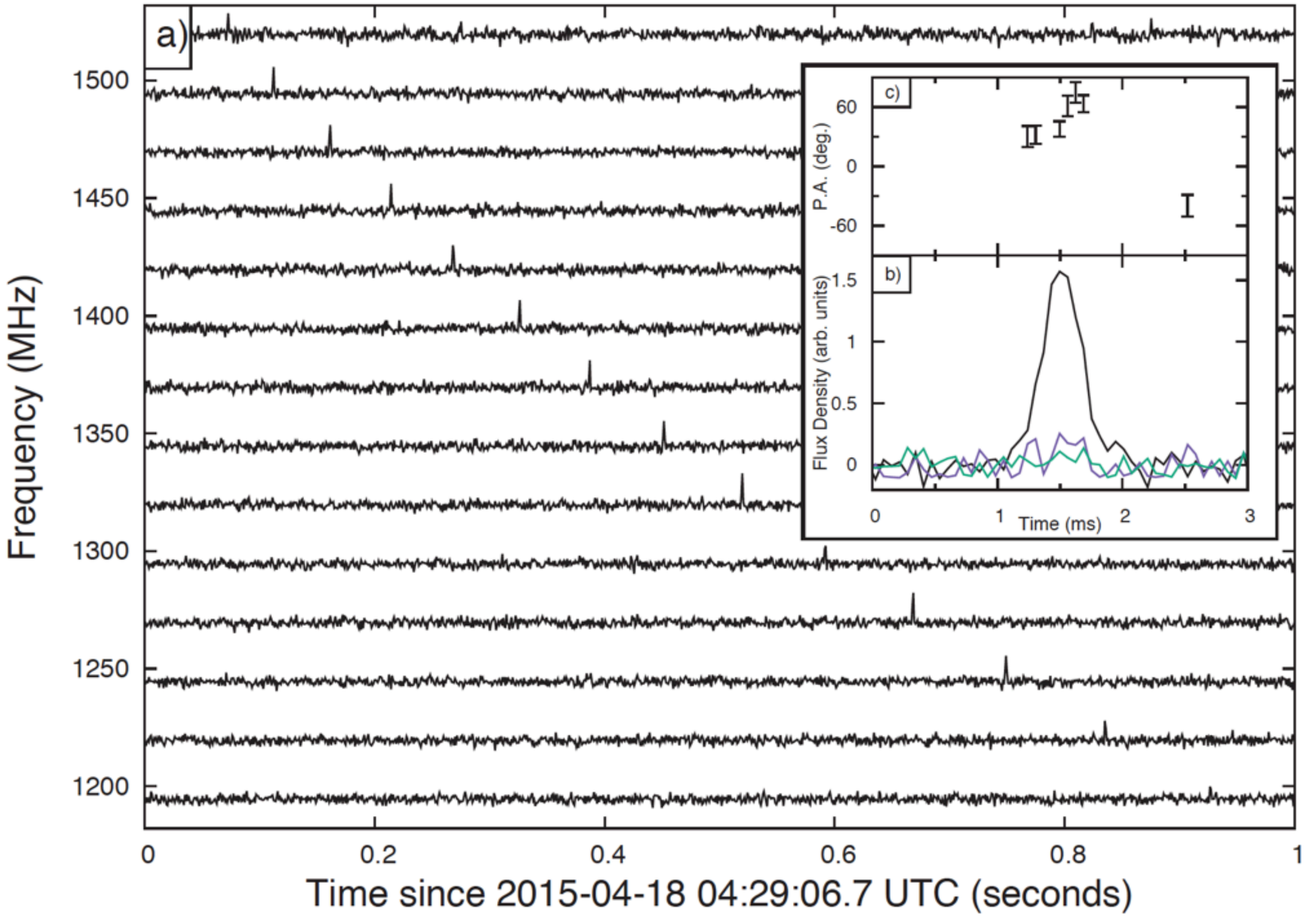
This is what an FRB looks like!

There are currently ~ 80 FRBs listed in the FRBCAT

1 msec duration ~ emitting object is ~ 300 km

- some FRBs show µ-sec timescales
- implies structures which are ~ 3 km!

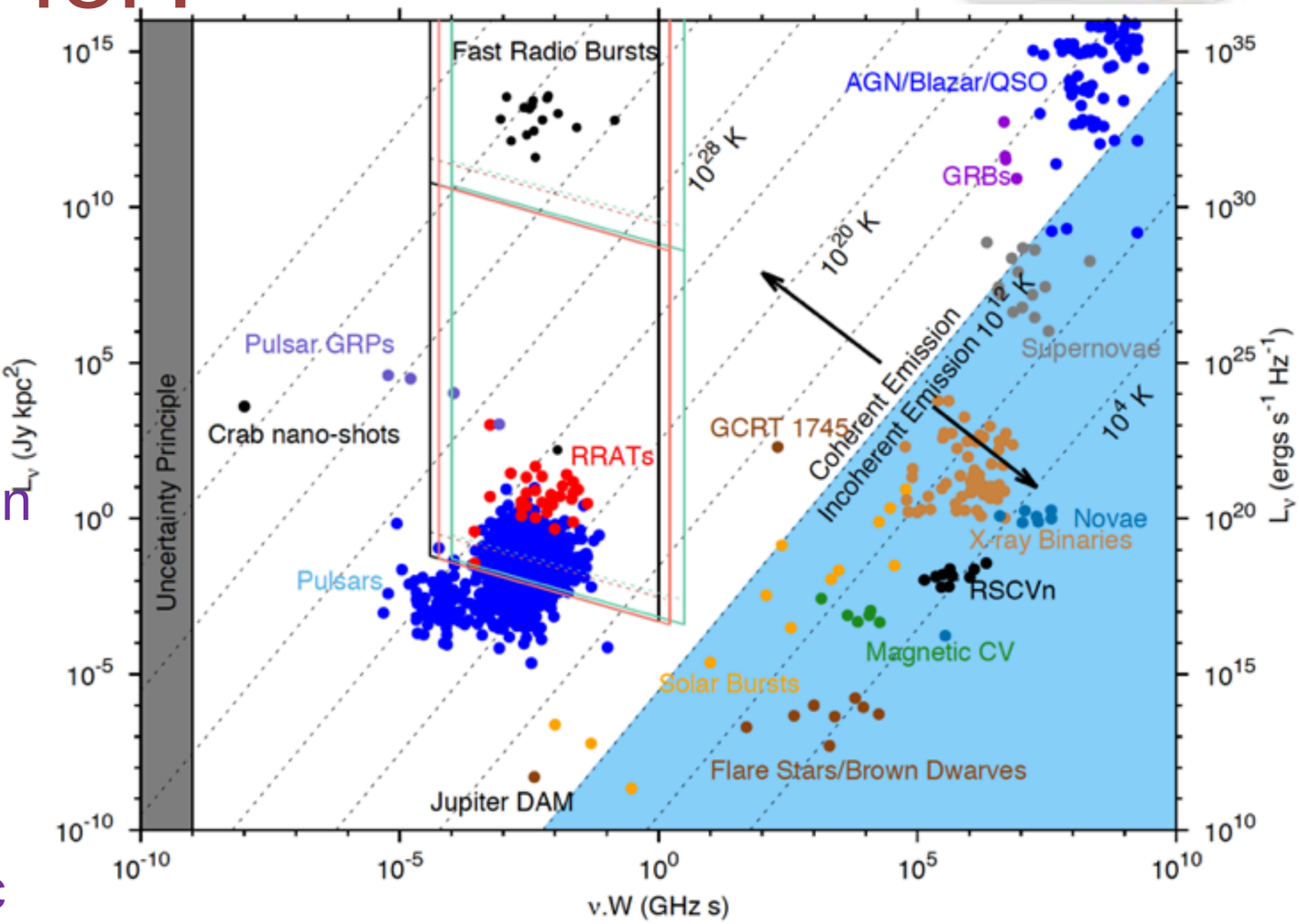
Keane et al., 2016, Nature, 530, 453



What are FRBs good for?

"Explore the unknown with Fast Transients at Cosmological Distances"

- find 1000s, localise, and distribute in redshift bins
- Dark Energy EoS depends on $\Delta DM(z)$
- FRB scattering ⇒ IGM turbulence
- rotation measures ⇒ IGM magnetic fields



Pietka et al., 2015, MNRAS, 446, 3687 (updated with more FRBs)

Current sample of known FRBs are not sufficient for any of these applications – need a LOT more!

Common time allocation process based on **scientific merit** and **technical feasibility**

Access **proportional to national share** in the project

Key Science Projects to take up 50-75% of observing time, with conventional PI-led projects taking up the remainder

Up to 5% Open Time available

Common area sky surveys

Triggered

Observatory interface to users, including data access and user support, to be provided through a network of SKA Regional Centres

Ability to form **sub-arrays** configured and operated independently of each other

3-pronged Commensal observing to enhance scientific productivity via sub-arrays, commensal data and processing

All data to be made **openly available** following a proprietary period

Flexible scheduling to ensure dynamic response to observing conditions and to provide for Targets of Opportunity and triggered events

SKA science-ready data are friendly for the non-radio astronomers

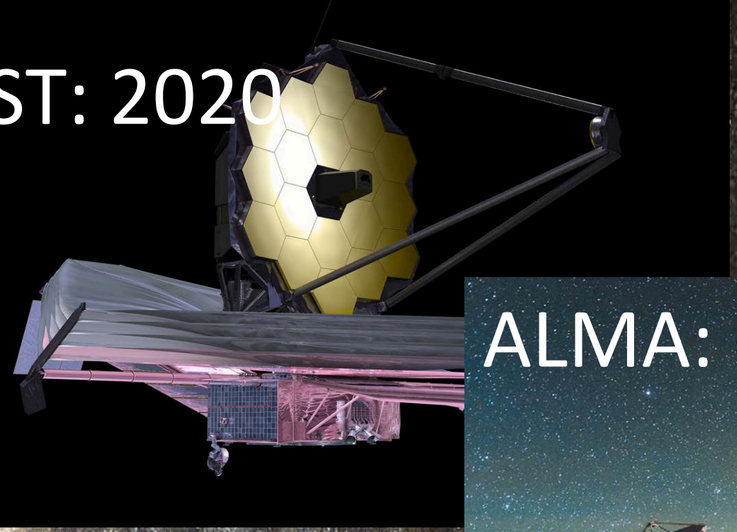
Current **SKA operational concept includes *coordinated proposals*** with other facilities

Open questions

- How do we evaluate and award time to coordinated proposals?
- On their own merit as a standalone? Depending on time being awarded at another instrument?
- How do we charge the time and/or compensate for it between the different communities?
- How do we cover the costs of the SKA Regional Centres for those non-SKA communities?
- Policies not yet finalized nor written

LIGO: operational

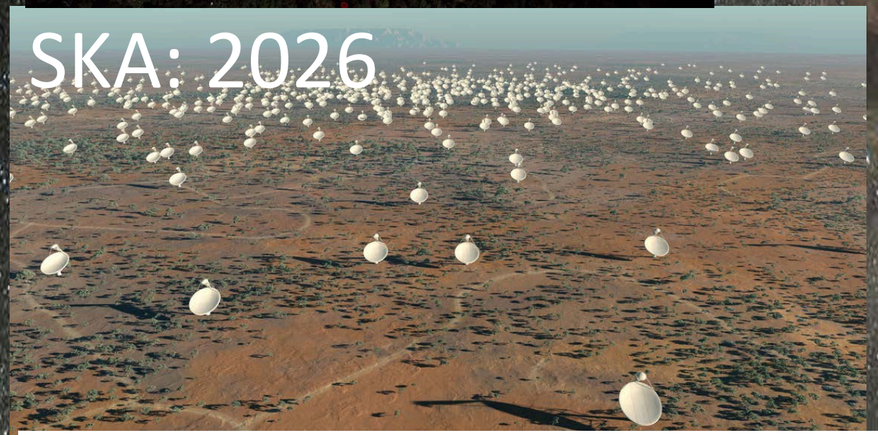
JWST: 2020



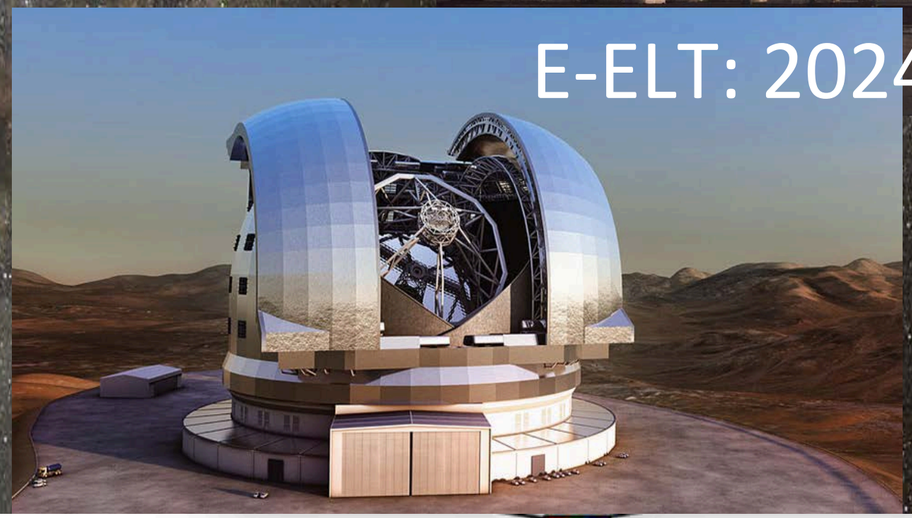
ATHENA: 2028

ALMA: operational

SKA: 2026



E-ELT: 2024



CTA: 2024