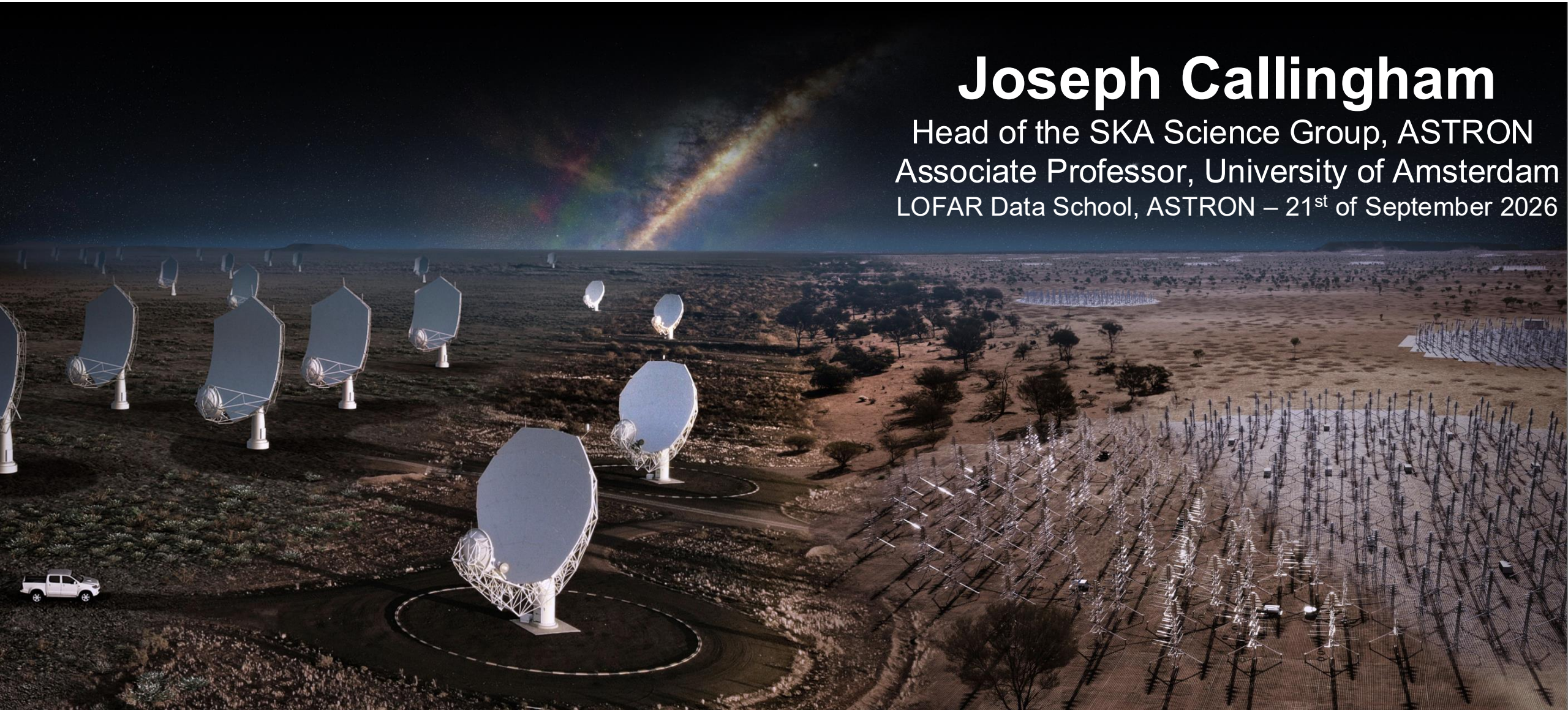
# The coming renaissance in radio astronomy



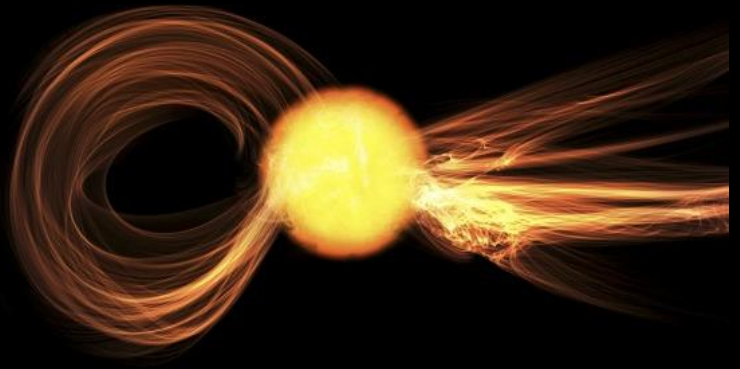

**Joseph Callingham**

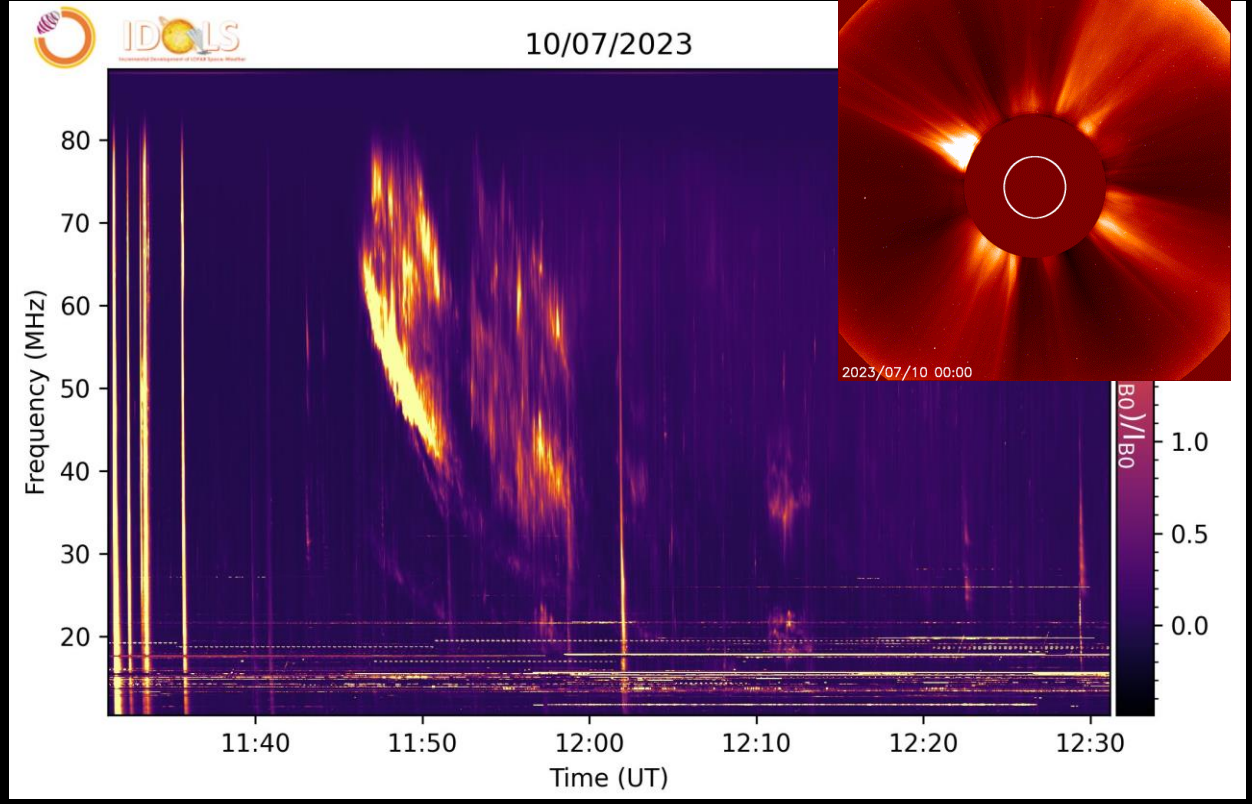
Head of the SKA Science Group, ASTRON

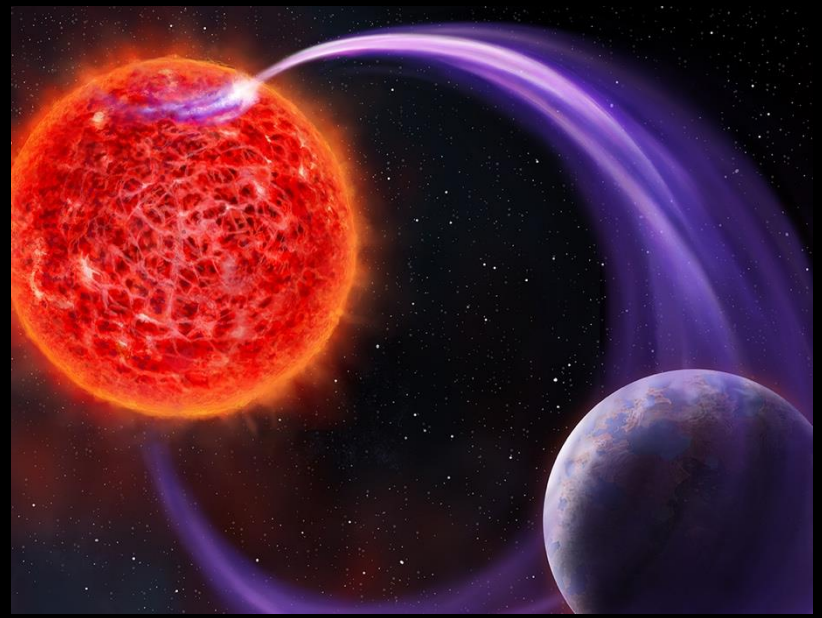
Associate Professor, University of Amsterdam

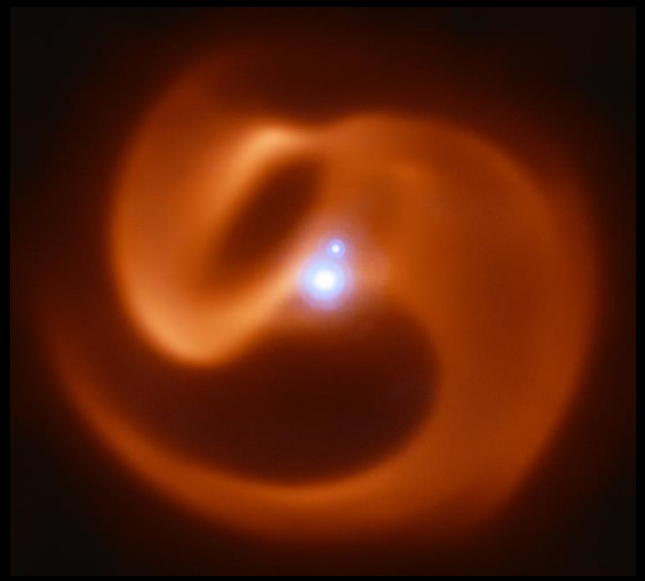

LOFAR Data School, ASTRON – 21st of September 2026

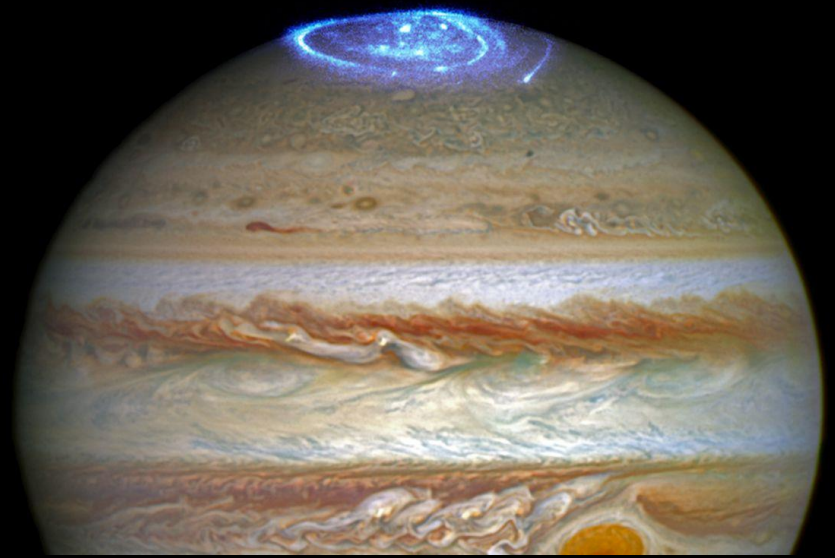
# How to make discoveries with a telescope?



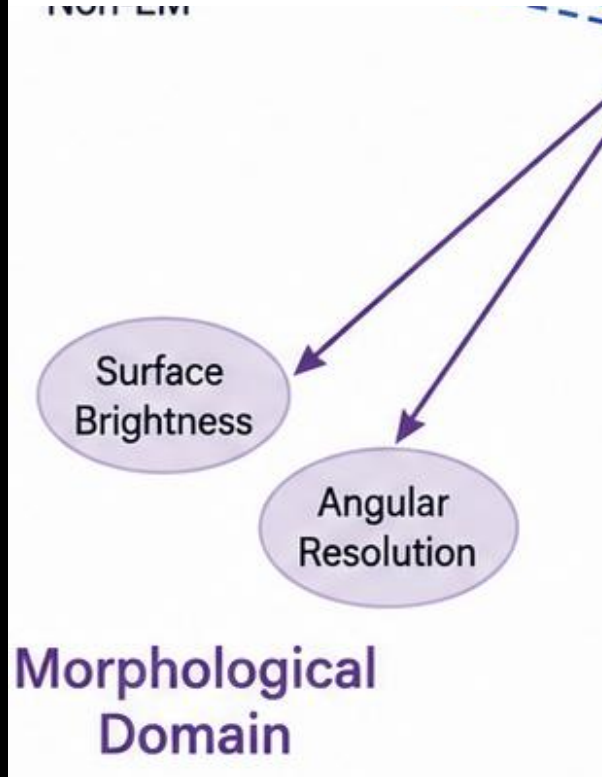




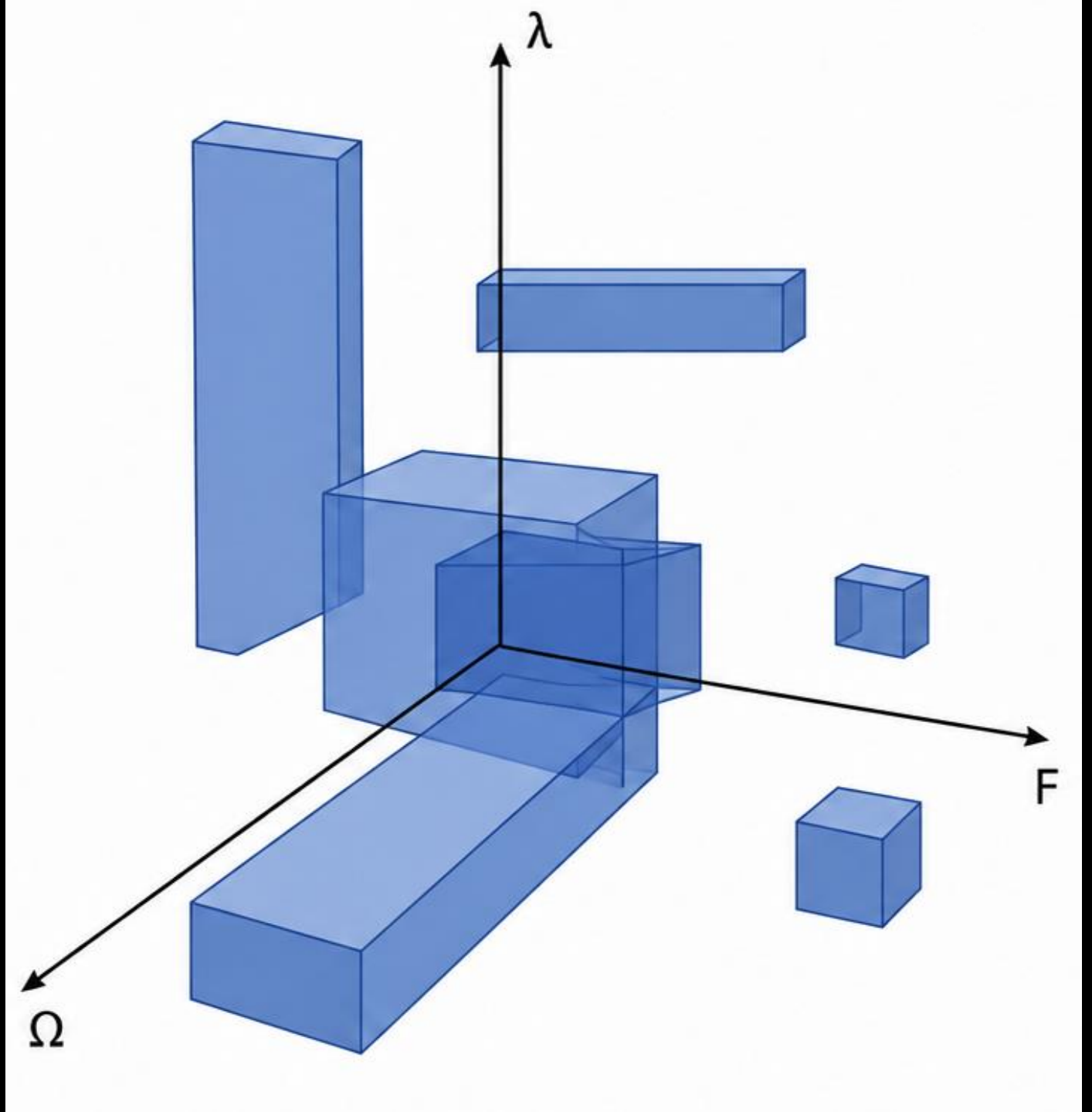


# Discovery Phase Space




Heavily burrowed from Harwit (1981)

# Discovery Phase Space



# Sometimes it takes a little reframing

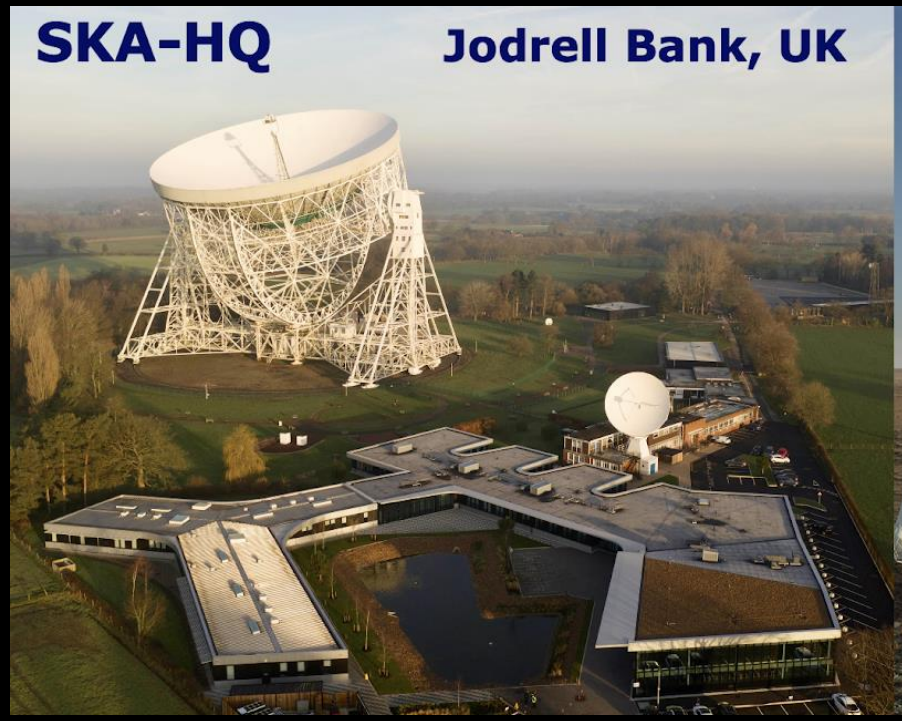


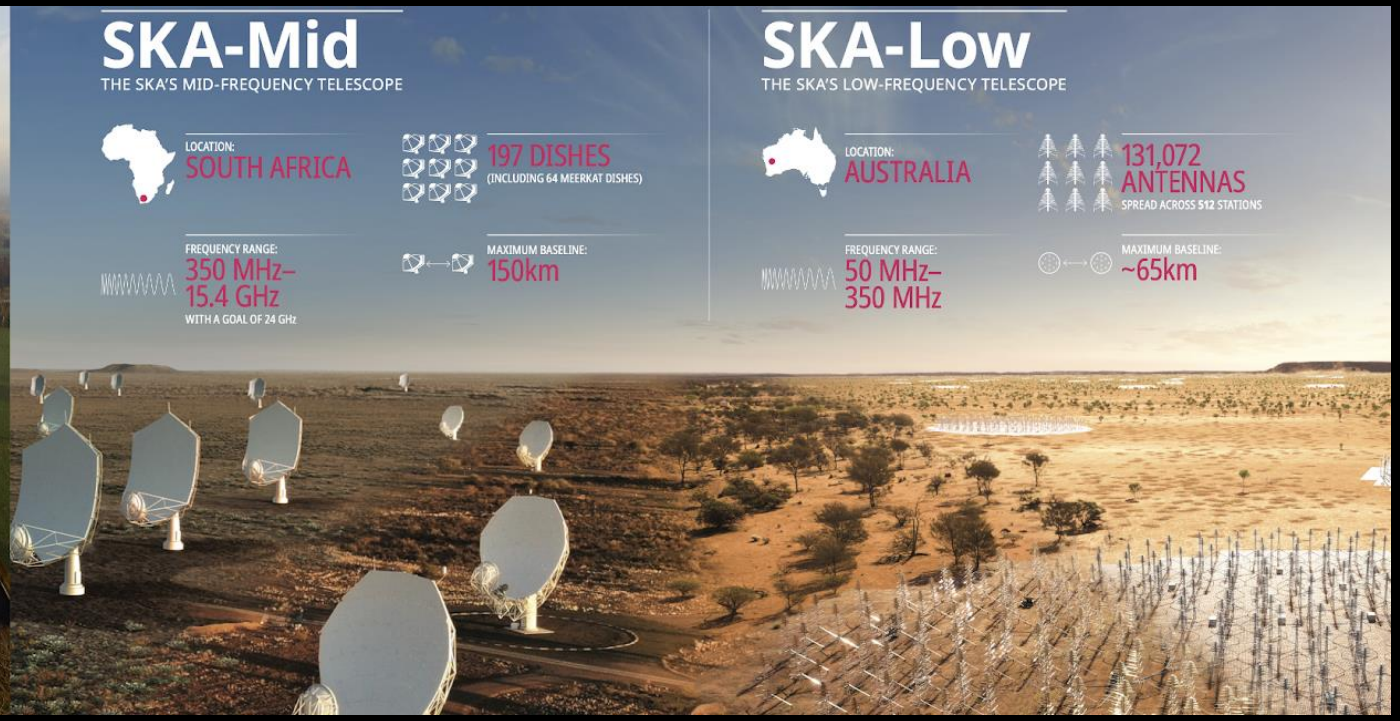


# The flagship missions (>~ 1 billion euros) - SKA

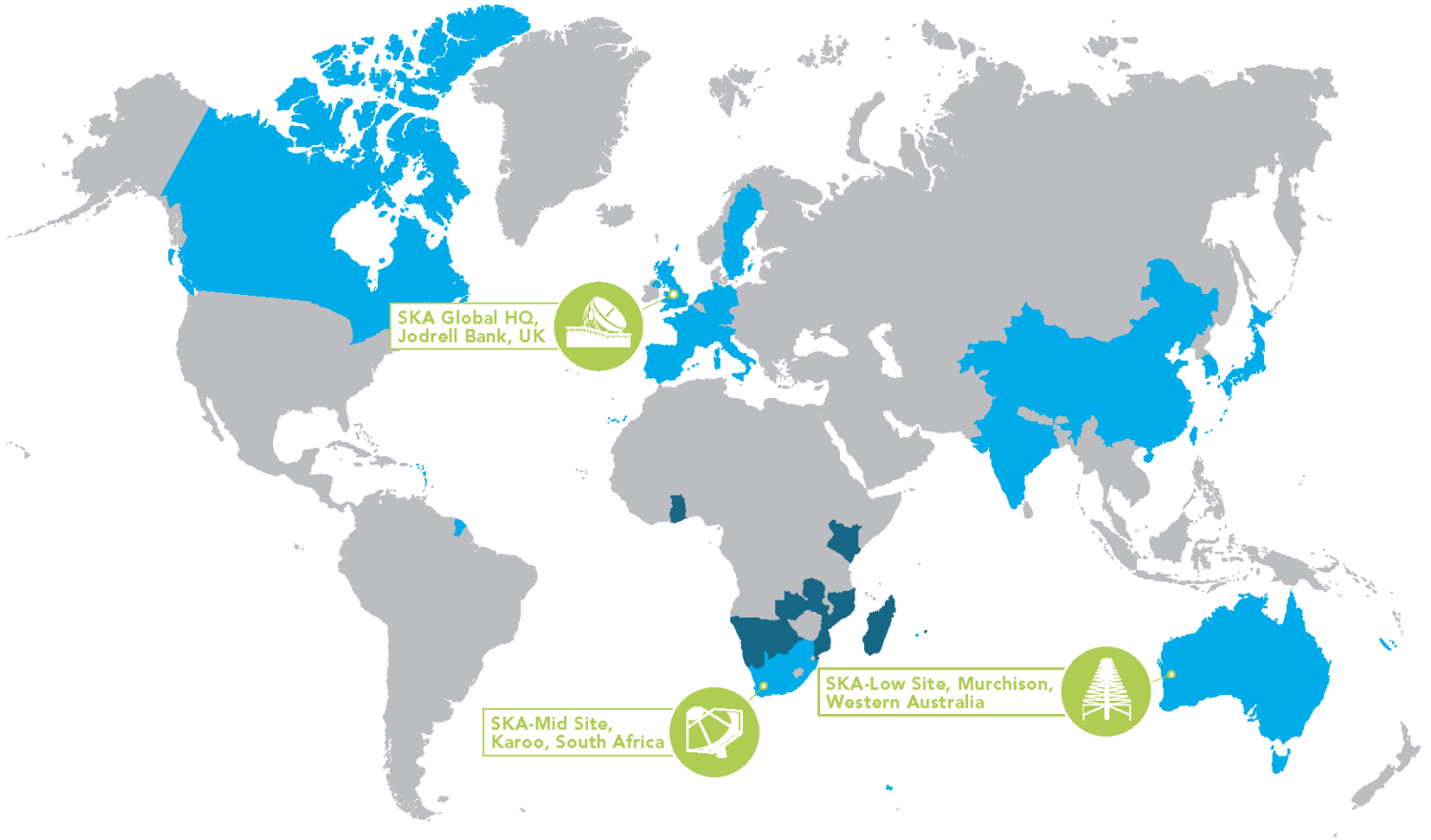
**SKA-Low**
307*/512 stations with 256 low frequency dipoles
50-350 MHz
65 km baselines
(11” at 110 MHz)
Murchison, Western Australia

**SKA-Mid**
80*/133 x 15m + 64 x 13.5m MeerKAT
0.35 - 15 GHz
150 km baselines
(0.22” at 1.7 GHz; 34 mas at 15 GHz)
Karoo, South Africa




Construction 2021-2028/2031 First Data in 2027/2029




SKA Partners – includes Members of the SKA Organisation – precursor to the SKAO –, current SKAO Member States*, and SKAO Observers (as of June 2021)

African Partner Countries

**SKAO Member States:**

- Australia
- China
- Italy
- Netherlands
- Portugal
- South Africa
- Spain
- Switzerland
- United Kingdom
- Canada
- Germany
- India
- Sweden
- **France**

**Joining soon (2027):**

- South Korea

**Joining later (2027+):**

- Japan

**Early Conversations:**

- Ireland
- Poland
- Thailand

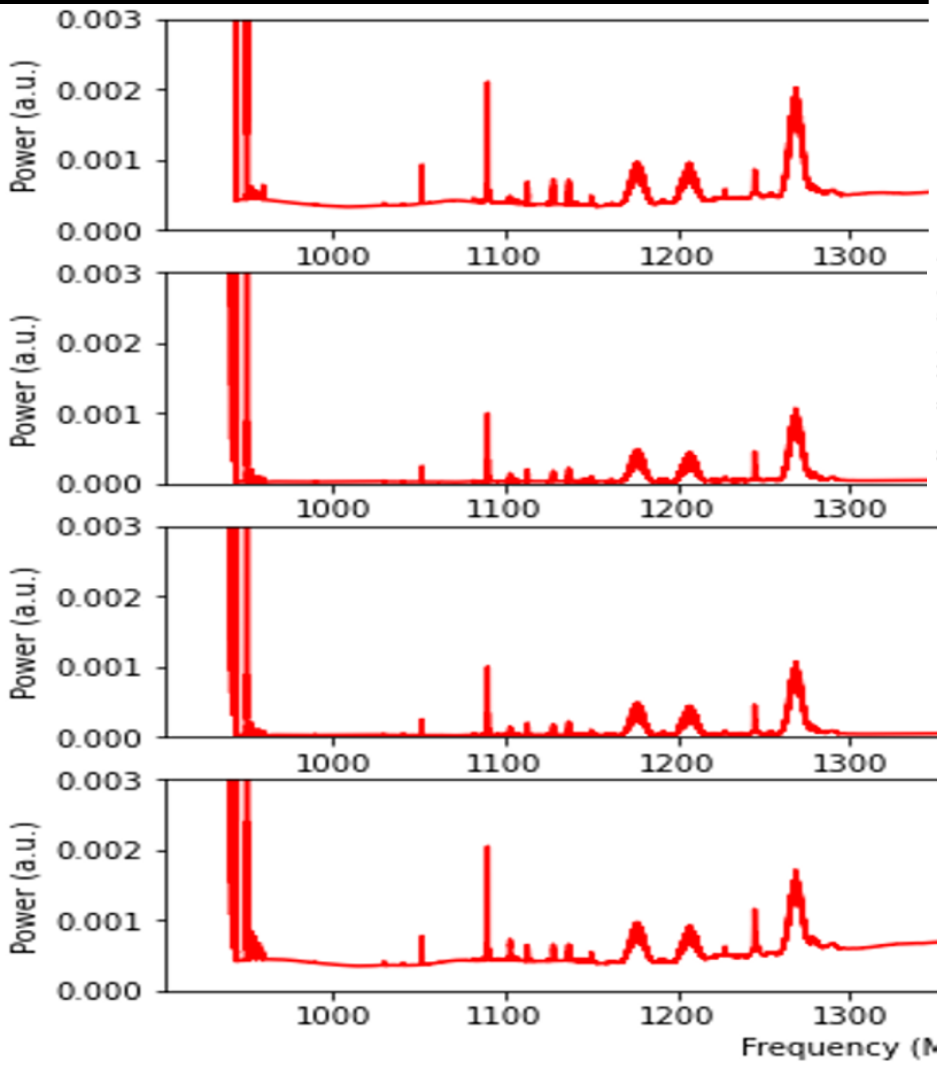
Status: April 2026

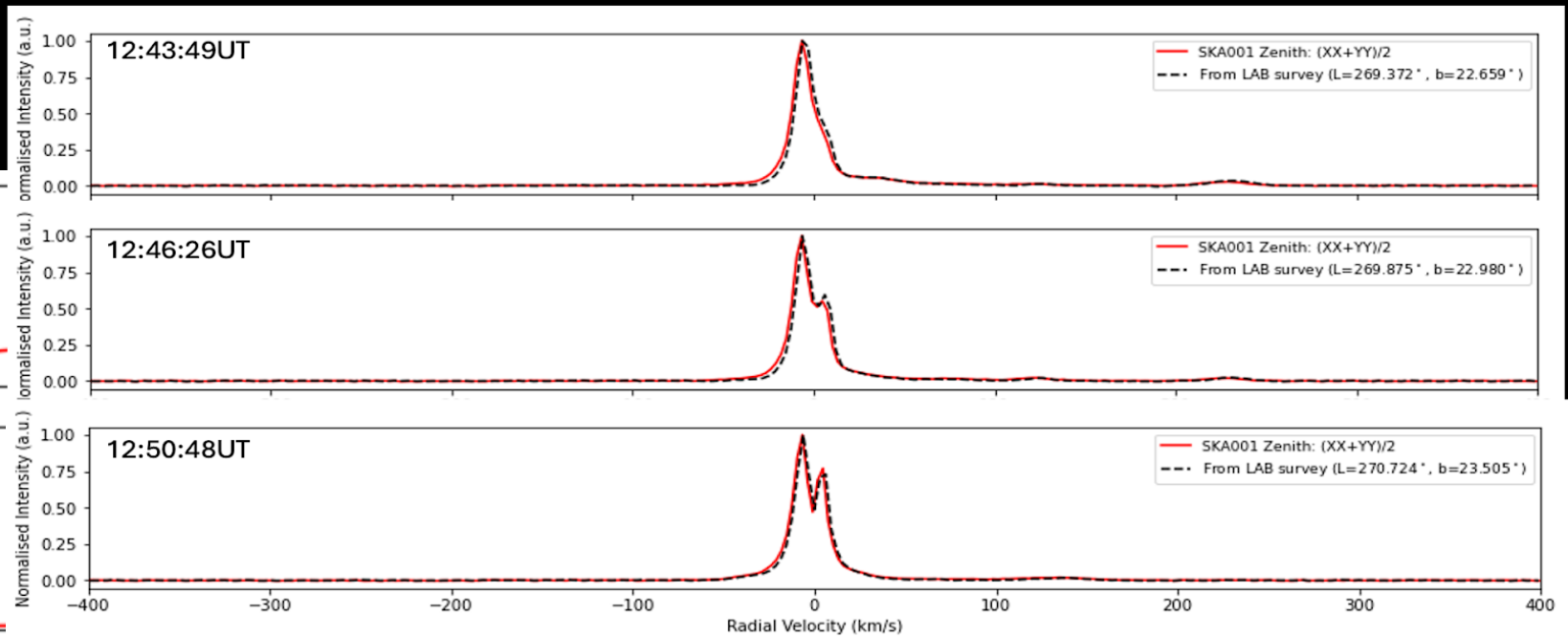
# SKA-Mid Construction Update

- 15 dish structures have been delivered to site
  - 4 more are currently in transit
- 7 “big lifts” have taken place,
- Dish structure testing
- commissioning activities continuing at pace, initial results are promising

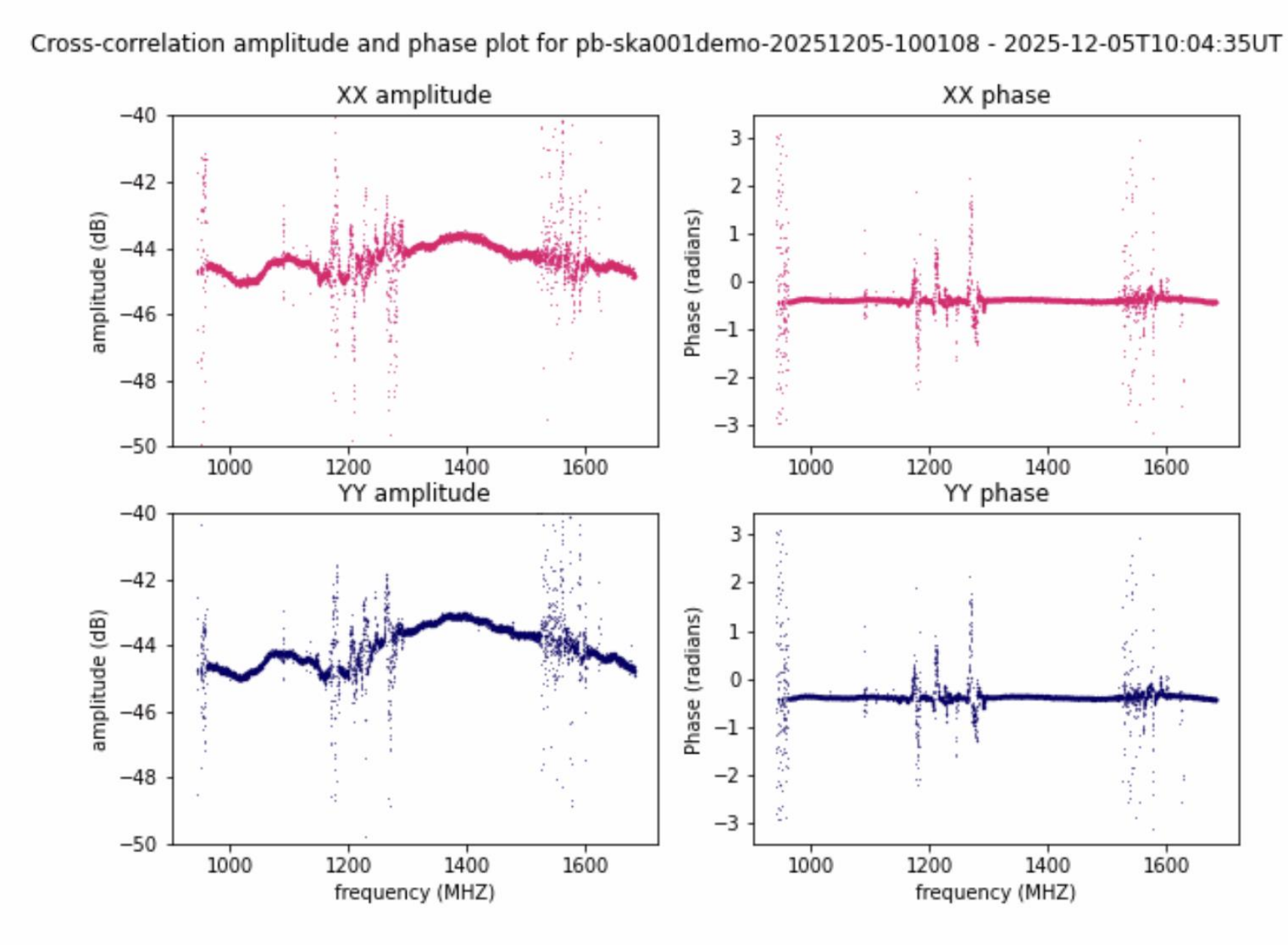


# First light for the first SKA Mid Dish



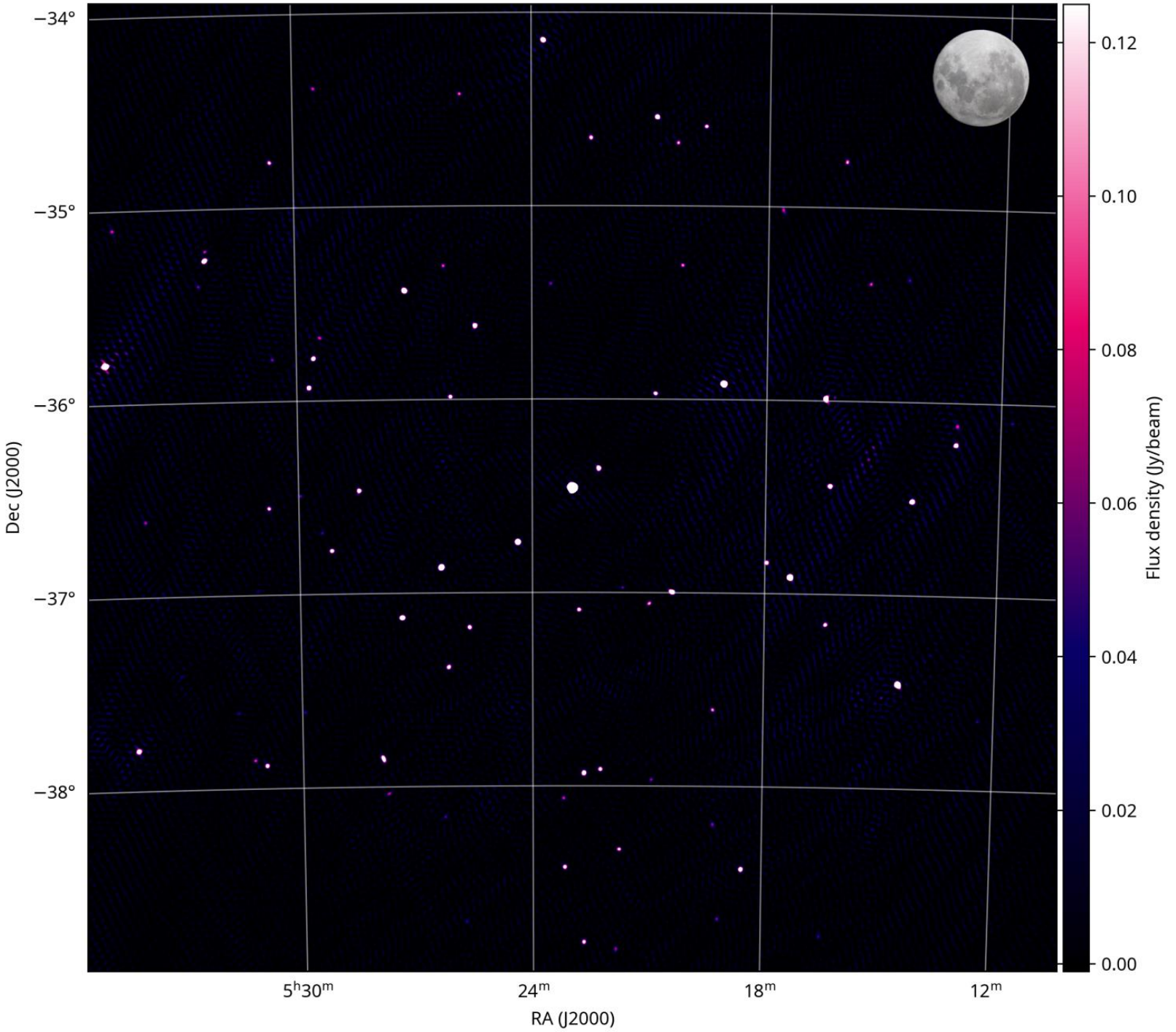



# SKA-mid comes alive!



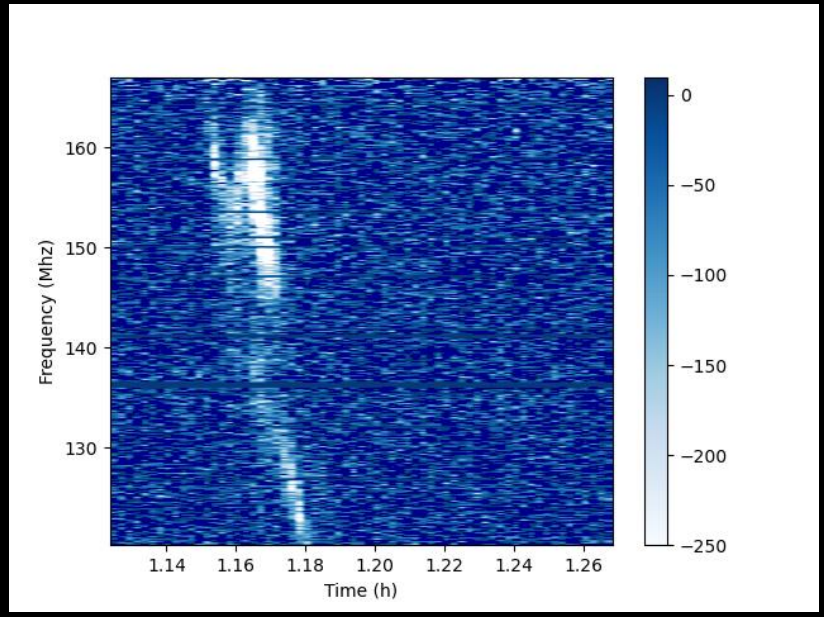
# First image from Low

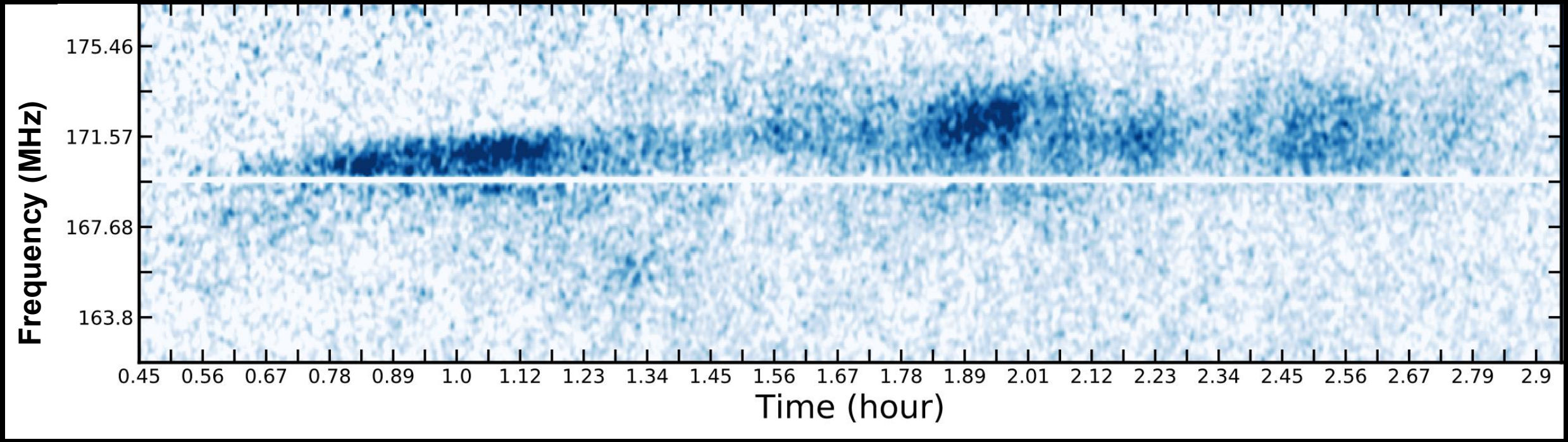
- >10,000 antennae installed!



# What will you do at 50 MHz to 15 GHz?

- Sensitive to coherent emission, such as plasma and ECMI – often high in the coronal layers of the star or from low B-field bodies
- Long term monitoring studies due to wide-field of view by SKA-Low
- Mass-loss rates from FFA

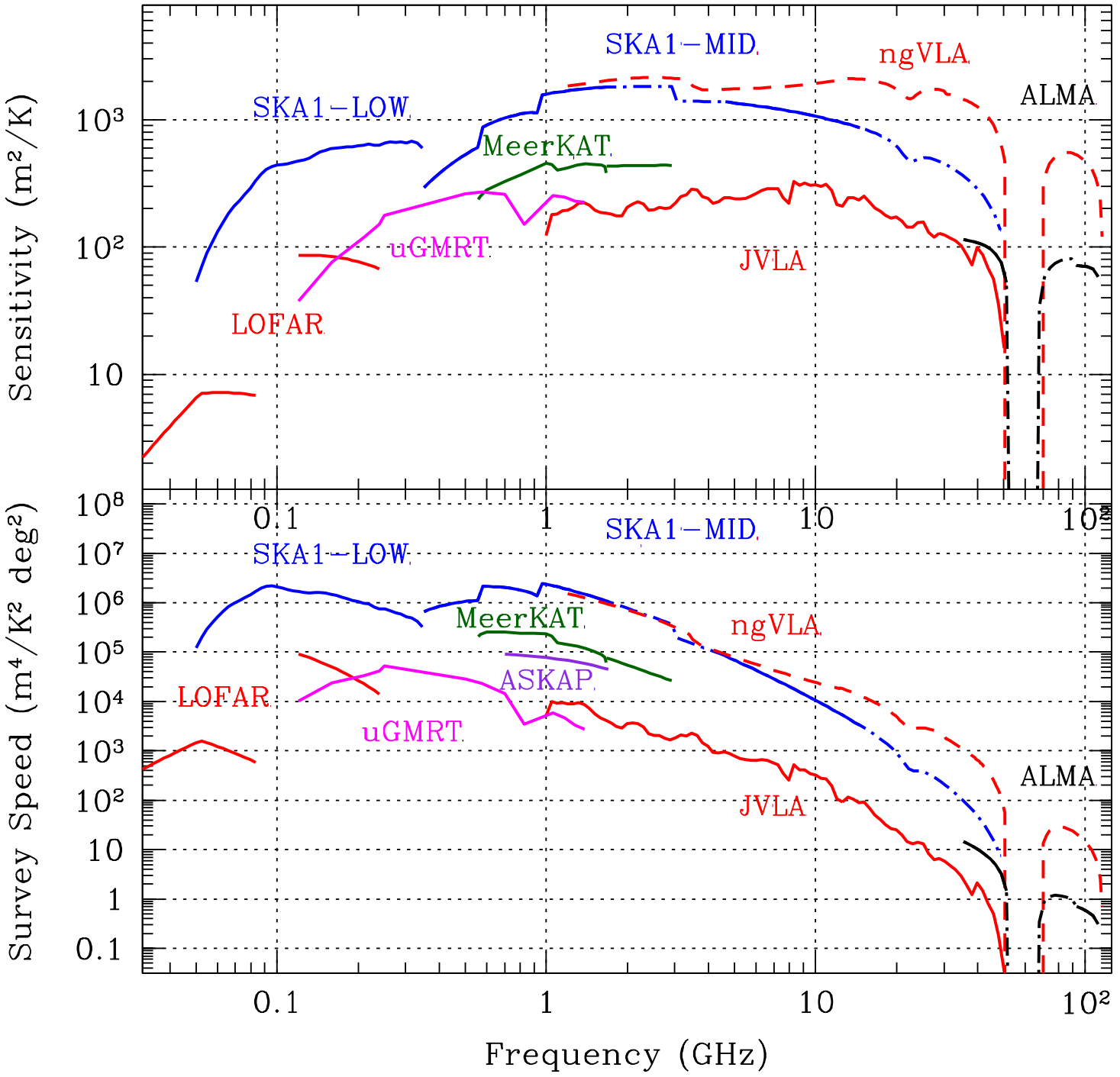



Callingham et al. (2021a)

# SKA Sensitivity and Survey Speed

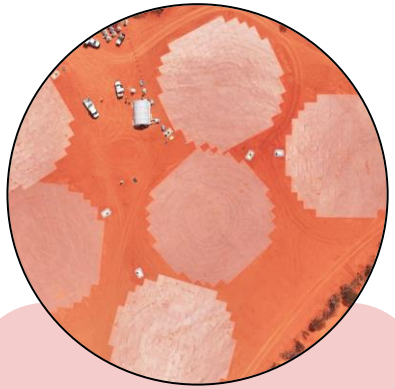
- Proto-type verified performance predictions now available at most frequencies
- Opportunity for seamless interface of SKA to ALMA capabilities
- LOFAR, MeerKAT and ASKAP already starting to open up this new parameter space
- ngVLA would supplement high frequency capabilities



# SKAO milestones

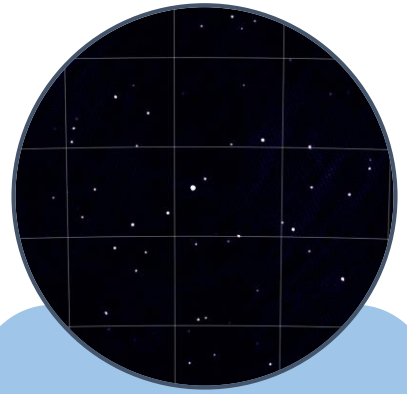
Community involvement starts

Credit: I. Heywood, SARAO



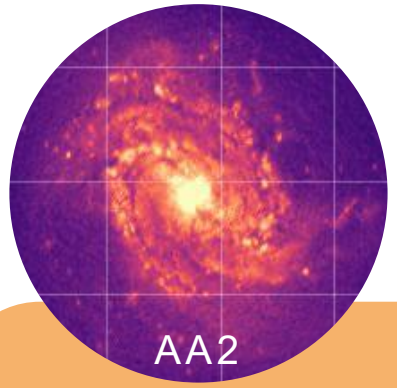
## Construction

- Building antennas, dishes, roads etc!
- Followed by Assembly, Integration and Verification



## Commissioning

- SKAO activity
- Collaborative across system verification and science commissioning

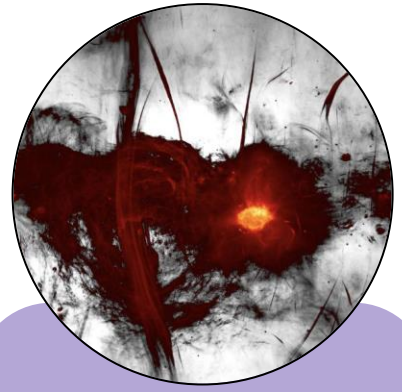






## Science Verification

- A full dress rehearsal of the end-to-end system for every mode of operation
- Once modes and pipelines are working, the community can submit target ideas
- Data will be publicly available for scrutiny
- Build trust and fostering an early science return



## Cycle 0

- Shared-risk PI projects
- SRCNet resources ready for user
- Proprietary periods



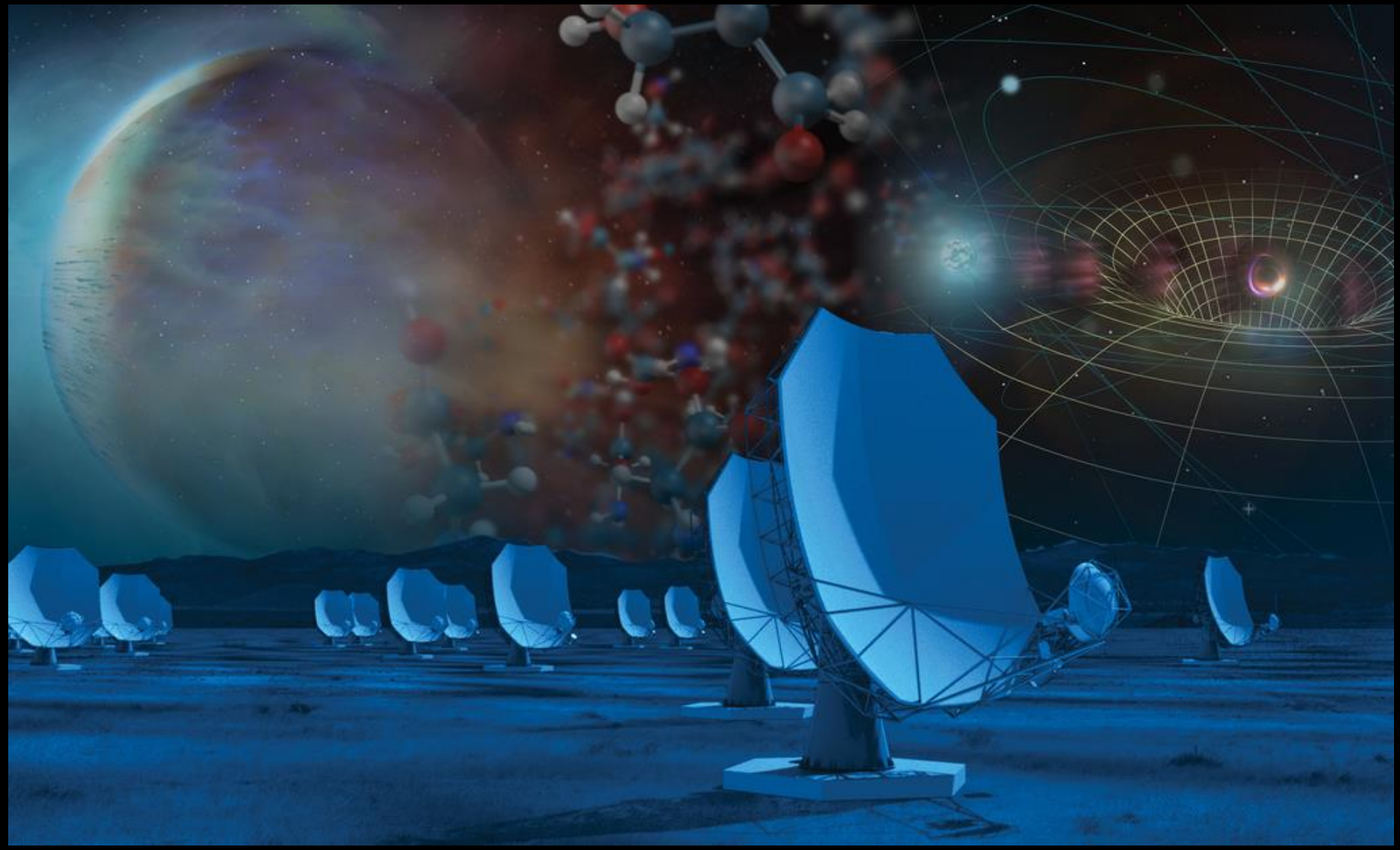
Now | Now | First half 2027 | First half 2029 | 2030



Now | Soon | First half 2029 | First half 2031 | 2032

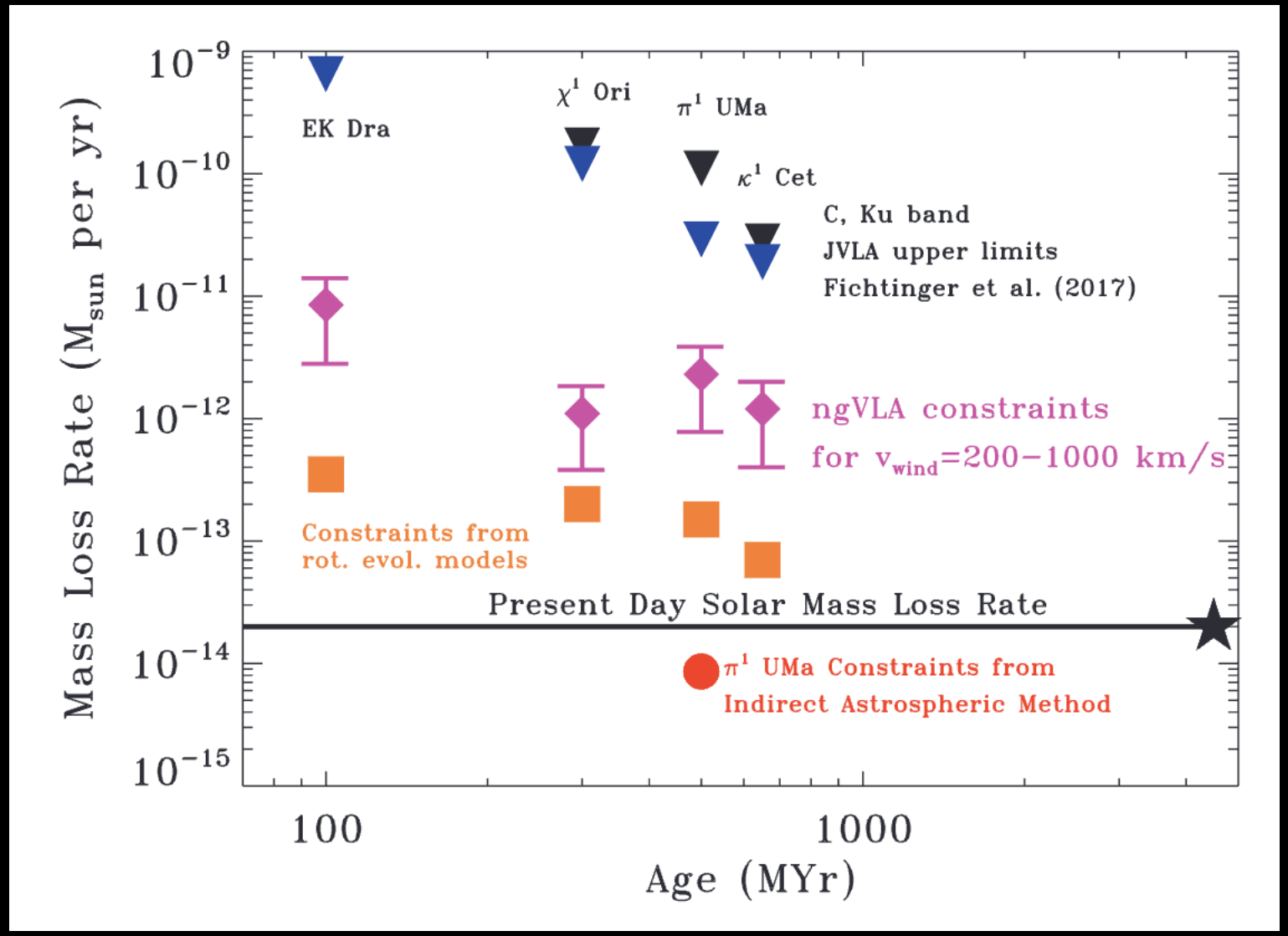
# The flagship missions (>~ 1 billion euros) – ngVLA

- Thermal universe science goals
- 1 to 100 GHz
- US-led
- Probably constructed ~5-10 years after SKA1 (mid-late 2030s)
- Favourably mentioned in the recent US decadal review
- Recent news that the VLBA will be upgraded with ngVLA antennas



# Mass loss estimates from free-free emission

- Sensitivity in 1 hour obs is ~0.02 Jy/beam.
- Test the mass loss rates for the nearest stars with known exoplanets
- Difficult to do at other wavelengths (such a Lyman absorption)




Osten et al. 2018

# The mid-term future (~3-10 years) - FAST Array

- 24 secondary 40-m antennas implanted within 5 km of the FAST dish at ~Lband
- 2 times more sensitive than SKA-Mid
- Monitoring and high t-f observations likely most interesting

Jiang et al. (2024)

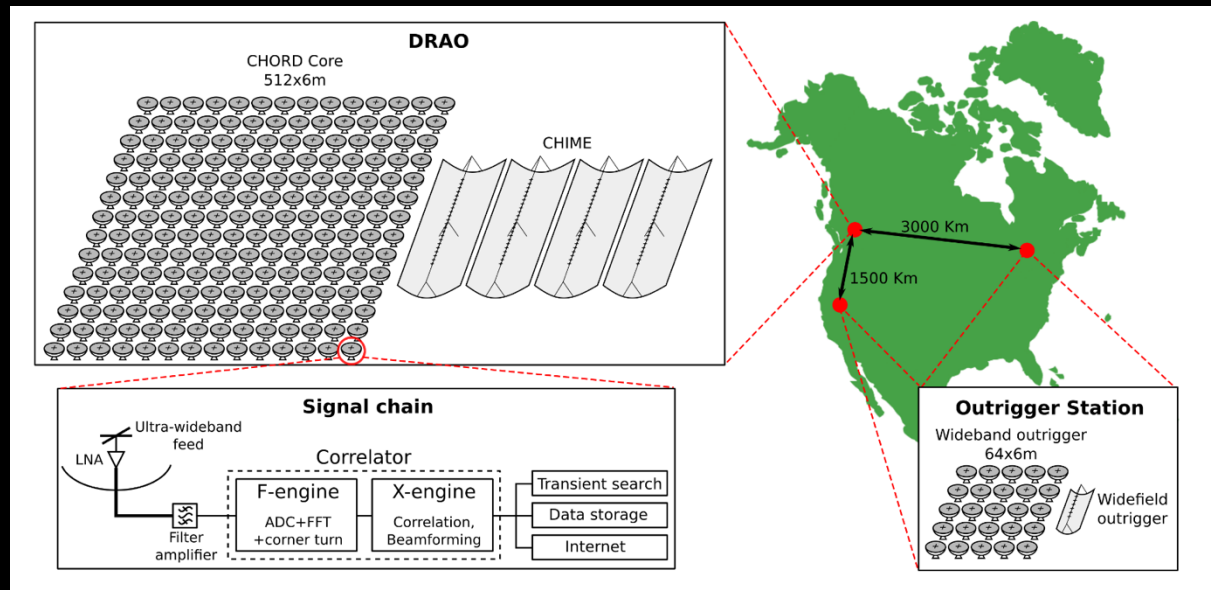




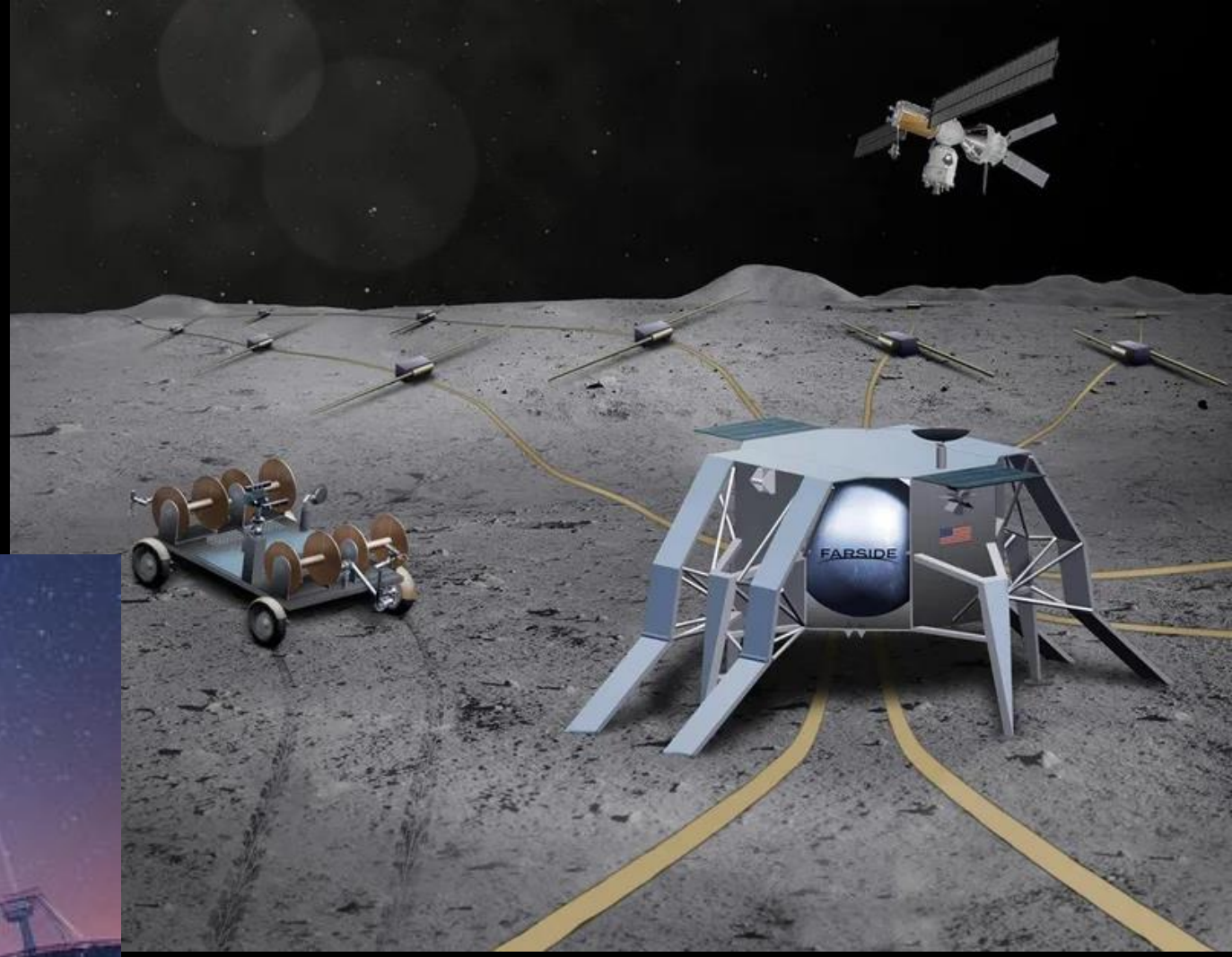
# DSA and CHORD

- 1650 x ~6 m dishes observing between 0.7 and 2 GHz. And planned to be operating ~2028
- DSA will detect $\sim 10^5$ and $\sim 10^3$ stars and LPTs per year (assuming RMS noise of 2$\mu$Jy in 15 minutes of integration).
- CHORD 512 x ~6 m observing between 300 MHz – 1500 MHz – operating around 2027
- CHORD will detect $\sim 10^3$ and $\sim 10^2$ stars and LPTs per year (assuming RMS noise of 20$\mu$Jy in 15 minutes of integration).





# The far future (10+ years)






# Summary

- SKA and ngVLA will represent an order of magnitude jump in sensitivity for 50 MHz to 100 GHz
- Facilitate science goals not accessible to us now
- SKA operational by 2030, ngVLA ~2035
- Lots of work underway with SKA pathfinders and precursors (LOFAR, ASKAP, FAST, GMRT etc)

