

SKAO

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

SKA-HQ

Jodrell Bank, UK



SKA-Mid

THE SKA'S MID-FREQUENCY TELESCOPE



LOCATION:
SOUTH AFRICA



197 DISHES
(INCLUDING 64 MEERKAT DISHES)

FREQUENCY RANGE:

**350 MHz–
15.4 GHz**

WITH A GOAL OF 24 GHz



MAXIMUM BASELINE:

150km

SKA-Low

THE SKA'S LOW-FREQUENCY TELESCOPE



LOCATION:
AUSTRALIA



**131,072
ANTENNAS**
SPREAD ACROSS 512 STATIONS

FREQUENCY RANGE:

**50 MHz–
350 MHz**



MAXIMUM BASELINE:

~65km

Sites selected for their radio quietness → low population density

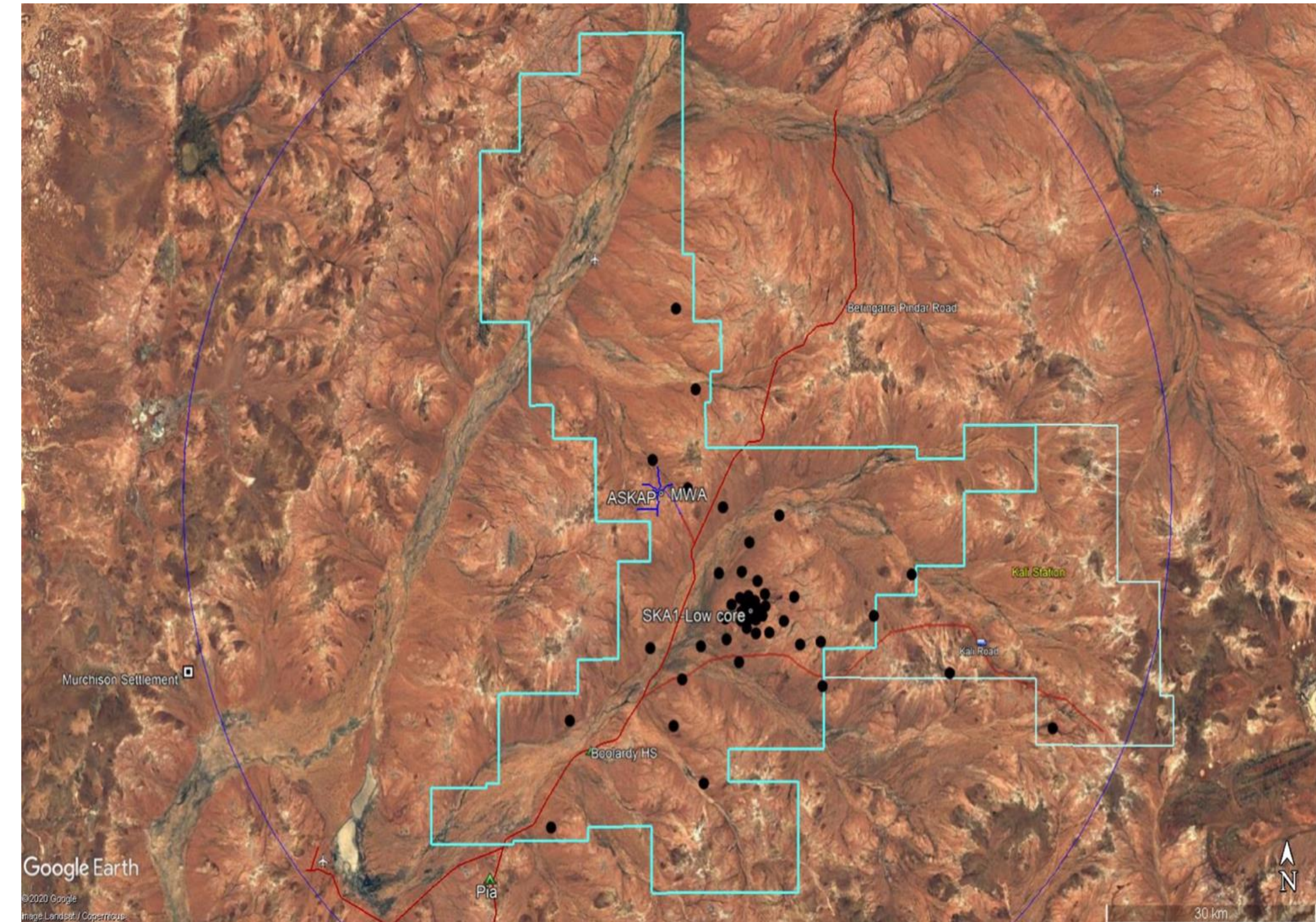
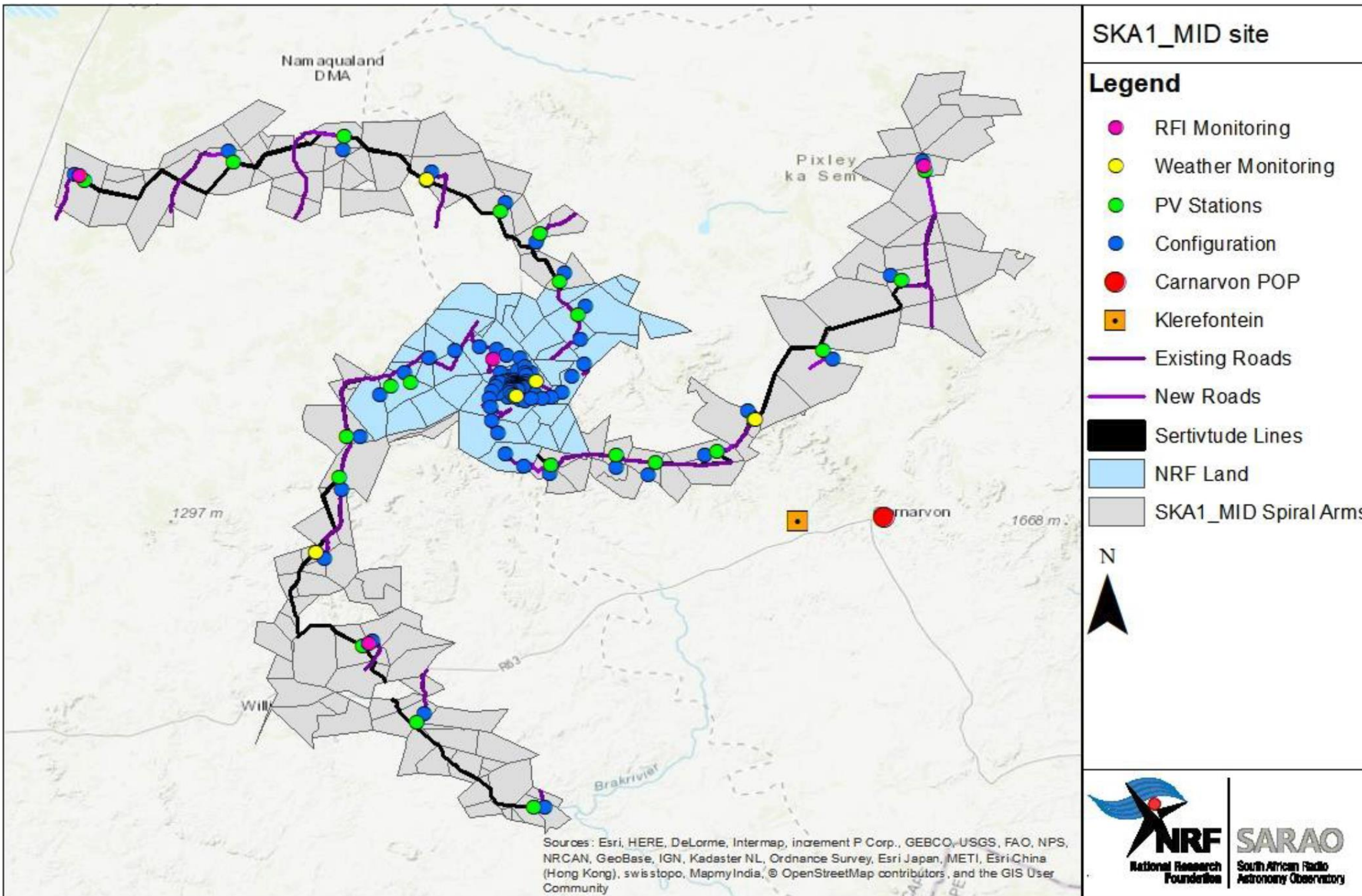
Total project cost: ~€2B; operational in 2029/2030



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

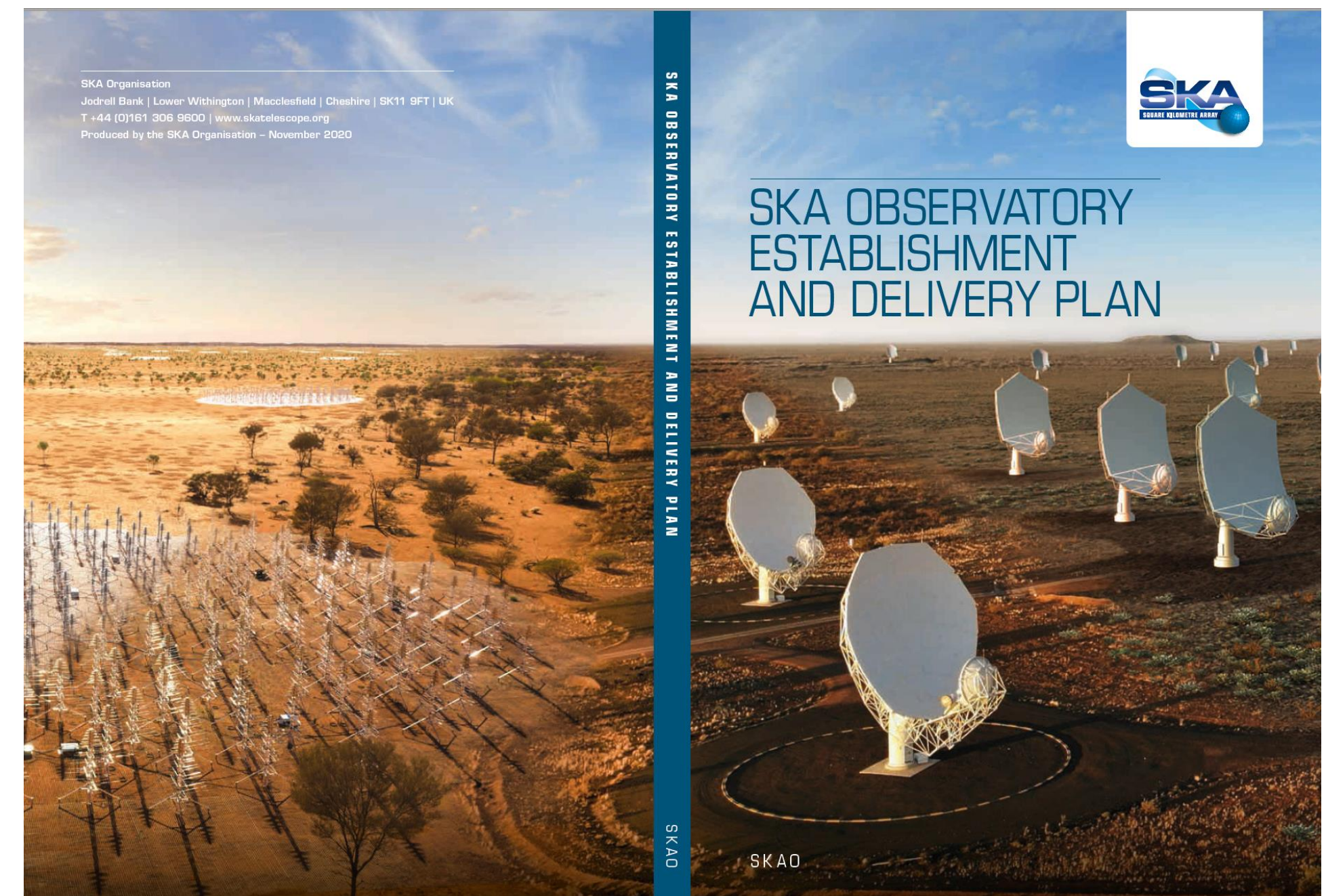
Delivering SKA Observatory

Feb 2021: SKAO born

June 2021: SKAO Council approved the Construction Proposal and the SKAO Establishment and Delivery Plan

July 2021: Construction activities began

October 2022: 42 contracts awarded, total cost ~€200M; more major contracts being prepared



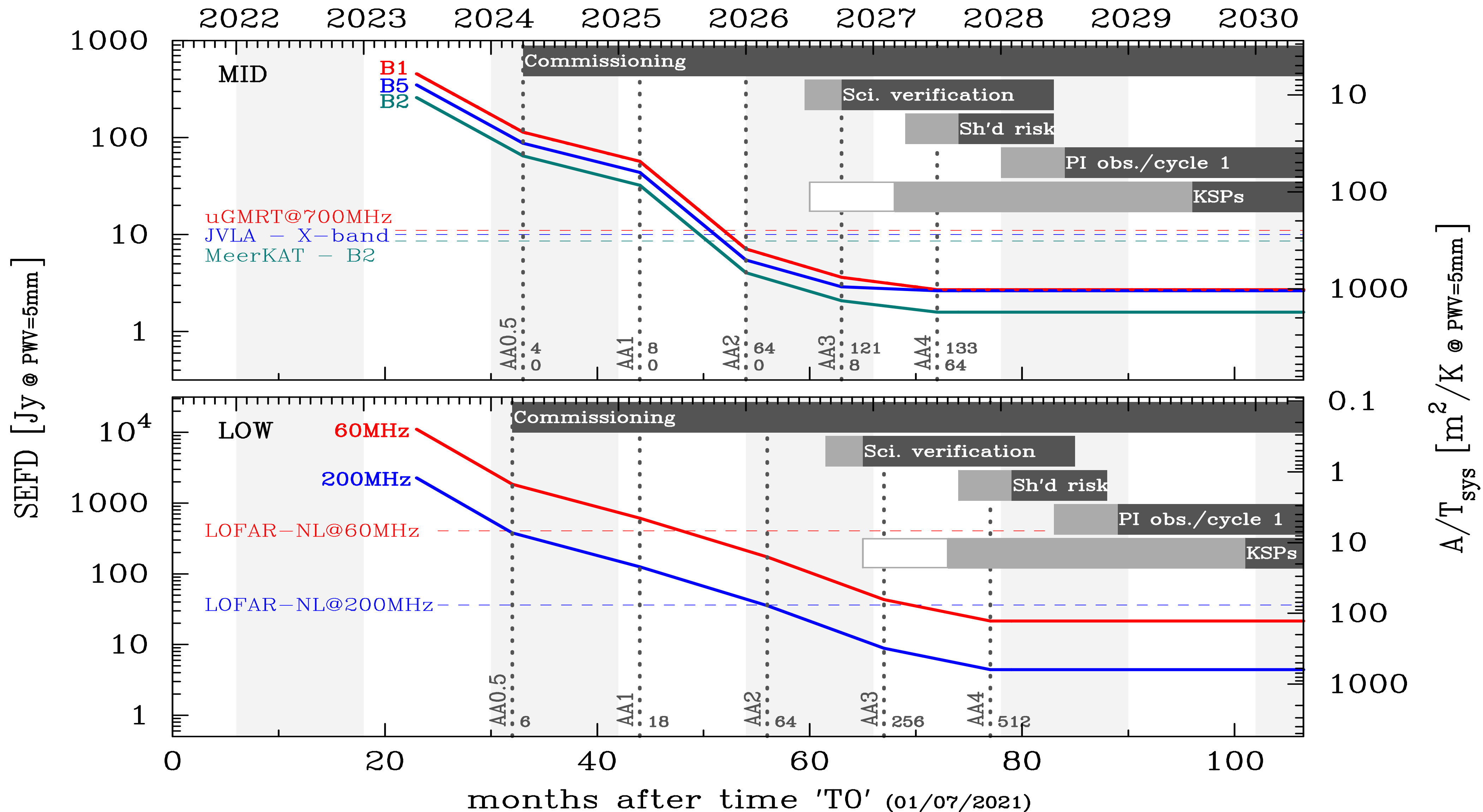
Construction Strategy

- Target: the SKA Baseline Design (197 Mid dishes; 512 Low stations: AA4)
- Not all funding yet secured, therefore follow Staged Delivery Plan (144 Mid dishes; 307 stations: AA*)
- First Milestone: Develop the earliest possible working demonstration of the architecture and supply chain (AA0.5).
- Then maintain a continuously working and expanding facility until achieve the baseline design.

Milestone Event	SKA-Mid (date)	SKA-Low (date)
AA0.5	2024 Jul	2024 May
AA1	2025 Sep	2025 May
AA2	2026 Jul	2026 Jul
AA*	2027 Jun	2027 Aug
Operations Readiness Review	2027 Aug	2027 Oct
End of Construction	2028 Jul	2028 Jul



The Evolution of Performance



Current key challenges

- Impact of external factors (inflation, labour shortages, supply chains) on construction costs and schedules: working with Council and member states to mitigate
- Pace of engagement in some of aspiring Member governments, potential for misalignment with the construction schedule.
- Pressures on staff are unrelenting, especially in Programmes and Business-Enabling functions
- There is the standard list of items SKAO watch and manage carefully, e.g.:
 - Residual design processes
 - Spectrum management, especially mega-constellations
 - Land access timescales
 - Stakeholder management (local and international)
 -



Summary

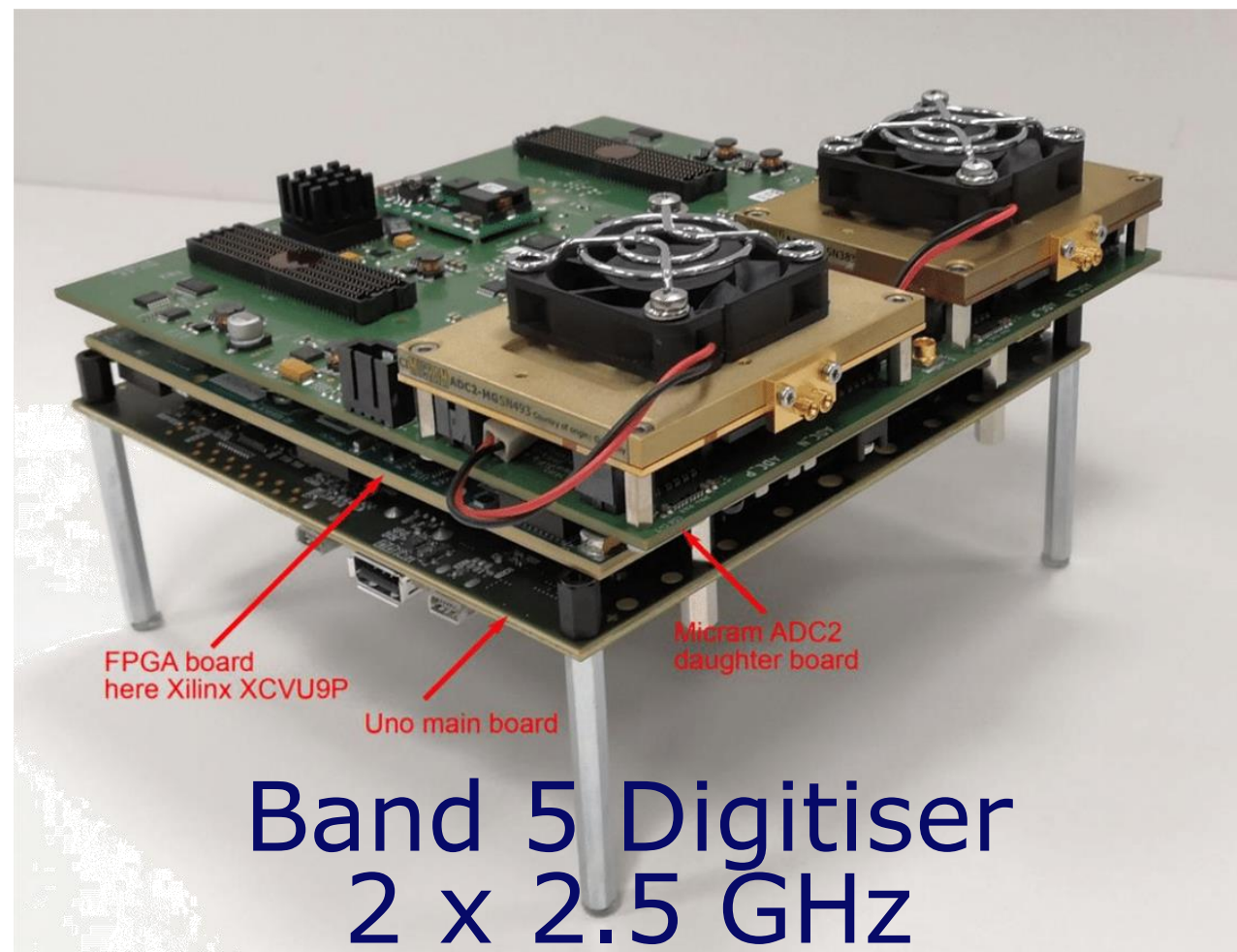
- Construction activities are proceeding at pace; residual design issues are being dealt with professionally and expeditiously
- Level of risk for the project has increased due to the global situation; mitigations are planned, but they require the commitment of additional resources from Members and the accession of new Members.
- SKAO presence in the site host countries is a major positive milestone
- SKAO's reputation and global visibility is growing substantially and positively.



Construction Photos



Recent Prototype and Construction Progress



AAVS2: Aperture Array Verification System 2



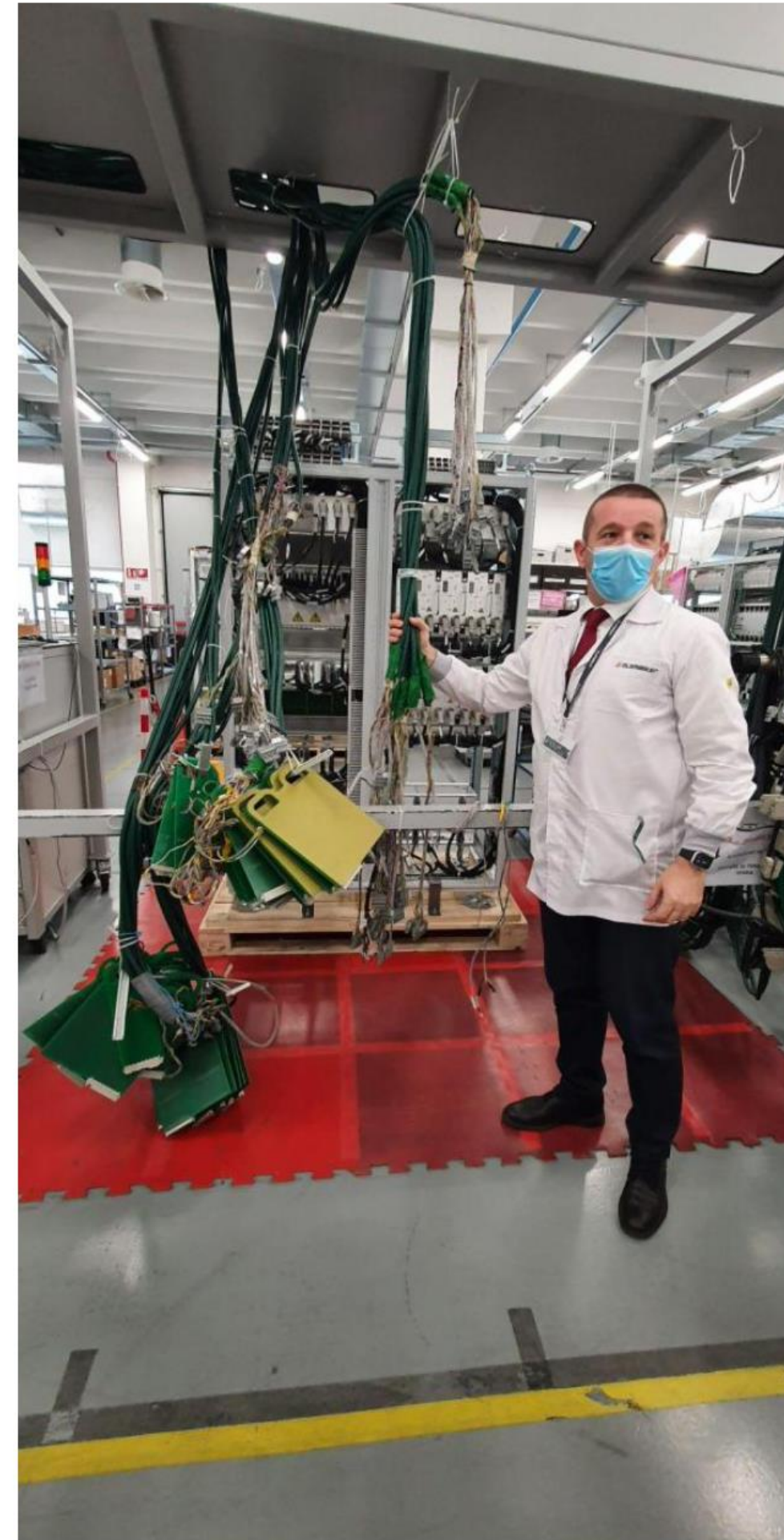


LOW – Italian Antenna Tenderer facilities visit





Production and testing facilities at ELEMASTER



Rack level testing of a railway management system at ELEMASTER



RF chamber at ELEMASTER





SPS - Sub rack delivered at GMRT in India





**MID TELESCOPE - SKAO at Laboratoire d'Astrophysique de Bordeaux (LAB)
FRANCE**

(From left, Ben Lewis (SKAO), Stephane Gauffre (LAB), Michel Perault (CNRS)
Shin'ichiro Asayama (SKAO), Robert Laing (SKAO))



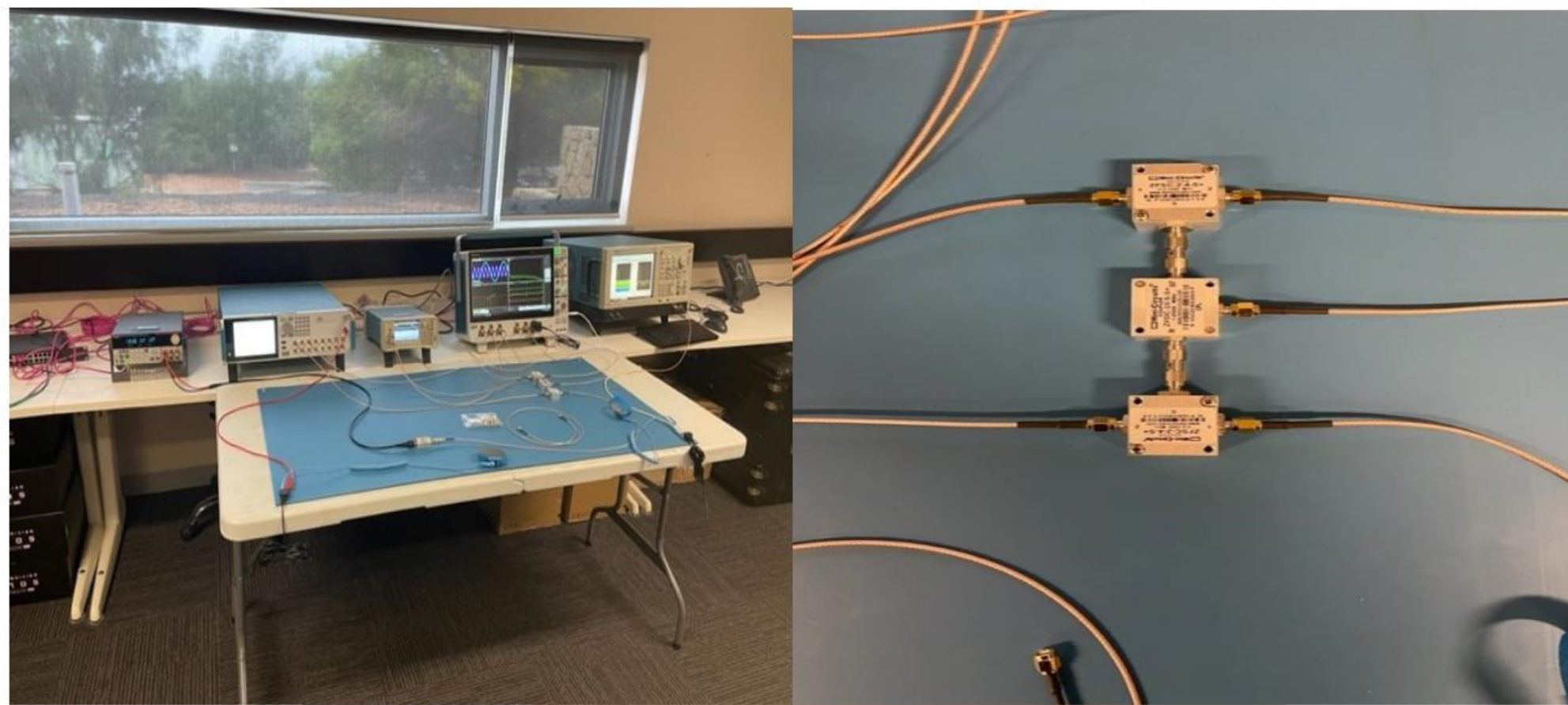
South Africa: interim Science Operations Center, Cape Town: architect's view of EOC in Klerefontain

SOC: open mid-October



Australia: interim SOC, Perth : interim Engineering Operations Center in Geraldton. Next slide: preparations for Integration Test Facility





During the **visit of the ITF Team** in Geraldton a recently equipped electronic laboratory was presented. The laboratory is equipped with the cutting-edge measurement equipment from the leading manufacturers, mostly Tektronix (oscilloscope, spectrum analyser, signal arbitrary generator) and Keysight (power supply).

The test laboratory meets all the basic ESD requirements (ESD mats equipped with ESD wrist bands with grounding). More equipment is planned to be purchased.

In this figure a sample test set up using directional couplers, splitters and attenuators is presented and all presented measurement equipment enables remote access through the stable ethernet connection (this means that the measurements can be conducted remotely when the DUT is physically connected).

The bottom picture presents two DELL servers used by the Viola Team.





During the **visit at Curtin University** in Australia a shielded FNDH box was presented in the EMC test facility. The FNDH box is a part of a PaSD contract and needs to meet demanding requirements related to the electromagnetic emissions, that is why it is tightly shielded.

During the Construction phase FNDH box will be placed near the antenna arrays and this is why proper shielding is a crucial aspect. The right picture presents the cover for the FNDH box with the copper finger stock which works as an electromagnetic gasket.





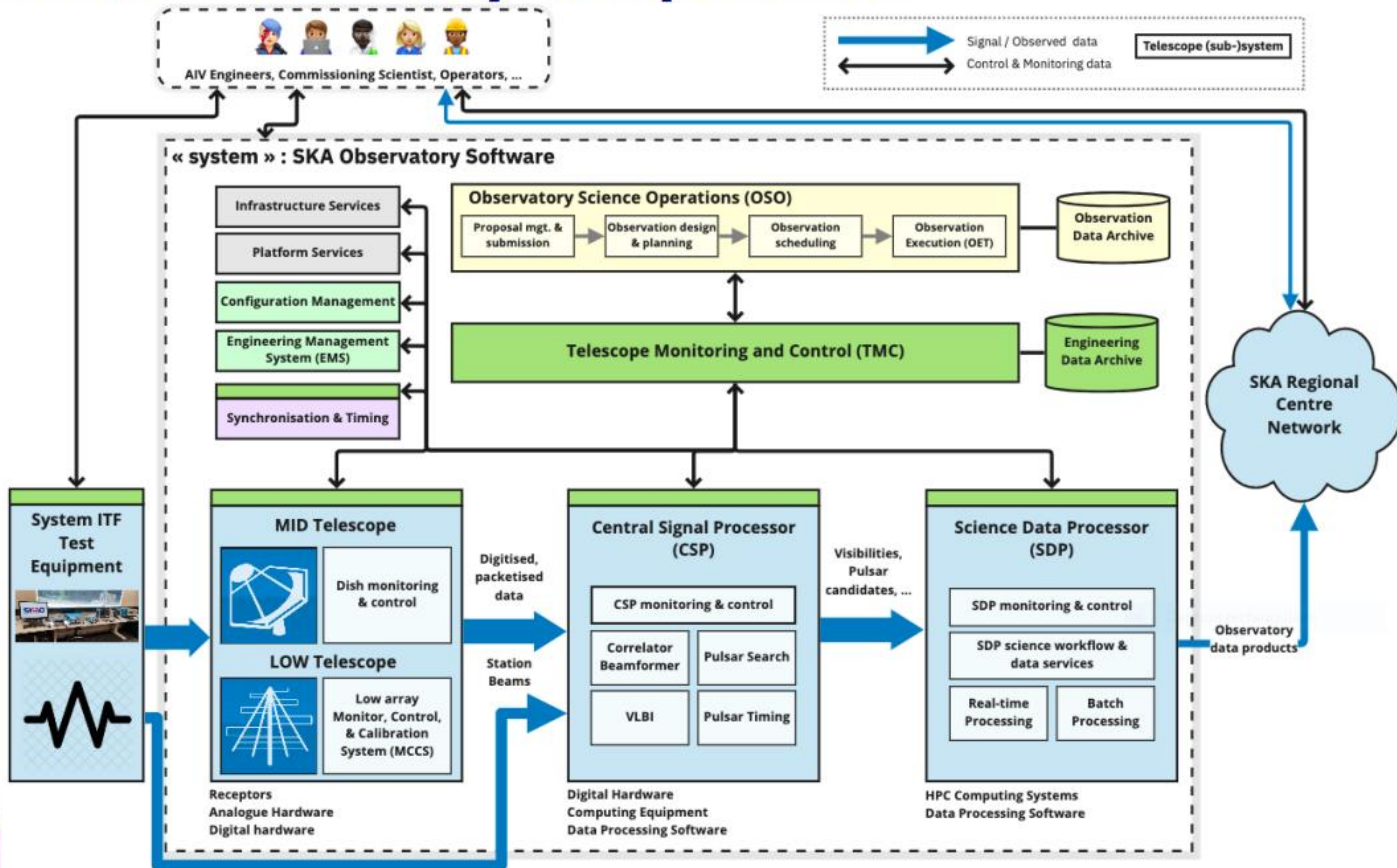
Meerkat Operator Demo
SKA HQ Staff were treated to a demonstration from the Meerkat telescope operating team in Cape Town.



SKAO vehicles now in both Australia and South Africa

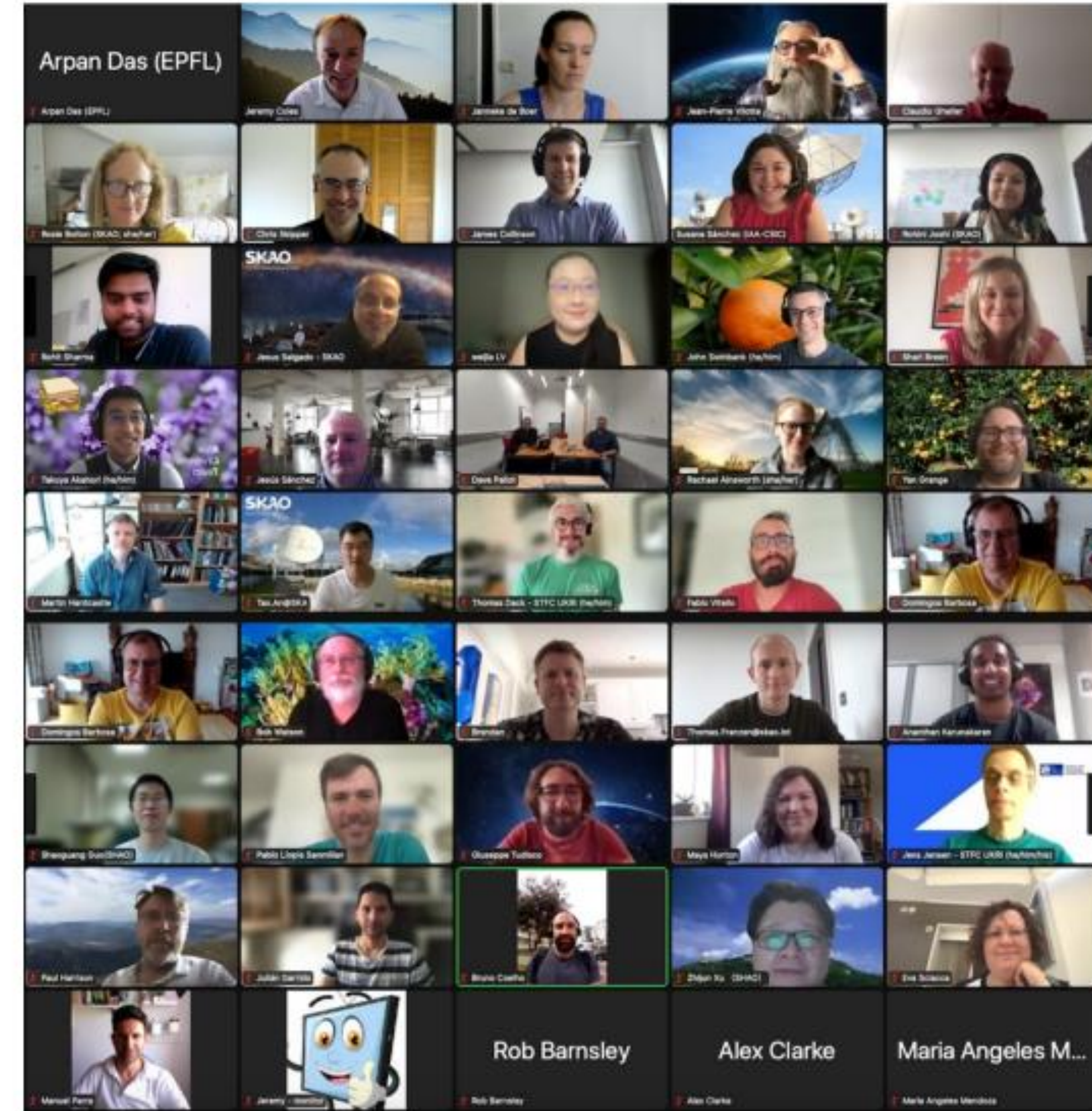


SKA Software - Key components



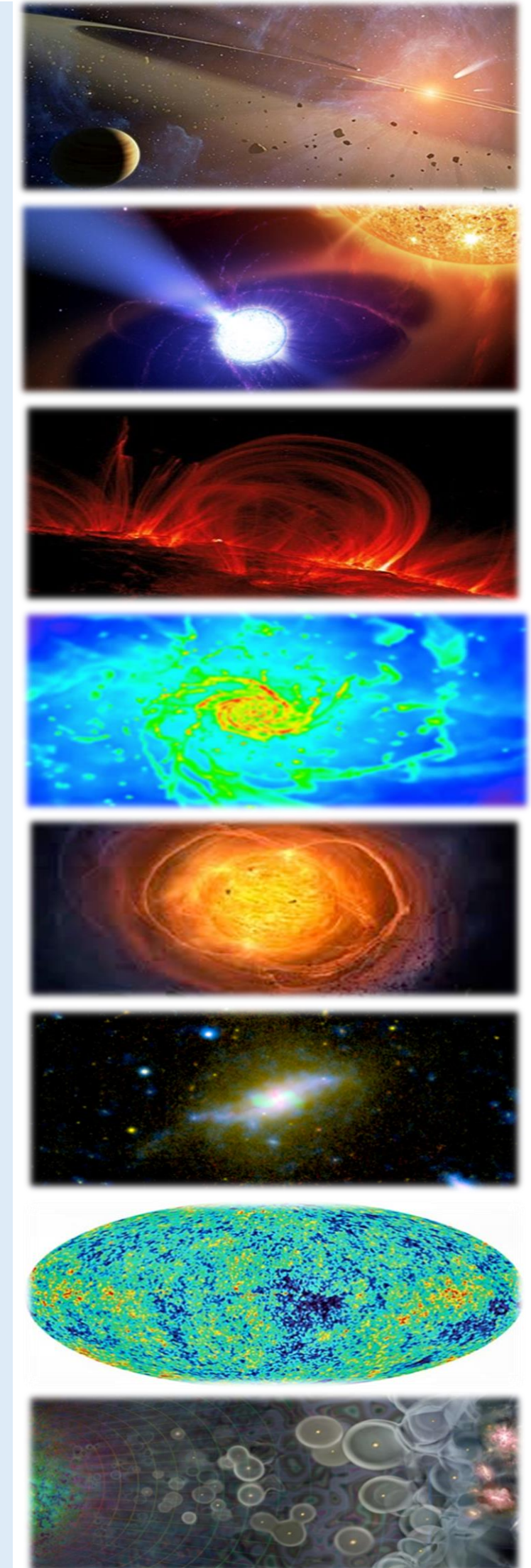
SRC Prototyping (June PI planning)

- Start of the Prototyping phase with a team of teams (50 developers, 20 observers) on the SRC ART
- Program Team: Rosie Bolton, Jeremy Coles, Jesus Salgado
- Science user engagement WG driving an improved understanding of the use cases



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?*

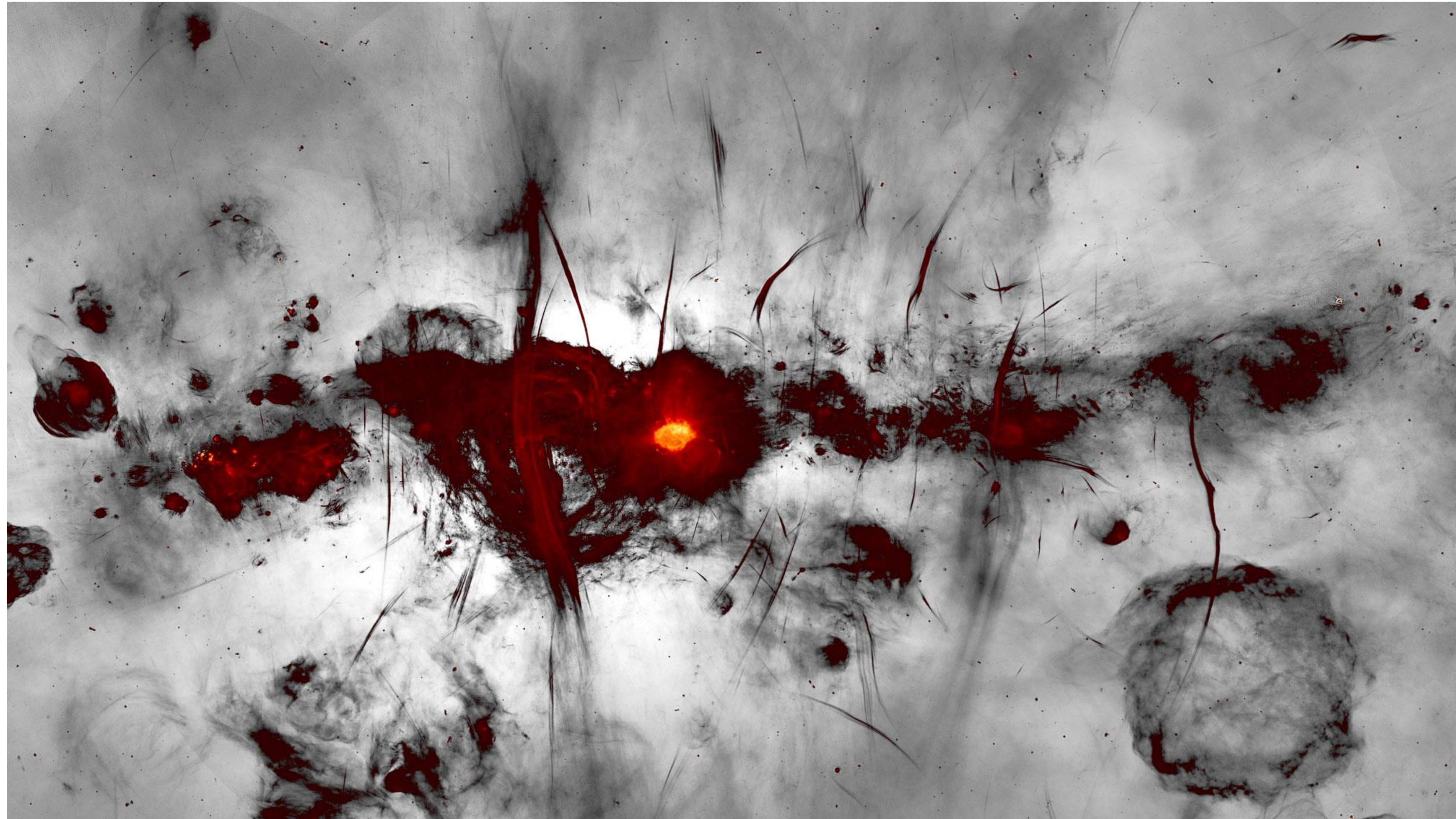




**SKA PRECURSORS
& PATHFINDERS**



Magnetically Driven Galactic and Cosmic Web Evolution



<https://www.sarao.ac.za/media-releases/new-meerkat-radio-image-reveals-complex-heart-of-the-milky-way/>

- Magnetic filaments in the central 500 pc of the Galaxy as imaged by MeerKAT

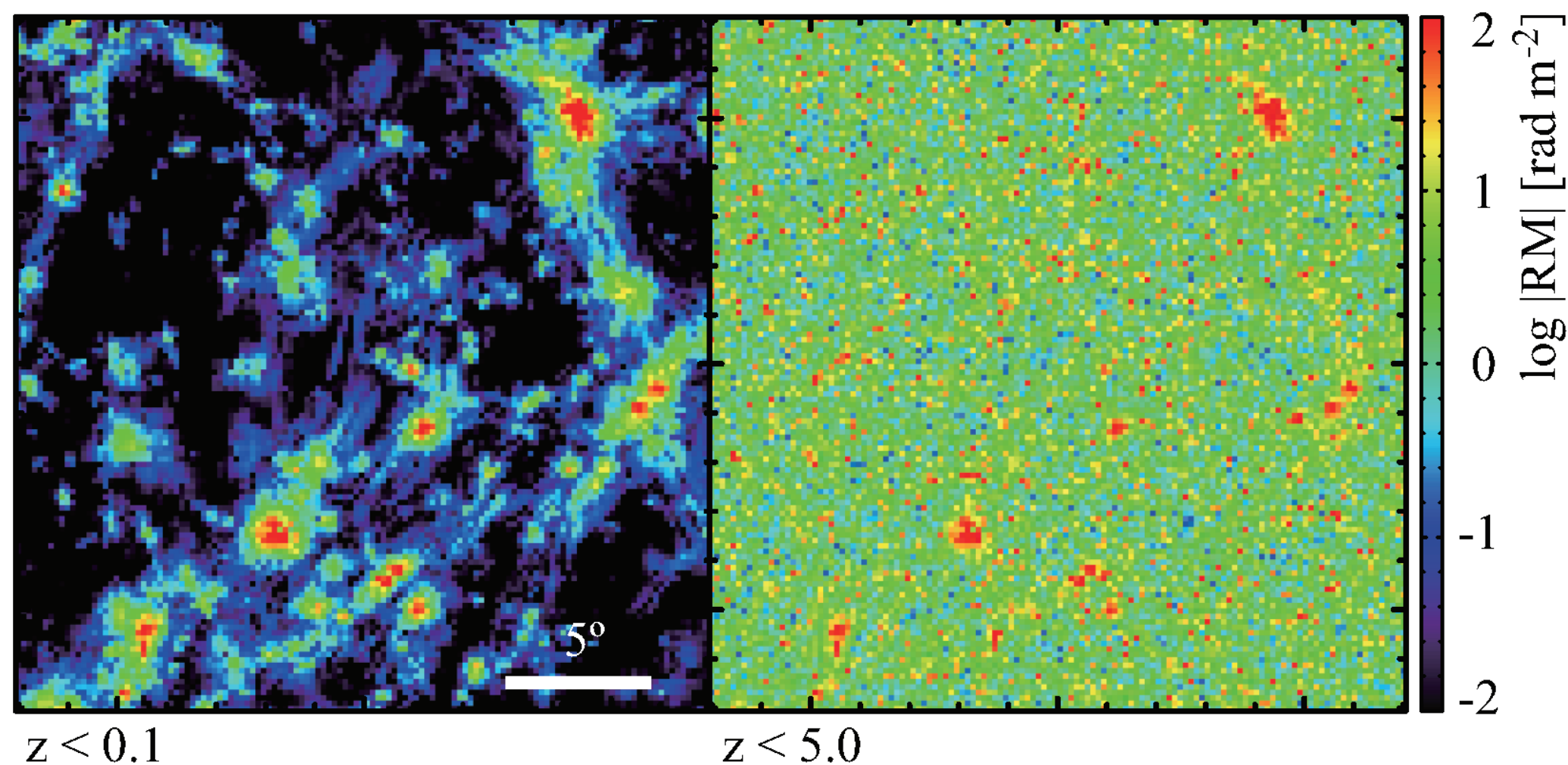
Heywood et al. 2022ApJ...925..165H



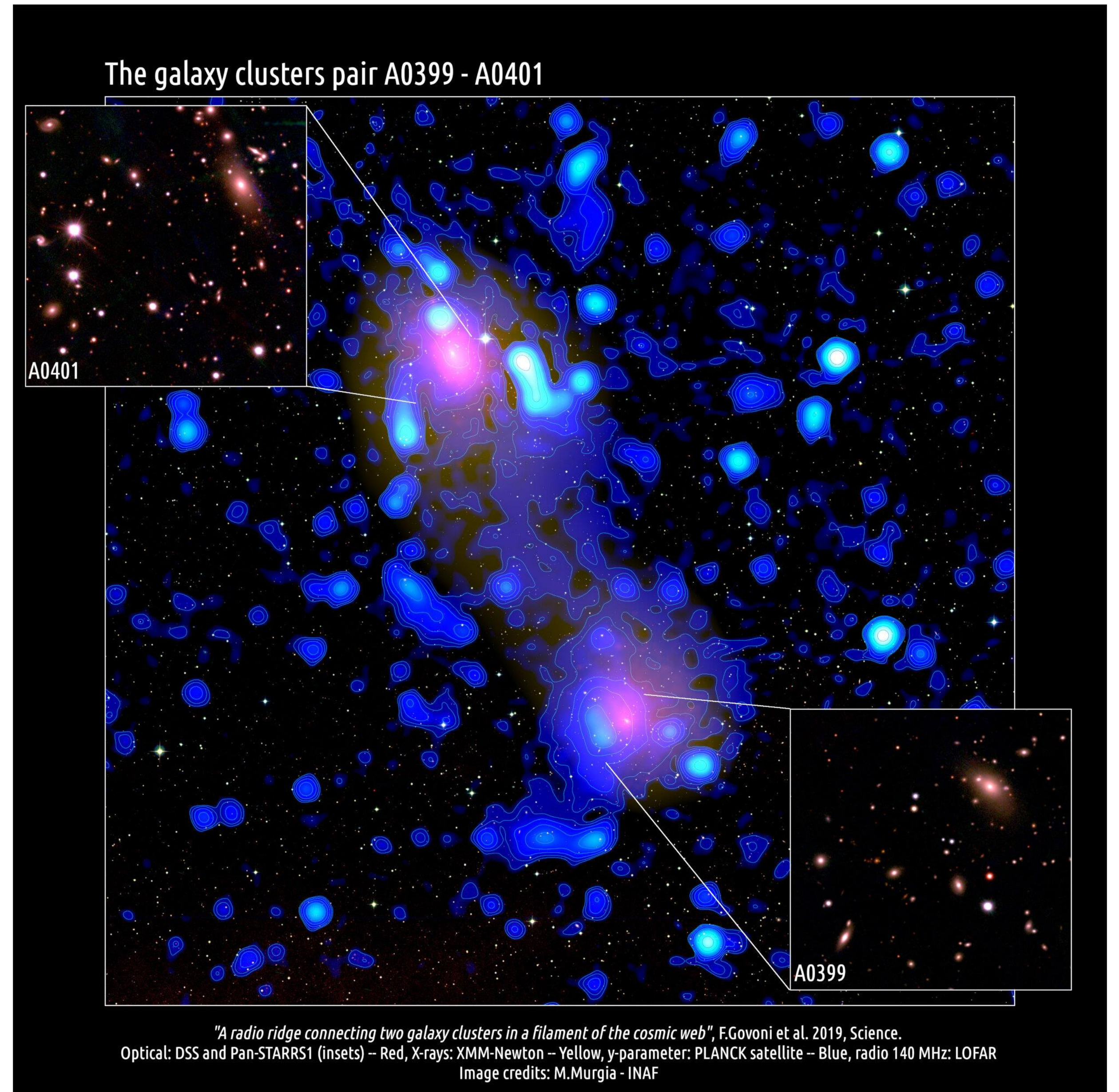
Magnetically Driven Galactic and Cosmic Web Evolution

- The magnetic cosmic web filament connecting the galaxy cluster pair A0399 – A0401 (at $z=0.07$) as imaged by LOFAR

Govoni et al. 2019Sci...364..981G



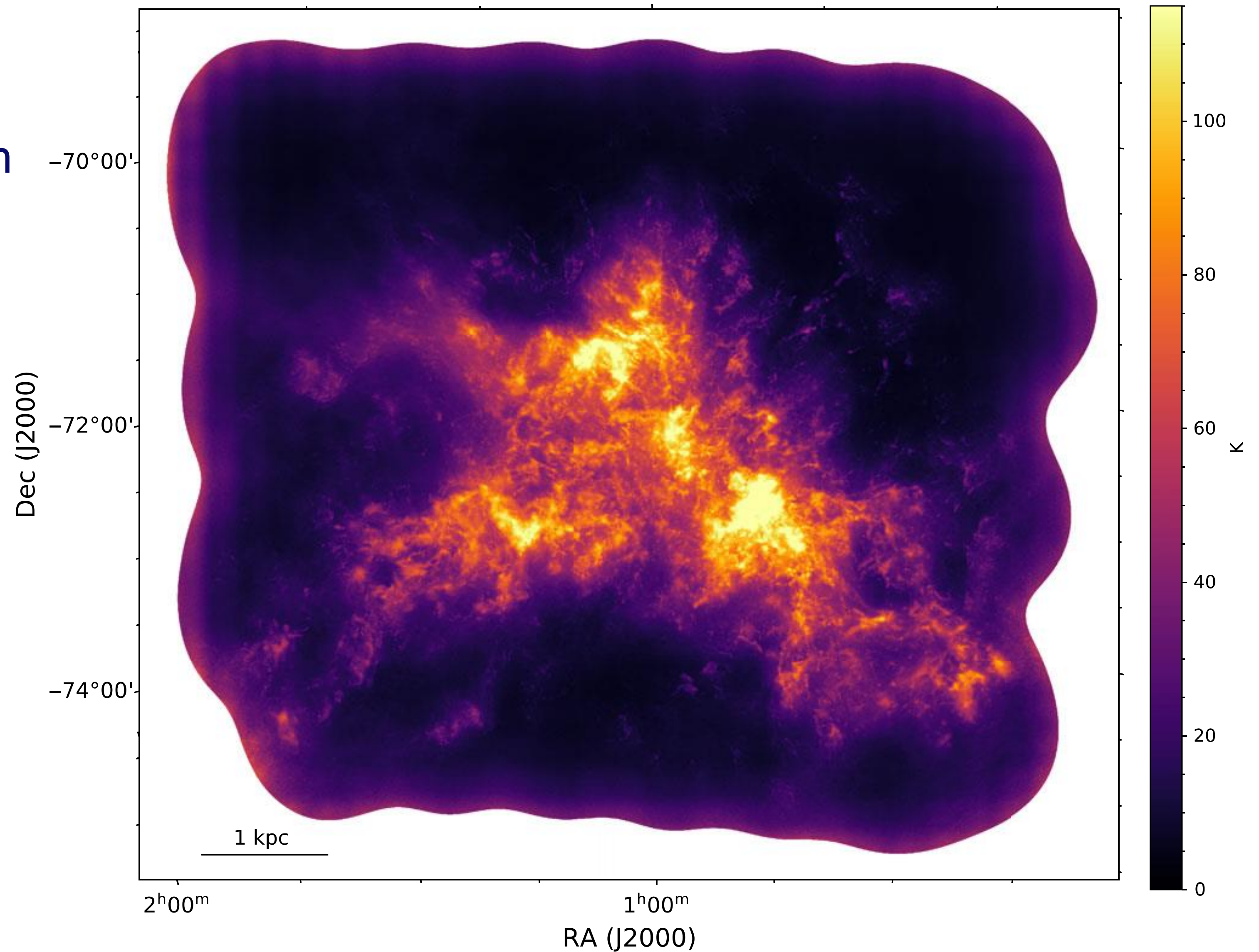
Magnetised cosmic web simulation
Akahori 2018Galax...6..118A



Probing Galaxy Assembly and Evolution with Neutral Hydrogen

- Witnessing accretion and tidal disruption of neutral hydrogen in the Small Magellanic Cloud imaged with ASKAP

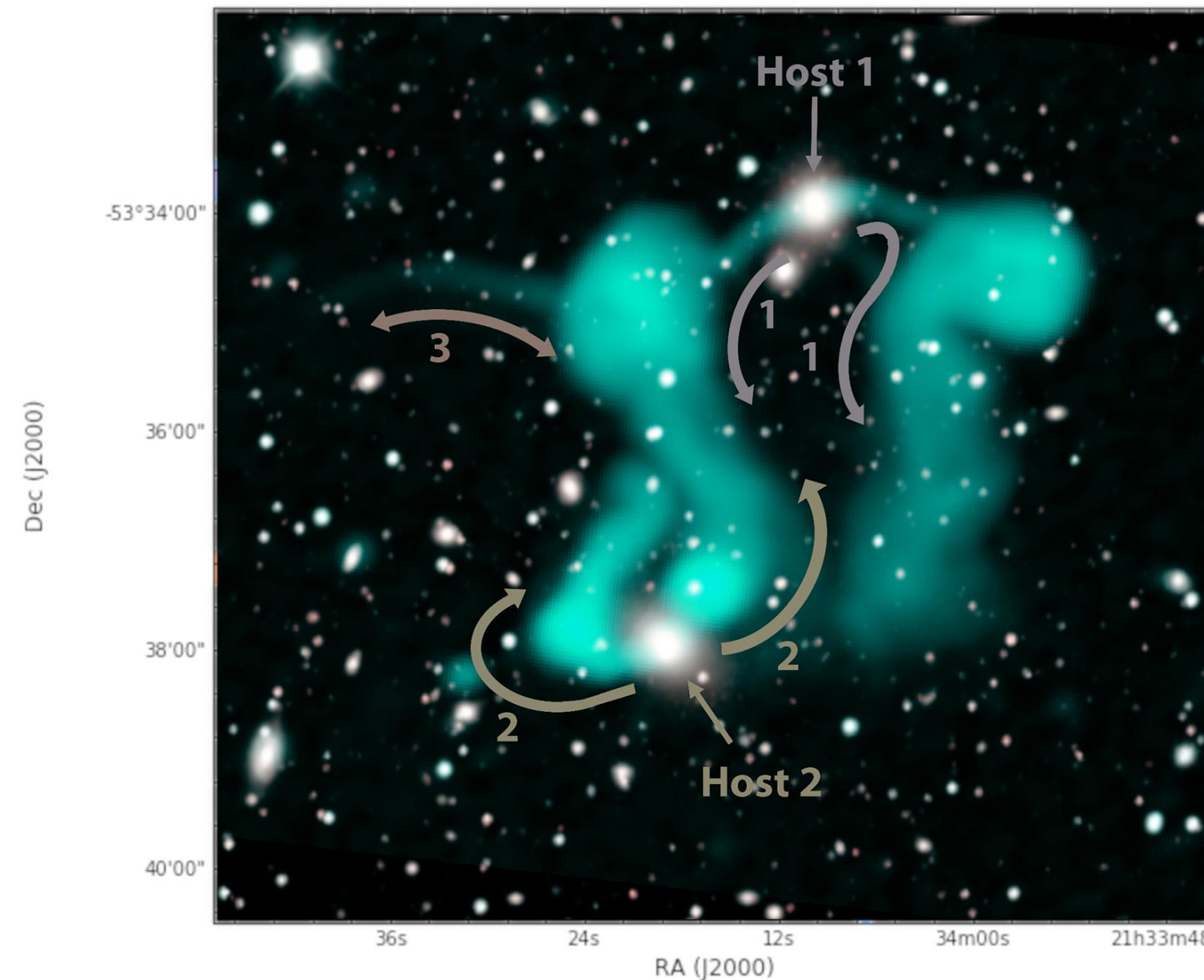
Pingel et al. 2022PASA...39....5P



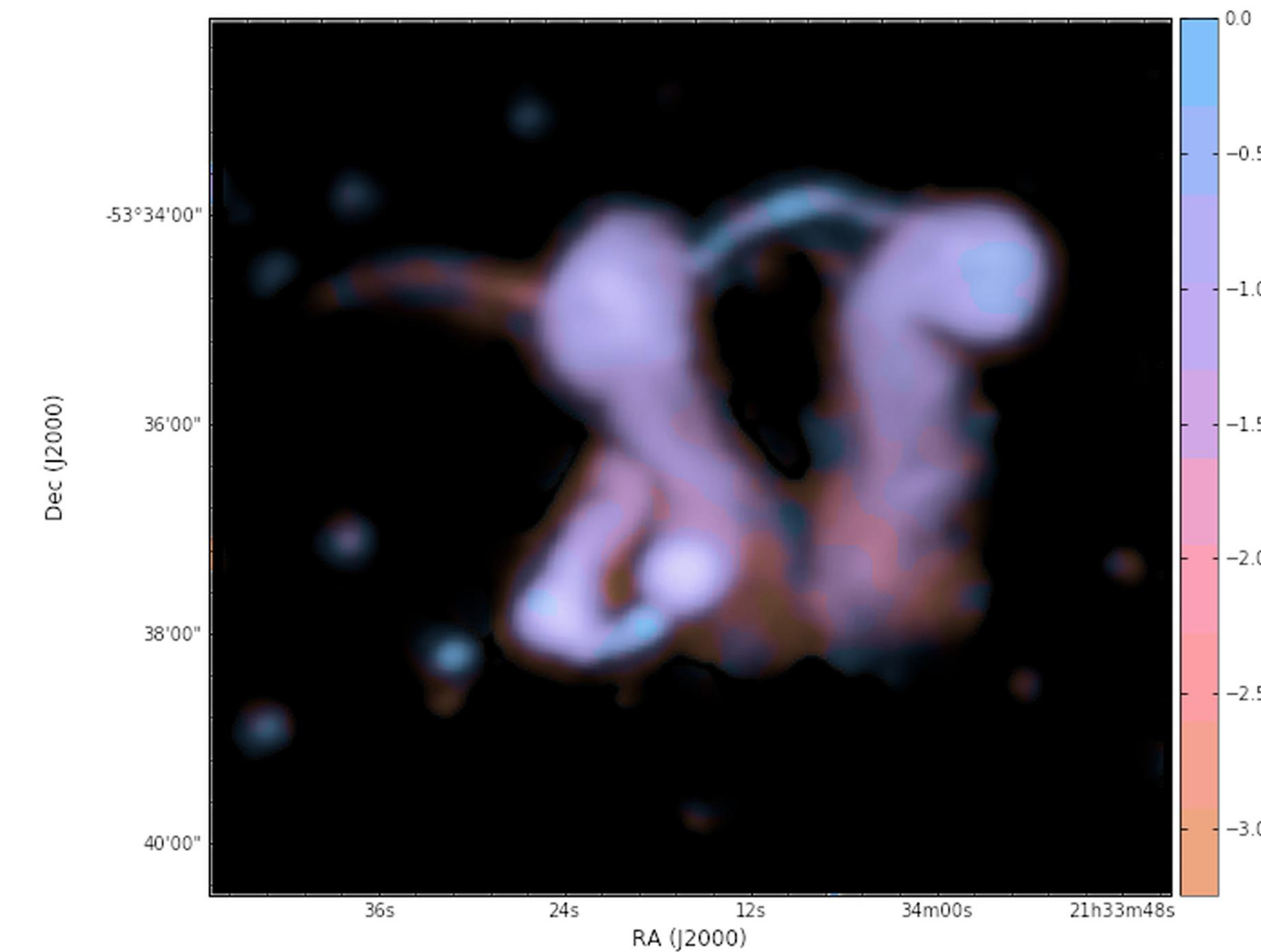
Probing Super-Massive Black Hole Evolution

- 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

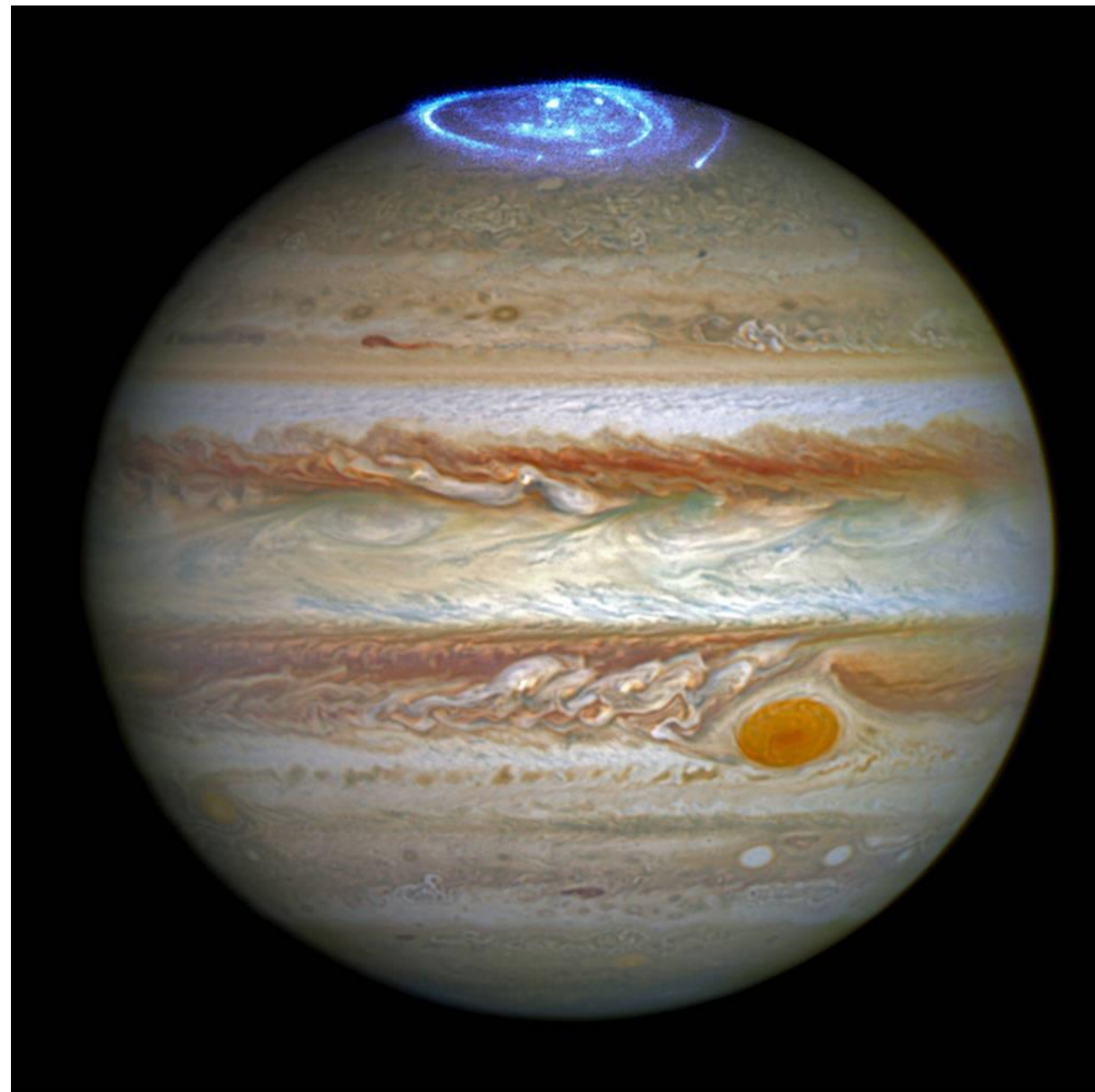


Radio Spectral Index

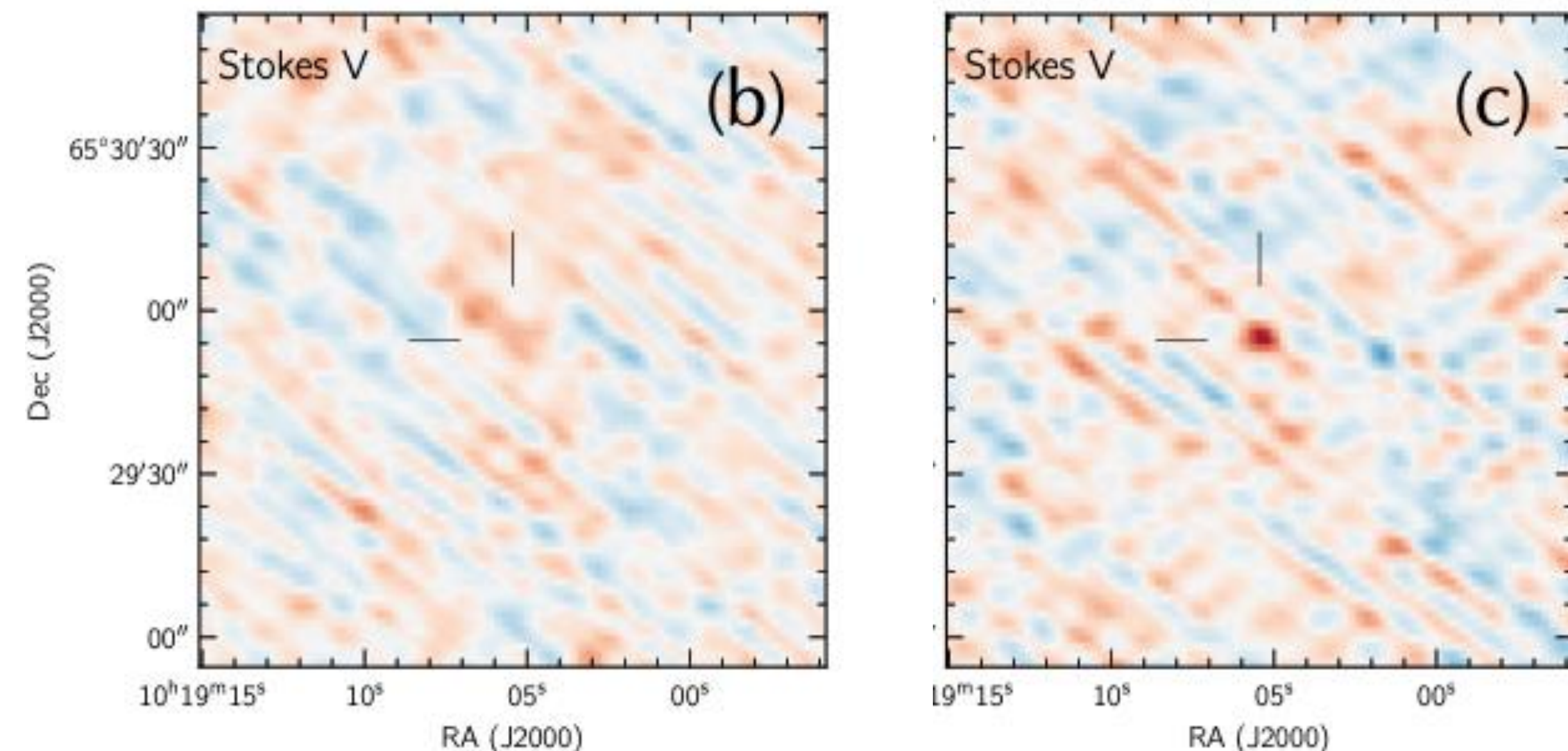


Characterisation of Exoplanets via Direct Detection

- Low frequency radio emissions from planetary aurora are very bright and highly polarized
- LOFAR detecting Brown Dwarfs – higher mass proxy (mass $\sim 13-80$ MJ) for exoplanets (< 13 MJ)
- SKA-Low sensitivity will enable direct detection of exoplanets (host star not polarized so not detected)



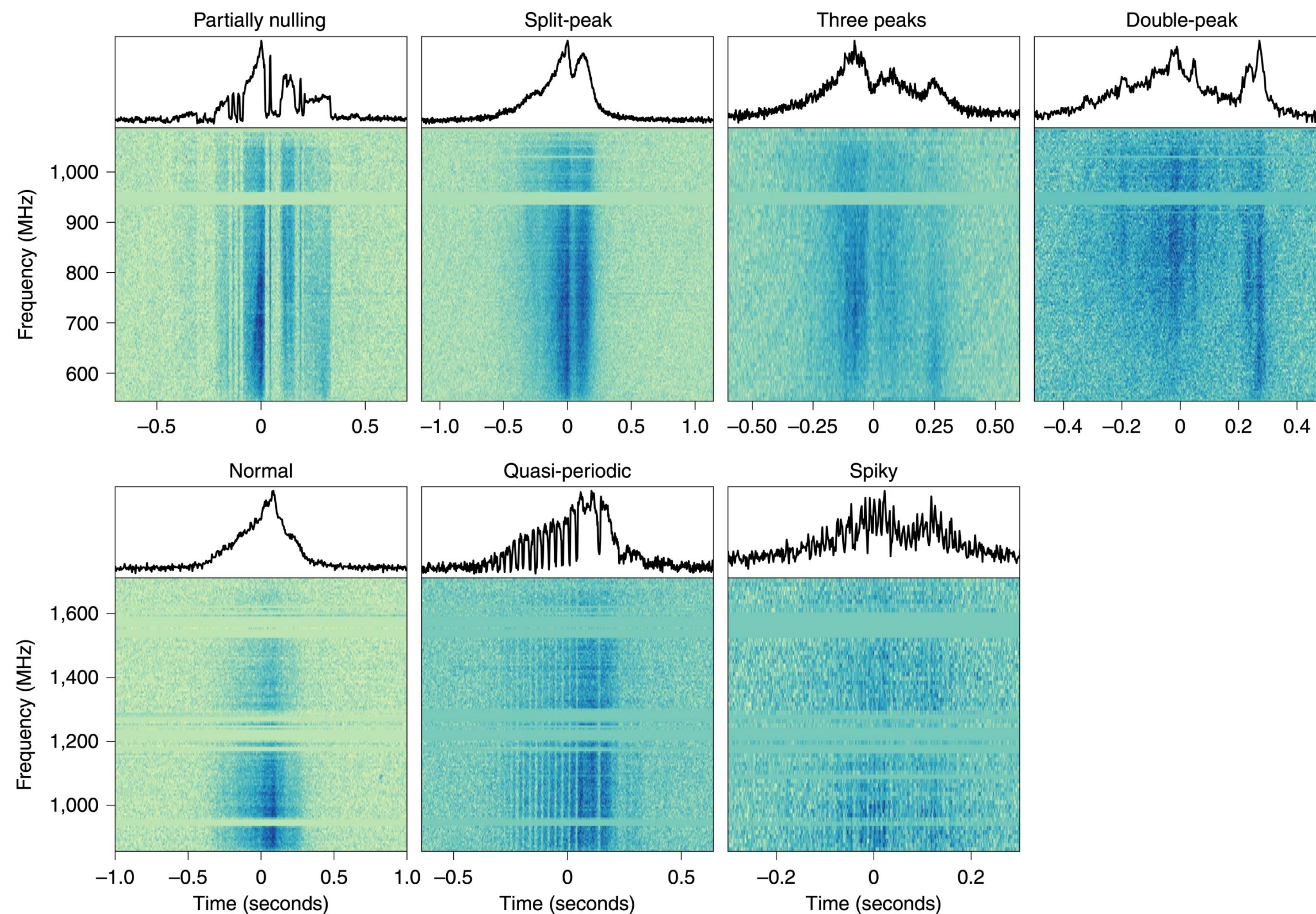
Aurora on Jupiter (credit: NASA)



Circularly polarised images (Stokes V; 30s) of radio bursts from the Brown Dwarf WISEPA J101905.63+652954.2 observed with LOFAR at 144 MHz (LoTSS) (Vedantham, Callingham, Zarka et al. submitted)

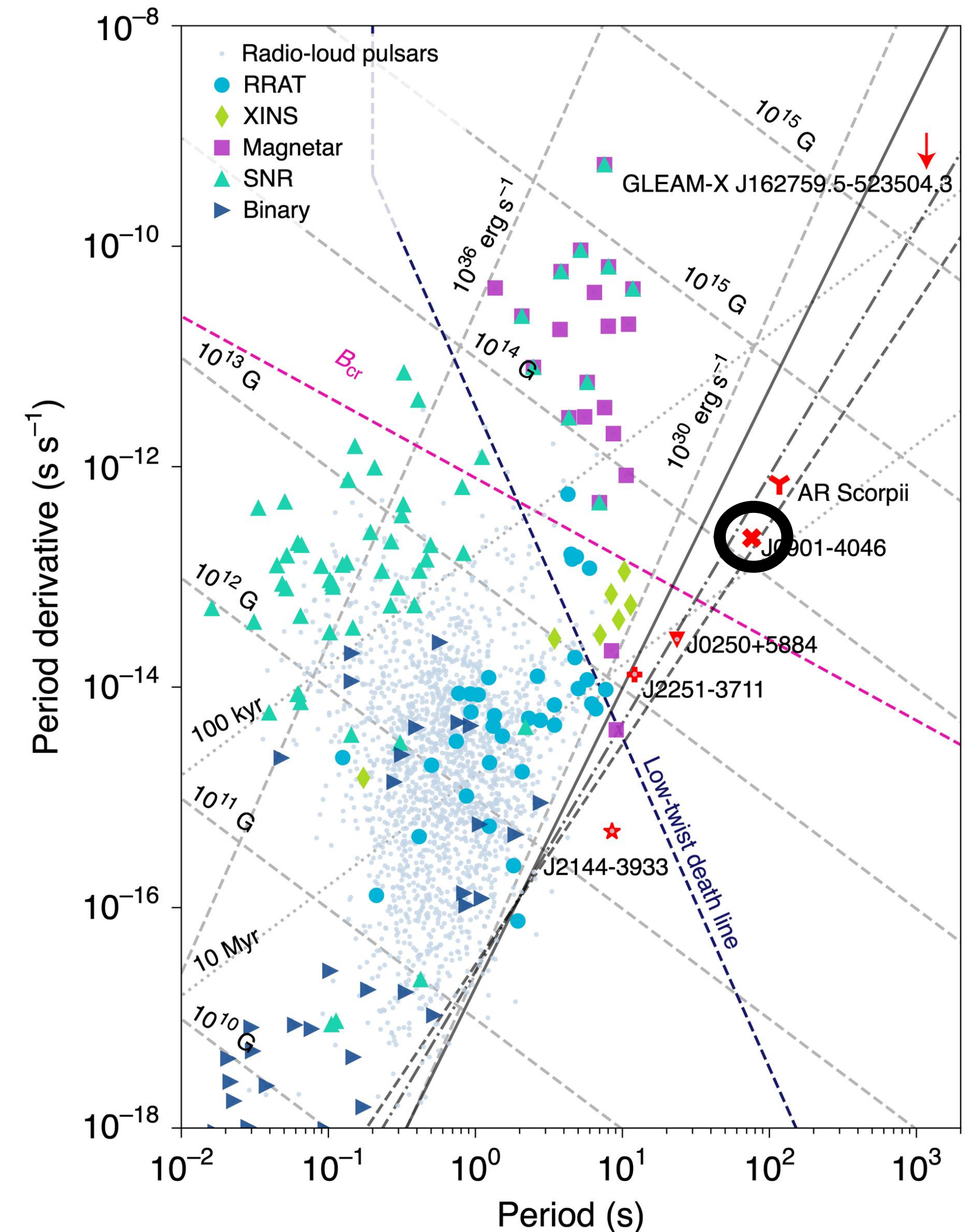


MeerKAT Discovery of ultra-long period Pulsar J0901-4046

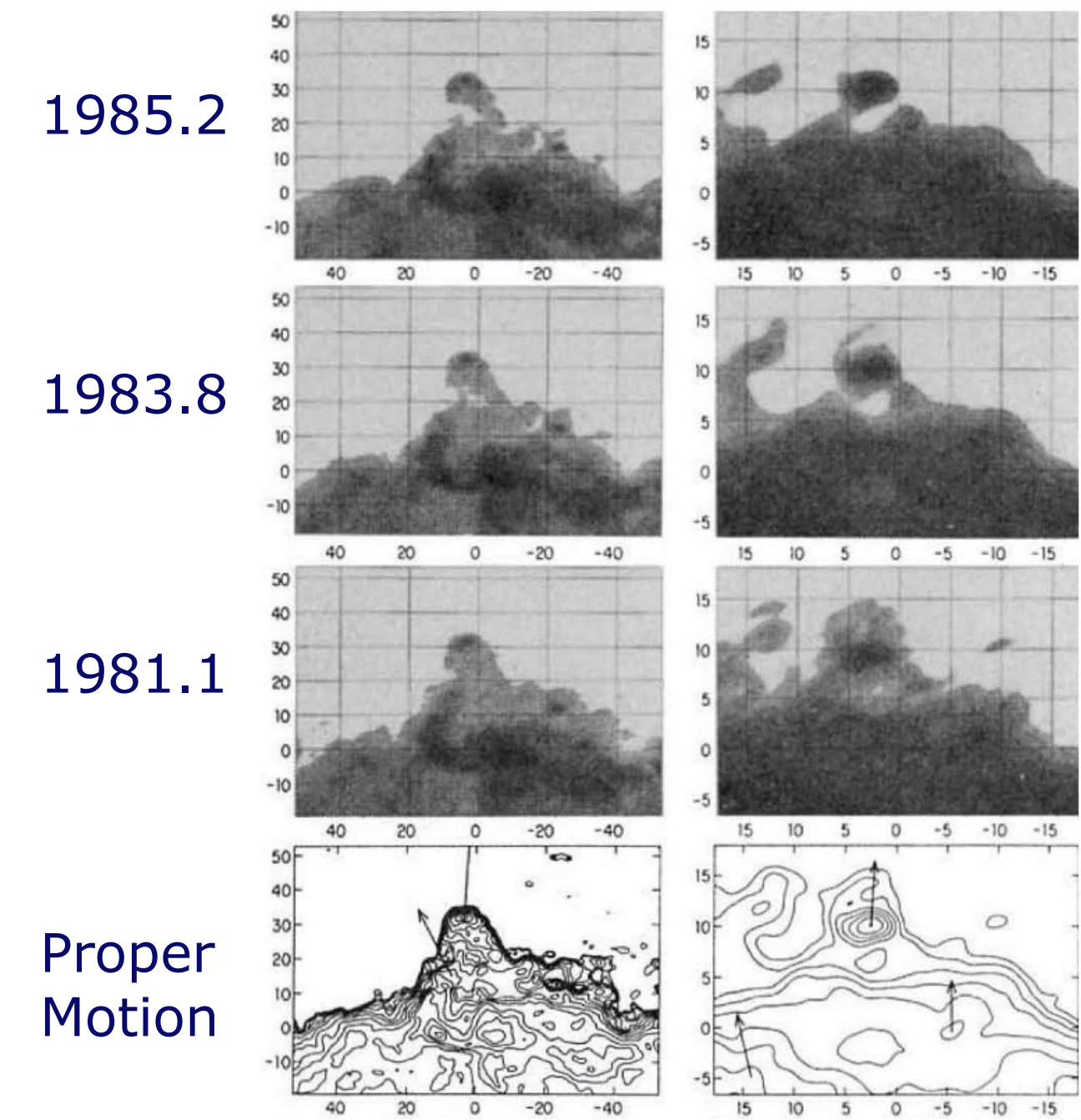
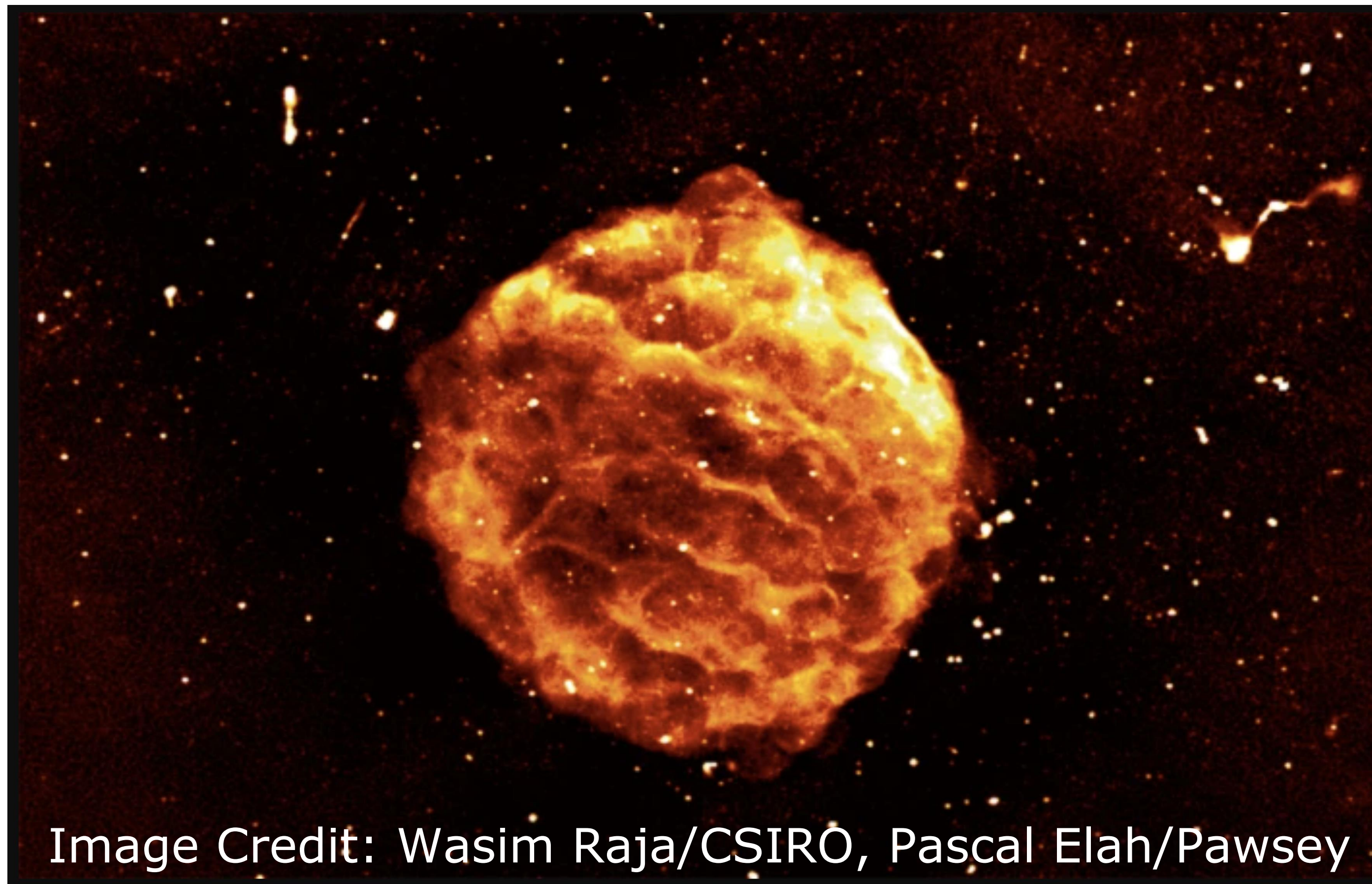


- Discovery of 76 second period pulsar with unusual time varying properties: eg. quasi-periodic, partial nulling may provide new insights into pulse emission mechanism

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



Wide-field Imaging of the Sky with ASKAP + Pawsey HPC

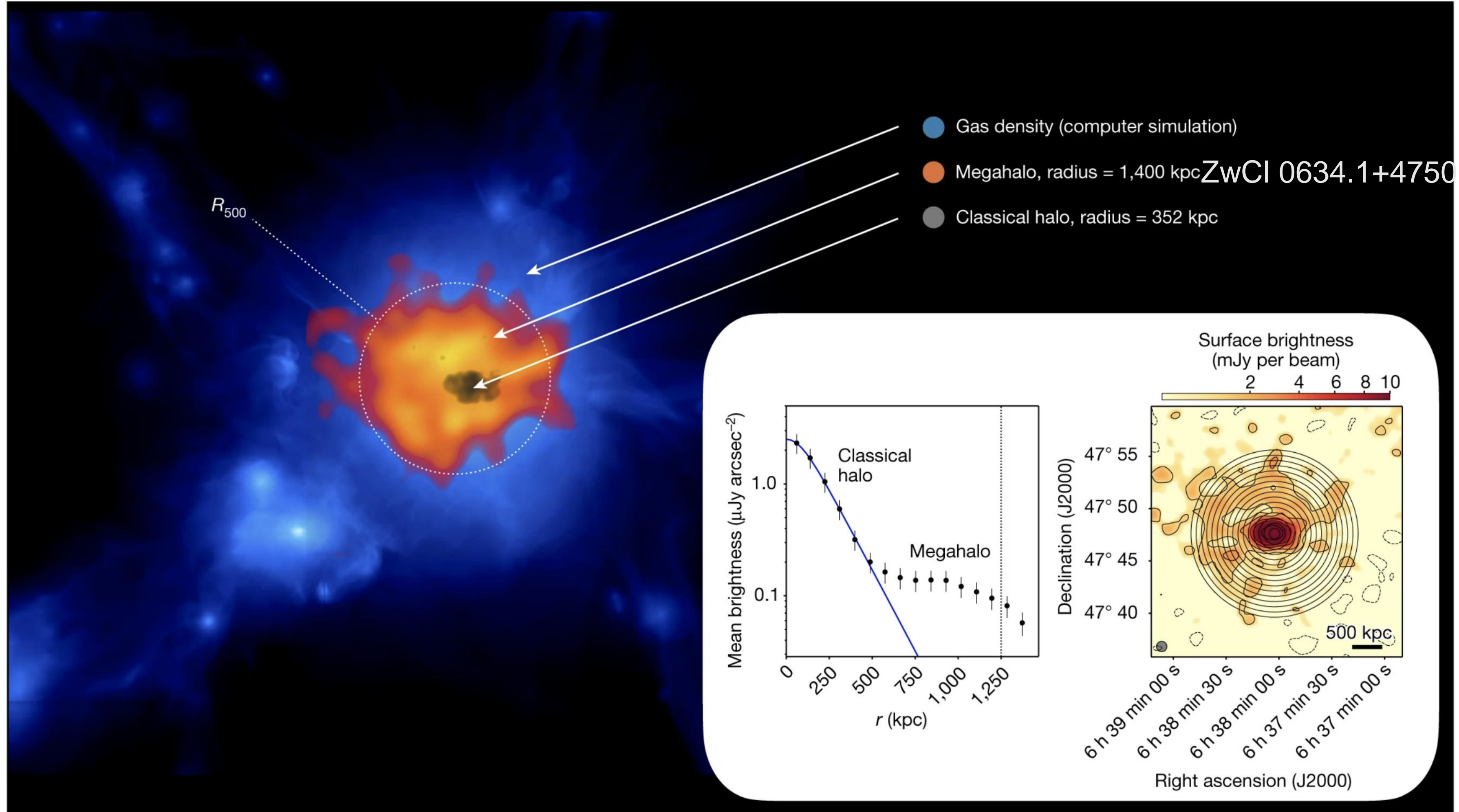


Time-lapse images of Cas A bow-shock features passing through SNR shell (Braun et al 1987, Nature 327, 395)

- Galactic SNR G261.9+5.5 imaged in 2022 as part of the wide-field EMU (Evolutionary Map of the Universe) sky survey with ASKAP
- Example of rare, "ejecta-powered" supernova remnants like Cassiopeia A, with morphology dominated by ejecta clumps bursting through shell of shocked circum-stellar matter



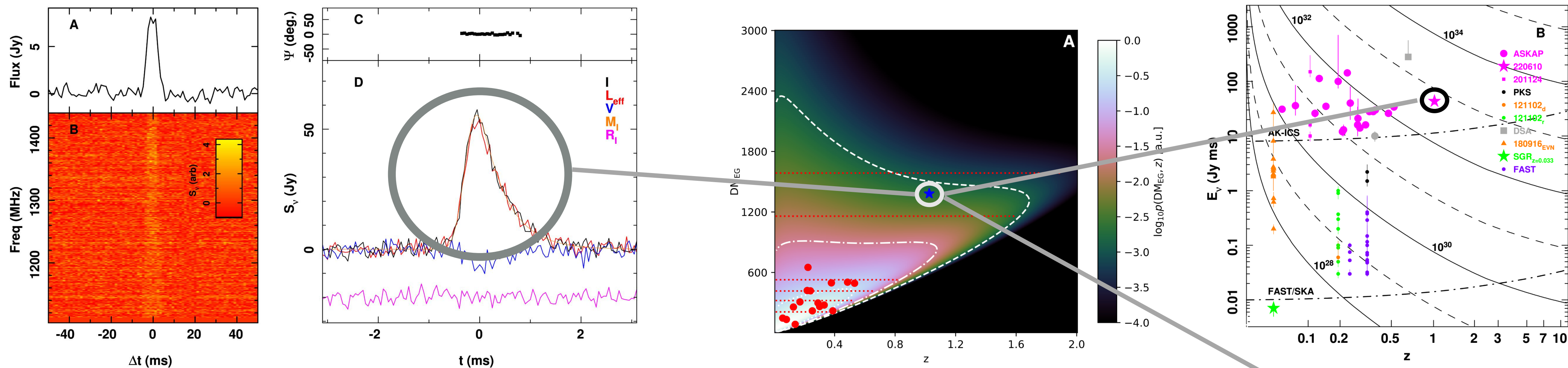
Probing Galaxy Cluster Evolution



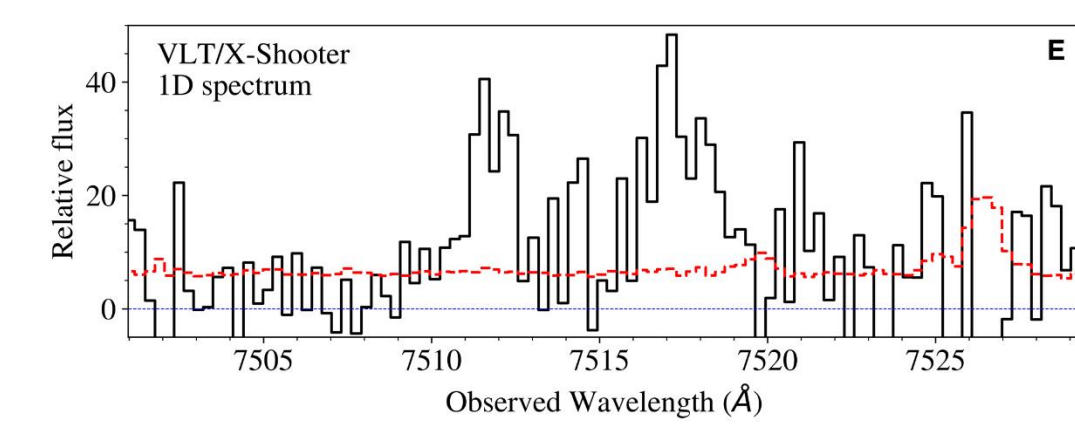
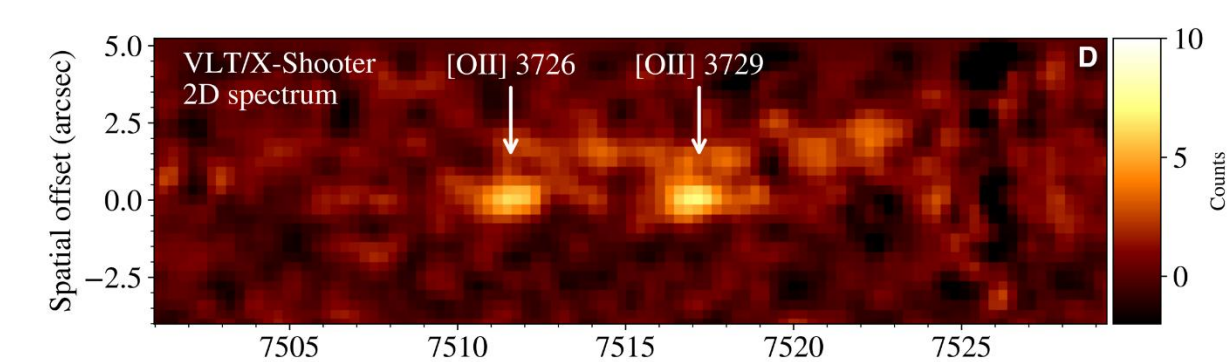
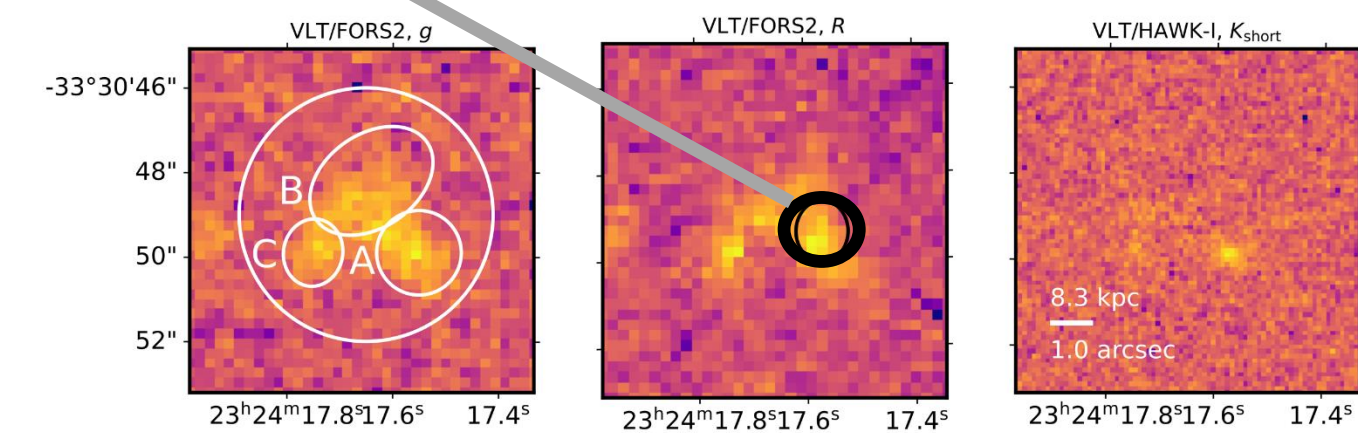
- Diffuse, steep spectrum “mega-halos” discovered in four galaxy clusters extending over several Mpc
Cuciti et al. Nature 609, 911–914 (2022), with LOFAR.



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 $RM = 215 \text{ rad m}^{-2}$
- Dispersion $DM = 1376 \text{ pc cm}^{-3}$ 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

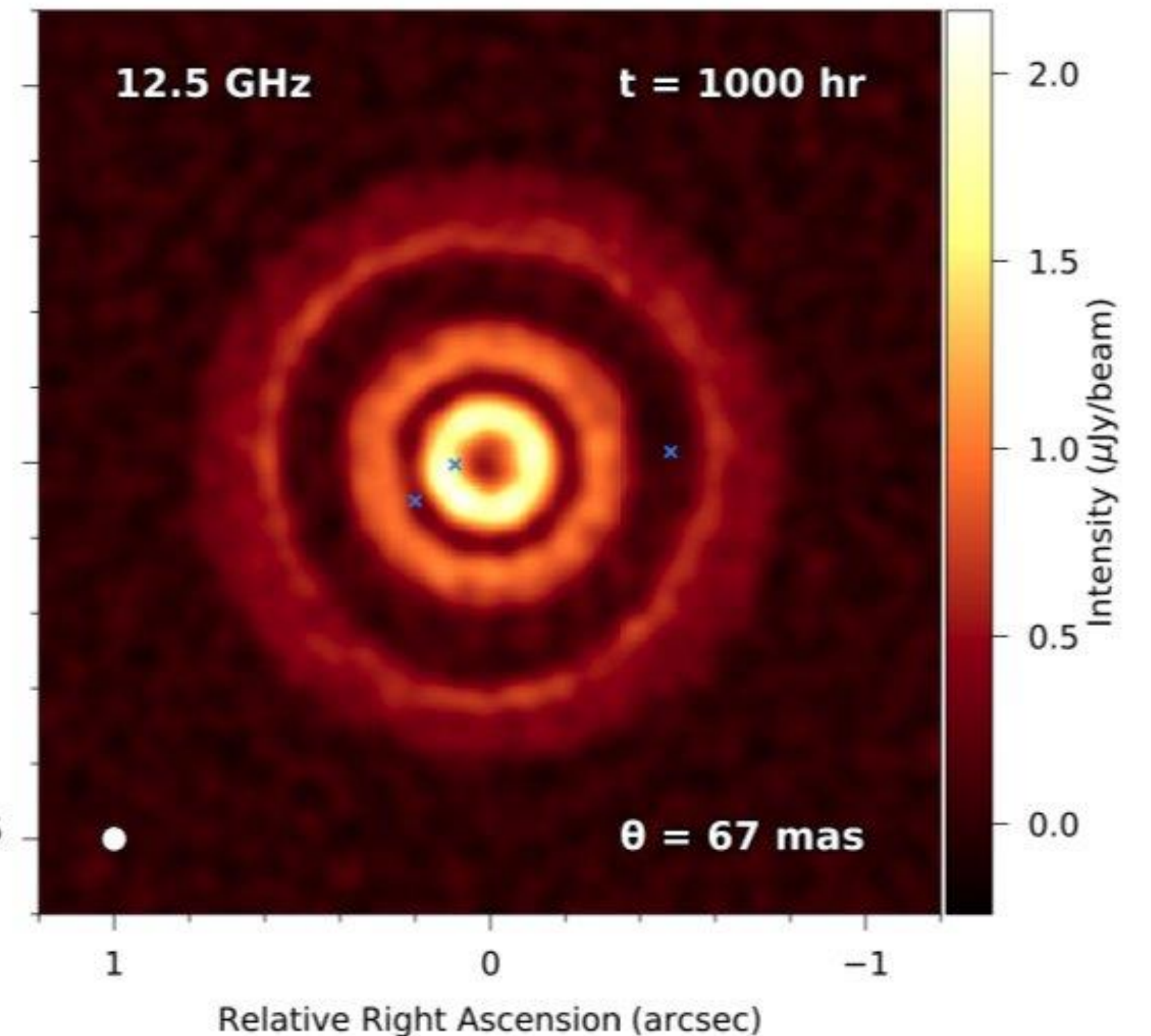
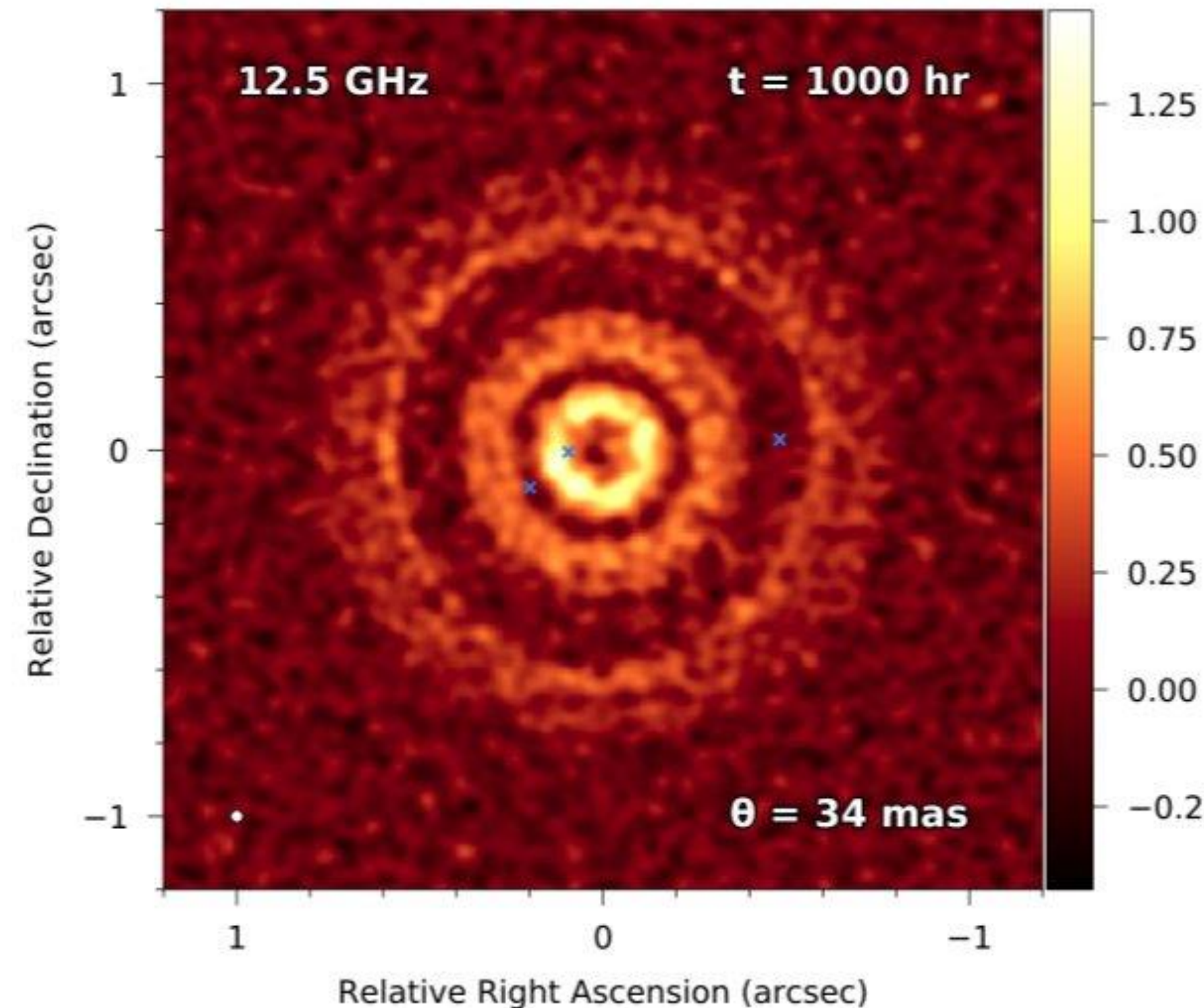
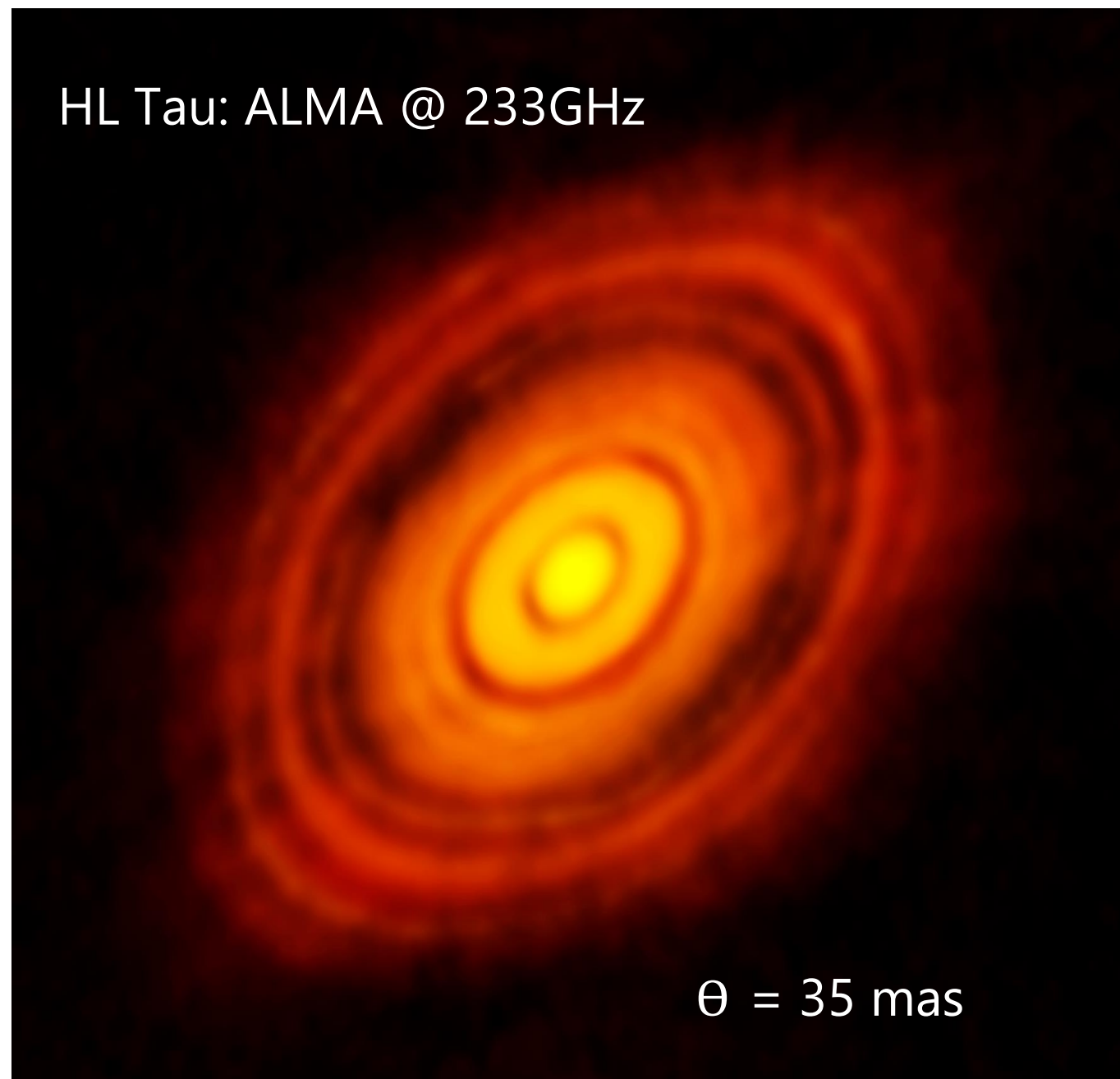


Ryder et al 2022, Science, under review



When/Where do Earth-like Planets form in Disks

- Formation of cm+ sized grains is a crucial step on the road to terrestrial planet formation
- Where and how does grain growth proceed?



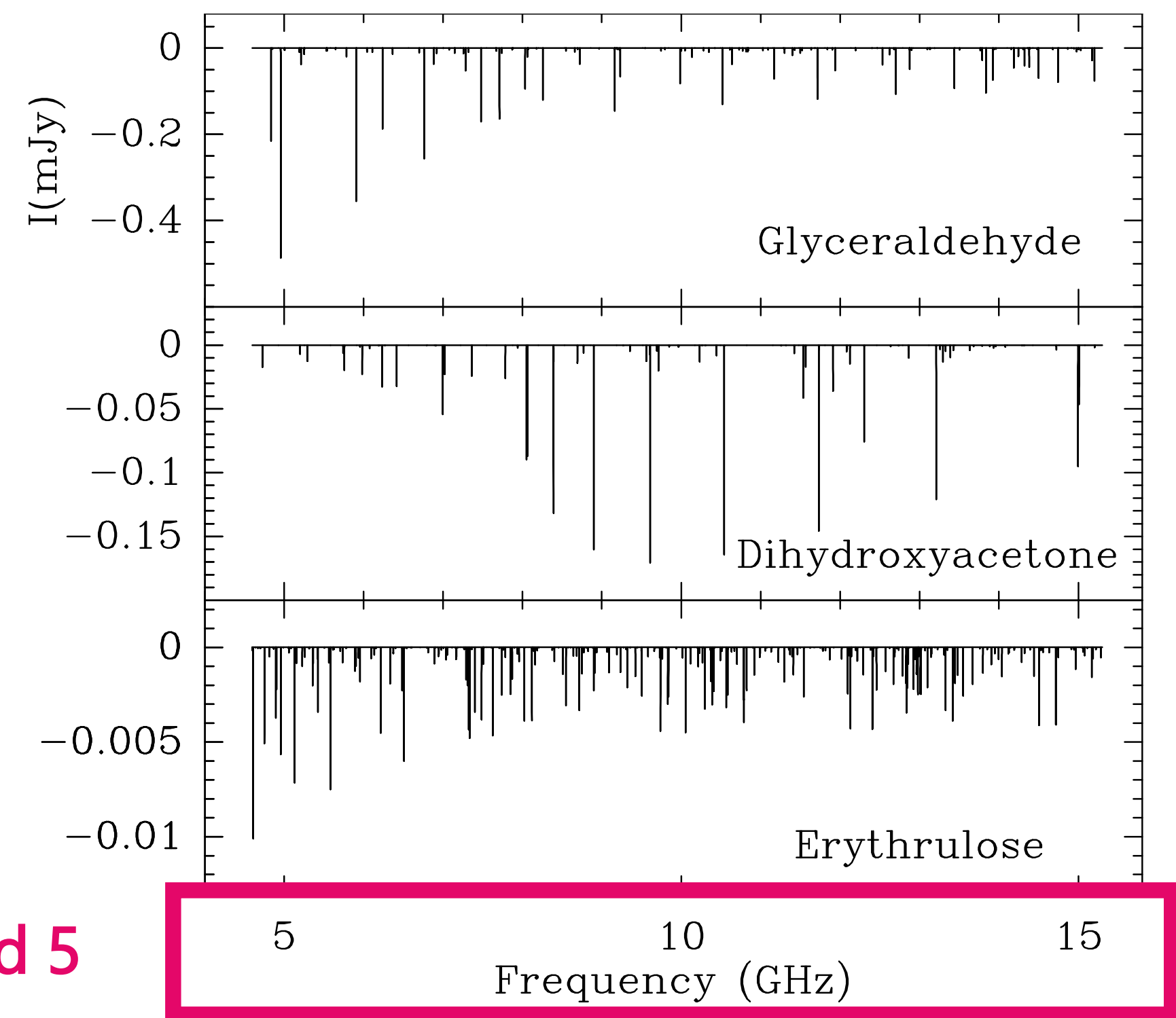
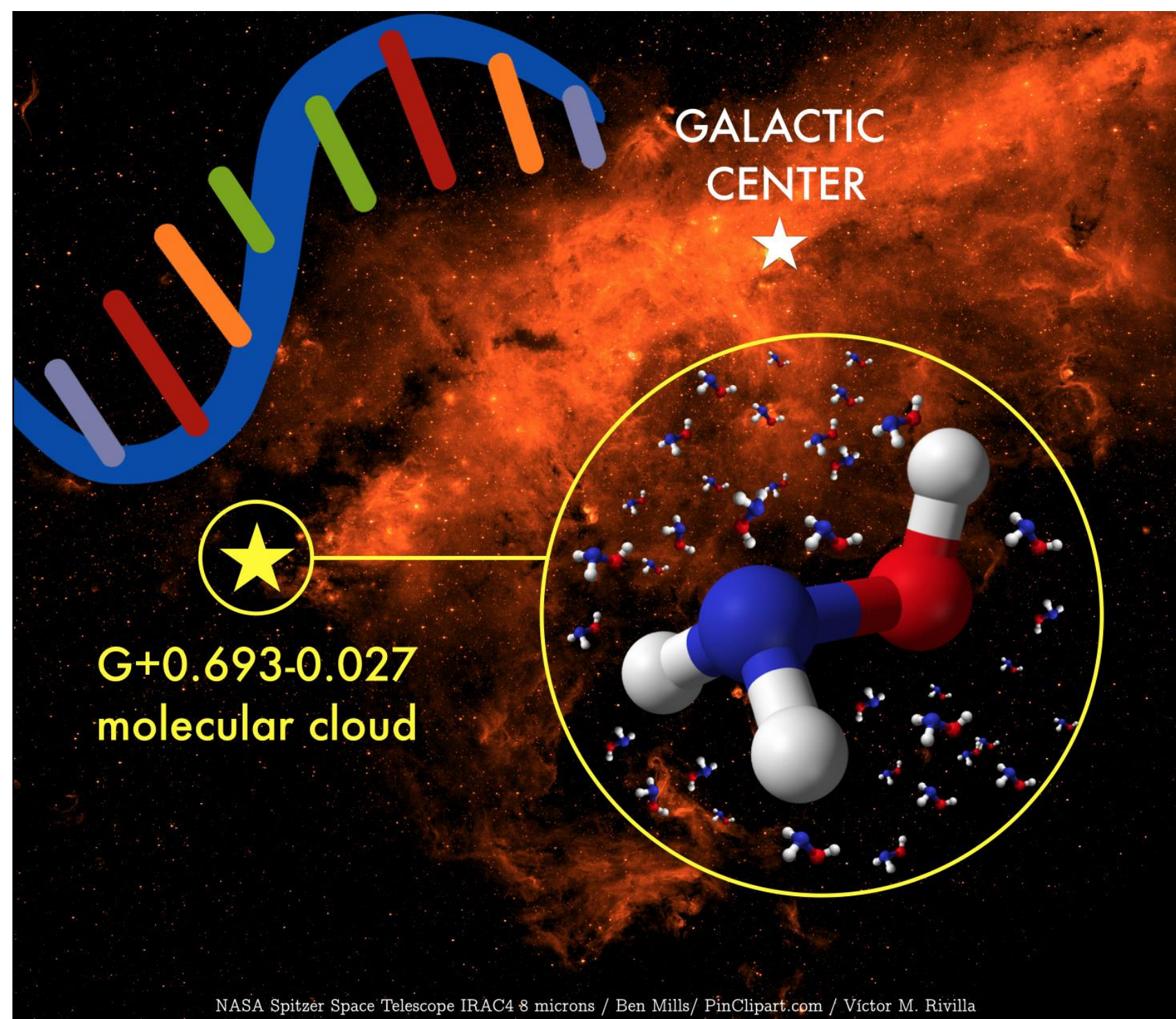
SKA covers the right λ 's to probe cm-size grains

- Simulations clearly show deep SKA observations will be able to observe pebbles in disks, and gaps/ring structure due to forming planets
(Band 5 simulation – Ilee et al. 2020MNRAS.498.5116I)



Pre-biogenic Molecules in Star-forming Regions

- Building blocks for life on Earth may have arrived from space (panspermia hypothesis)
- Detection of key pre-biogenic molecules (e.g. amino acids, complex sugars) in interstellar space is a "holy grail" of Cradle of Life studies



SKA Band 5

Detection of hydroxylamine (NH_2OH), key precursor to RNA
(IRAM 30-m; Rivilla et al. 2020ApJ...899L..28R)

Predicted spectrum of key large sugars toward G+0693.
Detection of the brightest (ie. deepest) lines requires 10s of hours integration with SKA1
(Jimenez-Serra et al. 2022FrASS...943766J)



Upcoming SKA Science Meetings

- Joint ESO/SKAO Conference and Workshop:
“Coordinated Surveys of the Southern Sky”
 - Now scheduled for week of 27 February 2023, in Garching, DE
- Joint SKAO/ngVLA Science Conference:
“New Eyes on the Universe: SKA & ngVLA”
 - Now scheduled for week of April 30 2023, in Vancouver, CA
 - Web site in development, SOC formed
- EAS 2023, Krakow, PL; SKAO Lunch Session (1.5 hour) proposed
- IAU GA 2024 in Cape Town; Letters of Intent for EoR and HI Symposia submitted by SKAO SWGs

Capture rectangulaire



SKAO

Construction Commencement Ceremony – C3

William Garnier – Director of Communications

18/10/2022 – SKAO-Council-07-13



Overall considerations

- Date now set – 5/12/2022
- Important milestone in SKAO calendar, officialising commencement of on-site activities
- SKAO event, in partnership with our local partners
- Working closely with local communities in shaping programme of the event



ALMA ground-breaking ceremony



ASKAP inauguration ceremony



Objectives and principles

- Celebrate on-site start of construction of the telescopes, building on 1.5 years of global procurement & constr. activities
- Celebrate new chapter of harmonious and fruitful relationship between partners (now incl. SKAO) and local and Indigenous communities
- Showcase international cooperation and raise awareness of countries' role and investment in the SKAO
- Celebrate SKAO's benefits to its Members (such as contracts) and local socio-economic impact
- Build and cement relationships with key local, national & international stakeholders (government, partners, collaborators, industry, etc.)
- Showcase 'validation' from local/Indigenous communities



C3 concept

- Telescope host countries:
 - Local event on site
 - Science Minister + emphasis on local authorities + local and Indigenous communities
 - In SA, presence of global science leaders attending World Science Forum
 - National and international media (interest from BBC, France 24, CCTV, Dutch NOS, etc.)
 - Bigger event in Perth/Cape Town
 - Perth: Evening event. Presence of Ambassadors + large number of local, regional, national stakeholders
 - Cape Town: Breakfast event (6/12). Presence of Ambassadors + large number of stakeholders
- Across the partnership
 - Partners encouraged to harness C3 by organising satellite events in their country during the week with their key stakeholders -> opportunity to involve their SKA-contributing people in this milestone and/or engage local media and emphasise country's role
 - SKAO will be supplying videos about C3 site events that can be used during satellite events
- SKAO HQ
 - Event for SKAO staff to celebrate their contribution and make them part of the moment.
 - Under consideration with UK partners: Event with UK stakeholders, incl. Sc. Minister + UK-based Ambassadors



Communication

- Importance of media (in host countries and across partnership)
 - Media pack being prepared: press release (incl. HoS/Ministerial quotes and recorded messages from SKAO partners: SKACON Steering Committee in charge), new imagery, new CGIs, new B-roll footage, construction activities video, etc.
- Social media campaign (SKAO countries invited to take part via SKACON); work with communities to get positive coverage ahead of the event
- Comms on ILUA following Wajarri celebration (and promotion) on 5 November → nicely sets the scene ahead of C3
- Briefing notes to be distributed to SKACON, in particular on local engagement and socio-economic impact.
- Countries (via SKACON) encouraged to develop briefing notes about country benefits





SKAO

Et merci, Michel!



Thank you

*We recognise and acknowledge the
Indigenous peoples and cultures that have
traditionally lived on the lands on which
our facilities are located.*

SKAO

www.skao.int