

MeerKAT

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SKA AFRICA
SQUARE KILOMETRE ARRAY



**National
Research
Foundation**



MeerKAT

- Initially conceived as SKA pathfinder.
- More Karoo Array Telescope — radio interferometer.
 - 64 x 13.5m dishes, with max physical baseline ~ 8km.
 - Currently operates at L-band (900-1670 MHz) and UHF (580-1015 MHz).
 - Full polarisation/band/synthesis observation: ~24TB
- Current Operations
 - Currently involved in science operations.
 - Includes Large Science Projects (LSPs) and Open Time Projects.
- 2022+
 - Commissioning of S-band receivers.
 - Construction and Integration of MeerKAT+ (+16 SKA1-Mid Dishes).



A brief history of MeerKAT

2003: SKA South Africa
Project Office established



2006: XDM groundbreaking
(eXperimental Development
Model)



2007: PED First Light
(Phased Experimental
Demonstrator)

2009: 1st Call for
MeerKAT science
projects

2010: MeerKAT
Concept Design Review



2012 May: SKA
Site announcement

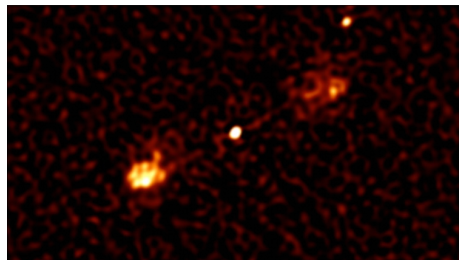
2012 Oct: KAT-7 (7-dish Karoo
Array Telescope) inaugurated



2014: 1st MeerKAT dish



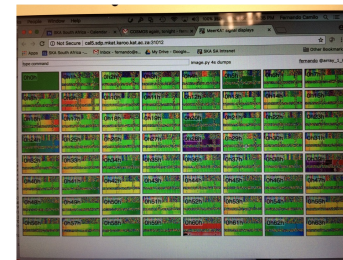
2015: MeerKAT receiver
production line inaugurated



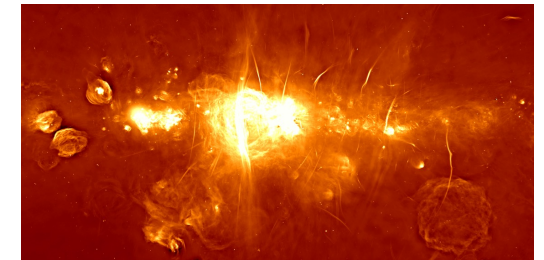
2016: MeerKAT First Light
with 16 dishes



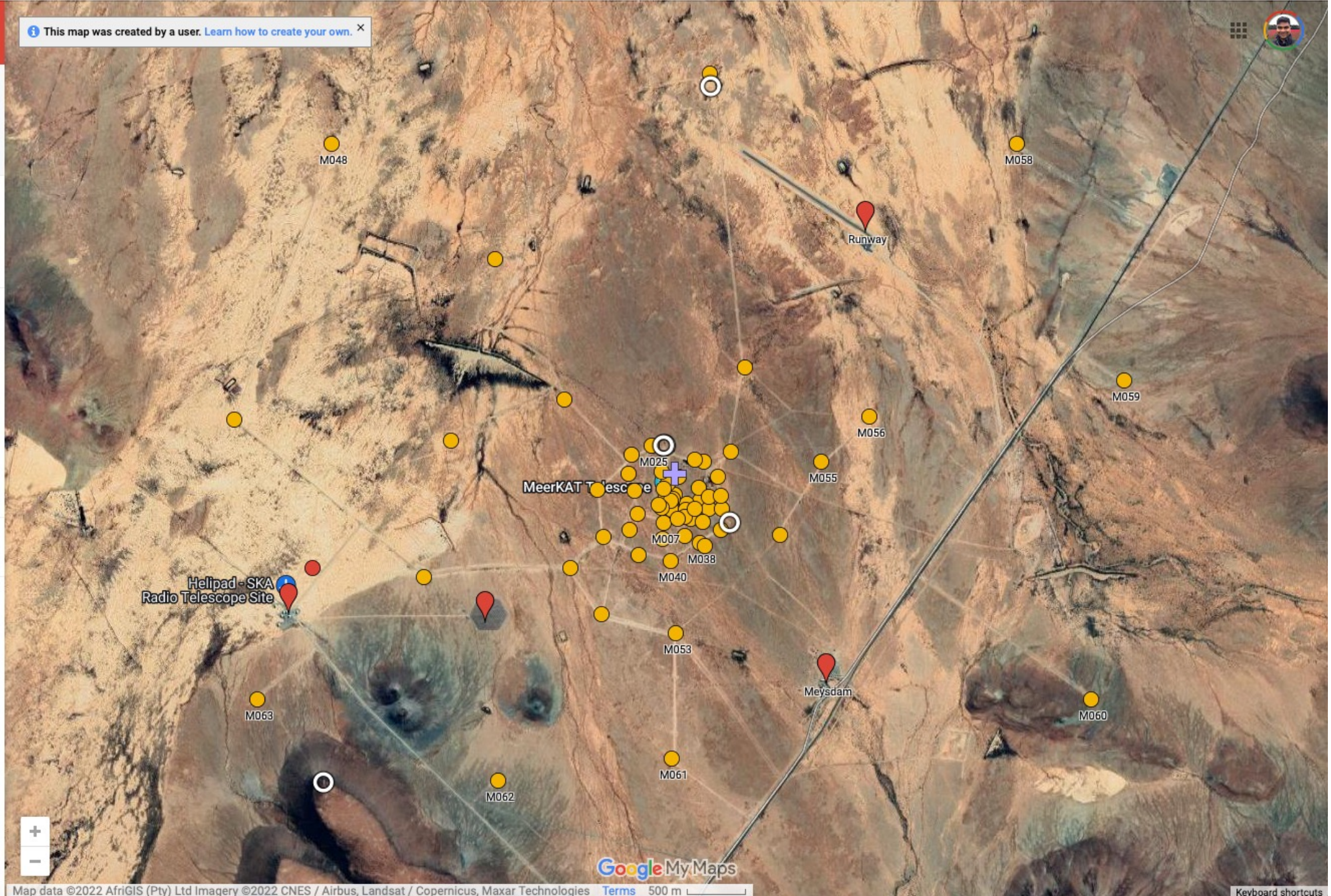
2017: Last MeerKAT
dish erected



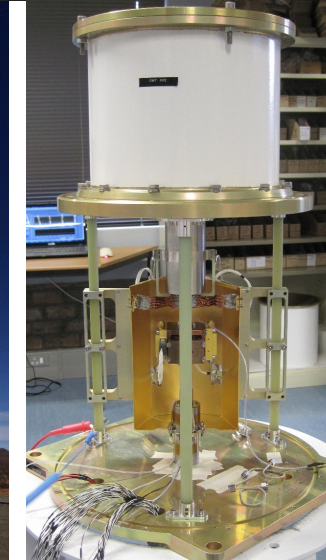
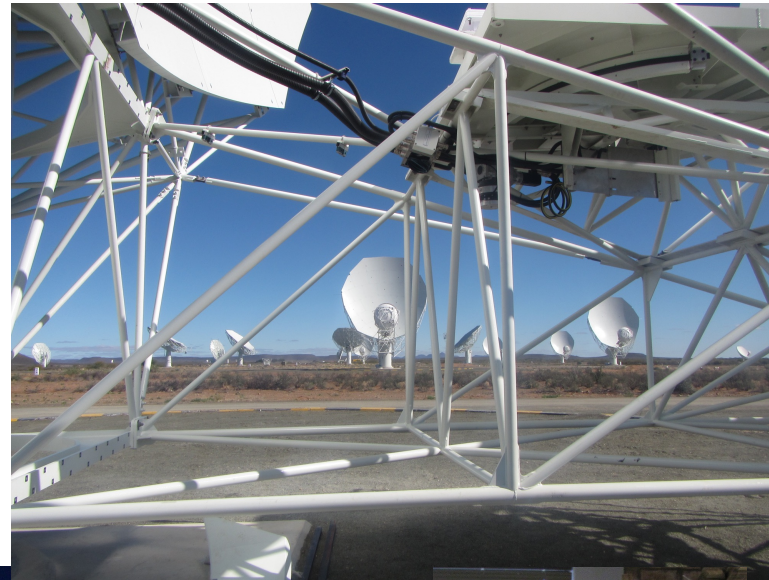
2018 Apr: 1st MeerKAT
observation with 64 dishes



2018 Jul: MeerKAT inaugurated



MeerKAT in the Karoo: SKA precursor



64 x 13.5-metre highly efficient **offset Gregorian dishes** spread over **8 km** (70% within 1 km diameter); superb **L-band receivers (0.9–1.67 GHz)**; also **UHF (0.58–1.0 GHz)** and **S-band (1.75–3.5 GHz – by MPIfR)**

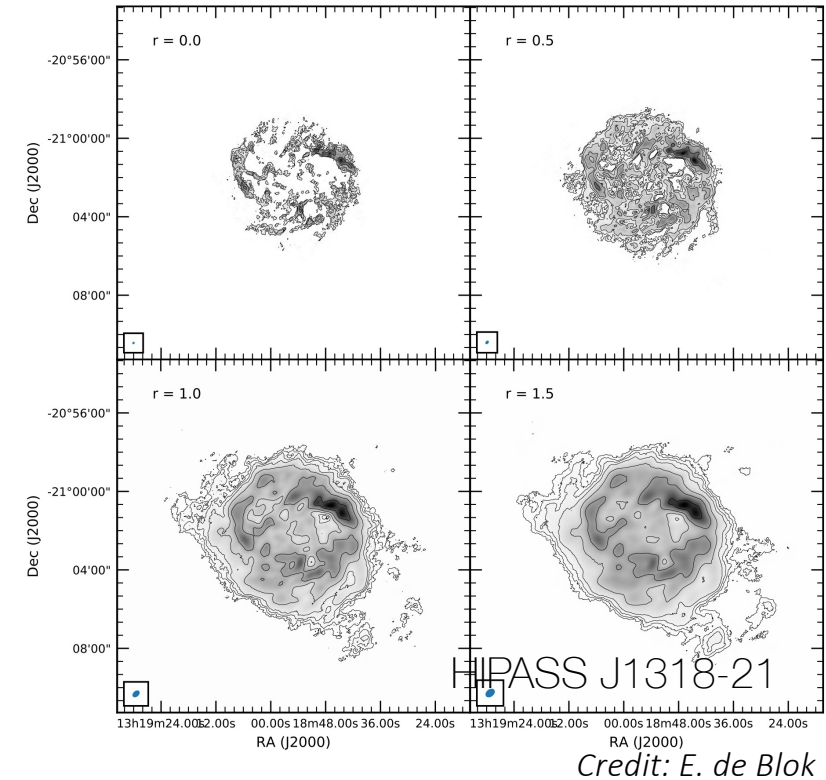
MeerKAT Science Programme

- [2010](#): Call for scientific proposals by SKA South Africa resulted in 10 approved Large Survey Projects (LSPs, >1000 hours of MeerKAT observing time over 5 years)
- [2016](#): MeerKAT is a different telescope than planned in 2009, and science has evolved
- SKA SA requested 8 LSPs to submit revised project plans; reviewed in [2017](#)
- 64 dishes operational since [2018](#) (plus continued development of capabilities)
- 2/3 of telescope time to be used by LSPs; 5% for DDT; rest awarded through periodic Calls:
 - [2019](#): 1st Open Time Call resulted in 38 projects, led by South African-based PIs
 - [2020–21](#): 2nd Call for ~1000 hours; 113 proposals from 18 countries requested 3400 hours; 57 projects awarded some time; 1/3 of submitted and accepted proposals have SA-based PIs
- Eventually, MeerKAT will be integrated into the SKA1-MID telescope



MeerKAT status, coming developments

- All 8 LSPs underway
- >50% of the time used for science (mostly at L-band)
- Imaging in 4k, 32k, Narrowband (32k across 107 MHz)
- Pulsar timing (1k) / searching (4k); >1000 pulsars observed
- Commensal users (MeerTRAP, MeerLICHT)
- UHF: observations have started
- S-band: being commissioned
- Further developments: SETI backend; some VLBI capability
- 3rd Open Time Call has just been released.



- MeerKAT is now operationally oversubscribed
- Many datasets are no longer proprietary, and (mainly visibilities) are available through the archive interface: <https://apps.sarao.ac.za/katpaws/archive-search>
- 81 refereed publications with MeerKAT data (77 since Aug 2019): [MeerKAT ADS Library](#)
- Beyond MeerKAT, there's MeerKAT extension (16 SKA1-MID dishes on baselines up to 17 km, with new correlator and science processor), and SKA

S-band status

- All 64 receivers installed
- Receptor level tests being completed
- Array level commissioning underway (MPIfR + SARA0)

name	centre	range
S0	2187.50	1750.00 – 2625.00
S1	2406.25	1968.75 – 2843.75
S2	2625.00	2187.50 – 3062.50
S3	2843.75	2406.25 – 3281.25
S4	3062.50	2625.00 – 3500.00



The future today: MK+ and SKA1-MID hardware



Pictures from SPF band 2 production



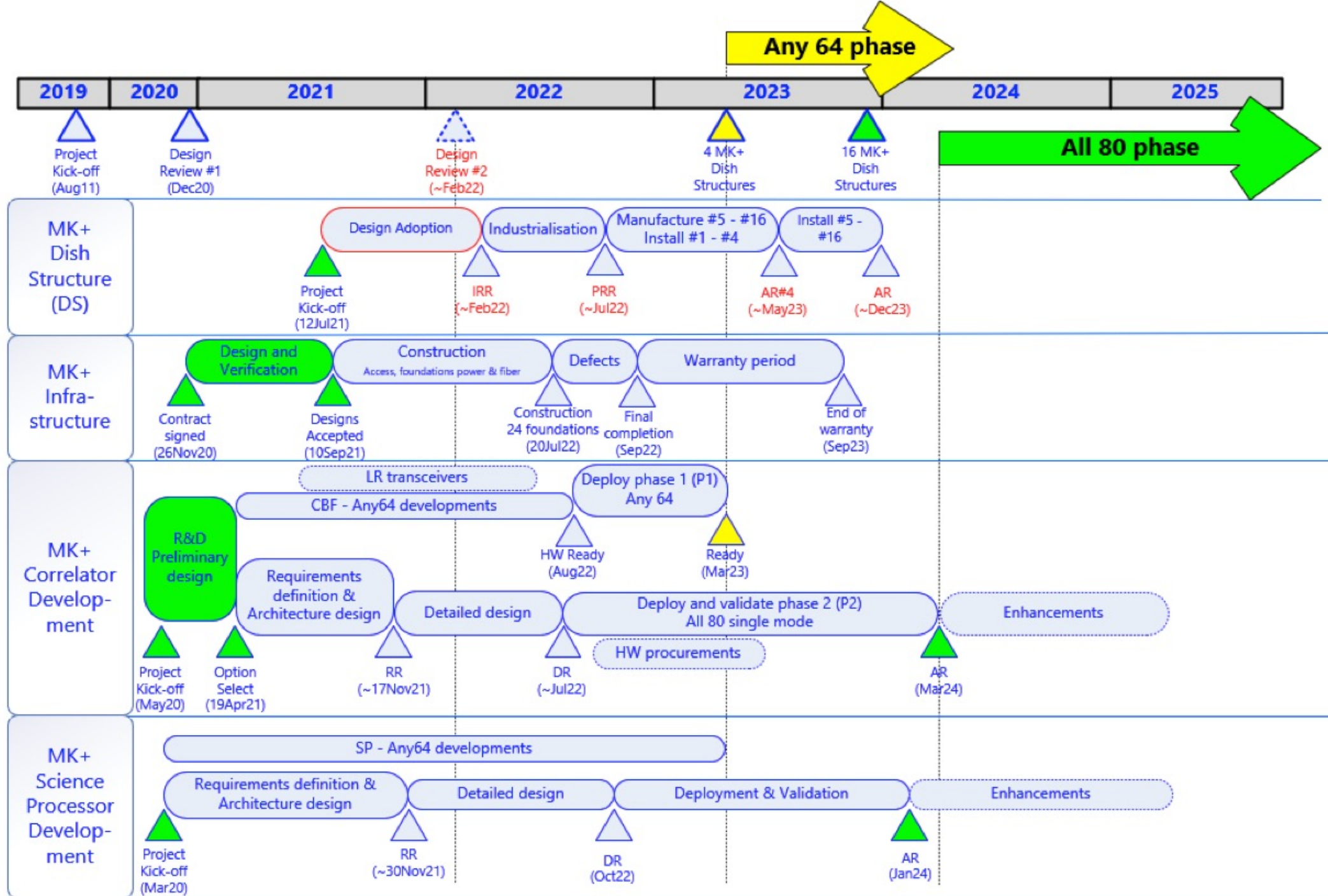
Figure 4: 2nd Stage amplification assemblies.

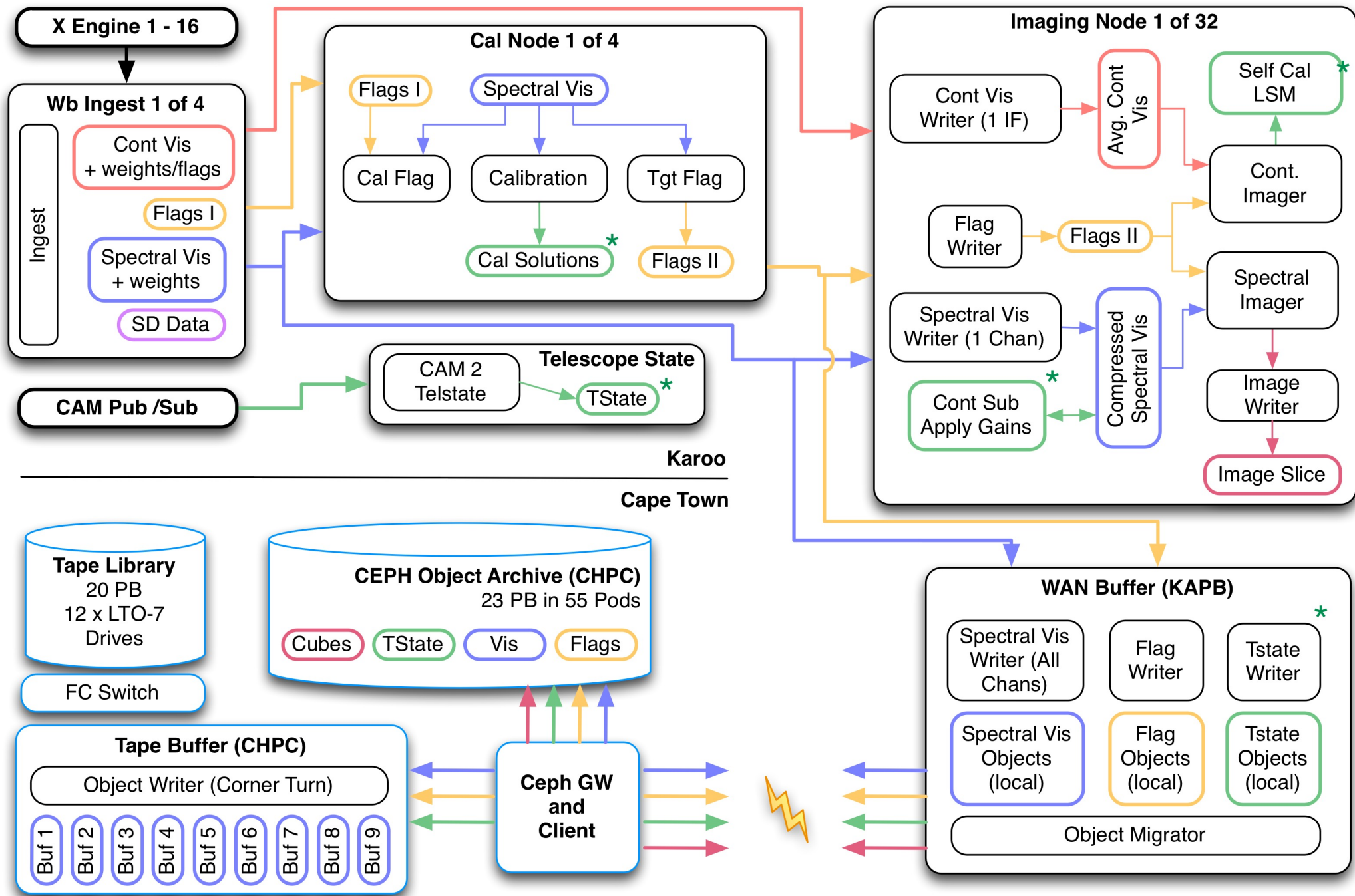


Figure 5: Power entry PCB assemblies.



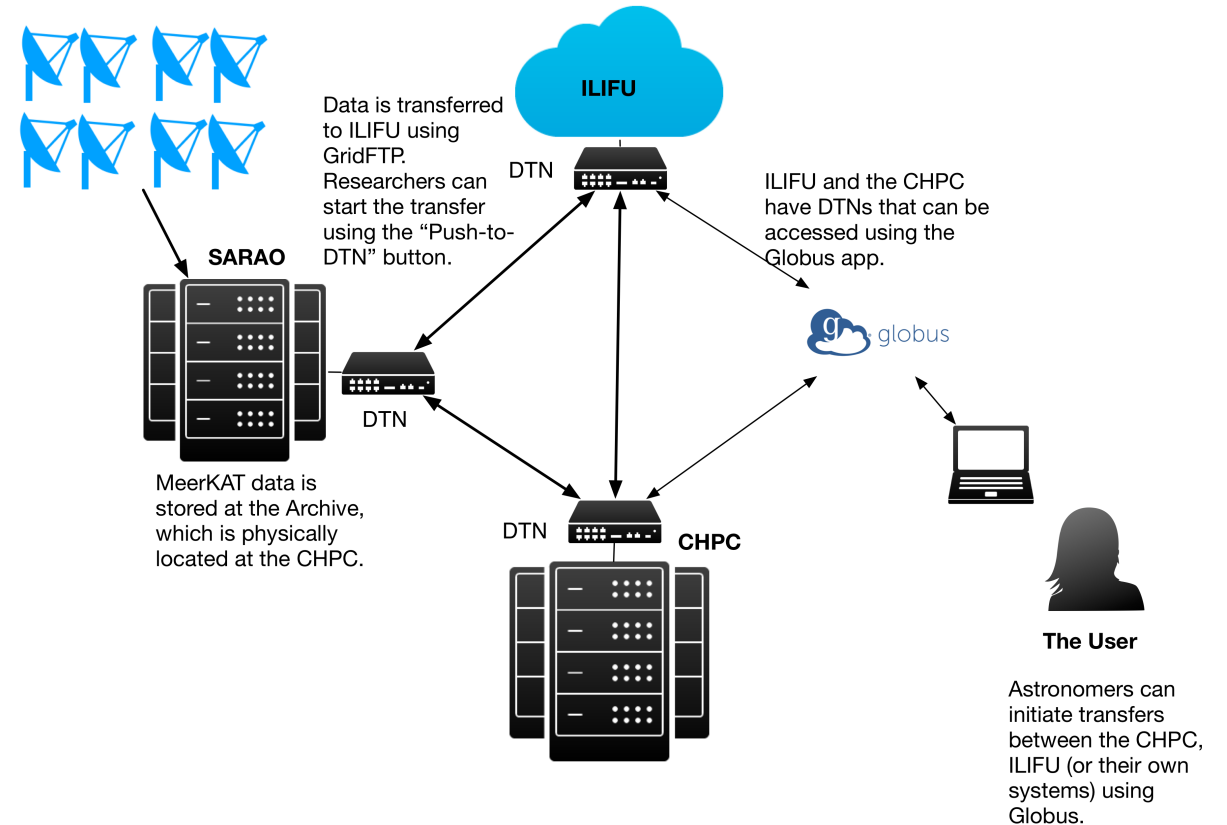
Figure 3: OMT dipole and coupler assembly.





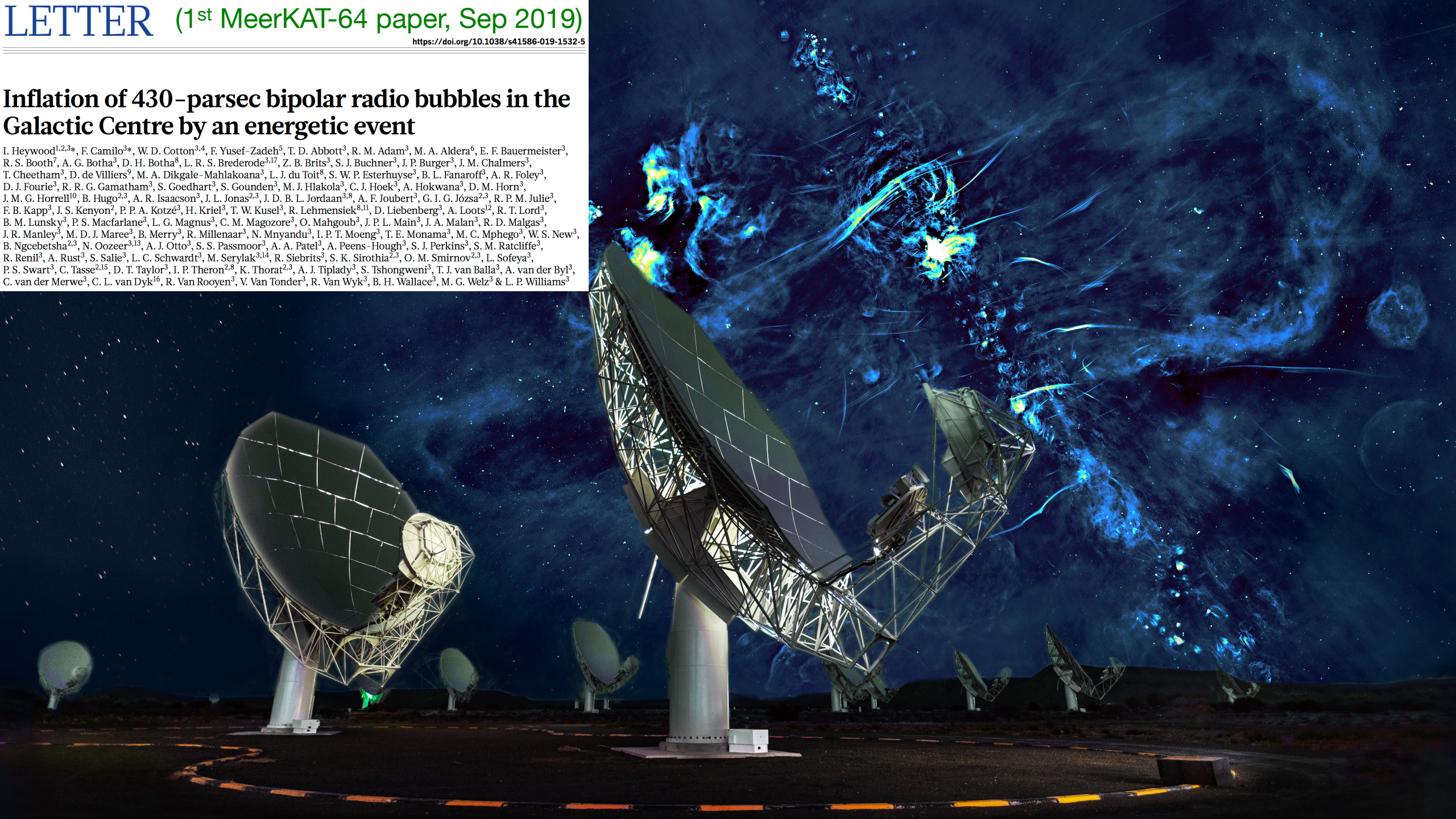
Research Computing Partnerships

- Karoo Array Processor: Correlator and Imaging.
- Centre for High Performance Computing (Cape Town/CSIR)
 - Archive and science computing.
- Inter-University Institute for Data Intensive Astronomy (Cape Town/UCT)
 - Academic/research computing.
 - Ilifu Cloud
 - Hosts 5 LSPs and 70% of SA based OTPs.
 - 100 Nodes (Openstack): SLURM Compute + Jupyter.
 - ~4PB (Mostly MeerKAT)



Inflation of 430-parsec bipolar radio bubbles in the Galactic Centre by an energetic event

I. Heywood^{1,2,3*}, F. Camilo^{3*}, W. D. Cotton^{3,4}, F. Yusef-Zadeh⁵, T. D. Abbott³, R. M. Adam³, M. A. Aldera⁶, E. F. Bauermeister³, R. S. Booth⁷, A. G. Botha³, D. H. Botha⁸, L. R. S. Brederode^{3,17}, Z. B. Brits³, S. J. Buchner³, J. P. Burger³, J. M. Chalmers³, T. Cheetham³, D. de Villiers⁹, M. A. Dikgale-Mahlakoana³, L. J. du Toit⁸, S. W. P. Esterhuyse³, B. L. Fanaroff³, A. R. Foley³, D. J. Fourie³, R. R. G. Gamatham³, S. Goedhart³, S. Gounden³, M. J. Hlakola³, C. J. Hoek³, A. Hokwana³, D. M. Horn³, J. M. G. Horrell¹⁰, B. Hugo^{2,3}, A. R. Isaacson³, J. L. Jonas^{2,3}, J. D. B. L. Jordaan^{3,8}, A. F. Joubert³, G. I. G. Józsa^{2,3}, R. P. M. Julie³, F. B. Kapp³, J. S. Kenyon², P. P. A. Kotzé³, H. Kriel³, T. W. Kusel³, R. Lehmensiek^{8,11}, D. Liebenberg³, A. Loots¹², R. T. Lord³, B. M. Lunskey³, P. S. Macfarlane³, L. G. Magnus³, C. M. Magozore³, O. Mahgoub³, J. P. L. Main³, J. A. Malan³, R. D. Malgas³, J. R. Manley³, M. D. J. Maree³, B. Merry³, R. Millenaar³, N. Mnyandu³, I. P. T. Moeng³, T. E. Monama³, M. C. Mphego³, W. S. New³, B. Ngcembetsha^{2,3}, N. Oozeer^{3,13}, A. J. Otto³, S. S. Passmoor³, A. A. Patel³, A. Peens-Hough³, S. J. Perkins³, S. M. Ratcliffe³, R. Renil³, A. Rust³, S. Salie³, L. C. Schwardt³, M. Serylak^{3,14}, R. Siebrits³, S. K. Sirothia^{2,3}, O. M. Smirnov^{2,3}, L. Sofeya³, P. S. Swart³, C. Tasse^{2,15}, D. T. Taylor³, I. P. Theron^{2,8}, K. Thorat^{2,3}, A. J. Tiplady³, S. Tshongweni³, T. J. van Balla³, A. van der Byl³, C. van der Merwe³, C. L. van Dyk¹⁶, R. Van Rooyen³, V. Van Tonder³, R. Van Wyk³, B. H. Wallace³, M. G. Welz³ & L. P. Williams³

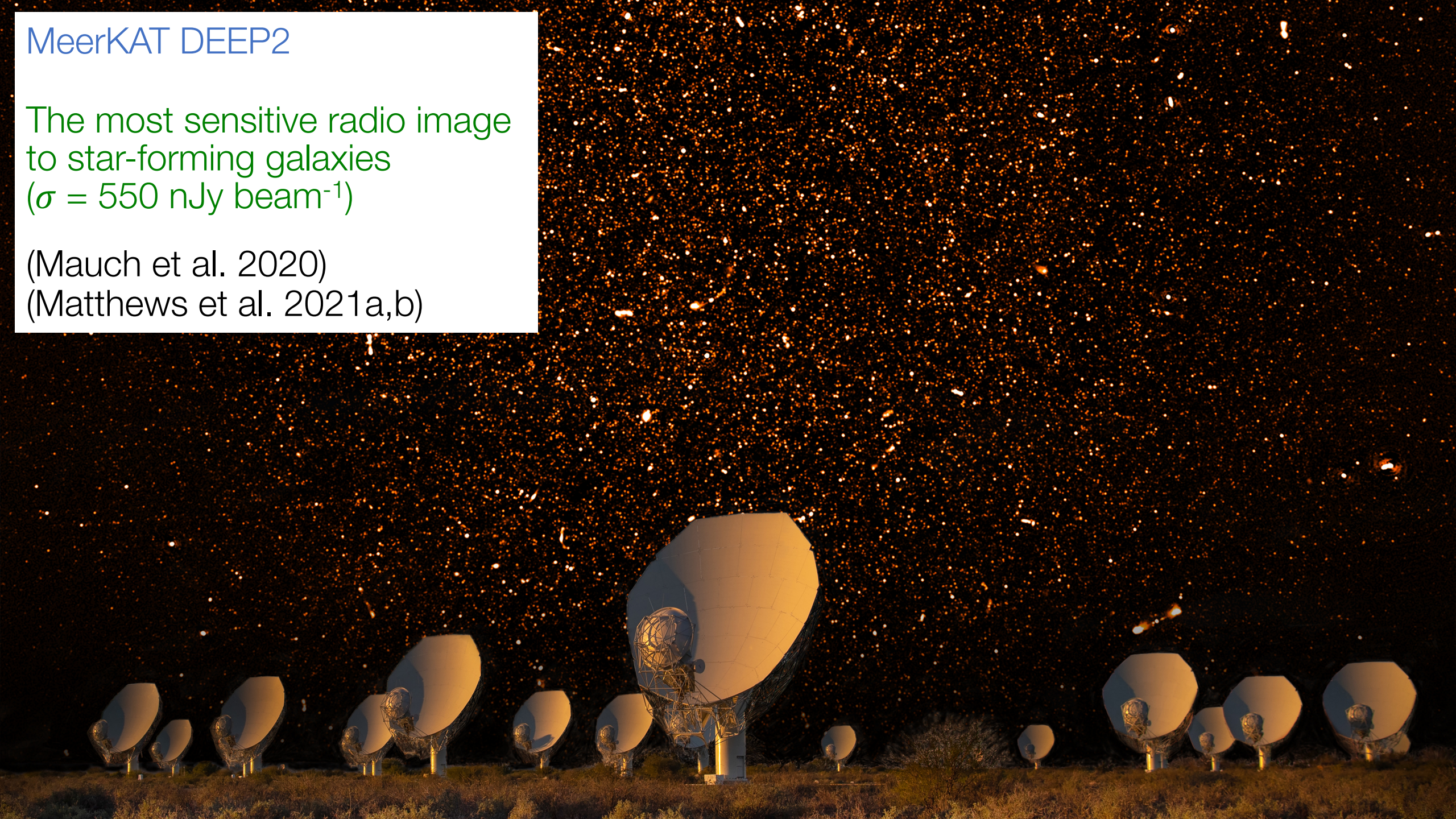


MeerKAT DEEP2

The most sensitive radio image
to star-forming galaxies
($\sigma = 550 \text{ nJy beam}^{-1}$)

(Mauch et al. 2020)

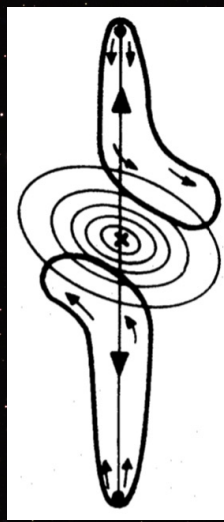
(Matthews et al. 2021a,b)



X-shaped galaxies: mystery solved

Hydrodynamical backflow
in giant radio galaxy PKS 2014-55

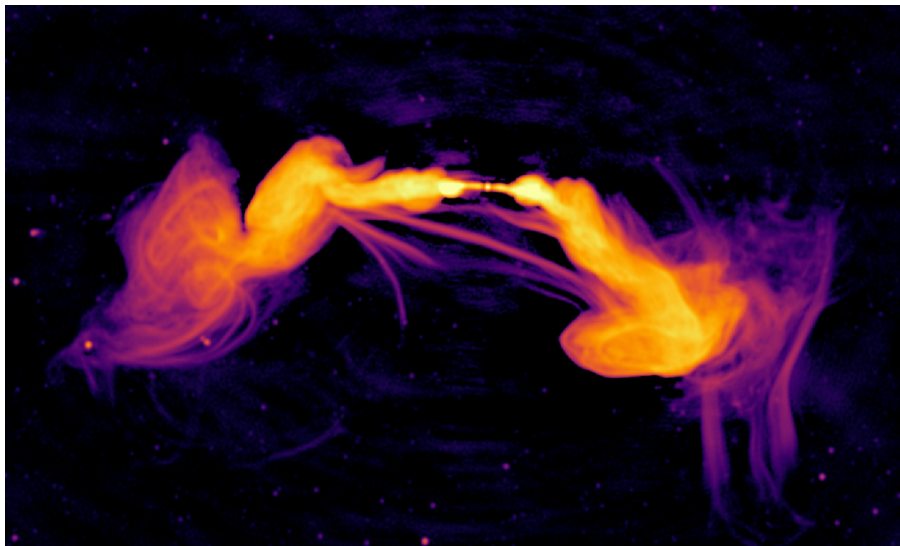
(Cotton et al. 2020)



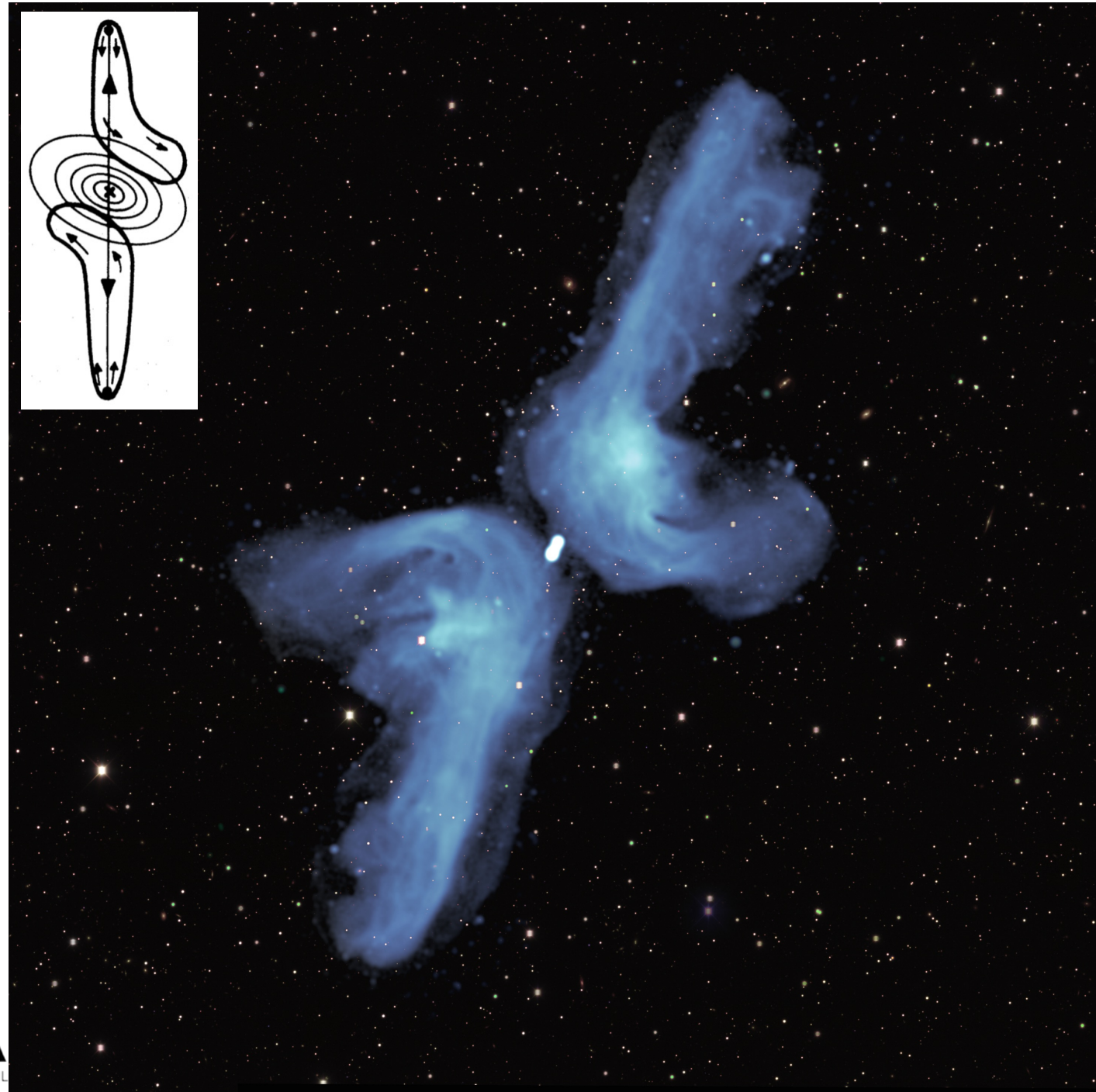
New mystery

Collimated synchrotron threads

(Ramatsoku et al. 2020)



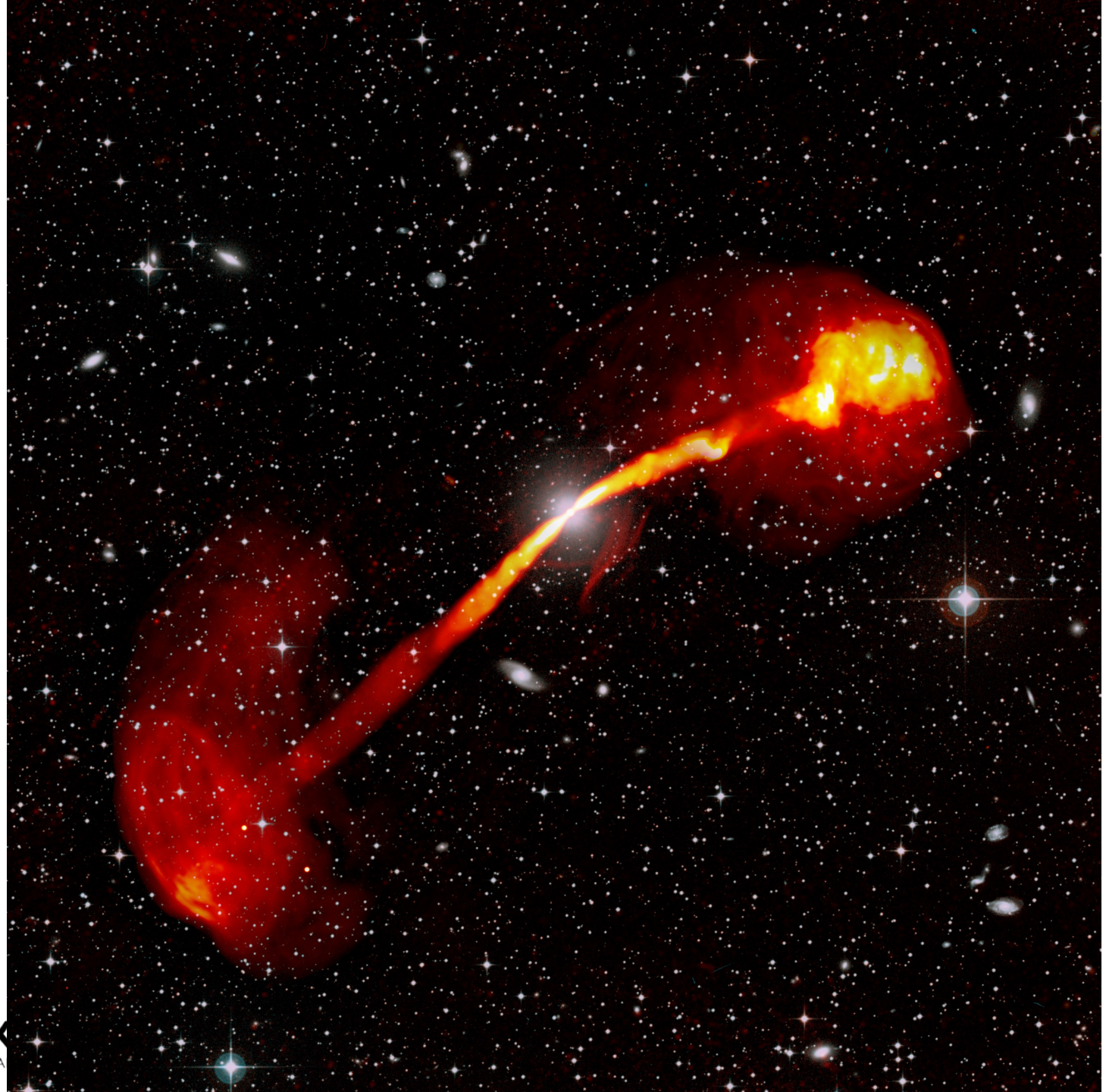
SKA
SQUARE KIL



Threads, ribbons, and rings in the radio galaxy IC 4296

“New results like this from
MeerKAT are set to overhaul
our understanding of
extragalactic radio sources”

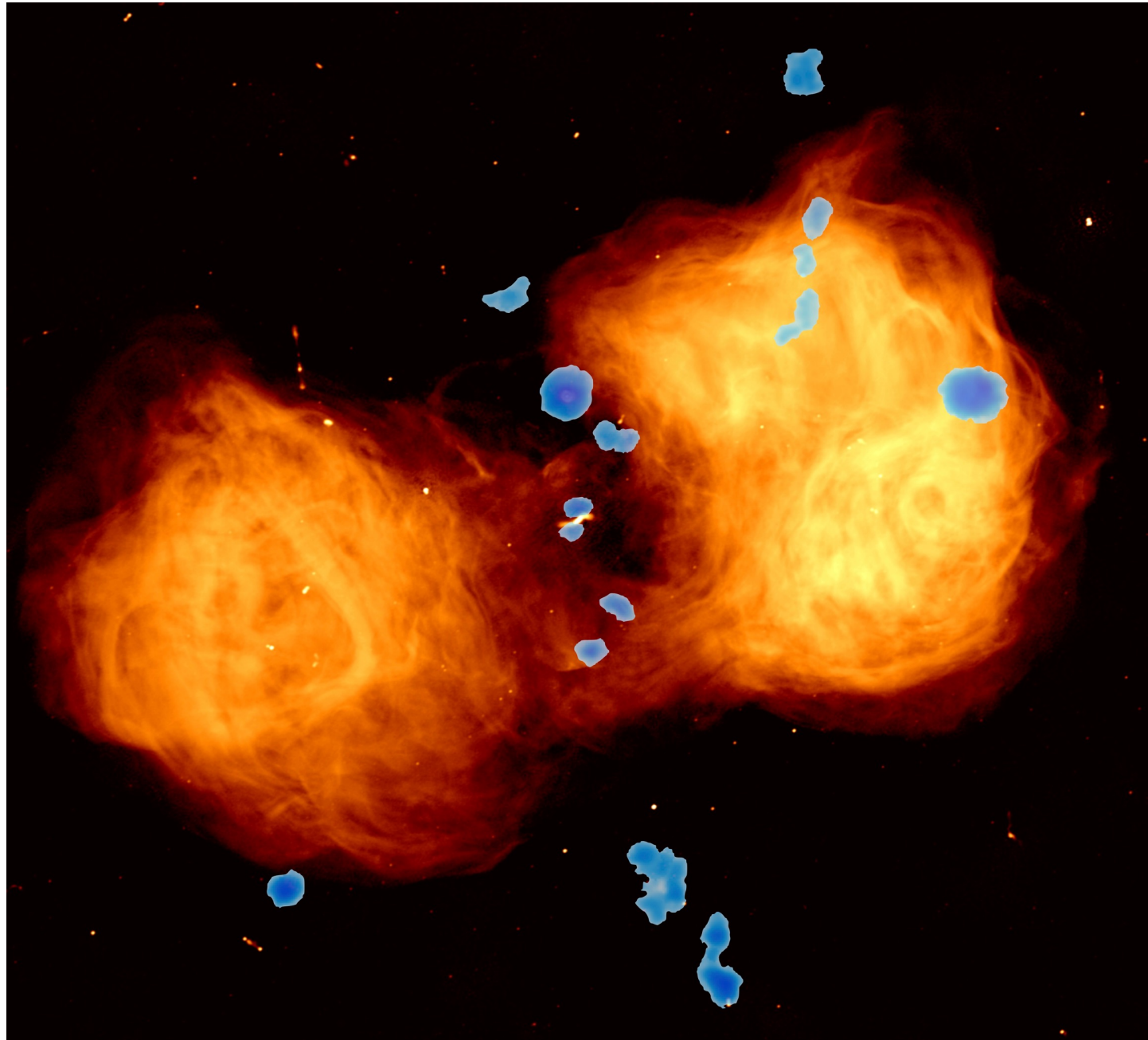
(Condon et al. 2021)



The missing hydrogen in Fornax A: found

(Serra et al. 2019)

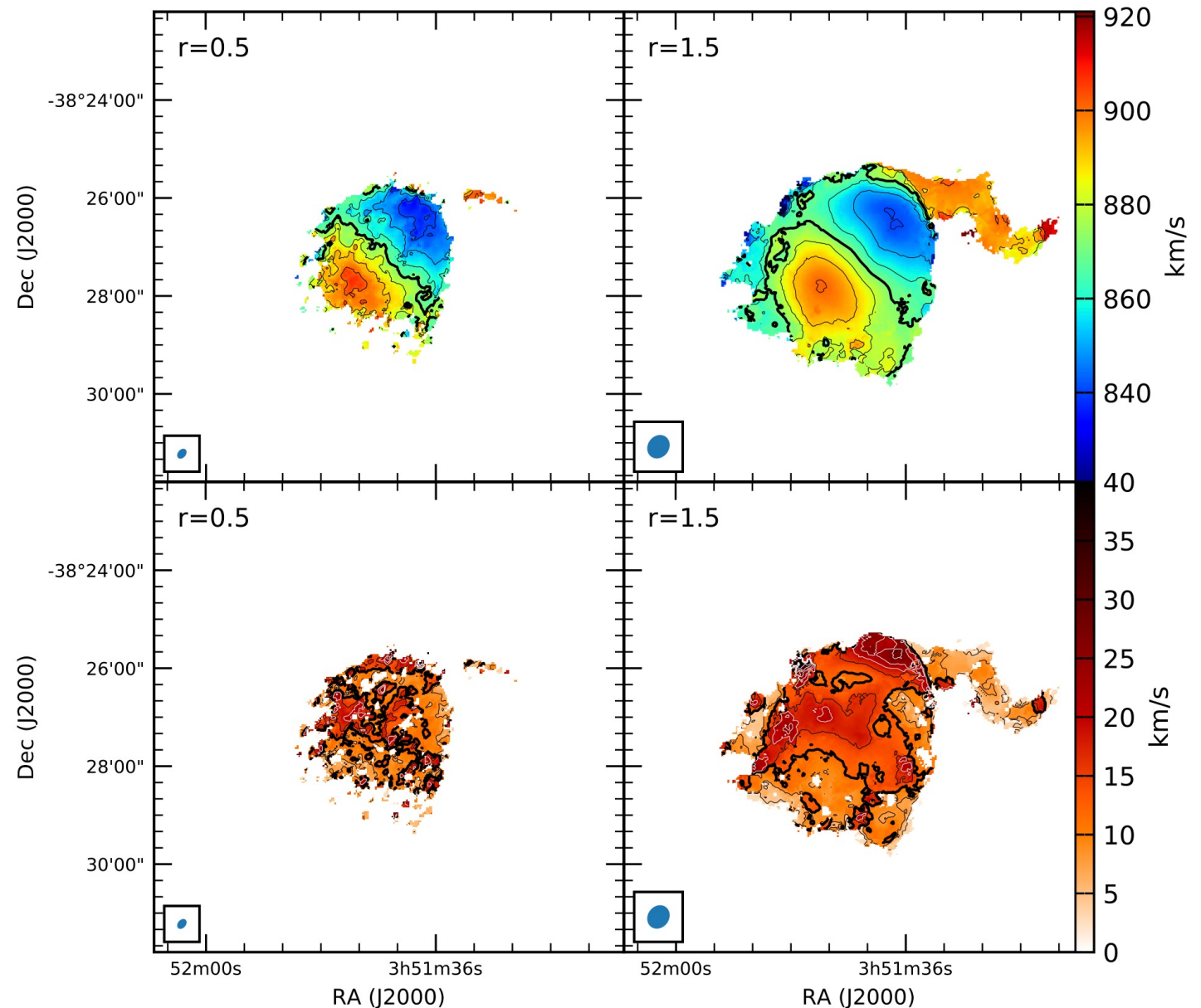
- 40 dishes, 8 hr
- 4k channels ($209 \text{ kHz} / 44 \text{ km s}^{-1}$)
- $\sim 14\times$ more hydrogen detected than previously known



First MeerKAT 32k paper

(de Blok et al. 2020)

- 59 dishes, 5 hr
- 32k channels (26 kHz / 5 km s⁻¹)
- “Exquisite [HI] imaging data... over a large range in angular resolution”

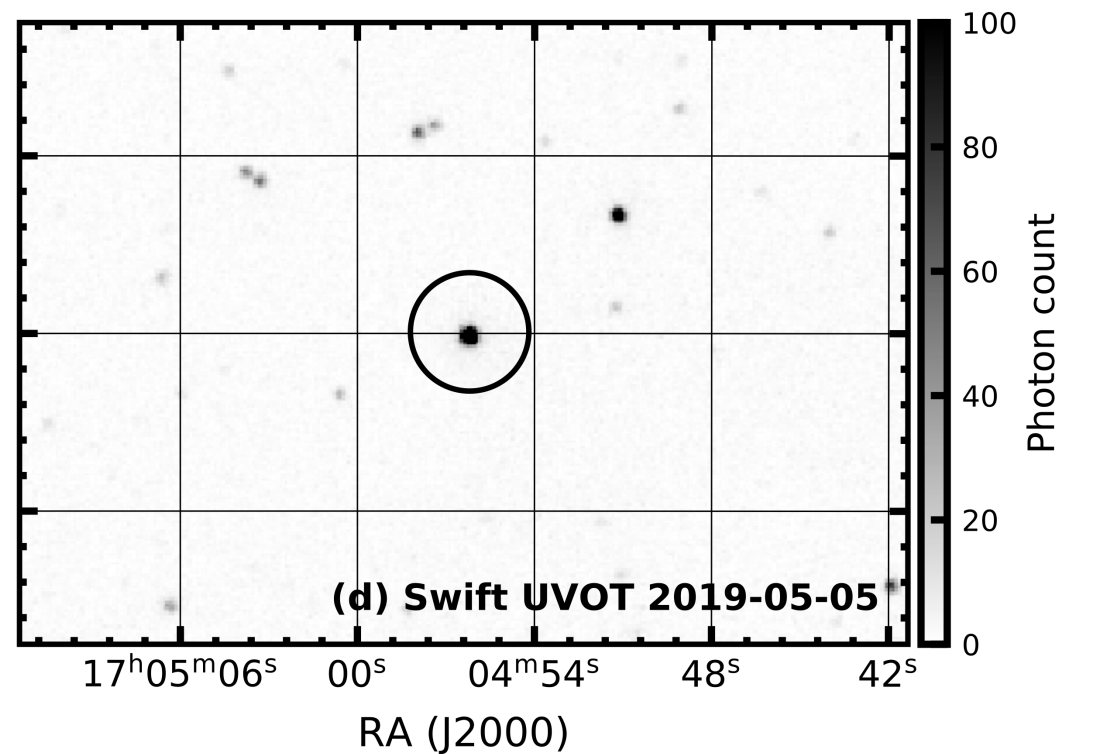
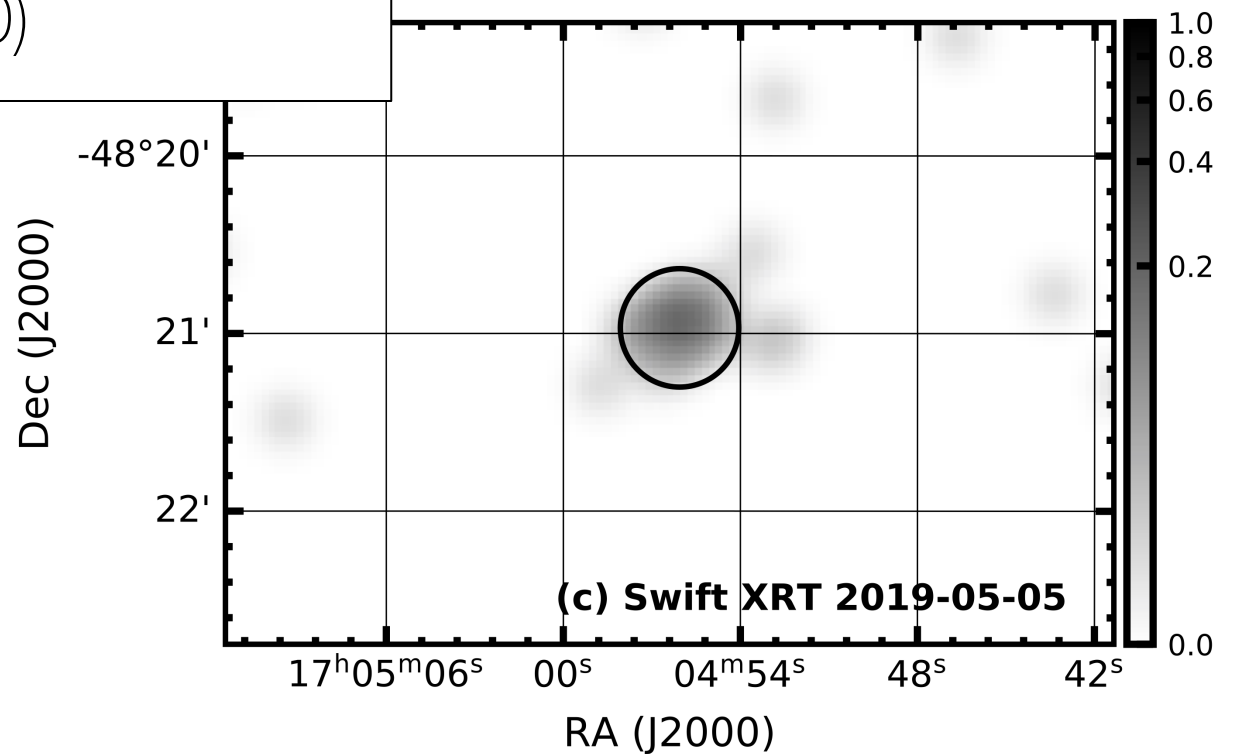
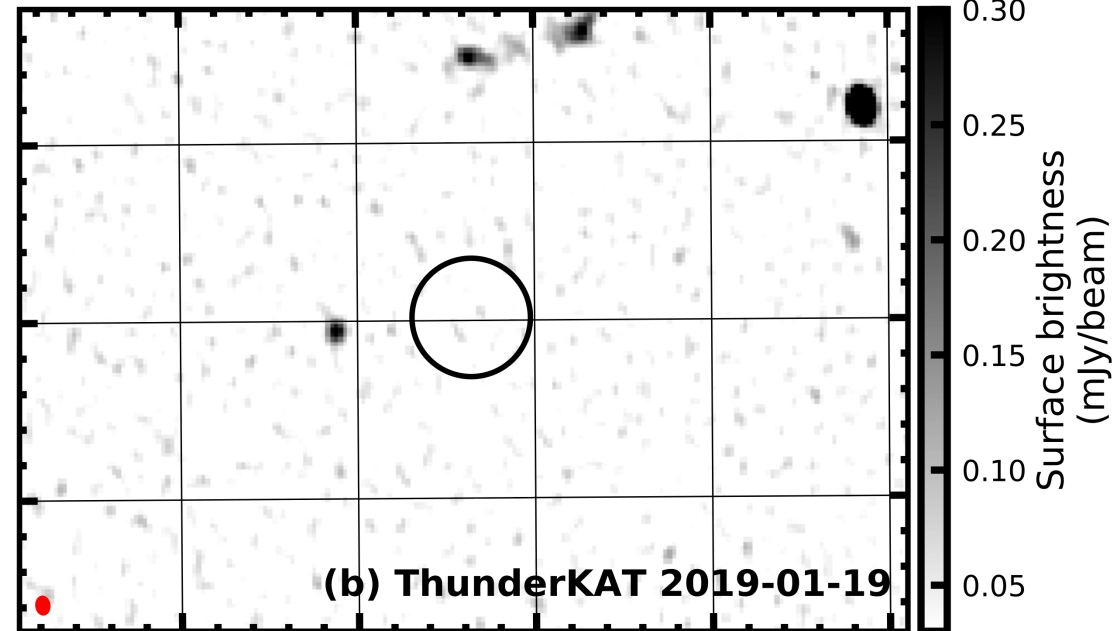
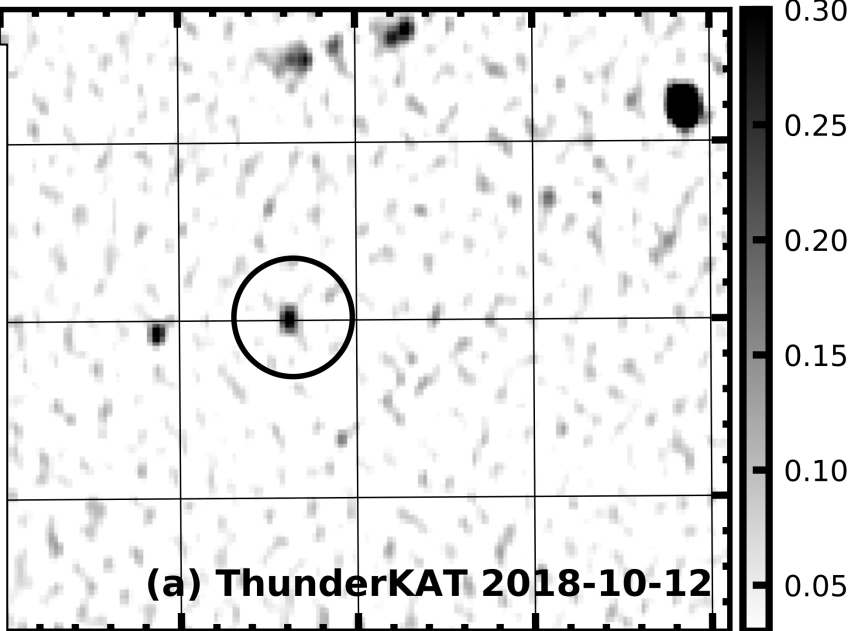


ESO 302-G014 / HIPASS J0351-38

ThunderKAT

Discovery of 1st
transient with
MeerKAT

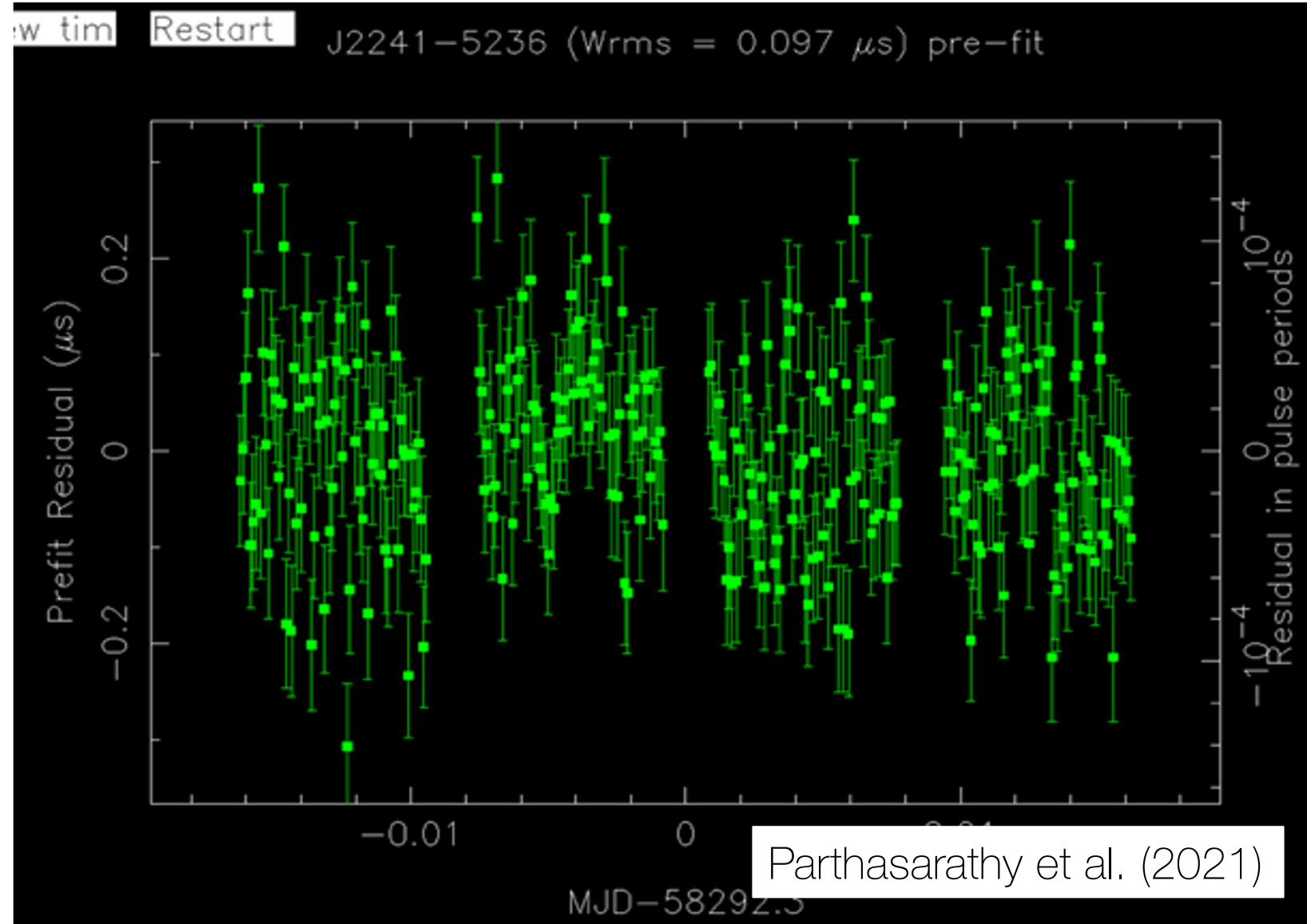
(Driessen et al.
2020)



Ultra high precision pulsar timing (MeerTime)

PSR J2241-5236

~4 ns timing in 1 hour –
new world record



SARAO legacy surveys

Galaxy
clusters

