

JODRELL BANK & E-MERLIN

SCIENCE HIGHLIGHTS



Image by Ant Holloway

TRANSIENTS

THE DYNAMIC AND EXPLOSIVE UNIVERSE

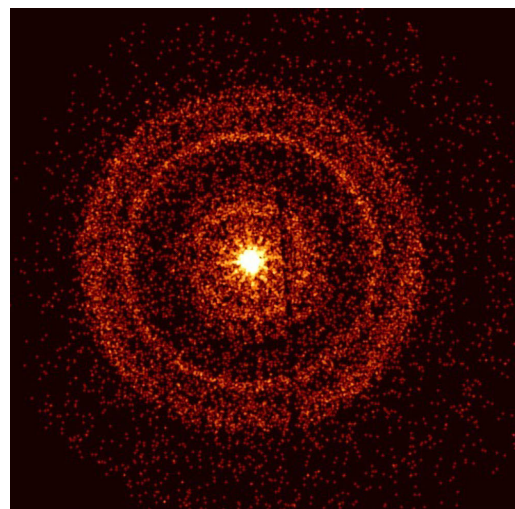
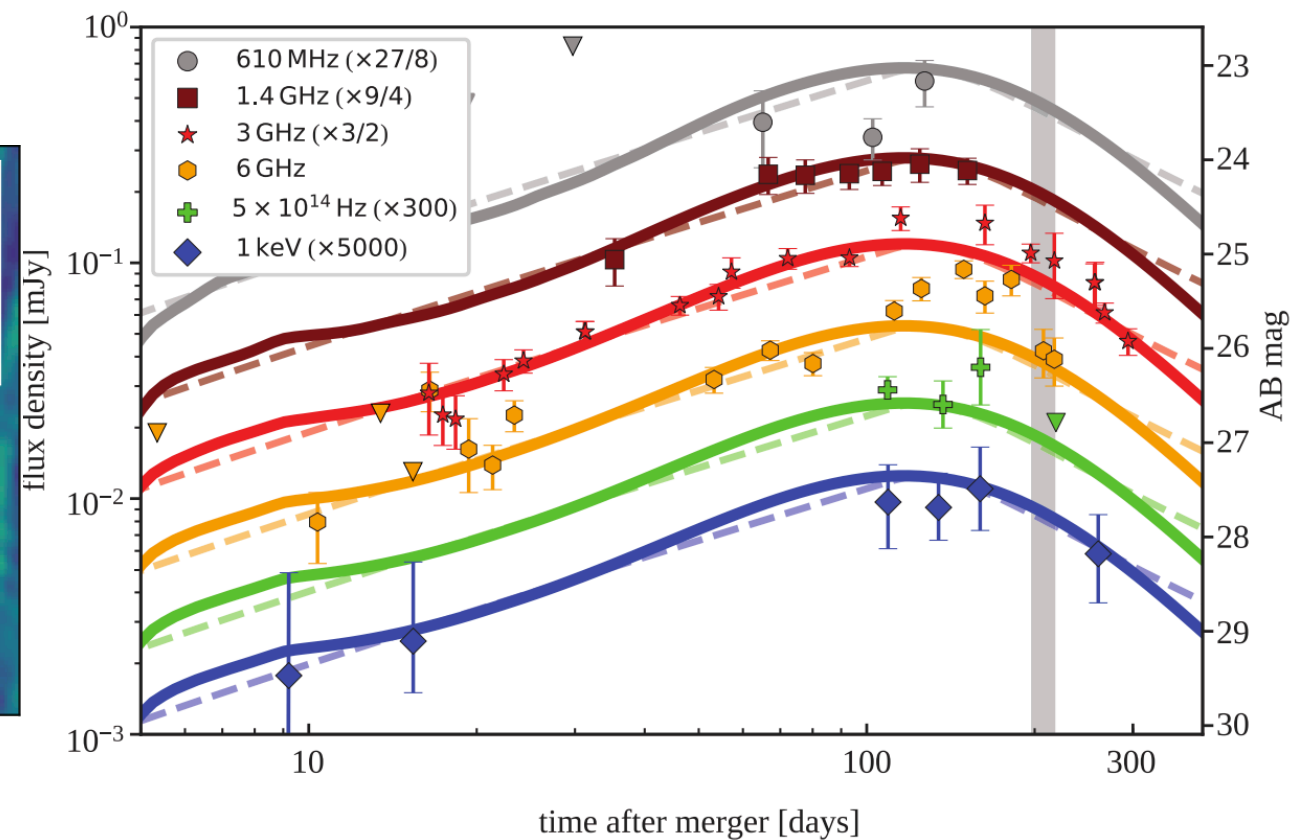
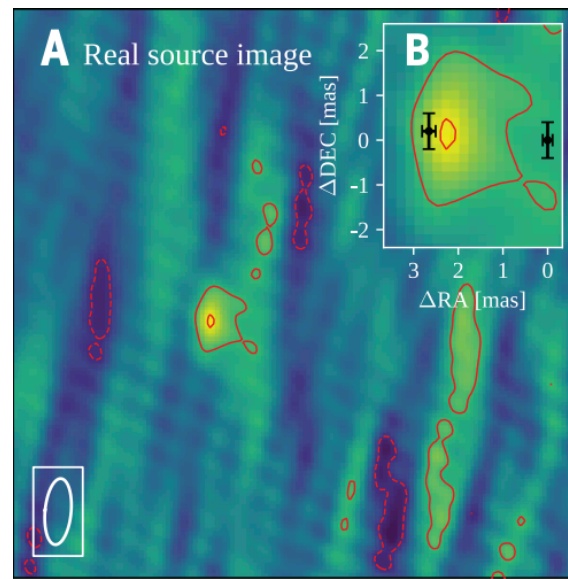
e-MERLIN is regularly used to study some of the most powerful explosions known in the Universe, ranging from stars being ripped apart by black holes, to the deaths of massive stars when they go supernova, to finding the radio afterglows of neutron star mergers. The unique and dynamic capabilities of e-MERLIN enable astronomers to study the transient Universe, providing an insight onto the most compact objects in the cosmos.



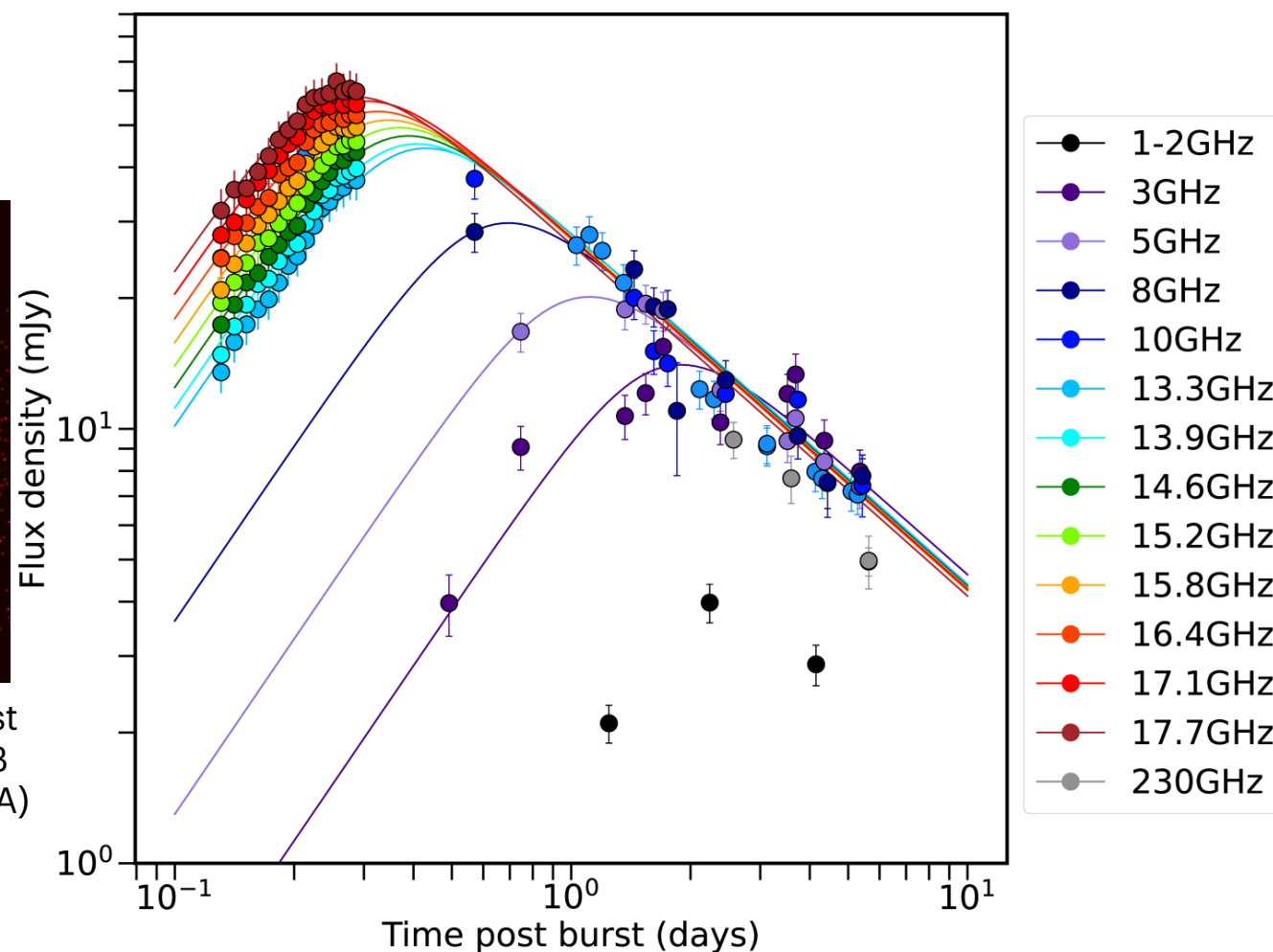
Radio signals from GW170817

Gravitational Wave astronomy hit the headlines in 2017 when GW170817 was found to have an electromagnetic counterpart. e-MERLIN observations, and as part of global VLBI observations detected the radio afterglow of the binary neutron star merger >200 days after the initial binary neutron star merger.

Ghirlanda et al. 2019, Science, arXiv:1808.00469



Swift X-ray image of the dust scattering rings around GRB 221009A (credit: Swift/NASA)



The 'Brightest of all Time' GRB that partially ionised our atmosphere

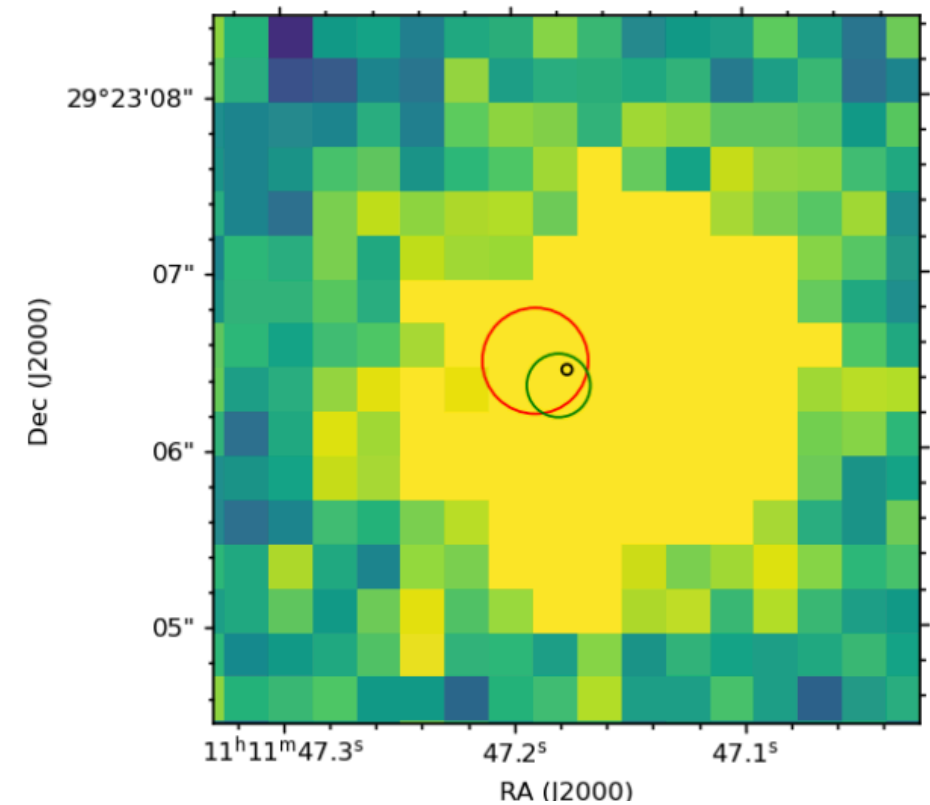
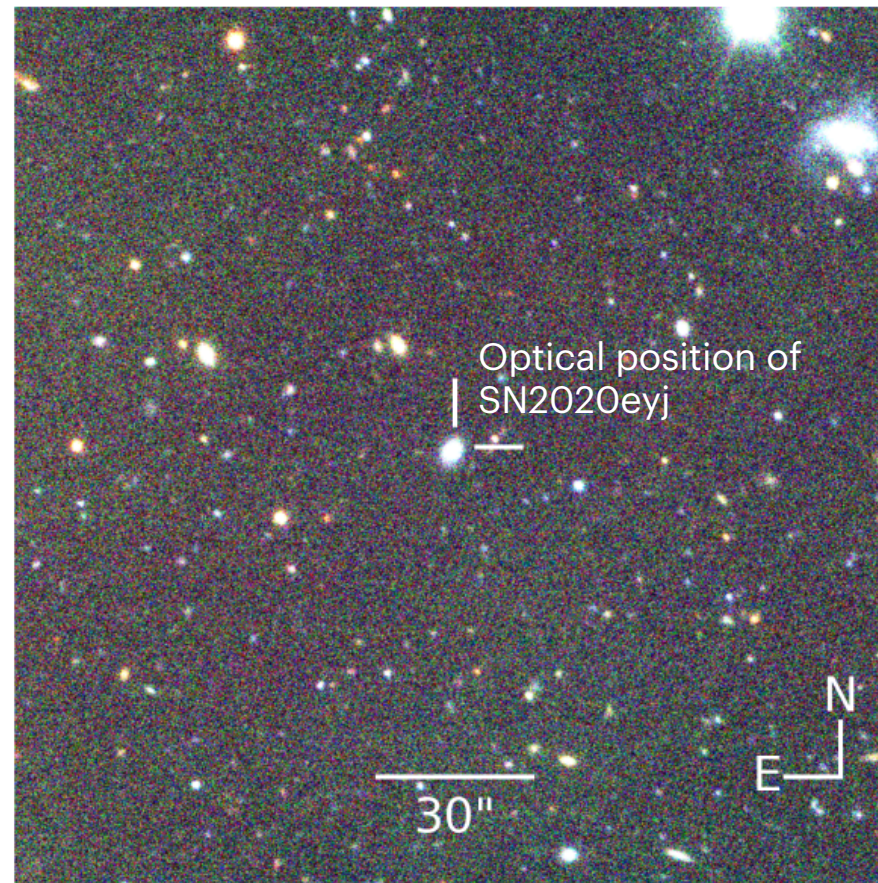
GRB 221009A produced one of the most powerful explosions ever observed by astronomers. e-MERLIN contributed to a worldwide multi-wavelength effort to follow in detail the reverse shock ejecta caused when the star exploded. The explosion was so close it partially ionised our atmosphere!

Bright, Rhodes et al. 2023, NatAst, arXiv:2303.13583

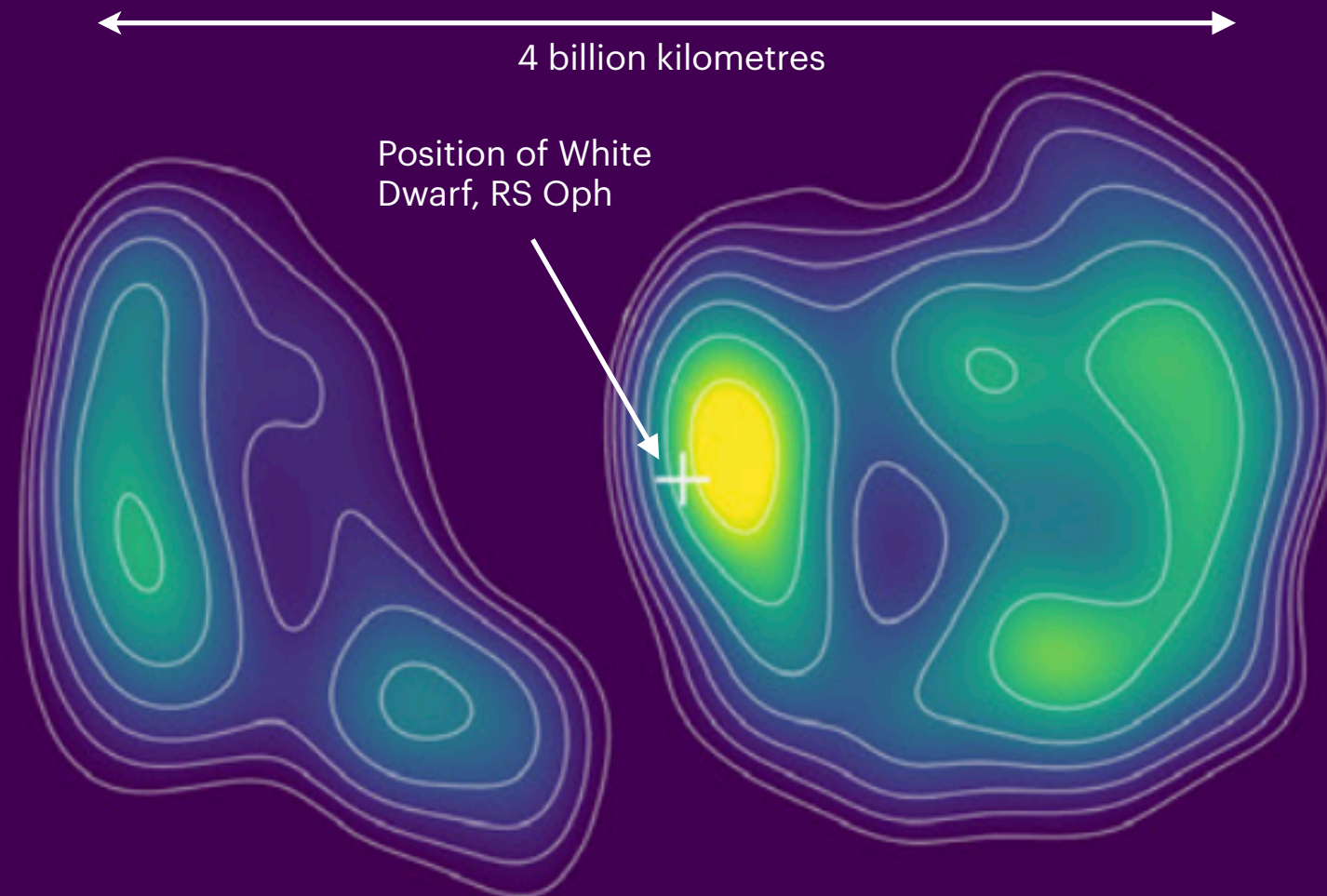
The first radio detection of a Type 1a supernova

e-MERLIN made the first ever radio detection of any Type 1a SN supernova (SN) as part of follow-up observations of SN2020eyj, more than 500 days after the initial stellar explosion. This work is used for modelling the progenitor systems of Type 1a SNe, which are crucial in calibrating the expansion of the Universe and measuring the cosmic distance ladder.

Kool et al. 2023, Nature, [arXiv:2210.07725](#)



Radio position of SN2020eyj in the black circle, overlaid on Pan-STARRS1 image



2021 Outburst of the recurrent nova RS Ophiuchi

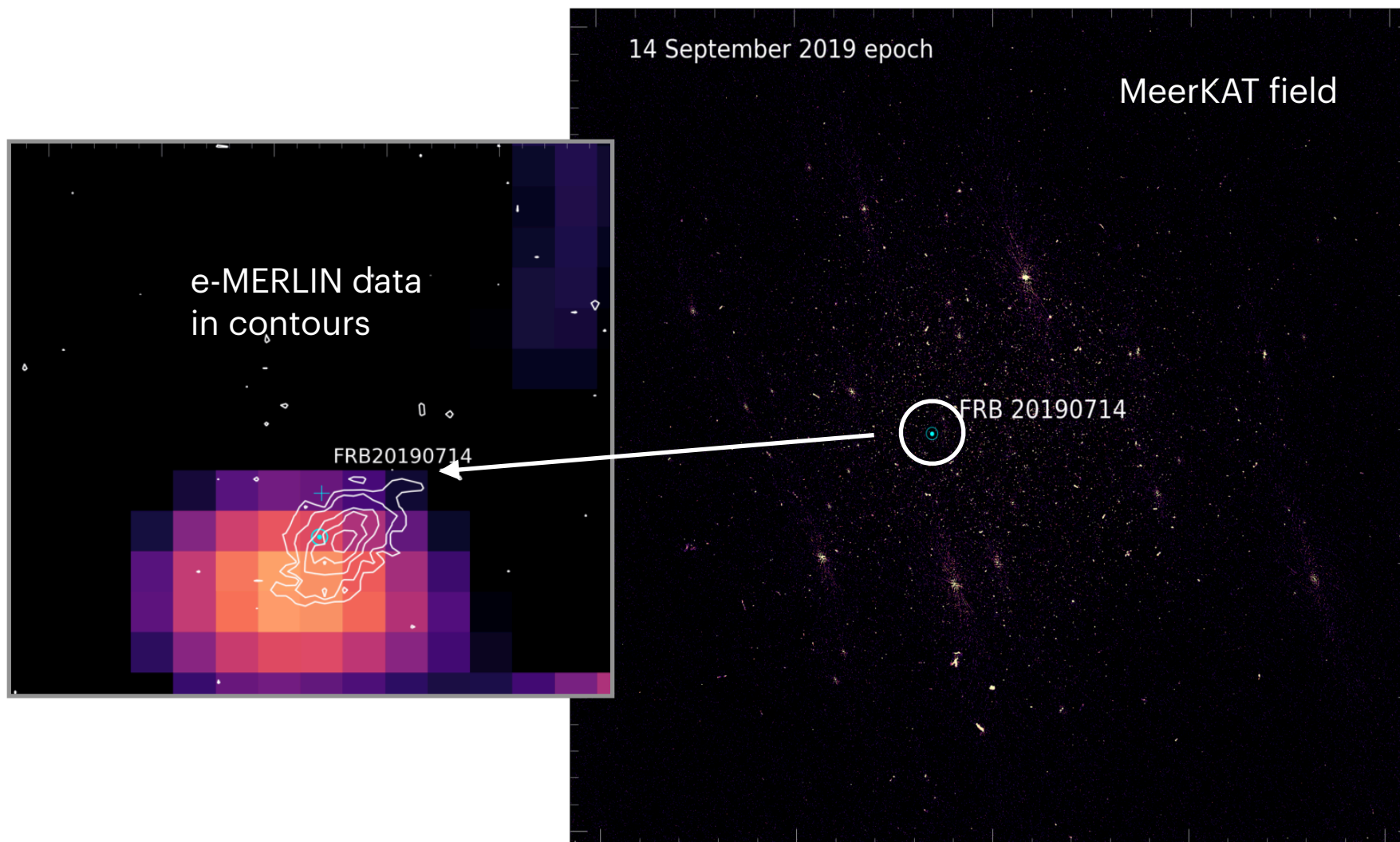
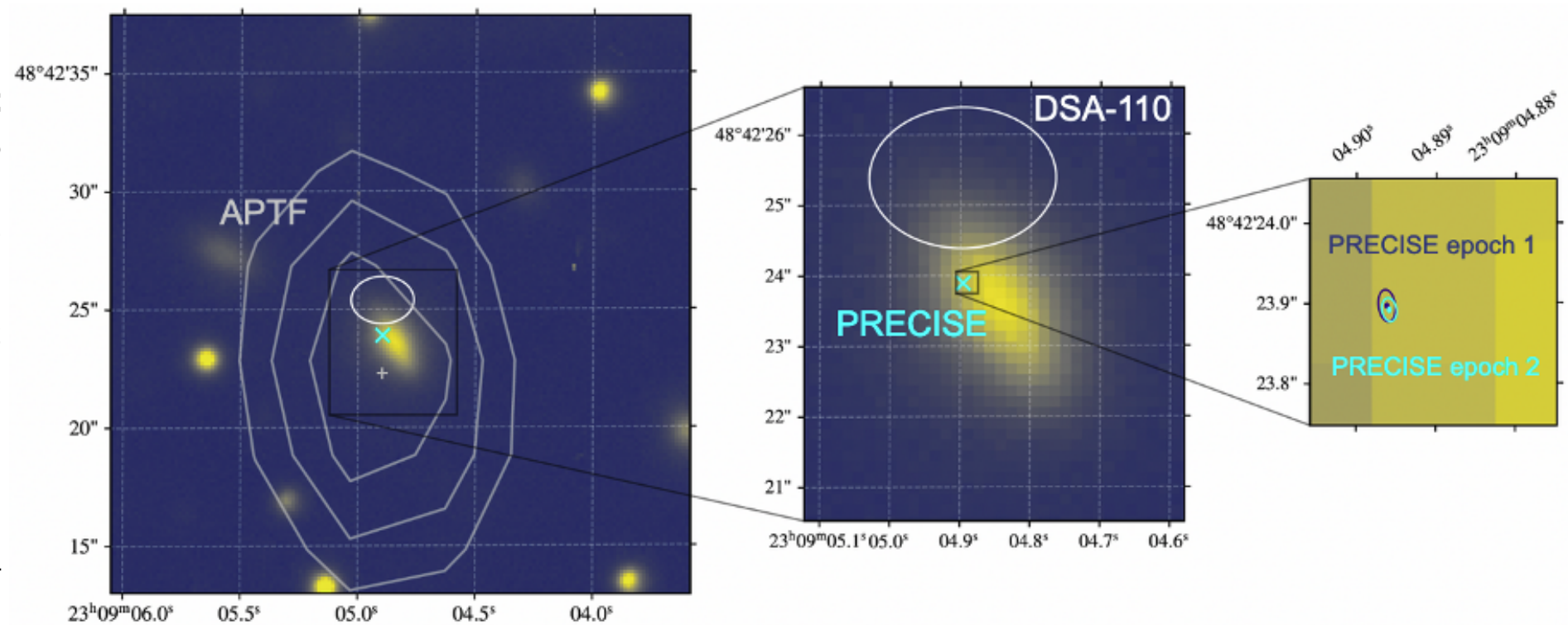
The recurrent nova RS Oph goes into outburst periodically when enough matter has accreted onto the surface of the white dwarf star in the binary system. EVN + e-MERLIN observations showed bi-polar lobes, moving at speeds of ~ 7000 km/s. The e-MERLIN data revealed the diffuse structures not seen clearly in previous outbursts.

*Munari et al. 2022, A&A, [arXiv:2209.12794](#)
Lico et al. 2024, A&A, [arXiv:2407.05794](#)*

PRECISE localisations of Fast Radio Bursts

As part of the EVN + e-MERLIN PRECISE programme, the signals from Fast Radio Bursts (FRBs) have been localised to mill-arc second precisions in distant galaxies. These data sets have shown a wide phenomenology of host galaxies in which the repeating FRBs reside.

Image from Hewitt et al 2024, ApJ, [arXiv:2312.14490](https://arxiv.org/abs/2312.14490)



Persistent Radio emission from Fast Radio Bursts with e-MERLIN

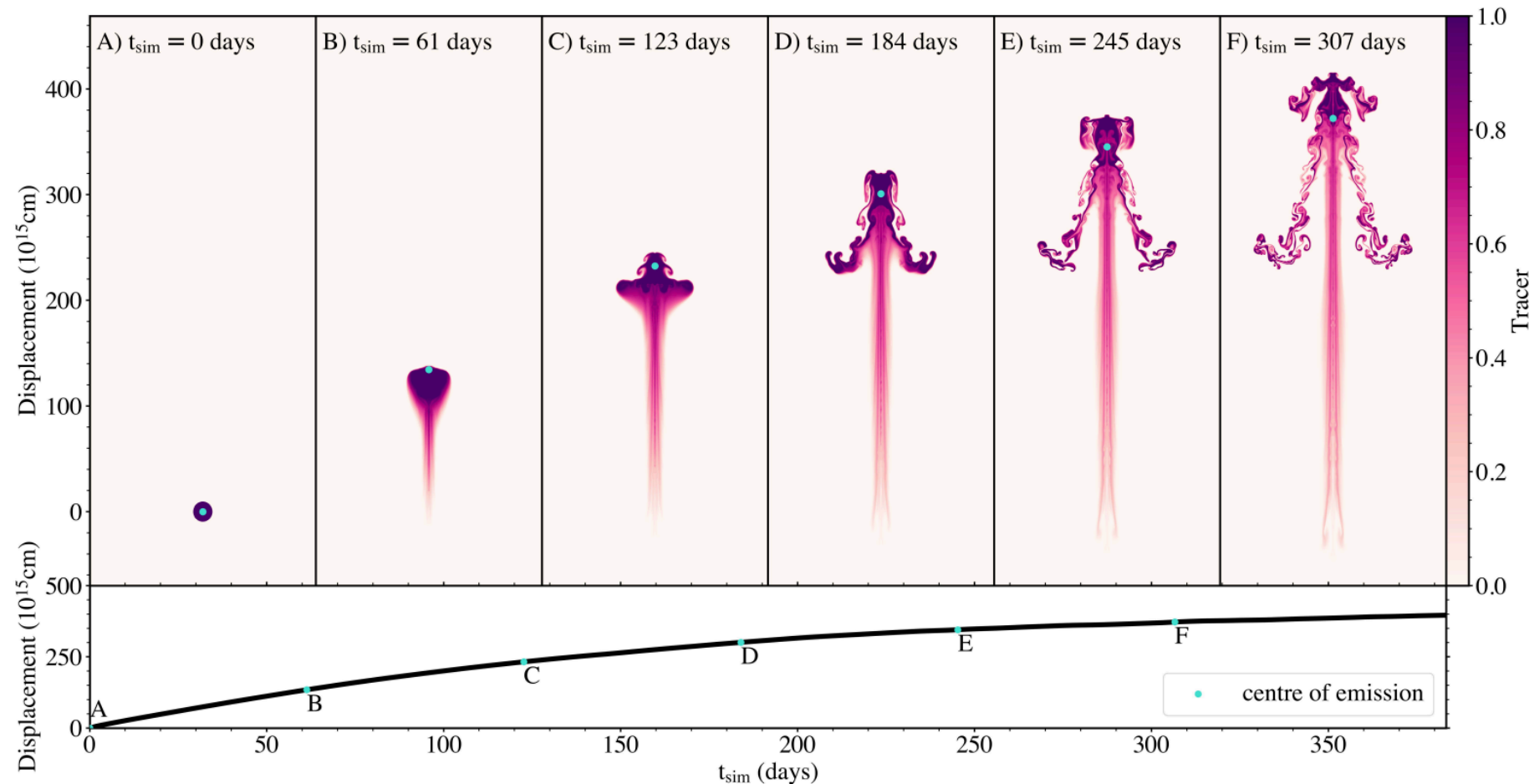
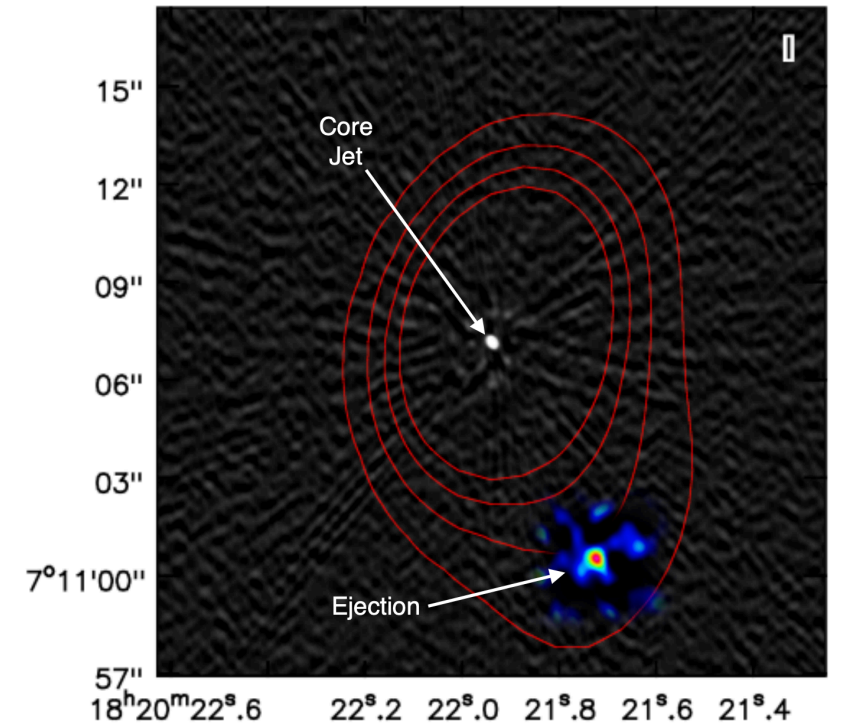
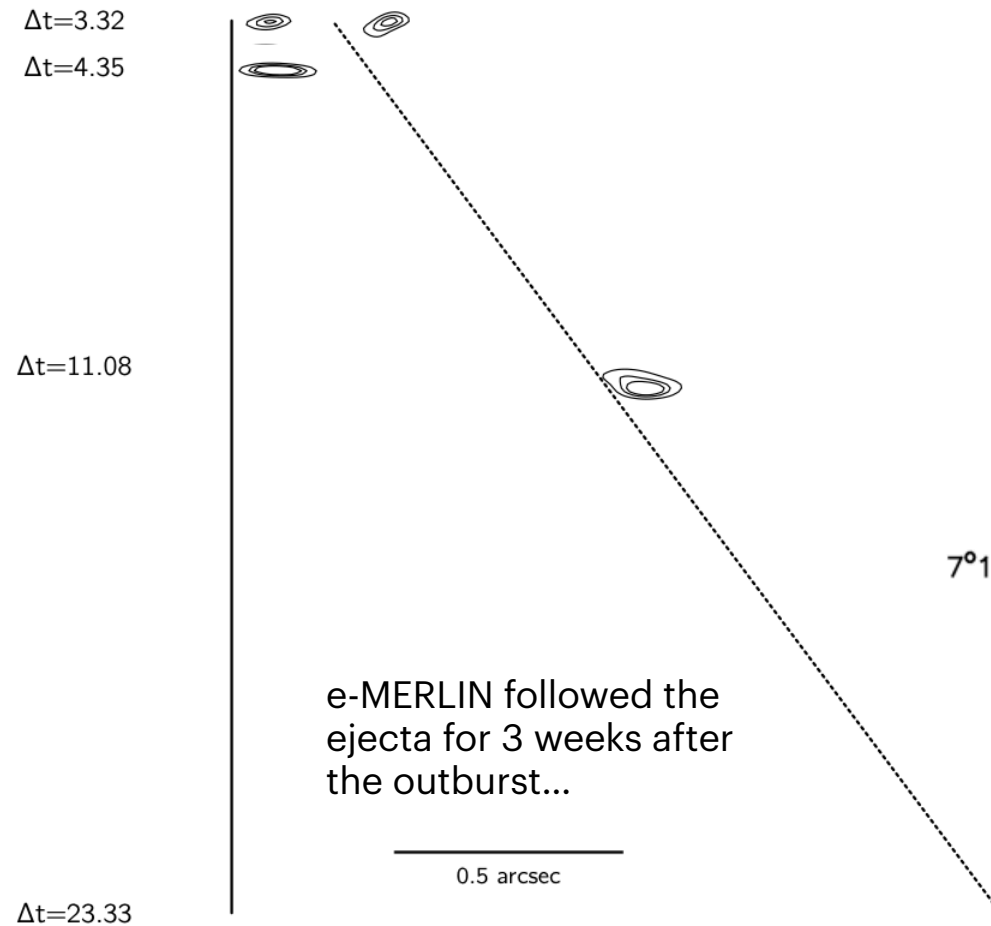
Persistent Radio Sources (PRSs) associated with FRBs have been found when sufficient localisation power is available. e-MERLIN has provided the high resolution necessary to detect the radio emission from these PRSs and localise them within host galaxies. For FRB 20190714, a localisation was found by e-MERLIN in a crowded MeerKAT field.

Chibueze et al. 2022, MNRAS, [arXiv:2201.00069](https://arxiv.org/abs/2201.00069)

2018 outburst of X-ray binary MAXI J1820+070

Rapid e-MERLIN observations of a new X-ray source in 2018 found a relativistically moving radio jet of plasma, launched into the interstellar medium. By using e-MERLIN in conjunction with MeerKAT at the same frequency, it was possible to estimate the size of the emitting region and the energy content of the ejecta.

*Bright et al. 2020/2025, NatureAst/
MNRAS, [arXiv:2003.01083](#)*



Modelling the relativistic ejecta from MAXI J1820+070

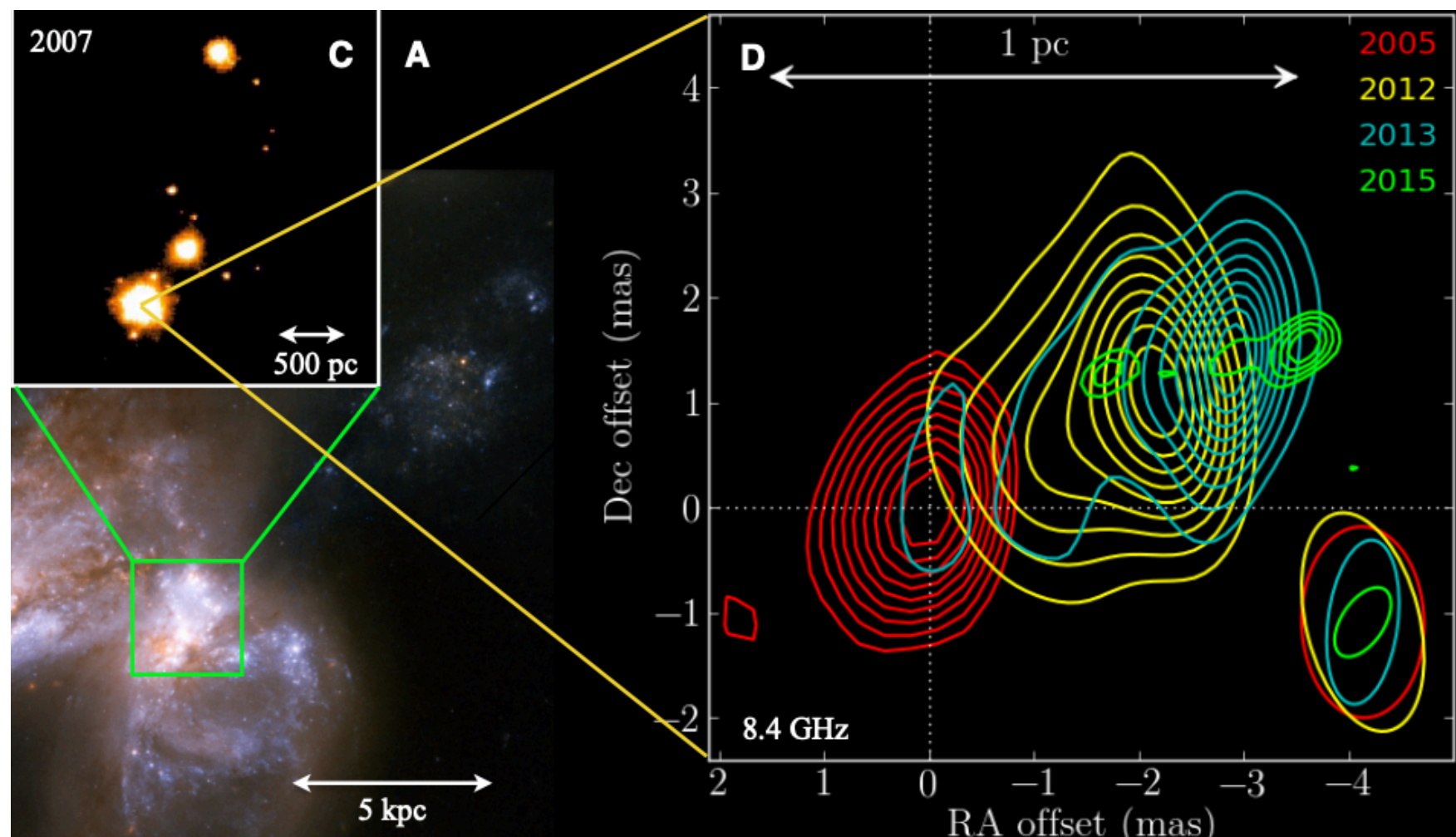
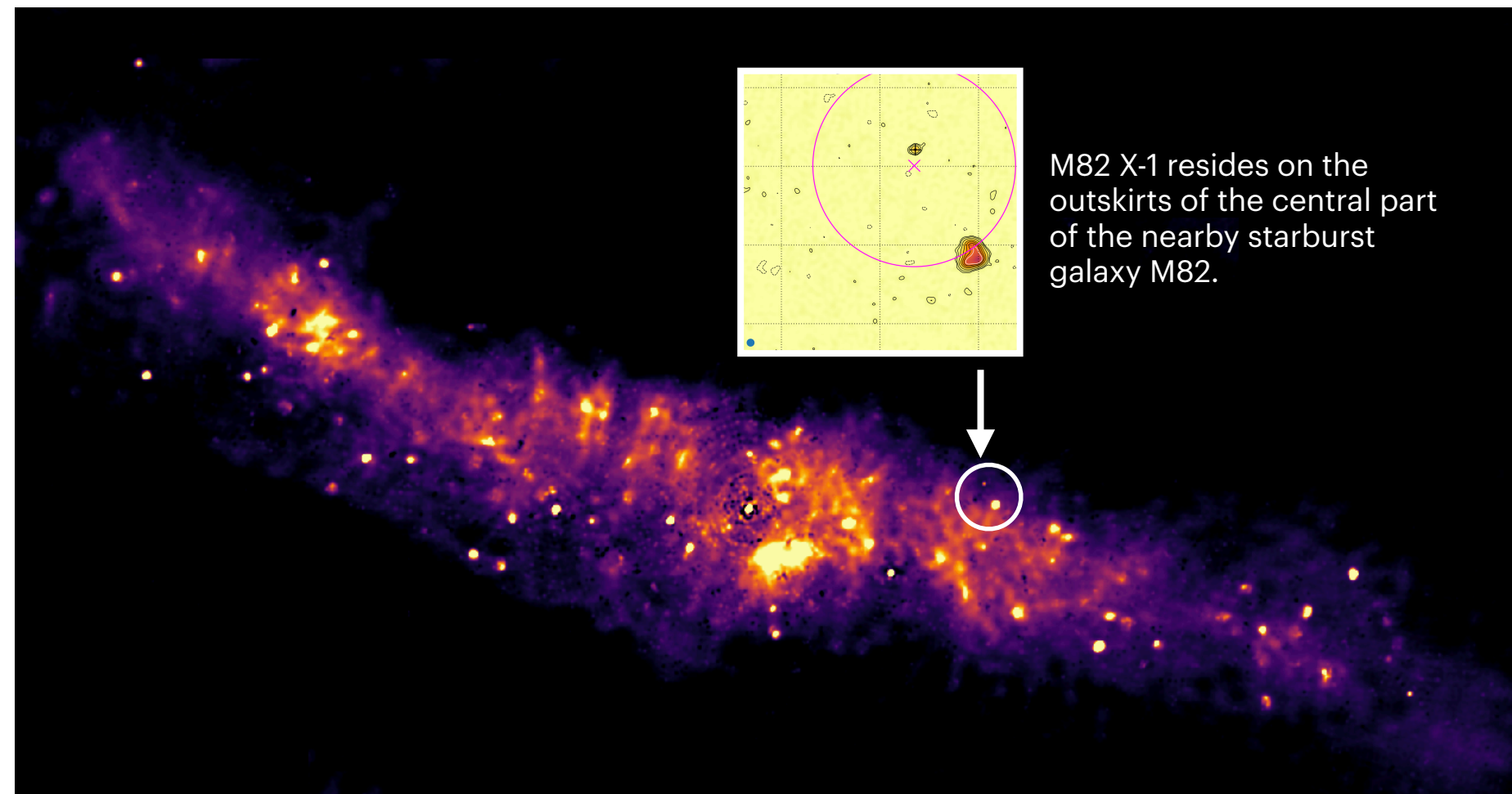
The e-MERLIN dataset of MAXI J1820+070 provided a rich database of information to test and simulate how radio plasma jets propagate and interact with the interstellar medium. This work is now being used to simulate what we may expect with the SKAO when it sees first light, as well as for other future radio interferometer arrays.

*Savard et al. 2025, MNRAS,
[arXiv:2504.20914](#)*

Transient radio emission from an intermediate-mass black hole

Intermediate-mass black holes (IMBHs) are the missing link between stellar-mass black holes we find in our own Galaxy, and super-massive black holes at the centres of galaxies. M82 X-1 is one of the best candidate IMBHs and e-MERLIN detected it at radio wavelengths, further confirming it's black hole nature.

Williams-Baldwin et al. 2025, MNRAS, arXiv:2504.18217



The dust enshrouded tidal disruption event in Arp 299

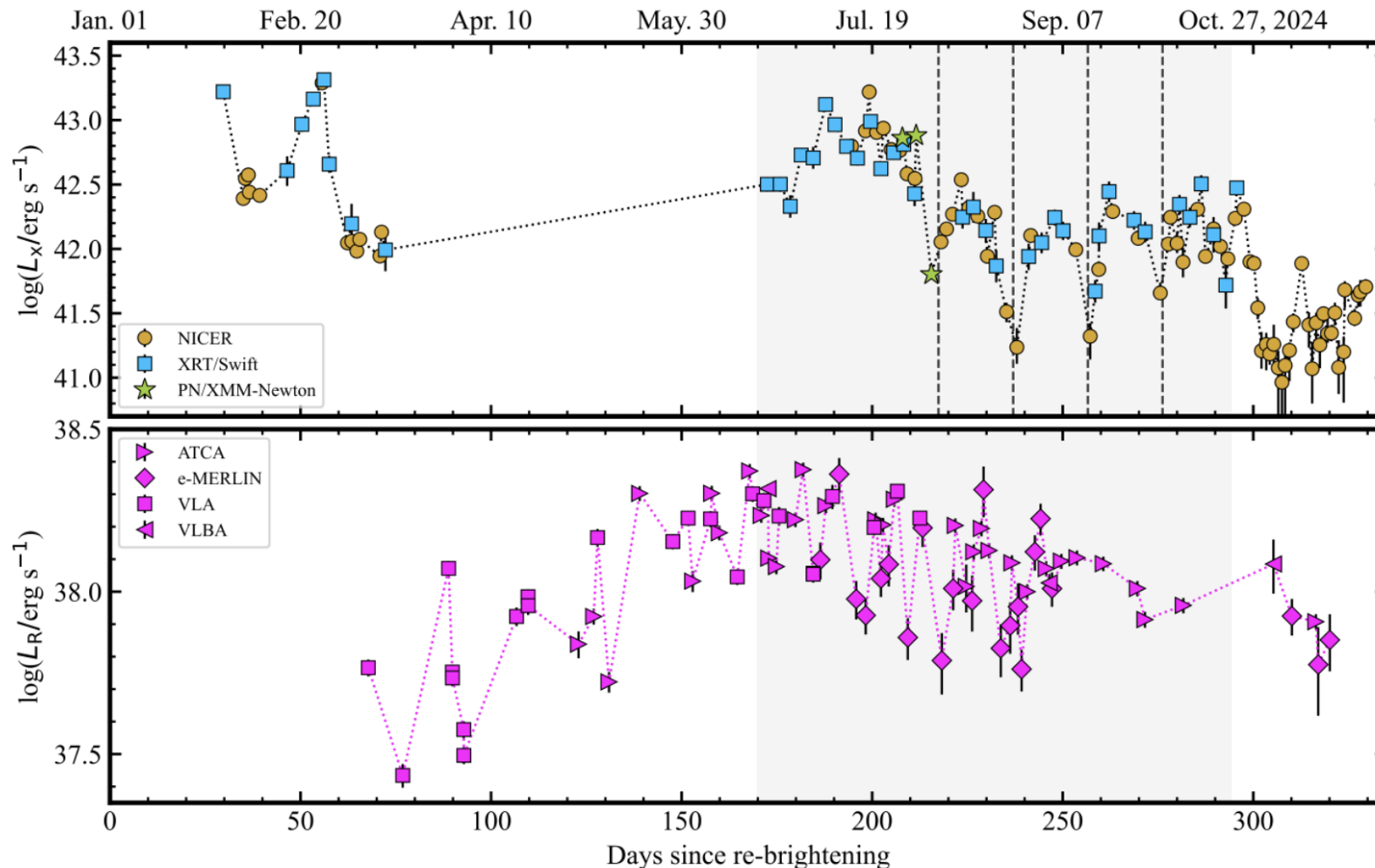
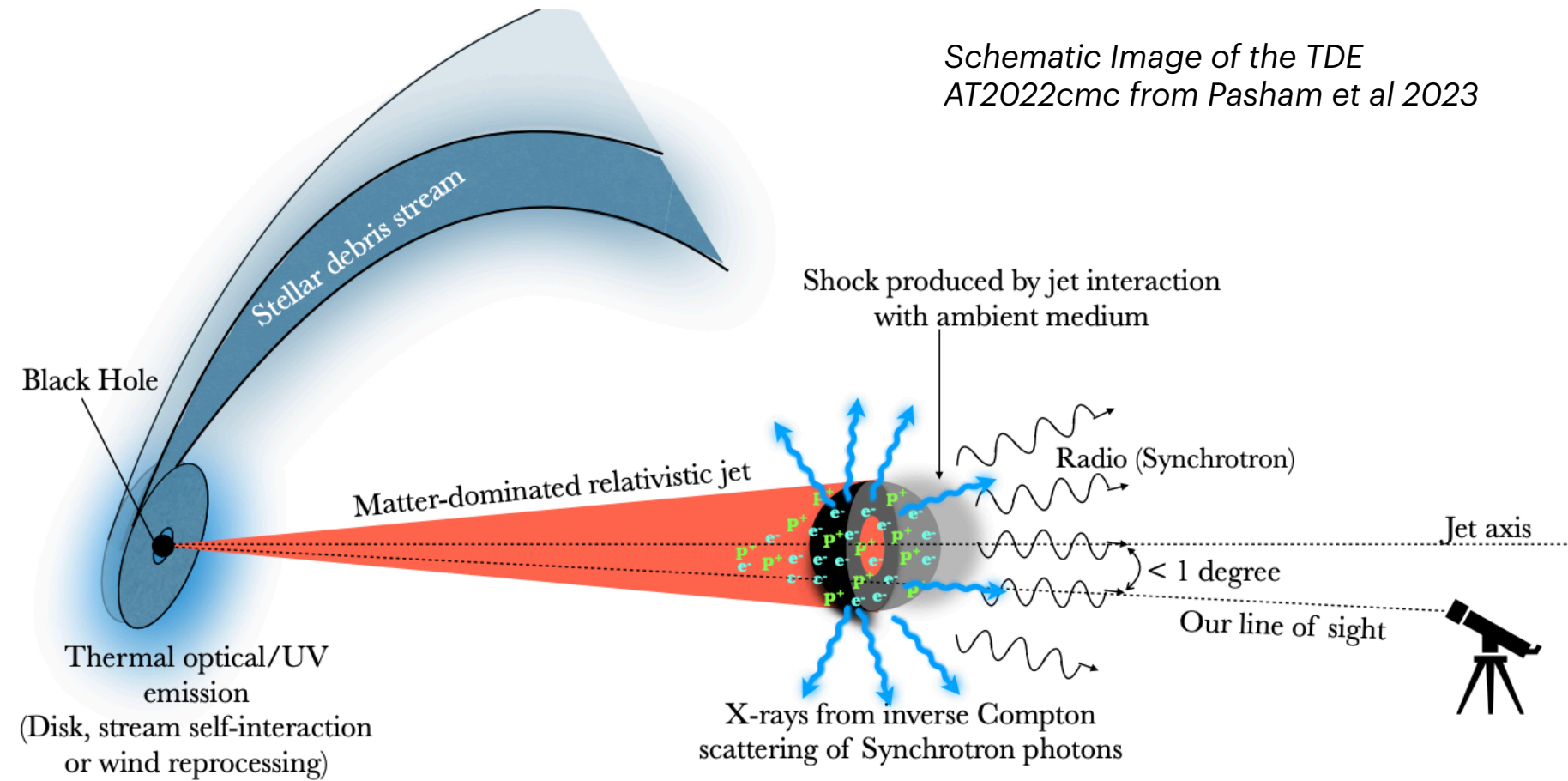
Tidal disruption events are caused when a star wanders too close to a black hole and is ripped apart by the immense tidal forces. In the nearby galaxy Arp 299, EVN + e-MERLIN observations showed a radio plasma jet moving a a quarter of the speed of light, in a dust enshrouded environment which completely obscured it in the optical light, but was directly observed in the radio band.

Mattila et al. 2018, Science, arXiv:1806.05717

Watching a cosmic engine turn on

e-MERLIN helped capture the birth of a powerful jet travelling at the speed of light when a star was destroyed by a supermassive black hole. By tracking the jet as it evolved, scientists gained new insights into how some of the most powerful phenomena in the Universe are created.

Pasham et al 2023, NatAst, arXiv:2211.16537 Rhodes et al. 2023, MNRAS, arXiv:2301.12770



A precessing disk from a tidal disruption event

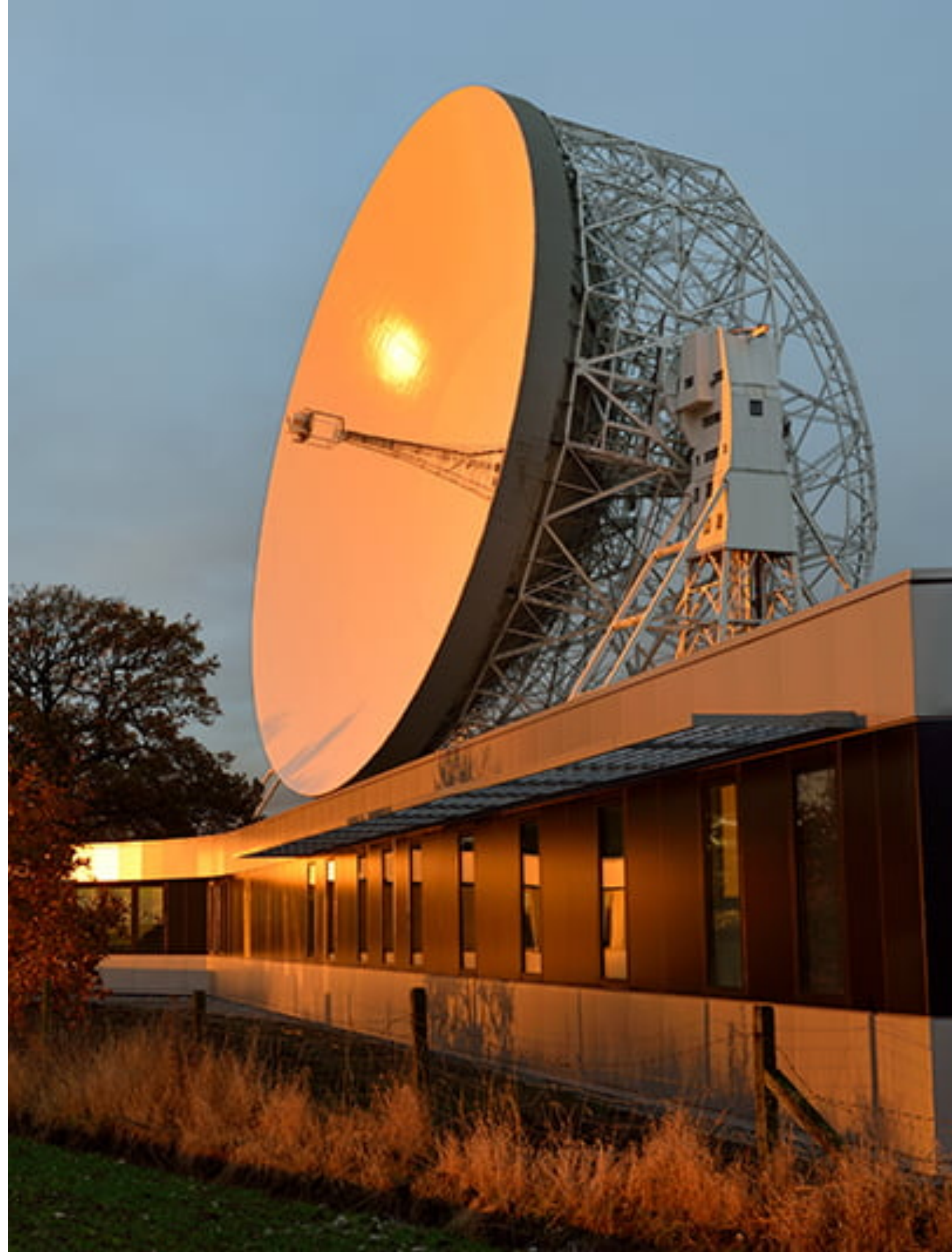
AT2020afhd showed a significant re-brightening and was confirmed as a tidal disruption event (TDE). The source showed a ~20 day quasi-periodic oscillation period, in line with the X-rays, suggesting a precession of the disk formed when the star was ripped apart, one of the first pieces of evidence for this phenomenon.

Wang et al. 2025, SciAdv, arXiv:2511.12477

STARS, STELLAR PHYSICS AND THE CRADLE OF LIFE

FROM STARDUST TO STARLIGHT

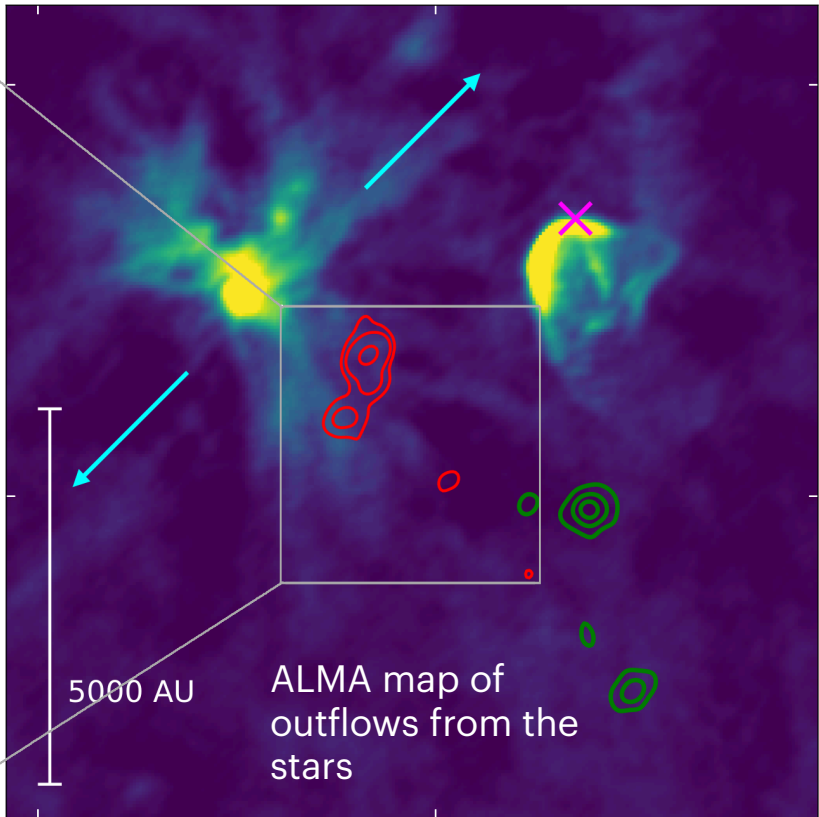
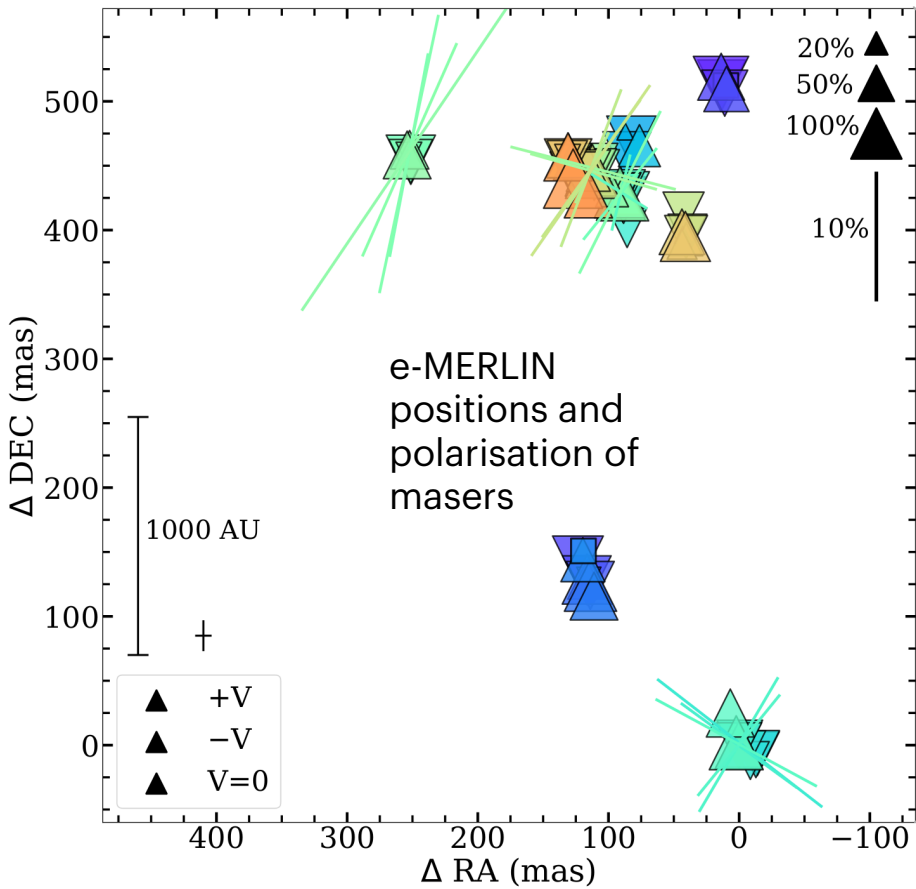
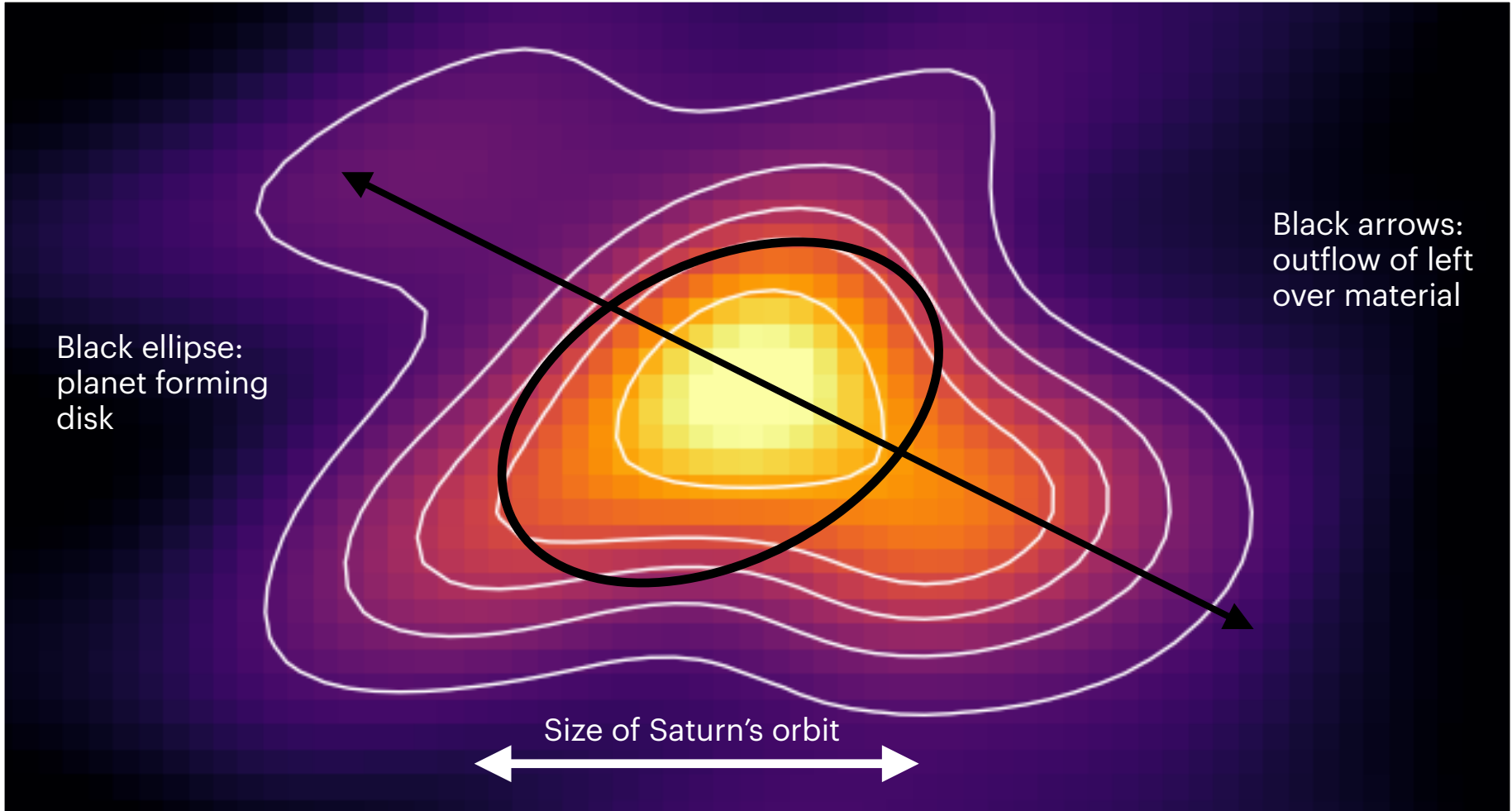
Stars define the light that we see. They also harbour the solar systems in which life can be born. How stars evolve is of crucial importance for understanding the enrichment of elements in galaxies to the birth of planets. e-MERLIN's ability to zoom into these regions, unaffected by the dust which surrounds them, makes it the ideal instrument for studying the stars in our galaxy, and further beyond.



Planet forming building blocks of life

e-MERLIN can zoom into the regions around proto-planetary disks and detect 'pebbles' of a few centimetres. This image of the nearby DG Tau system, 450 light years away, shows dust in the process of condensing into larger rocks, which will eventually form planets.

Hesterly and Greaves, in prep, RAS Press release, <https://www.ras.ac.uk/news-and-press/research-highlights/birth-solar-system-revealed-planet-pebbles>



A pair of young giant stars

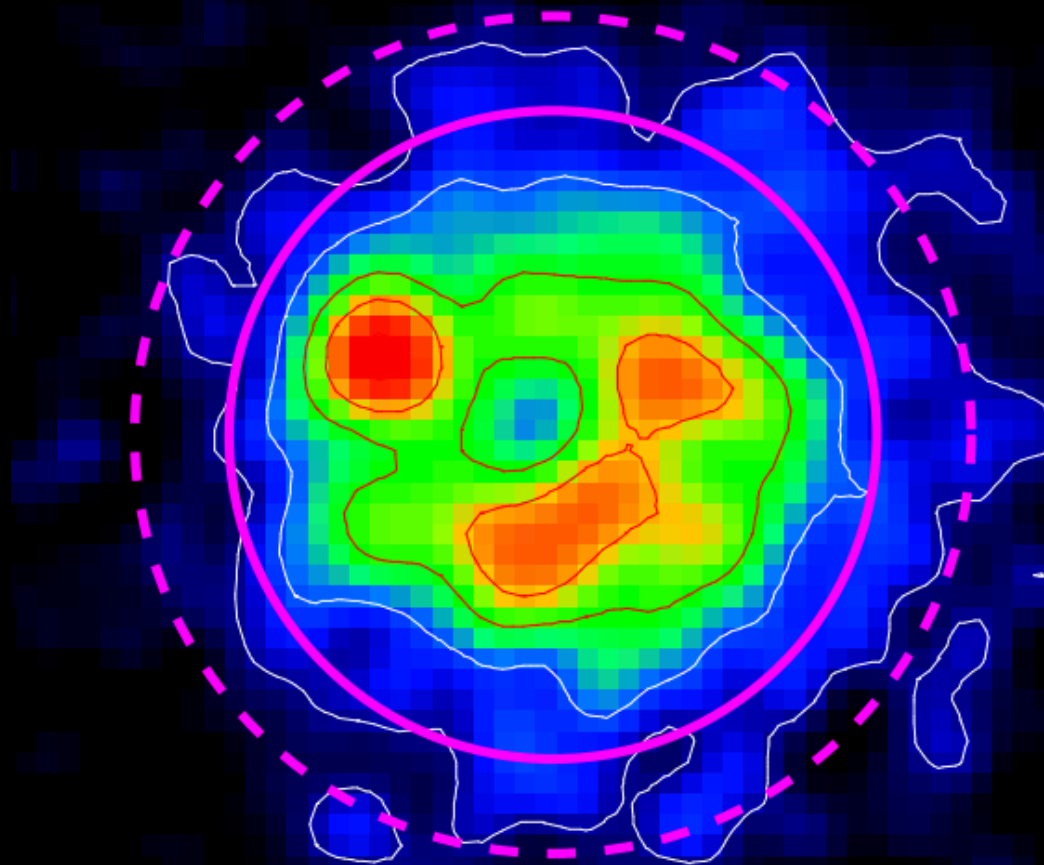
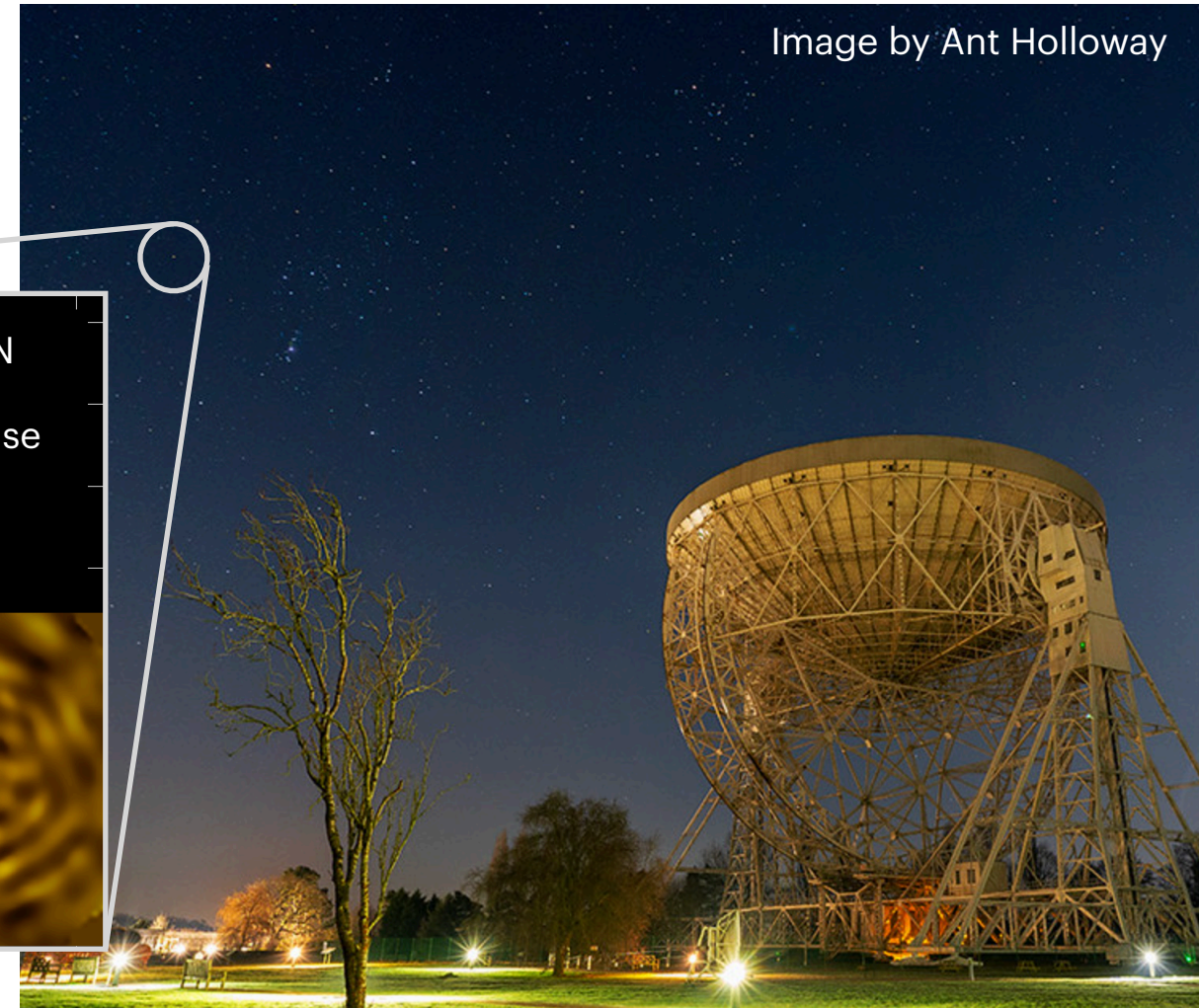
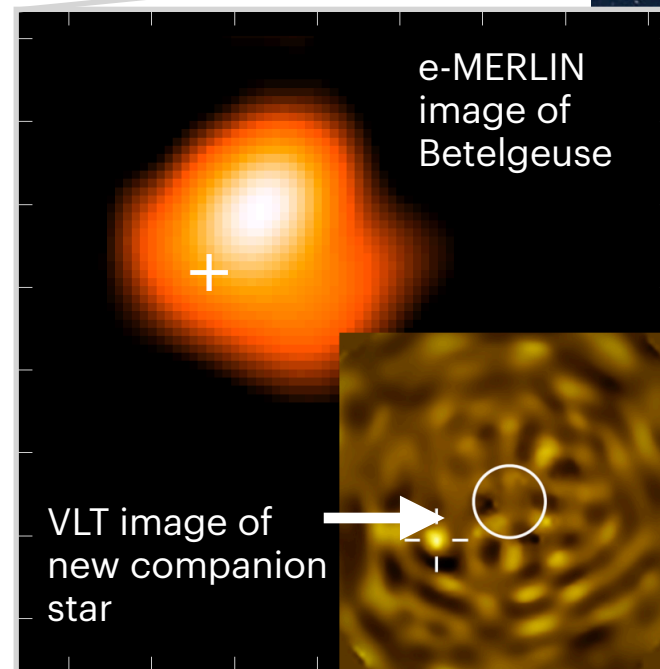
e-MERLIN can provide information on the chemistry of star systems from hydroxyl and methanal masers. By pin-pointing the position of the masers with e-MERLIN, the polarised emission from these regions enables scientists to study the magnetic fields, which play an important part in the rate at which giant stars like these are forming.

Kobak et al. 2025, A&A, [arXiv:2503.11379](https://arxiv.org/abs/2503.11379)

The radio atmosphere of Betelgeuse

Betelgeuse is the red giant star on the shoulder of the constellation, Orion. Optical imaging with the VLT revealed a new companion star to Betelgeuse. e-MERLIN radio imaging shows the companion lies within the extended radio atmosphere of Betelgeuse.

Dent, Matthews, Richards et al. in prep.,
Montarges et al, in prep, VLT/ESO Press
release, <https://www.eso.org/public/unitedkingdom/news/eso2611/?lang>



e-MERLIN image of the dying star OH 83.4-0.9. Inner and outer parts of the shell shown by magenta full and dashed circles

Measuring the Distance to Dying Stars

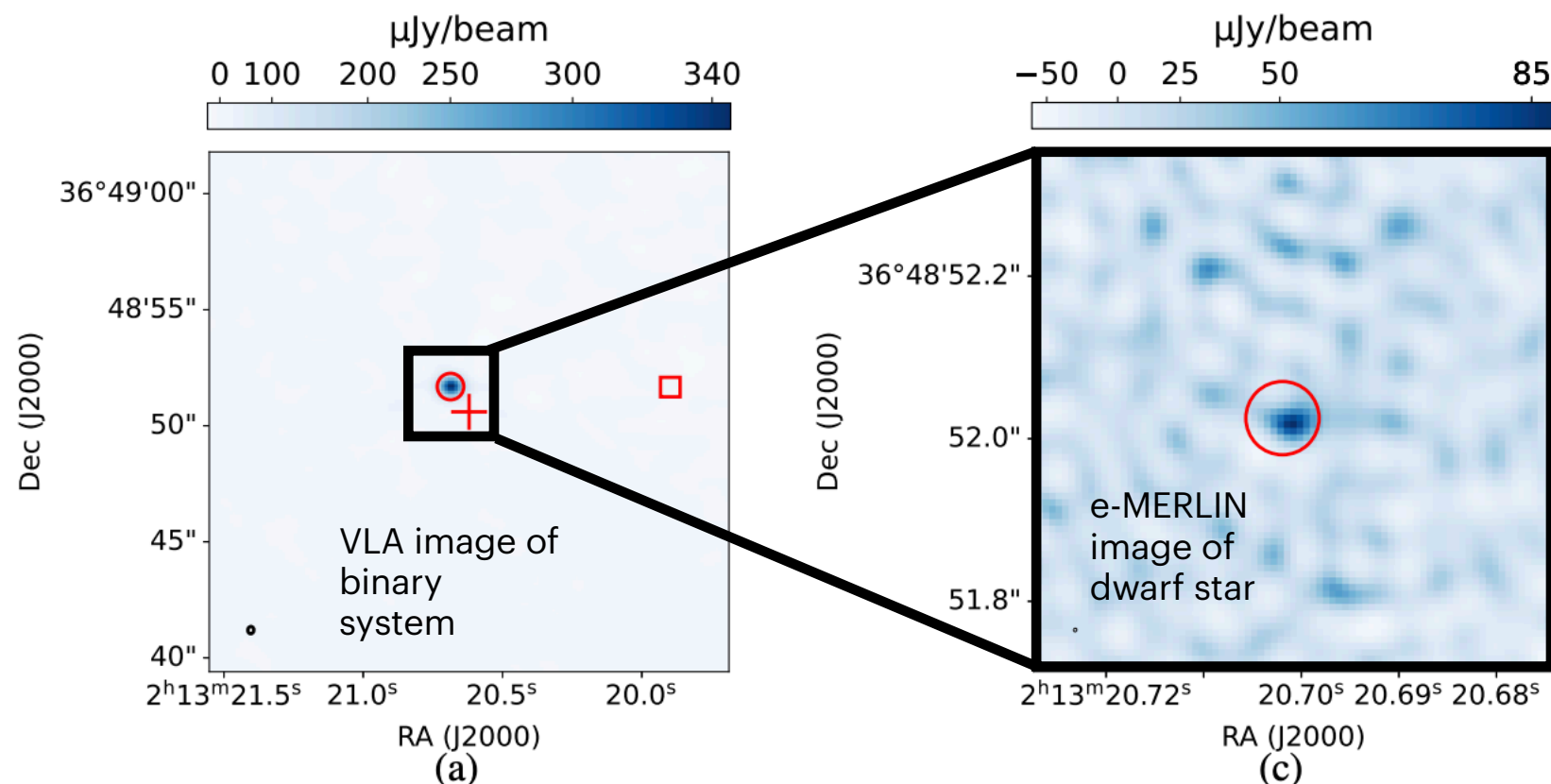
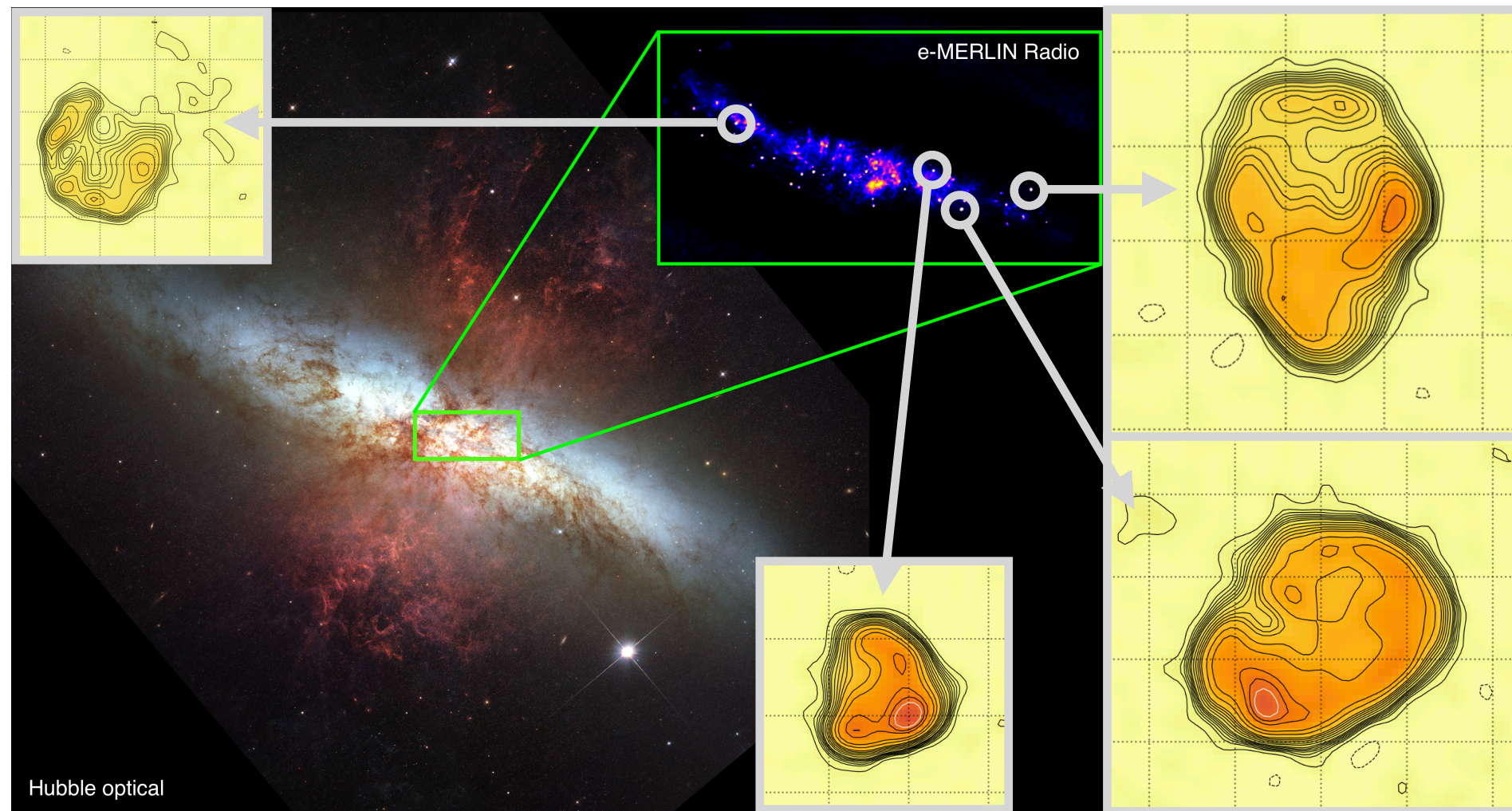
As stars like the Sun approach the end of their lives, they shed envelopes of gas into space. By using e-MERLIN to measure these expanding shells, it is possible to determine a precise distance to these stars, which is vital for understanding how dying stars recycle material back into the Galaxy, enriching the interstellar medium.

Etoka et al. 2018, IAU Proceedings,
[arXiv:1711.09694](https://arxiv.org/abs/1711.09694)

Five decades of radio monitoring of supernova remnants in M82

At the end of their lives, stars explode as supernova, a powerful explosion which sends a shock wave through the surrounding gas and dust. e-MERLIN and the EVN have studied the nearby starburst galaxy M82 for fifty years, cataloguing and monitoring how these supernova shells expand and evolve at speeds of 1000s km/s.

Walls et al. in prep, Williams-Baldwin et al. 2025, EVN Proceedings, [arXiv:2504.17500](#)



Radio emission from M dwarf stars

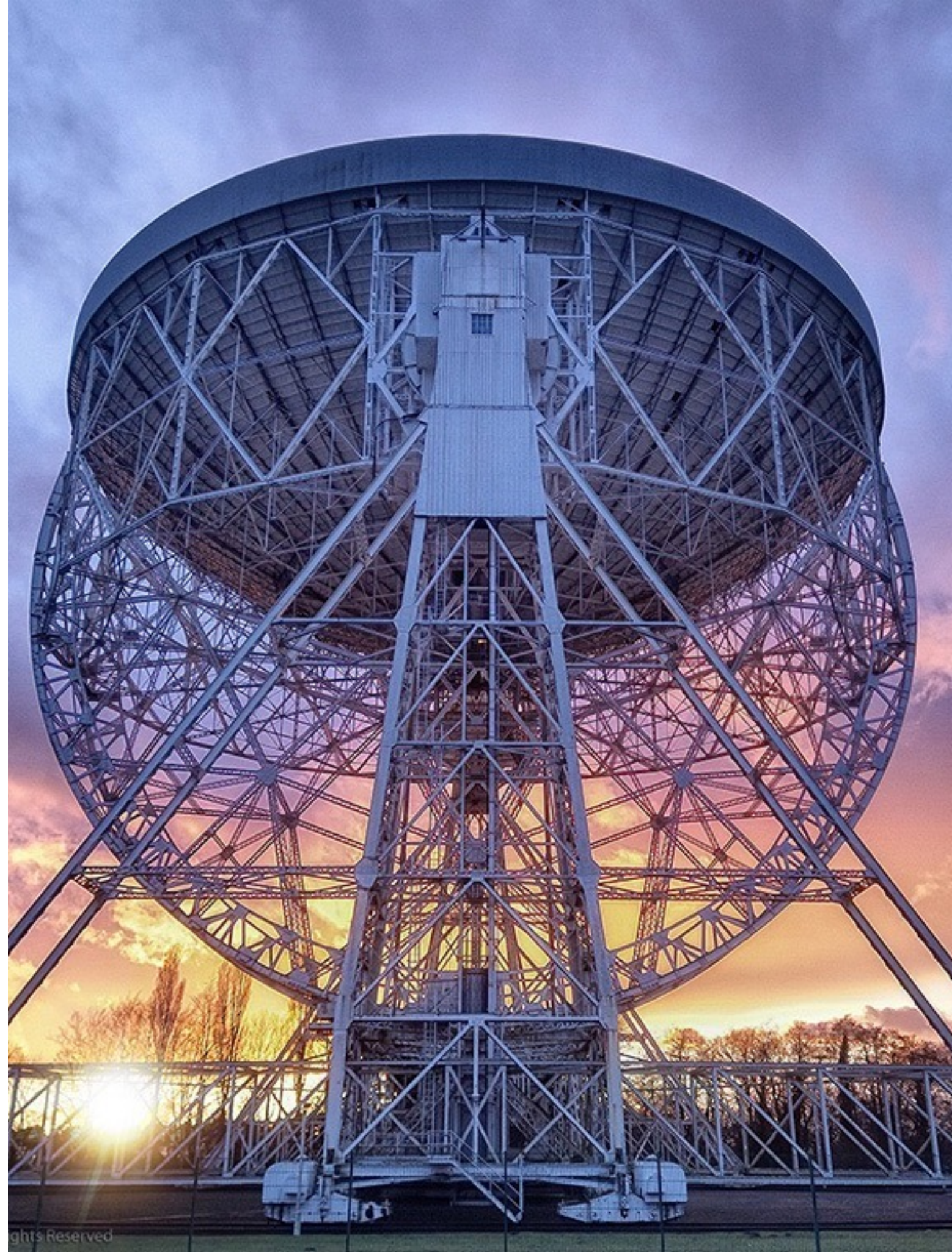
By using the high angular resolution of e-MERLIN, it is possible to zoom into nearby stars, and study the magnetic fields and what is causing the emission using multi-frequency observations. These sources are important for understanding how magnetic storms from stars may affect the planets that orbit them.

Wandia et al. 2025, MNRAS, [arXiv:2507.20681](#)

COSMOLOGY AND THE HIGH REDSHIFT UNIVERSE

THE MYSTERIES OF DARK MATTER

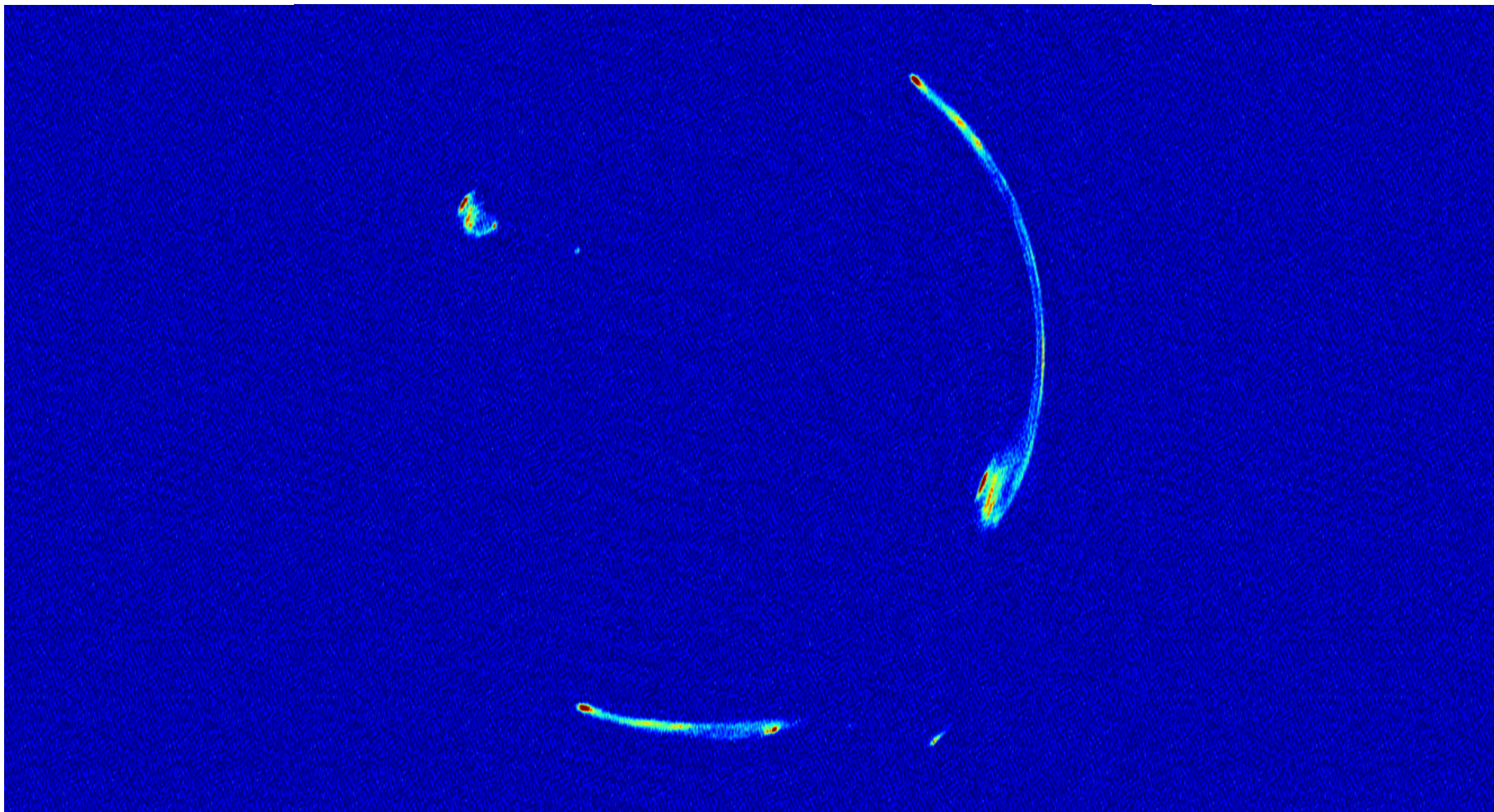
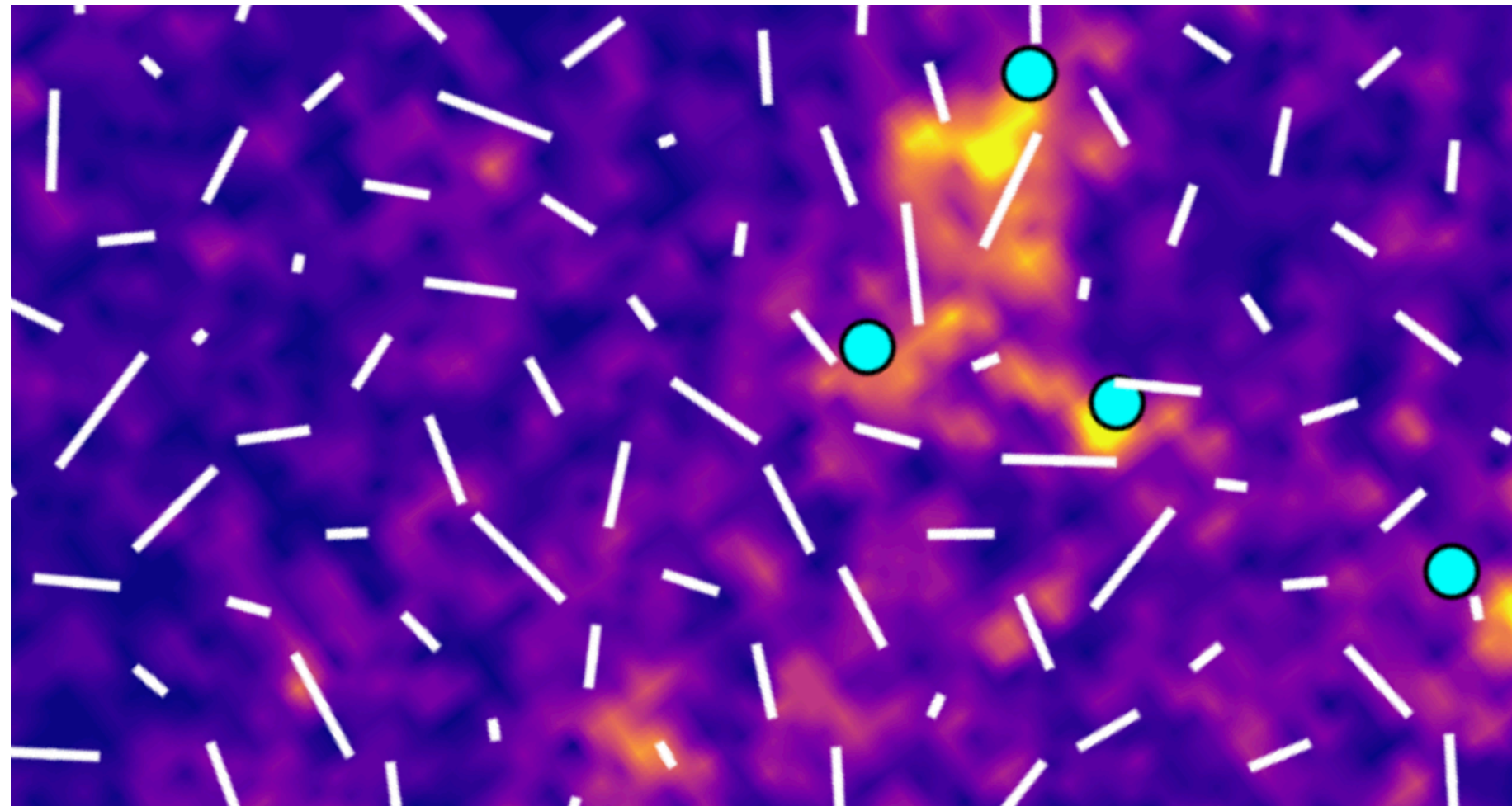
The Universe is full of matter than we can observe with visible light. But dark matter is invisible and can only be indirectly found using highly computational techniques from high resolution radio data. e-MERLIN provides high sensitivity observations which can probe deep into the history of the Universe, as well as find evidence for dark matter.



Weak Lensing with the SuperCLASS Survey

Gravity bends light as it travels through the Universe. These distortions in the shapes of distant galaxies can be measured to infer the presence and map dark matter distributions through a process called 'weak lensing'. The e-MERLIN SuperCLASS project, was the first to pioneer this technique using radio waves.

*Harrison et al 2020, MNRAS,
[arXiv:2003.01736](#)*



Einstein Rings caused by dark matter

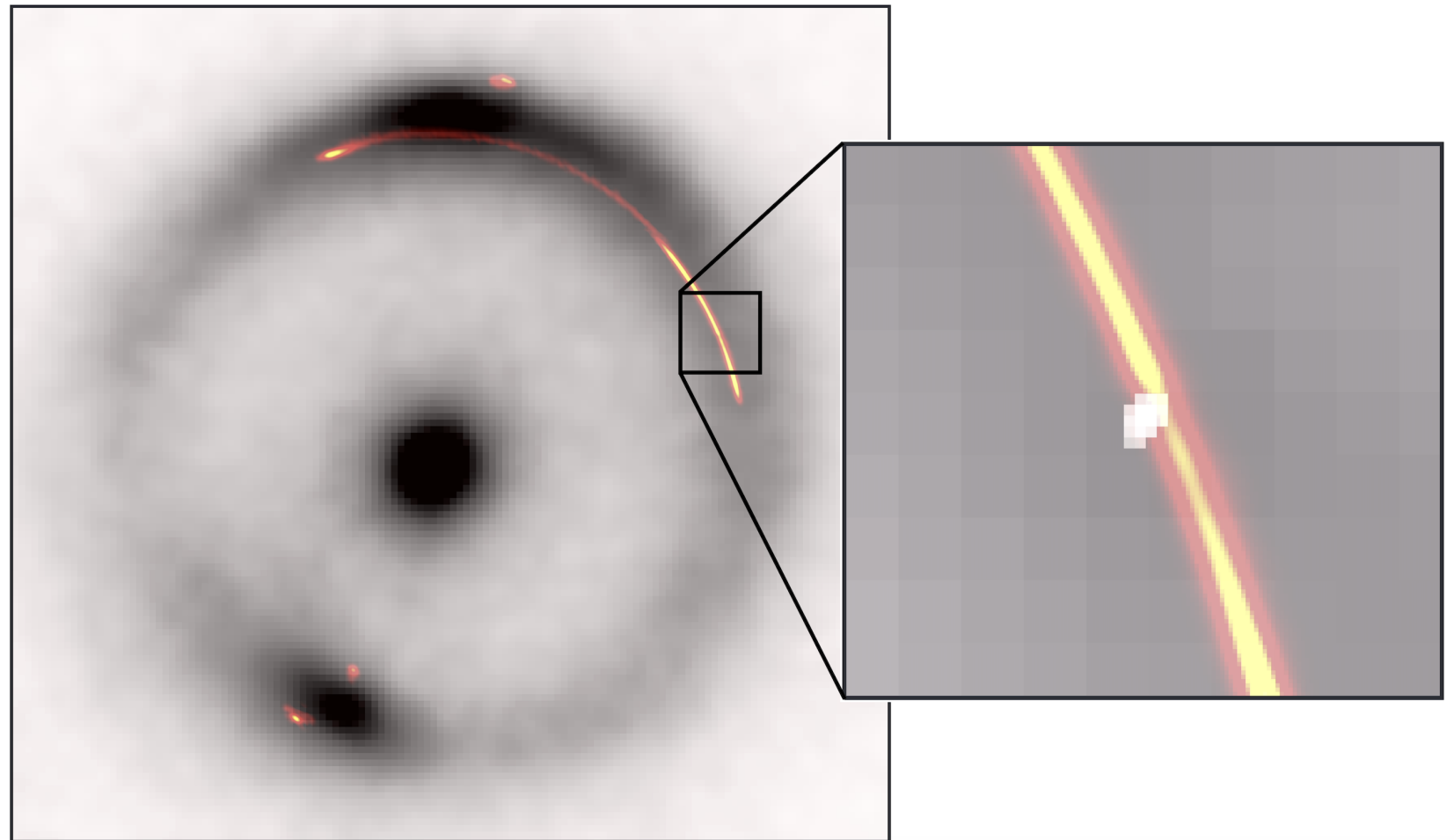
Strong gravitational lensing is caused by dark matter bending light behind it, to produce "Einstein Rings". The background object is magnified but smeared out, allowing us to peer deeper back into the history of the Universe. The bending of the light tells us about the underlying dark matter distribution which is only possible using an international array of telescopes and including Lovell for sensitivity.

*Spingola et al. 2018, MNRAS,
[arXiv:1807.05566](#)*

A dark million solar mass object in the distant Universe

Global VLBI + e-MERLIN observations of the Einstein Ring JVAS B1938+666 revealed a never before seen “dark object”, weighing a million solar masses. This is the lowest mass object known at such a large distance. It’s discovery paves the way for future studies of distant objects to potentially unlock further mysteries of the Universe..

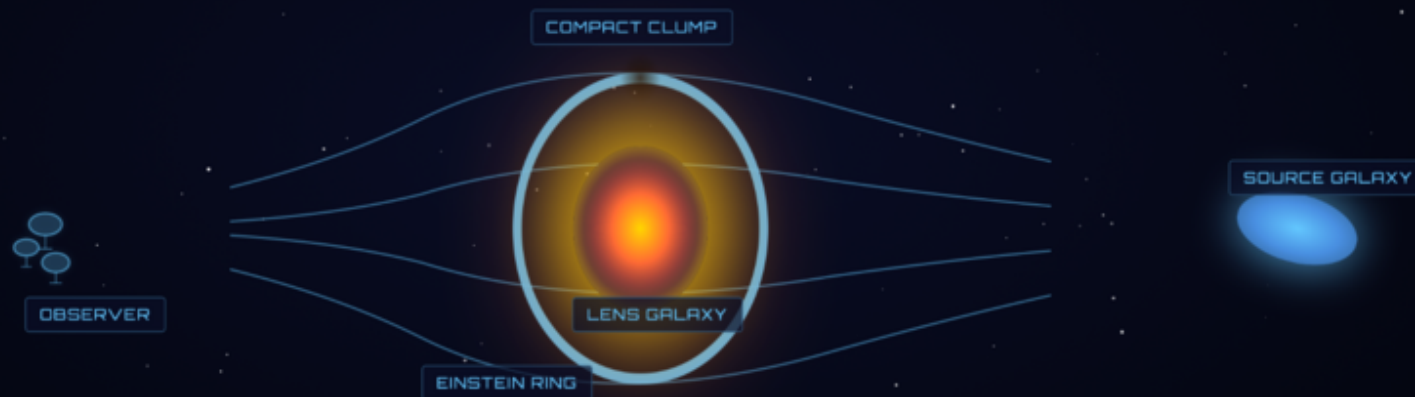
Powell et al 2025, NatAst, [arXiv:2510.07382](#)



GRAVITATIONAL LENS

Strong gravitational lensing occurs when a massive foreground galaxy warps spacetime, bending light from a background source into a luminous Einstein ring.

A compact clump of matter or dense object locally perturbs the Einstein ring, creating a localized distortion effect where it further deflects the lensed light.



Lens Galaxy Mass: $\sim 10^{11} M_{\odot}$
Invisible Matter Clump Mass: $\sim 10^6 M_{\odot}$
Lens Galaxy Redshift: $z \sim 0.8$
Source Galaxy Redshift: $z \sim 2.0$

A new challenge to dark matter

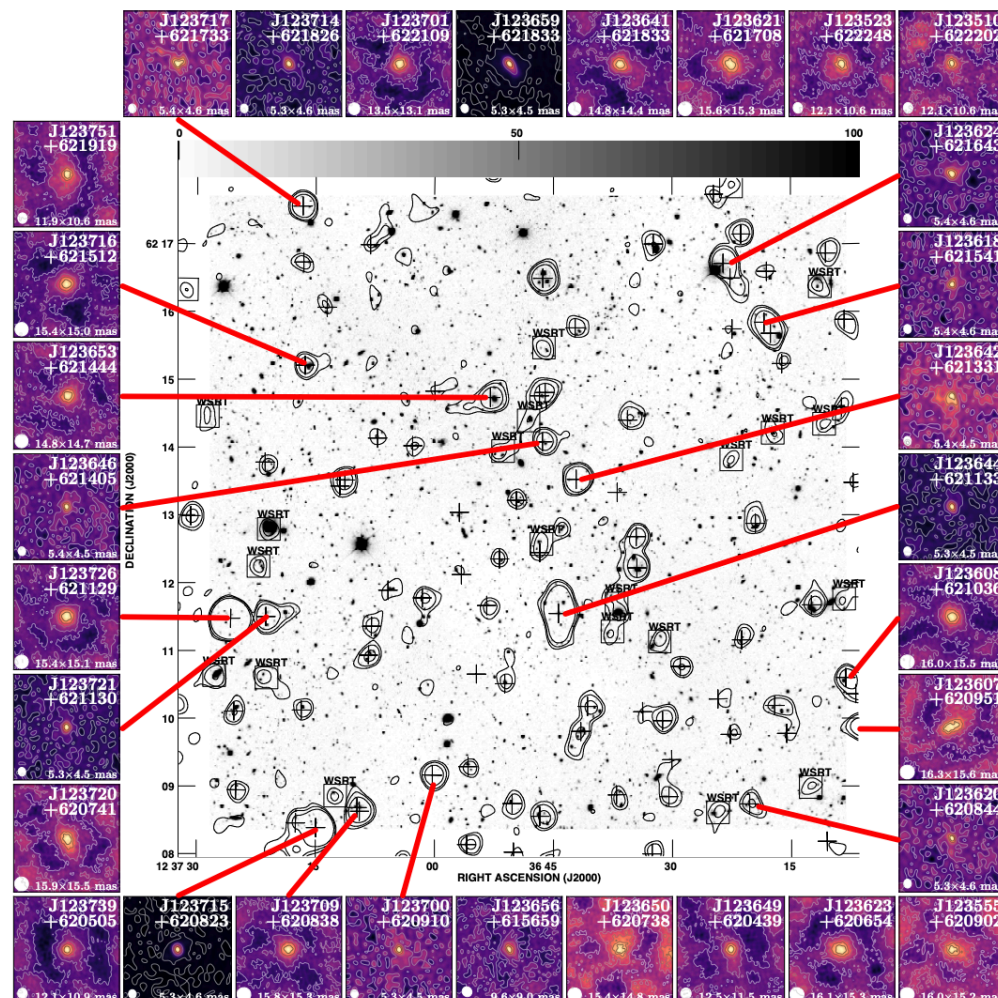
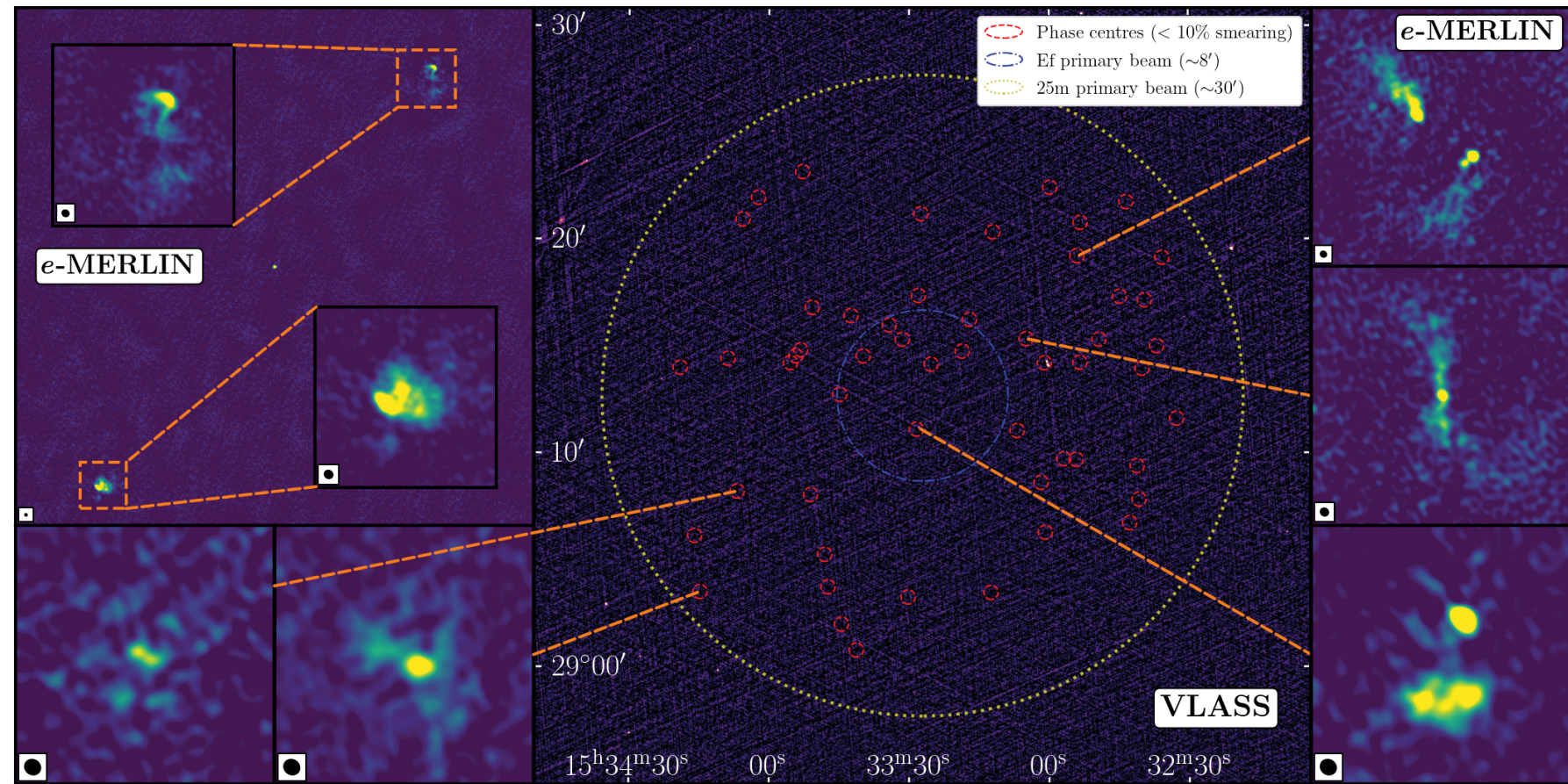
Further analysis of the JVAS B1938+666 Einstein Ring showed that the million solar mass object is hard to understand under current models of dark matter. The properties of this newly discovered object do not match up with any known astronomical object, but could be consistent with a self-interacting dark matter halo with a central collapsed black hole.

Vegetti et al. 2026, NatAst, [arXiv:2510.07382](#)

Star formation and black hole activity in the distant Universe

e-MERLIN's unique capabilities allow astronomers to zoom in on objects in the distant Universe, to find radio jets from black holes. Where jets do not exist, the radio emission can come from star formation. e-MERLIN provides the perfect intermediate scales for this research in Square Kilometre Array Pathfinder Radio Continuum Surveys

Njeri et al 2023, MNRAS, [arXiv:2212.01874](https://arxiv.org/abs/2212.01874)



EVN + e-MERLIN image of the Hubble Deep Field - North

Wide-field high-resolution imaging of the Hubble Deep Field North

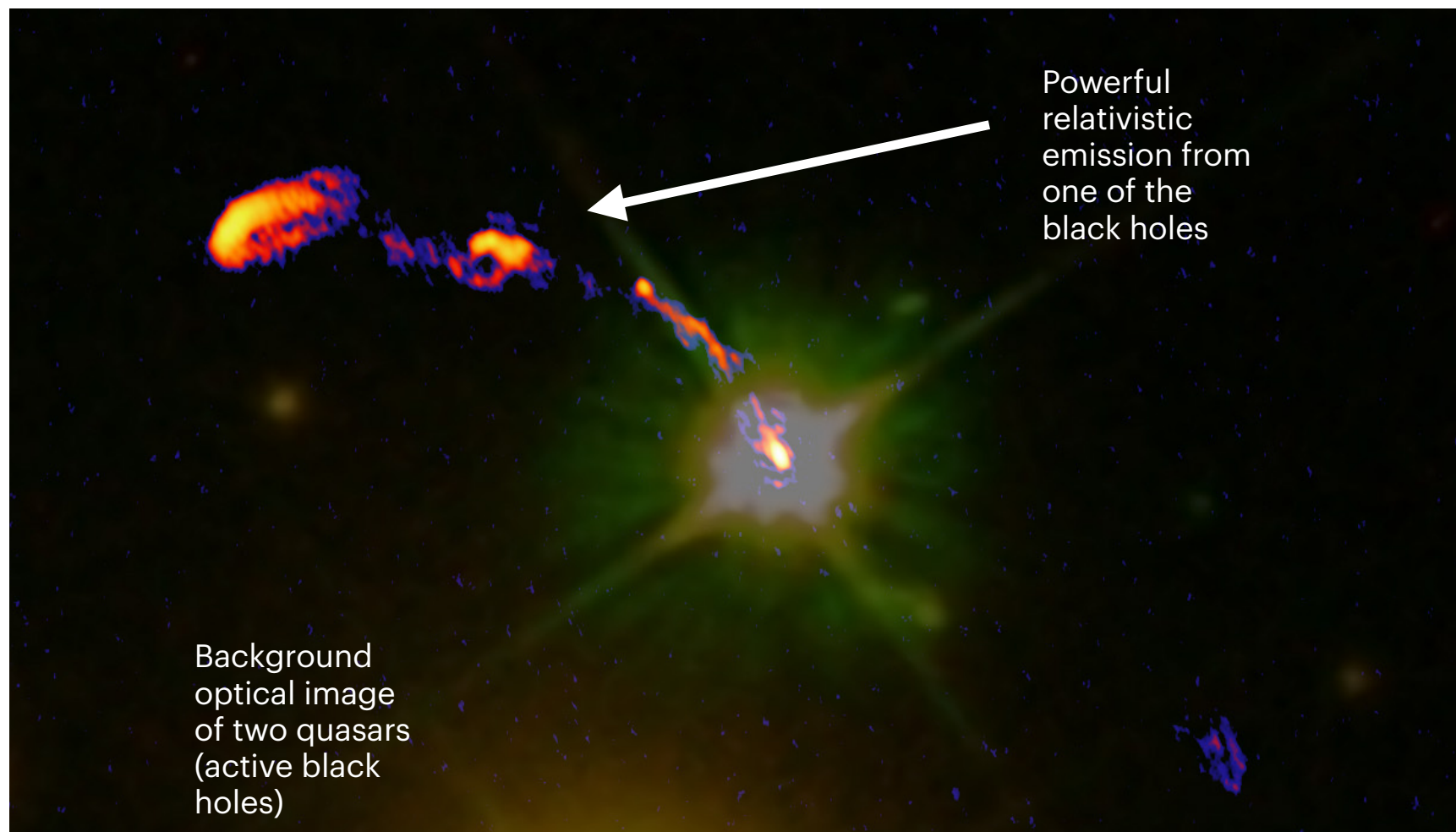
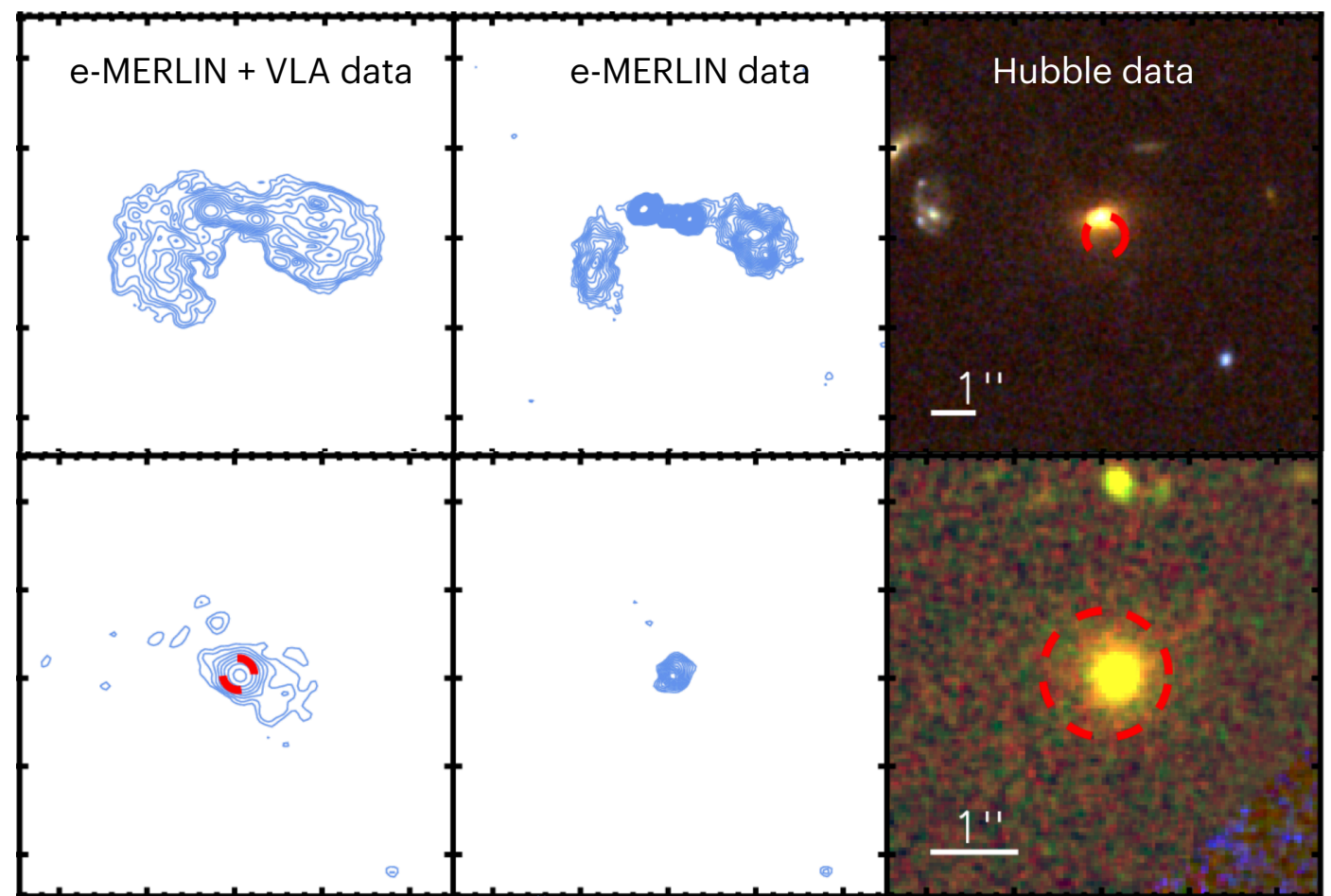
Observations of the important and highly studied Hubble Deep Field - North with e-MERLIN and the EVN have enabled astronomers to study how supermassive black holes feed. Some feed slowly whilst others are voracious and launch powerful relativistic radio jets, which is important for understanding how black holes evolve.

Radcliffe et al. 2018/2021, A&A, [arXiv:1808.04296](https://arxiv.org/abs/1808.04296) [arXiv:2103.08575](https://arxiv.org/abs/2103.08575)

Surveys of galaxy evolution with e-MERGE

By producing sensitive high resolution images of the intensely studied GOODS-North field, astronomers were able to zoom into the radio emission from black holes and stars during the era when most of the stars in the Universe were formed, providing new insights to galaxy evolution at the highest resolutions with e-MERLIN.

*Muxlow et al 2020, MNRAS,
[arXiv:2005.02407](https://arxiv.org/abs/2005.02407)*



Imaging the Double Quasar

The iconic Double Quasar provided one of the clearest demonstrations of Einstein's theory of gravity, with light bent from a distant black hole bent by the gravity of a foreground galaxy. Radio observations with e-MERLIN showed a bent powerful jet of material being launched into the space between galaxies, enabling the study of one of the most extreme environments in the Universe.

e-MERLIN Press Release. <https://www.jb.man.ac.uk/news/2010/emmerlin1/>

FUNDAMENTAL PHYSICS WITH PULSARS

STELLAR LABORATORIES OF EXTREME PHYSICS

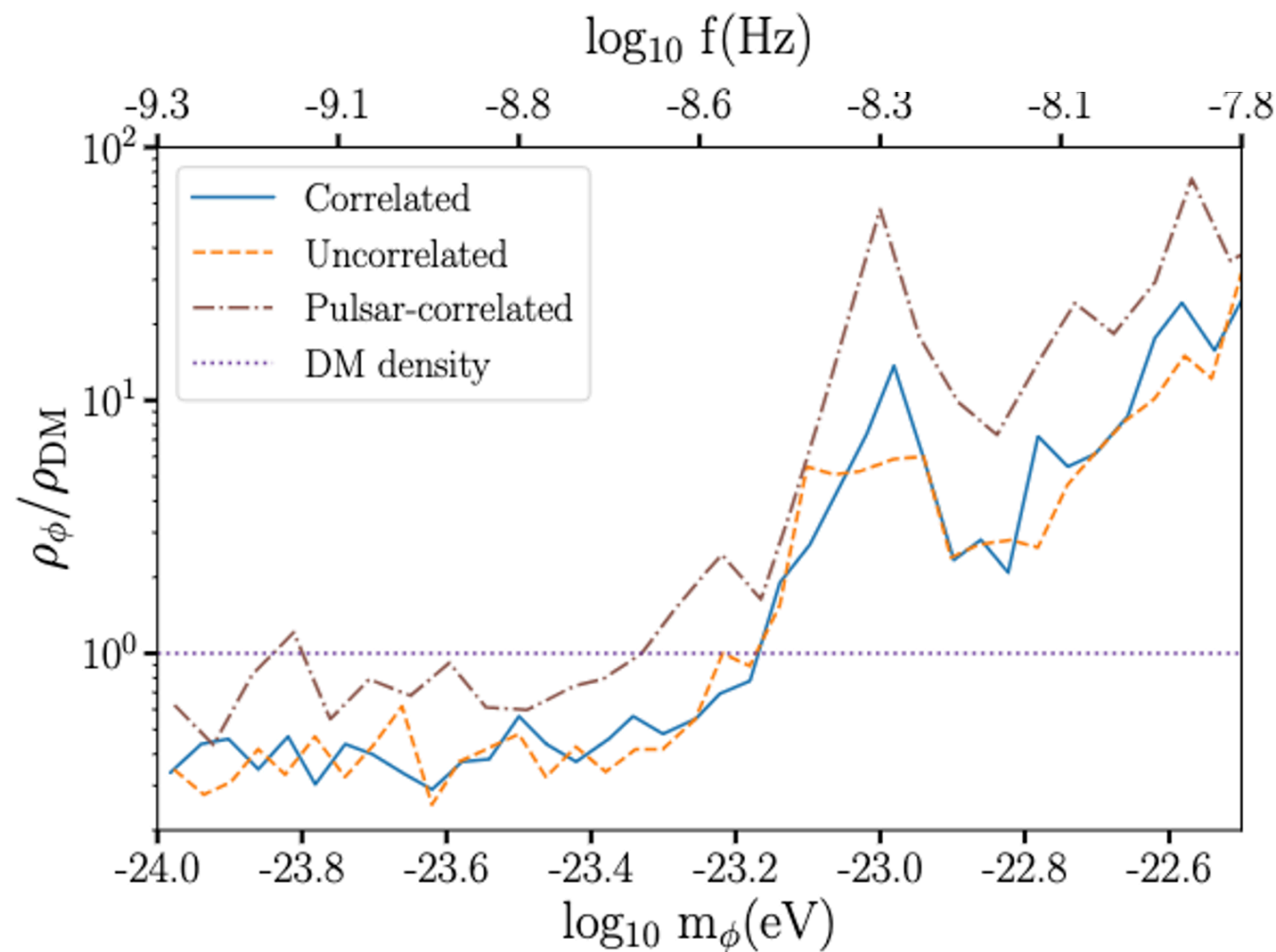
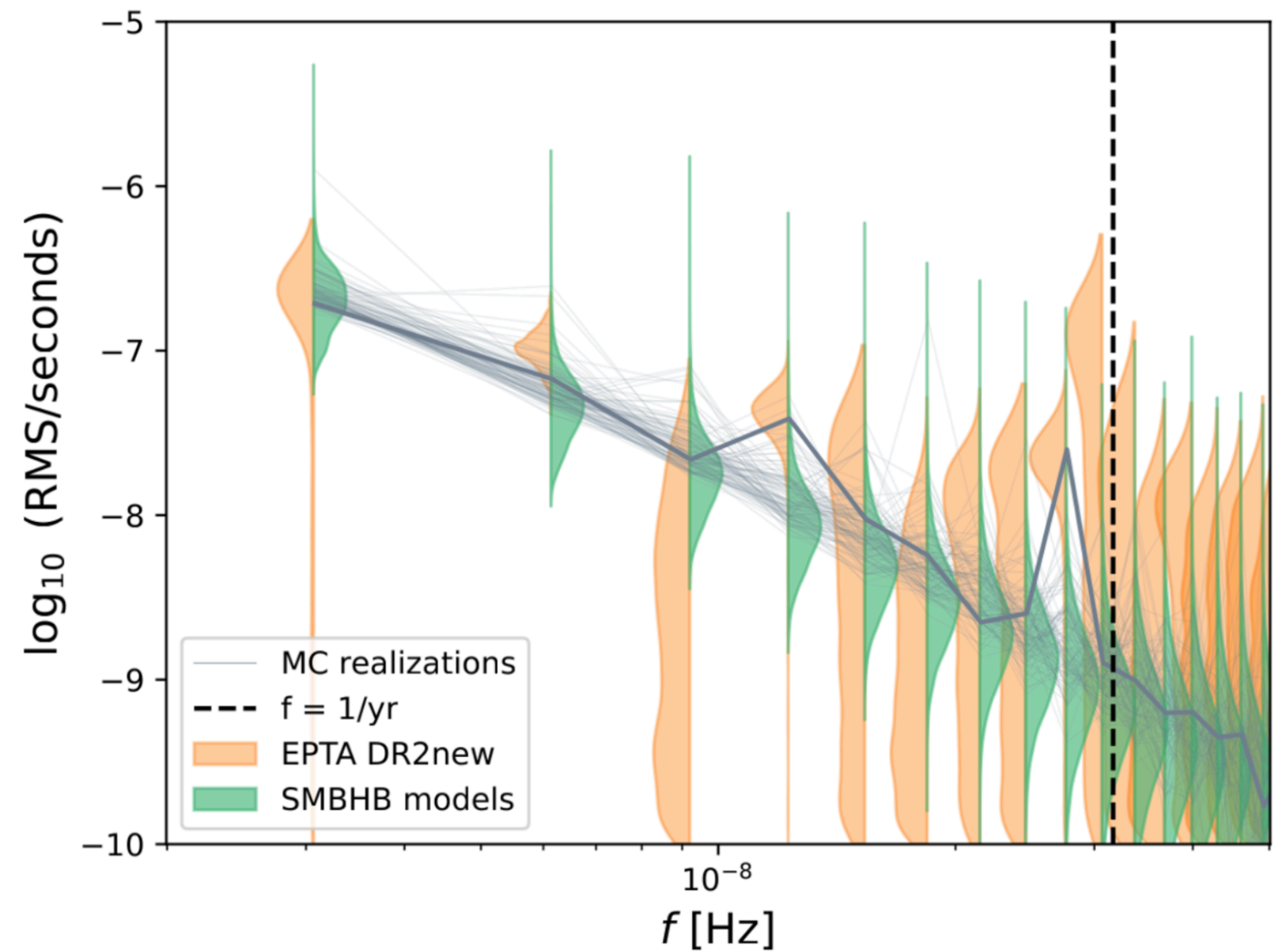
Pulsars are cosmic lighthouses which spin as fast as hundreds of times a second and shine beams of radio waves from their magnetic poles. With the Lovell telescope, their pulses are timed with extraordinary precision, making pulsars powerful natural laboratories for testing theories of gravity, studying matter under conditions impossible to recreate on Earth, and even searching for ripples in spacetime known as gravitational waves.



First evidence for ultra-low frequency Gravitational Waves

The Lovell Telescope is a key part of the European Pulsar Timing Array (EPTA), which uses pulsars as a galaxy-sized gravitational wave observatory. Recently, the first evidence for a background of gravitational waves from binary supermassive black holes was found - a vital clue to understanding black holes and the galaxies that host them.

EPTA Collaboration et al 2023, A&A, arXiv:2306.1622; arXiv:2306.16214; arXiv:2306.16227



Challenging the ultralight dark matter paradigm

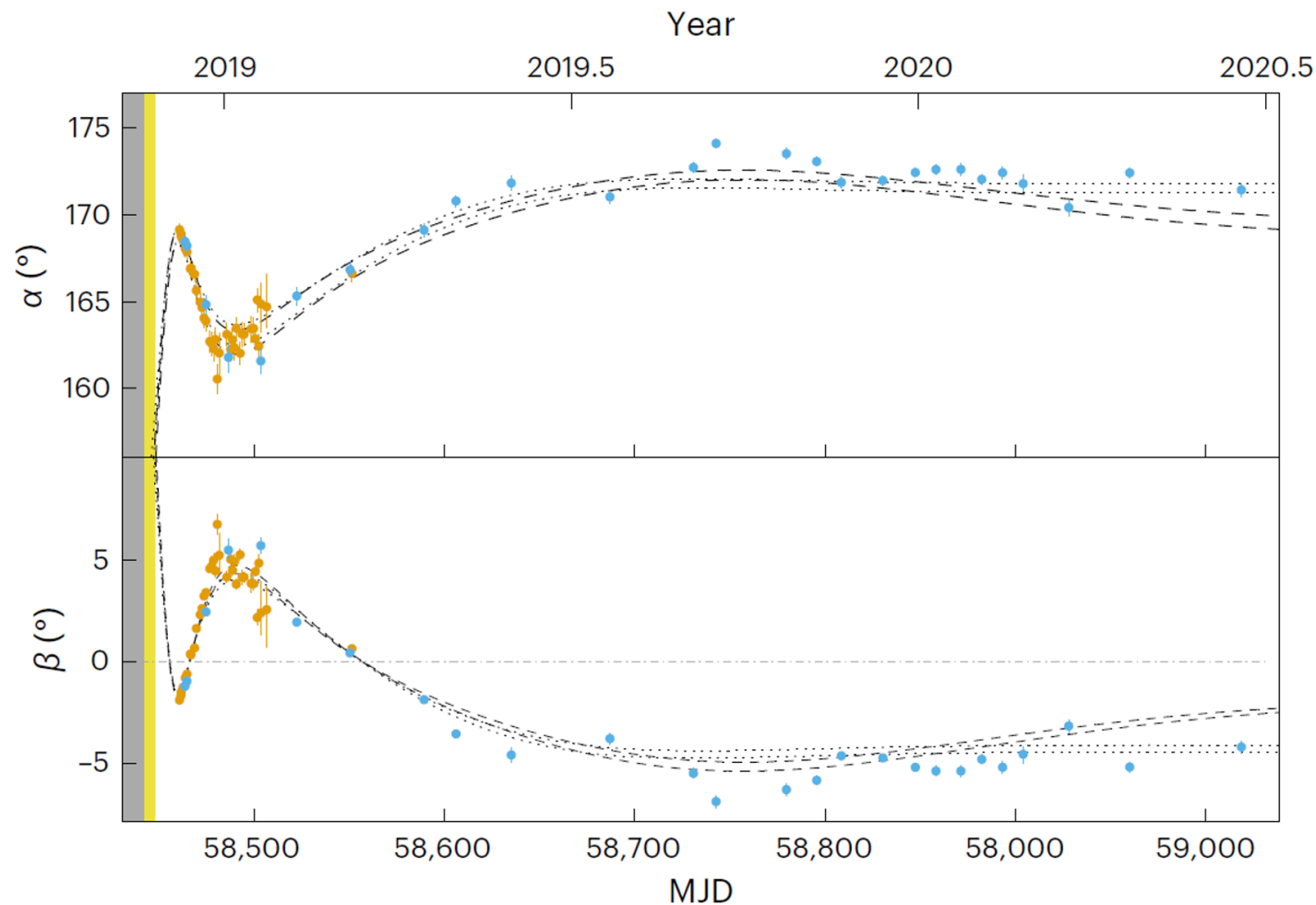
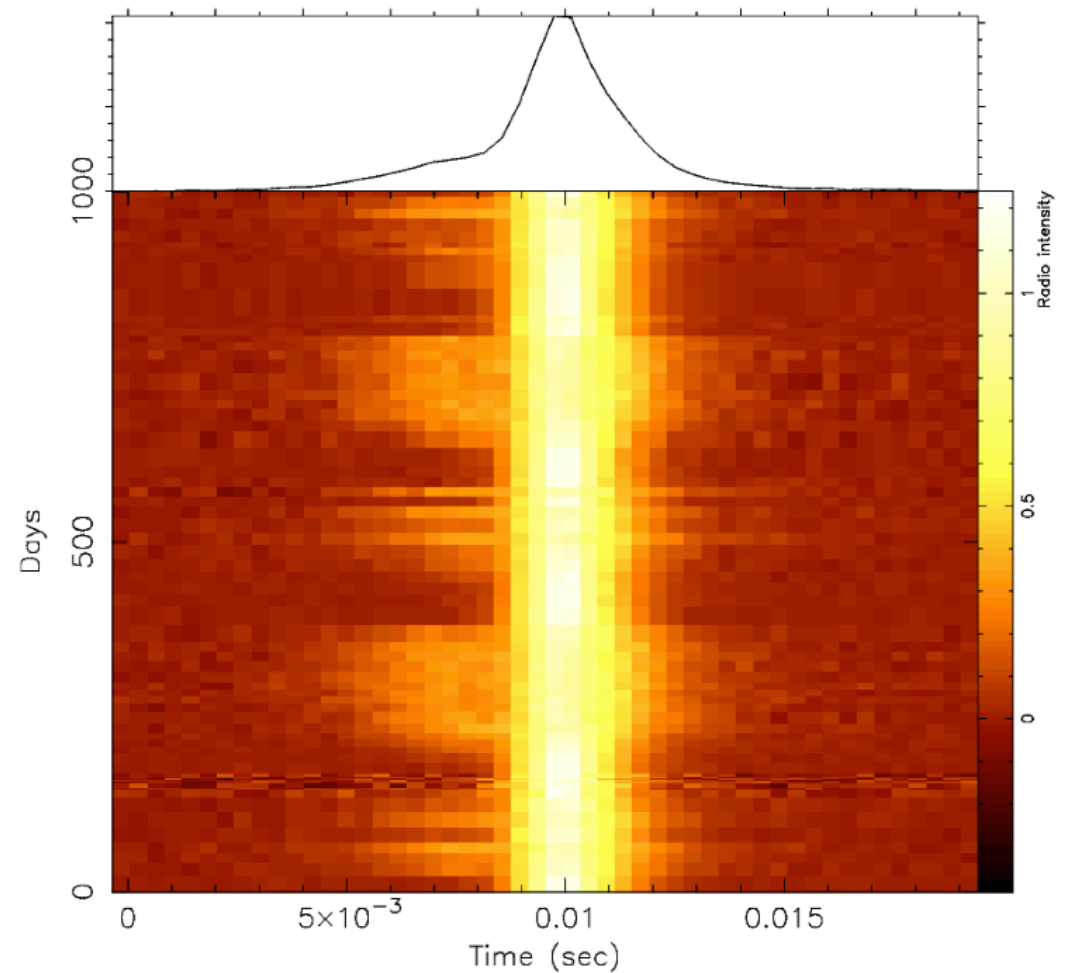
Using more than two decades of exquisitely precise observations of rapidly rotating neutron stars, the EPTA searched for the subtle gravitational signature of ultralight dark matter. No evidence for such a signal was found, allowing the team to place the strongest constraints yet on this class of dark matter.

EPTA Collaboration et al 2023, PhRvL, arXiv:2306.16228

Cosmic Clocks

Radio pulsars are famed for producing regular clockwise signals as they rotate. Yet, our sensitive observations with the Lovell telescope show that the pulses of many pulsars are not entirely stable. Their shapes change over a timescale of weeks/years, and their spin rate is affected as well. The most recent observations once more provides evidence for powerful processes in operation in pulsar magnetospheres.

Keith et al 2025, MNRAS [arXiv:2505.23413](#)



Wobble in the most powerful magnets in the Universe

Lovell telescope observations detected radio pulsations from a dormant star shortly after an X-ray outburst. The source of the pulsations is a type of pulsar known as a magnetar: the strongest magnets in the Universe. The polarised radio emission provides evidence for the magnetar undergoing free precession following the outburst: it made the star's spin wobble!

Desvignes et al 2024, NatAst, [10.1038/s41550-024-02226-7](#)

Glitches revealing exotic physics

The Lovell telescope monitors the pulses of over 800 pulsars. Some pulses grow apart, because the rotation of stars slow down over time. But sometimes pulsars speed up. These rotational “glitches” are caused by exotic processes in the interior, which is so dense that atoms and nuclei fall apart. These glitches allow us to understand exotic physics at densities that cannot be reproduced on Earth.

Basu et al 2022, MNRAS, [arXiv:2111.06835](#)
Liu et al. 2024, MNRAS, [arXiv:2406.09219](#)

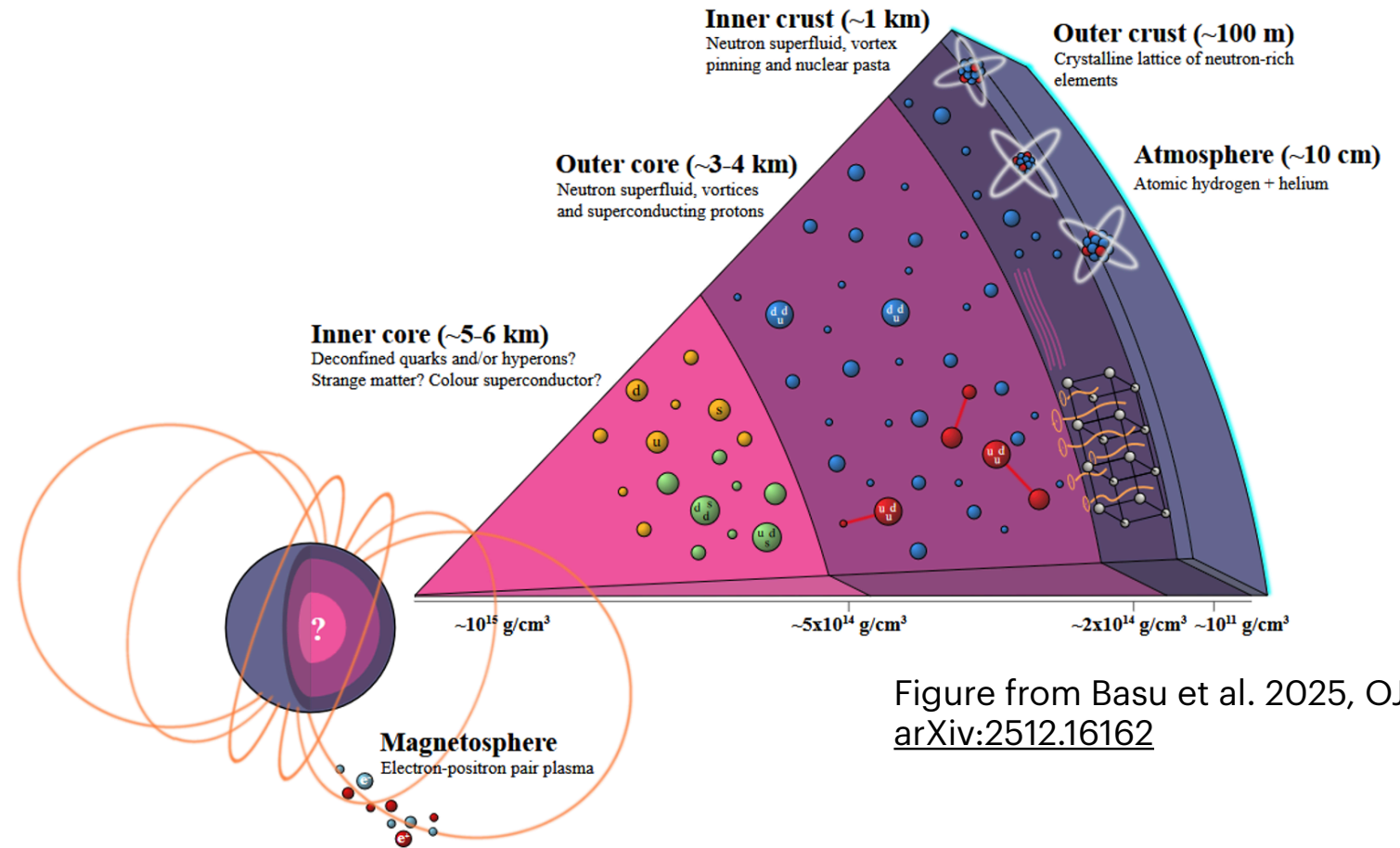
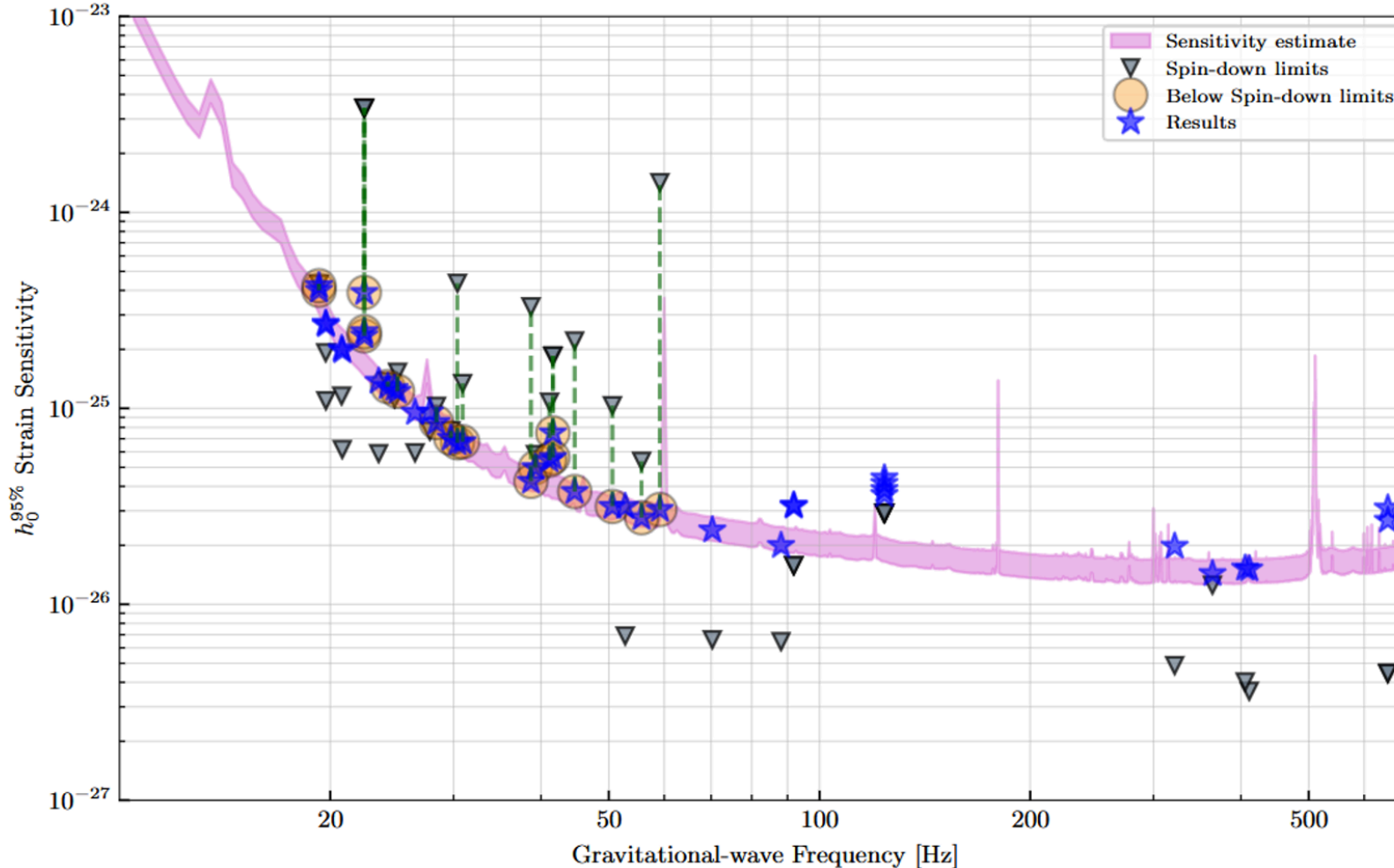


Figure from Basu et al. 2025, OJoA, [arXiv:2512.16162](#)



Pulsars as sources of gravitational waves

When pulsars spin they produce ripples in space-time known as gravitational waves. Despite efforts, no gravitational waves have been detected from spinning pulsars, which is why we know pulsars must be nearly perfect spheres. The most sensitive limits, hence our best understanding of pulsar interior physics, are greatly helped by the Lovell telescope observations which inform Earth-based detectors what signals to search for.

Abac et al 2026, ApJ, [10.1038/s41550-024-02226-7](#)

RADIO JETS AT ALL SCALES

DRIVING GALAXY EVOLUTION

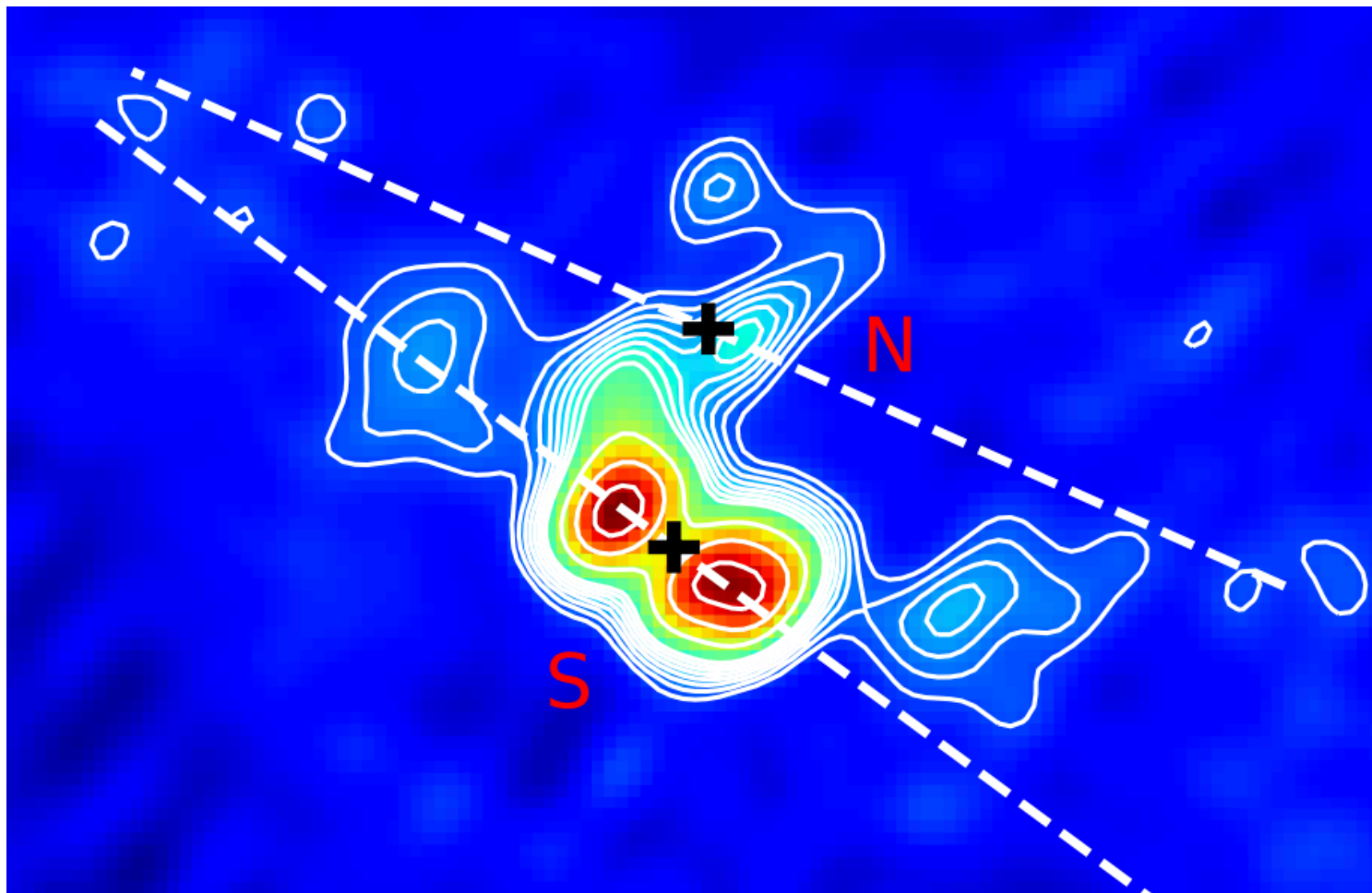
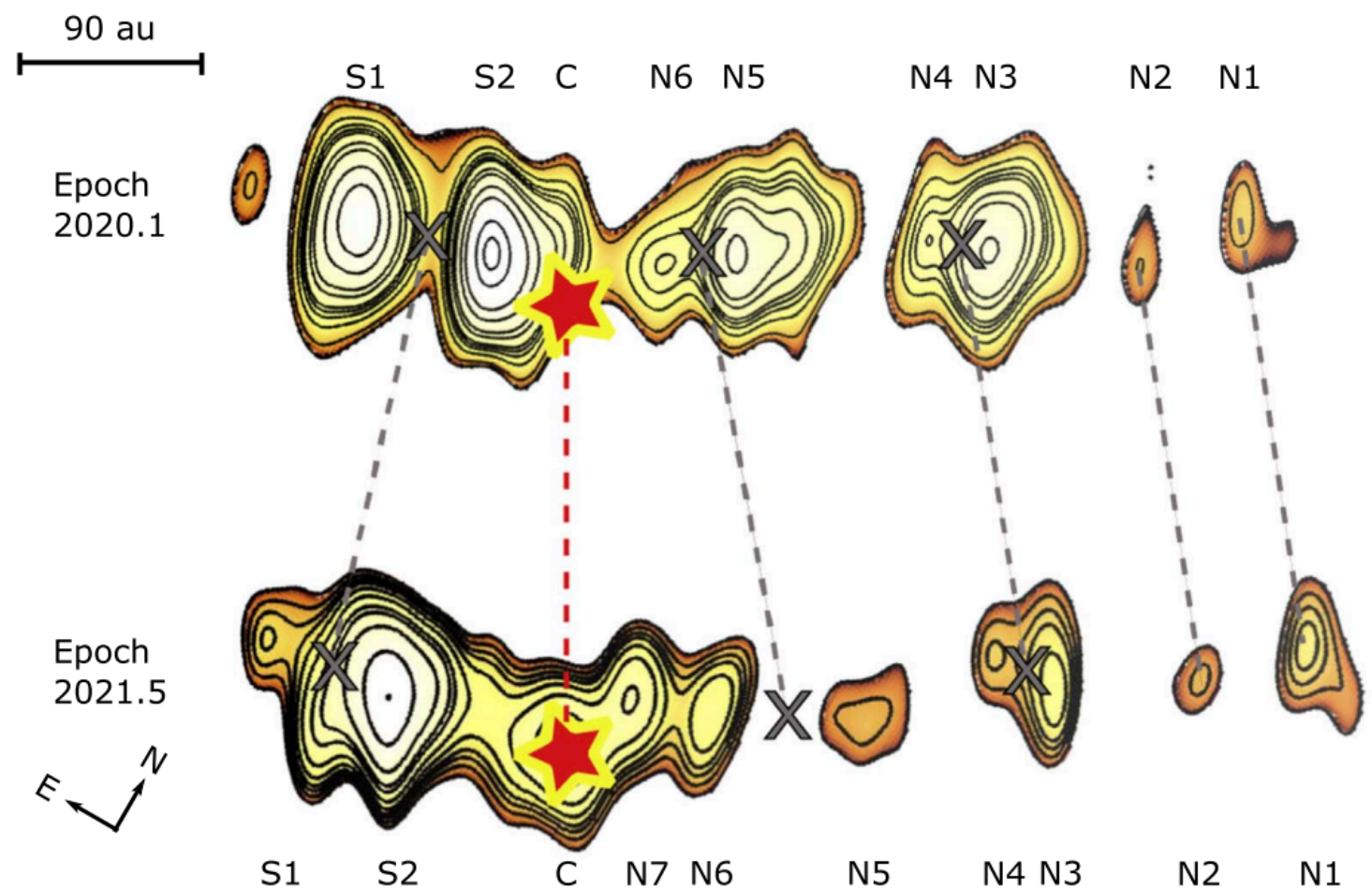
Radio plasma jet emission is observed from all types of astrophysical objects, from protostars to super-massive black holes. The emission propagates into the space between stars or galaxies, moulding and changing the regions they live in. How these jets are generated, collimated and launched to relativistic speeds in some cases, is unknown. e-MERLIN provides the necessary resolution to provide the answers.



Radio jets from protostars

In the process of a star being born, matter is blown away from the star in the form of a narrow radio jet. Some protostars are close enough that we can resolve this happening in real time. Observations with e-MERLIN for one such radio jet showed individual components moving over 18 months, providing astronomers with answers to how these jets are generated and launched.

Rodriguez-Kamenetzky et al. 2022, *ApJL*,
[arXiv:2205.10422](https://arxiv.org/abs/2205.10422)



Young Stellar Objects across the spectrum

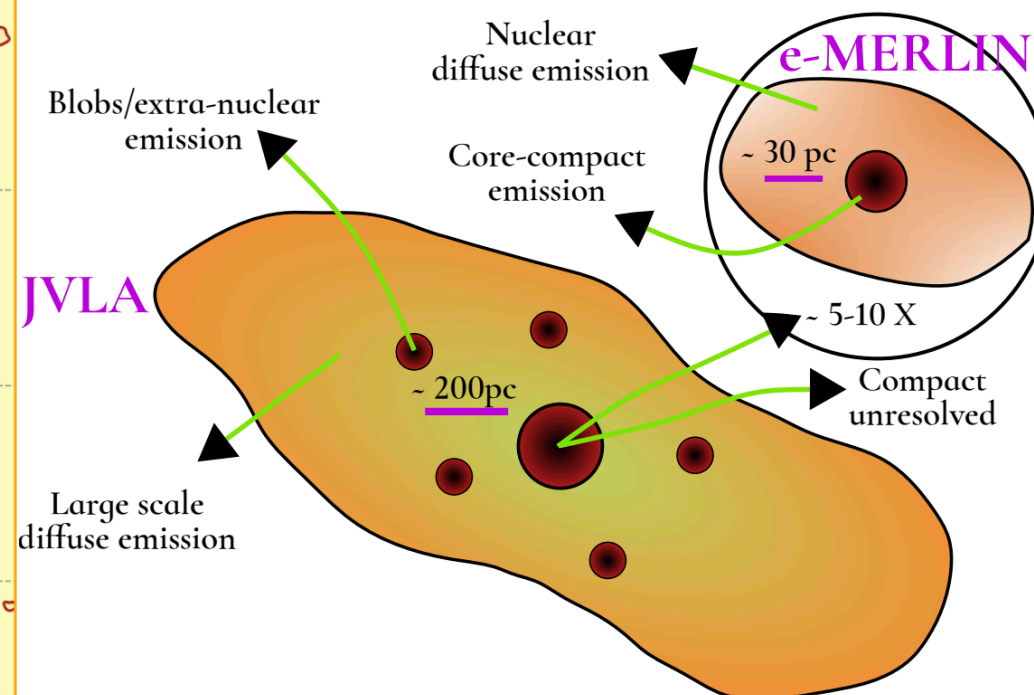
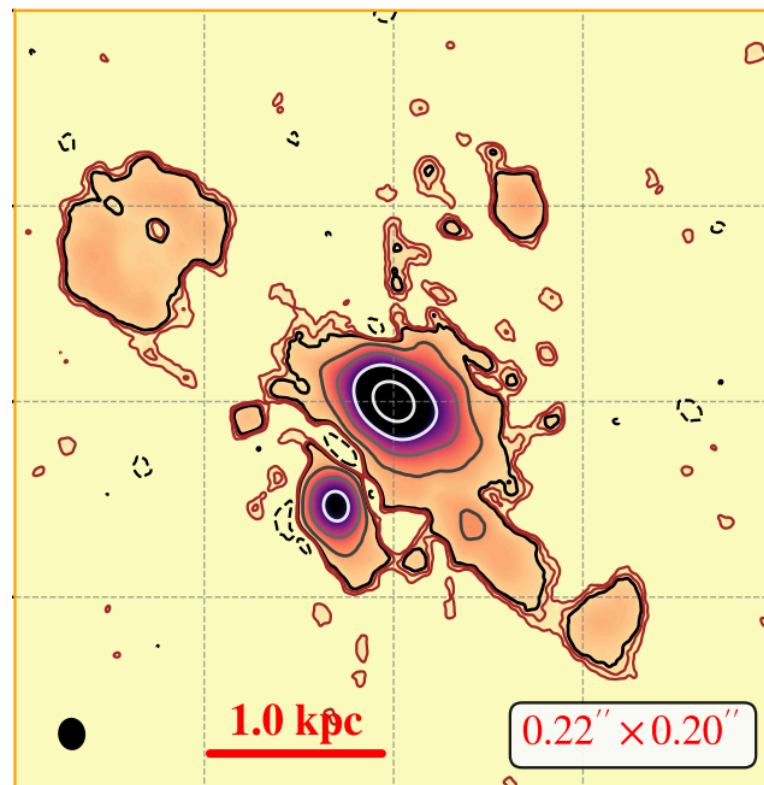
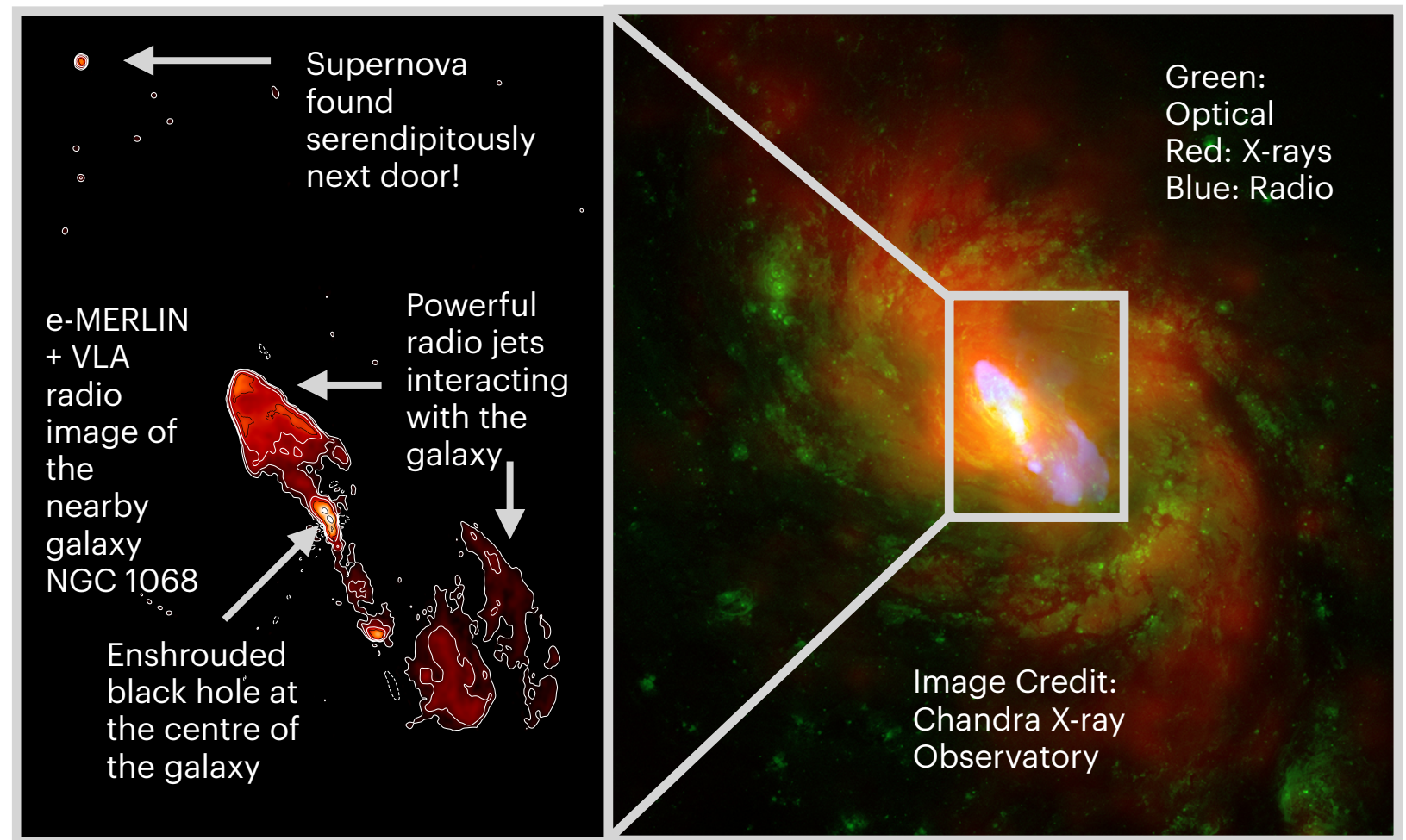
Combined images using the VLA, ALMA and e-MERLIN studied two young stellar objects studied their evolving radio jets across the spectrum to understand the mechanisms that lead to their radio emission. The data enable scientists to estimate the mass-loss rate of the protostars, crucial for studying how stars are born, grow and evolve.

Feeney-Johansson et al. 2023, *A&A*,
[arXiv:2307.12746](https://arxiv.org/abs/2307.12746)

The radio jets in the nuclear regions of nearby galaxies

e-MERLIN can zoom into the nuclear region of nearby galaxies, including NGC 1068, which shows radio plasma jets emanating from a central super-massive black hole. These jets drill through the surrounding environment and the large scale outflows power new star formation, shaping the galaxy over cosmic time. A supernova was even found lurking nearby!

Mutic et al 2024, MNRAS,
[arXiv:2510.07382](https://arxiv.org/abs/2510.07382)



Separating star formation from black hole activity

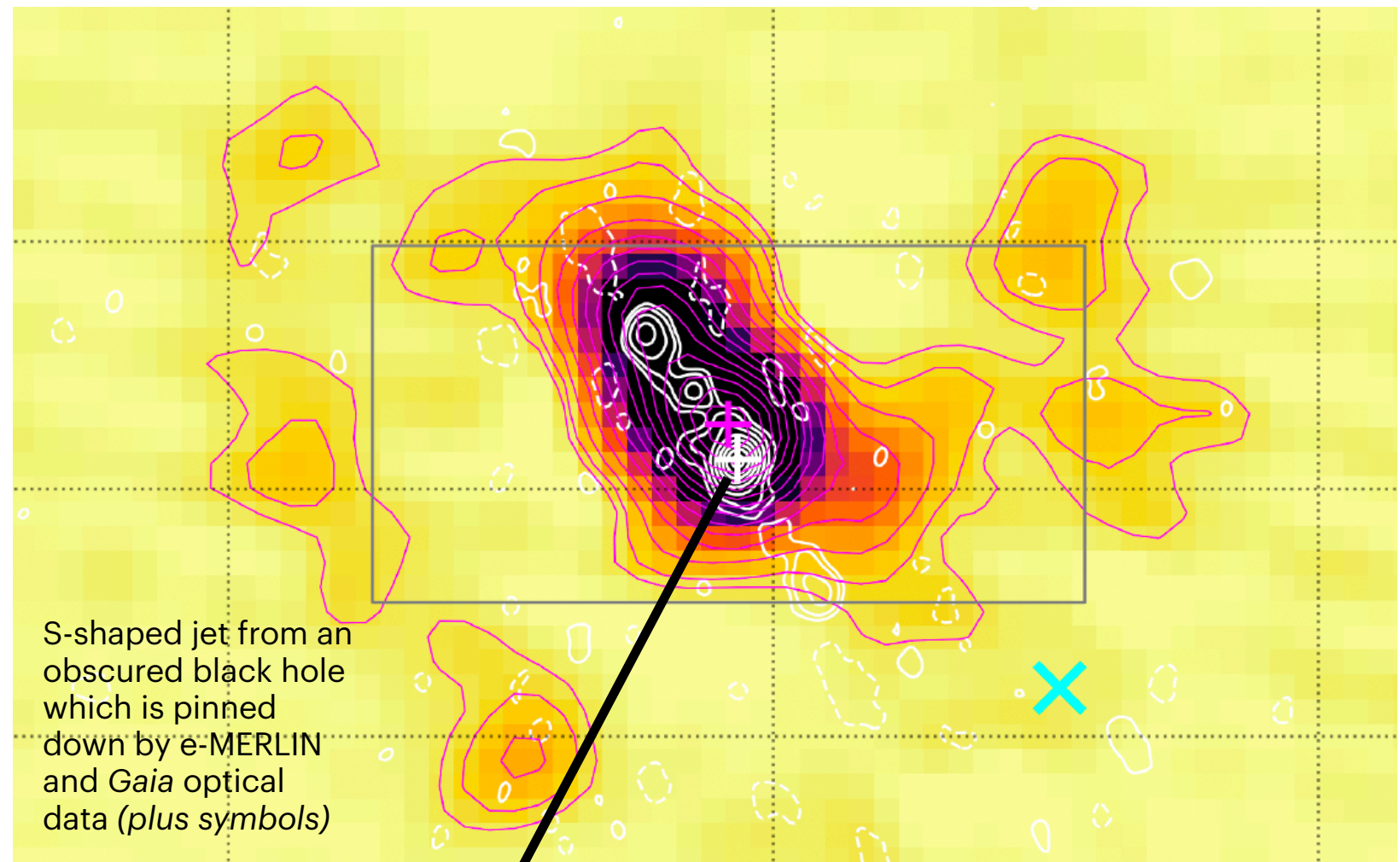
In nearby galaxies, star formation can often be the dominant source of radio emission. Removing this contribution can only be done with the high resolution of e-MERLIN. Modelling the contribution of star formation to black hole activity enables astronomers to correctly decode the link between the two to understand how galaxies grow.

Lucatelli et al 2025/2026, MNRAS,
[arXiv:2403.16872](https://arxiv.org/abs/2403.16872) [arXiv:2605.19658](https://arxiv.org/abs/2605.19658)

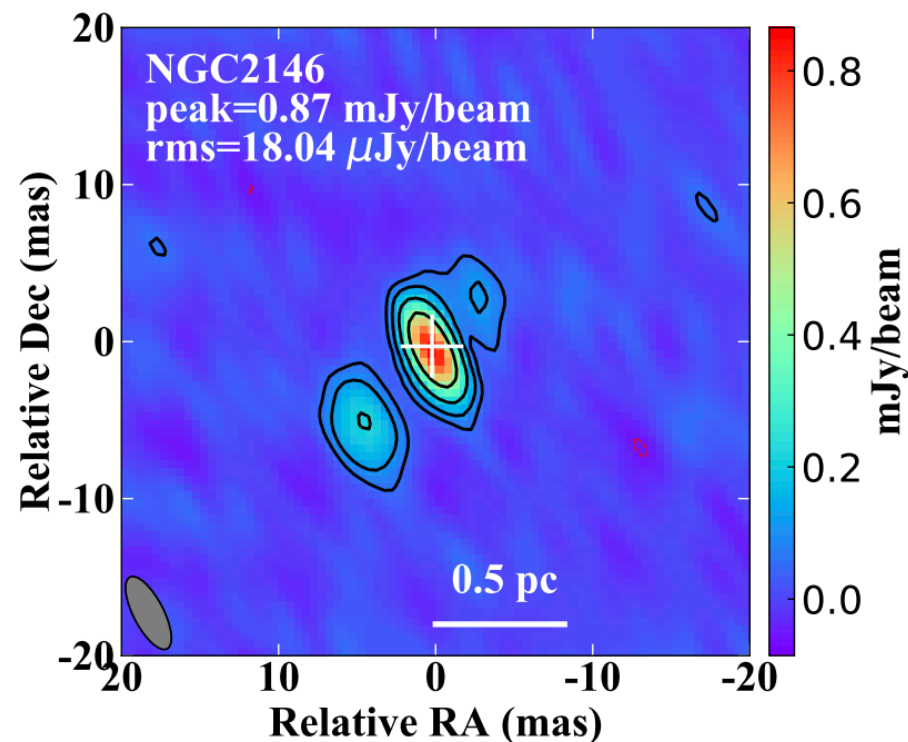
Blacks holes in our nearby Universe with LeMMINGs

Legacy e-MERLIN imaging of nearby galaxies revealed a population of previously undiscovered black holes, lurking in plain sight but behind gas, dust and star formation. These structures can only be seen with e-MERLIN, which can peer beyond the obscuring medium right into the heart of nearby galaxies.

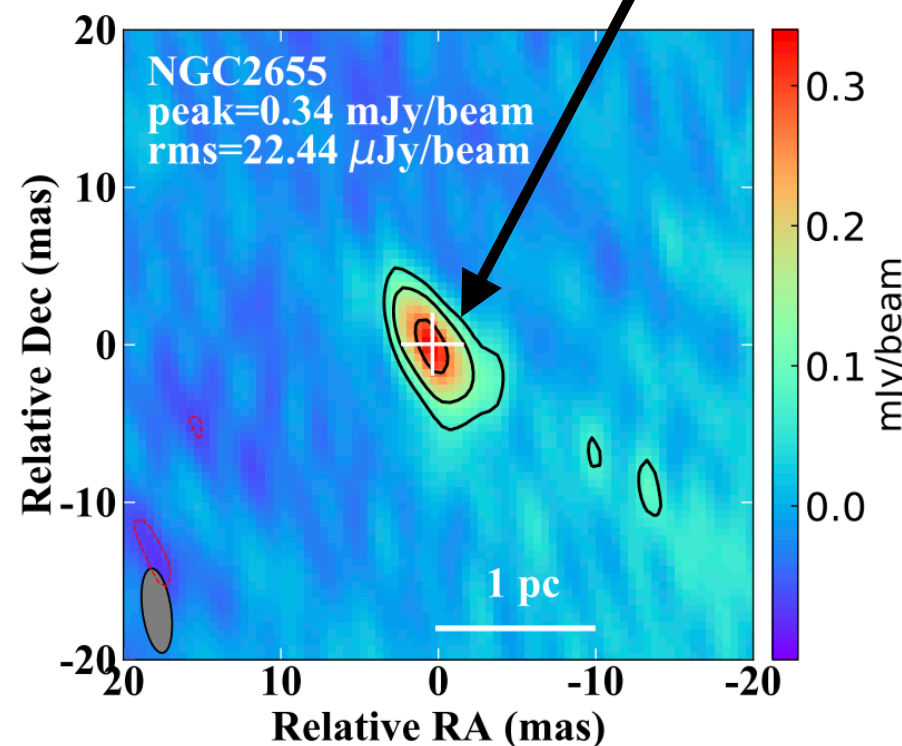
Baldi/Williams-Baldwin et al. 2018/2026,
MNRAS, [arXiv:2005.11403](#) [arXiv:2603.08562](#)



S-shaped jet from an obscured black hole which is pinned down by e-MERLIN and *Gaia* optical data (plus symbols)



Newly discovered black hole in NGC 2146, with tiny jets!



The large scale jets of NGC 2655 are removed to study the black hole.

Zooming into the smallest scale jets with EVN + e-MERLIN

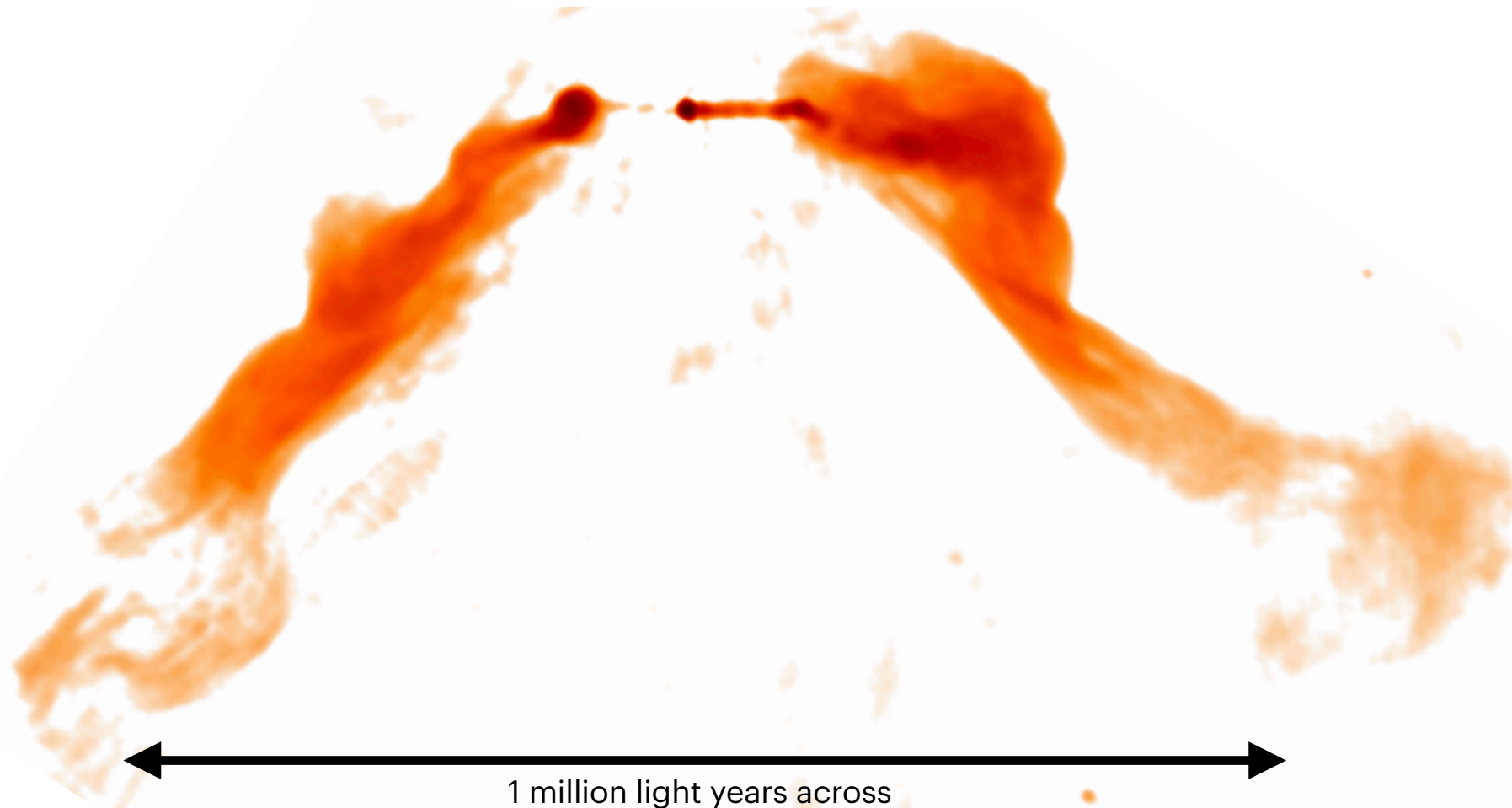
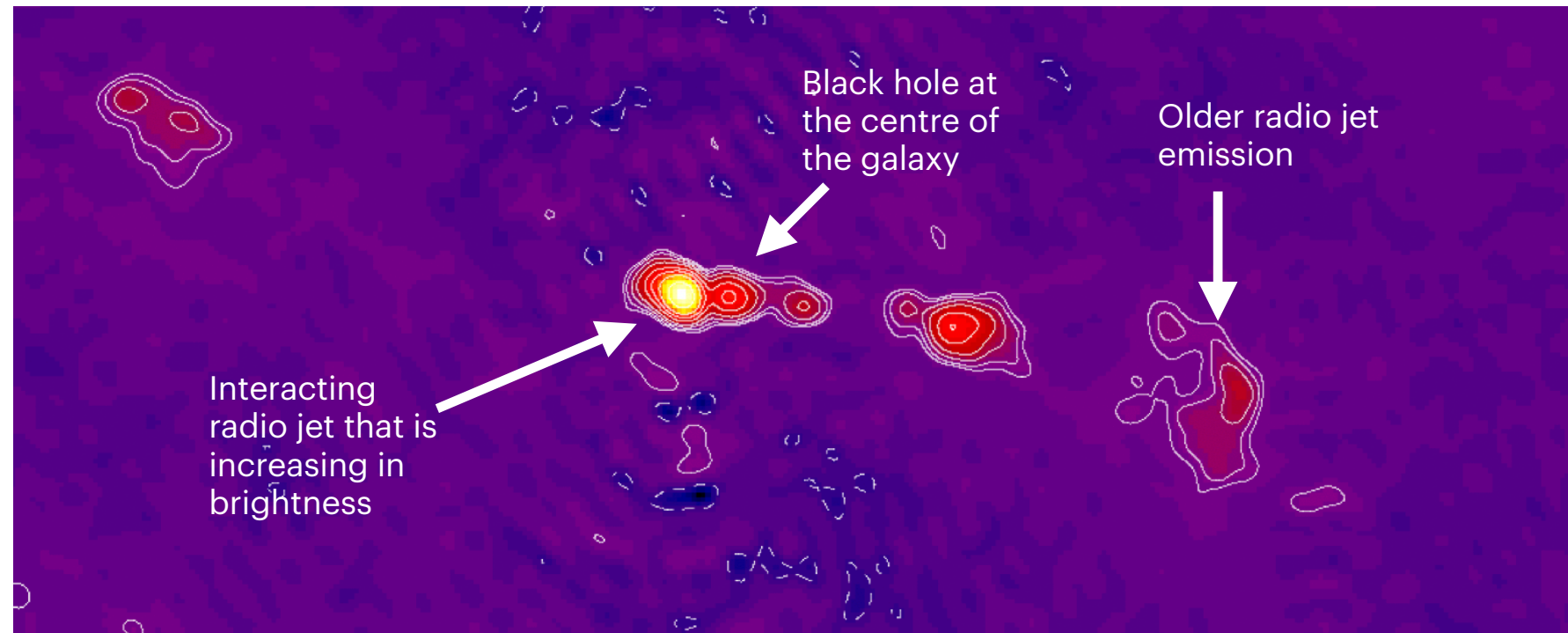
By combining e-MERLIN with the EVN, it's possible to zoom in even further, truly isolating the nuclear emission from a black hole. Or in the case of NGC 2146, discover a newly re-brightening black hole that was once thought to be a supernova remnant! Knowing whether a source is a black hole or not is crucial to pinning down relationships between black hole size and brightness.

Cheng et al. 2025, *ApJS*,
[arXiv:2502.12553](#)

The variable radio core of NGC 4151

Black holes are known to vary on timescales of decades. In the case of NGC 4151, only e-MERLIN could differentiate the source of the variable emission, in this case the central radio jet component and not the supermassive black hole had doubled in 20 years, caused by powerful shocks formed when the radio plasma hits nearby gas.

Williams et al 2020, MNRAS, arXiv:2004.10552



The relativistic radio jets of 3C465

e-MERLIN observations of the distant radio galaxy 3C465 shows powerful radio jets with a “Wide-Angle Tail”, caused by interaction of the relativistic radio plasma with the gas and dust that resides inside and between galaxies. These jets are estimated to be 90 million years old, which radio data from e-MERLIN was able to determine from the radio power.

Bempong-Manful et al. 2020, MNRAS, arXiv:2005.11403

UPGRADES AND NEW DEVELOPMENTS

LOOKING TO THE FUTURE OF RADIO ASTRONOMY

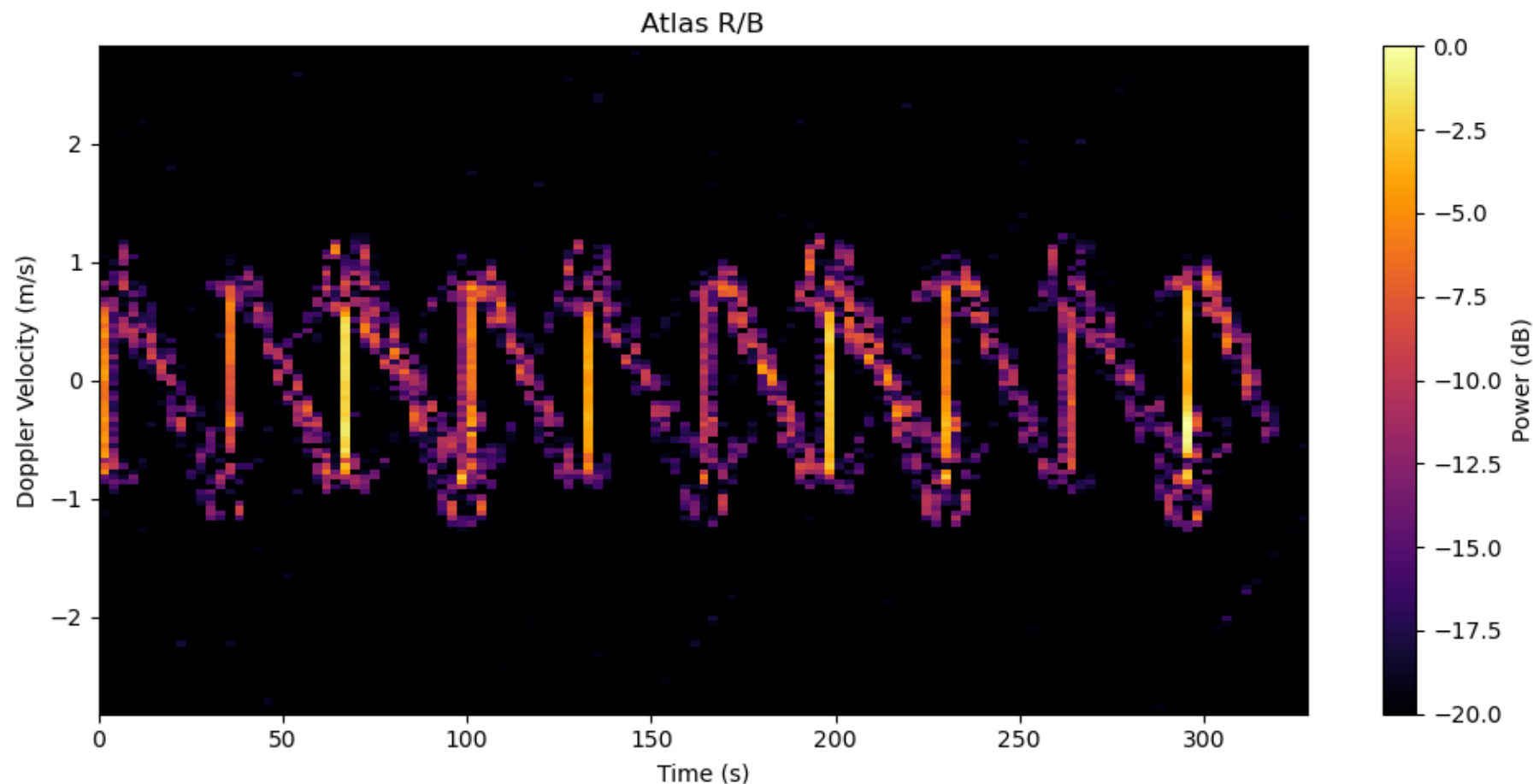
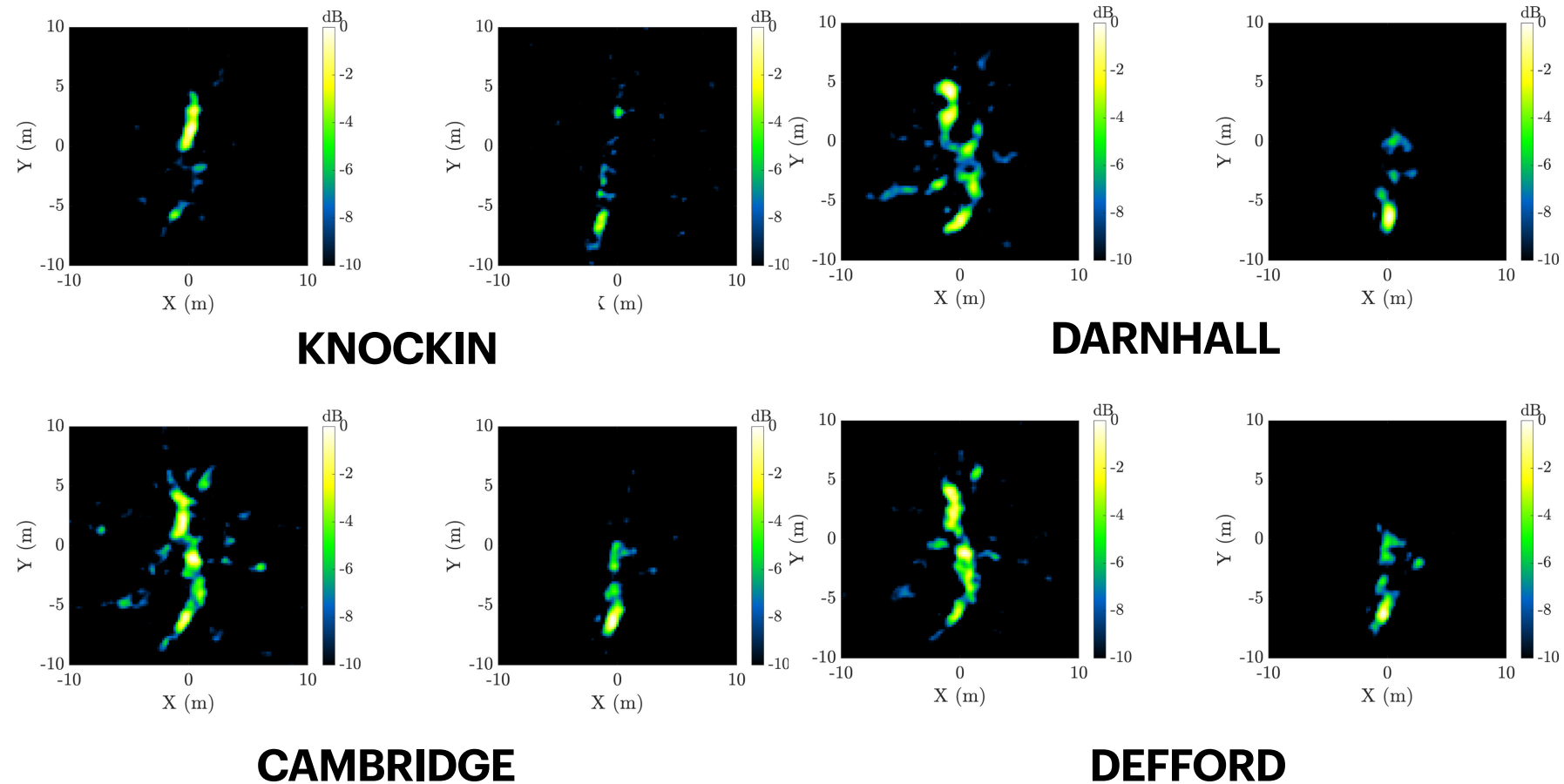
At Jodrell Bank, we are continuously developing new ways of studying the Universe. In particular, space situation awareness (SSA) is becoming a particularly important area of work as more satellites are launched into space every year. The potential for crashes between satellites will leave more debris in space which needs to be monitored. Radar observations with e-MERLIN and the Lovell can do this right now.



Imaging of space debris

Tomographic images (e.g. CT scans) can be made of boosters jettisoned from rockets using all e-MERLIN telescopes and tracked over time. We are working to utilise the network of telescopes to perform 3D positioning of these objects to improve orbit determination and monitor space debris in this congested space.

Serrano et al 2024, IET, <https://doi.org/10.1049/rsn2.12511>



Watching rocket bodies tumble in space

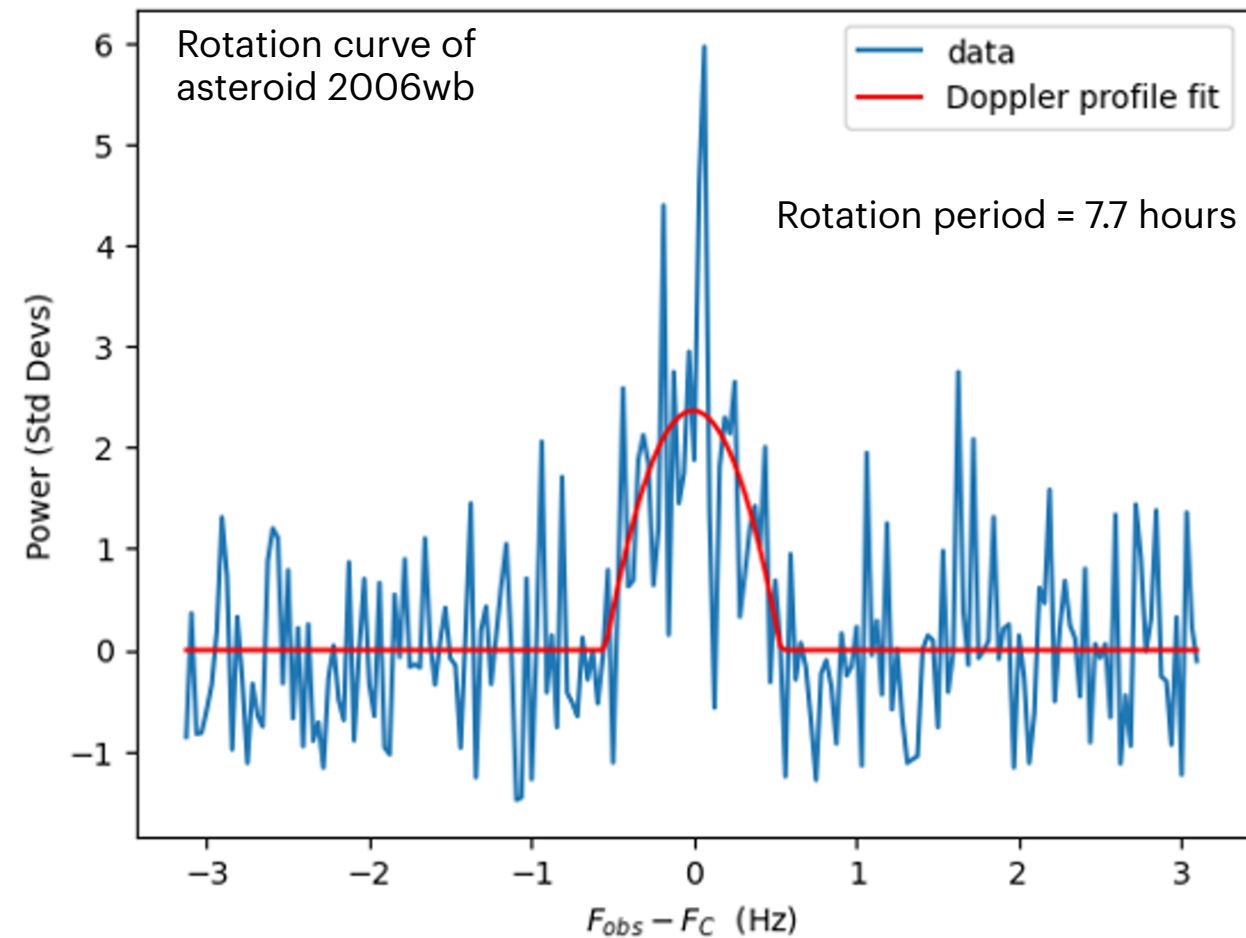
Objects tumble in space. This plot shows the tumbling motion of a 13m length rocket body at 24000km going end-over-end through space. The vertical bars show the 'flash' when the rocket body is side on when we can see the full extent of the rocket part. The spiral pattern is caused by reflection from one end of the rocket.

Ryder et al. in prep.

Tracking asteroids coming close to Earth

To ensure life on Earth continues, we must track objects in our Solar System. Asteroids coming from the direction of the Sun are particularly hard to spot, but using radar we can refine the orbit by making very precise measurements of their velocities as they approach Earth. In principle, we can probe the surface composition of asteroids, which could reveal how life came to be.

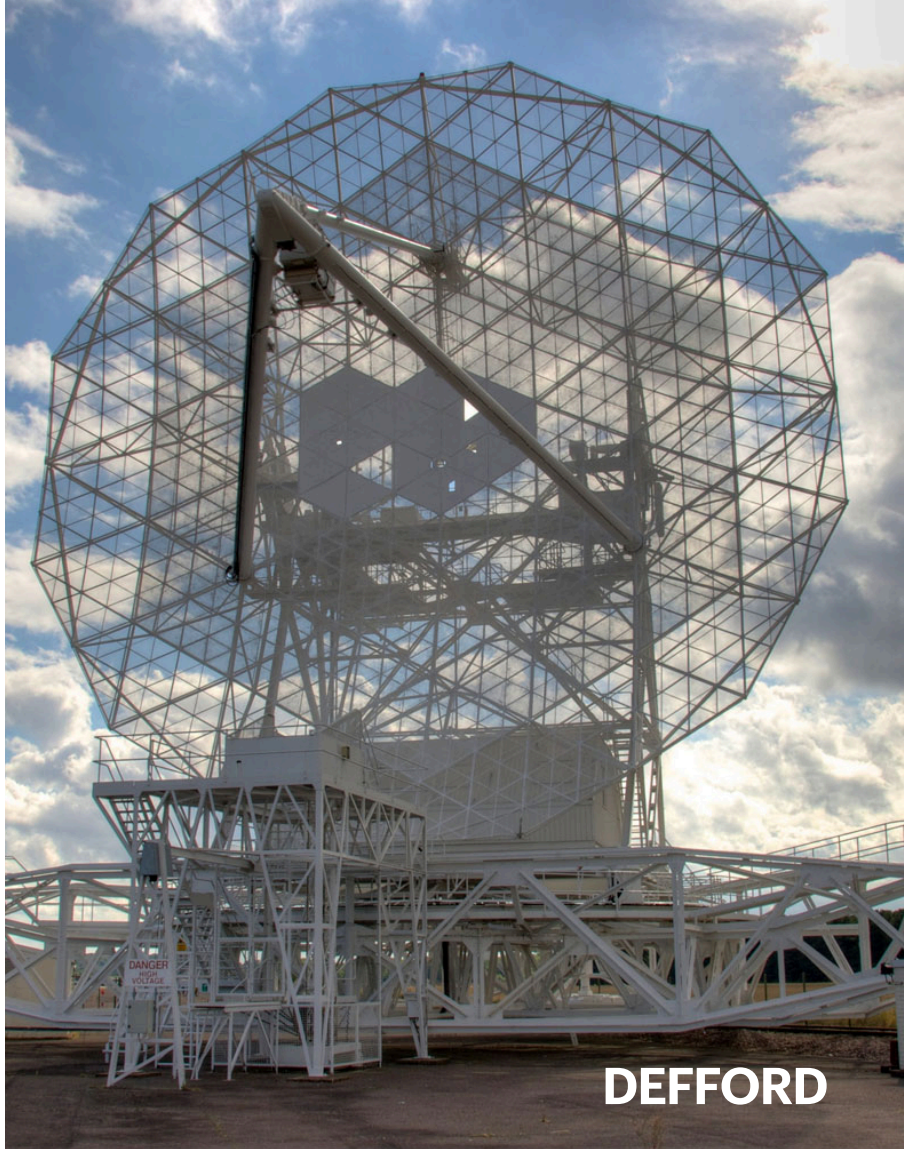
Ryder et al. in prep.



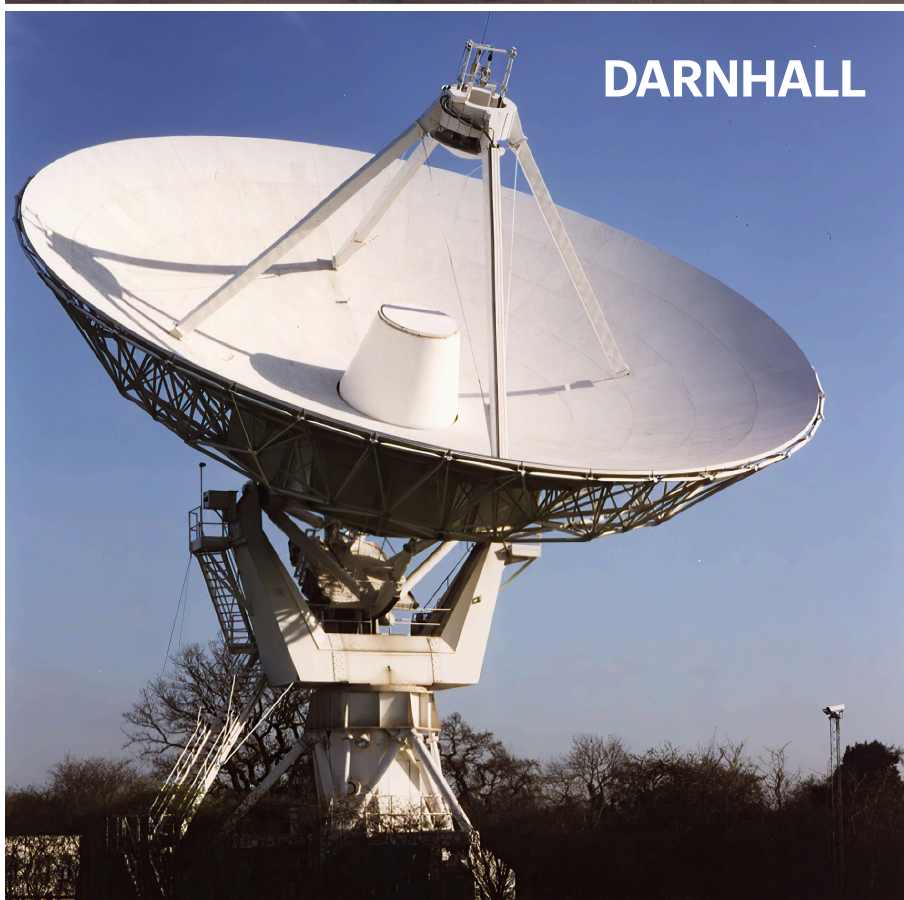
e-MERLIN digital upgrade to improve capabilities for the future

The new upgraded network will operate at over 100 Gigabits per second per telescope. Together with a new software correlator and forthcoming wide-band digitisation systems, the network will support the real-time transport of around 0.5 terabits per second of observational data to Jodrell Bank, significantly enhancing the capabilities for radio astronomy, Very Long Baseline Interferometry (VLBI), time-domain astrophysics and space domain awareness applications.

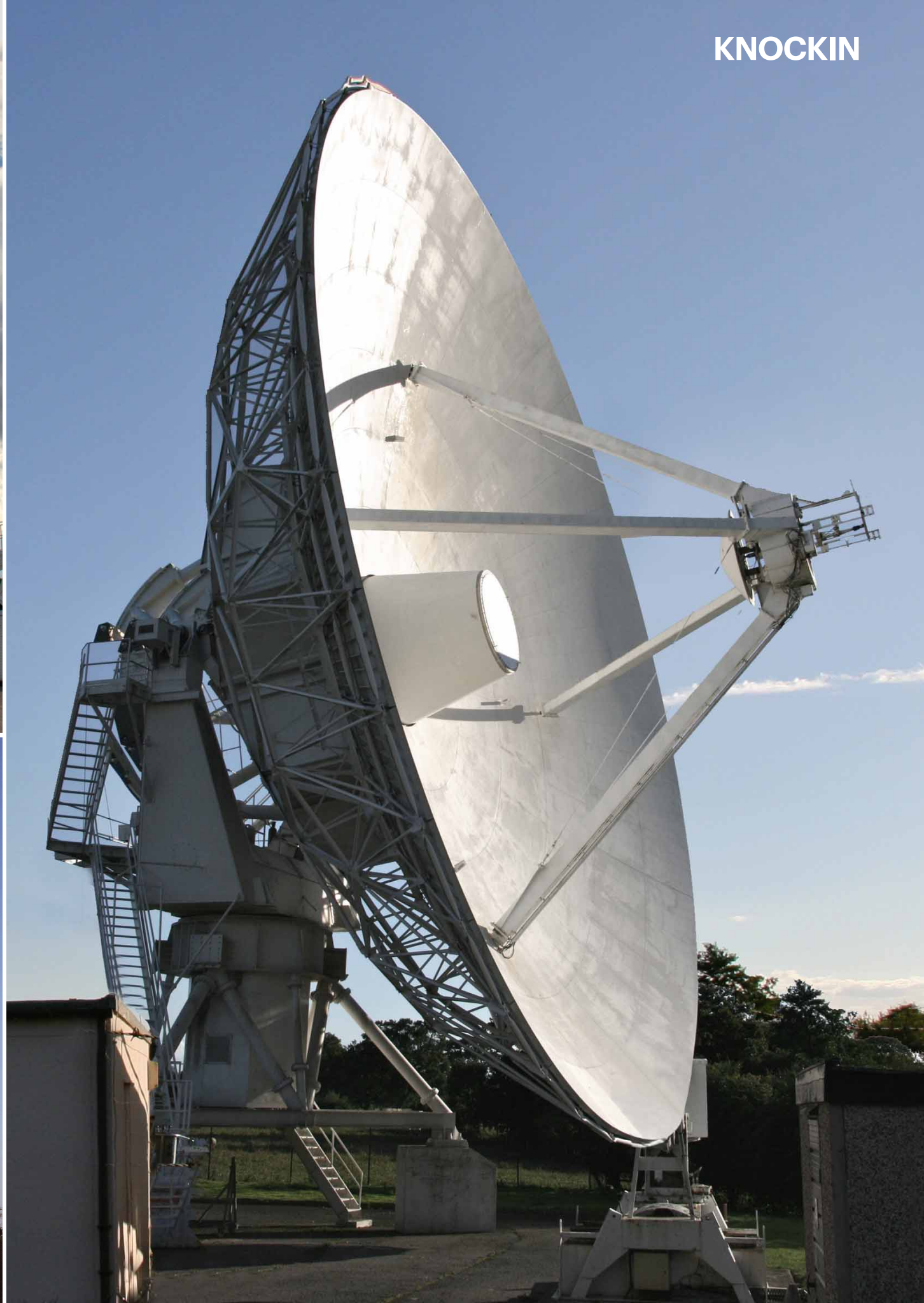
THE E-MERLIN NETWORK OF TELESCOPES



DEFFORD



DARNHALL



KNOCKIN

MK2



PICKMERE



CAMBRIDGE



LOVELL

