

Low-Frequency Observations of Galaxy Clusters

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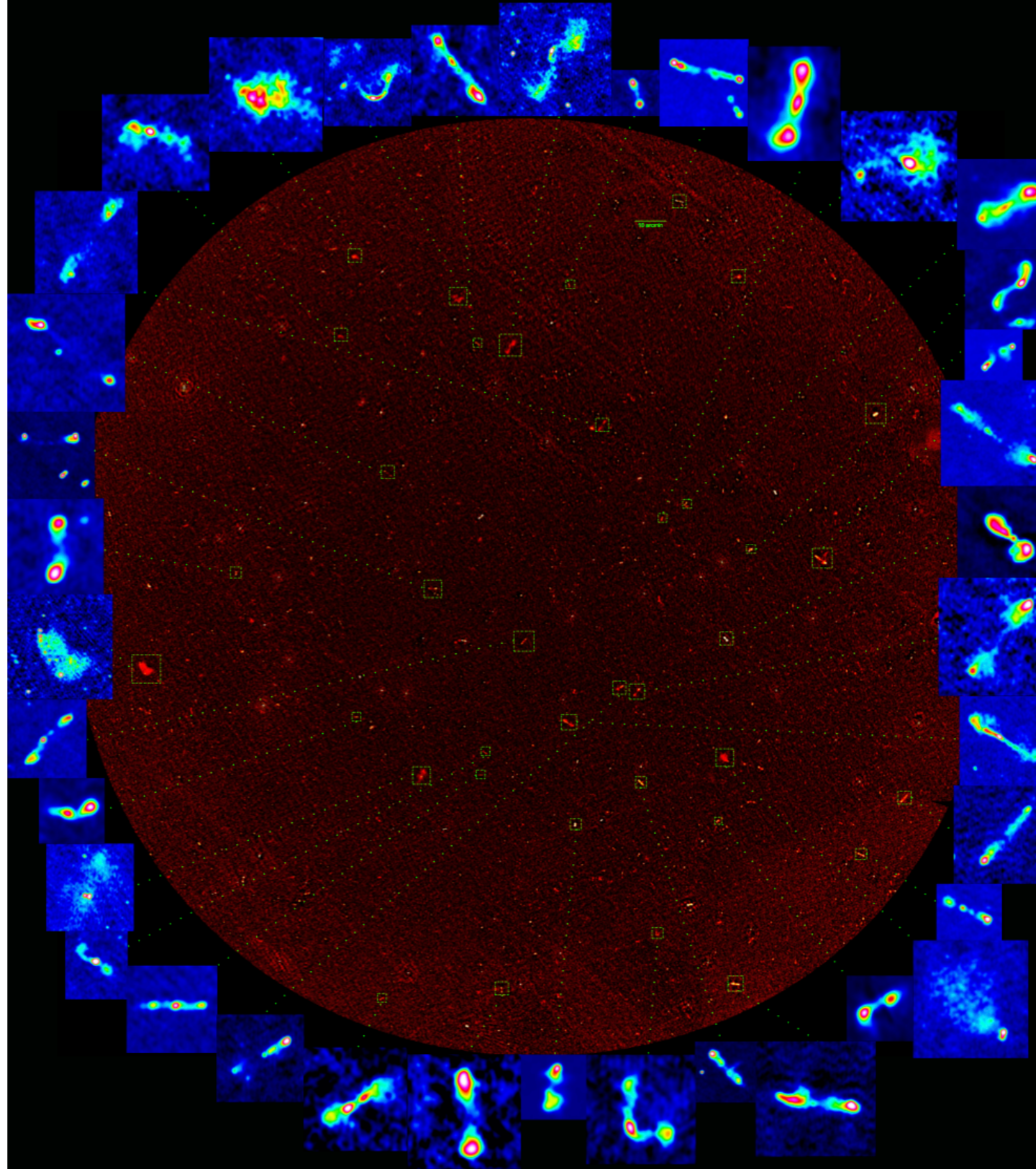
Laura Birzan (Hamburg)

Francesco De Gasperin (Hamburg)

Reinout van Weeren (CfA)

Let us look at some cosmic rays

Boötes field LOFAR @ 150 MHz



Abell 2744

Radio: cosmic rays + magnetic fields



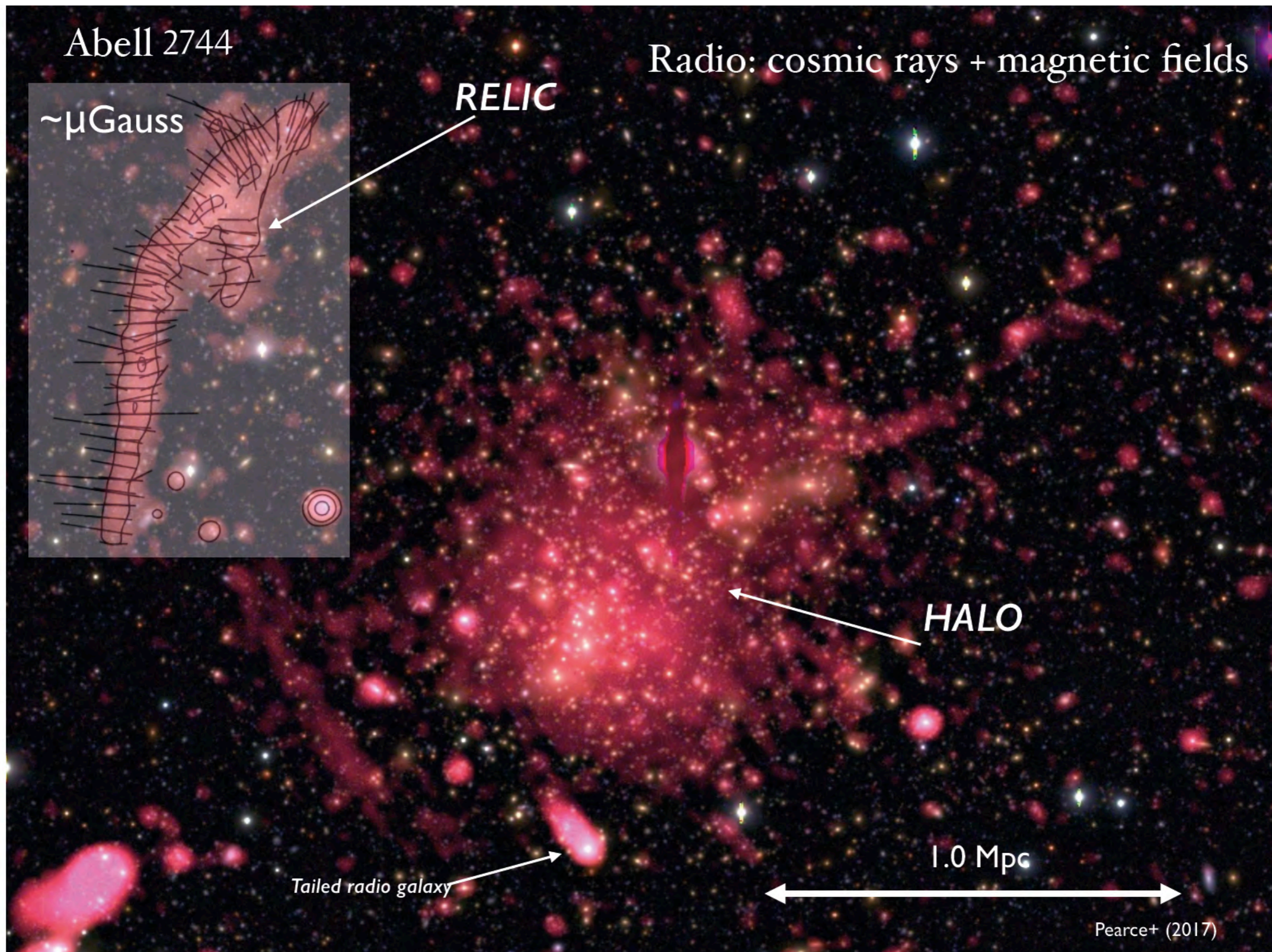
RELIC

HALO

Tailed radio galaxy

1.0 Mpc

Pearce+ (2017)



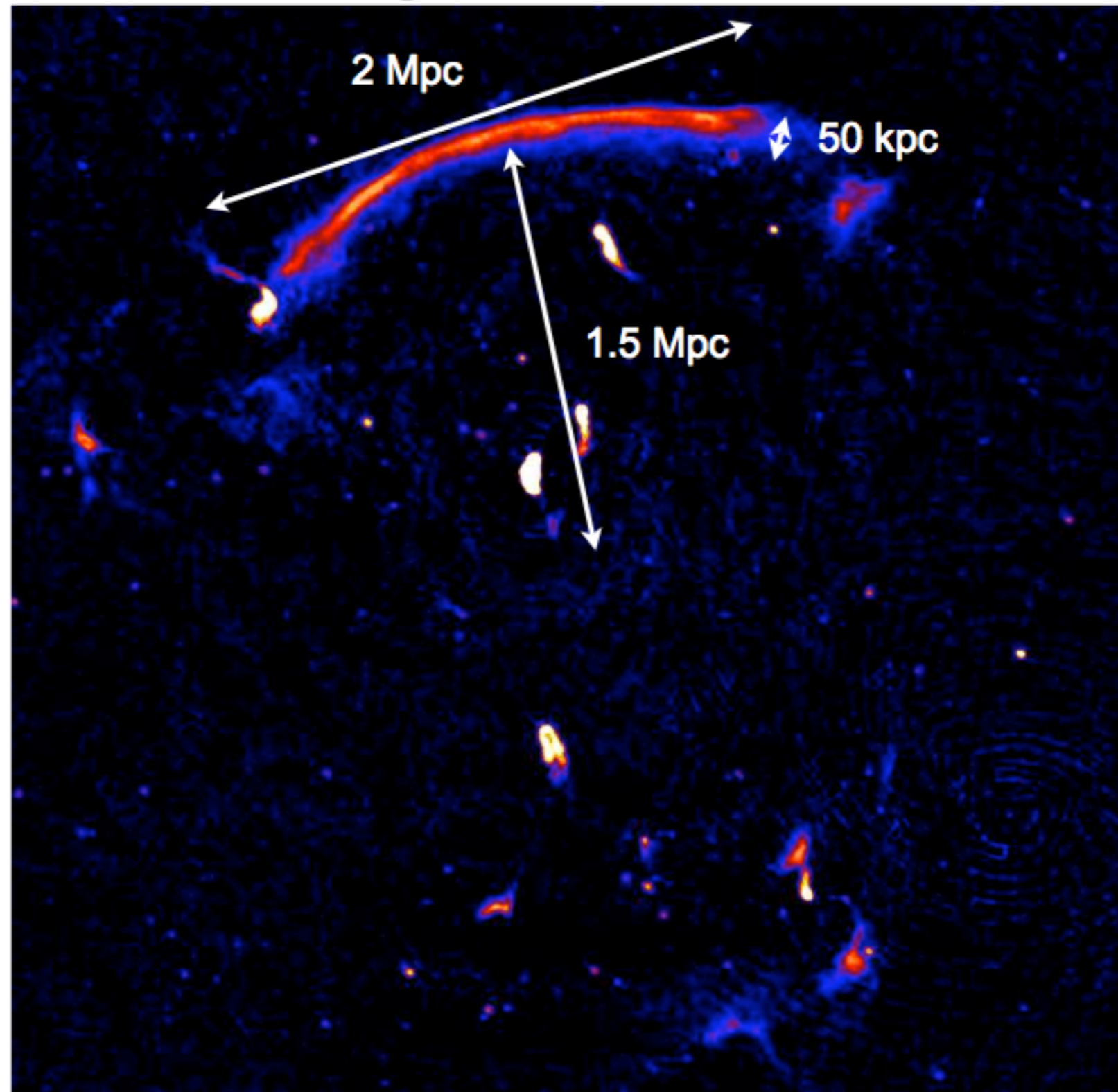
Why bother?

1. CR acceleration processes
2. Magnetogenesis
3. Important foreground, e.g. for DM searches
4. Cosmic web in synchrotron emission

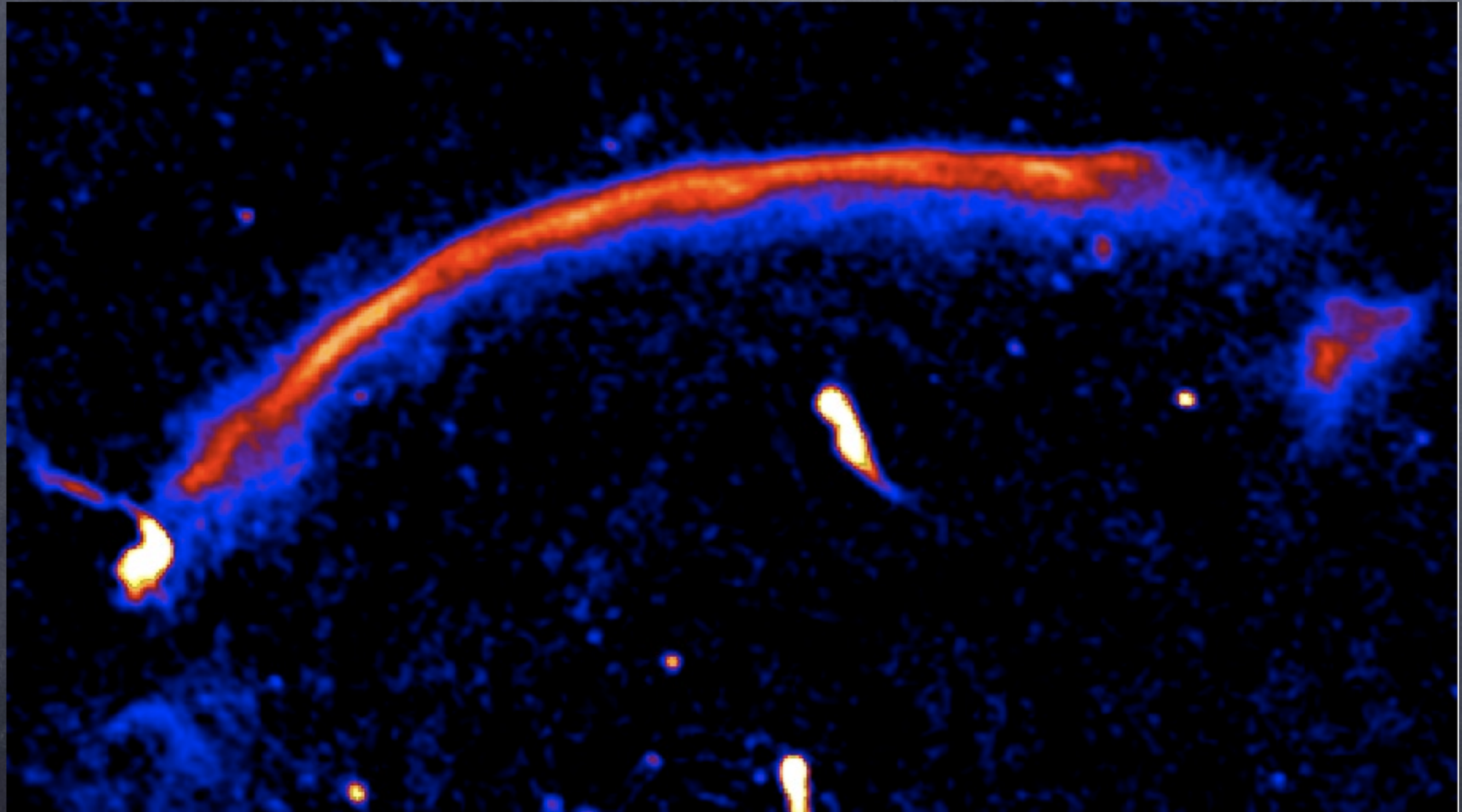
**There are at least two types
of relics**

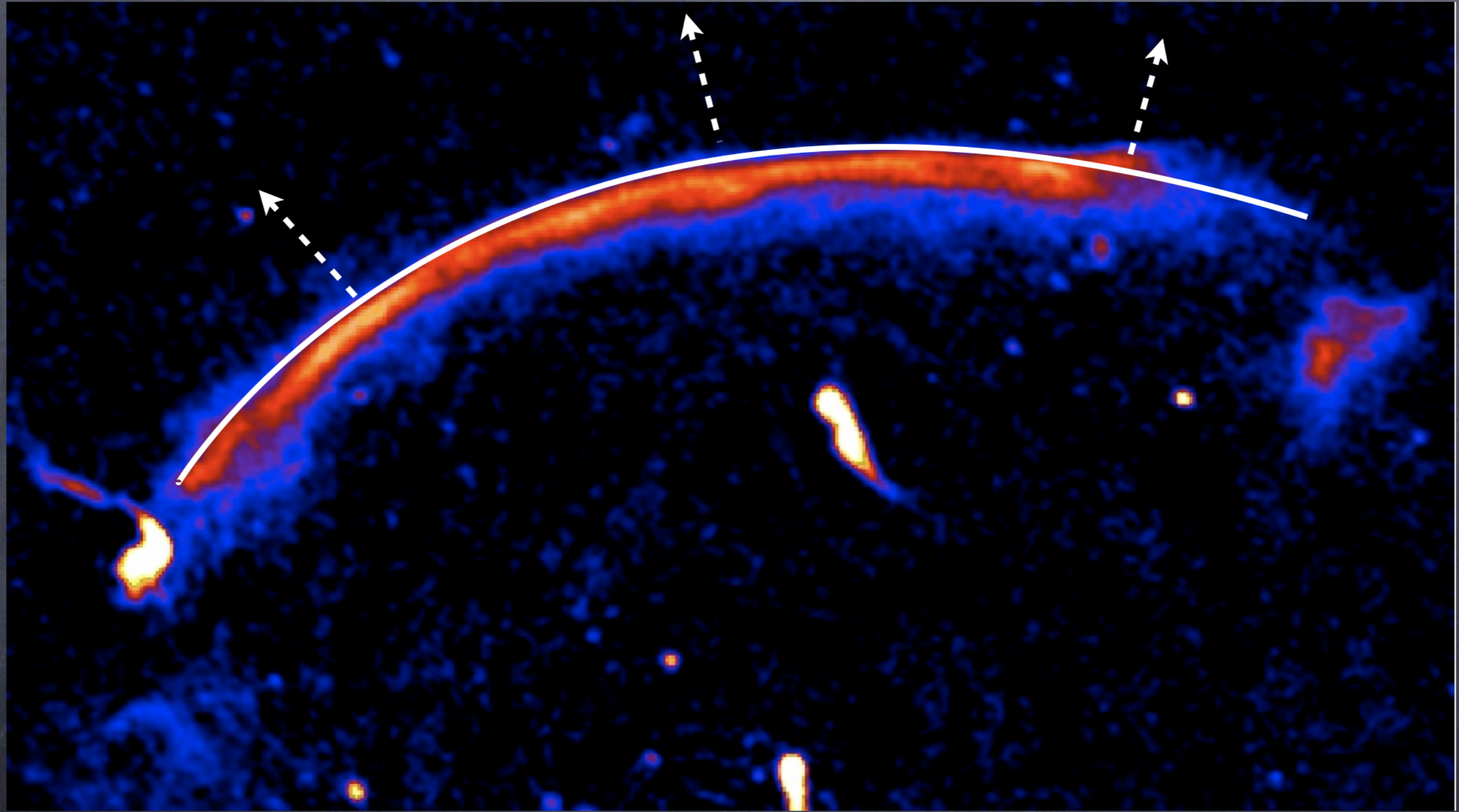
The sausage: CIZA J2242.8+5301

van Weeren, Röttgering, Brüggen, Hoefl, Science, 330, 347 (2010)



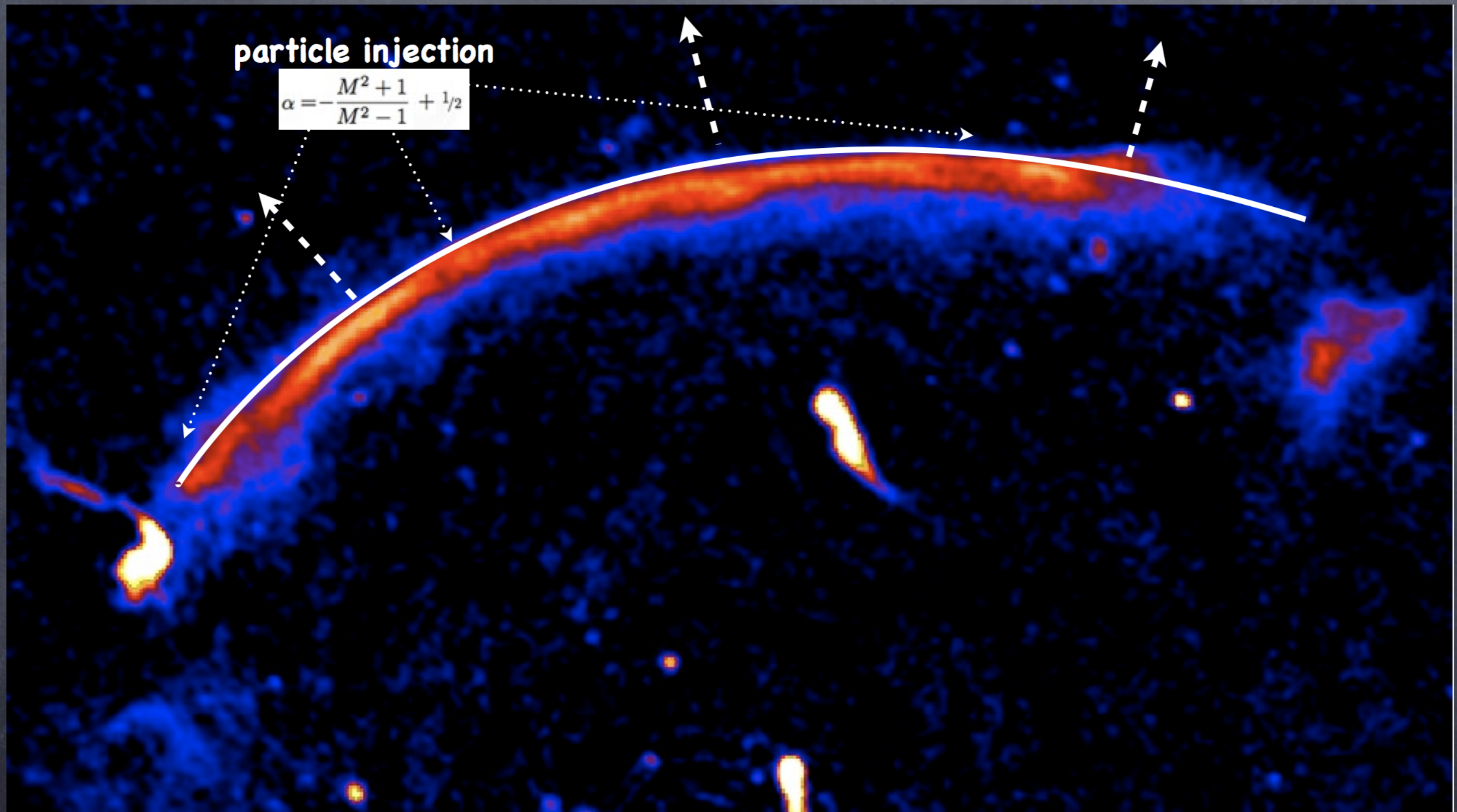
GMRT 610 MHz, resolution of $4.8 \text{ arcsec} \times 3.9 \text{ arcsec}$.
total on source time 9 hrs, bandwidth of 32 MHz.





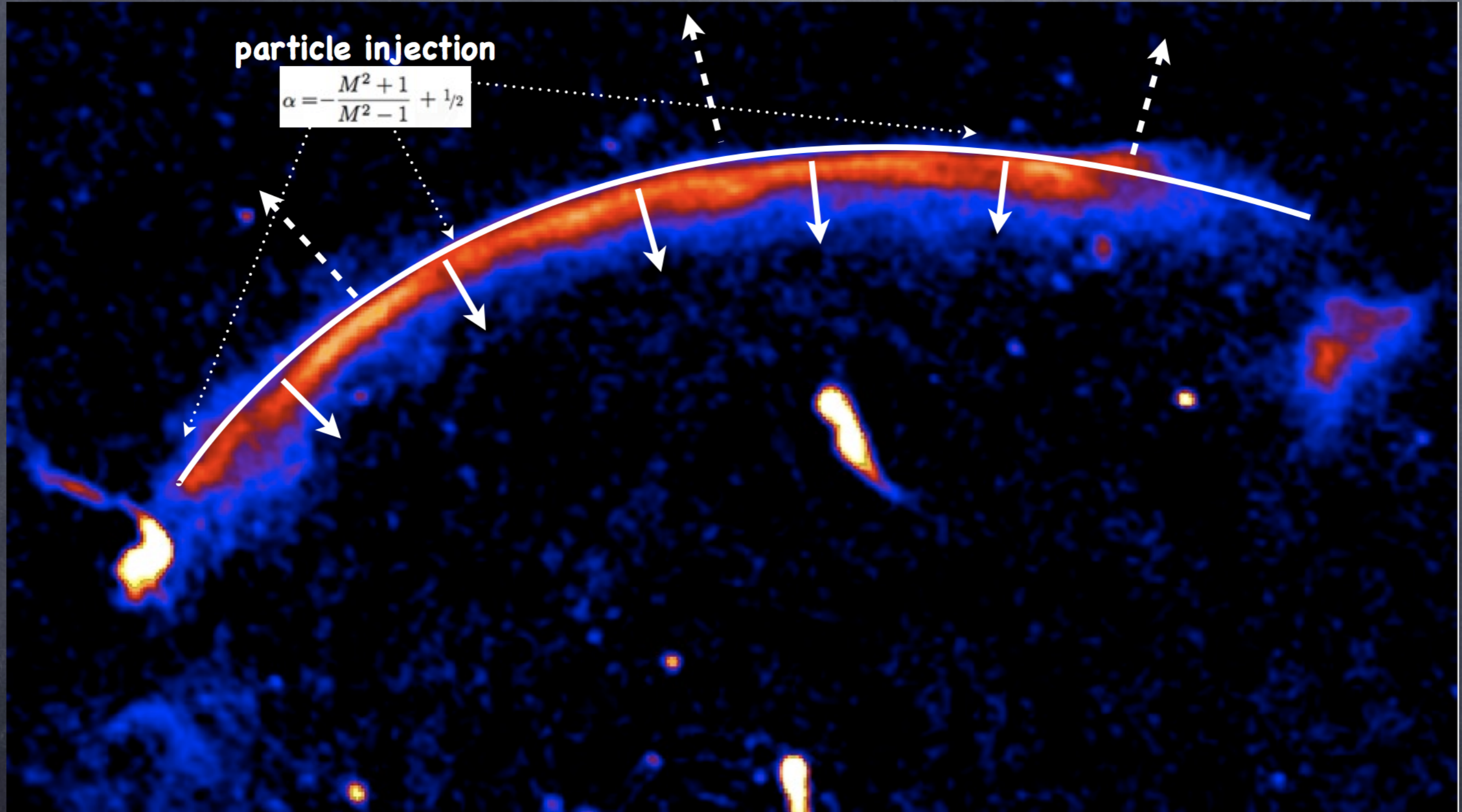
particle injection

$$\alpha = -\frac{M^2 + 1}{M^2 - 1} + 1/2$$



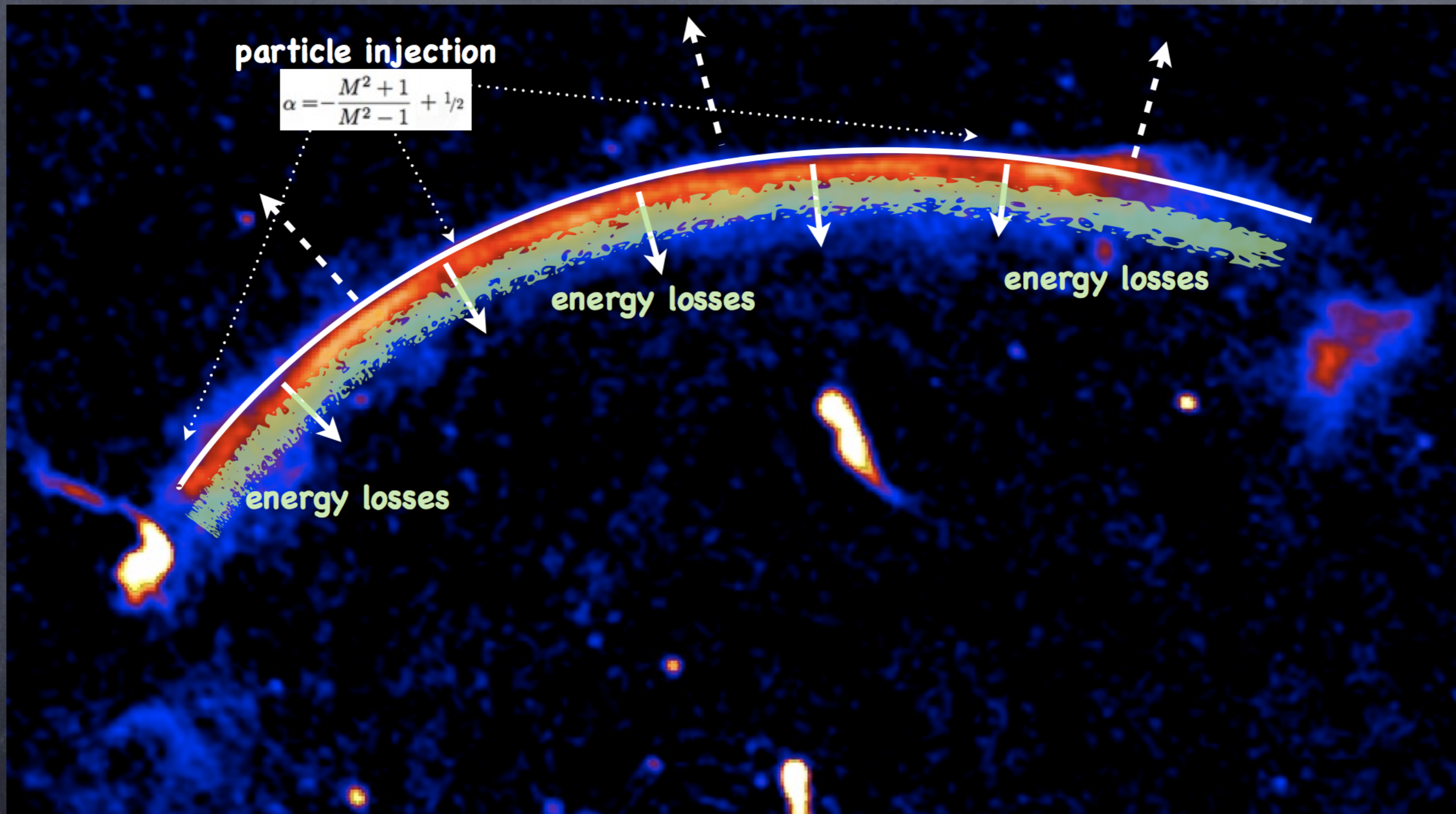
particle injection

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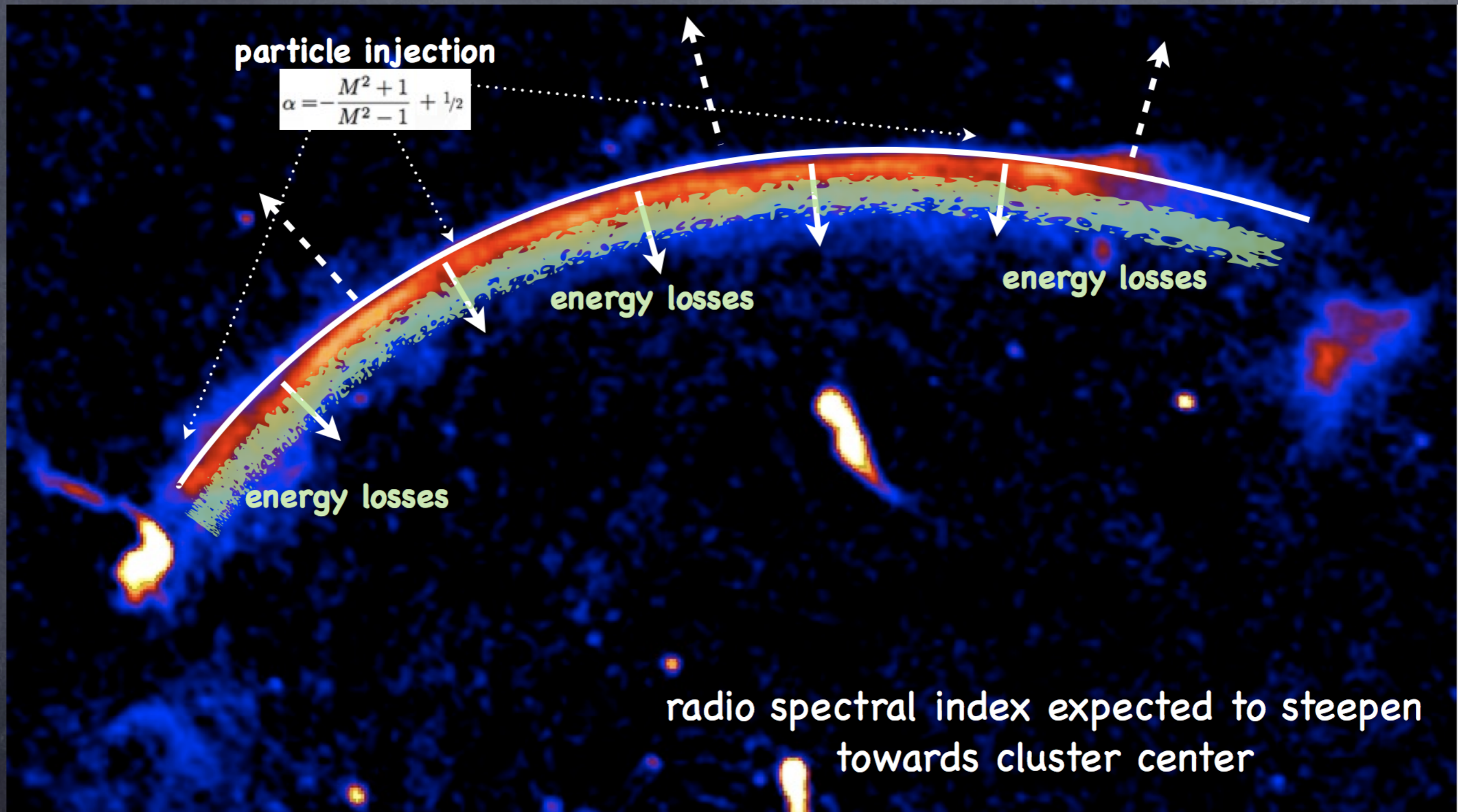
energy losses

energy losses

energy losses

particle injection

$$\alpha = -\frac{M^2 + 1}{M^2 - 1} + 1/2$$



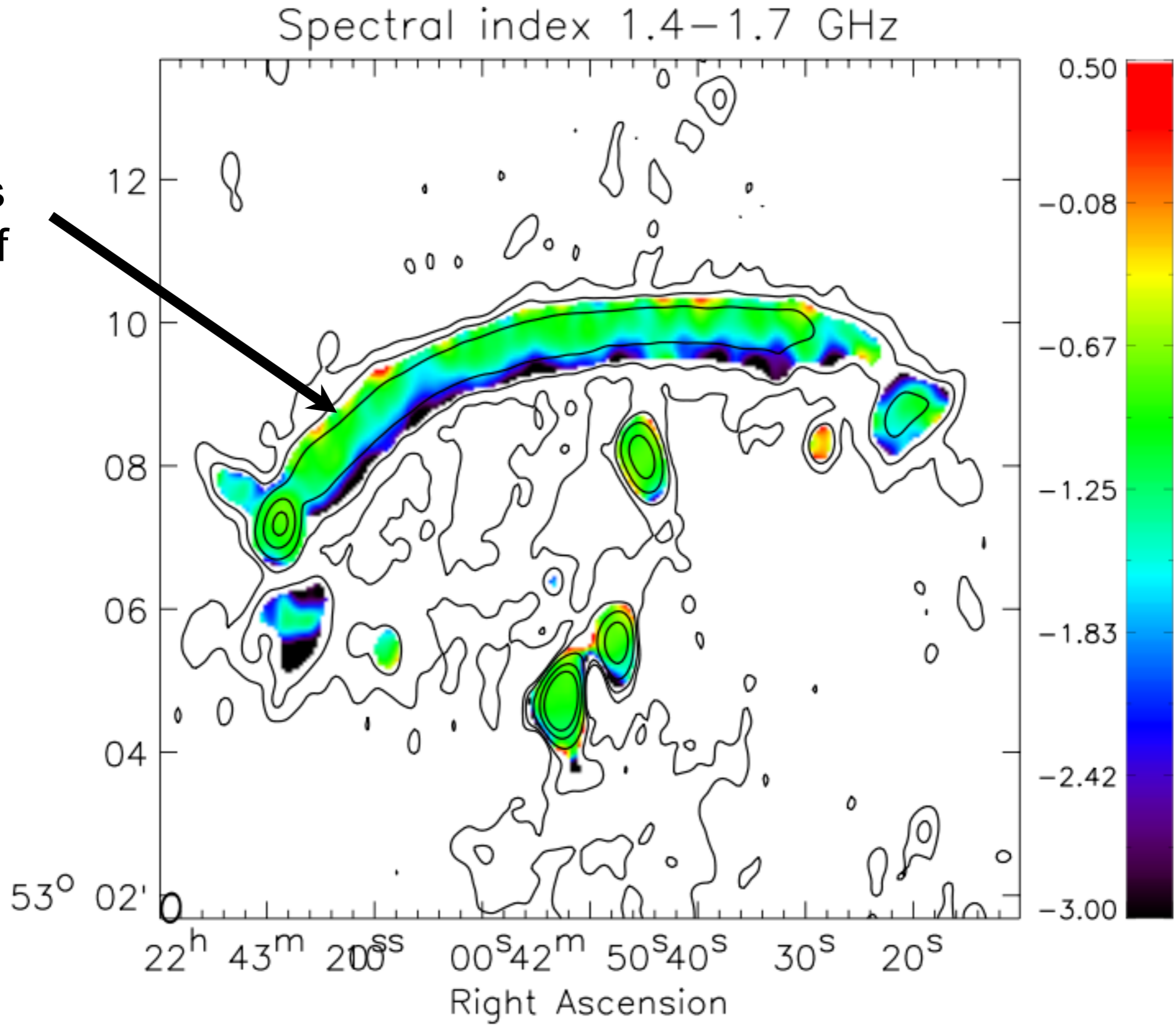
energy losses

energy losses

energy losses

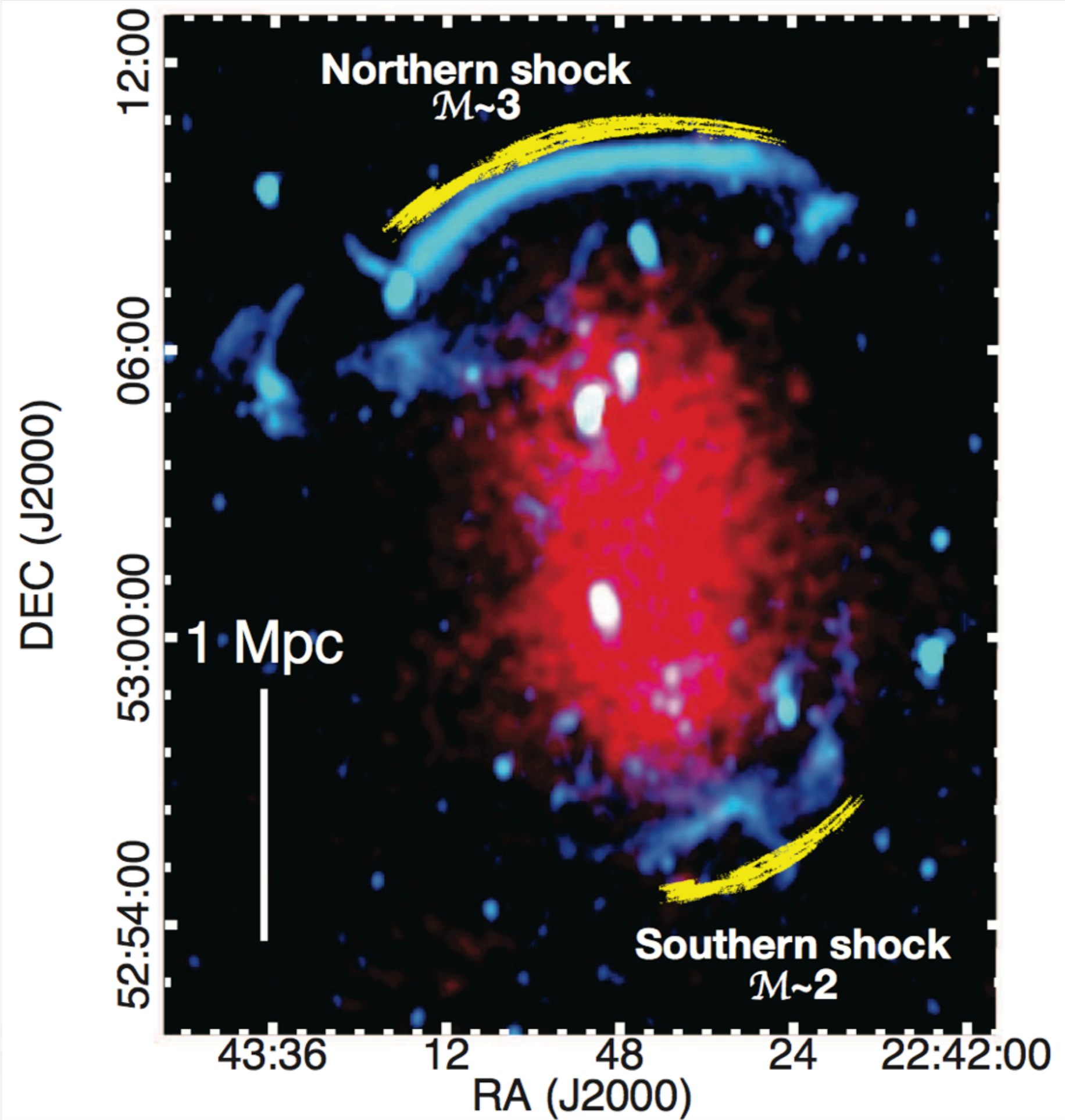
radio spectral index expected to steepen towards cluster center

Steepening
from -0.5 to
-2.5 towards
the centre of
the cluster



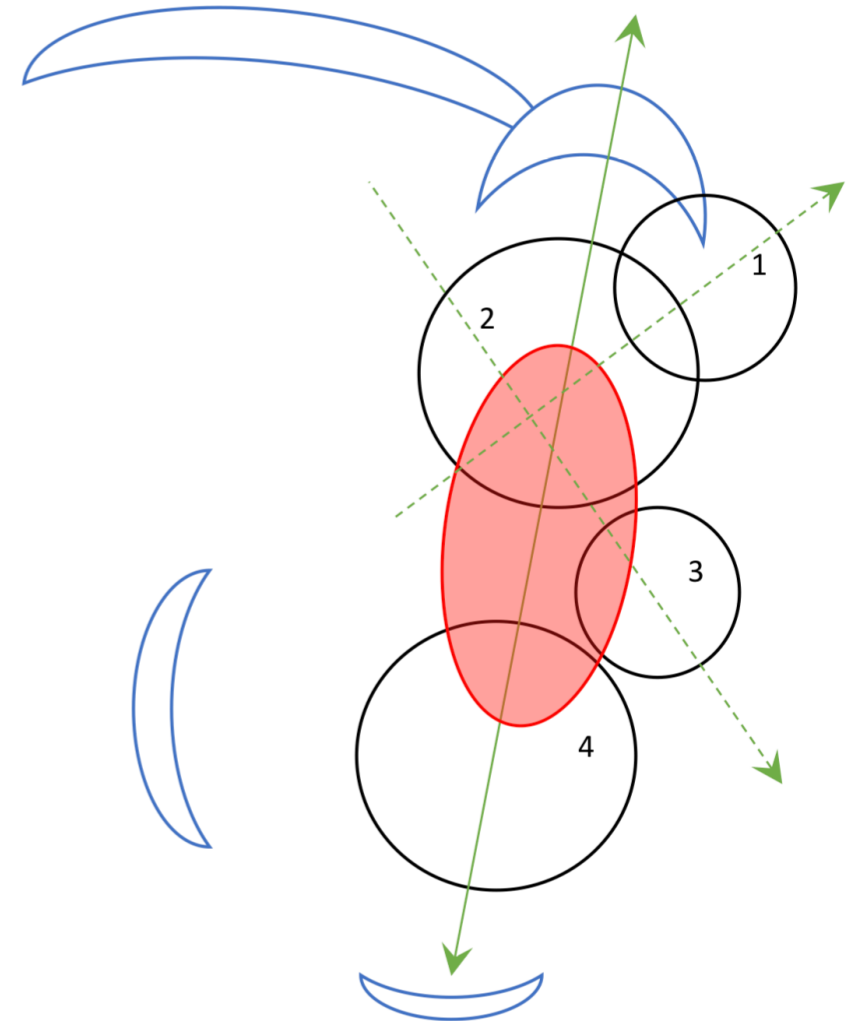
spectral index for at the front of the relic is -0.6 ± 0.05 . DSA gives a Mach number of 4.6

Akamatsu, van Weeren, Kawahara, Röttgering, MB,
Hoefl, Sobral, Oglean, Kaastra 2014



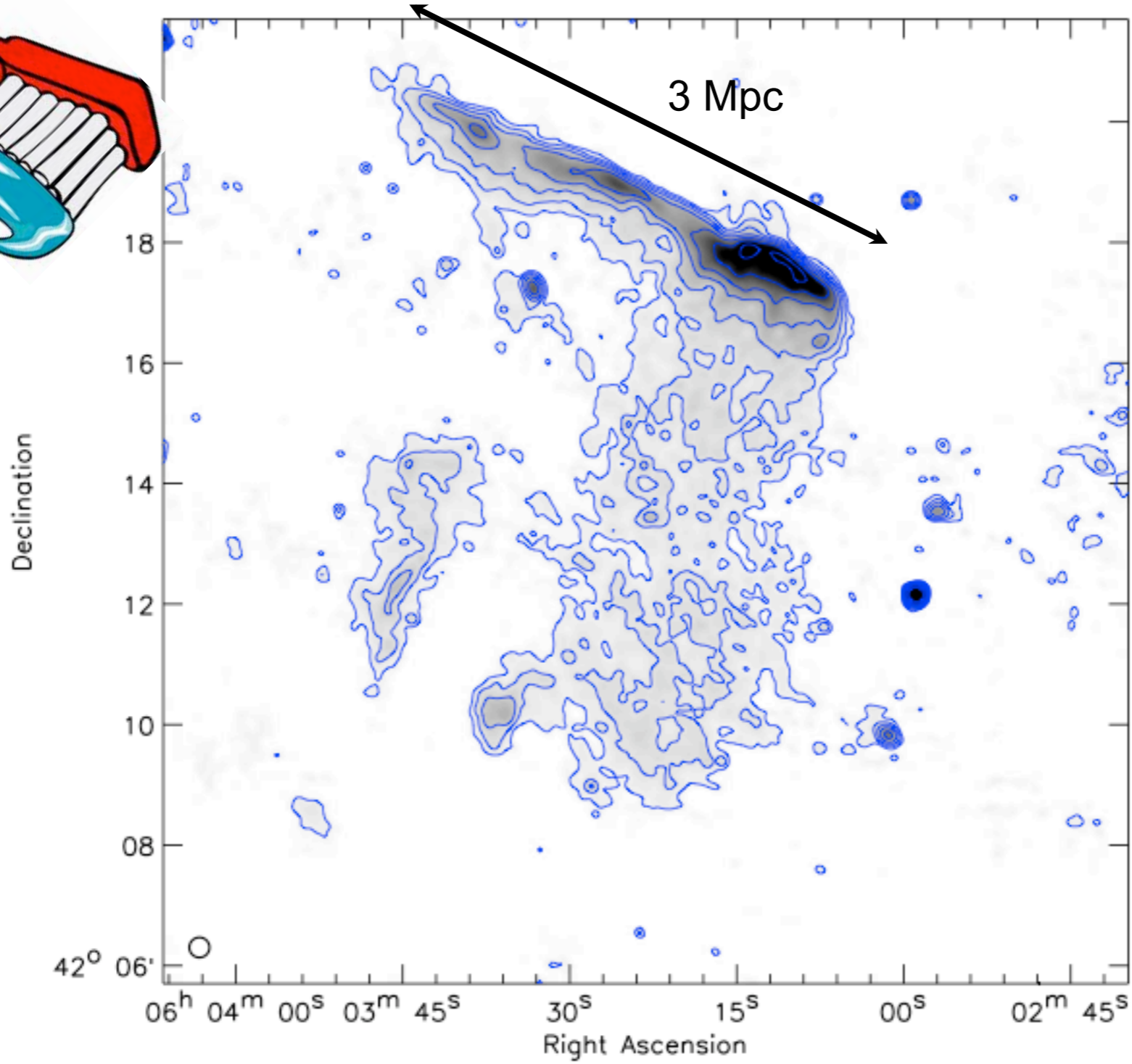
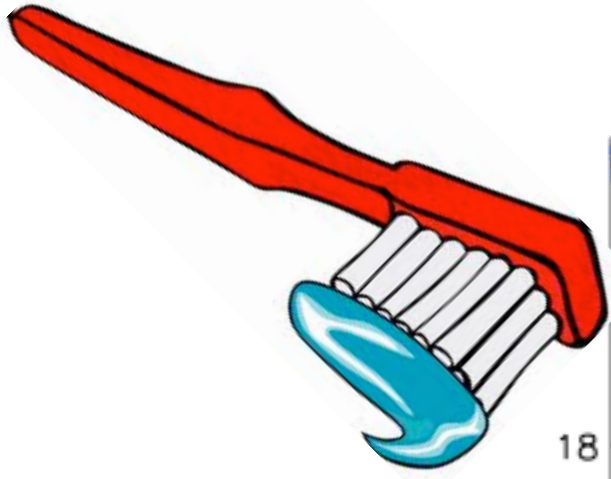
The unavoidable Toothbrush

Credit: van Weeren, MB, Chandra press



Golovich et al. (2018)
An Atlas of Relic Mergers

1RXS J0603.3+4213

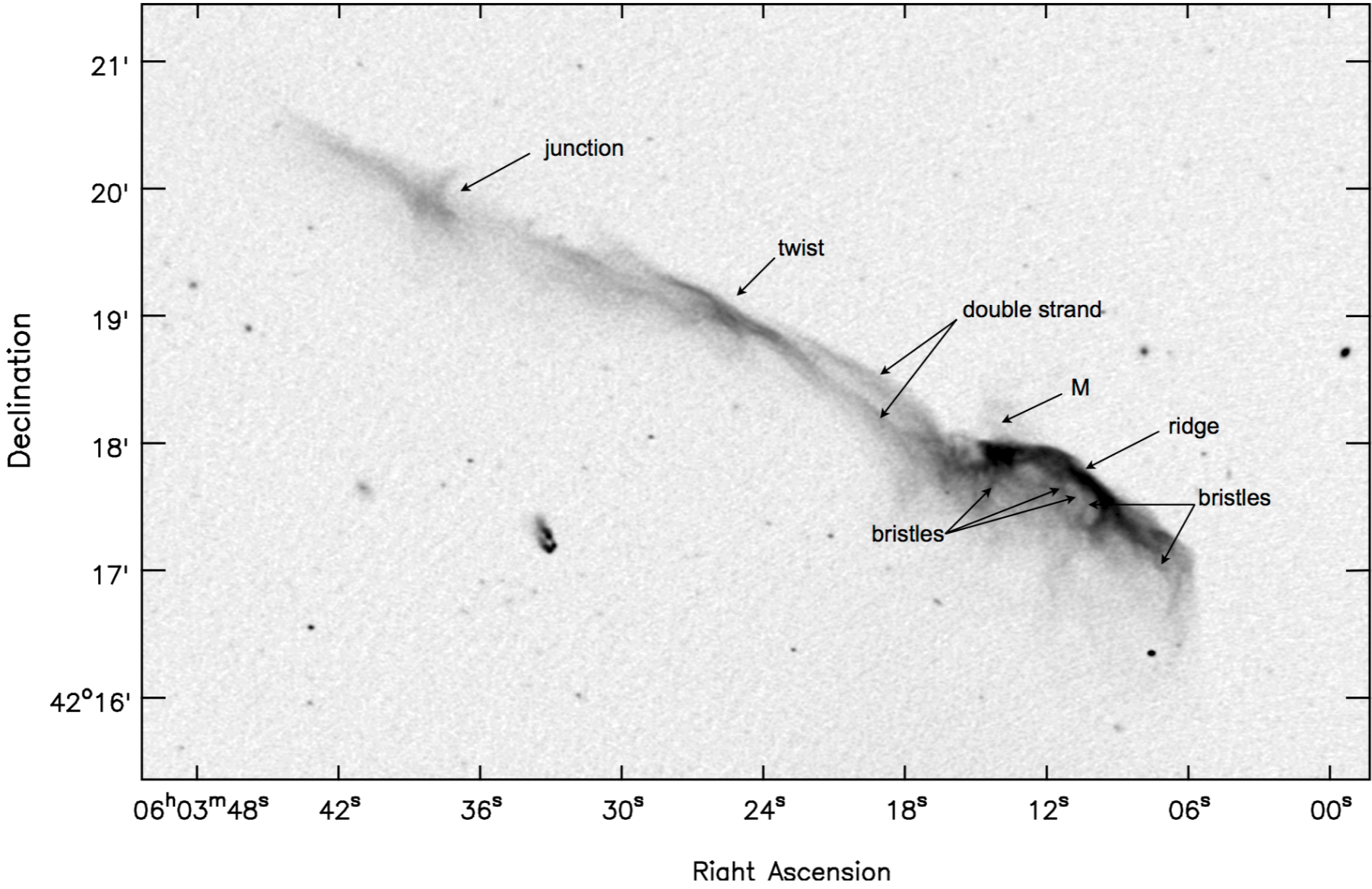


largest relic known
to date

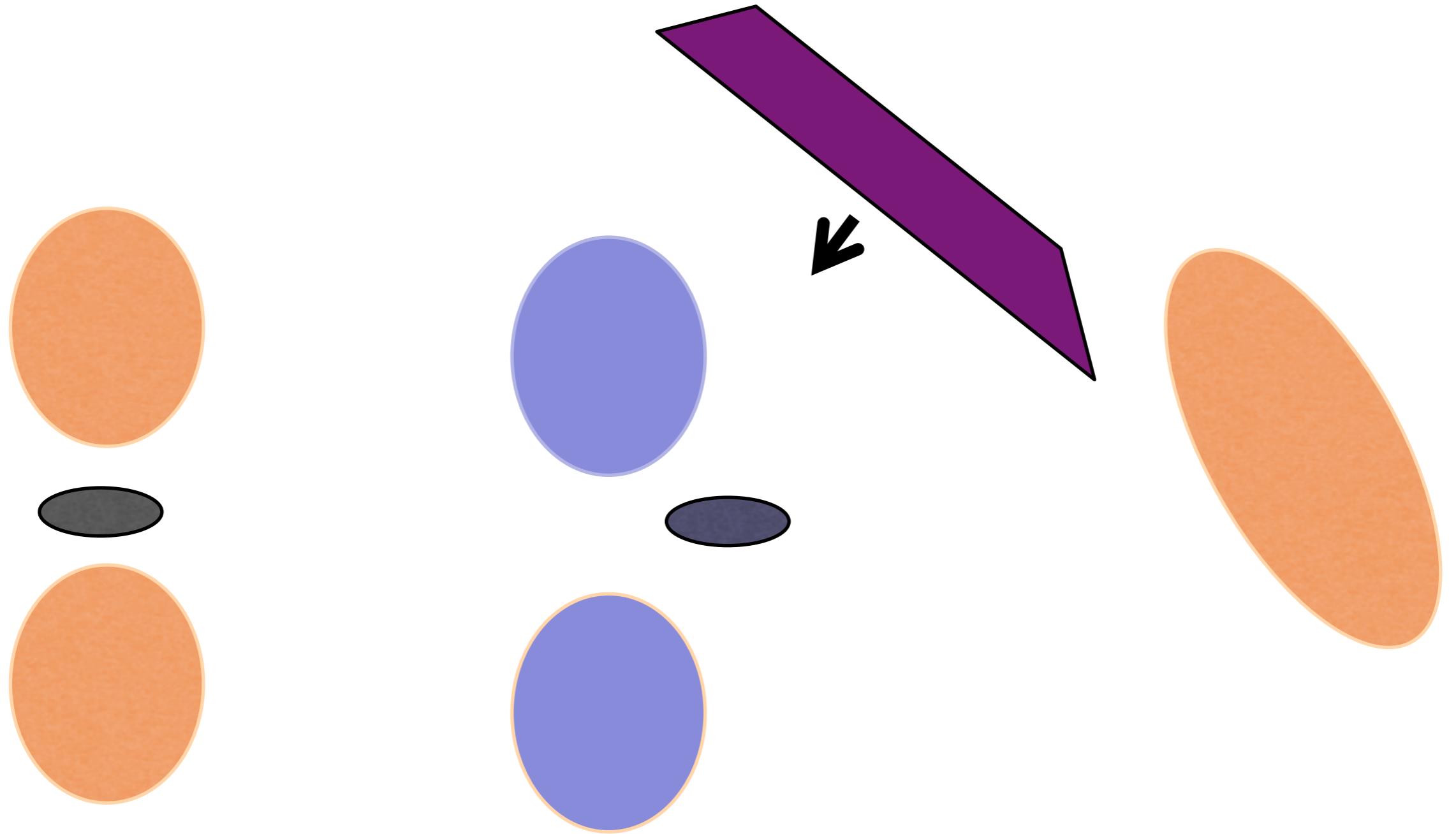
$z=0.25$

610 MHz GMRT map

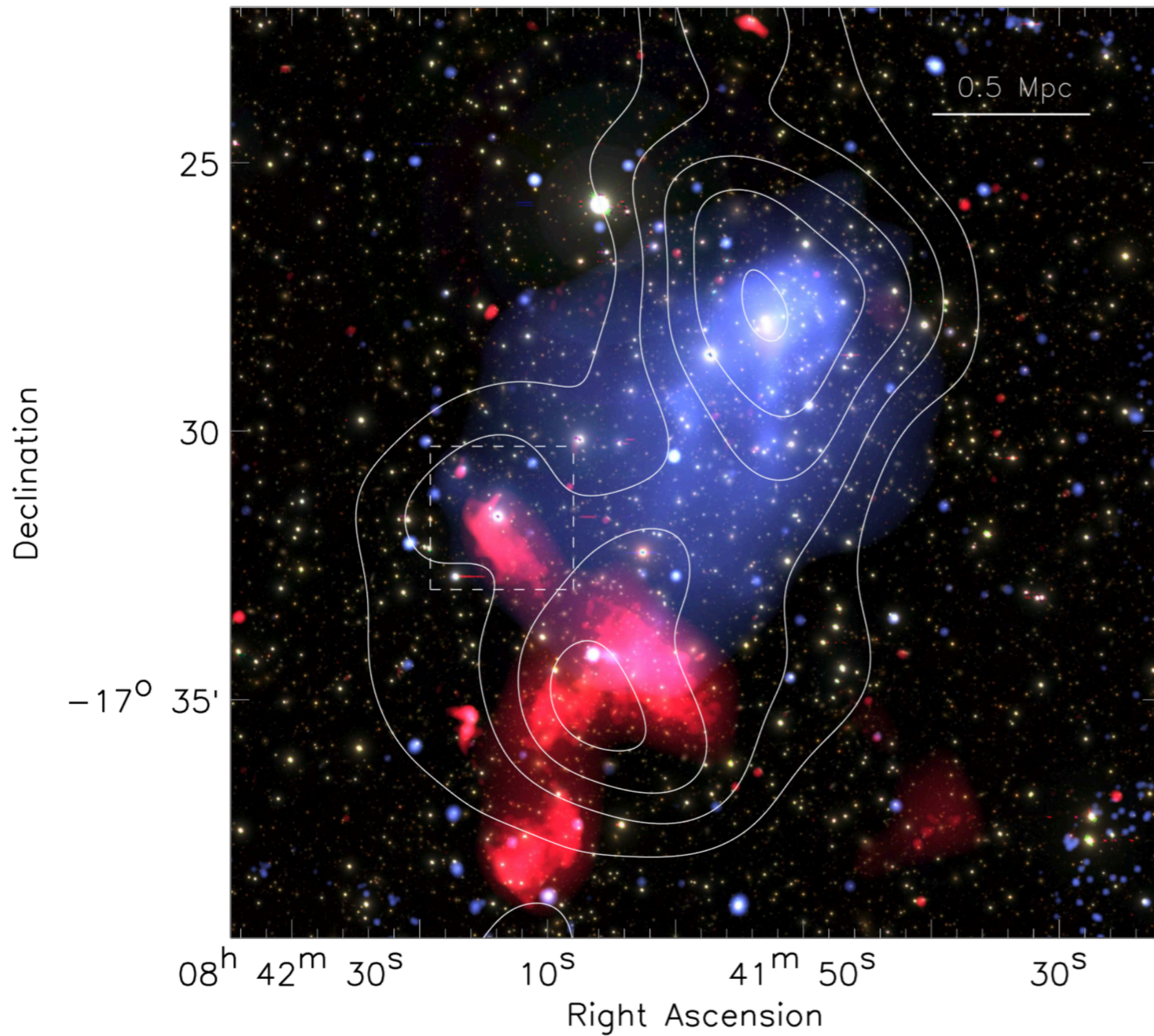
DEEP VLA OBSERVATIONS OF THE CLUSTER IRXS J0603.3+4214 IN THE FREQUENCY RANGE 1-2 GHz
Rajpurohit et al. 2017



Radio Phoenix

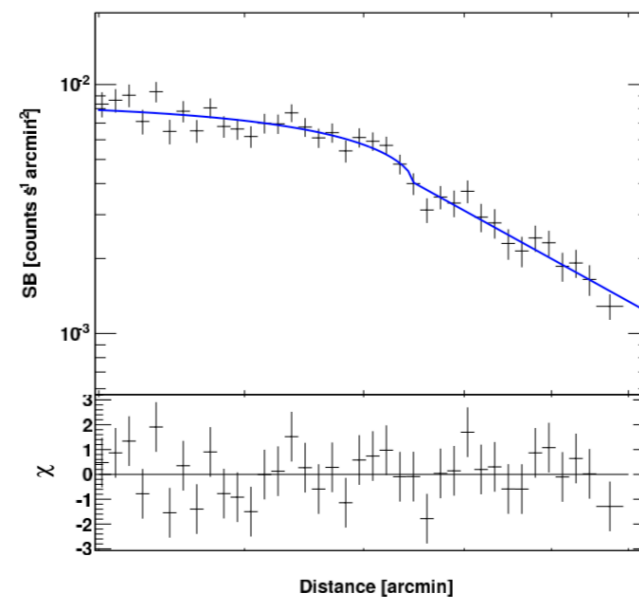
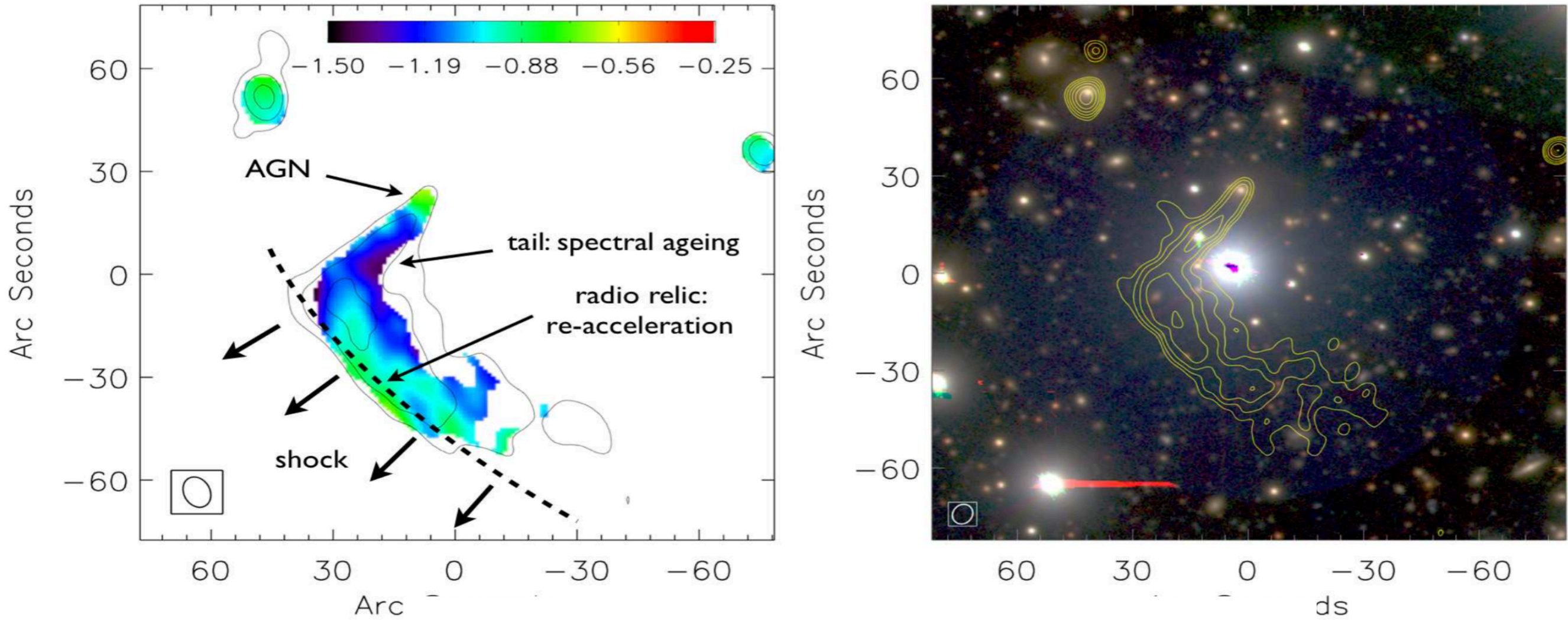


Abell 3411



van Weeren, Andrade-Santos, Dawson, MB et al. (2016)

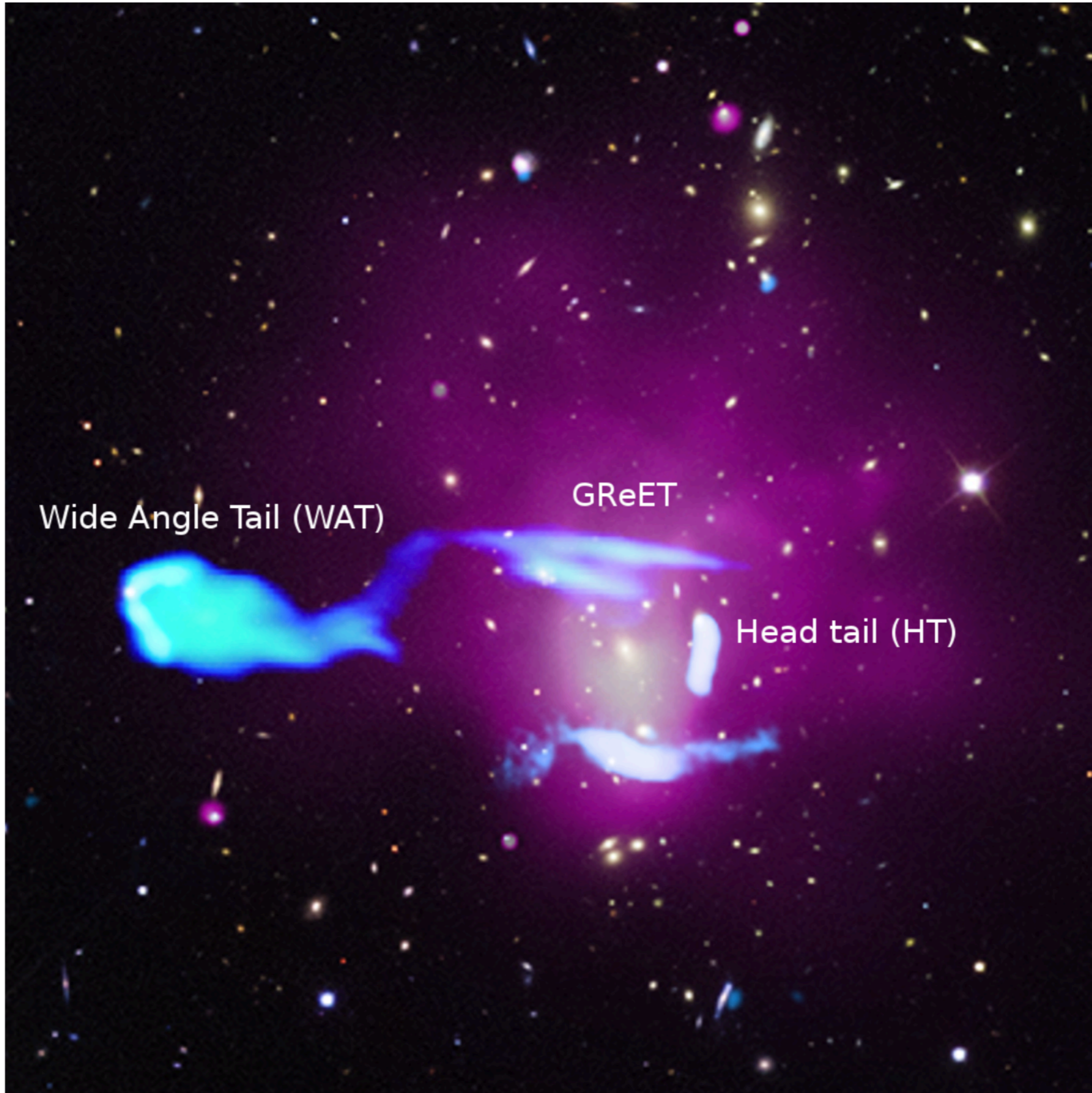
Abell 3411

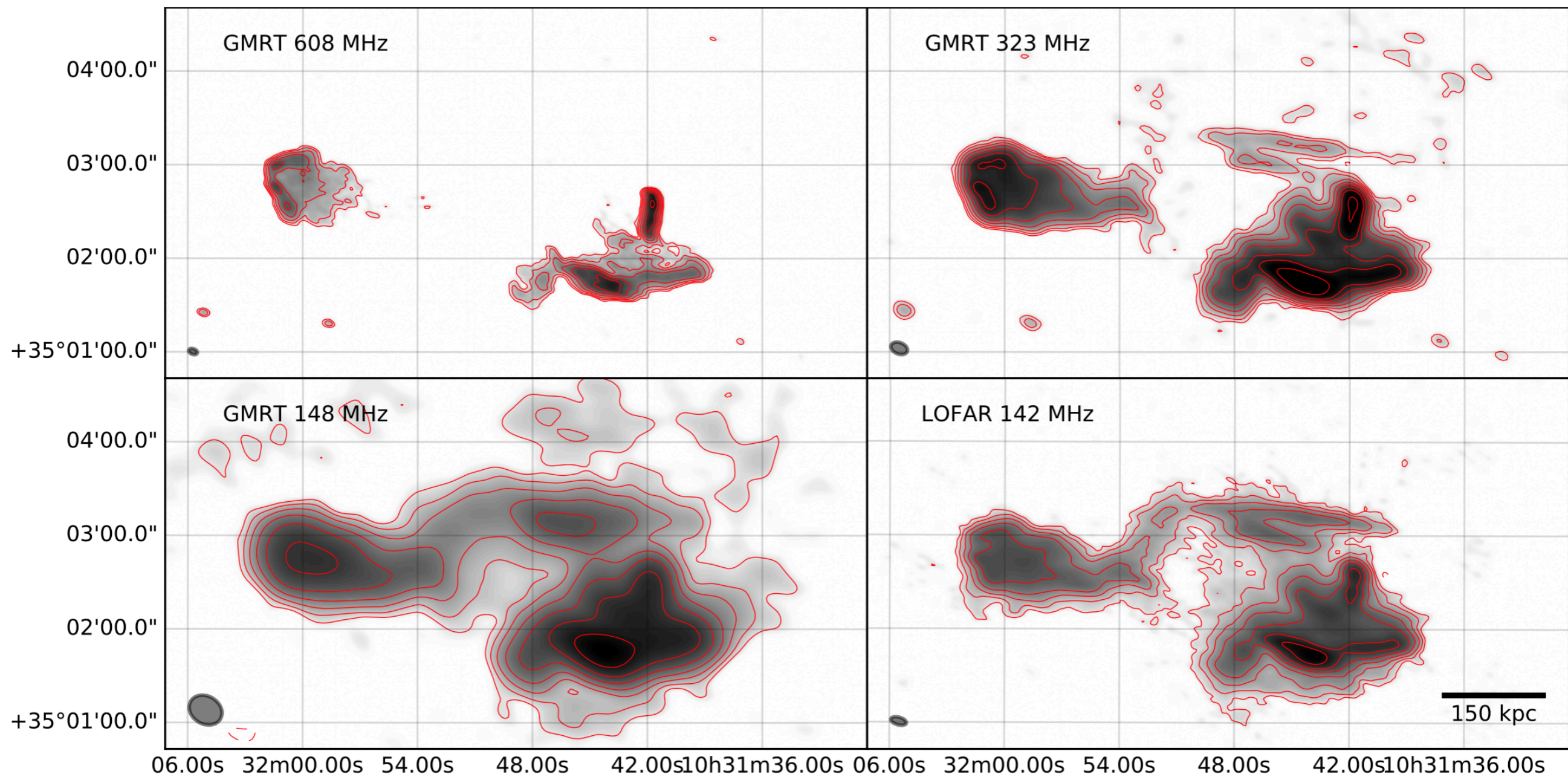


Abell 1033



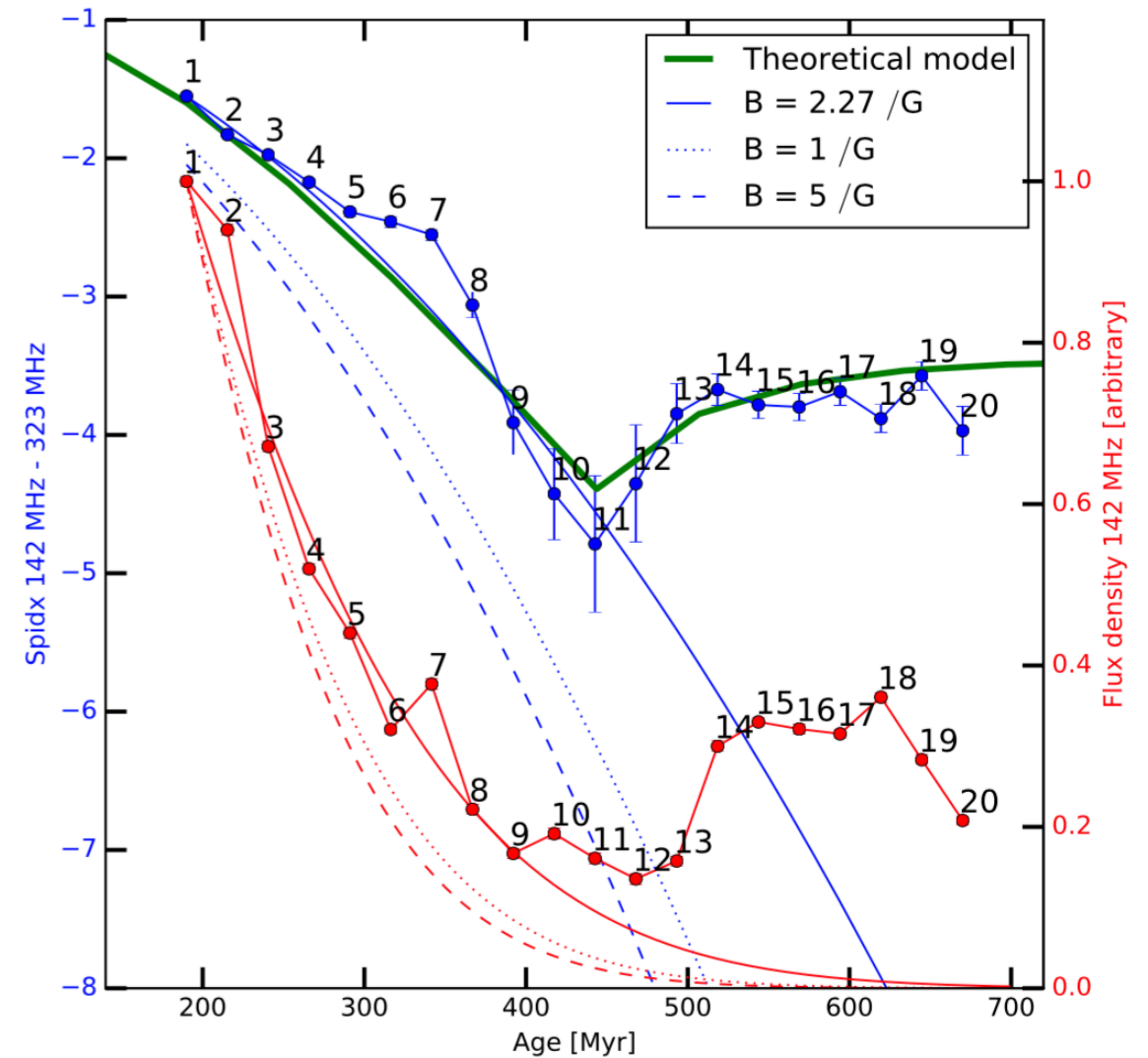
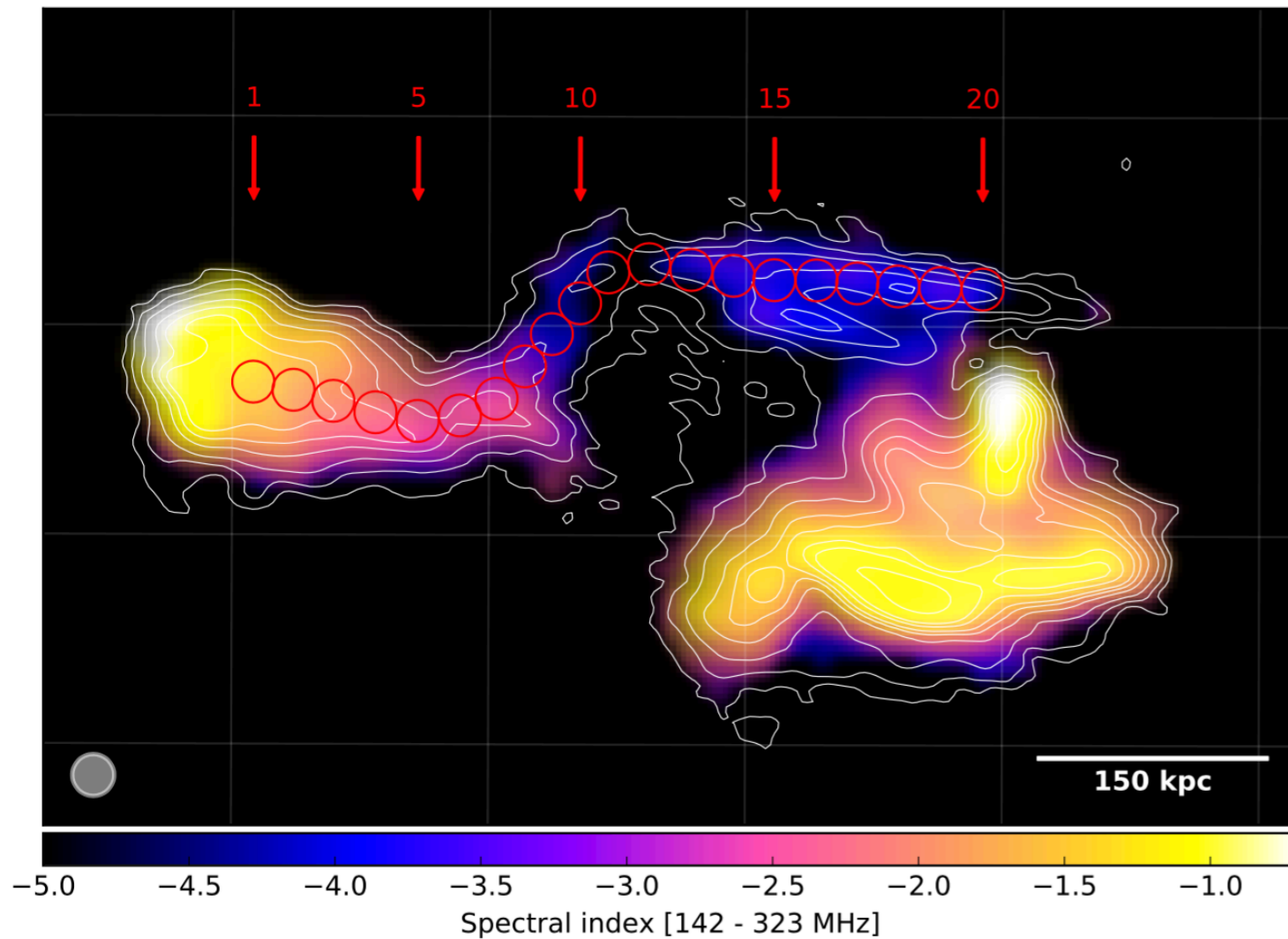
Abell 1033: a new type pf source? GReET: Gently Re-Energised Tail





(spectral index: $\alpha_{323}^{142} \simeq -4$)

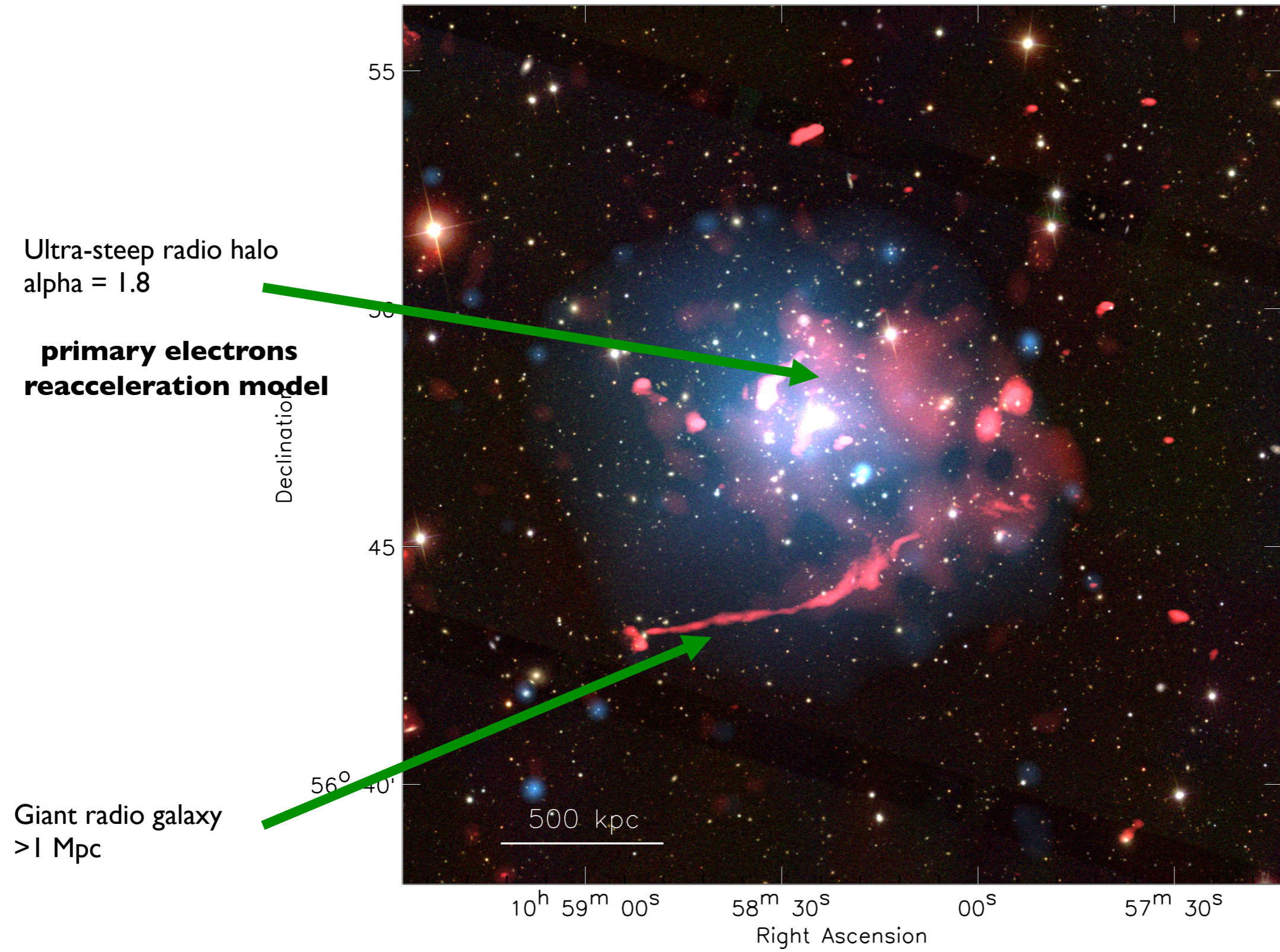
Abell 1033



Radiative age 600 Myr (2.3 μG), gal speed 730 km/s, vel disp of cluster 800 km/s

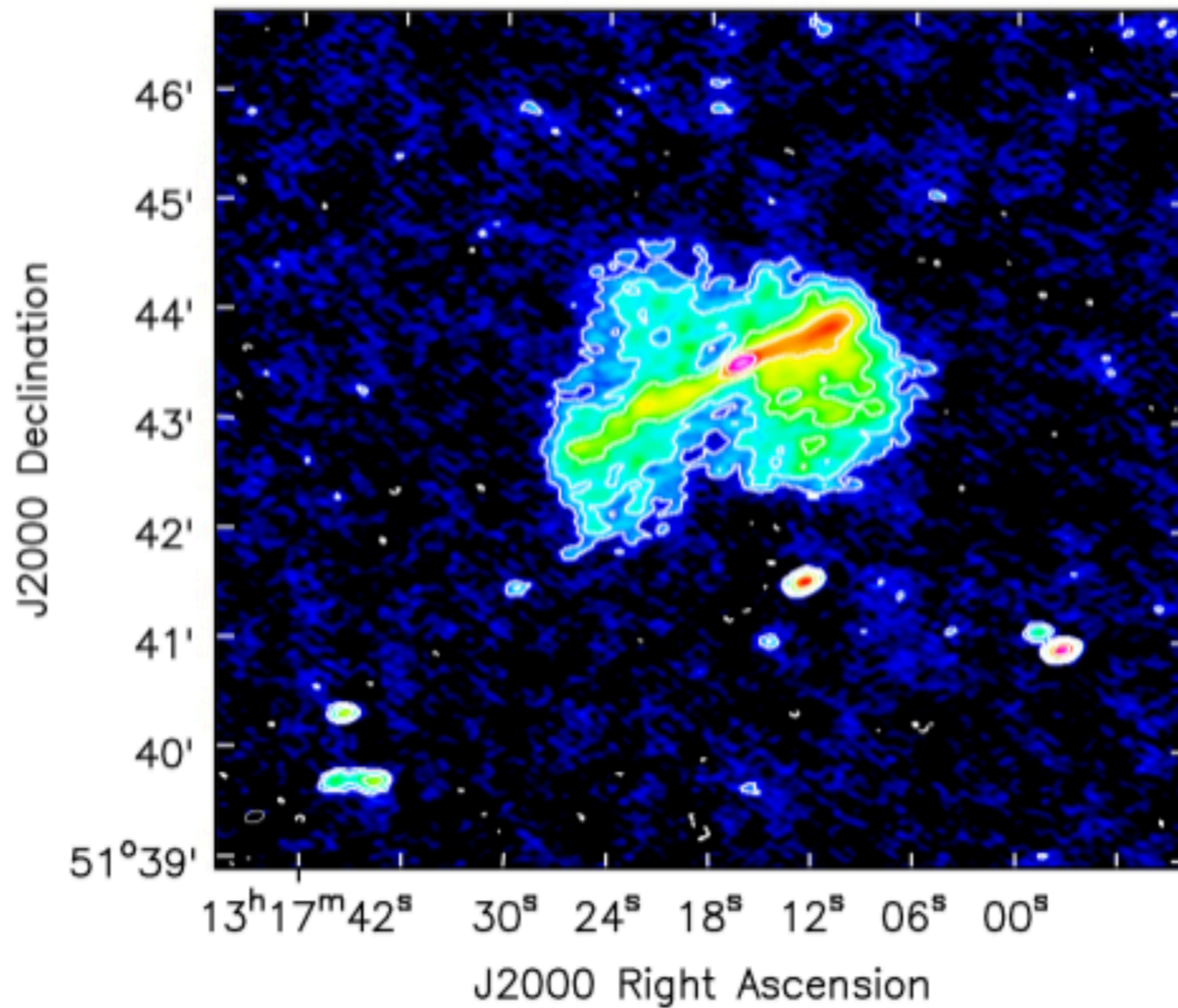
More to come: Abell 1132

Wilber, MB et al. (2017)



Radio-mode feedback in groups

MaxBCG J199.31832+51.72503



Savini, MB et al. (2017)

Talking points: Duty cycle, 630 kpc, FRI/FR II hybrid

Discussion points

1. Prospects of chasing CRe and CRp in LSS
2. What is the role of CRs in ICM/ISM : particle acceleration/transport/feedback
3. Do CRs tell us about past feedback? Fossil evidence

RELIQS & HALOS

- Resolution frontier
- Frequency frontier