Universiteit Leiden

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Radio-mode feedback in high-redshift galaxy clusters with the International LOFAR Telescope

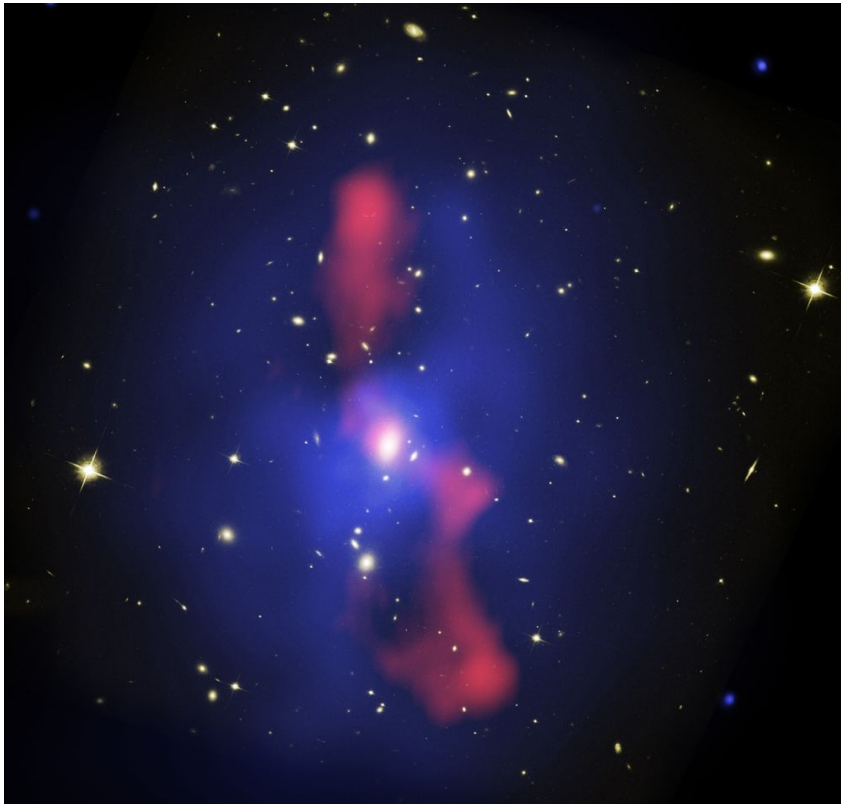
A new window on feedback opened by subarcsecond LOFAR-VLBI observations

R. Timmerman, R. J. van Weeren, A. Botteon, L. K. Morabito, F. Sweijen, H. J. A. Röttgering, L. Bîrzan, B. R. McNamara

LOFAR Family Meeting - 14 June 2023

Olsztyn, Poland

Measuring the amount of radio-mode feedback



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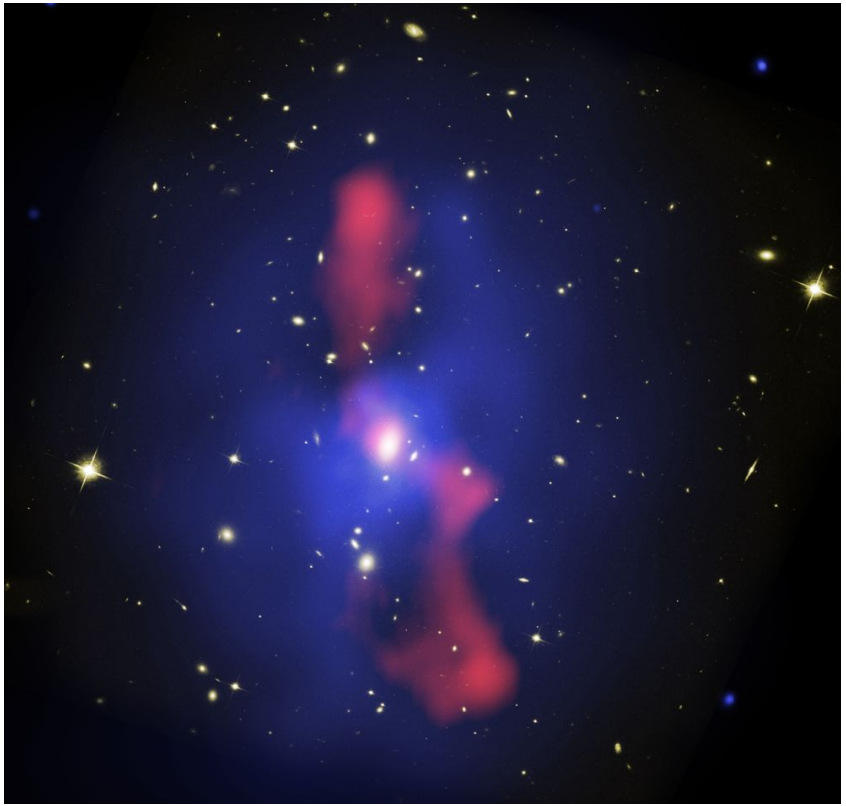

Radio

- Radio-mode feedback power derived from the **luminosity** and **spectral properties** of the radio lobes

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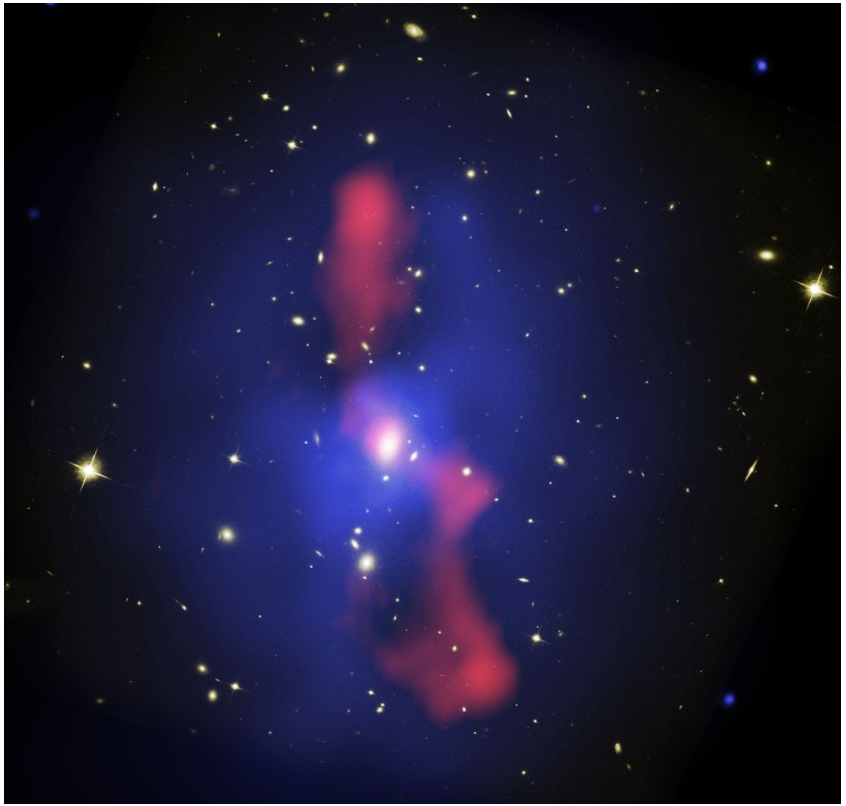

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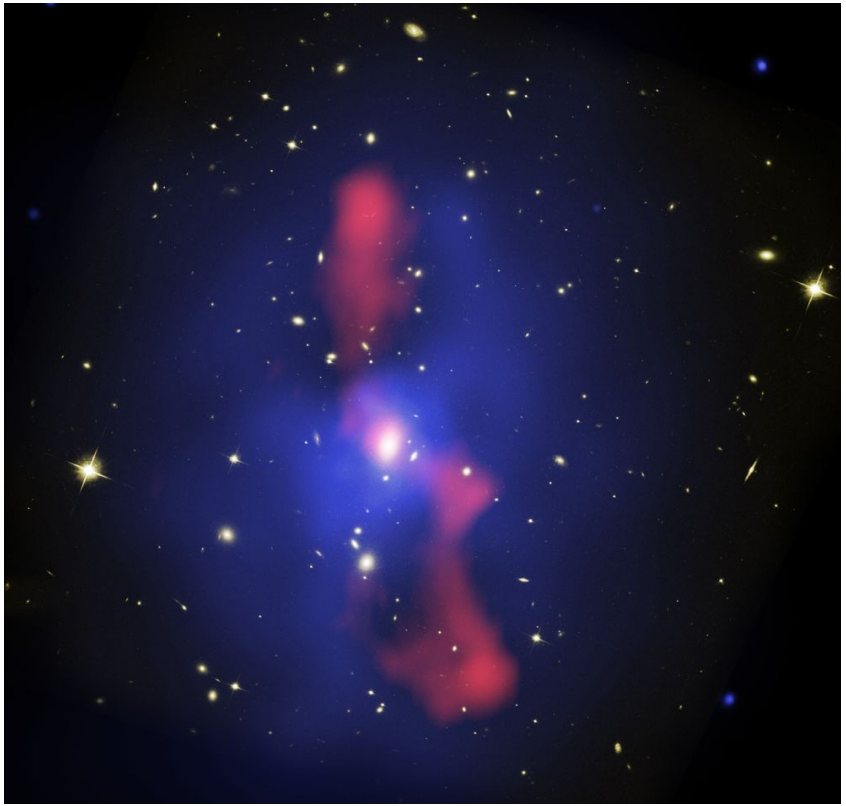

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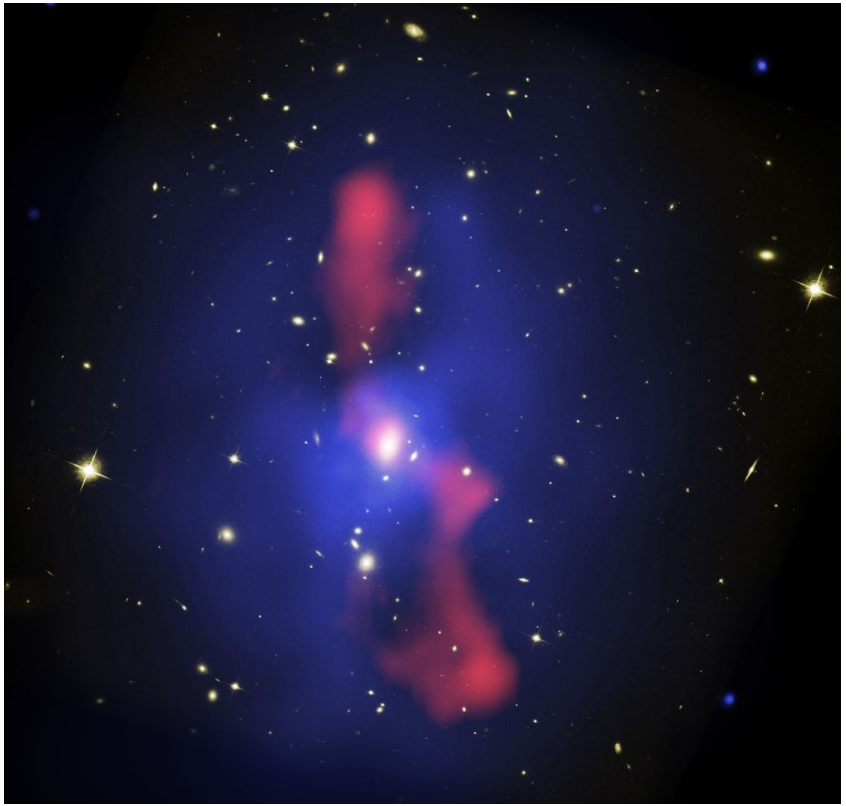

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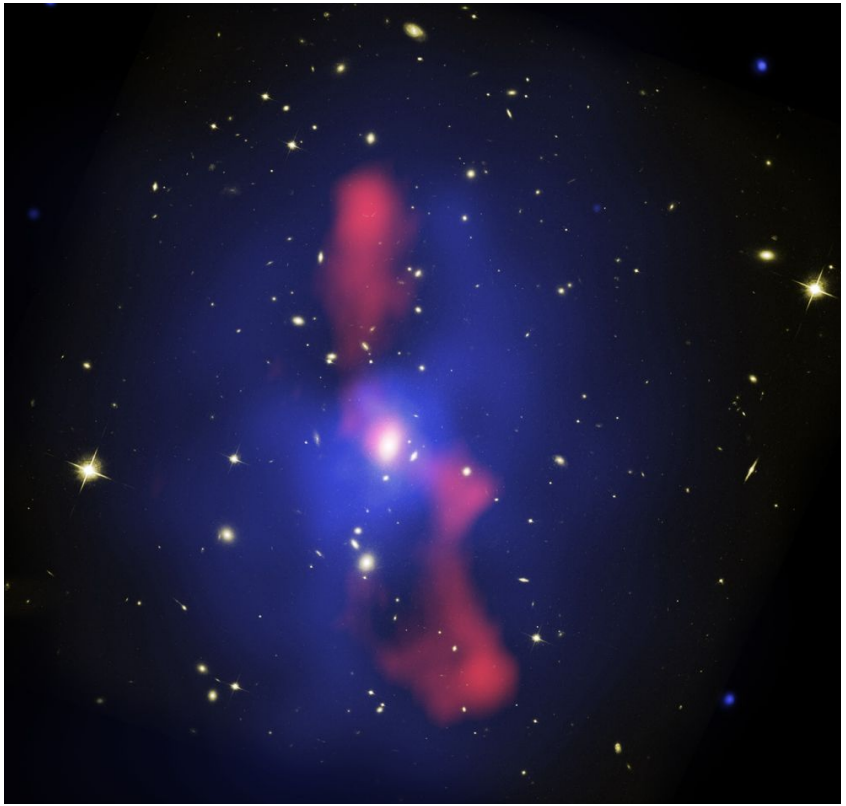

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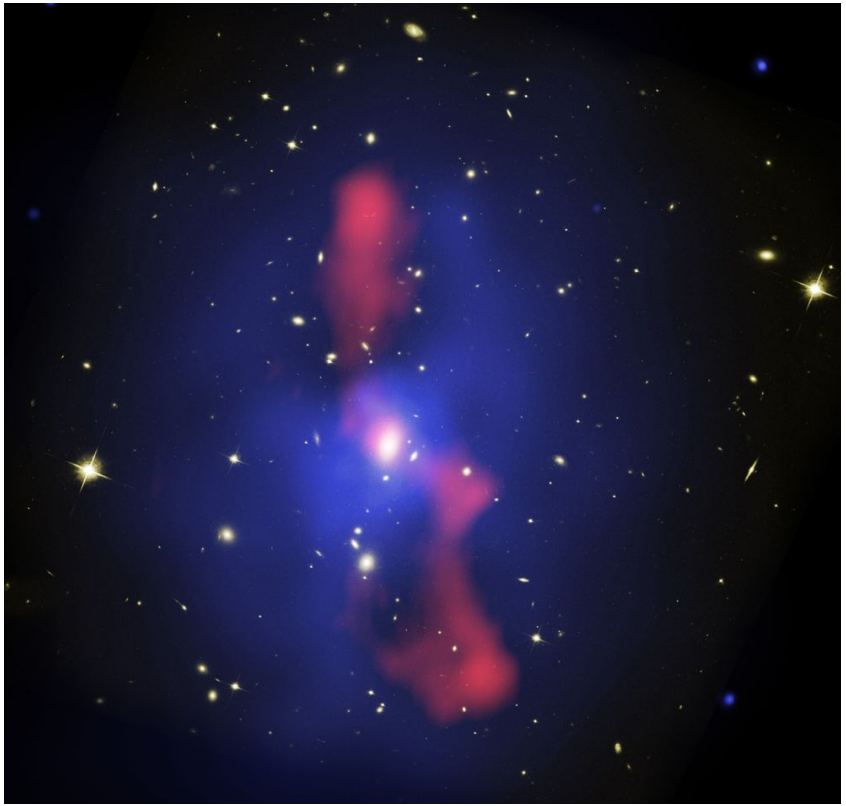

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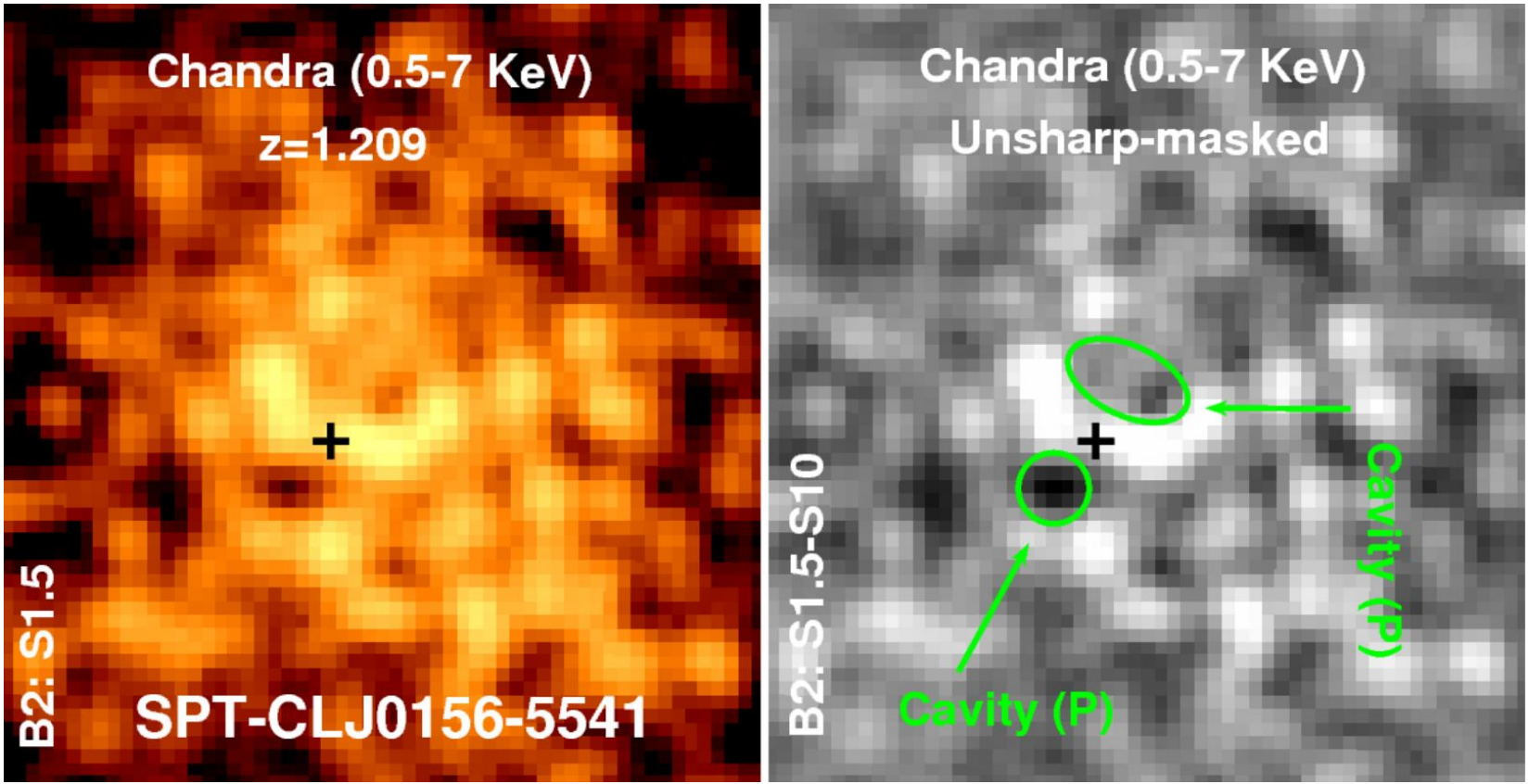
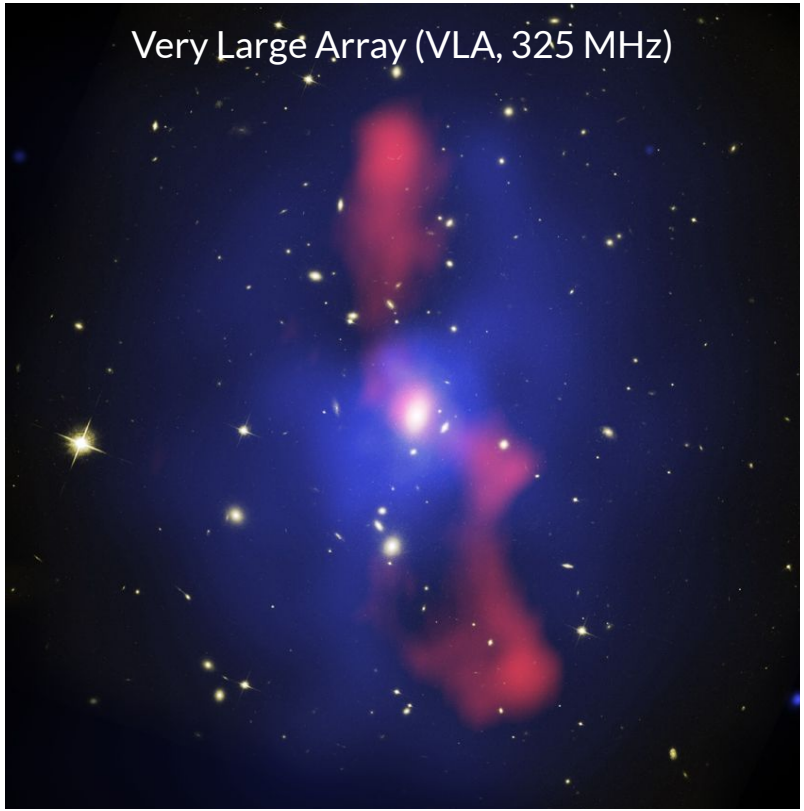
- Generally **preferred** for measuring amount of feedback

The challenge of high redshifts



(J. Hlavacek-Larrondo et al. 2015 ApJ 805 35)

The benefit of low-frequency radio



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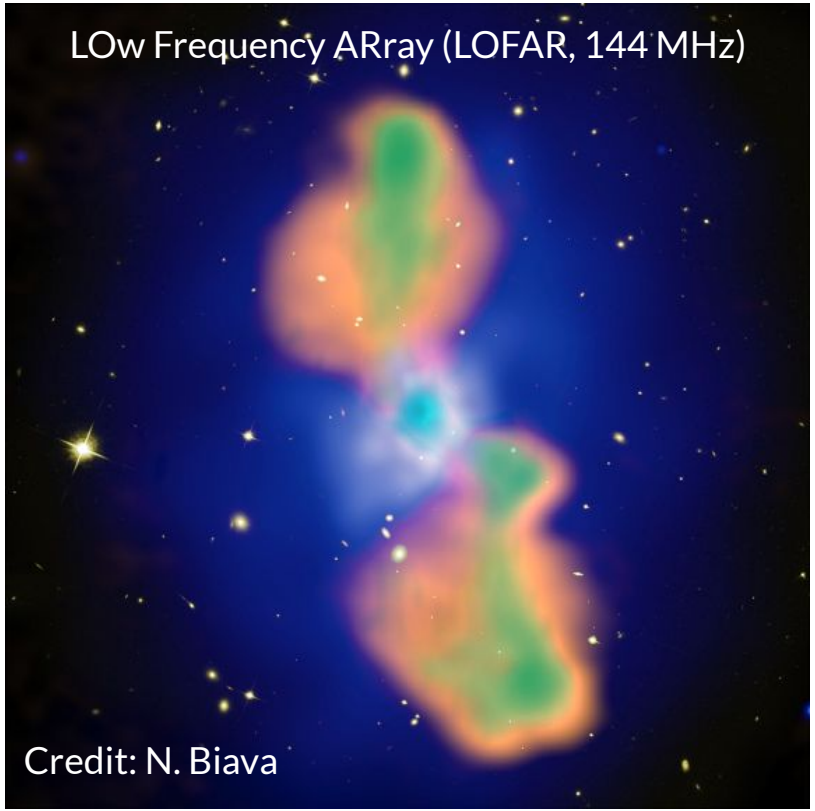
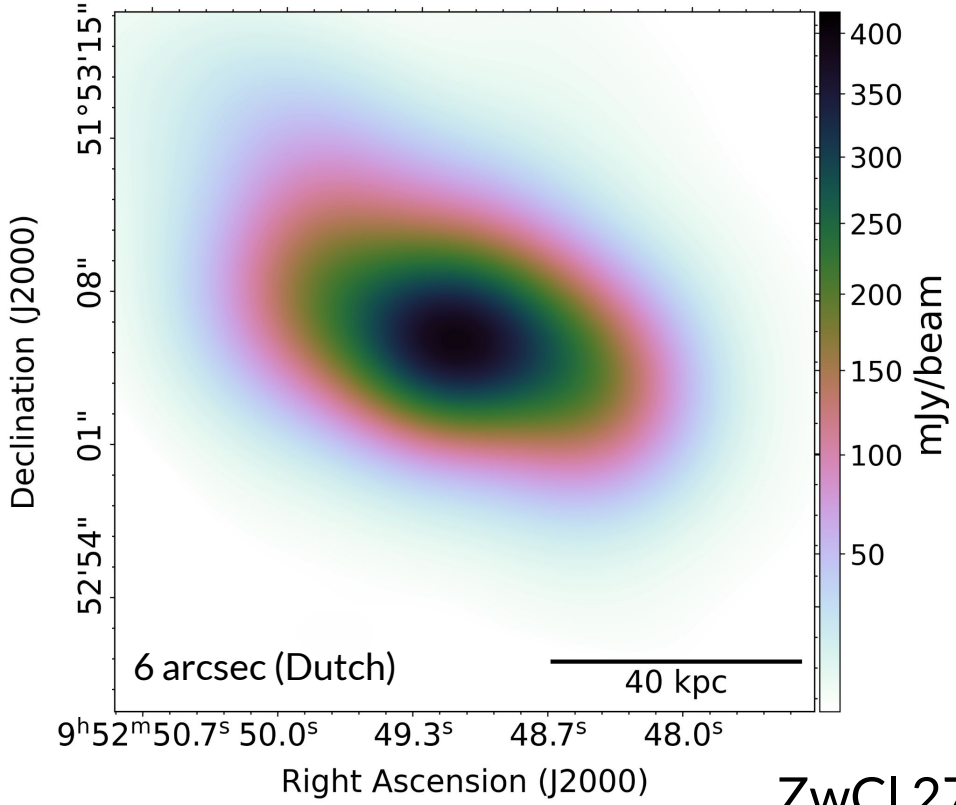


(N. Biava et al. 2021 A&A 650 A170)

Low frequencies at high angular resolutions



ZwCl 2701

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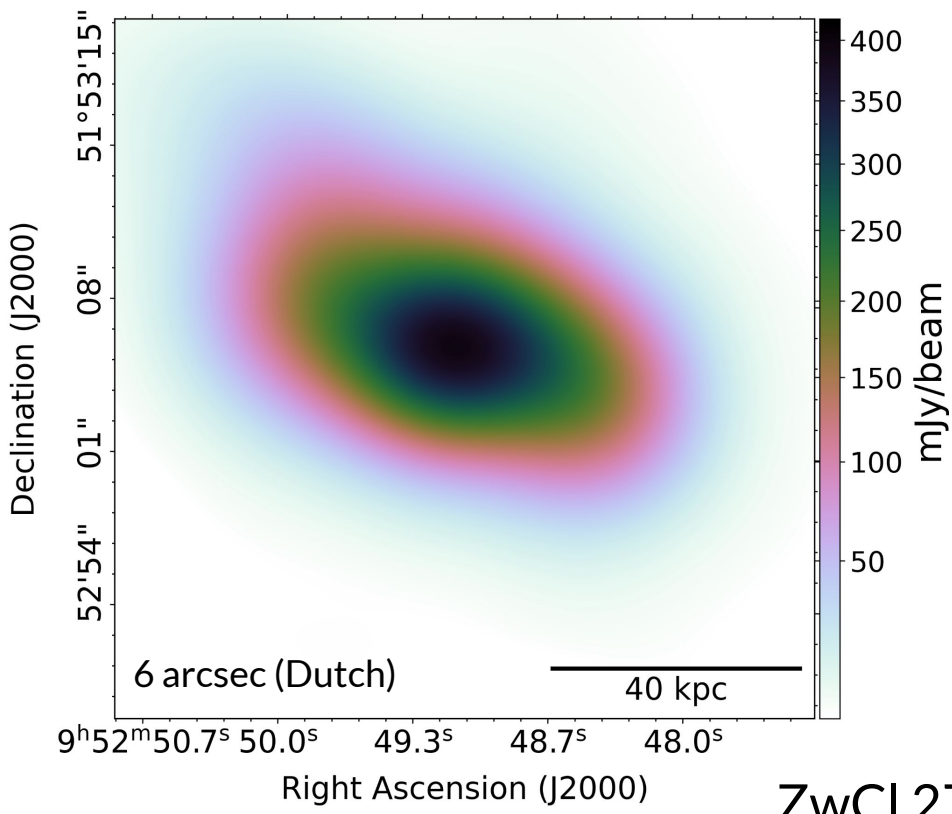
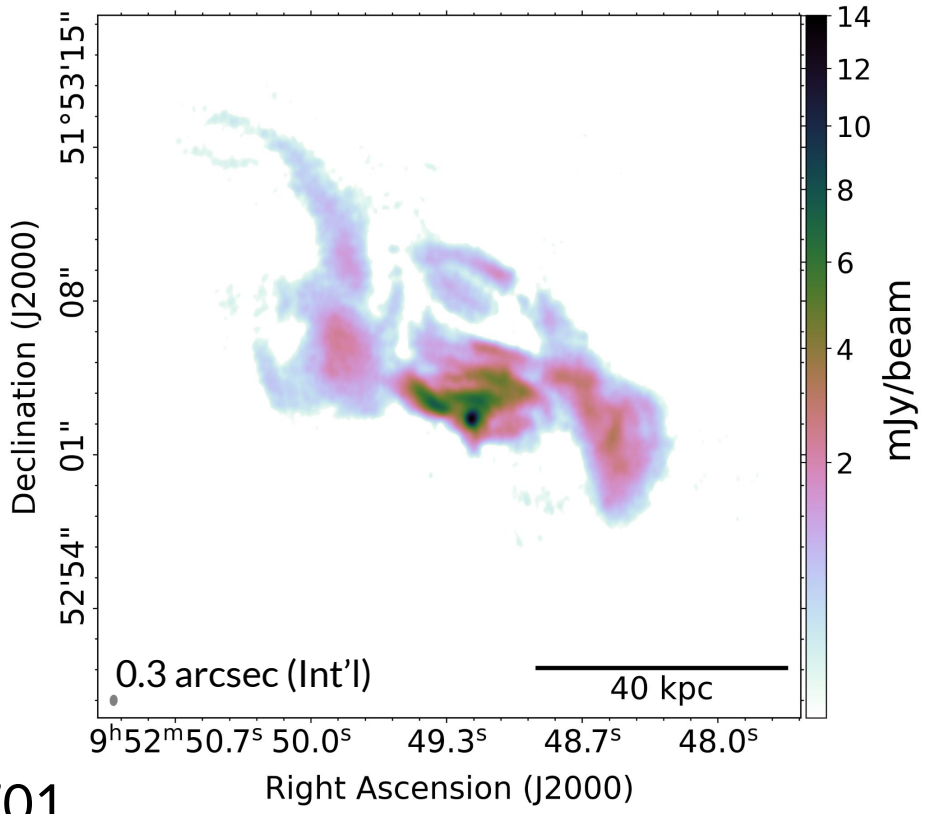
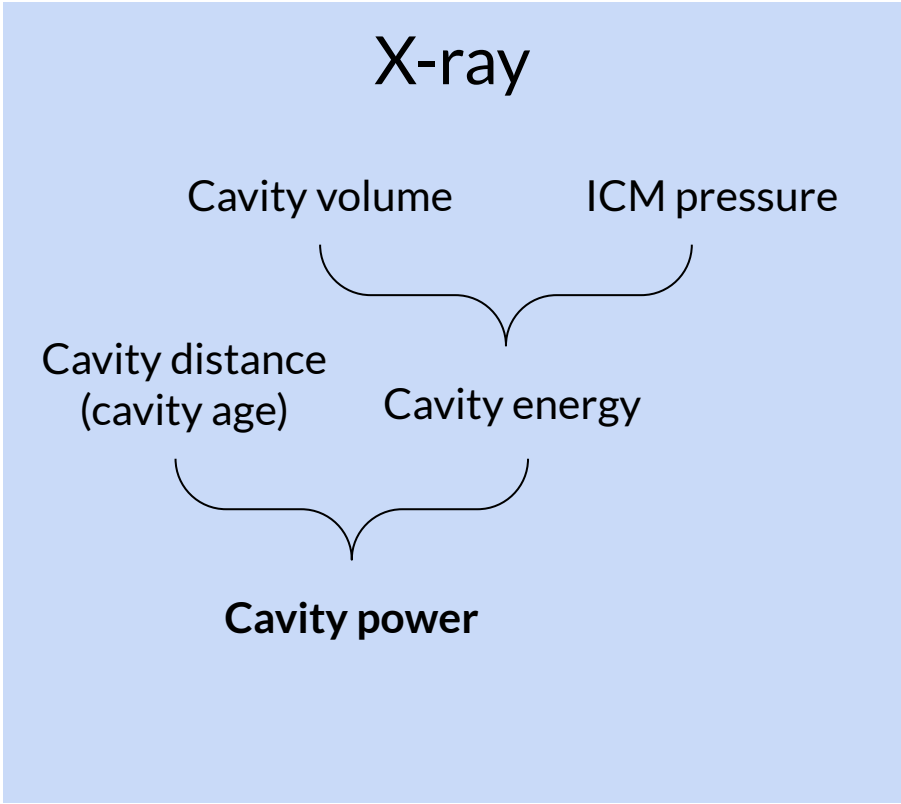


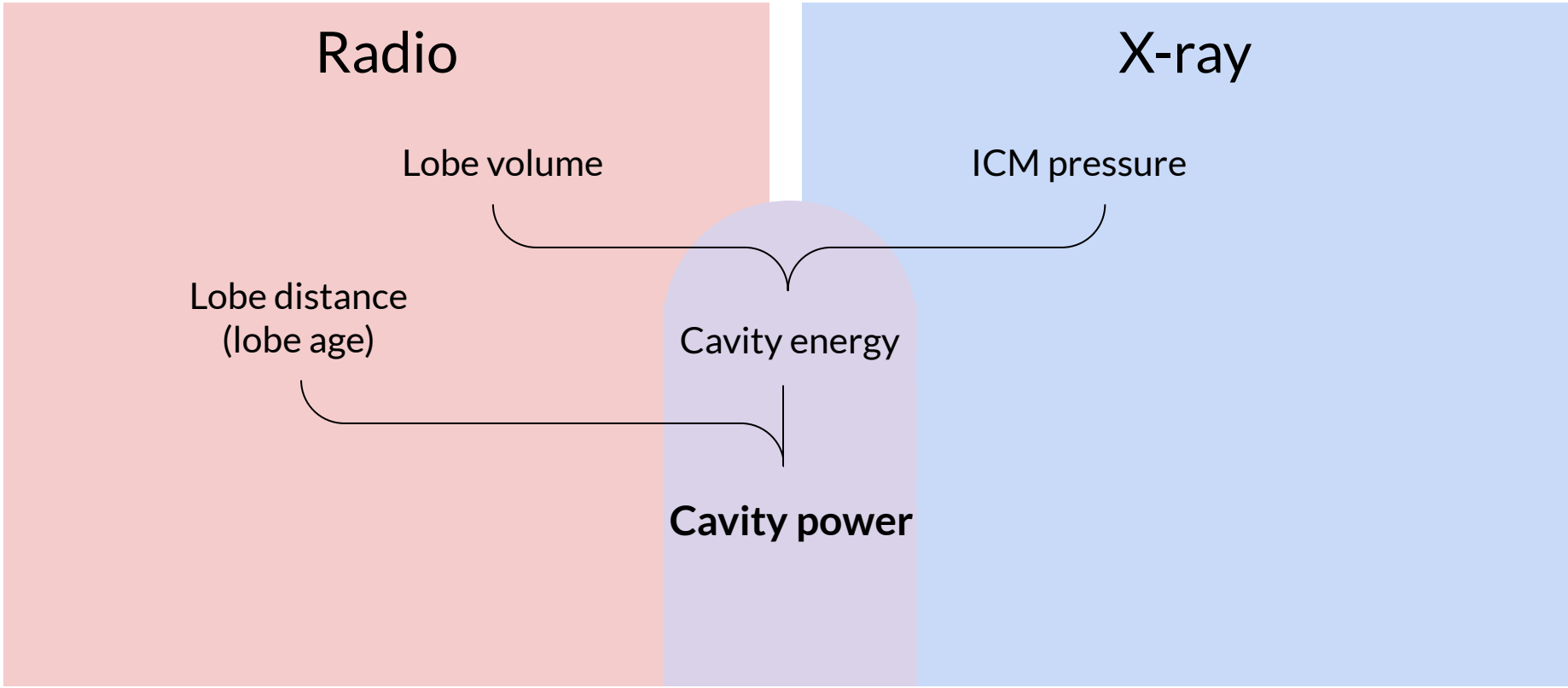


ZwCl 2701

The normal X-ray-based approach



The hybrid radio—X-ray approach



Low-redshift observations

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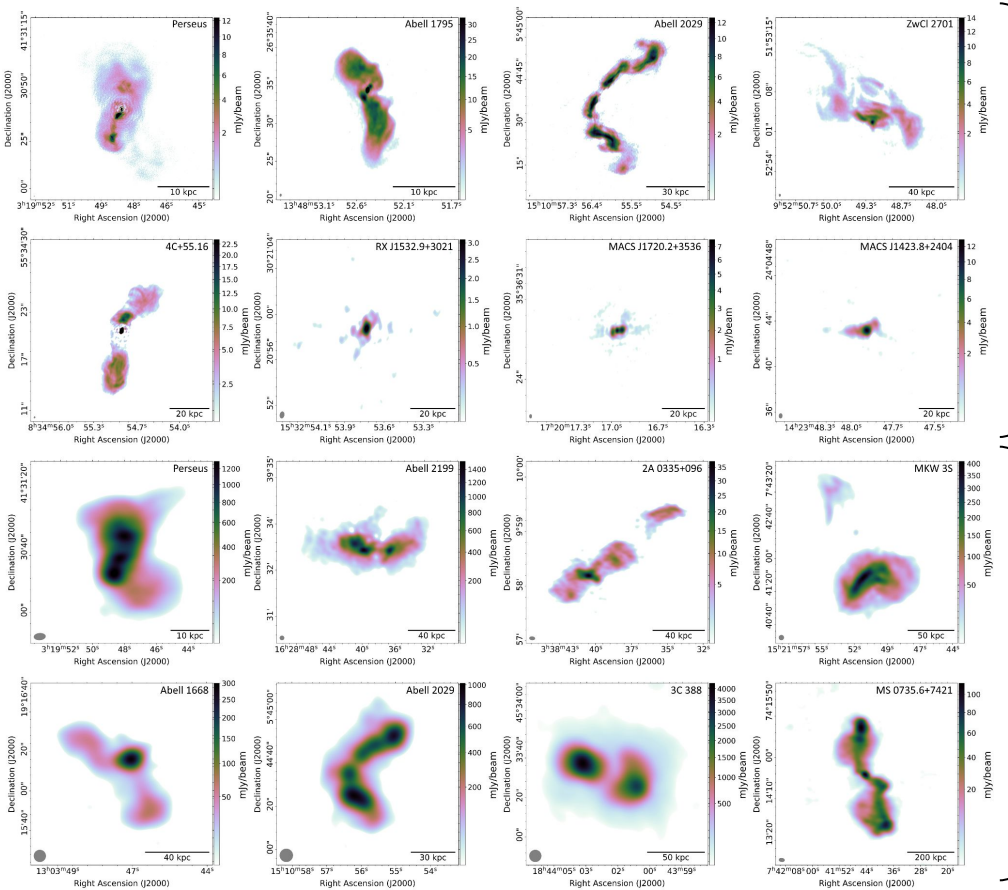
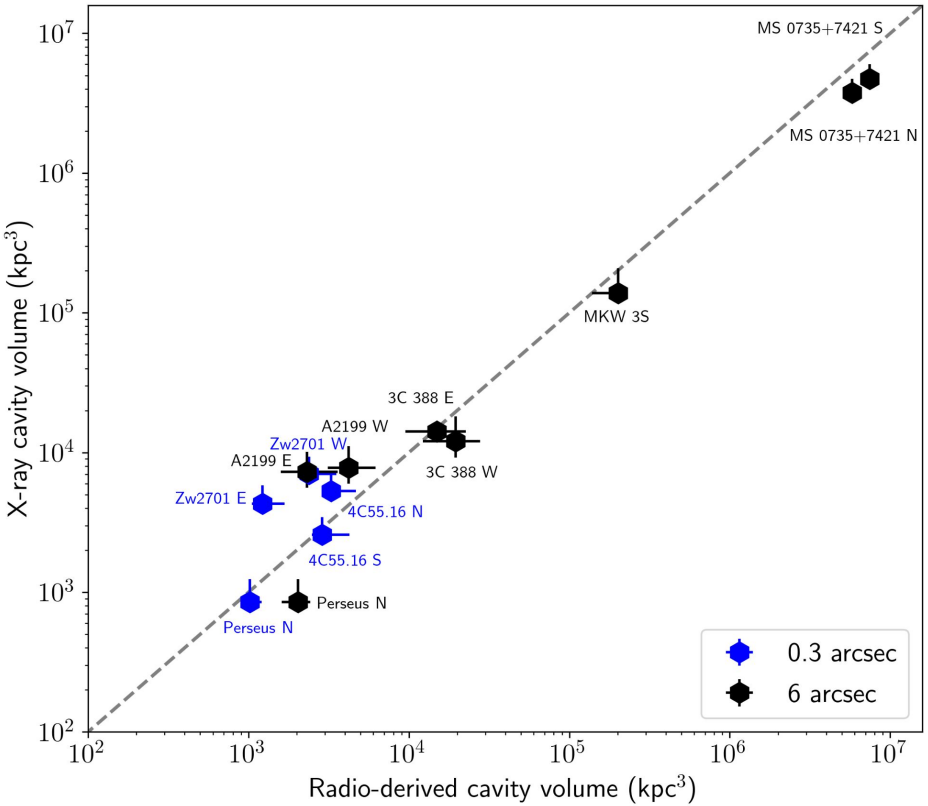


Cavity/lobe volume comparison



Selected cavities!

Overall **good** agreement

(**σ = 0.30 dex**)

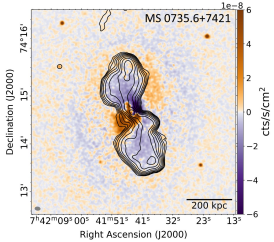
Previous monochromatic radio-based measurements resulted in **σ = 0.8 dex**

→ Low-frequency radio observations detect the **complete** radio lobes!

Further discussion points

Correlation **improves** with how well-defined cavities are

FOM = 2



σ = 0.34 dex

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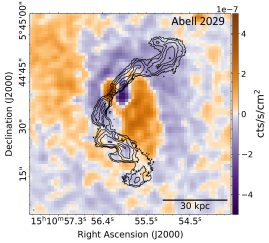

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Low-frequency radio lobes likely to be **valuable proxy**

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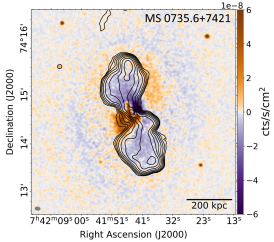

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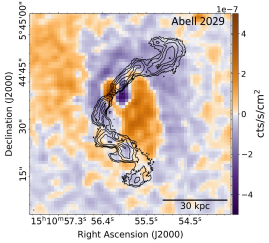

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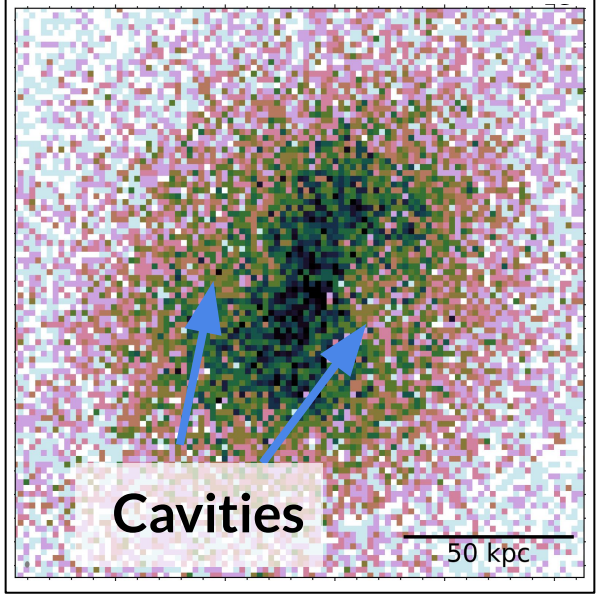
ZwCl 2701



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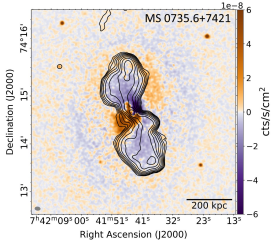

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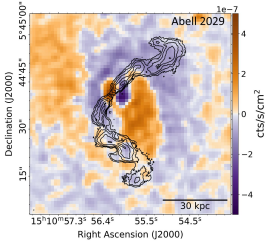

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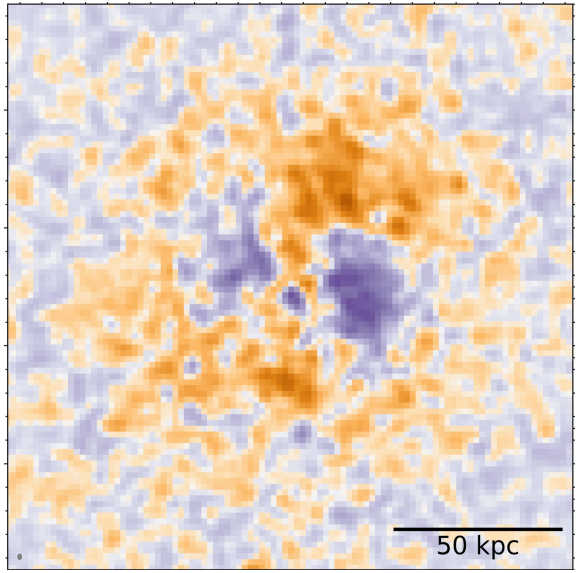

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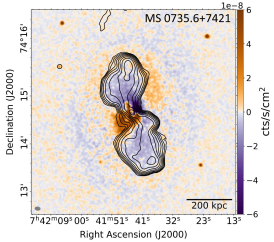

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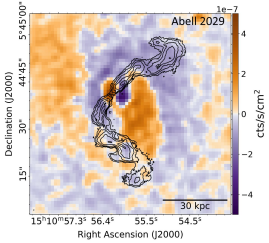

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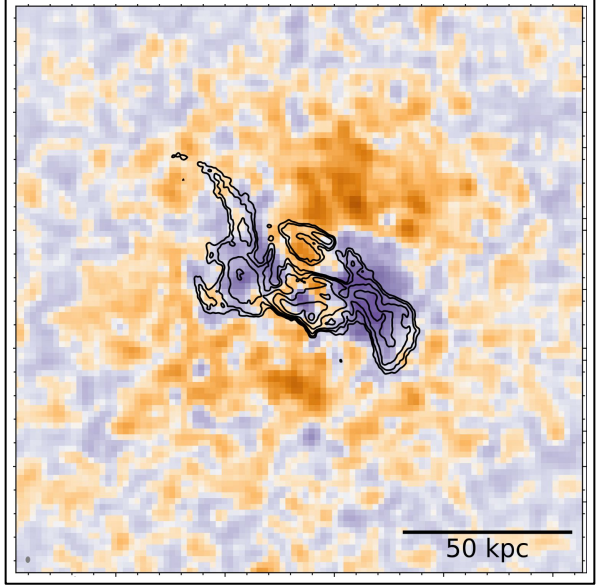

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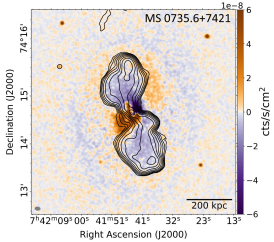

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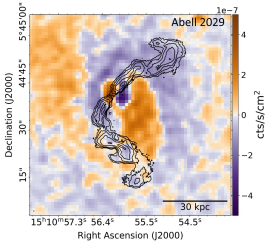

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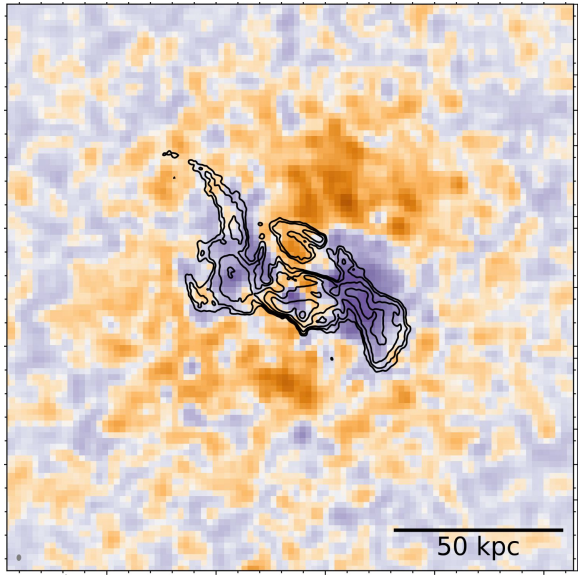
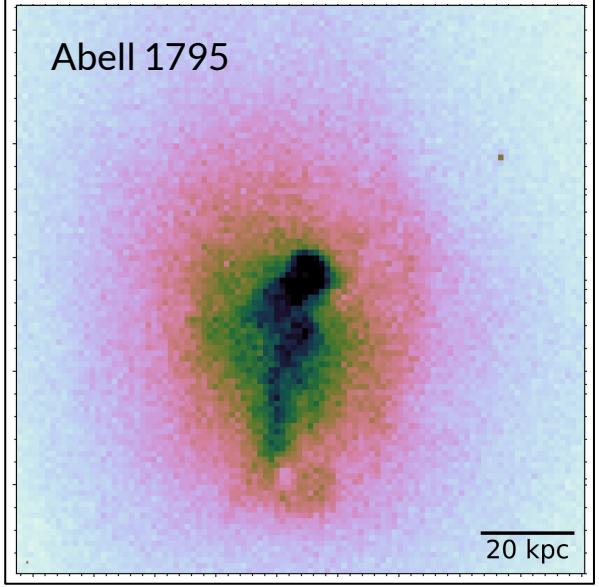


Radio lobes especially valuable with complex ICM structures



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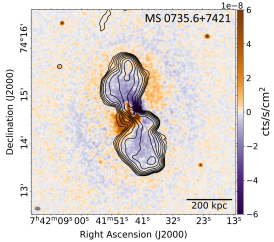

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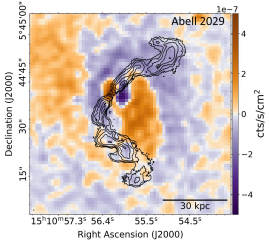

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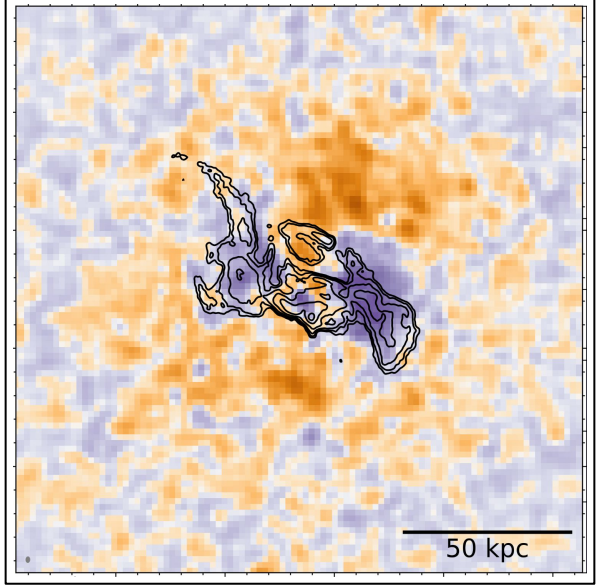

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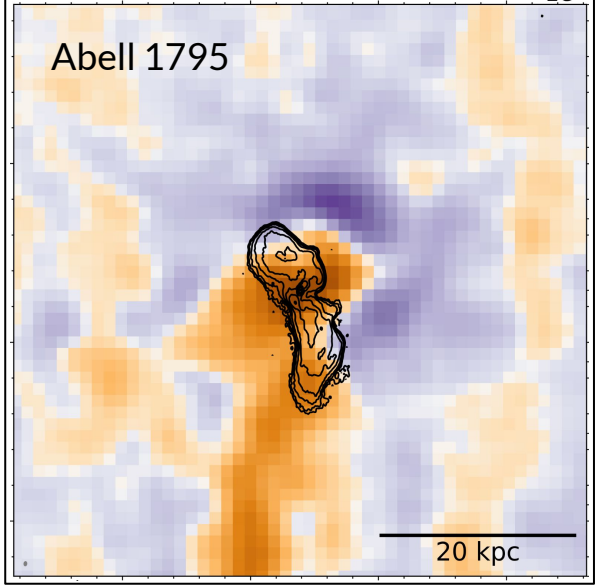


High-redshift observations

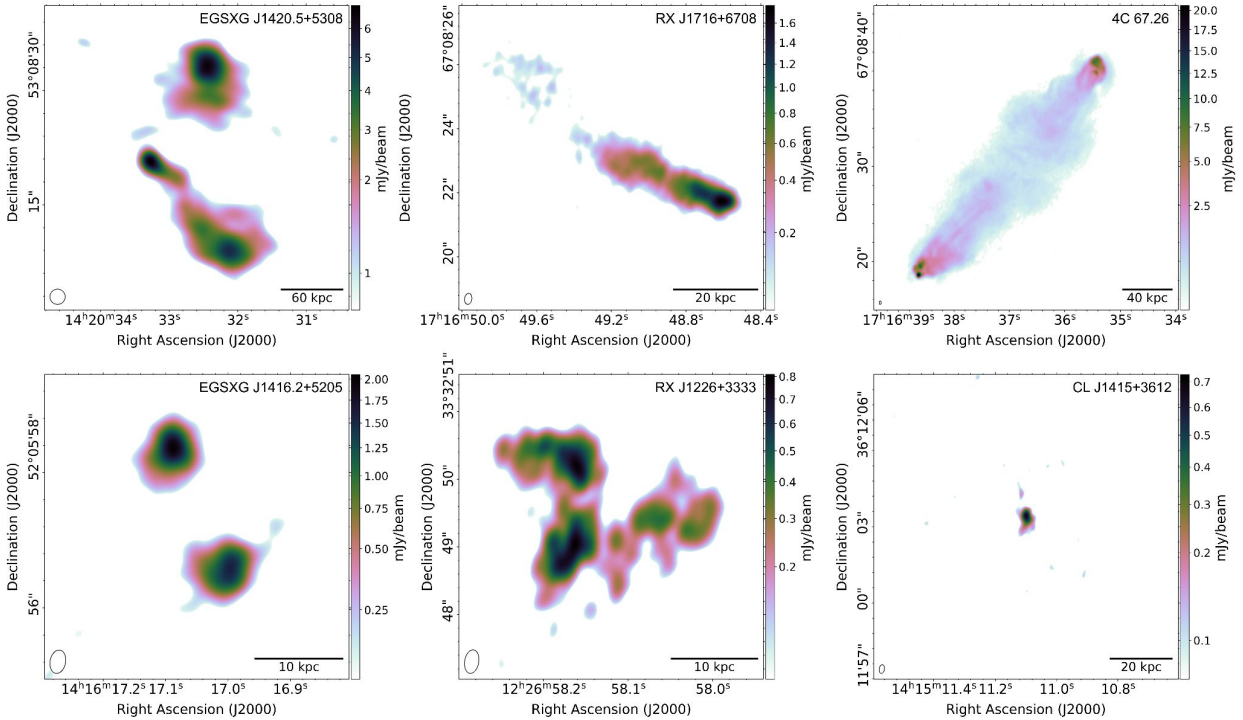
Sample:

- **13** cool-core clusters
- z > 0.6

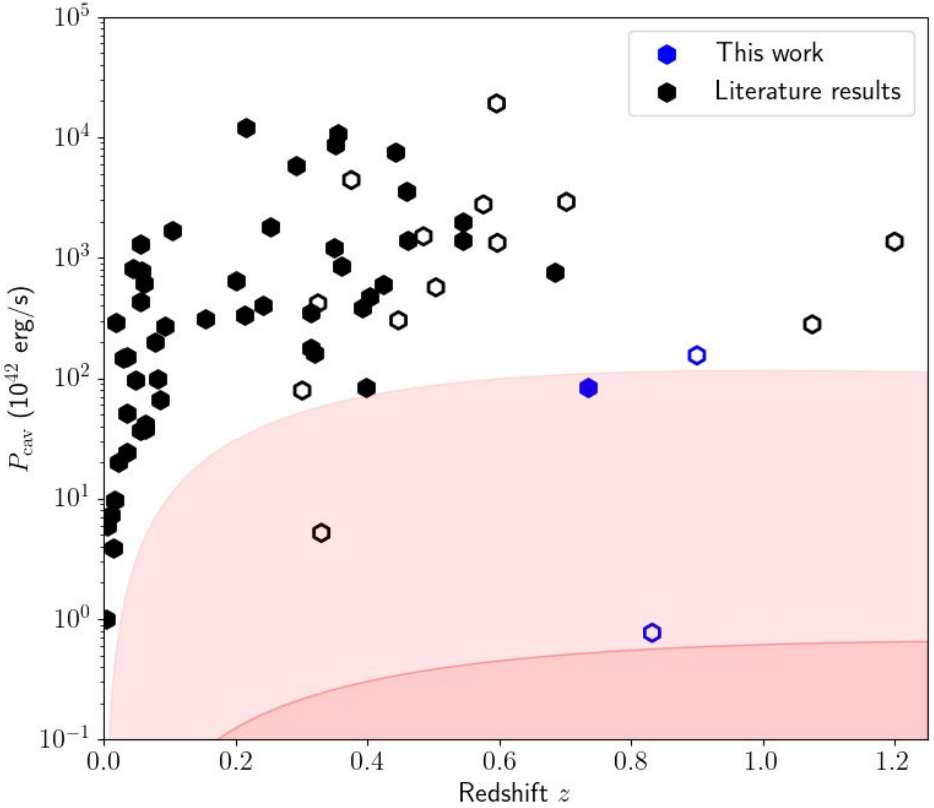
5 clusters with significant radio emission →
(+1 bright member galaxy)

3 central galaxies with clear radio lobes

→ **23%** success rate
(compared to **4.7%** based on previous X-ray observations)



Progress towards the high-redshift regime



6” limit

0.3” limit

Take-home messages

- Observing a large sample of targets with the ILT has been proven to be a realistic endeavour

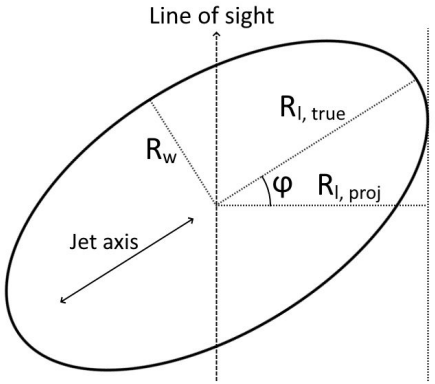
- The radio lobe ‘cavity’ volume measurements at 144 MHz are in good agreement with X-ray estimates, offering an additional opportunity to measure this quantity.

- **Recommendation** is to decide on a per-case basis whether to use X-ray cavities or radio lobes. **Follow the S/N!**

- We’ve started exploring the epoch of early formation and evolution of galaxy clusters!

Backup slides

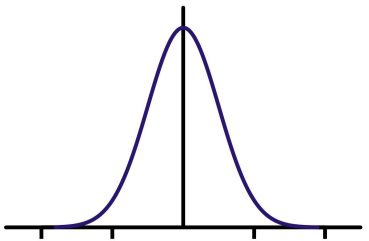
Projection-based uncertainties



Monte Carlo:

Projected dimensions → N guesses for line-of-sight angle → N “true” dimensions

True volume



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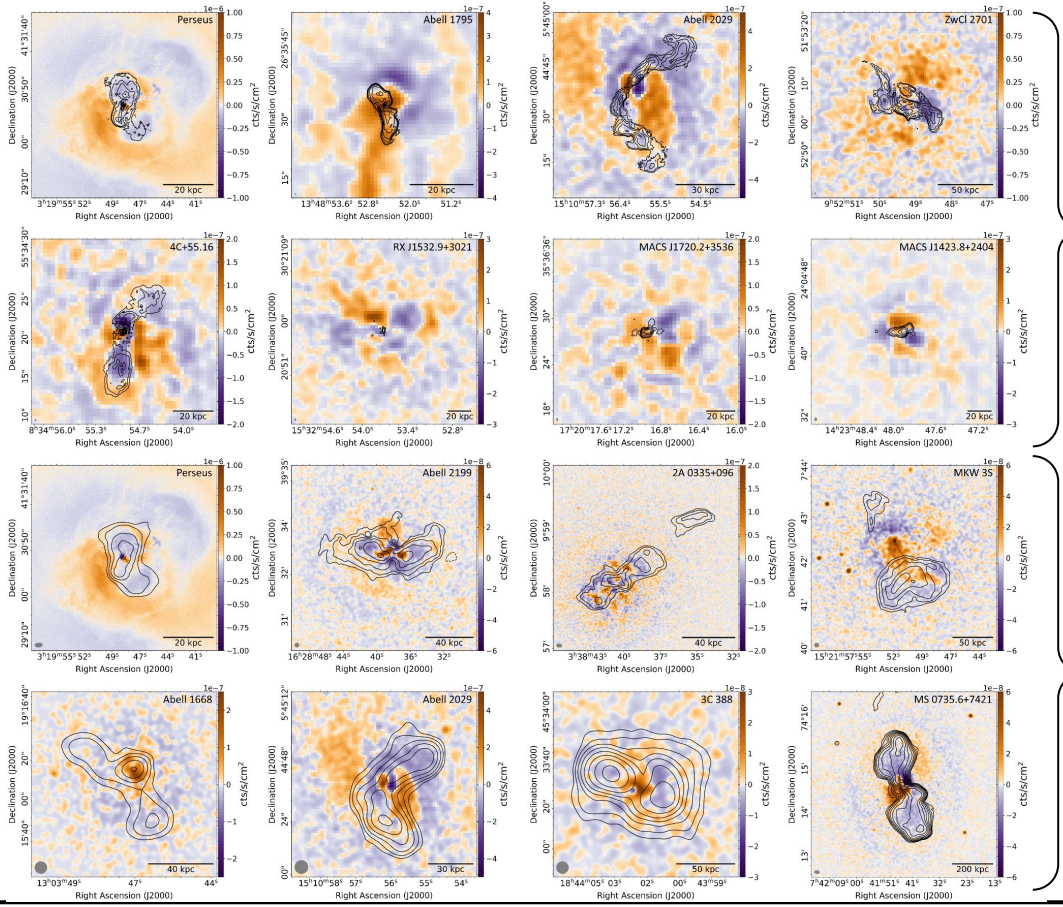

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