

29 November 2023, Catania - The Fourth National Workshop on the SKA project

Addressing the challenges of deep LOFAR observations of the Coma galaxy cluster

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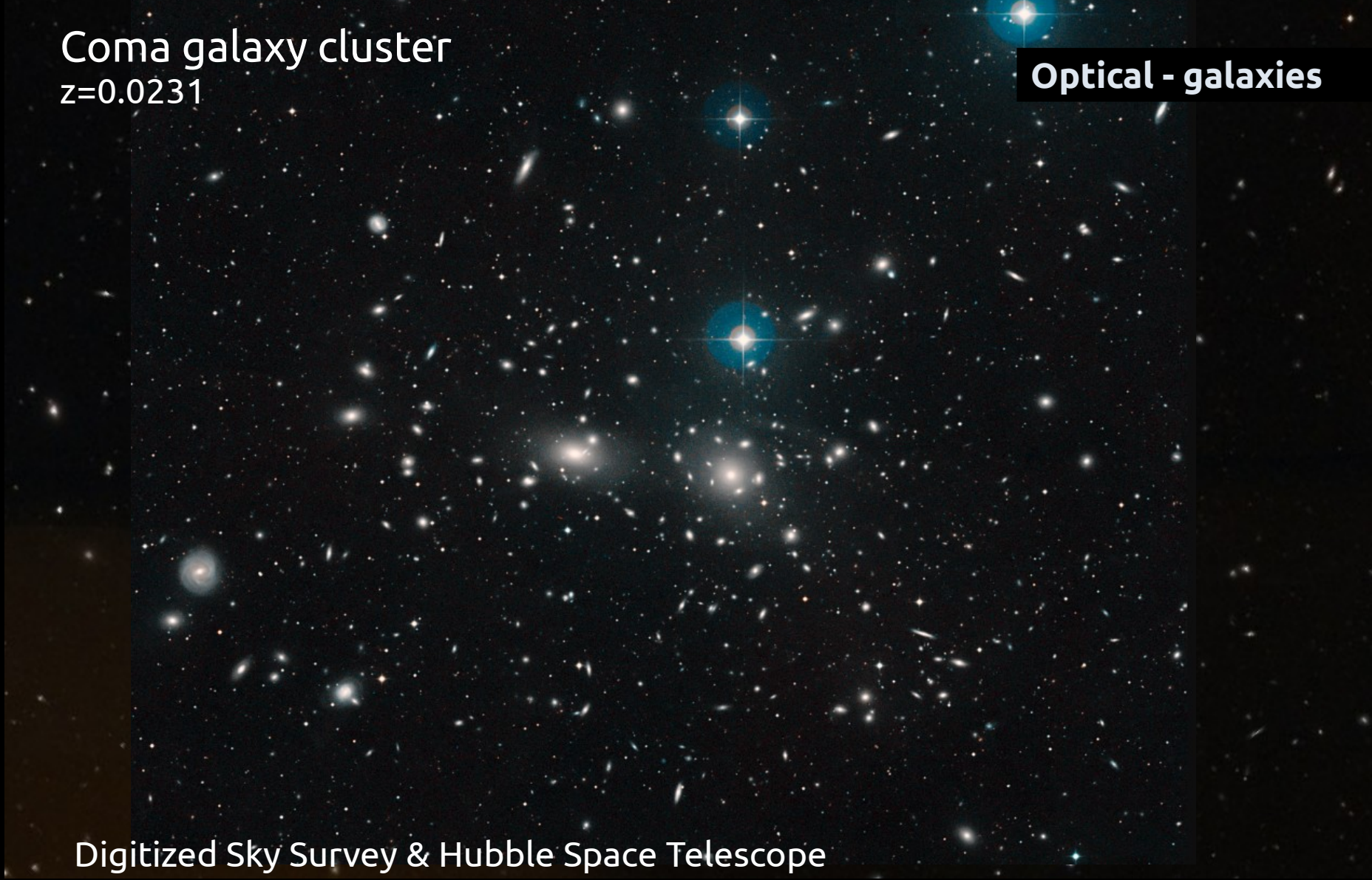
Collaborators: A. Bonafede, F. De Gasperin and many more

MIUR grant
FARE SMS

Coma galaxy cluster
 $z=0.0231$

Optical - galaxies

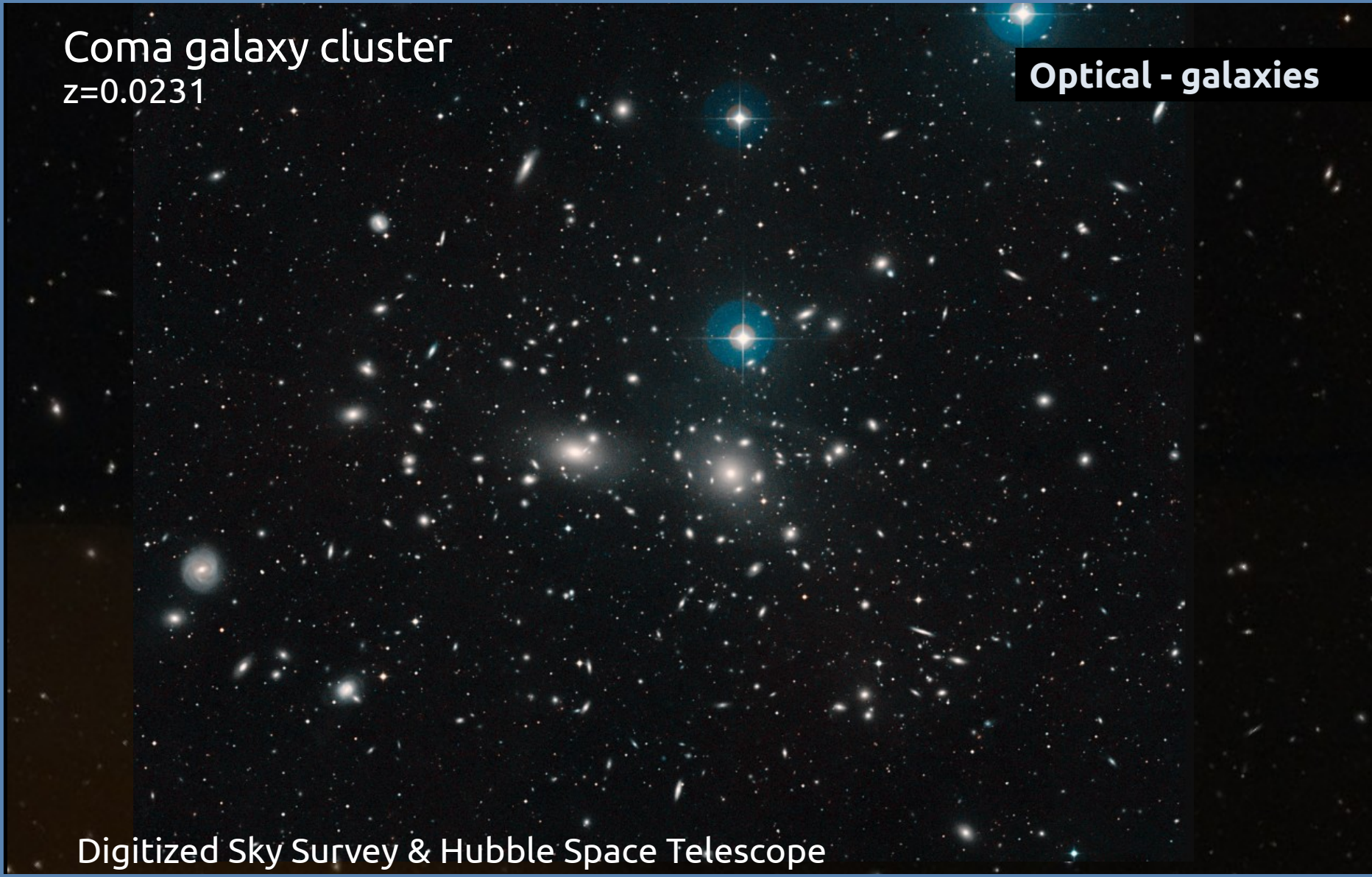
Digitized Sky Survey & Hubble Space Telescope



Coma galaxy cluster
 $z=0.0231$

Optical - galaxies

Digitized Sky Survey & Hubble Space Telescope



Coma galaxy cluster

$R_{500} \sim 47' \sim 1.32 \text{ Mpc}$

Optical - galaxies

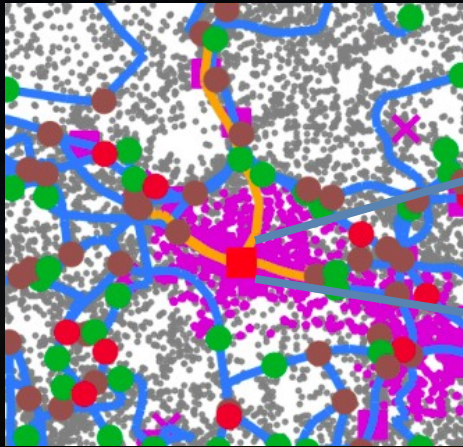


Coma galaxy cluster

$R_{500} \sim 47' \sim 1.32 \text{ Mpc}$

Optical - galaxies

Cross-road of cosmic
web filaments



Malavasi+20

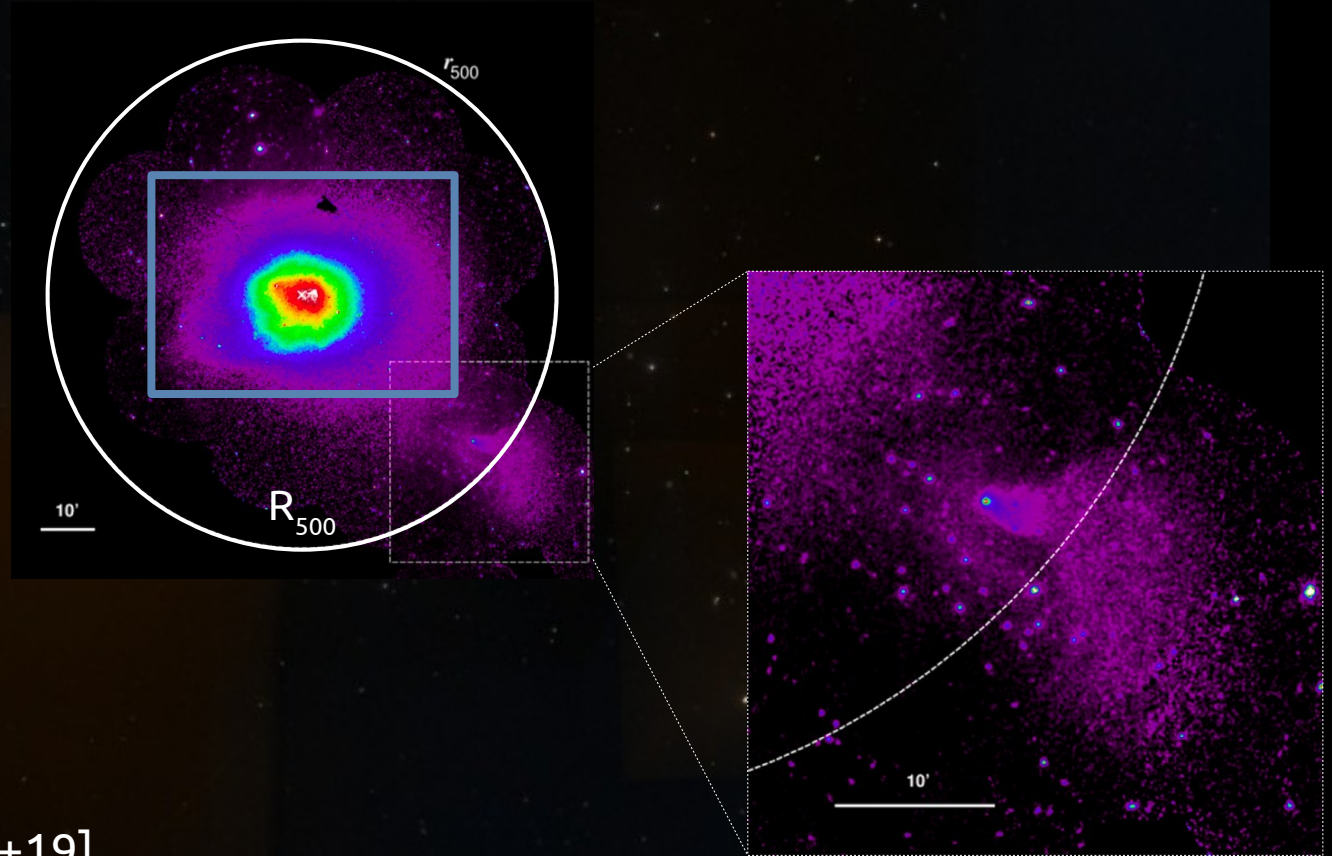


Digitized Sky Survey

Coma galaxy cluster

$M \sim 6 \times 10^{14} M_{\odot}$

Optical - galaxies
X-ray - Intra Cluster
Medium

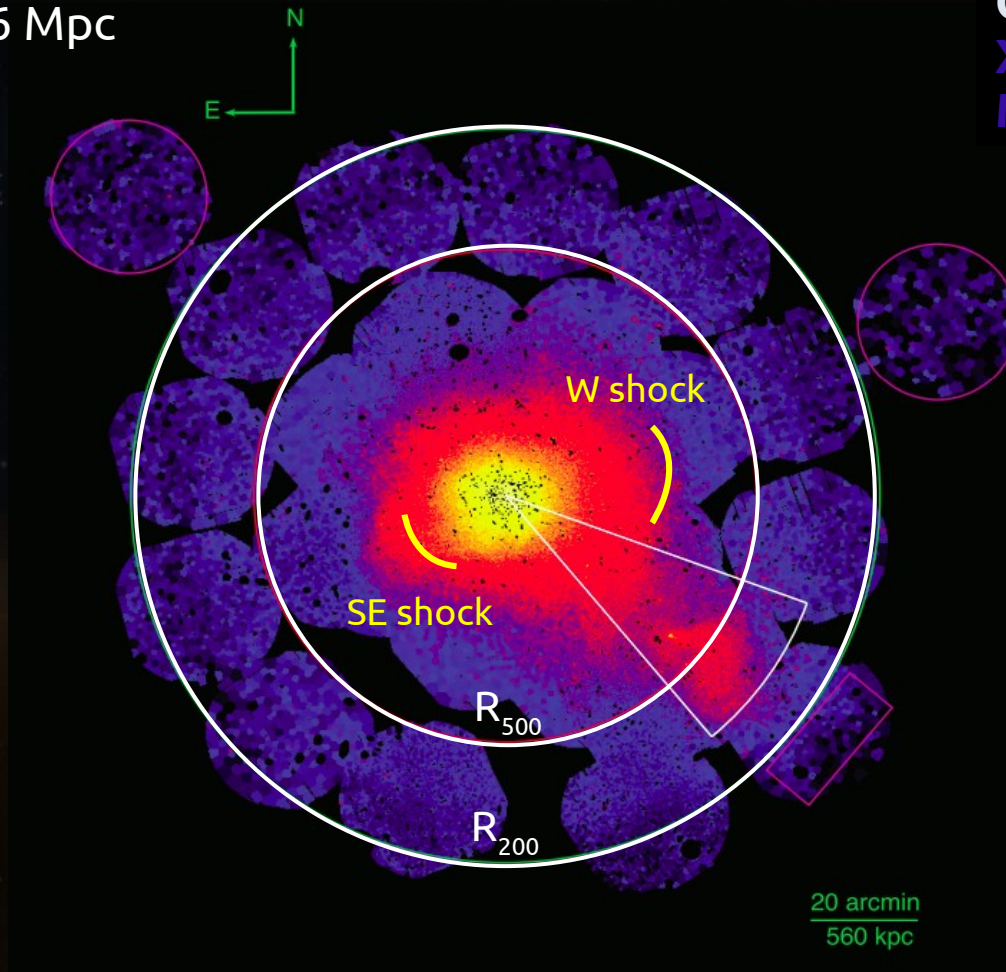


XMM-Newton [Lyskova+19]

Coma galaxy cluster

$R_{200} \sim 70' \sim 1.96 \text{ Mpc}$

Optical - galaxies
X-ray - Intra Cluster
Medium

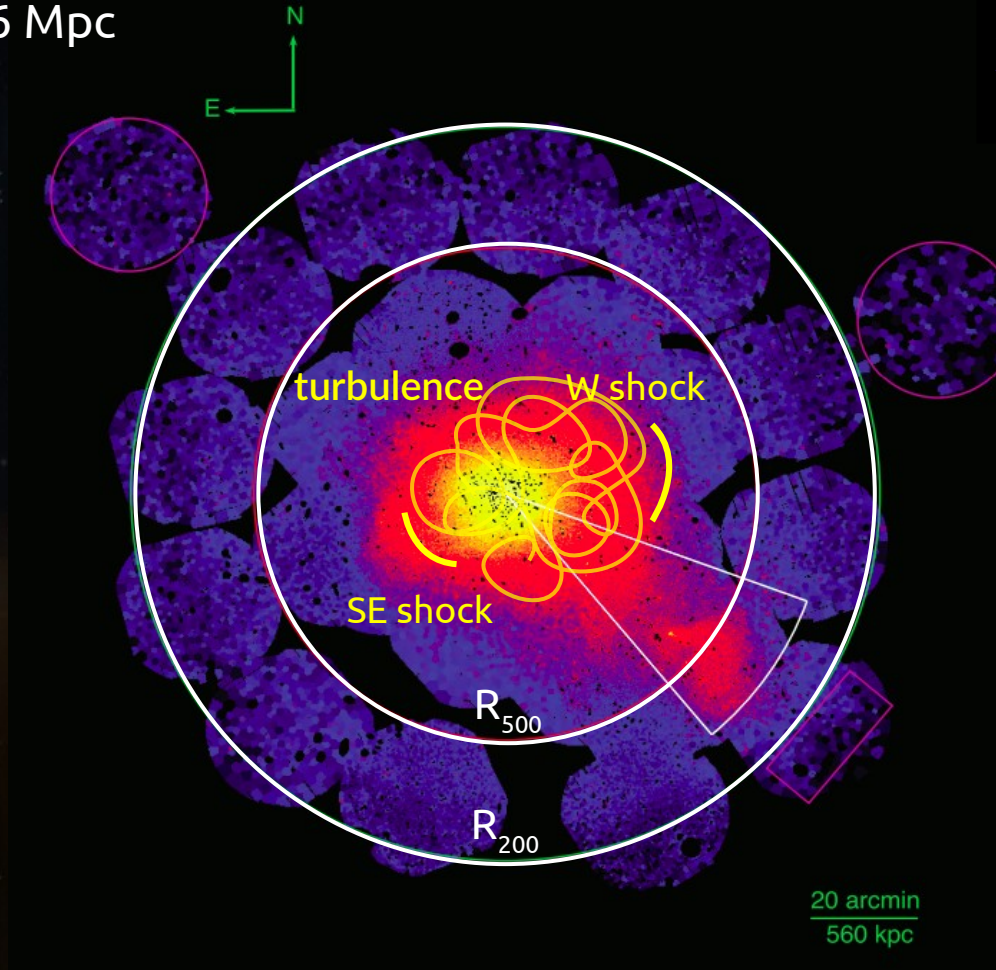


XMM-Newton [Mirakhor+20]

Coma galaxy cluster

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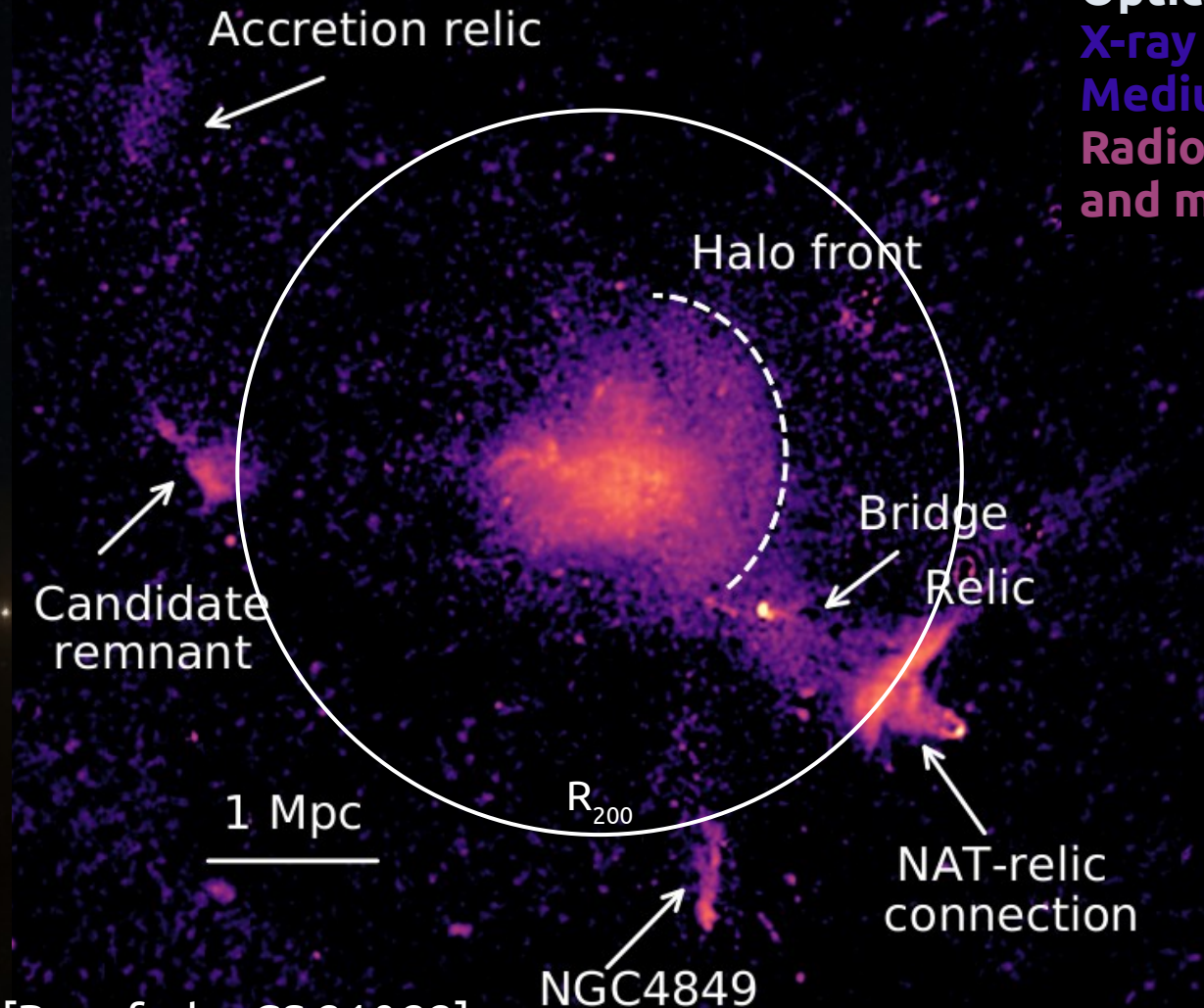
Optical - galaxies
X-ray - Intra Cluster
Medium



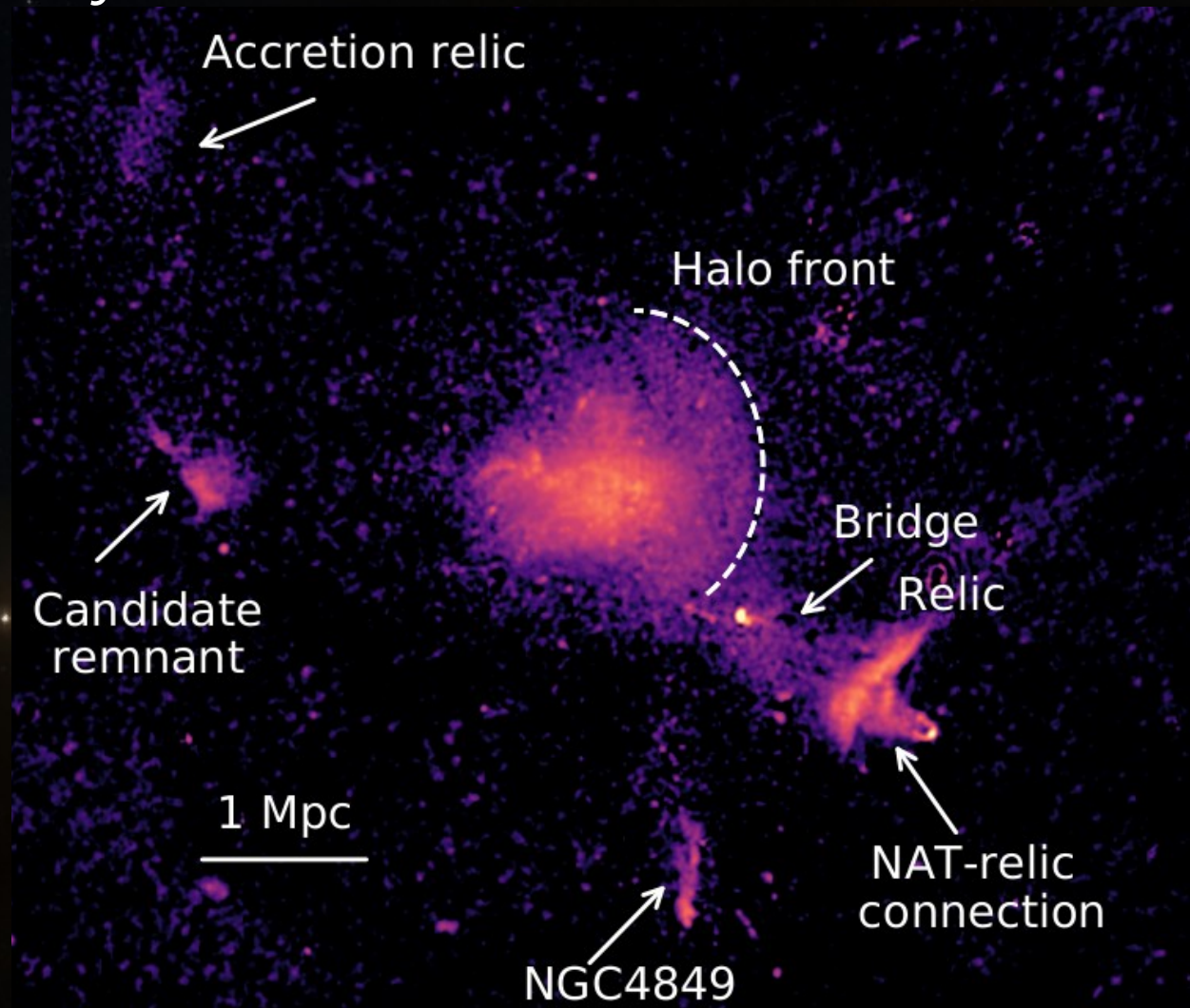
Accelerate
particles and
amplify
magnetic fields

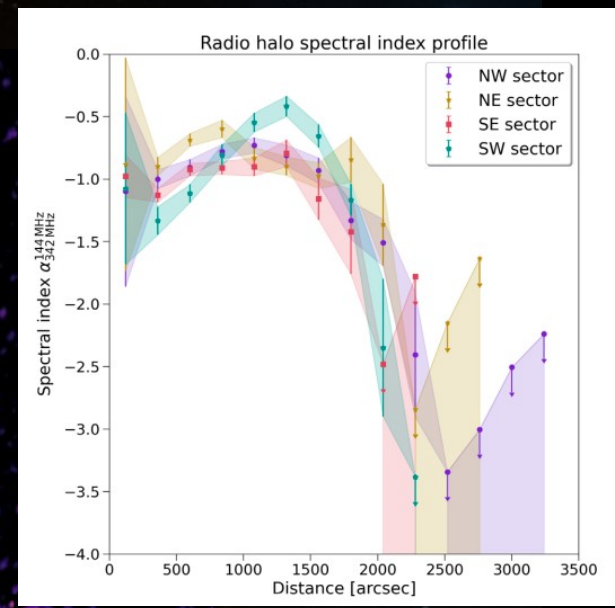
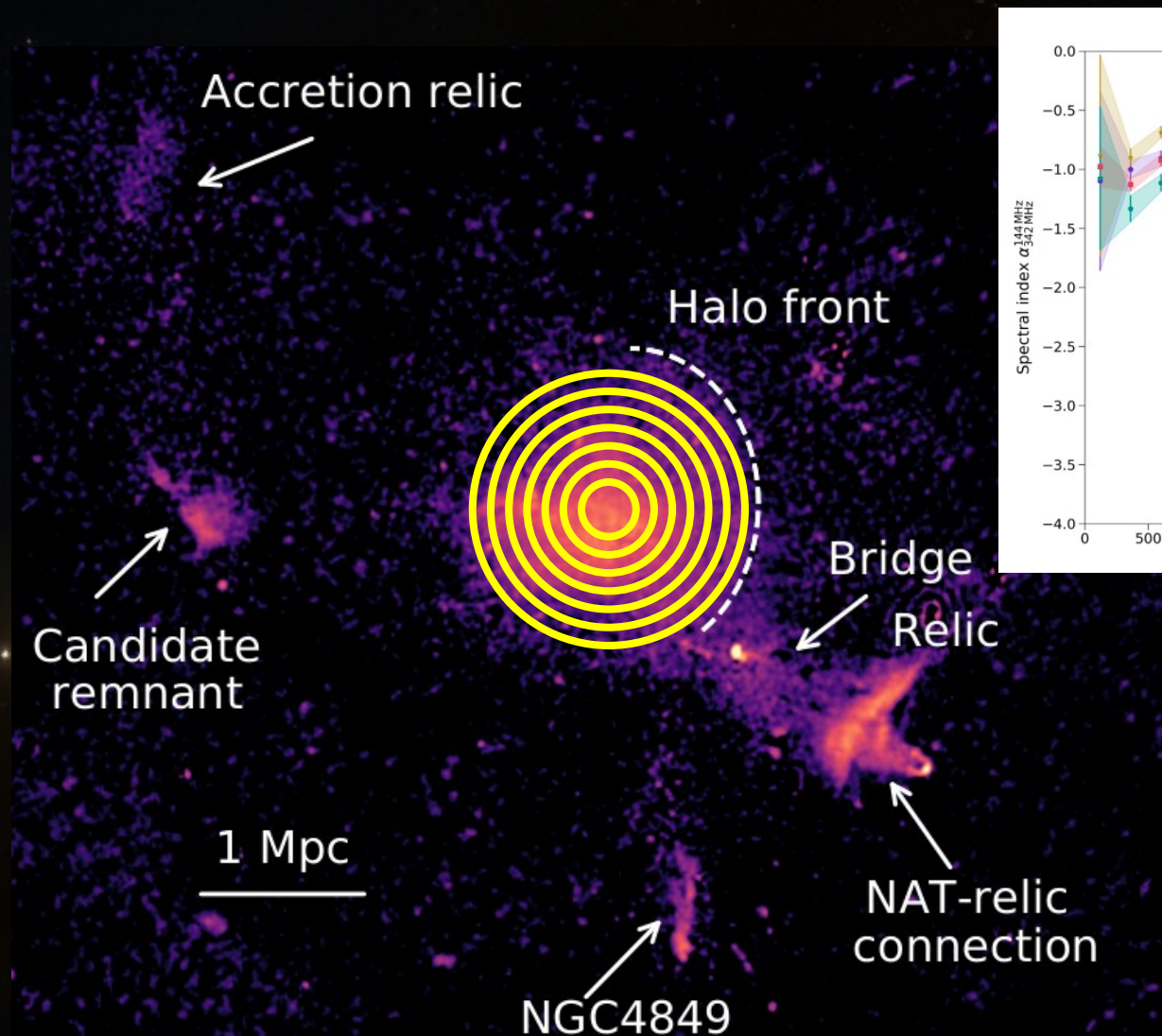
Coma galaxy cluster

Optical - galaxies
X-ray - Intra Cluster Medium
Radio - cosmic-rays and magnetic field

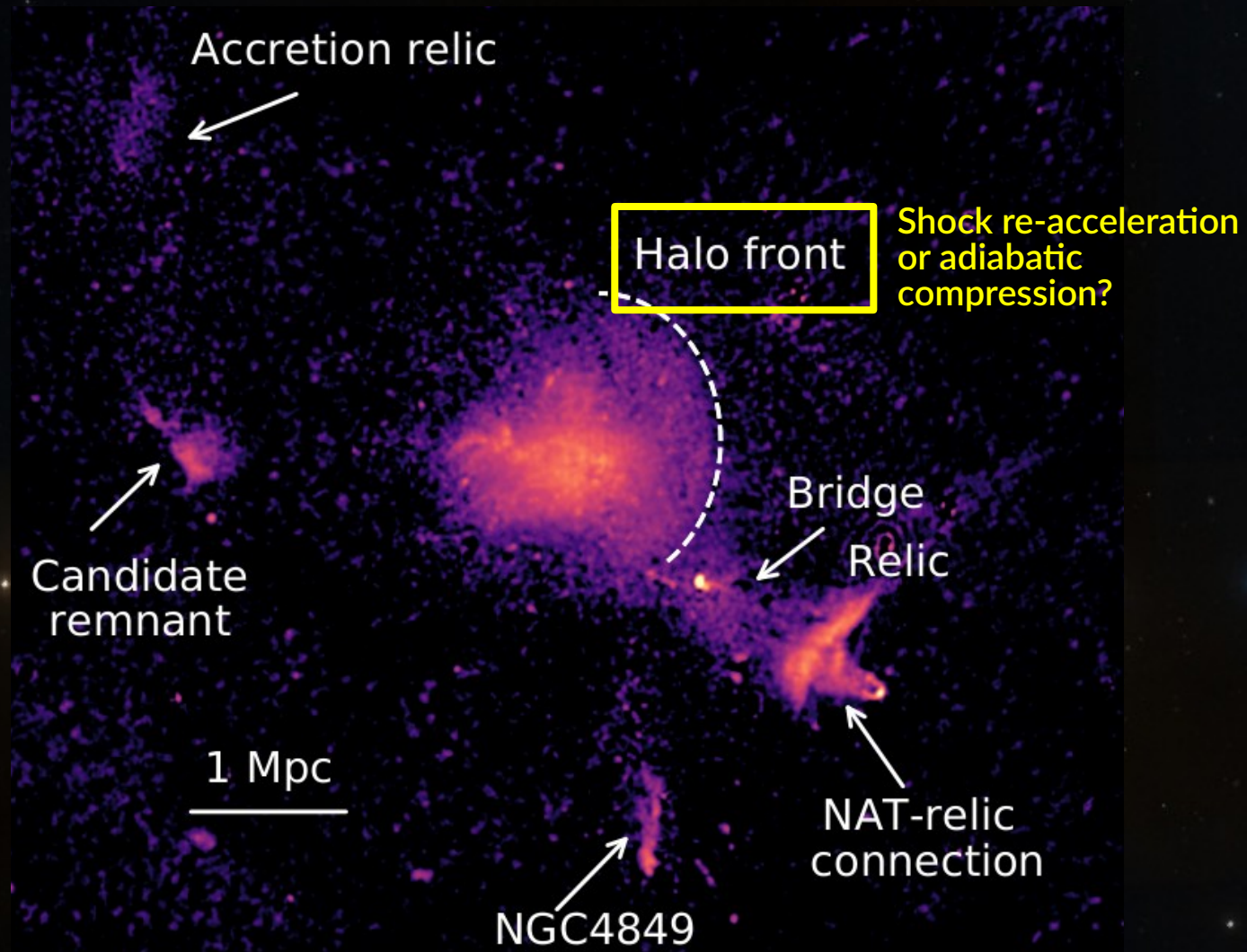


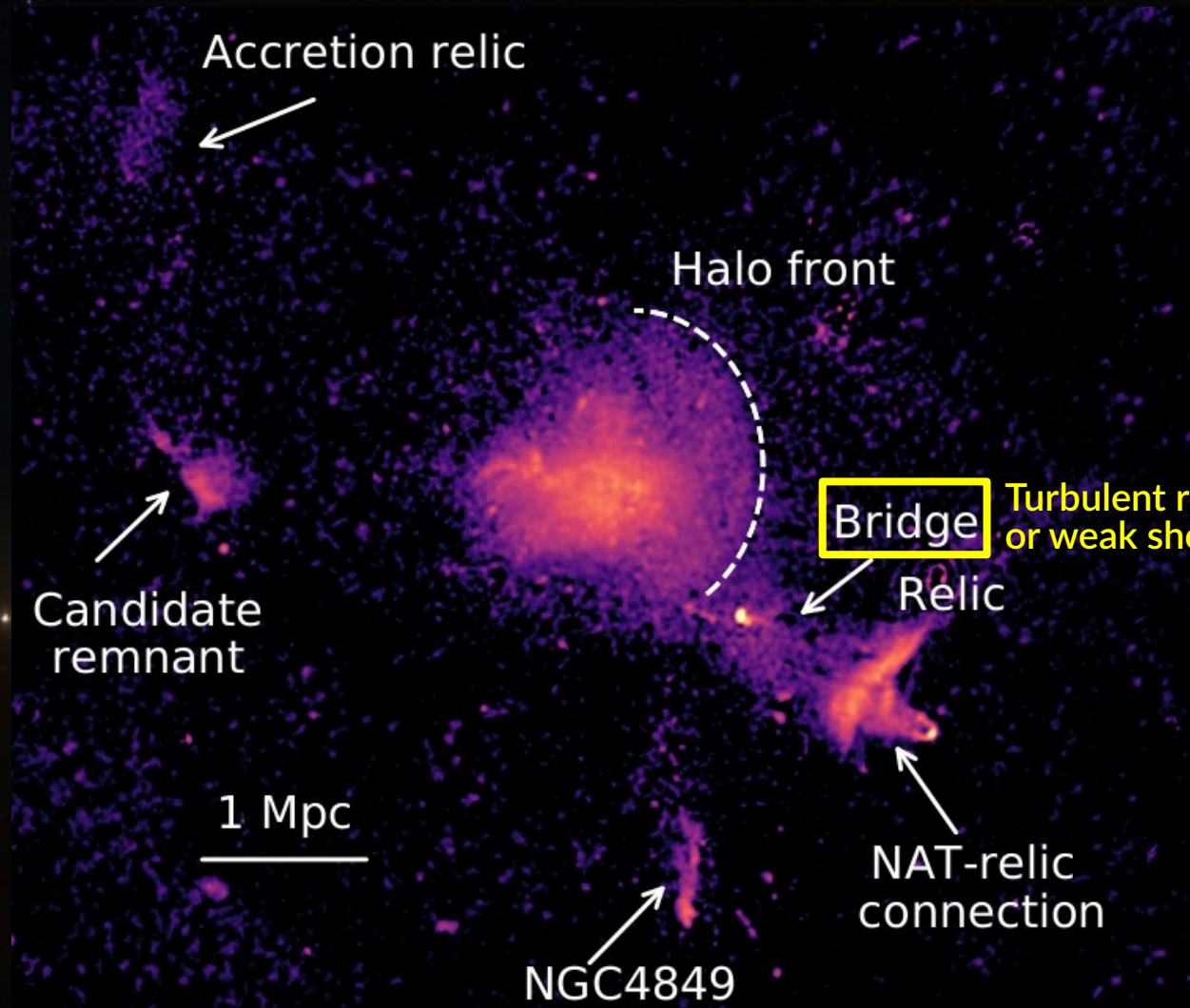
Coma galaxy cluster





Solenoidal or compressive turbulence?

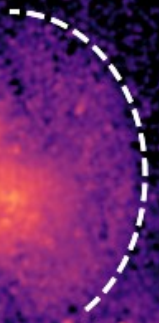




Accretion relic



Halo front



Candidate remnant



Bridge

Turbulent re-acceleration or weak shocks?

Relic



1 Mpc

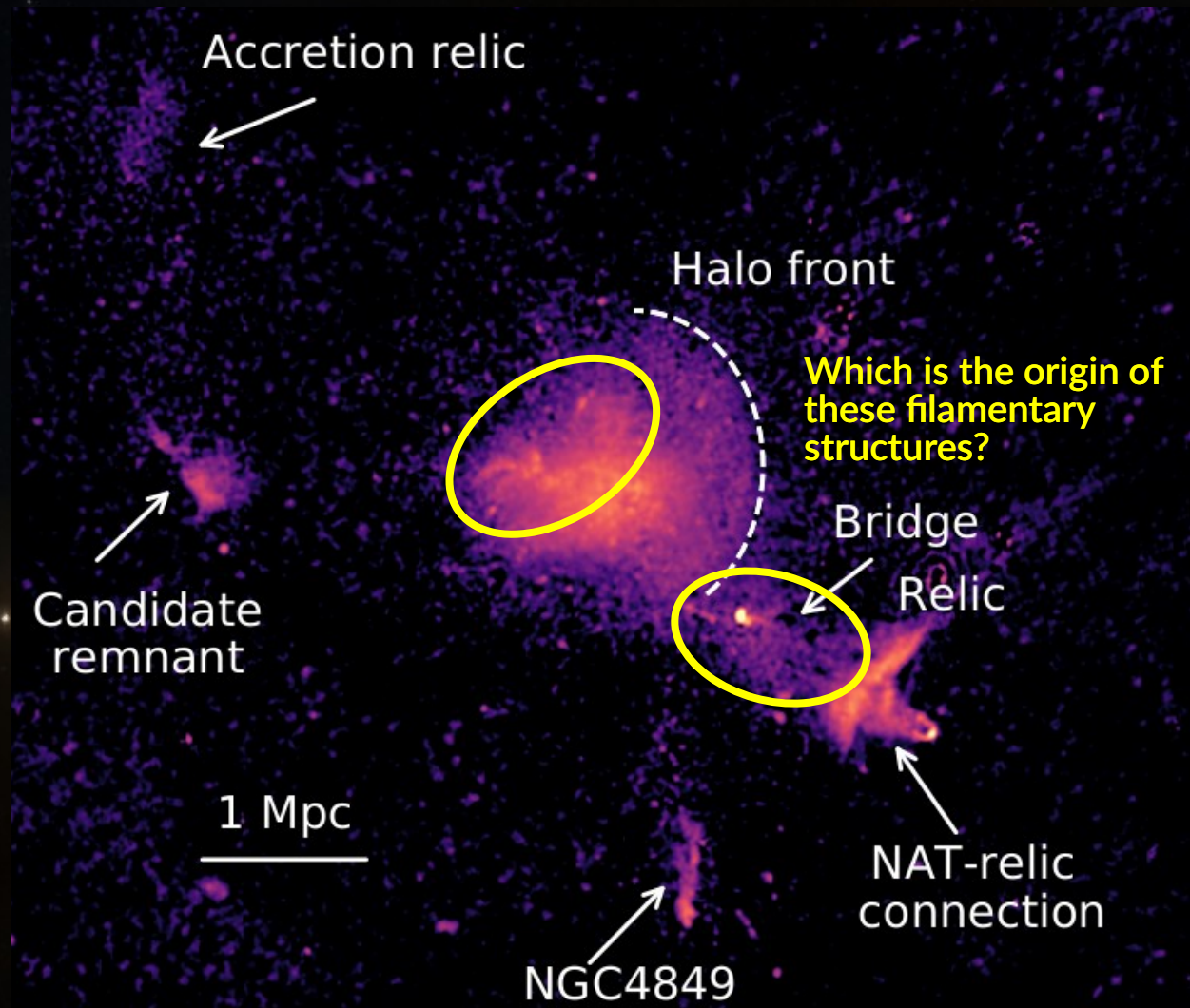


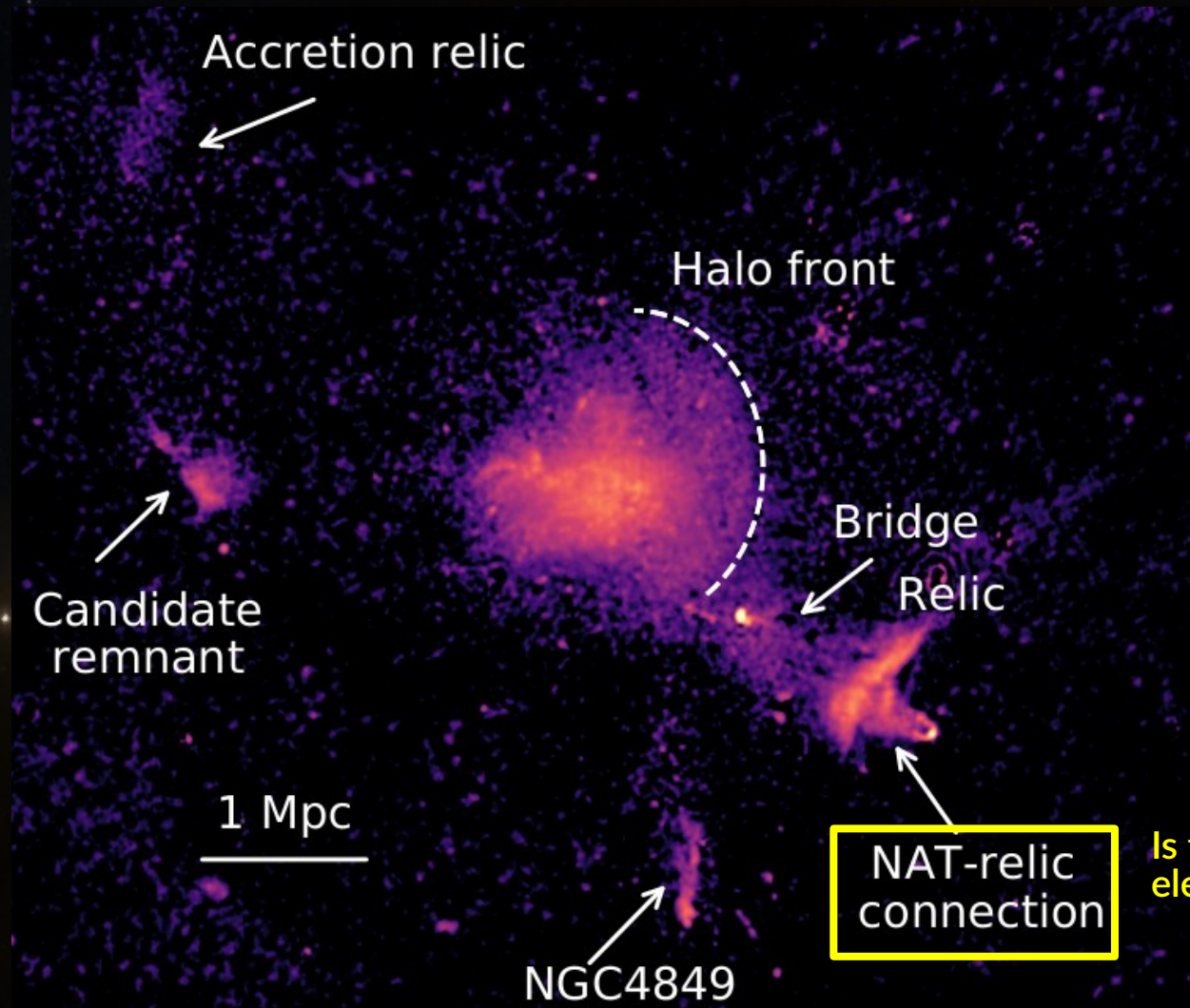
NAT-relic connection



NGC4849



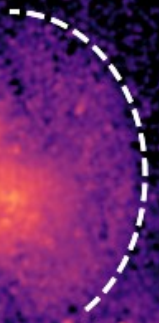




Accretion relic



Halo front



Candidate remnant



Bridge
Relic



NAT-relic connection

1 Mpc

NGC4849

Is the AGN furnishing electrons to the relic?

Which is the origin of these external structures?

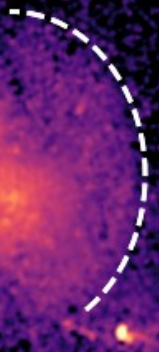
Accretion relic



Candidate remnant



Halo front



Bridge Relic



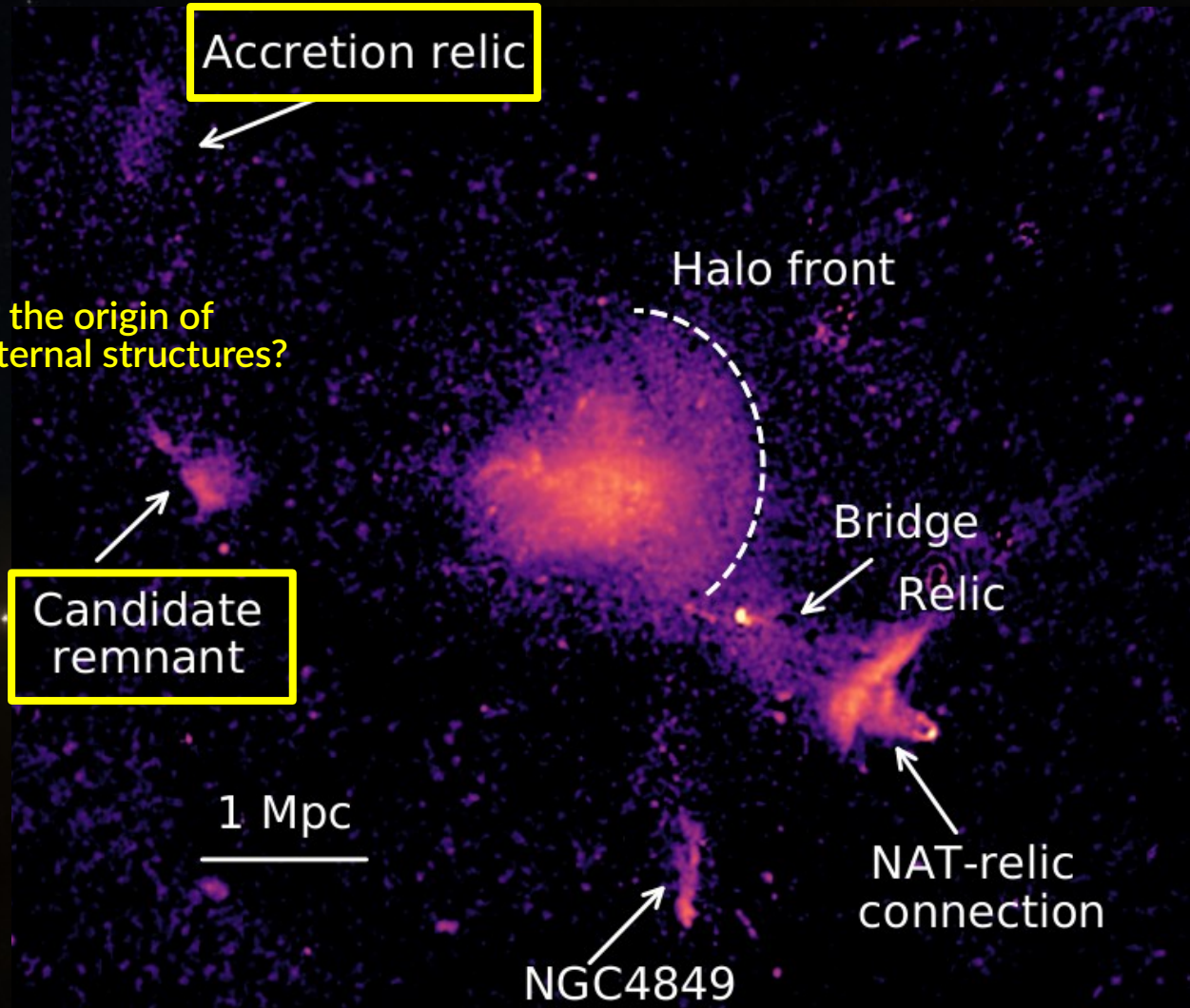
1 Mpc



NAT-relic connection



NGC4849



An in-deep view of the Coma cluster at 54 MHz with LOFAR

- 108 hours with LBA @ 54 MHz
- Aim: detailed spectral index study (in combination with HBA)
 - halo
 - halo front
 - bridge
 - accretion relic

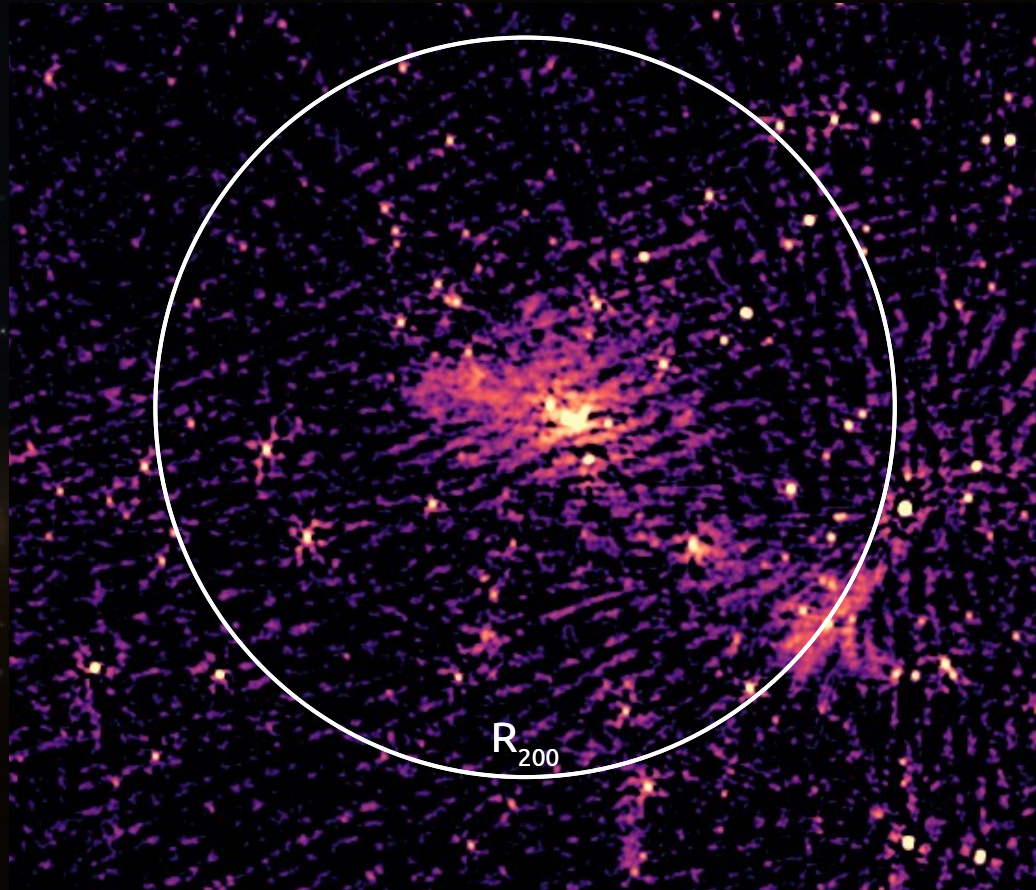
An in-deep view of the Coma cluster at 54 MHz with LOFAR

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Addressing the challenges
of deep LOFAR observations
of the Coma galaxy cluster

The starting point: LOFAR LBA Sky Survey

[De Gasperin+, 21&23]



Data processing
with LiLF
([https://github.com/
revoltek/LiLF](https://github.com/revoltek/LiLF))

On a LOFAR
dedicated node
with 512 GB RAM
and 2x64 cores

3 hours
beam: 60 arcsec
rms: 12 mJy/beam

LOFAR **LBA** from LoLSS (1 deg from pointing center)

I challenge: download the data

→ 40 days (20 each for the calibrator and Coma)



I challenge: download the data

→ 40 days (20 each for the calibrator and Coma)

II challenge: select the data

Direction independent calibration in chunks of 6 hours (16 hours x 19)



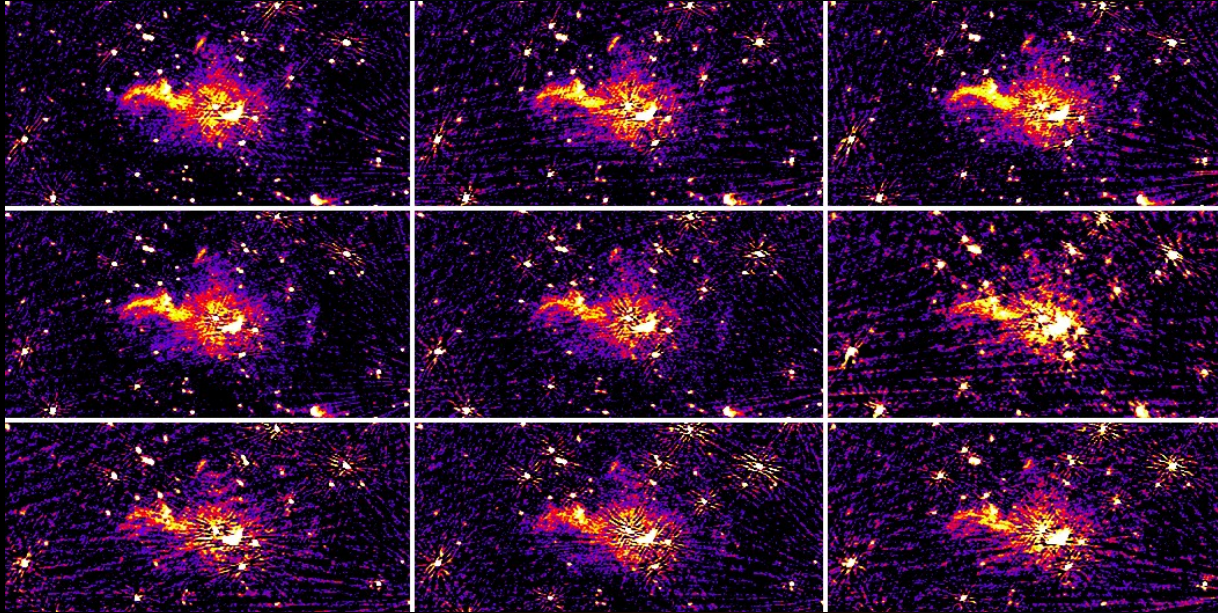
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1 hour DI calibrated images



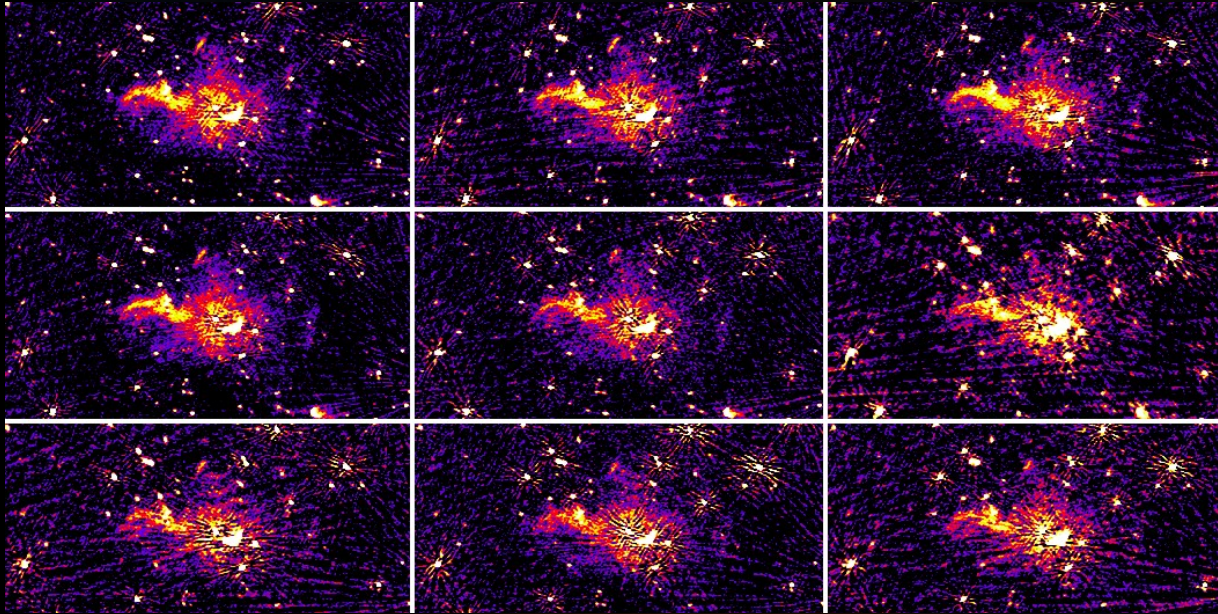
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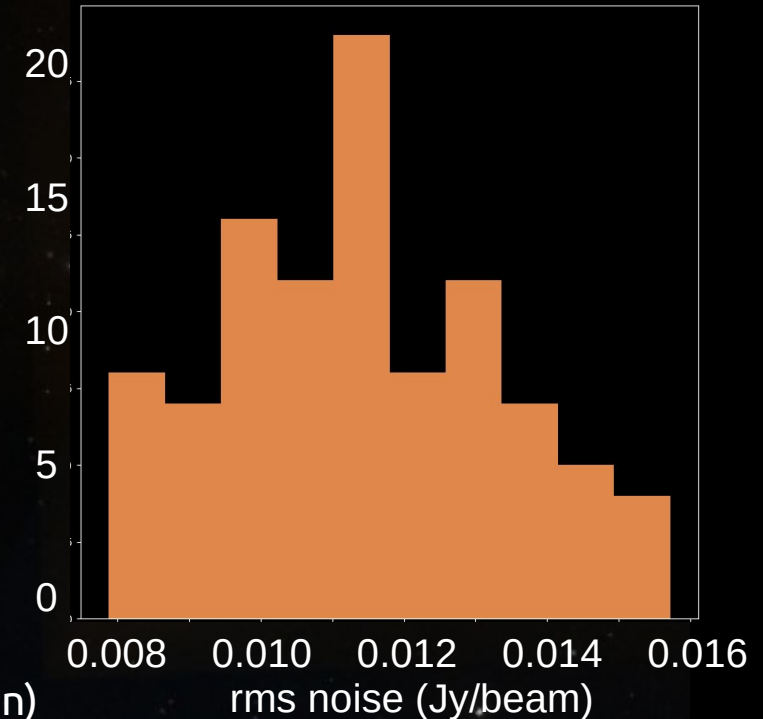
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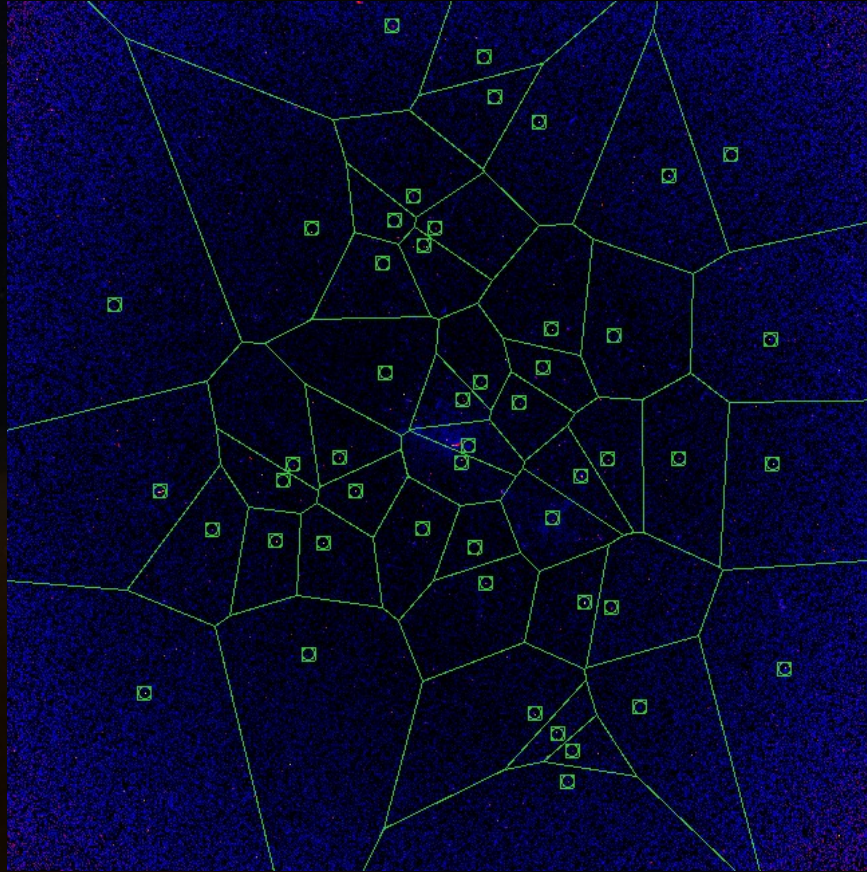
1 hour DI calibrated images



→ 80 hours with rms < 14 mJy/beam (under consideration)

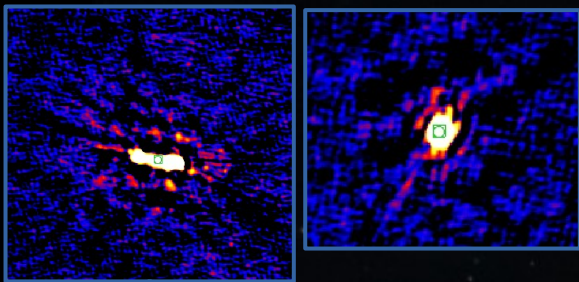


III challenge: direction dependent calibration (starting from the best 8 hours)

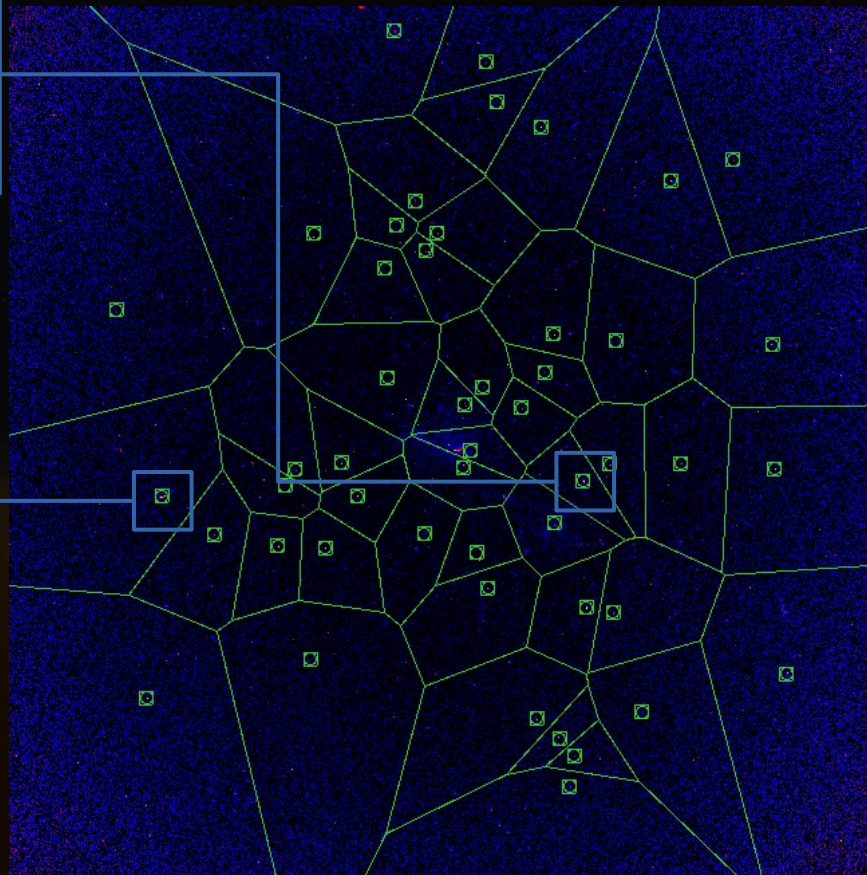


(1 week x 10)

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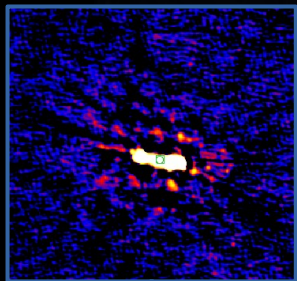


Two 3C sources
in the field

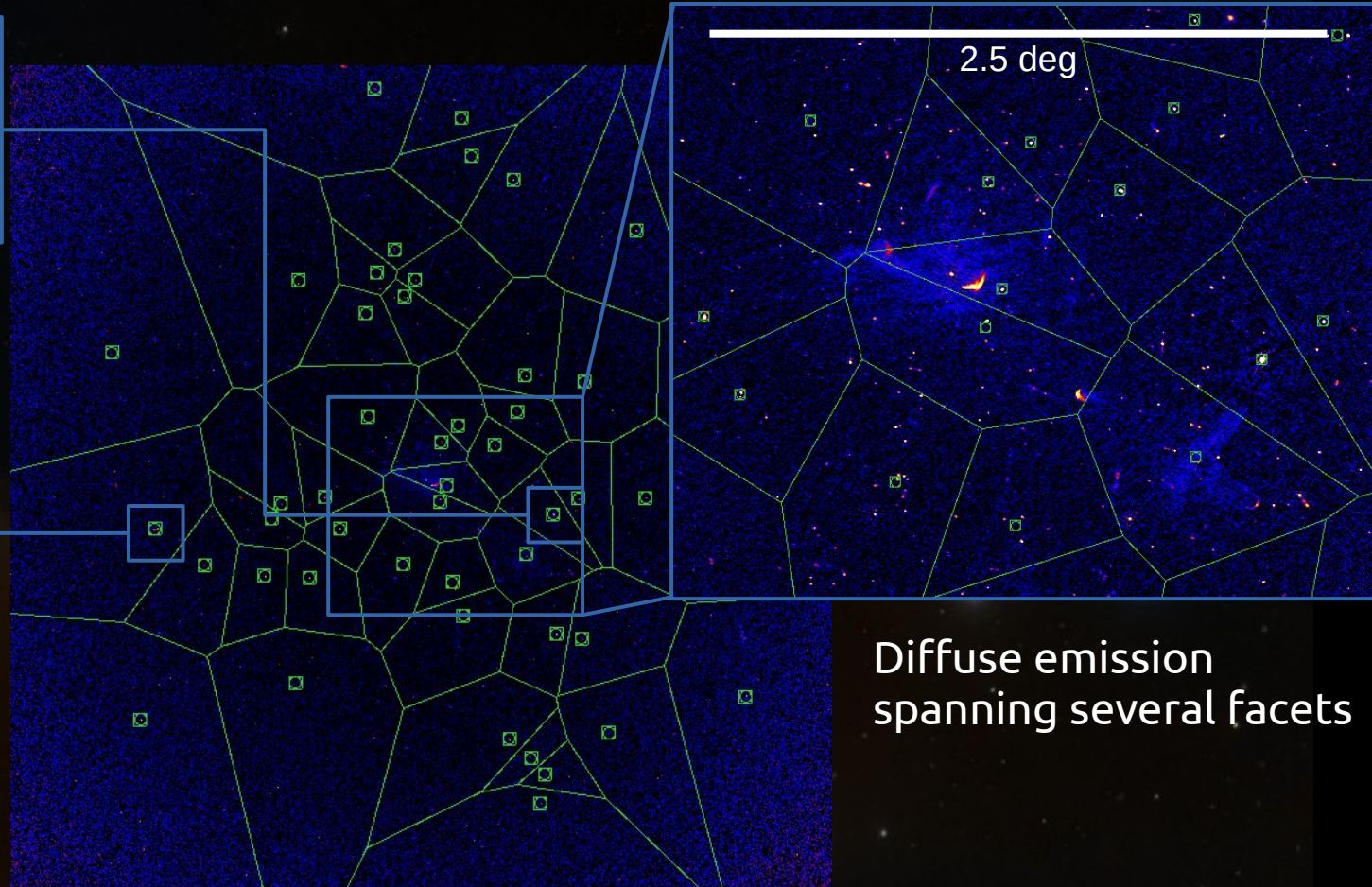


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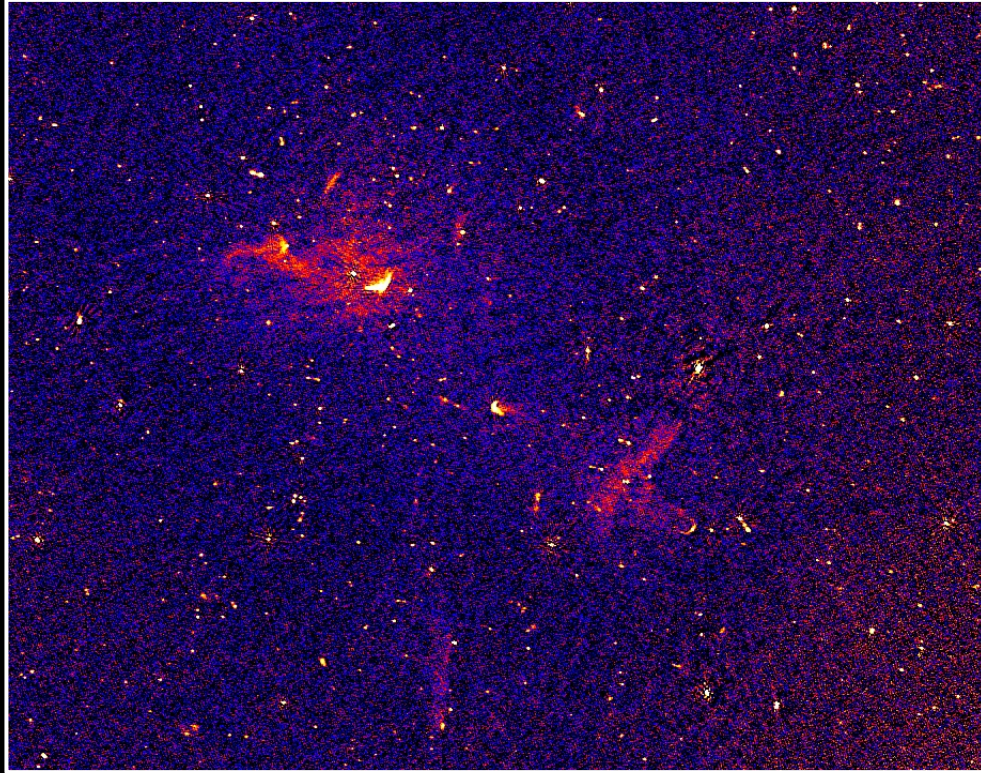
Two 3C sources
in the field



Diffuse emission
spanning several facets

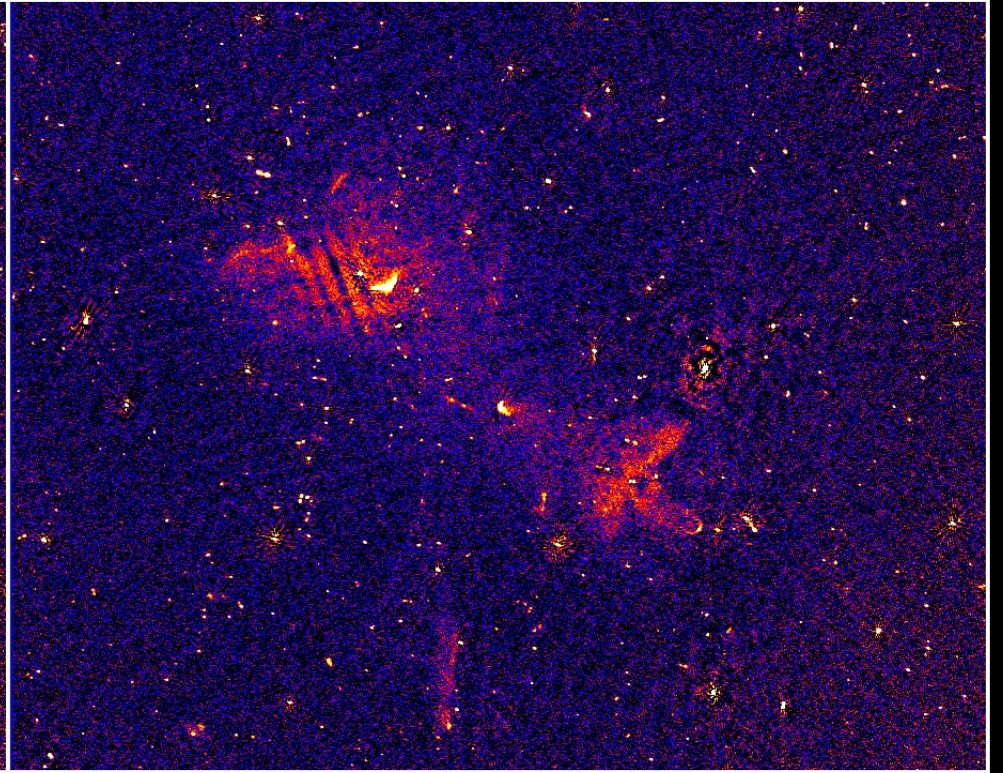
(1 week x 10)

IV challenge: imaging



WSclean with multi-facets

>2 days for 8h (7000x7000), >9 days for 30h (5000x5000)



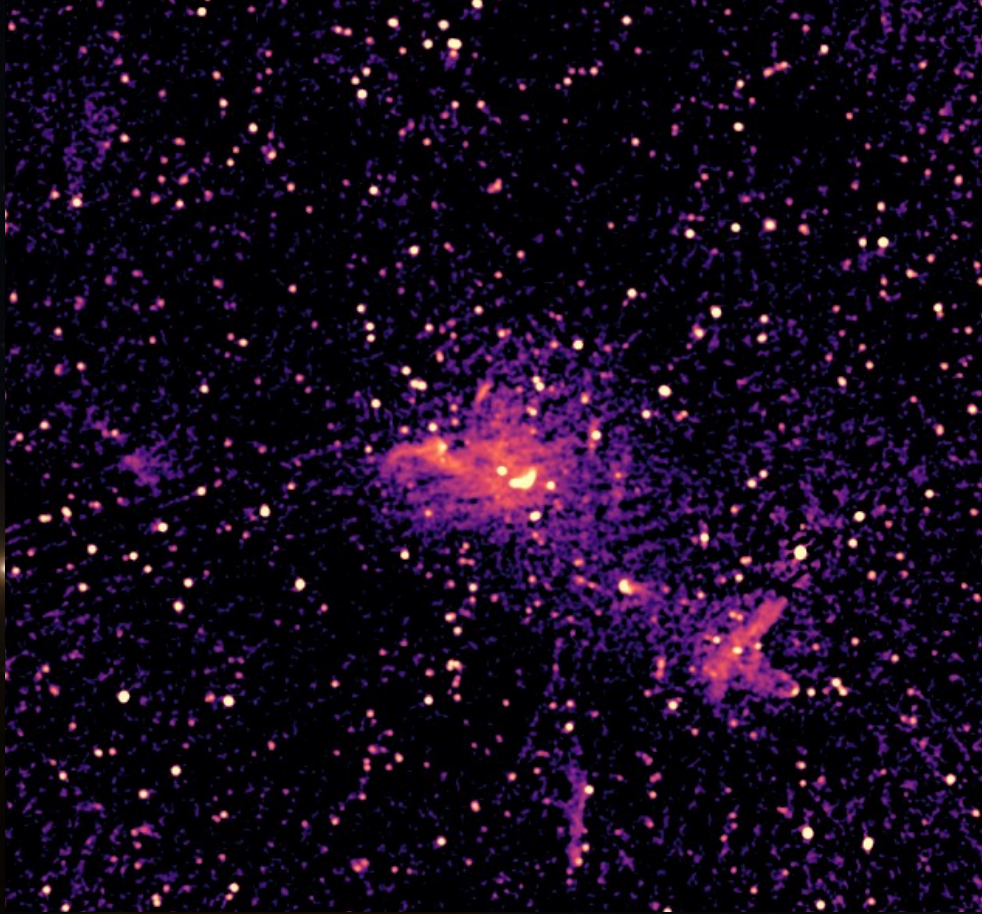
DDFacets

8 hours
beam: 15 arcsec
rms: 1.6 mJy/beam

...and after ~2000h = 90 days of processing time, and many more of human time...



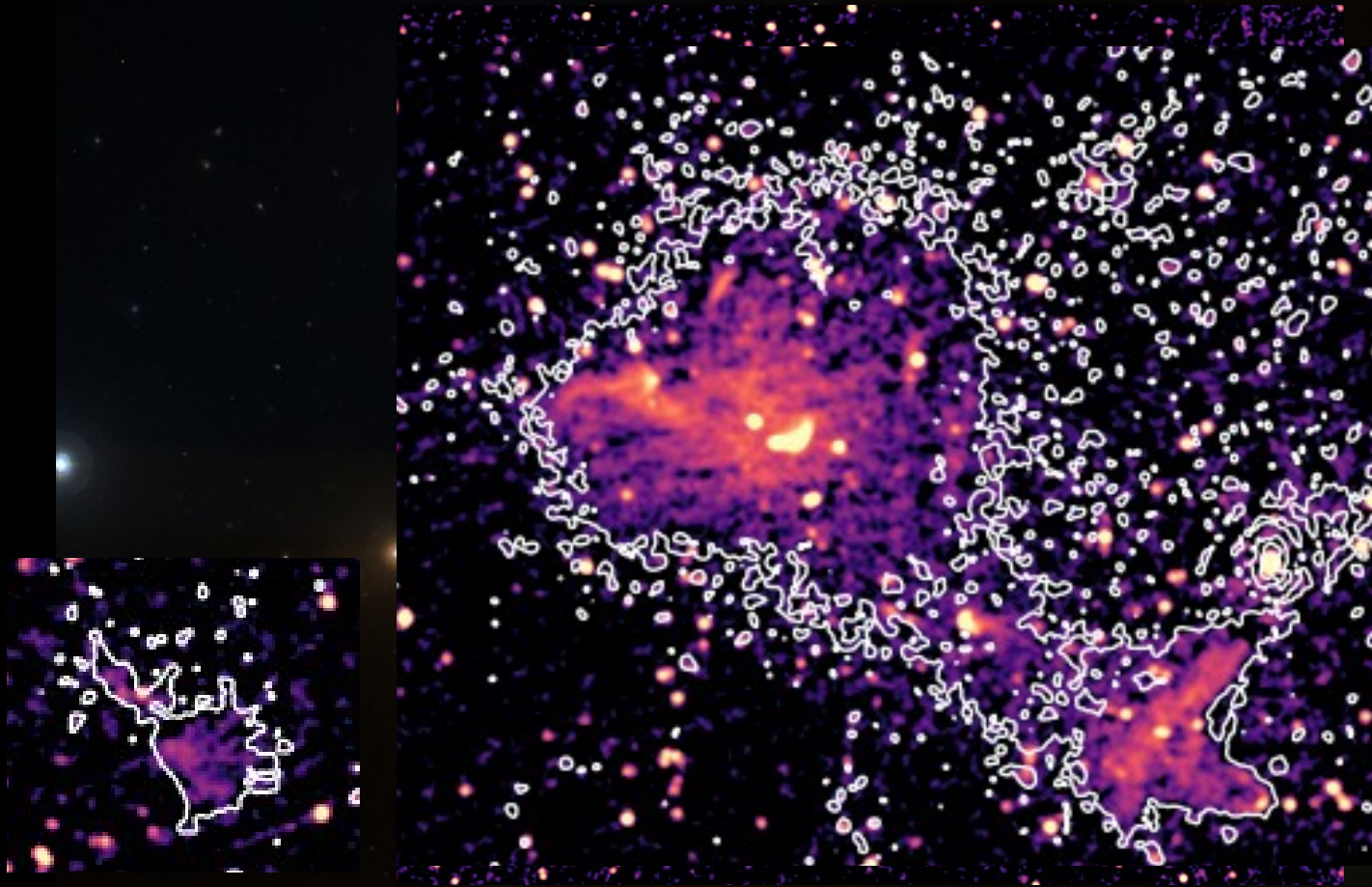
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LOFAR LBA, 8h [preliminary]

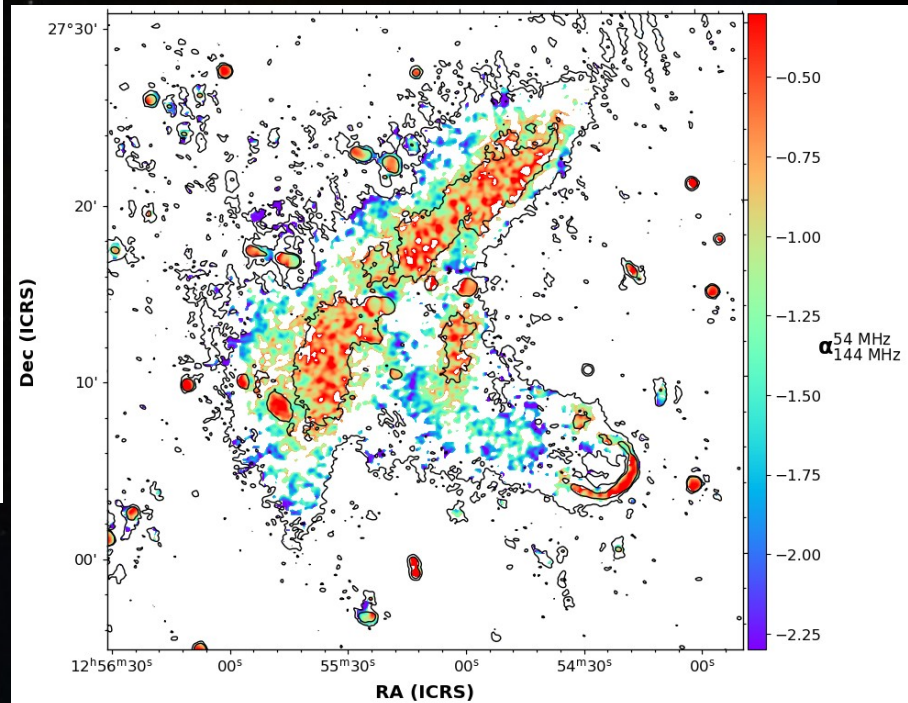
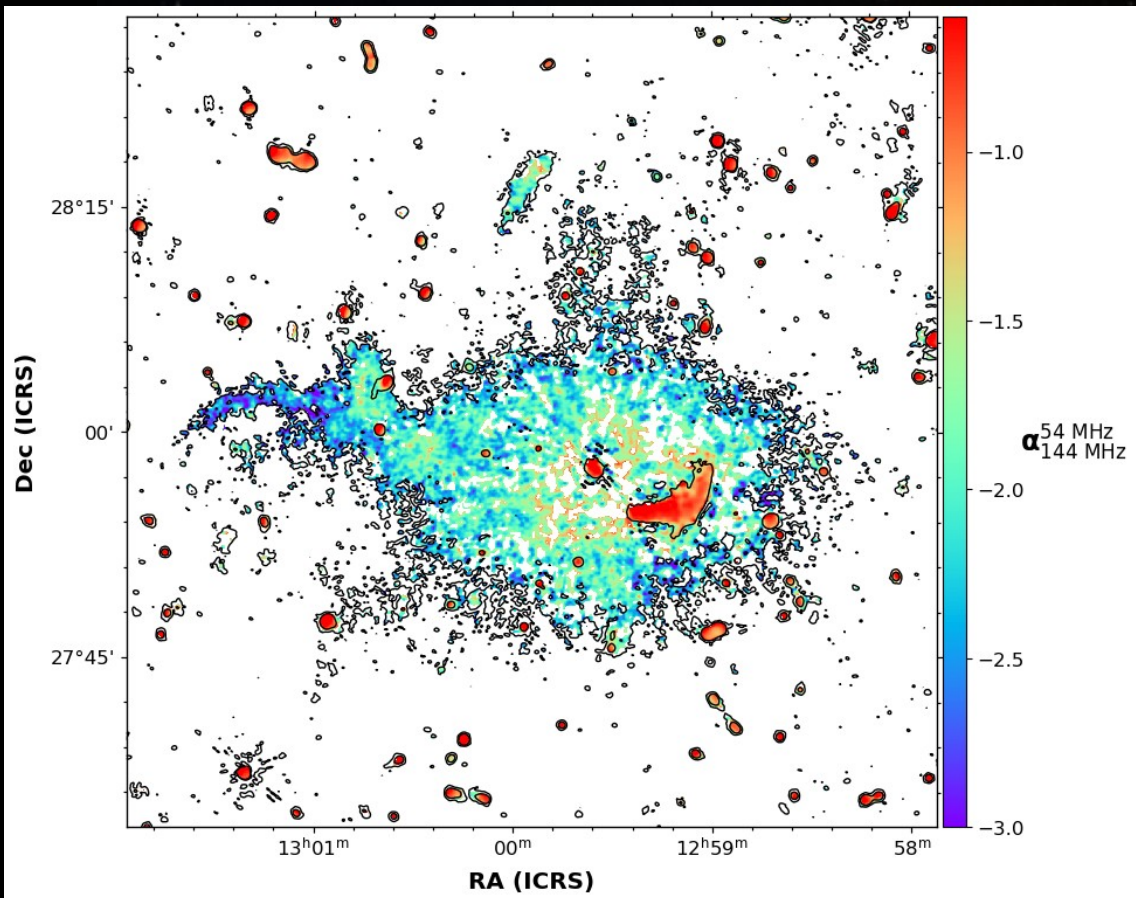
8 hours
beam: 60 arcsec
rms: 5 mJy/beam

...and after ~2000h = 90 days of processing time, and many more of human time...



LOFAR LBA+HBA contours [preliminary]

8 hours
beam: 60 arcsec
rms: 5 mJy/beam



LOFAR HBA+LBA spectral index [preliminary]

Tackling today's challenges to ensure readiness for tomorrow: the SKA

- Big data managing
- Wide-field and wide-band high-sensitivity images

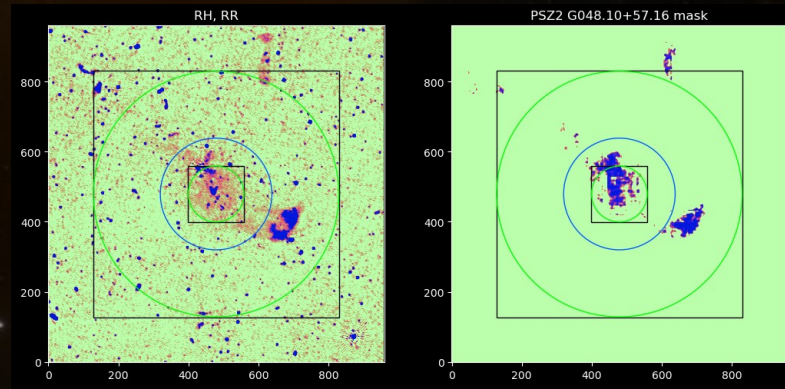


Tackling today's challenges to ensure readiness for tomorrow: the SKA

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- Wide-field and wide-band high-sensitivity images

→ and coming to surveys:

- Machine learning
to detect and
classify extended
sources
[Stuardi+ in prep.]

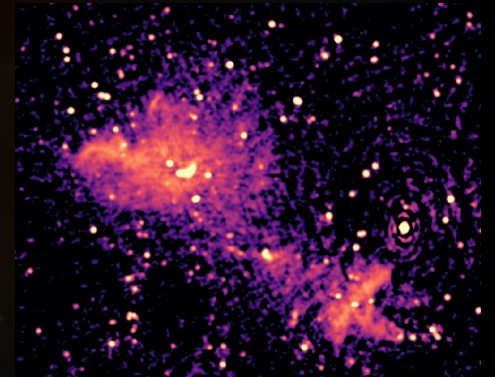
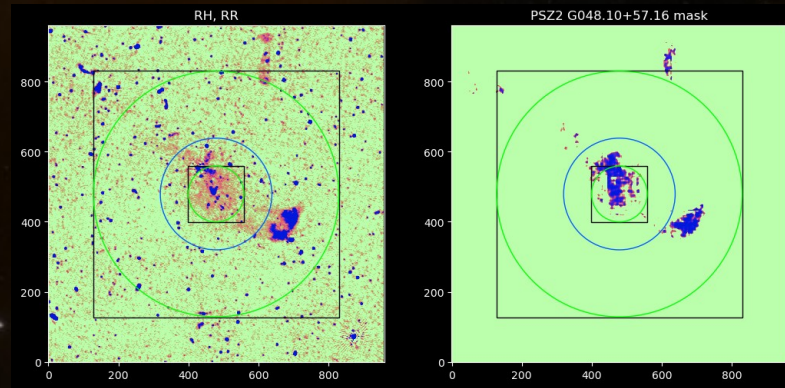


Tackling today's challenges to ensure readiness for tomorrow: the SKA

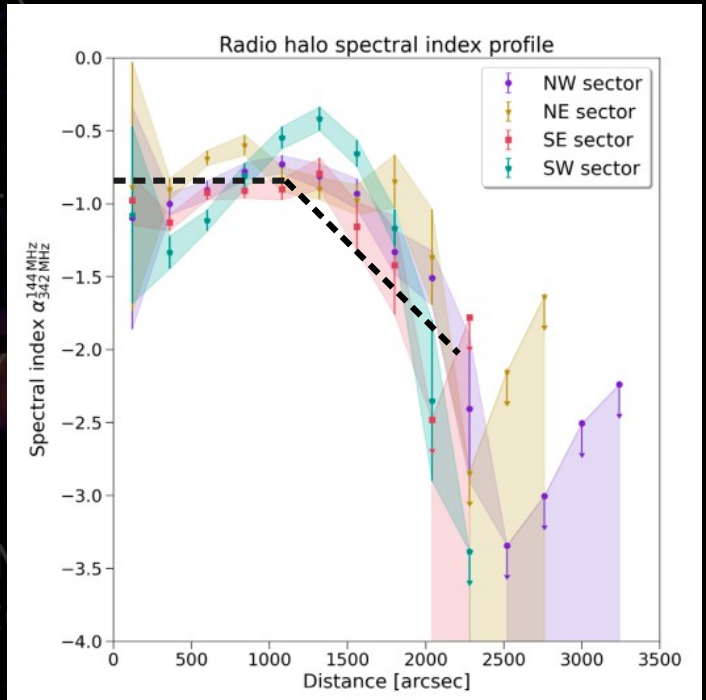
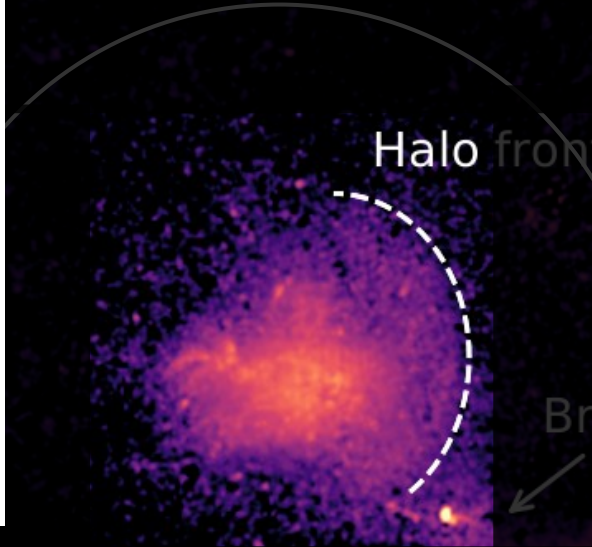
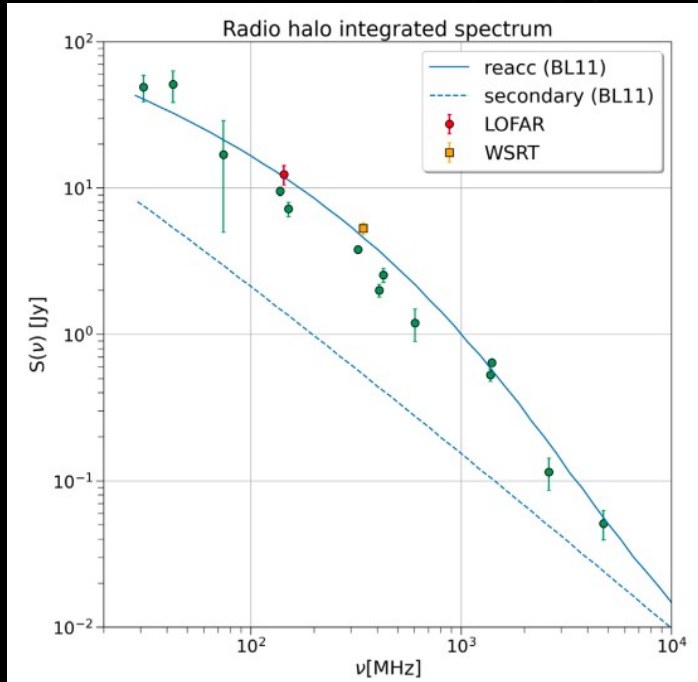
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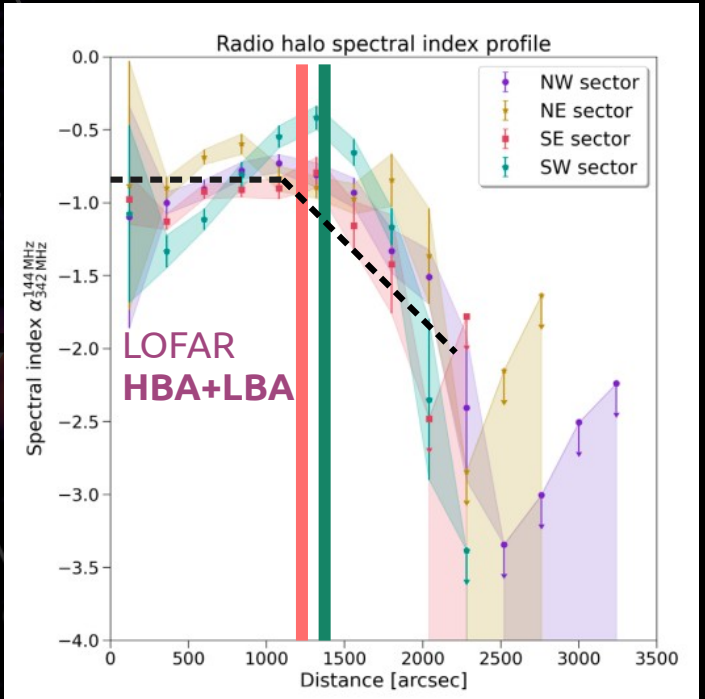
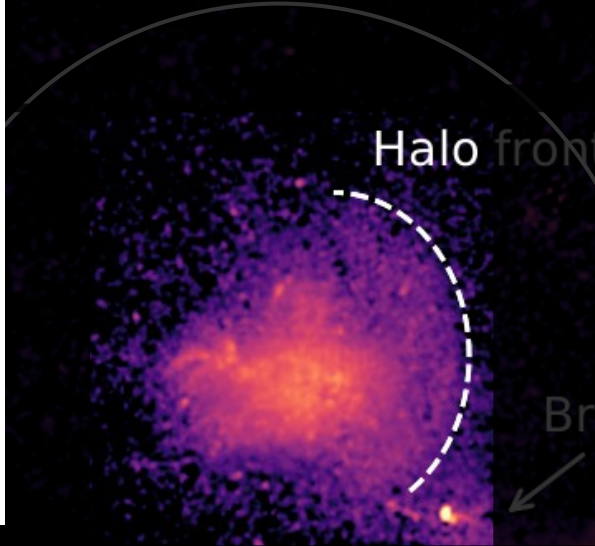
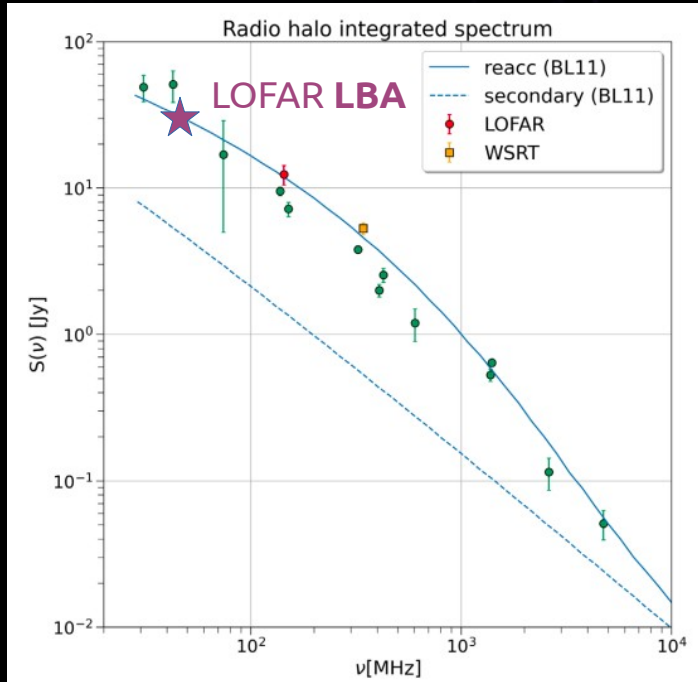
- Machine learning
to detect and
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To be continued...

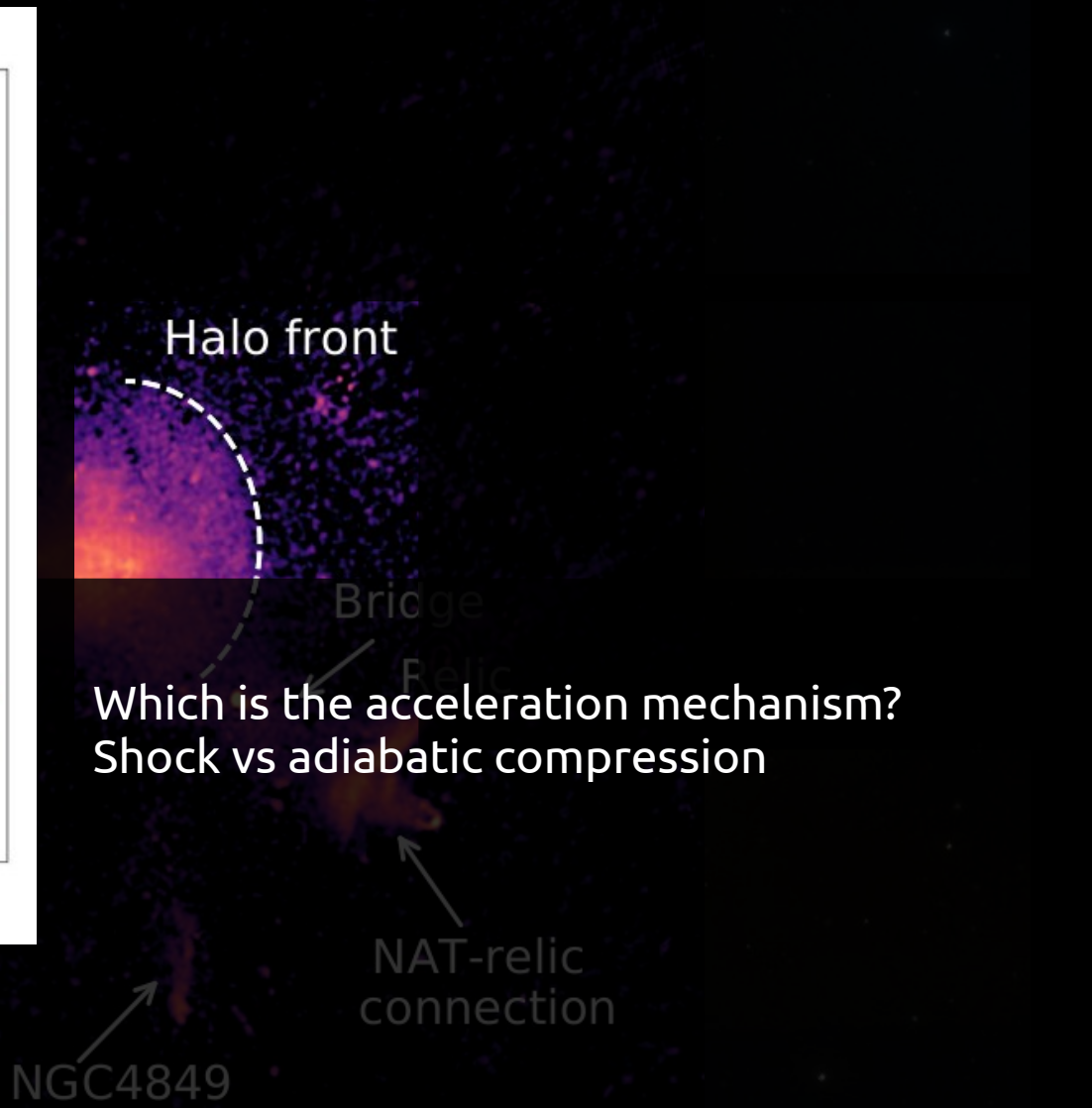
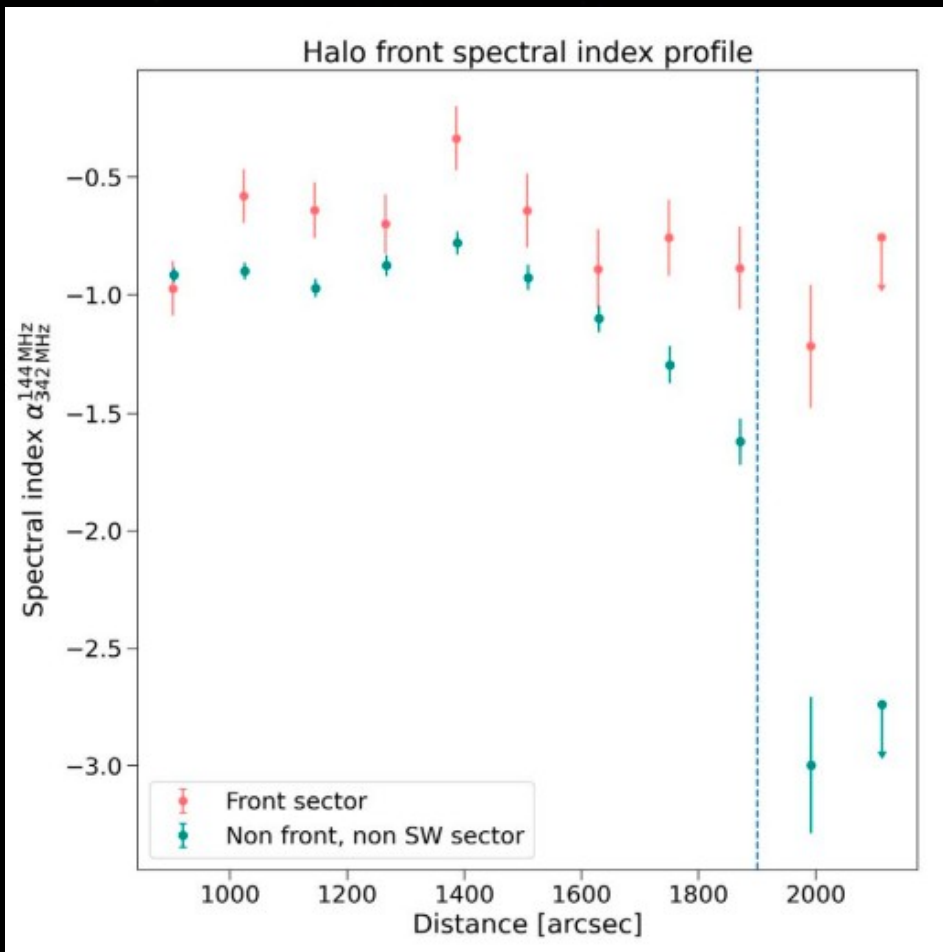


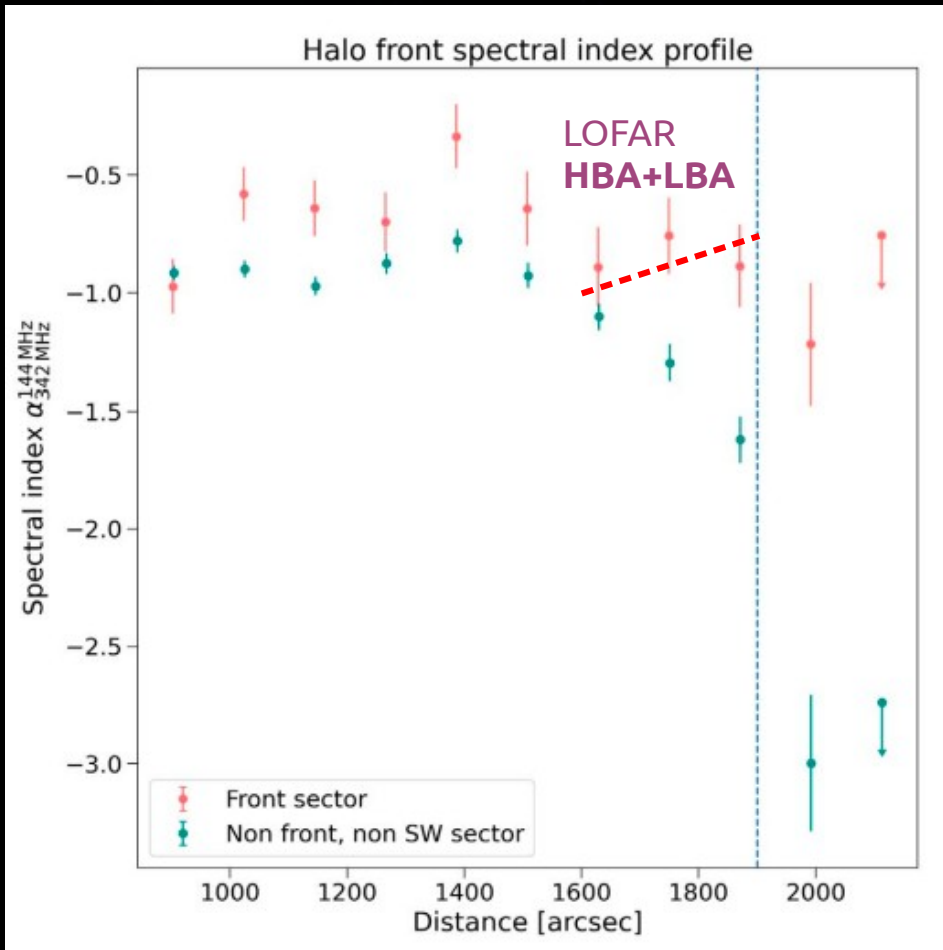
Which is the acceleration mechanism?
 Re-acceleration (curved spectrum)
 Compressive vs solenoidal turbulence



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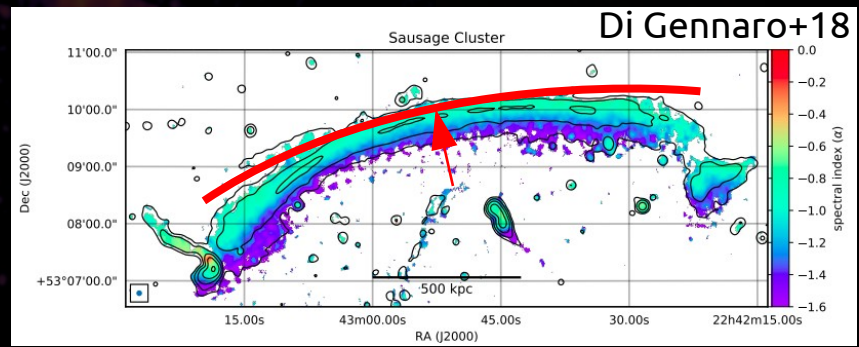
NGC4849

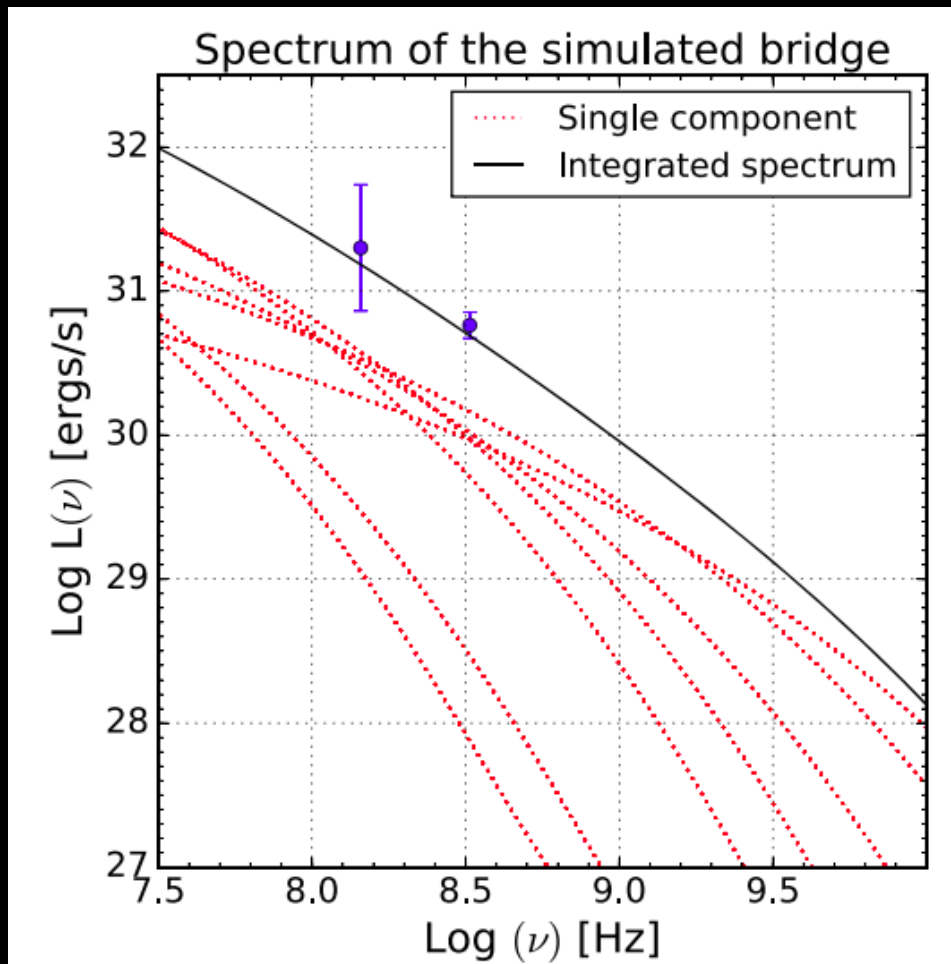




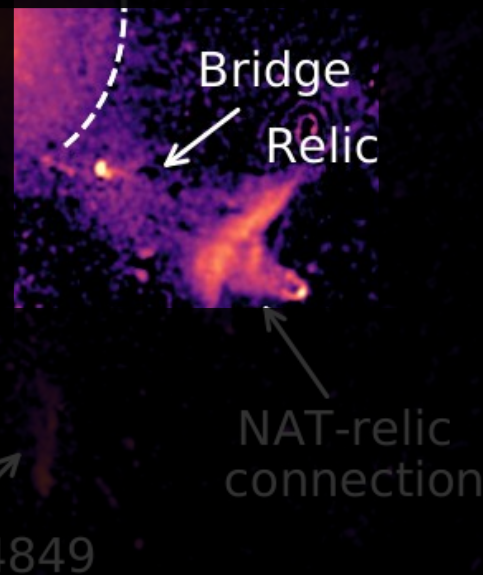
Which is the acceleration mechanism?
Shock vs adiabatic compression

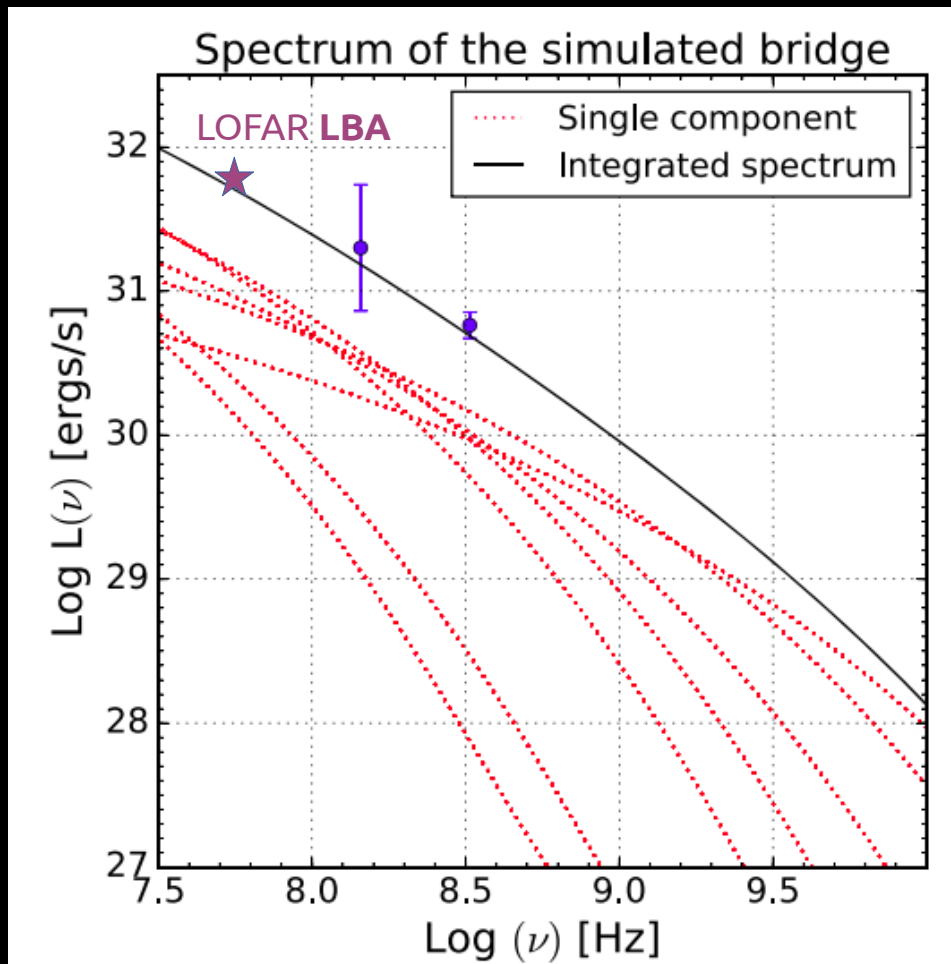
NGC4849



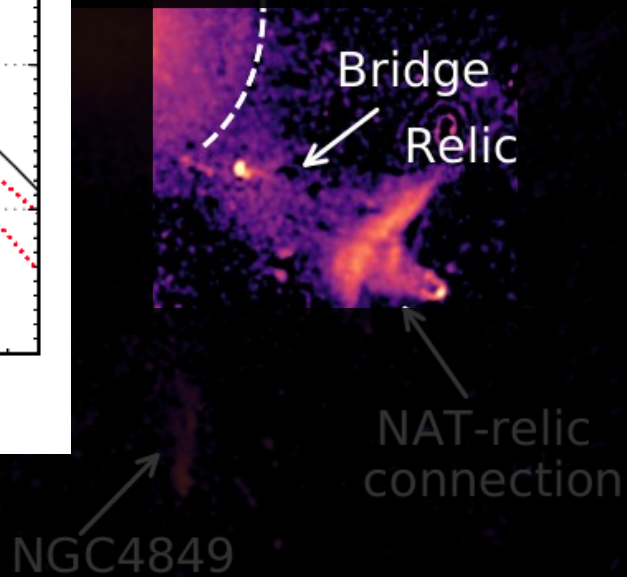


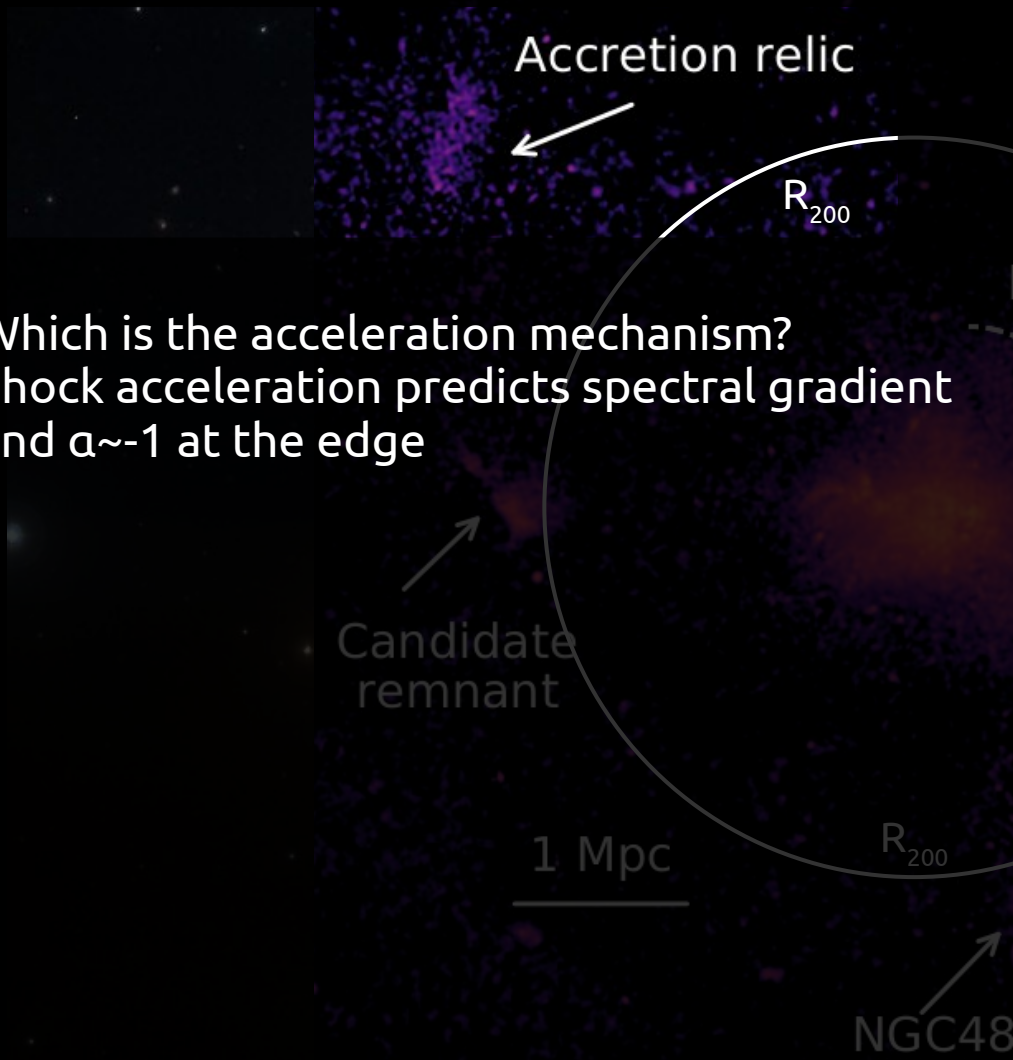
Which is the acceleration mechanism?
Turbulent re-acceleration predicts $\alpha \sim -1.5$



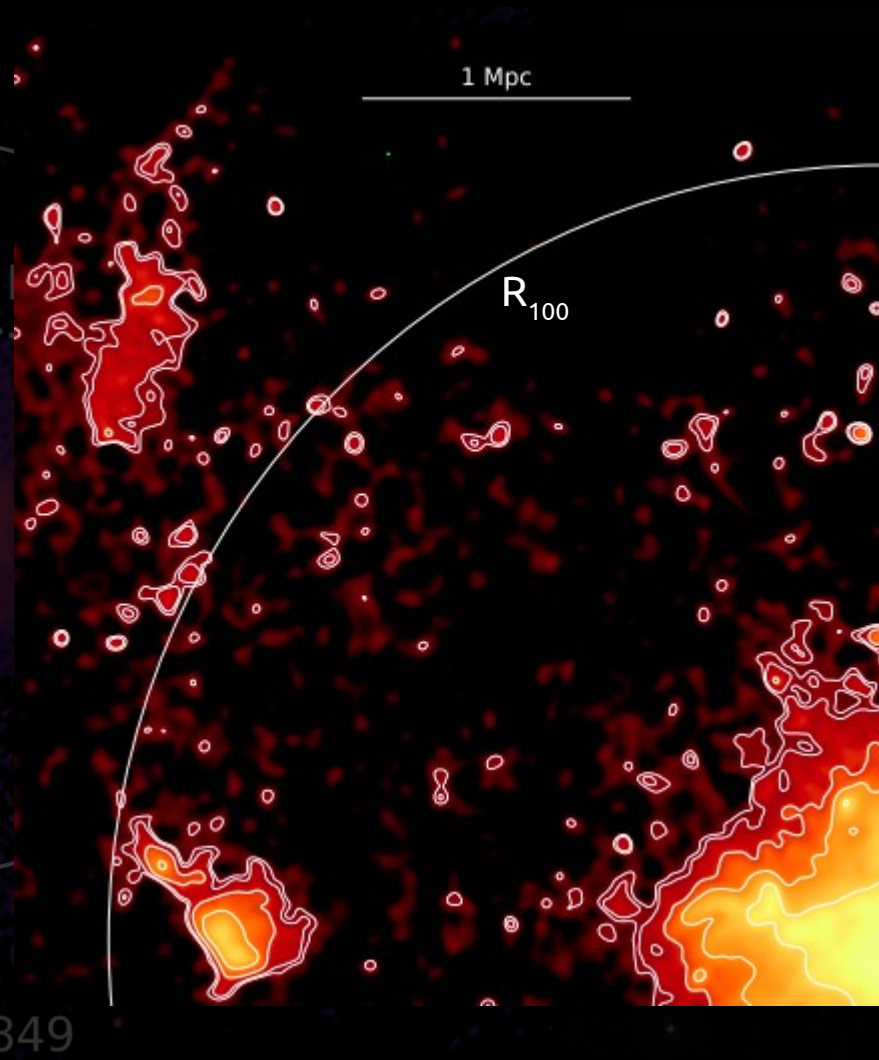


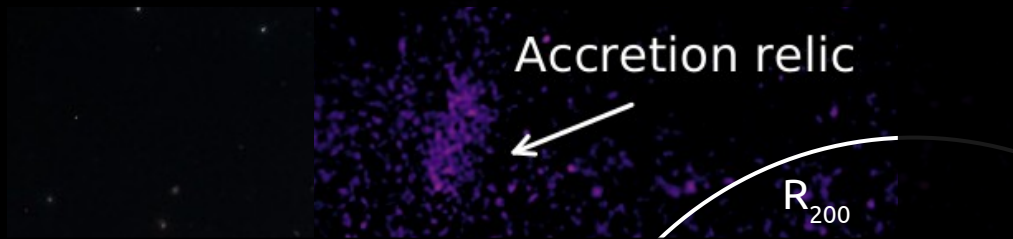
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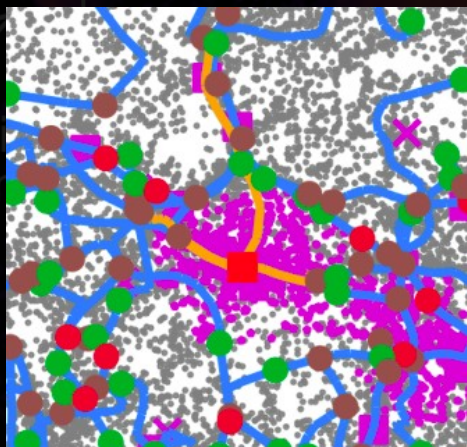


Which is the acceleration mechanism?
Shock acceleration predicts spectral gradient
and $\alpha \sim -1$ at the edge

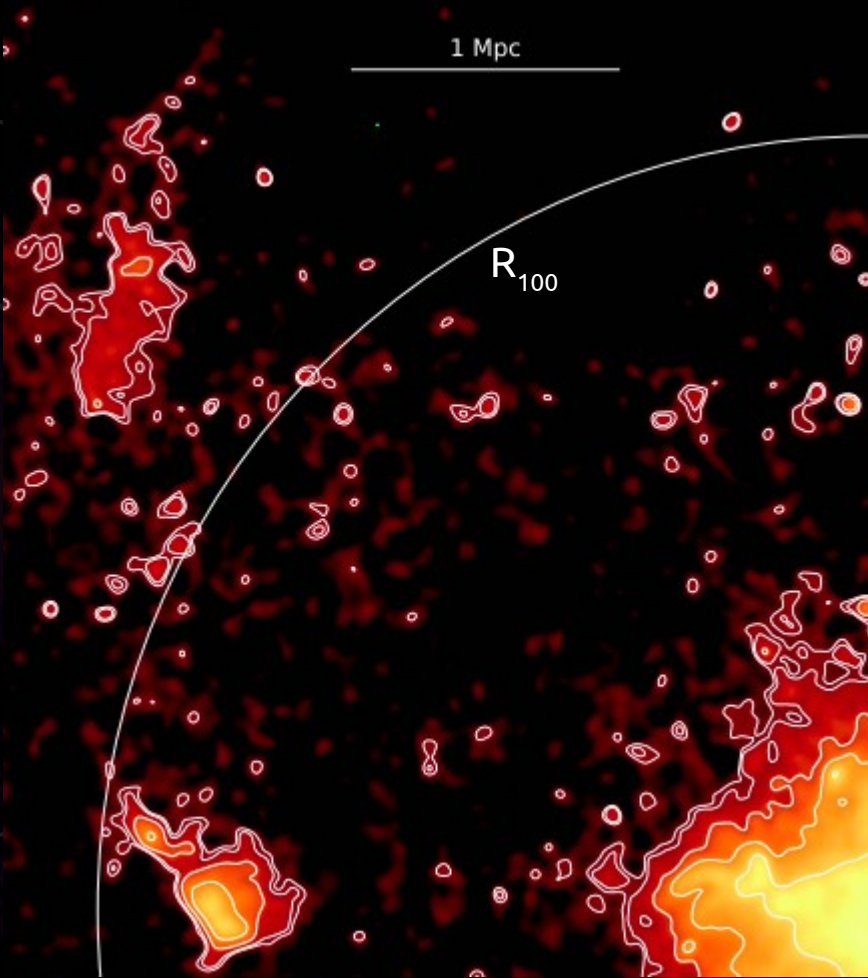




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Malavasi+20



NGC4849