Abell 399-401 radio bridge study

Using wide-field facet calibration

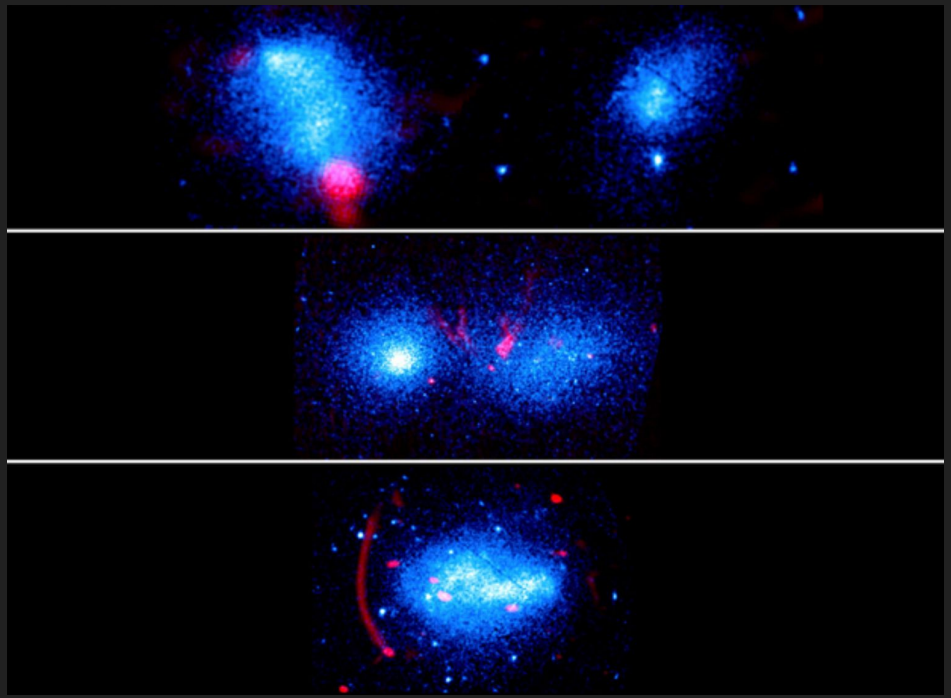
Jurjen de Jong

SPARCS 2022

Collaborators:
R. van Weeren, A. Botteon, R. Oonk, G.Brunetti, T. Shimwell, R. Cassano, H. Röttgering, C. Tasse

Universiteit Leiden

Galaxy cluster merger



Copyright: Abell 1758: ESA/XMM-Newton (X-rays); GMRT/TGSS (radio); 1E2215: NASA/Chandra (X-rays), GMRT (radio); CIZA J2242: ESA/XMM-Newton (X-rays); ASTRON/WSRT (radio)

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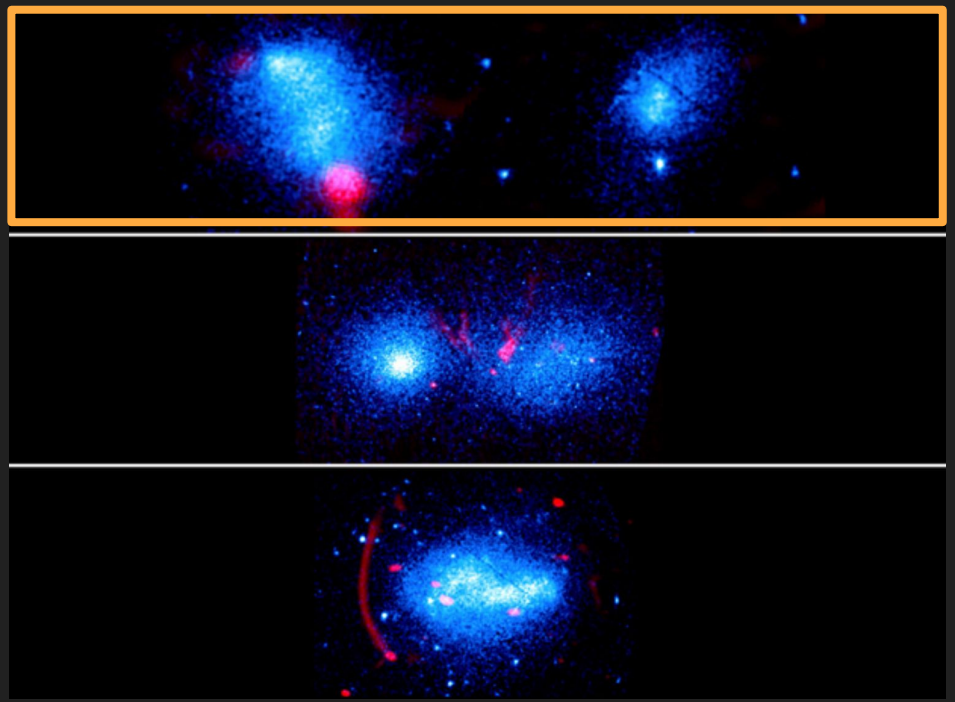
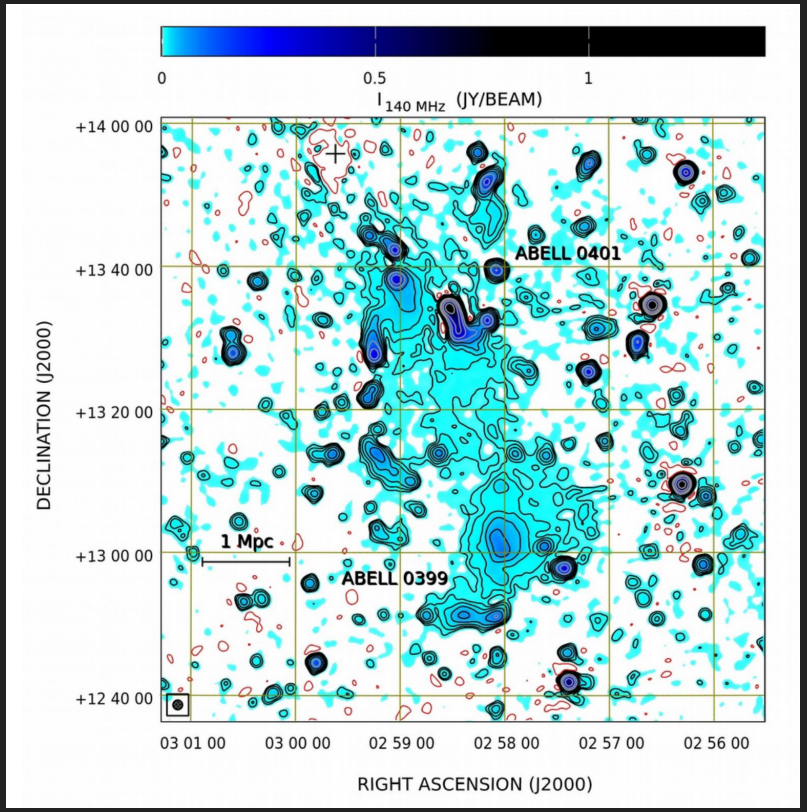


Radio bridge: Abell 399-401

- Filament between pre-merging clusters
- Magnetic fields and cosmic rays
- Diffuse synchrotron emission
- Abell 399-401: ~3 Mpc at z=0.072



Govoni et al. 2019

Radio bridge origin

- Lifetime electrons vs. bridge size →sub-Mpc vs. ~Mpc scale
- In-situ re-acceleration of fossil electrons
- Particle injection by shocks, AGN, Galactic winds, ...

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	Fermi-I (weak shocks) (Govoni et al. 2019)	**Fermi-II (turbulence)** (Brunetti et al. 2020)
Radio distribution	Substructure	Smooth/volume-filling
Radio/X-ray correlation	Weak	Strong

Open questions

1) Origin of cosmic rays in the radio bridge?

2) What is the main (re-)acceleration mechanism in the radio bridge?

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2) What is the main (re-)acceleration mechanism in the radio bridge?

Problem: Radio bridges are diffuse

LOFAR Data

- Abell 399-401
- 6x8-hour LOFAR observations
- HBA [120-168 MHz]
- Dutch stations

Calibration

Issues	Solutions	Case
Bright sources	Direction-dependent recalibration (van Weeren et al. 2021)	N=1

Calibration

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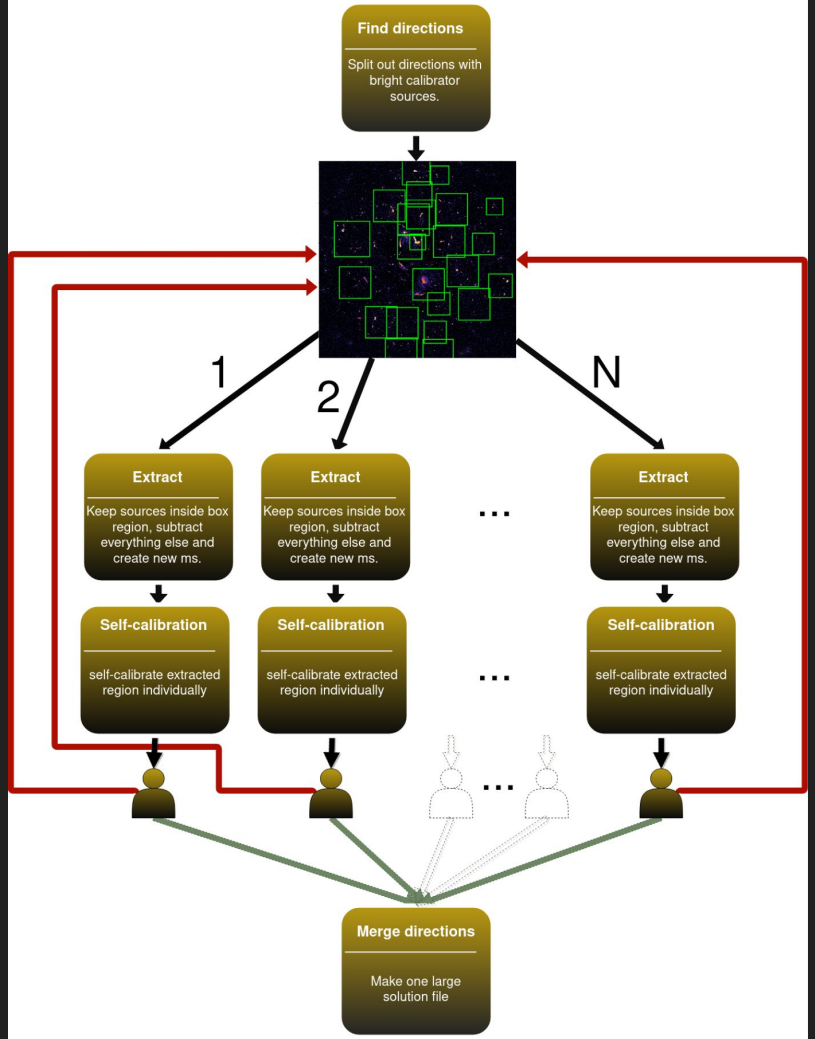
Bright sources	Direction-dependent recalibration (van Weeren et al. 2021)	N=1
Large object	Multiple recalibrations (de Jong et al. 2022 accepted)	N>1


Find directions
Split out directions with bright calibrator sources.
1
2
N
Extract
Keep sources inside box region, subtract everything else and create new ms.
Extract
Keep sources inside box region, subtract everything else and create new ms.
Extract
Keep sources inside box region, subtract everything else and create new ms.
Self-calibration
self-calibrate extracted region individually
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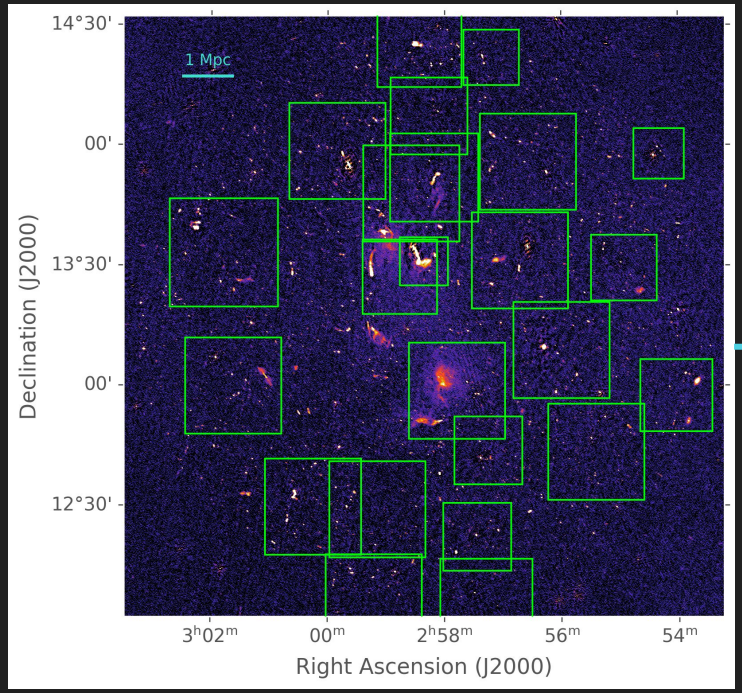
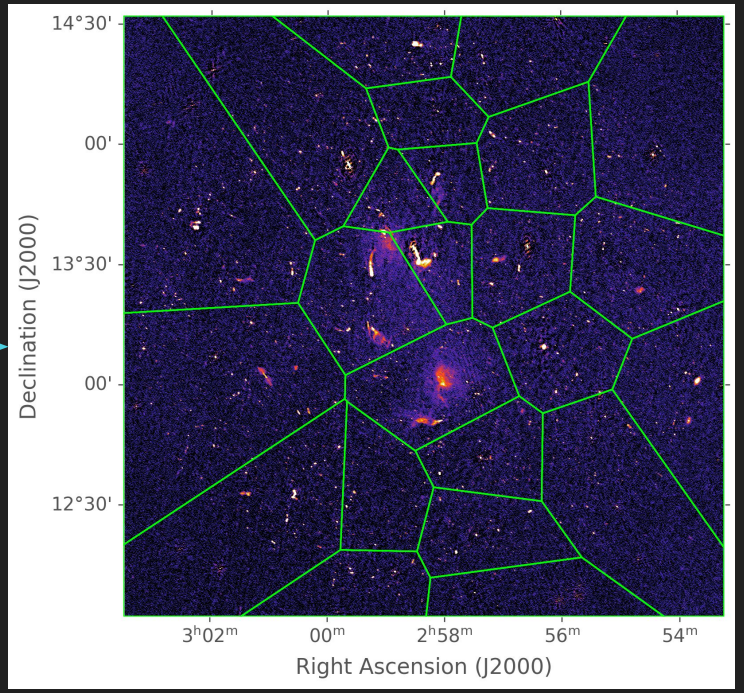
Merge directions
Make one large solution file


1 Mpc
14°30'
00'
13°30'
00'
12°30'
Declination (J2000)
3h02m
00m
2h58m
56m
54m
Right Ascension (J2000)


14°30'
00'
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3h02m
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54m
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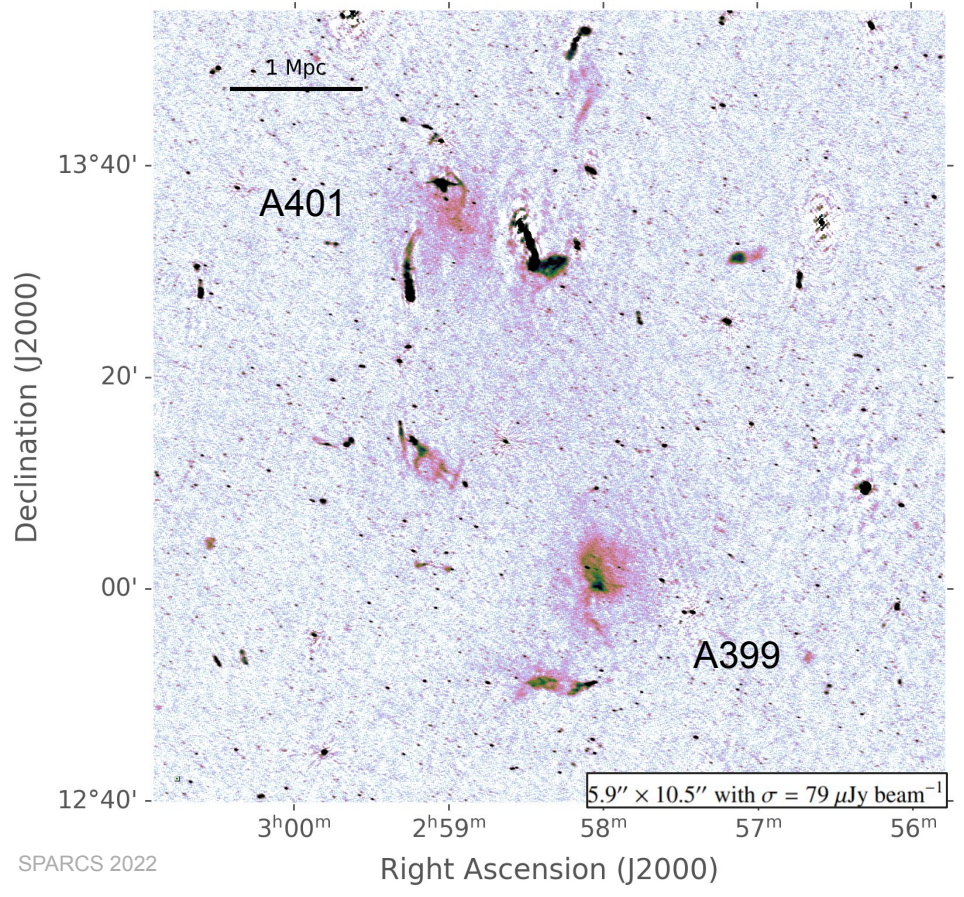
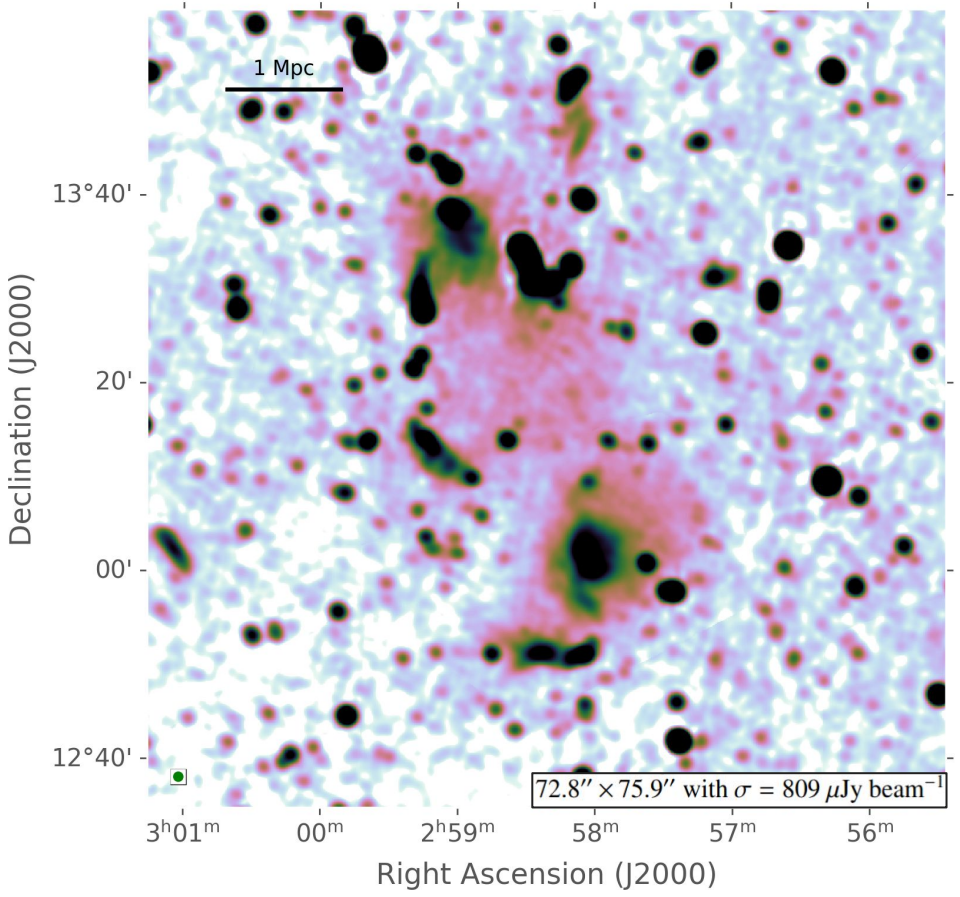
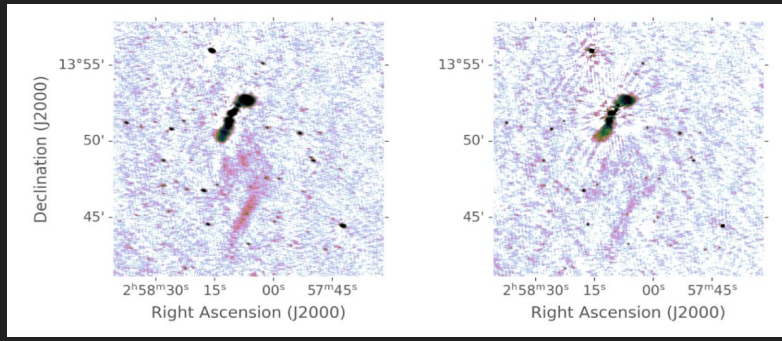
Results


1 Mpc
A401
A399
13°40'
20'
00'
12°40'
Declination (J2000)
3h00m
2h59m
58m
57m
56m
Right Ascension (J2000)
5.9″ × 10.5″ with σ = 79 μJy beam−1


1 Mpc
13°40'
20'
00'
12°40'
Declination (J2000)
3h01m
00m
2h59m
58m
57m
56m
Right Ascension (J2000)
72.8″ × 75.9″ with σ = 809 μJy beam−1

Recalibration vs. Standard (DDF)

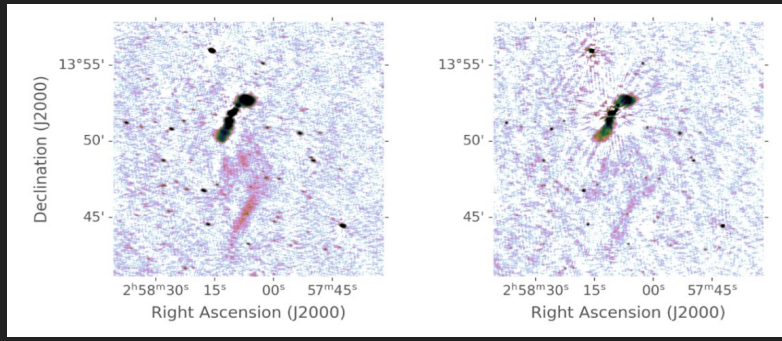
Recalibration | Standard



- 🙂 Similar sensitivity

Recalibration vs. Standard (DDF)

Recalibration | Standard



- 🙂 Similar sensitivity
- 😁 Dynamic range improvement factor ~1.6

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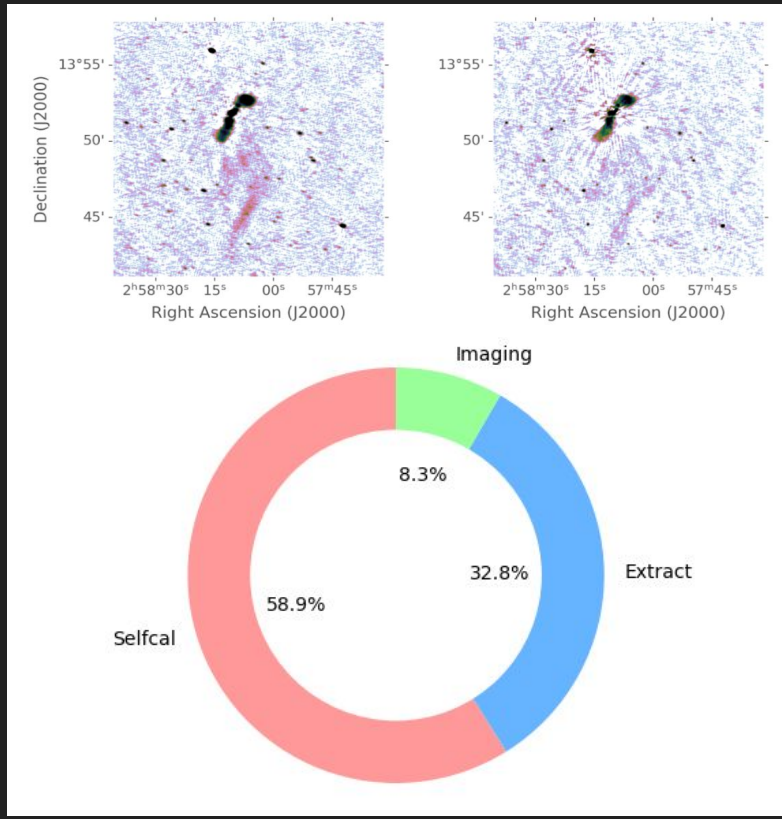
😕 Recalibration costs 16500 extra CPU core hours (expensive!)



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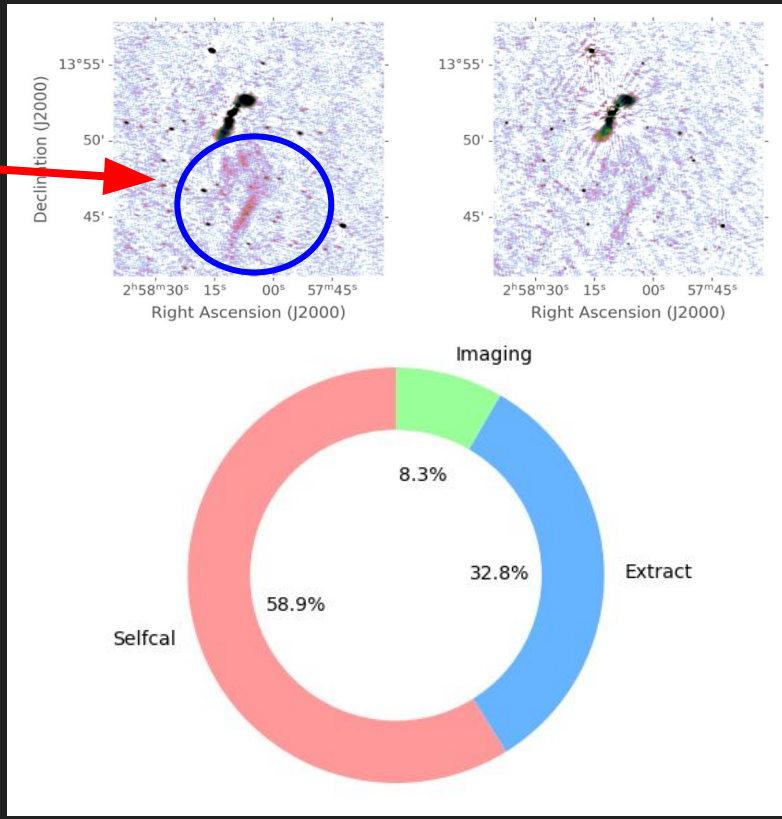
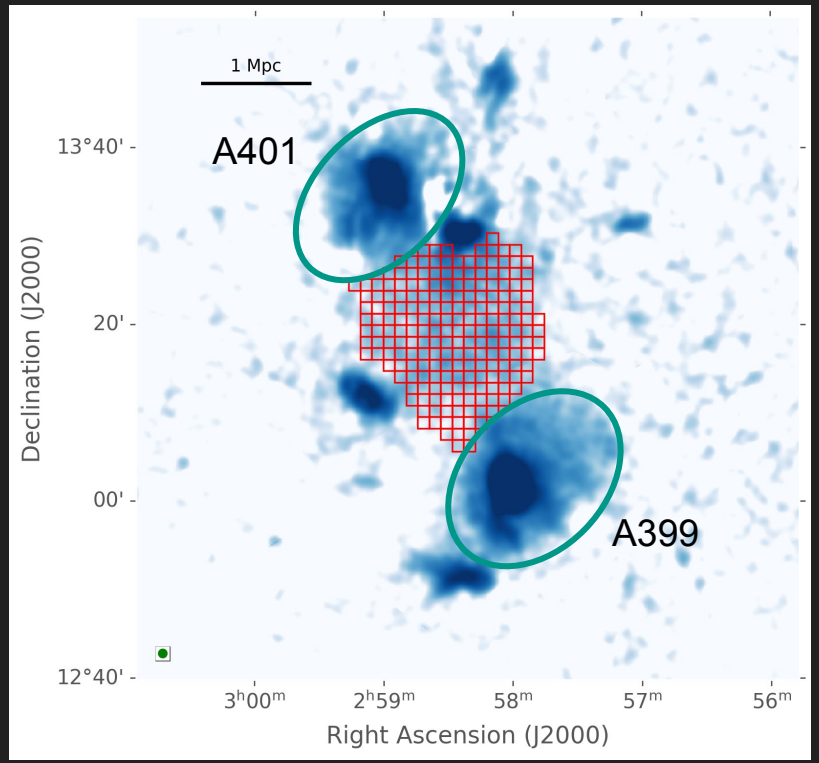
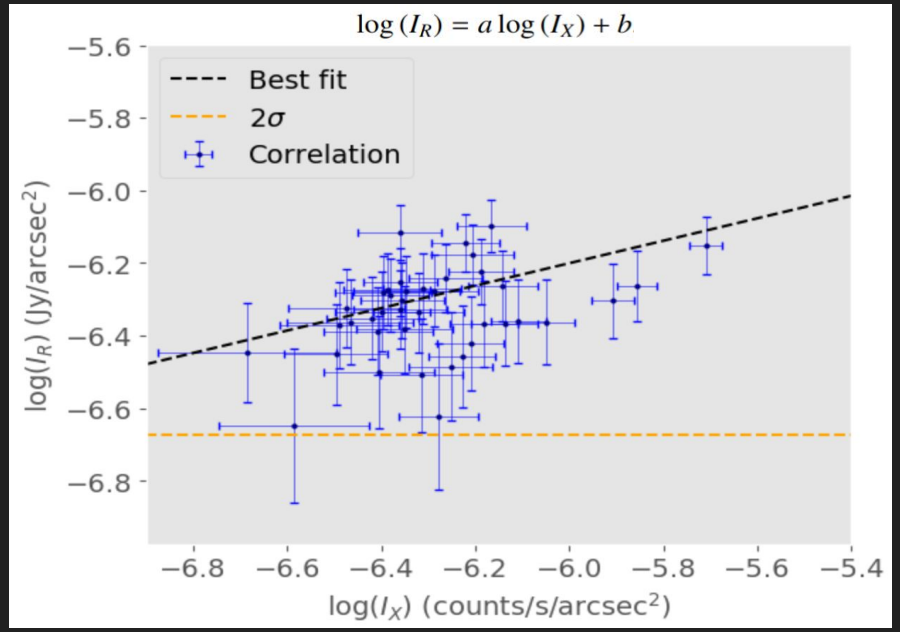


Radio/X-ray trend



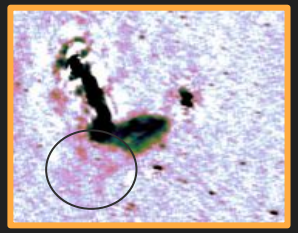
LOFAR

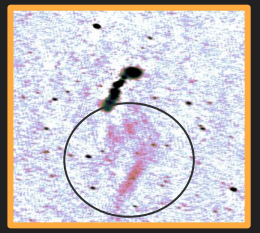


XMM-Newton

Results

1) Fossil plasma





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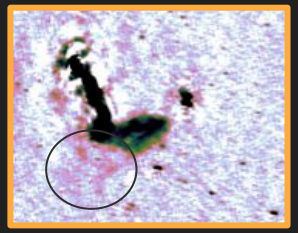
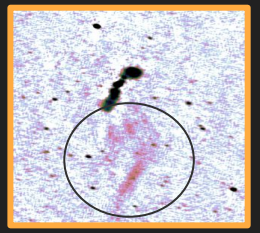
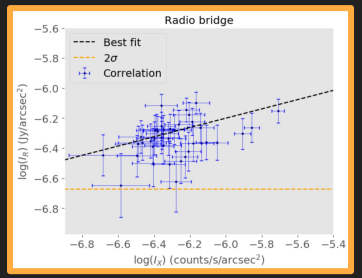




2) Trend between radio and X-ray



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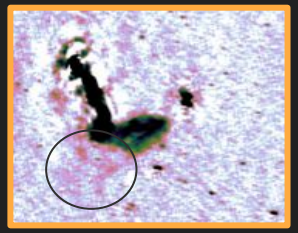

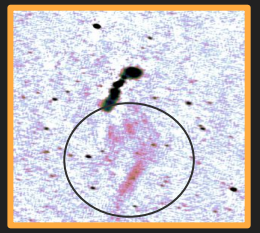

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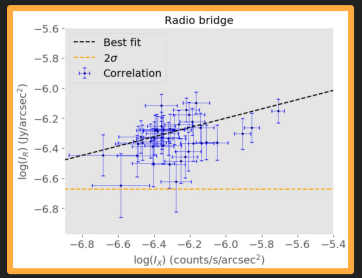

3) Steep spectral index –> **α > 1.5**

(Nunhokee et al. 2021)

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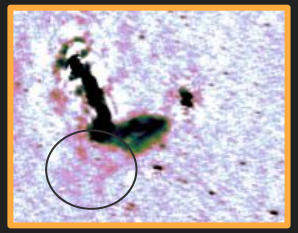

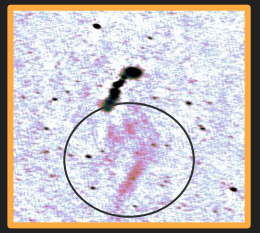

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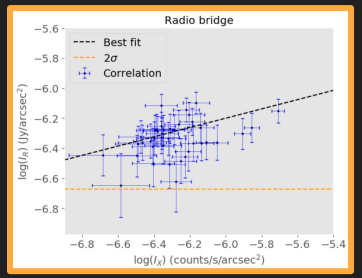

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(Nunhokee et al. 2021)

Fermi-II re-acceleration

(Predicted by Brunetti et al. 2020)

Summary

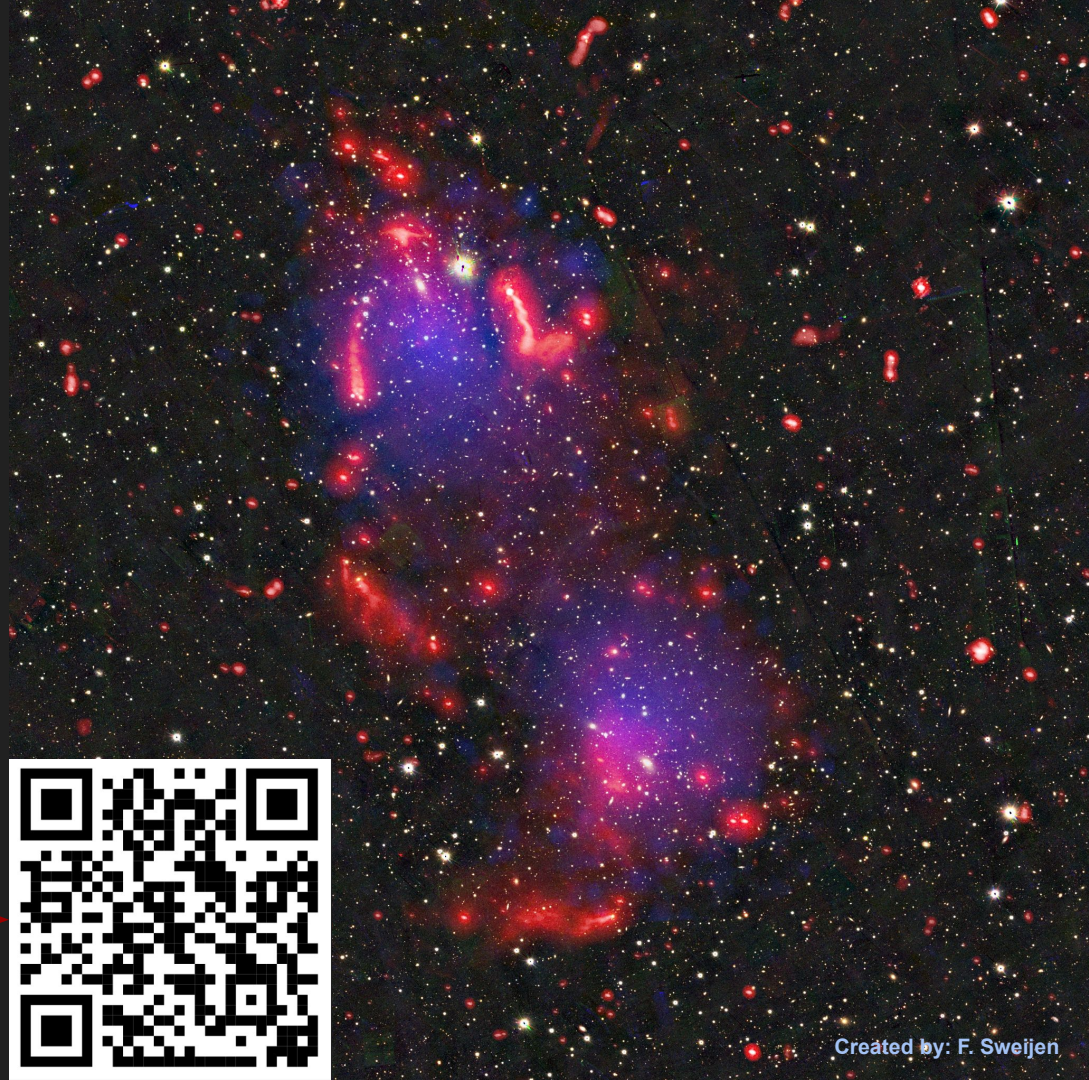
Calibration:

1. Recalibration strategy improves calibration of diffuse structures.
2. computationally expensive.

Science:

3. Radio bridge emission likely generated by Fermi-II re-acceleration of fossil plasma.
4. Fossil plasma might originate from past AGN activity.

J.M.G.H.J. de Jong et al. 2022 (accepted in A&A)



Created by: F. Sweijen

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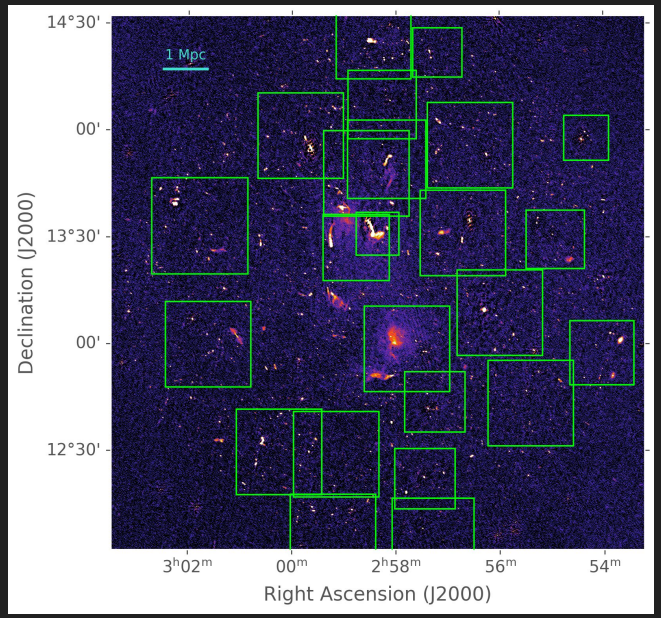
EXTRA SLIDES

1


1 Mpc
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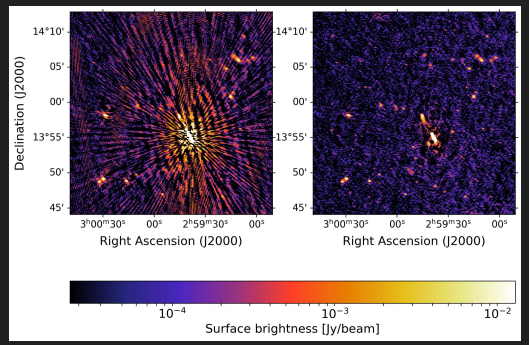
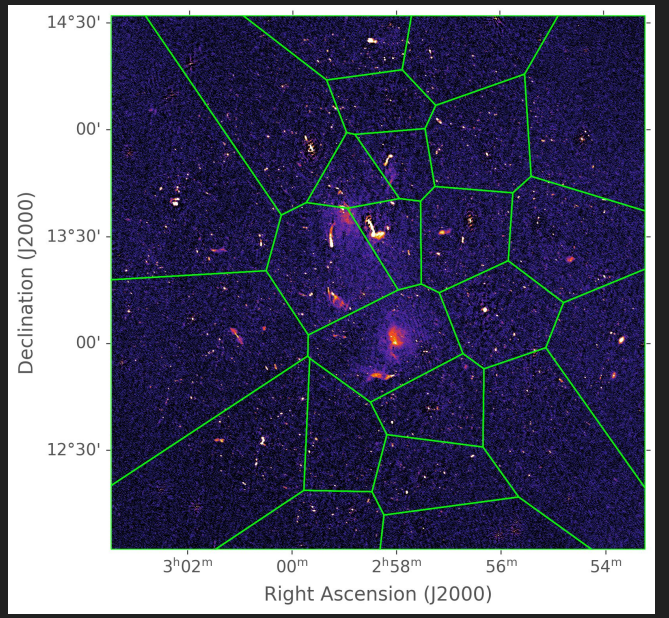
00'
13°30'
00'
12°30'
Declination (J2000)
3h02m
00m
2h58m
56m
54m
Right Ascension (J2000)

2


14°10'
05'
00'
13°55'
50'
45'
Declination (J2000)
3h00m30s
00s
2h59m30s
00s
Right Ascension (J2000)
10−4
10−3
10−2
Surface brightness [Jy/beam]

3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