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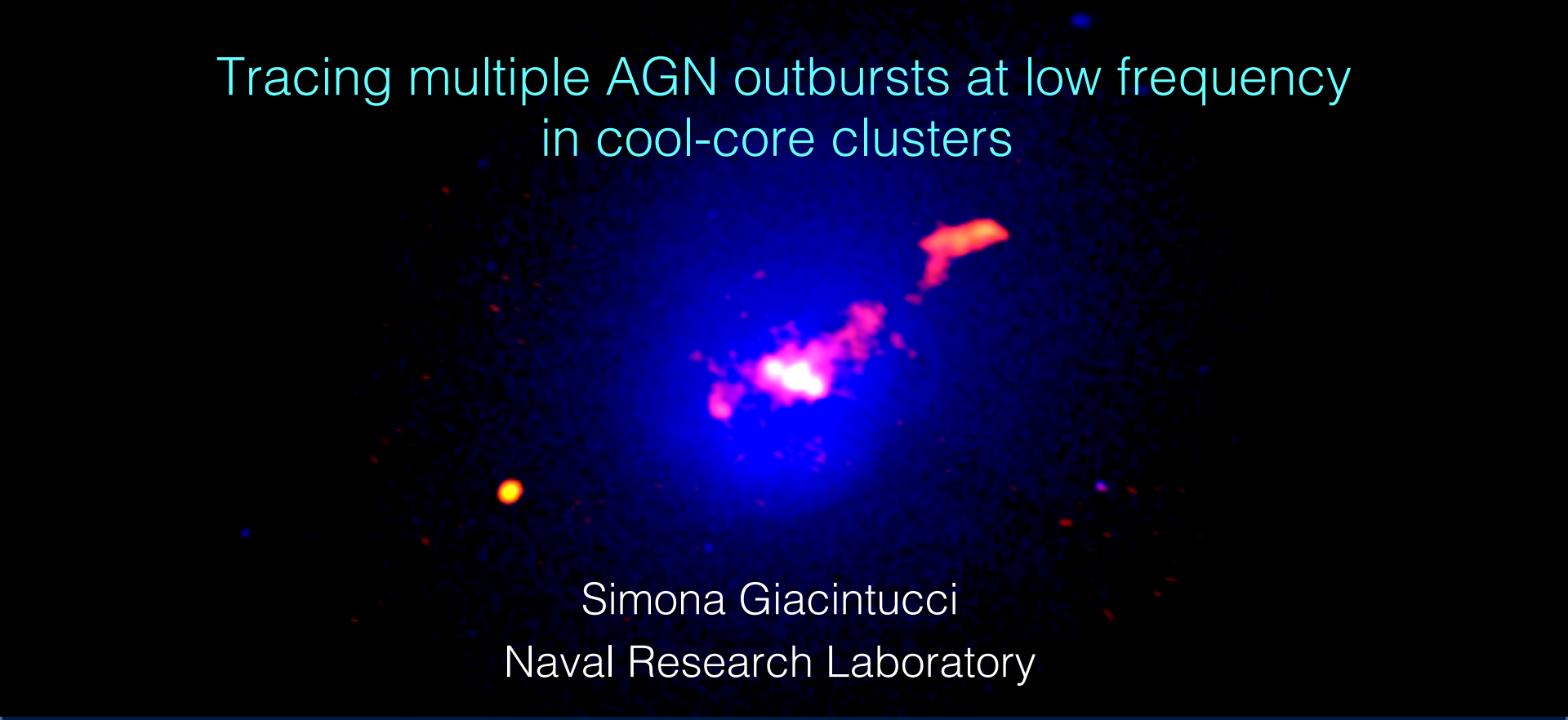
Tracing multiple AGN outbursts at low frequency in cool-core clusters



Simona Giacintucci
Naval Research Laboratory

Maxim Markevitch (GSFC), Tracy Clarke (NRL), Matteo Murgia (INAF-OAC), T. Venturi (INAF-IRA)

The Broad Impact of Low Frequency Observing, Bologna June 19-23, 2017

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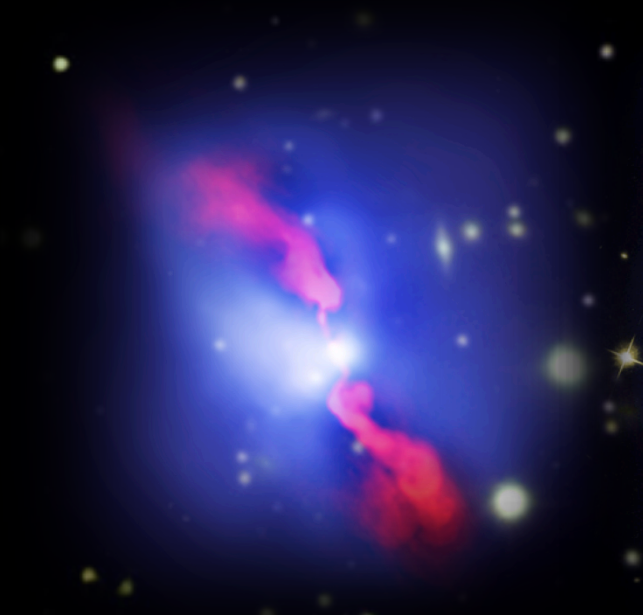
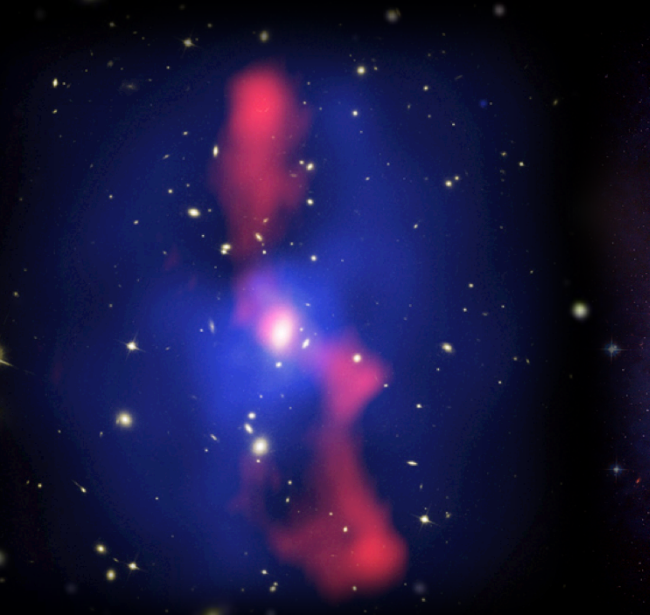
Radio bubbles in cool-core clusters

Hydra A



Kirkpatrick et al. 2009

MS 0735.6+7421



McNamara et al. 2005

Perseus (3C84)

Fabian et al. 2005

Blue: X-ray emission

Magenta: radio emission

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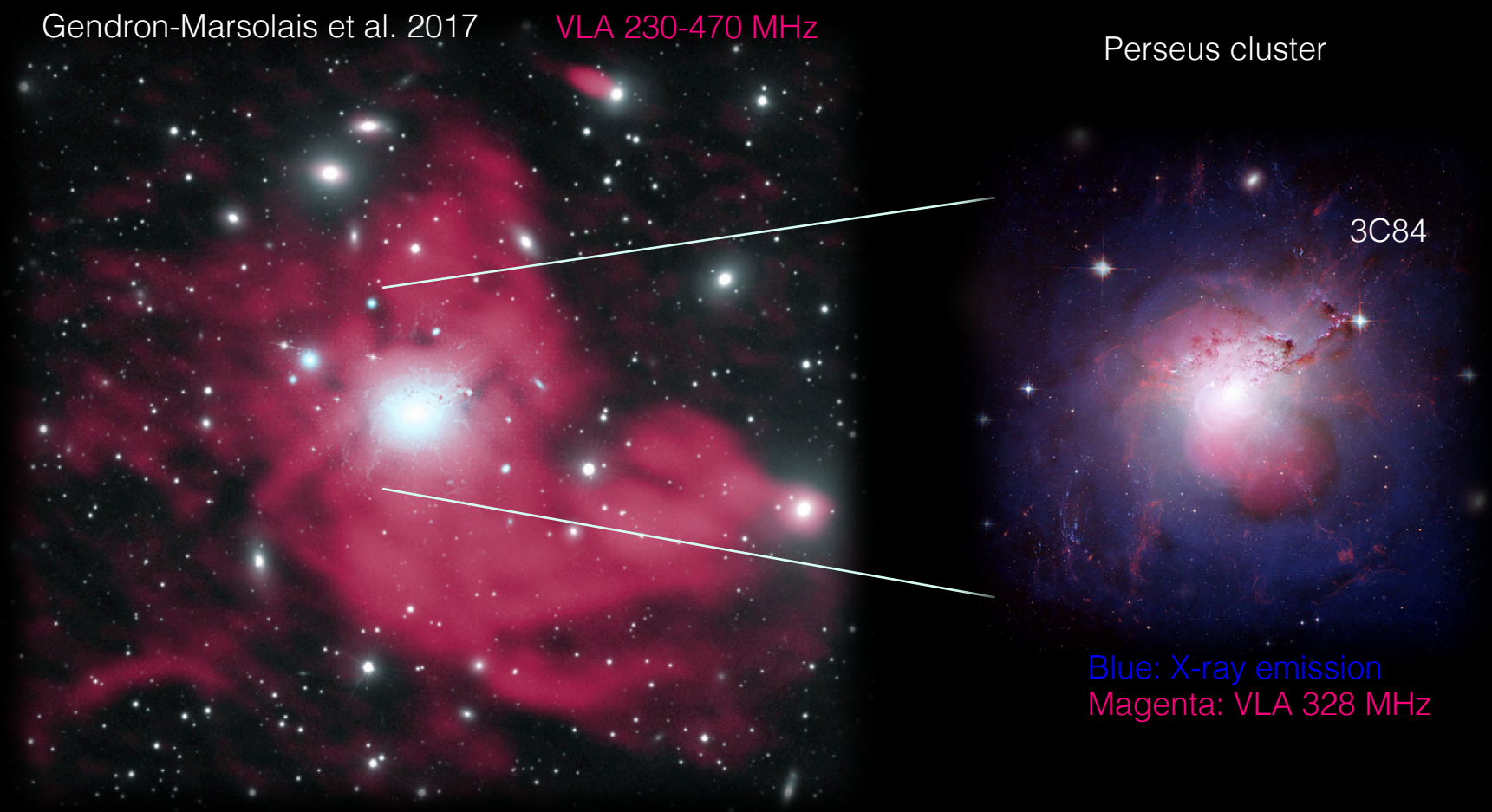
Radio minihalos in cool-core clusters



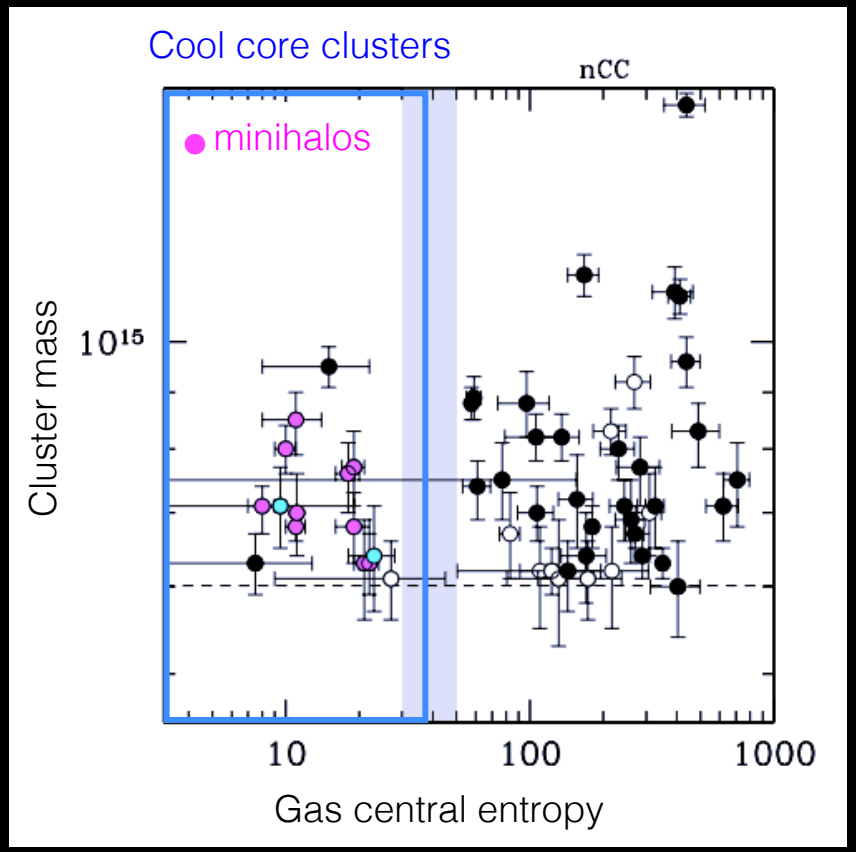
Diffuse radio emission on cluster core scale (r ~50 - 300 kpc), possibly linked to turbulence in the cool core (Gitti et al. 2002, ZuHone et al. 2013)

Radio minihalos in cool-core clusters

Gendron-Marsolais et al. 2017

VLA 230-470 MHz

Giacintucci et al. 2017



Almost all cool cores (~80%) in massive clusters possess a minihalo

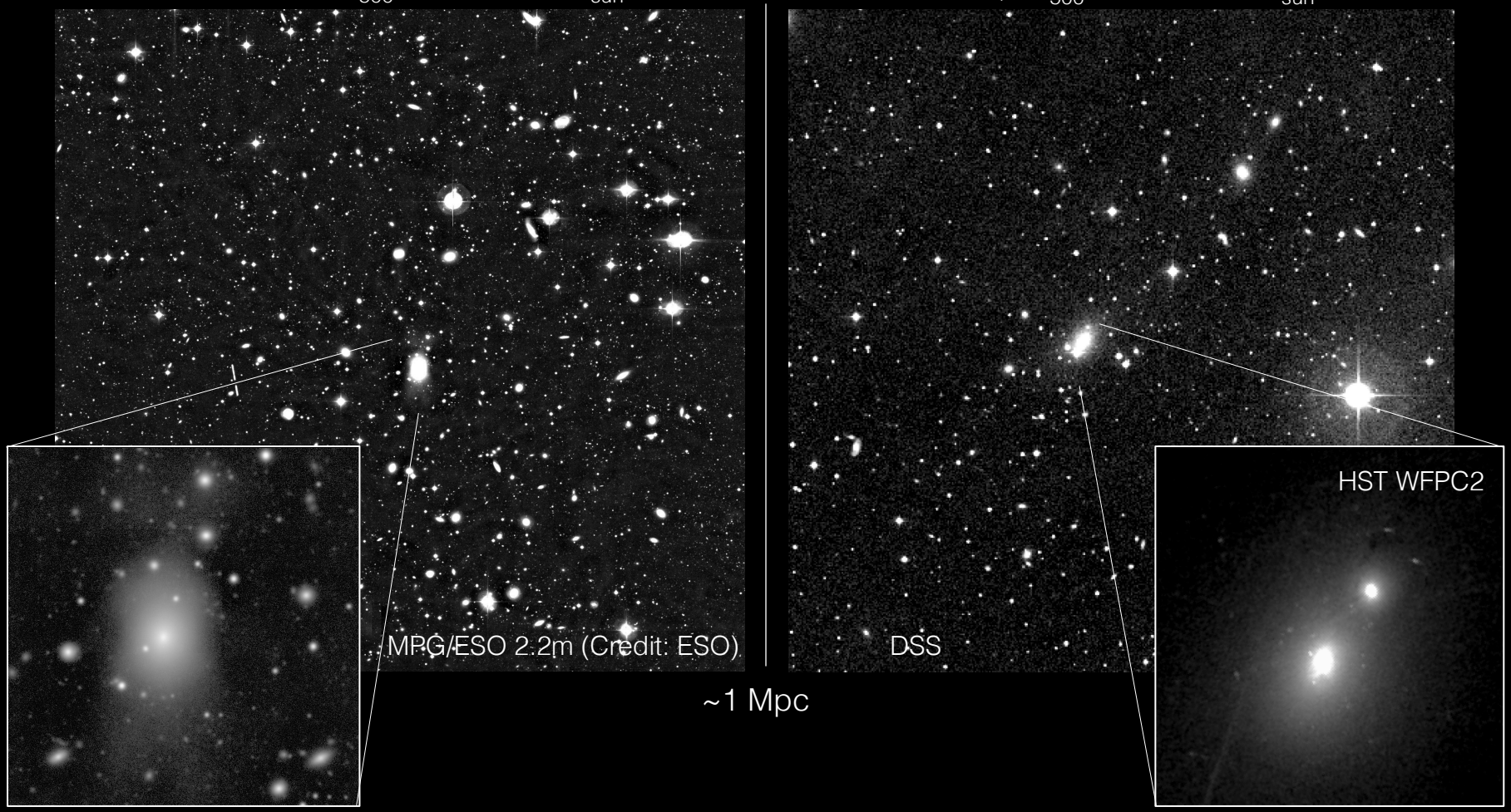
The galaxy clusters A496 and 2A0335+096

A496

z=0.0329, $M_{500} = 2.74 \times 10^{14} M_{sun}$

2A 0335+096

z=0.0349, $M_{500} = 2.27 \times 10^{14} M_{sun}$



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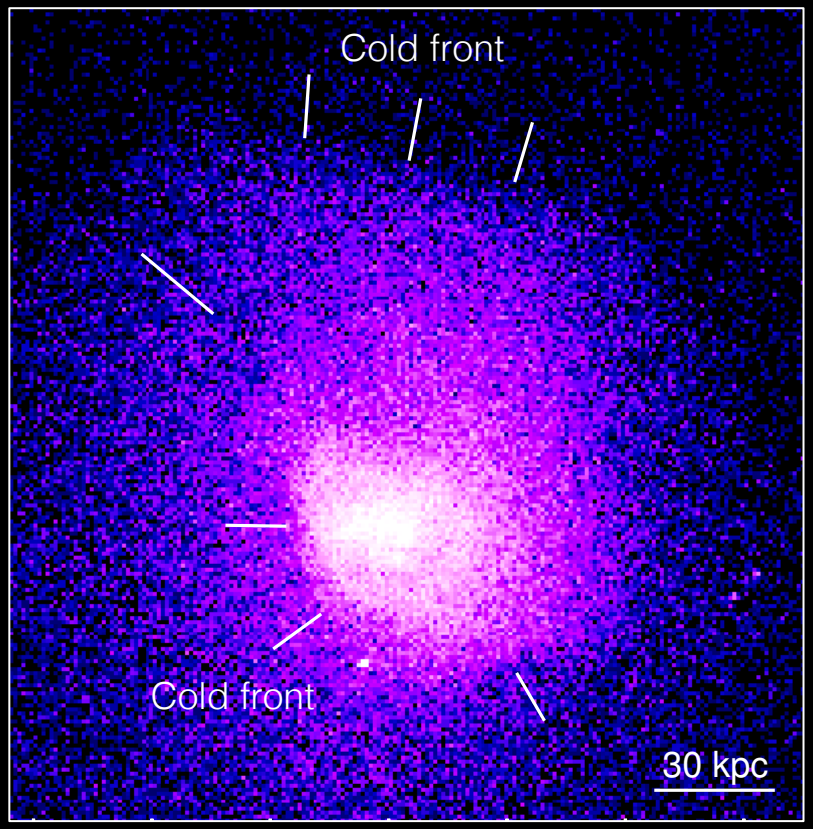
Sloshing cold fronts in the cool core

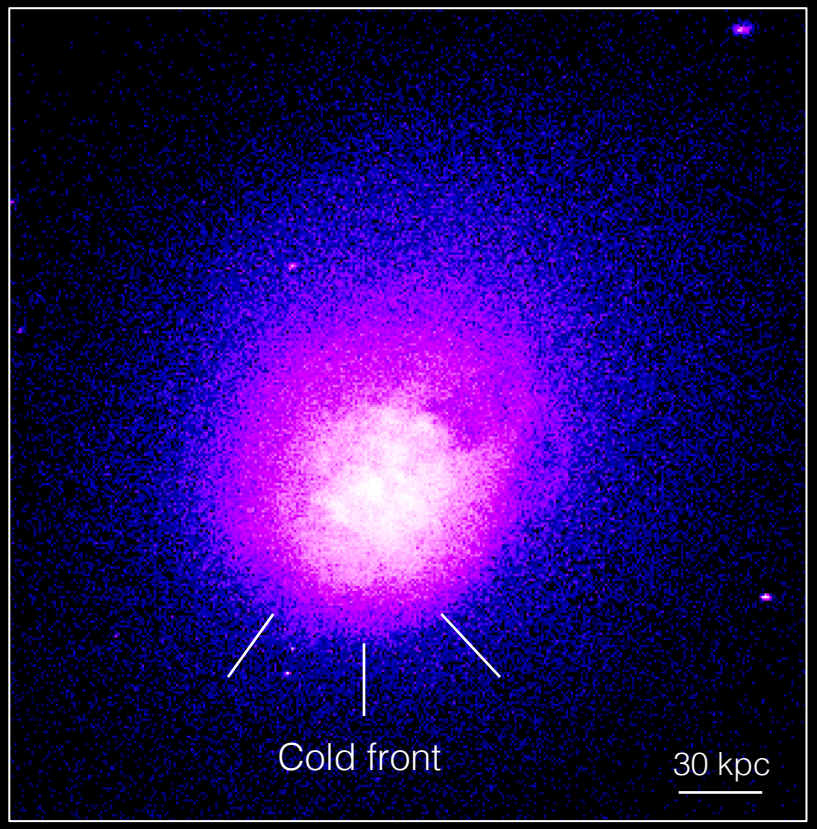
Chandra X-ray 0.5-4 keV images

A496



Dupke & White 2003, Dupke et al. 2007
Ghizzardi et al 2014

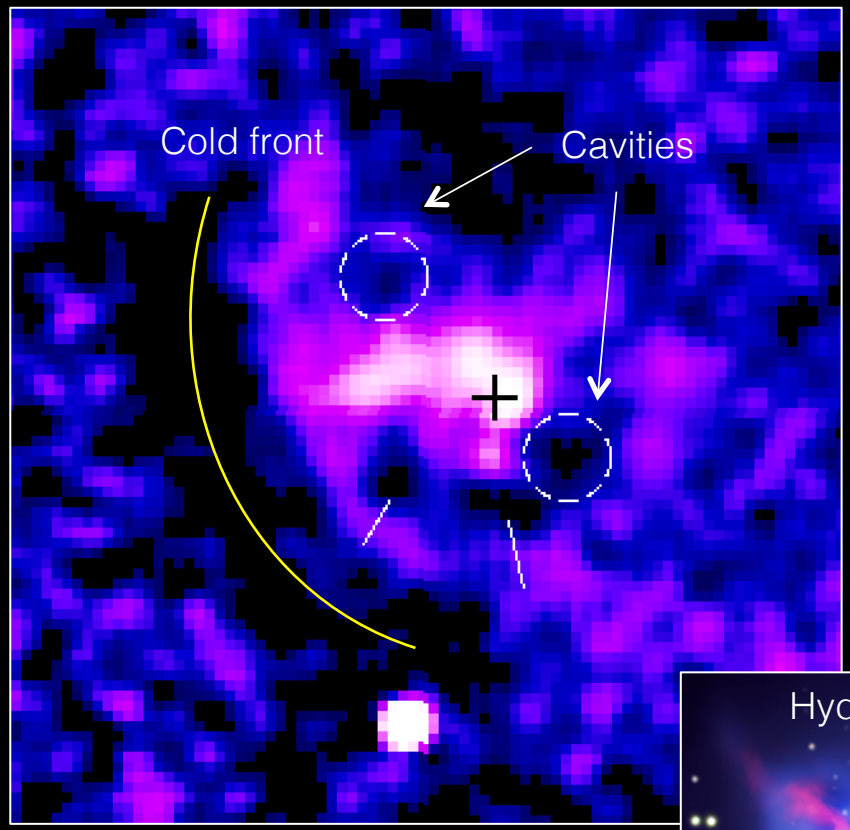
2A 0335

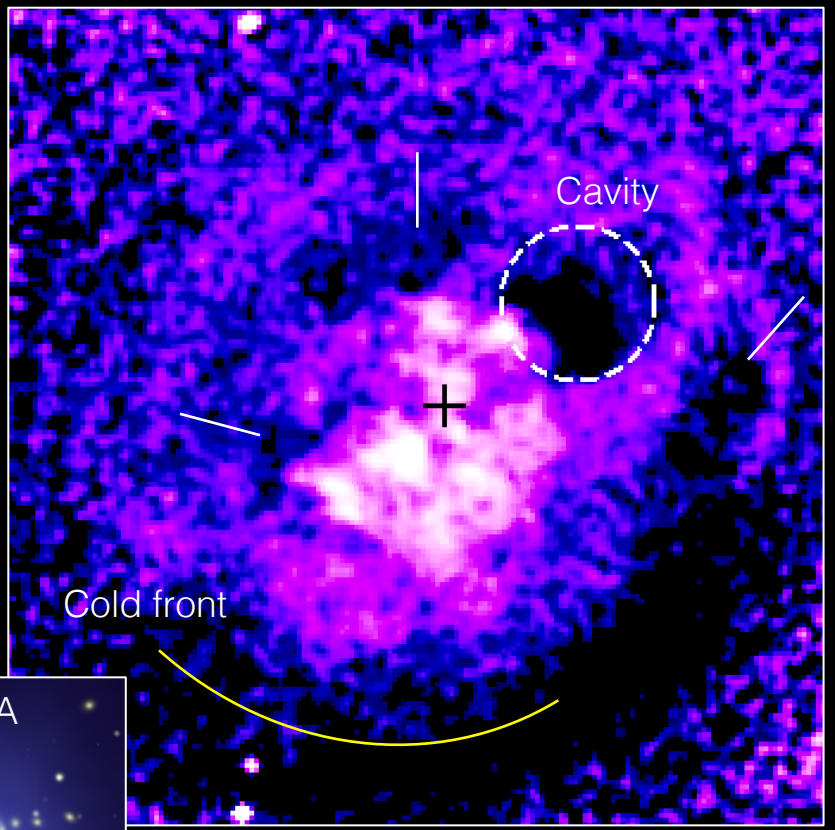


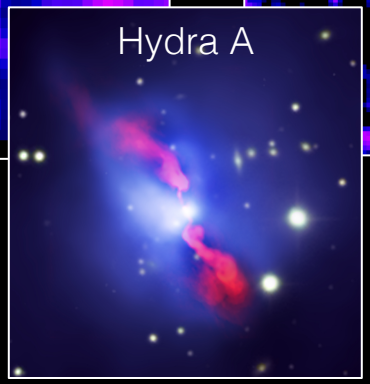
Mazzotta et al. 2003, Sanders et al. 2009

X-ray blobs and cavities in the cool core

A496 Chandra residual images 2A 0335







Giacintucci et al .

Mazzotta et al. 2003
Sanders et al. 2009

Central active radio galaxy

Chandra residual images

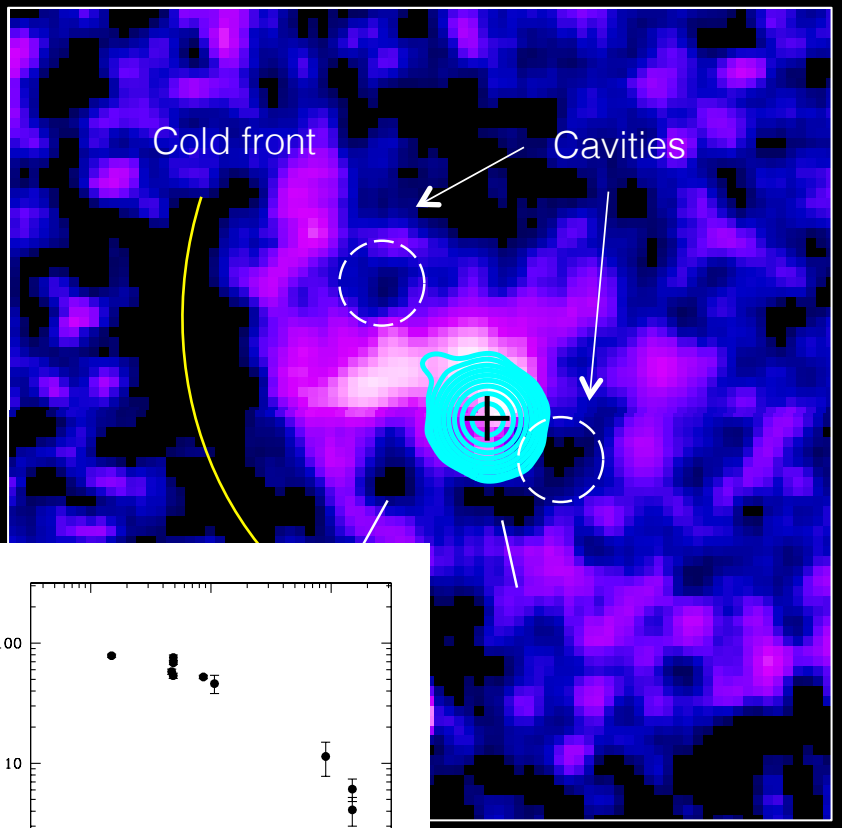
A496

2” res

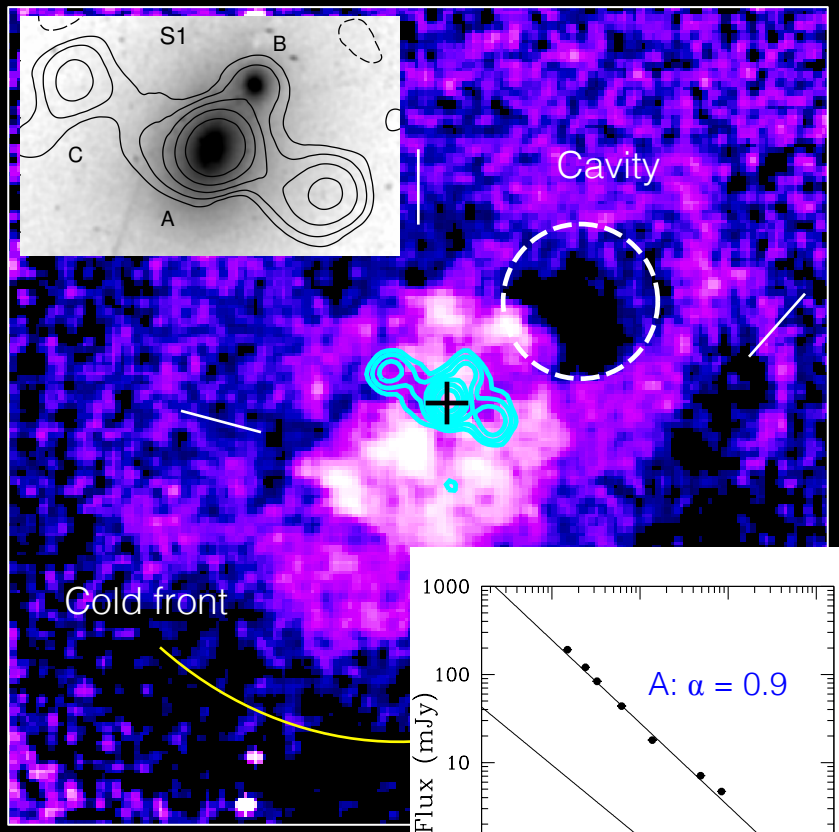
VLA 5 GHz

4” res.

2A 0335



Size < 0.3 kpc



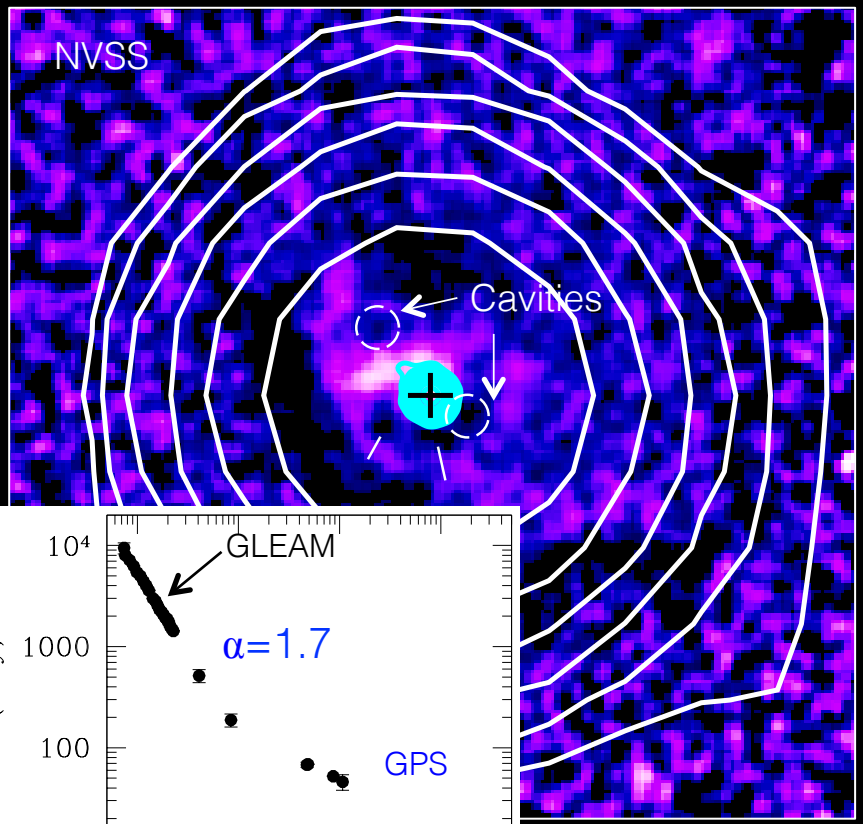
Size ~ 20 kpc

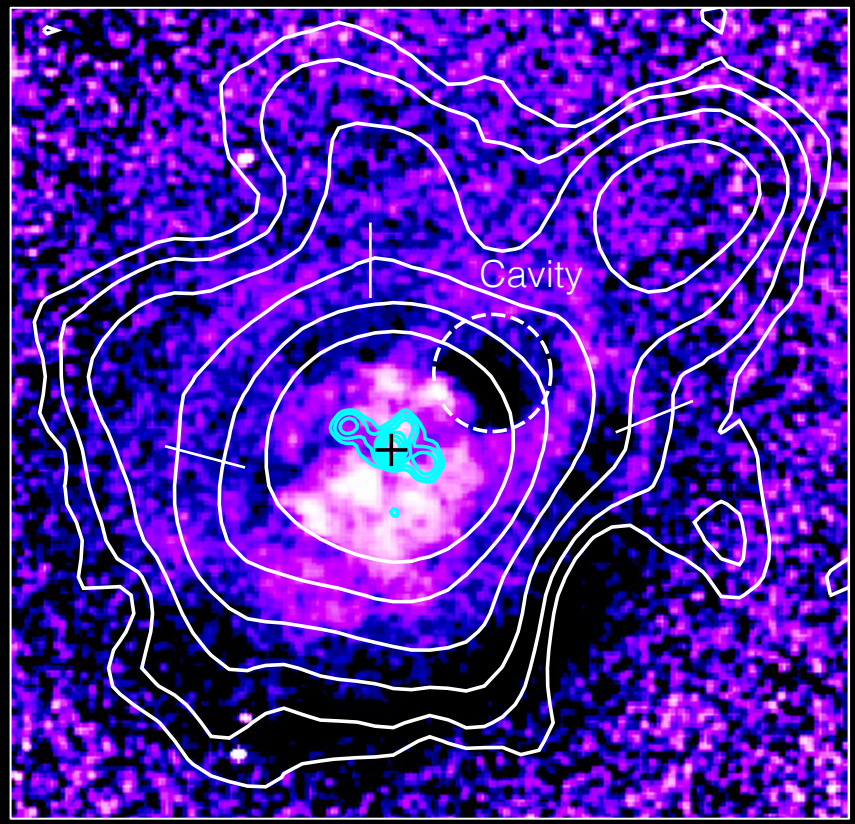
see also Hogan et al. 2015

Is there any radio emission in the cavities?

Chandra residual images

A496 45” res VLA 1.4 GHz 30” res. 2A 0335





see also Hogan et al. 2015

Radio minihalo

(Sarazin et al. 1995, Sanders et. 2009)

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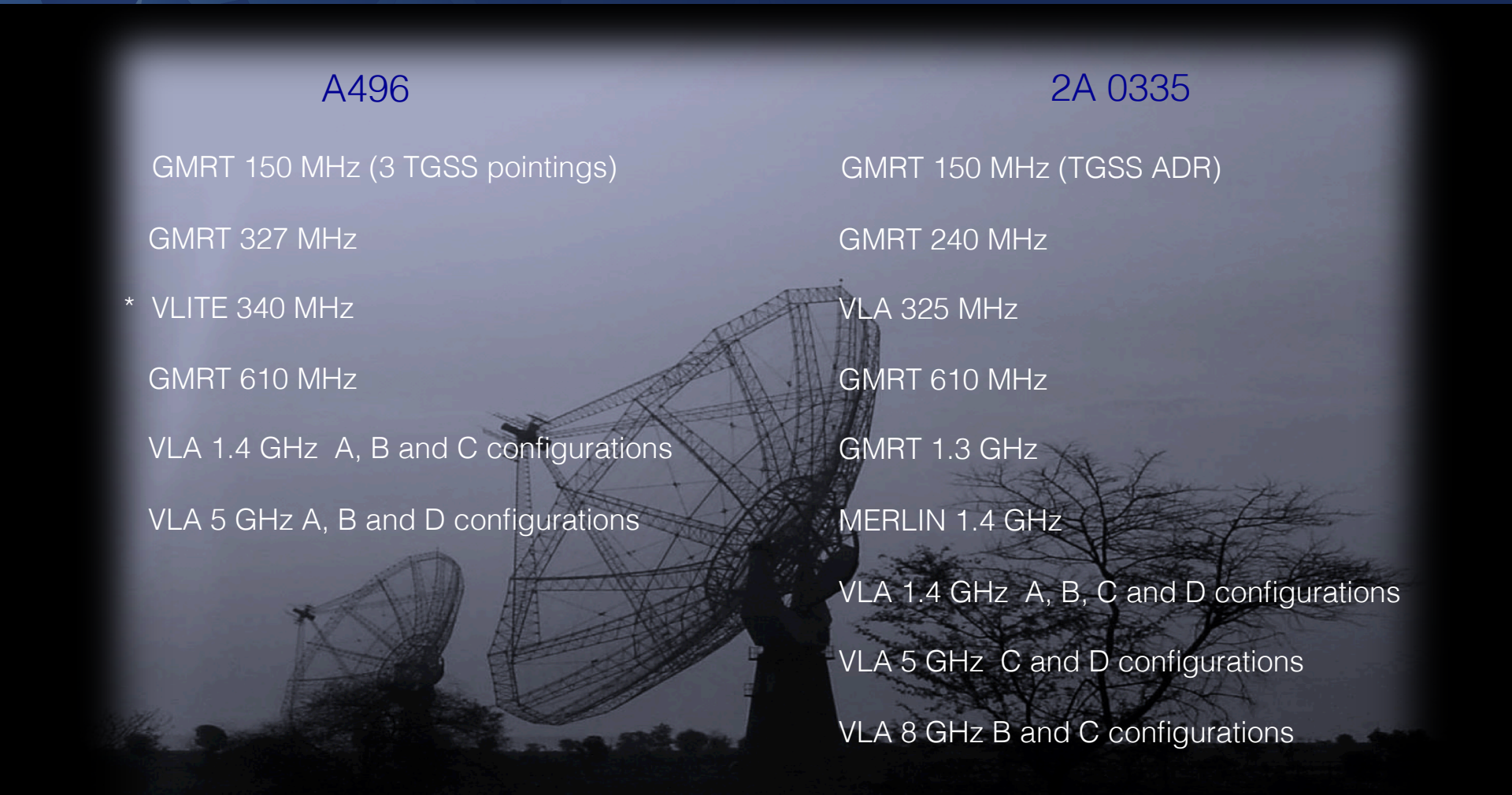
Radio data



A496

GMRT 150 MHz (3 TGSS pointings)

GMRT 327 MHz

* VLITE 340 MHz

GMRT 610 MHz

VLA 1.4 GHz A, B and C configurations

VLA 5 GHz A, B and D configurations

2A 0335

GMRT 150 MHz (TGSS ADR)

GMRT 240 MHz

VLA 325 MHz

GMRT 610 MHz

GMRT 1.3 GHz

MERLIN 1.4 GHz

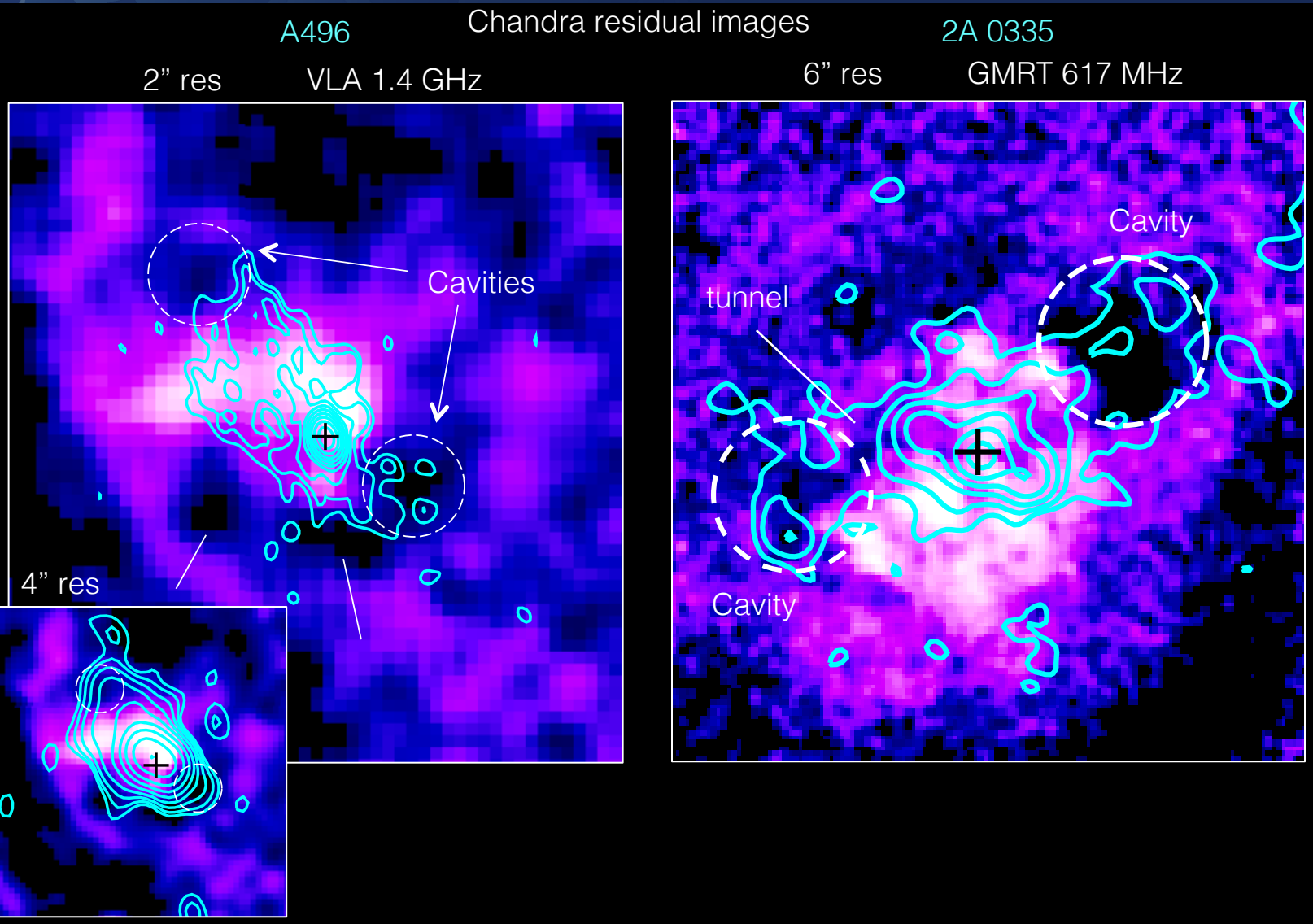
VLA 1.4 GHz A, B, C and D configurations

VLA 5 GHz C and D configurations

VLA 8 GHz B and C configurations

* VLA Low-band Ionosphere and Transient Experiment (see Tracy Clarke's poster)

Extended radio emission in the cavities

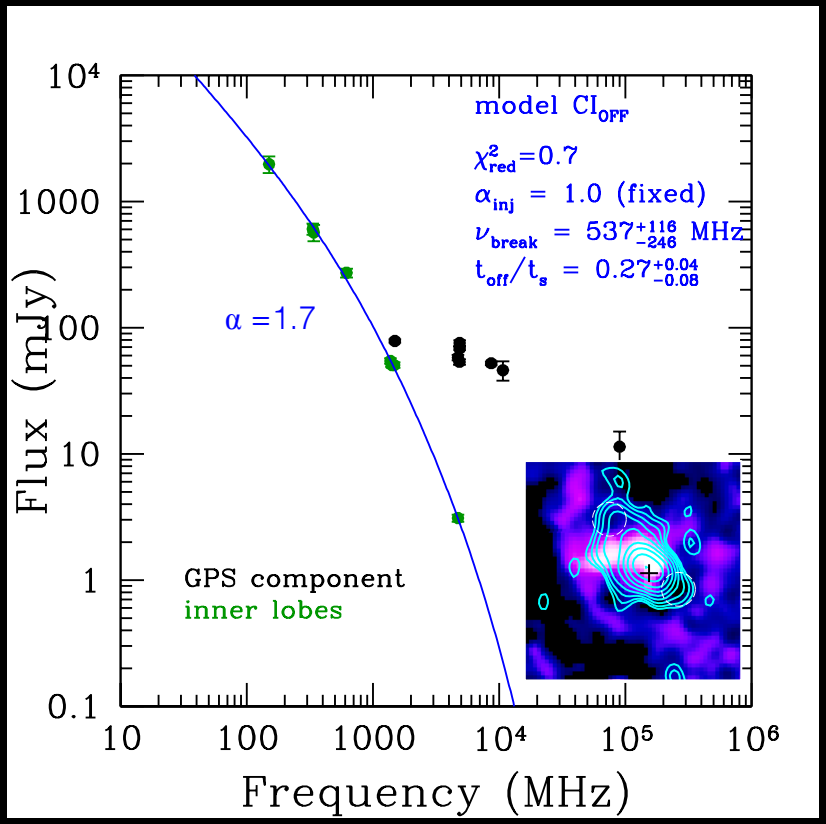


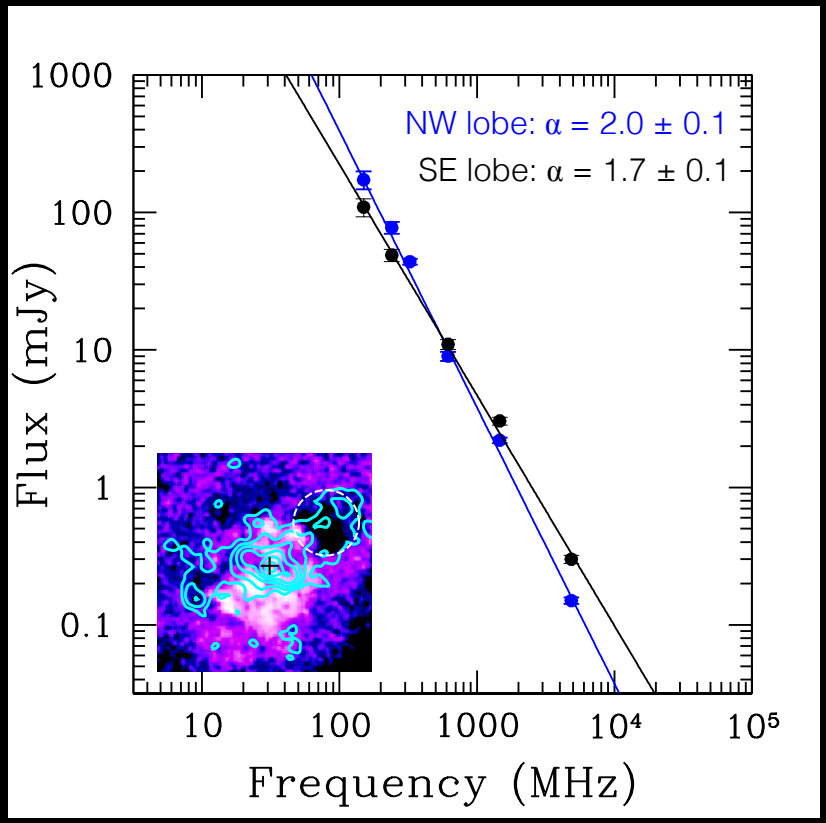
Relic lobes from past radio outburst

A496

2A 0335

Radio lobe spectra





for B_{min} = 14 μGauss:

t_s ~ 23 Myr

for B_{min} = 24 μGauss:

t_s > 28 Myr

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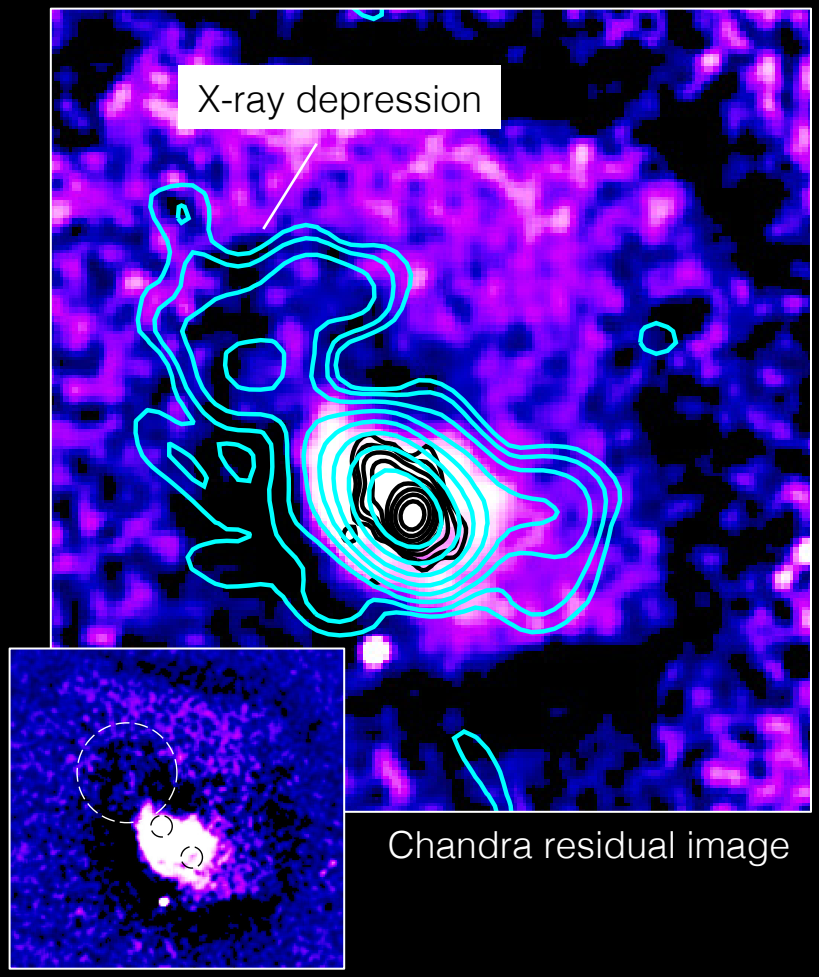
Relic lobes from an even older radio outburst?

A496

12” res GMRT 327 MHz



Chandra residual image

2A 0335

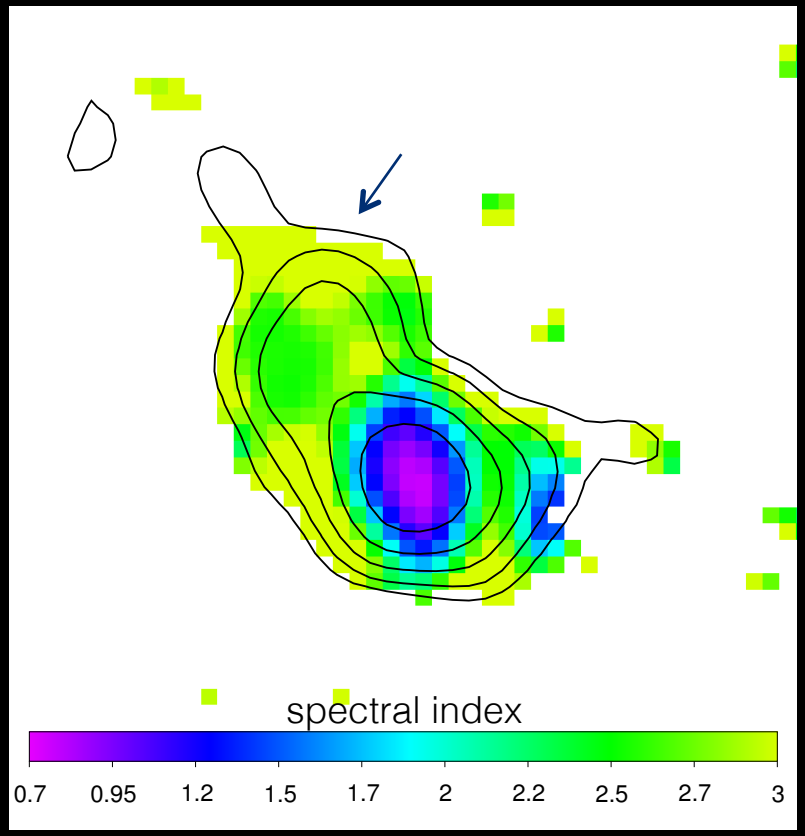
15” res GMRT 617 MHz

XMM+Chandra residual image

Relic lobes from an even older radio outburst

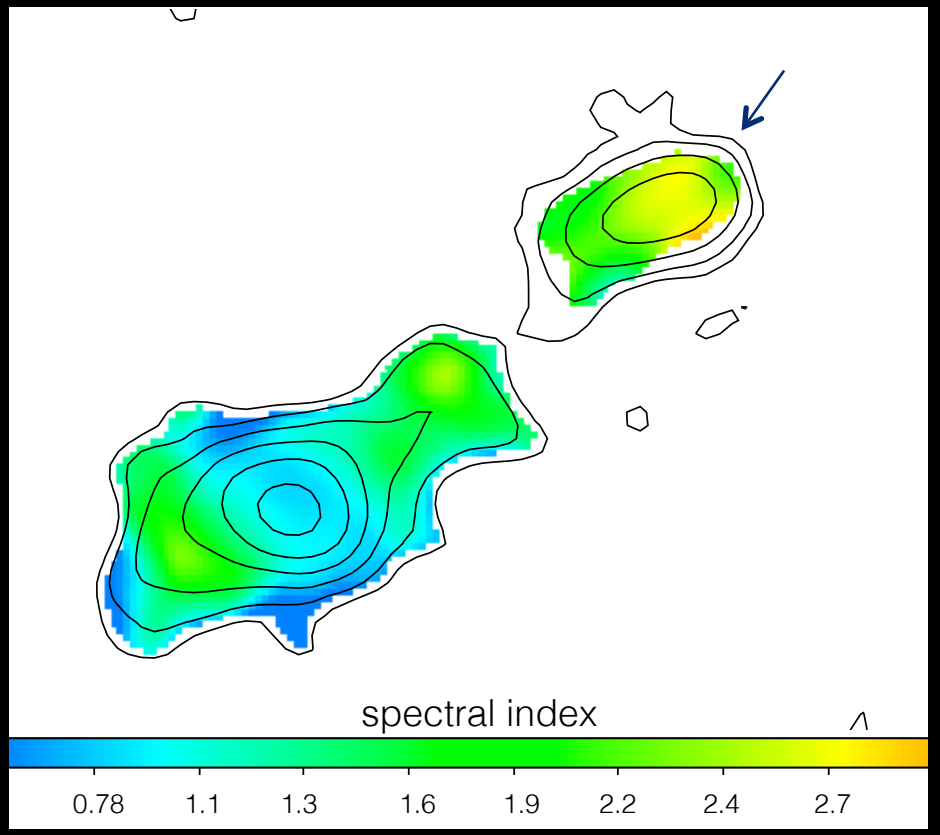
A496

GMRT 150-327 MHz



2A 0335

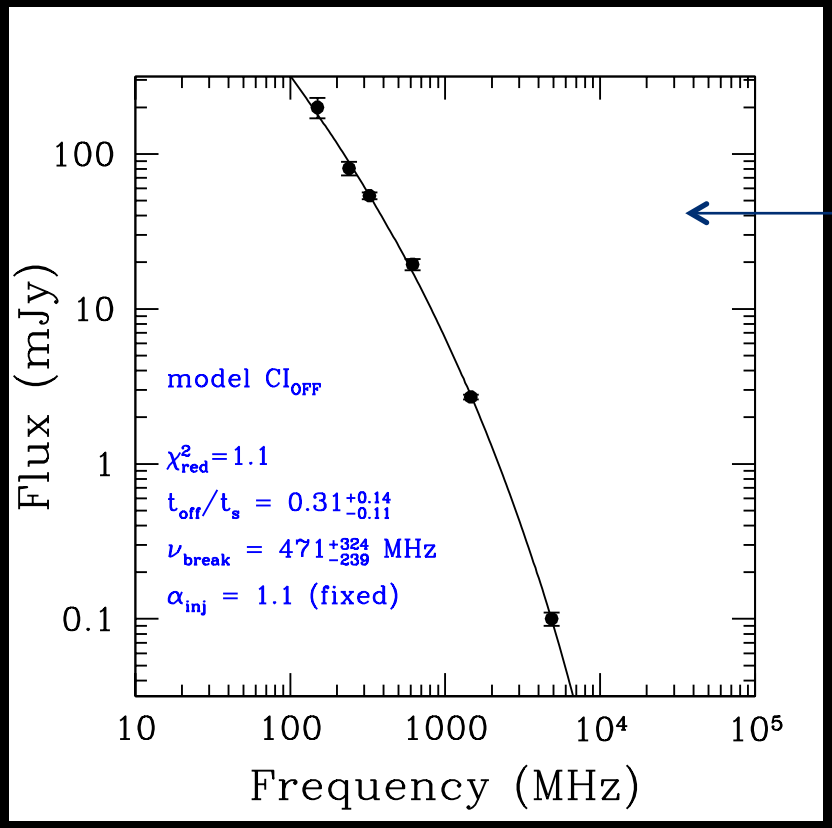
GMRT 617 MHz – VLA 1.4 GHz

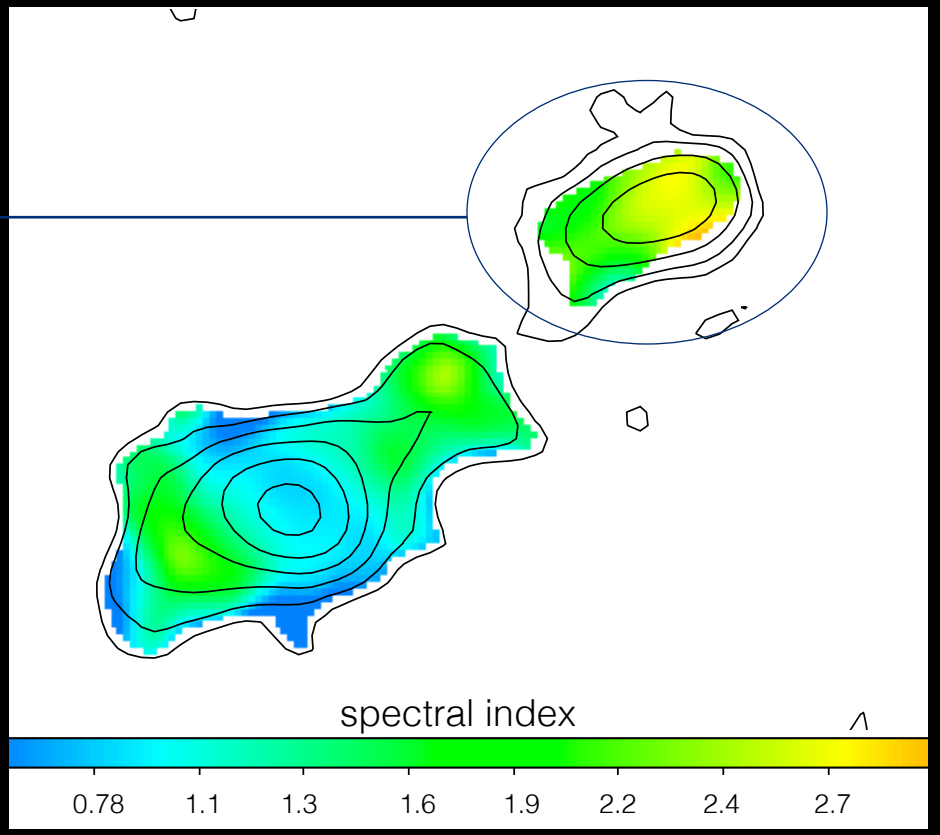


Relic lobes from an even older radio outburst

2A 0335

GMRT 617 MHz – VLA 1.4 GHz





for B_{min} = 10 μGauss

t_s ~ 60 Myr

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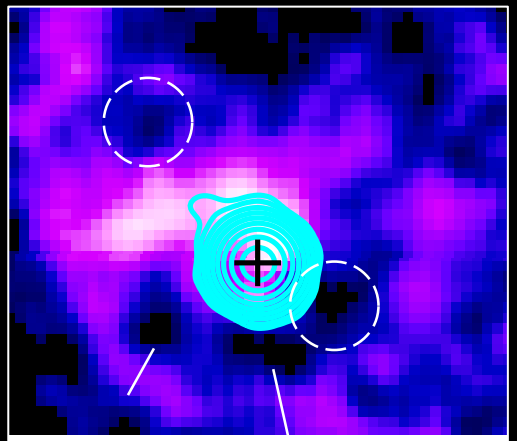
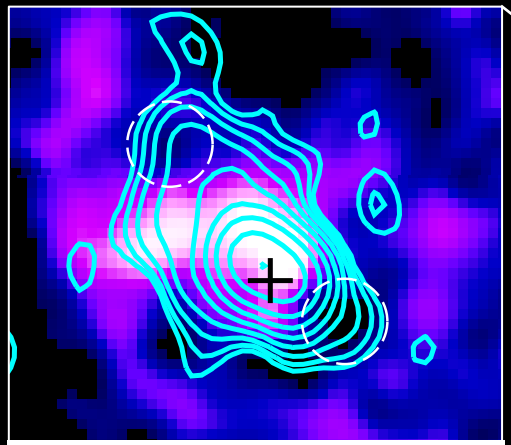
A history of 3 AGN outbursts

I. Current activity



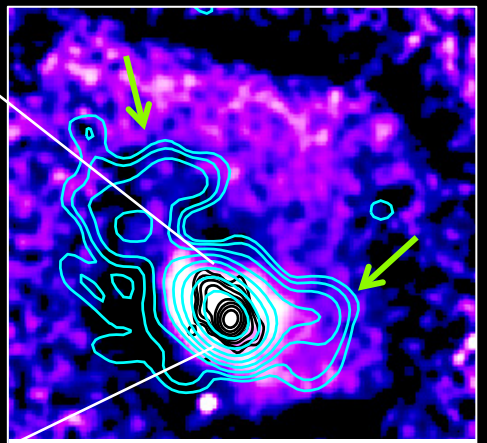
Size < 0.3 kpc

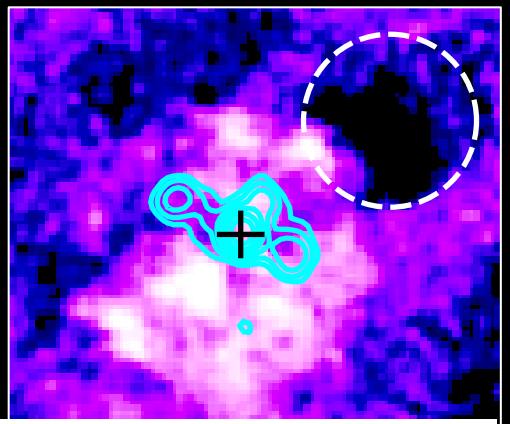
II. Past activity



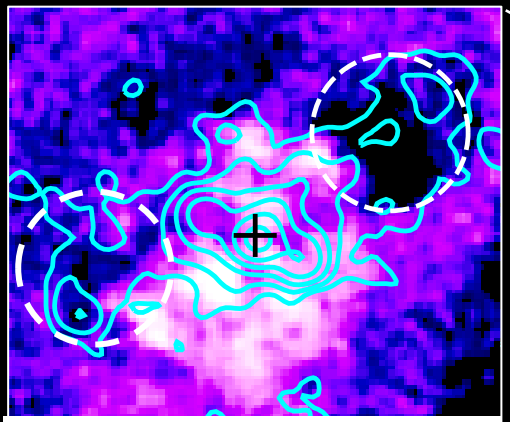
age~23 Myr

III. Even older activity

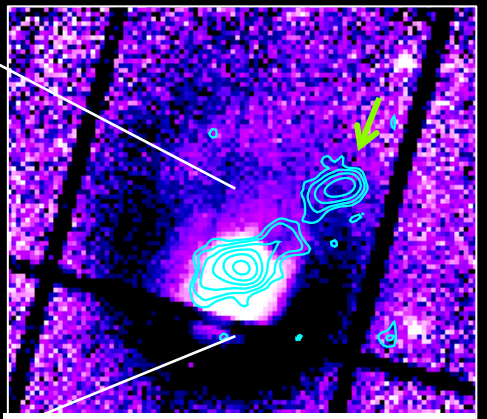




Size 20 kpc



age > 28 Myr



age~60 Myr

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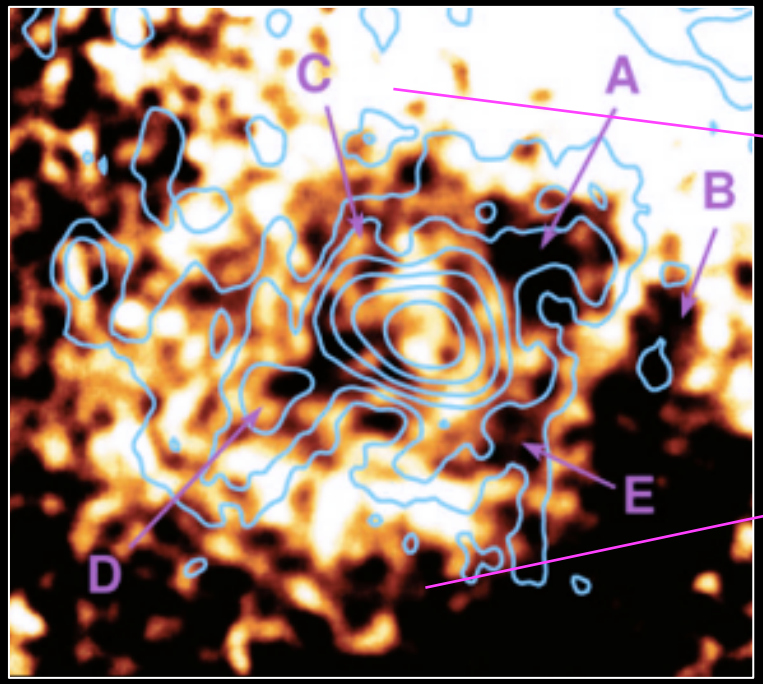
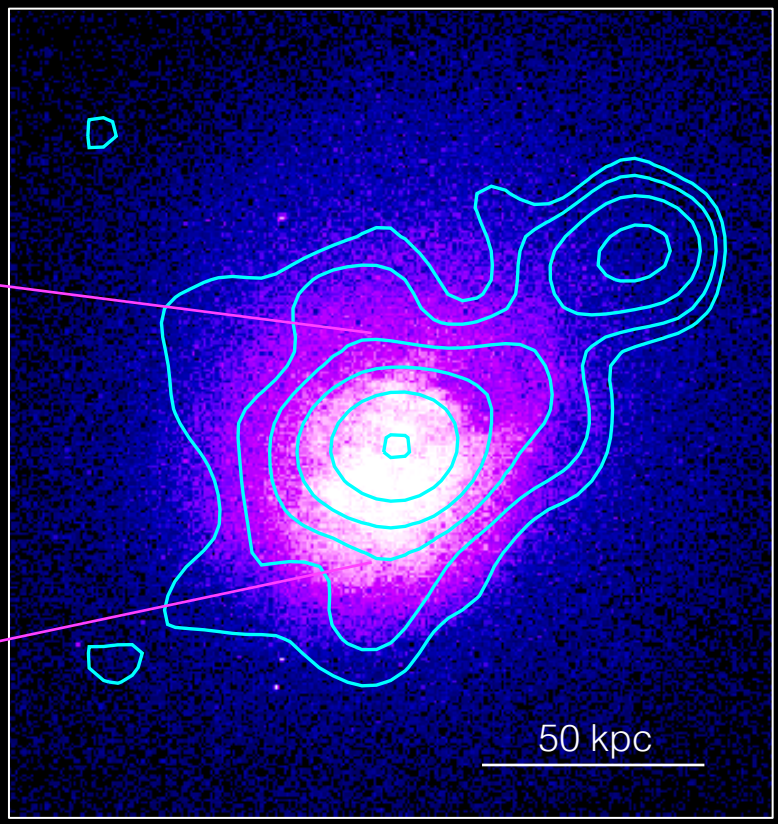
The minihalo in 2A 0335+096

Is the minihalo formed by episodes of AGN activity?



Sanders et. 2009



see also Sarazin et al. 1995

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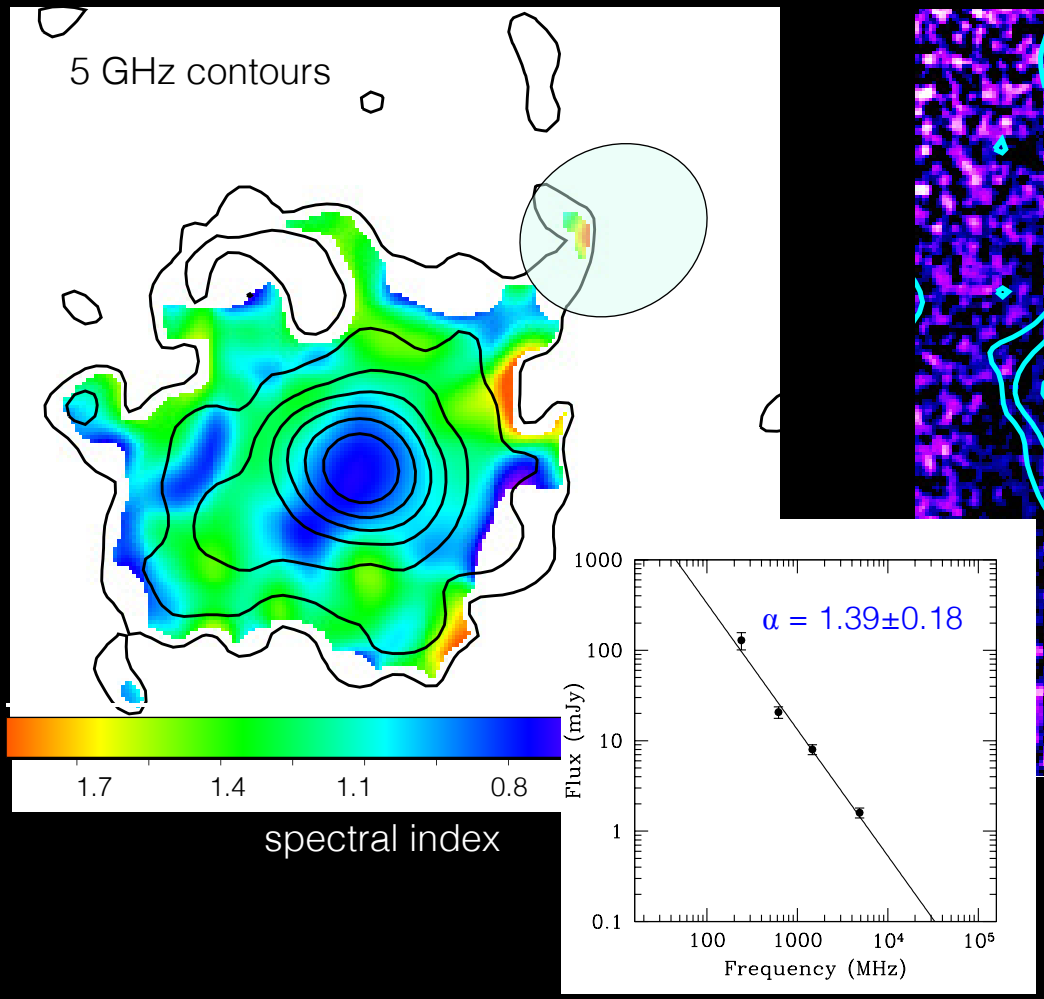
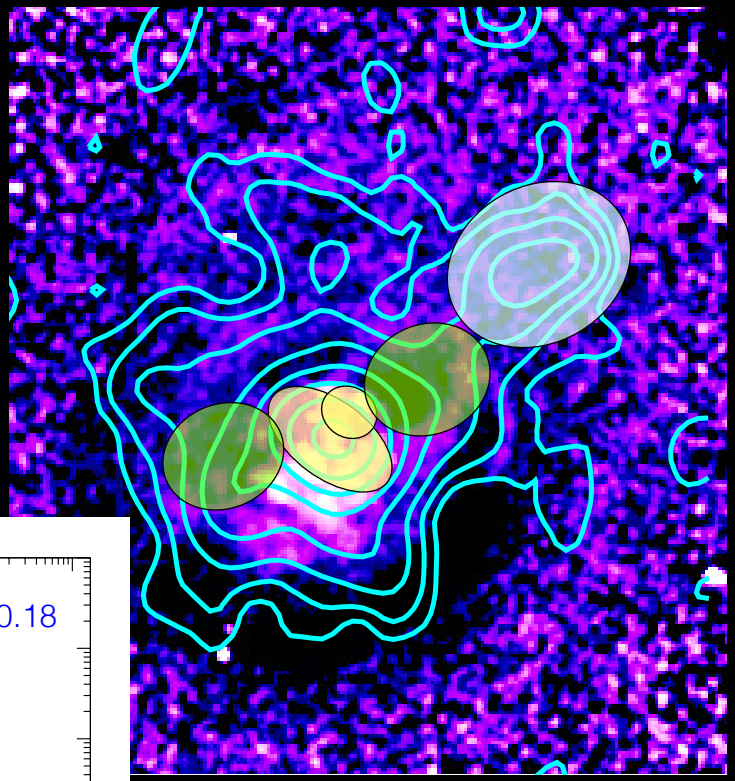
Minihalo spectrum

1.4- 5 GHz spectral index - 17” res

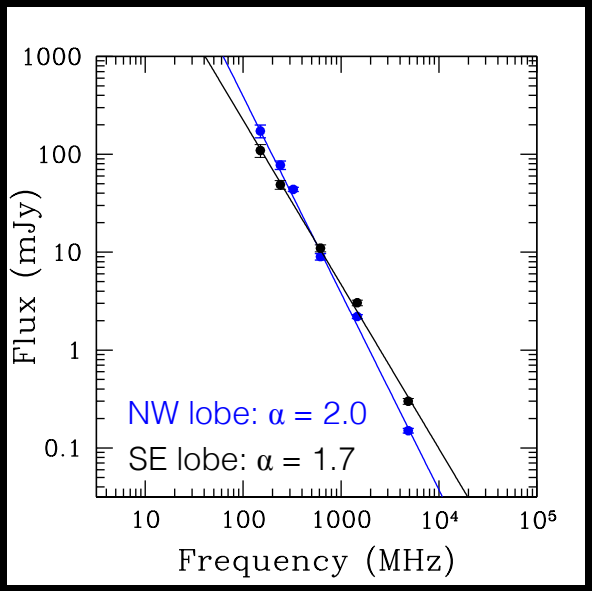


17” res VLA 1.4 GHz

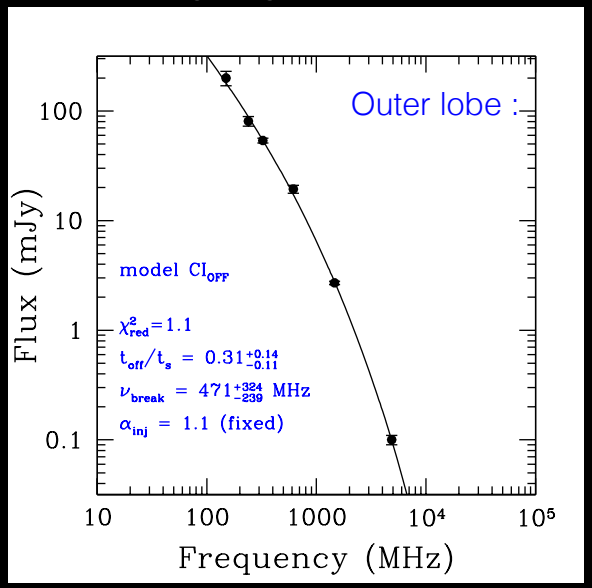


The minihalo spectrum is flatter than the spectrum of the relic lobes

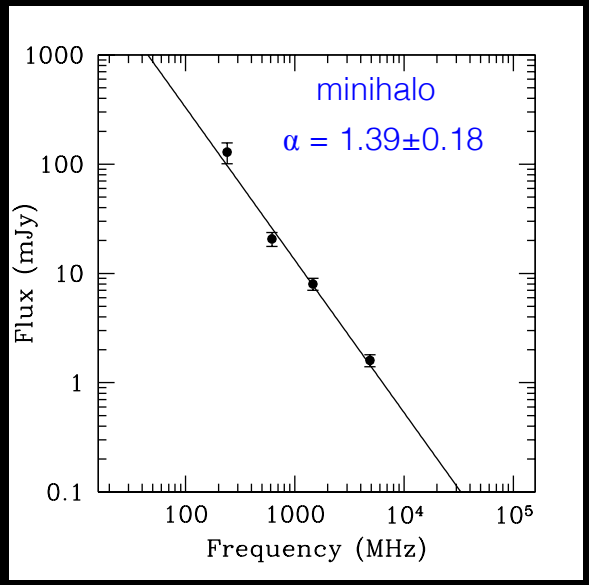
ageing electrons

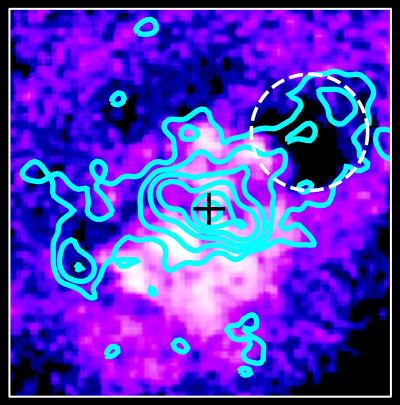


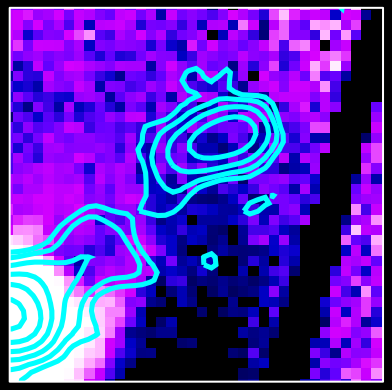
ageing electrons

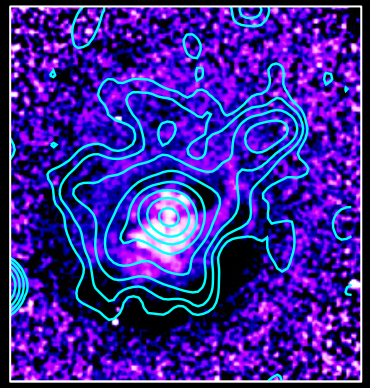


reaccelerated electrons









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Thank you