PROBING THE NON-THERMAL EMISSION IN THE PERSEUS CLUSTER WITH THE JVLA

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Université de Montréal

CRAQ
Comprendre l'Univers

X-TRA

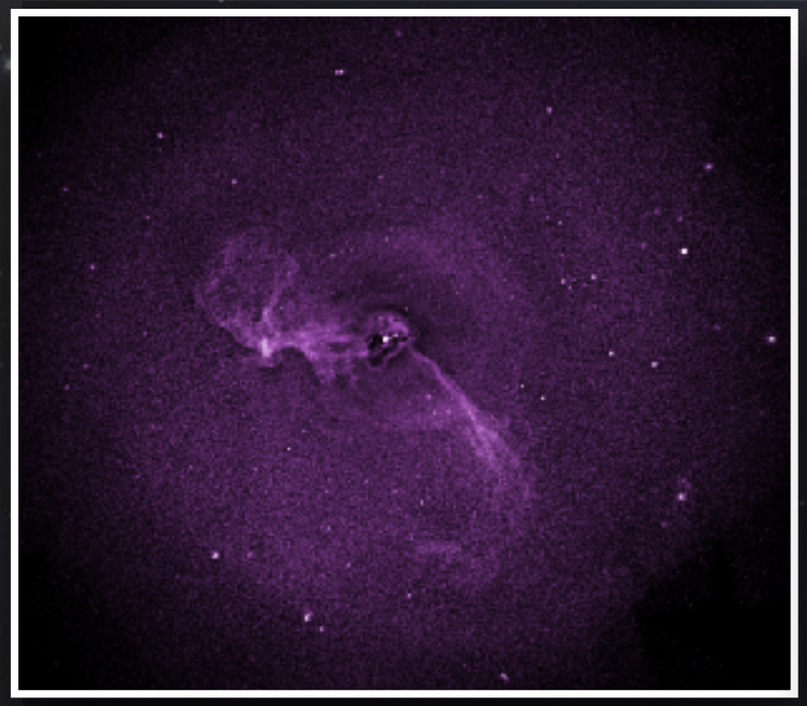
1 - Diffuse radio emission in clusters

2 - High dynamic imaging with JVLA

3 - Abell 2146: Mystery solved!

4 - Perseus: Mini-halo & friends

1 - Diffuse radio emission in clusters

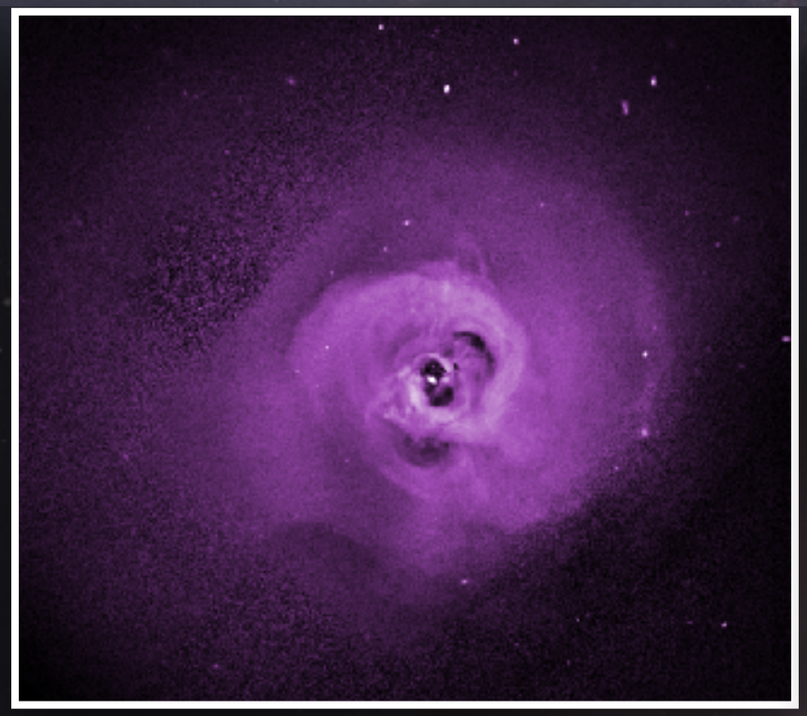


Virgo cluster

0.50 Ms Chandra

z = 0.003 (D = 19 Mpc)

Forman et al. 2007



Perseus cluster

1.4 Ms Chandra

z = 0.018 (D = 72 Mpc)

Fabian et al. 2011

NGC 5813 - Galaxy group

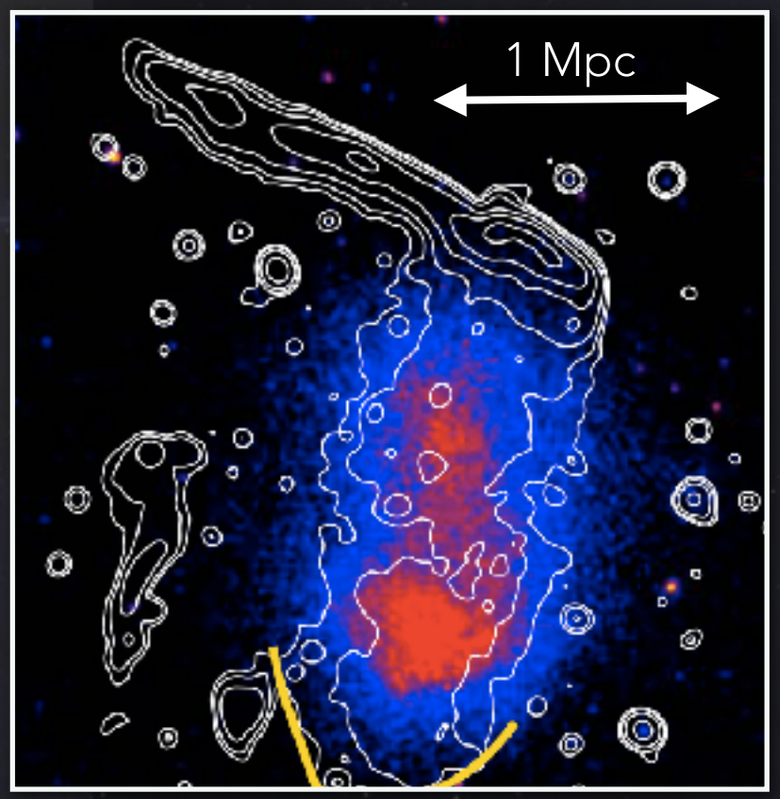
650 ks Chandra

z = 0.0065 (D = 30 Mpc)

Randall et al. 2015

1 - Diffuse radio emission in clusters

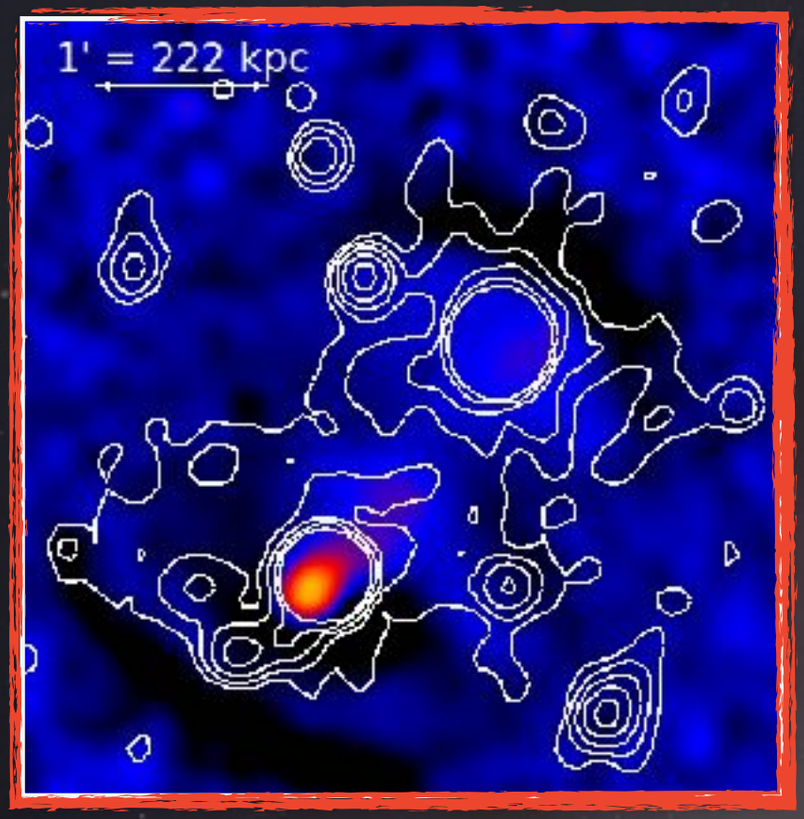
1-Radio relic



“Toothbrush” RX J0603.3+4214

VLA 1-2 GHz radio contours
+ Chandra image
(van Weeren et al. 2016, Rajpurohit et al. 2017)

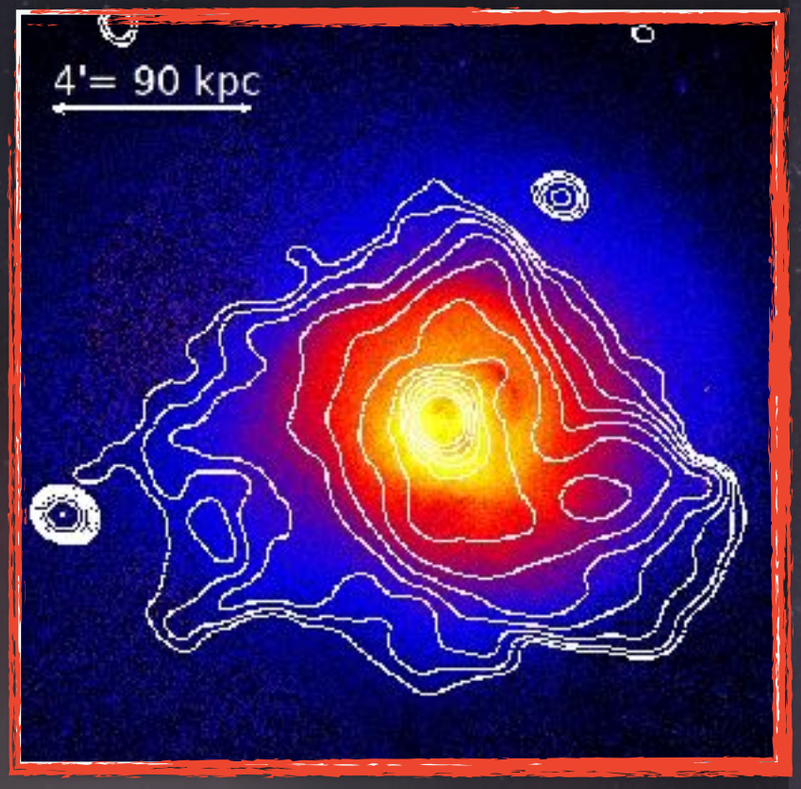
2-Radio halo



Abell 2146

1-2 GHz JVLA contours
(Hlavacek-Larrondo, **Gendron-Marsolais** et al. 2017)
+ Unsharp-masked Chandra
(Russell et al. 2010, 2012)

3-Mini-halo

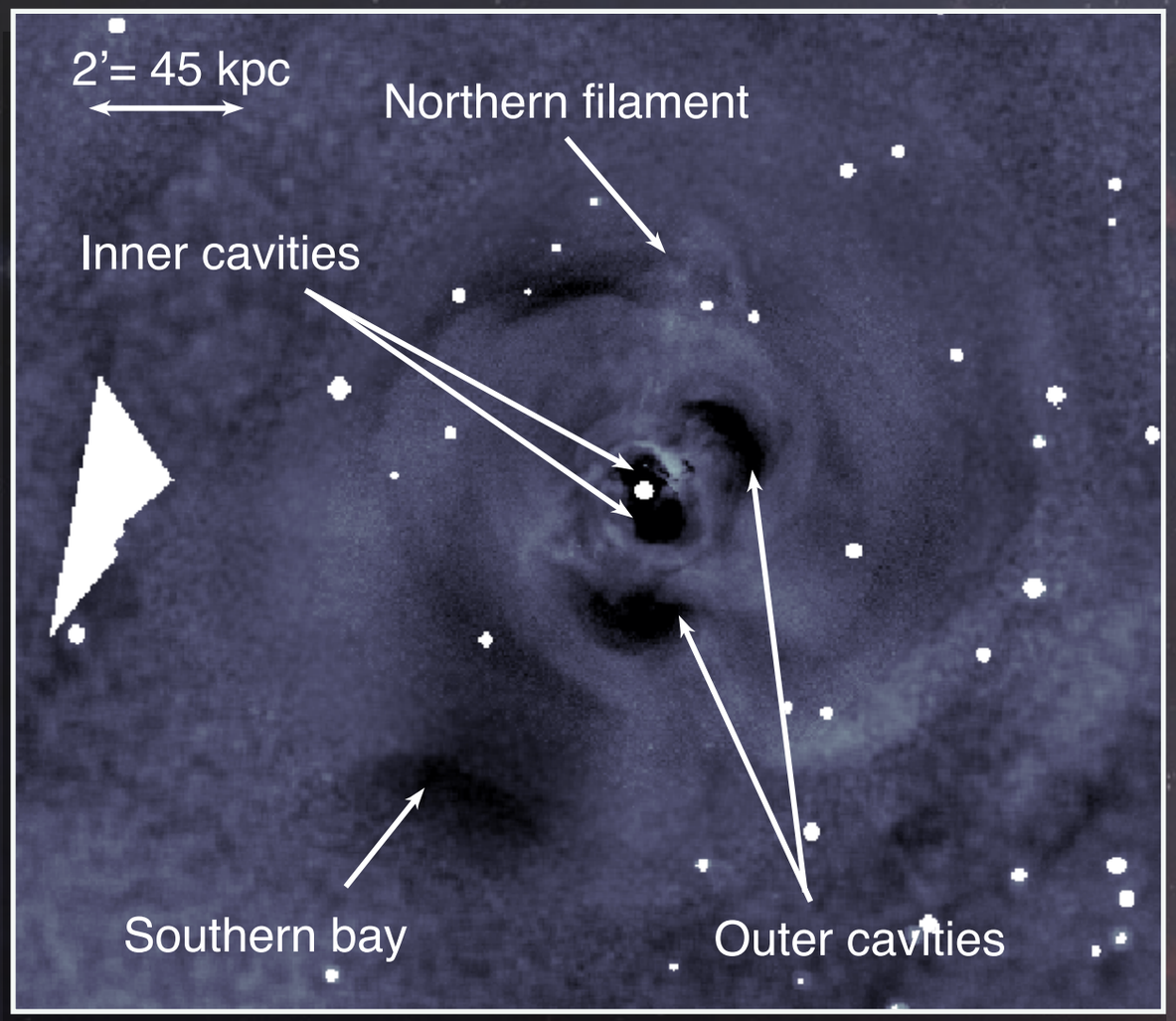


Perseus

270-430 MHz JVLA contours (**Gendron-Marsolais** et al. 2017)

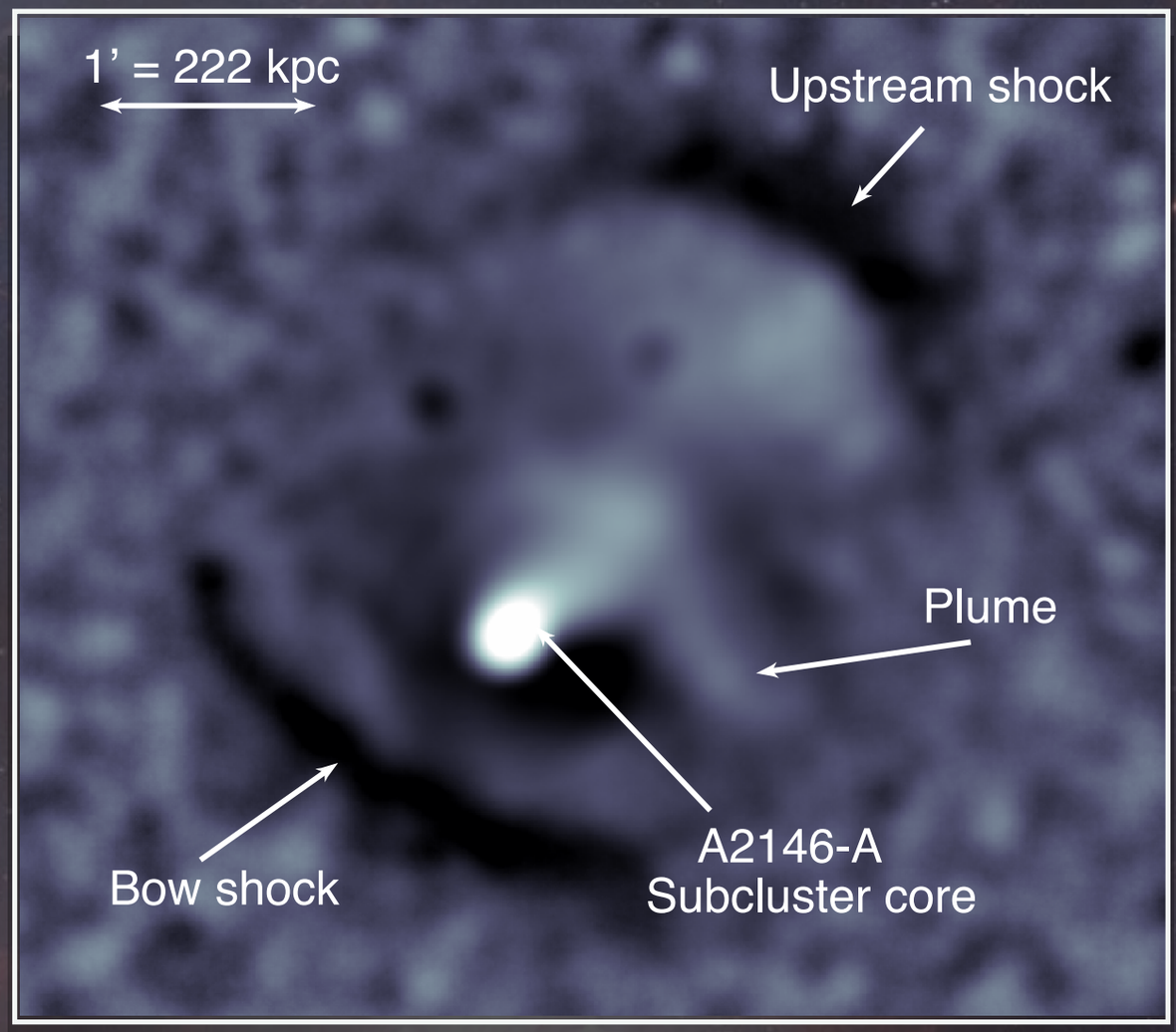
+ Chandra image
(Fabian et al. 2011)

Perseus



Chandra composite fractional residual image
(0.5-7 keV, 1.4 Ms, Fabian et al. 2011)

Abell 2146

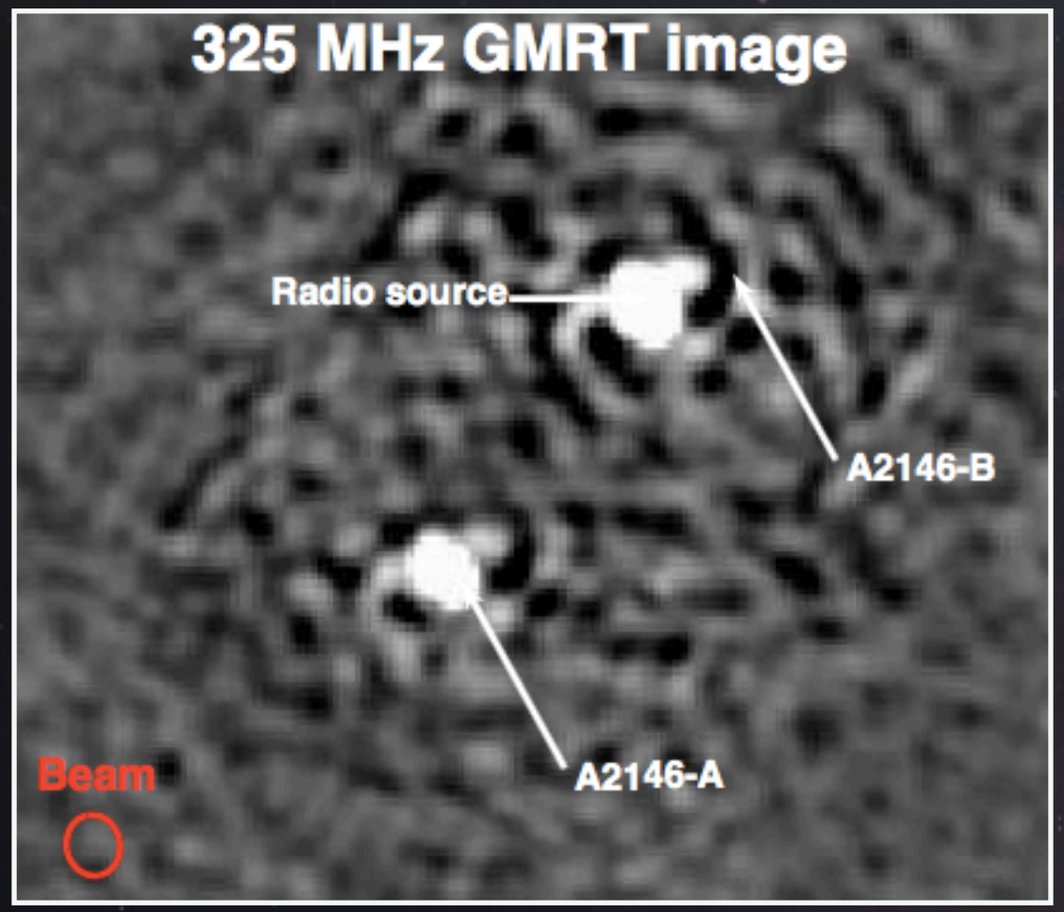


Unsharp-masked Chandra image
(0.3 – 7.0 keV, 420 ks, Russell et al. 2010, 2012)

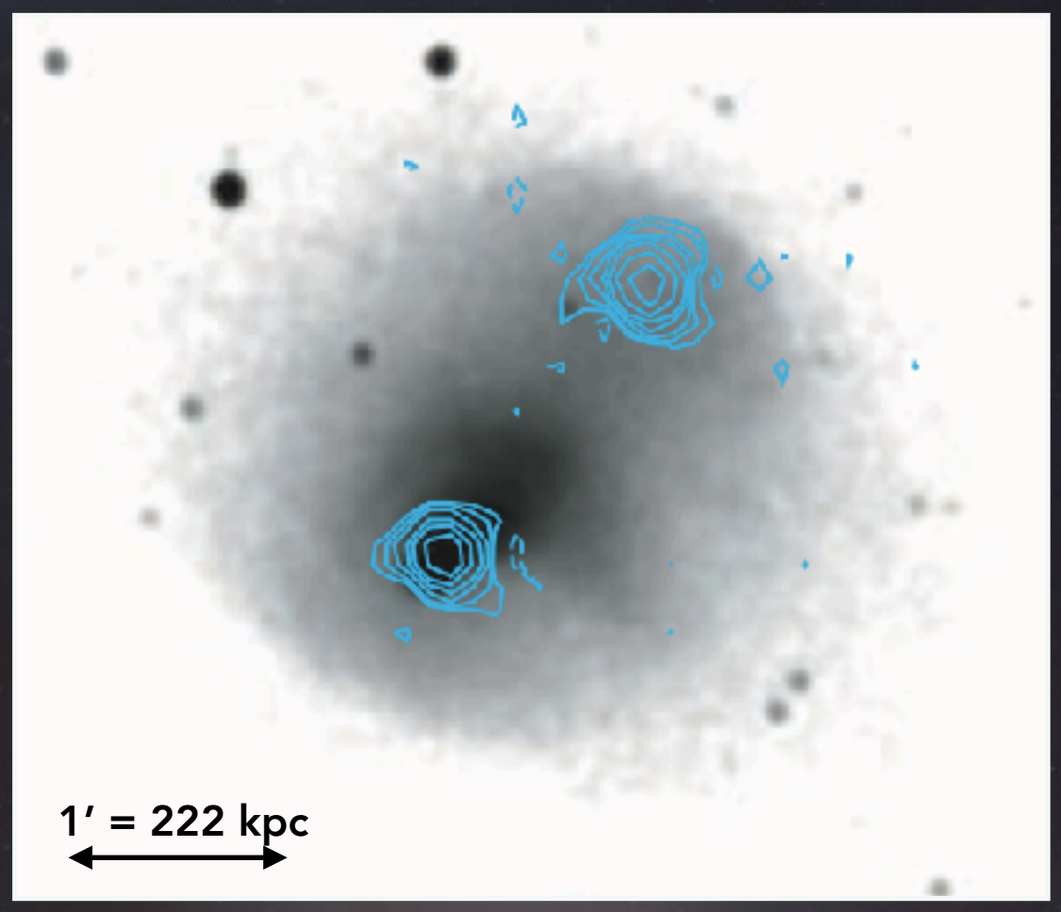
2 - High dynamic imaging with JVLA

	Perseus (z = 0.018)	**A2146 (z = 0.23)**
Frequency	P-band (230 - 470 MHz)	L-band (1-2 GHz)
Datasets	5 h (A-array) 10 h (B-array) 4 h (C-array) 3 h (D-array)	2.4h (B-array) 7.4h (C-array) 1.3h (D-array)
Resolution	From ~ 4″ to 20″	14.1″ × 13.5″
RMS	From ~300 to 900 μJy/beam	12 μJy/beam

3 - Abell 2146: Mystery solved!

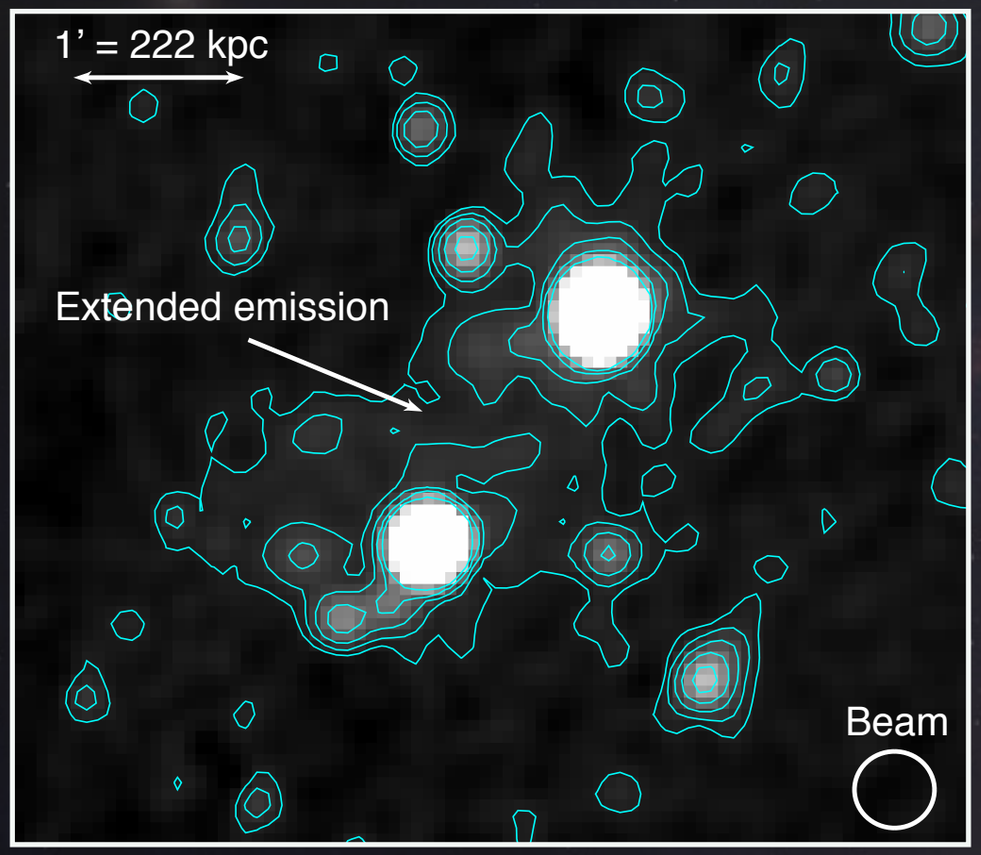


GMRT 325 MHz radio image (Russell et al. 2011)

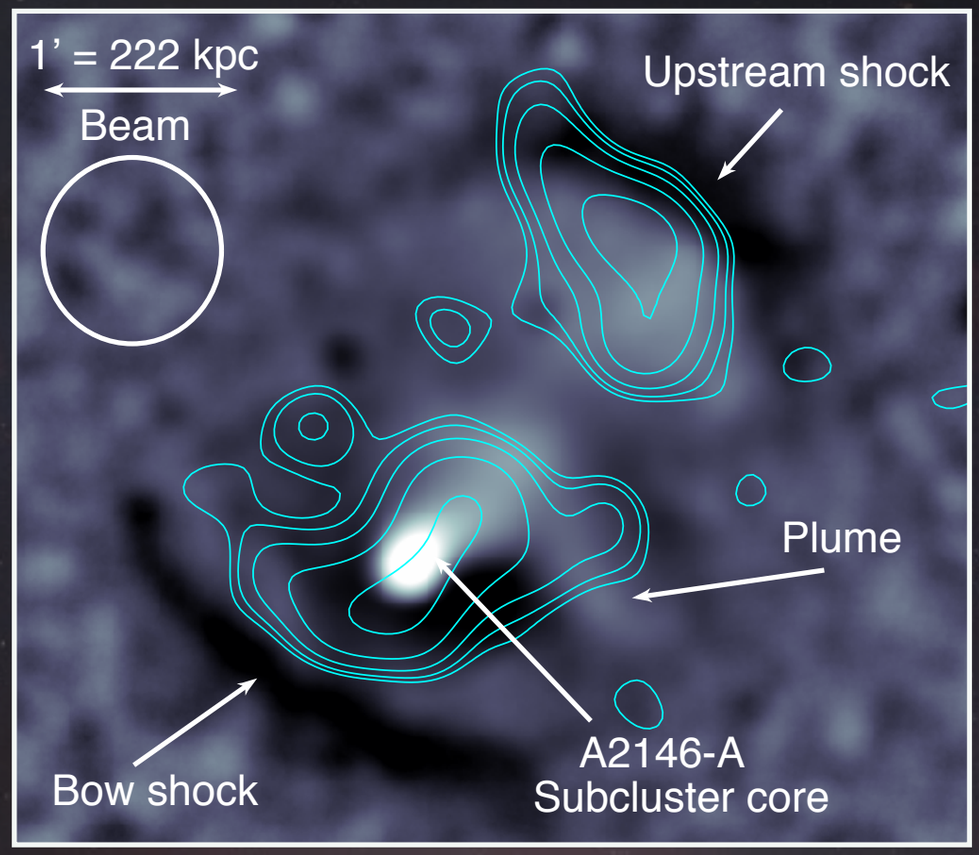


Chandra image (0.3 – 7.0 keV, 420 ks)
+ GMRT 325-MHz contours, beam = 9.3” × 8.1”
(Russell et al. 2011)

3 - Abell 2146: Mystery solved!



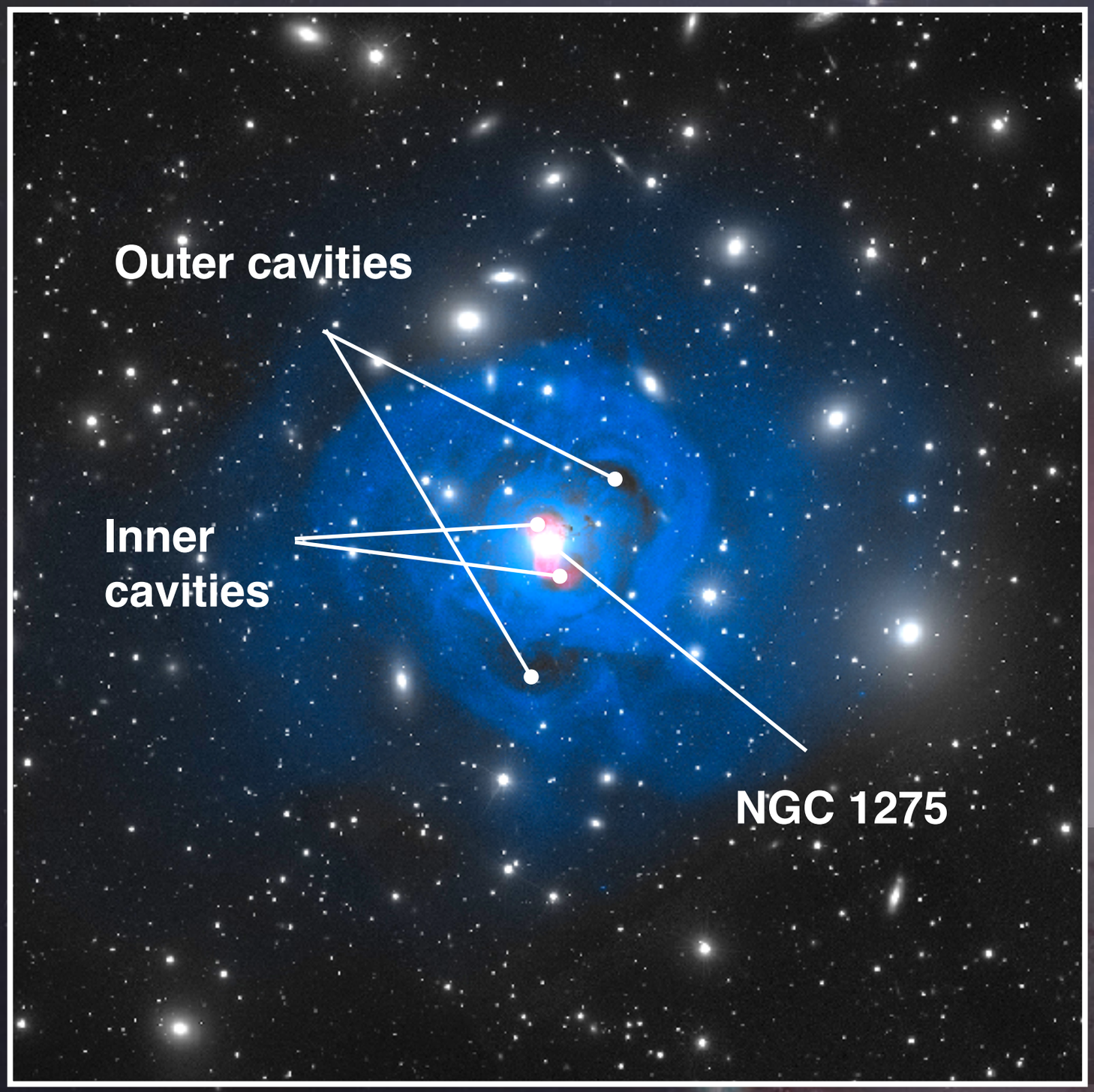
Low-resolution JVLA 1 – 2 GHz image (Hlavacek-Larrondo et al. 2017)



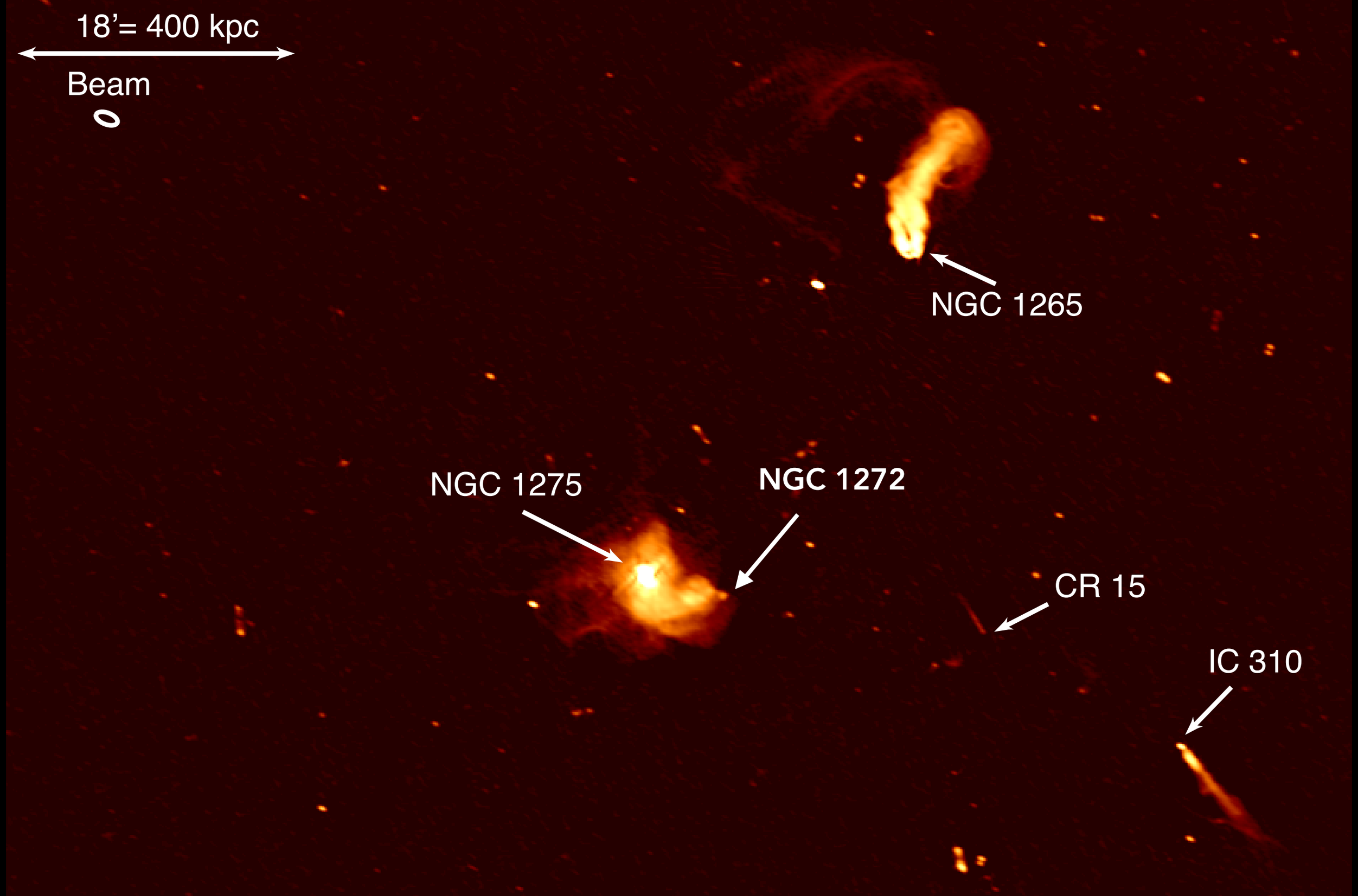
Unsharp-masked Chandra image (0.3 – 7 keV, 420 ks, Russell et al. 2010, 2012) + point source subtracted 1 – 2 GHz JVLA image contours starting at 3σ = 0.7 mJy/beam (Hlavacek-Larrondo et al. 2017)

- Faint structure ~850 kpc in size, elongated along merger axis, confined between bow & upstream shocks
- Multiple components
- Lowest radio power
- Suggest early stages of formation (~ 0.3 Gyr after core passage)

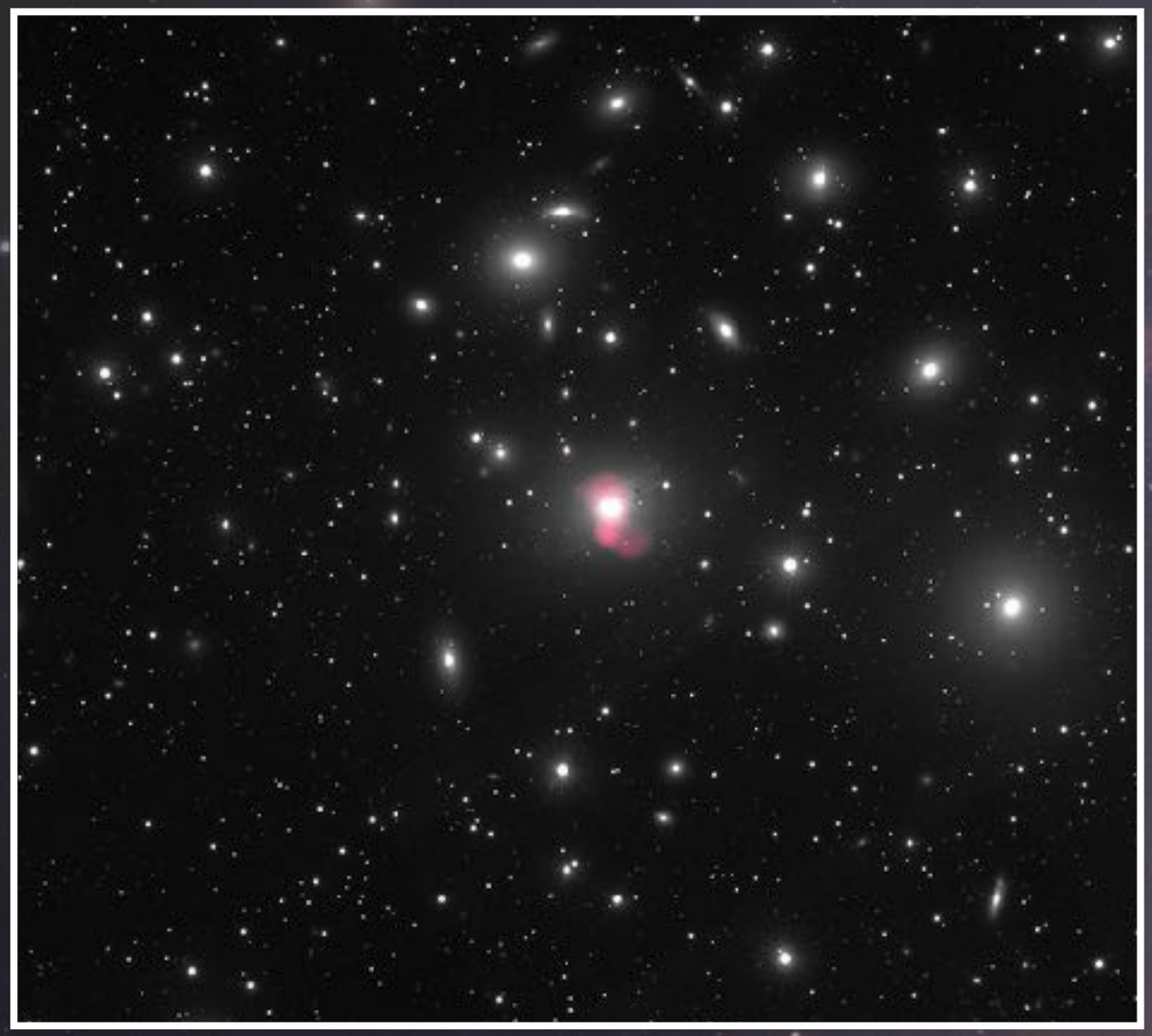
4 - Perseus: Mini-halo & friends



SDSS i-band mosaic
+ Chandra composite fractional residual image (0.5-7 keV, 1.4 Ms exposure, Fabian et al. 2011)
+ 328 MHz VLA radio image (NRAO/ VLA/G. Taylor)

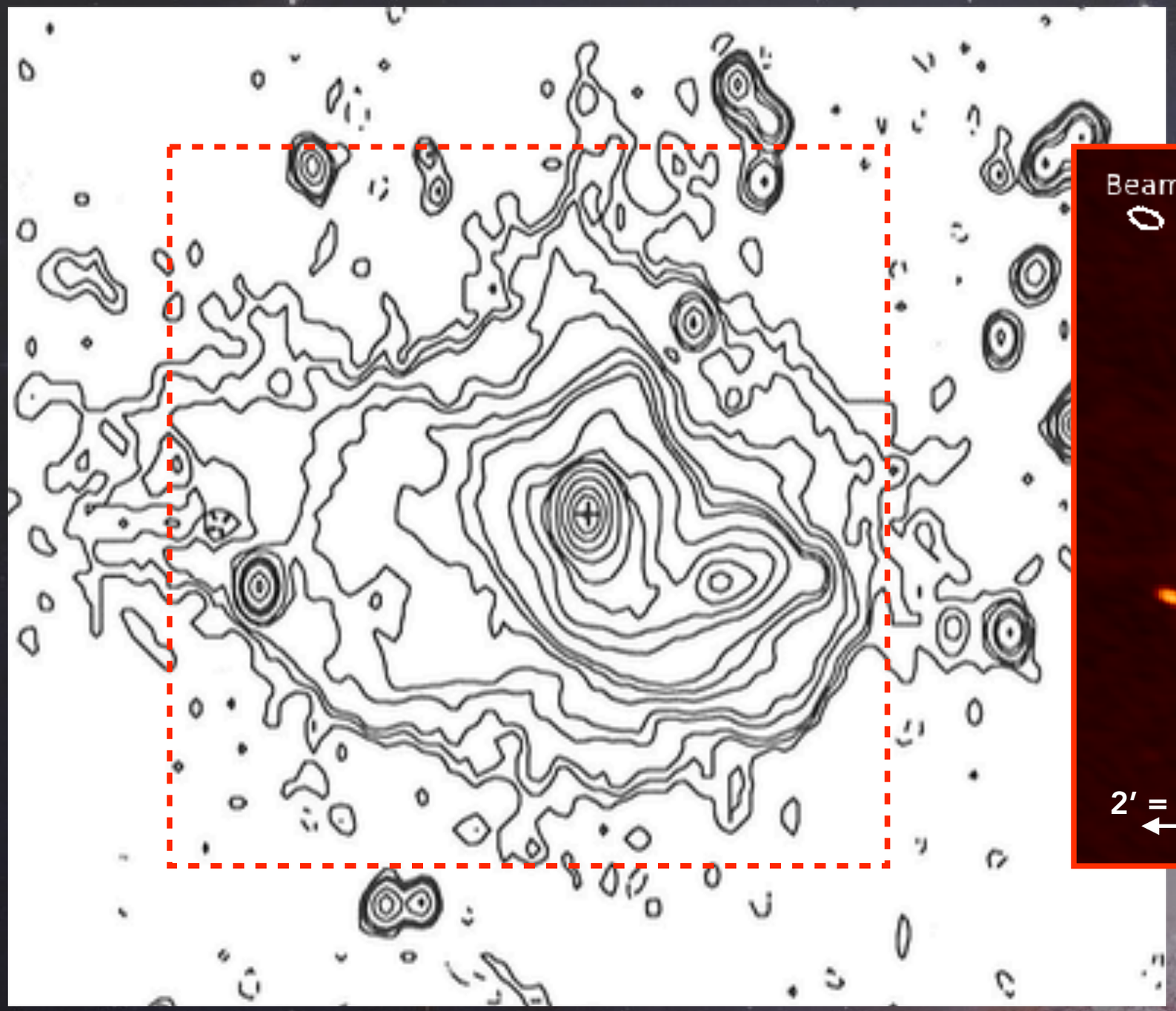


JVLA 230-470 MHz radio map in B-configuration
(5h, shared-risk proposal, PI Hlavacek-L.)
(rms =0.35 mJy/beam, beam 22.1”× 11.3”)
Gendron Marsolais et al. 2017

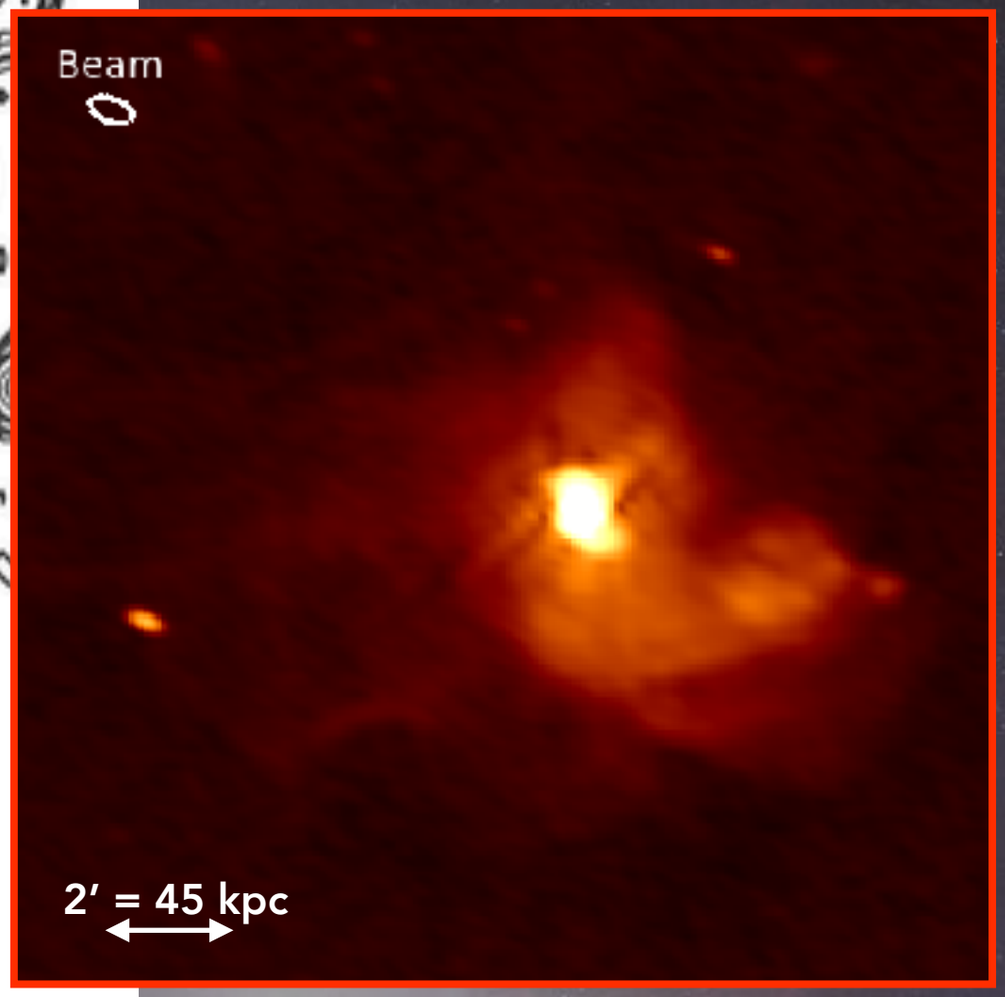


SDSS i-band mosaic
+ 328 MHz VLA
(Credit: NRAO/VLA/G. Taylor, 1998)

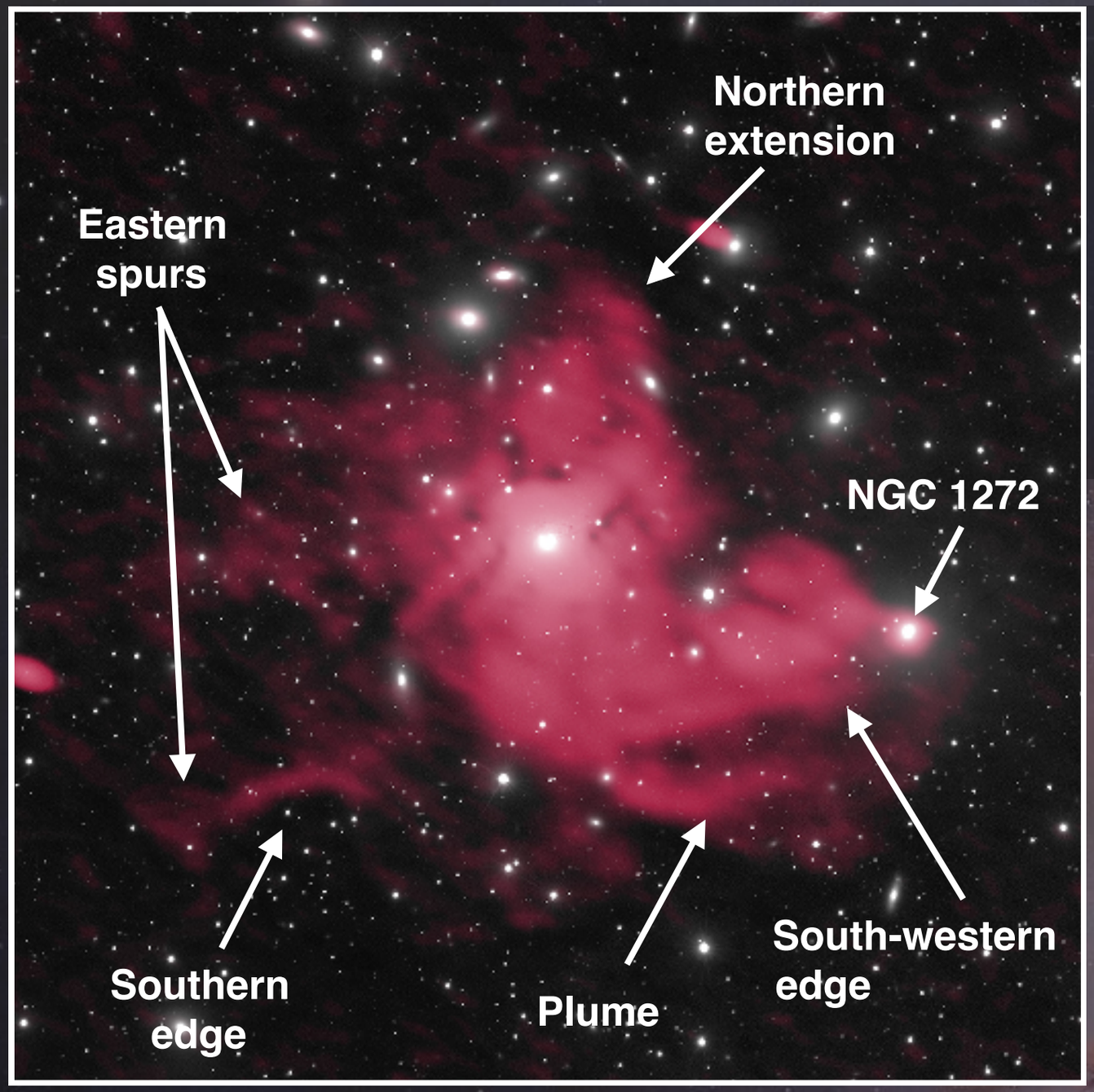
SDSS i-band mosaic
+ JVLA B-array 270-430 MHz
(Gendron-Marsolais et al. 2017, NRAO press release)



WSRT 609 MHz
rms =0.4 mJy/beam
beam 29”× 44”
Sijbring Thesis 1993

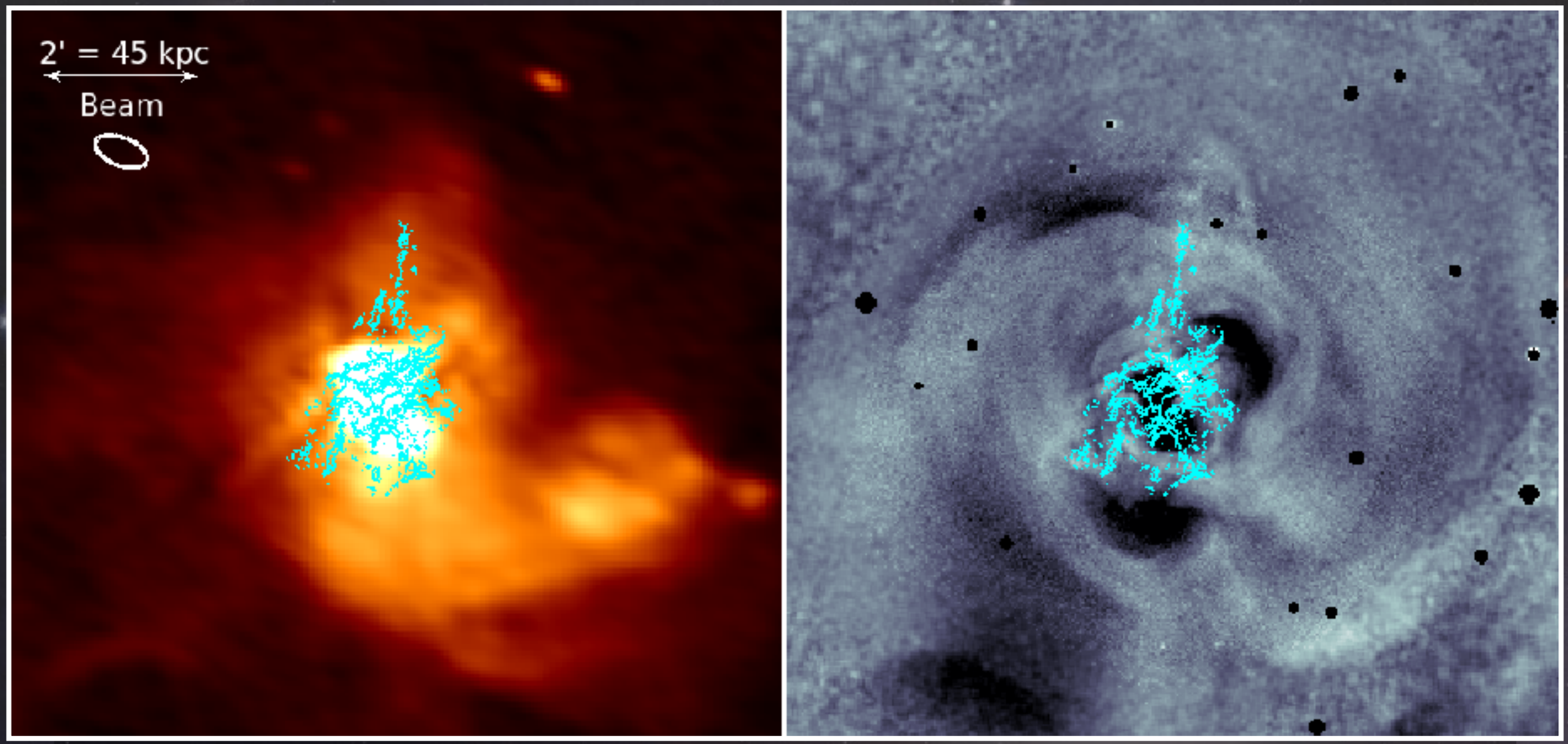


JVLA 230-470 MHz B-configuration
rms =0.35 mJy/beam,
beam 22.1”× 11.3”
Gendron Marsolais et al. 2017

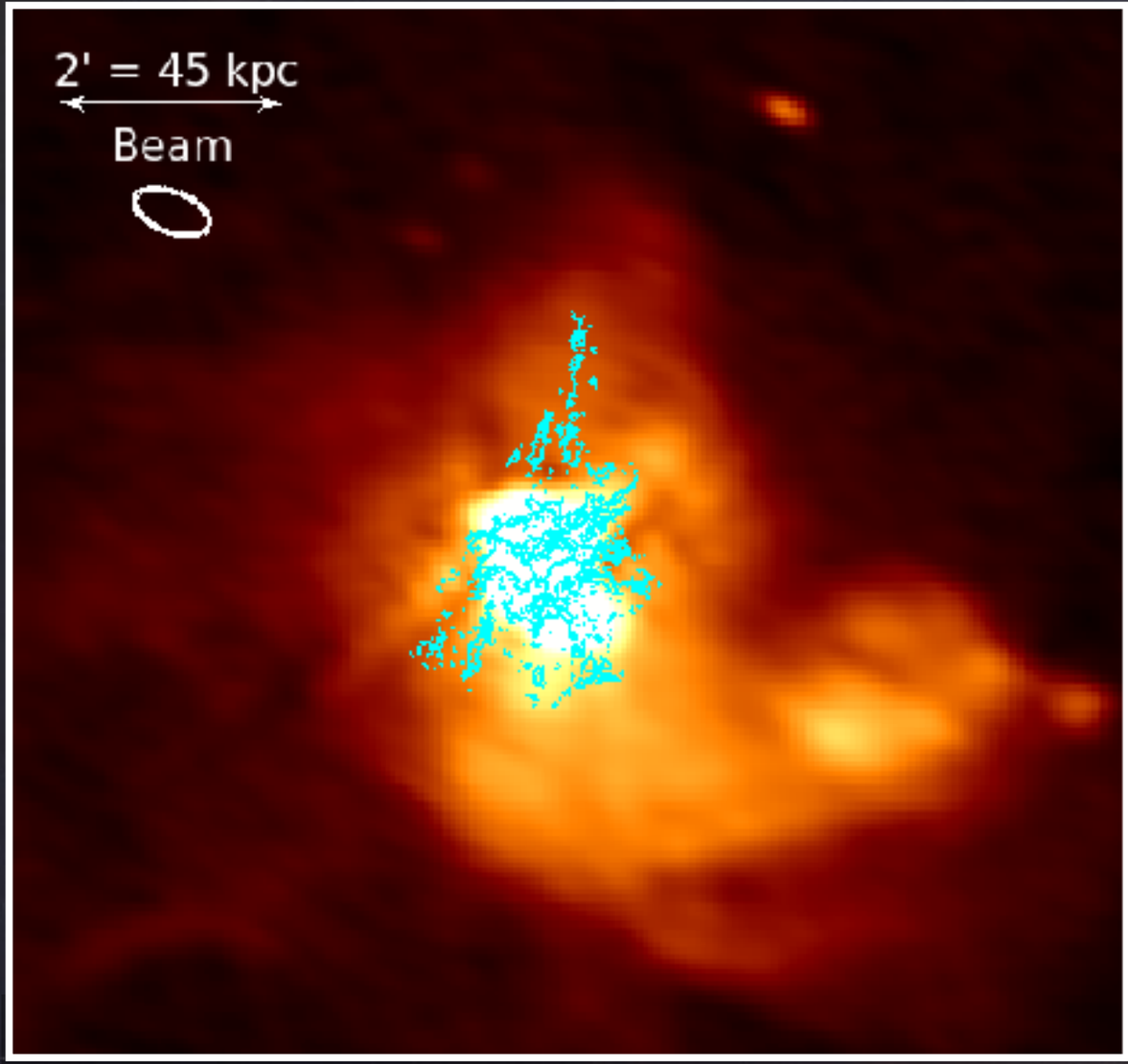


- Several new structures identified: Mini-halos are not diffuse, uniform radio sources, but rather have a rich variety of complex structures

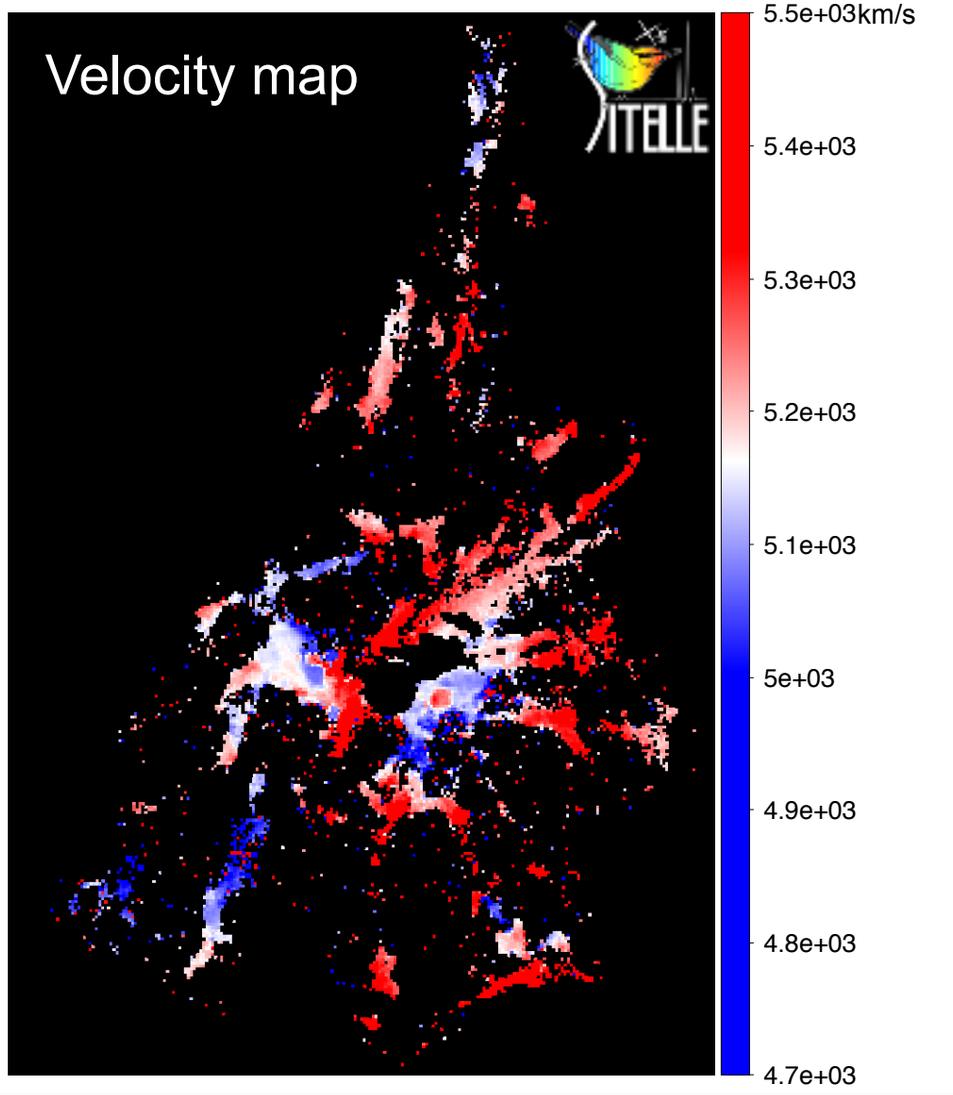
SDSS i-band mosaic
+ JVLA B-array 270-430 MHz
(Gendron-Marsolais et al. 2017)



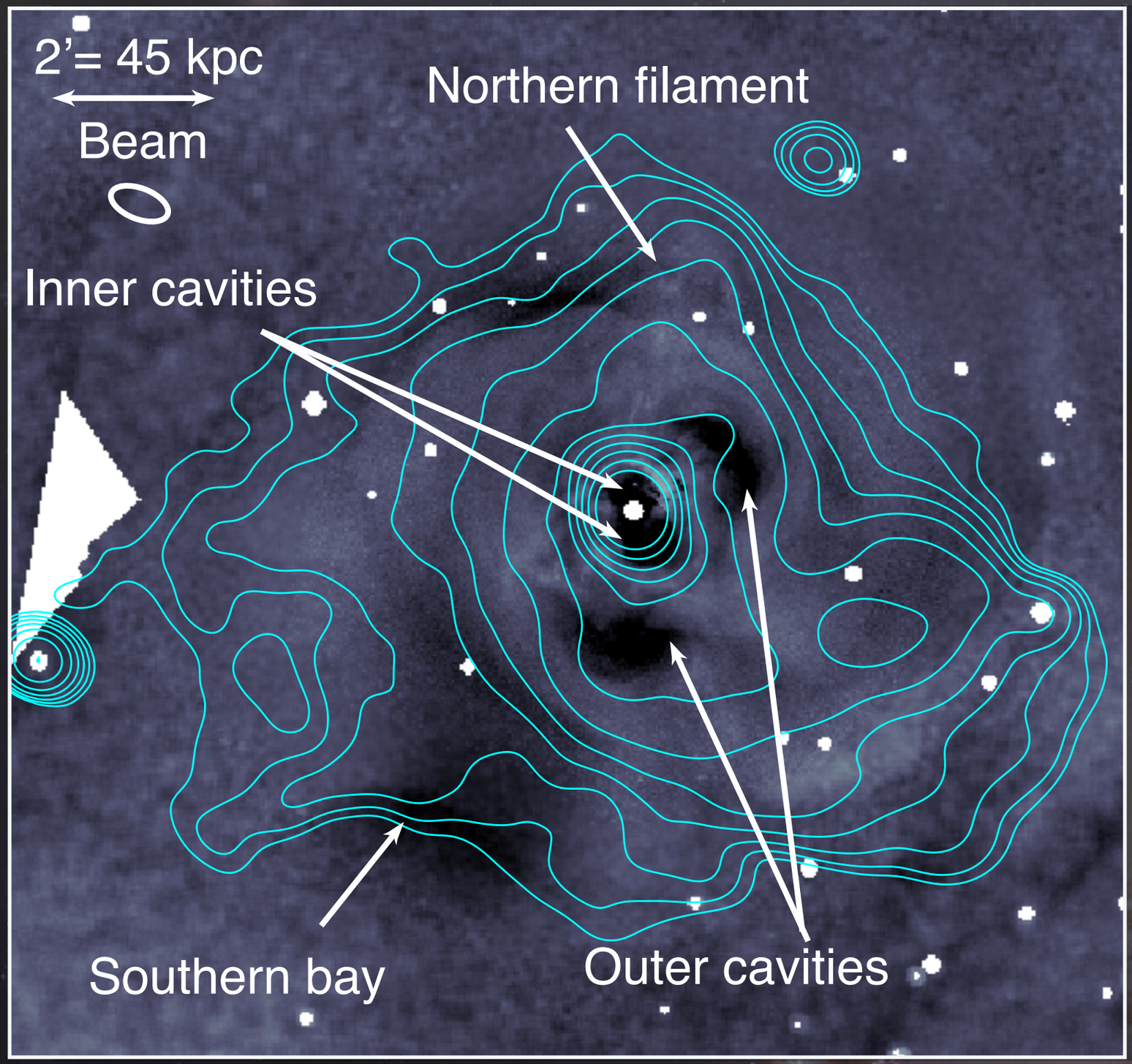
Chandra composite fractional residual image (0.5-7 keV, 1.4 Ms exposure, Fabian et al. 2011)
+ JVLA B-array 270-430 MHz (Gendron-Marsolais et al. 2017)
+ contours from SITELLE Hα flux map (starting at 3E10–17 erg/s/cm^2/pixel) (Gendron-Marsolais et al. 2018)



JVLA B-array 270-430 MHz
(Gendron-Marsolais et al. 2017)
+ contours from SITELLE Hα flux map
(starting at 3E10–17 erg/s/cm²/pixel)

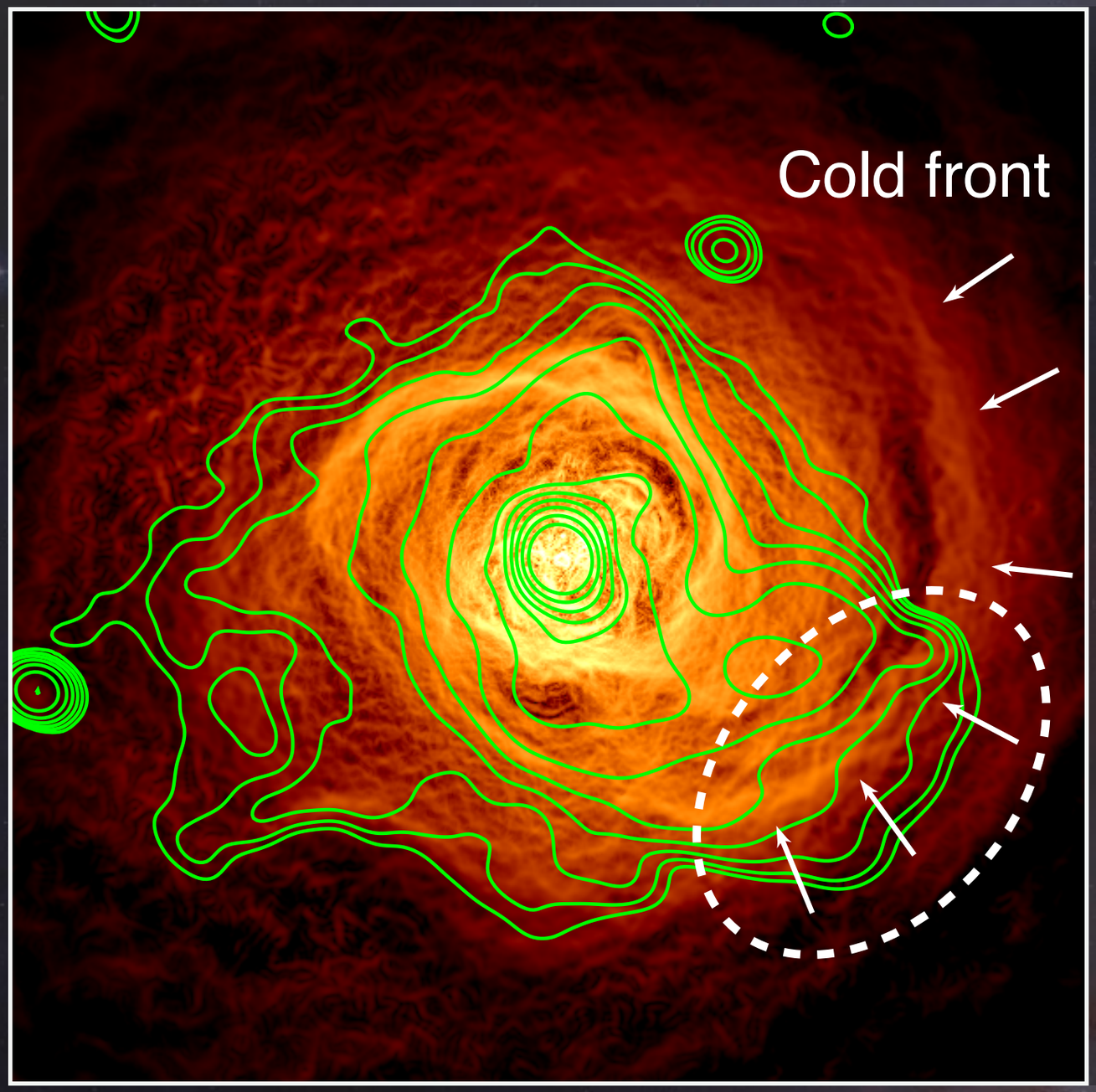


Sitelle velocity map
(Gendron-Marsolais et al. 2018)



- Emission avoids the southern bay (~ cold front but with opposite curvature, possibly caused by a Kelvin-Helmholtz instabilities, Walker et al. 2017)

Chandra composite fractional residual image (0.5-7 keV, 1.4 Ms, Fabian et al. 2011)
+ JVLA B-array 270-430 MHz contours from 5σ = 1.75 mJy/beam to 1 Jy/beam



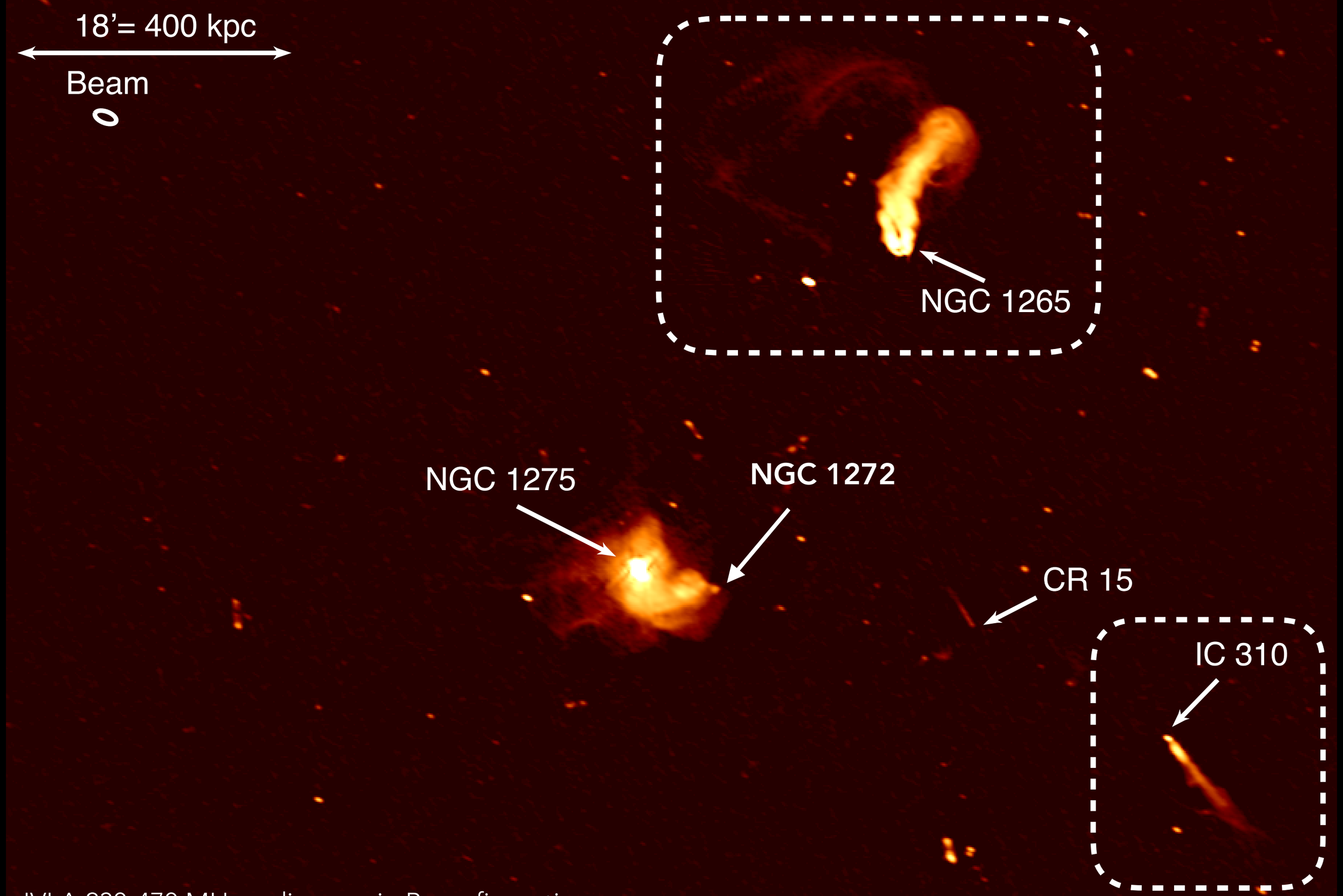
- Emission enclosed mostly behind the western sloshing cold front, fainter emission is also seen beyond, as if particles are leaking out

GGM filtered image of the merged X-ray observations with Gaussian width σ = 4 pixels (Sanders et al. 2016)
+ JVLA B-array 270-430 MHz contours from 5σ = 1.75 mJy/beam to 1 Jy/beam

Composite image

Public Prize of the national competition "Science Exposed » of the Natural Sciences and Engineering Research Council of Canada

SDSS i-band mosaic
+ Chandra composite fractional residual image (0.5-7 keV, 1.4 Ms exposure, Fabian et al. 2011)
+ JVLA B-array 270-430 MHz (Gendron-Marsolais et al. 2017)



JVLA 230-470 MHz radio map in B-configuration
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(rms =0.35 mJy/beam, beam 22.1”× 11.3”)
Gendron Marsolais et al. 2017

NGC 1265

NGC 1275

CR 15

IC 310

JVLA 230-470 MHz radio map in B-configuration
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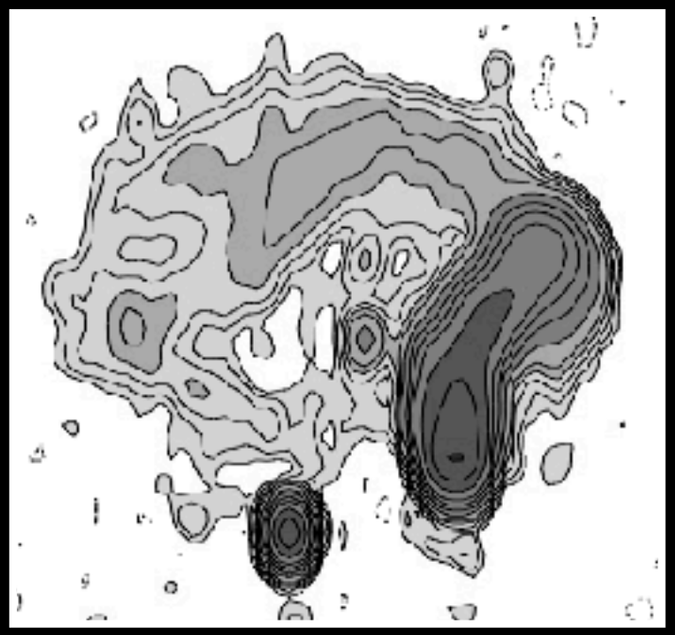
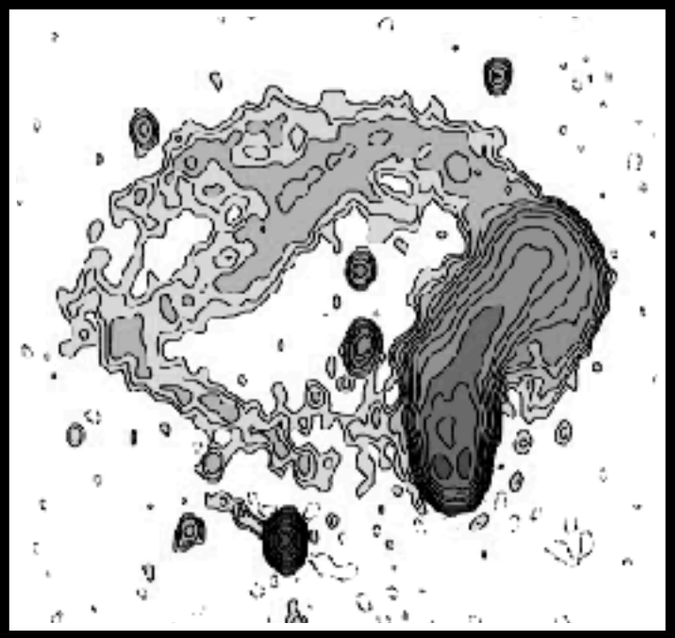
(rms =0.35 mJy/beam, beam 22.1″× 11.3″)
Gendron Marsolais et al. 2017

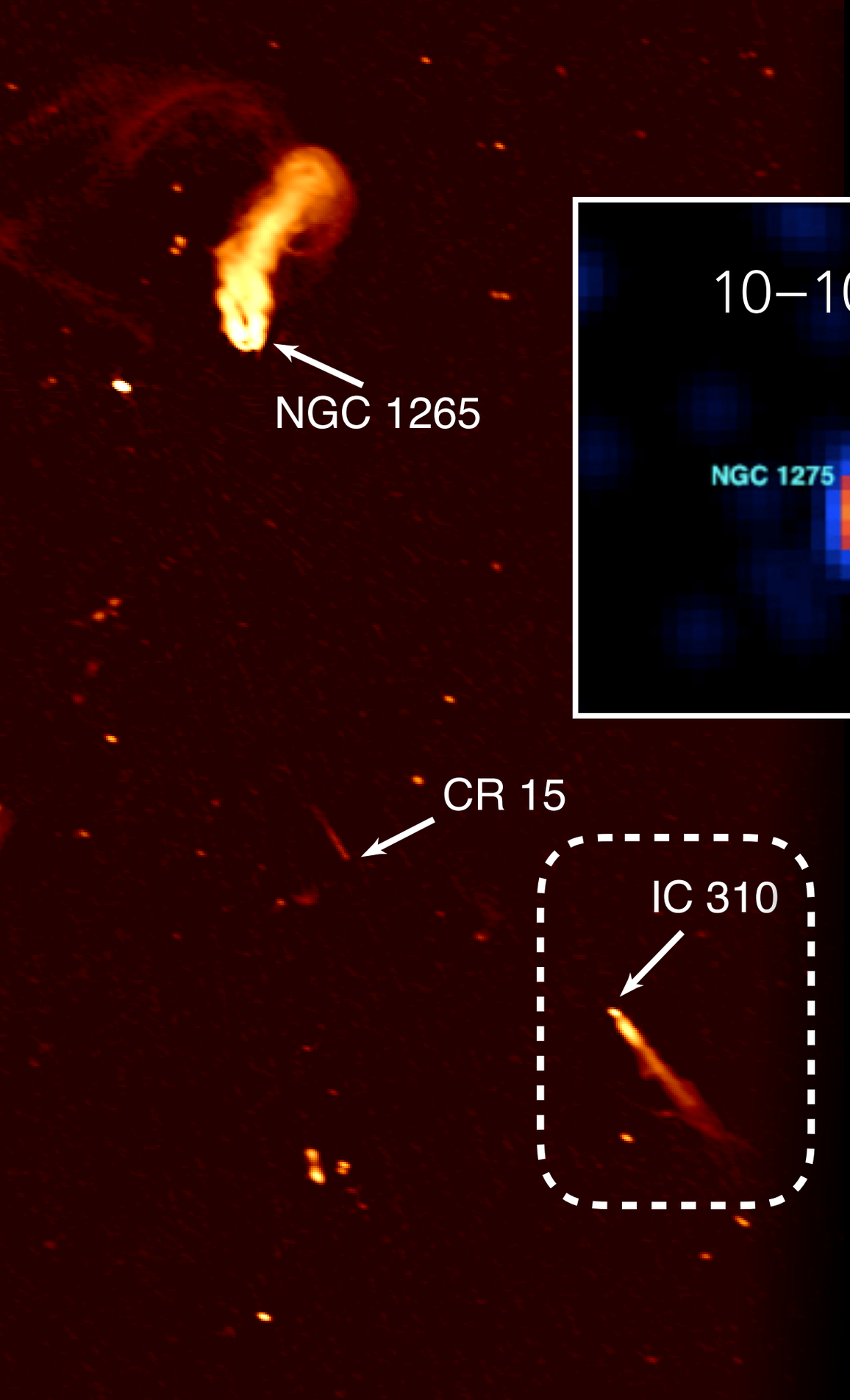


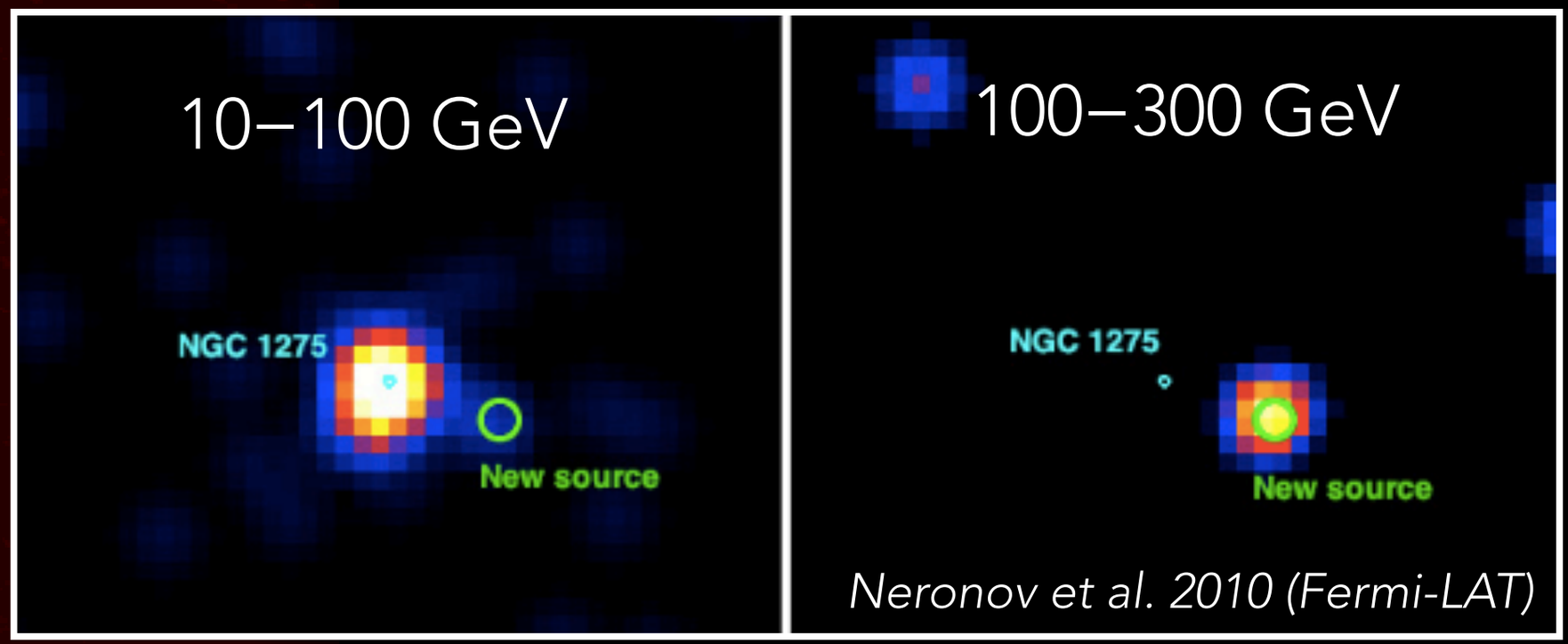
327 MHz (92 cm)



609 MHz (49 cm)

Sijbring & de Bruyn 1998
(WSRT)



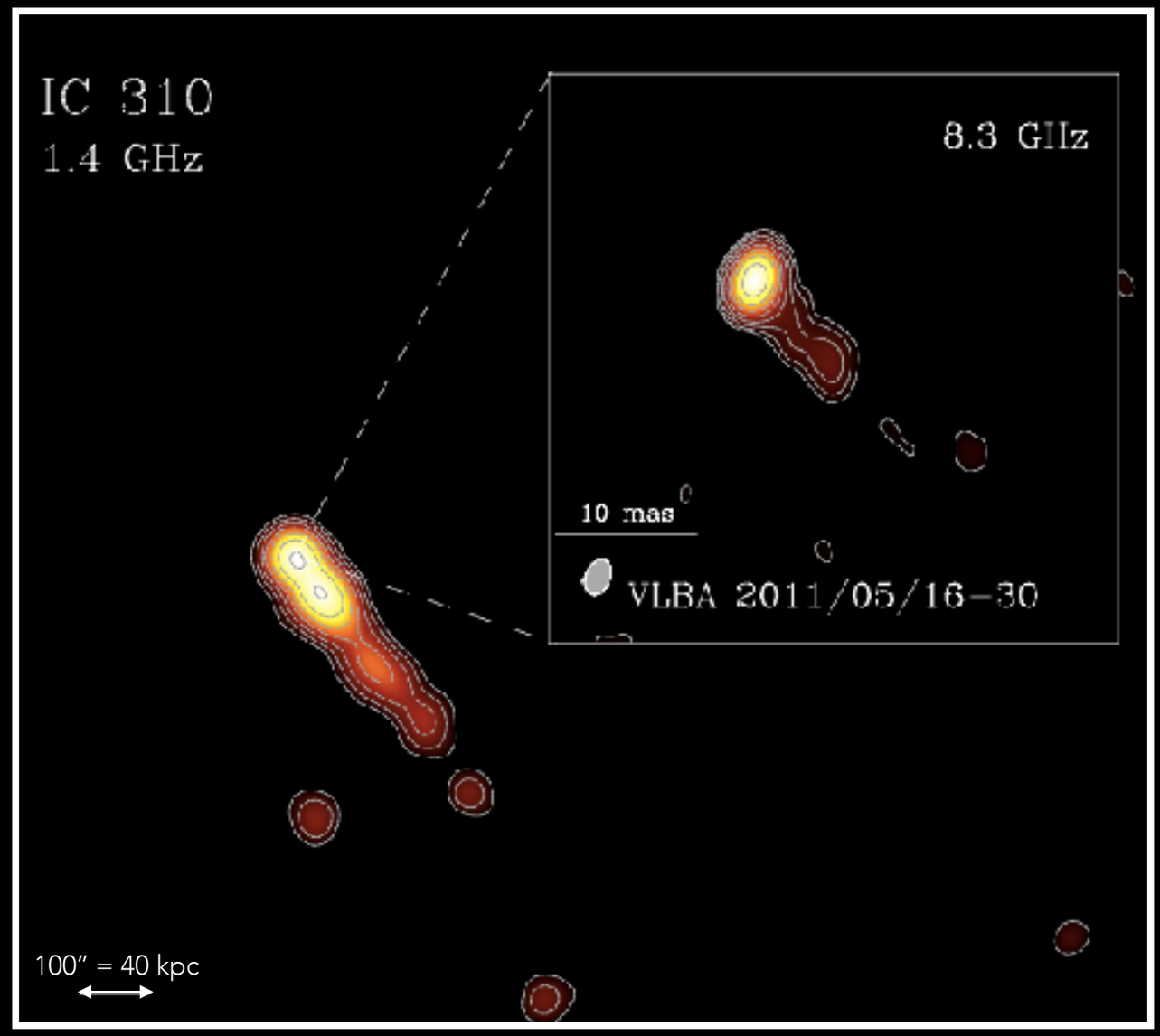


Detection with the *Fermi*-Large Area Telescope (LAT) at energies above 30 GeV (Neronov et al. 2010)
+ with the MAGIC telescopes above 260 GeV (Aleksic et al. 2010).

NGC 1265

CR 15

IC 310



Kadler et al. 2012
NVSS VLA 1.4 GHz (1993)
+ VLBA 7.9–8.8 GHz (2011)

- Illustrate the high-quality images that can be obtained with JVLA at low radio-frequencies and the necessity to obtain deeper, higher-fidelity radio images of extended emission in clusters to further understand their origin.
- Abell 2146: Mystery solved!
- Perseus cluster: Filaments everywhere!
- Future work:
  - Abell 2146: 2Ms upcoming Chandra observation (PI:Russell) + 4h awarded P band A-array JVLA (PI: G-Marsolais) + 200 ks NuSTAR
  - Perseus:
    - Complete A+B+C+D configurations 230-470 MHz JVLA datasets (including awarded 4h DDT proposal + 5h regular proposal, both PI: G.-Marsolais)
    - Spectral index map with L-band JVLA + GMRT observations

Merci!