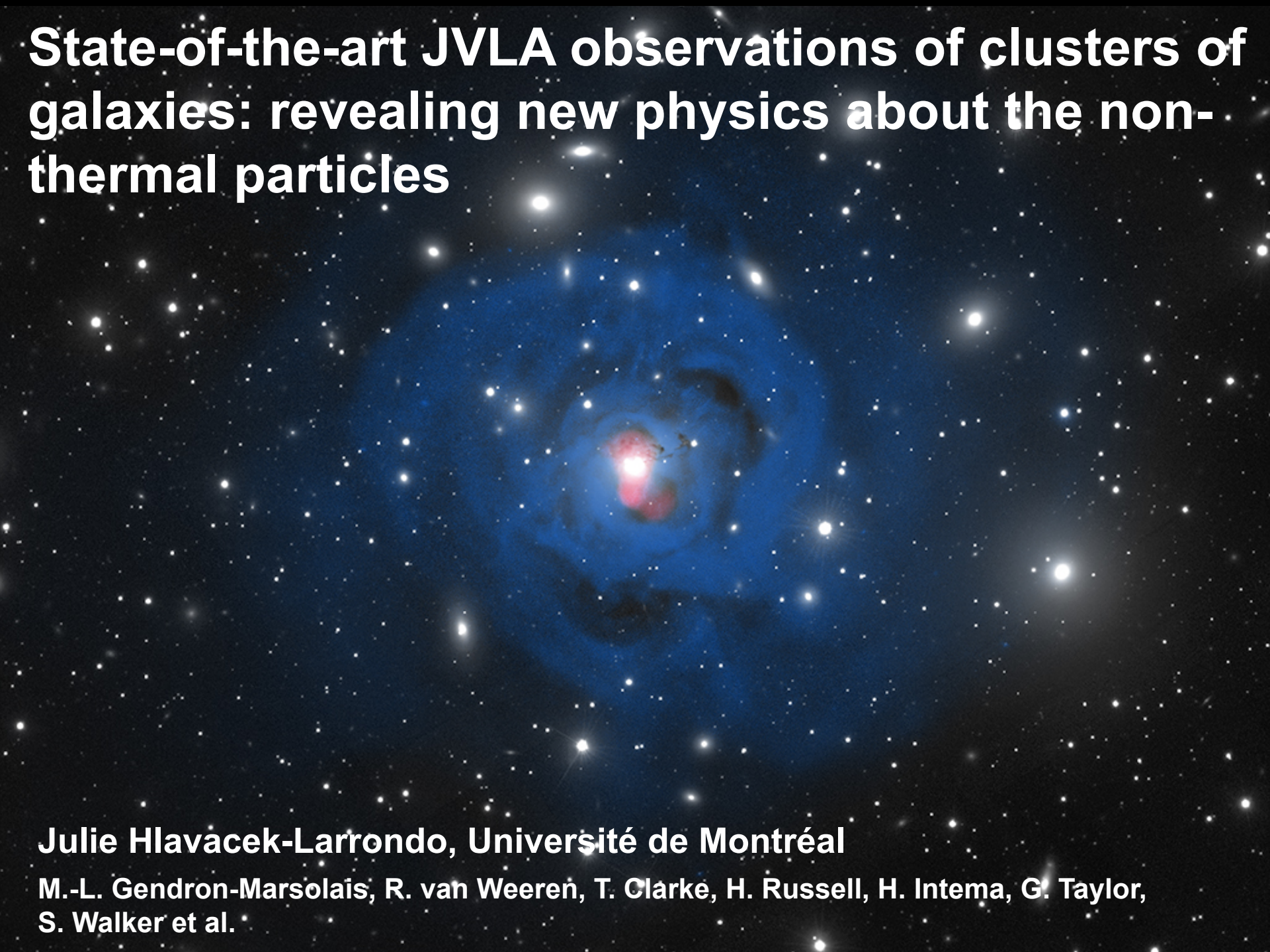
State-of-the-art JVLA observations of clusters of galaxies: revealing new physics about the non-thermal particles



Julie Hlavacek-Larrondo, Université de Montréal

M.-L. Gendron-Marsolais, R. van Weeren, T. Clarke, H. Russell, H. Intema, G. Taylor, S. Walker et al.

What can we learn about halos/relics/mini-halos from new observations that we don't already know?

Current Status: Mini-Halos

What do mini-halos look like?

Diffuse uniform radio structures (~50-300 kpc) centered on the cool core/central AGN, e.g. Gitti et al. 2002, Kale et al. 2013, Kale et al. 2015, Hlavacek-L. et al. 2013, Murgia et al. 2009, Cassano et al. 2008, etc.

Where de we find mini-halos?

Massive cool core clusters (~30 known so far), e.g. Giacintucci et al. 2017.

What is their origin?

- → **Found mostly in massive clusters, connection with the potential, e.g. Giacintucci et al. 2017.**
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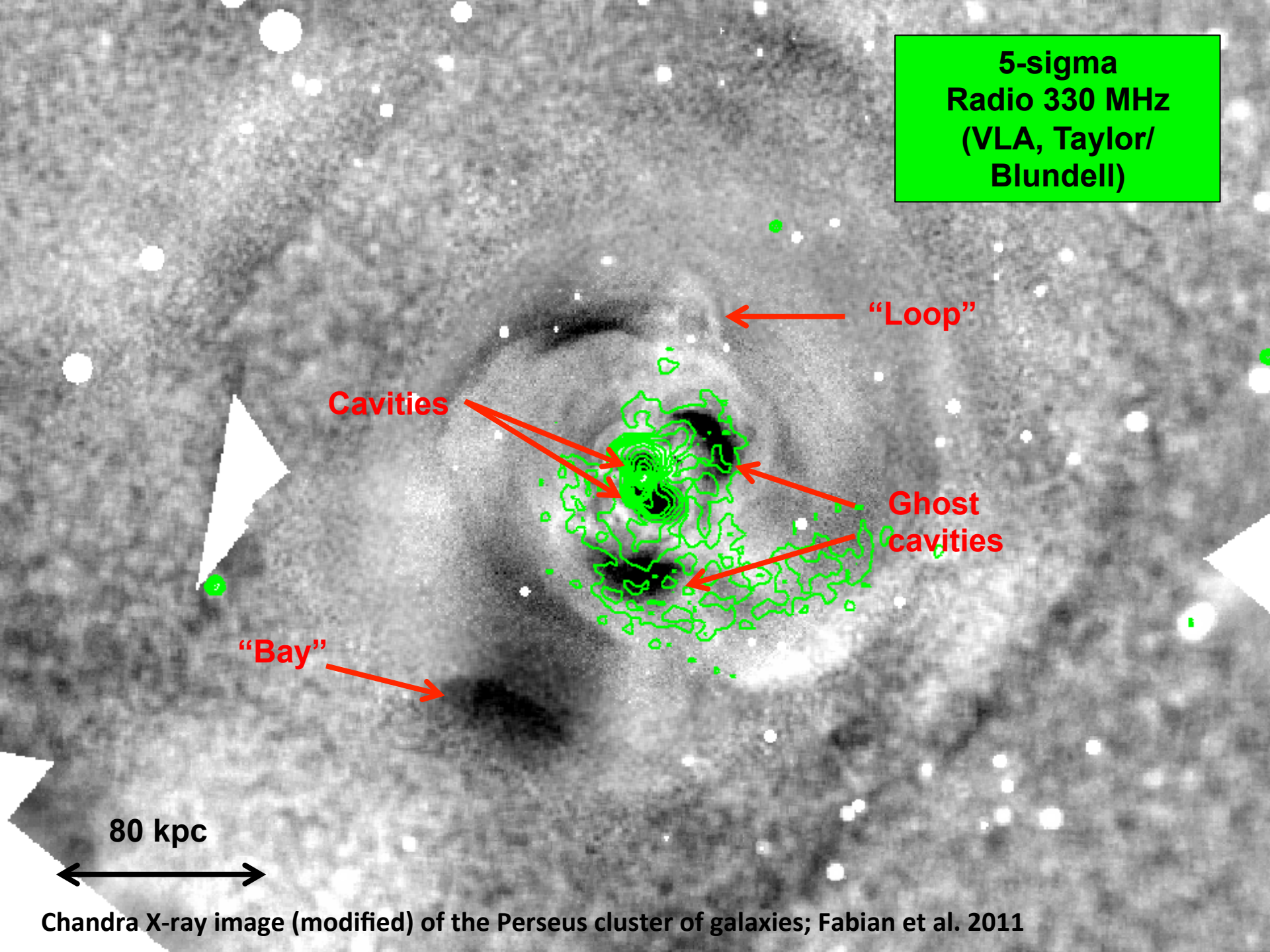
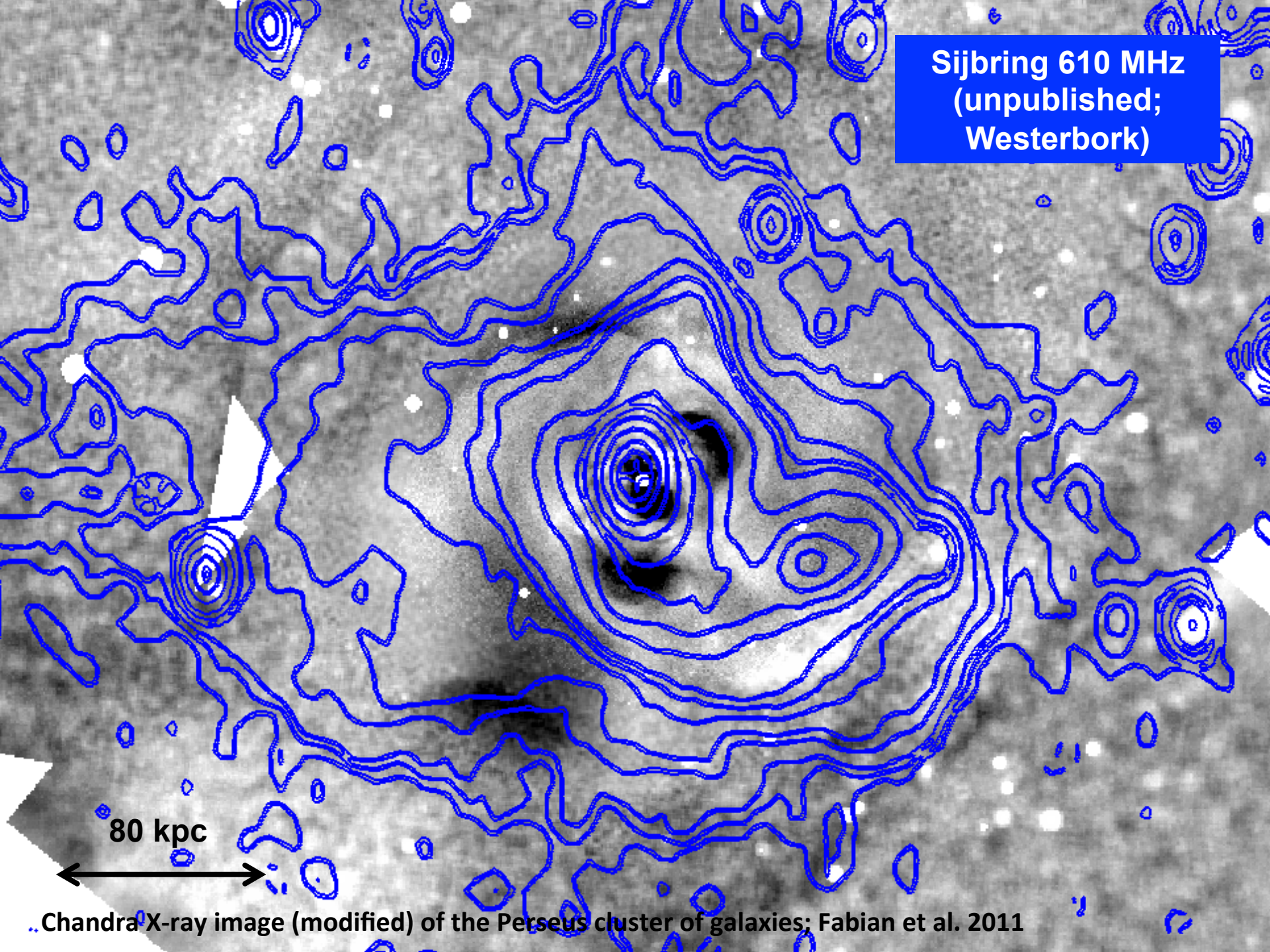


Chandra X-ray image (modified) of the Perseus cluster of galaxies; Fabian et al. 2011



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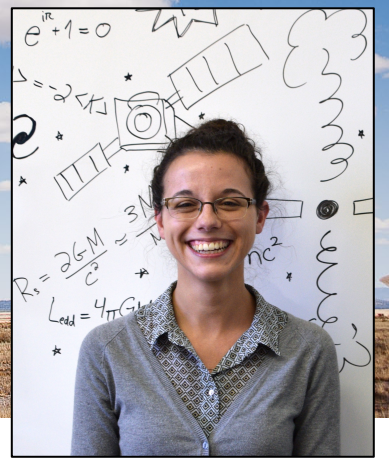
Jansky Very Large Array



Marie-Lou Gendron-Marsolais

Shared-risk proposal (2013, PI Hlavacek-L.)

→ P-band (270-430 MHz): 5 hours in B-config + 5 hours in A-config.

→ Challenges: RFI, prototype instruments, dynamic range limited (AGN 11 Jy bright!).

Jansky Very Large Array

ArXiv 1701.03791
(B-configuration)

rms = 0.35 mJy/beam; **beam** = 22.1″×11.3″ (8 kpc x 4 kpc); **Dyn. range** > 30 000.

(NRAO press release: https://public.nrao.edu/news/galaxy-cluster-mini-halo/**)**

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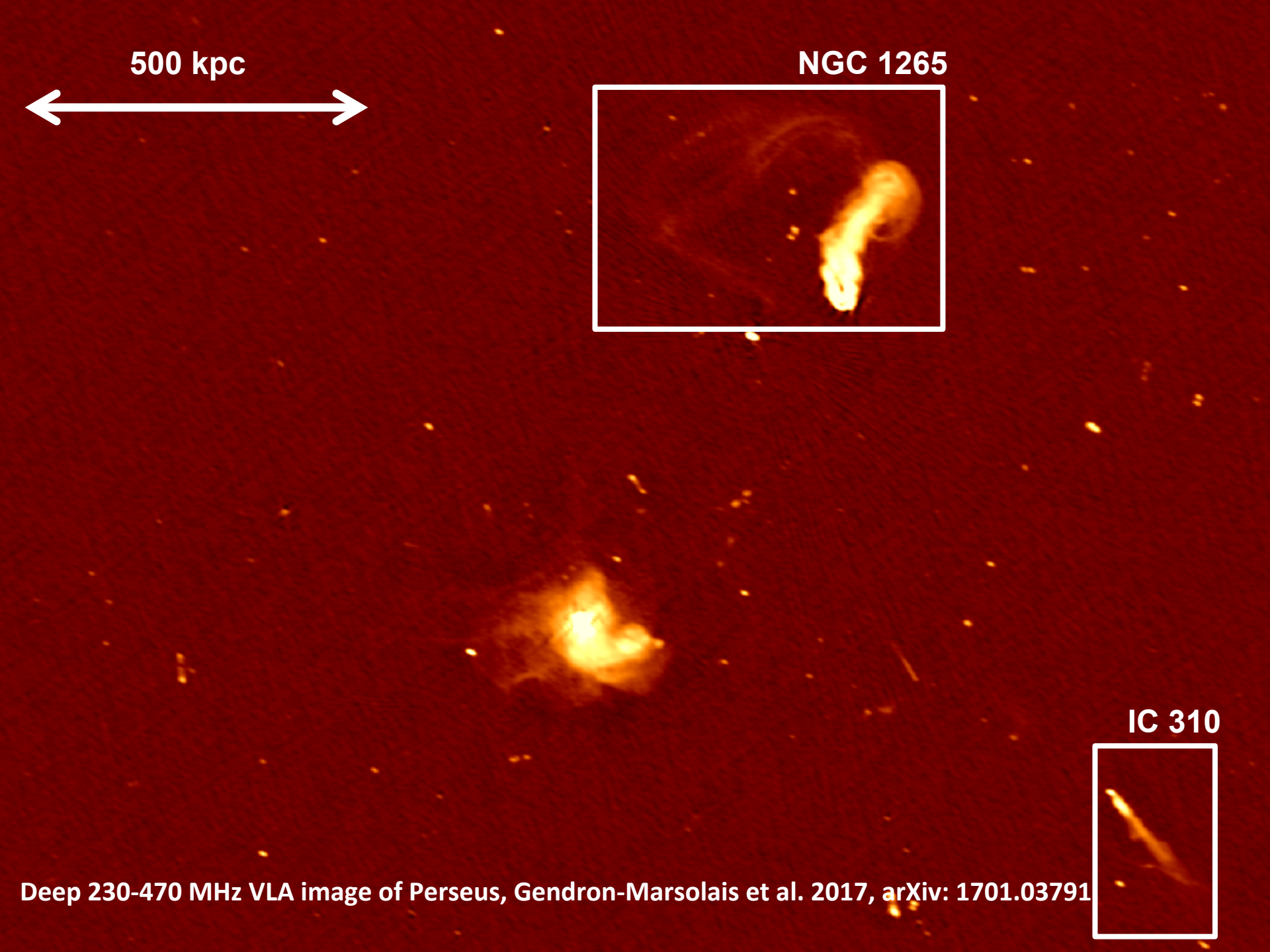
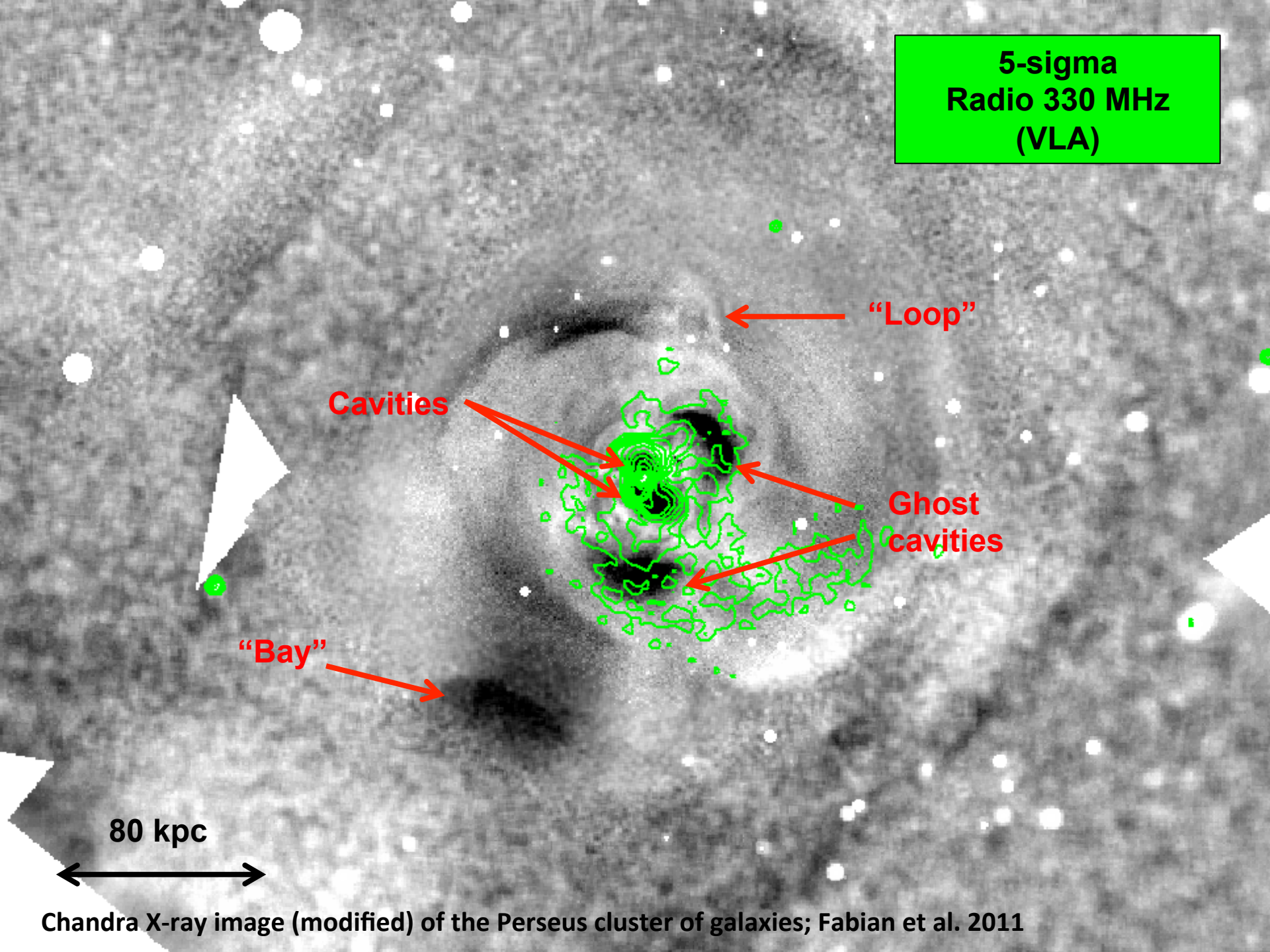


Deep 230-470 MHz VLA image of Perseus, Gendron-Marsolais et al. 2017, arXiv: 1701.03791



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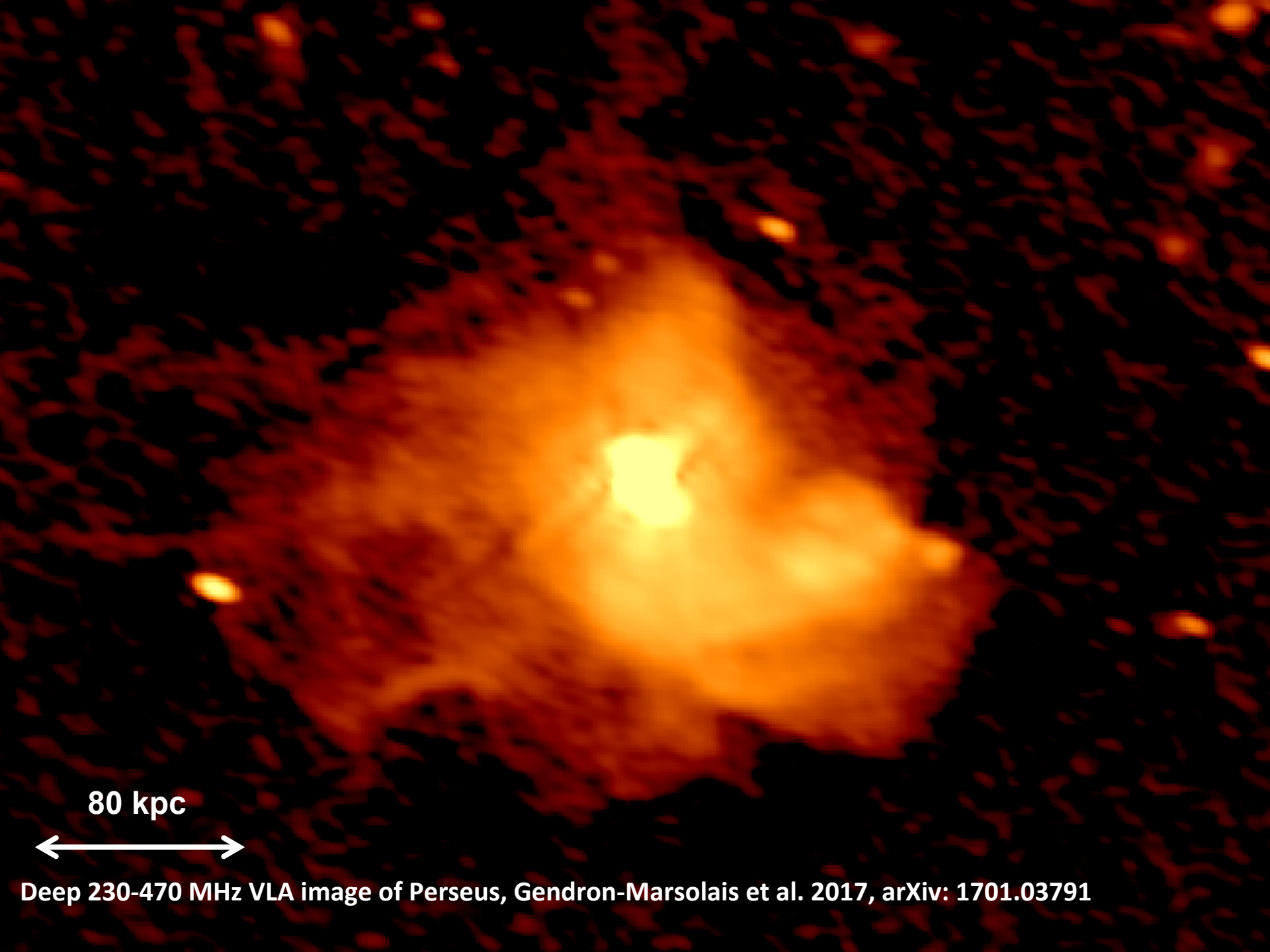

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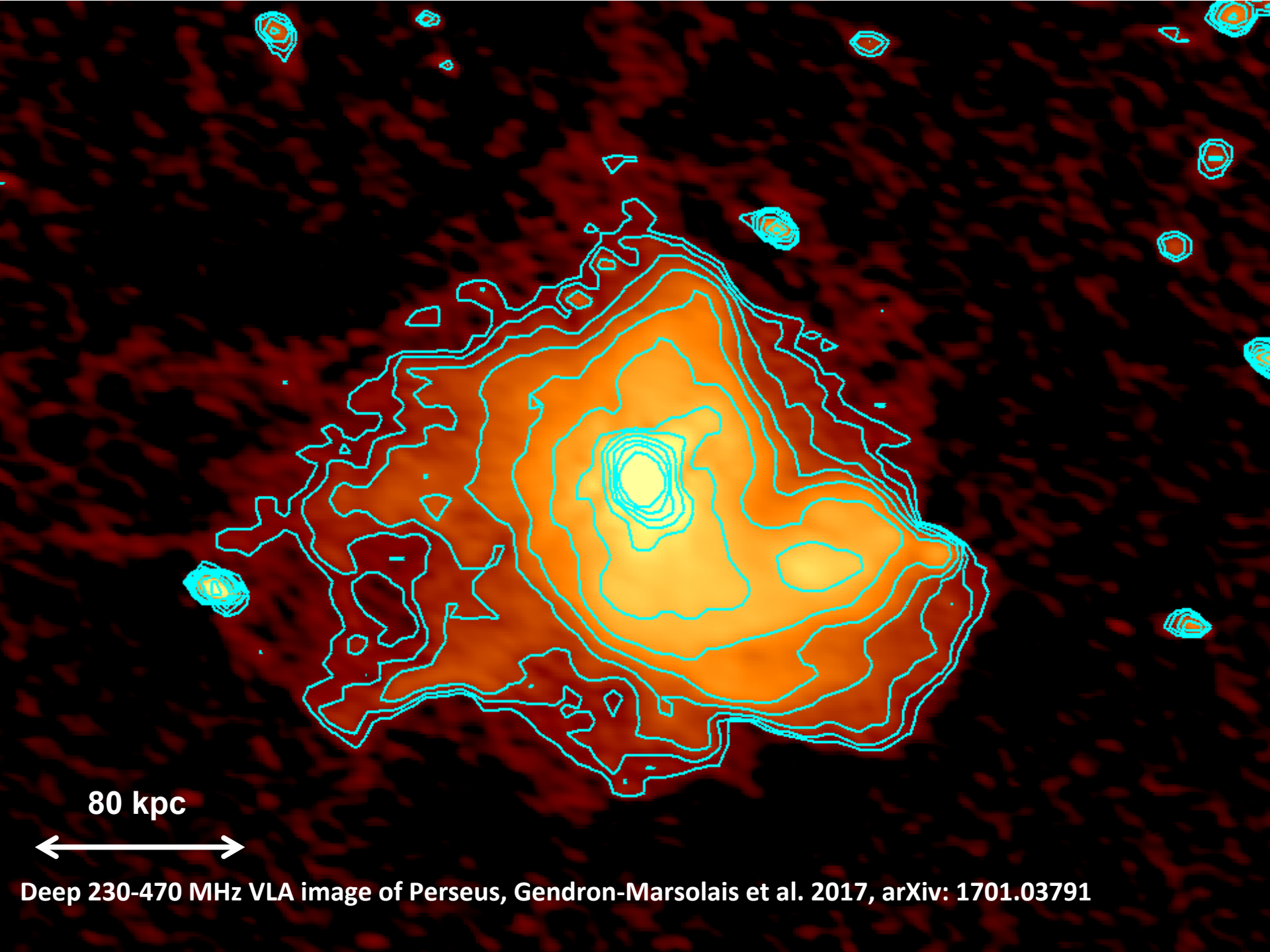

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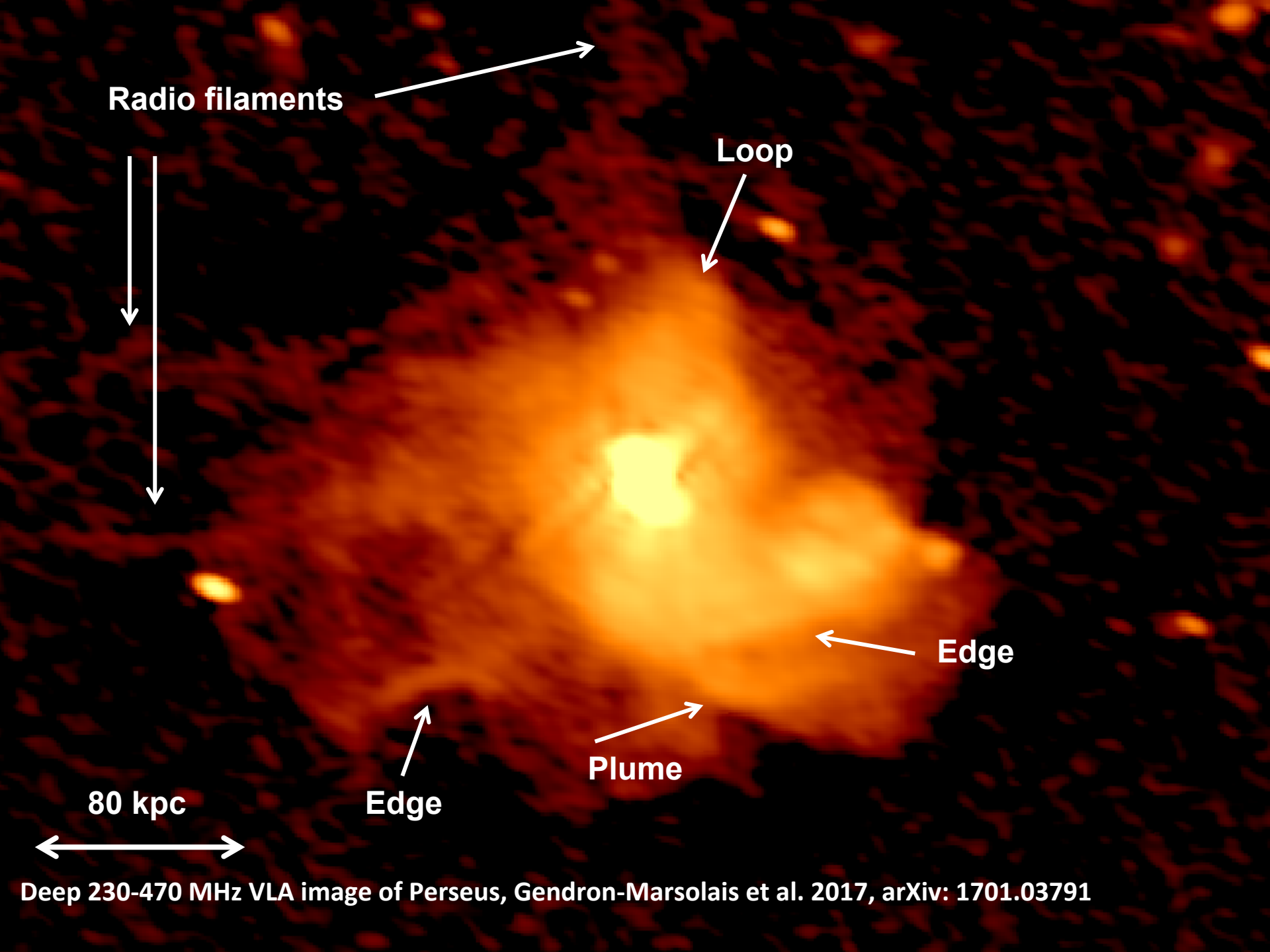

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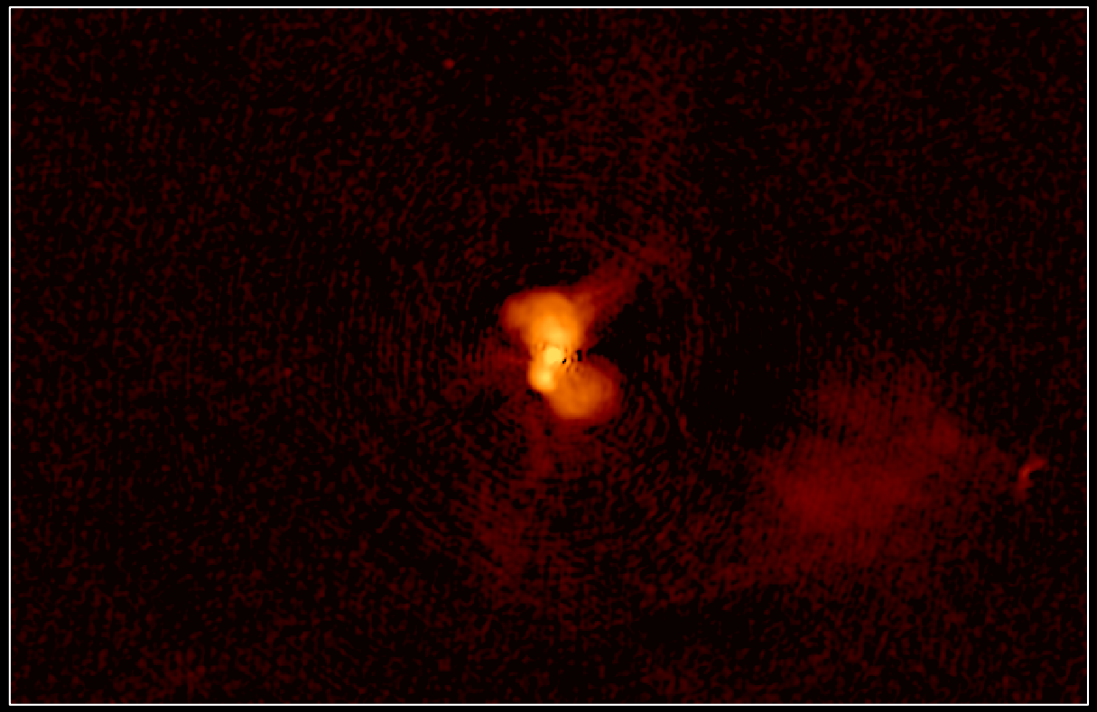
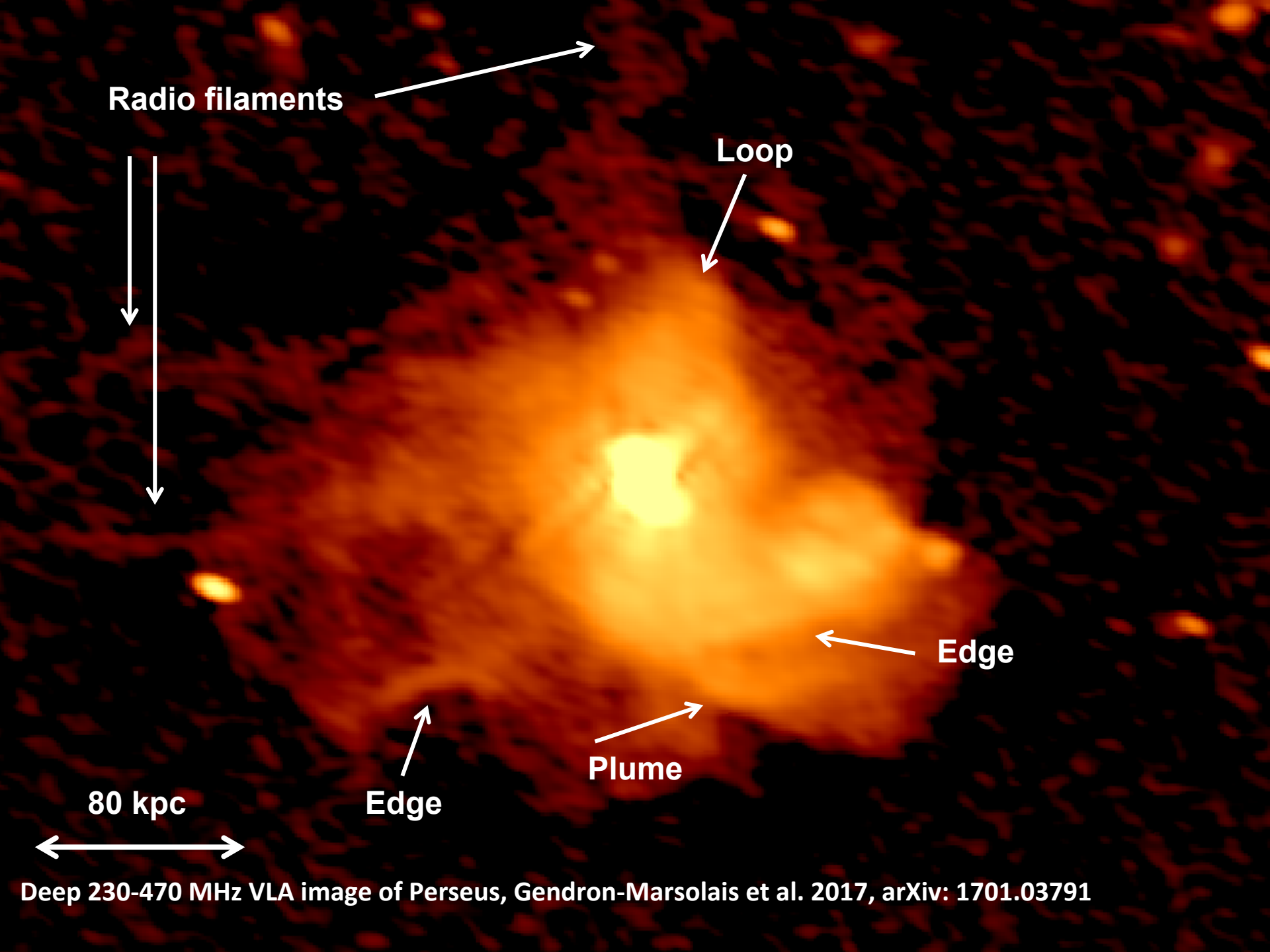
rms = 0.27 mJy/beam; **beam** = 3.7″×3.6″ (1.4 kpc x 1.3 kpc); **Dyn. range** > 30 000.



80 kpc

High-resolution 230-470 MHz VLA image of Perseus, Gendron-Marsolais, Hlavacek-L. et al. in prep.



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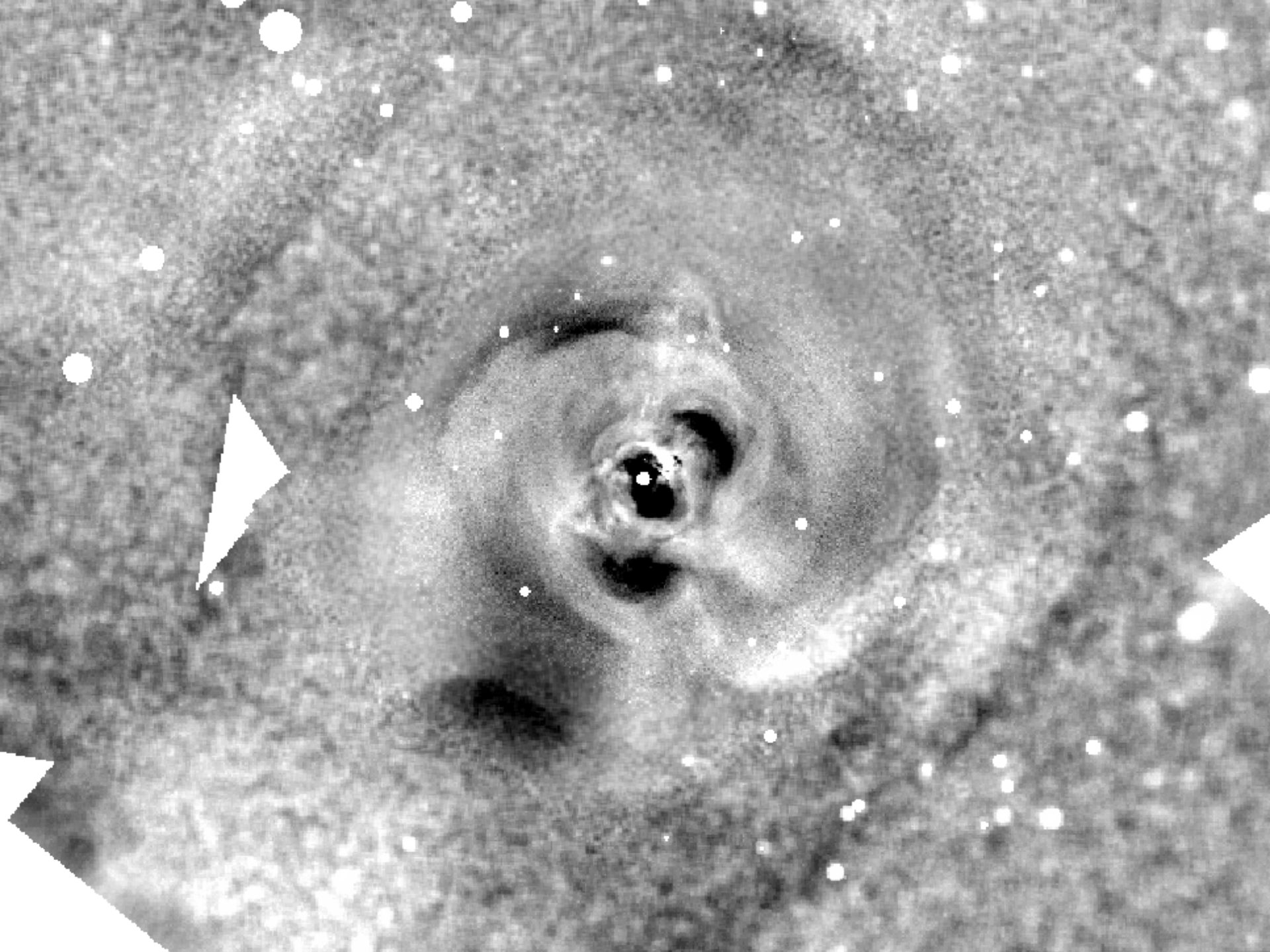

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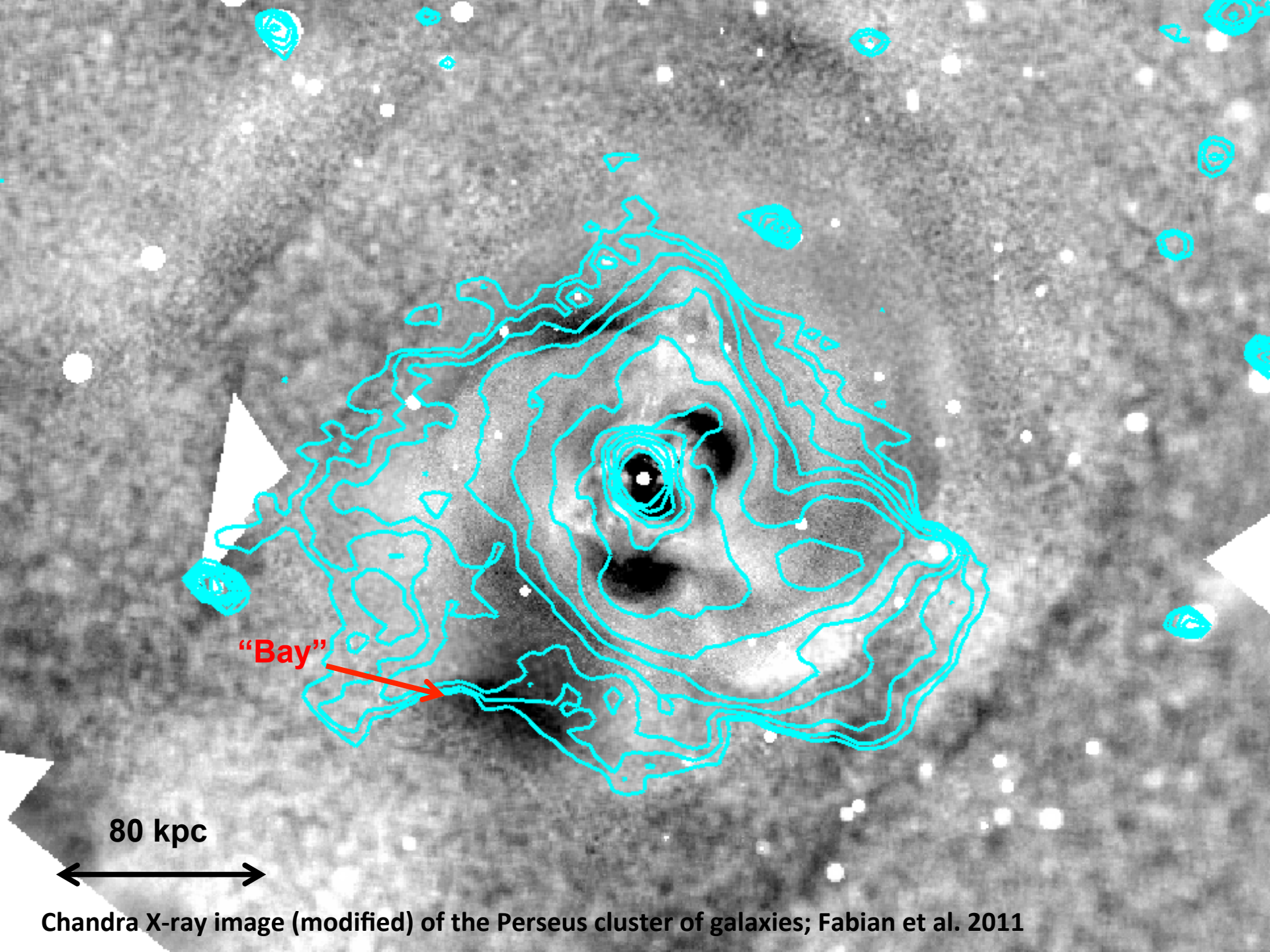
What else can we learn from such new/deep/high-resolution observations?



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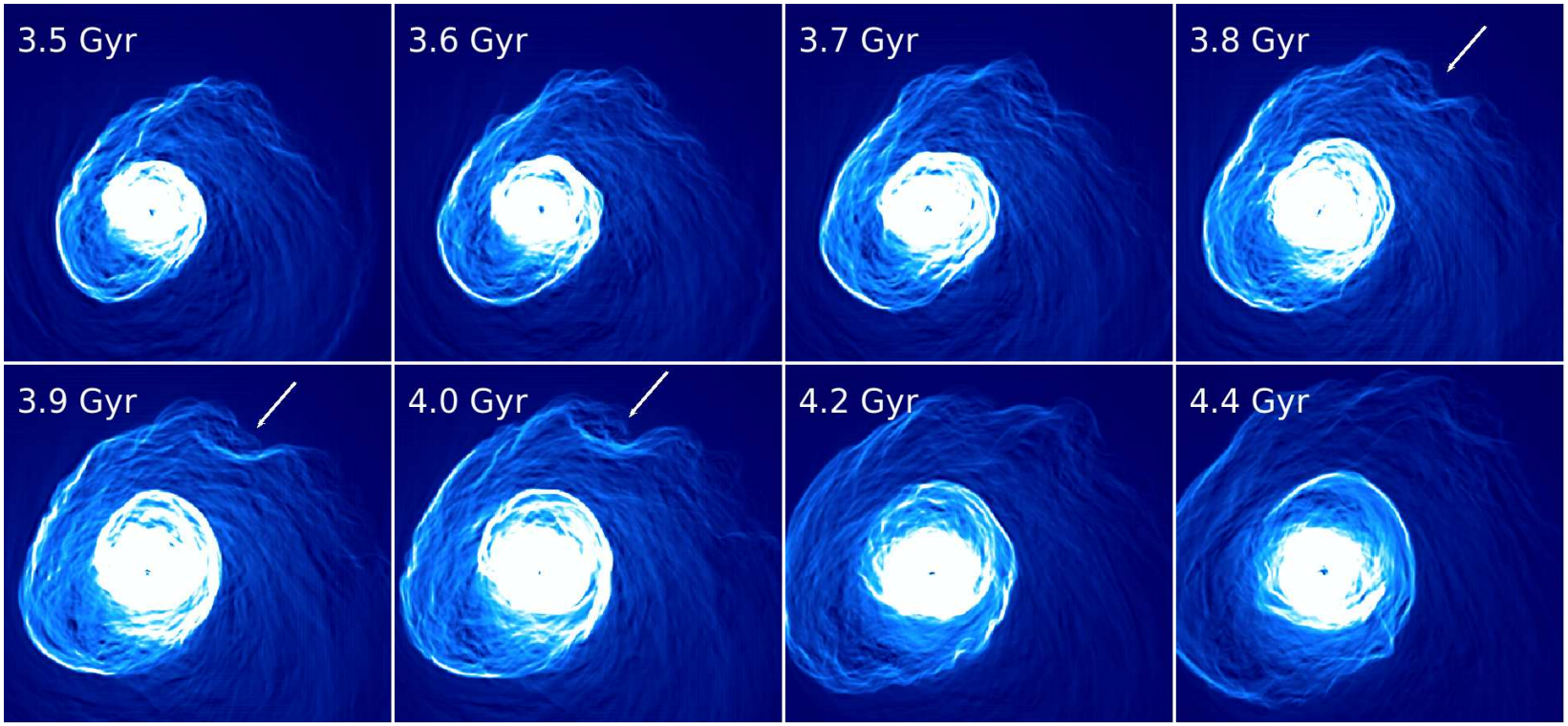
“Bays” in clusters of galaxies

ZuHone simulations



- → “Bays” have been interpreted as old X-ray cavities.
- → However, they have strange curvature and lack radio emission. Also seen in A1795 and Centaurus cluster.
- → Instead, these “bays” could be giant **Kelvin-Helmholtz instabilities**.

Walker, Hlavacek-Larrondo et al. 2017, arXiv: 1705.00011

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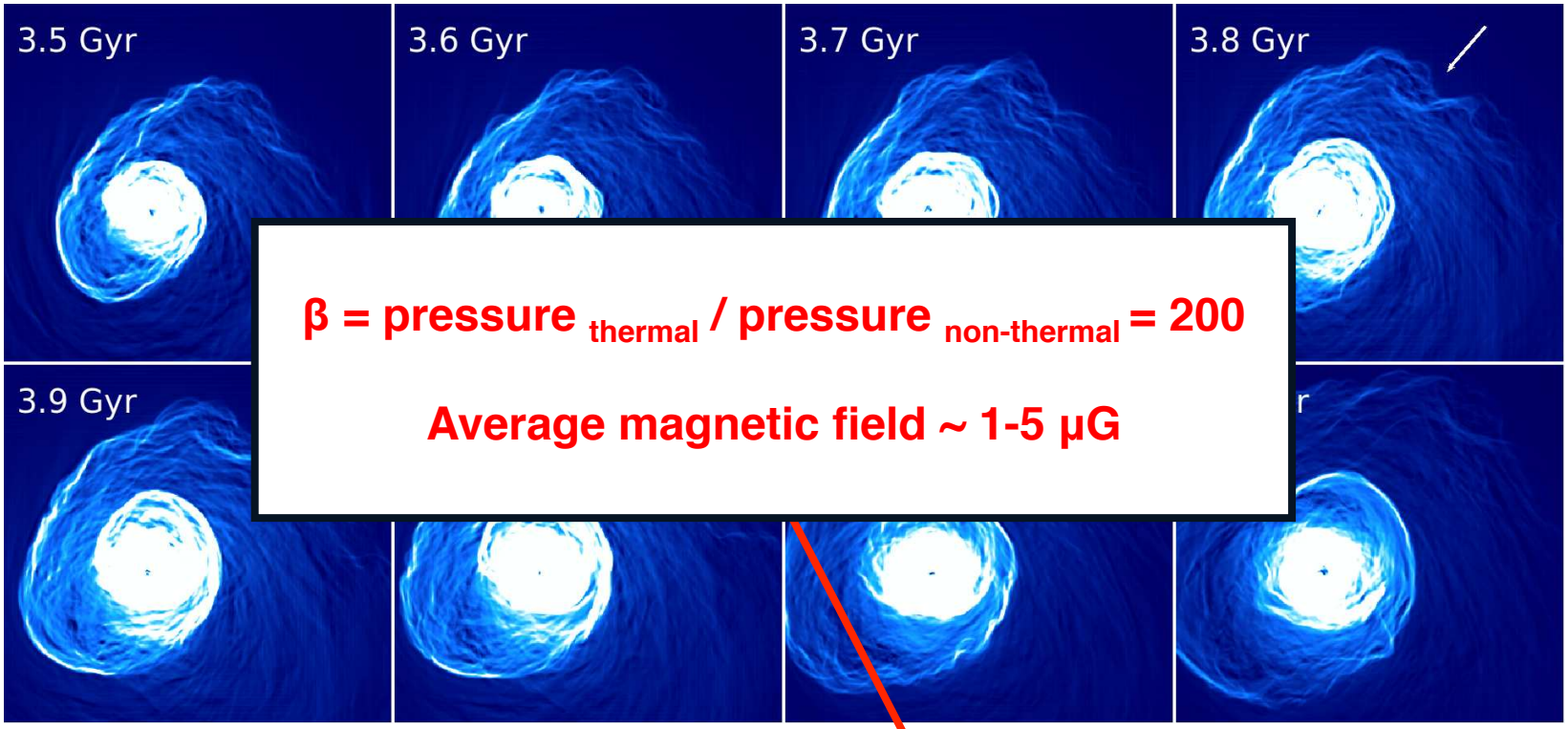

β = pressure $_{\text{thermal}}$ / pressure $_{\text{non-thermal}}$ = 200

Average magnetic field ~ 1-5 μG

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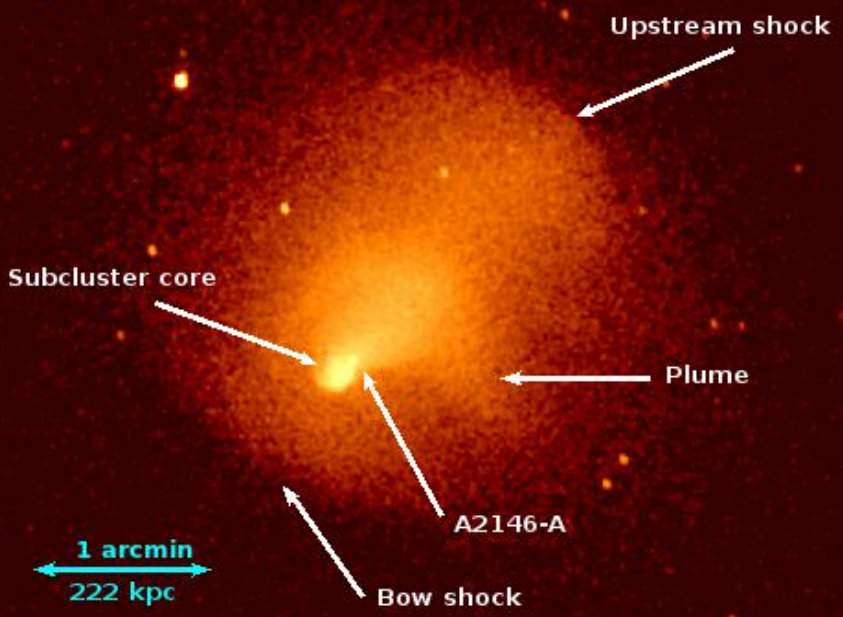
Abell 2146 (z=0.232)



Chandra X-ray image (418 ks); Russell et al. 2012 – stay tuned for 2 Ms of new Chandra data!

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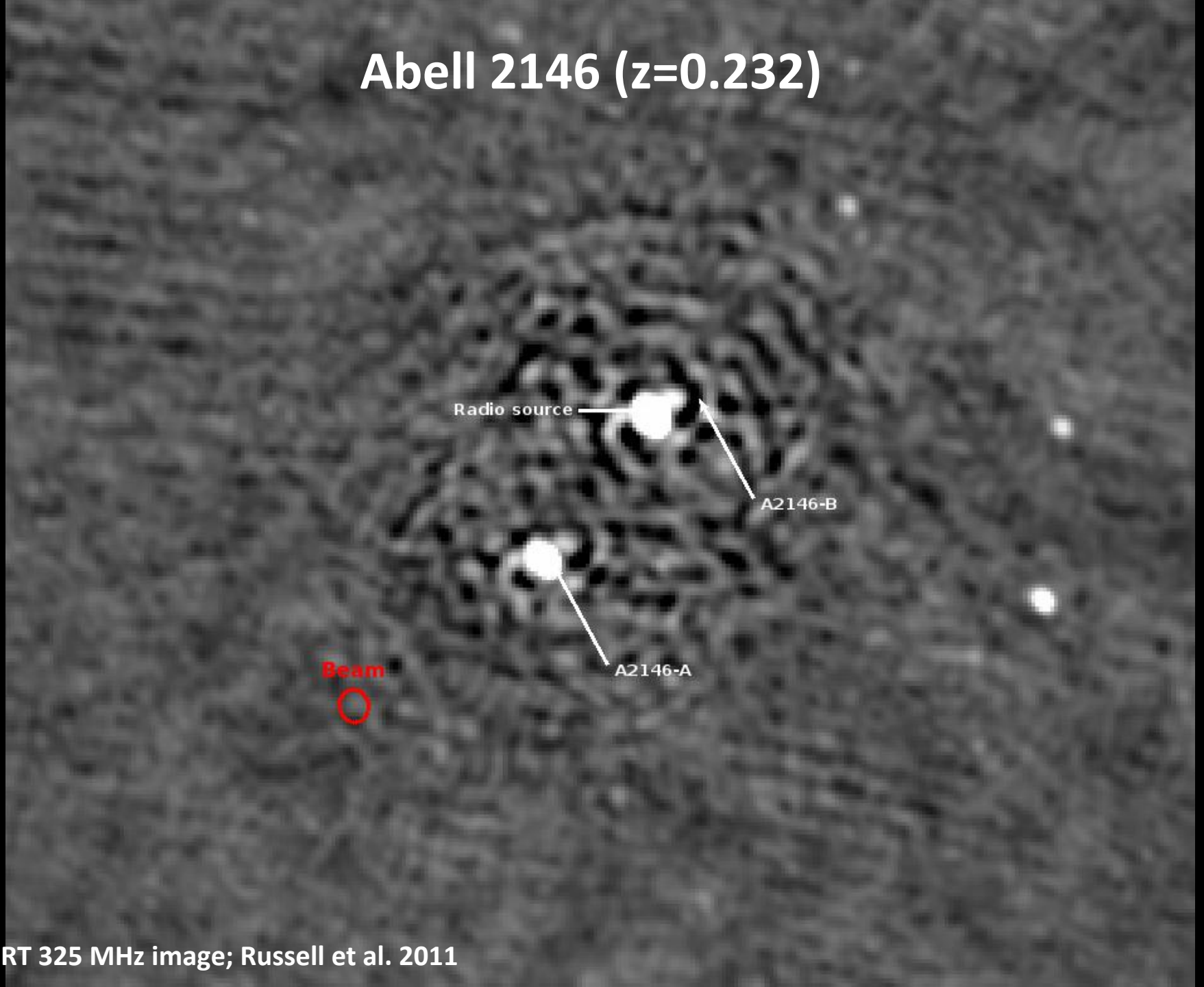
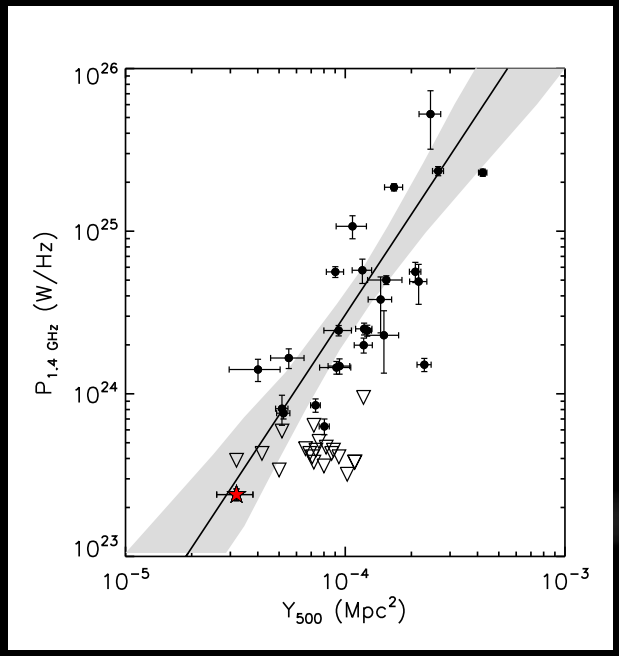


GMRT 325 MHz image; Russell et al. 2011

Abell 2146 (z=0.232)

New JVLA 1.4 GHz observations (16 hours); Hlavacek-L et al. 2017 arXiv: 1708.03641



Radio relic (origin = northern radio point source?)

Radio relic and / or radio halo?

New deep JVLA observations; Hlavacek-L et al. 2017 arXiv: 1708.03641

Université de Montréal

Julie Hlavacek-Larrondo, juliehl@astro.umontreal.ca

Take-Home Points

Main take home point: the upgraded JVLA has enabled a breakthrough in radio astronomy for many fields, including clusters of galaxies.

- → **New JVLA observations of Perseus** reveal that mini-halos are not uniform, diffuse structures, see **Gendron-Marsolais et al. 2017, arXiv: 1701.03791.**
- → Mini-halos appear to be reaccelerated both by **sloshing motions of the hot intracluster medium** (= turbulence from mergers) and by mechanisms related to the **BCG and its jets** (= turbulence from AGN?).
- → Plasma physics **(giant Kelvin-Helmholtz instability in Perseus?)**, see **arXiv: 1705.00011.**
- → **Population of extremely faint radio halos/relics,** as seen in A2146 (no longer a merger mystery), see **arXiv: 1708.03641**.

Fonds de recherche Nature et technologies Québec

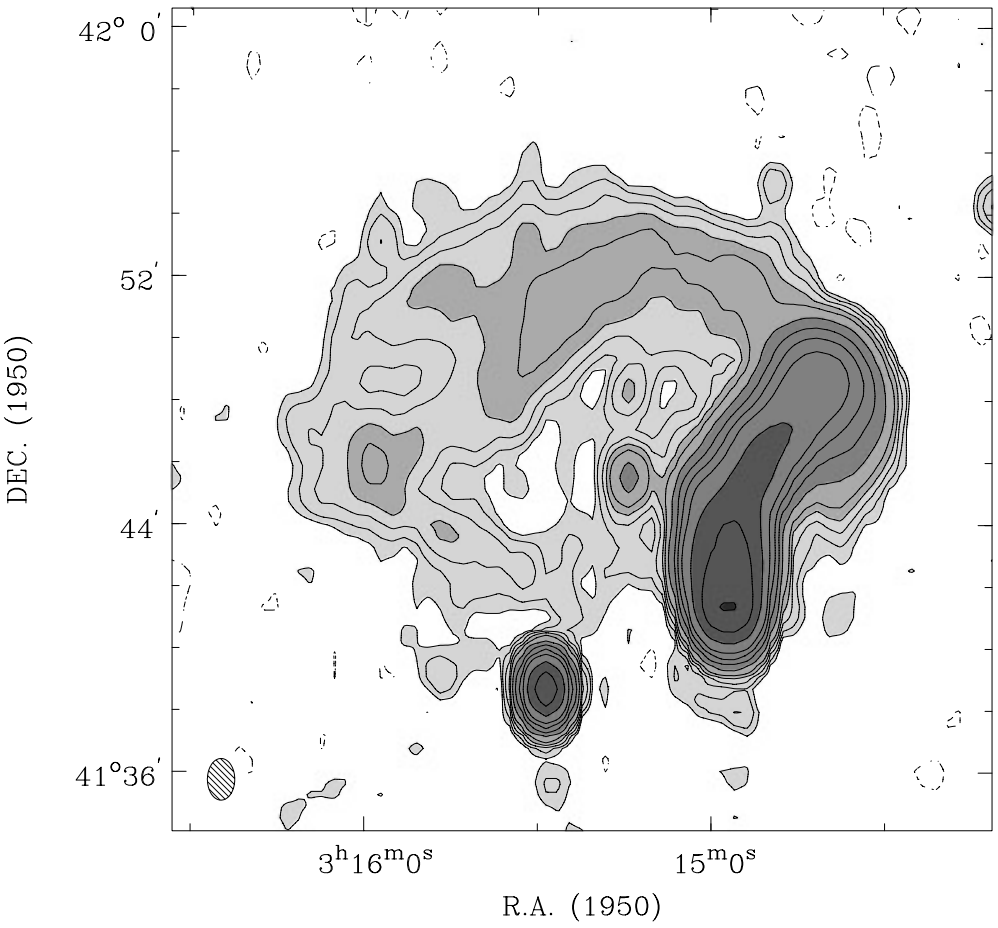
NSERC CRSNG

Canada Research Chairs

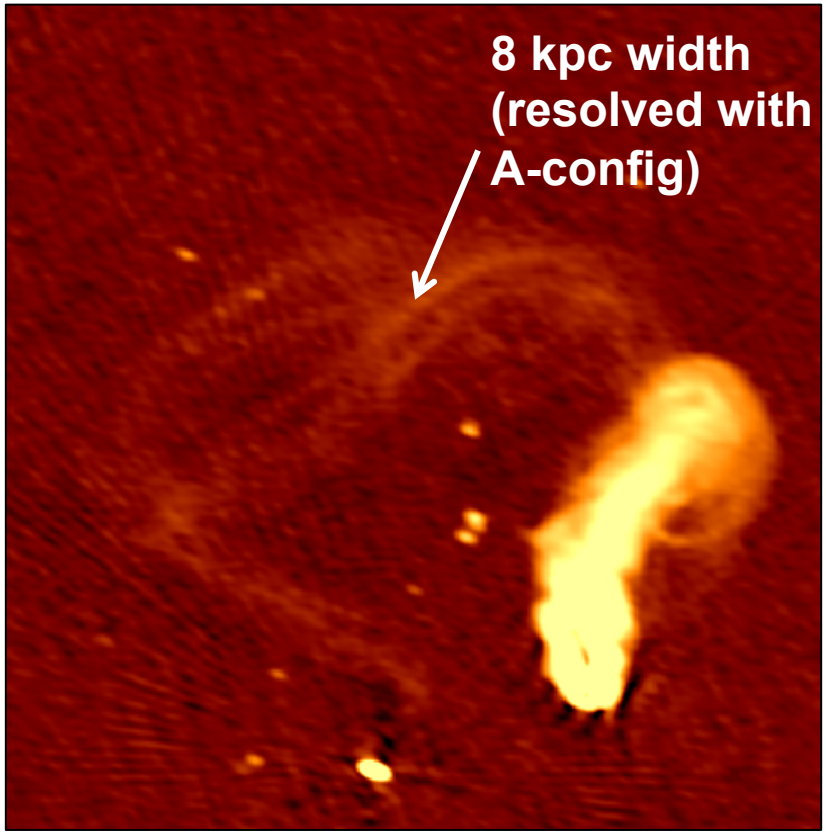
Gendron-Marsolais, Hlavacek-Larrondo et al. 2017 (see arXiv 1701.03791).

NGC 1265 (Narrow Angle Tail Source)

Sijbring et al. 1998: 325 MHz
Beam = 51”x77”

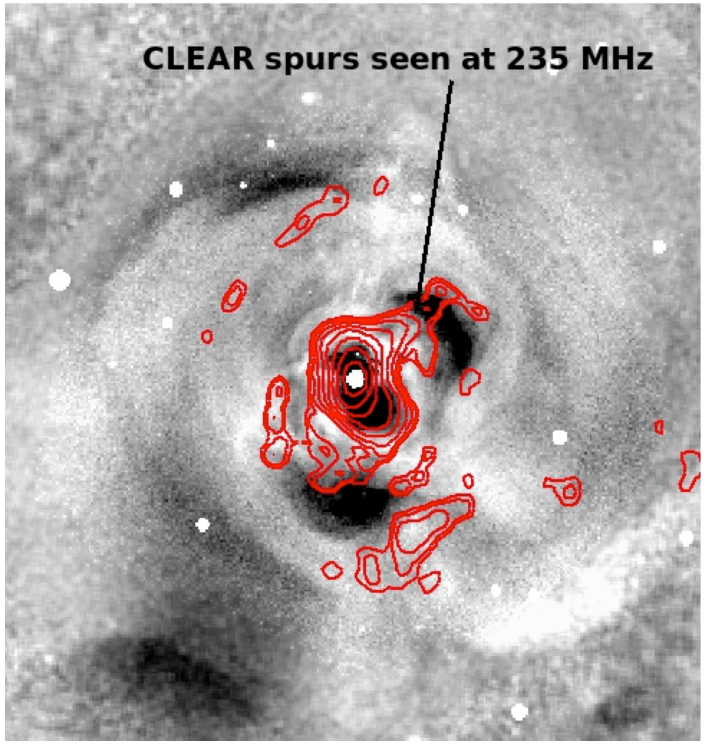


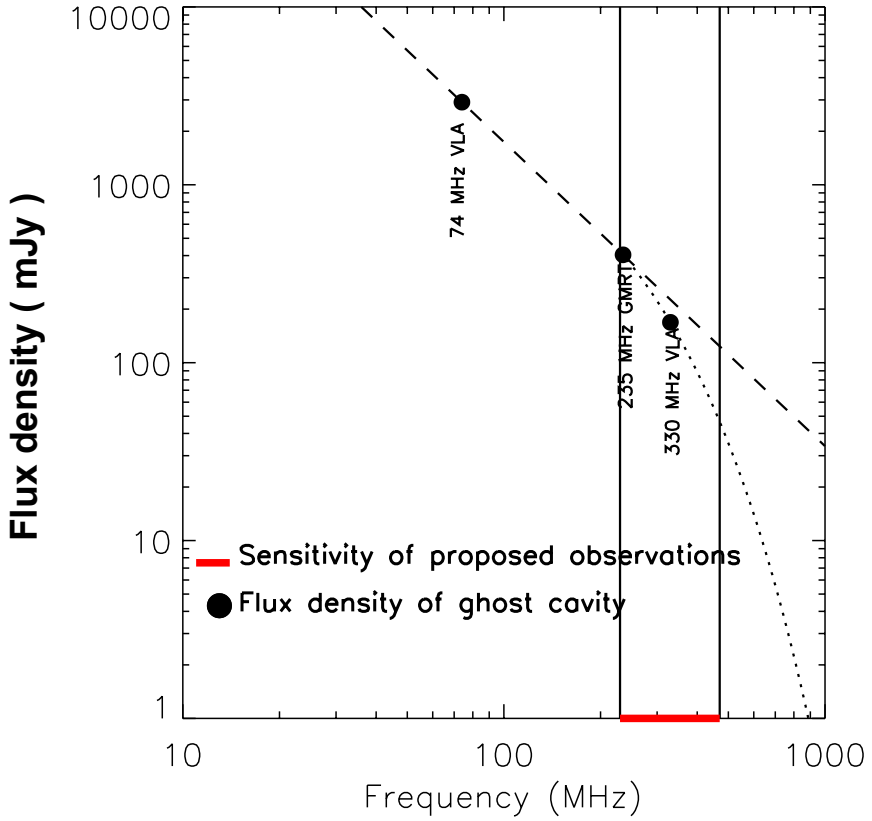
Gendron-M. et al. 2017 : 230-470 MHz
Beam = 22”x11” (5 times deeper).



The importance of AGN feedback in clusters

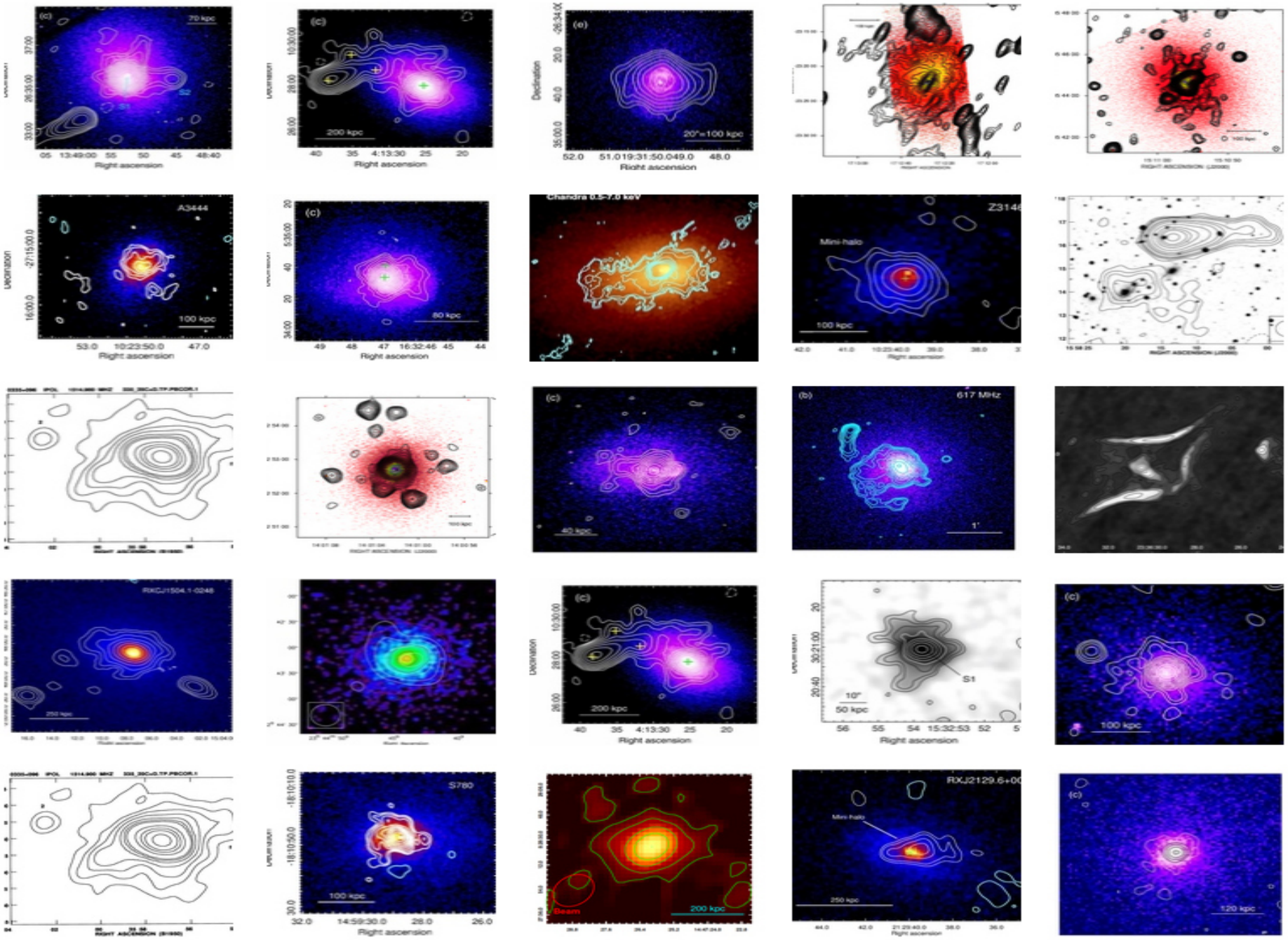
Perseus: 250 hours with Chandra + 235 MHz GMRT contours





→ **X-ray cavities in Perseus cluster: excellent for studying how relativistic particles age.**

→ New JVLA facilities at low frequencies (230-470MHz).



Collage of clusters with mini-halos; Credit: ARL/JHL