

Radio observations of nearby X-ray and optically bright giant elliptical galaxies and their interaction with the intergalactic medium

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Motivation: Why gE in radio band?

50 kpc

Optical (VLT)



NGC 1317
spiral galaxy



NGC 1316
giant elliptical galaxy

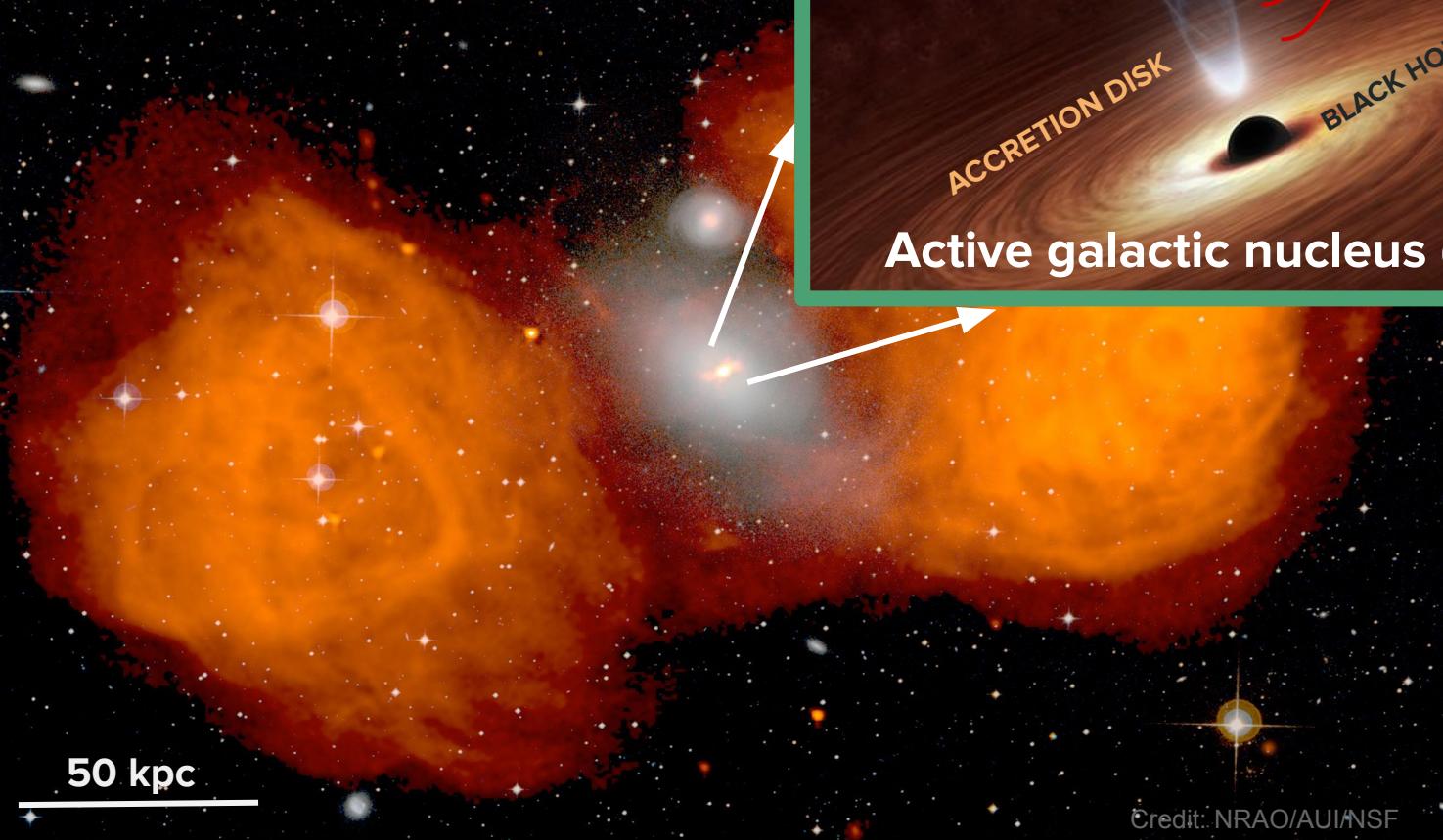
'red and dead'

- * old population of star
- * (almost) no star formation

NGC 1316

Radio (VLA)

Optical (VLT)

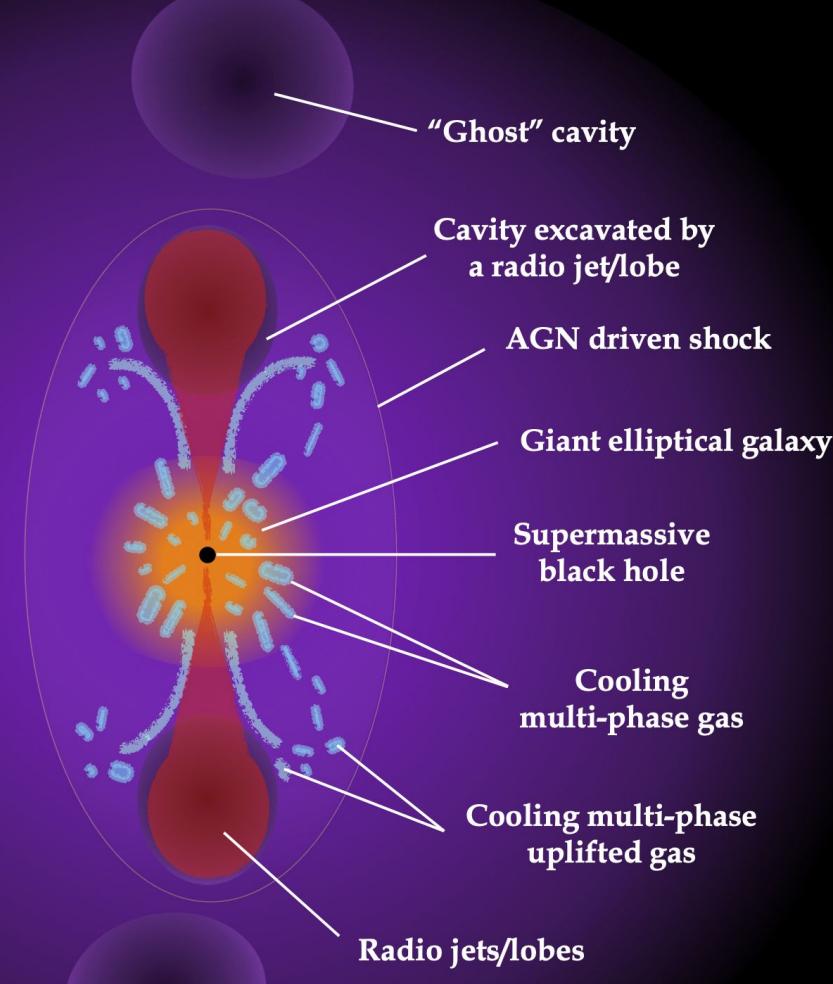


artist impression;
Credit:NASA/JPL-
Caltech

Credit: NRAO/AUI/NSF

Hot atmosphere

Radio-mechanical AGN feedback

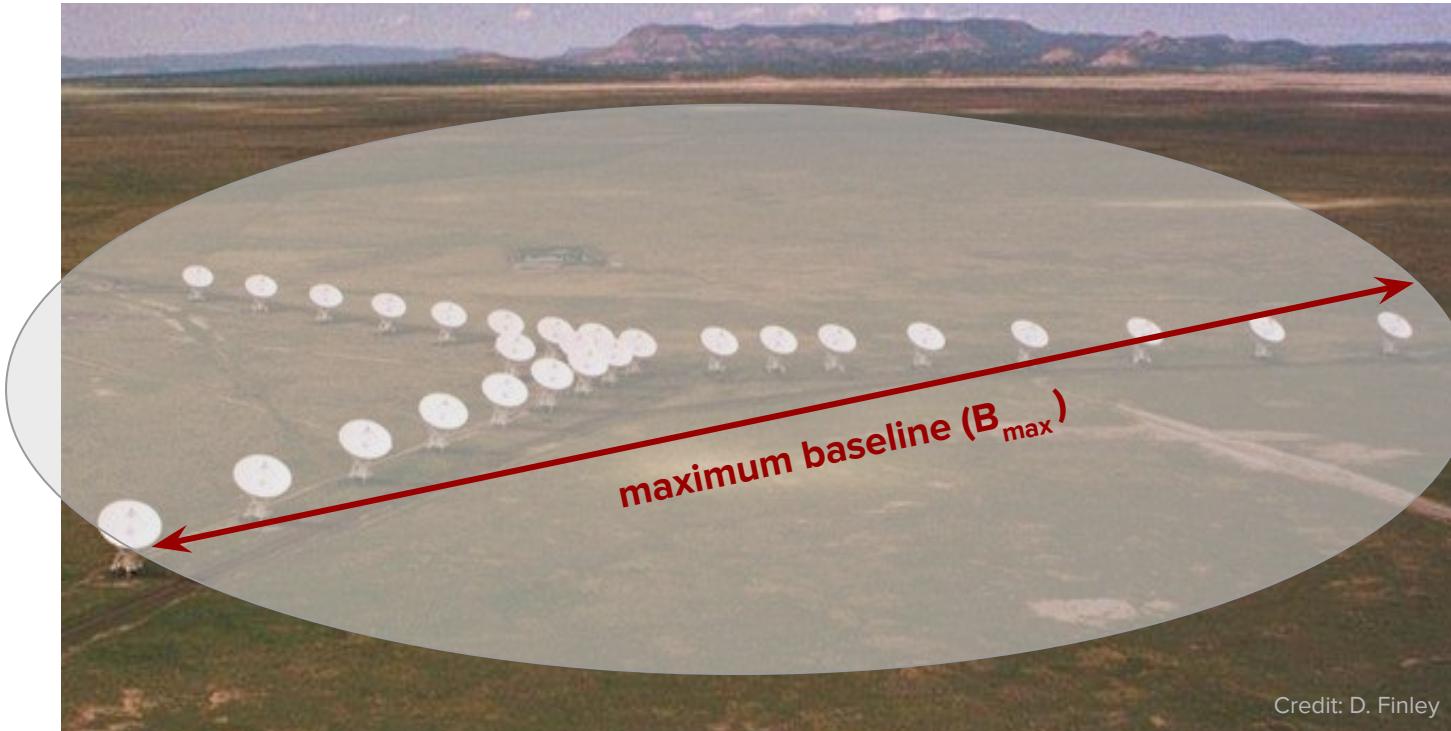


Questions to investigate

- ★ **What is detection rate of radio emission at 1-2GHz in the large sample of nearby gE galaxies?**
- ★ **Is the radio-mechanical AGN feedback widespread in gE?**
- ★ **What is the duty cycle of AGN?**
- ★ **What is the feeding mechanism of AGN?**

Karl Jansky Very Large Array

aperture synthesis telescope



Angular resolution ~ 1 arcsec

VLA A configuration with $B_{\max} = 35$ km at 1-2GHz

Configuration A : 35 km array diameter

Her A

1''

Configuration B : 11 km array diameter

4''

Credit: NASA, ESA, S. Baum and C.O'Dea (RIT), R. Perley and W. Cotton (NRAO/AUI/NSF) and Hubble Heritage Team (STScI/AURA)

Configuration C : 3 km array diameter

14''

150 kpc

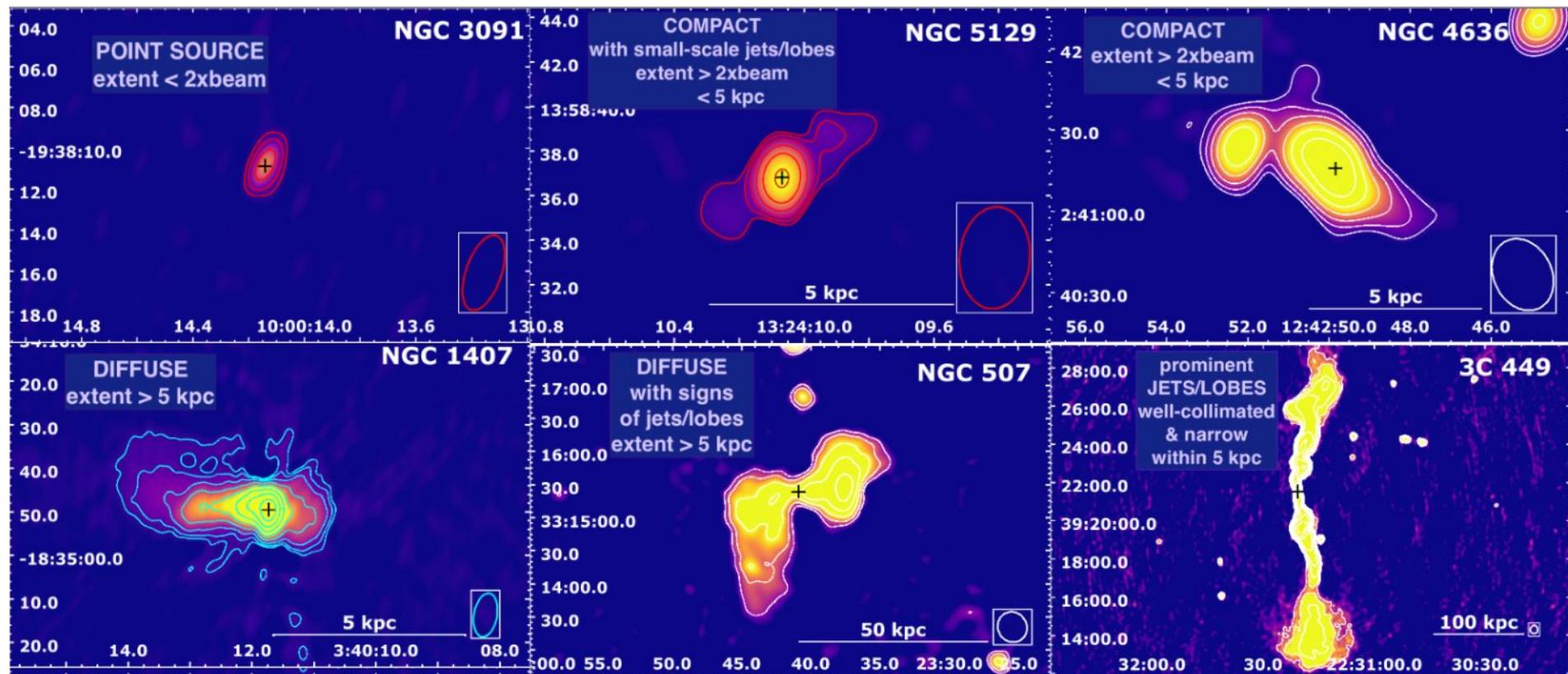
Configuration D : 1 km array diameter

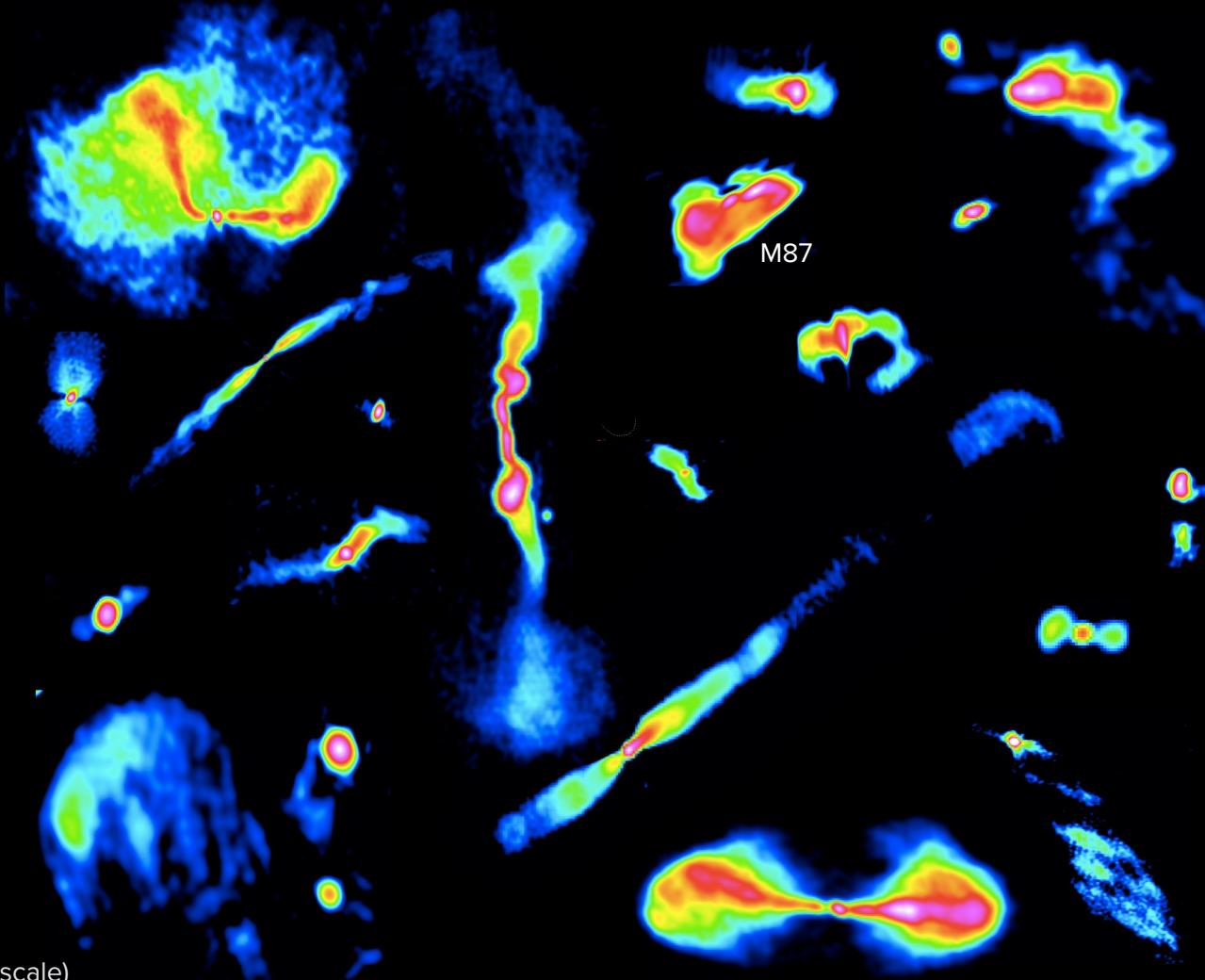
46''

VLA Statistical sample

- ★ parent study: **Dunn, 2010**
 - **high radio detection rate in nearby 18 giant ellipticals**
bright in **optical** and **X-rays**
 - **extended** radio for **10/18** sources => inconsistent with models
 - proposed extended sample
- ★ our sample of **42** galaxies:
 - 22 archival VLA data + **20 new VLA high resolution**
data observed in 2015 (PI: Werner)

Defined categories





extended sources (not to scale)

VLA Sample: Main aim

- ★ detection **rate** of **radio** emission inside of these galaxies?
 - morphology, extend, $P_{1.4\text{GHz}}$; interaction with the **X-rays**, optical and IR emission? (X-ray and H α study in Lakhchaura, 2018)
- ★ investigation of AGN duty cycle
 - AGN turning **ON** and **OFF** again (Maccagni, 2020)
 - AGN **constantly** switched **ON**, while continuously blowing out bubbles of relativistic plasma? (Allen, 2006)

Our main results

- ★ 98% - **radio** emission in the central region
(NGC 499 detected with LOFAR)
- ★ 64% - **extended** radio structures
- ★ 81% - environmental interactions in form of
X-ray cavities
(in some cases: **multiple** generations)

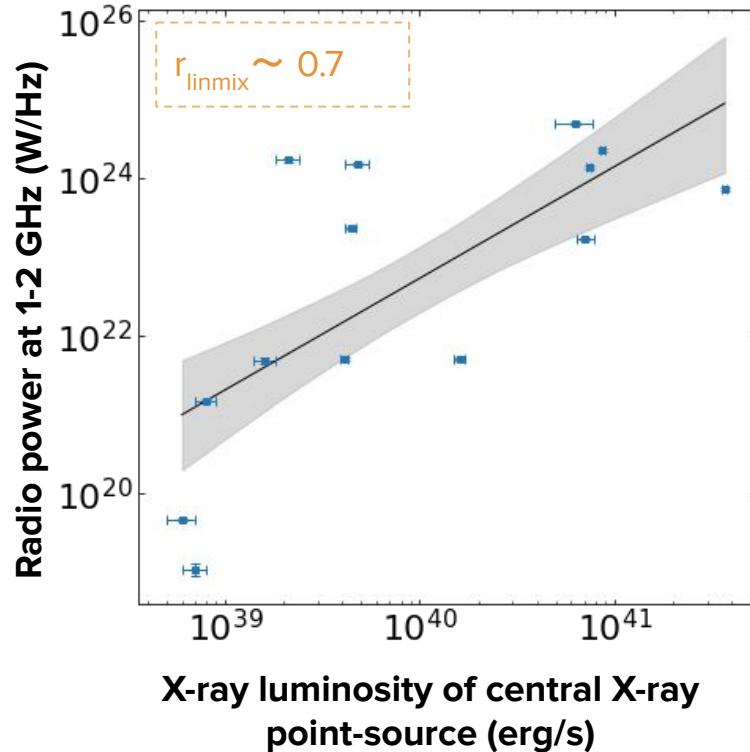
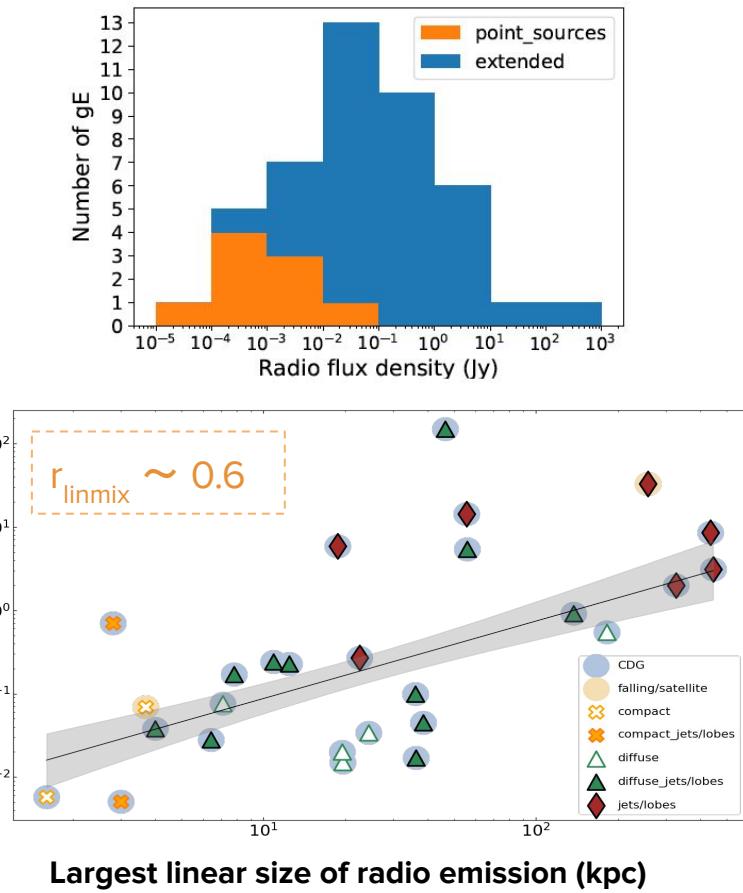
Our main results

- ★ 33% - point-like morphologies
 - 7/14 - show X-ray cavities & cavities in NGC 499
 - 5/14 - could be dominated by **star formation**
=> 3 out of 5 show X-ray cavities!

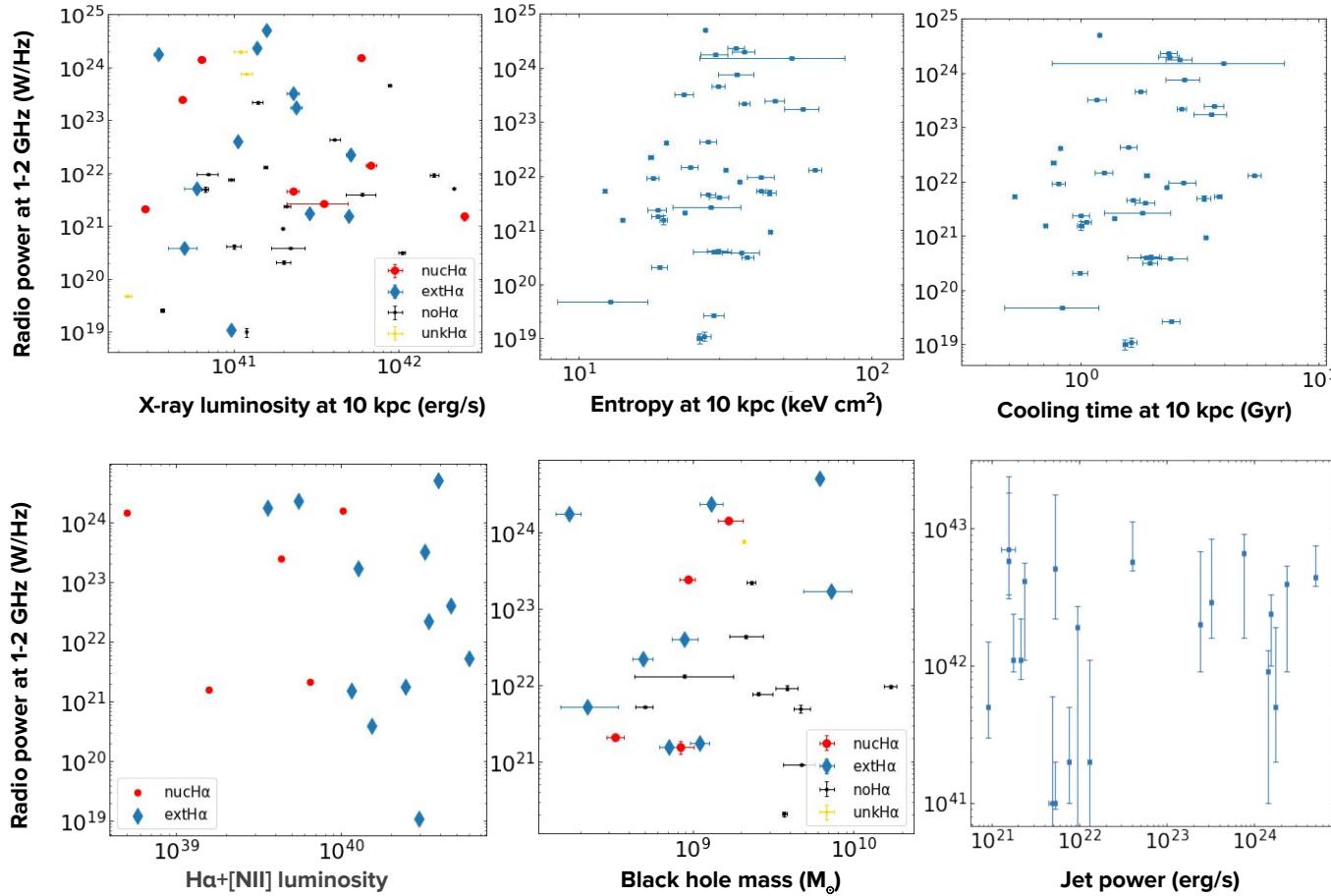
=> **majority of AGN in radio-mechanical feedback mode**

VLA sample: Statistics - correlations

Radio flux density at 1-2 GHz (Jy)

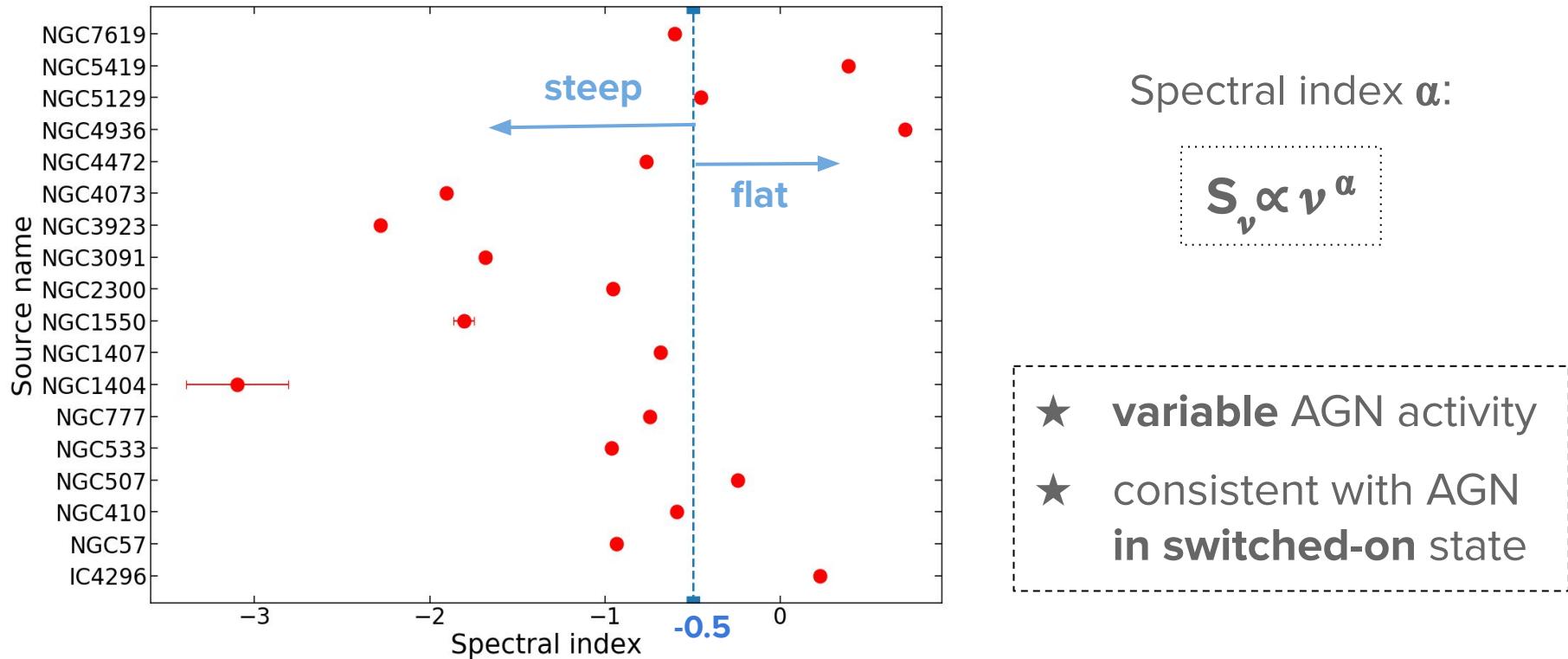


VLA sample: Statistics - no trends



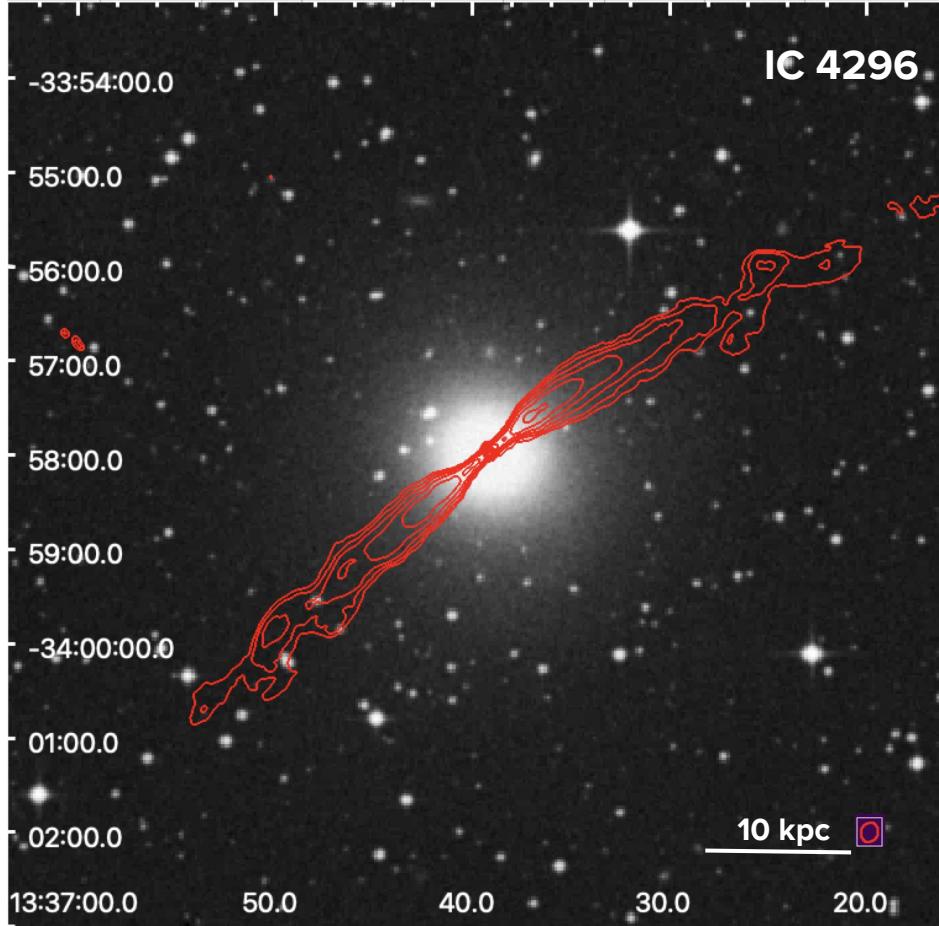
Mean spectral indices

at 1.7kpc from the core; within the L-band (1-2GHz)



Unusual giant elliptical galaxy IC 4296

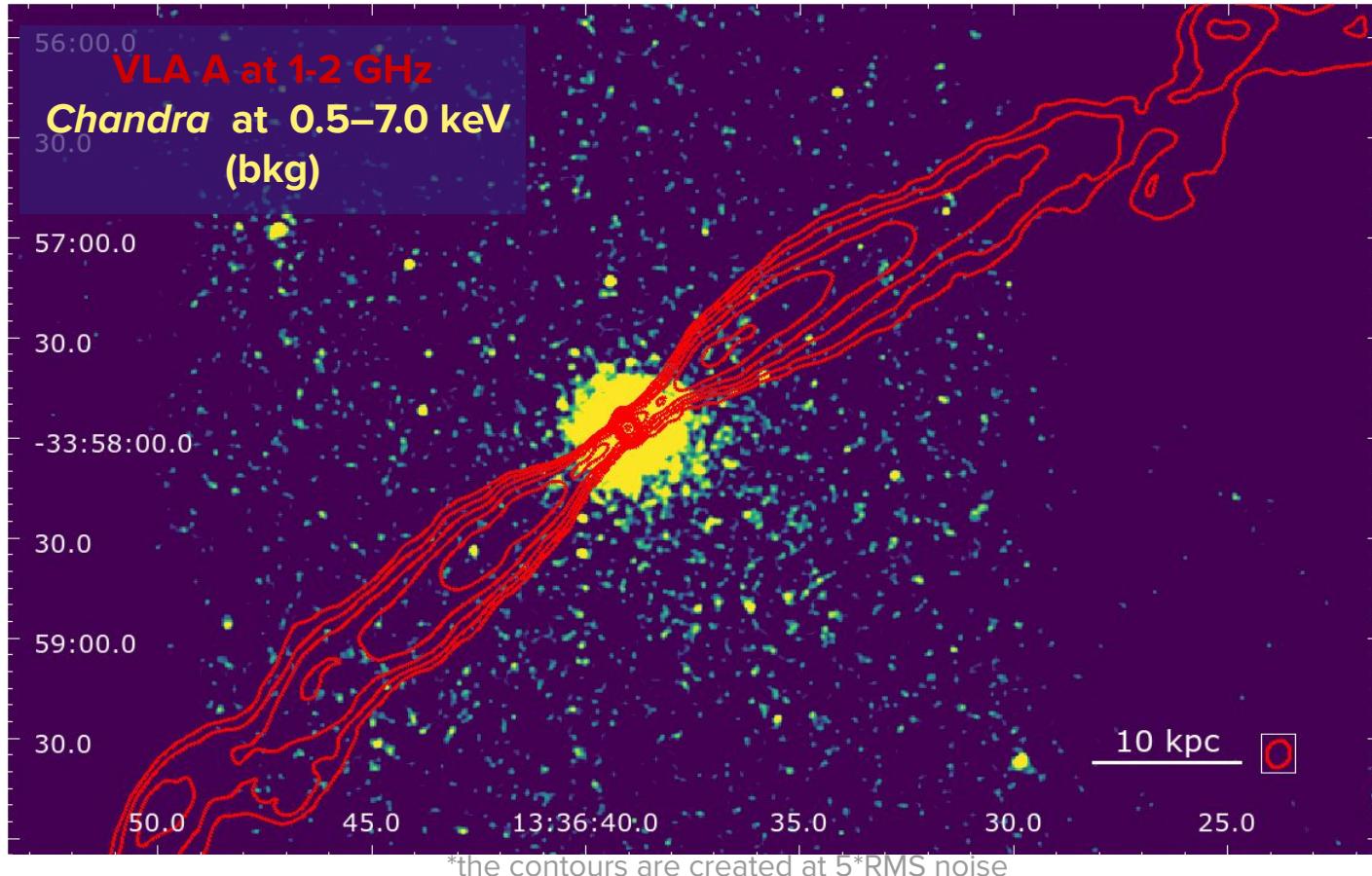
UK48-inch Schmidt
at 468 nm
VLA A at 1-2 GHz



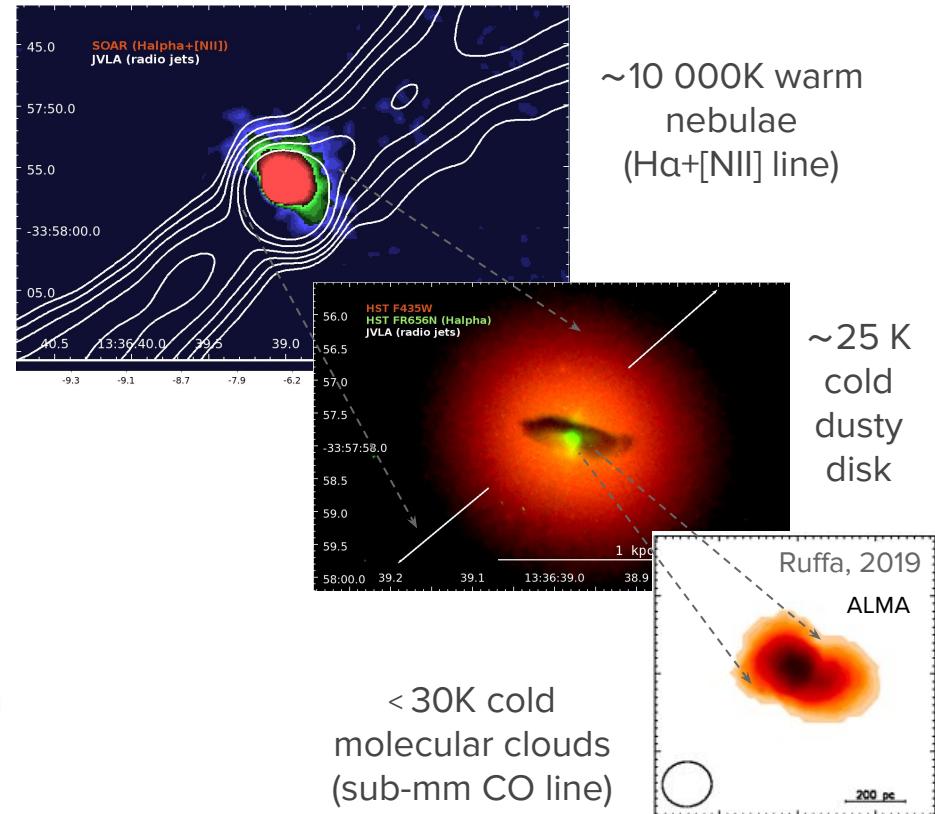
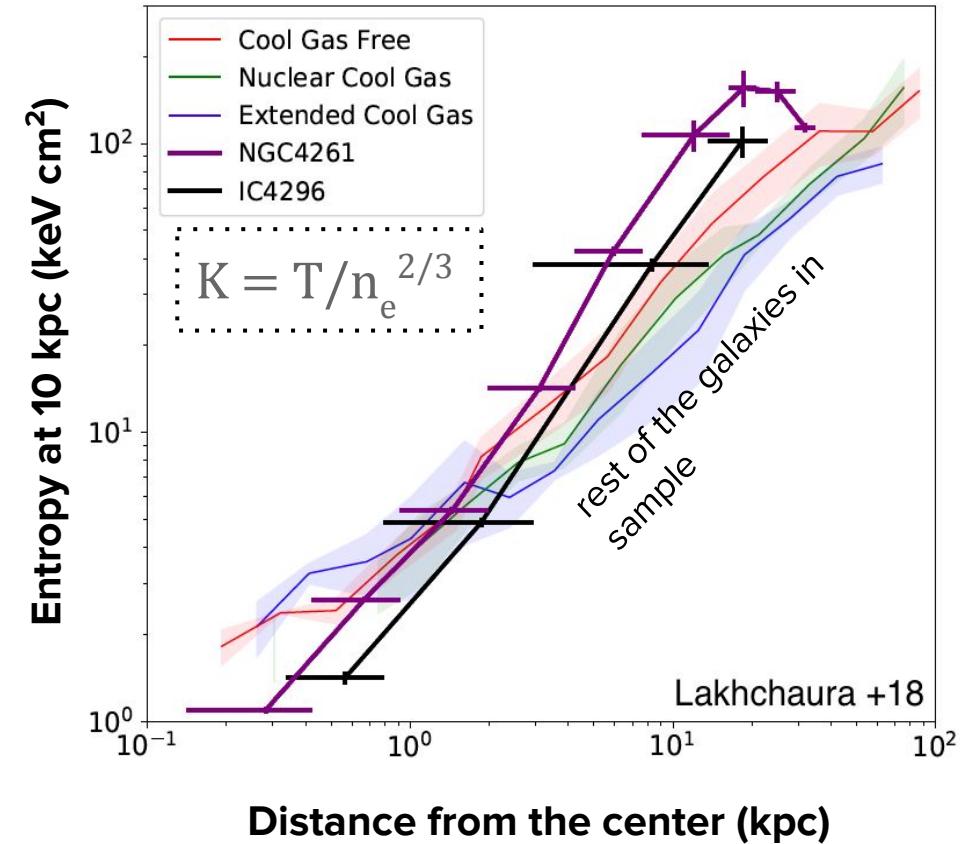
located in 1keV
group Abell 3565
at $z \sim 0.0125$

*the contours are created
at 5*RMS noise

Smoothed X-ray Chandra image of IC 4296

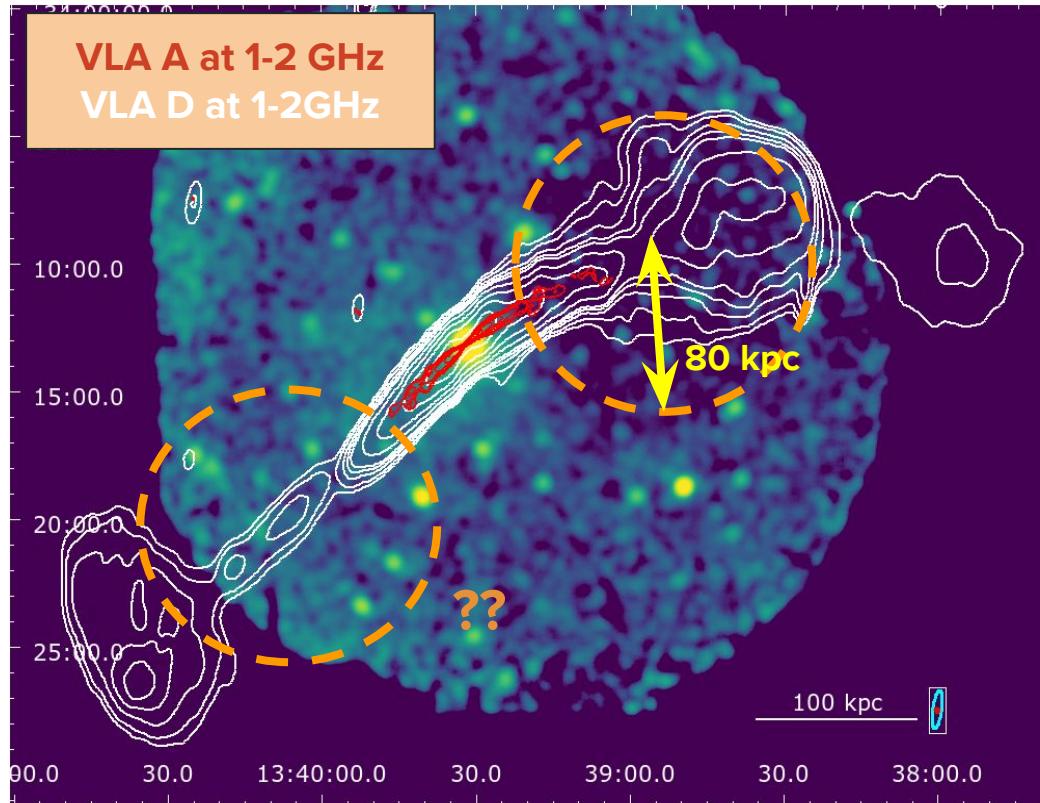


Entropy profile of IC 4296



XMM-Newton image & VLA D contours

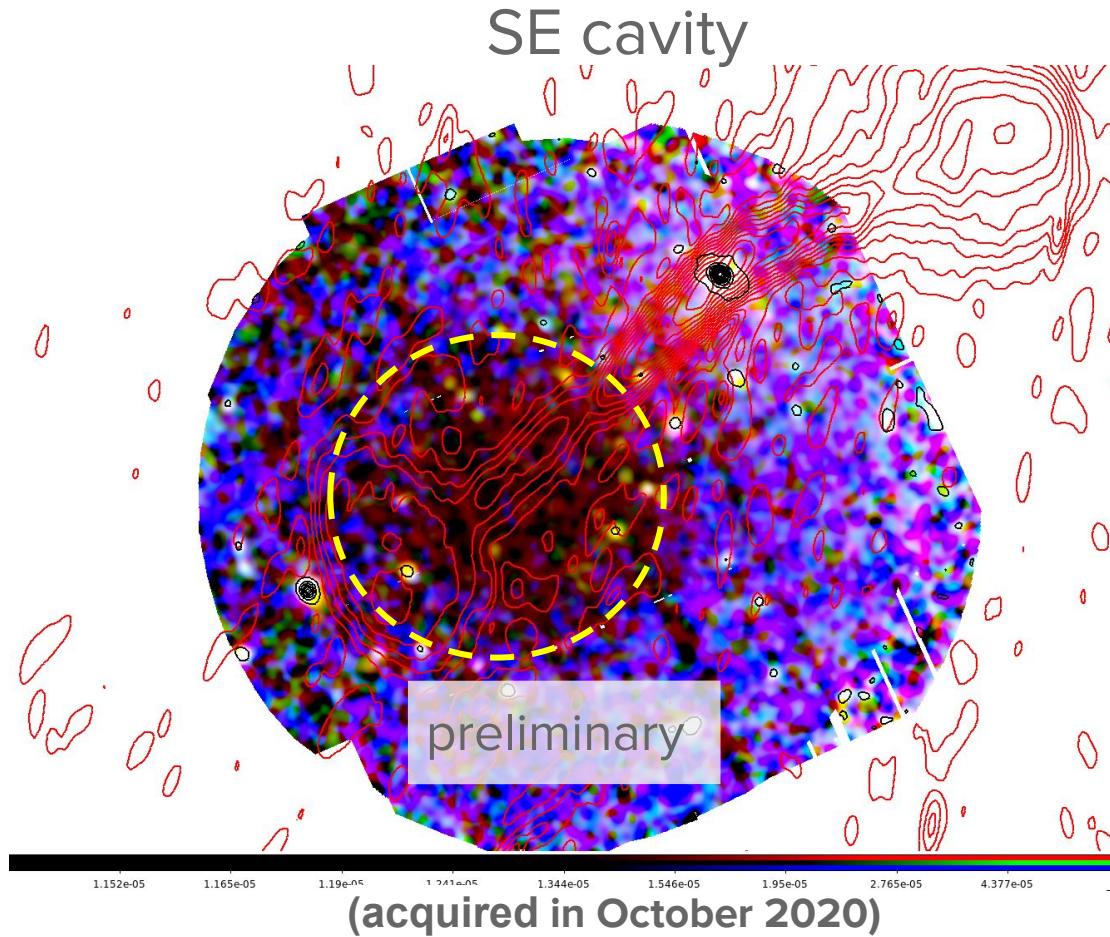
NW cavity & powerful jets



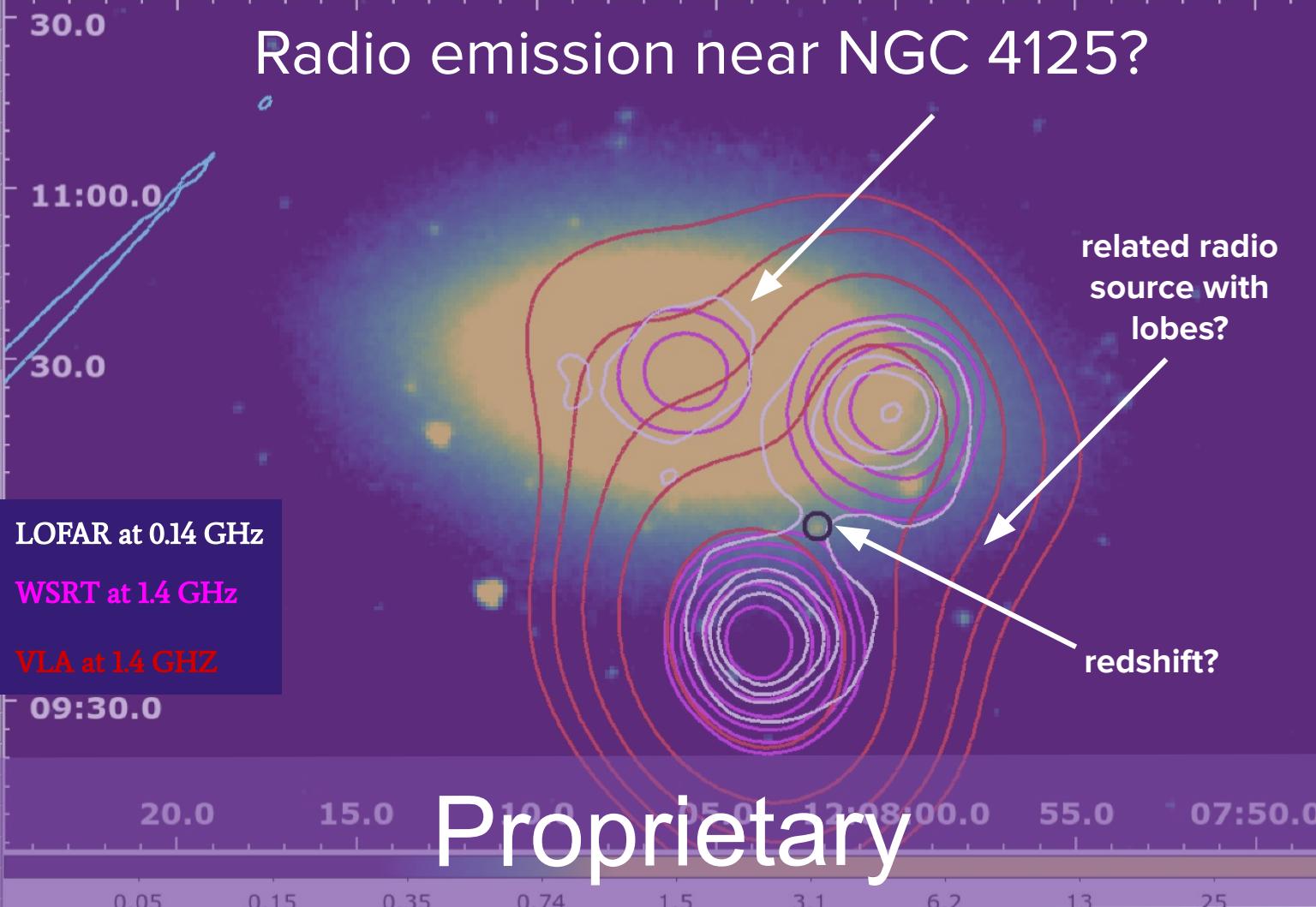
*the contours are created at 5*RMS noise

- 150 mil. years to inflate the cavity (at c_s) & work $\sim 10^{60}$ erg
=> supersonic **powerful** FRI source

Preliminary *XMM-Newton* data & VLA D contours



Radio emission near NGC 4125?



Our Questions & Conclusions

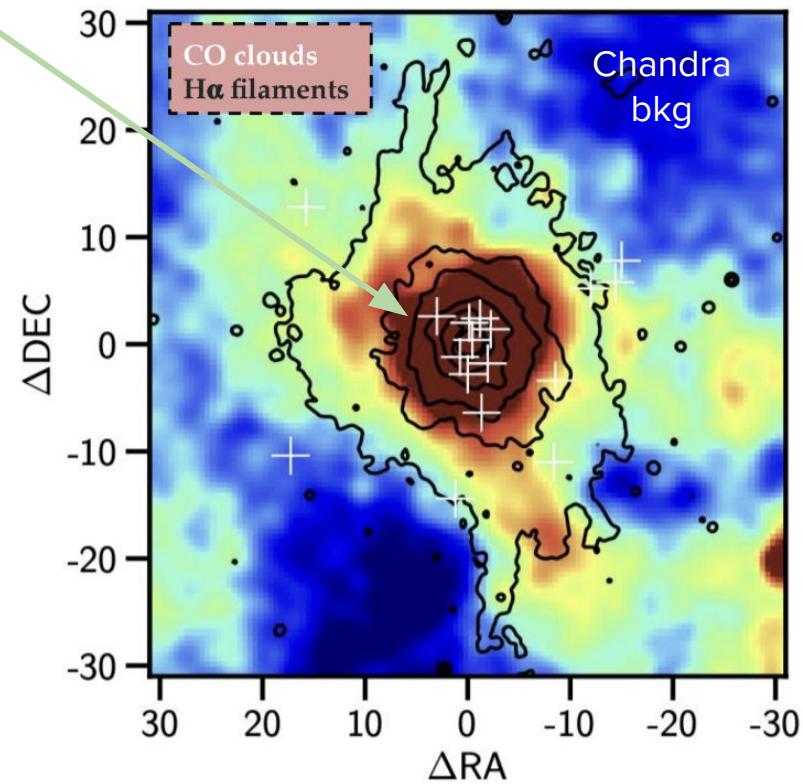
- ★ **high radio detection** rate at 1-2GHz in the large sample of giant ellipticals
- ★ **radio-mechanical** AGN feedback is **widespread** in these galaxies with a variable activity of their AGN
- ★ **duty cycle** is **high (41/42** radio detection)
- ★ feeding mechanism - future ALMA follow-up

FUTURE: Cold Molecular gas with ALMA in gE

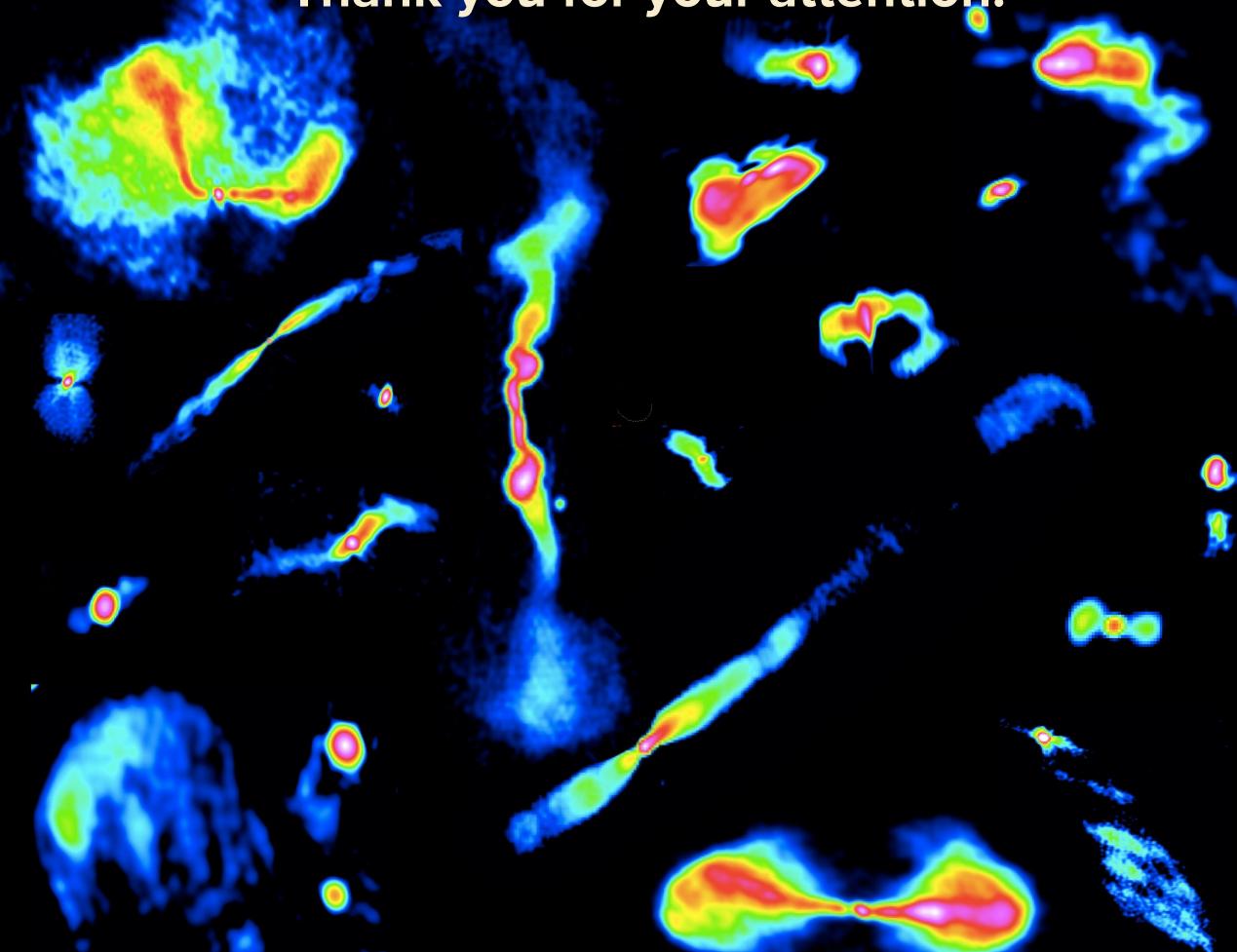
NGC 5044

2 kpc

H α +[NII]



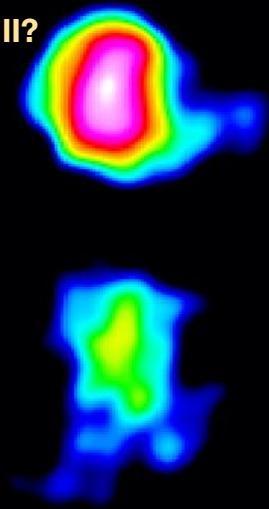
Thank you for your attention!



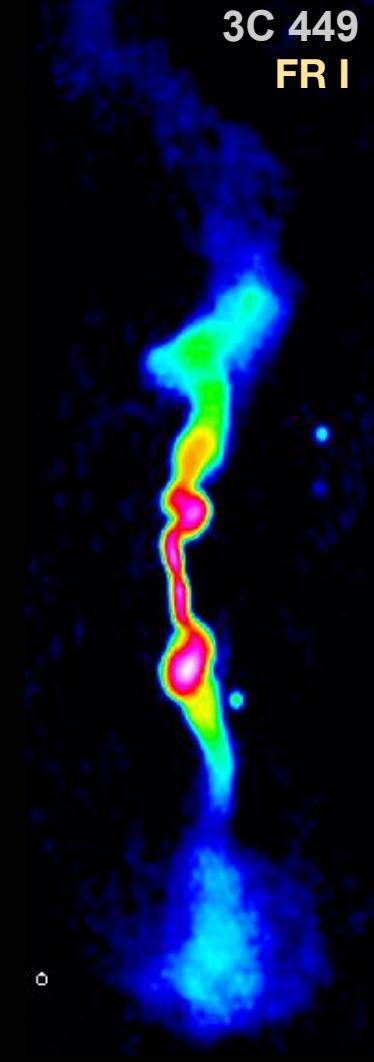
extended sources (not to scale)

Additional slide

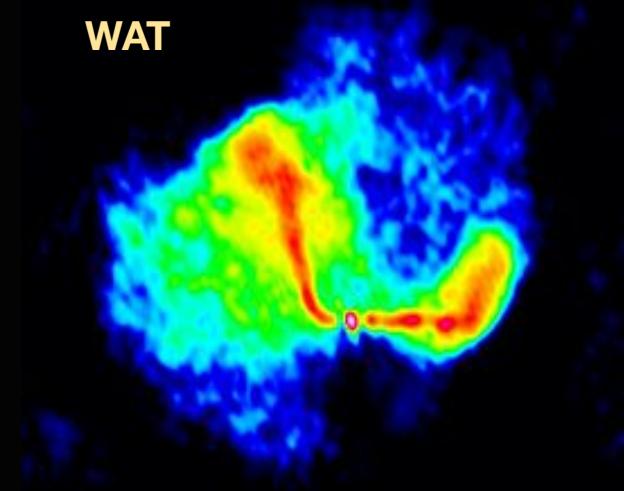
NGC 1600
FR II?



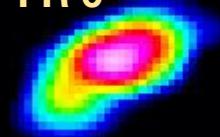
3C 449
FR I



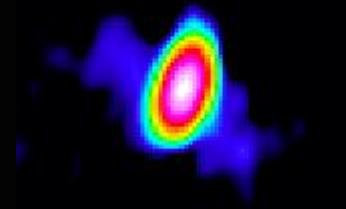
NGC 4782
WAT



NGC 777
FR 0



NGC 5129
COMPACT



Offset radio emission

recoiled BH, merging galaxies with only one active nucleus?

