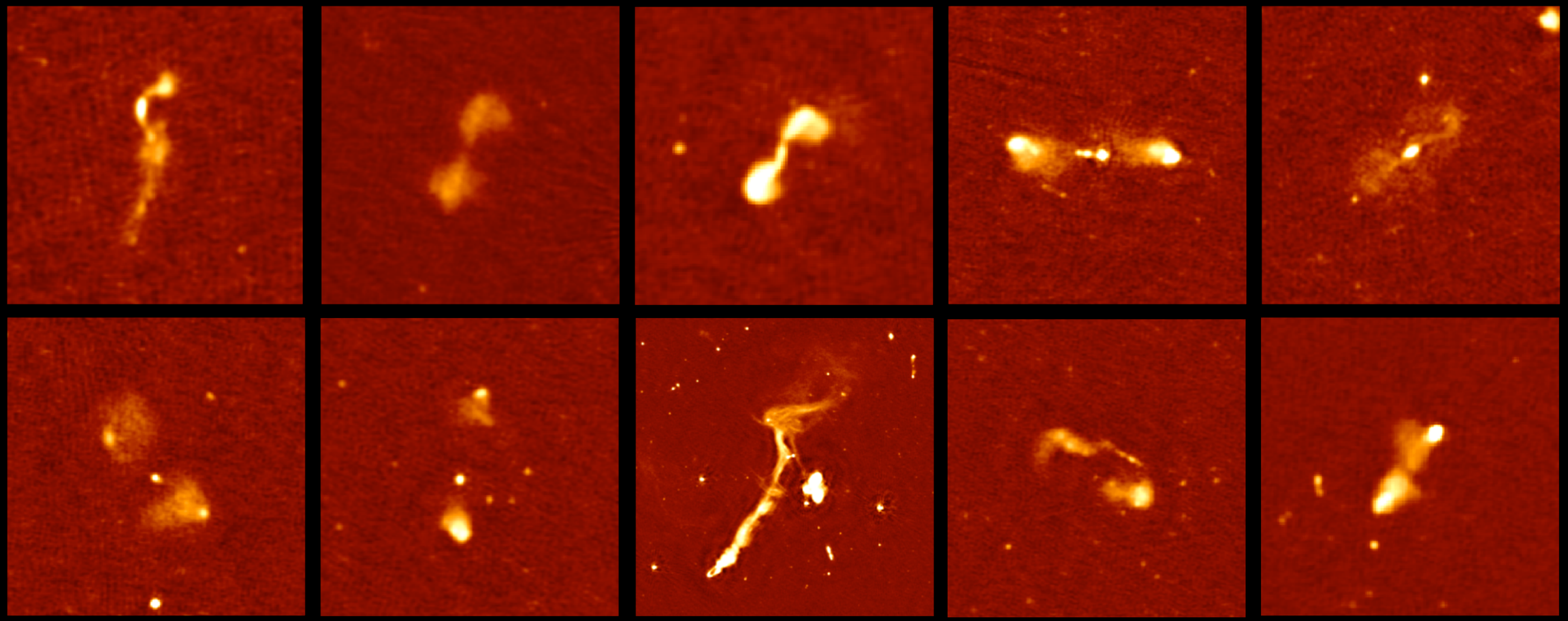


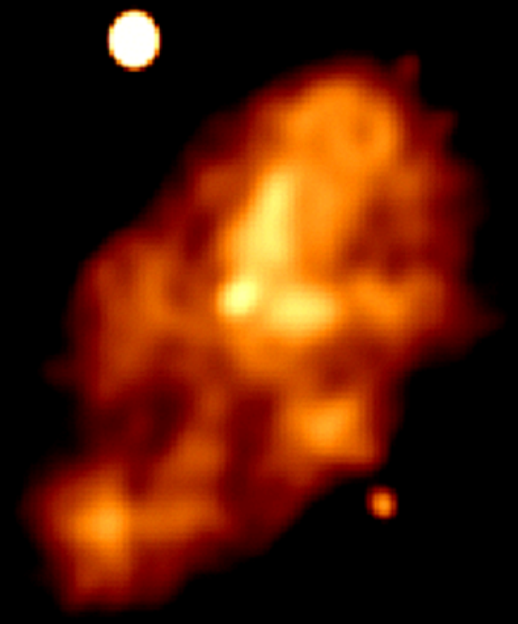
A renewed look at the impact of jetted AGN in the SKA era

Marisa Brienza

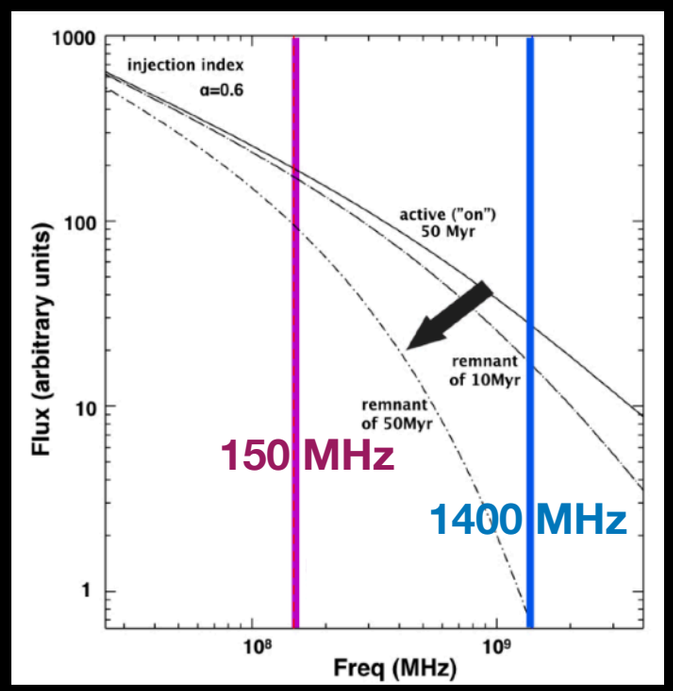
with Annalisa Bonafede, Franco Vazza, the LoTSS team and many others

A renewed look at the impact of jetted AGN in the SKA era

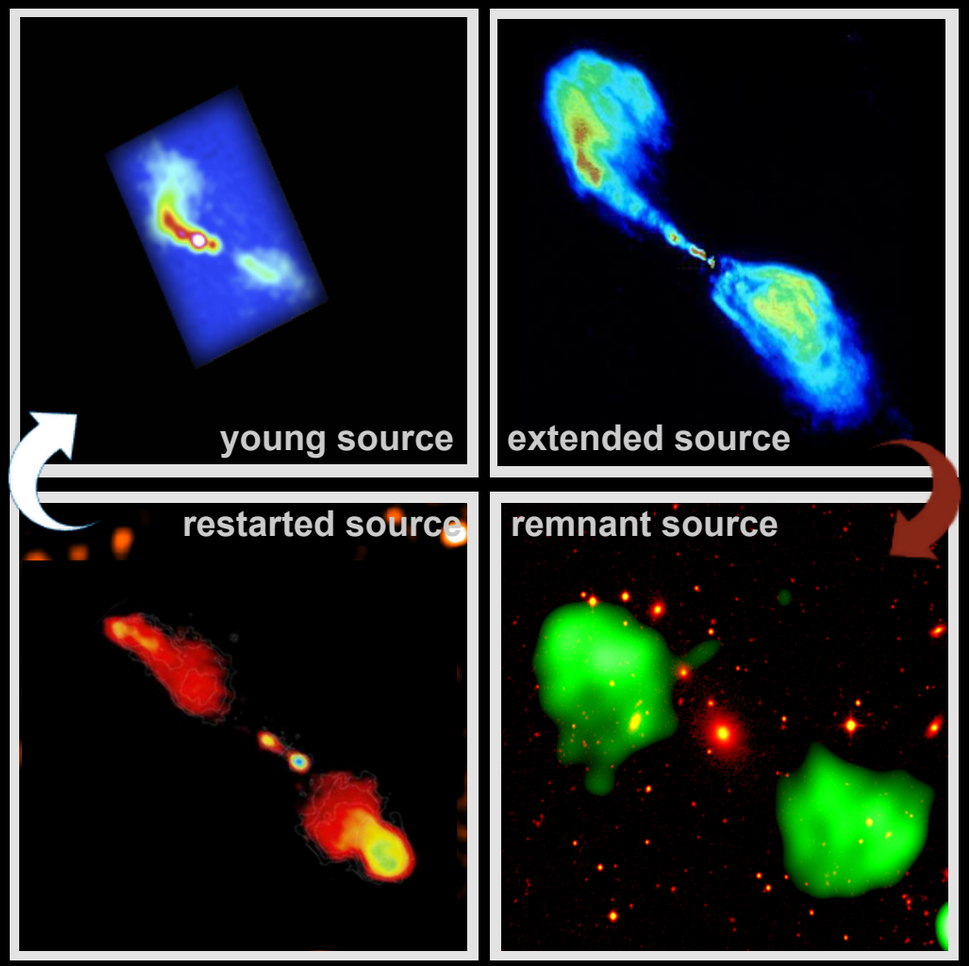
- Life-cycle of jets
- The interplay between jets and the surrounding environment

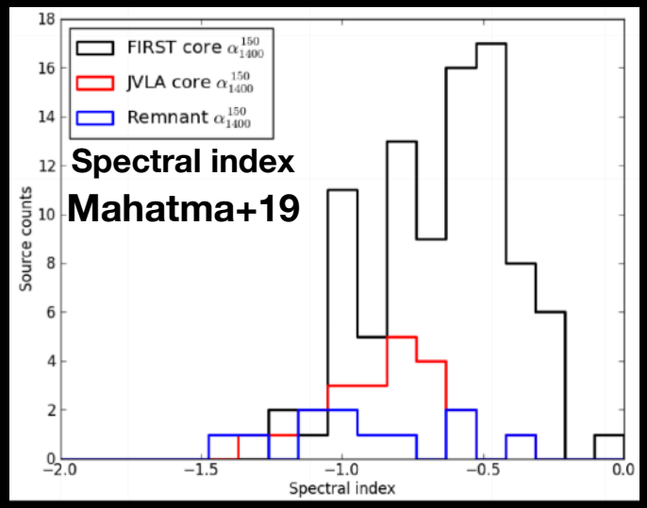


The remnant radio galaxy blob1
Brienza+2016



Life-cycle of jets



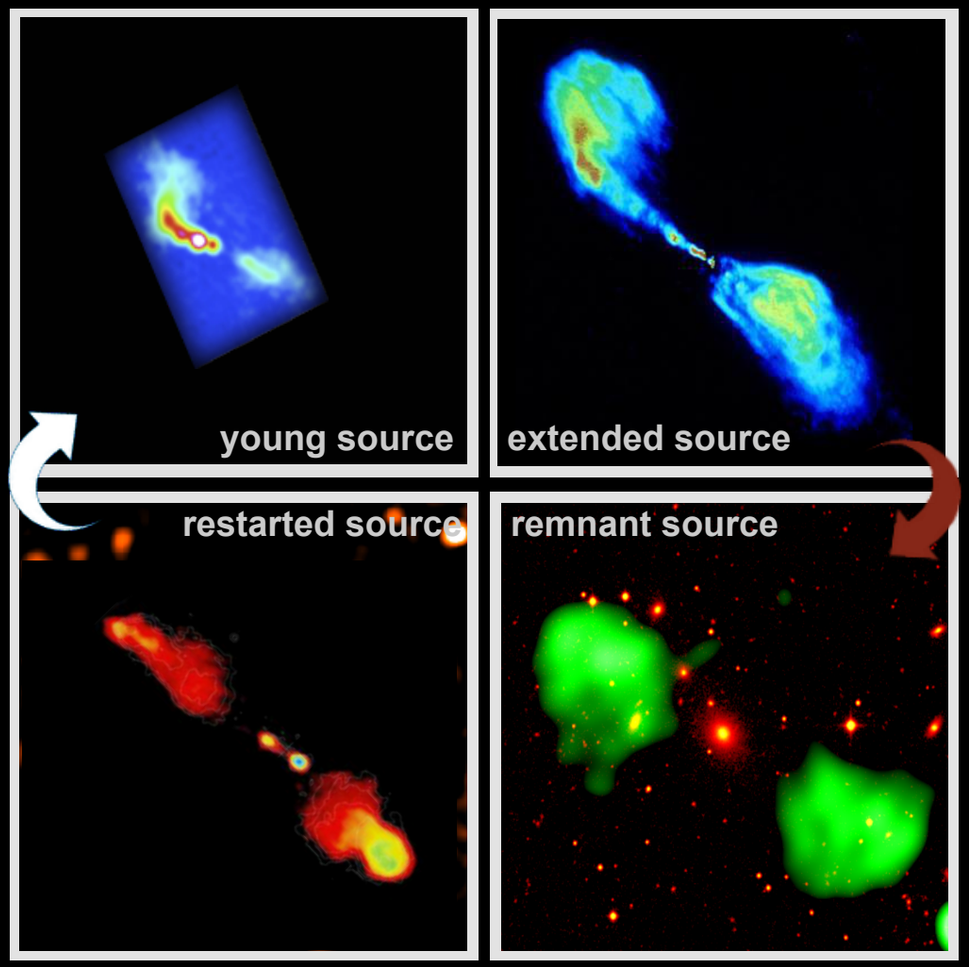


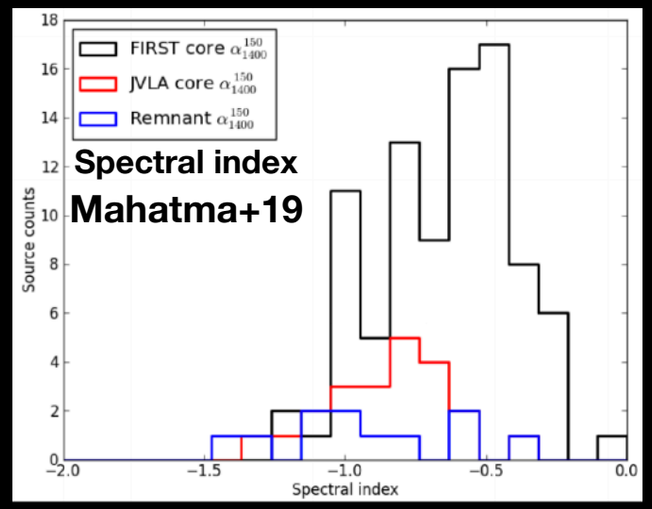
SAMPLES!

Hardcastle+2016
Godfrey+2017
Brienza+2017
Quici+2021
Jurlin+20, 21

<10% in radiogalaxy samples

Life-cycle of jets





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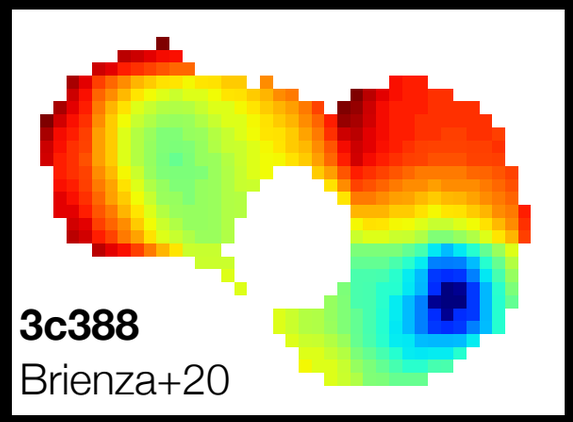
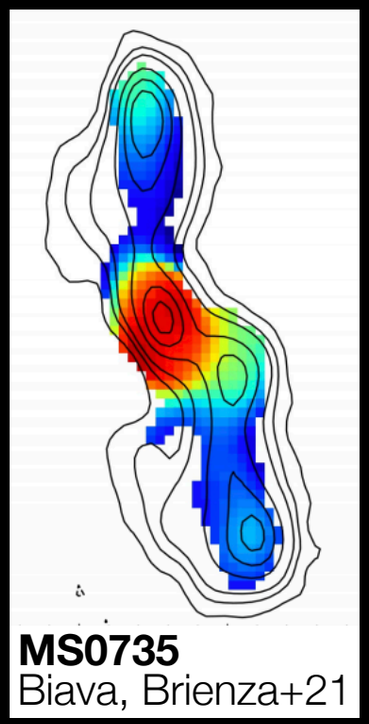
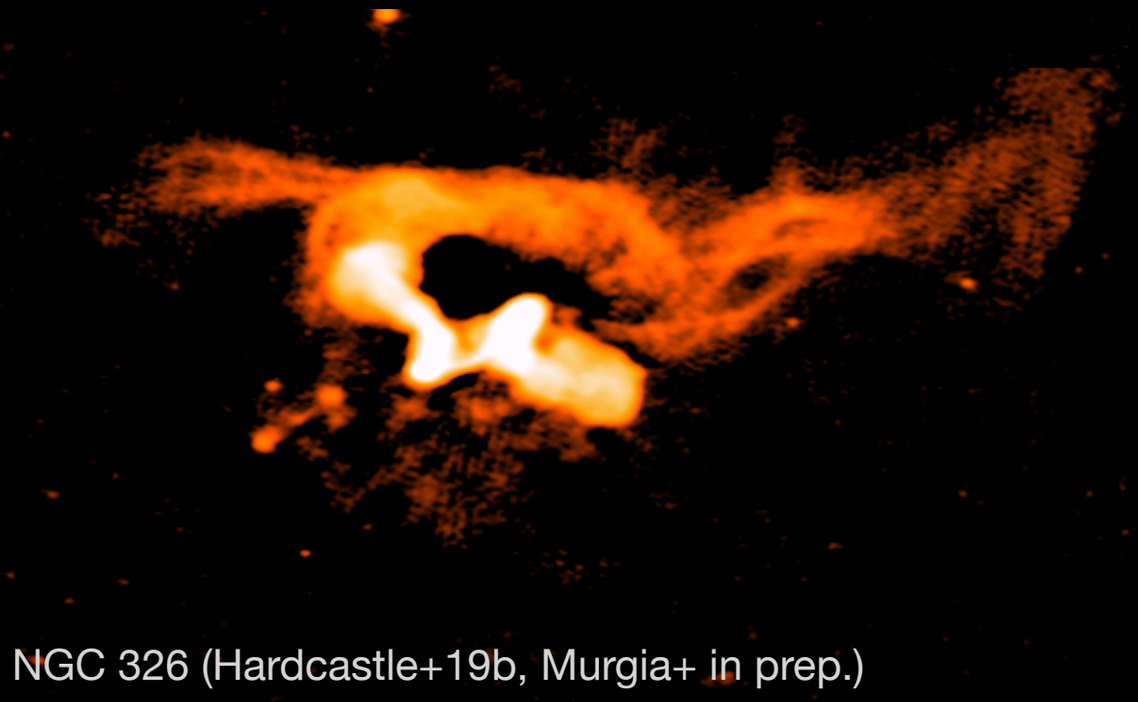


Spectral age maps

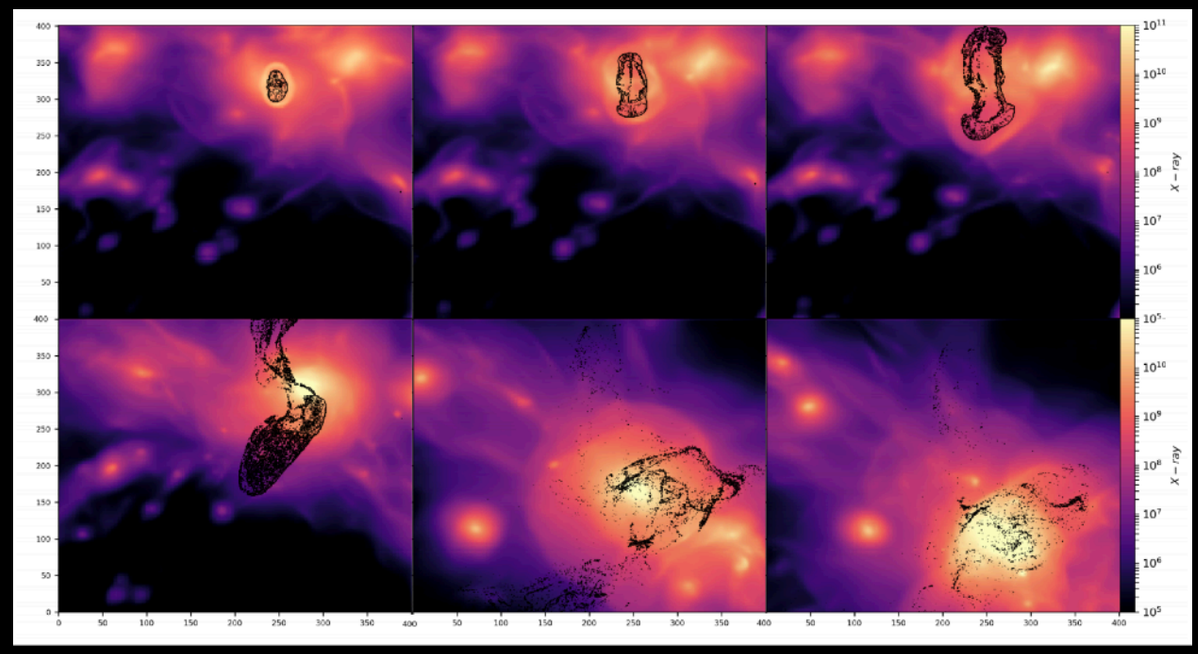


Very fast duty cycle!
Inactive phase/Active phase <30%
Active phase~ tens Myr

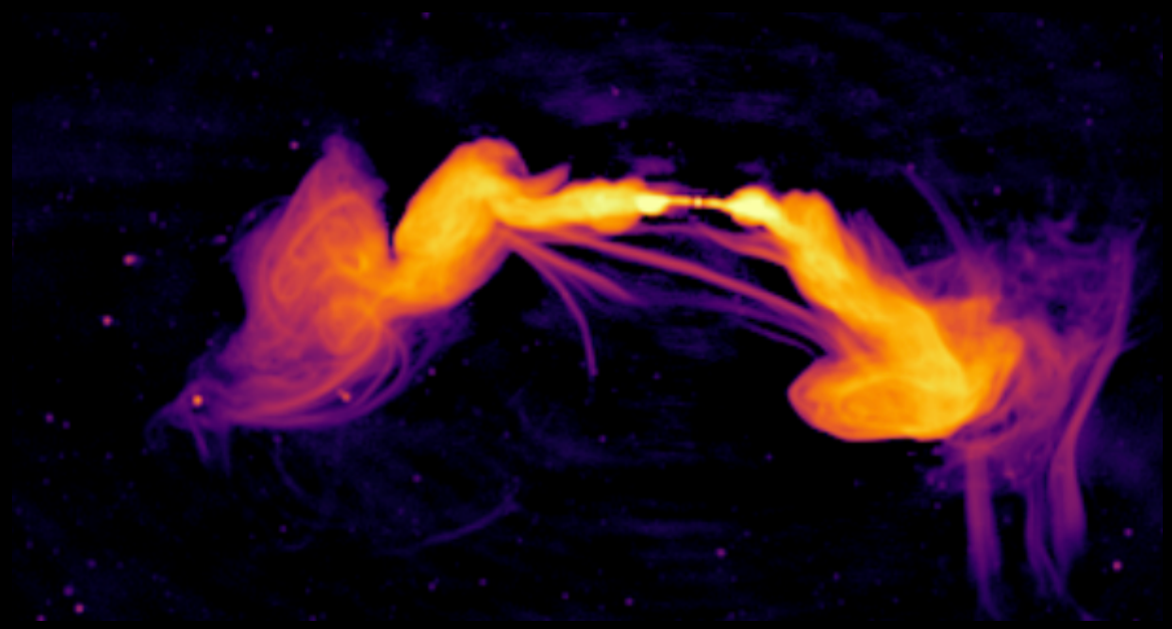
The interplay between jets and the surrounding environment



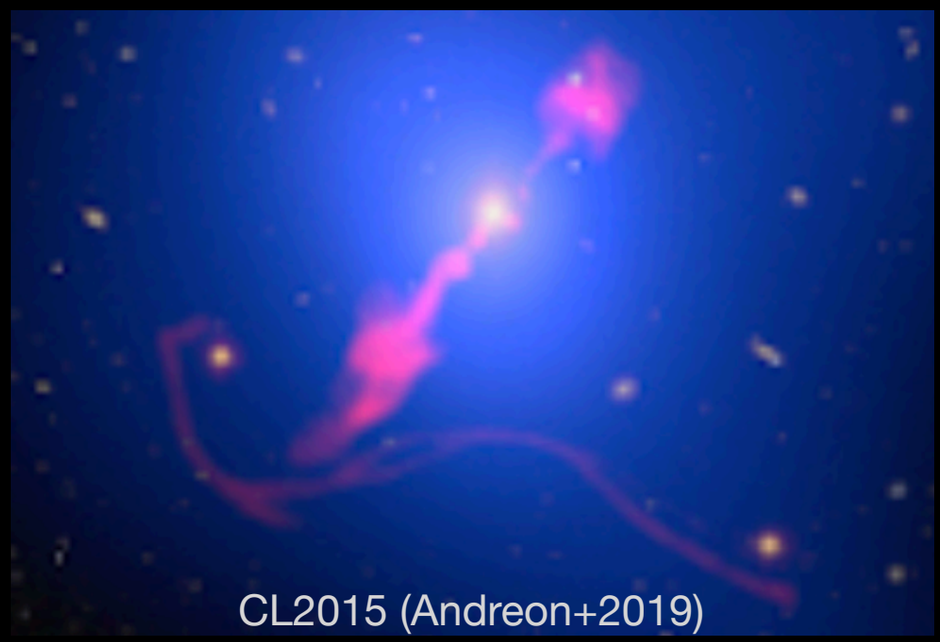
NGC 326 (Hardcastle+19b, Murgia+ in prep.)



Simulations by Vazza+2021

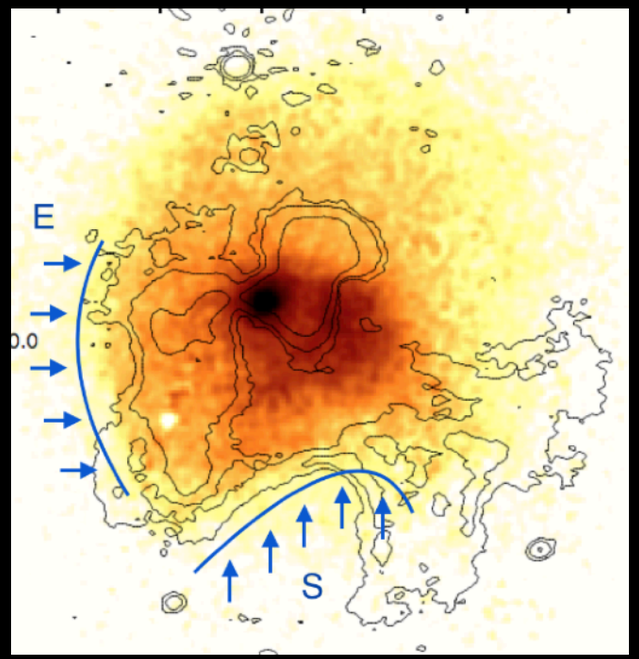


ESO 137-006 (Ramatsoku+2020)



CL2015 (Andreon+2019)

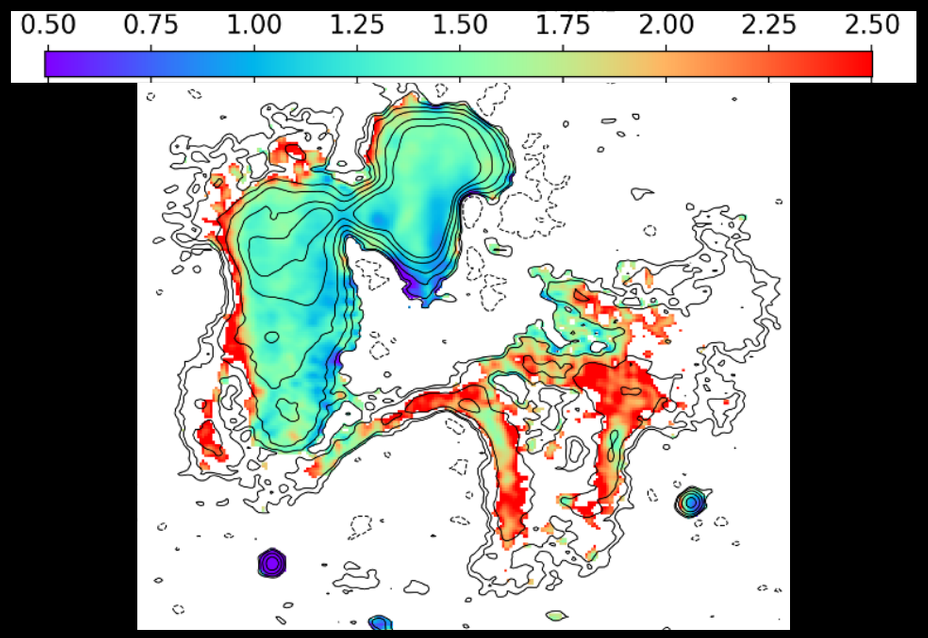
NGC507: AGN plasma transported by sloshing (Brienza et al. in prep.)



X-ray-radio
spatial coincidence
=
Clear interplay
between AGN
non-thermal
plasma and ICM

LOFAR 144 MHz

XMM 0.7-2 keV



Spectral index 144-400 MHz
(LOFAR+uGMRT)

6’ / 100 kpc

LOFAR 144 MHz
6” 0.2mJy/b

Brienza et al. NA in press

Nest200047
galaxy group 17 galaxies
based on 2MASS (Tully+15)
sigma=421 km/s
1.5×10^{14} M_{sun} (K_s luminosity)

BCG z=0.018
$\log(M_{star}/M_{sun})=11.56$
Low excitation radio galaxy

6’ / 100 kpc

LOFAR 144 MHz
6” 0.2mJy/b

Brienza et al. NA in press

multiple pairs of lobes
AGN recurrent activity

filaments of relativistic plasma and magnetic fields
few kpc wide and
up to 350 kpc long

outer lobes

Inner jets
25 kpc

Brienza et al. NA in press

6’ / 100 kpc

LOFAR 144 MHz
6” 0.2mJy/b

main filament

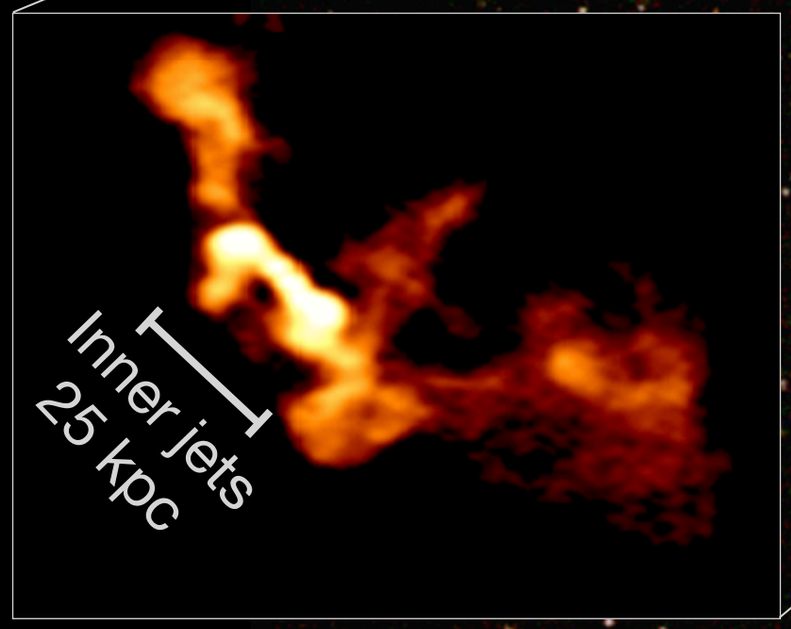
bridge

outer lobes

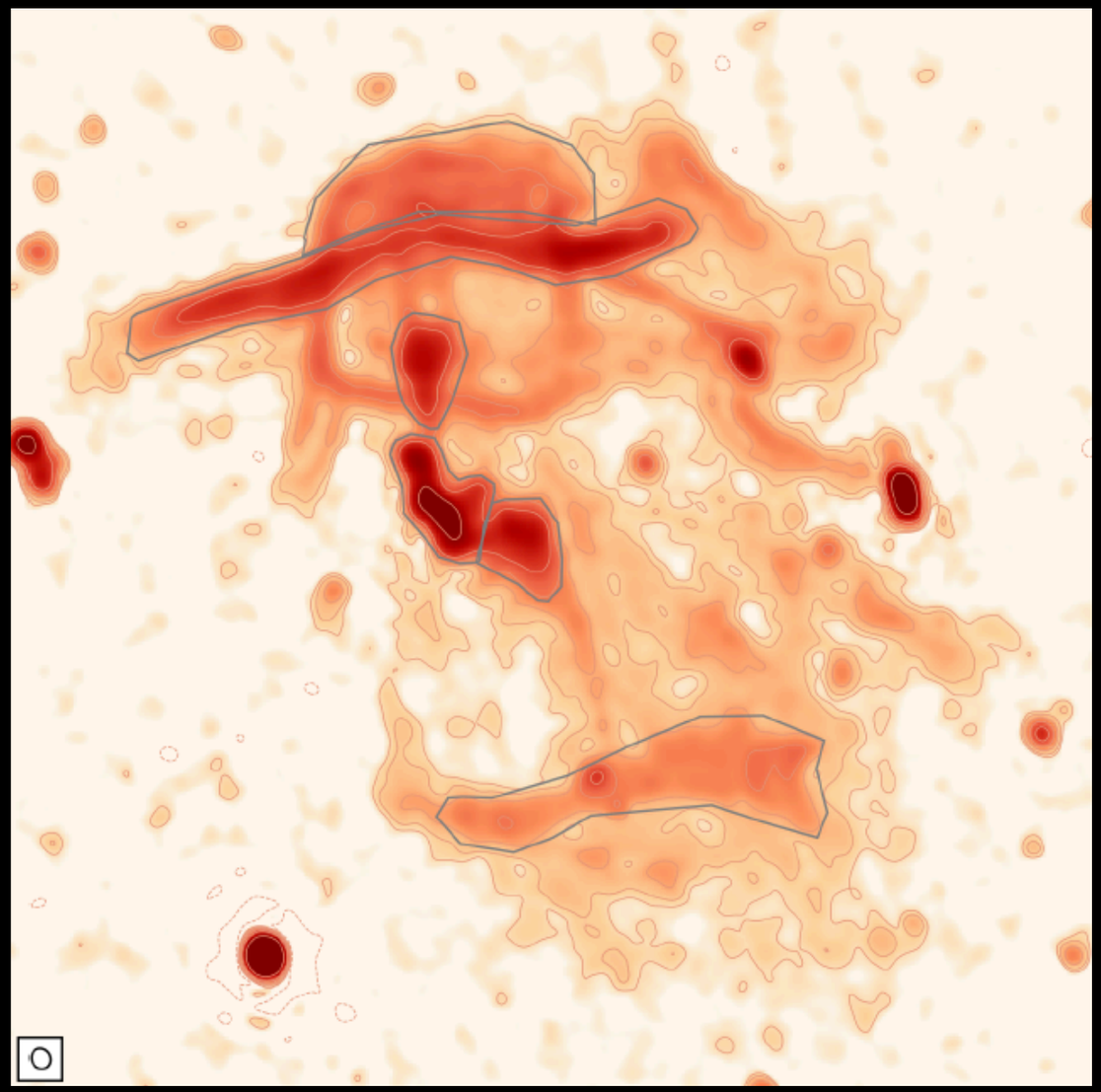
bridge

multiple pairs of lobes
AGN recurrent activity

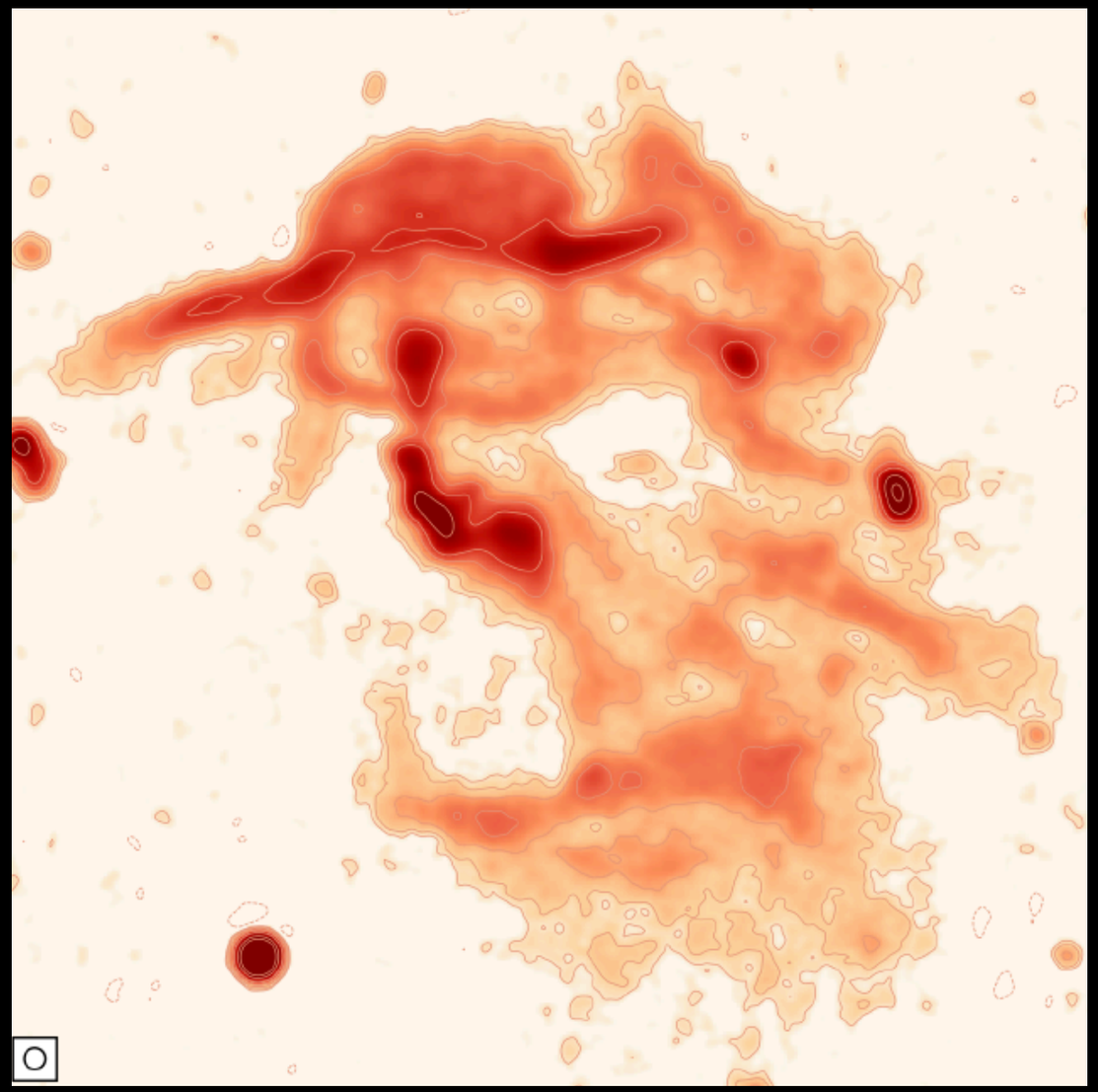
filaments of relativistic plasma and magnetic fields
few kpc wide and
up to 350 kpc long



A lot of extended, low surface brightness emission..

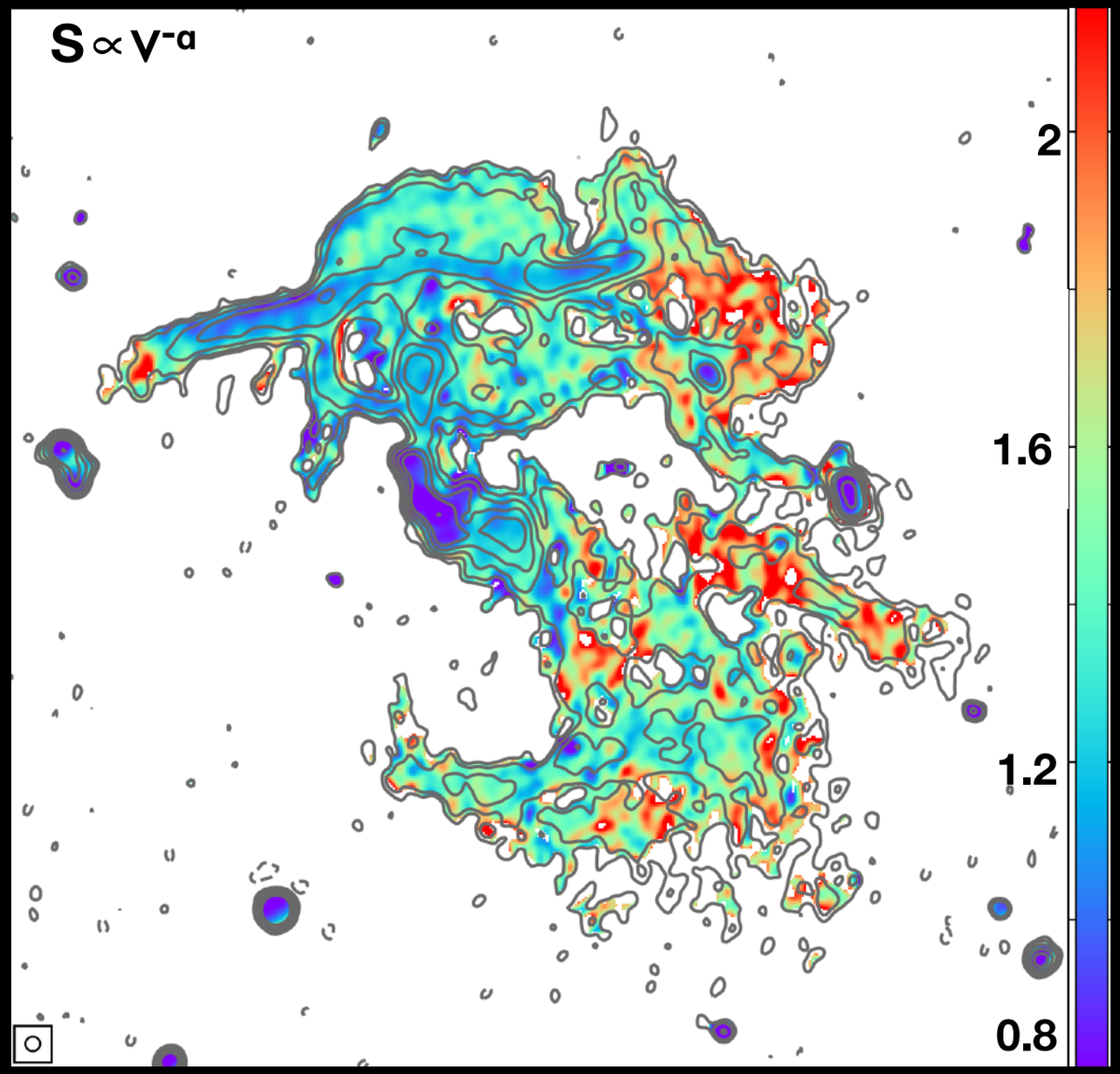


High band antennas
144MHz (16hr)
0.8 mJy/b 25”



Low-band antennas
54MHz (8h)
1.5 mJy/b 25”

Spectral index α(53-144 MHz)



central AGN
α =0.6-0.7
typical of active jets

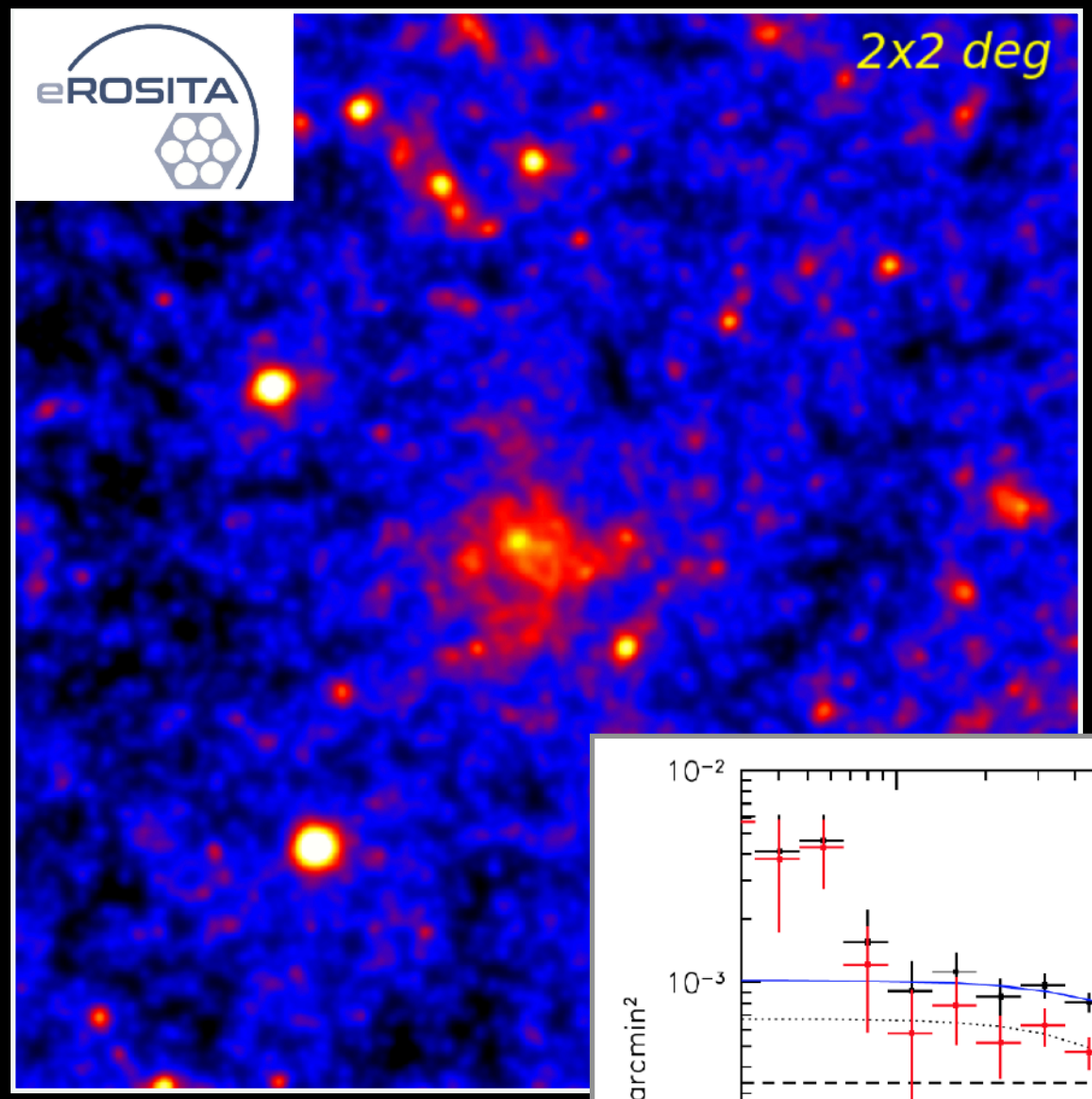
spectrum steepens
moving away from the central AGN

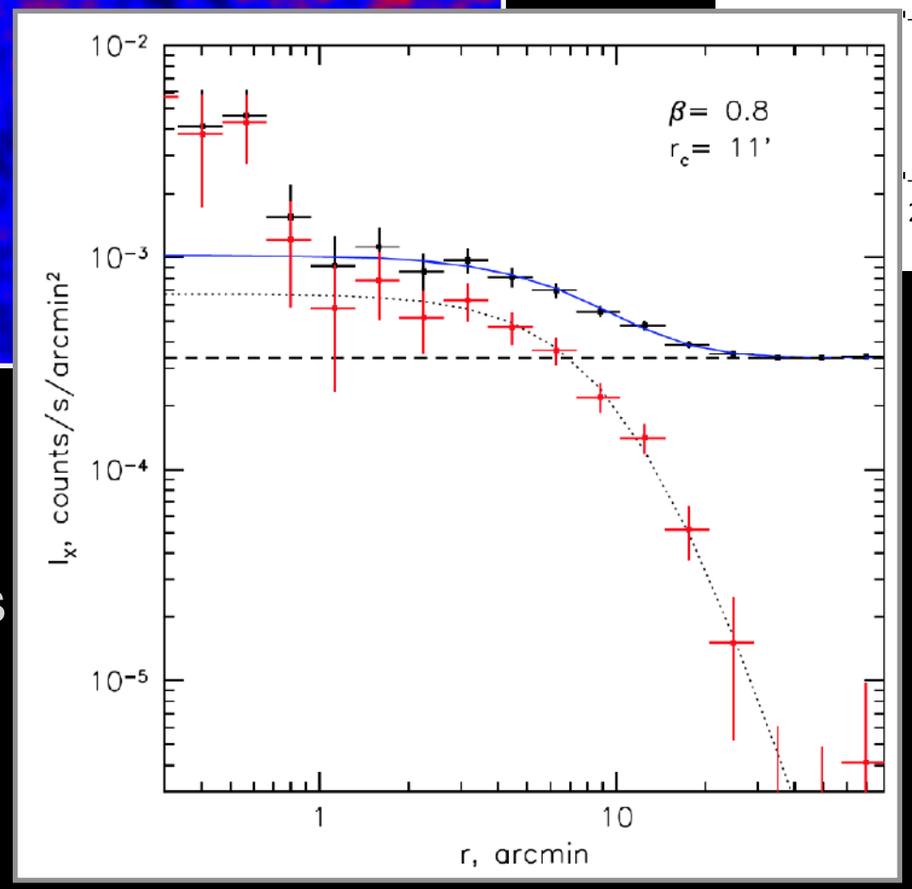
no clear gradient

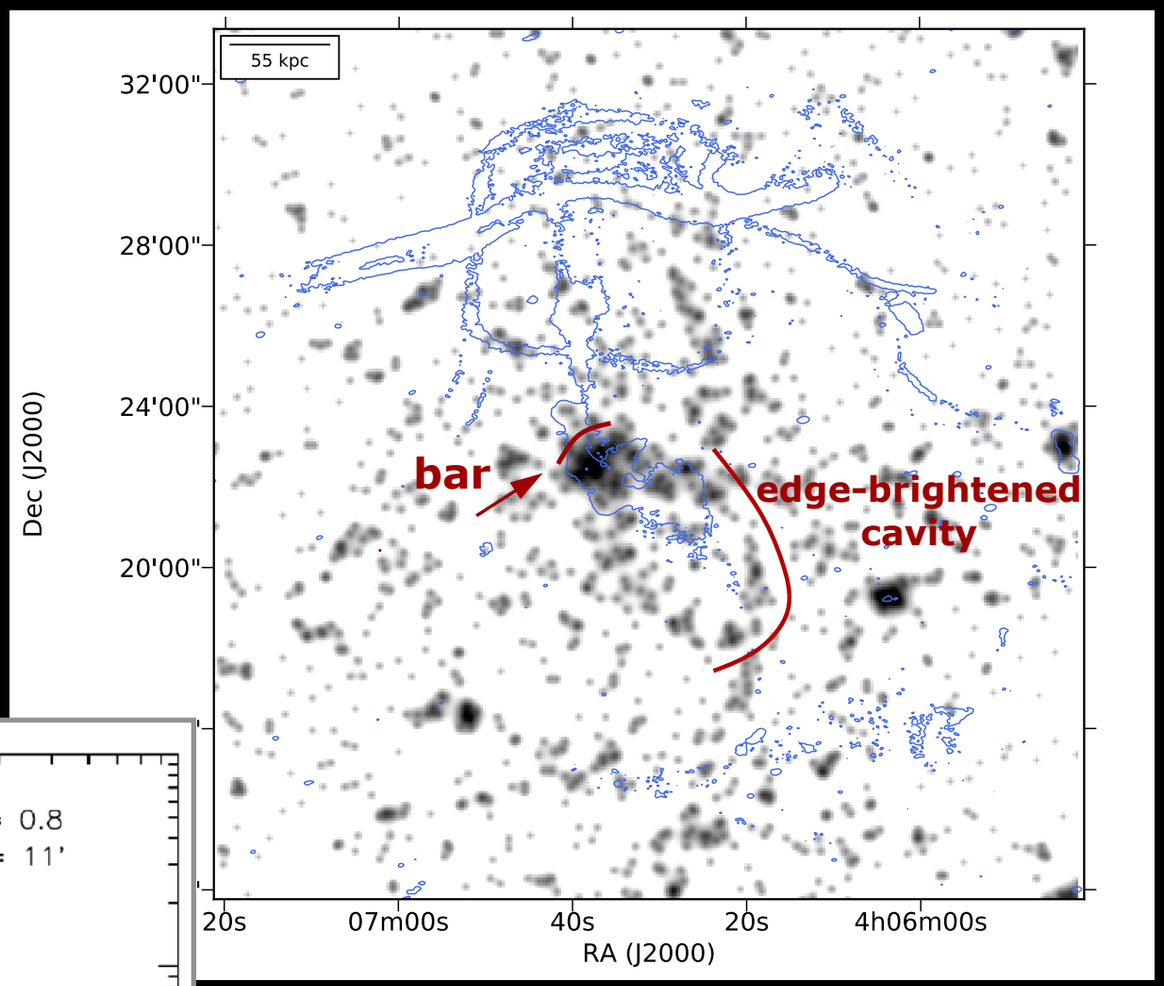
diffuse emission
ultra-steep α=1.4~2.5

main filament in the North
shows a flatter α than what expected at that distance (down to 0.75-0.9)
Compression?

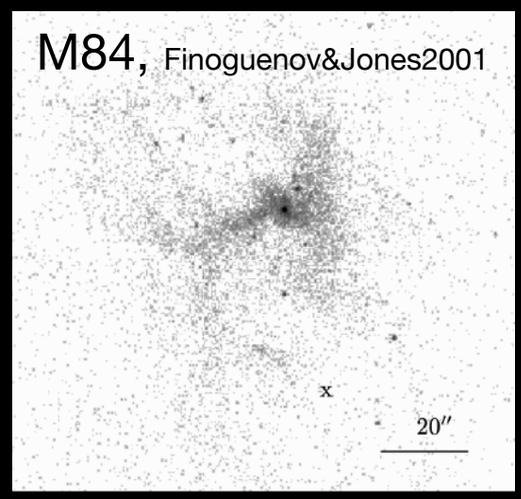
SRG/eRosita 0.5-2.3 keV (645s)







T_x = 2 keV
L_x = 5-10x10^{42} erg/s
M_x =~3-7x10^{13} M_{sun}



Evolution of AGN jet-driven bubbles

buoyancy velocity > jet expansion velocity
bubble starts rising into the ICM

Pressure gradient present around the bubble transforms a roughly spherical bubble into a torus (vortex ring)

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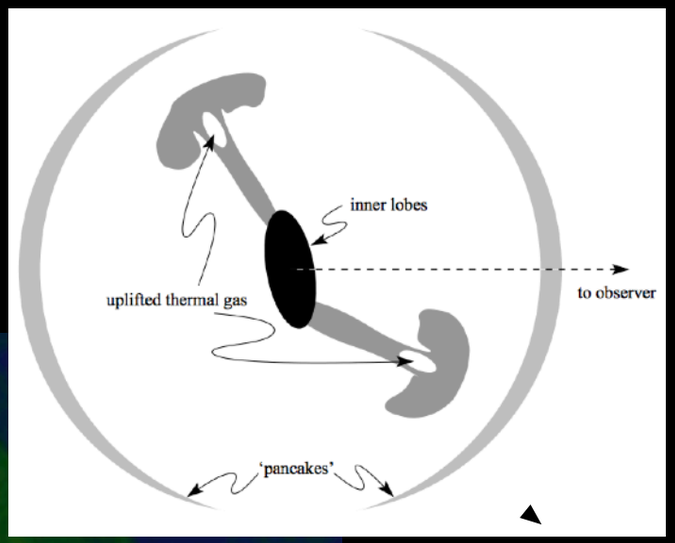
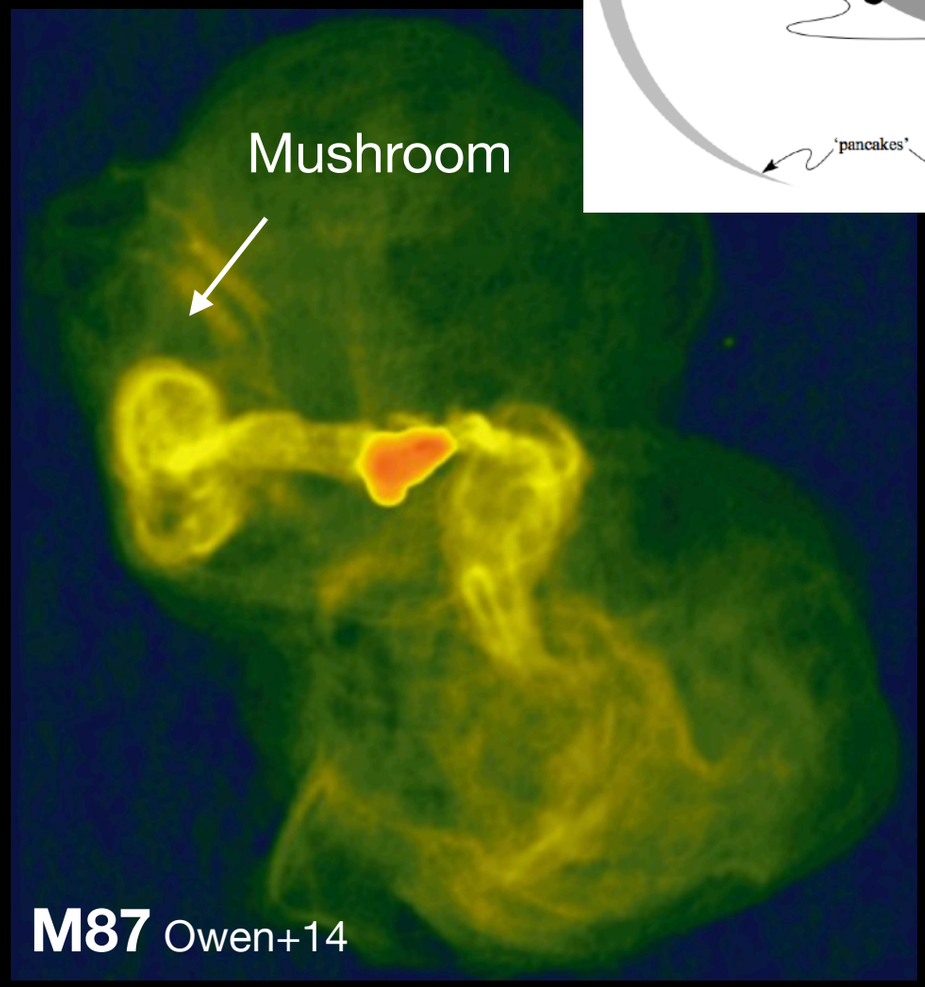
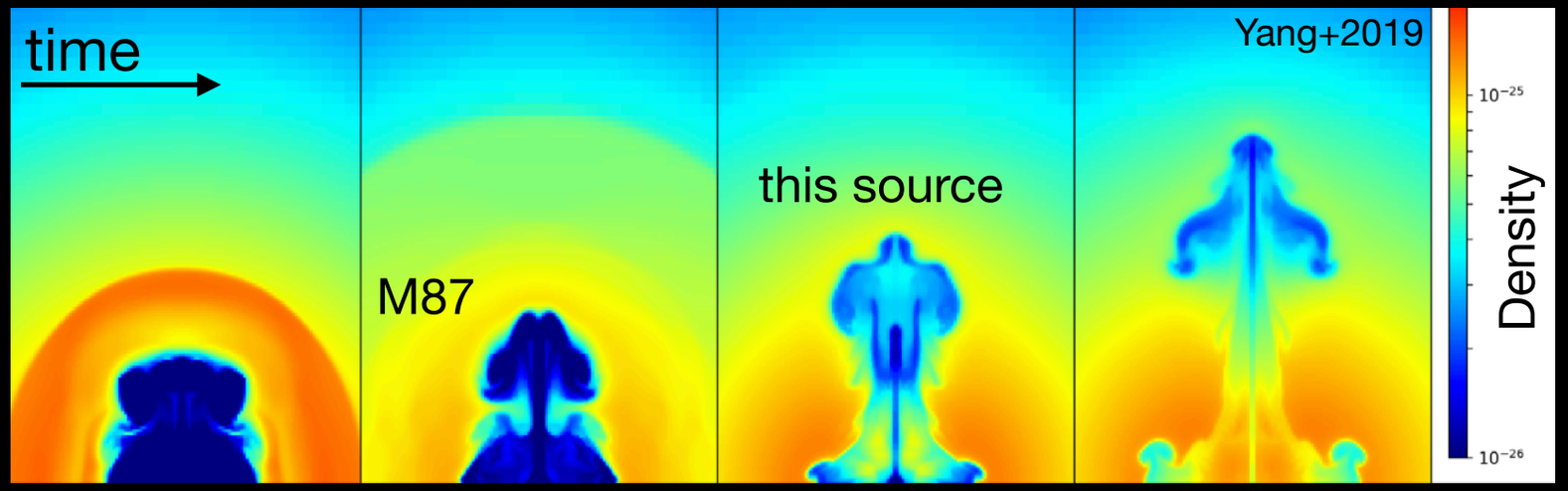


Churazov+2001

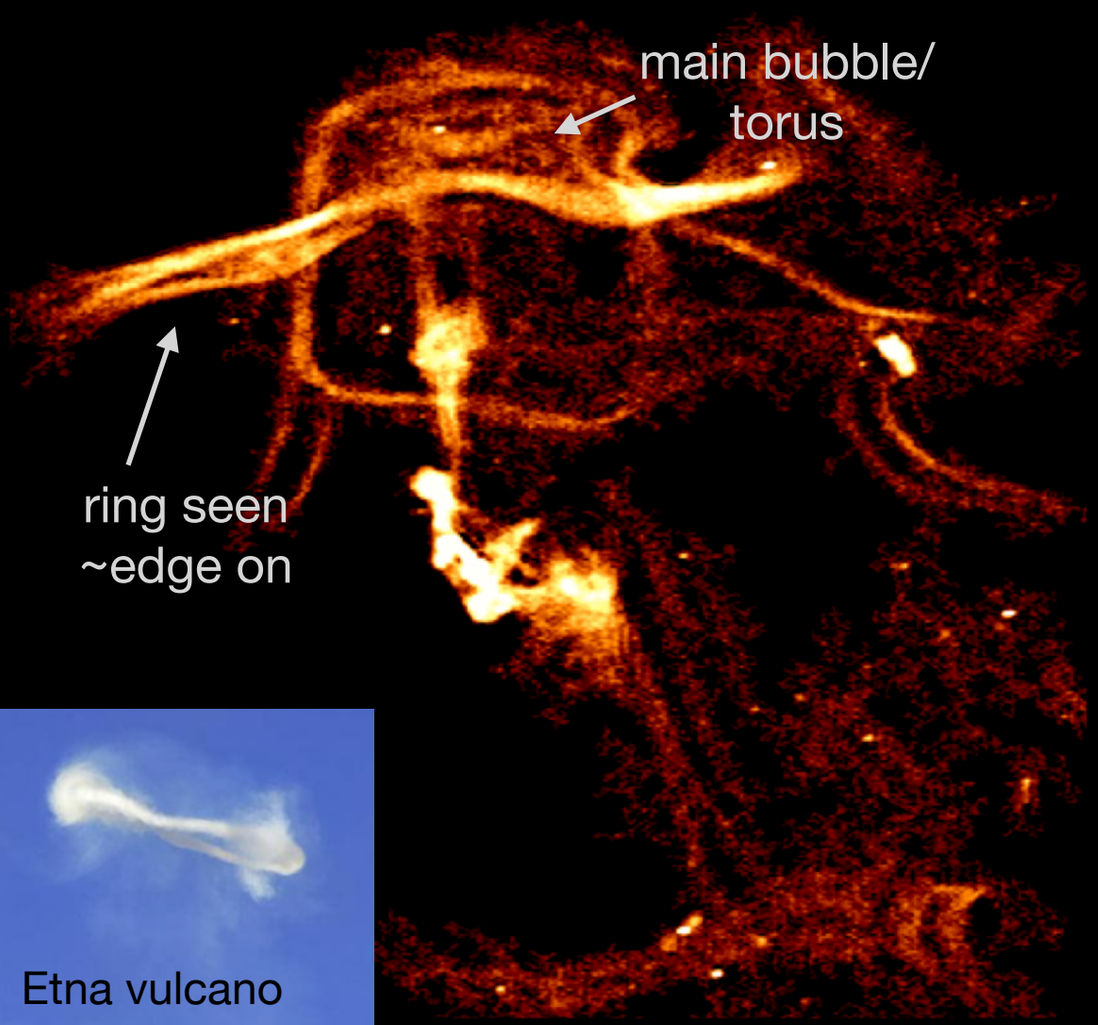


M87 Owen+14

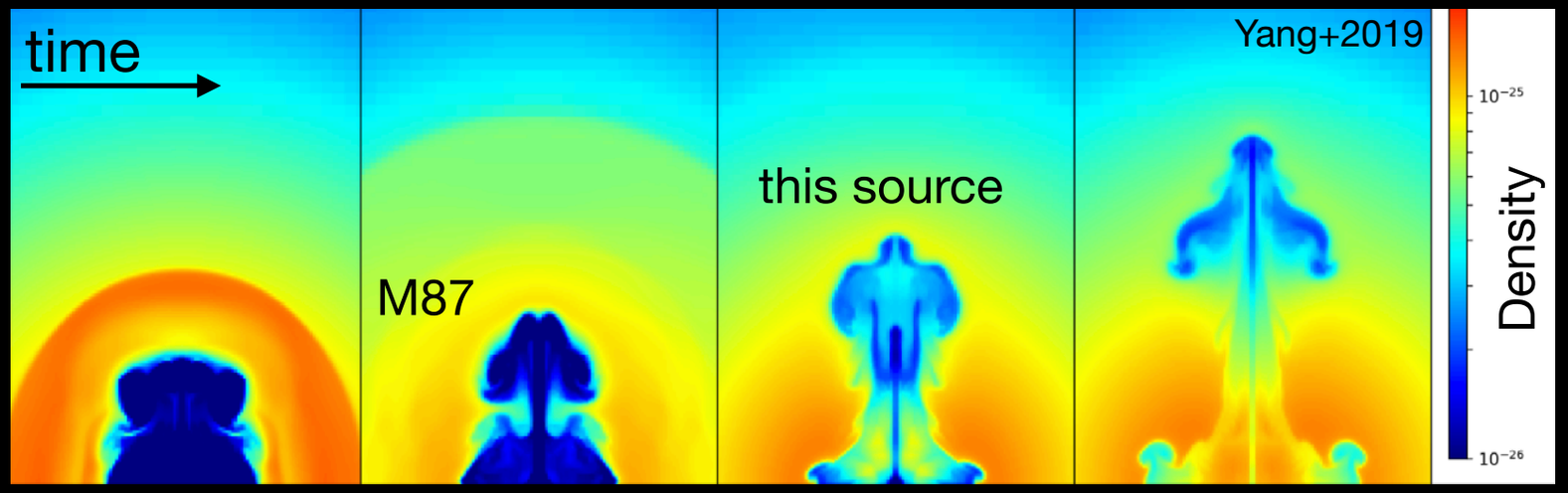
Very late phases of bubble evolution



e.g.
Brüggen et al. 2002, 2003,
Robinson et al. 2004;
Jones & De Young 2005;
Gardini 2007;
Dong & Stone 2009;
Ogiya et al. 2018;
Ehlert et al. 2018;
Zhang et al. 2018;
Candelaresi
& Del Sordo 2020



Very late phases of bubble evolution



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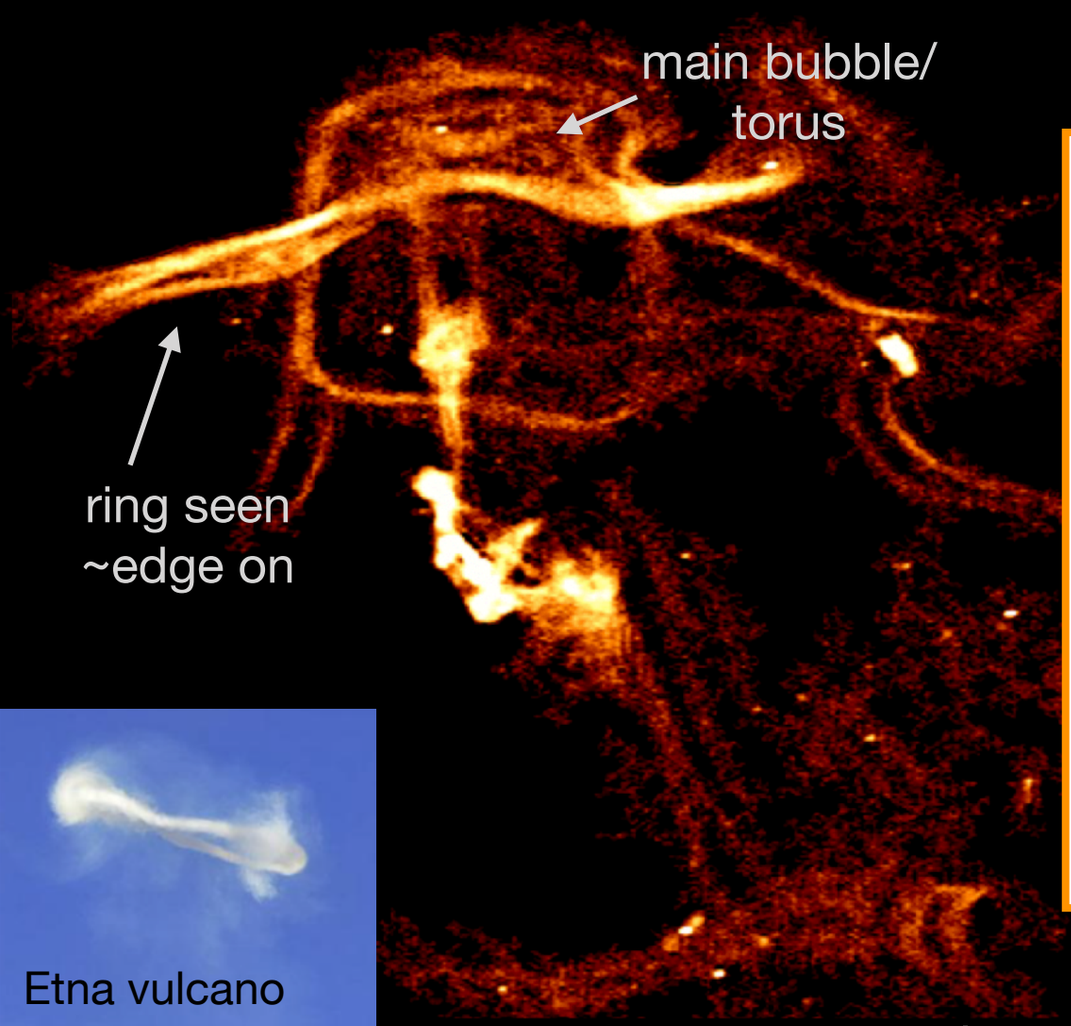
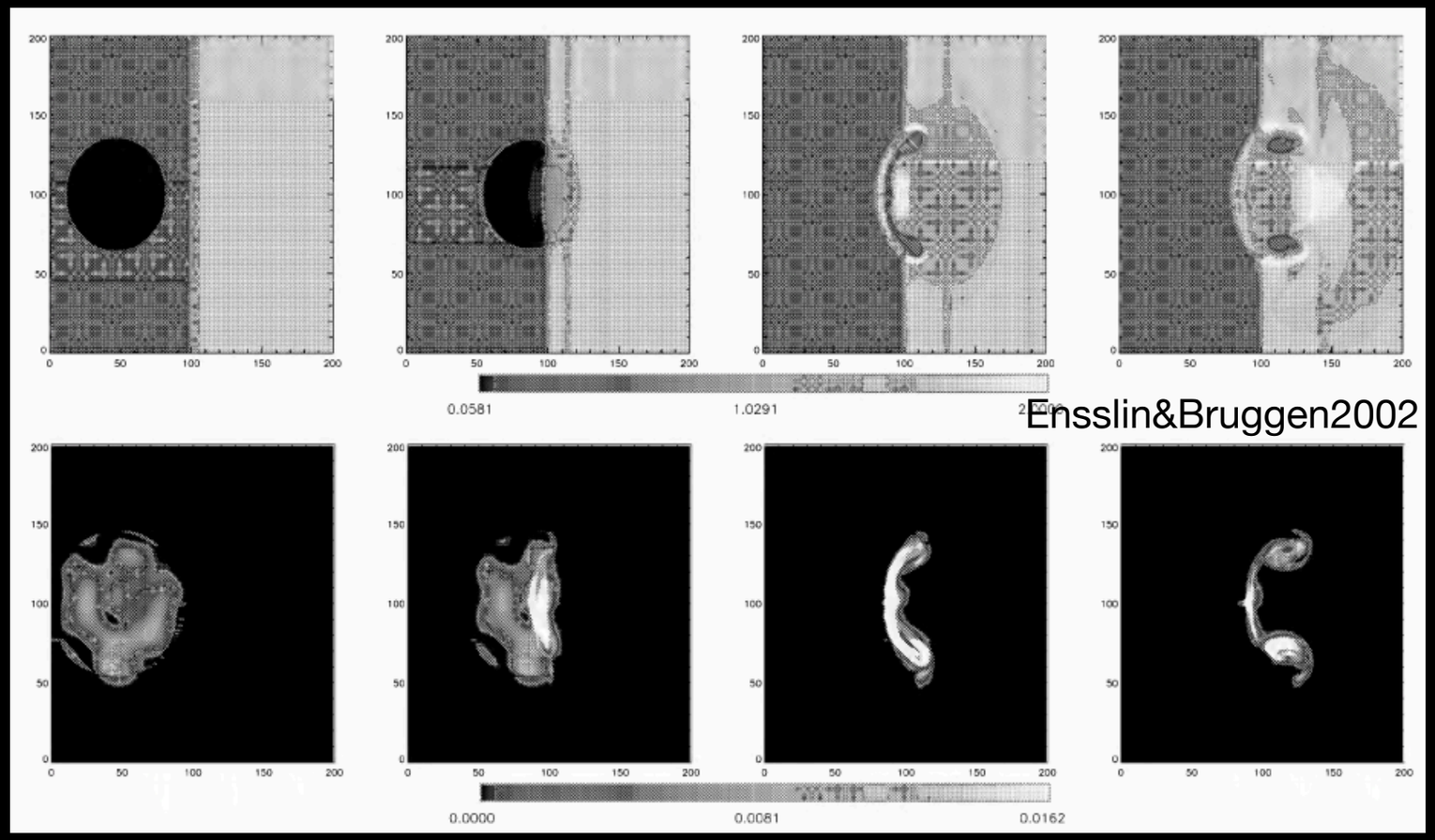


Bubbles age based on buoyancy ~200-300 Myr

Bubble power (pV/t)= 1~5 x 10^{42} erg/s consistent with Lx (5-10x10^{42}) = **AGN feedback = energy transfer effective even without complete mixing**

Impressive stability! K-H and R-T instabilities would be expected to disrupt the system on shorter timescales… but **magnetic field** might prevent them -> Alfven scale = 5-15 kpc = filaments width!

Alternative/complementary scenario



Ensslin&Bruggen2002

Weak shock waves through hot bubbles of remnant plasma can also alter the radio morphology.

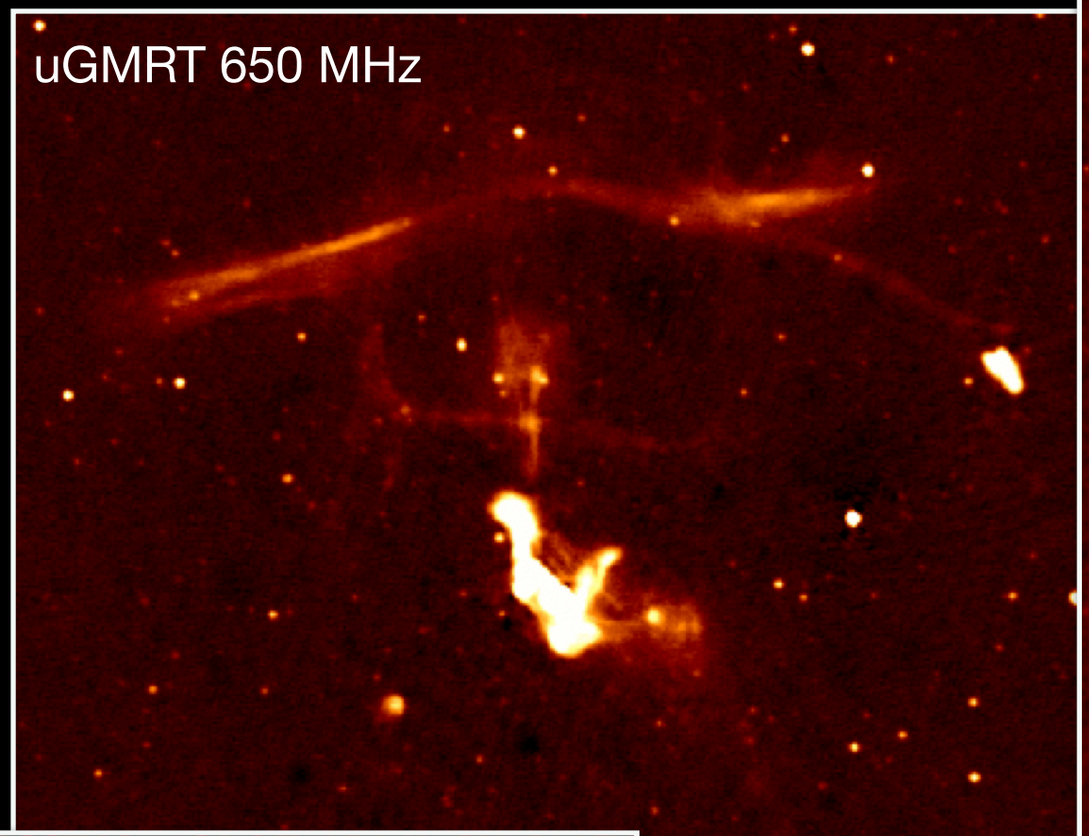
Different sound speeds inside and outside the remnant plasma = transformation of the bubble into a torus + filaments, rings, eddies

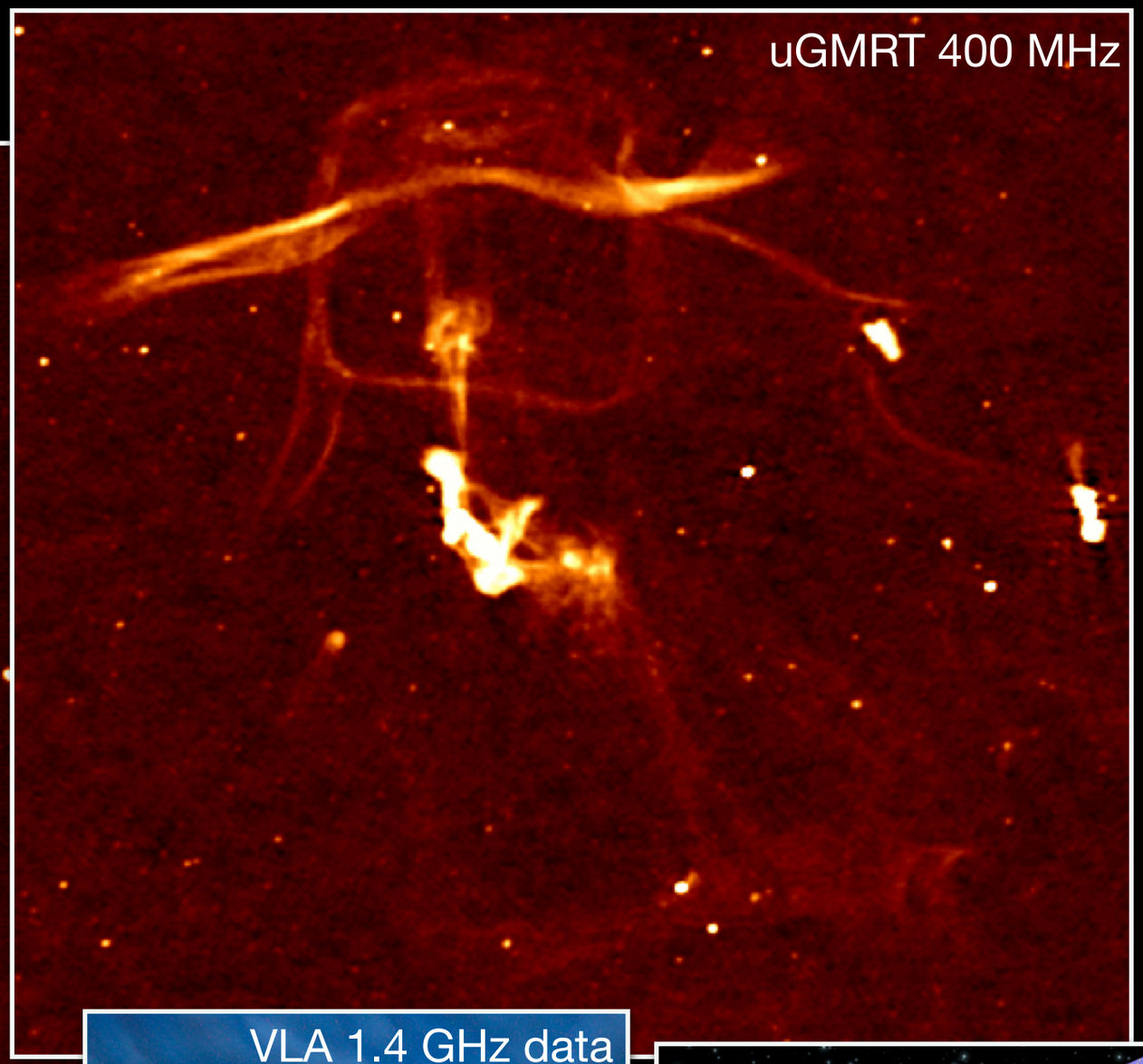
(proposed scenario for formation of radio relics and phoenices Enßlin & Brüggen 2002; Heinz & Churazov 2005)

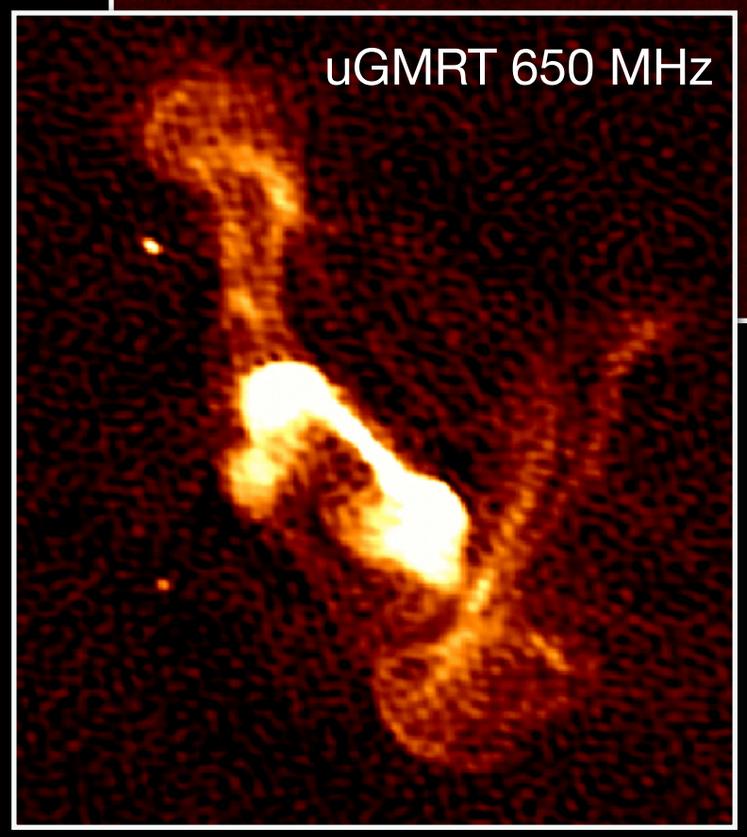
1) group dynamics?

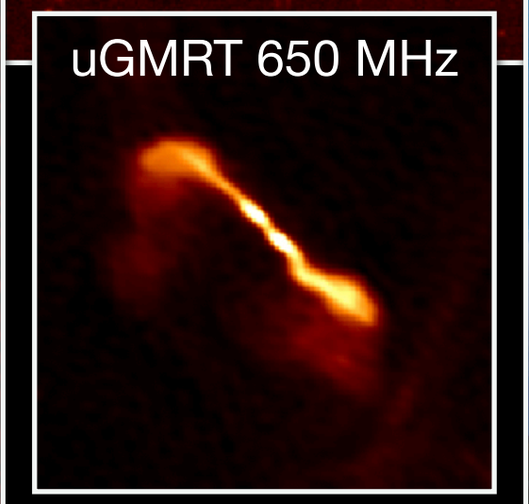
2) second AGN outbursts?

More to come!

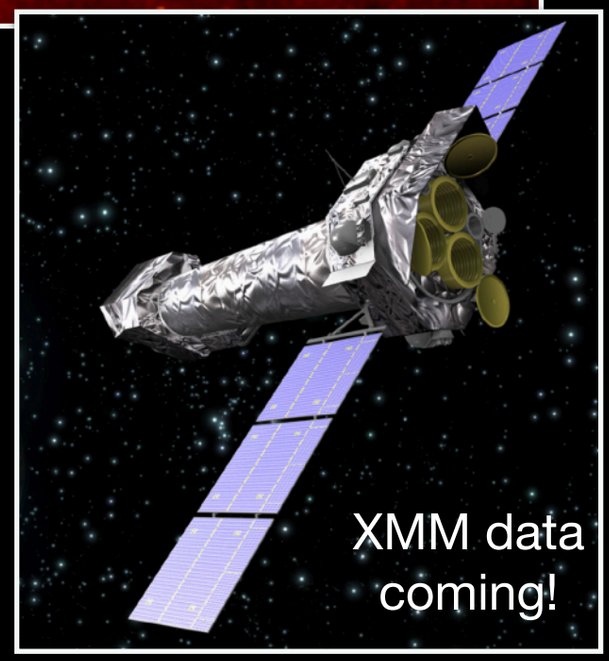

uGMRT 650 MHz


uGMRT 400 MHz


uGMRT 650 MHz


uGMRT 650 MHz


VLA 1.4 GHz data
coming!


XMM data
coming!

Conclusions

- MHz frequency new radio observations allow us to catch the oldest snapshots of the fossil AGN plasma evolution

- High-sensitivity and resolution observations allow us to appreciate for the first time the fine filamentary structures of this plasma

- Radiogalaxies offer always new challenges!