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Revelations from the best X-ray detection of a 2-sided jetted AGN

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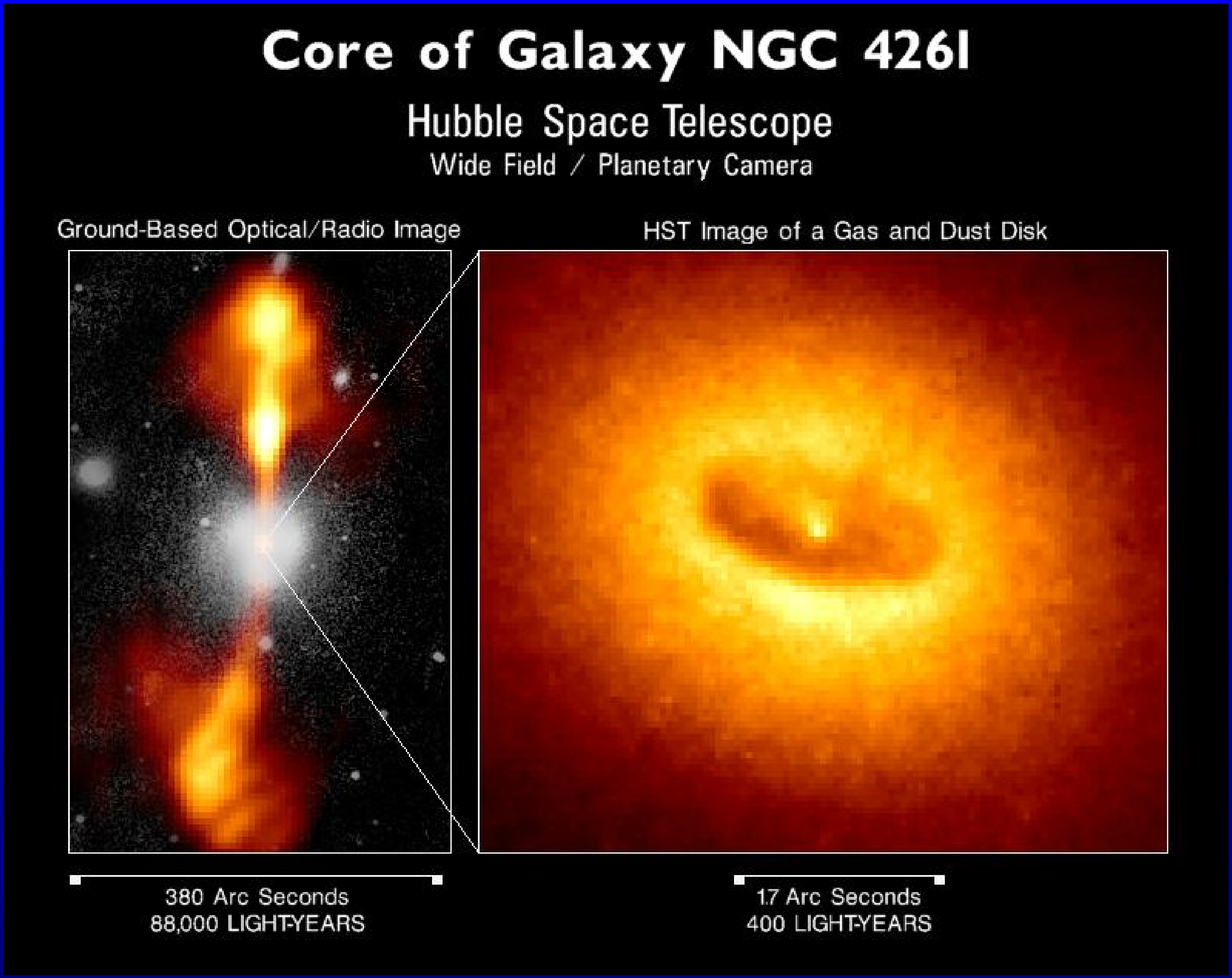
Outline

1. Introduction to NGC 4261/3C 270
2. Core X-ray spectrum: jet-related + component with unusually large N_H for the source type
3. Jet and counterjet X-ray emission: evidence for intermittency
4. Cavities and jet power
5. Disturbance of inner gas
6. Coronal stability
7. Summary

The Active Galaxy for public talks



But HST so north not up!

NGC 4261/3C 270

- Low-power FRI, only 30 Mpc away. Member of the most abundant class of radio galaxies.
- Twin-jet galaxy in plane of the sky (viewing angle ~63^0) with symmetry largely intact. Complications from the environment and special relativity minimized.
- In typical group, not cluster, atmosphere

Cumulative Chandra (130 ks) and XMM-Newton (160 ks)

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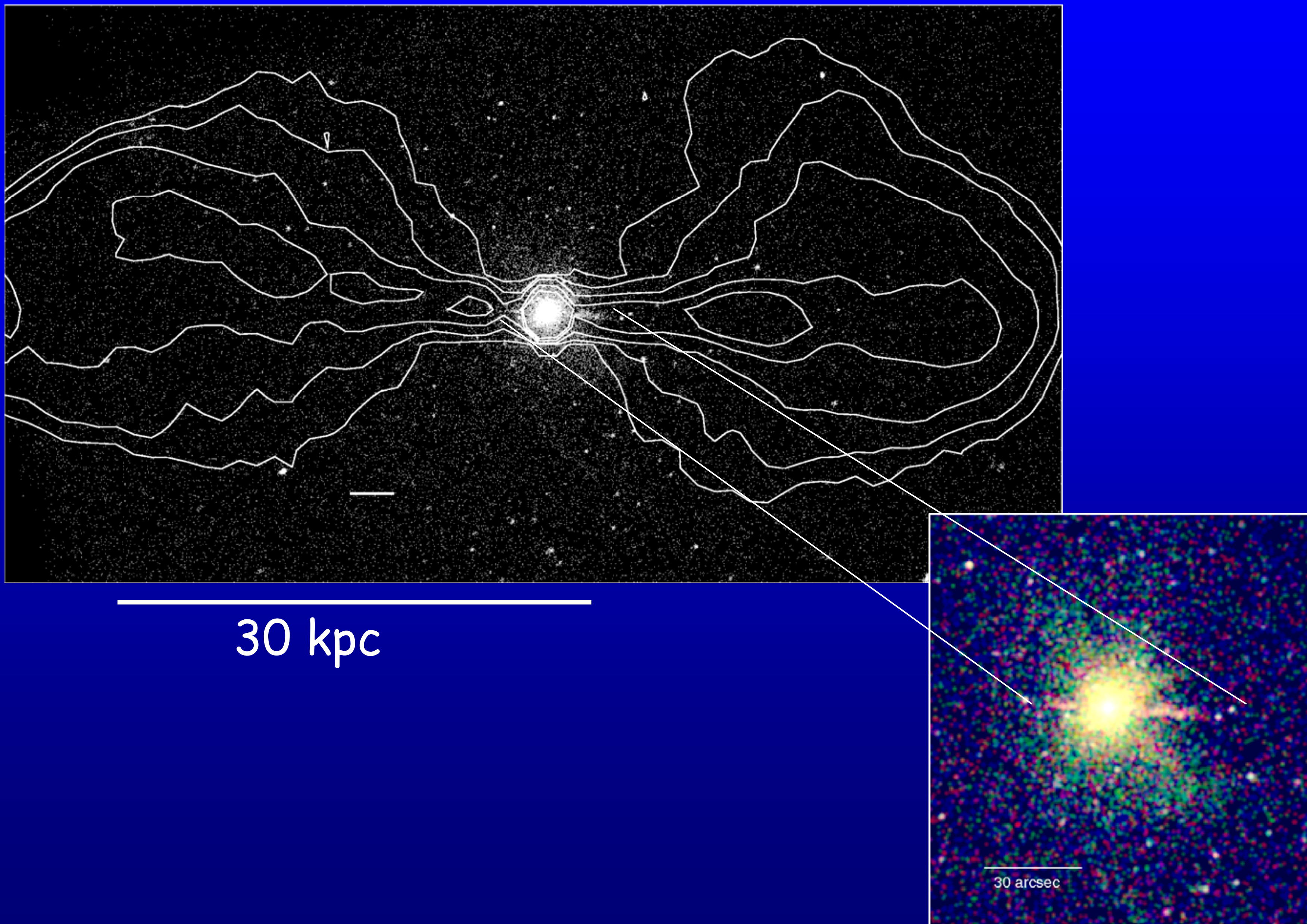
Worrall+ 2010 MNRAS 408, 701; O'Sullivan+ 2011 MNRAS in press (astro-ph)
others in prep

X-rays from the nucleus, inner jet and counterjet, galaxy gas, and group gas. e.g. from Chandra:

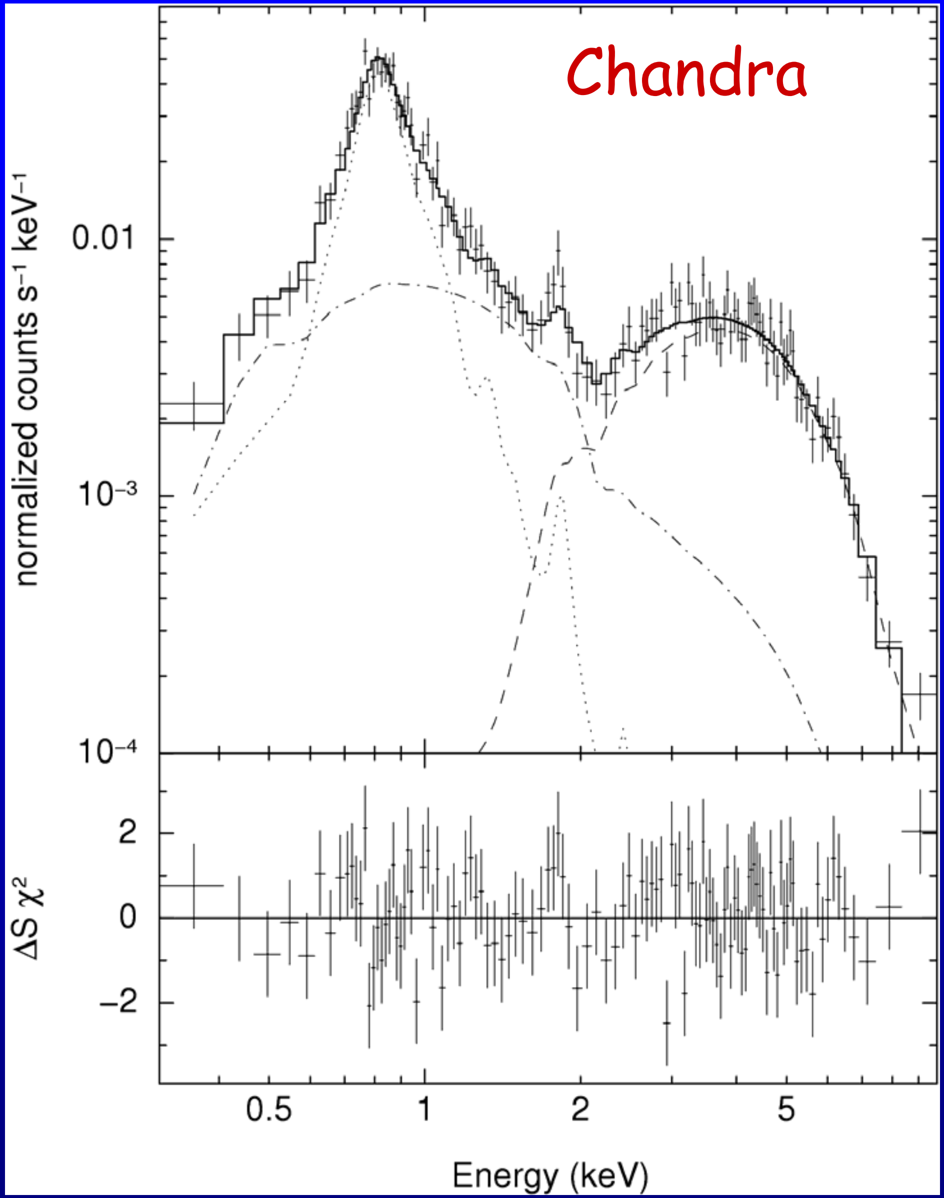


2. Core spectrum

FRIs often fit single, largely unabsorbed power law → jet-related, and shortage of cold, e.g., toroidal, gas.

But

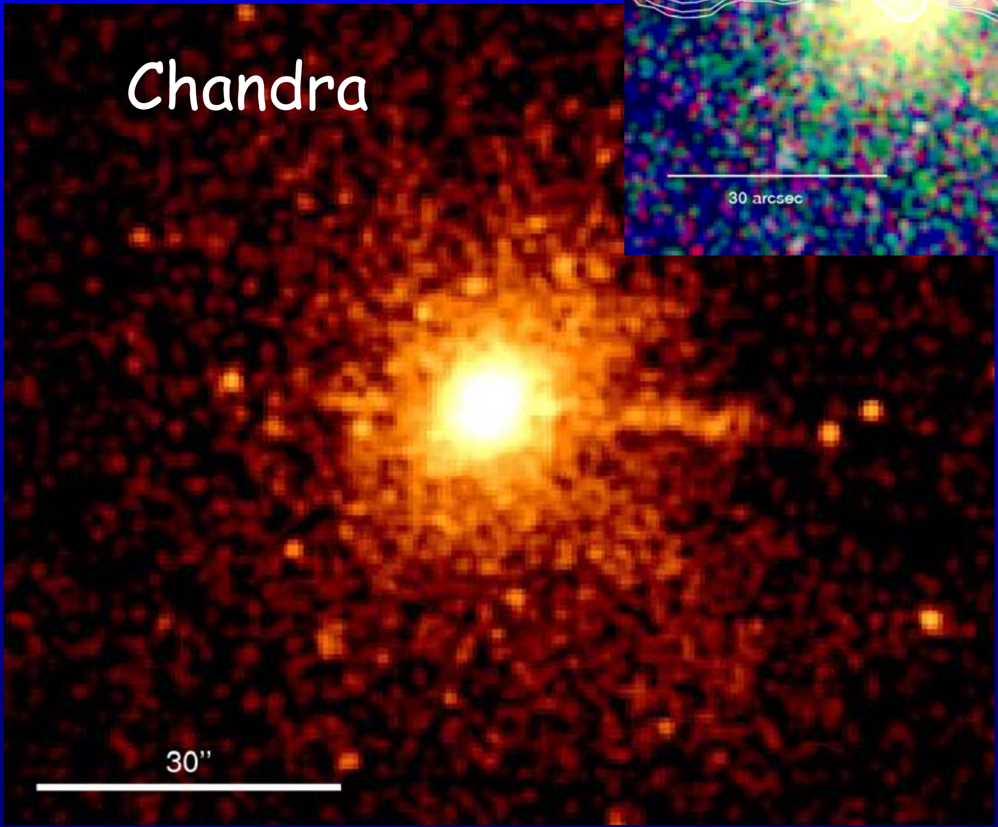
- Like Cen A, NGC 4261 has component with $N_H \sim 8 \times 10^{22}$ cm^{-2} [PL1]. Much more gas than implied by HST dust ring.
- Chandra resolution required to separate a second, weakly absorbed component, [PL2], and 0.6 keV gas

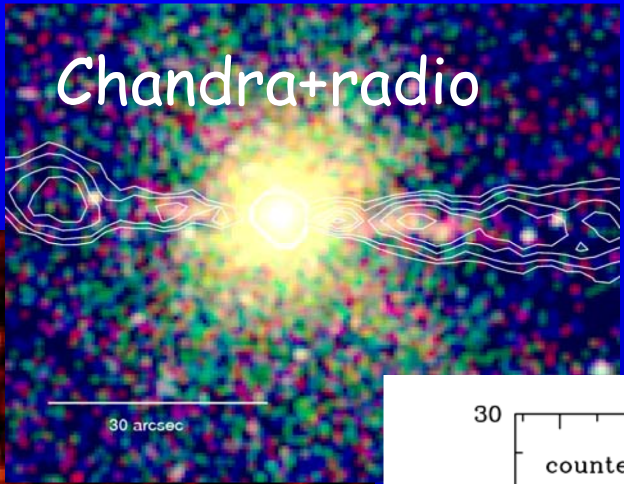


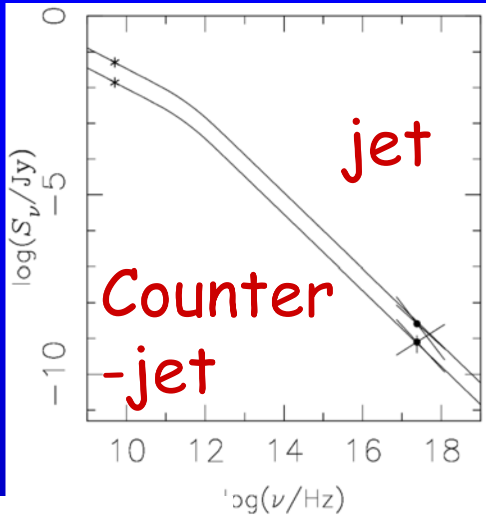
See also Chiaberge+ 2003, Gliozzi+ 2003, Sambruna+ 2003, Donato+ 2004, Zezas+ 2005.

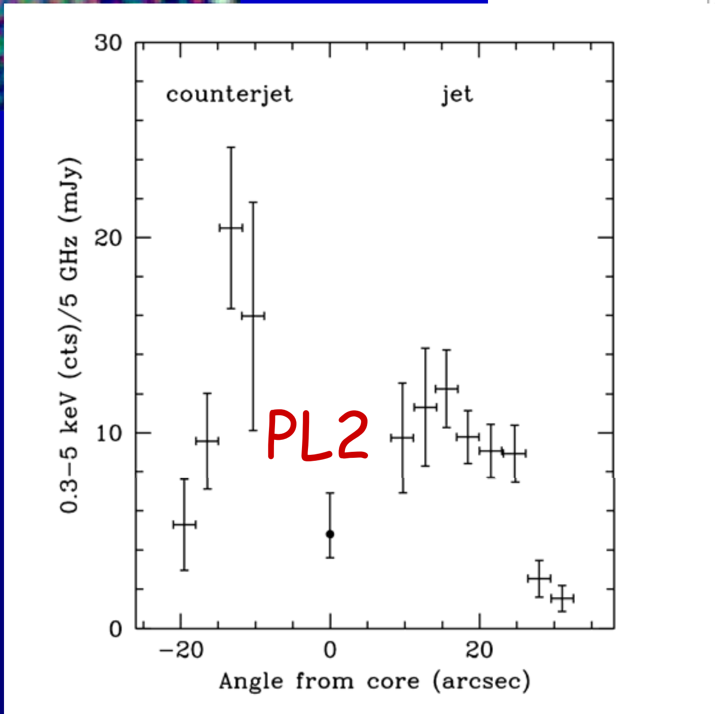
While buried PL1 is of uncertain origin (SSC or accretion flow), PL2 is almost certainly synchrotron from an extension of the jet and counter-jet towards the core.

PL2 N_H is consistent with dust ring









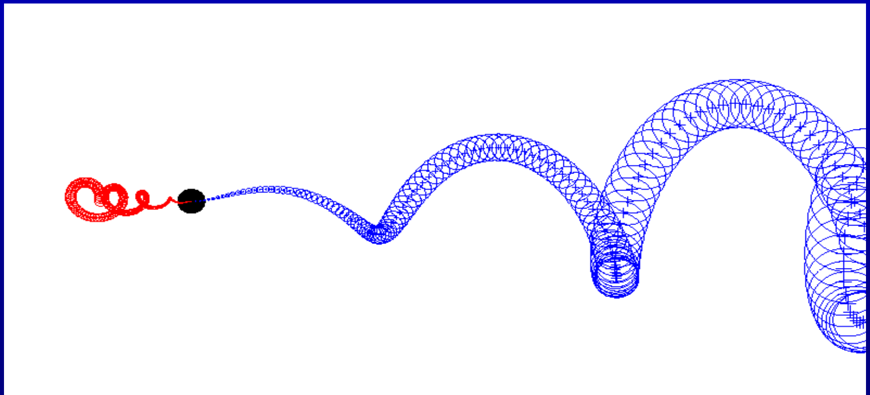
3. Jet intermittency

Jet-counterjet brightness contrast consistent with special relativity, $\theta = 63^{\circ}$, $v = 0.25c$.

If particle acceleration the same in both, the X-ray jet lengths should be the same after accounting for detection sensitivity. The jet is too long. Could be environmental, or…

Light travel time can explain this if the X-ray length is distance the jet has travelled after an ongoing "outburst" from the core. "Outburst" assumed needed for particle acceleration.

Exaggerated example, precessing, $\theta = 20^{\circ}$, $v = 0.84c$



Need current outburst to have gone on $\sim 6 \times 10^{4}$ yr.

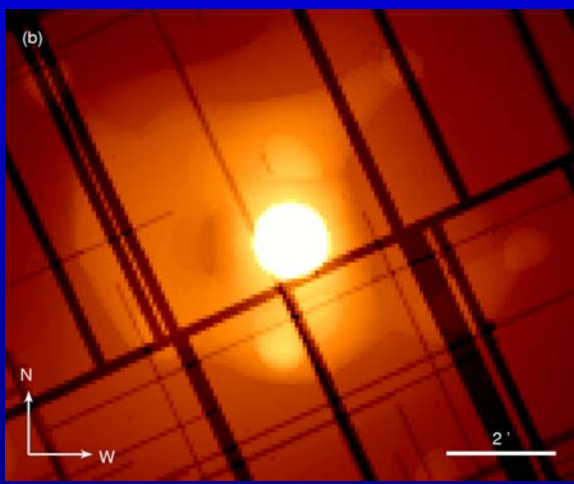
The hot-air-balloon model.

Don't need continuous jet outburst to keep lobes inflated!

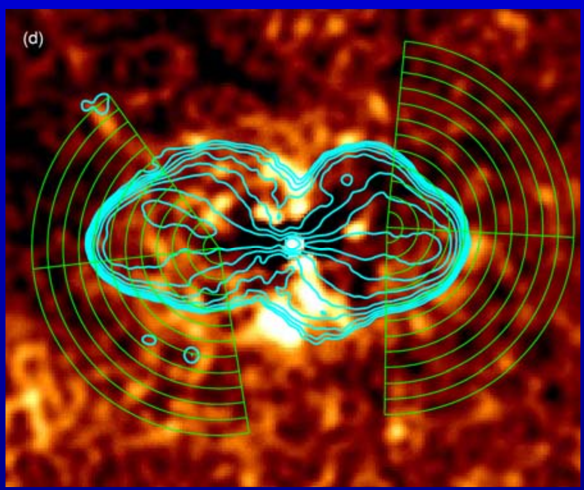
4. Cavities and Jet Power

XMM field large enough to cover radio lobes.

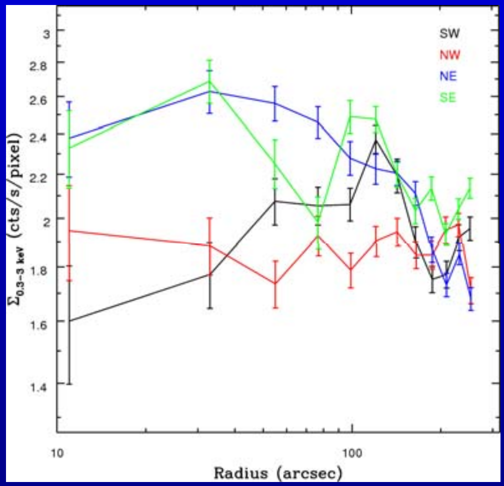
Pt-source subtraction and adaptive smoothing shows cavities



Subtraction of radially-symmetric gas components shows residual gas



Gas shell at ~100" around lobes to S consistent with ~sonic expansion

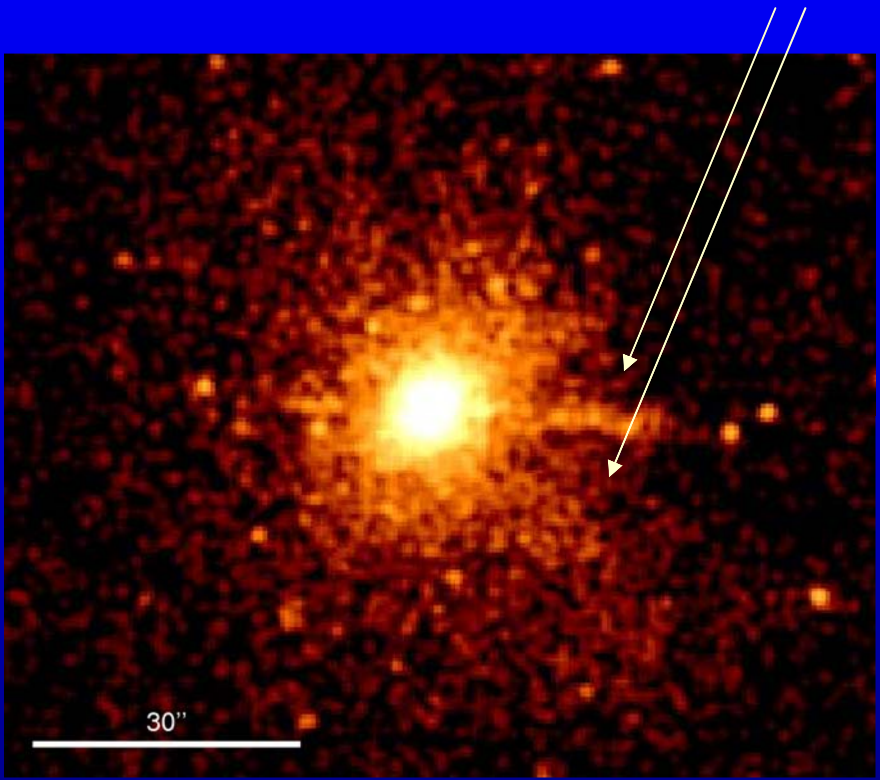


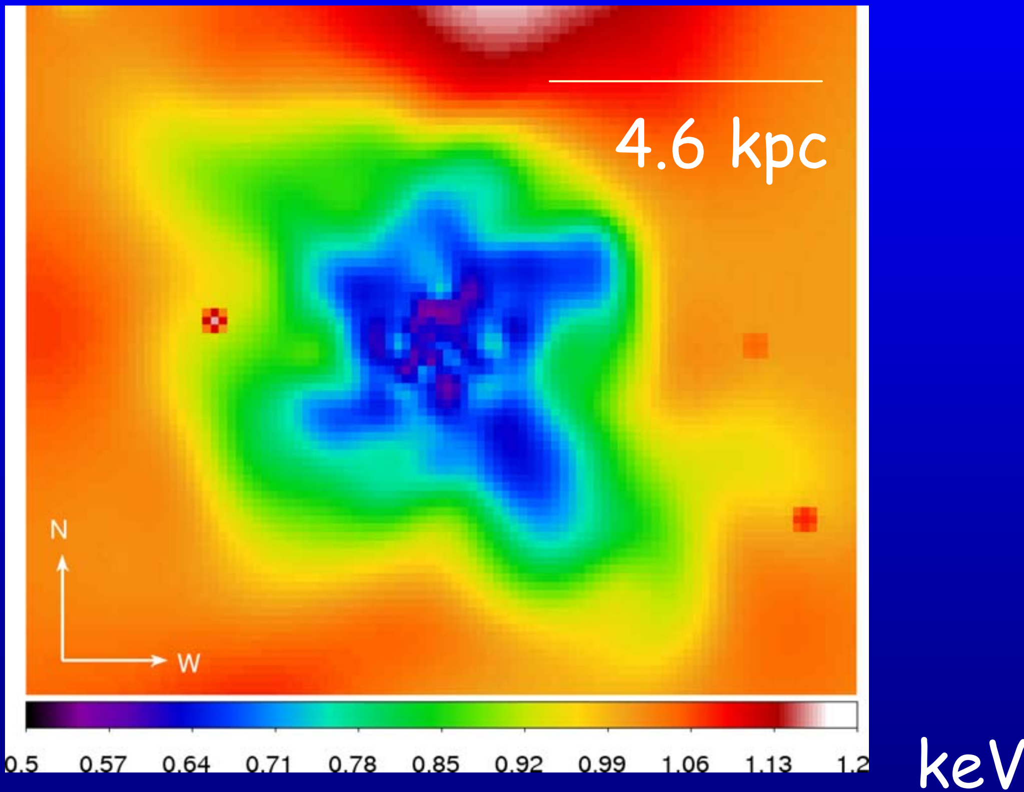
Cavity enthalpy + maximum source age -> L_{mech} > 10^{43} erg/s. ~60x luminosity in group gas. Less extreme results common for clusters.

5. Disturbance of Inner Gas

Wedges of galaxy gas displaced by old jet plasma

Chandra temperature map





Small ~0.65 keV galaxy core displaced by the radio source into an X-shaped structure.

Outer group gas reaches ~1.6 keV (see also Humphrey+ 2009)

6. Coronal Stability

Coronal gas can provide enough fuel for the AGN

But,
Too much mechanical power in the jet. Since it hasn't already heated the coronal gas it must plough through without heating.

No help for feedback models:

more jet → less gas infall → less black hole growth and star formation → less jet → more gas infall → more black hole growth and star formation → more jet

Summary

1. Nucleus isn't void of cold gas --- like Cen A & contrary to what is often stated for FRIs
2. X-ray synchrotron jet extends into core, but additional X-ray component present
3. Speculative argument suggests intermittency in jet outburst properties
4. Lobe mechanical power 60x more than needed to keep group gas hot
5. Small gas corona at ~0.65 keV is displaced into an X-shaped structure by the radio source. However, heating efficiency very low or corona would not be seen.
6. Feedback mechanism still a mystery!