Young extragalactic radio jets probed with X-rays

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- with -

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Outline

1. Observations of compact *(young)* extragalactic jets
2. Motivation: why compact jets are important?
3. Results
   - X-ray environment of compact radio jets
   - Compact radio sources across redshift range \( (z < 1 \text{ and } z > 4) \) samples
   - Broadband radio-to-X/gamma-ray spectra of young radio sources
   - First constraints on the origin of X-ray emission of young radio sources
4. Summary and future work (see also poster P84)
Radio identifications of compact extragalactic jets

Compact Symmetric Objects (CSO)


Tingay, de Kool (2003), 22 GHz VLBI radio imaging

7 mas ~ 2 pc
100 years old

PKS 1718-649

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Why do we study compact radio jets?

Kinematic methods suggest that jets in CSOs may be very young < 3000 years old (e.g. An & Baan 2012)

Unique opportunity to study an interesting aspect of the AGN / galaxy feedback process
- conditions in a galactic center at the time of a radio jet launch and initial jet expansion
- impact of a young expanding jet on the innermost regions of its hosts galaxy

CSOs, progenitors of the large scale radio galaxies

PKS 1718-649

7 mas ~ 2 pc
100 years old

3C 31
3C 223

never expand beyond the host galaxy
**CSO sample. X-ray absorption properties**

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- **X-ray absorbed sources**
  - Smaller radio size than X-ray unabsorbed sources with the same radio power, **OR**
  - Larger radio power than X-ray unabsorbed sources with the same radio size

- **So far, no detection of** $N_H(z) > 10^{23} \text{ cm}^{-2}$ **in CSO sources with radio size exceeding ~ 40 pc.**

  **Implications:**
  - Size of the region responsible for the X-ray obscuration?
  - Torus destruction by an expanding jet?
  - X-rays from radio lobes that expanded beyond the compact X-ray obscurer?
Compact radio sources across redshift range


**CSO z < 1**

Siemiginowska et al. 2016

**CSO z > 1**

Snios et al., in prep.

**J1606+3124**

Compton Thick candidate (high HR)

CSO radio morphology, size ~ 70 pc
Outstanding question. The site of X/$\gamma$-ray production?

Expanding radio lobes model framework (Begelman & Cioffi 1989; Stawarz et al. 2008; Ostorero et al. 2010)

- Follow the evolution of ultrarelativistic electrons injected from terminal jet hot spots to the expanding lobes
- Account for appropriate adiabatic and radiative energy losses
- Electrons Inverse Compton up-scatter the soft photon fields
Broadband modeling. Radio to X/γ-ray SED

MWA/ATCA, Tingay et al. 2015; Spitzer, Willett et al. 2010; Fermi/LAT, Migliori et al. 2016

Ostorero et al. 2010; Migliori et al. 2014

Sobolewska et al., in prep.

PRELIMINARY

n = 0.3 cm\(^{-3}\)

ALMA, Maccagni et al. 2018

PKS 1718-649

IERS B1404+286

Chandra + NuSTAR + XMM (Sobolewska et al. 2019)

No γ-ray Fermi/LAT detection

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Summary and future work

- Combining the low-z and high-z samples allows us to study compact radio sources across a wide range of intrinsic X-ray luminosity.
- High-energy CSO emission not due to IC processes in radio lobes? Or magnetic pressure dominates over electron pressure.
- First hard X-ray detections of CSOs (NuSTAR). To date, only PKS 1718-649 has been detected with Fermi/LAT.
- X-ray absorbed/unabsorbed CSO dichotomy:
  - difference in radio size for the same radio luminosity at 5 GHz (confinement?)
  - difference in radio luminosity for the same radio size (density of the environment? jet power?)
- Ongoing Chandra, XMM and NuSTAR observing programs
- New CSO candidates identified in the radio band; Callingham et al. 2017; Tremblay et al. 2016), ~10 with sizes 5 - 50 pc. X-ray follow-ups imperative