A Multiband Approach to AGN: Radioscopy & Radio Astronomy

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A Multiband Approach to AGN: Radioscopy & Radio Astronomy

In Collaboration with:
K.A. Weaver (GSFC)
&
The 2cmSurvey Team
(www.nrao.edu/2cmsurvey)
A Multiband Approach to AGN: Radioscopy & Radio Astronomy

**radioscopy** — Direct observation of objects opaque to light by means of some other form of radiant energy, as the Röntgen rays.

*Webster's Revised Unabridged Dictionary*

**radio astronomy** — The branch of astronomy that deals with the origin and nature of emissions from extraterrestrial sources in the radio wave range of electromagnetic radiation rather than in the visible range.

*The American Heritage® Dictionary of the English Language*
Outline of the Talk

- **Combined VLBI and X-Ray Observations of AGN:**
  - An X-Ray Spectral Survey of Core-Dominated Radio-Loud AGNs
  - The 2cm-X-Sample

- **NGC1052: Jet-Disk Coupling in an Active Galaxy**
  - Radio observations
  - X-ray observations
  - Combining VLBI and X-ray spectroscopy
  - Implications
An X-Ray Spectral Survey of Core-Dominated Radio-Loud AGNs

- Systematic survey of the X-ray properties of radio-loud core-dominated AGNs
- X-ray sample of 54 sources (the 2cm-X-Sample)
- Based on radio-core properties rather than extended stuff, e.g., radio lobes, etc.

Archival CHANDRA, XMM-Newton, ASCA, and BeppoSax data

VLBA 2cm Survey

www.nrao.edu/2cmsurvey
Kellermann et al. (1998), Zensus et al. (2002),
The 2cm-X-Sample

- Representative of the MOJAVE sample (the 133 radio-brightest compact AGN in the northern sky)
- See 2cmSurvey Paper 3 & 4 (Kellermann et al. 2004; Kovalev et al., in prep.)

Monitoring Of Jets in Active galaxies with VLBA Experiments

Kadler et al. (2004, astro-ph/0409300)

http://www.physics.purdue.edu/astro/MOJAVE/
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The X-Ray View of NGC1052

Extended emission:
- (Anti-)Correlated with the radio jet
- Thermal spectrum (0.5keV)

Nuclear emission:
- Extremely flat
- Heavily absorbed ($N_H \sim 10^{22}-10^{23}$ cm$^{-2}$ consistent with VLBI)

VLBI- and X-Ray Observations of NGC1052

- **The First Highly Relativistic, Broad Iron Line in a Radio-Loud AGN**
- Line Profile Discloses Disk Properties:
  - Emission from $6R_G - 60R_G$
  - Disk Inclination: $\approx 80^\circ$

  - Obscuring Torus
  - Jet Inclination: $60^\circ$-$80^\circ$
Caught in the Act: An Accretion-Ejection Event in NGC1052

- Violent Plasma Ejection in 1999/2000
- Variability of the Broad Iron Line

Kadler et al., submitted
Ros et al. in prep.
NGC1052 from 1999 to 2001: A Simple Model

1) "Quiet" jet

Steady disk

Accreting black hole

2) Partial ejection of matter from the inner disk

Disk has pulled back

Accretion of inner disk

3) Disk replenishes

New jet component travels outwards

New jet component (Shock in jet)
What Makes an AGN Radio-Loud?

- NGC1052 might tell us the answer, finally!
- A parsec-scale jet- plus iron-line monitoring can show us what triggers the production of jets!
- Occurrence of “dips” in the X-ray light curve? (like in 3C120; Marscher et al. 2002)
Another radio-loud candidate: 3C390.3

- Broad line radio galaxy at $z = 0.057$
- Sambruna et al. (1999) report a broad iron line

- No broad iron line visible with CHANDRA
- Complex extended structure discloses different emission mechanisms at work
• Non-ballistic motions on milliarcsecond scales seen in the 2cmSurvey monitoring
Radio-Quiet AGN – Not so Quiet After All

- Prominent broad iron lines seen in a sample of Seyfert galaxies
- Attractive targets for highly sensitive VLBI observations

Image: HEASARC website


[Graph showing radio flux density vs. X-ray flux for various AGNs]
Summary

- Radioscopy and radio astronomy are combined in a systematic radio X-ray spectral survey of compact AGN

- Combined VLBI and X-ray observations revealed
  - A highly relativistic, broad iron line in a radio-loud AGN: NGC1052
  - Association between line variability and jet production
  - Ultimately, NGC1052 might tell us what makes an AGN radio-loud
Differences Between Radio-Loud and Radio-Quiet AGNs

Both show power-law spectra

Radio-Quiet AGNs:
- Typical photon index $\sim 1.7-2.0$
  \( P_{E} \ [\text{Photons/keV}] \sim n^{-\Gamma} \Rightarrow \Gamma-1 = \alpha \)
- Optical emission from disk
- Comptonization in Disk-Corona
  (see, e.g., Fabian et al. 2000, PASP, 112, 1145)

Radio-Loud AGNs:
- Flatter photon indices $\sim 1.5-1.7$
- Which role plays the jet in the production of the nuclear X-rays?
- Do the X-rays tell us anything new about the jets?
Higher angular resolution reveals the jet contribution on arcsecond-scales! What about the parsec-scale jet?
VLBA Observations of NGC1052

Obscuring Torus

Multi-ν Observations

Multi-Epoch Observations

Jet Kinematics
(see Vermeulen et al. 2003, A&A, 401,113)
The Standard Model of AGN-Activity

Type 1:
One-Sided Jets;
Broad and Narrow Line Region;
No absorption of soft X-Rays

Type 2:
Two-Sided Jets;
Free-Free Absorption;
Narrow Line Region;
Strong Absorption of soft X-Rays

CXC/M. Weiss
AO 0235+164 – a WEBT Campaign

Raiteri et al. 2001

Radio and Optical Flux Monitoring
Broad Fe-Lines in AGNs

**Line Production:**
- X-ray continuum illuminates the accretion disk
- Incident photon can be Compton scattered by free or bound electrons ⇒ **Reflection Component**
- Photoelectric absorption can take place followed by fluorescent line emission or Auger de-excitation
- Fe Kα is the strongest fluorescent line (high cross-section for absorption; most abundant metal)

1. Optical emission from disk
2. Comptonization in Disk-Corona
3. Disk-Reflection
Line Profile:
• Fe Kα line is intrinsically narrow.
• Broadening can be attributed to the disk dynamics (Doppler shifts) and gravitational redshifting. ⇒ Characteristic broad, skewed line
• “Blue” End: Inclination angle – “Red” End: Inner Radius
0716+714

- Pronounced short term variability in March 2002
- Soft Lag of ~150s ⇒ Cooling

Another Type 1 Object: 1253-055 (3C279)

CHANDRA

$\Gamma = 1.4$

$N_H = 1.3 \times 10^{21} \text{ cm}^{-2}$

Homan et al. (2003)
100 ksec CHANDRA
(smoothed image)


3C279
(1.6GHz MERLIN –
Akujor et al. 1994)

1253-055
(3C 279)
0716+714 – A Hard Nut to Crack

Unclear kinematics:
Witzel et al. (1988), Gabuzda et al. (1998): Subluminal source
Jorstad et al. (2001): 0.9-1.2 mas/yr
Bach et al. (2003): 0.3-0.9 mas/yr

Aug 1994  Jul 1996 0.5 – 0.6 mas/yr or ~ 0.3 mas/yr  Jul 1999

VLBA 2cmSurvey  Mar 2001
0716+714

- 3 XMM epochs:
- Two distinct spectral components (synchrotron, IC)
- First direct distance measurement using the iron line: $z = 0.1$?
  (Wagner et al. 1996 estimated $z > 0.3$)