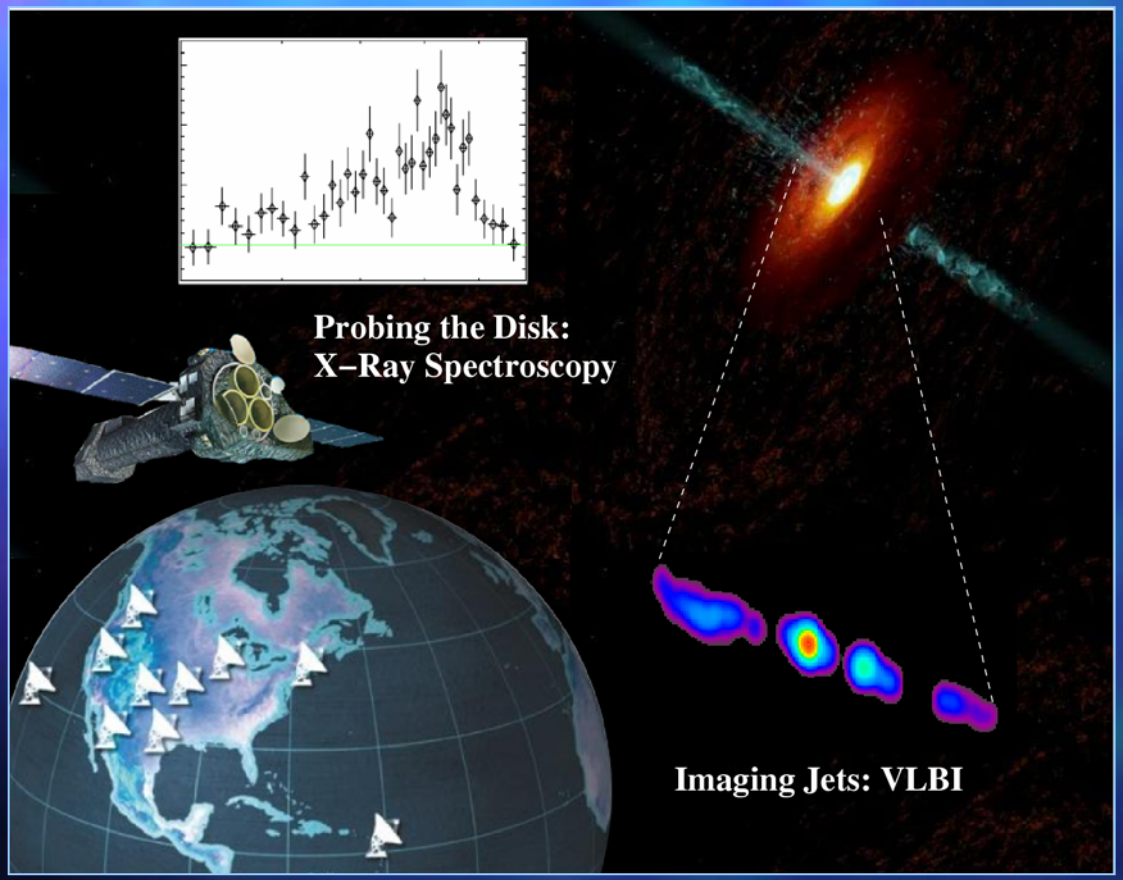
A Multiband Approach to AGN: Radioscopy & Radio Astronomy



Matthias Kadler
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and
E. Ros[1], J. Kerp[2], J.A. Zensus[1]

[1]MPIfR, [2]RAIUB

Bonn, (Oct. 1st,2004)

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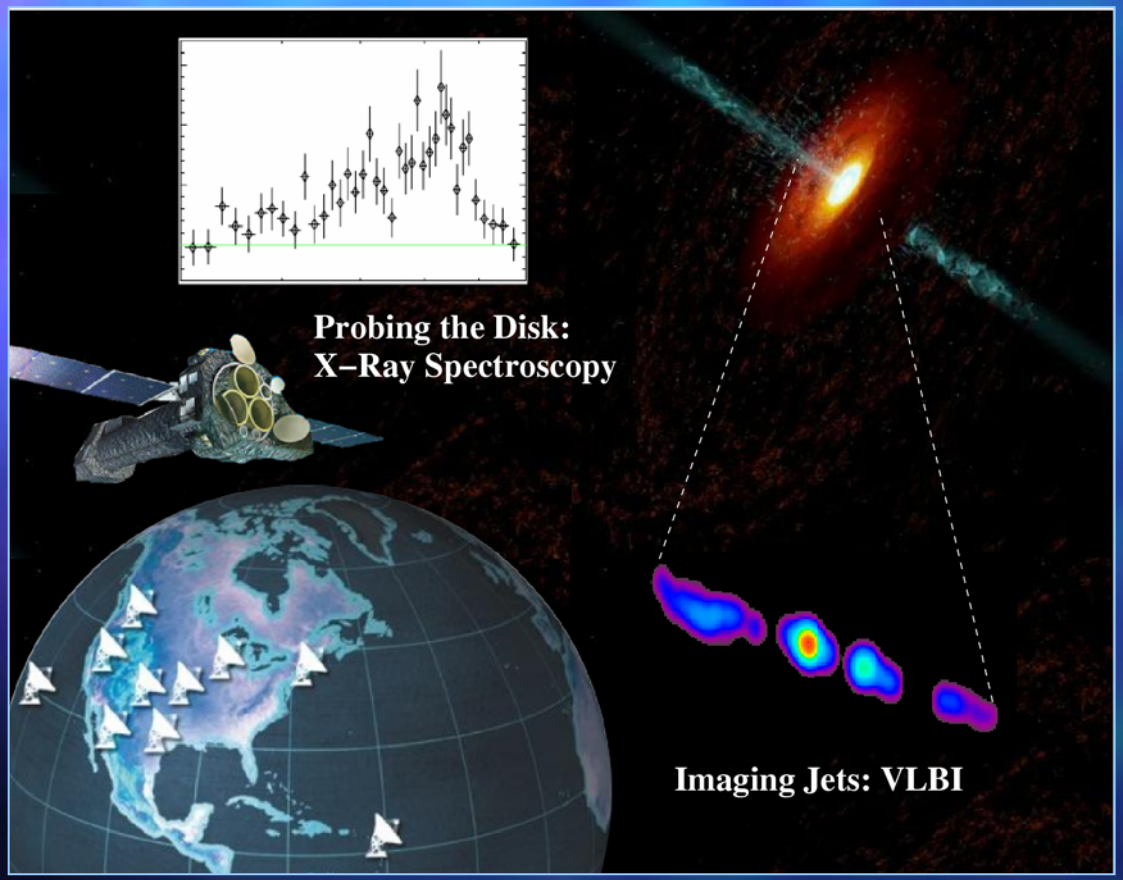


In Collaboration with:

K.A. Weaver

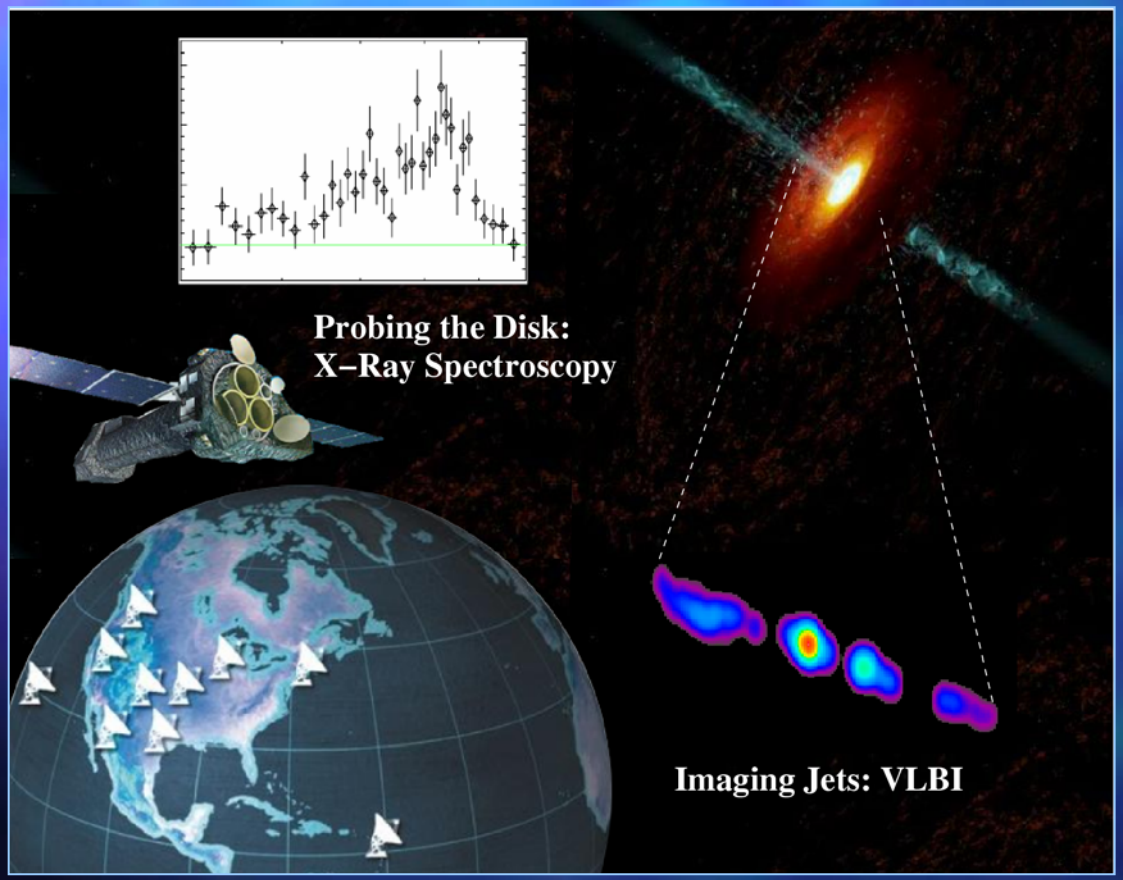
(GSFC)

&

The 2cmSurvey Team

(www.nrao.edu/2cmsurvey)

A Multiband Approach to AGN: Radioscopy & Radio Astronomy



<u>radioscopy</u> – 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

<u>radio astronomy</u> – 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

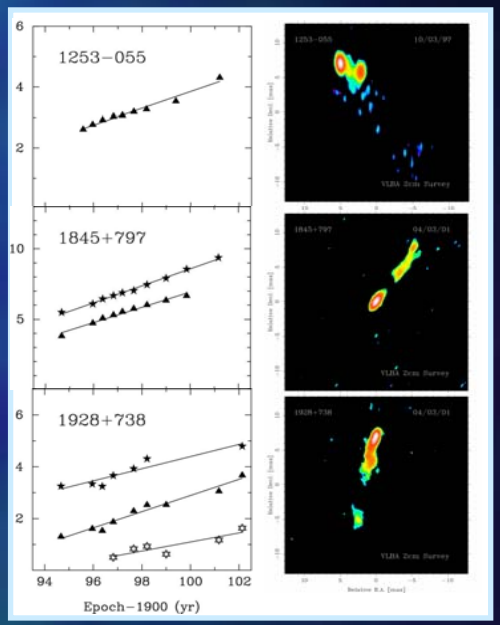
Outline of the Talk

- 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

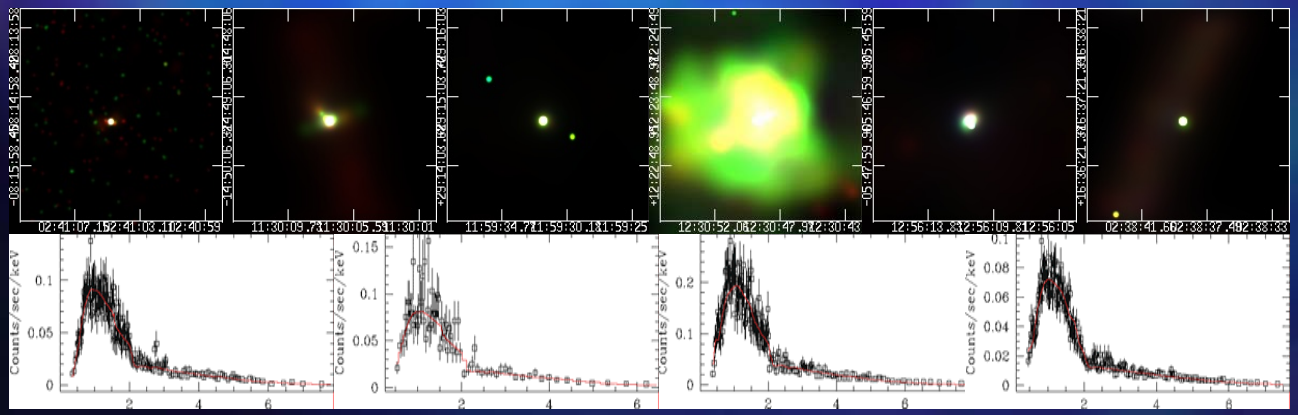
- Systematic survey of the X-ray properties of radio-loud core-dominated AGNs
- X-ray sample of 54 sources (the **2cm-X-Sample**)
- Based on radio-core properties rather than extended stuff, e.g., radio lobes, etc.

VLBA 2cmSurvey



www.nrao.edu/2cmsurvey

Kellermann et al. (1998), Zensus et al. (2002),

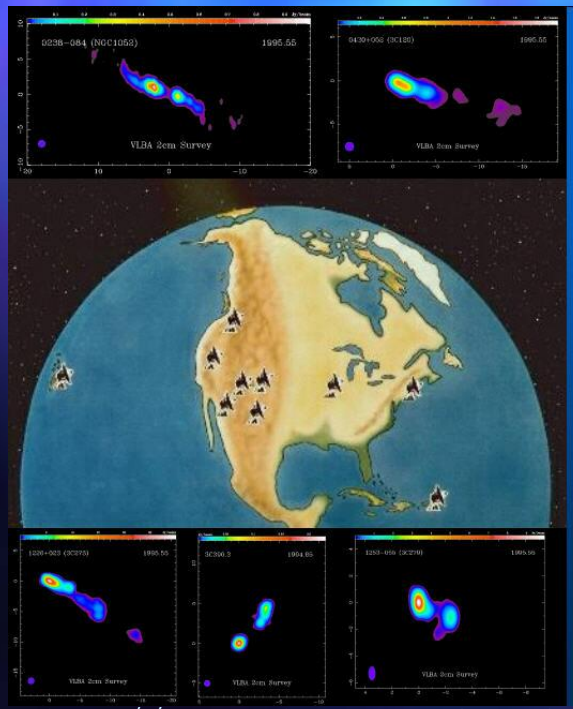


Archival *CHANDRA*, *XMM-Newton*, *ASCA*, and *Beppo*Sax data

The 2cm-X-Sample

- Representative of the MOJAVE sample (the 133 radio-brightest compact AGN in the northern sky)
- See 2cmSurvey Paper 3 & 4

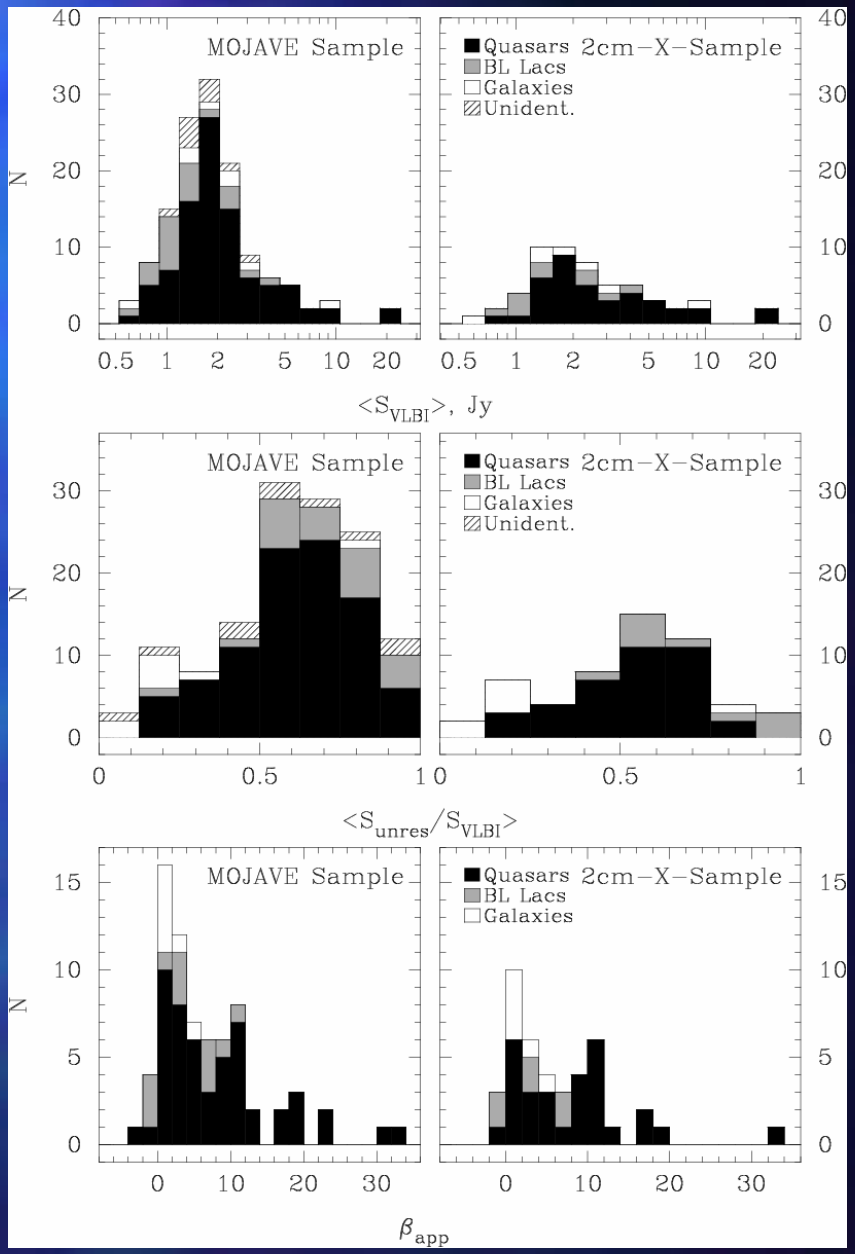
(Kellermann et al. 2004; Kovalev et al., in prep.)



Monitoring
Of
Jets in
Active galaxies with
VLBA
Experiments

http://www.physics.purdue.edu/astro/MOJAVE/

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



Source:	*Alt. Name*:	*CHANDRA*-Data:	*XMM*-Data	*ASCA*-Data	*Beppo*Sax-Data	Source:	*Alt. Name*:	*CHANDRA*-Data:	*XMM*-Data	*ASCA*-Data	*Beppo*Sax-Data
0007+106	III Zw 2		√	√	√	1228+126	M 87	√	√	√	√
0048-097	OB –080				√	1253-055	3C 279	√		√	√
0234+285	CTD 20				√	1308+326	OP +313		√	√	
0235+164	OD +160	√	√	√	√	1334-127	OP-158.3		√		
0238-084	NGC 1052	√	√	√	√	1413+135	OQ +122			√	
0316+413	3C 84	√	√	√	√	1458+718	3C 309.1	√			
0333+321	NRAO 140			√	√	1502+106	4C 10.39		√		
0415+379	3C 111		√	√	√	1510-089	OR -017	√		√	√
0420-014	OA +129			√	√	1611+343	DA 406				√
0430+052	3C 120	√	√	√	√	1633+382	4C38.41			√	
0458-020	DA 157	√				1641+399	3C 345	√			√
0528+134	OG +147			√	√	1655+077	OS +092	√			
0605-085	OH -010	√				1741-038	OT -068				√
0716+714			√	√	√	1749+096	4C 09.57			√	
0735+178	DA 237			√		1803+784					√
0736+017				√	√	1823+568	4C 56.27				√
0738+313	OI +363	√	√			1828+487	3C 380	√			
0827+243		√				1928+738	4C 73.18	√		√	√
0836+710	4C 71.07	√	√	√	√	1936-155					√
0851+202	OJ +287			√	√	1957+405	Cyg A	√		√	√
0923+392	4C 39.25	√		√		2134+004	DA 553				√
1038+064	4C 06.41		√	√		2145+067				√	
1055+018	4C 01.28	√				2200+420	BL Lac	√		√	√
1127-145	OM -146	√	√		√	2223-052	3C 446			√	√
1156+295	4C 29.45	√				2230+114	CTA 102			√	√
1222+216		√		√		2243-123	OY -176				√
1226+023	3C 273	√	√	√	√	2251+158	3C 454.3	√			√

The X-Ray View of NGC1052

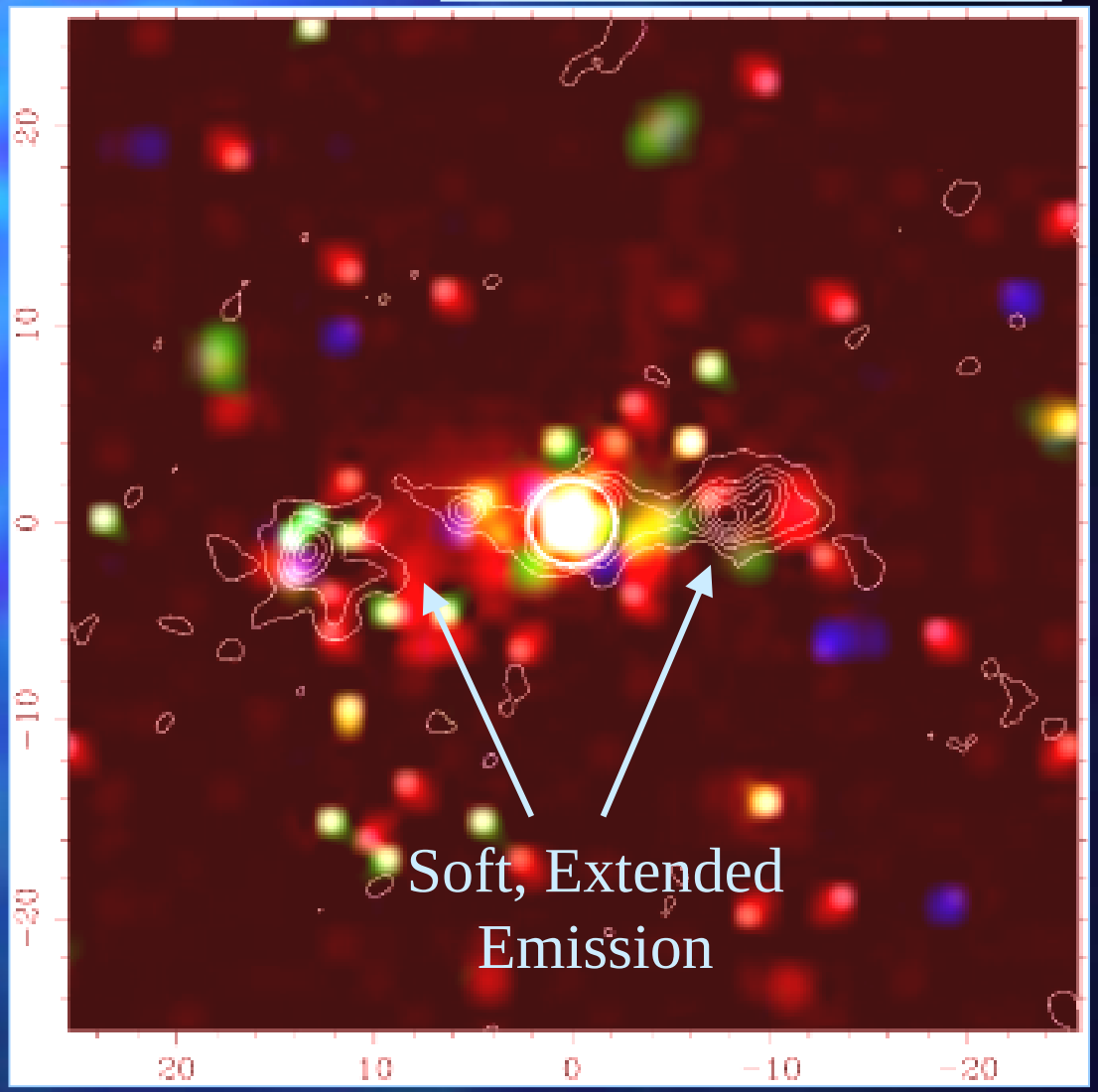
Kadler et al., 2004, A&A, 420, 467

<u>Extended emission:</u>

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

<u>Nuclear emission:</u>

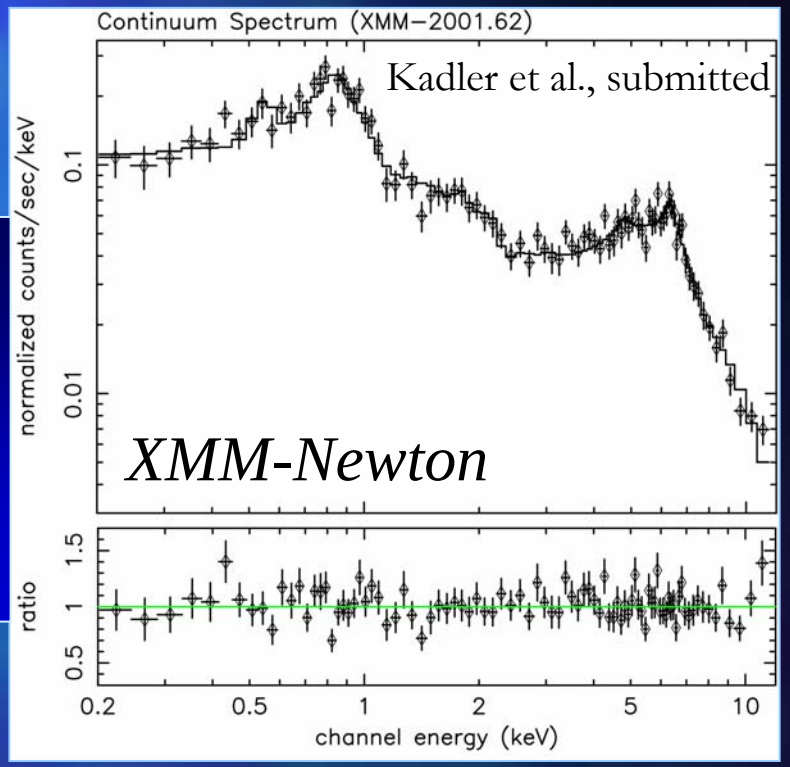
- Extremely flat
- Heavily absorbed ($N_H \sim 10^{22}$-10^{23} cm^{-2} consistent with VLBI)



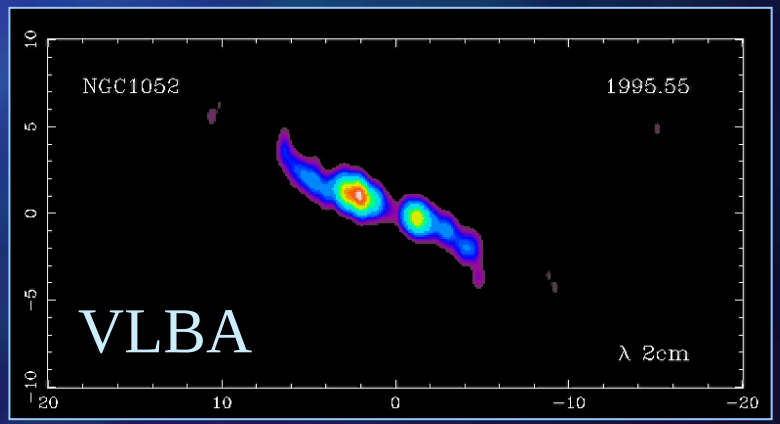
CHANDRA Image (0.1-3 keV)

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: ≈ 80°



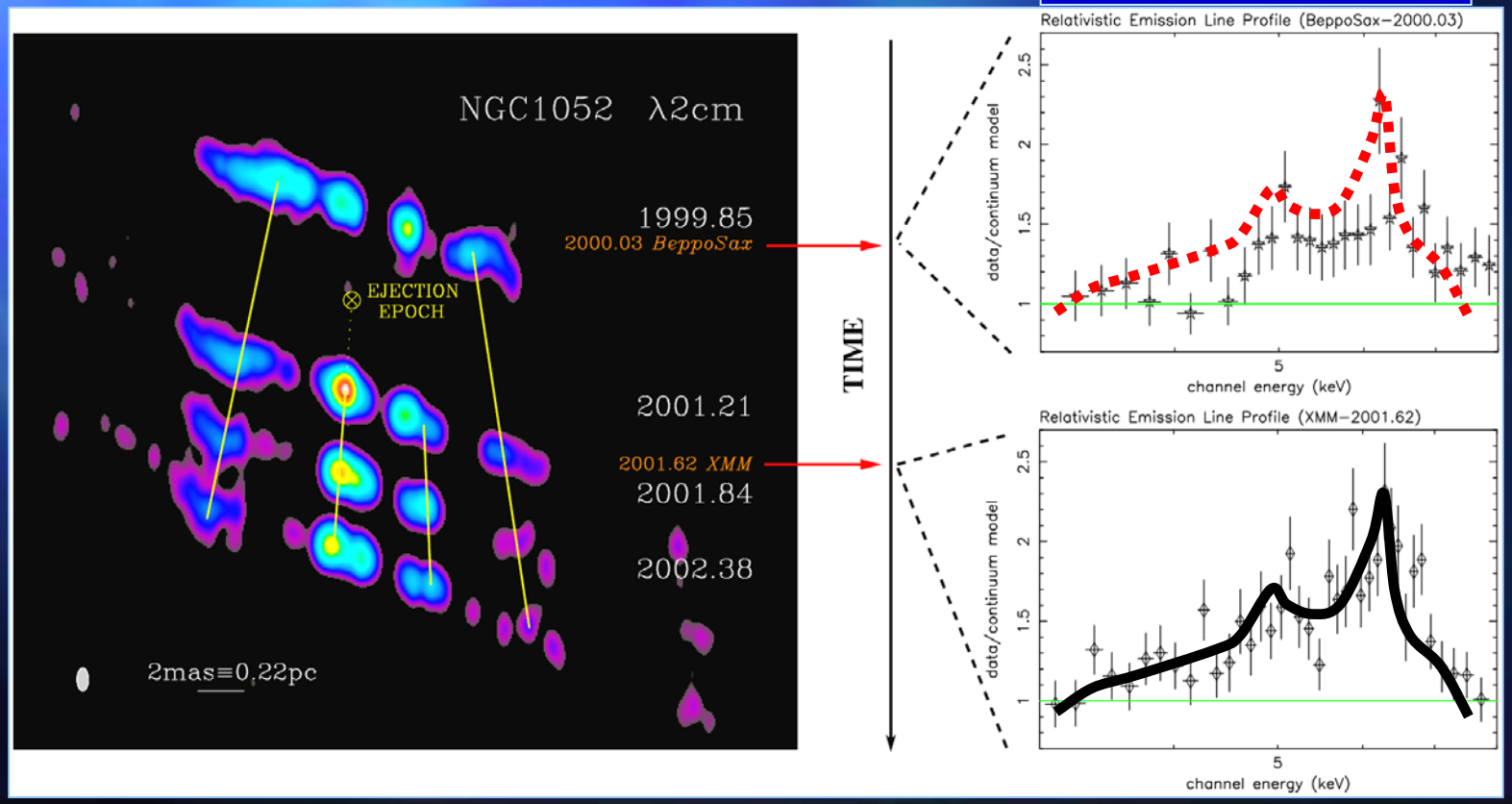
- VLBI Results (e.g., Kadler et al. 2004, A&A, in press; Vermeulen et al. 2003, A&A, 401,113) :
  - Obscuring Torus
  - Jet Inclination: 60°-80°



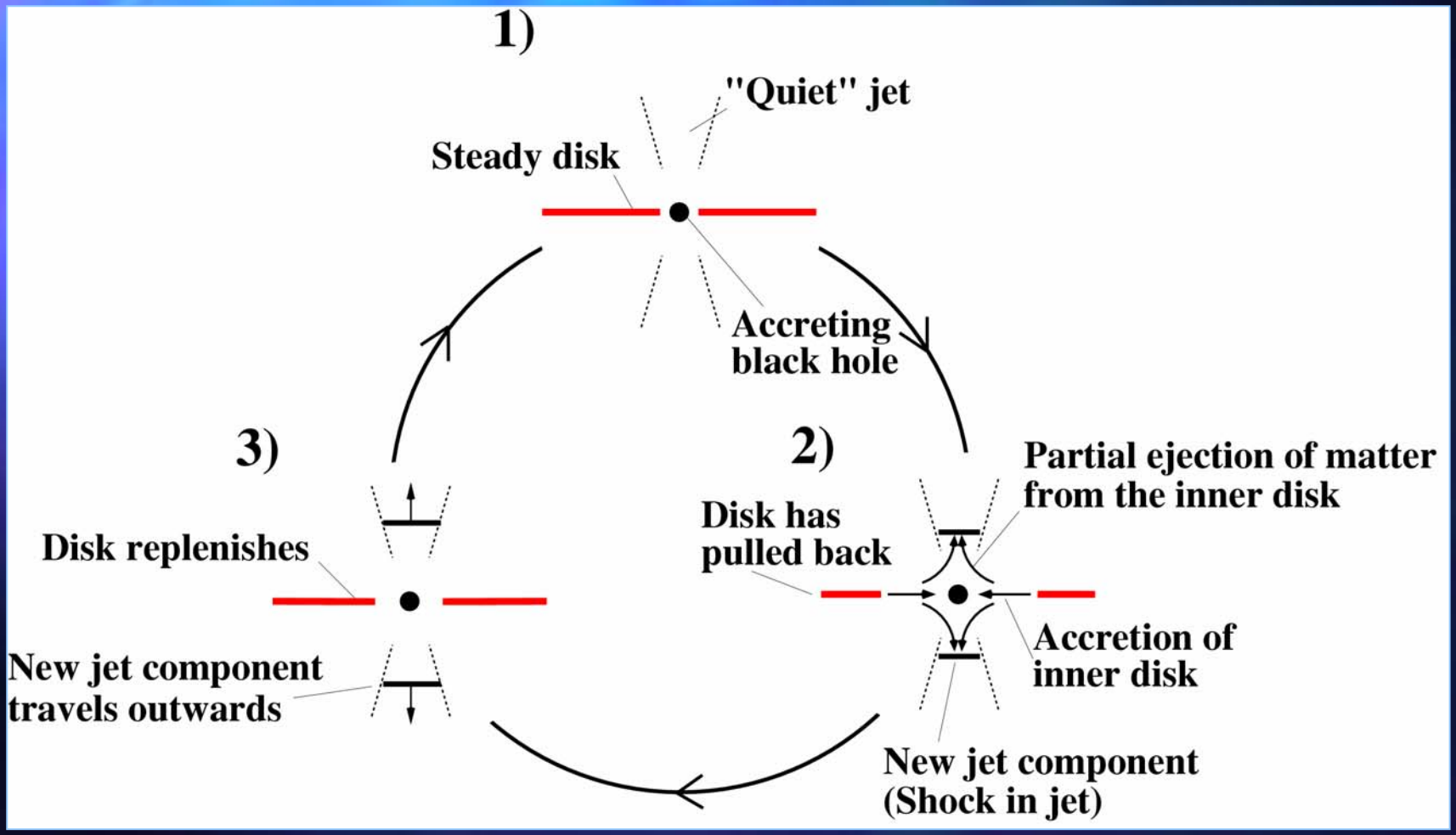
Caught in the Act: An Accretion-Ejection Event in NGC1052

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

Kadler et al., submitted
Ros et al. in prep.

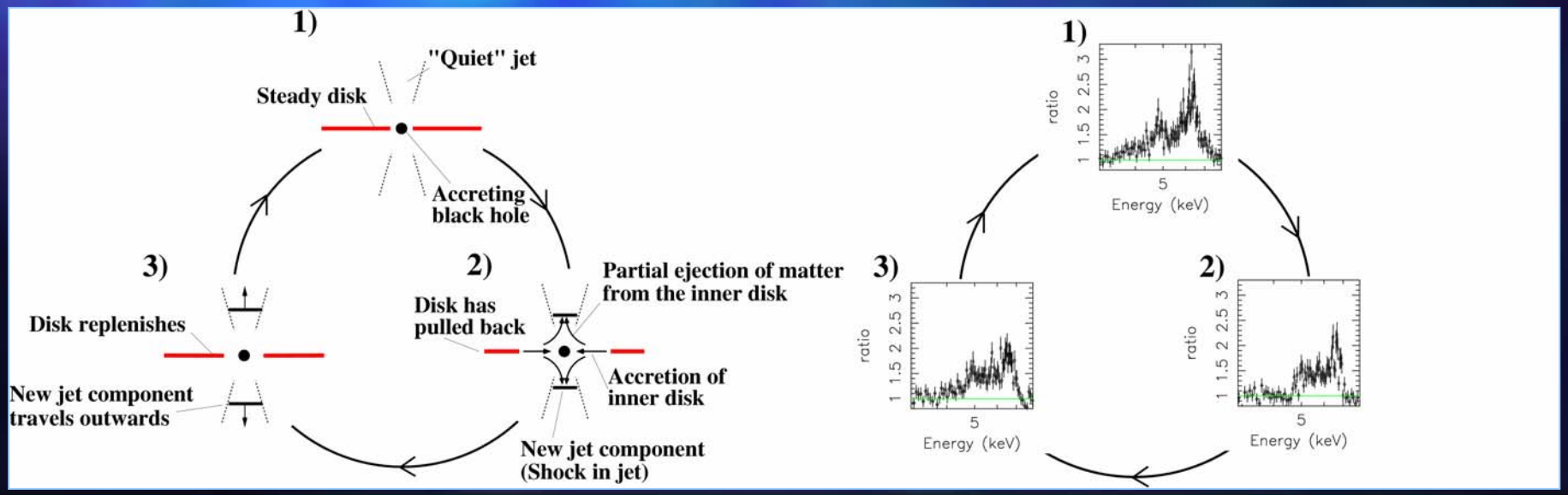


NGC1052 from 1999 to 2001:
A Simple Model

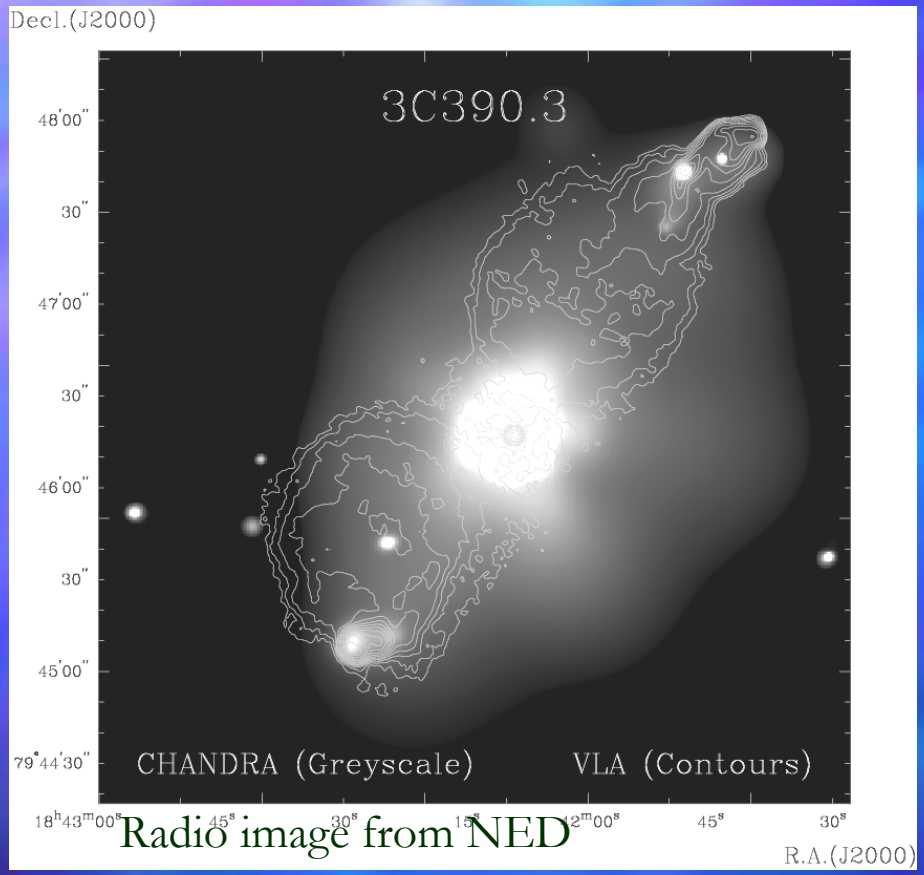


What Makes an AGN Radio-Loud?

- 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)

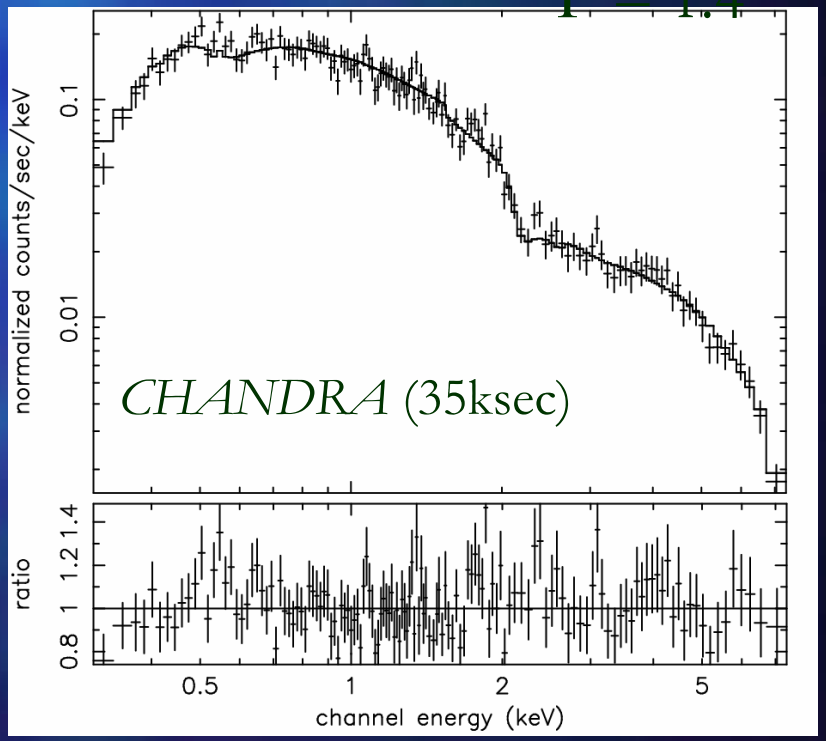


Another radio-loud candidate: 3C390.3



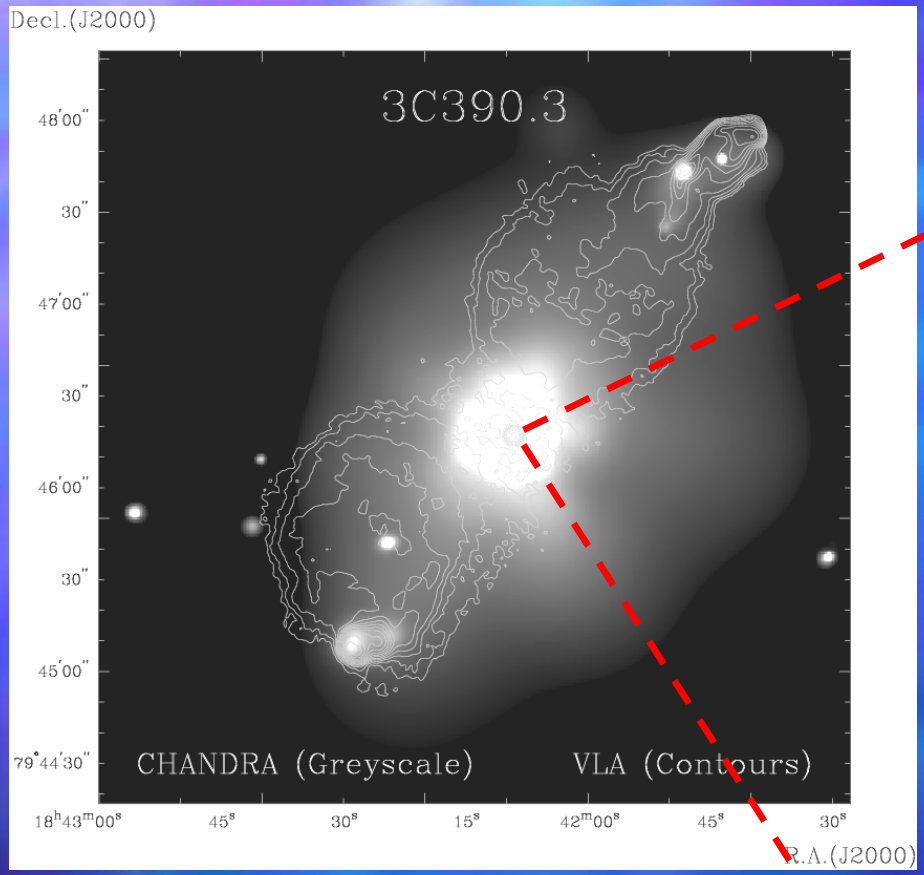
Radio image from NED

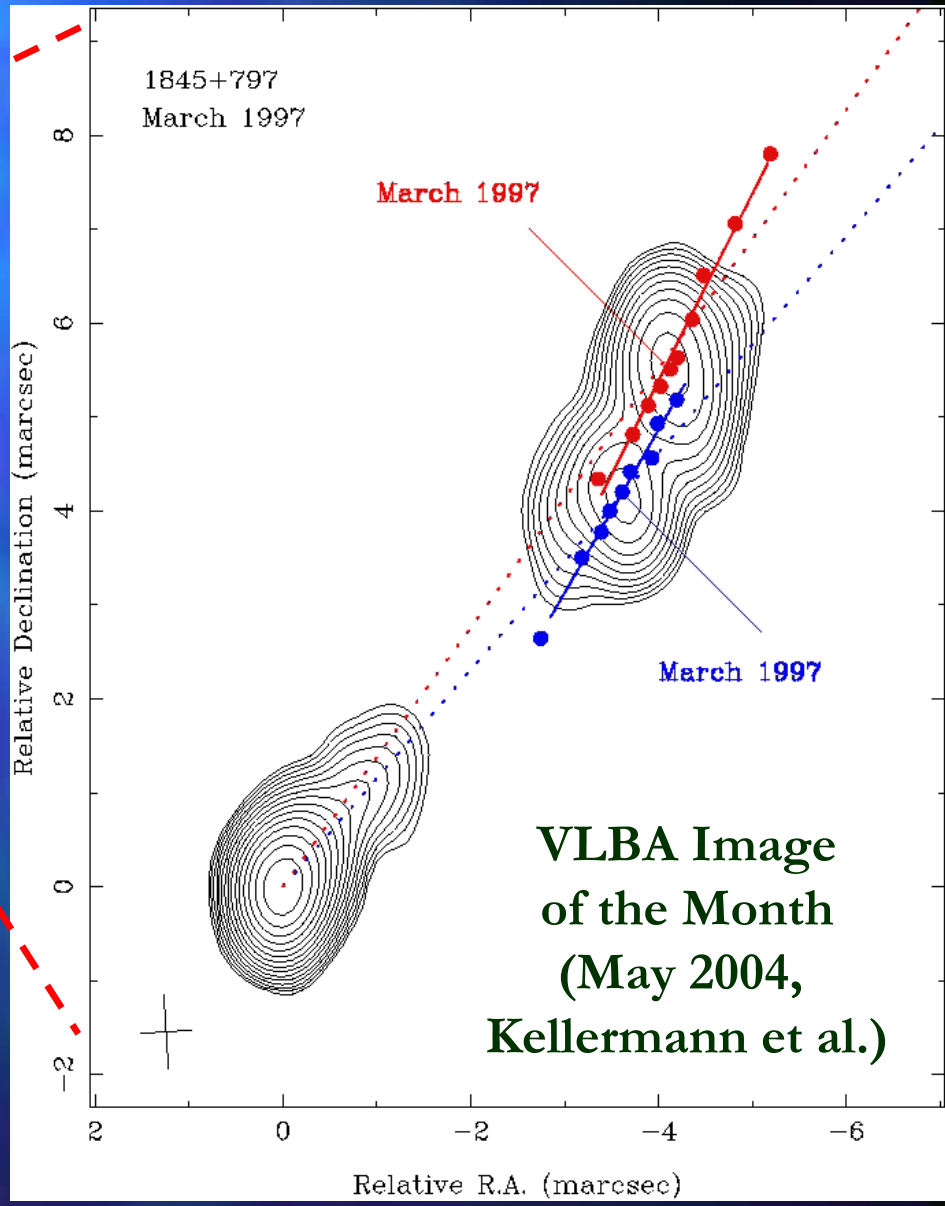
- Broad line radio galaxy at $z = 0.057$
- Sambruna et al. (1999) report a broad iron line



- No broad iron line visible with *CHANDRA*
- Complex extended structure discloses different emission mechanisms at work

3C390.3





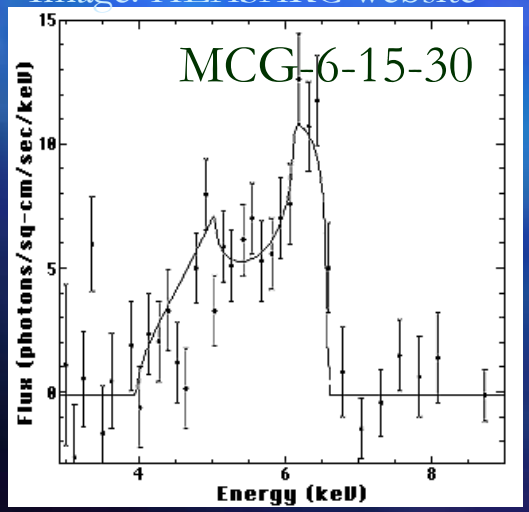
VLBA Image of the Month (May 2004, Kellermann et al.)

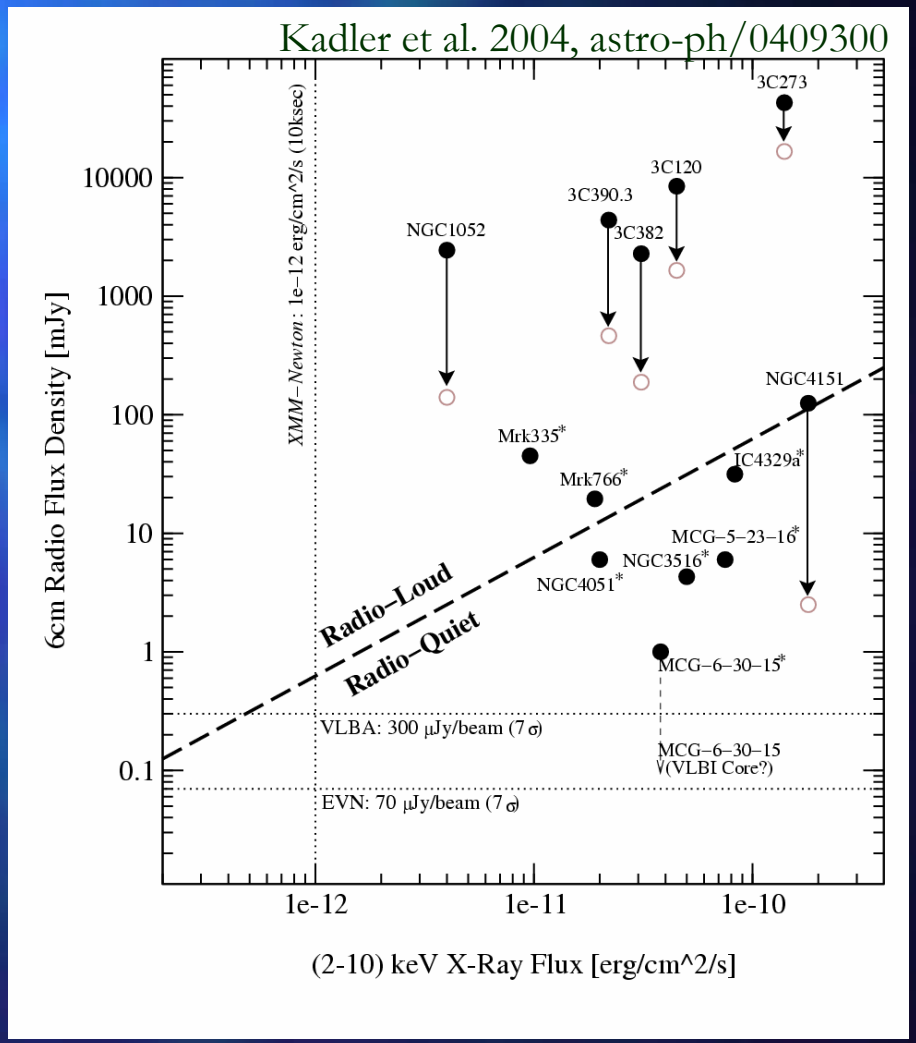
- Non-ballistic motions on milliarcsecond scales seen in the 2cmSurvey monitoring

Radio-Quiet AGN – Not so Quiet After All

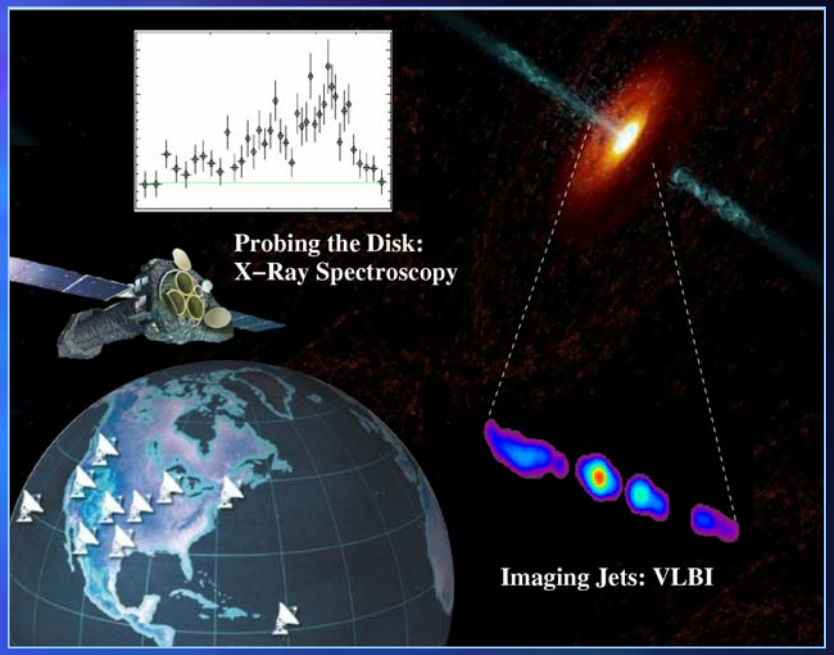
- Prominent broad iron lines seen in a sample of Seyfert galaxies
- Attractive targets for highly sensitive VLBI observations

Image: HEASARC website





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

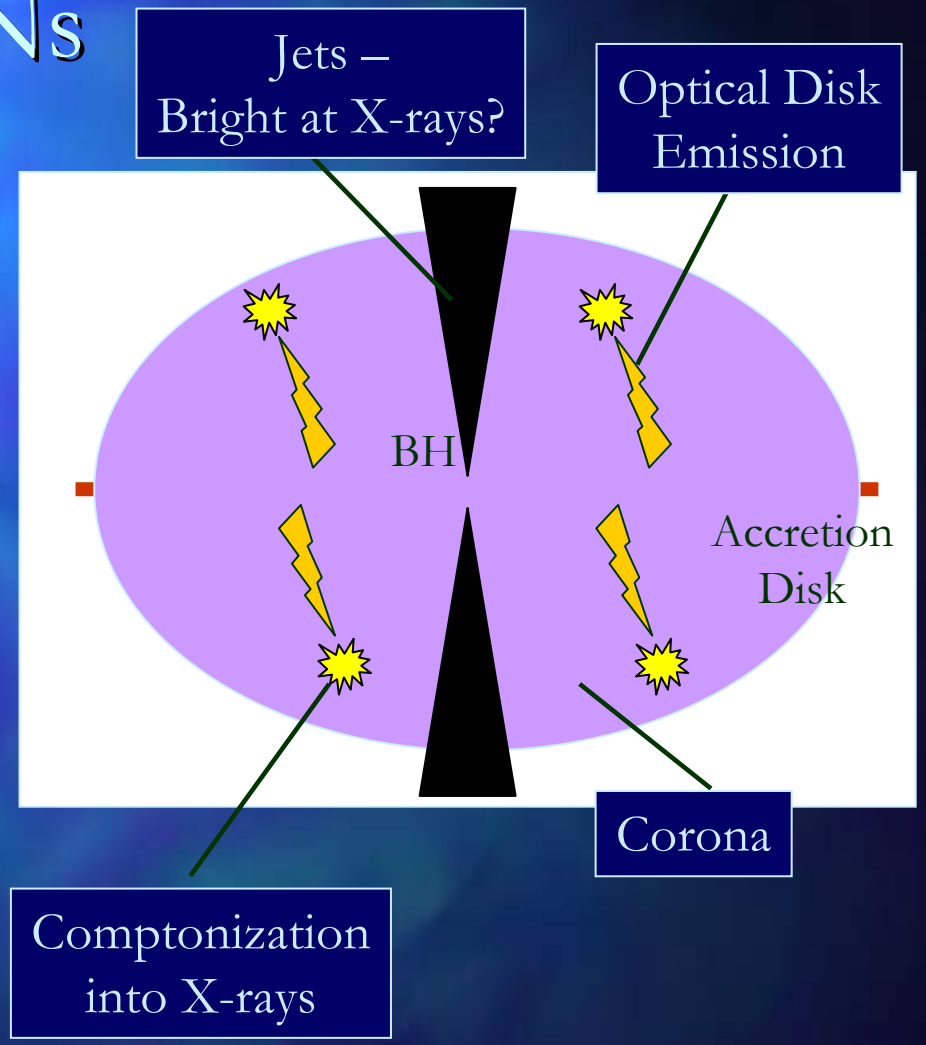
Both show power-law spectra

Radio-Quiet AGNs:

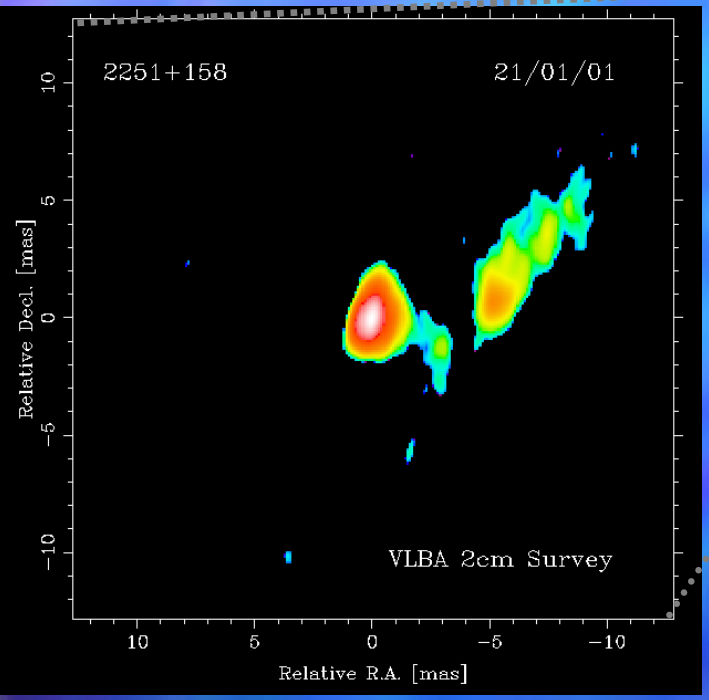
- Typical photon index ~ 1.7-2.0
  (P_E [Photons/keV] ~ $n^{-\Gamma} \Rightarrow \Gamma-1 = \alpha$)
- Optical emission from disk
- Comptonization in Disk-Corona
  (see, e.g., Fabian et al. 2000, PASP, 112, 1145)

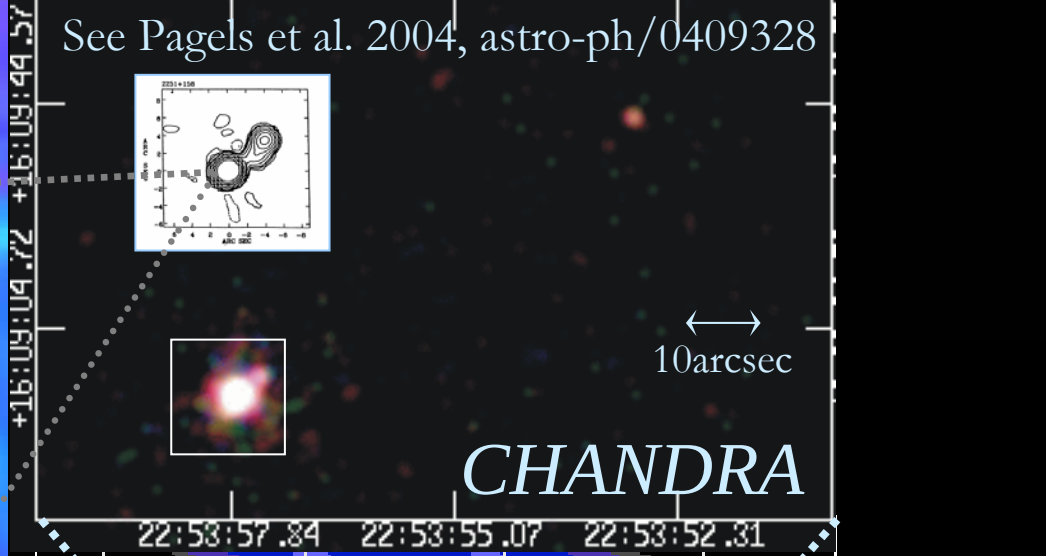
Radio-Loud AGNs:

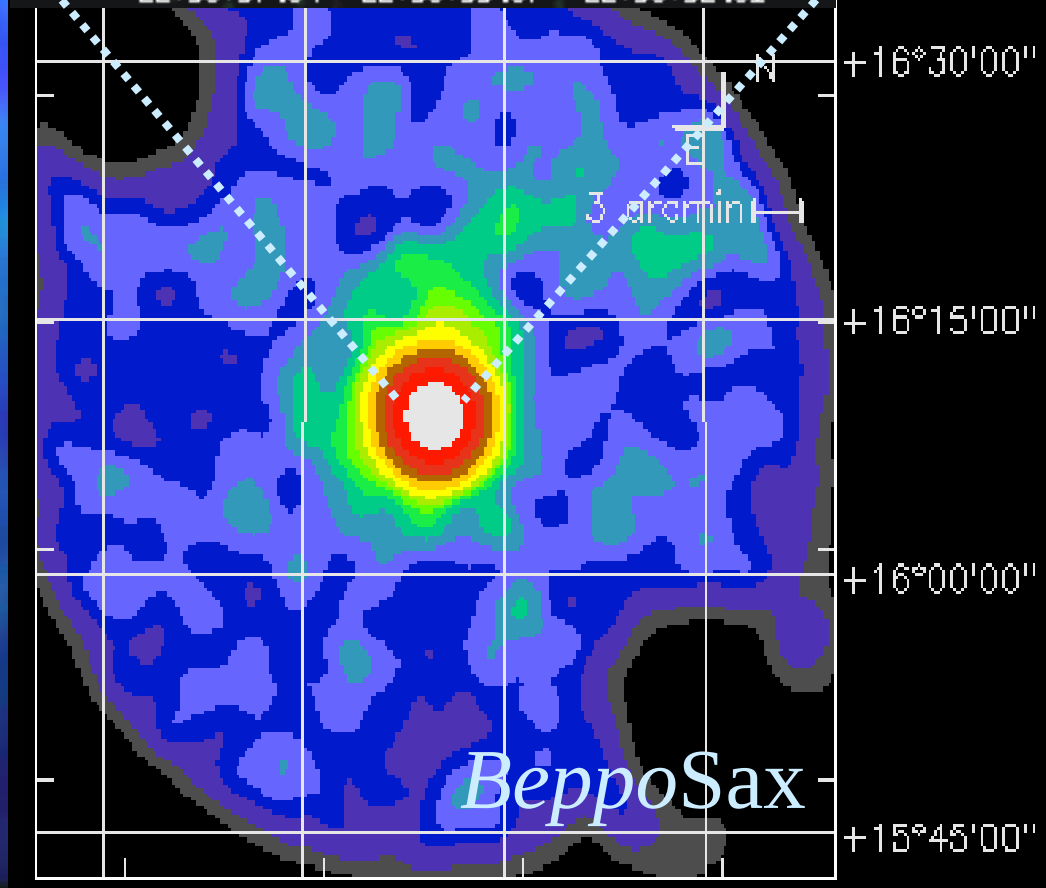
- Flatter photon indices ~ 1.5-1.7
- Which role plays the jet in the production of the nuclear X-rays?
- Do the X-rays tell us anything new about the jets?



3C454.3



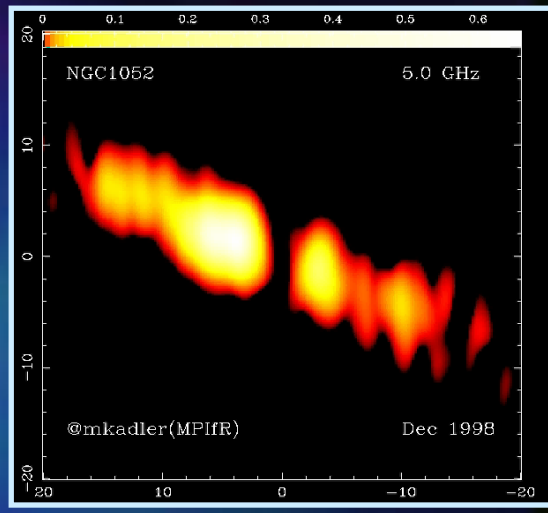




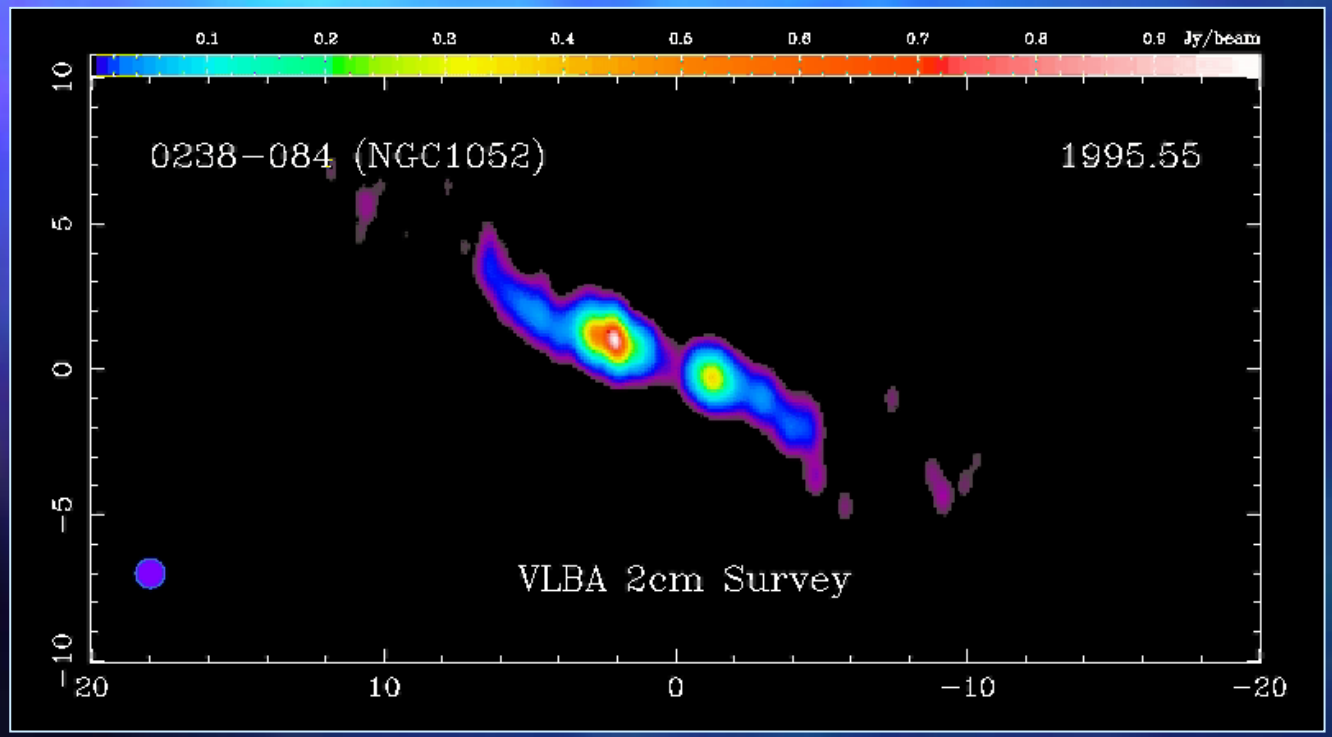
Higher angular resolution reveals the jet contribution on arcsecond-scales! What about the parsec-scale jet?

VLBA Observations of NGC1052

Obscuring Torus
(see Kadler et al. 2004, A&A, in press)



Multi-ν Observations



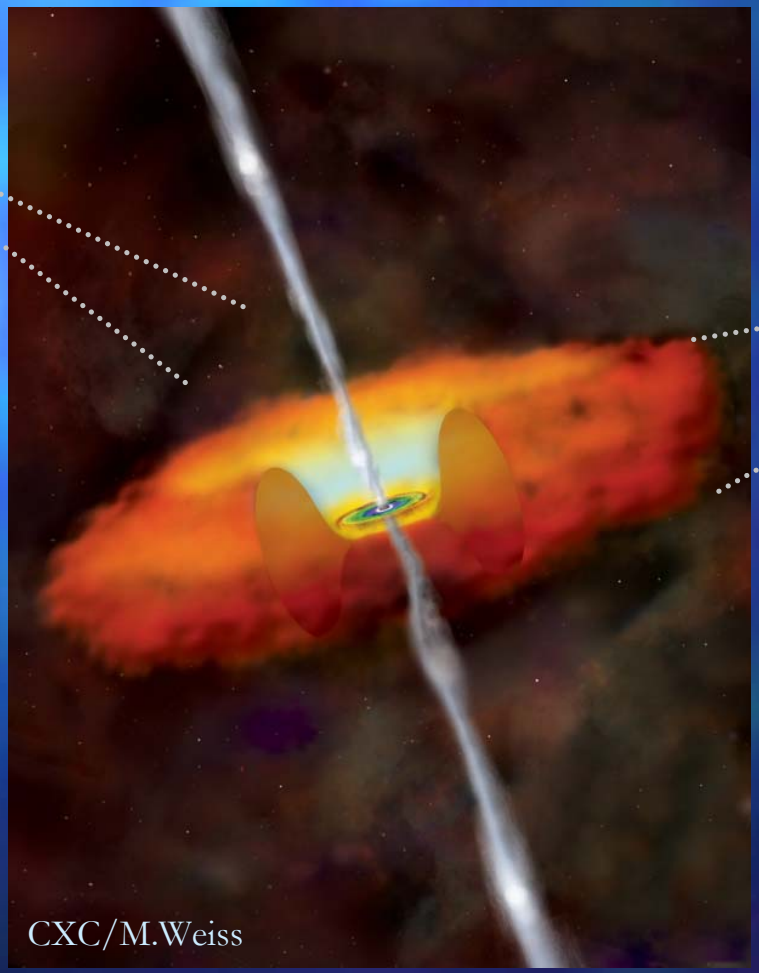
Multi-Epoch Observations

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



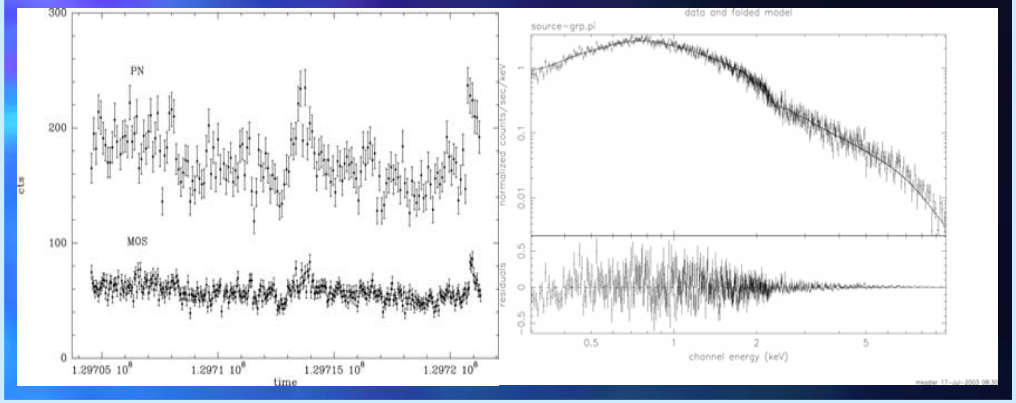
Type 2:

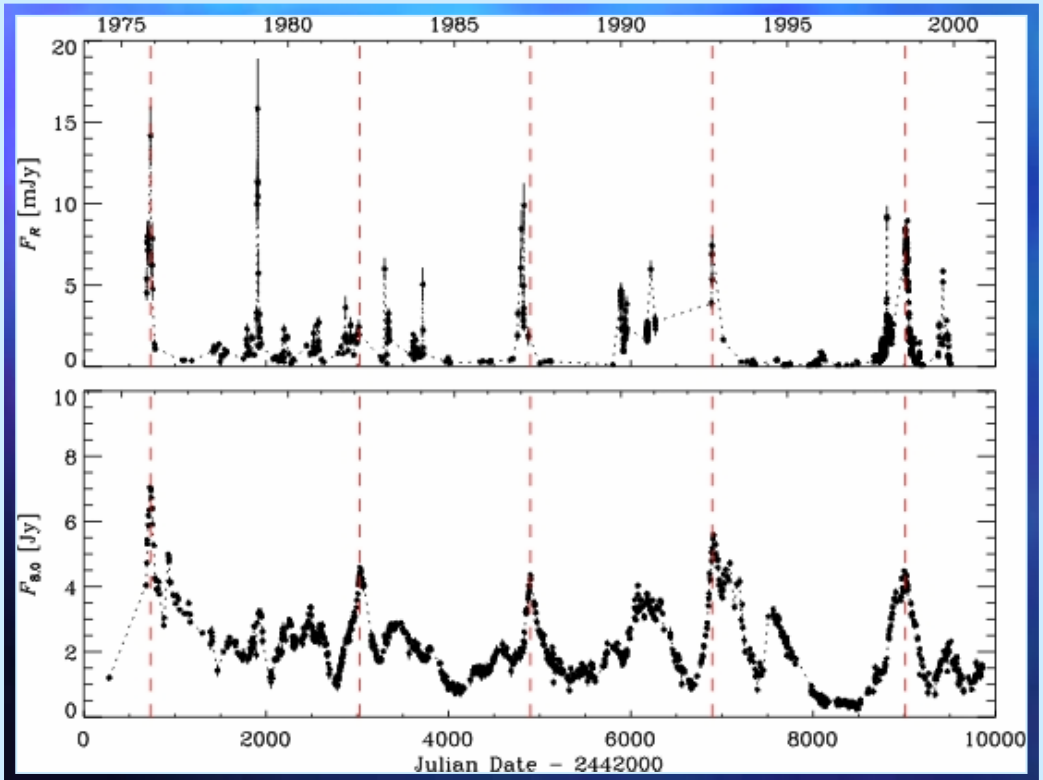
Two-Sided Jets;
Free-Free Absorption;
Narrow Line Region;
Strong Absorption of soft X-Rays

AO 0235+164 – a WEBT Campaign

Raiteri et al. 2001

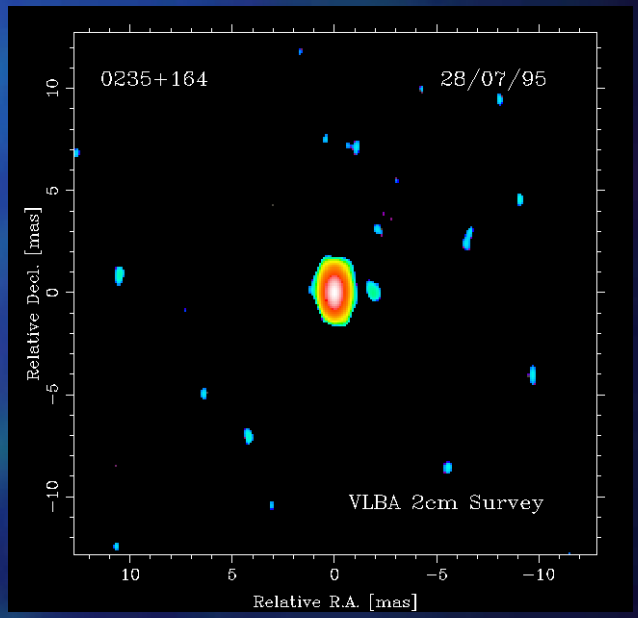
XMM



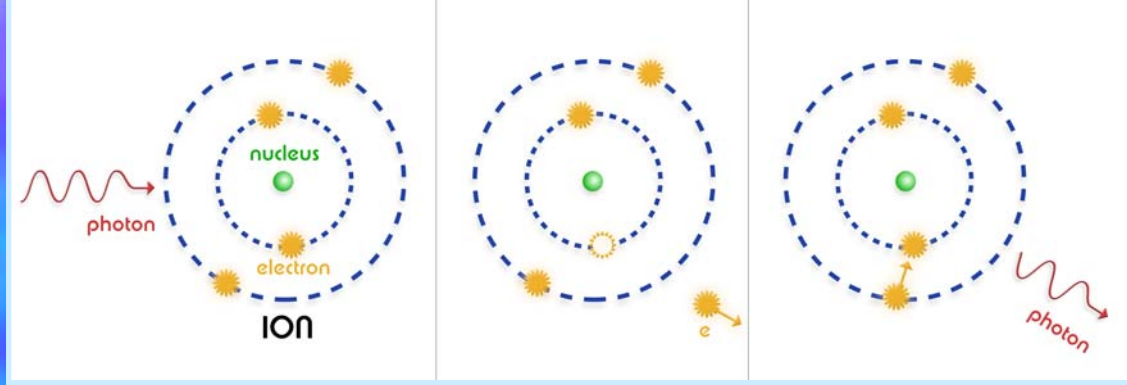


Radio and Optical Flux Monitoring

VLBI



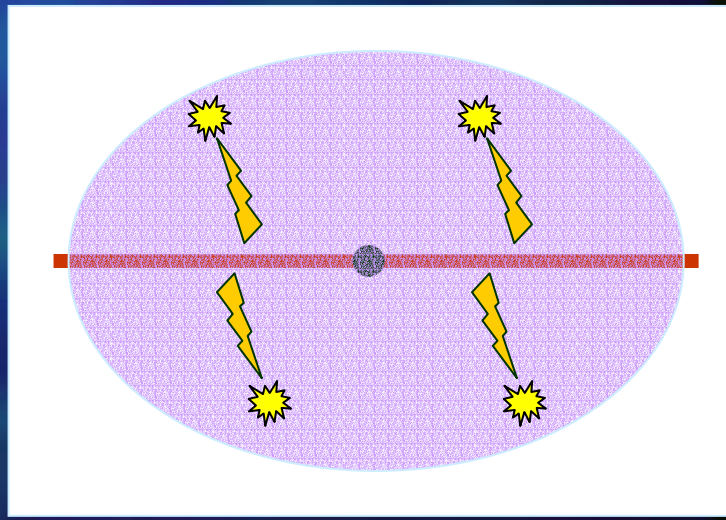
Broad Fe-Lines in AGNs



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)

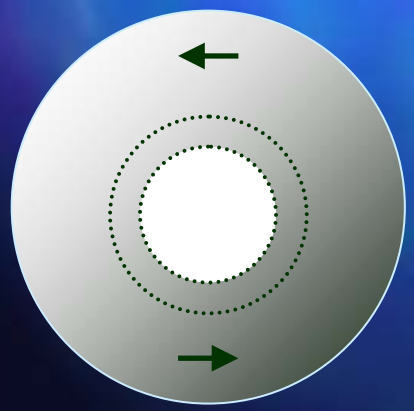
1. Optical emission from disk
2. Comptonization in Disk-Corona
3. Disk-Reflection

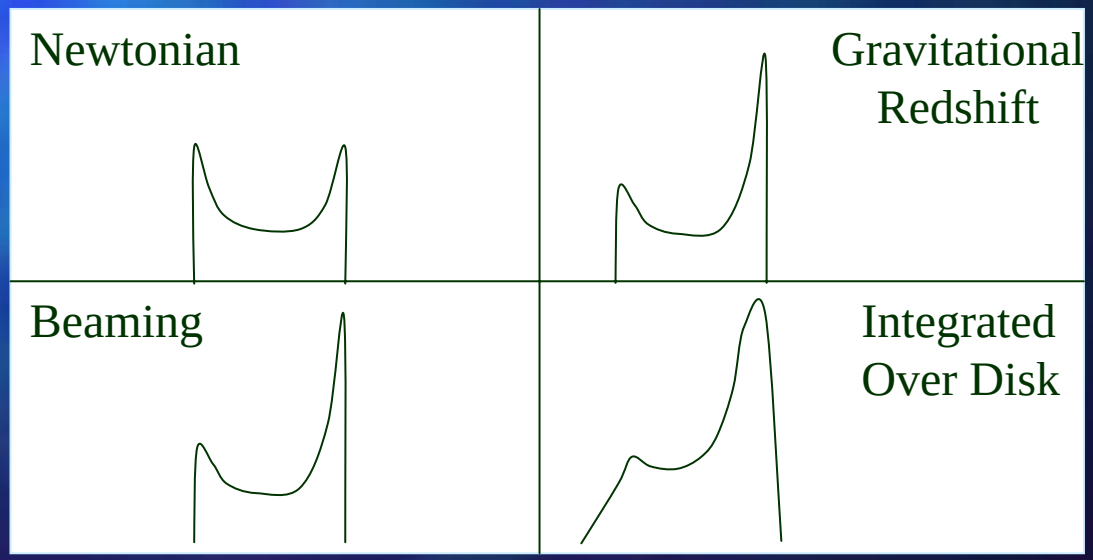


Broad Fe-Lines in AGNs II

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

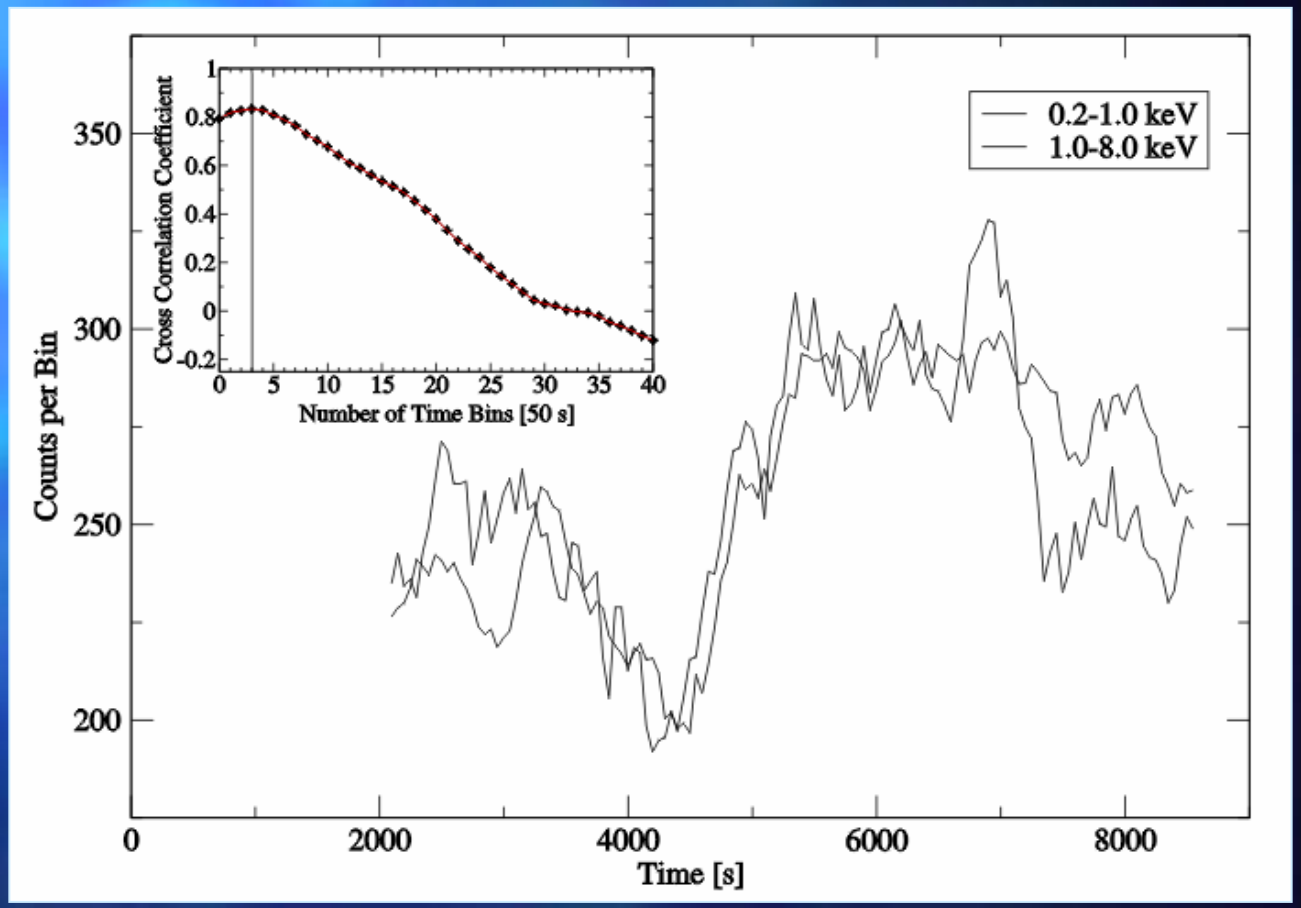




0716+714

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

⇒ Cooling

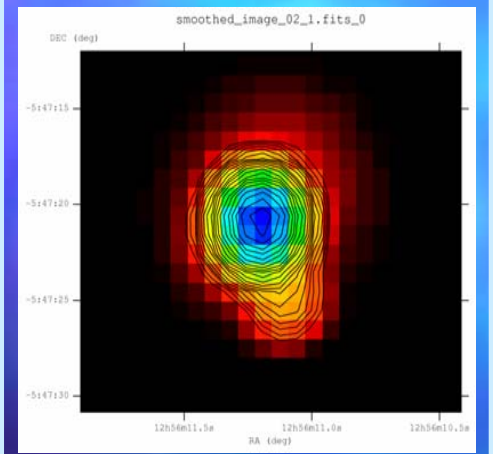


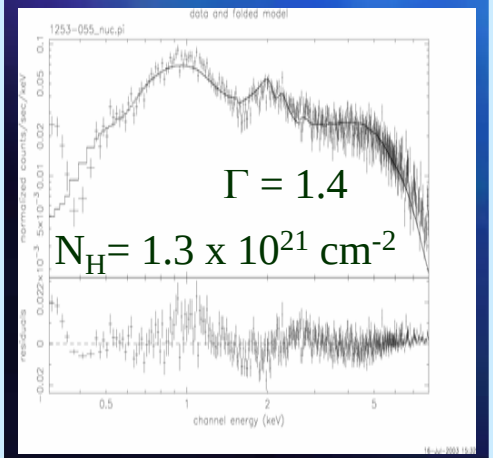
Kadler et al. 2003, A&A, submitted

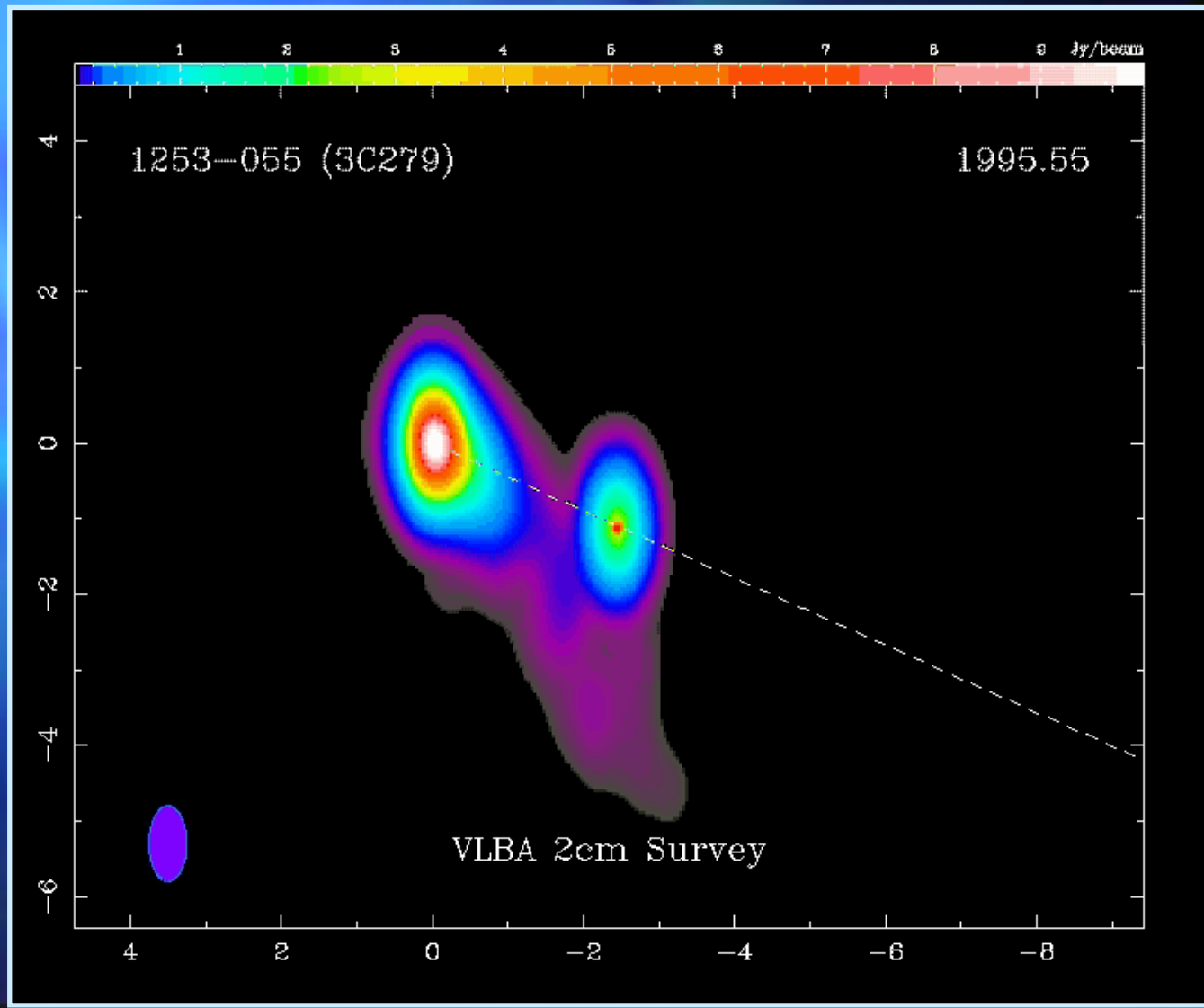
Another Type 1 Object: 1253-055 (3C279)

Homan et al. (2003)

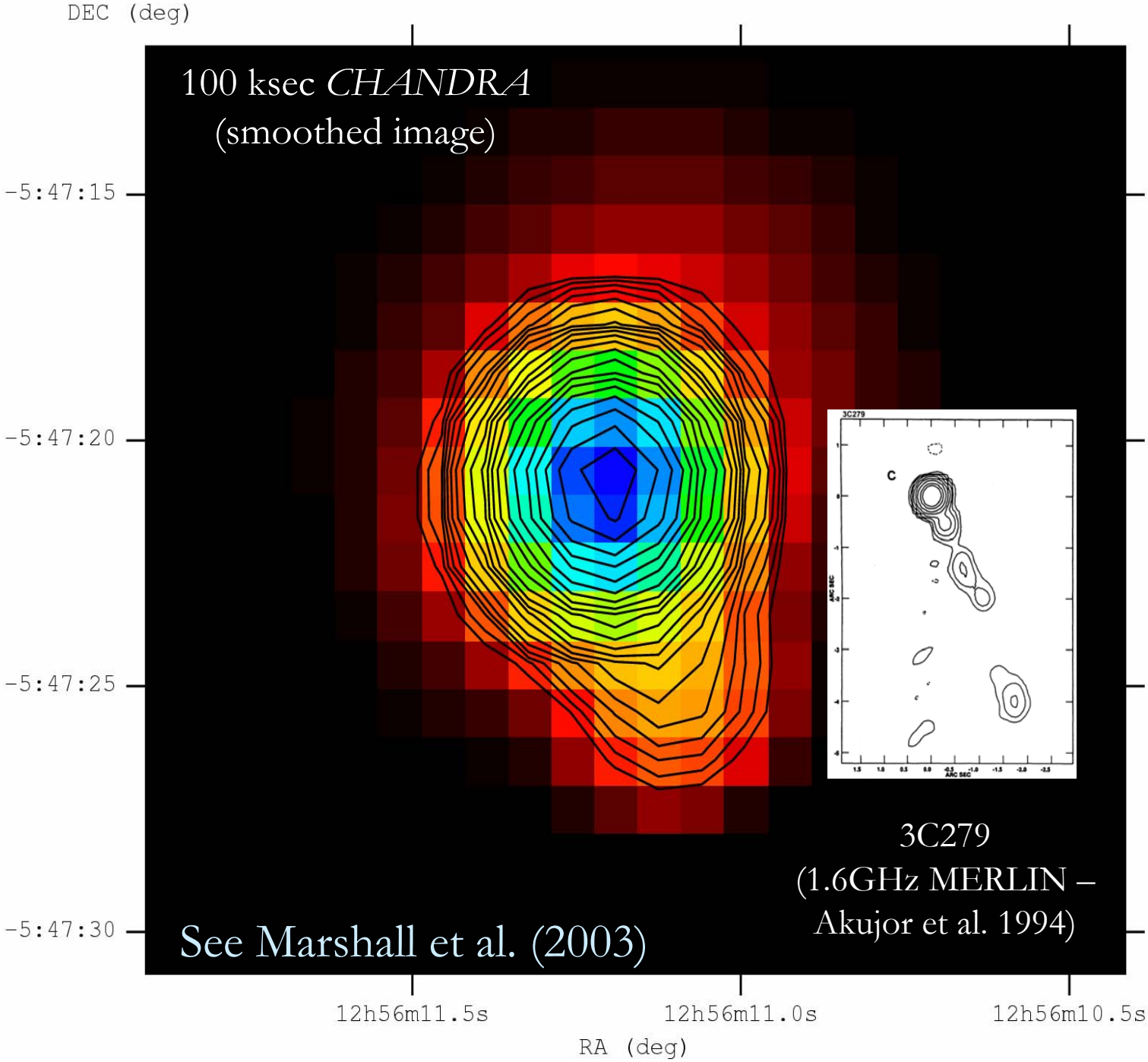
CHANDRA







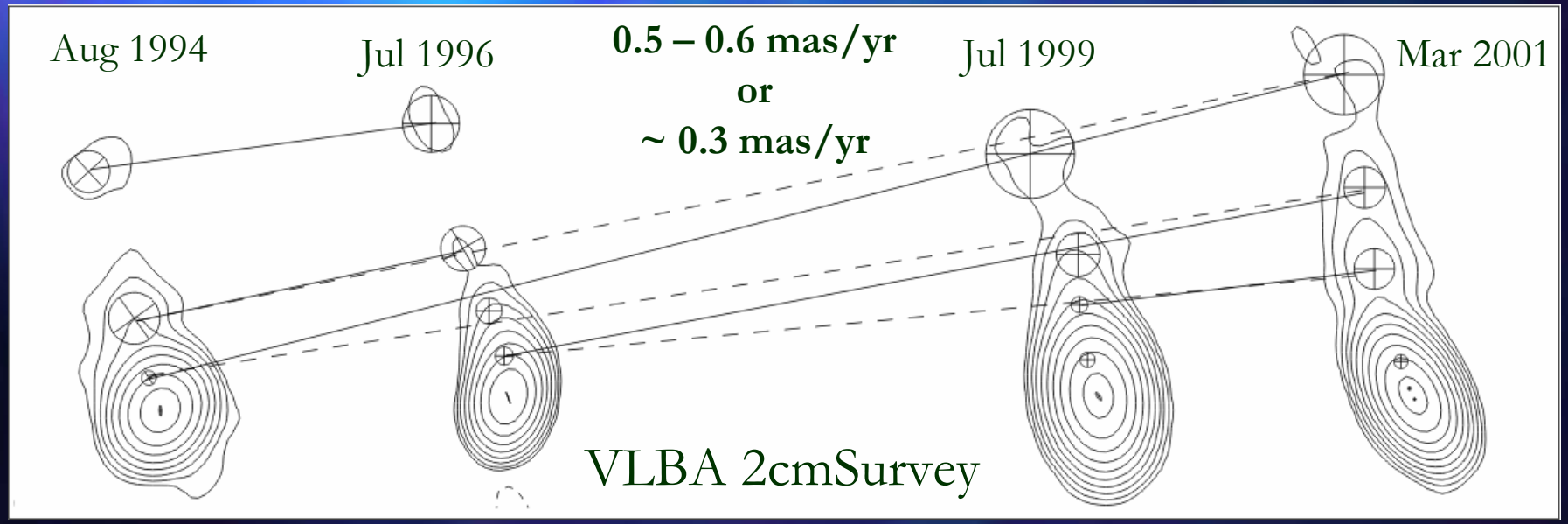
1253-055 (3C 279)



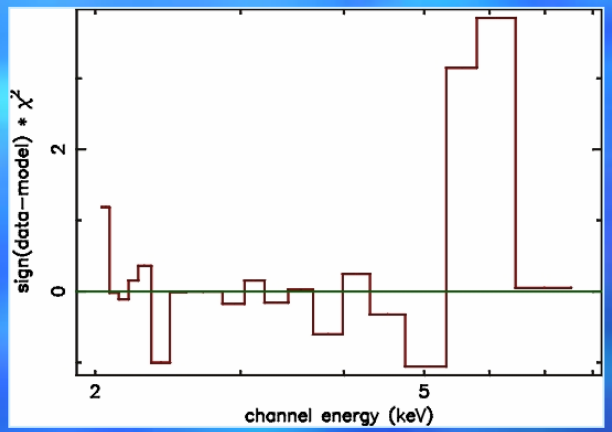
0716+714 – A Hard Nut to Crack

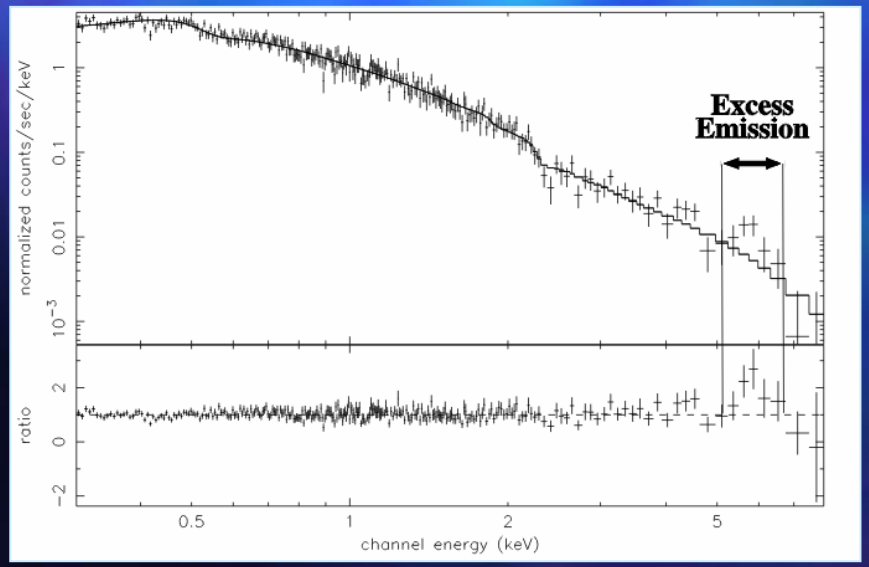
Unclear kinematics:

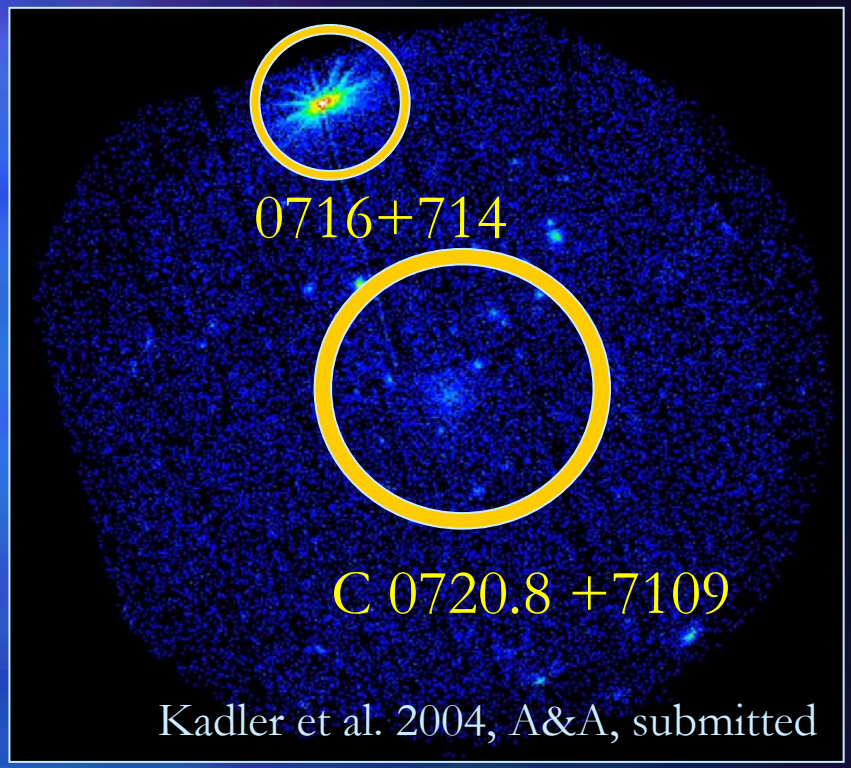
Witzel et al. (1988), Gabuzda et al. (1998):	Subluminal source
Jorstad et al. (2001):	0.9-1.2 mas/yr
Bach et al. (2003):	0.3-0.9 mas/yr



0716+714







Kadler et al. 2004, A&A, submitted

- 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)