NGC 1052 from VLBI to high energies

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Collaboration

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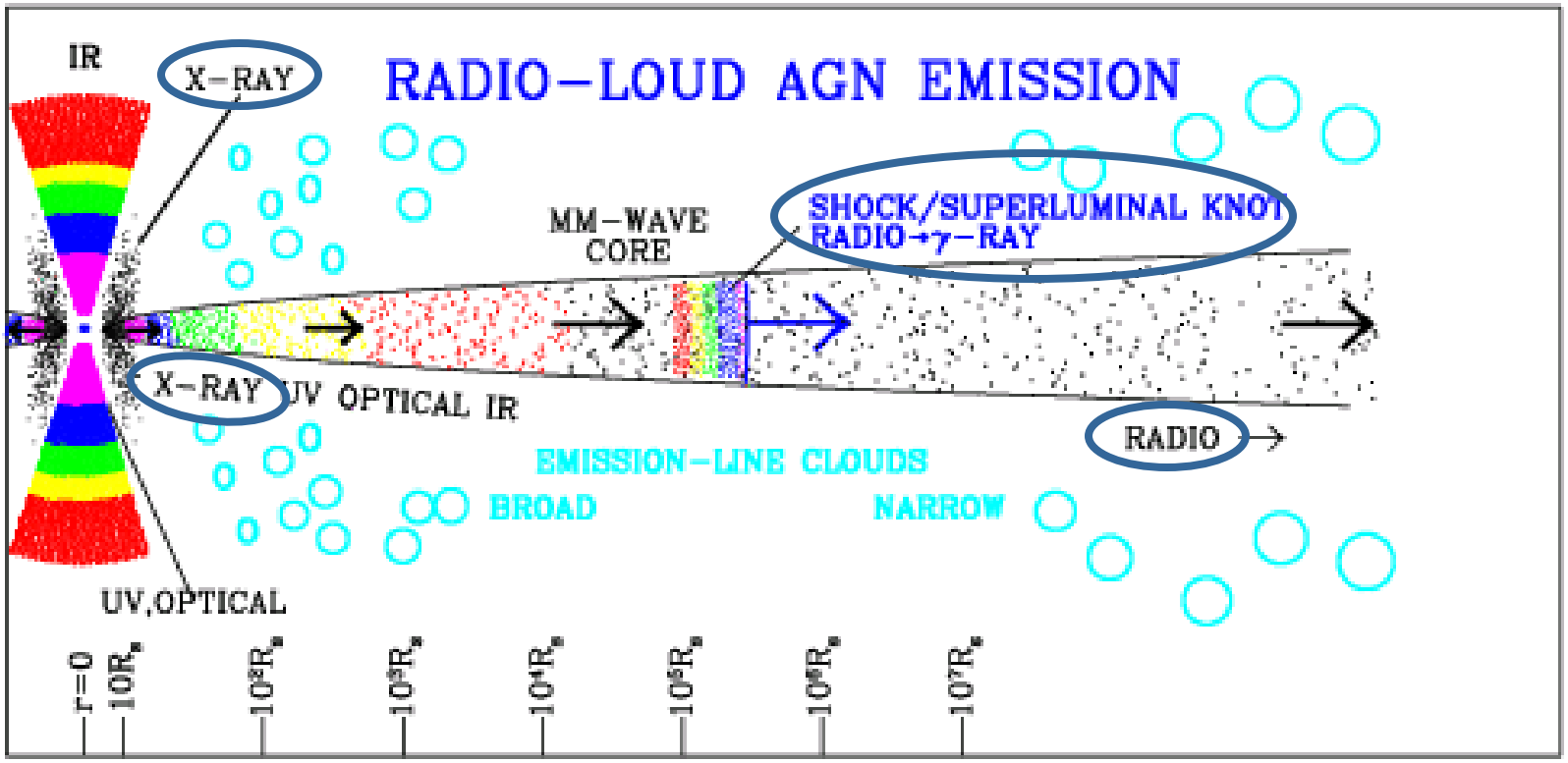
- Univ. Erlangen-Nuremberg: M. Kadler
- AIfA: J. Kerp
- LSW Heidelberg: S. Kaufmann
- GSFC/NASA: K. Weaver, L.W. Brenneman, J. Tueller
- BU: A. Marscher
- UMich: H. Aller, M. Aller, J. Irwin

… and the 2cm Survey/MOJAVE team

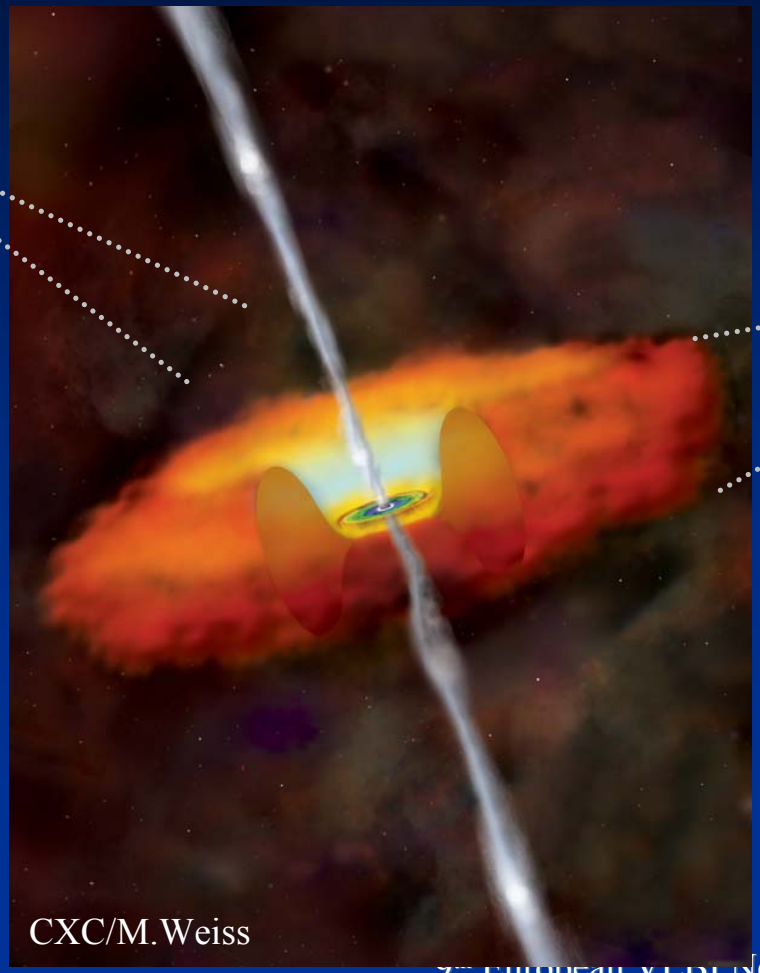
AGN emission regions



Picture: A. Marscher, Boston Univ.

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

Cartoon idea: M. Kadler

The AGN Radio/High Energy Connection

- Radio flux density monitoring
- Radio imaging with VLBI (milliarcsecond resolutions) probes the highly relativistic jets at sub-parsec scales and their time evolution
- Radio spectra and turnover frequency imaging reports on the jet physics and composition
- Polarization at the higher frequencies reveals the magnetic fields in the jet

The AGN Radio/High Energy Connection (ii)

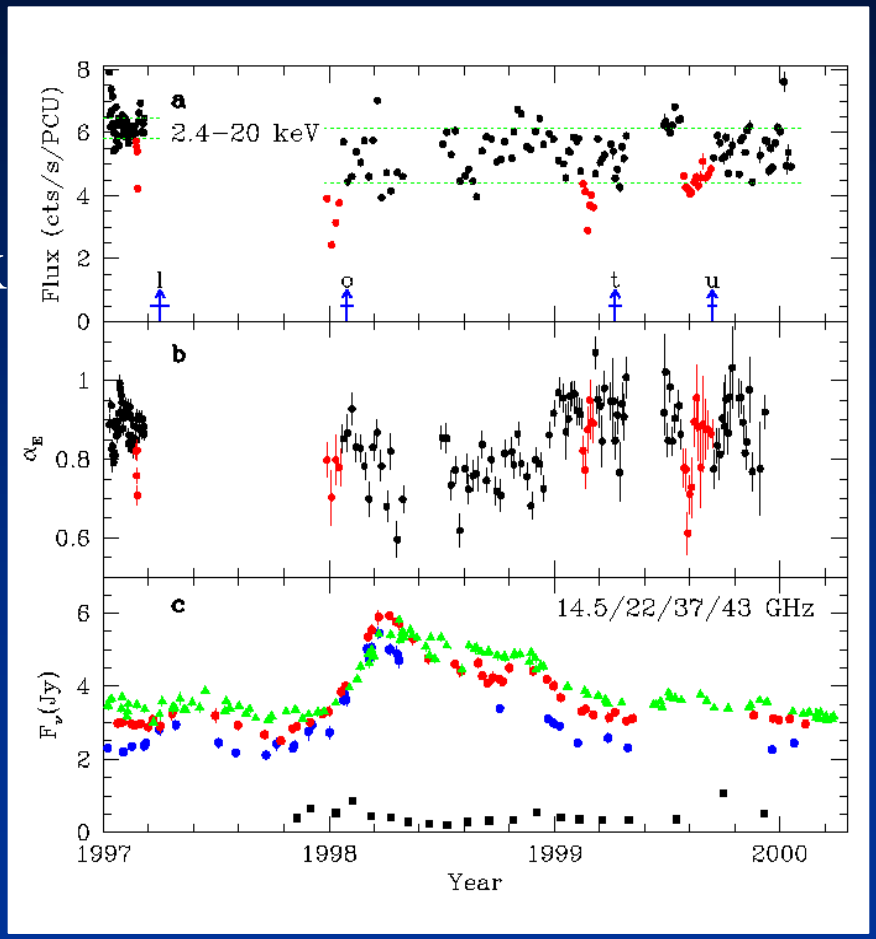
- AGN spectra show absorption, reflection and emission lines as well as a power-law continuum radiation
- The Fe-Kα line at 6.4 keV is the most prominent fluorescent line and probes the AGN circumnuclear environment
- AGN spectra show variability

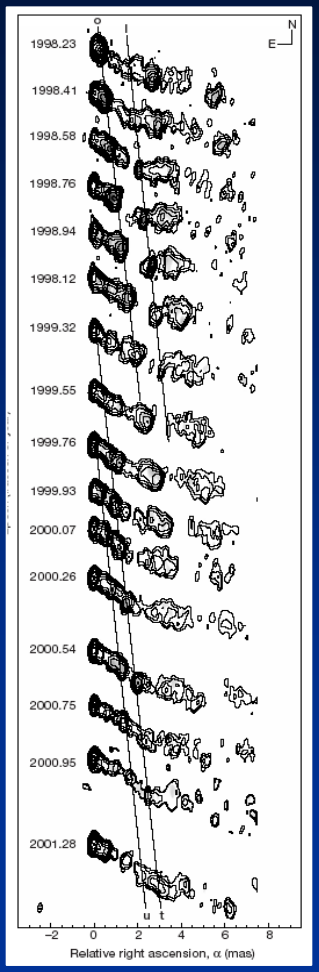
X-ray/Radio – the case of 3C 120

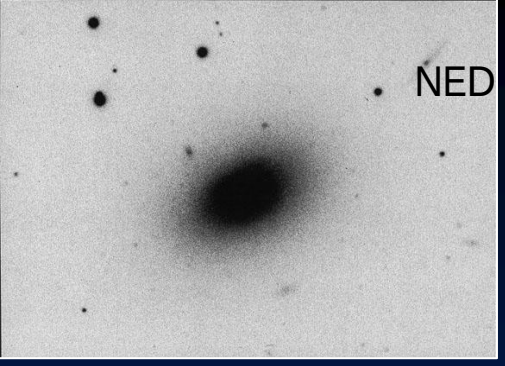
(Marscher et al. 2002)

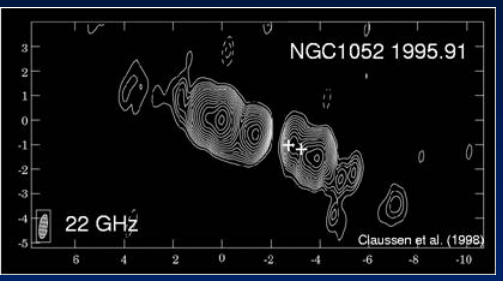
- The VLBI- and X-ray monitored galaxy 3C 120 exhibits X-ray flux "dips" prior to VLBI jet ejections (Marscher et al. 2002)

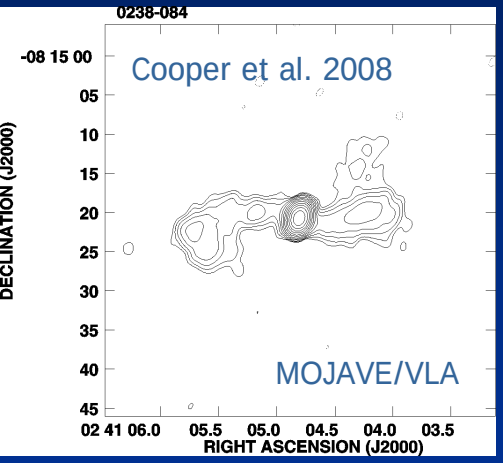
  ⇒ Observational link to study jet-disk coupling

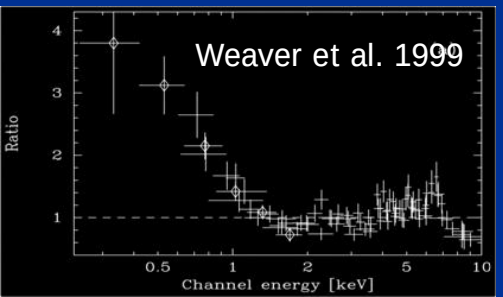








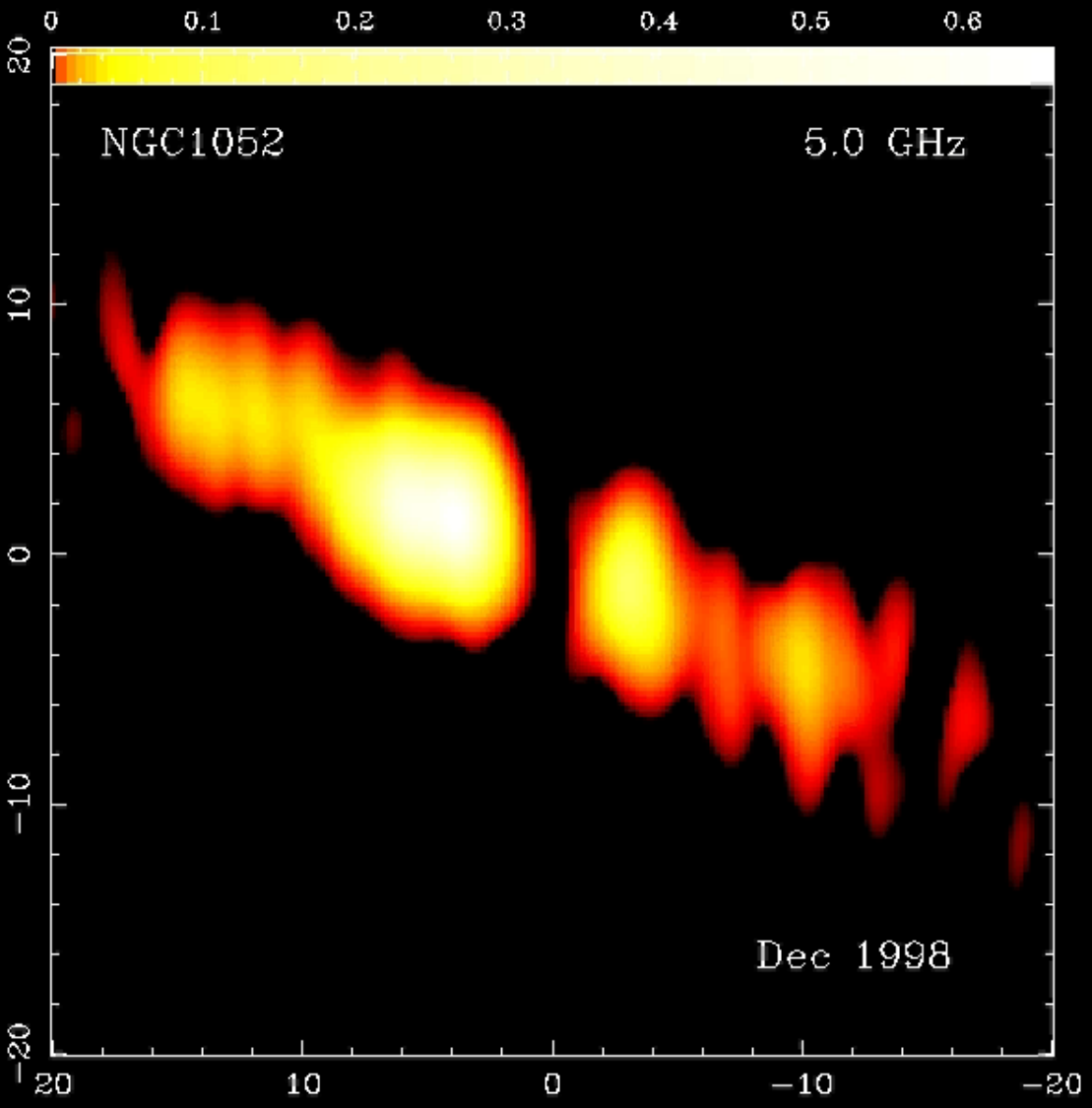




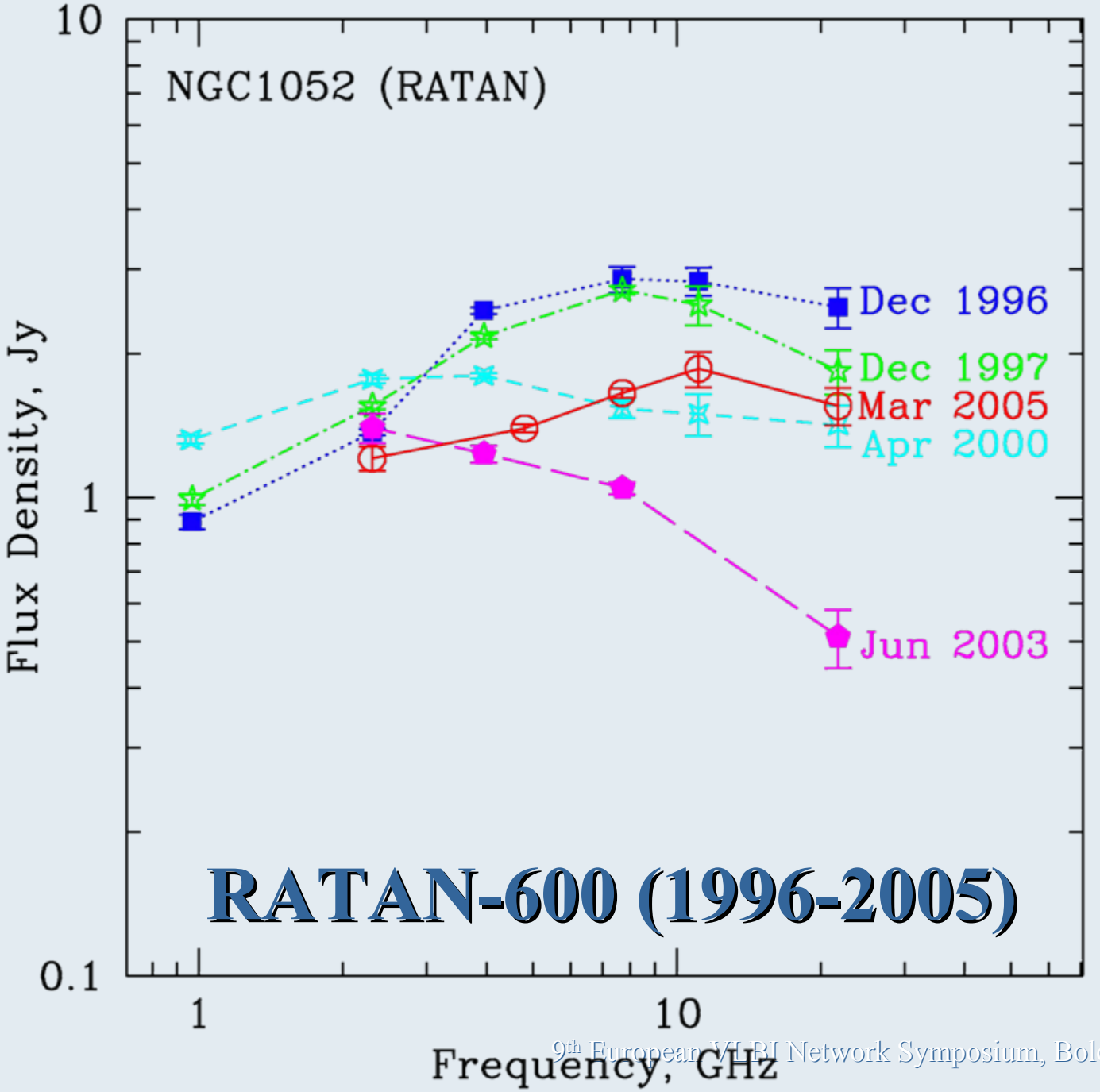
NGC 1052 – basic facts

- Elliptical, prototypical LINER galaxy (e.g., Mayall 1939, Fosbury et al. 1978, Barth et al. 1999)
- Nearby source (D=21.6Mpc) ! High linear resolution
- Twin-Jet System at VLA and VLBI scales, oriented close to the plane of the sky (e.g., Vermeulen et al. 2003, Cooper et al. 2008)
- H_2O maser emission along the western jet (Claussen et al. 1998, Sawada-Satoh et al. 2008)
- Evidence for an obscuring torus (Kellermann et al. 1999, Kameno et al. 2001, Kadler et al. 2004)
- Unusually flat X-ray spectrum (Weaver et al. 1999, Guainazzi et al. 1999, Guainazzi et al. 2001) and soft excess

The obscuring torus in NGC 1052



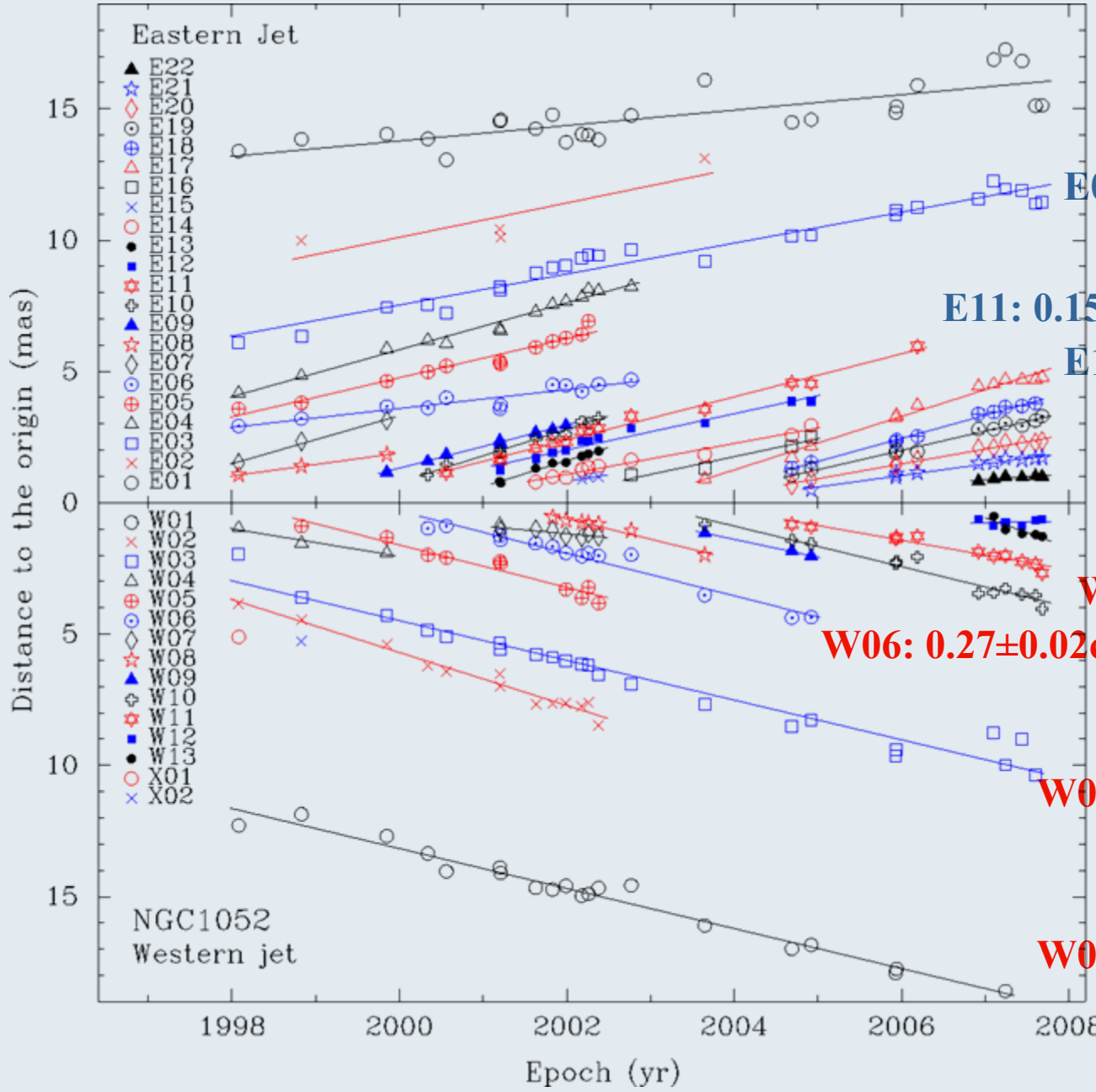
M. Kadler et al. (2004)



RATAN-600 (1996-2005)

14 years of 2cm Survey/ MOJAVE Monitoring

2 cm VLBA Kinematics



E01: 0.15±0.06c

E03: 0.27±0.01c

E11: 0.15±0.06c

E17: 0.34±0.01c

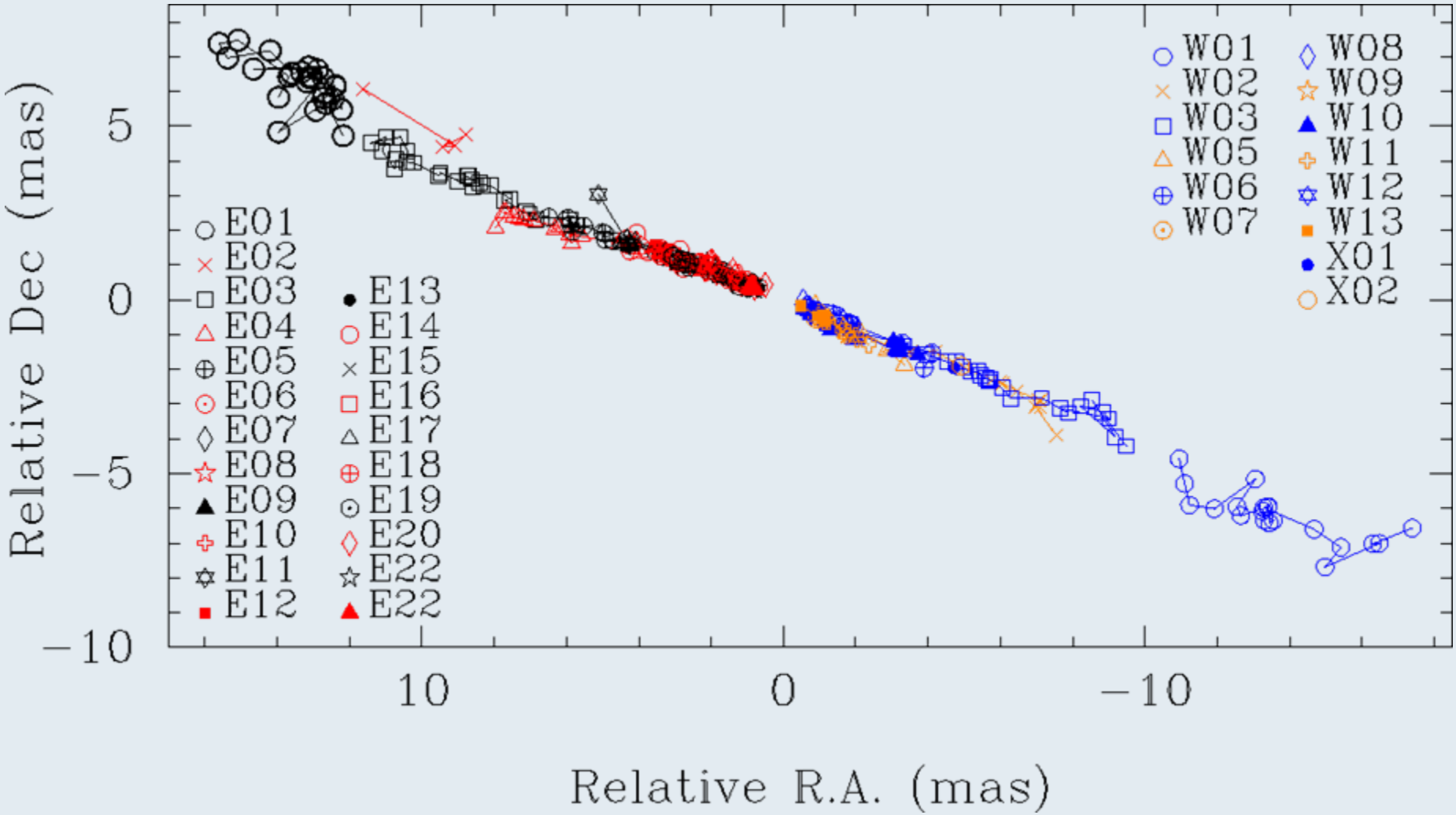
W11: 0.18±0.02c

W06: 0.27±0.02c

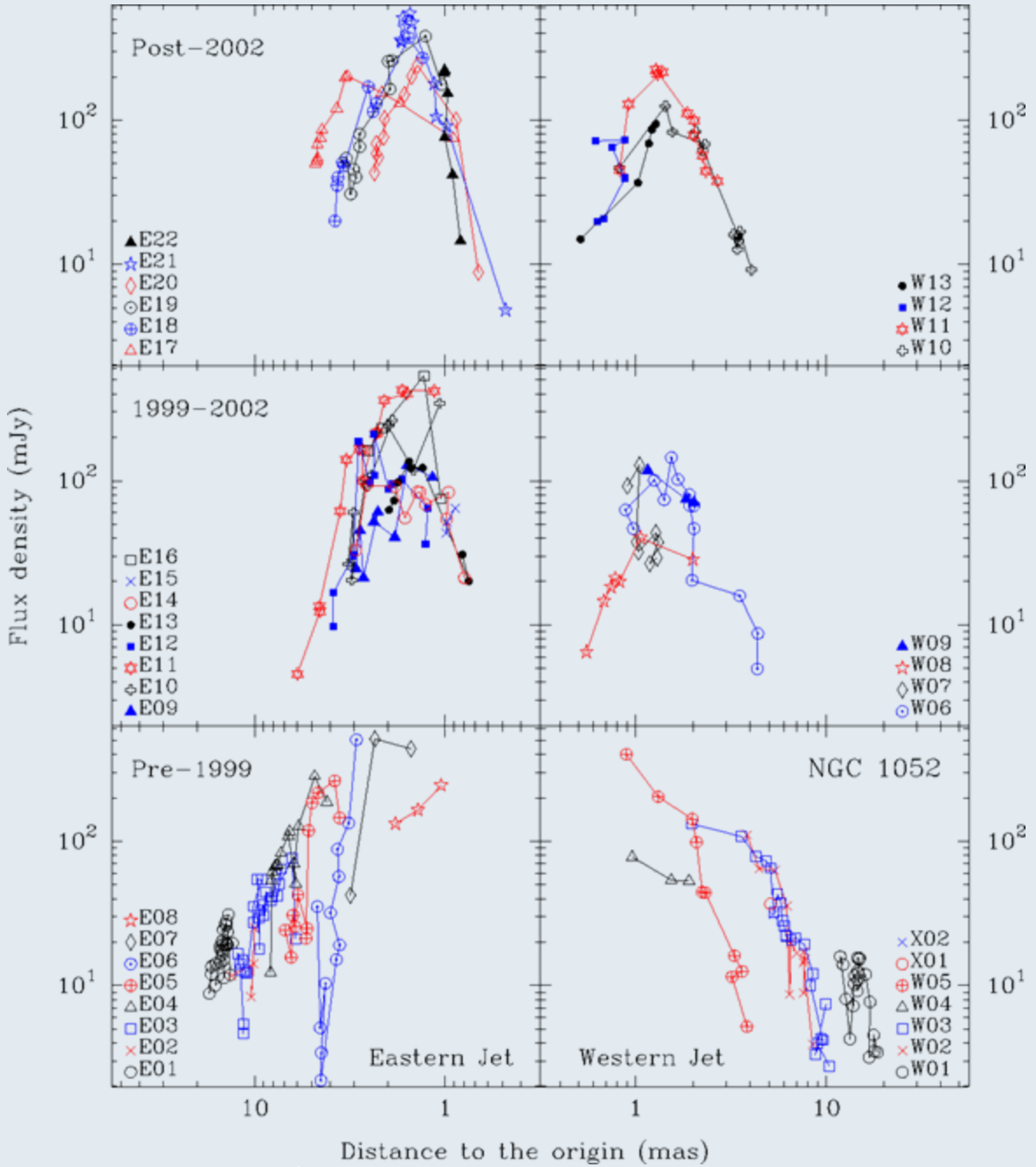
W03: 0.25±0.01c

W01: 0.25±0.01c

2 cm VLBA Model Fits: Stacked positions



2 cm VLBA Model Fits: Flux density vs. core distance

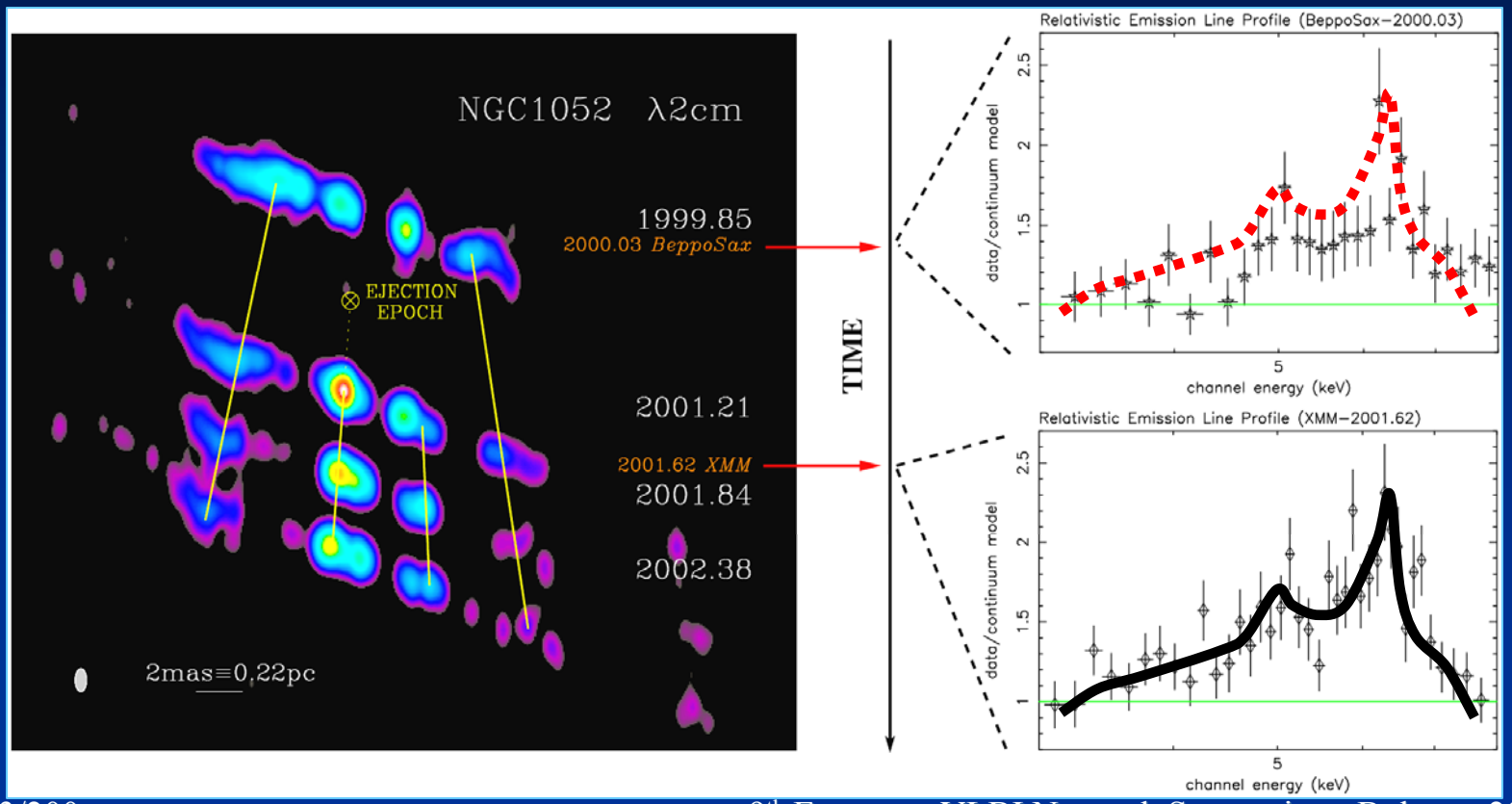


2cm observations since 1995

- Aparent speeds of 0.26c in jet and counter-jet
- Orientation angle: »70± to the LoS
- Obscuring torus in the central region, up to 0.2 pc over the receding jet
- Ejection of new jet components every 3-6 months corresponding to flux density outbursts

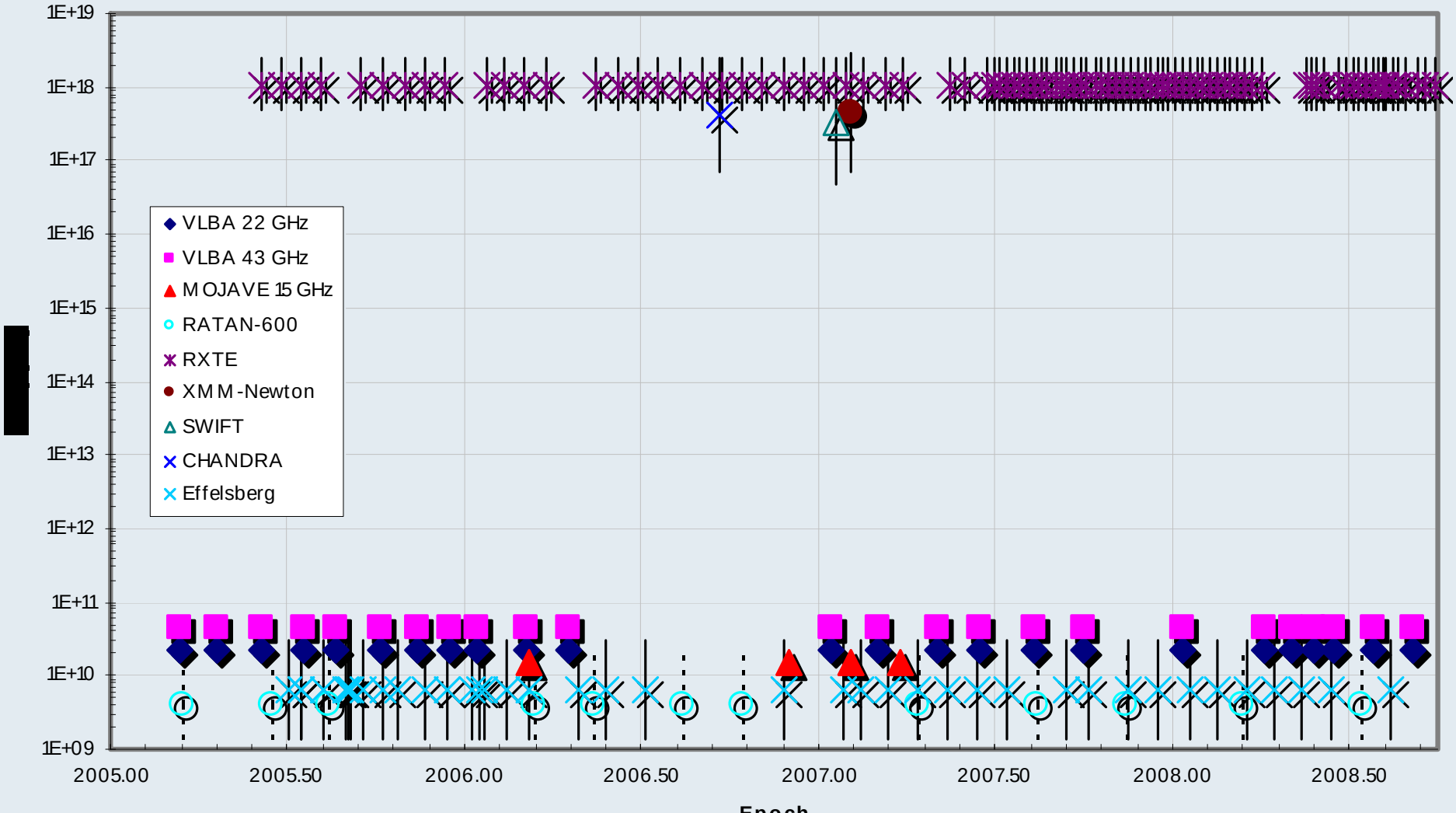
Accretion-ejection event ~2001.0

- Variable relativistic broad iron line profile before and after a VLBI component ejection



Kadler (2005), Kadler et al. (in preparation)

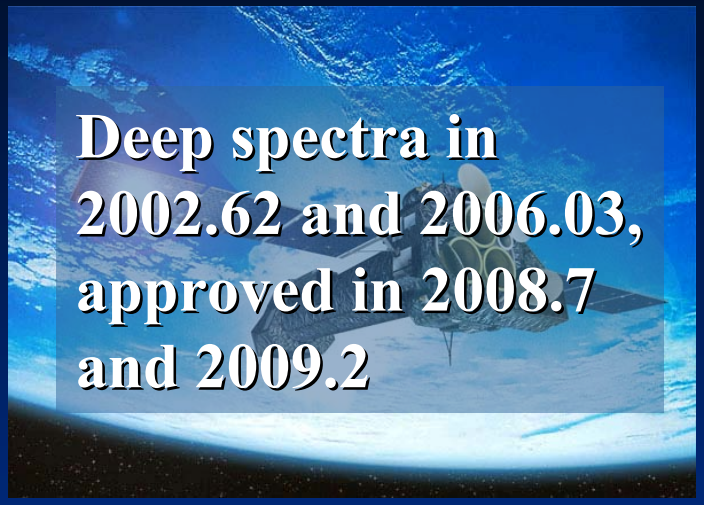
Multi-band campaign
Time sampling



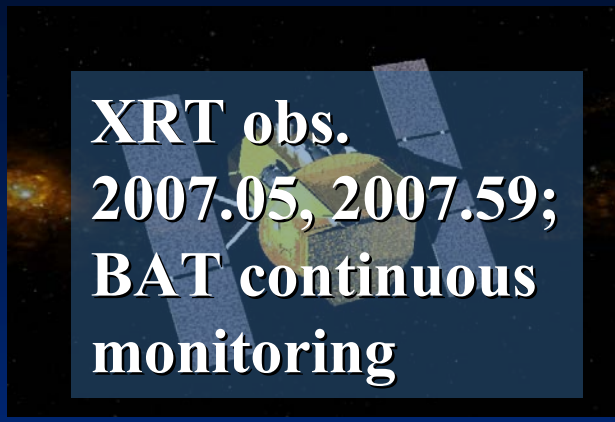
X-Ray Monitoring & Spectra

Once every three weeks until 2007.4 and weekly since then

Rossi X-ray Timing Explorer (RXTE)
Launch 12/1995



XMM-Newton
Launch 12/1999



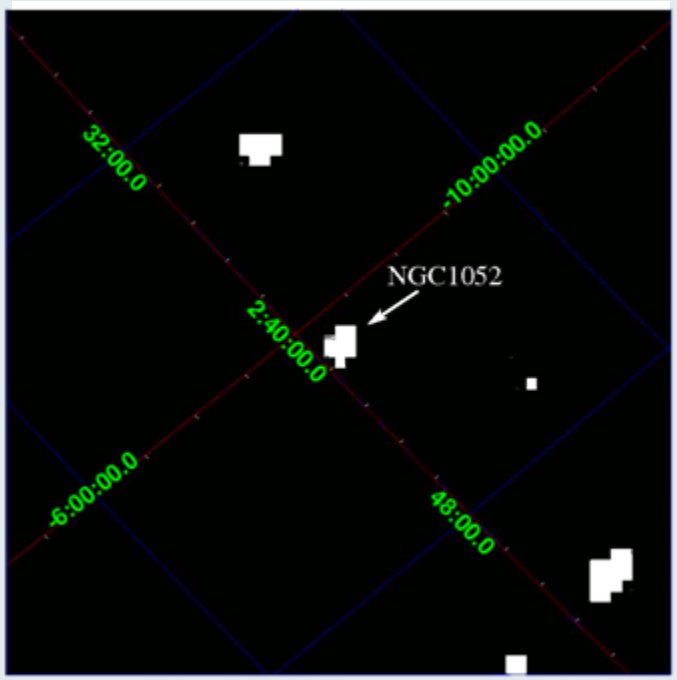
Swift
Launch 11/2004

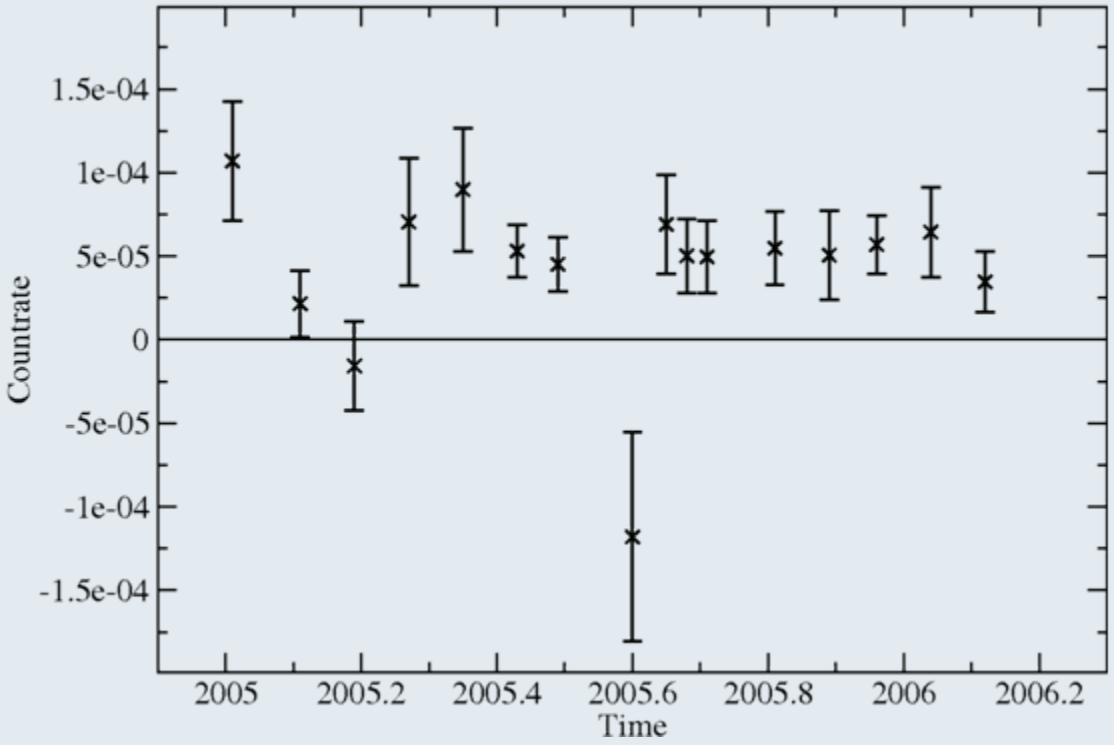
Chandra
Launch 07/1999

Suzaku (ASTRO-E2)
Launch 07/2005

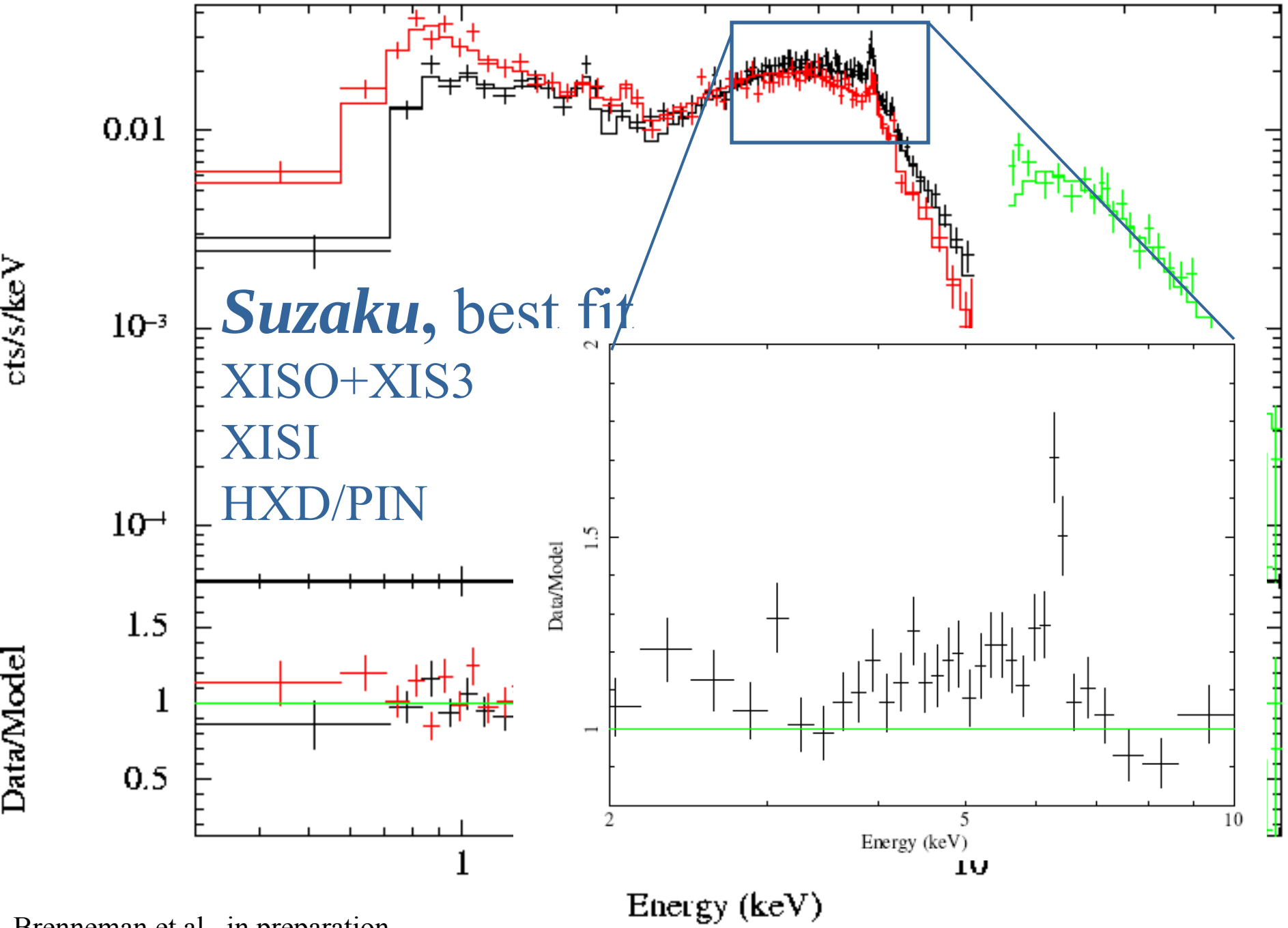
Swift Results (hard X-rays)

P.I.: N. Gehrels, Analysis: J. Tueller (GSFC)



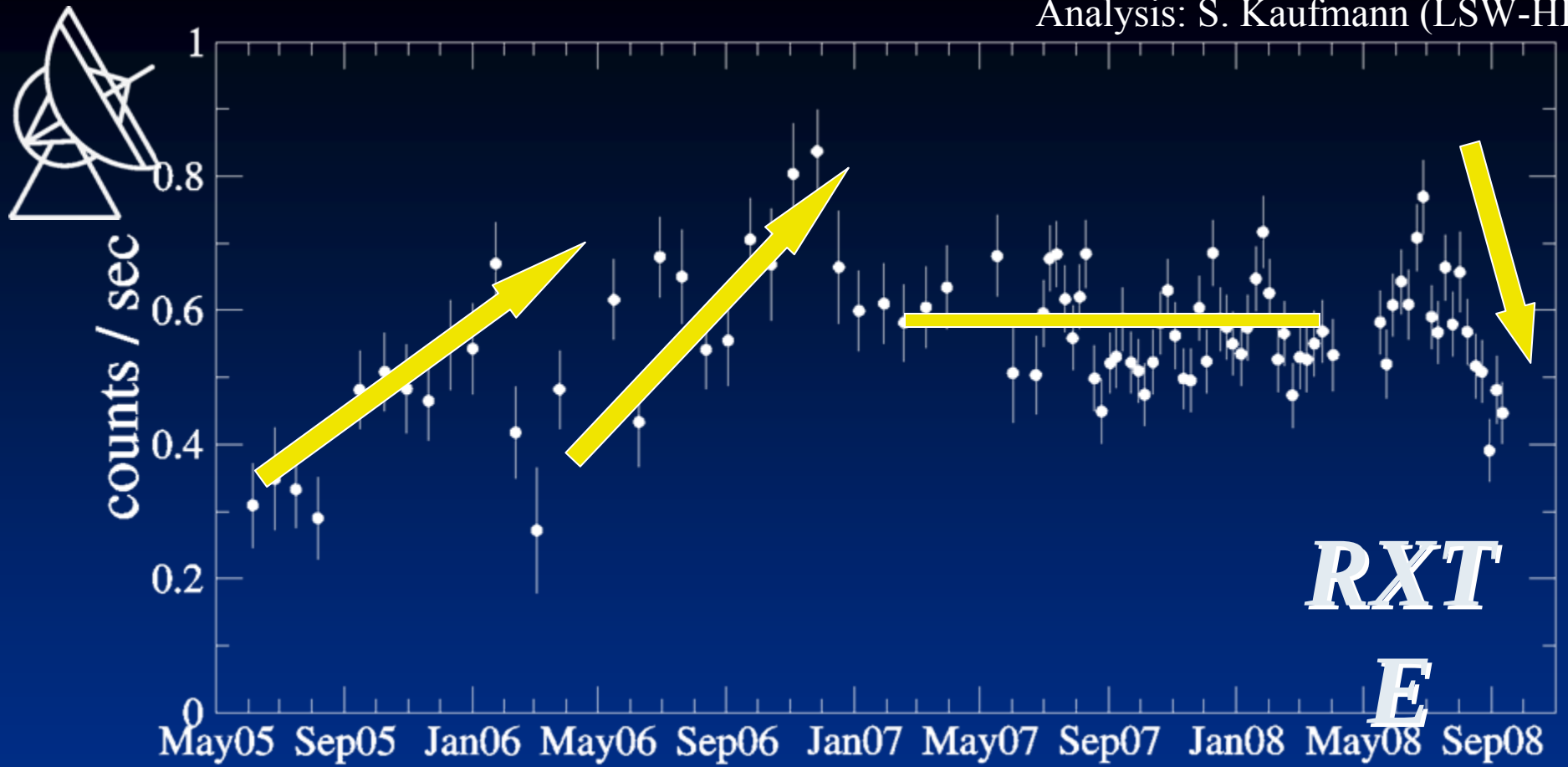


- 15-150 keV image and lightcurve with the BAT camera onboard the *Swift* GRB satellite



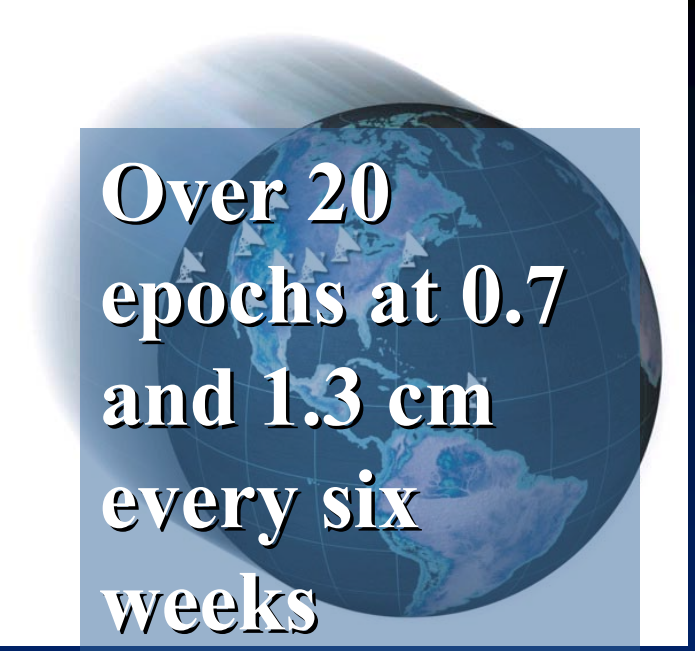
Brenneman et al., in preparation

Analysis: S. Kaufmann (LSW-HD



- Rising flux in late 2005 and late 2006
- Variable, non-flaring state since early 2007
- Dip in mid 2008 (new radio flare coming?) !

Radio Monitoring



Over 20 epochs at 0.7 and 1.3 cm every six weeks

Very Long Baseline Array

Frequent measurements at 15, 8 and 5 GHz

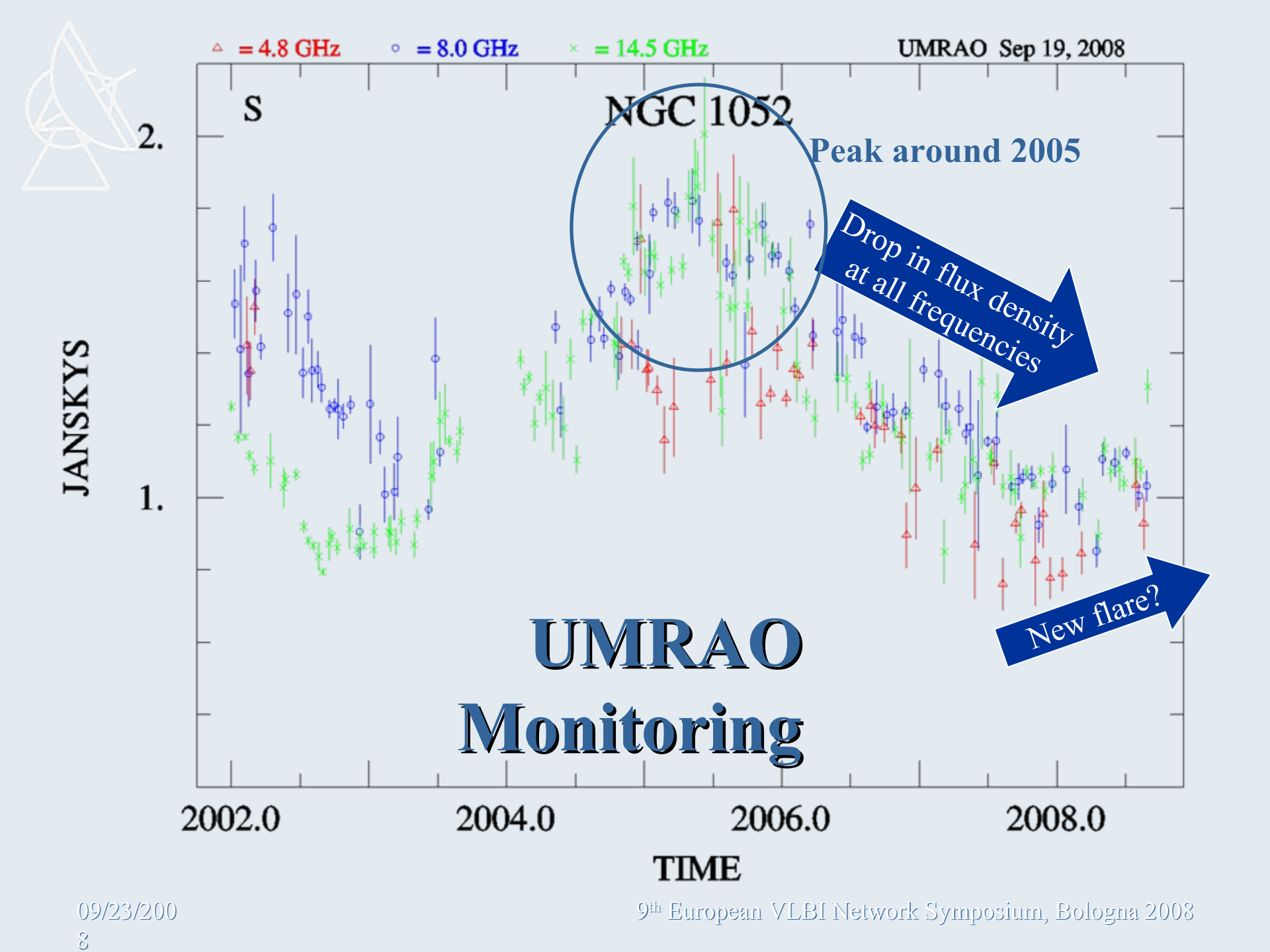
University of Michigan Radio Astronomy Observatory

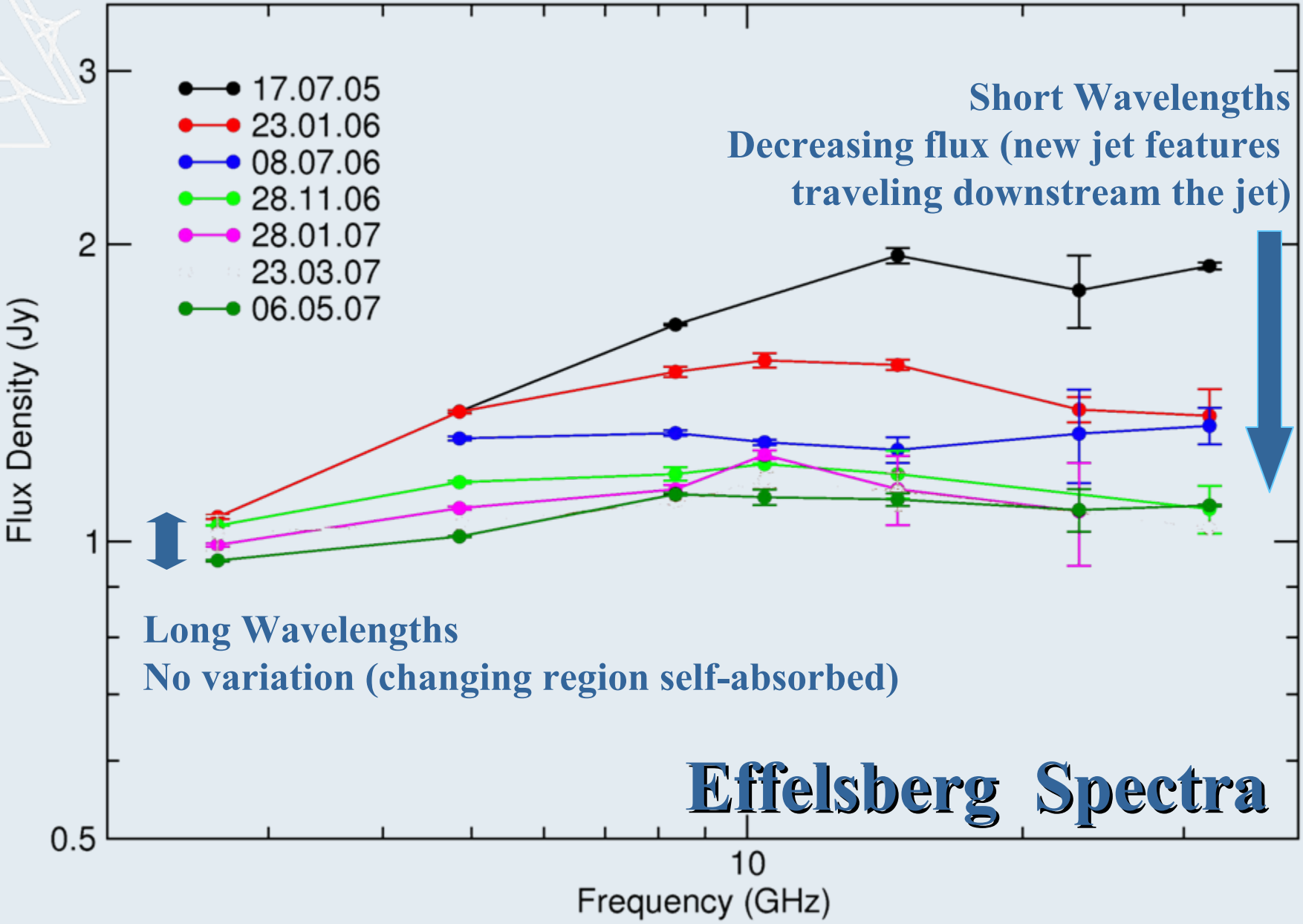
Effelsberg 100-m

Seven frequencies (from 1.4 to 30 GHz) every six weeks

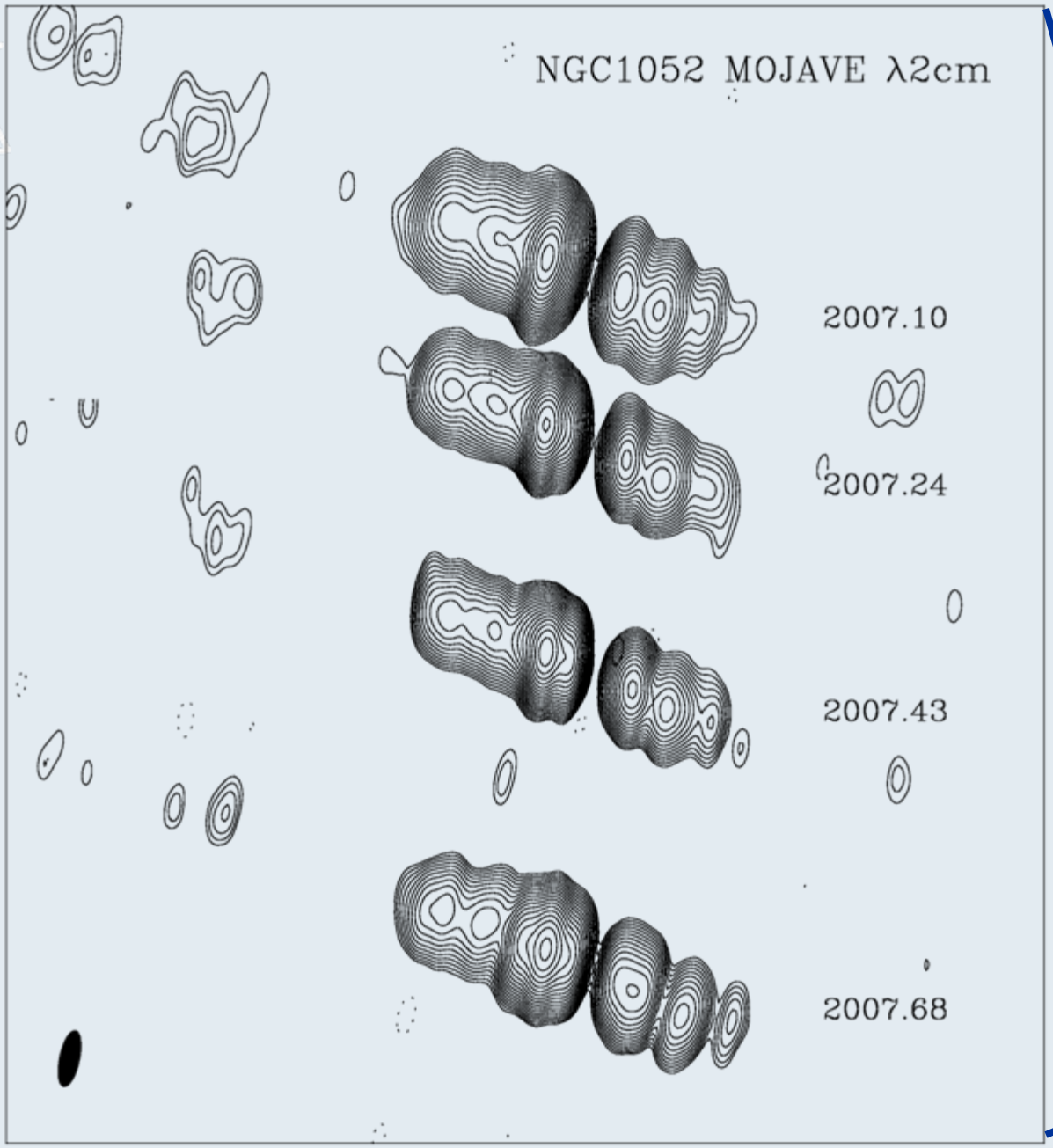
RATAN-600

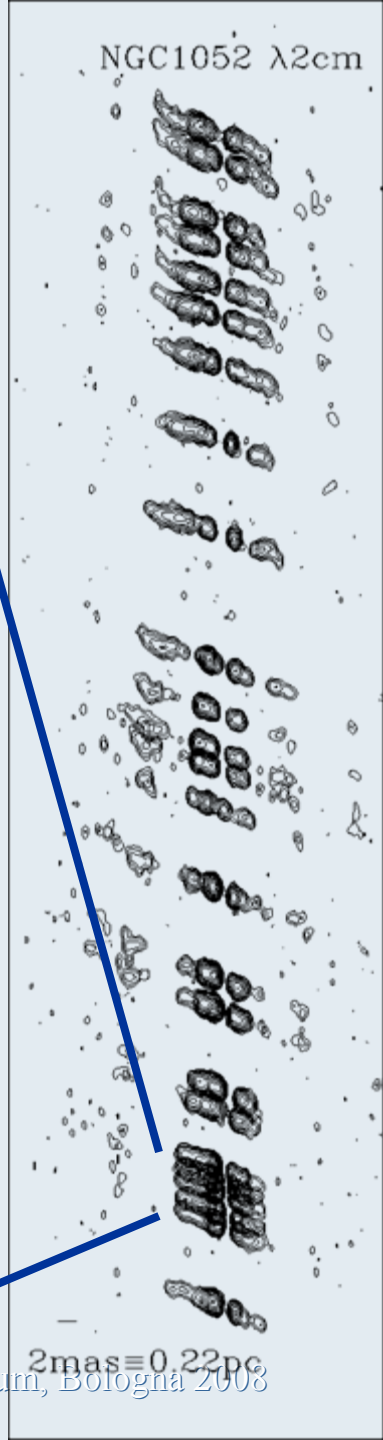
Six frequencies (from 1 to 22 GHz) every four months


= 4.8 GHz
= 8.0 GHz
= 14.5 GHz
UMRAO Sep 19, 2008
S
NGC 1052
Peak around 2005
Drop in flux density at all frequencies
New flare?
UMRAO Monitoring
JANSKYS
2.
1.
2002.0
2004.0
2006.0
2008.0
TIME

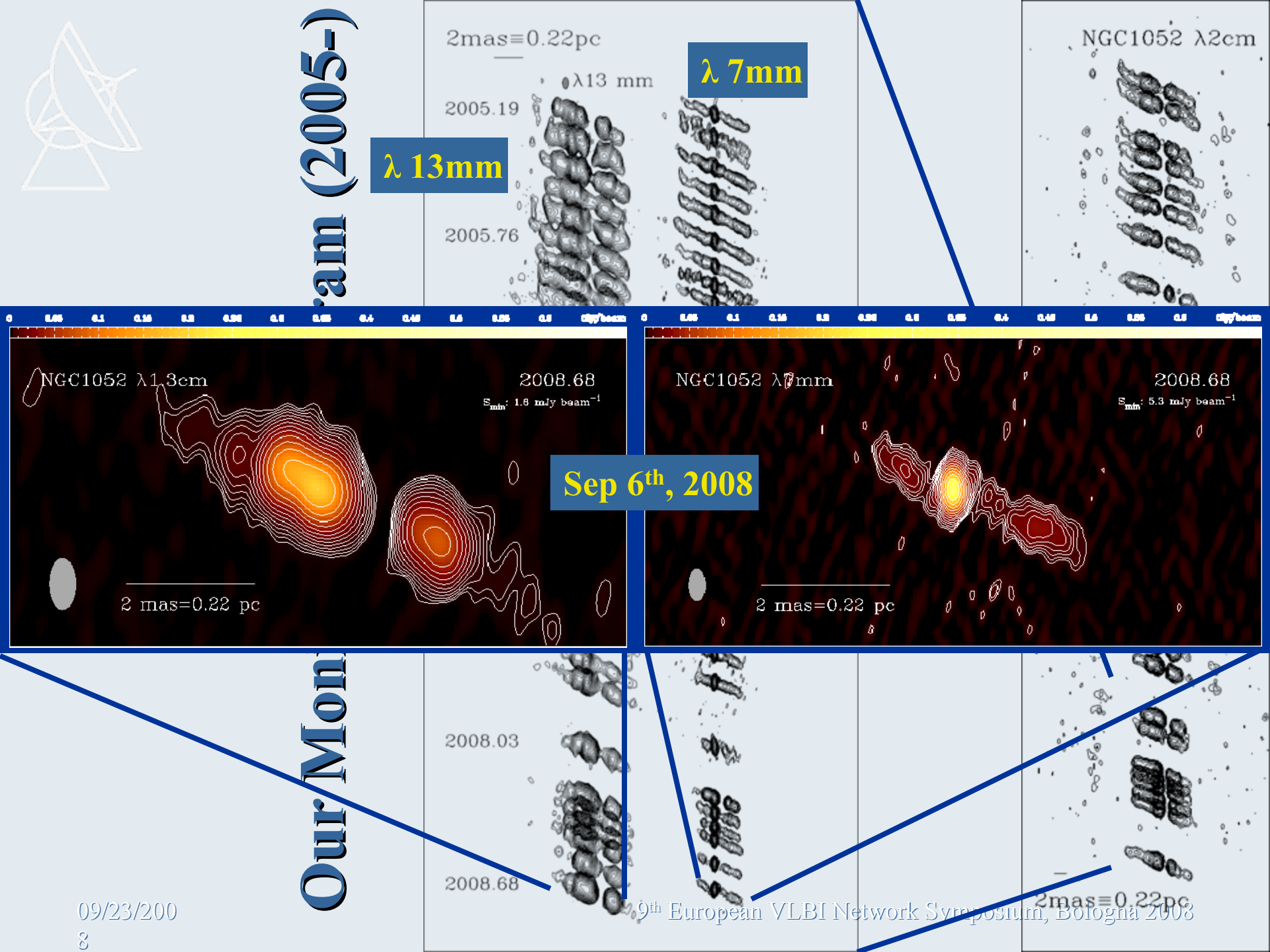

17.07.05
23.01.06
08.07.06
28.11.06
28.01.07
23.03.07
06.05.07
Short Wavelengths
Decreasing flux (new jet features
traveling downstream the jet)
Long Wavelengths
No variation (changing region self-absorbed)
Effelsberg Spectra
Flux Density (Jy)
Frequency (GHz)
3
2
1
0.5
10

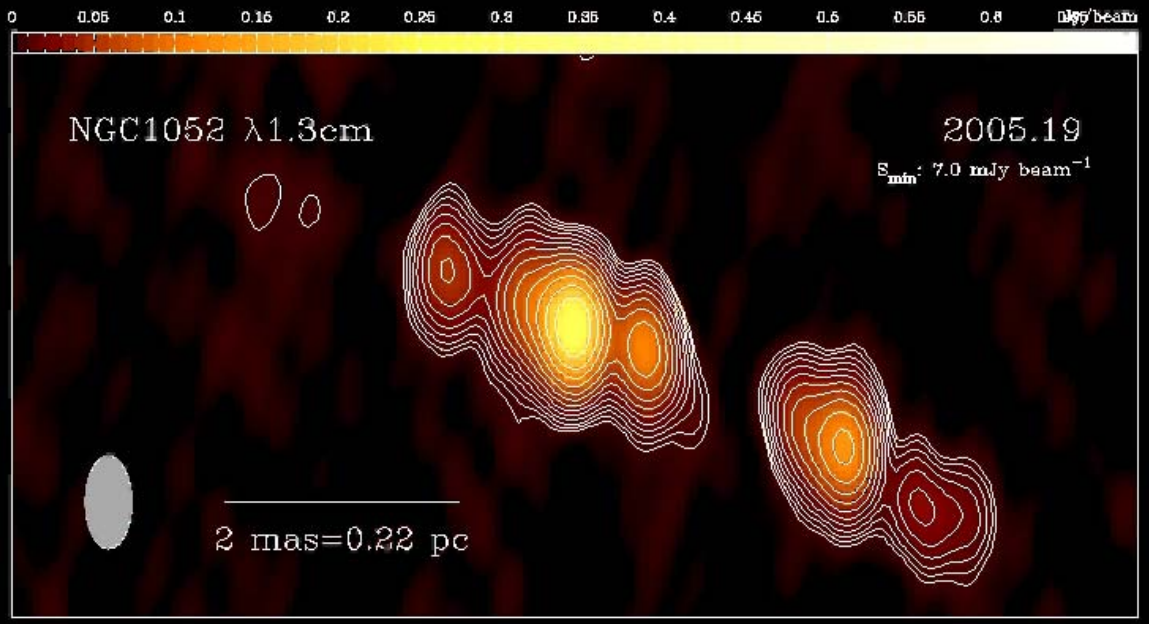
MOJAVE (2007 Epochs)

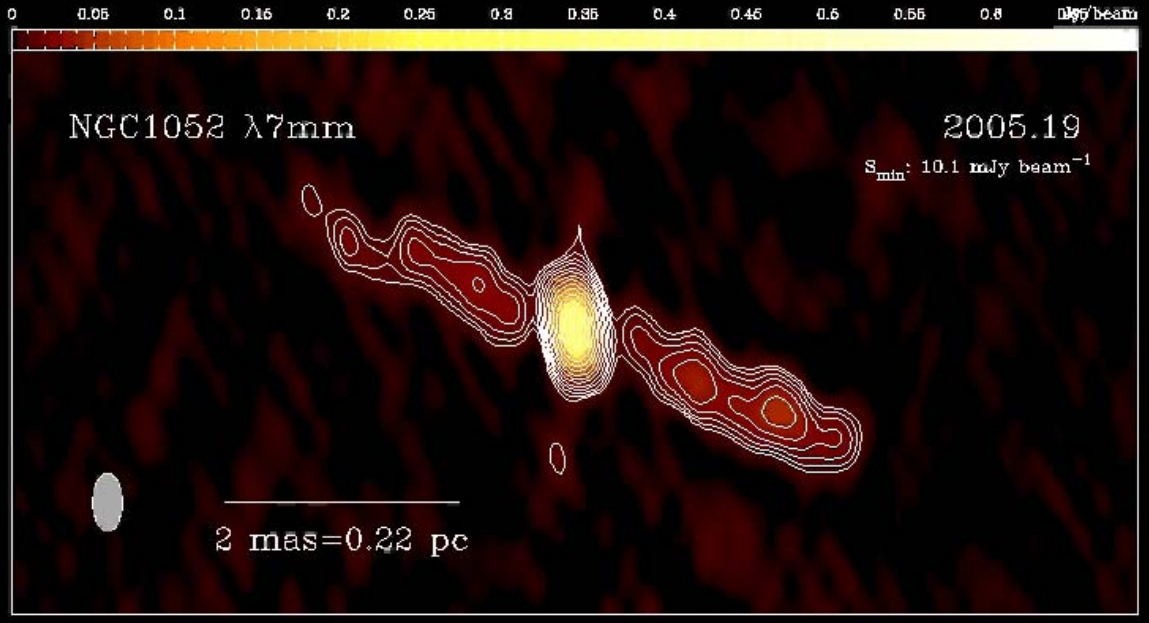




Our Monitoring Program (2005-)




0 0.05 0.1 0.15 0.2 0.25 0.3 0.35 0.4 0.45 0.5 0.55 0.6
NGC1052 λ1.3cm
2005.19
S_{min}: 7.0 mJy beam^{-1}
2 mas=0.22 pc


0 0.05 0.1 0.15 0.2 0.25 0.3 0.35 0.4 0.45 0.5 0.55 0.6
NGC1052 λ7mm
2005.19
S_{min}: 10.1 mJy beam^{-1}
2 mas=0.22 pc

Campaign preliminary results

- Quiet radio phase without bright ejections since 2005
- Two new radio components appear at the base of both jets, beginning to be visible after 03/2006
- Dramatic drops in X-ray flux in 02/2006, 11/2006 and 08/2008 – if similar to 3C 120, new jet components are expected (being patient!)
- UMRAO light curve shows beginning of new flare

Future work

- Astrometric registration of images, to identify the core and the optically thin features
- Detailed kinematics at 13 and 7mm wavelengths, combined with the MOJAVE results
- X-ray monitoring continues; more XMM observations approved
- 5 VLBA epochs at 7 and 13 mm in the queue
- Completion of campaign through 2008 and 2009

Summary

- X-ray Spectra: Significant Continuum and Broad-Line Fe Kα variability
- X-ray light curve: rising stages and dips, changes at the radio quiescent phase
- Radio imaging: Changing sub-pc scale structure, no evidence for big ejections since 2005
- Radio light curve monitoring: after flux decline, hints of activity since late 2007
- Ongoing campaign to be continued through 2009