THE X-RAY VIEW OF MISALIGNED AGNs

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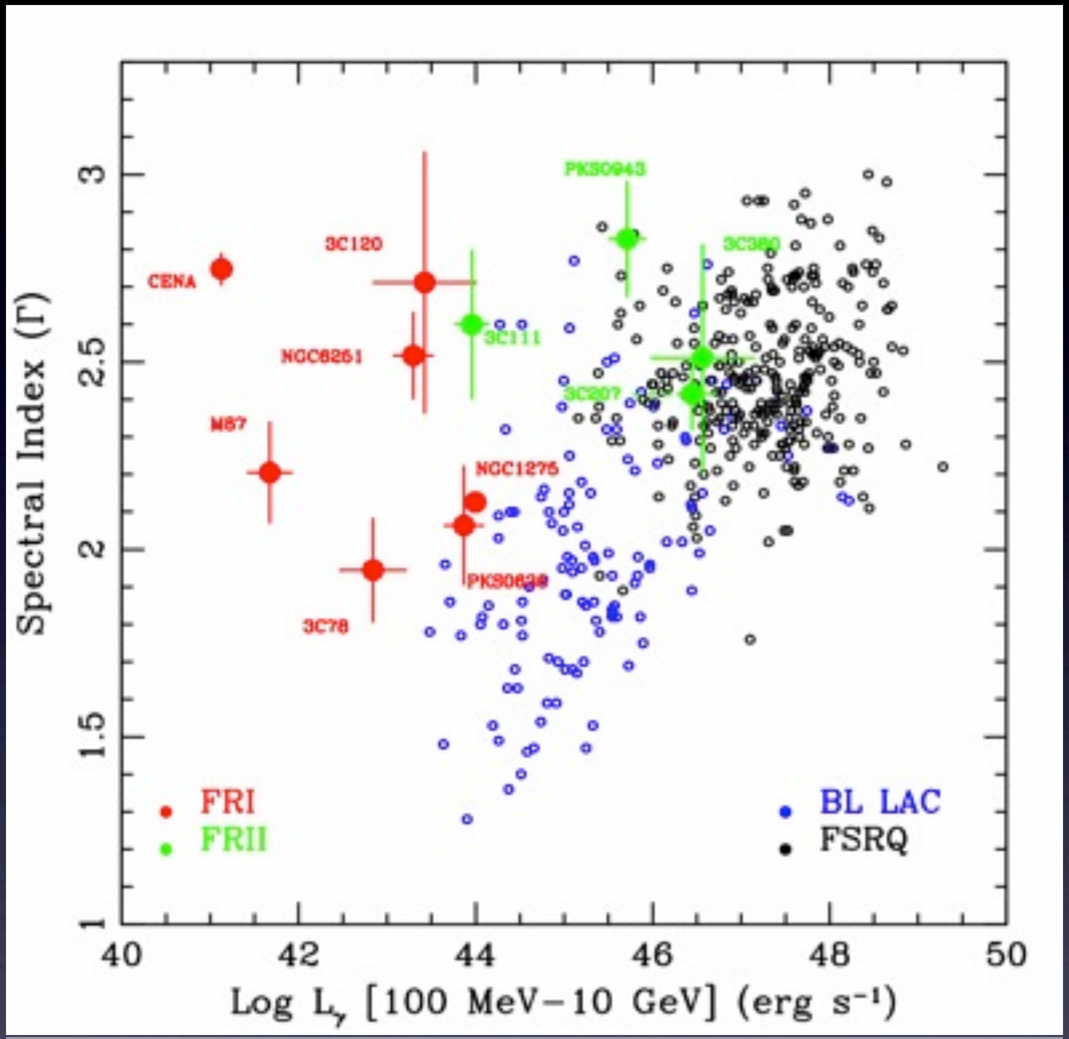
with many thanks to

Paola Grandi INAF/IASF Bologna

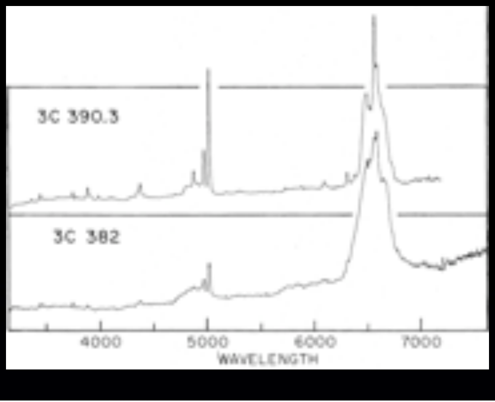
Fermi and Jansky: Our Evolving Understanding of AGN, St. Michaels, MD

MISALIGNED AGN (MAGN) *see P. Grandi's talk*

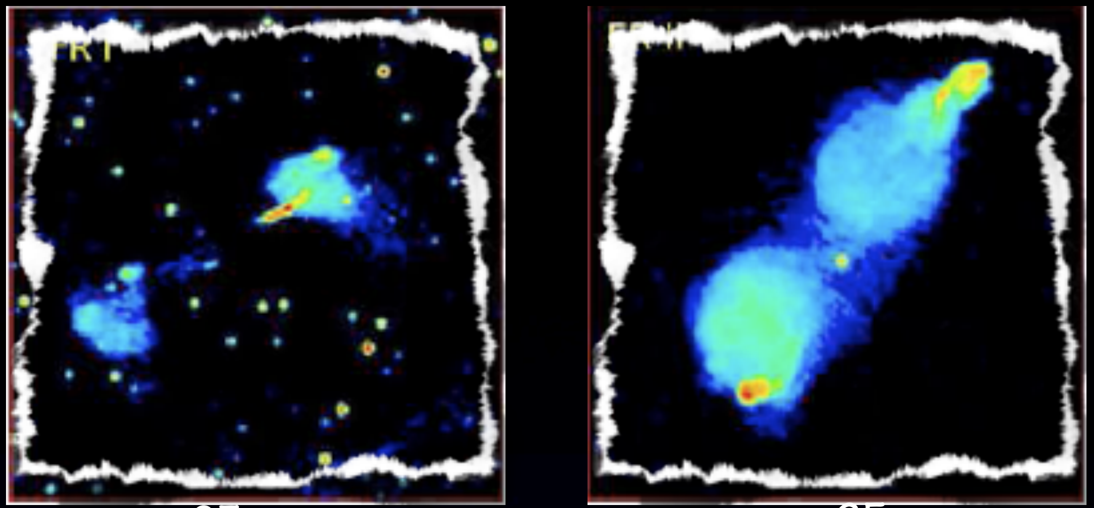
Sources with the jet pointed away from the observer



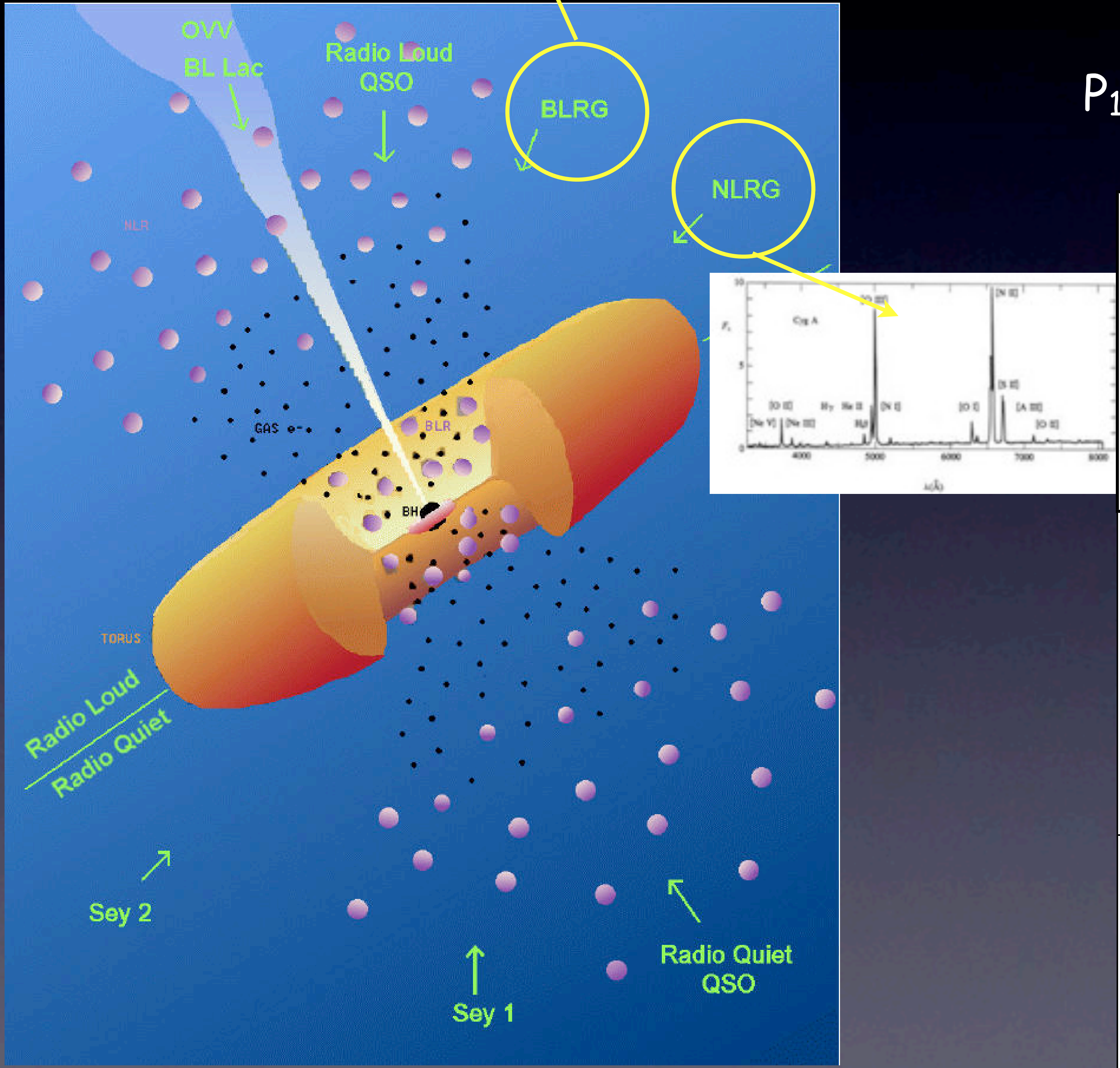
At zeroth order, the unified models of AGN identify FRIs and FRIIs with the parent population (the misaligned counterparts with respect to the jet direction) of BL Lacs and FSRQs.



Fanaroff & Riley 1974



$P_{178MHz}<10^{25}$ W Hz^{-1} sr^{-1} $P_{178MHz}>10^{25}$ W Hz^{-1} sr^{-1}



originally from Urry & Padovani 1995

BLRGs Broad Line Radio Galaxies	bright continuum and broad emission lines from hot high velocity gas	FRII
NLRGs/HEG Narrow Line Radio Galaxies/High Excitation Galaxies	weak continuum and only narrow emission lines	FRII
NLRGs/LEG Narrow Line Radio Galaxies/ Low Excitation Galaxies	narrow emission lines: $EW_{[OIII]}>10$ Å and/or O[II]/O[III]>1	FRII FRI

It is still unclear what causes the FRI/FRII dichotomy

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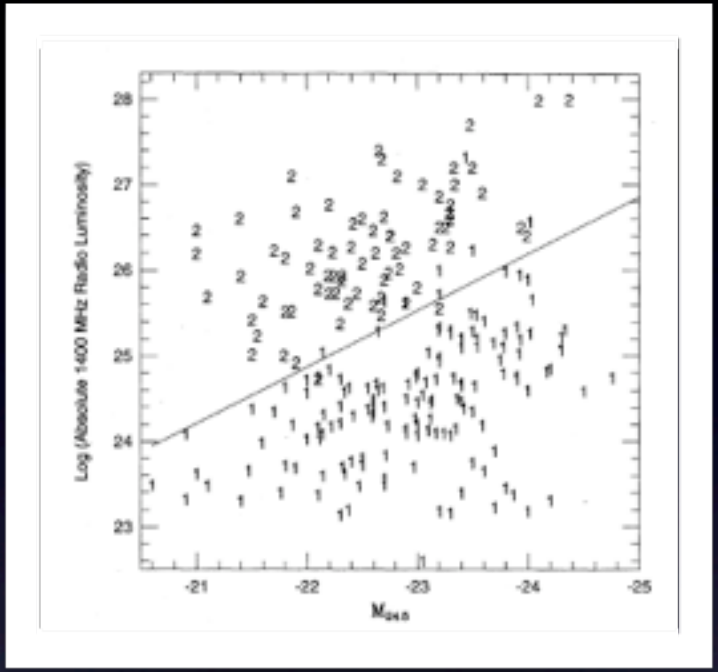
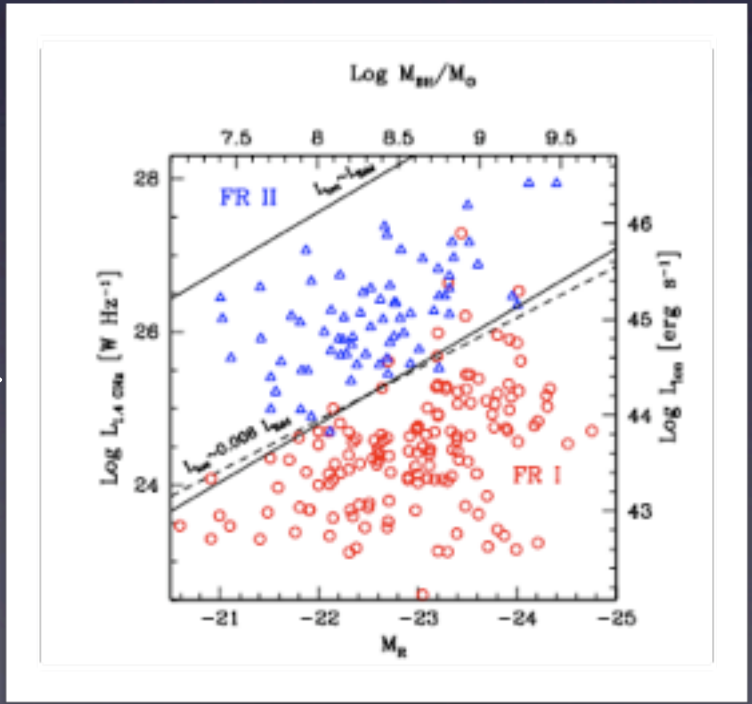
1) Ledlow & Owen (1994) found a correlation between the radio power at the FRI/FRII transition and the host galaxy magnitude



2) Bicknell 1995 points to different ways in which the jet interacts with the ambient medium: the FRI jets start highly relativistic and decelerate between the subpc and kpc scales

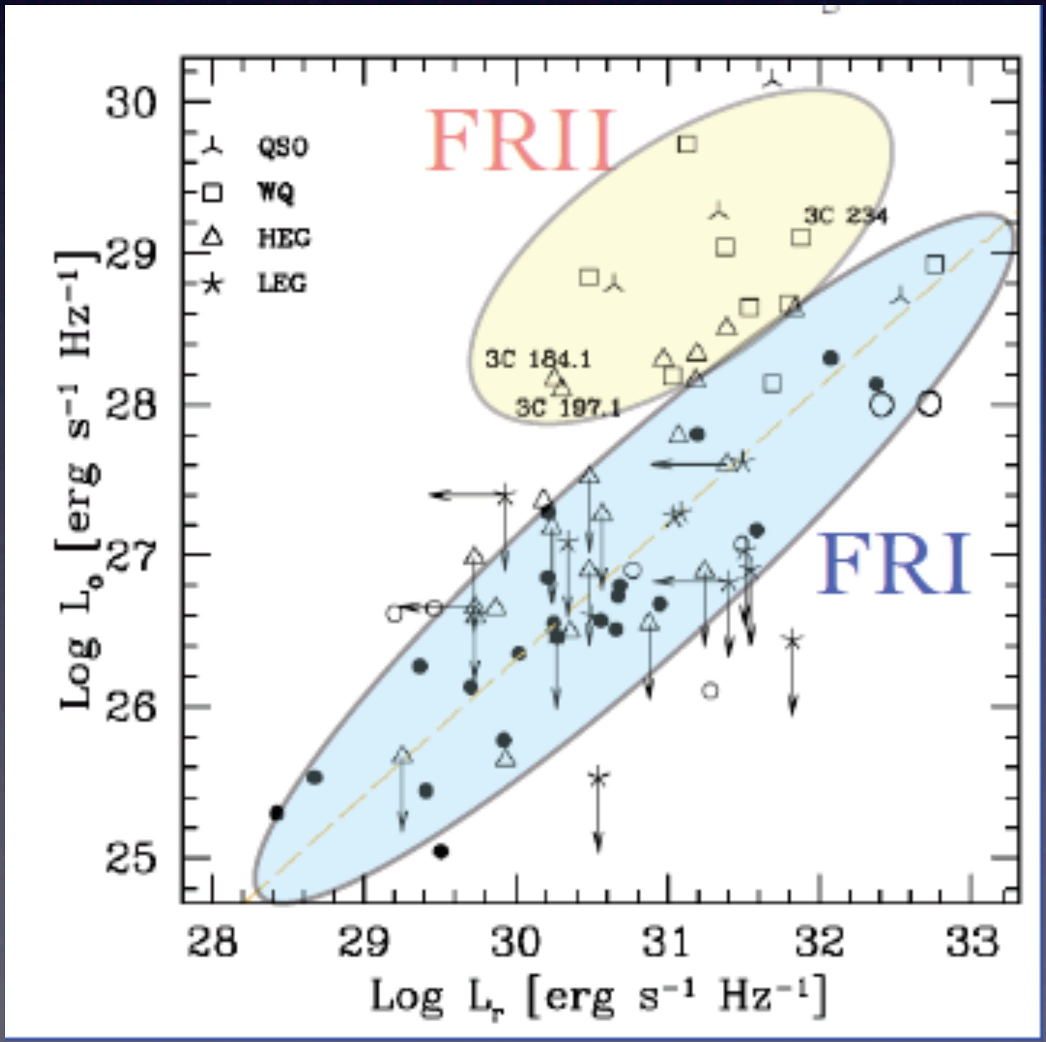
3) Baum et al. (1995) and Reynolds et al. (1996) suggest different nuclear intrinsic properties of the accretion and jet formation and the jet content

4) Ghisellini & Celotti (2001) indicate that the **accretion process** itself might play a key role in the deceleration and dichotomic behavior by affecting the pc-kpc scale environment

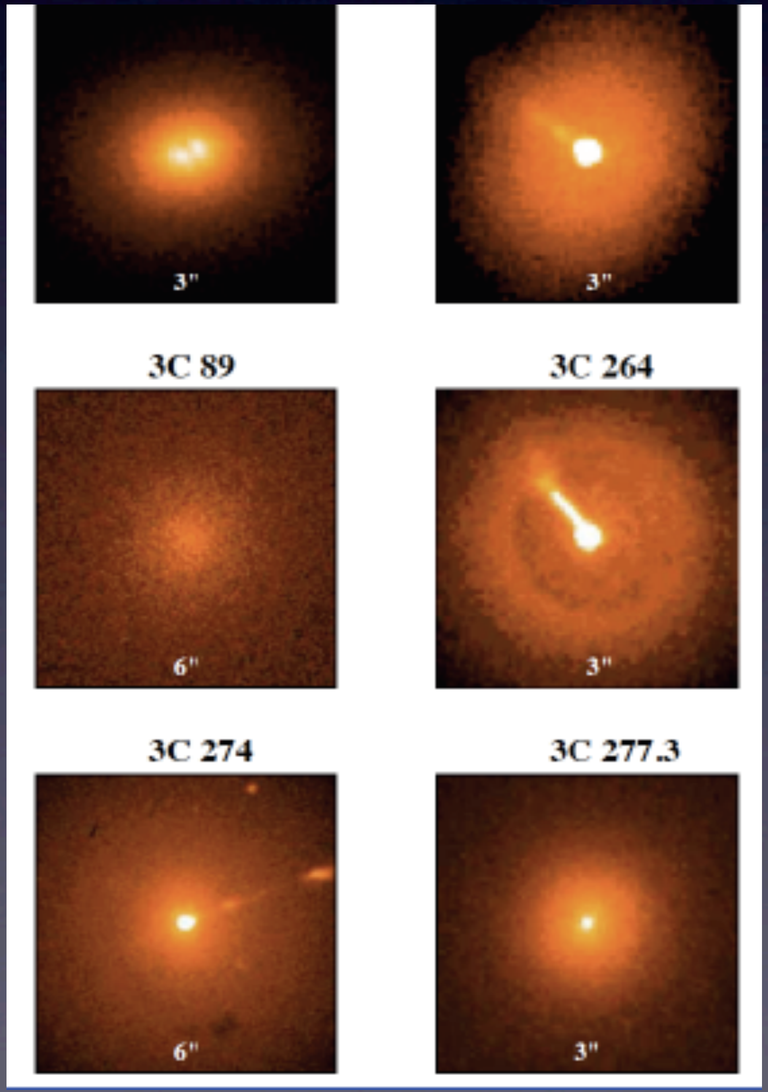


Optical observations seem to indicate that FRIs and FRIIs have different accretion regimes

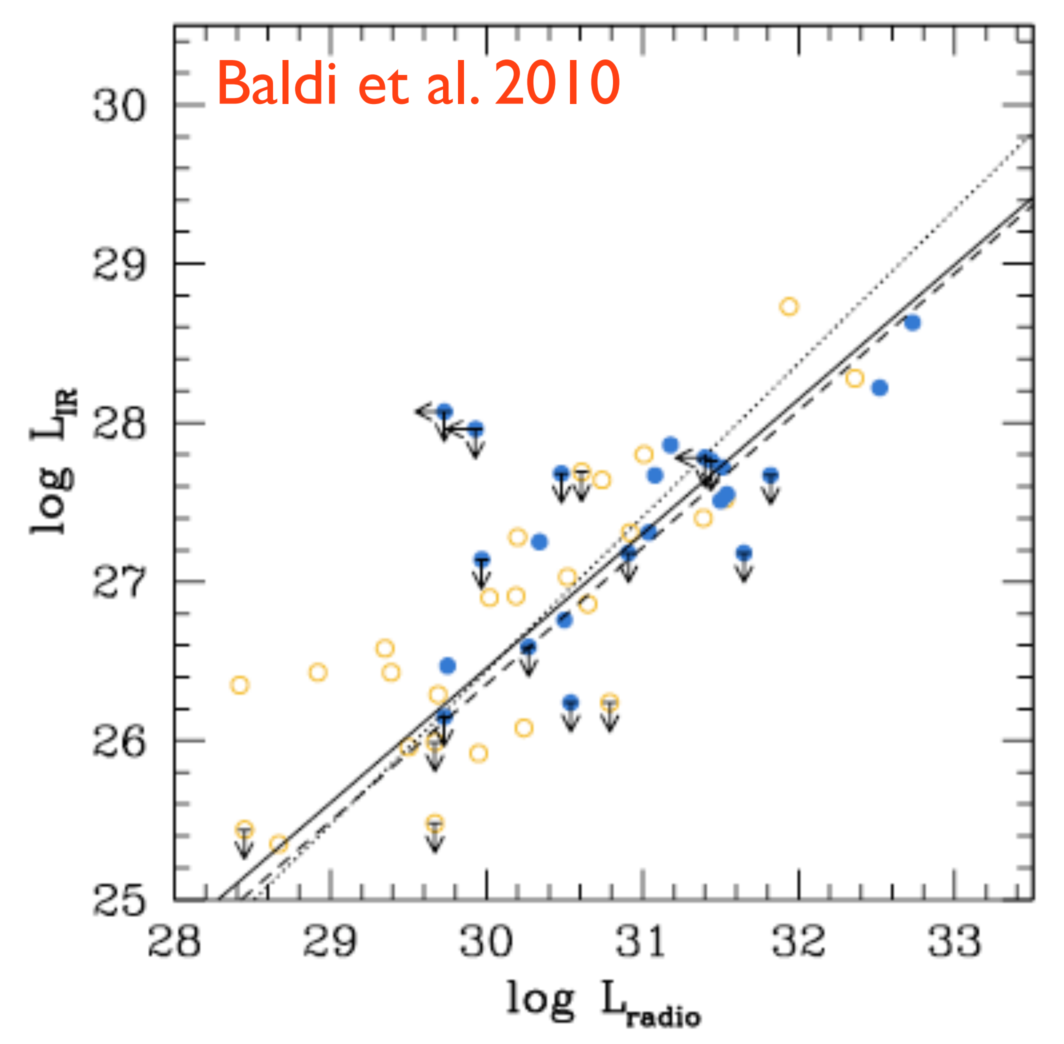
The optical flux of FRI shows a strong correlation with the radio core one over four decades, arguing for a non-thermal synchrotron origin of the nuclear emission (Chiaberge et al. 2002)



There is no nuclear absorption in FRI HST images. The weakness of the optical lines is not due to obscuration (Chiaberge et al. 2002)

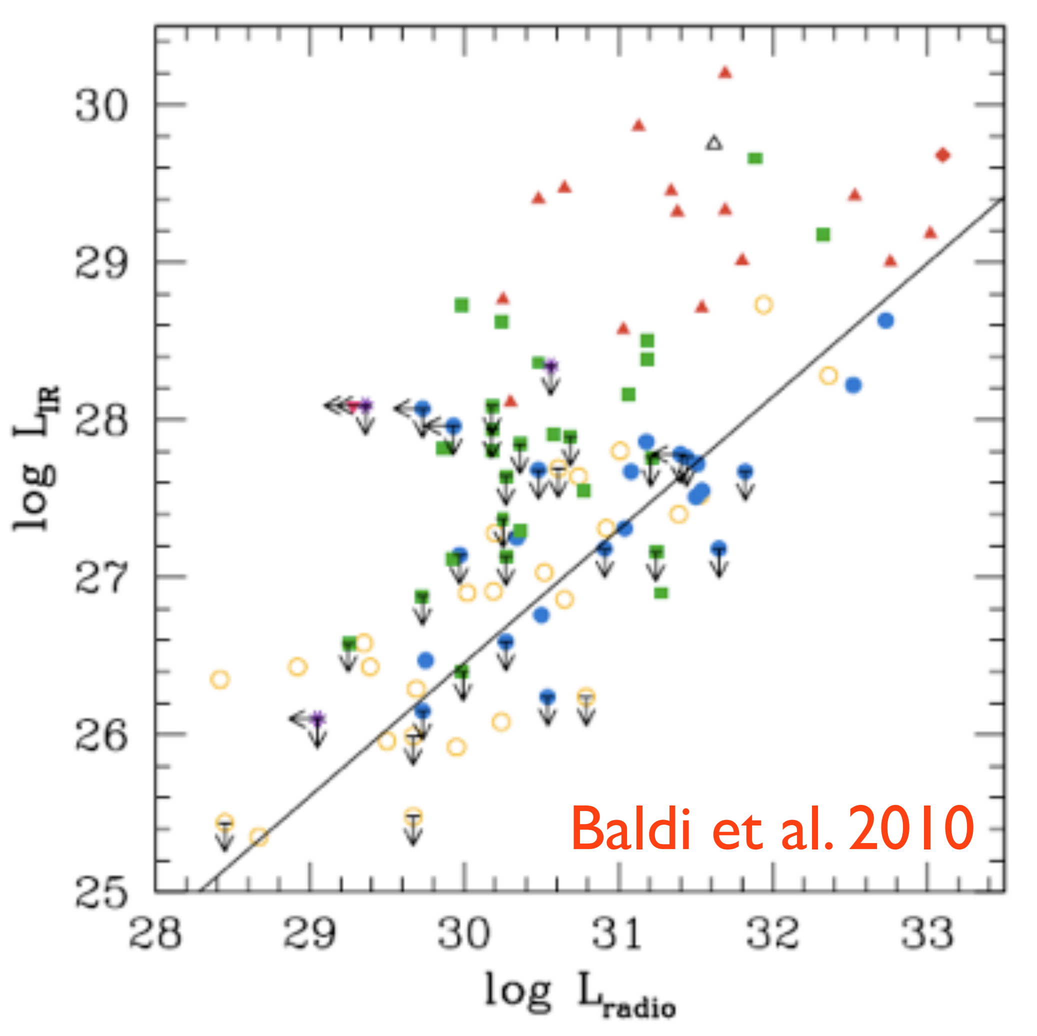


This scenario is also supported by IR observations



Baldi et al. 2010

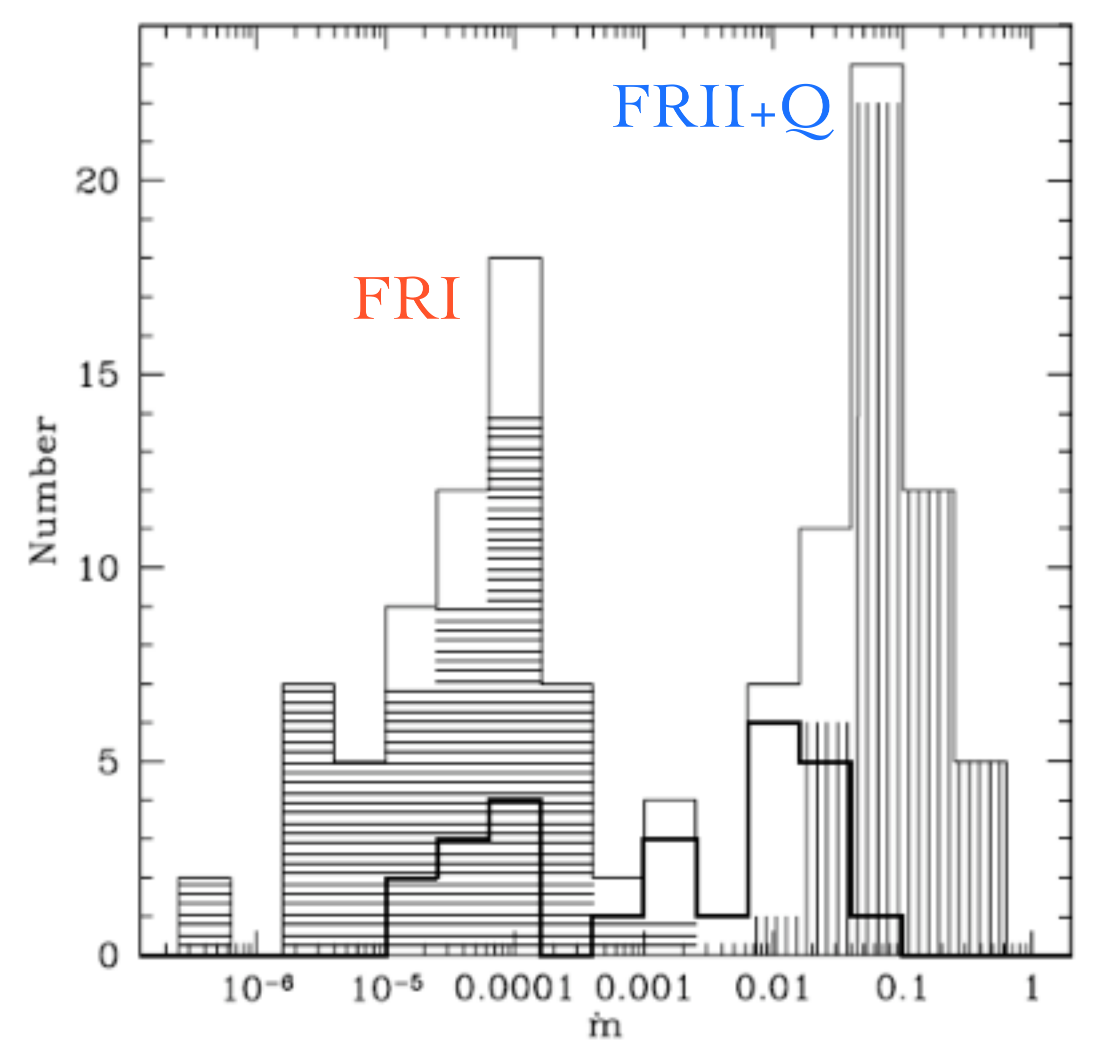
The NIR nuclear emission of FRIs has a non-thermal origin



Baldi et al. 2010

FRIIs show an unresolved NIR nucleus and a large NIR excess --> hot circumnuclear dust (dusty torus)

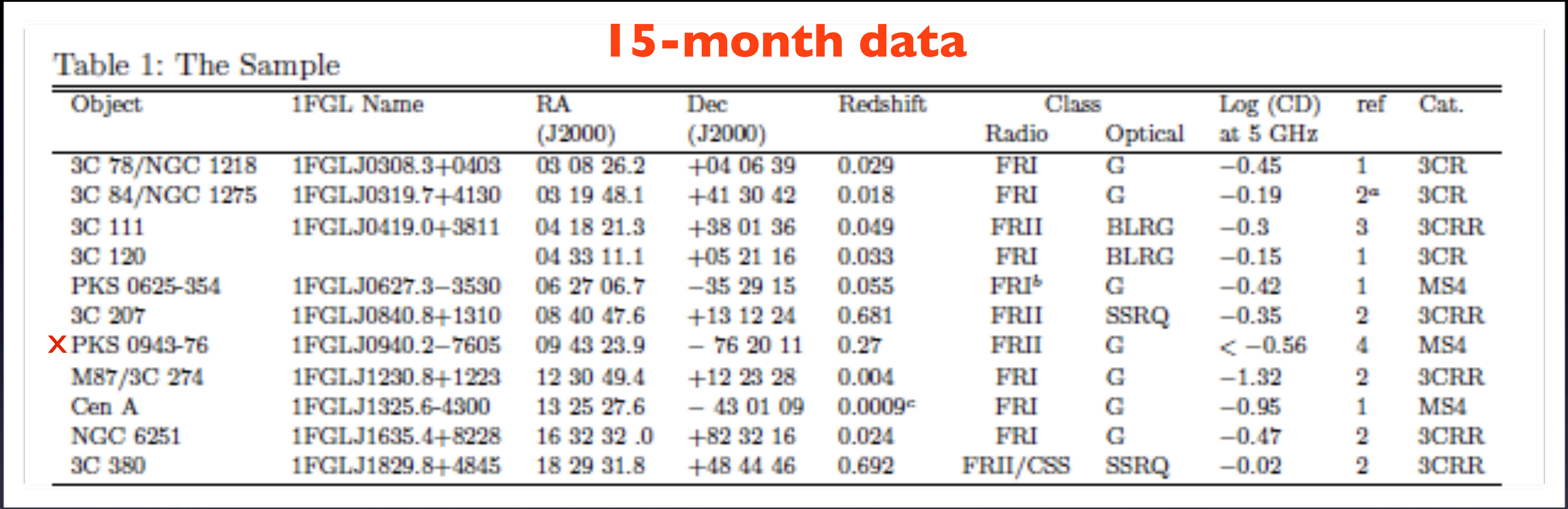
The accretion rate distribution is bimodal:
Low accretion rate => FRI
High accretion rate => FRII +Quasar



Marchesini et al. 2004

Investigate the X-ray spectral properties of MAGNs

→ direct study of the spectral behavior of the X-ray nuclei



15-month data

Table 1: The Sample

Object	1FGL Name	RA	Dec	Redshift	Class		Log (CD)	ref	Cat.
		(J2000)	(J2000)		Radio	Optical	at 5 GHz		
3C 78/NGC 1218	1FGLJ0308.3+0403	03 08 26.2	+04 06 39	0.029	FRI	G	−0.45	1	3CR
3C 84/NGC 1275	1FGLJ0319.7+4130	03 19 48.1	+41 30 42	0.018	FRI	G	−0.19	2^a	3CR
3C 111	1FGLJ0419.0+3811	04 18 21.3	+38 01 36	0.049	FRII	BLRG	−0.3	3	3CRR
3C 120		04 33 11.1	+05 21 16	0.033	FRI	BLRG	−0.15	1	3CR
PKS 0625-354	1FGLJ0627.3−3530	06 27 06.7	−35 29 15	0.055	FRI^b	G	−0.42	1	MS4
3C 207	1FGLJ0840.8+1310	08 40 47.6	+13 12 24	0.681	FRII	SSRQ	−0.35	2	3CRR
✗ PKS 0943-76	1FGLJ0940.2−7605	09 43 23.9	− 76 20 11	0.27	FRII	G	< −0.56	4	MS4
M87/3C 274	1FGLJ1230.8+1223	12 30 49.4	+12 23 28	0.004	FRI	G	−1.32	2	3CRR
Cen A	1FGLJ1325.6-4300	13 25 27.6	− 43 01 09	0.0009^c	FRI	G	−0.95	1	MS4
NGC 6251	1FGLJ1635.4+8228	16 32 32 .0	+82 32 16	0.024	FRI	G	−0.47	2	3CRR
3C 380	1FGLJ1829.8+4845	18 29 31.8	+48 44 46	0.692	FRII/CSS	SSRQ	−0.02	2	3CRR

Abdo, A.A., et al. 2010, ApJ, 720, 912

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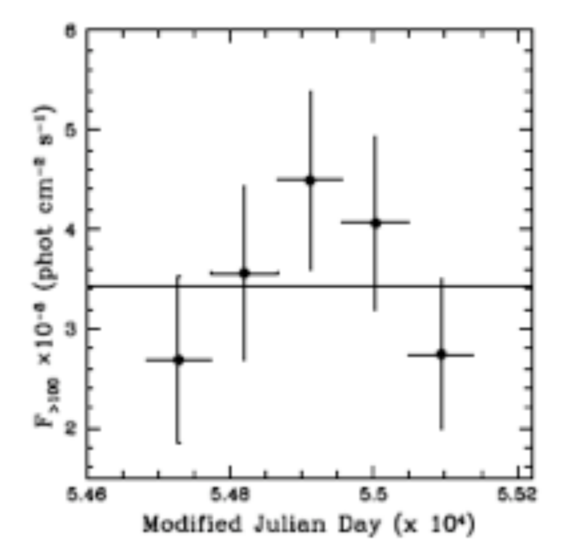
Fornax A
Pictor A?

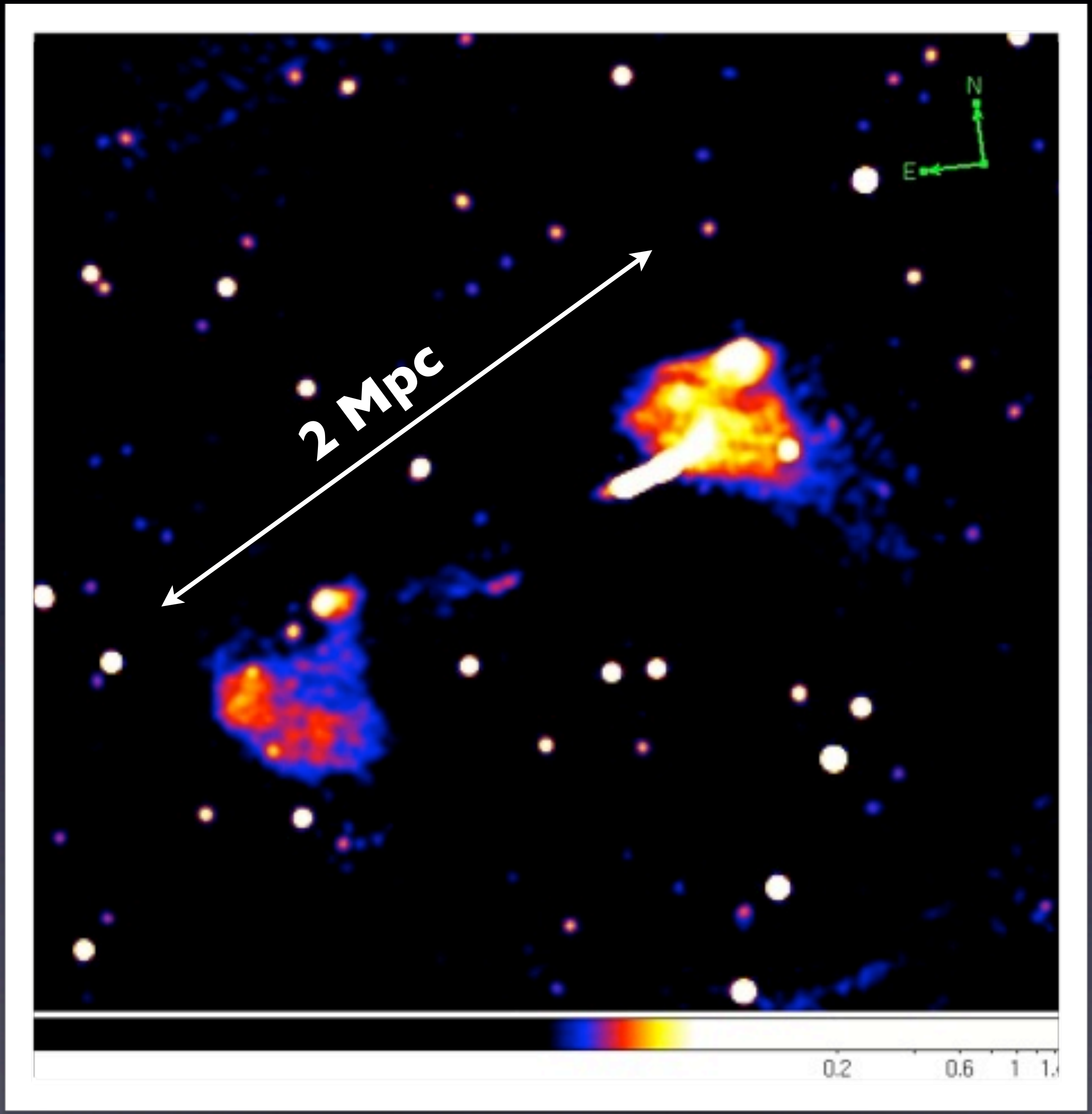
} **24-month data**

8 FRI-4 FRII

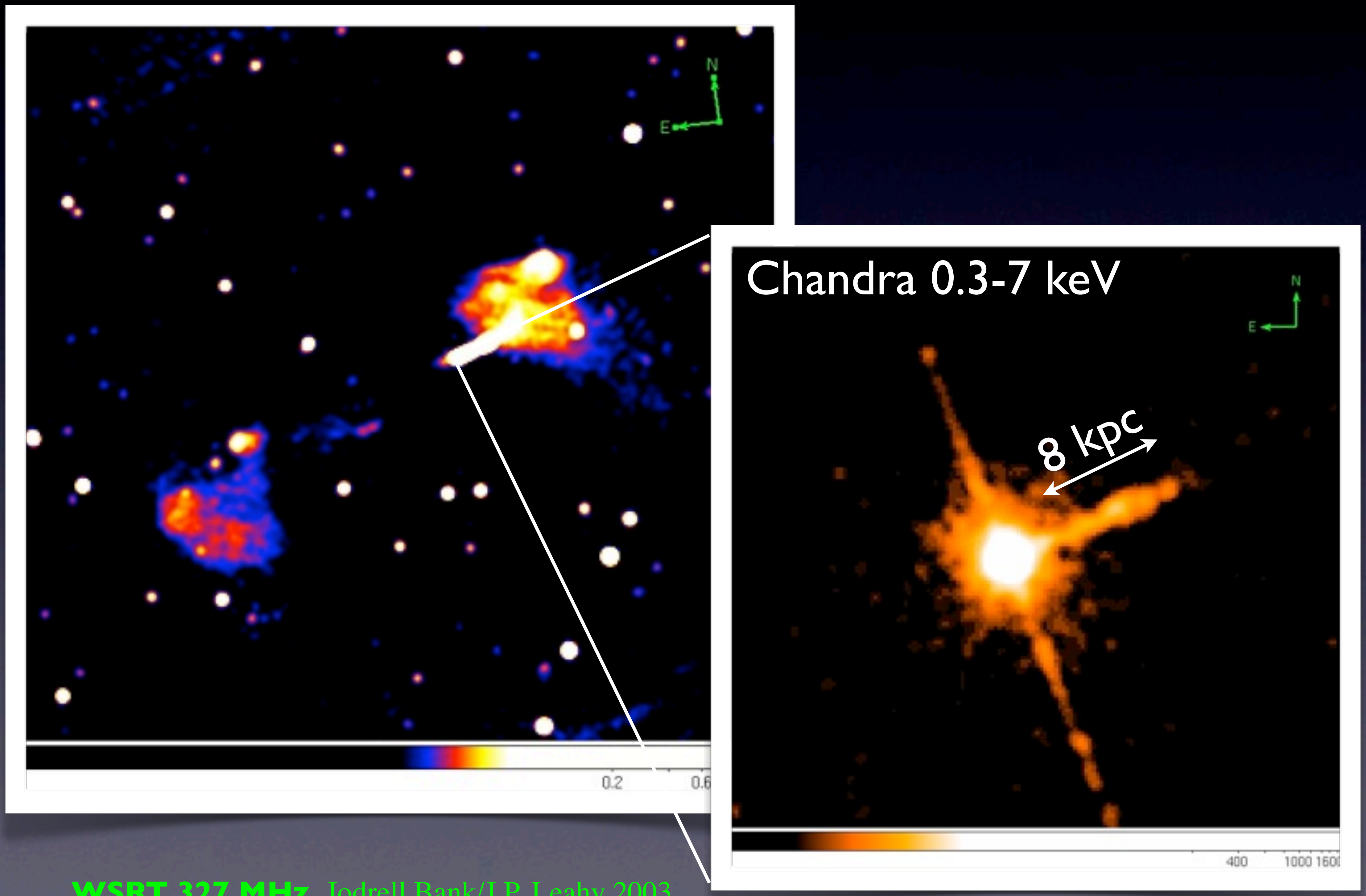
FRI: NGC 6251



Fermi-LAT lightcurve between 100 MeV-100 GeV
(Migliori et al. 2011)

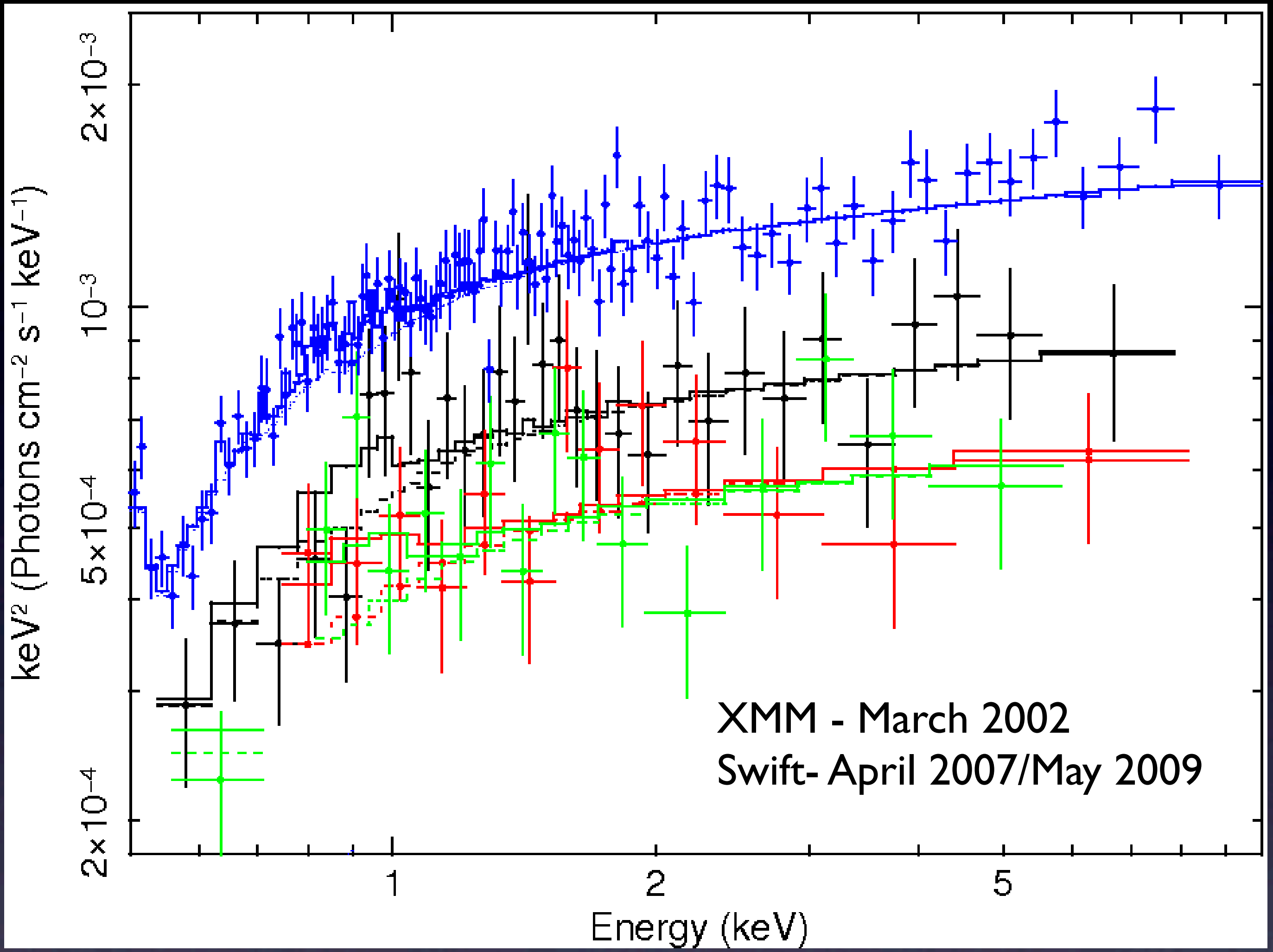


WSRT 327 MHz Jodrell Bank/J.P. Leahy 2003



WSRT 327 MHz Jodrell Bank/J.P. Leahy 2003

XMM-Newton and Swift



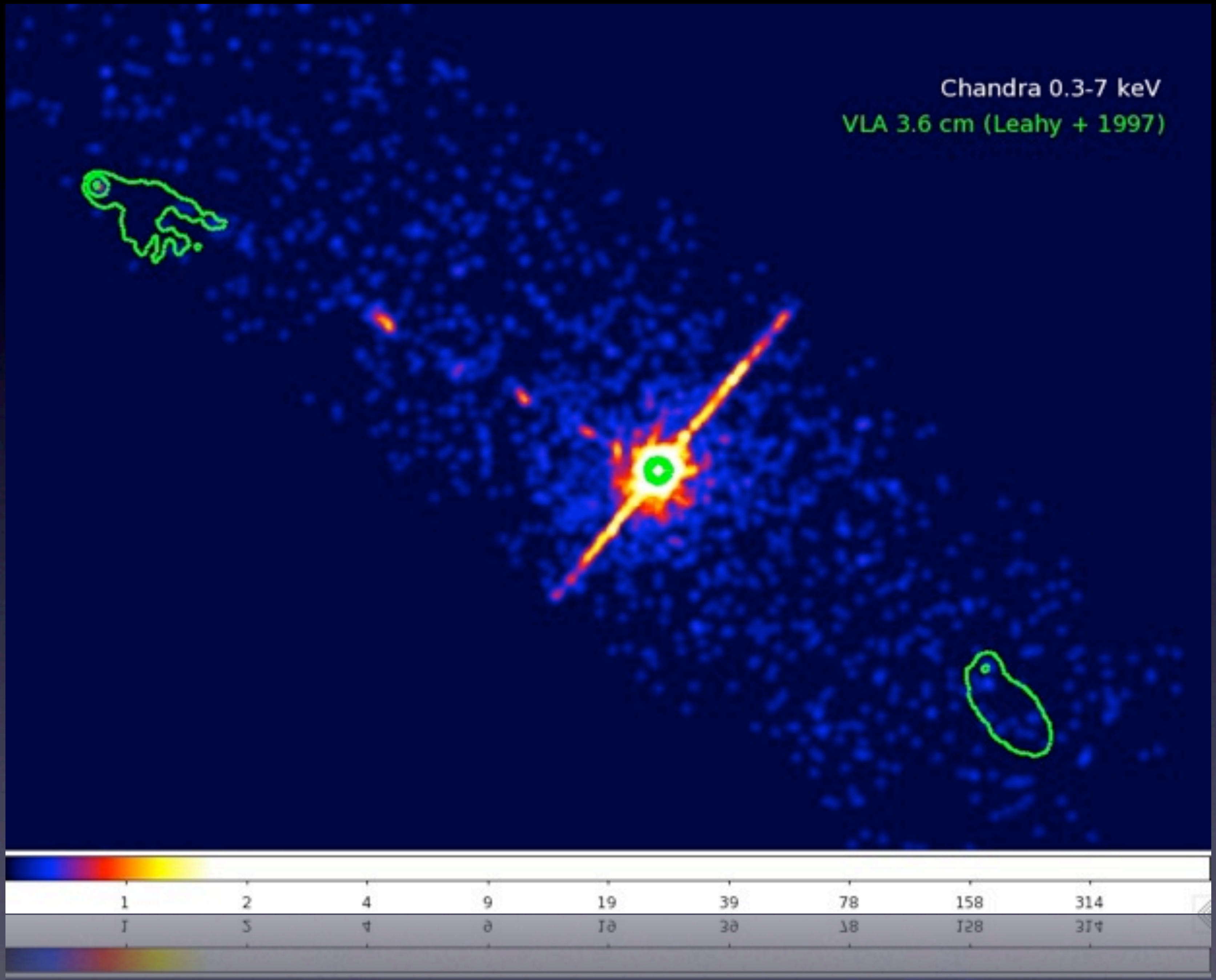
$\Gamma=1.89\pm0.04$

$kT=0.6\pm0.02$ keV

$F_{(2\text{-}10keV)}=3.6\times10^{-12}$ erg cm^{-2} s^{-1}

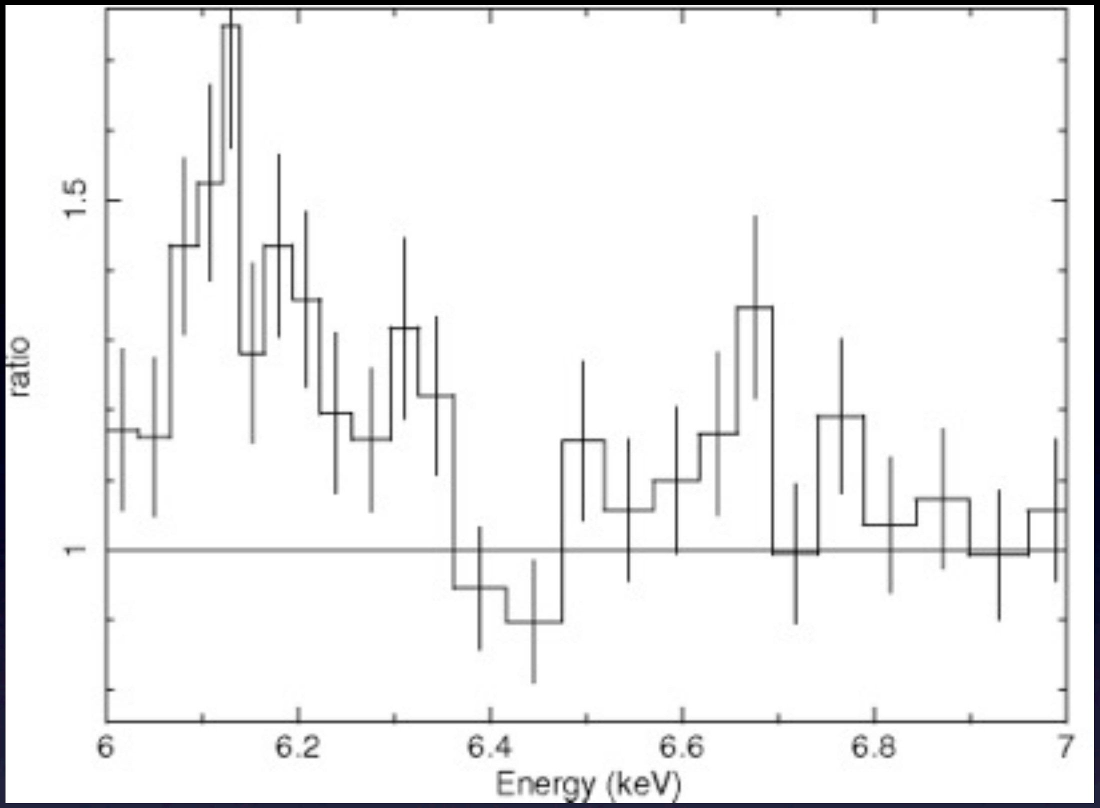
- **No iron Kα line**
- X-ray variability detected on time scale of years

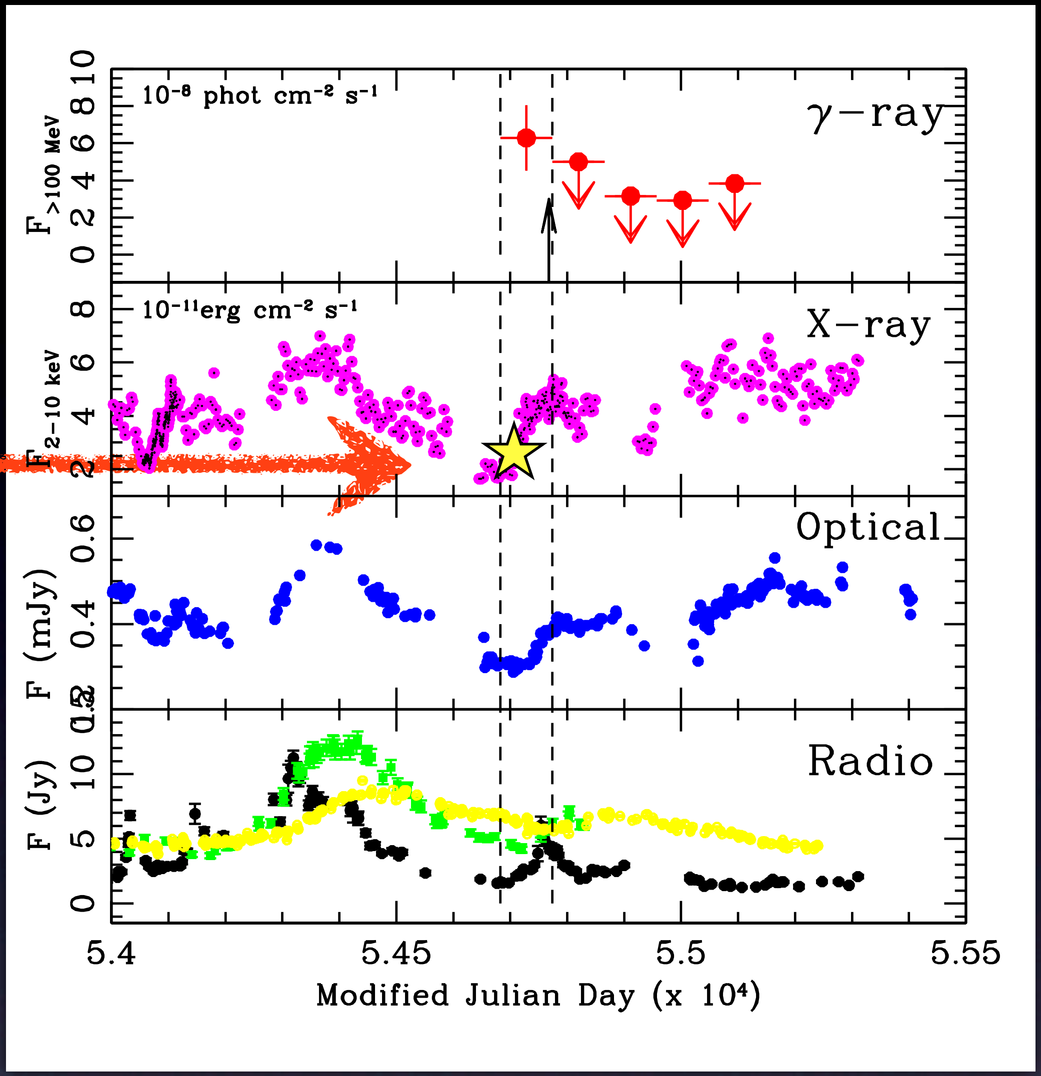
FRII: 3C 111



see also Hogan et al. 2011

Suzaku 22 August 2008





$\Gamma=1.57\pm0.06$

$E_{Fe}=6.4\pm0.02$ keV

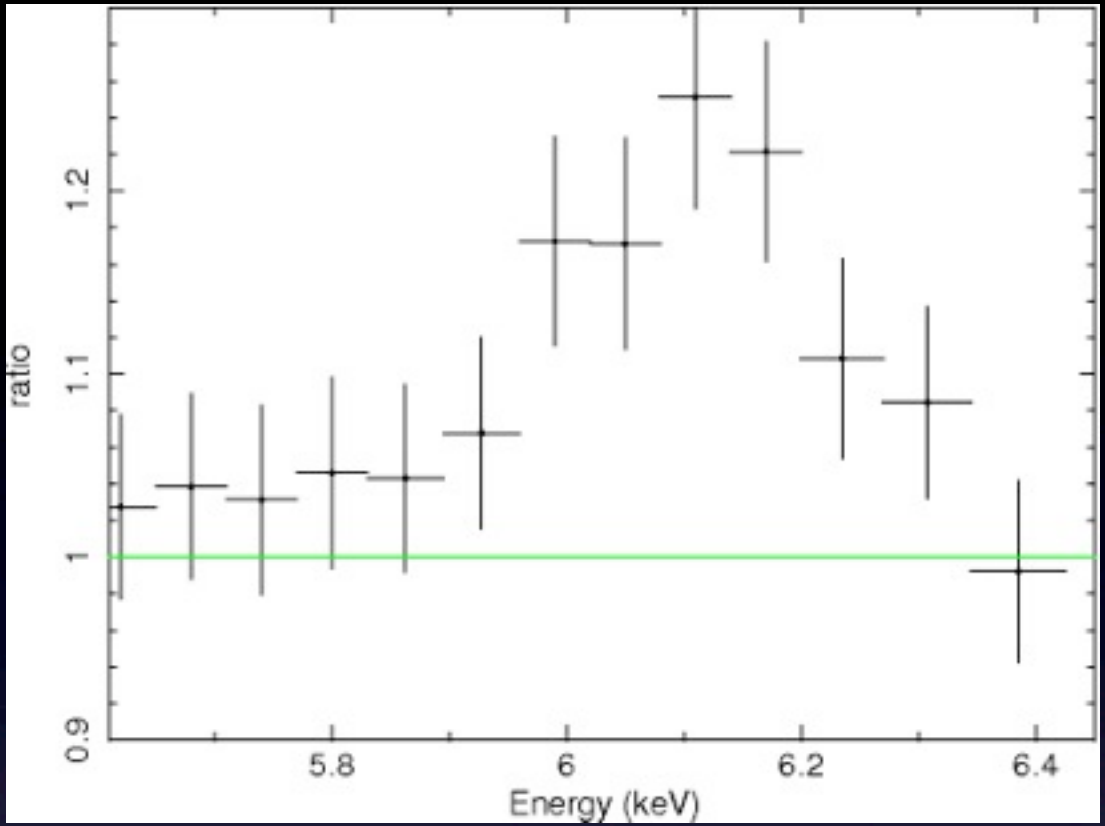
$\sigma=0.05\pm0.03$ keV

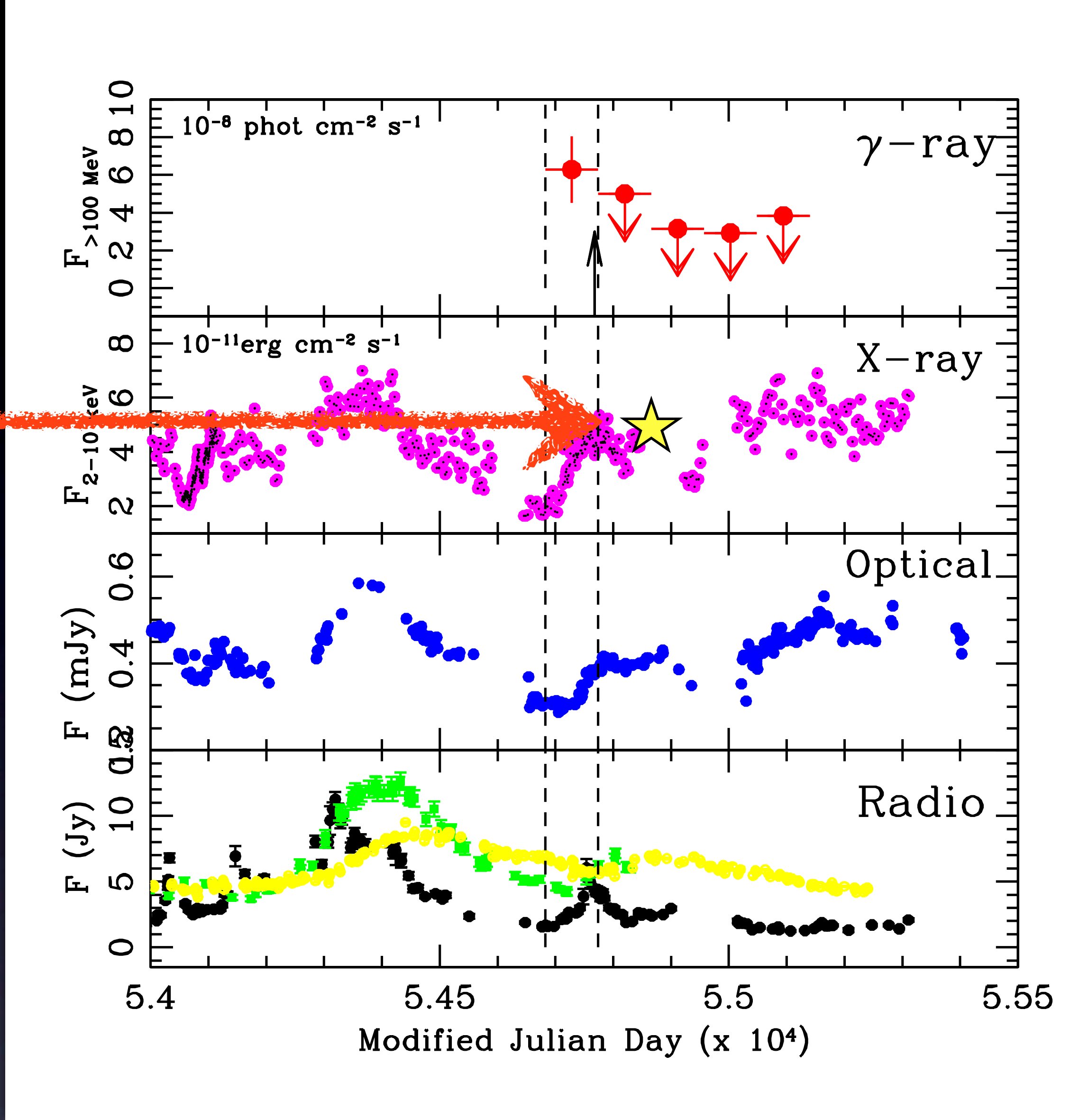
EW=62 eV

$F_{(2\text{-}10keV)}=1.7\times10^{-11}$ erg cm^{-2} s^{-1}

see also Ballo et al. 2011

XMM-Newton 15 February 2009





$\Gamma=1.63\pm0.01$

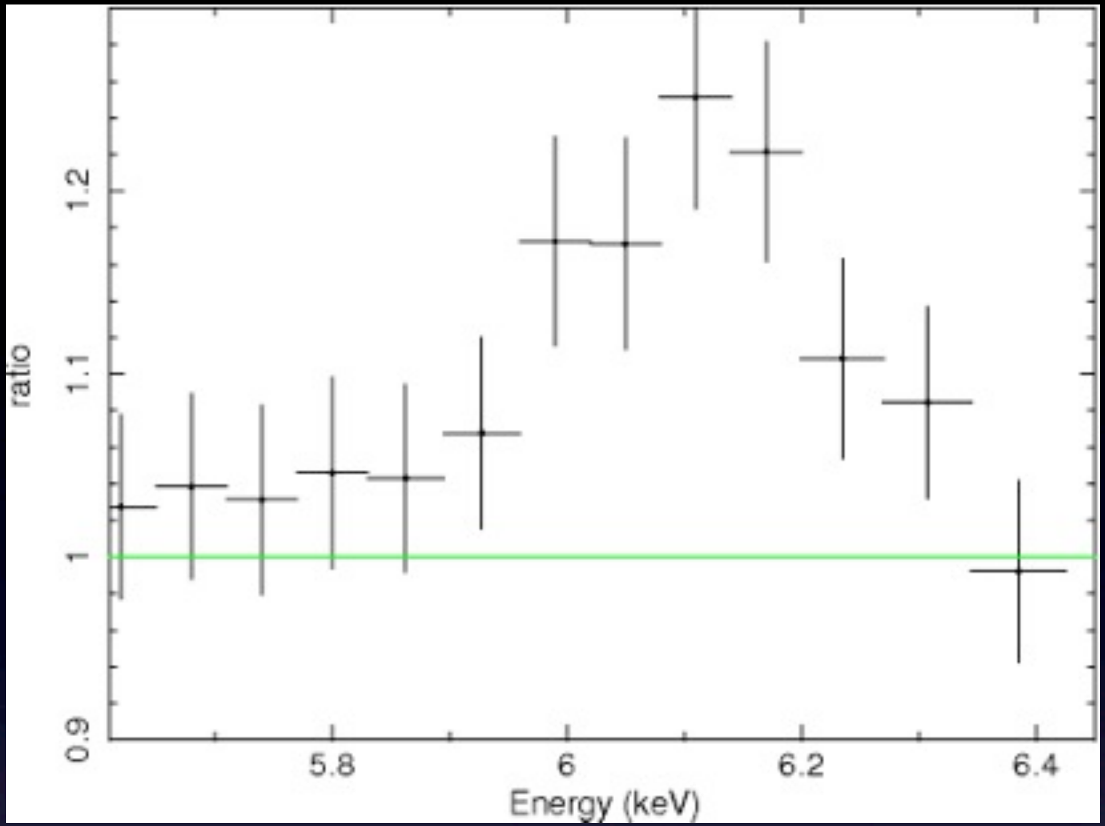
$E_{Fe}=6.40\pm0.05$ keV

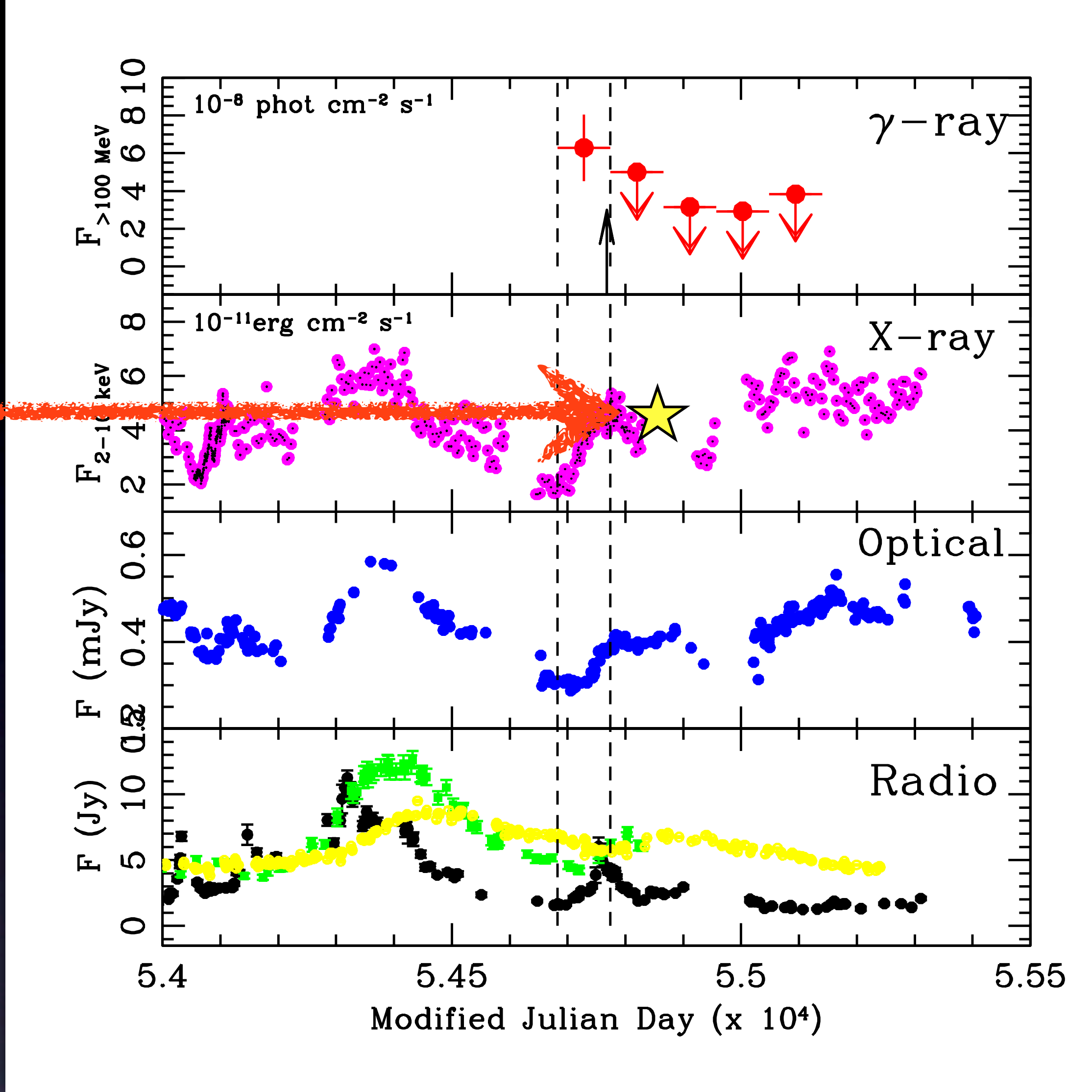
$\sigma<0.15$ keV

EW=56 eV

$F_{(2\text{-}10keV)}=4.7\times10^{-11}$ erg cm^{-2} s^{-1}

XMM-Newton 15 February 2009





$\Gamma=1.63\pm0.01$

$E_{Fe}=6.40\pm0.05$ keV

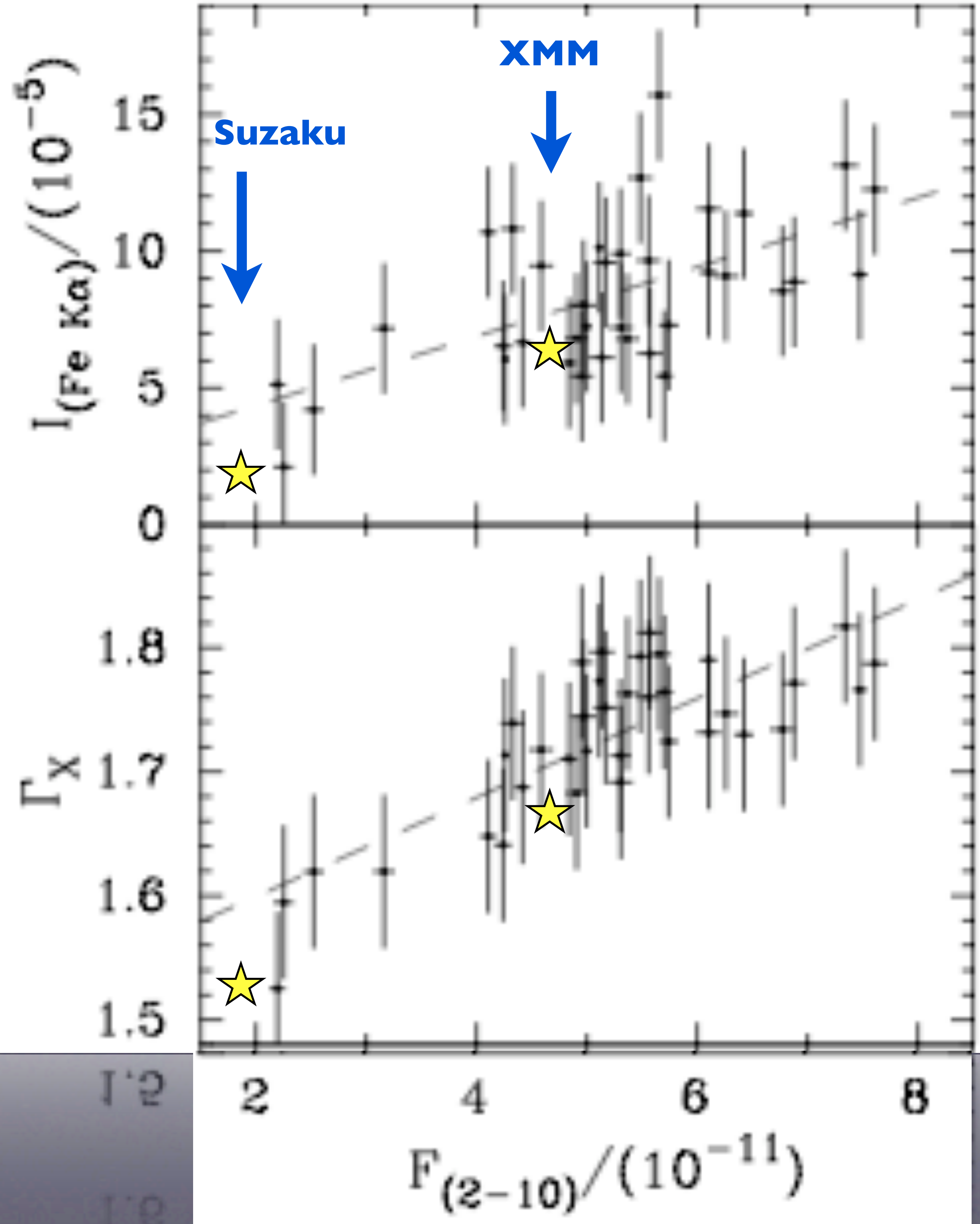
$\sigma<0.15$ keV

EW=56 eV

$F_{(2-10keV)}=4.7\times10^{-11}$ erg cm^{-2} s^{-1}

The line is produced in the Broad Line Regions at ~160 R_G

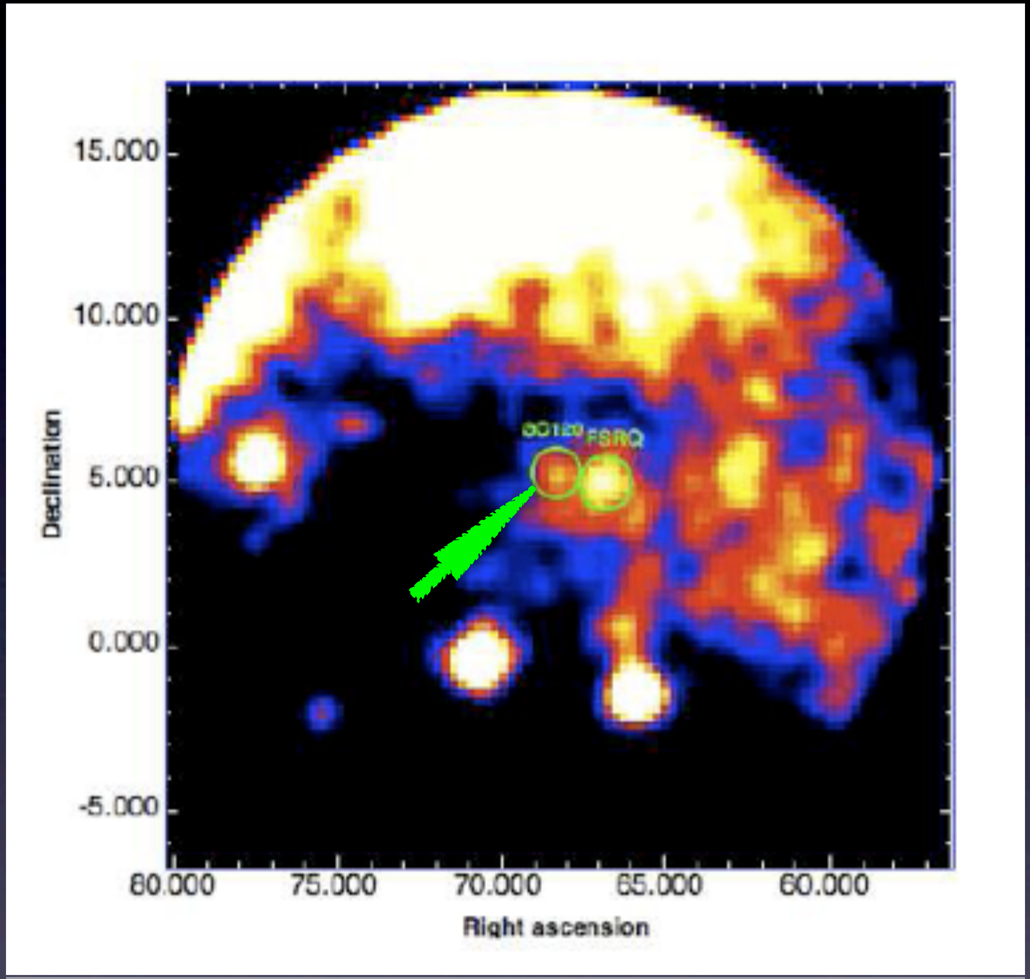
(see also Chatterjee et al. 2011)



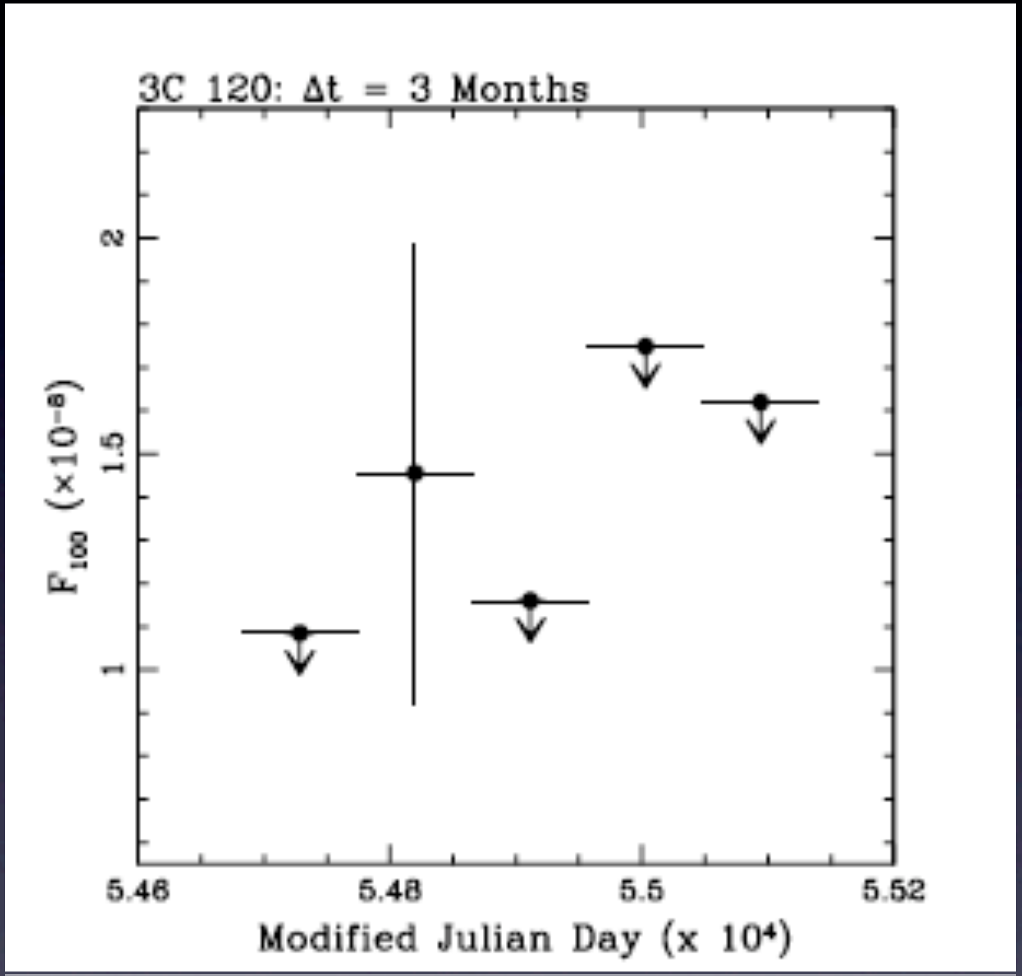
Chatterjee et al. 2011

Peculiar case: 3C 120

An FRI with a powerful accretion disk



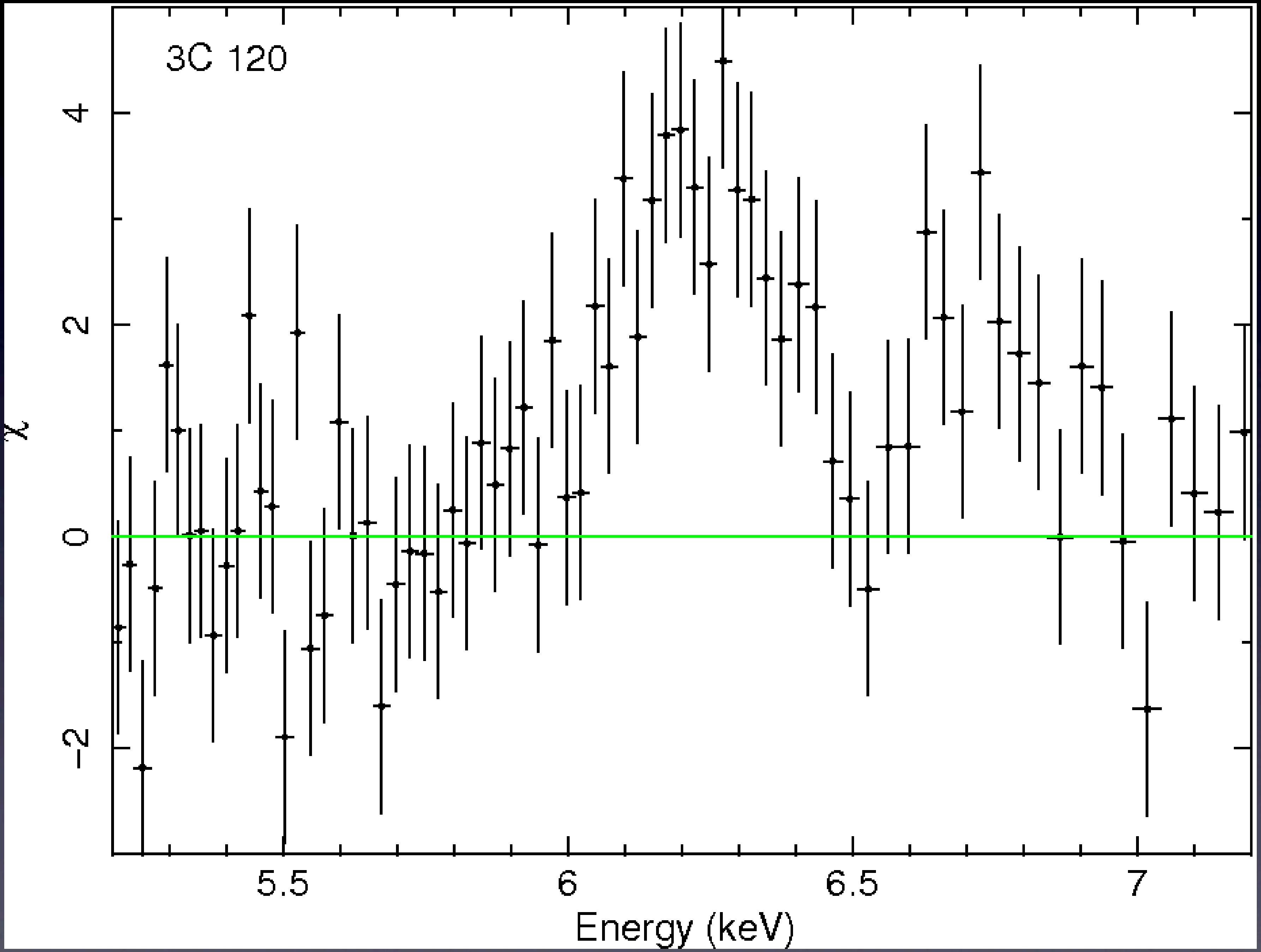
Count sky map between 100 MeV and 100 GeV



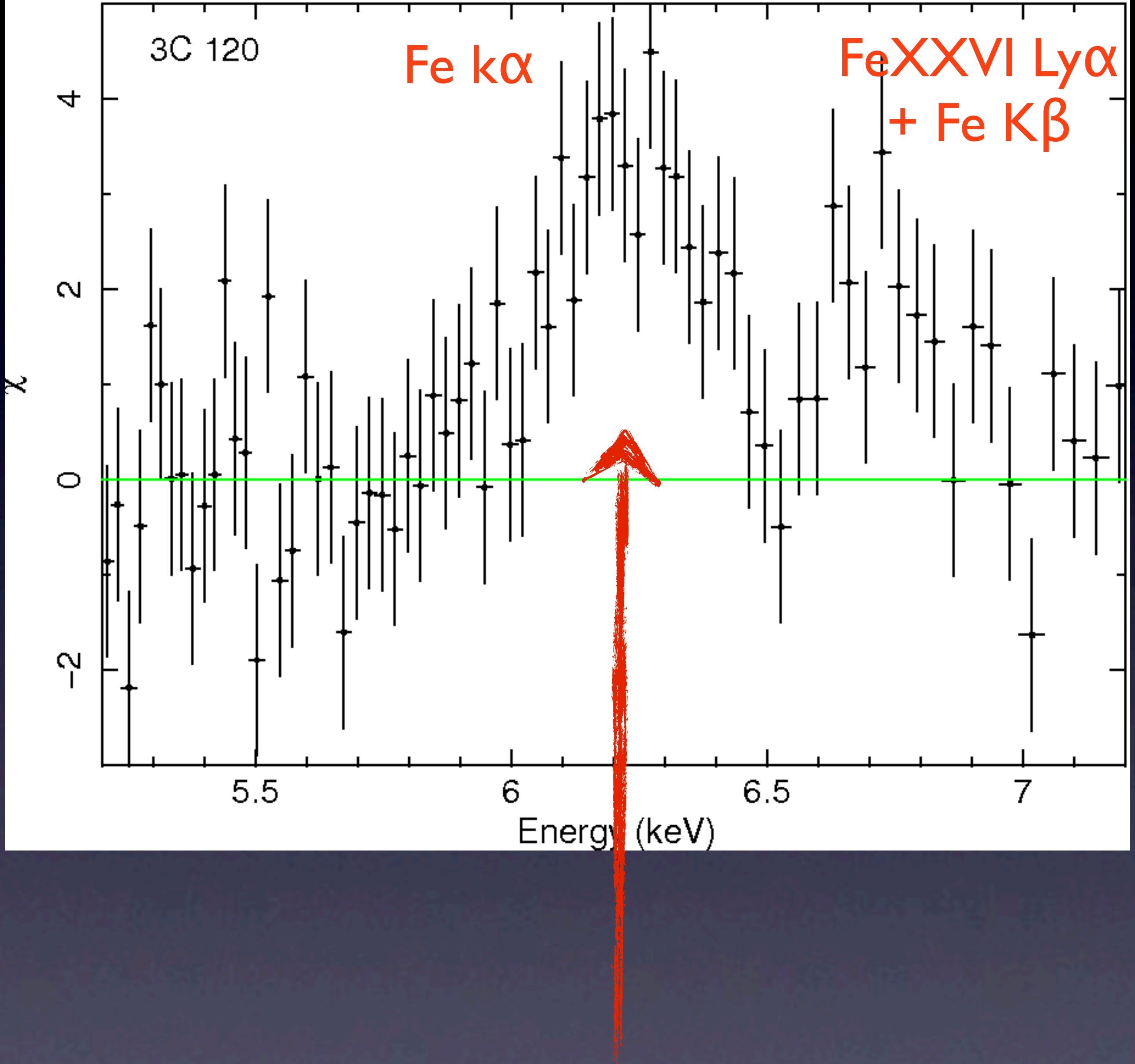
Light curve between 100 MeV and 100 GeV

Abdo, A.A., et al. 2010, ApJ, 720, 912

XMM-Newton



XMM-Newton



$\Gamma=1.79\pm0.01$

$E_l=6.42\pm0.03$ keV

$\sigma_l=0.14\pm0.03$ keV

$EW_l=86$ eV

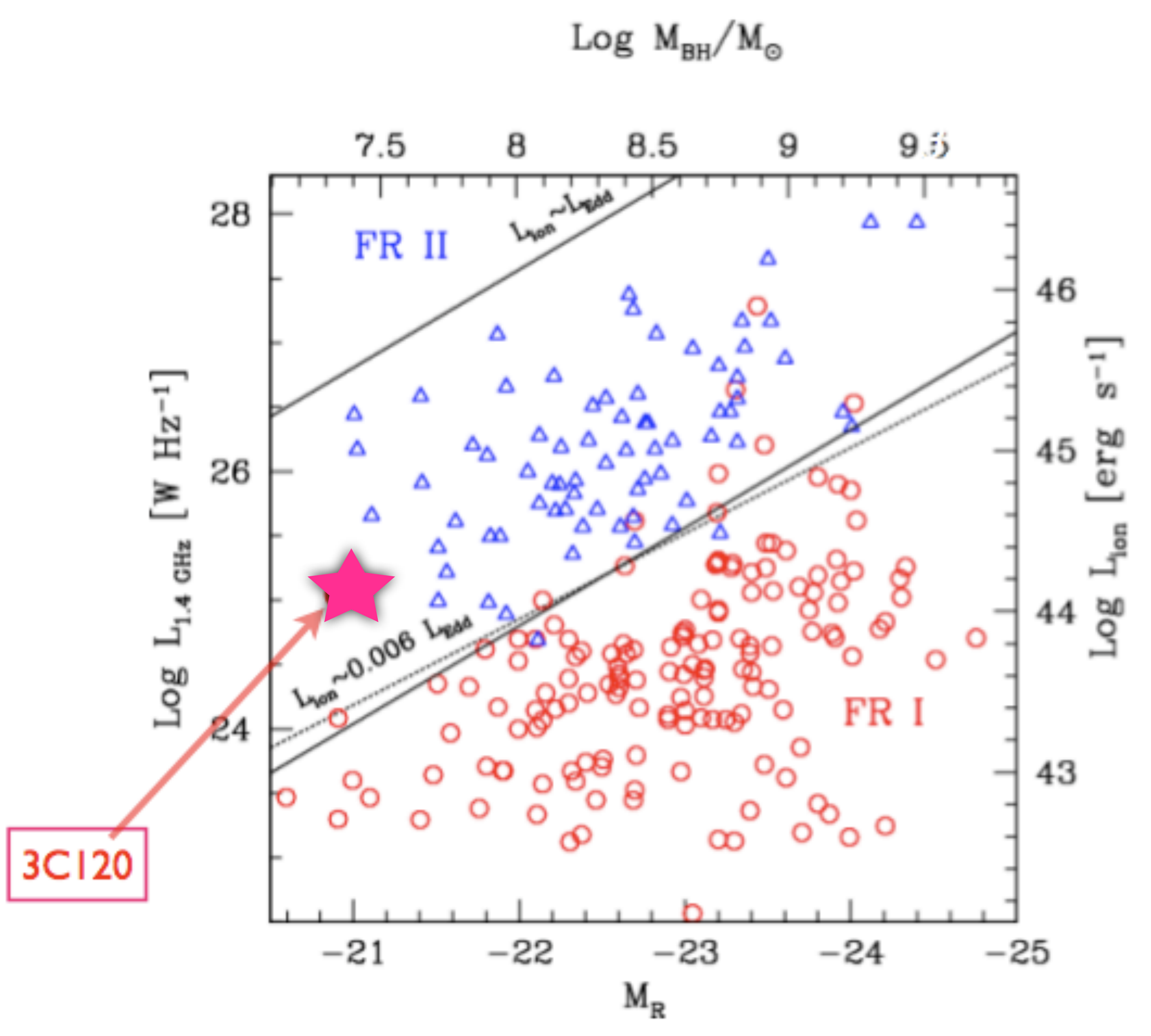
$E_l=6.94\pm0.04$ keV

$\sigma_l=0.06$ keV

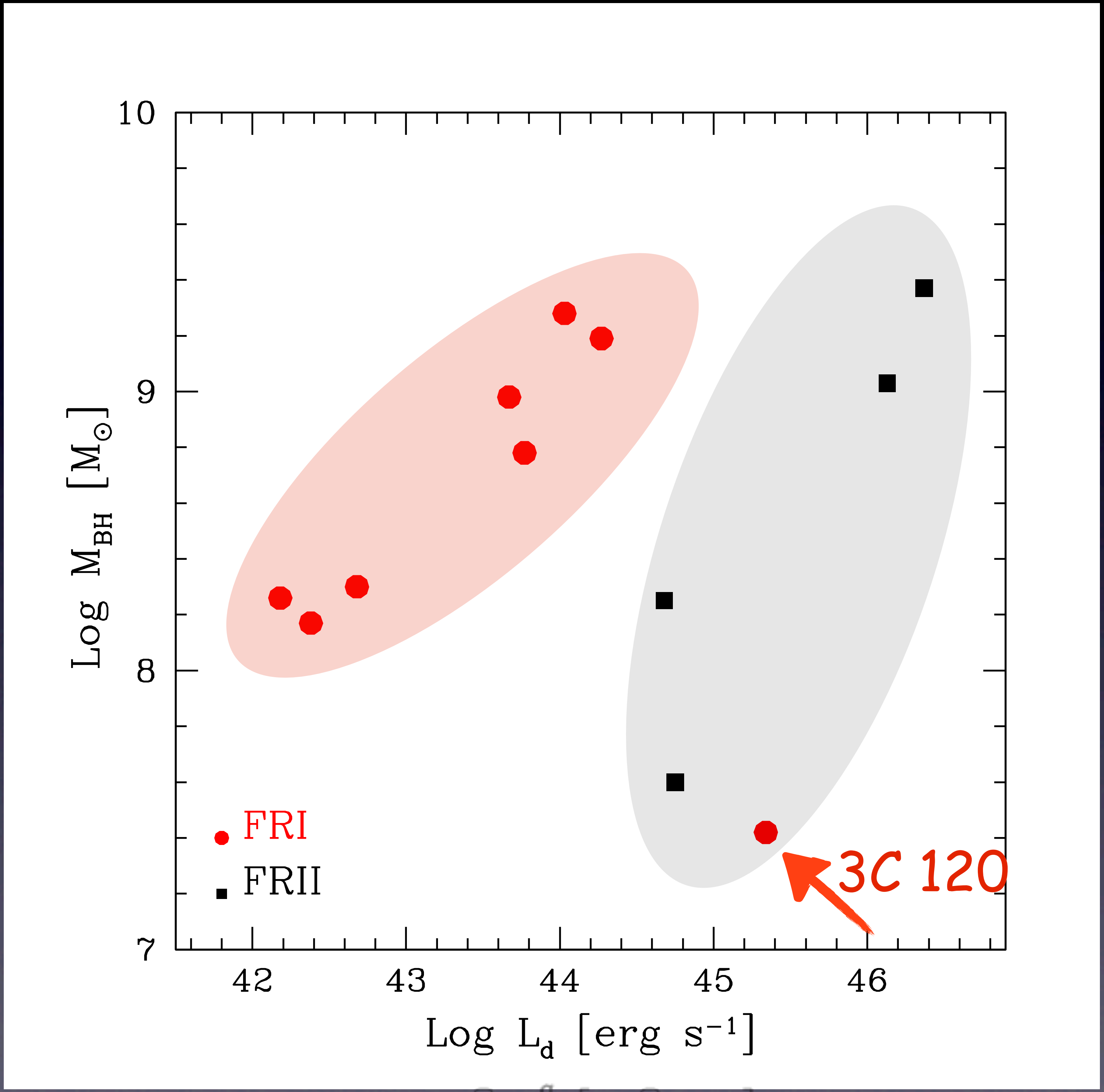
$EW_l=31$ eV

$F_{(2-10keV)}=4.5\times10^{-11}$ erg cm^{-2} s^{-1}

The Fe Kα line is produced in the Broad Line Region (Ogle et al. 2005)


Log $M_{BH}/M_\odot$
7.5
8
8.5
9
9.5
28
26
24
Log $L_{1.4\ GHz}$ [W Hz^{-1}]
46
45
44
43
Log L_{ion} [erg s^{-1}]
FR II
FR I
L_{ion}~L_{Edd}
L_{ion}~0.006 L_{Edd}
−21
−22
−23
−24
−25
M_R
3C120

MAGN sample



Name	Class	N_H	F_X	Γ_X	FeKα	F_γ	Γ_γ
3C84	FRI	<0,1	1,24	1,80	no	222	2,13
3C120	FRI	0,088	4,5	1,76	yes	29	2,71
M87	FRI	0,023	0,16	2,40	-	24	2,21
6251	FRI	0,054	0,45	1,89	no	36	2,52
3C78	FRI	<0,1	0,045	2,0	no	4,7	1,95
CENA	FRI	8,3	29	1,50	yes	214	2,75
0625-35	FRI	<0,1	0,26	2,52	no	4,8	2,06
FORA	FRI	0,02	0,014	1,70	no	9,78	2,29
3C207	SSRQ	<0,13	0,16	1,62	yes	24	2,42
3C380	CSS	-	0,4	1,54	-	31	2,51
3C111	FRII	0,77	4,5	1,63	yes	40	2,54
PICA	FRII	<0,01	0,6	1,72	yes	<15	2,50

* N_H is in 10^{22} cm^{-2}

* F_X is in units of 10^{-11} erg cm^{-2} s^{-1}

* F_γ is in units of 10^{-9} phot cm^{-2} s^{-1}

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often produced in the BLR

* N_H is in 10^{22} cm^{-2}

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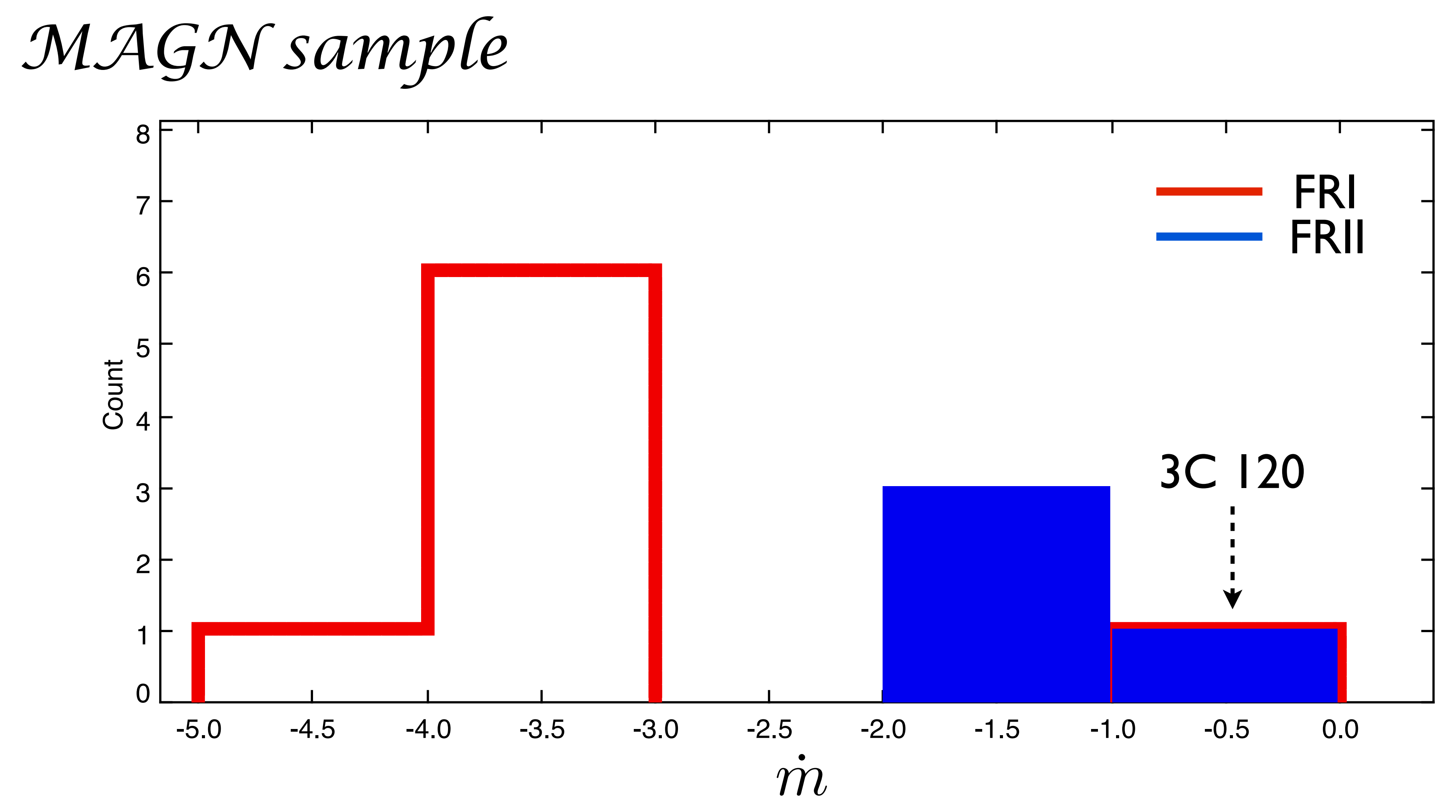
* F_γ is in units of 10^{-9} phot cm^{-2} s^{-1}

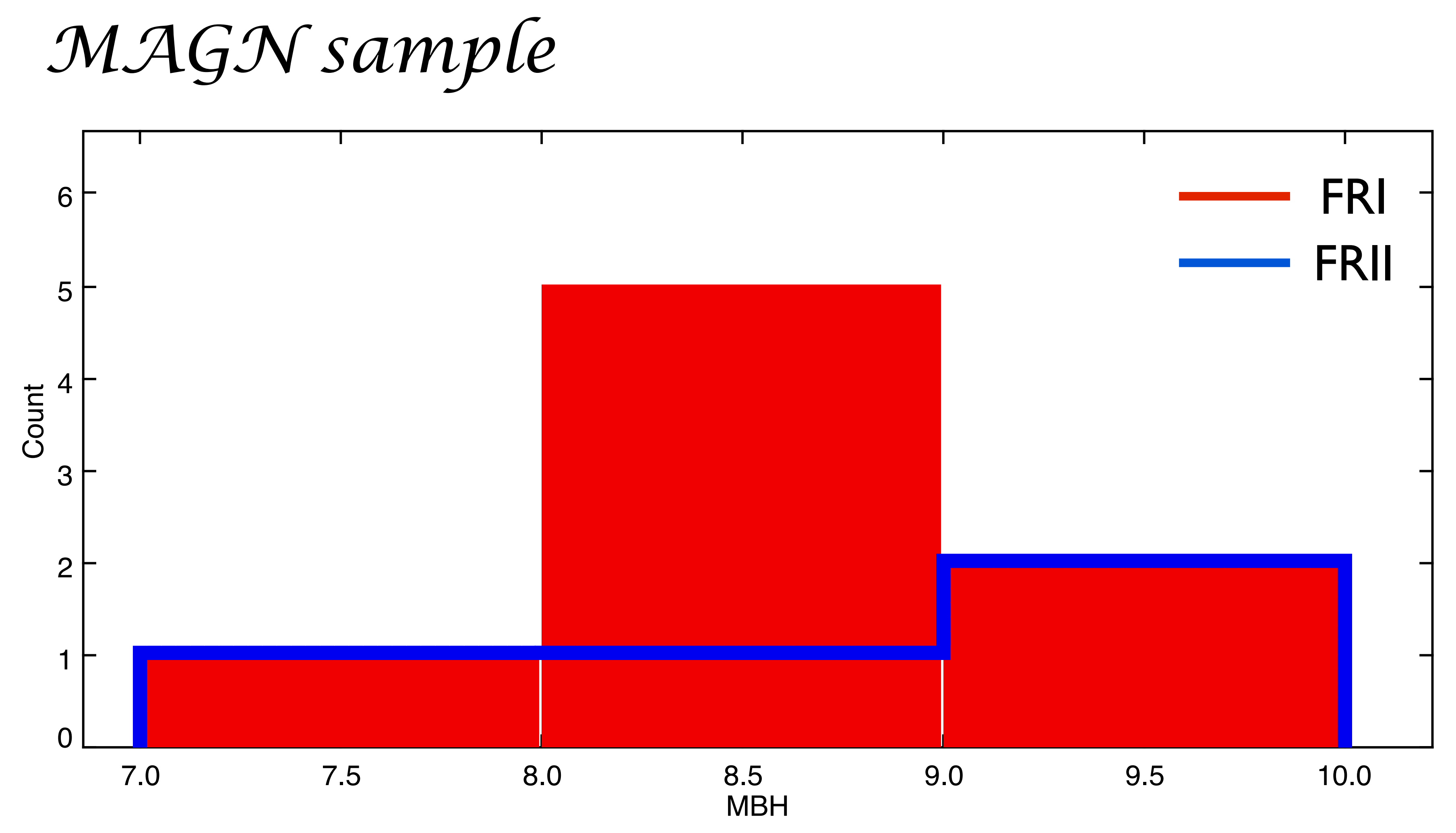
A possible bimodality in the Eddington ratio



MAGN sample

FRI

No difference in the black hole mass between FRIs and FRIIs



Optical ➲ non-thermal synchrotron origin of FRI emission
➲ inefficient accretion flows
➲ lack of dusty torus

NearIR ➲ non-thermal origin of FRI NIR emission
➲ FRIIs probably surrounded by a hot circumnuclear dust

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X-rays ➲ FRIs are on average less absorbed than FRIIs and have steeper spectral indices
➲ generally the iron line is not present in FRIs but is present in FRIIs often originating in the BLR
➲these indications point towards an inefficient accretion regime in FRIs and efficient accretion flow in FRIIs

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Different accretion regime ⇔ Different nuclear environment

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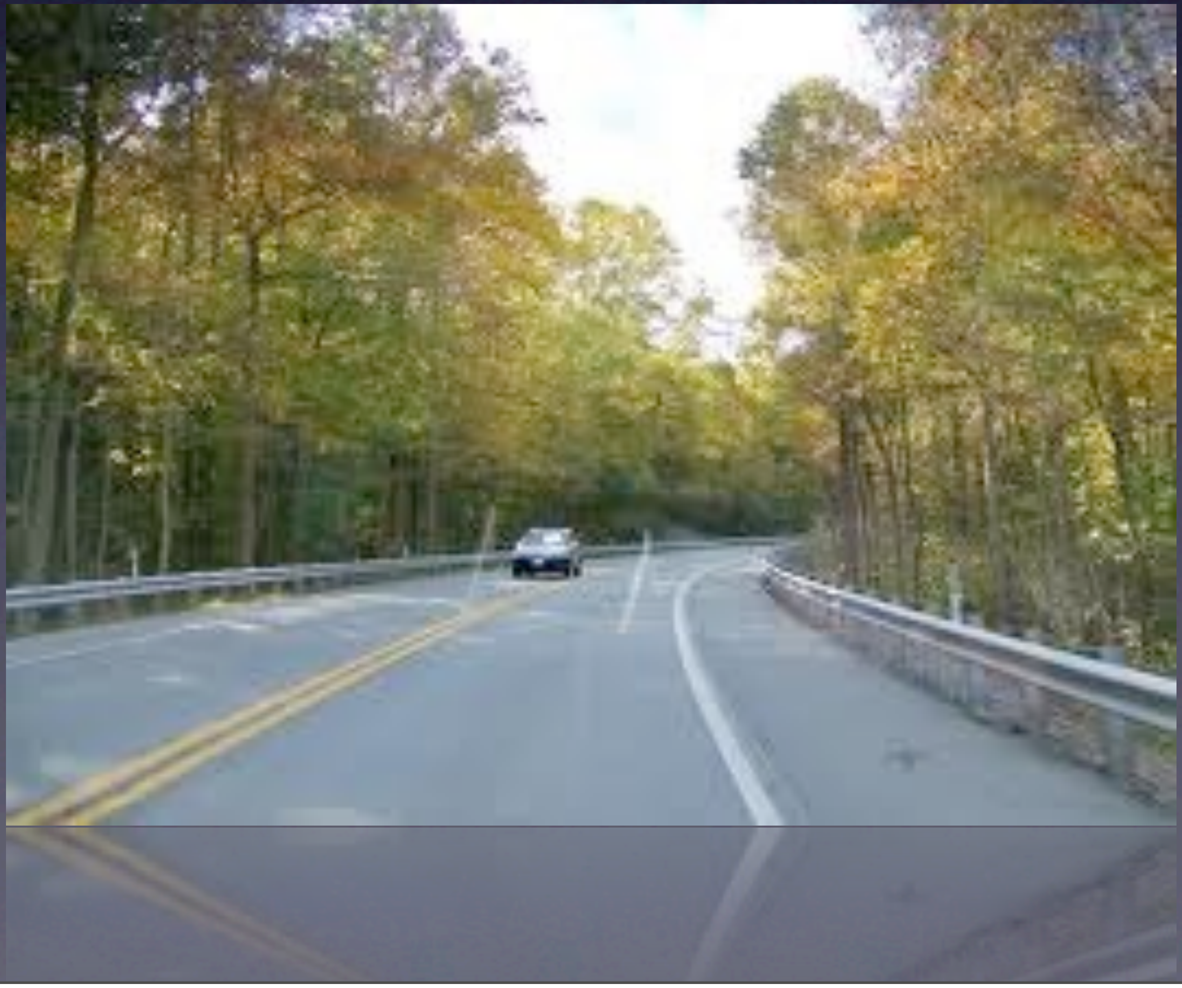
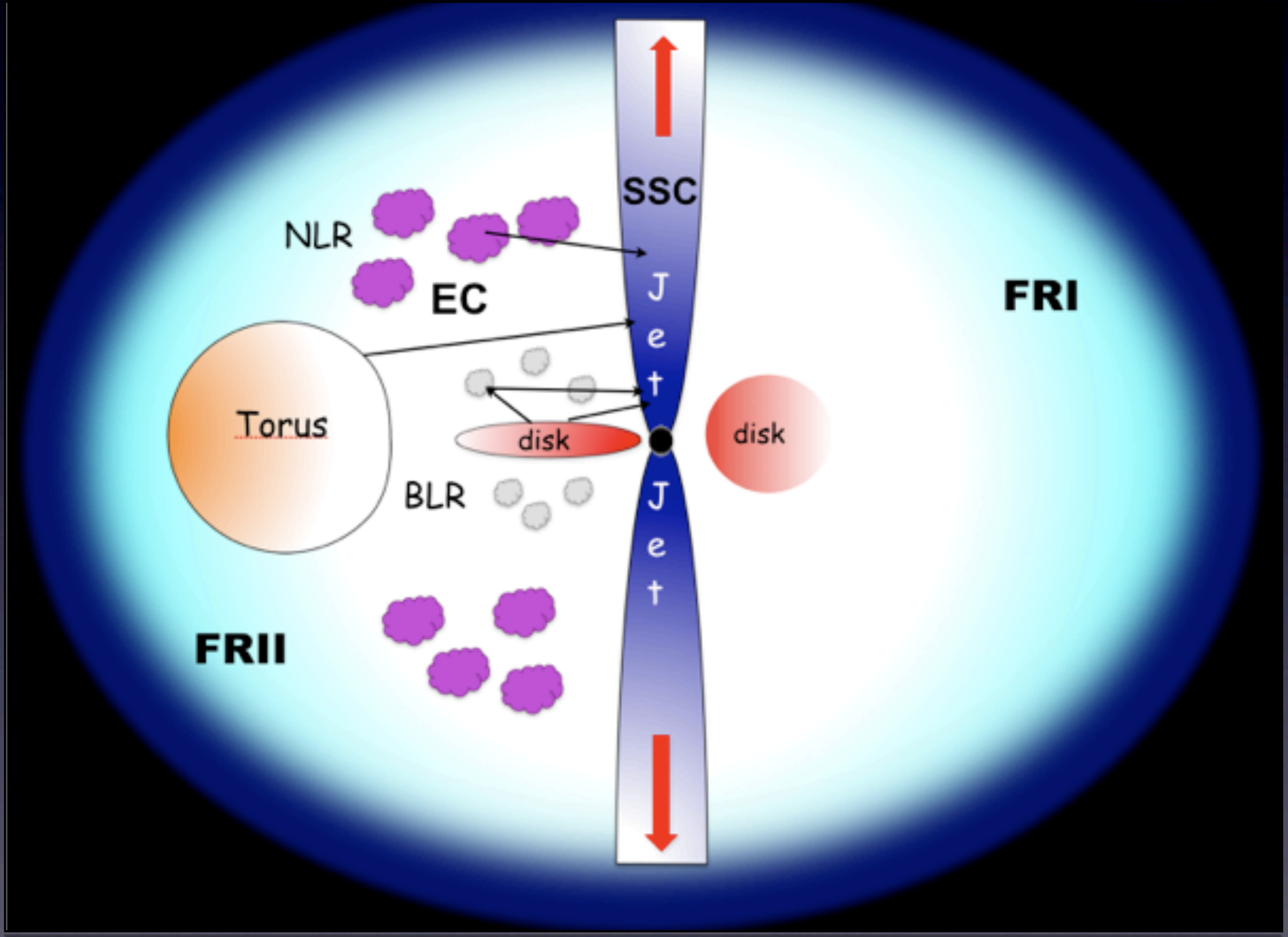


...contrarily to what is observed in FRIs

This would explain why, at zeroth order, EC processes are dominant in FRIIs (*the jet propagates through an ambient rich in photons*), while in FRIs, the SSC process dominates (*fewer seed photons*).



SUMMARY

The X-ray analysis of the MAGN sample has pointed out:

➡ FRIs are on average less absorbed than FRIIs (no dusty torus) and have steeper spectral indices;

➡ generally the iron line is not present in FRIs but is present in FRIIs often originating in the BLR;

➡ these indications point towards an inefficient accretion regime in FRIs and efficient accretion flow in FRIIs;

    ➡ efficient disks ionize the BLR clouds --> sources of seed photons --> **EC dominate in FRIIs**

    ➡ inefficient accretion flows --> paucity of photons --> **SSC dominate in FRIs**

Thank you