Multi-wavelength Studies on Microquasars and AGNs

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Dept. of Astronomy, PKU

- 1960, Astronomy division in geophysics department; undergraduate program
- 1979, Postgraduate program
- 1998, CAS-PKU Beijing Astrophysics Center
- 2000, Department of Astronomy established (Chair: Prof. Jiansheng Chen)
- April 2008, 9 faculty members + 30 postgraduates + 40 undergraduates

Cosmology & Galaxy formation: Jiansheng Chen, Zu-Hui Fan

AGN & BH: Fukun Liu, Xue-Bing Wu

Planet, Star & ISM: Xiao-Wei Liu, Eric Peng, Hua-Wei Zhang

Particle Astrophysics: Ren-Xin Xu

Astrophysics Technology: Jian Zhang

Emeritus: Guojun Qiao, Xinji Wu & Yuefang Wu

Outline

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- Broadband SED of Microquasars
- Radio/X-ray correlation of AGNs
- CO line width and M-σ relation of quasars
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Main Collaborators:
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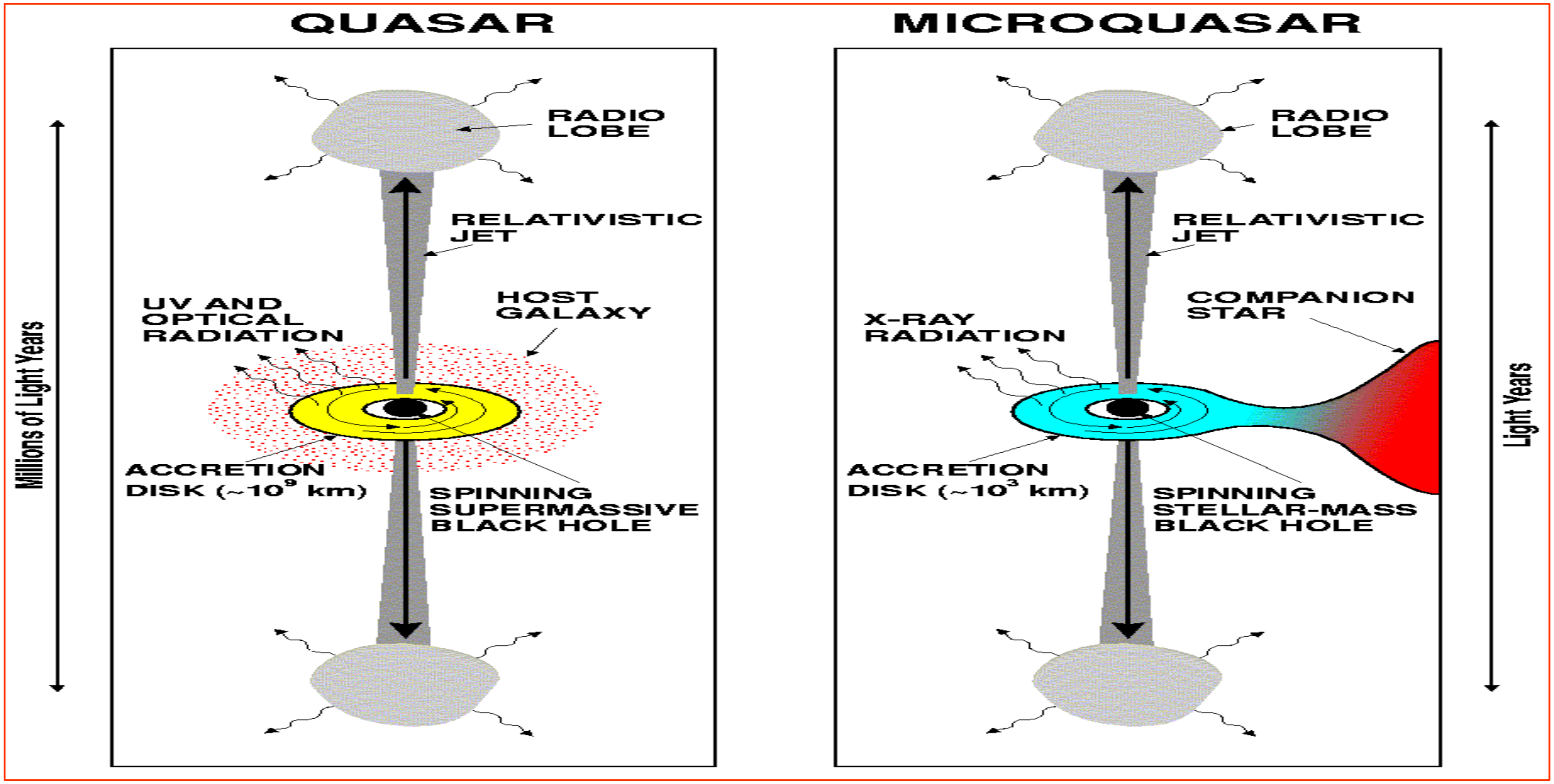
1. Introduction

BH systems at different scale:

Common ingredients: BH, accretion disk, jet, ...



Mirabel (2004)

Multi-wavelength study of Microquasars

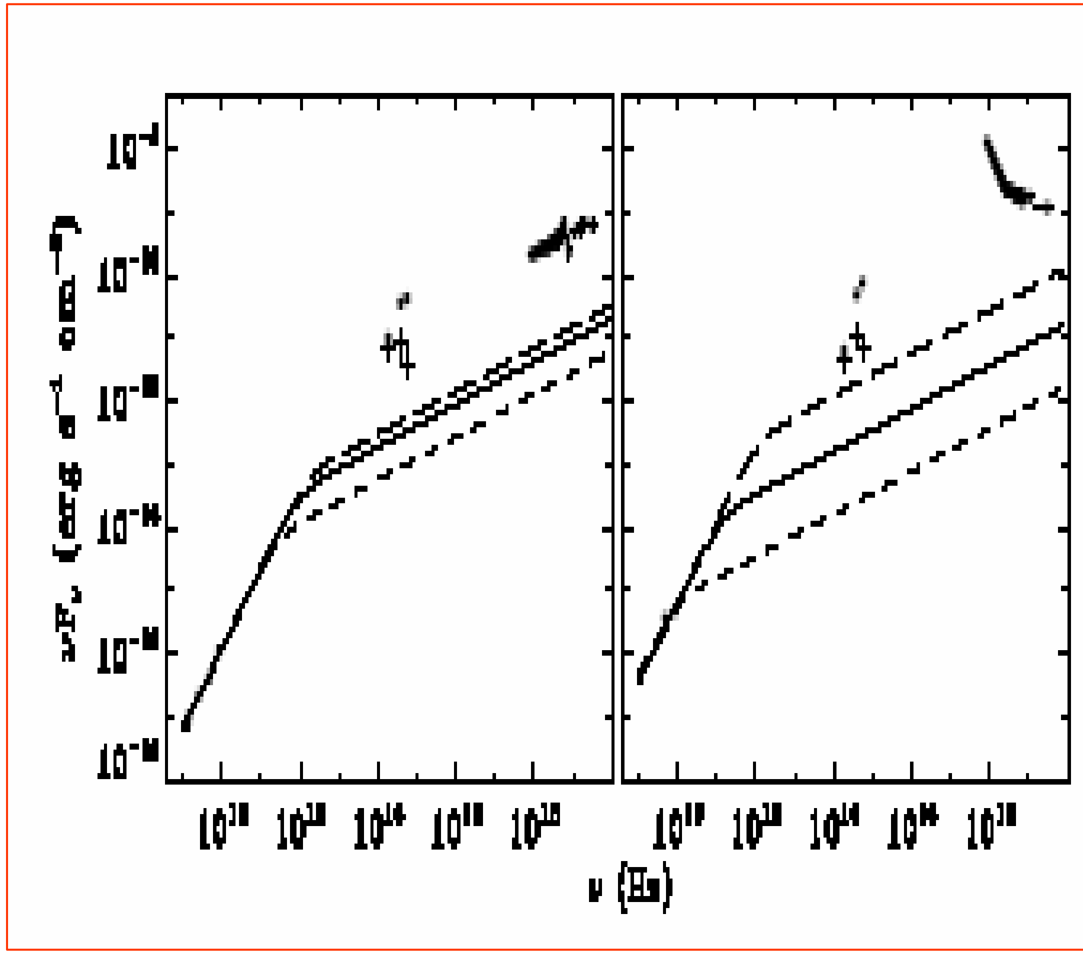
Radio: Jet

IR: Companion

Opt: Companion

X-ray: Accretion, Jet

Gamma-ray: Jet



(Xue, Wu & Cui 2008, MNRAS, 384,440)

Multi-wavelength study of AGNs

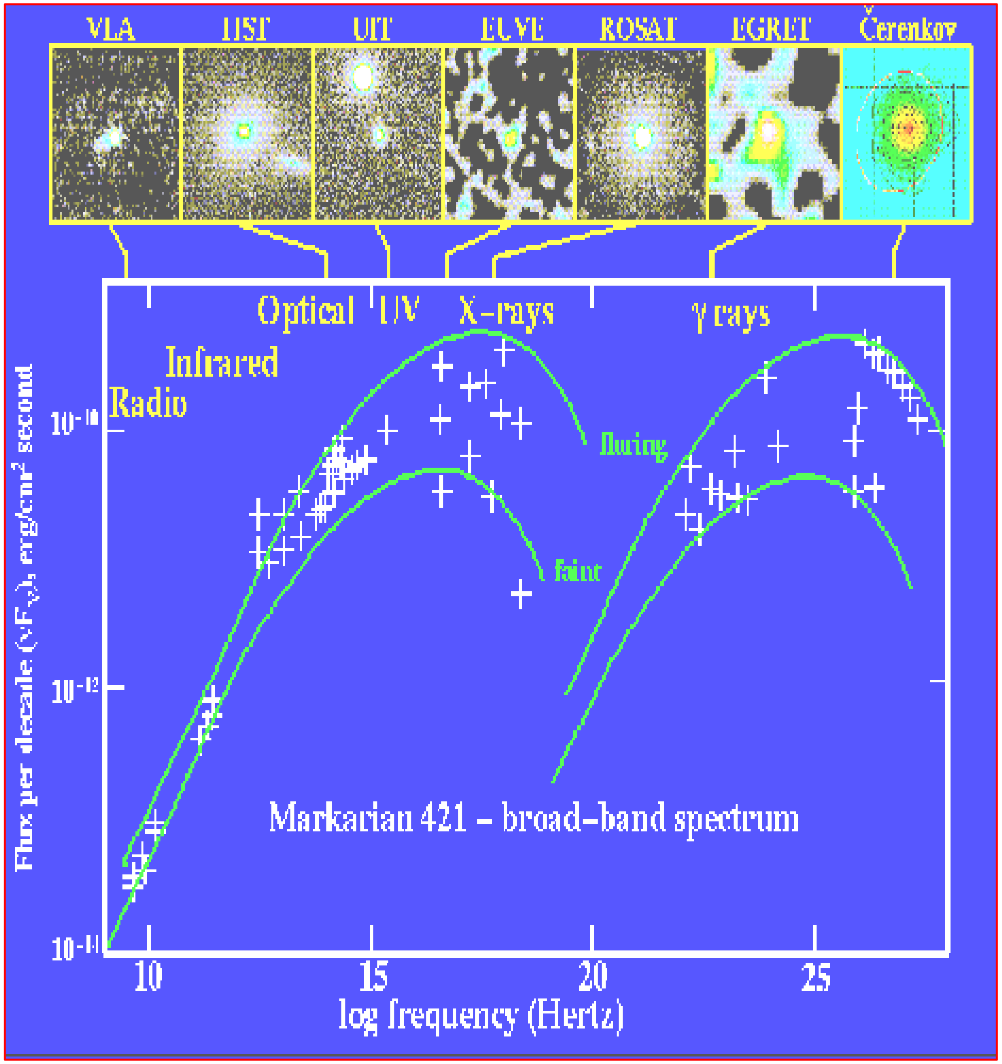
Radio: Jet

IR: Torus, Host-G., Jet

UV/Opt: Accretion, Jet, Host-G.

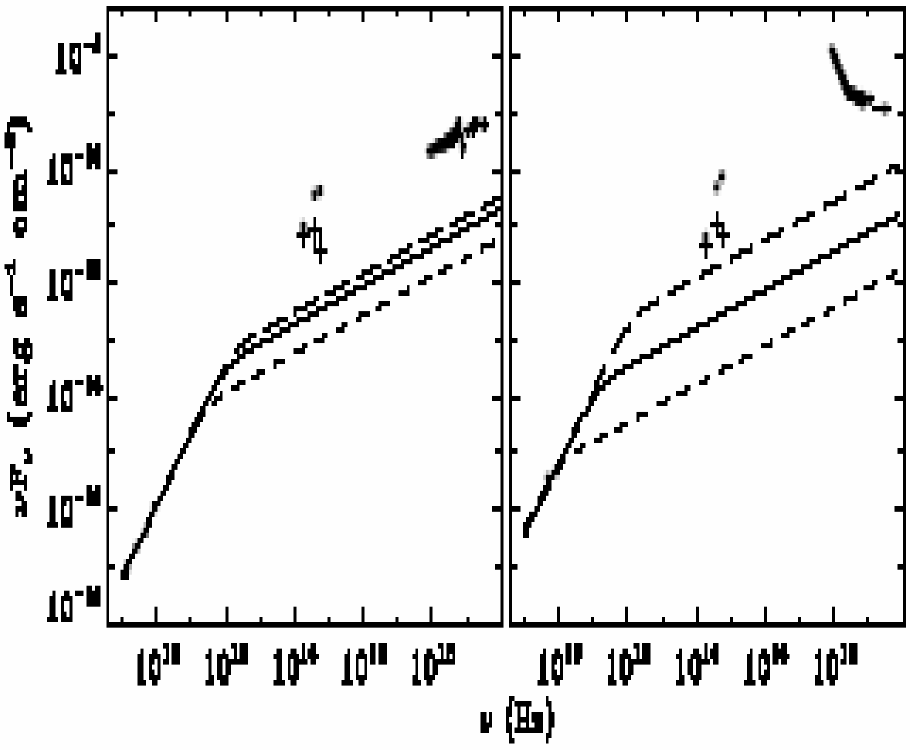
X-ray: Accretion, Jet

Gamma-ray: Jet

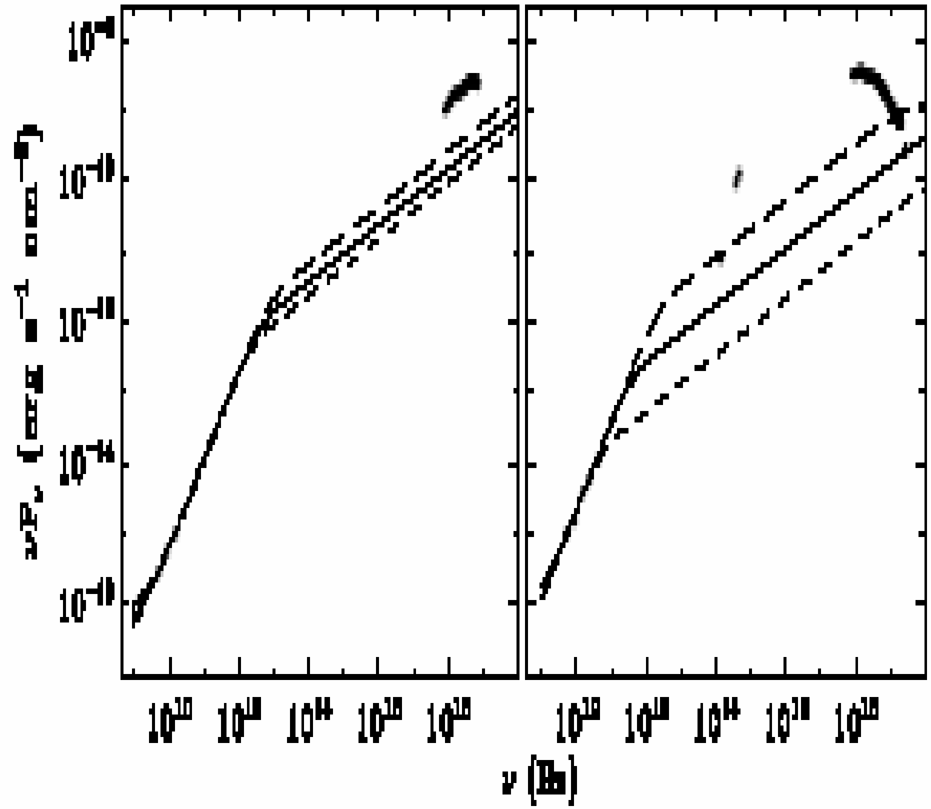


2. Broadband SED of Microquasars

XTE J1550-564

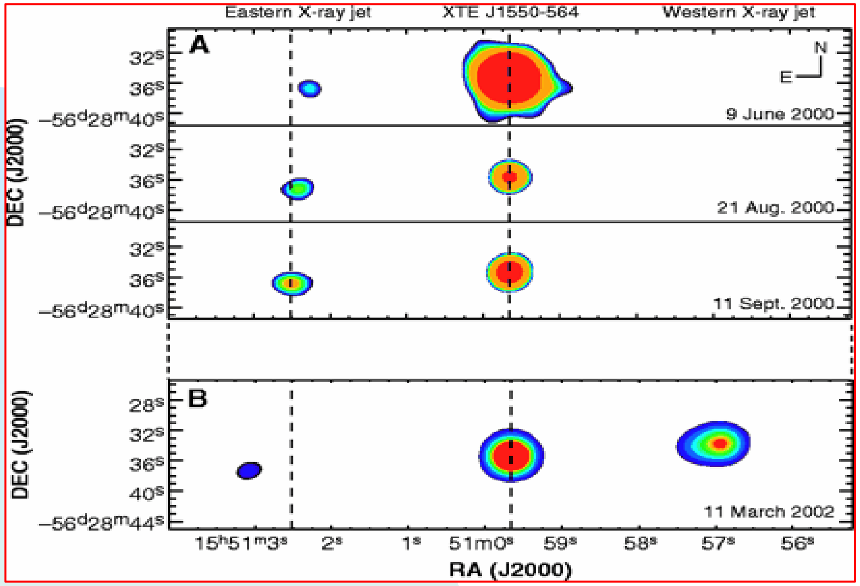


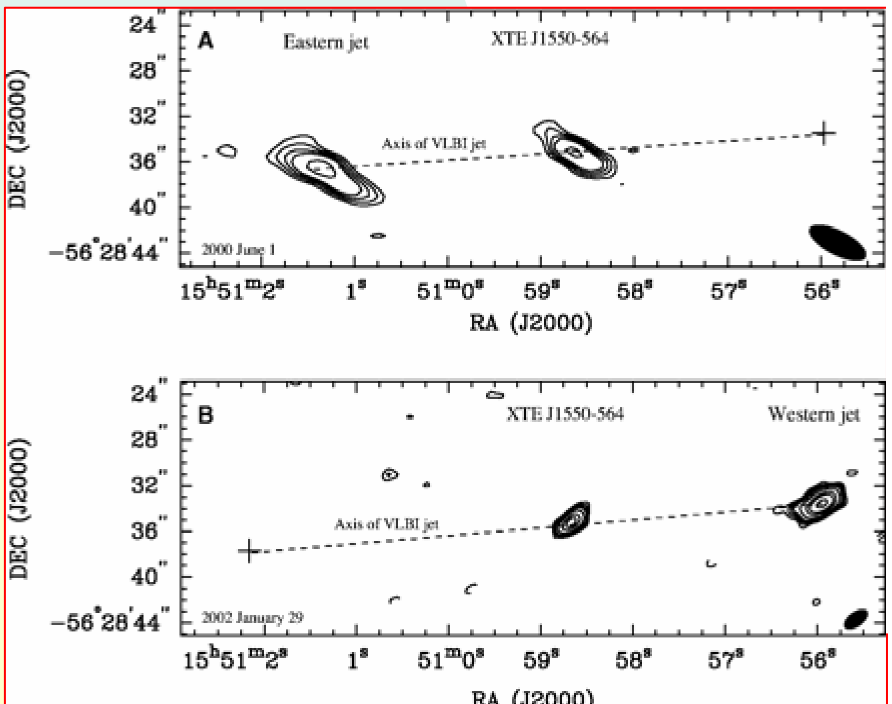
H 1743-322

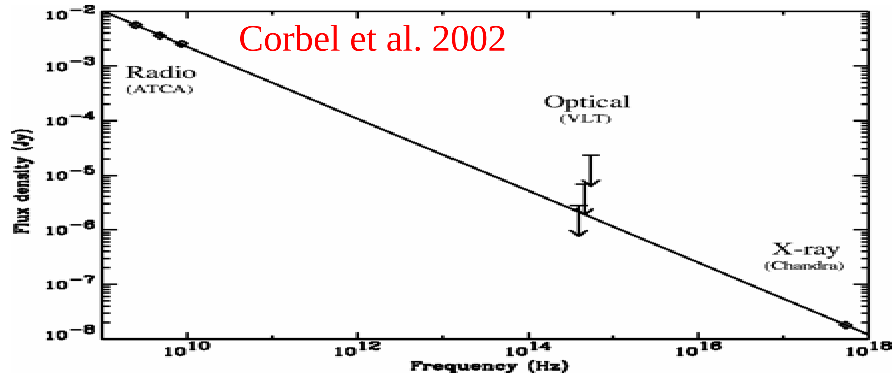


(Xue, Wu & Cui 2008)

Jet Emission







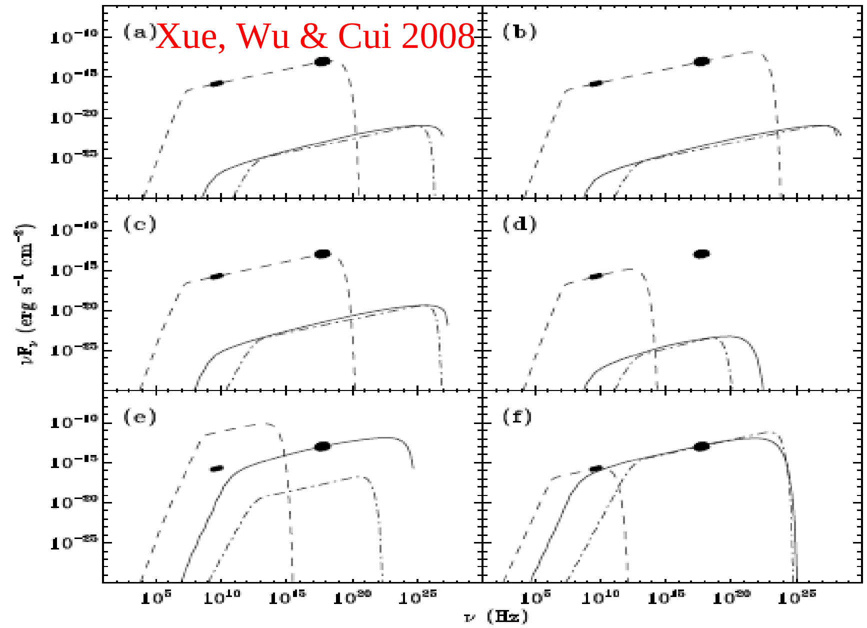
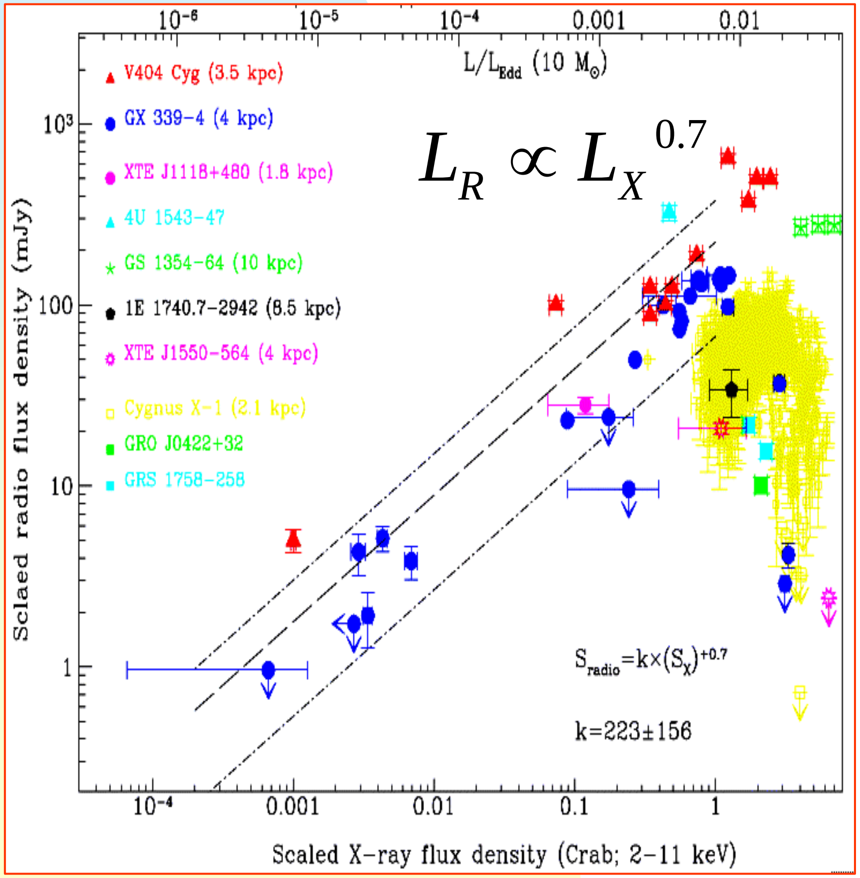


Table 3. Model parameters for the western jet 'blob' in XTE J1550−564

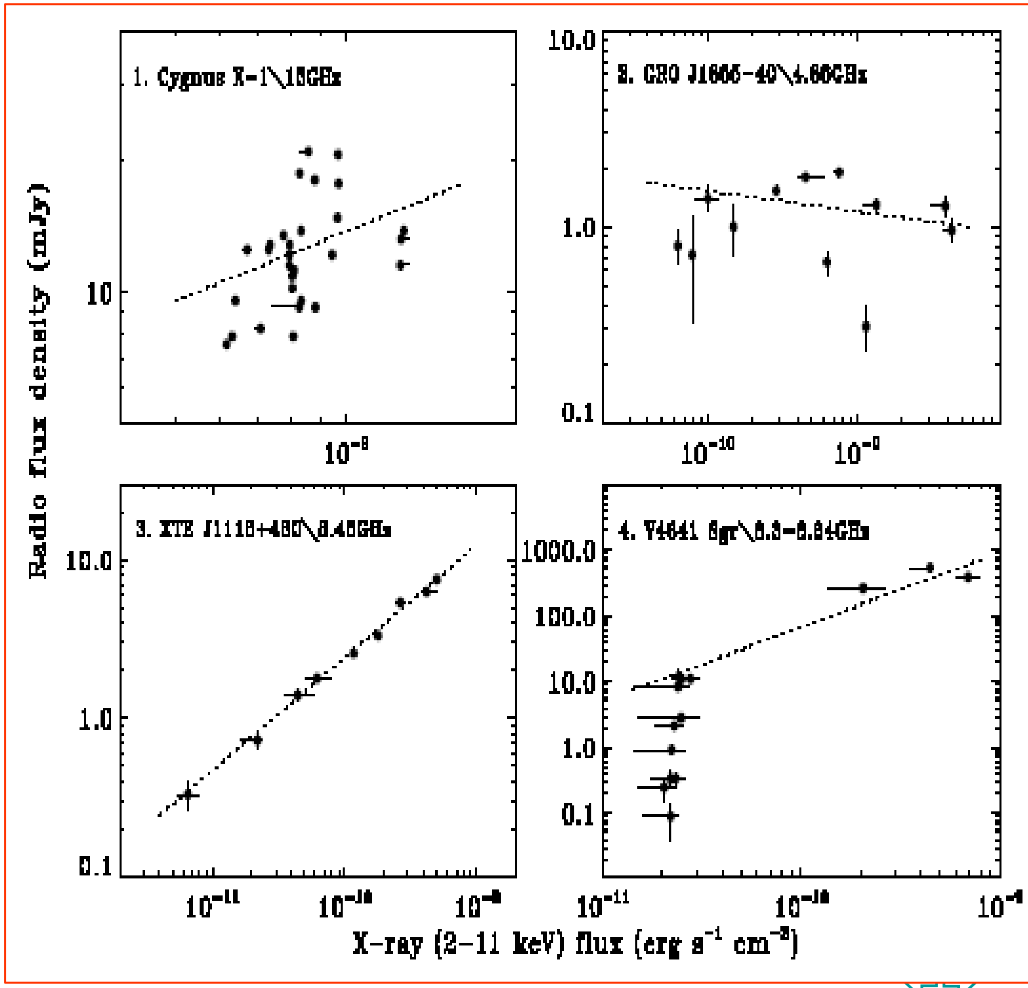
Case Number	B (Gauss)	$E_{tot}/m_e c^2$ (cm^{-3})	γ_{max}	p
(a)	0.016	25.1	1.6×10^7	2.31
(b)	0.032	79.5	5.0×10^8	2.32
(c)	0.002	1.2×10^3	3.0×10^7	2.32
(d)	0.032	0.06	1.0×10^4	2.20
(e)	0.003	4.0×10^5	1.0×10^5	2.30
(f)	8.0×10^{-9}	1.5×10^{11}	1.6×10^6	2.30

Radio/X-ray correlation in Microquasars

Gallo, Fender & Pooley (2003)

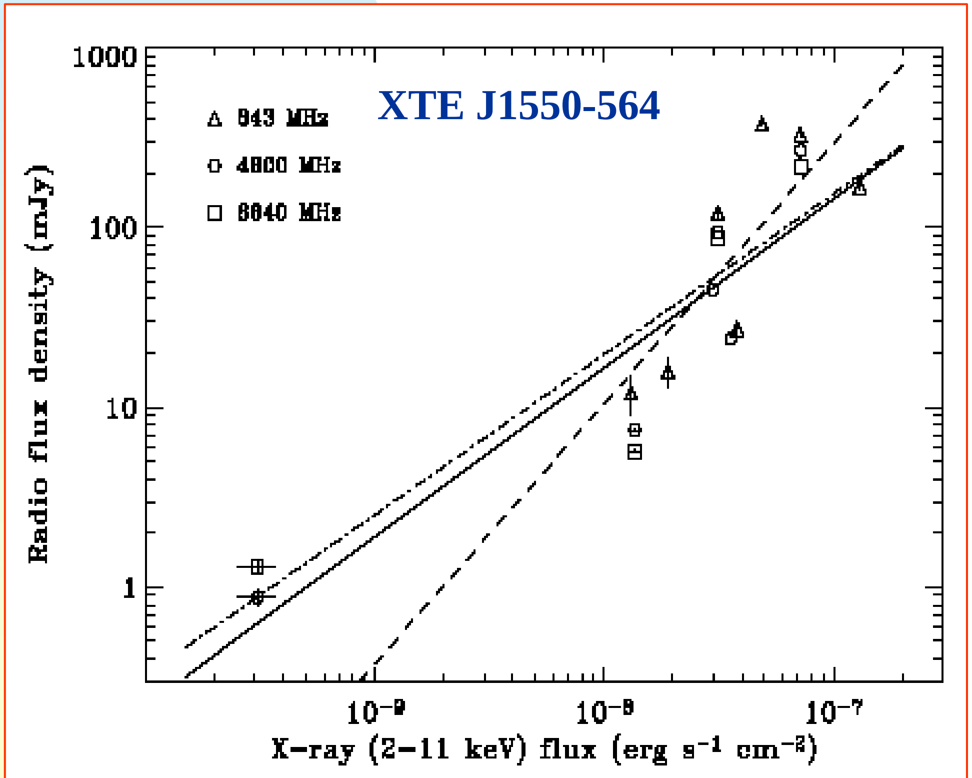


Xue & Cui (2007)

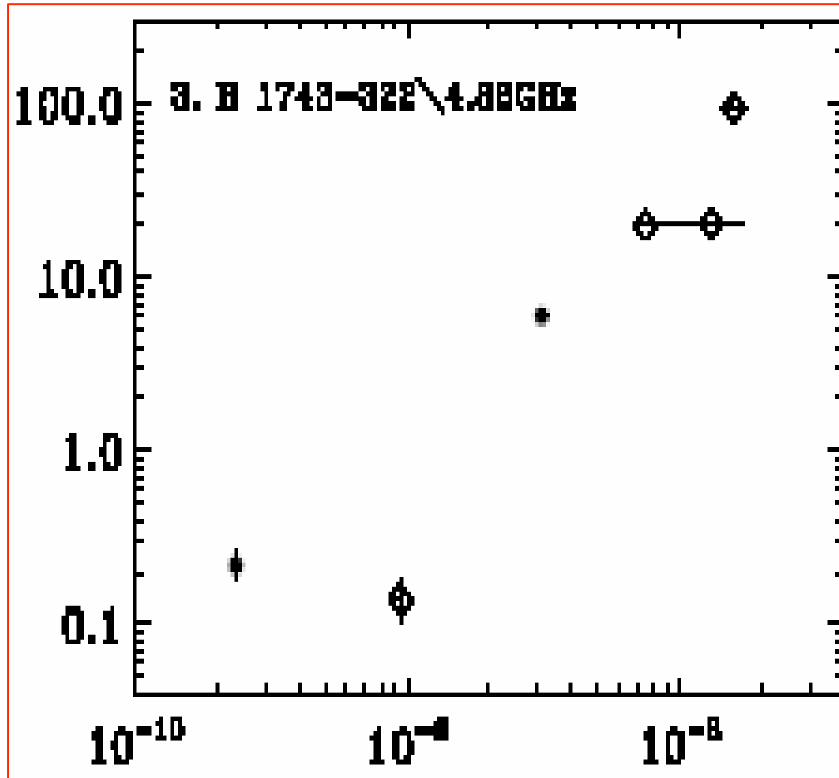


Radio/X-ray correlation in Microquasars

Xue, Wu & Cui (2008, MNRAS)



Xue & Cui (2007, A&A)



=>Radio/X-ray correlation is frequency dependent and probably evolving with time

3. Radio/X-ray correlation of AGNs

- **BH**: Mass (M)
- **Accretion flow**: X-ray emission(L_X)
- **Jet**: Radio emission(L_R) (+L_X in some cases)
- Any common relationship among L_R, L_X and M?

A fundamental plane of black hole activity

(Merloni, Heinz, & Di Matteo, 2003, MNRAS)

$$\log L_R = (0.60^{+0.11}_{-0.11}) \log L_X + (0.78^{+0.11}_{-0.09}) \log M + 7.33^{+4.05}_{-4.07}$$

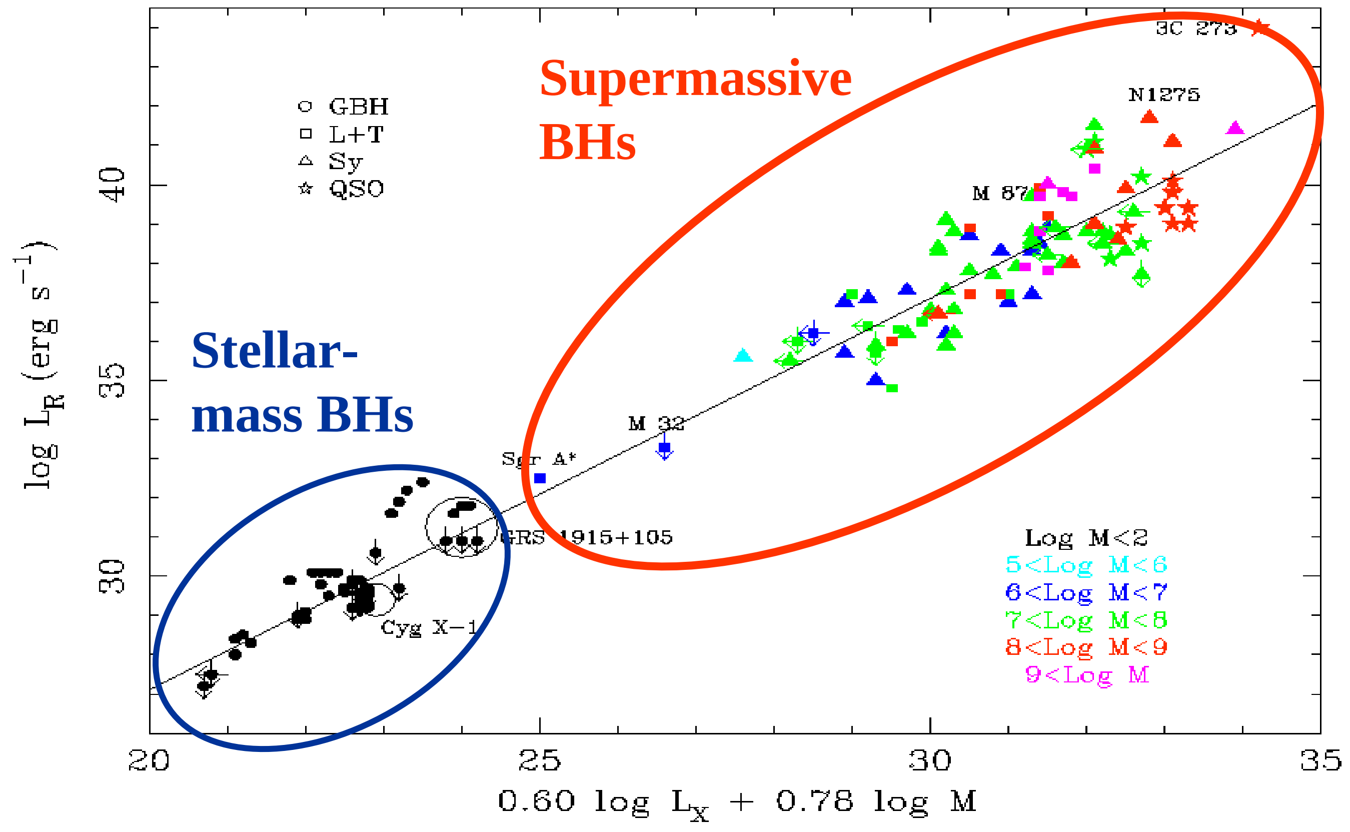


Figure 4. The edge-on view of the "fundamental plane of black hole activity". The solid line shows the best fitting function (5).

Test with a uniform sample from multi-wavelength surveys

- Problems of previous studies
  - non-uniform samples
- Our sample 1
  - a relatively uniform, low-z radio and X-ray emitting broad line AGN sample selected from SDSS(DR1)-RASS-FIRST surveys (Wang, Wu & Kong 2006, ApJ, 645,890)
  - including 76 radio-loud and 39 radio-quiet AGNs
- Our sample 2
  - 725 SDSS(DR5)-RASS-FIRST broad line AGNs, including 498 radio-loud and 227 radio-quiet AGNs (Li, Wu, & Wang 2008, ApJ, submitted)

AGN black hole mass estimates based on SDSS optical spectra

- **Virial law (Kaspi et al. 2000, 2005)**

$$M = 1.464 \times 10^5 (\frac{R_{BLR}}{light-days})(\frac{V_{FWHM}}{10^3 kms^{-1}})^2 M\odot$$

- **R-$L_{H\beta}$ relation (Wu et al. 2004, A&A)**

$$Log R_{BLR}(light-days) = (1.381 \pm 0.080) + (0.684 \pm 0.106) Log(L_{H\beta}/10^{42} ergs^{-1})$$

- **McLure -Jarvis (2002) relation**

$$M = 3.37(\frac{\lambda L_{3000}}{10^{44} ergs^{-1}})^{0.47}(\frac{V_{FWHM,MgII}}{kms^{-1}})^2 M_{\odot}$$

$$Log(\frac{L_r}{10^{40} erg\, s^{-1}}) = \xi_{RX} Log(\frac{L_X}{10^{44} erg\, s^{-1}}) + \xi_{RM} Log(\frac{M}{10^8 M_\odot}) + Const.$$

Table 3. The derived fundamental plane relation

Weak/no correlation with M

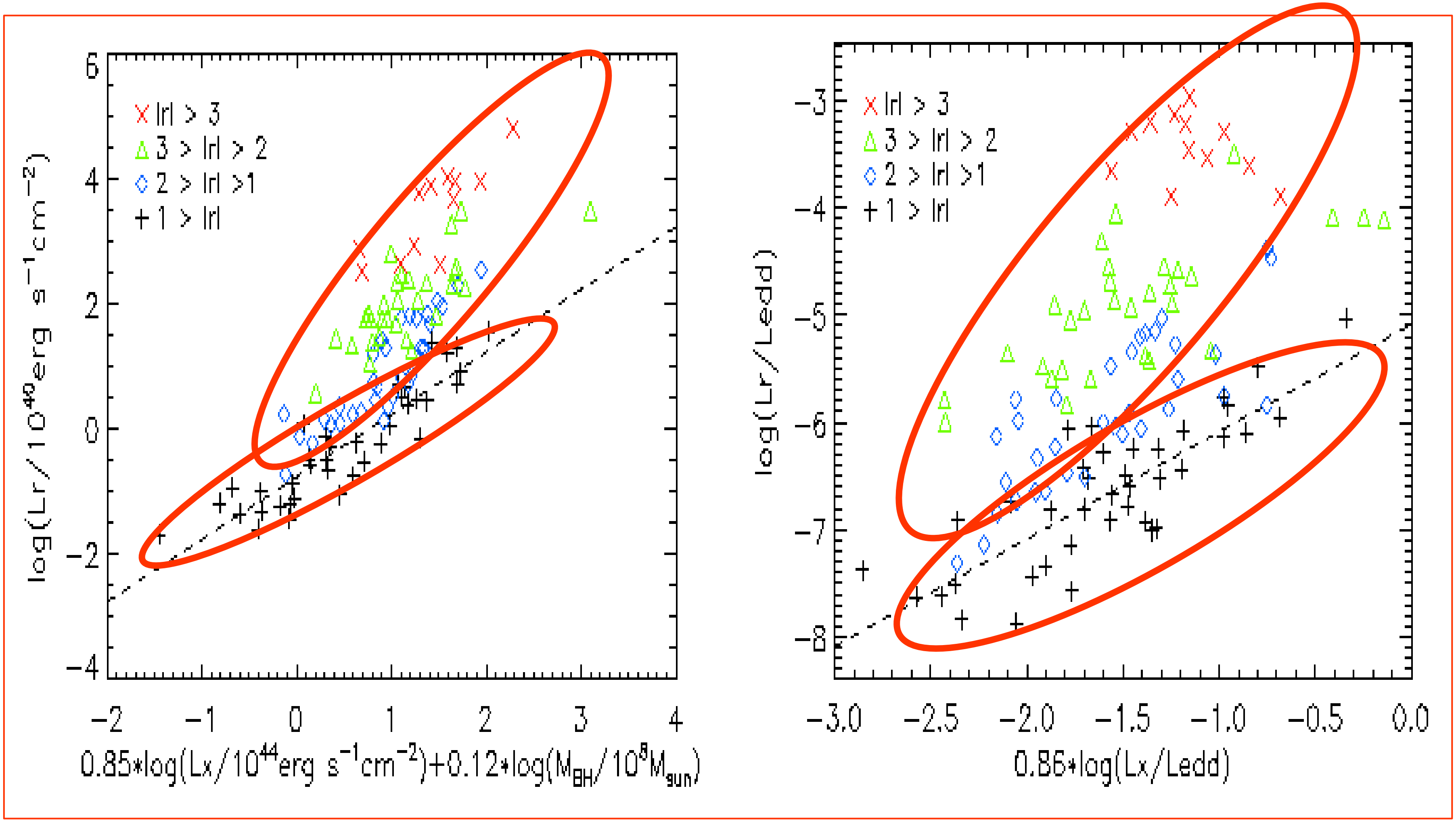
Subsample	Number	ξ_{RX}	ξ_{RM}	Const.	σ_r
Total	115	1.33 ± 0.15	0.30 ± 0.18	-0.40 ± 0.14	0.89
Radio loud	76	1.39 ± 0.17	0.17 ± 0.21	-0.17 ± 0.21	0.77
Radio quiet	39	0.85 ± 0.10	0.12 ± 0.13	-0.77 ± 0.07	0.38
Merloni et al. (2003)	-	0.60 ± 0.11	$0.78^{+0.11}_{-0.09}$	$7.33^{+4.05}_{-4.07}$	0.88

Different slopes

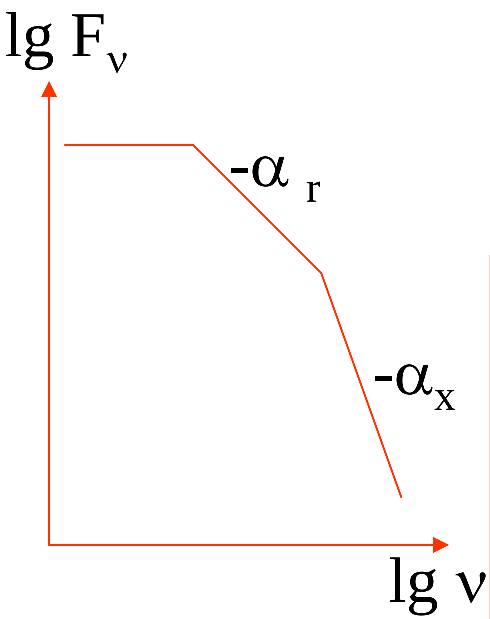
For radio-quiet sources:

$$Log(\frac{L_r}{L_{Edd}}) = (0.86 \pm 0.10) Log(\frac{L_X}{L_{Edd}}) + (-5.08 \pm 0.19)$$

Difference between radio-loud and radio-quiet AGNs in the radio--X-ray correlation



Heinz (2004, MNRAS)



$$N(\gamma) \propto \gamma^{-P}$$

Scaling relations for scale-invariant cooled jets (both Lr & Lx are from jets):

$$F_r \propto M^{\xi_{RM}} F_x^{\xi_{RX}}$$

$$\xi_{RM} = \frac{(2p + 13 - (2 + p)\alpha_r)(p - 1 - \alpha_x) - (2\alpha_r)}{(p + 4)(2p + 1 - 3\alpha_x)}$$

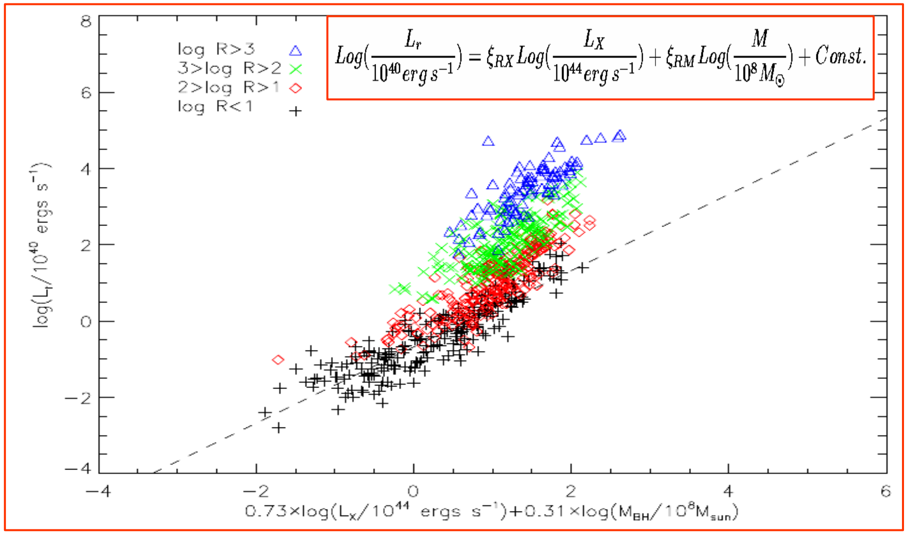
$$\xi_{RX} = \frac{2p + 13 + (p + 6)\alpha_r}{(p + 4)(2p + 1 - 3\alpha_x)}.$$

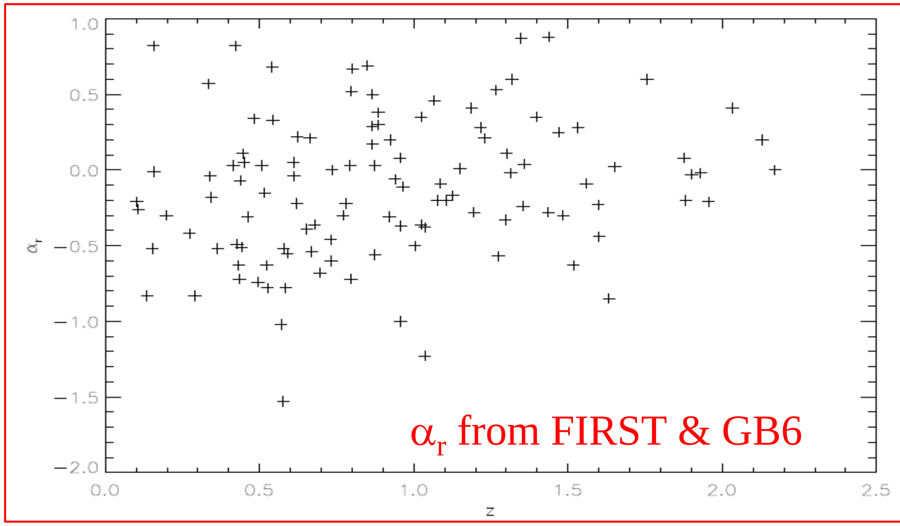
For canonical synchrotron spectrum of p=2, α_r=0.5, α_x=1

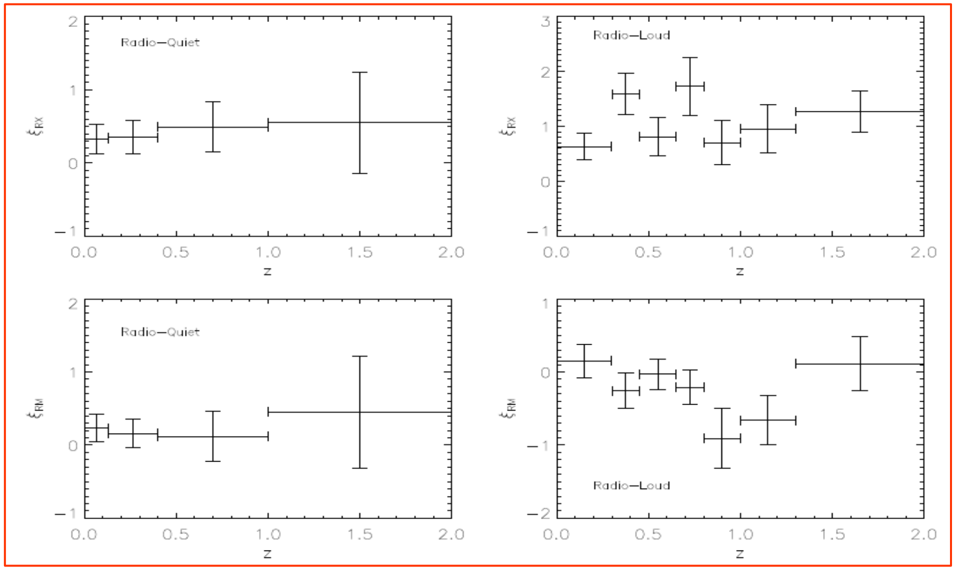
→ $$L_R \propto M^0 L_X^{1.42}$$

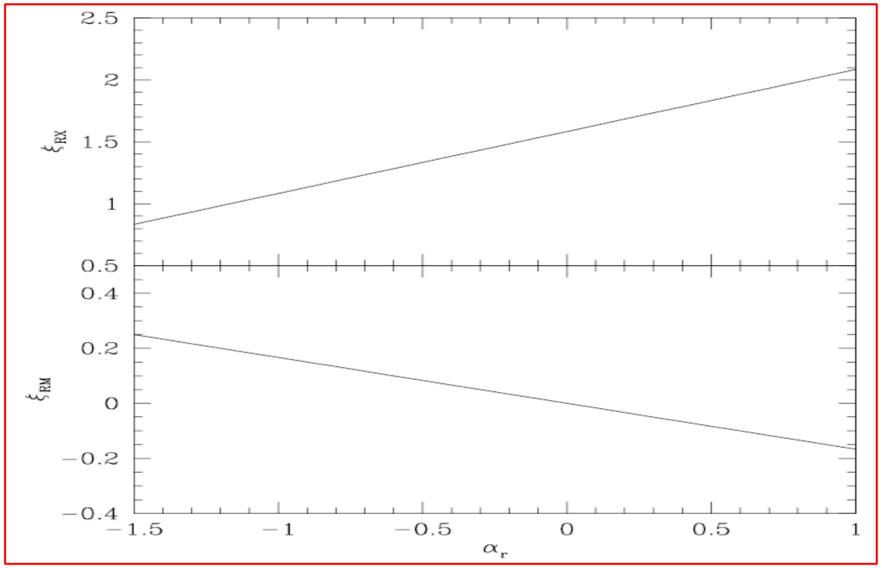
Consistent with our results for radio-loud AGNs!

Check with a larger sample of 725 SDSS(DR5)-RASS-FIRST AGNs (Li, Wu & Wang 2008)



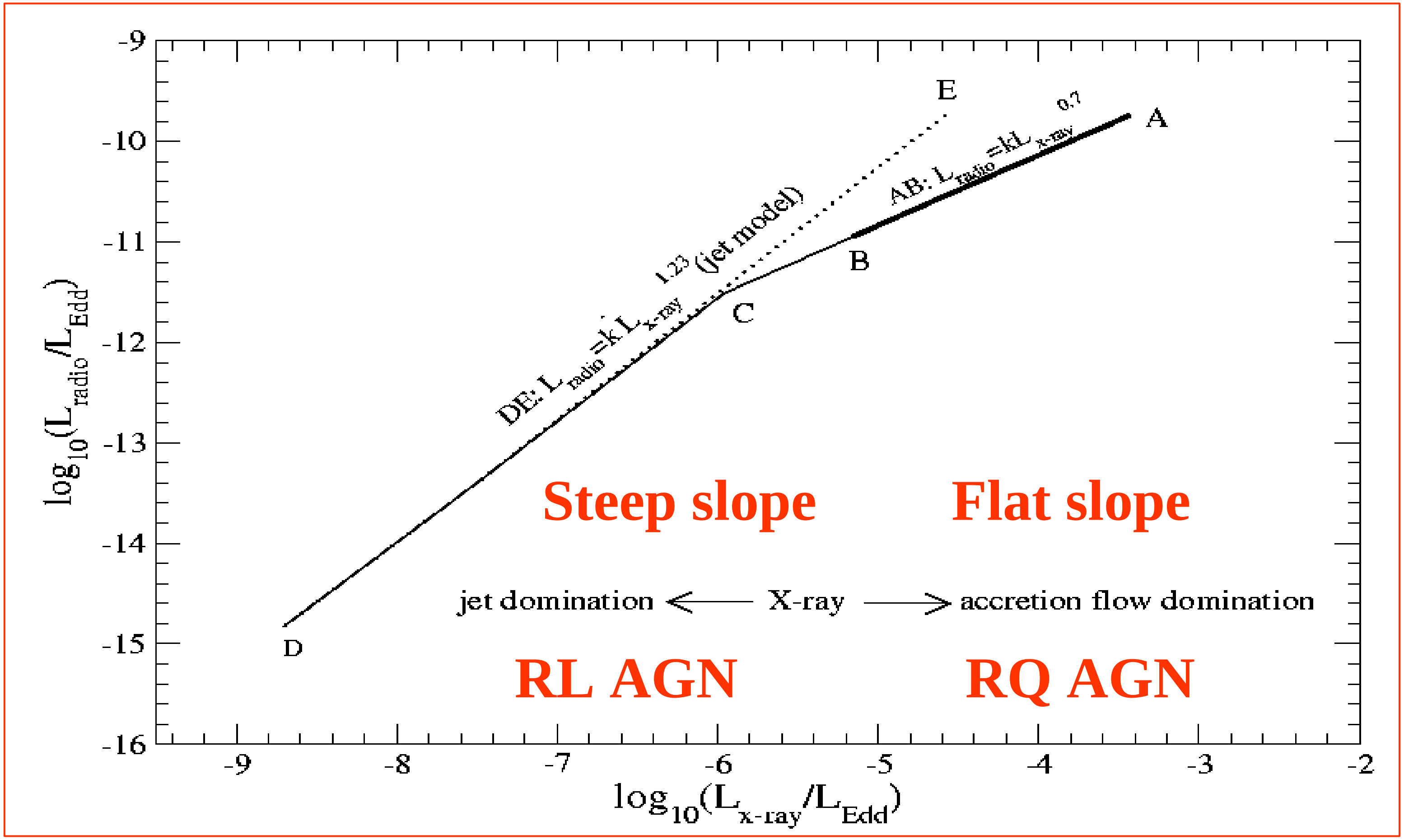






Radio -X-ray correlation for different X-ray origins

(Yuan & Cui 2005, ApJ)



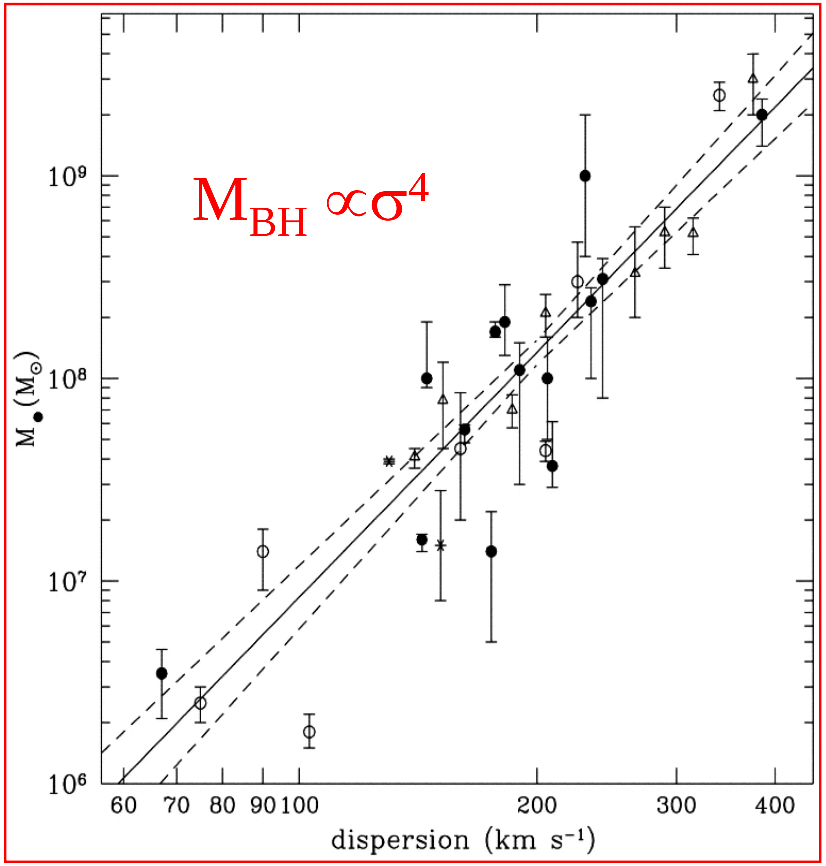
Consistent with our results obtained with a uniform AGN sample!

(Radio-quiet AGN has a shallower slope than radio-loud AGN)

4. CO line width and M-σ relation of quasars

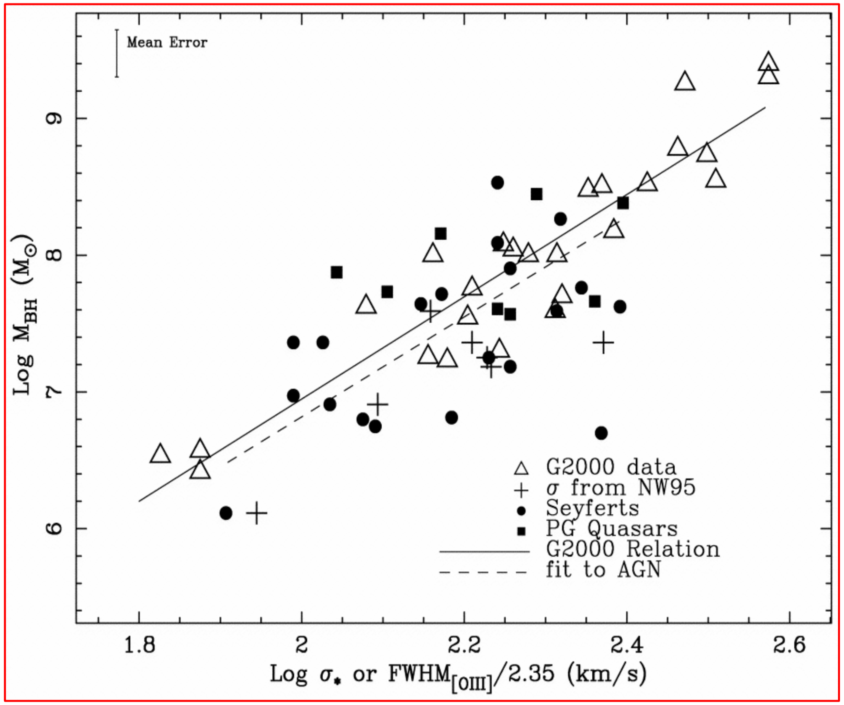
Physics of the black hole - bulge relation:

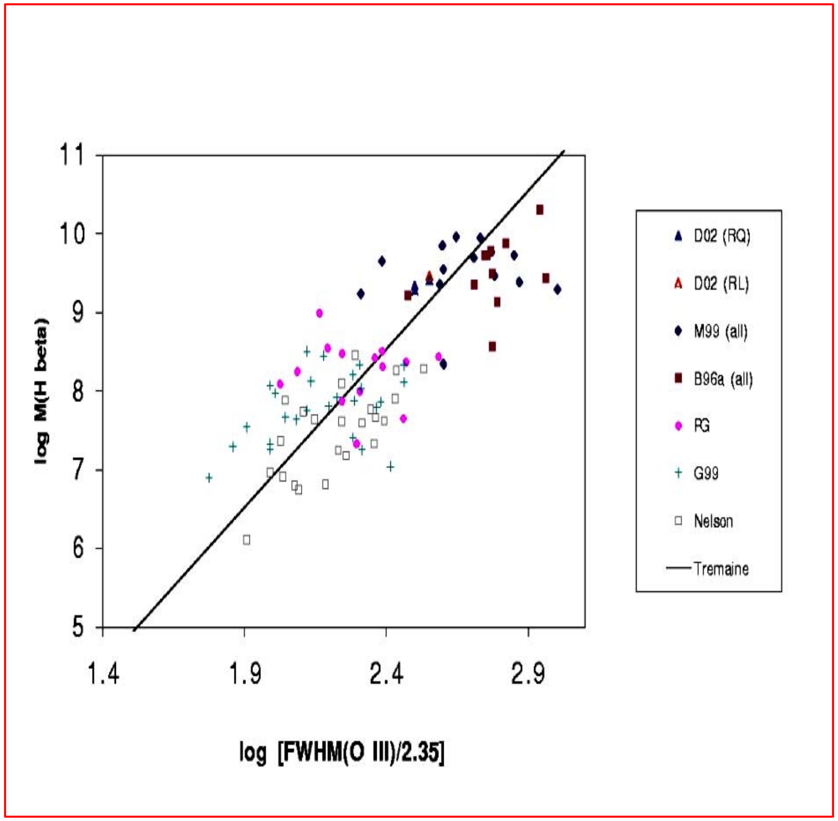
- **Close tie between BH and galaxy formation & evolution**
- **Feedback scenario (Silk & Rees 1998; King 2003, 2005;…)**
- **Two-direction starburst feedback model: Xu, Wu & Zhao (2007 ApJ, 664,198); Xu & Wu (2007 ApJ, 667,92)**



Tremaine et al. (2002)

M - σ relation of quasars

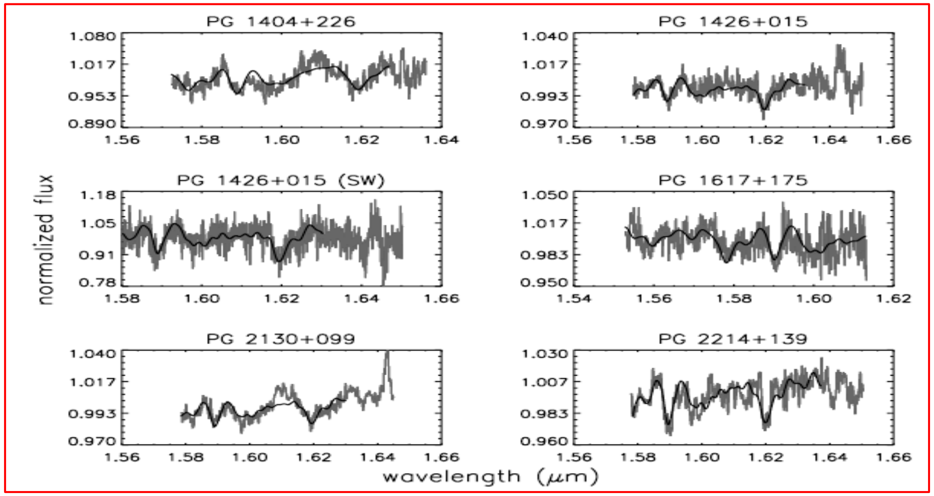




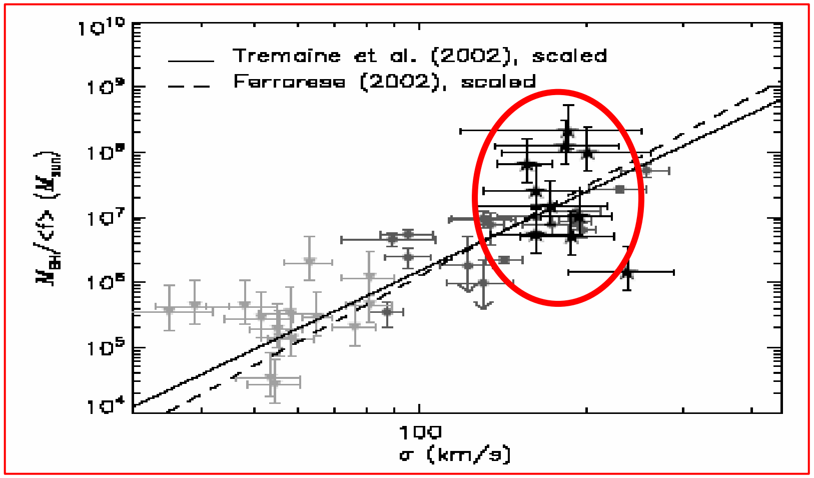
For quasars: direct measurement of σ is difficult; σ=FWHM([OIII])/2.35 is usually adopted (Nelson 2000; Shields et al. 2003); galaxy growth is contemporaneous with black hole growth up to z=2~3 (however, Woo et al. 2008)

PG quasars with measured σ

- Dasyra et al. (2006, ApJ)
  - Long integration near IR H-band spectroscopy with VLT



Source	σ (km s^{-1})
PG 0007+106	201 (±61)
PG 0050+124	188 (±36)
LBQS 0307−0101	207 (±49)
PG 1119+120	162 (±28)
PG 1126−041	194 (±29)
PG 1211+143	. . .
PG 1229+204	162 (±32)
PG 1404+226	237 (±52)
PG 1426+015[a]	185 (±67)
PG 1617+175	183 (±47)
PG 2130+099	172 (±46)
PG 2214+139	156 (±18)



High-z Quasars

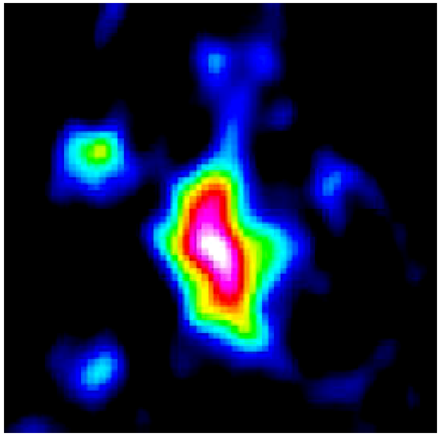


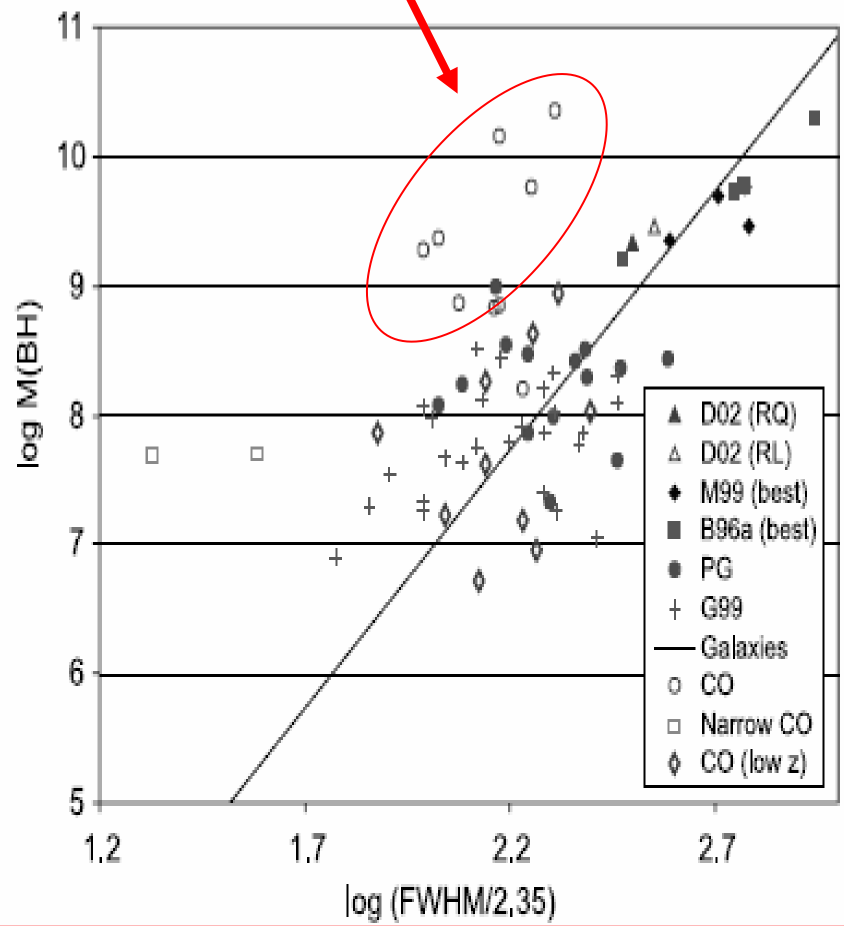
Fig. 2 The velocity integrated CO 3-2 emission from J1148+5251 imaged by the VLA at 0.4" resolution (Walter et al. 2004). The total flux is 0.15 Jy km s^{-1}, and the source is clearly resolved, with a full extend of about 1". The figure is about 3" on a side.

SDSS J1148+5251 (z=6.42)

Walter et al. (2004)

- CO molecular line detected for a number of hi-z quasars (Solomon & Vanden Bout 2005 ARA&A)
- CO line width as a surrogate for σ (Shields et al. 2006 ApJ, 641, 683)
- σ=FWHM(CO)/2.35

Hi-z quasars, outliers?



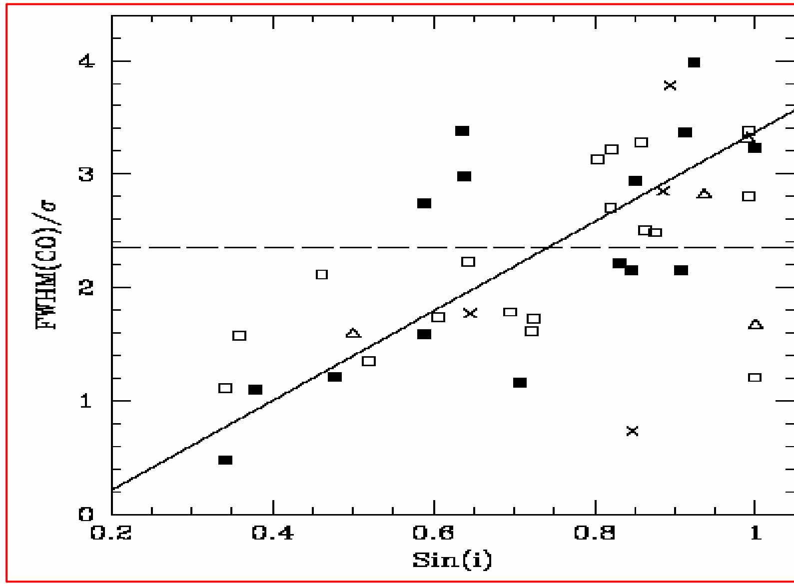
(Shields et al. 2006)

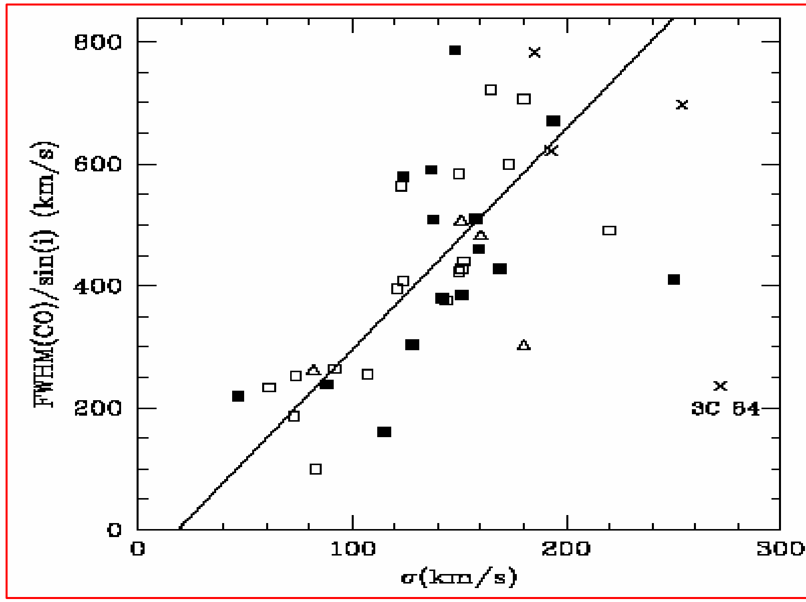
High-z Quasars

- Can we use σ=FWHM(CO)/2.35 ?(No)
- A test with CO detected 33 Seyfert galaxies **(Wu 2007, ApJ, 657, 177)**
- A better correlation using inclination-corrected line width

$$\mathrm{FWHM(CO)}/\sin i = -(67.16 \pm 80.18) + (3.62 \pm 0.68)\,\sigma.$$

- CO molecular disk coplanar with the galaxy disk (Heckman et al. 1989)

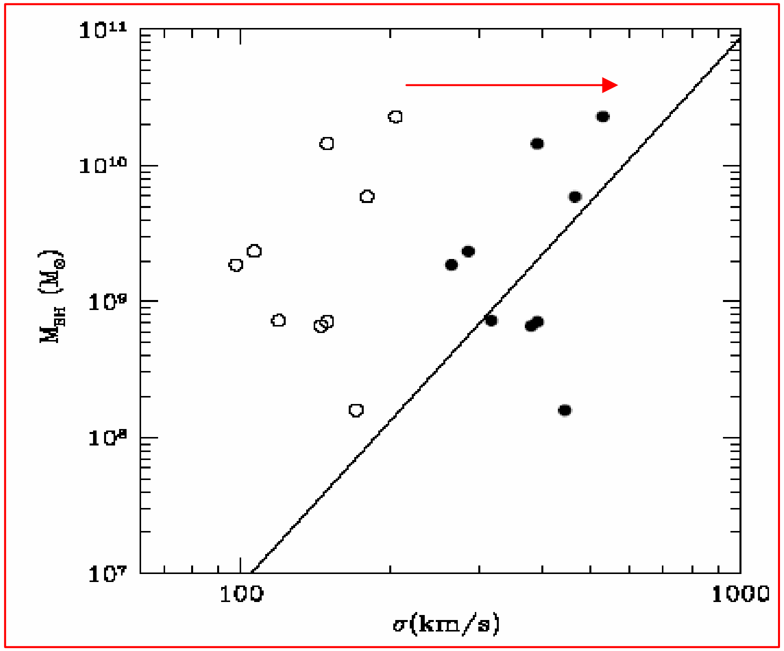




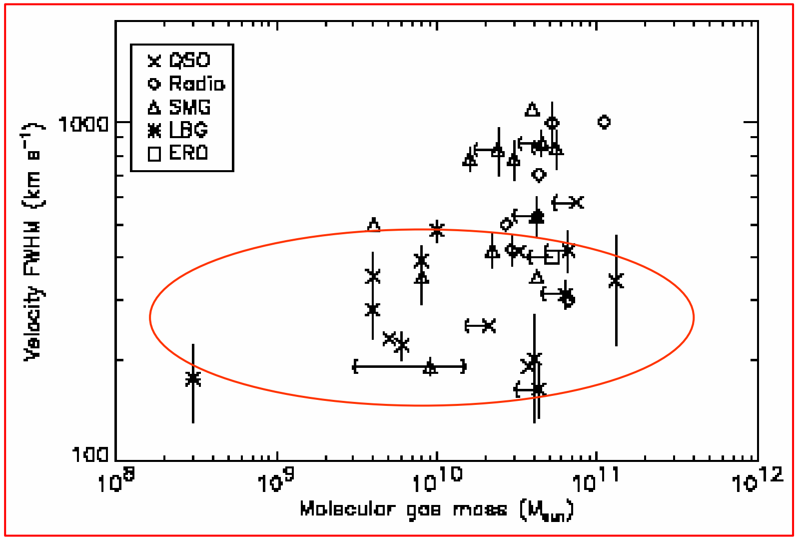
Wu (2007, ApJ)

High-z Quasars

- Assuming inclination ~15° for hi-z quasars, we can re-estimate σ values using the inclination-corrected CO line width and study the M - σ relation at Hi-z
- Small inclinations (~15°) are also probably needed to explain the narrowness of CO line of hi-z quasars compared with the sub-millimeter galaxies (SMG) (Greve et al. 2005; Carilli & Wang 2006)



Wu (2007, ApJ)



Carilli & Wang (2006,AJ)

5. Summary

- **Multiwavelength data collected with powerful instruments are crucial to probe the physics nature of AGN and Microquasars.**
- **Radio/X-ray correlation in Microquasars may not be universal, reflecting a complex accretion-jet physics.**
- **BH fundamental plane of AGNs seems independent on the BH mass, and is different for radio-loud and radio-quiet AGNs. This may be related to different origins of X-ray emissions.**
- **Inclination-corrected CO line width can be taken as a surrogate for the stellar velocity dispersion. M-σ relation of nearby quasars is consistent with the local one. However, it's too early to say too much on the M-σ relation at hi-z universe.**