Using the Black Hole Fundamental Plane

to constrain Blazar Jet Physics

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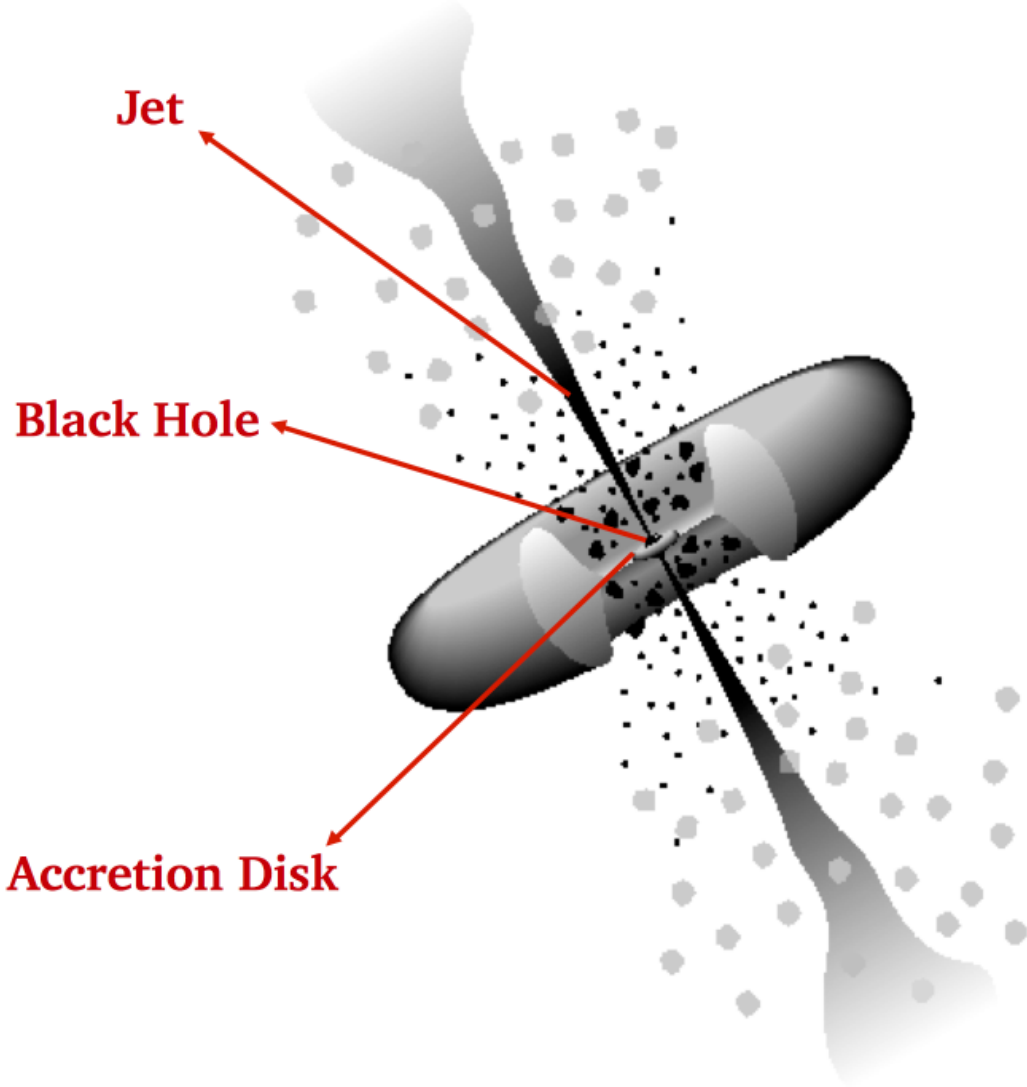
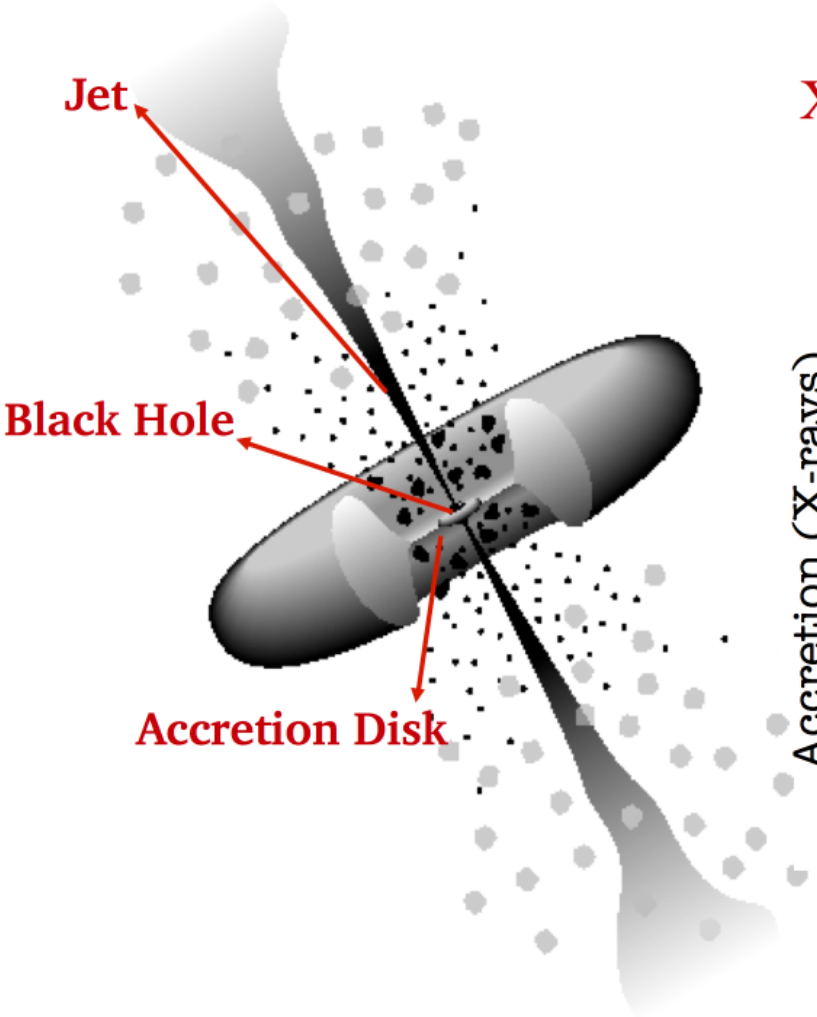
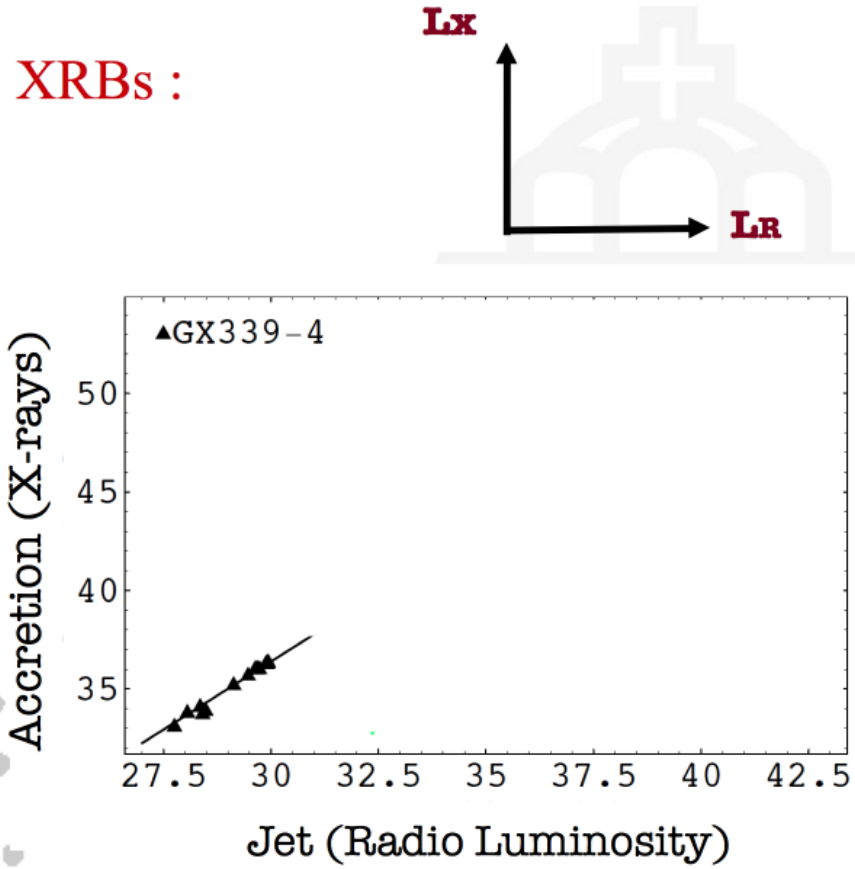
Accreting Black Hole Systems



Jet Disk coupling in XRBs

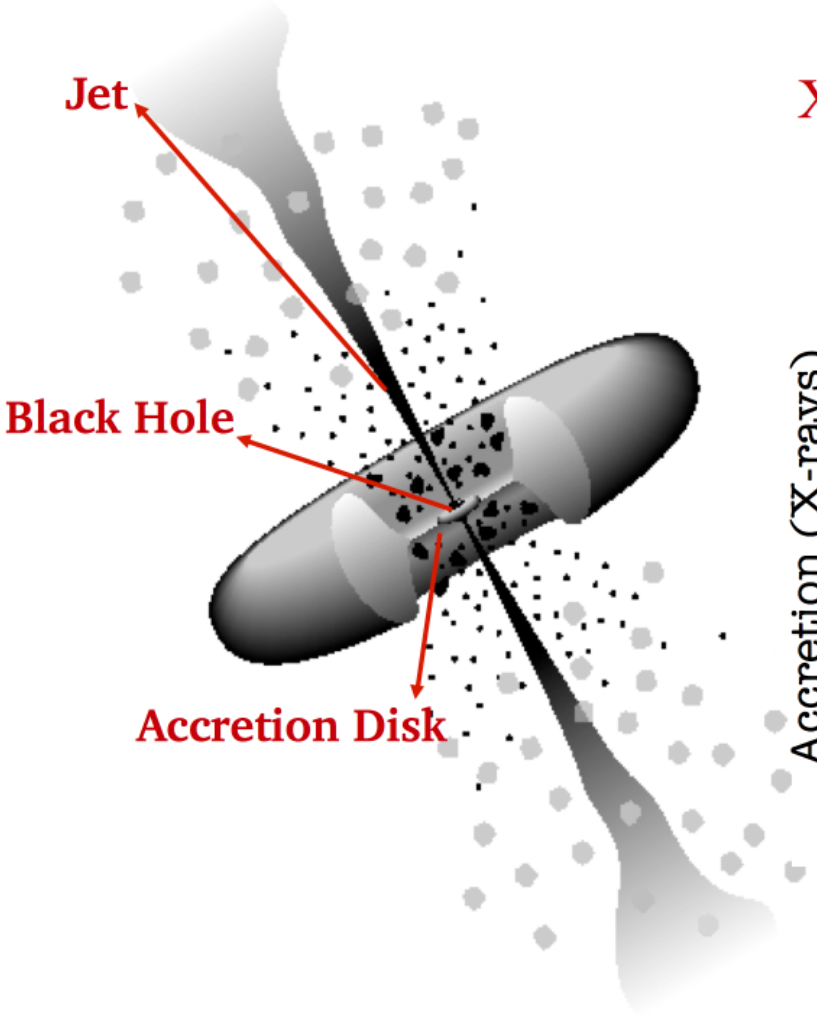


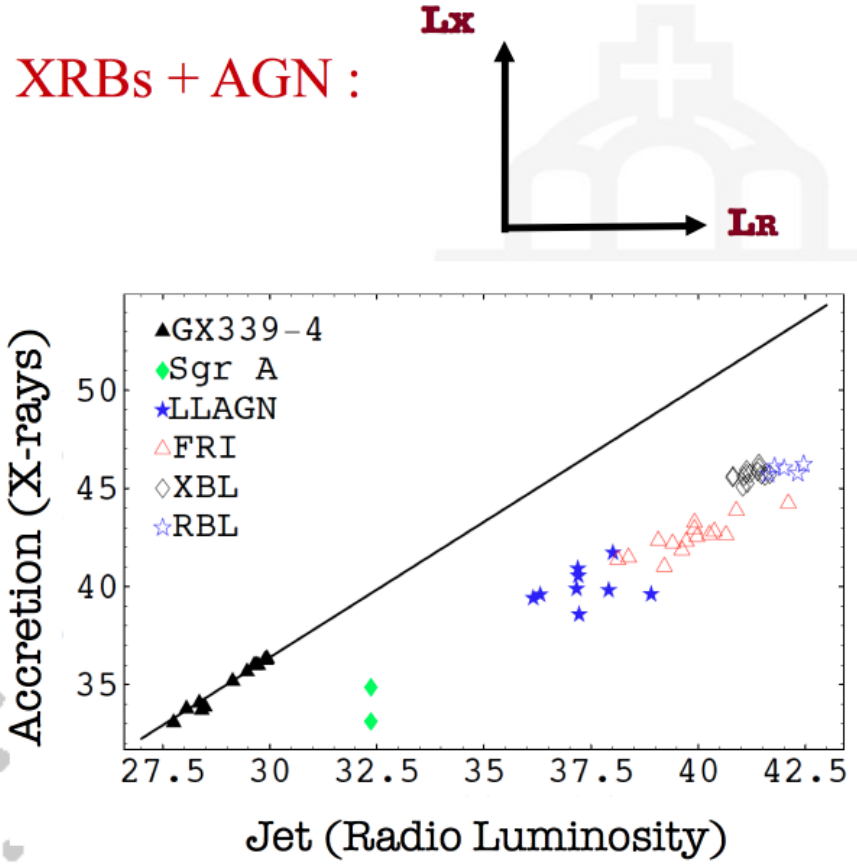
XRBs :



Gallo et al. 2003, Corbel et al. 2003 etc.

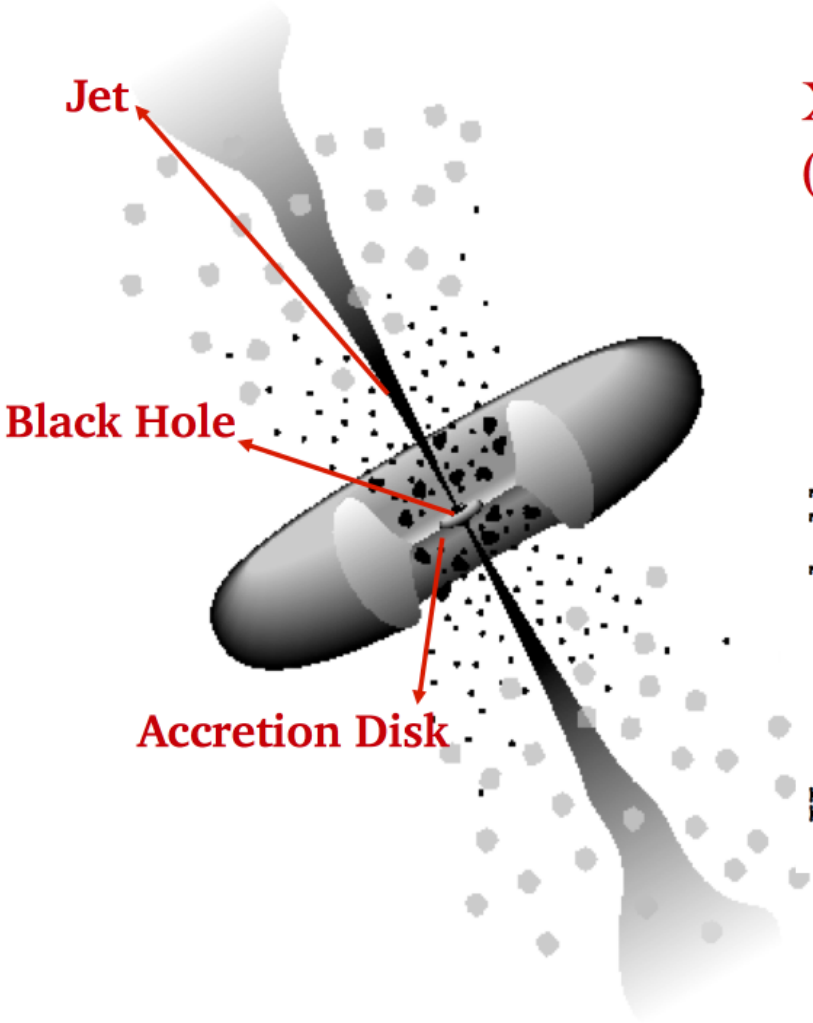
Jet Disk coupling in AGN



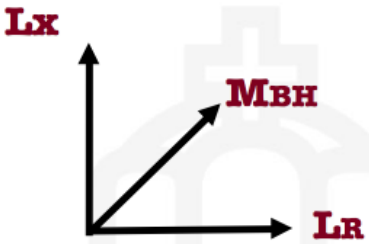


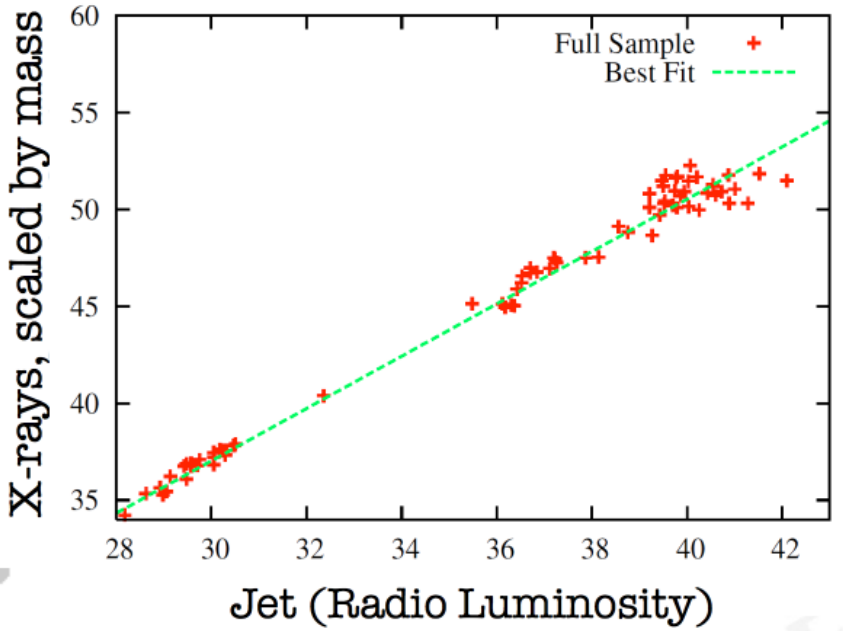
Falcke et al. 2004, Hardcastle & Worrall 1999

Fundamental Plane : Motivation



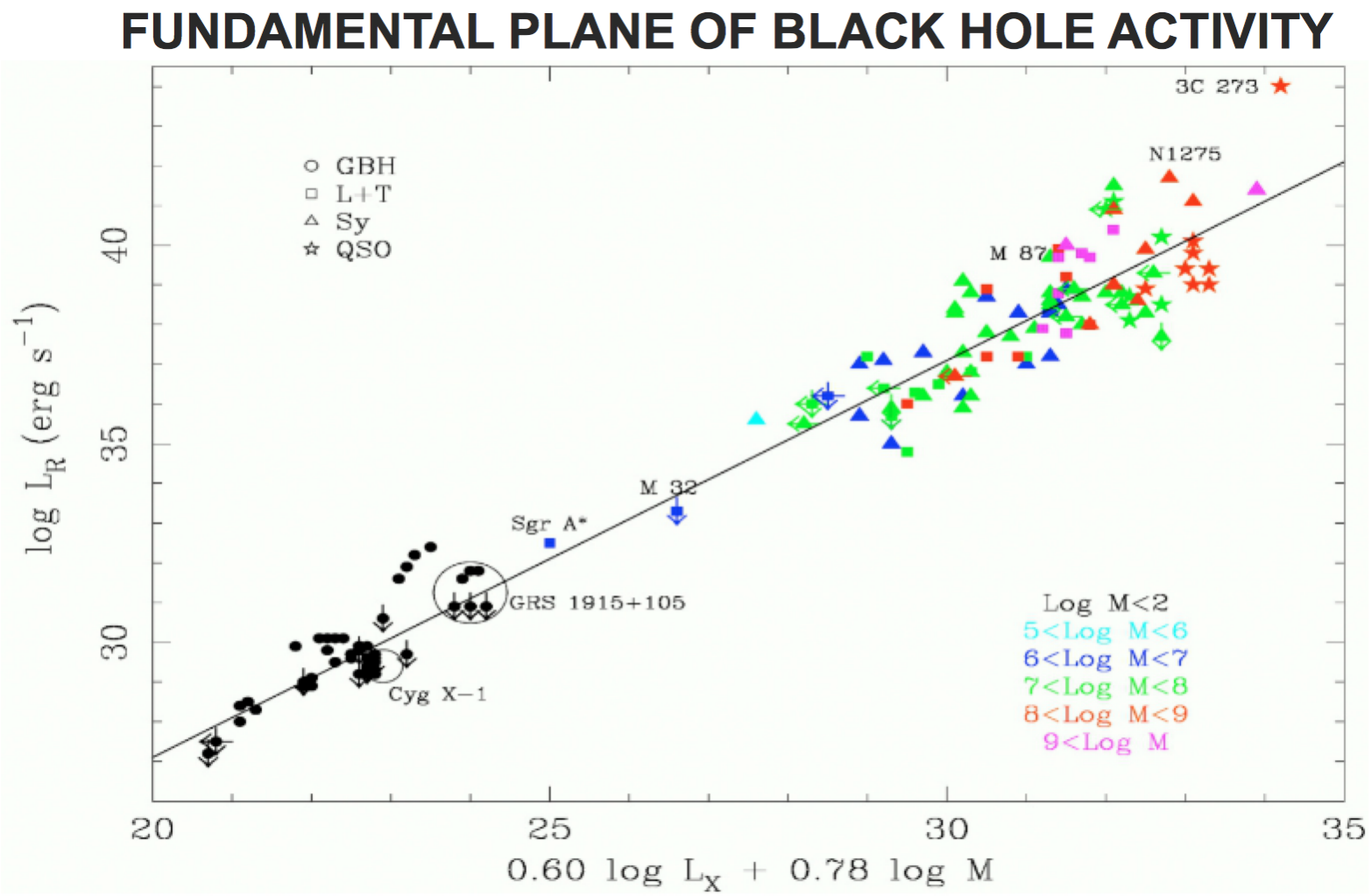
XRBs + AGN :
(scaled by mass)





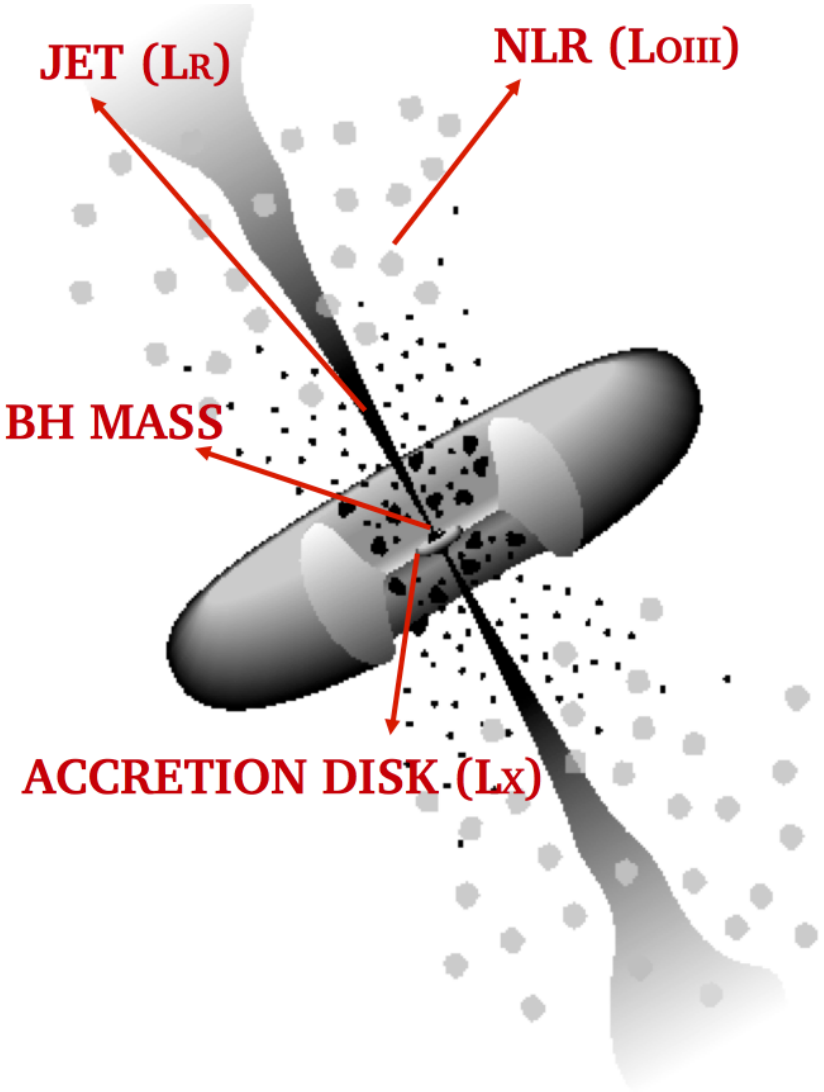
Koerding et al. 2006

Fundamental Plane : Introduction



Merloni et al 2003, Falcke et al 2004

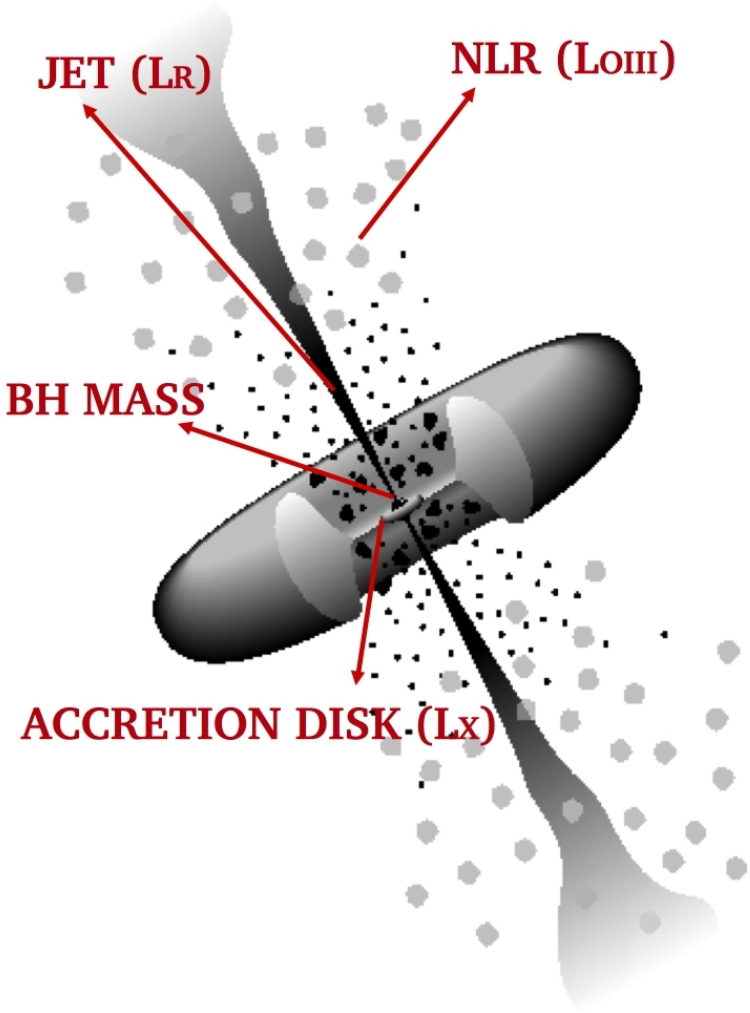
Optical Fundamental Plane : Introduction



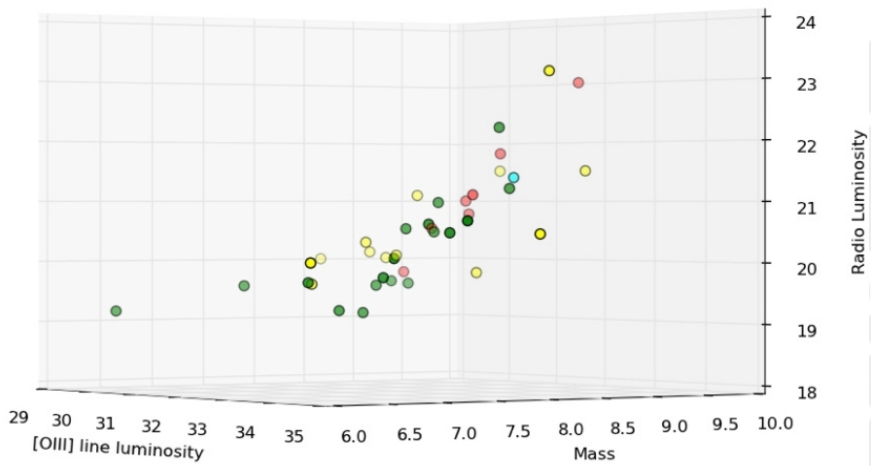
- **X-ray emission :**
  Arises from the hot corona surrounding the accretion disc or the base of relativistic jet

- **[OIII] line emission :**
  Arises from the gas at the Narrow Line Region (NLR), excited by ionizing radiation produced in the innermost accretion flow

Optical Fundamental Plane : Introduction



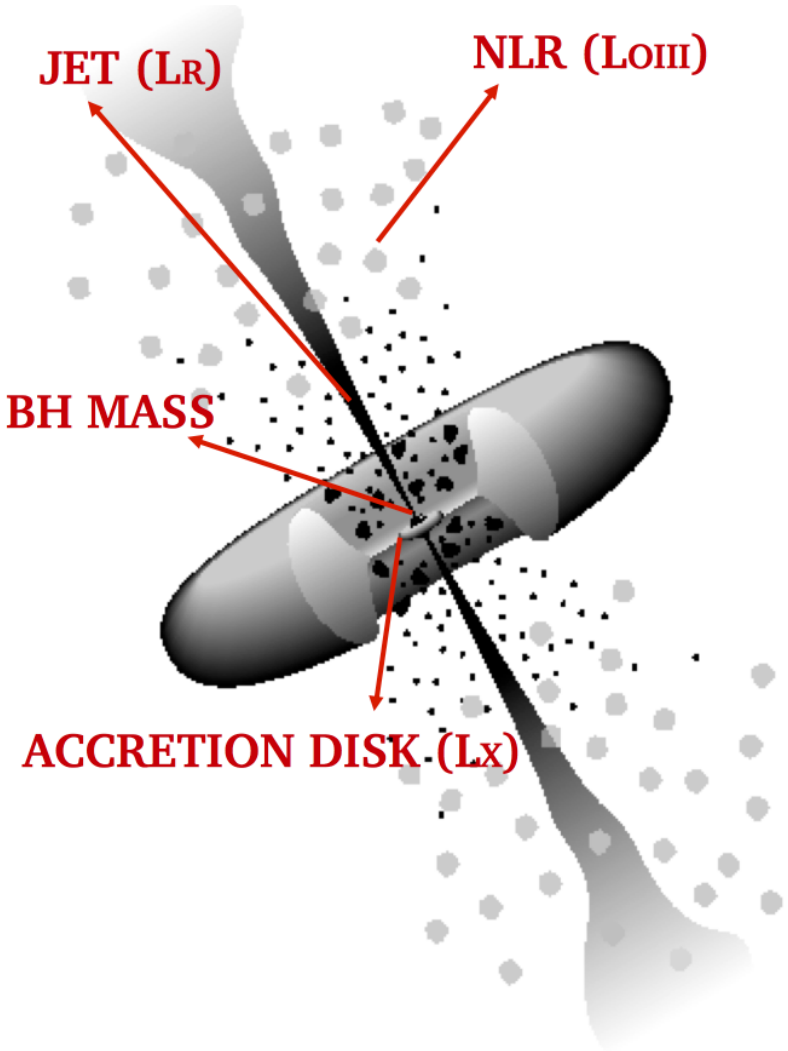
For SMBH alone :



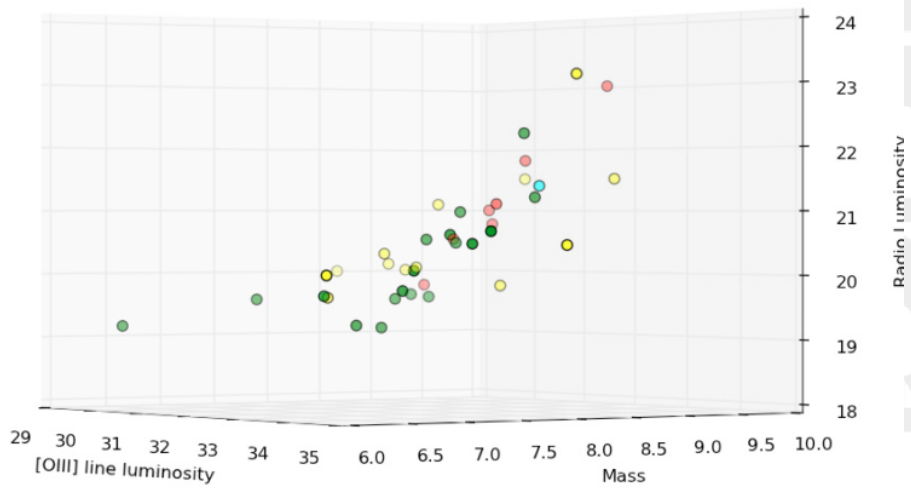
L_R : 15 GHz, VLA (Nagar et al 2005)
L_{OIII} : Palomar (Ho et al 1997)
M_{BH} : Stellar velocity dispersion (Ho et al 2009)

LLAGN sample taken from the Palomar Spectroscopic Survey (Ho et al 1995)

Optical Fundamental Plane : Introduction



For SMBH alone :

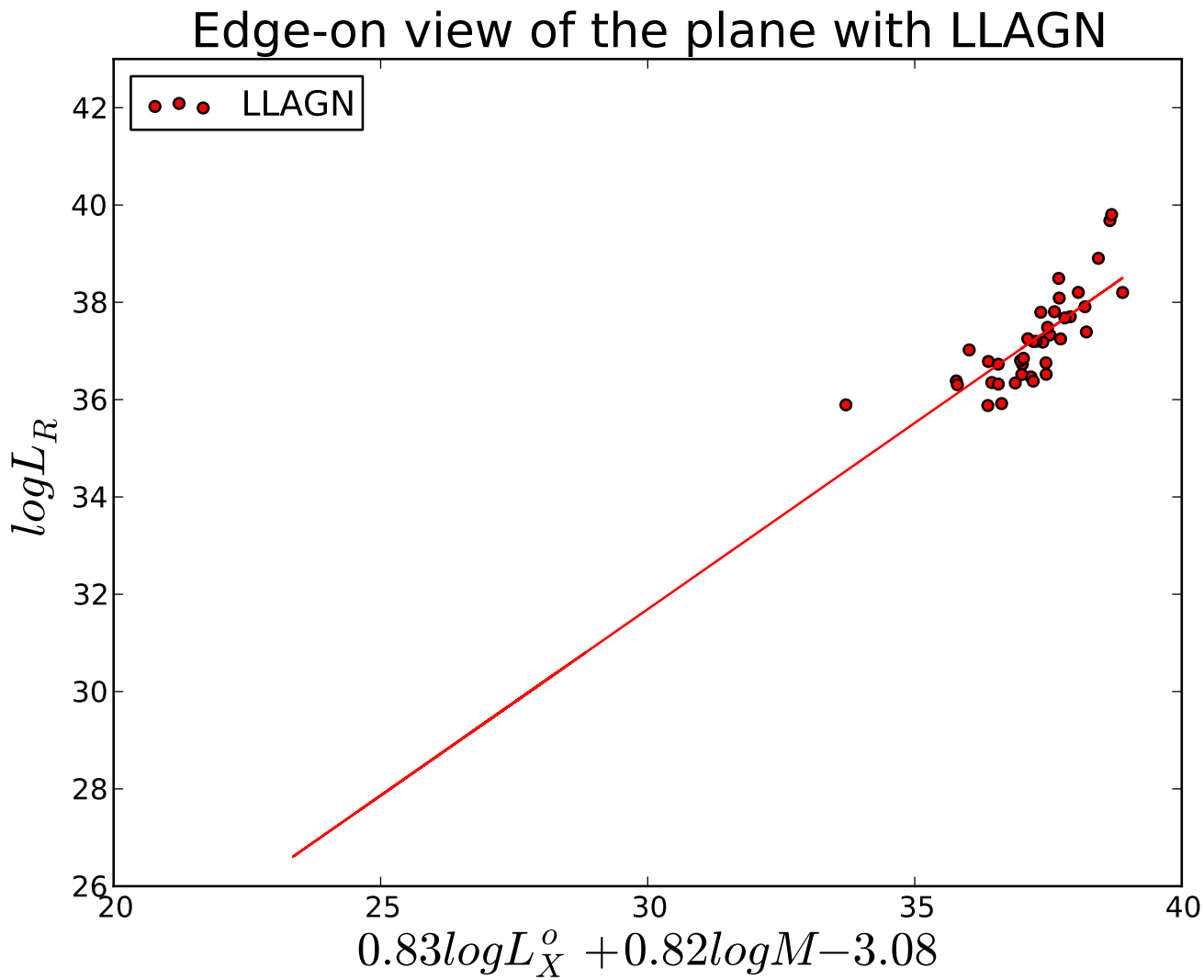


To compare with XRBs :

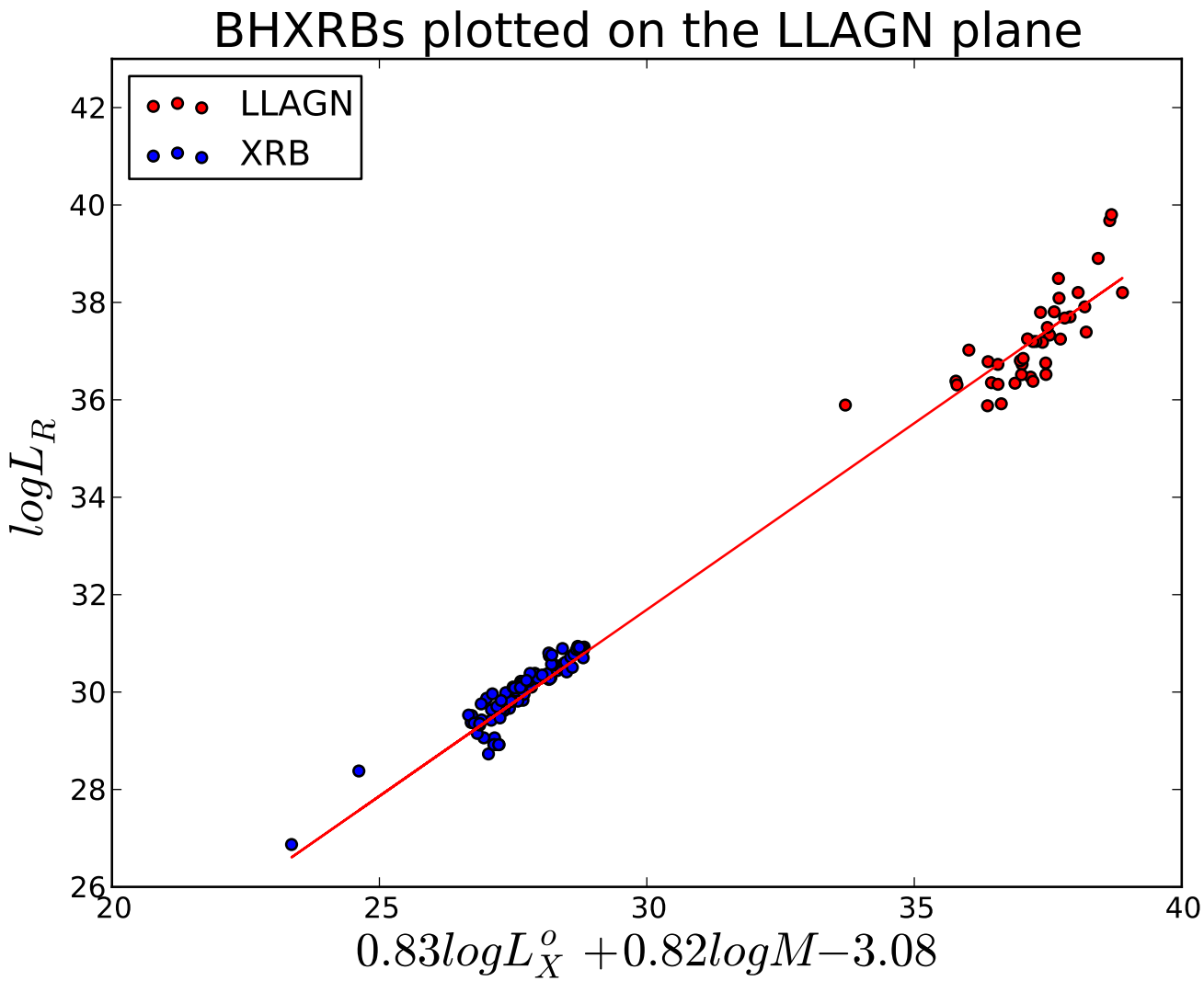
$L_{3\text{-}20keV} / L_{OIII} = 2.15$ dex

Heckmann et al. 2005

Optical Fundamental Plane

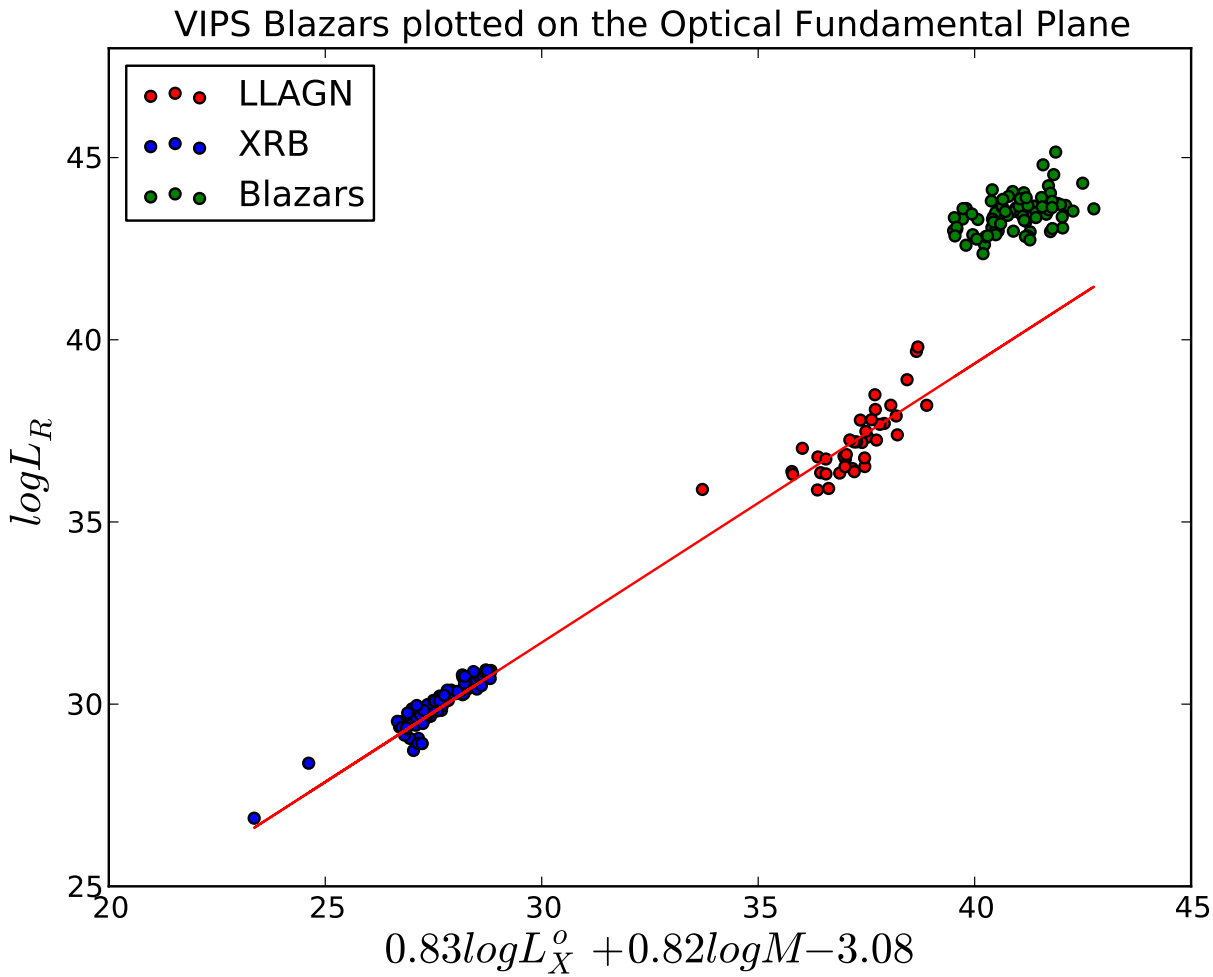


Optical Fundamental Plane



Saikia et al. MNRAS 2015

Blazars on the Optical Fundamental Plane



* Relativistic **beaming**
* Lower **flux limit** of VIPS : 85 mJy at 8.5 GHz Blazars from VIPS sample

Beaming in Jets

RELATIVISTIC BEAMING

$$L_{observed} = \delta^{p} L_{intrinsic}$$

δ = Kinematic Doppler Factor

$= [\, \Gamma (1 - \beta \cos \Theta) \,]^{-1}$

Bulk Lorentz factor

Angle to line of sight

p = 2 - a, for continuous jets

p = 3 - a, for discrete jets

where, a is spectral index of the jet : $S_\nu \propto \nu^{a}$

Urry & Padovani 1995, Ghisellini et al. 1993.

RELATIVISTIC BEAMING

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$= [\ \Gamma\ (1 - \beta \cos \Theta)\ ]^{-1}$

p = 2 - α, for continuous jets

p = 3 - α, for discrete jets

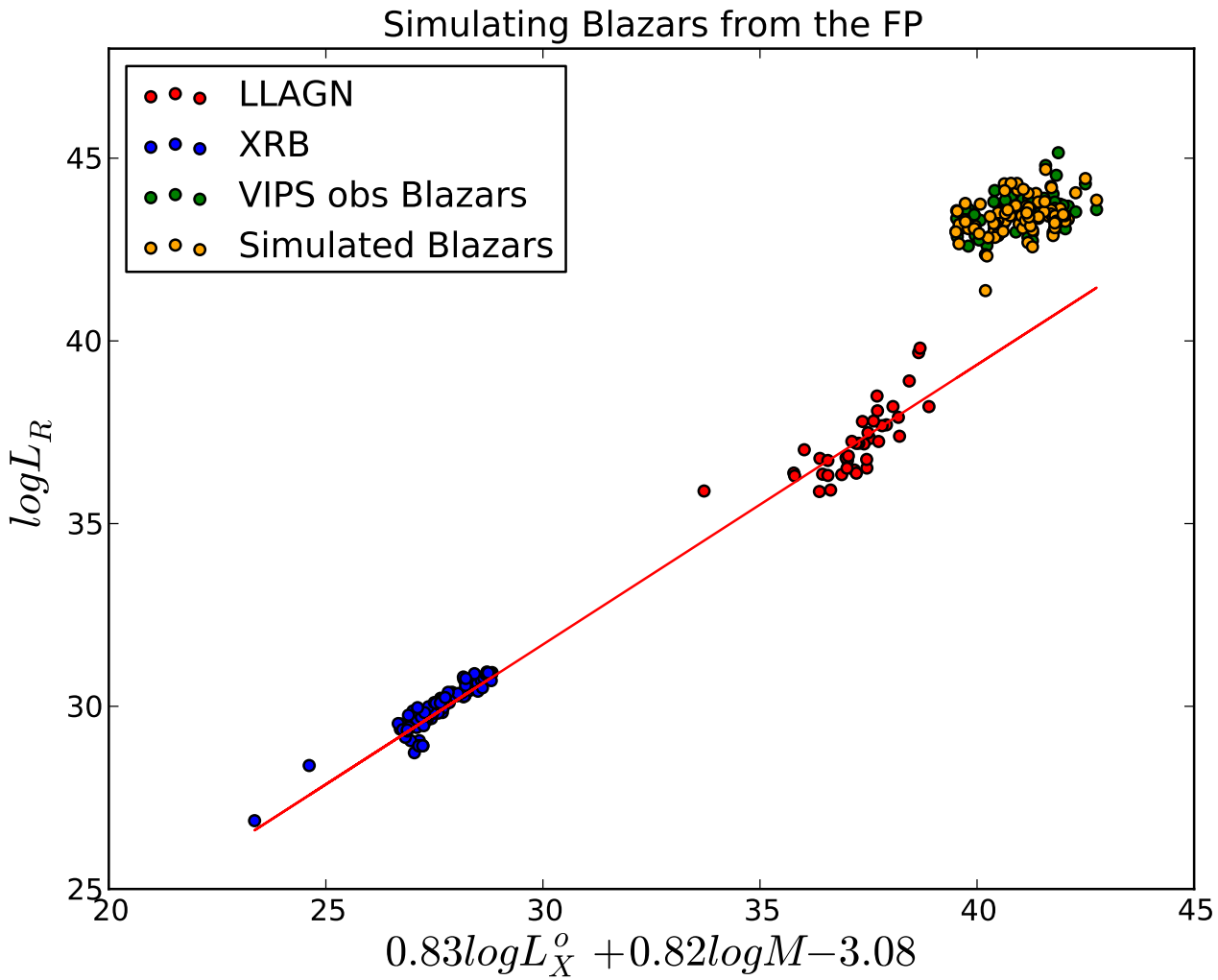
where, α is spectral index of the jet : $S_\nu \propto \nu^{\alpha}$

Form of Lorentz distribution :

$$N(\Gamma) = \Gamma^{-\alpha}$$

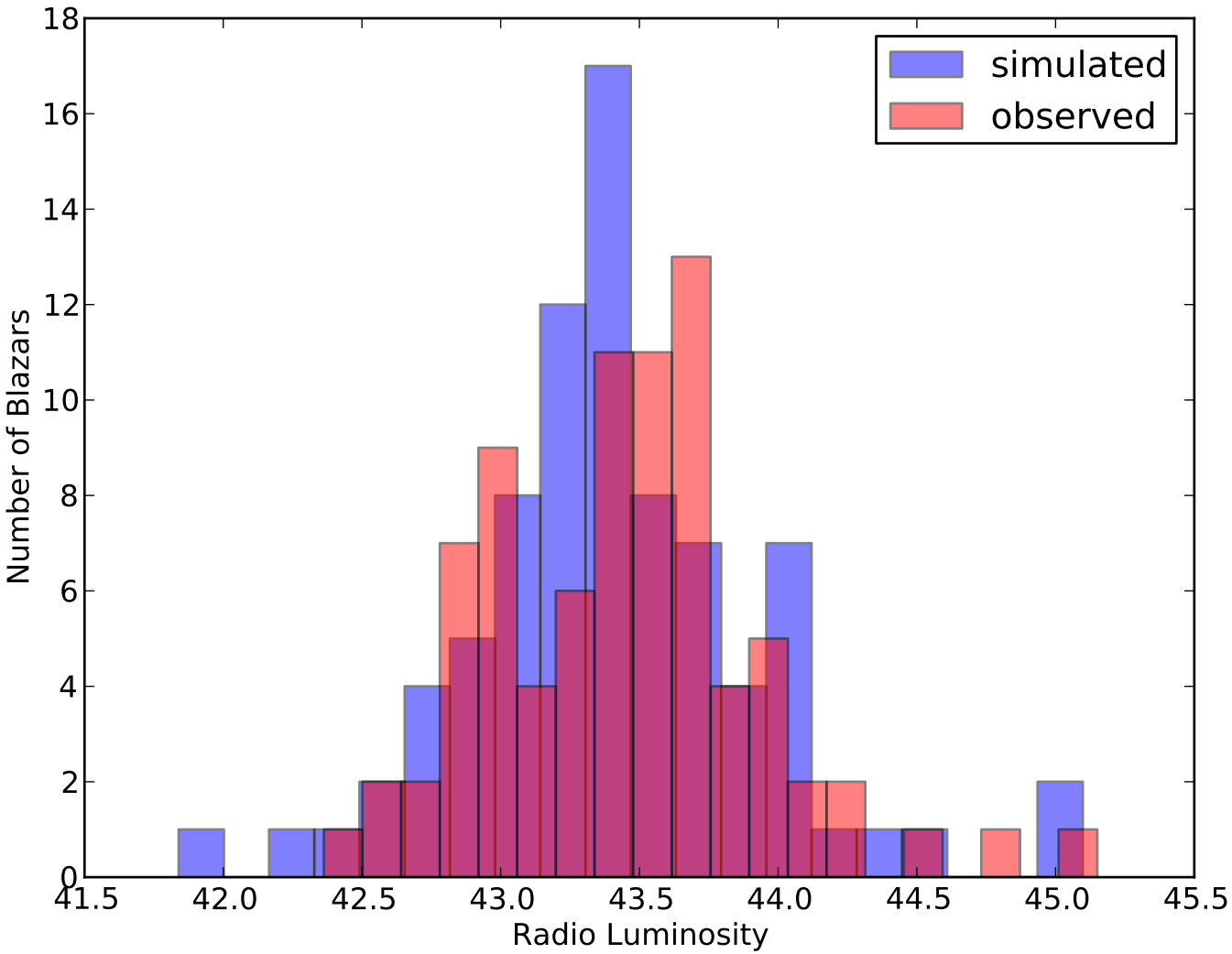
Lister and Marscher 1997, Hovatta et al 2009 etc

Simulated Blazars from the plane



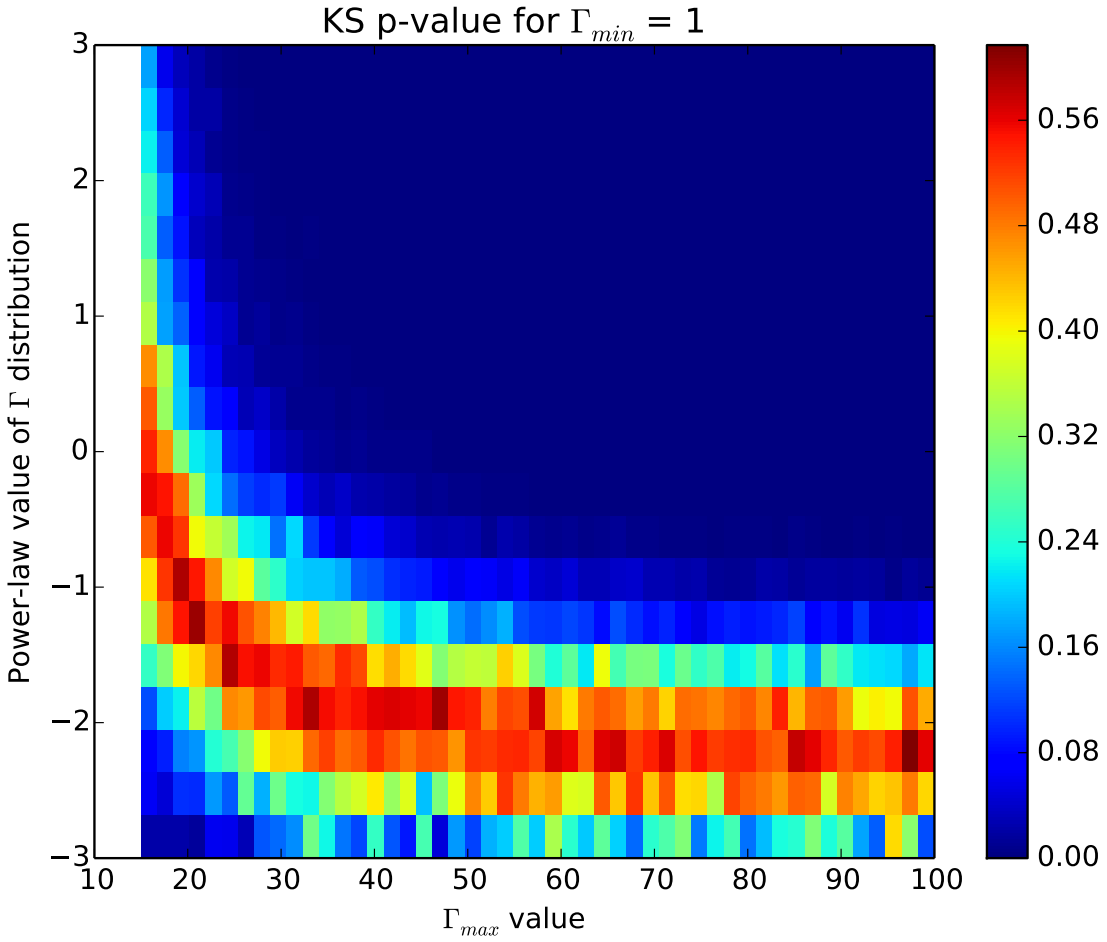
Saikia et al. 2015, in prep.

Radio Luminosity Histograms - Kolmogorov-Smirnov Test

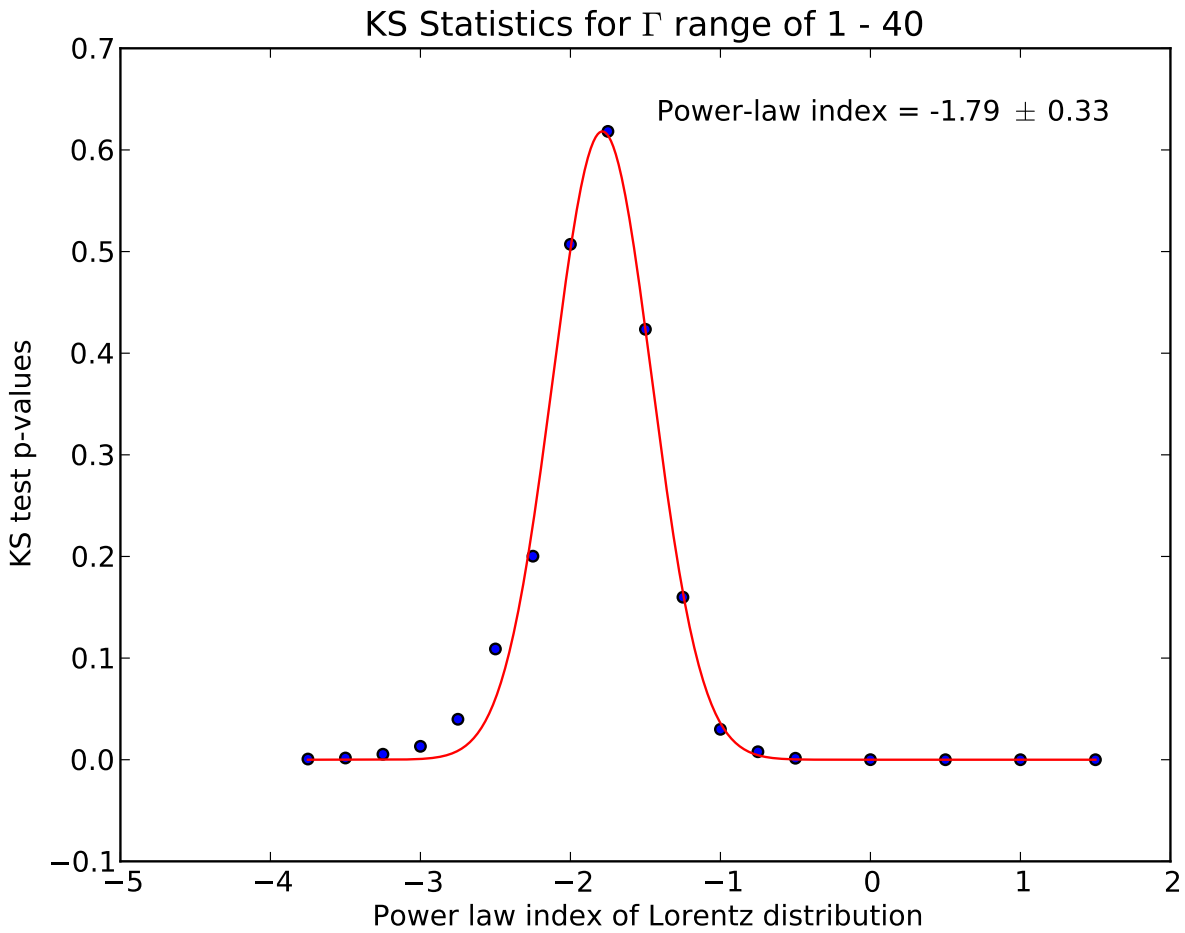


Kolmogorov-Smirnov test p-value = 0.63

Constraining the Lorentz factor distribution



Lorentz factor distribution



We constrain the Lorentz factor distribution to be $\mathbf{N}(\Gamma) = \Gamma^{-1.79 \pm 0.33}$ for a Γ range of 1-40.

Summary

Conclusion

- Report : the Optical fundamental plane of black hole activity.
- Show : that the plane can be uniquely established from the SMBH sample alone.
- Use it : to constrain the blazar Lorentz factor distribution as $N(\Gamma) = \Gamma^{-1.79 \pm 0.33}$ for $1 < \Gamma < 40$.