Power-unification of weakly accreting black holes and the Radio/X-ray correlation

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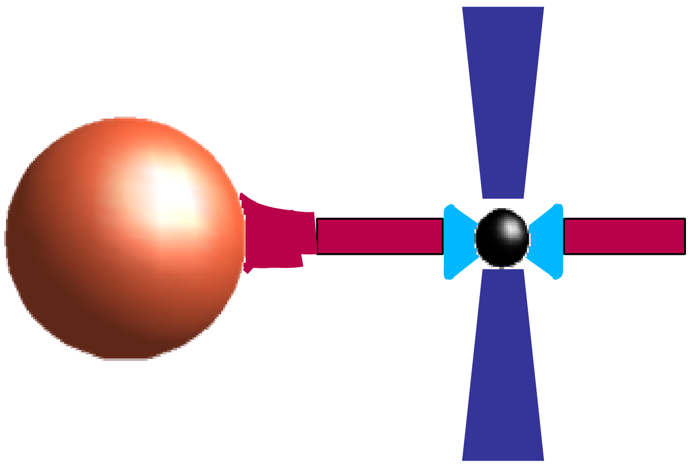
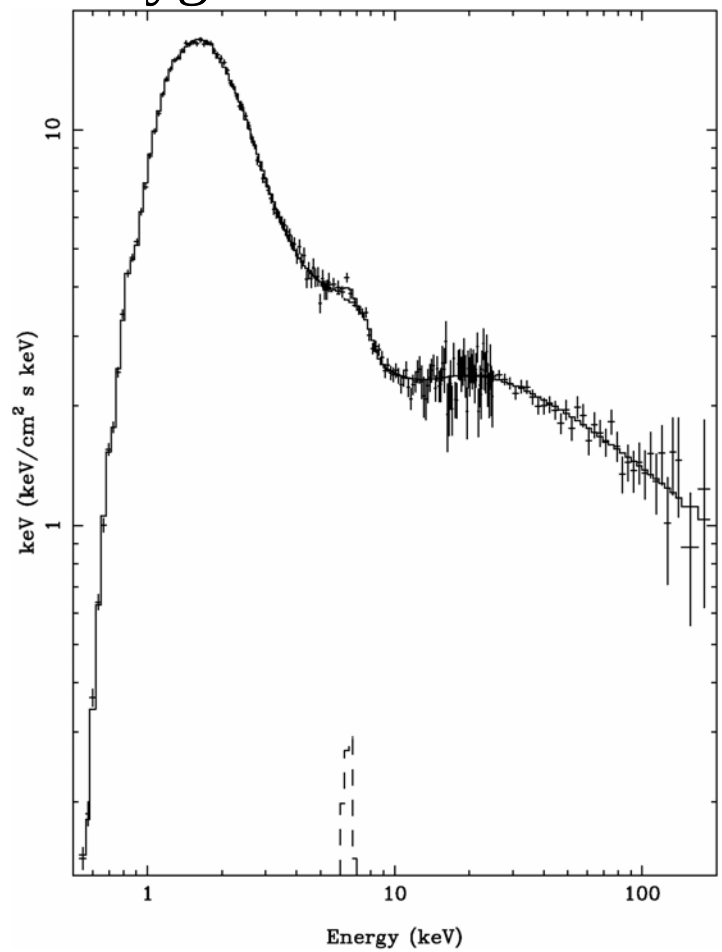
Thermally dominated state aka “high-soft state”



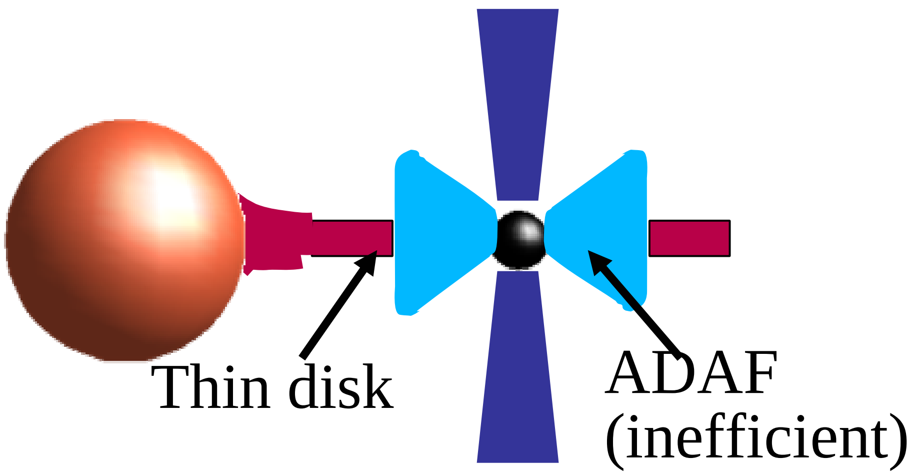
- Thin disk nearly up to the BH
- Disk dominates overall luminosity
- Often feeble or non-existent jet
- Beware hysteresis!
  (Maccarone 2003)

Cyg X-1

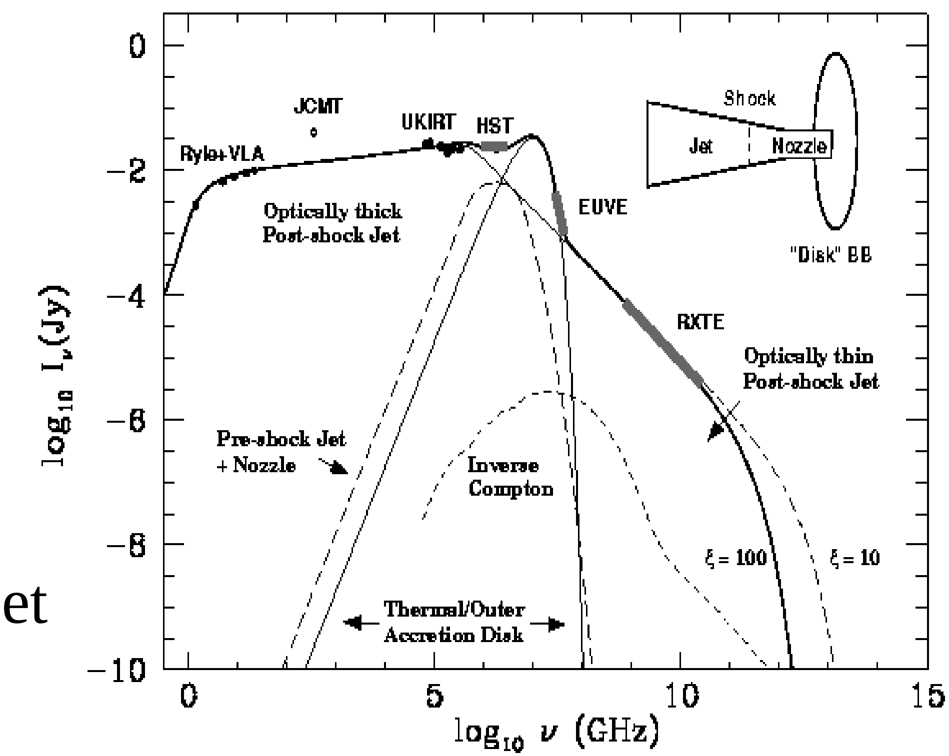


Frontera et al. 2001

The “non-thermally” dominated state aka “low-hard” state

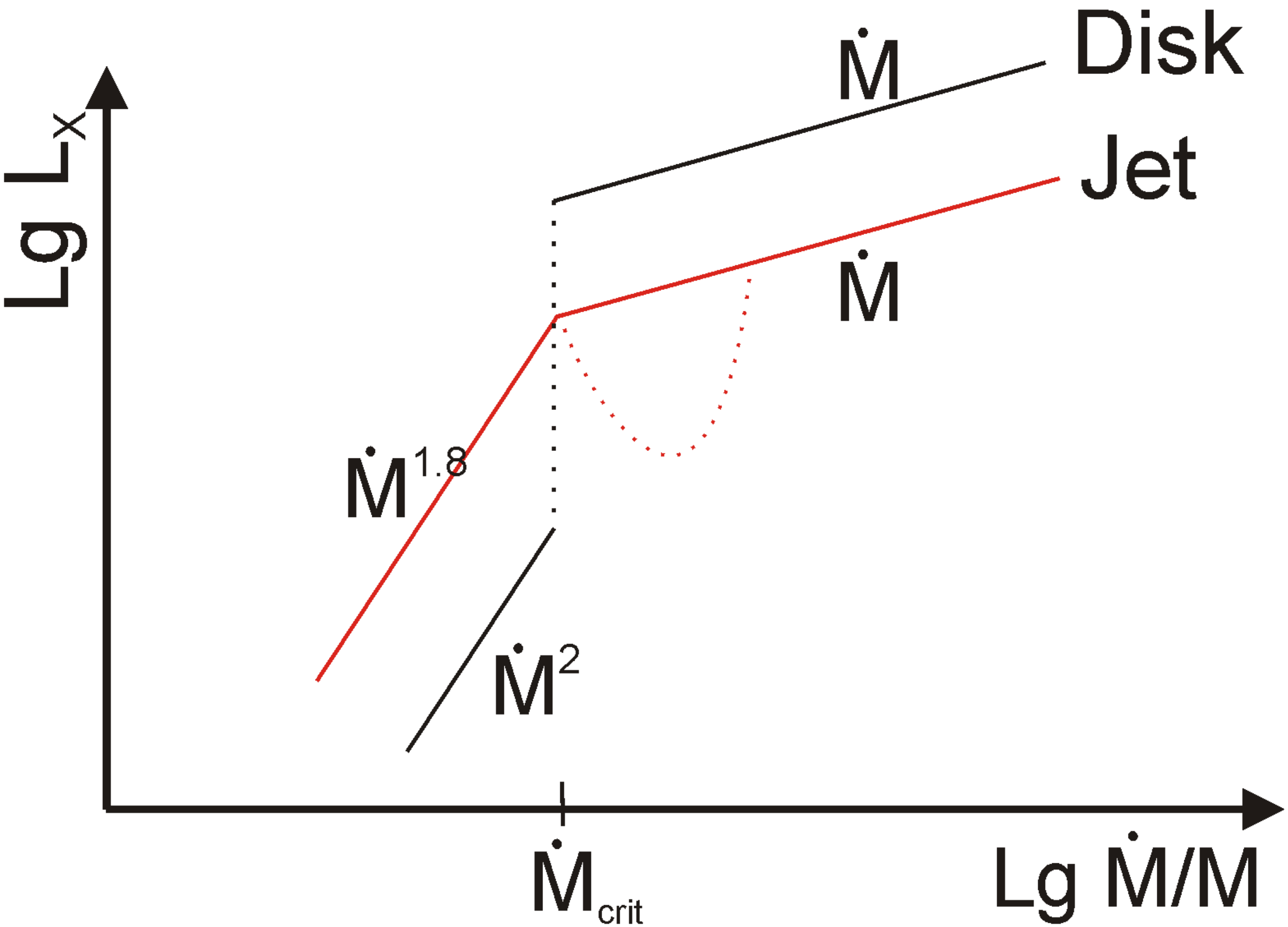


- Thin standard disk turns into an inefficient flow (?DAF) far out (Esin et al. 1997)
- Power-law spectra
- Jet may dominate the overall luminosity (radio!, NIR, X-rays!?)
- Corona only models often used!!!



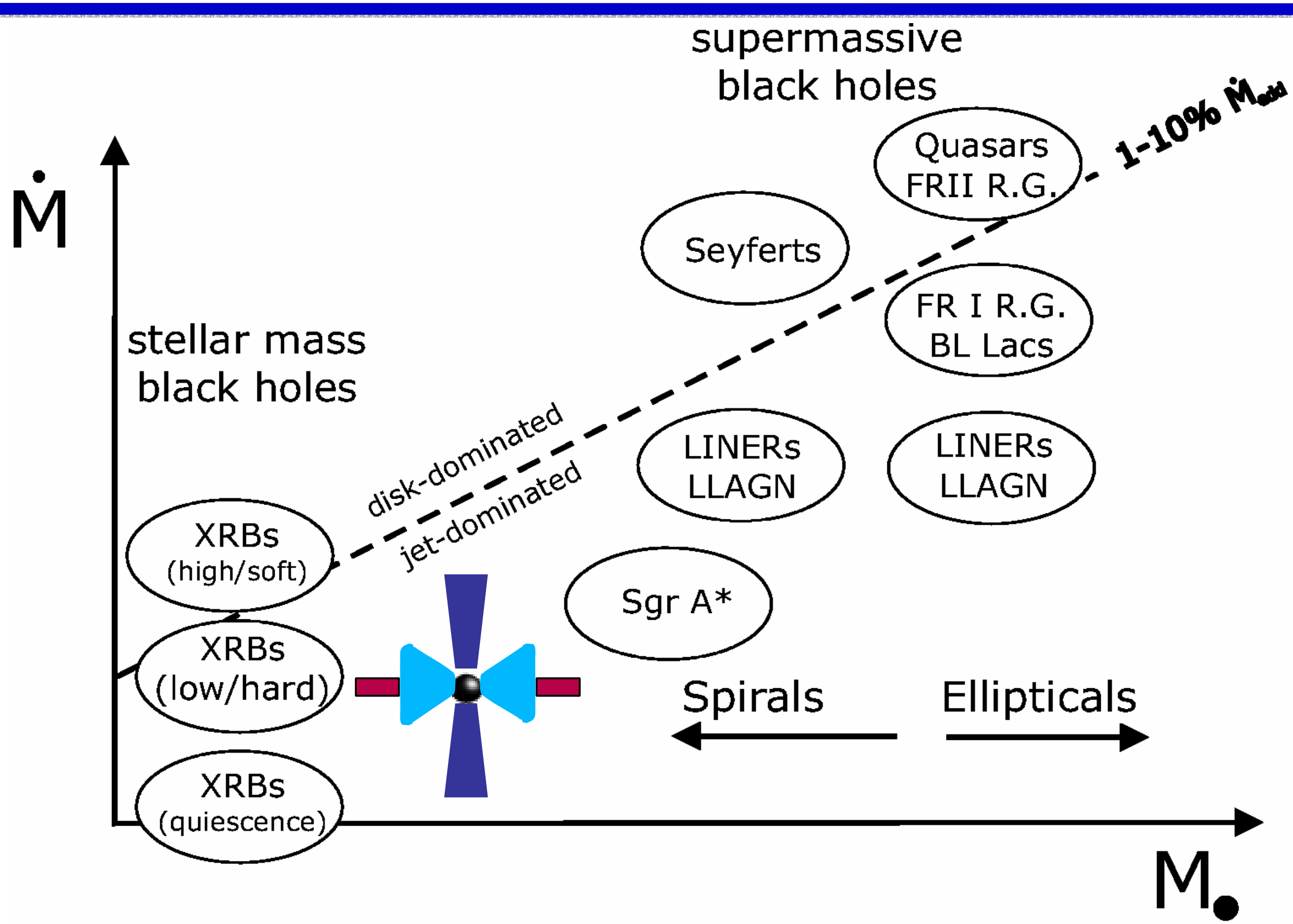
Markoff, Falcke, Fender 2001

Jet and Disk scaling



- Jet in the synchrotron regime
- Disk:
  - ADAF or similar (Narayan & Yi)
  - Standard disk

Power Unification of Compact Objects



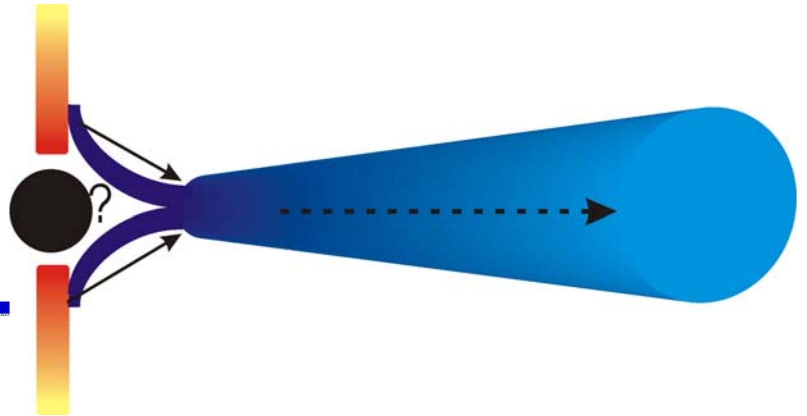
Falcke, Koerding, Markoff (2004)

Main parameters: orientation, BH mass, accretion power

Classification through broadband SED properties:
Lines, "big blue bump", ADAF signatures

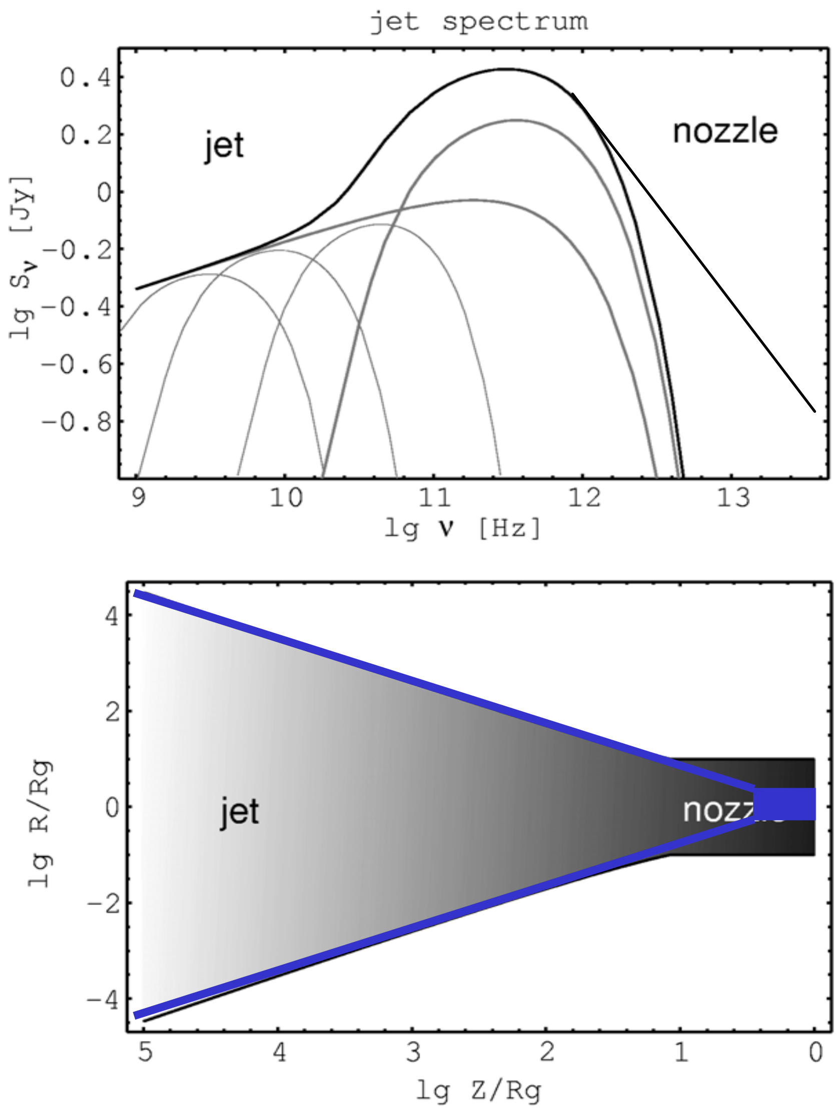
All jet dominated sources should be described with the same model.

Jet Model

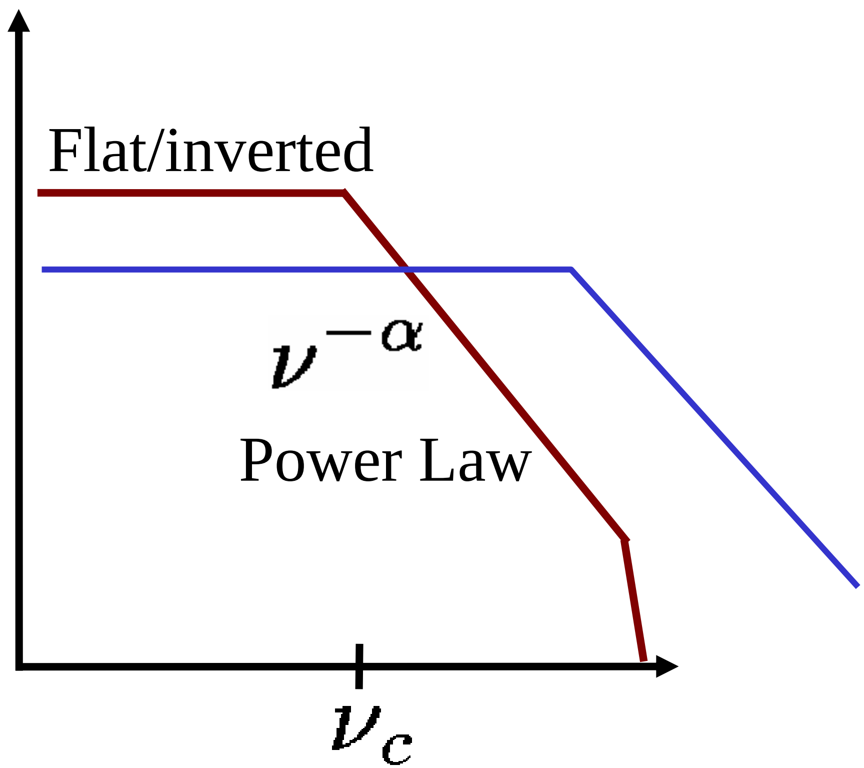


- Hydrodynamical analytical model
  - Jet launching parameterized as “black box”
  - Scale invariant geometry
  - Assumes equipartion of energy in magnetic fields, relativistic particles and turbulent plasma
  - No radiation losses included
  - Blandford & Königl (1979), Falcke & Biermann (1995), …
- New approaches
  - Parameterization for black hole mass and accretion power scaling
  - Dependence of the dominant emission process on the parameters
  - Possible quenching mechanisms

“Steady” spectrum from a jet

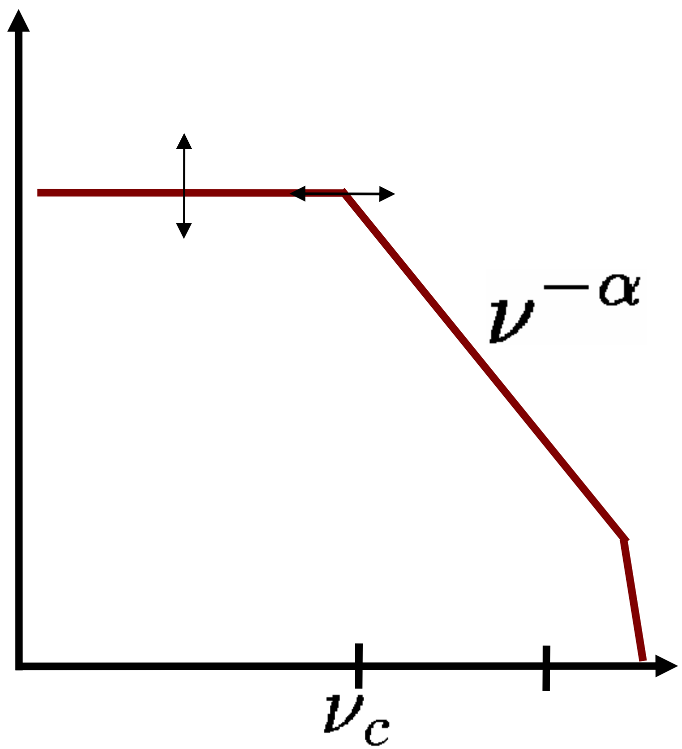


Bandford et al. 79, Falcke et al 1995



- Superposition of selfabsorbed synchrotron spectra at different positions of the jet
- Cutoff of PL: Acceleration model

The Fundamental Plane of Accreting Black Holes for continuous emission



Scaling laws for jets predict for the radio flux:

$$S_{\rm Radio} \propto \dot{M}^{17/12}$$

For the turnover frequency (SSA):

$$\nu_c \propto \dot{M}^{2/3} M^{-1}$$

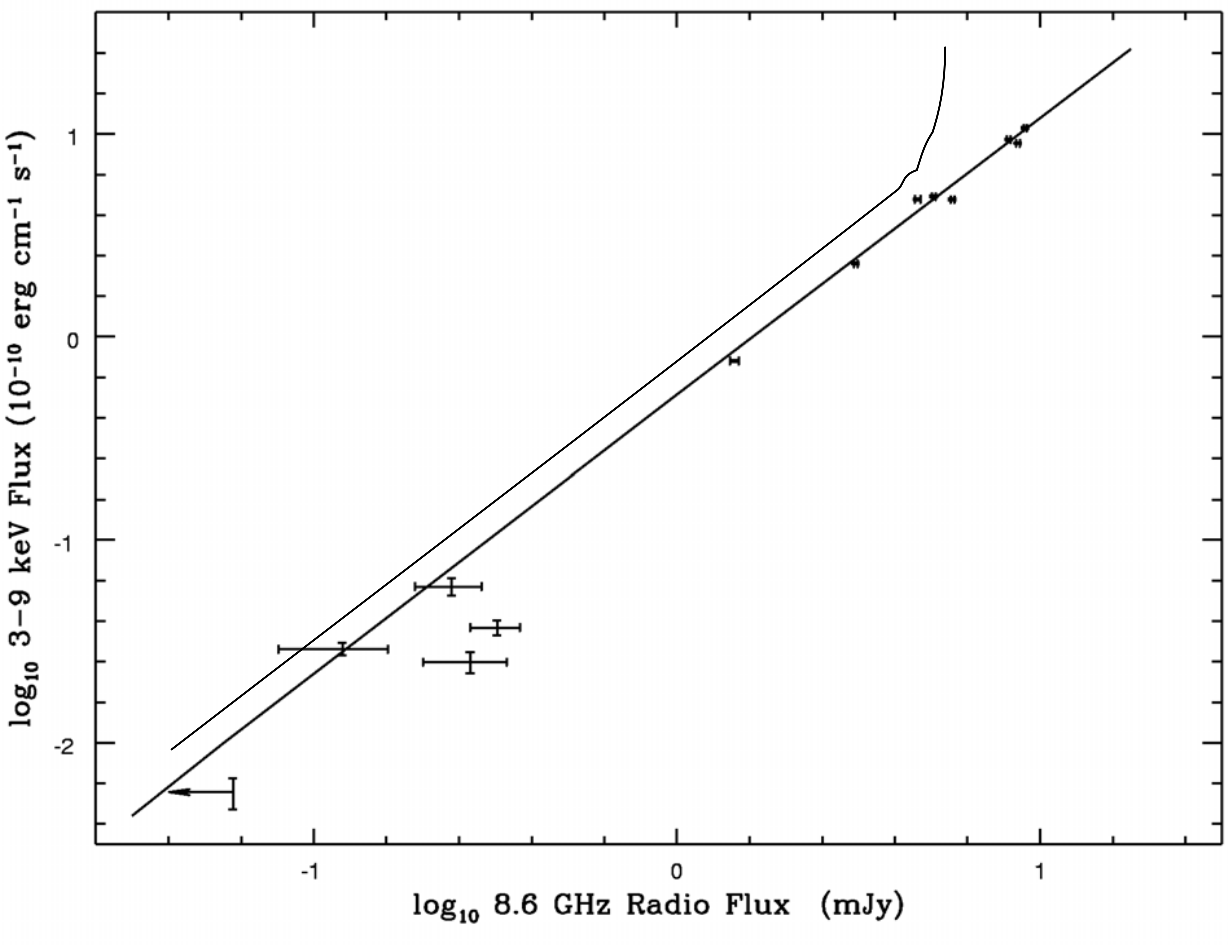
For X-ray emission (if below cutoff)

$$S_{\rm X\text{-}ray} = S_{\rm Radio} \left(\frac{\nu_c}{\nu_X}\right)^{0.6}$$

$$S_{\rm X-ray} \propto S_{\rm Radio}^{1.38} M^{-0.81}$$

Falcke & Biermann 1995, Markoff et al. 2003, Falcke, Körding, Markoff (2004);
Fundamental plane see also Merloni et al. 2003, Heinz et al. 2002

Radio/X-ray Correlation



- GX339-4 at different epochs
- Fitted power law index: 1.41
- Predicted value: 1.38!
- SSC for X-rays
  - Coefficient > 2
- X-rays from disk: Jet/disk coupling always 1!

Corbel et al 2003, Markoff et al. 2003, Gallo et al.2003

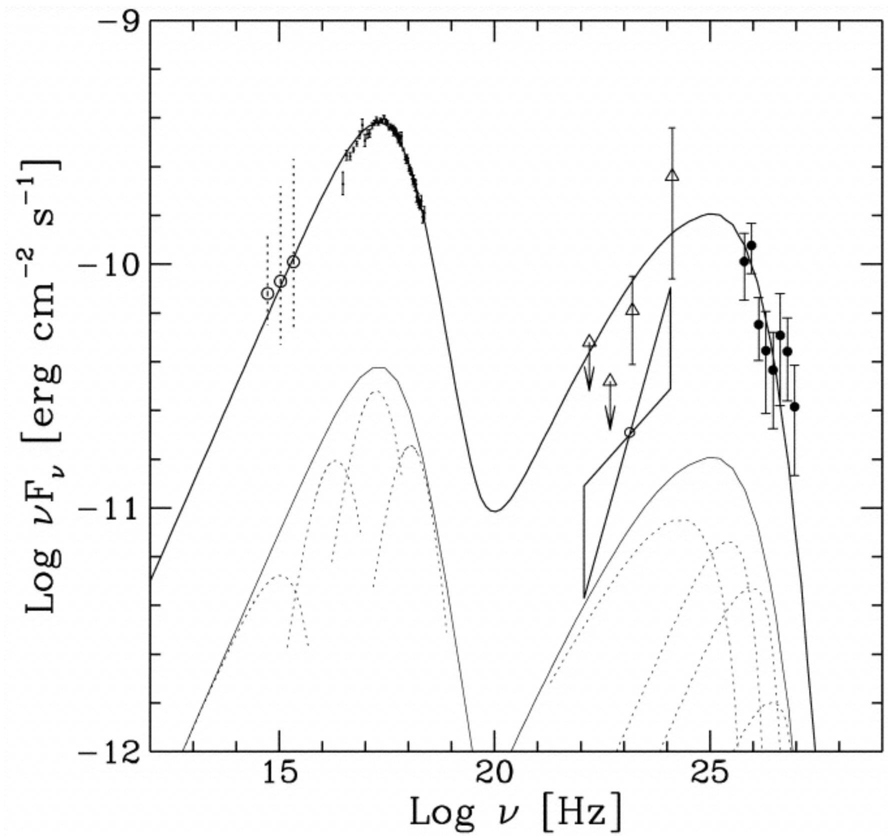
Observing the synchrotron peak

- Note: Spectrum may (will) shift with mass!
  - X-rays ≠ X-rays
- Synchrotron cutoff for High peaked BL Lacs near X-rays
- LBLs cut off before!

↓

Observe at frequencies on the synchrotron peak!

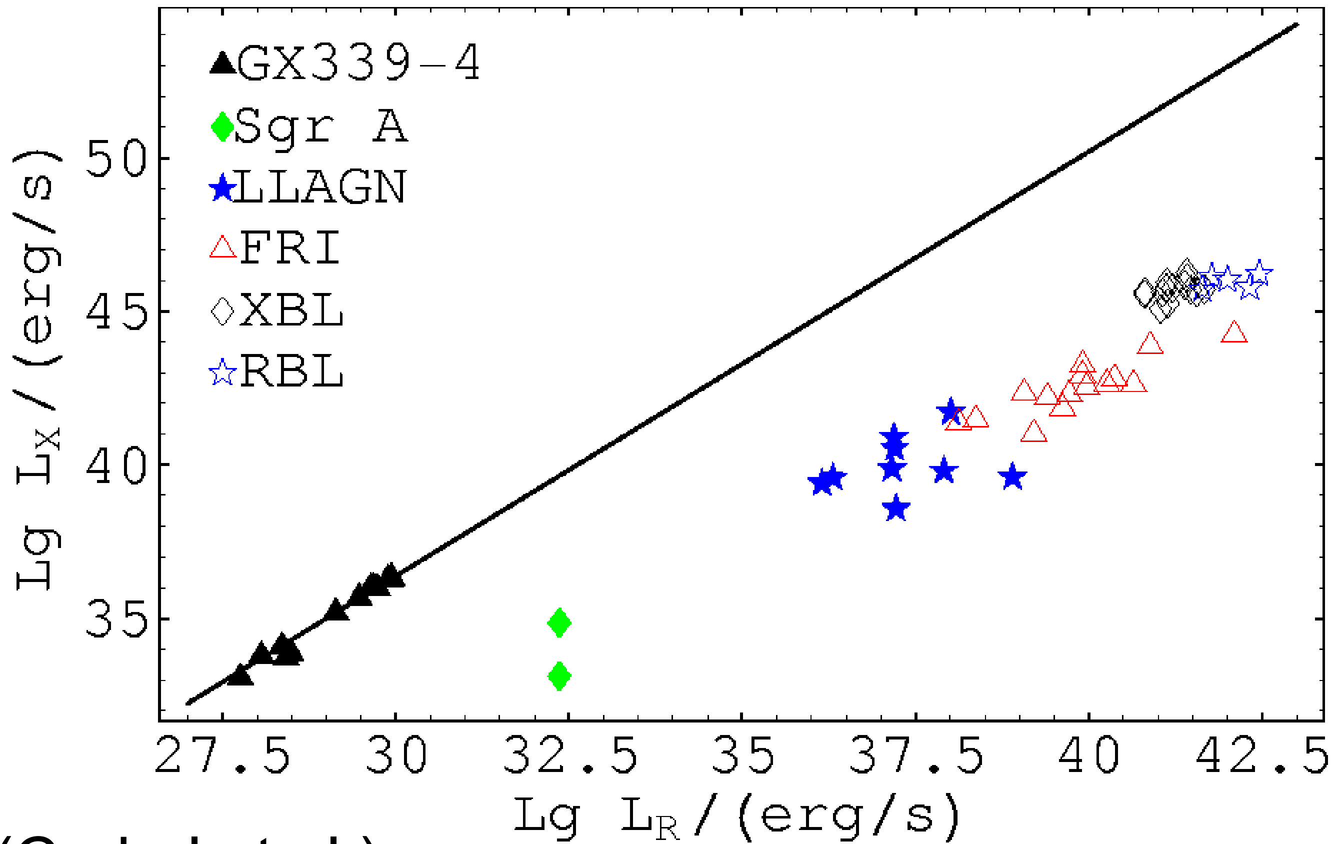
& Interpolate



Maraschi et al.

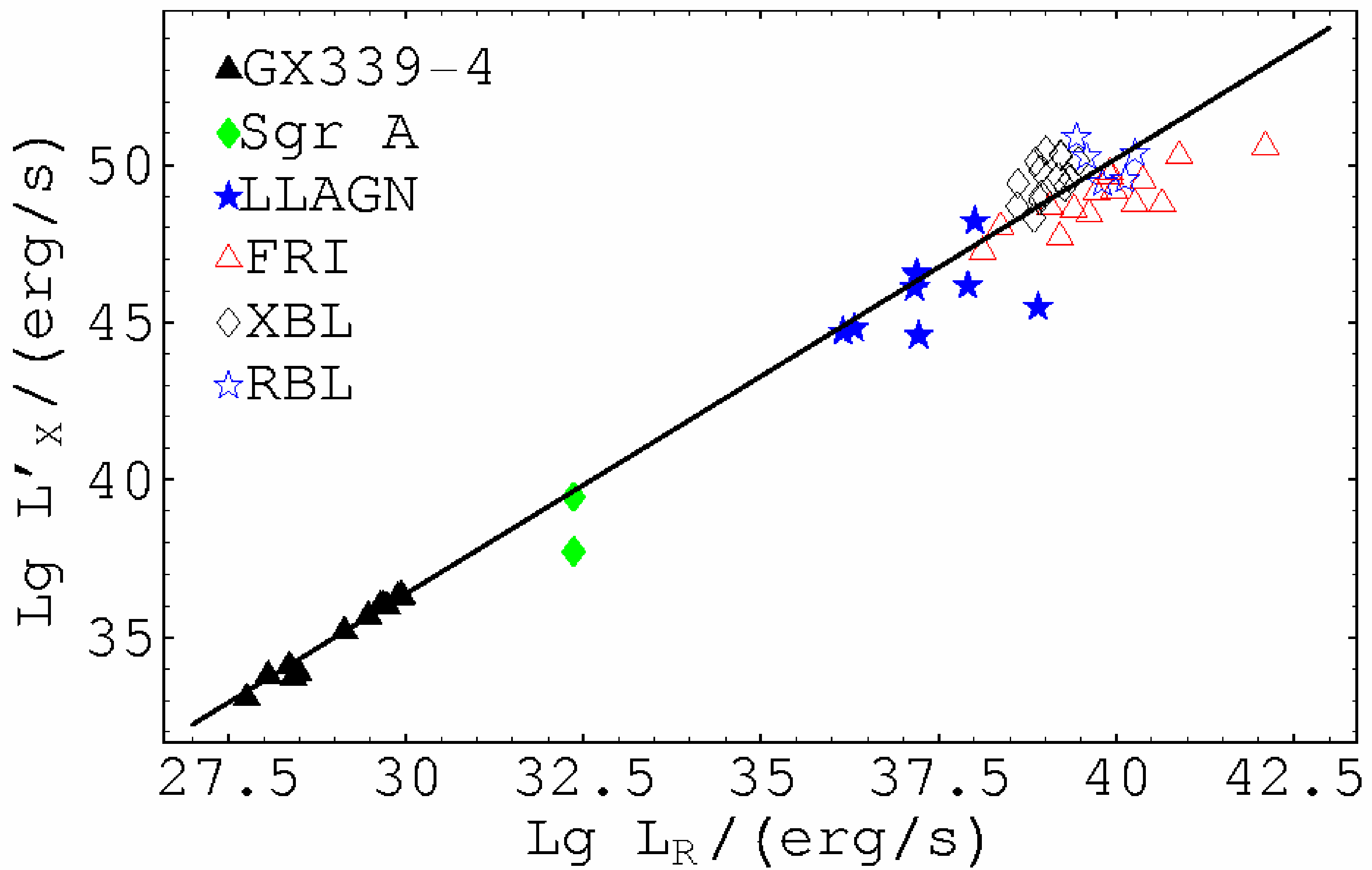
Observing frequencies: FRI,BL Lac : Optical; XRB, LLAGN : X-ray

Uncorrected Radio/ X-ray correlation



Black: GX339-4 (Corbel et al.)
Blue: Liner (Terashima & Wilson)
Red: FRI (Chiaberge et al.)
Open black+blux: BL Lac (Sambruna et al.)
Green: Sgr A (Baganoff et al, Melia& Falcke)

Radio/Xray: XRB to AGN!



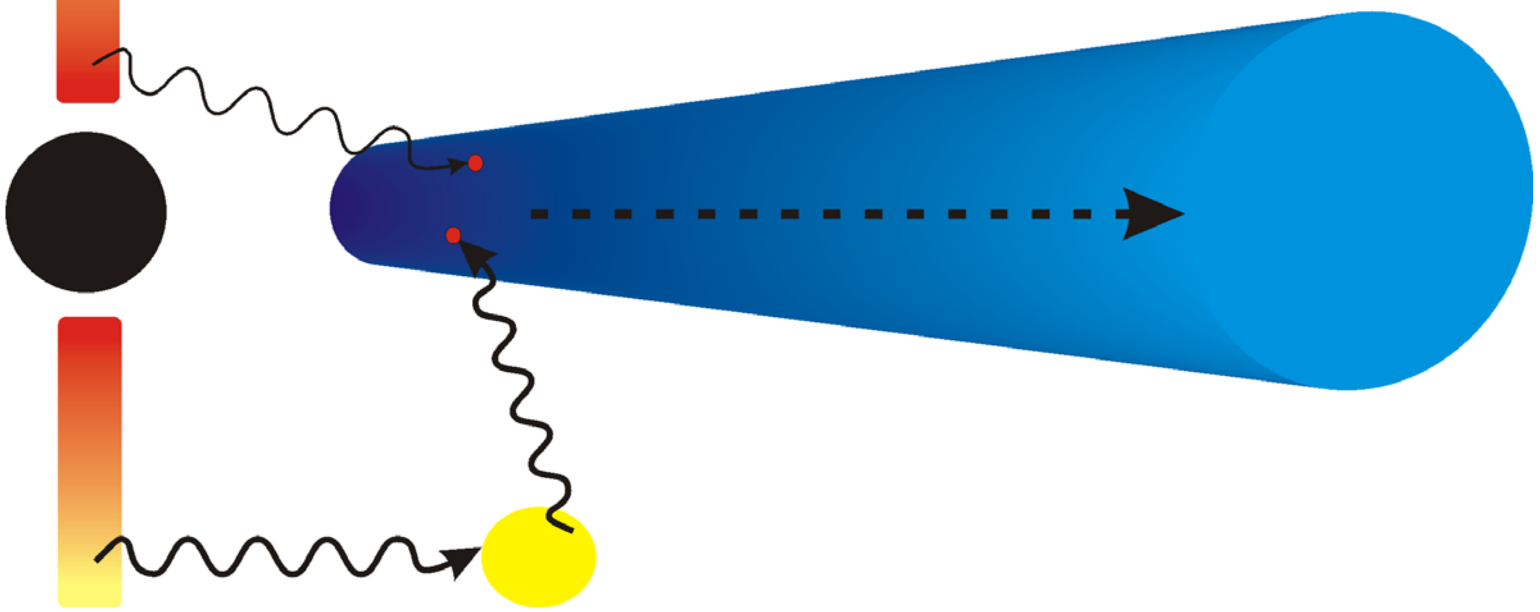
Compare Merloni, Heinz et al. 2003

Further tests

- Importance of jets
  - X-ray variability of XRBs can be explained by a pivoting power law (Körding & Falcke 2004)
    - Pivoting crucial, not the time lags due to successive Comptonization
  - Reflection components can be obtained with jet models as well (Markoff & Nowak 2004)

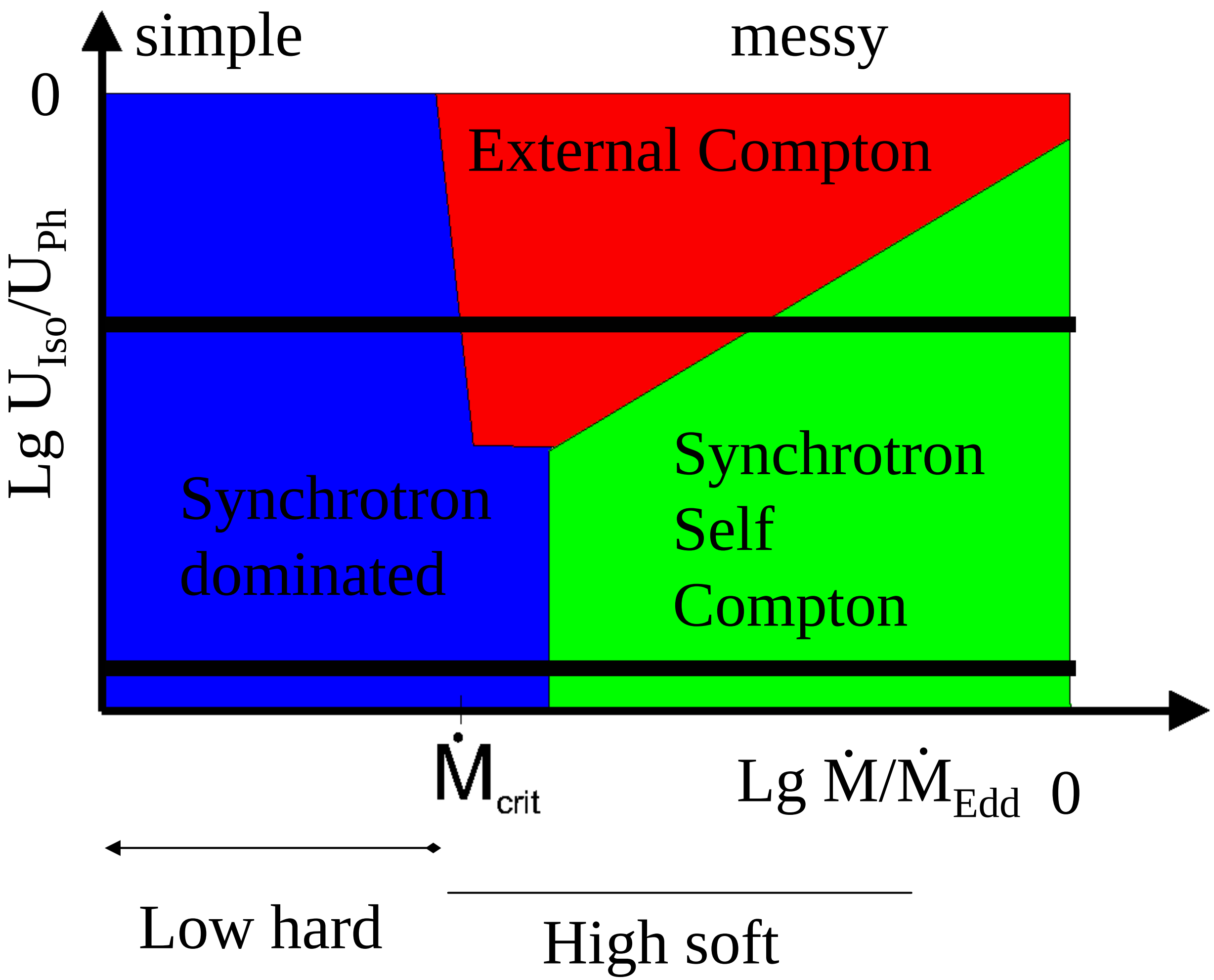
Towards higher accretion rates

Why are jets of stellar black holes in the high state quenched or instable?



- Energy budget
- Irradiation of jet: Quenching by irradiation?
  - Disk external Compton
  - External Compton from scattered photons

Dominant Emission Process



- Variable disk efficiency
  - Above critical accretion rate: Standard disk
  - Below: inefficient disk
- External Compton dominates: the whole jet may get quenched!
  - Other possibility: Quenching by MHD (but FR II RG!)

Conclusions

- The jet is an important feature of both XRBs and AGN
- AGN and XRBs can be unified:
  - Standard orientation dependent unification
  - Power + black hole mass unification
    - Fundamental Plane of accreting black holes
    - Scale invariant geometry tested
- Scaling laws for jets can be established
  - Dominant emission process depends on accretion rate + isotropic radiation field
  - External Compton may provide a quenching mechanism