

Jets from Compact X-ray Sources

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Introduction

- ❑ In my opinion, jets from compact X-ray sources have not been given proper attention.
- ❑ Most people treat jets simply as “fireworks”, which do nothing else than emit radio waves.
- ❑ Due to shortage of time, I will restrict myself to jets from black-hole X-ray binaries only.

I hope to convince you that

- The jet is a central player in the observed phenomena and not simply an embellishment.

The jet model

- In a series of four papers

Reig, Kylafis, Giannios 2003, A&A

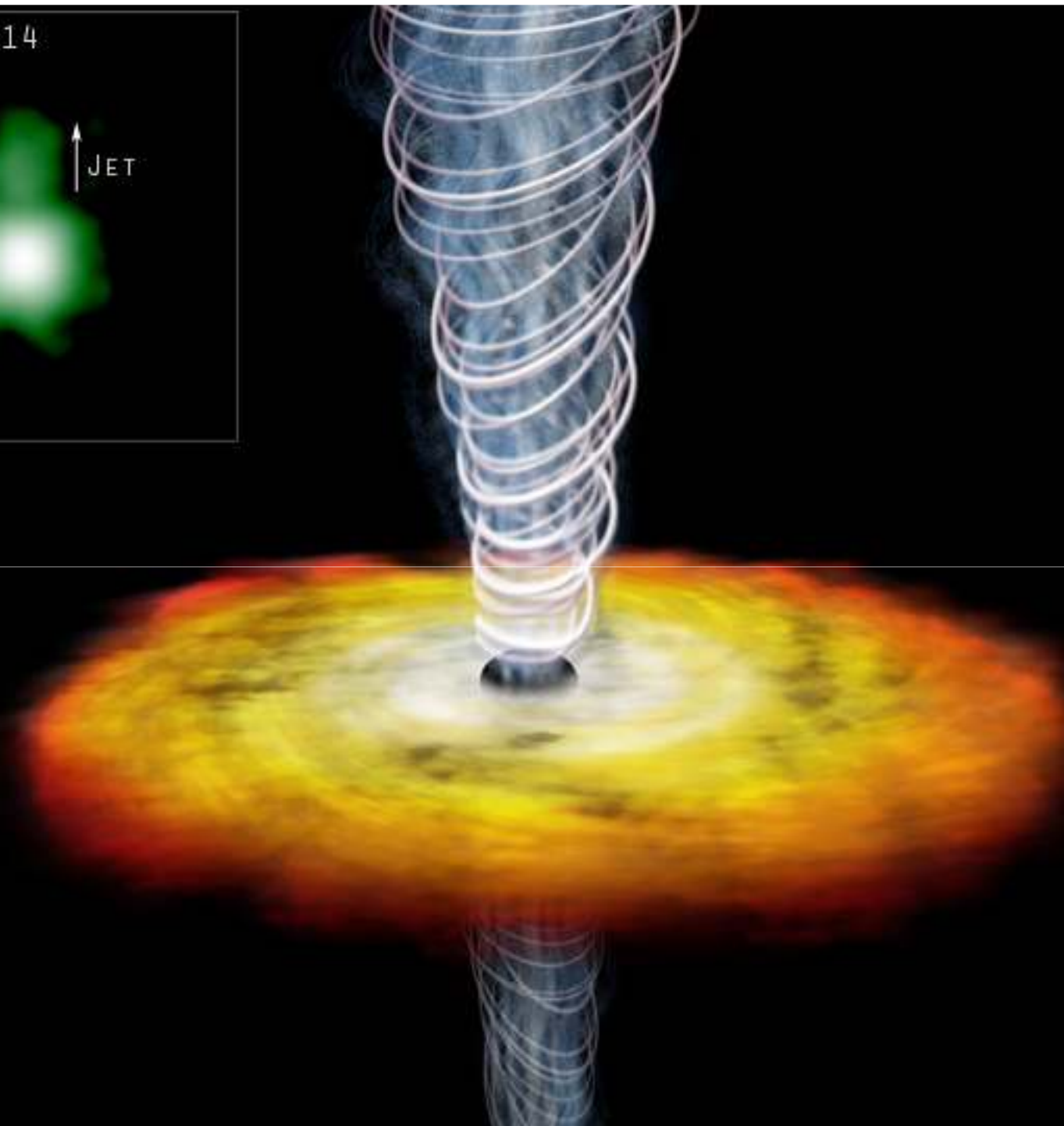
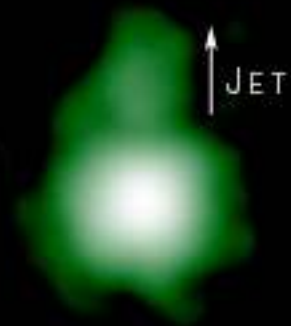
Giannios, Kylafis, Psaltis 2004, A&A

Giannios 2005, A&A

Kylafis, Papadakis, Reig, Giannios, Pooley, 2008

we proposed a simple jet model, that explains much more than any other model.

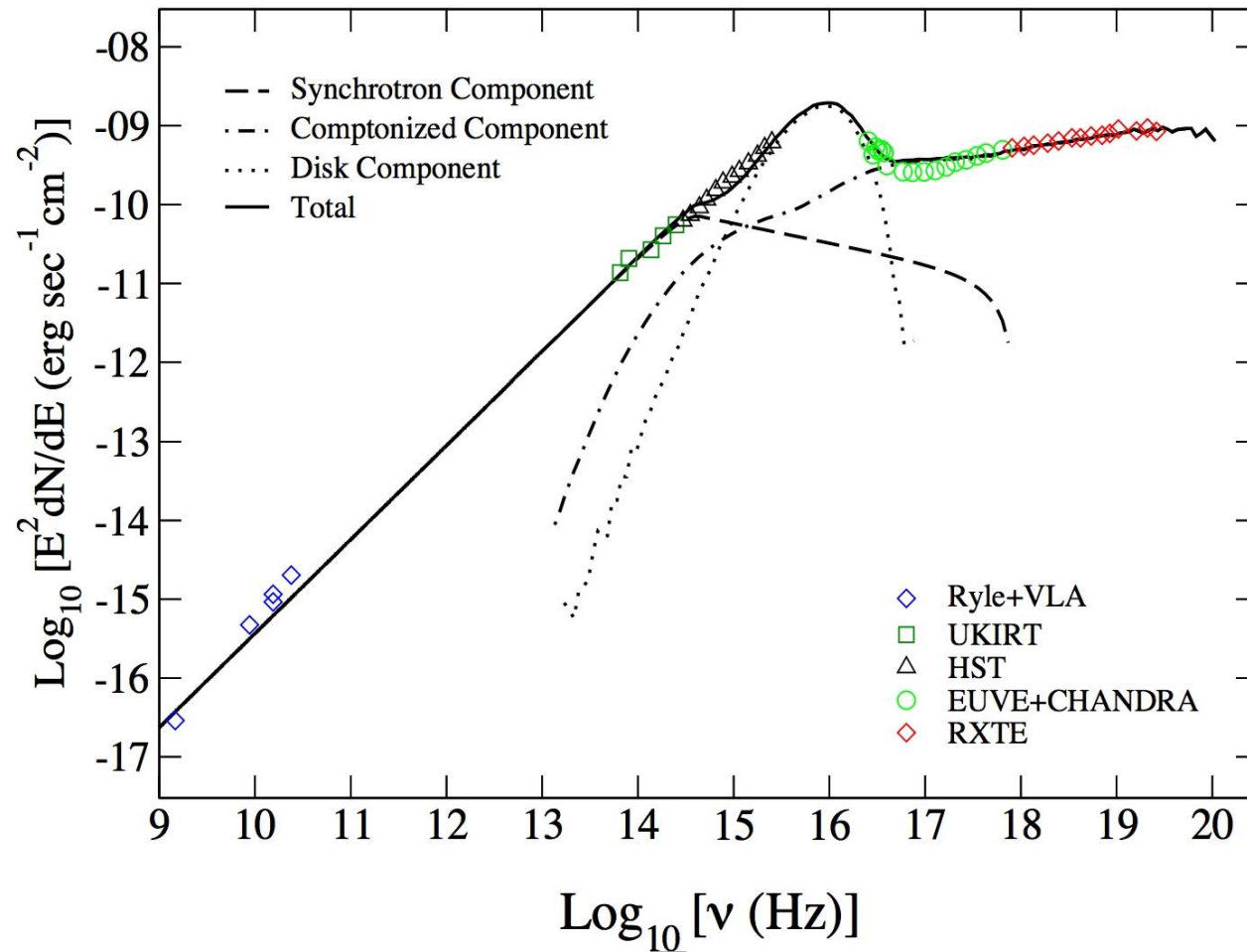
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Observations to distinguish models

- ENERGY SPECTRUM (explained by several models).

Giannios 2005, A&A



- Model and observations for XTE J 1118+480

Further observations to distinguish models

- TIME LAGS: The hard X-ray photons lag the soft ones (again explained by several models).
- More on this if there are questions.

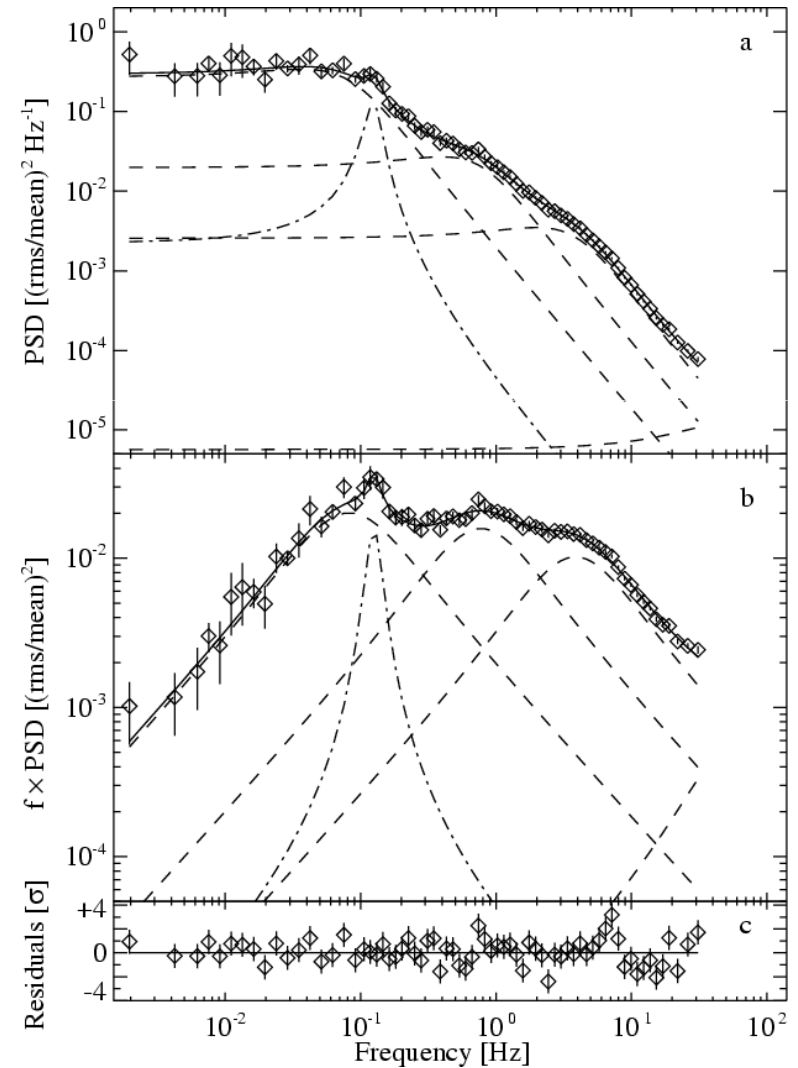
More stringent observational constraints

- ▣ The **long-term variability** of Cyg X-1 was studied by Pottschmidt et al. (2003), A&A and revealed a number of very stringent constraints.

Pottschmidt et al. (2003), A&A

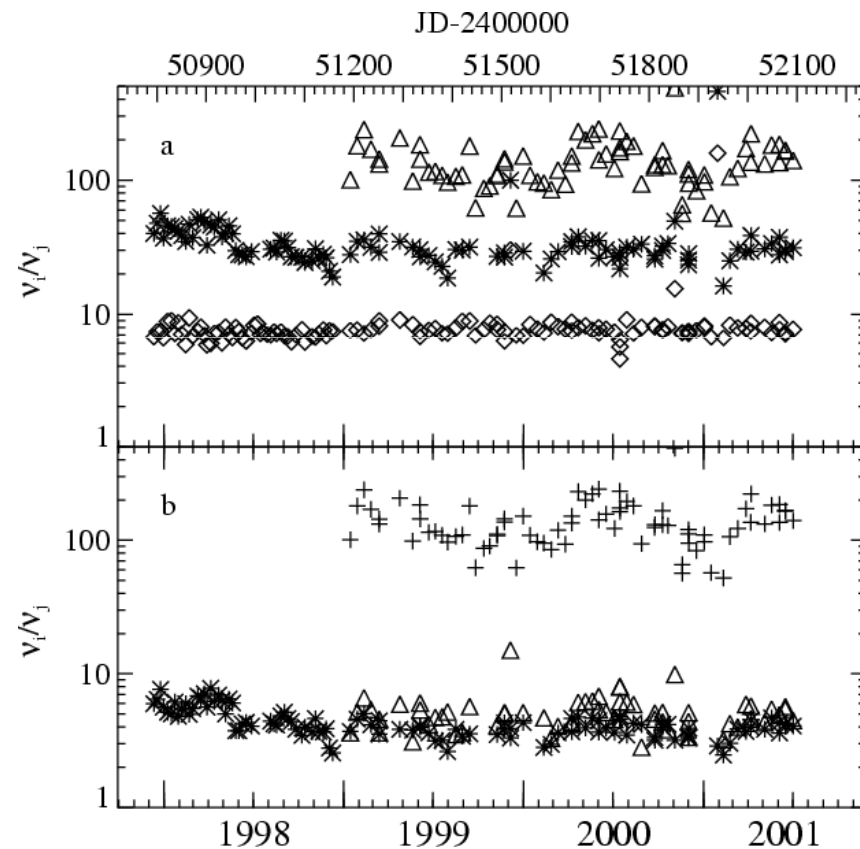
- The power spectrum of Cyg X-1 was fitted with four broad Lorentzian profiles that have peak frequencies

$$\nu_1, \nu_2, \nu_3, \nu_4$$



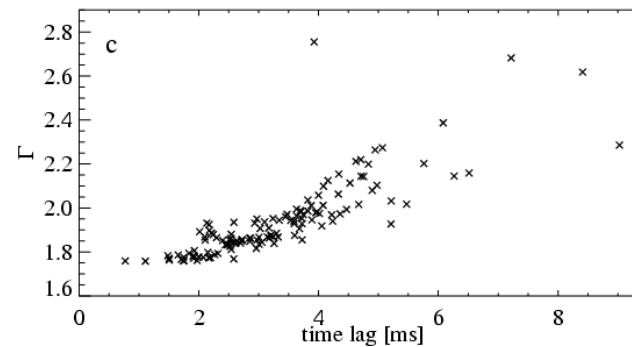
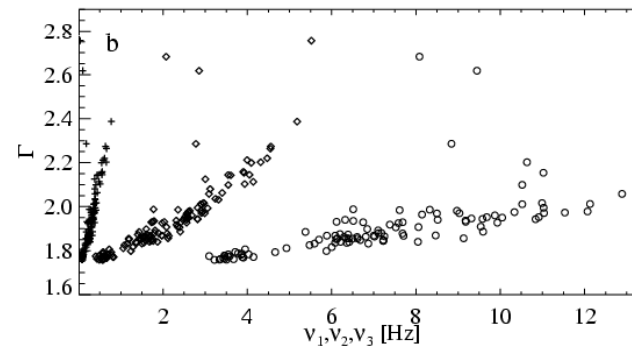
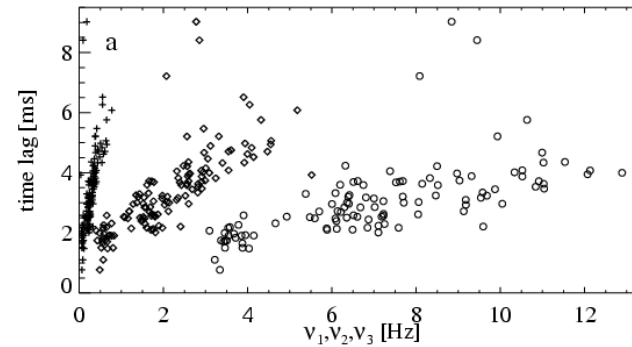
Pottschmidt et al. (2003), A&A

- The ratios of the peak frequencies are CONSTANT!!!



Pottschmidt et al. (2003), A&A

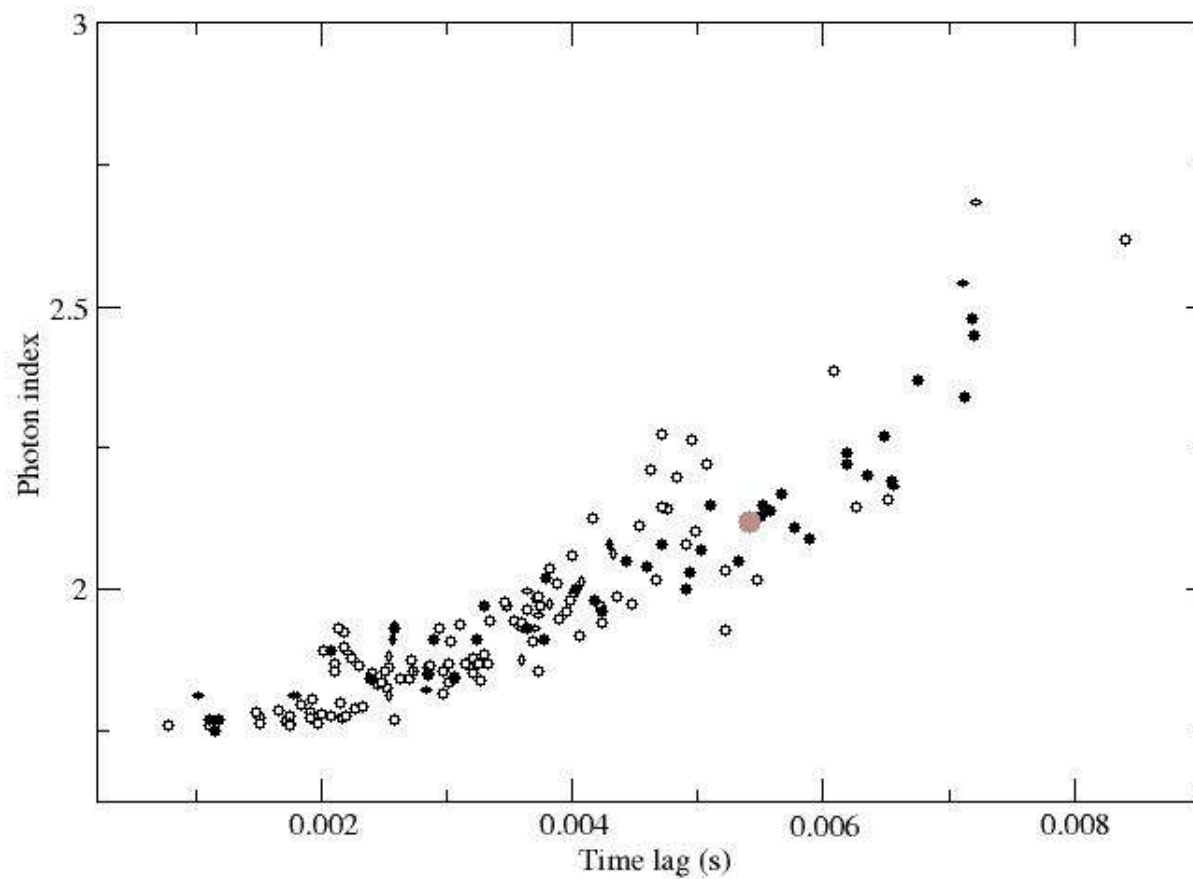
- Very stringent correlations:



Our jet model

- We varied two parameters: The density (or equivalently the optical depth) and the radius of the base of the jet.
- We were able to reproduce the Γ - $\langle \text{timelag} \rangle$ correlation.

Gamma vs. $\langle \text{timelag} \rangle$



Identification of the Lorentzian peak frequencies.

- Using just the density and the radius at the base of the jet, can we think of a combination that has the dimensions of frequency (inverse timescale)?

Identification of the Lorentzian peak frequencies.

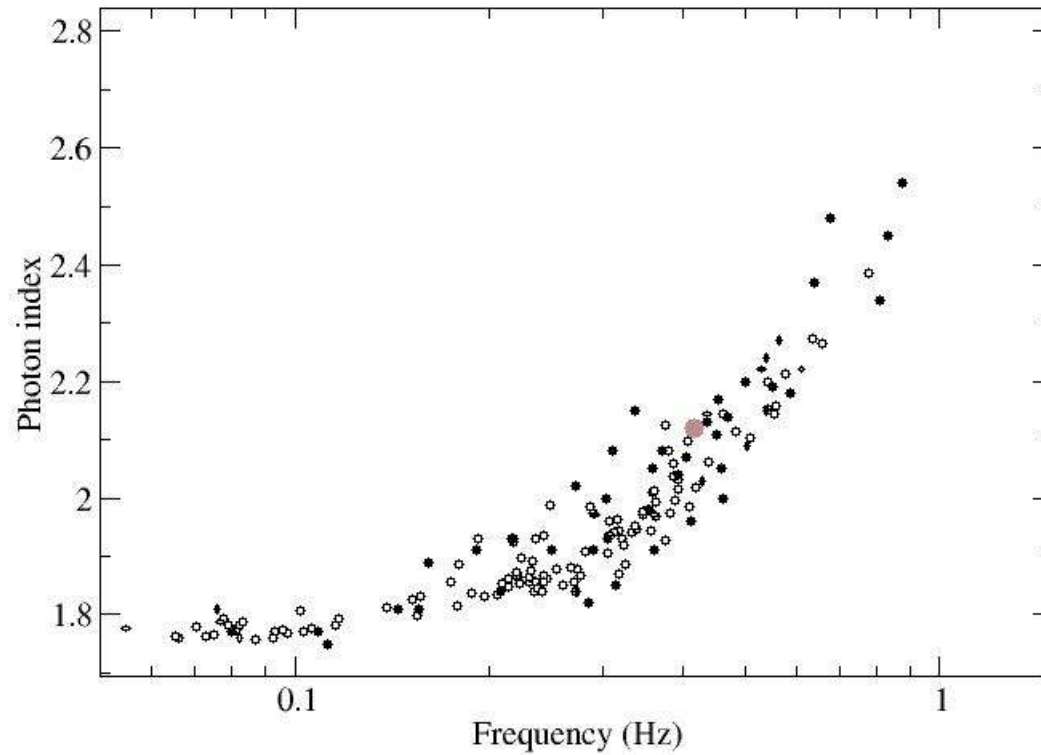
- The only inverse timescale, that we can think of, is

$$\frac{\dot{M}_{outflow}}{M_{available\ for\ outflow}}$$

Identification of the Lorentzian peak frequencies

$$\frac{\dot{M}_o}{M_o} = \frac{\pi R_o^2 n_o u_{flow}}{M_o} = CR_o^2 n_o \propto \nu_1$$

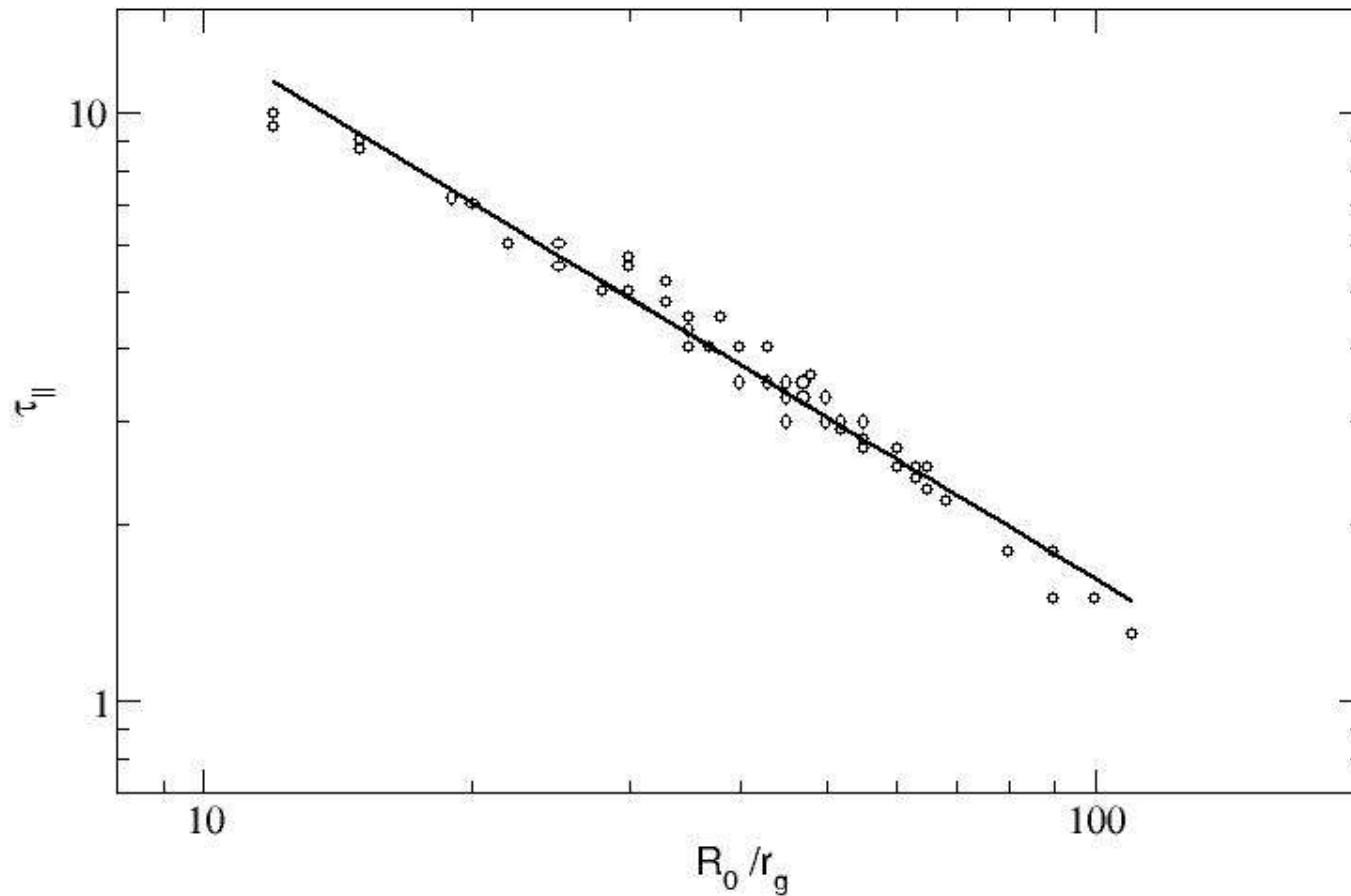
Gamma vs. peak frequency 1



An important relation

- The values of the density and the radius of the jet at its base, that we used in the previous correlations, are **correlated** !!!

Density vs. Radius at base of jet



Therefore,

$$\frac{\dot{M}_o}{M_o} \propto \frac{R_o^2 n_o}{M_o} \propto \frac{R_o}{M_o} \propto R_o$$

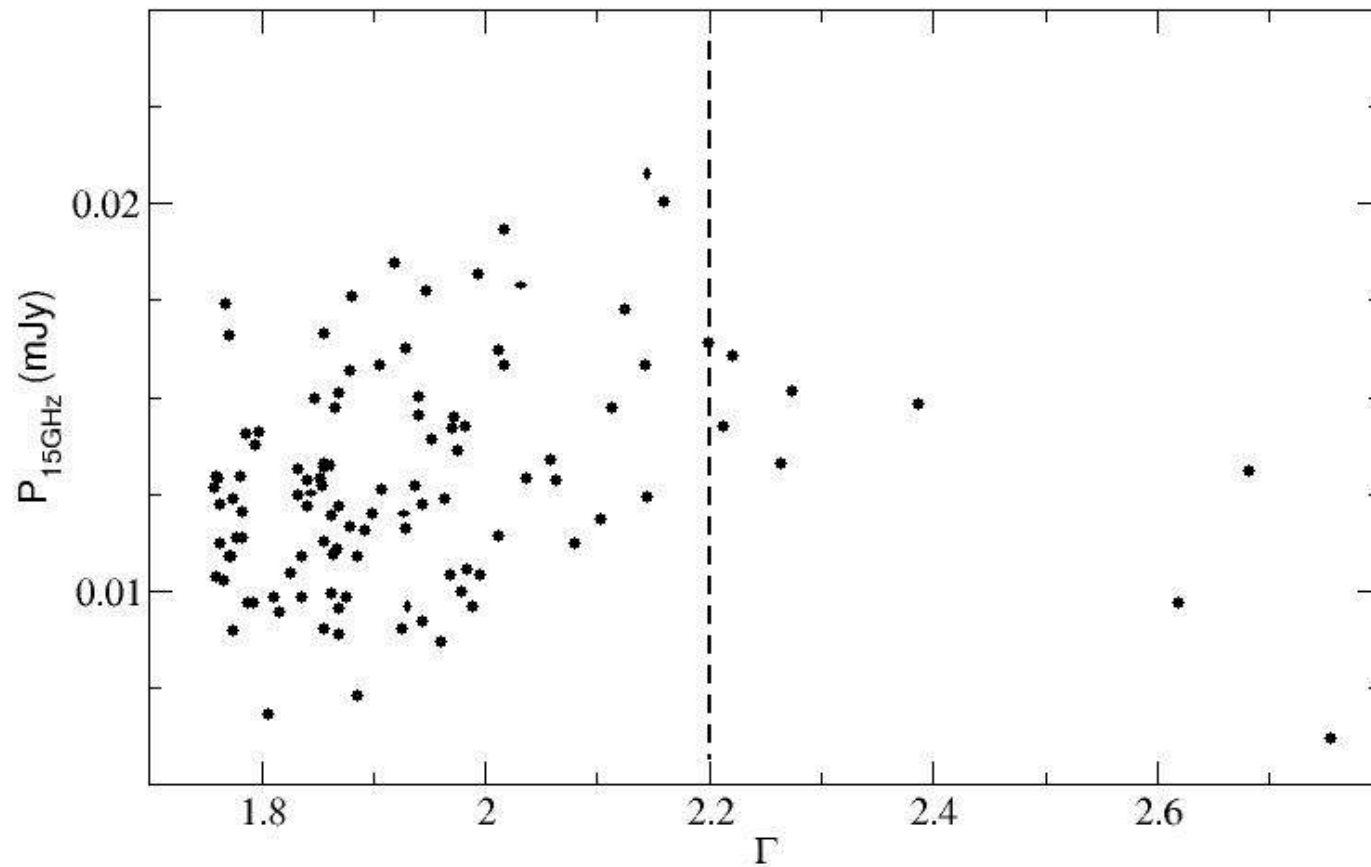
Conclusion

- If our model has anything to do with reality, it forces us to think that, the characteristic frequencies of variation **increase** with radius.
- This is not what we normally think.
- The “party line” is that the frequencies of variability **decrease** with radius (e.g. QPOs as Keplerian frequencies).
- Let’s push the jet model further!

Additional constraint

- Our jet model PREDICTS a positive correlation between radio flux and Γ .
- Such a correlation has not been seen or proposed before.
- In Cyg X-1 we have found this correlation. It is not very tight, but it is certain (Kendall's tau=0.21, i.e., probability $< 0.2\%$ that there is no correlation).

Radio flux vs Gamma



Additional constraints

- Our jet model **must** predict/confirm the reflection component and its correlations with other observables.
- We are working on it.
- Our simplifying, but unphysical assumption, that the jet velocity is constant throughout the jet must be modified. **The acceleration of the jet must be taken into account.**



THANK YOU

FOR YOUR ATTENTION