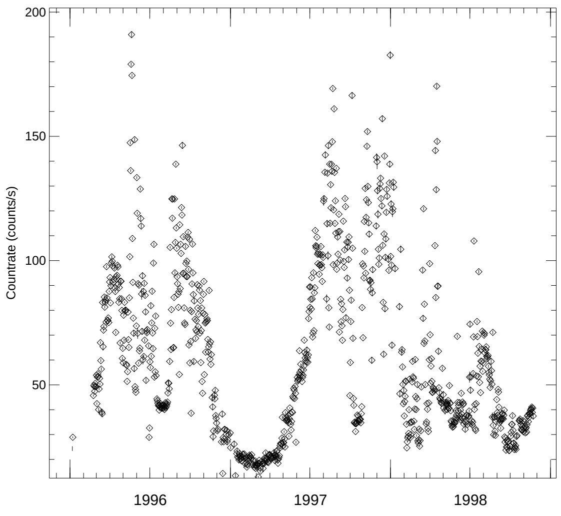
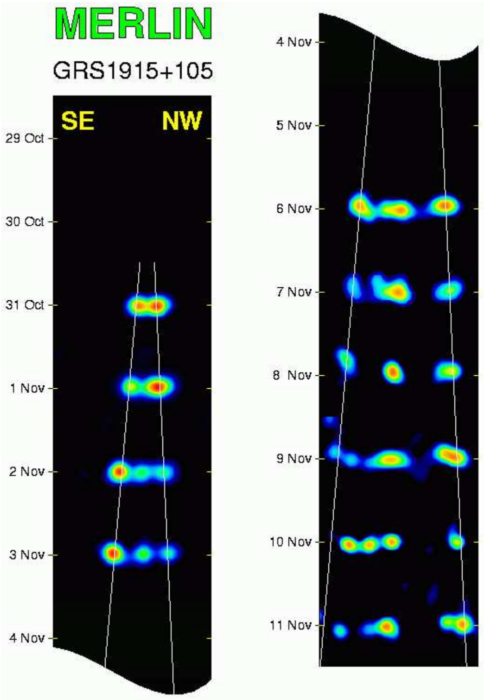
Microquasars, I

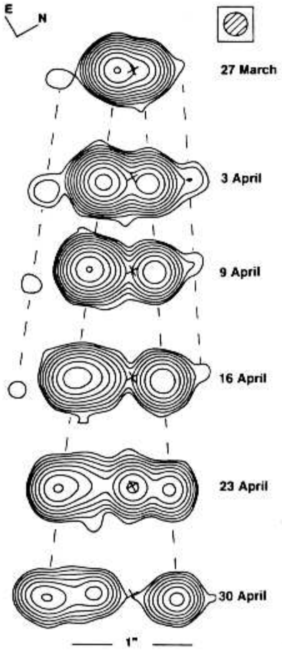


Some black holes show very interesting long and short term behavior in all wavebands

RXTE-ASM 2–12 keV lightcurve of GRS 1915+105

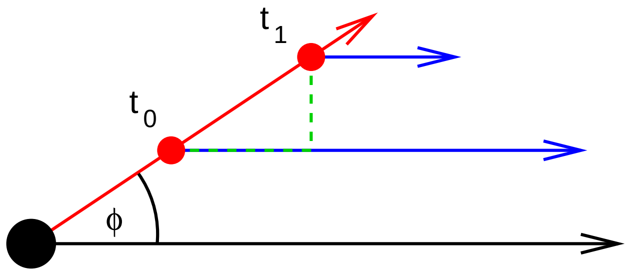


1997 radio campaign: ∼10% higher speeds;
Fender et al. (1998)



GRS 1915+105 1994 March/April: weekly radio images show blob ejection events.
Scale ∼10000 AU
Ballistic motion of events ⟹ no deceleration!
Inferred speeds: $(0.65 \pm 0.08)c$ und $(1.25 \pm 0.15)c$
⟹ superluminal motion!

Microquasars, IV



Consider blob moving towards us with speed v and angle ϕ with respect to line of sight, emitting light signals at t_0 and $t_1 = t_0 + \Delta t_\mathrm{e}$

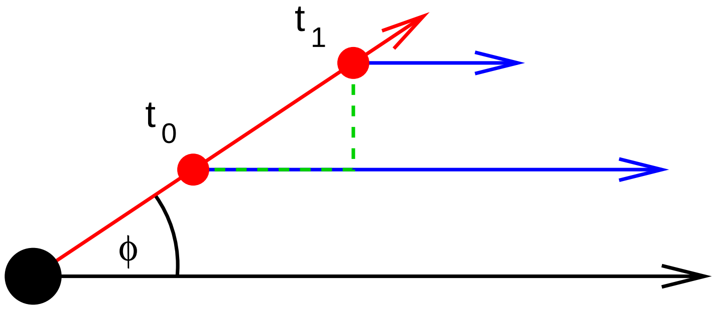
Light travel time: Observer sees signals separated by

$$\Delta t_\mathrm{o} = \Delta t_\mathrm{e} - \Delta t_\mathrm{e}\frac{v}{c}\cos\phi = \left(1 - \frac{v}{c}\cos\phi\right)\Delta t_\mathrm{e} \tag{7.1}$$

Observed distance traveled in plane of sky:

$$\Delta \ell_\perp = v \Delta t_\mathrm{e} \sin\phi \tag{7.2}$$

Microquasars, V



Apparent velocity deduced from observations:

$$v_{\text{app}} = \frac{\Delta\ell_\perp}{\Delta t_{\text{o}}} = \frac{v\Delta t_{\text{e}}\sin\phi}{\left(1-\frac{v}{c}\cos\phi\right)\Delta t_{\text{e}}} = \frac{v\sin\phi}{\left(1-\frac{v}{c}\cos\phi\right)} \qquad (7.3)$$

$\Longrightarrow$ For v/c large and ϕ small: $v_{\text{app}} > c$

previously only seen in Active Galaxies (“Quasars”) $\Longrightarrow$ Microquasars

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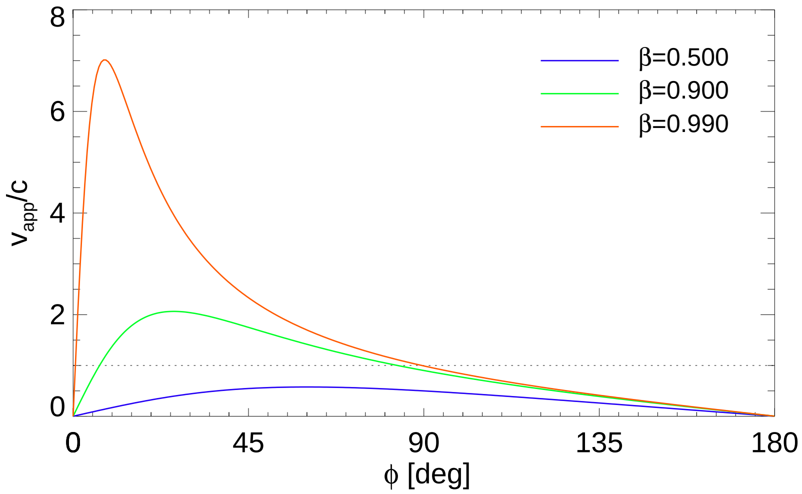
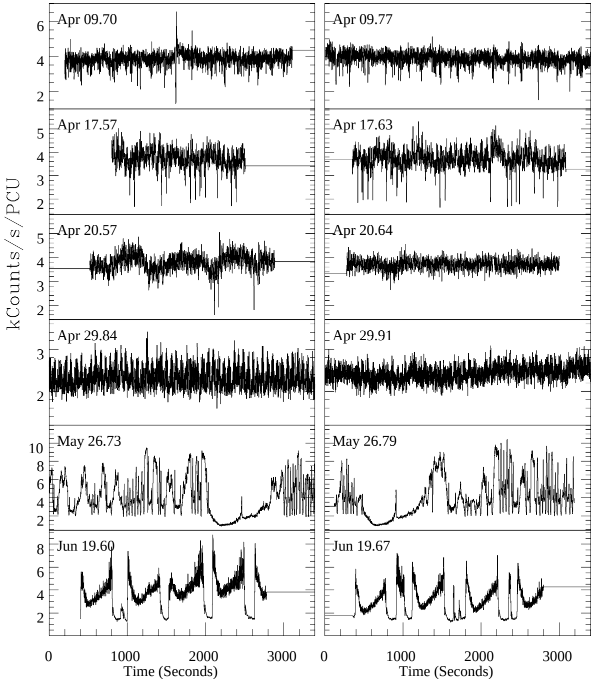
Microquasars, VI



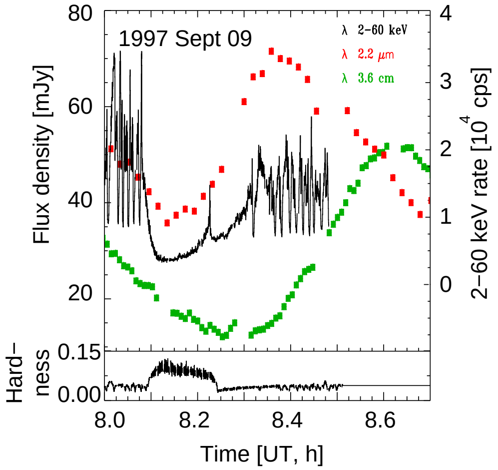
Superluminal motion: Microquasars have jet speeds close to c



GRS 1915+105, RXTE/PCA, 2–60 keV, 1 s resolution lightcurves

Brightness Sputters, Large-Amplitude Oscillations

$\Longrightarrow$ Microquasars show very complex short term variability in the X-rays!



(GRS 1915+105; after Mirabel et al., 1998)

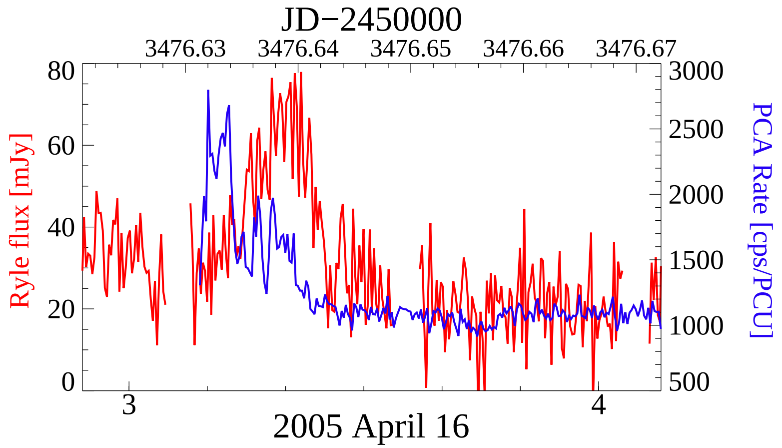
Microquasars allow study of dynamics of jet formation

Works much better than in AGN because of shorter timescales involved.

Flaring episodes: clear radio–X-ray relationship

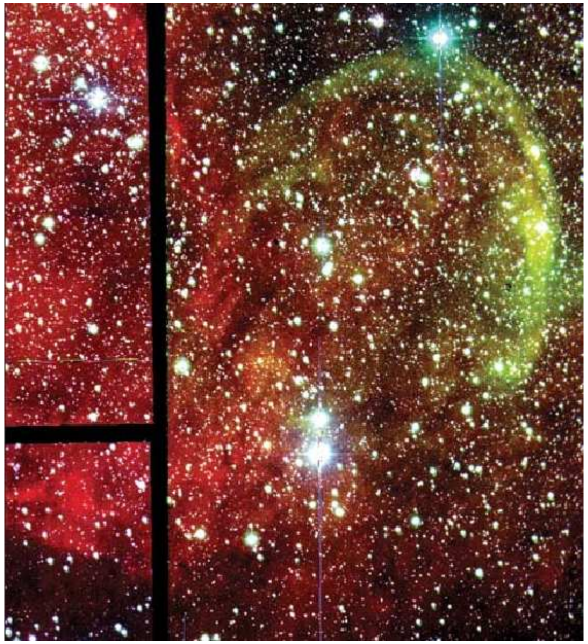
$\Longrightarrow$ “disk-jet-connection”

(cf. Mirabel & Rodríguez, 1994;
Pooley & Fender, 1997; Eikenberry et al., 1998; Klein-Wolt et al., 2002;
Fender & Belloni, 2004;
Rothstein, Eikenberry & Matthews, 2005. . .)



(Cyg X-1, 2005 April 16 Wilms et al., 2007, Ryle: 15 GHz, PCA: 2–60 keV)

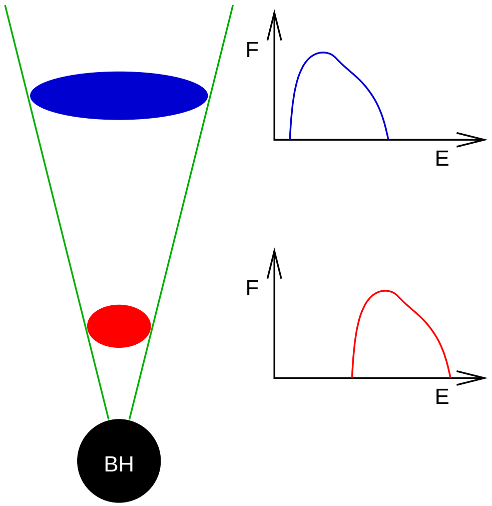
Correlated radio–X-ray flaring also seen in “normal” black holes.



Gallo et al. (2005): Interaction of jet with interstellar medium: galactic black hole jets can be comparable in power to their X-ray luminosity.

Russell et al. (2007)
For Cyg X-1, $L_{\text{jet}} = 0.3 \ldots 1.0\,L_{\text{X}}$.

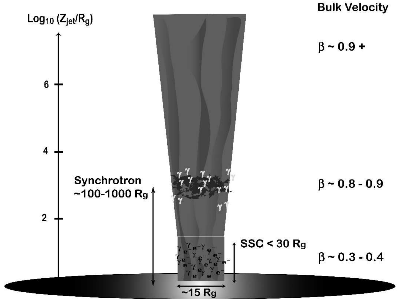
(Maccarone & Koerding, 2006, Figure by D. Russell)



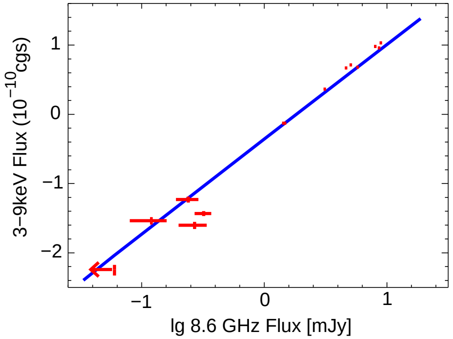
Short-term radio–X-ray correlations can be explained with the synchrotron bubble model

(van der Laan, 1966;
Hjellming & Johnston, 1988)

X-rays: Jet Models?



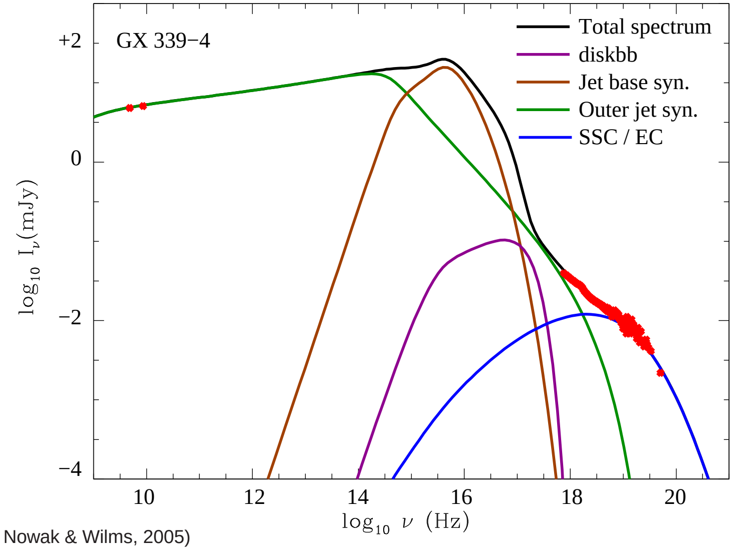
(Markoff & Nowak, 2004)



(Markoff et al., 2003)

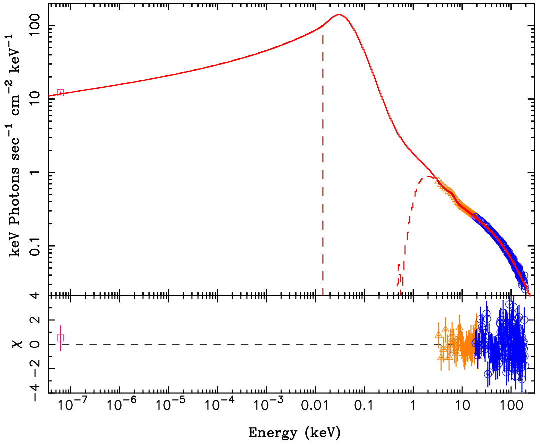
Synchrotron+SSC from a jet can explain observed long-term correlations between radio and X-rays

X-rays: Jet Models?



(Markoff, Nowak & Wilms, 2005)

X-rays: Jet Models?



(Markoff, Nowak & Wilms, 2005)

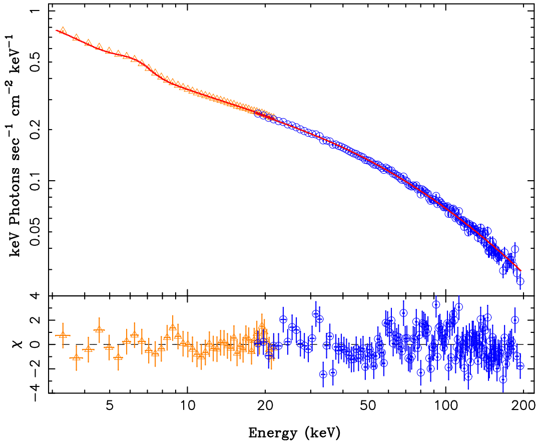
Fit of synchrotron radio jet model gives χ^2 comparable to Comptonization ($\chi^2_{\rm red} = 1.17$).

X-rays mainly due to synchrotron self-Compton radiation from fairly large jet base (10–15 r_g).

Systematics caused by ionisation or smearing of reflection hump?

Is the Compton corona the base of the jet?

X-rays: Jet Models?



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