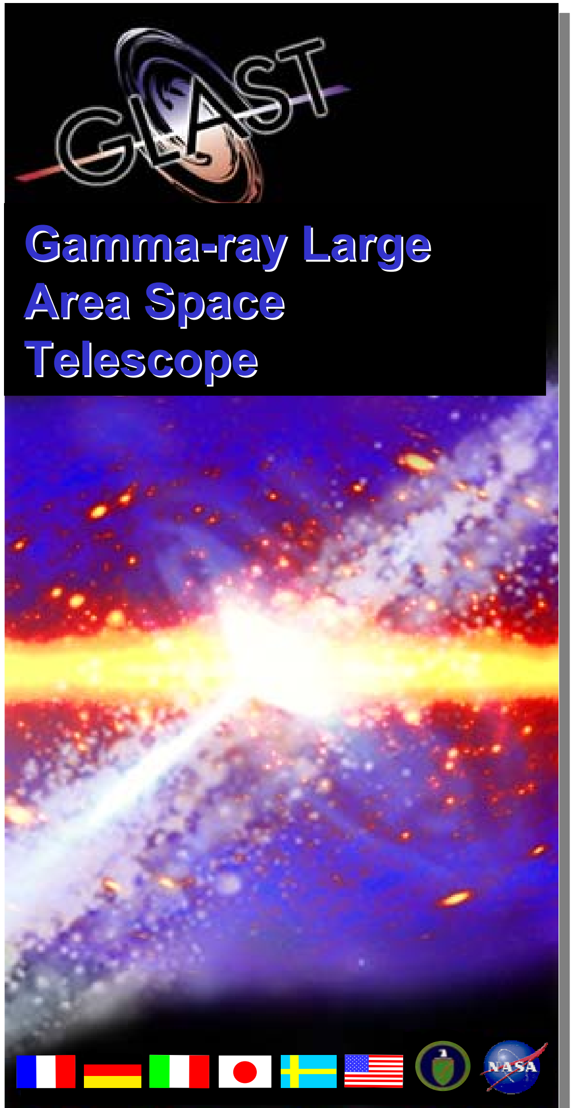


GLAST Science at Lunch

Micro-Quasars and GLAST??

Richard Dubois

Outline

- MicroQuasars in the press
- What & where
- What's in a name? Analogies to quasars?
- What observations tell us
- Prospect of high energy photons
- Microblazars??

References:
- Mirabel astro-ph 0405433
- Fender and Maccarone astro-ph 0310538
- Romero et al astro-ph 0402285
- Fender and Belloni astro-ph 0406483

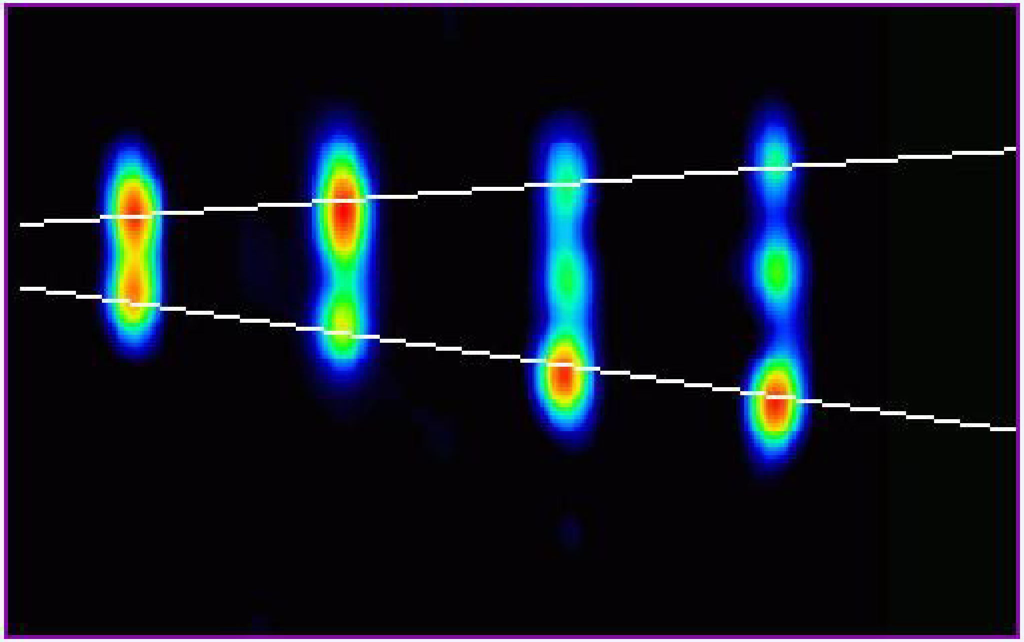
http://jet.uah.edu/microquasar/

Thanks to Greg and Berrie for advice!

Astronomy Picture of the Day

Discover the cosmos! Each day a different image or photograph of our fascinating universe is featured, along with a brief explanation written by a professional astronomer.

December 2, 1997



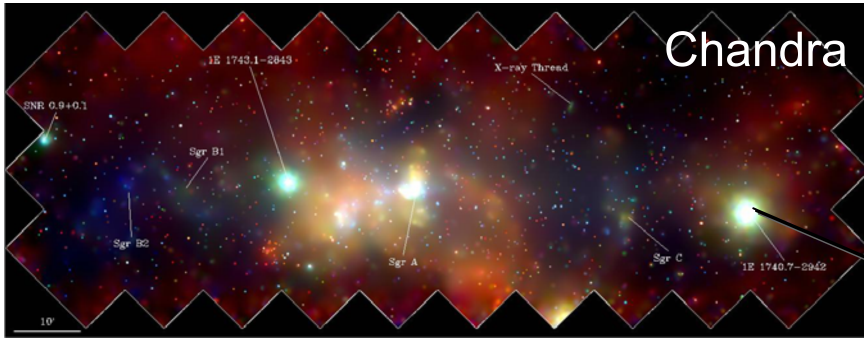
Micro-Quasar GRS1915 Puffs
Credit: R. Spencer (U. Manchester) et al., MERLIN, Jodrell Bank

Explanation: On the far side of our Galaxy, gas clouds explode away from a small black hole. This might seem peculiar, as black holes are supposed to *attract* matter. But material falling toward a black hole collides and heats up, creating an environment similar to a quasar that is far from stable. In the above time-lapse sequence, micro-quasar GRS1915 expels bubbles of hot gas in spectacular jets. These computer enhanced radio images show one plasma bubble coming almost directly toward us at 90 percent the speed of light, and another moving away. Each of the four frames marks the passage of one day. Originally detected on October 29th, these bubbles have now faded from view.

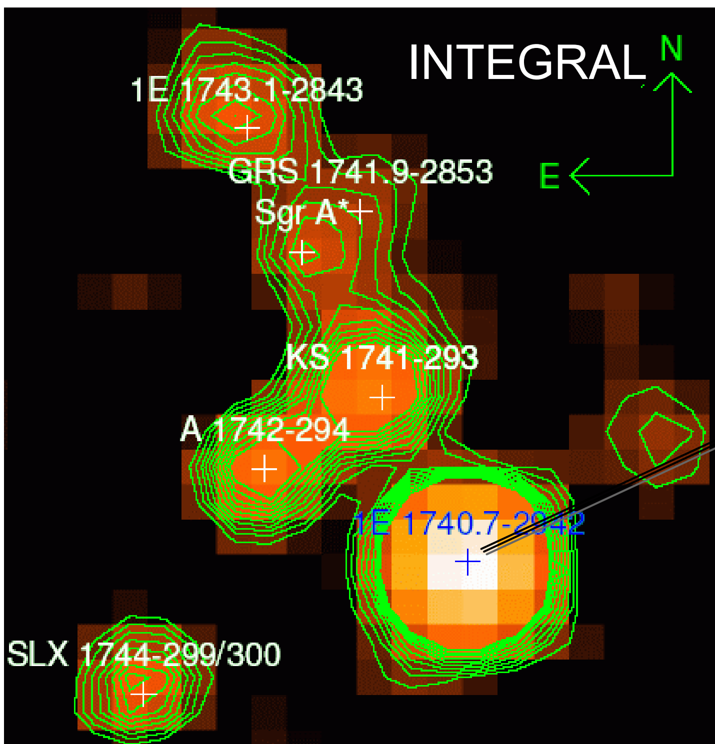
MICROQUASAR

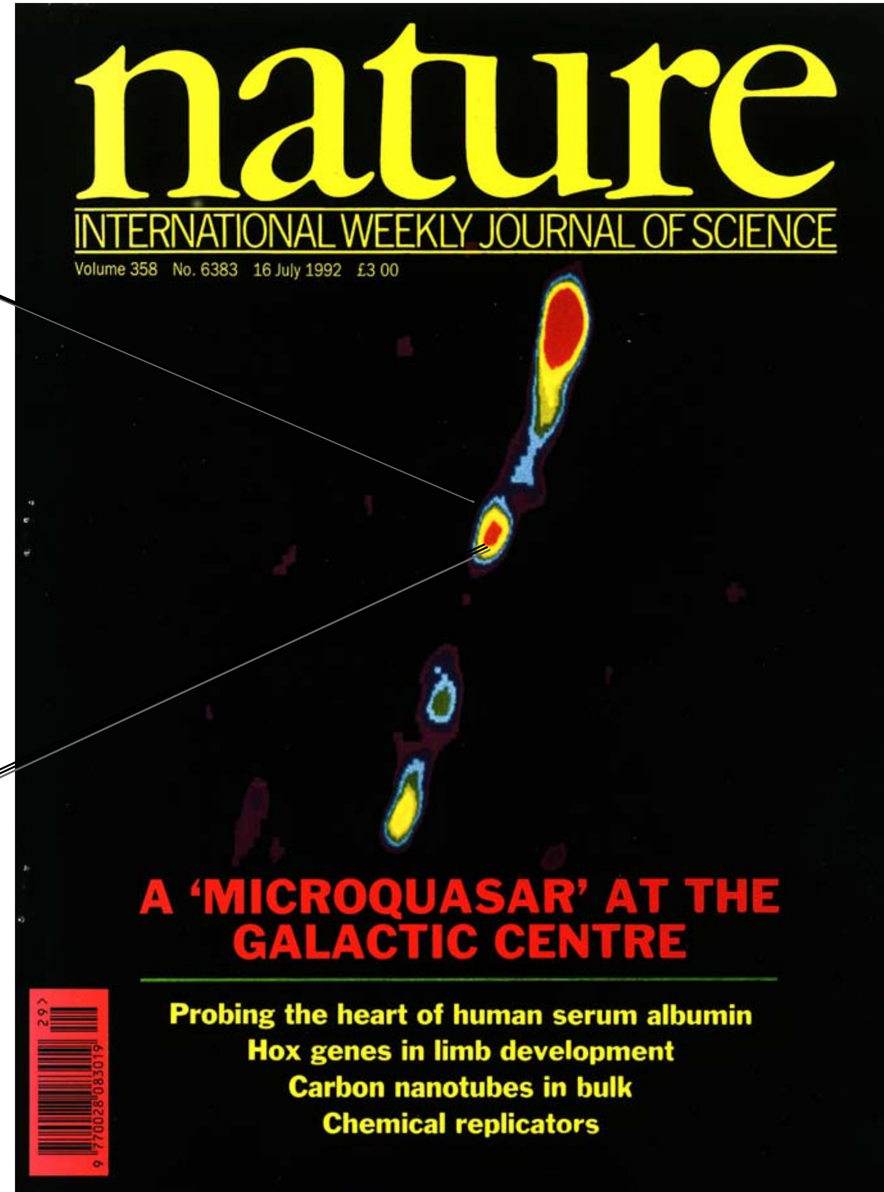
Wang et al. ApJ 2002

M., Rodriguez, Cordier, Paul, Lebrun, 1992



Belanger, Goldwurm, Goldoni, ApJ 2003





First of Kind: GRS 1915+105

- Discovered 1992 with WATCH instrument on GRANAT, then by BATSE in our galaxy ~ 12 kpc away
- Time-variable radio and IR components found in 1993
- Radio variability correlated with hard X-ray flux
- ~ 15 solar mass BH with companion star
- Discovered superluminal radio components in 1994 with VLA at estimated distance of 12.5 kpc
  - first galactic superluminal source

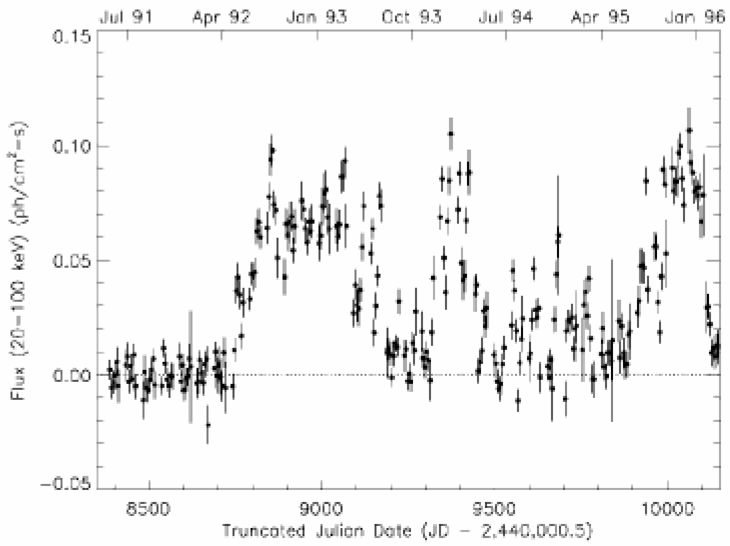
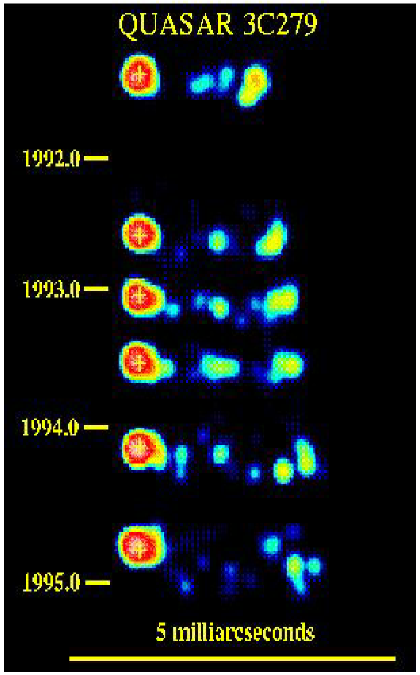
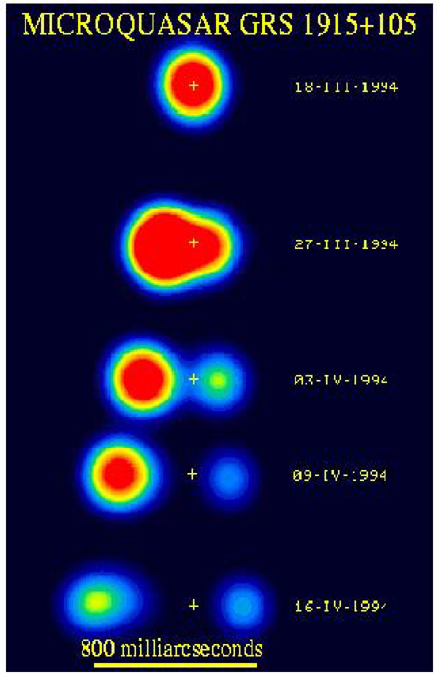


Figure 1: BATSE 20–100 keV light curve of GRS 1915+105 in 5-day bins. Flux conversion was done with a Γ=2.5 power-law model (from Harmon et al. 1997). Time ranges from mid-1991 to the launch of RXTE.

From Fender & Belloni

Superluminal Motion





Measure both jets:

Proper motions and Doppler shifts yield distance, velocity and angle.

Smaller Doppler shifts make for apparently brighter receding jets in μQ

Estimating Masses

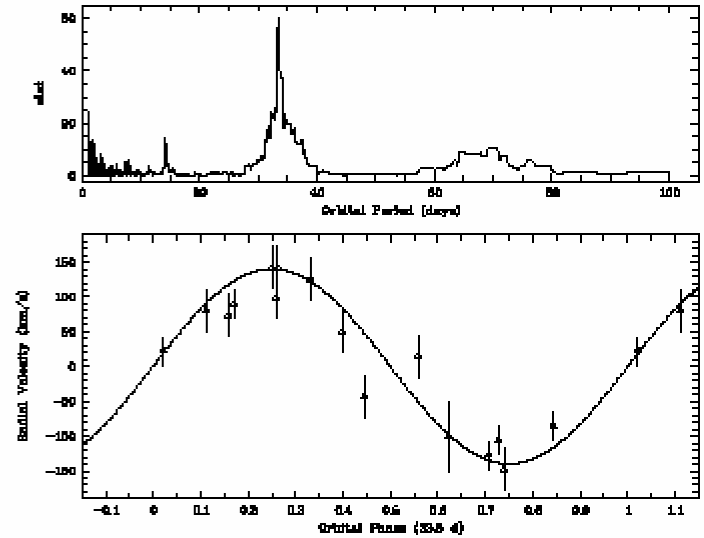
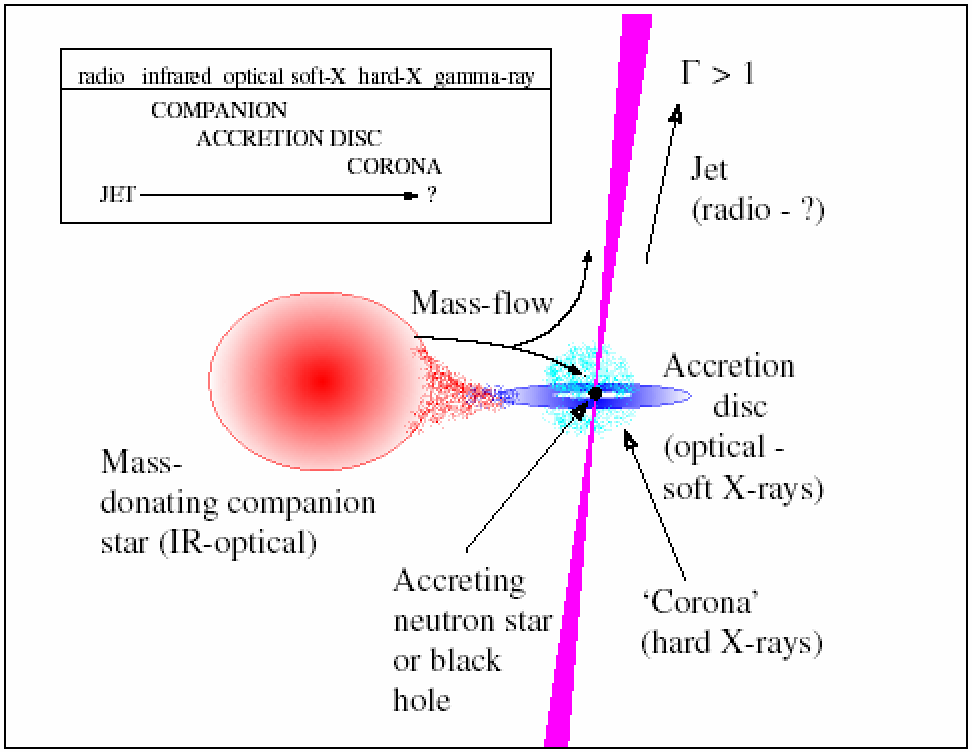
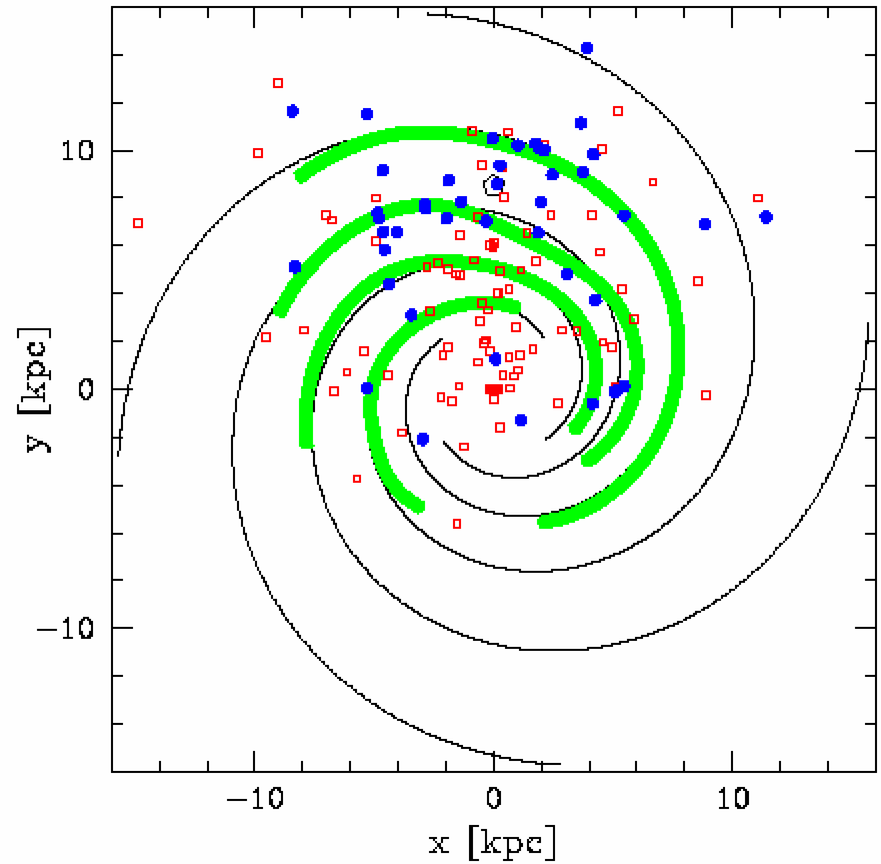


Figure 24: Orbital parameters of GRS 1915+105 from IR spectroscopy (Greiner et al. 2001). The top panel shows the most likely orbital period, of 33.5 days, for the binary. The lower panel shows the radial velocity data folded on this orbital period. From these data a mass function—corresponding to an absolute lower limit on the mass of the accreting object—of 9.5 ± 3.0 M⊙ can be derived. Assuming a companion mass of 1.2 M⊙ and an orbital inclination equal to the angle the jets make with the line of sight, i.e., 70., then Greiner et al. estimate a mass of 14 ± 4 M⊙ for the black hole.

What and Where



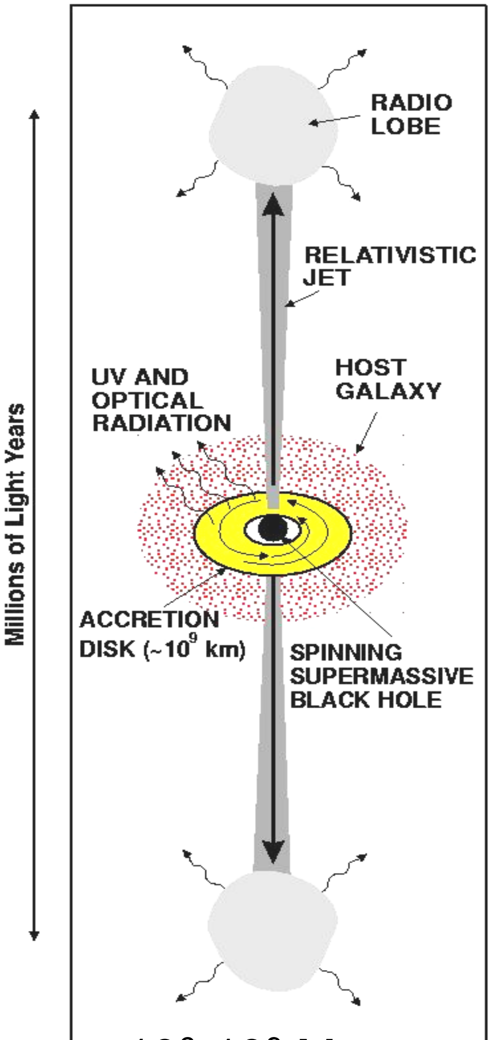


microQuasar ≡ X-ray binary with jets

No preferred location in galaxy.
Sun at (0,8.5)

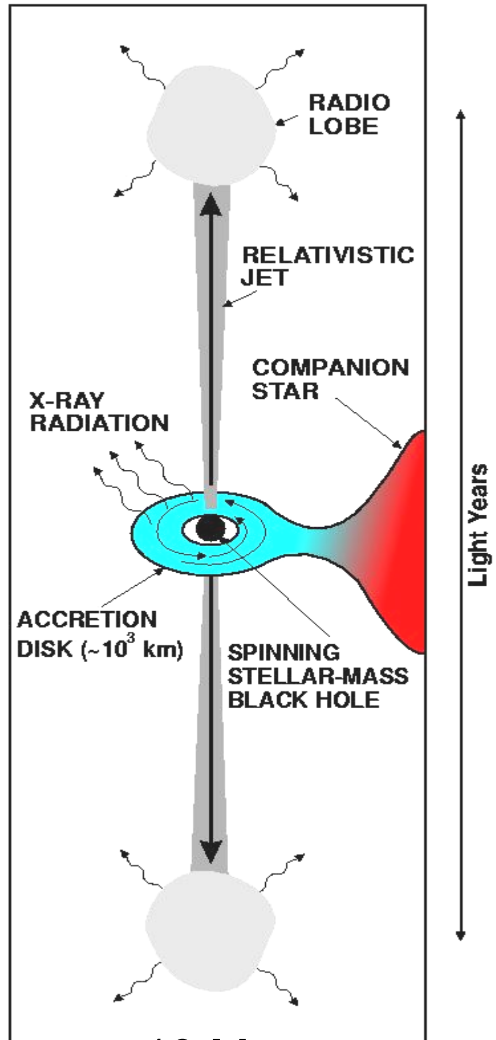
QUASAR-MICROQUASAR ANALOGY

QUASAR



10^6-10^9 $M_\odot$

MICROQUASAR



10 $M_\odot$

M. & L.F. Rodriguez; Nature 1992, 94, 98

The scales of length and time are proportional to M_{BH}

$R_{sh} = 2GM_{BH}/c^2$; $\Delta T \alpha M_{BH}$

The maximum color temperature of the accretion disk is:

$T_{col} \alpha (M/ 10M_\odot)^{-1/4}$

(Shakura & Sunyaev, 1976)

For a given accretion rate:

$L_{Bol} \alpha M_{BH}$; $l_{jet} \alpha M_{BH}$;

$\varphi \alpha M_{BH}^{-1}$; $B \alpha M_{BH}^{-1/2}$

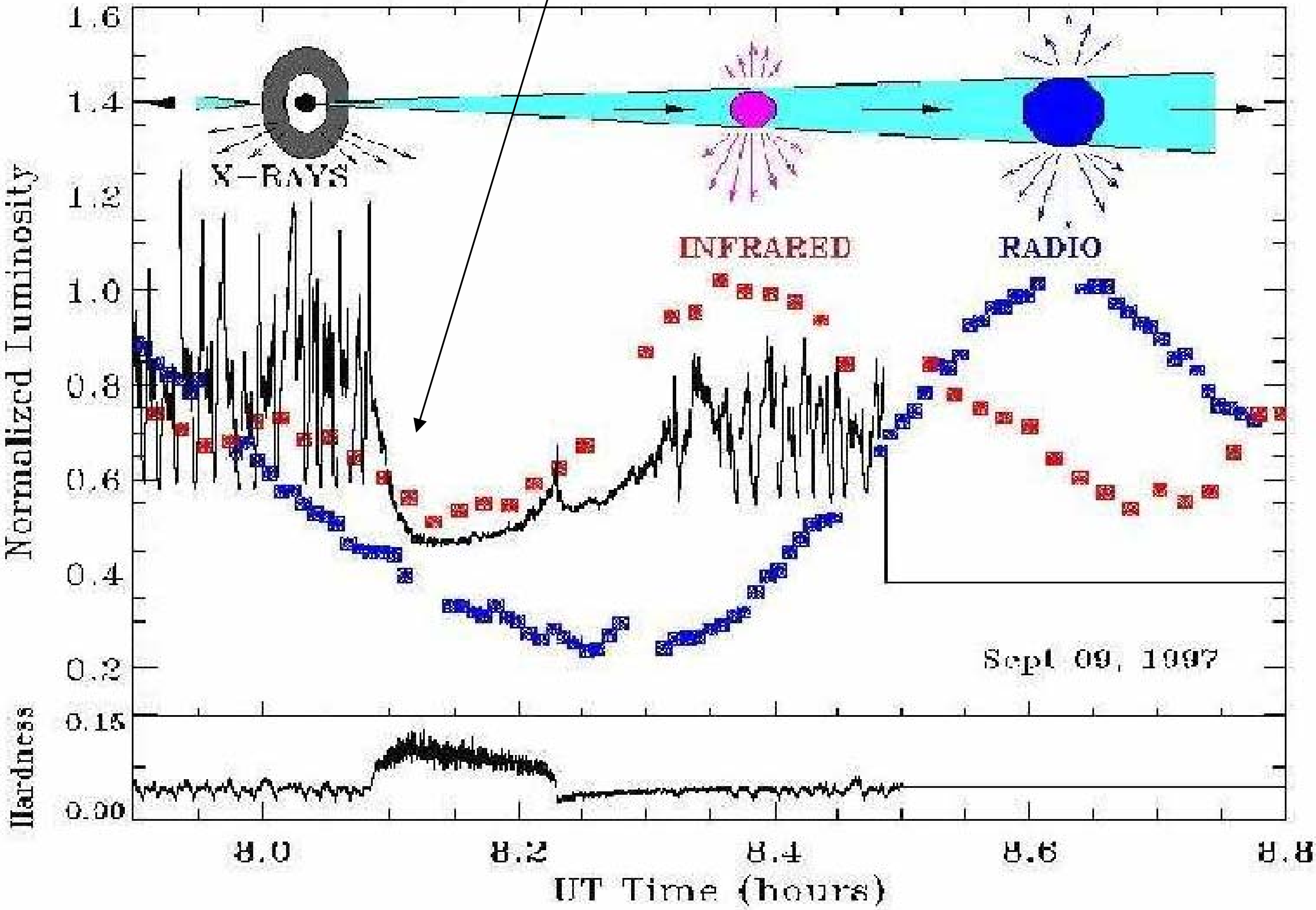
(Sams, Eckart, Sunyaev, 96; Rees 04)

Length scale better for spatial measurements with quasars

From Mirabel: Hong Kong 2003

Disk-jet connection - 1

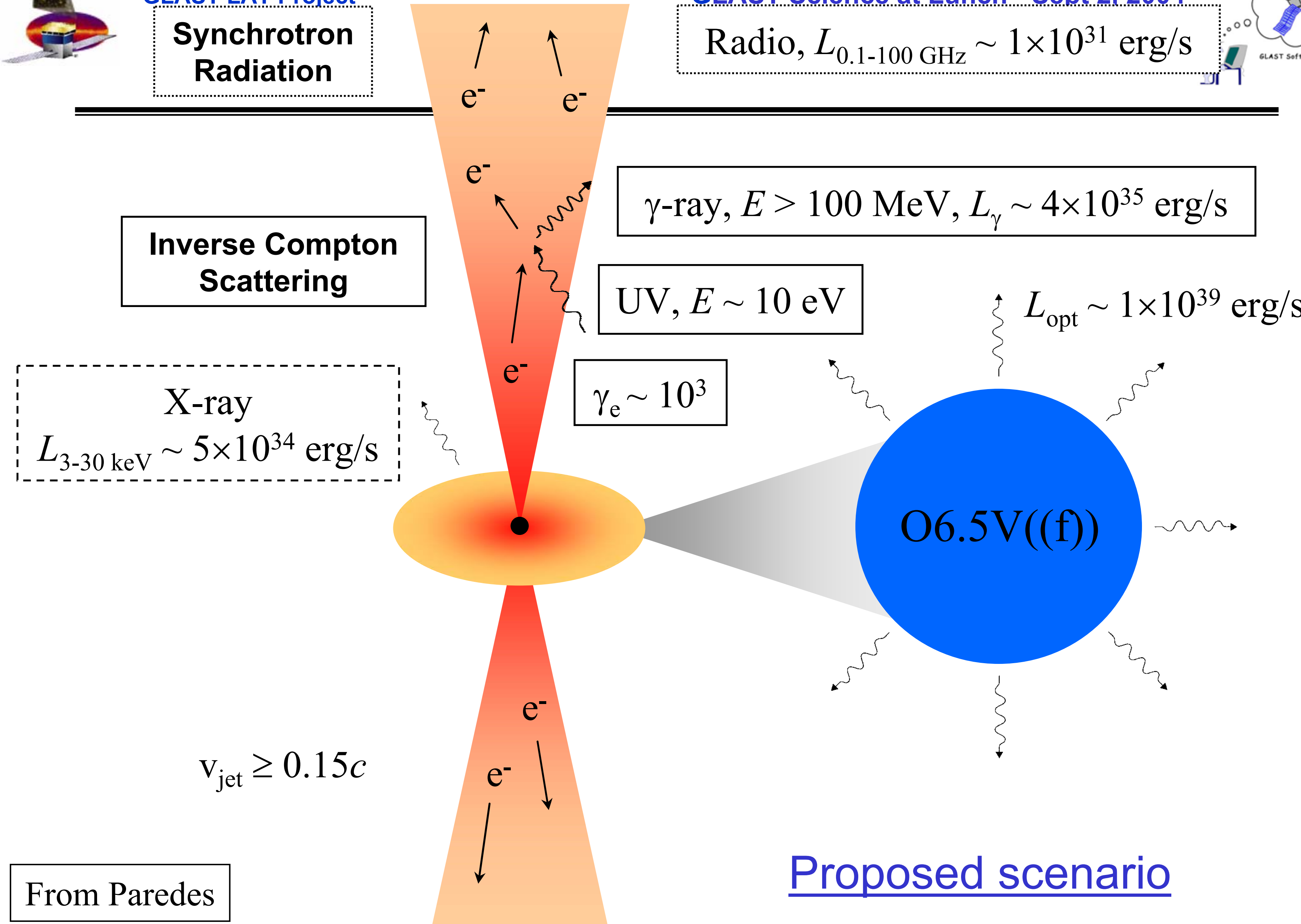
onset of jets



Similar “flushing” in quasars can take years!!

Disk-jet Connection - 2

- Jets appear after drop of x-ray flux
- Jets are produced during replenishment of inner accretion disk
- Jet injection can last up to 10 mins
- Time delay in jet flares consistent with AGN model of adiabatically expanding clouds
- Synchrotron emission up to IR and maybe X-rays. Jets of electrons up to TeV.
- Radio images show jets extend 100 AU (15M km)



From Paredes

Proposed scenario

Picture of Disk Emission

Hard - jets

Soft – no jets

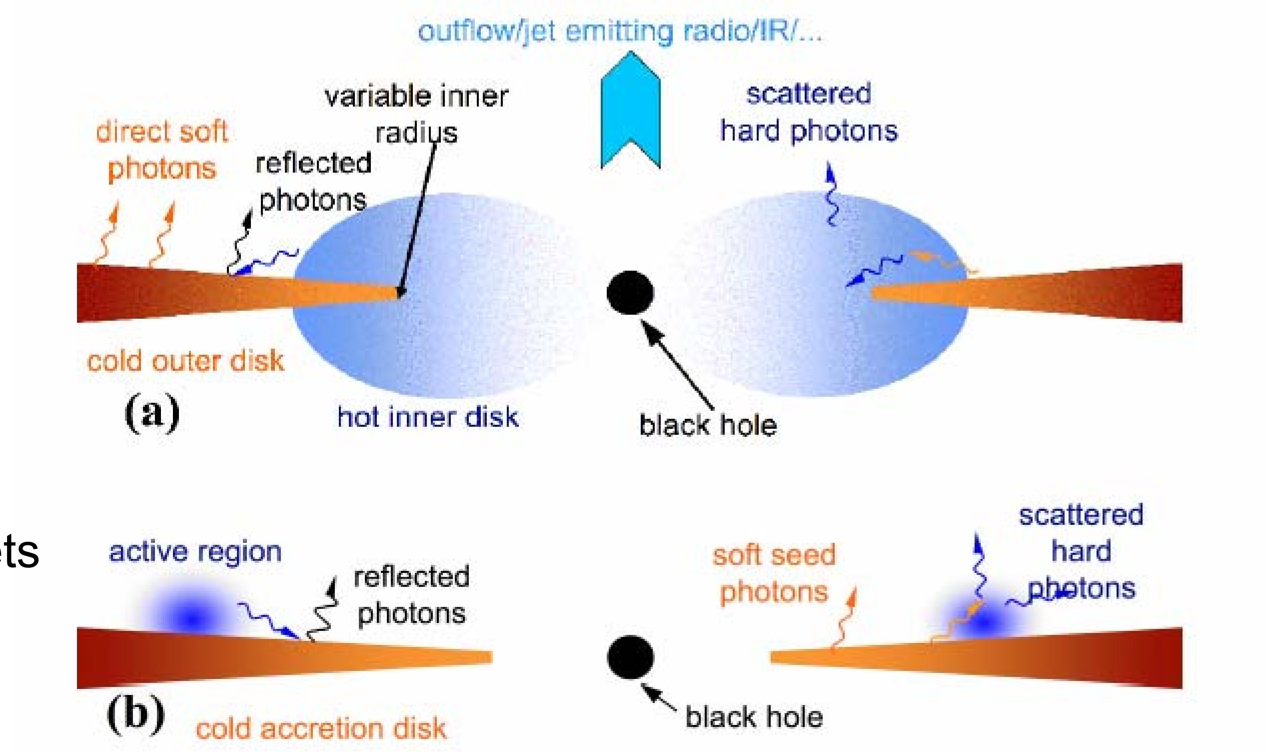
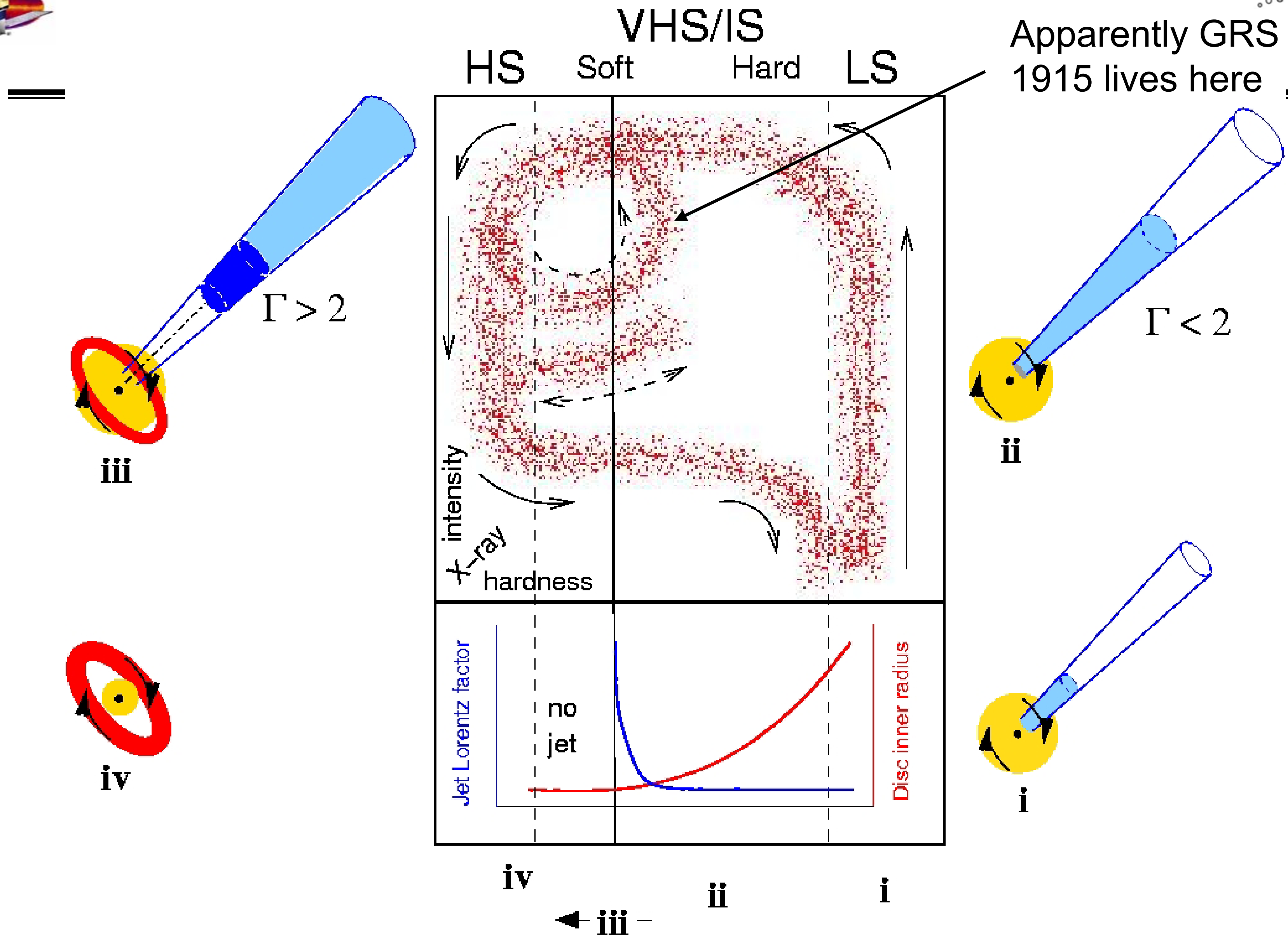


Fig. 14. (a) A schematic representation of the likely geometry in the hard state, consisting of a hot inner accretion flow surrounded by optically-thick accretion disk. The hot flow constitutes the base of the jet (with the counter-jet omitted from the figure for clarity). The disk is truncated far away from the minimum stable orbit, but it overlaps with the hot flow. The soft photons emitted by the disk are Compton upscattered in the hot flow, and emission from the hot flow is partly Compton-reflected from the disk. (b) The likely geometry in the soft state consisting of flares/active regions above an optically-thick accretion disk extending close to the minimum stable orbit. The soft photons emitted by the disk are Compton upscattered in the flares, and emission from the flares is partly Compton-reflected from the disk.

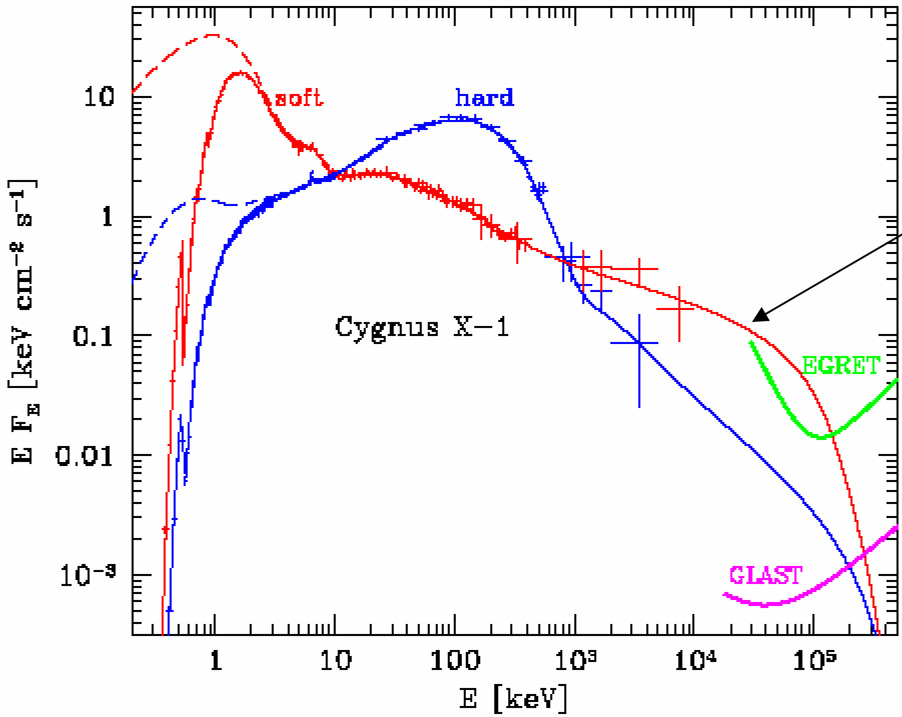


The association of hard X-rays with jets…

Fender, Belloni & Gallo (2004)

Potential Flux Limits - Disk

Andrzej A. Zdziarski and Marek Gierliński



No cutoff known for this tail

X-ray portion of spectrum accounted for by disk effects

Disk energies < 10's MeV

Fig. 1. Spectra of the soft state of 1996 June and of the average hard state of Cyg X-1. The models10), 26) (solid curves) in both states consist of hybrid Comptonization of disk blackbody photons, Compton reflection and fluorescent Fe K emission. The dashed curves give the model spectra before absorption. We also show the upper limit from the EGRET observations in the hard state and an expected sensitivity of GLAST, see §2.2 for details. See astro-ph for color versions of this and subsequent figures.

For the effective area of www-glast.slac.stanford.edu/software/IS/glast_lat_performance.htm and requiring 20 photons per unit lnE. This relatively large number is intended to approximately take into account the presence the strong diffuse emission in the Galactic plane region.

Expected Photon Spectrum - Jets

Q: What sets the flux normalization in these models??

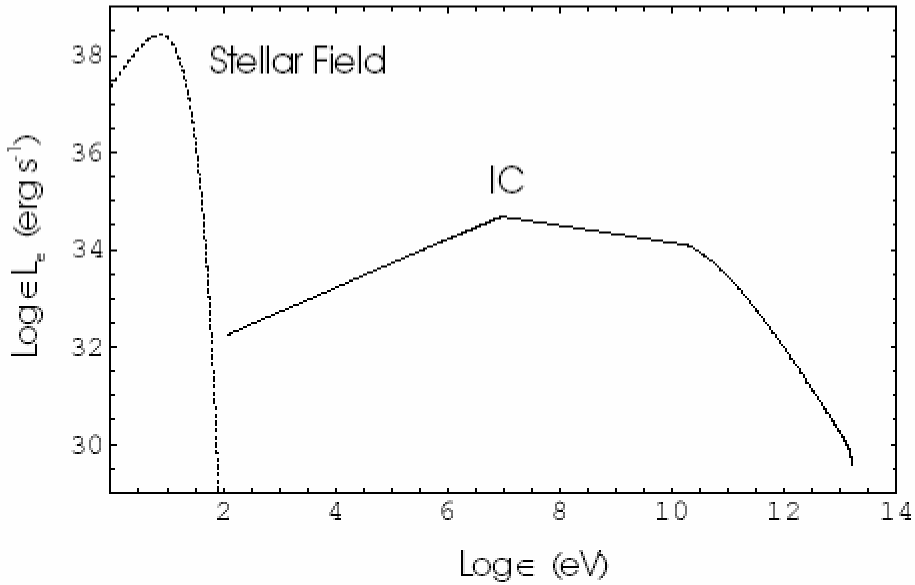
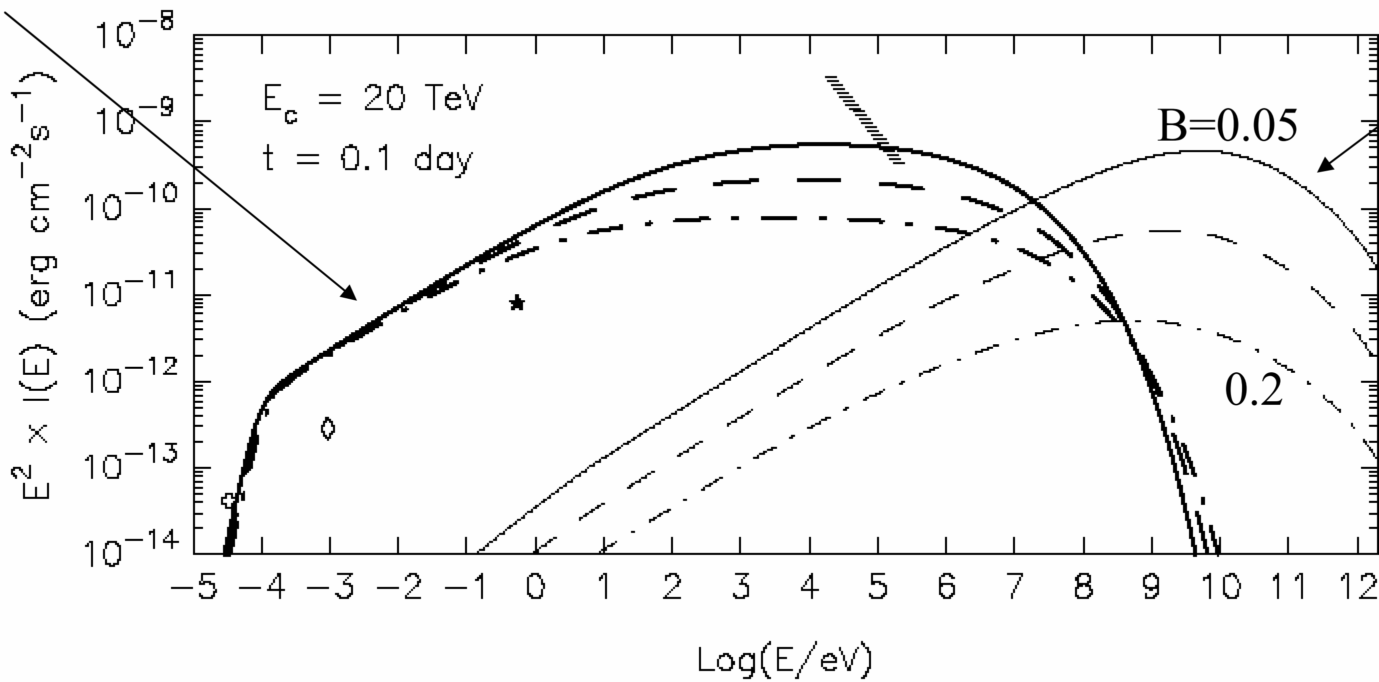


Figure 2. Inverse-Compton spectral energy distribution for a microquasar with a massive stellar companion. Leptons in the jet are assumed to have a power-law energy distribution with an index $\alpha = 2$ and a high-energy cutoff at multi-TeV energies. Notice the softening of the spectrum at high-energies due to the Klein-Nishina effect.

From Romero et al.

Flux and Magnetic Fields - Jets

synchrotron



inverse Compton

GLAST sensitivity permits seeing these

Figure 12: The fluxes of the synchrotron (heavy lines) and IC (thin lines) radiations which could be expected from GRS 1915+105 at t = 0.1 day after ejection of a pair of radio clouds, calculated in the case of exponential cut-off energy Ec = 20TeV, assuming 3 different values for the magnetic field at the instant t = t0: B0 = 0.05G (solid lines) B0 = 0.1G (dashed line), and B0 = 0.2G (dot–dashed lines). All other model parameters are the same as in Fig.11.

Q: why aren't these anti-correlated if large B means more synchrotron?? $S_\nu \propto B^{1+\alpha}$

Hadrons - Jets?

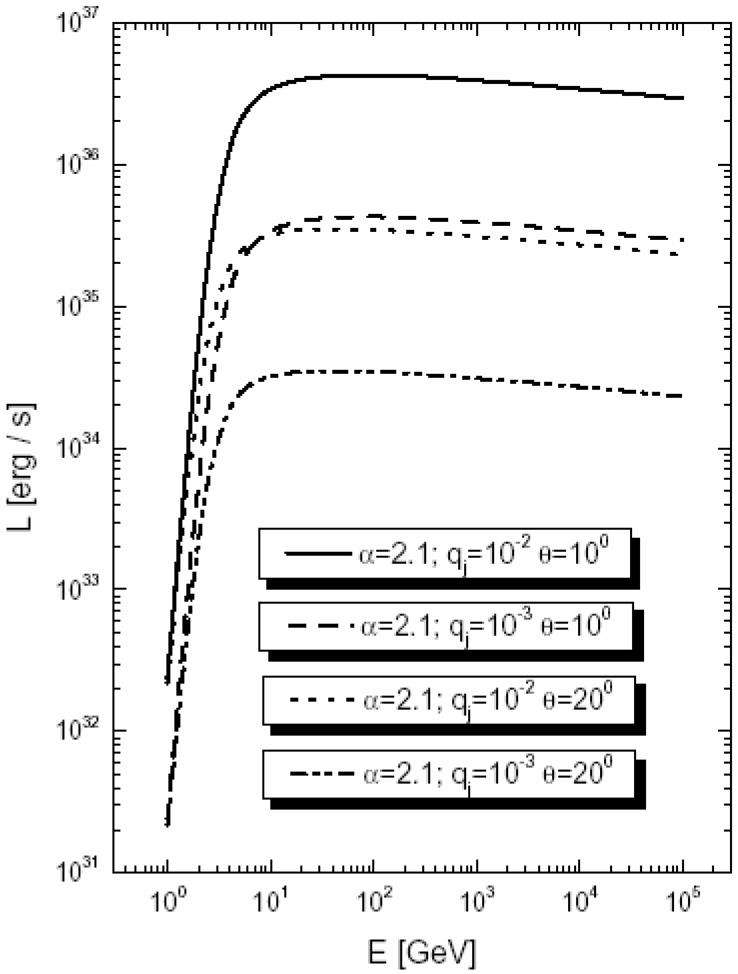
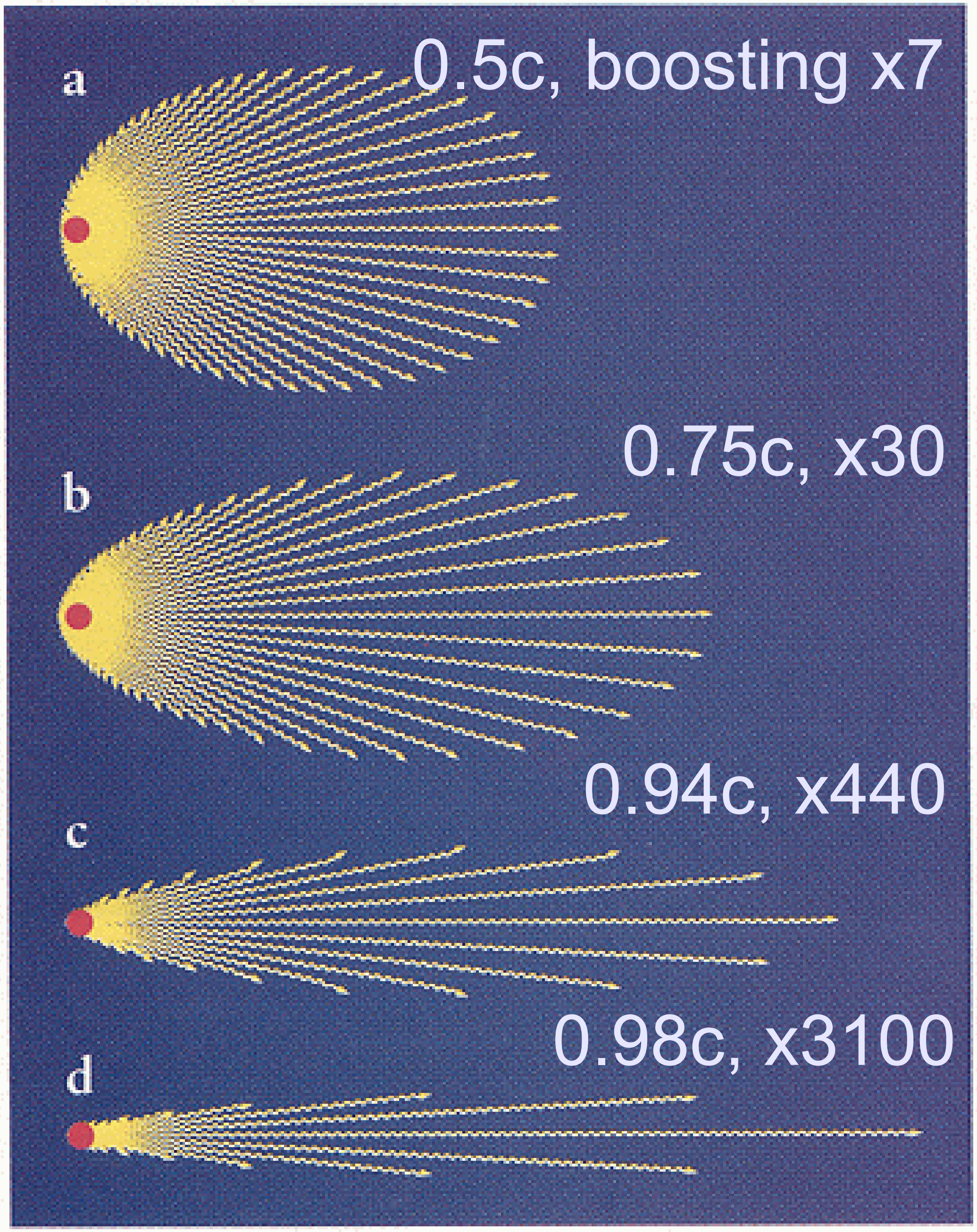


Figure 3. Spectral energy distribution produced by the interaction of a hadronic jet of a microquasar with the wind of the massive stellar companion. Curves for different jet/disk coupling constants and viewing angles are presented. The index in the proton power-law distribution is 2.1 in all cases.

Romero et al

Would also want to see π^0 enhancement around 100 MeV

'Microblazar' idea discussed in



Mirabel & Rodriguez (1999) [see also Romero, et al. 2002; Georganopoulous et al. 2002]

Whereby 'regular' jets from X-ray binaries, possibly precessing, may result in observed γ-ray emission…

but what if there is an even more strongly beamed component… ?

From Fender

How about them microQuasars?

- They appear to be nearby small scale models of AGNs
  - Easier to study for some things
    - But size-wise quasars appear larger even though far away
    - Win out on timing and 2-jet observations
  - How accurate a model of AGNs are they?
    - Just because something happens in microQ's that fit in our attention span, does that mean is also happens in 'real' AGNs. Presumably need better models of both.
  - Can look at differences between BH and NS X-ray binaries
    - Is only difference effect of accreting matter on surface rather than down hole?
  - Entertaining puppies! Lots of things going on at many wavelengths

- What to learn from GLAST
  - Details of high energy production
    - B fields?
    - hadrons?
    - Could learn both about disk and jet behaviour
    - Limits can presumably constrain models
    - Low rates would preclude us seeing the short timescale phenomena
  - Hard (and narrow) core jets – microBlazars??
    - I'm still not clear on the evidence for them
    - Need to luck out and have them point at us