MICROQUASAR JETS

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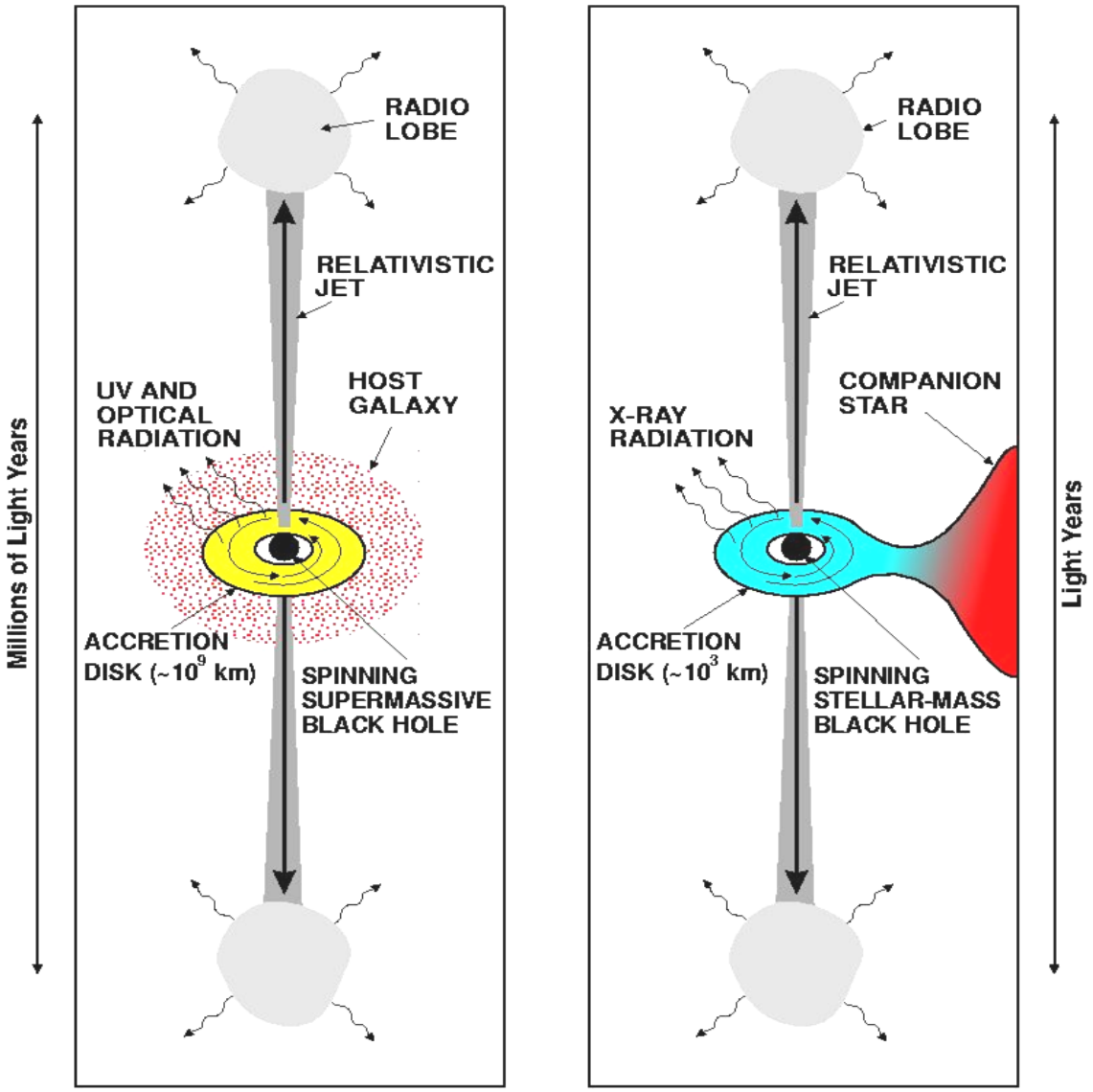
- Disk/jet transitions
- Gamma-ray emission
- Polarization
- 511 keV annihilation line?

AGN/QUASAR-MICROQUASAR ANALOGY

QUASAR **MICROQUASAR** Mirabel & Rodríguez Nature 1998



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

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

Unique system of equations:

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:

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

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

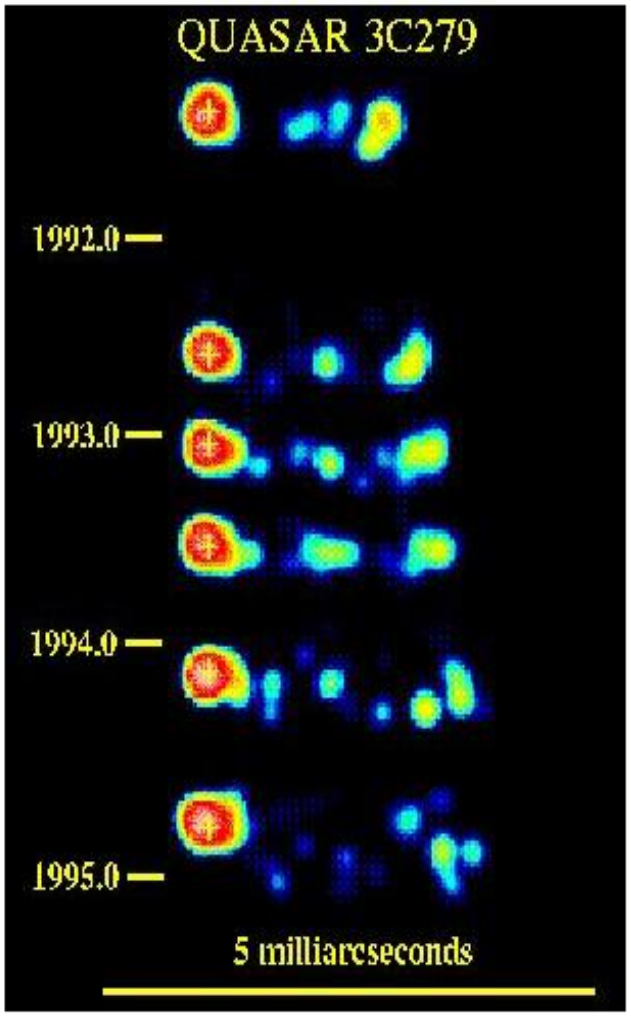
(Sams, Eckart, Sunyaev, 96; Rees 2004)

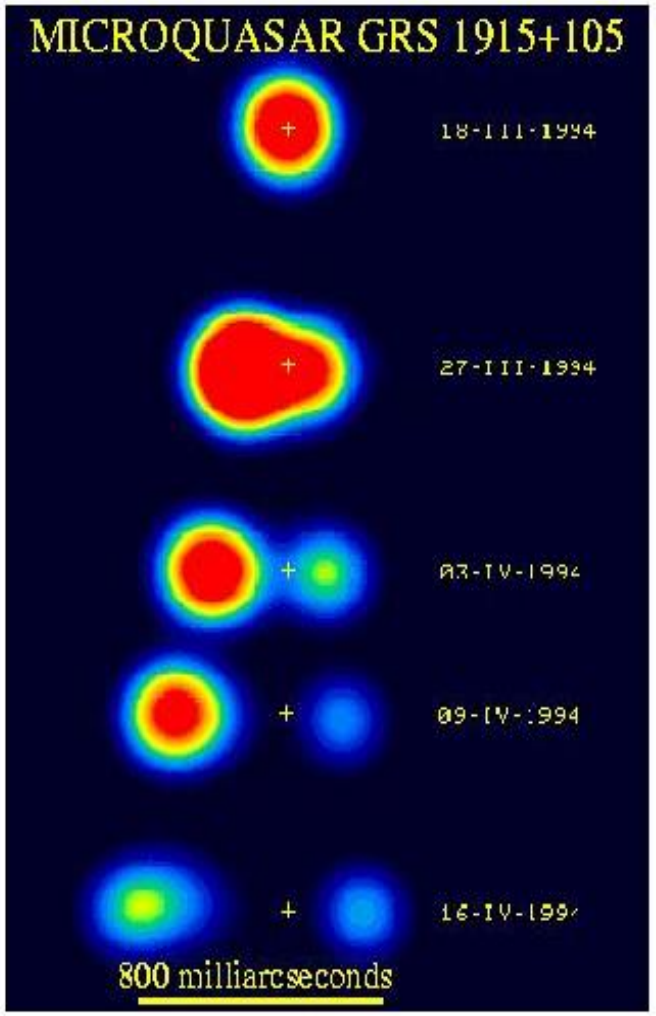
COMPLEMENTARITY BETWEEN μQSO AND QSO JETS

Mirabel & Rodríguez (Nature,1994)

VLBI
22 GHz
~1,3 cm

~marcsec
scale





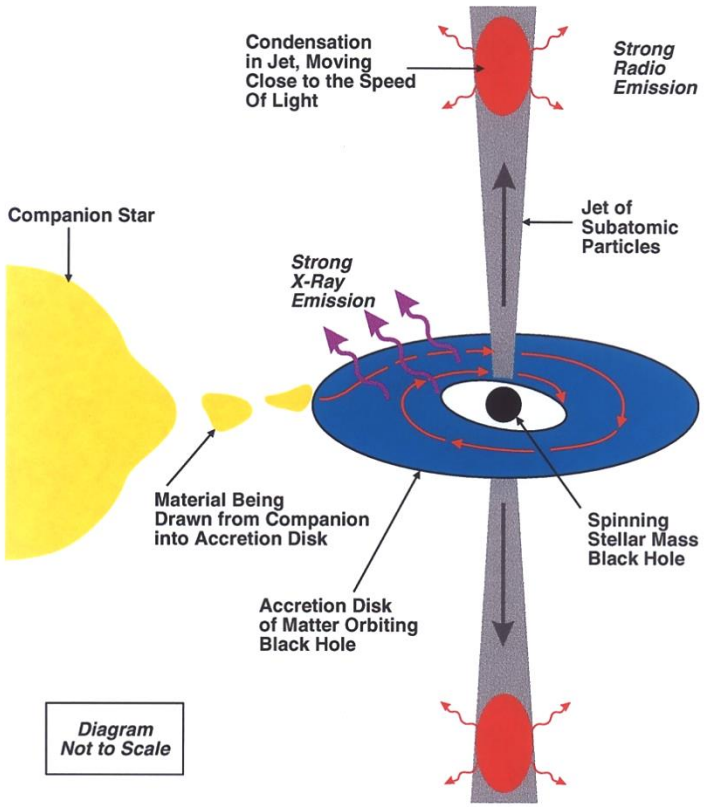
VLA
8.4 GHz
~3,5 cm

~subarcsec
scale

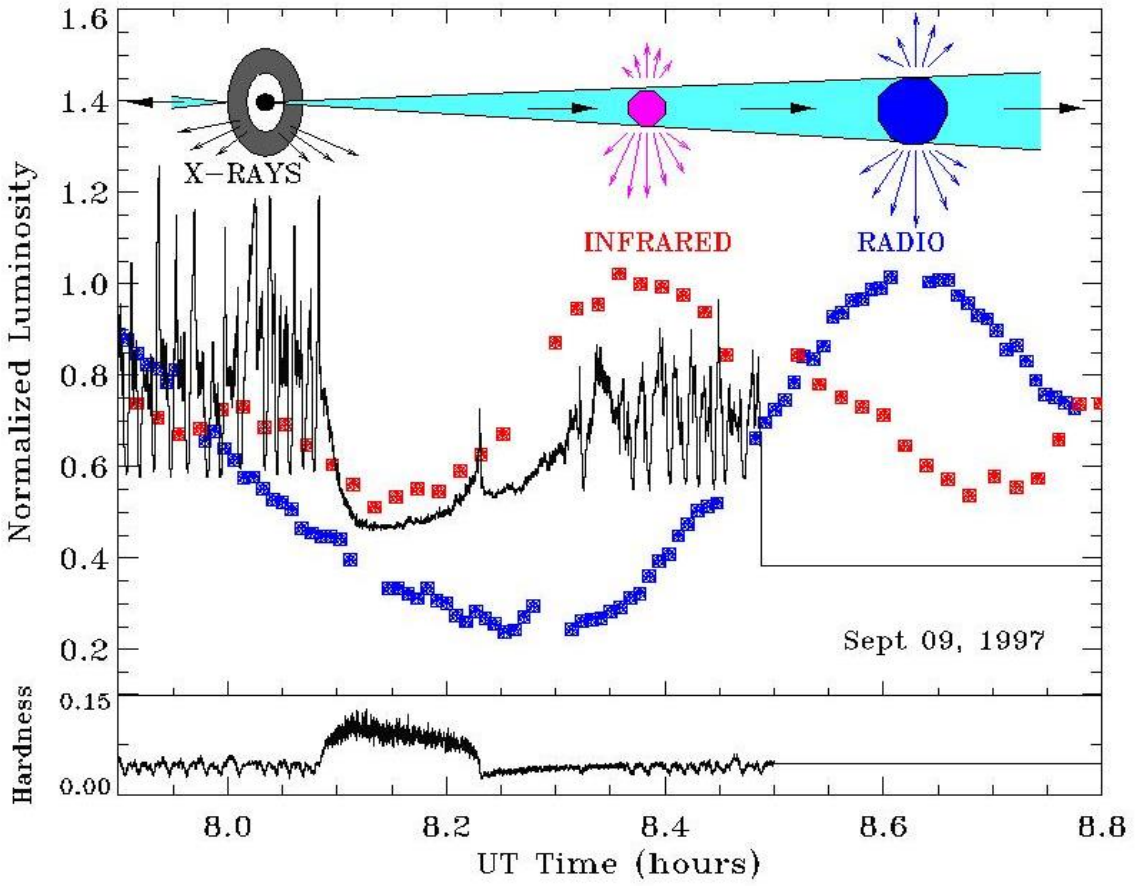
1) **μQSO JETS MOVE ON THE PLANE OF THE SKY ~10^3 TIMES FASTER**
2) **μQSO JETS ARE TWO-SIDED ⇒ ALLOWS TO SOLVE EQUATIONS**
3) **COLLIMATION OF JETS BETTER IN AGN** e.g. 30-100 R_{sh} in M87

HOW ARE JETS LAUNCHED? ACCRETION – JET CONNECTION

$$\Delta T \propto M_{BH}$$



Mirabel, Dhawan, Chaty et al. 1998



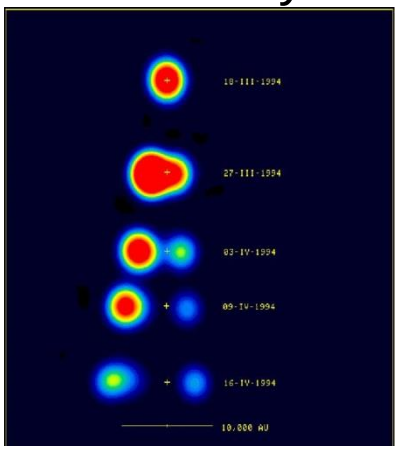
- DROP OF X-RAYS⇒MATTER MAY GO THROUGH THE HORIZON OF BH?
- AFTER 5m A SPIKE MARKS THE ONSET OF A JET, FIRST SEEN IN THE IR, THEN AT RADIO WAVES, WITH TIME/FREQUENCY DEPENDENCE
- INTERPRETED AS ADIABATIC EXPANSION OF THE PLASMA JET

WHEN IS THE HIGH ENERGY EMISSION PRODUCED? UNIVERSAL DISK-JET COUPLING IN BLACK HOLES

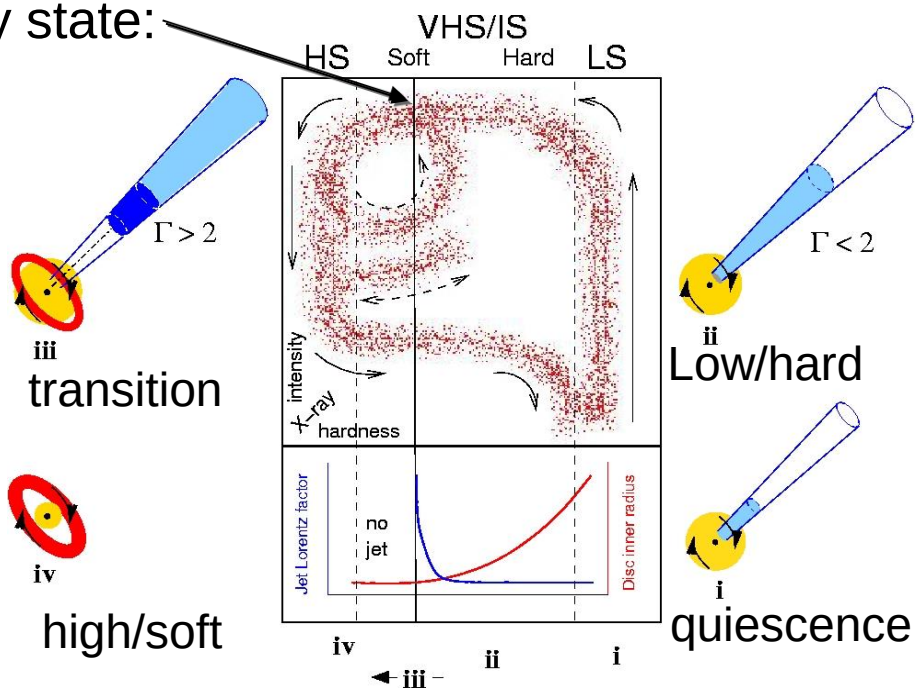
Fender, Belloni & Gallo (2006)

Outburst with rapid transition from hard to soft X-ray state:

Soft X-rays

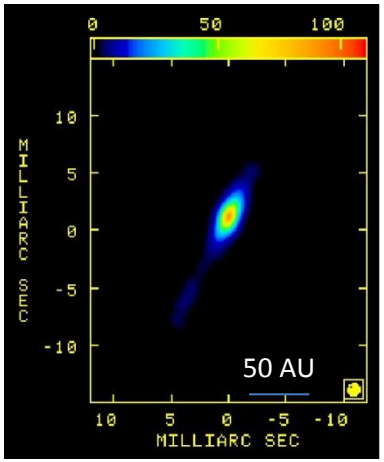


Transient, optically thin radio jets: $\Gamma > 2$



Ribó + (2004)

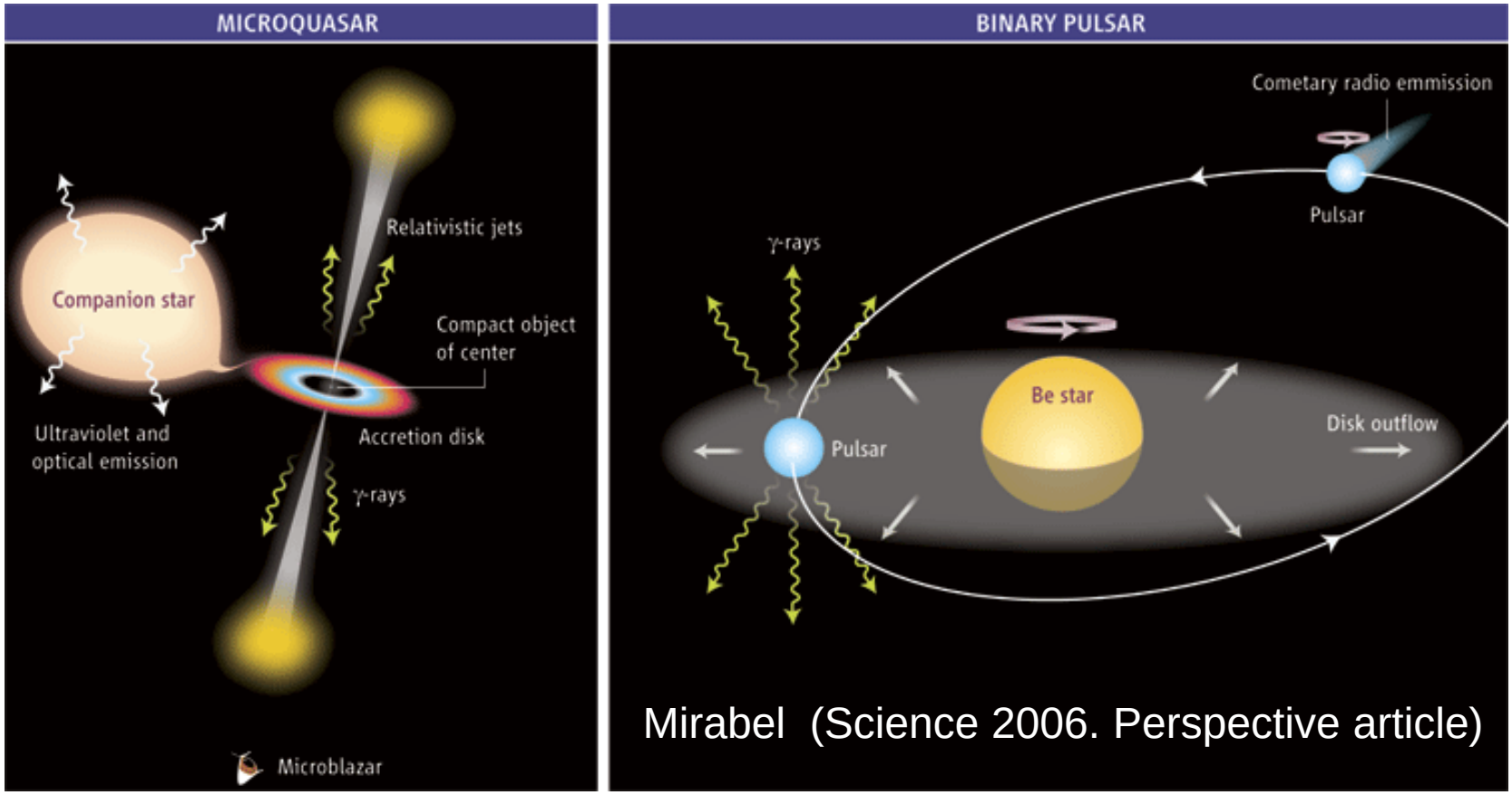
In low-hard state



Flat spectrum radio source: $\Gamma < 2$

- Disk-jet coupling also observed in QSOs (Marscher+ Nature 2004)
- Are the transient radio jets associated to transient γ-ray flares?
- Hints of a few % linear polarization at radio and NIR
- .4–2 MeV in Cyg X-1 is 67+/-30% polarized (Laurent+ Science 2001)

GeV/TeV EMISSION FROM COMPACT BINARIES



Cygnus X-3, Cygnus X-1

PSR B1259-63; LS 5039?; LS I +61 303?
HESS J0632+057?...

Talk by Paredes…

MICROQUASARS AT GeV/TeV

Ribó's review at the 38th COSPAR Scientific Assembly

Several microquasars have been observed at GeV/TeV energies:

- **Cygnus X-3**: detected by *AGILE* >100 MeV and *Fermi*/LAT (Tavani+ Nature 2009, Abdo+ Science 2009) and upper limits by MAGIC (Saito+2009; Aleksic+ 2010).
  WR donor, P=4.8 h, and jet axis close to the line of sight (Marti+)**.**

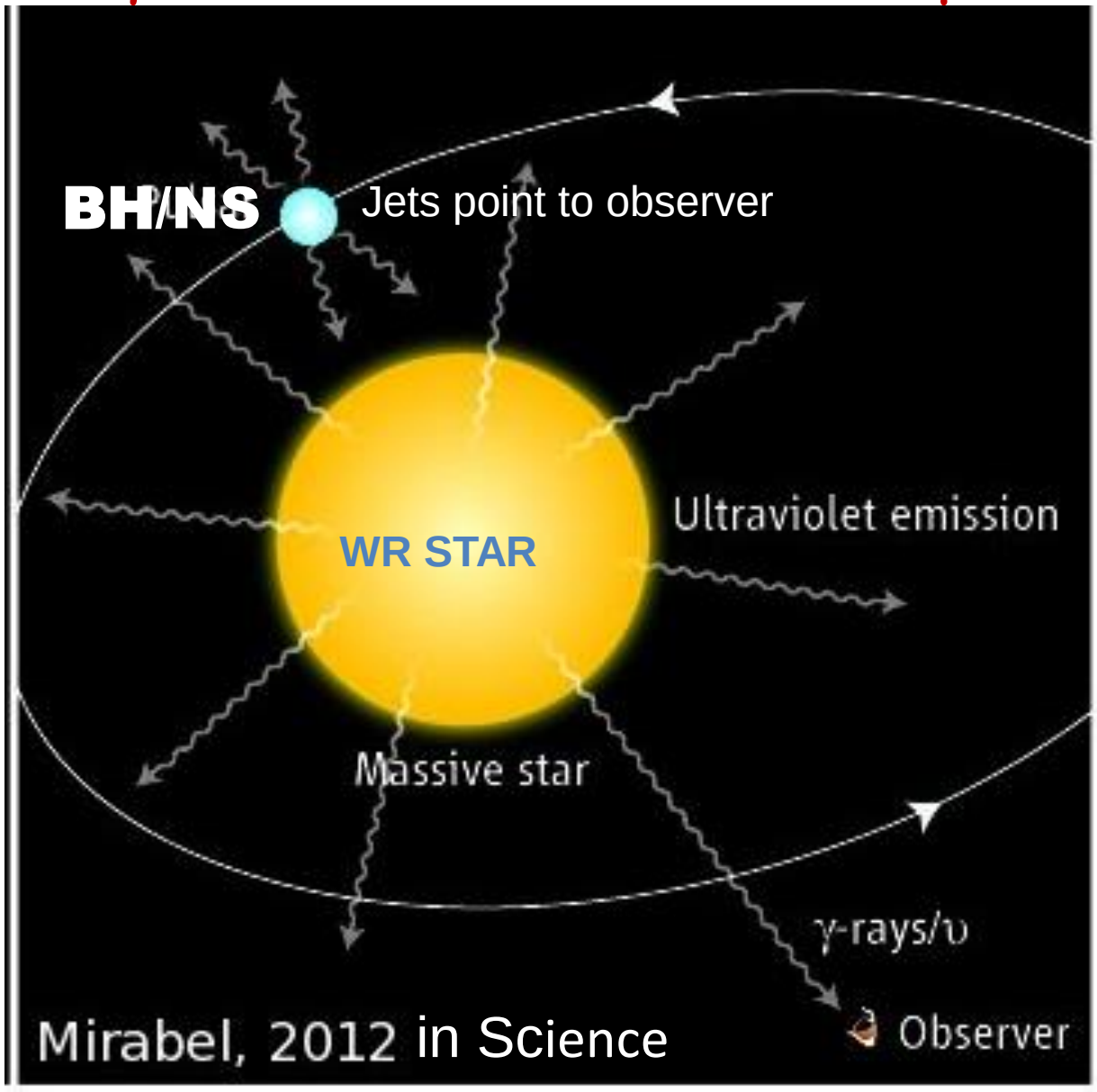
- **Cygnus X-1:** detected @ >100 MeV by A*GILE* (Sabatini+2010) and marginally detected by MAGIC (Albert+2007). Not detected by *Fermi*/LAT.
  O9.7 lab donor, P=5.6 days, in a circular orbit.

- **GRS 1915+105:** upper limits by MAGIC & HESS (Saito+ 2009, Acero+2009).
  P~30 days. Jet at 70° with line of sight. Red giant donor of ~1 $M_\odot$

- **SS 433:** upper limits by MAGIC (Saito+ 2009, 31st ICRC; Aleksic+ 2011).
  Massive donor but jet axis close to the plane of the sky

DETECTED IN BH-HMXBs WITH JET AXIS NOT FAR FROM THE LINE OF SIGHT ⇒ ARE GeVs/TeVs DOPPLER BOOSTED?

WHERE IS THE HIGH ENERGY EMISSION PRODUCED?
γ-RAY FLARES FROM THE μQSO Cyg X-3



GeV emission when compact source is behind the WR star ⇒

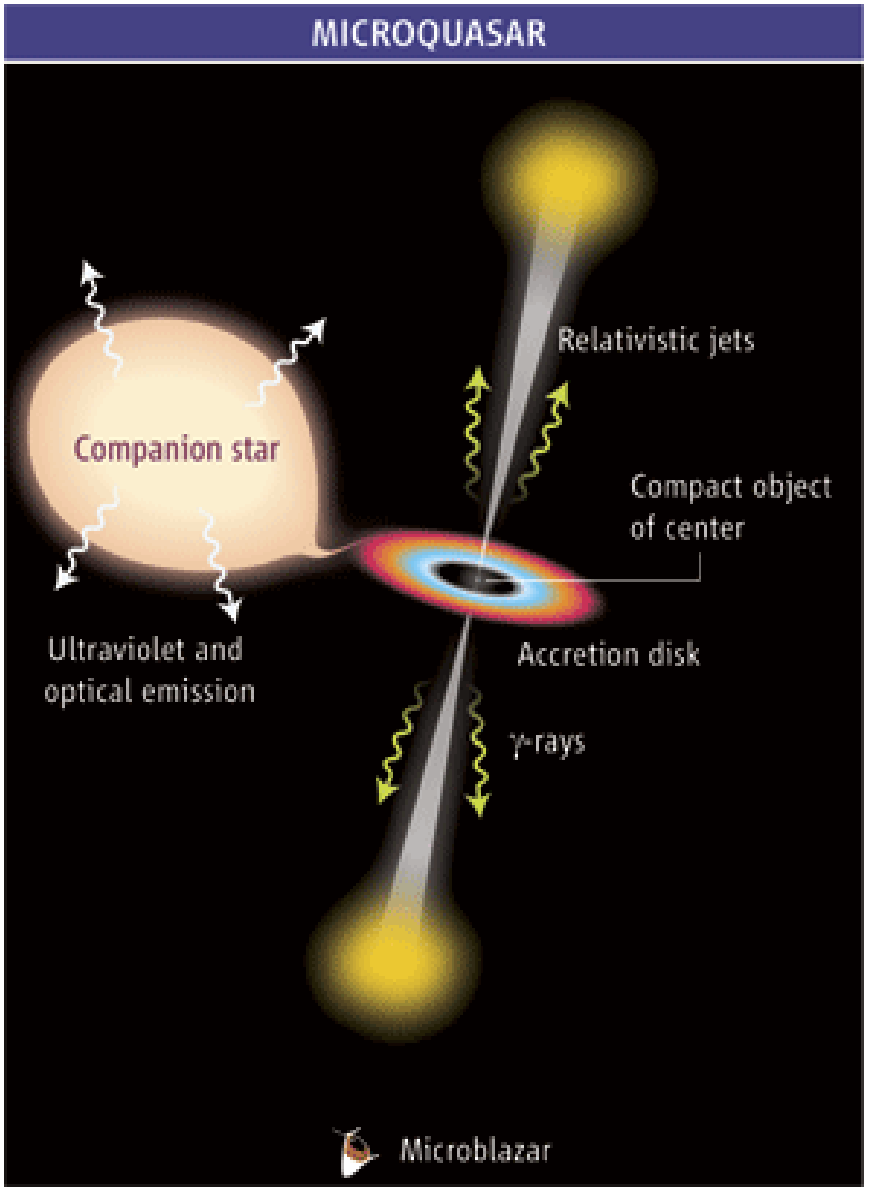
Relativistic electrons in the jet up-scatter photons emitted by the WR star.

The GeV orbital variability is naturally explained.

Modelling shows that the jet must be oriented close to the line of sight, & that the gamma-ray emitting electrons cannot be located within the system (Dubus+2010;Bednarek+2010)

Gamma rays produced by inverse Compton on stellar UV photons: Blazars, GRBs?

Models for the HE/VHE emission in microquasars



***Leptonic models**: Inverse Compton*
*Synchrotron S*elf Compton (SSC)
Atoyan & Aharonian 1999; Latham+ 2005

External Compton (EC)
Paredes+2000,Science; Kaufman Bernadó+2002; Georganopoulos+ 2002

SSC+EC
Bosch-Ramon+2004;Dermer & Böttcher 2006

Synchrotron jet emission
Markoff+2003

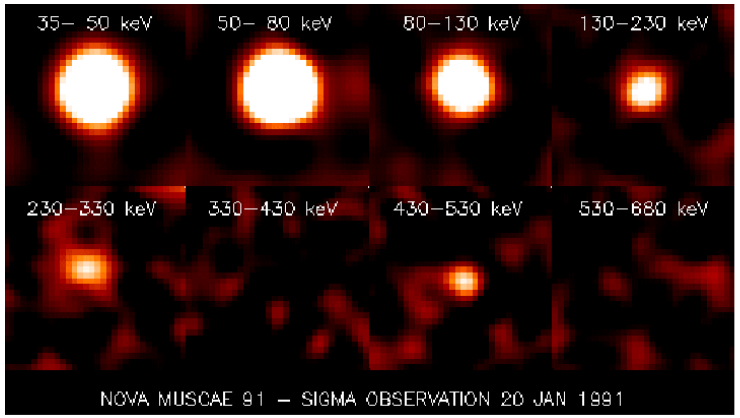
Hadronic models: Pion decay
Romero et al. 2003, A&A, 410, L1
Bosch-Ramon et al. 2005, A&A, 432, 609

Besides by neutrinos, how ASTROGAM discriminate between Leptonic & Hadronic?

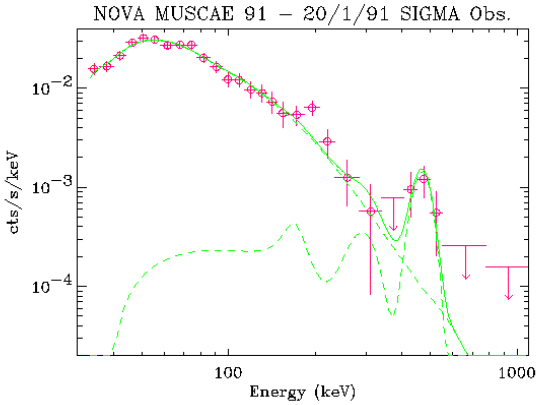
511 keV annihilation line?

Goldwurm+ (1992); Sunyaev+ (1992)

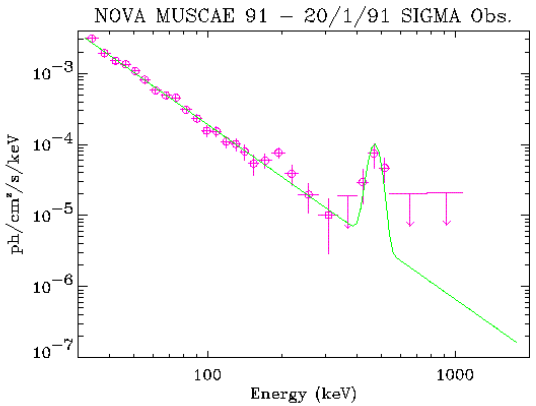
NOVA Musca (GRS 1124-68)



Count spectrum



Photon spectrum



- Pair production in the hot plasma of the innermost region of an accreting BH. Annihilation of positrons in a colder medium would produce the 476 keV line.
- The excess emission at 180-210 keV may result from scattering of the line in cold electrons in the outer accretion disk of the BH.
- Episodic excess at ~500 keV may have also been detected in Cygnus X-1 (Ling+1987) and 1E 1740.7-2942 (Bouchet+ 1991)
- Could this emission excess be due to a transition from an atomic nucleus as observed in novae? (talk by Hernanz)

NEED TO IMPROVE THE SENSITIVITY