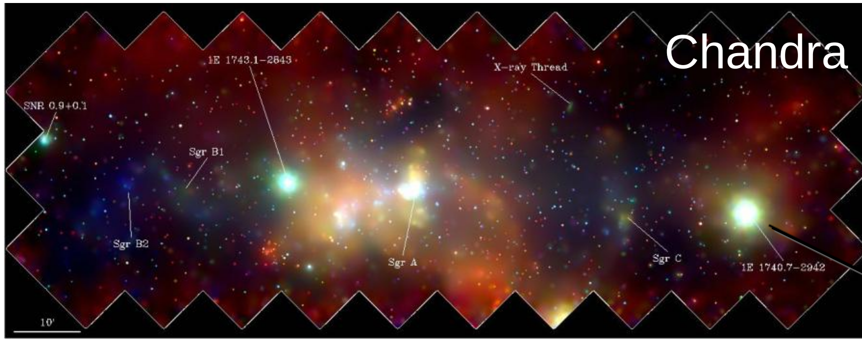
PLAN

- History of μQSO research in the last 20 years
- Analogy between AGN and μQSOs
- Evidences for dark, energetic jets in μQSOs
- Accretion disk/Jet coupling in black holes
- Gamma-ray emission from μQSO jets
- References on neutrino production in μQSOs
- Formation of stellar black holes (μQSOs)
- Cosmic evolution of black hole binaries (μQSOs)
- μQSOs in the dark ages & galactic structure

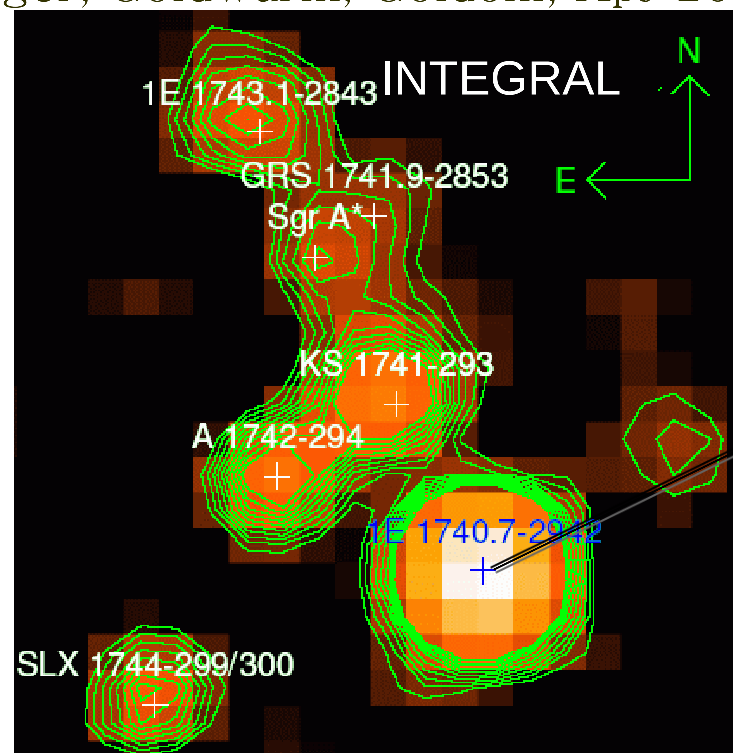
Mirabel et al. A&A 528, A149 (2011); Mirabel astro-ph (2011); Nature N&V

A μQSO IN THE GALACTIC CENTRE REGION

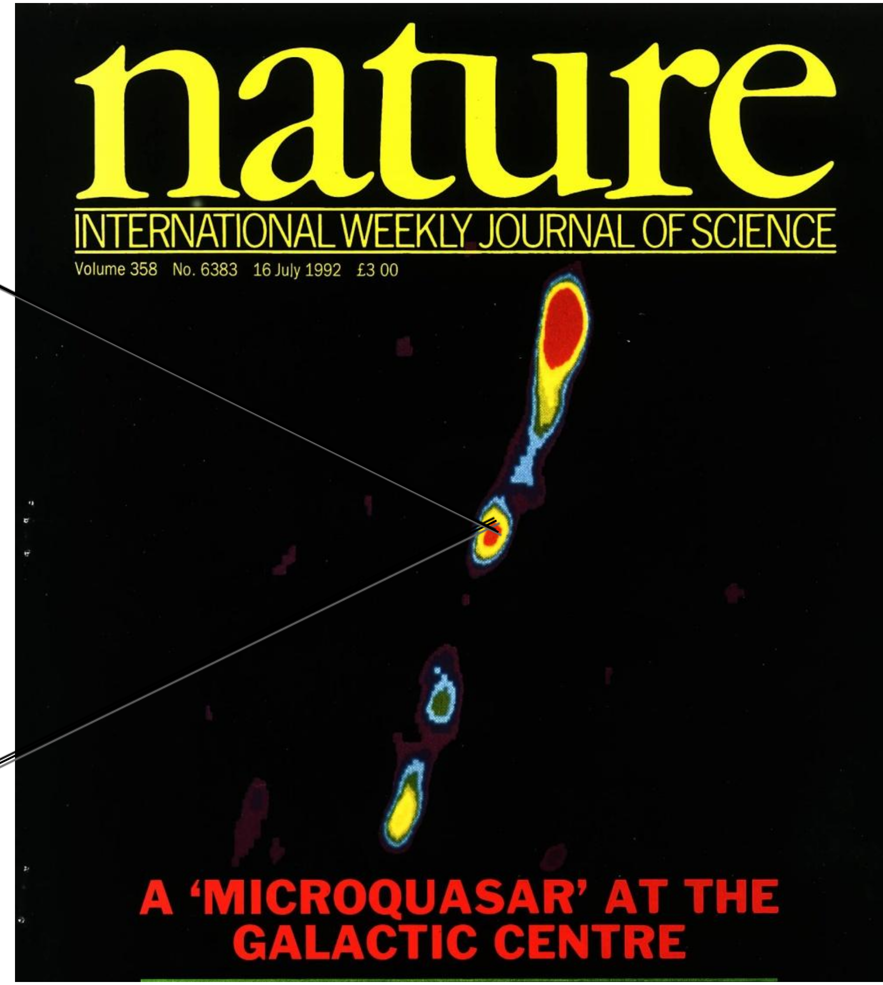
Wang et al. ApJ 2002



Belanger, Goldwurm, Goldoni, ApJ 2003



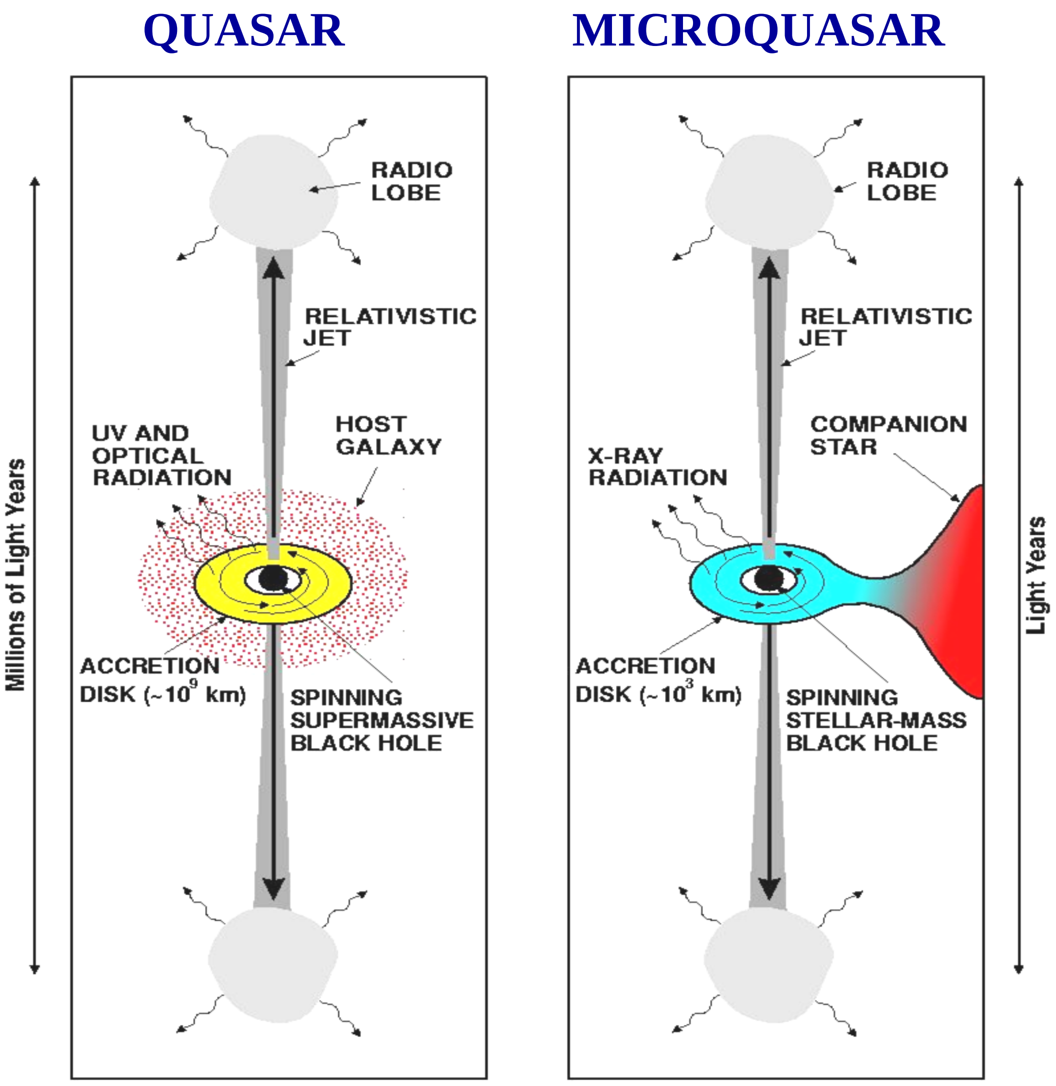
Mirabel, Rodríguez, et al, 1992



So far VII Microquasar workshops &

IAU Symp. 275 in Buenos Aires (2010)

QUASAR-MICROQUASAR ANALOGY



$E_{BH} \sim 0.1\ (m_{acc}\ C^2)$ (Lynden-Bell, 1970)

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)

Waited era of space astronomy

For a given accretion rate:

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

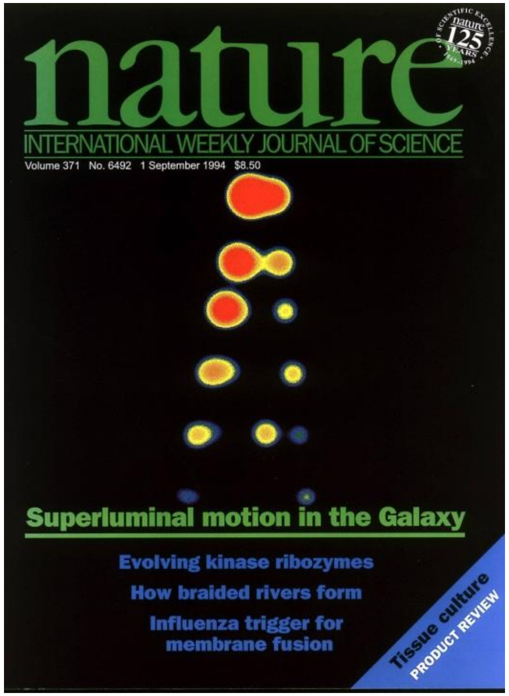
$\varphi\ \alpha\ M_{BH}^{-1}$; $B\ \alpha\ M_{BH}^{-1/2}$

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

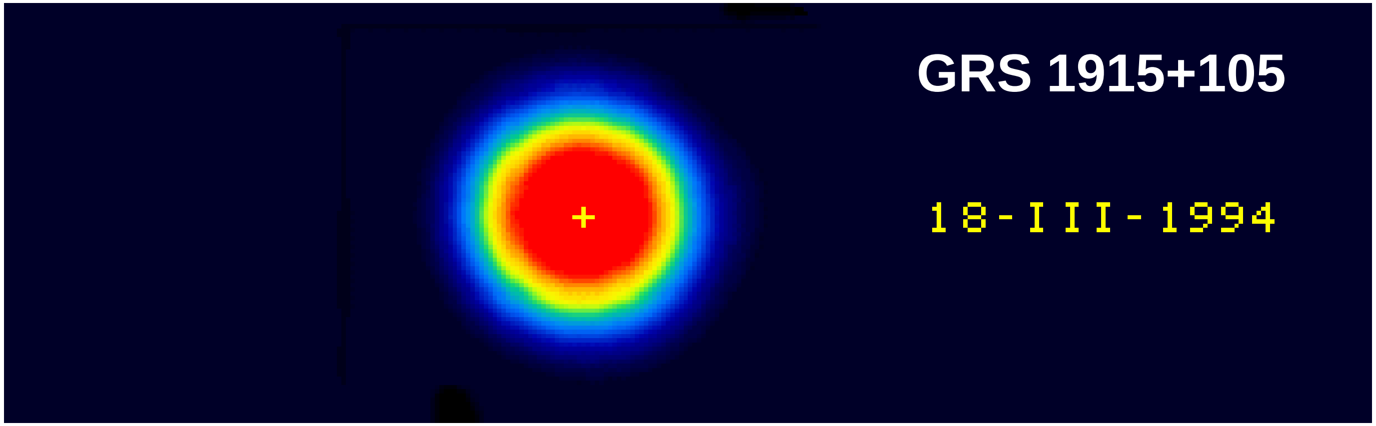
APPARENT SUPERLUMINAL MOTIONS IN μQSOs AS IN QSOs ?

SUPERLUMINAL EJECTION IN A μQSO

Mirabel & Rodríguez (1994)

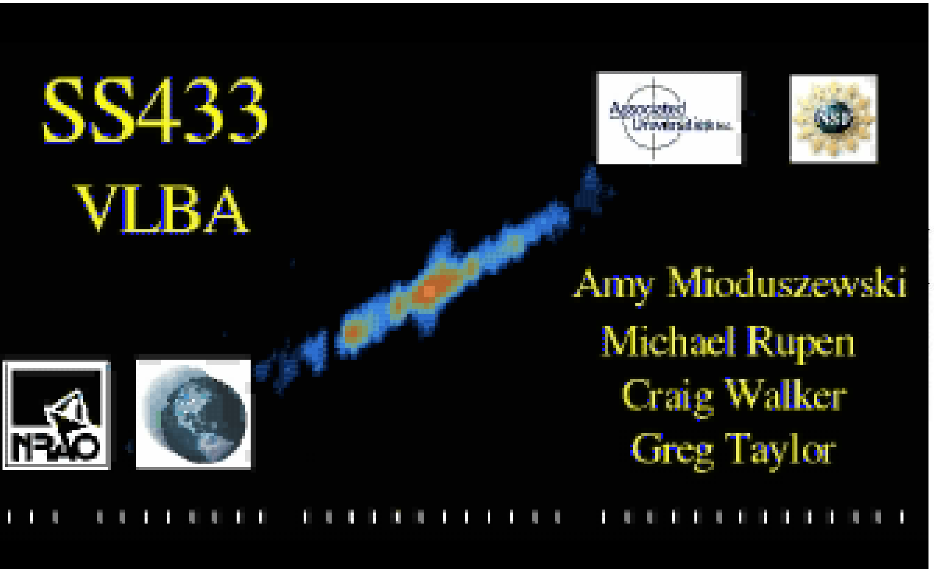


1 arcsec



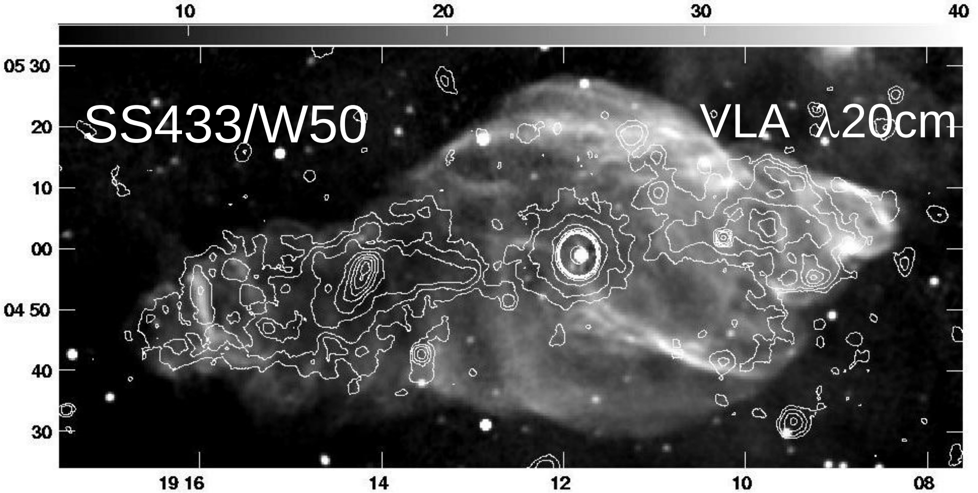
V_{app} > C for a DISTANCE > 8 Kpc

DARK JETS FROM BLACK HOLES



1arcsec

Radio (Dubner et al); X-rays: (Brinkmann et al)

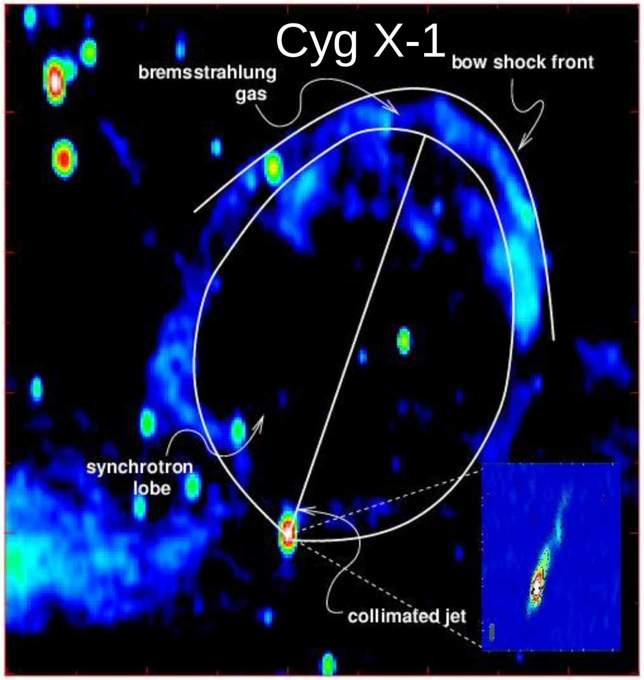


$1^o = 60$ pc

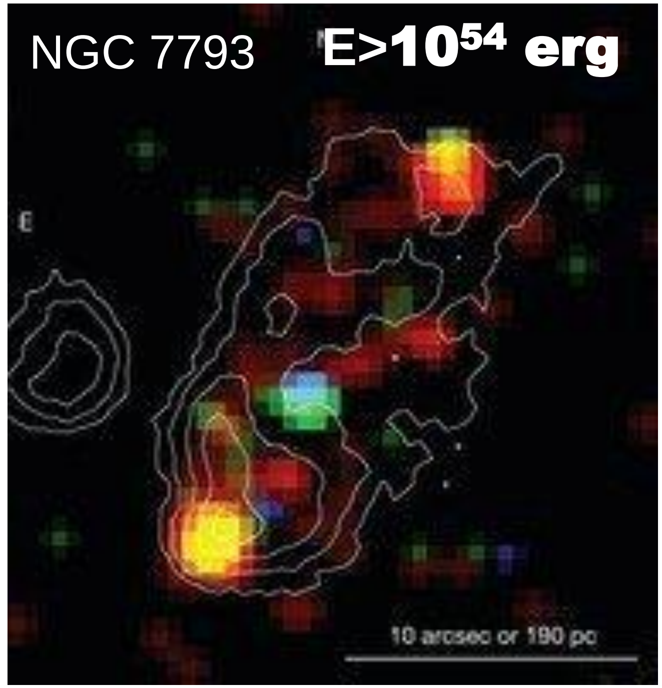
- **ATOMIC NUCLEI MOVING AT 0.26c ⇒**
- **MECHANICAL LUMINOSITY > 10^{39} erg/sec**
- **NON RADIATIVE JETS = "DARK" JETS**
- **>50% OF THE ENERGY IS NOT RADIATED**

POWERFUL JETS IN μQSOs

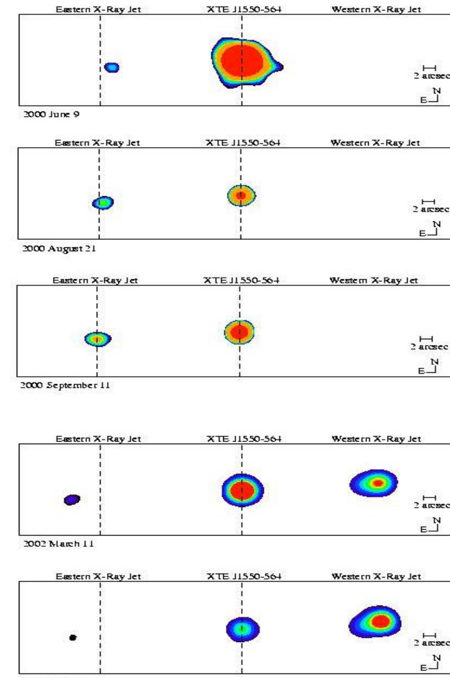
Gallo et al. (Nature, 2005)



Pakull et al. (Nature, 2010)



Corbel+ (Science 2002,05)



Moving X-ray jets in XTE J1550-564 & H1743-322 (Corbel et al. Science) ⇒

- **Formation of a double-lobe X-ray/radio source in real time**
- **X-rays are produced by synchrotron from TeV electrons**

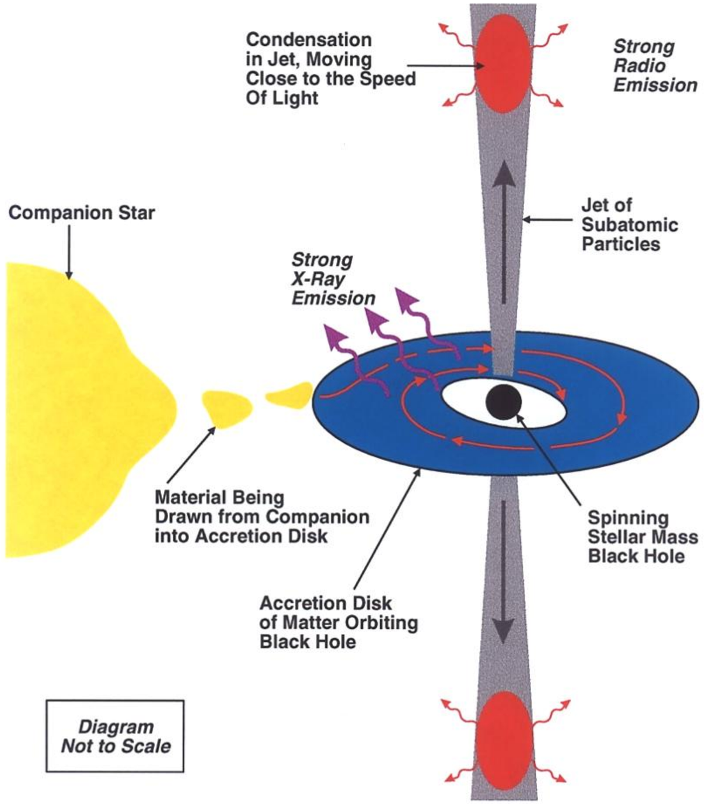
□μQSO energy injection > 100 times that of a core coll SN

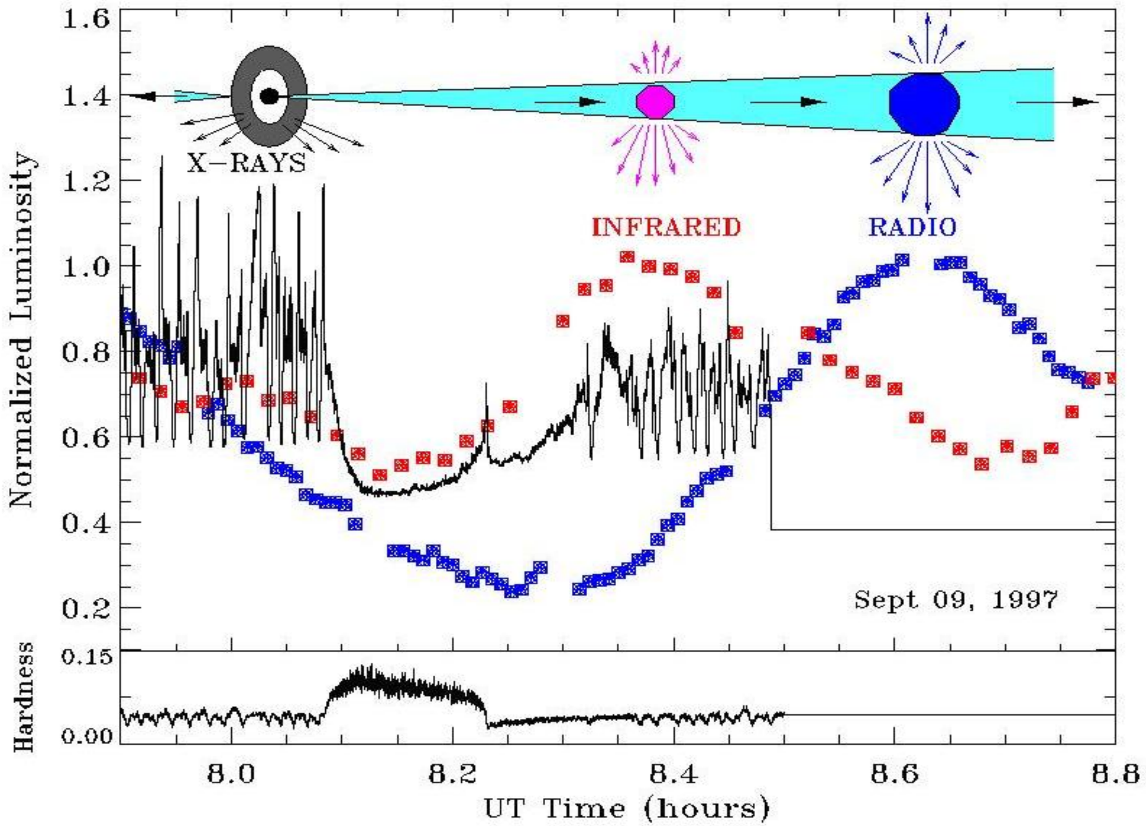
JET-ACCRETION DISK COUPLING

$\Delta T \; \alpha \; M_{BH}$

1 hr = 30 yr in SgrA*

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





•THE ONSET OF THE JET IS AT THE TIME OF AN X-RAY "SPIKE": SUDDEN REFILL OF THE DISK & SHOCK THROUGH COMPACT JET

•SAME IN 3C120 BUT IN TIME SCALES OF YEARS (Marscher et al. Nature2002)

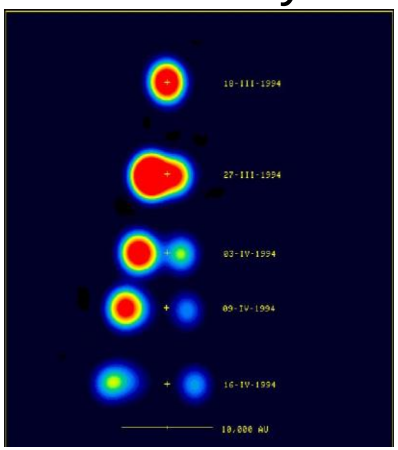
UNIVERSAL DISK-JET COUPLING IN BLACK HOLES

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

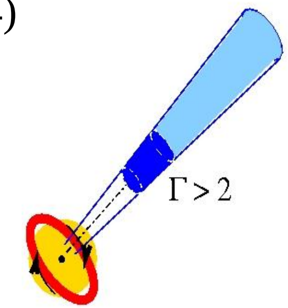
Fender, Belloni & Gallo (2004)

Mirabel & Rodriguez (1994)

Soft X-rays

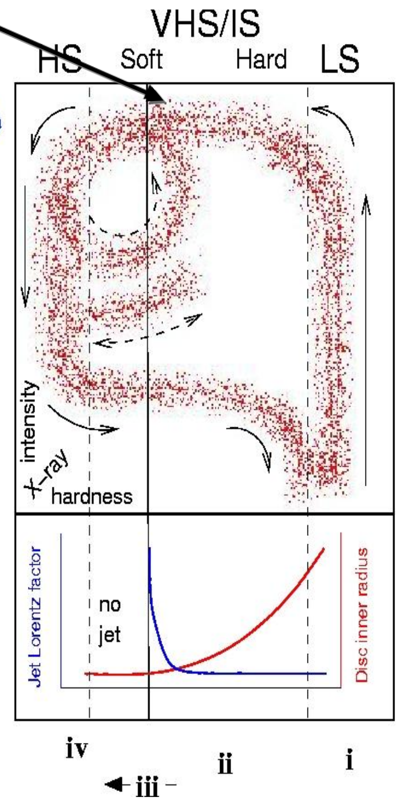


Transient, optically thin radio jets: $\Gamma > 2$



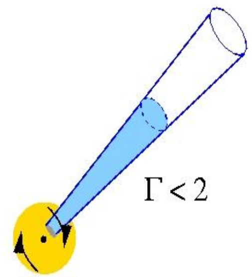
iii

iv

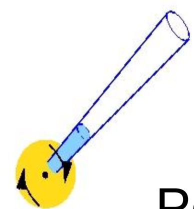


Dhawan, Mirabel, Rodriguez (1999)

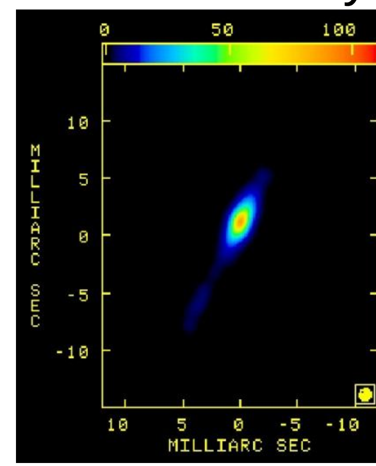
Low-hard X-rays



ii



i

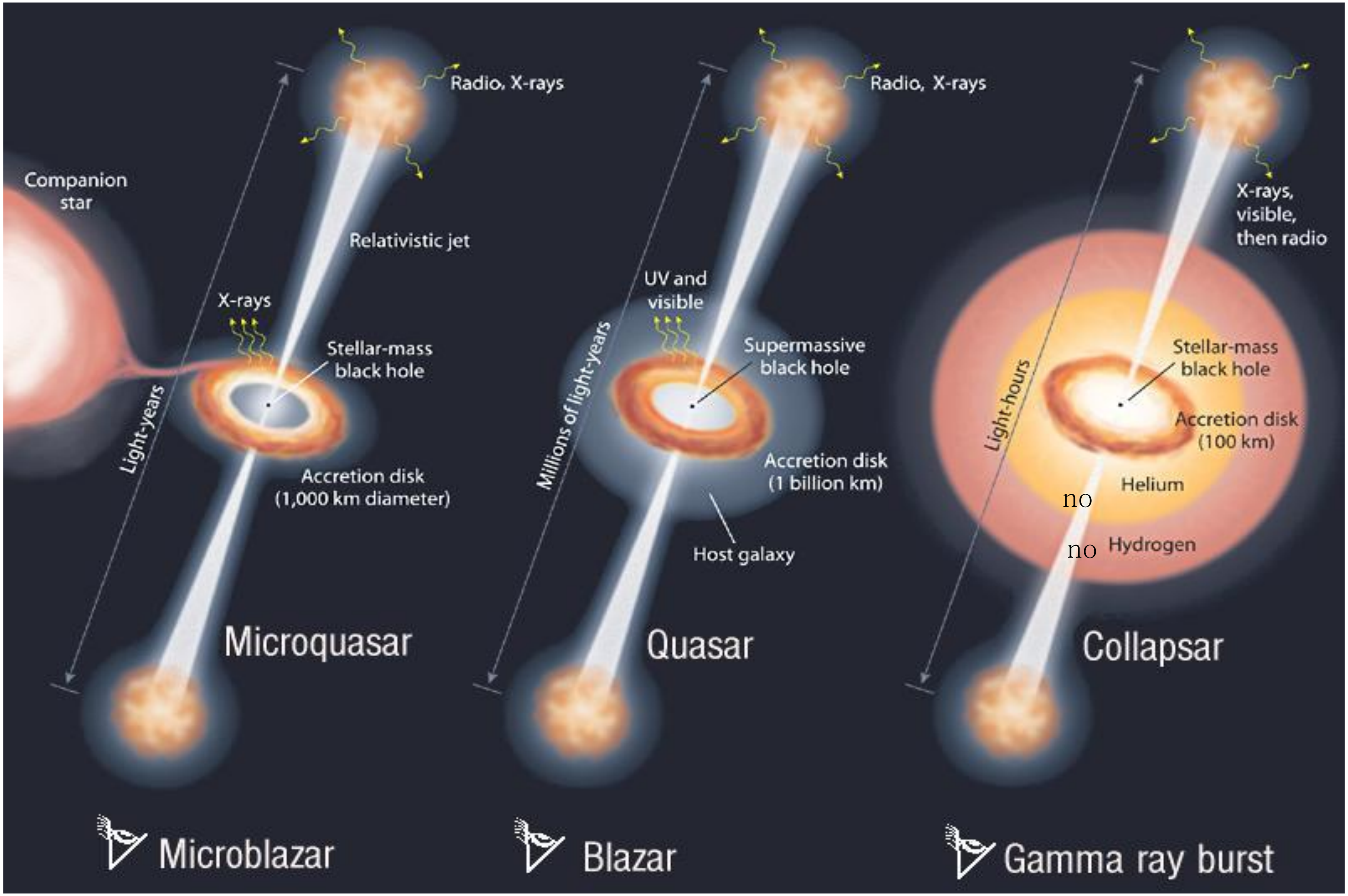


Persistent, flat spectrum, radio source: $\Gamma < 2$

- **The transient radio jets may be produced by internal shocks.**
- **BH stellar binary states are related to different AGN types.**

QSO - μQSO - GRB ANALOGY

HAVE THE SAME 3 BASIC INGREEDIENTS (Mirabel & Rodríguez, S&T 2002)



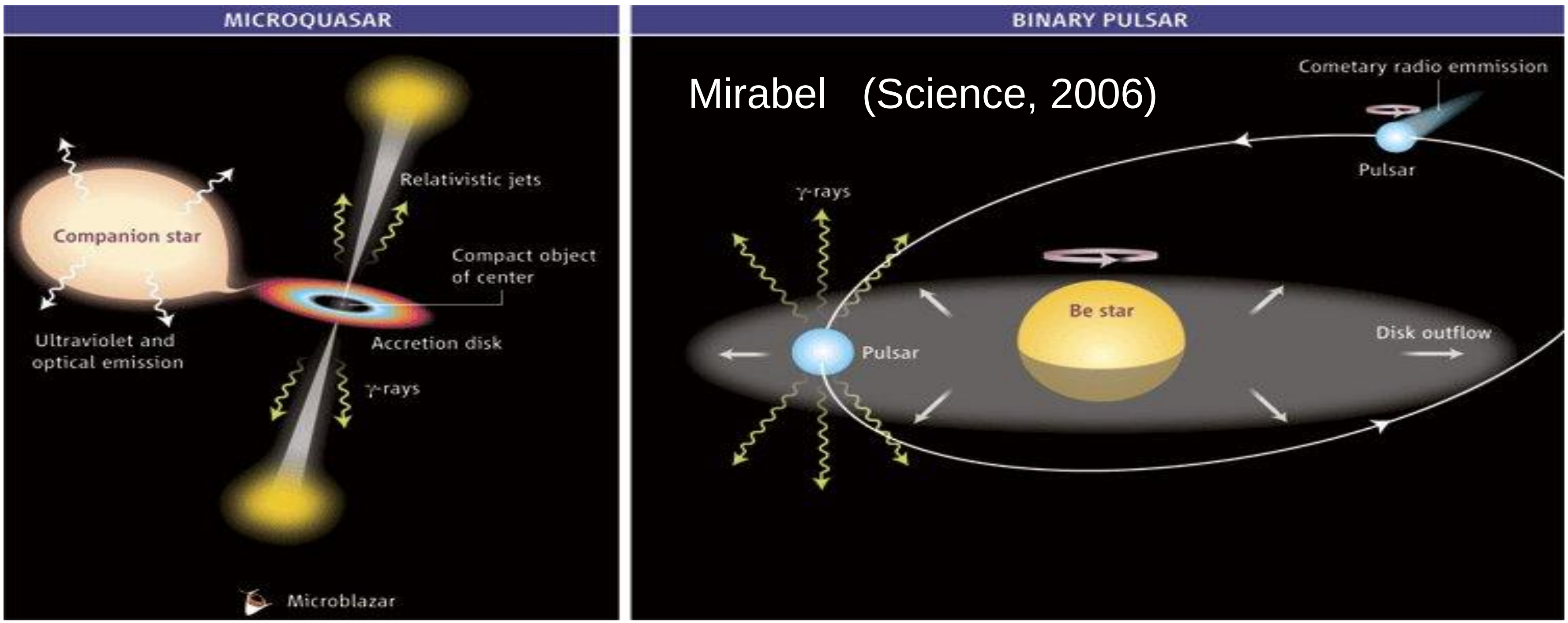
AN UNIVERSAL MAGNETO-HYDRODINAMIC MECHANISM FOR JETS IN BHs?

GAMMA-RAY BINARIES AT GeVs & TeVs

1 MeV = 10^6 eV; 1 GeV = 10^9 eV; 1 TeV = 10^{12} eV

•**VHE (>100 GeV):** from LS 5039, PSR B1259-63, LSI +61 303 & possibly Cyg X-1

•**HE (>30 MeV):** from the μQSO Cyg X-3 with Fermi and Agile & PSR B1259-63 (Fermi)



Pulsar wind: In LSI +61 303 it spins as a function of orbital phase (Dhawan et al. 2006)

μQSO jets in non μblazar sources: Romero+ (2005-7); Cyg X-1 ? (Albert, Paredes+)

TeV intraday variability from M87 supports the jet models (Aharonian... Science, 2006)

Γ–rays from the HMXB Cyg X-3 (Fermi & AGILE)

- Leptonic model by

Kaufman, Romero, Mirabel (2005)

- Hadronic model by

Romero & Vila (2008)

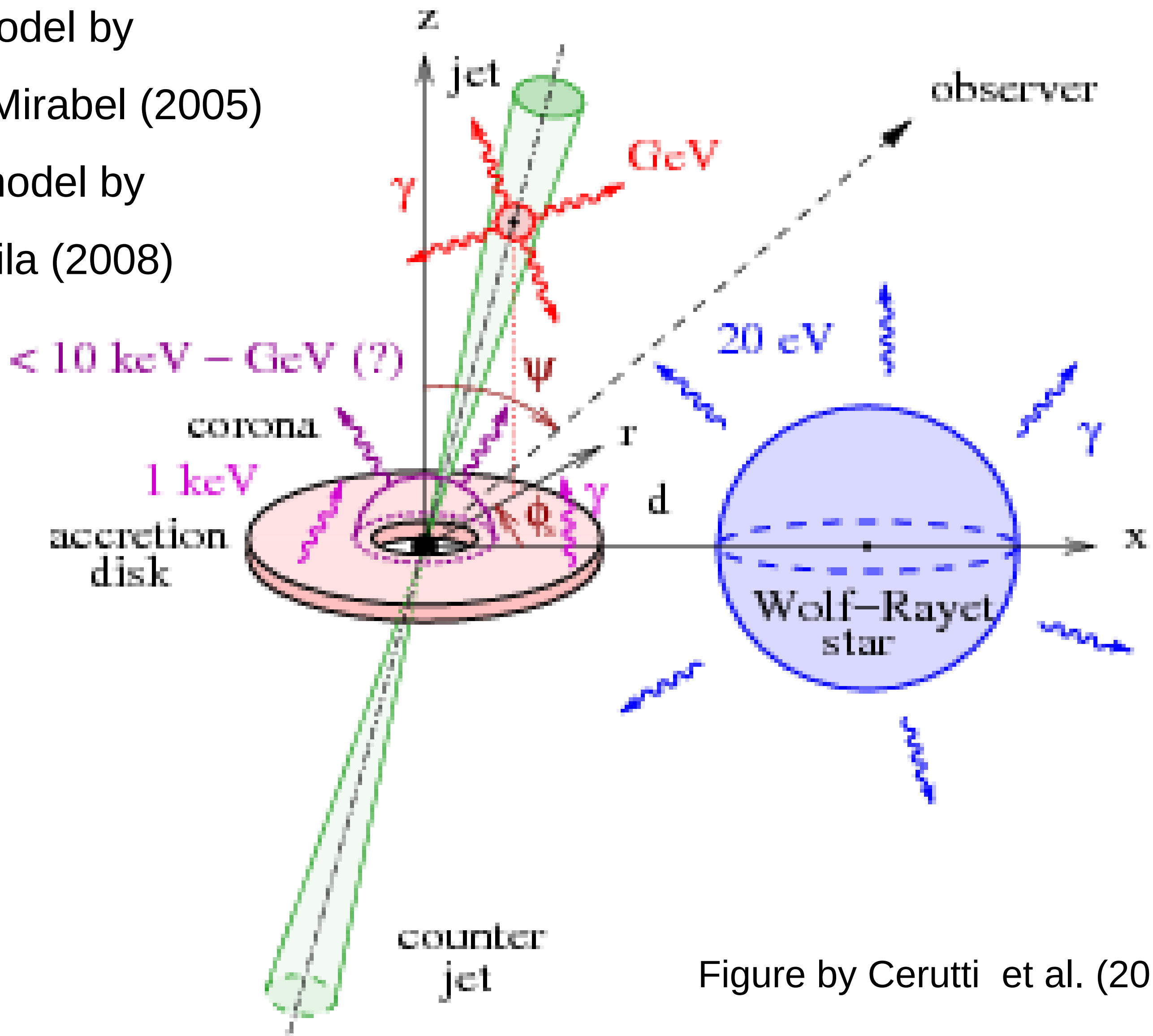
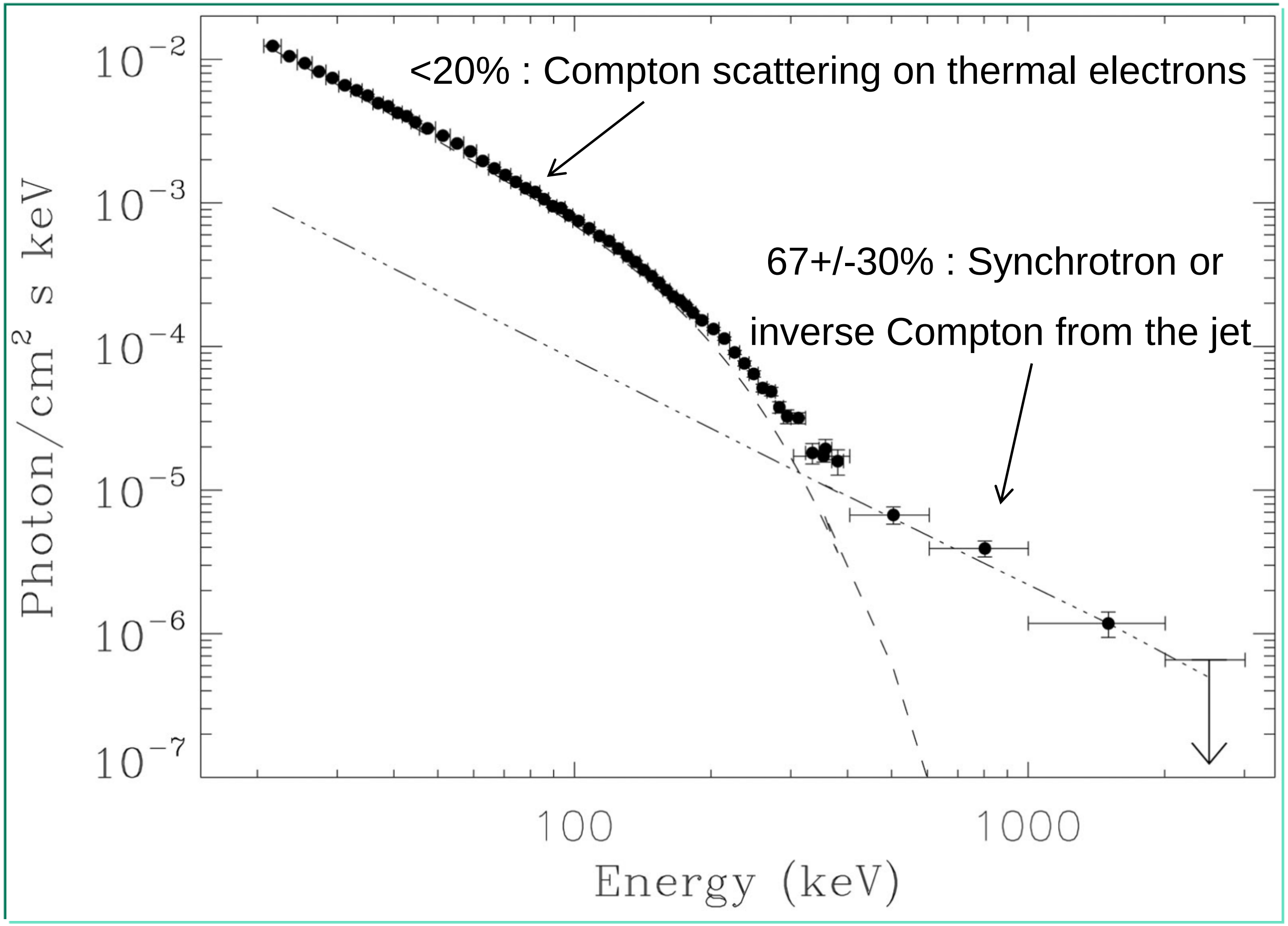


Figure by Cerutti et al. (2011)

Polarized Gamma-ray emission from Cyg X-1

(Laurent et al. Science express of 24 March, 2011)



- **For 10 mG synchrotron radiation at MeV imply electron energies of a few TeVs**
- **Jet produce TeV photons detected with Magic & the γ-rays detected with AGILE**

CONCLUSION

- Gamma-ray μQSOs are HMXBs where the massive donor star produces massive winds.
- Those stellar winds are composed of dense clumps, and since the jets are dynamically dominated by cold protons, p-p interactions create mesons that decay before interaction, leading to the production of γ–rays and neutrinos. (Romero et al.)
- Because of the amplitude of time variability, the best μQSO candidate for the detection of neutrinos may be Cyg X-3, which has been detected in outburst by Fermi and AGILE.

The ANTARES Telescope Neutrino Alert System

(Ageron et al. 23 March 2011)

- Abstract
- The ANTARES telescope has the capability to detect neutrinos produced in astrophysical transient sources. Potential sources include gamma-ray bursts, core collapse supernovae, and flaring active galactic nuclei, and microquasars. To enhance the sensitivity of ANTARES to such sources, a new detection method based on coincident observations of neutrinos and optical and gamma-ray signals has been developed. A fast online muon track reconstruction is used to trigger a network of small automatic optical telescopes. Such alerts are generated for special events, such as two or more neutrinos, coincident in time and direction, or single neutrinos of very high energy.

The number of gamma-ray μQSQs in the Milky Way may be small compared with AGN, but because of the short time scales of the phenomena, μQSQs are unique laboratories to probe the high energy physics in relativistic jets.