MICROQUASAR

"Gamma-ray Sky from Fermi: Neutron Stars and their Environment"

II. High Energy Phenomena around Black Holes

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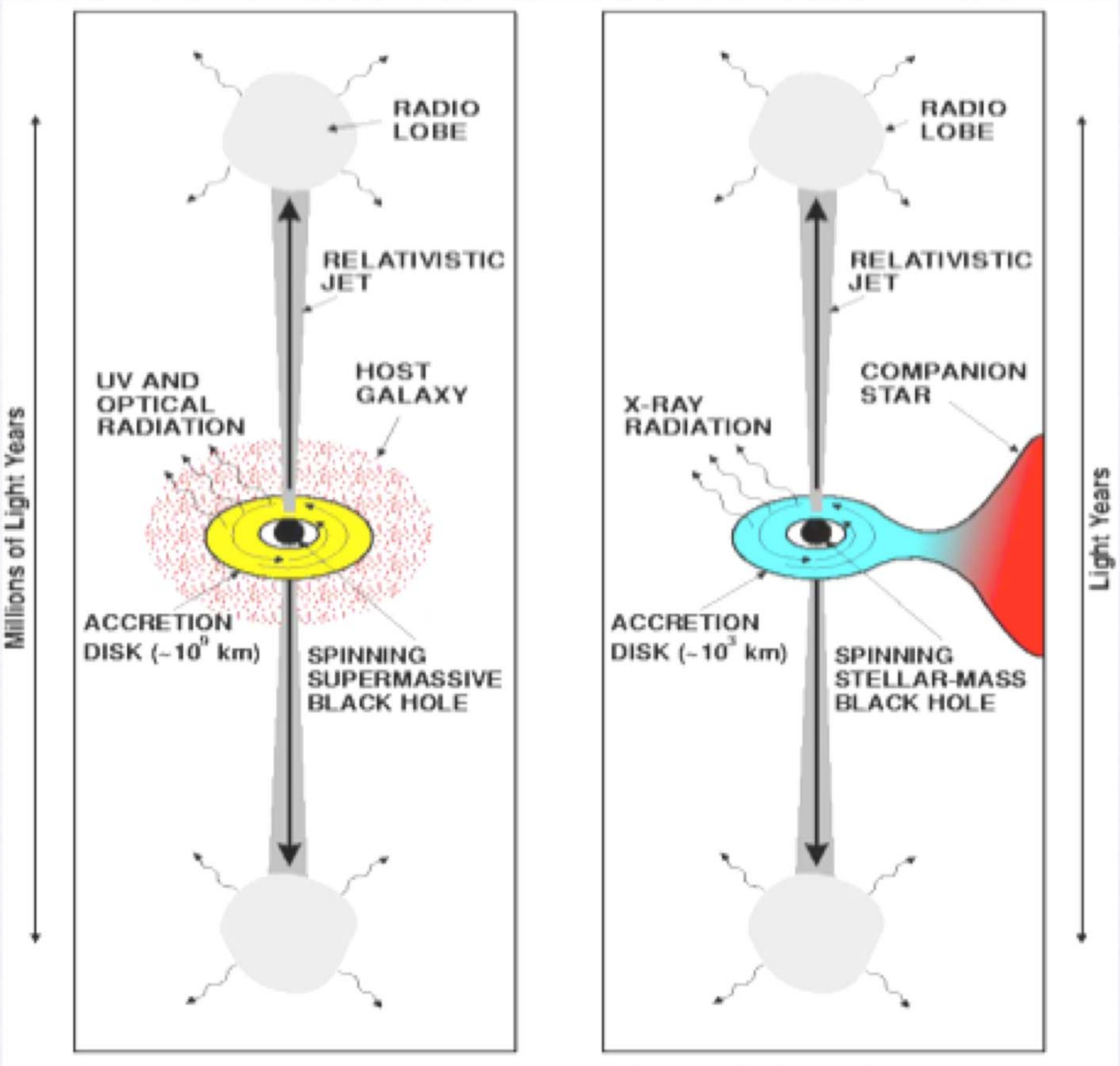
OUTLINE

- General Properties of Microquasars:
  - Physical Scenario
  - Gamma-Ray Production in Microquasars

- Fermi Galactic Microquasars (in 1FGL):
  - LS 5039, LS I +61 303 and Cygnus X-3

- An Outlook:
  - Microquasar Jets or Pulsar Winds?
  - Dark Outflows and Super-Eddington Sources
  - Disk-Jet Coupling
  - Microquasar-GRB connections

General Properties - Physical Scenario



The maximum color temperature of accretion disk is $T_{col} \propto (M_{BH}/10M_{\odot})^{-1/4}$
The characteristic scale and time are proportional to M_{BH}: $R_{sh} = 2GM_{BH}/c^2$

High Mass Microquasars

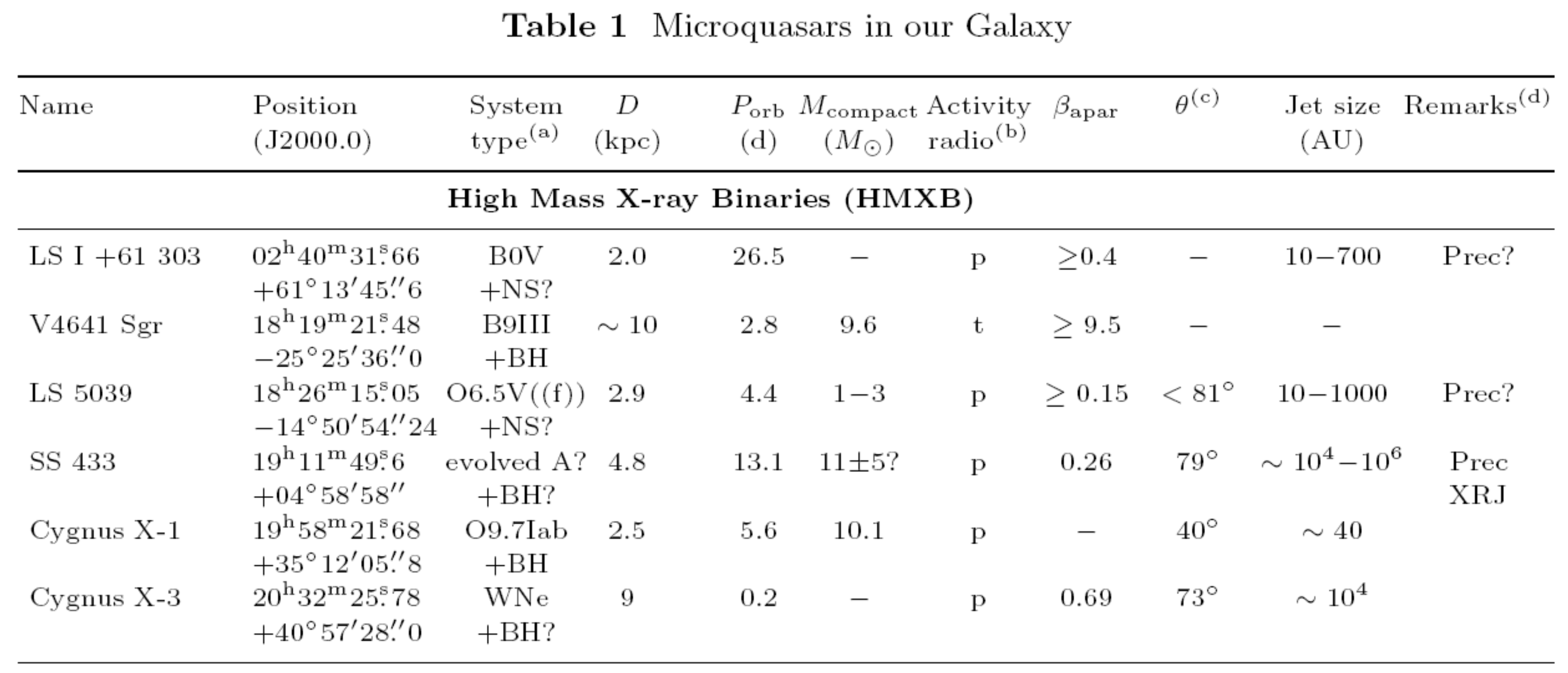
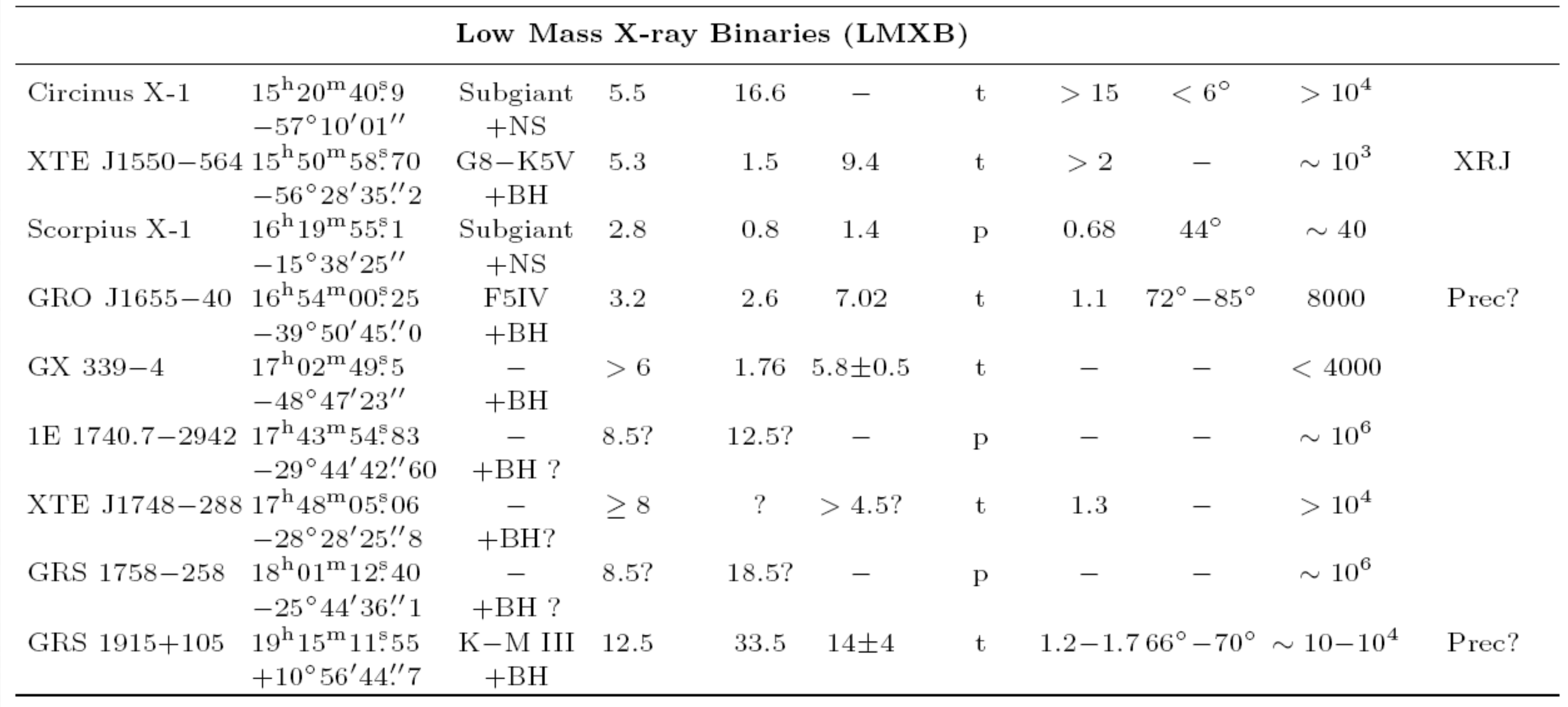


Table 1 Microquasars in our Galaxy

Name	Position (J2000.0)	System type$^{(a)}$	D (kpc)	$P_{\rm orb}$ (d)	$M_{\rm compact}$ ($M_\odot$)	Activity radio$^{(b)}$	$\beta_{\rm apar}$	$\theta^{(c)}$	Jet size (AU)	Remarks$^{(d)}$
High Mass X-ray Binaries (HMXB)										
LS I +61 303	$02^{\rm h}40^{\rm m}31^{\rm s}.66$ $+61^\circ13'45''.6$	B0V +NS?	2.0	26.5	–	p	≥ 0.4	–	10–700	Prec?
V4641 Sgr	$18^{\rm h}19^{\rm m}21^{\rm s}.48$ $-25^\circ25'36''.0$	B9III +BH	~ 10	2.8	9.6	t	≥ 9.5	–	–	
LS 5039	$18^{\rm h}26^{\rm m}15^{\rm s}.05$ $-14^\circ50'54''.24$	O6.5V((f)) +NS?	2.9	4.4	1–3	p	≥ 0.15	$< 81^\circ$	10–1000	Prec?
SS 433	$19^{\rm h}11^{\rm m}49^{\rm s}.6$ $+04^\circ58'58''$	evolved A? +BH?	4.8	13.1	11 ± 5?	p	0.26	79°	$\sim 10^4-10^6$	Prec XRJ
Cygnus X-1	$19^{\rm h}58^{\rm m}21^{\rm s}.68$ $+35^\circ12'05''.8$	O9.7Iab +BH	2.5	5.6	10.1	p	–	40°	~ 40	
Cygnus X-3	$20^{\rm h}32^{\rm m}25^{\rm s}.78$ $+40^\circ57'28''.0$	WNe +BH?	9	0.2	–	p	0.69	73°	$\sim 10^4$	

Paredes (2005)

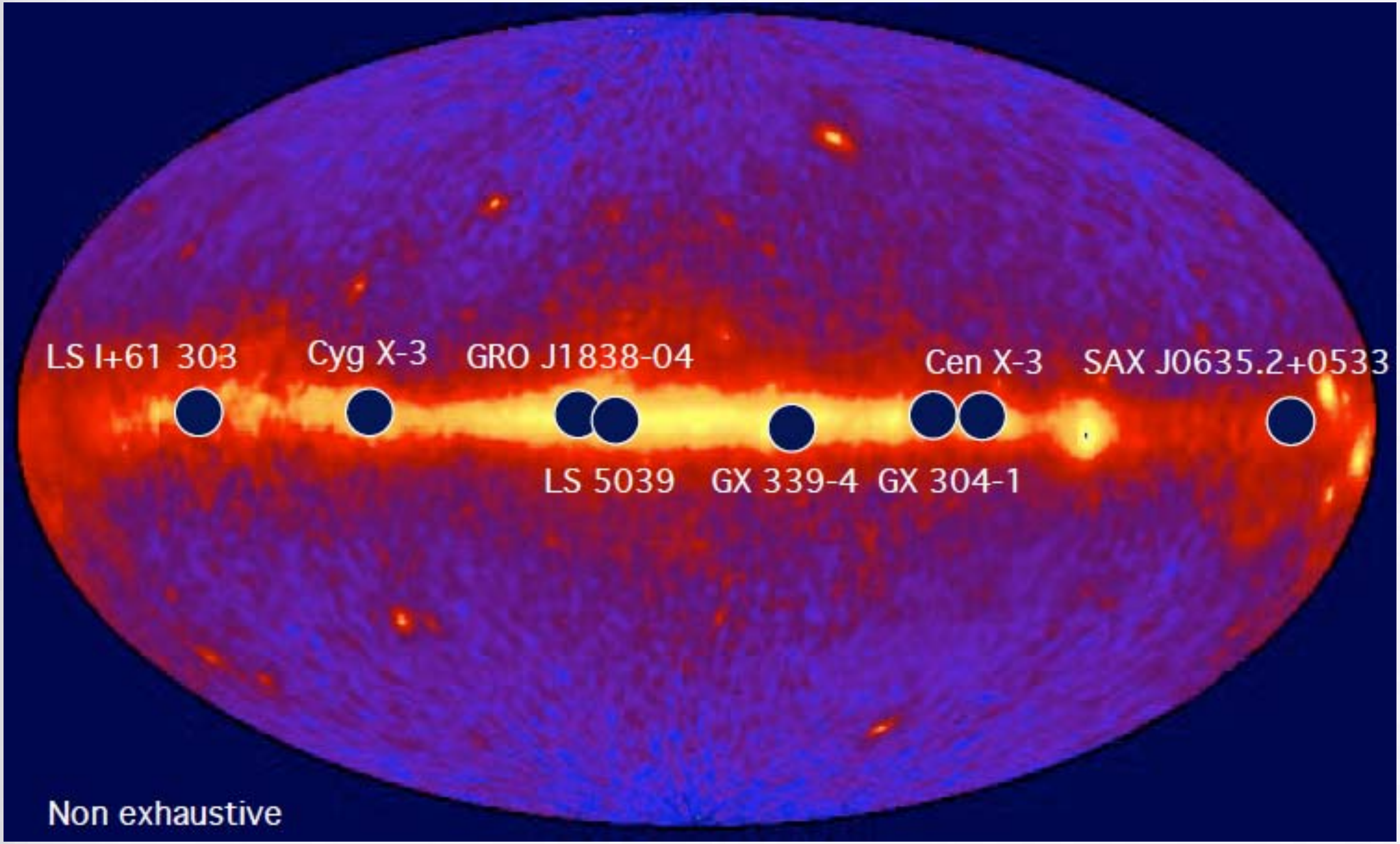
Low Mass Microquasars



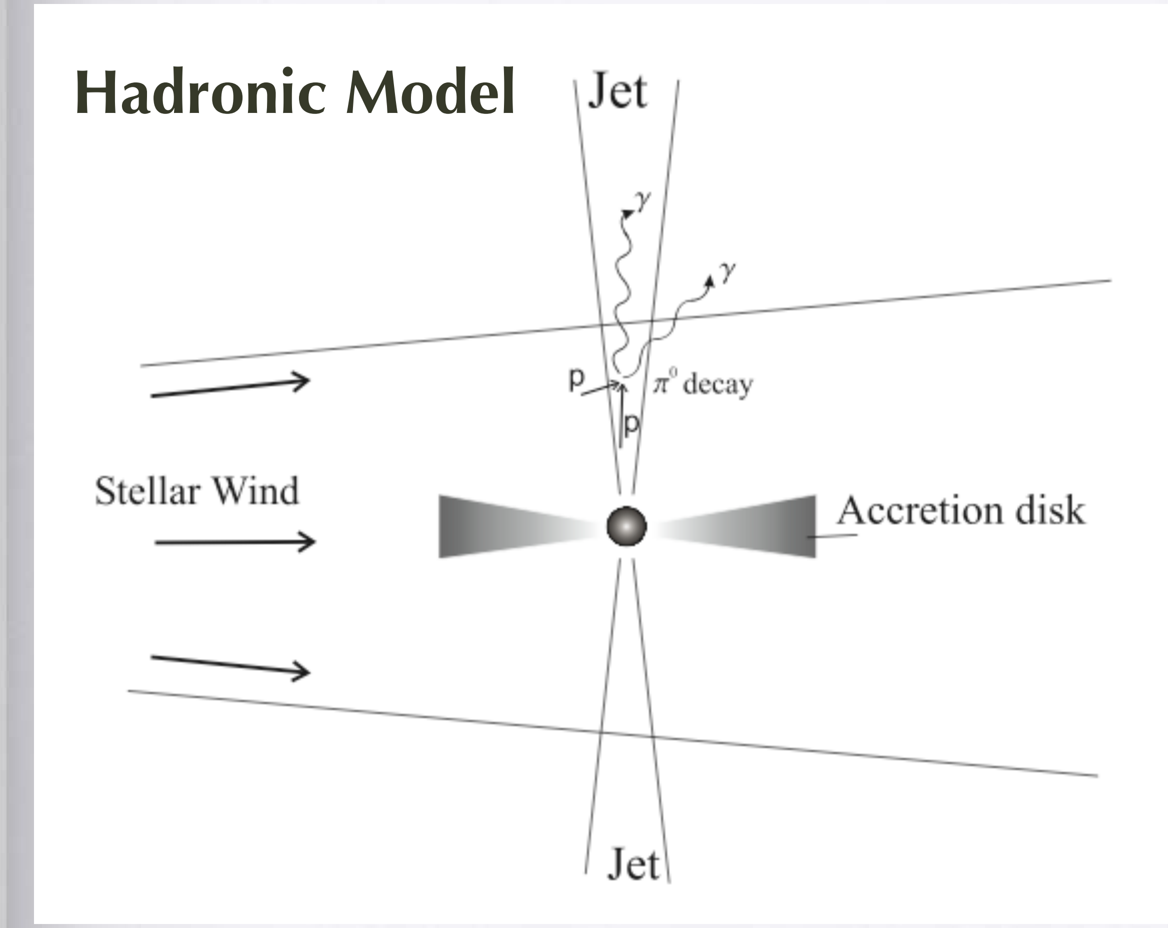
Low Mass X-ray Binaries (LMXB)										
Circinus X-1	$15^{h}20^{m}40^{s}.9$ $-57^\circ 10' 01''$	Subgiant +NS	5.5	16.6	–	t	> 15	$< 6^\circ$	$> 10^4$	
XTE J1550−564	$15^{h}50^{m}58^{s}.70$ $-56^\circ 28' 35''.2$	G8−K5V +BH	5.3	1.5	9.4	t	> 2	–	$\sim 10^3$	XRJ
Scorpius X-1	$16^{h}19^{m}55^{s}.1$ $-15^\circ 38' 25''$	Subgiant +NS	2.8	0.8	1.4	p	0.68	44°	~ 40	
GRO J1655−40	$16^{h}54^{m}00^{s}.25$ $-39^\circ 50' 45''.0$	F5IV +BH	3.2	2.6	7.02	t	1.1	$72^\circ - 85^\circ$	8000	Prec?
GX 339−4	$17^{h}02^{m}49^{s}.5$ $-48^\circ 47' 23''$	– +BH	> 6	1.76	5.8 ± 0.5	t	–	–	< 4000	
1E 1740.7−2942	$17^{h}43^{m}54^{s}.83$ $-29^\circ 44' 42''.60$	– +BH ?	8.5?	12.5?	–	p	–	–	$\sim 10^6$	
XTE J1748−288	$17^{h}48^{m}05^{s}.06$ $-28^\circ 28' 25''.8$	– +BH?	≥ 8	?	> 4.5?	t	1.3	–	$> 10^4$	
GRS 1758−258	$18^{h}01^{m}12^{s}.40$ $-25^\circ 44' 36''.1$	– +BH ?	8.5?	18.5?	–	p	–	–	$\sim 10^6$	
GRS 1915+105	$19^{h}15^{m}11^{s}.55$ $+10^\circ 56' 44''.7$	K−M III +BH	12.5	33.5	14 ± 4	t	1.2−1.7	$66^\circ - 70^\circ$	$\sim 10 - 10^4$	Prec?

Paredes (2005)

Galactic gamma-ray Microquasars



General Properties - γ ray production

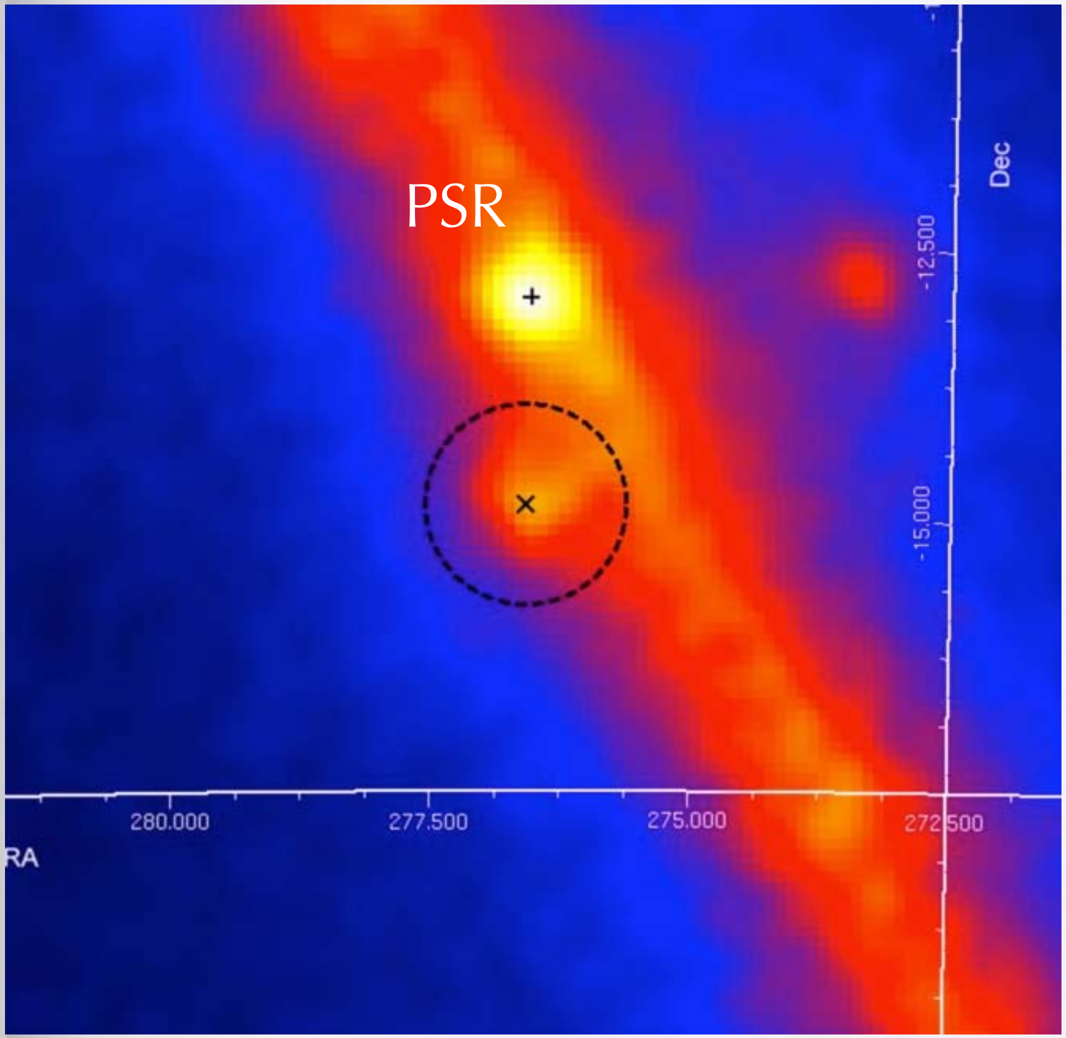


- $p_{jet} + p_{wind *} \rightarrow \pi^0 \rightarrow 2\gamma$

Leptonic Model

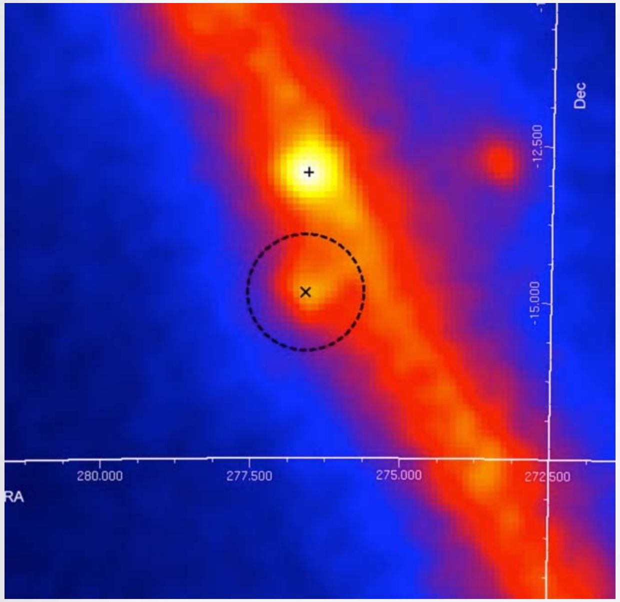
- ions accelerates leptons
- leptons rushes into photon/E/B field (of disk, star, jet)
- IC scattering, Bremsstrahlung, sychrotron radiation → γ

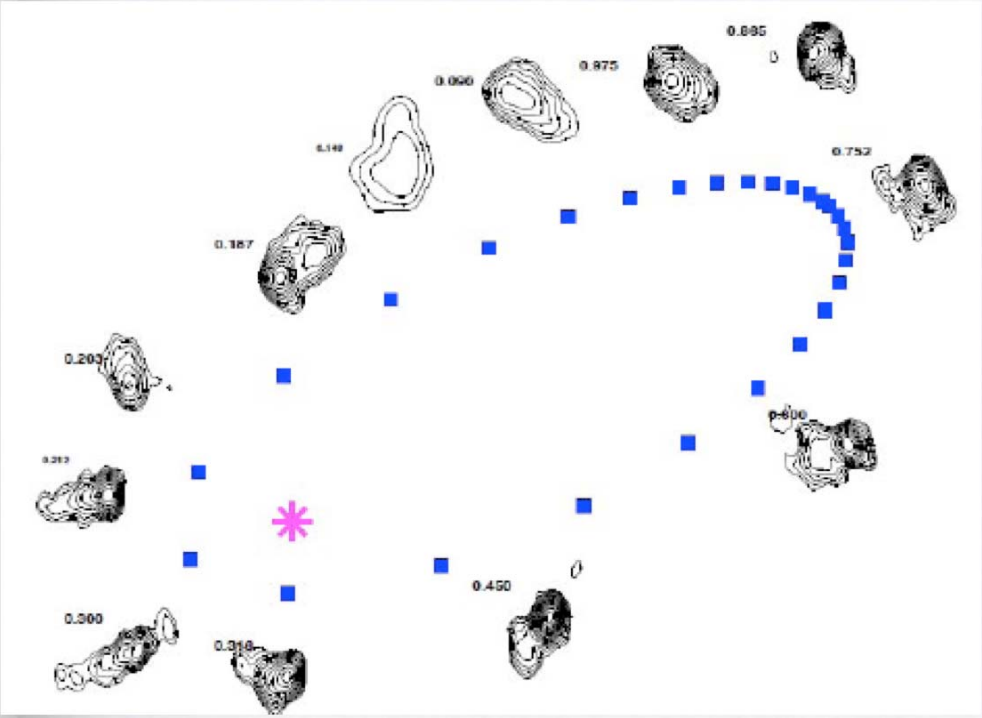
Fermi Galactic Microquasars: LS 5039



- HMXB
- P_{orb} = 3.9day, correlated in gamma-ray (GeV)
- Light curve characterized by a broad peak around superior conjunction, agree with IC scattering models.
- cutoff in the spectrum: indicative of magnetospheric emission similar to the emission seen in many pulsars by Fermi.

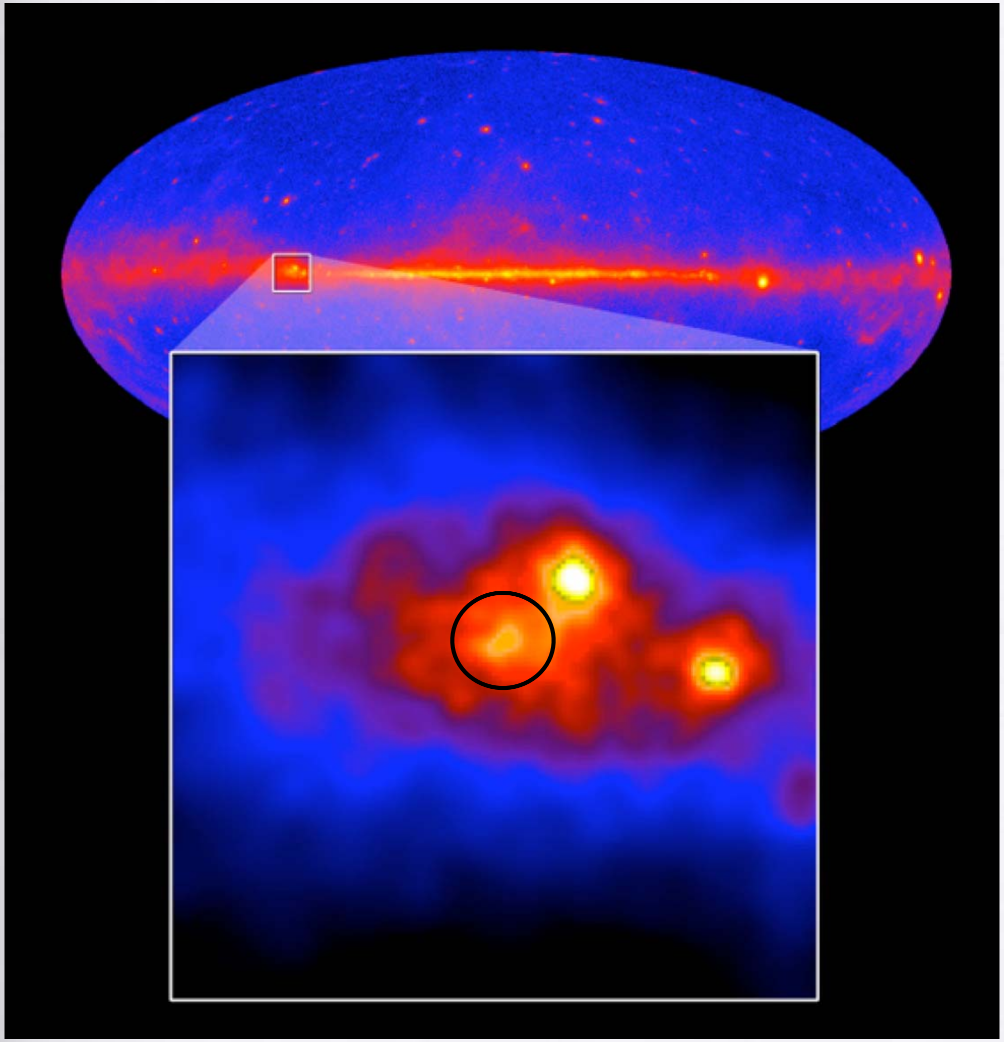
Fermi Galactic Microquasars: LS I +61 303





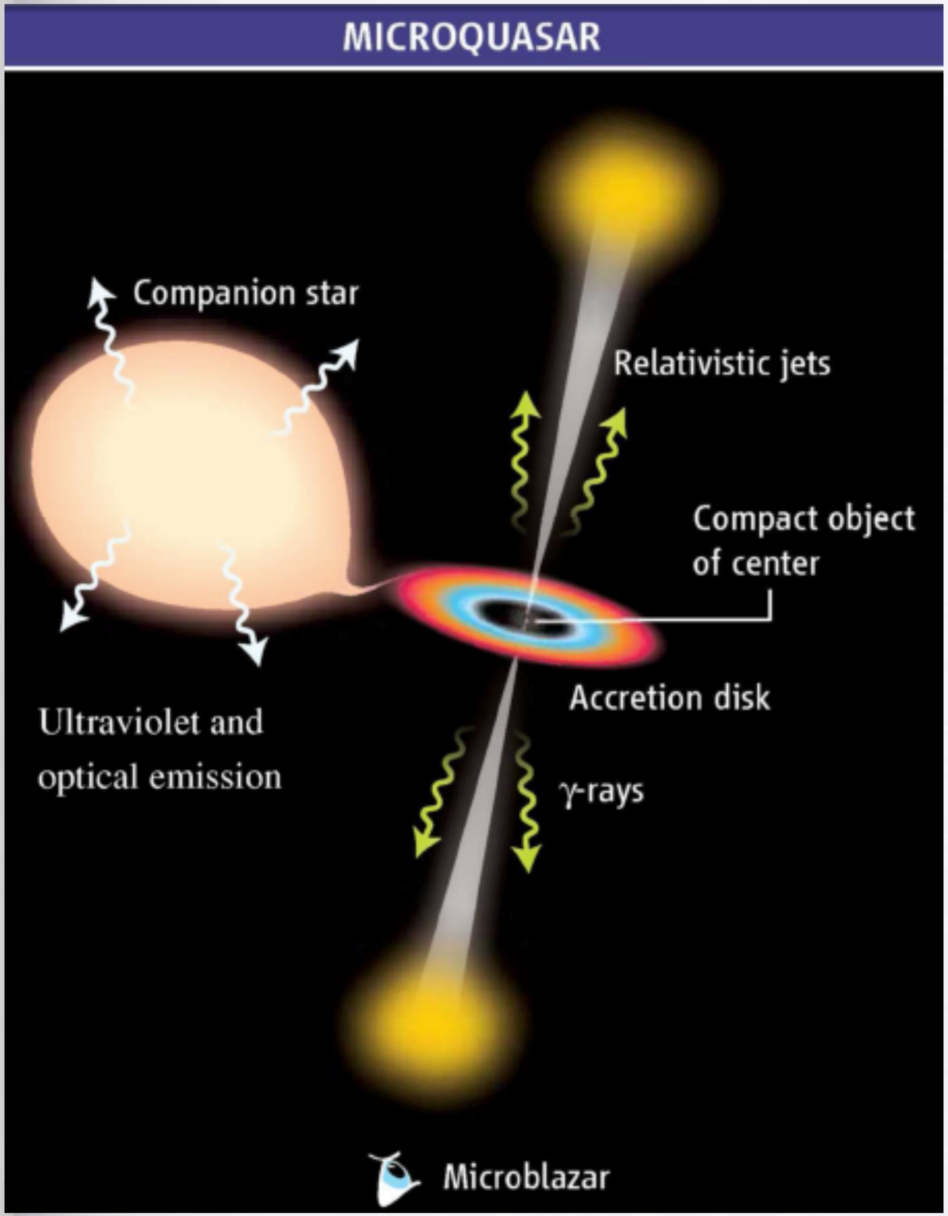
- HMXB: B0 Ve star
- Gamma ray timing variability correlates with P_{orb} = 26.6 day
- LC: a broad peak after periastron, a smaller peak before apastron → IC scattering
- no spectral change with orbital phase.
- perhaps not jet but pulsar wind (PWN-like in VLBA)

Fermi Galactic Microquasars: Cygnus X-3



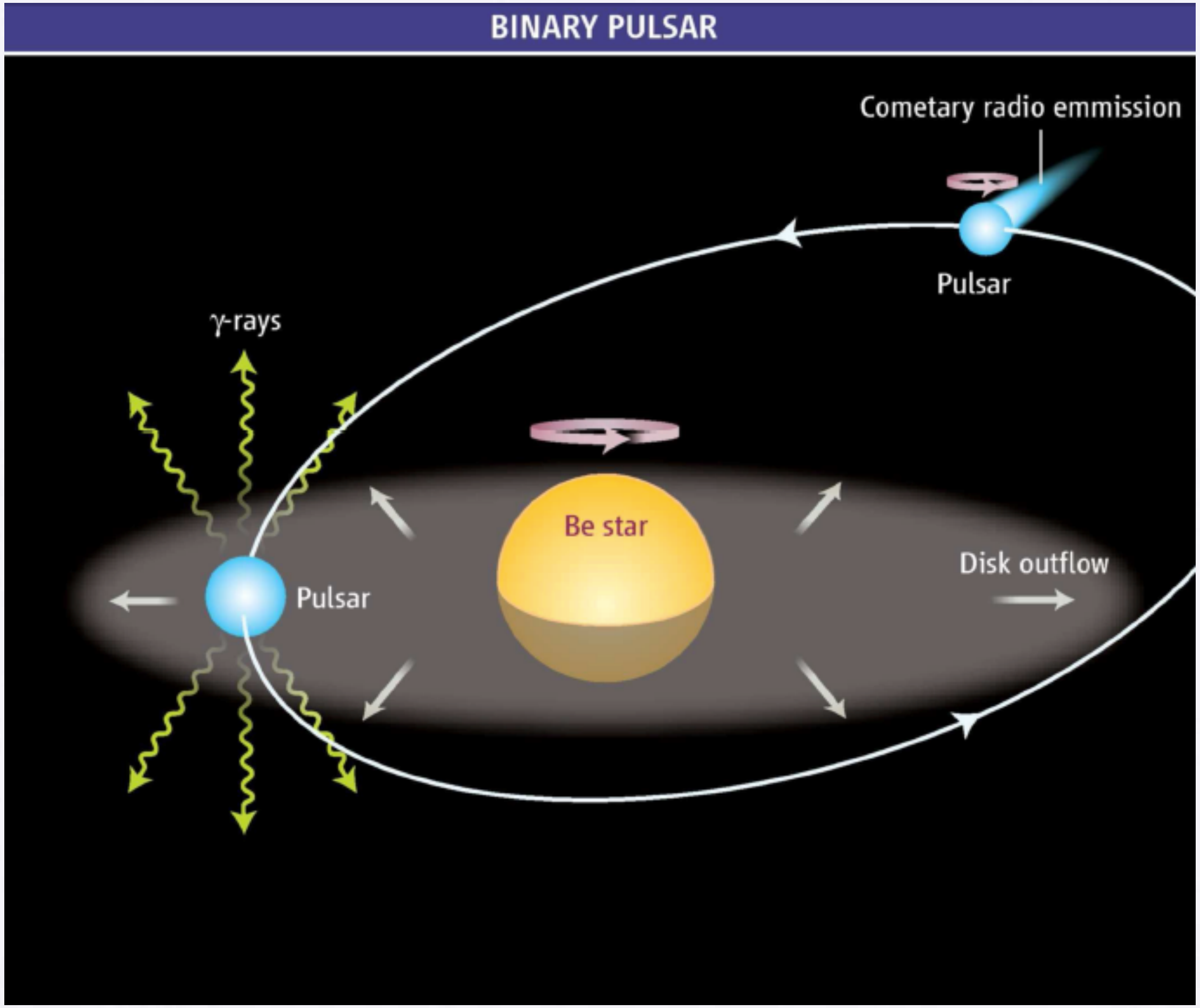
- HMXB: companion V1521 Cyg -- WR star
- P_{orb} = 4.8hr, correlated in gamma-ray
- gamma-ray emission preceded flaring in the radio jet by roughly five days
- periodic radio outbursts with P = 367day: shock wave from a flare of 1/3 c.

Microquasar Jets or Pulsar Winds



Microquasars are powered by NS or stellar-mass BHs) via accretion from a companion. The jets boost the energy of stellar winds to the range of very energetic gamma-rays.

Microquasar Jets or Pulsar Winds



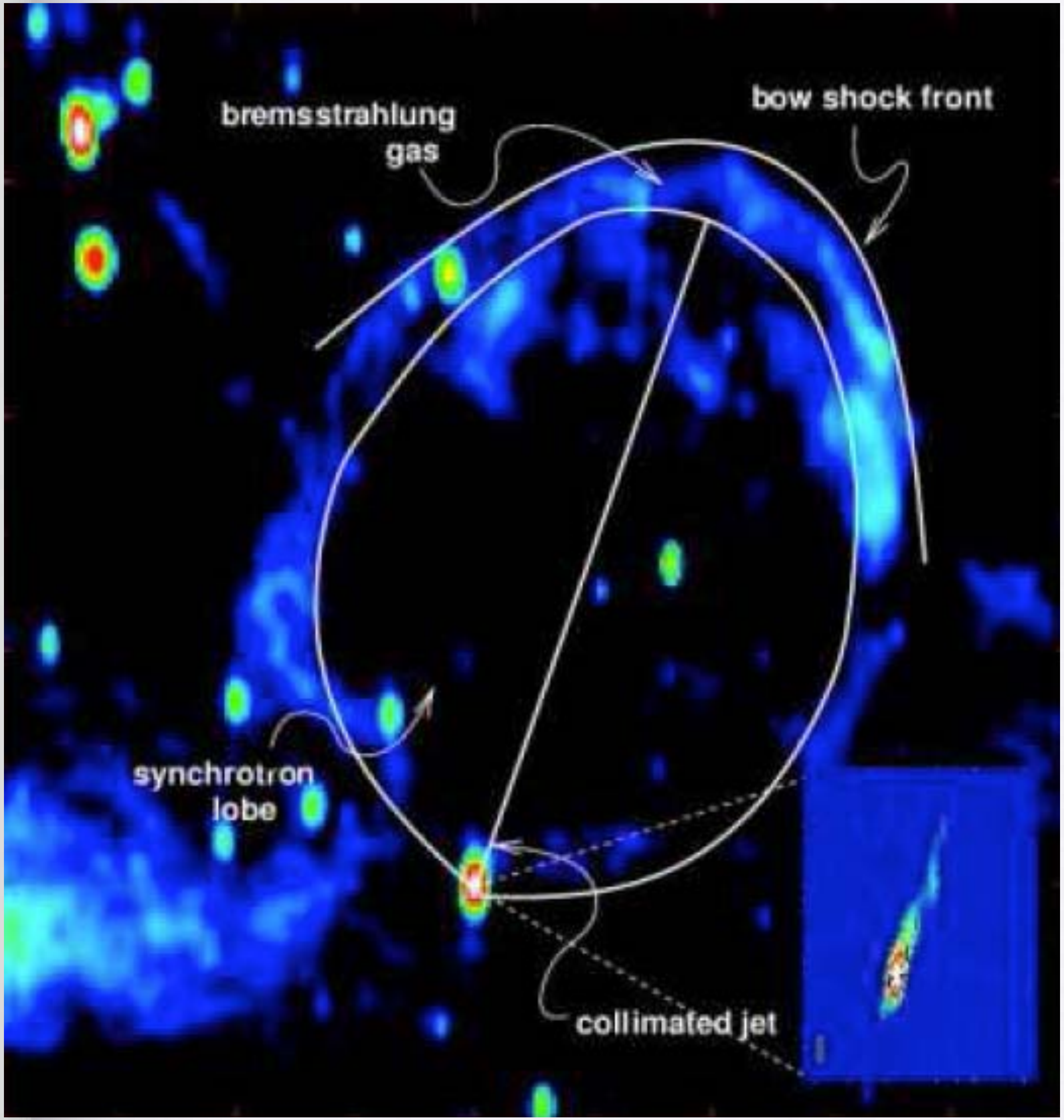
Pulsar winds are powered by rotation of neutron stars; the wind flows away to large distances in a comet-shape tail, as has been shown in to be the case for LS I +61 303. Interaction of this wind with the companion-star outflow may produce very energetic gamma-rays.

Microquasar Jets or Pulsar Winds

- Jet
- $e_{jet} + UV^* \rightarrow \gamma$
- $p_{jet} + p_{wind\,*} \rightarrow \pi^0 \rightarrow 2\gamma$
- CO closer to star: accretion rate ↑
- $\gamma + \gamma_* \rightarrow e^\pm$

- Pulsar Winds
- $e_{pulsar\ wind} + UV^* \rightarrow \gamma$
- $p_{wind} + p_{wind\,*} \rightarrow \pi^0 \rightarrow 2\gamma$
- CO closer to star: wind more compressed
- $\gamma + \gamma_* \rightarrow e^\pm$

Dark Outflows and Super-Eddington Sources



Jet-powered nebula around Cygnus X-1 from Gallo et al.(2005).

Dark Outflows and Super-Eddington Sources

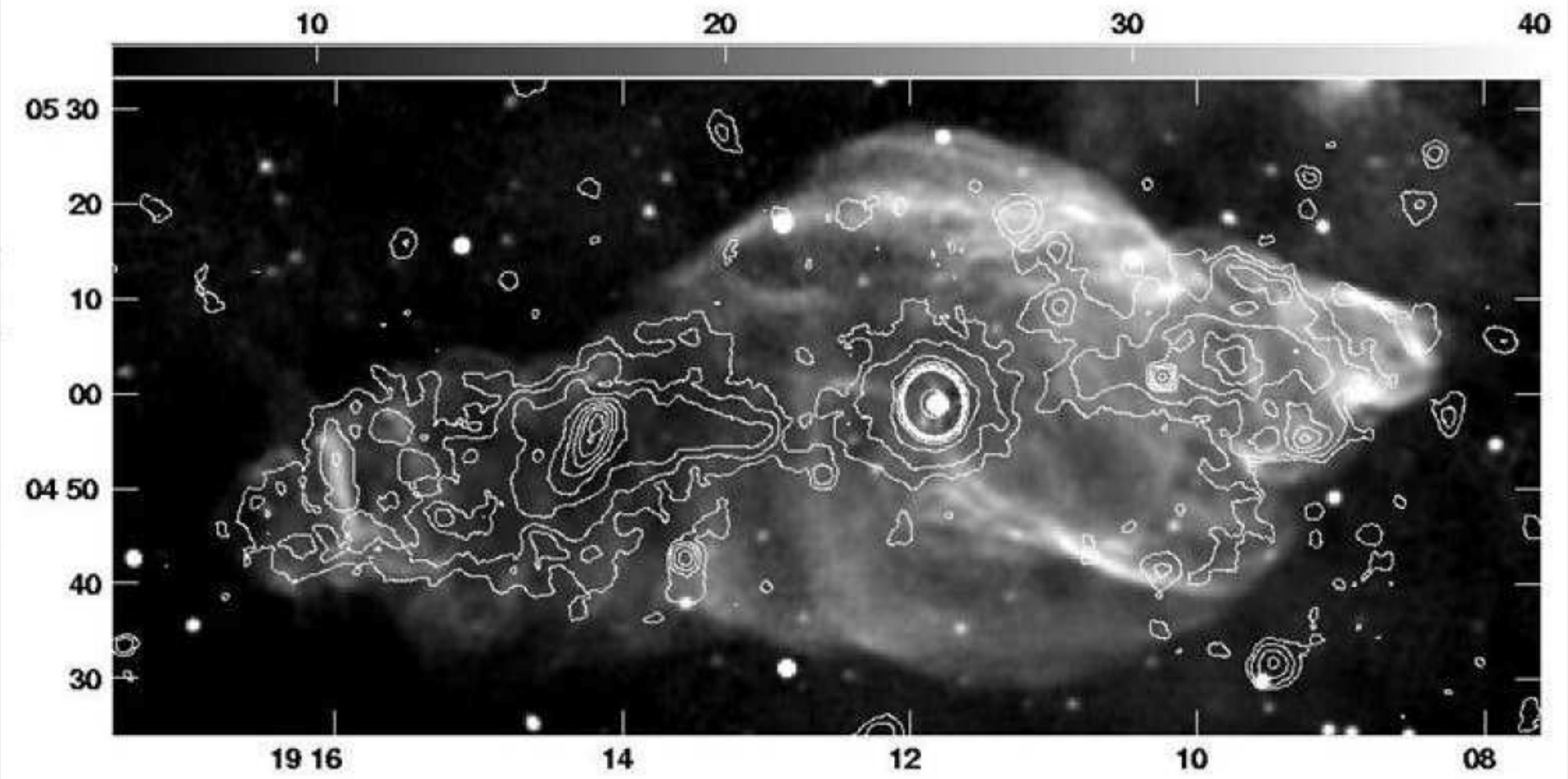


Image at 20cm of the nebula W50 that hosts SS 433, from Dubner et al.

more than 50% of the energy is not radiated

more than 30% of the accreted mass is being ejected in the form of massive winds and relativistic jets

Disk-Jet Coupling

nature

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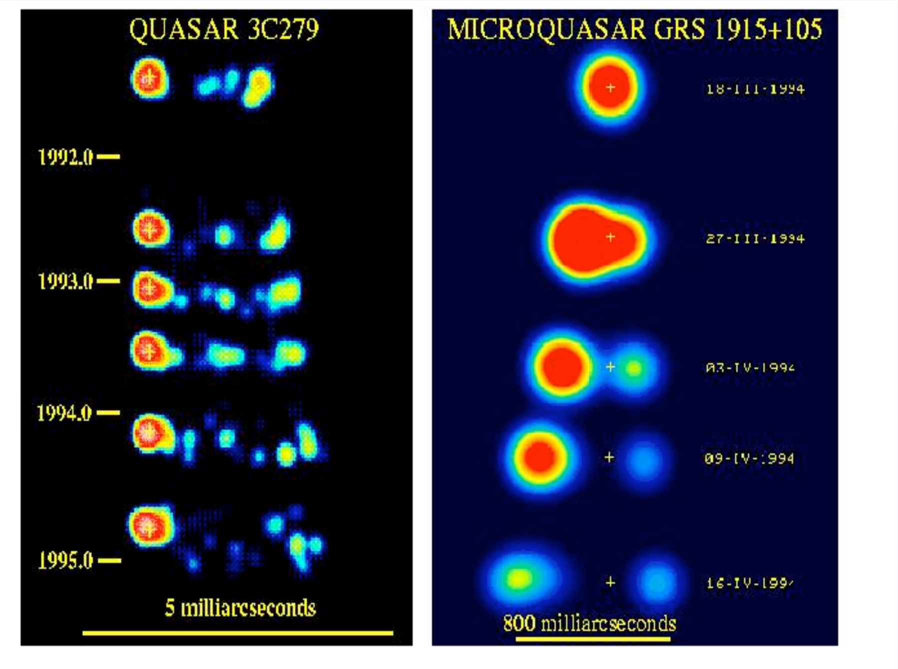
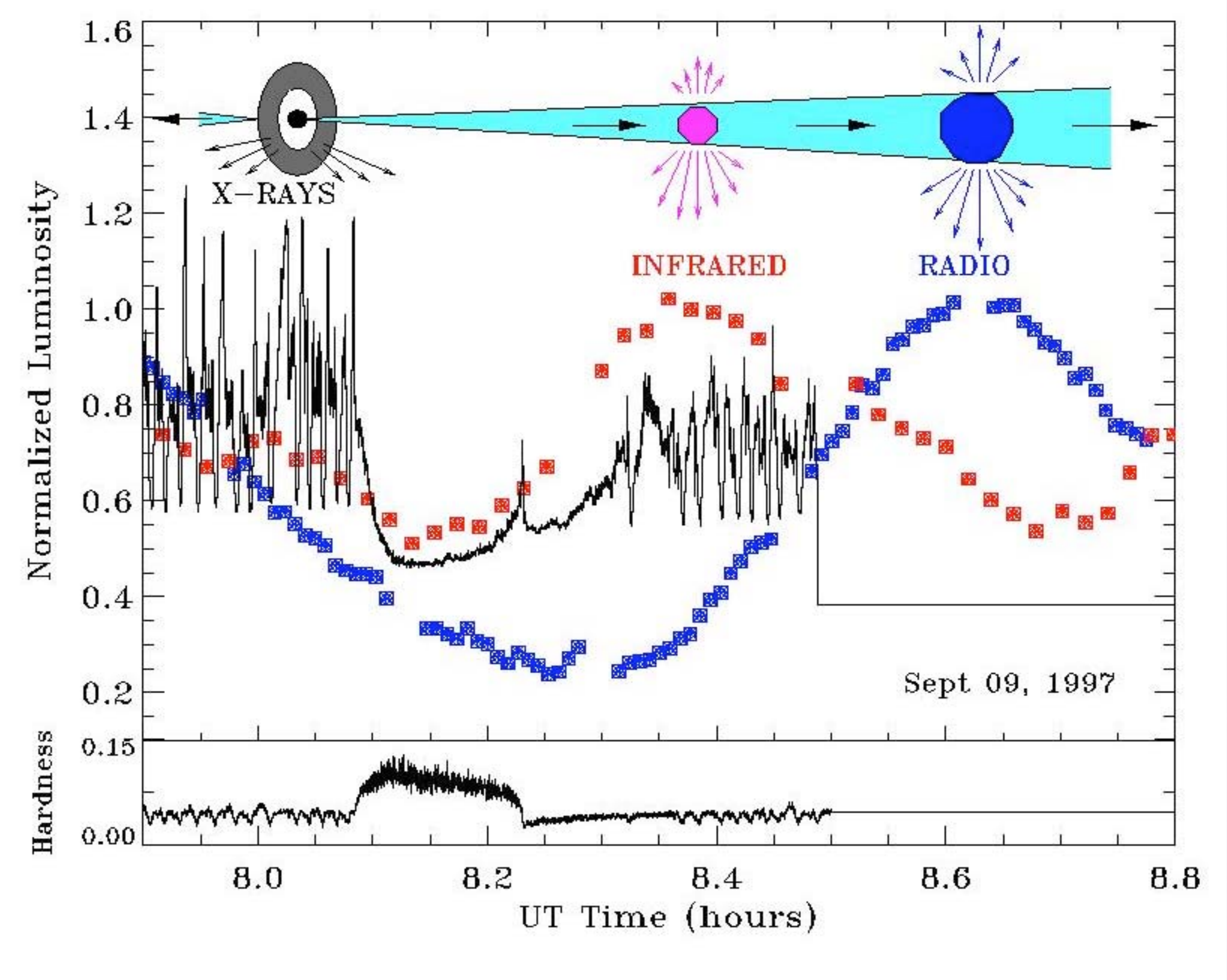
Superluminal motion in the Galaxy



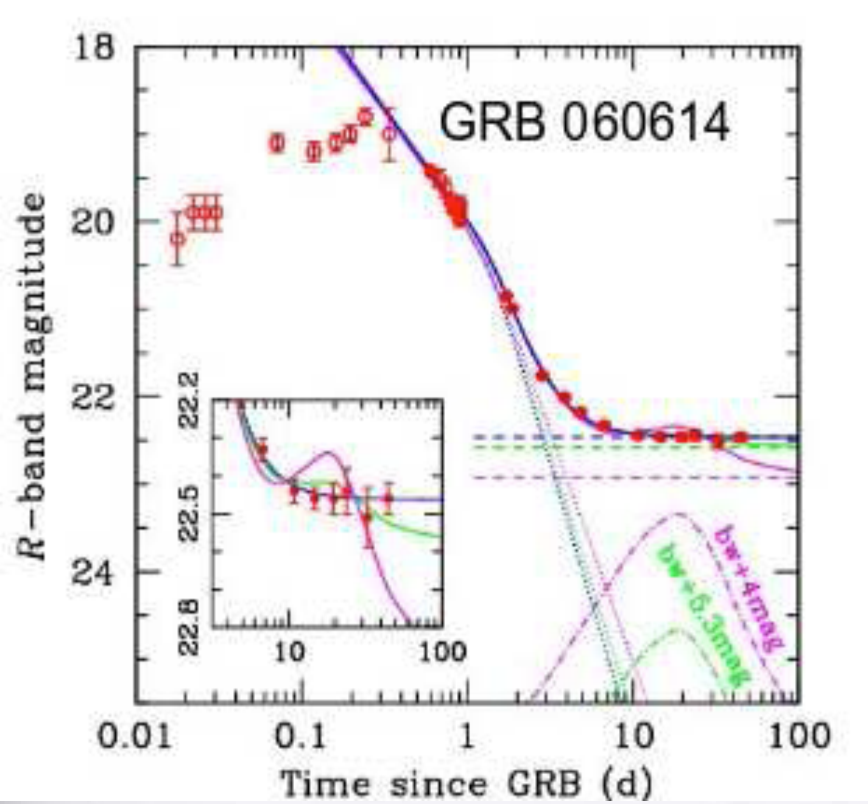
Superluminal ejection in GRS 1915+105

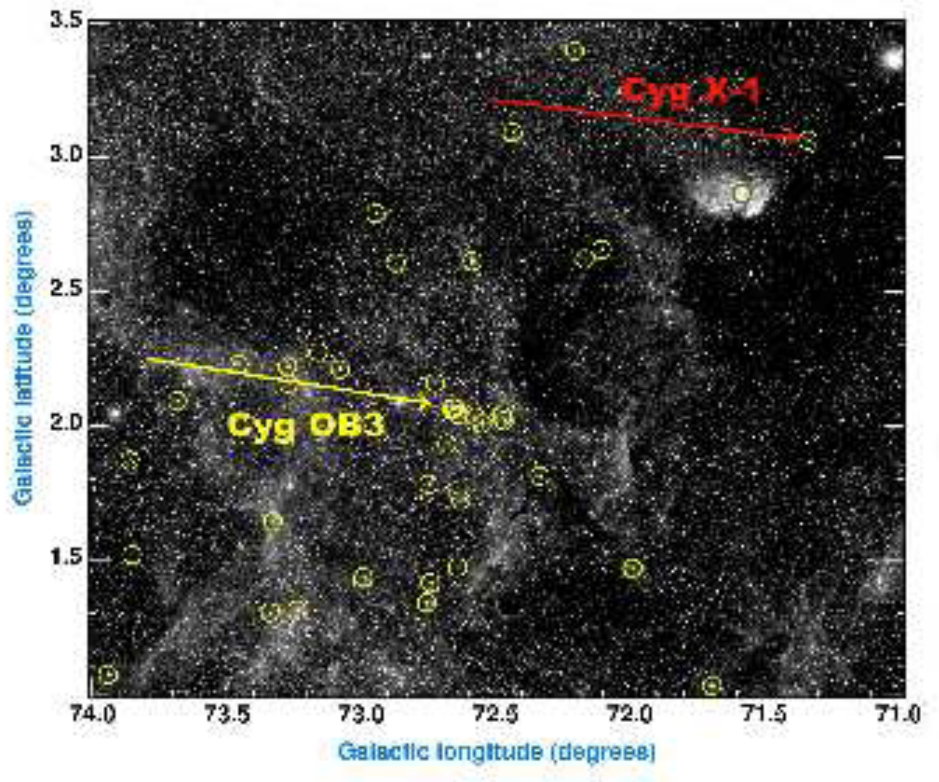
Disk-Jet Coupling



multiwavelength simultaneous observations of instabilities in the accretion disk and the genesis of jets

Microquasar-GRB connections





from the chemical composition found in the atmosphere of the donor star and runaway velocity of GRO J1655-40 it was proposed that the black hole in this microquasar was formed through a very energetic supernova.

Keep working,
(to you all) make discoveries!
(to microquasar) make jets!

~Thank you!~