Resolved Jets and Long-Period Black Hole X-ray Novae

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Punch Line:

• Considering BHXN only, Resolved, relativistic, moving jets are seen ONLY in Long-Period Systems.

• Considering BHXN only, Short-Period Systems show
radio outbursts consistent with jets…..
but none are clearly resolved (2 extended?)

• Random Probability: ~3% (1.8σ)

❖ Next 10 min: Why only BHXN, Biases?, Individual Cases, …etc, and
❖WHY ONLY LONG PERIOD BHXN?

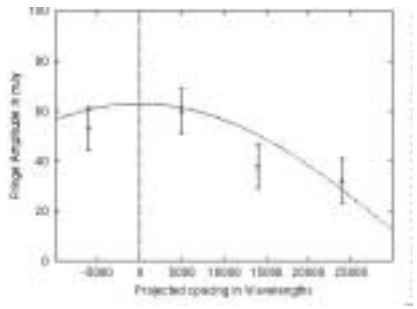
Considering ONLY BHXN: Why?

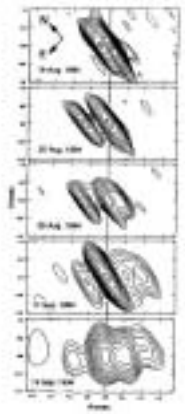
- Jets Complex! Simple, Well Defined set (14 objects, no NS) may allow insights.
- Dynamical Data:
  - Orbital Period (Clear division at 1 day, 6>, 8<)
  - Physical Size
  - Evolutionary State (main sequence or evolved)
  - Mass Transfer Rate (GR or nuclear evolution)
  - Well Studied! L_X, Spectra, Radio

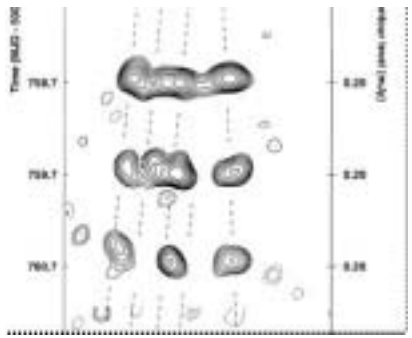
Data: ‘Multiple Component’

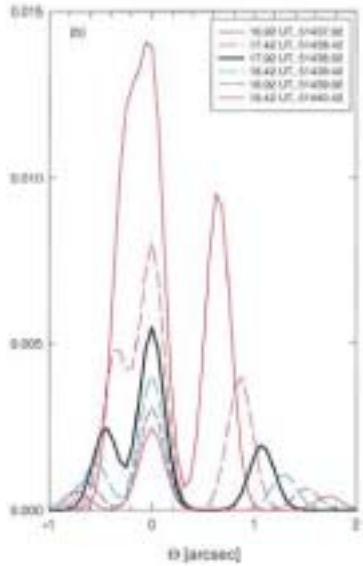
Short Period

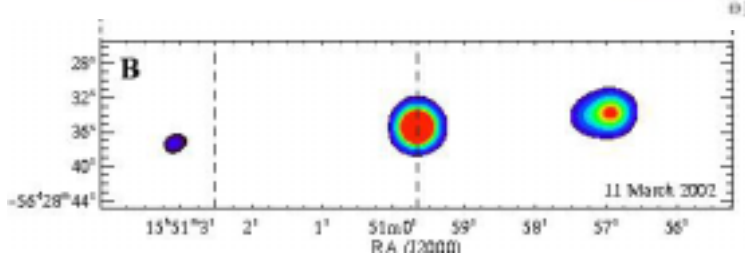
Long Period







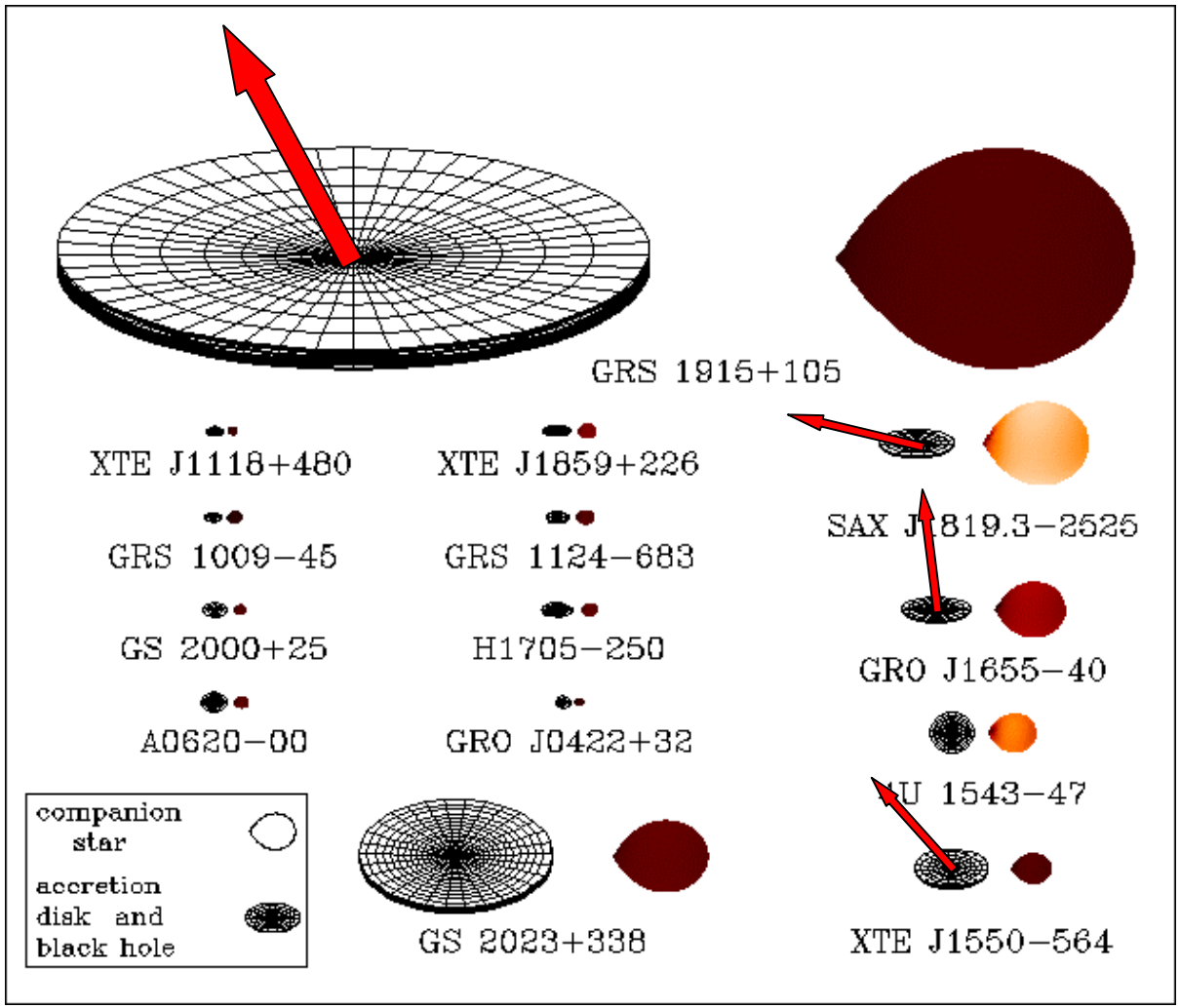




A0620: Fringe visibility
XTEJ1859: faint extension

GROJ1655, GRS1915, SAX 1819,
XTEJ1550: clear Multiple Components

X-Ray Nova Gallery



Gallery courtesy Jerry Orosz

The Data (from the literature)

TABLE 1

MULTIPLE-COMPONENT RADIO JETS IN BHXNs

ID (1)	Outburst Year (2)	Spectral Type (3)	P_{orb} (hr) (4)	L_{max}, L_{Edd} (ergs s^{-1}) (5)	D (kpc) (6)	M_X ($M_\odot$) (7)	i (8)	MC? (9)	Size (10)	Radio Observatory (11)	Delay* (12)
Short-Period Systems											
XTE J1118+480	2000	K7 V–M0 V	4.1	36.1 (1), 38.9	1.9	6.5–7.2	81 ± 2	N	<0.″001 (2)	VLA, VLBA, Merlin, Ryle	1 month (2, 3, 4)
GRO J0422+32	1992	M0 V	5.1	37.7 (5), 38.7	2.6 (4)	3.7–5.0	44 ± 2	N	<0.″14 (6)	VLA	10 days (7)
GRS 1009−45	1993	K6–M0	6.8	39.67 (8, 9), 38.6	9 (10, 11)	3.6–4.77	67?	N/A	N/A	NONE	N/A (12, 13)
A0620−00	1975	K4 V	7.8	38.6 (14, 15), 39.1	1.1 (16)	8.7–12.9	40.8 ± 3	N(?)	≤3″	JBLGBI	14 days (17, 18)
GS 2000+25	1988	K5 V	8.3	38.6 (16, 19), 38.9	2.7	7.1–7.8	64.0 ± 1.3	N	<1.″2	VLA	9 days (20)
XTE J1859+226	1999	...	9.2	38.9 (21), 39.0	11 (22)	7.6–12.0?	High	N(?)	≤1″	VLA, Merlin	2 days (13)
GRS 1124−683	1991	K4 V	10.4	38.9 (16, 23), 38.9	5.1 (24)	6.5–8.2	54 ± 2	N	<2″	ATCA, MOST	9 days (25)
H1705−250	1977	K3 V	12.5	38.6 (16, 26), 38.9	8.6	5.6–8.3	>60	N/A	N/A	VLA	11 yr (27)
Long-Period Systems											
4U 1543−47	2002	A2 V	26.8	39.5 (11), 39.0	7.5 (28)	8.4–10.4	20.7 ± 1.5	N	<1″	MOST	1.5 days (29)
XTE J1550−564	1998	G8 IV–K4 III	37.2	39.2 (30, 31), 39.0	5.3	8.4–10.8	72 ± 5	Y	>20″	VLA, ATCA, MOST, VLBI, LBA	2 days (32, 33)
GRO J1655−40	1994	F6 III	62.4	38.7 (34), 38.8	3.2	6.0–6.6	70.2 ± 1.2	Y	0.″1–5″	VLA, VLBA	10 days (35, 36, 37)
SAX J1819.3−2525 (V4641 Sgr)	1999	B9 III	67.6	39.8 (38), 38.9	10	6.8–7.4	75 ± 2	Y	0.″25	VLA, Merlin	1 day (39)
GS 2023+338 (V404 Cyg)	1989	K0 IV	155	39.4 (40, 41), 39.1	3 (42)	10.0–13.4	56 ± 4	N	~0.2 mas	VLA	9 days (43)
GRS 1915+105	1992	K–M III	804	39.8 (44), 39.2	12.5	10.0–18.0	70 ± 2	Y	>1″	VLA, Merlin	4 months (45, 46)

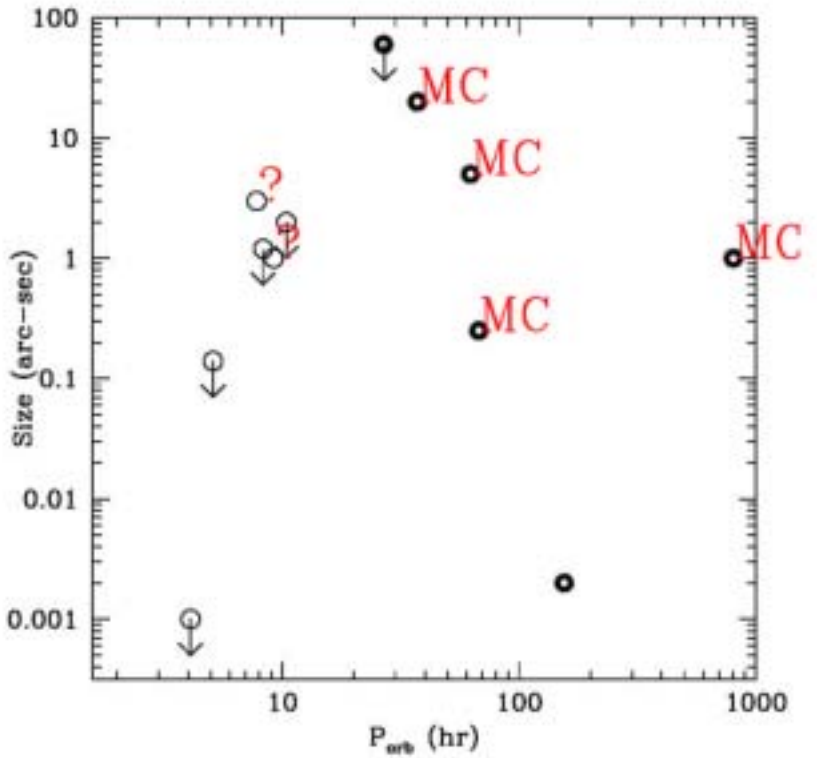
NOTES.—The dynamical data (periods, masses, inclinations) are taken from Orosz 2003. Distances and spectral types are from Lee, Brown, & Wijers 2002, unless otherwise noted. Maximum outburst luminosities are from Garcia et al. 1998 or NGM97, unless otherwise noted, but have been adjusted to be bolometric. The X-ray energy bands listed below correspond to the range covered by the observations. Radio data are from a variety of sources, often multiple.

* "Delay" refers to the time between X-ray discovery and the first radio interferometric observations.

ADDITIONAL REFERENCES.—(1) 1–160 keV, McClintock et al. 2001; (2) Mirabel et al. 2001; (3) Fender et al. 2001; (4) Pooley & Waldram 2000; (5) 2–600 keV, Esin et al. 1998; (6) Shrader et al. 1994; (7) Han & Hjellming 1992a; (8) Chen, Shrader, & Livio 1997; (9) Tanaka et al. 1993; (10) Filippenko et al. 1999; (11) this work; (12) Masetti, Bianchini, & Della Valle 1997; (13) Brocksopp et al. 2002; (14) 2–18 keV Elvis et al. 1975; (15) 2–80 keV, Ricketts, Pounds, & Turner 1975; (16) Narayan, Garcia, & McClintock 1997; (17) Davis et al. 1975; (18) Kuulkers et al. 1999; (19) Terada et al. 2002; (20) Hjellming et al. 1988; (21) Hynes et al. 2002; (22) Zurita et al. 2002; (23) Greiner et al. 1994; (24) Gelino, Harrison, & McNamara 2001; (25) Ball et al. 1995; (26) Cooke et al. 1984; (27) Nelson & Spencer 1988; (28) Orosz et al. 2002a; (29) Hunstead & Webb 2002; (30) Orosz et al. 2002b; (31) Sobczak et al. 2000; (32) Hannikainen et al. 2001; (33) Corbel et al. 2002; (34) Zhang et al. 1997b; S.-N. Zhang 2002, private communication; (35) Harmon et al. 1995; (36) Tingay et al. 1995; (37) Hjellming & Rupen 1995; (38) Orosz et al. 2001; (39) Hjellming et al. 2000; (40) Tanaka 1989; (41) Zycki, Done, & Smith 1999; (42) Shahbaz et al. 1994; (43) Han & Hjellming 1992b; (44) Greiner, Morgan, & Remillard 1998; (45) Mirabel et al. 1993; (46) Mirabel & Rodriguez 1994.

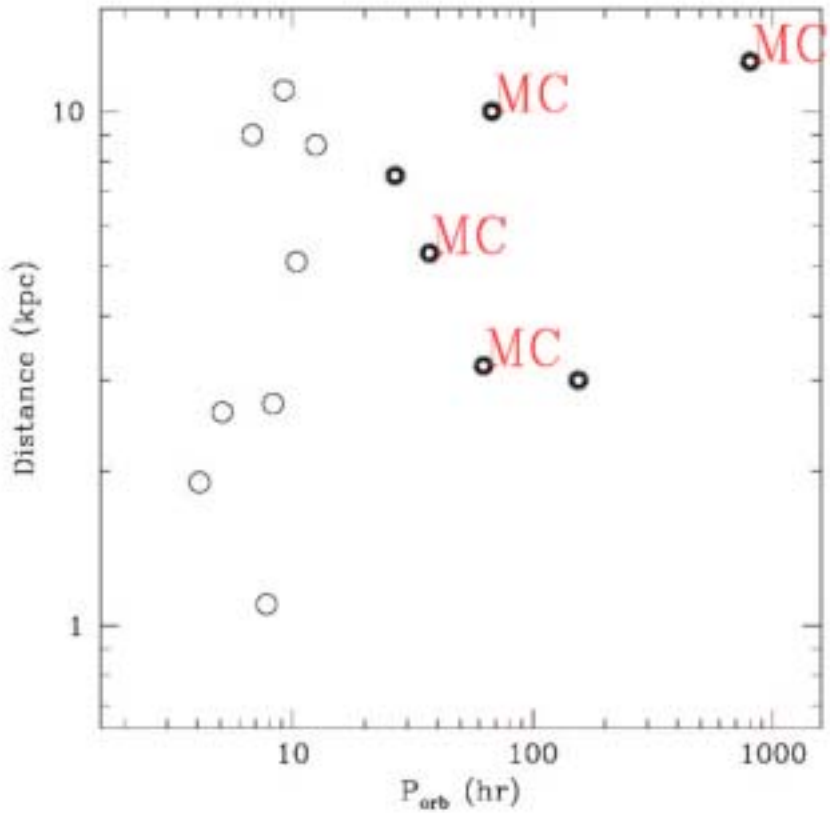
Garcia etal 2003 ApJ: L_X, Angular Limits computed

Data: Sizes and Limits



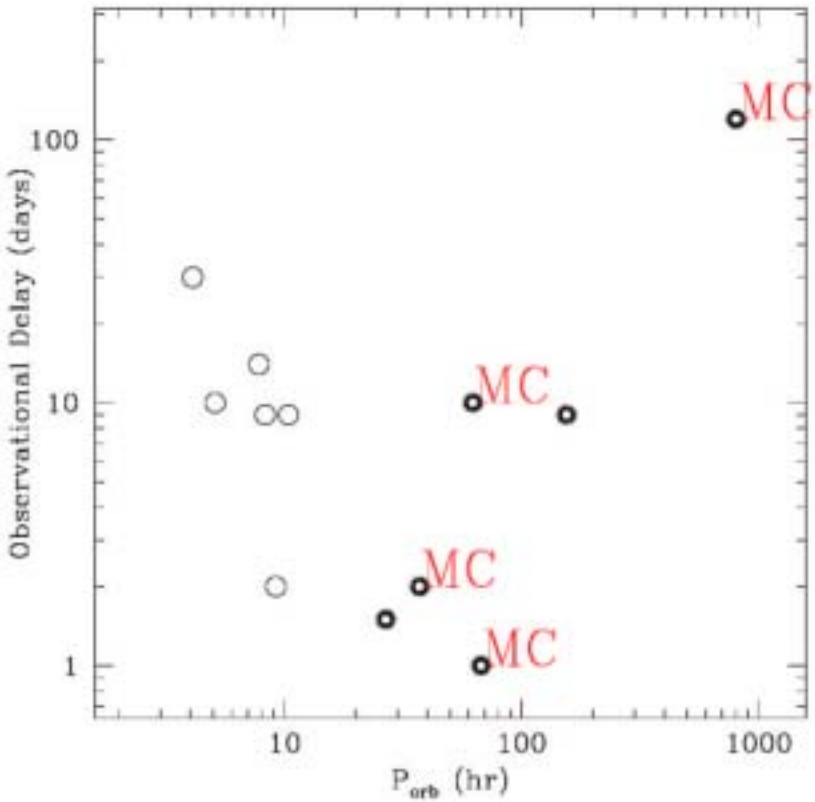
Sizes, limits similar (long vs. short period)
No bias in telescope resolution
(long periods not resolved due to higher resolution)

Biases: Distance?



Distances overlap – Long Period (resolved) sources NOT closer: some Short Period closer!

Biases: Observational Delay?



Some jets decay fast (SAX 1819), some last (XTE J1550)
No clear bias (P_{ORB} not known at time of outburst!)

Biases(Why?): Orbital Size?

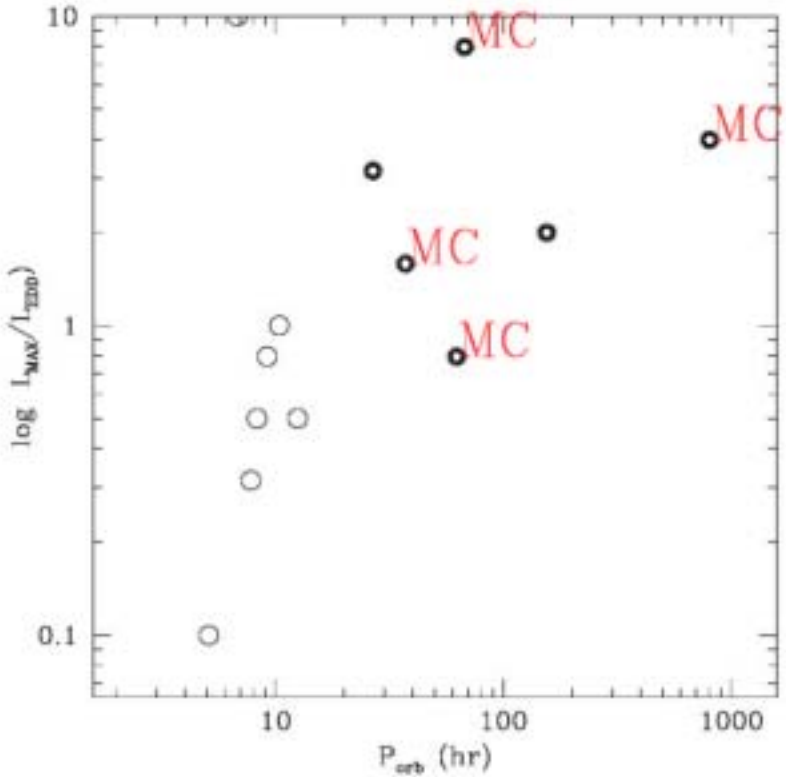
- AGN Jets >> BHXN Jets
- P>1 Day > P<1 Day?

GRO J0422+32, XTE J1118+480 (Shortest P_{ORB}, tightest Jet limits) to SAX J1819, GRO J1655

a -> 5a (orbit size increases nearly order of magnitude)

Not negligible – Might be part of reason?

Why: L_X / L_{EDD}?



All Resolved Jets ~>L_{EDD}, also (same?) P>1day

Necessary – not sufficient:

GS2023+338, 4U1543-47 (LP, L_X>L_{EDD}, no jets)

Why: Spin?

- Blandford & Znajek 1977 – Spin may launch jets
- Evidence for Spin in BHXN: MCD, QPOs, Broad Fe Lines:
  - Spin implied, but unclear if well known!
- MCD: High T_{IN} = Spin
  - Zhang etal 1997 1655-40, 1915+105 a~1 (J!)
  - 1124-68, 2000+25 a~0 (no jets)
  - Hynes etal 2002 1859+226 spin low (no jets)
  - Sobczack etal 1999, 1655-40 0<a<0.5
    - MCD hard! 1655-40 (jets) spin high, low…?
- QPO: High ν = Spin
  - Strohmayer etal 01 1655-40 0.15<a<0.5(a>0.9?) J
  - Remillard etal 02 1550-564 0.1 <a<0.6(a>0.9?) J
  - Miller etal 01 1550-564 a>0 J
  - Morgan etal 97 1915+105 a>0 J

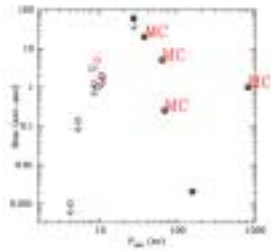
Why: Spin?

- Fe Lines: Broad = Spin
- Miller etal 02 SAX J1819 a~0 (J)
- Martocchia etal 03 1915+105 a>0 (J)

- 3 of 4 Jets Sources show a>0
  - 1655(MCD, QPO) a>0
  - 1915(MCD,QPO,Fe) a>0
  - 1550(QPO) a>0
  - SAX J1819(Fe) a~0
- What about 4U1543-47, GS2023+338?
  - Both $L_X > L_{EDD}$, P>1day, NO jets = NO spin??

Why: Spin?

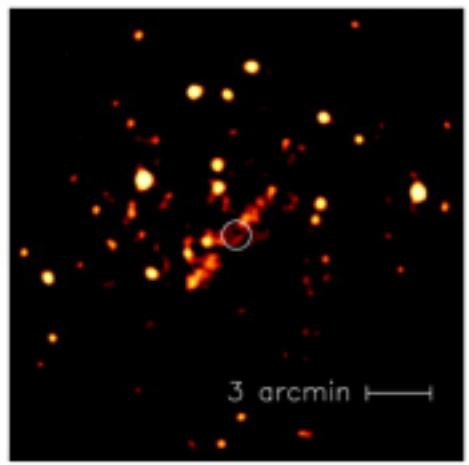
- What about 4U1543-47, GS2023+338?
  - Both $L_X > L_{EDD}$, P>1day, no jets = NO Spin?
- 4U1543-47:
  - Park etal 8/2003: MCD, Fe Line: a>0
  - MOST: 1 arcmin resolution
- GS2023+338
  - Zhang etal 97: MCD, No Soft Excess: a<0 ?
  - Zycki etal 99: Soft excess there, hidden by N_H
- Unclear!



Summary

- Long Period BHXN have MC Jets (SP do not)
- $L_X > L_{EDD}$ Necessary for Large Jets (not sufficient)
  - Long Period Systems have $L_X > L_{EDD}$
- Data ALLOW Spin, $a>0$ & $L_X > L_{EDD}$ = Jets, BUT
  - Spin measurements difficult

- Only takes ONE Short Period system to disprove!
  - 4U1755-33 Angelini & White 2003
  - P_{ORB}=4.4h, fossil jet!
  - BHXN?
  - $L_X > L_{EDD}$, not LP vs SP



Why: Spin?

- Fe Lines: Broad = Spin
- Miller etal 02 — SAX J1819 — a~>0 (J)
- Martocchia etal 03 — 1915+105 — a>0 (J)
- Miller etal 02 — 1650-500 (P_{ORB}=0.2122d?) — a~1
- Miller etal 03 — GX339+4 — a~1 (J)
  - Not considered: P_{ORB} secure?, BHX Novae?
- 3 of 4 Jets Sources show a>0
  - 1655(MCD, QPO) a>0
  - 1915(MCD,QPO,Fe) a>0
  - 1550(QPO) a>0
  - SAX J1819(Fe) a~0
- What about 4U1543-47, GS2023+338?
  - Both $L_X > L_{EDD}$, P>1day, NO jets = NO spin??

Why: Spin?

- What about 4U1543-47, GS2023+338?
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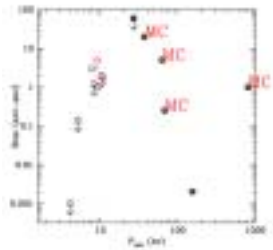

- GS2023+338
  - Zhang etal 97: MCD, No Soft Excess: a<0 ?
  - Zycki etal 99: Soft excess there, hidden by N_H
- Short Period – no Spin?
- 6 of 8 show soft excess

•XTE J1859+226	MCD	a~0	(Hynes etal 02)
•1124-683, 2000+25	MCD	a~0	(Zhang etal 97)
•1650-500	Fe	a~1	(Miller etal 02)