X-ray and radio properties of black hole candidates

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Outline

Something old
X-ray states and radio jets, unified model, radio/X-ray diagram, jet vs accretion power

Something new
Spins and Lorentz factors: observational constraints on spin-powering of jets

Something borrowed
First accurate parallax distance to a black hole candidate
Neutron stars vs. black holes: the complete SED
Black hole X-ray binary outbursts
X-ray states: (low/)hard & quiescent

McClintock & Remillard 2006

Radiatively inefficient inflow (ADAF, CDAF, JDAF, ADIOS..)

X-ray states: (high/)soft

McClintock & Remillard 2006

Radiatively efficient inflow (thin disc)


![Graph showing energy distribution of X-ray states.](image)
Not all jets are created equal

Cyg X-1
Stirling et al. ‘01

GRS1915+105
Mirabel et al. ‘94

SS433
Blundell et al. 2004

1E140.7-2942
Mirabel et al. al ‘99
Black hole outburst: a journey

Fender Belloni Gallo 2004; Fender Homan Belloni 2009 (more later: Belloni’s talk)
X-ray jets

Corbel et al. 2003

Corbel et al. 2005

Angelini et al. 2003
Radio nebulae

Cyg X-1, WRST  Gallo et al. 2005

SS433 W50, VLA

Russell et al. 2006
Tapping on black hole spin

Extraction of energy from a rotating black hole (Penrose '69), to power relativistic jets (Blandford-Znajek '77, McKinney '05)

Sikora Swartz & Lasota 2007

(Volonteri et al 2008 for interpretation)
Constraints on spin powering of jets I.

BH XRB spin from disc fitting

BH XRB spin from reflection (including Fe line)

AGN spin (all from reflection)

All spin measurements (BH + AGN)

Fender Gallo & Russell (submitted)
Constraints on spin powering of jets II.

Gallo Fender Pooley 2003, Gallo et al. (in prep.)
## Constraints on spin powering of jets III.

<table>
<thead>
<tr>
<th>Source</th>
<th>Mass ((M_\odot))</th>
<th>Spin estimate</th>
<th>Radio</th>
<th>Refs</th>
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<tr>
<td></td>
<td></td>
<td>Disc</td>
<td>Reflection</td>
<td></td>
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<tr>
<td>M33 X-7</td>
<td>15.6 ± 1.5</td>
<td>0.77 ± 0.05</td>
<td>No radio</td>
<td>1,6,7</td>
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<td>LMC X-1</td>
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<td>0.90 ± 0.04</td>
<td>No radio</td>
<td>1,7</td>
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<tr>
<td>LMC X-3</td>
<td>&lt; 0.8</td>
<td>0.03</td>
<td>No radio</td>
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<td>13</td>
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<td>GS 1124-68</td>
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<td>4U 1543-47</td>
<td>9.4 ± 1.0</td>
<td>0.7–0.85</td>
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<td>GRO J1655-40</td>
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<td>GRS 1915+105</td>
<td>14 ± 4</td>
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<td>0–0.15</td>
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<td>10</td>
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<tr>
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<td>~ 0.7</td>
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<td>11</td>
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<td>0.998</td>
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<td>XTE J1550-564</td>
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<td>&lt; 0.8</td>
<td>0.76 ± 0.01</td>
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<td>XTE J1650-500</td>
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<td>Cygnus X-1</td>
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<td>4U 1957+11</td>
<td>3–16</td>
<td>0.8–1.0</td>
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Fender Gallo & Russell (submitted)
Constraints on spin powering of jets IV. Hard state

Reflection

Disk

Fender Gallo & Russell (submitted)
Constraints on spin powering of jets IV. Ejections

Reflection

Disk
Black holes vs neutron stars: SEDs

V404 Cygni

Jet vs. accretion power: >30%

4U 0614+091

Jet vs. accretion power: 10%
First accurate parallactic distance to a black hole candidate

**V404 Cygni**

7 epochs: VLBA, phased VLA, EVN, GBT

$D = 2.37 \pm 0.14 \text{ kpc}$

Next generation radio telescopes (EVLA, eMERLIN etc.) will get them all!

Miller-Jones et al. (to be submitted)
X-ray and radio properties of black holes: Summary

Something old
X-ray states and radio jets, unified model, radio/X-ray diagram...So far, so good. More in next talk.

Something new
No observational evidence for spin-powering of jets: either
- one or more method for estimating jet power is wrong
- one or more method for estimating spin is wrong
- jet power/velocity are NOT related to spin

Something borrowed
- Accurate parallax distance to V404 Cyg, d=2.37±0.17 kpc
- Neutron stars vs. black holes: 10% vs 30% of accretion power channeled into a jet