Are ULXs Intermediate Mass Black Holes?

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High Energy Talk
16 January 2008
Intermediate Mass Black Holes

- $20 < M_{\text{IMBH}} < 10^6$

- Mass range is not well characterized

- We are confident there are SMBH at the centers of galaxies

- We are confident there are stellar mass BH

- In between is fuzzy

- No reason why they cannot exist

- Might shed light on SMBH formation process
Ultra-Luminous X-Ray Sources

- **X-Ray Binaries (XRB)** involve a BH accreting matter from a stellar companion
- **Stellar Mass BH** top out at 20 $M_{\text{Sun}}$
- **ULXs** have fluxes much larger than expected for a 20 $M_{\text{Sun}}$ object accreting at the Eddington limit
- **Means** $L > 3 \times 10^{39}$ ergs s$^{-1}$ implies intermediate mass
- **X-ray luminosity** in the 2-10 keV band will be few-10x smaller, define $L_x > 10^{39}$ ergs s$^{-1}$ as an ULX
• NGC 1313
• Found the ULX was off-center by ~1' (~1 kpc)
• Common with ULX within galaxies
• Cannot be a SMBH- dynamical friction effects
Census

Colbert & Ptak cataloged 87 ULX

1/5 galaxies contain

45 have $L_x > 3 \times 10^{39}$

11 have $L_x > 10^{40}$

Brightest in M82, peak $L_x$ of $9 \times 10^{40}$ ($M > 700 \, M_{\odot}$)
Can use Multi-color disk (MCD) model

Assume inner disk at 6 Schwarzschild

ASCA fitting gives temps to high for IMBH

XRB 0.4-1 keV, ULX have 1.1-1.8 keV

High temps consistent with LMBX micro-quasars
Solutions

- Possibly Beaming
- Kerr Geometry resulting in frame dragging
- ADAF (Advection-Dominated Accretion Flow)
  - Normally: Acc-Energy-Heat-Radiation-Cooling
  - ADAF: Acc-Heat-Hot Gas Advected In
  - Requires $L \ll \text{Ledd}$
- More observations
XMM/Chandra Spectra

- Don't always agree with ASCA findings
- ASCA's data poor
- Find power-law or a single disk fits often work
- Power law might be background nuclei
- XMM and Chandra often find lower temps
- NGC 1313 X1, X2 ~150 eV
- Fe Kα
X-Ray Variability

- Random or periodic variability rules out clusters of XRBs
- Long term variability (>1 yr)
- Over half of ULX have >50% variability
- Some short term periodicity
- Hours to days
- Lack of data, however

Liu et al 2002
Quasi-Periodic Oscillations

- QPO reported for X-1 in M82
- 54 mHz
- Originates in disk
- Strengthens IMBH theory
- Power spectrum does not vary on rapid timescales (0.1 Hz)
- Dissimilar to XRB
IMBH in Globular Clusters

- Bondi-Hoyle accretion
- 2-3% of RGB stars produce an ISM
- Produce x-ray and radio emission
- Sub-eddington
- Grindlay et al 2001 possibly found a 500 M_{Sun} BH in 47 Tuc

\[ r_w \approx 0.22 \text{ pc}(20m_f/M)^{1/2}(r_c/1 \text{ pc}) \]
G1 in Andromeda

- Stripped galactic nucleus
- 3 XMM observations
- Polley and Rappaport find $L_x = 2 \times 10^{36}$ ergs s$^{-1}$
- Could be sub-Edd
- Could be XRB
- Break degeneracy with spatial resolution
- Expect IMBH to be 50 mas from center
- Spectroscopy required
**Beaming**

- **Explains overall flux**
- **Uses known sources and tested methods**
- **Explain association with SF regions**
- **QPO causes problems**
- **Relativistic beaming indicates** $F_X/F_{\text{radio}} \sim 10^{-1000}$
- **ULXs show** $10^5 - 10^6$
More Thoughts on Beaming... from King 2008

- Claims do not need large beaming fraction
- Just exceptionally high accretion rates
- Inner disk acts as a BB with strong emission
- $dM \sim 50 \, dM_{\text{edd}}$

$$L \simeq \frac{L_E}{b} \left[ 1 + \ln \left( \frac{M}{M_E} \right) \right]$$

$$b = \frac{0.016m_1}{L_{40}} \left[ 1 + \ln \left( \frac{490R_9}{m_1} b^{1/2} \right) \right]$$
Mapelli et al simulated the Cartwheel ring galaxy

Known to contain 17 bright X-ray sources ($>5 \times 10^{38}$ ergs s$^{-1}$)

N-body SPH sims show that most are explained by LXRB

1-5 are still potential IMBH

Disagreement between sims and observation, however
Greene and Ho (2007) detect IMBH in AGN

$10^5 - 10^6 \, M_{\odot}$

Picked candidates from SDSS - followed up with Chandra

8/10 targets revealed sources

5/8 had spectra

Not good BB fits

The Other End: IMBH in AGN
Other Issues/Discussion

- **Sources could be super-Eddington**
- **Only increase by ~10x**
- **Temperature discrepancy needs resolution**
- **Need to definitively rule out beaming**
- **More observations to break degeneracy**
- **Wide wavelength coverage and radial velocity measurements are required**

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**Fig. 7.**—Plot of $\chi^2$ vs. black hole mass marginalized over $M/L$. The solid line represents the constant $M/L$ model, while the dashed line has an $M/L$ profile that rises at large radii according to Fig. 6. The difference in $\chi^2$ between the no-black-hole mass and the best fit is 5 for a constant $M/L$, which implies a significance of over 97%. The case with a varying $M/L$ shows an even higher $\Delta \chi^2$ with the no-black-hole model and allows for a higher mass black hole. We add 37 to the $\chi^2$ for the varying $M/L$ model, since it is a better fit to the data.