Probing the Origin of the Intermediate Mass Black Hole ESO 243-49 HLX-1

Sean Farrell | ARC Postdoctoral Fellow
Sydney Institute for Astronomy (SIfA) | The University of Sydney
Intermediate mass black holes: why you should care

- Formation process of super-massive black holes (SMBHs) is unknown
- Two leading theories:
  - *Stellar death*: massive Pop III stellar remnants grow via mergers/accretion
  - *Direct collapse*: dense gas clouds collapse to form $\sim 10^3$-$10^5 \, M_\odot$ black holes that grow by mergers/accretion
- Either way, *IMBHs predicted to have played an important role in SMBH formation* (Volonteri 2010)
- Also implications for dark matter annihilation, gravitational wave radiation, and epoch of reionization
Discovery of the Brightest ULX

- HLX-1 discovered coincident with edge-on S0a galaxy ESO 243-49 at ~100 Mpc (Farrell et al. 2009)
- Max unabsorbed \( L_x = 1.3 \times 10^{42} \) erg s\(^{-1}\), ~1,000 times Eddington limit of 10 M\(_{\odot}\) black hole
- VLT optical spectroscopy confirmed distance & luminosity (Wiersema et al. 2010)
- Spectral state transitions observed similar to stellar mass black hole binaries (see poster 129.03 by M. Servillat)
- Transient radio emission from ballistic jets detected (Webb et al. 2012)
- Observational evidence all points to a 9,000 – 90,000 M\(_{\odot}\) intermediate mass black hole (Webb et al. 2012)
ESO 243-49 HLX-1

Broad-band Spectral Fitting

› HLX-1 observed by HST in Nov 2010
› X-ray data dominated by thermal emission from accretion disc, but disc model doesn’t fit UV/optical/NIR data
› Irradiated disc + stellar population provides excellent fit, however two unique solutions:
   - Young pop + low reprocessing
   - Old pop + high reprocessing
› Stellar mass for both solutions $\sim 10^6 M_\odot$ (Farrell et al. 2012)
› Can use variability of disc emission to break model degeneracies

Farrell et al. (2012)
Broad-band Spectral Fitting

› HLX-1 observed ~2 months after HST by the VLT (Soria et al. 2012)
› Optical flux appeared to drop by factor ~2 inconsistent with dominant stellar comp.
› Fitting HST + VLT data simultaneously removes some degeneracy
› SED fitting indicates a higher contribution from irradiated disc & lower stellar mass (Farrell et al. in prep)
› Old stellar age solution no longer viable
› However, variability could be spurious due to over-subtraction of background
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Farrell et al. in prep
Investigating the origin of HLX-1

- Star formation not expected to occur in galaxy halo
- Stars too young for it to be a classical globular cluster
- Dust lanes in early type galaxies have been linked to gas-rich minor mergers (e.g. Shabala et al. 2012)
- Central black hole of host galaxy predicted to turn on within ~200 Myr following merger
- No point-like X-ray emission detected from nucleus, so not active yet (Servillat et al. 2011)

Conclusions:
- HLX-1 could be stripped remnant of dwarf galaxy accreted < 200 Myr ago (Farrell et al. 2012)
- 10 more orbits of HST plus simultaneous XMM data coming to confirm stellar age