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

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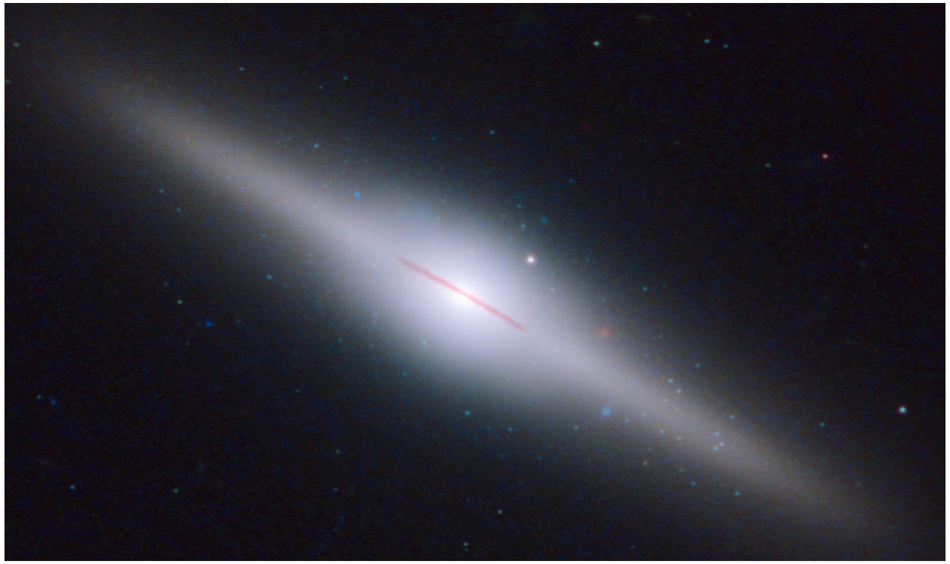

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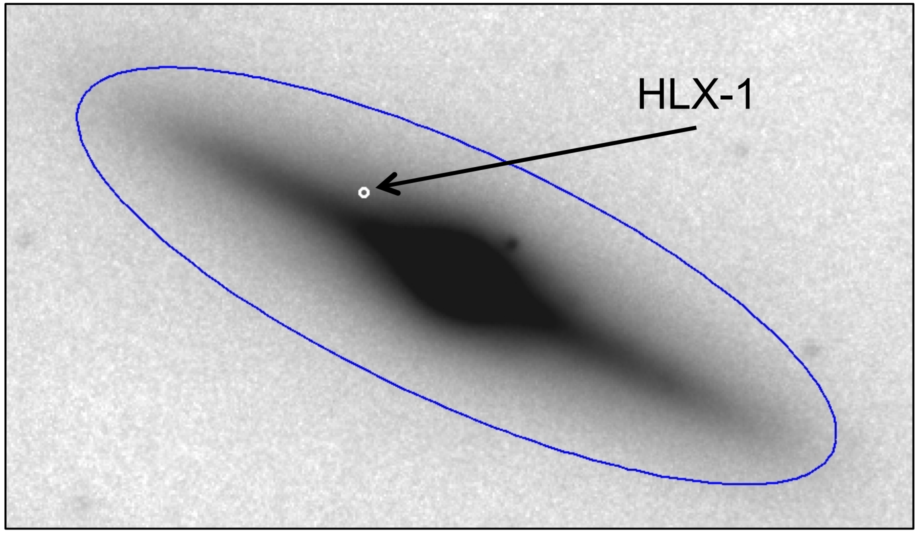
Intermediate mass black holes: why you should care

The Hubble extreme deep field

- 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 ~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

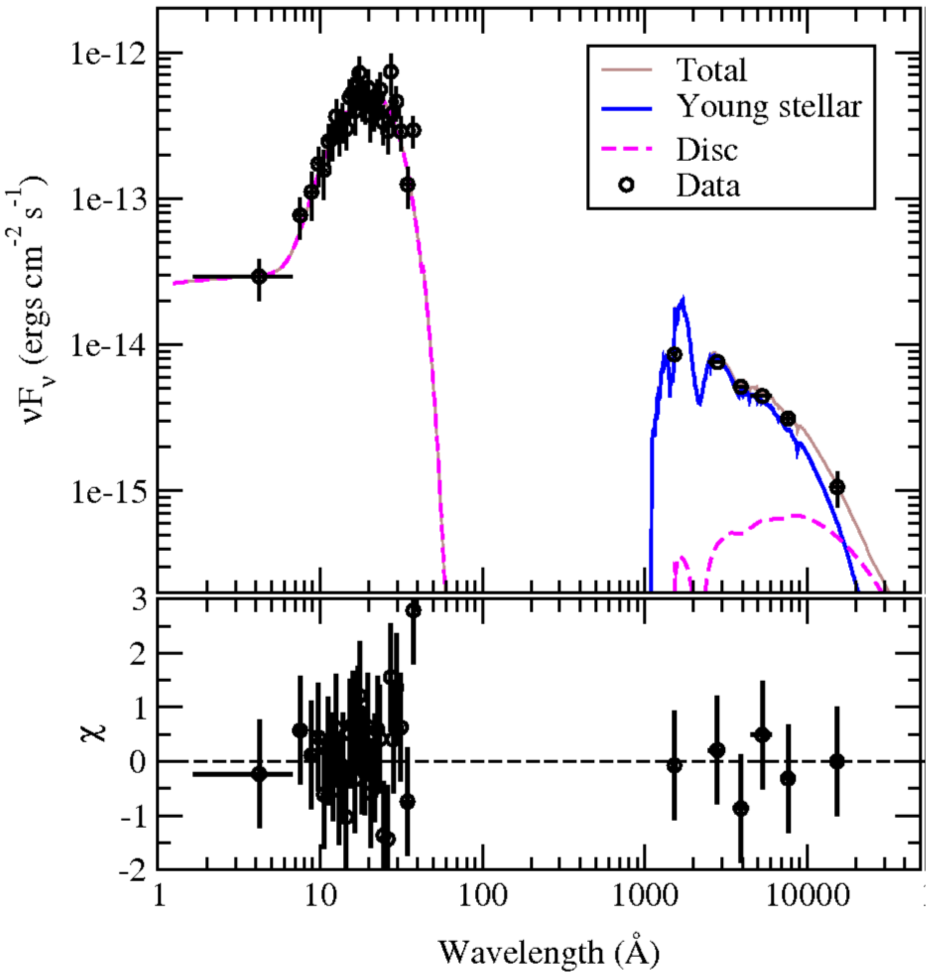


VLT R-band optical image of the galaxy ESO 243-49 with the Chandra position of HLX-1 indicated by the white circle (Farrell et al. 2009; Webb et al. 2010)

- 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

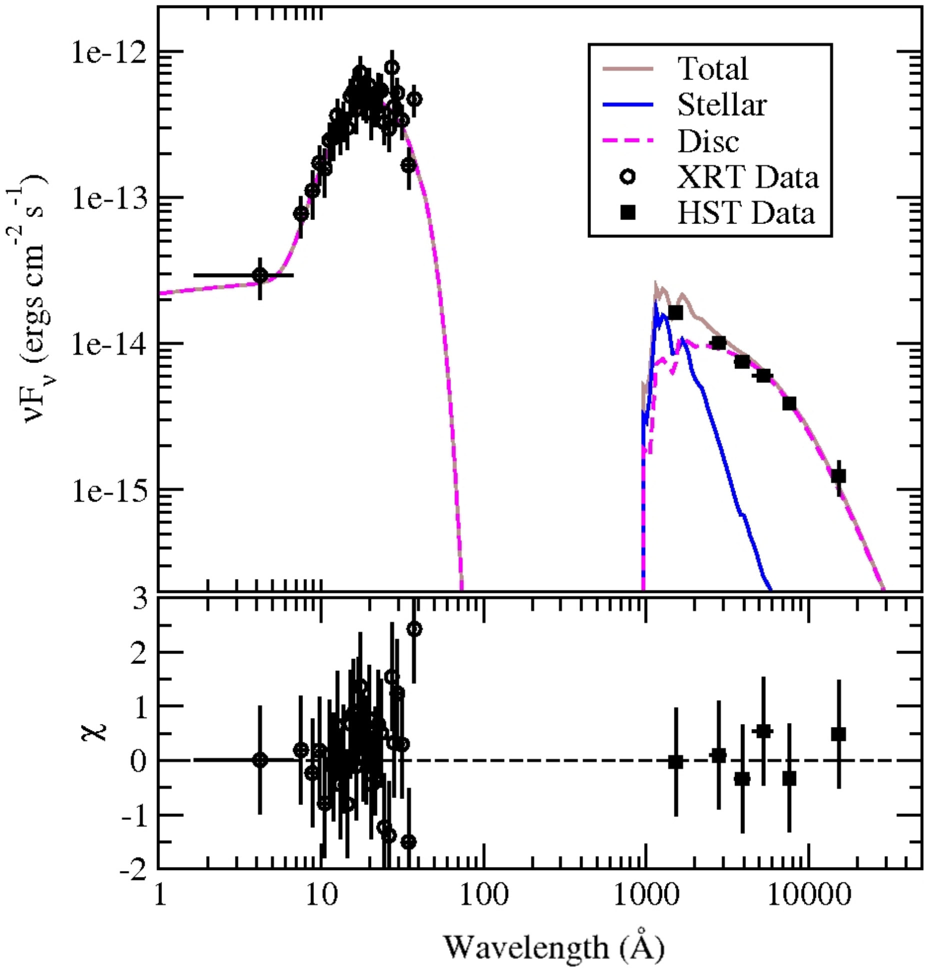
Broad-band Spectral Fitting



- 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 ~10^6 $M_\odot$ (Farrell et al. 2012)
- Can use variability of disc emission to break model degeneracies

Farrell et al. (2012)

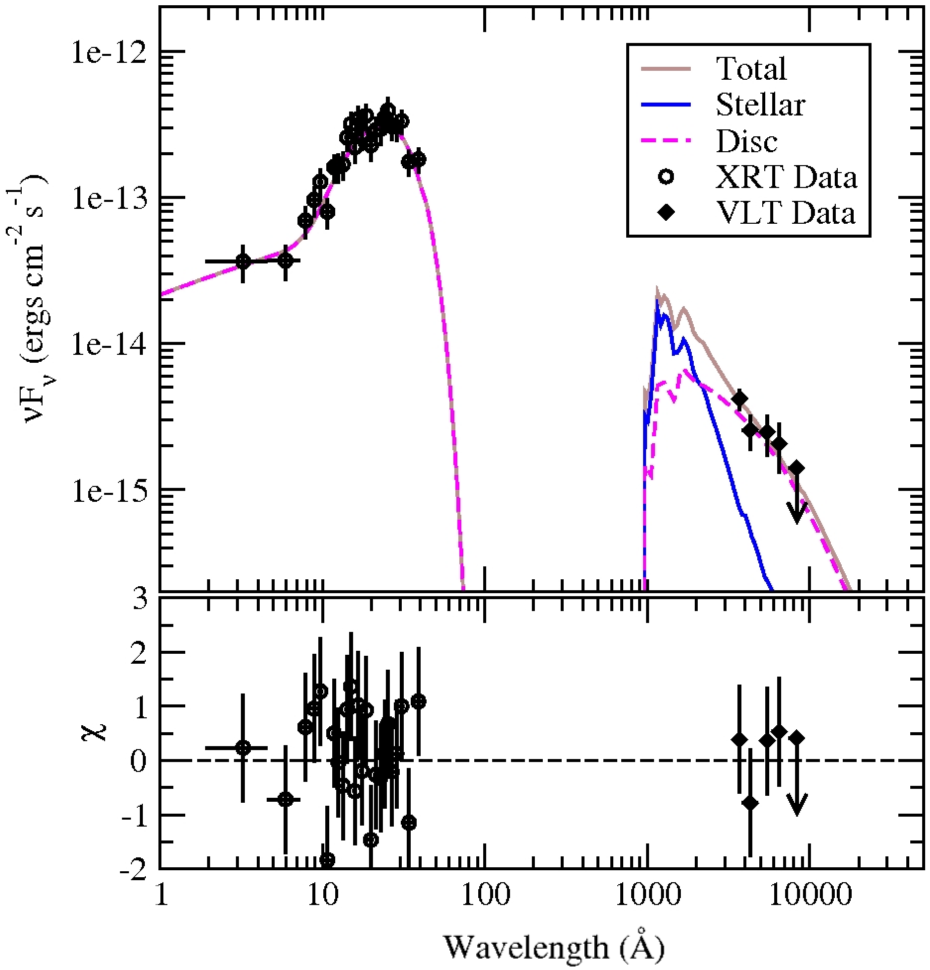
Broad-band Spectral Fitting



- 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

Farrell et al. in prep

Broad-band Spectral Fitting



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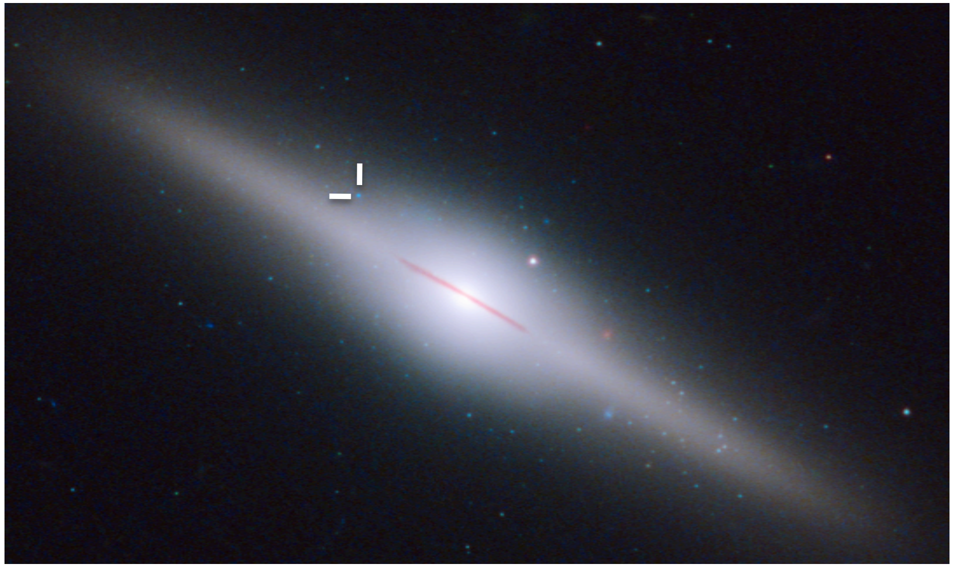
Investigating the origin of HLX-1



HST press release image of ESO 243-49

- 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