Searching for Distant Wandering Massive Black Holes with Chandra

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Intro: Wandering Off-nuclear Massive Black Holes

Produced in various processes, e.g.,:

- Collapse of massive population III stars in the early Universe
- Runaway merging of massive stars in young compact star clusters
- Tidal strip of merging satellite galaxies in minor mergers
- Kicks from major mergers

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Intro: Ultracompact Dwarf

Ultracompact dwarf galaxies (UCDs):

Among the densest stellar systems in the Universe

From tidally stripped merging satellite galaxies?

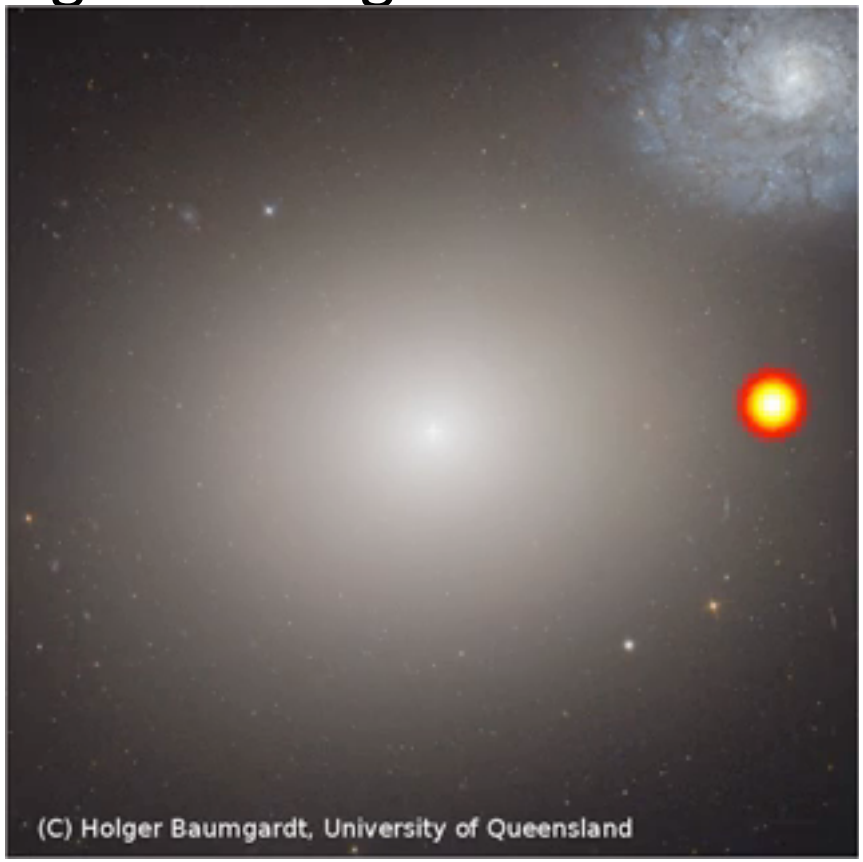
M60-UCD1: rh ~ 24 pc

d=16.5 Mpc

M_{tot} ~ 2X10^8 $M_\odot$

M_{BH} ~ 2X10^7 $M_\odot$

(Strader et al 2013, Seth et al. 2014)



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Intro: Hyperluminous X-ray Sources

Ultraluminous X-ray sources (>10^{39} erg/s):

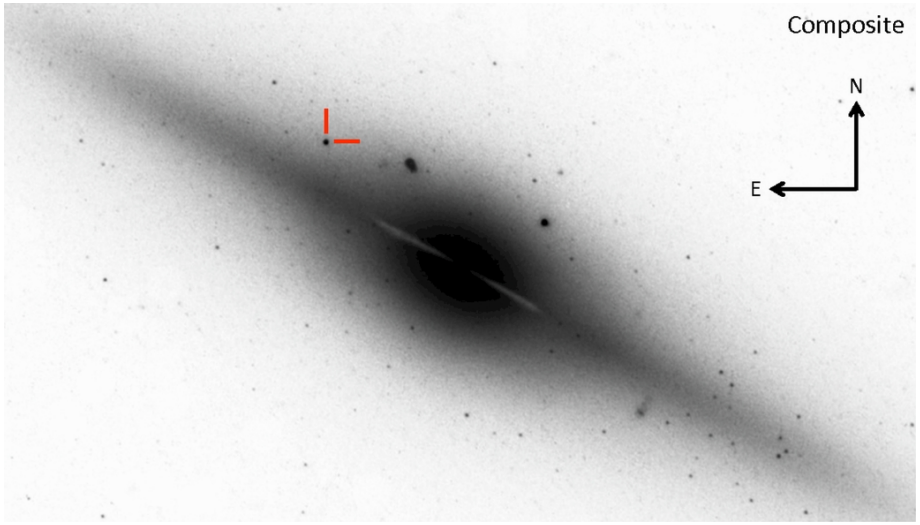
Super-Eddington accreting stellar-mass BH/NS

(Middleton et al. 2012, 2013, Bachetti et al. 2014)

Hyperluminous X-ray sources (HLXs, >10^{41} erg/s):

Intermediate-mass BH (10^2—10^5 $M_\odot$)?

HLX-1: peak L_X ~ 10^{42} erg/s
in a S0 galaxy
d=90 Mpc
M_{BH} ~ 10^4 $M_\odot$



ESO 243-49 HLX-1 (Farrell et al. 2009, 2012)

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New HLX: 3XMM J141711.1+522541

Lin et al. 2016, ApJ, 821, 25

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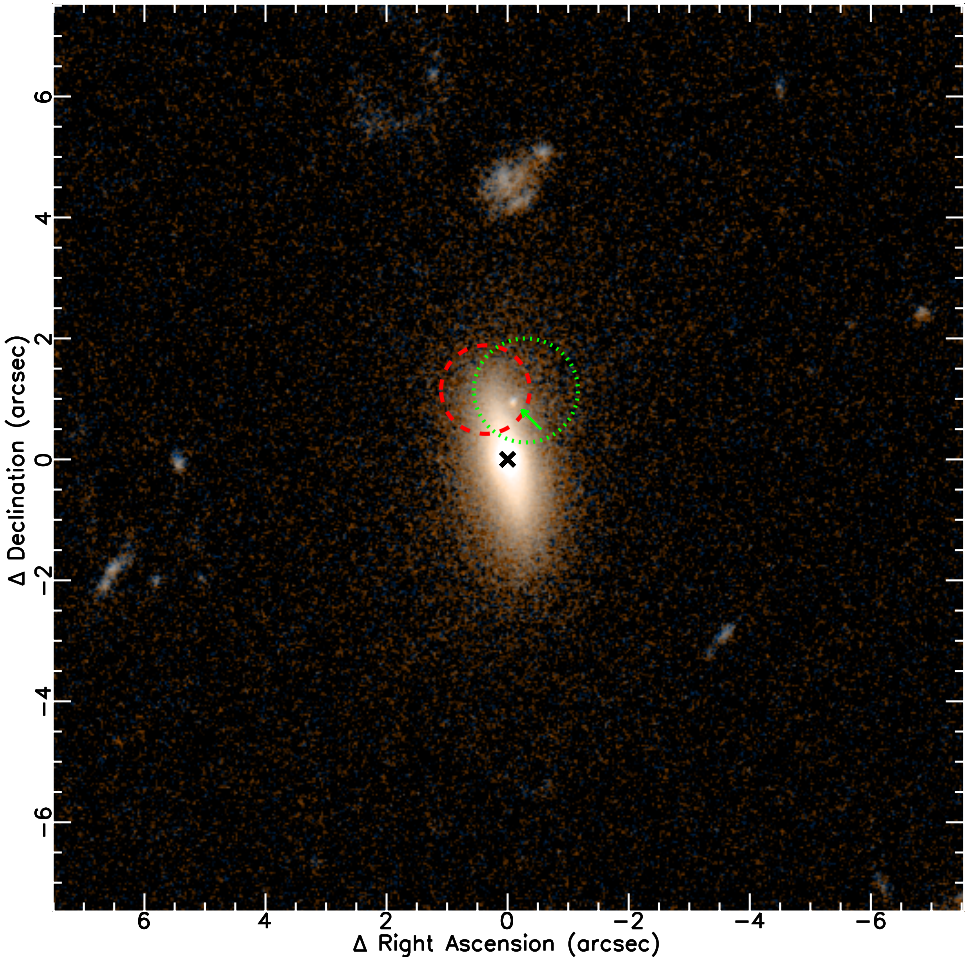
The Host Beyond Gpc

In the Extended Groth Strip
A S0 galaxy
z=0.42, d_L=2.3 Gpc



Red: F814W, blue: F606W

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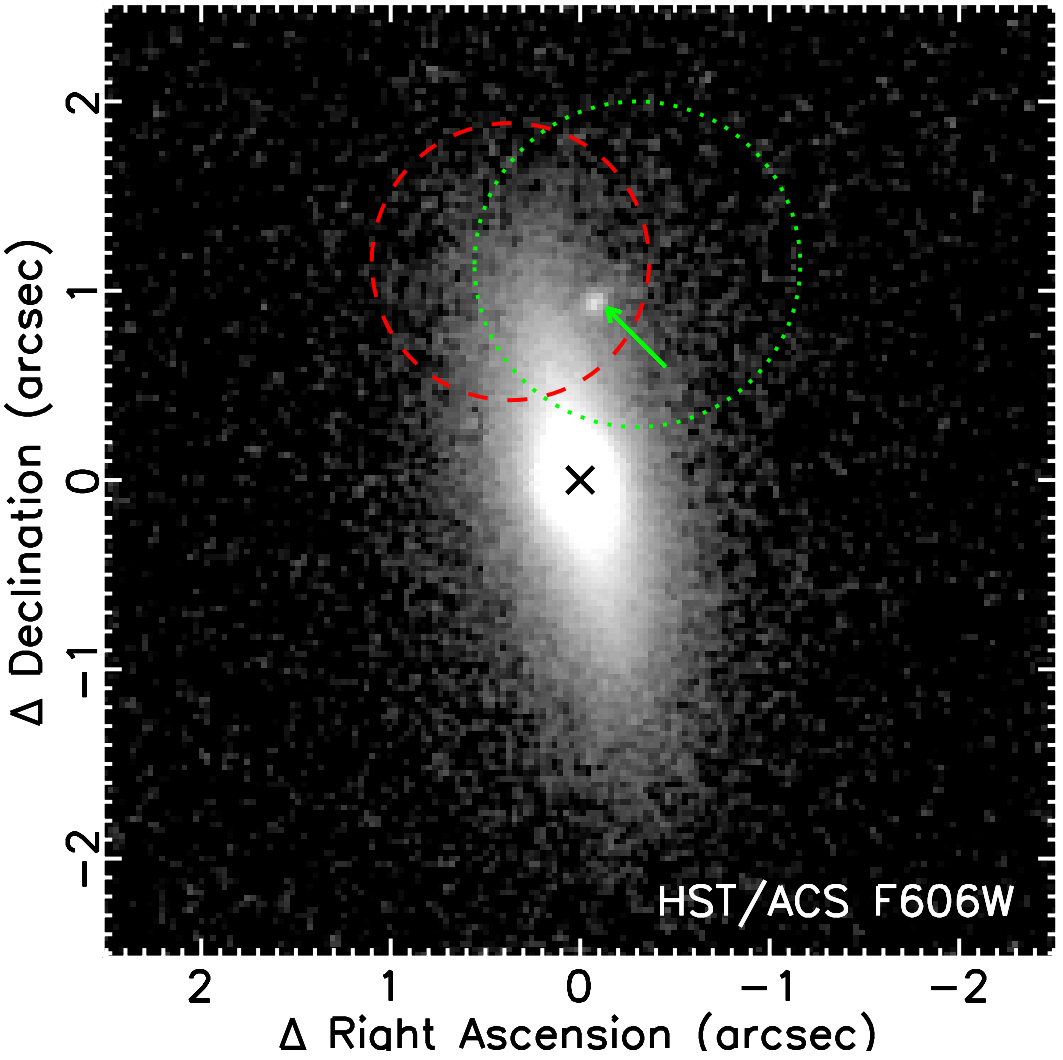
Off-nuclear Nature

In the Extended Groth Strip
A S0 galaxy
z=0.42, d_L=2.3 Gpc

Circles are 95% positional errors
(green: Chandra, red: XMM)



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1 arcsec = 5.5 kpc

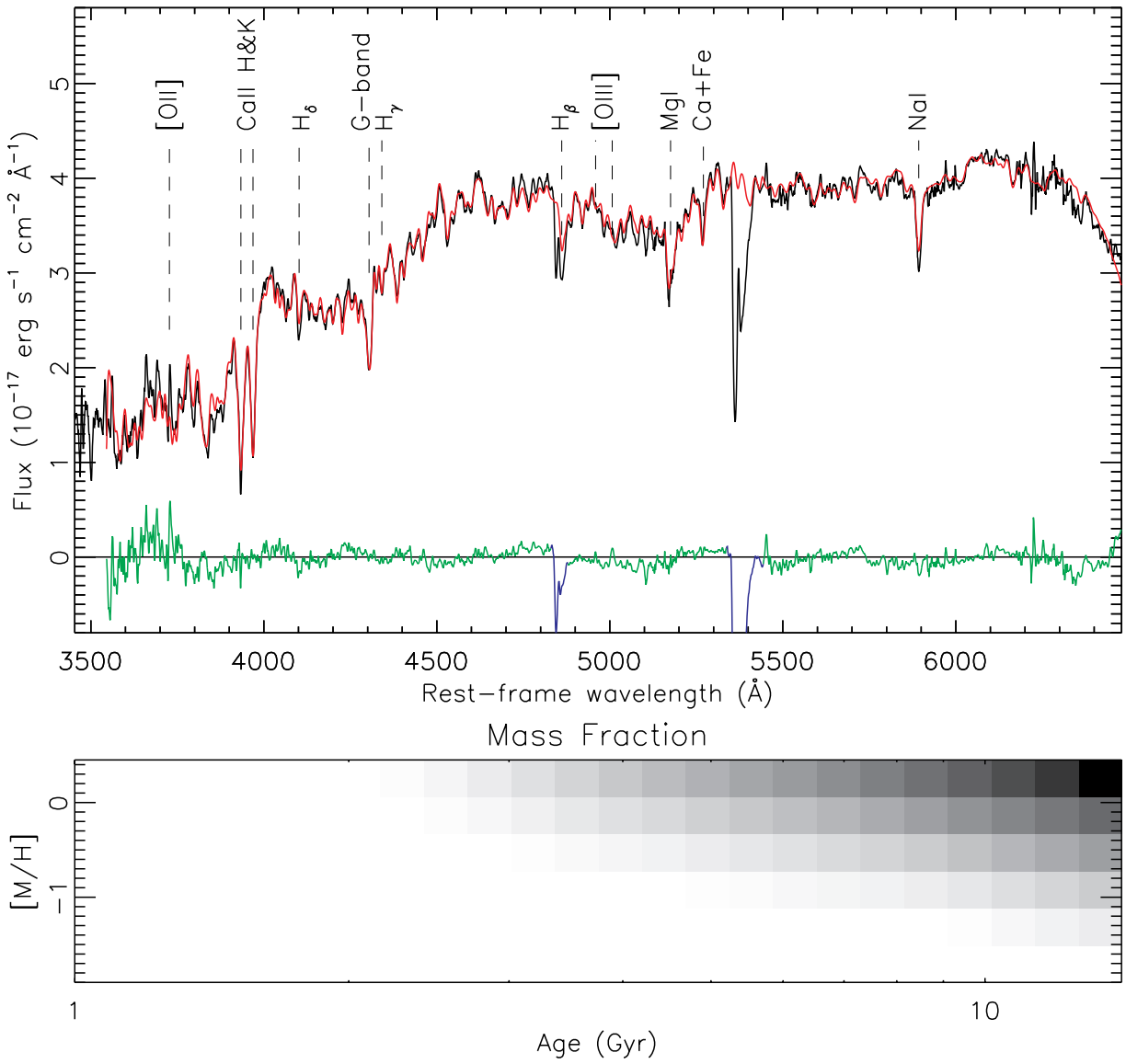
Inactive Host

z=0.42, d_L=2.3 Gpc
Age: 9 Gyr
Mass: 4X10^{11} $M_\odot$
Lum: 3X10^{10} $L_\odot$
L_{OIII} < 2.3X10^{39} erg/s

→L_{bol}<2X10^{41} erg/s

$\sigma_\star$ ~ 247 km/s

→M_{BH}~ 4X10^8 $M_\odot$



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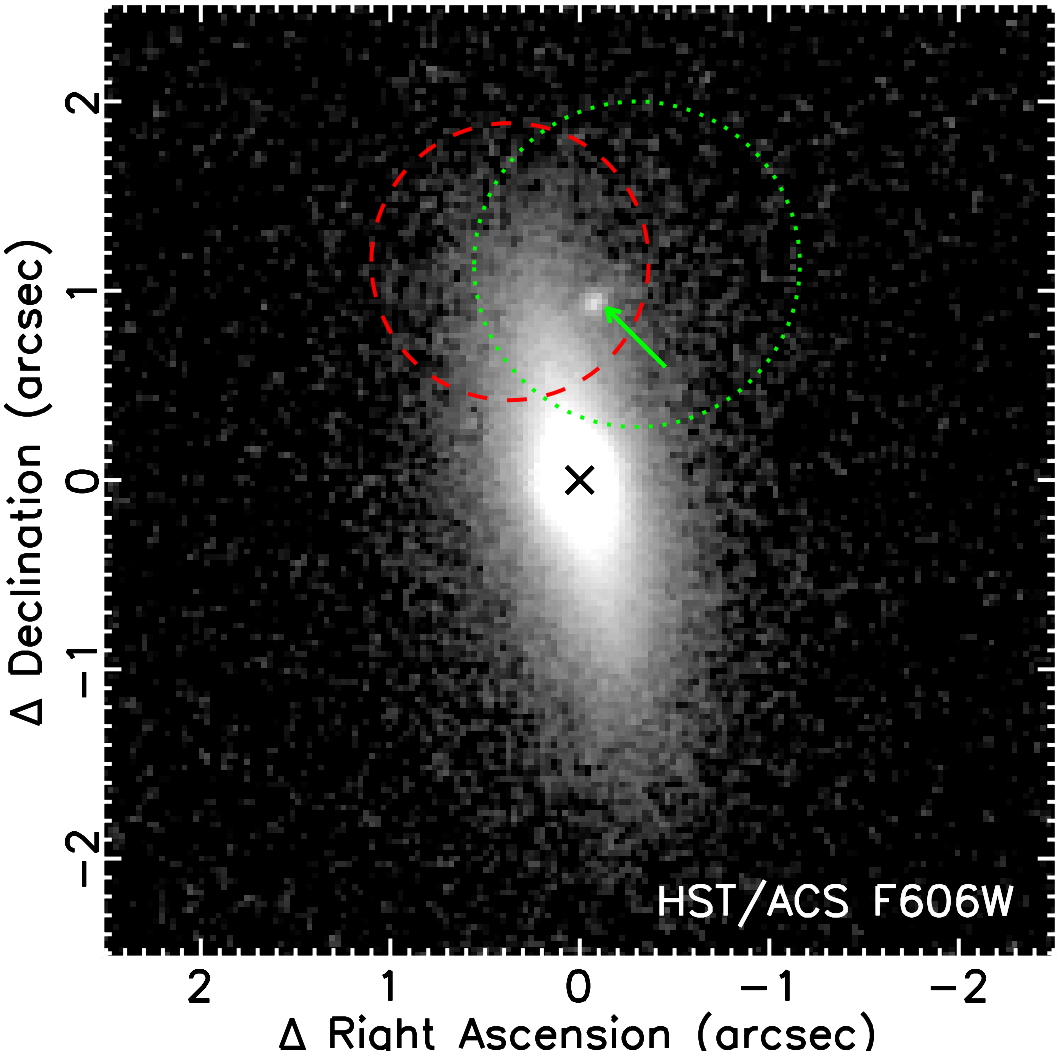
Ultra-compact Optical Counterpart

Projected Offset:
0.94 arcsec=5.2 kpc
Mass: ~6X10^7 $M_\odot$
Lum: ~6X10^8 $L_\odot$
R_{eff}: < 100 pc
→Ultra-compact dwarf (UCD)



1 arcsec = 5.5 kpc

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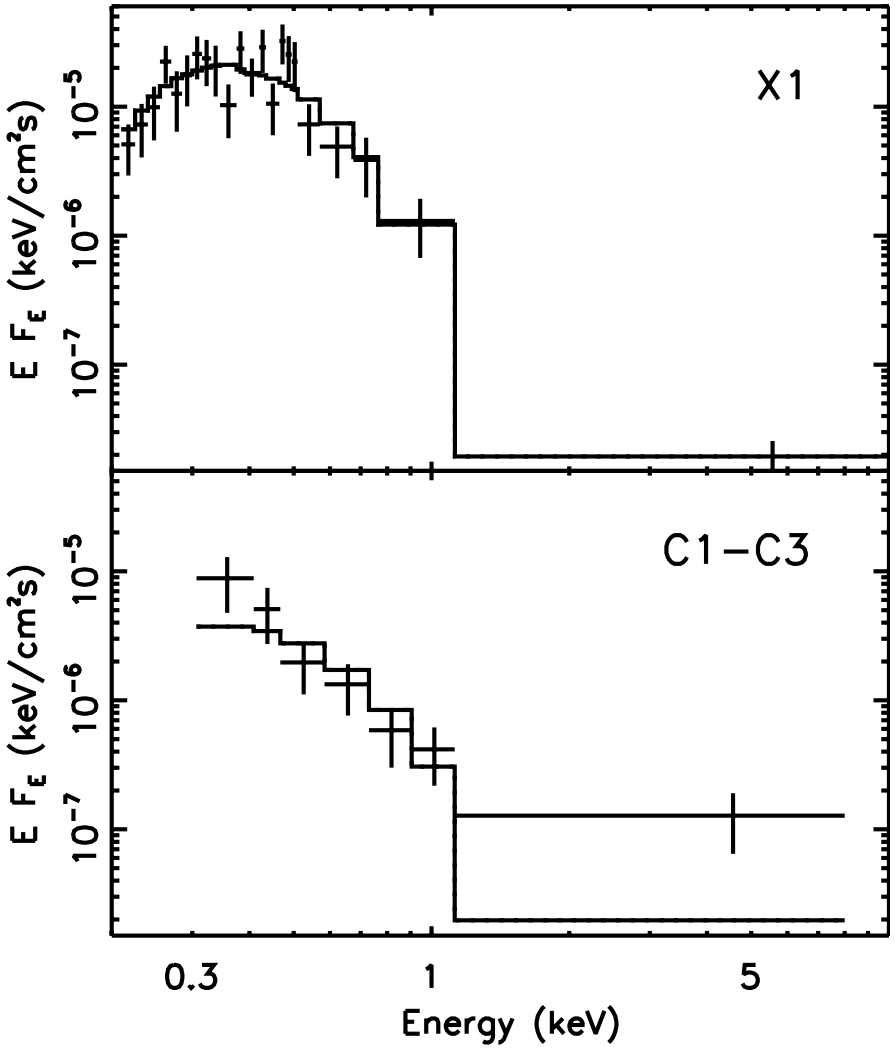
Ultrasoft X-ray Spectra



2000 July

kT_{disk}=0.13±0.02 keV

L_X=3.8X10^{43} erg/s

2002 Aug

kT_{disk}=0.17±0.04 keV

L_X=0.5X10^{43} erg/s

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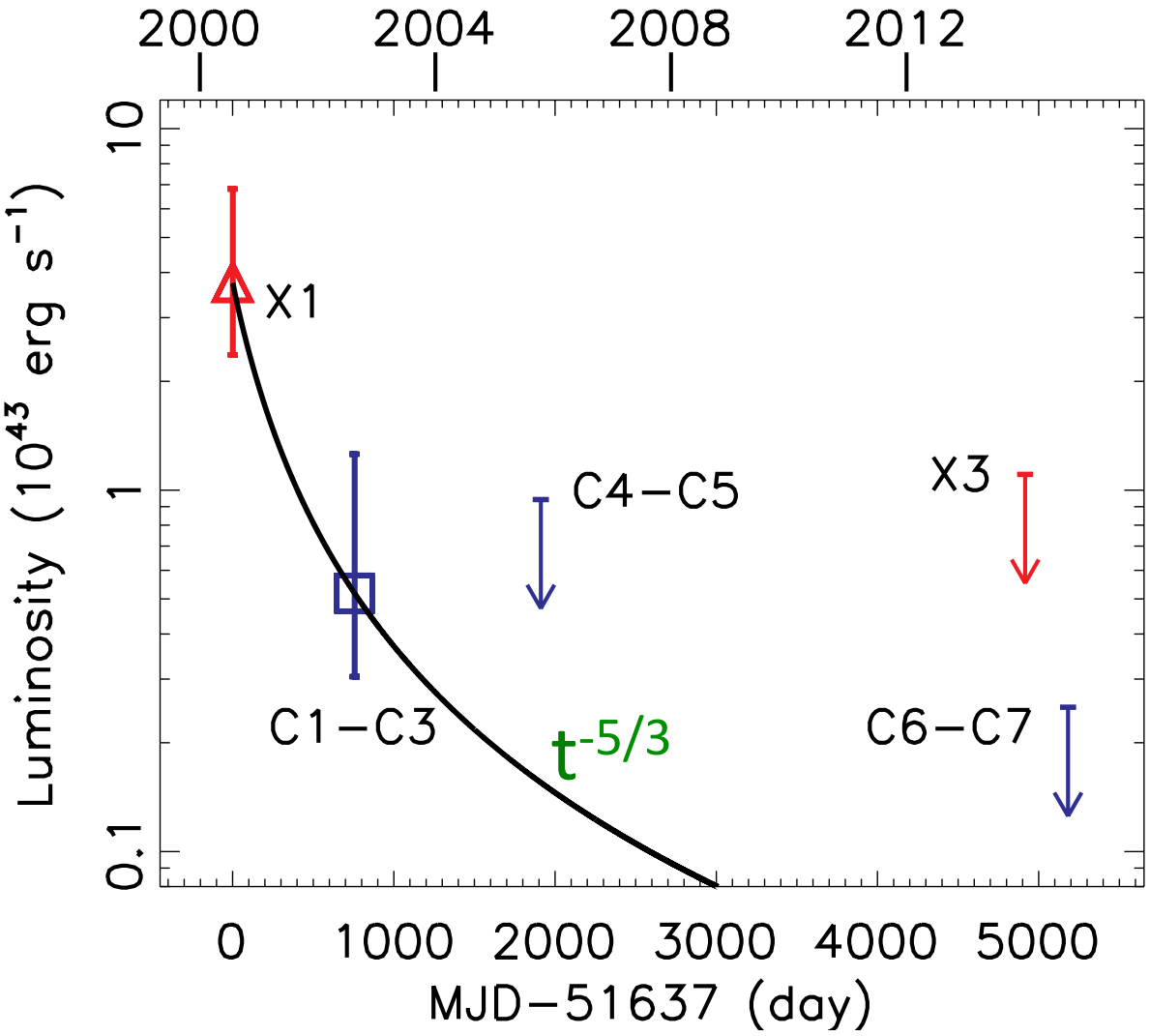
Luminosity Curve: Caught in Outburst

Undetected later
→Variation factor >14



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Source Nature

- An off-nuclear massive compact counterpart
- The ultrasoft X-ray outburst
- Peak L_X implies a BH of ~10^5 $M_\odot$

→ A massive BH embedded in the nucleus of a stripped satellite galaxy with the X-ray outburst due to tidal disruption of a surrounding star by the BH

Lin et al. 2016, ApJ, 821, 25

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Source Nature

NOT from the nucleus of the host galaxy:

- Position inconsistency
- X-ray spectra too soft to be from standard AGNs
- Nuclear inactivity from optical spectrum
- Central SMBH too massive to disrupt the star outside the event horizon

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Search with Chandra

- New era of discovering wandering massive BHs beyond Gpc, especially through detection of off-nuclear tidal disruption events (Komossa et al 2008)
- Special sources unlike AGNs: off-nuclear HLXs, large X-ray to optical ratio, highly variable, soft X-ray spectra
- Require Chandra's high angular resolution and low background

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Thanks You

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