The accreting intermediate mass black hole candidate ESO 243-49 HLX-1

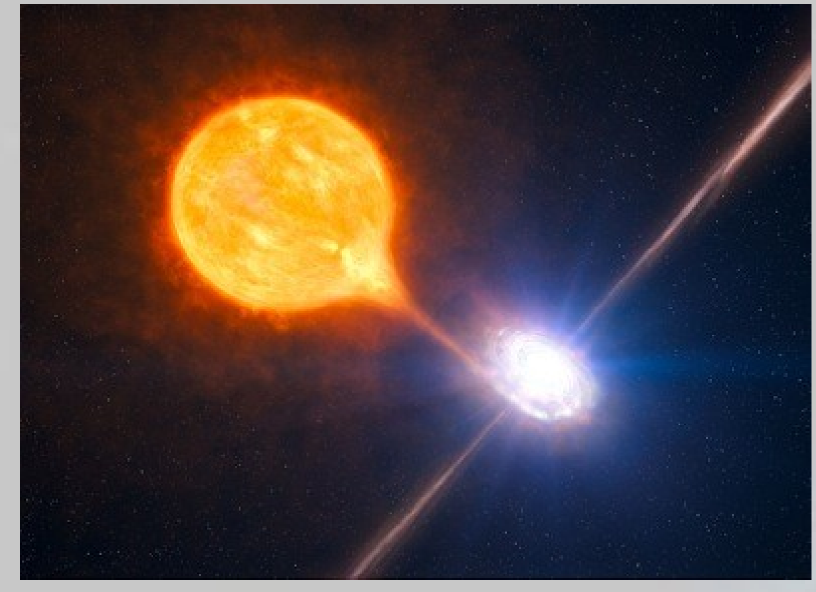
Natalie Webb

astrophysique & planétologie

Institut de Recherche en Astrophysique et Planétologie
Toulouse, France

T. Alexander, F. Antonini, D. Barret, S. Corbel, D. Cseh, G. Dubus, S. Farrell, R. Fender, N. Gehrels, O. Godet, A. Graham, T. Kawaguchi, C. Knigge, J.-P. Lasota, E. Lenc, D. Lin, J. Lombardi, T. Maccarone, M. Servillat, O. Straub, J. Vingless

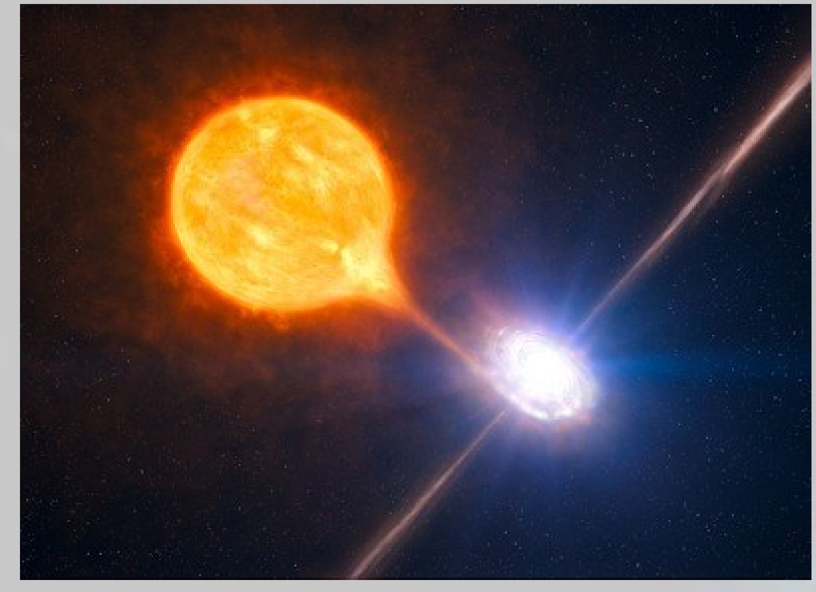
Scientific rationale



Stellar mass: ~3-20 $M_\odot$

Supermassive:~10^{6-10} $M_\odot$ (SMBH)

Scientific rationale

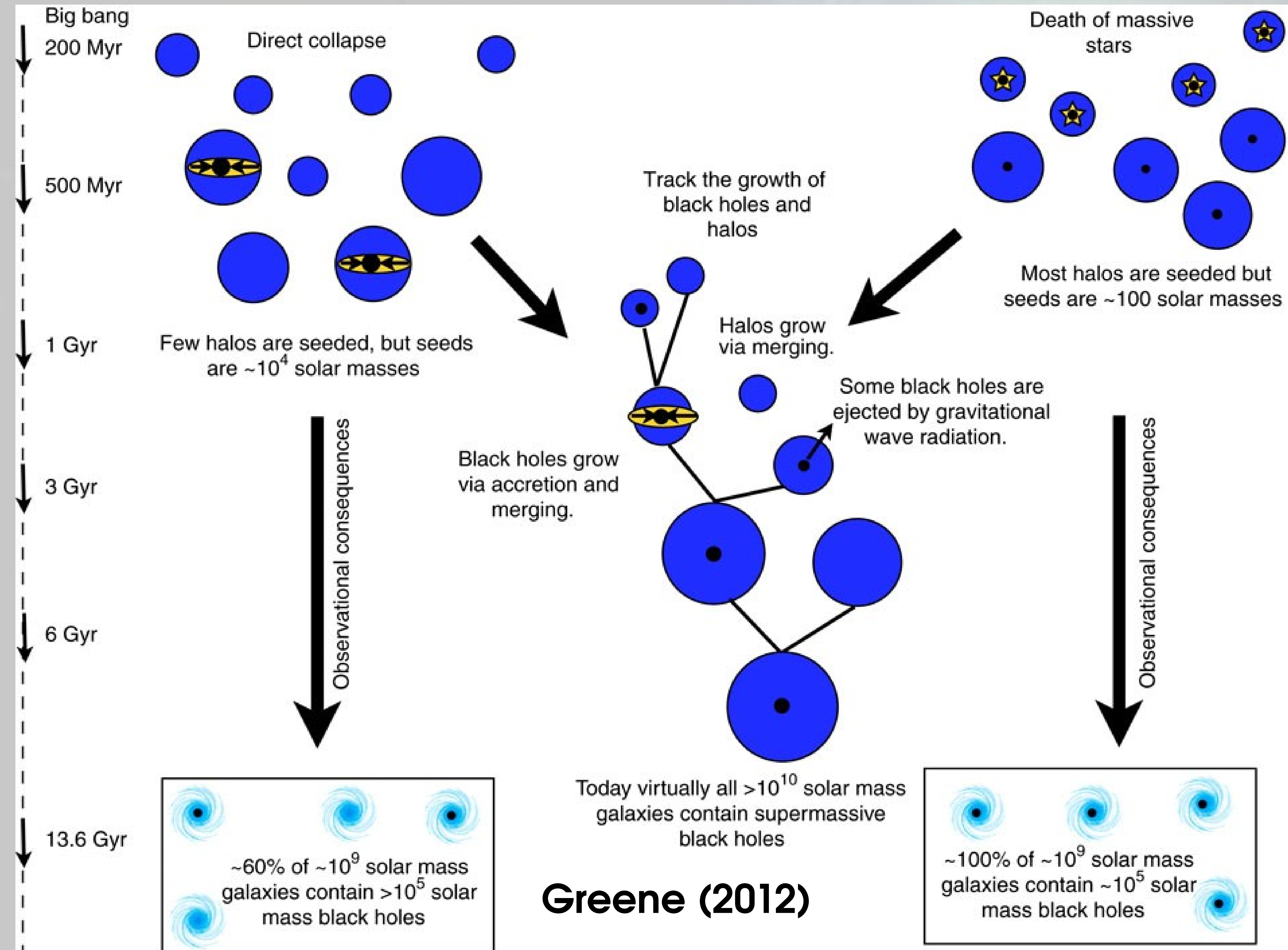


Stellar mass: ~3-20 $M_\odot$

Intermediate mass: $\sim 10^{2\text{-}5}\ M_\odot$ (IMBH)

Supermassive: $\sim 10^{6\text{-}10}\ M_\odot$ (SMBH)

IMBH are thought to play a major role in the formation of SMBH


Big bang
200 Myr
500 Myr
1 Gyr
3 Gyr
6 Gyr
13.6 Gyr
Direct collapse
Few halos are seeded, but seeds are ~10^4 solar masses
Observational consequences
~60% of ~10^9 solar mass galaxies contain >10^5 solar mass black holes
Track the growth of black holes and halos
Halos grow via merging.
Some black holes are ejected by gravitational wave radiation.
Black holes grow via accretion and merging.
Today virtually all >10^{10} solar mass galaxies contain supermassive black holes
Death of massive stars
Most halos are seeded but seeds are ~100 solar masses
Observational consequences
~100% of ~10^9 solar mass galaxies contain ~10^5 solar mass black holes

Greene (2012)

Searching for new compact objects

XMM-Newton
SURVEY SCIENCE CENTRE

2XMM : 22nd August 2007
– 191870 unique sources

2XMMi (DR3) : 15th April 2010
– 262902 unique sources

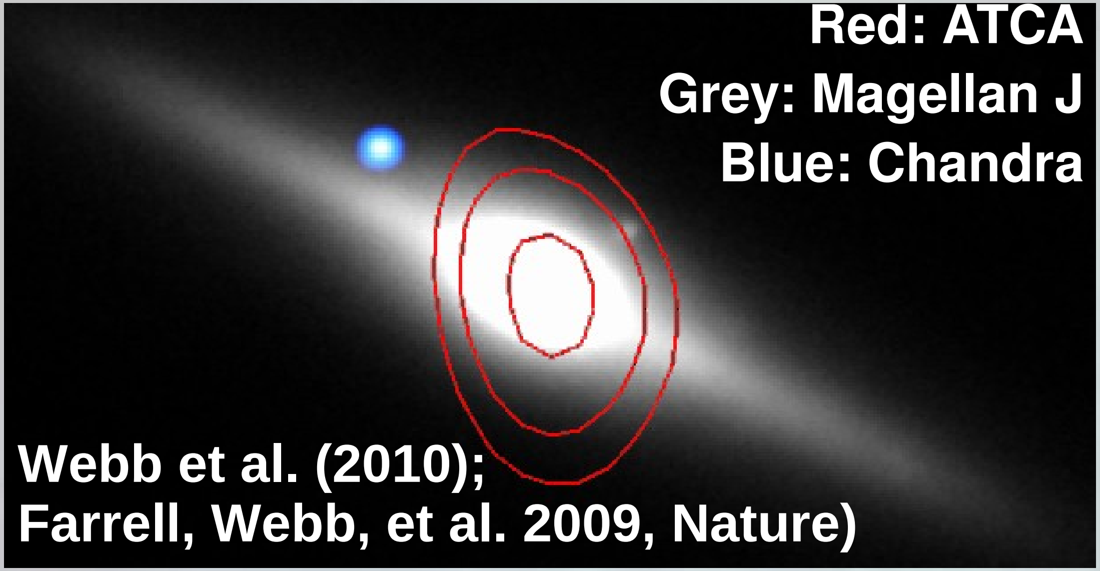
3XMM (DR4) : 23rd July 2013
– 372278 unique sources

See poster I 10

Watson et al. (2009)

HLX-1

2XMM J011028.1-460421
Spectrum, Γ= 3.4±0.3
~8” from nucleus of ESO 243-49 (z=0.0224, ~95 Mpc)



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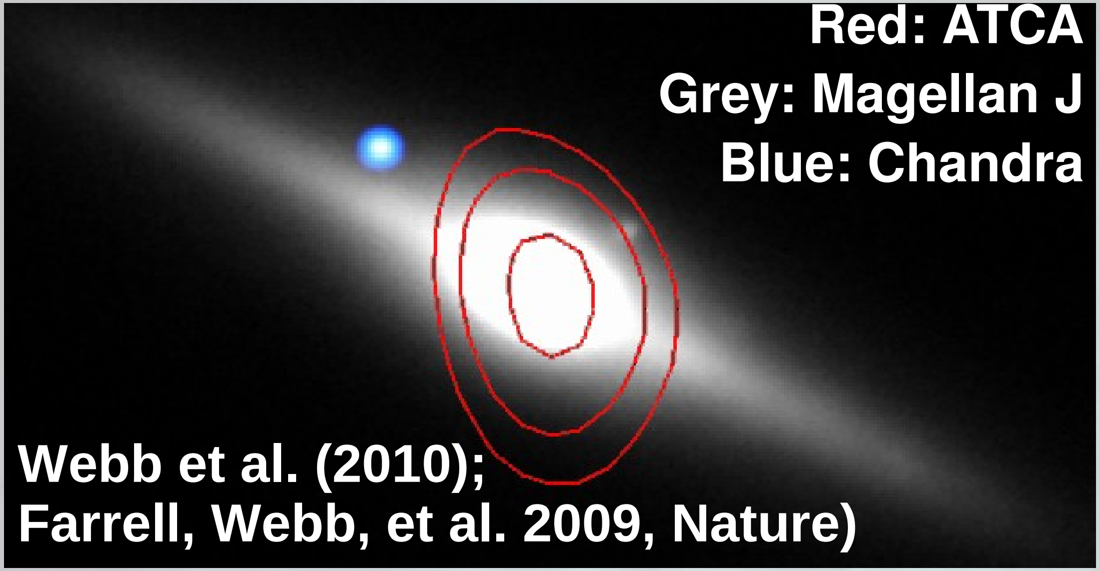

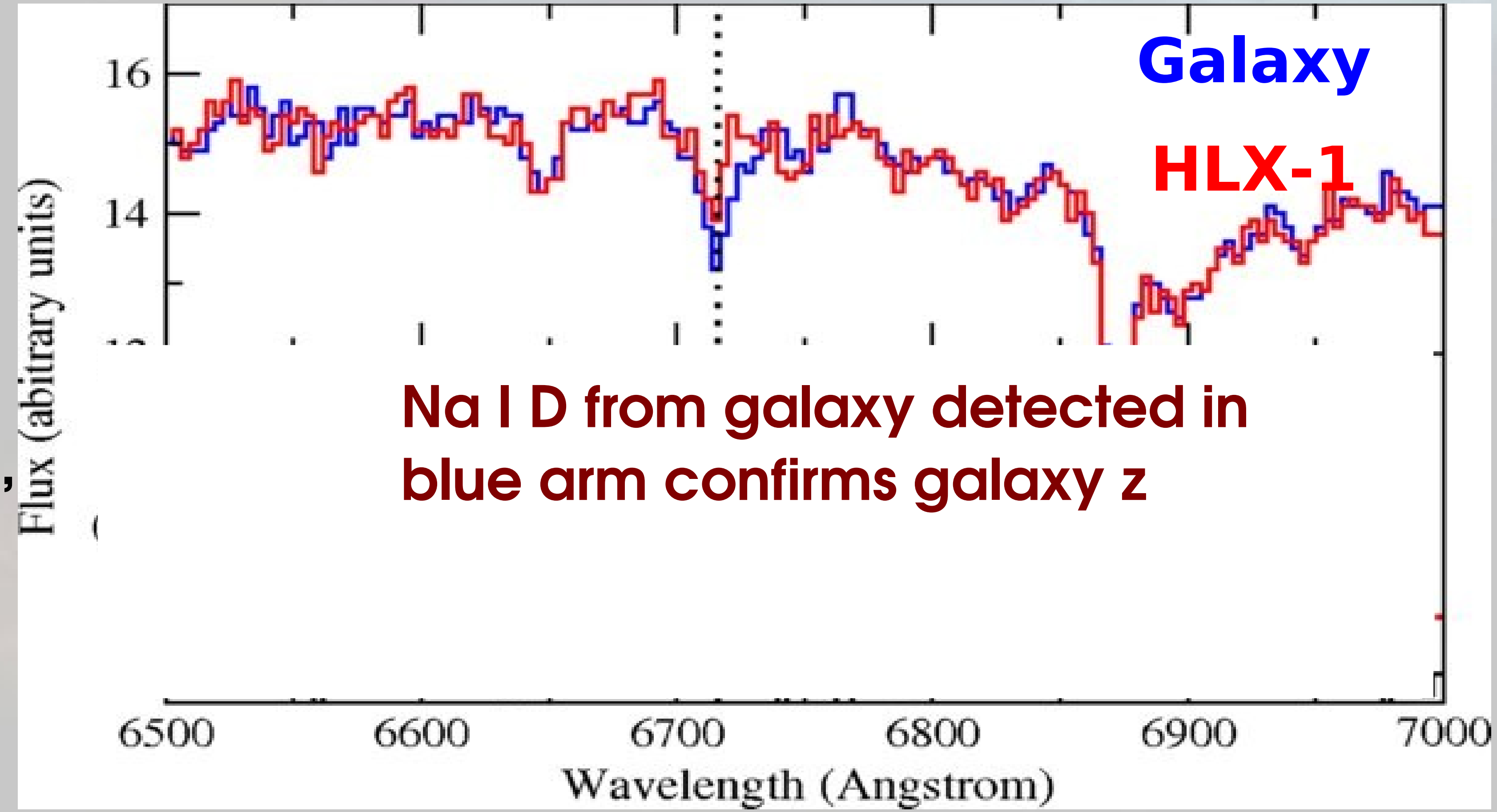

(Wiersema, Farrell, Webb, et al., 2010)

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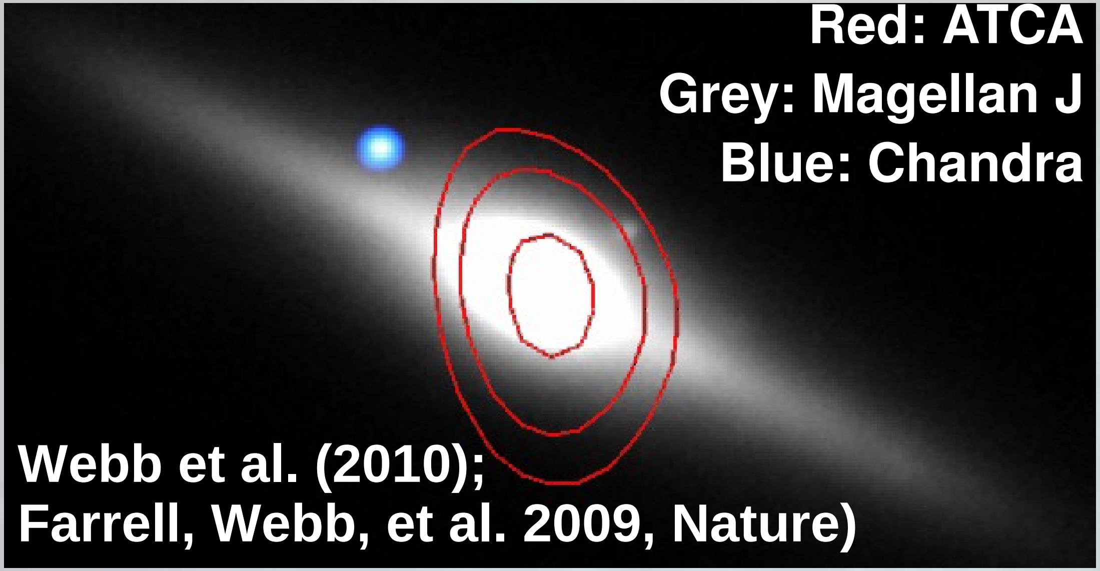

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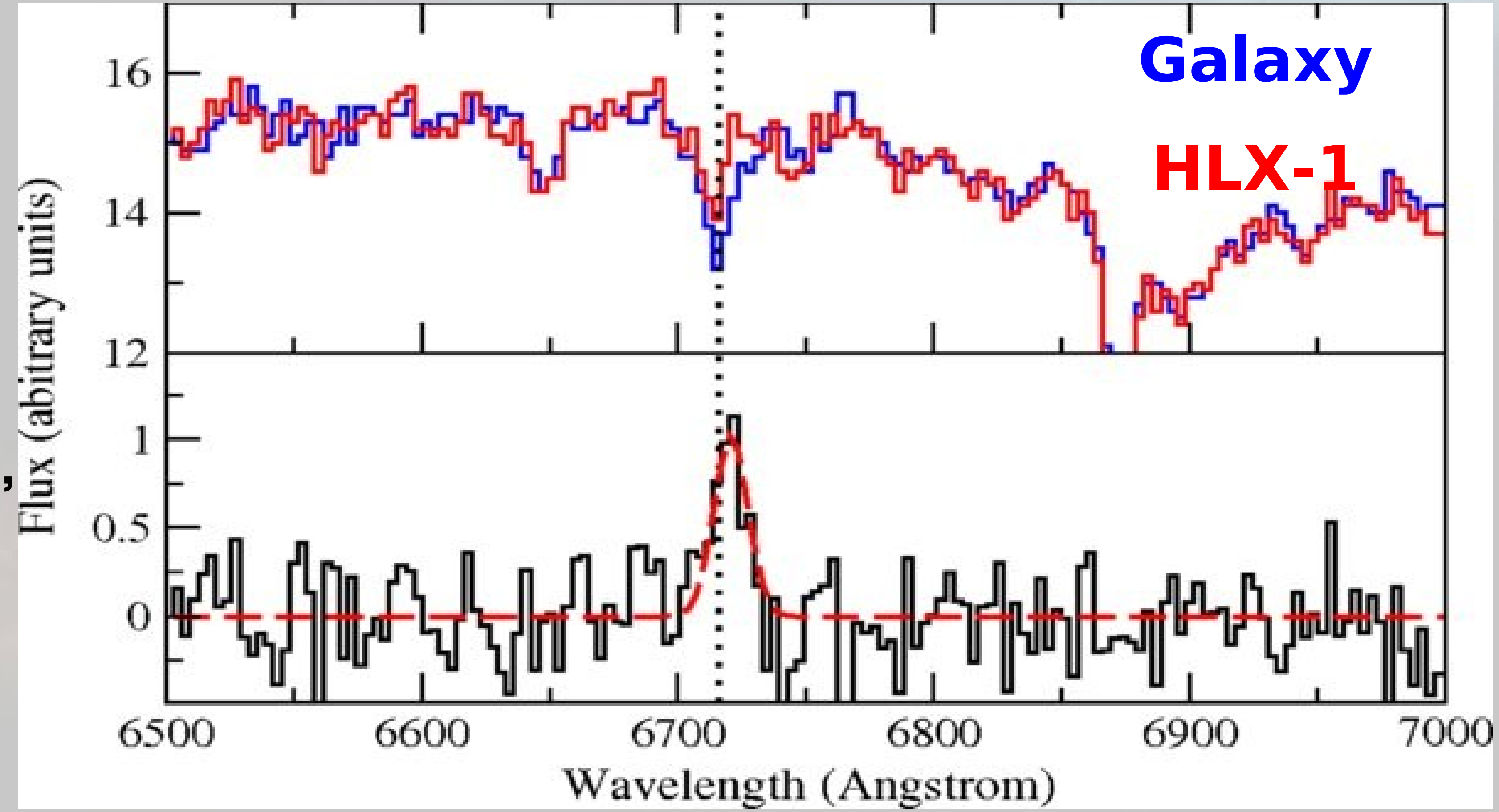

HLX-1 X-ray luminosity

Associated with ESO 243-49 => $L_x = 1.1 \times 10^{42}$ erg s^{-1} (0.2-10.0 keV)

=> from the Eddington luminosity (L_{Edd}), $M = 5000\ M_\odot$

Superceding L_{Edd} by a factor 10 (Begelman 02) => $M > 500\ M_\odot$

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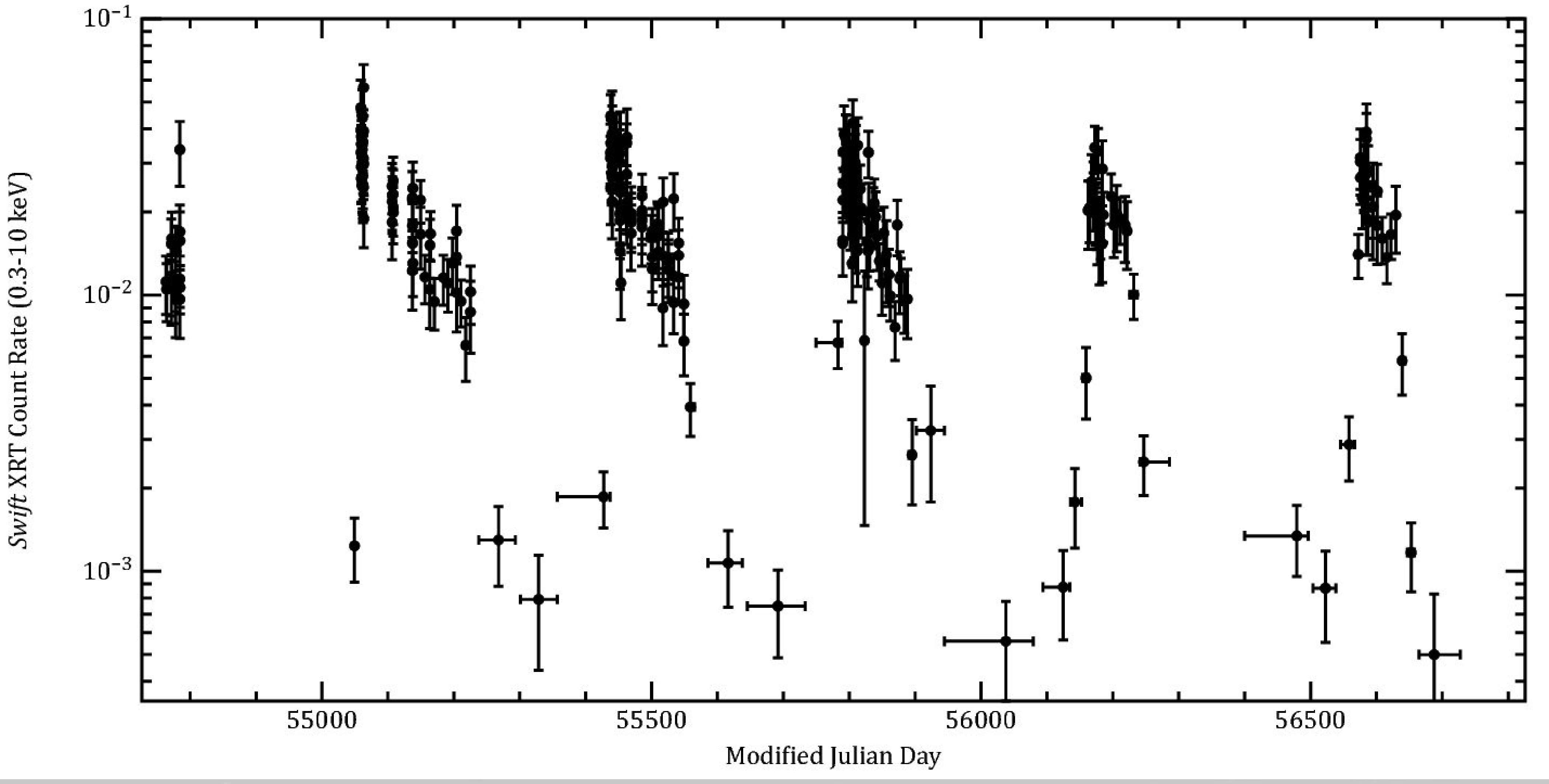
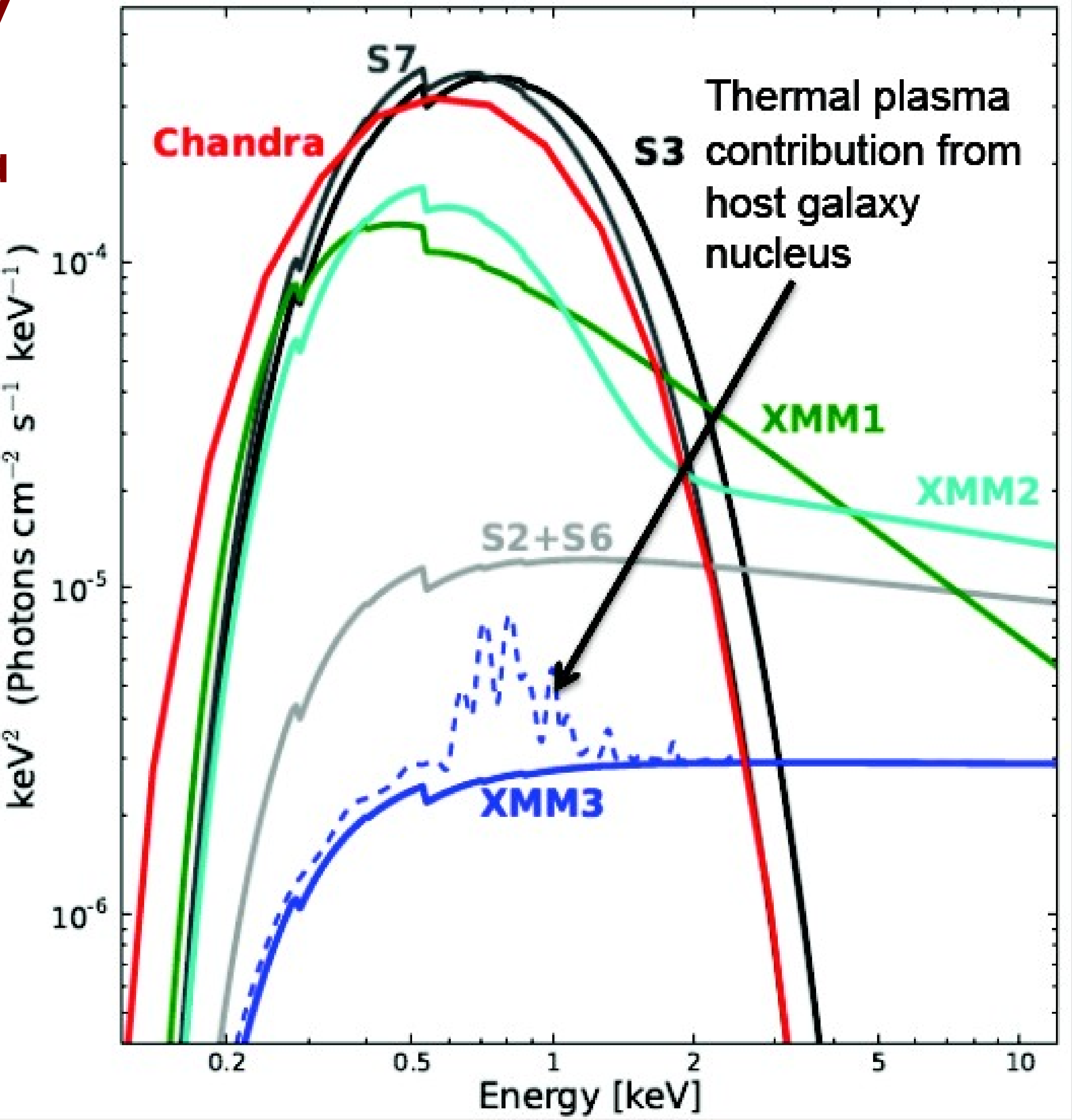


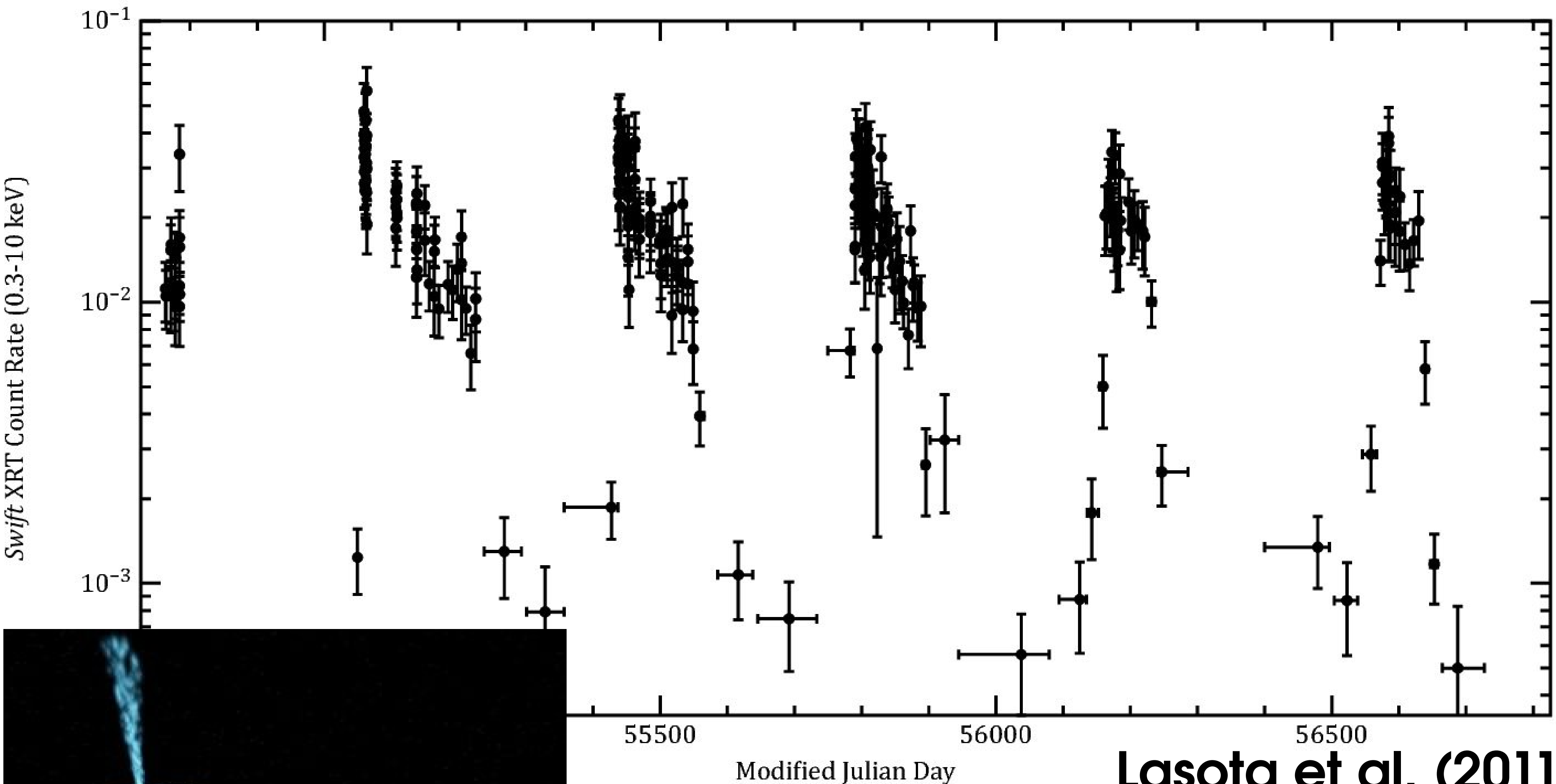
X-ray variability

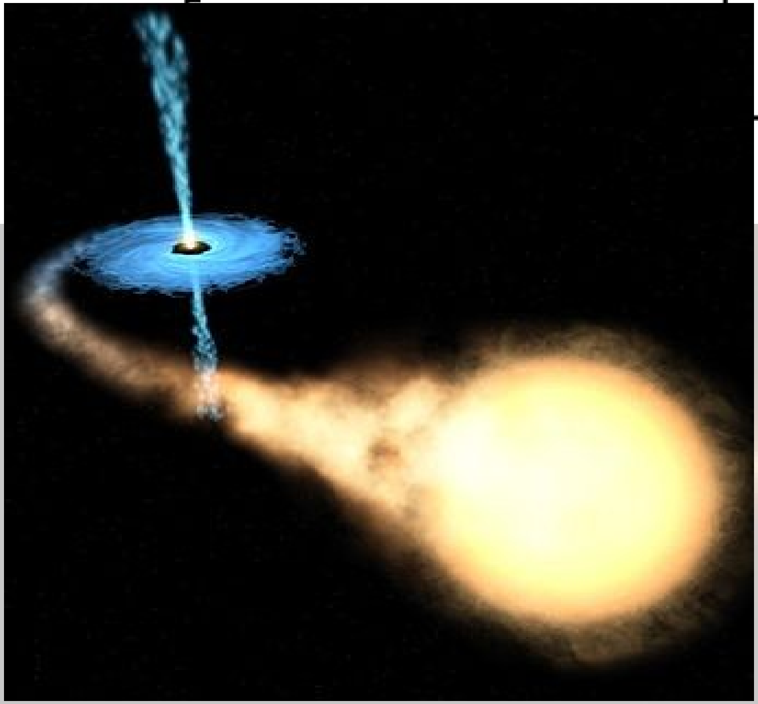
Fitting thermally dominated spectra with relativistic models (BHSPEC, KERRBB, slimbh, Kawaguchi, 2003) constrains mass to 10^3 - 10^5 $M_\odot$

Accretion sub/ near Eddington

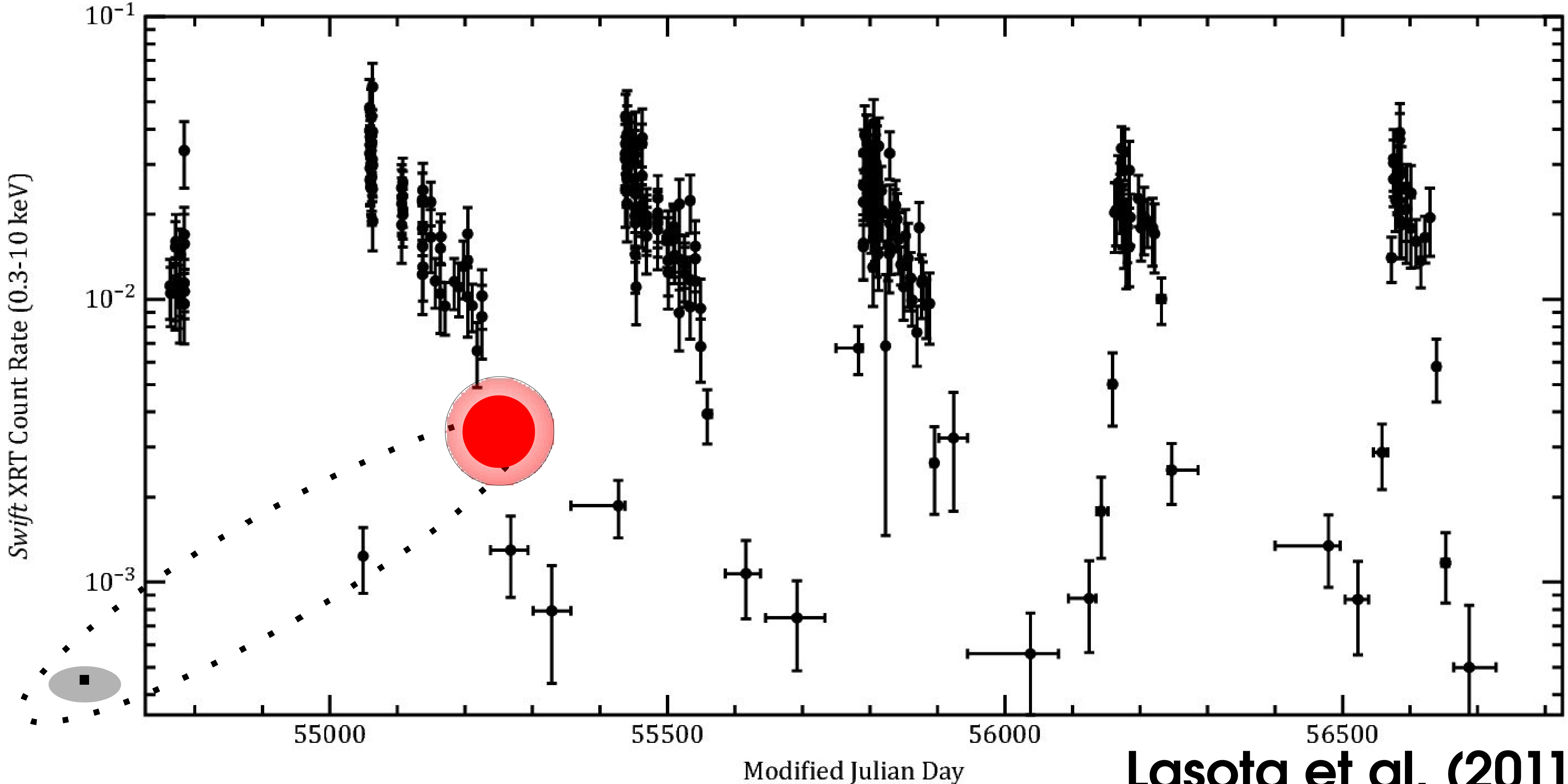
(Godet et al., 2009; Davis et al., 2011; Servillat et al., 2011; Godet et al., 2012 Straub et al. sub)







Lasota et al. (2011)



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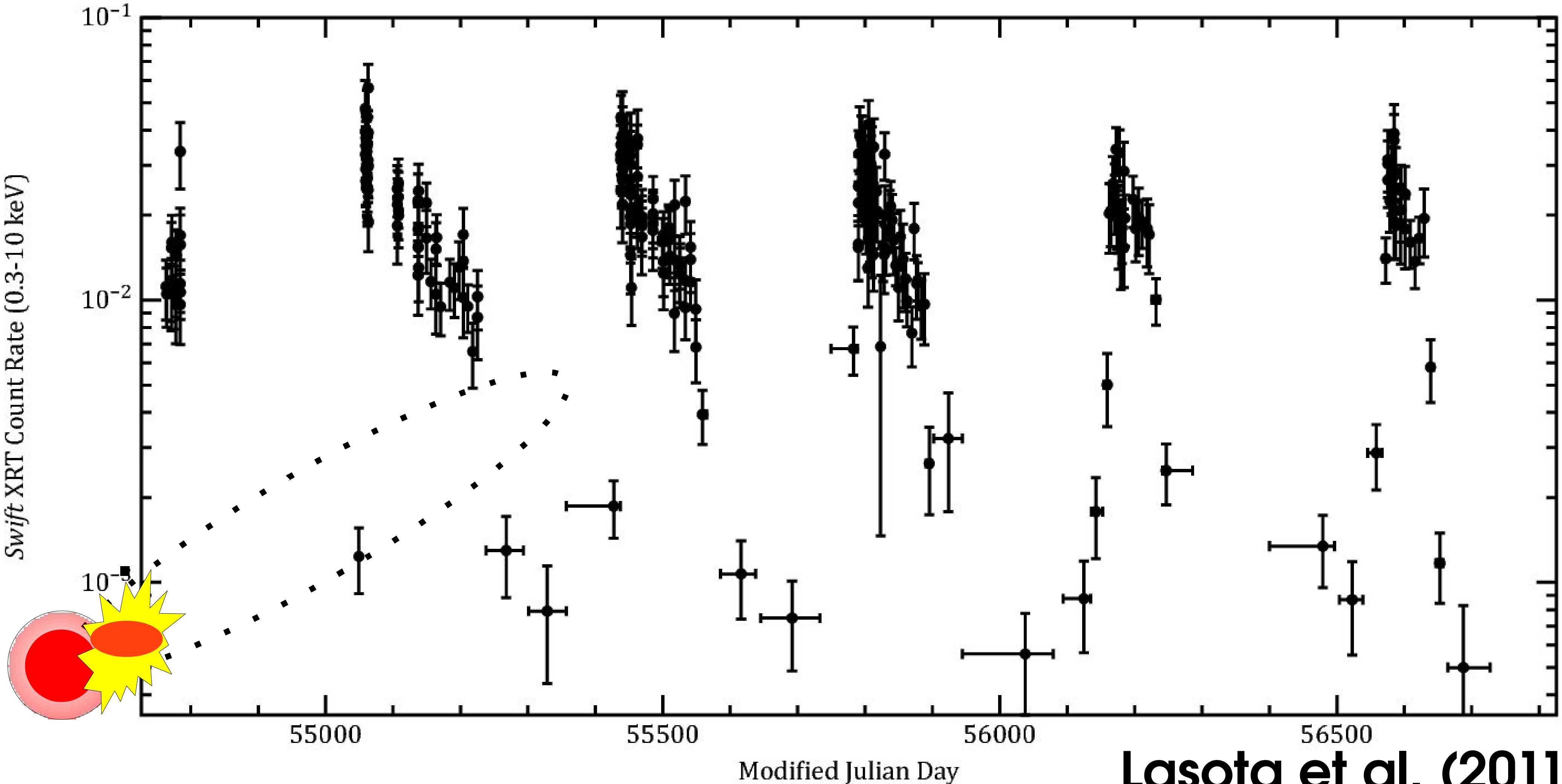
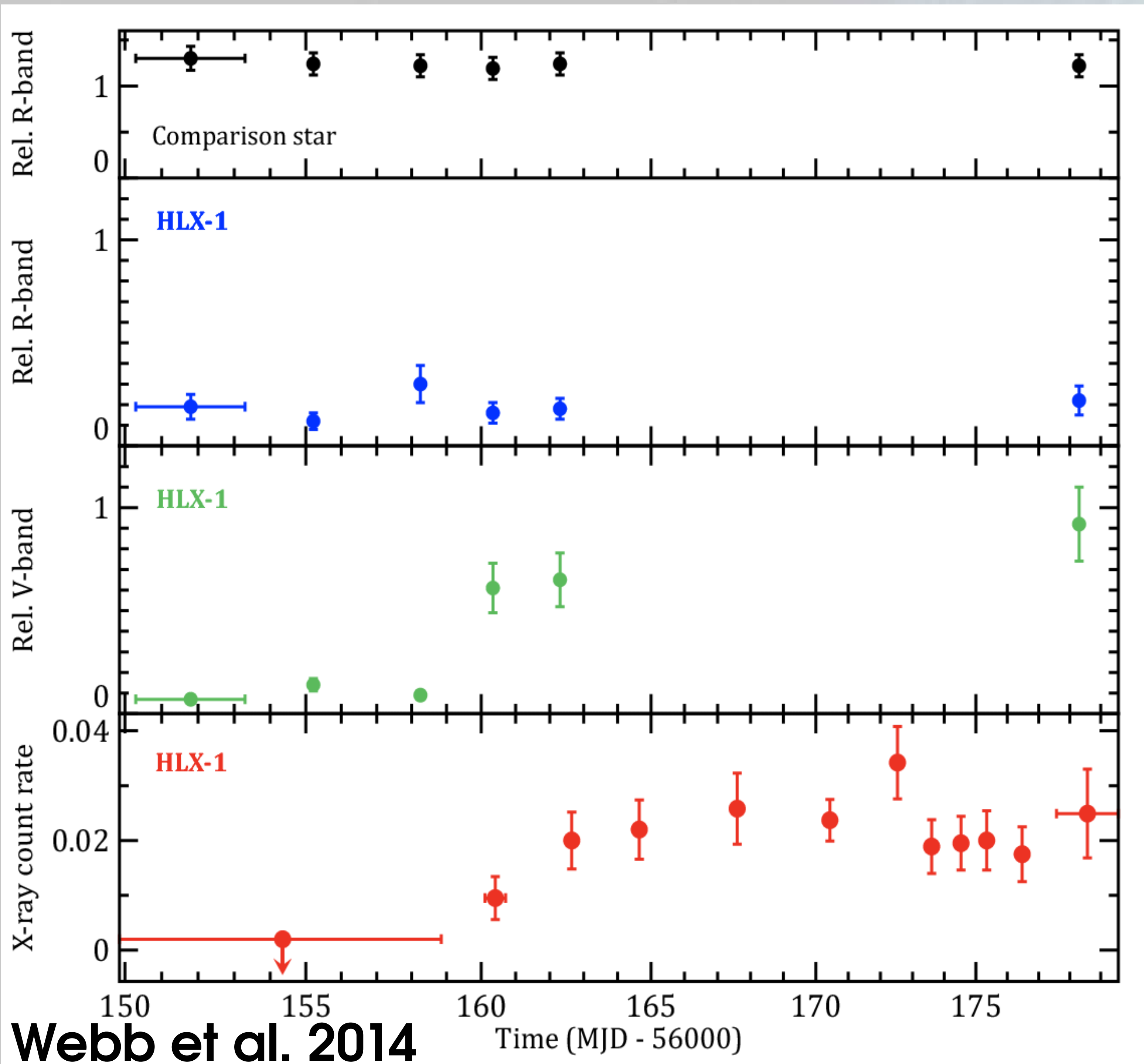


Lasota et al. (2011)

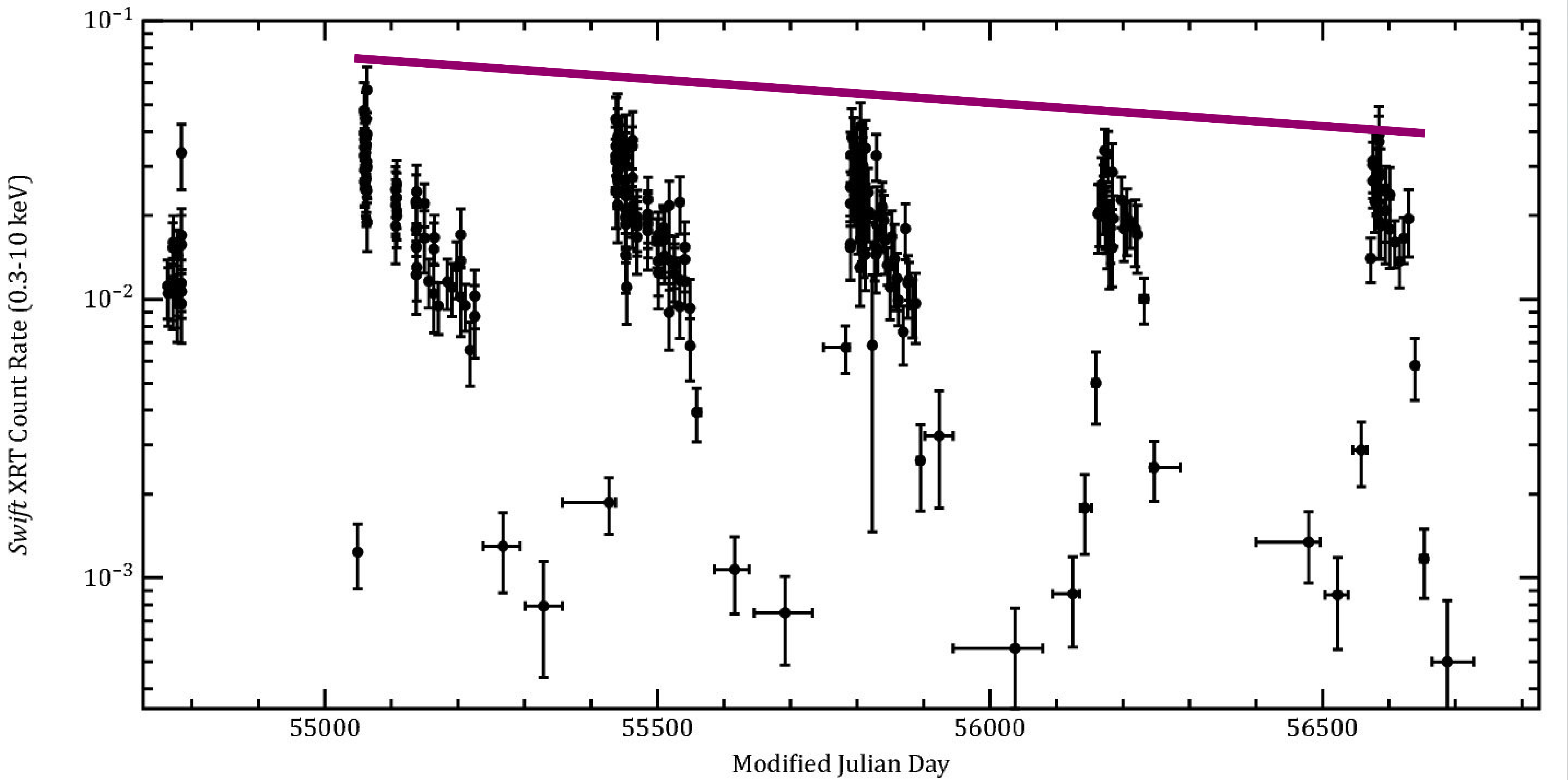
Outburst 2012



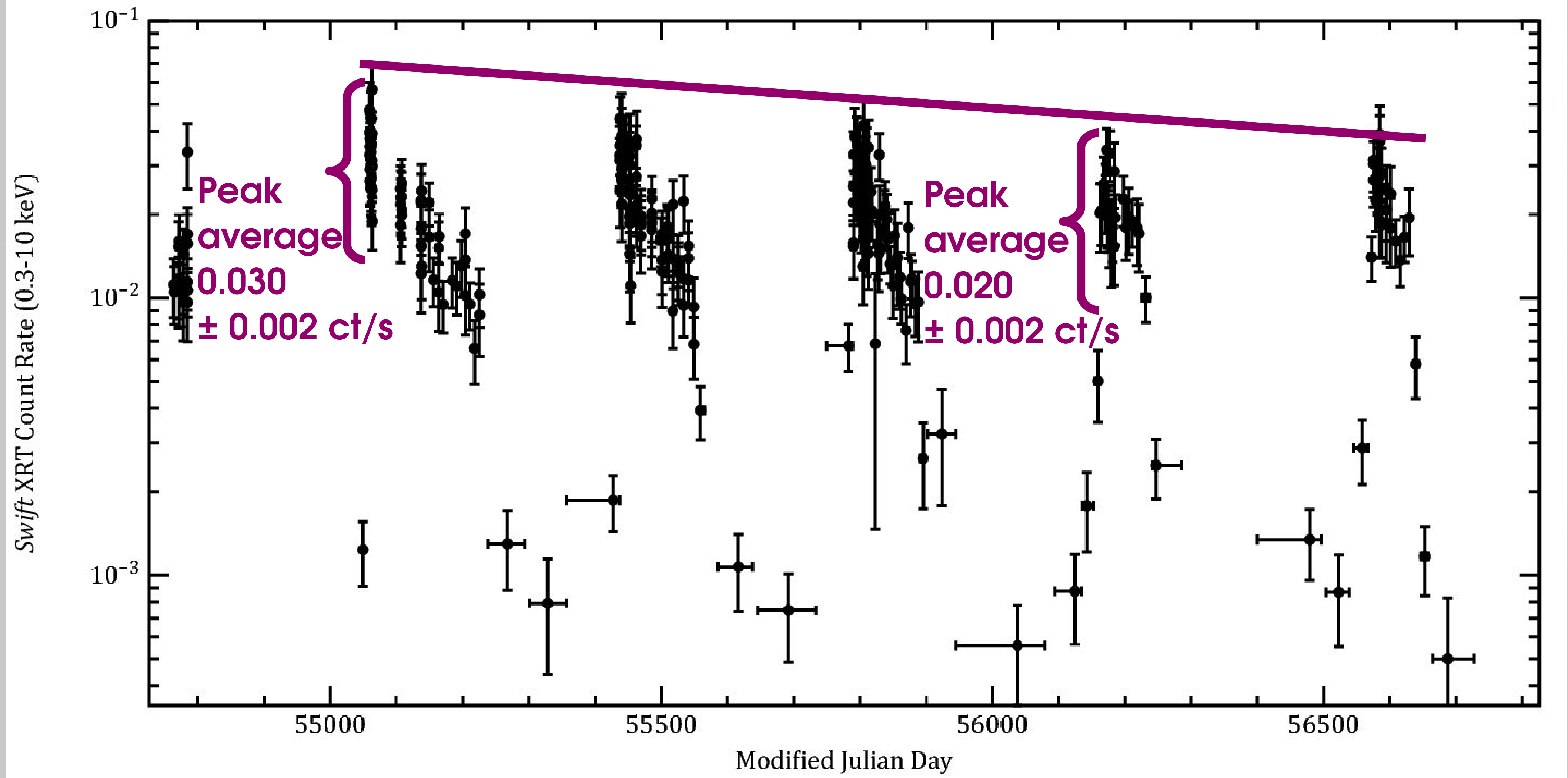
Webb et al. 2014

Rapid optical/ X-ray rise indicates matter impacts disc close ($\sim 10^{11}$ cm) to black hole.

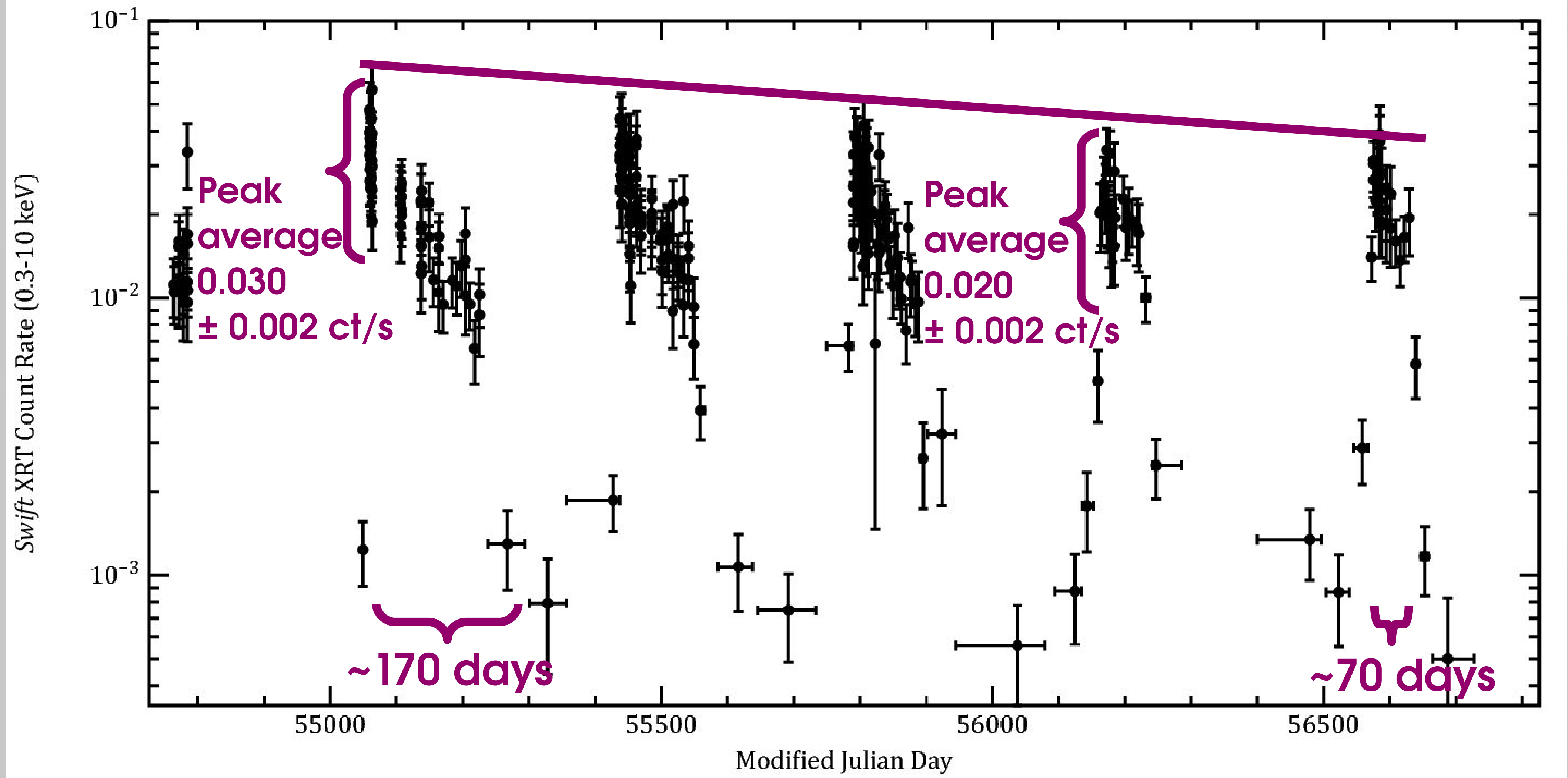
Matter propagated through disc by waves (not viscosity as in standard disc instability model).



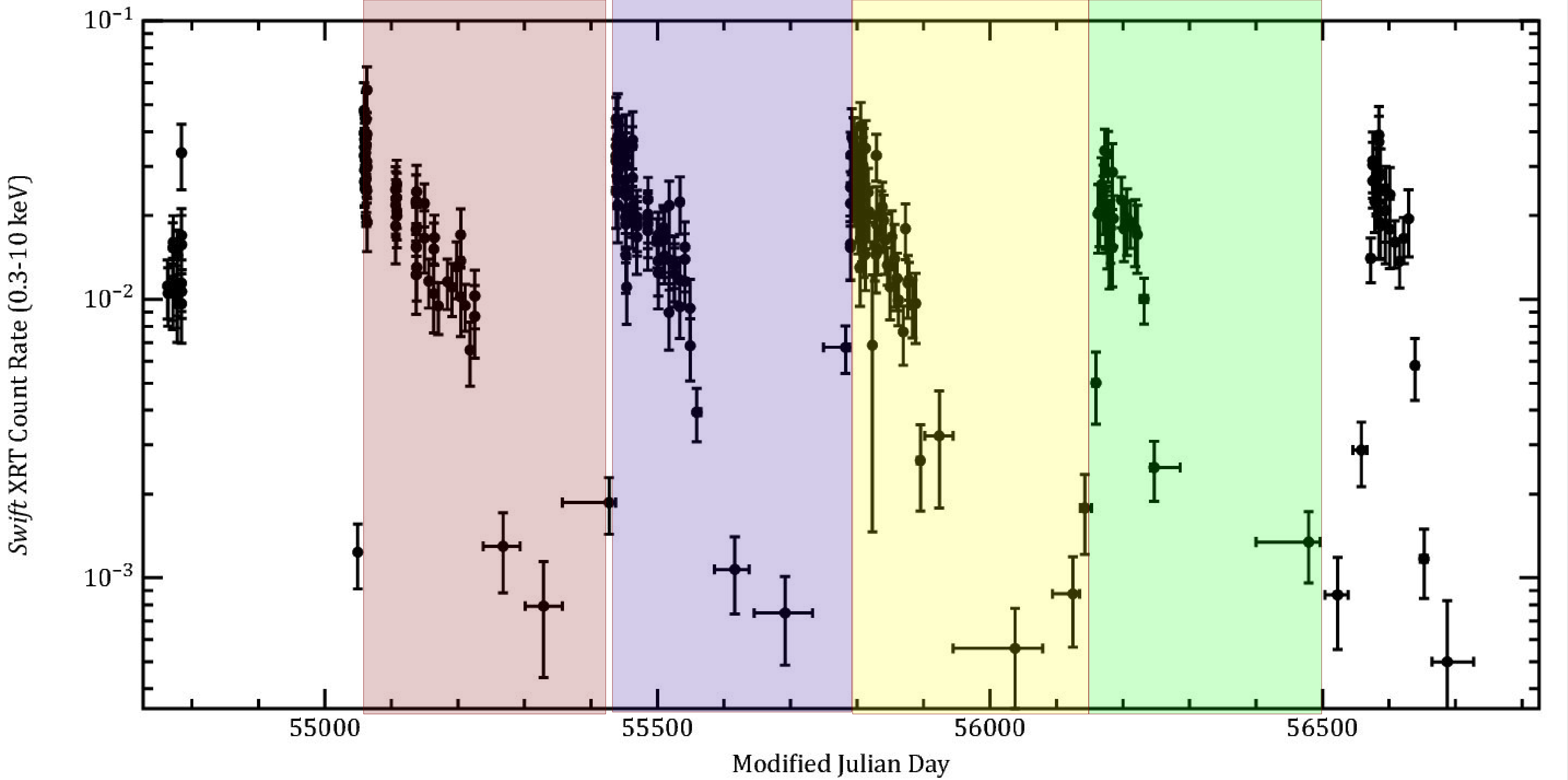
10^{-1}
10^{-2}
10^{-3}
Swift XRT Count Rate (0.3-10 keV)
55000
55500
56000
56500
Modified Julian Day



Peak average 0.030 ± 0.002 ct/s
Peak average 0.020 ± 0.002 ct/s
10^{-1}
10^{-2}
10^{-3}
55000
55500
56000
56500
Modified Julian Day
Swift XRT Count Rate (0.3-10 keV)



Peak average 0.030 ± 0.002 ct/s
Peak average 0.020 ± 0.002 ct/s
~170 days
~70 days
10^{-1}
10^{-2}
10^{-3}
55000
55500
56000
56500
Swift XRT Count Rate (0.3-10 keV)
Modified Julian Day



SPH modelling (Gaburov et al. 2010)

Can a highly eccentric binary form and remain bound?

Results of modelling show it is possible

Likely that the donor is something like a white dwarf

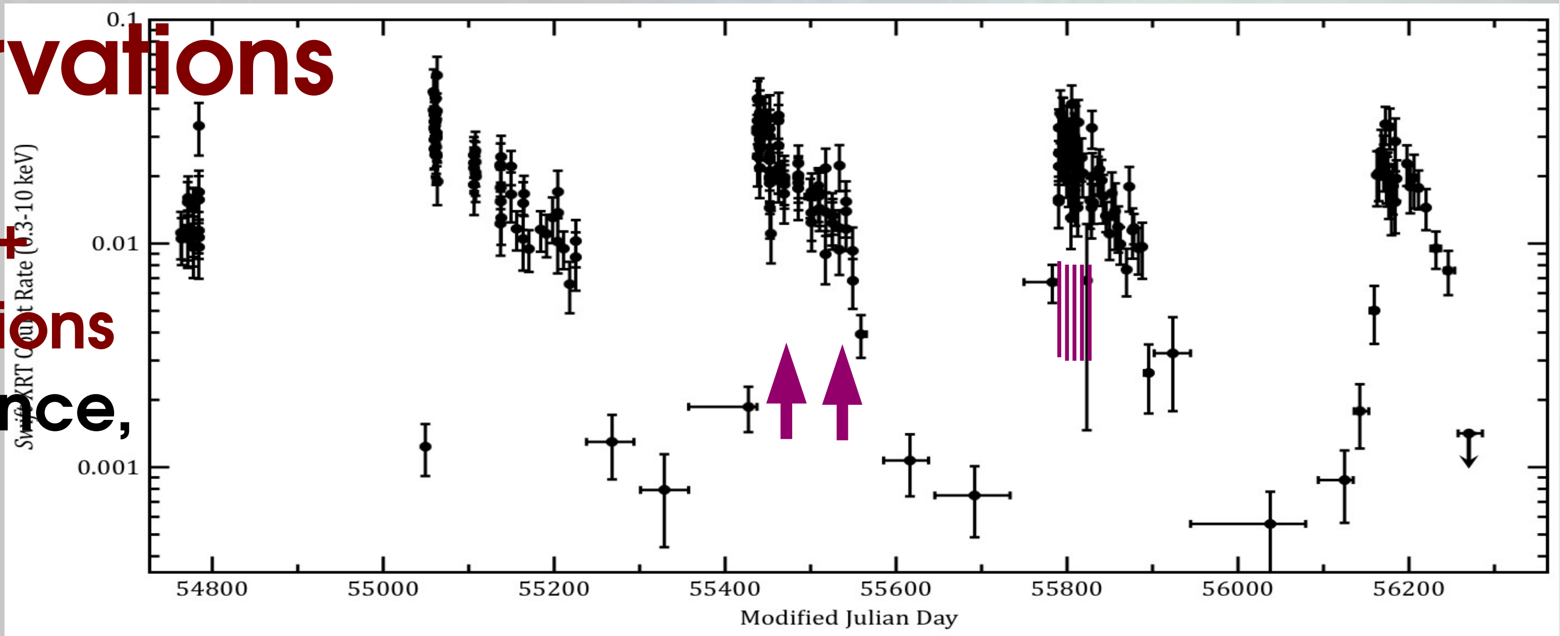
But accretion rates are then difficult to understand

(Godet et al., sub.)

Radio observations

7 x 12 hrs ATCA 5 + 9 GHz observations

(Webb et al., Science, 2012)



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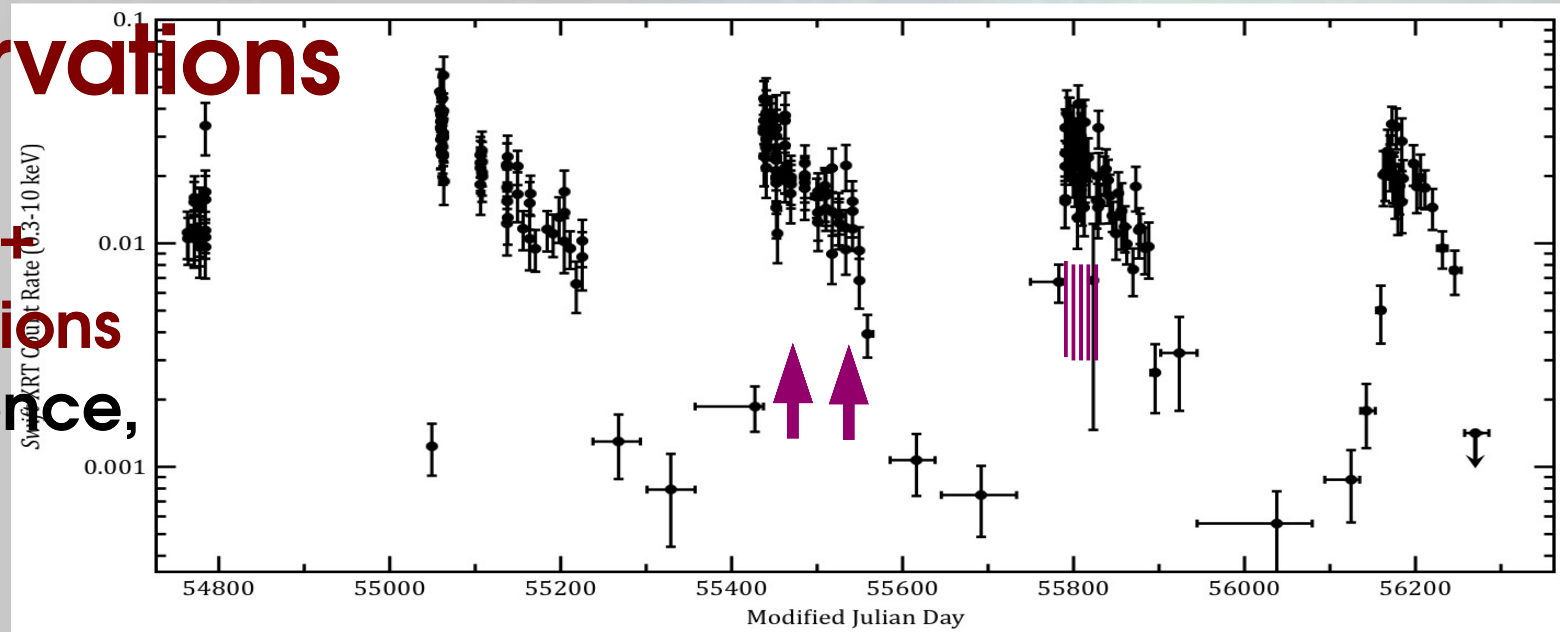
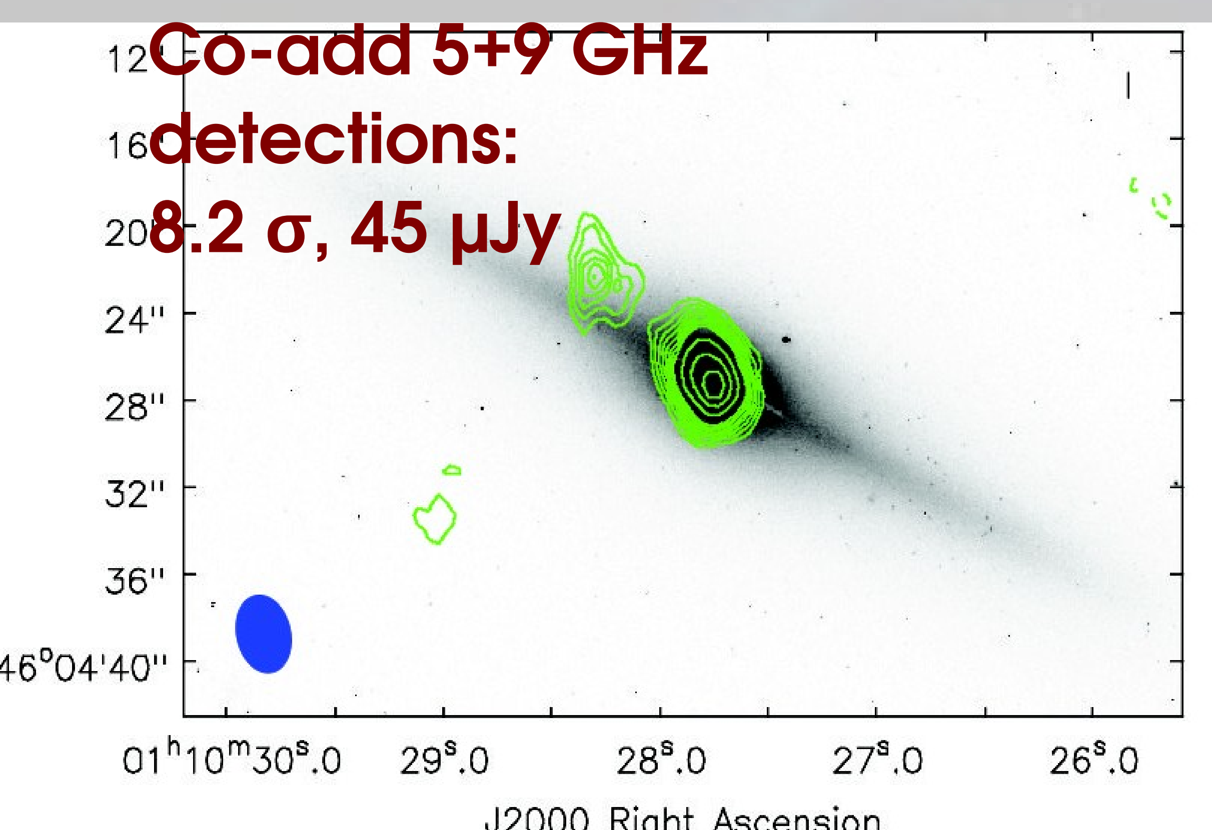


Co-add 5+9 GHz detections: 8.2 σ, 45 μJy



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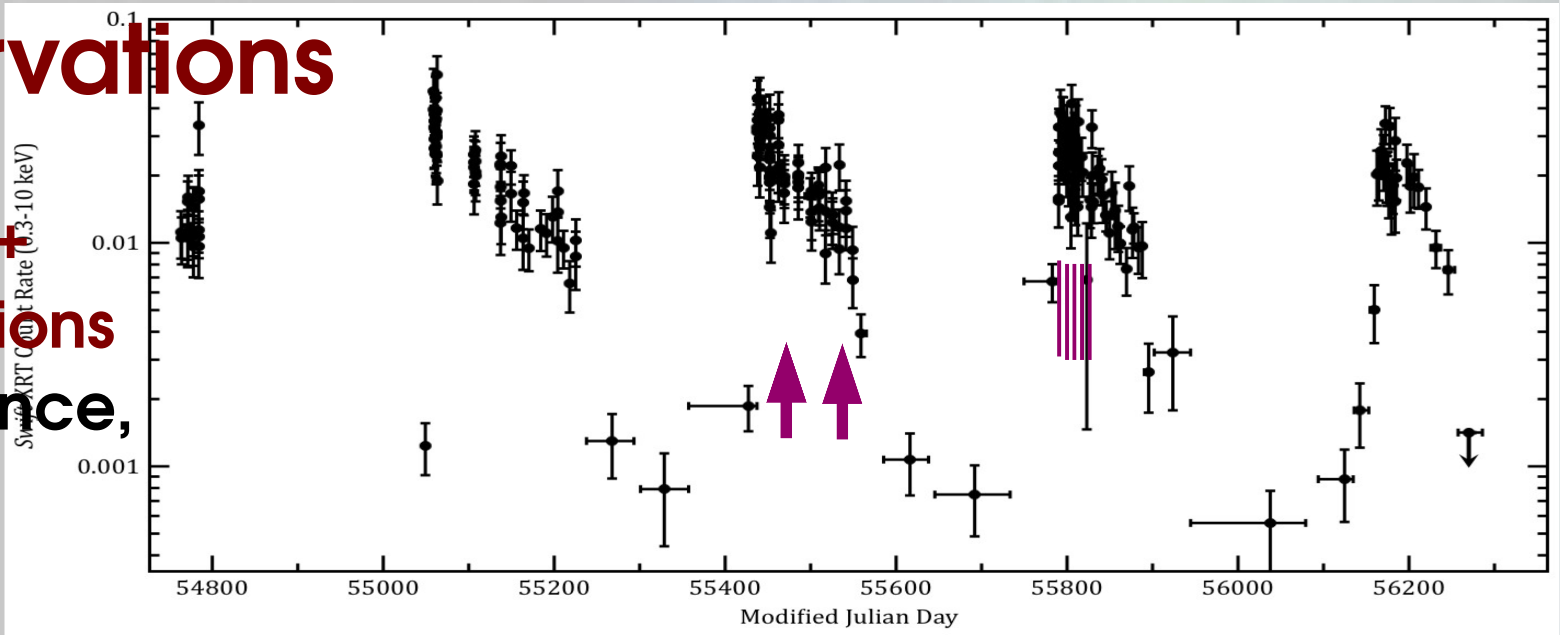

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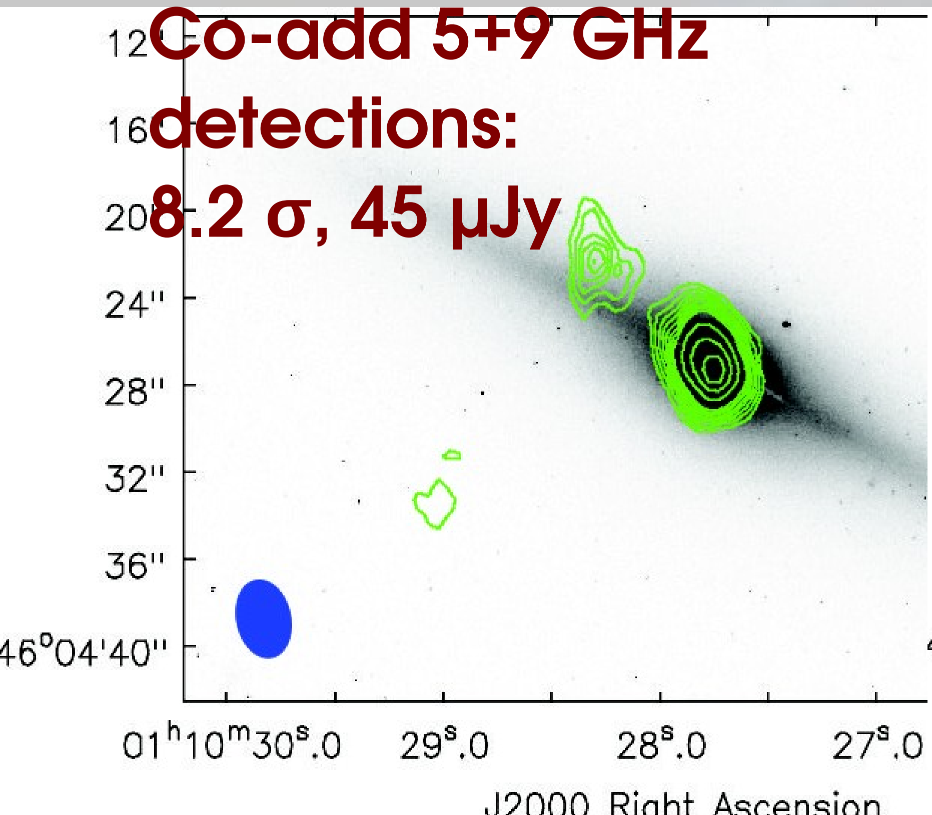
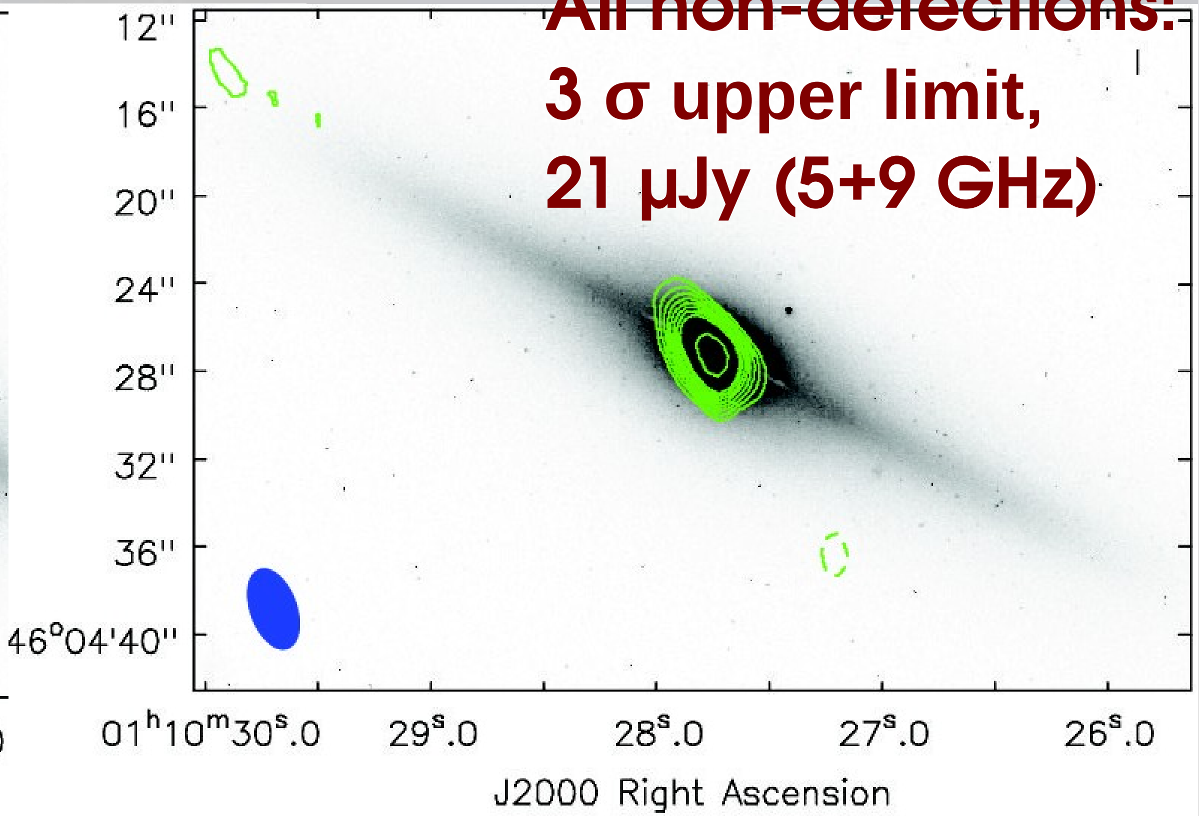


All non-detections:
3 σ upper limit,
21 μJy (5+9 GHz)



Mass estimate of HLX-1

•Radio flares from Galactic black hole binaries when the X-ray luminosity is 10-100% Eddington luminosity (e.g. Fender, Belloni & Gallo 2004)

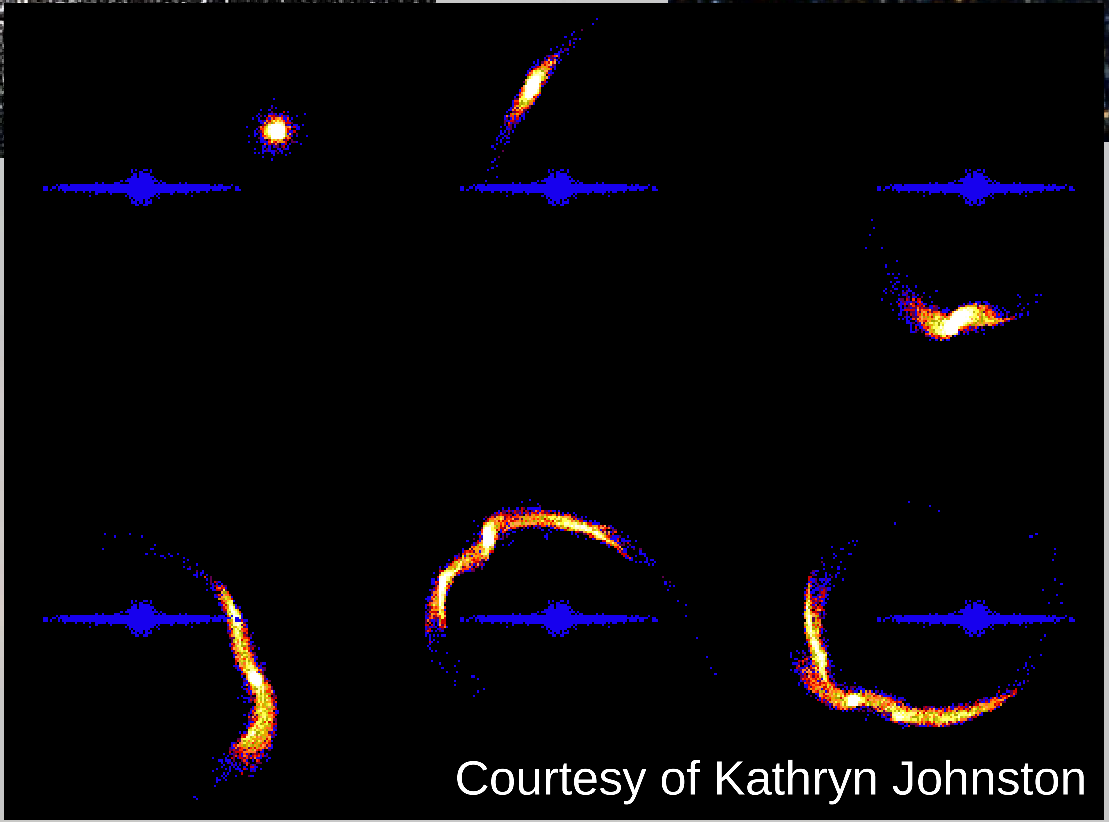
•HLX-1 shows similar behaviour to Galactic black hole binaries

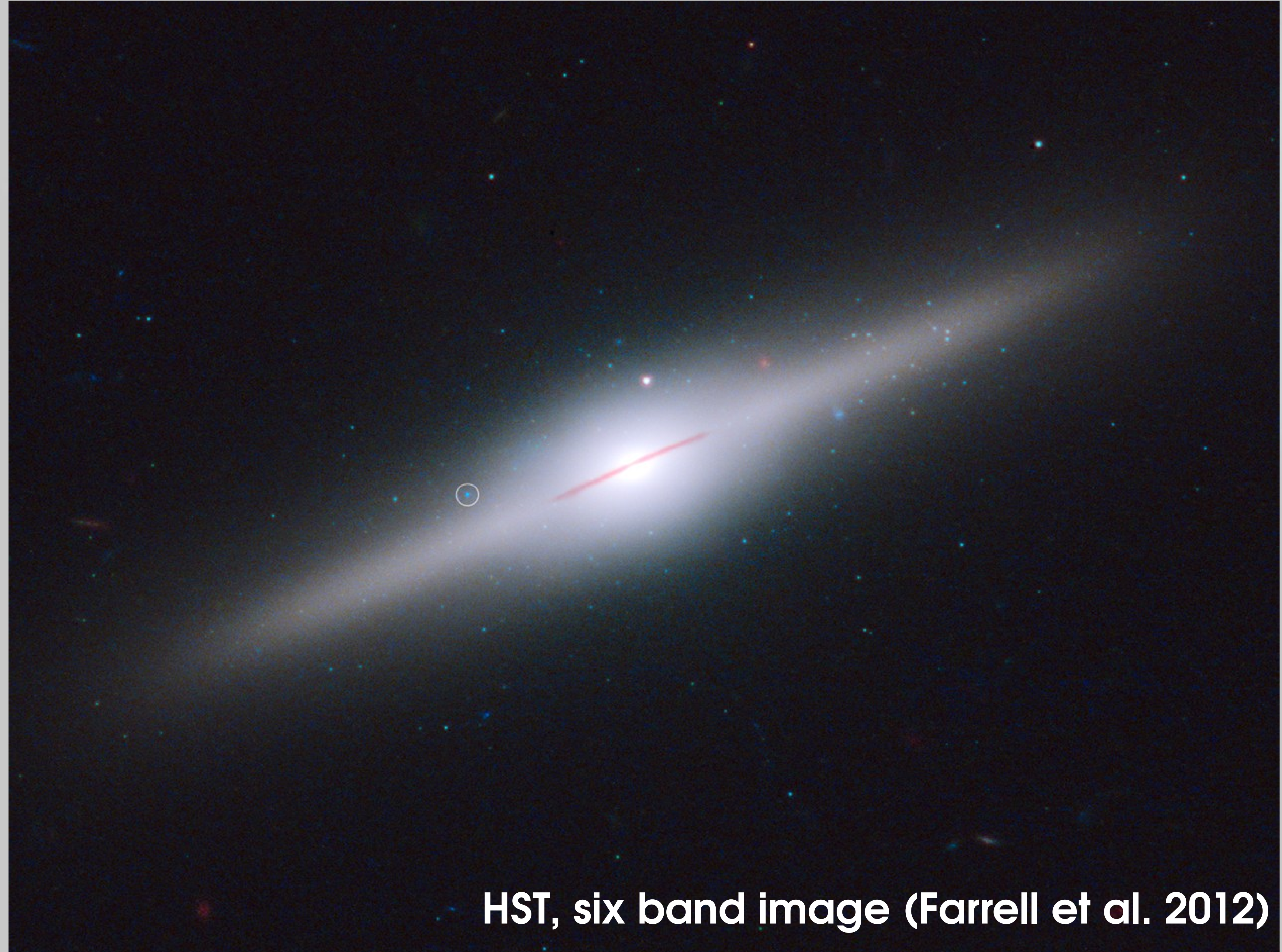
•Assume HLX-1 radio flares occur at 10-100% Eddington

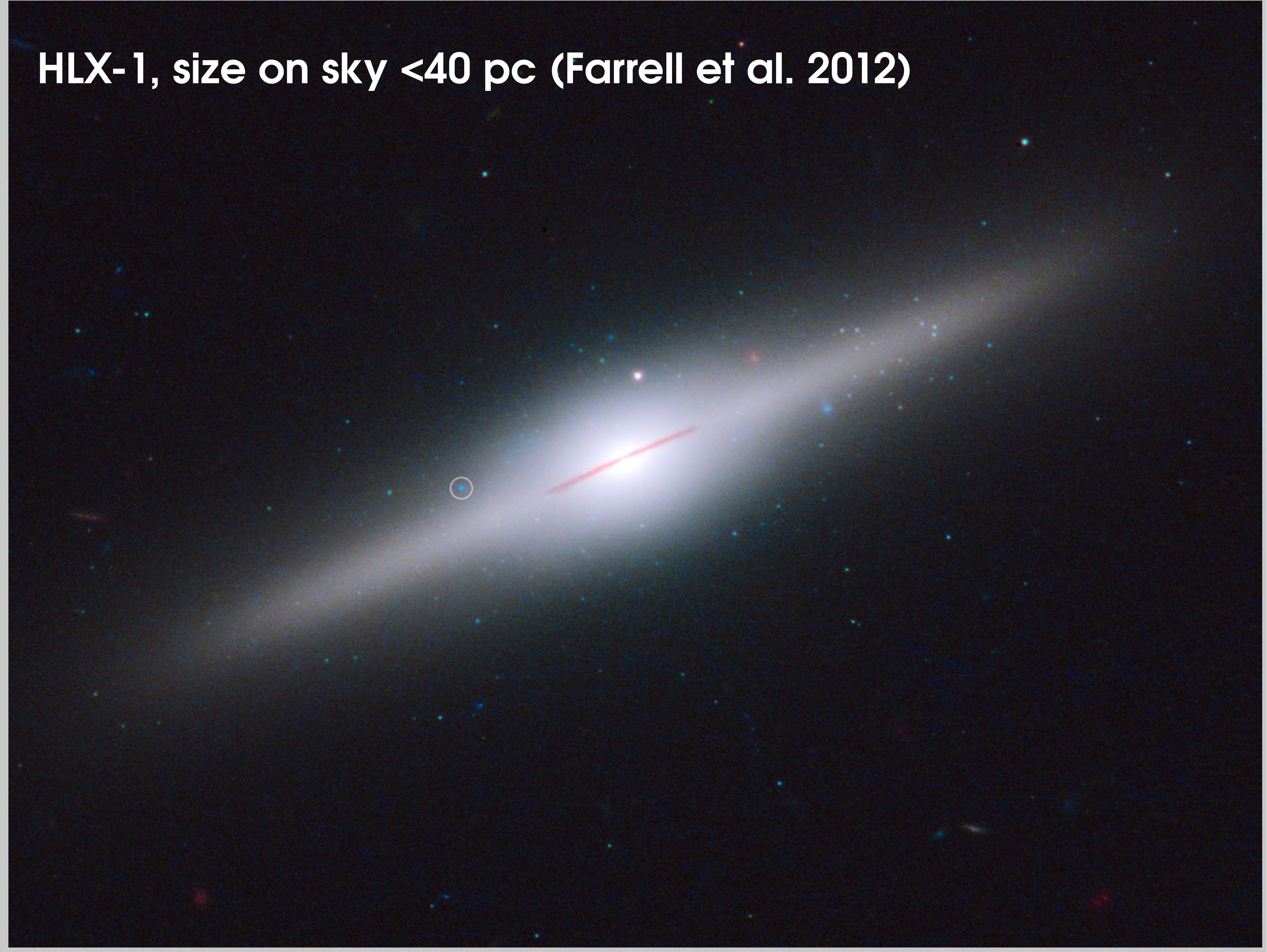
=> black hole mass between $9.2 \times 10^3\ M_\odot$ and $9.2 \times 10^4\ M_\odot$

Webb et al (Science, 2012)

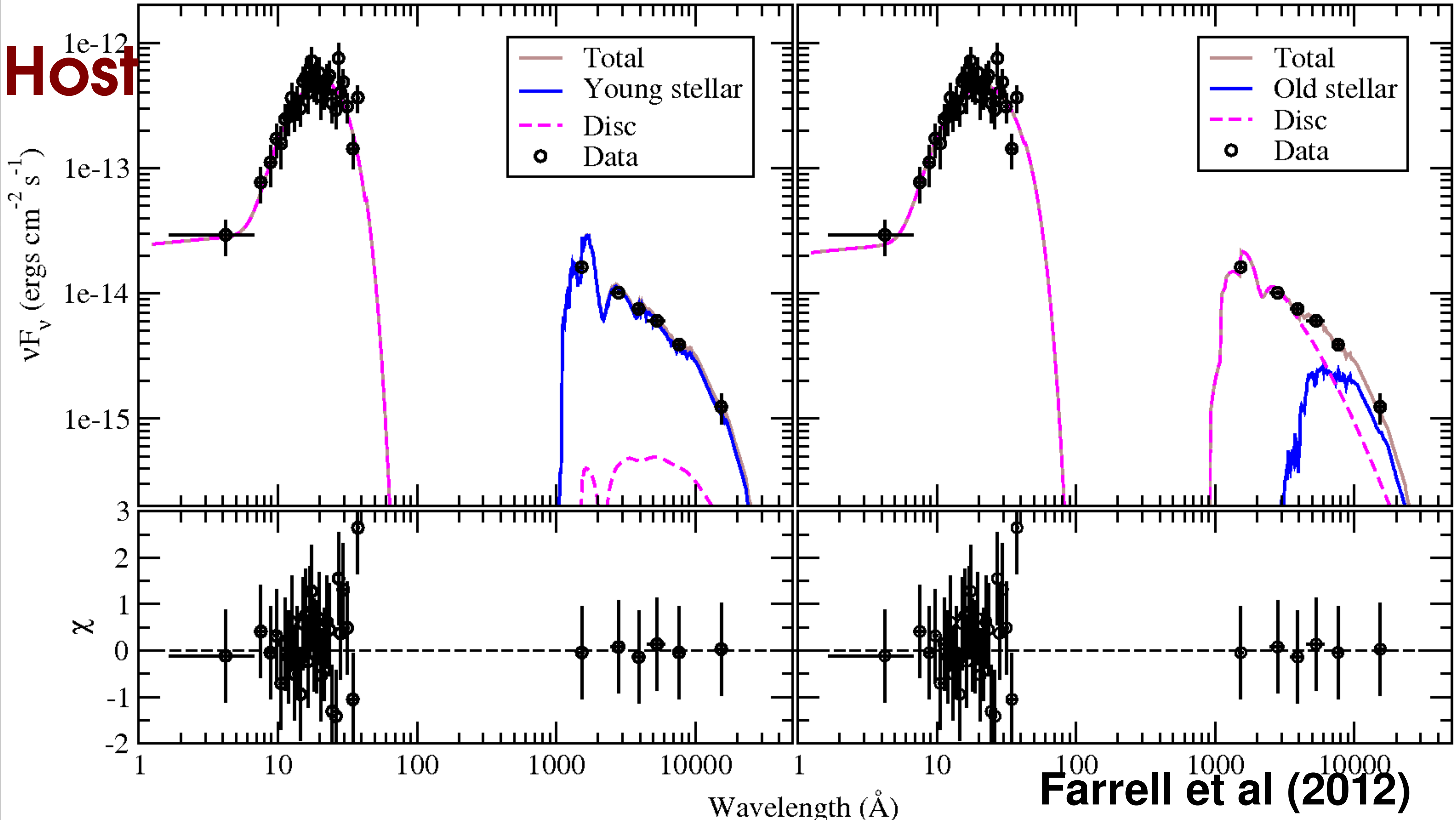
Where do intermediate mass black holes form and evolve today?




HST, six band image (Farrell et al. 2012)


HLX-1, size on sky <40 pc (Farrell et al. 2012)

Host



Farrell et al (2012)

Age:	**<1.3 x 10^{7} years**	**1.3 x 10^{10} years**
Mass:	**4 x 10^{6} $M_{\odot}$**	**6 x 10^{6} $M_{\odot}$**
Disc irradiation:	**8 x 10^{-7}**	**0.098**
X^2 (d.o.f.):	**23.38 (27)**	**24.28 (27)**

10^6 $M_\odot$ too small to form 10^4 $M_\odot$ black hole (e.g. Mapelli et al. 2012)

Possible radial velocity offset of ~400 km/s compared to ESO 243-49 (Soria, Hau & Pakull 2013)

May be a dwarf galaxy that has been stripped in a merger with ESO 243-49 (Webb et al. 2010, Mapelli et al. 2013)

Currently analysing two further HST/XMM datasets, X-shooter data and will have MUSE integral field observations next week ☺

Summary

First good intermediate mass black hole (IMBH) candidate discovered with mass between $9 \times 10^3\ M_\odot$ and $9 \times 10^4\ M_\odot$

Difficult to understand the accretion mechanism

May reside in stellar cluster, possibly due to minor merger