Wind-driven cycles in the IMBH HLX-1

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The University of Western Australia

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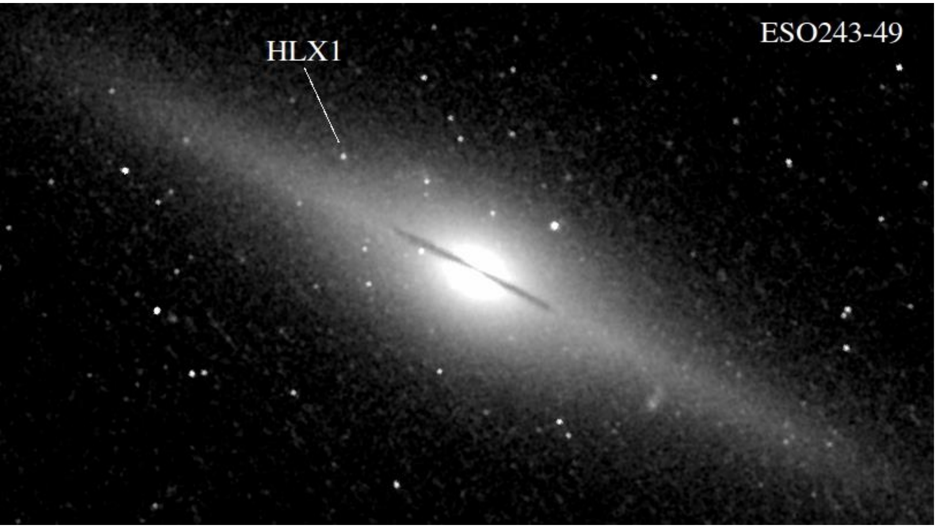
Overview

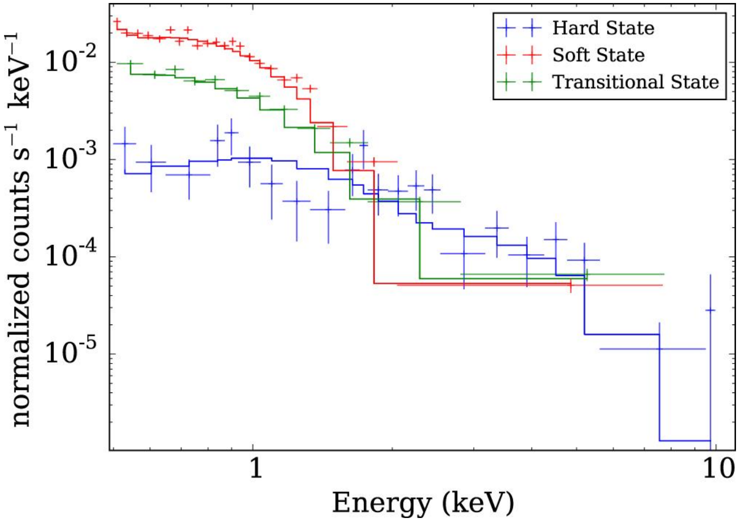
1. Size of the system

2. Timescale of the oscillation

3. Proposed physical mechanism

Main properties





$L_{(0.3\text{-}10\ \mathrm{keV})}$ oscillates between ~ 2e40 erg/s – 1e42 erg/s

Power-law, Γ ~ 1.5

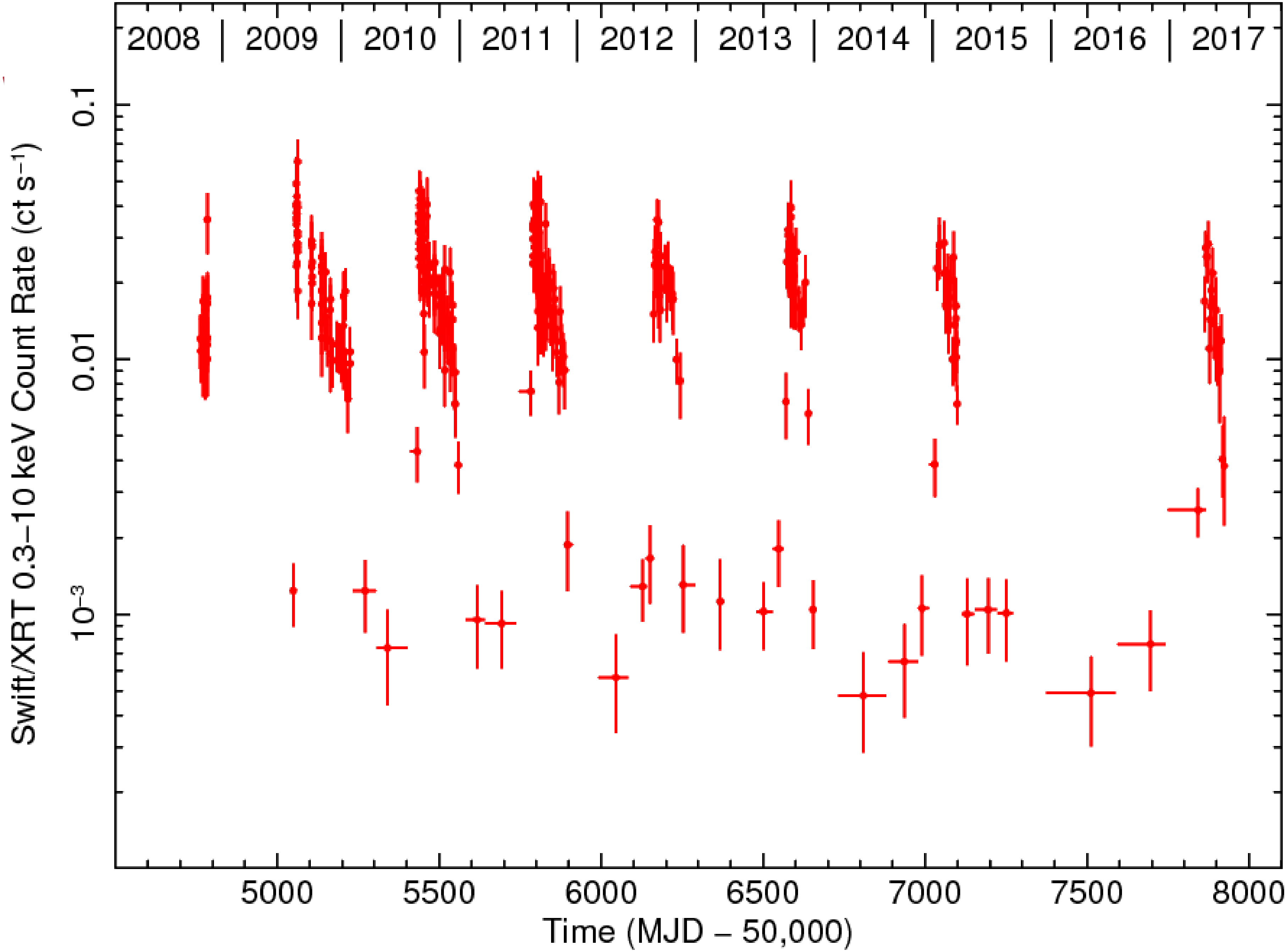
Low/hard state

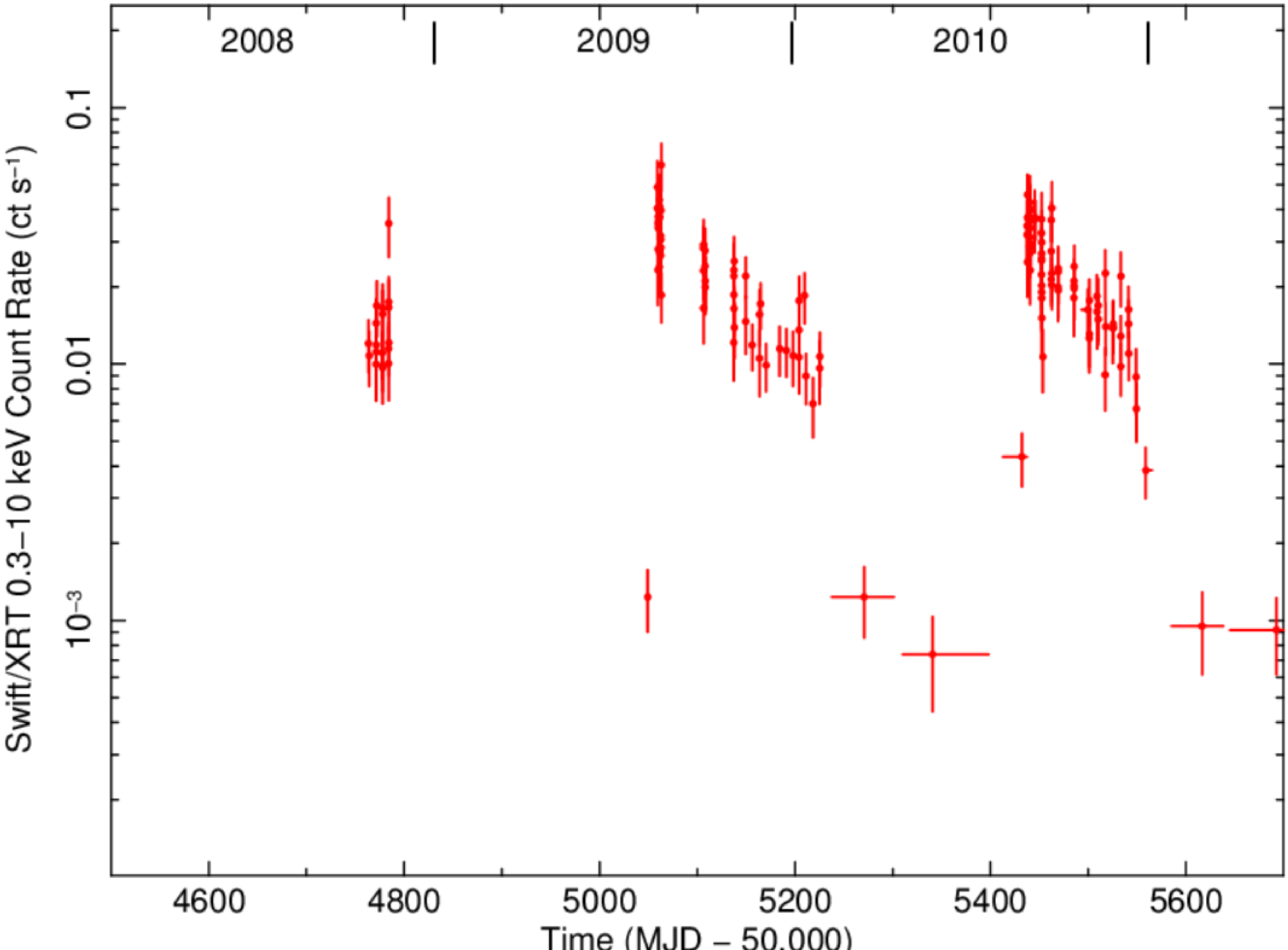
Diskbb, T_{in} = 0.24 keV

High/soft state

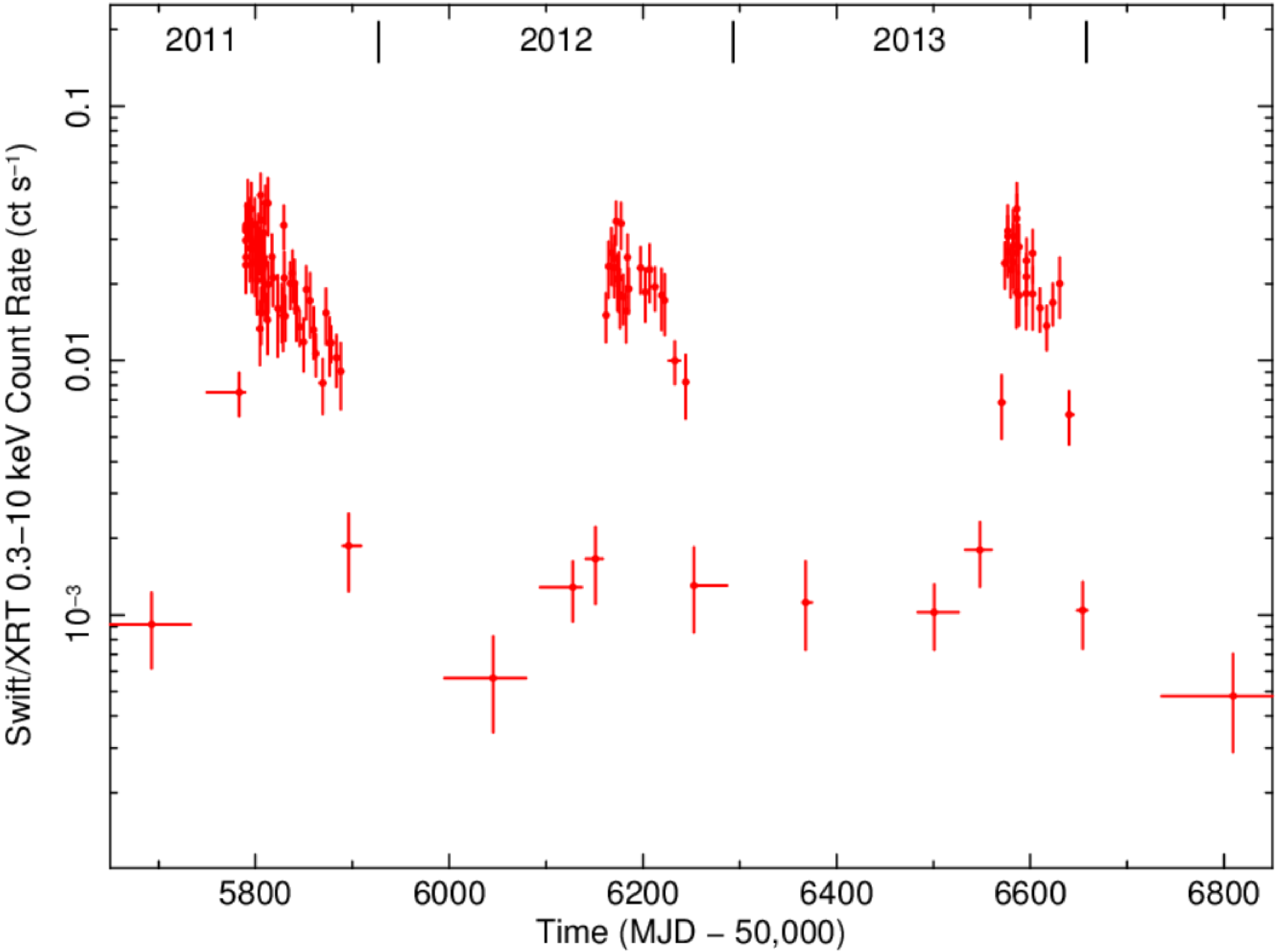
Radio flaring seen during the hard to soft transition (Webb et al 2012)

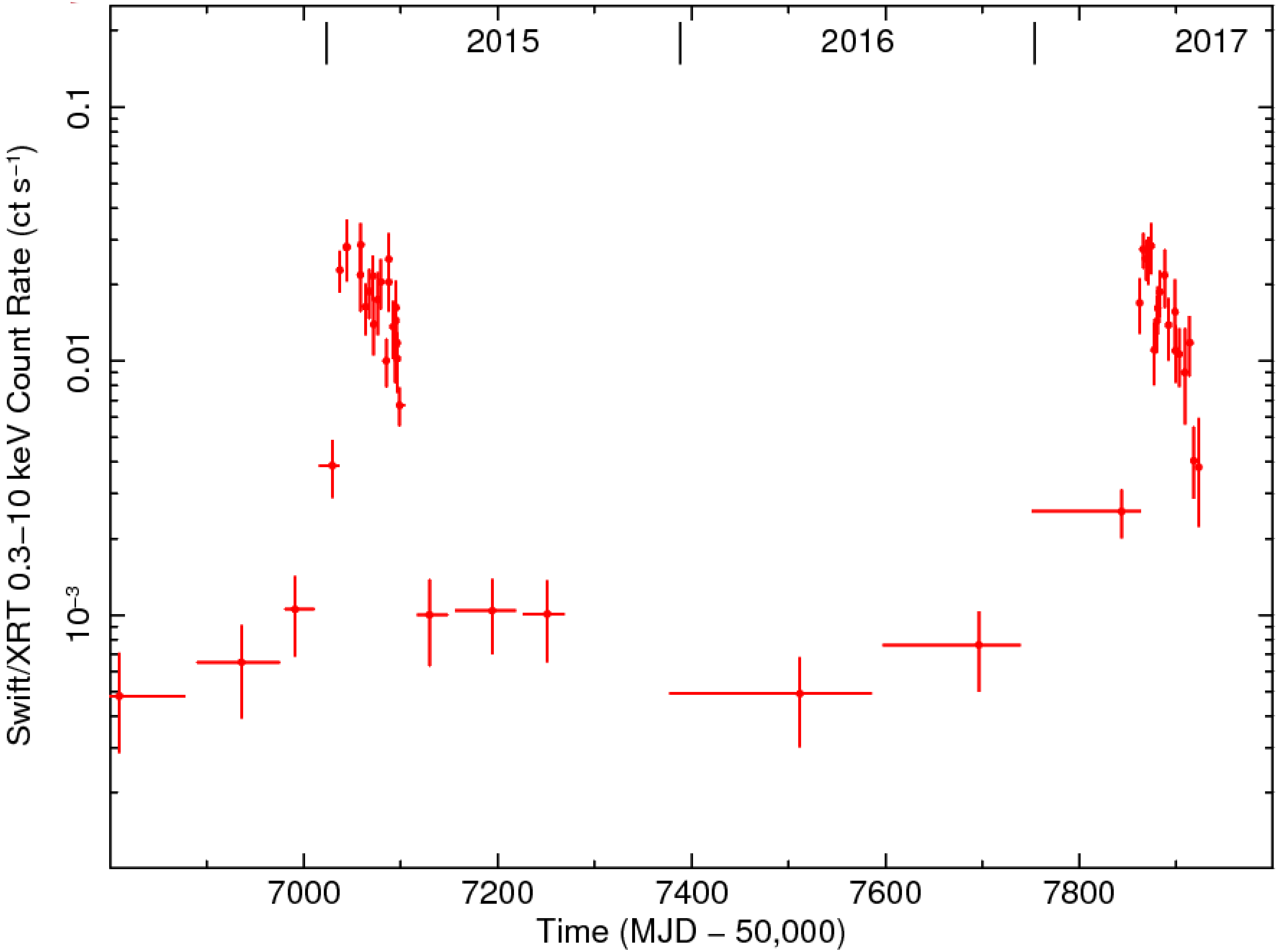
Optical counterpart with M_V ~ -11 mag + narrow Hα emission
(Soria et al. 2010,2012,2013, Wiersema et al. 2012, Farrell et al. 2014)


2008
2009
2010
2011
2012
2013
2014
2015
2016
2017
Swift/XRT 0.3–10 keV Count Rate (ct s^{-1})
0.1
0.01
10^{-3}
5000
5500
6000
6500
7000
7500
8000
Time (MJD – 50,000)

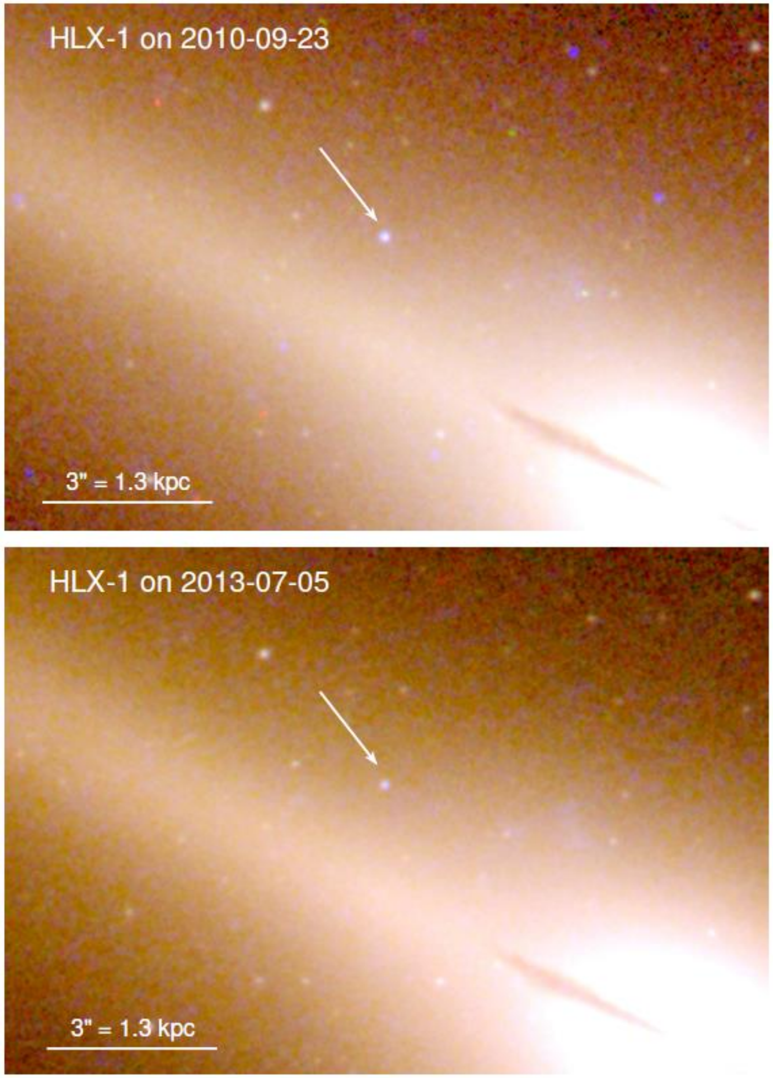


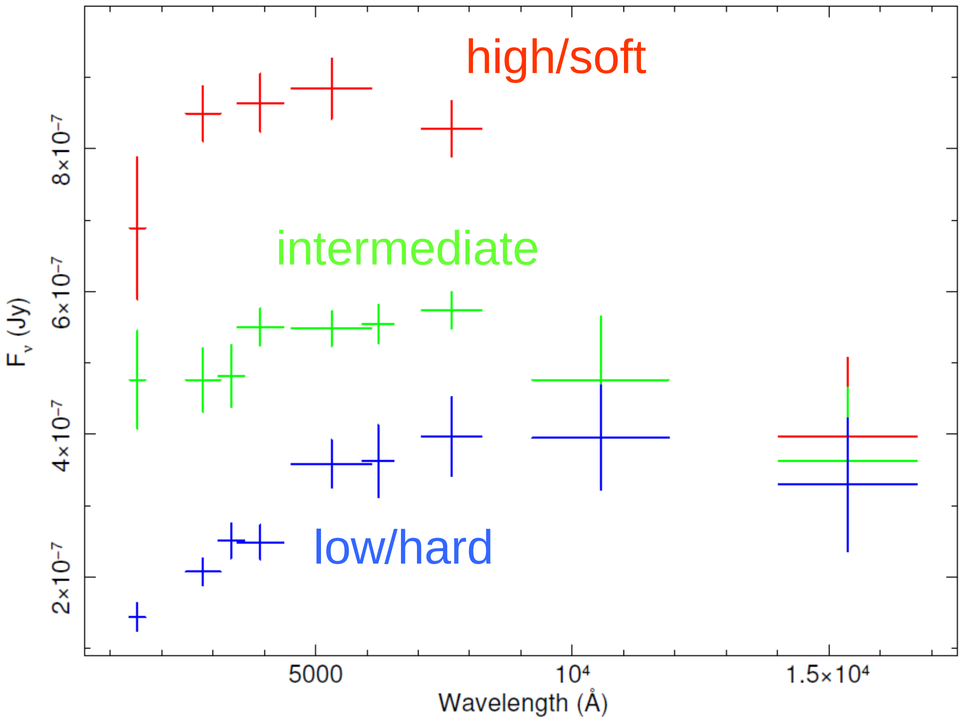
2008
2009
2010
Swift/XRT 0.3–10 keV Count Rate (ct s^{-1})
0.1
0.01
10^{-3}
4600
4800
5000
5200
5400
5600
Time (MJD – 50,000)


2011
2012
2013
0.1
0.01
10^{-3}
Swift/XRT 0.3–10 keV Count Rate (ct s^{-1})
5800
6000
6200
6400
6600
6800
Time (MJD – 50,000)


2015
2016
2017
Swift/XRT 0.3–10 keV Count Rate (ct s⁻¹)
0.1
0.01
10⁻³
7000
7200
7400
7600
7800
Time (MJD – 50,000)

Irradiated disk or star cluster?



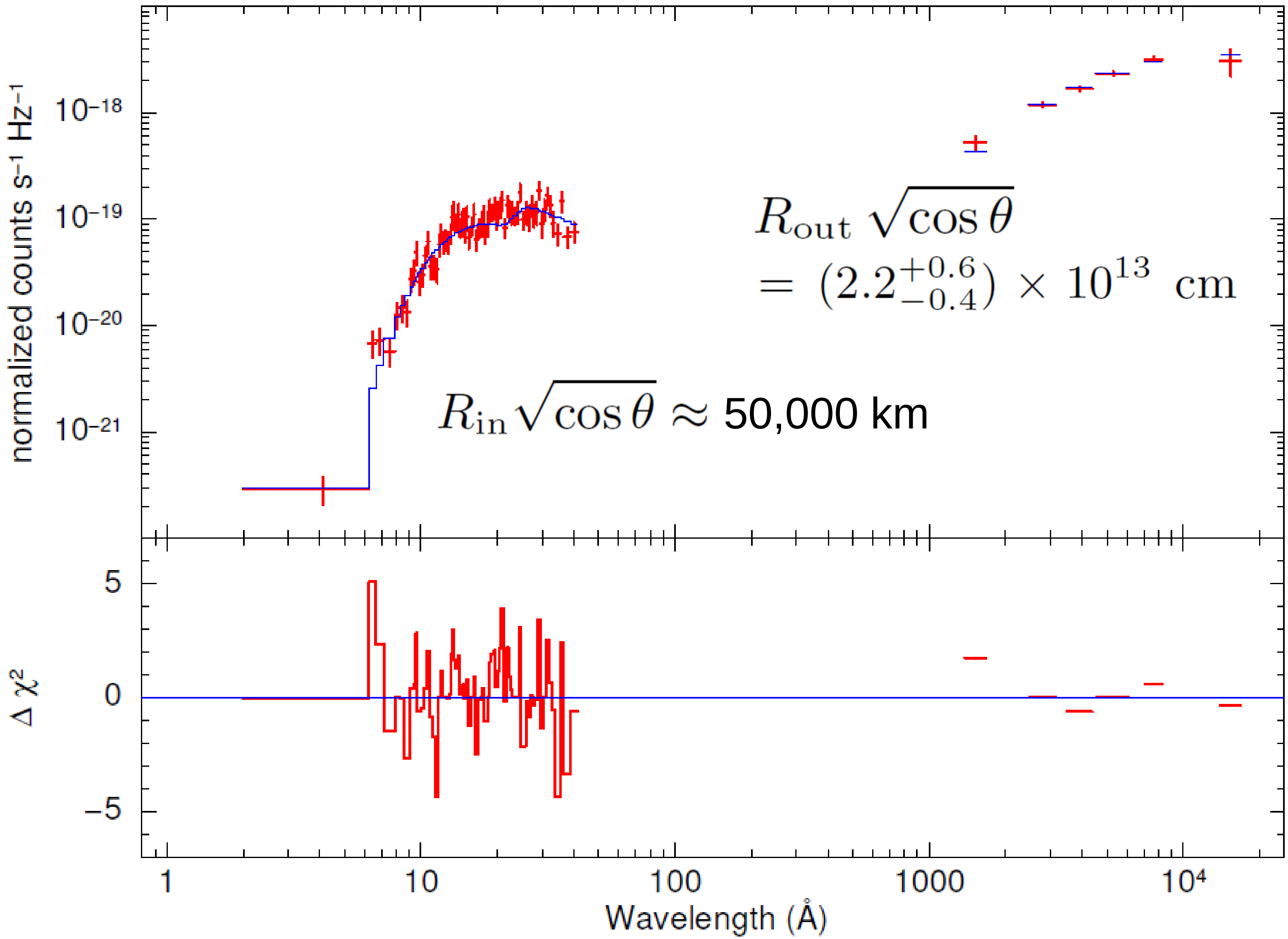


Blue/UV light scales with L_X

Red/IR light ~ constant (Soria et al 2017)

Irradiated disk dominates blue/UV

Inner and outer disk radius



Discrepancy in the disk size

Outburst rise time, duration, decline time suggest
R_{out} ~ a few 10^{11} cm

Integrated luminosity of each outburst suggests
Δm ~ a few 10^{28} g ~ mass of a standard disk within
R_{out} ~ a few 10^{11} cm

Optical luminosity suggests R_{out} ~ 3 x 10^{13} cm
(*but from there, viscous timescale > 100 yr*)

Physical reason for the outbursts

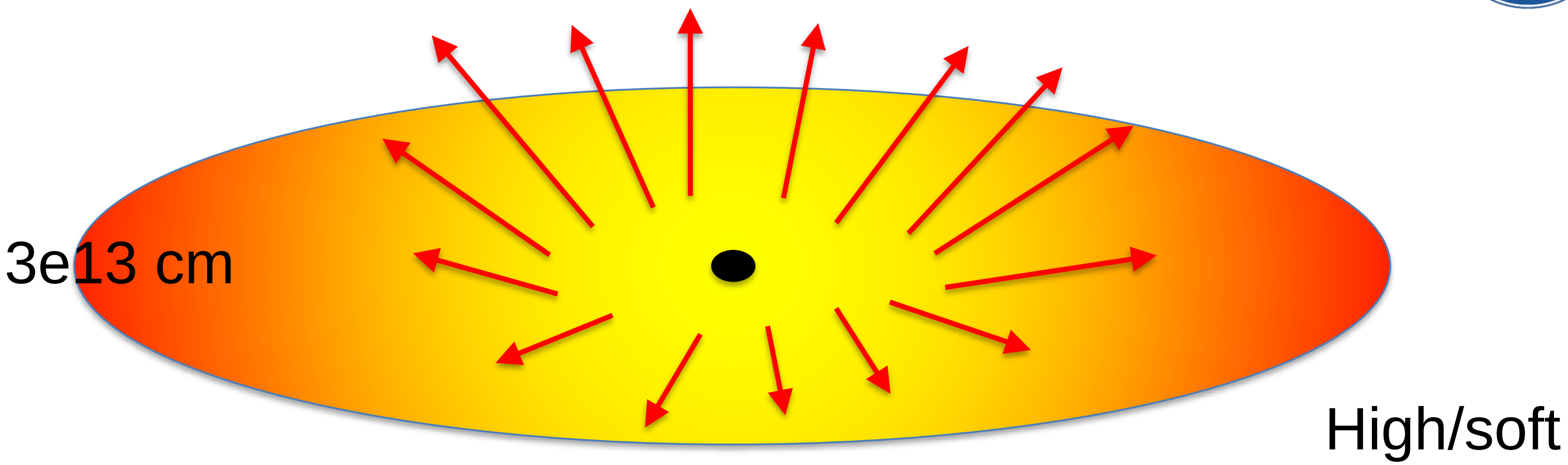
Thermal-viscous instability?
NO: irradiation too strong, timescale too short for TVI

Mass transfer instability?
NO: it would take > 100 yrs for inner disk to notice

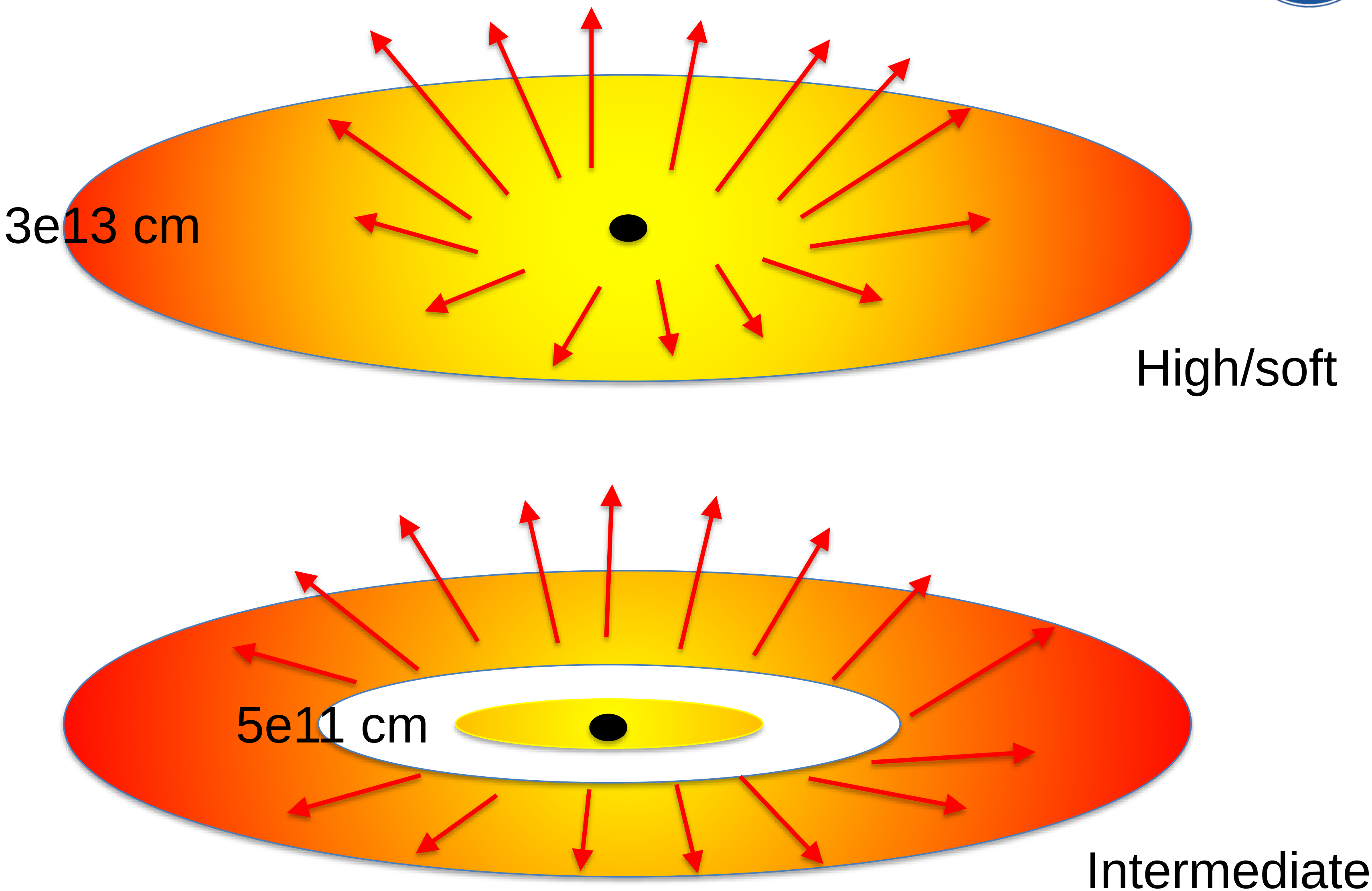
Periastron passage of highly eccentric orbits?
NO: timescale changed from ~ 1 yr to ~ 2yrs

We propose outbursts are driven by wind feedback
(Shields et al. 1986)

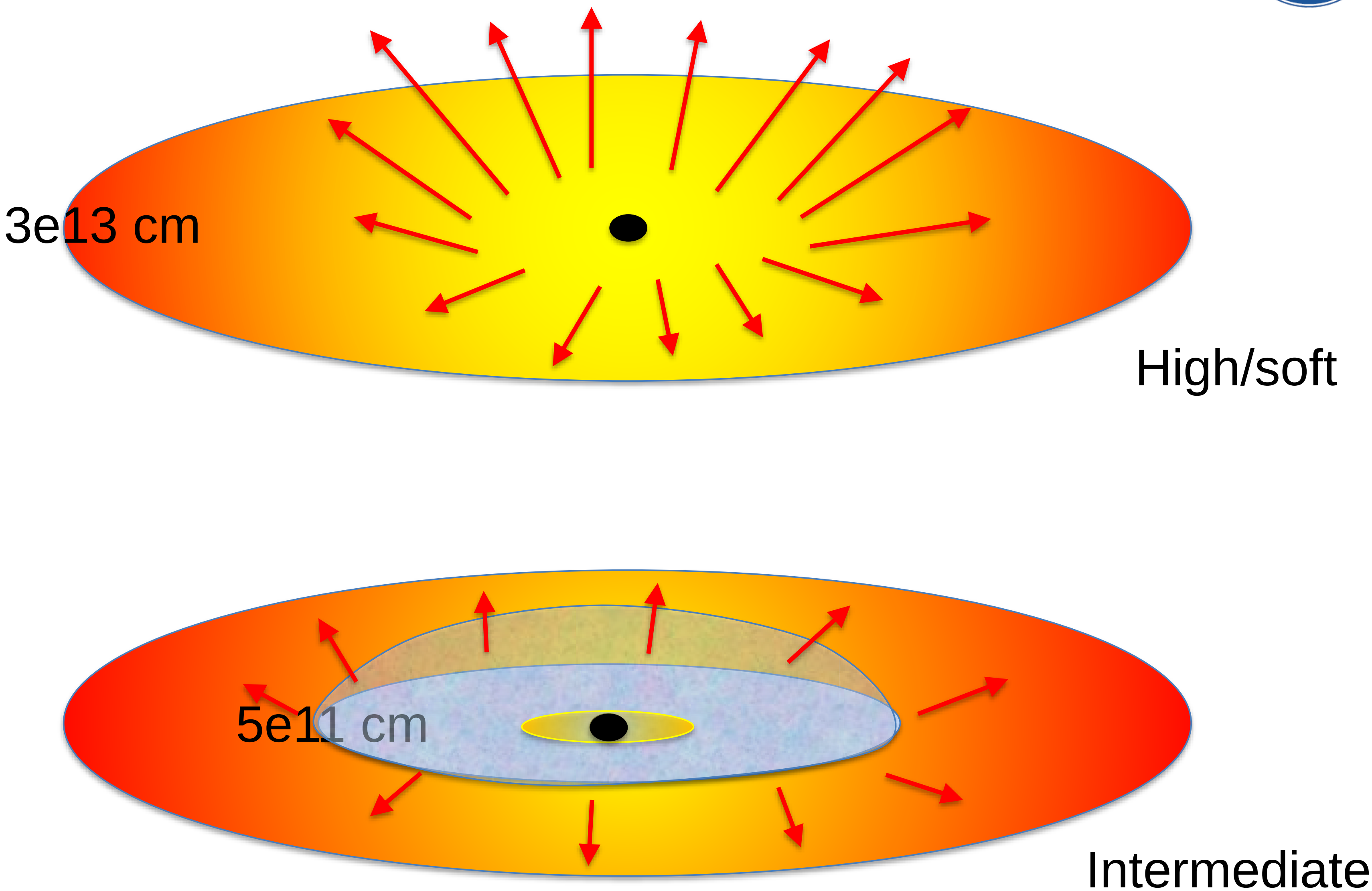
Wind-driven oscillation



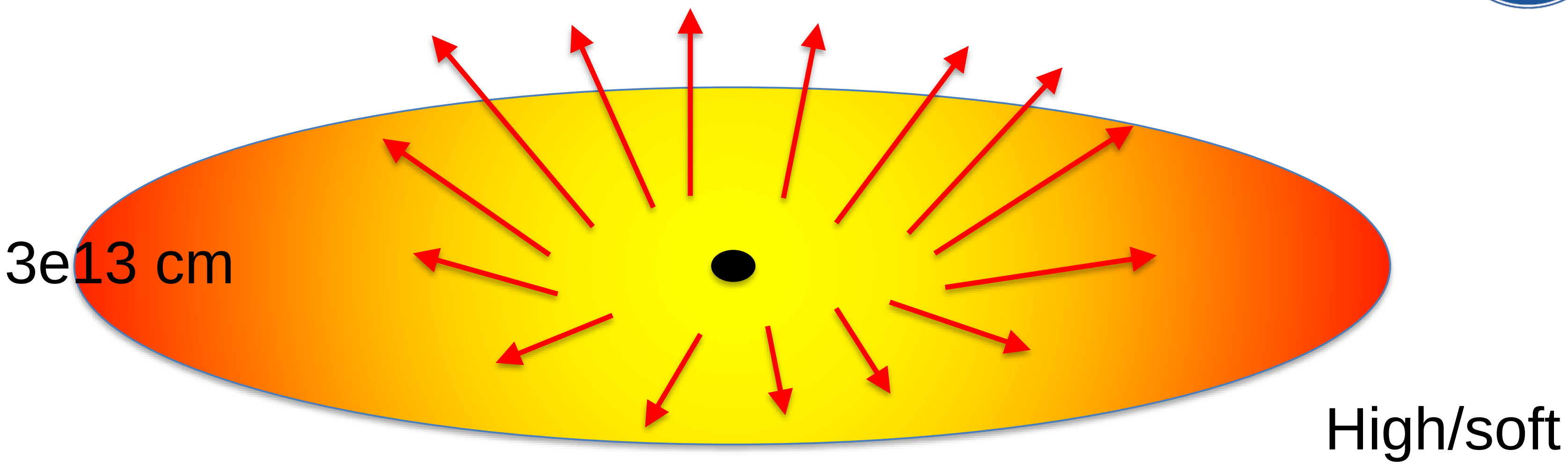
Wind-driven oscillation



Wind-driven oscillation



Wind-driven oscillation

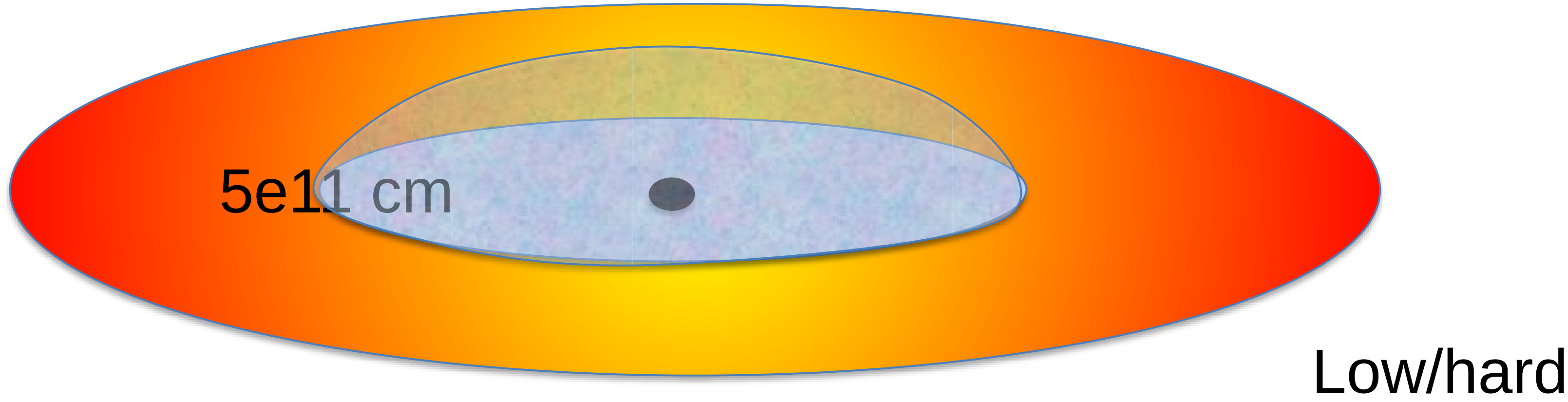


Analogy with V404 Cyg

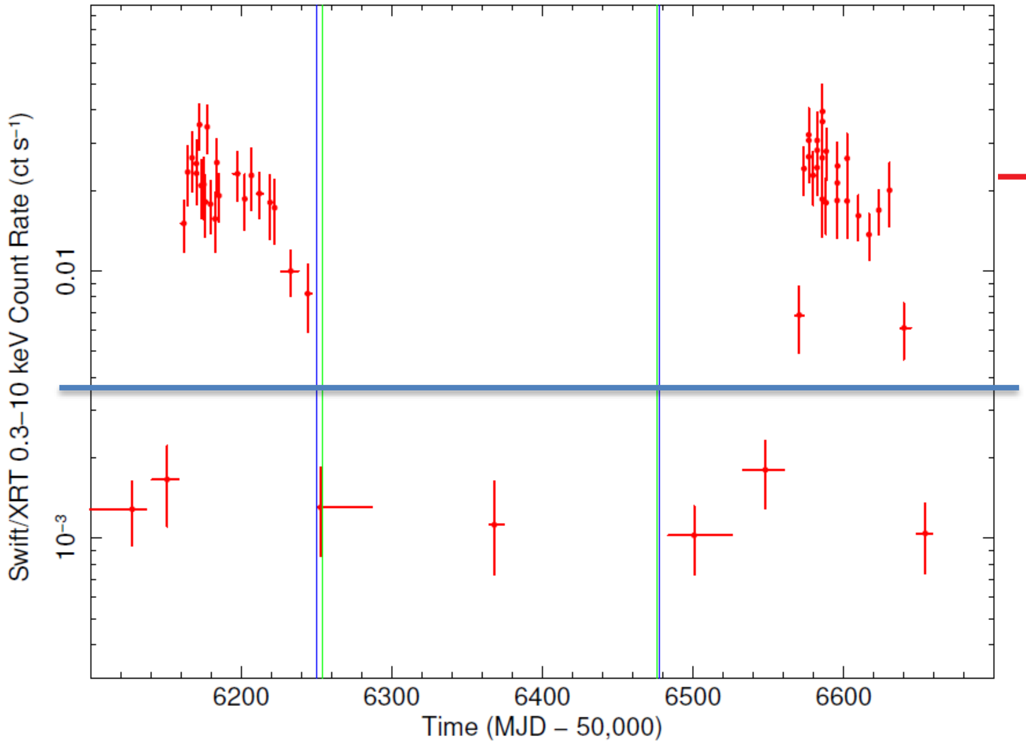
(Munoz-Darias et al 2016)

PID Controller with time delay

(oscillatory behaviour well known to engineers)



Soft-to-hard transition



$L_{X,tr}$ ~ 0.01—0.03 L_{Edd}
~ 4 x 10^{40} / (cos θ) erg/s

2 observational constraints:

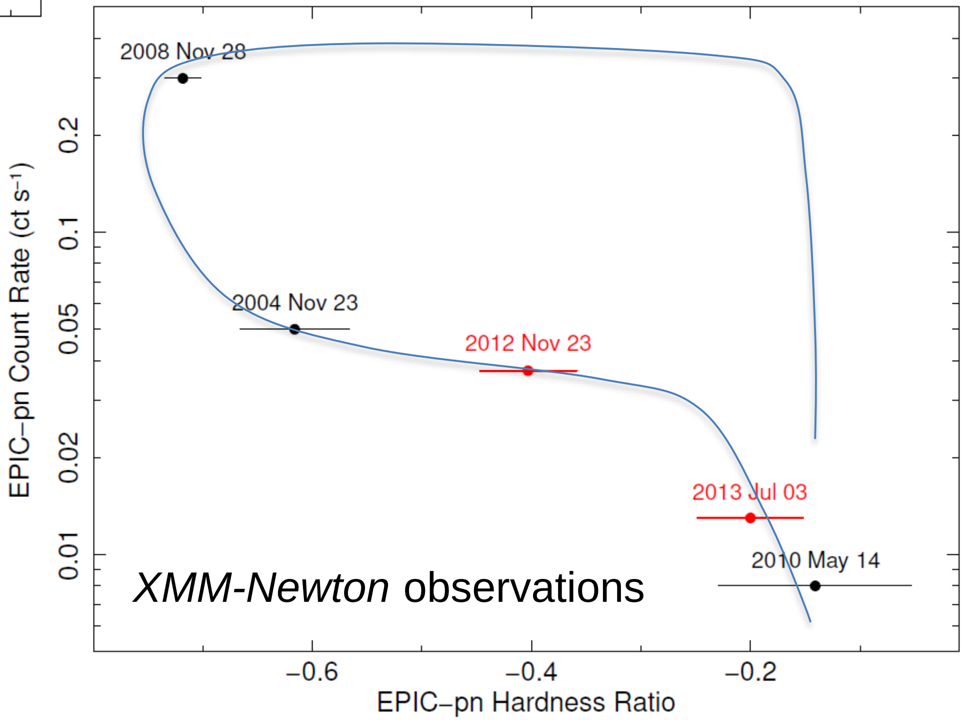
$R_{in} = f(M, a, \theta)$

$L_{X,tr} = g(M, \theta)$

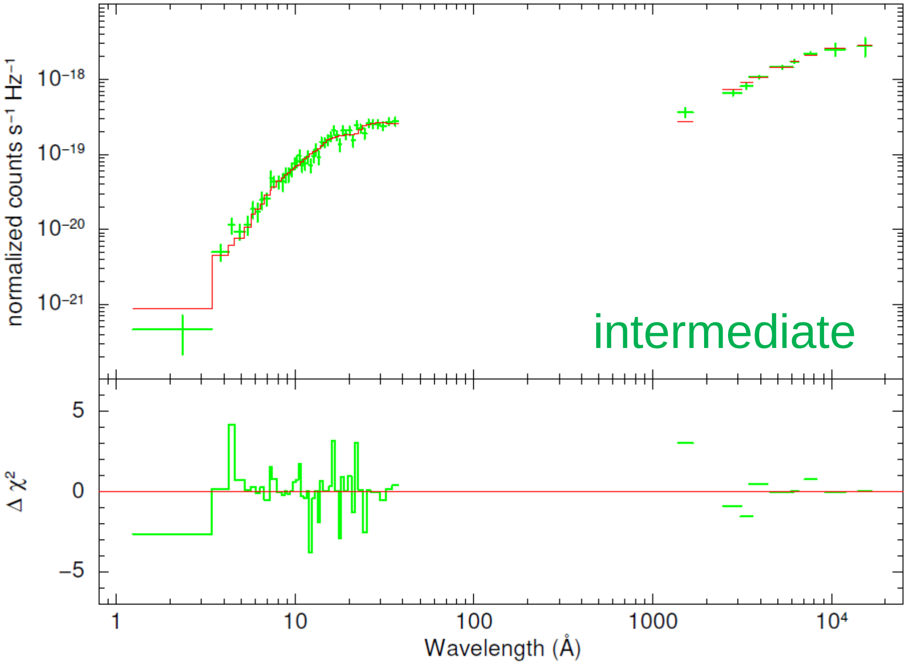
M cos θ ~ 2 ($^{+2}_{-1}$) 10^4 M_{sun}

a/M >~ 0.7

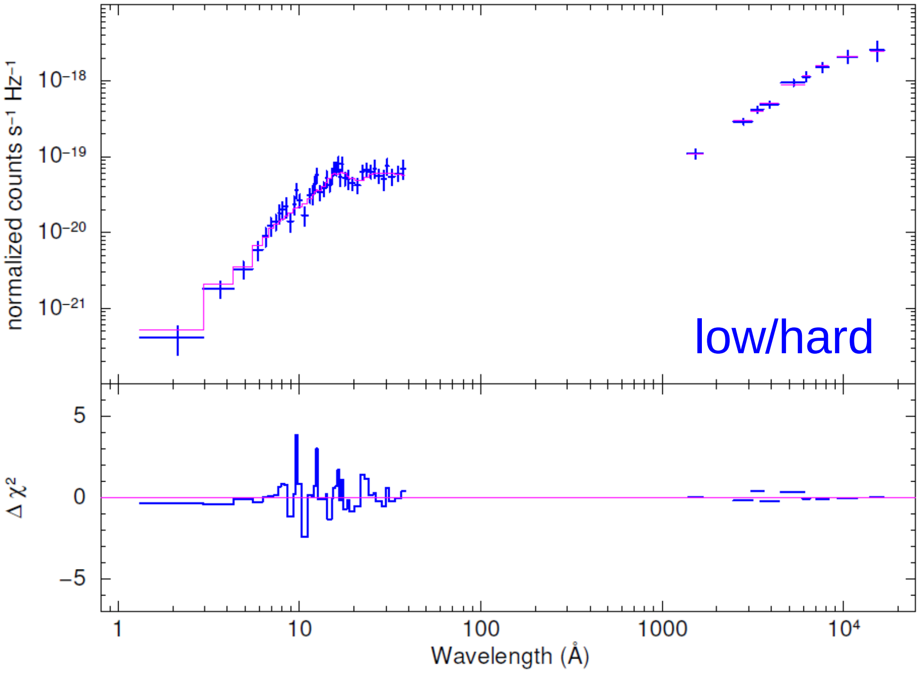
θ likely < 60 deg ➜ *a/M* >~ 0.9



Star cluster in addition to a disk?

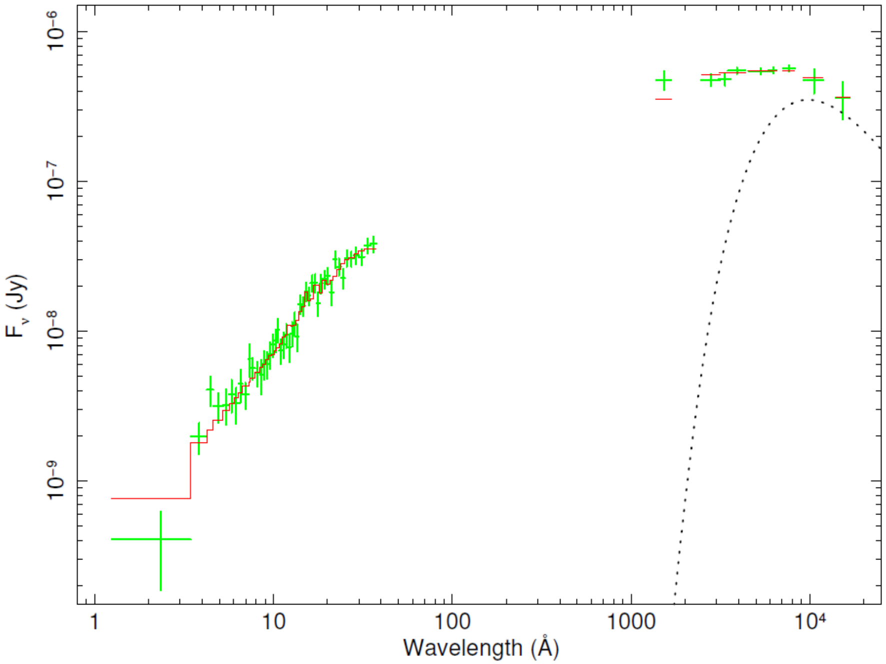


Optical emission
= blue/UV component
+ red/IR component



Red/IR component consistent with (constant) star cluster

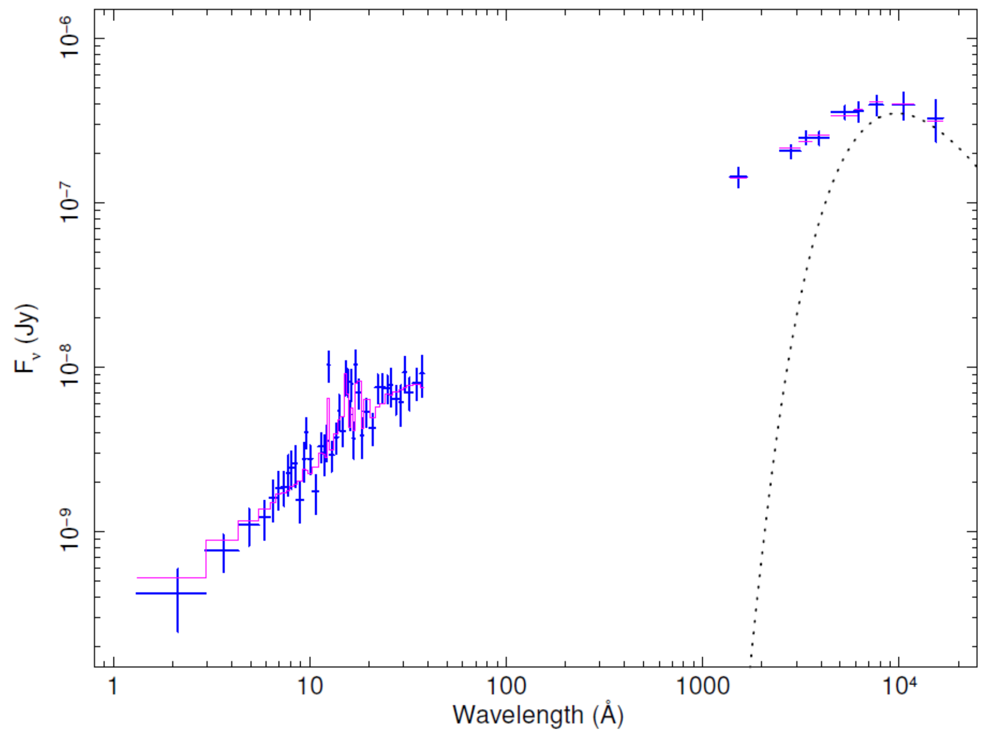
Star cluster in addition to a disk?



If red/IR component
= star cluster

$M_V \sim -9.2$ mag
B-V ~ 0.8 mag

age >~ 6 Gyr
$M \sim 3 \times 10^6 M_{sun}$



Summary

1. Optical light dominated by irradiated disk (blue/UV) + old stellar population (red)

2. Recurrent outbursts may be due to wind-driven oscillation in the inner disk

3. Applying canonical BH states gives $M \cos\theta \sim 2\ (^{+2}\ _{-1})\ 10^4\ M_{sun}$, a/M >~ 0.9