Highly Variable X-ray Sources and Tidal Disruption Events in the *XMM-Newton* SLew survey (XMMSL)

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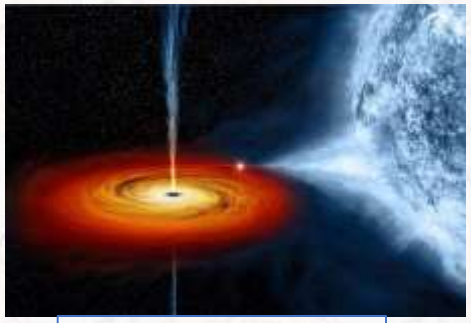
NATIONAL ASTRONOMICAL OBSERVATORIES, CAS

X-ray transients and variabilities

Stellar flares



X-ray Binaries

Active galactic nuclei

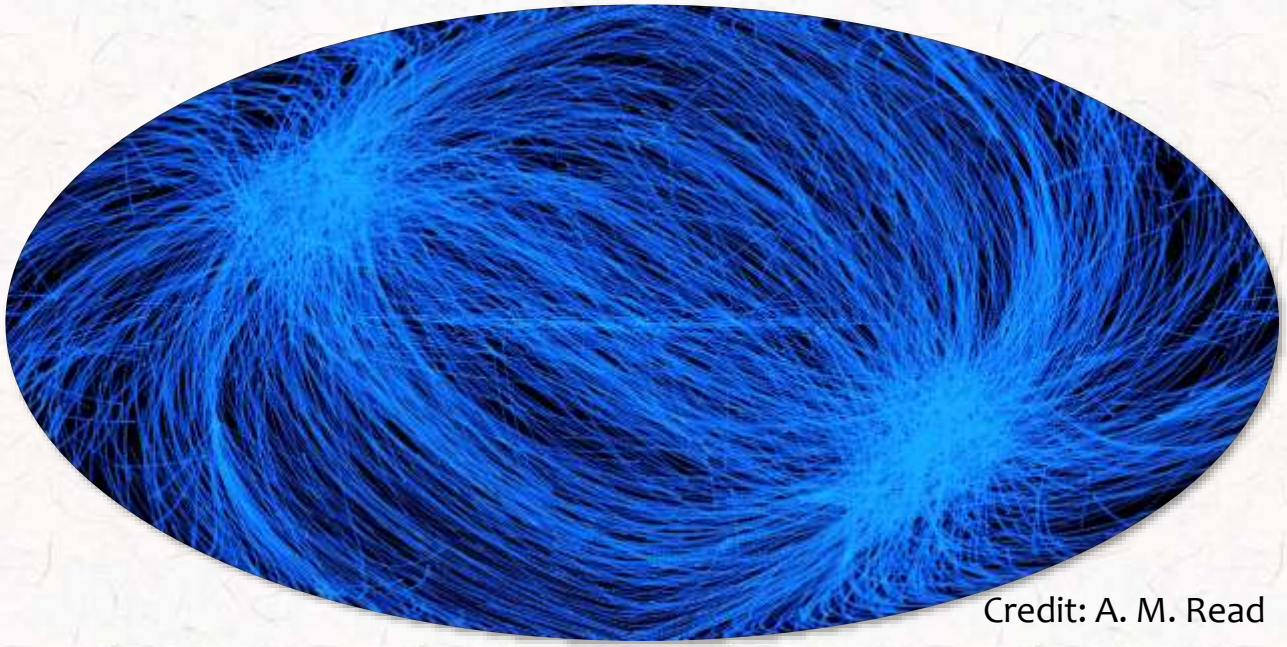
Tidal Disruption Events

Systematic study provides information to uncover their nature and the mechanism causing the variabilities.

***XMM-Newton* SLew survey (XMMSL)**

Provides predictions for the long term transients/variable sources EP will detect.

XMM-Newton SLew survey (XMMSL)



Credit: A. M. Read

Slews used in the creation of XMMSL2
84% sky coverage, limiting flux: 6e-13 erg/s/cm2
(between 2001-08-26 and 2014-12-31)

Previous work

- Sample study: e.g. X-ray extragalactic transients in the LIGO/VIRGO horizon (Kanner+ 2013), Highly variable AGN in XMMSL (Strotjohann+ 2018).
- Individual transients: e.g. TDE (e.g. Esquej+ 2008; Saxton+ 2012, 2014, 2017), nova (e.g. Read+ 2008, 2009).

Lacking an overall census of the variable sources

Our work:

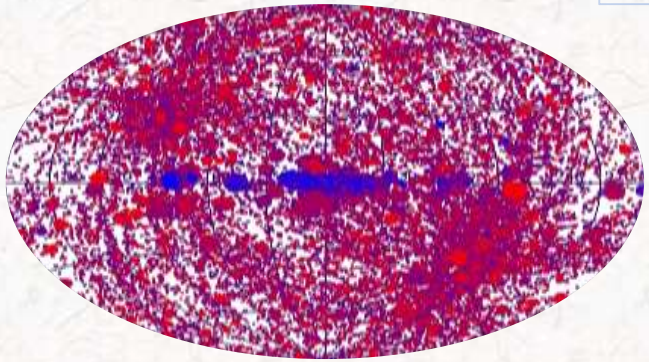
1. Systematic study of highly variable sources with XMMSL2/RASS>10 (Li et al. 2022)
2. Discover more interesting transients, especially TDEs (Li et al. 2020)

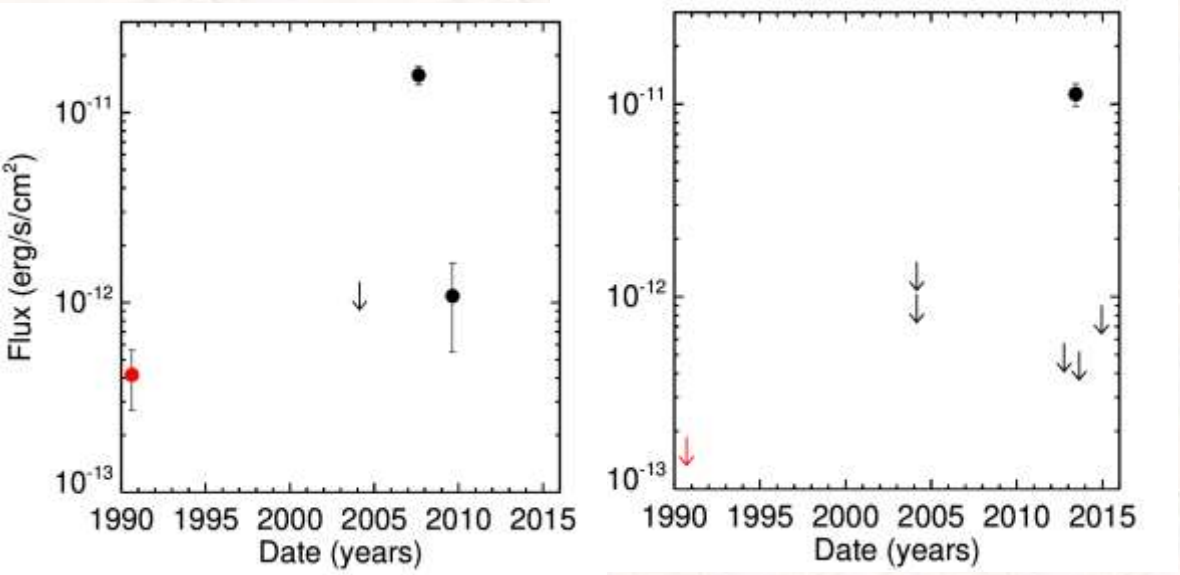
Highly Variable Source Sample

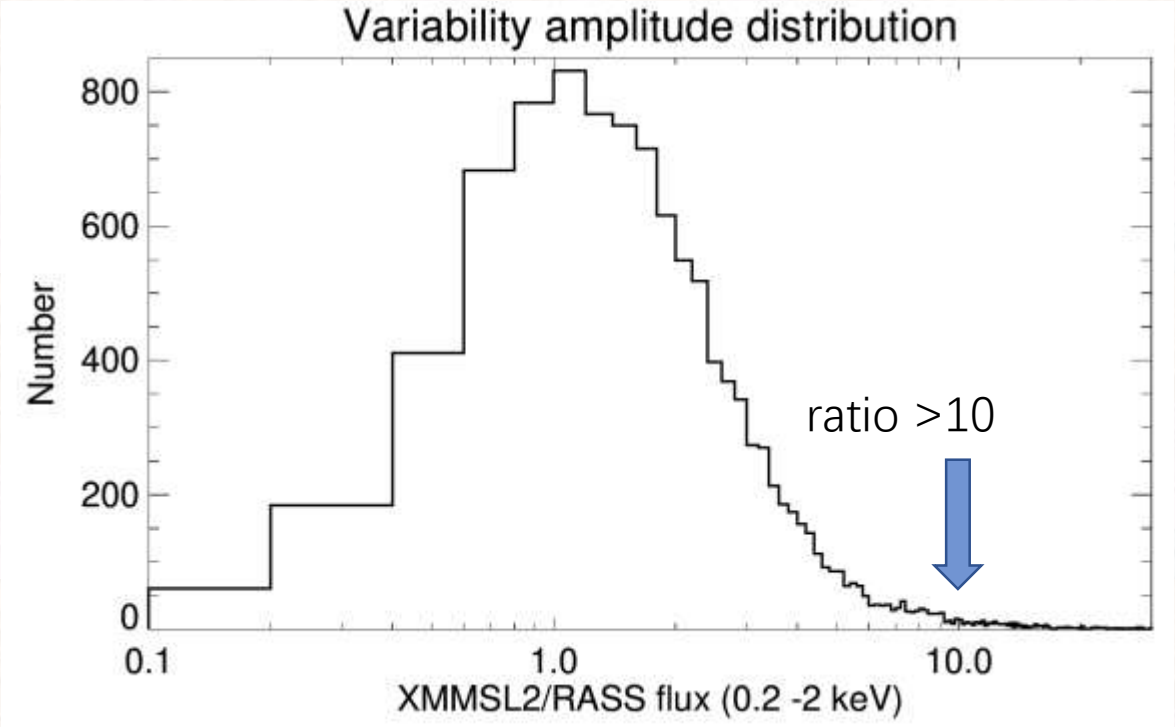
Comparing with ROSAT All Sky Survey (~1991)

XMMSL2 (credit: XMMSL home page)

10463 sources







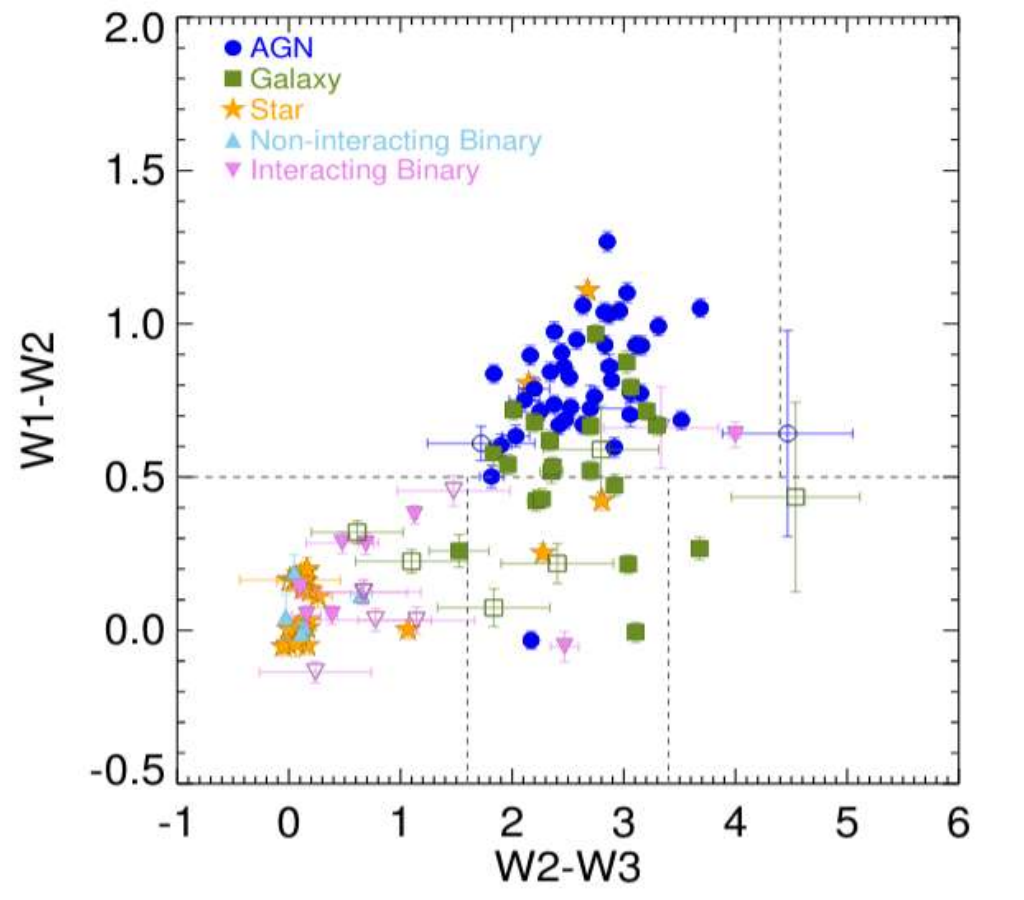
265 (2.5%) sources with variability amplitude>10

Source Identification

SIMBAD, NED

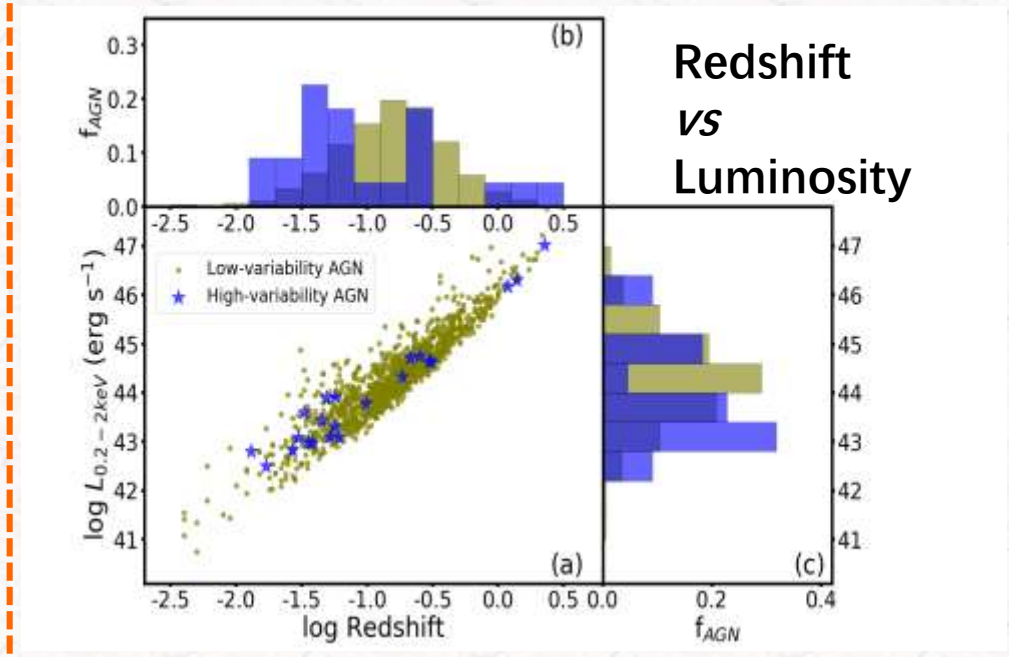
GAIA, WISE

250 out of 265 identified



Wise colour-colour diagram

Active Galactic Nuclei (60/265)

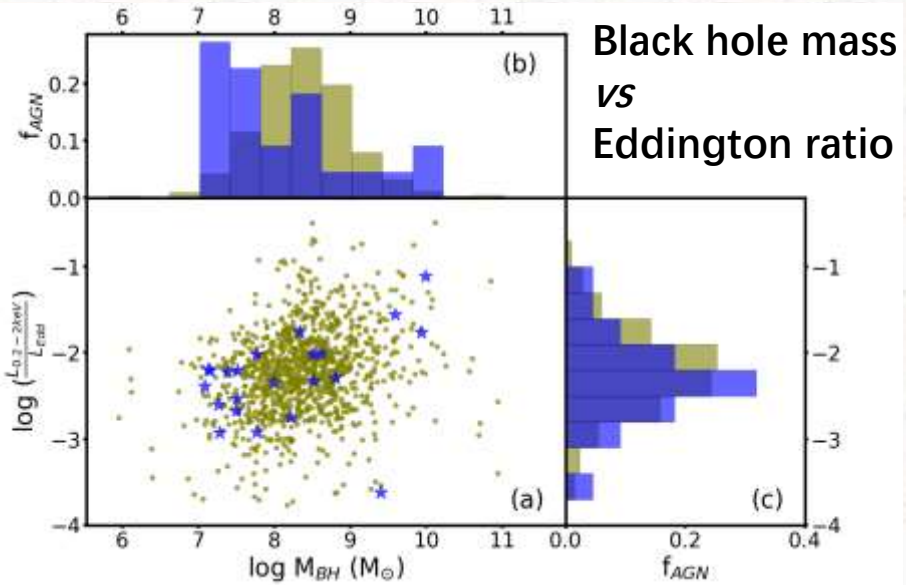


Redshift *vs* Luminosity

Figure 9. (a): Redshift and unabsorbed soft X-ray luminosity distribution of the high-variability (blue stars) and low-variability AGN (green circles).

Comparison sample of low-variability AGN (1135): 0.3<XMMSL2/RASS<3

Figure 10. (a): Eddington ratio and black hole mass distribution of the high-variability (blue stars) and low-variability AGN (green circles). (b):



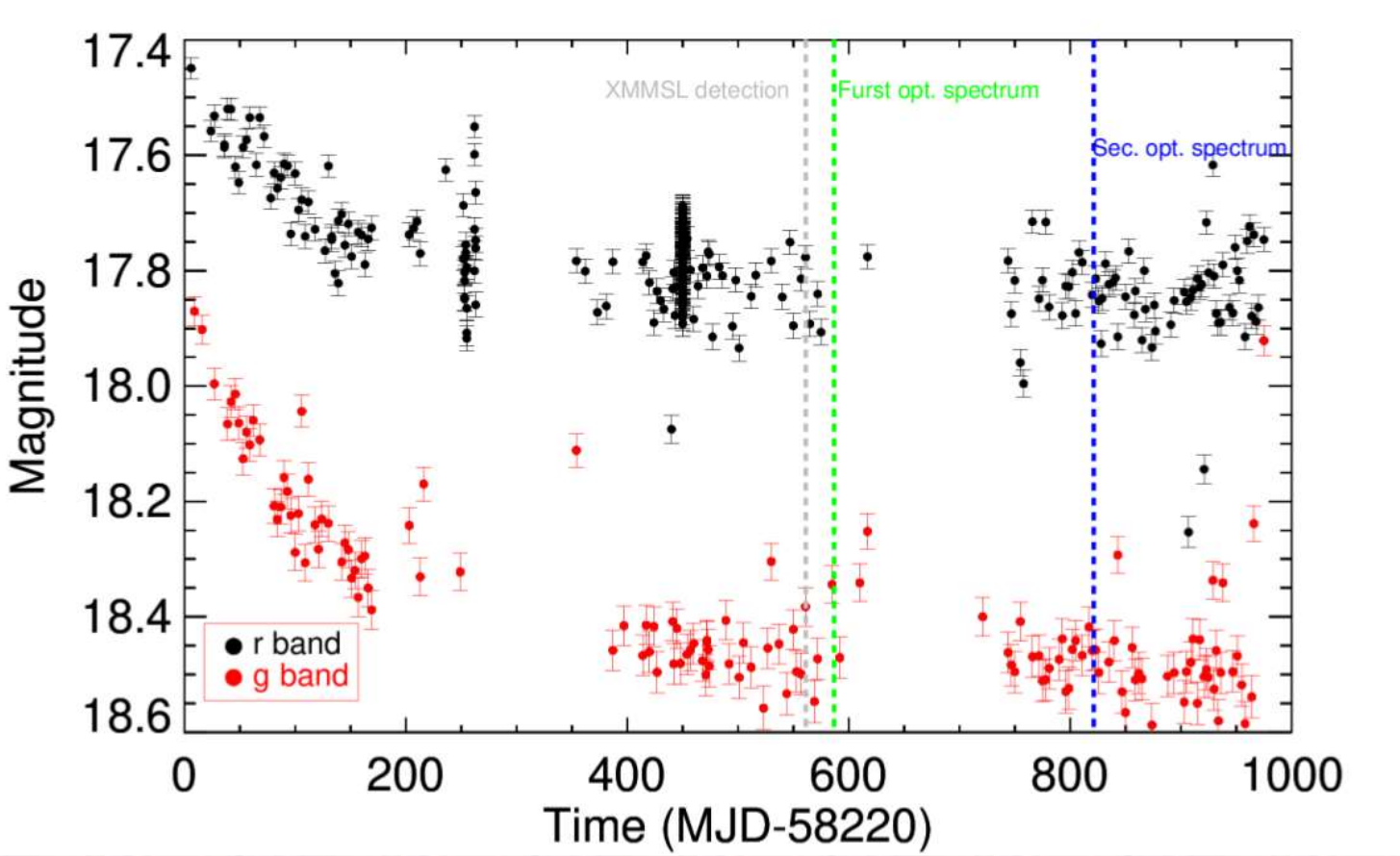
Black hole mass *vs* Eddington ratio

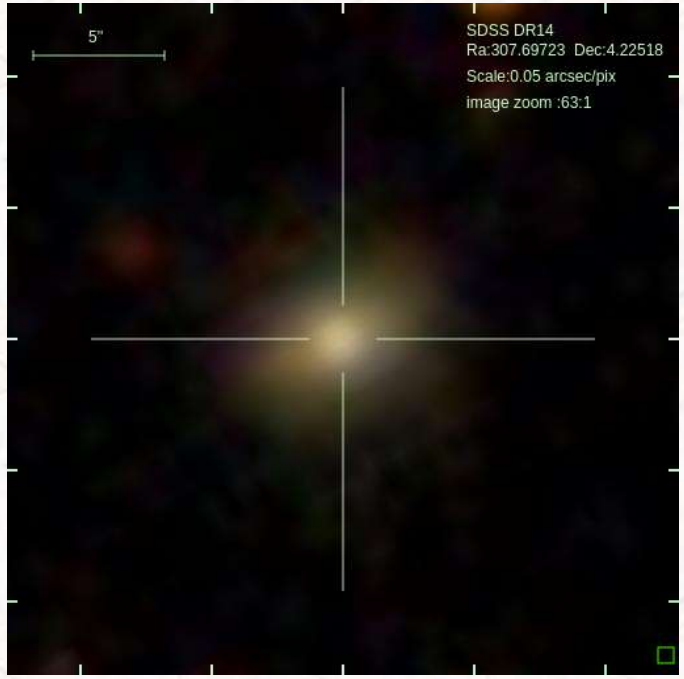
KS test probability: comparison of high- and low-variability AGN sample

Redshift: 0.0004, Luminosity: 0.02
Black hole mass: 0.009, Eddington ratio: 0.5

Highly variable AGN tend to have lower luminosity, redshift and black hole mass.

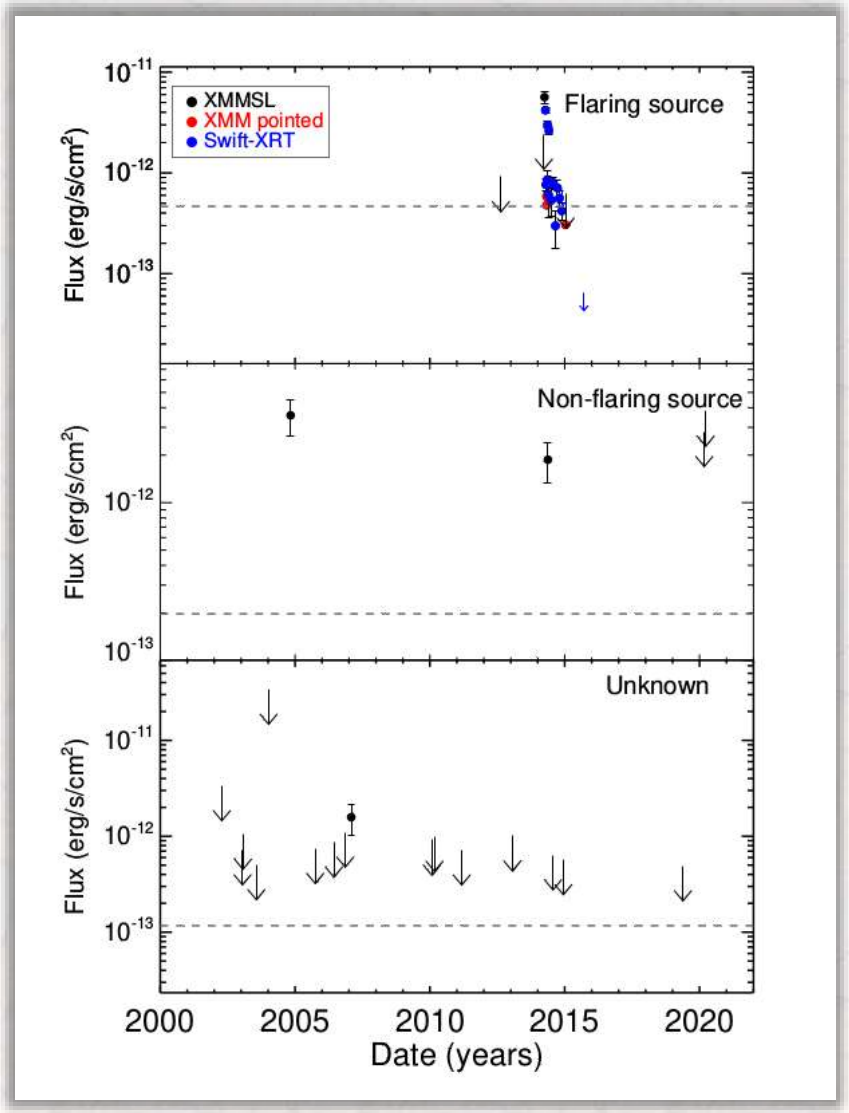
Interesting individual sources





Highly variable typeII AGN

Galaxies (63/265)



Flaring source

13 in total

4+1+more TDE candidates

Non-flaring source

16 in total

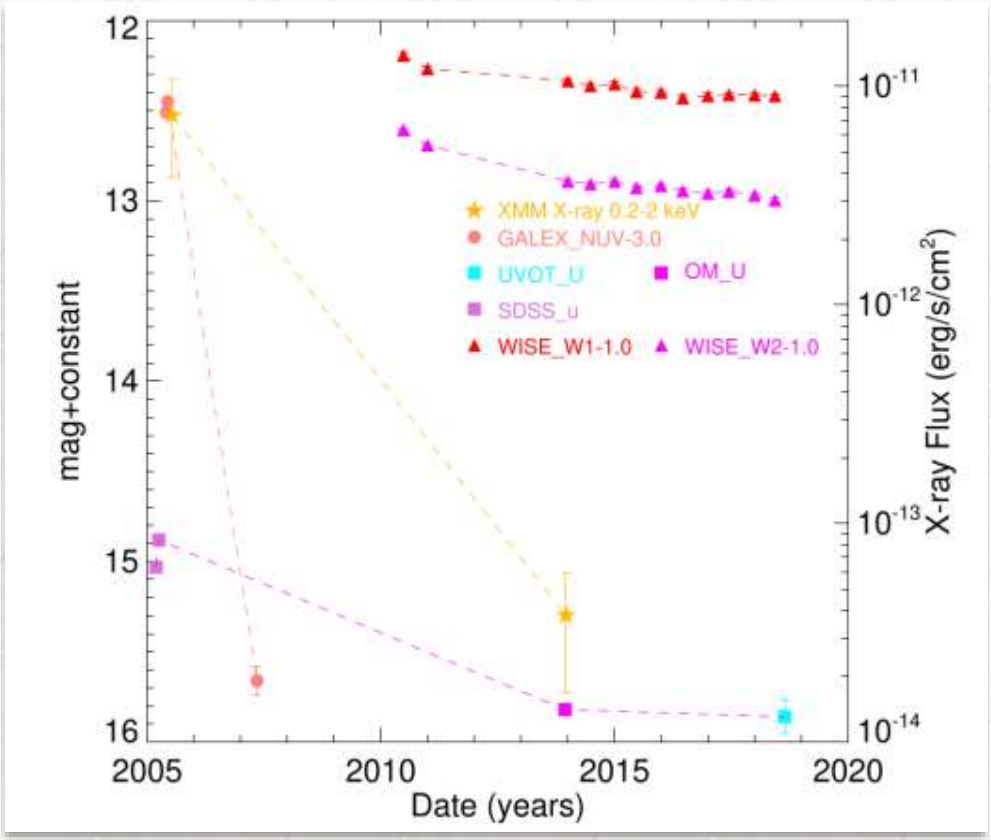
AGN-like colour:9
Likely AGN or long-decay TDE: 7

Unknown source

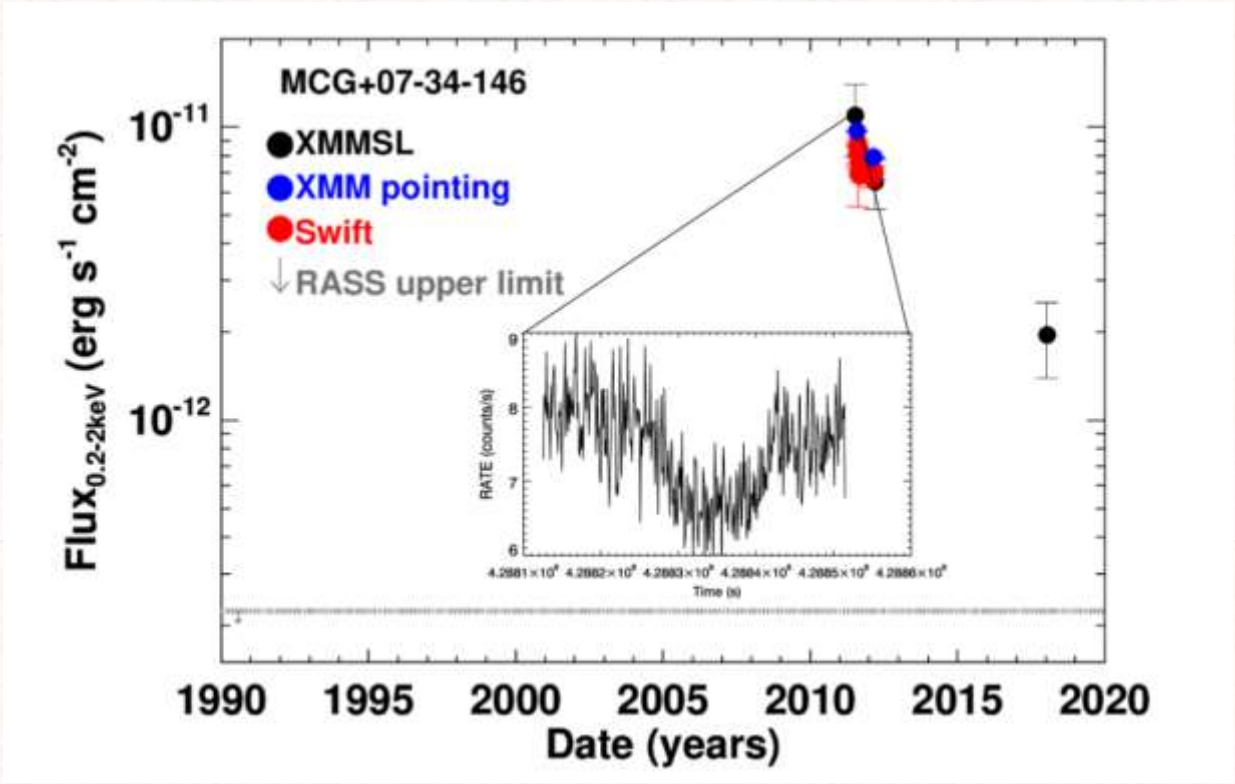
34 in total

AGN or TDE or other

Interesting individual sources (TDE)

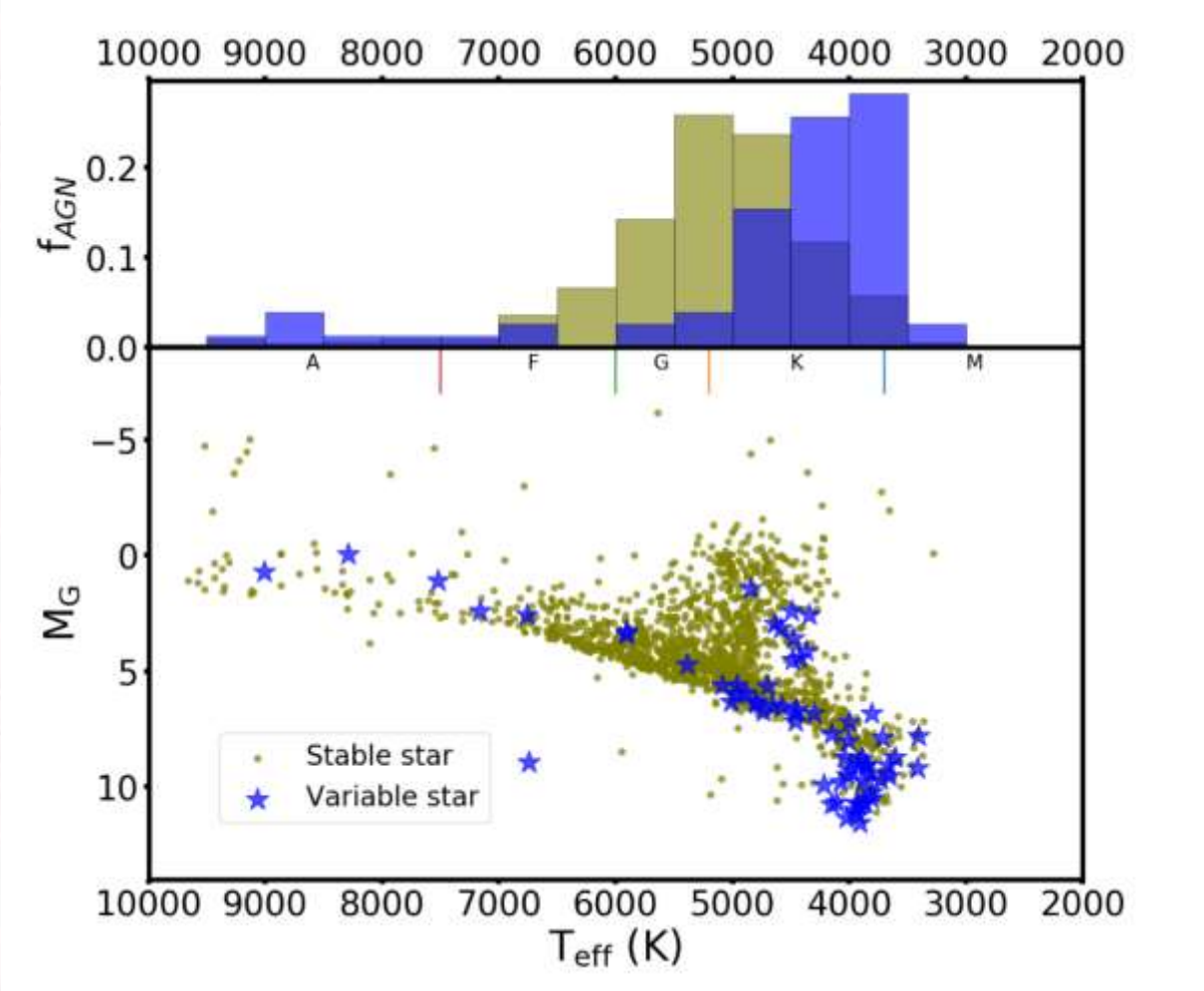


XMMSL1 J1319+2259



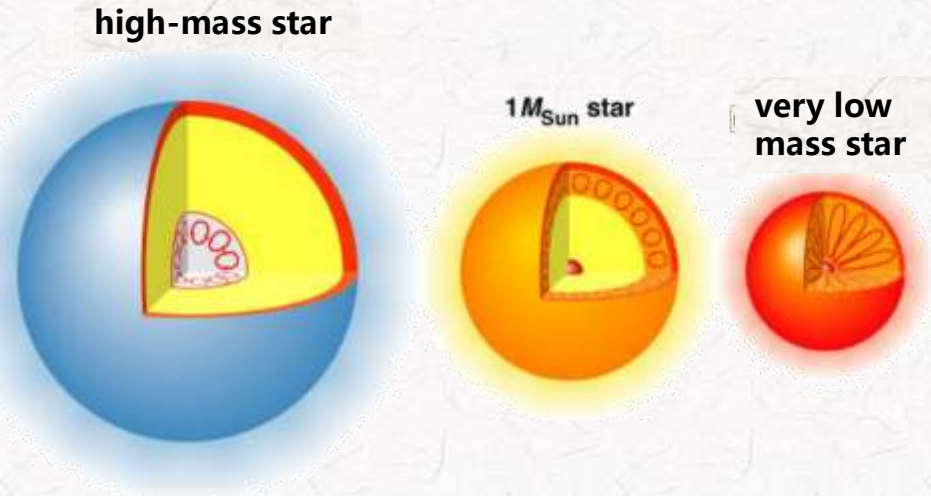
TDE candidate in a starforming galaxy

Stars (95/265)



Non-variable and variable stars on HR diagram

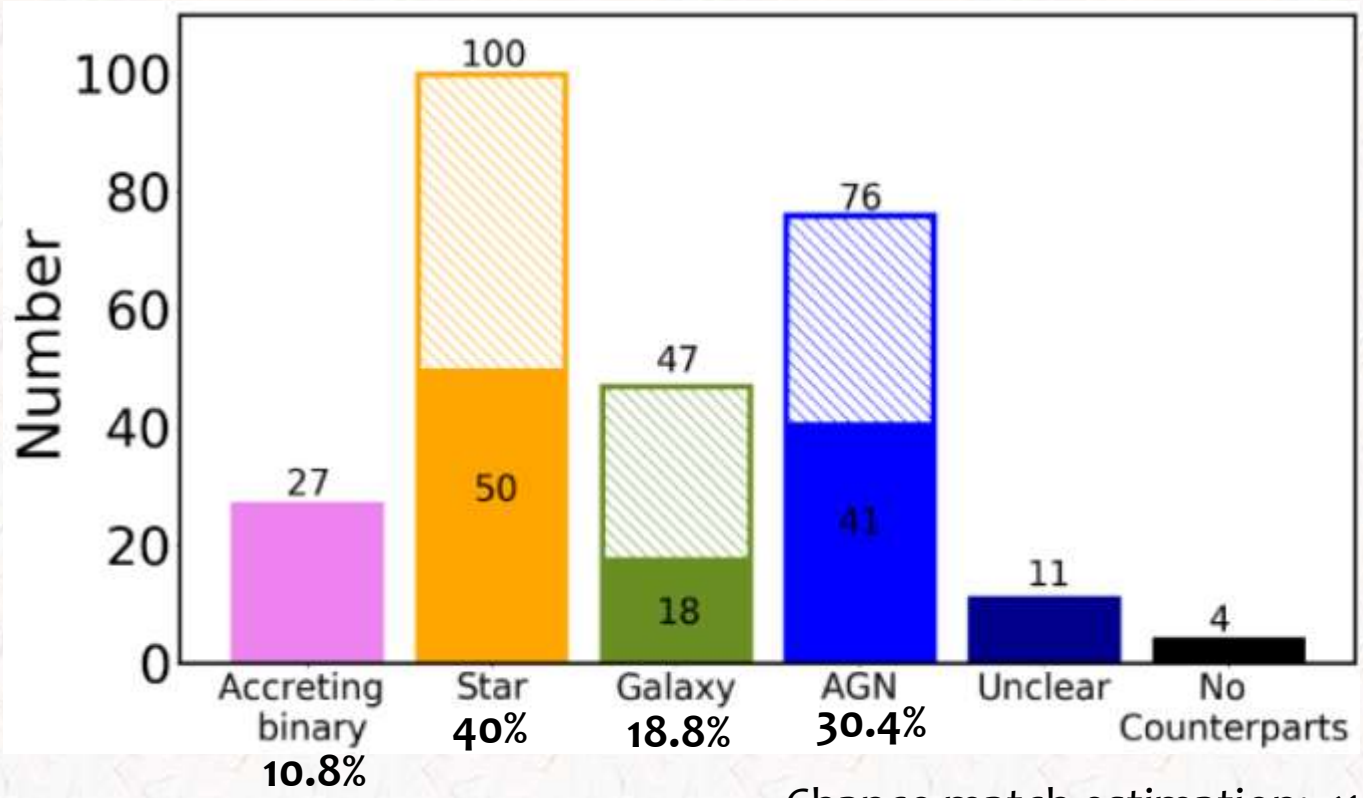
Comparison sample of non-variable star (1763): 0.3<XMMSL2/RASS<3



Most highly variable stars are late type.

Results of Identification

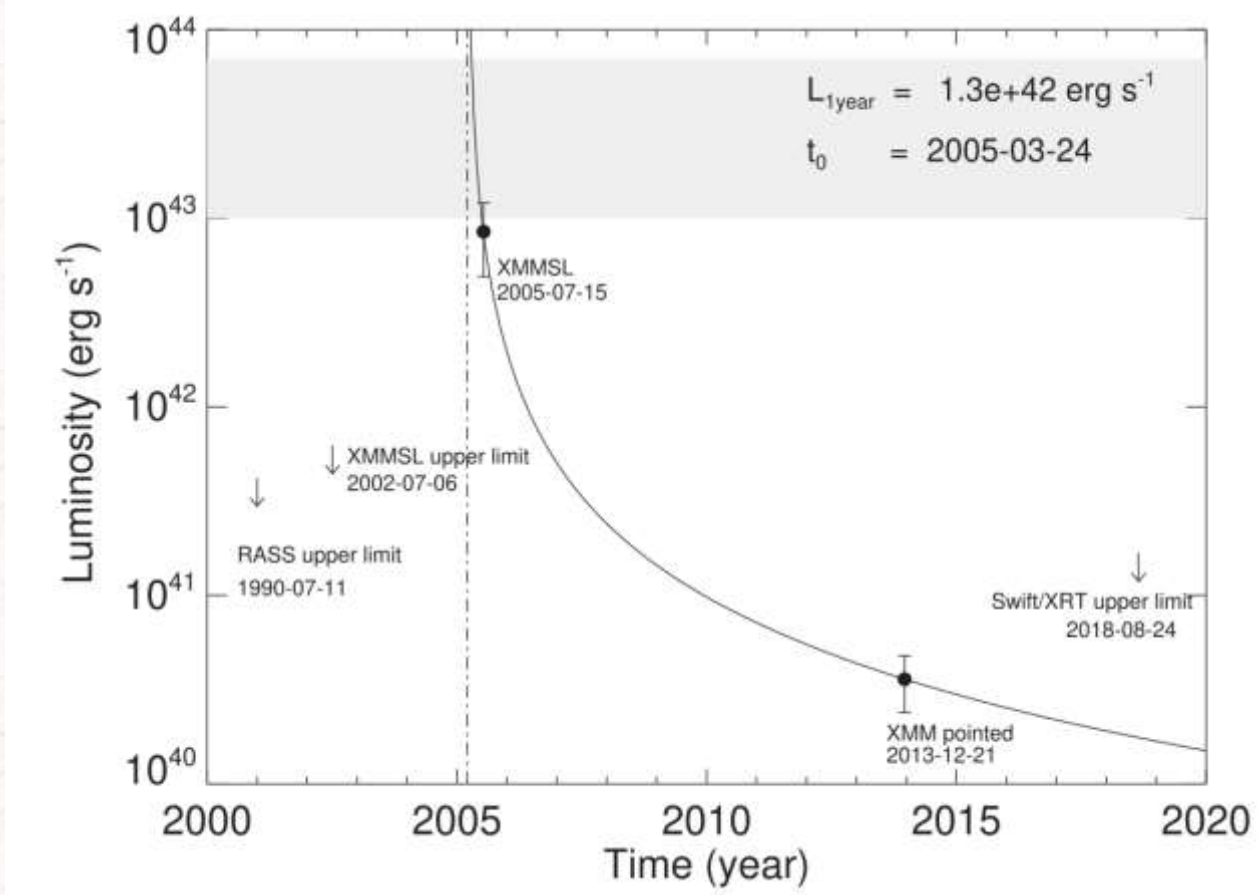
Li Dongyue, Starling, R. C., Saxton R. D., Pan Haiwu, Yuan Weimin. 2022, MNRAS, 512, 3858.

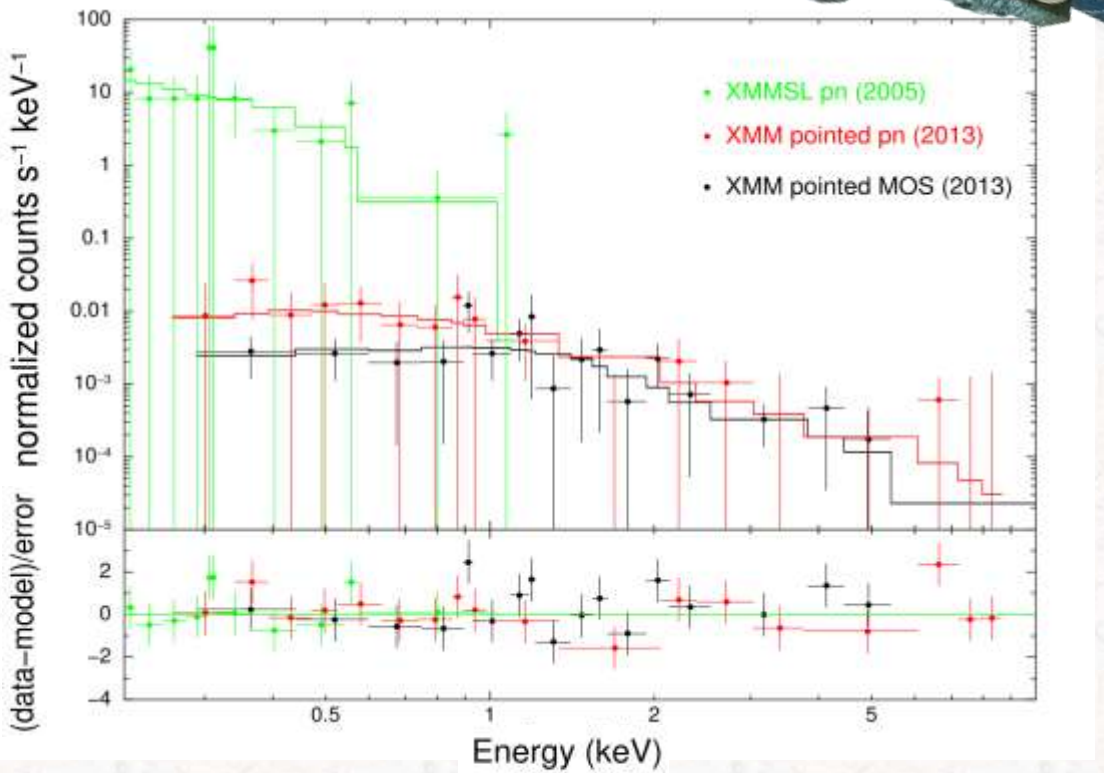


Chance match estimation: <10%

Catalogue release: http://paperdata.china-vo.org/Li.Dongyue/xmmsl2_variables_final_upload.csv

XMMSL1 J1319+2259 (X-ray data)



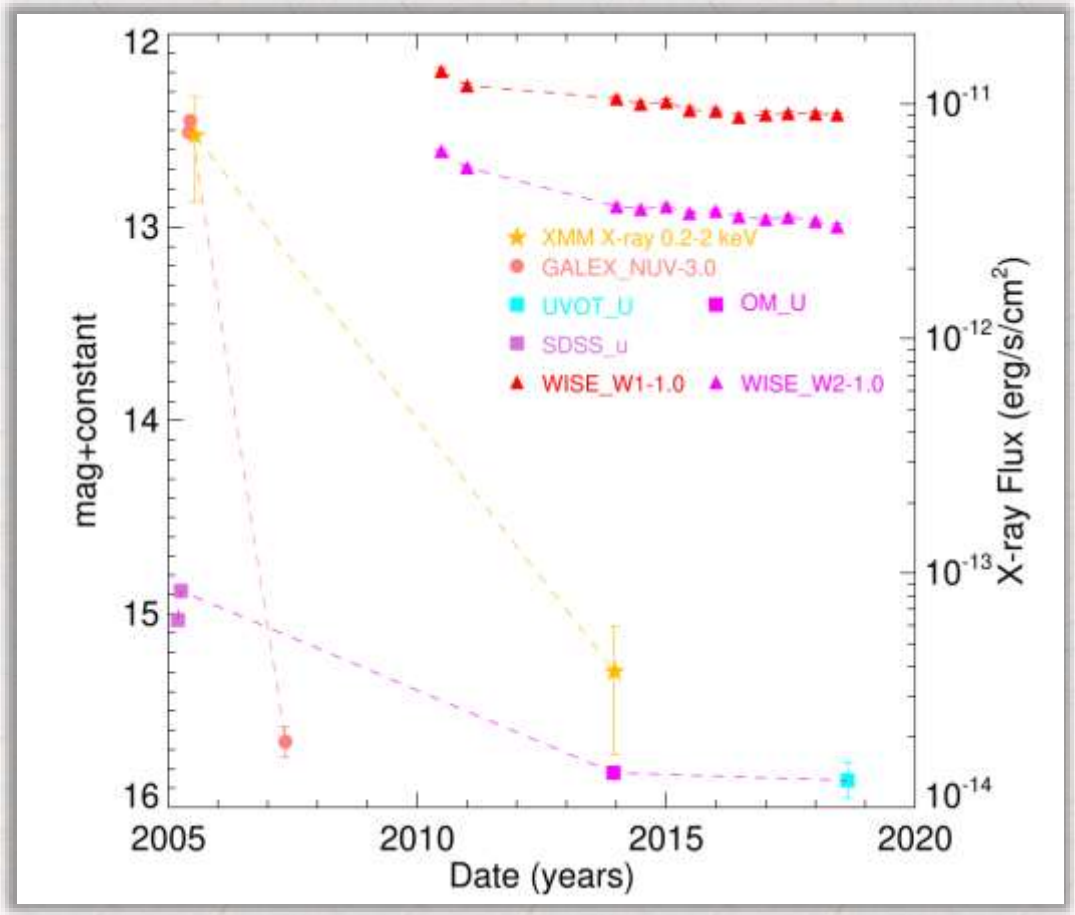


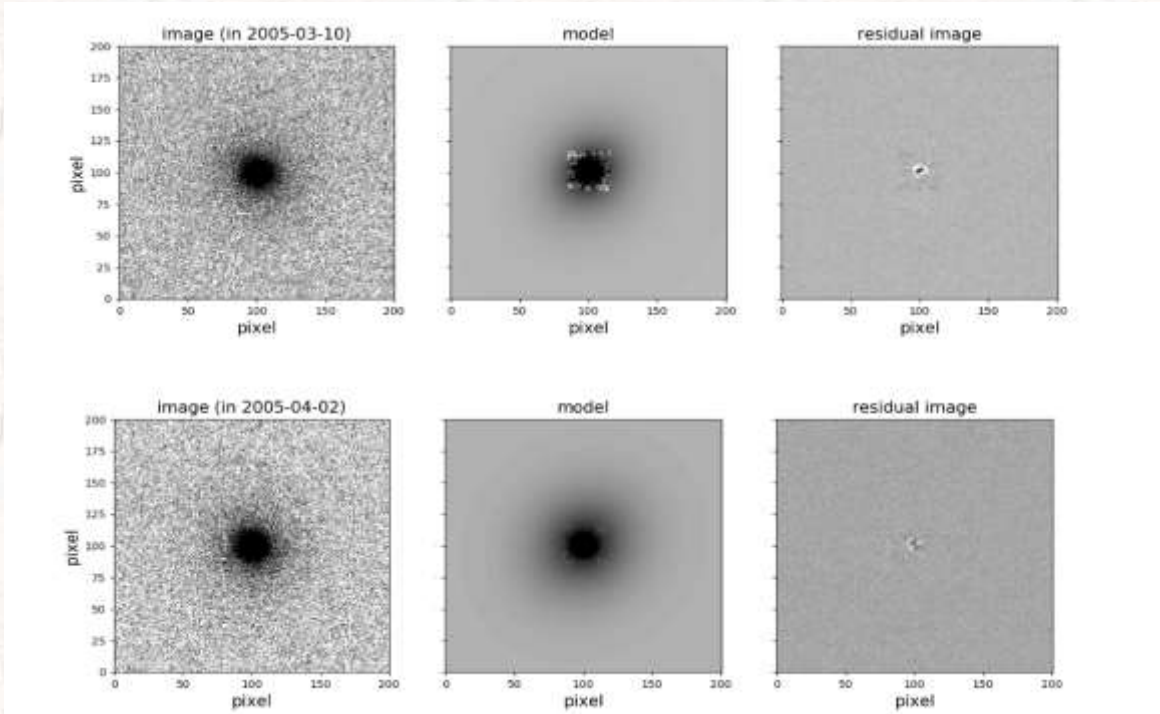
$$L(t) = L_{1\,\mathrm{yr}} \times \left[\frac{t - t_0}{1\ \mathrm{yr}}\right]^{-5/3} \mathrm{erg\ s^{-1}}$$

Outburst time: ~2005 March

Obs	Model	Γ	kT (eV)
pointed	tbabs*(zpo)	$2.1^{+0.5}_{-0.5}$	(−)
slew	tbabs*(zpo)	$4.4^{+2.0}_{-1.7}$	(−)
〃	tbabs*(zbb)	(−)	$64.2^{+31.2}_{-22.0}$
〃	tbabs*(zpo+zbb)	2.1(fixed)	$64.0^{+31.2}_{-22.1}$

Multiwavelength Photometry

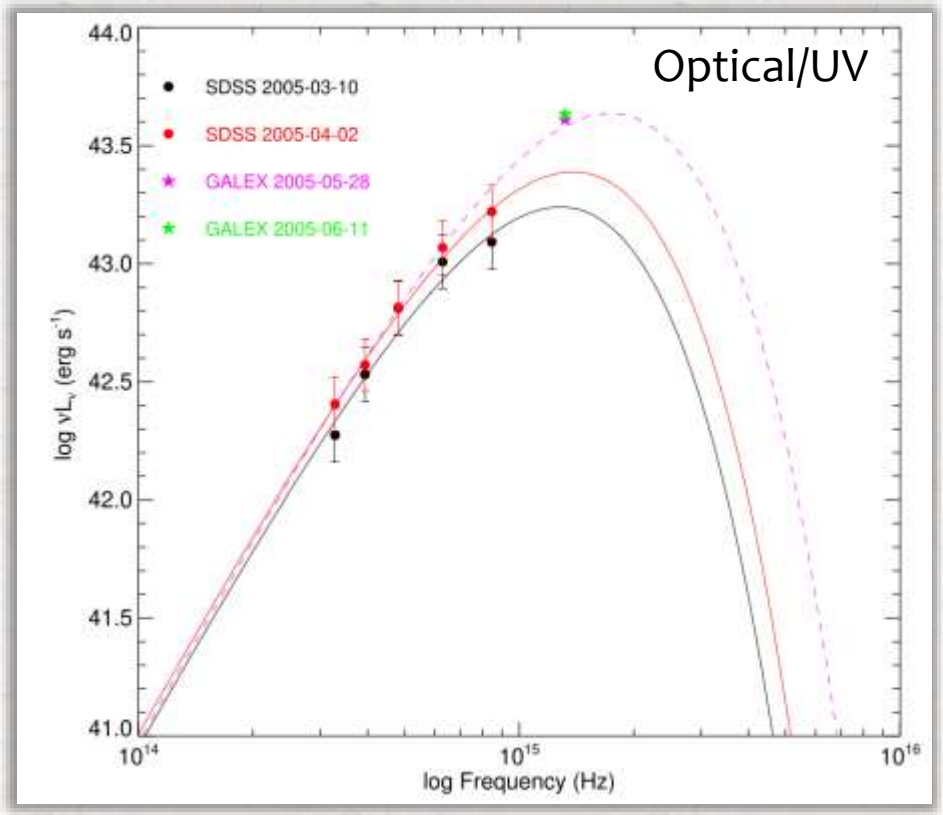


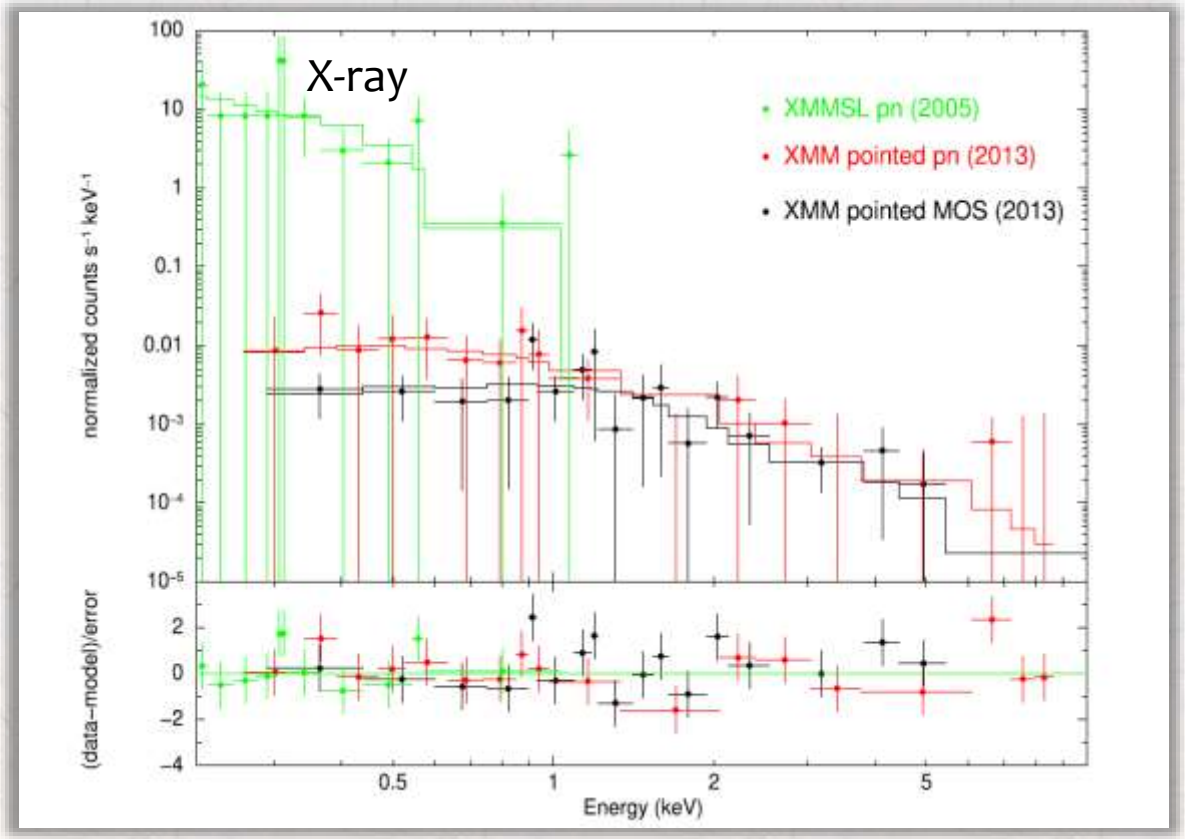


X-ray: ~270
Optical： 1 magnitude UV： 3 magnitude
IR： kept declining from 2011-2018

Separate nuclei and galaxy light by
2D image decomposition using GALFIT

SEDs of the flare



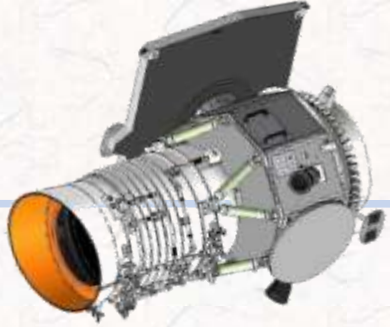


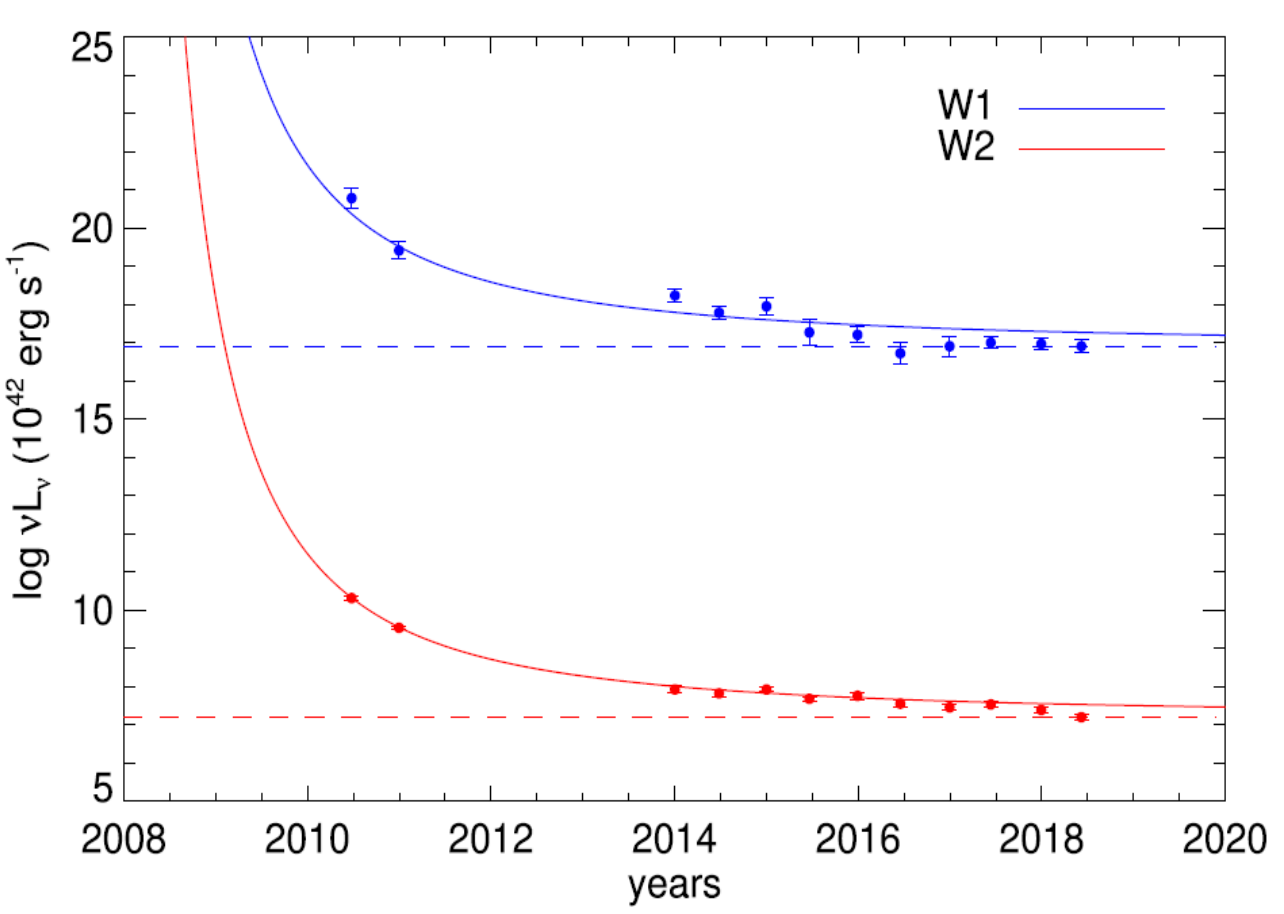
Assuming black body radiation:

Temperature: $(1-2)\times 10^4 K$
Luminosity: $(2-6)\times 10^{43}$ erg s $^{-1}$
Emission region: $100R_{\rm g}$ $(R_{\rm g}=\frac{GM_{\rm BH}}{c^2})$

Temperature: ~60eV $(7\times 10^5\ K)$
Luminosity: 1.5×10^{43} erg s $^{-1}$
Emission region: several $R_{\rm g}$ $(R_{\rm g}=\frac{GM_{\rm BH}}{c^2})$

Infrared echo





Smoothed W1 and W2 light curves of NGC 5092 and the dust reradiation model.

Assuming $L(t) \propto t^{-5/3}$, and the time lag between IR and X-ray emission is t_d

Assuming T=1000K

$t_d = 2.5 \pm 0.1$ yr

A schematic of the flare

Observer

Optical/UV continuum

$(1\text{-}2)\times10^4\ K$

X-ray

$(7\times10^5\ K)$

Several R_g

~100 R_g

~0.7 pc

Dust (1000K)

Dust (1000K)

Summary

1. 265 sources with XMMSL2/RASS>10. 250 (94.3%) identified, 40% stars, 10% accreting binaries, >30.4% AGN.

Li Dongyue, Starling, R. C., Saxton R. D., Pan Haiwu, Yuan Weimin. 2022, MNRAS, 512, 3858.

2. Most highly variable stars are late type. Highly variable AGN tend to have lower luminosity, redshift and black hole mass.

3. A new TDE showing optical/UV and X-ray brightening, and clear IR echo, taking place around a BH with $M_{\rm BH} = 5.0^{+5.6}_{-2.9} \times 10^7\,M_\odot$ Enlarges the limited sample (only several).

Li Dongyue, Saxton R. D., Yuan Weimin. et al. 2020, ApJ, 891, 121.