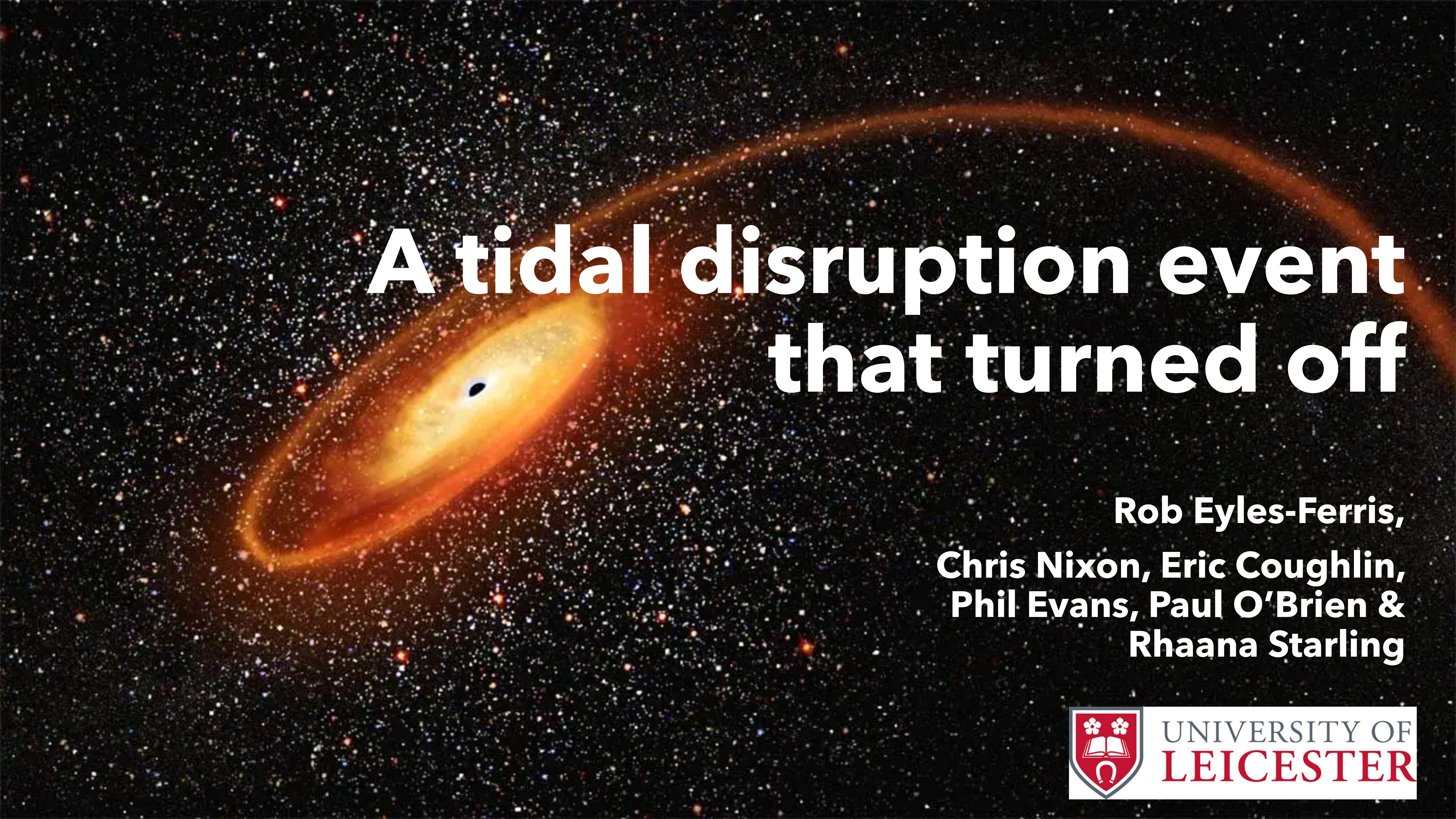


A tidal disruption event that turned off

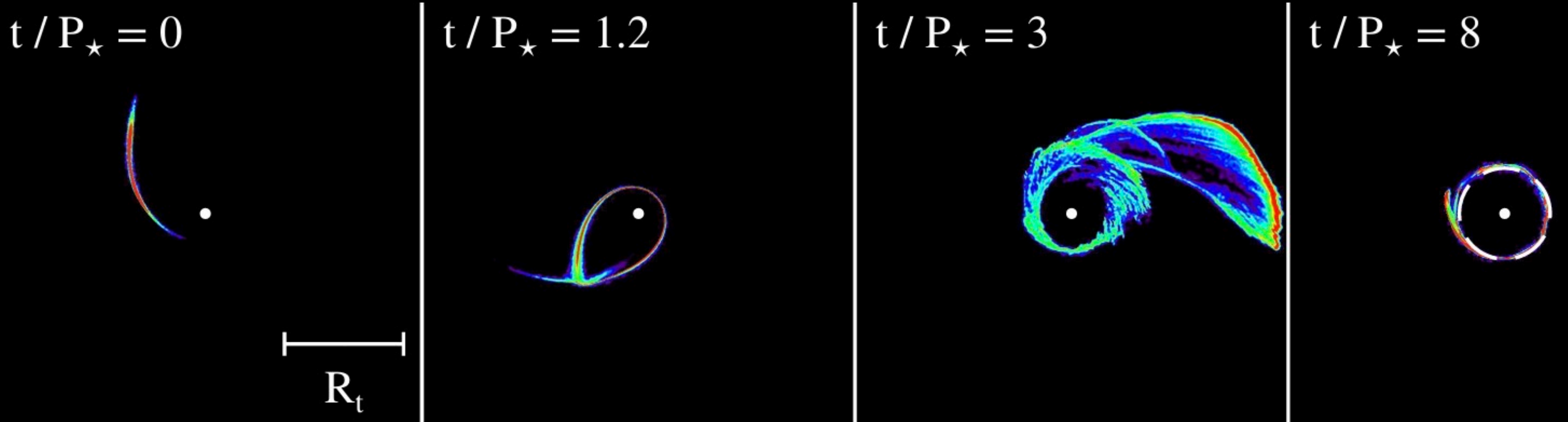
Rob Eyles-Ferris,

Chris Nixon, Eric Coughlin, Phil Evans, Paul O'Brien & Rhaana Starling

UNIVERSITY OF LEICESTER

What are tidal disruption events?

- Stars get torn apart when they get too close to a supermassive black hole and ~half the material remains bound to be accreted
- Fallback rate typically declines as $t^{-5/3}$ for a full disruption or $t^{-9/4}$ for a partial disruption
- Accretion rate can be highly super-Eddington at early times
- Typical hosts are green valley and centrally concentrated galaxies



Bonnerot et al. 2016

What do TDEs look like (X-rays)?

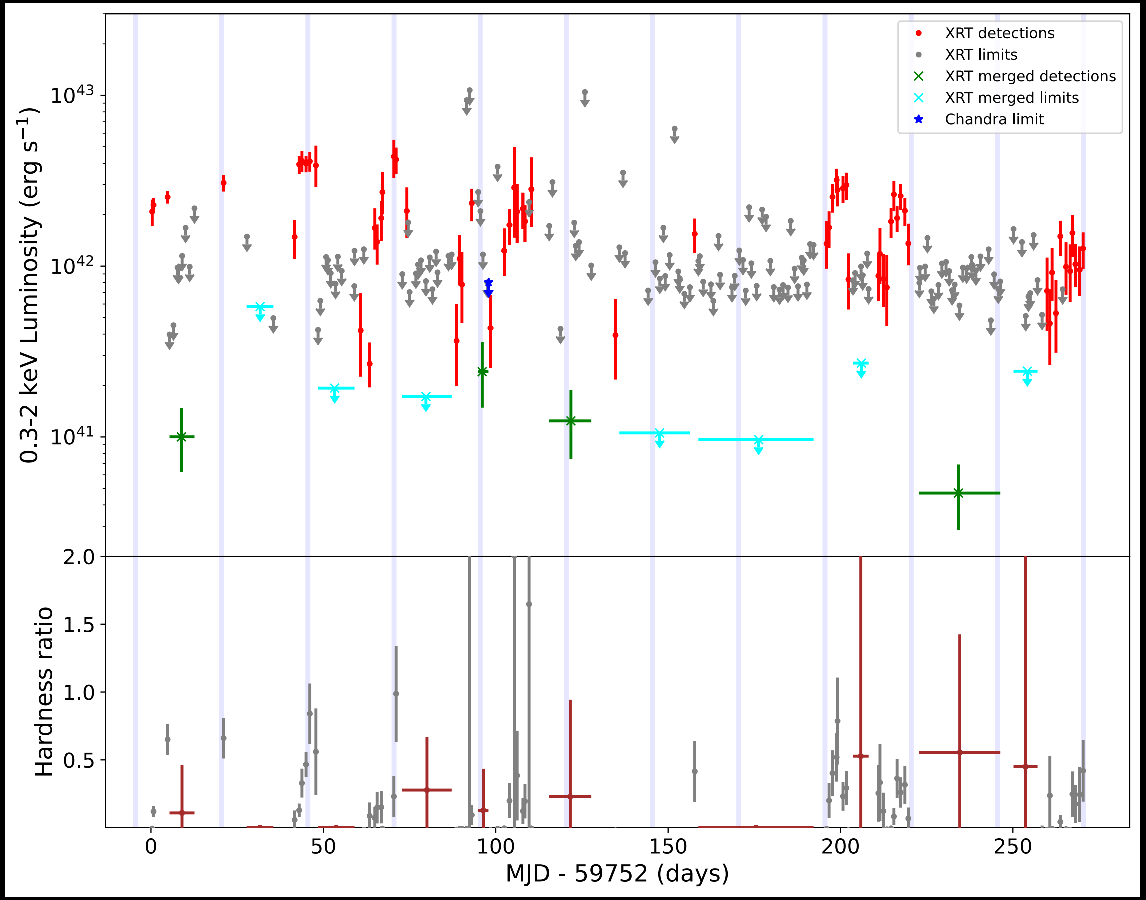
- Most emission is thermal from the accretion flow or stream self-interactions
  - Soft or super-soft spectra – typical blackbody temperatures ~50 to ~100 eV
- Decline consistent with fallback rate decline
  - Remain luminous for years (over a decade in some cases)
- UVOIR counterparts in some cases but not all (probably angular dependence)

- 4 TDEs (out of ~100) have relativistic jets
  - 3 found by *Swift*

- Repeating partial TDEs/QPEs/PNTs
  - Quasi-periodic thermal emission as a star is repeatedly disrupted

How can we find X-ray TDEs?

- First, we need an X-ray catalogue
- The Living *Swift*-XRT Point Source Catalogue
  - All the point sources *Swift* has observed
  - 330 429 sources as of yesterday
  - Living – this is a unique resource
- Has a built in transient detector*
  - Already made a significant TDE contribution with the discovery of rpTDE Swift J0230



Evans et al. 2023

*See poster by Srijan Srivastava

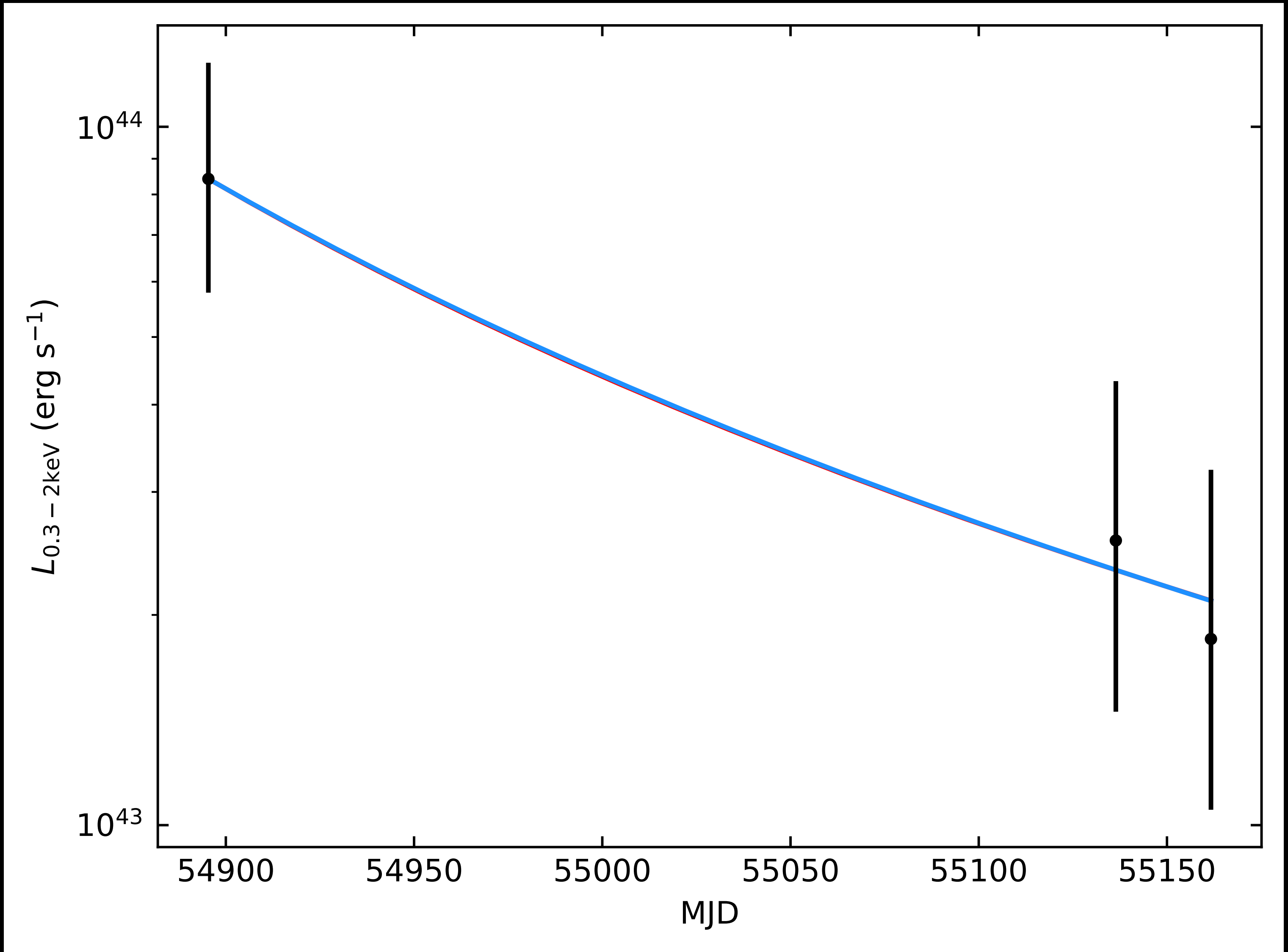
How can we find X-ray TDEs?

- Often look for flaring sources
- But TDEs are supersoft so can use the spectra instead
  - Works with *XMM-Newton* (Sacchi et al. 2023) and eROSITA (Eyles-Ferris et al. in prep)
- Set some criteria and we get ~400 sources to manually classify
- Picked up pretty much all the TDEs *Swift* has observed
- 6 new candidates including LSXPS J0956

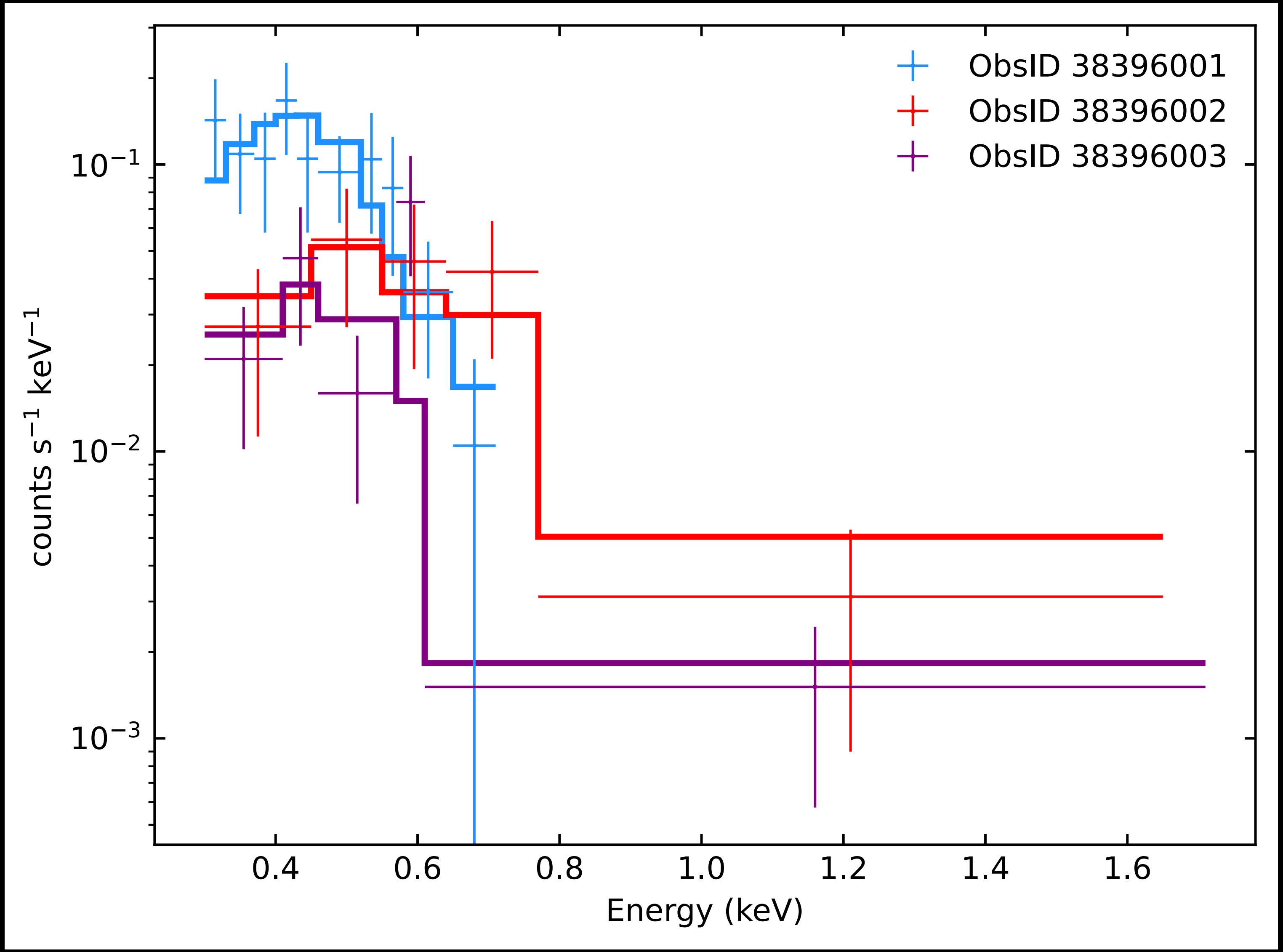
Source type	Number (% of full sample)
Stellar	116 (31.2%)
AGN candidates	137 (36.8%)
Diffuse galaxy/cluster emission	67 (18.0%)
Known transients	42 (11.3%)
Known TDEs	24 (6.5%)
New transient candidates	6 (1.6%)

How can we find X-ray TDEs?

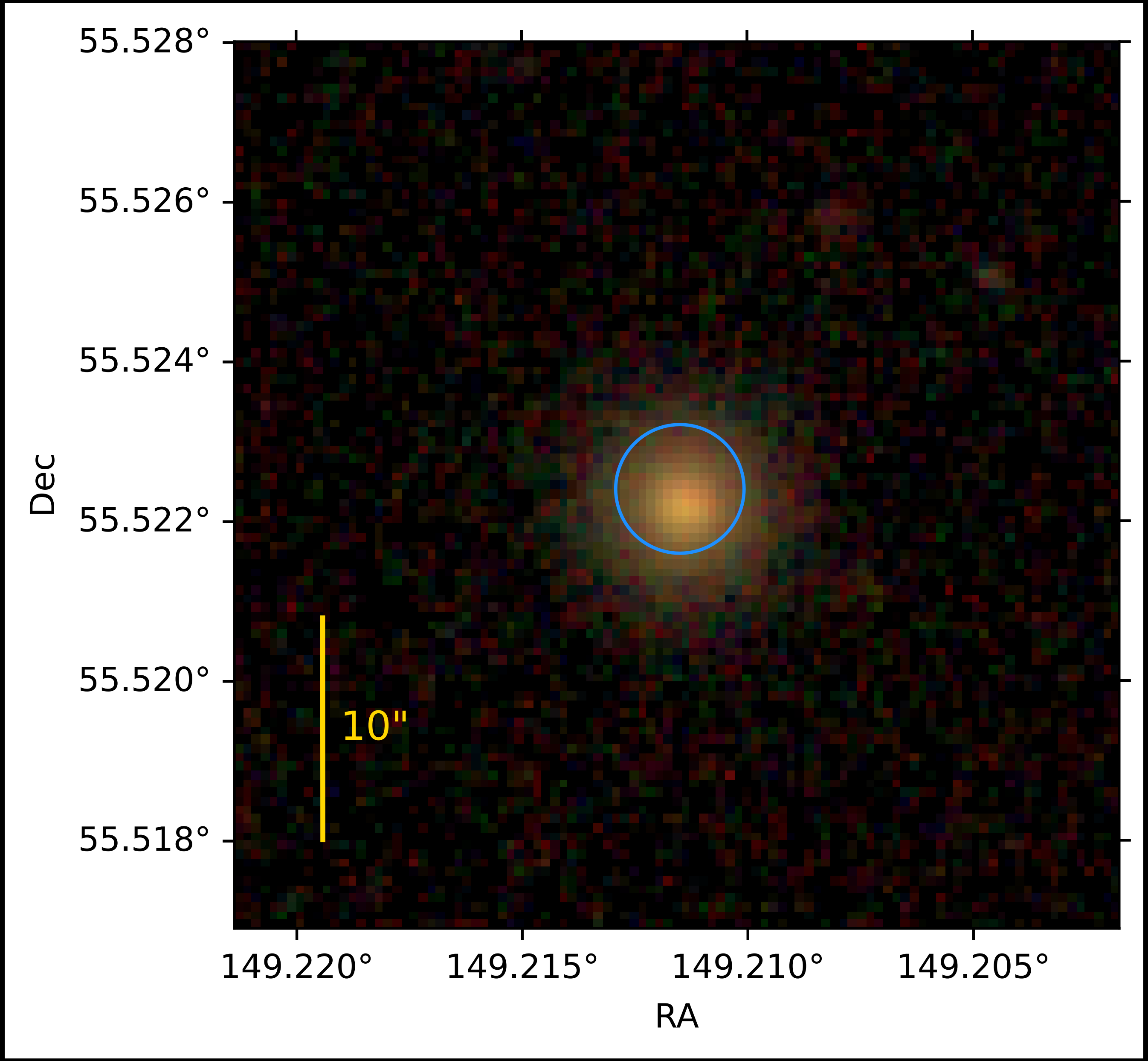
- Consistent with a $t^{-5/3}$ or $t^{-9/4}$ decay
- Soft thermal spectra
- Spatially consistent with the nucleus of a galaxy
- Host often green valley galaxy



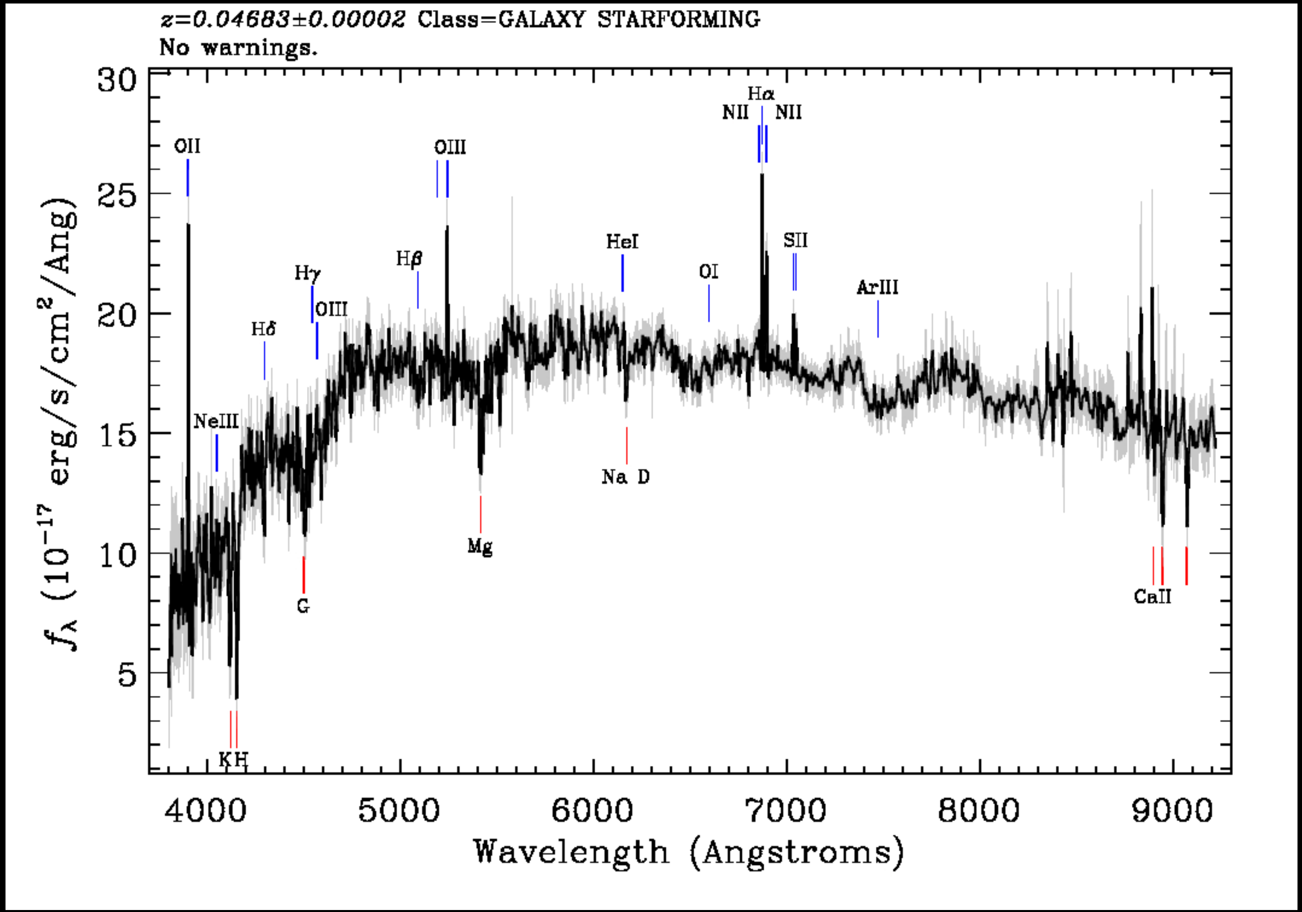
Eyles-Ferris et al. in prep.

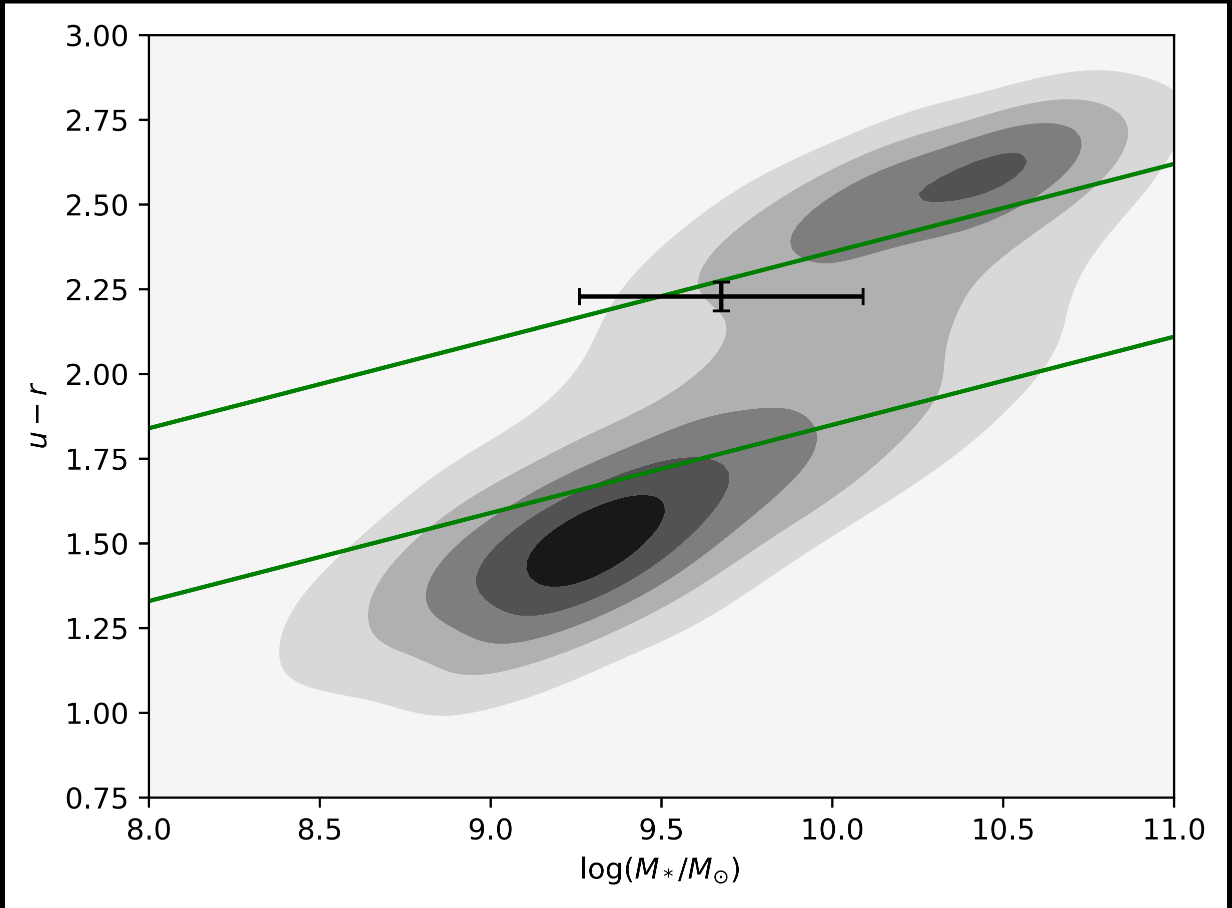


Eyles-Ferris et al. in prep.



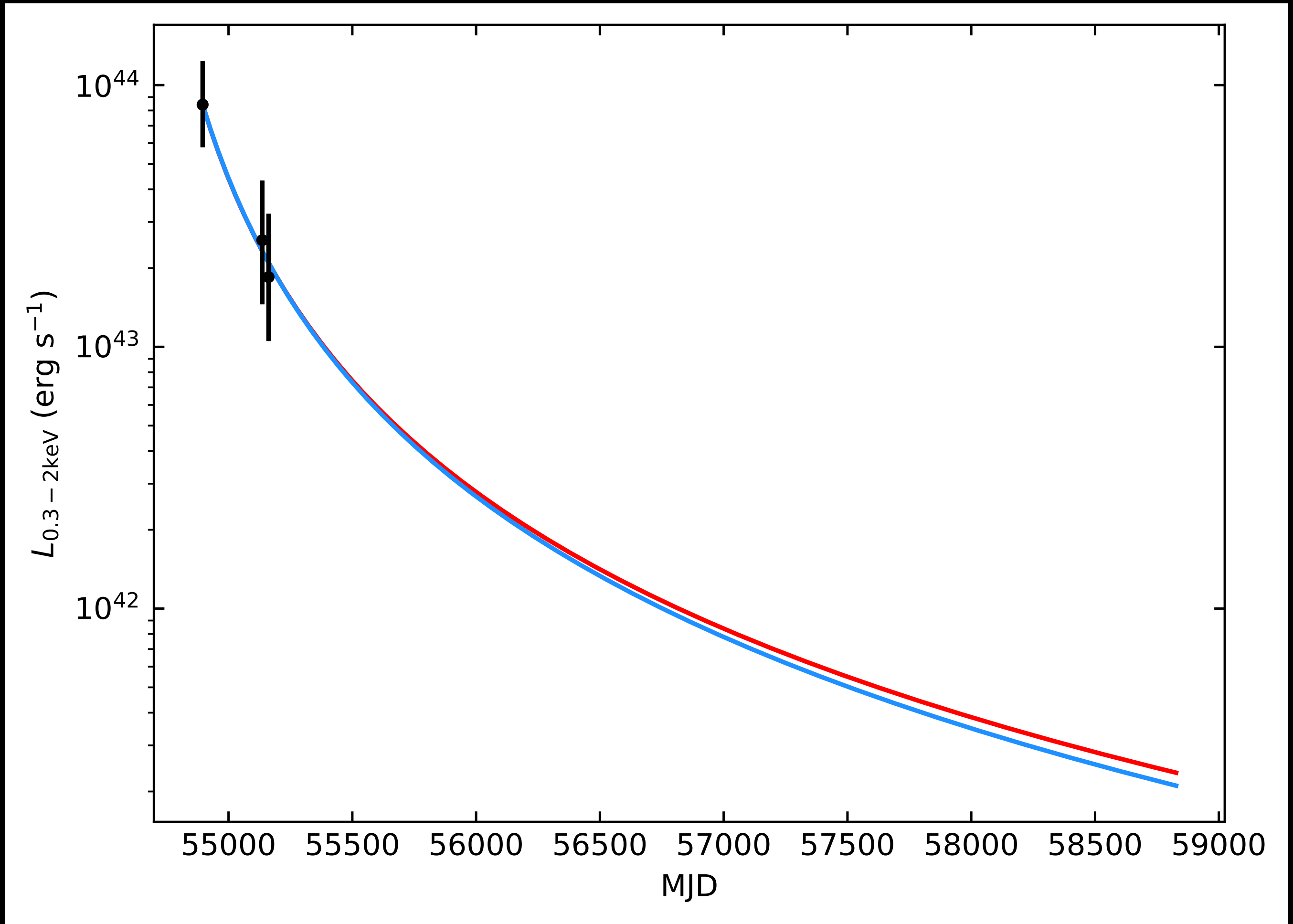
Eyles-Ferris et al. in prep.





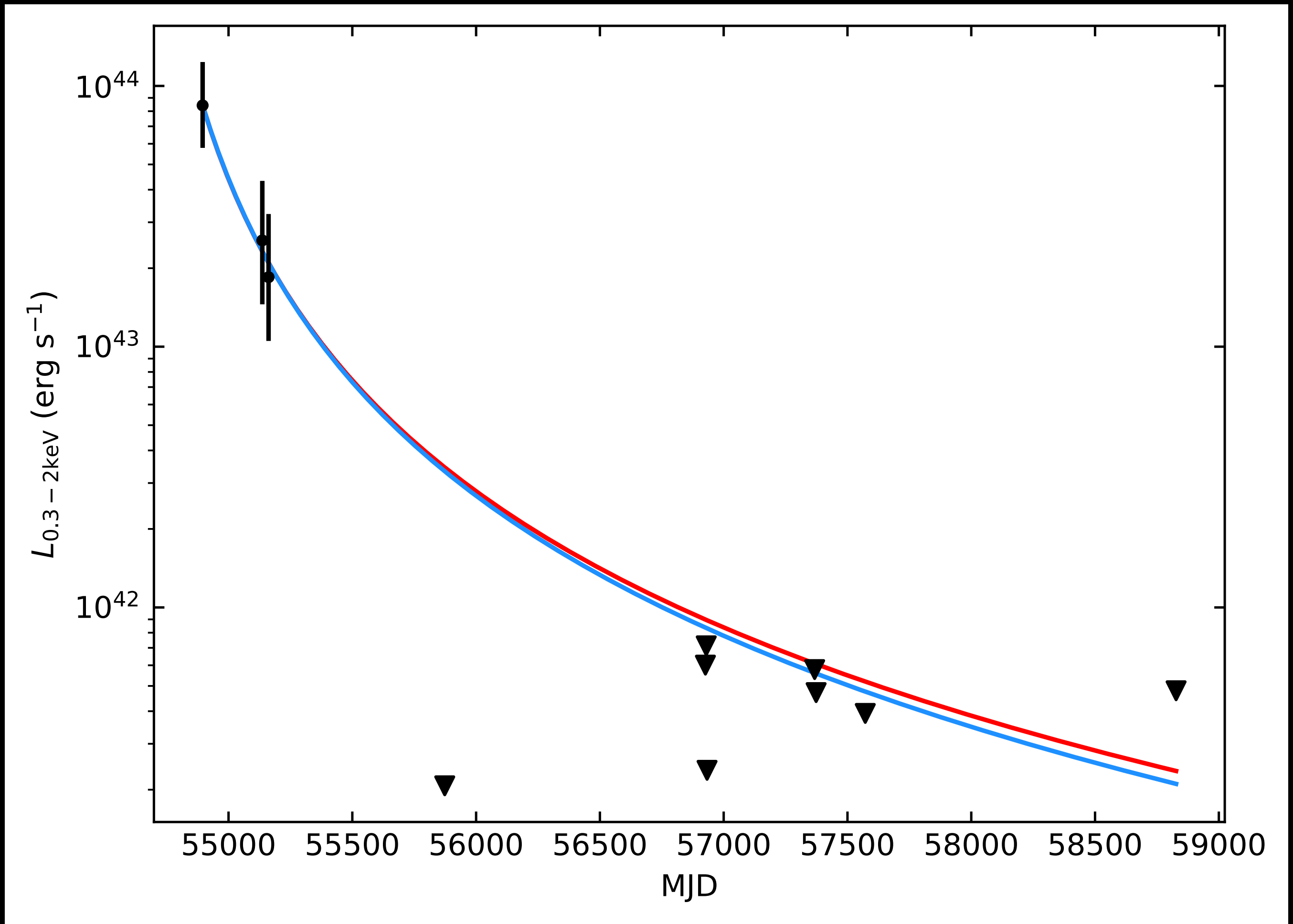
Eyles-Ferris et al. in prep.

So what makes LSXPS J0956 special?



Eyles-Ferris et al. in prep.

So what makes LSXPS J0956 special?



Eyles-Ferris et al. in prep.

Can we explain this behaviour?

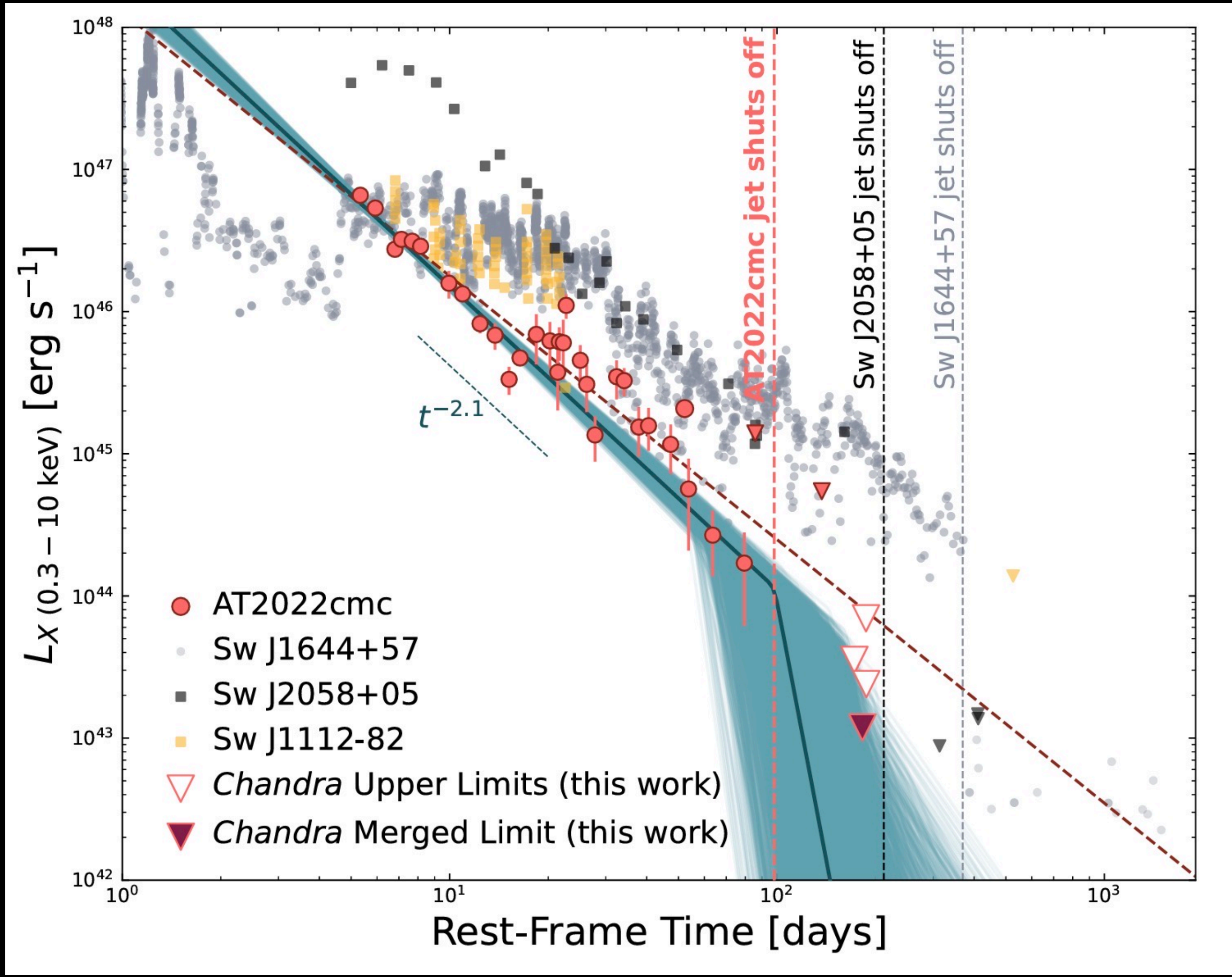
- Repeating TDEs/periodic nuclear transients do fade quickly
  - Monte Carlo modelling based on observed duty cycles
  - <1% chance of reproducing the light curve

- But there are other options

Jetted TDEs

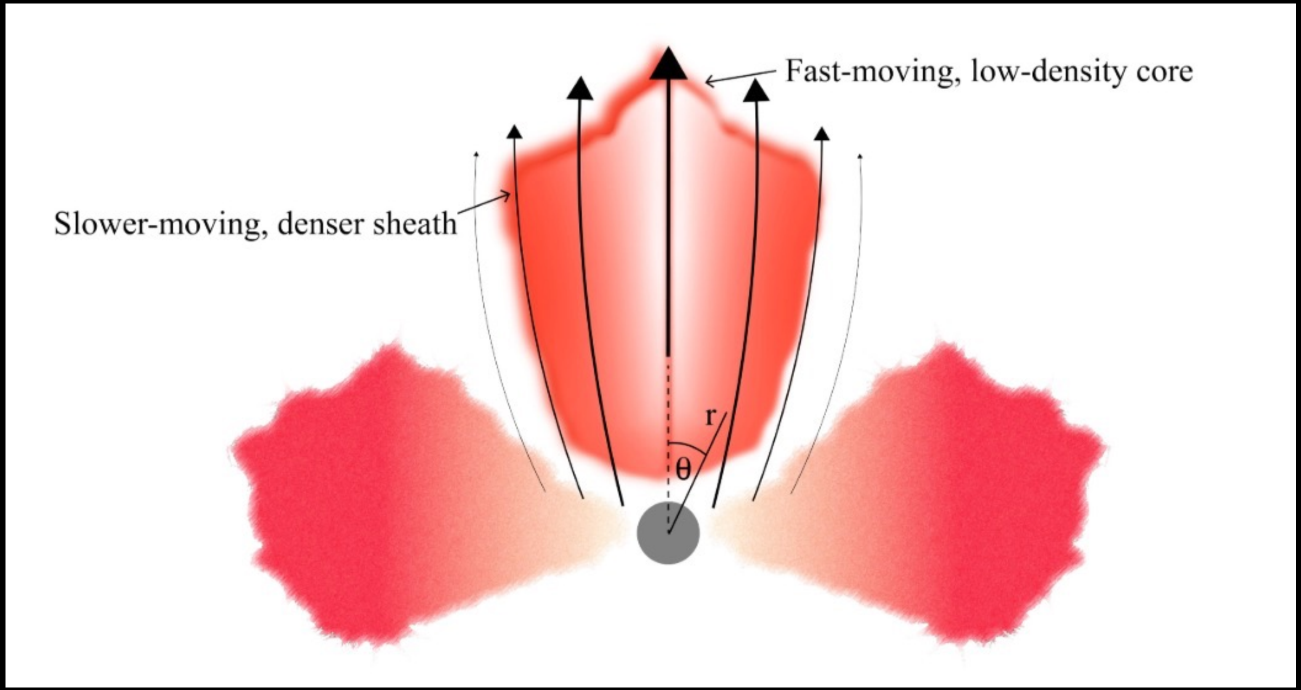
- Some TDEs do show this exact behaviour – jetted TDEs
- Fade slowly before abruptly declining
  - Seems to be tied to black hole mass/accretion rate dropping below Eddington
  - Timescale works with estimated black hole mass

- But…
  - These are jets so should have power law spectra…



Eftekhari et al. 2024

An off-axis jet



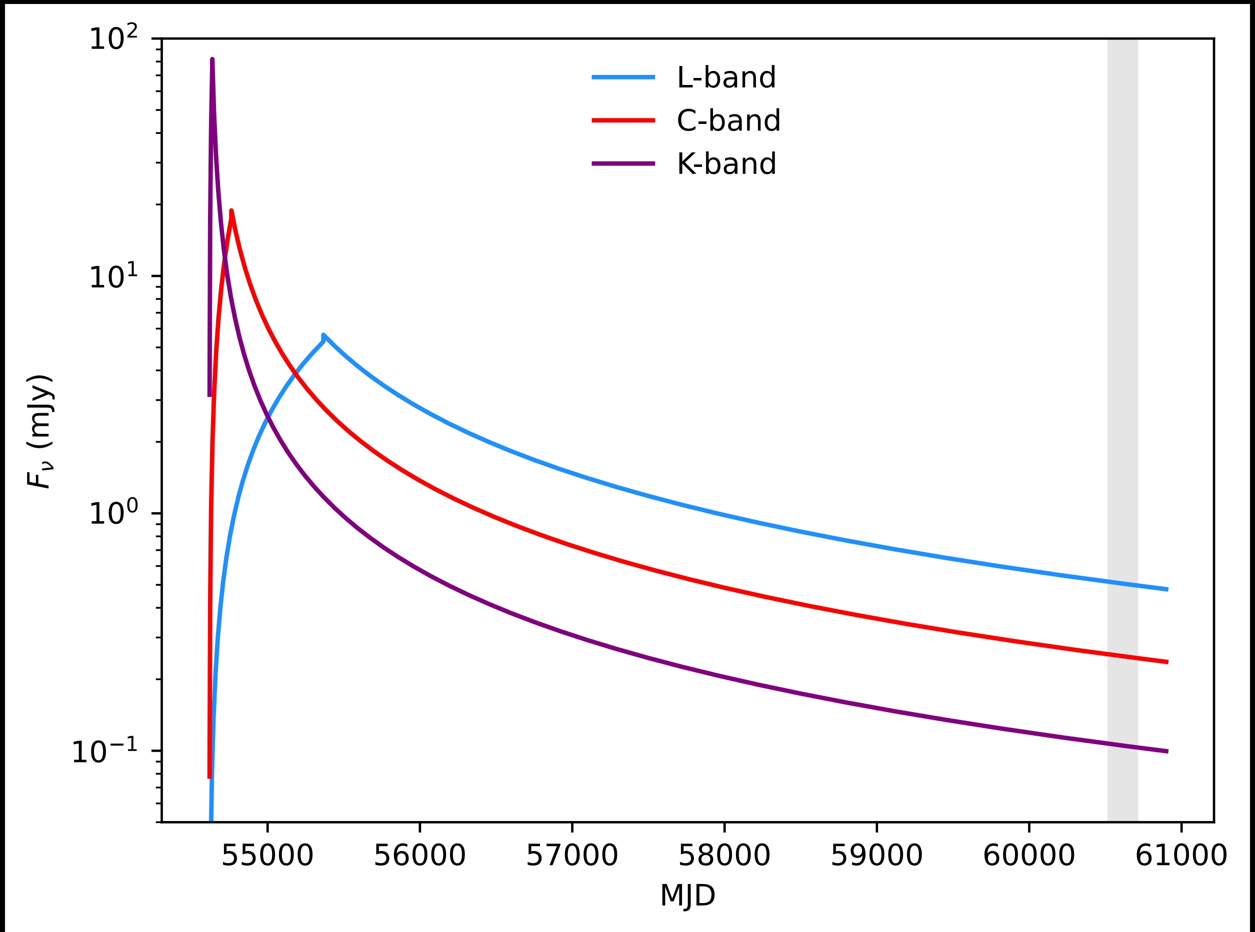
Coughlin and Begelman, 2020

- How about a structured jet?
- Viscous-like interactions between jet and medium produces slower moving and dense sheath
- Line of sight is aligned with the sheath
  - Optically thick
  - Varying optical depth and composite regions produce effective photosphere and quasi-thermal spectrum
- First example of an X-ray off-axis jetted TDE?

Testing the jet model

- Radio observations can be used to test this model.

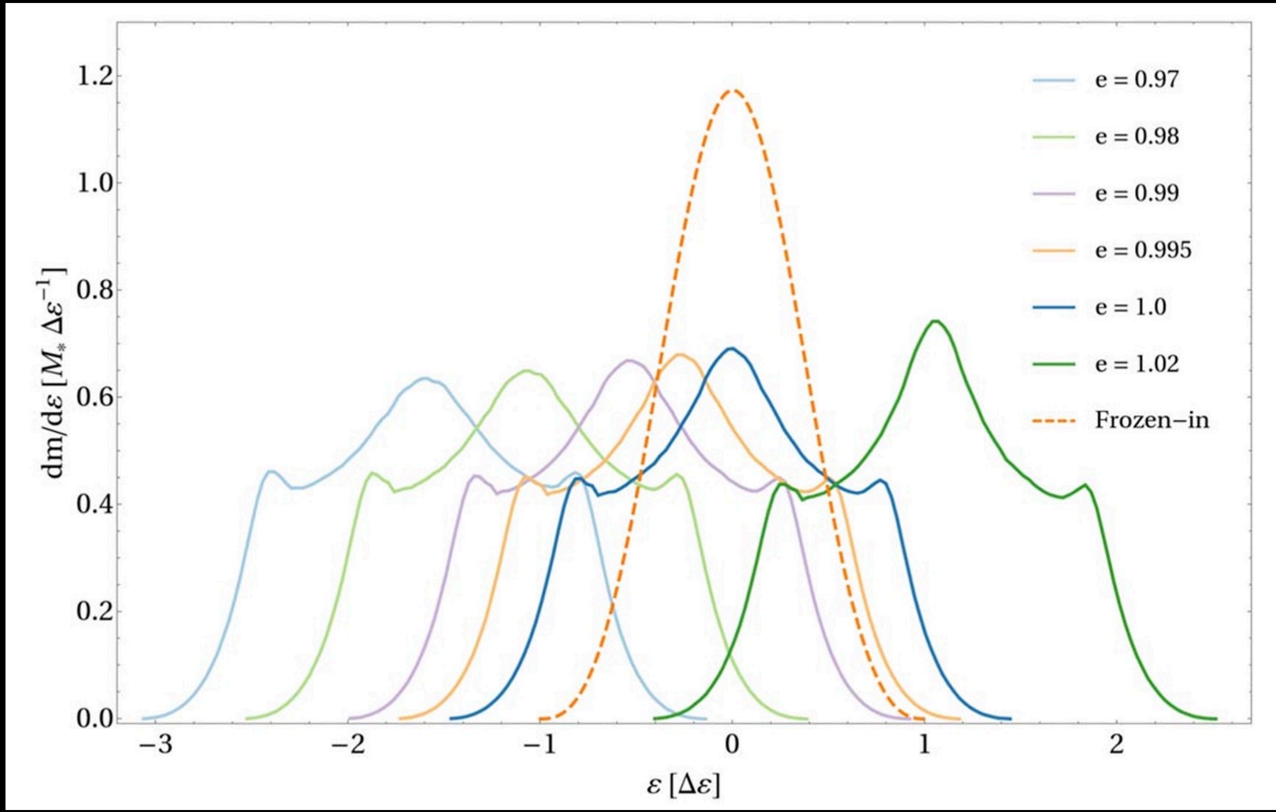
- eMERLIN observed last year
- Full analysis is on going but non-detection
  - $E_{jet} \gtrsim$ 1-2 orders of magnitude smaller than Swift J1644+57
- Not necessarily ruled out but…



Eyles-Ferris et al. in prep.

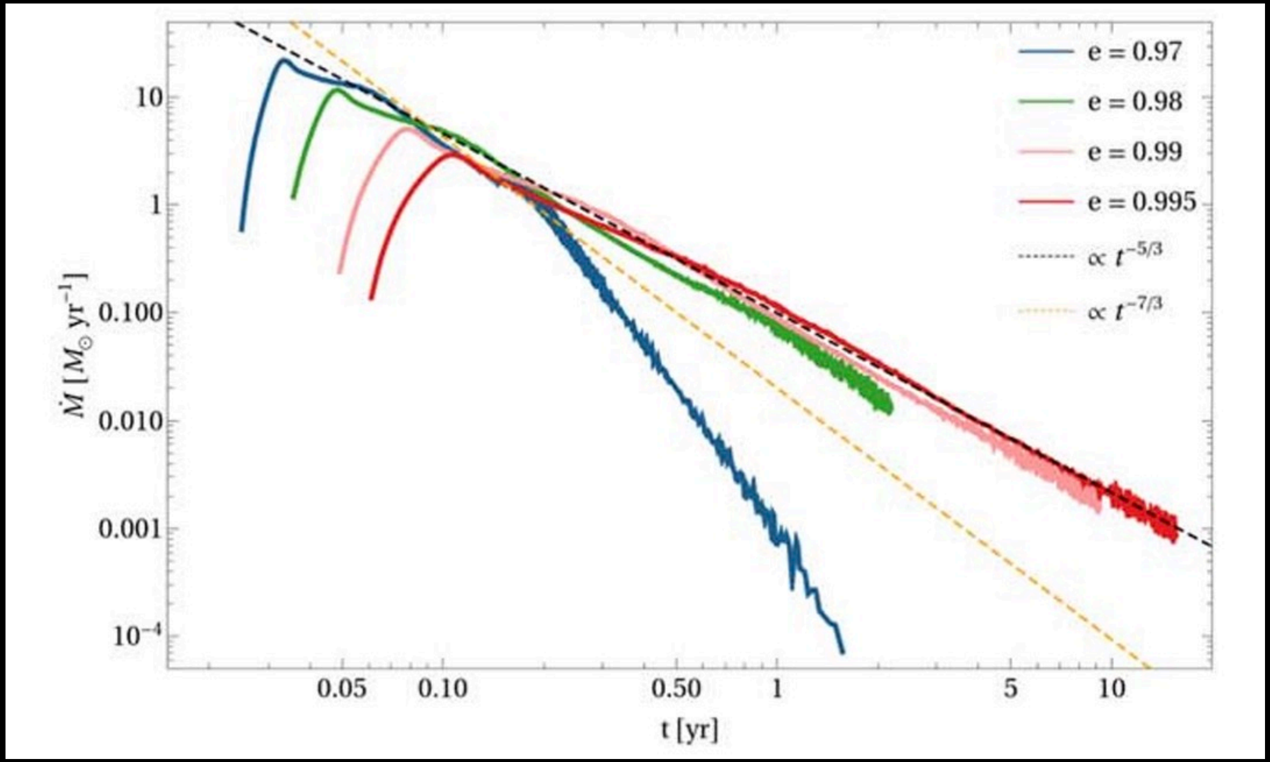
Another option – fully bound TDEs

- Stars are normally assumed to have parabolic orbits
  - Means ~half the material is bound when its disrupted
- But this fraction depends on the eccentricity of the orbit
  - More circular orbits mean more debris is bound
  - Below e_{crit}^{-}, all debris is bound
- Can produce the orbit through Hills capture



Cufari, Coughlin and Nixon, 2022

What do fully bound TDEs look like?



Cufari, Coughlin and Nixon, 2022

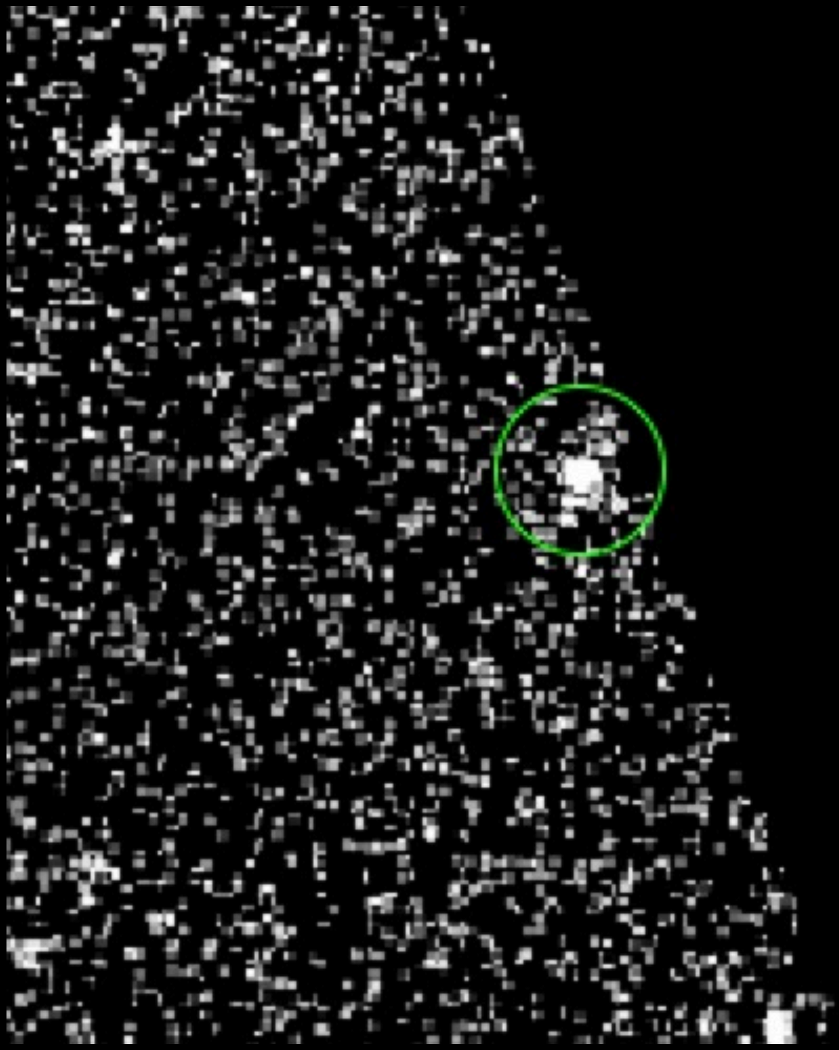
- Fallback rate rises and initially decays slowly
- Sudden drop at late time as the entire star is accreted
  - Can derive this time analytically
- For a Solar type star and a $10^7\ M_\odot$ black hole, e ~ 0.98 gives required timescale
  - Numerical simulations will confirm
- First example of a fully bound TDE?

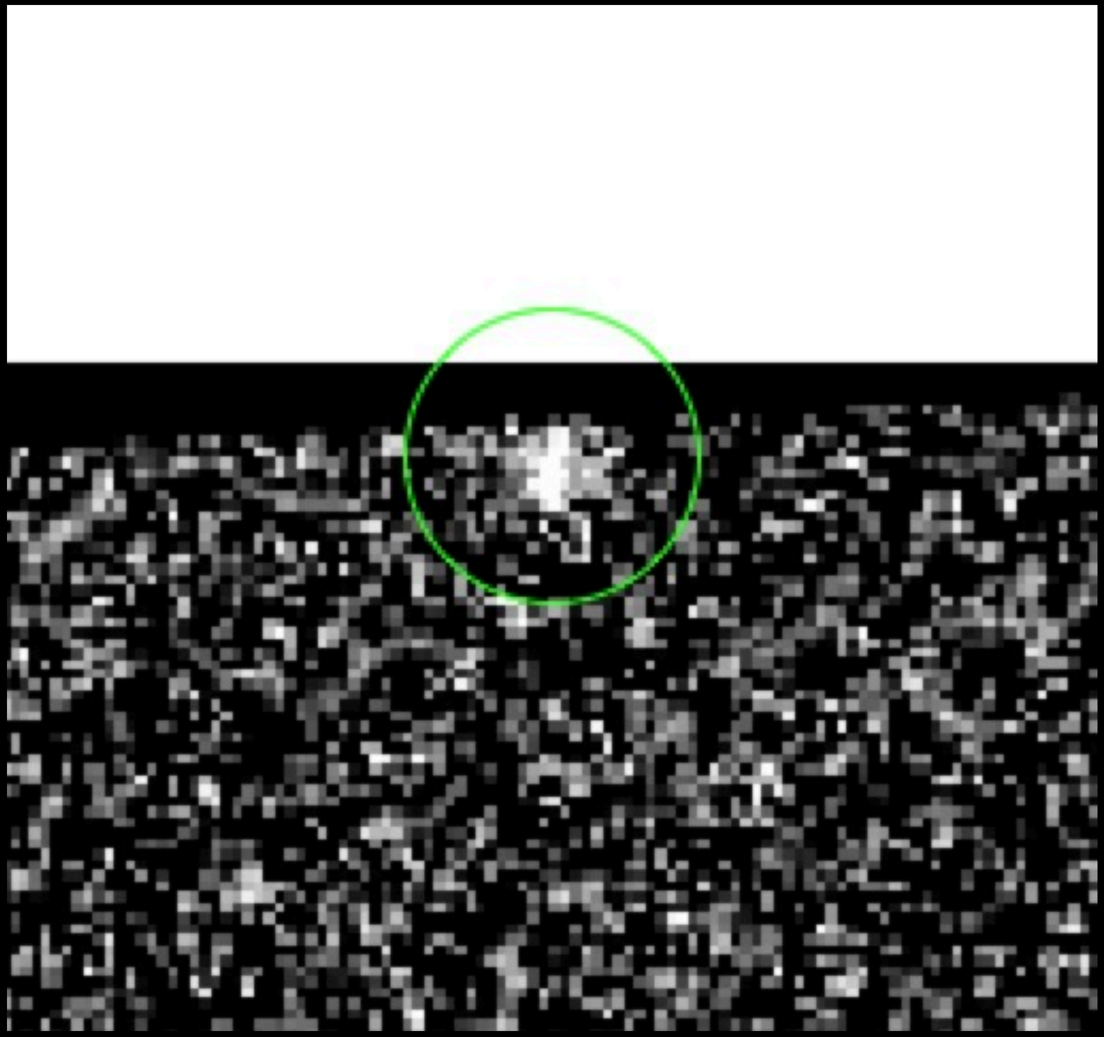
Conclusions

- LSXPS J0956 is unique – a thermal X-ray TDE that turns off
- Two possible models
  - Off-axis jetted TDE
  - Fully bound TDE
- Do all jetted TDEs look like jetted TDEs?
- Are eccentric orbits common in TDEs and how do they affect them?

- Either way, another first and major TDE discovery for *Swift*!

BONUS SLIDE – What about UVOT?





BONUS SLIDE – What about UVOT?