The unluckiest star: A spectroscopically confirmed repeated partial tidal disruption event AT 2022dbl

Lin et al. arXiv 2405.10895

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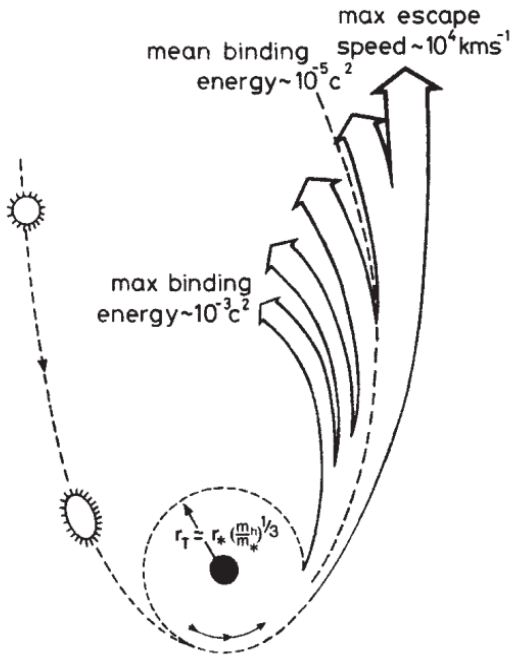
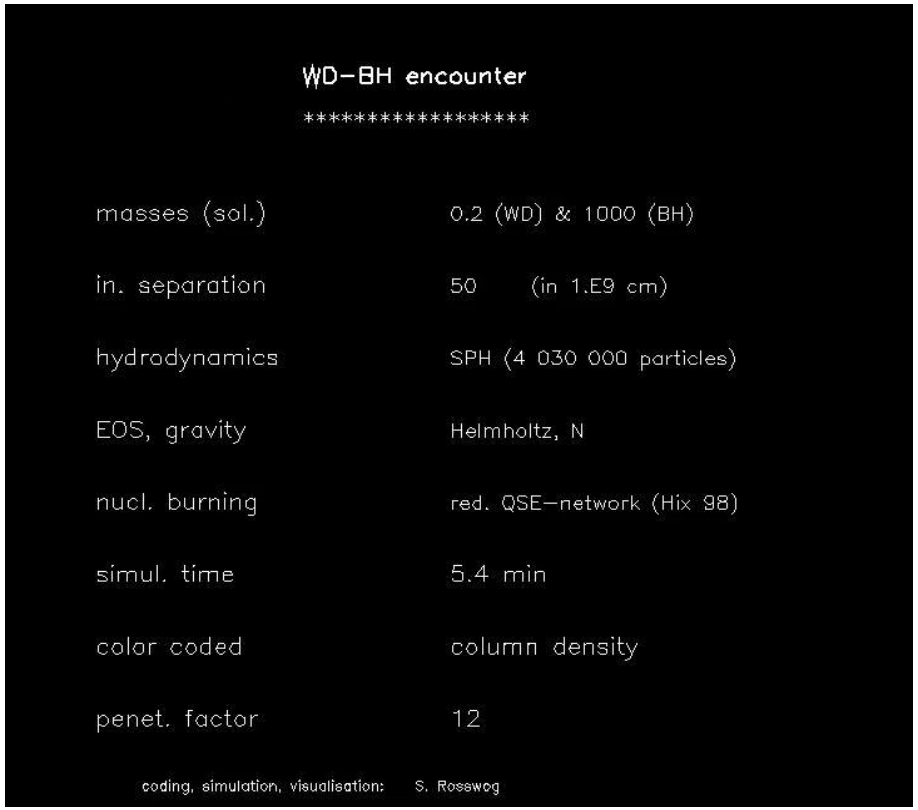
Tidal disruption events: full disruption (FTDE)



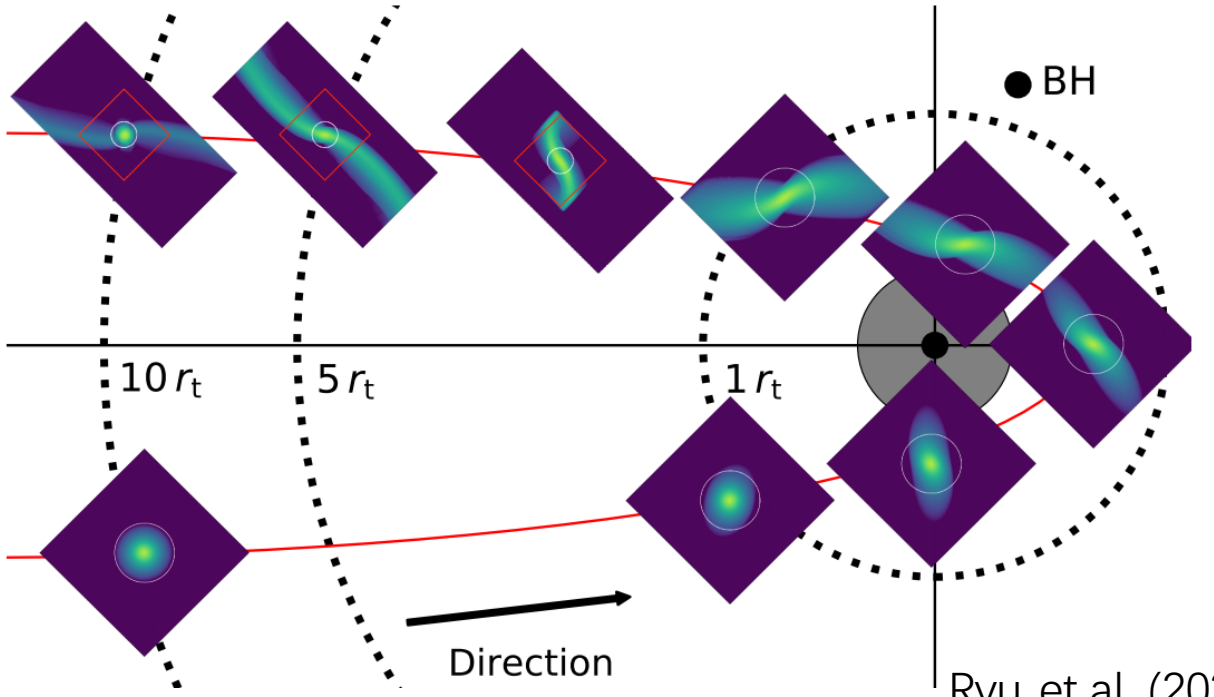


$$r_t = r_s\left(\frac{M_{BH}}{m_s}\right)^{\frac{1}{3}} = 23 r_{sch}\left(\frac{r_s}{R_{sun}}\right)\left(\frac{m_s}{m_{sun}}\right)^{-1/3}\left(\frac{M_{BH}}{10^6 M_{sun}}\right)^{-2/3}$$

http://compact-merger.astro.su.se/Movies/IMBH1000_WD02_4e6parts_P12_N.mov

Partial tidal disruption event (PTDE)

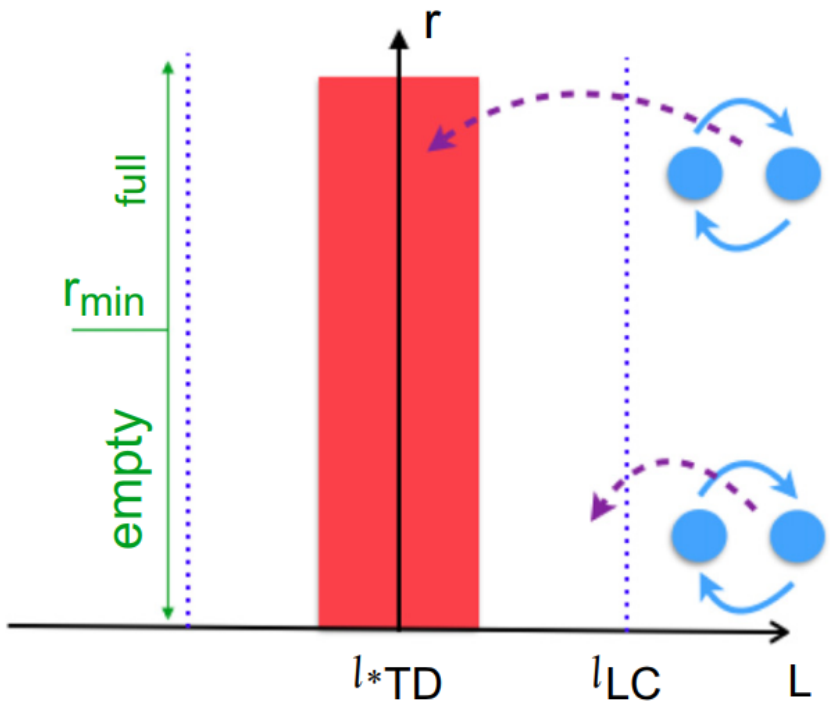
- A star passing by the SMBH with pericentric distance r_p slightly larger than r_t could also cede part of its mass to the SMBH, producing a partial tidal disruption event.
- Key difference between PTDE and FTDE: A remnant core will survive (let's call it the "leftover star") and could produce many more PTDEs or end its life in FTDE.



Ryu et al. (2020)

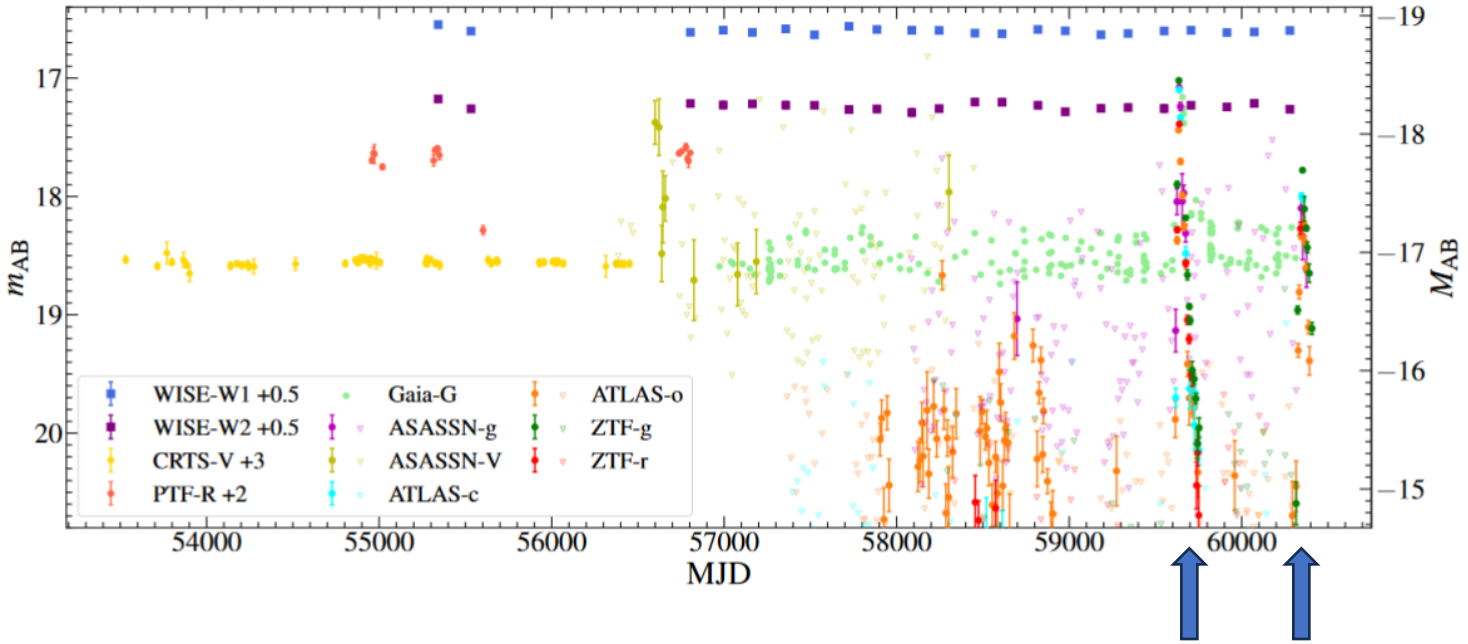
Possible Mechanisms for Repeated PTDEs

- Single MBH
  - Repeated PTDEs by a single star, comes from disruption of binary star (Hills mechanism)
  - Double TDEs by two stars, originated from binary star (Mandel & Levin, 2015)
- Binary star + MBH binary on milli-pc-scale (Wu & Yuan, 2018)

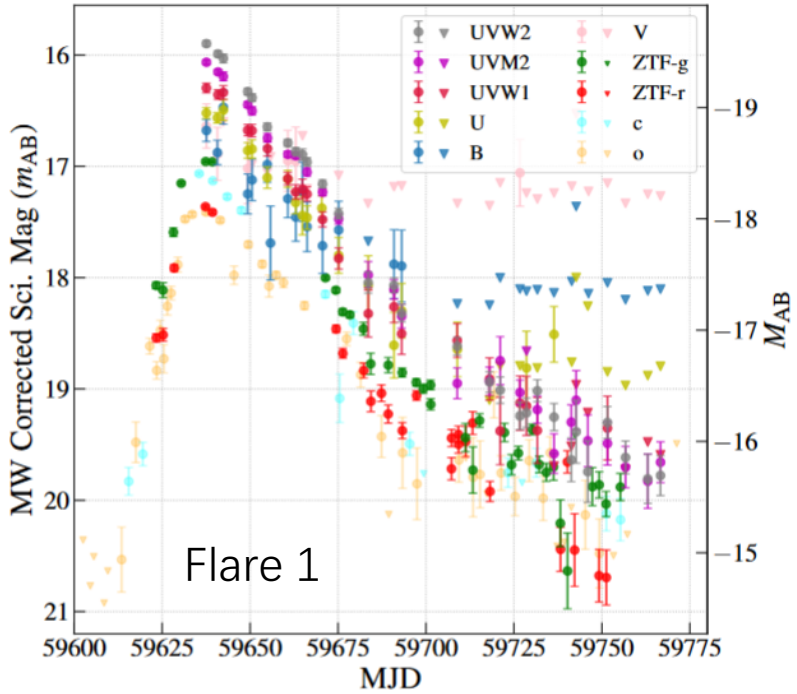


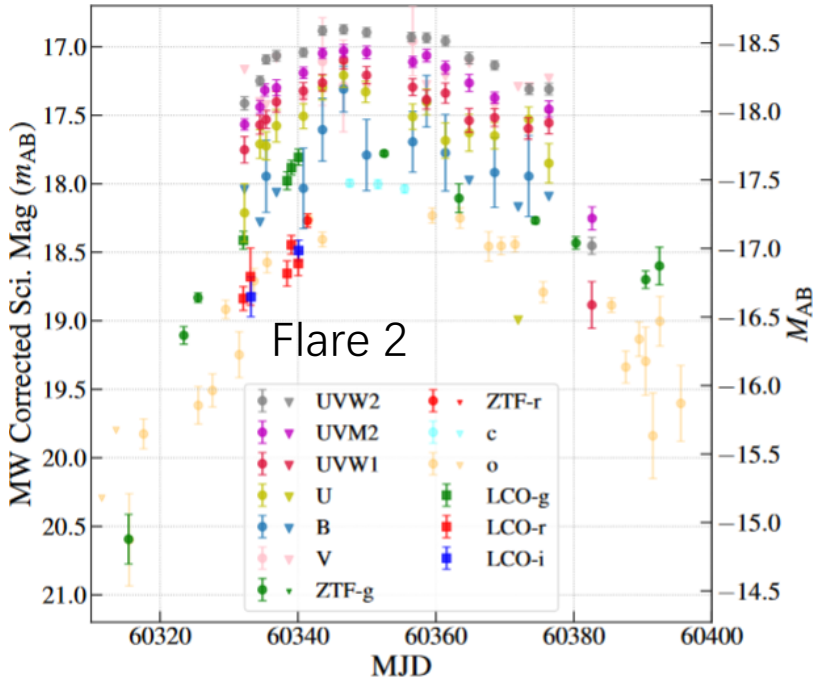
Mandel & Levin (2015)

This work



Time interval: ~710 days



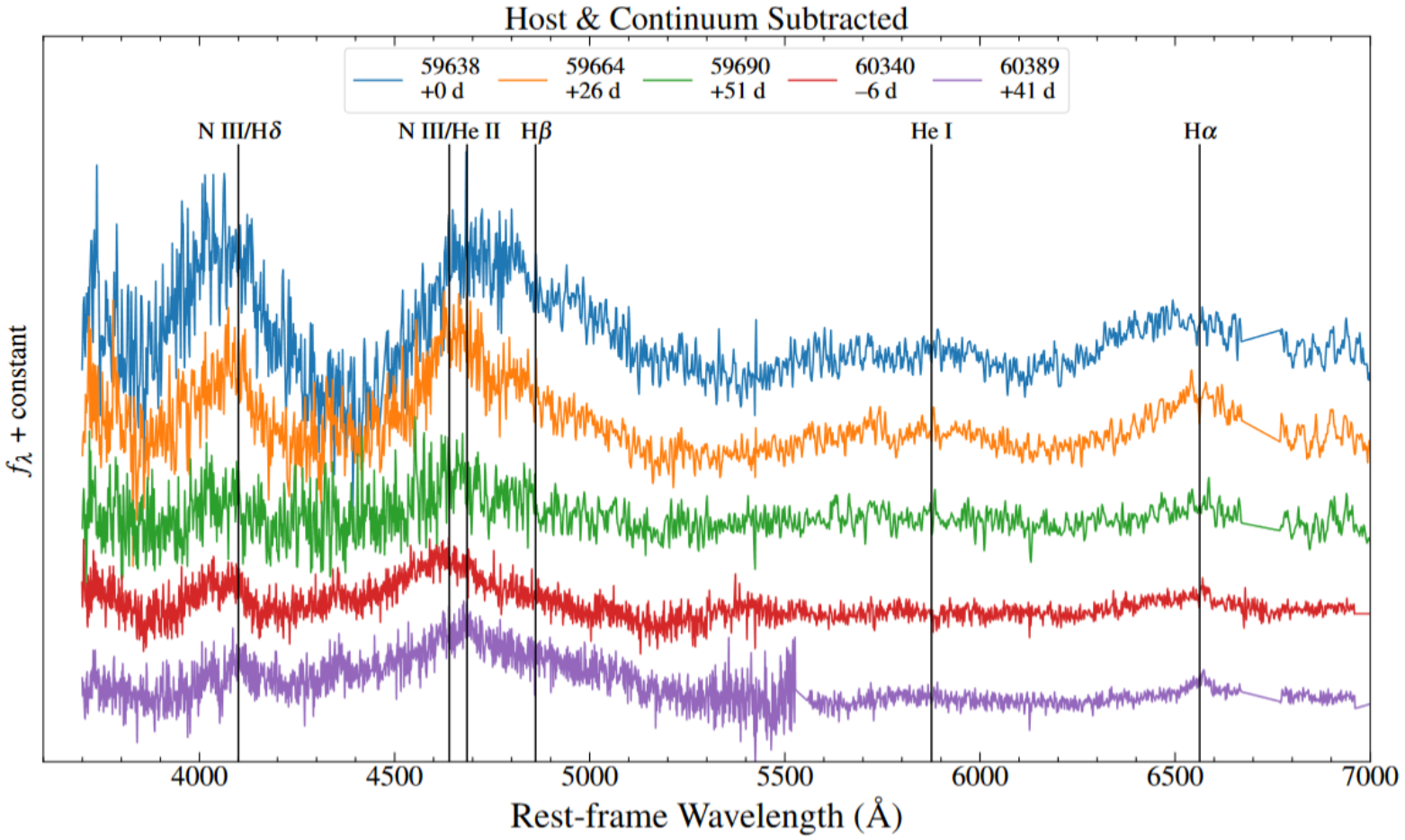


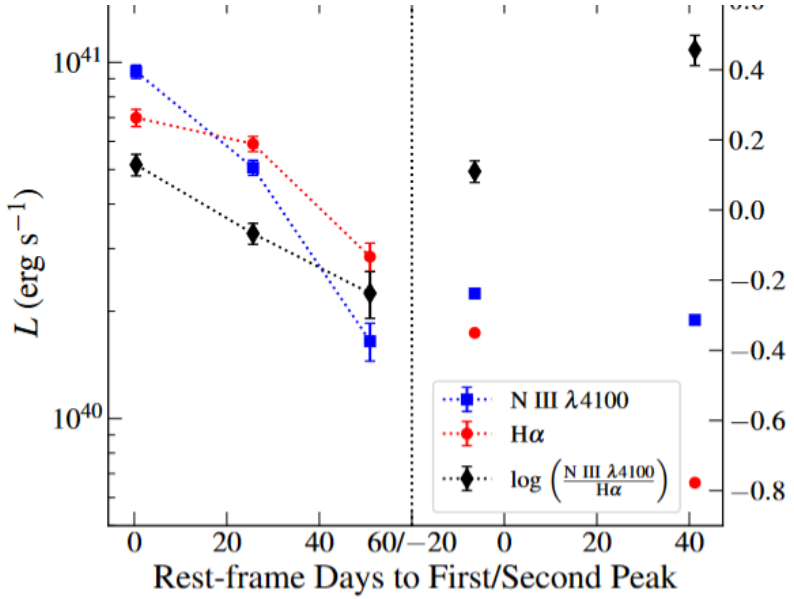
AT 2022dbl is a clear example of an optical/UV repeated pTDE, in quiescent galaxy

If, the third flare is observed in the future, strong evidence.

pTDE from the same star

The N III λ4100 line (rare in TDEs) appeared in both flares





Published repeated pTDEs

Table 2. List of published repeated pTDEs

Name	Host Type	Band	Period/Interval (Days)	Flares	Peak Evolution
ASASSN-14ko[1,2,3,4]	Seyfert 2	Opt./UV/X-ray†	115.2	∼30	Similar
eRASSt J045650.3–203750[5,6]	Quiescent	X-ray/UV†	299→193	5	Lower
AT2018fyk[7,8]	LINER/Retired	UV/X-ray	∼1200	2	Lower
RX J133157.6-324319.7[9,10]	Quiescent	X-ray	∼10000	2	Similar
AT 2020vdq[11,12,13]	E+A	Opt./UV*/X-ray*	∼870	2	Higher
AT 2022dbl[14]	QBS	Opt./UV	∼710	2	Lower

NOTE—
– Band: † Not periodic. * Not observed during the first flare.
– Period/Interval: Only ASASSN-14ko shows a nearly constant period of 115.2 days. eRASSt J045650.3–203750 is ongoing; it has shown 5 flares with the interval declining from 299 days to ∼193 days. Other pTDEs show only two flares.
– Peak Evolution: The peak luminosity of the earlier flare versus that of the later flare.

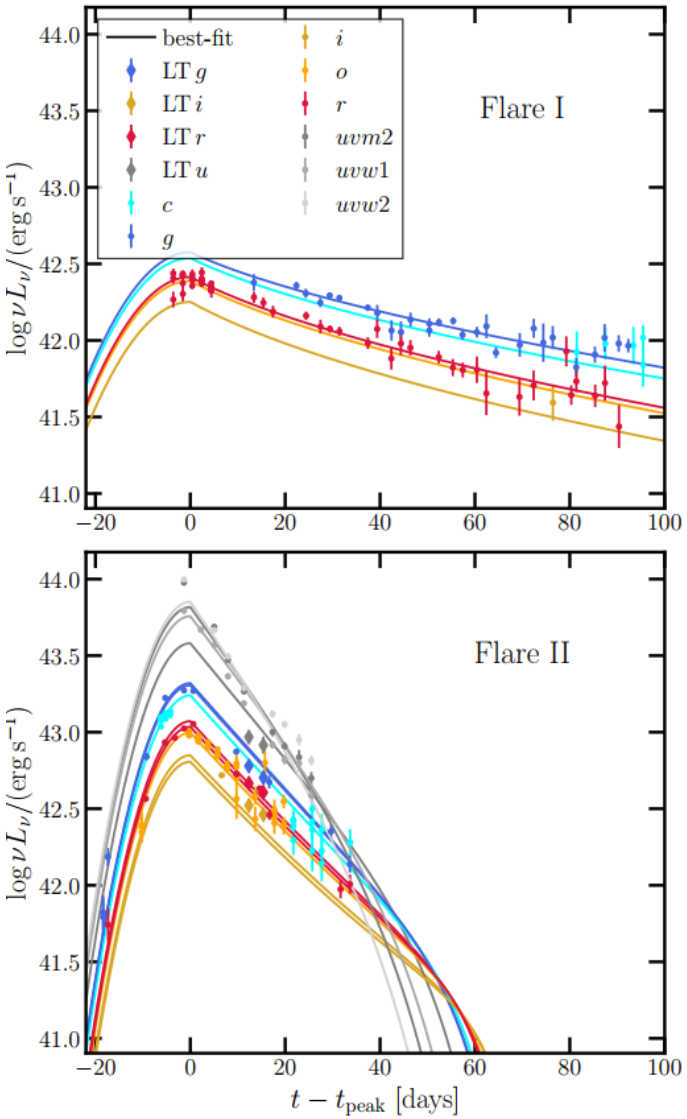
AT 2020vdq (Somalwar et al. 2023): occurred in E+A galaxy, which has high intrinsic rate

The first systematically identified repeating partial tidal disruption event

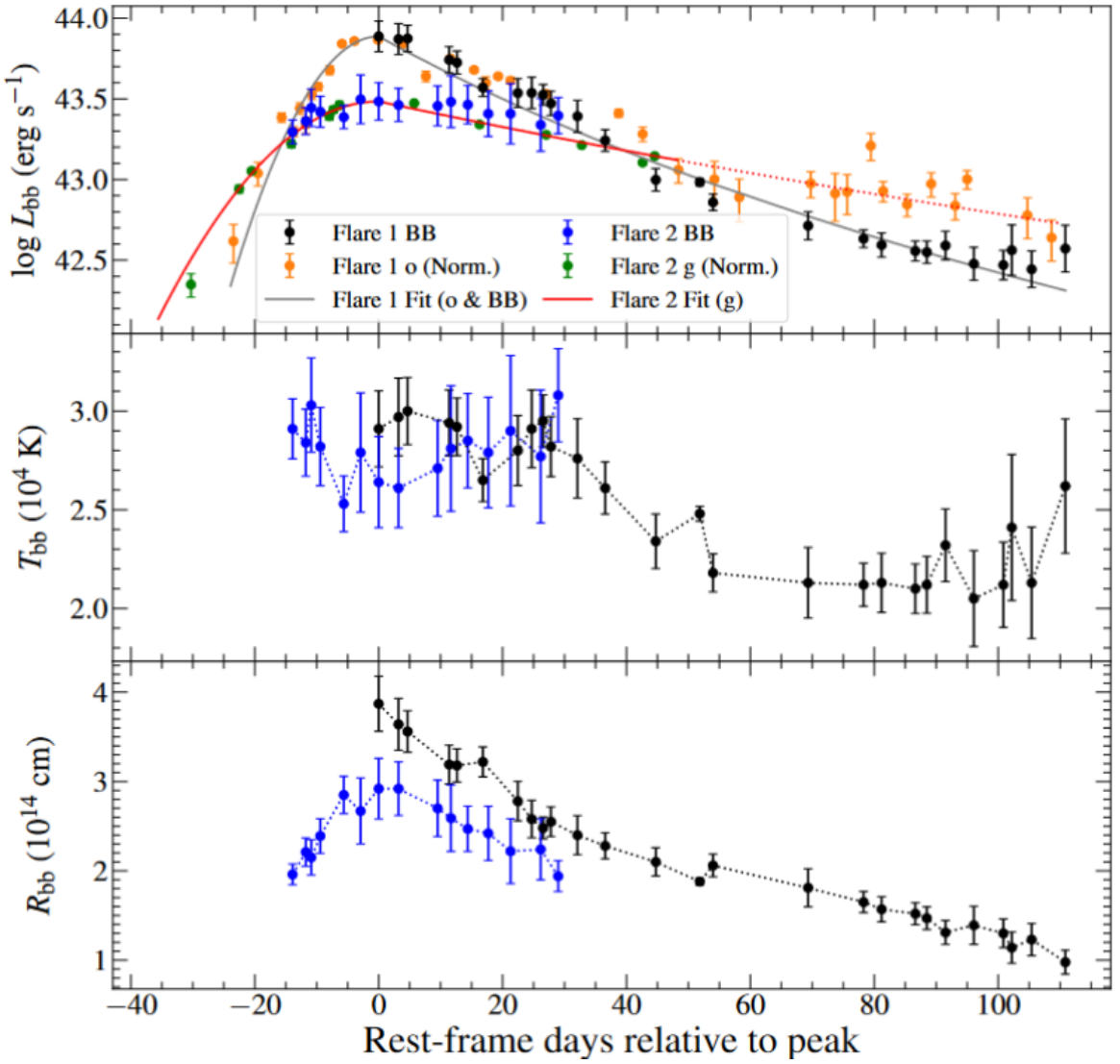
Jean J. Somalwar,[1] Vikram Ravi,[1] Yuhan Yao,[2,3] Muryel Guolo,[4] Matthew Graham,[1] Erica Hammerstein,[5] Wenbin Lu,[6] Matt Nicholl,[7] Yashvi Sharma,[1] Robert Stein,[1] Sjoert van Velzen,[8] Eric C. Bellm,[9] Michael W. Coughlin,[10] Steven L. Groom,[11] Frank J. Masci,[11] and Reed Riddle[12]

2020vdq v.s. 2022dbl

2020vdq: Flare 2 is brighter



2022dbl: Flare 1 is brighter



Conclusion

- AT 2022dbl is a clear example of an optical/UV repeated pTDE, in quiescent galaxy
  - Produced by the same star
- Repeated pTDEs provide valuable opportunities to test optical/UV emission models, as another flare is expected in the coming years.

Other potential sources

- Yao et al. (2023) published 30+ new TDEs (before Sept. 2021), of which
  - 5 show re-brightening signature: **2019baf, 2019ehz, 2020acka, 2021uqv, 2020vdq(#)**
  - The rebrightening of **2020mot** may be hidden in the observation gap

Somalwar et al (2023), the second peak is brighter

Tidal Disruption Event Demographics with the Zwicky Transient Facility: Volumetric Rates, Luminosity Function, and Implications for the Local Black Hole Mass Function

Yuhan Yao [1], Vikram Ravi [1], Suvi Gezari [2,3], Sjoert van Velzen [4], Wenbin Lu [5], Steve Schulze [6]