

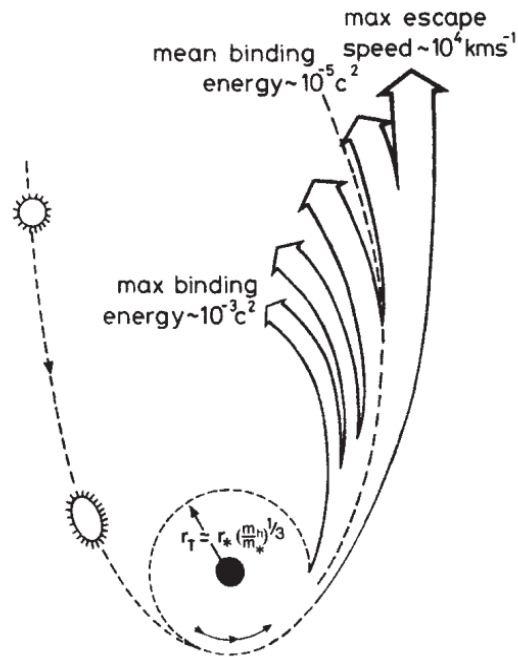
# The unluckiest star: A spectroscopically confirmed **repeated partial tidal disruption event** AT 2022dbl

Lin et al. arXiv 2405.10895

Submitted to ApJ Letter

Journal Club, 2024-05-29

# Tidal disruption events: full disruption (FTDE)



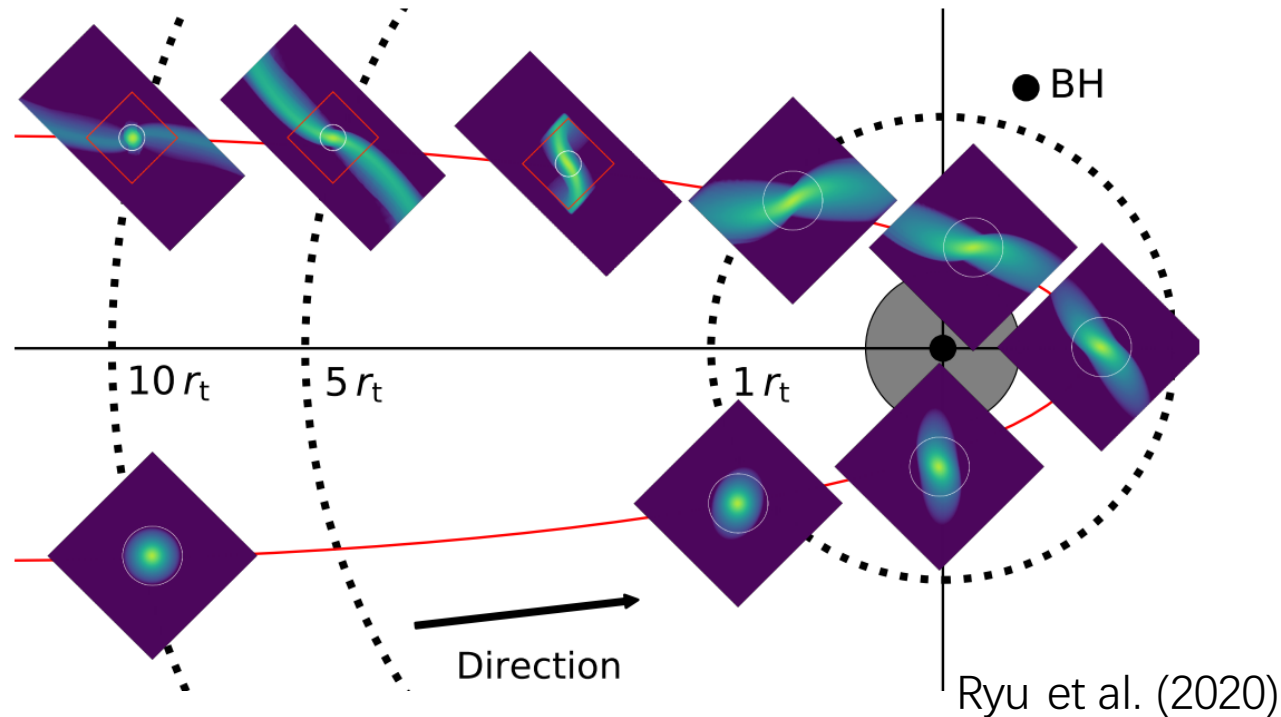
$$r_t = r_s \left( \frac{M_{BH}}{m_s} \right)^{1/3} = 23 r_{sch} \left( \frac{r_s}{R_{sun}} \right) \left( \frac{m_s}{m_{sun}} \right)^{-1/3} \left( \frac{M_{BH}}{10^6 M_{sun}} \right)^{-2/3}$$

WD-BH encounter	
*****	
masses (sol.)	0.2 (WD) & 1000 (BH)
in. separation	50 (in 1.E9 cm)
hydrodynamics	SPH (4 030 000 particles)
EOS, gravity	Helmholtz, N
nucl. burning	red. QSE-network (Hix 98)
simul. time	5.4 min
color coded	column density
penet. factor	12
coding, simulation, visualisation: S. Rosswog	

[http://compact-merger.astro.su.se/Movies/IMBH1000\\_WD02\\_4e6parts\\_P12\\_N.mov](http://compact-merger.astro.su.se/Movies/IMBH1000_WD02_4e6parts_P12_N.mov)

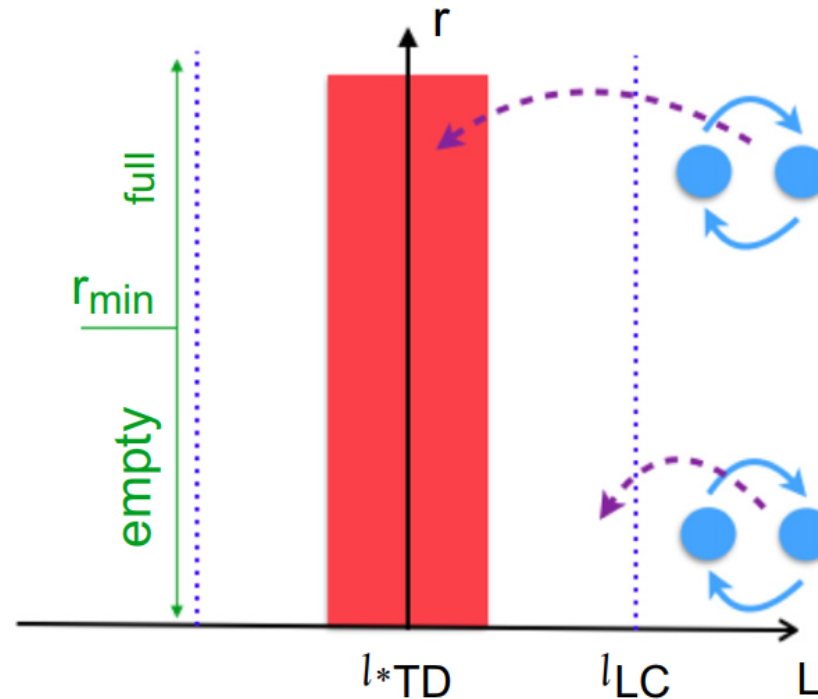
# Partial tidal disruption event (PTDE)

- 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.



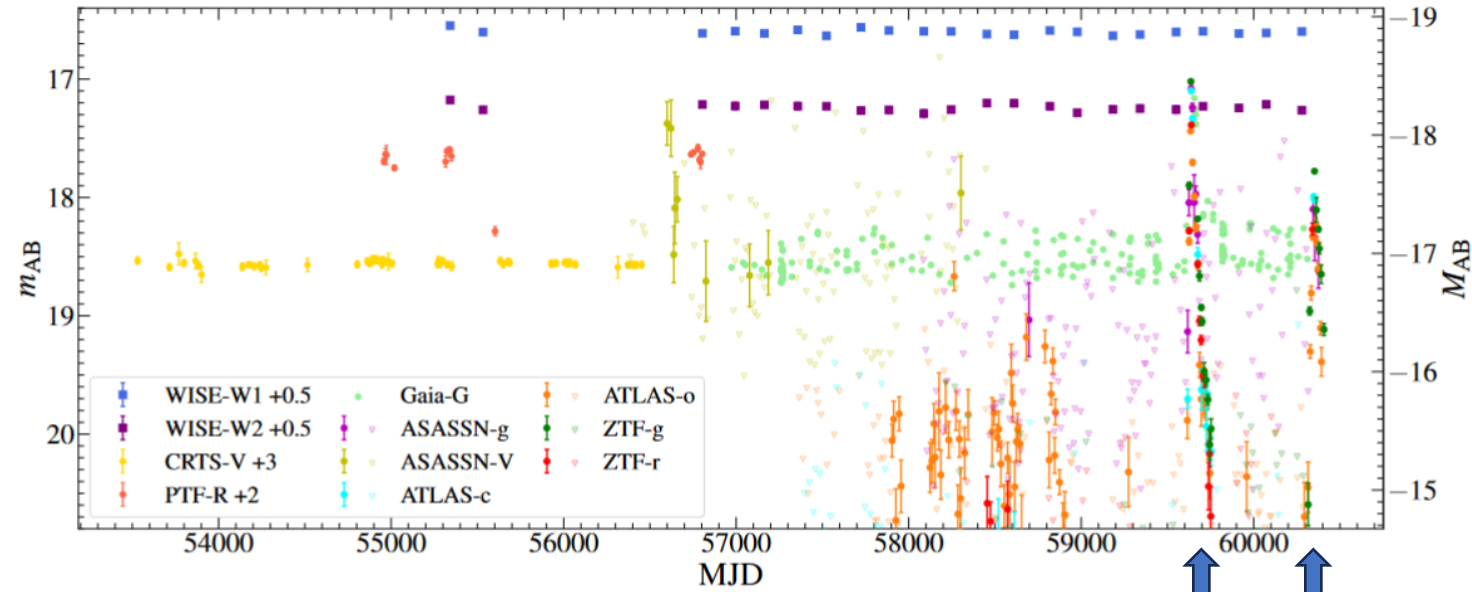
# Possible Mechanisms for Repeated PTDEs

- 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)

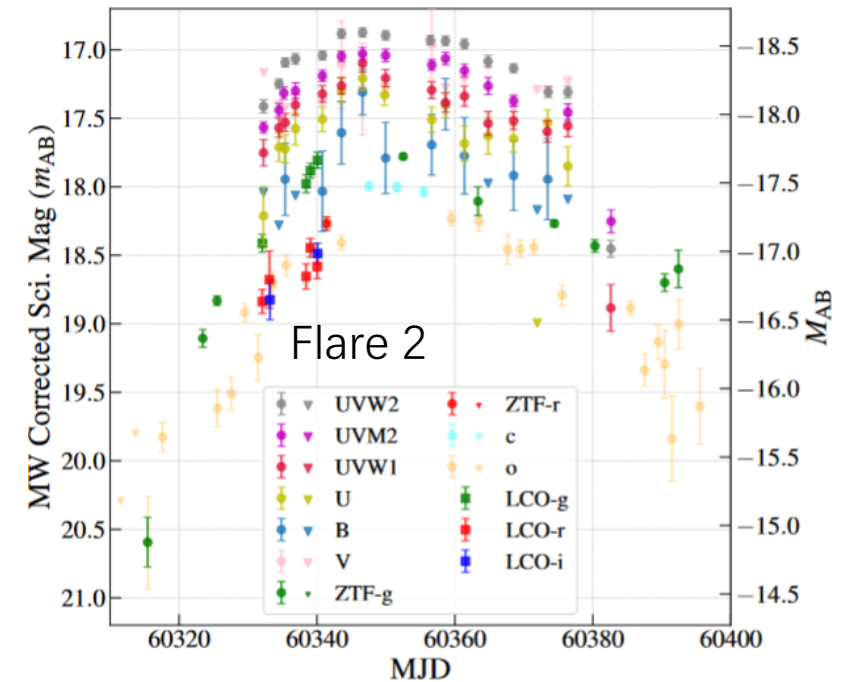
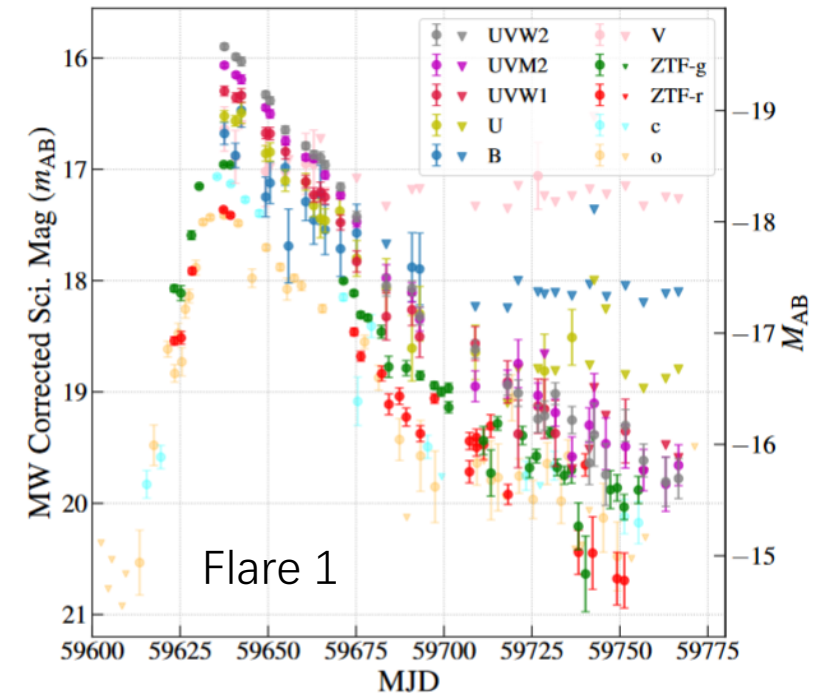
# This work



Time interval:  $\sim 710$  days

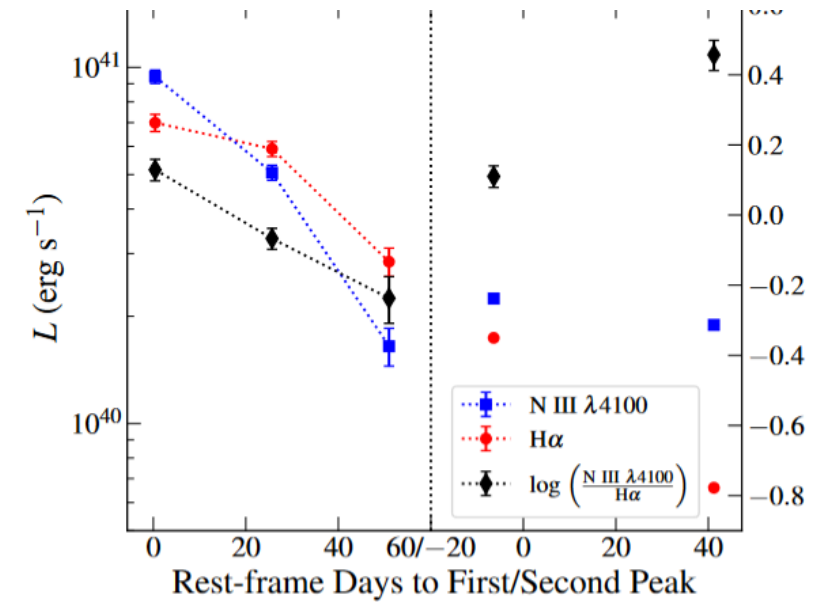
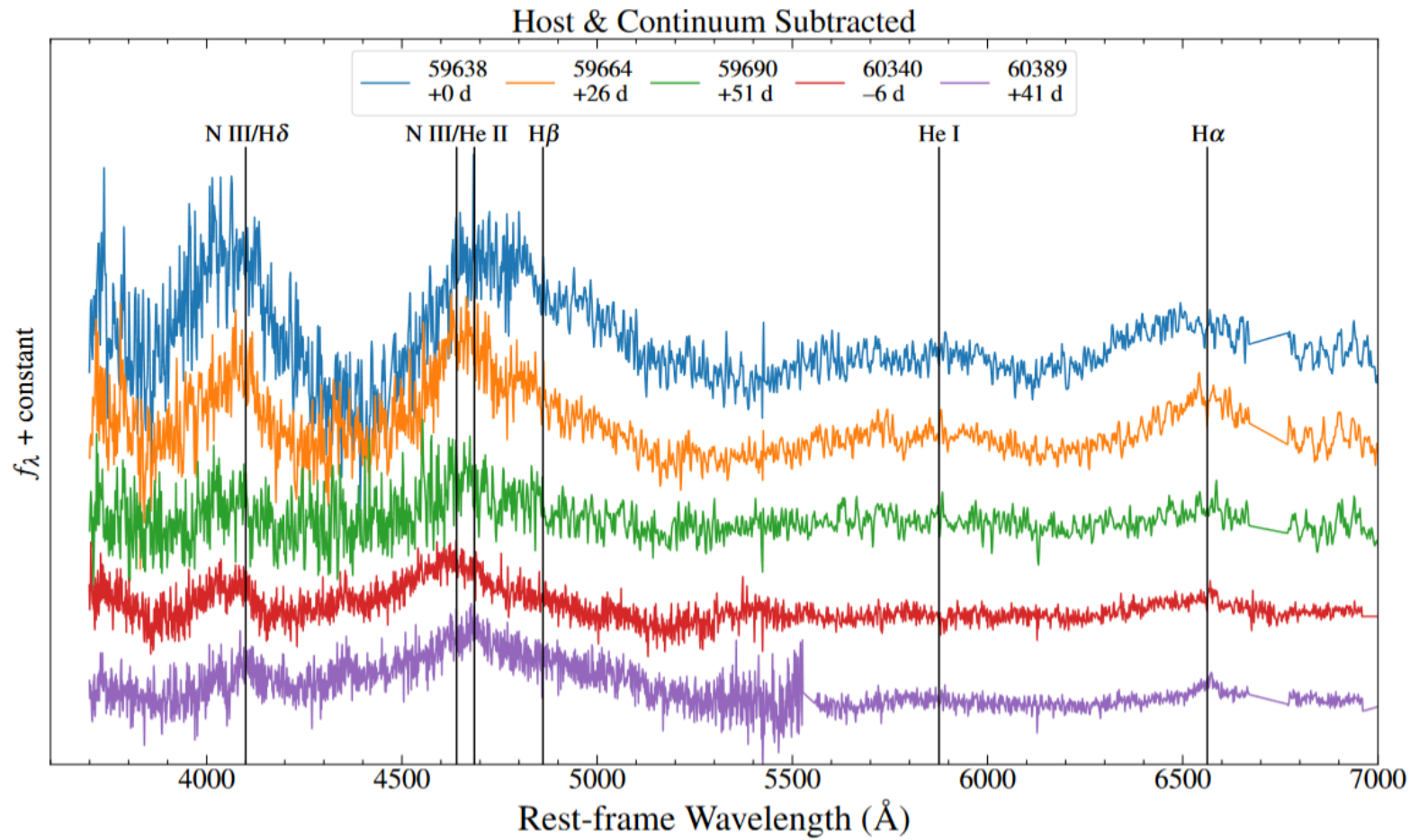
AT 2022dbl is a clear example of an optical/UV repeated pTDE, in quiescent galaxy

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



# pTDE from the same star

The N III  $\lambda 4100$  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 <sup>1,2,3,4</sup>	Seyfert 2	Opt./UV/X-ray <sup>†</sup>	115.2	~30	Similar
cRASS <sub>1</sub> J045650.3–203750 <sup>5,6</sup>	Quiescent	X-ray/UV <sup>†</sup>	299→193	5	Lower
AT2018fyk <sup>7,8</sup>	LINER/Retired	UV/X-ray	~1200	2	Lower
RX J133157.6–324319.7 <sup>9,10</sup>	Quiescent	X-ray	~10000	2	Similar
AT 2020vdq <sup>11,12,13</sup>	E+A	Opt./UV*/X-ray*	~870	2	Higher
AT 2022dbl <sup>14</sup>	QBS	Opt./UV	~710	2	Lower

NOTE—

- Band: <sup>†</sup> Not periodic. \* Not observed during the first flare.
- Period/Interval: Only ASASSN-14ko shows a nearly constant period of 115.2 days. cRASS<sub>1</sub> 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

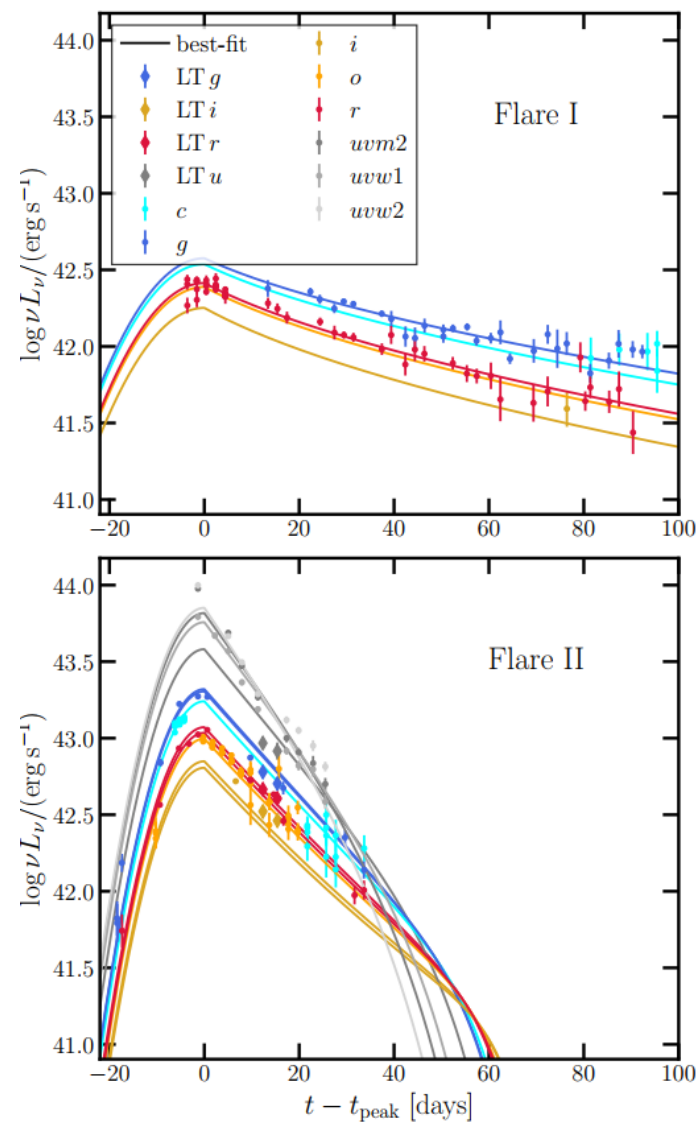
## The first systematically identified repeating partial tidal disruption event

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ERICA HAMMERSTEIN <sup>5</sup> WENBIN LU <sup>6</sup> MATT NICHOLL <sup>7</sup> YASHVI SHARMA <sup>1</sup> ROBERT STEIN,<sup>1</sup>  
SJOERT VAN VELZEN <sup>8</sup> ERIC C. BELLM <sup>9</sup> MICHAEL W. COUGHLIN <sup>10</sup> STEVEN L. GROOM <sup>11</sup> FRANK J. MASCI <sup>11</sup>  
AND REED RIDDLE <sup>12</sup>

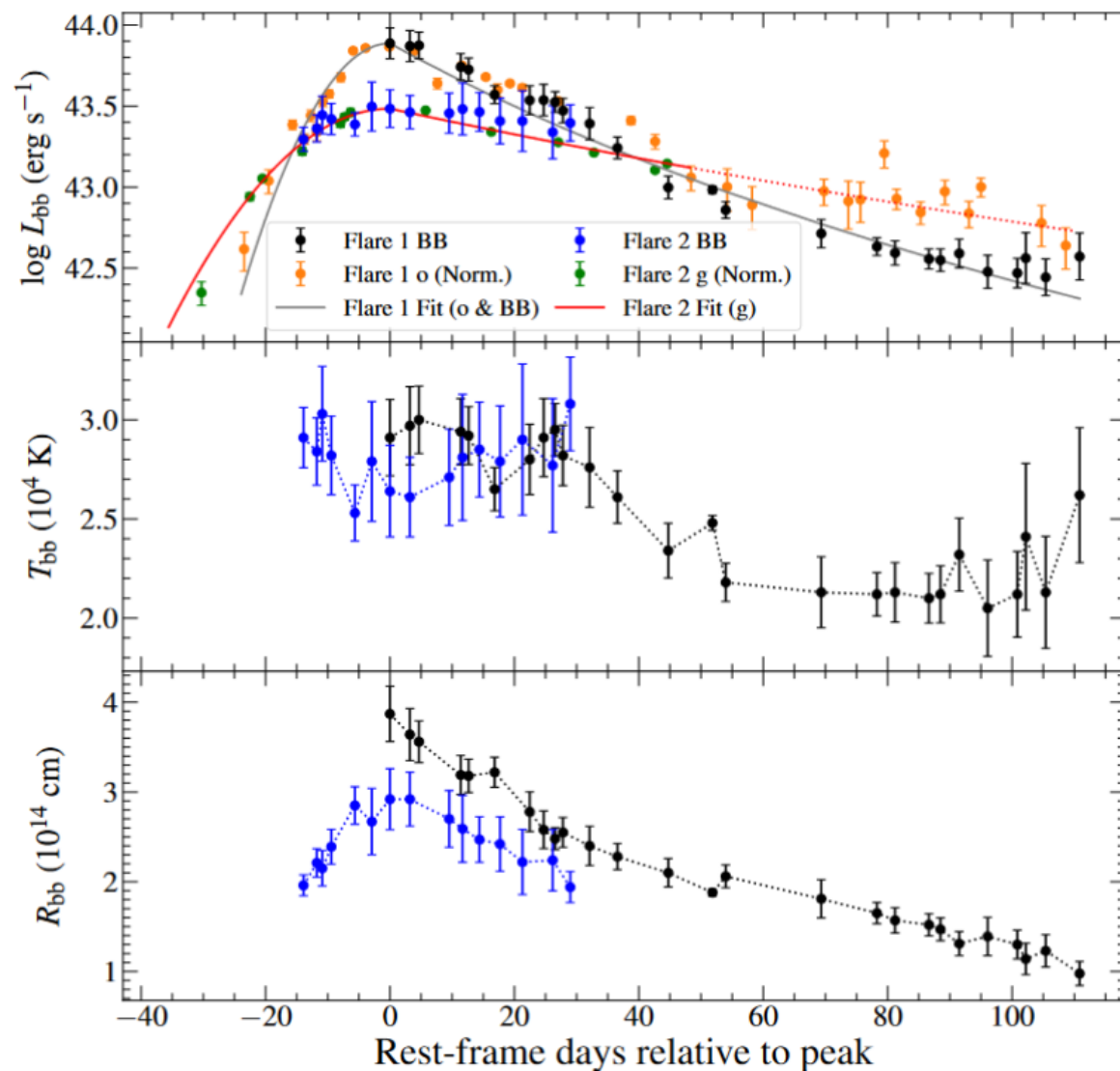


# 2020vdq v.s. 2022dbl

2020vdq: Flare 2 is brighter



2022dbl: Flare 1 is brighter






# Conclusion

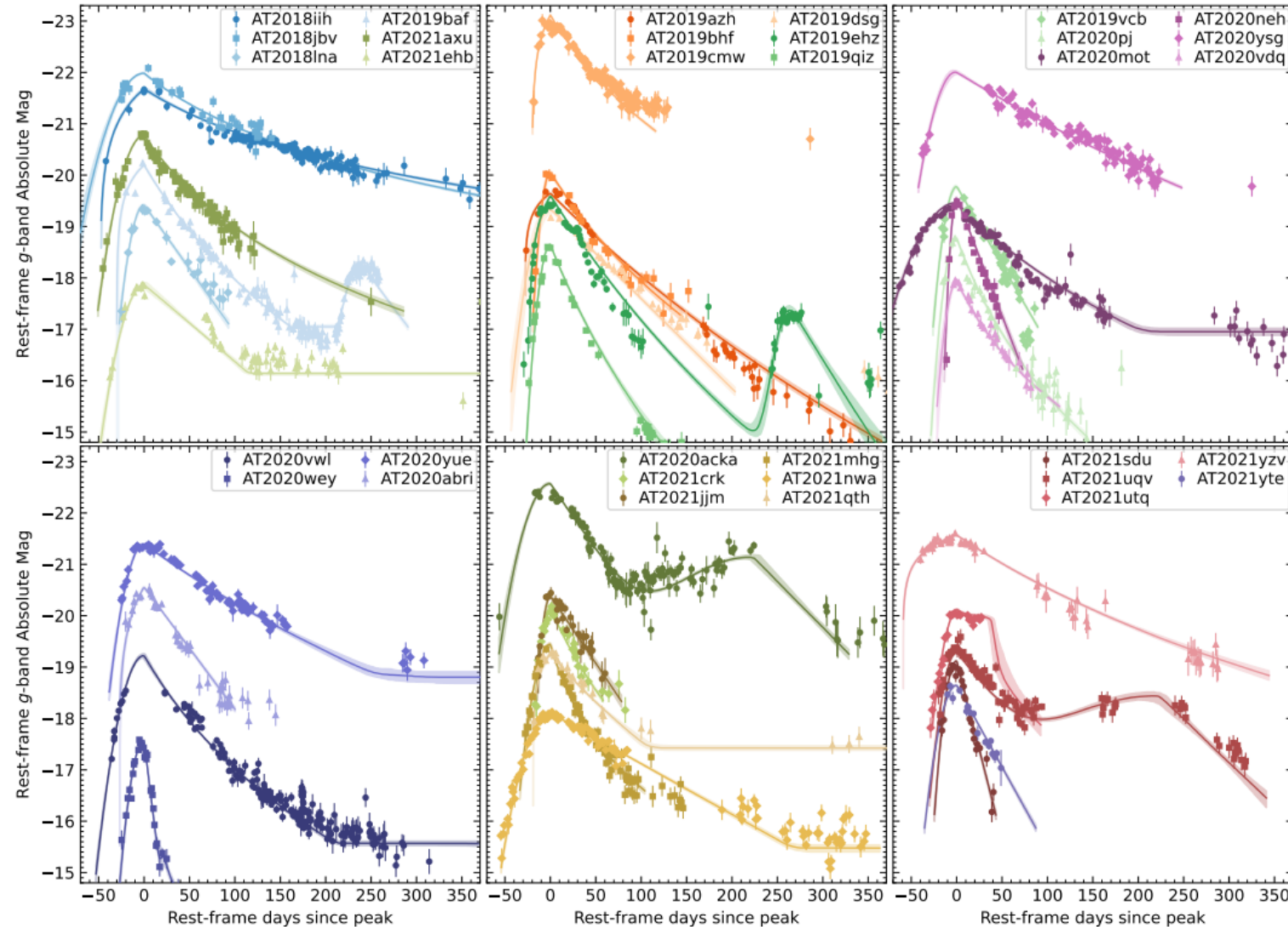
- AT 2022dbl is a clear example of an optical/UV repeated pTDE, in quiescent galaxy
  - Produced by the same star
- Repeated pTDEs provide valuable opportunities to test optical/UV emission models, as another flare is expected in the coming years.

# 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

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

YUHAN YAO <sup>1</sup>, VIKRAM RAVI <sup>1</sup>, SUVI GEZARI <sup>2,3</sup>, SJOERT VAN VELZEN <sup>4</sup>, WENBIN LU <sup>5</sup>, STEVE SCHULZE <sup>6</sup>



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