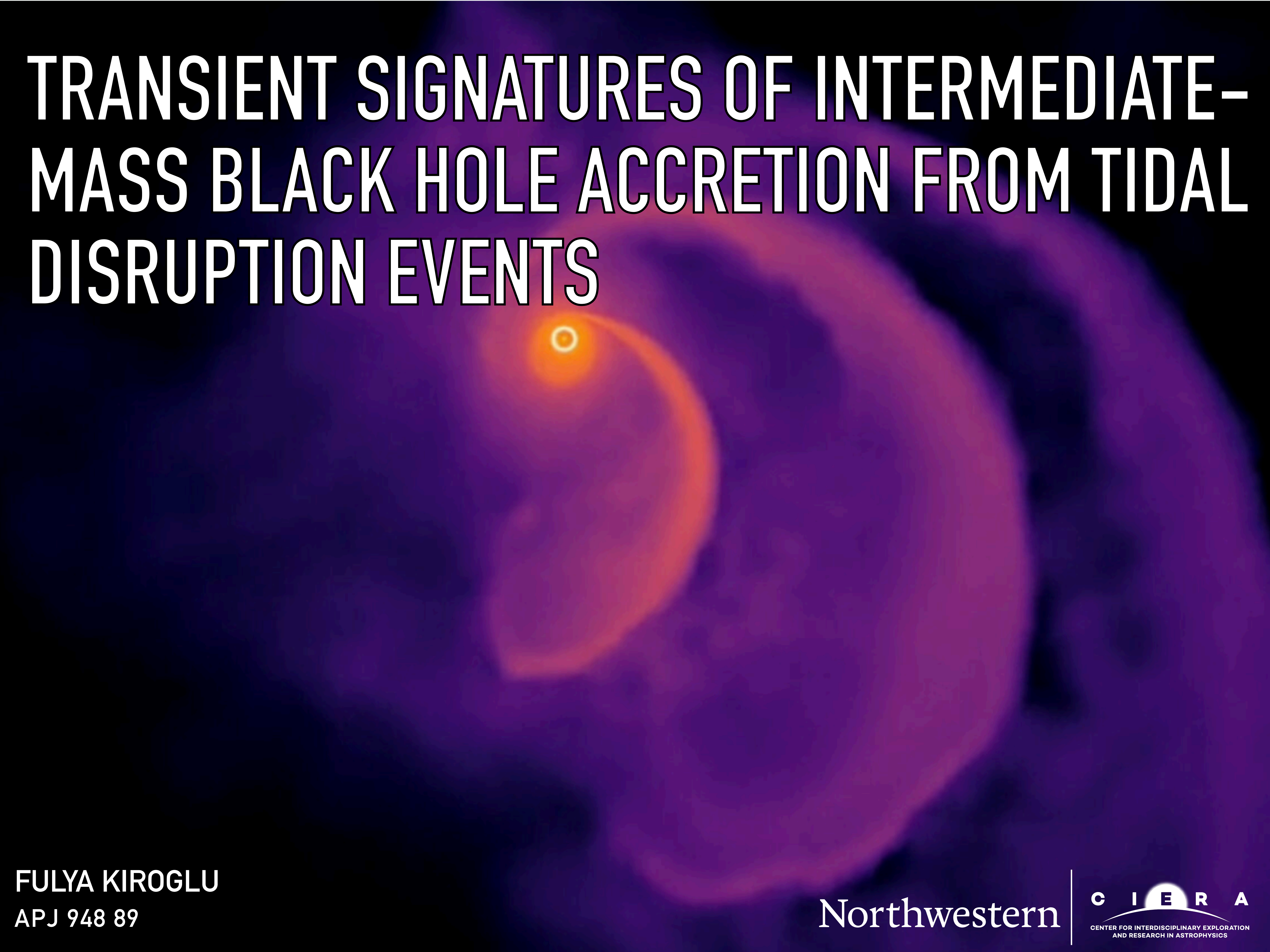
TRANSIENT SIGNATURES OF INTERMEDIATE-MASS BLACK HOLE ACCRETION FROM TIDAL DISRUPTION EVENTS



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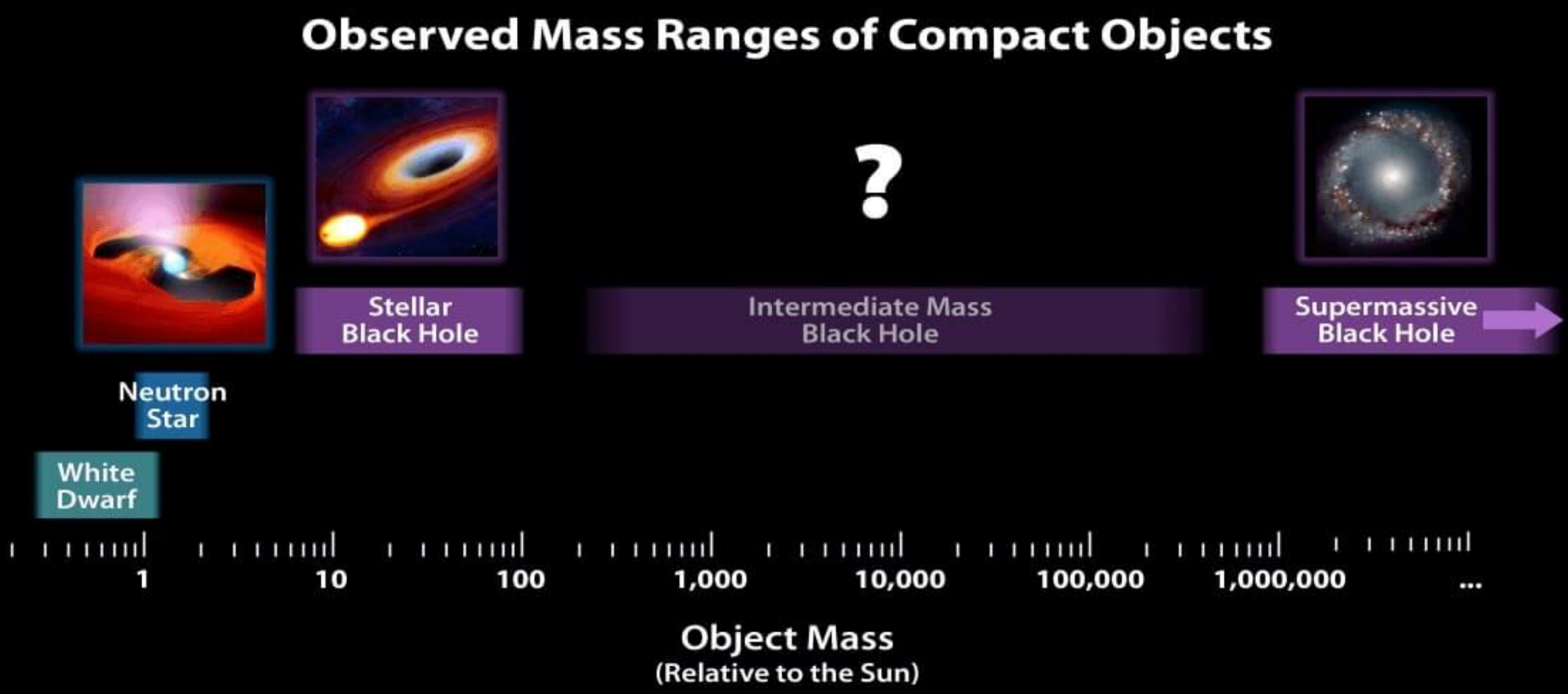
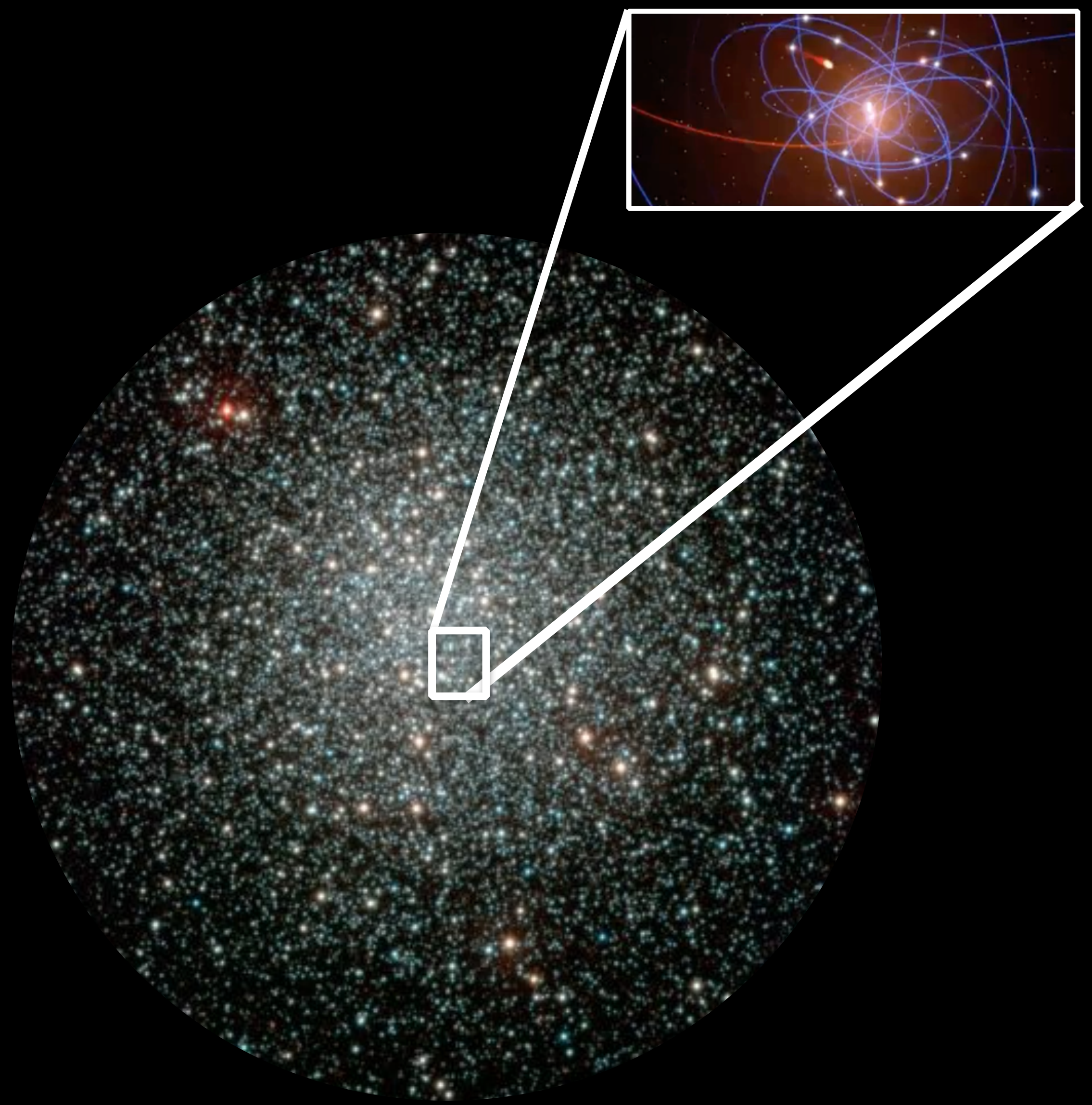
Intermediate-Mass Black Holes (IMBHs)



NASA/JPL-Caltech

Forming IMBHs in Dense Star Clusters

- Massive stellar mergers at early times
- Sequential mergers of stellar-mass black holes
- Stellar black hole seeds accreting gas
  - Gas rich system
  - Gas from disrupted stars and supernovae



Globular Cluster NGC 3201
ESO/M.-R. Cioni/VISTA Magellanic Cloud survey

e.g., Portegies Zwart 2001, Mackey+2008, Breen & Heggie 2013, Morscher+2015, Heggie & Giersz 2014, Rodriguez+2015, 2016, Chatterjee+2017, Arca Sedda+2018, Askar+2018, Lopez & Batta 2019, Banerjee 2018, Antonini & Gieles 2020, Kremer+2019, 2020, Gonza`lez et al. 2021)

Observational Signatures

- Spatial and kinematic structure of the host cluster
- *Creation of hypervelocity main sequence escapers during strong dynamical interactions between binaries and an IMBH (e.g., Gualandris & Portegies Zwart 2007)*
- Possible radio, X-ray, and gravitational wave emissions due to dynamical collisions or mass-transfer

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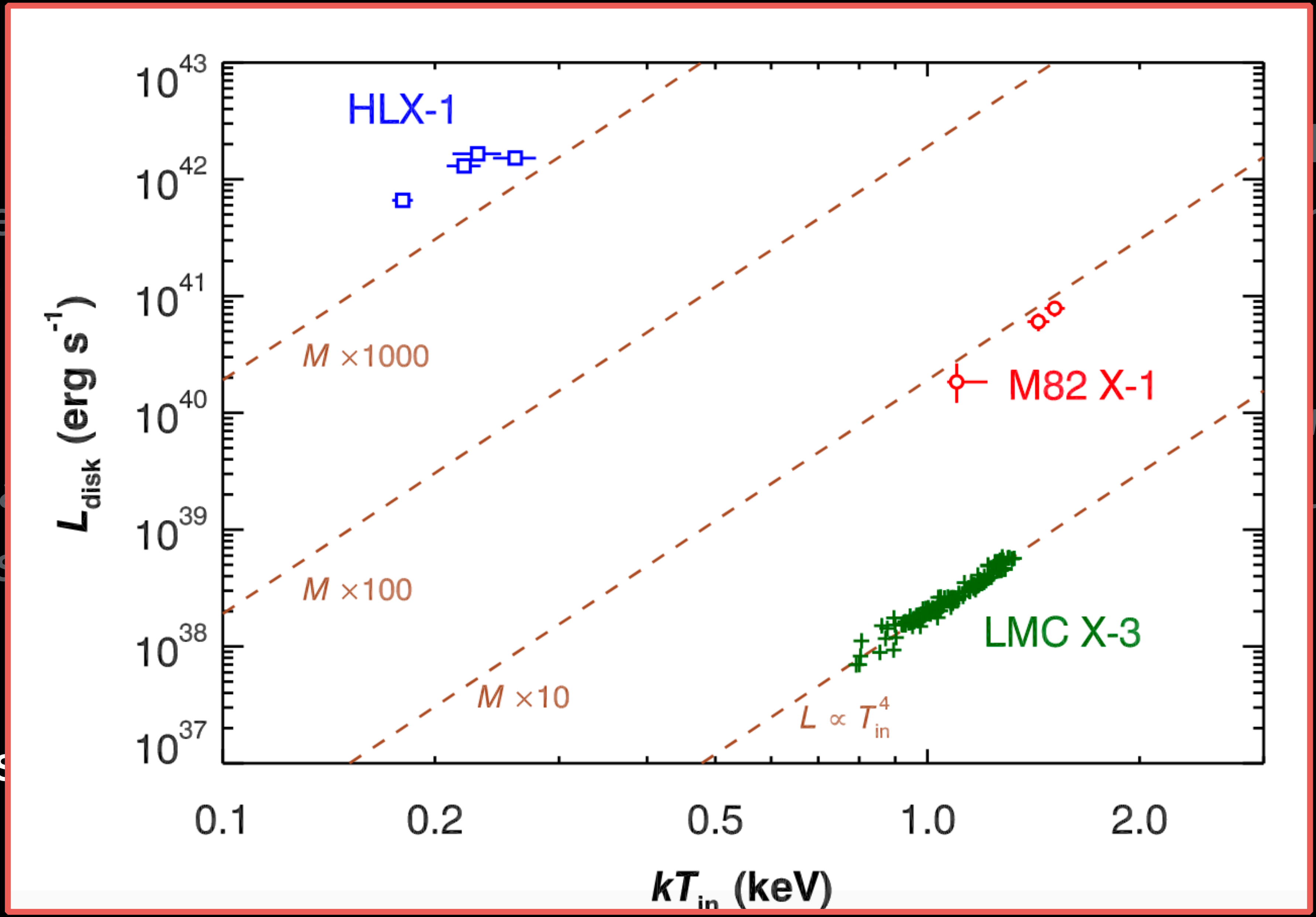
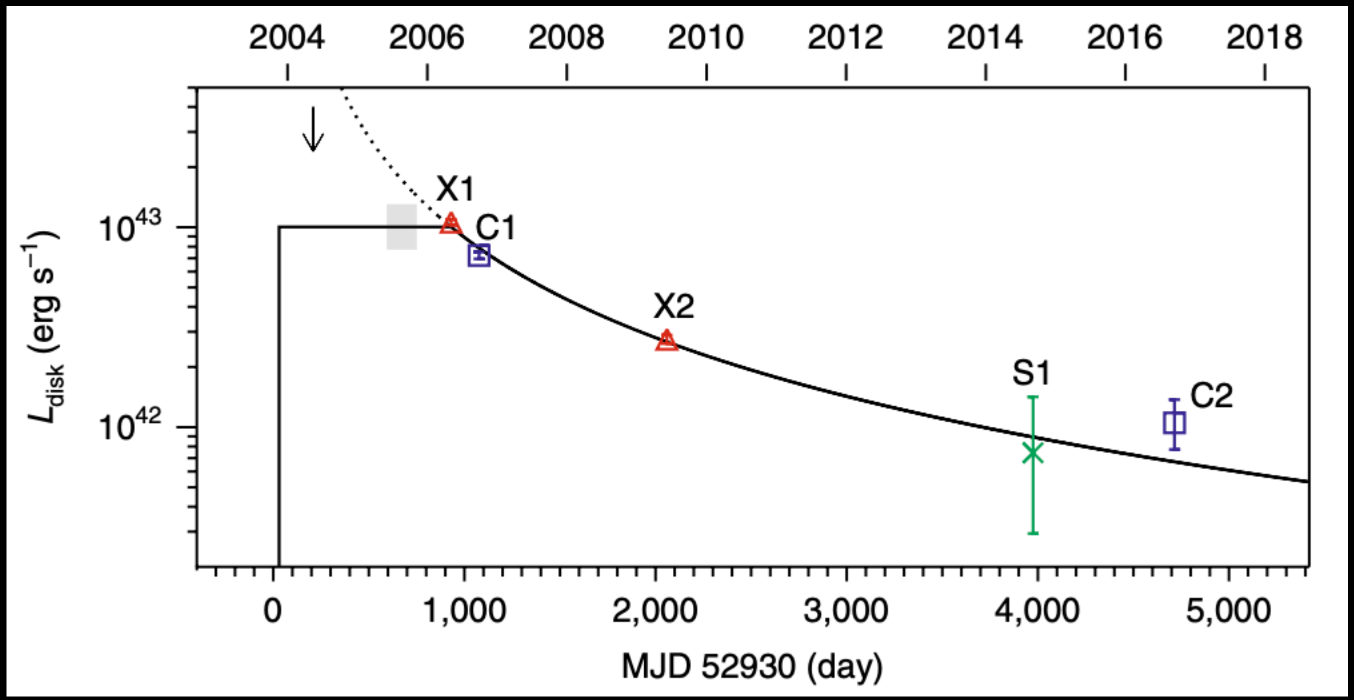
- *Creation … ng dynamic … ualandris & Portegies* …
- Possible … dynamical collisions …

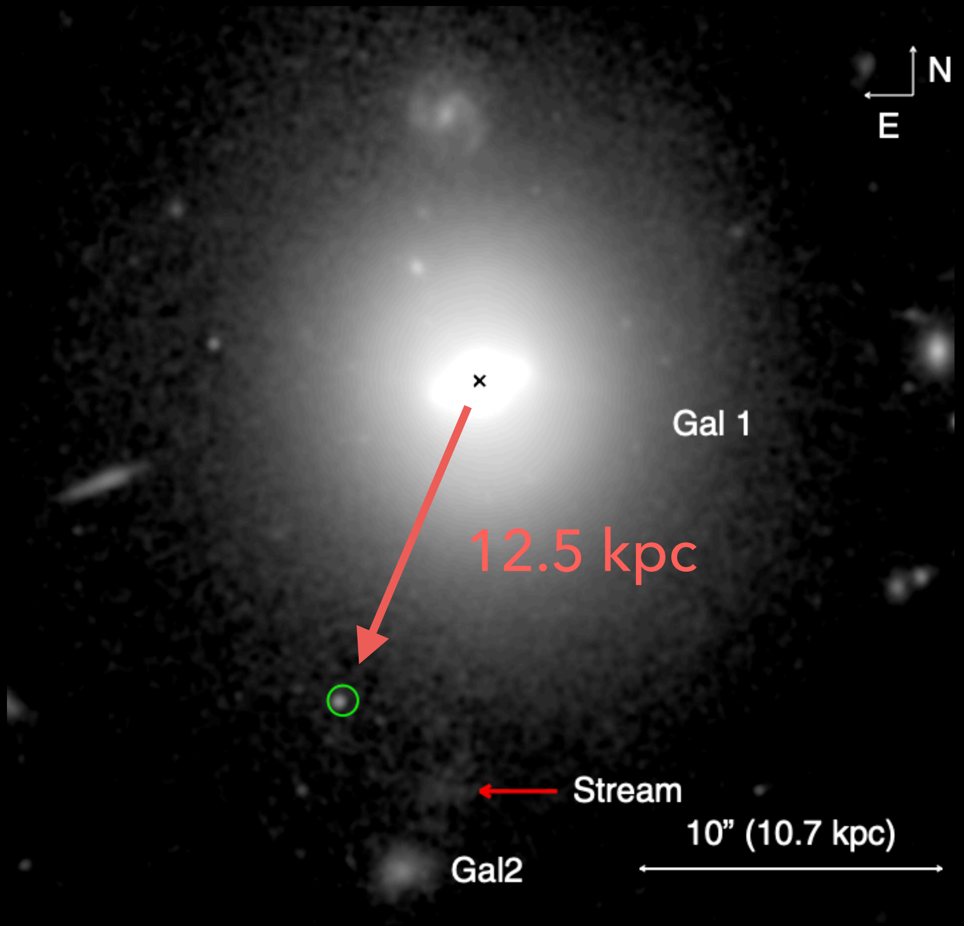


Kaaret + 2017

A luminous X-ray outburst from an intermediate-mass black hole in an off-centre star cluster

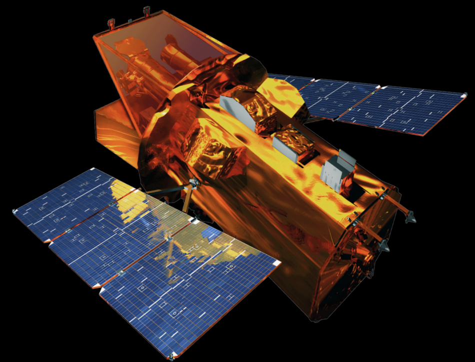


Lin + 2018

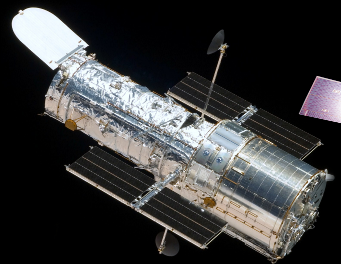


HST/ACS imaging, Lin+ 2018

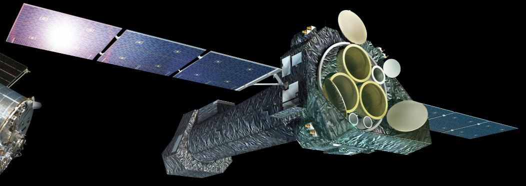
- Thermal-state signature
- Very high luminosities
- Ultra-soft X-ray spectra
- Power-law evolution of the light curve



Swift/XRT

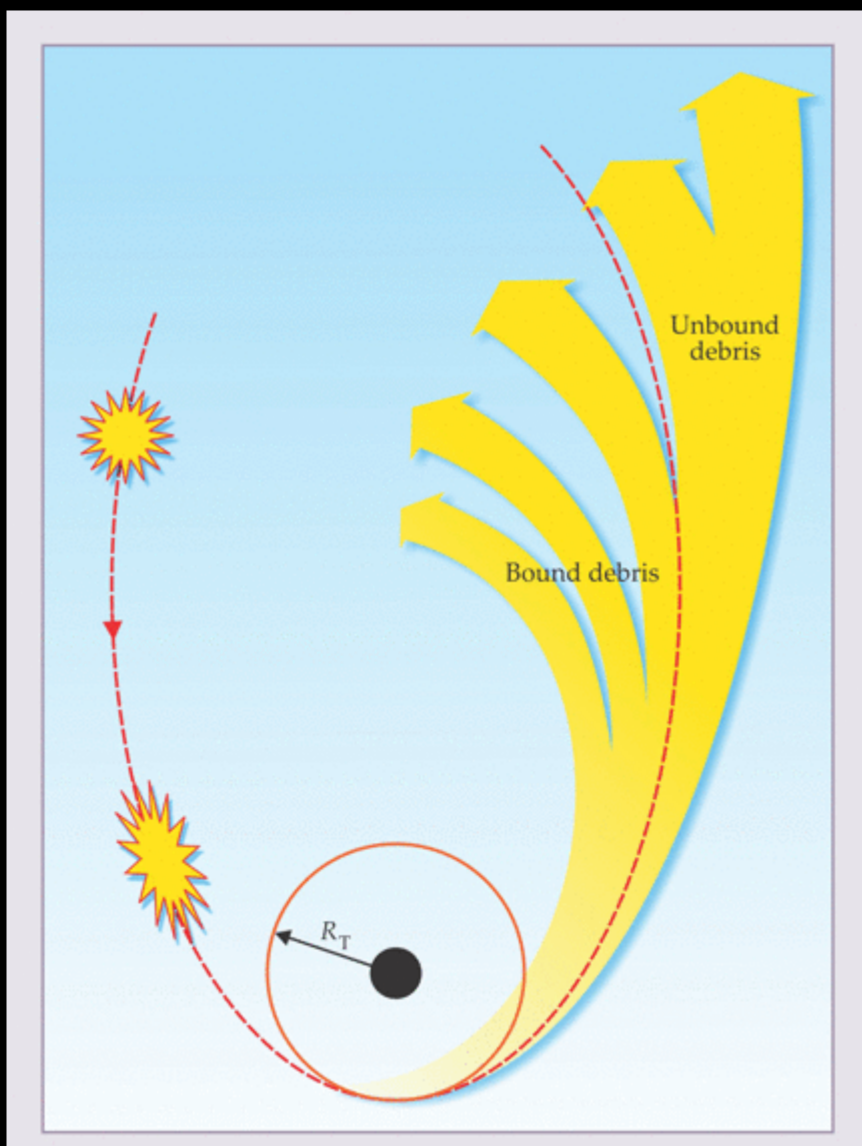


HST



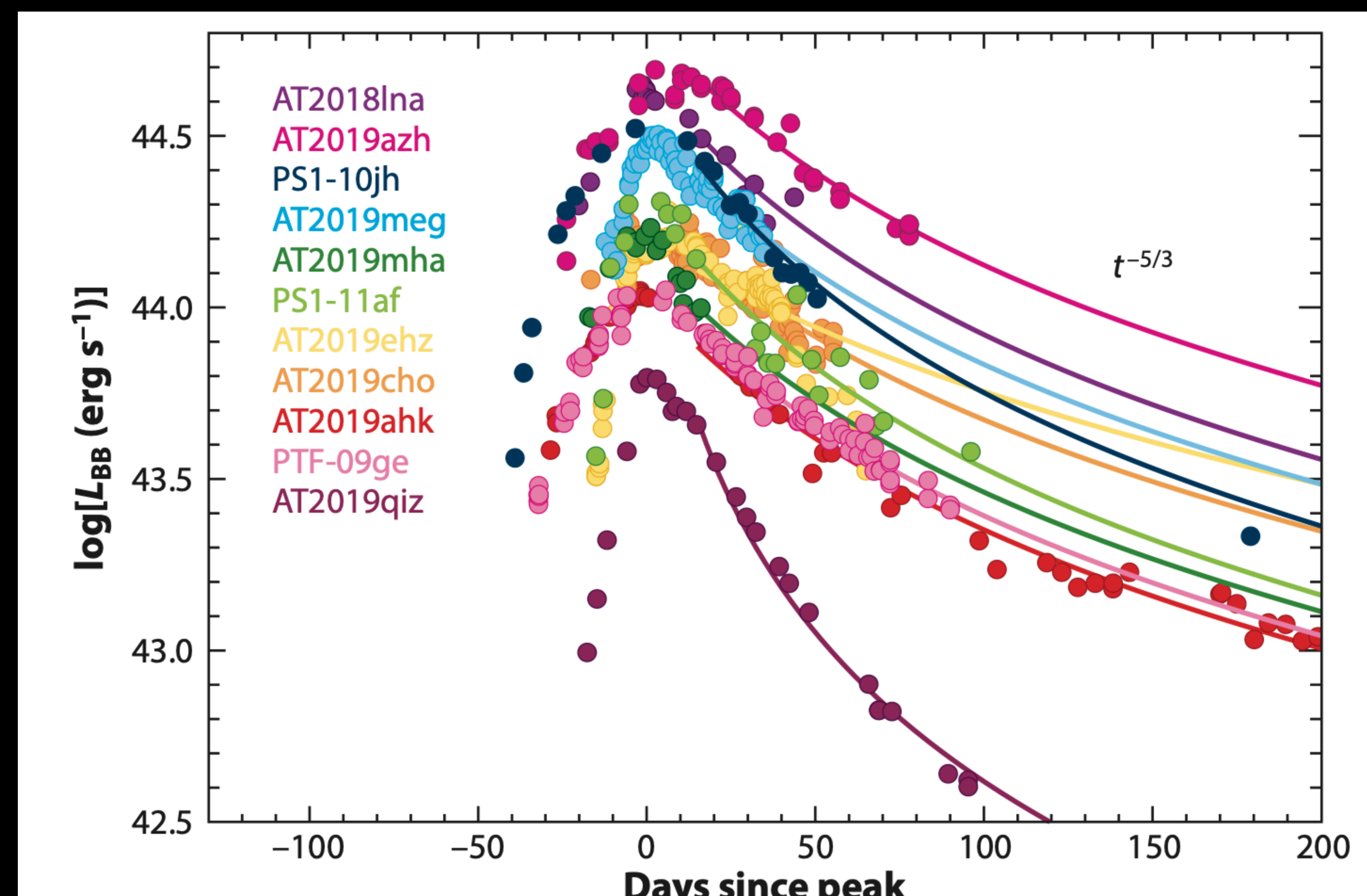
XMM-Newton

Tidal Disruption Events



Credit: *S. Gezari, Physics Today*

$$R_T \approx \left(\frac{M_{\rm BH}}{M_\star}\right)^{1/3} R_\star$$

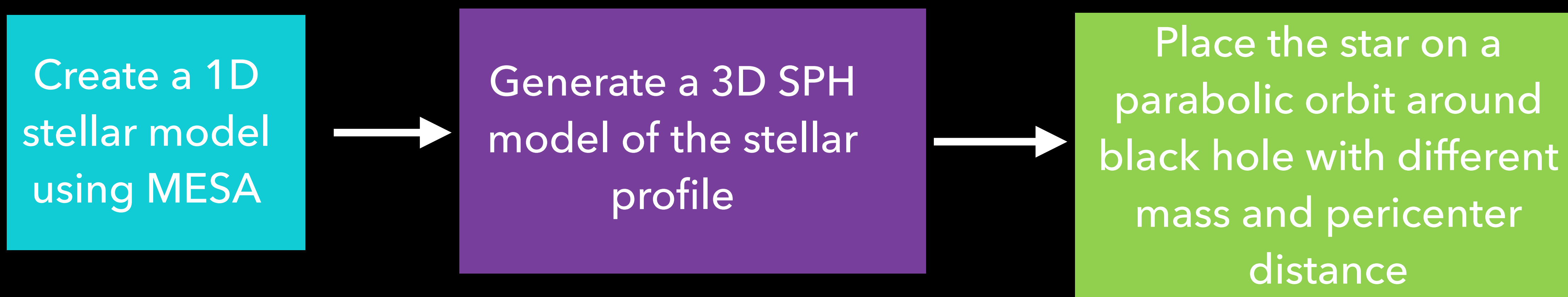


van Velzen + 2020

TDEs have a light curve that follows the general shape of the theoretical TDE fallback rate

$$dM/dt \propto t^{-5/3}$$

Analysis of Hydrodynamic Calculations



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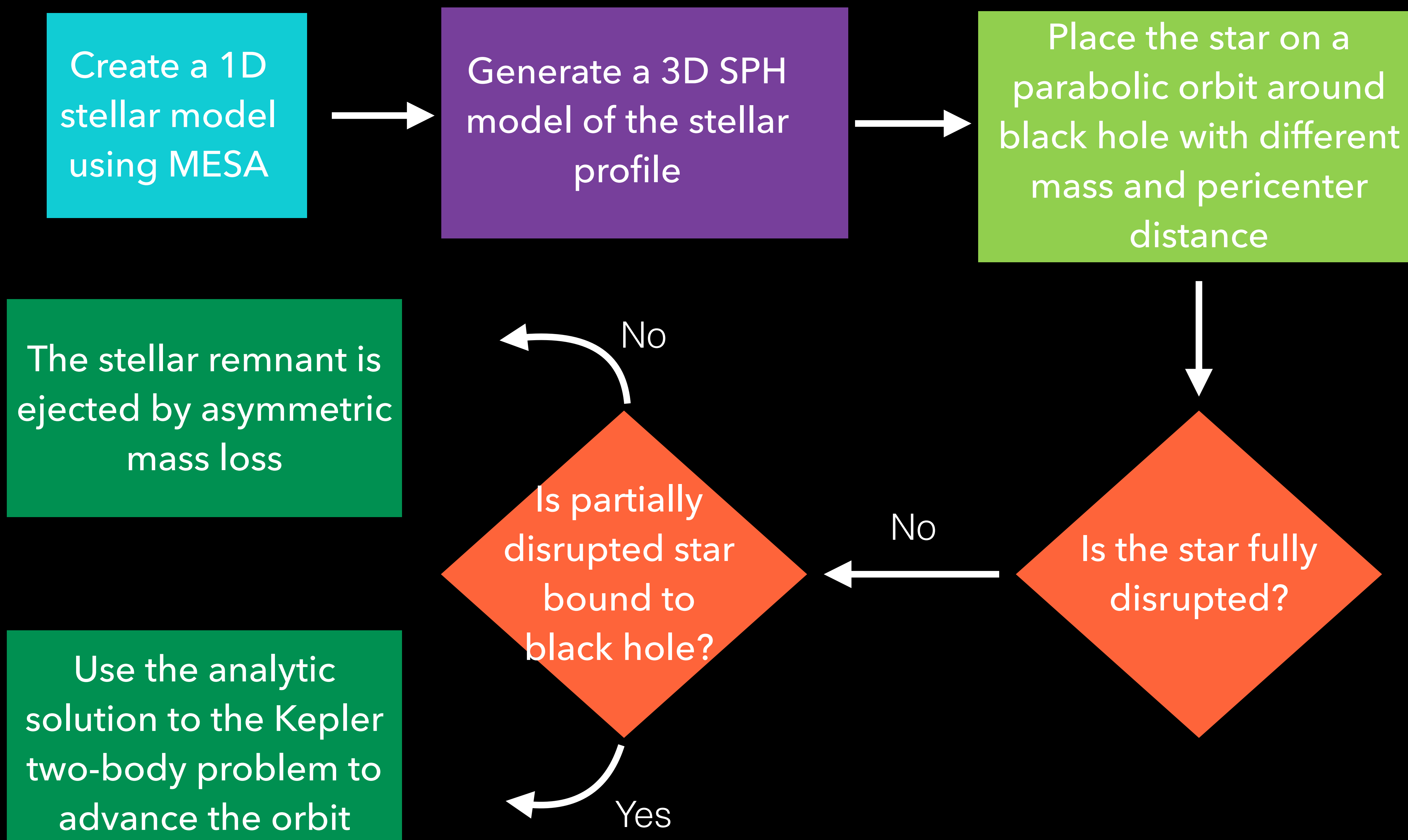
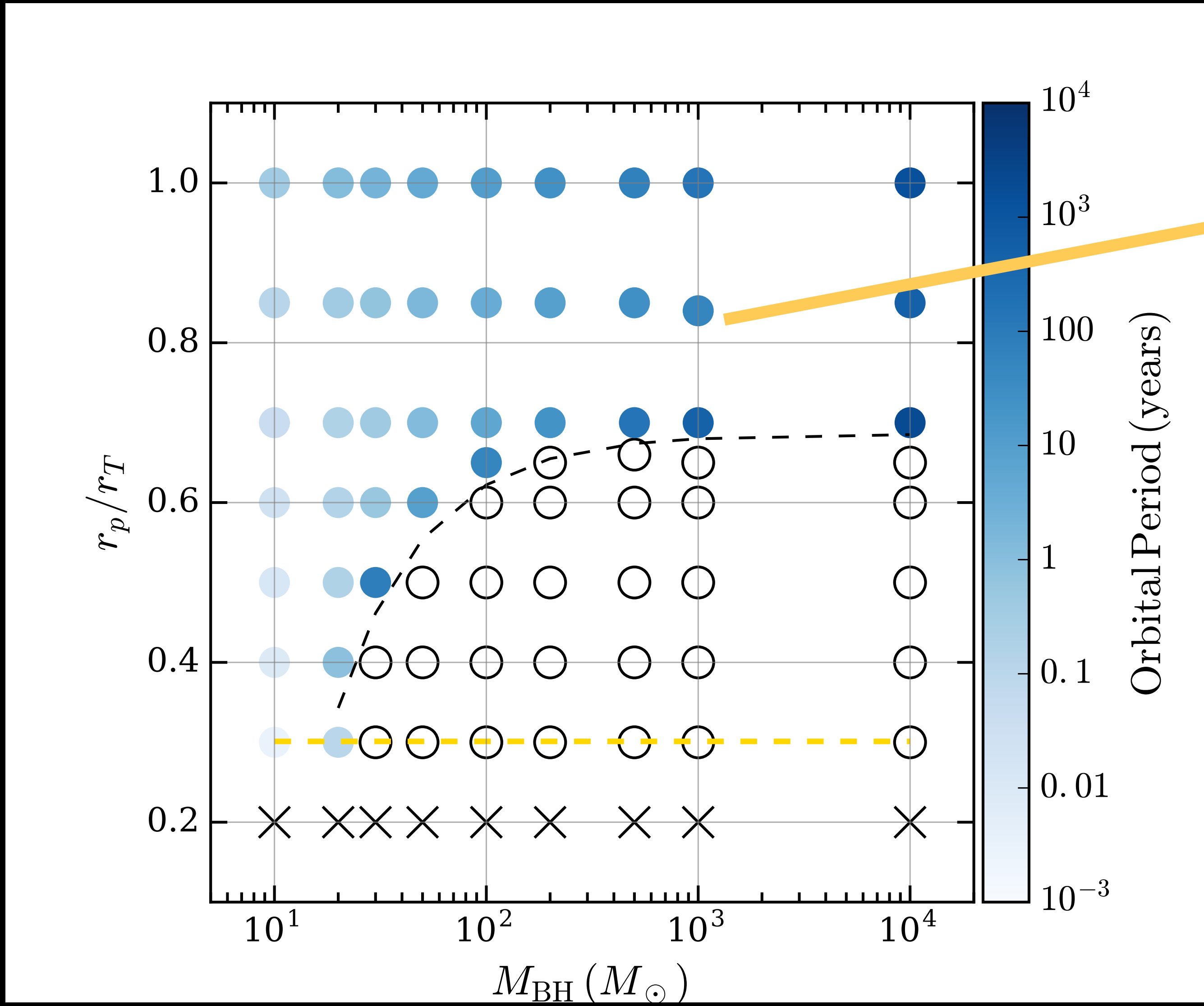


Results of the Hydrodynamic Models

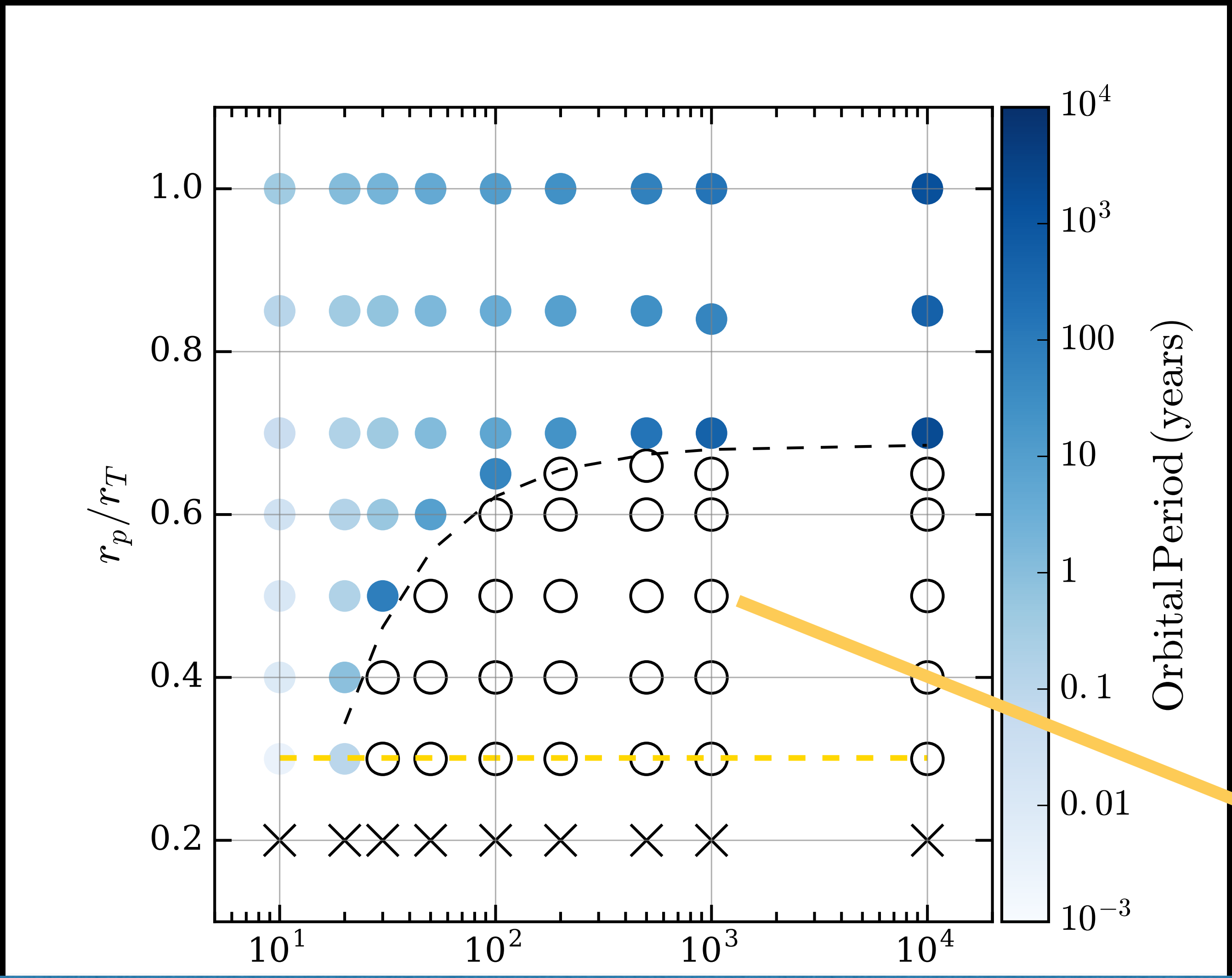


Kıroğlu + 2023

For $r_p/r_T \gtrsim 0.6$:

- The star is only partially disrupted
- The remnant is bound to black hole and undergoes another pericenter passage

Results of the Hydrodynamic Models

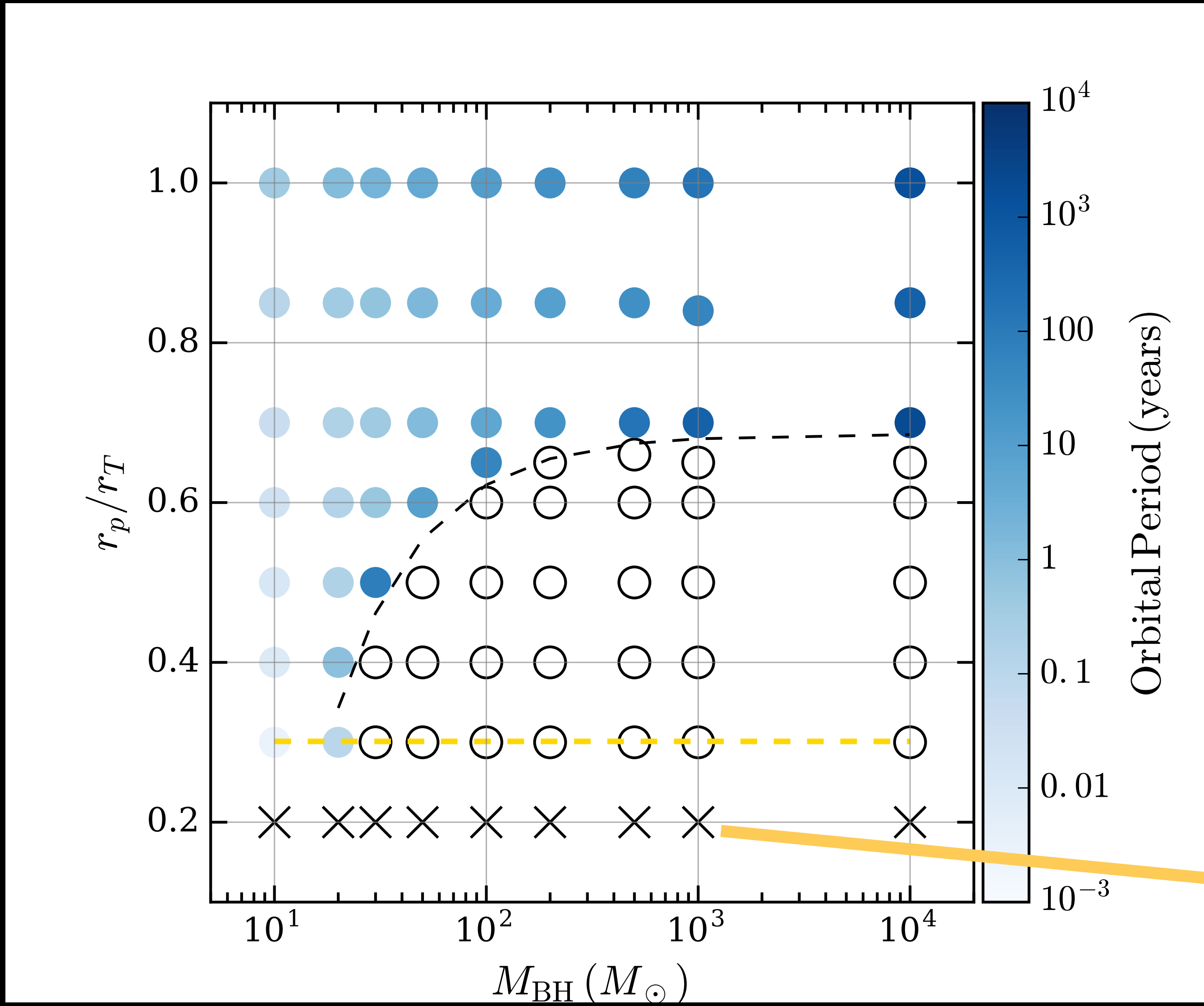


Star receives a kick if $M_{\rm BH} > 20M_\odot$
Star is more likely to be ejected for higher $M_{\rm BH}$

For $0.3 \lesssim r_p/r_T \lesssim 0.6$:

- The star is only partially disrupted
- It receives a kick to be ejected from its host cluster

Results of the Hydrodynamic Models



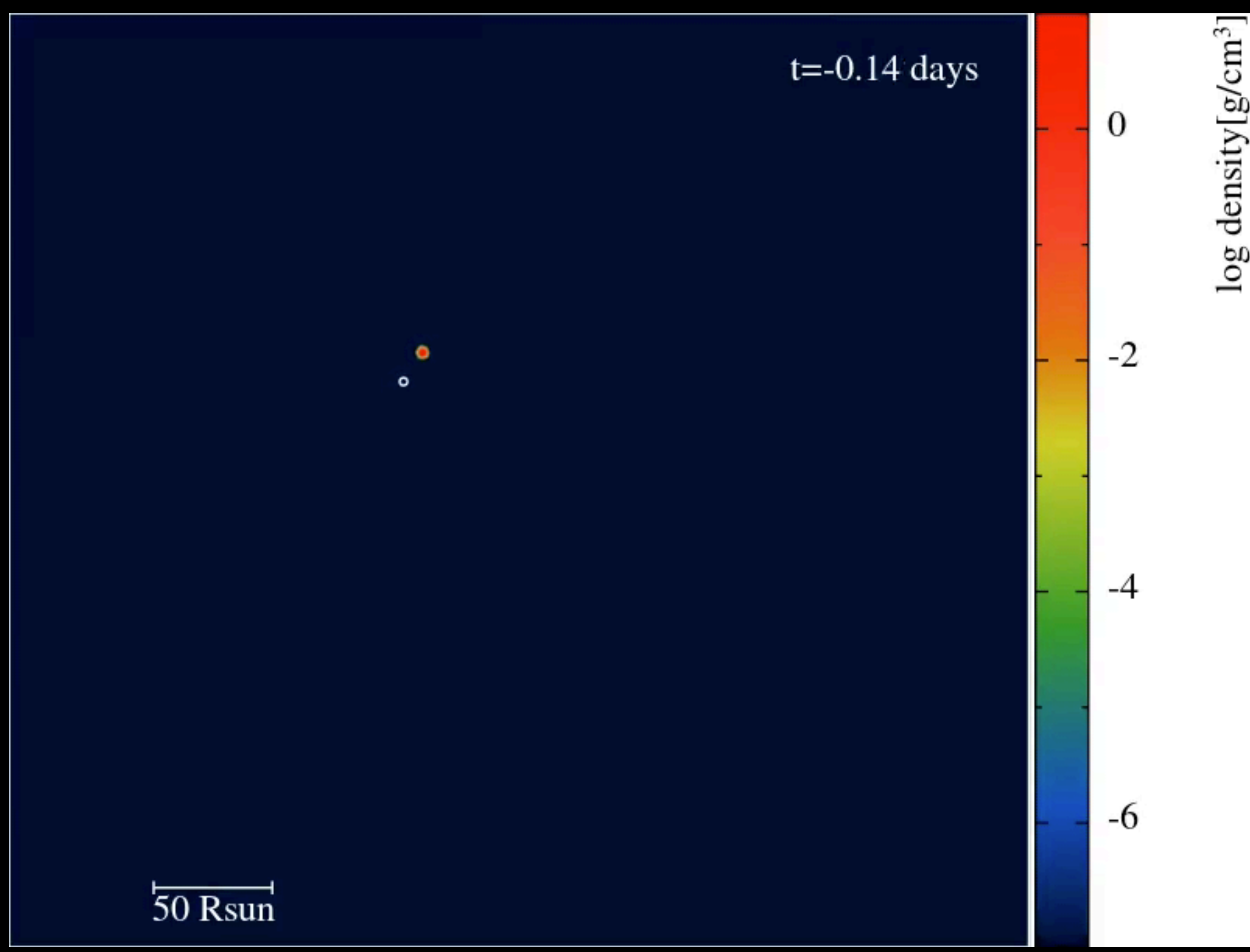
Kıroğlu + 2023

For $r_p/r_T \lesssim 0.3$:

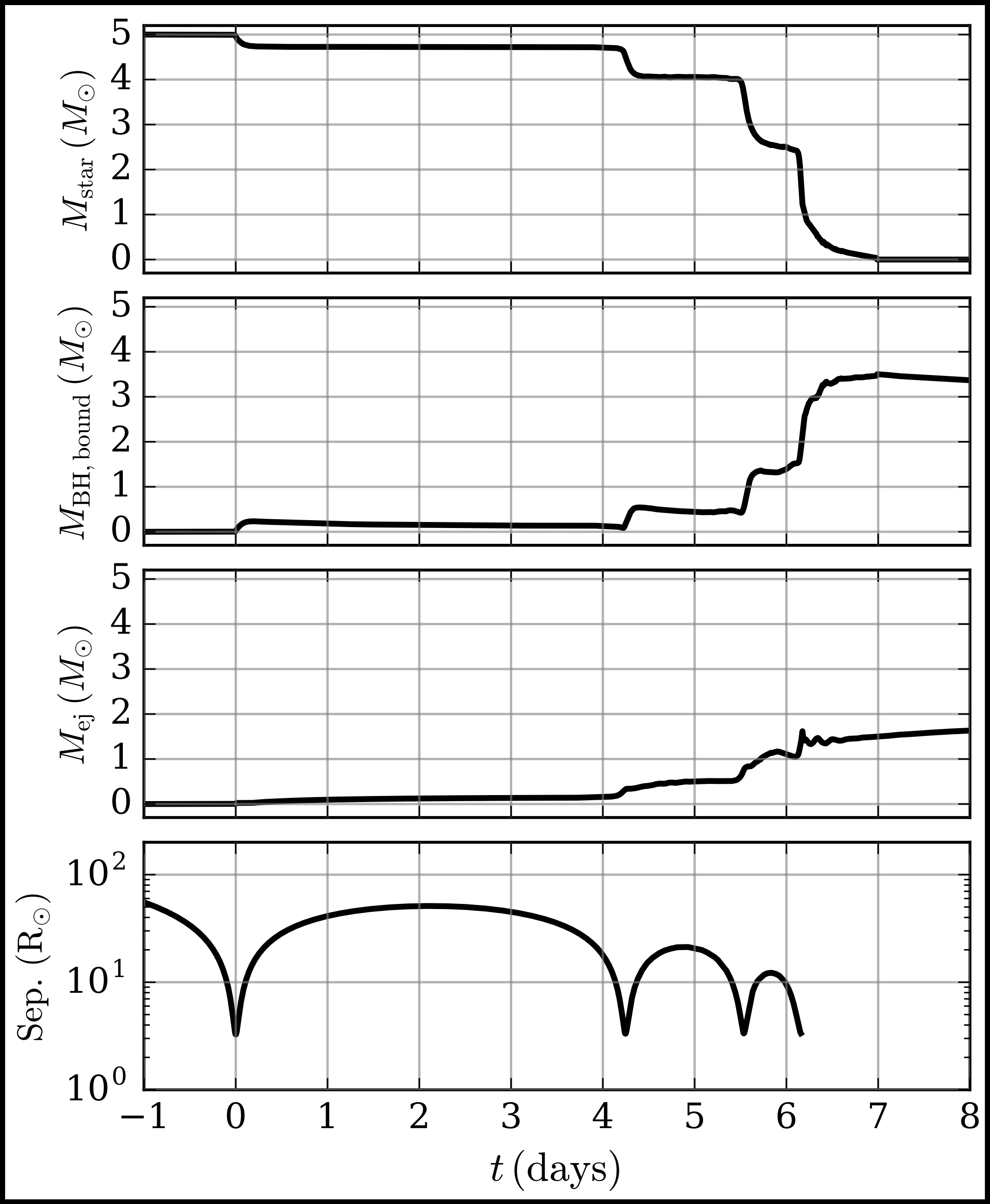
✳ The star is fully disrupted

A Stellar-mass BH TDE: Inspiral + Merger

$M_{BH} = 10\,M_\odot, M_\star = 5\,M_\odot, r_p = r_T$



Kremer + 2022

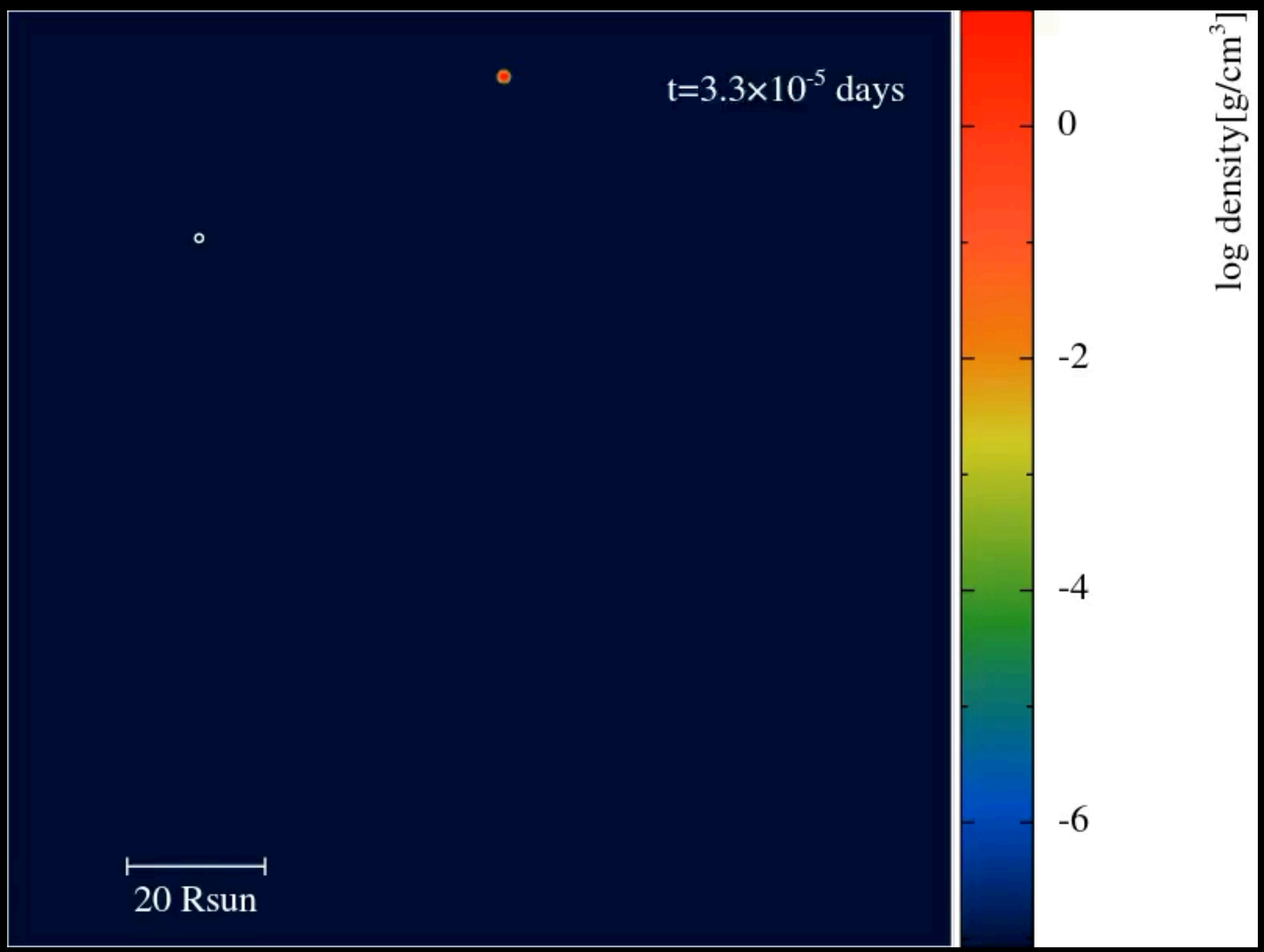


Kremer + 2022

- Outcome: Partial disruption of star
- 4 total passages lead to inspiral + merger

An IMBH TDE: Partial Disruption + Ejection

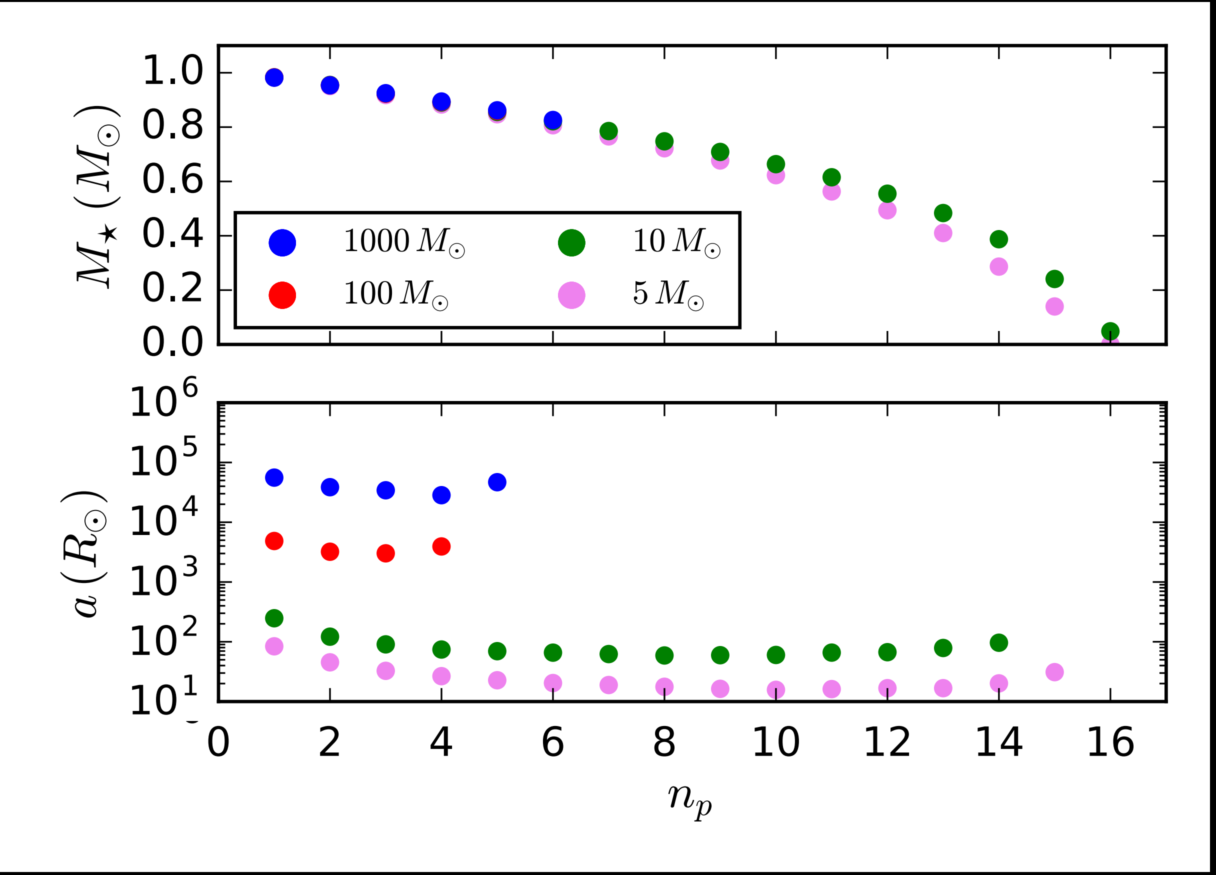
$M_{\rm BH} = 100\,M_\odot, M_\star = 1\,M_\odot, r_p = 0.4\,r_T$

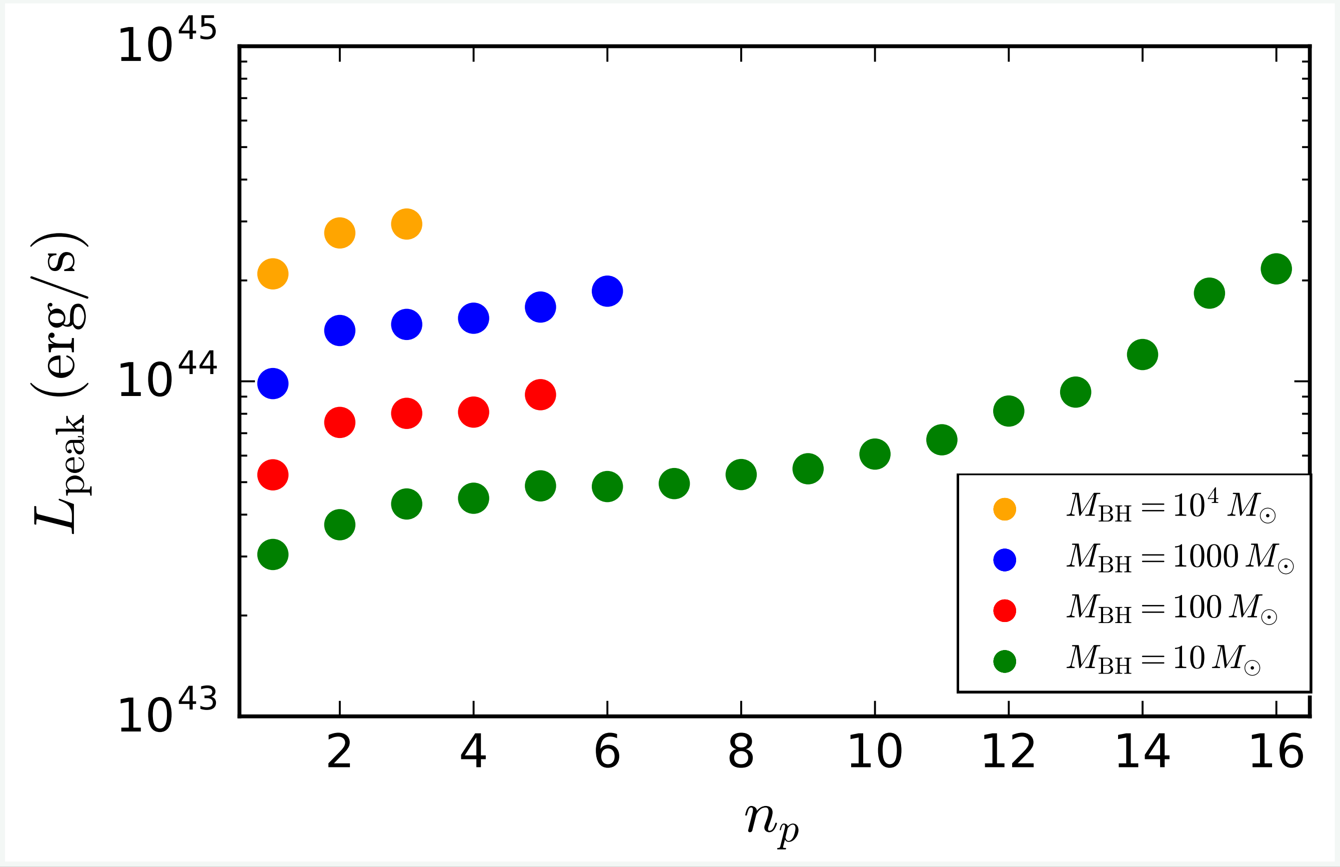


Kıroğlu + 2023

- *Outcome: Partial disruption of star*
- $0.3\,M_\odot$ *the remnant is ejected with* $v_{\rm kick} \approx 300\,{\rm km\,s^{-1}}$

Repeated Tidal Disruption Events





Kıroğlu + 2023

- Number of close passages increases with decreasing black hole mass
- Brightness of the accretion flares increases after each pericenter passage

Credit: Sophia Dagnello, NRAO/AUI/NSF

Conclusions

I. TDE observations may enable an inference of the IMBH and disrupted star properties and understanding aspects of accretion theory

II. The total number of subsequent close passages depends on the mass ratio and pericenter distance

III. Each time the star loses mass, it becomes more luminous, creating a flare signature that astronomers can search for in the hunt for IMBHs

IV. Interactions with a more massive black hole lead to fewer pericenter passages before the star is ejected.