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POLSKIE TOWARZYSTWO ASTRONOMICZNE

WHY IS THE LOUDEST STELLAR HEARTBEAT SO LOUD?

Piotr Kołaczek-Szymański & Piotr Łojko

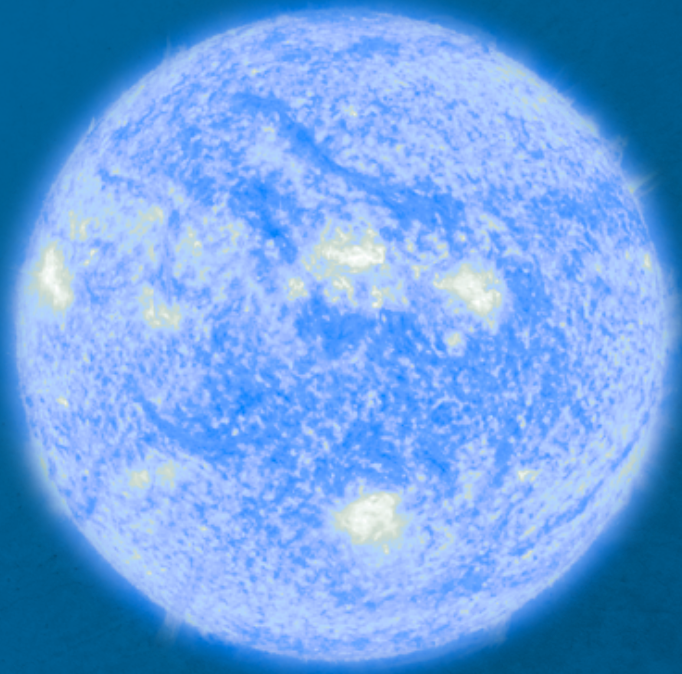
in cooperation with Andrzej Pigulski, Tomasz Różański and Dawid Moździerski

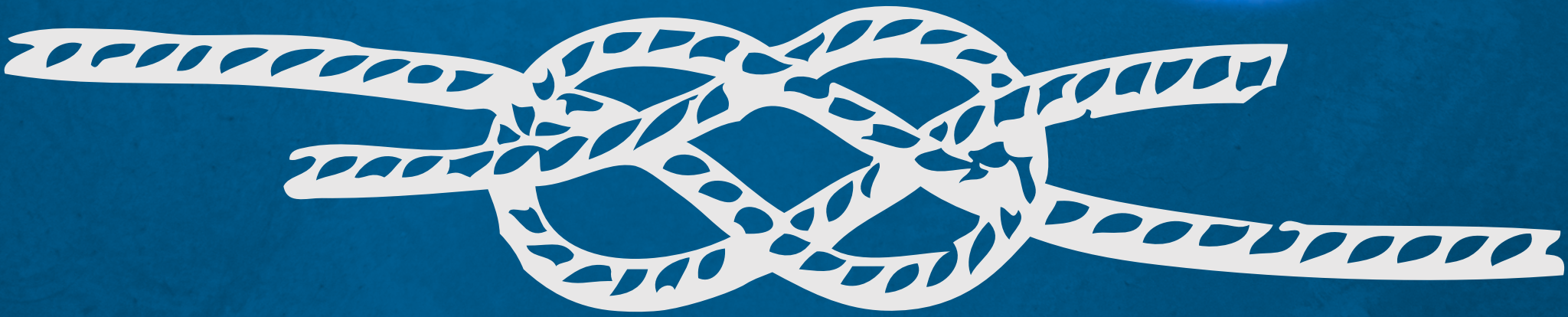
University of Wrocław, Astronomical Institute

EVOLUTION OF MASSIVE STARS

the Sun

=





COMPLICATED PROBLEM

EVOLUTION

INTERNAL MIXING

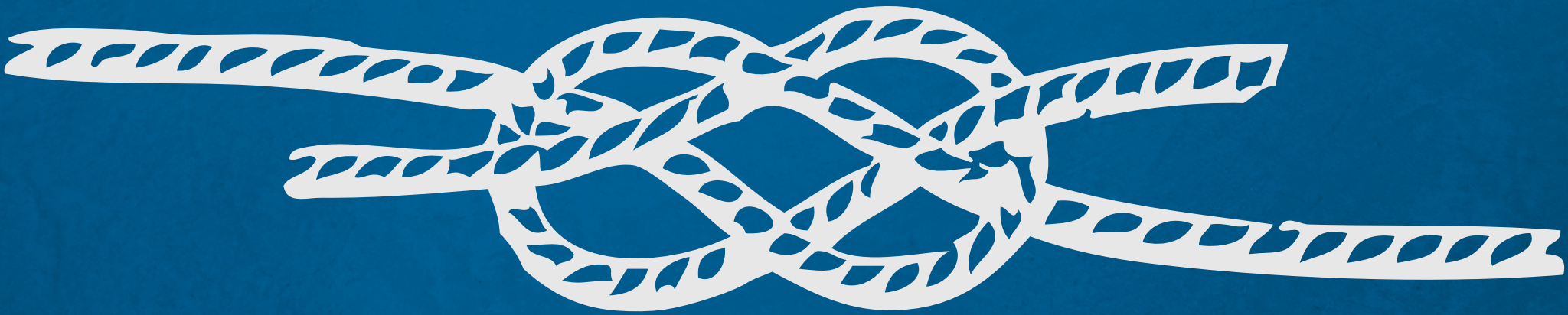
ROTATION

METALLICITY

BINARITY

TIDES

PULSATIONS



STELLAR WIND

The cosmic breeze or a hurricane?

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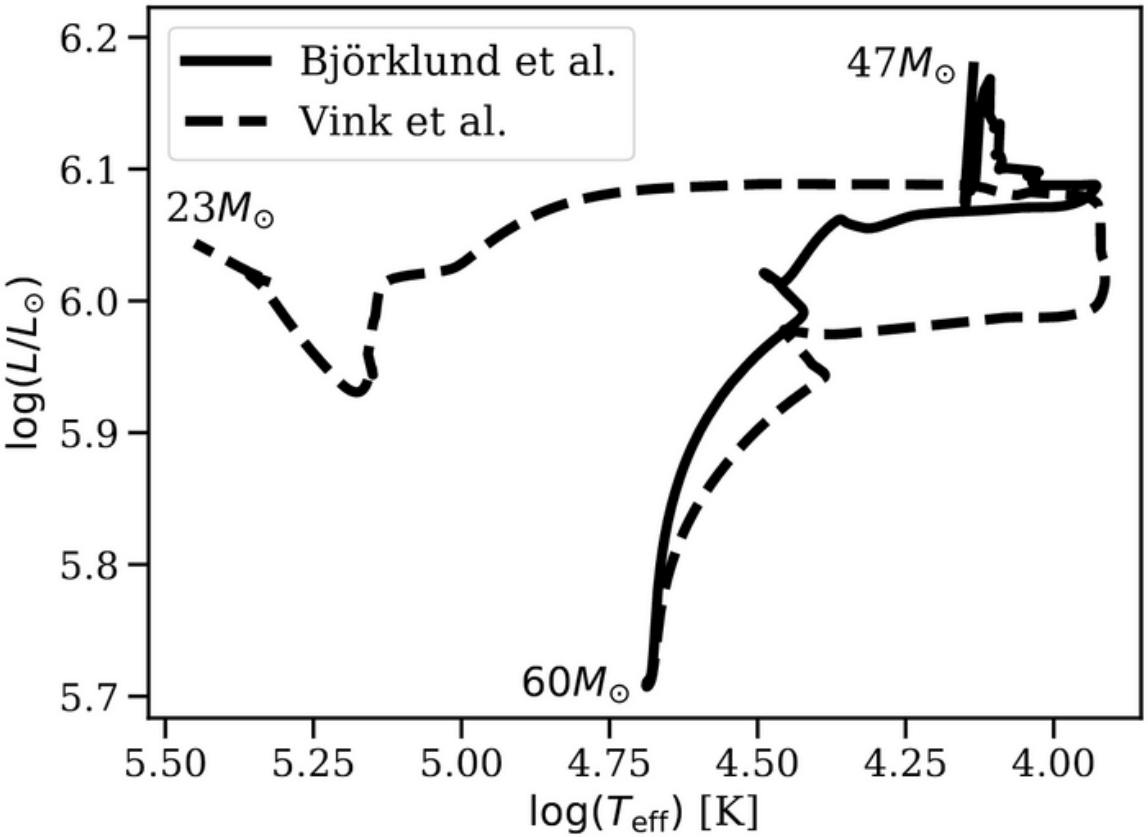
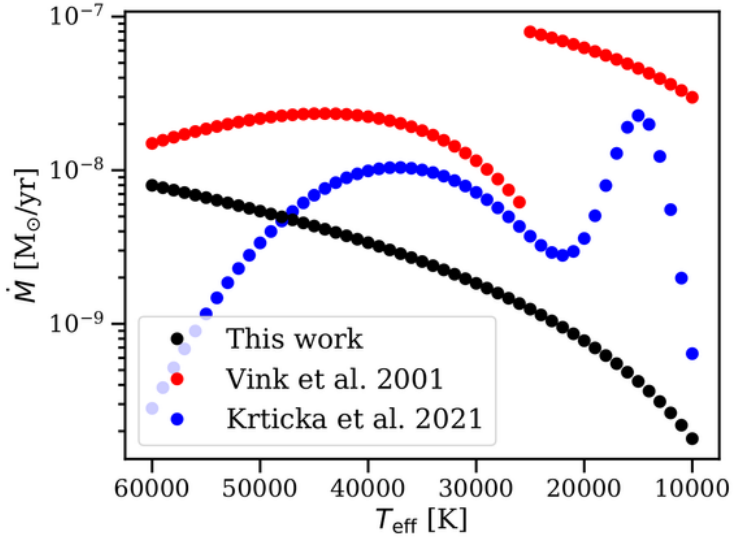
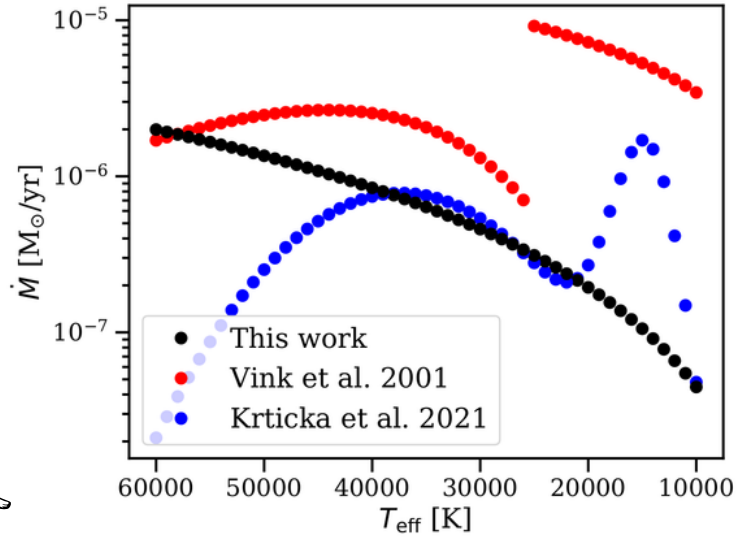
Bjorklund et al. (2023)







The impact of change in the prescription of wind mass-loss rate on the evolution of a massive star

Huge differences in commonly used wind mass-loss rate prescriptions for 15 (upper panel) and 50 (lower panel) solar mass star

Our hero – MACHO 80.7443.1718 (ExtEV)

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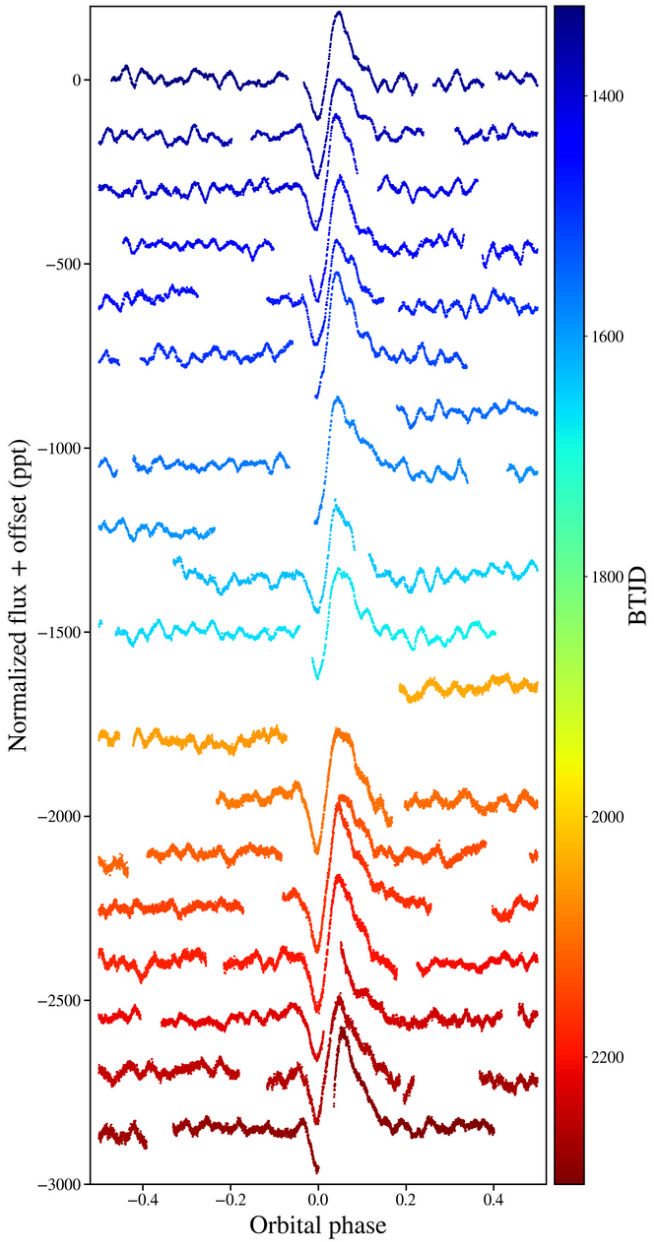

QUICK FACTS

- Located in the LMC (V=13.5 mag)
- SB1-type eccentric binary system
- The primary is a blue supergiant (B0 Iae)
- Orbital period = 32 days
- Discovered in MACHO survey, re-discovered by Jayasinghe et al. (2019) as an eccentric ellipsoidal variable (aka „heartbeat star")
- The total range of light changes = 0.4 mag!
- Tidally excited oscillations (TEOs) and stochastic variability are present in the light curve
- The first heartbeat star where TEOs significantly change their amplitudes and frequencies!

PROBLEM: How to explain the extreme amplitude?

SALT-HRS spectra and the orbital solution

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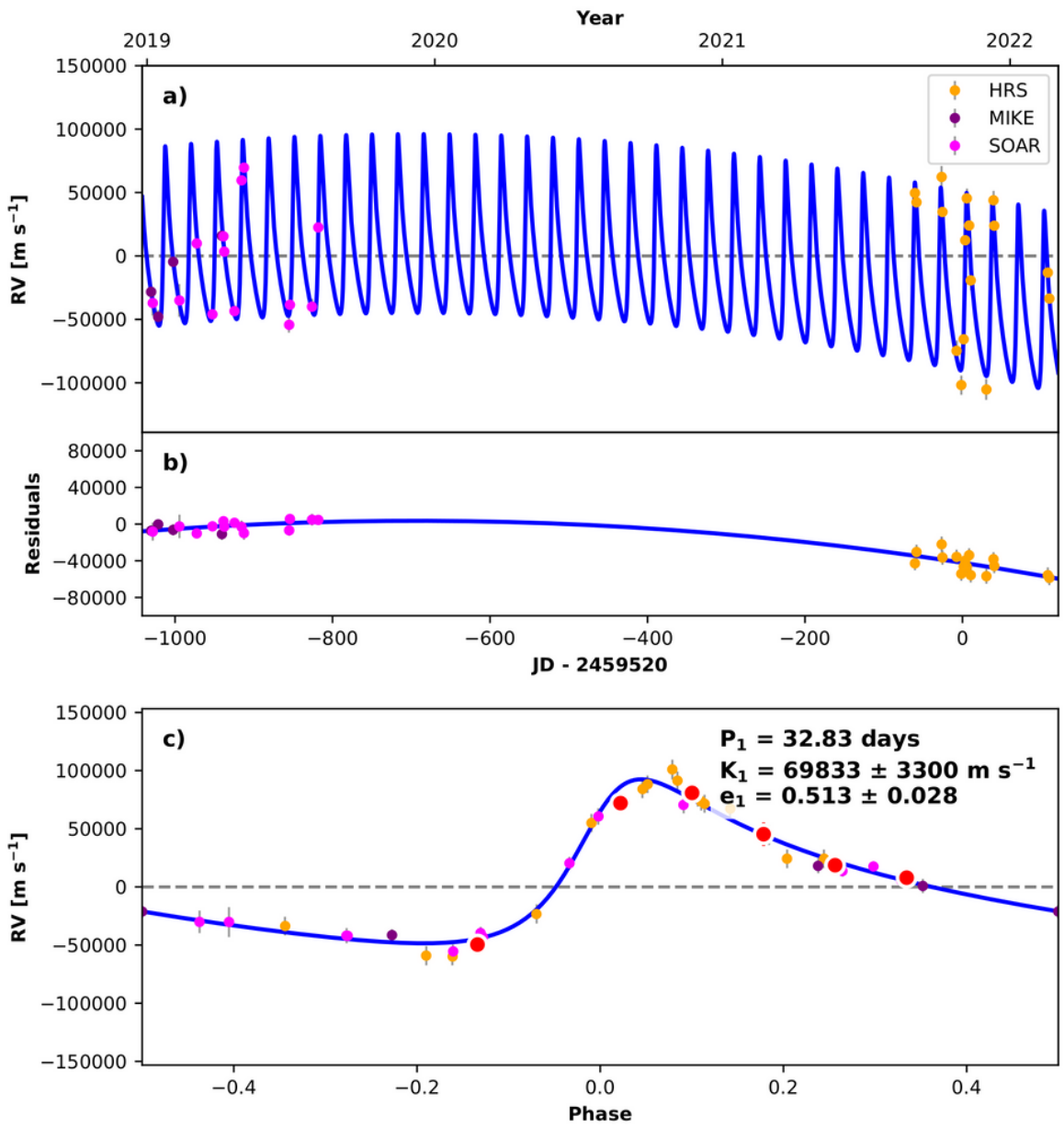

- 16 „useful" spectra obtained with SALT-HRS in 2021 and 2022
- Still no sign of lines of the secondary component
- Significant improvement of the previous ephemeris and orbital parameters
- The possible presence of distant tertiary component

ExtEV is NOT an extreme heartbeat star ...

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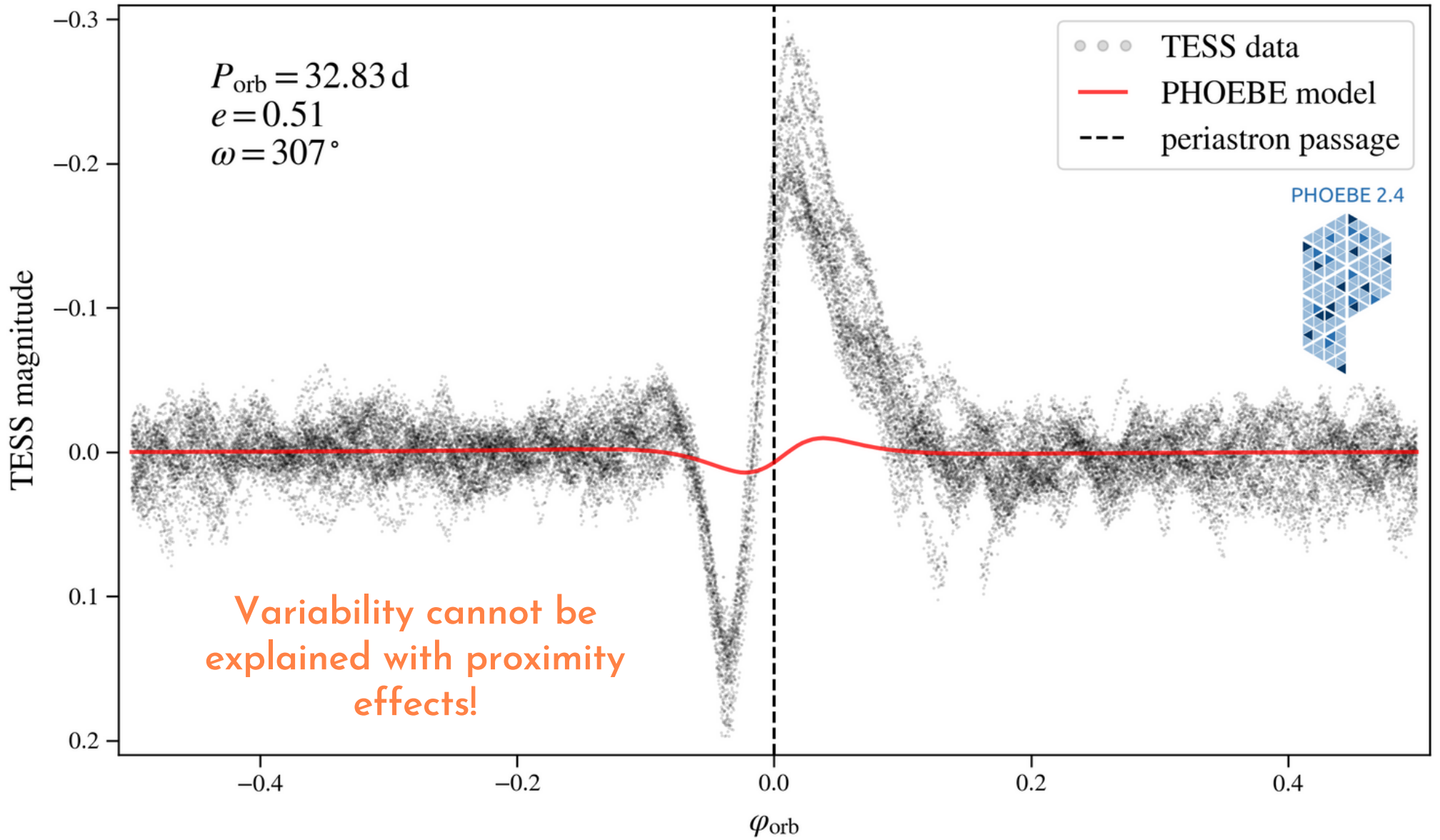
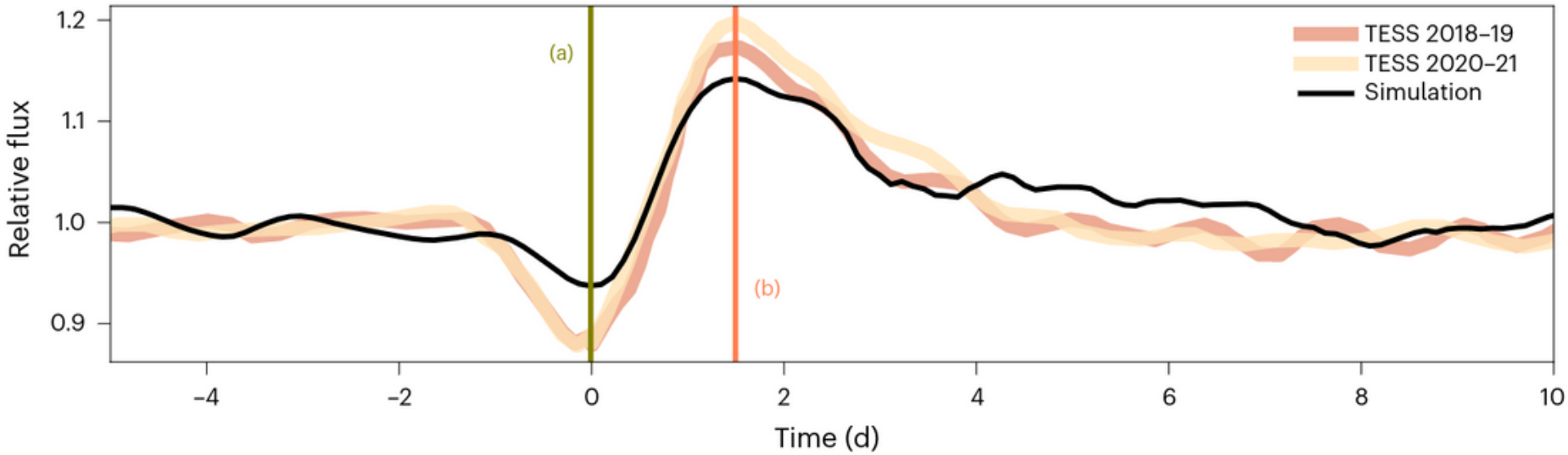
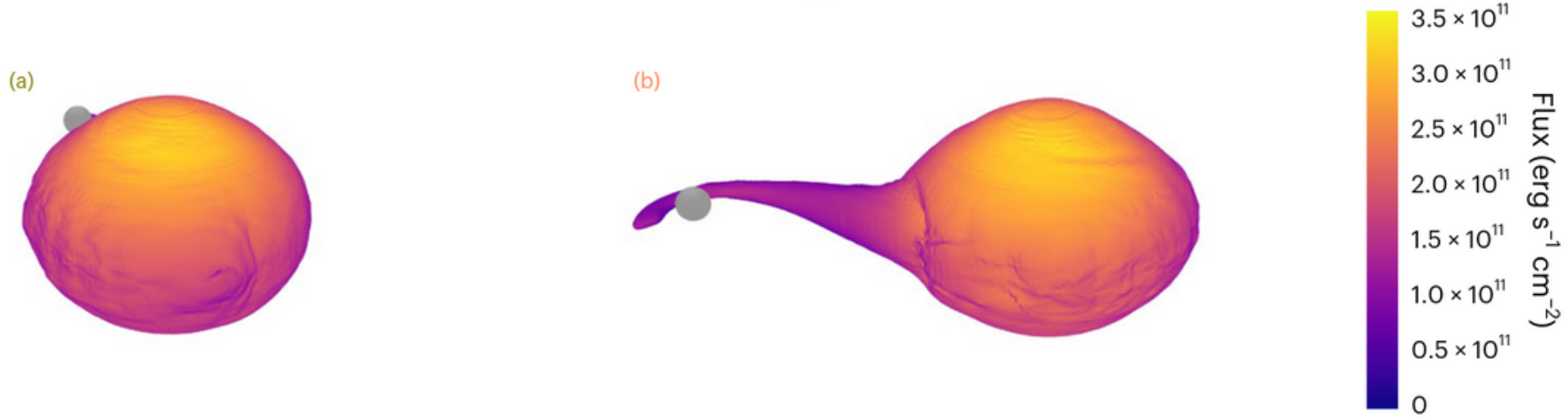


ExtEV is NOT an extreme heartbeat star ...





MacLeod & Loeb (2023) – possible non-linear breaking of tidal waves

... nor the B[e] supergiant with a disk

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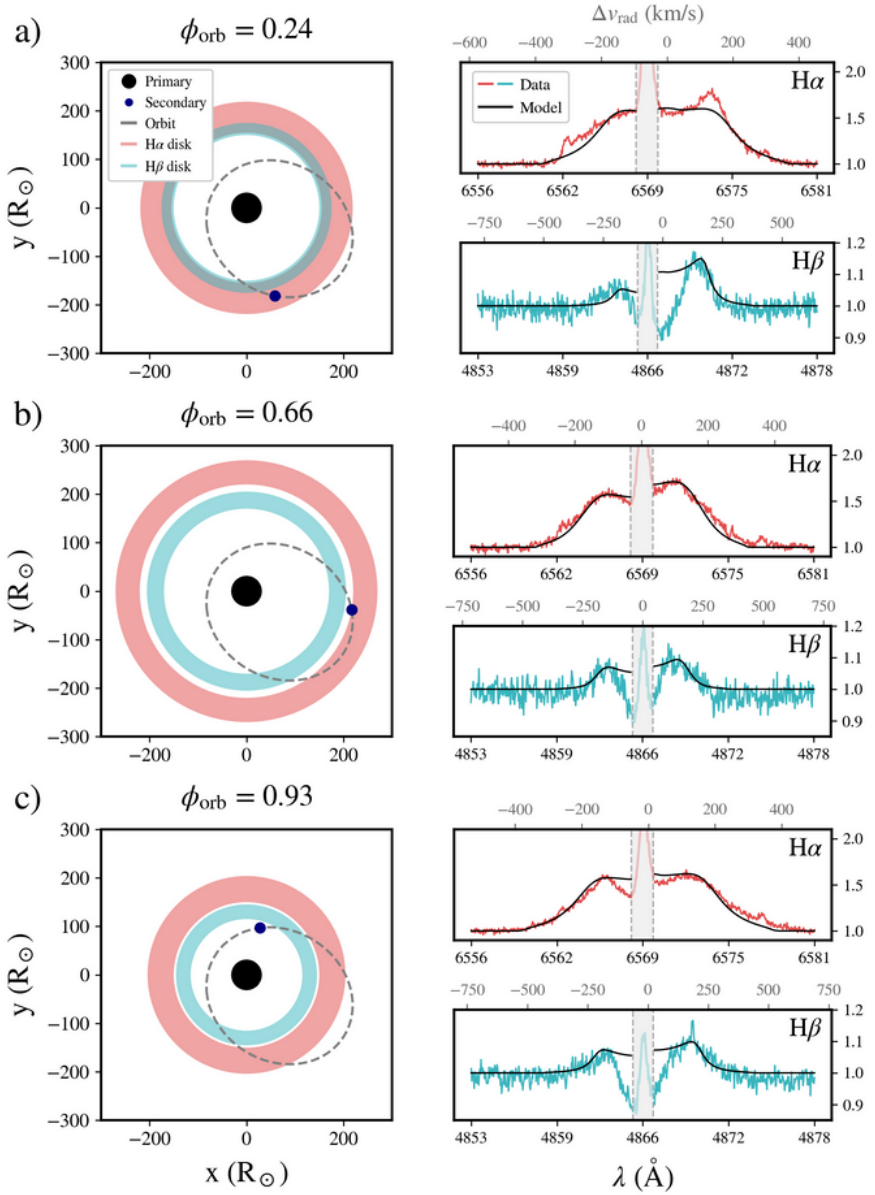
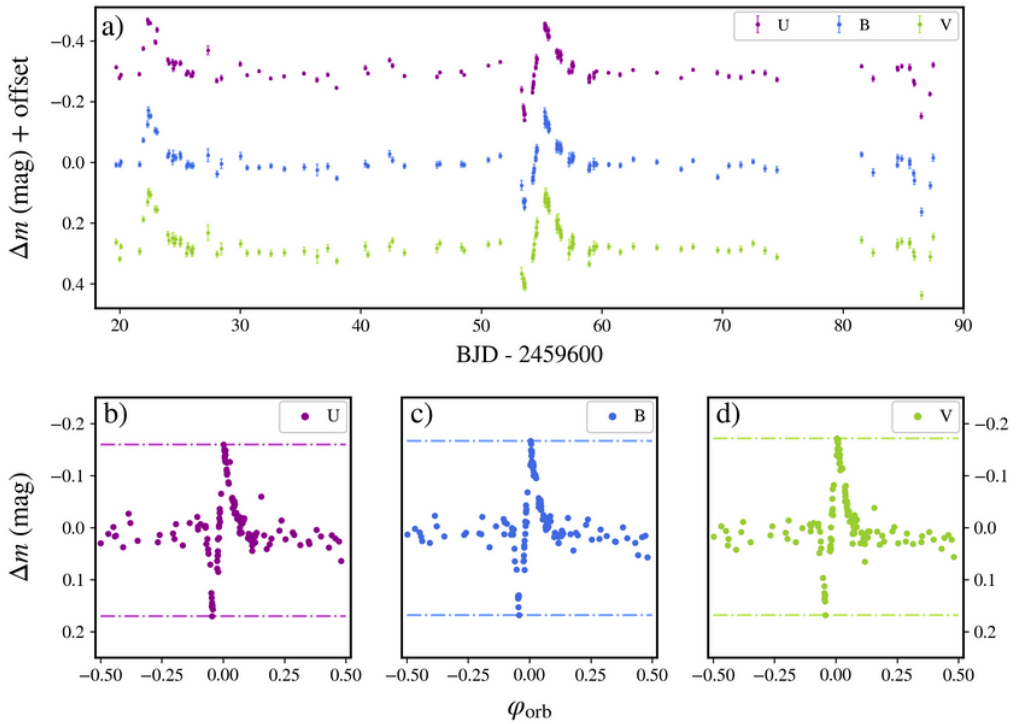


Emission in Balmer lines cannot originate solely from a disk near the primary component

The total range of light changes is the same in U, B, V and TESS filters (the light curve has „gray" nature)

Las Cumbres Observatory LCO



Wind-wind collision (WWC) binary systems

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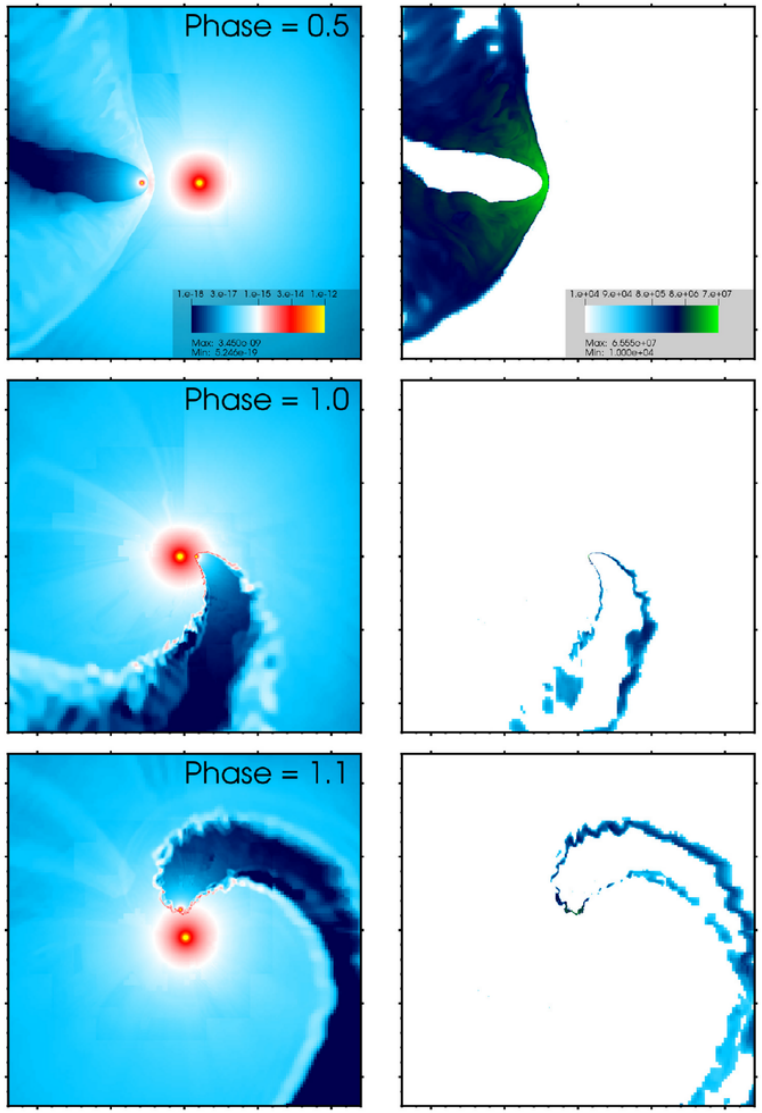
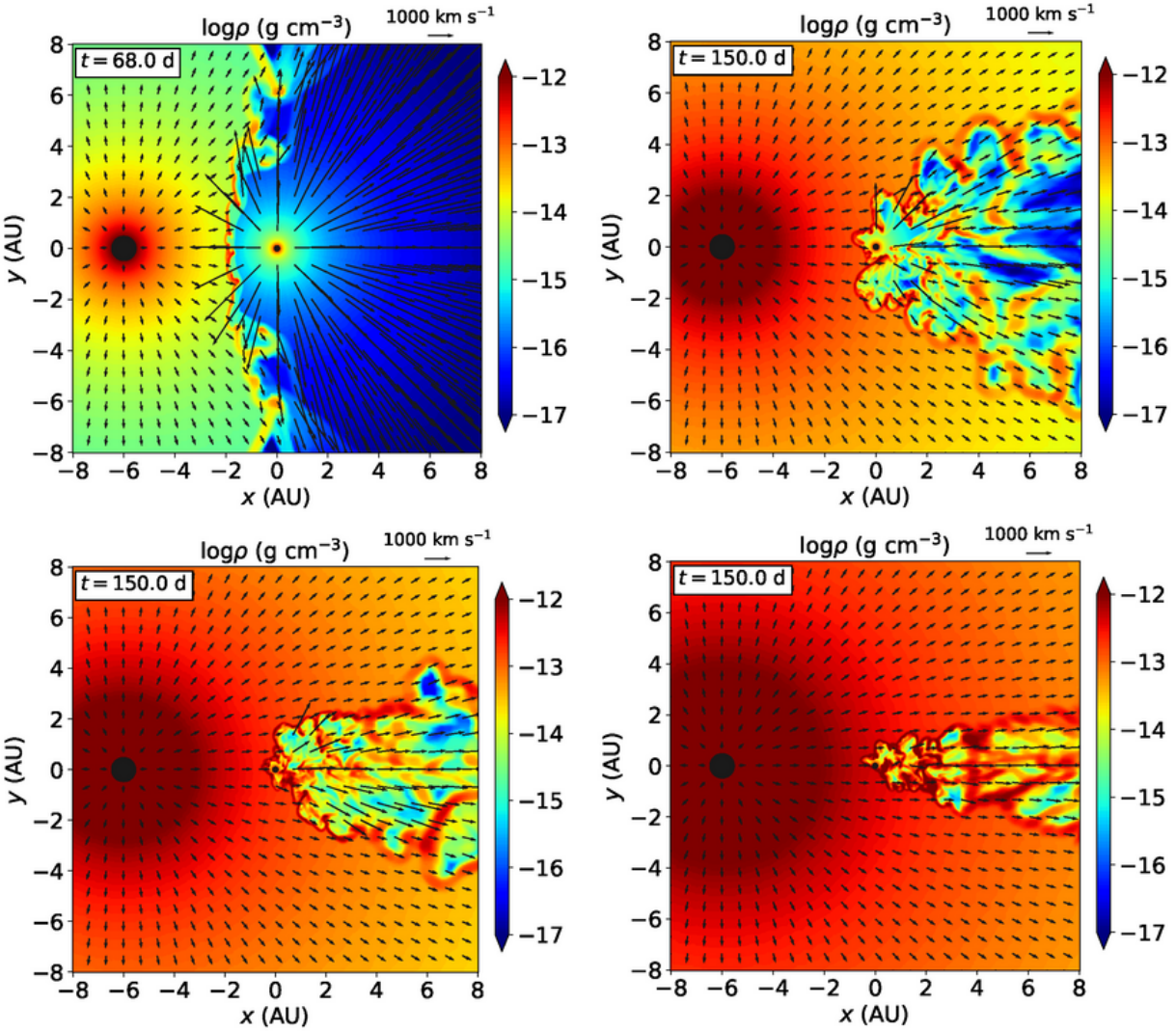


Parkin & Gosset (2011)



Kashi & Michaelis (2022)

The optical light curve of a WWC binary

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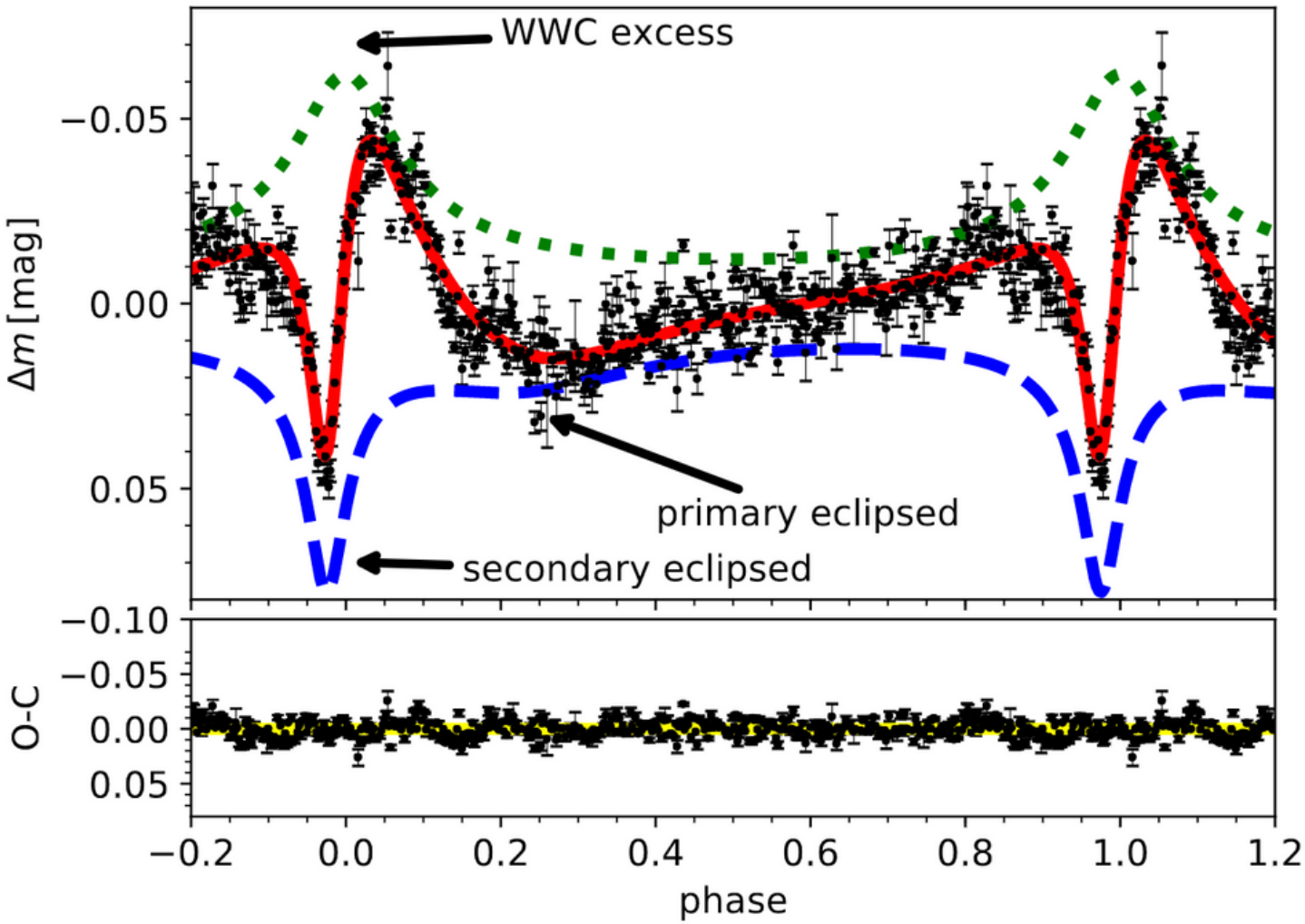
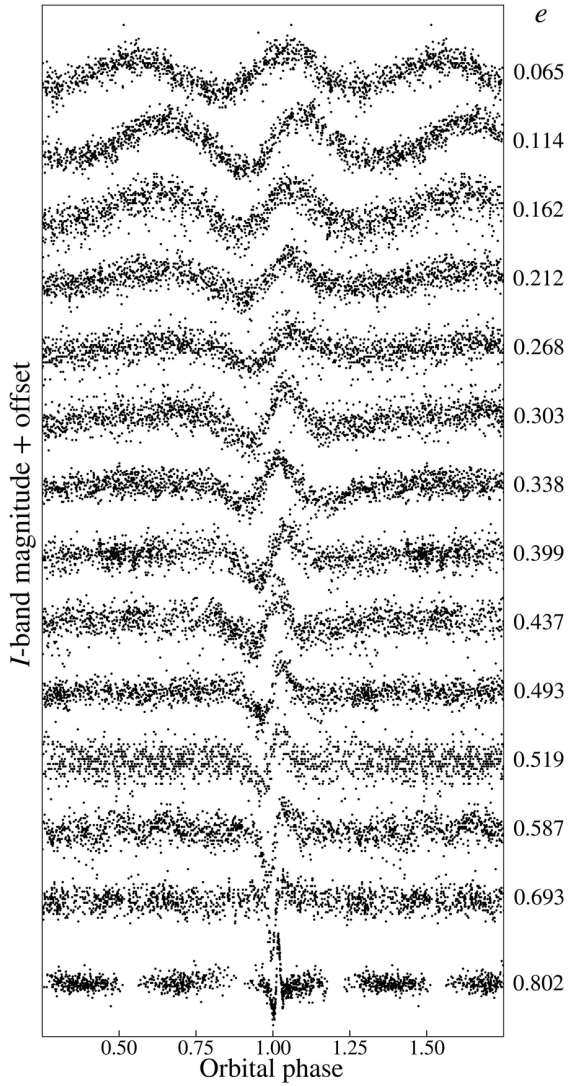
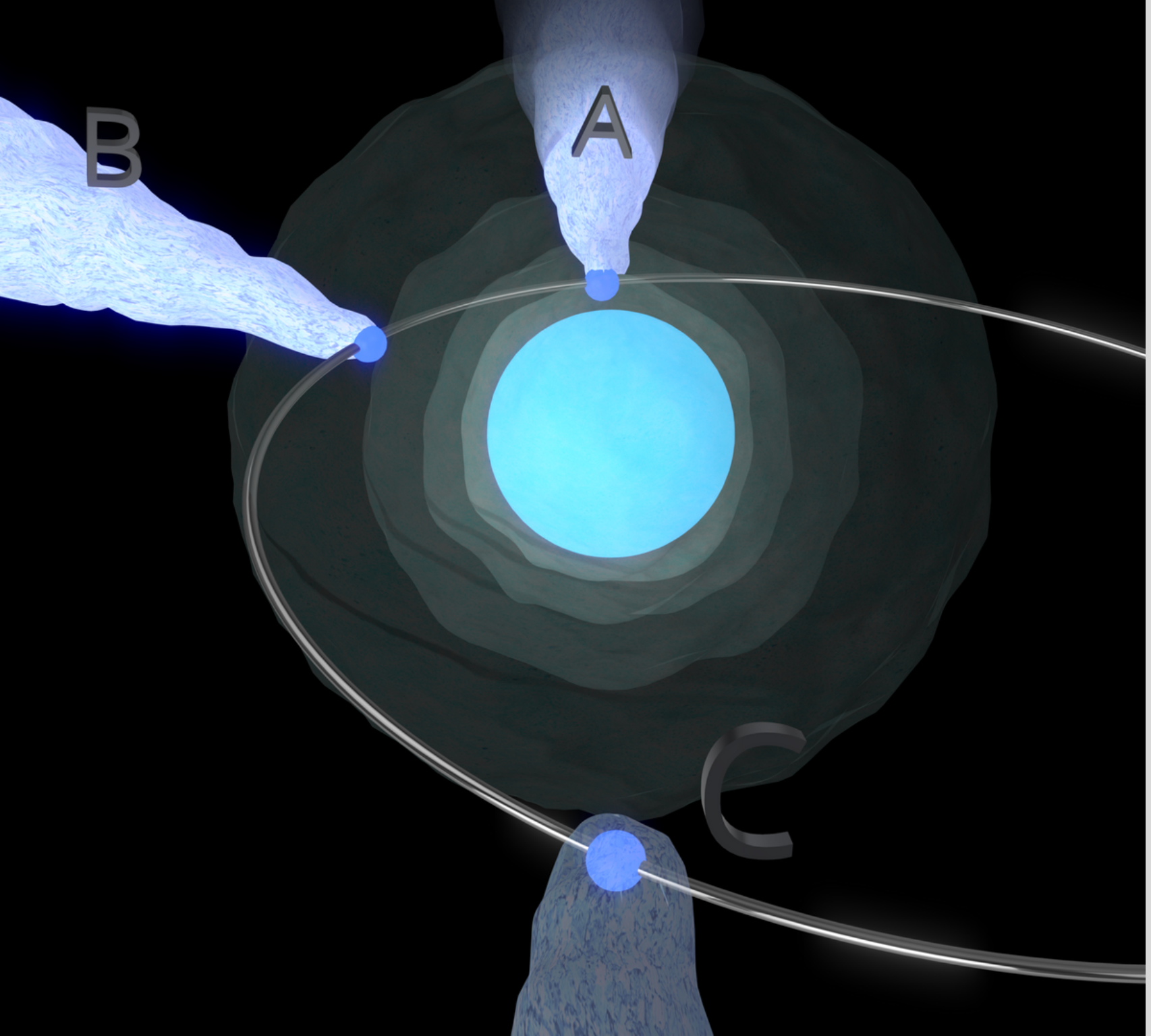


Shenar et al. (2021)



Wrona et al. (2022)



A

The atmospheric eclipse of the secondary component

B

The maximum emission of wind-wind collision (WWC) region

C

Secondary component eclipsed by the WWC cone

The EXTREME stellar wind of ExtEV

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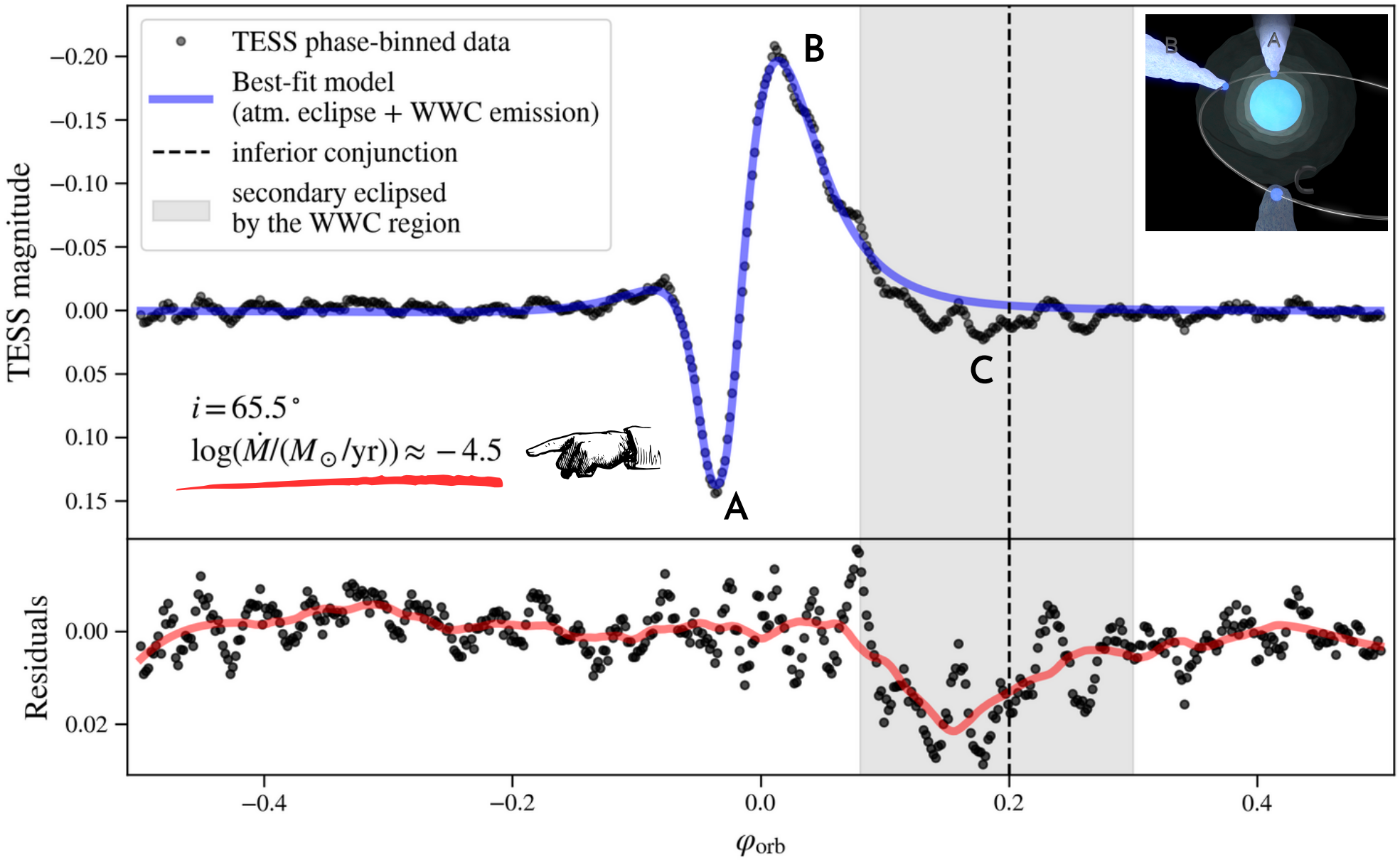
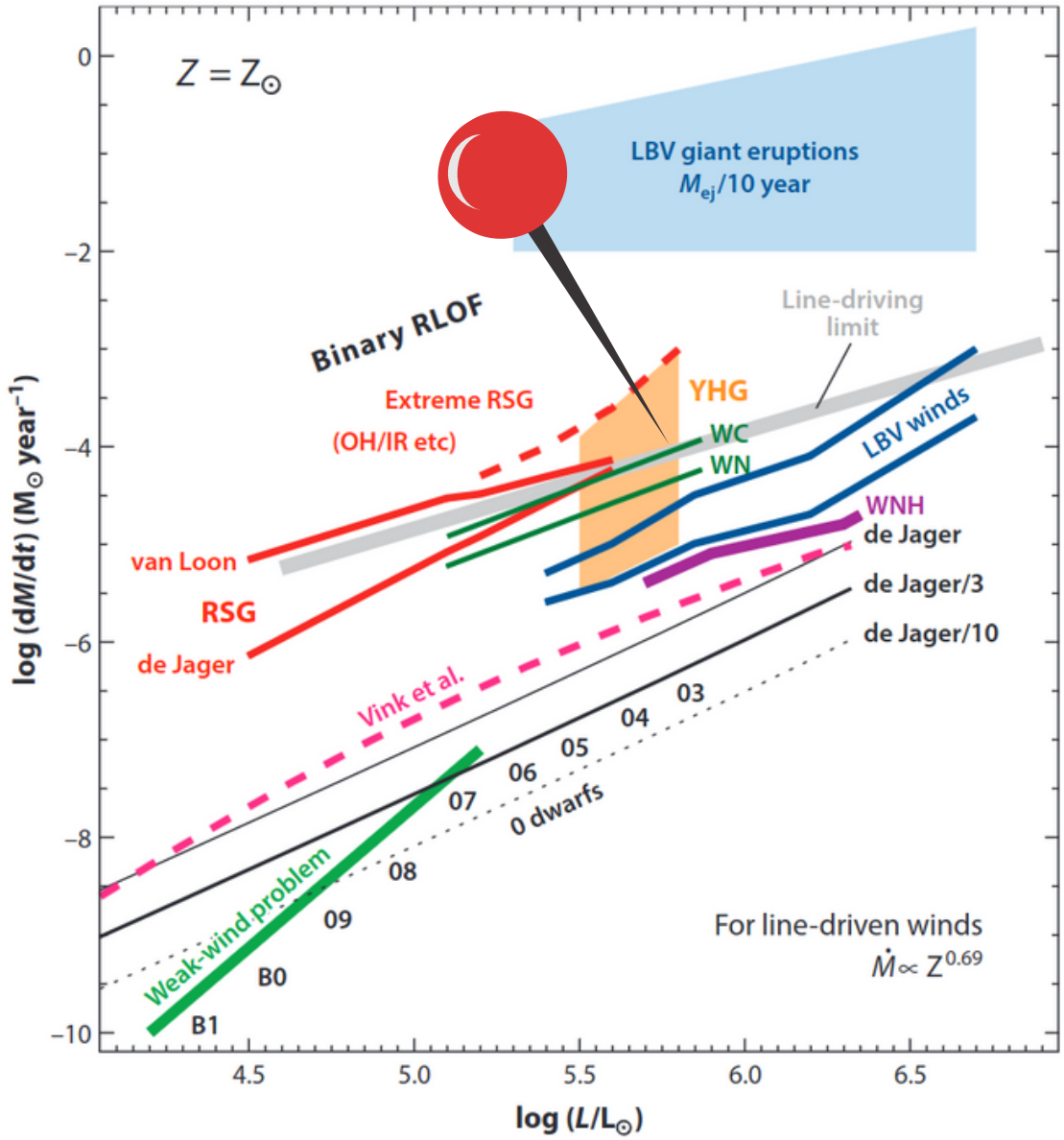


Mass loss in ExtEV vs. other stars



Smith (2014)

CONCLUSIONS

- ExtEV is actually an exceptional WWC binary
- Its mass loss rate is enhanced about 100 times (while the primary component is not a WR or AGB/RGB star!)
- ExtEV is a perfect and very rare laboratory to study the mutual interplay between mass loss due to wind, tides, rotation and TEOs

$\log(\dot{M}_{1,\mathrm{wind}}/(M_\odot\ \mathrm{yr}^{-1}))$	Reference
−4.35	**This work**
−5.63	Vink et al. (2001)
−6.13	Krtička et al. (2021)
−6.27	Björklund et al. (2023)

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WWC BINARY

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Near- and mid-IR properties of ExtEV

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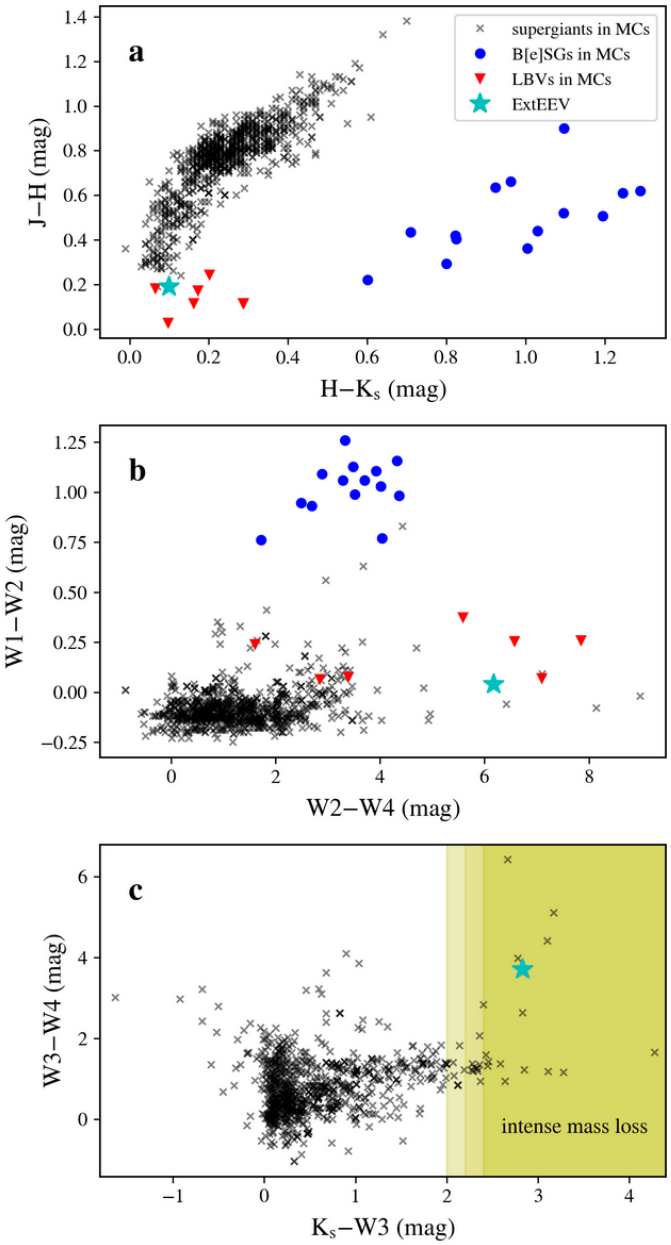
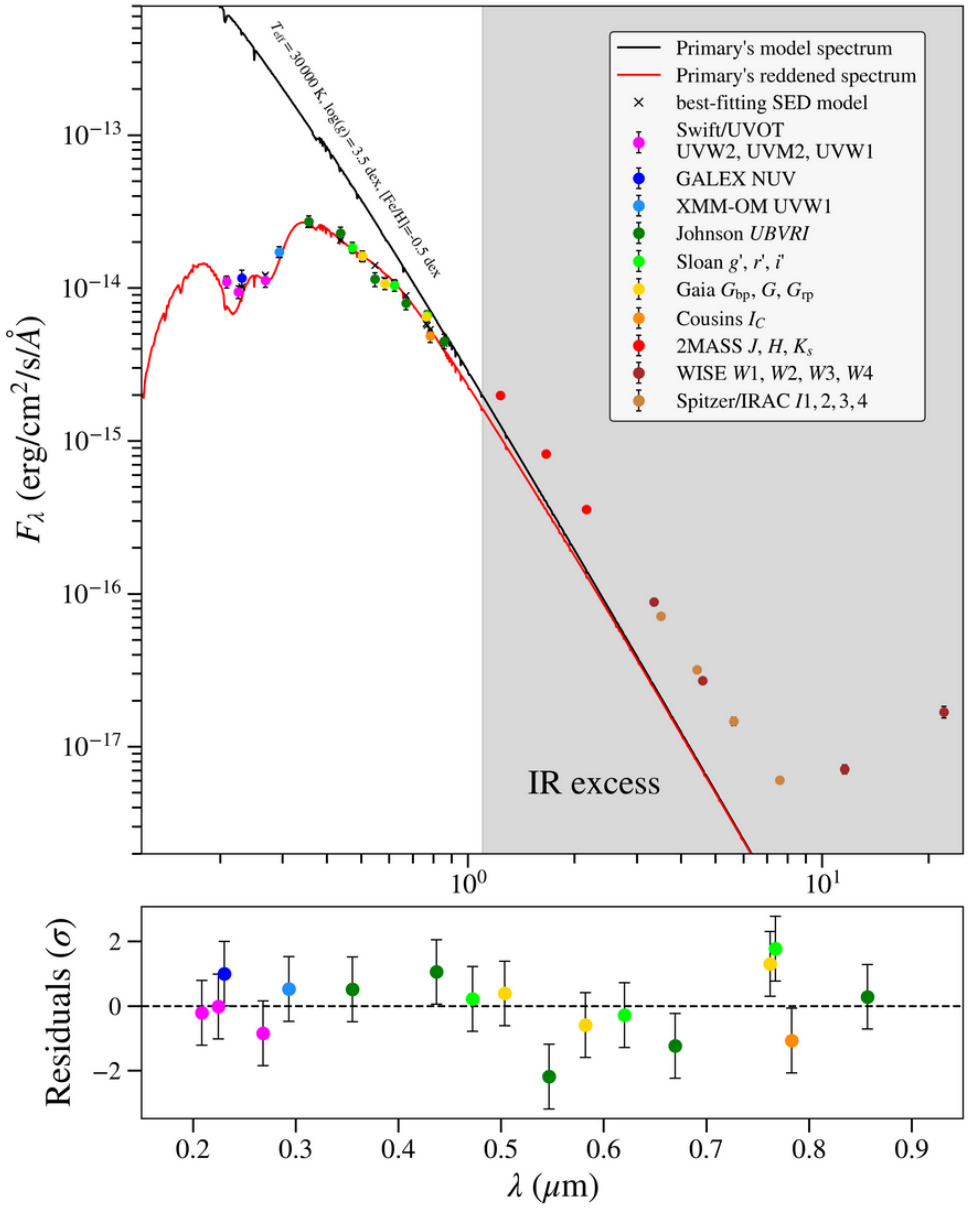
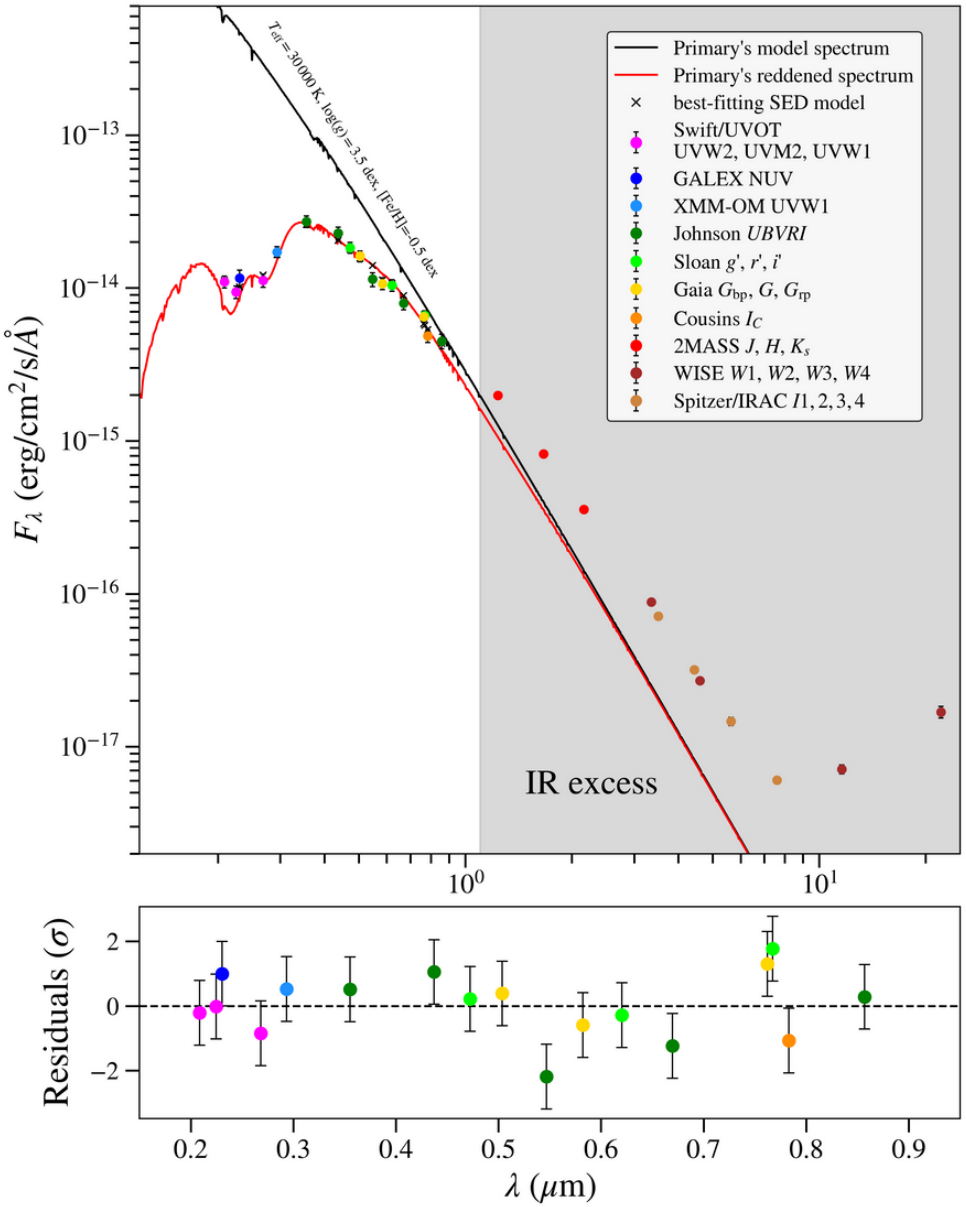
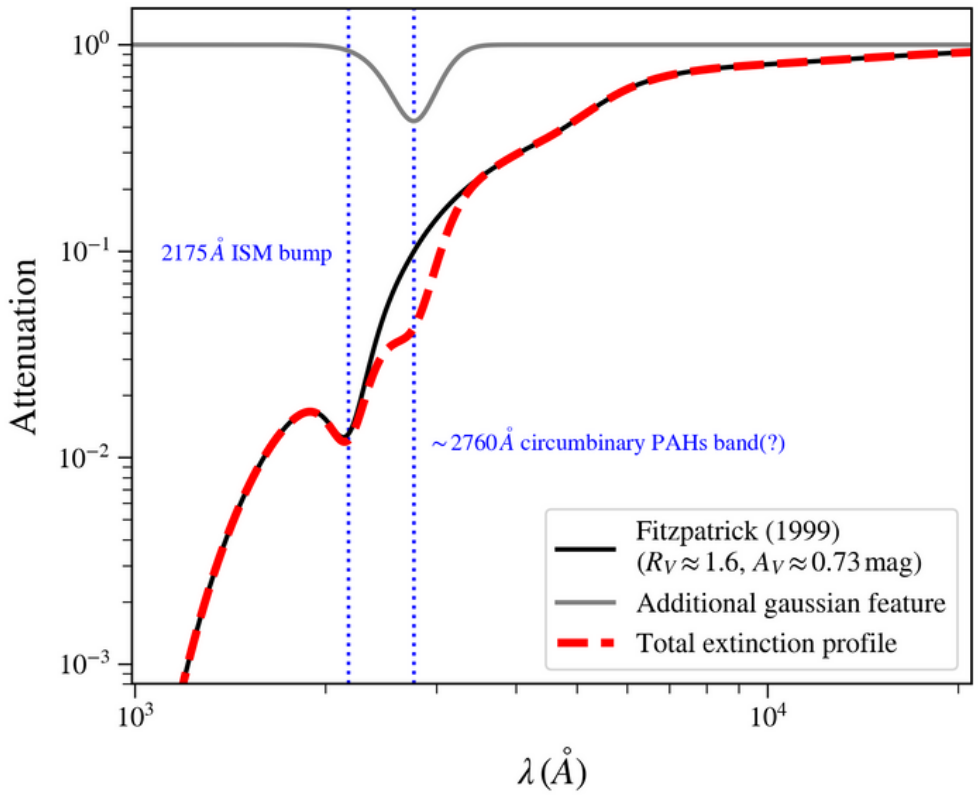




Mysterious absorption feature in near-UV





Additional broad absorption feature is necessary to model SED in the near-UV. It may suggest the presence of dust or molecules (e.g. PAHs) untypical for ISM.

Progenitor's and current mass of ExtEV

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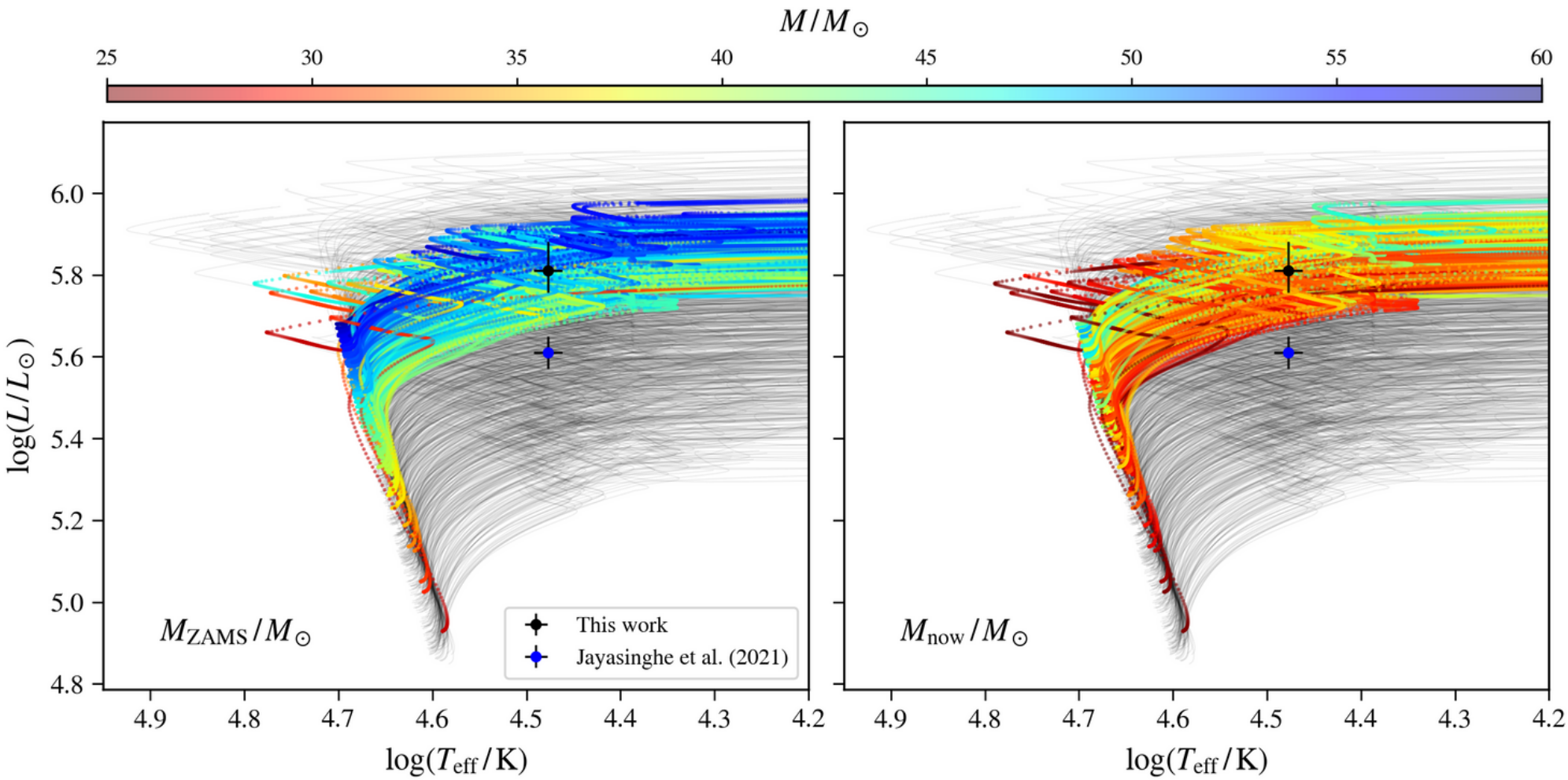

MESA