A TESS view of dwarf nova superoutbursts

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Dwarf novae and superhumps

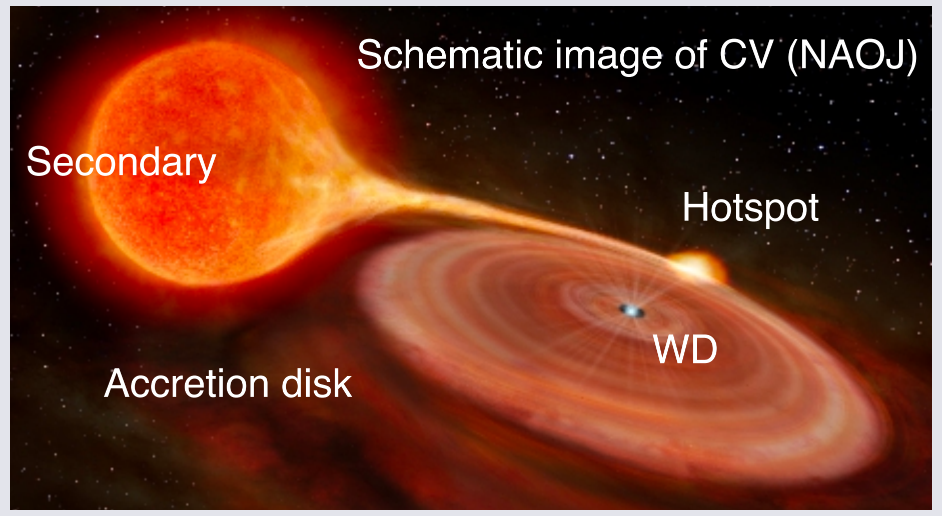
Cataclysmic variables (CVs)

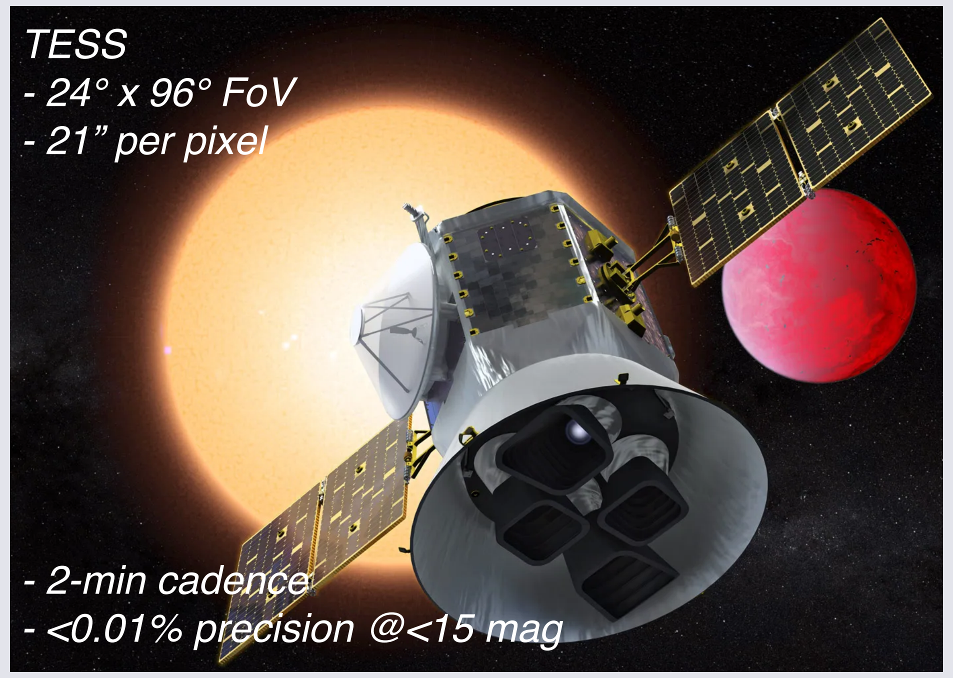
- White dwarf + secondary + accretion disk
- Simple & bright laboratory of accretion.
- Outbursts explained by disk thermal instability.

WZ Sge-type dwarf novae (e.g., YT+26b)

- The most evolved population in CVs.
- A large-amplitude (>6 mag) outburst.
- An outburst once in a decade or longer.
- A deformed disk produces small modulations. (superhumps; ~0.1 mag & ~90 min; Kato+09)
- Kepler detected one WZ Sge star in outburst, only with 30-min cadence (Ridden-harper+19).
- The early phase of their outbursts is poorly understood due to unpredictable & fast (<2 d) rise to the outburst maximum.

Could the TESS's large FoV (24°x96°) and fast cadence (2-min) provide new insights?



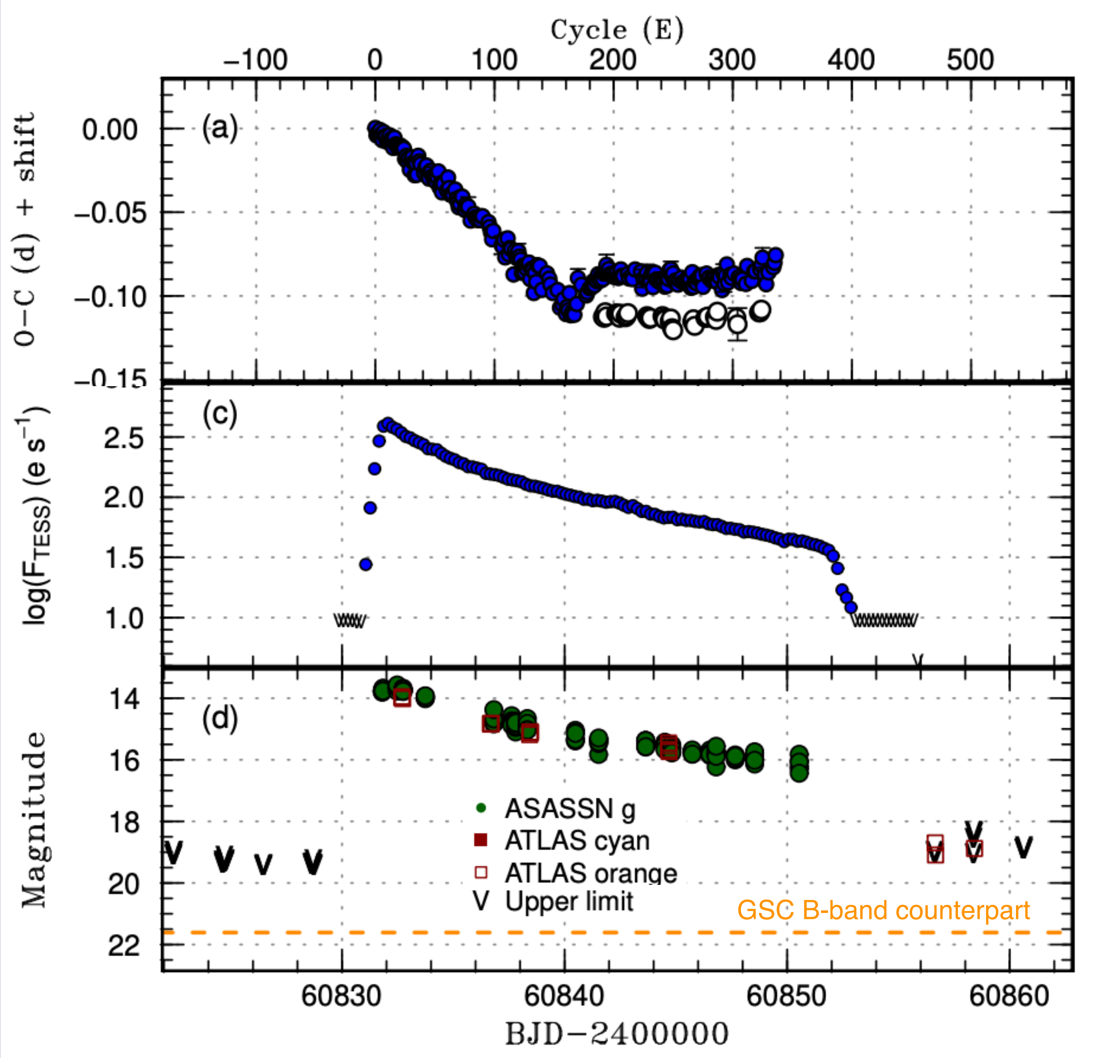


Outbursting WZ Sge in TESS

1. Crossmatch WZ Sge stars in the VSX catalog and TESS full-frame images.
2. Background subtraction and photometry with TESSreduce package (Ridden-Harper+21).
3. Smoothing light curve by LOWESS, period determination by PDM, and *O-C* of superhumps.

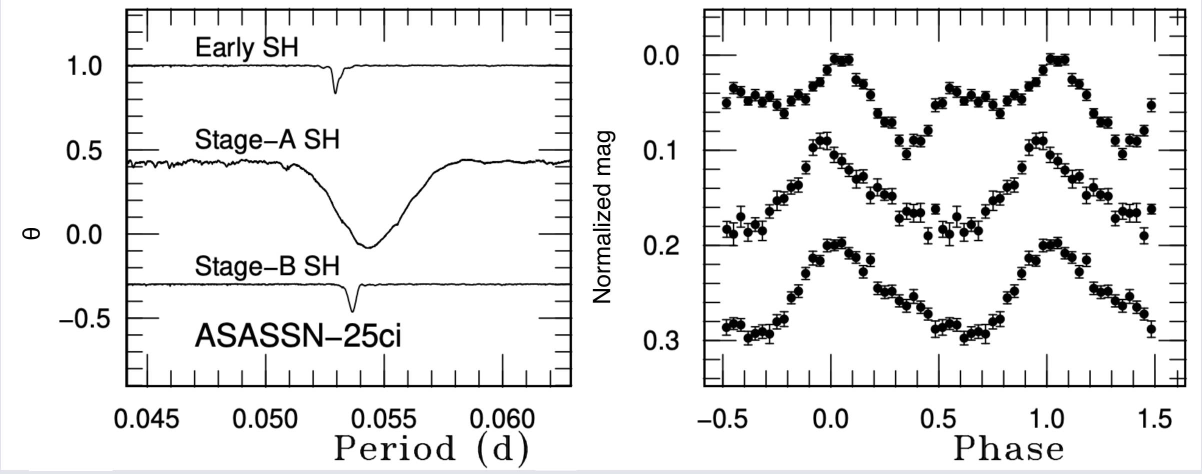
Seven WZ Sge stars in outburst (YT+25,26a).

- Superhumps are clearly present in all systems.
- Orbital period & mass ratio determined for all systems with some candidate period bouncers.



↑(top) O-C diagram of superhump maxima. (middle) TESS light curve. (bottom) ASASSN & ATLAS data.

↓(left) PDM results of different superhump stages. (right) averaged superhump profiles.



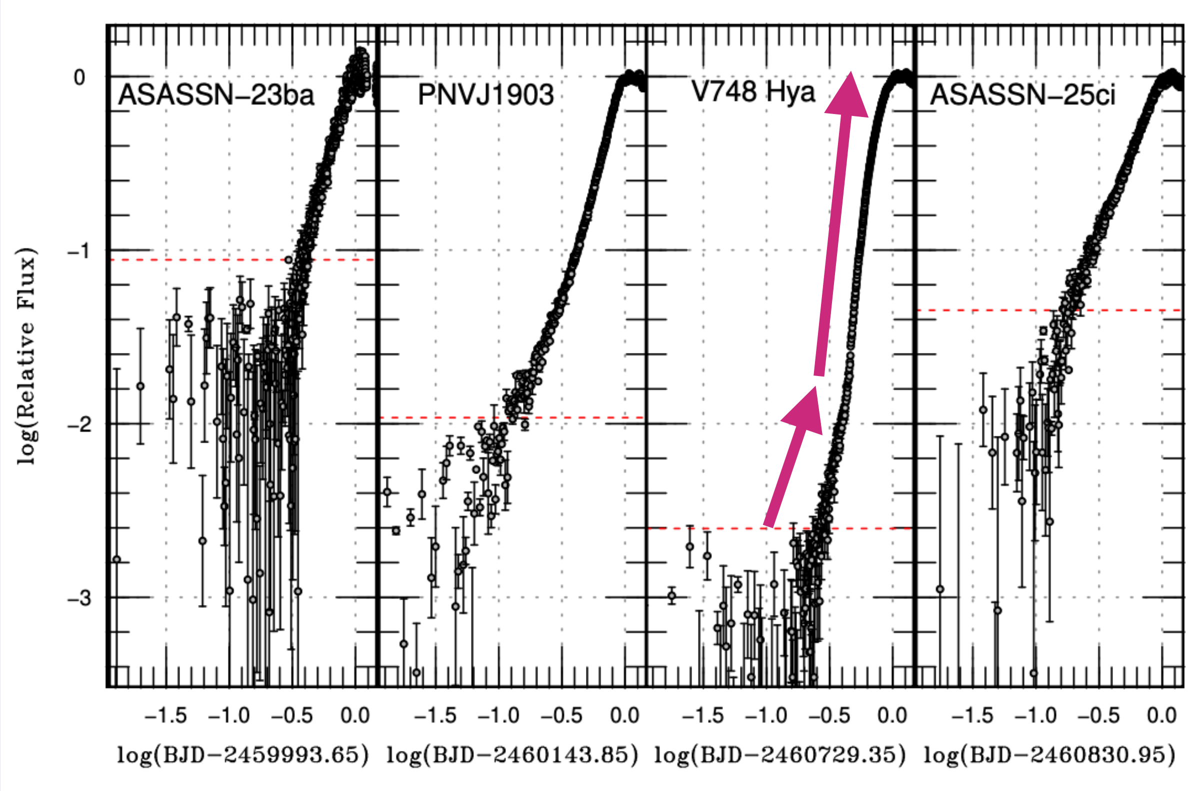
Discussion #1; broken rise

Four outbursts are observed from the rise.

Outburst rise timescale is 0.1—0.3 d/mag.
: consistent with an outside-in outburst
(the outer disk first triggers an outburst).

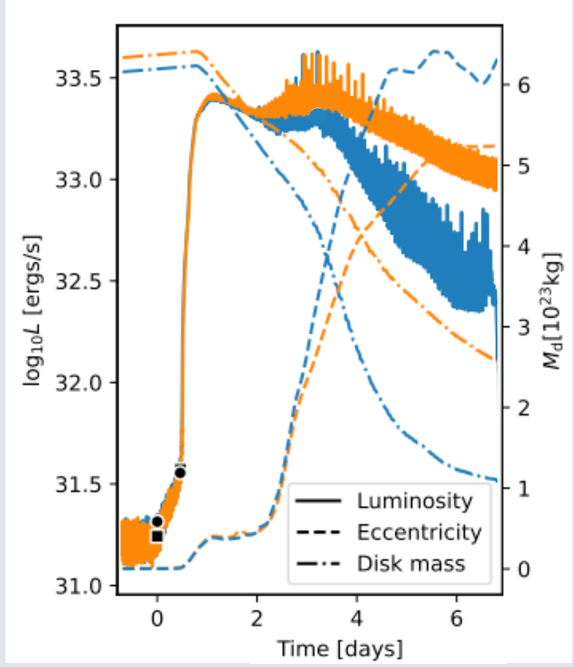
Rise is approximated as a powerlaw in flux scale.
: Broken powerlaw in V748 Hya & PNV J1903.

Similar behavior seen in simulated light curve.
: We interpret this as ***witnessing the start of propagation of the heating wave in a disk.***



↑TESS light curves around outburst rise. Y-axis is scaled to the outburst maximum. Red horizontal lines represent the averaged upper limits before an outburst.

→Simulated dwarf nova outburst in Jordan+24. Black dots represent the epochs when the outer disk transitions to outburst state and when the heating wave starts to propagate into the inner disk.



Discussion #2; no hump in rise

An outburst in WZ Sge stars is purely a disk phenomenon (outburst from a $\simeq 10^{24}$ g disk) or requires a mass transfer burst (MTB; $> 10^{18}$ g s^{-1} to transfer $\simeq 10^{24}$ g in <10 days) from the secondary?
: ***MTB must enhance the hotspot luminosity & will be observed as a large orbital modulation.***

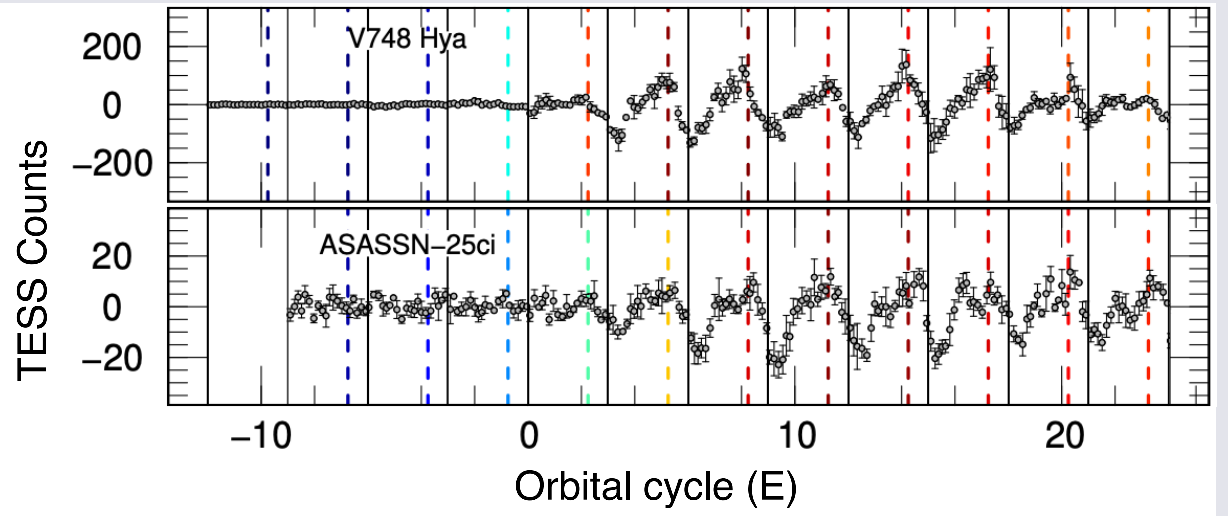
We detect double-peaked hump from the deformed disk, but no orbital modulation are present around the outburst rise & maximum.

In V748 Hya, with its Gaia distance at ~280 pc, inclination~60°, and assuming 10,000-K blackbody SED, non-detection of orbital humps constrains an upper limit of the mass-transfer rate in outburst.

$$L_{\rm hot\ spot} \simeq 1.0 \times \frac{\dot{M}_{\rm tr}}{10^{15}\ {\rm g\ s^{-1}}} \times 10^{30}\ {\rm erg\ s^{-1}}\ \text{(Smak 02)}$$

Upper limit of the hump amplitude $< 10^{31}$ erg s^{-1}
➡ mass-transfer rate $< 10^{16}$ g s^{-1}

- This is < x10 from quiescence ($\simeq 10^{15}$ g s^{-1}) *even if MTB occurs.*
- ***Too low for the values required in the MTB models.*** (e.g., Hameury+97)



↑Smoothed light curve of V748 Hya and ASASSN-25ci around outburst rise & maximum. Humps after E=0 are due to disk deformation. Presented humps are averaged for three cycles.

Reference

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Ack.; NRF-SAAO/UCT/VSNET/TESS