Nature of Z And-type outbursts in symbiotic binaries

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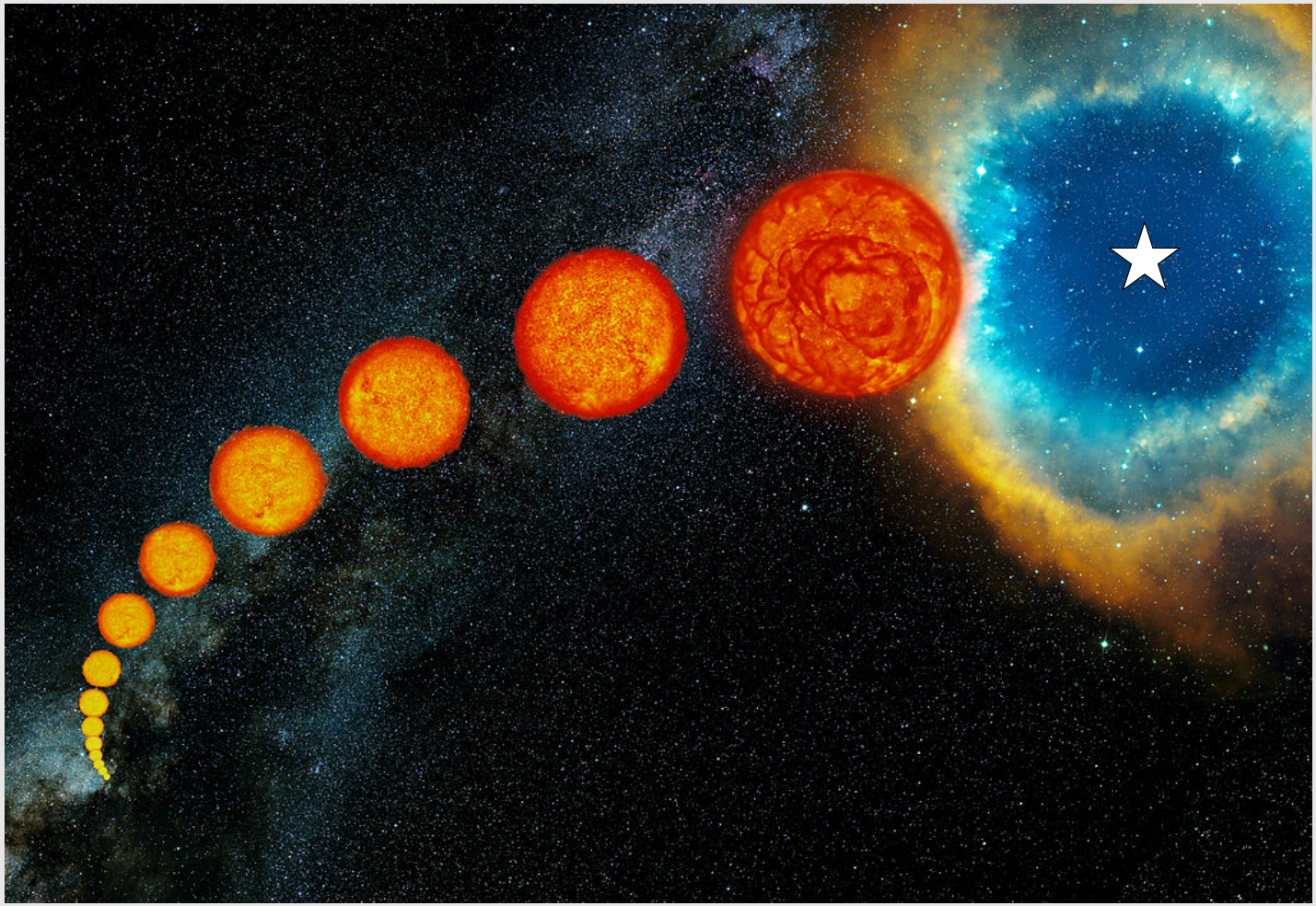
White dwarfs as the end point of normal (sun-like) stars

After running out of nuclear fuel, the Sun's core collapses into a white dwarf and the outer layers will be expelled like a planetary nebula. The time-scale of PN is relatively short - it lasts ‘only’ a few tens of millennia.



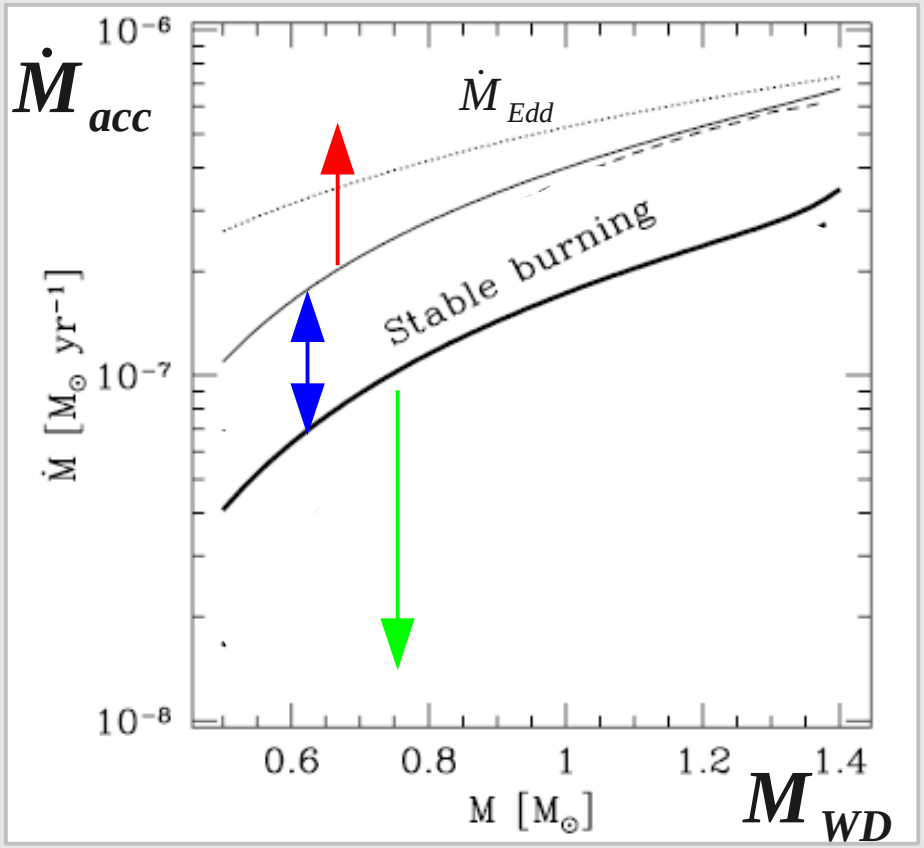
Artistic sketch of the evolution of the Sun from the interstellar clouds, through the current state of a normal star, the red giant stage to the final stage of a white dwarf surrounded by a planetary nebula.

The core collapses - part of its gravitational energy heats up the core at > 100 000 K, and a part ‘blows’ the outer layer giving rise to a planetary nebula.

Accreting white dwarfs in binary systems – outbursts

Energy output:

$$L_{WD} = L_{acc.} + L_{nucl.} = G\frac{M_{WD}\dot{M}_{acc}}{R_{WD}} + \eta X \dot{M}_{acc} \quad (\eta = 6.3\times10^{18}\,\mathrm{erg/g},\ X \equiv 0.7)$$



Shen & Bildsten (2007)

Accreting WD increases its mass:

(i) at low rates up to $\Delta M \rightarrow P_{crit}$:
ignition of a **nova outburst**

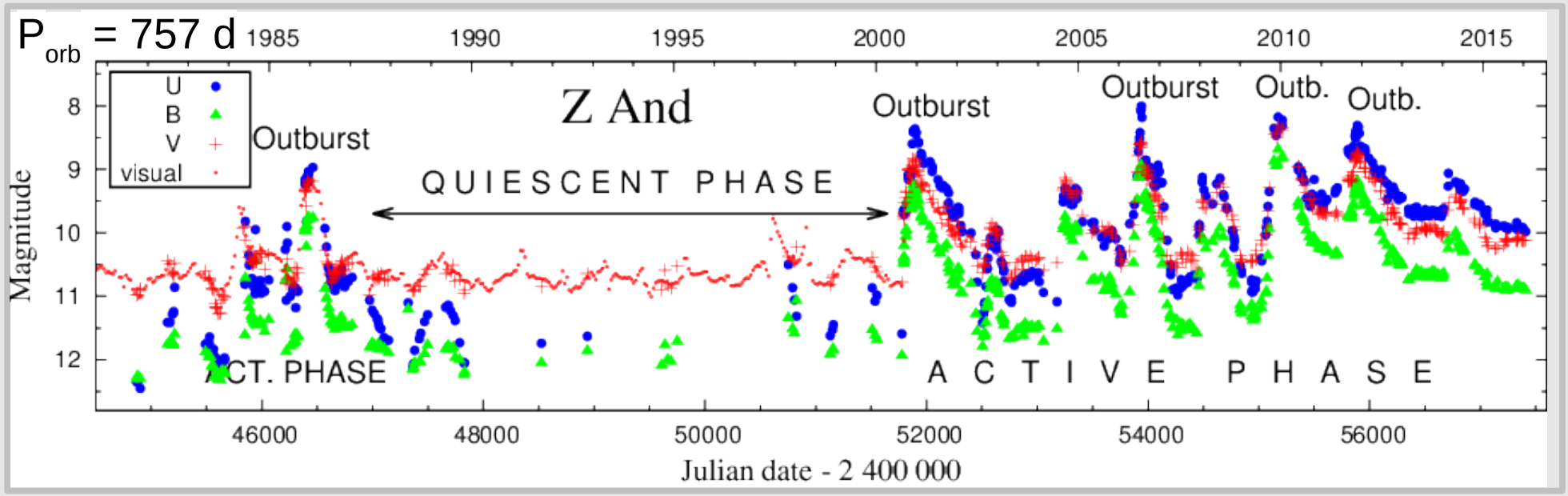
(ii) at high rates of ~10^{-7} M_{Sun}/year:
stable H-burning in a shell

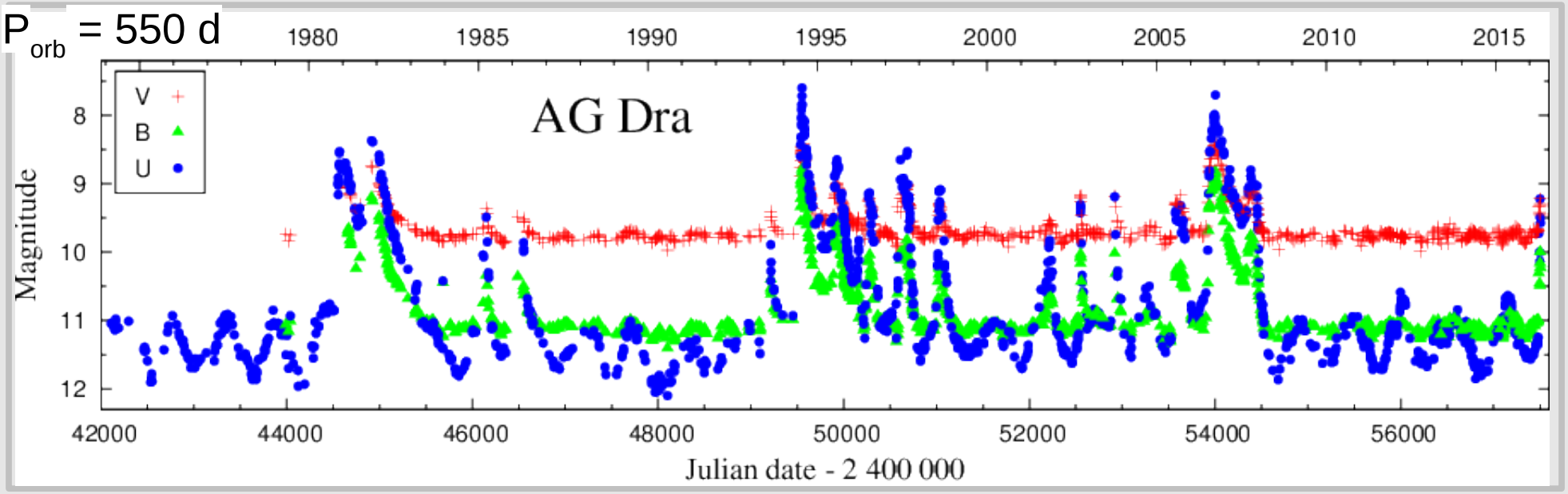
(iii) if rates >~10^{-7} M_{Sun} /year:
Z And-type outbursts

(iv) if $P >\sim P_{deg}$ (M_{WD} > ~1.4 M_{sun}):
collapse & ignition of C+O
→ **supernova Ia explosion**

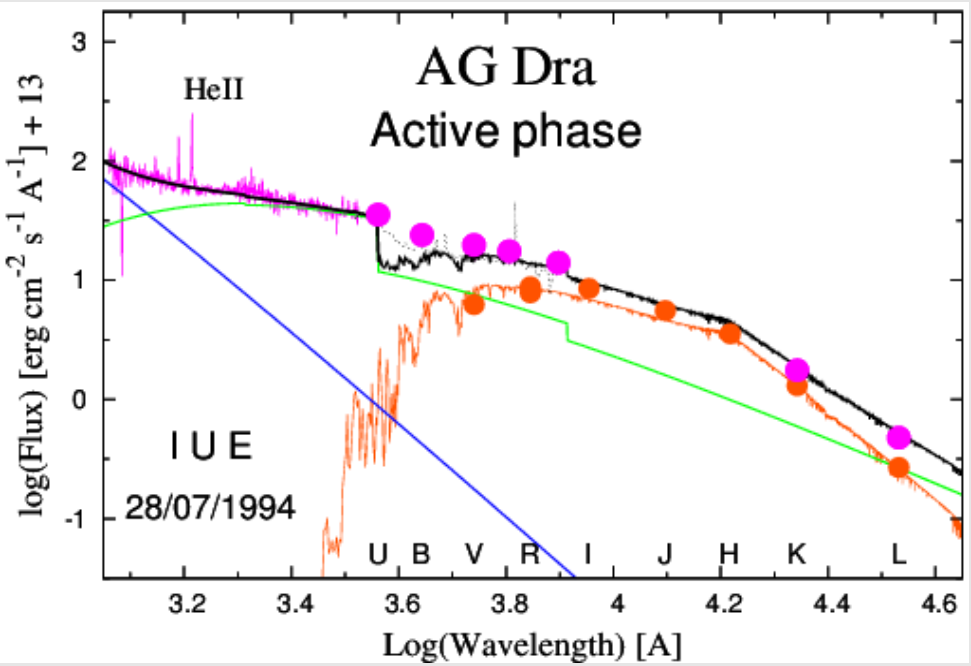
Z And-type outbursts – light curve

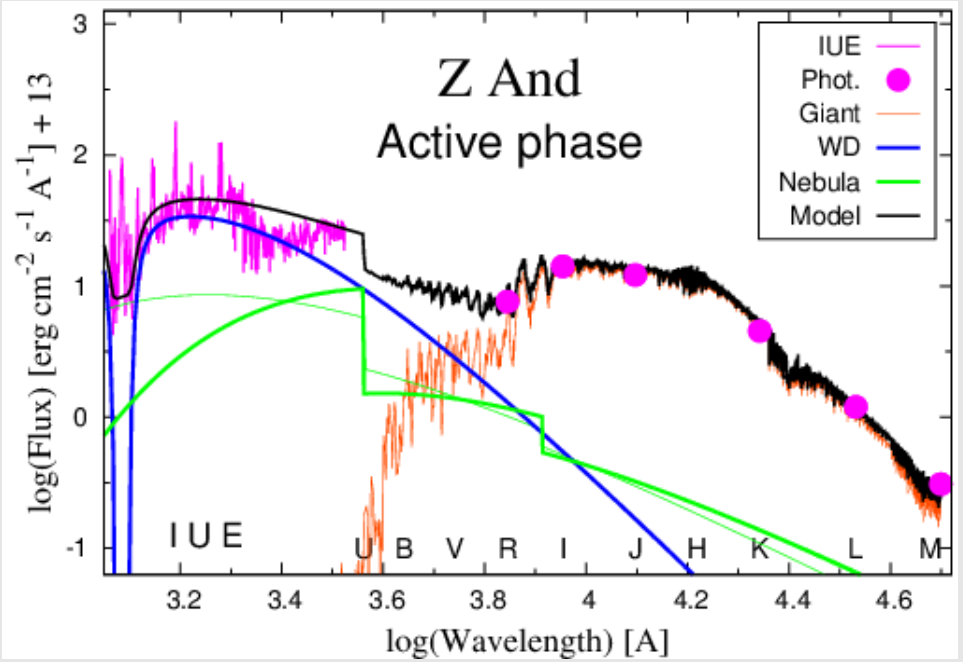
(What is the nature of Z And-type outbursts?)

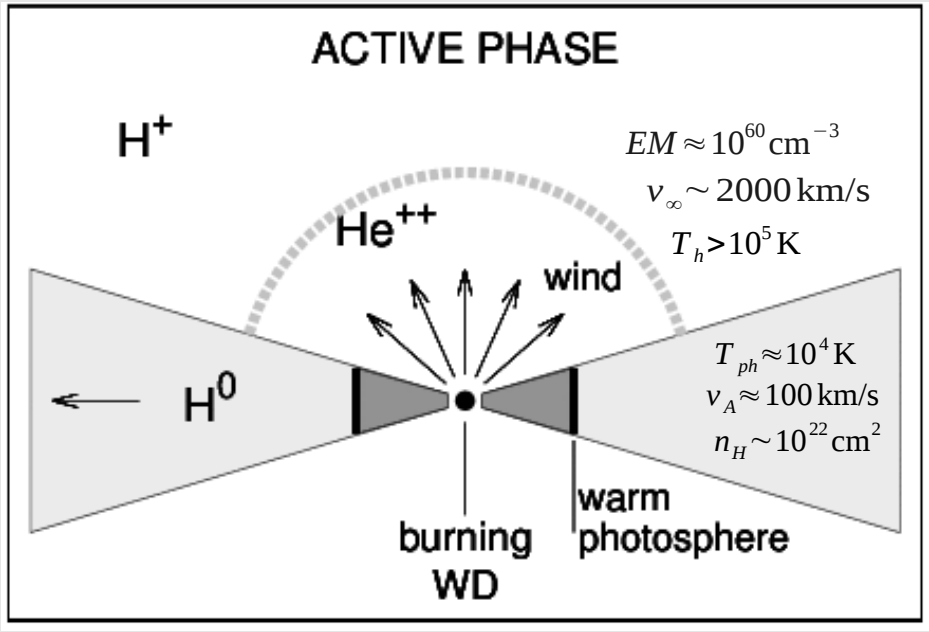




Z And-type outbursts – spectral energy distribution







Parameters of the hot component during ***active phases***

$T_{WD} \approx 10^5 / 10^4\,K$, depending on 'i'

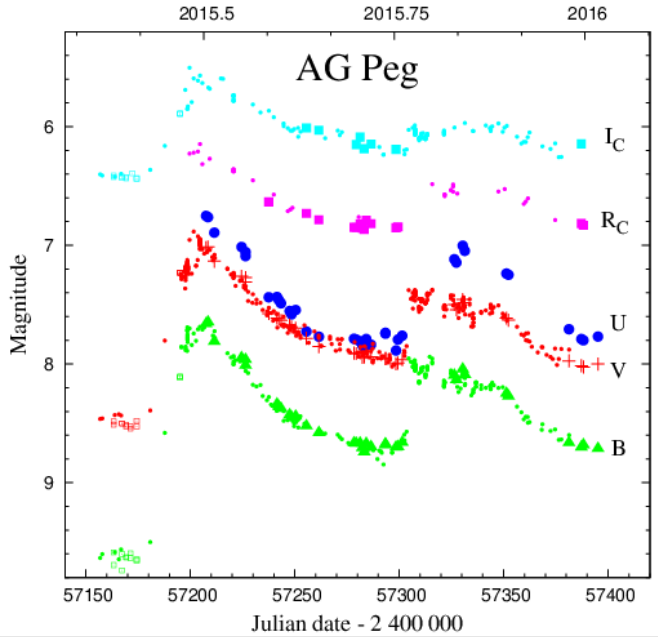
$L_{WD} \approx 10^4\,L_{Sun}$; $EM \approx 10^{60}\,\mathrm{cm}^{-3}$

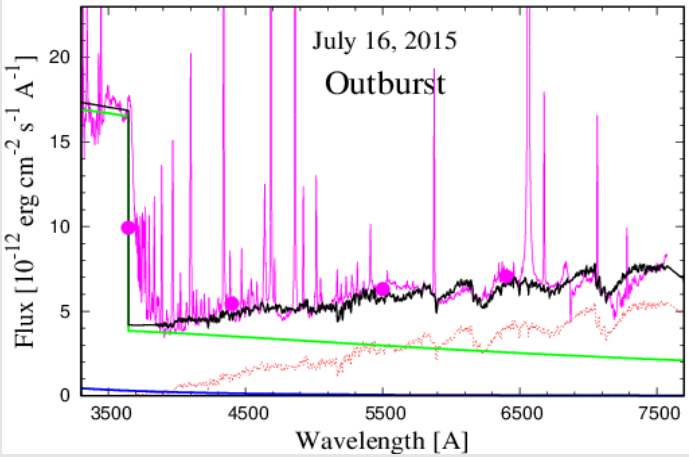
$\dot{M}_{WD} \approx 10^{-6}\,M_{Sun}/yr$; $v_\infty \sim 2000\ km/s$

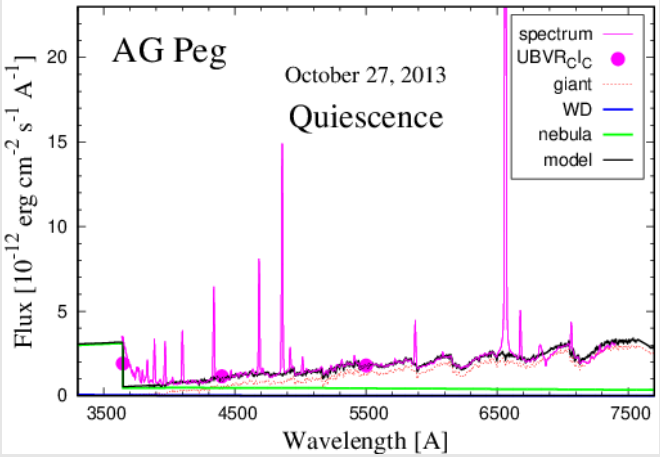
If i ~ 90°, radiation from
a warm pseudophotosphere + a strong nebular emission → *disk-like structure* around the WD (here Z And).

If i << 90°, nebular emission dominates the optical (here AG Dra).

Z And-type outbursts by AG Peg and HBHA 1704-05





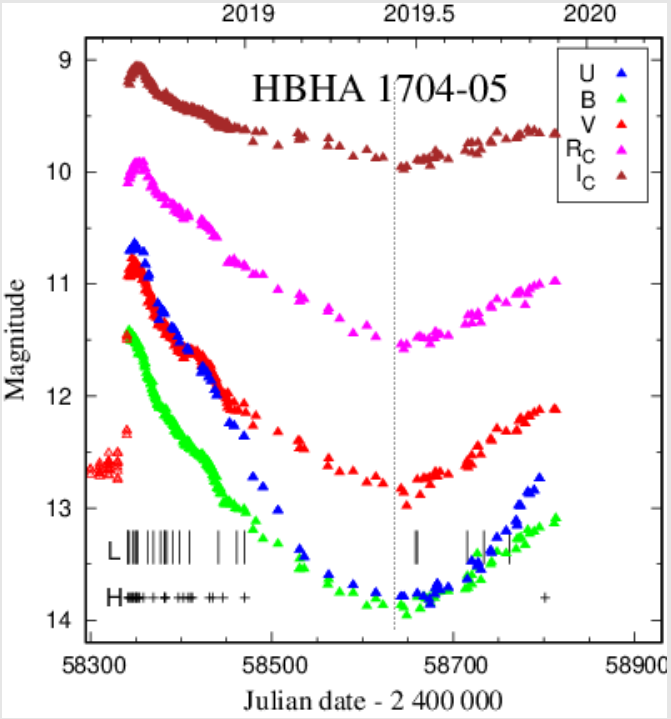


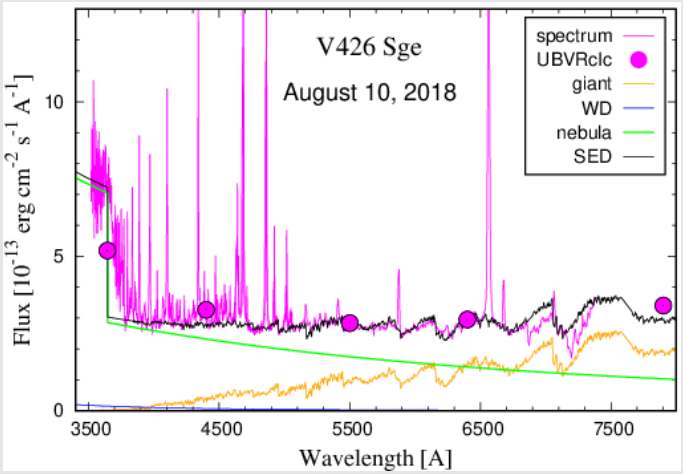
Outburst

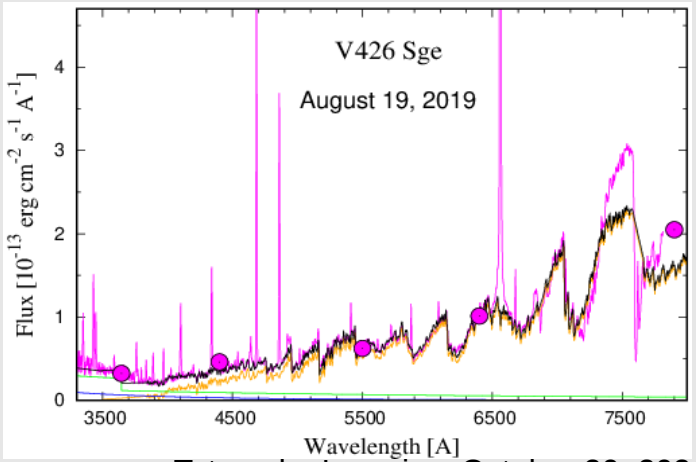
$$EM \sim 10^{60-61}\,cm^{-3},$$
$$T_{WD} \sim 2\times10^{5}\,K,$$
$$R_{WD}^{eff} \sim 0.12\,R_{Sun},$$
$$L_{WD} \sim a\,few\times10^{37}\,erg/s,$$
$$\dot{M} = a\,few\times10^{-6}\,M_{Sun}/year.$$

Quiescence

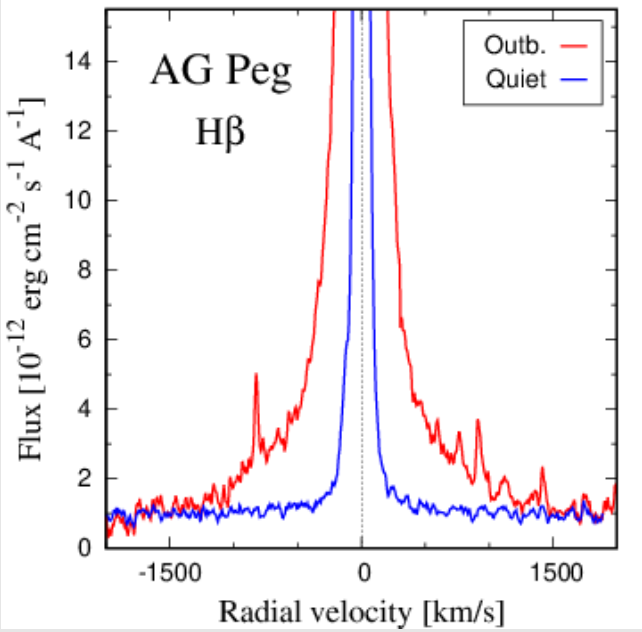
$$EM \sim a\,few\times10^{59}\,cm^{-3},$$
$$T_{WD} \sim 1.5\times10^{5}\,K,$$
$$R_{WD}^{eff} \sim 0.05\,R_{Sun},$$
$$L_{WD} \sim a\,few\times10^{36}\,erg/s,$$
$$\dot{M} = a\,few\times10^{-8}\,M_{Sun}/year.$$







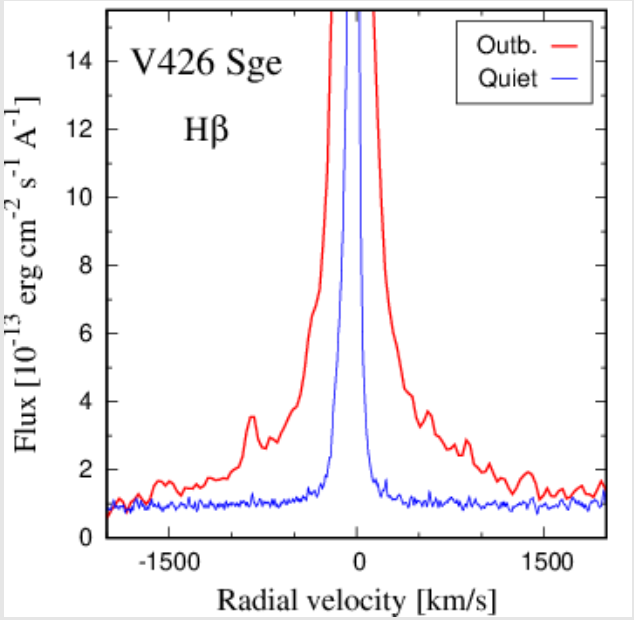
Nature of Z And-type outbursts

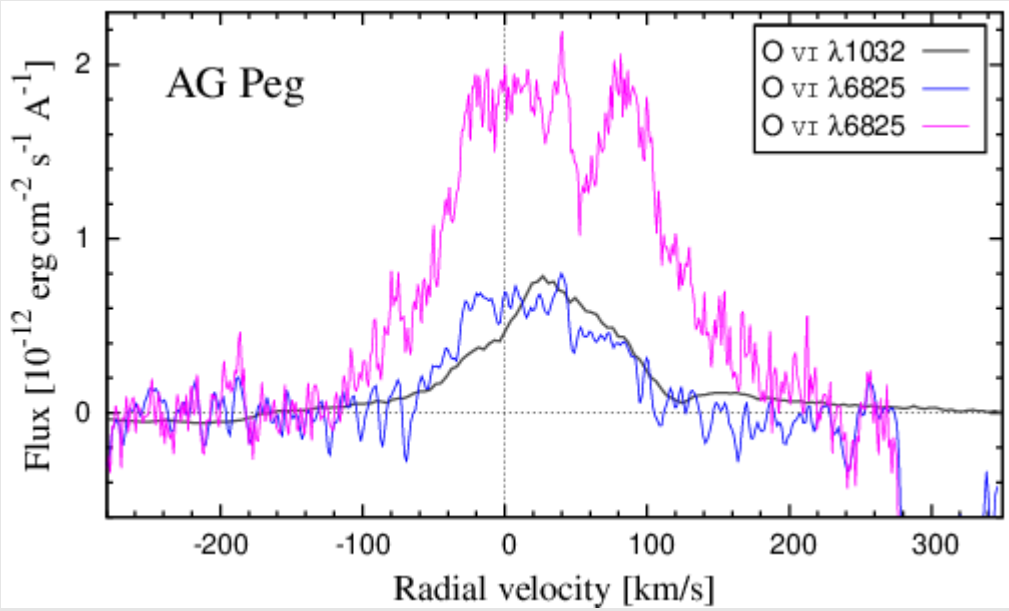


During Z And-type outbursts a strong wind blows at rates of

a few x 10^{-6} M_{sun}/year

From modelling *EM* and *line profiles*





Significant broadening and high fluxes of the Raman- scattered OIV λ6825 line indicate the presence of the neutral *disk-like structure* encompassing the WD.

$$\sigma_{Ram}(1032) = 4.4 \times 10^{-24}\, cm^2$$

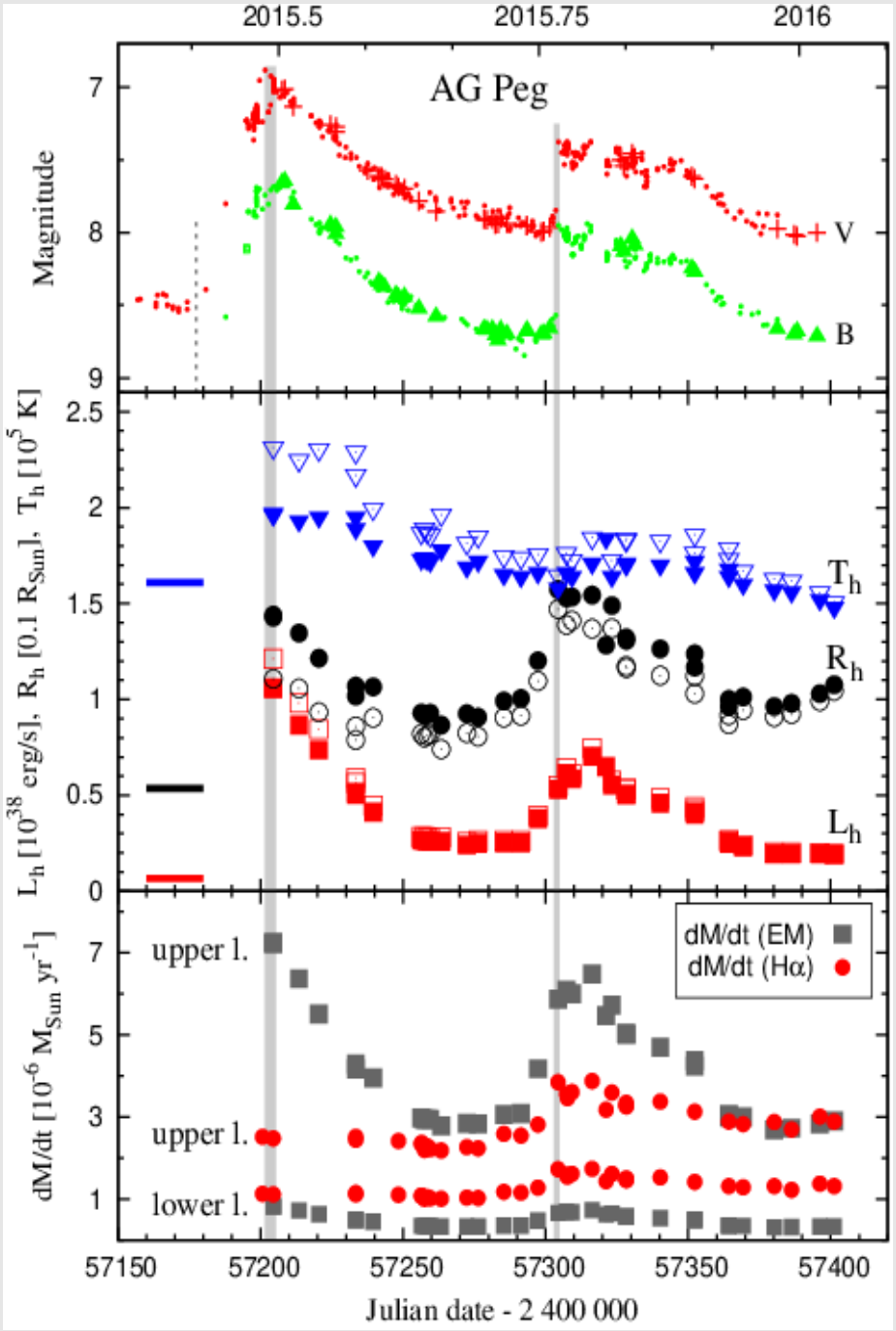
→

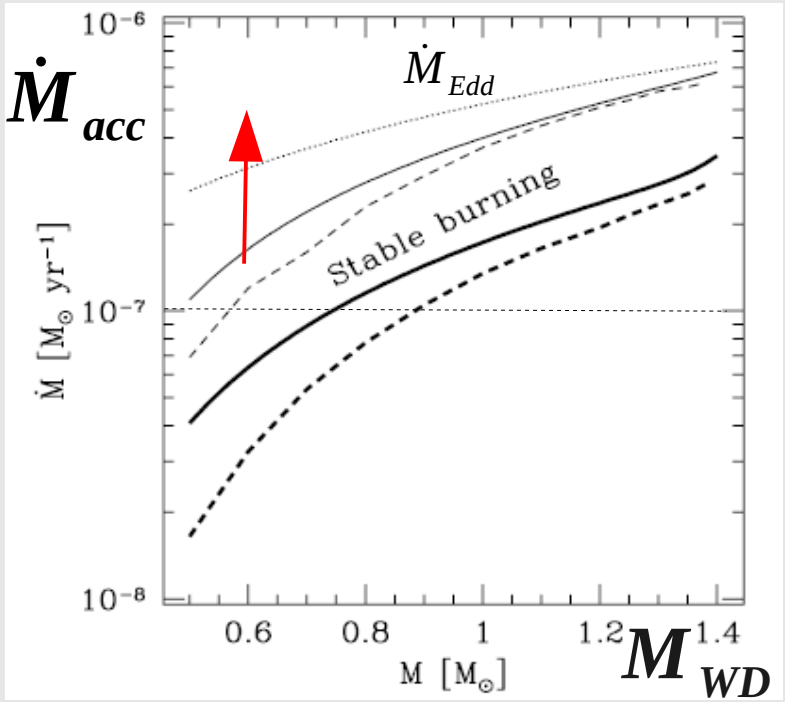
$$N_H \gtrsim 2 \times 10^{23}\, cm^{-2}$$

to cause sufficient optical depth of H atoms

Nature of Z And-type outbursts

$L_{WD} \sim 10^{37-38}\, erg/s, \quad \dot{M} \gtrsim 10^{-6}\, M_{sun}/year$





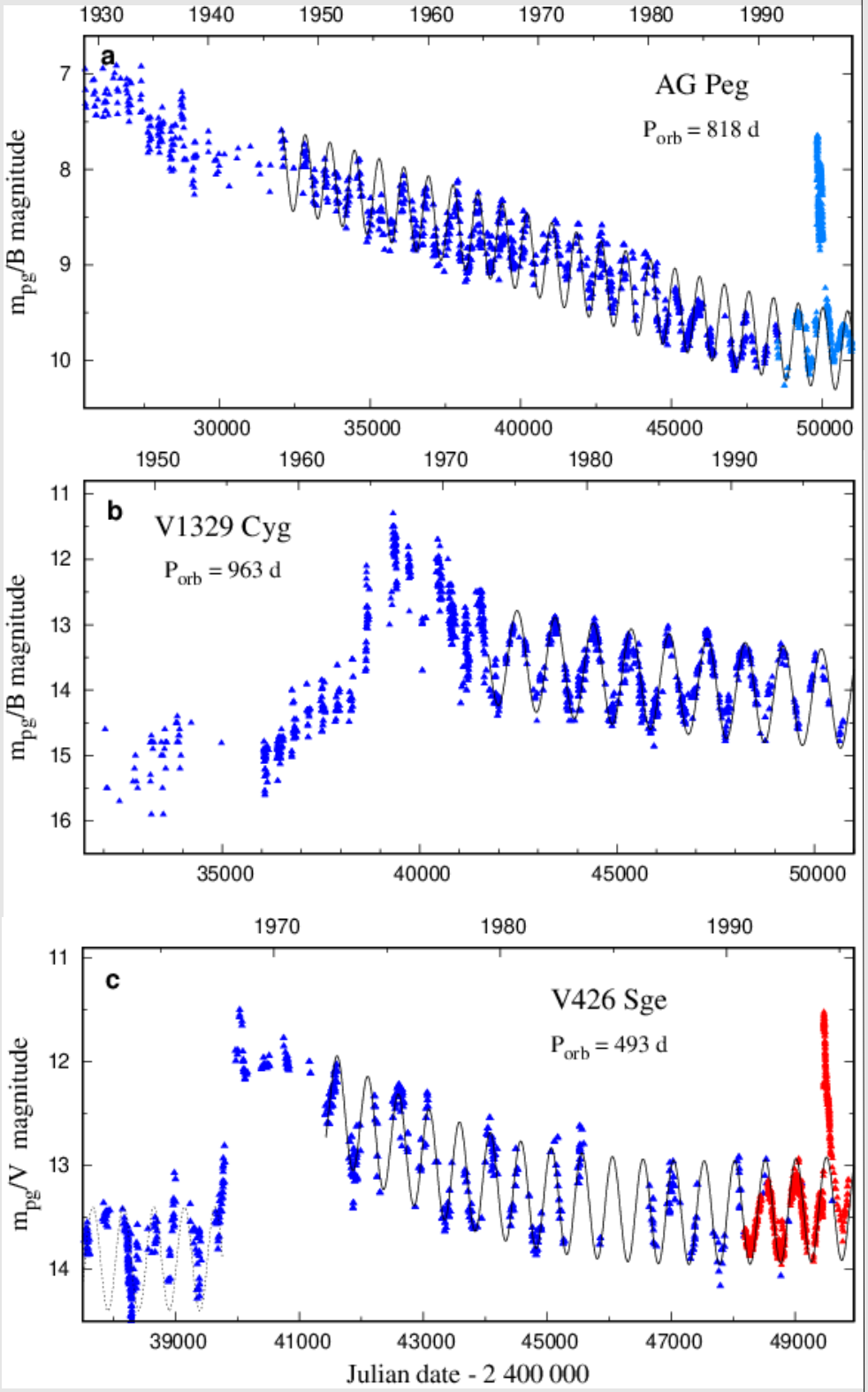
If $\dot{M}_{acc}$ exceeds the stable-burning limit, optically thick **wind blows** from the WD, and

L_{WD} ~ a few x 10^{37} erg/s.

What ignites the outburst?

(i) A disruption of the accretion disk → infall of H-rich material onto the WD.

(ii) Variation in the mass-transfer from the red giant.



Connections between basic types of symbiotic stars

$\dot{M}_{acc} \simeq \dot{M}_{stable}$: *Quiet* ***nuclear−burning*** *SySts*
(e.g., Sy Mus, RW Hya, V443 Her,...)

$\dot{M}_{acc} \gtrsim \dot{M}_{stable}$: **Z And−*type*** ***outburst*** *occurs*
classical SySts
(e.g., Z And, CI Cyg, AG Dra,...)

$\dot{M}_{acc} \prec \dot{M}_{stable}$: ***Accretion−powered*** *SySts*
(e.g., EG And, CQ Dra, SU Lyn,...)

Some consequences

- Accretion-powered SySts are progenitors to nova-like outbursts (symbiotic nova or recurrent symbiotic nova, depending on the time-scale of outbursts).
- After the symbiotic nova outburst, the following eventual outburst is of Z And-type.
- All classical SySts experienced a symbiotic nova outburst in the past.

Thank you for your attention

Based on:

- A. Skopal, S. Shugarov, M. Sekeras, M. Wolf, T.N. Tarasova, F. Teyssier, M. Fujii, J. Guarro, O. Garde, K. Graham, T. Lester, V. Bouttard, T. Lemoult, U. Sollecchia, J. Montier, D. Boyd. *New outburst of the symbiotic nova AG Pegasi after 165 years.* In: *Astronomy & Astrophysics* **604**, article no. A48, p. 1-19 (2017).

- A. Skopal, S. Shugarov, U. Munari, N. Masetti, E. Marchesini, R. Komzik, E. Kundra, N. Shagatova, T. N. Tarasova, C. Buil, C. Boussin, V. I. Shenavrin, F.-J. Hambsh, S. Dallaporta, A. Frigo, O. Garde, A. M. Zubareva, P. Dubovsky, P. Kroll. *The path to Z And-type outbursts: The case of V426 Sagittae (HBHA 1704-05).* In: *Astronomy & Astrophysics* **636**, article no. A77, p. 1-18 (2020).

Data sourced:

Optical photometry and spectroscopy obtained by small telescopes at observatories of AsU SAV (G1, G2, SP) and amateur spectra collected in the ARAS database. For HBHA 1704-05 optical data were complemented with *Swift*-XRT and UVOT data.

Acknowledgements: This work was supported by a grant of the Slovak Academy of Sciences VEGA No. 2/0008/17 and by the Slovak Research and Development Agency under the contract No. APVV-15-0458.