The Emergence of a Neutral Wind Region in the Orbital Plane of Symbiotic Binaries during Their Outbursts

Augustin Skopal
Astronomical Institute, Slovak Academy of Sciences, Tatranská Lomnica, Slovakia

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1. Symbiotic binaries – a short introduction

2. Quiescent and active phases of symbiotic stars

3. Formation of a disk-like structure during outbursts

and its consequence:

4. The emergence of a neutral near-orbital-plane region

5. Future work

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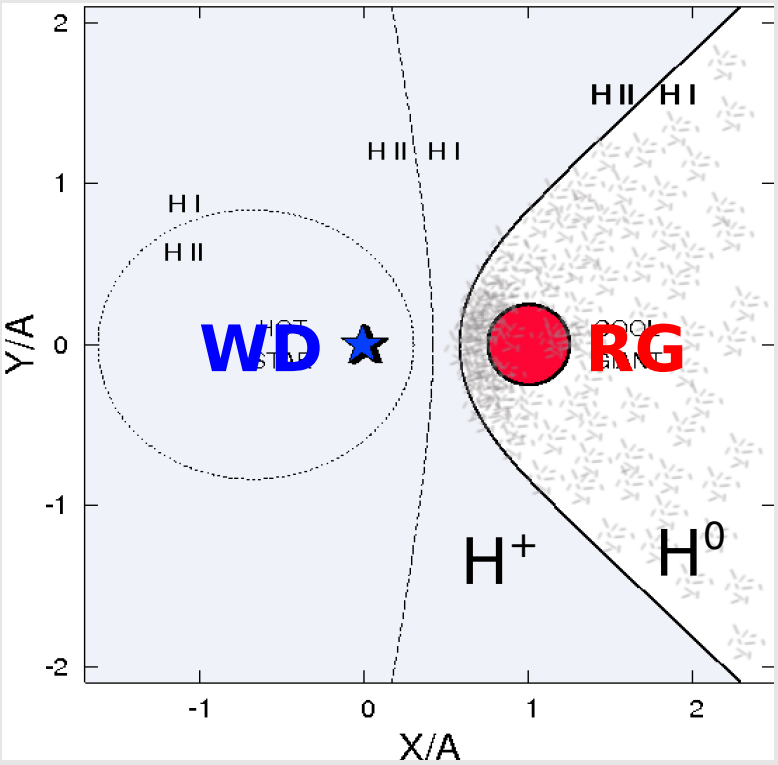
T.L., October 4, 2023

Symbiotic Binaries

The widest interacting binary systems: Cool giant + White dwarf

P_{orb} ~ 100 x (days - years)

Basic interaction: Mass loss from the RG + Accretion by the WD



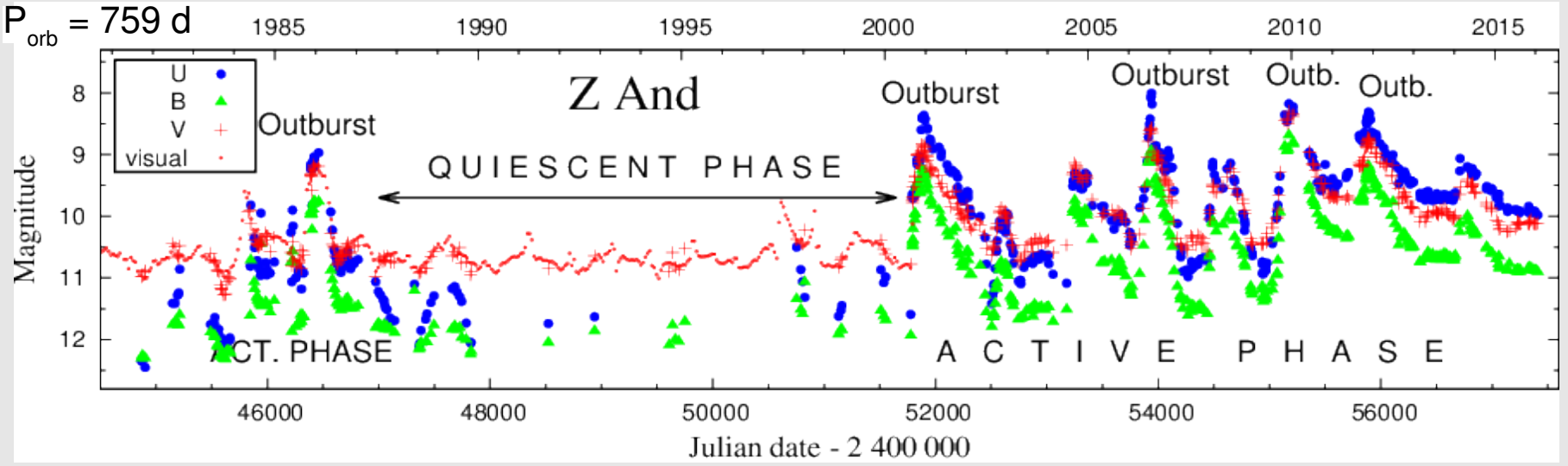
Seaquist et al. 1984, ApJ, 284, 202

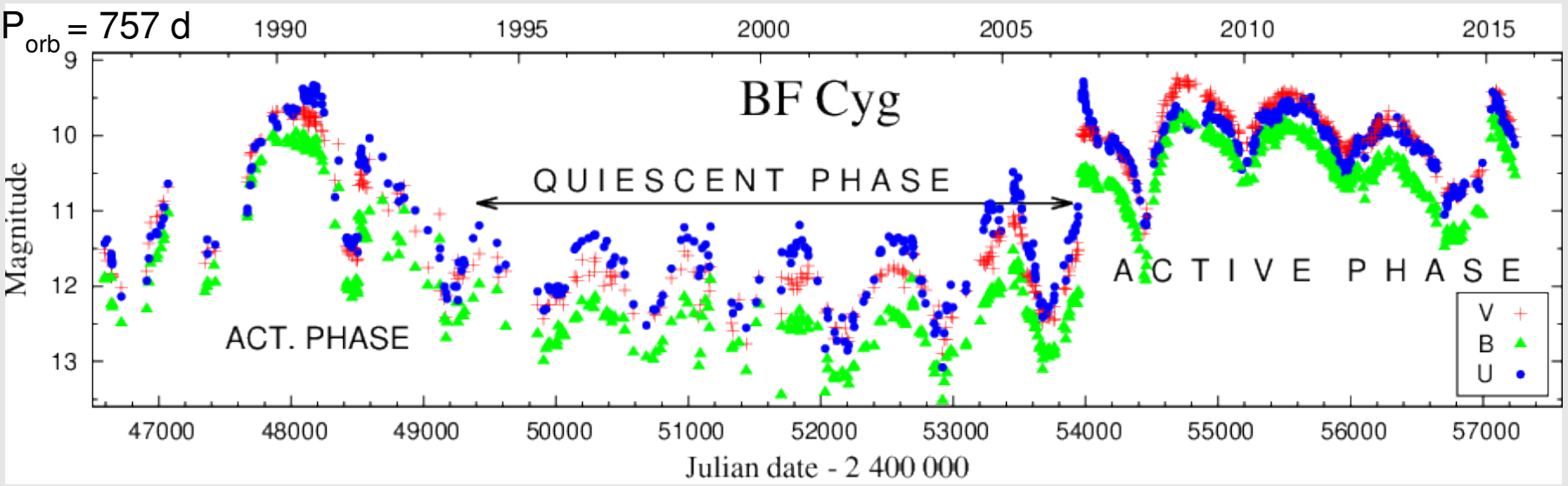
Accretion from the RG wind
(at 10^{-8}–10^{-7} M_{Sun}/yr)
==>
Hot & Luminous WD
==>
Ionization of the RG wind
==>
Symbiotic nebula

Quiescent & Active phases of symbiotic stars

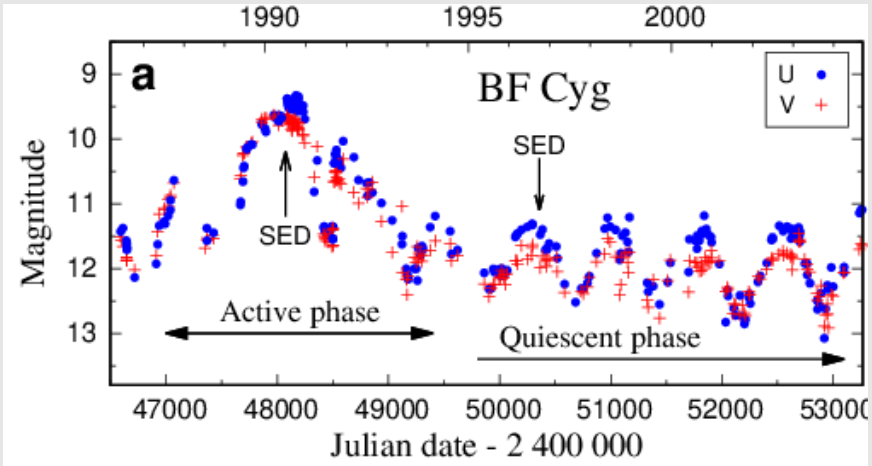
According to the light variations in the optical, we distinguish between the **quiescent** and **active** phases of symbiotic stars (SySts)

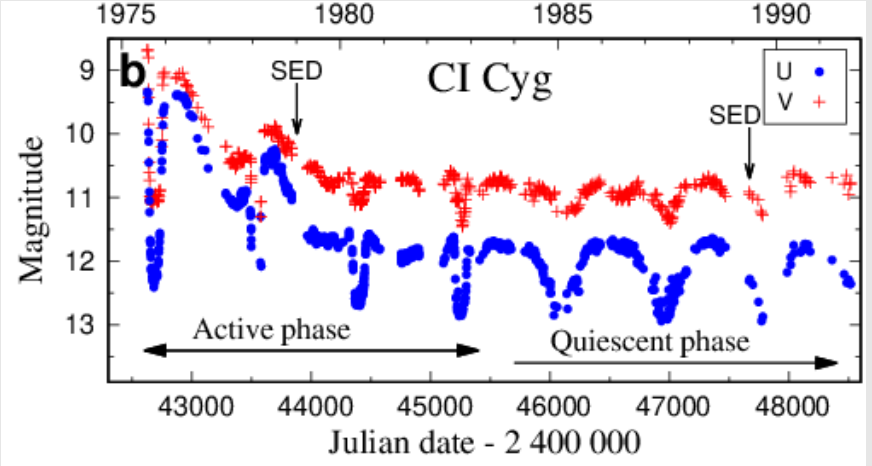
1. Z And type outbursts

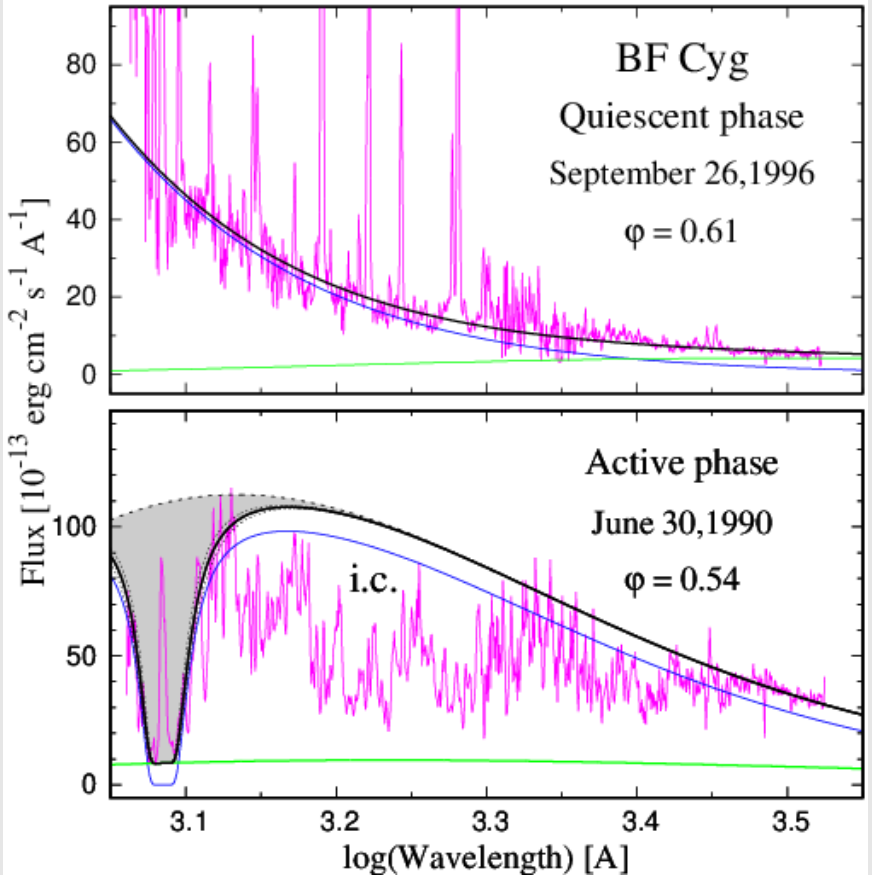


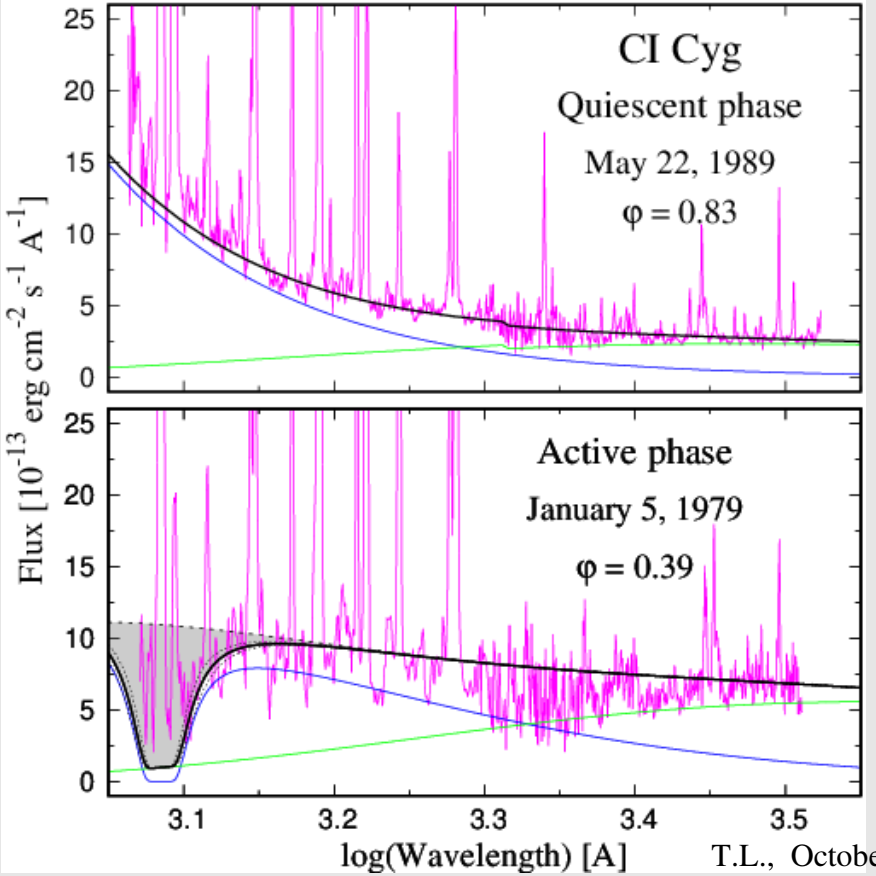


Q- & A-phases: LCs + UV-SED for eclipsing systems – basic changes









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Dramatic changes during transition from Quiescent to Active phase:

	Q-phase	→	A-phase
Light curve:	wave-like var.	→	narrow minima (eclipses)
UV-SED: T(WD)	1–2 x 10^5 K	→	1–3 x 10^4 K
EM	~10^{59} cm^{-3}	→	~10^{60} cm^{-3}
Rayleigh scattering	sp. conj.	→	around the orbit

Simultaneous presence of

1. a warm pseudophotosphere (T~1-2 x 10^4 K)
2. a strong nebular emission (EM = $n^p n_e V \sim 10^{60}$ cm^{-3})

The former is not capable of giving rise to the latter component:

$$L_{ph}(\text{shell}) \ll \alpha_B \times EM$$

→ the presence of a hot ionizing source that is not seen by the observer.

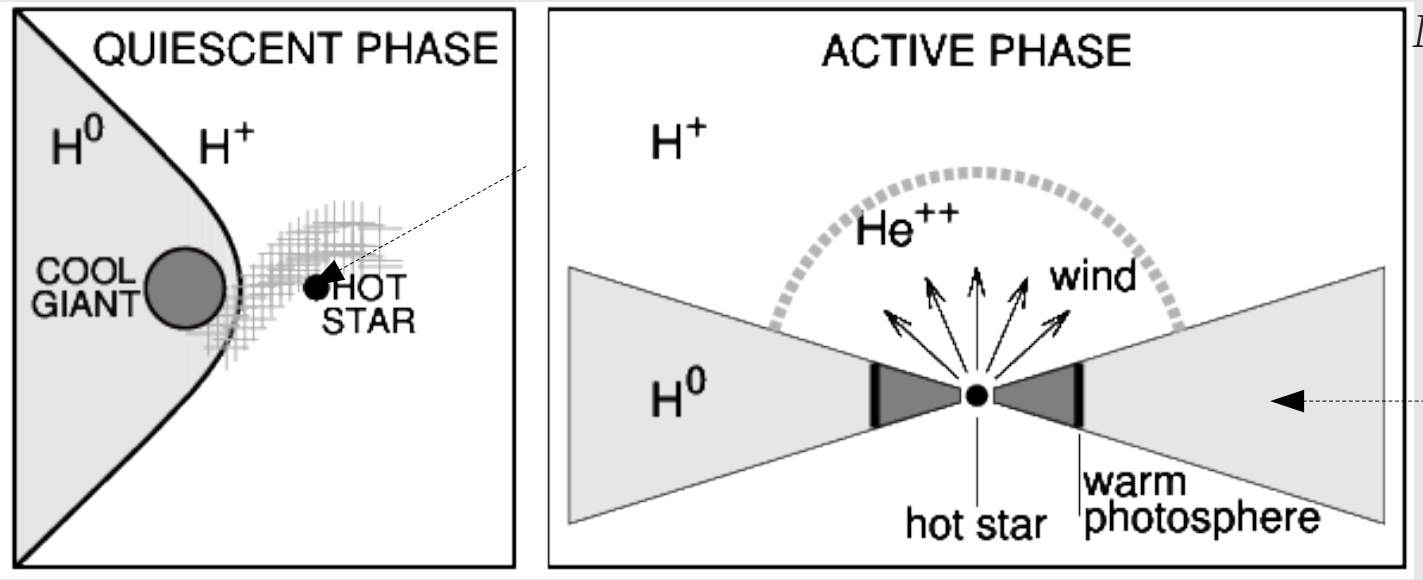
The biconical ionization structure of the hot component

Biconical ionization structure during outbursts of symbiotic stars

$\dot{M}_{WD} \approx 10^{-8}\, M_{Sun}/yr$

$L_{WD} \approx 10^{3}\, L_{Sun}$

$EM \approx 10^{59}\,\mathrm{cm}^{-3}$



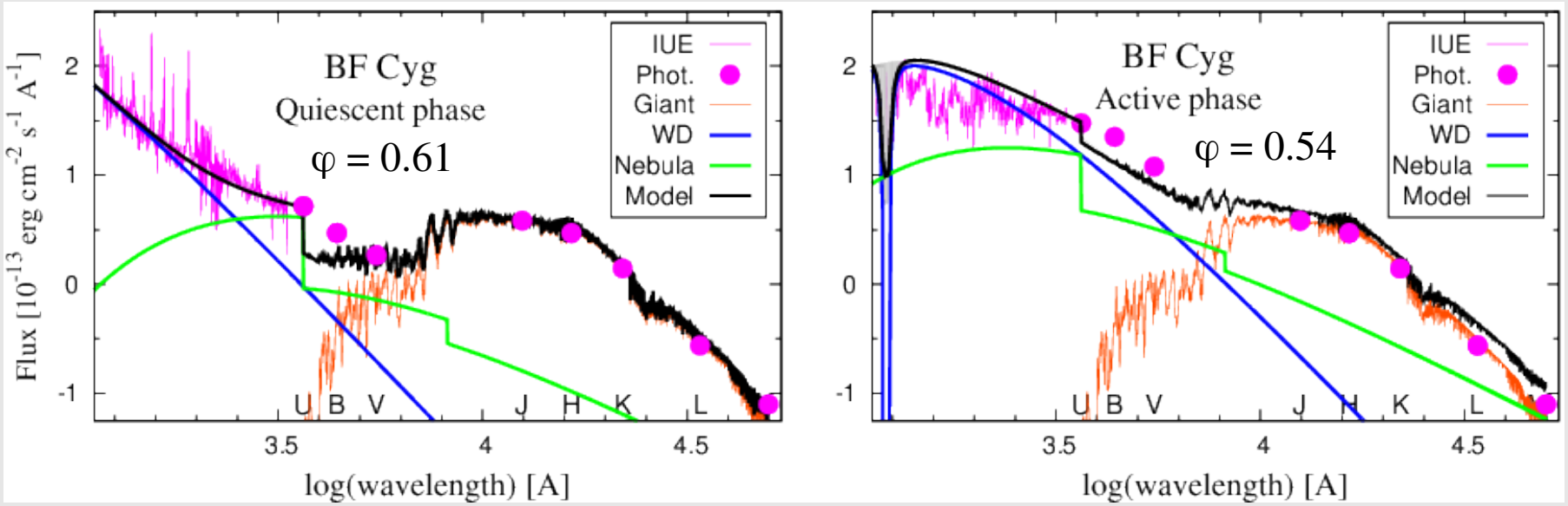
$\dot{M}_{WD} \approx 10^{-6}\, M_{Sun}/yr$

$L_{WD} \approx 10^{4}\, L_{Sun}$

$T_{shell} \approx 10^{4}\, K$

$EM \approx 10^{60}\,\mathrm{cm}^{-3}$

Skopal (2005), Skopal at. al. (2011)



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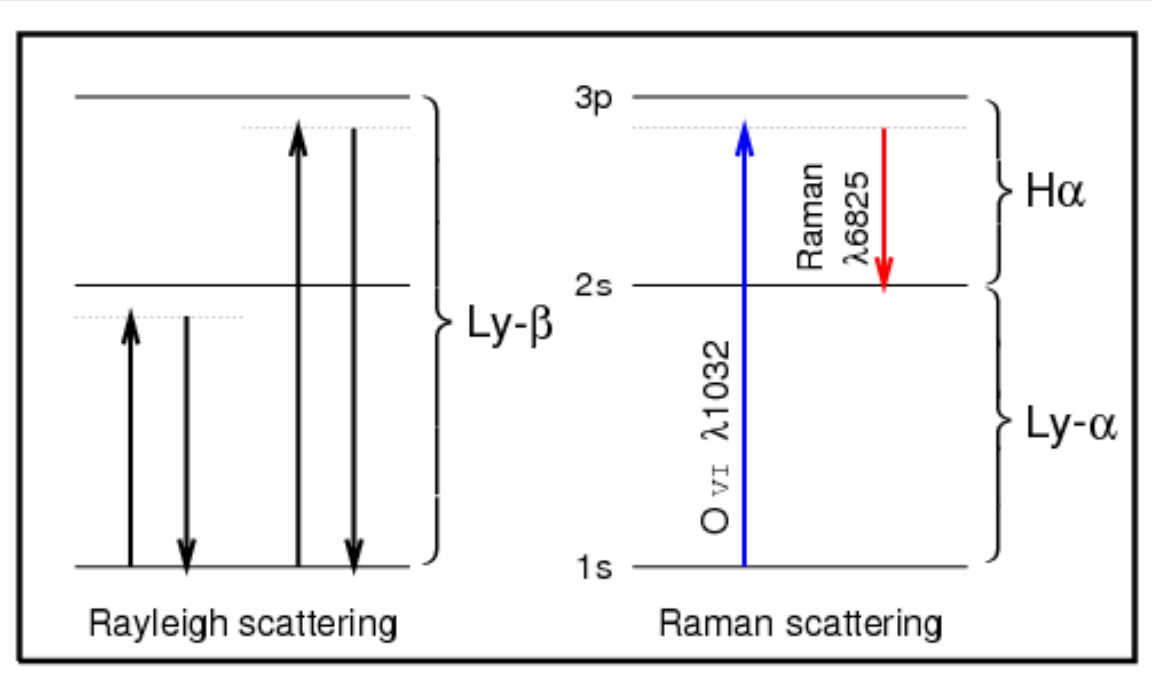
Rayleigh and Raman Scattering processes

Raman and Rayleigh scattering processes are conditioned by simultaneous presence of neutral atoms and high energy photons. SySts thus represent an ideal medium for these processes.



cross-sections σ:

$$\sigma_{Ray}(\lambda) = \sigma_e \left[\sum_k \frac{f_{1k}}{(\lambda/\lambda_{1k})^2 - 1} \right]^2$$

$$\sigma_{Ray}(1032) = 34 \times \sigma_e \%$$
$$\sigma_{Ram}(1032) = 6.6 \times \sigma_e$$
$$\sigma_e = 6.65 \times 10^{-25} cm^2 \%$$

Left: Schematic energy level diagram for Rayleigh scattering around Ly-α and Ly-β.
Right: Raman scattering of OVI 1032A photons by neutral hydrogen.

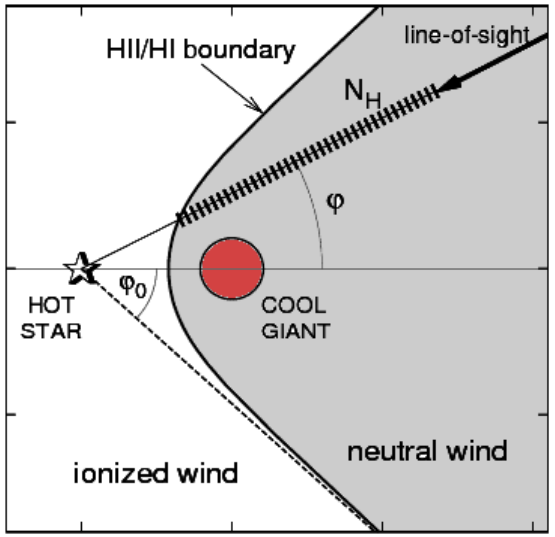
Intermedial levels around main levels are very unstable. Electron captured at the intermedial level is immediately stabilized by a transition to a main level.

Schmidt (1989, A&A, 211, L31), Nussbaumer et al. (1989, A&A, 211, L27)

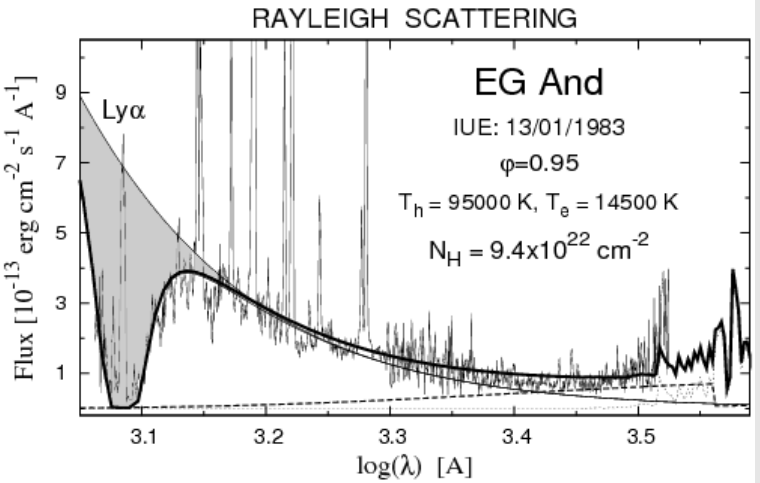
Rayleigh scattering can strongly attenuate the continuum around hydrogen Lyman lines.

Example of quiescent phase

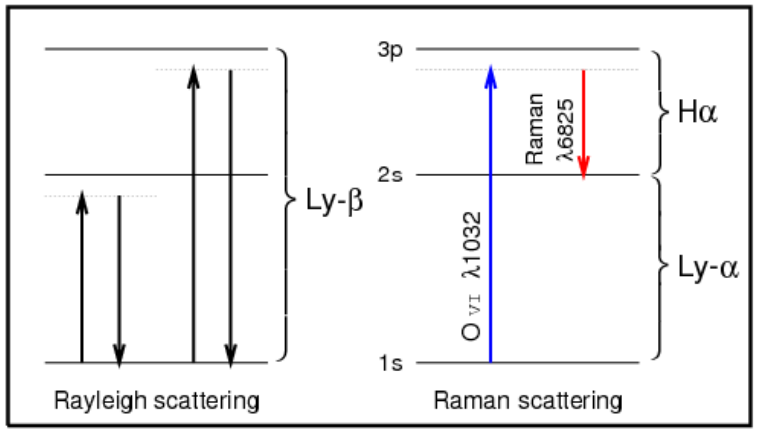
The Rayleigh scattering can be observed only if the line-of-sight intersects the neutral region, which is around inferior conjunction of the giant during quiescence.



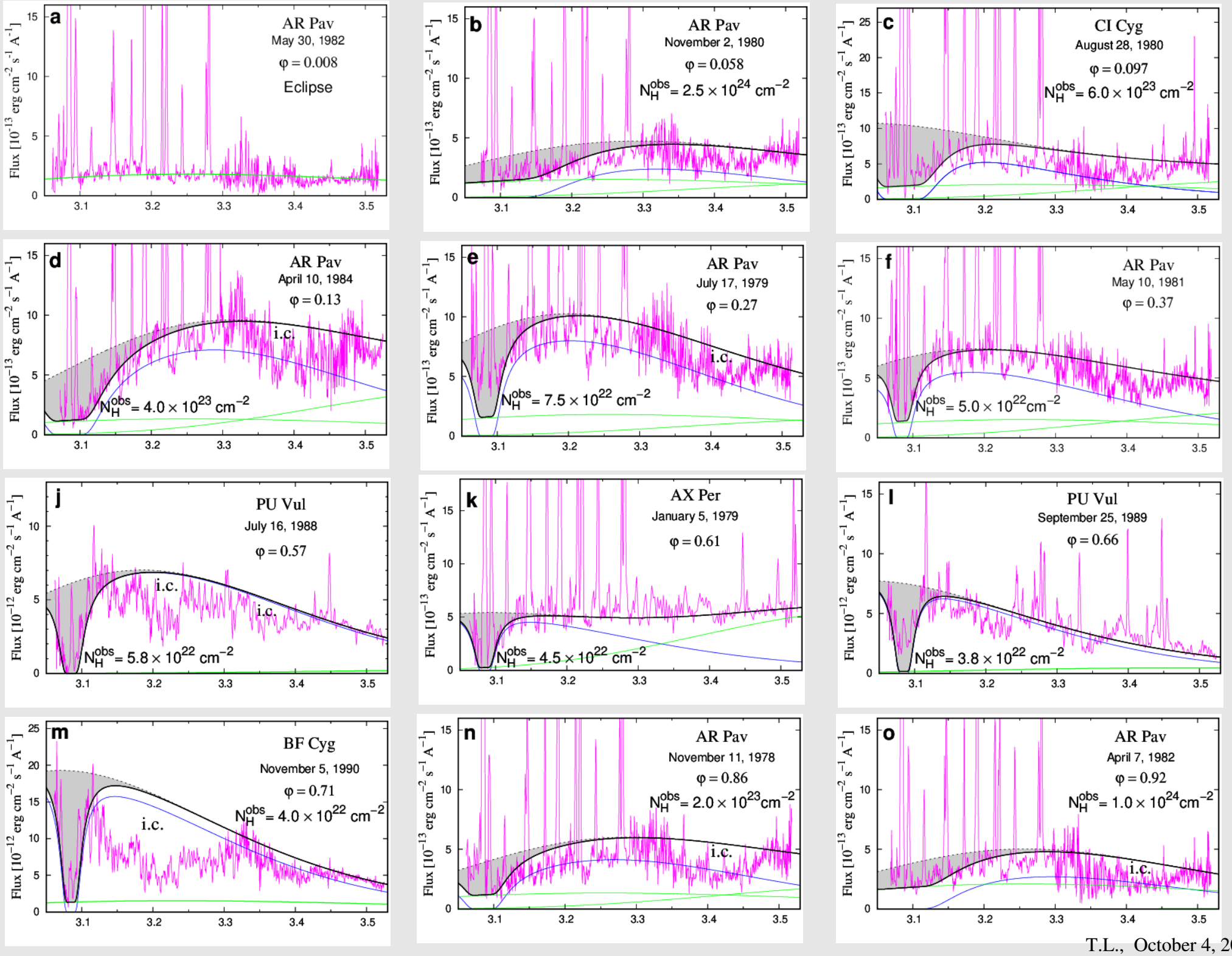
Quiescent SySt EG And:
The continuum around Ly-α is Rayleigh attenuated with N_H = 9.4E+22 cm^{-2} .



Schematic energy diagram for Rayleigh & Raman scattering



Raman & Rayleigh scattering probe the ionization structure, kinematic and displacement of H^0 zone.



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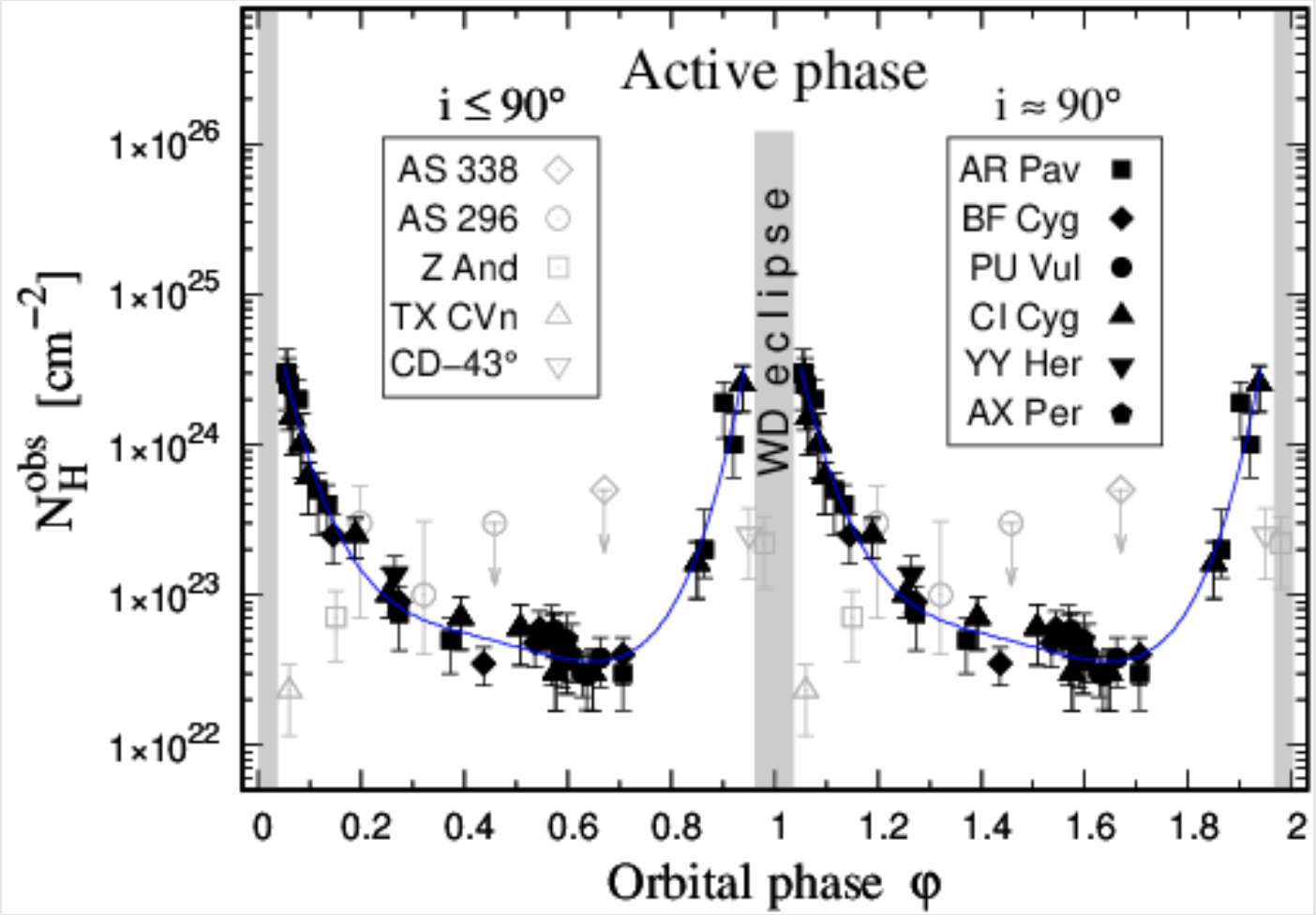
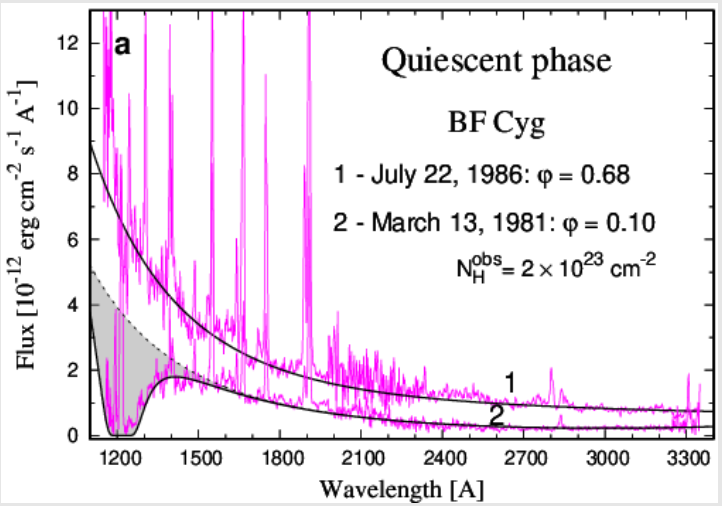
The emergence of a neutral wind region in the orbital plane during outbursts

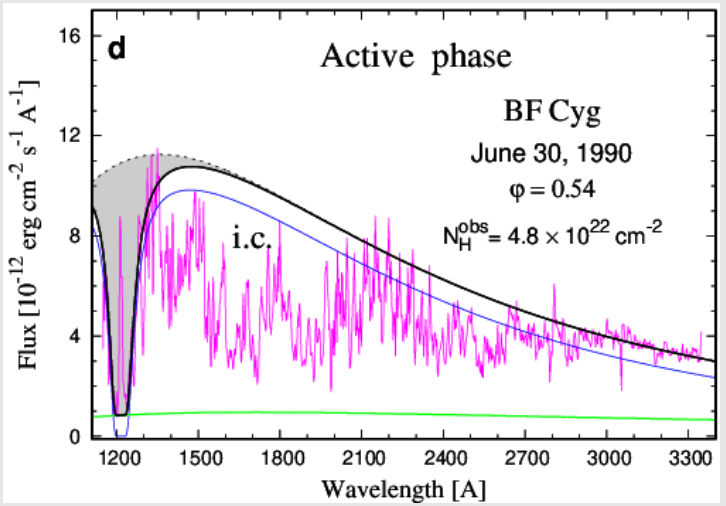
Eclipsing systems: *Rayleigh scattering during outbursts*: $N_H = 10^{22} - 10^{24}\,\mathrm{cm}^{-2}$. Asymmetry of $N_H(\varphi)$ as in HMXBs.



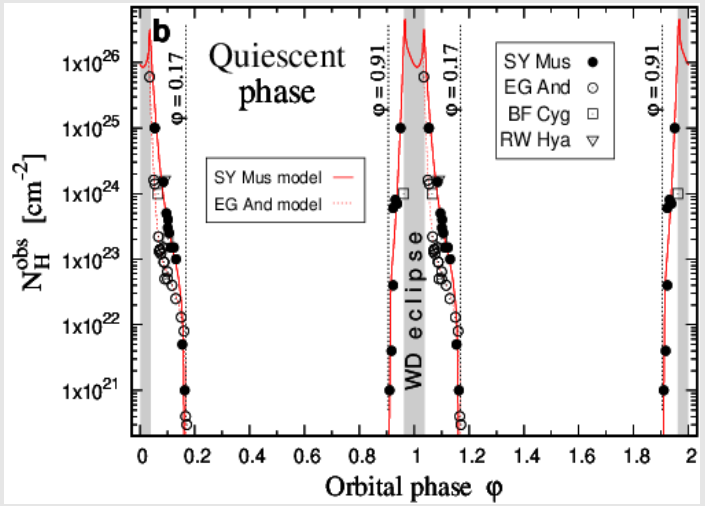
During active phases, a neutral region consisting of wind from the giant emerges in the orbital plane. It is observable here due to the formation of a dense disk-like structure around the WD during outbursts, which blocks ionizing radiation from the central burning WD in the orbital plane. The orbitally-related asymmetry of the measured column densities could be attributed to tidal streams and accretion wakes as for HMXBs.

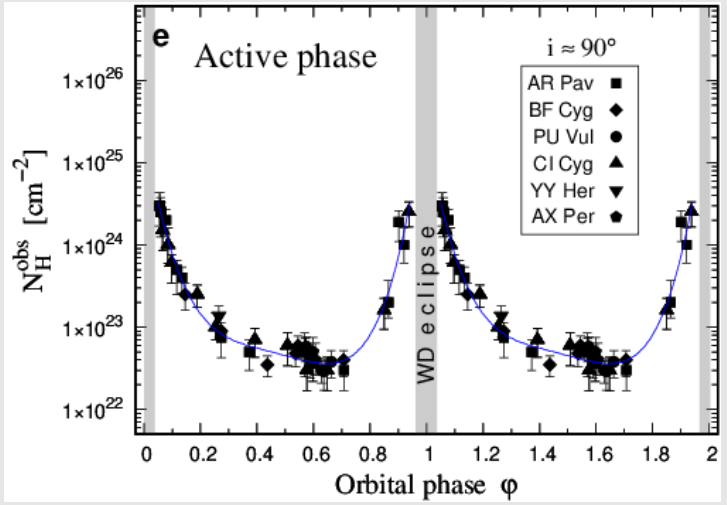
The symbiotic phenomenon in a nutshell



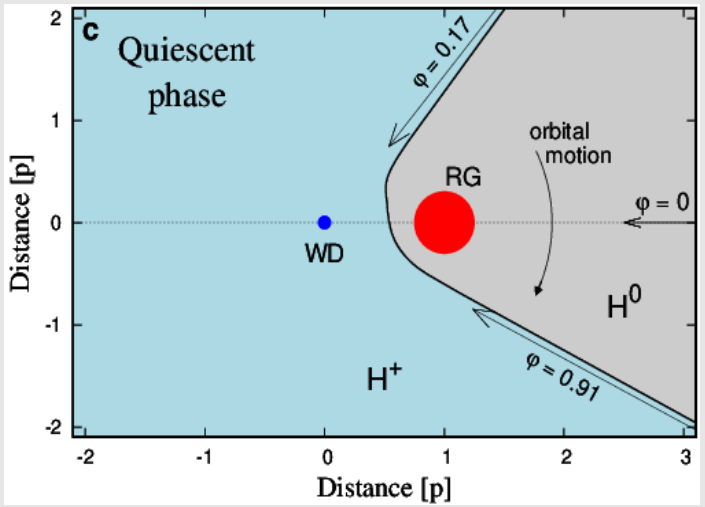


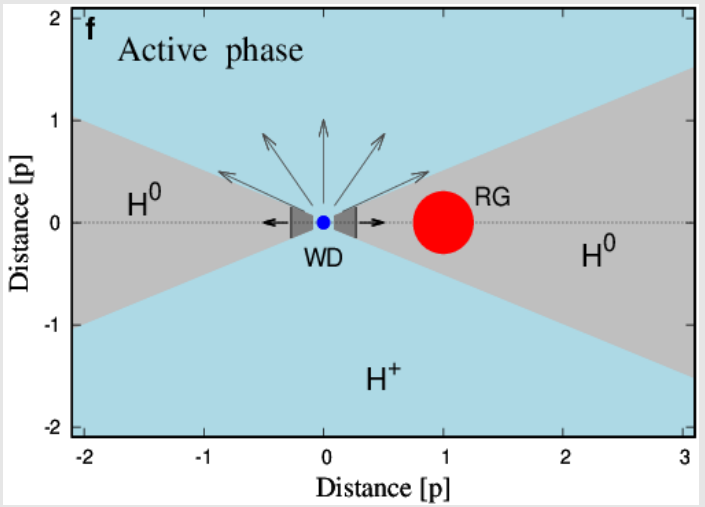
Characteristic UV spectra





Hydrogen column densities





Corresponding ionization structure

Conclusion and future work

The high values of N_H measured during active phases of eclipsing SySts at any orbital phase indicate the presence of a neutral region in the orbital plane consisting of wind from the giant.

Its emergence is connected with the formation of a flared disk structure around the exploding WD that blocks its ionizing radiation in the orbital plane

Future work:

- Modeling N_H values around the orbit – focusing of the wind ?!

- Testing theoretical modeling of the wind morphology – comparison with the observed N_H .

- Creation of a disk-like structure around the exploding WD can be conductive to the explanation of more violent classical nova outbursts.

Thank you for your attention

Based on:
A. Skopal, *The Emergence of a Neutral Wind Region in the Orbital Plane of Symbiotic Binaries during Their Outbursts.* In: The Astronomical Journal, 165:258 (19pp), 2023 June

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