Light curve asymmetry
of the symbiotic binary SY Mus
as a result of absorption by the wind
from its giant component

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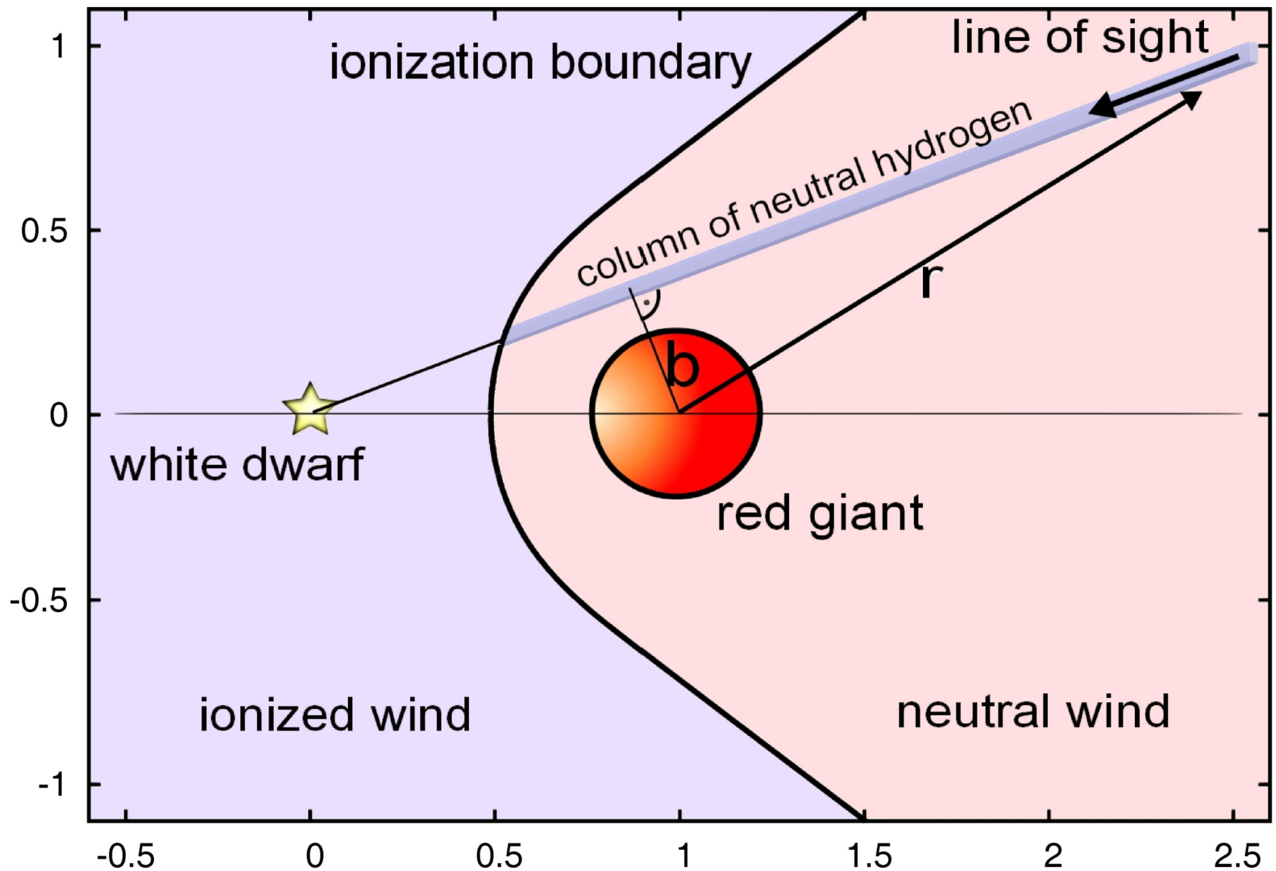
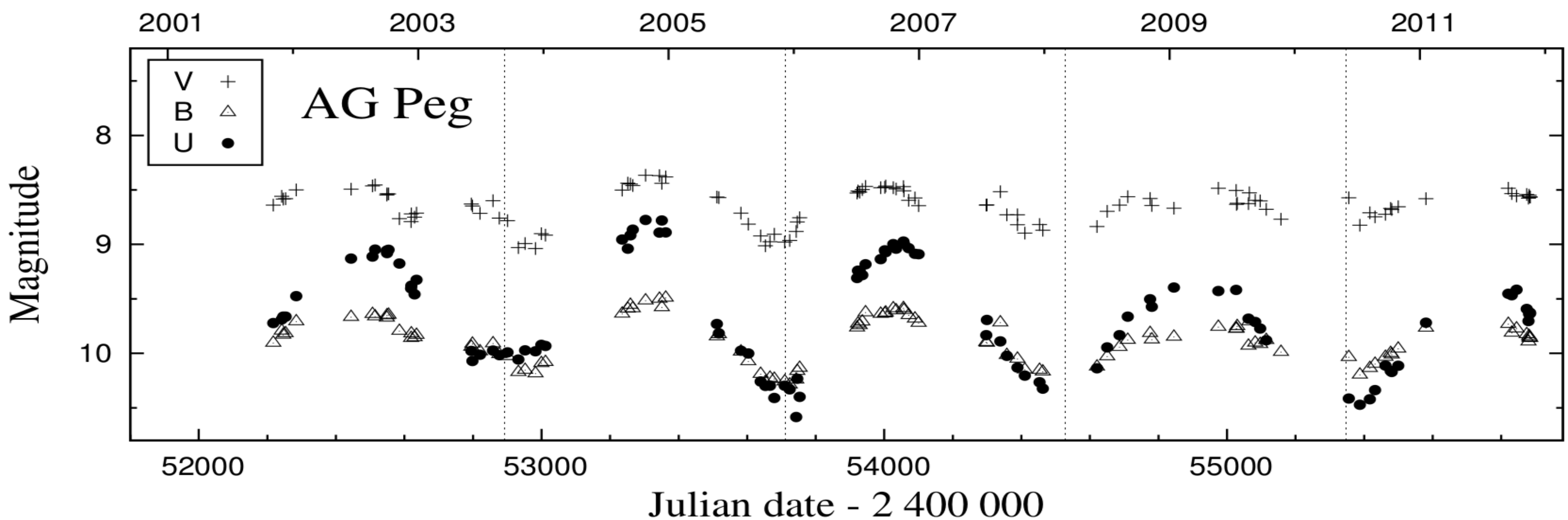
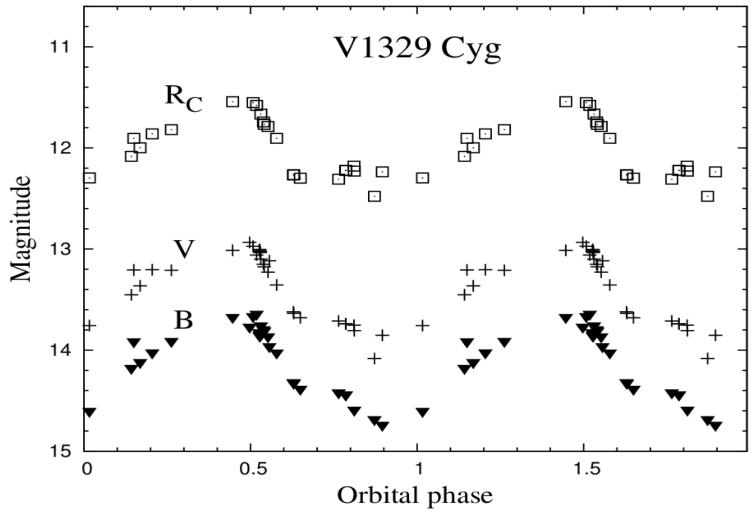
Symbiotic stars



Asymmetric light curves

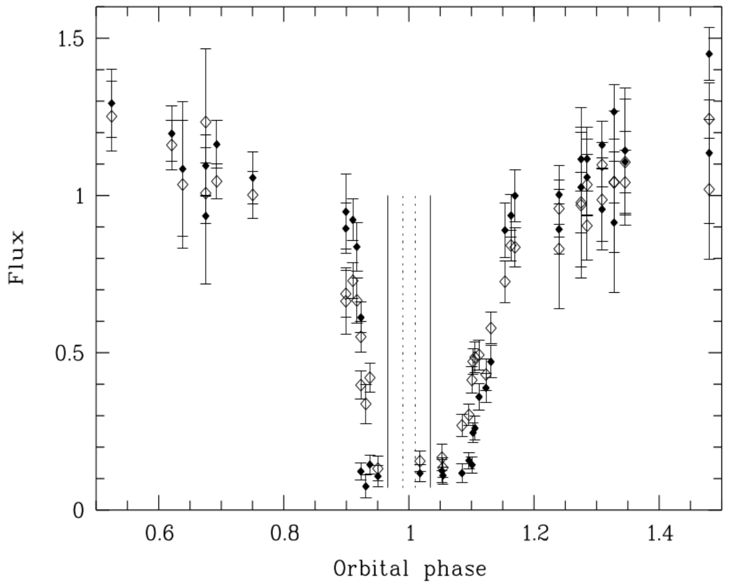




Skopal et al. (2012)
AN 333, No. 3, 242

SY Muscae

- $i = 84°$
- white dwarf + red giant
- asymmetry in UV light curves



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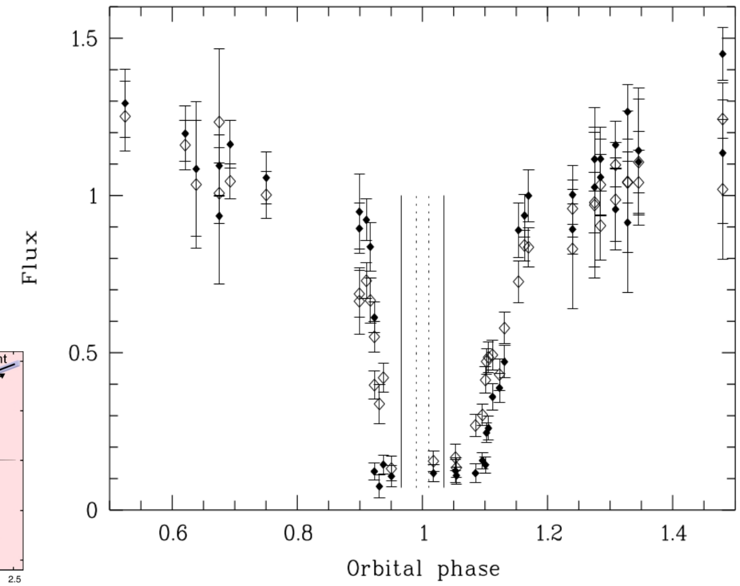

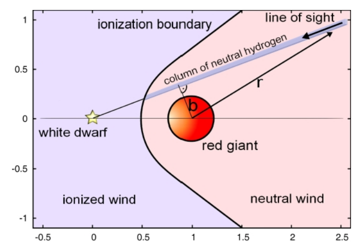

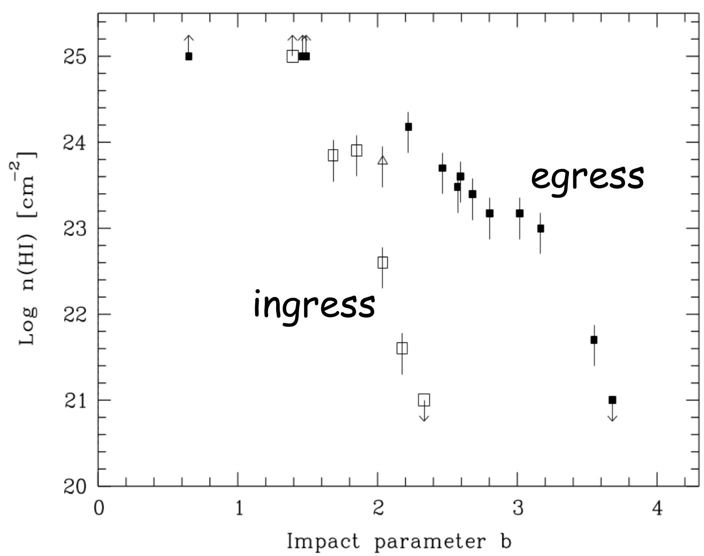

Dumm et al. (1999), A&A 349, 169:
asymmetric wind distribution
- possible cause of the asymmetry in LCs

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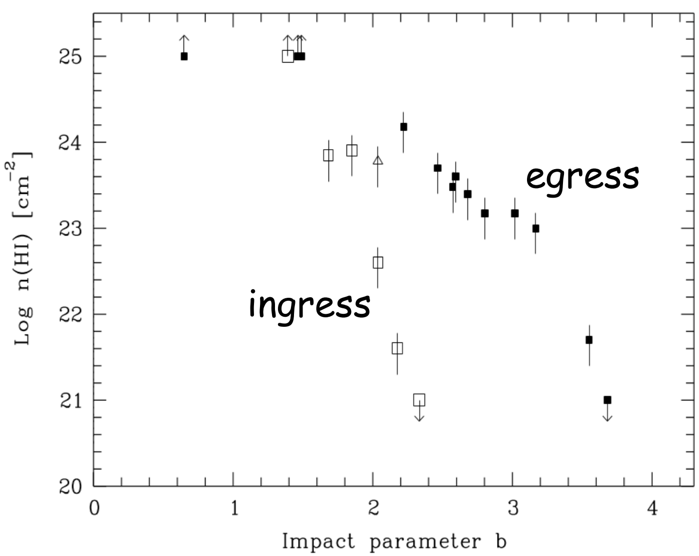
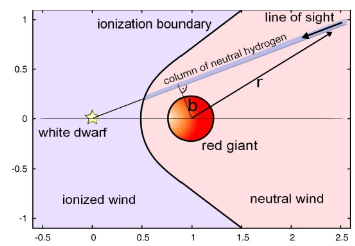
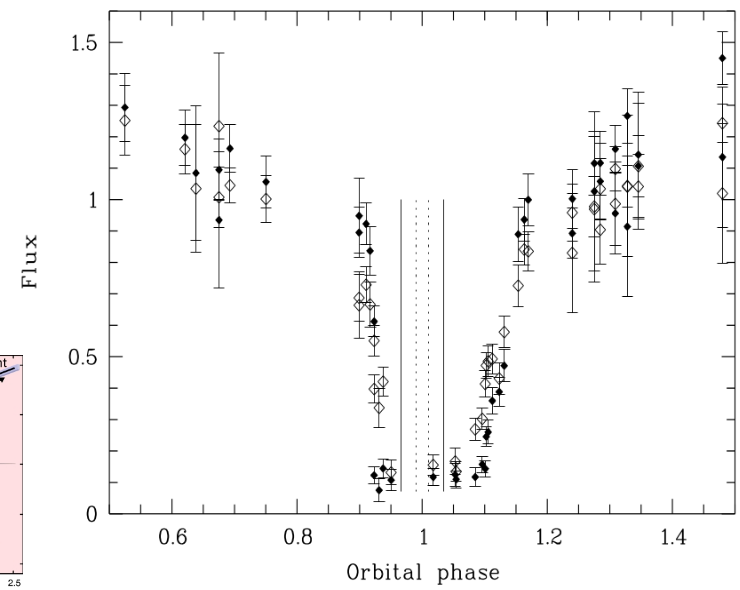






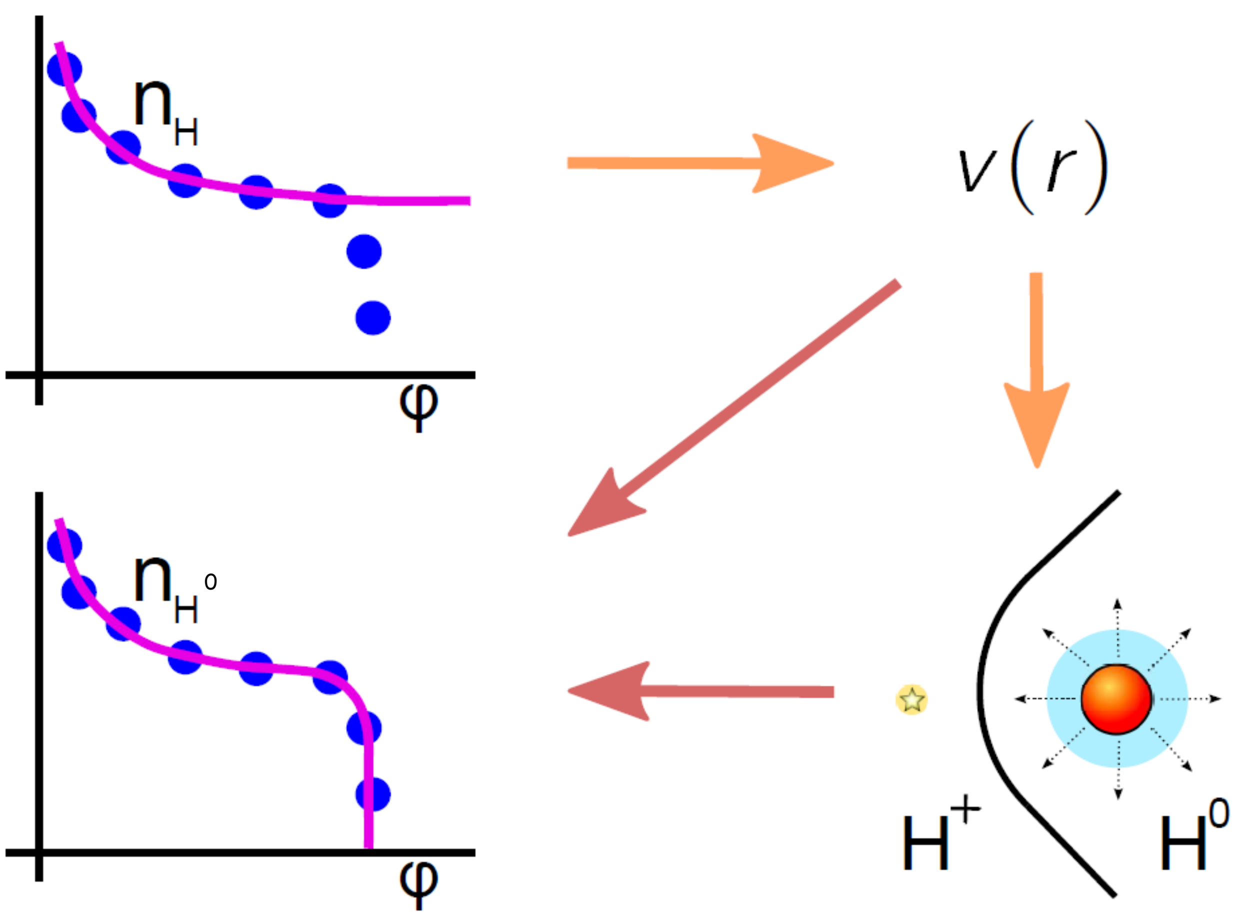
Dumm et al. (1999), A&A 349, 169:
asymmetric wind distribution
- possible cause of the asymmetry in LCs

Can we justify it in a quantitative way?

We already have...

- ingress and egress velocity profiles
- ionization structure
- indication of the wind focusing towards orbital plane

Shagatova et al. (2016)
A&A 588, A83



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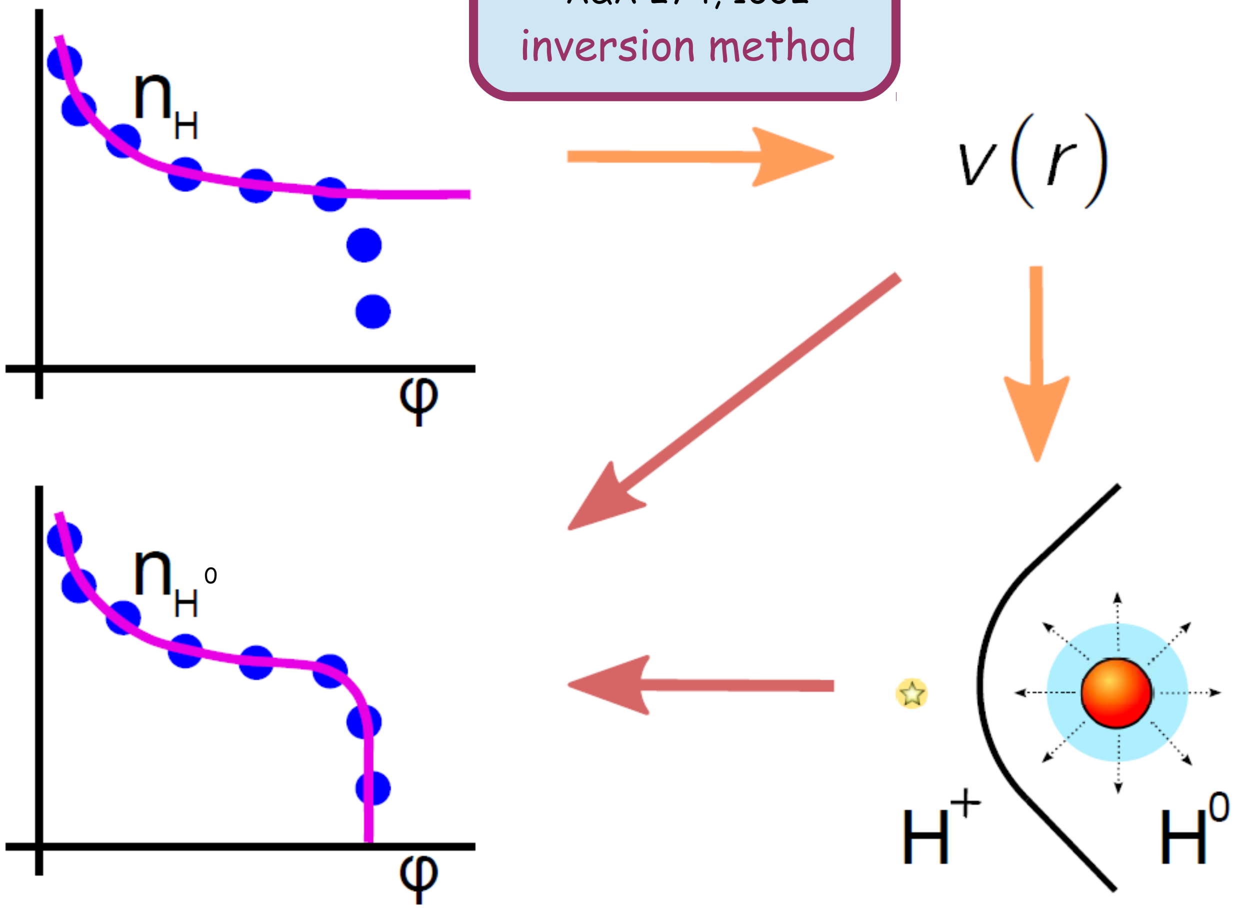
A&A 274, 1002
inversion method



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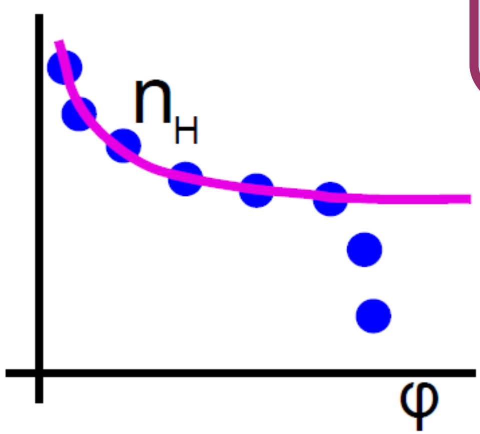
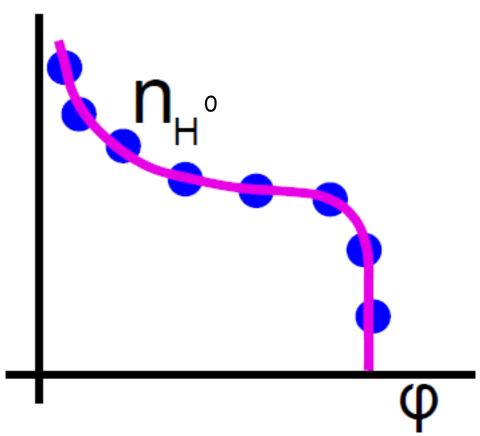
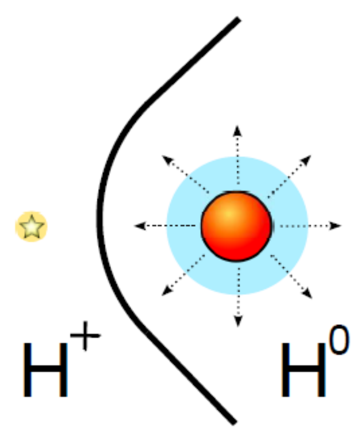


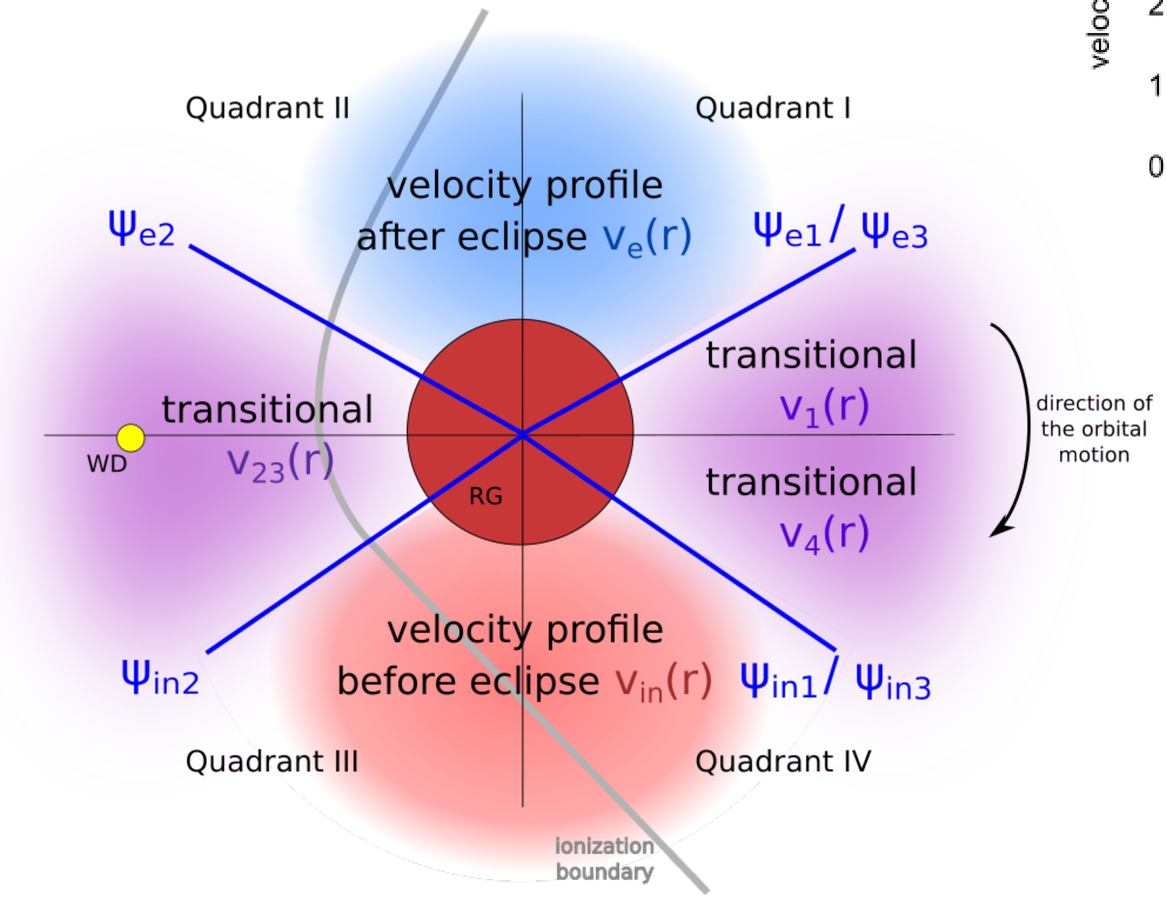
$v(r)$

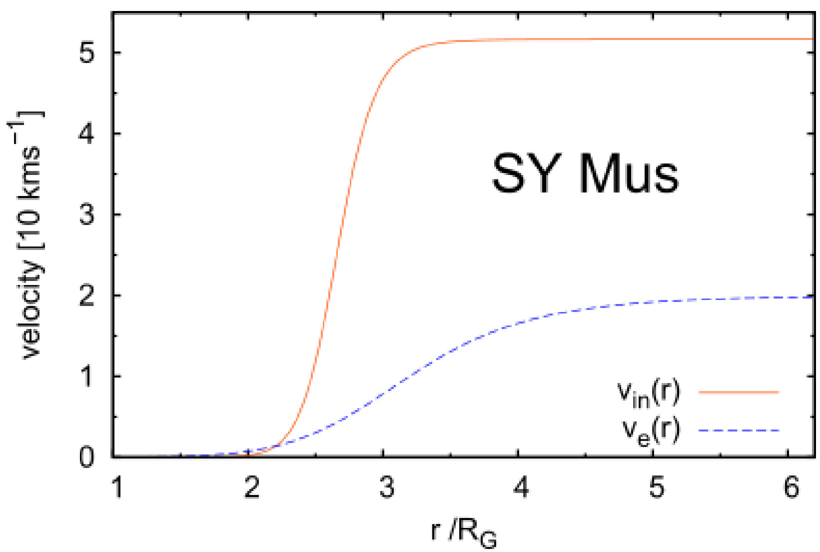
Seaquist et al. (1984)
ApJ 284, 202
ionization boundary





Velocity profiles

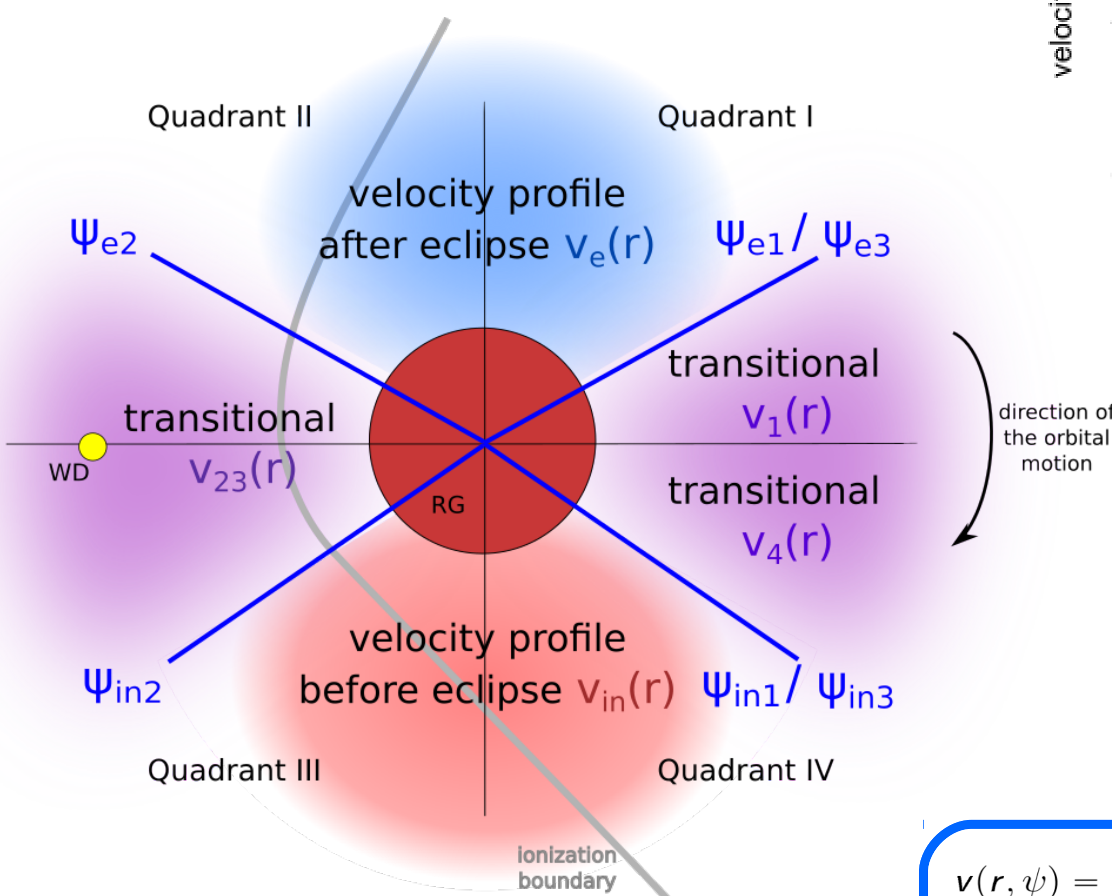


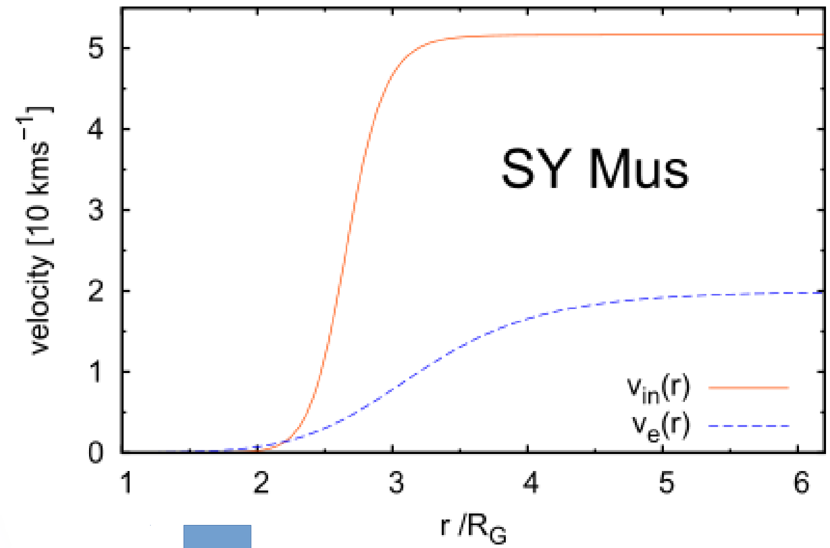


Assumption:
Gradual change of the velocity profile from $v_e(r)$ to $v_{in}(r)$.

- interconnection by a smooth function

Velocity profiles





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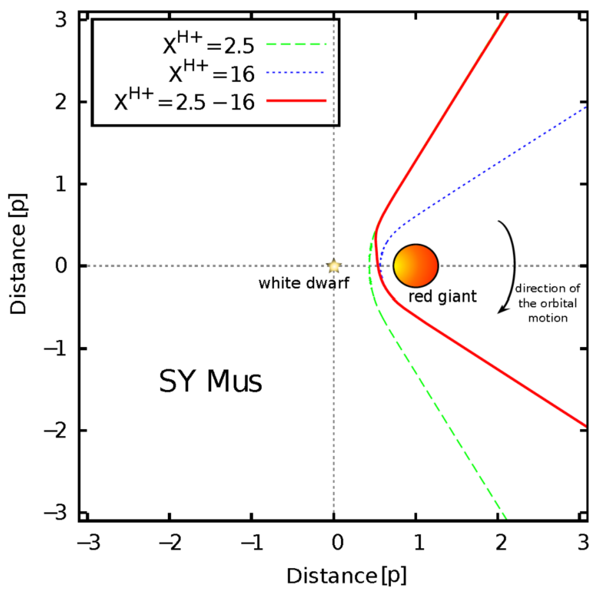
Gradual change of the velocity profile from $v_e(r)$ to $v_{in}(r)$.

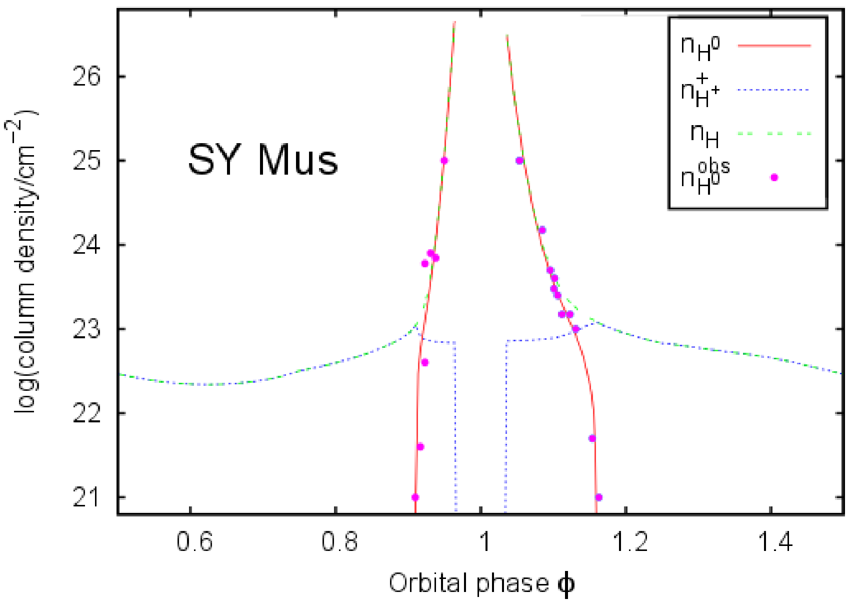
- interconnection by a smooth function

$$v(r,\psi) = v_{in}(r)\cos^2(C(\pm\psi \pm \psi_{in})) + v_e(r)\cos^2(C(\psi - \psi_e))$$

$$C = \frac{\pi}{2}\frac{1}{\psi_{in} - \psi_e}$$

Unified model





- ionization structure

- column density distribution of neutral and ionized hydrogen

UV continuum light curves modelling

Sources of radiation:

$$F_\lambda(\varphi) = F_\lambda^{\mathrm{h}}(\varphi) + F_\lambda^{\mathrm{n}}(\varphi)$$

WHITE DWARF

$$F_\lambda^{\mathrm{h}}(\varphi) = \pi B_\lambda(T_{\mathrm{h}}) e^{-\tau_\lambda(\varphi)}$$

NEBULA

$$F_\lambda^{\mathrm{n}}(\varphi) = \alpha_\lambda \sin[2\pi(\varphi - 0.25)] + \beta_\lambda$$

RED GIANT

Attenuation:

$$\tau_\lambda(\varphi) = \tau_\lambda^0(\varphi) + \tau_\lambda^+(\varphi)$$

$$\tau_\lambda^0(\varphi) = \sigma_{\mathrm{Ray}}(\lambda) n_{\mathrm{H}^0}(\varphi) + \kappa_{\mathrm{H}^-}(\lambda) n_{\mathrm{H}^-}(\varphi)$$

$$\tau_\lambda^+(\varphi) = \sigma_{\mathrm{e}^-}^+ n_{\mathrm{e}^-}^+(\varphi) + \sigma_{\mathrm{H}^0}^+(\lambda, \mathrm{T_e}) \mathrm{n}_{\mathrm{H}^0}^+(\varphi)$$

$$n_{\mathrm{e}^-}^+(\varphi) = 1.2\, n_{\mathrm{H}^+}^+(\varphi)$$

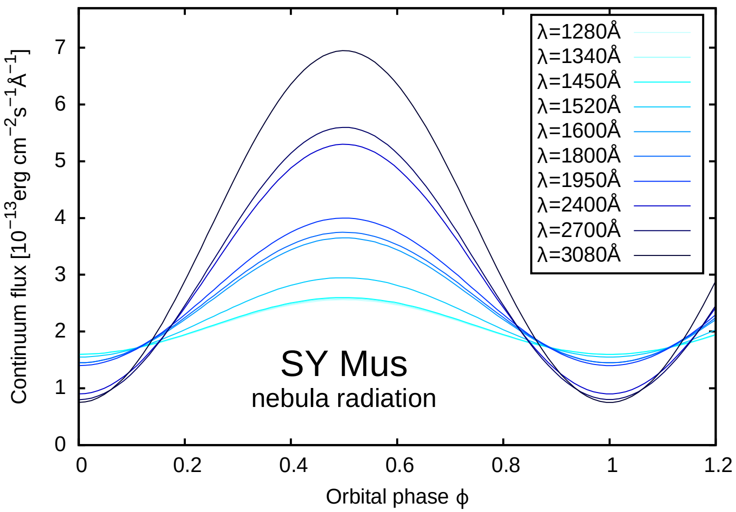
- geometrical attenuation of nebular radiation modelled by a sine wave

- negtectable contribution in UV

Observations

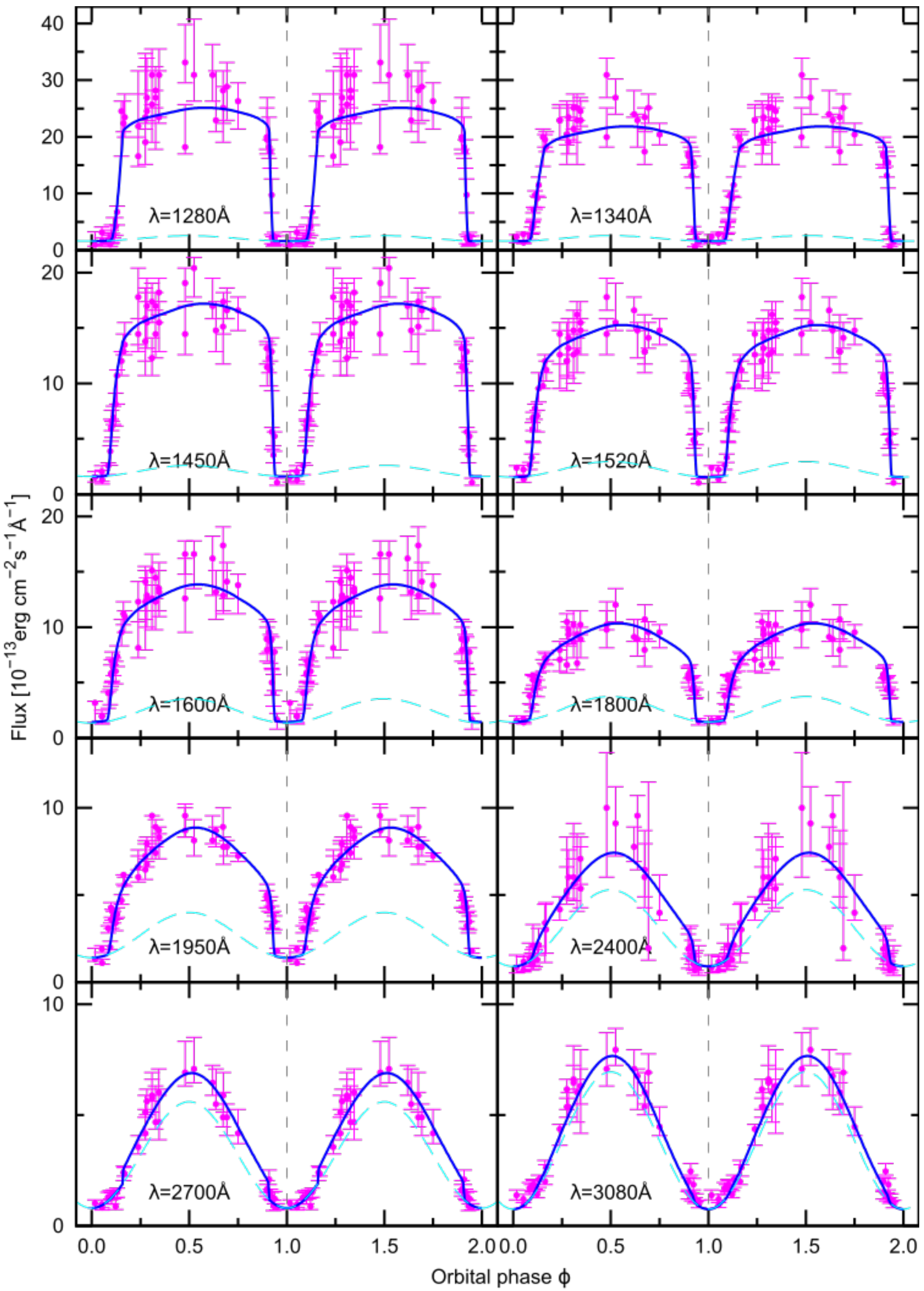
UV continuum light curves
at 10 wavelengths from 1280 to 3080Å
from 44 IUE SWP, LWP/LWR spectra

Model



$$n_{\mathrm{H}^-}(\varphi) = 5.0\times10^{-7} n_{\mathrm{H}^0}(\varphi)$$

$$n^{+}_{\mathrm{H}^0}(\varphi) = 1.5\times10^{-4} n^{+}_{\mathrm{H}^+}(\varphi)$$



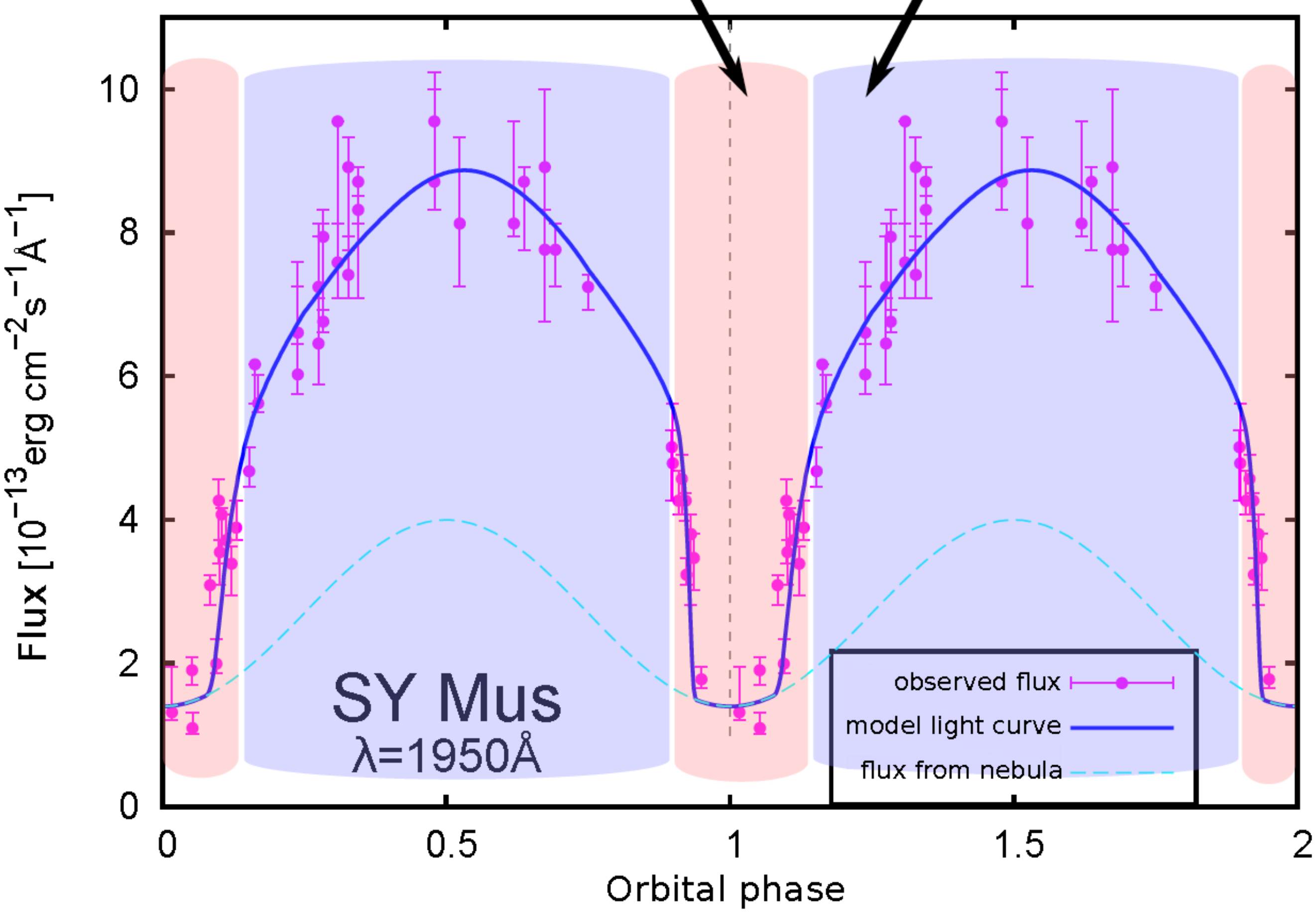
Shape of the asymmetric light curve

- the profile of attenuation around eclipse is given by the absorption in neutral region

--> the only variable there is $n_{H^-}(\varphi)$

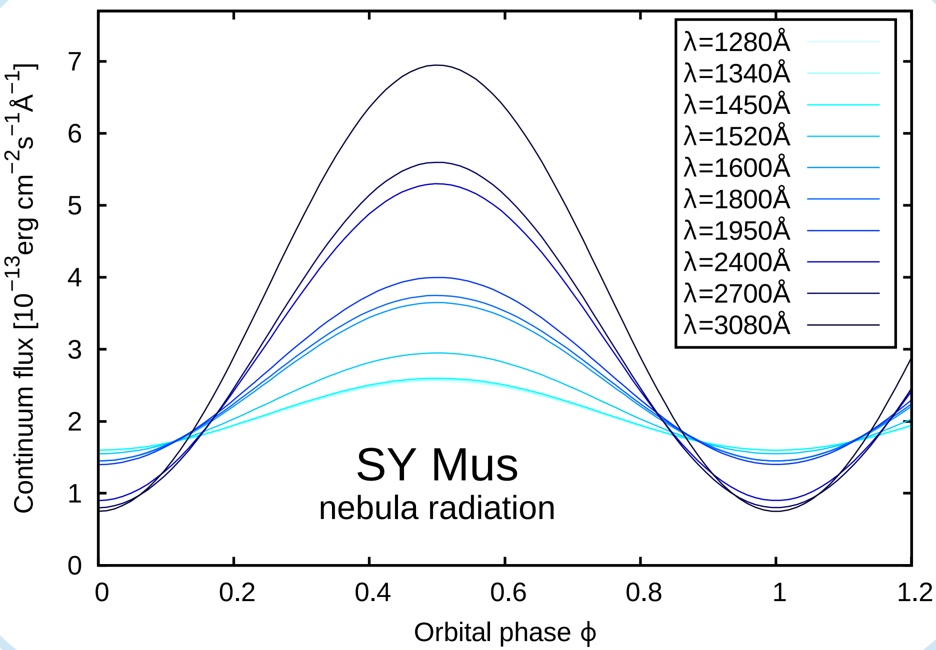
- at other phases, it is given by the absoption in ionized region

--> the only variable there is $n^{+}_{H^0}(\varphi)$



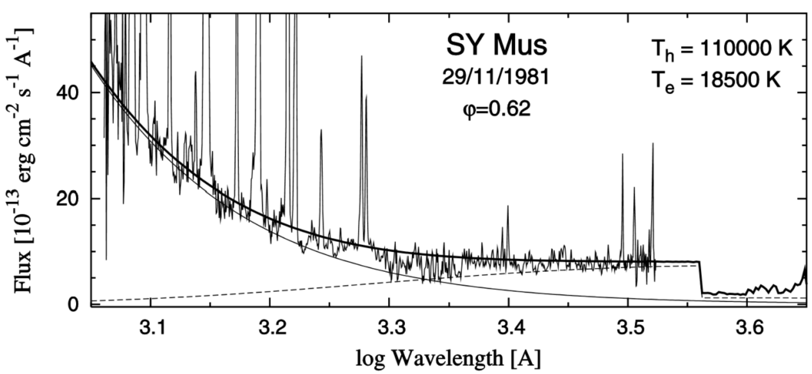
- vertical range of the light curve is determined by nebular radiation

Variations of the nebular flux

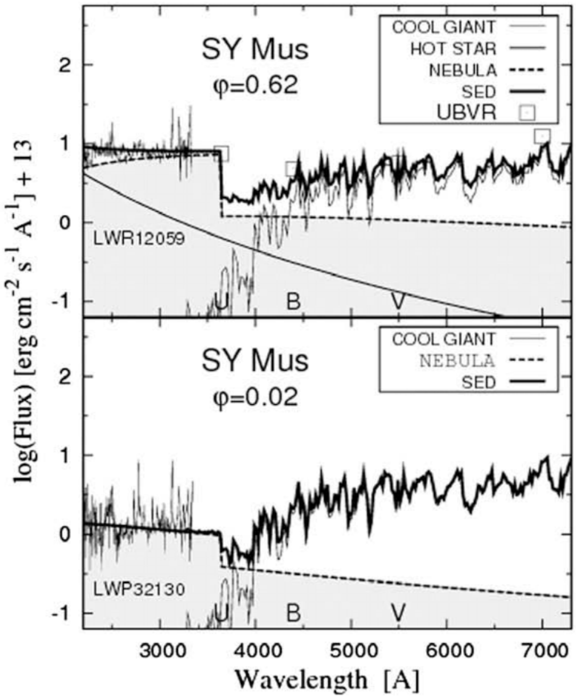


Comparison with SED models:

- values of fluxes differ by a factor 1.04 – 1.89 (which depends on the quality of the data at given wavelength)



(Skopal (2005), *A&A* 440, 995)



(Skopal (2009), New Astronomy 14, 336)

Parametrized column densities

$$n_{\mathrm{H}^-}(\varphi) = 5.0\times10^{-7} n_{\mathrm{H}^0}(\varphi)$$
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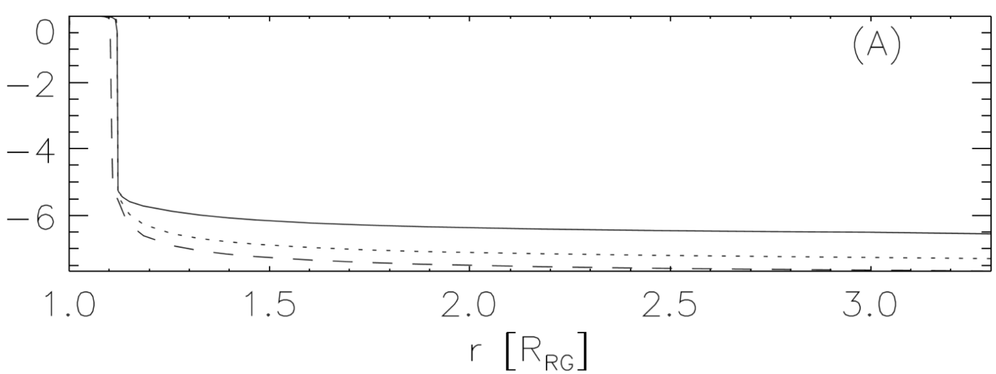
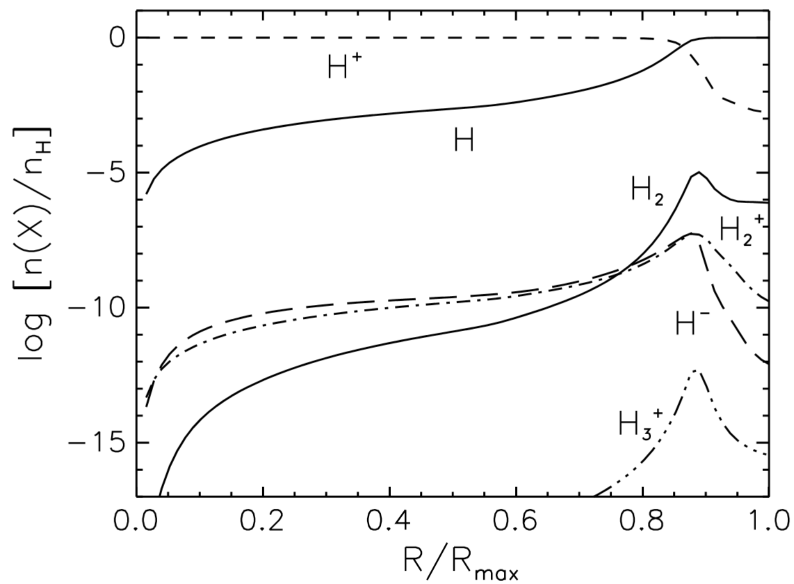
- planetary nebulae

- S-type symbiotic stars



Schwank et al. (1997), A&A 319, 166



Aleman & Gruenwald (2004), ApJ 607, 865

Assumptions and limitations of the model

- purely hydrogen RG wind flowing radially

- quality of the dataset

- sources of attenuation of the light curves (H^0, H^- and e^-)

$$n_X \sigma_X / n_{H^0} \lesssim 10^{-29}$$
$$n_X \sigma_X / n^+_{H^+} \lesssim 10^{-26}$$

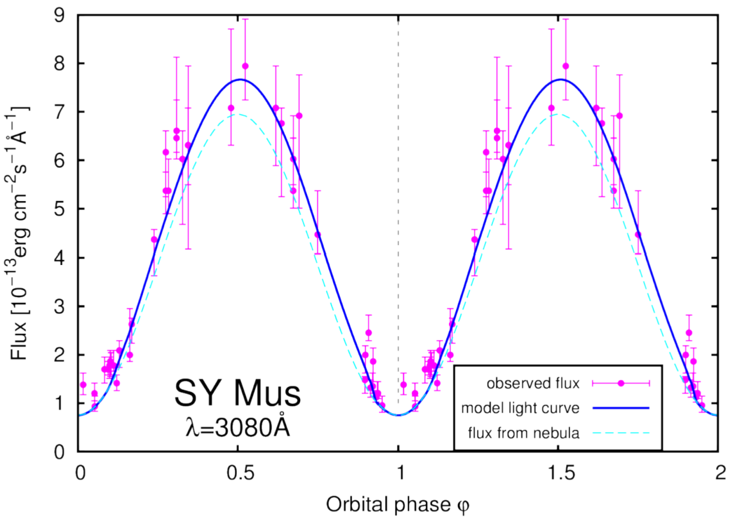
Neglectable effect: - H^+, e^- in neutral region
- H_2^+, H^- in ionized region

$$n_{H^-}(\varphi) = 5.0\times10^{-7} n_{H^0}(\varphi)$$
$$n^+_{H^0}(\varphi) = 1.5\times10^{-4} n^+_{H^+}(\varphi)$$

- upper estimates

- approximation of the variations of the nebular flux by a sine wave

$$F^n_\lambda(\varphi) = \alpha_\lambda \sin[2\pi(\varphi - 0.25)] + \beta_\lambda$$



Conclusions

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LC asymmetry is caused by the asymmetric distribution of the wind from RG.

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Thank you for attention!