Broad Wings around Hα and Hβ in the S-type Symbiotic Stars

Seok-Jun Chang[1], Hee-Won Lee[1] and Ho-Gyu Lee[2]

[1] Department of Physics and Astronomy, Sejong University, Seoul

[2] Korea Astronomy and Space Science Institute

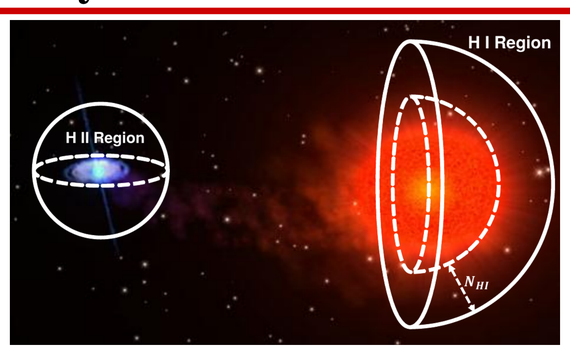
csj607@gmail.com

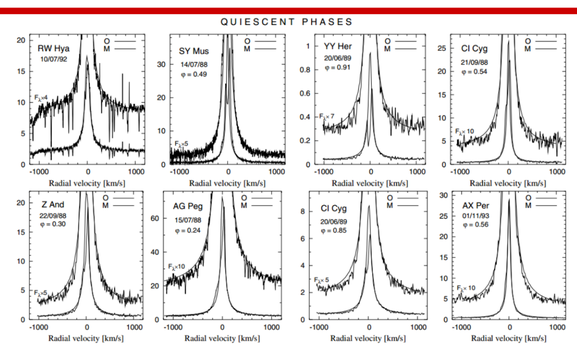
seokjun.weebly.com

1. Abstract

Symbiotic stars are binary systems composed of a hot white dwarf and a mass losing giant. Many symbiotic stars are known to exhibit broad wings around Balmer emission line. We show high resolution spectra of S-type symbiotic stars, Z Andromedae and AG Draconis, obtained with the ESPaDOnS and the 3.6 m Canada-France- Hawaii Telescope (CFHT), in which we find prominent broad wings around Balmer lines. We adopt Monte-Carlo technique to consider two types of wing formation mechanisms, which are Thomson scattering by free electron in H II region and Raman scattering by atomic hydrogen in H I region. We find that Thomson wings of Hα and Hβ have the same widths in the Doppler space due to the cross section independent of wavelength. In contrast, Raman Hα wings are 3 times broader widths than Hβ counterparts, which is attributed to the different cross sections and branching ratios. Our CFHT data show that Hα wings of Z Andromedae and AG Draconis are broader than Hβ wings, lending strong support to the Raman scattering origin of Balmer wings in these objects.

2. Symbiotic Stars

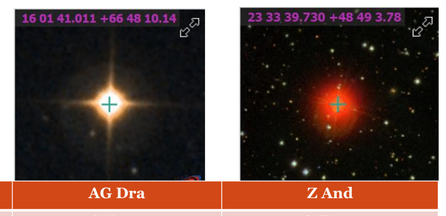




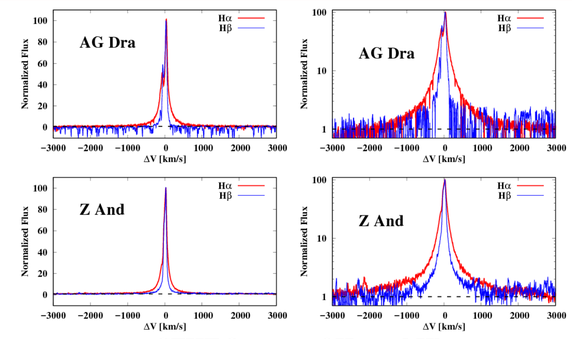
Hα Wings in Symbiotic Stars (Skopal 2006)

Symbiotic stars are interacting binary system composed of a mass losing red giant and a white dwarf. The optical spectra of symbiotic stars show Raman scattered lines and strong broad Hα wing of which the width are broader than 1,000 km/s. According to IR spectra, symbiotic stars are classified into 'S' type and 'D' type. D-type symbiotic stars exhibit an IR excess by a warm dust component with $T_e = 10^3$ K, but spectra of S-type don't include the excess. Those mean that this binary system consists of hot H II region near a white dwarf and cold H I region near a red giant.

3. AG Dra & Z And



	AG Dra	Z And
Type	S-Type	S-Type
P_{orbit}	550 Days	760 Days
M_{WD}	$0.5M_{sun}$	$0.75M_{sun}$
M_{Red}	$1.0M_{sun}$	$2.0M_{sun}$

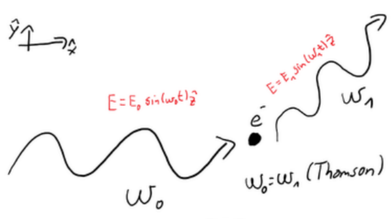


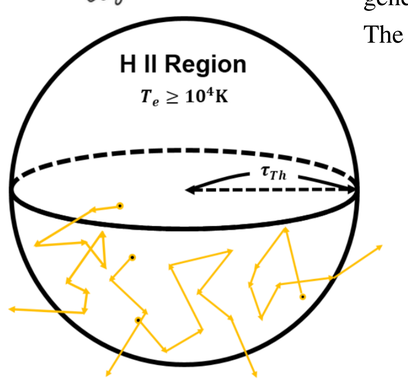
CFHT Spectra of Ha and Hb

The left panel show parameters and images of S-Type symbiotic stars, AG Dra and Z And. AG Dra is known to be a yellow symbiotic stars including a K-type giant component. Z And is regarded as a prototypical symbiotic star with an M-type giant.

In the right panel, we overplotted their normalized CFHT spectra of Ha and Hb in linear and logarithmic scale. The two overplotted spectra show different profile and strength of broad wings on $\Delta V > 500$ km/s. We adopt two scattering processes, Thomson scattering and Raman scattering to analysis the broad wings of Hα and Hβ.

4-1 Thomson Scattered Wing

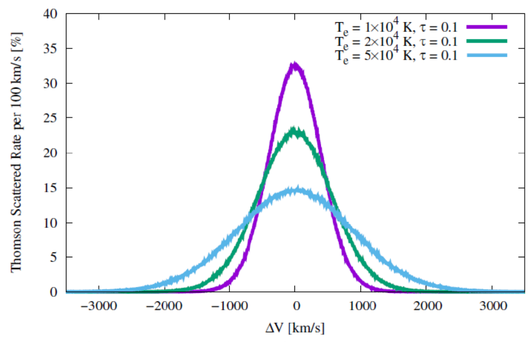




Scattering Geometry

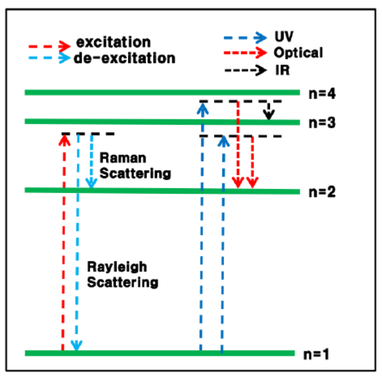
In H II region, photons are Thomson scattered by free electrons. This processes is wavelength independent for fixed cross section $\sigma = 0.665\times10^{-24}$ cm^2. For this reason, Thomson scattered show same widths at any emission lines.

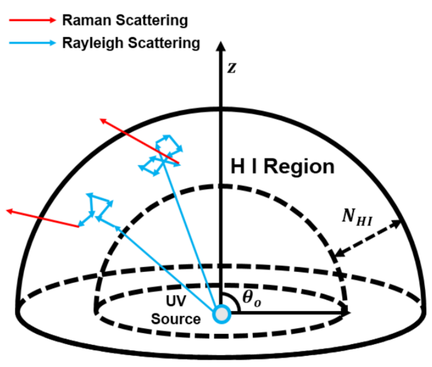
We consider uniform scattering and emission spherical region and generate Thomson scattered wings for various electron temperature T_e. The wing follows thermal **Gaussian distribution** of free electrons.



Thomson Scattered Wings for Various Temperature

4-2 Raman Scattered Wing

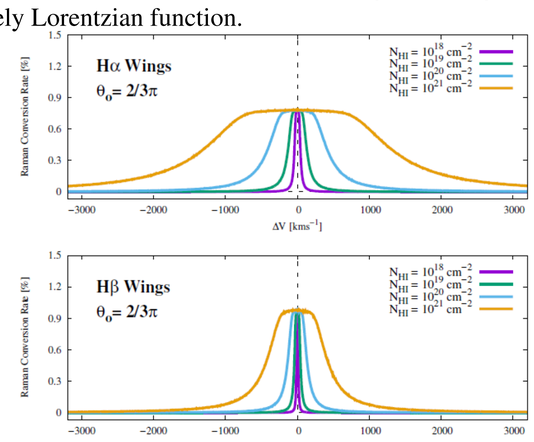




Scattering Geometry

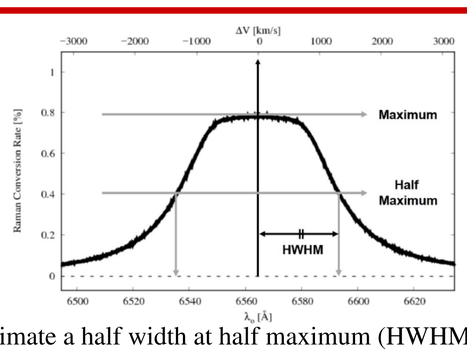
Raman scattering is inelastic scattering by atomic hydrogen. When UV photon excite bound electron from $n = 1$ to $n > 2$, excited electron is de-excited to $n = 1$ or intermediate states. The transition between $n > 2$ and intermediate state is termed Raman scattering.

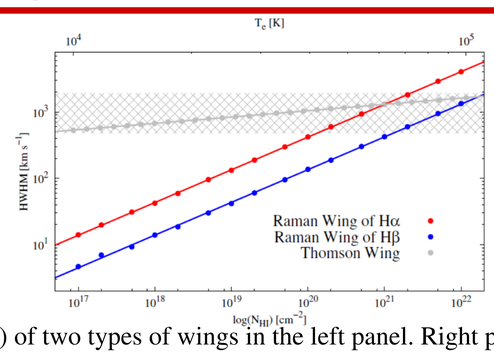
We assume half spherical H I region and flat UV continuum and compute Raman scattered wings of Hα and Hβ of which widths are different. The wings broaden for higher H I column density N_{HI} follow **Lorentzian function** as the total cross section by atomic hydrogen are approximately Lorentzian function.



Raman Scattered Wings for Various Column Density

4-3 Widths of Scattered Wings





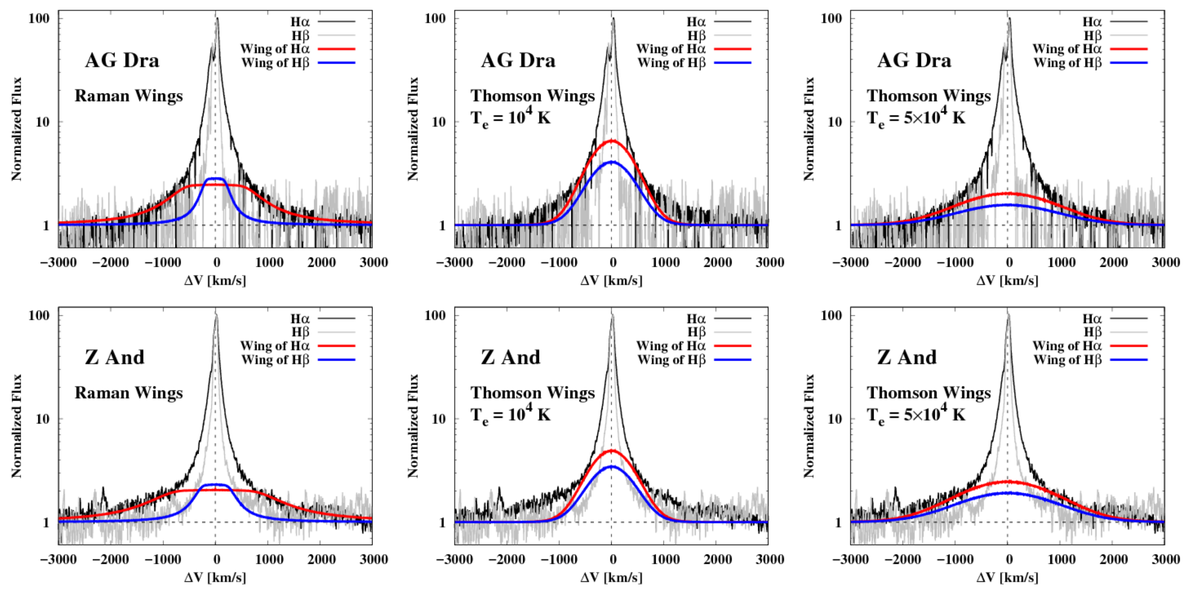
We estimate a half width at half maximum (HWHM) of two types of wings in the left panel. Right panel relation between HWHM and electron temperatures T_e for Thomson wings and HWHM and column densities N_{HI} for Raman wings. We drive those relations,

$$\mathrm{HWHM_{Raman\,H\alpha}} = 418\ \mathrm{N_{20}^{0.49}\ km\ s^{-1}} \qquad \mathrm{N_{20}} = \frac{\mathrm{N_{HI}}}{10^{20}\mathrm{cm^2}}$$

$$\mathrm{HWHM_{Raman\,H\beta}} = 135\ \mathrm{N_{20}^{0.49}\ km\ s^{-1}} \qquad \mathrm{T_4} = \frac{\mathrm{T_e}}{10^4\mathrm{K}}$$

$$\mathrm{HWHM_{Thomson}} = 532\ \mathrm{T_4^{0.49}\ km\ s^{-1}}.$$

5. Results

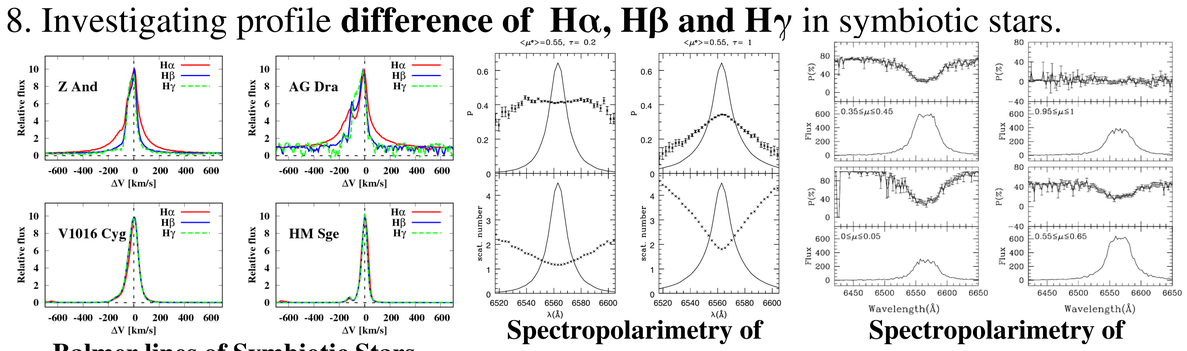


In logarithmic scale, we fitted both spectra of Hα and Hβ through same scattering process to reveal origin of Balmer broad wings. Figures are the top panels for AG Dra and bottom panels for Z And. In the left panels, we fitted broad wings using Raman scattered wings. We set column densities $N_{HI} = 5\times10^{20}$ cm^{-2} for AG Dra and 10^{22} cm^{-2} for Z And. In the center and right panels, we consider two type of Thomson wings, normal H II region on $T_e = 10^4$ K (center) and hot H II region on $T_e = 5\times10^4$ K (right).

We notice that Raman wings provide better fit than Thomson wings. When we consider only Thomson wings, hot H II region are more well-fitted than normal H II region. However, Thomson cross section is too small to generate enough scattered photon in hot H II region.

6. Summary & Future Works

1. Spectra of symbiotic stars show **broad wings around Hα.**
2. **Thomson wings** are broadened by high **electron temperature T_e.**
3. The HWHM of Thomson wings have to be exceeded 550 km/s.
4. **Raman wings** are broadened by high **H I column density N_{HI}.**
5. Raman wings of Hα and Hβ show **different widths.**
6. Raman wings show better fit than Thomson wings in S-type symbiotic star.
7. Analysis of two wings on **spectropolarimetry.**
8. Investigating profile **difference of Hα, Hβ and Hγ** in symbiotic stars.



Balmer lines of Symbiotic Stars | **Spectropolarimetry of Thomson Scattering** | **Spectropolarimetry of Raman Scattering**

7. Reference

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