Formation of Broad Balmer Wings in Symbiotic Stars

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1. Abstract

Symbiotic stars are binary systems composed of a hot white dwarf and a mass losing giant. These objects exhibit many prominent emission lines and also show Raman scattered O VI features at 6825 and 7088. Another characteristic is the presence of broad wings around Balmer lines. Broad wings can be formed through Thomson scattering by free electrons and Raman scattering of Lyman beta and higher series by neutral hydrogen. In this poster presentation we produce broad wings around H alpha and H beta adopting a Monte Carlo technique via these mechanisms in order to make a quantitative comparison of these wings. Thomson wings are characterized by the exponential cut-off given by the thermal width whereas the Raman wings are dependent on the column density and continuum shape in the far UV region. A brief discussion is provided.

2. Introduction

Symbiotic stars(SSs) are binary systems of a active white dwarf and a mass losing giant. Some fraction of slow stellar wind from the giant is gravitationally captured by and accreted onto the white dwarf. In this process of slow stellar wind accretion, it is controversial whether an accretion disk will be formed around the white dwarf. Strong far UV radiation from the hot white dwarf is responsible for the prominent emission lines in symbiotic stars. In particular, Balmer emission lines are accompanied by broad wings, for which the origin can be traced to Thomson scattering by free electrons, Raman scattering by neutral hydrogen or fast wind consisting of hot tenuous gas. In this poster presentation, a Monte Carlo method is adopted to produce wings via Thomson scattering and Raman scattering in order to make a quantitative comparisons.

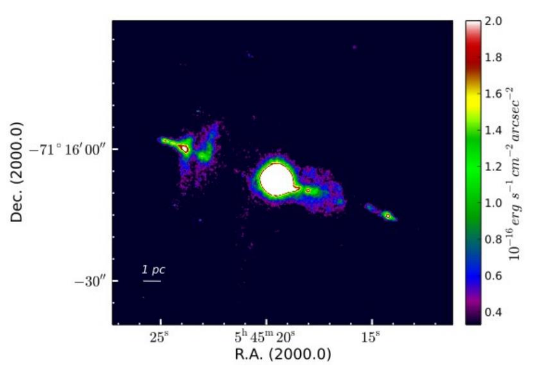
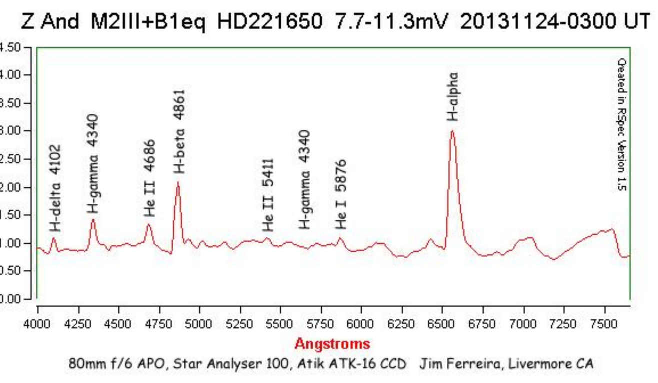
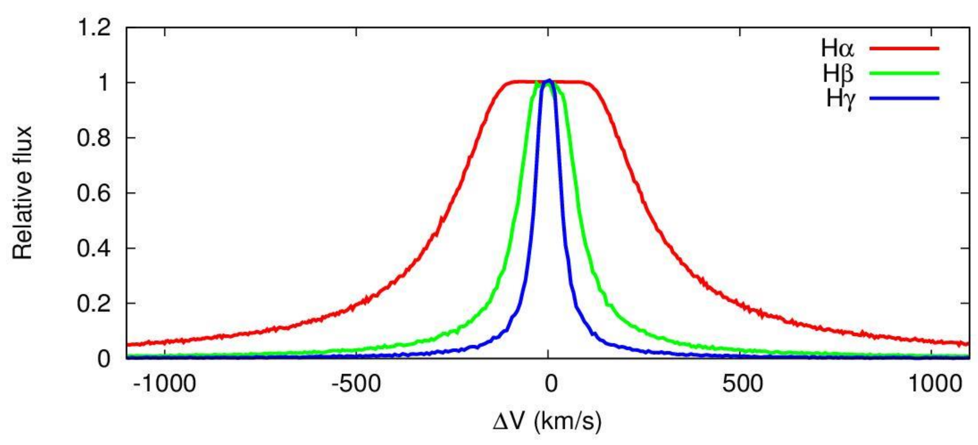


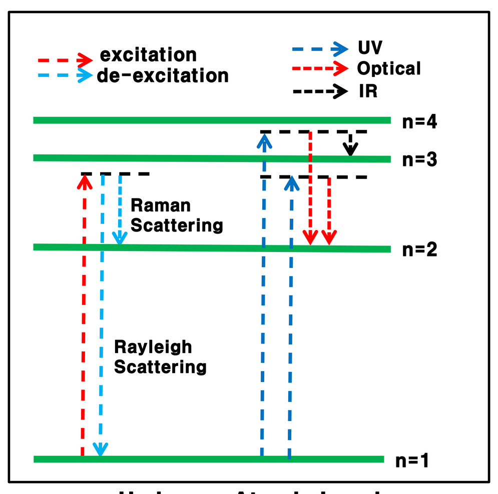
Image of Symbiotic Stars, Sanduleak's star (Angeloni et al. 2011)



Spectrum of Symbiotic Stars, Z And

◆ Raman Scattering



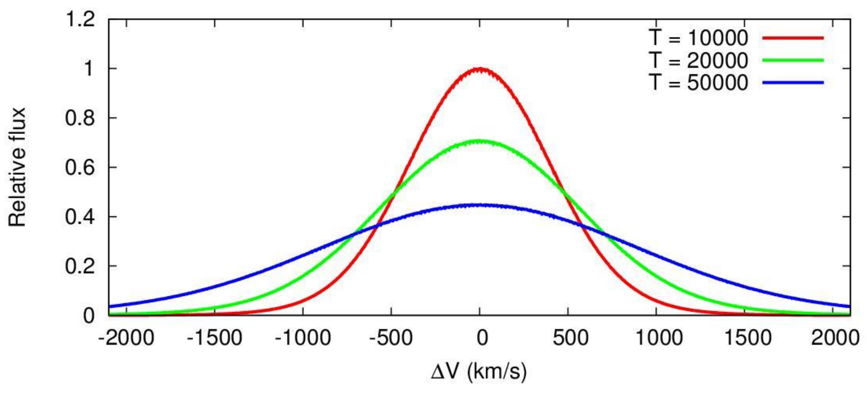


Hydrogen Atomic Level

Raman scattering by atomic hydrogen

1. A far UV photon is incident on a hydrogen atom in the ground state.
2. The hydrogen atom de-excites into 2s state with a re-emission of an optical photon.
3. Inelasticity of scattering broadens the profile width.

◆ Thomson Scattering



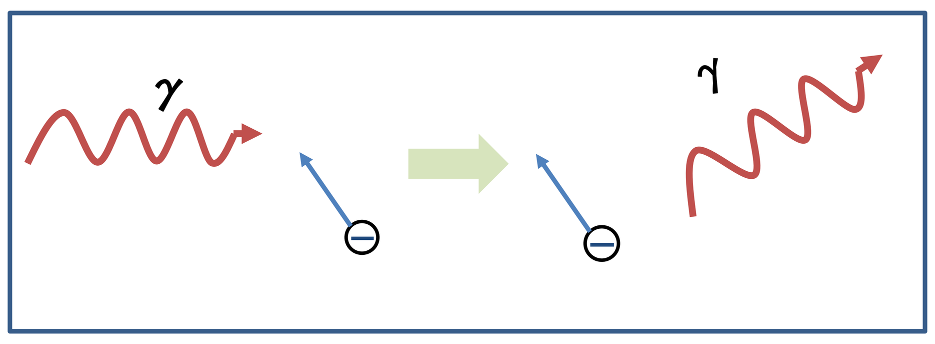
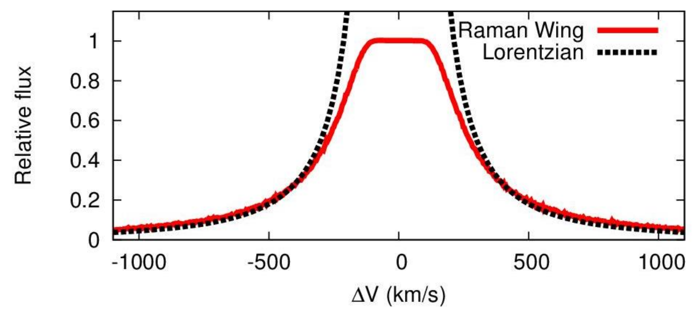


Diagram of Thomson Scattering

Thomson scattering by free electrons

1. Free electrons move much faster than heavy ions, which results in line broadening.
2. The wing widths are determined by the electron temperature and the wing flux is determined by the Thomson scattering optical depth.

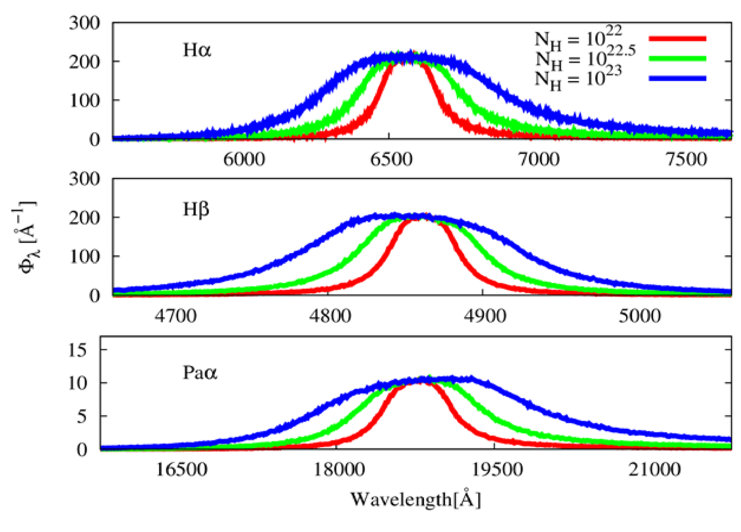
3. Properties of Raman scattering

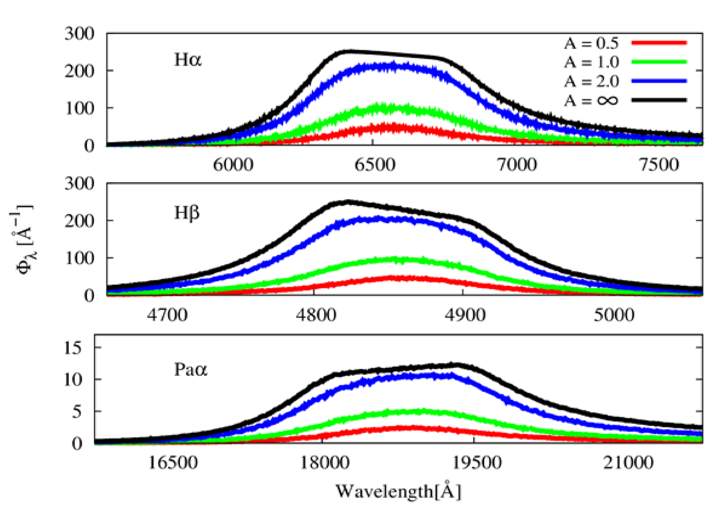


Raman scattering wings trace the total scattering cross section multiplied by the branching ratio. Lorentzian function provides an excellent fit to the line profile in an extended wavelength space encompassing the shoulder and wing regions.

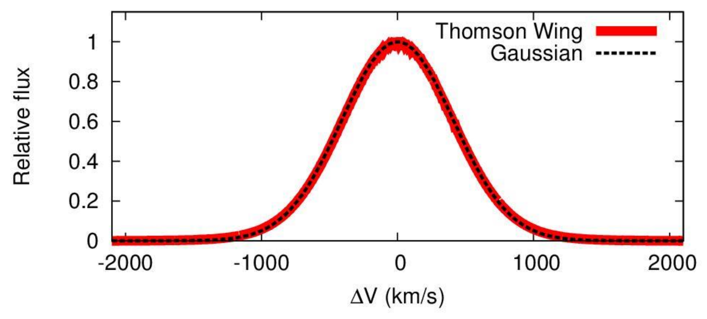
Raman wings are governed by two factors, one is the HI column density and the other is the covering factor of the scattering region.

1. When we increase the HI column density the wing width increases due to the increase of the wavelength range corresponding to the scattering optical depth of unity.
2. The covering factor determines the fraction of the scattered radiation out of the incident radiation yielding the overall strength of the wings.





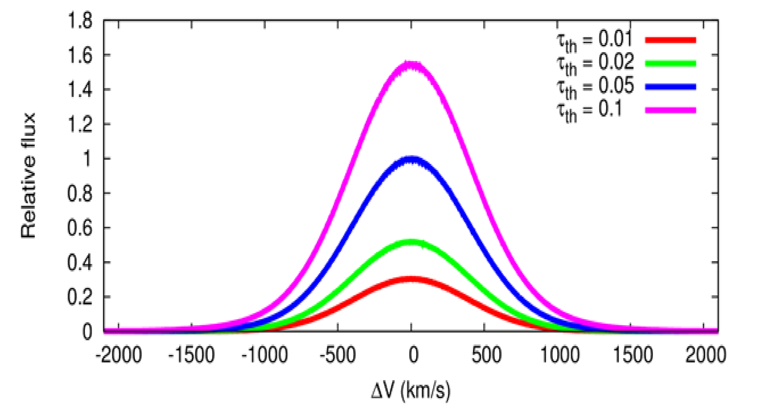
4. Properties of Thomson Scattering

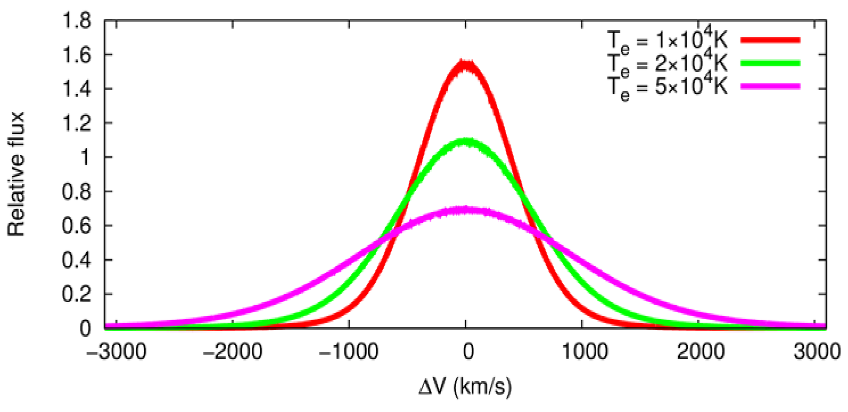


Thomson scattering wings by free electrons are well approximated by Gaussian. A typical width is ~500km/s for a temperature of the H II region ~ 10^4K

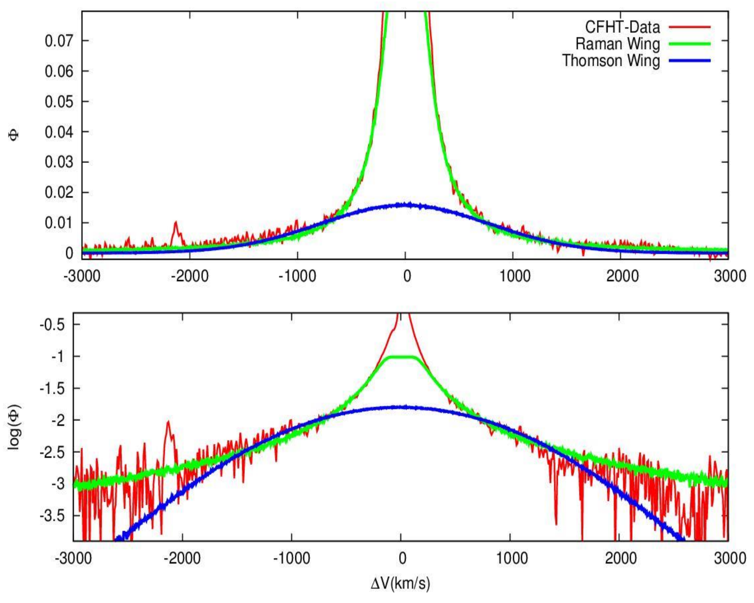
Thomson wings are characterized mainly by the column density and the temperature of the free electron region.

1. As long as the Thomson scattering optical depth does not exceed unity, the overall strength of the Thomson wings is approximately proportional to the Thomson optical depth or the column density of free electrons.
2. The width of the Thomson wings is determined by the velocity distribution of free electrons and hence controlled by the temperature.





5. Comparison of Raman and Thomson Wings



We overplot the Thomson and Raman wings around H alpha in the Doppler parameter space. It appears that the both scattering wings provide an overall satisfactory fit to the observed data, the spectrum of Z And.

The same overplot of the Thomson and Raman wings using the logarithmic scale in the vertical axis. The exponential cut-off of the Thomson wings is clearly seen in this log scale plot.

Thomson and Raman Wings with CFHT-Data, Z And

6. Summary and Discussion

1. The widths and strengths of Thomson wings are determined by the temperature and scattering optical depth of the ionized region, whereas those of Raman wings are governed by the HI column density and the strength of far UV radiation.
2. Thomson wings exhibit an exponential cut-off, which may be revealed in a log-scale plot from an observational data with a sufficient signal-to-noise ratio.
3. Raman wings for higher Balmer series emission exhibit narrower widths due to atomic physical properties.

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