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Examples of scattering processes in symbiotic binaries

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Abstract. Symbiotic stars (SS) are interacting binaries consisting of a cool giant and a white dwarf (WD). Their circumstellar environment is ideal for observing the effects of scattering processes. Here we introduce examples of Thomson, Rayleigh and Raman scattering and determined the efficiency for the latter to 10 % for V1016 Cyg. The investigation of symbiotic star's environment throughout the scattering processes can provide valuable information about, for example, physical properties of the symbiotic nebula (Thomson scattering), physical conditions around the hot WD (Raman scattering) and the ionization structure in the binary (Rayleigh scattering).
Key words: binaries: symbiotic

1. Thomson scattering

The radiation arising close to the WD can be scattered by free electrons in the ionized environment of the binary - the symbiotic nebula (SN). Despite its extremely small cross section, $\sigma_T = 6.625 \times 10^{-25}\mathrm{cm}^2$, the conditions around the WD are sufficient to observe the effect of Thomson scattering in the form of very broad wings of intense emission lines, such as OVI 1032Å, 1038Å and HeII 1640Å (Fig. 1). By modeling the theoretical line profiles (see Castor et al., 1970) we determined the mean electron optical depth, τ_e, and the mean electron temperature, T_e, in AG Dra (Sekeráš & Skopal, 2012). The mean value of T_e increases from quiescent to active phases from 19 200 K to 32 300 K and that of τ_e from 0.056 to 0.64, respectively. The increase of τ_e during the active phase indicates a supplement of free electrons into the SN from the enhanced ionized wind from the WD.

2. Raman scattering

When the radiation produced in the SN passes through the neutral part of the giant's wind, it can be Raman or Rayleigh scattered by the hydrogen atoms (Nussbaumer et al. 1989). Raman scattering is a process when a photon excites the atom from its ground state to an intermediate state, which is immediately stabilized by a transition to a different lower main energy level, resulting in

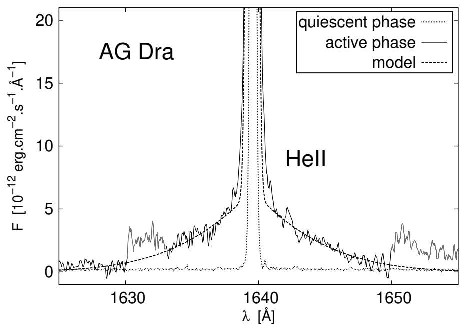

Figure 1. Broadening of the HeII 1640Å line wings by Thomson scattering in symbiotic star AG Dra during an active phase (Sekeráš & Skopal, 2012).

emitting a photon of a different frequency. The most famous examples of Raman scattering are represented by emission lines at 6825Å and 7082Å, as a result of the scattering OVI 1032Å, 1038Å line photons by neutral hydrogen. Some HeII emission lines are also very suitable for Raman scattering (e.g. Lee et al. 2003). For example, in the broad wings of the Hα line at 6545Å, there is an emission from the Raman scattered line HeII 1025Å. We investigated this case on our original spectrum of V1016 Cyg, obtained by the 1.88-m telescope of the David Dunlap Observatory, University of Toronto, equipped with a single-dispersion spectrograph in April 2006 (Fig. 2). Assuming that the nearby HeII 6527Å line originates in the same region as the HeII 1025Å line, the linewidth of the observed 6545Å emission feature satisfies the expected broadening by the Raman transition with a factor of 6.4. From theoretical intensities of HeII emission lines

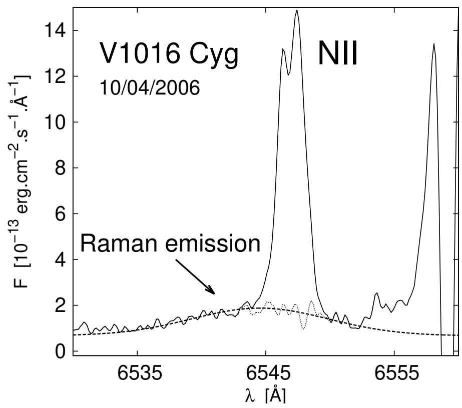

Figure 2. Raman emission in the spectrum of symbiotic star V1016 Cyg (Sekeráš & Skopal, in preparation).

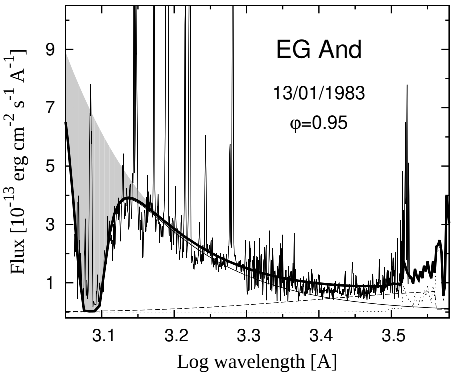

Figure 3. Attenuation of the continuum in the spectrum of symbiotic star EG And by the Rayleigh scattering (gray area, Skopal, 2005).

we were able to determine the Raman scattering efficiency to 10 %. Our results are consistent with those derived by Lee et al. (2003).

3. Rayleigh scattering

When the continuum radiation from the WD passes the neutral part of the giant's wind (for systems with high orbital inclination), it can be Rayleigh scattered. Here an atom excited from its ground state to an intermediate state is immediately stabilized by a transition to the same bound state, followed by reemission of a photon with the same wavelength. The effect is well indicated as an attenuation of the continuum around hydrogen lines of the Lyman series (e.g. Vogel, 1991, here Fig. 3). From this continuum absorption we can determine the column densities around the cool giant as a function of the orbital phase, and thus to map the ionization structure of the symbiotic binary.

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