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Stellar Wind Accretion and Raman O VI Spectroscopy of the Symbiotic Star AG Draconis

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Abstract. Raman scattered O VI features at 6825 Å and 7082 Å found in symbiotic stars are important spectroscopic tools to probe the mass transfer process. Adopting a Monte Carlo approach, we perform a profile analysis of Raman O VI features of the yellow SySt AG Draconis and make a comparison with the spectrum obtained with CFHT. It is assumed that the accretion flow is convergent on the entering side with enhanced O VI emission and the flux ratio $F(1032)/F(1038) \sim 1$, whereas on the opposite side the flow is divergent with low O VI emission and $F(1032/F(1038) \sim 2$. Our best fit to the spectrum is obtained from our model with a mass-loss rate of the giant $\sim 4 \times 10^{-7}\ \mathrm{M_\odot\ yr^{-1}}$. A slight red wing excess in the spectrum suggests the presence of bipolar neutral components receding in the directions perpendicular to the binary orbital plane with a speed $\sim 70\mathrm{km\ s^{-1}}$

Keywords. binaries: symbiotic - stars: individual: (AG Dra) - accretion disks - radiative transfer

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1. Raman O VI Spectroscopy of the Symbiotic Star AG Draconis

Symbiotic stars (SySts) are a wide binary system of a giant and a hot white dwarf, where various astrophysical activities are attributed to accretion of a fraction of slow stellar wind from the giant. Very broad features at 6825 Å and 7082 Å, unique to symbiotic stars, are formed through Raman scattering of O VI 1032 Å and 1038 Å with atomic hydrogen (Schmid 1989). They are characterized by complicated profiles that reflect the kinematics of the O VI emission region around the white dwarf. AG Dra, having a K type giant mass donor, is known as a yellow symbiotic star.

We present our high resolution spectrum of AG Dra obtained with the ESPaDOnS installed on the *Canada-France-Hawaii Telescope* on 2014 September 6. In Fig. 1, the upper and lower panels show the parts of the *CFHT* spectrum of AG Dra around Raman O VI 6825 Å and 7082 Å, respectively. The 7082 Å feature exhibits a clear double peak structure, whereas a prominent blue shoulder is found in the 6825 Å feature. The full width at zero intensity (FWZI) is measured to be $200\ \mathrm{km\ s^{-1}}$.

2. Raman O VI Profile Analysis

Fig. 2 shows a schematic illustration of the model adopted in our profile analysis. The slow stellar wind region around the giant is identified with the Raman scattering site, on

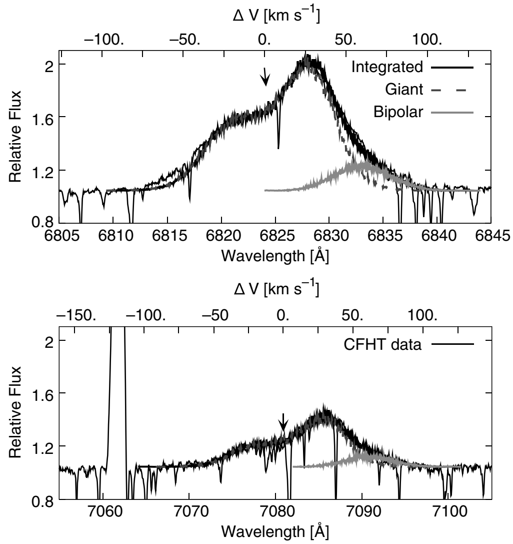

Figure 1. Our best fit result is consistent with the assumption of the asymmetric accretion flow around the white dwarf and additional receding components.

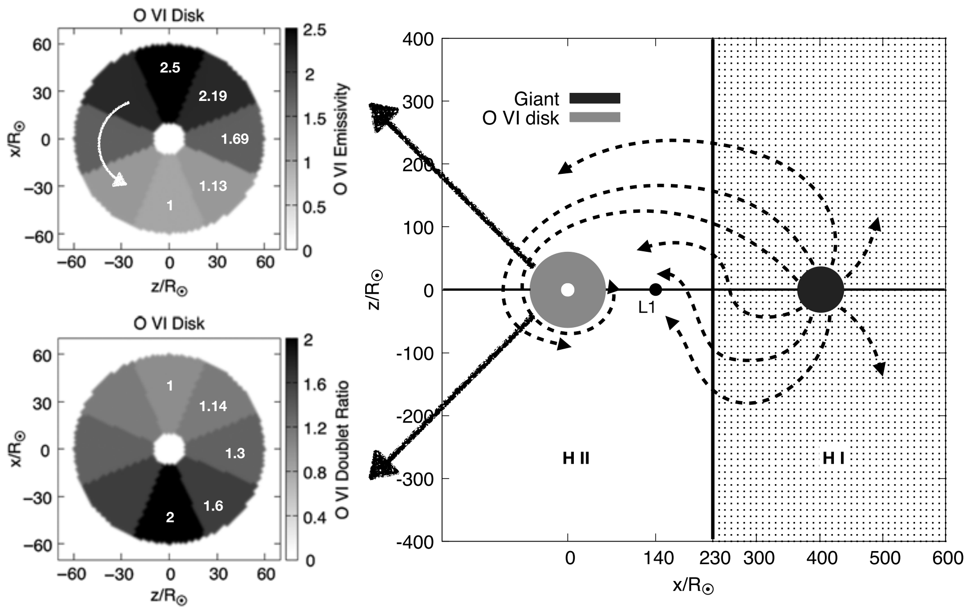

Figure 2. Schematic illustration of the ionization front of AG Dra. Inset figures are the emissivity of O VI (upper panel) and flux ratios (lower panel) as a function of the azimuthal angle.

which copious O VI 1032 Å and 1038 Å photons are incident. We also assume that the O VI emission region constitutes a part of the accretion flow around the white dwarf, where the entering side is of higher density than the opposite side (Heo & Lee 2015).

Based on the measured FWZI, we take the range of Keplerian velocities of the O VI emission region from 40 km s^{-1} to 70 km s^{-1} with the white dwarf mass $M_{WD} = 0.5\,M_{\odot}$ (Mikołajewska 2002). In view of the clear disparity of the 6825 Å and 7082 Å profiles, we

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also consider the flux ratio $F(1032)/F(1038)$ varying locally, where $F(1032)/F(1038) \sim 1$ near the entering region and increases to ~ 2 on the opposite side.

The best fit is obtained with the mass loss rate of the giant $\dot{\mathrm{M}} = 4 \times 10^{-7}\,\mathrm{M}_{\odot}\ \mathrm{yr}^{-1}$, for which the Raman conversion efficiency ~ 0.1 is deduced (e.g. Birriel *et al.* 2000). We also find excess in the red wing part in both the 6825 Å and 7082 Å features, which can be explained by placing additional neutral regions moving away from the binary orbital plane in the perpendicular directions with a speed of $70\,\mathrm{km\ s}^{-1}$. We propose that the additional neutral component may be associated with the collimated outflows in AG Dra reported in the radio study by Torbett & Campbell (1987).

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