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MIKE High Resolution Spectroscopy of Raman-scattered O VI and C II Lines in the Symbiotic Nova RR Telescopii

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Abstract. We present a high-resolution optical spectrum of the symbiotic nova RR Tel obtained with *MIKE* at Magellan-Clay telescope. RR Tel is a wide binary system of a hot white dwarf and a Mira with an orbital period of a few decades, where the white dwarf is accreting through gravitational capture of some fraction of material shed by the Mira. We find broad emission features at 6825, 7082, 7023, and 7053 Å, which are formed through Raman scattering of far-UV O VI $\lambda\lambda$ 1032 and 1038 Å, C II $\lambda\lambda$ 1036 and 1037 Å with atomic hydrogen. Raman O VI features exhibit clear double-peak profiles indicative of an accretion flow with a characteristic speed ~ 30 km s^{-1}, whereas the Raman C II features have a single Gaussian profile. We perform a profile analysis of the Raman O VI by assuming that O VI emission traces the accretion flow around the white dwarf with a fiducial scale of 1 AU. A comparison of the restored fluxes of C II $\lambda\lambda$ 1036 and 1037 from Raman C II features with the observed C II λ1335 multiplet is consistent with the distance of RR Tel $\sim$ 2.6 kpc based on interstellar extinction of C II.

Keywords. binaries: symbiotic - stars: individual (RR Tel) - line: profiles - radiative transfer

1. Raman O VI Features and Accretion Flow

Unique spectral features at 6825 and 7082 Å with a broad width $\sim$ 20 Å are detected in a majority of symbiotic stars (Harries & Howarth 1996). The emission bands were identified as Raman-scattered O VI $\lambda\lambda$ 1032 and 1038 features by H I (Schmid 1989). Subsequent studies reveal that the Raman O VI features provide strong constraints on the kinematics of emission nebulae around the white dwarf and extend our understanding of the mass loss process in symbiotic systems (e.g. Heo *et al.* 2016).

In Fig. 1, we present the Raman-scattered O VI $\lambda\lambda$ 1032 and 1038 features at 6825 and 7082 Å of RR Tel in the left and right panels, respectively. The observations were performed on 2017 July 26 with *MIKE* spectrograph mounted on the Magellan-Clay telescope. The Raman O VI features of RR Tel are characterized by double-peak profiles with a peak separation of $\sim$ 60 km s^{-1}. The inelasticity of Raman-scattering requires that the Raman profiles reflect only the relative kinematics between the emission region and the scattering region, irrespective of the observer's sightline. The observed profiles of Raman O VI features are well fit with an O VI accretion disk around the white dwarf with a physical size of 1 AU. The disparate profiles of the two Raman O VI features are attributed to the local variation of the ratio $F(1032)/F(1038)$ in the O VI accretion disk

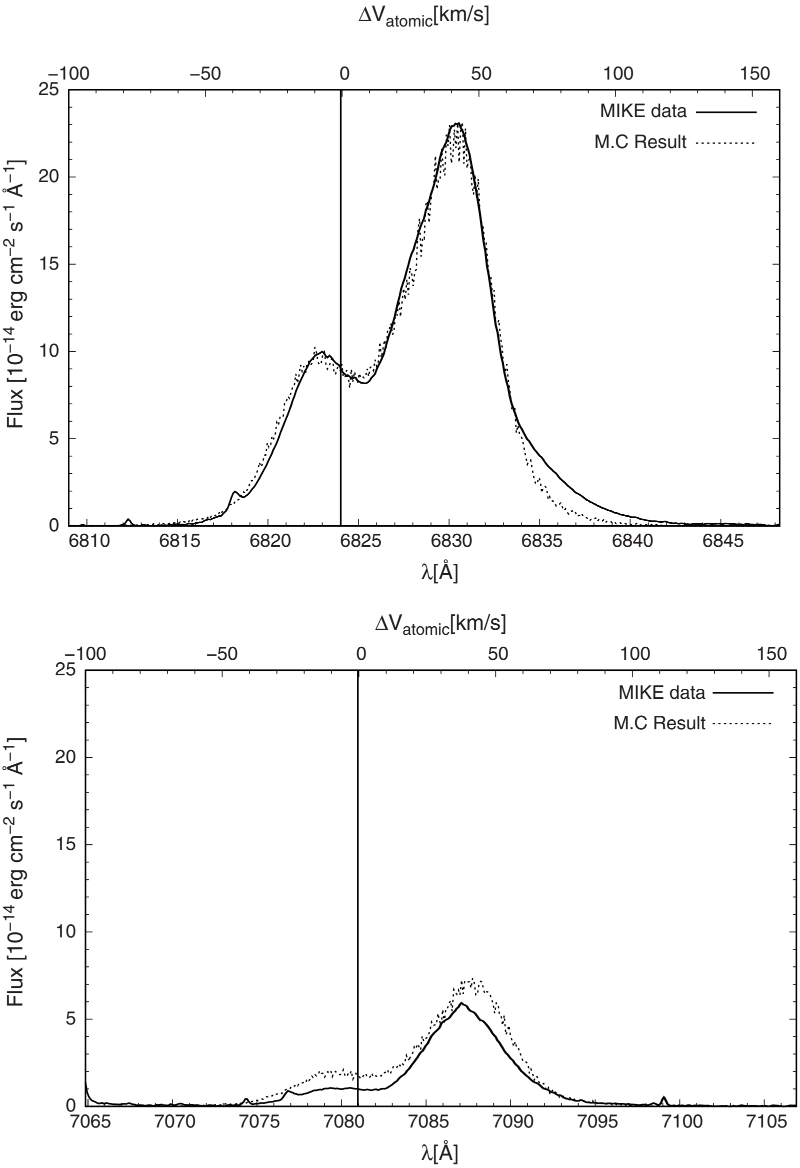

Figure 1. The Raman-scattered O VI $\lambda\lambda$1032 and 1038 at 6825 Å (left) and 7082 Å (right) in RR Tel. The solid line shows the *MIKE* observation, while the dotted line represents the result of our Monte Carlo simulations.

as discussed by Heo & Lee (2015). The red emission part, assumed to be of high density, is characterized by the flux ratio $F(1032)/F(1038) \sim 1$, whereas the blue emission region is much more sparse resulting in $F(1032)/F(1038) \sim 2$. Adopting the asymmetric O VI accretion disk model supplemented by the locally varying $F(1032)/F(1038)$, the best fit result is obtained for the mass loss rate $\dot{M} \sim 2\times\ 10^{-6}$ $M_\odot$ yr^{-1} and the giant wind terminal velocity $v \sim 10$ km s^{-1}.

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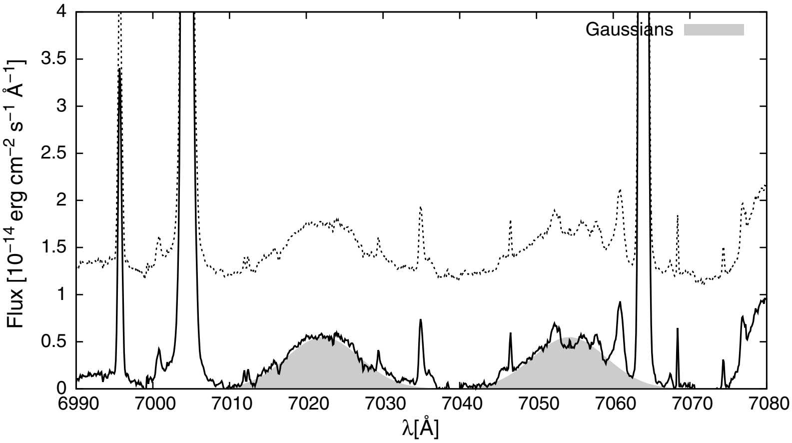

Figure 2. The Raman-scattered C II λλ1036 and 1037 at 7025 and 7052 Å. Our best fits with single Gaussian are shown by gray shaded regions.

2. Raman C II Features and Interstellar Extinction

Schild & Schmid (1996) detected two weak, broad emissions at 7023 and 7054 Å in the symbiotic nova V1016 Cyg. They identified the emission features as Raman-scattered lines of C II doublet λλ 1036 and 1037 Å by H I. Fig. 2 shows our *MIKE* spectrum of RR Tel in the range of the Raman C II features. The two features are well fitted with a single Gaussian profile, whose FWHM $\sim$ 11.3 Å and the center wavelengths of 7022.2 and 7054.3 Å, respectively. The total fluxes are obtained with $F(7023) = 6.56 \times 10^{-14}$ erg cm^{-2} s^{-1} and $F(7054) = 6.55 \times 10^{-14}$ erg cm^{-2} s^{-1}, which are about 6 times weaker than Raman O VI 1038 feature.

From our Monte Carlo analysis of the observed Raman scattered C II features, significant fluxes of C II λλ 1036 and 1037 $F(1036) = 6.06 \times 10^{-10}$ erg cm^{-2} s^{-1} and $F(1037) = 6.05 \times 10^{-10}$ erg cm^{-2} s^{-1} are expected, respectively. These far-UV lines are absent in the *FUSE* data, whereas the *IUE* data indicate the presence of C II 1335 triplet, implying the heavy interstellar extinction of C II λλ 1036 and 1037. The optical depths of C II λλ 1036 and 1037 and C II 1335 deduced from the comparison of the *FUSE* data, *IUE* data and Raman C II fluxes lead us to estimate the lower bound of the C II column density $N(CII) \sim 1.50\times10^{14}$ cm^{-2} toward RR Tel, which appears consistent with the presumed distance $D \sim 2.6$ kpc.

Acknowledgements

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