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 λλ 1032 and 1038 Å, C II λλ 1036 and 1037 Å with atomic hydrogen. Raman O VI and 7082 features exhibit clear double-peaked profiles indicative of an accretion flow with a characteristic speed ~ 30 km/s, 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 representative scale of 1 AU. We also find O VI doublet at 3811 and 3834 Å, which are blended with other emission lines. Our profile decomposition shows that the O VI λλ 3811 and 3834 doublet exhibit a single Gaussian profile with a width ~ 25 km/s. A comparison of the restored fluxes of C II λλ 1036 and 1037 from Raman C II features with the observed C II λ 1335 multiplet is consistent with the distance of RR Tel = 2.6 kpc based on interstellar extinction of C II.

1 RR Telescopi

- dusty-type symbiotic nova consisting of a Mira variable and a white dwarf (Whiteoak 2003)
- After a nova-like outburst in 1944, its brightness is slowly fading from its peak V ~30 mag in 1946 to V = 11.5 mag in 2017.
- Distance ~ 2.6 kpc (Schmidt & Schild 2002)

2 MIKE Observation

- The Magellan Inamori Kyocera Echelle (MIKE)
- 6.5-m Magellan-Clay Telescope, Las Campanas Observatory, Chile
- Spectral Coverage: (Blue) 3,350 ~ 5,000 Å (Red) 4,900 ~ 9,500 Å
- Resolving Power: (Blue) R = 27,000 (Red) R = 35,000
- Observed on 26 July, 2017 with total exposure time of 2,400 sec
- We find broad features at 6825, 7023, and 7053 Å, which are formed through Raman scattering of O VI and C II by H.

3 Raman-Scattered Features in RR Tel

- Raman scattering is an inelastic scattering process generating a photon with frequency different from that of an incident photon. The incident photon with hν = hν0 + IE, resulting in a significantly longer wavelength than the incident one and a broad width amplified by s/c.
- The heterogeneity environment in the symbiotic stars (SSs) includes the nebular region photoionized by strong far-UV radiation from the hot source and the dense neutral region around the cool companion, providing an excellent laboratory to study Raman scattering by H (Schmidt 1997).

4 Emission Region Model

- Raman O VI features of RR Tel are characterized by double-peaked profiles with peak separation of ~ 60 km/s, whereas the Raman C II features at 7023 and 7053 Å exhibit a single Gaussian profile with FWHM ~ 10 Å.
- 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 features are well fit with the emission nebulae around the white dwarf with a hierarchical structure characterized by the inner O VI accretion disk and the extended C II region.
- The disparate profiles of two Raman O VI features are attributed to the local variation of the ratio F(Raman)/F(O VI) in the O VI accretion disk. The red emission part, assumed to be of high density, is characterized by the flux ratio F(Raman)/F(O VI) ~ 1.
- Adopting the asymmetric O VI accretion disk model supplemented by the locally varying F(Raman)/F(O VI), the best fit is obtained for the mass loss rate M = 2x10^{-14} M☉/yr and the giant wind terminal velocity v = 10 km/s.

5 O VI λλ 3811, 3834 Doublet

- We find O VI λλ 3811, 3834 doublet, which are significantly blended with other lines. Profile decomposition is performed to isolate O VI λλ 3811, 3834 doublet. The profile width of O VI doublet of ~ 25 km/s is inferred from N V λλ 4603, 4611 and C IV λλ 5801, 5812 doublets having isoelectronic configurations and not blended. O VI λ 3811 line is blended with OVI λ 3810. To decompose the blended profiles into four emissions (He II 3833, He I 3833, O VI 3834 and H I 3835) at 3834 Å, use is made of the profiles of H I 3889 & He II 3887, and H I 4965 & 4967 lines.

6 C II and Interstellar Extinction

- Significant fluxes of C II λλ 1033, 1037 and F(1037) = 0.9 x 10^{-19} erg cm^{-2} s^{-1} and F(1033) = 0.2 x 10^{-19} erg cm^{-2} s^{-1} are expected, respectively, from our Monte Carlo analysis of the observed Raman scattered C II features.
- These far-UV lines are clearly absent in the FUSE data, whereas the IUE data indicate the presence of C II λλ 1033 triplet, implying the heavy interstellar extinction of C II λλ 1036, 1037. The optical depths of far-UV C II λλ 1036 and 1037 and C II λ 1335 deduced from the comparison of the FUSE data, IUE data and Raman C II features lead us to estimate the lower bound of the C II column density N(C II) ~ 9.8x10^{17} cm^{-2} toward RR Tel, which appears consistent with the presumed distance D ~ 2.6 kpc.

7 References

- Yeom, T. & Kim, J. H. 2003, ASP Conf. Ser., 203, 41