Raman-scattered O VI λ1032 and He II λ1025 and Bipolar Outflow in the Symbiotic Star V455 Sco

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ABSTRACT

Raman-scattering by atomic hydrogen is a unique spectroscopic process that may probe the mass transfer and mass loss phenomena in symbiotic stars(SSs). In the high resolution spectra of the S-type SS V455 Sco obtained with the Magellan-Clay telescope, we note the presence of two Raman-scattered features, one at around 6825Å with a triple-peak profile formed from Raman scattering of O VI λ1032 and the other Raman-scattered He II λ1025 at around 6545Å. We transform the Raman O VI feature to the rest frame determined by the optical emission line He I λ7065 to find that the line center of the Raman O VI at 6825Å feature falls on the dip dividing the blue peak and the central peak. Adopting an accretion flow model with additional contribution from a collimated bipolar outflow, we propose that the blue and central peaks are contributed from the accretion flow and the bipolar flow is responsible for the remaining red peak. With the absence of [N II] λ6548, the Raman-scattered He II λ1025 at around 6545Å is immersed in the broad Hα wings that appear to be formed by Raman-scattering of far-UV continuum near Lyman series. Our Monte-Carlo line profile study of the Raman He II at 6545Å shows that the He II emission region may be localized to the part of the O VI emission region coreresponding to the Raman O VI central peak.

INTRODUCTION

Symbiotic Stars (SSs)

- Interacting wide binary systems of an active WD and a mass losing giant
- Slow stellar wind from the giant
- Classification
  D(Dusty)-type: a Mira variable with a thick dust shell
  S(Stellar)-type: a normal giant

Raman-scattering

- Inelastic scattering
- The wavelength of Raman-scattered radiation in vacuum :

$$\lambda_{RV} = \frac{\lambda_{Ly\alpha}\lambda_i}{\lambda_{Ly\alpha}-\lambda_i} \qquad (\lambda_{Ly\alpha} = 1215.67\text{Å})$$

- A strong far-UV emission region + a thick H I scattering region
- **Raman spectroscopy provides a unique opportunity to understand mass transfer process of the SSs.**

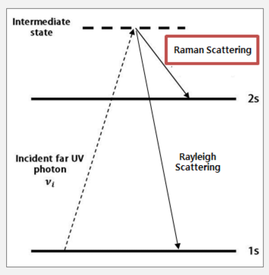

Fig 1. A Schematic diagram showing Raman scattering process involving H I

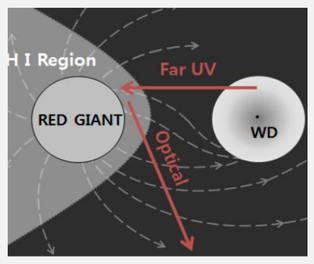

Fig 2. An illustration of Raman-scattering of far-UV radiation by H I in a SS

OBSERVATION

V455 Scorpii

- S(Stellar)-type symbiotic star
- A white dwarf + a M6.5 giant
- Distance ~ 4.3 kpc
- Orbital period ~ 1400 days

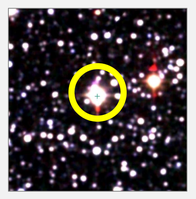

Fig 3. 2MASS image of V455 Sco

MIKE Observation

- The Magellan Inamori Kyocera Echelle
- 6.5m Clay Telescope , LCO, Chile
- Spectral Coverage: 4,900~9,500 Å
- Resolving Power: ~22,000
- Observing Date: 7, March, 2015
- Exposure Time : 1,000sec

Fig 4. Magellan-Clay Telescope

RAMAN O VI and BIPOLAR OUTFLOW

Triple-peak Profile

- A number of SSs exhibit broad emission features at around 6825Å and 7082Å which are formed through Raman-scattering of O VI λλ 1032, 1038 by atomic hydrogen (Schmid 1989).
- Raman O VI features in SSs are known to exhibit complicated profiles including double-peak profiles and triple-peak profiles and strong polarization.
- **In the V455 Sco spectrum (Fig. 5), the Raman-scattered O VI λ1032 feature exhibits a triple-peak profile.**
- We transformed the observed spectrum into the Doppler factor (ΔV) space (upper x-axis of Fig.5), which is measured by an imaginary observer that is at rest with respect to the giant.

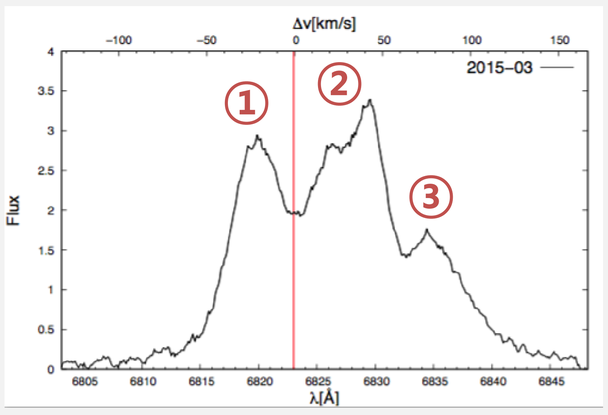

Fig 5. MIKE spectrum around the Raman-scattered O VI λ1032 at 6825Å. The upper axis corresponds to the Doppler factor ΔV

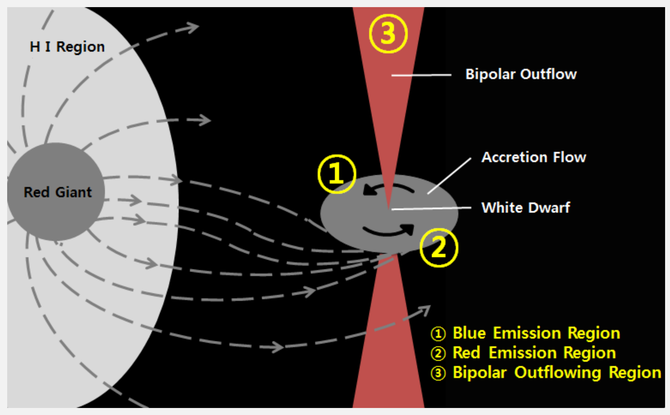

Fig 6. A schematic illustration of the accretion and bipolar outflow in V455 Sco

Accretion Flow + Bipolar Outflow Model

- In the Doppler factor(ΔV) space, the first dip is found to correspond to 0 km/s and the two main peaks are -30km/s and +40km/s.
- An accretion flow is divided into the "① Blue Emission Region (BER)" and the "② Red Emission Region (RER)", where the BER approaches and the RER recedes from the imaginary observer located at the giant.
- Adopting the accretion flow model, we propose that **① the blue peak and ② central peak are contributed from the accretion flow** around the WD. We find that the O VI emission region lies within 1AU from the WD.
- **③ The remaining red peak**, is formed from O VI coming from the bipolar outflowing region with a speed of ~+80km/s.

RAMAN He II λ1025

Raman He II λ1025 at 6545Å in Hα wing

- The presence of He II λ4686 and He II λ6527 emission lines in the V455 Sco spectrum implies the existence of the Raman-scattered He II features.
- **A Raman-scattered He II λ1025 at 6545Å was found by subtracting Hα wing given by $\Delta\lambda^{-2}$.** Without being blended by [N II] λ6548, it will contribute to clarifying the Raman-scattering processes of He II.

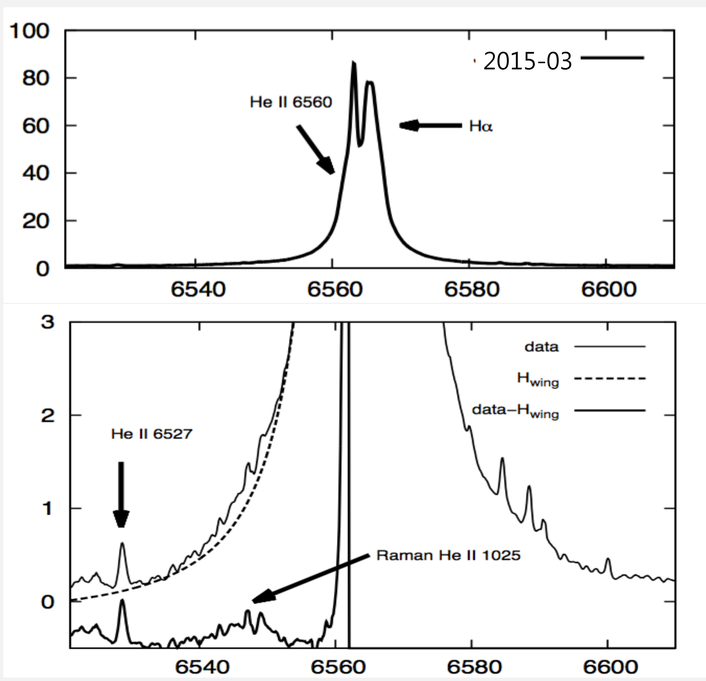

Fig 7. MIKE spectrum of the V455 Sco near Hα. Hα wings were subtracted using $\Delta\lambda^{-2}$ profile to isolate the Raman He II feature.

DISCUSSION

1) Spectropolarimetry will provide more interesting information regarding the mass transfer process. We expect that the third peak of Raman O VI is polarized with the position angle differing by π/2 from that of the blue and central peaks.
2) It is noteworthy that the profile of Raman-scattered O VI λ1032 at 6825Å feature differs from that of its twin 7082Å feature. A detailed quantitative comparison of the two Raman O VI profiles could provide a good amount of information about the density structure in the O VI emission region around hot WD.
3) We also find a Raman-scattered He II λ972 feature at 4850Å. A profile analysis of the two Raman He II features will allow us to investigate the H I column density and the covering factor of the scattering region and furthermore, estimate the mass loss rate in SSs.

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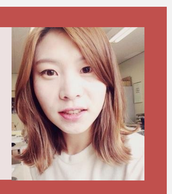

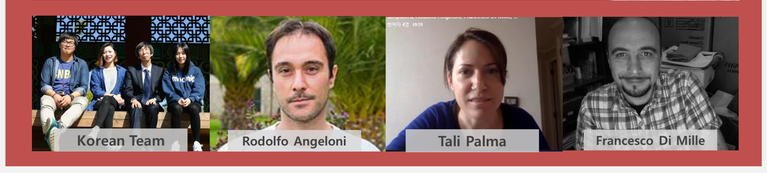

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