O VI Raman Spectroscopy of the S-type 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. We present the high-resolution spectra of the S-type symbiotic star V455 Sco obtained with the Du Pont telescope and Magellan telescope in Las Campanas Observatory, Chile. We note that the Raman-scattered O VI λ1032 at 6825 Å exhibits a triple-peak profile. Adopting an accretion flow model with an additional contribution from a collimated bipolar outflow, we propose that the blue and central peaks are formed via Raman-scattering of O VI line photons from the accretion flow and that the bipolar flow is responsible for the remaining red peak. In this work we consider the two possibile scenarios for the red peak. In the first scenario we place a clumpy O VI emission region in the bipolar flow that has a recession speed of ~+70km/s. In the other scenario, there exists clumpy neutral blobs immersed in the hot tenuous bipolar wind. It is also noted that V455 Sco exhibits the Raman-scattered He II λ1025 feature at 6545 Å without being blended by [N II] λ6548. We perform Monte Carlo simulations to show that our spectra can be successfully fitted.

1. INTRODUCTION

Symbiotic Stars

- Interacting binaries of a giant + an white dwarf
- Slow stellar wind from the giant
- D(dusty)-type: a Mira variable with thick dust shell
  S(stellar)-type: a normal giant

Raman Scattering

- Inelastic scattering

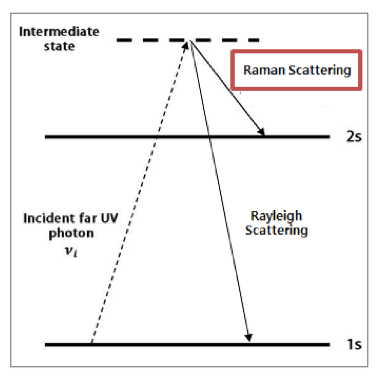


Fig 1. A schematic diagram showing the Raman scattering process involving H I

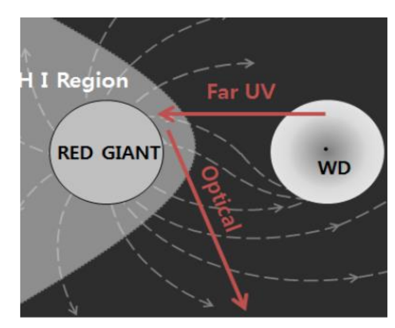


Fig 2. An illustration of Raman-scattering of far-UV radiation by H I in a symbiotic star

- The wavelength of Raman-scattered radiation in vacuum : $\lambda_{RV} = \frac{\lambda_{Ly\alpha}\lambda_i}{\lambda_{Ly\alpha}-\lambda_i}$ $(\lambda_{Ly\alpha} = 1215.67\text{Å})$
- 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 symbiotic stars.**

2. OBSERVATION

V455 Scorpii

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

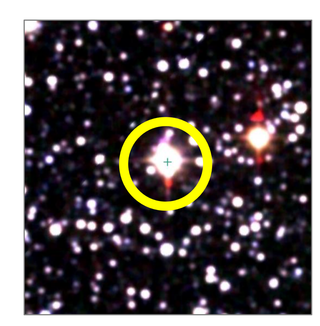
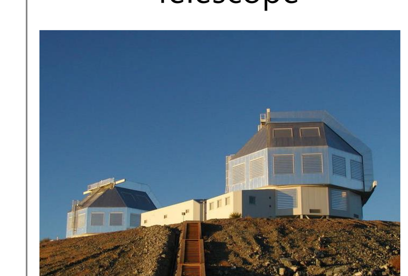


Fig 3. 2MASS image of V455 Sco

Echelle Spectrograph

Las Campanas Observatory, Chile	2.5 m Du Pont Telescope 	6.5m Magellan Telescope 
Spectral coverage	3,700~7000	4,900~9,500 Å (red)
Resolving power	~ 45,000 (7 km/s)	~ 22,000 (red)
Date	9, June, 2014	7, May, 2015
Exposure time	2,000 sec	1,000 sec

3. RAMAN-SCATTERED O VI λ1032

Triple-peak Profile

- Broad emission features at 6825Å and 7082Å are formed through Raman-scattering of O VI λλ 1032, 1038 by atomic hydrogen (Schmid 1989). Raman O VI features in symbiotic stars are known to exhibit complicated profiles including double-peak profiles and triple-peak profiles.
- **In the V455 Sco spectrum (Fig. 4), 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.4), which is measured by an imaginary observer that is at rest with respect to the giant.

Accretion Flow Model

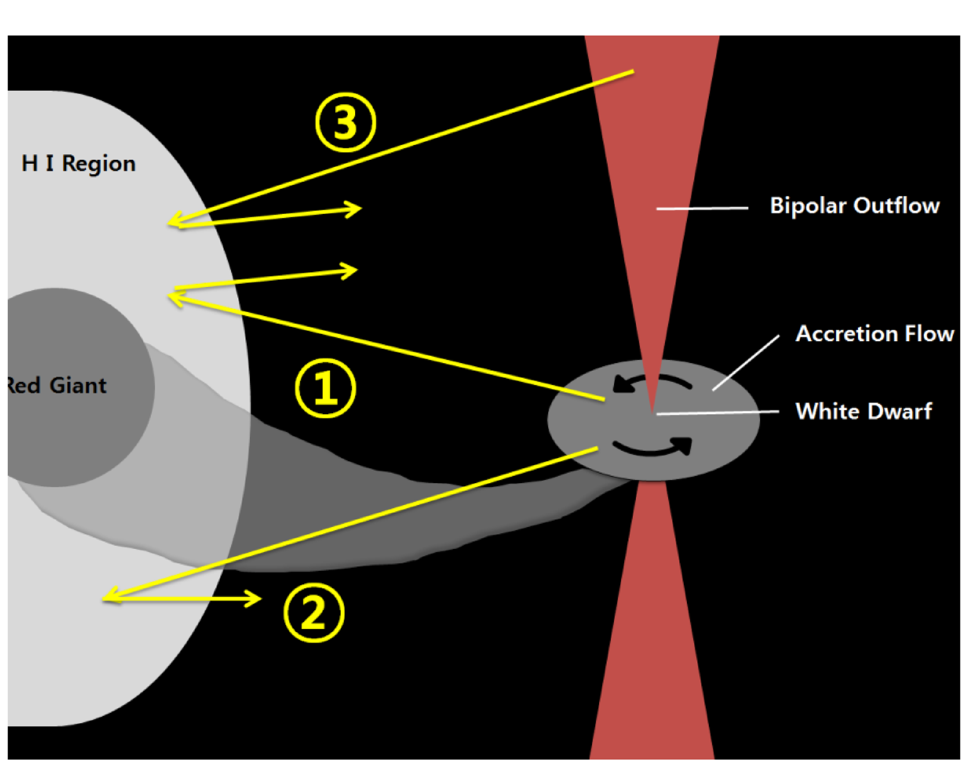
- In the Doppler factor(ΔV) space, the first dip is found to correspond to 0 km/s and the velocity range of the two peaks is between -30km/s and+30km/s.
- An accretion flow is divided into the "① Blue Emission Region (BER)" and the "② Red Emission Region (RER)", where the BER approaches and the RER recedes from the imaginary observer.
- Adopting the accretion flow model, we propose that **① the blue peak and ② the central peak are formed via Raman scattering of O VI photons from the accretion flow** around the white dwarf. We find that the O VI emission region lies within 1AU from the white dwarf.

How is the third peak formed?

- We consider the two possible scenarios for **③ the remaining red peak**, which is located at ~+70km/s.

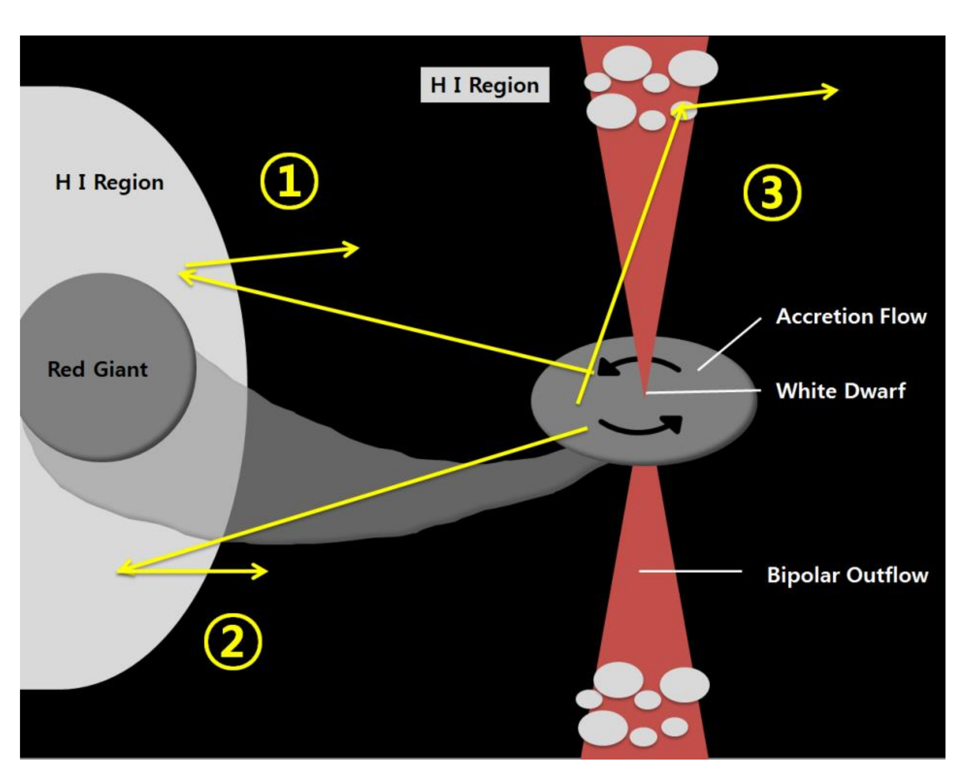
Model 1

There exists an O VI emssion region that constitutes the bipolar collimated outflow. The third peak is formed from Raman scattering of O VI coming from this region which moves away with a velocity ~70km/s.



Model 2

There are clumpy neutral blobs immeresed in the hot teneous bipolar wind. O VI photons from the accretion flow are Raman-scattered in this region with the speed of ~ 70km/s to constitute the third peak.



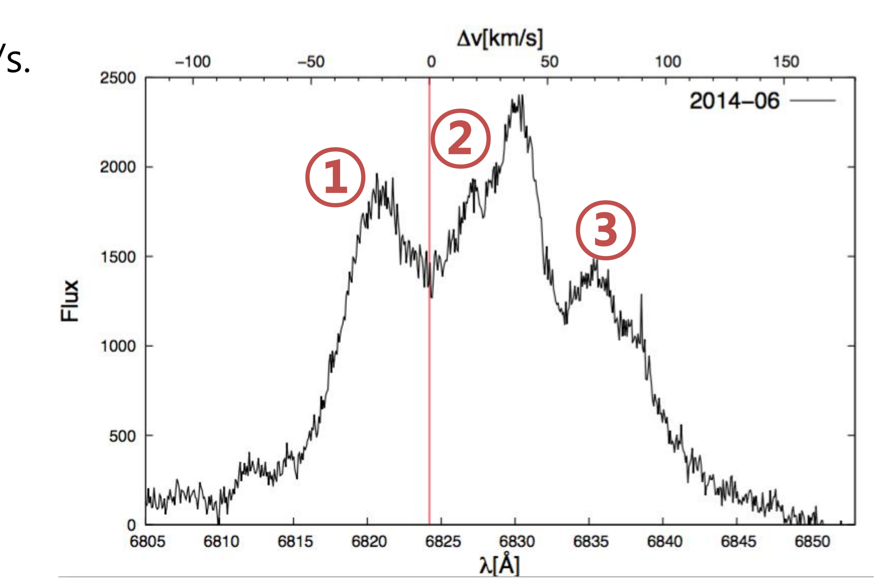


Fig 4. Du Pont spefctrum of the V455 Sco around the Raman-scattered O VI λ1032 at 6825 Å

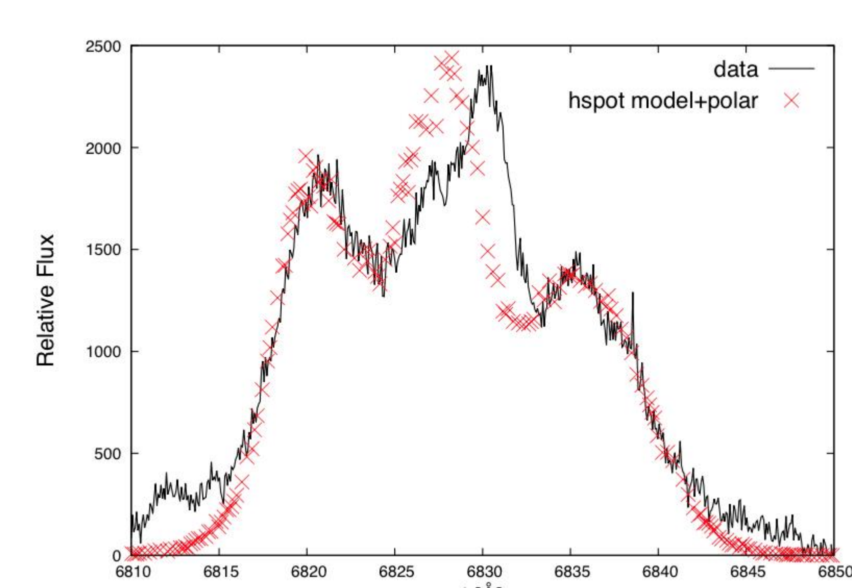


Fig 5. Monte-Carlo profile fit to Raman-scattered O VI λ1032 using Model 2

4. RAMAN-SCATTERED He II λ1025 at 6545 Å

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

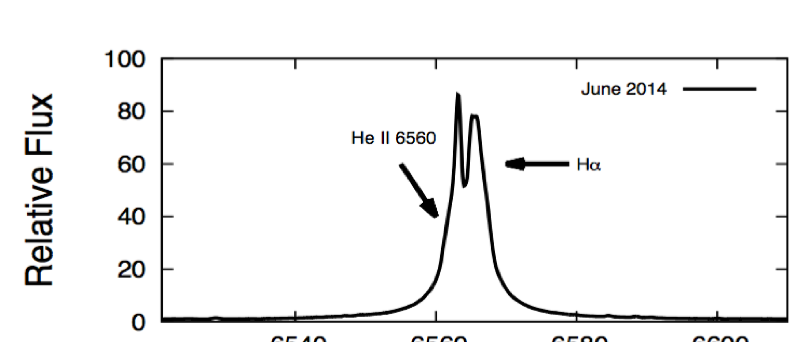


Fig 6. MIKE spectrum of the V455 Sco near Hα

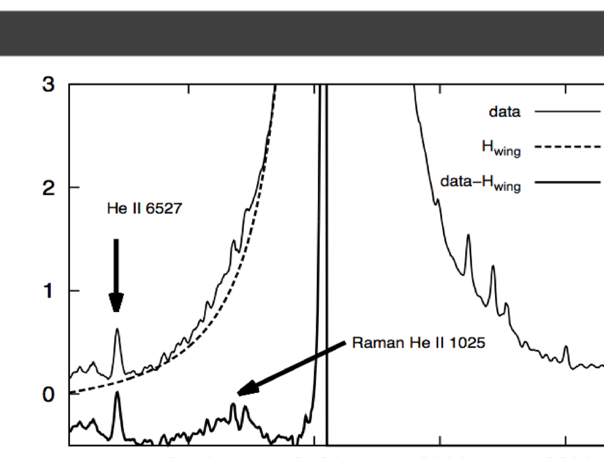


Fig 7. Subtraction of Hα wings

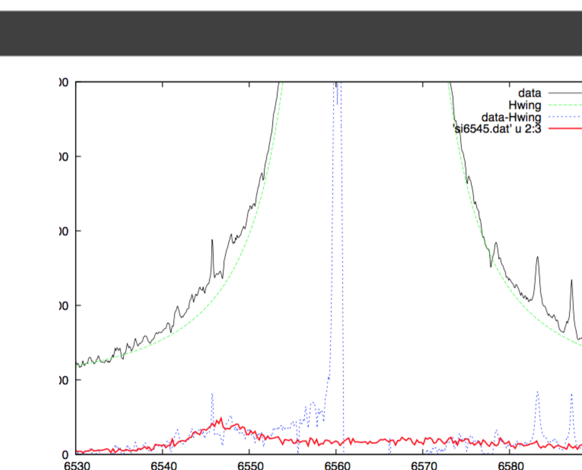


Fig 8. Monte-Carlo profile fitting

5. DISCUSSION

1) Spectropolarimetry will provied more interesting information regarding the mass transfer process in V455 Sco. We expect that the third peak is polarized with the position angle differing by π/2 from that of the blue and central peaks.
2) More detailed spectroscopy including other high excitation lines will shed more light on distinguishing the two models.

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