

# Raman-Scattered Ne VII $\lambda 973$ at 4881 Å in the Symbiotic Star V1016 Cyg

Jeong-Eun Heo<sup>1</sup>, Hee-Won Lee<sup>1</sup>  
and Byeong-Cheol Lee<sup>2</sup>

<sup>1</sup> Department of Astronomy and Space Science, Sejong University

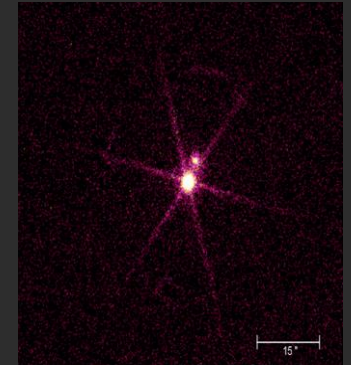
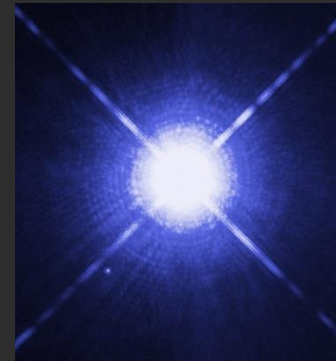
<sup>2</sup> Korea Astronomy Space Science Institute

# CONTENTS

1. INTRODUCTION
2. BOES OBSERVATION
3. MONTE CARLO RESULTS
4. DISCUSSION

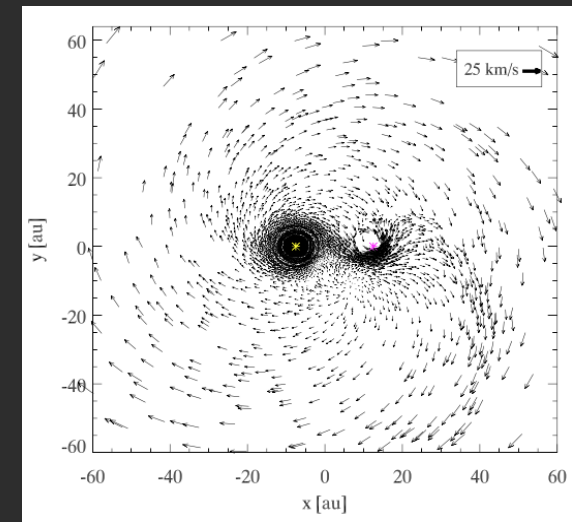
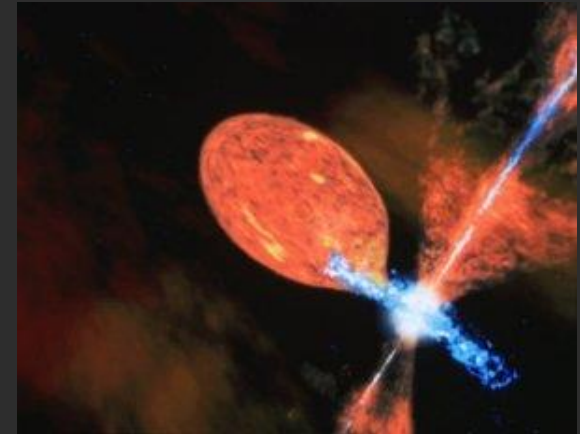
## • WHITE DWARF BINARY SYSTEMS

- Non-interacting binaries  
: e.g. Sirius A, B
- Roche lobe overflowing systems  
: Cataclysmic variables
- Stellar wind accretion systems  
: Symbiotic stars



- **SYMBIOTIC STARS**

- **Wide binary systems**  
: a giant + a hot white dwarf
- Long orbital period
- Slow stellar wind from a giant  
: **Wind accretion flow**
- Mass loss rate:  $10^{-5} \sim 10^{-7} M_{\odot}/\text{yr}$
- **Candidate of Type Ia SNe Progenitor**

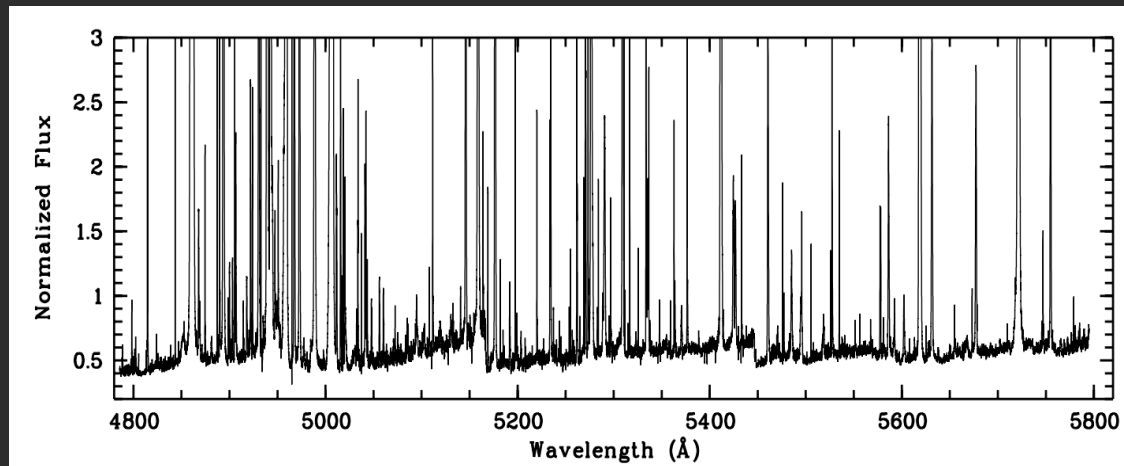


S. Mohamed & Ph. Podsiadlowski, 2012

- **SPECTROSCOPY IN SYMBIOTIC STARS**

- TiO absorption bands + Emission lines (Far UV~)

RR Tel



P. L. Selvelli &amp; P. Bonifacio, 2000

- Existence of an IR excess
  - D-type : a Mira variable with thick dust shell
  - S-type : a normal red giant

# • RAMAN SCATTERING

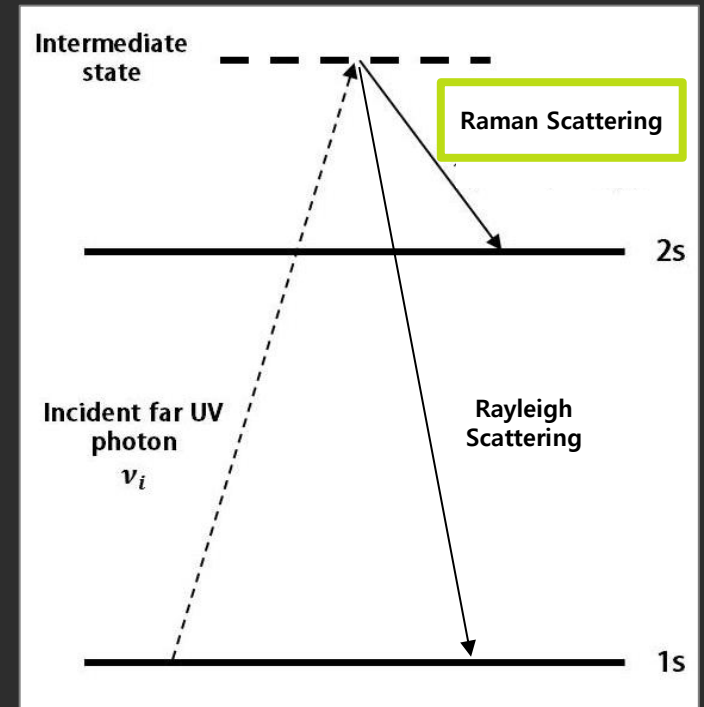
- Inelastic scattering
- The wavelength of Raman scattered photon in vacuum

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

: **Far UV → Optical**

$$\frac{\Delta\lambda_R}{\lambda_R} = \left(\frac{\lambda_R}{\lambda_i}\right) \frac{\Delta\lambda_i}{\lambda_i}$$

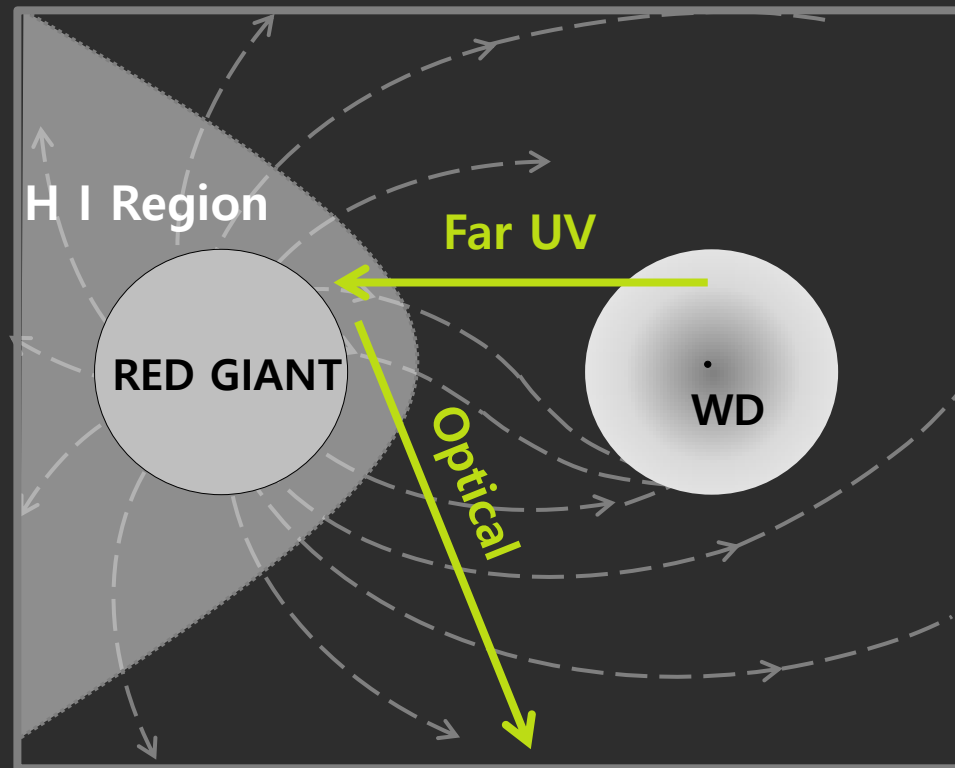
: **Broadened profiles**



Schematic energy level diagram for Raman scattering by H I

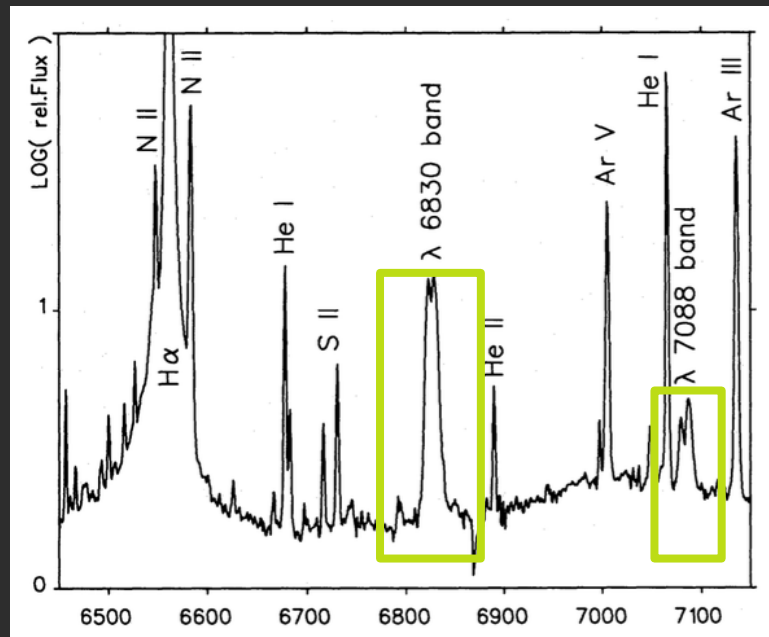
- **RAMAN SPECTROSCOPY IN SYMBIOTIC STARS**

- A highly thick H I region + A strong far UV emission



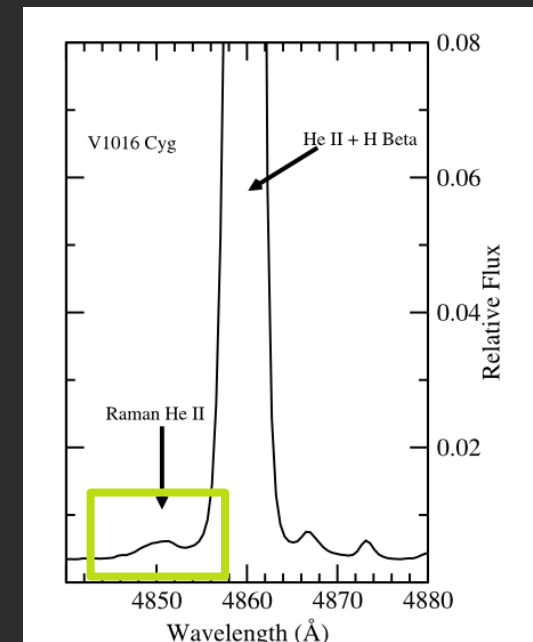
# • RAMAN SPECTROSCOPY IN SYMBIOTIC STARS

O VI  $\lambda\lambda$  1032, 1038  
→ Raman O VI 6825, 7088



Schmid H. M., 1989

He II  $\lambda$  972  
→ Raman He II 4850

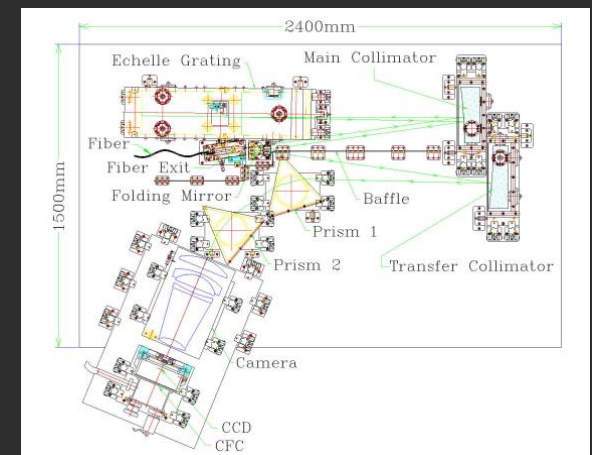
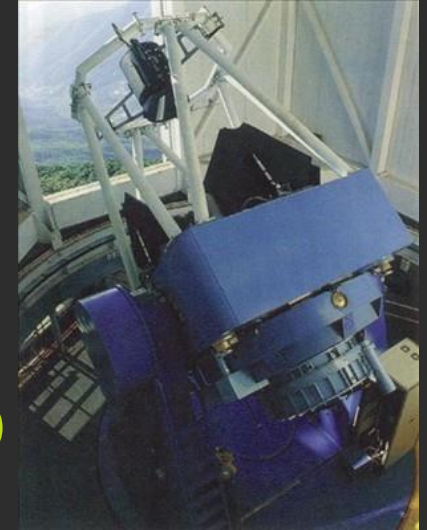


Birriel, J., 2004



## BOES OBSERVATION

- Bohyun Optical Astronomical Observatory
- 1.8m optical telescope
- **Bohyunsan Optical Echelle Spectrograph (BOES)**
- Spectral Coverage of BOES  
: 3,600~10,500 Å
- High-resolution spectroscopic observation with long exposure

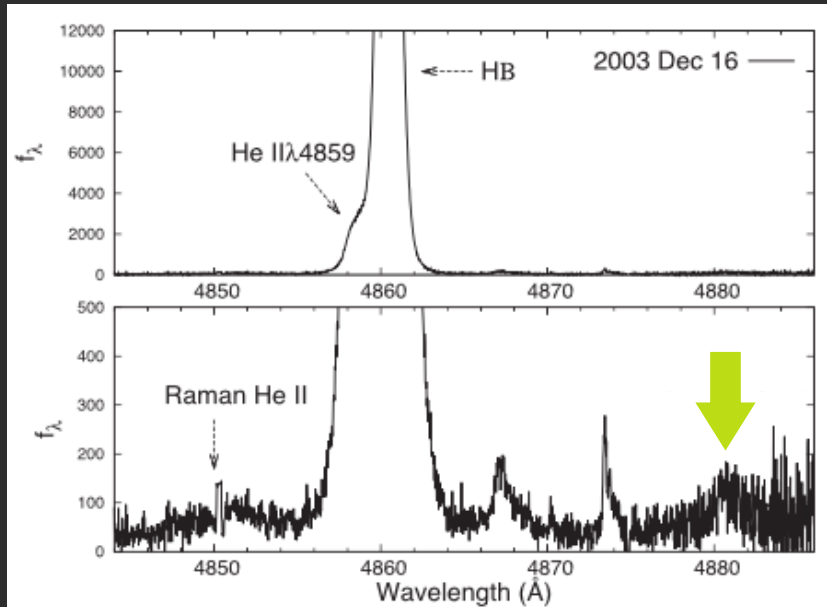


## V1016 CYGNI

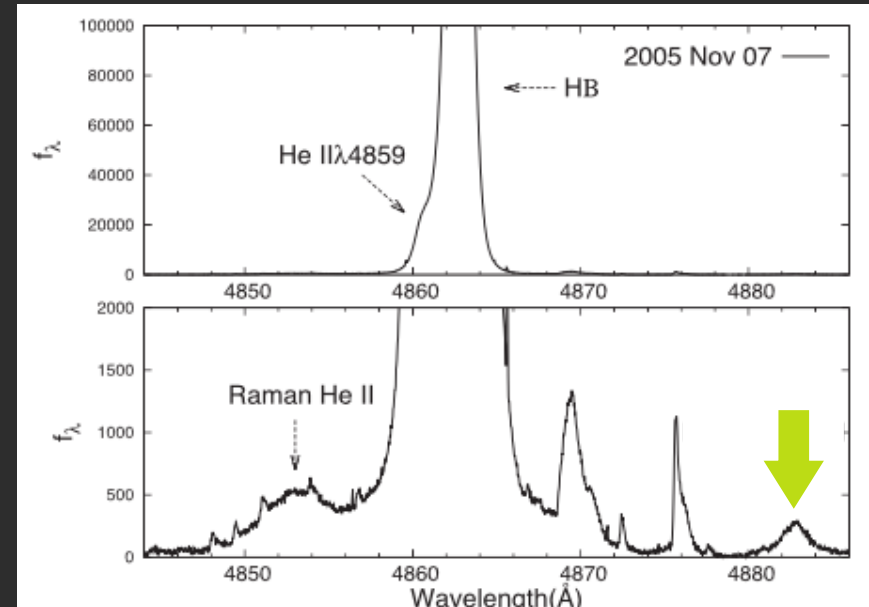
- **'D(Dust)' type symbiotic novae**  
: highest temperature and luminosity of the symbiotic star
- A Mira + A white dwarf
- Distance  $\sim 3\text{kpc}$
- Orbital period  $\gtrsim 10\text{ yr}$



# BOES SPECTRUM OF V1016 CYGNI



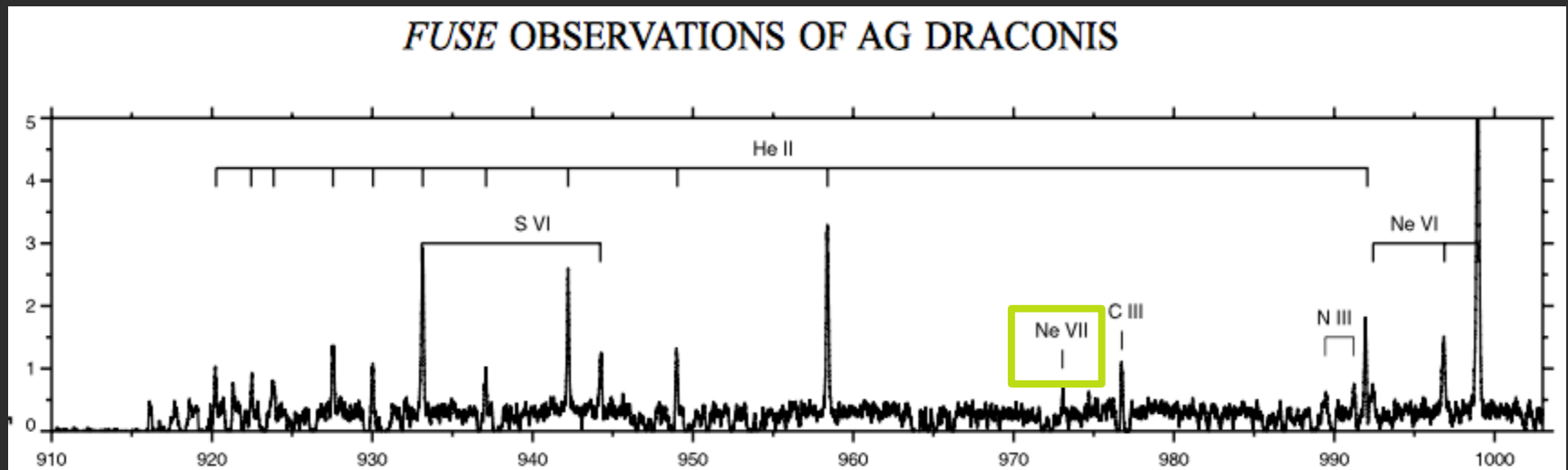
2003-12-16 | 3000 sec | R ~ 44,000



2005-11-07 | 7200 sec | R ~ 30,000

**This feature is quite broad, which is consistent with the primary characteristic of a Raman scattered feature.**

## Far UV Ne VII 973



Young et al., 2005

- Ionization potential of Ne VII: 207.3 eV

V1016 Cyg is of higher temperature than AG Dra,  
this leads to an interesting possibility that  
V1016 Cyg may show the emission line Ne VII  $\lambda 973$ .

# MONTE CARLO SIMULATION

Far UV

Optical

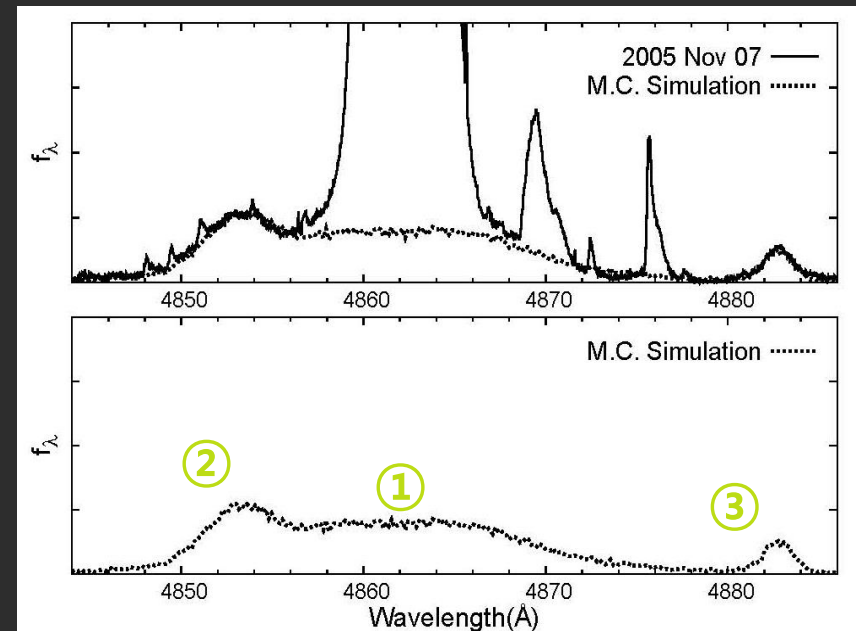
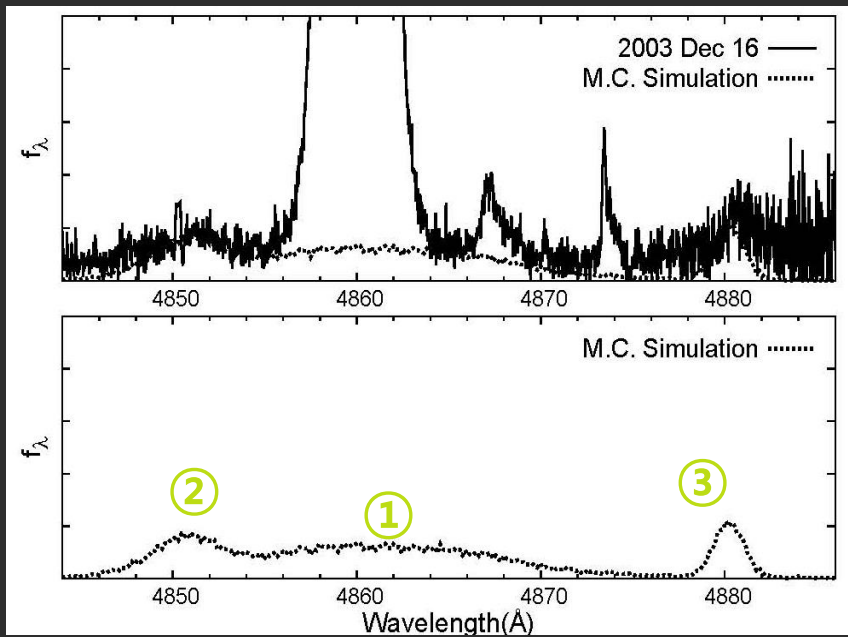
- ① Continuum around Ly $\gamma$
- ② He II  $\lambda$  972 (971.112 Å)
- ③ Ne VII  $\lambda$  973 (973.302 Å)

RAMAN  
SCATTERING

- ① Broad wings around H $\beta$
- ② Raman He II (4850.74 Å)
- ③ Raman Ne VII (4880.53 Å)

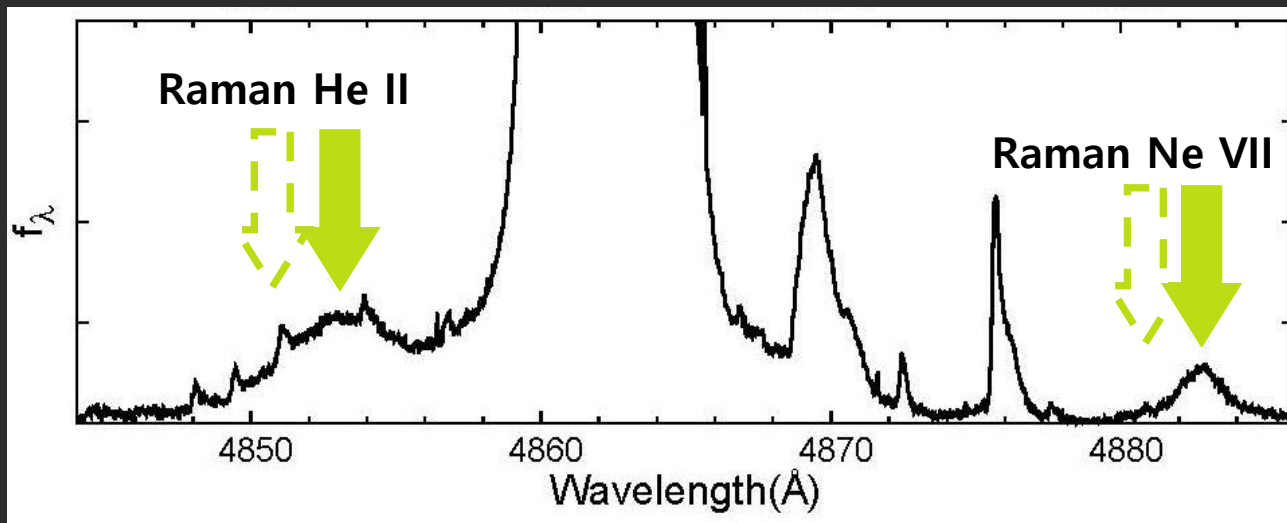
- Neutral hydrogen column density  $N_{HI} = 1.2 \times 10^{21} cm^{-2}$
- Assuming that both He II and Ne VII emission regions are coincide.

# MONTE CARLO RESULTS



- 1) The broad feature found around 4881 Å is formed through Raman scattering of Ne VII $\lambda$ 973 by atomic Hydrogen.

## MONTE CARLO RESULTS

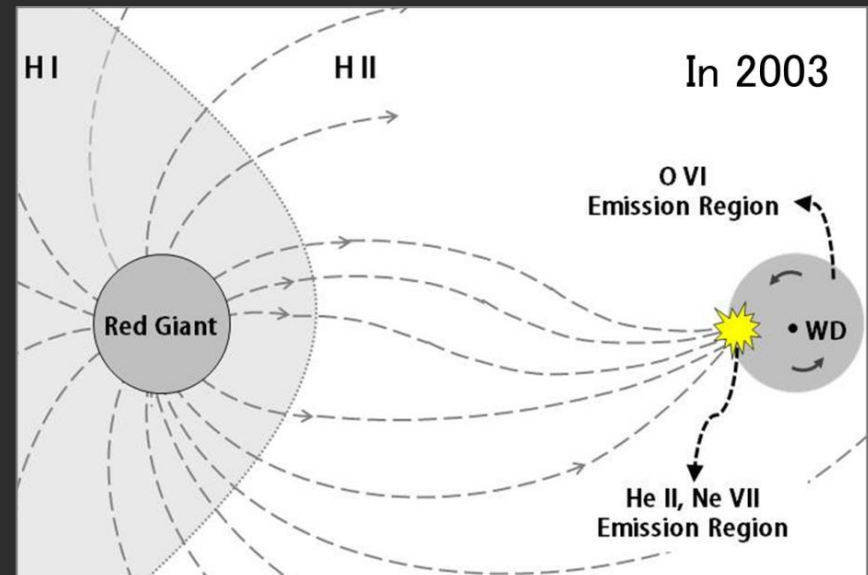


2003: **at rest** → 2005:  $v = +20 \text{ km s}^{-1}$

- 2) Both He II and Ne VII emission regions have **same kinematics** with respect to H I region.
- 3) In the 2005 spectrum **Raman He II and Ne VII are redshifted** by an amount exceeding  $2\text{\AA}$  ( $\sim 20 \text{ km/s}$ ).

## INTERPRETATION

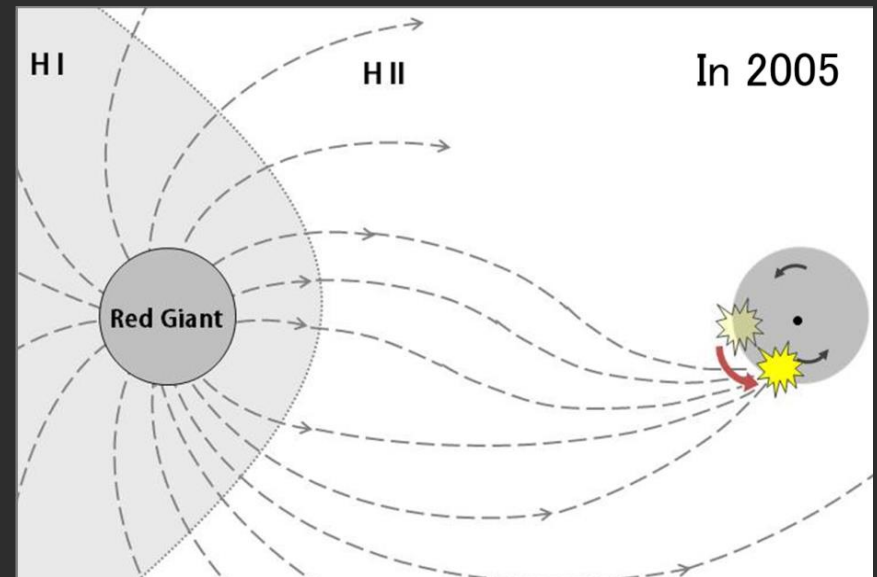
- 1) The broad feature found around 4881 Å in the spectrum of V1016 Cyg is formed through **Raman scattering of Ne VII $\lambda$ 973**.  
→ Violent wind accretion flow
- 2) Both the He II and Ne VII emission regions are coincide.  
→ **Locally enhanced density and temperature region** in the accretion flow.
- 3) A temporal change in relative velocities  
→ The density enhanced region may have moved.



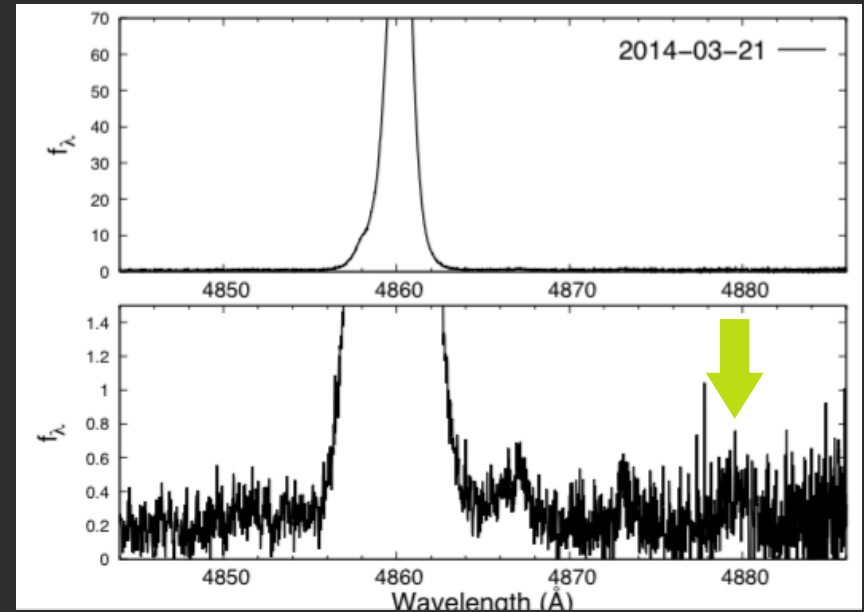
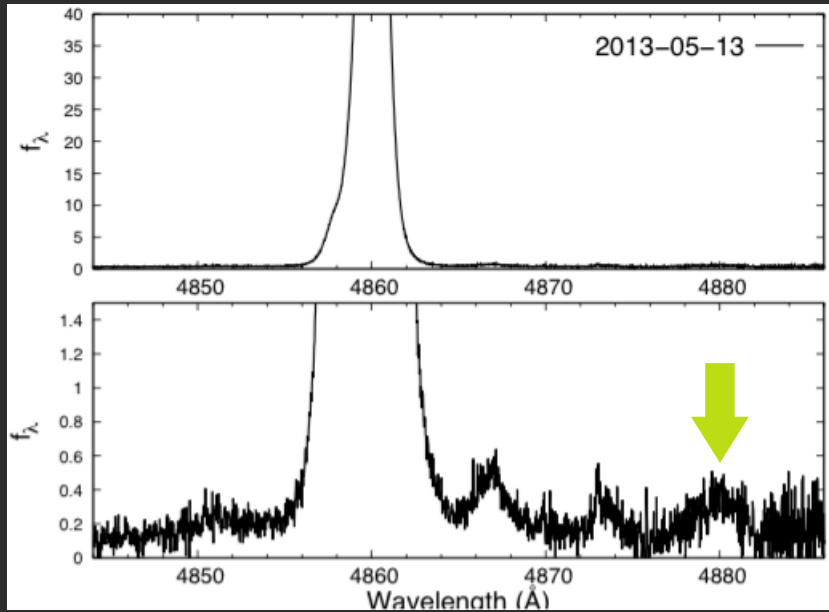


## INTERPRETATION

- 1) The broad feature found around 4881 Å in the spectrum of V1016 Cyg is formed through **Raman scattering of Ne VII $\lambda$ 973**.  
→ Violent wind accretion flow
- 2) Both the He II and Ne VII emission regions are coincide.  
→ **Locally enhanced density and temperature region** in the accretion flow.
- 3) A temporal change in relative velocities  
→ The density enhanced region may have moved.



# FUTURE WORK



- Time series observation
- Spectropolarimetry
- Using large telescope : Other targets (PN, AGN..)

**THANK YOU 😊**