Raman-Scattered Ne VII λ973 at 4881 Å in the Symbiotic Star V1016 Cyg

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• **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**: $10^{-5} \sim 10^{-7} M_\odot/yr$

- **Candidate of Type Ia SNe Progenitor**

S. Mohamed & Ph. Podsiadlowski, 2012
• **SPECTROSCOPY IN SYMBIOTIC STARS**

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

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

P. L. Selvelli & P. Bonifacio, 2000
• Raman Scattering

- Inelastic scattering

- The wavelength of Raman scattered photon in vacuum

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

  : 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 λ 1032, 1038**
\[\rightarrow\text{Raman O VI 6825, 7088}\]

**He II λ 972**
\[\rightarrow\text{Raman He II 4850}\]

Schmid H. M., 1989

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 $\sim 3$ kpc

- Orbital period $\geq 10$ yr
This feature is quite broad, which is consistent with the primary characteristic of a Raman scattered feature.
Far UV Ne VII 973

- 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 λ973.
MONTE CARLO SIMULATION

Far UV

1. Continuum around Lyα
2. He II $\lambda$ 972 (971.112 Å)
3. Ne VII $\lambda$ 973 (973.302 Å)

Optical

1. Broad wings around Hβ
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.
1) The broad feature found around 4881 Å is formed through Raman scattering of Ne VIIλ973 by atomic Hydrogen.
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 2Å (~20km/s).
INTERPRETATION

1) The broad feature found around 4881 Å in the spectrum of V1016 Cyg is formed through Raman scattering of Ne VIIλ973. → 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.
1) The broad feature found around 4881 Å in the spectrum of V1016 Cyg is formed through Raman scattering of Ne VIIλ973. → Violent wind accretion flow

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FUTURE WORK

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