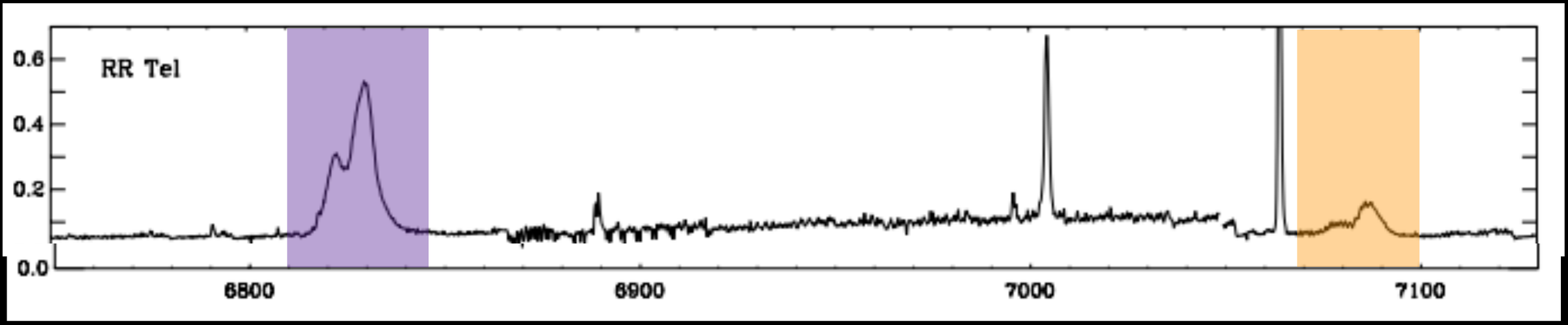
Can Raman O VI Features Trace the Evolutionary Paths of Symbiotic Stars?

Jeong-Eun Heo
Gemini Observatory/NSF NOIRLab
jeong-eun.heo@noirlab.edu

Raman O VI Features

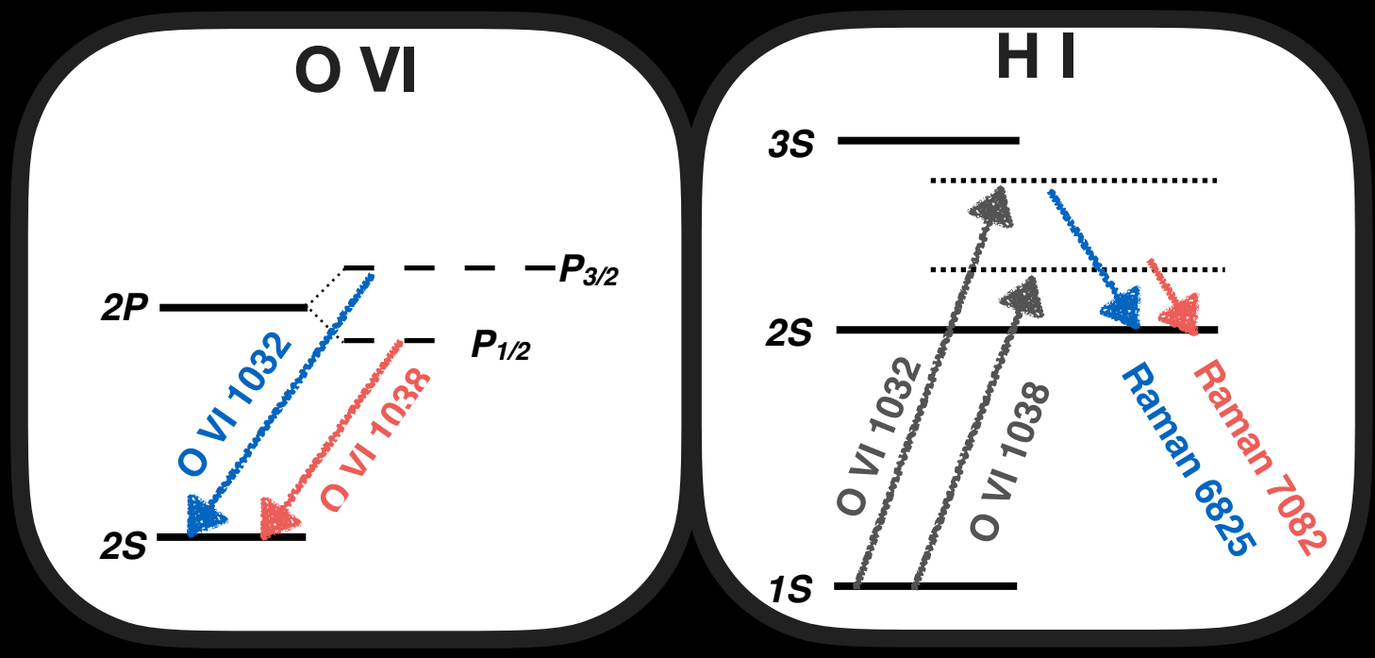
- Two emission bands at 6825 and 7082Å with a broad width of 20-30Å
- They have been detected only in SySts

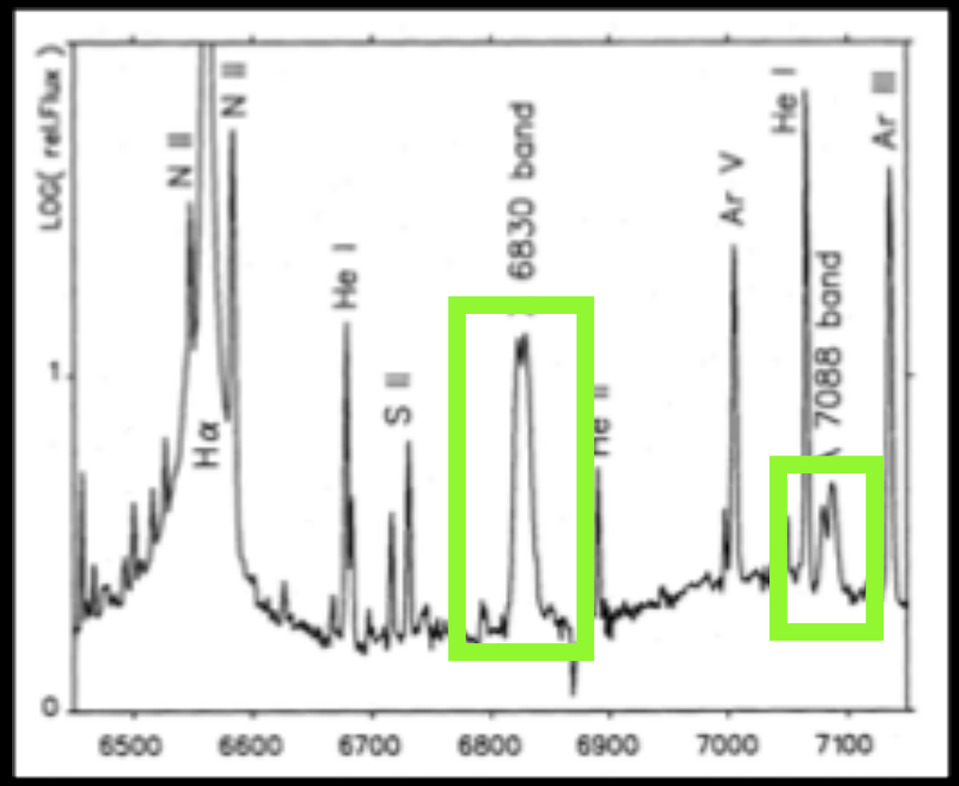


Munari et al., 1992

Raman O VI Features

- In 1989, Schmid identified those features as **Raman-scattering of O VI $\lambda\lambda$ 1032 and 1038 doublet by H I**

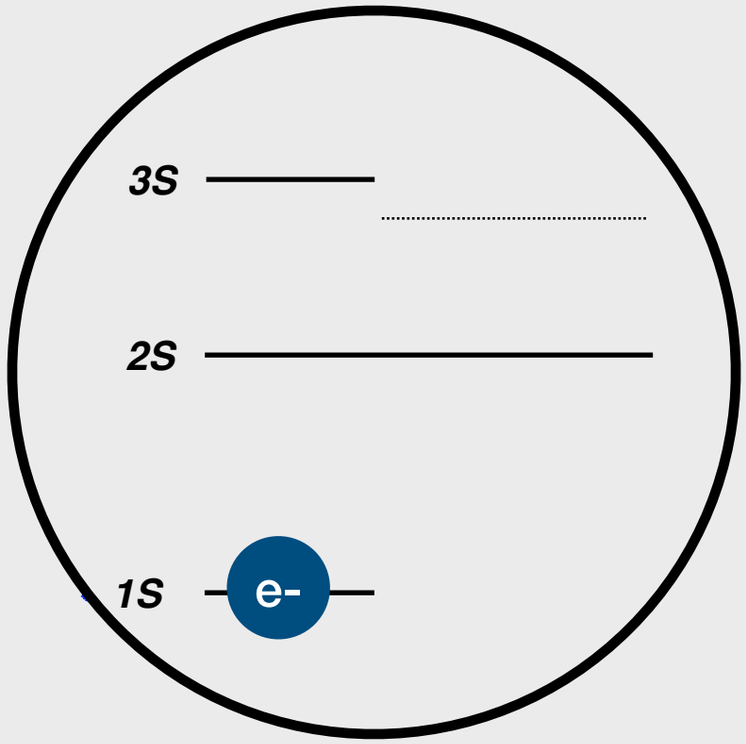




Schmid H. M., 1989

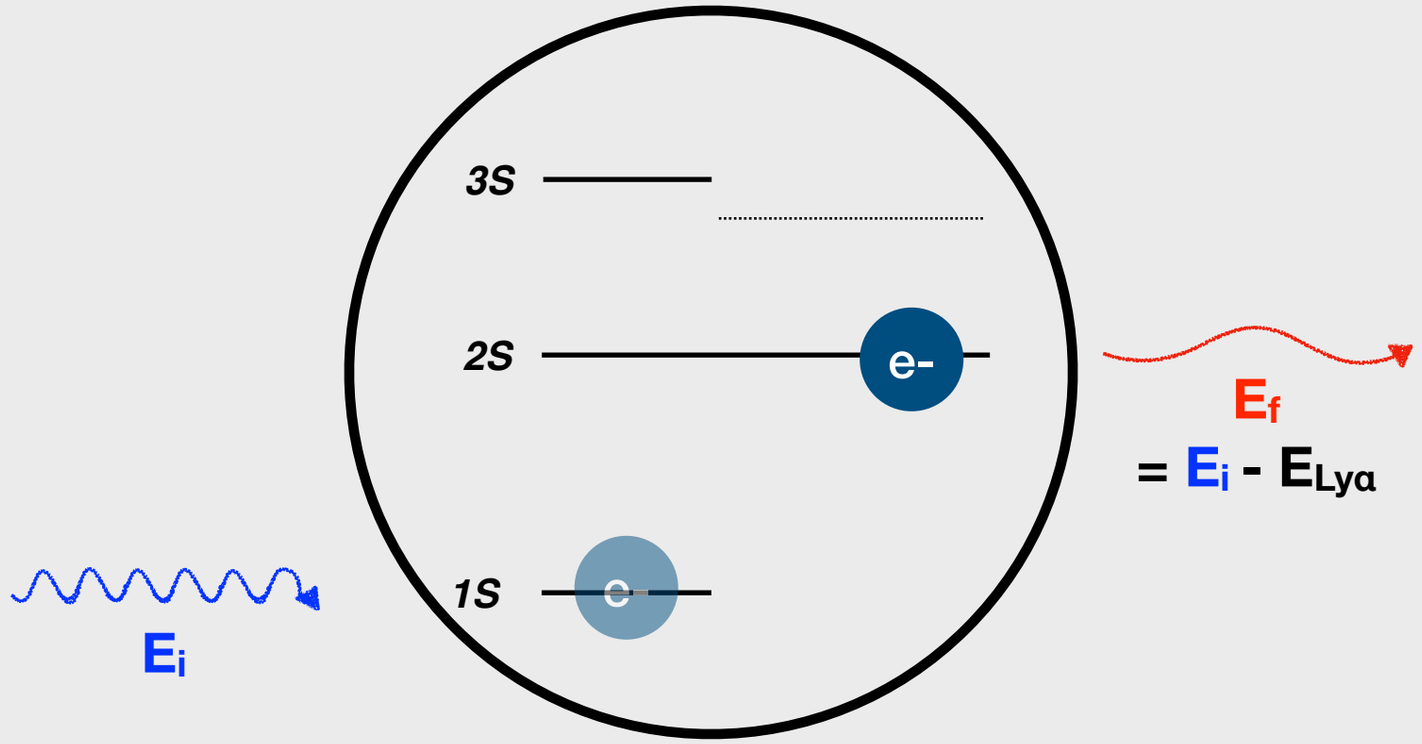
Raman Scattering by Atomic Hydrogen

Atomic Hydrogen

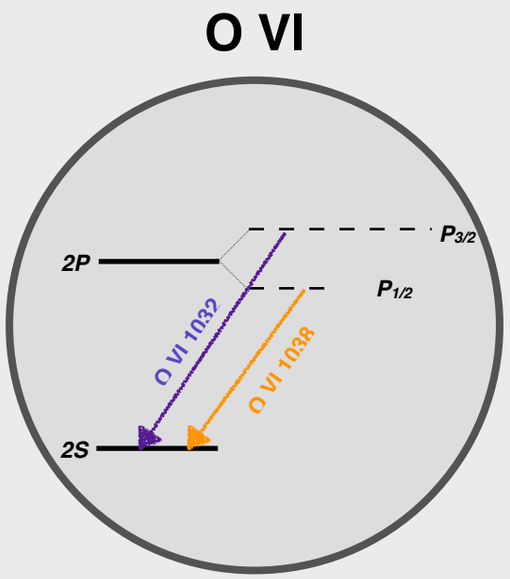


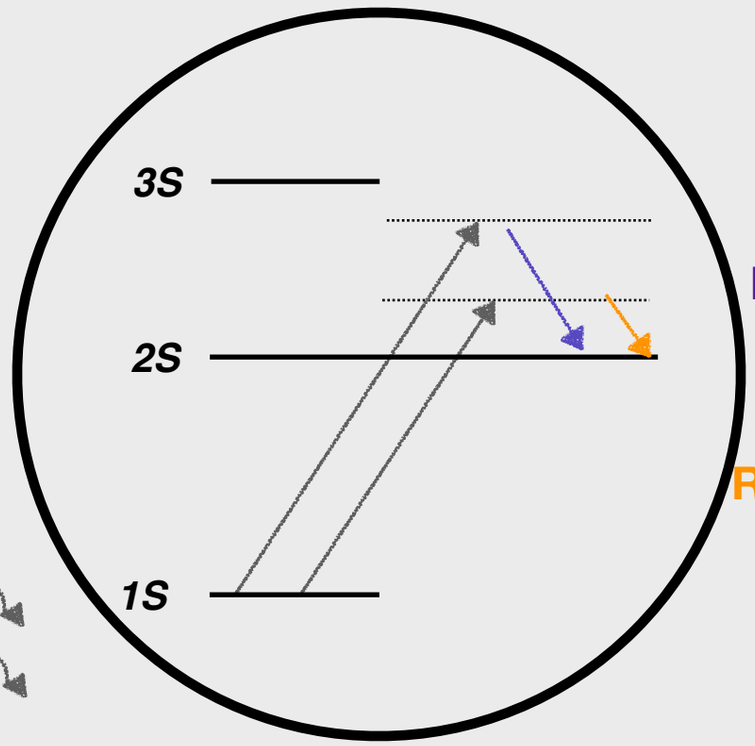
Raman Scattering by Atomic Hydrogen

Atomic Hydrogen



Raman-scattered O VI Features





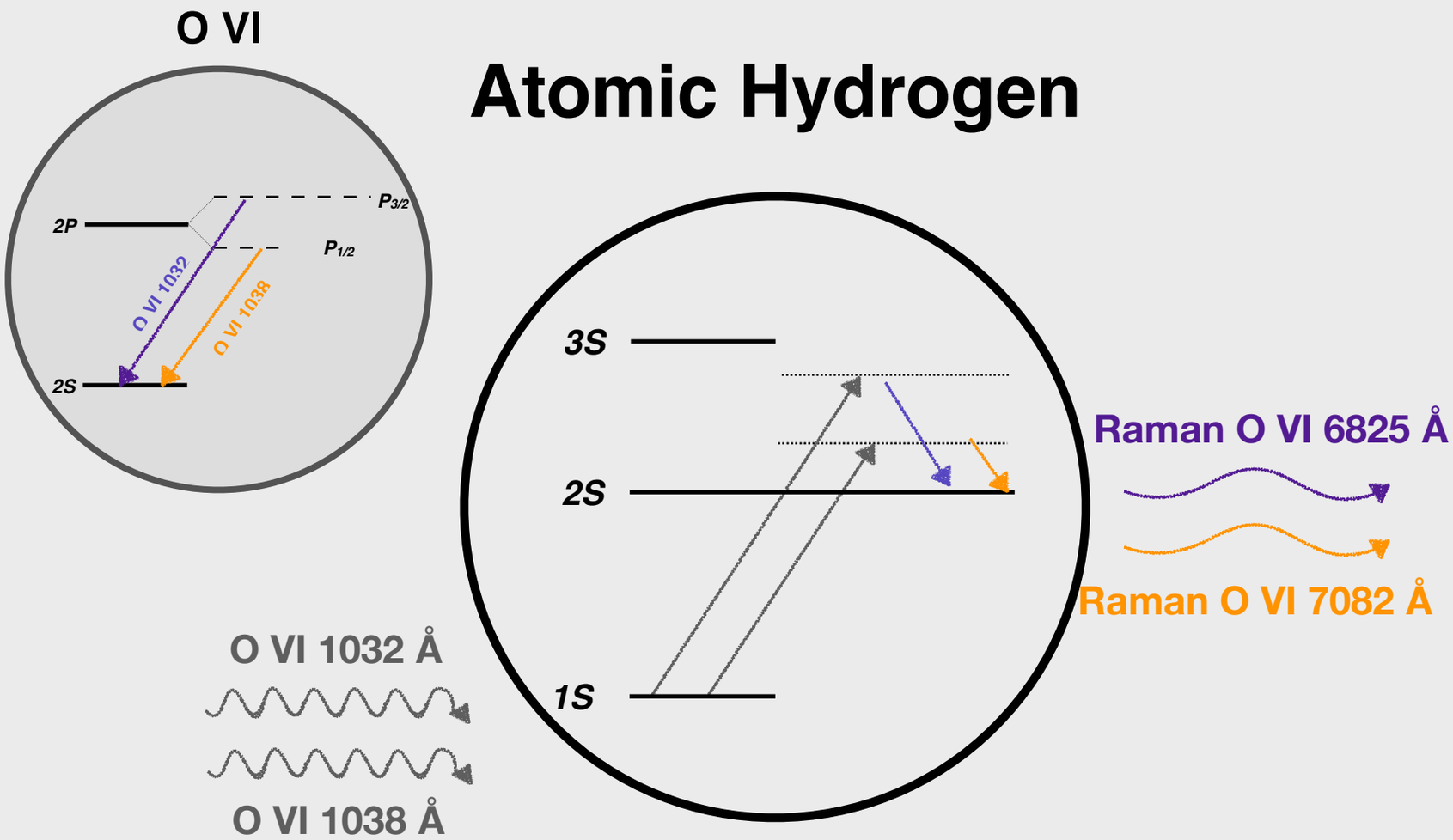
Raman O VI 6825 Å

Raman O VI 7082 Å

O VI 1032 Å

O VI 1038 Å

Raman-scattered O VI Features



A very strong far-UV emission source

+

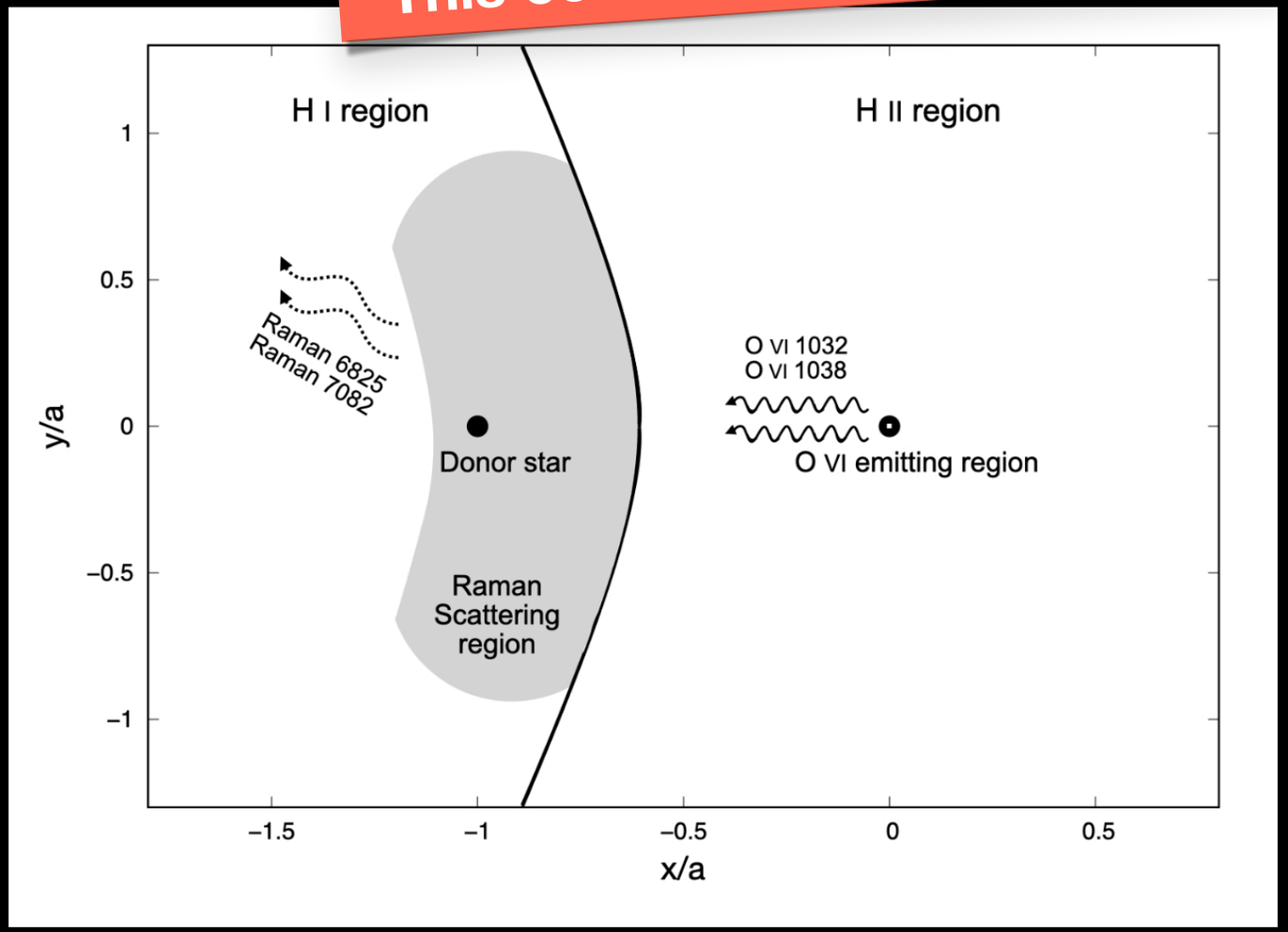
A thick neutral hydrogen region

Raman O VI in SySts

- **A very strong far-UV emission source:**
  Accretion around the white dwarf

- **A thick neutral component:**
  the stellar wind of the cool giant

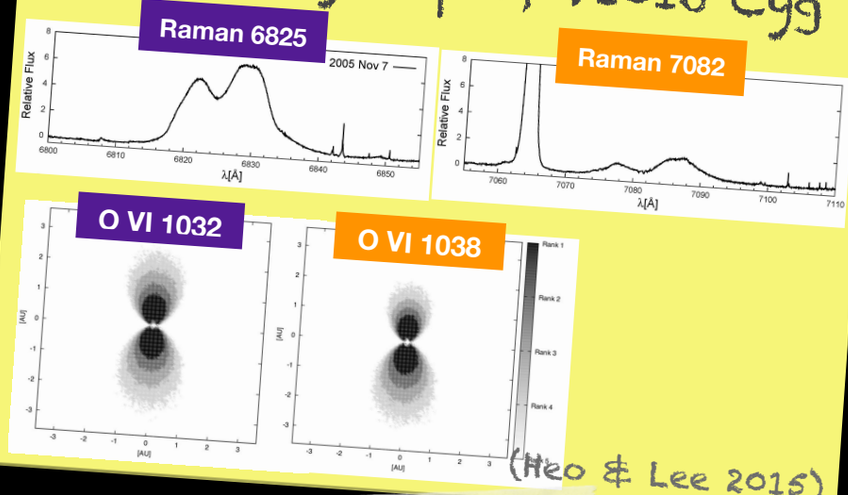
This condition is ideally met in symbiotic stars.



(Heo et al. 2021)

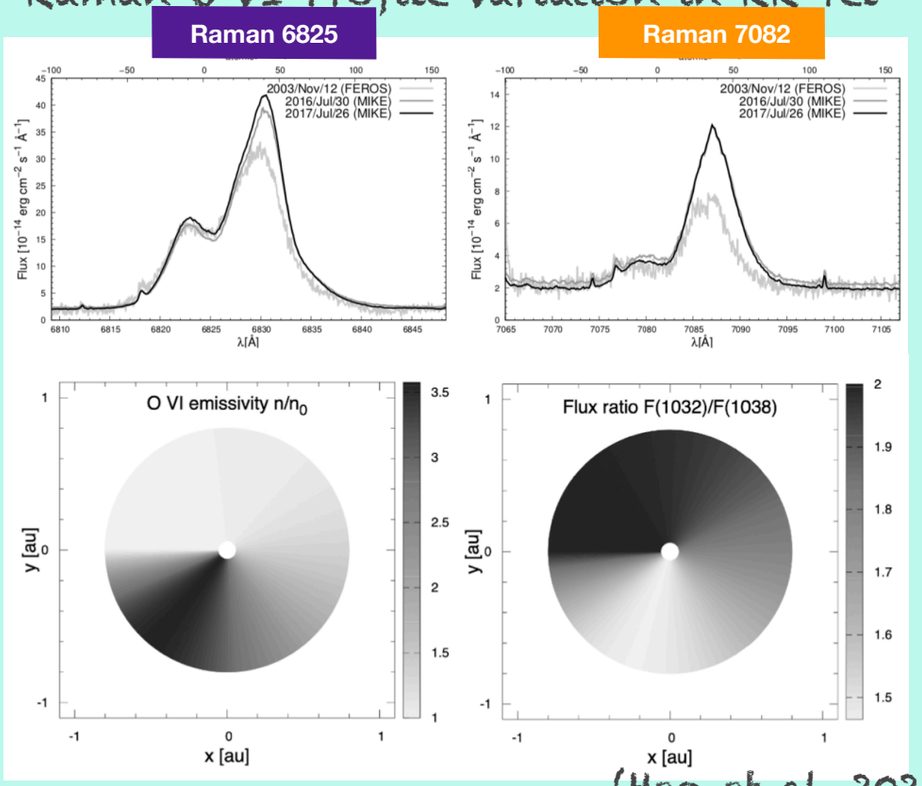
Profile Analysis of Raman O VI

Emissivity Map of V1016 Cyg



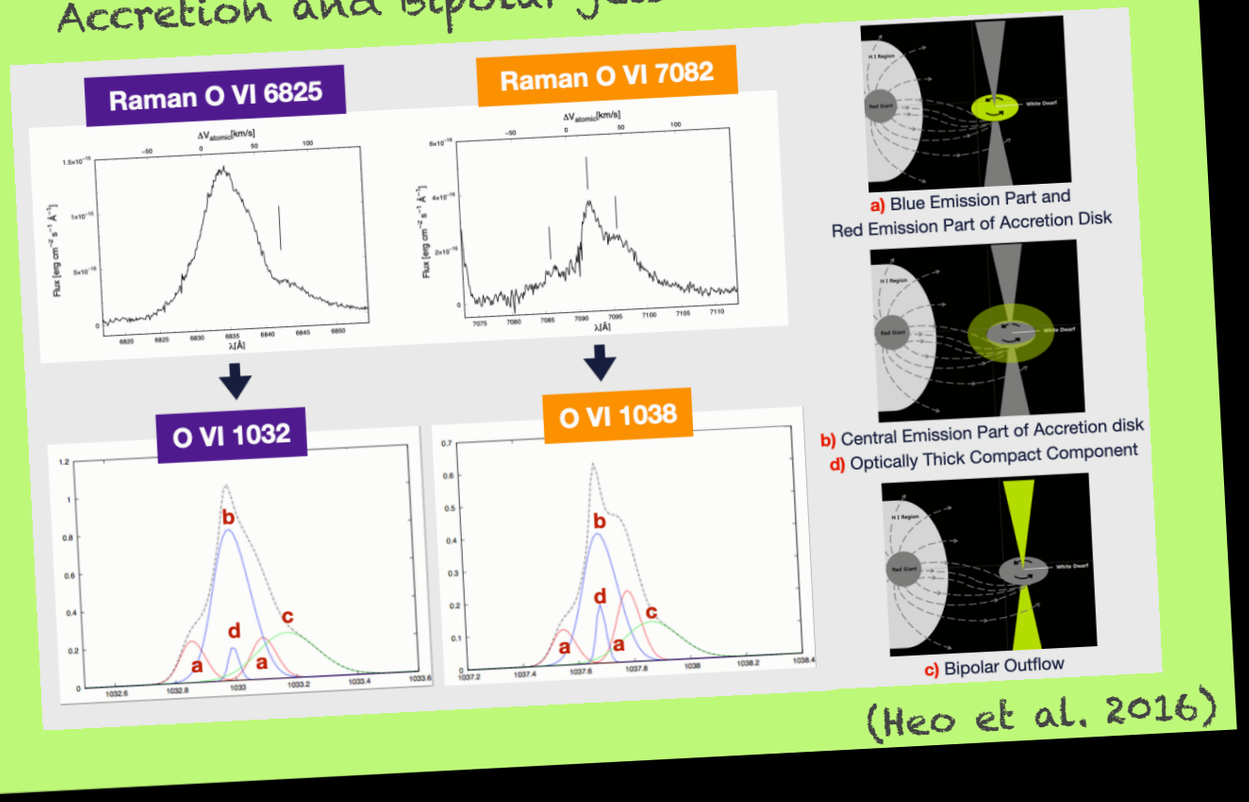
(Heo & Lee 2015)

Raman O VI Profile Variation in RR Tel



(Heo et al. 2021)

Accretion and Bipolar jets in Sanduleak's Star

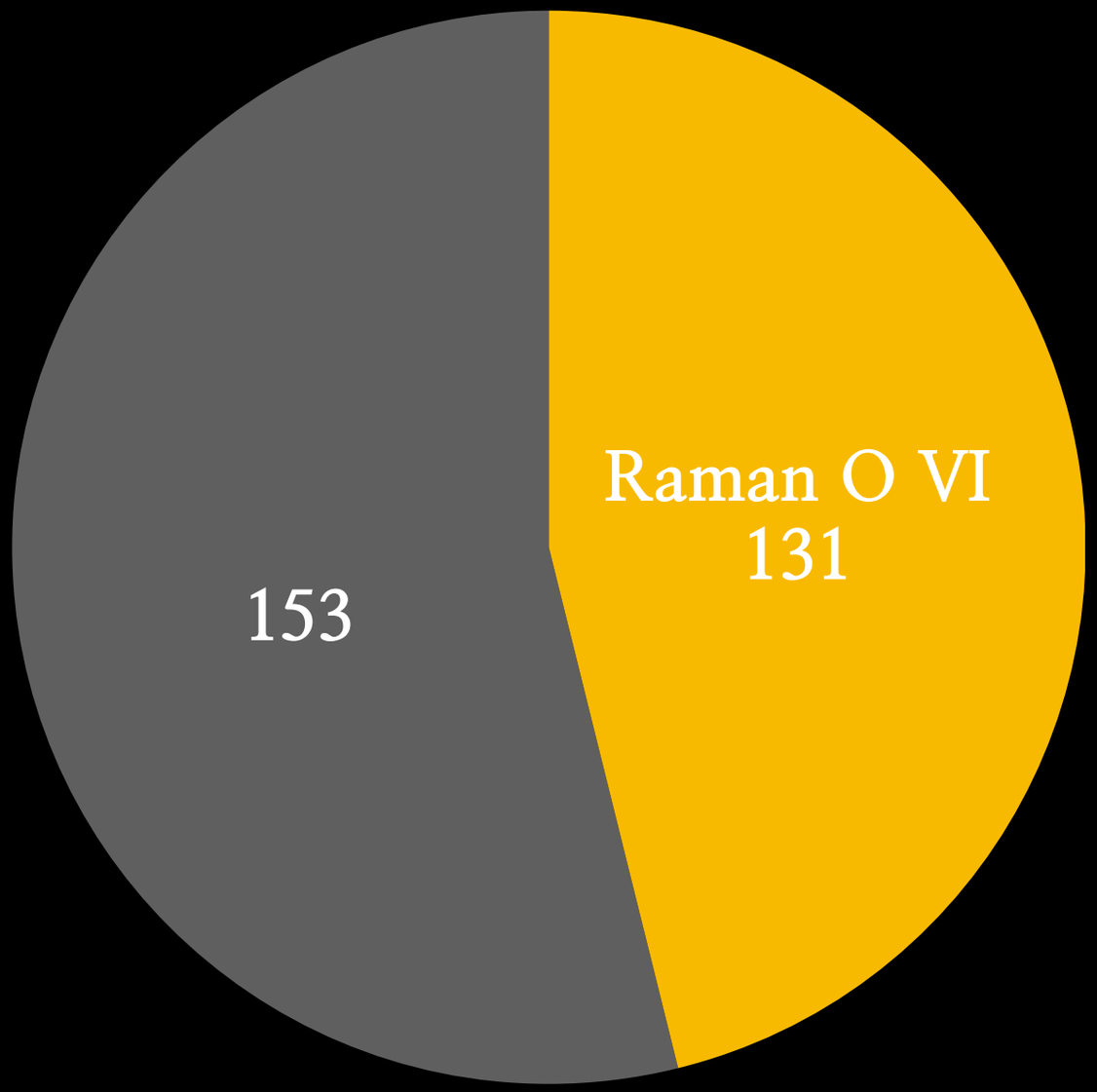


(Heo et al. 2016)

- **Relative motion** of the incident radiation source and the hydrogen gas.
- These Raman O VI features provide valuable insights into **the dynamics and geometry of the system.**

Can Raman O VI Features Trace the Evolutionary Paths of Symbiotic Stars?

Galactic SySts



New Online Database of Symbiotic Variables

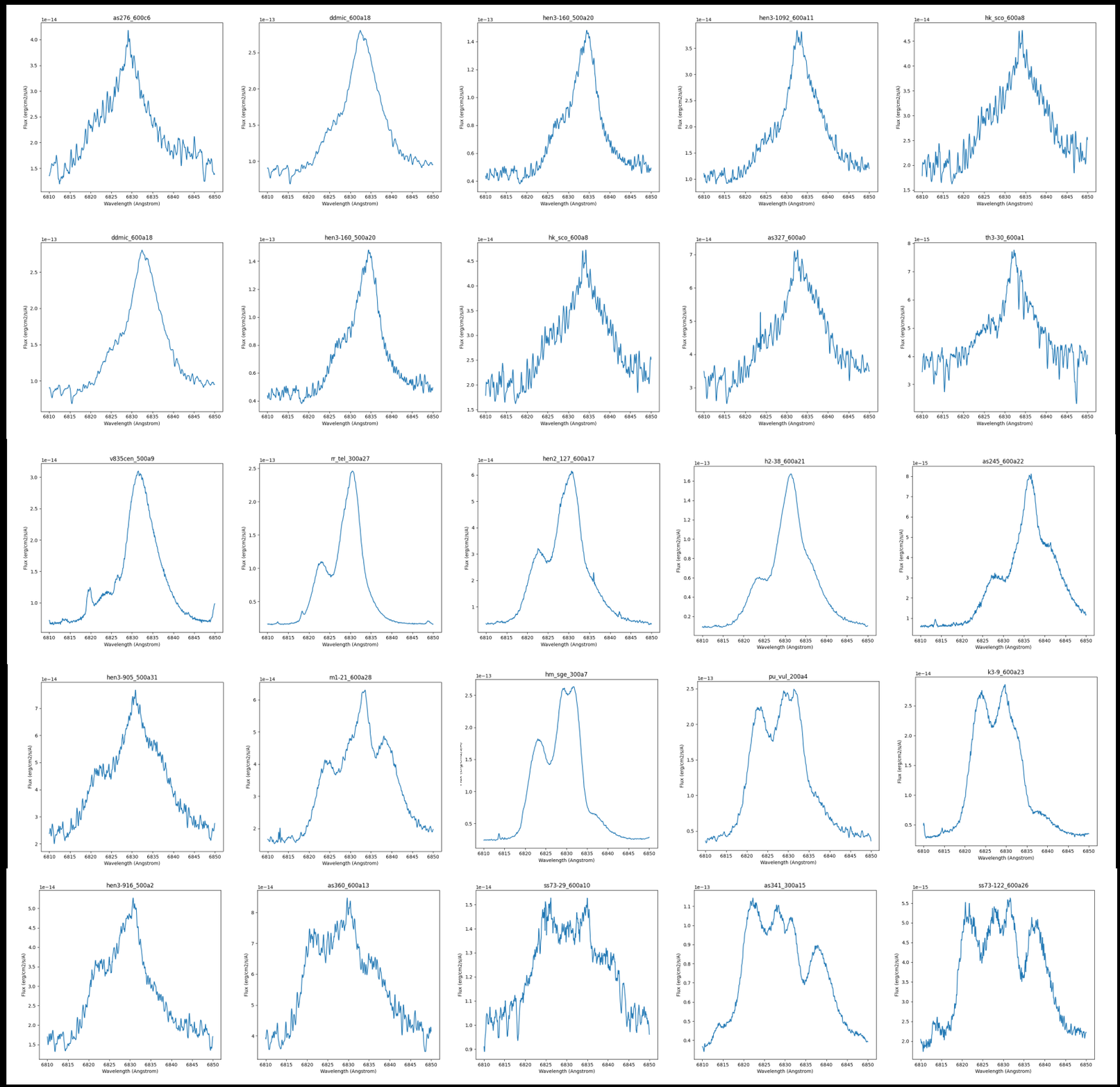
(June 02, 2024)

High-R. Data (2016-2022)

The Magellan Inamori Kyocera Echelle spectrograph (MIKE)

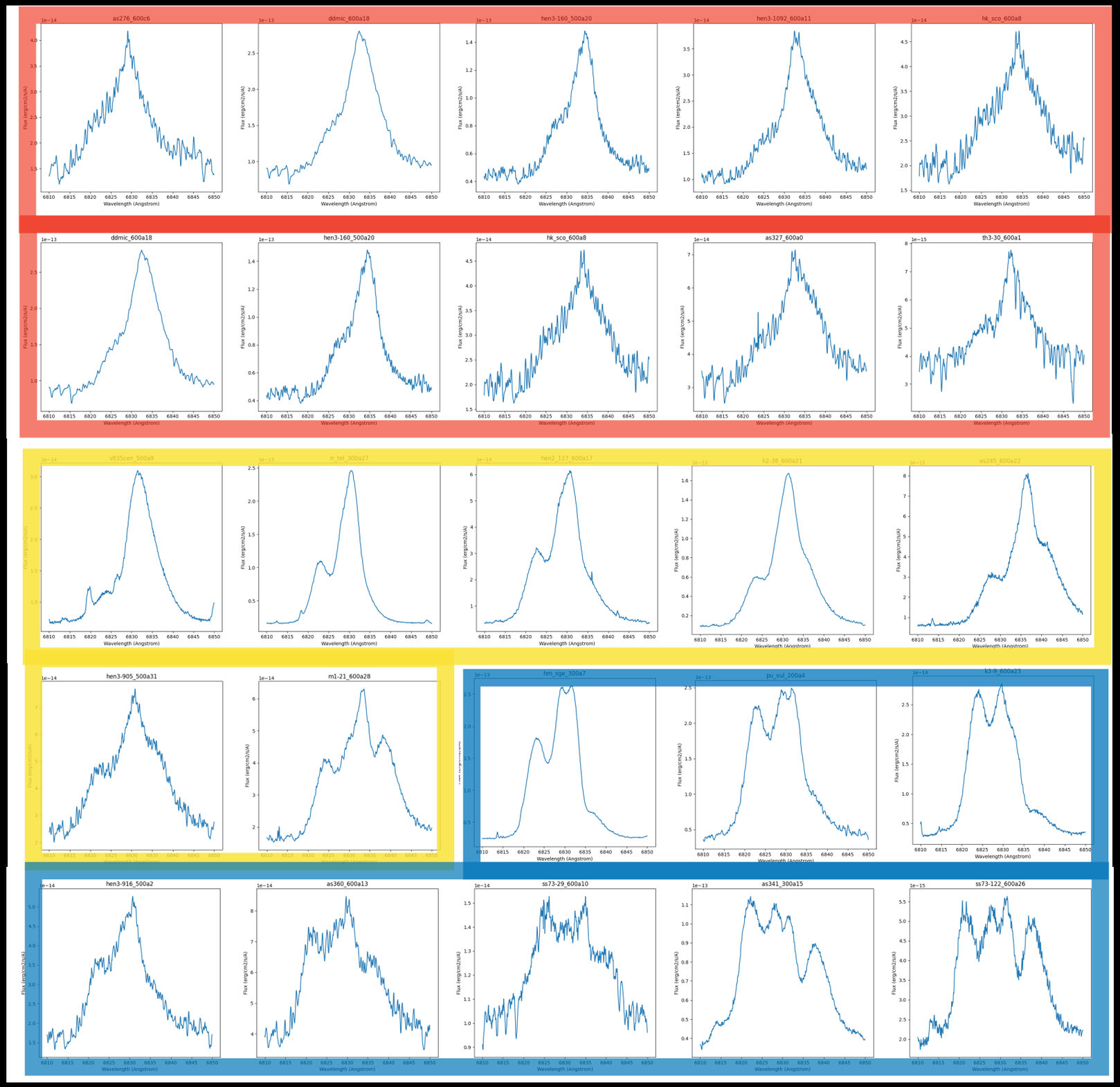
- 6.5 m Magellan-Clay/ MIKE, Las Campanas Observatory, Chile
- λ: 3200-5000Å (Blue), 4900-10000Å (Red)
- R ~ 41,500 (Blue) , ~ 32,500 (Red)
- Reduced with the CarPy pipeline

Raman O VI 6825 in Galactic SySts



Heo et al. (in prep)

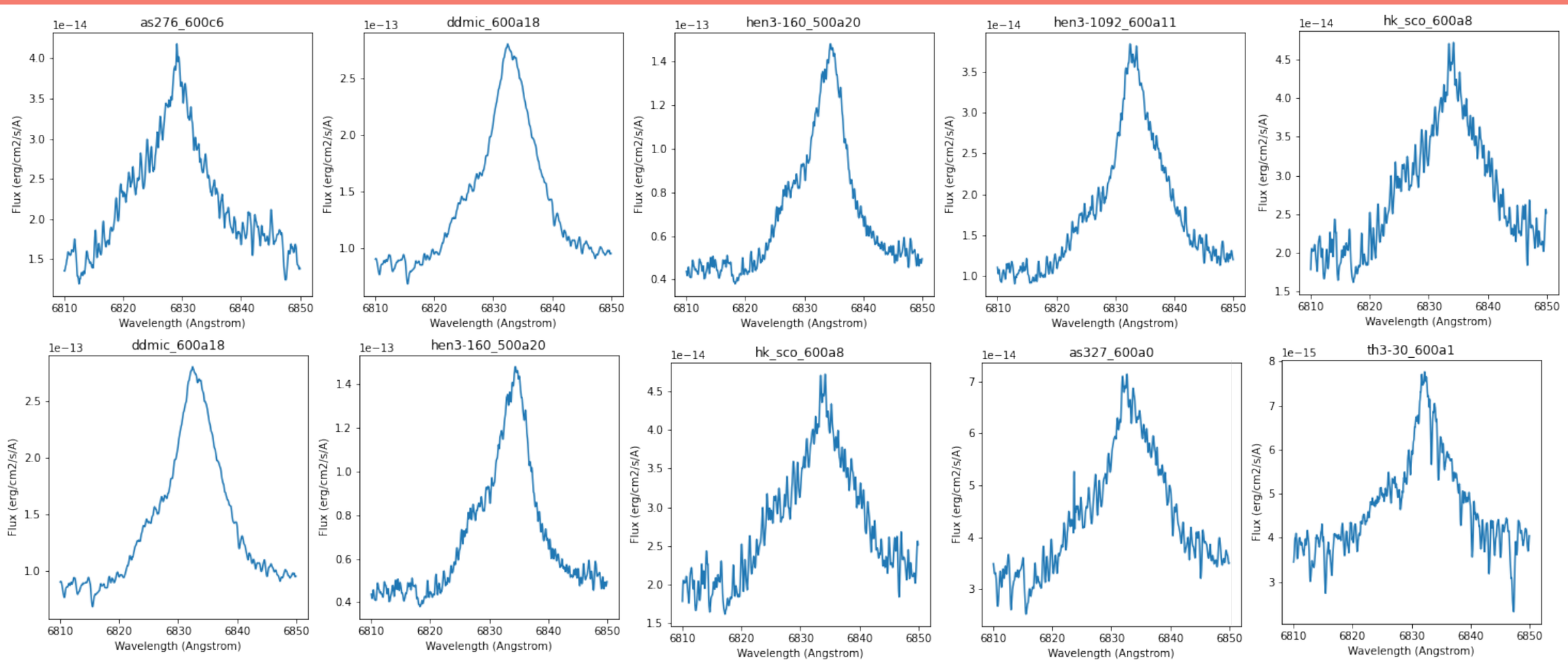
Raman O VI 6825 in Galactic SySts



Heo et al. (in prep)

Raman O VI 6825 in Galactic SySts

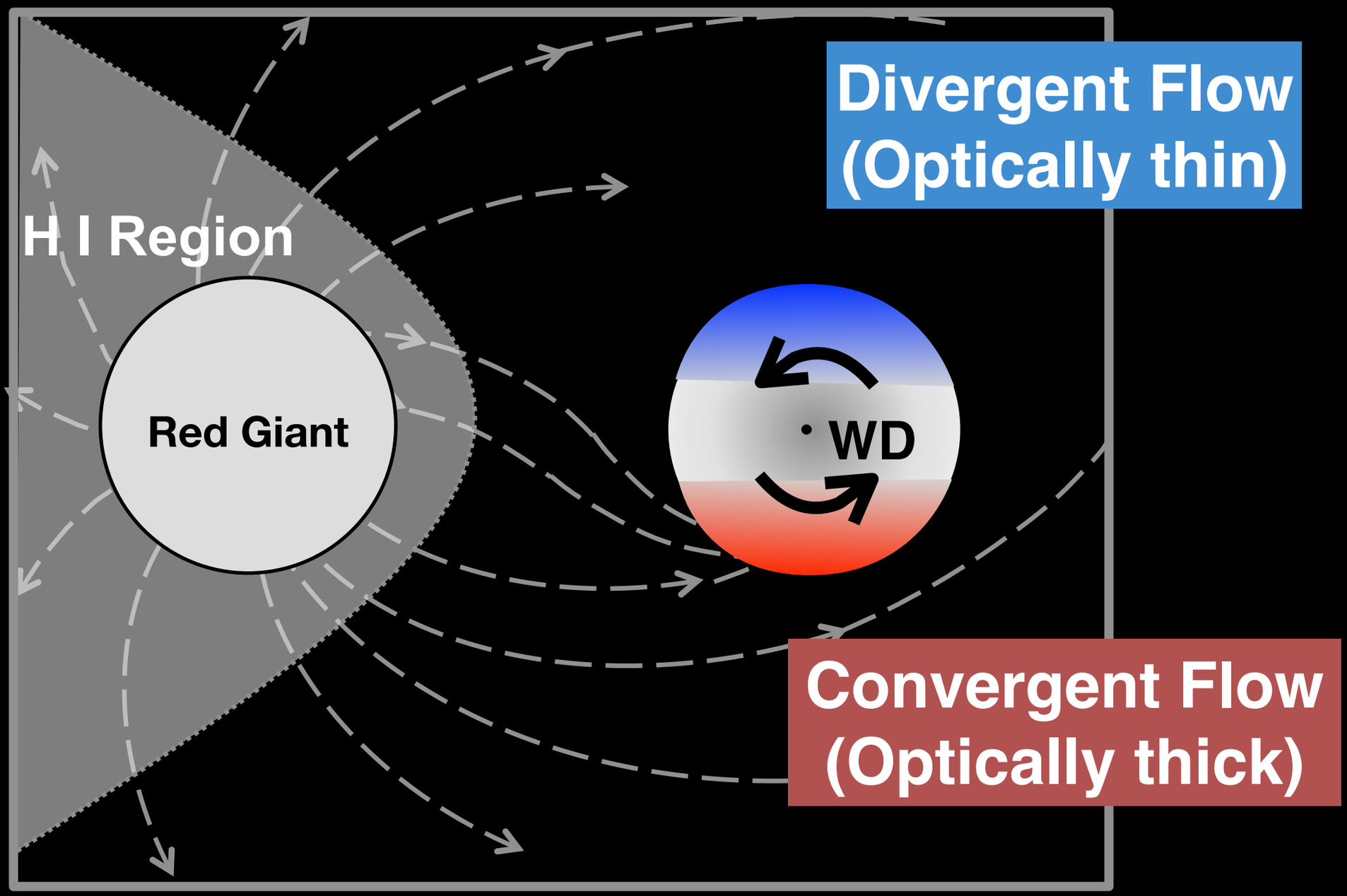
1) Single peaked profile



- Widths < 30Å
- Red-shifted profiles

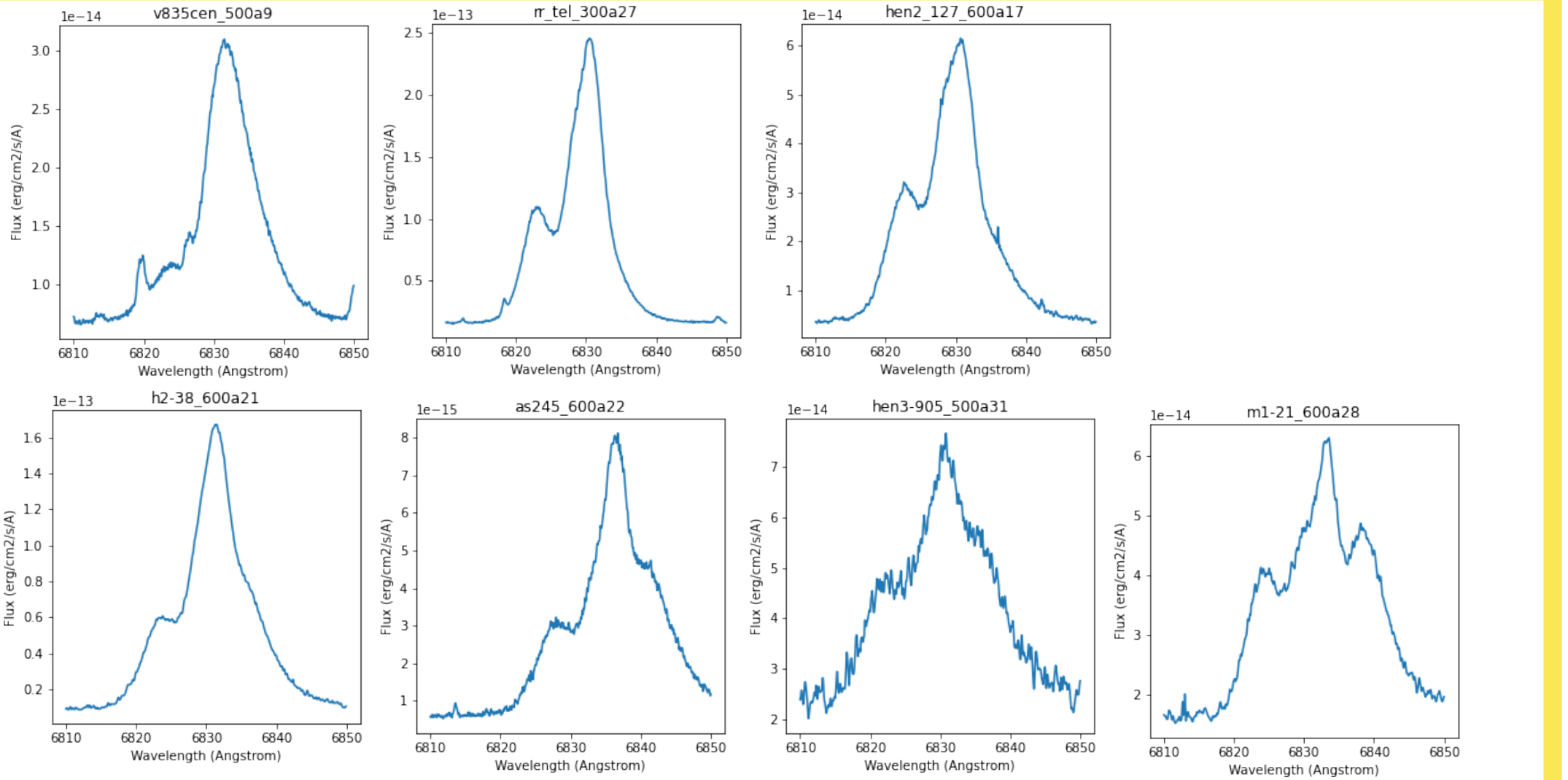
Heo et al. (in prep)

Raman O VI and Accretion Flow



Raman O VI 6825 in Galactic SySts

2) Double/triple with dominant second peak



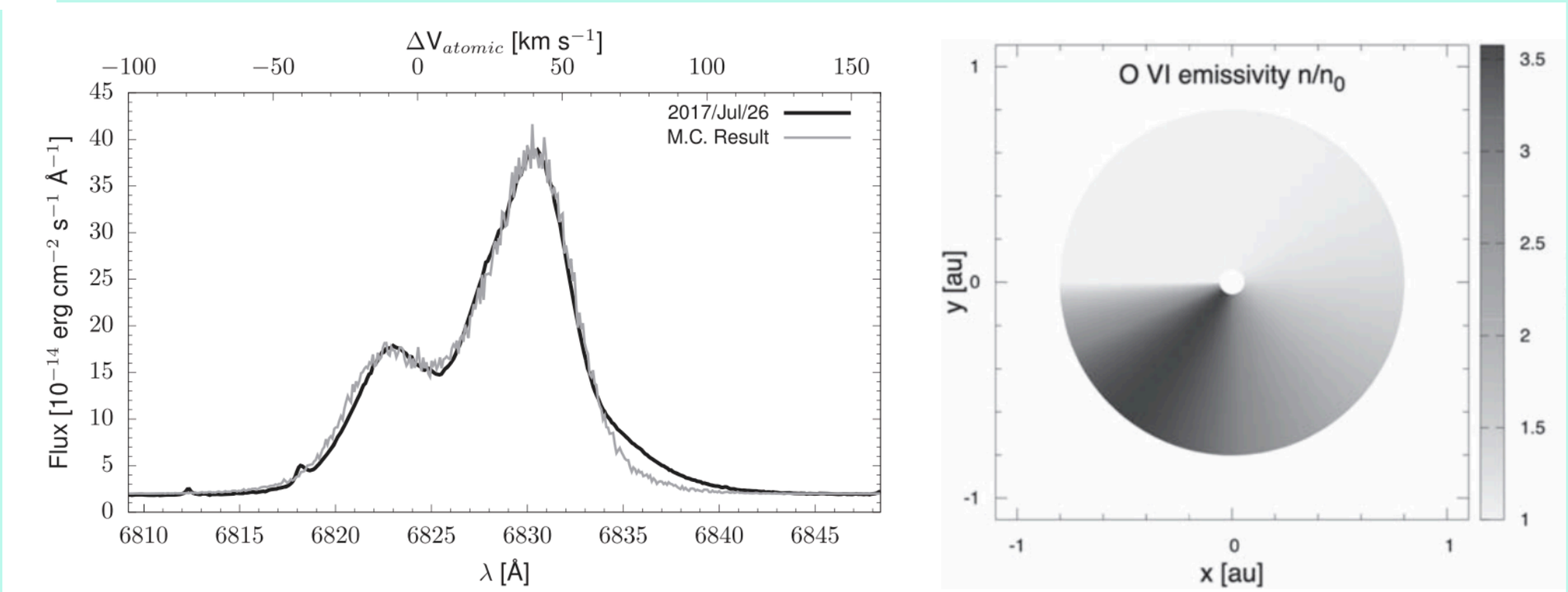
- Clear double peak structure

Heo et al. (in prep)

Raman O VI 6825 in Galactic SySts

2) Double/triple with dominant second peak

RR Tel

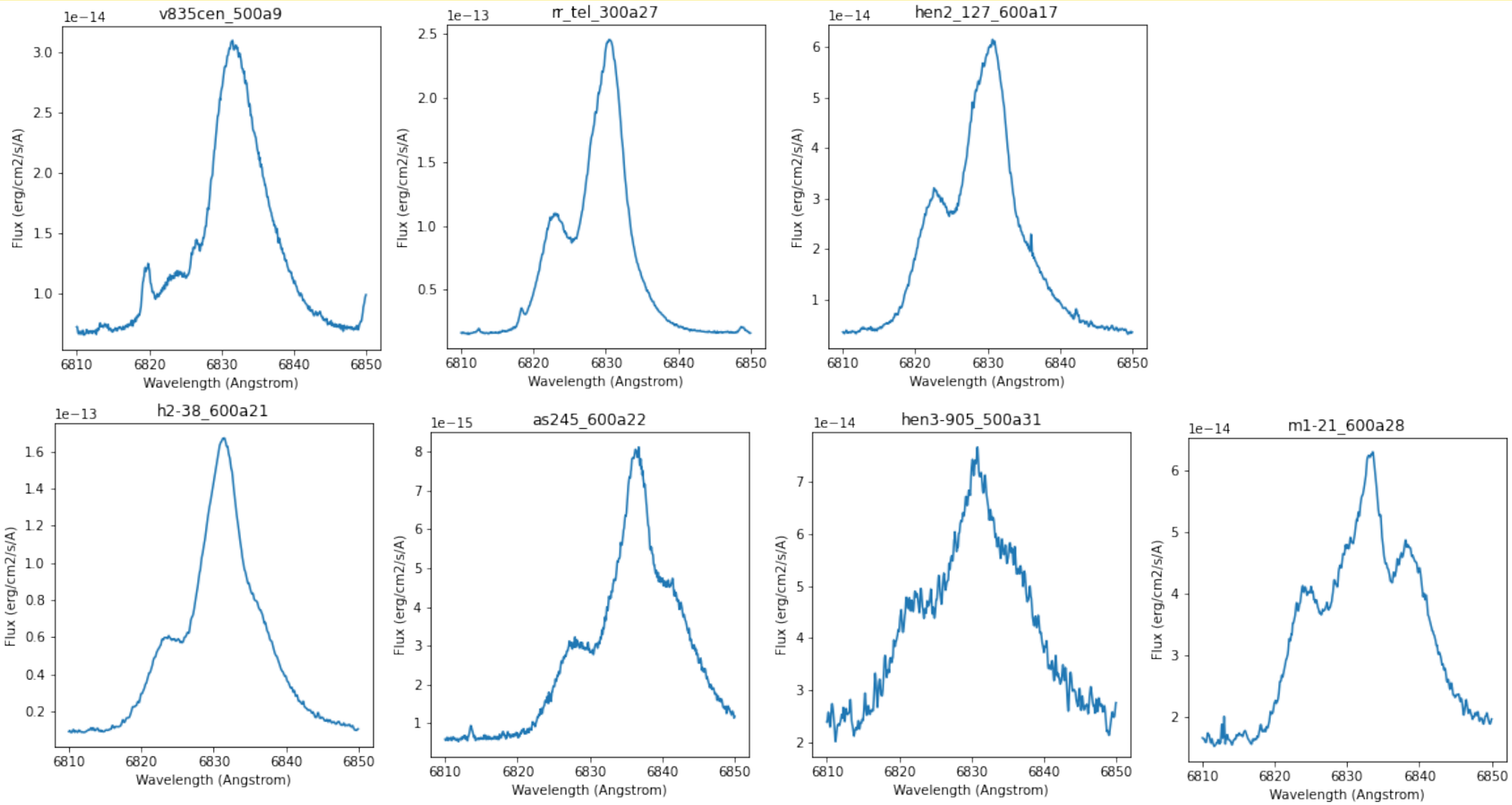


(Heo et al. 2021)

- Keplerian accretion disk model with **azimuthally asymmetric matter distribution:** v_{min}~ 35 km/s, a physical size of the disk ~ 0.8 au
- **Stellar wind and STB ionization front model:** Mira wind v_{∞}~20 km/s and Mloss~ 2*10-6 $M_{\odot}yr^{-1}$
- **Double peak profile and the stable accretion disk**

Raman O VI 6825 in Galactic SySts

2) Double/triple with dominant second peak

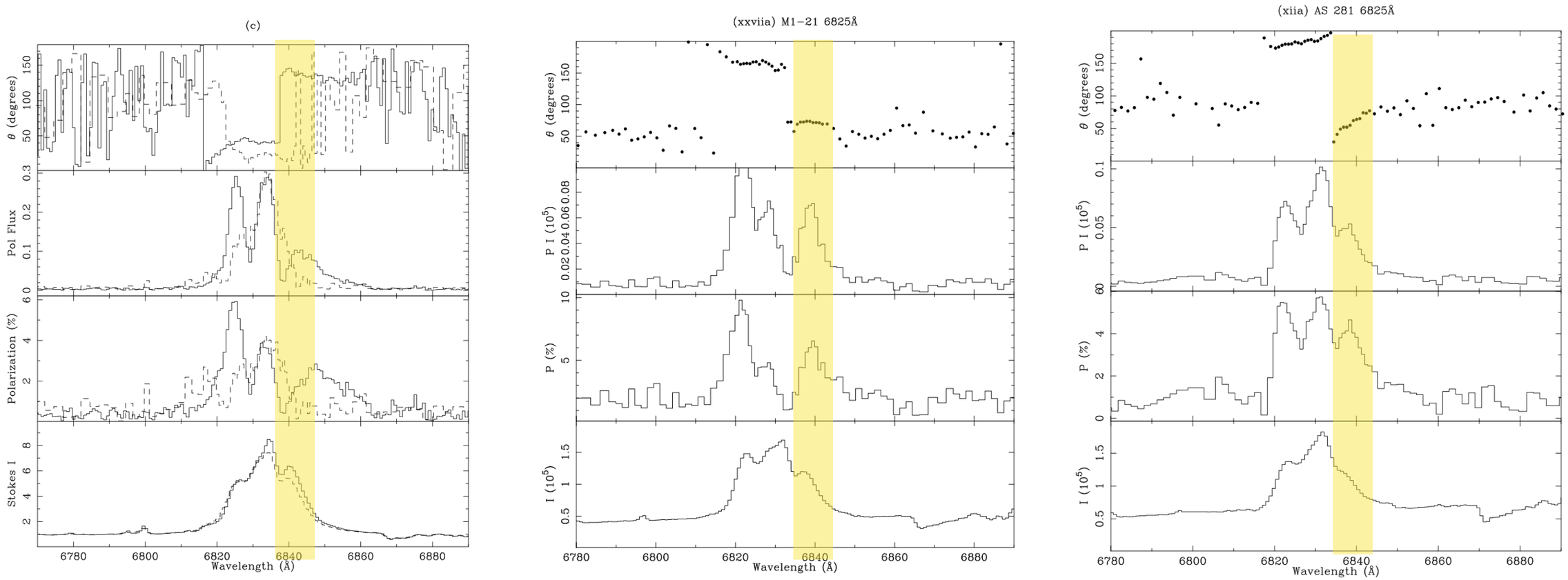


- Clear double peak structure
- Third peak at ~80km/s

Heo et al. (in prep)

Raman O VI 6825 in Galactic SySts

2) Double/triple with dominant second peak

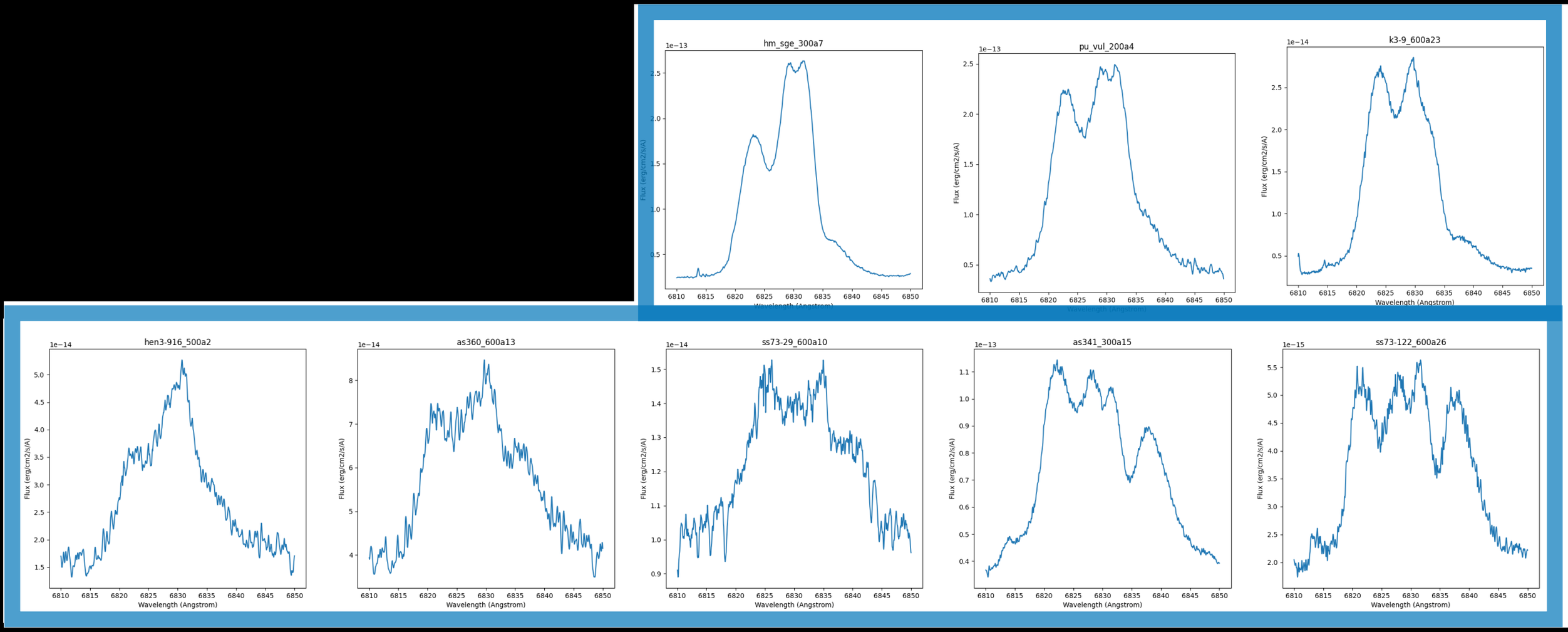


Harries, T. J., & Howarth, I. D. (1996)

- Third peak and jet?

Raman O VI 6825 in Galactic SySts

3) Multiple peak with enhanced first peak

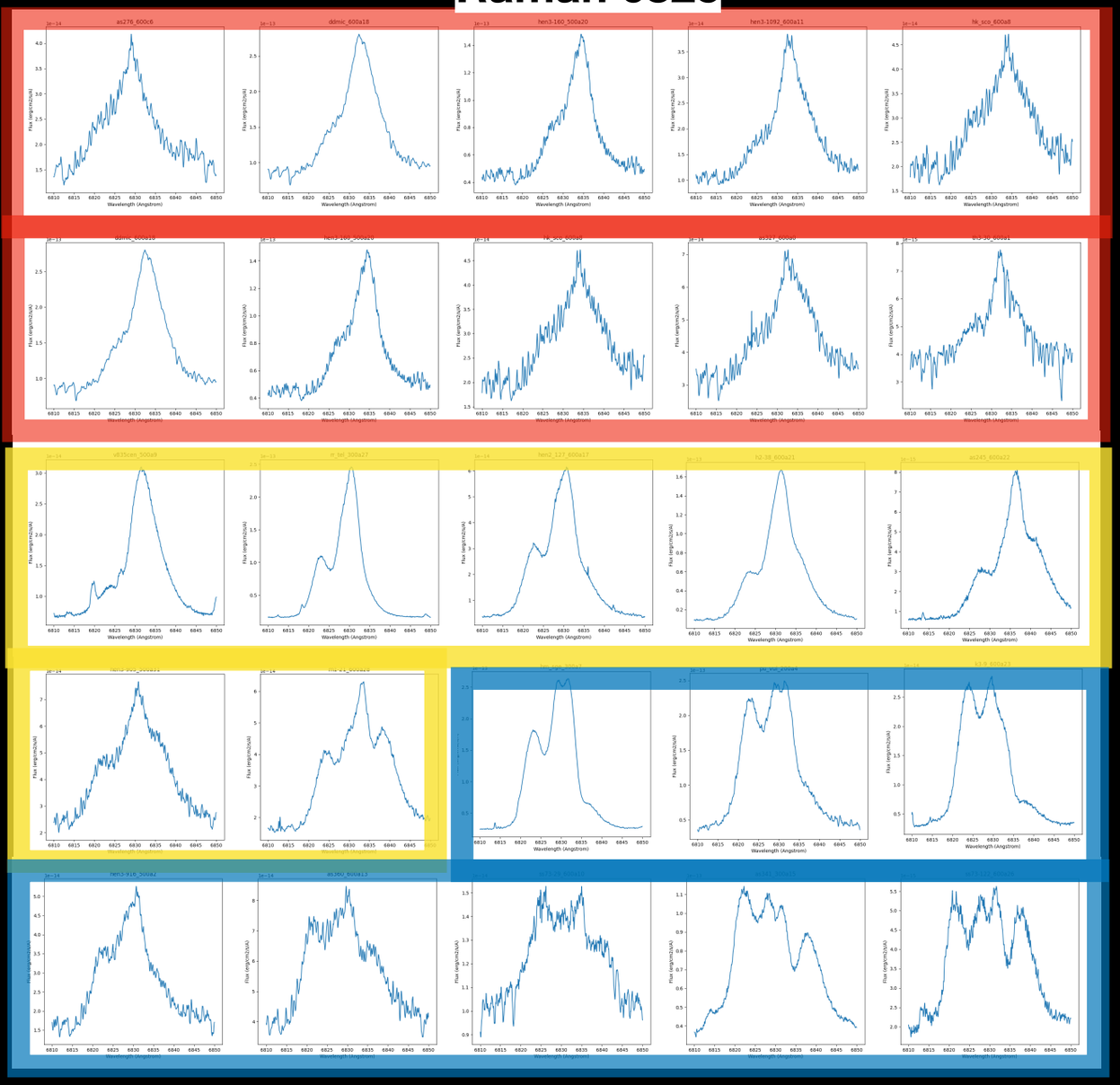


- Multi components with clumpy structures?
- Circumstellar binary medium?

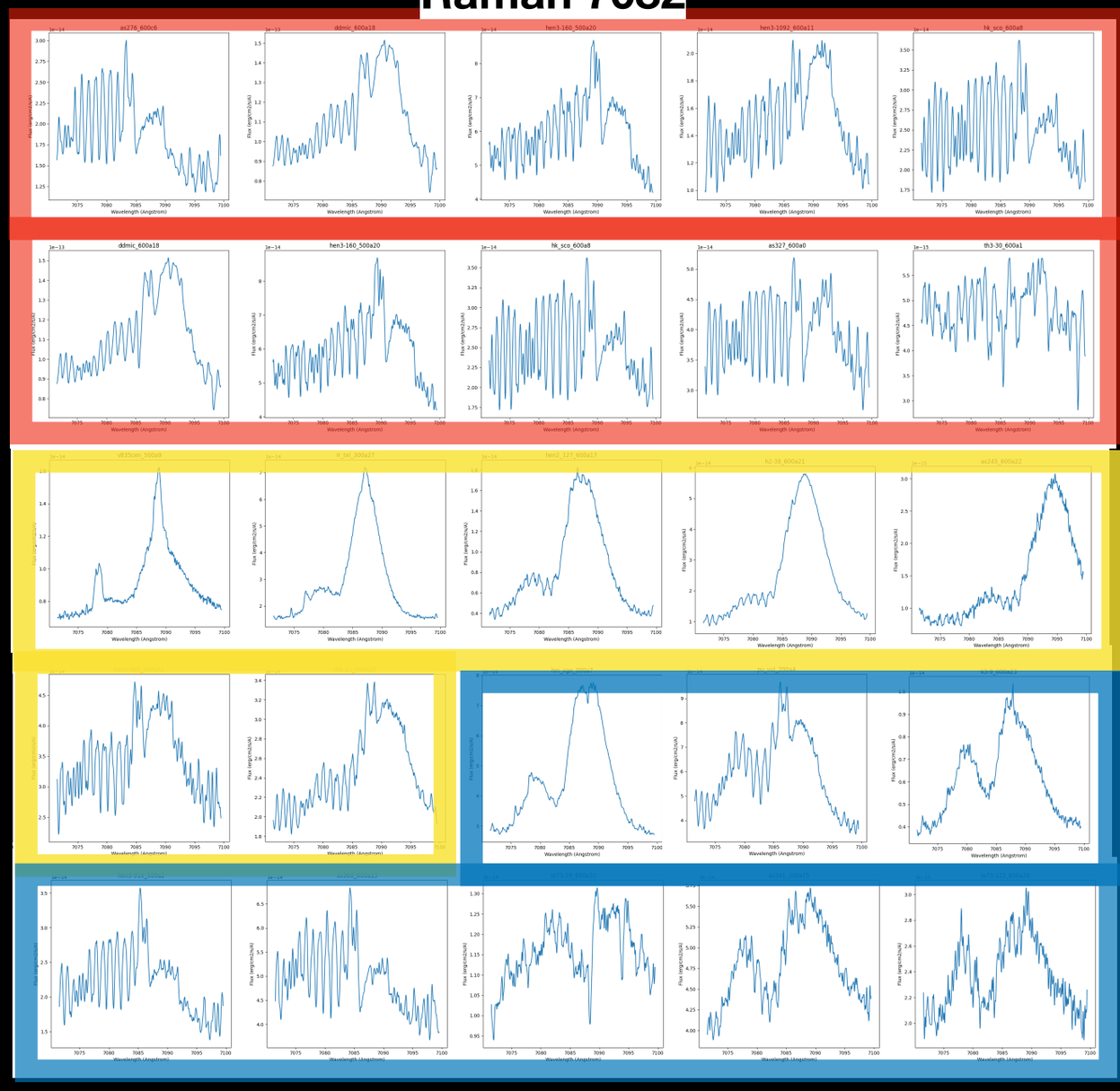
Heo et al. (in prep)

Raman 6825 & 7082

Raman 6825



Raman 7082



- The Raman O VI features at 6825 & 7082 have different profiles despite having the same origin.
- The combination of differing scattering cross-sections and optical depth, kinematic effects, and the physical conditions of the scattering region all contribute to these observed differences.

Heo et al. (in prep)

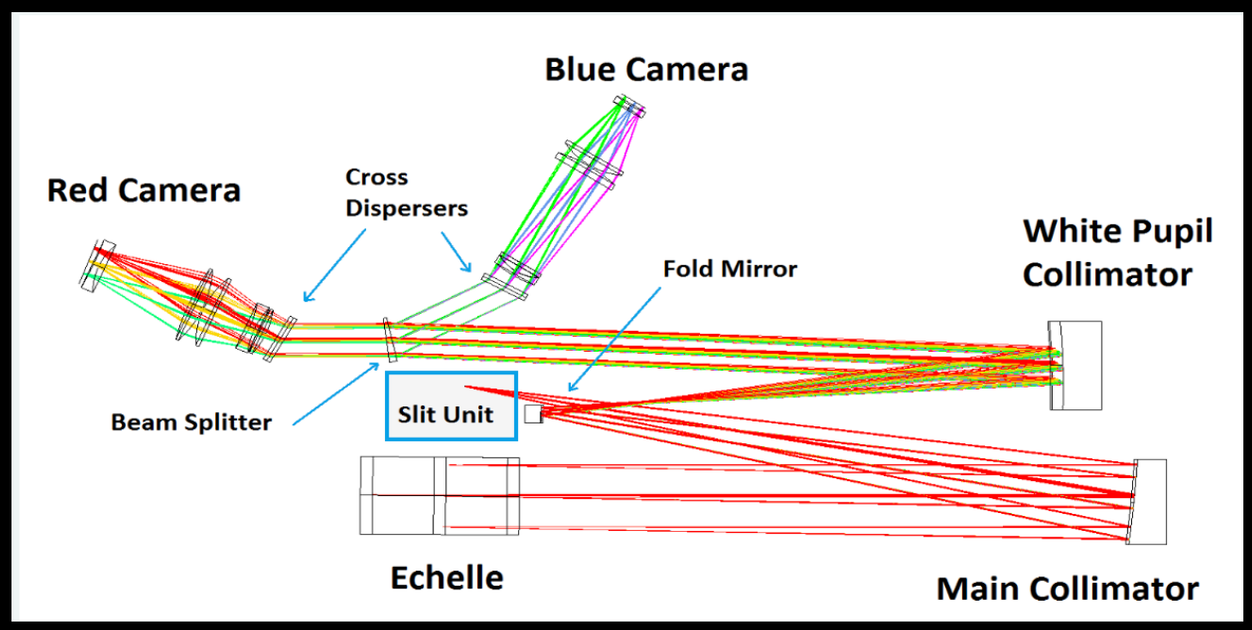
Raman O VI in Galactic SySts

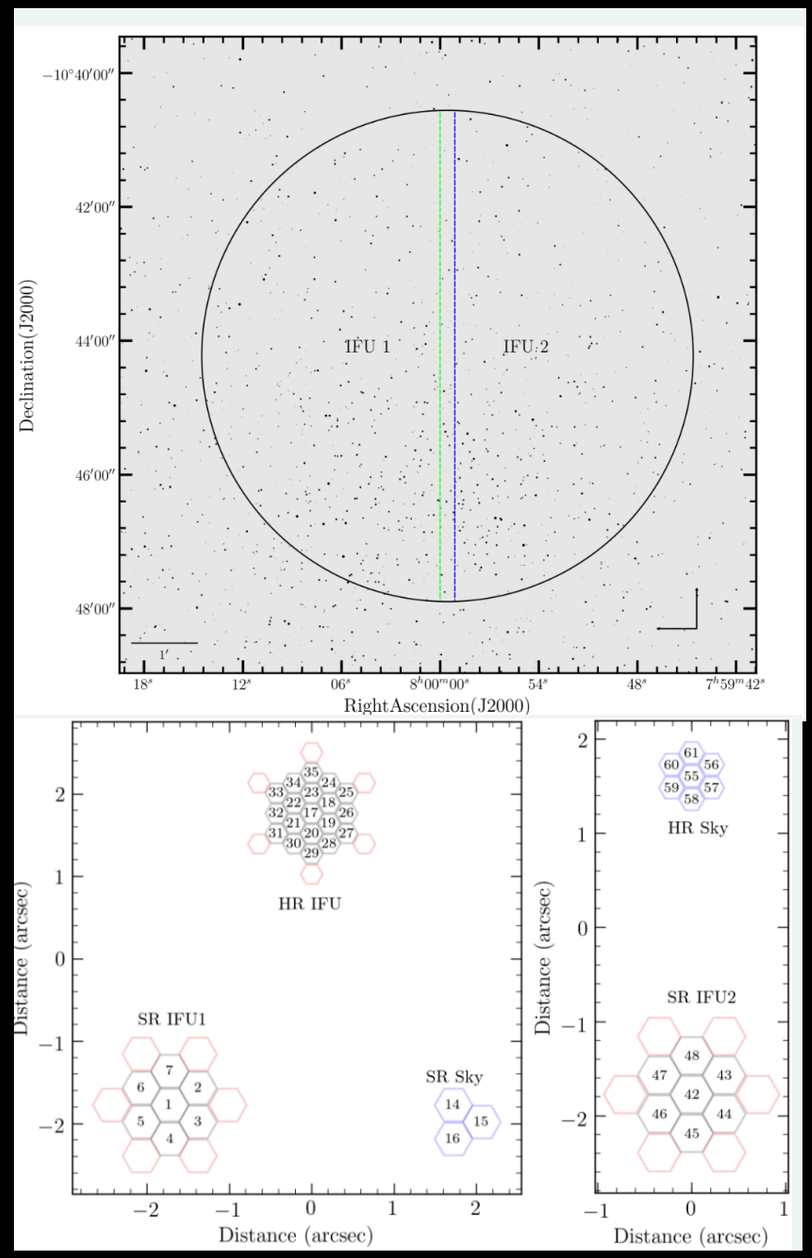
- Physical parameters (e.g., orbital period, IR properties, WD temperature, the stellar type of the cool companion) in the observed SySts.
  → **The evolutionary stage of the SySts forming Raman O VI features**
- Flux ratios of strong emission lines (e.g., F(Raman6830)/F(HeII4686))
  → **A new diagnostic tool to characterize the symbiotic nebulae**
- Outburst history
  → to confirm our scenario that Raman O VI profiles provide information of bipolar jet outflow
- X-ray characteristics
  → The hardness of X-ray depends on the existence of accretion and nuclear burning on their WD surface

GHOST

Gemini High-resolution Optical SpecTrograph

- Total wavelength range: 363-950 nm
- Standard Resolution mode:
  R~50,000 (single/ dual targets mode)
- High resolution mode:
  R~75,000 single target

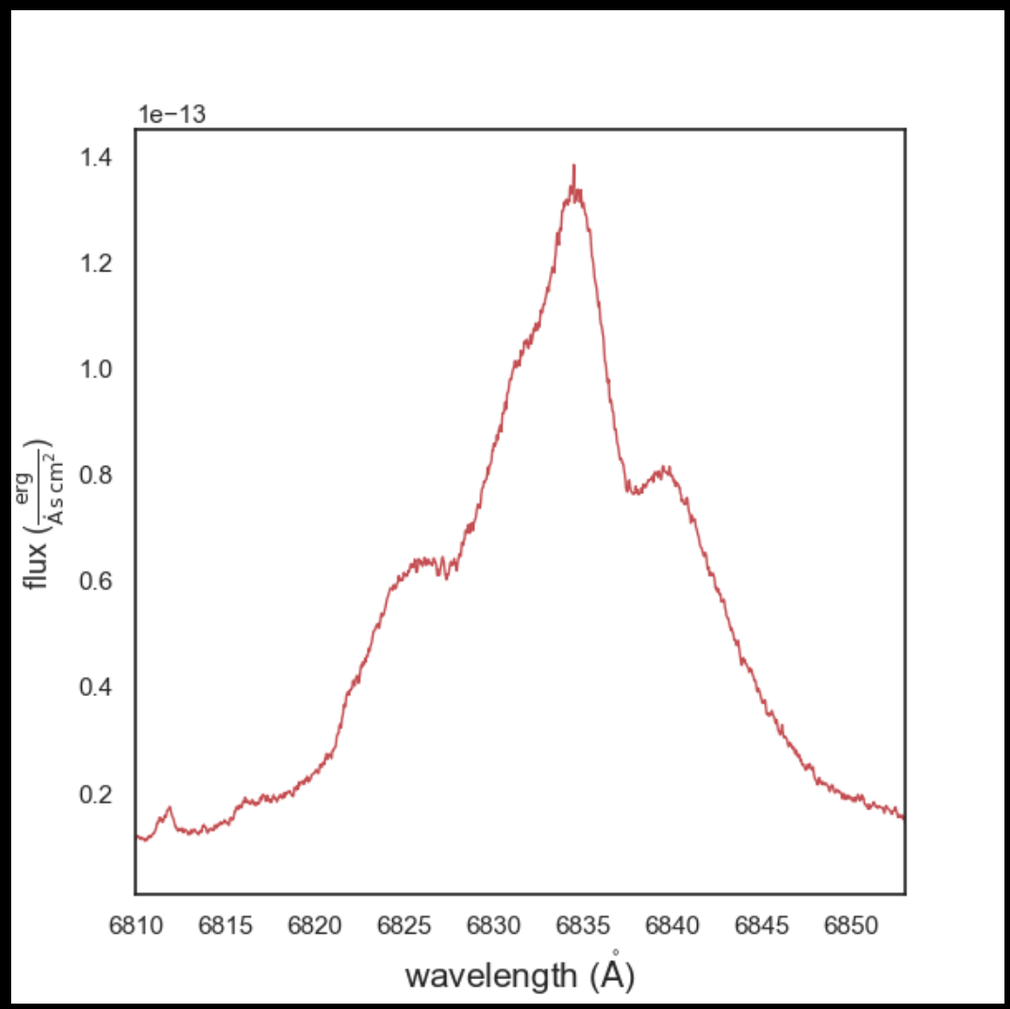


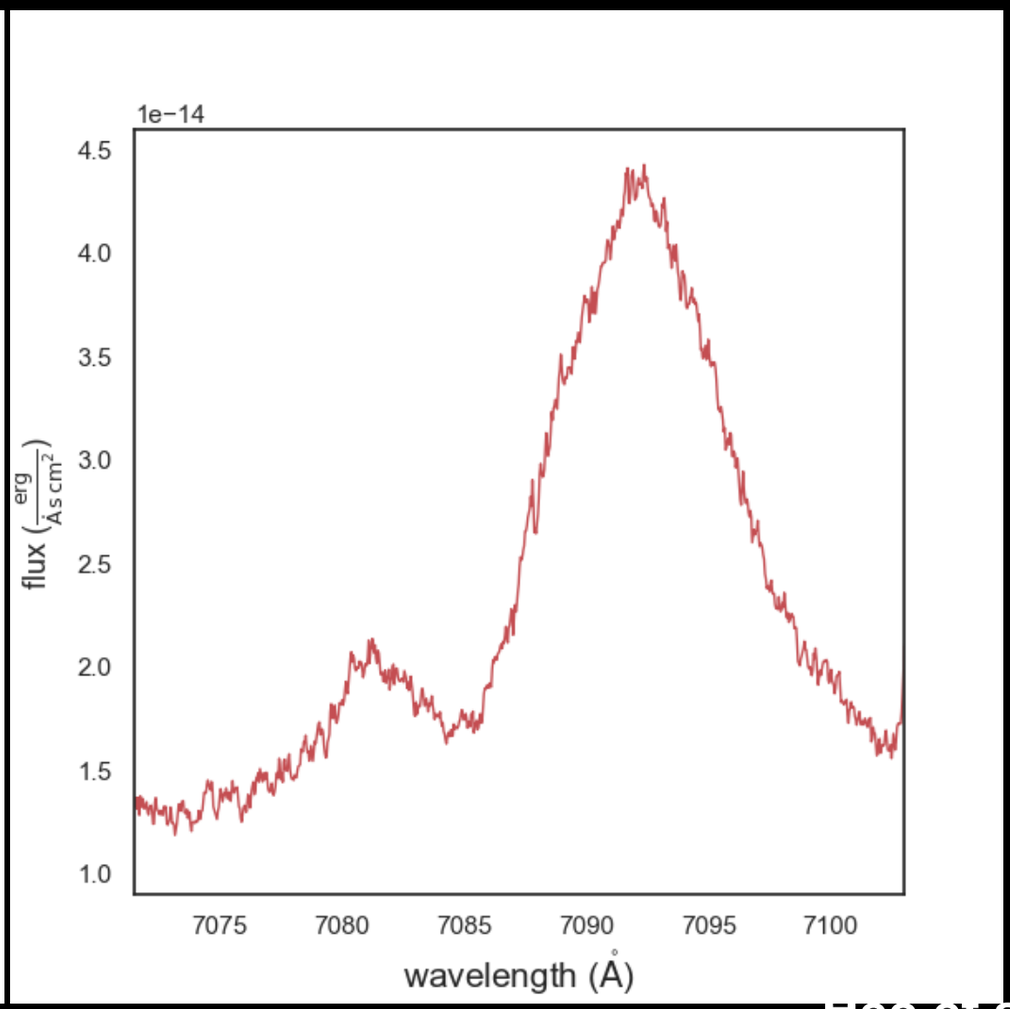


GHOST data

V366 Car

- May 16, 2023 during SV run
- Standard, single target mode. 1x2 binning
- 450 sec (150sec *3)





Heo et al. (in prep)

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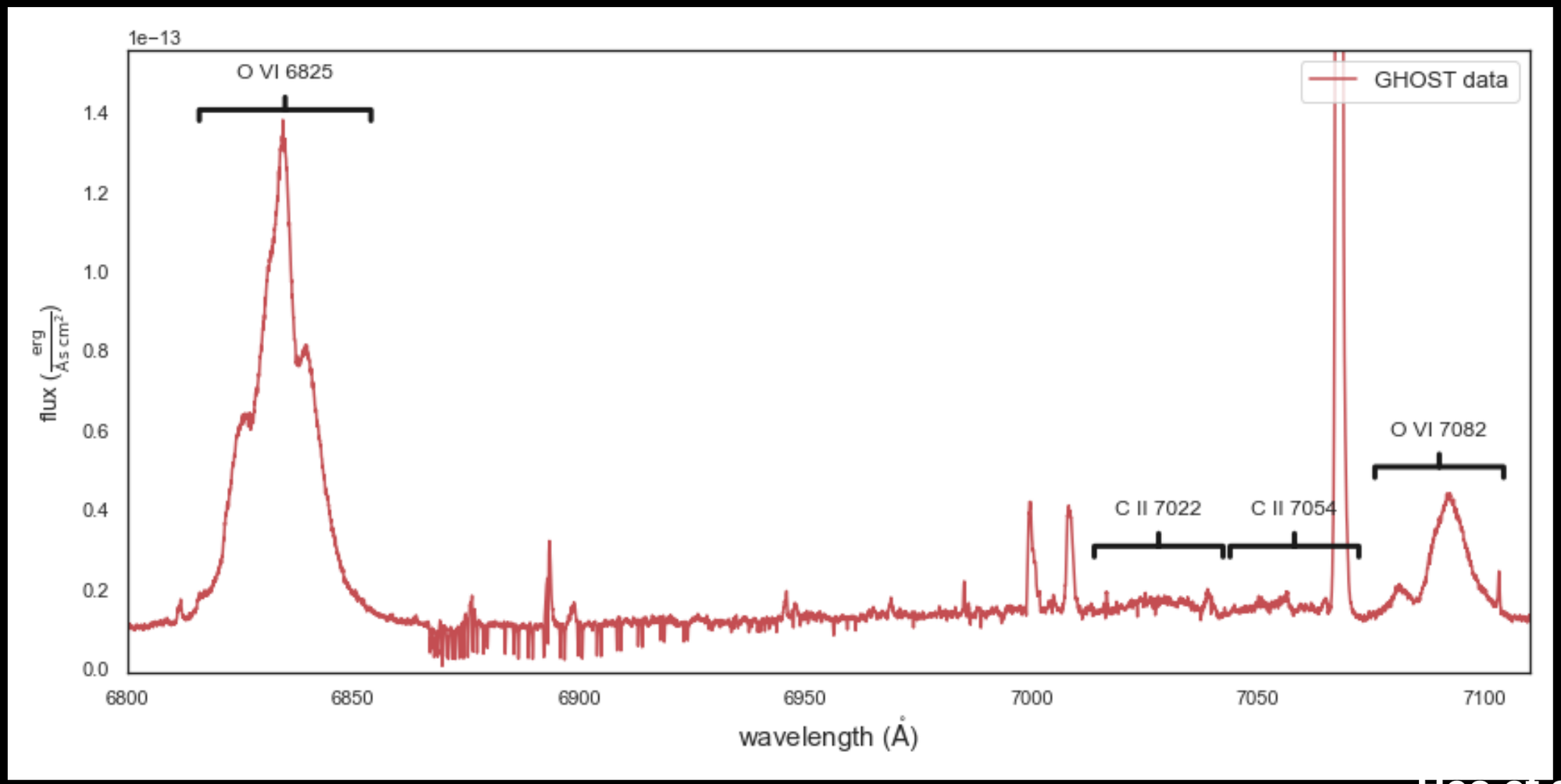
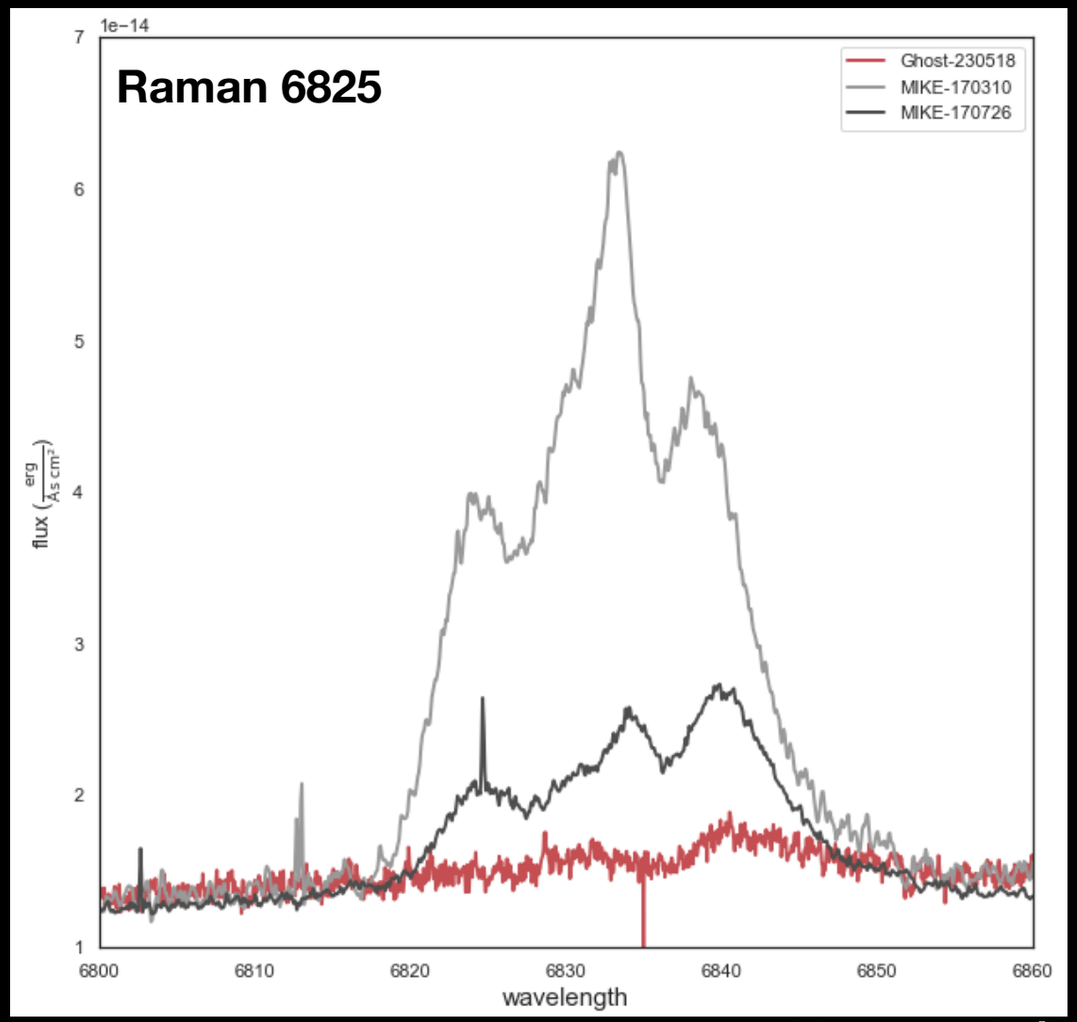


Heo et al. (in prep)

GHOST data

M 1-21

- May 18, 2023 during SV run
- Standard, single target mode. 1x2 binning
- 540 sec (180sec *3)



Heo et al. (in prep)

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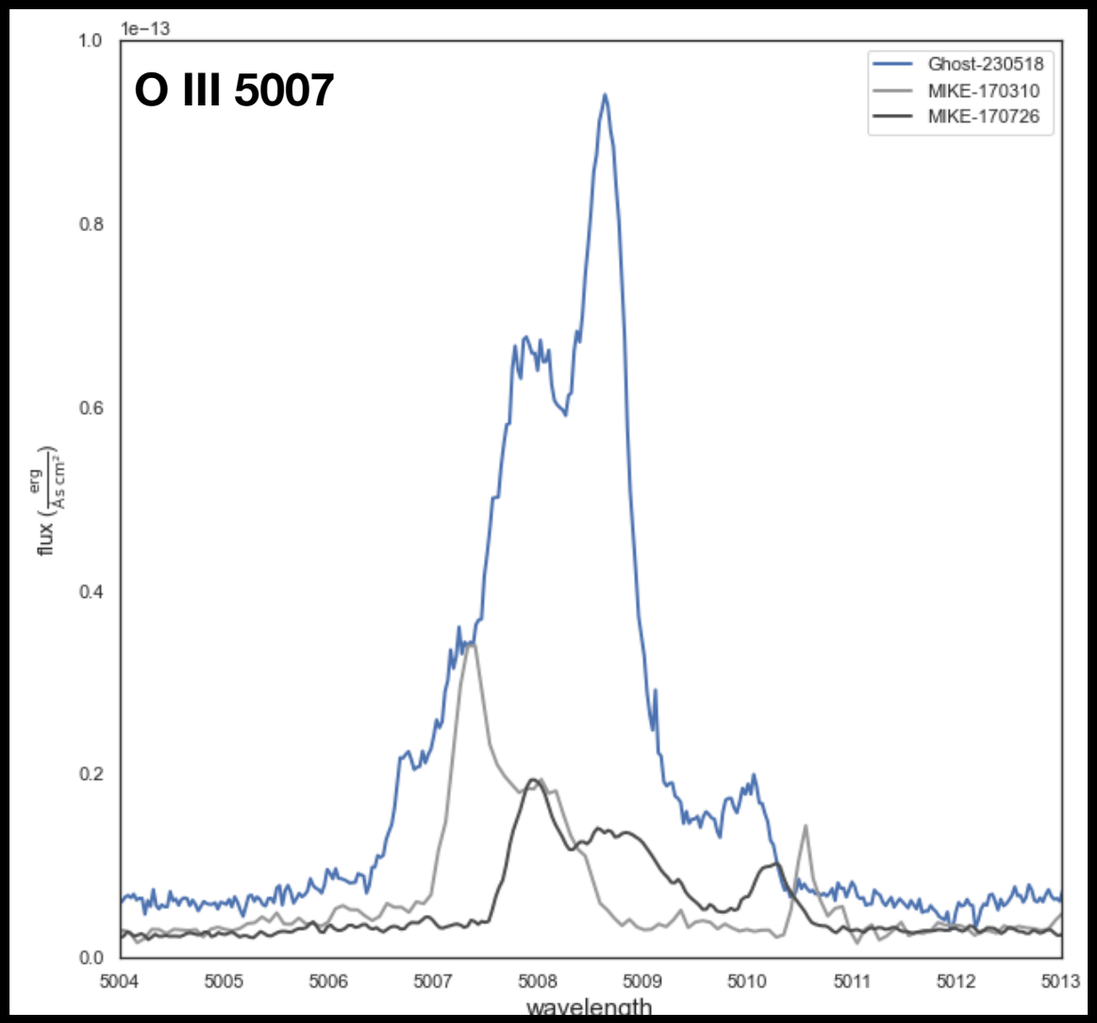

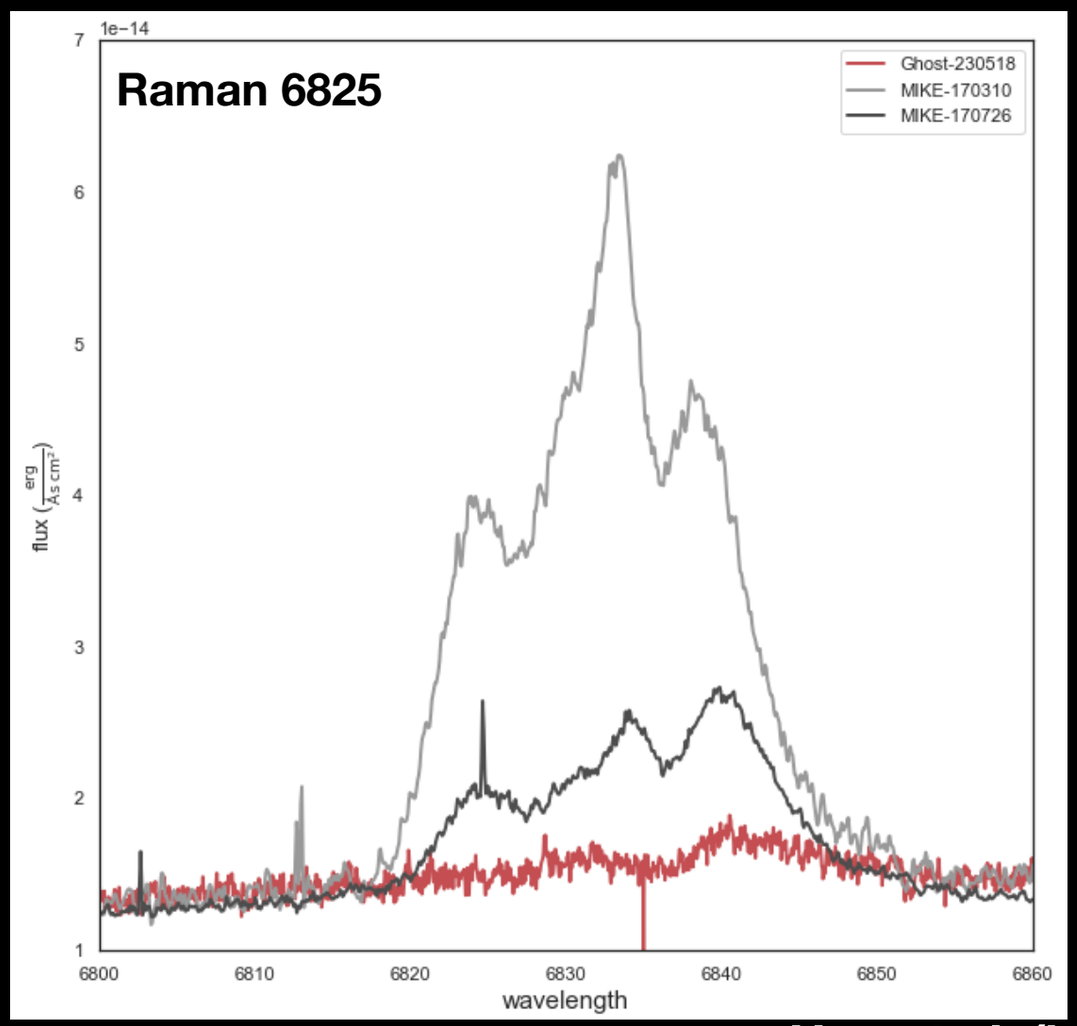

Heo et al. (in prep)

GHOST

Gemini High-resolution Optical SpecTrograph

- **Gemini open policy for US time**

  US time is open to all astronomers worldwide including those at non-US institutions

- **GHOST reduced data**

  US NGO will provide reduced data to all programs, regardless of country

Summary

- Raman O VI features have the potential to trace the evolutionary paths of symbiotic stars.

- We continue to focus on expanding the sample size and conducting more comprehensive observations with instruments like GHOST.

- Our understanding of the relationship between Raman O VI features and evolutionary stages, potentially leading to new insights and breakthroughs in the field of symbiotic star research

Thank you

Illustrated by Chat GPT 4o