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CN2017A-143

Galactic panel
Tali Palma | tpalma@astro.puc.cl
UNAB
astronomer

Deep High-resolution spectroscopy of Raman-scattered O VI features in Southern Symbiotic Stars

Abstract

In the framework of Chile-Sejong-KASI 3-year project entitled ”High Resolution Spectroscopic Study of Wind Accretion and Mass Loss in Stellar Systems Involving White Dwarfs”, we request 1 night with MIKE at the Magellan-Clay Telescope. Our main goal is acquisition of high-resolution spectra of a selected sample of southern Symbiotic Stars (SSs) exhibiting Raman-scattered O VI features at 6825 and 7082A. Multiple-peak profiles characteristic of Raman features is a useful diagnostic of the O VI emission region including an accretion flow around the white dwarf (WD), because they provide special edge-on view as seen by an giant. Through the quantitative profile analysis of these features, we will produce a map of O VI distribution around the WD and obtain best fitting parameters to the data to infer the terminal speed of the H I wind from the giant. Therefore this deep high-resolution spectroscopy will allow us to investigate both the mass loss and the accretion processes in S

Observing Blocks

Instrument/Telescope	Req. time	Min. time	1^{st} Option	2^{nd} Option
MIKE/Magellan / Clay	1 nights	1 nights	March 27	April 15

CoIs

Name	Institution	e-mail	Observer?
Jeong-Eun Heo	OCL	jeung6145@gmail.com	True
Rodolfo Angeloni	OCL	rangelon@gemini.edu	False
Francesco Di Mille	OCL	fdimille@lco.cl	True
Hee-Won Lee	OnCL	hwlee@sejong.ac.kr	False
Seok-Jun Chang	OnCL	csj607@gmail.com	False

Status of the project

- Past nights: 0
- Future nights: 1
- Long term: False
- Large program: False
- Thesis: False

List of Targets

ID	RA	DEC	Mag
Hen 3-160	08:24:52.8	-51:28:36.0	V=15.4
V366 Car	09:54:43.3	-57:18:52.4	V=13
SY Mus	11:32:05.5	-65:25:08.0	V=10.9
Hen 3-828	12:50:58.0	-57:50:47.0	V=13.4
Hen 3-905	13:30:37.2	-57:58:18.0	V=13.4
Hen 3-916	13:35:28.9	-64:45:45.0	V=12.9
V835 Cen	14:14:09.4	-63:25:46.1	V=12.9

SCIENTIFIC AIM AND RATIONALE

SCIENTIFIC RATIONALE

Symbiotic Stars (SSs) are long-period interacting binary systems containing a compact object, usually a White Dwarf (WD), and a mass losing giant. Symbiotic activities including prominent emission lines and erratic variabilities are believed to occur through slow wind accretion, in which the evolved giant transfers material to the companion. The wind accretion phenomena make SSs a possible candidate for Type Ia supernova progenitors (Dimitriadis et al. 2014, Mikołajewska 2013, Dilday et al. 2012). However wind accretion in SSs has been poorly investigated compared to accretion through Roche lobe overflow in cataclysmic variables. Having a giant as mass donor, SSs are also very interesting objects to study mass loss processes characterizing the late stage of stellar evolution.

An ideal spectroscopic tool to study the mass loss and mass transfer processes in SSs is Raman-sscattered features of far-UV lines formed through inelastic scattering with atomic hydrogen. In particular, two broad features at 6825 and 7082 Å are Raman-scattered O VI $\lambda\lambda$ 1032 and 1038, which are known to appear only in *bona fide* SSs (Schmid 1989; Nussbaumer et al. 1989). These features exhibit multiple-peak profiles including double- or triple-peak indicative of the presence of an accretion disk and bipolar outflow. Due to special inelasticity of scattering, the profiles of these features reflect only the relative kinematics between the H I scattering region and the far-UV O VI emission region and are quite independent of the observer's line of sight, allowing us a unique edge-on perspective of the mass transfer process as seen by an imaginary observer in front of the giant (Lee & Lee 1997). Usually, red peaks tend to be stronger than blue counterparts in Raman 6825 and 7082 bands, which implies that the accretion stream around the WD component is asymmetric and may also be accompanied by a bipolar outflow (see Fig. 2, Heo et al. 2016).

More useful information can be obtained from a detailed comparison of the two profiles in the O VI far UV parent Doppler factor space, where the blue part is more suppressed in Raman 6825 than in Raman 7082 (Lee & Kang 2007, Heo & Lee 2015). The severe suppression in the blue part is attributed to the fact that the blue emission region is optically thin so that $F(1032)/F(1038) \sim 2$, whereas the red part is optically thick characterized by the flux ratio $F(1032)/F(1038) \sim 1$ (Kang & Lee 2008; Schmid et al. 1999). With this strategy, we successfully fitted the Raman O VI profiles in Sanduelak's star recently obtained with MIKE by assuming that the O VI emission region can be decomposed into an accretion disk, a bipolar outflow and a compact, optically thick component. The mass loss rate was estimated by computing the representative column density of the H I scattering region in the nebulae (see Fig. 1, Heo et al. submitted to ApJ). As a by-product of this spectroscopic observation, we expect to secure other Raman features including Raman-scattered He II λ 1025, 972 and 949 at 6545 Å 4850 Å and 4332 Å and C II $\lambda\lambda$ 1036, 1037 features at 7025 and 7053 Å. In 2016B semester, indeed, we discovered Raman-scattered C II $\lambda\lambda$ 1036 and 1037 features at 7025 and 7053 Å in the symbiotic star RR Tel with MIKE (see Fig. 3).

SCIENTIFIC AIM

With this CNTAC proposal, we request 1 night of high-resolution spectroscopy with MIKE at the Magellan-Clay telescope representative sample of SSs known to exhibit Raman O VI 6825 and 7082 Å bands. The main goal is to secure clear profiles of Raman O VI features in these objects in order to characterize both the mass loss and the accretion processes in SSs through the quantitative profile analysis of those features. In particular, Raman 7082 is relatively weak compared to Raman 6825 so that deep high-resolution spectroscopy is required for our profile comparison study. Our profile comparison will enable us to visualize the accretion stream around the WD in SSs with fine details.

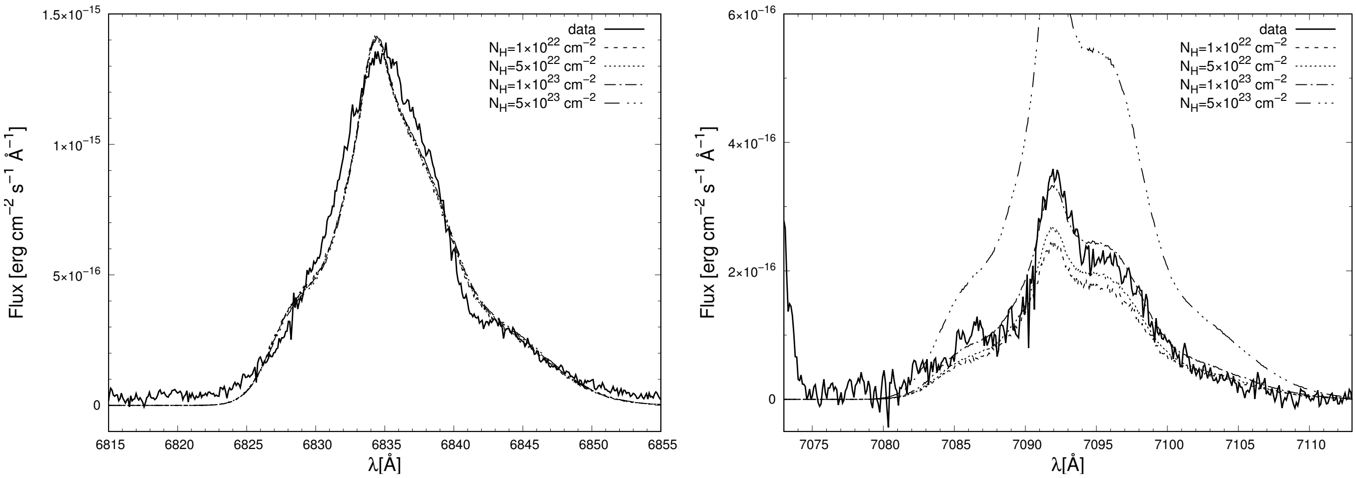

Figure 1: Raman-scattered O VI bands at 6825 Å (left panel) and 7082 Å (right panel) of Sanduleak' star obtained with MIKE (3×900 sec exposures). The solid line shows the observation, while the dotted line represents the results of our Monte Carlo simulations for various N_{HI}. We normalize the simulated spectra with the observed Raman 6825 Å band and look for the best fitting profile of the observed Raman 7082 Å band. A good fit is obtained for $N_{HI} \sim 1 \times 10^{23}$ cm^{-2}(Heo et al. 2016 submitted to ApJ).

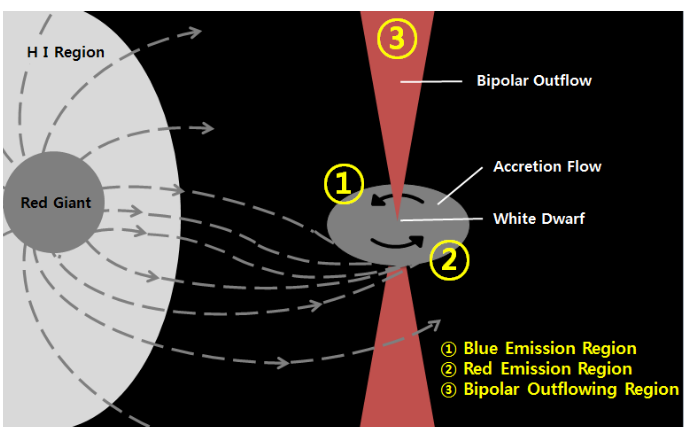

Figure 2: A schematic illustration (not to scale) of a symbiotic star. The emission region is identified with the accretion flow, which is divided into the "blue emission region" and the "red emission region" denoted by BER and RER, respectively (from Heo & Lee 2015), around the hot white dwarf and an additional bipolar outflow.

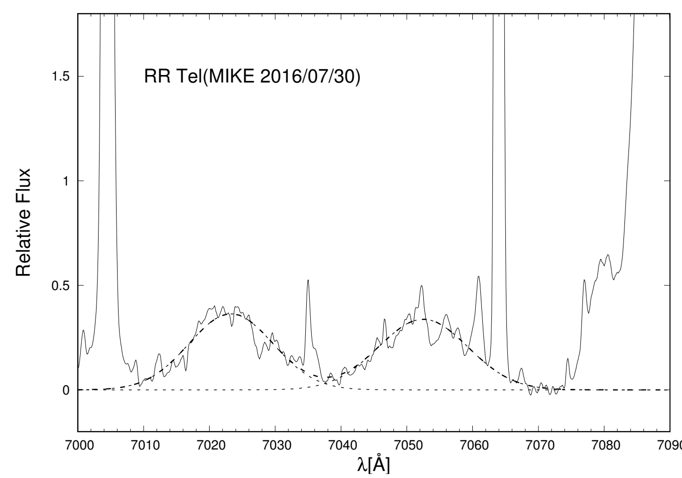

Figure 3: Raman C II features at 7025 and 7053 Å of RR Tel that we discovered with MIKE in July 2016 (4×500 sec exposures) through the Chilean proposal CN2016B-82. The solid line shows the data and the Gaussian fit for each line are represented by dotted line. The profile of Raman C II features show single-peak profile, implying that the geometry and kinematics of C II and O VI emission regions are quite different (Heo et al., in preparation).

Name	α	δ	Epoch	Mag.
Hen 3-160	08 24 52.8	-51 28 36.0	J2000	V=15.4
V366 Car	09 54 43.3	-57 18 52.4	J2000	V=13
SY Mus	11 32 05.5	-65 25 08.0	J2000	V=10.9
Hen 3-828	12 50 58.0	-57 50 47.0	J2000	V=13.4
Hen 3-905	13 30 37.2	-57 58 18.0	J2000	V=13.4
Hen 3-916	13 35 28.9	-64 45 45.0	J2000	V=12.9
V835 Cen	14 14 09.4	-63 25 46.1	J2000	V=12.9
Hen 3-1092	15 47 10.6	-66 29 16.0	J2000	V=13.5
KX TrA	16 44 35.2	-62 37 14.0	J2000	V=12.4
Hen 3-1341	17 08 36.6	-17 26 30.0	J2000	V=12.5
Hen 3-1342	17 08 55.0	-23 23 35.0	J2000	V=12.7
H 1-36	17 49 48.1	-37 01 27.9	J2000	V=12
Bl 3-14	17 52 25.9	-29 46 00.0	J2000	V=14.3
AS 255	17 57 08.7	-35 15 38.0	J2000	V=12.5
AS 276	18 09 09.6	-41 13 26.0	J2000	V=12

Table 1: Target list

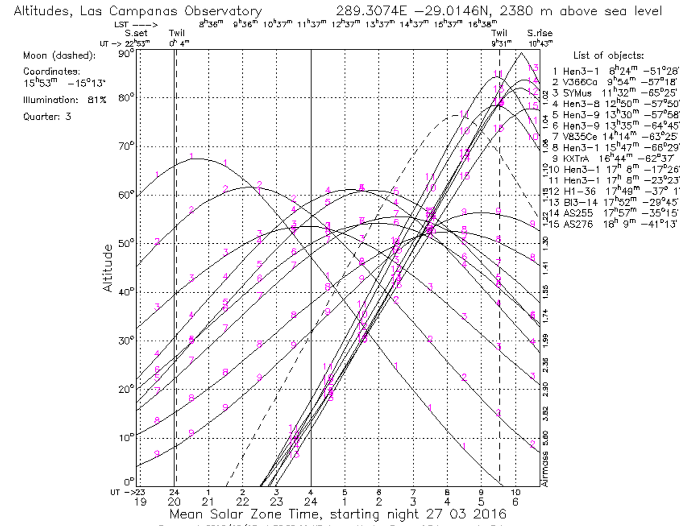

Figure 4: Target visibility for the night of March 27 from Las Campanas Observatory

References

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Schmid, H. M. 1989, A&A, 211, 31

Schmid, H. M., et al. 1999, A&A, 348, 950

CURRENT STATUS OF THE PROJECT

This proposal is part of the recently started 3-year project entitled *"High Resolution Spectroscopic Study of Wind Accretion and Mass Loss in Stellar Systems Involving White Dwarfs"*, completely funded by the Korea Astronomy and Space Science Institute (KASI) with the explicit goal of fostering collaborative research between Korean and Chilean astronomers. The official webpage of the project is at http://korea-chile.com.

We have submitted for this semester (2017A) a similar proposal with GRACES at GEMINI-North for deep high-resolution spectroscopy of a representative sample of the northern SSs. The proposal is still under evaluation.

In the framework of this collaboration, last semester we were awarded half a night with MIKE at Magellan Clay telescope. The data reduction process is completed and the data analysis is currently ongoing (Fig. 3, Heo et al. in preparation). Our preliminary analysis suggests that Raman C II profiles are more sensitively affected by the H I wind velocity, making this newly discovered Raman features a promising spectroscopic tool able to probe the H I region in SSs.

Publications

Heo, J.-E., Angeloni, R., Di Mille, F., Palma, T., et al., 2016 Submitted to ApJ, *A Profile Analysis of Raman-scattered O VI Bands at 6825 Å and 7082 Å in Sanduleak's Star*

Lee, Y.-M, Lee, D.-S., Chang, S.-J., et al., 2016 Accepted for publication in ApJ, *A Monte Carlo Study of Flux Ratios of RamanScattered O VI Features at 6825 Å and 7082 Å in Symbiotic Stars*

Heo, J.-E., Angeloni, R., Di Mille, F., Palma, T., et al. 2016, JPhCS, 728, 2014: *Raman-scattered O VI* λ *1032 and He II* λ *1025 and Bipolar Outflow in the Symbiotic Star V455 Sco*

Chang, S.-J., Heo, J.-E., Di Mille, F., et al. 2015, ApJ, 814, 98: *Formation of Raman Scattering Wings around* $H\alpha$*,* $H\beta$*, and* $Pa\alpha$ *in Active Galactic Nuclei*

Heo, J.-E. & Lee, H.-W. 2015, JKAS, 48, 105: *Accretion Flow and Disparate Profiles of Raman Scattered O VI* λ*1032, 1038 in the Symbiotic Star V1016 Cygni*

Ahn, S.-H. & Lee, H.-W. 2015, JKAS, 48, 195: *Polarization of Lyman* α *Emergent from a Thick Slab of Neutral Hydrogen*

Bach, K. & Lee, H.-W. 2015, MNRAS, 446, 264: *Accurate* $Ly\alpha$ *scattering cross-section and red damping wing in the re-ionization epoch*

Pietrukowicz, P., Latour, M., Angeloni, R., et al. 2015, AcA, 65, 63: *A Low-Resolution Spectroscopic Exploration of Puzzling OGLE Variable Stars*

Lee, H.-W., Heo, J.-E. & Lee, B.-C. 2014, MNRAS, 442, 1956: *Raman-scattered Ne VII* λ*973 at 4881Å in the symbiotic star V1016 Cygni*

Lee, H.-W., Heo, J.-E. & Lee, B.-C. 2014, ASPC, 482, 195: *Raman Scattered He II 4332 and Photoionization Model in the Symbiotic Star V1016 Cygni*

Angeloni, R., Ferreira Lopes, C. E., Masetti, N., et al. 2014, MNRAS, 438, 35: *Symbiotic stars in OGLE data - I. Large Magellanic Cloud systems*

Lee, H.-W. 2013, ApJ, 772, 123: *Asymmetric Absorption Profiles of* $Ly\alpha$ *and* $Ly\beta$ *in Damped* $Ly\alpha$ *Systems*

TECHNICAL DESCRIPTION

We request 1 night of MIKE at the Magellan-Clay Telescope with the 0.7 arcsec slit, able to deliver a spectral resolution R≥30,000. The high resolving power of MIKE and the large collecting area of the Magellan-Clay telescope make this instrument/telescope configuration the ideal facility for our project, as we have already demonstrated with the previous time allocation (e.g., CN2016B-82, Heo et al., 2016, submitted to ApJ; Heo et al., in preparation - see also Figs. 1 & 3).

We selected the 15 southern SSs already known to exhibit Raman O VI features (Harries & Howarth 1996, 2000; Schmid & Schild 1994, 1996) and that are visible from Las Campanas in semester 2017A. MIKE does not have a real ETC; however, based on our previous experience with the instrument and the tabulated zero points as from the MIKE official webpage, a count rate of 5 e-/pixel at 6000 Å is obtained for a V∼13 mag star when we assume 0.8 arcsec seeing and airmass 1. In order to reach S/N∼100 per pixel we need an overall time on target of 2,000 seconds that, given the brightness distribution of our targets, can be considered as an averaged estimate. Also, we need short exposures not to saturate the strongest line (e.g., Hα) for flux calibration. With this in mind, our strategy is to collect 1×30 sec and 4×500 sec exposures for each target. We will also observe standard objects for flux calibration three times at night and take wavelength calibration lamps after each target. Taking into account the overheads including target slew and aquistion, readout time in 'slow, low-noise mode' (160 sec), we estimate that it will take ∼40 min for 1 object. For a total of 15 objects, ∼10 hours is required: we thus request 1 night of MIKE telescope time.

It is important to notice that the target list in Table.1 shows that our targets are well distributed in both magnitude and RA (see also Fig. 4). This means that we can easily optimized the observing strategy (e.g., target priority, slit width and exposure time) depending on the real-time conditions of the night. For example, we could decide to focus on the brightest objects if the sky is partially cloudy or the seeing far from optimal, without compromising our need of high spectral resolution. Being awarded half a night would still be acceptable, since it would allow us to observe half of the present sample, still providing a valuable sample of high-quality spectra.