Spectroscopy of post-AGB star IRAS 01005+7910

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Infrared source IRAS 01005+7910 is identified with an 11-mag peculiar star which has been previously found to be a post asymptotic giant branch star of early spectral type. There is significant spectral variability detected earlier. Over 30 spectra were obtained with high resolution $(15000 - 60000)$ in spectral range $3500 - 7800$ ÅÅ. In this work the results of the spectral monitoring of this object are presented. The detailed analysis of radial velocities was carried out. Radial velocities derived from different absorption lines show variability within the same spectrum. Significant variability of radial velocities is demonstrated on the scale of one day. The variability of line profiles is present. The constant radial velocity -51 ± 1.4 km/s of forbidden lines was detected. Shell expansion velocity is estimated from widths of forbidden emission line profiles. The hydrogen and helium line profiles demonstrate the complicated and changing picture both of accretion and outflow in envelope.

Introduction

Intermediate-mass stars (with initial masses of $3 - 8\ M_{\odot}$) that evolve from the asymptotic giant branch (AGB) to a planetary nebula (PN) are observed at the short proto-planetary nebula (PPN) phase. These objects evolve with increasing effective temperatures and almost constant luminosities, spanning a range of spectral types between B and G. At the end of this stage a star ionizes circumstellar gaseous-dusty envelope and becomes a PN. The evolution of intermediate-mass stars was described in detail, e. g., in [1].

High resolution optical spectra of only few hot post-AGB stars have been analysed [10]. The optical spectra of these stars show various absorption lines typical for OB spectral types, emission lines of He I, O I etc. and some nebular emission lines. The variability of the main parameters detected in several post-AGB stars stimulates a spectroscopic monitoring of these objects.

IRAS 01005+7910 (hereafter IRAS 01005) is located far from the galactic plane ($b = 16°$) and identified with peculiar star of spectral type B1.7 with $T_{eff} = 21500$ K [5]. In contrast to the most of PPNe, maser emission has been detected neither in CO nor in OH bands [7]. This result indicates that the object is very close to the PN stage [6]. The IR spectrum contains various emission bands which are characteristic of carbon-rich PPNe [4]. A similar-sized nebulosity with irregular morphology was detected with Hubble Space Telescope [11].

A first high-resolution spectroscopic data was analysed in [5]. Significant spectral variability was detected. Here we present the results of spectral monitoring of IRAS 01005 for the epoch $1999 - 2008$.

Observations and data reduction

Our spectroscopic data were obtained at the 6-m telescope of the Special Astrophysical Observatory, Russian Academy of Sciences with high resolution. There are 32 spectra, 22 of them were obtained with signal-to-noise ratio $S/N \geq 60$. 24 spectra were obtained with NES echelle spectrograph [9] with spectral resolution $R \geq 45000$. Observations cover the time period between 1999 and 2008.

All the spectra were reduced using the modified [12] `ECHELLE` context of the `MIDAS` software package. The cosmic ray traces were removed by median averaging of two subsequent spectra. A hollow cathode Th-Ar lamp was used for the wavelength calibration.

The rms uncertainties of the radial velocity measurements are 1 km/s (the uncertainty from a single line).

Results

Spectral features

The spectra reveal absorption lines of C II, C III λ4647 Å, N II, O II, Al III, Si II λ4128 Å, λ4131 Å, Si III, S II, Ne I and emission lines of Si II, O I, [Fe II], [N I/II], [S II]. Both absorption and emission components are present in H I, He I, Na $D_{1,2}$, Fe III, Mg II (λ4481 Å) and in some C II lines. Some weak Diffuse Interstellar Bands (DIBs) are also present.

The IRAS 01005 spectrum is very similar to that of normal supergiant 9 Cep ($V = 4.^m8$, B2Ib). Several spectra of 9 Cep with high S/N ratio has been taken at NES spectrograph. A spectral atlas of these objects was made. The atlas demonstrates certain spectral properties of IRAS 01005: P Cyg-like profiles of some spectral lines, nebular emissions, reduced metallicity. In Fig. 1 we show a fragment of atlas with several peculiar features.

The resonance Na I lines show 5 constant absorption components (−11, −28, −52, −65.5, −73 km/s) at a resolution of $R \geq 45000$. H, K Ca II lines show similar distribution of components in radial velocity scale. Some spectra show emission components of Na D_2 in blue and red wing. Interstellar nature of three absorption components may be confirmed by velocities distribution of H 21 cm [3] and CO [2] emission observed in this direction. In Fig. 2 we demonstrate 10 profiles of H 21 cm emission from Hat Creek High-Latitude H I Survey [3] in heliocentric radial velocity scale. These profiles were observed in the area of 43 arcmin radius around the IRAS 01005. The velocity resolution of profiles is 2 km/s.

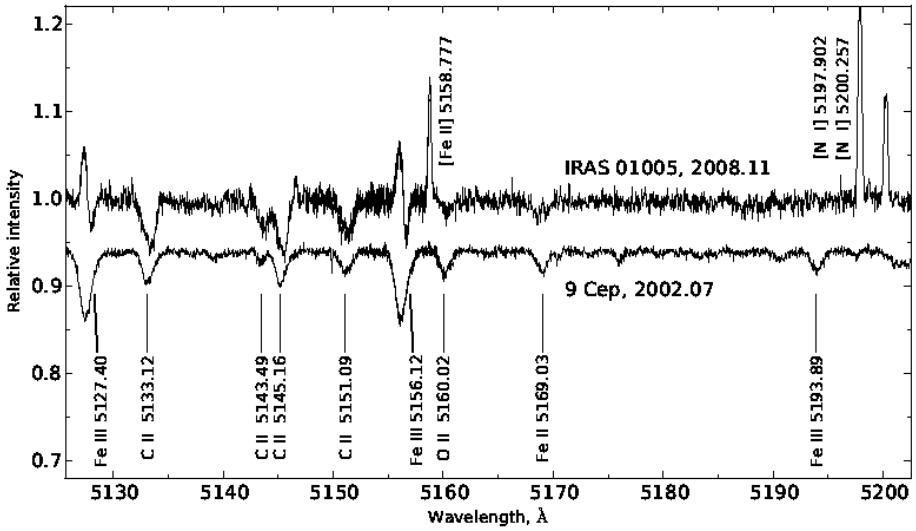

Figure 1: Fragment of spectral atlas of IRAS 01005 and 9 Cep

The hydrogen Balmer lines from H_α to H_γ have asymmetric single-peaked emission profiles which are variable, but blue slope remains constant. The He I line profiles vary from straight to inverse P Cyg-type in a very short timescale and correlates weakly with those of H I.

Spectral variability

All of the lines except forbidden emission lines show variability in radial velocities and line profiles. Resulting value of radial velocity derived from forbidden lines is -51 ± 1.4 km/s. This velocity is close to absorption component of Na I $D_{1,2}$ lines, which is not produced by interstellar medium. Thus we can determine this velocity as systemic.

Radial velocities derived from different absorption lines, even from those of the same element, show variability within the same spectrum. For Si III triplet 4552–4574 Å and 5739 Å line difference is up to 5 km/s.

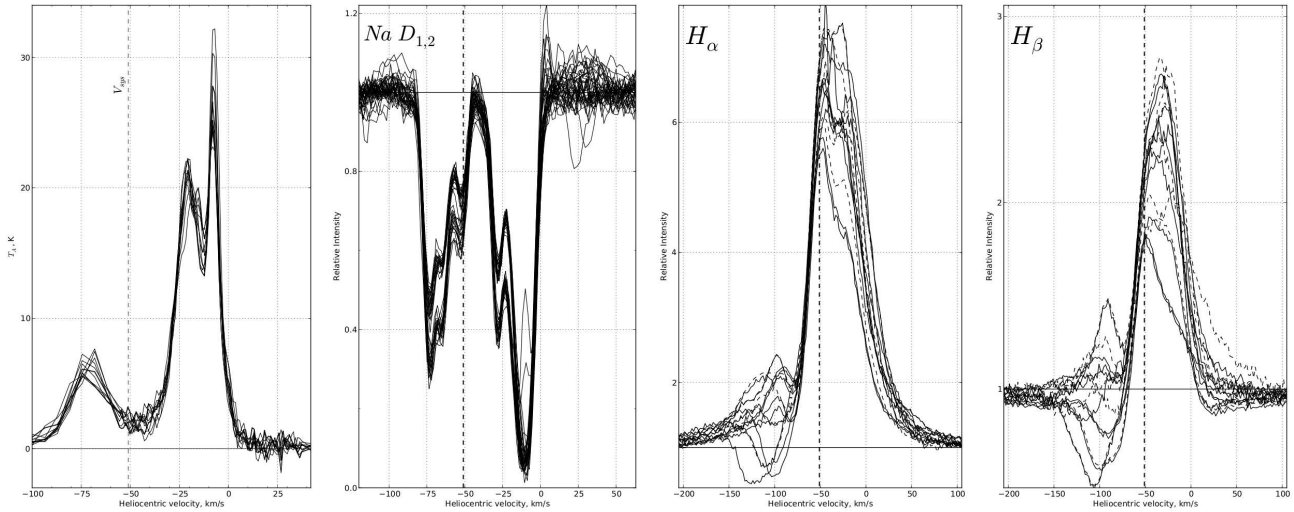

Figure 2: Spectral line profiles in heliocentric radial velocity scale for various dates. From left to right: H 21 cm emission observed in directions close to IRAS 01005, the resonance Na I $D_{1,2}$ lines (D_1 is upper), H_α and H_β line profiles. Dashed line shows systemic velocity.

Values of radial velocities change from -20 to -56 km/s (Fig. 3). Variability of radial velocities is demonstrated on the timescale of one day. The variability of line profiles is apparent, demonstrating asymmetric shape on different dates.

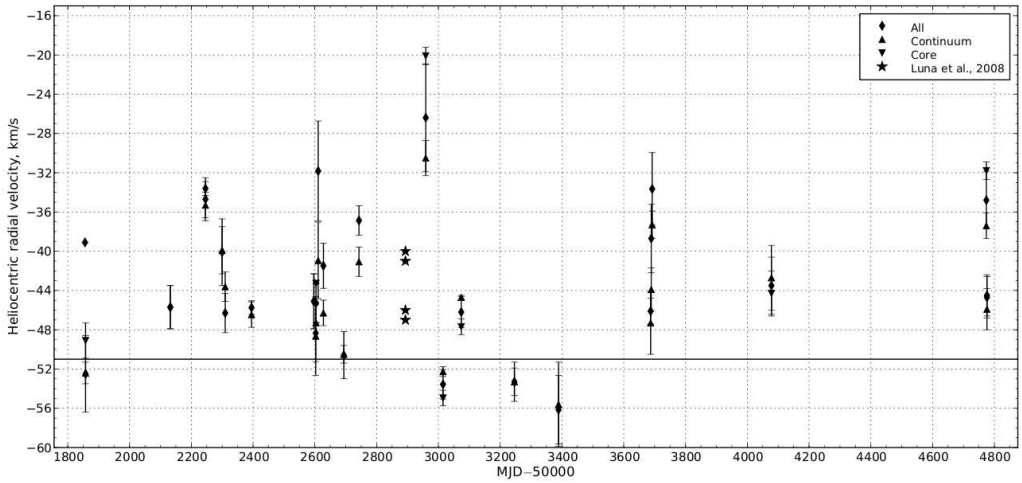

Figure 3: Variability of several absorption lines for various dates. Upward- and downward-pointing triangles show radial velocity measurements close to continuum and close to line core respectively. The error bars show standard deviation for several line measurements. Star markers show measurements of C, N, O, Si from [8]. The horisontal solid line shows systemic velocity.

Nebular expansion velocities

We derive nebular expansion velocity estimates from FWHM of forbidden emission lines, corrected for instrumental profile. The width of instrumental profile was measured using oxygen telluric lines. In Table 1 we present some equivalent widths and nebular expansion velocities.

Table 1: Nebular expansion velocities and equivalent widths for several forbidden emission lines in the spectra of IRAS 01005+7910.

Wavelength, Å	element	$2V_{exp}$, km/s	EW, mÅ
5197.902	[N I]	22 ± 1.1	79
5200.257	[N I]	21 ± 1.4	46
6548.050	[N II]	17 ± 2.2	43
6583.450	[N II]	17 ± 2.2	blend
6716.440	[S II]	22 ± 4.5	31
6730.816	[S II]	19 ± 3	39
4814.534	[Fe II]	18 ± 2.7	25
5158.777	[Fe II]	18.5 ± 2.5	42

Conclusions

Forbidden emission lines demonstrate constant radial velocity. The resonance Na $D_{1,2}$ doublet shows five constant absorption components. Three of them assumed to have interstellar origin. One has a velocity close to that derived from forbidden lines. Thus we can determine this velocity as systemic. Nebular expansion velocity was determined. The value is typical for this kind of objects. The list of identified lines in spectral range $3500 - 7800$ ÅÅ containing radial velocity measurements was prepared. The hydrogen and helium line profiles demonstrate the complicated and changing picture both of accretion and outflow in envelope.

Acknowledgement

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