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Stellar and circumstellar lines in the spectra of protoplanetary nebulae

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Abstract. We present an analysis of high resolution spectra in the optical and near infrared wavelength region for cool protoplanetary nebulae with the goal to identify lines of carbon bearing molecules and some less studied neutron capture elements. The site of formation of CN and C_2 lines in the spectra of IRAS 22272+5435 and IRAS Z02229+6208 appears to be an extended stellar atmosphere and inner/outer CSE. The abundance of thulium was estimated for the first time in the photosphere of IRAS22272+5435, log $\epsilon(Tm) \simeq 1.5$.

Keywords. stars: AGB and post-AGB, stars: atmospheres, stars: circumstellar matter, stars: individual (IRAS 22272+5435, IRAS Z02229+6208), line: identification

1. Introduction

The atmospheres and circumstellar envelopes (CSEs) of AGB and post-AGB stars are the most remarkable chemical laboratories in the Galaxy. Many aspects of photospheric and circumstellar chemistry are still not understood, e.g. why some post-AGB stars are extremely s-process enriched while others are not enriched at all, where is the site of formation of broad unidentified features and what species take part in their formation.

2. Observations

Spectra of IRAS 22272+5435 and IRAS Z02229+6208 were monitored using the high-resolution spectrometer VUES of the Vilnius University installed on the 1.65 m telescope at the Moletai Observatory (Lithuania) and the CARMENES instrument on the 3.5 m telescope at the Centro Astronómico Hispano en Andalucía (CAHA) at Calar Alto.

3. Results and conclusions

Numerous lines of C_2 and CN molecules are seen in the spectra both in absorption and emission (Puķītis et al. 2023; Začs & Puķītis 2023). Figure 1 illustrates variability of IRAS Z02229+6208 spectra in the wavelength region redward of the CN Red system (2,0) bandhead at 7850 Å. The strongest blueshifted CN absorptions are seen in the two spectra observed near the light minima. The width of these CN lines is lower on average in comparison with that for the photospheric atomic lines, FWHM $\simeq 16$ km s^{-1} and 23 km s^{-1}, respectively. In the spectra observed near the light maxima blueshifted emissions are seen. In addition, narrow blueshifted CN (2,0) system absorption lines are identified. The mean FWHM for these lines was found to be FWHM $\simeq 0.14$ Å (5.4 km s^{-1}). The site of formation of the broad/variable molecular absorption and emission appears to be an extended atmosphere of a cool post-AGB star affected by stellar pulsation. The

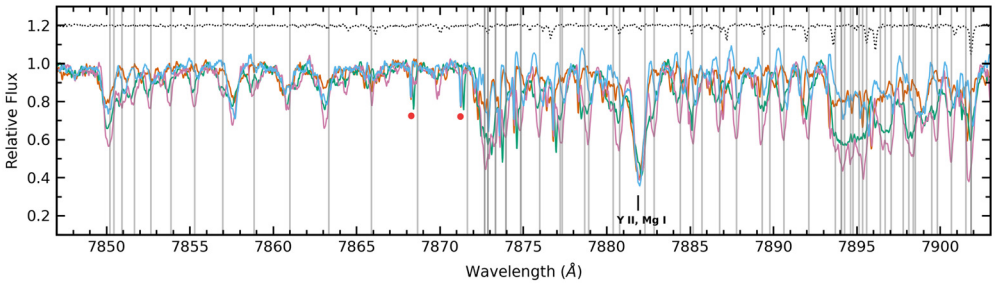

Figure 1. Time series of four IRAS Z02229+6208 spectra in the wavelength region from 7847 to 7903 Å observed from 2022 July 23 (red) to 2022 October 14 (blue). The telluric spectrum is shown by the dotted line on the top of the figure. Variable blueshifted CN Red system (2,0) lines, marked with vertical lines, are seen near the light minimum, along with narrow CN (2,0) CSE lines. Two less blended CSE lines are marked by red dots.

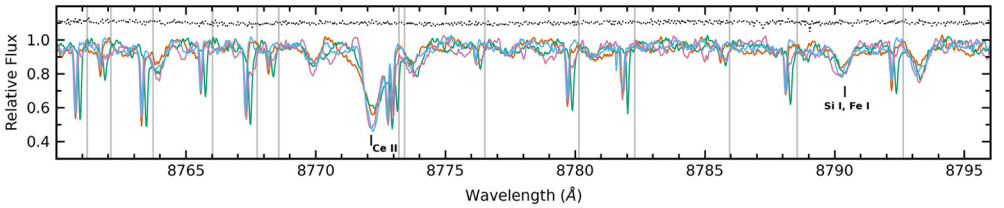

Figure 2. Same as Figure 1, but in the wavelength region from 8750 to 8800 Å. Narrow blueshifted C_2 Phillips system (2,0) lines are identified.

narrow CN (2,0) lines are formed most probably in the CSE produced during the AGB stage.

We examined two spectral regions in the near infrared wavelength region with the aim of finding the lines of C_2 Phillips system. Figure 2 illustrates the wavelengths region redward of the C_2 Phillips system (2,0) bandhead at 8750 Å, where the intensity of CN Red system lines is lower. A number of narrow blueshifted C_2 (2,0) lines are seen in the spectra. The mean radial velocity of the identified lines was found to be similar in all the spectra, δRV = –11.0 ± 0.2 km s^{-1}, relative to the mass center. The mean FWHM for selected lines was found to be $\simeq$ 0.14 Å (5.4 km s^{-1}). Thus, the site of formation of the narrow Phillips system lines seems to be the CSE produced during the AGB stage.

Abundances of elements with the atomic numbers between Z = 64 and 69 are a good criteria to distinguish between nucleosynthesis in the s- and r-process. We inspected the spectra of IRAS22272+5435 in the optical wavelength region with the aim of finding the lines of less studied neutron capture elements thulium and holmium. Weak thulium lines are identified at 5009.77, 5346.49, and 5684.76 Å and the thulium abundance was estimated for the first time, log $\epsilon(Tm) \simeq 1.5$ on average. The method of model atmospheres and spectral synthesis was used for the abundance calculation.

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References

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