Spectroscopic monitoring of early stage post-AGB stars

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Shaping of planetary nebulae

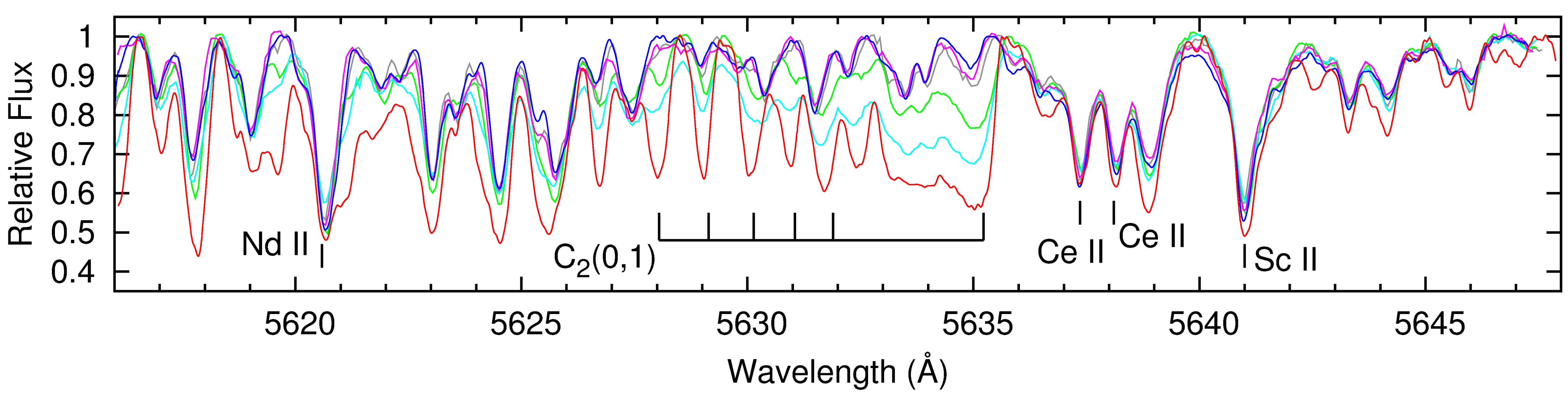
The role of different processes in shaping of planetary nebula (PN) around post-asymptotic giant branch (post-AGB) stars is not fully understood. It is known that formation of PN begins in AGB stage when intense stellar winds expel outer layers of the star. Virtually all AGB stars are observed to have spherically symmetric wind-created envelopes; however, only around 20% of PN are found with such symmetry with the rest showing mostly elliptical or bipolar morphologies. It is known that the rapid transition to non-spherical morphology and a change in the nature of stellar wind occurs near the end of AGB and beginning of post-AGB phases. Recently, binary interactions have been thought of as the main shapers of PN; however, cases of non-spherical envelopes around unlikely binaries are known. It is possible that an intrinsic change in the nature of stellar wind during the post-AGB phase plays an important role in the formation of the PN. While there is poor knowledge of wind launching mechanism in post-AGB stage, it is more or less understood in AGB stars with the current paradigm being that molecule interaction with shock waves in the extended atmosphere produce dust grains which, by the pressure of stellar radiation, drive the stellar wind. Spectroscopic monitoring provides a possibility to reveal and study dynamic processes in the extended atmospheres of such stars.

The observed stars

We have carried out spectroscopic monitoring of HD 235858 and HD 161796. Former is a carbon rich G type star and the latter – oxygen rich F type star. Both are pulsationally variable post-AGB supergiants in early stage – they are relatively cool and likely to have winds that share similarities with the ones operating in AGB stars. Both have aspherical wind-created envelopes; however, there is no evidence for binarity. It was neither revealed in long term radial velocity monitoring (Hrivnak et al. 2017) nor latest Gaia data seems to support it (Parthasarathy 2022). Results of our work suggest that monitoring of these and other similar post-AGB stars has a potential to advance the knowledge of stellar wind in this evolutionary phase.

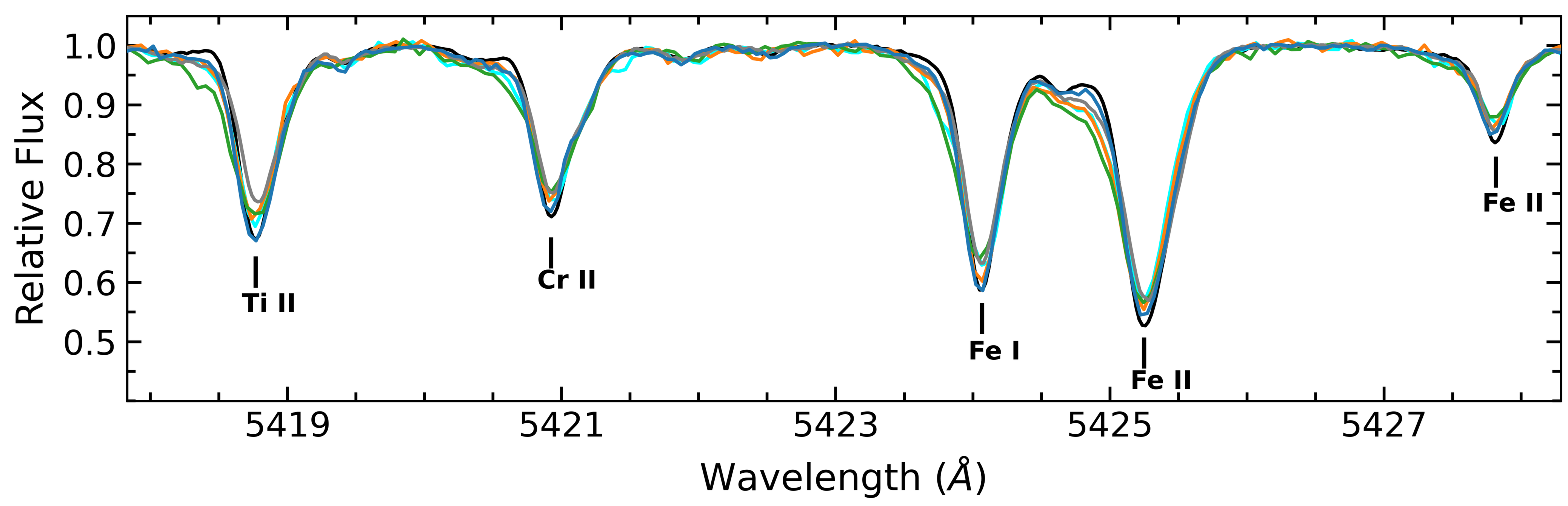
Wind-related variability

For HD 235858 time-domain spectroscopic observations have revealed pulsation induced cool outflow (Začs et al. 2016). This was inferred from intensity variations of blueshifted molecular lines of various bands, although significant molecular features are not normally expected in G type stellar spectrum.



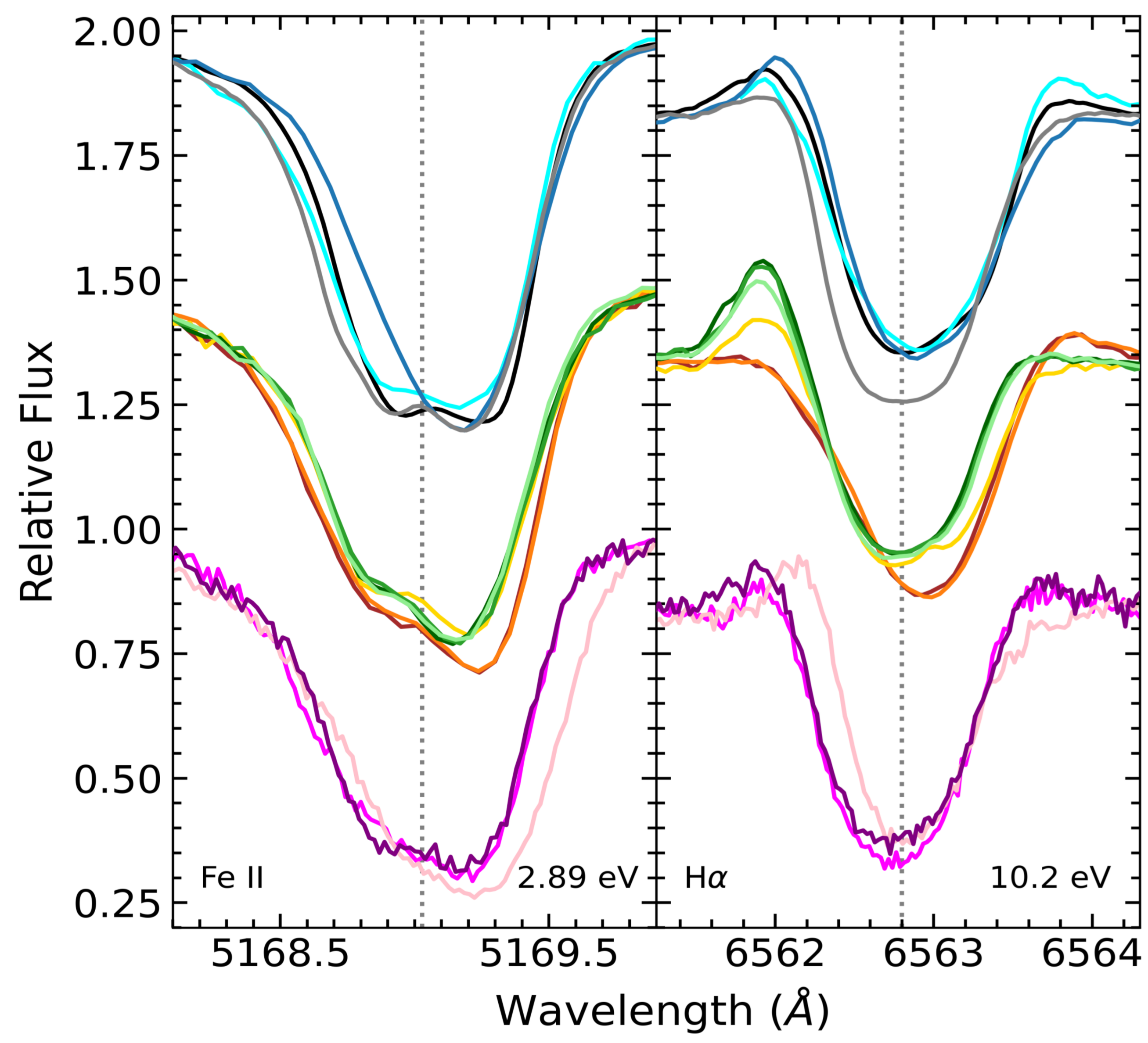
Variation of C_2 Swan band in spectra of HD 235858. Different colours depict different spectra acquired in the time span from 2002 to 2011. When the star is at maximum light and color pulsation phases (blue line) no prominent molecular features are observed. At minimum light and color phase (red line) strong molecular absorptions are visible.

For HD 161796 spectra acquired at multiple epochs point to an outflow of warm matter from the stellar surface (Puķītis, Začs, & Grankina 2022). This follows from the specific variation of absorption line profiles – blue wings are variable most often being extended while red wings remain virtually unchanged.



Typical variation of medium strength absorption lines in spectra of HD 161796. Different colours depict different spectra acquired in the time span from 2003 to 2013. Two extreme cases are 2009 spectrum (black line) where there seems to be lack of absorption in blue wings and 2011 spectrum (green line) where extended blue wings are prominent.

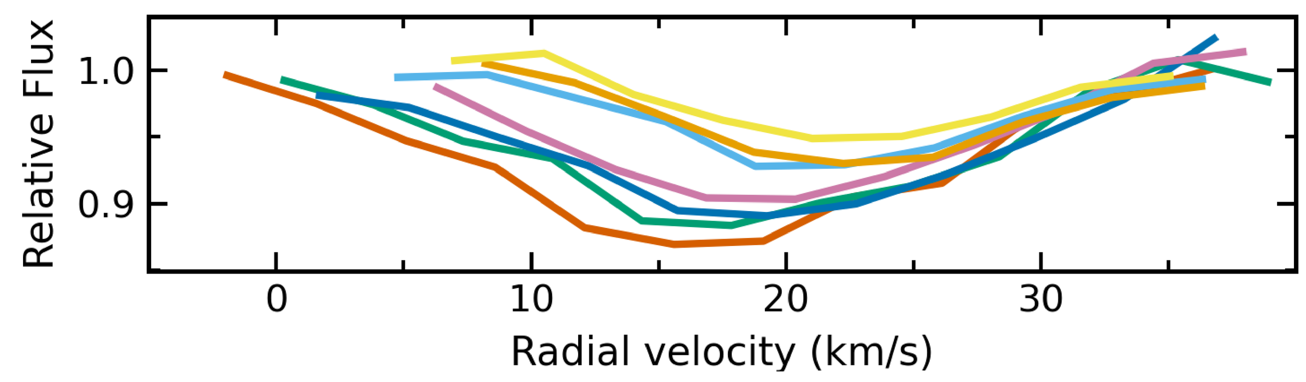
Also, the specific shape of Hα profile and its variation support the conclusion of outflow from HD 161796. For both stars splitting of intense absorption lines can be observed which is a manifestation of shocks which, in turn, are an integral part of wind launching for related stars.



Variation of two intense spectral lines in HD 161796. Left: Profile of Fe II 5169 Å line for which splitting is seen. Right: variable central part of the Hα line. The shape of the Hα profile seen in HD 16176 was interpreted by Sánchez Contreras et al. (2008) to be a consequence of incipient mass loss. Different colours depict different spectra acquired in the time span from 2003 to 2013. Spectra are shifted by radial velocity measured from large number of weak and medium strength lines. Dotted vertical lines denote rest wavelength of the transition.

Other prospects

We foresee that studies similar to the one presented here will uncover variety of dynamical processes in the atmospheres of post-AGB stars. For example, based on interday variability of some molecular features, we concluded that HD 235858 suffered an episode of infall of matter (Začs & Puķītis 2021).



Variation of CN Red system 9203 Å line in the spectra of HD 235858 observed at different nights within 11 days. The profile depicted with red line was observed first. In the following days intensity decreased and radial velocity of the line increased. After 11 days the yellow profile was observed.

Additionally, monitoring over longer periods of time (years, tens of years) can provide evolutionary rates of post-AGB objects allowing to test current evolutionary models of such stars.

Observations with NOT

We plan on proposing NOT/FIES observations for monitoring of homogeneous sample of cool post-AGB stars to study both short- and long-term variations. NOT is well suited for such task since 2.56m mirror allows to acquire good quality (S/N~100) spectra in reasonable time even for the dimmest targets we are interested in ($V \sim 12^m$) and FIES can deliver the necessary spectral resolution (R>40000). Also, we foresee use of the NTE instrument which will allow us to extend spectral variation studies to the near infrared, unveiling variation in more spectral lines of different species and excitation energies, thereby probing dynamics in a wider range of the extended atmospheres of such stars.

References

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Acknowledgements

We acknowledge support from the Latvian Science Council under the grant lzp-2020/1-0088 and the project "Strengthening of the Capacity of Doctoral Studies at the University of Latvia within the Framework of the New Doctoral Model", identification No. 8.2.2.0/20/I/006

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