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Radial velocity variability in post-AGB stars: V448 Lac

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Abstract. To investigate the binary hypothesis in the formation of planetary nebulae, we have been doing long-term photometry and radial velocity (RV) monitoring of bright post-AGB stars which possess bipolar or ellipsoidal nebulae but no indication of a disk in their spectral energy distribution, indicative of a binary companion. RV's are determined by cross correlating high-resolution spectra with a line mask. Stellar variability and companions both deform the cross correlation function (CCF) and induce periodic variations in the RV. To uniformly quantify the asymmetry of the CCF from a Gaussian, we propose to fit the CCF profile with a Gauss-Hermite series and determine all CCF parameters (RV, skewness, FWHM, and depth) in one single fit. We analyze the correlation and time series of these CCF parameters for V448 Lac and conclude that its RV variability is most likely due to stellar pulsation and not to an orbiting body.

Keywords. line:profiles, methods:data analysis, techniques: radial velocities, stars: AGB and post-AGB, individual (V448 Lac)

1. Introduction

We have been doing long-term photometry and radial velocity study of seven bright post-AGB stars which possess bipolar or ellipsoidal nebulae but no indication of a disk in their spectral energy distribution, to investigate the binary hypothesis for shaping planetary nebulae (Hrivnak *et al.* 2013, Hrivnak *et al.* 2017).

V448 Lac (IRAS 22223+4327) is a metal-poor, C-rich, F-type post-AGB star. Its spectral energy distribution is double peaked, with a peak in the visible arising from the (reddened) photosphere and a second peak in the mid-infrared arising from reradiation from cool dust, but has no near-infrared excess which would be an indication for the presence of a disk. The disk type post-AGB stars have been shown to be binaries (Manick *et al.* 2017).

2. Observations and analysis

We obtained 107 high-resolution spectra of V448 Lac with the HERMES spectrograph (Raskin *et al.* 2011) mounted on the 1.2-m Mercator telescope at La Palma from 2009 to 2017 in the framework of a large program on evolved binaries (Van Winckel *et al.* 2010). The individual RV's are obtained by cross-correlating the reduced HERMES spectra with a software mask for F0 type star containing a large set of distinct spectral lines typical for the spectral type. The CCF profile is a weighted mean of all photospheric lines included in the mask. Spectral lines of pulsating, active, and binary stars are notoriously asymmetric. To determine the RV, the CCF is usually fit by a Gaussian and several authors have tried to quantify the CCF asymmetry with an extra parameter related to the bisector (Queloz *et al.* 2001, Boissé *et al.* 2011) or by fitting a double Gaussian to the CCF (Figueira *et al.* 2013). To uniformly quantify the asymmetry of the CCF from a Gaussian, we propose to fit the CCF profile with a Gauss-Hermite series and determine all CCF parameters (RV, skewness, FWHM, and depth) consistently in one single fit for each observation. The lowest order term of the series is a Gaussian, higher orders quantify the (a)symmetry of the Gaussian profile. We fit the CCF using the Kapteyn package (Terlouw & Vogelaar 2015). The skewness parameter is equivalent to the bisector inverse span as defined by Queloz *et al.* (2001).

For V448 Lac we determined the correlation between the CCF shape indicators (depth, FWHM, and skewness) with RV. We find that the depth is not correlated with RV, the FWHM is anti-correlated with RV, and the skewness parameter is correlated with RV. The latter warns us that the signal is related to the stellar surface and not to an orbiting body. However, it is peculiar that the sign of the slope is opposite to what is usually found in the literature (Delgado *et al.* 2018).

3. Period determination

Period determination of the CCF parameters was done with the generalized Lomb Scargle method (GLS; Zechmeister & Kürster 2009). We find a period of 86.6 days for the RV and a strong period of 86.4 days for the CCF depth, both in agreement with the photometric period of 86.8 days. The RV is about −0.25 period out of phase with the light curve, while the depth of the CCF is in phase with the photometry. The star is brightest when hottest and smallest (Hrivnak *et al.* 2018), which is when the CCF is shallowest. For the skewness parameter and FWHM we don't find the periodicity of 86.6 days as found in the RV and photometry. When phased to 86.6 days they show more erratic variations.

Further analysis of the spectral lines in V448 Lac aims to investigate the phenomena of stellar variability causing these characteristics of the CCF parameters.

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