Re-Visiting the Seismic Properties of the PMS δ-Scuti Star V346 Ori

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Abstract. In order to test Pre-Main Sequence (PMS) evolutionary models, one needs to compare model evolutionary tracks with the position of several PMS stars in the H-R diagram. A way of obtaining these parameters relies on the use of asteroseismological techniques in pulsating PMS stars. Based on new observations of the PMS star V346 Ori, we present a development in the study of the brightness variations in this star. We discuss the results in the context of radial oscillations in PMS stars.

Keywords: stars: evolution - stars: fundamental parameters - stars: Herbig Ae - stars: oscillations - stars: V346 Ori

1. Introduction

For studying the stellar formation process is of capital importance the existence of reliable and accurate Pre-Main Sequence (PMS) evolutionary models. Placing PMS stars in the H-R diagram and comparing their position with evolutionary tracks can provide information on the mass and age of those stars (Hillendrand, 1997). These are crucial parameters for star formation studies.

Evolutionary models are constructed using different assumptions, which result in different evolutionary tracks for the same stellar mass value. It is imperative to establish reliable PMS evolutionary tracks. To achieve this goal independent estimates of PMS stellar masses are required.

Following Marconi and Palla (1998) identification of the instability strip for PMS stars, and given that the identification of pulsations can help constraining the mass in these stars (Marconi et al., 2000, 2001), we set out to identify and characterise the oscillation properties of a number of PMS stars. One of these stars, the PMS Herbig Ae star V346 Ori falls inside the PMS instability strip and hence is expected to display oscillations. Pinheiro et al. (2002) hinted the presence of two pulsation frequencies for this star but those results still lacked confirmation.

2. Observations, Data Reduction & Analysis

To further explore the pulsational properties of V346 Ori, two sets of observations were taken: during the nights of 4th and 7th of November 2001 the 1.52m 'Cassini' telescope, located in Loiano, was used with the three channel photometer TTCP (allowing to take simultaneous observations of object, comparison star, and sky) to observe in the Johnson U, B, and V bands; the 1m Jacobous Kapteyn Telescope (JKT), in La Palma, was used in the nights of 27th and 28th of November and 1st of December 2001, with the JAG CCD camera, observing in the Johnson V band. Standard procedures were used to reduce the observations producing the differential photometry discussed here.

The quality of the JKT data and of Loiano’s observations from 7th of November were limited by poor weather conditions, henceforth we will concentrate on the observations taken on the 4th of November.

![Figure 1. Light curve of V346 Ori in the Johnson U band (filtered data) and fitted signal using four frequencies.](image)

To remove real high frequency fluctuations present in the data, which are likely due to the presence of circumstellar gas around V346 Ori, we applied a low pass filter, using a cut-off frequency of 490 d\(^{-1}\), i.e. so that it would not affect the δ-Scuti type of periods being searched.

For searching pulsation frequencies in V346 Ori, the Lomb Normalised Periodogram (LNP) was used (IDL implementation). The data analysis was performed on the filtered data and it was carried out on a frequency by frequency basis: whenever a frequency was found we removed it from the data by subtracting the fitted periodic signal and repeated the analysis on the residuals. This procedure was iterated until no other frequency was apparent, and applied to the U-, B- and V-bands. The same analysis was performed using Period98 (www.astro.univie.ac.at/~dsn/), obtaining similar results.

Table I shows the four identified frequencies, their associated uncertainties as determined from the width of the corresponding peaks in the LNP, and the
amplitude of the fitted periodic signal for the U-band. F1 and F2 correspond to the frequencies whose presence was hinted by Pinheiro et al. (2002), based on JKT observations from December 2000. These were estimated at the time to be $34.2 \pm 4.9$ c/d and $21.2 \pm 3.8$ c/d, which, within the uncertainties, agree with those now obtained. Additionally, a third and fourth frequencies were tentatively identified. These are $45.4$ and $18.4$ c/d, with uncertainties of 2.5 c/d, but their presence cannot be unequivocally demonstrated with this data set. Despite that, the phase diagrams seem to hint for their presence and the false alarm probability associated to their peaks in the LNP are $5.3 \times 10^{-21}$ and $6.5 \times 10^{-12}$, respectively, for F3 and F4. The best fit obtained by fitting four frequencies to the data is presented in Fig. 1.

### 3. Discussion

By taking into account only F1 and F2, as in Pinheiro et al. (2002), our linear non-adiabatic radial oscillation models interpret these frequencies as corresponding to a 1.55 $M_\odot$ star, with $T_{\text{eff}}=7410$ K and $\log(L/L_\odot)=0.74$, pulsating in the fundamental (F2) and second overtone (F1). If we also include F3 and F4 in the analysis, and take the same radial assumption, the best model that shows oscillations with the observed frequencies corresponds to a 1.70±0.10 $M_\odot$ star, with $T_{\text{eff}}=7700\pm80$ K, and $\log(L/L_\odot)=0.965\pm0.015$, pulsating in the fundamental (F4), first (F2), third (F1), and fifth overtones (F3). These possible solutions are plotted in the HR diagram of Fig. 2.

The proposed results (square in Fig. 2) are in good agreement with van den Ancker’s et al. (1998) estimate for the V346 Ori’s effective temperature. On the other hand, the new luminosity estimate implies that this star is much closer than the Orion star forming region (upper triangle in Fig. 2) but further away than the Hipparcos closest estimate (lower triangle in Fig. 2). In addition, and according to the PMS evolutionary tracks displayed in Fig. 2 (Palla and Stahler, 1993), V346 Ori appears very close to the ZAMS, a location that by itself does not allow us to fully address the star’s evolutionary status.

The fact that V346 Ori oscillates is now beyond doubt. Whether more than two frequencies are present in the star’s light curve is still open to debate. We
hint at the presence of at least two other frequencies but more data are needed in order to be conclusive.

The results presented here reflect clearly the importance of mode identification for comparison with the models. Without that we can not be conclusive regarding the global parameters of the star.

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