Oscillations in Young Stellar Objects

F.J.G. Pinheiro, D.F.M. Folha, M.J.P.F.G. Monteiro

Centro de Astrofísica da Universidade do Porto, Porto, Portugal

M. Marconi, V. Ripepi

Osservatorio Astronomico di Capodimonte, Napoli, Italy

F. Palla

Osservatorio Astrofisico di Arcetri, Firenze, Italy

Abstract. We report the discovery of periodicities in the light curve of the Herbig Ae star V346 Ori. We interpret these variations as the superposition of at least two signals with periods $P_1 = 42 \pm 6$ min and $P_2 = 68 \pm 12$ min resulting from stellar oscillations. The computation of linear non-adiabatic pulsation models for Pre-Main Sequence (PMS) stars reproduces these periods for a $1.5\,M_\odot$ star with $T_{\rm eff} = 7300\,{\rm K}$ and $\log L/L_\odot = 0.74$, pulsating in the fundamental and second overtones.

1. Introduction

PMS evolutionary models are produced by different groups, each employing different treatments of convection and/or opacities and also using a different zero-point for the calculated ages. A powerful test of models is to independently derive accurate values for the mass of PMS objects and compare their position in the H-R diagram with model predictions for the determined masses.

Marconi & Palla (1998) investigated the pulsational properties of PMS stars within the mass range 1-4 $M_\odot$ using non-linear calculations of radial modes and derived the location in the H-R diagram of the instability strip for these stars. The identification of pulsation frequencies in these stars allows to constrain fundamental stellar parameters such as the mass, luminosity and effective temperature, and hence to test evolutionary models.

2. Observations, Data Reduction and Analysis

The observations reported here were carried out on the 1 metre Jacobus Kapteyn Telescope (JKT) in La Palma, during the night of 12 December 2000. A 5.5×5.5 arcmin field-of-view containing V346 Ori and the comparison stars HD35408 and HD35409 was used, alternating exposures between the Strömgren u and v bands.

To search for periodic variability in V346 Ori's lightcurve we used the Lomb Normalised Periodogram (LPN) analysis. Such analysis is advantageous in the

case of unevenly spaced data. In addition, it allowed us to rigorously obtain the false alarm probability for any peak in the periodogram.

We see two significant peaks in the periodogram of both bands. They occur at frequencies of about 34 d^{-1} and 21 d^{-1} with errors of about 4.5 d^{-1}. In order to improve on the results found, we merged the u and v band data sets into one single light curve. Before merging the two data sets, the v-band data was scaled so that the amplitude of variations in this band was similar to that in the u band. This was roughly achieved by multiplying each v band data point by the ratio of the standard deviations in each data set. The LNP of the merged light curve clearly shows two very significant peaks, with frequencies 34.2±4.9 d^{-1} and 21.2±3.8 d^{-1}, their associated false-alarm probabilities are respectively 3.5×10^{-5} and 0.004. On the basis of the above results we fitted (by means of a linear least-squares procedure) the merged light curve with the sum of two periodic signals. The frequencies derived above were kept fixed and the amplitudes and phases were determined by the least squares solution. For the frequency 34.2±4.9 d^{-1}, we obtained an amplitude of 5.8±0.5 mmag and phase −0.26±0.09 rad; for the frequency 21.2±3.8 d^{-1} we obtained an amplitude of 4.3±0.5 mmag and phase 0.31±0.12 rad.

3. Discussion

The computation of linear non-adiabatic pulsation models for PMS stars reproduces the periods detected, for a 1.5 $M_\odot$ star with $\log L/L_\odot = 0.74$ and $T_{\text{eff}} = 7300$ K, pulsating in the fundamental (F_1=34.2 d^{-1}) and second (F_2=21.2 d^{-1}) overtone. The uncertainties in the observed frequencies do not allow us to estimate the mass, luminosity and effective temperature to better than 34%, 27% and 5%, respectively.

Our estimate for V346 Ori's luminosity places the star much nearer than the distance to the Orion star forming region. This impinges directly on the interpretation of V346 Ori as a PMS Object. In fact, based on the star's position in the surface gravity vs. effective temperature diagram, Kovalchuch & Pugach (1997) claim that V346 Ori is not a PMS star. The PMS evolutionary track intersects V346 Ori's position in the H-R diagram very near to the ZAMS. In this region it is impossible to tell whether a star is indeed a PMS object just from its location on it. Hence, with the current data we are not in a position to fully address V346 Ori's evolutionary state. After V351 Ori (Marconi et al., 2001), V346 Ori may be the second star misclassified as a PMS object.

References

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Richard Townsend desperately tried to make a crazy picture of Stan Owocki (to the right) as a revenge for the picture on page 138. Sorry Rich, beyond any comparison !