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Asteroseismic constraints on the Pleiades distance

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Abstract. The global parameters of the Pleiades cluster are derived from the comparison of observed and computed frequencies of six multi-periodic δ Scuti stars. The best frequency fits lead to a distance modulus of 5.70 in good agreement with the pre-Hipparcos MS fitting methods.

Key words. Stars: oscillations: δ Sct – Galaxy: open clusters and associations: Pleiades

1. Introduction

The distance of the Pleiades cluster from the earth as determined from Hipparcos parallaxes is approximately 10% shorter than that previously derived from main sequence (MS) fitting methods. Although several recent studies support the traditional long distance of ∼ 133 pc [e.g. Pan et al. (2004), Munari et al. (2004), Percival et al. (2005))], it is also known that a high abundance of helium and a low metallicity could account for a short distance of ∼ 118 pc (e.g. Pinsonneault et al. (1998)). In this work we carry out a comparison of observed and computed frequencies of a sample of six δ Scuti stars belonging to the Pleiades cluster, observed by means of the STEPHI network in several multi-site campaigns, in order to derive the global cluster parameters from the best frequency fits.

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2. Modelling

The target stars are shown in Table 1. The seismic models were constructed as explained in Fox-Machado et al. (2003). We have computed theoretical isochrones of the Pleiades cluster considering five metallicities, namely [Fe/H] values of $-0.0794, -0.0488, 0.0668, 0.1484, 0.1794$; three ages, A, of 70, 100 and 130 Myr and four distance moduli, $m_V - M_V$, of 5.39, 5.50, 5.60 and 5.70 mag.

Figure 1 shows two of such isochrones of 100 Myr with solar and sub solar metallicities. The resulting distance modulus were added to the isochrone magnitudes and correspond to 5.70 mag and 5.39 mag respectively. While the former is in agreement with the MS fitting methods, the latter is consistent with the Hipparcos distance within 1-σ error. The masses (M) and rotation rates (Ω) of the stars were estimated following Pérez

Table 1. Target stars

Star	HD	ST	$v \sin i$ (km s^{-1})	N
V624 Tau	23156	A7V	20	7
V534 Tau	23567	A9V	90	7
V647 Tau	23607	A7V	20	6
V650 Tau	23643	A3V	175	4
–	23194	A5V	20	3
–	23628	A4V	150	2

Hernández et al. (1999) by correcting its observational positions for the rotational effect in the HR diagram and considering all the possible combination between the cluster parameters. We have constructed a grid of pseudorotating models for the six stars. Then, the eigenfrequencies of those models were computed up to second order in the rotation rate covering the frequency range of the observed pulsational peaks. Interpolations between $\Omega_{\rm rot}$ and ν were applied.

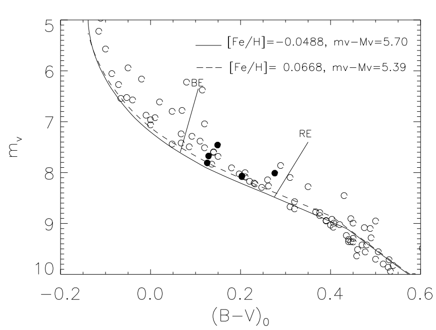

Fig. 1. Colour-magnitude diagram of the Pleiades cluster. The target stars are represented by filled circles. Two isochrones of 100 Myr computed with $Z = 0.020, Y = 0.28$ (continuous line) and $Z = 0.015, Y = 0.30$ (dashed line) are shown.

Finally, we have compared the observational frequencies ($f_{\rm obs}$) with the theoretical ones ($f_{\rm cal}$) at each interpolated $\Omega_{\rm rot}$. We look for the best mode solution for each model by minimizing the quantity: $\chi^2 = \frac{1}{N}(\sum_{j=1}^{j=N}(f_{{\rm obs},j} - f_{{\rm cal},j})^2)$, where, N is the number of observational frequencies. Since we expect the same [Fe/H], d and A for all the stars in the cluster, we computed the average quantity $\epsilon = \sqrt{\frac{1}{6}(\sum_{i=1}^{i=6}\chi^2_{min,i})}$, where $\chi_{min,i}$ is the smaller χ for a given star (corresponding to a particular $\Omega_{\rm rot}$). Figure 2 shows ϵ against distance modulus, where one can see that short distances yield to worse solutions. The best fits correspond to Z=0.02, Y=0.28, A=70, $m_V - M_V$ = 5.70.

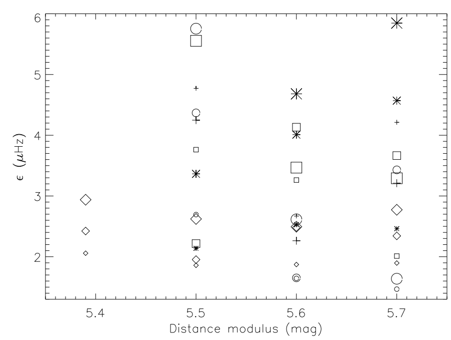

Fig. 2. Minimum values of the mean square root of the difference between observational and theoretical frequencies for models with given values of [Fe/H], $\alpha_{\rm ov}$ and A against distance modulus. The metallicity of the models are indicated by the following symbols: squares $Z = 0.015, Y = 0.250$, rhombies $Z = 0.015, Y = 0.30$, circles $Z = 0.020, Y = 0.28$, asterisks $Z = 0.025, Y = 0.25$, crosses $Z = 0.025, Y = 0.30$. The symbol sizes are related with the age of the models as follows: small 70 Myr, middle 100 Myr, large 130 Myr.

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