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The impact of GAIA astrometry on the evolutionary status of the seismic analog HD 42618

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Abstract. Last year, the satellite Gaia from ESA released its first data in astrometry (Gaia DR1), including new parallax measurements of millions of stars. Among these results, we were interested in the new parallax measurement of the CoRoT target HD 42618. This parallax, which is 1.5 mas lower than the one measured by Hipparcos, therefore corresponds to a greater distance and consequently to a larger luminosity. This implies a change in its evolutionary status, that we have studied from spectroscopic data, seismic analysis from photometric CoRoT data, and stellar evolution models. We show that the Gaia astrometric measurements can have an impact on the estimated evolutionary status of a solar-type star and, in the case of HD 42618, it implies some disagreements with the seismic data.

Resumo. No ano passado, o satélite Gaia da ESA disponibilizou seus primeiros dados em astrometria (Gaia DR1), incluindo novas medidas de paralaxe de milhões de estrelas. Entre estes resultados, nós interessamos na nova medida de paralaxe do alvo CoRoT HD 42618. Esta paralaxe, que é 1,5 mas menor que a medida por Hipparcos, corresponde, portanto, a uma maior distância e consequentemente a uma maior luminosidade. Isso implica uma mudaną em seu estatuto evolutivo, que estudamos a partir de dados espectroscópicos, análise sísmica de dados fotométricos CoRoT e modelos de evolução estelar. Mostramos que as medidas astrométricas de Gaia podem ter um impacto sobre o estado evolutivo estimado de uma estrela de tipo solar e, no caso da HD 42618, isso implica alguns desentendimentos com os dados sísmicos.

Keywords. astrometry – solar analog – evolutionary status – asteroseismology

1. Introduction

New parallaxes from Gaia DR1 allow to analyze the impact of this parameter on the evolutionary status of stars. For the CoRoT target HD 42618, the new parallax is 1,5 mas lower than the one measured by Hipparcos. It implies a larger luminosity, which has an impact on the stellar age. We calculated evolutionary models with the Toulouse-Geneva Evolution Code (TGEC, see Hui-Bon-Hoa 2008) to study the evolutionary status of HD 42618 in a HR diagram using spectroscopic parameters from Morel et al. (2013). We calculated the theoretical frequencies of our models to compare to the observed frequencies of the analog star (Barban et al. 2013).

2. Data

To construct the HR diagram, we used the fundamental parameters inferred by Morel et al. (2013) from spectroscopic data obtained with HARPS ($T_{\rm eff}$ = 5765 ± 17 K, $[Fe/H] = -0.10 \pm 0.02$) and the luminosity calculated from the apparent magnitude $V = 6.839$ (SIMBAD database), the parallaxes from Hipparcos (p = 42.55 mas, case 1 hereafter) and Gaia DR1 (p = 41.05 mas, case 2), and the bolometric corrections calculated according to VandenBerg & Clem (2003). The observed frequencies have been inferred from the CoRoT light curve by Barban et al. (2013).

3. Results and conclusions

Our models calculated with the TGEC include atomic diffusion, meridional circulation (Théado & Vauclair 2003) and tachocline (Brun et al. 1998), which calibration allows to match the solar lithium abundance in a solar model. The models matching the observed point in a HR diagram (Fig. 1) have similar masses in both cases, in agreement with the seismic-inferred mass $M = 0.9 \pm 0.1$ $M_\odot$ by Barban et al. (2013), but diverge in age by around 2 Gyr. In both cases, the surface lithium is completely destroyed. Large separations of the frequencies of the models do not agree with observed ones in both cases, showing models with larger density in case 1 and with lower density in case 2, compared to the observed large separations (Fig. 2). Differences in the large separations of both set of models are consistent with the differences on age. Small separations of the frequencies of the models, which are sensitive to the age of the model, account for the observations only in case 1. In case 2, the calculated small separations are significantly lower than the observed ones, indicated a model too old.

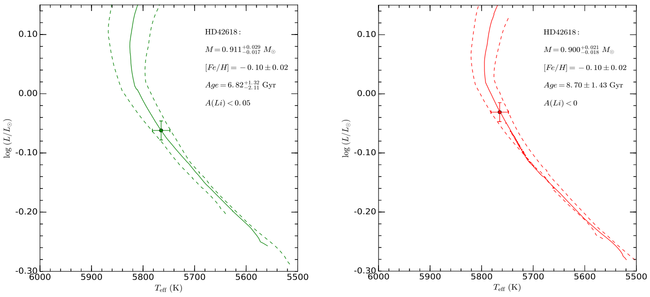

Figure 1. HR diagram for HD 42618, on the left using the Hipparcos parallaxe (case 1), on the right using the Gaia parallaxe (case 2). Mass, metallicity, age and lithium abundances of the models are indicated in the figure.

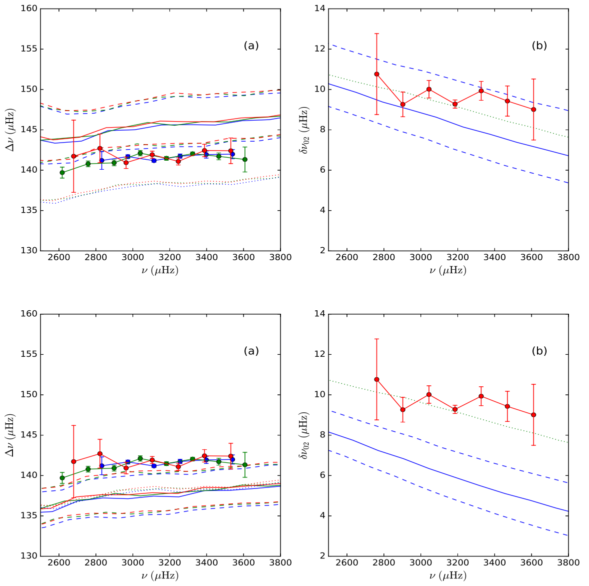

Figure 2. (a) large separations $\Delta\nu$ (blue for l = 0, green for l = 1, and red for l = 2), and (b) small separations $\delta\nu_{02}$ of the oscillation frequencies of the HD 42618 model in case 1 (up) and in case 2 (bottom). Continuous and dashed lines are for calculated models in the range of masses determined by Fig. 1. Dotted line is a solar model and linked circles are the separations of the observed frequencies.

As an additional constraint, we calibrated the tachocline thickness of the models to account for the observed lithium abundance (A(Li) = 1.28 ± 0.06, Morel et al. 2013). Tachocline thicknesses, which model the shear layer of differential rotation below the convective zone, have been reduced by a factor of 1.4±0.2 in case 1 and 1.6±0.2 in case 2, which seems reasonable. Calibrated models are presented in Figs. 3 and 4. The masses are still very similar and the difference in ages is smaller (around 1.5 Gyr). In both cases, large separations are slightly larger for models with calibrated tachocline (about 1 μHz larger), improving the comparison with observation in the case 2 accounting for the model with the larger mass in our range of masses (M = 0.930 $M_{\odot}$). Small separations of case 2 are still lower than the observed ones.

These results show that we have a better agreement of the large separations with the models of the case 2 (Gaia parallax), and in particular with the models with the calibration of the tachocline thickness to account for the observed lithium abundance. It suggests that the tachocline thickness, which depends on the differential rotation, is an important parameter to calibrate for the characterization of solar analog stars. However, the small separations of our models account for the observed ones only with the models of the case 1 (Hipparcos parallax).

In conclusion, even if the models with calibration of the tachocline are better matching the observations in the case of Gaia parallax, the large difference of the small separations with the observations are indicating that our modeling of the evolutionary status is not completely satisfactory. The same study but considering a 2σ error bar on the spectroscopic parameters could allow to have a larger set of models, to find the better one that account for both spectroscopic and seismic observations.

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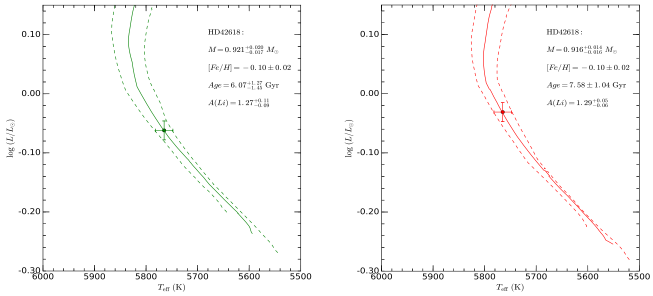

Figure 3. Same as Fig. 1 but using models with calibrated tachocline thickness to match the observed lithium abundance.

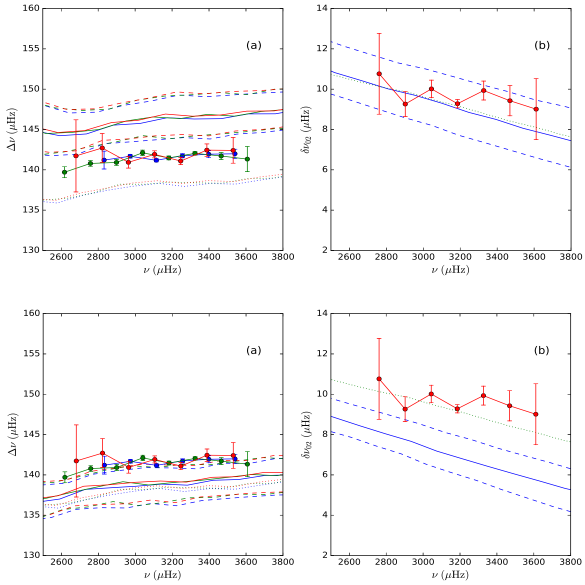

Figure 4. Same as Fig. 2 but using models with calibrated tachocline thickness to match the observed lithium abundance.

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