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A Continuing Challenge through Cosmic Time
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Using Gaia to measure the atmospheric dynamics in AGB stars

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Abstract. We use 3D radiative-hydrodynamics simulations of convection with CO5BOLD and the post-processing radiative transfer code Optim3D to compute intensity maps in the Gaia G band [325–1030 nm]. We calculate the intensity-weighted mean of all emitting points tiling the visible stellar surface (i.e., the photo-center) and evaluate its motion as a function of time. We show that the convection-related variability accounts for a substantial part to the Gaia DR2 parallax error of our sample of semiregular variables. Finally, we denote that Gaia parallax variations could be exploited quantitatively to extract stellar parameters using appropriate RHD simulations corresponding to the observed star.

Keywords. stars: atmospheres – stars: AGB – astrometry – parallaxes – hydrodynamics

1. Introduction

AGBs are low- to intermediate-mass stars that evolve to the red giant and asymptotic giant branch increasing the mass-loss during this evolution. Their complex dynamics affect the measurements and amplify the uncertainties on stellar parameters. The convection-related variability, in the context of Gaia astrometric measurement, can be considered as "noise" that must be quantified in order to better characterize any resulting error on the parallax determination.

2. Methods

We employed the code Optim3D (Chiavassa *et al.* 2009) to compute intensity maps (Fig. 1, left panel) in the Gaia G photometric system (Evans *et al.* 2018). For this purpose, we based the calculation on snapshots from the radiation-hydrodynamics (RHD) simulations of AGB stars (Freytag *et al.* 2017) computed with CO^5BOLD (Freytag *et al.* 2012) code.

3. Comparison and predictions

First, we extracted the parallax error (σ_ϖ) from Gaia DR2 for a sample of semiregular variables (SRV) from Tabur *et al.* (2009), Glass & van Leeuwen (2007), and Jura *et al.* (1993) that match the theoretical luminosities of RHD simulations. It has to be noted that σ_ϖ may still vary in the following data releases because: (i) the mean number of measurements for each source amounts to 26 (Mowlavi *et al.* 2018) and it will be 70–80 times in total at the end of the nominal mission; (ii) and new solutions may be applied to adjust the imperfect chromaticity correction (Arenou *et al.* 2018).

We investigated if the parallax errors of our SRV sample can be explained by the resulting motion of the stellar photo-center seen in the RHD simulations. Fig. 1 (central panel)

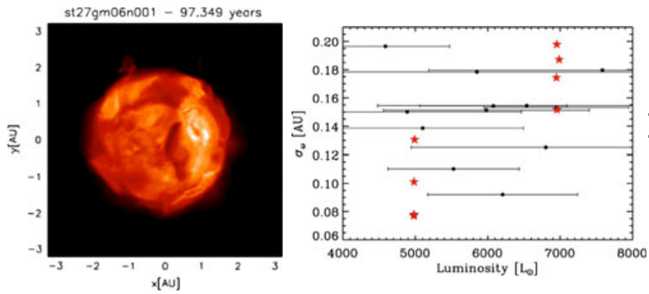

Figure 1. *Left:* Example of the squared root intensity map in the Gaia G photometric system (Evans *et al.* 2018). *Center:* luminosity against the parallax error of the observations (σ_ϖ, circle symbol in black) and the standard deviation of the photo-center displacement for the RHD simulations (σ_P, star symbol in red). *Right*: σ_P against logarithm of the stellar period for RHD simulations. Figures from Chiavassa *et al.* (2018).

displays that Gaia parallax errors are in good agreement with the standard deviations of the photo-center displacement in the simulations (in particular for higher luminosities). This attests that convection-related variability accounts for a substantial part to the parallax error in Gaia measurements. In addition to this, Fig. 1 (right panel) reveals the correlation between the photo-center displacement and the logarithm of the pulsation: larger values of σ_P correspond to longer pulsation periods.

4. Summary

The visible fluffy stellar surface (Fig. 1, left) is made of shock waves, that are produced in the interior and that are shaped by the top of the convection zone as they travel outward. The surface is characterized by the presence of few large and long-lived convective cells accompanied by short-lived and small scale structures. As a consequence, the position of the photo-center is affected by temporal fluctuations. We found a good agreement with observations probing that convection-related variability accounts for a substantial part to the parallax error. This result let us denote that parallax variations from Gaia measurements could be exploited quantitatively using appropriate RHD simulations corresponding to the observed star. More details can be found in Chiavassa *et al.* (2018).

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