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Letter from the International ISSI team "SH0T: the Stellar path to the H0 Tension in the Gaia, TESS, LSST and JWST era"

Clementini, Gisella <gisella.clementini@inaf.it> 24 ottobre 2022 alle ore 08:39
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To the Gaia Data Processing and Analysis Consortium Executive

Subject: Impact of Gaia parallaxes to constrain the distance scale and the tension between cosmic microwave background and distance ladder measurements of the Hubble constant.

Dear Colleagues,

I am writing to you on behalf of the members of the International ISSI team: "SH0T: the Stellar path to the H0 Tension in the Gaia, TESS, LSST and JWST era" (https://www.issibern.ch/teams/shot/).

During our latest team meeting in Bern in July, we discussed extensively how Gaia's ability to provide the absolute foundation to the distance scale is currently limited by a non-constant parallax offset. We therefore drafted this letter to recommend that the non-constant parallax offset issue, specifically in the context of reducing its dependence on target properties, be assigned a significant priority in future data processing by the Gaia Data Processing and Analysis Consortium.

Background

One of the most debated issues in modern astrophysics is the current sharp conflict existing between the measurements of the expansion rate of the Universe (the Hubble constant, H0) as inferred from the anisotropy of the cosmic microwave background (CMB) and as measured from different distance indicators in the local Universe (distance ladder measurements). The CMB measures the properties of the Universe a few hundred thousand years after the Big Bang (Early-Universe probes); the distance ladder measures the expansion of the Universe now (Late-Universe probes).

If the Big Bang theory of the origin and evolution of our Universe is correct, these measurements should agree on the value of H0 within the errors. However, currently there is clear disagreement at the 4-5 sigma level between Early and Late Universe measurements. This could point to a serious measurement error (which has not been identified despite several years of improvements), or imply the need to revise our understanding of the cosmos and its fundamental physical laws.

The Gaia mission plays a crucial role in this context, as it provides unprecedented parallax measurements for fundamental standard candles of the cosmic distance ladder, thus allowing to improve the accuracy of the astronomical distance ladder and quantify the H0 tension by specifically tackling uncertainties and systematics affecting different methods to measure astronomical distances.

A concern with the Gaia parallax offset

However, the existence of a magnitude- and color-dependent parallax offset is limiting the ability of Gaia parallaxes to constrain the distance scale.

The non-constant parallax offset is likely one of the most significant limitations, and is especially impactful for the distance scale and the determination of the Hubble constant. By some estimates, the parallax offset contributes to an increase of uncertainty by a factor 1.5 to 2.5 (depending on the sample and on the assumptions made in the internal offset determination) in the calibration of the period-luminosity relation of Milky Way Cepheids.
The fact that the parallax offset depends on the observed properties of the target, such as magnitude and color, suggests that there remain significant limitations in the low-level processing of data. It is possible that these limitations go all the way to the Image Parameter Determination.

If an improvement to the low-level processing to lift the offset problem is too difficult to undertake in time for DR4, we recommend to invest additional resources and efforts along the lines of Lindegren et al. (2021) to improve the characterization of the offset as a function of magnitude, color and position, particularly for bright sources where the offset is most uncertain and where many variable stars live.

We still recommend an improved processing for variable sources, by taking into account color and magnitude variation, because it would allow an improvement of the overall parallax and astrometric solution precision.

This could be done at the level of the secondary solution, that is, outside the primary sources. Thus, it would be not necessary to repeat the global iteration for these sources. Epoch magnitude and color could be obtained from the Gaia scan data for the variables themselves and the variability ephemeris derived from them.

We therefore suggest that revisiting the non-constant parallax offset issue, specifically in the context of reducing its dependence on target properties, be assigned a significant priority in future processing by the Gaia Data Processing and Analysis Consortium.
This would greatly benefit the legacy of Gaia's impact in general, as well the ability of Gaia to provide an accurate trigonometric distance scale to match the precision of the CMB's anisotropies.

Yours faithfully, the ISSI SH0T team

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