Gaia bright stars: improving accuracy under saturation

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Abstract

The Gaia **nominal magnitude range spans G = [6.0 - 20.0]**. Significant effort has been invested in extending it in the bright end [1]. However, the astrometric and photometric performance is far from ideal (the Poisson limit) for stars with G = [6.0 - 12.0]. The most probable cause is a combination of two effects not sufficiently well modeled: across-scan rate and saturation. In this poster, we explore the **role of saturation**.

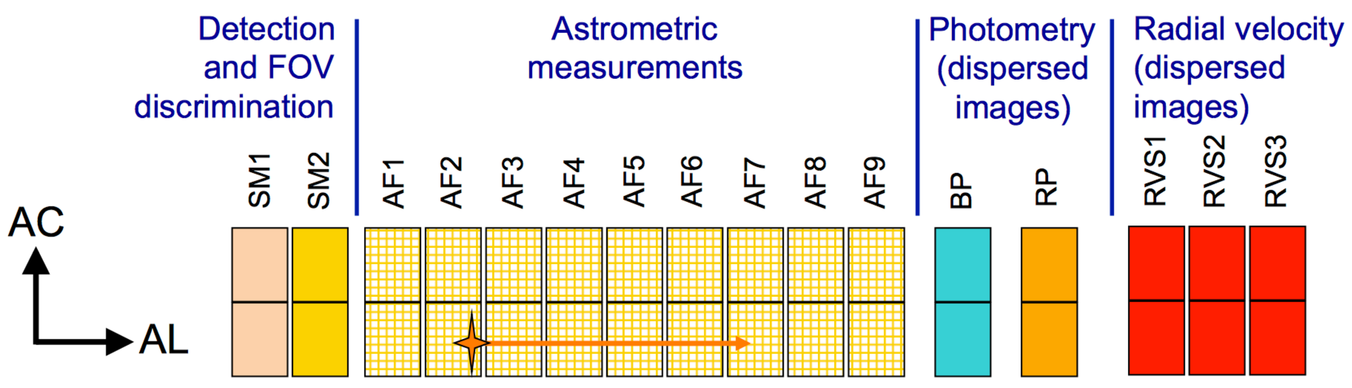

Fig 1. Two out of seven CCD rows in the Gaia focal plane. Credit:] Enabling science with Gaia observations of naked-eye stars (2016) [1].

The ultimate goals are to improve the Gaia data analysis for bright stars and to use this knowledge to calibrate the data obtained using special techniques (SIF and VO-sync) [2].

Centroiding using the center of mass

This flow chart (Fig. 2) introduces the center of mass as a simple centroiding method. Firstly, we used non-saturated images as an input data. Then, in order to determine how saturation affects the centroid estimation, we performed pixels masking (Fig. 3). In each iteration we increase the number of saturated (masked) pixels by one, in brightness order, and then repeat calculations.

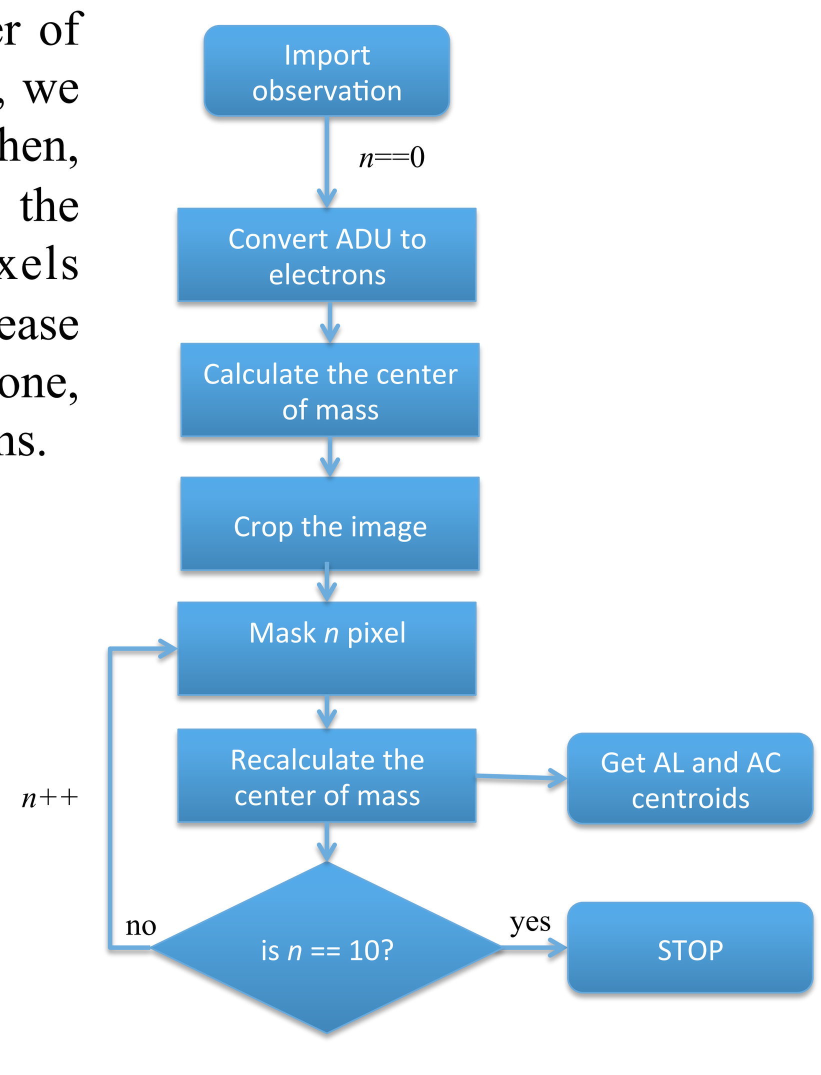

Fig 2. Flow chart of the center of mass algorithm.

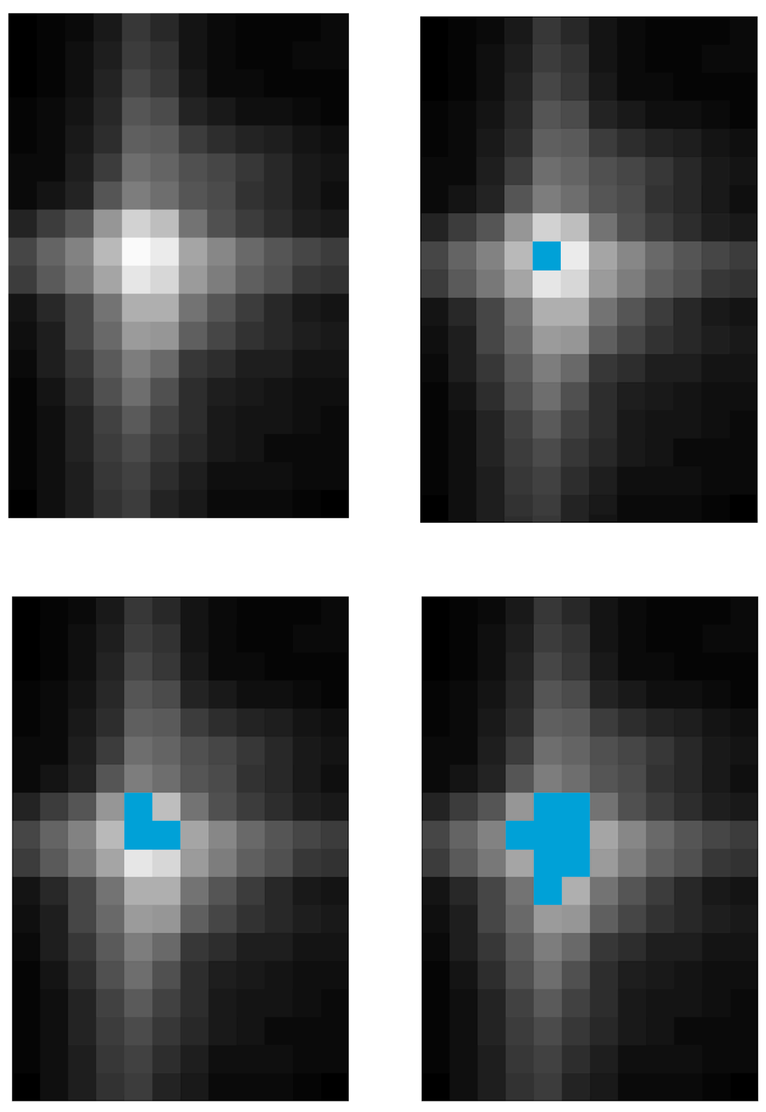

Fig 3. Simulating the saturation effect by using pixels masking (blue). For each image the center of mass was calculated excluding the masked samples.

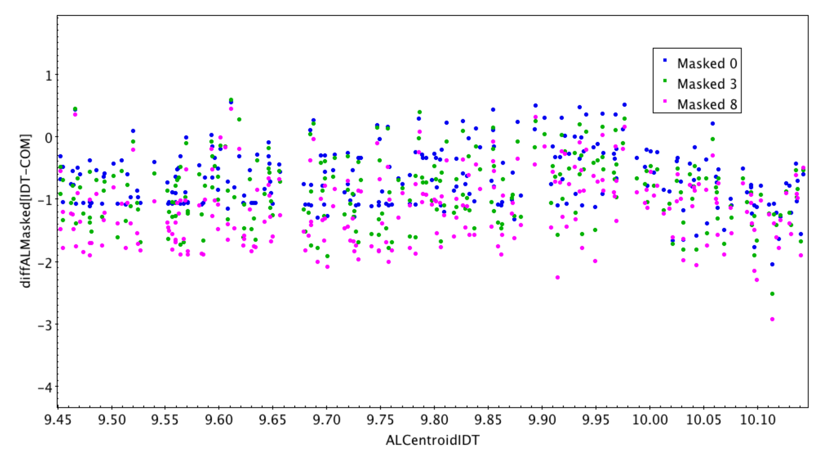

Fig 4. Comparison between the Initial Data Treatment (IDT) results and center of mass estimation for along scan (AL) centroid for n masked pixels (n = 0, 3, 8). Accuracy of the center of mass is lower than the one provided by IDT (~0.003 pixel).

Future work

As we have shown in this work, the centroiding of saturated stars to be included in the GAIA catalog still has room for improvement. The center of mass methodology, albeit simpler by not needing any PSF model, remains highly ineffective. Thus the PSF model fitting method is, for now, the best of the two. But the lack of a good viable PSF model hinders the accuracy of its results. Additionally, even with a better PSF model, systematic errors are always present. Those has to be modeled taking into account different kind of dependencies. For this reason, our next steps will be to tackle these issues by:

1. Defining a better PSF model.
2. Looking for dependencies between the along-scan centroid and other parameters as telescope CCD, across-scan position, wavelength, field of view etc.

[1] J. Sahlmann et al., *Enabling science with Gaia observations of naked-eye stars* (2016)
[2] *Gaia Data Release 1* (2016)

Centroiding by fitting the PSF model

This algorithm (Fig. 5) is based on fitting the PSF model [3] to the actual data.

First, we introduced a few test cases using simulated data. We defined the centroid offset toward the ideal PSF model (Fig. 6) and shifted the observation. As expected, when using the ideal PSF model, we obtained the results corresponding with the initial observation shift.

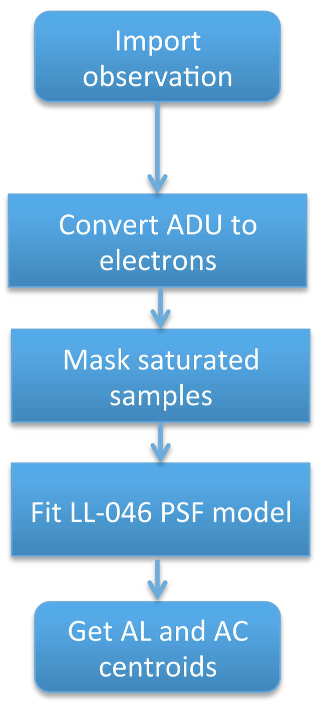

Fig 5. Flow chart of the algorithm.

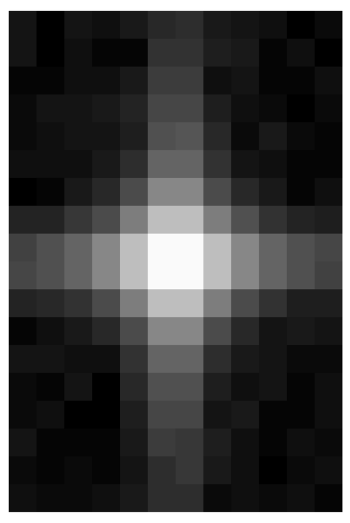

Fig 6. Point spread function model used for the fitting.

However, fitting the introduced PSF model to the real data resulted in lower accuracy in both along and across-scan centroids. In order to correct the estimations we need to replace the imperfect PSF model with the one corresponding to the actual data, which will be the next step in the centroiding process (*Future work*).

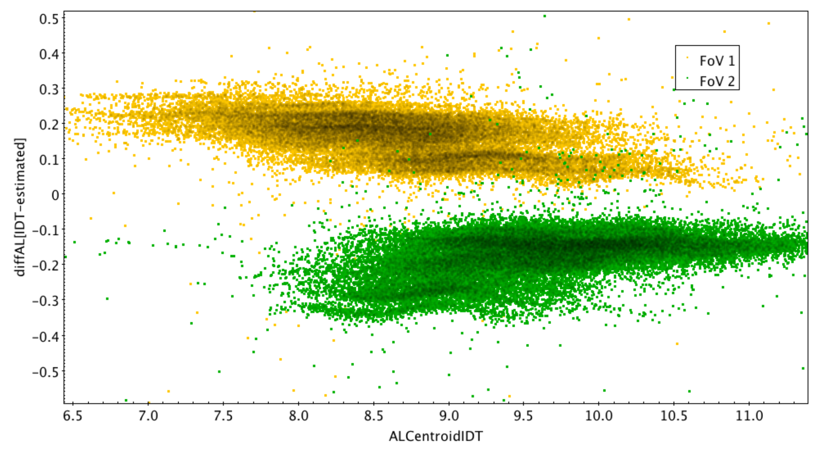

Fig 7. Along scan (AL) centroid accuracy within the Initial Data Treatment (IDT) results for both fields of view.

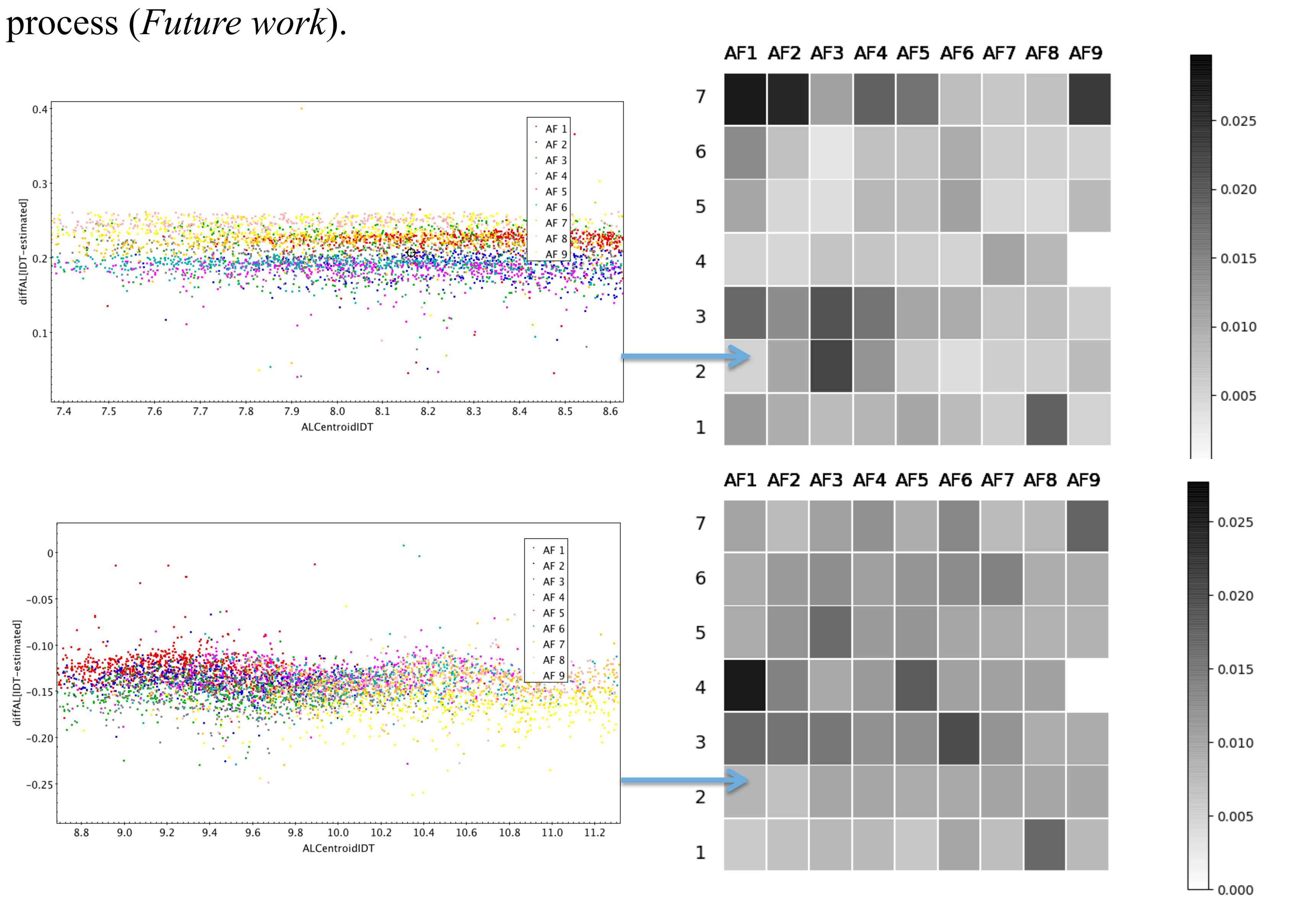

Fig 8. (Left) Differences in the along scan (AL) centroid estimation between the Initial Data Treatment (IDT) results and the PSF model fitting. The plots show the results for the CCD row 2, and fields of view 1 (top) and 2 (bottom). (Right) Median absolute deviation of AL differences for each CCD. The dimmer the color, the better the accuracy obtained for this CCD.

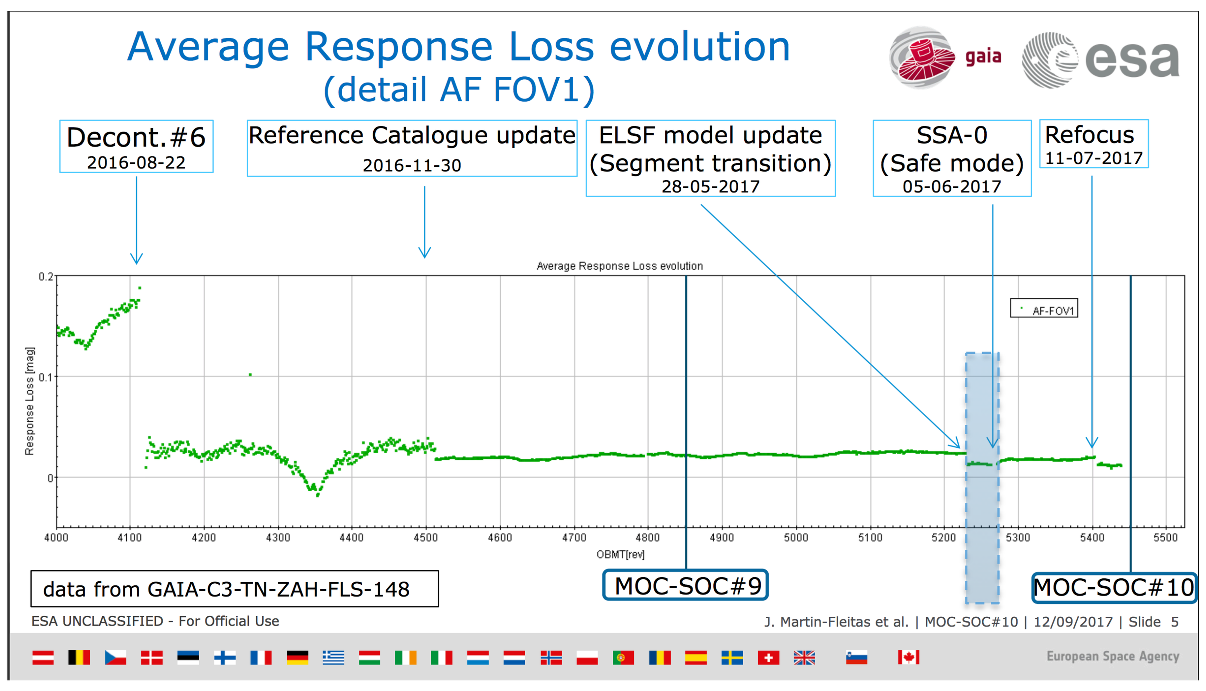

Fig 9. Observations used for getting the centroid results are coming from the period after the ELSF model update (28/05 – 05/06/2017) (shaded area) [4].

[3] L. Lindegren, *GAIA–LL046* (2003)
[4] J. Martin-Fleitas, MOC-SOC coordination meeting #10 (12/09/2017)