Fitting the *Gaia* EDR3 photometric uncertainties

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Abstract

This document provides a relationship to predict the average photometric error in G, $G_{\rm BP}$ and $G_{\rm RP}$ *Gaia* EDR3 magnitudes as a function of magnitude.

Document History

Issue	Revision	Date	Author	Comment
2	0	2021-07-09	JMC	New approach using B-splines and sources with similar number of observations
1	0	2021-06-15	JMC	Approved by FDA
D	1	2021-06-11	JMC	Comments by FDA
D	0	2021-05-12	JMC	Creation of the document

1 Fitting magnitude uncertainties in *Gaia* EDR3

For some simulation purposes it may be useful to have available some relatively simple way of fitting the uncertainties in the *Gaia* EDR3 magnitudes.

In order to fit the uncertainties we used the same data plotted in Fig. 14 by Riello et al. (2021). This data was derived using the mode of the distribution of those sources having similar number of observations in *Gaia* EDR3 (about $N^{G}_{\rm obs} \sim 200$ in AF and $N^{\rm XP}_{\rm obs} \sim 20$, with XP meaning either BP or RP). For each band, the B-splines fitting was done restricting the magnitude range to $4 < G_{\rm XP} < 21$ mag[1], being $G_{\rm XP} = G$, $G_{\rm BP}$ or $G_{\rm RP}$.

We used cubic B-splines Python routine to fit the data (`splref`) with a variable-resolution knot grid to ensure a smooth behaviour at the bright end, where less data points are available while accurately reproducing the systematics present in other magnitude ranges. The estimation of the expected uncertainties as a function of the magnitude can be seen in Fig. 1, overplotted to the data used to derive the fitting. The derived cubic B-splines coefficients and the position of the knots are included in Table 2.

As the fit is based on sources with similar number of observations, the relationship can easily be rescaled to derive the photometric uncertainties for sources with different number of observations, following the same approach explained in Jordi et al. (2010):

$$\log(\sigma_{N_{\rm obs}}) = \log(\sigma_{200}) - \log\left(\sqrt{\frac{N_{\rm obs}}{200}}\right) \quad (1)$$

where $\sigma_{N_{\rm obs}}$ is the uncertainty for the G-band photometry derived for $N_{\rm obs}$ observations, while σ_{200} is the B-spline provided here for sources with about 200 observations in AF. For the $G_{\rm BP}$ and $G_{\rm RP}$ photometry the 200 in the final term of the equation needs to be replaced by 20. Figure 2 shows the result of this rescaling on G-band photometric uncertainties.

[1]The extrapolation of the relationships provided here to magnitudes outside this range is not recommended.

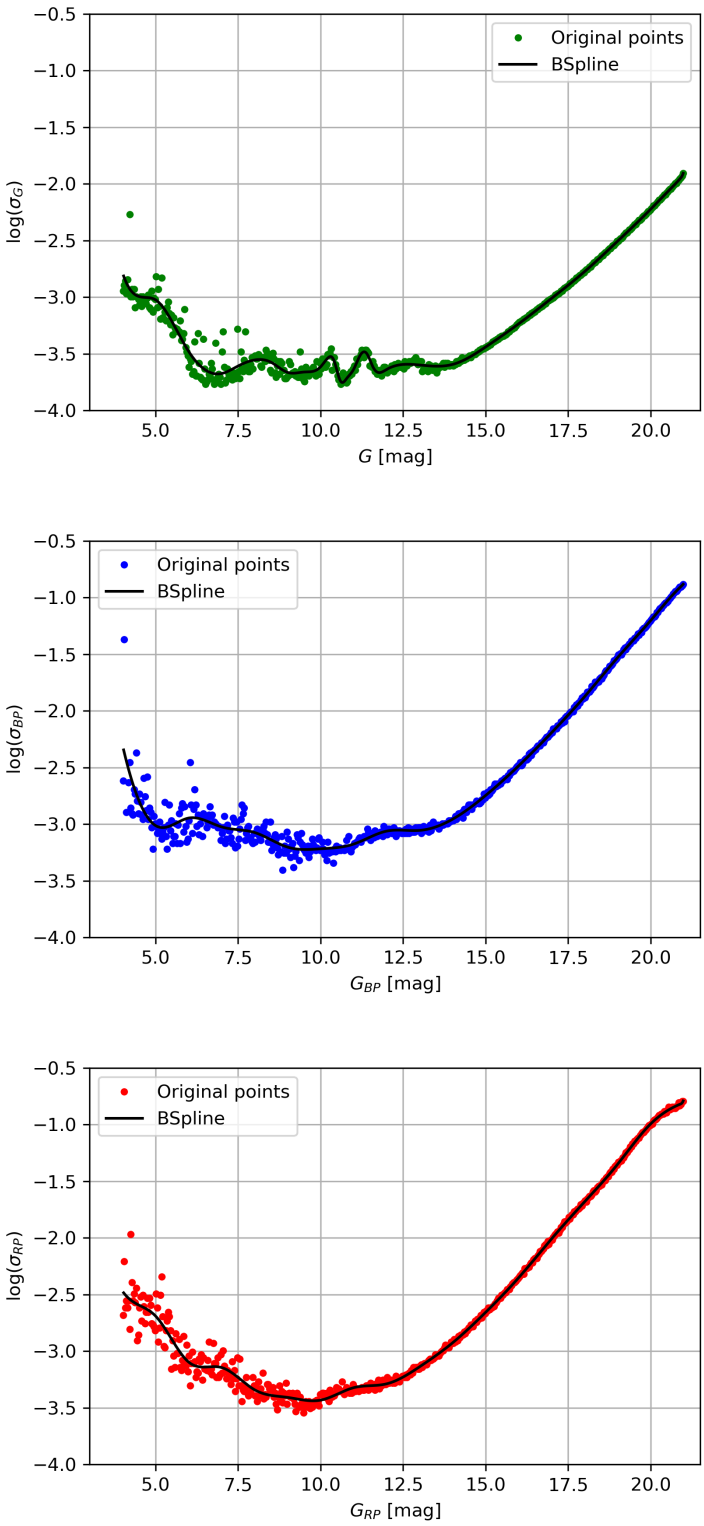

FIGURE 1: *Gaia* EDR3 magnitude uncertainties for G (top), $G_{\rm BP}$ (center) and $G_{\rm RP}$ (bottom) and the fitted B-splines.

TABLE 2: Knots and coefficients derived in this work fitting cubic B-splines to the data in Fig. 14 by Riello et al. (2021).

G knots	G coeffs	BP knots	BP coeffs	RP knots	RP coeffs
4.01667	-2.79887909	4.01667	-2.32338865	4.01667	-2.47826261
4.01667	-3.08151944	4.01667	-2.7347354	4.01667	-2.60799603
4.01667	-2.84639276	4.01667	-3.17685799	4.01667	-2.57160952
4.01667	-3.56581772	4.01667	-2.85931381	4.01667	-3.23730068
5.0	-3.72691989	5.0	-3.06319467	5.0	-3.0577367
6.0	-3.60270497	6.0	-3.03465194	6.0	-3.39917882
7.0	-3.5436255	7.0	-3.24178883	7.0	-3.39272922
7.5	-3.55291006	8.0	-3.21522612	8.0	-3.48046476
8.0	-3.69643657	9.0	-3.20568965	9.0	-3.2825215
8.5	-3.64899144	10.0	-3.02017022	10.0	-3.32760274
9.0	-3.67061528	11.0	-3.08397926	11.0	-3.14042529
9.5	-3.53485525	12.0	-2.97514949	12.0	-2.93931369
10.0	-3.4978671	13.0	-2.75388736	13.0	-2.66040611
10.2	-3.8080462	14.0	-2.49080265	14.0	-2.36268719
10.4	-3.70531135	15.0	-2.19398139	15.0	-2.00067133
10.6	-3.65814306	16.0	-1.88249501	16.0	-1.67932569
10.8	-3.49039948	17.0	-1.51867789	17.0	-1.36591438
11.0	-3.4627759	18.0	-1.22363879	18.0	-0.96526757
11.2	-3.65010982	19.0	-0.97861134	19.0	-0.84902968
11.4	-3.67777902	20.0	-0.89172014	20.0	-0.81220472
11.6	-3.58065738	20.9	-0.88153184	20.9	-0.79051121
11.8	-3.59787309	20.98333	0.0	20.98333	0.0
12.0	-3.63099015	20.98333	0.0	20.98333	0.0
13.0	-3.4425947	20.98333	0.0	20.98333	0.0
14.0	-3.2403399	20.98333	0.0	20.98333	0.0
15.0	-3.01000111				
16.0	-2.782245				
17.0	-2.50489				
18.0	-2.27662556				
19.0	-2.08203507				
20.0	-1.98780053				
20.5	-1.93253788				
20.9	-1.90632763				
20.98333	0.0				
20.98333	0.0				
20.98333	0.0				
20.98333	0.0				

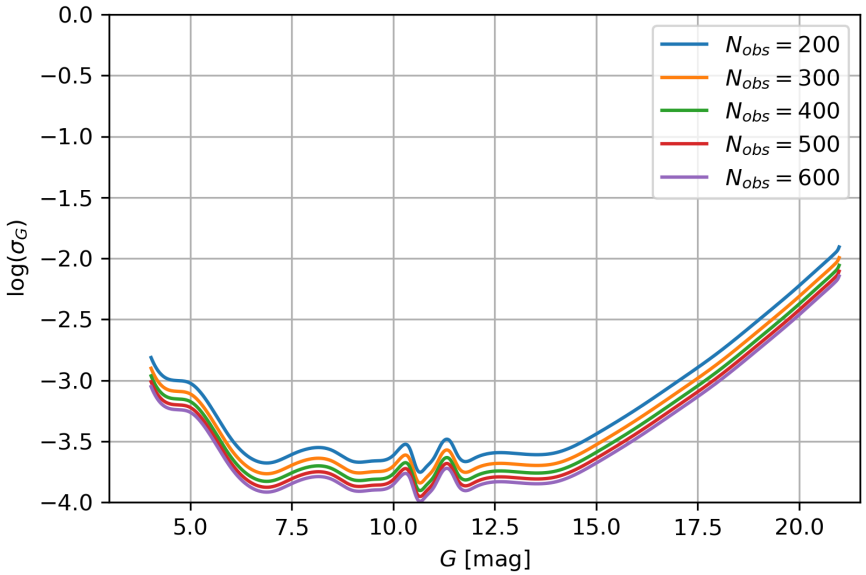

FIGURE 2: *Gaia* EDR3 magnitude uncertainties for G scaled at different number of observations.

We provide a Jupyter Notebook (`EDR3_Photometric_Uncertainties.ipynb`) showing how to estimate the uncertainties in a given band and for a given set of number of observations. The code uses the values in Table 2, which can be found in csv format in the `LogErrVsMagSpline.csv` file.

2 References

Jordi, C., Gebran, M., Carrasco, J.M., et al., 2010, A&A, 523, A48, ADS Link

Riello, M., De Angeli, F., Evans, D.W., et al., 2021, A&A, 649, A3, ADS Link

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