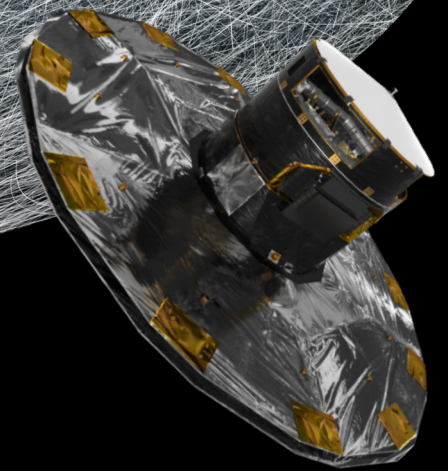


Gaia EDR3 en tus manos

C. Jordi, C. Fabricius, P. Ramos
University of Barcelona, ICCUB-IEEC
o behalf of DPAC



Gaia EDR3 en tus manos
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A long history



- Launch 19-Dec-2013
- Science operations 25-Jul-2014
- DR1 (14 months) 14-Sep-2016
- DR2 (22 months) 25-Apr-2018
- End of nominal mission 16-Jul-2019
- **EDR3 (34 months) 3-Des-2020**
- First mission extension end-2020
- DR3 (EDR3 + new products): H1-2022
- Second mission extension end 2022
- DR4 (66 months) TBD
- Third mission extension 2025 ?
- Final catalogue TBD

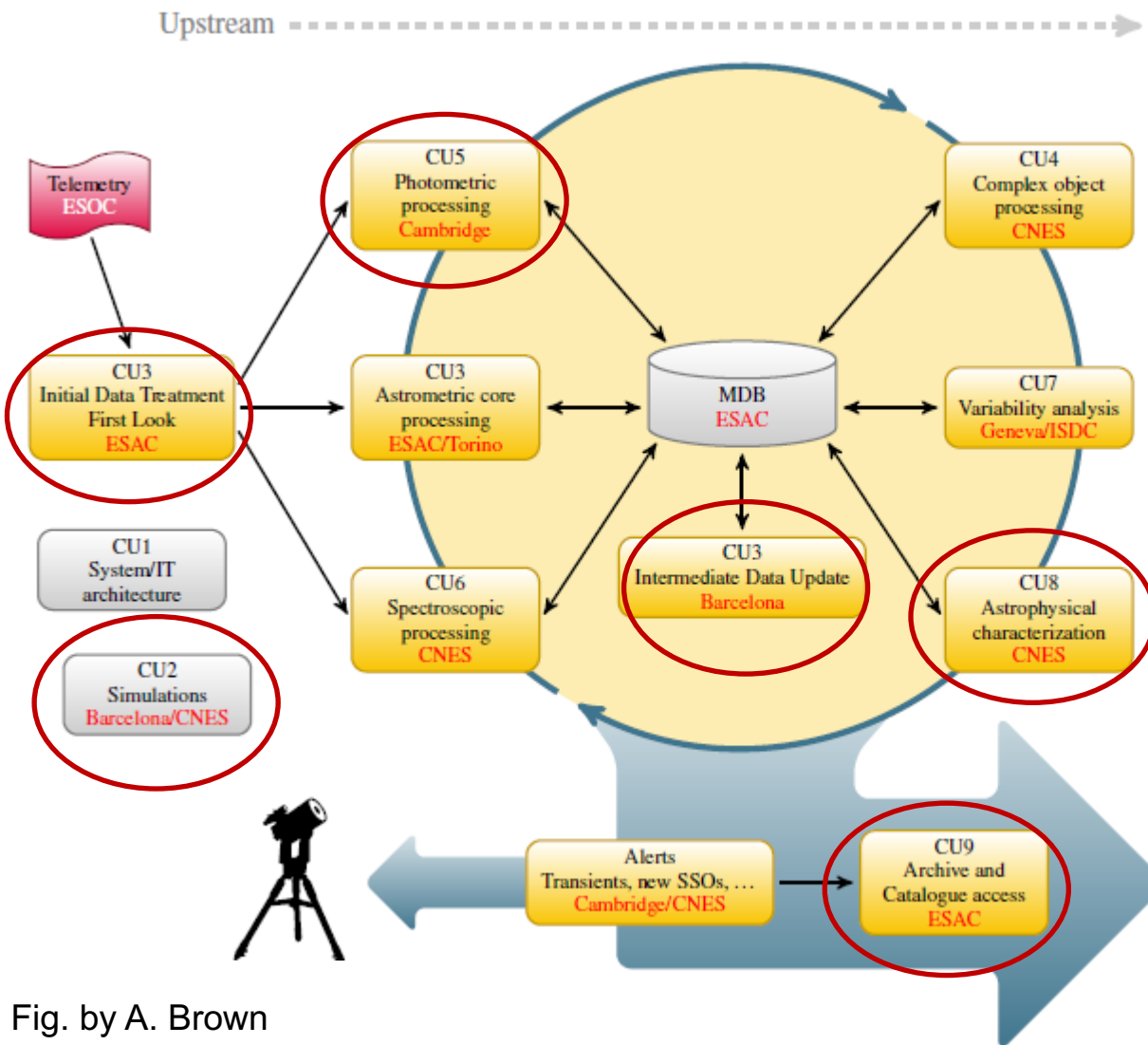
Credits: ESA/Gaia

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Data Processing and Analysis Consortium



78 billion transits (34 months)
EDR3: 1 Zettaflop (10^{21} flops)

Fig. by A. Brown



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GAIA EARLY DATA RELEASE 3



1 811 709 771
stellar positions

1 806 254 432
brightness
in white light

1 542 033 472
brightness
in blue light

1 540 770 489
colour

7 209 831
radial
velocities

1 467 744 818
parallax and
proper motions

1 614 173
extragalactic
sources

1 554 997 939
brightness
in red light

#SpaceCare #ExploreFarther

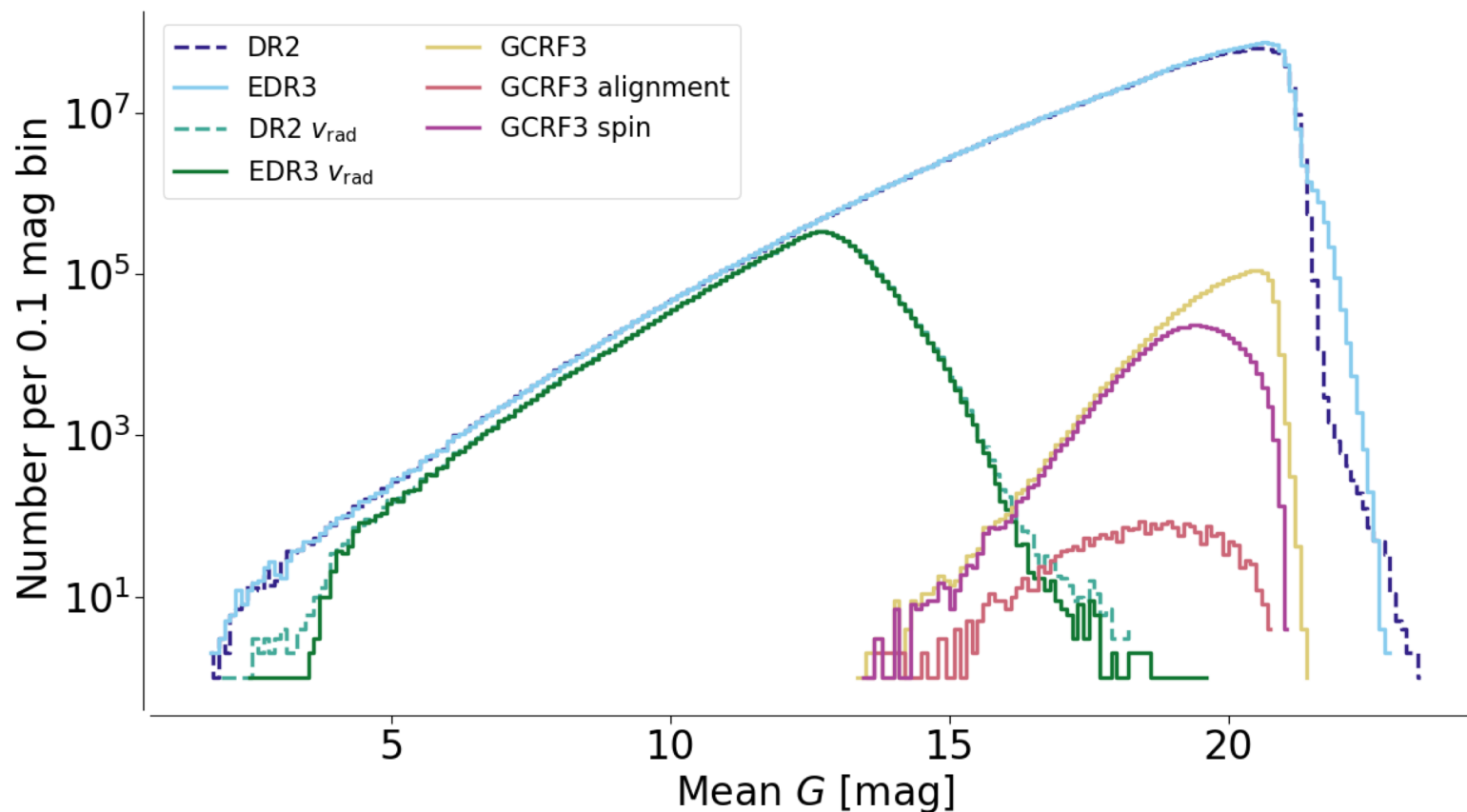


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Gaia EDR3 contents



Gaia Collaboration, Brown et al (2020, A&A)



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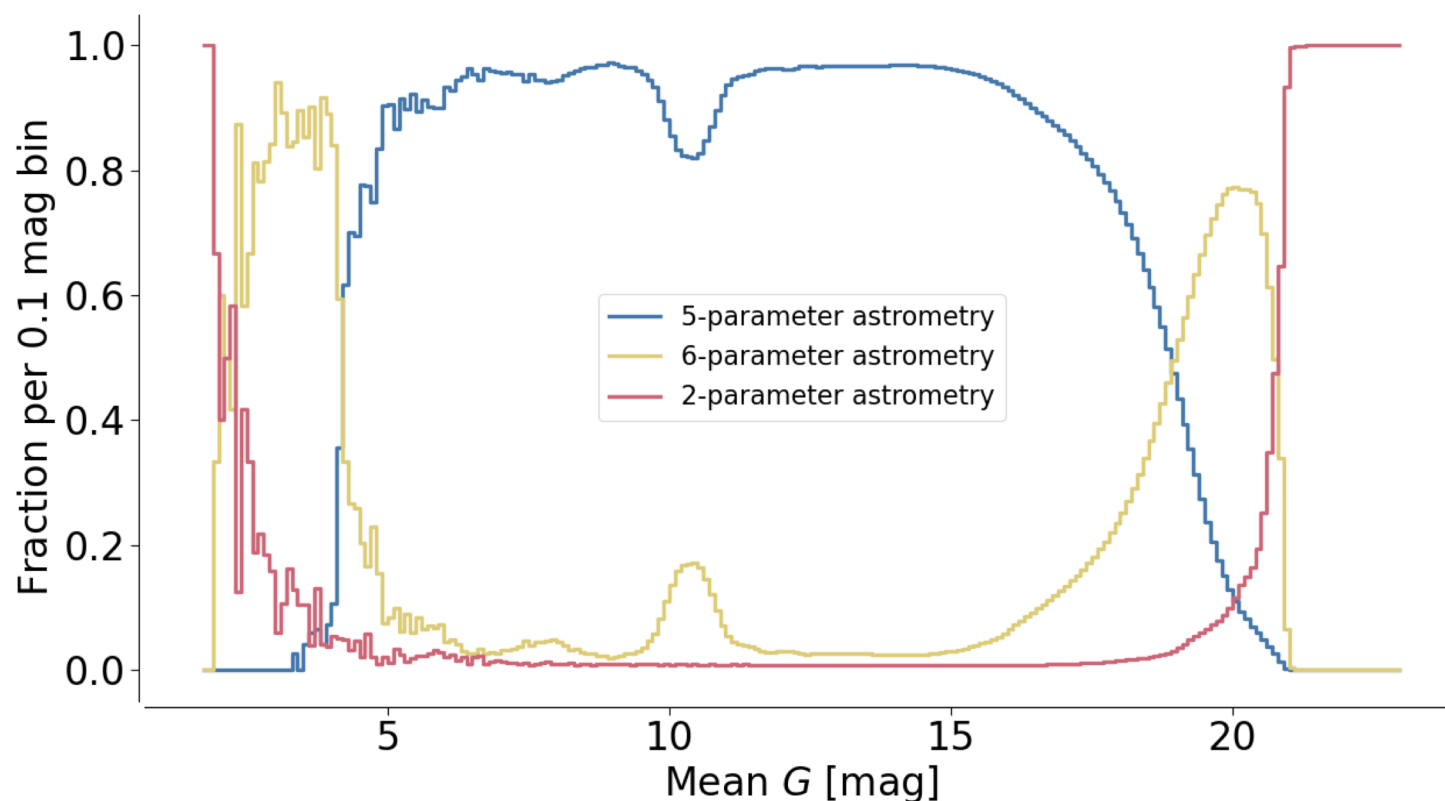


Astrometric contents

5p: $\alpha, \delta, \mu_{\alpha*}, \mu_{\delta}, \varpi$

6p: $\alpha, \delta, \mu_{\alpha*}, \mu_{\delta}, \varpi, \text{pseudocolor}$

2p: α, δ



Gaia Collaboration, Brown et al (2020, A&A)



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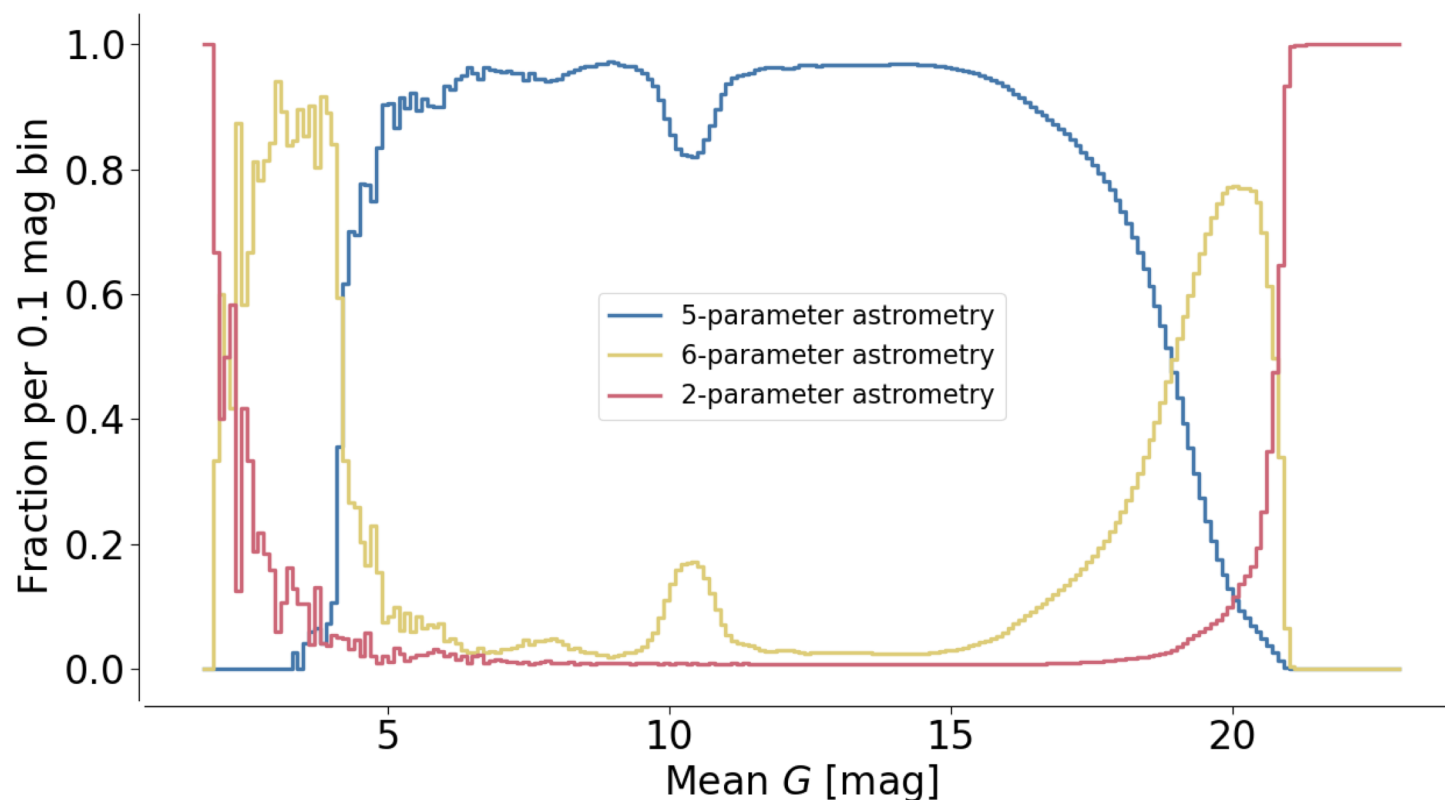
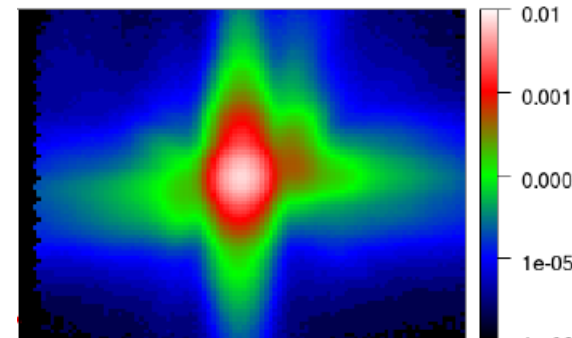


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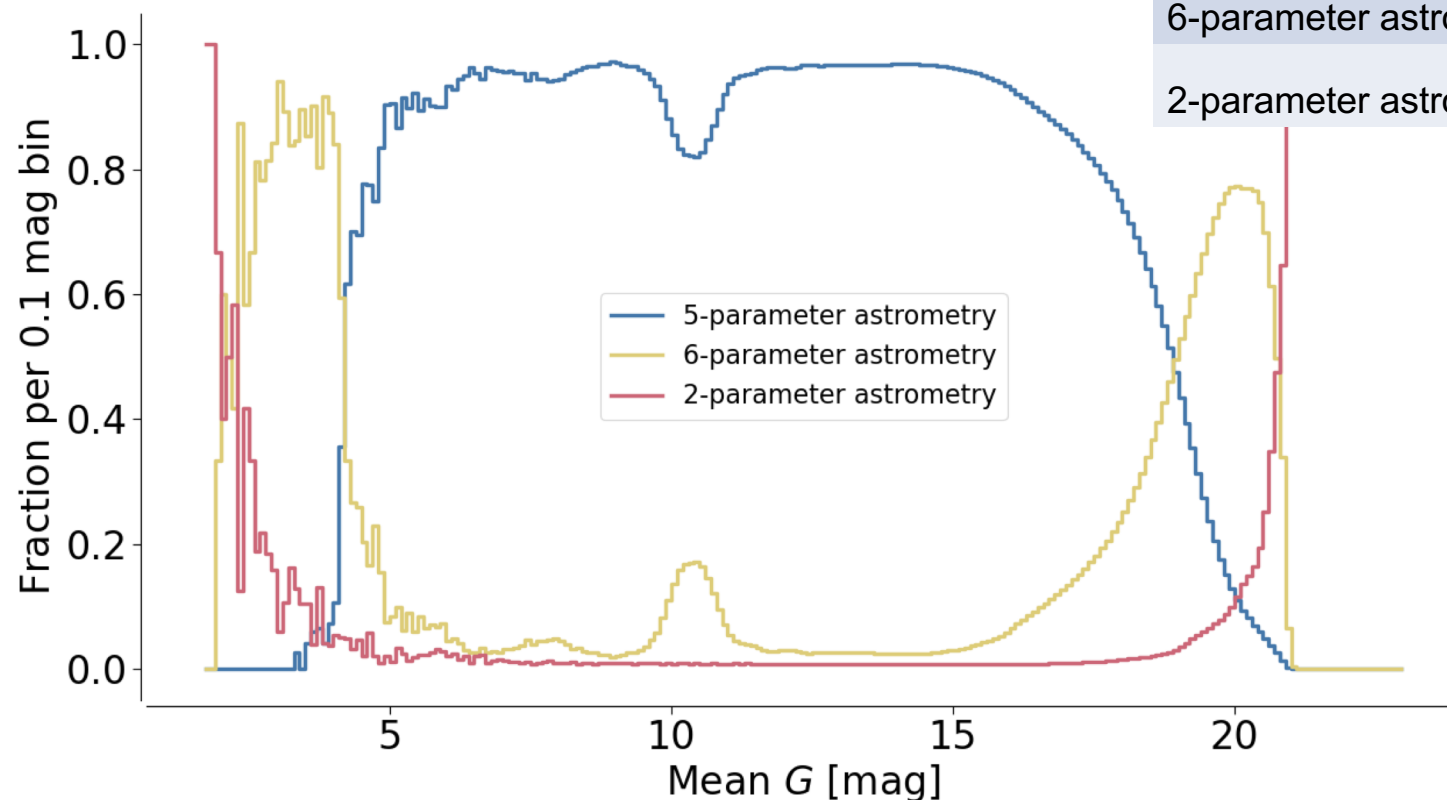
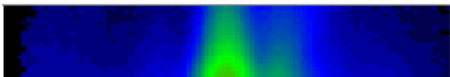


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2p: α, δ

Data	Number
Total	1 811 709 711
5-parameter astrometry	585 416 709
6-parameter astrometry	882 328 109
2-parameter astrometry	343 964 953

Gaia Collaboration, Brown et al (2020, A&A)



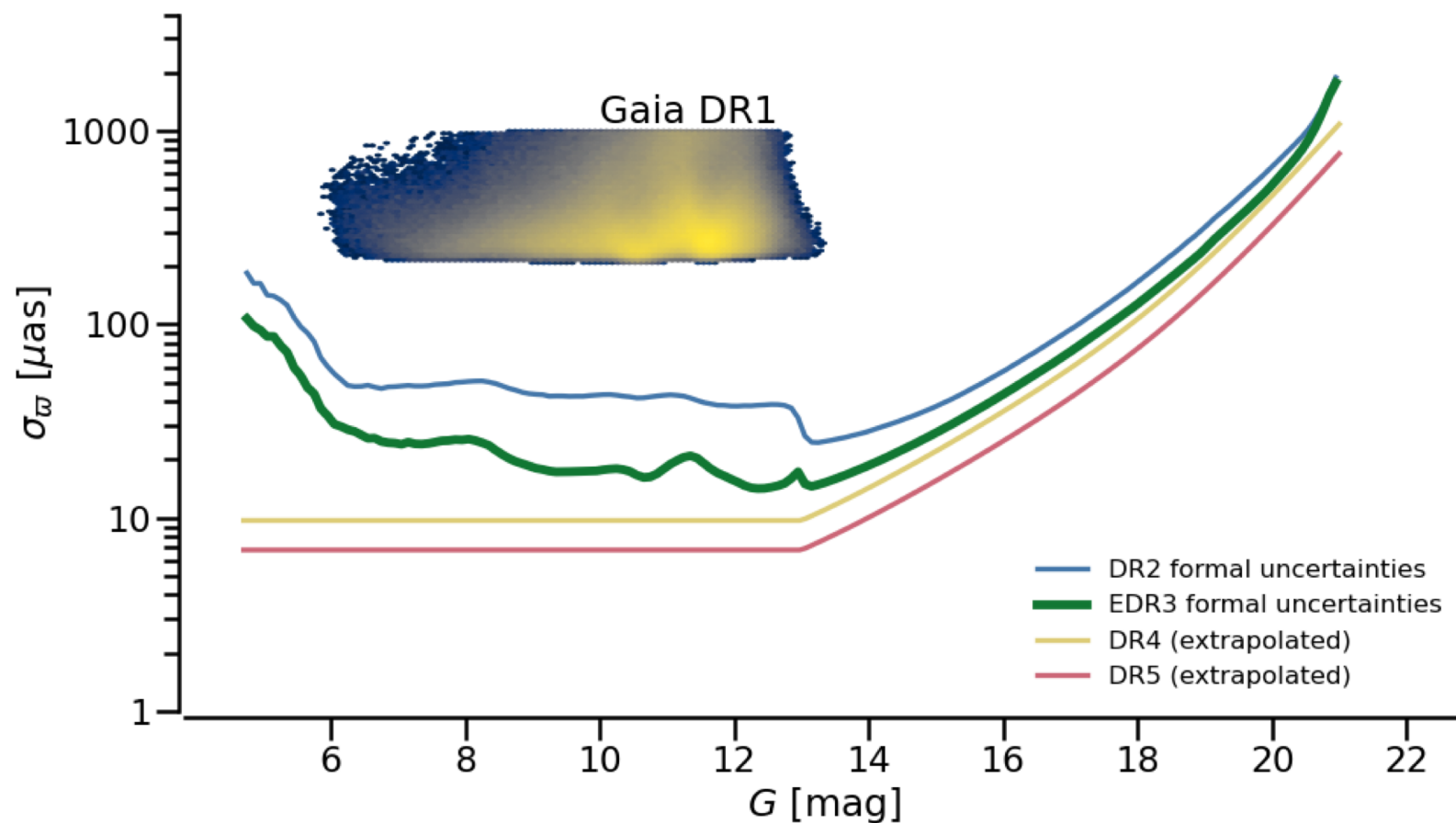
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Astrometric contents

30% improvement on uncertainties
reduction of systematics (bright stars,
zero point)



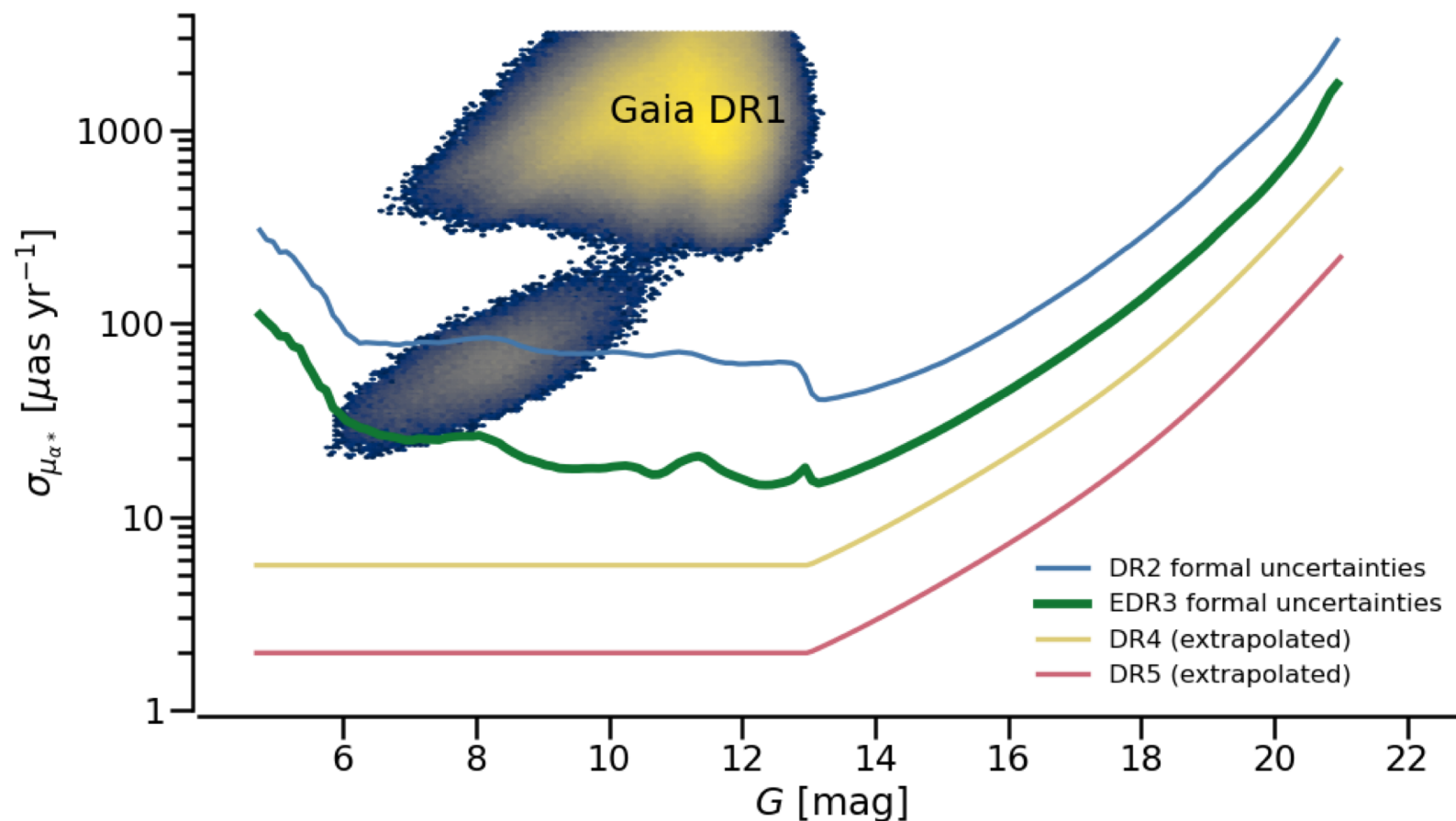
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Astrometric contents

factor 2 improvement on uncertainties
reduction of systematics (bright stars,
spin CRF)



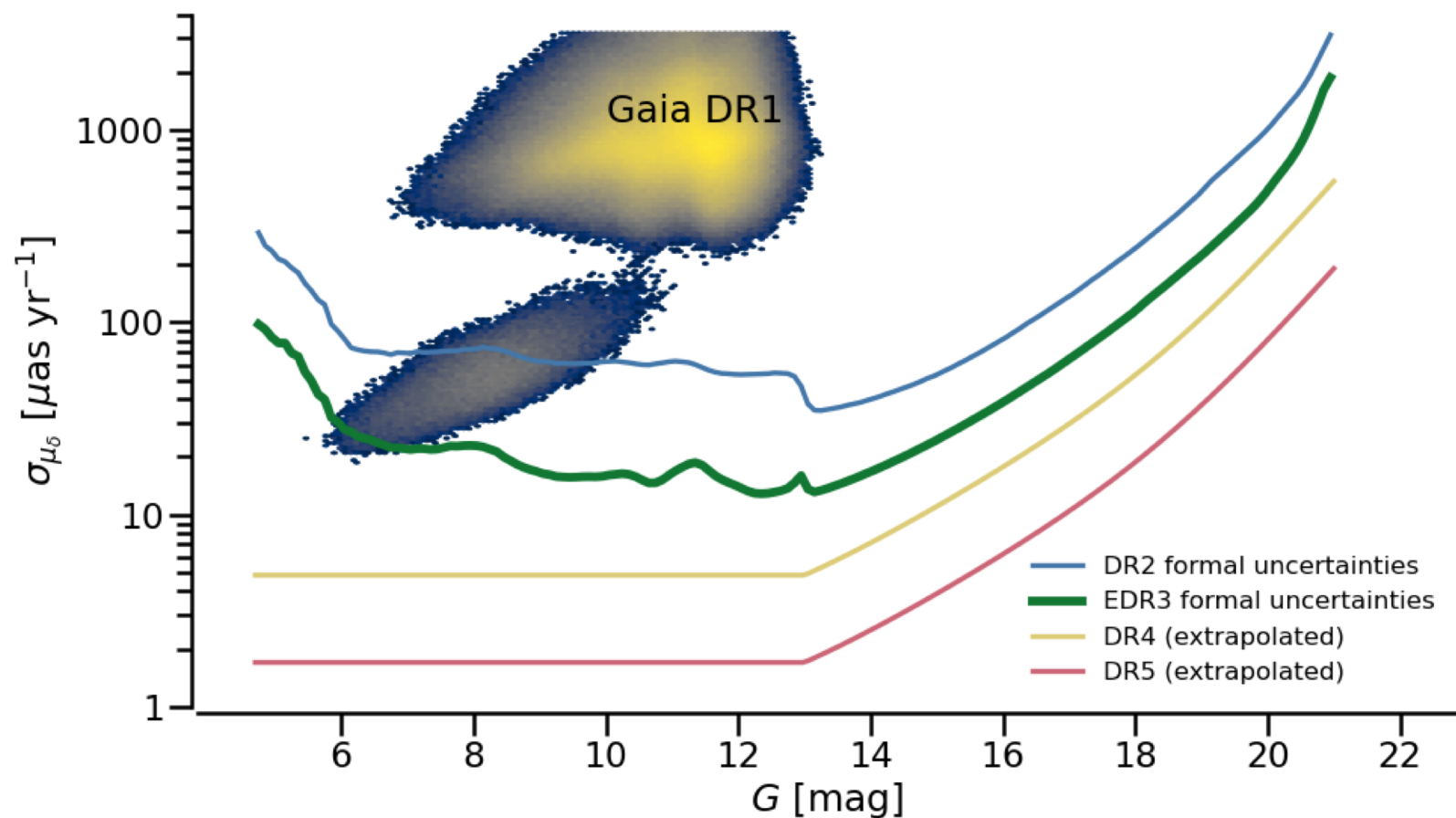
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factor 2 improvement on uncertainties
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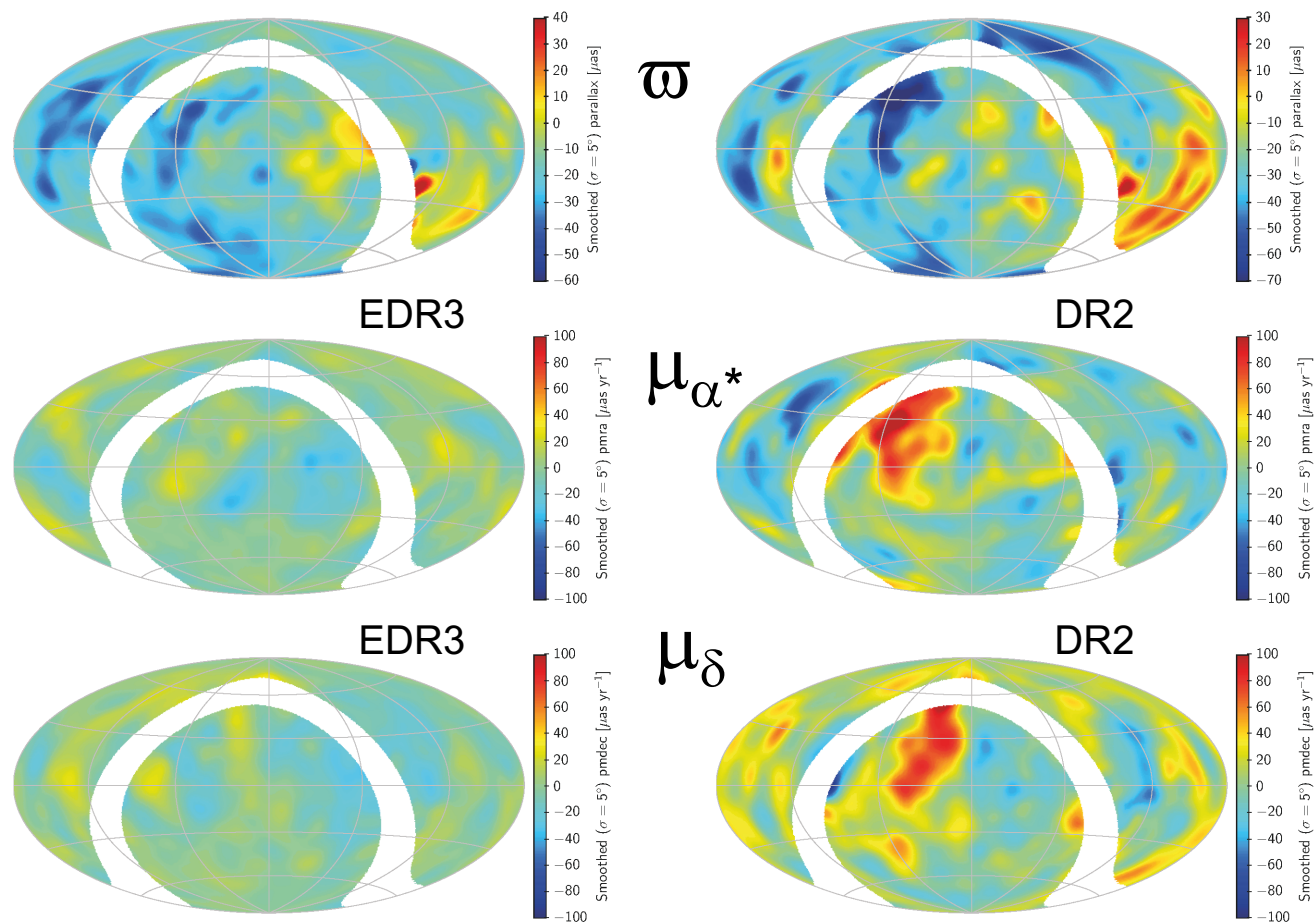


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Astrometric contents



Systematics as mapped through quasar parallaxes and proper motions

- Global parallax zero point: $-17 \mu\text{as}$
- RMS angular variations: $26 \mu\text{as}$ and $33 \mu\text{as/yr}$

Lindegren et al (2020, A&A)

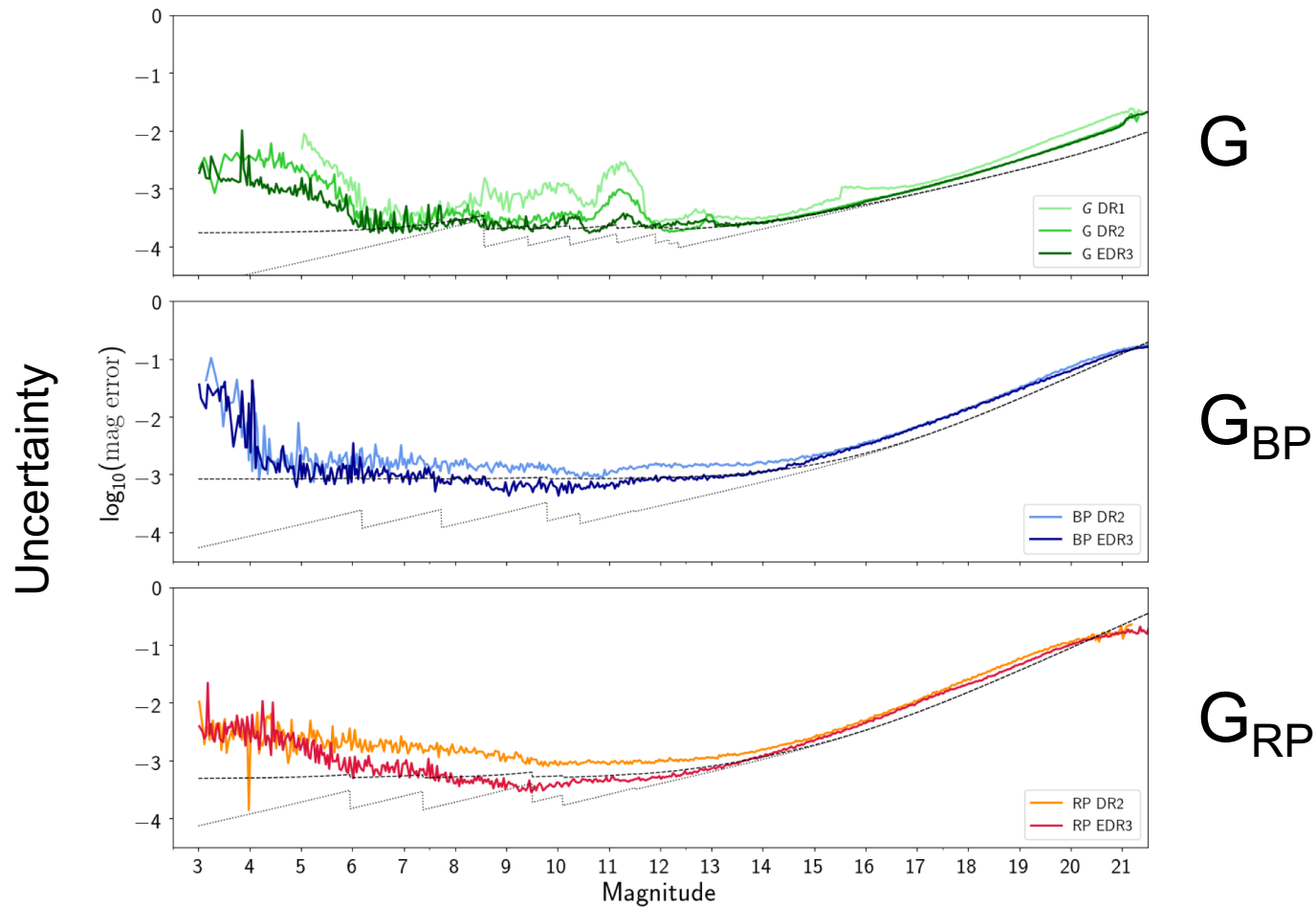


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Photometric contents



Riello et al (2020, A&A)

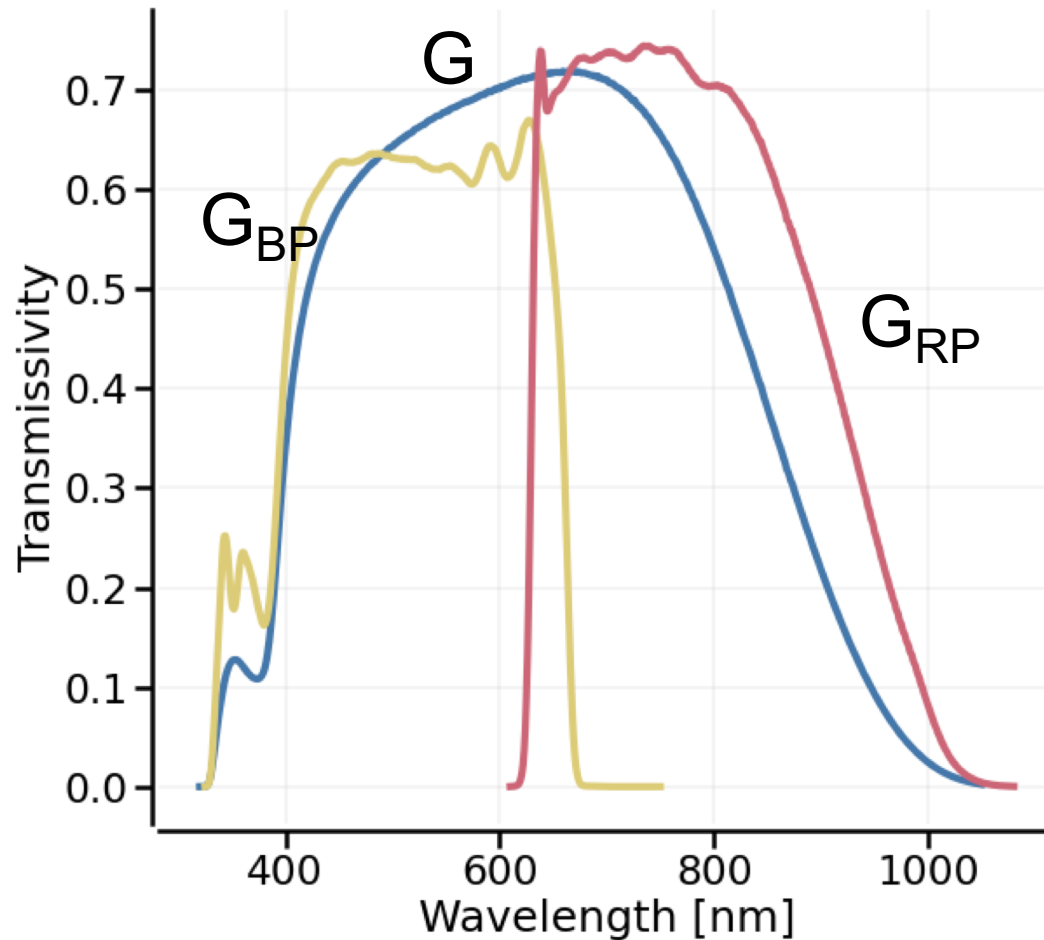


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Photometric contents



Passbands (slightly) different from Gaia DR2

- Reflects different average instrument
- Will change also for DR4 and DR5

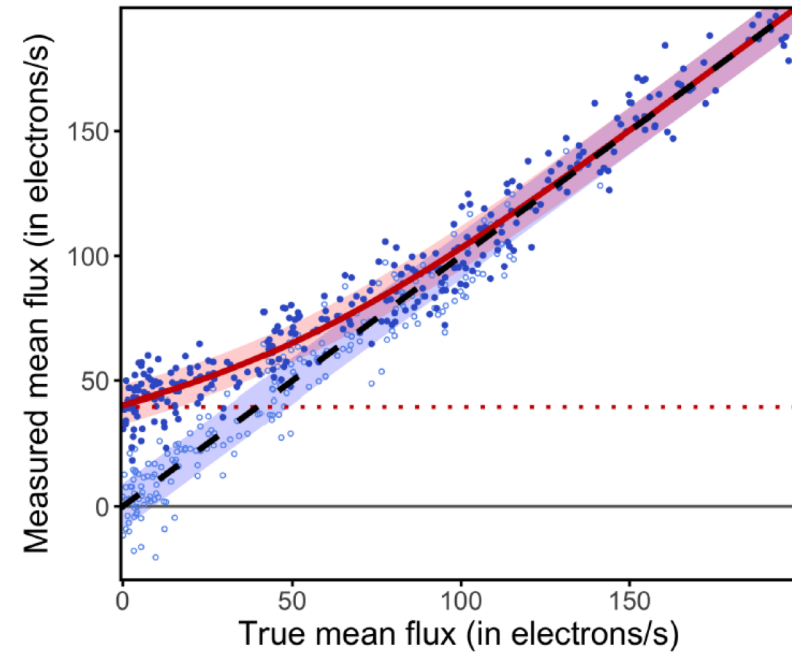
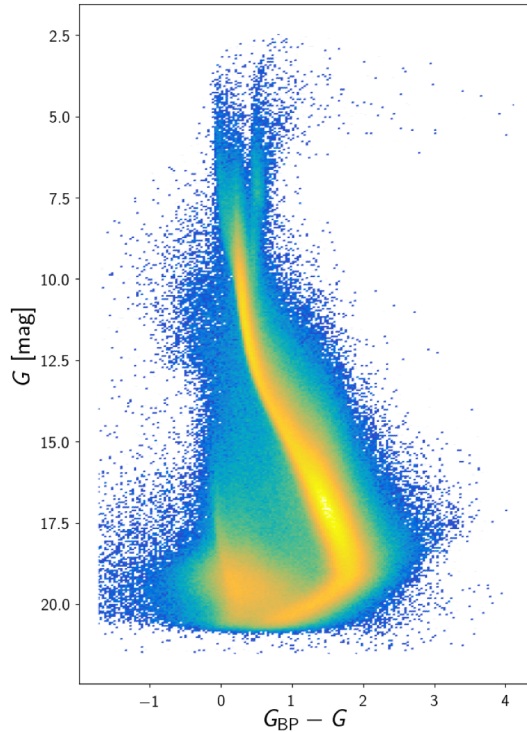
Riello et al (2020, A&A)



Gaia EDR3 en tus manos
3 diciembre 2020



Photometry limitations



- At faint end BP flux overestimated $G_{BP} > 20.5$
 - Sources appear too blue
- Use $(G - G_{RP})$ instead to study faint red sources

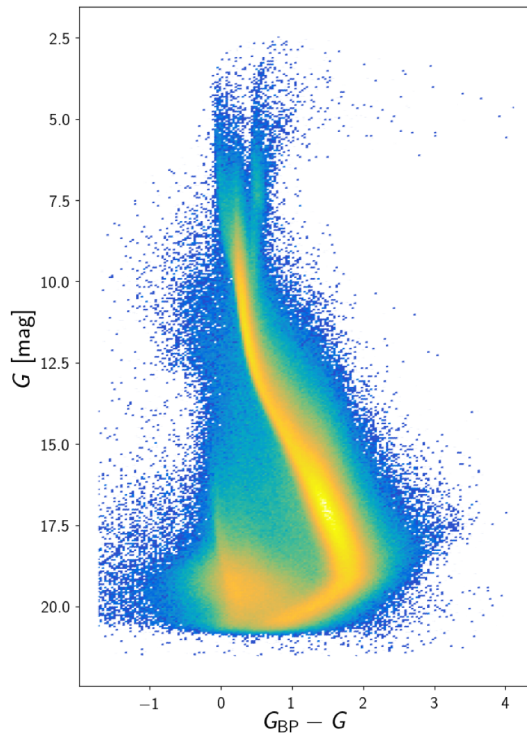
Riello et al (2020, A&A)
Fabricius et al (2020, A&A)



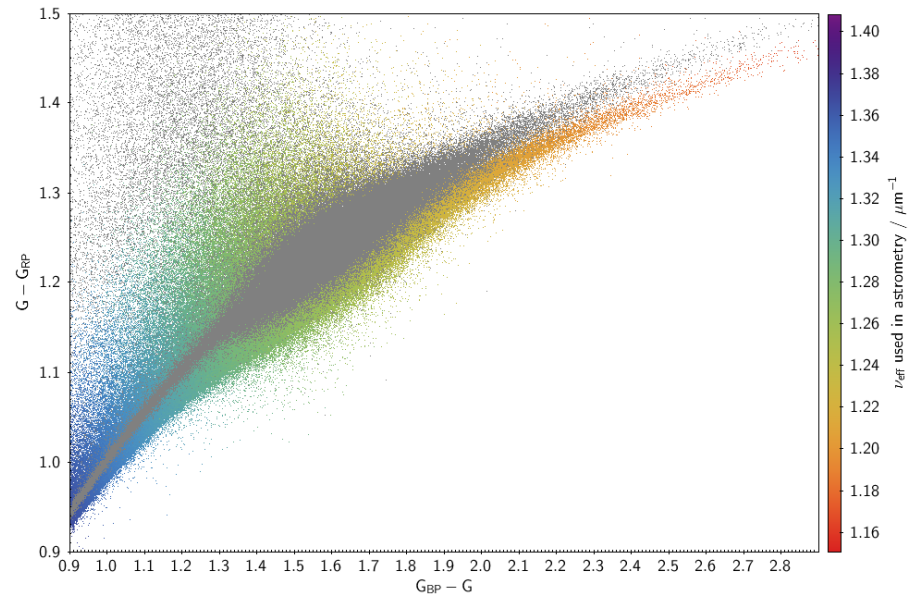
Gaia EDR3 en tus manos
3 diciembre 2020



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- G-band photometry for sources with 6-parameter astrometry should be corrected
- Formulae and ADQL/Python recipes available

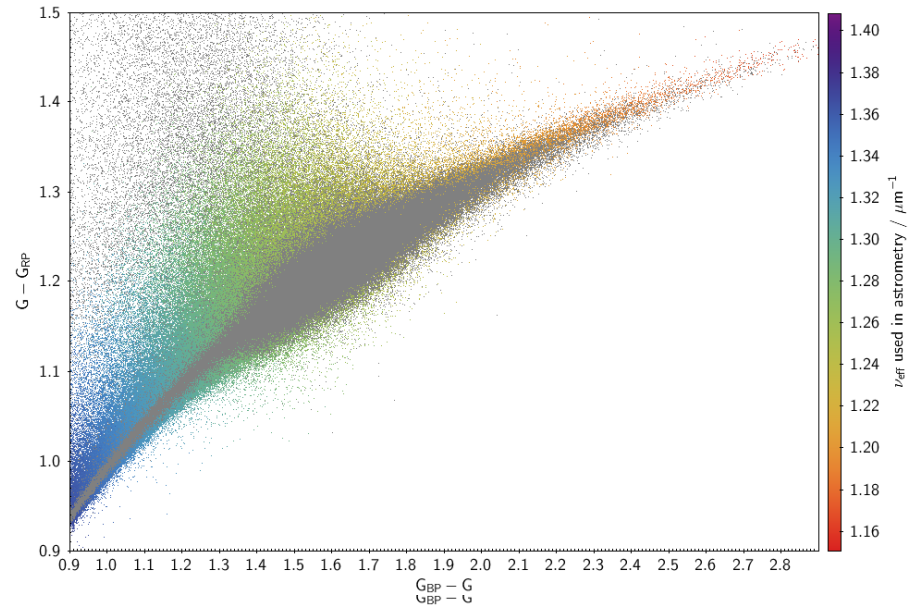
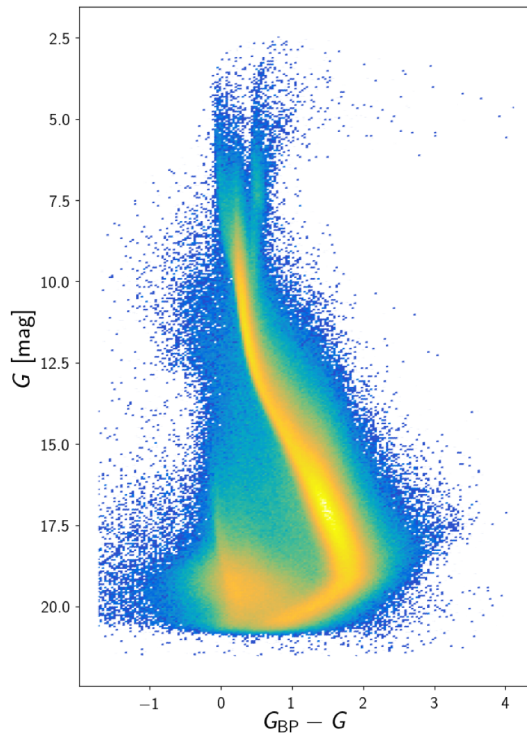
Riello et al (2020, A&A)



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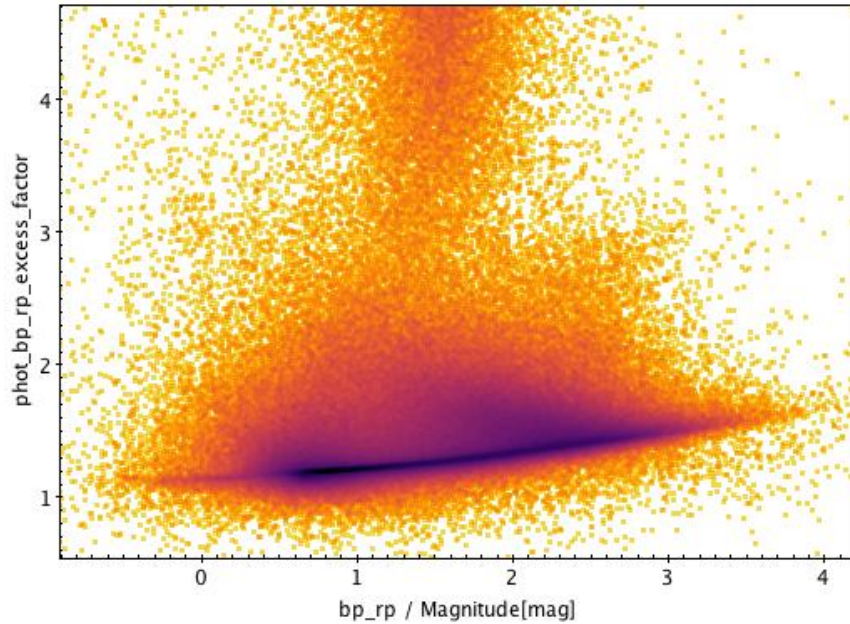
Riello et al (2020, A&A)



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Photometry: a note on the flux excess factor



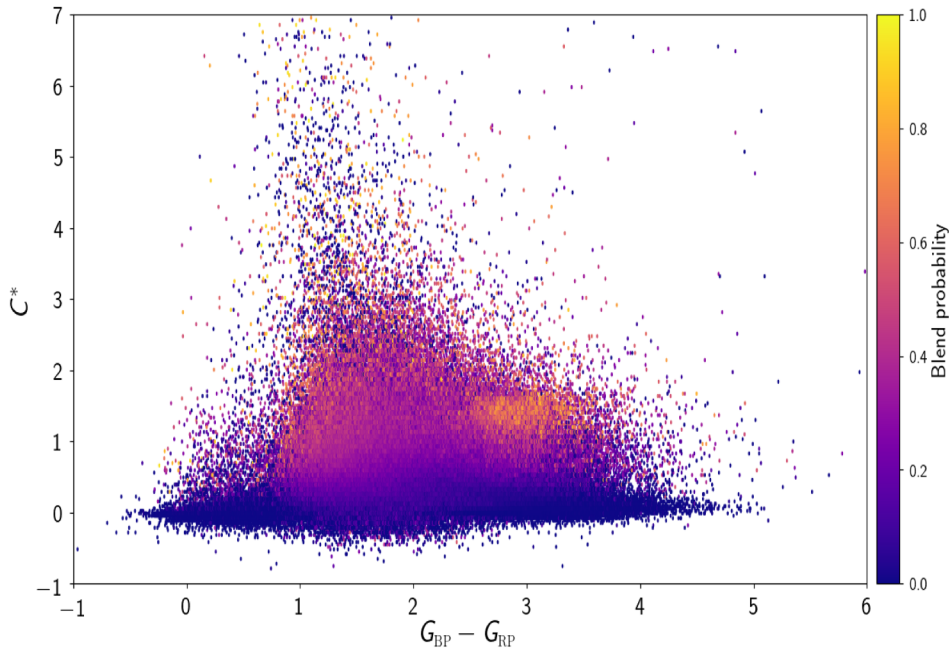
Riello et al (2020, A&A)



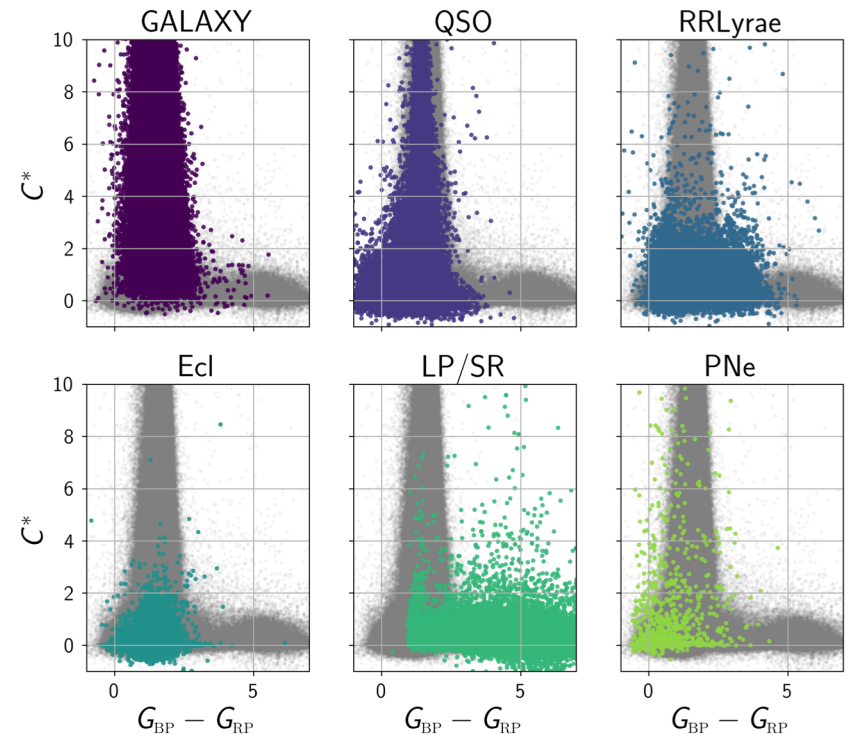
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Photometry: a note on the flux excess factor



- Recommendation it to use corrected form of flux excess factor C^*
 - Formulae and ADQL/Python recipes available
- Flux excess can indicate issues with crowding or background subtraction
 - *but also contains astrophysical information*



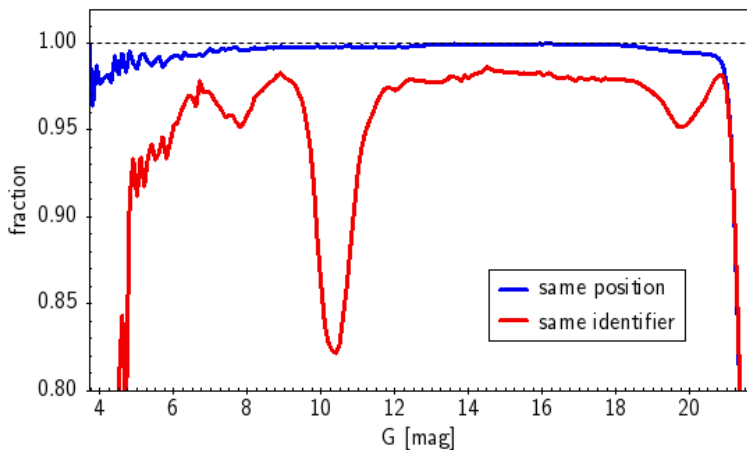
Riello et al (2020, A&A)



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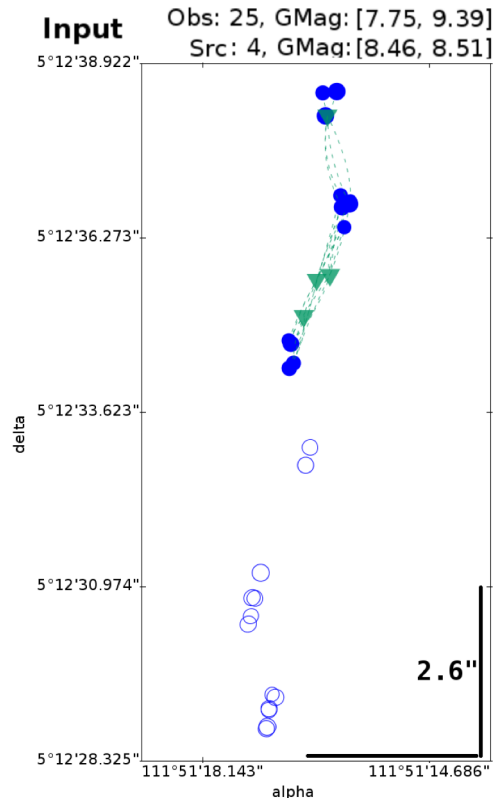


Notable changes DR2 to EDR3



Source list evolution

- Improved linking of observations to sources
- Improved recovery of HPMs
- Much more stable source list
- Use dr2_neighbourhood table to trace your favourite DR2 sources



- Reference epoch for Gaia EDR3 is 2016.0
- Completeness in crowded regions improved
- Lower limit on source separations is now 0.18 arcsec
 - Otherwise marked as duplicated sources

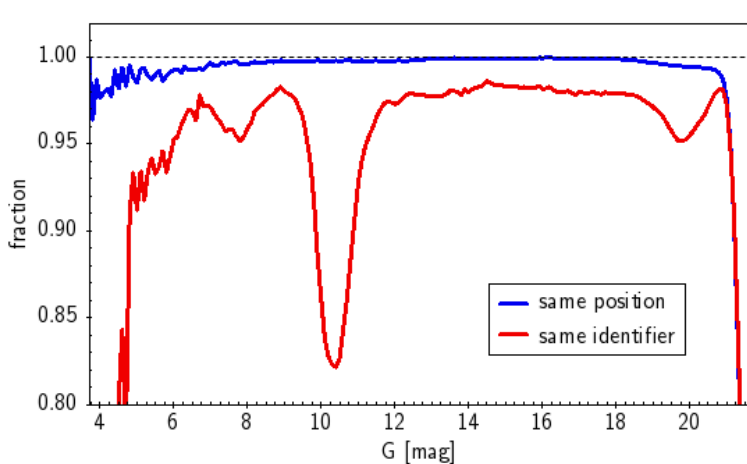


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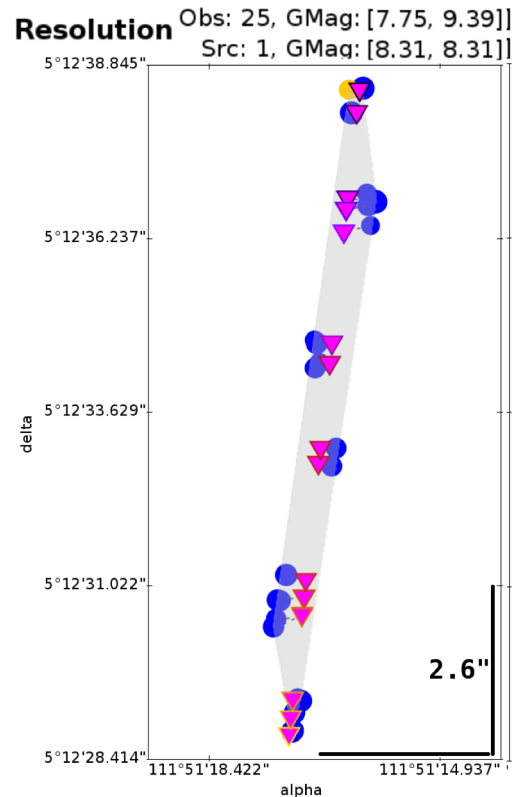


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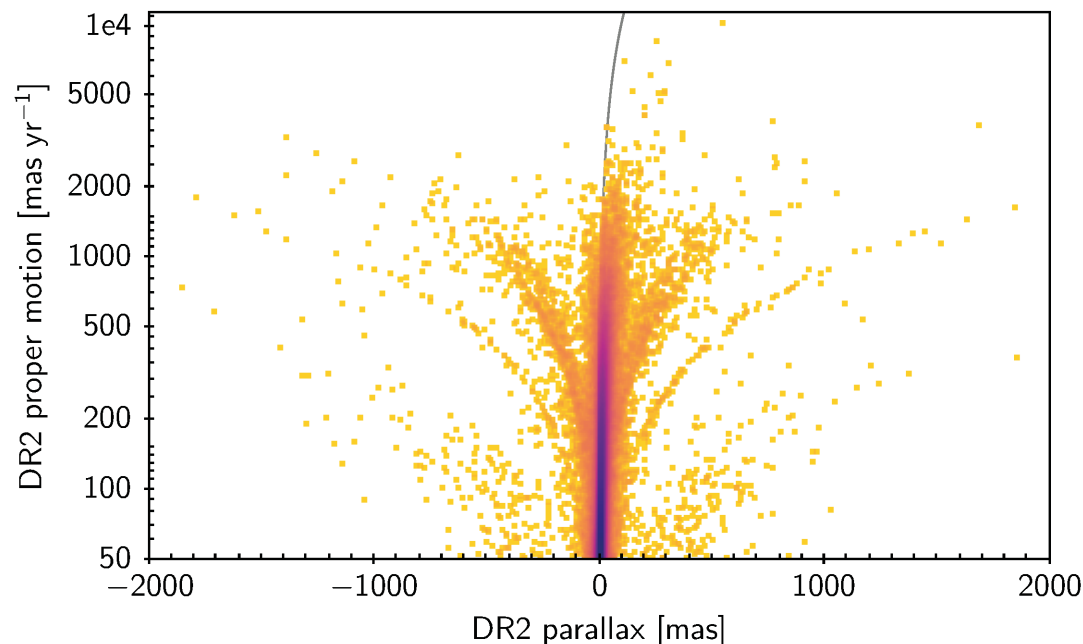


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Astrometry limitations



Spurious parallaxes and proper motions still present

- Much less frequent than in Gaia DR2
- Spurious solutions produce smaller errors on astrometry

Source-to-observation-match changes

- `matched_transits`
- `new_matched_transits`
- `matched_transits_removed`

Data quality indicators

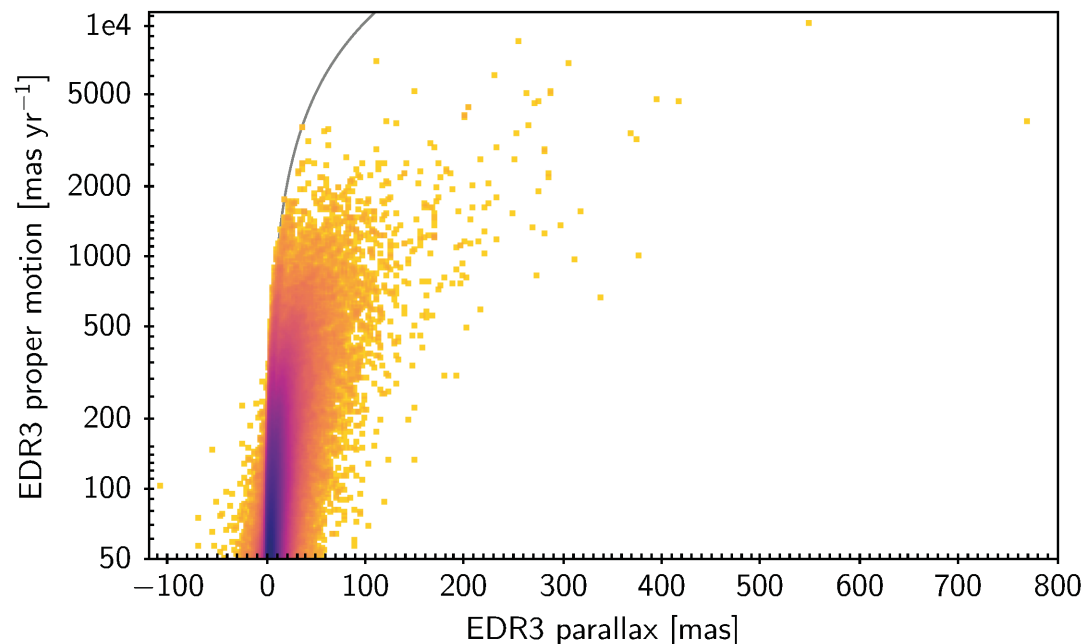
- `ruwe`
- `ipd_gof_harmonic_amplitude`
- `ipd_gof_harmonic_phase`
- `ipd_frac_multi_peak`
- `ipd_frac_oddwin`



Gaia EDR3 en tus manos
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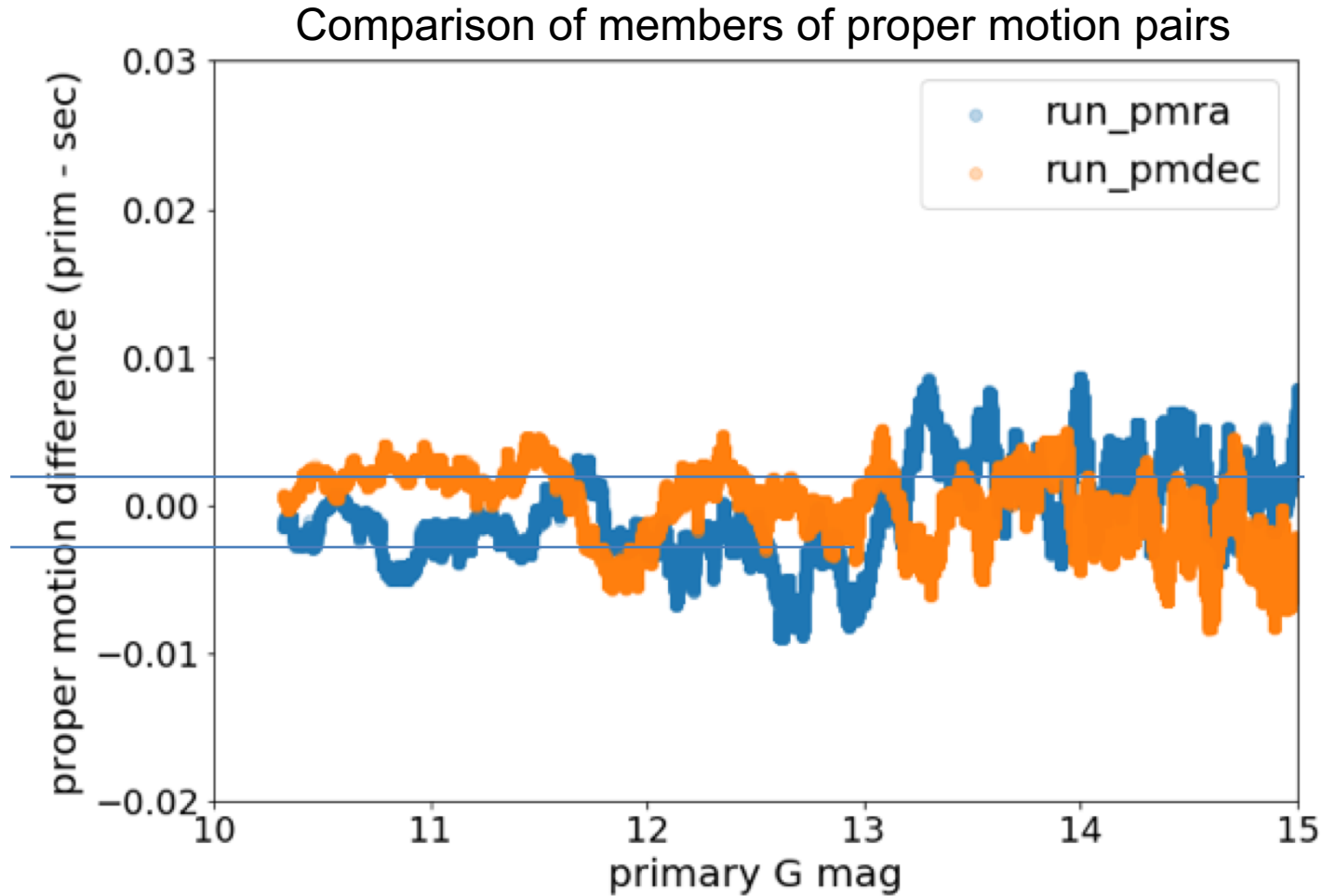
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- `ipd_gof_harmonic_phase`
- `ipd_frac_multi_peak`
- `ipd_frac_oddwin`



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Small step in proper motion at G 13 mag – much smaller than in DR2



The offset is probably also present in μ_δ

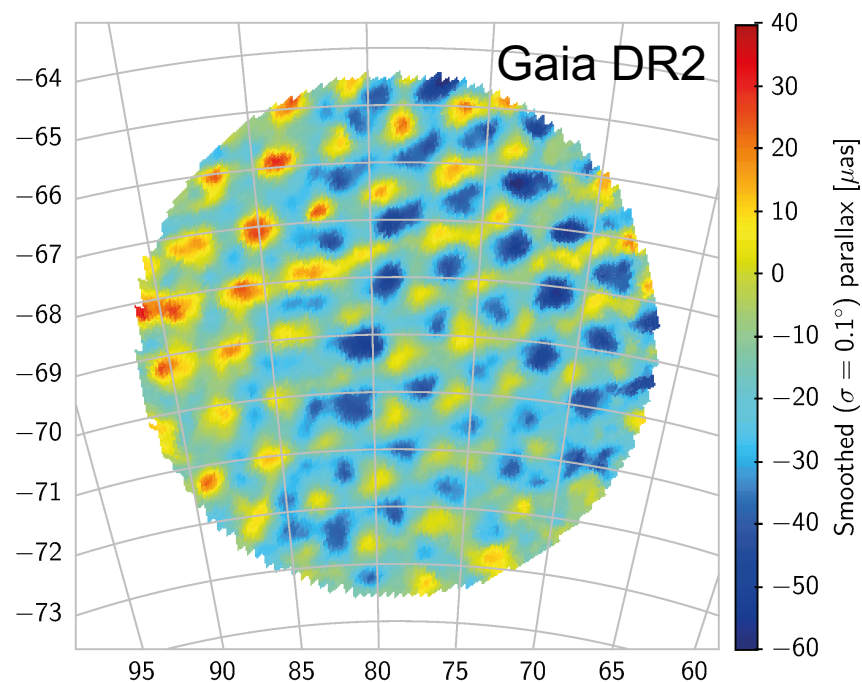


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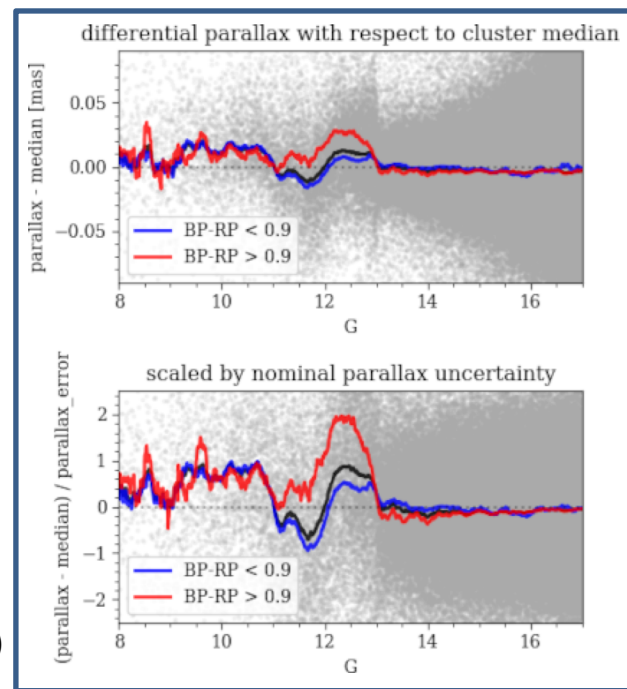


Astrometry limitations



Parallax zero-point variations still present (significantly suppressed)

- Tentative recipe is presented to correct for the variations
- Python code at https://gitlab.com/icc-ub/public/gaiadr3_zeropoint
- Proper motions also show systematics and angular correlations

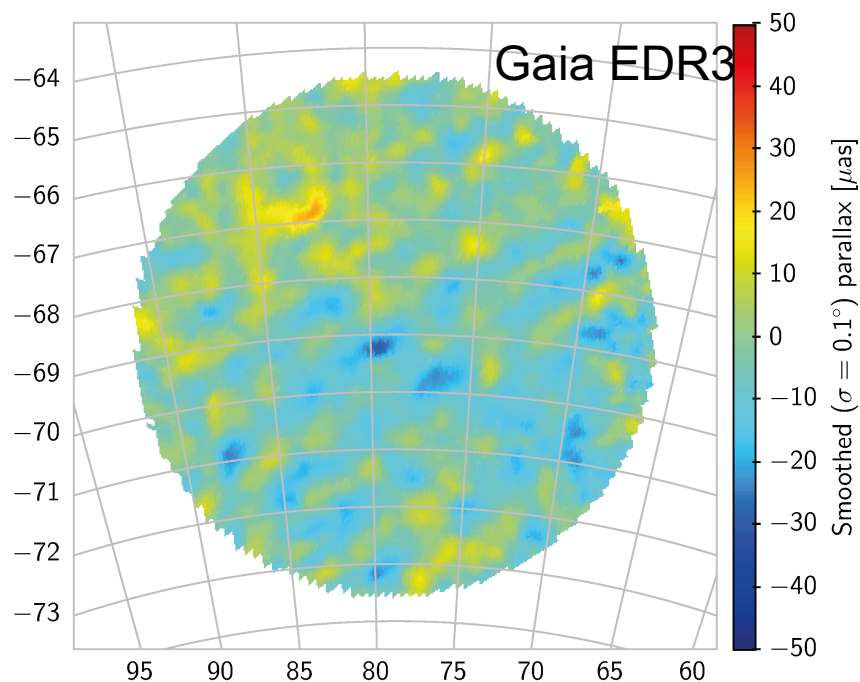


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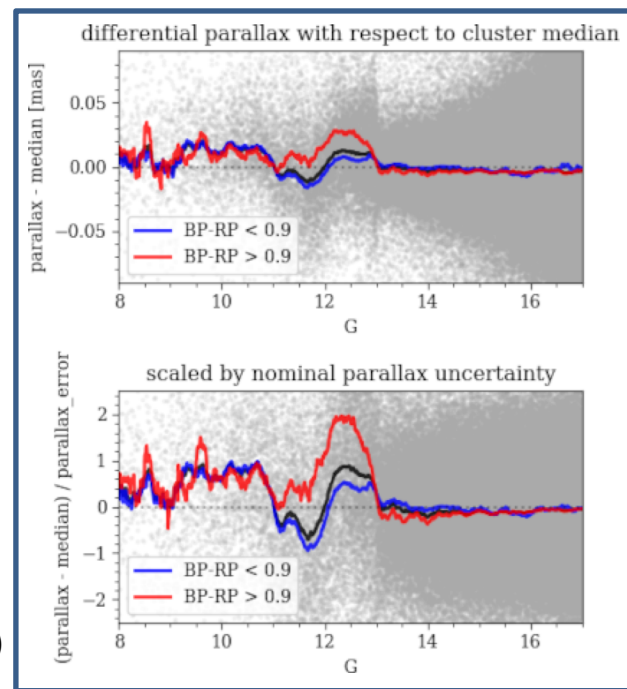


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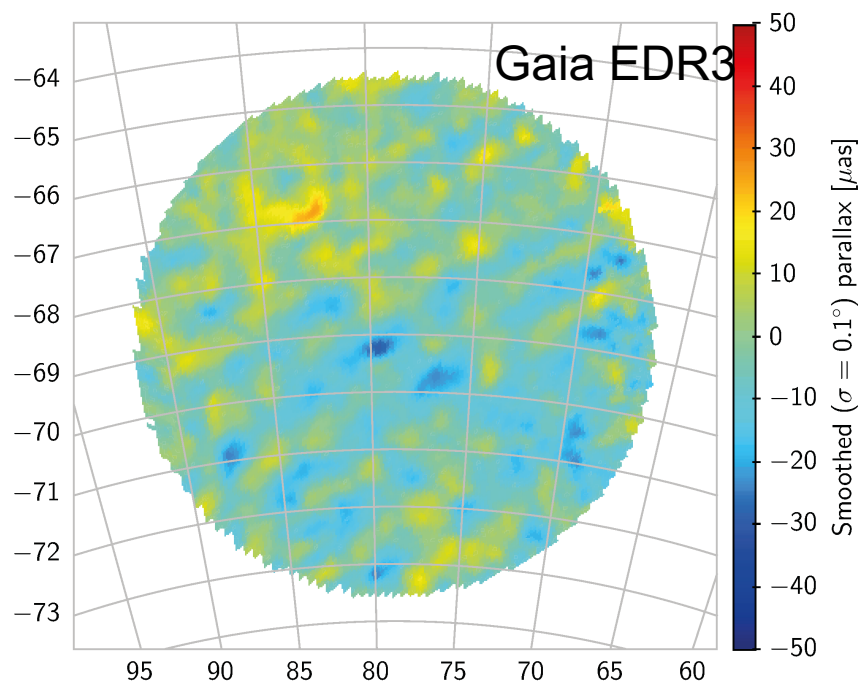


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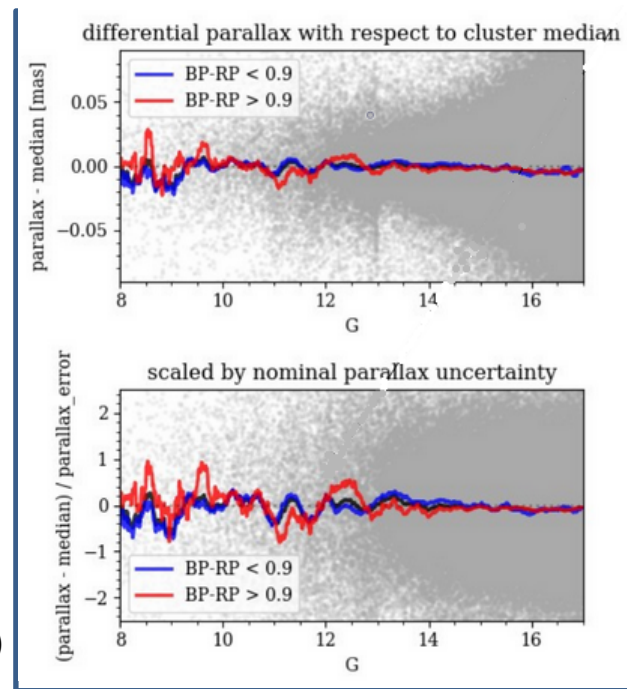


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Gaia EDR3 known issues

KNOWN ISSUES WITH THE GAIA EDR3 DATA

This page lists any issues found in Gaia Early Data Release 3 which could not be incorporated into the official data release, or which were discovered after the release of the data and publication of the release documentation. The [Gaia EDR3 contents](#) page contains a summary of limitations that are known, and documented, at the release. Further information can be found from the [data release documentation](#), as well as from the [data release processing papers](#).

Overview:

- [Photometry: Sources with missing G fluxes](#)

PHOTOMETRY - SOURCES WITH MISSING G FLUXES

POOR INPUT COLOUR RECOVERY

The sources in this issue were originally found to be much fainter than expected during the validation phase and subsequently their photometry was removed from the Gaia EDR3 catalogue. The cause of this was found to be poor input Spectral Shape Coefficient, SSC, (colour) values. Following this, the transits for these sources were all processed as Bronze sources i.e. using default SSCs, for all three flux types (G, G_{BP} and G_{RP}) and generating weighted mean flux values (and their errors) for each source. This will make the source consistently Bronze. See Section 8.2 of Riello et al. 2020 for more details.

In this file, magnitudes have been generated from the fluxes using the formula:

$$zp - 2.5 \cdot \log_{10}(\text{flux})$$

where the zero-points are the Gaia EDR3 VEGAMAG ones which can be found in Riello et al. 2020 (Section 7, Table 3).

This issue affects 5,401,215 sources.

Note that the G_{BP} magnitudes will still be affected by the bias mentioned in Section 8.1 of Riello et al. 2020. Care should be taken when using G_{BP} magnitudes fainter than 20.3. See also Section 9.2 for some suggestions on possible filtering criteria.

DOWNLOAD THE FILE

Please connect with an FTP client of your choice or using the terminal to [ftp.cosmos.esa.int](#) and navigate to the folder GAIA_PUBLIC_DATA. Here you can find a folder PhotometryEDR3. The file with details on these sources can be found there along with a readme.txt file.

INSUFFICIENT VALID TRANSITS

During the validation of the Gaia EDR3 catalogue, 54,125 sources were found not to have a mean G flux available in the Gaia EDR3 catalogue even though astrometric information was available for them. Investigation showed that these sources had too few valid transits for photometric processing. The validity criteria are different in the photometric and astrometric processing chains.

As a convenience to the user, a median G_{VPU} on-board magnitude (see Gaia EDR3 Documentation Section 1.1.3.5.3) is provided for these sources, but stored with a reduced precision (10%). This is to stop users misguidedly trying to use these values for science. They are purely a general indicator of the brightness of the source. It must be stressed that these values are uncalibrated and on a different photometric system to that of the G values in Gaia EDR3.

DOWNLOAD THE FILE

The file with details on these sources can be downloaded through this [link](#).



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Gaia EDR3 data model

New names

- astrometricMatched**Observations** --> astrometricMatched**Transits**
- matched**Observations** --> matched**Transits**
- radialVelocity --> **dr2**RadialVelocity
- radialVelocityError --> **dr2**RadialVelocityError
- rvNbTransits --> **dr2**RvNbTransits
- RvTemplateTeff --> **dr2**rvTemplateTeff
- RvTemplateLogg --> **dr2**rvTemplateLogg
- RvTemplateFeH --> **dr2**rvTemplateFeH



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Gaia EDR3 data model

New fields

- pm
- newMatchedTransits
- matchedTransitsRemoved
- ipdGofHarmonicAmplitude
- ipdGofHarmonicPhase
- ipdFracMultiPeak
- ipdFracOddWin
- ruwe
- photBpNContaminatedTransits
- photBpNBlendedTransits
- photRpNContaminatedTransits
- photRpNBlendedTransits
- scanDirectionStrengthK1..4
- scanDirectionMeanK1..4

when source_id unchanged from DR2

image statistics.
useful for identifying source
that are not isolated

suspicious XP observations,
but included in mean photometry



Gaia EDR3 en tus manos
3 diciembre 2020



Gaia EDR3: <https://www.cosmos.esa.int/web/gaia/early-data-release-3>

GAIA EDR3 INFO

Information on Gaia Early Data Release 3 contents, completeness and limitations. The page will be updated from time to time.

GAIA EDR3 PAPERS

Find [here](#) the titles of the expected papers describing the data processing and demonstrating the science potential of Gaia Early Data Release 3, including [Python code](#) accompanying the papers.

GAIA EDR3 DOCUMENTATION

The data release documentation for Gaia Early Data Release 3, describing the processing of the data from raw to Gaia EDR3 will appear both on webpages and through a downloadable PDF-file.

- Available at release -

GAIA EDR3 DATA RELEASE EVENTS

Interested to follow one of the Gaia EDR3 release events? Here we announce the various events and how to join.

GAIA EDR3 DATA MODEL

The draft Gaia EDR3 data model is available now to help the user community prepare for the release.

[Download here](#)

GAIA EDR3 KNOWN ISSUES

Similar to what was done for Gaia DR2, issues with the Gaia EDR3 data, found after the release of data and documentation, will be published.

- Available at release -

GAIA EDR3 PASSBANDS

Find [here](#) a description of the Gaia EDR3 passbands.

GAIA EDR3 DATA

Gaia Early Data Release 3 data will be made available from the Gaia Archive and its partner data centres.

- Available at release -

PYTHON ACCESS

Gaia data can be accessed using Python. Learn more about the [astroquery](#) package for Gaia [here](#).

Some [source code](#) comes along with the Gaia EDR3 papers.

ADQL QUERIES

While downloading the data will be possible, bring instead your code to the data. Use ADQL queries to extract the data and then download only the resulting table.

TUTORIALS AND HELP

Help is available to guide you through the process of getting the data you need. Check out the tutorials, they are very instructive!

GAIA EDR3 PRIMER

After the release of Gaia EDR3, we hope to bring you the Gaia EDR3 primer to help you use Gaia EDR3.

- Available after release -

PUBLIC OUTREACH MATERIAL

An overview of news and stories on the Gaia Mission and Gaia science are given here. The press release by ESA on Gaia EDR3 will be shared through here.

- Available at release -

GAIA EDR3 STORIES

A selection of stories on the processing towards Early Data Release 3 and the science potential of the data will be made available on the release day.

- Available at release -

GAIA DATA CREDITS

When using Gaia EDR3 data, please acknowledge the work of the people involved and provide credits and necessary citations. Each release comes with its own credit lines.

- Available at release -

QUESTIONS

Contact the Gaia Helpdesk.



Gaia EDR3 en tus manos
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Gaia EDR3: <https://www.cosmos.esa.int/web/gaia/early-data-release-3>

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GAIA EDR3 PAPERS

Find [here](#) the titles of the expected papers describing the data processing and demonstrating the science potential of Gaia Early Data Release 3, including [Python code](#) accompanying the papers.

GAIA EDR3 KNOWN ISSUES

Similar to what was done for Gaia DR2, issues with the Gaia EDR3 data, found after the release of data and documentation, will be published.

- Available at release -

ADQL QUERIES

While downloading the data will be possible, bring instead your code to the data. Use ADQL queries to extract the data and then download only the resulting table.

GAIA EDR3 STORIES

A selection of stories on the processing towards Early Data Release 3 and the science potential of the data will be made available on the release day.

- Available at release -

GAIA EDR3 DOCUMENTATION

The data release documentation for Gaia Early Data Release 3, describing the processing of the data from raw to Gaia EDR3 will appear both on webpages and through a downloadable PDF-file.

- Available at release -

GAIA EDR3 PASSBANDS

Find [here](#) a description of the Gaia EDR3 passbands.

TUTORIALS AND HELP

Help is available to guide you through the process of getting the data you need. Check out the tutorials, they are very instructive!

GAIA DATA CREDITS

When using Gaia EDR3 data, please acknowledge the work of the people involved and provide credits and necessary citations. Each release comes with its own credit lines.

- Available at release -

GAIA EDR3 DATA RELEASE EVENTS

Interested to follow one of the Gaia EDR3 release events? Here we announce the various events and how to join.

GAIA EDR3 DATA

Gaia Early Data Release 3 data will be made available from the Gaia Archive and its partner data centres.

- Available at release -

GAIA EDR3 PRIMER

After the release of Gaia EDR3, we hope to bring you the Gaia EDR3 primer to help you use Gaia EDR3.

- Available after release -

QUESTIONS

Contact the Gaia Helpdesk.



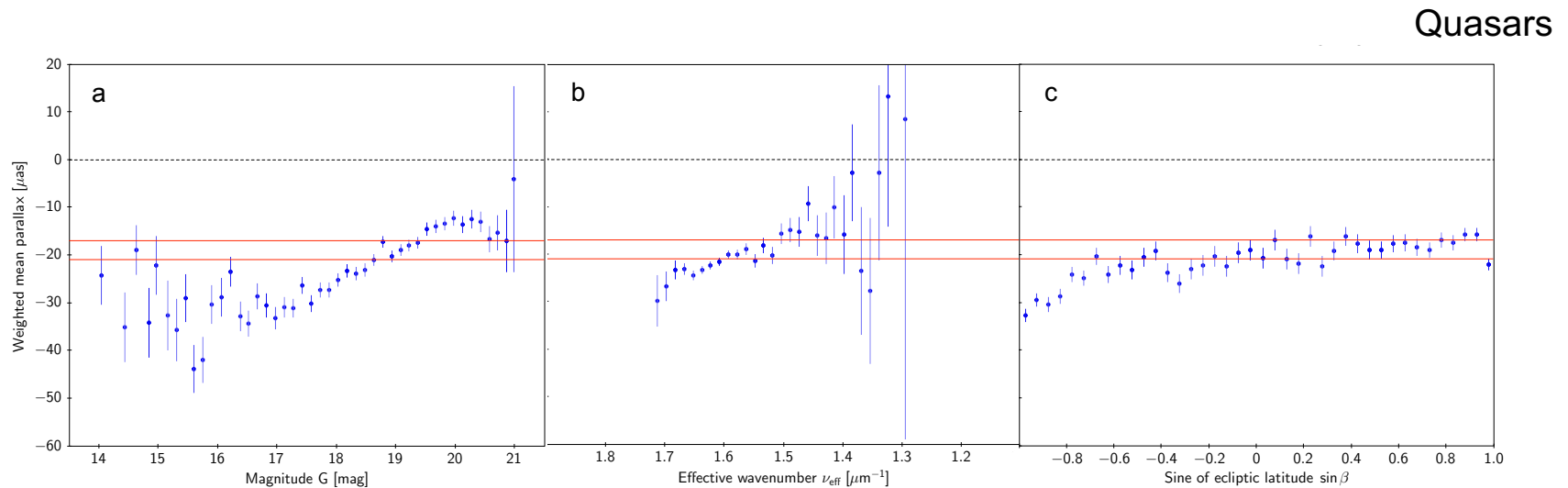
Gaia EDR3 en tus manos
3 diciembre 2020

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Parallax bias versus magnitude, colour, and position

- Gaia parallaxes are biased: $-17 \mu\text{as}$ globally ($-23 \mu\text{as}$ in DR2)
- The bias is not fixed but depends (at least) on:
 - G-magnitude
 - Colour
 - Sky position
 - Source type (5- or 6-p)
- Different traces can be used to model its behaviour:
 - Quasars
 - Large Magellanic Cloud
 - Binary stars (*physical pairs*)

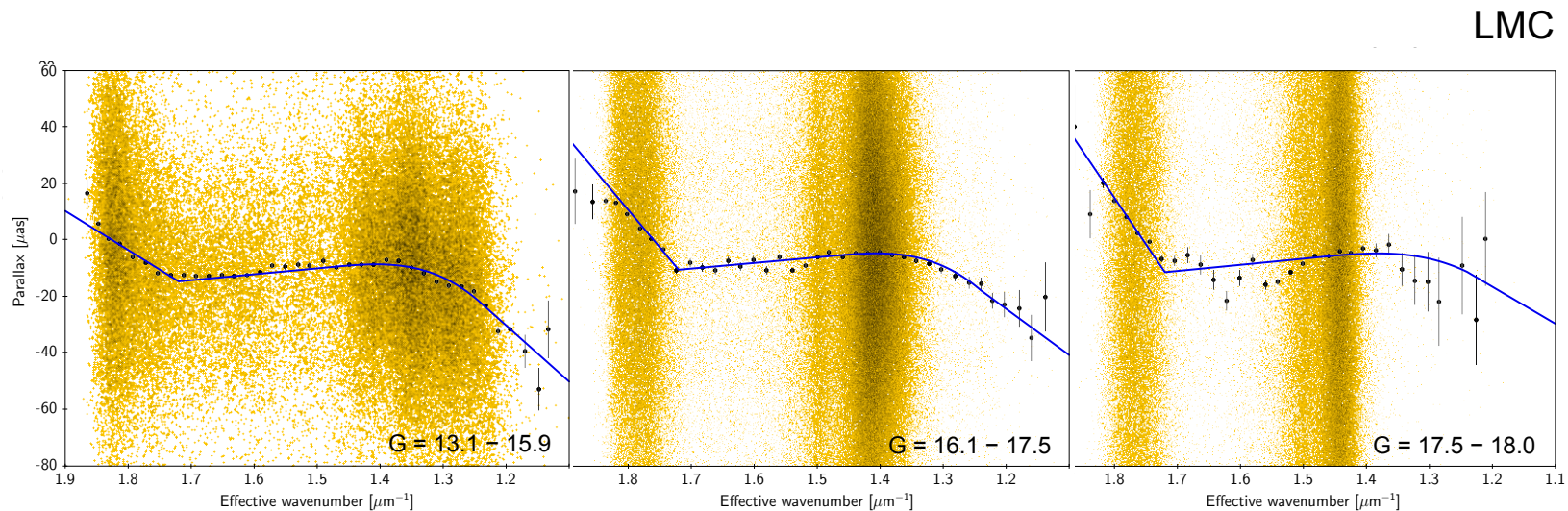


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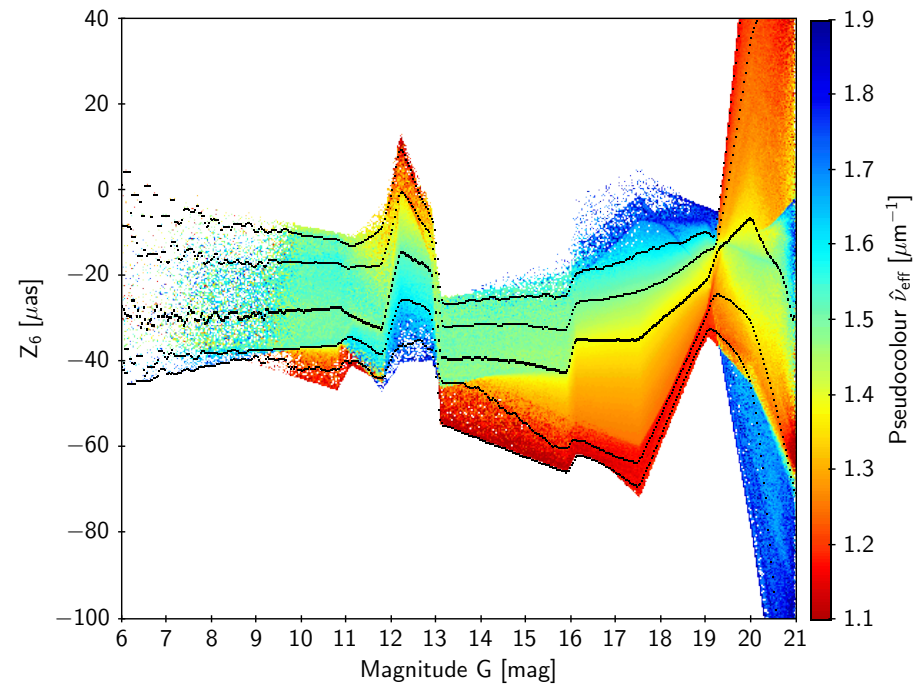
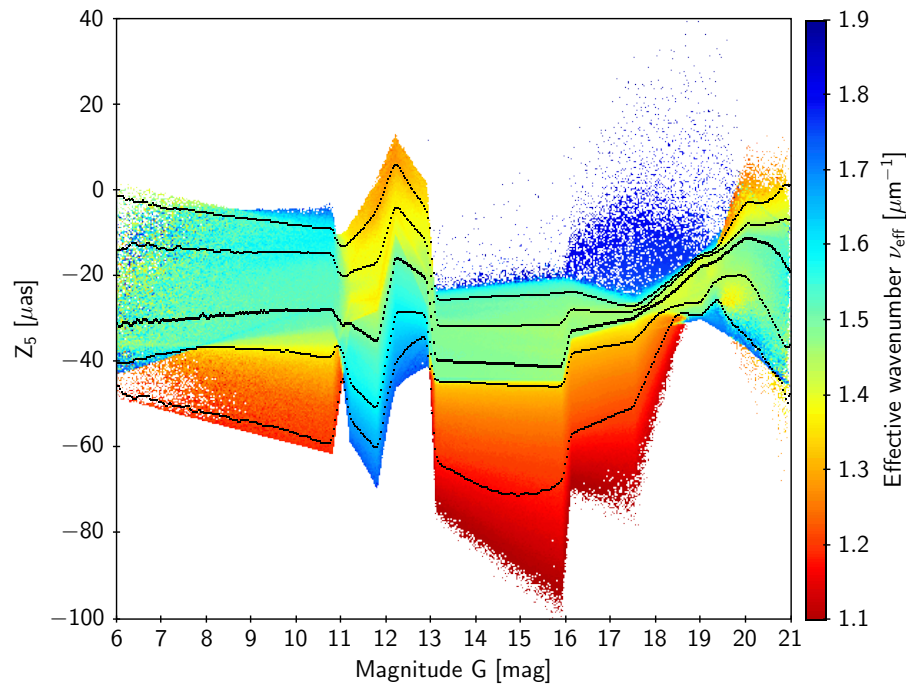
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Parallax bias versus magnitude, colour, and position

$$Z(G, \nu_{\text{eff}}, \beta) = \sum_j \sum_k q_{jk}(G) c_j(\nu_{\text{eff}}) b_k(\beta)$$

$$[\varpi^{\text{corr}} = \varpi - Z(G, \nu_{\text{eff}}, \beta)]$$



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Gaia EDR3 facilities

- Parallax zero-point functions in Python
 - Python: gitlab.com/icc-ub/public/gaiadr3_zero_point

Try out the Gaia (E)DR3 zero-point correction code

Example data was obtained with the following query

```
select * from gaiadr3.gaia_source
where phot_g_mean_mag between 17.9 and 18.1
and random_index between 700000000 and 701000000
```

This results in 21594 sources with a mix of 2-p, 5-p, and 6-p astrometric solutions.

```
In [1]: import numpy as np
        from astropy.table import Table

        from zero_point import zpt
        zpt.load_tables()
```

Read the data

```
In [2]: data = Table.read('ZPrandomG18.fits', format='fits')

        gmag = data['phot_g_mean_mag']
        nueffused = data['nu_eff_used_in_astrometry']
        psc = data['pseudocolour']
        ecl_lat = data['ecl_lat']
        soltype = data['astrometric_params_solved']
```

Blindly use the get_zpt function

Using the `get_zpt()` function blindly will fail if there are source with 2-p solutions in the input list. Thus the line of code below will lead to a runtime error.

```
In [3]: zpvals = zpt.get_zpt(gmag, nueffused, psc, ecl_lat, soltype)
```



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Gaia EDR3 facilities

- Parallax zero-point functions in Python
 - Python: gitlab.com/icc-ub/public/gaiadr3_zeropoint
- Flux corrections:
 - Python: @agabrown in GitHub (gaiaedr3-flux-excess-correction and gaiaedr3-6p-gband-correction)

```
def correct_gband(bp_rp, astrometric_params_solved, phot_g_mean_mag, phot_g_mean_flux):
    """
    Correct the G-band fluxes and magnitudes for the input list of Gaia EDR3 data.

    Parameters
    -----
    bp_rp: float, numpy.ndarray
        The (BP-RP) colour listed in the Gaia EDR3 archive.
    astrometric_params_solved: int, numpy.ndarray
        The astrometric solution type listed in the Gaia EDR3 archive.
    phot_g_mean_mag: float, numpy.ndarray
        The G-band magnitude as listed in the Gaia EDR3 archive.
    phot_g_mean_flux: float, numpy.ndarray
        The G-band flux as listed in the Gaia EDR3 archive.

    Returns
    -----
    The corrected G-band magnitudes and fluxes. The corrections are only applied to
    sources with a 6-parameter astrometric solution fainter than G=13, for which a
    (BP-RP) colour is available.

    Example
    -----
    gmag_corr, gflux_corr = correct_gband(bp_rp, astrometric_params_solved, phot_g_mean_mag, phot_g_mean_flux)
    """
```



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Gaia EDR3 facilities

- Parallax zero-point functions in Python
 - Python: gitlab.com/icc-ub/public/gaiadr3_zeropoint
- Flux corrections:
 - Python: @agabrown in GitHub (gaiaedr3-flux-excess-correction and gaiaedr3-6p-gband-correction)
 - ADQL: Appendices B and C of Gaia Collaboration, A.G.A. Brown et al. 2020

Job name:

[Query examples](#)

```

1 SELECT source_id,ra,dec,parallax,pmra,pmdec,bp_rp,
2 if_then_else(
3   bp_rp > -20,
4   to_real(case_condition(
5     phot_g_mean_mag - 2.5*log10( (1.00525 -0.02323*greatest(0.25, least(bp_rp, 3))
6     +0.01740*power(greatest(0.25, least(bp_rp, 3)),2)
7     -0.00253*power(greatest(0.25, least(bp_rp, 3)),3)) ),
8     astrometric_params_solved != 95,
9     phot_g_mean_mag,
10    phot_g_mean_mag < 13,
11    phot_g_mean_mag,
12    phot_g_mean_mag < 16,
13    phot_g_mean_mag - 2.5*log10( (1.00876 -0.02540*greatest(0.25, least(bp_rp, 3))
14    +0.01747*power(greatest(0.25, least(bp_rp, 3)),2)
15    -0.00277*power(greatest(0.25, least(bp_rp, 3)),3)) )
16  )),
17 phot_g_mean_mag
18 ) as phot_g_mean_mag_corr
19 FROM gaiadr3.gaia_source
  
```

Ctrl+Space for query autocompletion

[Reset Form](#) [Submit Query](#)



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Gaia archive

- Main table: `gaiaedr3.gaia_source`
- DR2 to EDR3 match table: `dr2_neighbourhood`
- Gaia-CRF3 tables:
 - `agn_cross_id`, `frame_rotator_source`
- Simulations, GUMS and GOG version 20:
 - `gaia_universe_model`, `gaia_source_simulation`
- Gaia pointing: `commanded_scan_law`
- Pre-computed cross-matches
 - Hipparcos, Tycho-2/Tycho Double Star Catalogue
 - SDSS DR13, Pan-Starrs1 DR1.1
 - SkyMapper DR2, URAT1
 - 2MASS, AllWise, GSC2.3, APASS DR9, RAVE DR5

EDR3 known issues:

<https://www.cosmos.esa.int/web/gaia/edr3-known-issues>

- Photometry for sources without G-fluxes



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GUMS and GOG tables

- **GUMS: Gaia Universe Model Simulation:** `gaiaedr3.gaia_universe_model`

The Universe Model developed for the simulation of the mission is a set of algorithms for computing the positions at any time, and observational properties of objects expected to be observed by the Gaia instruments.

The table contains astrometry, photometry and physical parameters of simulated sources, without error.

- **GOG: Gaia Object Simulator:** `gaiaedr3.gaia_source_simulation`

The Gaia Object Generator is a simulation tool to directly get Catalogue, Main Database (MDB) and final (in the sense of statistically equivalent to the final mission data) Gaia mission data.

The table includes the simulated result of the observation by Gaia of the GUMS sources, including the observational errors.

Both tables can be used for statistical analyses of parameters not yet published (physical parameters, spectral type, ...)



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Further information and guidance

Gaia EDR3 pages: <https://www.cosmos.esa.int/web/gaia/early-data-release-3>

Papers

- *Summary of the contents and survey properties*, Gaia Collaboration et al
- *The astrometric solution*, Lindegren et al
- *Photometric content and validation*, Riello et al
- *Parallax bias versus magnitude, colour and position*, Lindegren et al
- *The celestial reference frame (GAIA-CRF3)*, Klioner et al
- *Updated radial velocities from Gaia DR2*, Seabroke et al
- *Catalogue Validation*, Fabricius et al
- *Building the Gaia DR3 source list - Cross-match of Gaia observations*, Torra et al
- *Modelling and calibration of Gaia's point and line spread functions*, Rowell et al
- *Cross-match with external catalogues - Algorithm and results*, Marrese et al

Performance verification papers

- *The Gaia catalogue of nearby stars*, Gaia Collaboration, Smart, et al
- *Structure and properties of the Magellanic Clouds*, Gaia Collaboration, Luri, et al
- *The Galactic anticentre*, Gaia Collaboration, Antoja, et al
- *Acceleration of the solar system from Gaia astrometry*, Gaia Collaboration, Klioner, et al



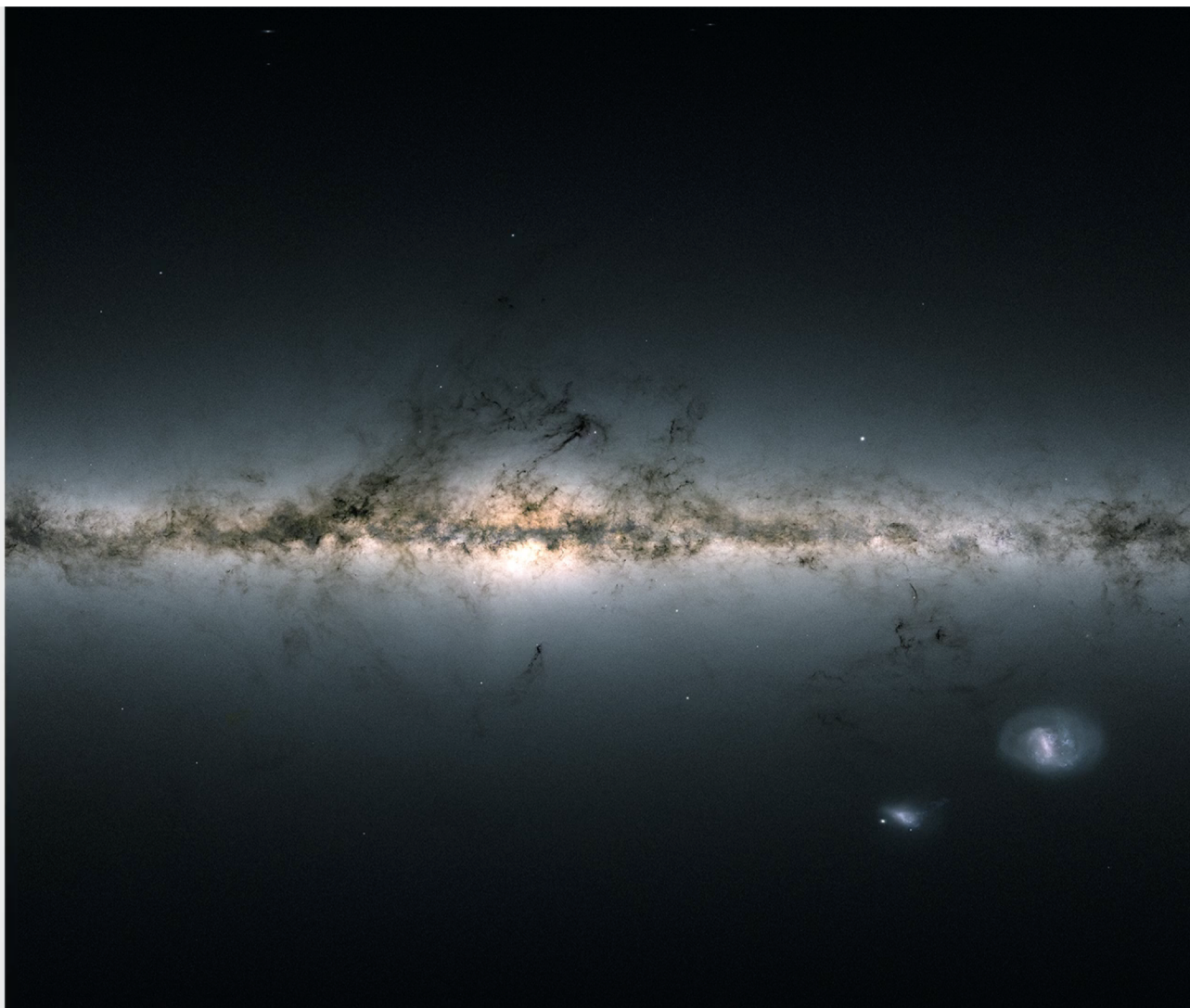
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Gaia EDR3

December 3, 2020
12:00 CET



<https://www.cosmos.esa.int/web/gaia/edr3-startrails>



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