Gaia Data Release 3

Documentation release 1.0

European Space Agency (ESA)
and
Gaia Data Processing and Analysis Consortium (DPAC)

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Executive summary

The third Gaia data release, Gaia DR3, contains the astrometry and broad-band photometry already published as part of Gaia EDR3 and introduces a large variety of new data products:

- A much expanded radial velocity survey, as well as magnitudes of sources in the $G_{\rm RVS}$ band, and a spectral line broadening parameter $v_{\rm broad}$;
- Mean BP, RP, and RVS spectra for a large subset of sources;
- A much expanded collection of variable sources, covering 24 variability types;
- Photometric time series for all variable sources;
- The Gaia Andromeda Photometric Survey which contains the photometric time series for all sources (variable and non-variable) in a 5.5° radius field around M31;
- Object classification, including a self-organised map (SOM) of poorly classified sources;
- Astrophysical parameters (APs) from mean BP/RP spectra, including Markov-Chain Monte Carlo (MCMC) samples;
- Astrophysical parameters from mean RVS spectra;
- Chemical abundances from mean RVS spectra;
- Diffuse interstellar band parameters from mean RVS spectra;
- Non-single star solutions;
- QSO and galaxy candidates, including redshifts, QSO host detections, and QSO host and galaxy light profiles;
- Solar system objects (SSO), including reflectance spectra derived from epoch BP/RP spectra;
- Total galactic extinction maps at various HEALPix levels;
- Archived photometric science alerts.

Table 1: Number of sources of a certain type, or the number of sources for which a given data product is available in Gaia DR3.

Data product or source type	Number of sources	Comments
Total	1 811 709 771	
5-parameter astrometry	585 416 709	
6-parameter astrometry	882 328 109	
2-parameter astrometry	343 964 953	
Gaia-CRF3 sources	1 614 173	
ICRF3 sources used for frame orientation	2007	
Gaia-CRF3 sources used for frame spin	428 034	
G-band, mean magnitude	1 806 254 432	
$G_{\rm BP}$-band, mean magnitude	1 542 033 472	
$G_{\rm RP}$-band, mean magnitude	1 554 997 939	
Photometric time series	11 754 237	
Gaia Andromeda Photometric Survey	1 257 319	Photometric time series for all sources in a 5.5° radius field around M31
Mean radial velocity	33 812 183	$G_{\rm RVS} < 14$, $3100 < T_{\rm eff} < 14\,500$ K
$G_{\rm RVS}$-band, mean magnitude	32 232 187	
$v_{\rm broad}$	3 524 677	spectral line broadening parameter
Radial velocity time series	1898	Sample of Cepheids and RR Lyrae
BP/RP mean spectra	219 197 643	$G < 17.65$ with small number of exceptions
RVS mean spectra	999 645	AFGK spectral types with SNR > 20, and sample of lower SNR spectra
Variable sources	10 509 536	See Table 2
Object classification	1 590 760 469	
Self-organised map of poorly classified sources	1	30×30 map and prototype spectra
APs from mean BP/RP spectra	470 759 263	$G < 19$, see Table 2
APs from mean RVS spectra	5 591 594	
Chemical abundances from mean RVS spectra	2 513 593	Up to 12 elements
DIBs from mean RVS spectra	472 584	
Non-single stars	813 687	astrometric, spectroscopic, eclipsing, orbits, trends, see Table 2
QSO candidates	6 649 162	High completeness, low purity
QSO redshifts	6 375 063	
QSO host galaxy detected	64 498	
QSO host galaxy light profile	15 867	
Galaxy candidates	4 842 342	High completeness, low purity
Galaxy redshifts	1 367 153	
Galaxy light profiles	914 837	
Solar system objects (SSOs)	158 152	Epoch astrometry and photometry
SSO BP/RP reflectance spectra	60 518	
Total galactic extinction maps	5	HEALPix levels 6–9, and optimum HEALPix level
Photometric science alerts	2612	Triggered in the period 25-07-2014 to 28-05-2017

Table 2: Further details on the number of sources of a certain type, or the number of sources for which a given data product is available in Gaia DR3.

Data product or source type	Number of sources	Comments
Variable sources		
Total	10 509 536	
Classified with supervised machine learning	9 976 881	24 variability types or type groups
Active galactic nuclei	872 228	
Cepheids	15 021	
Compact companions	6 306	
Eclipsing binaries	2 184 477	
Long-period variables	1 720 588	
Microlensing events	363	
Planetary transits	214	
RR Lyrae stars	271 779	
Short-timescale variables	471 679	
Solar-like rotational modulation variables	474 026	
Upper-main-sequence oscillators	54 476	
Astrophysical parameters from mean BP/RP spectra		
Total	470 759 263	$G < 19$
Spectroscopic parameters	470 759 263	
Interstellar extinction and distances	470 759 263	
MCMC samples from the BP/RP AP estimation	449 297 716	
APs assuming an unresolved binary	348 711 151	
MCMC samples from BP/RP unresolved binary AP estimation	348 711 151	
Evolutionary parameters	128 611 111	mass, age, evolutionary stage
Stars with emission-line classifications	57 511	
Sources with spectral types	217 982 837	
Hot stars with spectroscopic parameters	2 382 015	
Ultra-cool stars	94 158	
Cool stars with activity index	1 349 499	
Sources with Hα emission measurements	235 384 119	
Non-single stars		
Total	813 687	
Acceleration solutions	338 215	
Orbital astrometric solutions	169 227	including astroSpectroSB1 combined solutions
Orbital spectroscopic solutions (SB1/SB2)	220 372	including astroSpectroSB1 combined solutions
Trend spectroscopic solutions	56 808	
Eclipsing binaries	87 073	including eclipsingSpectro combined solutions

The archive contents are summarized in Table 1 and Table 2, while Table 3 provides a list of all tables available in the Gaia DR3 archive.

The astrometric data in Gaia DR3 are the same as those of Gaia EDR3, hence there is a global parallax bias, in the sense Gaia − 'true', of about −0.017 mas, which has not been 'corrected' in the data. Details are provided by

(Lindegren et al. 2020), including a proposed recipe for correcting the parallaxes for the bias as a function of sky position, G magnitude and colour $G_{\rm BP}-G_{\rm RP}$. The broad-band photometric contents (G, $G_{\rm BP}$, $G_{\rm RP}$) are also the same as in Gaia EDR3 with the following exception. For Gaia EDR3 a milli-magnitude level correction was applied to the G-band photometry for sources with 6-parameter and 2-parameter astrometric solutions. This correction was provided in the form of Python code and Astronomical Data Query Language (ADQL) recipes. *These corrections are included in Gaia DR3 and should thus not be applied when working with broad-band photometry extracted from the Gaia DR3 data tables in the Gaia archive.*

The data collected between 25 July 2014 and 28 May 2017 – during the first 34 months of the Gaia mission – have been processed by the Gaia Data Processing and Analysis Consortium (DPAC), resulting in Gaia DR3. A summary of the release properties is provided in Gaia Collaboration et al. (2022k). The overall scientific validation of the data is described in Babusiaux et al. (2022) and Fabricius et al. (2021) (astrometry, broad-band photometry). Background information on the Gaia mission and the spacecraft can be found in Gaia Collaboration et al. (2016b), with a more detailed presentation of the Radial Velocity Spectrometer (RVS) in Cropper et al. (2018). In addition, Gaia DR3 is accompanied by dedicated papers, all part of a Special Issue of A&A, that describe the processing and validation of the various data products: Lindegren et al. (2021) for the Gaia DR3 astrometry, Riello et al. (2021) for the Gaia DR3 photometry, and Gaia Collaboration et al. (2022g) for the Gaia celestial reference frame.

The processing of the BP/RP spectra for Gaia DR3 is described in De Angeli et al. (2022), with details on the internal calibration model provided in Carrasco et al. (2021). The external flux calibration is described in Montegriffo et al. (2022) and is based on a set of spectro-photometric calibrators described in Pancino et al. (2021) and references therein. The processing of the RVS spectra and the various data products derived from these spectra is described in Katz et al. (2022) (radial velocity processing and validation), Blomme et al. (2022) (radial velocities of hot stars), Damerdji et al. (2022) (double-lined spectra), Frémat et al. (2022) (determination of $v_{\rm broad}$), Sartoretti et al. (2022) ($G_{\rm RVS}$ magnitudes and the RVS pass-band), and Seabroke & et al. (2022) (mean RVS spectra).

The Gaia Andromeda Photometric Survey consists of broad-band photometric time series for all sources (variable and non-variable) located in a 5.5° radius region centred on M31. This survey is described in Evans et al. (2022) and is based on the photometry presented in Riello et al. (2021).

An overview of the variable source processing and analysis can be found in Eyer et al. (2022). Specific aspects of the variable source processing are described in: Gavras et al. (2022) (cross-match of Gaia DR3 sources with variable sources from the literature); Rimoldini et al. (2022) (machine learning classification of variable sources); Clementini et al. (2022) and Ripepi et al. (2022) (Cepheids and RR Lyrae stars, including radial velocity time series); Lebzelter et al. (2022) (long period variables); Distefano et al. (2022) (solar-like variability and rotational modulation); Marton (2022) (young stellar objects); Wyrzykowski et al. (2022) (microlensing events); Mowlavi et al. (2022) (eclipsing binaries); Gomel et al. (2022) (ellipsoidal variables with possible compact object secondaries); Panahi et al. (2022) (candidate transiting exoplanets); and Carnerero et al. (2022) (active galactic nuclei).

Non-single star solutions are provided for the first time in Gaia DR3, including astrometric (Halbwachs et al. 2022), spectroscopic (Gosset 2022), and eclipsing binaries (Siopis 2022) (where solutions from the combinations of astrometry and radial velocities, or eclipsing binary light curves and radial velocities are also provided). Details on the astrometric determination for systems with sub-stellar companions are provided in Holl et al. (2022b). Relevant to both non-single stars and variable sources, Holl et al. (2022a) discuss how the Gaia scanning law can introduce spurious periods in the analysis of photometric, astrometric, or radial velocity time series.

The extragalactic content of Gaia DR3 is described in Gaia Collaboration et al. (2022b). The process of estimating light profiles of extended objects (resolved galaxies and QSO host galaxies) is detailed in Ducourant et al. (2022), and Delchambre et al. (2022) describe the classification of QSOs and unresolved galaxies and how redshifts are derived for these objects.

The processing and validation of the solar system objects in Gaia DR3 is described in Tanga et al. (2022) (astrom-

etry, photometry, orbits) and in Gaia Collaboration et al. (2022f) (BP/RP reflectance spectra).

Gaia DR3 presents a classification of the majority of sources in the Gaia source list and a large collection of astrophysical data. This data is derived from the combination of basic Gaia observational data, the parallaxes, BP/RP and RVS spectra, and the broad-band photometry. An overview of the processing modules that classify sources and derive astrophysical parameters is provided in Creevey et al. (2022). Fouesneau et al. (2022b) and Delchambre et al. (2022) provide more details on the quality and validation of the stellar and non-stellar parameters, respectively. The latter include total galactic extinction maps and an analysis of outliers in the space of BP/RP spectra in addition to the extragalactic content mentioned above. Details on the extraction of the main astrophysical parameters from the BP/RP spectra is given in Andrae et al. (2022). From the RVS spectra stellar atmospheric parameters and detailed abundances are derived, as well as the parameters of the diffuse interstellar bands present in these spectra. The details are provided by Recio-Blanco & et al. (2022). From the Calcium infrared triplet in the RVS spectra one can also derive a chromospheric activity index. This process is described in Lanzafame et al. (2022).

Nine papers accompanying Gaia DR3 provide an impression on the immense scientific potential of this release. Gaia Collaboration et al. (2022c) presents clean samples of high quality astrophysical parameters of several specific types of stars. Gaia Collaboration et al. (2022i) uses Gaia astrometry, radial velocities and element abundances derived from RVS mean spectra to conduct a chemo-dynamical analysis of Milky Way disc and halo populations. Gaia Collaboration et al. (2022j) discusses the distribution of the diffuse interstellar band at 862 nm in the context of interstellar extinction within a few kpc from the Sun. Gaia Collaboration et al. (2022e) explores non-axisymmetric features in the disc of the Milky Way, spiral arms and the bar, in both configuration and velocity space. Gaia Collaboration et al. (2022a) presents a clean catalogue of binary stars, discussing its completeness and some statistical features of the orbital elements in comparison with external catalogues. In addition, a catalogue of tens of thousands of masses of binary components is provided. Gaia Collaboration et al. (2022f) presents reflectance spectra, derived from BP/RP spectra, for solar system objects, discussing the scientific potential of the combination of accurate orbital data and composition information derived from the reflectance spectra. Gaia Collaboration et al. (2022h) shows how synthetic photometry can be obtained from flux calibrated BP/RP spectra for any pass-bands fully enclosed in the Gaia wavelength range. Applications employing synthetic photometry for a number of well known photometric systems are discussed. Gaia Collaboration et al. (2022d) investigates the properties of high-mass main sequence pulsators, showing that Gaia DR3 data are suitable for the identification of nearby OBAF-type pulsators. Finally, Gaia Collaboration et al. (2022b) summarises the Gaia processing of extragalactic sources, describing the statistical properties of two high purity samples of galaxies and QSOs available in Gaia DR3. For several of the above papers there are accompanying data that are also included in Gaia DR3: a subset of the samples defined in Gaia Collaboration et al. (2022c) (archive tables `gaiadr3.gold_sample_*`), the synthetic photometry from Gaia Collaboration et al. (2022h) (archive table `gaiadr3.synthetic_photometry_gspc`), binary component masses from Gaia Collaboration et al. (2022a) (archive table `gaiadr3.binary_masses`), as well as solar system object osculating orbital elements from Tanga et al. (2022) (archive table `gaiadr3.sso_orbits`).

Data from Gaia DR3, as well as from Gaia DR1, Gaia DR2, and Gaia EDR3, can be retrieved from the Gaia ESA Archive (GEA), which is accessible from `https://archives.esac.esa.int/gaia`. The archive also provides various tutorials on data access and data queries plus an integrated data model (i.e., description of the various fields in the data tables). In addition, Luri et al. (2018) provide concrete advice on how to deal with Gaia astrometry, with recommendations on how best to estimate distances from parallaxes. The Gaia archive features a visualisation service which can be used for quick initial explorations of the entire Gaia DR3 data set. Carefully validated, pre-computed cross matches between Gaia DR3 and a selected set of large surveys is provided, with details described in Marrese et al. (2019, 2022). Finally, Gaia DR3 contains the (intended) pointing of the Gaia telescopes as a function of time (`commanded_scan_law` table) and simulated Gaia catalogues (`gaia_universe_model` and `gaia_source_simulation` tables).

Gaia DR3 includes large amounts of data which are not easily stored in standard tabular form. This concerns the mean BP/RP/RVS spectra, photometric time series, and Markov-Chain Monte Carlo samples. Instead, these

products are hosted by a dedicated service designed to handle massive data requests that is accessible via the DataLink protocol. How to discover and access the DataLink products in Gaia DR3 is described here.

Through the Gaia DR3 web pages several supplementary sets of information will be provided:

- Auxiliary data
- Software tools to facilitate the use of Gaia DR3.
- Any issues with the Gaia DR3 contents arising after the publication of the release will be listed on the "known issues" pages.

Summary of miscellaneous links:

- Gaia archive (data access);
- Gaia DR3 Datamodel description (table and field descriptions);
- Gaia mission home page (news, images, publications, outreach material, etc.);
- Gaia tools;
- Gaia DR3 data processing and science verification papers;
- Gaia helpdesk;
- Gaia FAQs;
- Gaia DR3 credit and citation instructions;
- Online version of Gaia DR3 documentation;
- Pdf version of Gaia DR3 documentation;
- Gaia acronym list;
- Gaia on Twitter and Gaia on Facebook.

Table 3: Summary of all the tables available in the Gaia DR3 archive. For an extensive description of these tables and their contents see Chapter 20.

Table name	Short description
Main source catalogue	
gaia_source	
Astrophysical parameter tables	
astrophysical_parameters	main table with astrophysical parameters
astrophysical_parameters_supp	additional astrophysical parameters
total_galactic_extinction_map	extinction map at 4 HEALPix levels
total_galactic_extinction_map_opt	extinction map at optimum resolution
oa_neuron_information	content of the self-organized map of poorly classified sources
oa_neuron_xp_spectra	prototype BP/RP spectra for neuron of the above SOM
mcmc_samples_gsp_phot	MCMC samples from BP/RP AP estimation
mcmc_samples_msc	MCMC samples from BP/RP unresolved binary AP estimation
Auxiliary tables	
commanded_scan_law	commanded attitude of the Gaia spacecraft
Cross-matches	
dr2_neighbourhood	Gaia DR2 to Gaia DR3 match table
allwise_best_neighbour	AllWISE: best neighbour for each matched Gaia source
allwise_neighbourhood	AllWISE: all good neighbours for each matched Gaia source
apassdr9_best_neighbour	APASS DR9
apassdr9_join	Convenience table for joining APASS DR9 with cross-match results
apassdr9_neighbourhood	
gsc23_best_neighbour	GSC2.3
gsc23_join	
gsc23_neighbourhood	
hipparcos2_best_neighbour	Hipparcos2
hipparcos2_neighbourhood	
panstarrs1_best_neighbour	Pan-STARRS DR1
panstarrs1_join	
panstarrs1_neighbourhood	
ravedr5_best_neighbour	RAVE DR5
ravedr5_join	
ravedr5_neighbourhood	
ravedr6_best_neighbour	RAVE DR6
ravedr6_join	
ravedr6_neighbourhood	
sdssdr13_best_neighbour	SDSS DR13
sdssdr13_join	
sdssdr13_neighbourhood	
skymapperdr2_best_neighbour	SkyMapper DR2
skymapperdr2_join	
skymapperdr2_neighbourhood	
tmass_psc_xsc_best_neighbour	2MASS
tmass_psc_xsc_join	
tmass_psc_xsc_neighbourhood	
tycho2tdsc_merge_best_neighbour	Tycho-2 merged with TDSC
tycho2tdsc_merge_neighbourhood	

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Table 3 – continued from previous page

Table name	Short description
urat1_best_neighbour	URAT-1
urat1_neighbourhood	
	Extra–galactic tables
galaxy_candidates	classification/characterisation parameters of galaxy candidates
galaxy_catalogue_name	catalogues used to select galaxies for morphological parameterization
qso_candidates	classification/characterisation parameters of QSO candidates
qso_catalogue_name	catalogues used to select QSOs for morphological parameterization
	Non-single stars tables
nss_two_body_orbit	non-single-star orbital models
nss_acceleration_astro	non-single-star astrometric models for sources with non-linear proper motions
nss_non_linear_spectro	non-single-star orbital models for spectroscopic binaries
nss_vim_fl	non-single-star models for Variability Induced Mover solutions
	Epoch photometry
epoch_photometry	light curves in G, $G_{\rm BP}$, and $G_{\rm RP}$
	Reference frame
gaia_crf3_xm	cross-match information for the Gaia-CRF3 sources
agn_cross_id	sources whose positions and proper motions define Gaia-CRF3
frame_rotator_source	sources used to compute the Gaia-CRF3
	Science alerts tables
science_alerts	Photometric Science Alerts from 25-07-2014 to 28-05-2017
alerts_mixedin_sourceids	identifier for sources linked to transits from primary and other sources
	Simulation tables
gaia_source_simulation	outputs from the Gaia Object Generator
gaia_universe_model	simulated galactic stars from the Gaia Universal Model Simulation
	Solar system object tables
sso_source	data related to Solar System objects observed by Gaia
sso_observation	Solar System object observations
sso_reflectance_spectrum	mean BP/RP reflectance spectra of asteroids
	Spectroscopic tables
rvs_mean_spectrum	RVS mean sampled spectra
xp_summary	auxiliary information about the mean BP/RP spectra
xp_continuous_mean_spectrum	mean BP/RP spectra in continuous basis function representation
xp_sampled_mean_spectrum	BP/RP externally calibrated sampled mean spectrum
	Variability tables
vari_summary	source_id to vari* table link; statistical parameters of time series
vari_classifier_result	variability classification results of all variable source classifiers

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Table 3 – continued from previous page

Table name	Short description
vari_classifier_definition	descriptions of classifiers used in table vari_classifier_result
vari_classifier_class_definition	descriptions of published classes for each classifier
vari_agn	information on AGN properties
vari_cepheid	information on Cepheid stars
vari_compact_companion	information on compact companion candidates
vari_eclipsing_binary	properties of eclipsing binaries resulting from the variability analysis
vari_epoch_radial_velocity	epoch radial velocity data points for a sub-set of variable stars
vari_rad_vel_statistics	statistical parameters of radial velocity time series
vari_long_period_variable	information on Long Period Variable stars
vari_microlensing	information on microlensing events
vari_ms_oscillator	information on main-sequence oscillators
vari_planetary_transit	candidate planetary transit events
vari_rotation_modulation	information on solar-like stars with rotational modulation
vari_rrlyrae	information on RR Lyrae stars
vari_short_timescale	information on short-timescale variable sources
Performance verification	
binary_masses	binary component masses
gold_sample_carbon_stars	information on carbon stars golden sample
gold_sample_fgkm_stars	information on FGKM stars golden sample
gold_sample_oba_stars	information on OBA young disk stars golden sample
gold_sample_solar_analogues	information on solar analogues golden sample
gold_sample_spss	information on spectrophotometric standard stars golden sample
gold_sample_ucd	information on ultra-cool dwarfs golden sample
synthetic_photometry_gspc	synthetic photometry based in BP/RP spectra
sso_orbits	solar system object osculating orbital elements