

## VStar Retrieval of Gaia Variable Star Light Curve Data

This plugin allows you to read light curve data for any of the Gaia DR2/DR3 stars that were identified by Gaia processing as variable and therefore have photometry available. Data are accessed directly from the Gaia web service. The passbands can either be the Gaia red (RP), green (G) and blue (BP) or they can be transformed to V, Rc, Ic.

### Gaia Mission

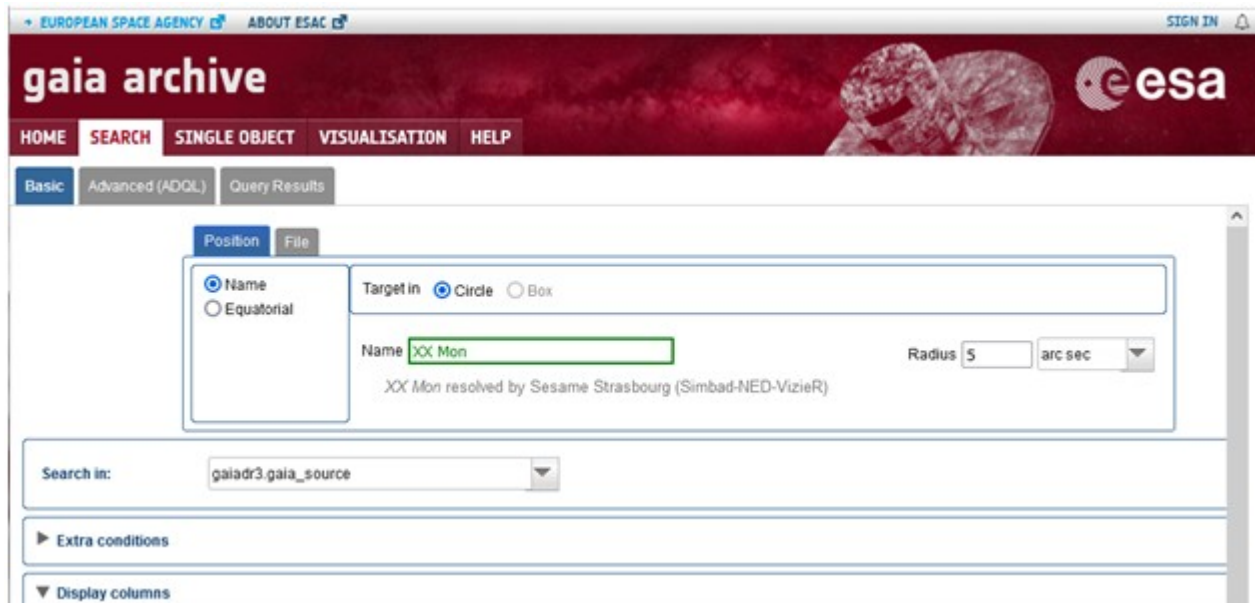
Gaia is a spacecraft launched by the European Space Agency (ESA) to measure the positions and distances to stars. The Gaia coverage includes the entire sky from magnitude 5 to 20. In 2022 the project has made its third data release, known as [Gaia Data Release 3](#) (DR3).

Gaia captures photometry in three passbands, shown graphically [here](#), and described in detail in the paper [Gaia Data Release 2 Photometric content and validation](#). As part of the processing pipeline, Gaia identifies sources that appear to be variable using a set of machine learning algorithms. Currently (on Apr 2th 2023) the “Gaia Data Release 3 (Gaia DR3) Part 4 Variability” [catalog](#) contains 11754237 sources (records).

### Obtaining Gaia source\_id

Each Gaia star is identified by a unique key, the **source\_id**. The [Gaia archive](#) is available for interactive and programmatic access with a well-documented set of interfaces. The Help link provides access to a number of tutorials. Only the simple query interface will be discussed here.

Consider the classical Cepheid, XX Mon. From the Gaia archive page, click Search to go to the basic query screen and enter XX Mon in the name field.



Then open the Display columns section and select the **phot\_variable\_flag** column. This will allow you to determine if Gaia has identified this star as variable and therefore has light curve data available.

▼ Display columns

☐ solution\_id
☒ ra
☐ parallax\_error
☒ pmdec
☐ ra\_pmdec\_corr
☐ parallax\_pmdec\_corr
☐ astrometric\_n\_bad\_obs\_al
☐ astrometric\_params\_solved
☐ ra\_pseudocolour\_corr
☐ astrometric\_matched\_transits
☐ matched\_transits\_removed
☒ ruwe
☐ scan\_direction\_mean\_k1
☐ phot\_g\_n\_obs
☐ phot\_bp\_n\_obs
☐ phot\_rp\_n\_obs
☐ phot\_bp\_rp\_excess\_factor
☐ phot\_proc\_mode
☐ radial\_velocity\_error
☐ rv\_expected\_sig\_to\_noise
☐ rv\_template\_teff
☐ vbroad\_error
☐ rvs\_spec\_sig\_to\_noise
☐ ecl\_lat
☒ has\_xp\_sampled

☐ designation
☐ ra\_error
☐ parallax\_over\_error
☐ pmdec\_error
☐ dec\_parallax\_corr
☐ pmra\_pmdec\_corr
☐ astrometric\_gof\_al
☐ astrometric\_primary\_flag
☐ dec\_pseudocolour\_corr
☐ visibility\_periods\_used
☐ ipd\_gof\_harmonic\_amplitude
☐ scan\_direction\_strength\_k1
☐ scan\_direction\_mean\_k2
☐ phot\_g\_mean\_flux
☐ phot\_bp\_mean\_flux
☐ phot\_rp\_mean\_flux
☐ phot\_bp\_n\_contaminated\_transits
☒ bp\_rp
☐ rv\_method\_used
☐ rv\_renormalised\_gof
☐ rv\_template\_logg
☐ vbroad\_nb\_transits
☒ phot\_variable\_flag
☐ in\_qso\_candidates
☒ has\_rvs

☒ source\_id
☒ dec
☐ pm
☐ ra\_dec\_corr
☐ dec\_pmra\_corr
☐ astrometric\_n\_obs\_al
☐ astrometric\_chi2\_al
☐ nu\_eff\_used\_in\_astrometry
☐ parallax\_pseudocolour\_corr
☐ astrometric\_sigma5d\_max
☐ ipd\_gof\_harmonic\_phase
☐ scan\_direction\_strength\_k2
☐ scan\_direction\_mean\_k3
☐ phot\_g\_mean\_flux\_error
☐ phot\_bp\_mean\_flux\_error
☐ phot\_rp\_mean\_flux\_error
☐ phot\_bp\_n\_blended\_transits
☐ bp\_g
☐ rv\_nb\_transits
☐ rv\_chisq\_pvalue
☐ rv\_template\_fe\_h
☐ grvs\_mag
☐ i
☐ in\_galaxy\_candidates
☒ has\_epoch\_photometry

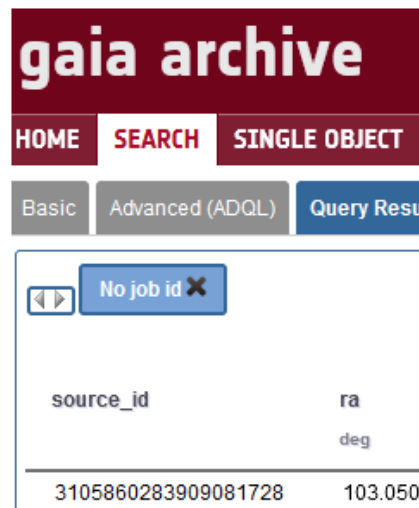
☐ random\_index
☐ dec\_error
☒ pmra
☐ ra\_parallax\_corr
☐ dec\_pmdec\_corr
☐ astrometric\_n\_obs\_ac
☐ astrometric\_excess\_noise
☐ pseudocolour
☐ pmra\_pseudocolour\_corr
☐ matched\_transits
☐ ipd\_frac\_multi\_peak
☐ scan\_direction\_strength\_k3
☐ scan\_direction\_mean\_k4
☐ phot\_g\_mean\_flux\_over\_error
☐ phot\_bp\_mean\_flux\_over\_error
☐ phot\_rp\_mean\_flux\_over\_error
☐ phot\_rp\_n\_contaminated\_transits
☐ g\_rp
☐ rv\_nb\_deblended\_transits
☐ rv\_time\_duration
☐ rv\_atm\_param\_origin
☐ grvs\_mag\_error
☐ b
☒ non\_single\_star
☒ has\_epoch\_rv

☐ ref\_epoch
☒ parallax
☐ pmra\_error
☐ ra\_pmra\_corr
☐ parallax\_pmra\_corr
☐ astrometric\_n\_good\_obs\_al
☐ astrometric\_excess\_noise\_sig
☐ pseudocolour\_error
☐ pmdec\_pseudocolour\_corr
☐ new\_matched\_transits
☐ ipd\_frac\_odd\_win
☐ scan\_direction\_strength\_k4
☐ duplicated\_source
☒ phot\_g\_mean\_mag
☐ phot\_bp\_mean\_mag
☐ phot\_rp\_mean\_mag
☐ phot\_rp\_n\_blended\_transits
☒ radial\_velocity
☐ rv\_visibility\_periods\_used
☐ rv\_amplitude\_robust
☐ vbroad
☐ grvs\_mag\_nb\_transits
☐ ecl\_lon
☒ has\_xp\_continuous
☒ has\_mcmc\_gspphot

Submit the query and you will see the row of data from the main Gaia table. Make sure the **phot\_variable\_flag** says “VARIABLE”.

Basic Advanced (ADQL) Query Results												
1/2	No job											
source_id	ra	dec	parallax	pmra	pmdec	ruwe	phot_g_mean_mag	bp_rp	radial_velocity	phot_variable_flag	non_single_star	has_xp_continuous
	deg	deg	mas	mas yr <sup>-1</sup>	mas yr <sup>-1</sup>		mag	mag	km s <sup>-1</sup>			
3105860283909081728	103.0507050071039	-2.8066596245041555	0.2205189026288878	-0.6824064349399178	-0.10901203724307632	0.855873	11.504902	1.6136398	63.539997	VARIABLE	0	true

Make note the **source\_id** or copy it to the clipboard.



The image shows the Gaia archive search results page. At the top, there is a red header with the text "gaia archive". Below the header, there are three tabs: "HOME", "SEARCH", and "SINGLE OBJECT". Under the "SEARCH" tab, there are three sub-tabs: "Basic", "Advanced (ADQL)", and "Query Results". The "Query Results" sub-tab is selected. Below the sub-tabs, there is a blue button with the text "No job id" and a red 'X' icon. Below the button, there is a table with two columns: "source\_id" and "ra". The "ra" column has a unit "deg" below it. The table has one row with the values "3105860283909081728" and "103.050".

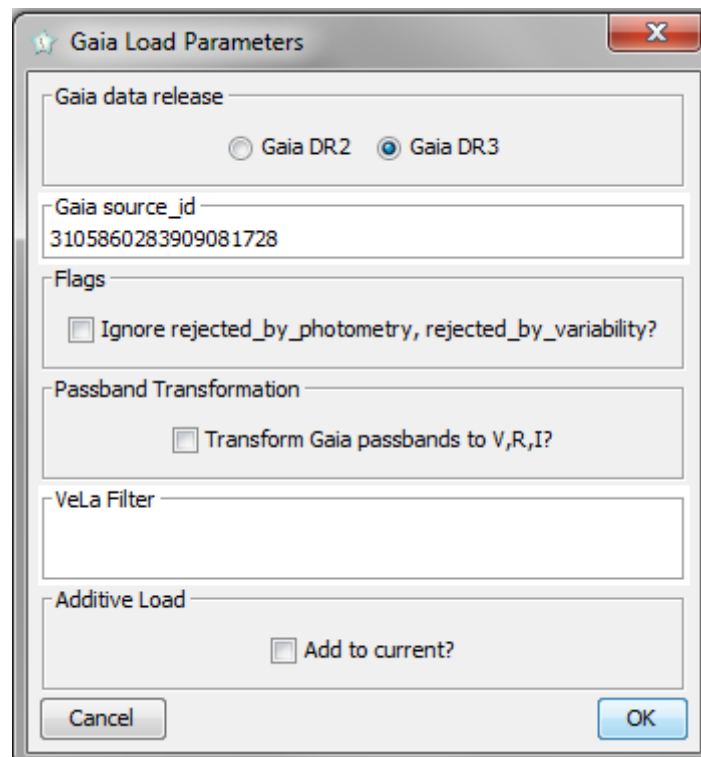
source_id	ra deg
3105860283909081728	103.050

A more advanced approach might do a proximity search using equatorial coordinates and specifying the variable flag equal to "VARIABLE" in the Extra Conditions section.

### Using the Gaia Plugin

The Gaia plugin is installed like any other as described [here](#).

Select "New star from Gaia DR2/DR3 Photometry" on the VStar file menu to open the dialog box.



The image shows the "Gaia Load Parameters" dialog box. It has a title bar with a star icon and the text "Gaia Load Parameters". The dialog box contains several sections with checkboxes and radio buttons. The "Gaia data release" section has two radio buttons: "Gaia DR2" and "Gaia DR3", with "Gaia DR3" selected. The "Gaia source\_id" section has a text box containing "3105860283909081728". The "Flags" section has a checkbox labeled "Ignore rejected\_by\_photometry, rejected\_by\_variability?". The "Passband Transformation" section has a checkbox labeled "Transform Gaia passbands to V,R,I?". The "VeLa Filter" section has a text box. The "Additive Load" section has a checkbox labeled "Add to current?". At the bottom, there are "Cancel" and "OK" buttons.

**Gaia Load Parameters**

Gaia data release

☐ Gaia DR2 ☒ Gaia DR3

Gaia source\_id

3105860283909081728

Flags

☐ Ignore rejected\_by\_photometry, rejected\_by\_variability?

Passband Transformation

☐ Transform Gaia passbands to V,R,I?

VeLa Filter

Additive Load

☐ Add to current?

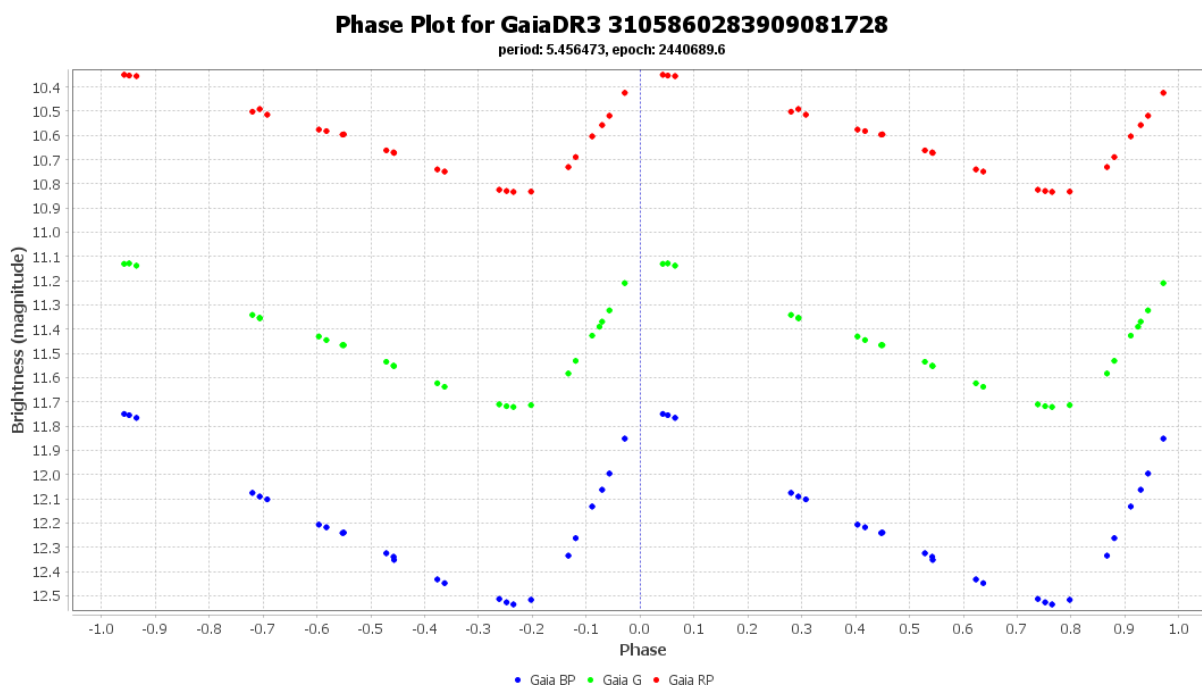
Cancel OK

Enter the **source\_id** you obtained from the Gaia Archive. By default, the Gaia passbands will be represented in VStar as Blue, Green and Red for Gaia's BP, G and RP, respectively. If you would rather have the passbands transformed to V, Rc and Ic check the Passband Transformation box. The transformation equations used are given in [Gaia Data Release 2 Photometric content and validation](#), Appendix A. You can also choose to add the light curve data to the existing VStar observations by checking the Additive Load box.

In order to transform the Gaia passbands, three observations in the Gaia passbands closely spaced in time must exist. Therefore, if transformation is selected, Gaia observations that do not occur in triples will be considered invalid and appear at the bottom of the VStar Observations tab. The Gaia variability processing may have marked some observations in the light curve as rejected for processing with the variability machine algorithms. These will be marked as Discrepant in VStar and appear with a gray color. If transformation is selected and any one of the three observations involved in the transformation are discrepant, then all three of the resulting V, R and I observations will be marked discrepant.

The observation time from Gaia is Barycentric Julian Date (BJD).

The phase diagram with Gaia DR3 data for the XX Mon is shown below:



## Advanced Gaia Queries

You will likely want to perform more advanced queries against the Gaia DR3. The Advanced (ADQL) tab of the Gaia Archive provides access not only to the main Gaia table, but the tables created by the variability processing as well.

The screenshot shows the Gaia Archive website's Advanced (ADQL) query interface. At the top, there's a header with the European Space Agency (ESA) logo and navigation links like HOME, SEARCH, SINGLE OBJECT, VISUALISATION, and HELP. Below this, a sidebar on the left lists various data categories under 'Gaia Data Release 3', including 'Other', 'Gaia Data Release 1', 'Gaia Data Release 2', 'Gaia Data Release 3', 'Astrophysical parameters', 'Auxiliary', 'Cross match', 'Extra-galactic', 'Non-single stars', 'Performance verification', 'Reference frame', 'Science alerts', 'Simulation', 'Solar system', 'Spectroscopy', and 'Variability'. The main area features a search bar with 'gaia' entered, a 'Job name' field, and a 'Query examples' link. Below the search bar, there's a 'Reset Form' button and a 'Submit Query' button. A message 'No results found' is displayed above a table with columns: Status, Job, Creation date, Num. rows, and Size. At the bottom, there's a 'Download format' dropdown set to 'VOTable', and buttons for 'Apply jobs filter', 'Filter this session', 'Select all jobs', and 'Delete selected jobs'. A footer link for '[Cookie policy] (v3.2.1)' is visible.

gaia

Job name:

Query examples

Ctrl+Space for query autocompletion

Reset Form Submit Query

No results found

Status	Job	Creation date	Num. rows	Size
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Download format: VOTable

Apply jobs filter Filter this session ☒ Select all jobs ☐ Delete selected jobs

[Cookie policy] (v3.2.1)

You can expand these tables to see the columns and data descriptions are easily accessed from here as well.

Rev	Date	Description
B	2023-04-02	Updated according to the last plugin's release (PMAK)
A	2020-11-01	Initial release (Cliff Kotnik)