

## VStar Retrieval of Gaia Variable Star Light Curve Data

This plugin allows you to read light curve data for any of the Gaia DR2 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 2018 the project has made its second of three data releases available, known as Gaia Data Release 2 (DR2). The key statistics and complete documentation can be found [here](#). Of note is that Gaia DR2 contains five parameter astrometry for 1.3 billion stars.

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. As of the second release, more than 0.5 million variable sources have been identified. These are not a complete list nor are they fully vetted. They should be as potential variables. A crossmatch against the 0.5 million stars in the AAVSO Variable Star Index showed about 120,000 matches. This indicates Gaia represent a very large source of as yet unstudied variables. Chapter 7 of the Gaia documents describes the variability processing in detail.

### 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\_error

☐ dec\_parallax\_corr

☐ pmra\_pmdec\_corr

☐ astrometric\_gof\_al

☐ astrometric\_primary\_flag

☐ astrometric\_matched\_observations

☐ duplicated\_source

☒ phot\_g\_mean\_mag

☐ phot\_bp\_mean\_mag

☐ phot\_rp\_mean\_mag

☐ g\_rp

☐ rv\_template\_logg

☐ designation

☒ ra\_error

☐ parallax\_over\_error

☐ ra\_dec\_corr

☐ dec\_pmra\_corr

☐ astrometric\_n\_obs\_al

☐ astrometric\_chi2\_al

☐ astrometric\_weight\_al

☐ visibility\_periods\_used

☐ phot\_g\_n\_obs

☐ phot\_bp\_n\_obs

☐ phot\_rp\_n\_obs

☐ phot\_bp\_rp\_excess\_factor

☒ radial\_velocity

☐ rv\_template\_fe\_h

☒ source\_id

☒ dec

☐ pmra

☐ ra\_parallax\_corr

☐ dec\_pmdec\_corr

☐ astrometric\_n\_obs\_ac

☐ astrometric\_excess\_noise

☐ astrometric\_pseudo\_colour

☐ astrometric\_sigma5d\_max

☐ phot\_g\_mean\_flux

☐ phot\_bp\_mean\_flux

☐ phot\_rp\_mean\_flux

☐ phot\_proc\_mode

☒ radial\_velocity\_error

☒ phot\_variable\_flag

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

phot_g_mean_mag	bp_rp_mag	radial_velocity	radial_velocity_error	phot_variable_flag	teff_val
		km.s <sup>-1</sup>	km.s <sup>-1</sup>		K
20588	1.6295767	60.45632657628234	8.131065373863171	VARIABLE	4284.3335

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 navigation bar with 'HOME', 'SEARCH', 'STATISTICS', and 'V'. Below this, there are tabs for 'Basic', 'Advanced (ADQL)', and 'Query Res'. The 'Basic' tab is selected. The search results are displayed in a table with columns 'source\_id' and 'ra deg'. The first row shows '3105860283909081728' and '103.05070'.

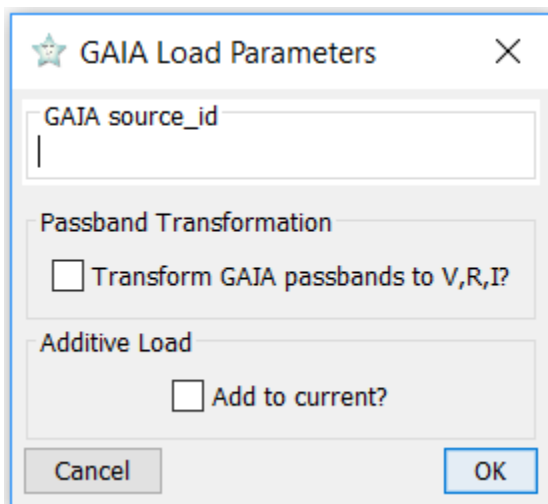
source_id	ra deg
3105860283909081728	103.05070

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 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 a close button. The dialog contains a text field for 'GAIA source\_id', a section for 'Passband Transformation' with a checkbox 'Transform GAIA passbands to V,R,I?', and a section for 'Additive Load' with a checkbox 'Add to current?'. At the bottom, there are 'Cancel' and 'OK' buttons.

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). If you perform an additive load with other observations using a different time frame, you will be asked to provide the celestial coordinates so that VStar can convert to a common time frame. The plugin does not query the Gaia archive for these coordinates at this time and you will need to enter them manually.

## Advanced Gaia Queries

You will likely want to perform more advanced queries against the Gaia DR2. 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 interface. At the top is a dark red header with the text "gaia archive" in white. Below the header is a navigation bar with four tabs: "HOME", "SEARCH", "STATISTICS", and "VISUALISATION". The "SEARCH" tab is active. Below the navigation bar is a sub-navigation bar with three tabs: "Basic", "Advanced (ADQL)", and "Query Results". The "Advanced (ADQL)" tab is active. On the left side of the main content area, there is a sidebar with a list of tables. The tables are grouped under "Gaia Data Release 1" and "Gaia Data Release 2". Under "Gaia Data Release 2", there are sub-groups: "Auxiliary", "Cross match", "Solar System", and "Variability". The "Variability" group is expanded, showing a list of tables: "gaiadr2.vari\_cepheid", "gaiadr2.vari\_classifier\_class\_o", "gaiadr2.vari\_classifier\_definitio", "gaiadr2.vari\_classifier\_result", "gaiadr2.vari\_long\_period\_varia", "gaiadr2.vari\_rotation\_modulati", "gaiadr2.vari\_rrlyrae", "gaiadr2.vari\_short\_timescale", "gaiadr2.vari\_time\_series\_stati", and "gaiadr2.gaia\_source". On the right side of the main content area, there is a form with a "Job name:" label and a text input field. Below the input field is a "Ctrl+Space fi" label. Below the input field is a "No results four" label. Below the "No results four" label is a "Status" label.

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