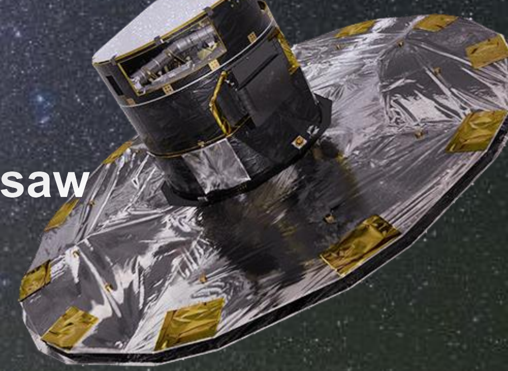
Synergies and connections between the Gaia and OGLE catalogs of variable stars

Igor Soszyński

Astronomical Observatory, University of Warsaw



The OGLE Project
prehistory

Bohdan Paczyński (1940-2007)

The OGLE Project
prehistory

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GRAVITATIONAL MICROLENSING BY THE GALACTIC HALO

BOHDAN PACZYŃSKI[1]
Princeton University Observatory
Received 1985 August 1; accepted 1985 October 23

"It is clear that the observational project is not simple, but one of its by-products, a systematic discovery of a large number of variable stars in a nearby galaxy, is attractive, even if no lensing events are discovered."

The OGLE Project
history

OGLE-I

1992 – 1995

Swope Telescope

1 m

Las Campanas Observatory, Chile

OGLE-II + OGLE-III + OGLE-IV

1997 – now

Warsaw Telescope

1.3 m

Las Campanas Observatory, Chile

The OGLE Project
history

Stage	Camera [pixels]	Area [deg²]	Stars [$\times 10^6$]	Data flow [TB/yr]	Main targets
OGLE-I 1992–1995	**4 M**	**1.5**	**6**	**0.09**	**Galactic bulge**
OGLE-II 1997–2000	**4 M**	**27**	**44**	**0.4**	**Galactic bulge** **Magellanic Clouds**
OGLE-III 2001–2009	**64 M**	**170**	**389**	**3.8**	**Galactic bulge** **Magellanic Clouds**
OGLE-IV 2010 – ?	**256 M**	**3600**	**2000**	**40**	**Galactic bulge** **Galactic disk** **Magellanic Clouds**

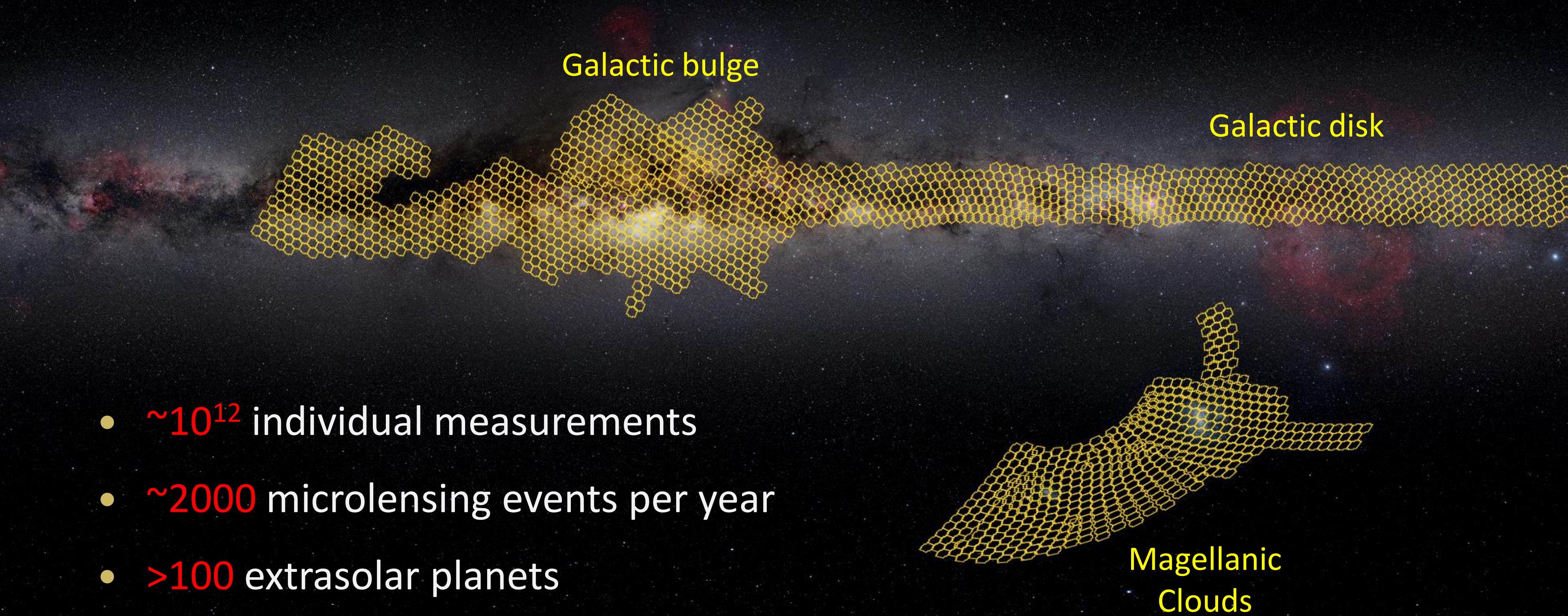
OGLE

Optical Gravitational Lensing Experiment

- **Long-term optical sky survey** for variability
- **1.3-meter Warsaw Telescope** at Las Campanas Observatory, Chile
- 32-chip CCD camera with a field of view of **1.4 square degrees**
- Standard Johnson-Cousins ***VI*** filters
- Typical cadence: from **20 minutes** to **several days**
- Time span: **1992 – now**
- Targets: **Galactic bulge, Galactic disk, Magellanic Clouds**
- Precision of the photometry: **4 mmag**

OGLE fields

- Sky coverage: ~3600 square degrees
- ~2 billion stars monitored



- $\sim 10^{12}$ individual measurements
- ~2000 microlensing events per year
- >100 extrasolar planets
- >1 million variable stars discovered

The OGLE Collection of Variable Stars

https://ogledb.astrouw.edu.pl/~ogle/OCVS/
ftp://ftp.astrouw.edu.pl/ogle/ogle4/OCVS/

Type of variable stars	Environments	Number of stars
Classical Cepheids	LMC, SMC, MW	11 703
Type II Cepheids	LMC, SMC, MW	2 010
Anomalous Cepheids	LMC, SMC, MW	389
RR Lyrae stars	LMC, SMC, MW	128 273
δ Scuti stars	LMC, SMC, MW	30 204
Long-Period Variables (Miras, SRVs, OSARGs)	LMC, SMC, MW	403 636
Eclipsing binaries	LMC, SMC, MW	510 782
Dwarf novae	LMC, SMC, MW	1 091
R Coronae Borealis stars	LMC	23
TOTAL		**1 088 111**

The OGLE Collection of Variable Stars

https://ogledb.astrouw.edu.pl/~ogle/OCVS/
ftp://ftp.astrouw.edu.pl/ogle/ogle4/OCVS/

OGLE Collection of Variable Stars

Welcome page
News/Changes
updated: 2022-04-29

Search stars:

Classical Cepheids
Anomalous Cepheids
Type II Cepheids
RR Lyr Stars
Miras
delta Scuti Stars
Heartbeat Stars
Eclipsing Stars

All Variable Types

Query Help

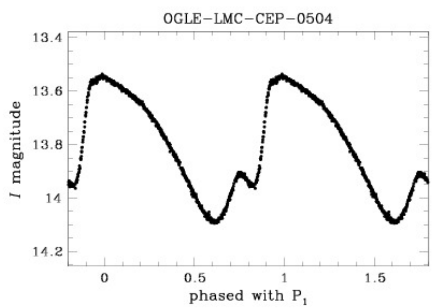
Other variable types are available in the OGLE-III Collection (2000-2013):

Long Period Variables
Double Periodic Variables (LMC)
R CrB Stars (LMC)
δ Sct Stars (LMC)

OGLE website

OGLE-IV Photometry of OGLE-LMC-CEP-0504 (direct link)
Download: object I-band V-band photometry Finding chart
RA[h]/Dec[d] (J2000, hex↔dec): 04:57:56.71 -68:48:57.6
PS lighcurve phased with P_1
RA[d]/Dec[d] (J2000, hex↔dec): 74.48629 -68.816000
All data
Star type: Classical Cepheid, mode F
Identification: OGLE-III: LMC126.8.39800; OGLE-IV: LMC531.26.15716; OTHER: HV12505
New Query

```
I = 13.792 mag, V = 14.838 mag, V-I = 1.046 mag
P_1 = 14.3929624 d, dP_1 = 8.49E-5 d, T0_1 = 6004.74277 d, A_1 = 0.543 mag, R21_1 = 0.142, phi21_1 = 4.935 rad, R31_1 = 0.124, phi31_1 = 1.799 rad
```

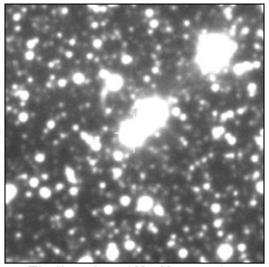


I-band photometry
(673 data points)

```
HJD-2450000  mag   err
------------------------
5261.55766 13.814 0.005
5261.59934 13.814 0.005
5262.57508 13.911 0.005
5262.59343 13.906 0.005
5264.54162 14.077 0.005
... 663 lines skipped ...
7472.56491 13.546 0.005
7476.52061 13.695 0.005
7488.47442 13.587 0.005
7499.49762 13.911 0.005
7507.46988 13.859 0.005
```

V-band photometry
(120 data points)

```
HJD-2450000  mag   err
------------------------
5275.53339 14.926 0.004
5286.49075 14.567 0.004
5446.88766 14.780 0.004
5459.82123 14.614 0.004
5476.80761 14.894 0.004
... 110 lines skipped ...
6997.78974 14.407 0.004
7007.74269 15.156 0.004
7137.48579 15.109 0.004
7332.73607 14.814 0.004
7366.71348 15.315 0.004
```

N
E

Finding chart (60x60 arcsec)

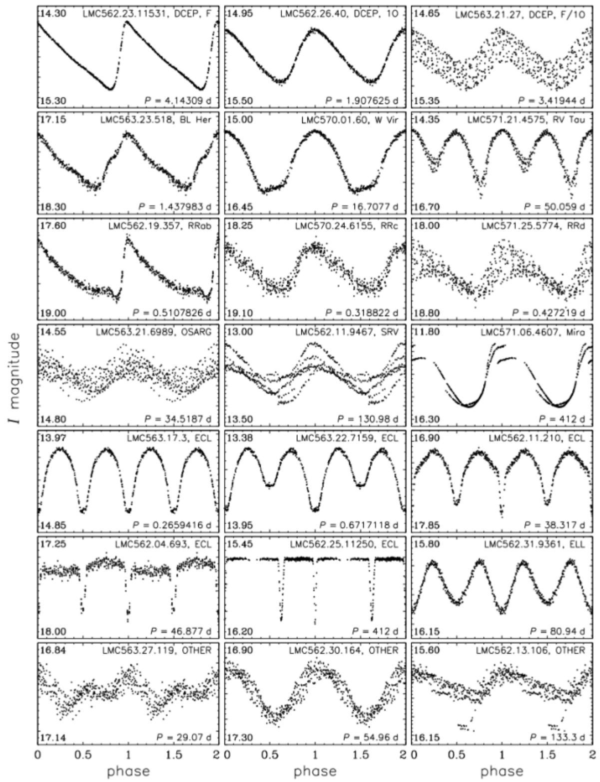
Soszyński *et al.*, 2015a, Acta Astron., 65, 297 (classical Cepheids in the LMC and SMC) paper overview
Soszyński *et al.*, 2017a, Acta Astron., 67, 103 (classical and anomalous Cepheids in the LMC and SMC) paper overview
Soszyński *et al.*, 2017b, Acta Astron., 67, 297 (classical, type II, and anomalous Cepheids toward the Galactic Center) paper overview
Udalski *et al.*, 2018, Acta Astron., 68, 315 (clasical and type II cepheids in Galactic disk and bulge) paper overview
Soszyński *et al.*, 2020, Acta Astron., 70, 101 (additional classical, type II, and anomalous Cepheids toward the Galactic Disk and Center) paper overview

Data come from the On-line Data Download site for: LMC SMC BLG GD

ACTA ASTRONOMICA
Vol. **62** (2012) pp. 219–245

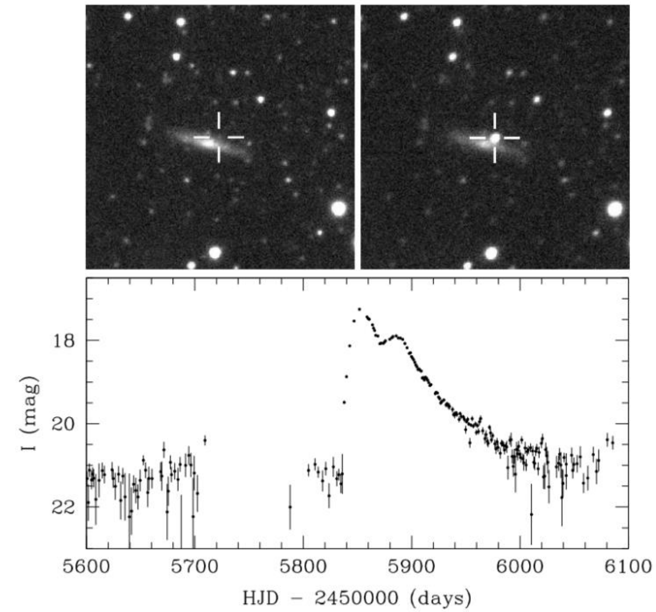
The Optical Gravitational Lensing Experiment. Gaia South Ecliptic Pole Field as Seen by OGLE-IV*

I. Soszyński[1], A. Udalski[1], R. Poleski[1], S. Kozłowski[1], Ł. Wyrzykowski[1,2], P. Pietrukowicz[1], M.K. Szymański[1], M. Kubiak[1], G. Pietrzyński[1,3], K. Ulaczyk[1] and J. Skowron[4,1]



5.3 square degrees around the South Ecliptic Pole:

- ✓ 6789 variable stars
- ✓ 1925 background galaxies
- ✓ 11 supernova candidates
- ✓ proper motion of 3309 stars

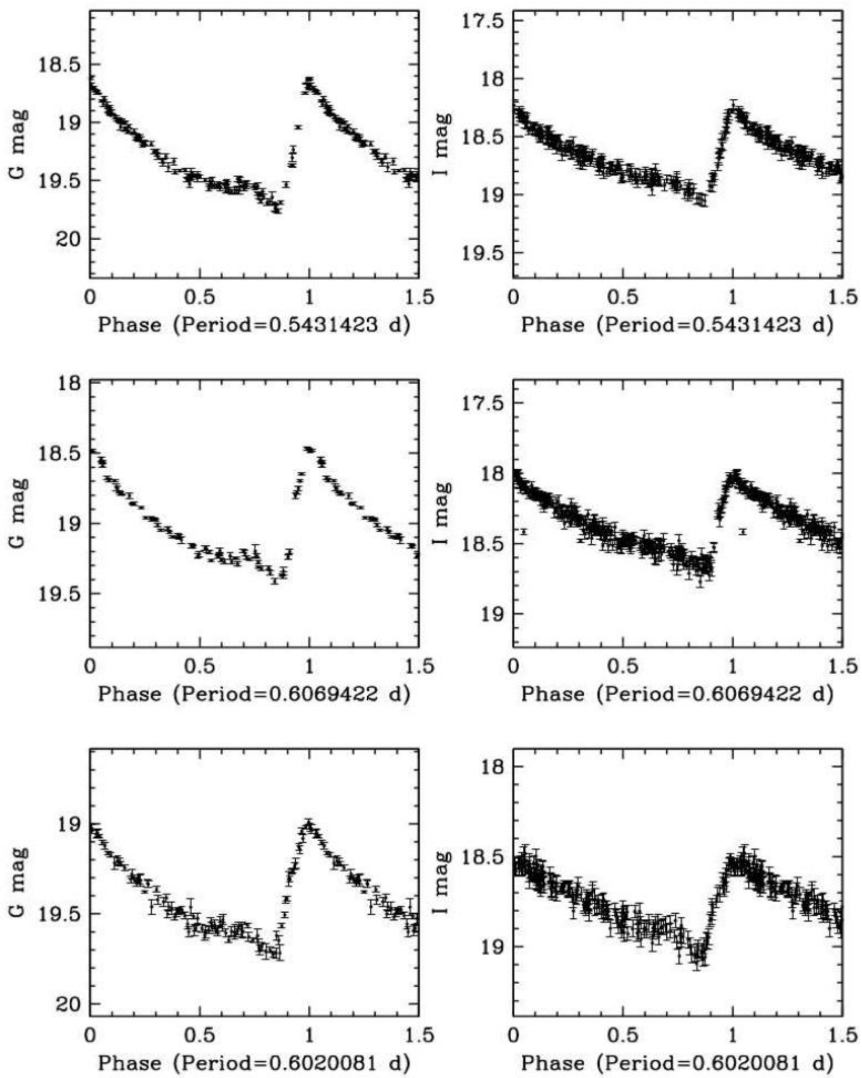


Clementini (2016):

First Gaia light curves of RR Lyrae stars around the South Ecliptic Pole compared to the OGLE light curves

RR Lyrae stars in the LMC:

↓ Gaia ↓ ↓ OGLE ↓



ACTA ASTRONOMICA
Vol. **66** (2016) pp. 433–453

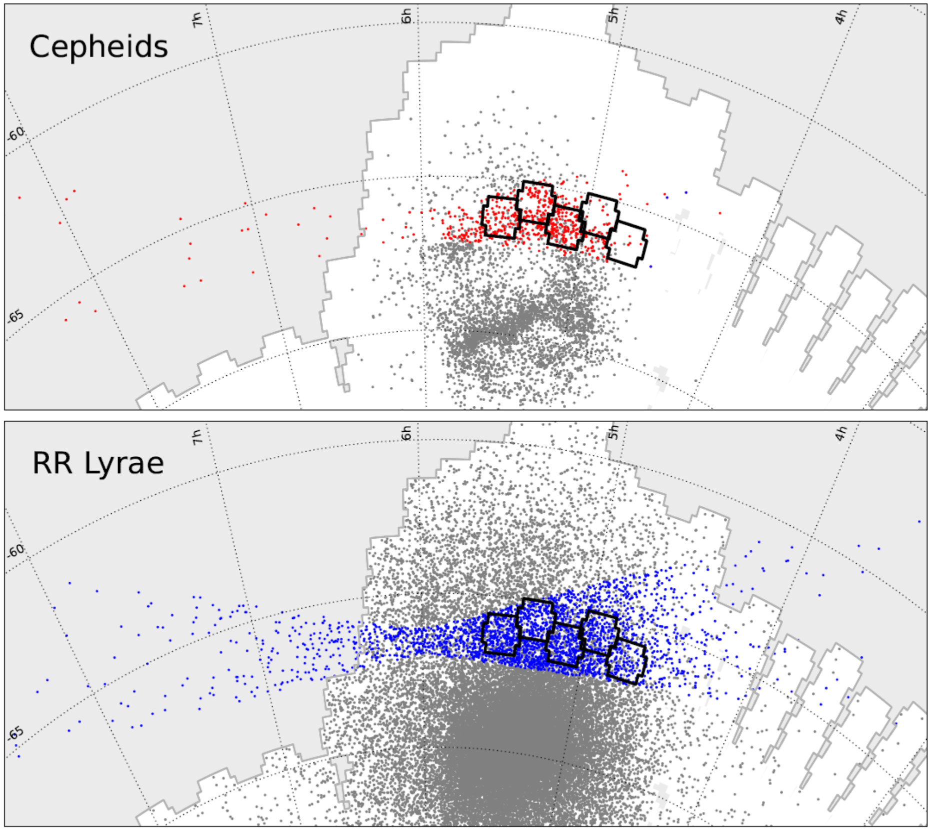
Gaia and Variable Stars

A. Udalski[1], I. Soszyński[1], D.M. Skowron[1], J. Skowron[1],
P. Pietrukowicz[1], P. Mróz[1] R. Poleski[1,2],
M.K. Szymański[1], S. Kozłowski[1], Ł. Wyrzykowski[1],

Udalski et al. (2016):

"The number of misclassified stars is low indicating reliable performance of the Gaia data pipeline."

"The completeness of the Gaia DR1 samples of Cepheids and RR Lyr stars is at the level of 60–75% as compared to the OGLE Collection dataset."

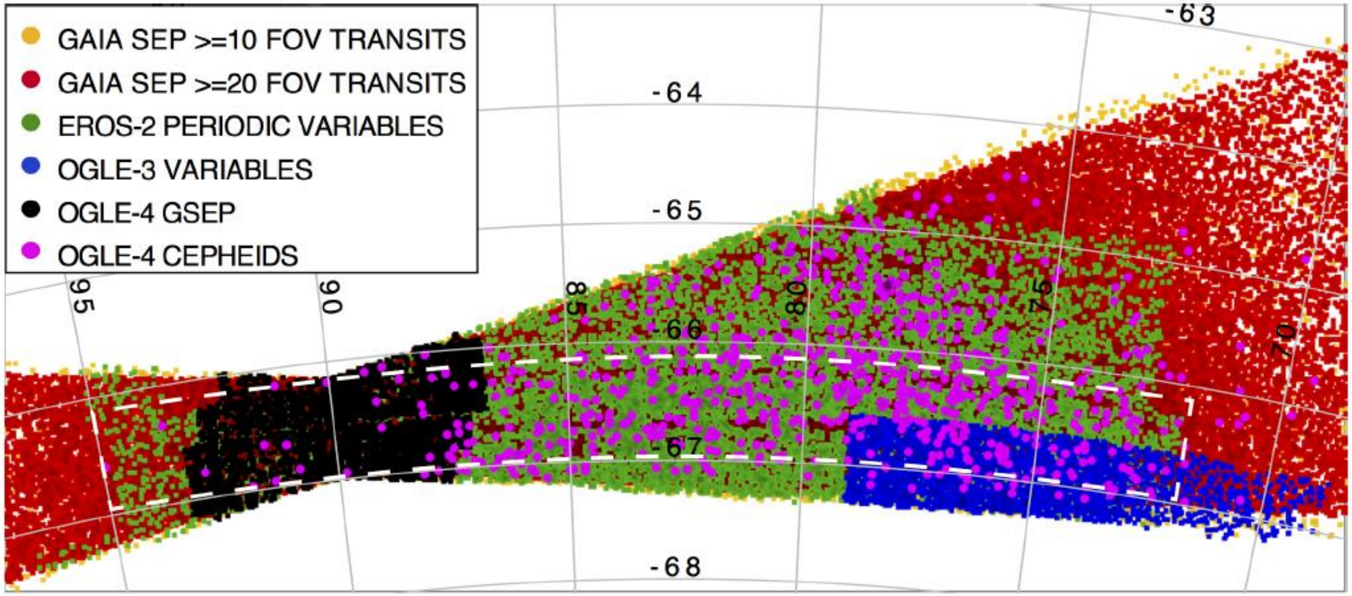


Gaia Data Release 1

The variability processing & analysis and its application to the south ecliptic pole region

L. Eyer[1], N. Mowlavi[1], D.W. Evans[2], K. Nienartowicz[3], D. Ordóñez[4], B. Holl[4], I. Lecoeur-Taibi[4], M. Riello[2], G. Clementini[22], J. Cuypers[5], J. De Ridder[6], A.C. Lanzafame[7,8], L.M. Sarro[9], J. Charnas[4], L.P. Guy[4], G. Jevardat de Fombelle[3], L. Rimoldini[4], M. Süveges[4], F. Mignard[14], G. Busso[2], F. De Angeli[2], F. van Leeuwen[2], P. Dubath[4], M. Beck[1], J.J. Aguado[9], J. Debosscher[6], E. Distefano[8], J. Fuchs[15], P. Koubsky[15], T. Lebzelter[21],

Eyer et al. (2017): **"The completeness estimates found by Udalski et al. (2016) are consistent with our results."**



Gaia DR3 compared to OGLE

	gaia	OGLE
Number of observed stars	~1.8 billion	~2 billion
Sky coverage	All sky	Galactic bulge and disk, Magellanic Clouds
Total number of photometric measurements	367 billion	1.2 trillion
Time span	~3 years	~10 years (OGLE-IV) ~30 years (OGLE-I – OGLE-IV)
Photometric passbands	G, G_{BP}, G_{RP}	V, I (Johnson-Cousins system)
Limiting magnitudes	8 – 21 (G)	12 – 21 (I)
Median numbers of photometric measurements per star	G: 44 G_{BP}: 40 G_{RP}: 41	I: 500 – 700 V: 50 – 100
Number of variable stars	9 976 881	1 088 111 (+)
Classification methods	Automatic	Automatic + Visual inspection

Impact of Gaia variable stars on OCVS

Soszyński et al. (2018):

4.1. Cross-Match with Other Catalogs

In order to test the completeness of our collection of type II Cepheids in the Magellanic Clouds, we cross-matched it with the GCVS (Artyukhina *et al.* 1995), the catalog of periodic variable stars detected from the EROS-2 survey (Kim *et al.* 2014), and the catalog of Cepheids recently published as a part of the Gaia Data Release 2 (DR2, Clementini *et al.* 2018, Holl *et al.* 2018).

Soszyński et al. (2019):

on the position in the period *vs.* period ratio (Petersen) diagram. As a result, we found 1157 RR Lyr stars, two classical Cepheids, six anomalous Cepheids, and three type II Cepheids in the outer fields of the Magellanic System. Additionally, the light curve template fitting and cross-identification with the Gaia DR2 catalog of classical pulsators (Clementini *et al.* 2019, see Section 4) increased the number of RR Lyr variables in the central regions of the Magellanic Clouds by 229, classical Cepheids by two, and anomalous Cepheids by one object. We also reclassified three variables located in the Magellanic Bridge from classical Cepheids into anomalous Cepheids (one of them located in the Milky Way halo). The old

Soszyński et al. (2022):

Finally, our collection of δ Sct stars detected toward the SMC consists of 2810 objects. In addition, the OCVS has been enriched with nine new classical Cepheids and 123 RR Lyr stars identified as a by-product of the present search for δ Sct stars or a result of cross-matching the OGLE database with the Gaia DR3 catalog of Cepheids (Ripepi *et al.* 2022) and RR Lyr stars (Clementini *et al.* 2022). A more detailed comparison of the Gaia DR3 and OGLE catalogs in the area of the Magellanic System will be discussed in the forthcoming paper presenting the OGLE collection of δ Sct stars in the LMC (Soszyński *et al.* in prep.).

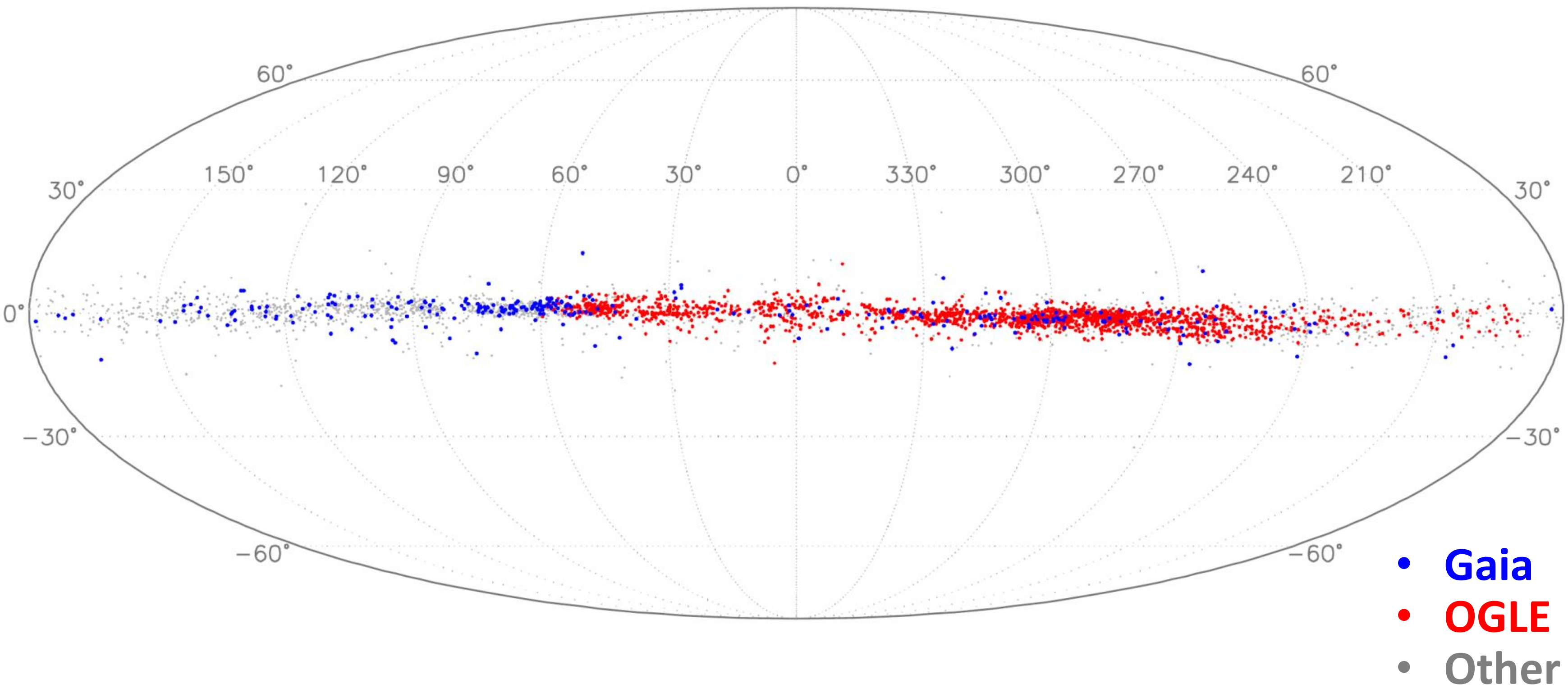
doi: 10.32023/0001-5237/71.3.2

ACTA ASTRONOMICA
Vol. **71** (2021) pp. 205–222

Classical Cepheids in the Milky Way

P. Pietrukowicz, I. Soszyński and A. Udalski

3666 classical Cepheids in the Milky Way



Impact of OCVS on Gaia variable stars

Rimoldini et al. (2023):

Catalogs of variable stars used as training sets for the Gaia the machine learning algorithms.

References. (1) Bernhard et al. (2015); (2) Cunha et al. (2019); (3) ESA (1997); (4) Hey et al. (2019); (5) Hümmerich et al. (2018); (6) Jayasinghe et al. (2018, 2019a,b); (7) Pojmanski (2002); (8) Renson & Manfroid (2009); (9) Richards et al. (2012); (10) Watson et al. (2006, VSX version 2019-11-12); (11) Gaia Collaboration et al. (2022c); (12) Ma et al. (2013); (13) De Cat (catalogue COMP_SPB_BCEP_DECAT_PR in Gavras et al. 2022); (14) Stankov & Handler (2005); (15) Mennickent et al. (2002); (16) Sabogal et al. (2005); (17) Clementini et al. (2019); (18) Drake et al. (2014b); (19) M 31 (catalogue GAIA_M31_CEP_GAIA_2018 in Gavras et al. 2022); (20) Marquette et al. (2009); (21) Palaversa et al. (2013); (22) Pellerin & Macri (2011); (23) Ripepi et al. (2019); (24) Soszyński et al. (2008a,b, 2010a,c, 2011b, 2015, 2020); (25) Soszyński et al. (2012); (26) Soszyński et al. (2017); (27) Udalski et al. (2018); (28) Zak (catalogue GAIA_CEP_ZAK_2018 in Gavras et al. 2022); (29) Drake et al. (2014a); (30) *Gaia* science alerts (catalogue GAIA_TRANSIENTS_ALERTS_2019 in Gavras et al. 2022); (31) Mróz et al. (2015); (32) Ritter & Kolb (2003); (33) Szkody et al. (2011); (34) Bradley et al. (2015); (35) Chen et al. (2020); (36) De Ridder (catalogue GAIA_DR2_CLASS_DSCT_SXPHE_SELECTION in Gavras et al. 2022); (37) Debosscher et al. (2007, 2011); (38) Hamanowicz et al. (2016); (39) Kahraman Aliçavuş et al. (2016); (40) Pigulski et al. (2009); (41) Poleski et al. (2010); (42) Rimoldini et al. (2019); (43) Sarro et al. (2013); (44) Süveges et al. (2012); (45) Uytterhoeven et al. (2011); (46) Van Reeth et al. (2015); (47) Drake et al. (2017); (48) Kirk et al. (2016); (49) Pawlak et al. (2013); (50) Pawlak et al. (2016); (51) Rybizki (catalogue GAIA_ECL_RYBIZKI_2018 in Gavras et al. 2022); (52) Soszyński et al. (2016a); (53) Southworth (2011, updated list available at https://www.astro.keele.ac.uk/jkt/tepcat/html-catalogue.html); (54) Alfonso-Garzón et al. (2012); (55) Bergeat et al. (2001); (56) Braga et al. (2019); (57) Demers & Battinelli (2007); (58) Heinze et al. (2018); (59) Kim et al. (2014); (60) Mauron et al. (2019); (61) Mould et al. (2004); (62) Soszyński et al. (2009b, 2011c, 2013); (63) Spano et al. (2011); (64) Suh & Hong (2017); (65) Woźniak et al. (2004); (66) Kruszyńska (catalogue COMP_MICROLENSING_GAIA in Gavras et al. 2022); (67) Soszyński et al. (2009c); (68) Abbas et al. (2014); (69) Benkő et al. (2006); (70) Boettcher et al. (2013); (71) Braga et al. (2016); (72) Corwin et al. (2006, 2008); (73) Drake et al. (2013a,b); (74) Dall'Ora et al. (2006, 2012); (75) Garofalo et al. (2013); (76) Garofalo (catalogue GAIA_RRL_GAROFALO_SELECTION in Gavras et al. 2022); (77) Kinemuchi et al. (2006); (78) Musella et al. (2009, 2012); (79) Pritzl et al. (2002, 2003); (80) Sesar et al. (2014, 2017); (81) Siegel (2006); (82) Skottfelt et al. (2015); (83) Soszyński et al. (2009a, 2010b, 2011a, 2014, 2016b, 2019); (84) Torrealba et al. (2015); (85) Watkins et al. (2009); (86) Eker et al. (2008); (88) Roelens et al. (2018); (89) Slawson et al. (2011); (90) Chang et al. (2015); (91) De Medeiros et al. (2013); (92) Distefano (catalogues GAIA_ROT_GAIA_2017, GAIA_BY_DISTEFANO_2019, KEPLER_GAIA_BY_ROT_DISTEFANO_2020, and TESSGAIA_BY_ROT_DISTEFANO_2020 in Gavras et al. 2022); (93) Drake (2006); (94) Hartman et al. (2010); (95) Howell et al. (2016); (96) Lanzafame et al. (2018); (97) Martínez-Arnáiz et al. (2010); (98) Medhi et al. (2007); (99) Messina et al. (2010, 2011); (100) Reinhold & Gizon (2015); (101) Shibayama et al. (2013); (102) Sikora et al. (2019); (103) Walkowicz et al. (2011); (104) Wu et al. (2015); (105) Žerjal et al. (2017); (106) Niemczura (2003); (107) Akras et al. (2019); (108) Beauchamp et al. (1999); (109) Bognár et al. (2020); (110) Dufour et al. (2011); (111) Dunlap et al. (2010); (112) Eyer et al. (2020); (113) Gianninas et al. (2005); (114) Hermes et al. (2012, 2013a,b); (115) Kepler et al. (2014); (116) Kurtz et al. (2013); (117) Nitta et al. (2009); (118) Quirion et al. (2007); (119) Williams et al. (2016); (120) Bredall et al. (2020); (121) Varga-Verebélyi et al. (2020); (122) Krone-Martins (catalogue GAIA_GAL_GAIA_2018 in Gavras et al. 2022).

Eyer et al. (2023):

Table 7. Variability type completeness and contamination estimates of the SOS tables with respect to available cross-matched reference catalogues. For the classification variability types without specific studies, we refer to Rimoldini et al. (2022b). The surveys used as references are SDSS (Lyke et al. 2020), OGLE (Udalski et al. 1992), ASAS-SN (Kochanek et al. 2017), ZTF (Graham et al. 2019).

Group	Variability type	Catalogue (and region)	Completeness	Contamination
AGN	agn	Gaia-CRF3	51%	≤ 5%
AGN	agn	SDSS-DR16Q[a]	47%	≤ 5%
Cepheids	Classical Cepheids	OGLE IV (MW)	> 86%	<2%
Cepheids	All Cepheids	OGLE IV (LMC & SMC)	~ 90%	<1%
Eclipsing binaries	eclipsing_binary	OGLE-IV (LMC/SMC/Bulge)	33/45/19%	~5%
LPV	long_period_variable	ASAS-SN and OGLE III-LPV[b]	79–83%	0.7–2%
Microlensing	microlensing	OGLE-IV (Bulge, Disk)	30-80%	< 1%
Rotation modulation	rotation_modulation	ZTF	0.4 %[c]	6%
Rotation modulation	rotation_modulation	ASAS-SN	0.4%	14%
RR Lyrae stars	rrlyr	OGLE-IV (LMC)	83%	<1.8%
RR Lyrae stars	rrlyr	OGLE-IV (SMC)	94%	<8%
RR Lyrae stars	rrlyr	OGLE-IV (Bulge-up)	79%	<0.15%
RR Lyrae stars	rrlyr	OGLE-IV (Bulge-down)	82%	-

Catalogs of variable stars used to estimate completeness and contamination of the Gaia catalog.

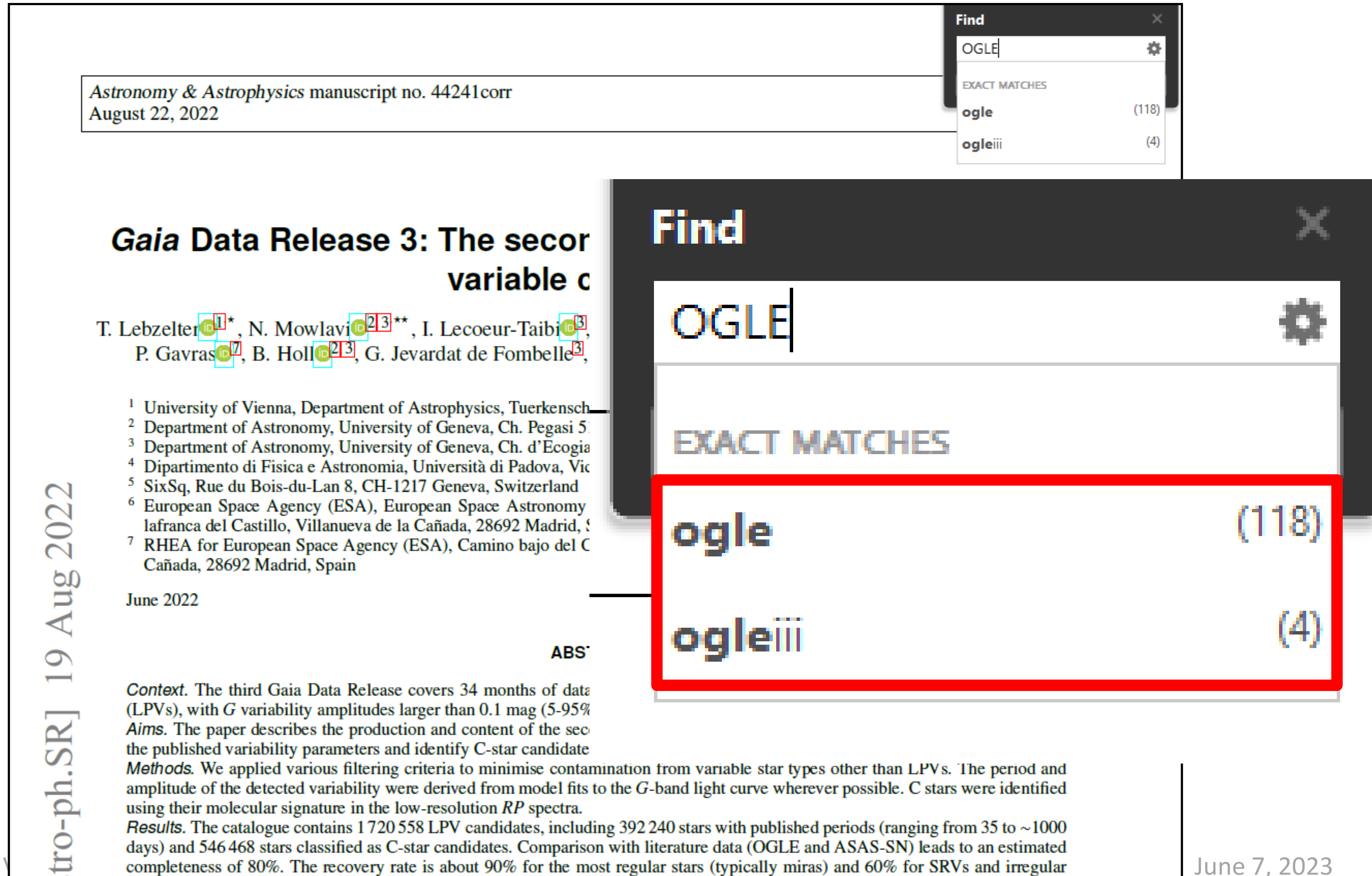
Gavras et al. (2022): "Table 2 shows the rank-ordered list of literature catalogues, where generally the higher a catalogue is in the list, the more accurate it is."

Table 2. Rank-ordered list of literature catalogues.

Catalogue
GAIA_CEP_RIPEPI_2019
GAIA_DR2_CLASS_DSCT_SXPHE_SELECTION
GAIA_CEP_ZAK_2018
GAIA_GALAXY_CLEMENTINI_2020
GAIA_RRL_GAROFALO_SELECTION
KEPLERGAIA_BY_ROT_DISTEFANO_2020
TESSGAIA_BY_ROT_DISTEFANO_2020
GAIA_BY_DISTEFANO_2019
OGLE_BLAP_PIETRUKOWICZ_2017
OGLE4_CEP_OGLE_2020
OGLE4_VAR_OGLE_2019
OGLE4_BLG_RRL_SOSZYNSKI_2019
OGLE4_GD_RRL_SOSZYNSKI_2019
CATALINA_RRAB_TORREALBA_2015
OGLE4_GSEP_VAR_SOSZYNSKI_2012
NSVS_RRAB_KINEMUCHI_2006
CATALINA_CSS_RRAB_DRAKE_2013
CATALINA_MLS_RRAB_DRAKE_2013
•••
ASAS_VAR_RICHARDS_2012
SDSS_VAR_IVEZIC_2007
INTEGRAL_VAR_ALFONSOGARZON_2012
OGLE4_MICROLENSING_OGLE4_2016
HATNET_COMP_PLEIADES_SOLAR_LIKE_HARTMAN_2010
OGLE4_LMC_CEP_RR_OGLE4_2016
OGLE4_BLG_CEP_RR_OGLE4_2016
OGLE4_SMC_CEP_RR_OGLE4_2016
OGLE4_LMC_ECL_OGLE4_2017
OGLE4_SMC_ECL_OGLE4_2017
OGLE4_CEP_RR_OGLE_2016
OGLE_BLG_EB_SOSZYNSKI_2016

Gaia Data Release 3: The second *Gaia* catalogue of long-period variable candidates

T. Lebzelter[1]*, N. Mowlavi[2,3]**, I. Lecoeur-Taibi[3], M. Trabucchi[4,2]***, M. Audard[2,3], P. García-Lario[6], P. Gavras[7], B. Holl[2,3], G. Jevardat de Fombelle[3], K. Nienartowicz[5], L. Rimoldini[3], and L. Eyer[2,3]



Astronomy & Astrophysics manuscript no. 44241corr
August 22, 2022

Gaia Data Release 3: The secor
variable c

T. Lebzelter[1]*, N. Mowlavi[2,3]**, I. Lecoeur-Taibi[3],
P. Gavras[7], B. Holl[2,3], G. Jevardat de Fombelle[3],

1 University of Vienna, Department of Astrophysics, Tuerkensch
2 Department of Astronomy, University of Geneva, Ch. Pegasi 5
3 Department of Astronomy, University of Geneva, Ch. d'Ecogia
4 Dipartimento di Fisica e Astronomia, Università di Padova, Vic
5 SixSq, Rue du Bois-du-Lan 8, CH-1217 Geneva, Switzerland
6 European Space Agency (ESA), European Space Astronomy
lafranca del Castillo, Villanueva de la Cañada, 28692 Madrid, S
7 RHEA for European Space Agency (ESA), Camino bajo del C
Cañada, 28692 Madrid, Spain

June 2022

arXiv:...[astro-ph.SR] 19 Aug 2022

ABS

Context. The third Gaia Data Release covers 34 months of data
(LPVs), with *G* variability amplitudes larger than 0.1 mag (5-95%
Aims. The paper describes the production and content of the sec
the published variability parameters and identify C-star candidate
Methods. We applied various filtering criteria to minimise contamination from variable star types other than LPVs. The period and amplitude of the detected variability were derived from model fits to the *G*-band light curve wherever possible. C stars were identified using their molecular signature in the low-resolution *RP* spectra.
Results. The catalogue contains 1 720 558 LPV candidates, including 392 240 stars with published periods (ranging from 35 to ~1000 days) and 546 468 stars classified as C-star candidates. Comparison with literature data (OGLE and ASAS-SN) leads to an estimated completeness of 80%. The recovery rate is about 90% for the most regular stars (typically miras) and 60% for SRVs and irregular

Gaia Data Release 3: The second *Gaia* catalogue of long-period variable candidates

T. Lebzelter[1]*, N. Mowlavi[2,3]**, I. Lecoeur-Taibi[3], M. Trabucchi[4,2]***, M. Audard[2,3], P. García-Lario[6], P. Gavras[7], B. Holl[2,3], G. Jevardat de Fombelle[3], K. Nienartowicz[5], L. Rimoldini[3], and L. Eyer[2,3]

Lebzelter et al. (2022):

"[…] large catalogues of LPVs have been produced as by-products of various sky surveys. One of the most influential catalogues in this context was produced by the Optical Gravitational Lensing Experiment (OGLE) team."

"The catalogues of LPVs in the Magellanic Clouds and Galactic Bulge produced within the third phase of the Optical Gravitational Lensing Experiment (OGLE-III) represent one of the highest-quality datasets for studying these stars, and an appropriate reference for validating the second Gaia catalogue of LPV candidates."

Gaia Data Release 3: The second *Gaia* catalogue of long-period variable candidates

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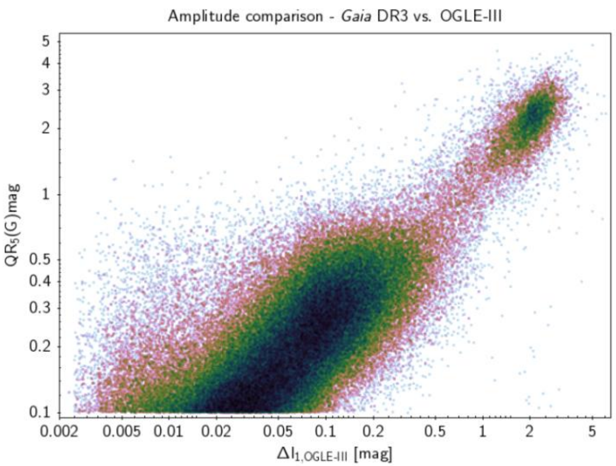
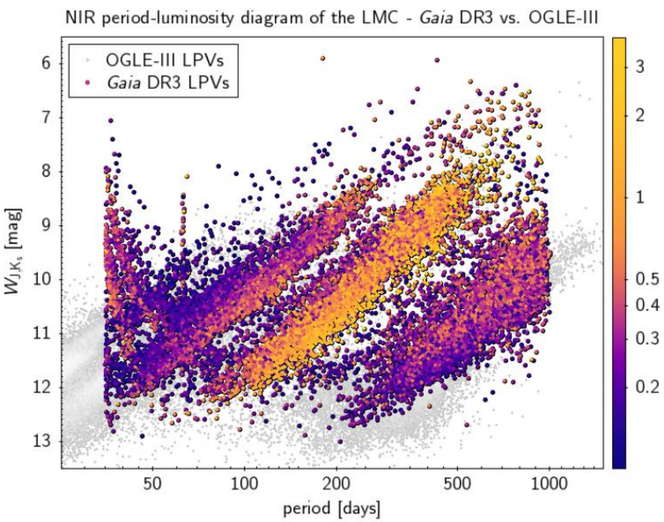
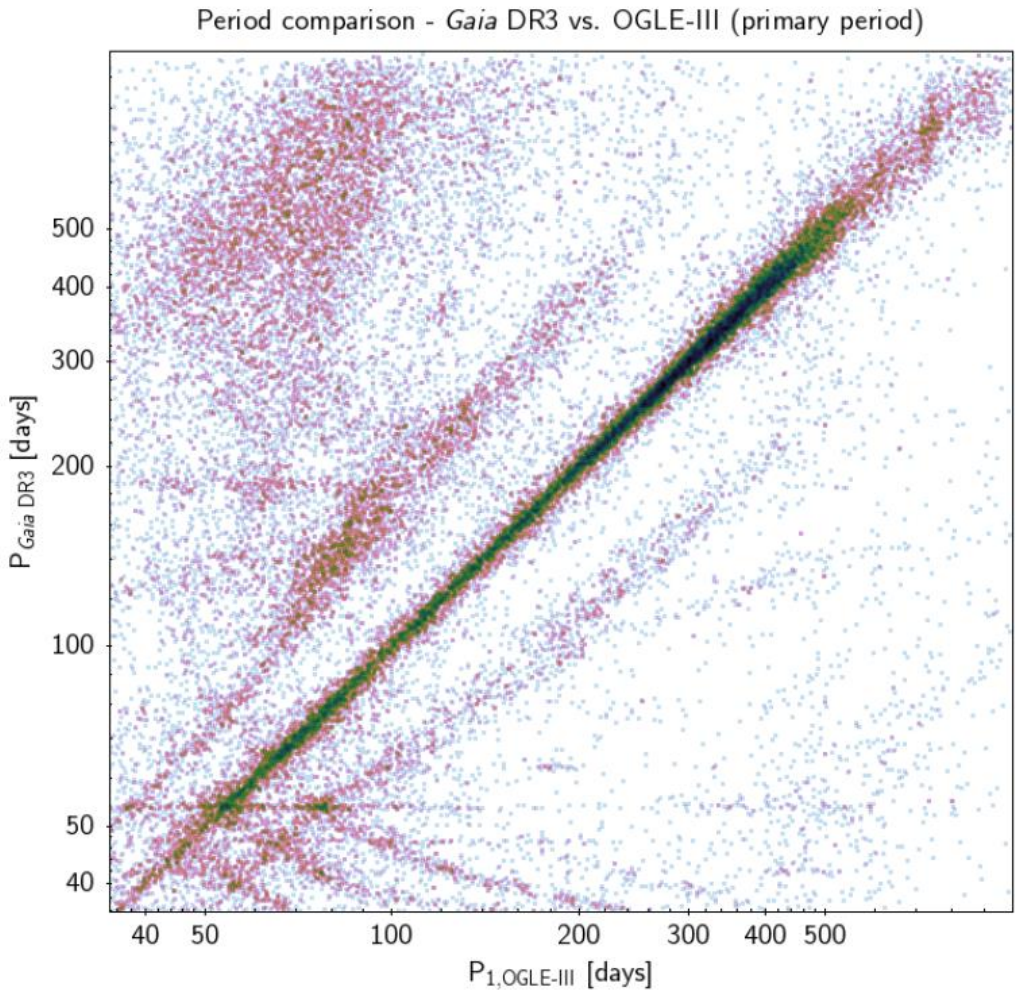


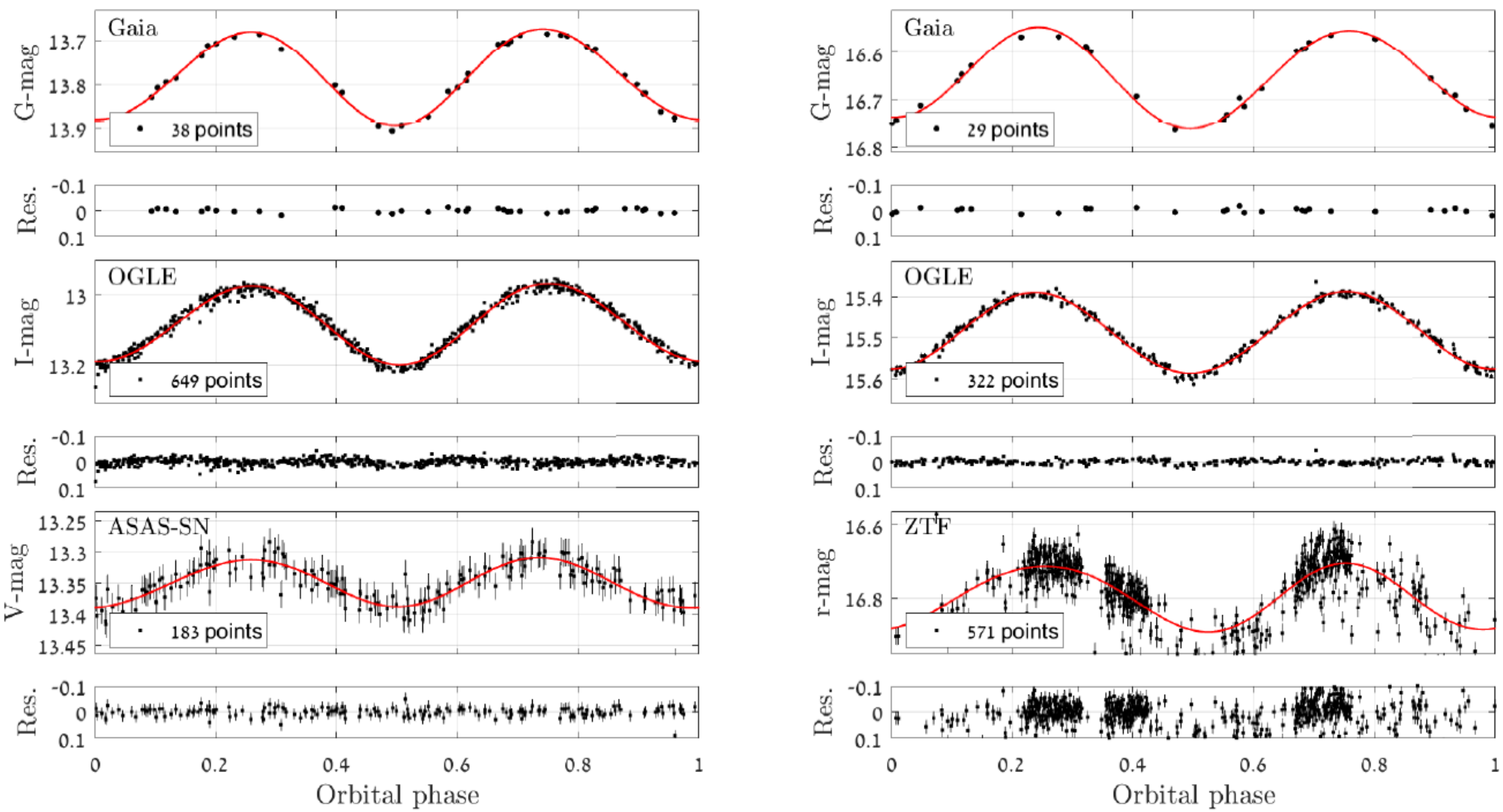




Gaia Data Release 3:

Ellipsoidal Variables with Possible Black-Hole or Neutron Star secondaries

R. Gomel[1], T. Mazeh[1], S. Faigler[1], D. Bashi[1], L. Eyer[2], L. Rimoldini[3], M. Audard[2], N. Mowlavi[2,3], B. Holl[3], G. Jevardat[3], K. Nienartowicz[3], I. Lecoeur[3], and L. Wyrzykowski[4]



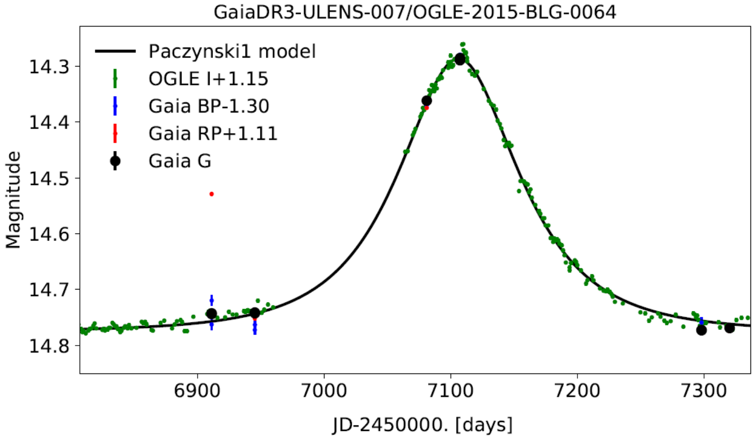
Gaia Data Release 3

Microlensing events from all over the sky

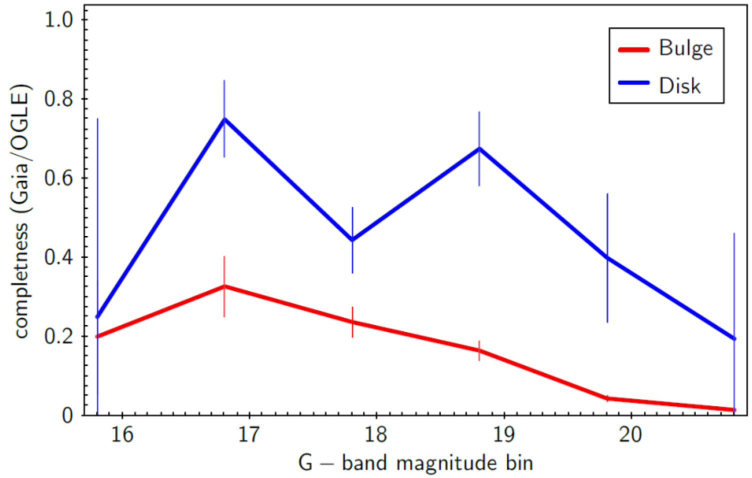
Ł. Wyrzykowski[1,⋆], K. Kruszyńska[1], K. A. Rybicki[1,2], B. Holl[3,4], I. Lecœur-Taïbi[4], N. Mowlavi[3,4], K. Nienartowicz[4,5], G. Jevardat de Fombelle[4], L. Rimoldini[4], M. Audard[3,4], P. Garcia-Lario[6], P. Gavras[7], D. W. Evans[8], S. T. Hodgkin[8], and L. Eyer[3,4]

Wyrzykowski et al. (2022):

Gaia DR3 catalog contains 363 microlensing events, of which 268 were alerted by the OGLE survey.



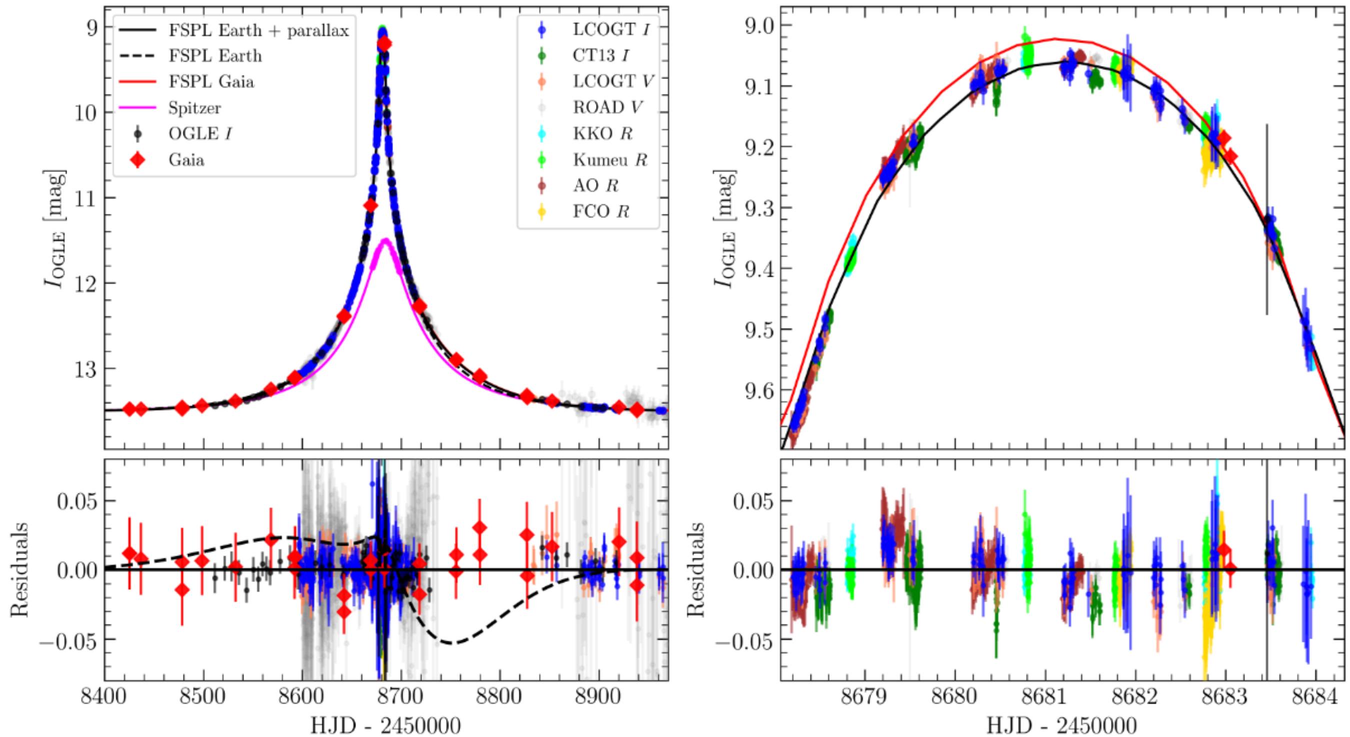
The OGLE sample was used to assess the completeness and contamination of the Gaia DR3 catalog.



Single-lens mass measurement in the high-magnification microlensing event Gaia19bld located in the Galactic disc

K. A. Rybicki[1], Ł. Wyrzykowski[1], E. Bachelet[2], A. Cassan[3], P. Zieliński[1], A. Gould[4,5], S. Calchi Novati[6], J. C. Yee[7], Y.-H. Ryu[8], M. Gromadzki[1], P. Mikołajczyk[9], N. Ihanec[1], K. Kruszyńska[1], F.-J. Hambsch[10,11], S. Zoła[12], S. J. Fossey[13], S. Awiphan[14], N. Nakharutai[15], F. Lewis[16,17], F. Olivares E.[18], S. Hodgkin[19], A. Delgado[19], E. Breedt[19], D. L. Harrison[19,20], M. van Leeuwen[19], G. Rixon[19], T. Wevers[19], A. Yoldas[19], A. Udalski[1], M. K. Szymański[1], I. Soszyński[1], P. Pietrukowicz[1], S. Kozłowski[1], J. Skowron[1], R. Poleski[1], K. Ulaczyk[21,1], P. Mróz[1,22], P. Iwanek[1], M. Wrona[1], R. A. Street[2], Y. Tsapras[23], M. Hundertmark[23], M. Dominik[24], C. Beichman[6],

Gaia19bld: $M_L = 1.13 \pm 0.03\ M_\odot$ $D_L = 5.52^{+0.35}_{-0.64}$ kpc



Gaia18aen: First symbiotic star discovered by *Gaia*★

J. Merc[1,2], J. Mikołajewska[3], M. Gromadzki[4], C. Gałan[3], K. Iłkiewicz[3,5], J. Skowron[4], Ł. Wyrzykowski[4], S. T. Hodgkin[6], K. A. Rybicki[4], P. Zieliński[4], K. Kruszyńska[4], V. Godunova[7], A. Simon[8], V. Reshetnyk[8], F. Lewis[9,10], U. Kolb[11], M. Morrell[11], A. J. Norton[11], S. Awiphan[12], S. Poshyachinda[12], D. E. Reichart[13], M. Greet[14], and J. Kolgjini[14]

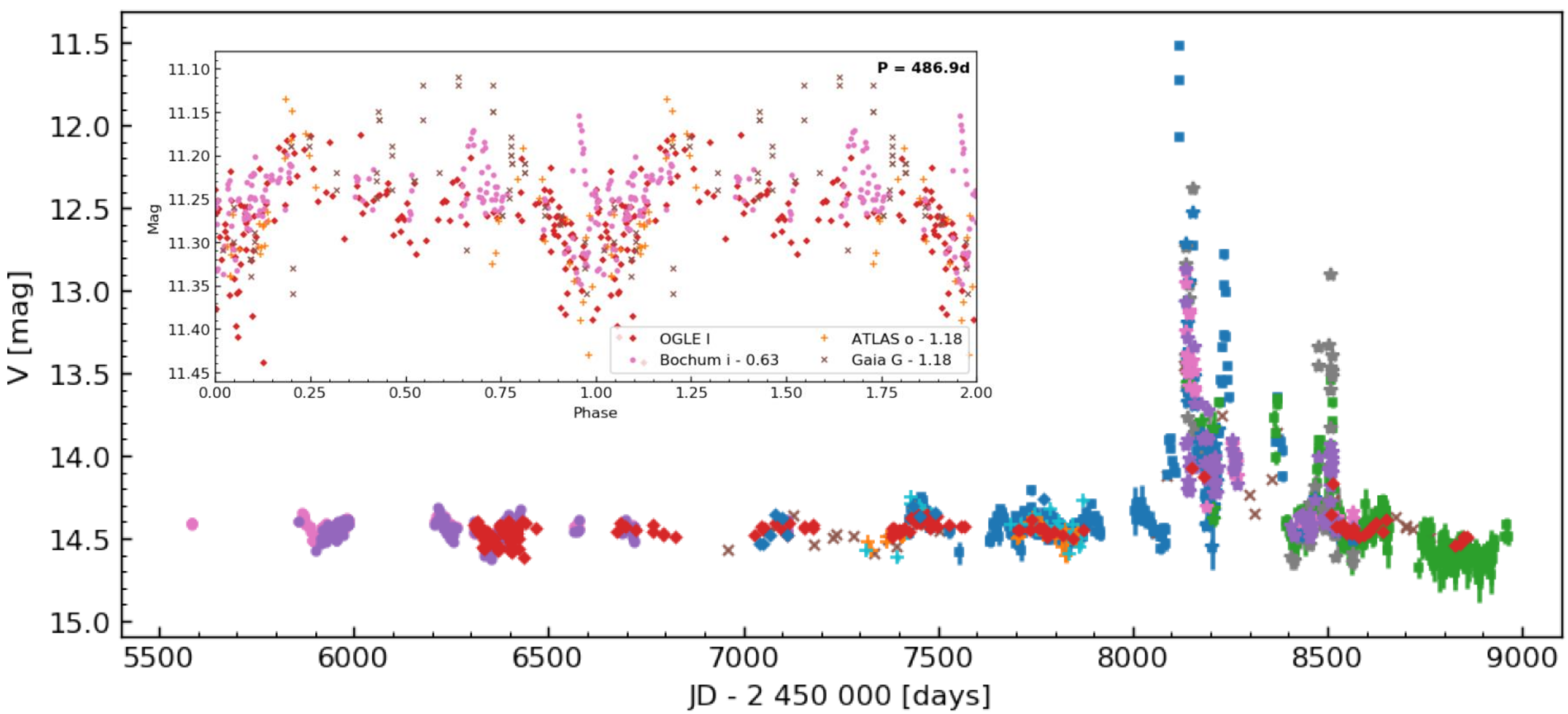


Fig. 7. Light curves of Gaia18aen. Individual light curves in various filters were shifted to the level in the OGLE *V* filter for clarity; values of shifts are shown in the figure legend. Different colors denote different filters.

Cepheids from Gaia and OGLE

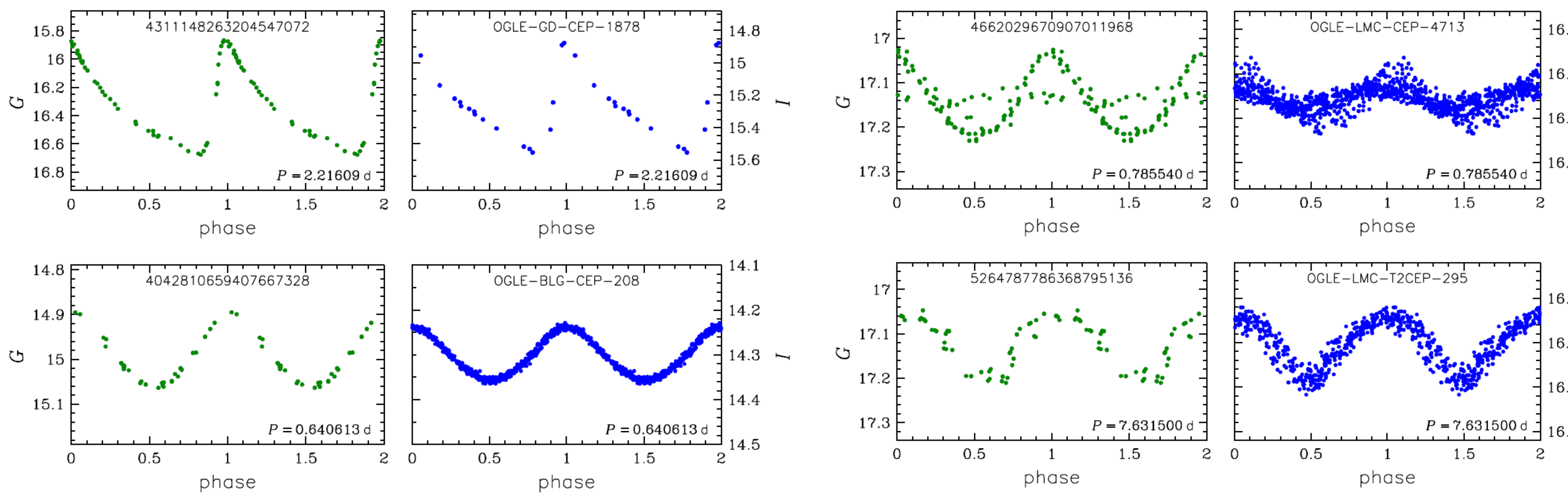
Ripepi et al. (2022): 15,006 Cepheids of all types in the Gaia DR3 catalog

12,036 of them are observed by the OGLE survey

11,752 of them have been included in the OCVS

108 Gaia Cepheids have been added to the OCVS

↓ Gaia ↓ ↓ OGLE ↓ ↓ Gaia ↓ ↓ OGLE ↓

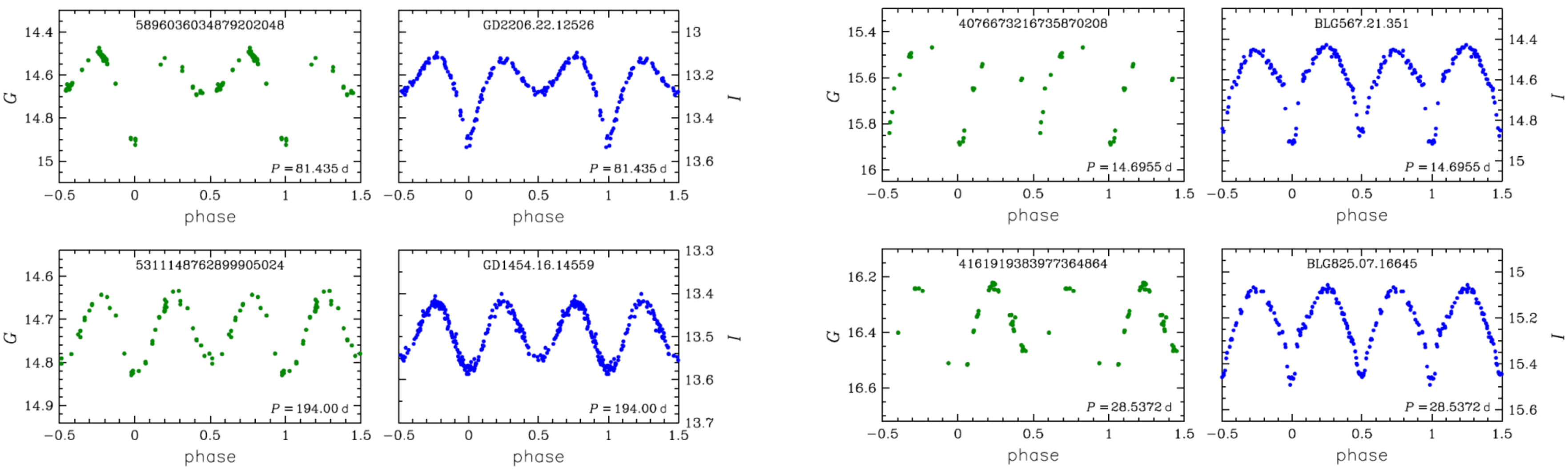


Cepheids from Gaia and OGLE

The Gaia catalog of Cepheids contains over 50 eclipsing binaries, several long-period variables, and other types of variable stars.

However, the contamination rate is very low, at the level of 1-2%.

↓ Gaia ↓ ↓ OGLE ↓ ↓ Gaia ↓ ↓ OGLE ↓



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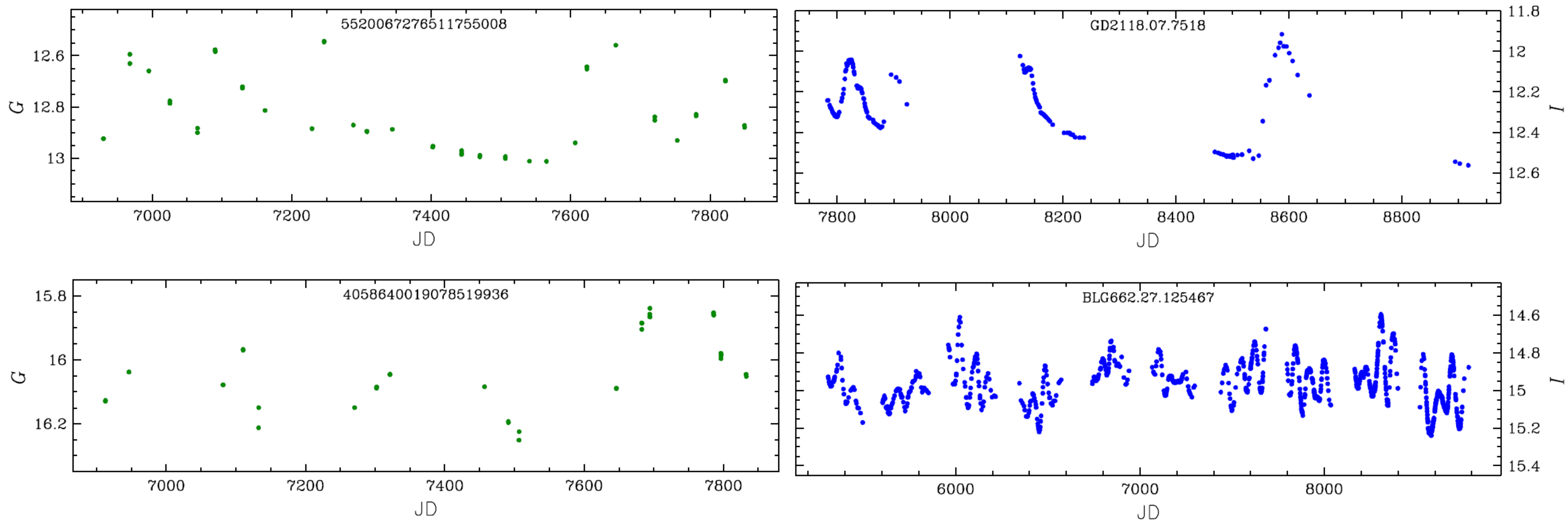

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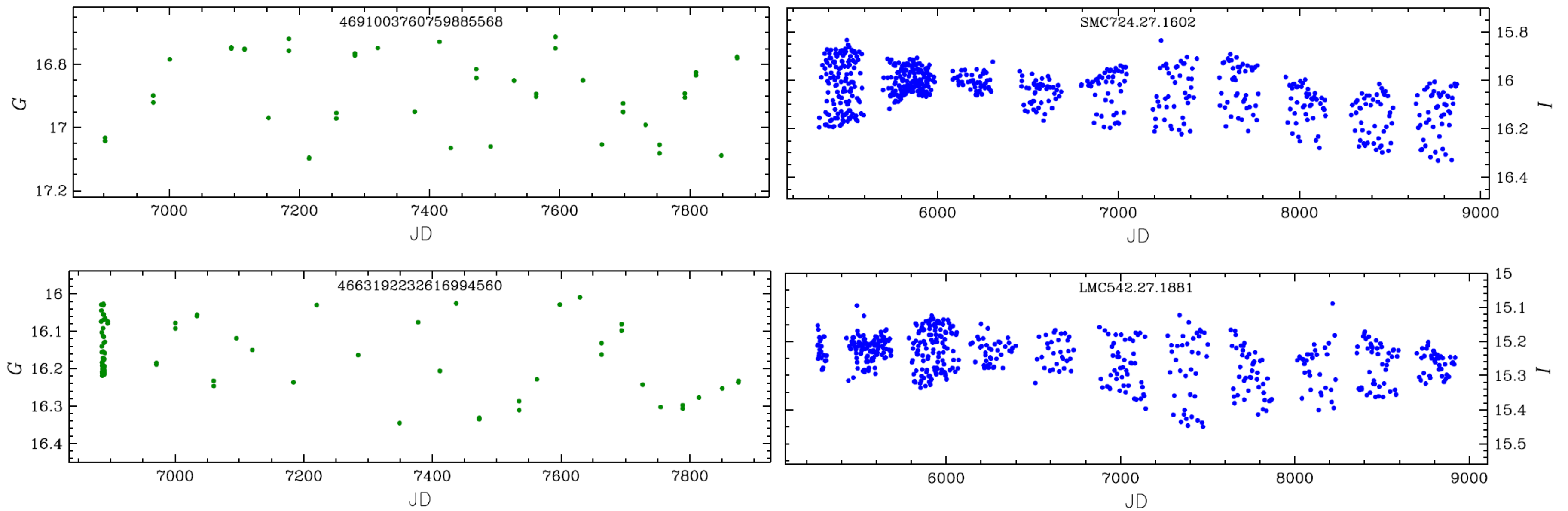
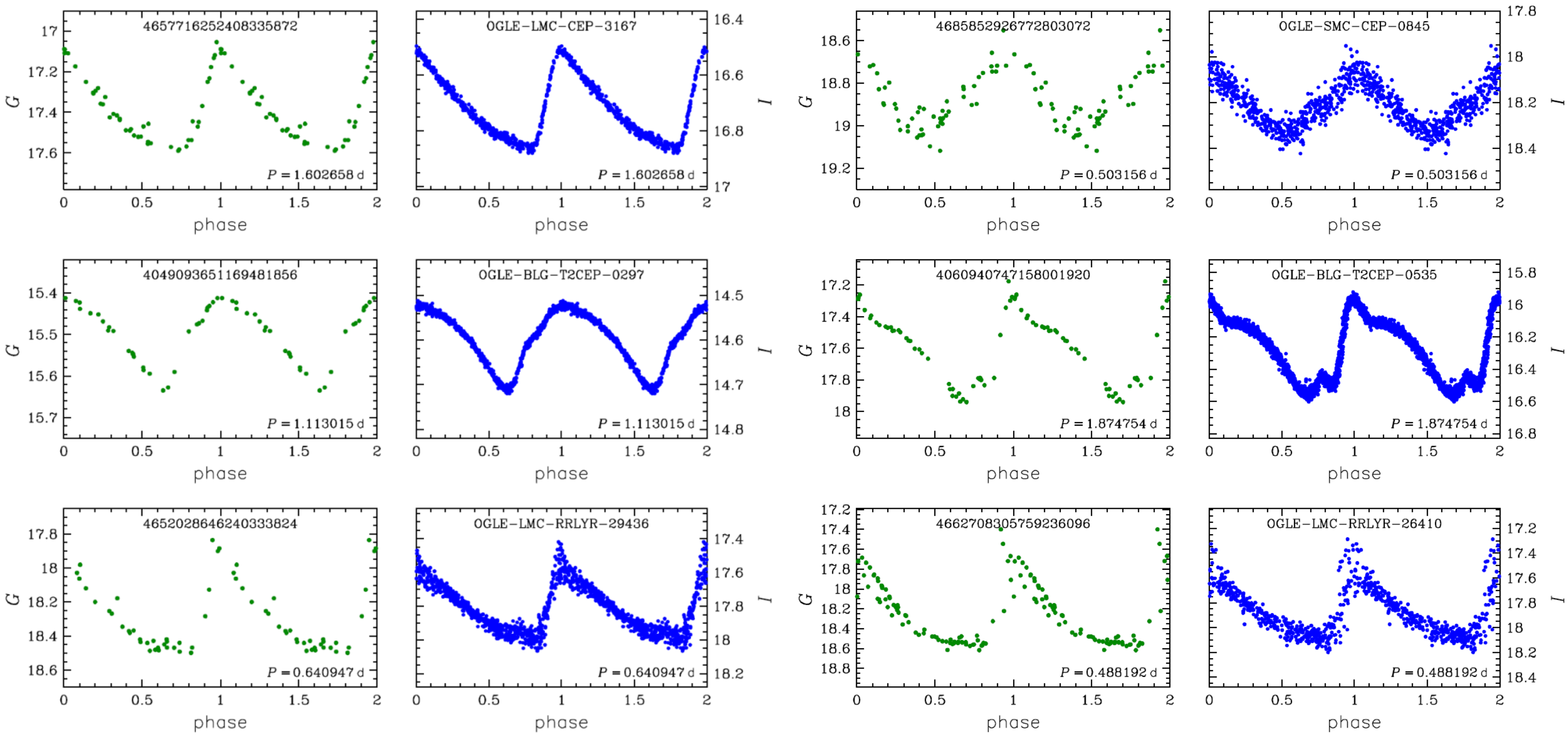
↓ Gaia ↓ ↓ OGLE ↓



Cepheids from Gaia and OGLE

5% of Gaia's classical Cepheids, 15% of type II Cepheids, and 50% of anomalous Cepheids have a different classification in the OCVS.

↓ Gaia ↓ ↓ OGLE ↓ ↓ Gaia ↓ ↓ OGLE ↓



RR Lyrae stars from Gaia and OGLE

Clementini et al. (2022):

"To build our custom catalogue, we primarily used the OGLE catalogues for RR Lyrae stars as reference, which have a high completeness and purity for the LMC, SMC, and the MW bulge and disc"

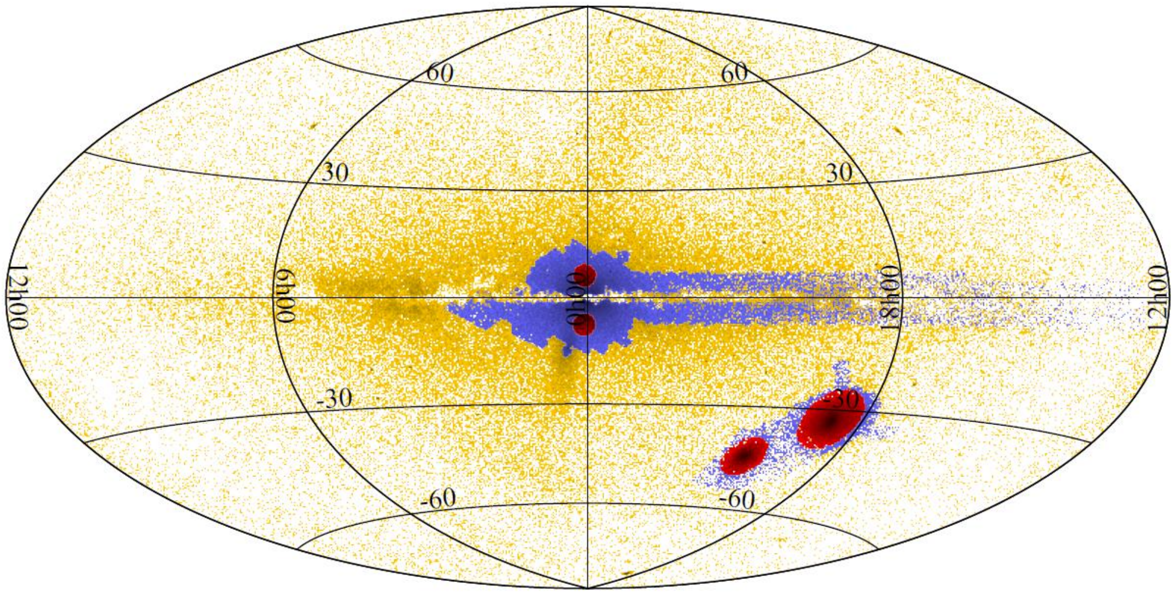


Fig. D.1. Regions (red areas) in the footprint of the OGLE-IV RR Lyrae stars (violet symbols) that we used to estimate the completeness, contamination, and percentage of new discoveries of the final clean catalogue of DR3 RR Lyrae stars (orange symbols) in the LMC, SMC, and in the Galactic bulge. For the LMC, we used a circular region with 8.3° in radius centred at (RA=81.5° Dec=−70.1°), for the SMC a region with 5.6° in radius centred at (RA=13.2°, Dec=−72.9°), and for the MW bulge, we used two regions with 3° degree in radius centred at (RA=274.7°, Dec=−31.8°; bulge-up) and (RA=261.2°, Dec=−24.9°; bulge-down).

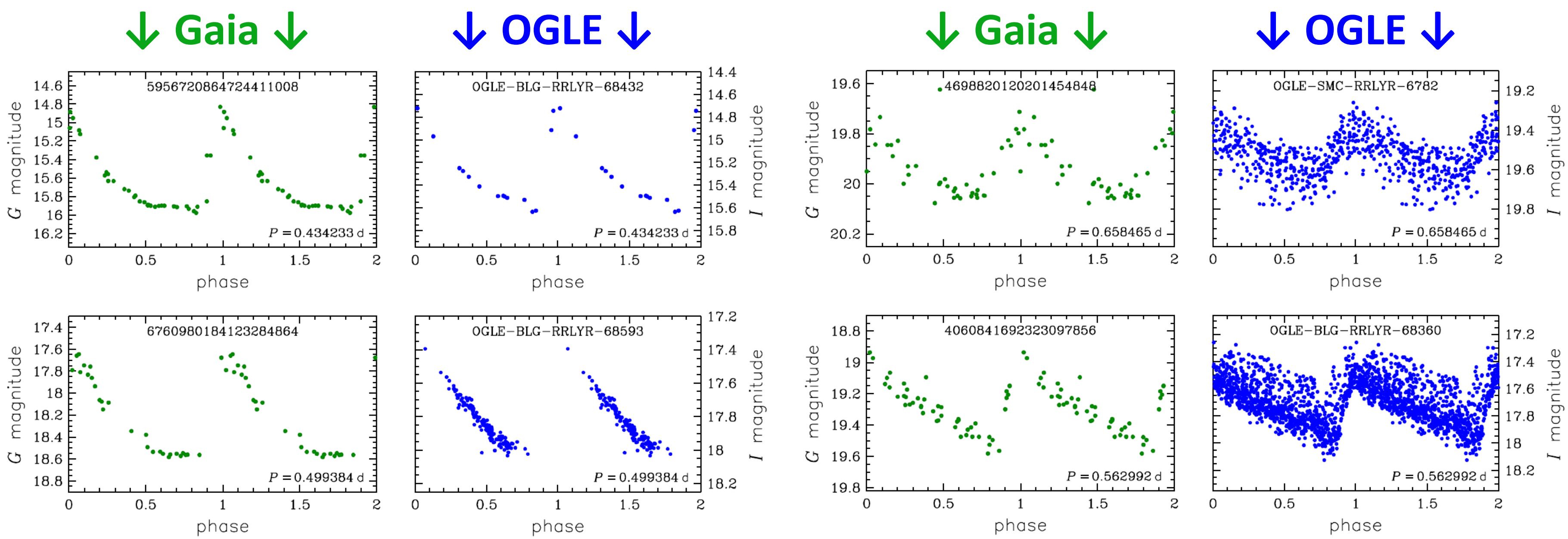
RR Lyrae stars from Gaia and OGLE

Clementini et al. (2022): 270,905 RR Lyrae stars in the Gaia DR3 catalog

148,287 of them are observed by the OGLE survey

101,984 of them have been included in the OCVS

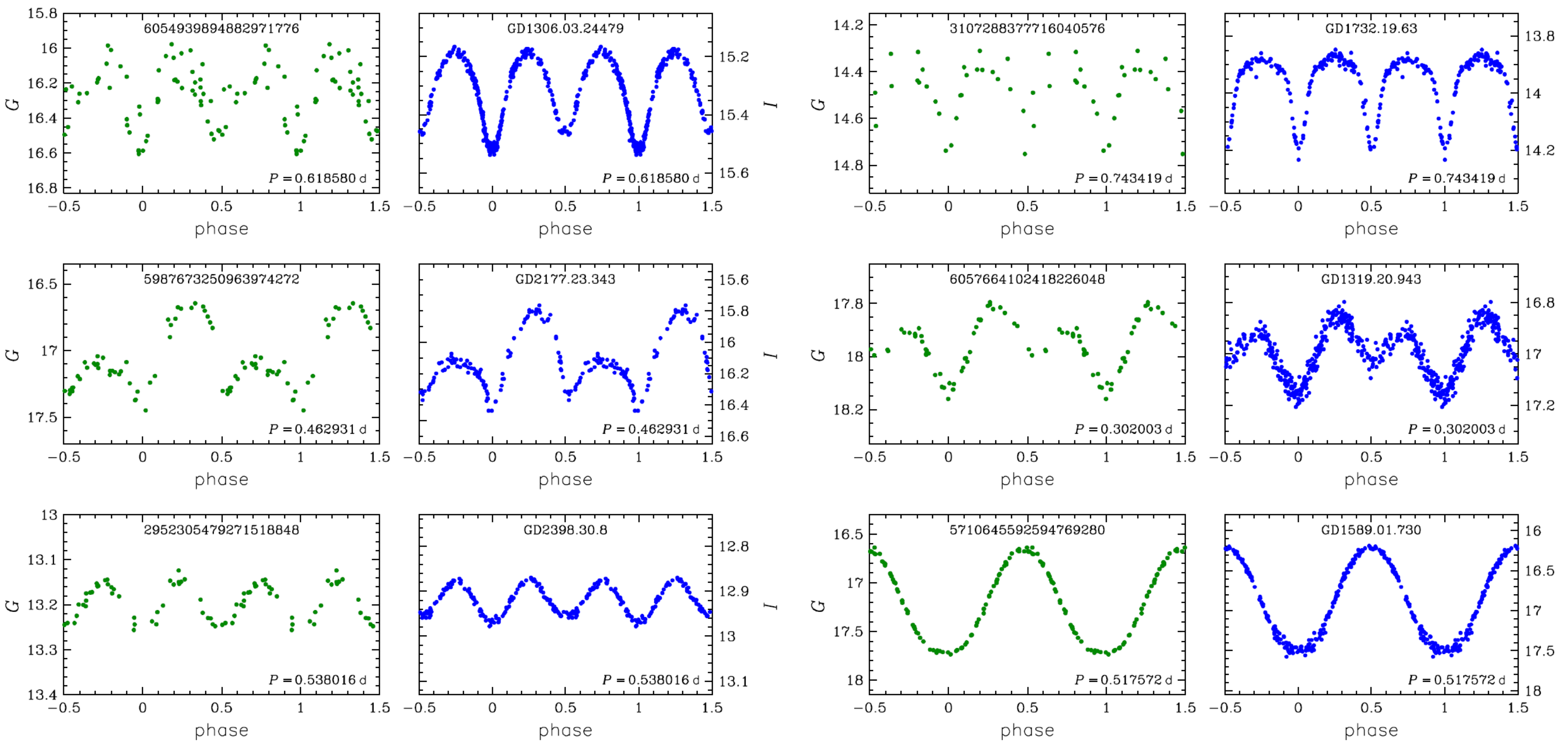
2563 Gaia RR Lyrae stars were (or will be) added to the OCVS



RR Lyrae stars from Gaia and OGLE

The Gaia catalog of RR Lyrae stars contains about 300 binary systems.

↓ Gaia ↓ ↓ OGLE ↓ ↓ Gaia ↓ ↓ OGLE ↓

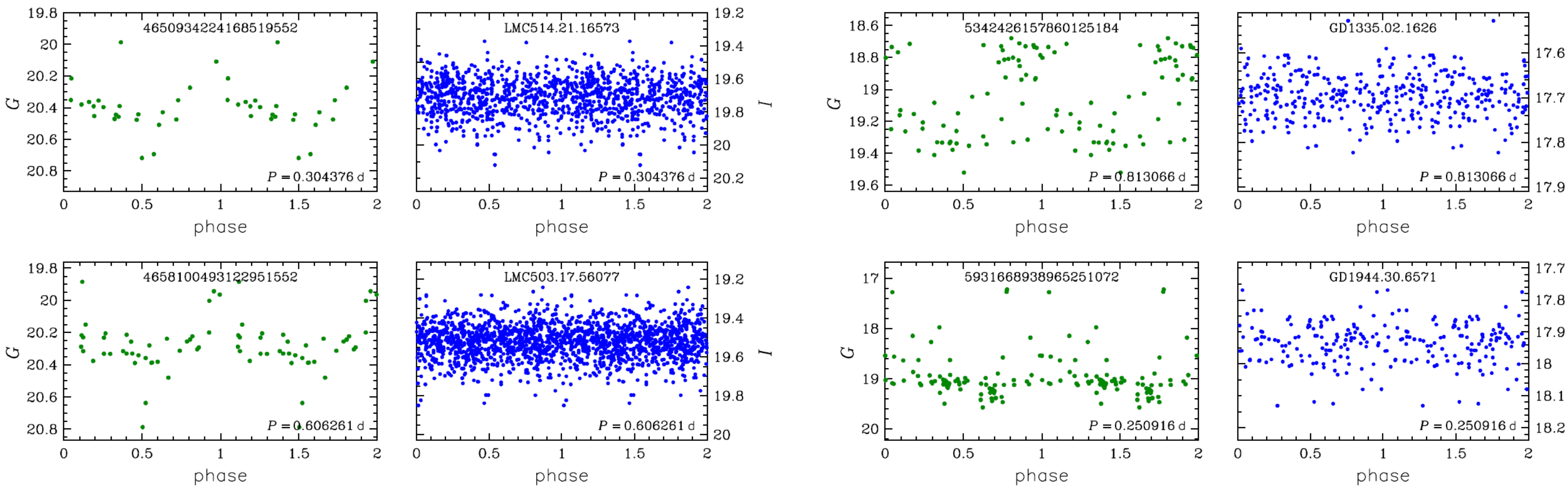


RR Lyrae stars from Gaia and OGLE

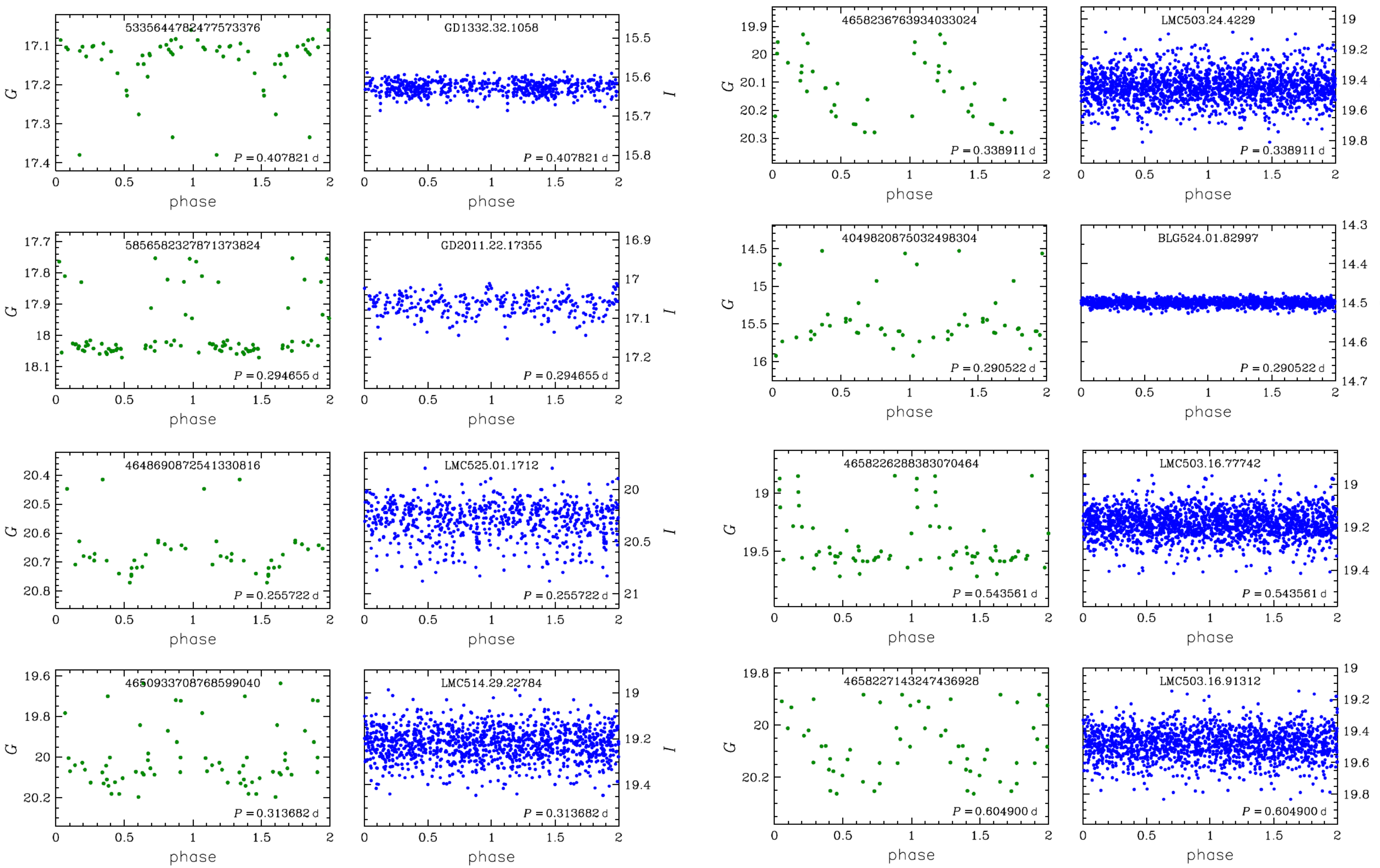
Over 40,000 objects classified as RR Lyrae stars <u>do not show</u> clear periodic variability.

Contamination rate: ~28%.

↓ Gaia ↓ ↓ OGLE ↓ ↓ Gaia ↓ ↓ OGLE ↓



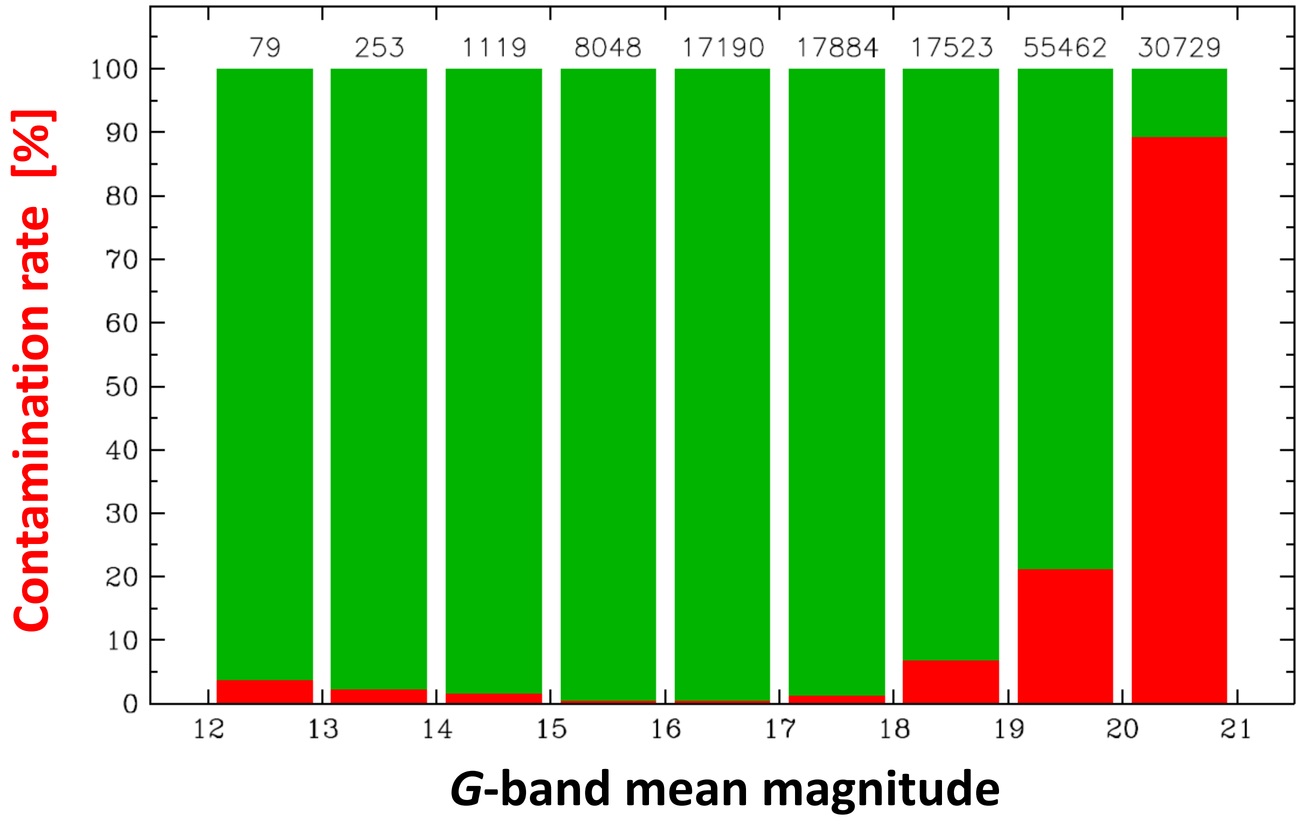
RR Lyrae stars from Gaia and OGLE



RR Lyrae stars from Gaia and OGLE

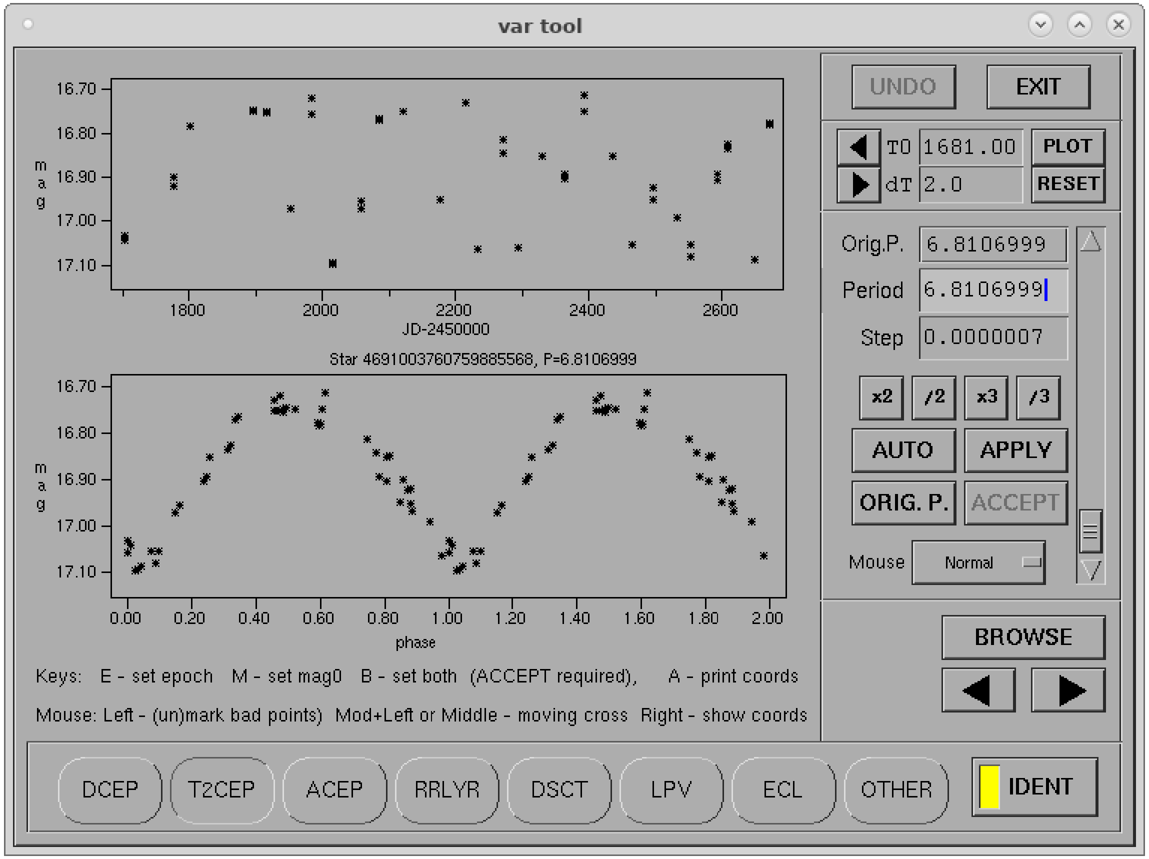
Contamination rate vs. brightness for RR Lyrae stars

148,287 Gaia RR Lyrae stars observed by OGLE



Visual inspection of the light curves

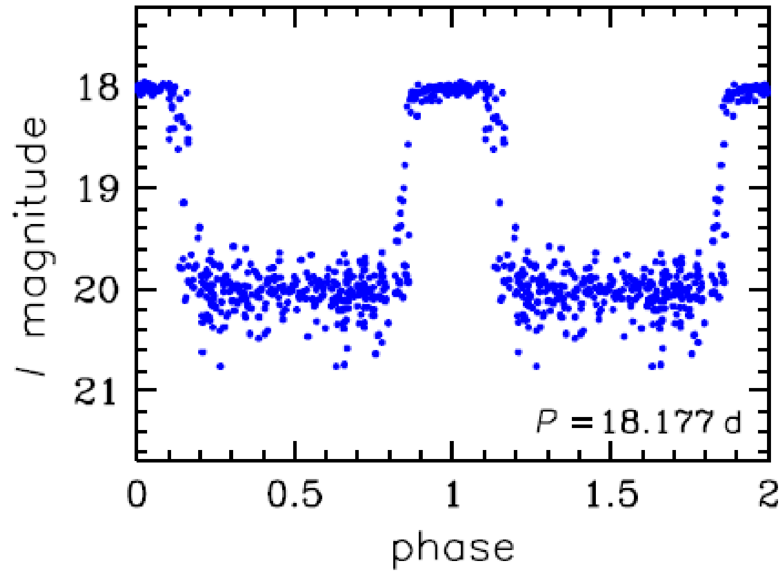
Vartool (by Michał Szymański)



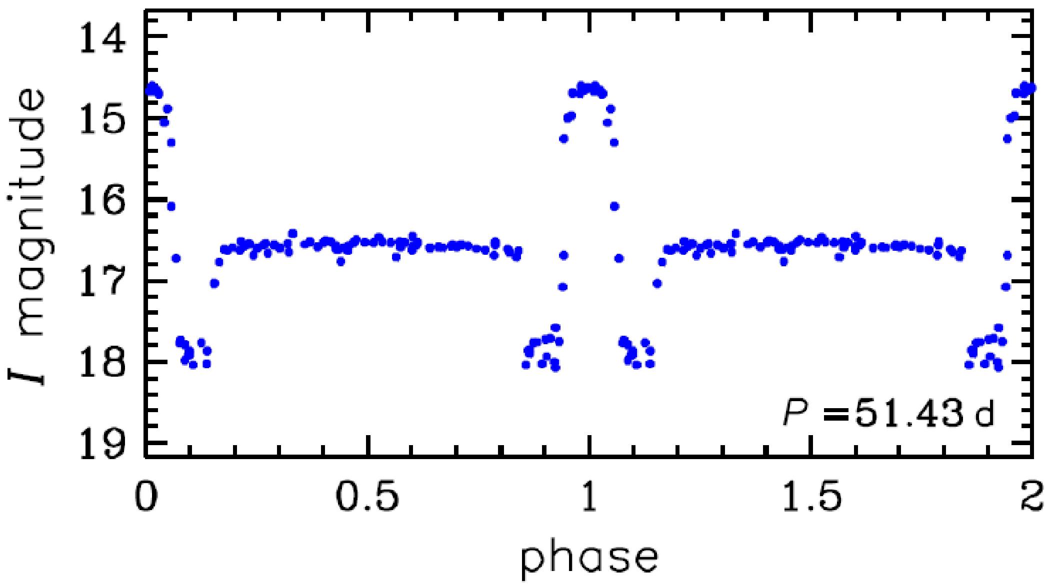
CONCLUSIONS

- The Gaia and OGLE catalogs of variable stars mutually influence each other, enhancing the completeness and purity of both collections.
- The newly discovered Gaia variables significantly contribute to the expansion of the OGLE Collection of Variable Stars, both before and after the publication of its subsequent parts.
- The OGLE variable stars are used for:
  - Training the Gaia machine learning algorithms,
  - Evaluating the Gaia classification,
  - Estimating the completeness and contamination rates of the Gaia catalog,
  - Testing the reliability of the measured periods and amplitudes of variable stars.

What is it?



What is it?



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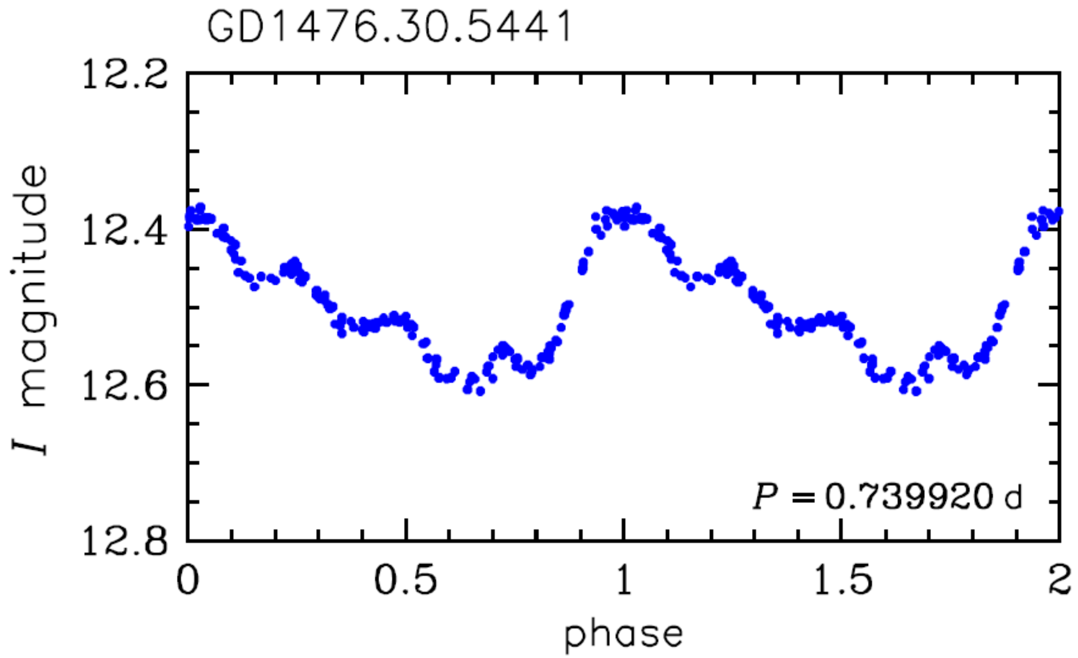

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