CCDPhot
an engine behind CPCS 2.0

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10th OPTICON Gaia Science Alerts Workshop

Catania, 18-20.12.2019

Genesis

Genesis

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+ Przemysław Bruś (University of Wrocław)

Zbigniew Kołaczkowski

Genesis

CPCS 2.0 = CPCS 1.0 + CCDPhot
+ Web Interface

Contrib. Astron. Obs. Skalnaté Pleso **49**, 125 – 131, (2019)

CPCS 2.0 – new automatic tool for time-domain astronomy

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Received: November 15, 2018; Accepted: February 25

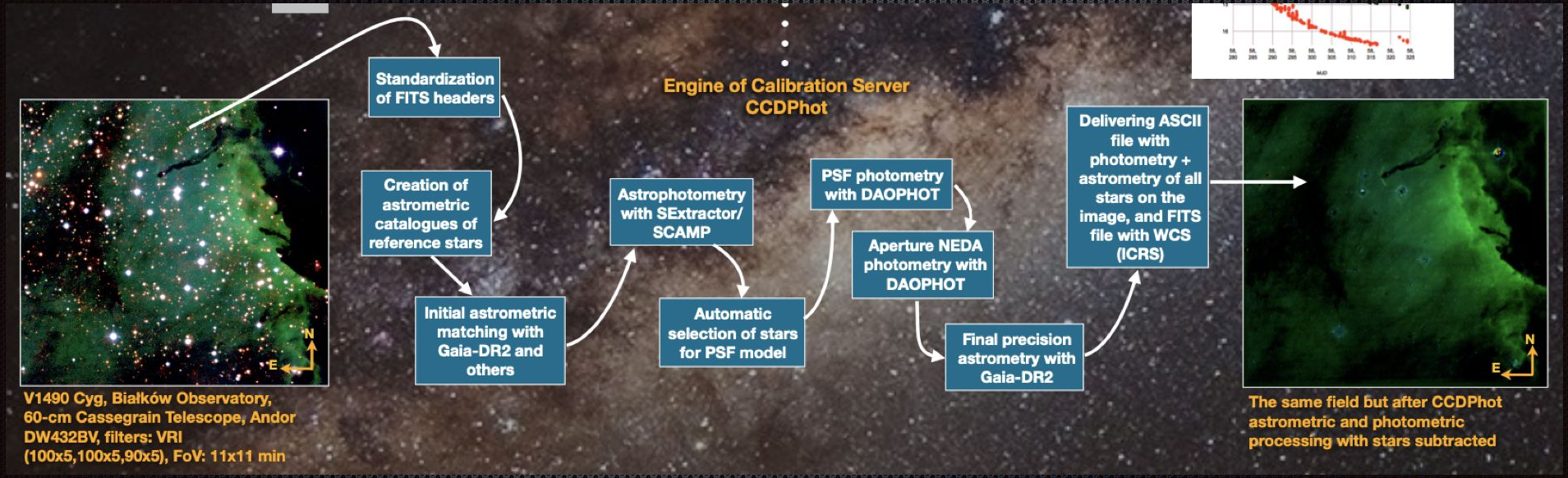
Abstract. The Cambridge Photometric Calibration Server (CPCS) has been designed to respond to the need of automated rapid photometric data calibration and dissemination for transient events, primarily from *Gaia* space mission. The Calibration Server has been in operation since 2013 and has been used to calibrate around 50 000 observations of hundreds of transients. We present the status of the tool and demonstrate improvements made in the newest version, which is enhanced with build-in profile photometric measurement. After tests and implementation on the dedicated website, the new Server will be able to combine imaging data from multiple telescopes and is intended to provide science-ready photometric data within minutes from observations. We also present the OPTICON-supported network of telescopes for *Gaia* alerts follow-up.

Key words: time-domain astronomy – photometry – automatic data reduction and calibration – *Gaia* Science Alerts

What does it do?

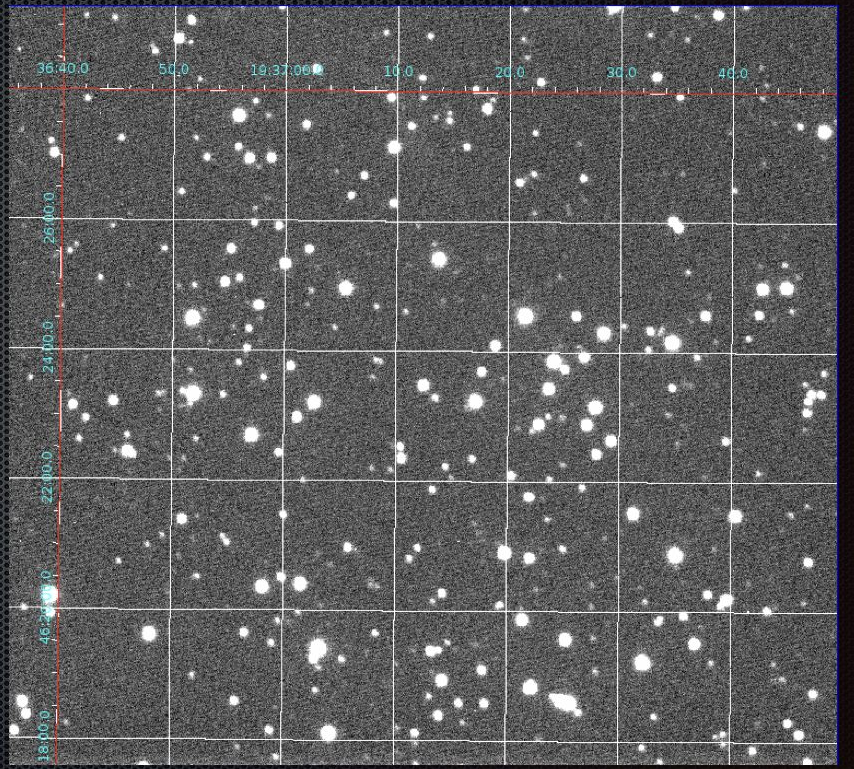
- Aperture photometry
- Aperture photometry with neighbours subtraction
- SExtractor photometry
- PSF photometry
- Astrometry with Gaia DR2 data
- Calculating additional parameters (background level, seeing…)

How does it work?

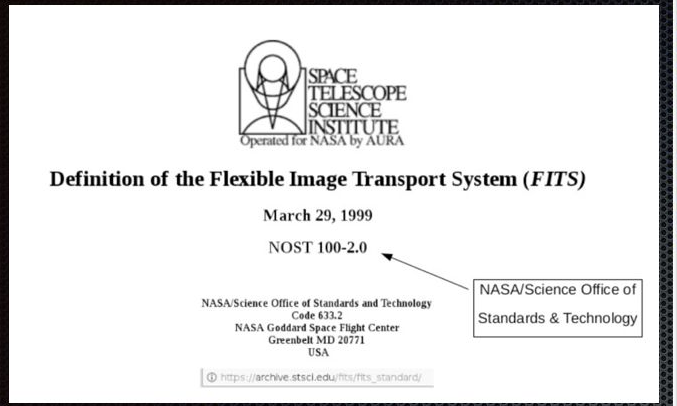


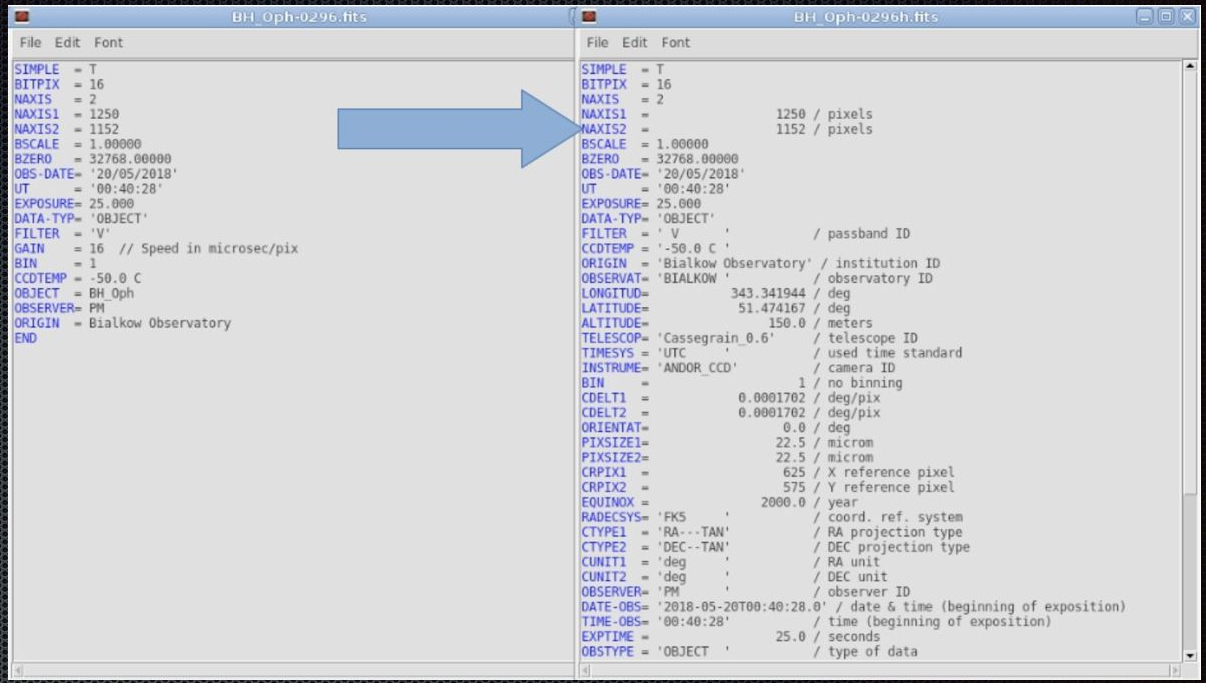
Output data

```
#   1 NUMBER                  Running object number
#   2 ALPHA_J2000             Right ascension of centroid (J2000)                    [hour:min:sec]
#   3 DELTA_J2000             Declination of centroid (J2000)                        [deg:arcmin:arcsec]
#   4 X_PSF                   Centroid position estimate along x                     [pixel]
#   5 Y_PSF                   Centroid position estimate along y                     [pixel]
#   6 MAG_PSF                 Profile magnitude  (allstar)                           [mag]
#   7 MAGERR_PSF              Error of profile magnitude                             [mag]
#   8 MAG_APER                Aperture magnitude  (daophot)                          [mag]
#   9 MAGERR_APER             Error of aperture magnitude                            [mag]
#  10 MAG_AUTO                Kron-like elliptical aperture magnitude (sextractor)   [mag]
#  11 MAGERR_AUTO             RMS error for AUTO magnitude                           [mag]
  63 19:37:03.2274 46:19:25.618  467.977  181.930  12.2624   0.0022  12.2370   0.0011   9.2255   0.0011
  16 19:36:39.3165 46:20:13.553   64.730  263.498  12.3627   0.0049  12.3500   0.0012   9.3617   0.0012
  87 19:37:21.4739 46:24:33.754  779.950  682.144  12.4234   0.0032  12.3990   0.0012   9.4127   0.0012
  48 19:37:34.6222 46:24:09.833 1001.323  641.615  12.6559   0.0017  12.6390   0.0014   9.6527   0.0013
  27 19:36:51.7985 46:24:29.961  279.428  679.876  12.6621   0.0033  12.6510   0.0014   9.6653   0.0013
 110 19:36:51.9183 46:23:20.402  280.416  566.416  12.7283   0.0024  12.7060   0.0014   9.7081   0.0014
 115 19:37:32.1020 46:19:14.920  955.465  160.975  12.7928   0.0017  12.7770   0.0015   9.7850   0.0014
 104 19:37:34.9758 46:20:53.723 1005.092  321.790  12.8048   0.0019  12.7910   0.0015   9.8022   0.0015
 125 19:37:04.2020 46:18:07.660  483.356   54.640  12.8064   0.0015  12.7820   0.0015   9.7946   0.0014
 123 19:37:29.2520 46:29:21.700  914.400 1150.684  12.8888   0.0112  -9.9999  -9.9999  -9.9999  -9.9999
 121 19:37:24.0818 46:23:52.080  823.413  613.877  12.8990   0.0061  12.8790   0.0016   9.8672   0.0015
 134 19:37:13.7638 46:25:25.670  650.624  767.754  12.9466   0.0034  12.9280   0.0016   9.9462   0.0016
 137 19:37:25.6328 46:18:36.709  845.778   99.386  13.0081   0.0026  12.9830   0.0017  -9.9999  -9.9999
 147 19:37:17.0926 46:23:14.633  705.078  553.660  13.0702   0.0032  13.0430   0.0017  10.0551   0.0017
  81 19:36:57.1301 46:22:42.441  367.821  503.774  13.0950   0.0028  13.0780   0.0018  10.0958   0.0017
  88 19:37:02.6855 46:23:13.025  462.004  552.896  13.1833   0.0037  13.1670   0.0019  10.1832   0.0018
 158 19:37:05.4606 46:24:58.430  510.268  724.416  13.2020   0.0028  13.1850   0.0019  10.2023   0.0018
 162 19:36:48.1522 46:19:37.921  213.468  204.076  13.2029   0.0025  13.1800   0.0019  10.1969   0.0018
  91 19:36:55.8081 46:27:37.544  349.779  985.196  13.2401   0.0014  13.2220   0.0020  10.2414   0.0018
 174 19:37:28.5169 46:24:18.276  898.501  656.073  13.2860   0.0031  13.2620   0.0020  10.2791   0.0019
 180 19:37:19.7673 46:20:55.073  748.449  325.739  13.3019   0.0035  13.2730   0.0020  10.2863   0.0019
 179 19:37:27.7862 46:23:10.037  885.380  544.887  13.3313   0.0040  13.3000   0.0021  10.3139   0.0019
 186 19:36:58.1820 46:20:22.492  383.564  275.374  13.3971   0.0031  13.3710   0.0022  10.3870   0.0020
```



FITS headers





FITS he

Definition of the

# DESCRIPTION	KEYWORD (in FITS)	KEYWORD (standard)	FORMAT	VALUE(s)	COMMENT	CONF FLAG (True/False)
OBSERVATORY						
Observatory	-	OBSERVAT	str	PT5M_La_Palma	observatory ID	False
Observer	-	OBSERVER	str	Liam_K_Hardy	observer ID	False
Observatory longitude [deg]	-	LONGITUD	float	28.76075	deg	False
Observatory latitude [deg]	-	LATITUDE	float	-17.88144	deg	False
Observatory altitude [m]	-	ALTITUDE	float	2383	meters	False
Telescope	TELE	TELESCOP	str	Dall-Kirkham_0.5	telescope ID	False
Organization	ORIGIN	ORIGIN	str	PT5M	institution ID	False
TIME (start of exposition)						
Time system	-	TIMESYS	str	UTC	used time standard	False
Date	DATE-OBS	DATE-OBS	yyyy/mm/dd	-	date of exposure	False
Time	-	TIME-OBS	hh:mm:ss	-	time of exposure	False
Julian date	-	JD	float	-	middle of exposure	False
Exposition time	EXPOSURE	EXPTIME	float	-	seconds	False
INSTRUMENT						
Instrument name	INSTRUME	INSTRUME	str	QSI_532	camera ID	False
Detector X size [pix]	NAXIS1	NAXIS1	int	1092	pixels	True
Detector Y size [pix]	NAXIS2	NAXIS2	int	736	pixels	True
Binning	XBINNING	BIN	int	2	binning-2	False
Instr. mode, readout speed	-	READTIME	int	3000	ns/pix	False
Gain	EGAIN	GAIN	float	1.3	e/ADU	True
Read-out noise	-	RDNOISE	float	8 : 11 & 14 ADU for 2x2 & 3x3 binning respectively		True
Saturation limit	-	SATURATE	int	65535	ADU	True
Pixel scale along x-axis	-	CDELT1	float	0.000077778	deg/pix (for 1x1 bin)	True
Pixel scale along y-axis	-	CDELT2	float	0.000077778	deg/pix (for 1x1 bin)	True
Position angle	-	ORIENTAT	float	0.0	deg	False
Image type	TYPE	OBSTYPE	str	SCIENCE | OBJECT	type of data	True
Filters	FILTER	FILTER	str	B, V, R, I	passband ID	True
Pixel size along x-axis	XPIXSZ	PIXSIZE1	float	13.6	microm	False
Pixel size along y-axis	YPIXSZ	PIXSIZE2	float	13.6	microm	False
X reference pixel (center)	CRPIX1	CRPIX1	int	546	X reference pixel	True
Y reference pixel (center)	CRPIX2	CRPIX2	int	368	Y reference pixel	True
OBJECT & WCS						
Object name	OBJECT	OBJECT	str	-	object name	False
Epoch of coord. system	EQUINOX	EQUINOX	float	2000.0	year	False
Coord. system	RADECSYS	RADECSYS	str	FK5	coord. ref. system	False
Coord. type projection RA	CTYPE1	CTYPE1	str	RA---TAN	RA projection type	False
Coord. type projection DEC	CTYPE2	CTYPE2	str	DEC--TAN	DEC projection type	False
Coord. unit RA	-	CUNIT1	str	deg	RA unit	False
Coord. unit DEC	-	CUNIT2	str	deg	DEC unit	False
Right Ascension	RA2	RA	float	-	deg	False
Declination	DEC2	DEC	float	-	deg	False
Right Ascension WCS	CRVAL1	CRVAL1	float	-	deg	False
Declination WCS	CRVAL2	CRVAL2	float	-	deg	False

Moving parts

- SCAMP (Bertin)
- SExtractor (Bertin)
- **DAOPHOT** (Stetson)
- WCS Tools (Harvard)
- IRAF / PyRAF (NOAO)
- astropy
- *VARTOOLS (Princeton)*

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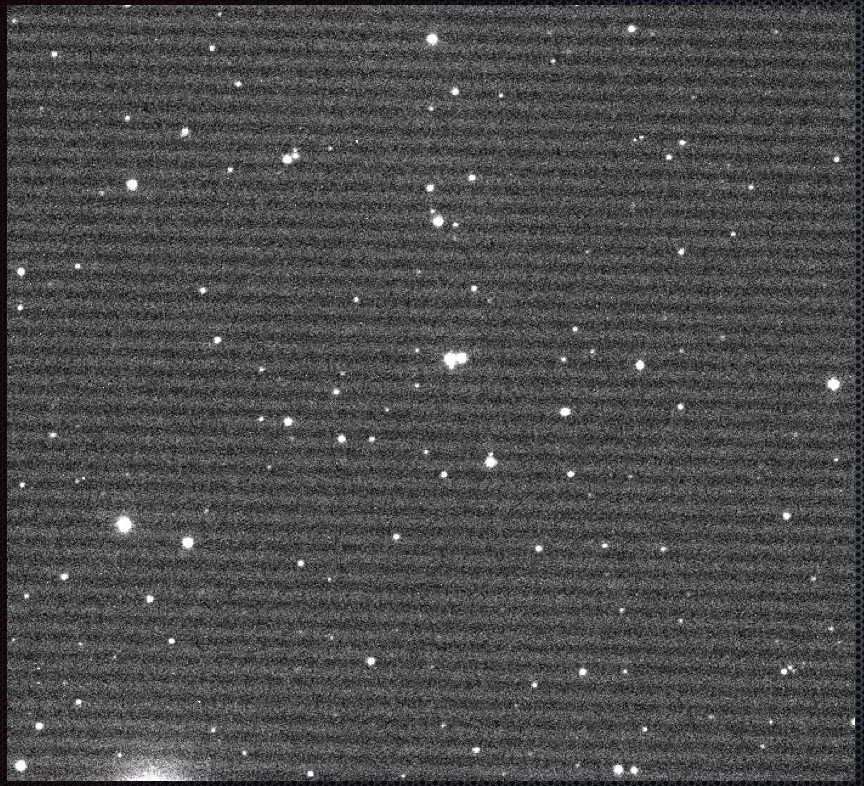
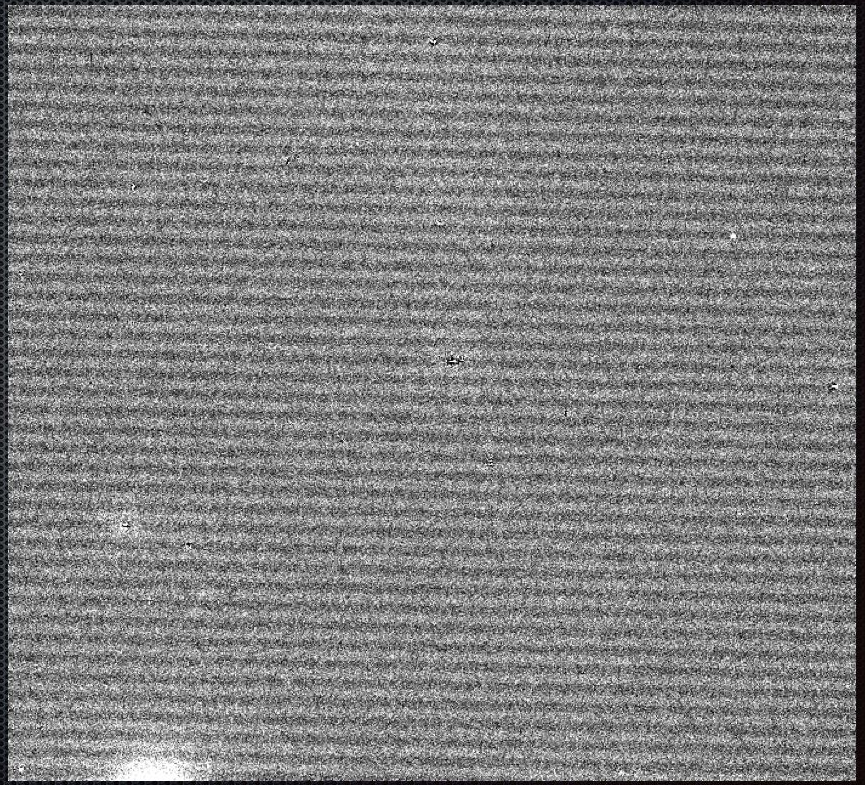
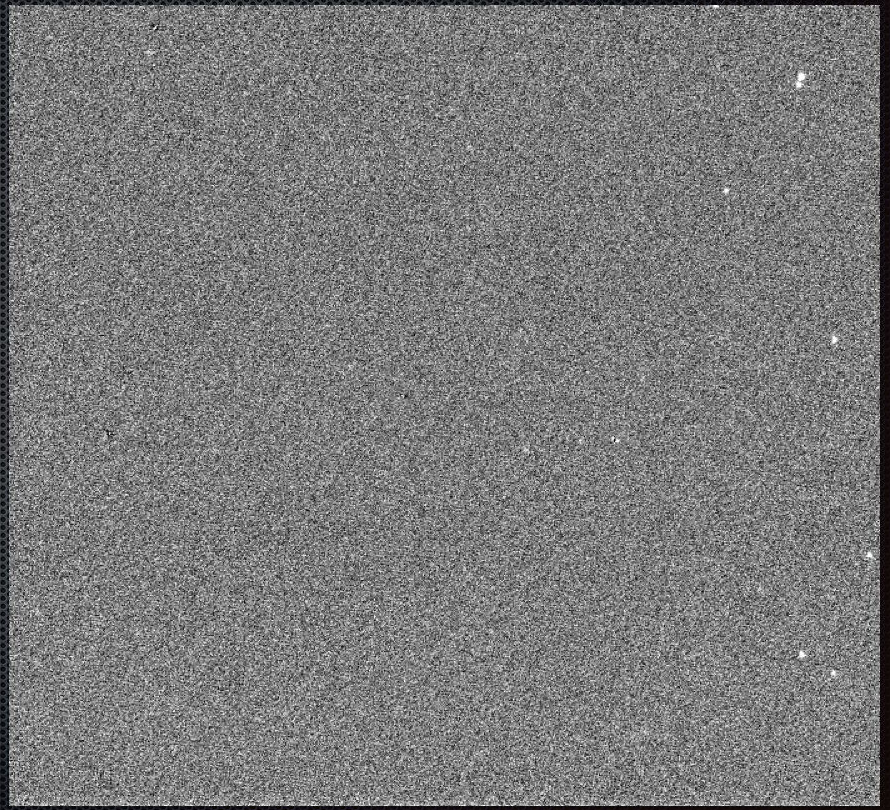
```
[INFO]    : File    1 /    1
[INFO]    : Workflow for NGC6811-0015-bdtfh
[PROCESS] : Initial astrometry
            Detected (SExtracted) stars     : 280 (278)
            Reference catalogue (CDS)       : URAT-1
            Matching field with catalogue   : done! 161 sources (contrast: 22.600 > 5.0)
            Creating a coordinate grid      : done!
[PROCESS] : SExtractor workflow
            All objects / Stats based on    : 336 / 7 stars
            Object altitude / Airmass       : 50.51 deg / 1.2957
            Background level                : 6.87 ADU
            Average seeing                  : 4.539 arcsec
            Performing photometry           : done!
[PROCESS] : Checking astrophotometry        : ok!
[PROCESS] : DAOPHOT/ALLSTAR photometry
            Looking for input data          : found!
            Total number of objects         : 2032
            Stars selected for PSF fitting  : 57
            Looking for stars               : done!
            Aperture photometry (for PSF)   : done!
            Preparing PSF stars             : 56 stars
               > Choosing PSF method        : variable
            Preliminary PSF estimation      : done! Chi: 0.0765 / Roundness: 1.06
            PSF fitting (iter: 1)
               > Choosing PSF method        : variable
               > Calculating PSF            : done! Chi: 0.0765 / Roundness: 1.06
            PSF fitting (iter: 2)
               > Calculating PSF            : done! Chi: 0.0754 / Roundness: 1.05
               > Fitting PSF model          : done!
            PSF fitting (iter: 3)
               > Calculating PSF            : done! Chi: 0.0737 / Roundness: 1.05
               > Fitting PSF model          : done!
            PSF fitting (iter: 4 & final)
               > Calculating PSF            : done! Chi: 0.0730 / Roundness: 1.05
               > Subtracting stars          : done!
            Performing final calculations
               > DAOPHOT group photometry   : done!
               > ALLSTAR group photometry   : done!
            Preparing PSF results           : done!
            NEDA aperture photometry        : done!
[OK]      : Photometry successful.
[PROCESS] : Processing files...dxy...axy...nsd...ncd...ida...ok!
[PROCESS] : Preparing auxiliary files...ok!
[PROCESS] : Preparing results files...ok!
[PROCESS] : Performing precision astrometry
            RA / Dec fit rms [arcsec]       : 0.0384 / 0.0455
            Field center (SExtractor/SCAMP) : RA=19:37:12.334 Dec=+46:23:27.53 Epoch=J2000
            Field center (DAOPHOT/ccmap)    : RA=19:37:12.340 Dec=+46:23:27.38 Epoch=J2000
            RA & DEC differences [arcsec]   : 0.067 & -0.144
[PROCESS] : Performing Gaia DR1/DR2 astrometry
            Number of Gaia reference stars  : 364
            Using 4th degree polynomial fit : done!
            RA / Dec fit rms [arcsec]       : 0.0305 / 0.0493
            Field center (Gaia/ccmap)       : RA=19:37:12.798 Dec=46:23:15.80 Epoch=2015.5
            PyRAF astrometry with Gaia reference cat. in file: NGC6811-0015-bdtfh.gphot.

============================================================
  All results stored in the RESULTS directory.
  The parameters of reduction process can be found in file:
  RESULTS/test_NGC6811_phot.log
============================================================

3.2G    RESULTS
```

Examples

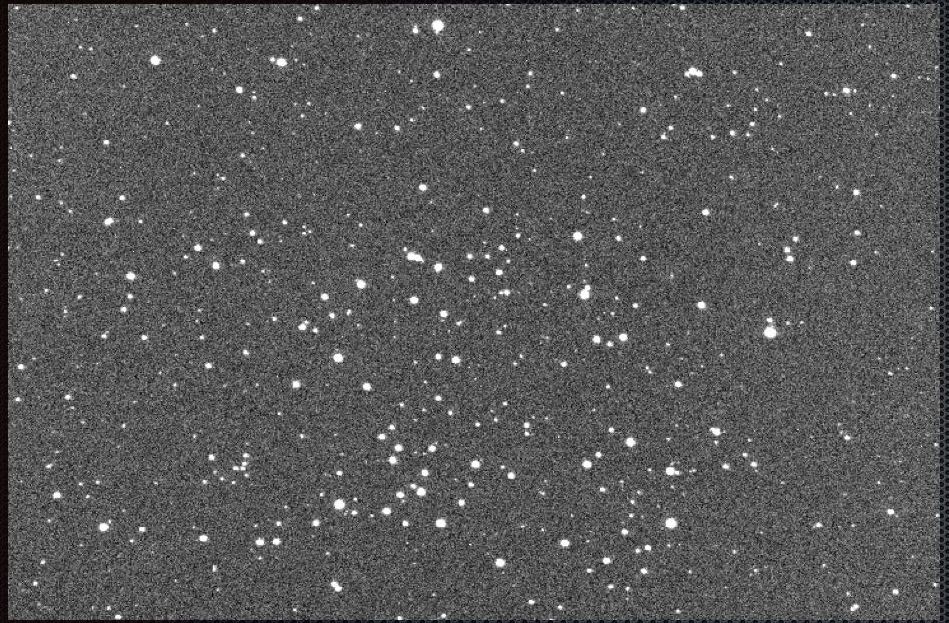


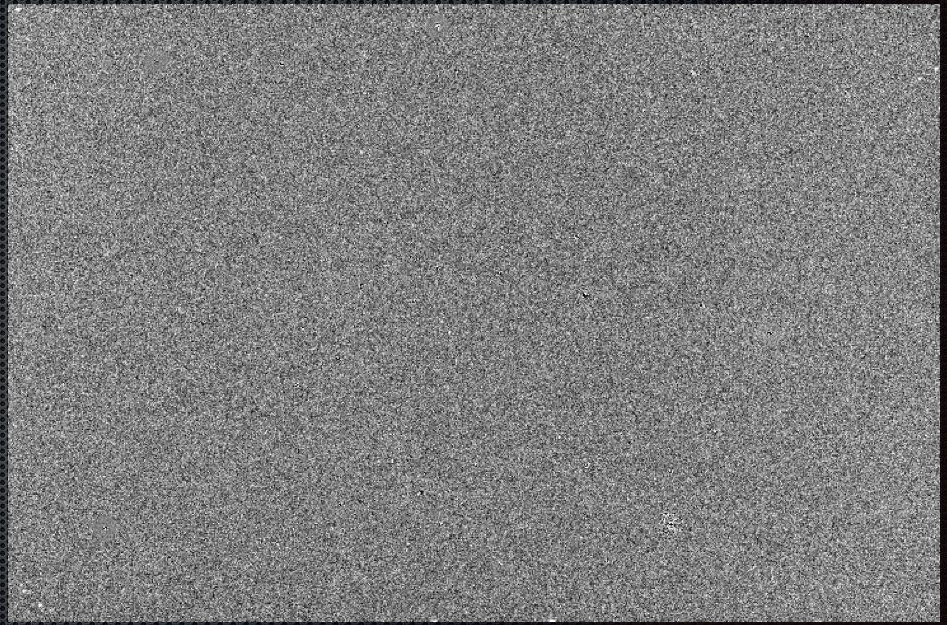


Examples



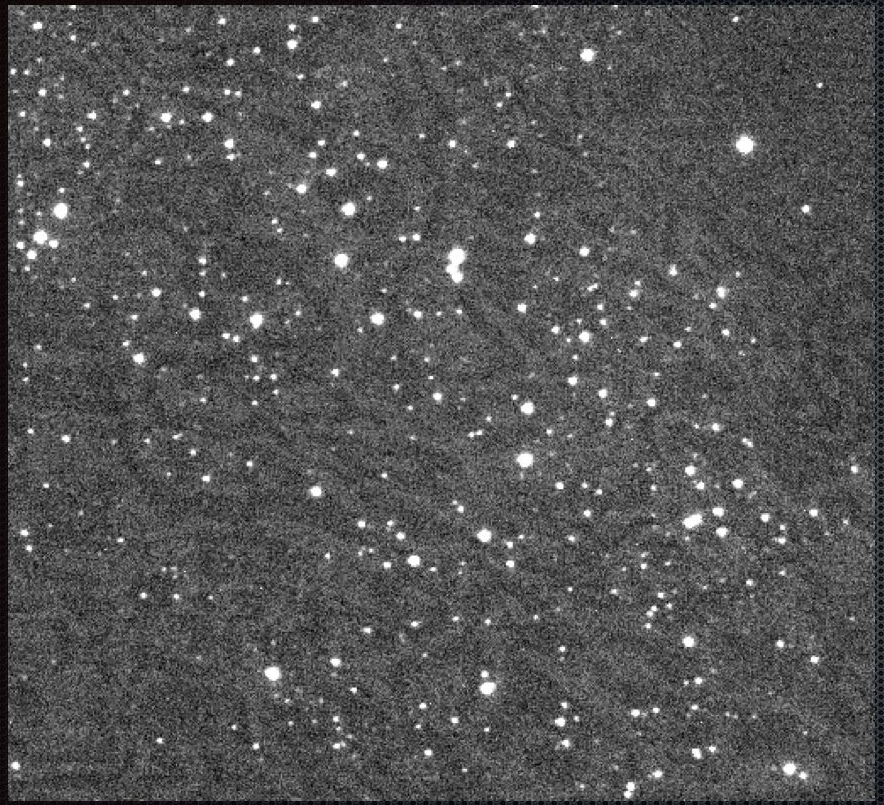
Examples

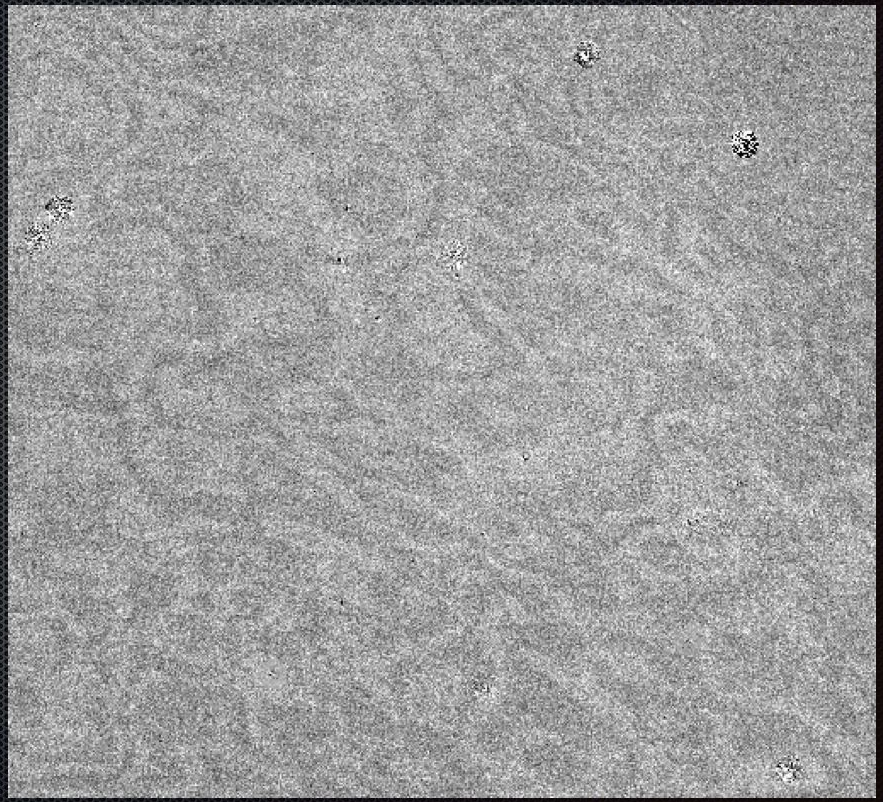




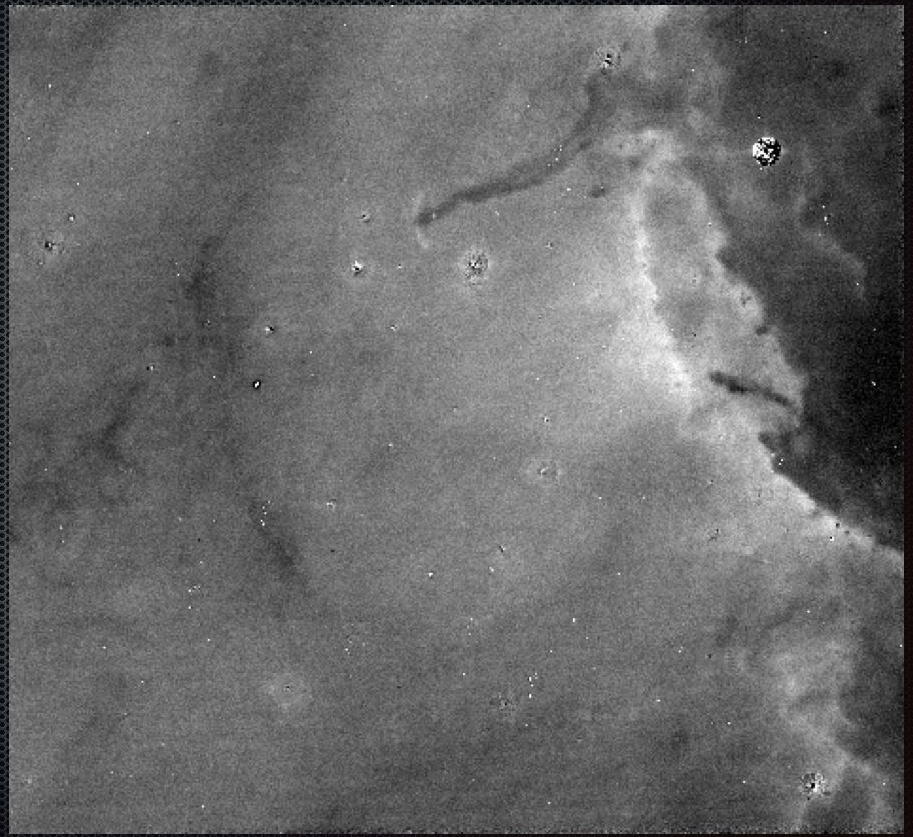
Examples

Examples





Examples



Examples

Examples

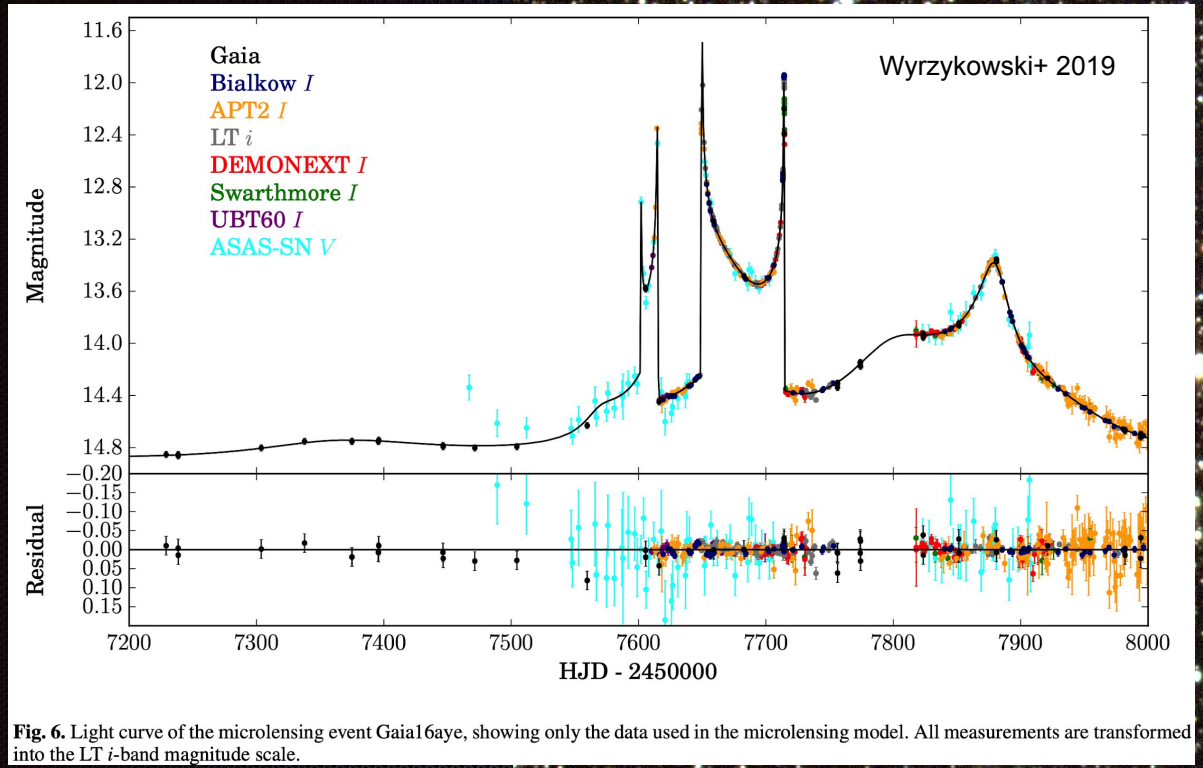
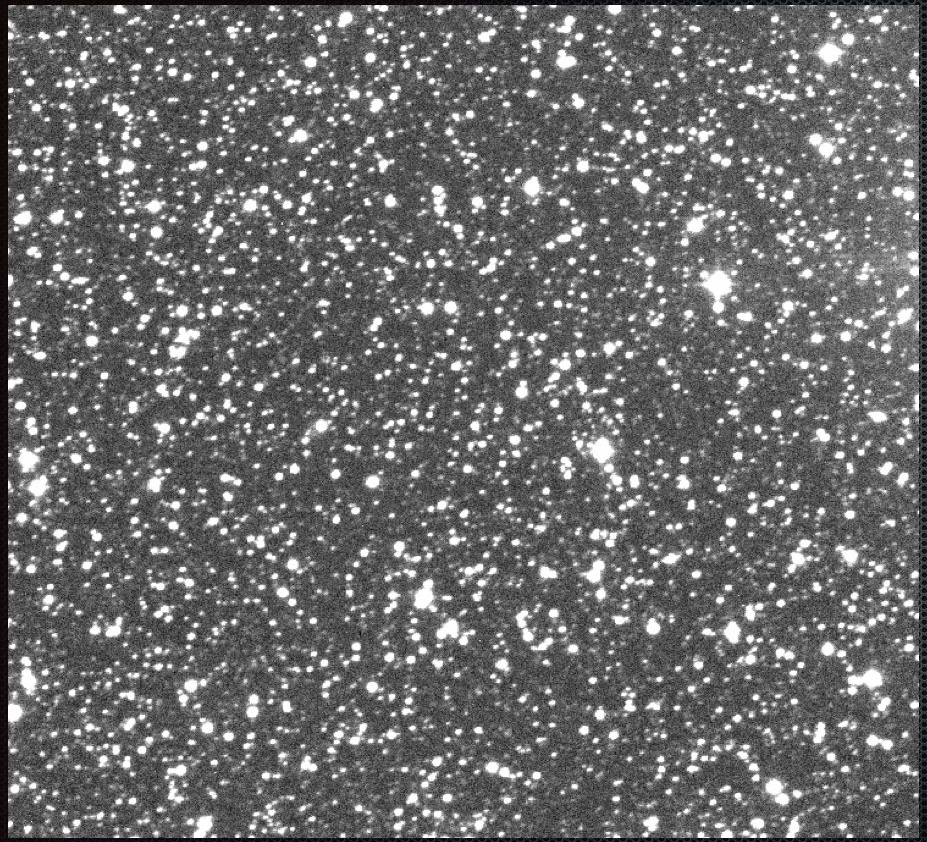
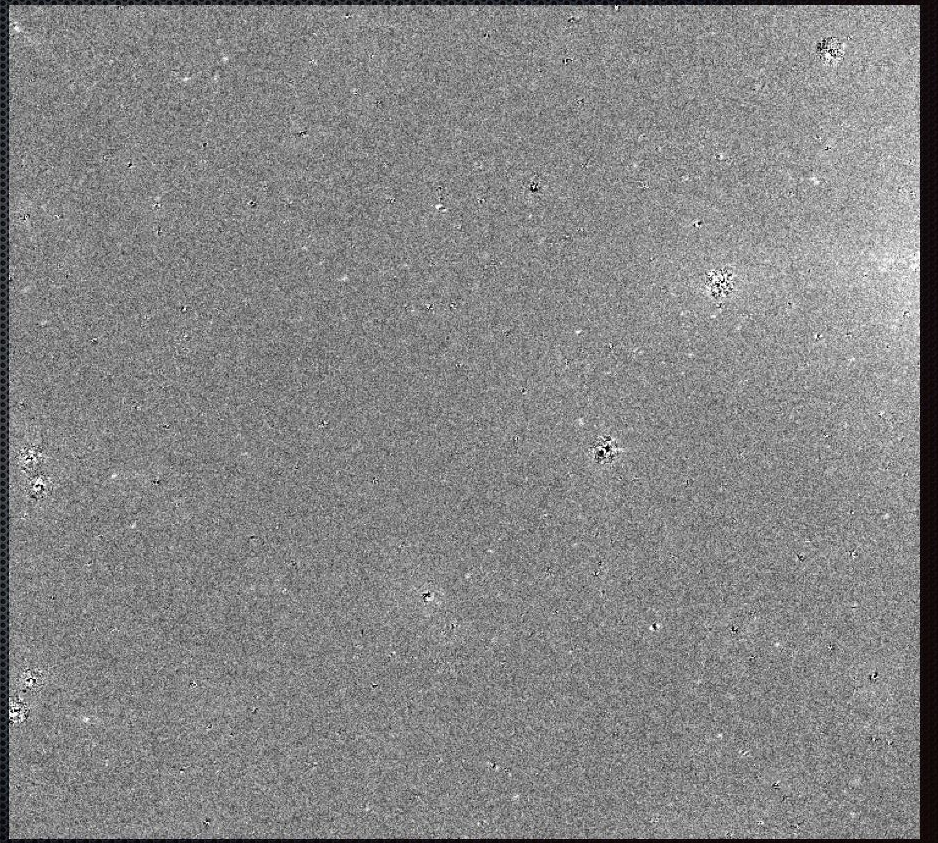


Fig. 6. Light curve of the microlensing event Gaia16aye, showing only the data used in the microlensing model. All measurements are transformed into the LT *i*-band magnitude scale.

Examples

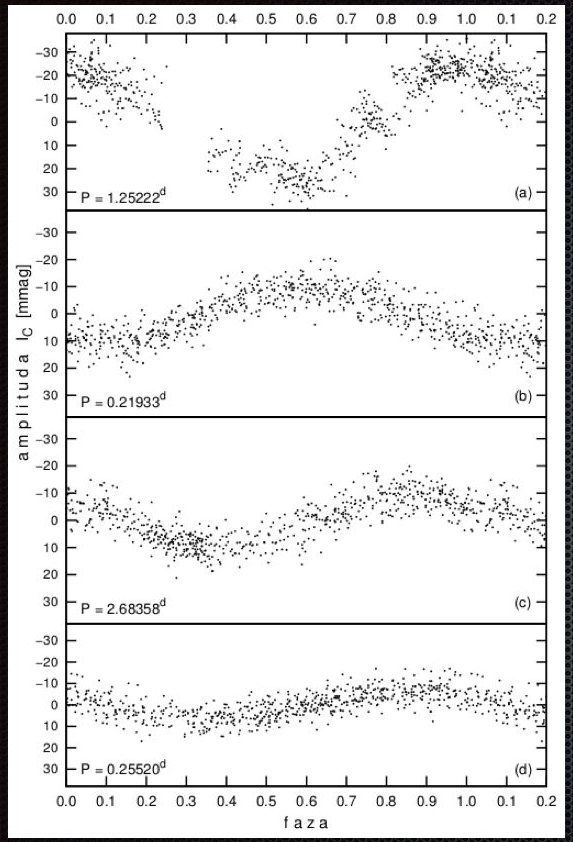


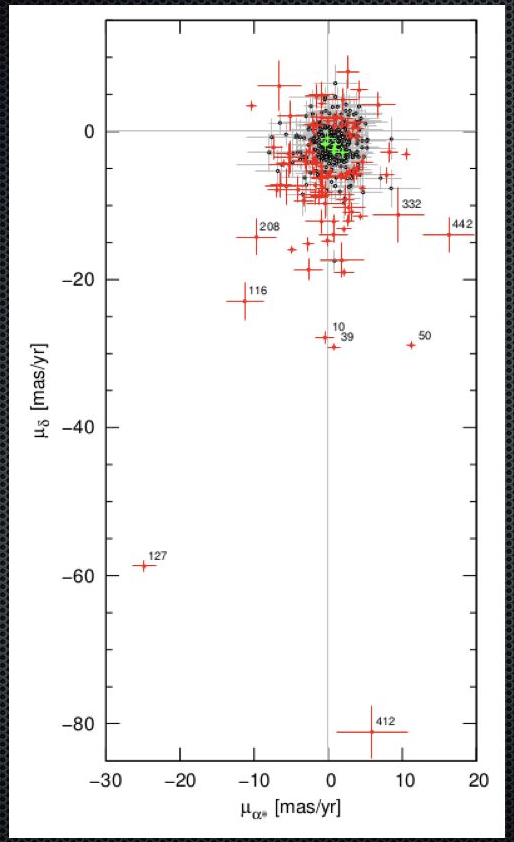


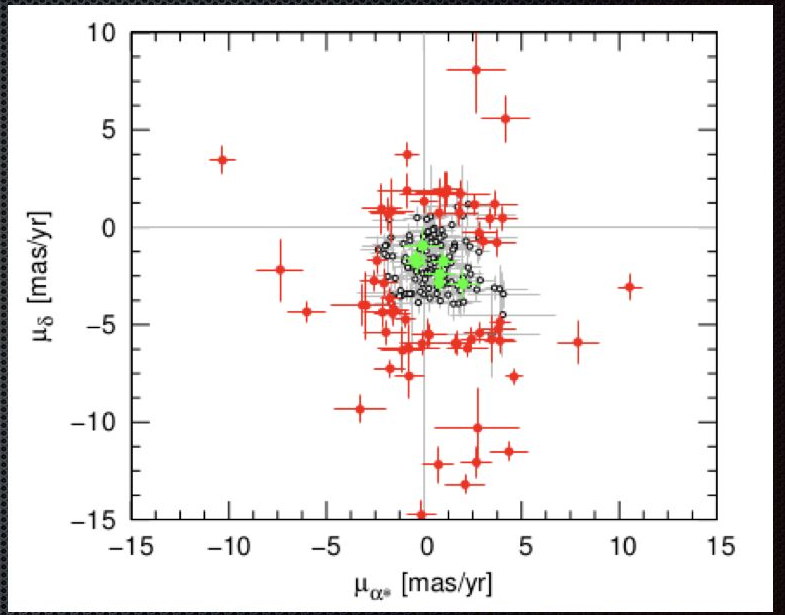
Not just a pipeline

- Tools for data manipulation (light curves, CMDs…)
- Creating plots
- Fourier analysis (including calculating decomposition parameters)
- Sine/cosine model fitting
- LCs detrending
- Searching for variable sources
- Creating list of stars (PSF model stars as well)
- Standard photometry
- Easy FITS stacking

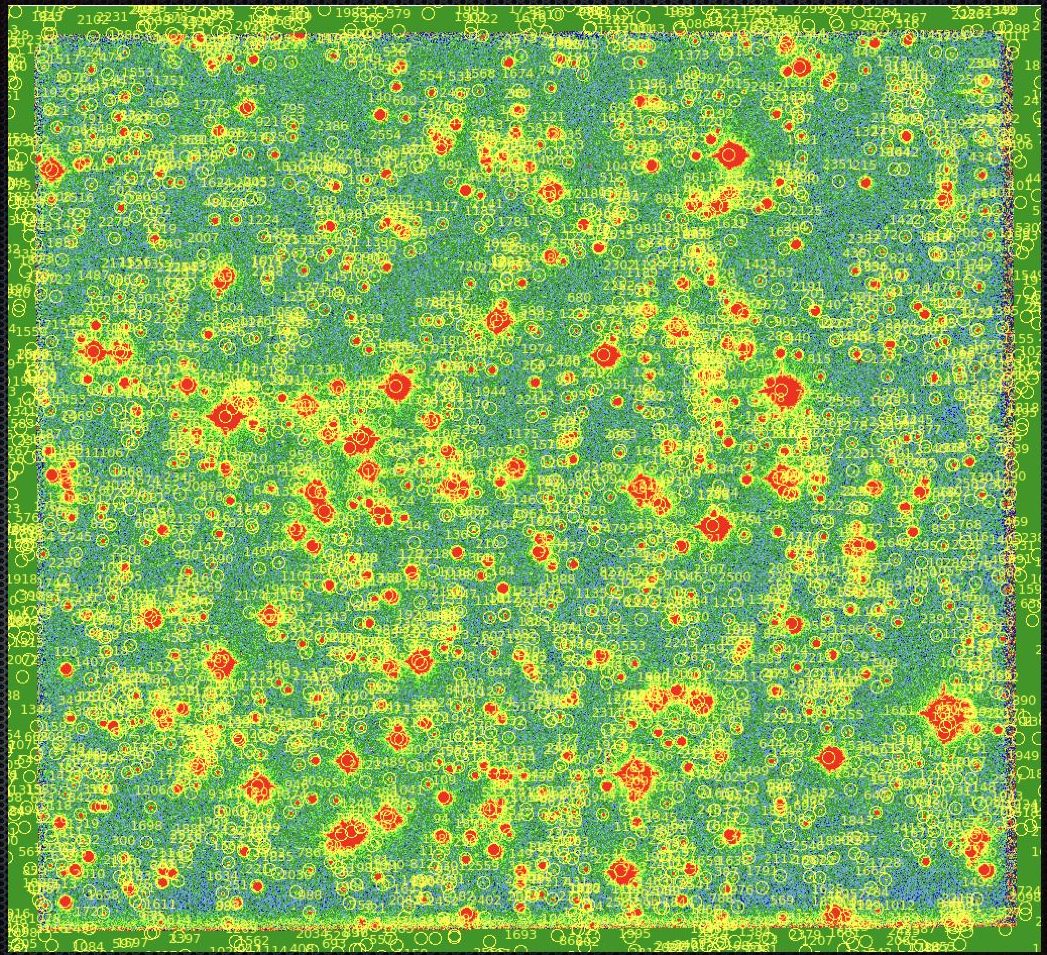
Not just a pipeline



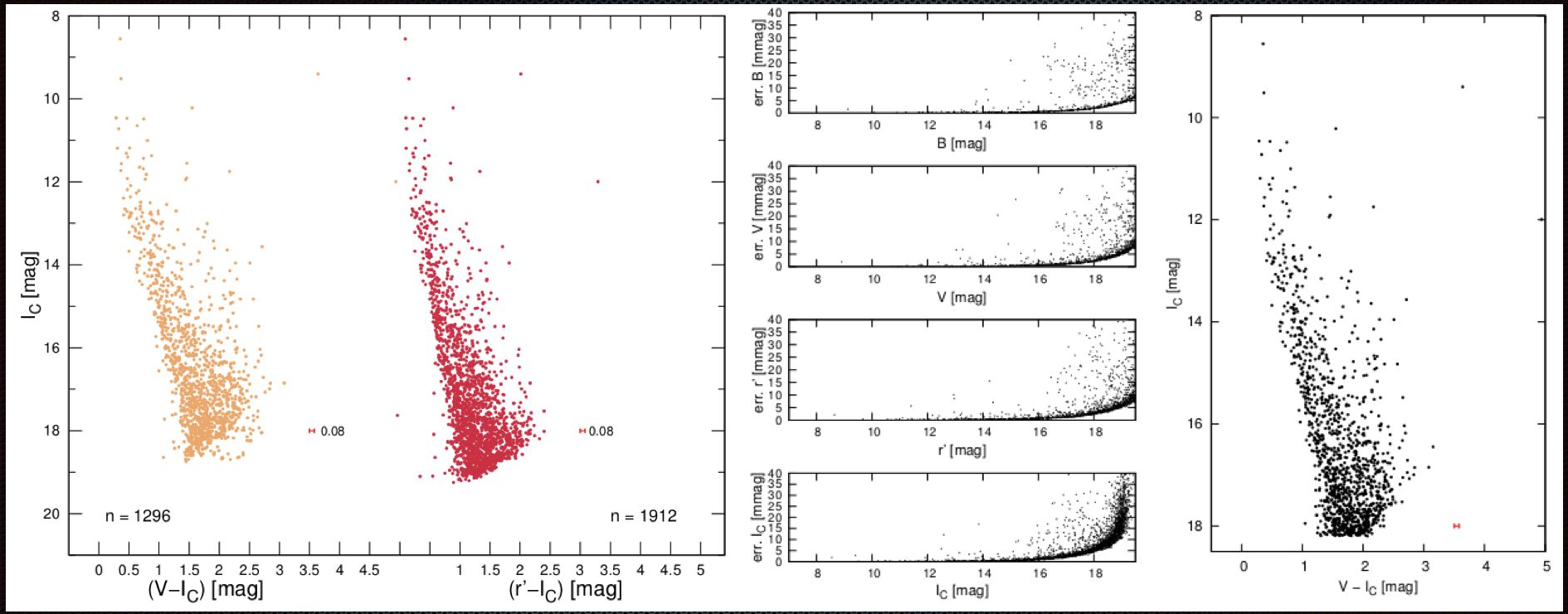




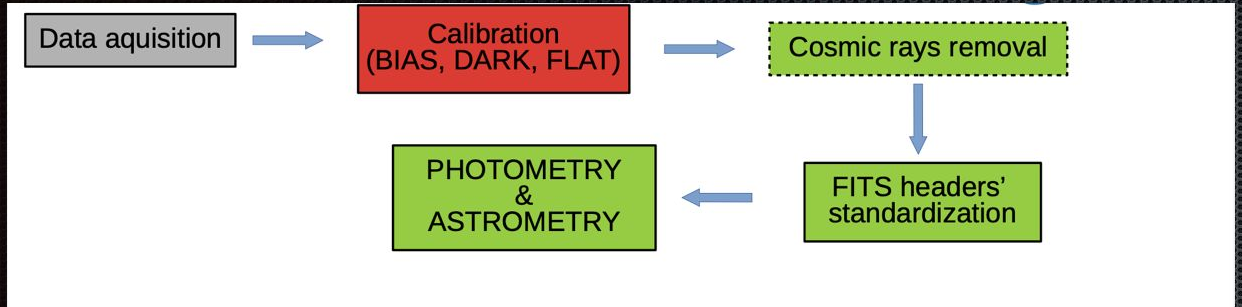
Not just a pipeline



Not just a pipeline



Future



2457619.35344	19:40:01.1306	30:07:53.423	550.075	522.321	15.2359	0.0121	15.2970	0.0214	12.3403	0.0190	2.06	1.0756	619.9	1
2457619.35488	19:40:01.1296	30:07:53.410	552.642	526.545	14.7989	0.0072	14.8400	0.0115	11.8876	0.0111	2.07	1.0752	355.09	2
2457619.35632	19:40:01.1311	30:07:53.383	554.636	524.520	14.8150	0.0078	14.8720	0.0108	11.9029	0.0112	1.89	1.0748	360.53	3
2457619.37253	19:40:01.1309	30:07:53.398	542.815	525.682	14.5645	0.0066	14.6080	0.0072	11.6250	0.0076	2.08	1.0737	176.43	4
2457619.37397	19:40:01.1306	30:07:53.412	543.752	524.055	14.5735	0.0065	14.6020	0.0079	11.6191	0.0079	2.19	1.0740	197.25	5
2457619.37541	19:40:01.1291	30:07:53.412	545.985	522.477	14.5611	0.0067	14.5970	0.0086	11.6275	0.0084	2.29	1.0742	219.91	6
2457623.41504	19:40:01.1299	30:07:53.399	644.733	564.851	14.5289	0.0059	14.5436	0.0059	11.6371	0.0063	2.36	1.1176	61.79	7
2457623.41637	19:40:01.1306	30:07:53.413	647.957	563.537	14.5257	0.0056	14.5336	0.0059	11.6359	0.0062	2.29	1.1197	62.19	8
2457623.41770	19:40:01.1306	30:07:53.406	651.862	562.741	14.5295	0.0056	14.5236	0.0066	11.6227	0.0070	2.73	1.1218	62.47	9
2457623.43315	19:40:01.1307	30:07:53.408	641.099	561.960	14.5684	0.0048	14.5846	0.0064	11.6649	0.0073	2.31	1.1505	68.33	10

2457619.353440	19:40:01.1306	30:07:53.423	550.075	522.321	2.1120	0.0122	2.1453	0.0214	2.1956	0.0190	2.06	1.0756	619.90	1
2457619.354880	19:40:01.1296	30:07:53.410	552.642	526.545	2.1161	0.0074	2.1249	0.0115	2.1936	0.0111	2.07	1.0752	355.09	2
2457619.356320	19:40:01.1311	30:07:53.383	554.636	524.520	2.1113	0.0080	2.1236	0.0108	2.1853	0.0112	1.89	1.0748	360.53	3
2457619.372530	19:40:01.1309	30:07:53.398	542.815	525.682	2.1202	0.0071	-9.9999	-9.9999	2.1759	0.0076	2.08	1.0737	176.43	4
2457619.373970	19:40:01.1306	30:07:53.412	543.752	524.055	2.1217	0.0069	2.1276	0.0079	2.1700	0.0079	2.19	1.0740	197.25	5
2457619.375410	19:40:01.1291	30:07:53.412	545.985	522.477	2.1157	0.0069	2.1237	0.0086	2.1933	0.0084	2.29	1.0742	219.91	6
2457623.415040	19:40:01.1299	30:07:53.399	644.733	564.851	2.0984	0.0061	-9.9999	-9.9999	2.1099	0.0063	2.36	1.1176	61.79	7
2457623.416370	19:40:01.1306	30:07:53.413	647.957	563.537	2.0960	0.0057	-9.9999	-9.9999	2.1126	0.0062	2.29	1.1197	62.19	8
2457623.417700	19:40:01.1306	30:07:53.406	651.862	562.741	2.0974	0.0057	2.0835	0.0066	2.1234	0.0070	2.73	1.1218	62.47	9
2457623.433150	19:40:01.1307	30:07:53.408	641.099	561.960	2.0971	0.0050	2.0934	0.0064	2.0924	0.0073	2.31	1.1505	68.33	10

Future

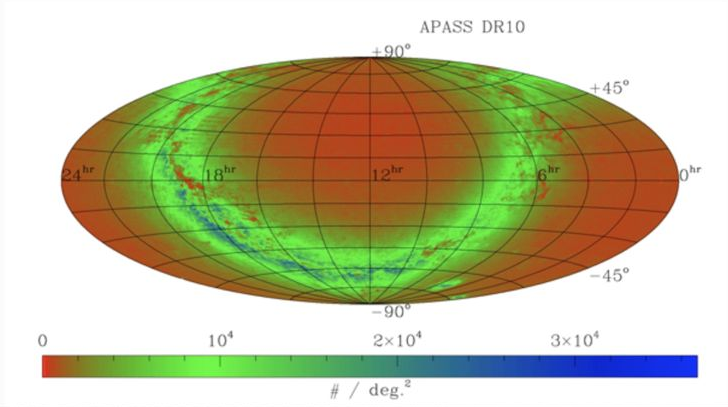
Cerro Armazones Observatory (Atacama Desert, Chile)

APASS: The AAVSO Photometric All-Sky Survey

Data Release 10 is now available.

Through a grant from the Robert Martin Ayers Sciences Fund, the AAVSO is performing an **all-sky photometric survey**. This survey is conducted in eight filters: **Johnson B** and **V**, plus **Sloan u', g', r', i', z_s** and **Z**. It is valid from about *7th magnitude to about 17th magnitude*. Precise, reliable standardized photometry in this magnitude range is in high demand, both from our observers and from the professional community. Such a catalog will allow many research programs to quickly establish transformation between systems and efficiently achieve conversion of photometry to more fundamental physical properties. It will bridge the gap between Tycho2 and SDSS, plus cover the entire sky at the same depth as UCAC. The survey will take approximately one more year to complete.

Data release 1 of APASS occurred on 2010 September 10, and contained photometry for approximately four million stars distributed among several hundred discrete fields between -10.15 < Dec < +87.35. There have been 9 additional data releases in the intervening years, with the latest, **Data Release 10,** occurring on November 16, 2018. We expect the next data release in early 2019 covering the ~100 additional north/south nights acquired through the end of 2016. The catalog now contains photometry for 128 million objects in about 99% of the sky. About 510,000 images have been taken so far!



Summary

- CCDPhot is going to be 100% free to use by anyone
- Photometry and precision astrometry are performed on FITS images with standardised headers
- CCDPhot is a photometric engine behind CPCS 2.0
- Full pipeline presentation in prep. (Mikołajczyk et al. 2020)
- CCDPhot is ready to incorporate Gaia DR3 and URAT-2
- To start using CCDPhot, please mail to: mikolajczyk@astro.uni.wroc.pl or pzielinski@astrouw.edu.pl

CCDPhot

an ~~a~~ the engine behind CPCS 2.0

Thank you!