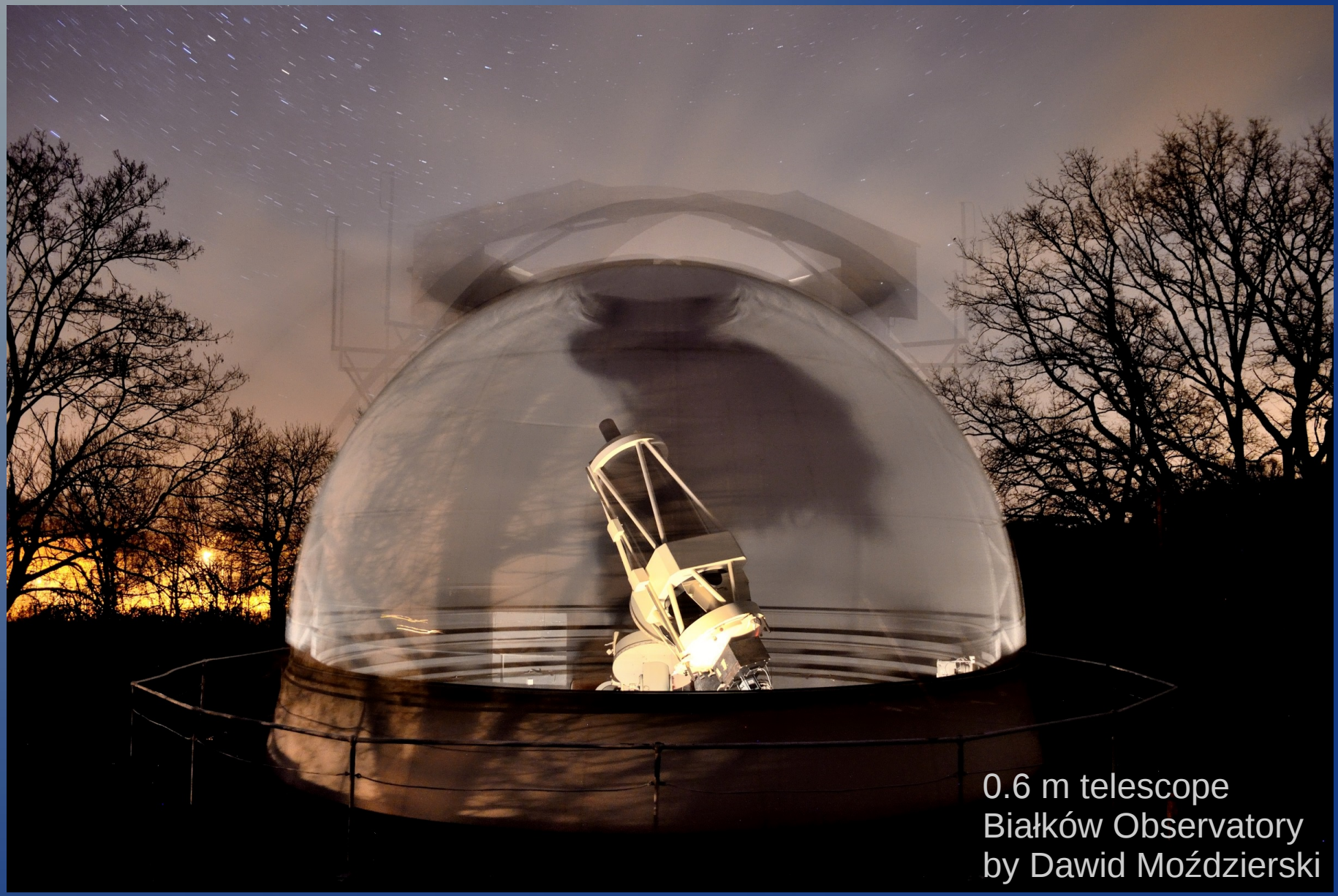
Photometry and astrometry with CCDphot



0.6 m telescope
Białków Observatory
by Dawid Moździerski

Zbigniew Kołaczkowski, CAMK

Gaia Alerts Workshop, Warszawa 2017.12.07

Demands of Gaia Alerts photometric follow-up
(Calibration Server 1.0)

- Multi-band observations close to some photometric system (with all necessary instrumental calibrations)
- Recommended aperture photometry (SEXTRACTOR), expected photometric errors smaller than 0.1 mag
- Astrometric precision ~ 1 arcsec (Astrometry.net)
- All instrumental measurements uploaded to CPCS as soon as possible (~ 24 h)

http://gsaweb.ast.cam.ac.uk/followup

CCDphot
Automatic photometric and astrometric reduction of CCD frames

- **Requirements:** python-2.7+, IRAF/PyRAF, Numpy, Pyfits, CDSclient, SEXTRACTOR, SCAMP, DAOphot, WCStools.

Main tasks:

- Initial instrumental and ‘field’ configuration (std_hdr.py, astcat.sh)
- Recognition of the ‘unified’ FITS header (parameter setting)
- Preliminary astrometric solution for the field and aperture photometry of auto-detected sources

  (SEXTRACTOR + SCAMP + reference astrometric catalogue)
- Aperture and PSF photometry, new XY positions (DAOphot / Allstar).
- Final astrometric solution tied to Gaia-DR1 (IRAF/PyRAF).
- Transformation of all measurements to the standard photometric system (make_std_phot.py).
- Registration of many useful parameters in one output file.

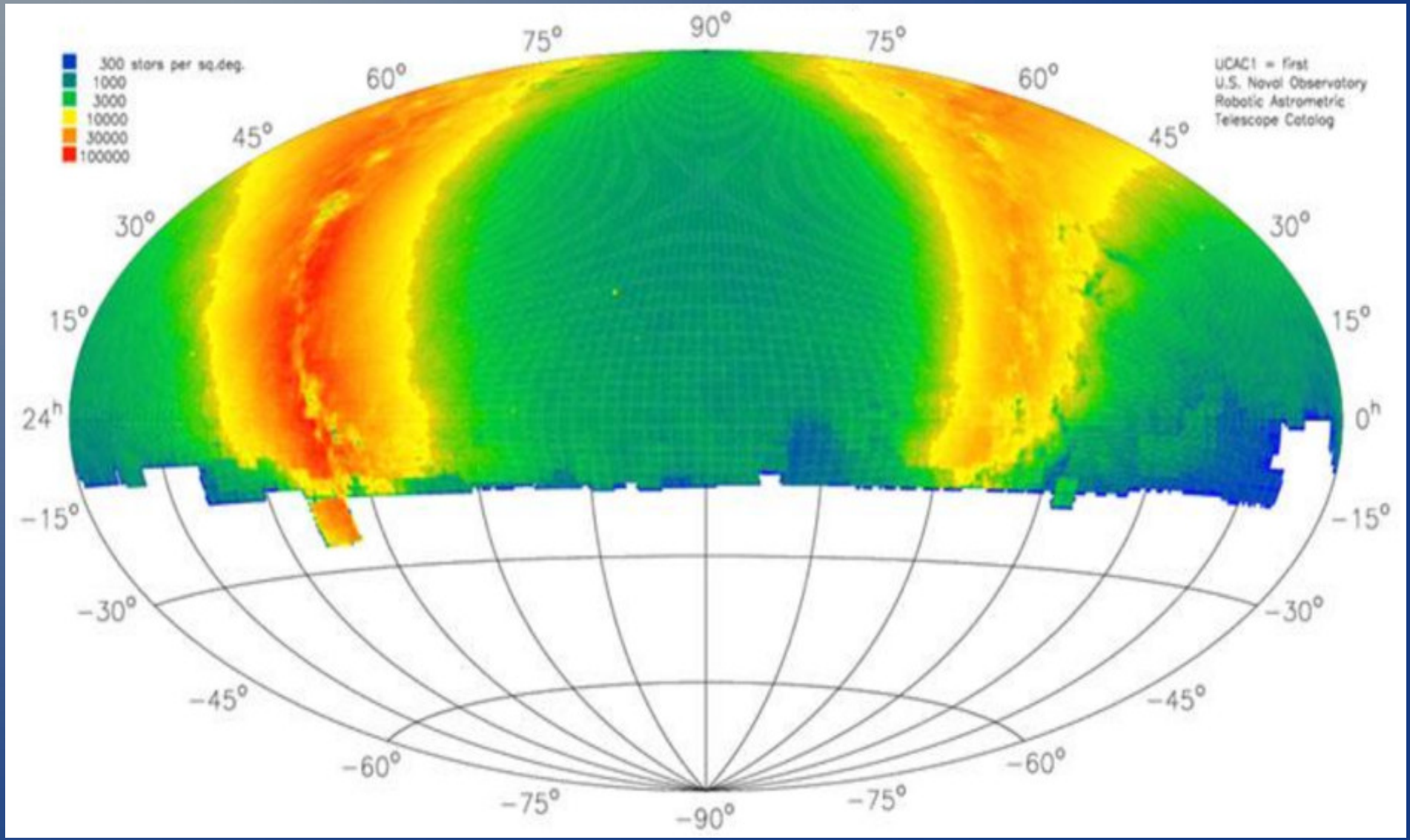
```
#       DESCRIPTION            KEYWORD    KEYWORD      FORMAT            VALUE(s)                 COMMENT
#                             (in FITS)  (standard)
#-------------------------------------------------------------------------------------------------------
# OBSERVATORY
  Observatory                : -        : OBSERVAT : str        :  LOIANO                    : -
  Observer                   : OBSERVER : OBSERVER : str        :  -                         : -
  Observwatory longitude [deg] : -      : LONGITUD : float      :  348.66611                 : -
  Observatory latitude [deg] : -        : LATITUDE : float      :   44.25917                 : -
  Observatory altitude [m]   : -        : ALTITUDE : float      :  785.0                     : -
  Telescope                  : TELESCOP : TELESCOP : str        :  1.52                      : -
  Organization               : ORIGIN   : ORIGIN   : str        :  Bologna_Astronomical_Observatory : -

# TIME (start of exposition)
  Time system                : -        : TIMESYS  : str        :  UTC                       : -
  Date                       : DATE-OBS : DATE-OBS : yyyy/mm/dd :  -                         : "-"
  Time                       : UT       : TIME-OBS : hh:mm:ss   :  -                         : ":"
  Julian date                : JDMID    : JD       : float      :  -                         : middle of exp.
  Exposition time            : EXPTIME  : EXPTIME  : float      :  -                         : -

# INSTRUMENT
  Instrument name            : INSTRUME : INSTRUME : str        :  BFOSC                     : -
  Detector X size [pix]      : NAXIS1   : NAXIS1   : int        :  1341                      : -
  Detector Y size [pix]      : NAXIS2   : NAXIS2   : int        :  1300                      : -
  Binning                    : -        : BIN      : int        :  1                         : -
  Instr. mode, readout speed : -        : READTIME : int        :  -                         : ns/pix
  Gain                       : -        : GAIN     : float      :  2.22                      : e/ADU
  Read-out noise             : -        : RDNOISE  : float      :  1.38                      : ADU
  Saturation limit           : -        : SATURATE : int        :  52000                     : ADU
  Pixel scale along x-axis   : -        : CDELT1   : float      :  0.58                      : deg/pix
  Pixel scale along y-axis   : -        : CDELT2   : float      :  0.58                      : deg/pix
  Position angle             : -        : ORIENTAT : float      :  0.0                       : deg
  Image type                 : IMAGETYP : OBSTYPE  : str        :  object                    : -
  Filters                    : FILTERS  : FILTER   : str        :  2 7 | g-Gunn r-Gunn       : -
  Pixel size along x-axis    : -        : PIXSIZE1 : float      :  22.5                      : microm
  Pixel size along y-axis    : -        : PIXSIZE2 : float      :  22.5                      : microm
  X reference pixel (center) : -        : CRPIX1   : int        :  625                       : -
  Y reference pixel (center) : -        : CRPIX2   : int        :  575                       : -

# OBJECT & WCS
  Object name                : OBJECT   : OBJECT   : str        :   -                        : -
  Epoch of coord. system     : EPOCH    : EQUINOX  : float      :   2000.0                   : year
  Coord. system              : -        : RADESYS  : str        :   FK5                      : -
  Coord. type projection RA  : -        : CTYPE1   : str        :   RA---TAN                 : -
  Coord. type projection DEC : -        : CTYPE2   : str        :   DEC--TAN                 : -
  Coord. unit RA             : -        : CUNIT1   : str        :   deg                      : -
  Coord. unit DEC            : -        : CUNIT2   : str        :   deg                      : -
  Right Ascension            : RA       : RA       : float      :   -                        : hours
  Declination                : DEC      : DEC      : float      :   -                        : deg
  Right Ascension WCS        : -        : CRVAL1   : float      :   -                        : deg
  Declination WCS            : -        : CRVAL2   : float      :   -                        : deg
```

The log file with parameters after reduction

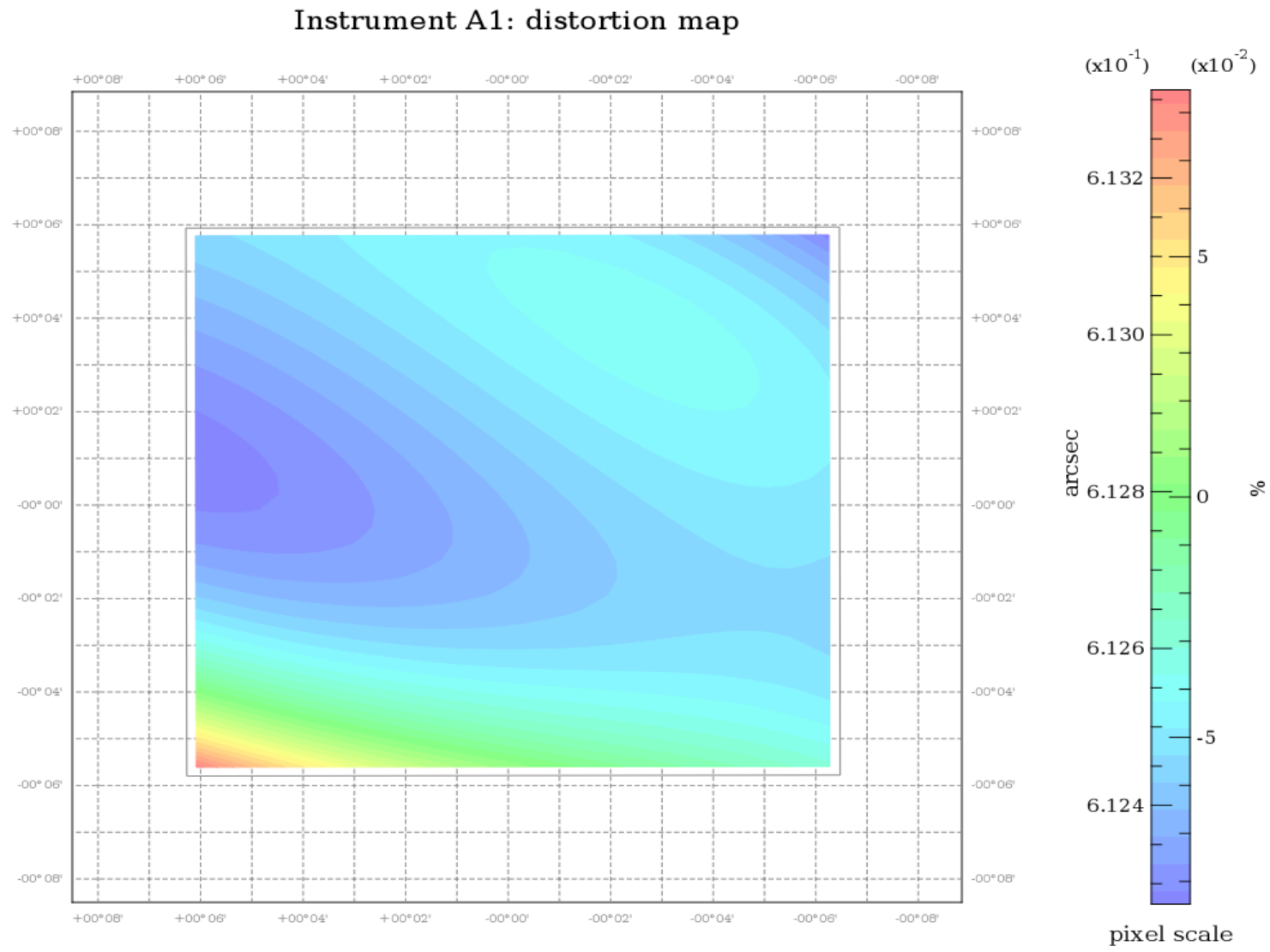
(ccdphot output)

# filename	date_UTC	time_UTC	exp	rm	filter	object	RA_2000	DEC_2000	JD_middle	sid_time	HA	alt	airm	HJD_middle	N_obj	sky	fwhm_x	fwhm_y	seeing
#			s				hh:mm:ss	dd:'':""	d	hh:mm:ss	hh:mm:ss	deg		d		ADU/pix	pix	pix	arcsec
Gaia16aye-0068-bdtf.fits	2016 11 08	17 35 25	120.00	16	B	Gaia16aye	19:40:06.422	+30:06:44.16	2457701.23362	21:56:24	2:15:45	57.13	1.1906	2457701.23291	5102	55.04	4.369	3.727	2.481
Gaia16aye-0069-bdtf.fits	2016 11 08	17 37 50	120.00	16	B	Gaia16aye	19:40:06.301	+30:06:44.60	2457701.23530	21:58:49	2:18:10	56.80	1.1951	2457701.23458	5182	54.53	4.453	4.069	2.612
Gaia16aye-0070-bdtf.fits	2016 11 08	17 40 19	120.00	16	V	Gaia16aye	19:40:06.189	+30:06:45.82	2457701.23703	22:01:18	2:20:39	56.45	1.1999	2457701.23631	7578	103.04	4.672	4.103	2.689
Gaia16aye-0071-bdtf.fits	2016 11 08	17 42 44	120.00	16	V	Gaia16aye	19:40:06.072	+30:06:46.33	2457701.23870	22:03:44	2:23:05	56.11	1.2047	2457701.23799	7753	105.20	4.102	4.361	2.594
Gaia16aye-0072-bdtf.fits	2016 11 08	17 45 10	100.00	16	R	Gaia16aye	19:40:05.950	+30:06:46.90	2457701.24028	22:06:00	2:25:21	55.79	1.2093	2457701.23956	10543	129.90	4.444	3.771	2.518
Gaia16aye-0073-bdtf.fits	2016 11 08	17 47 15	100.00	16	R	Gaia16aye	19:40:05.839	+30:06:47.41	2457701.24173	22:08:06	2:27:27	55.49	1.2136	2457701.24101	10827	132.33	3.928	3.725	2.346
Gaia16aye-0074-bdtf.fits	2016 11 08	17 49 22	100.00	16	I	Gaia16aye	19:40:06.440	+30:06:41.28	2457701.24319	22:10:13	2:29:34	55.19	1.2180	2457701.24248	11531	111.11	3.996	3.848	2.404
Gaia16aye-0075-bdtf.fits	2016 11 08	17 51 27	100.00	16	I	Gaia16aye	19:40:06.277	+30:06:41.70	2457701.24464	22:12:18	2:31:39	54.89	1.2225	2457701.24392	11416	110.33	4.150	3.765	2.426
Gaia16aye-0077-bdtf.fits	2016 11 08	17 55 02	120.00	16	B	Gaia16aye	19:40:05.973	+30:06:42.25	2457701.24725	22:16:04	2:35:25	54.34	1.2307	2457701.24653	4970	58.75	5.913	4.175	3.092
Gaia16aye-0078-bdtf.fits	2016 11 08	17 57 27	120.00	16	B	Gaia16aye	19:40:05.778	+30:06:43.11	2457701.24892	22:18:29	2:37:50	53.99	1.2362	2457701.24821	4799	59.21	4.547	3.976	2.612
Gaia16aye-0079-bdtf.fits	2016 11 08	17 59 56	120.00	16	V	Gaia16aye	19:40:06.441	+30:06:44.34	2457701.25065	22:20:59	2:40:20	53.63	1.2420	2457701.24993	7080	119.66	4.321	4.104	2.582
Gaia16aye-0080-bdtf.fits	2016 11 08	18 02 21	120.00	16	V	Gaia16aye	19:40:06.548	+30:06:44.90	2457701.25233	22:23:24	2:42:45	53.27	1.2477	2457701.25161	7516	117.81	3.871	3.917	2.387
Gaia16aye-0081-bdtf.fits	2016 11 08	18 04 48	100.00	16	R	Gaia16aye	19:40:06.460	+30:06:45.34	2457701.25391	22:25:41	2:45:02	52.94	1.2532	2457701.25319	9238	149.91	5.702	4.002	2.974
Gaia16aye-0082-bdtf.fits	2016 11 08	18 06 52	100.00	16	R	Gaia16aye	19:40:06.231	+30:06:45.92	2457701.25535	22:27:46	2:47:07	52.63	1.2583	2457701.25463	9268	153.04	5.059	3.961	2.765
Gaia16aye-0083-bdtf.fits	2016 11 08	18 08 60	100.00	16	I	Gaia16aye	19:40:06.466	+30:06:46.43	2457701.25683	22:29:54	2:49:15	52.31	1.2636	2457701.25611	11224	122.71	3.948	4.077	2.460
Gaia16aye-0084-bdtf.fits	2016 11 08	18 11 04	100.00	16	I	Gaia16aye	19:40:06.244	+30:06:46.70	2457701.25826	22:31:58	2:51:19	52.01	1.2689	2457701.25755	10283	125.73	5.021	4.165	2.815

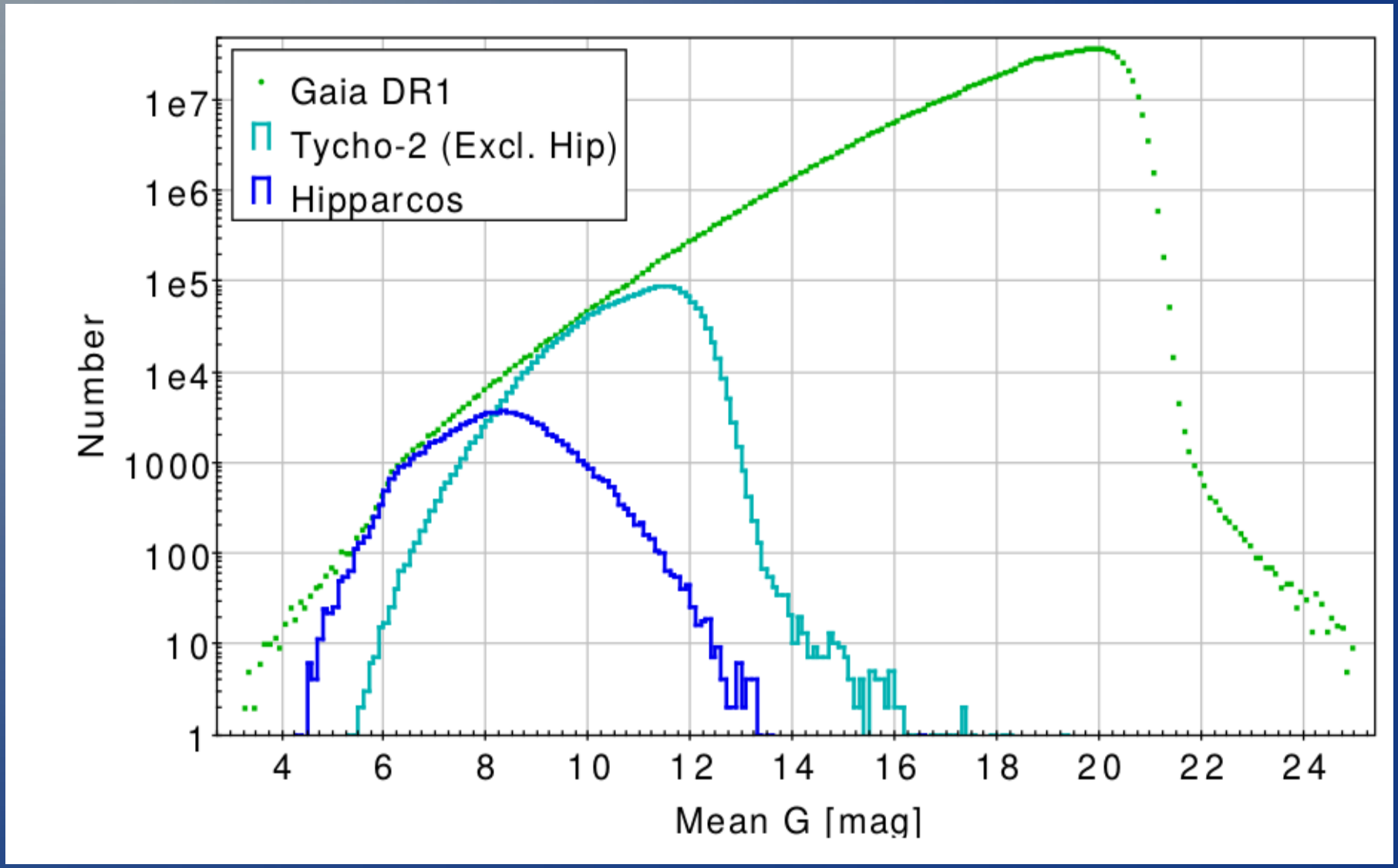
Recommended reference astrometric catalogues
UCAC-4 (2012) or URAT-1 (2015)



Preliminary astrometric solution SCAMP

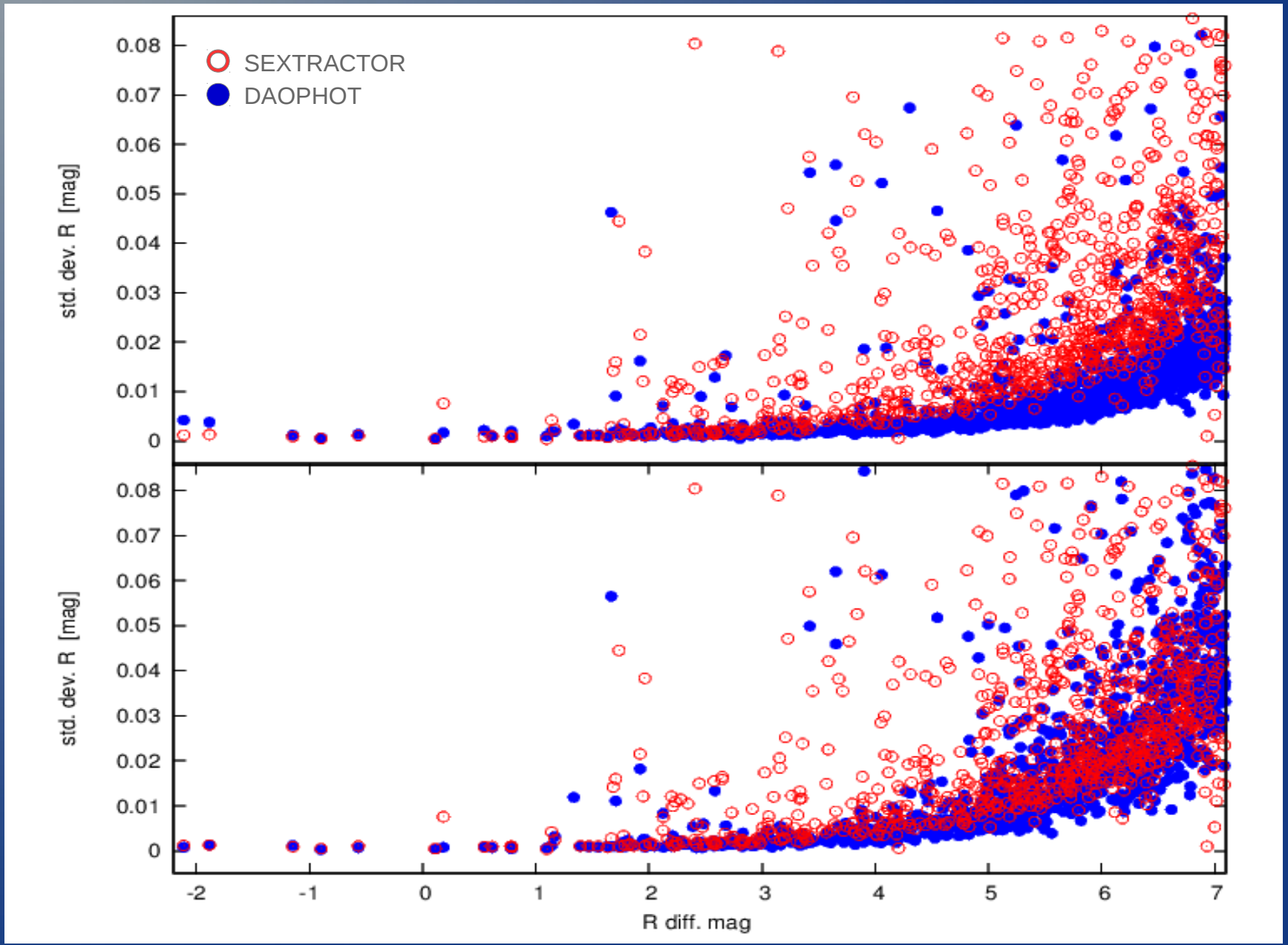


Completness of Gaia DR 1

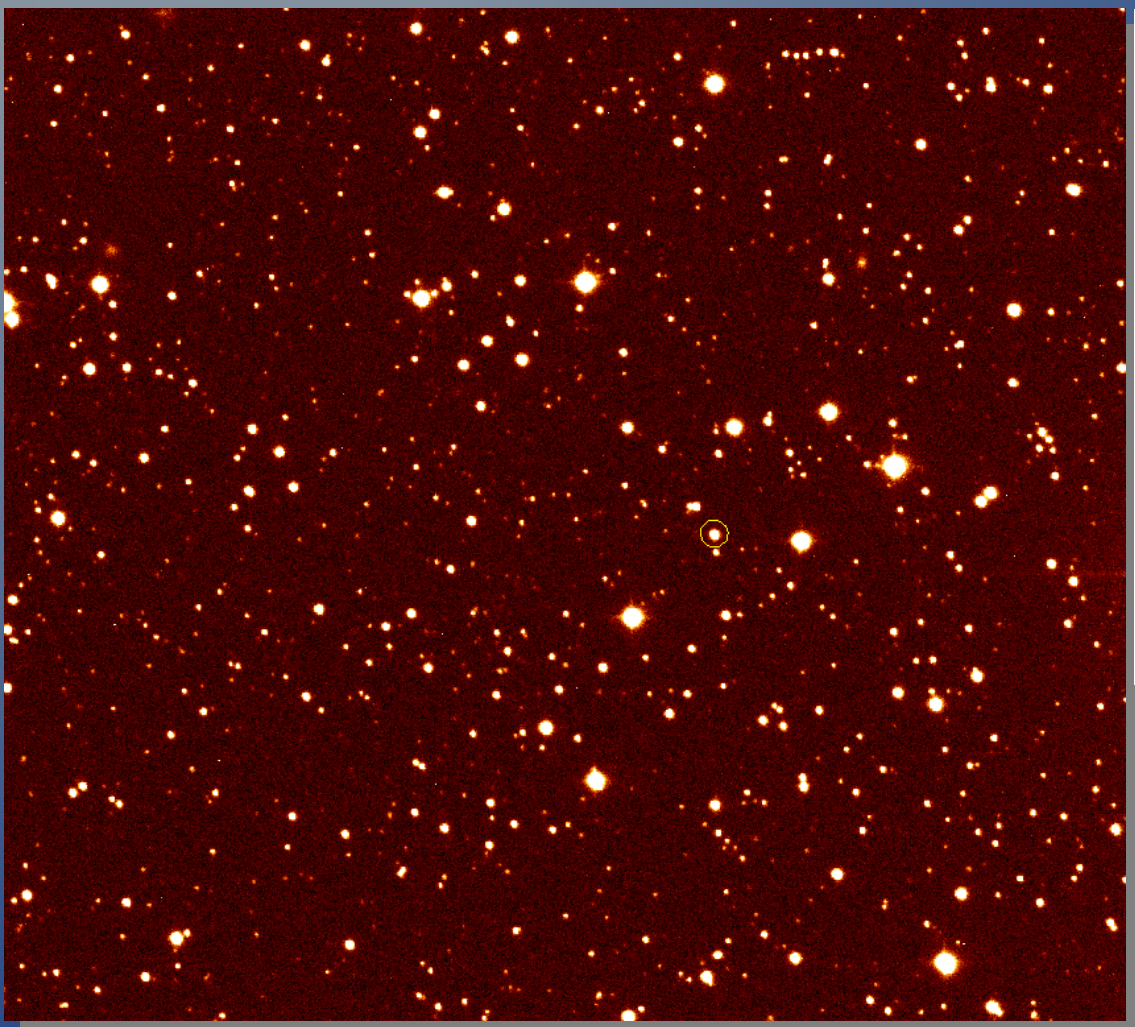


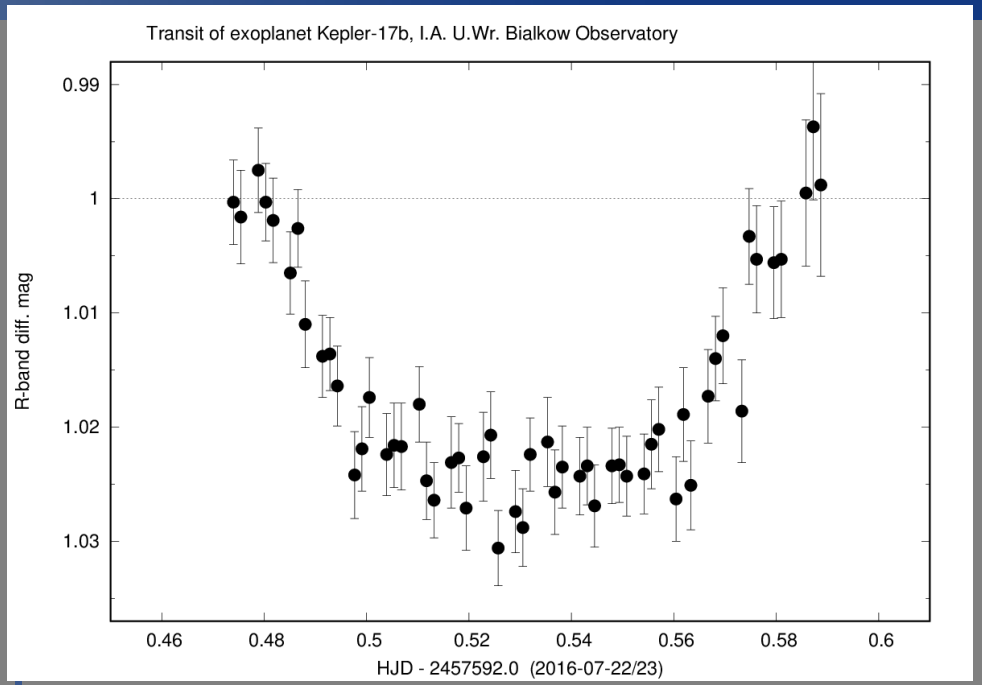
Gaia Data Release 1, Gaia Collaboration, A&A 2016

Comparison of photometric precision
SEXTRACTOR - DAOPHOT



High quality differential photometry transit of exoplanet Kepler 17b





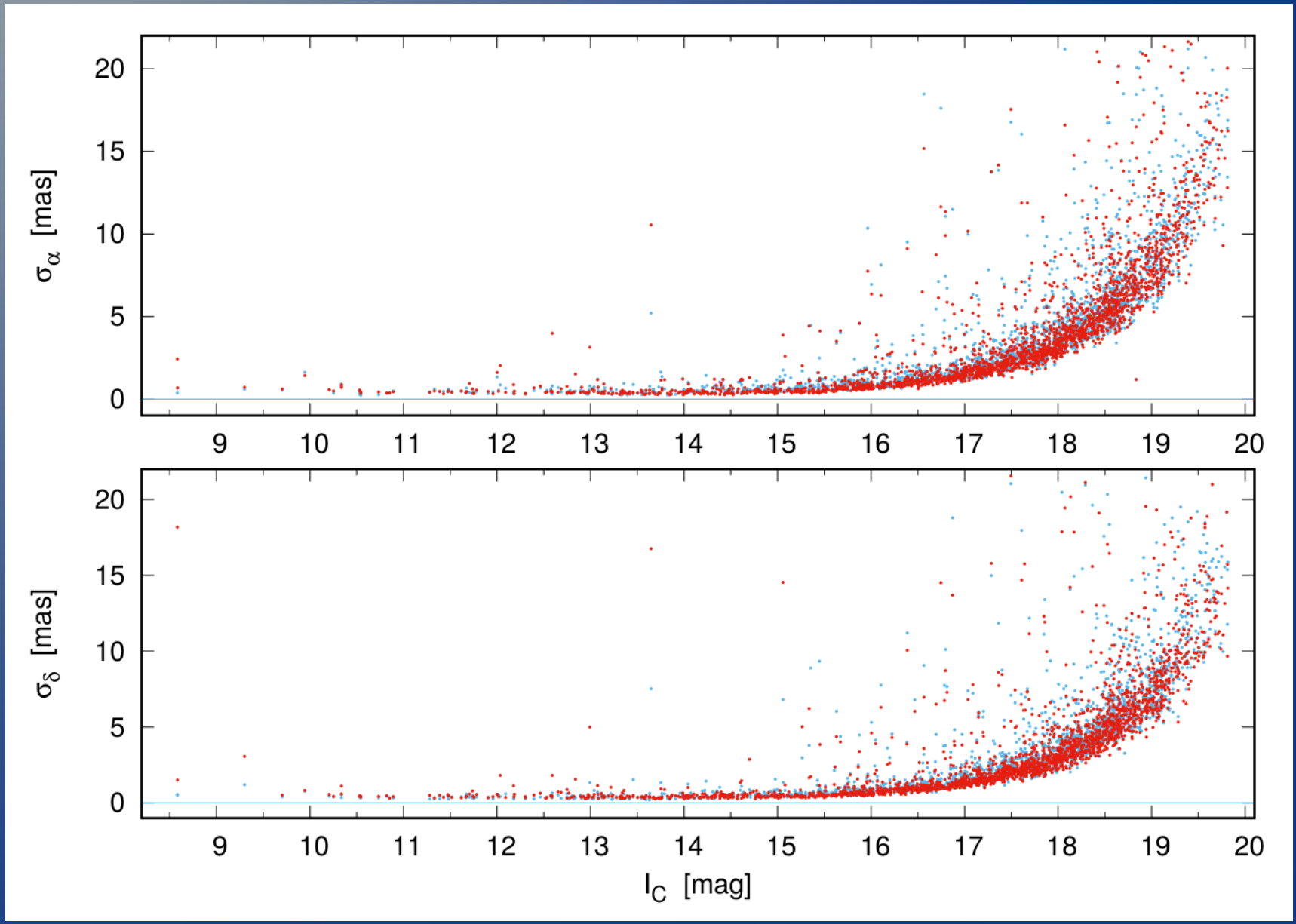
Solar-like star

m_R = 13.6 mag

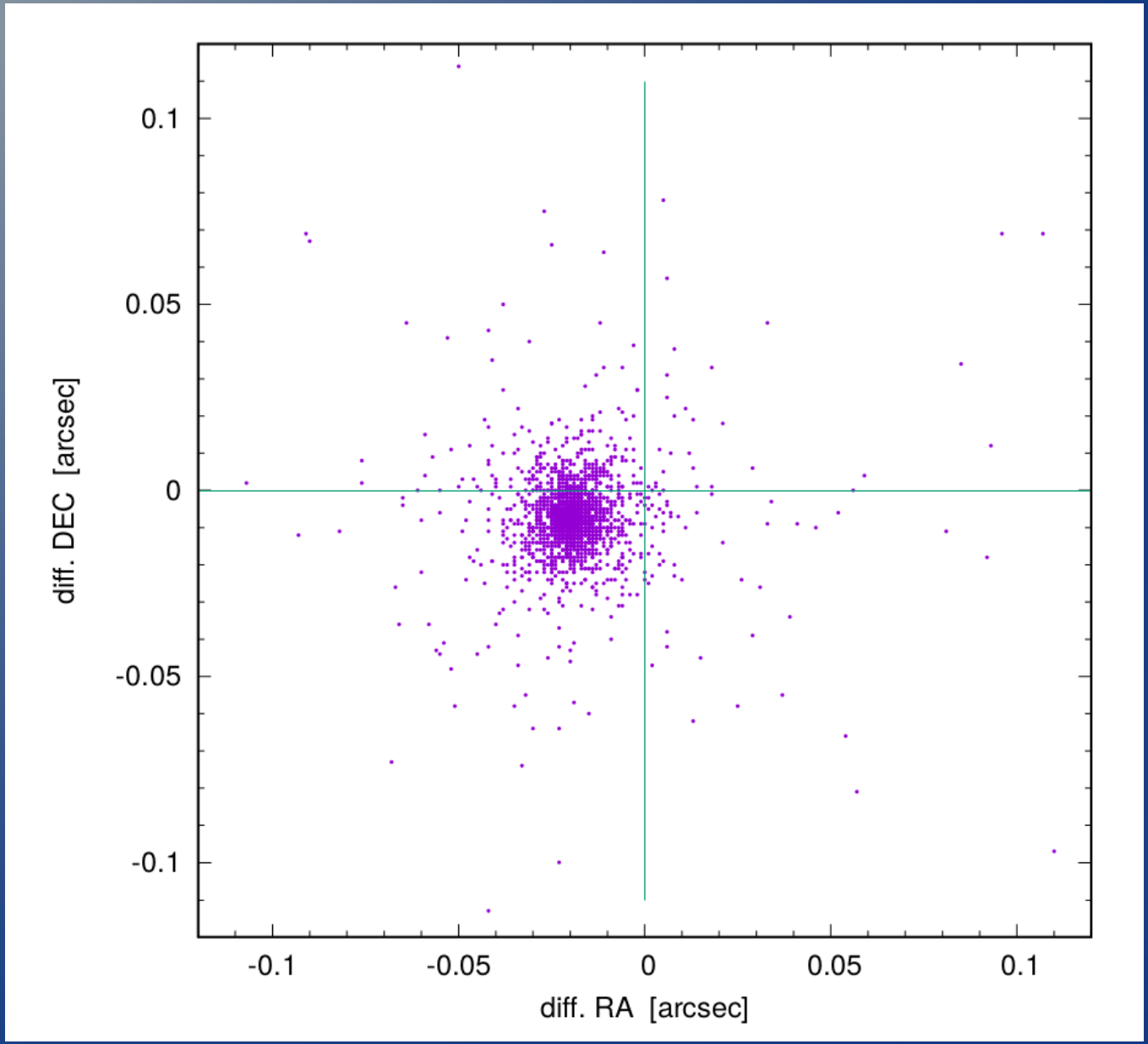
R_p = 1.25 R_J

Comparison of astrometric precision

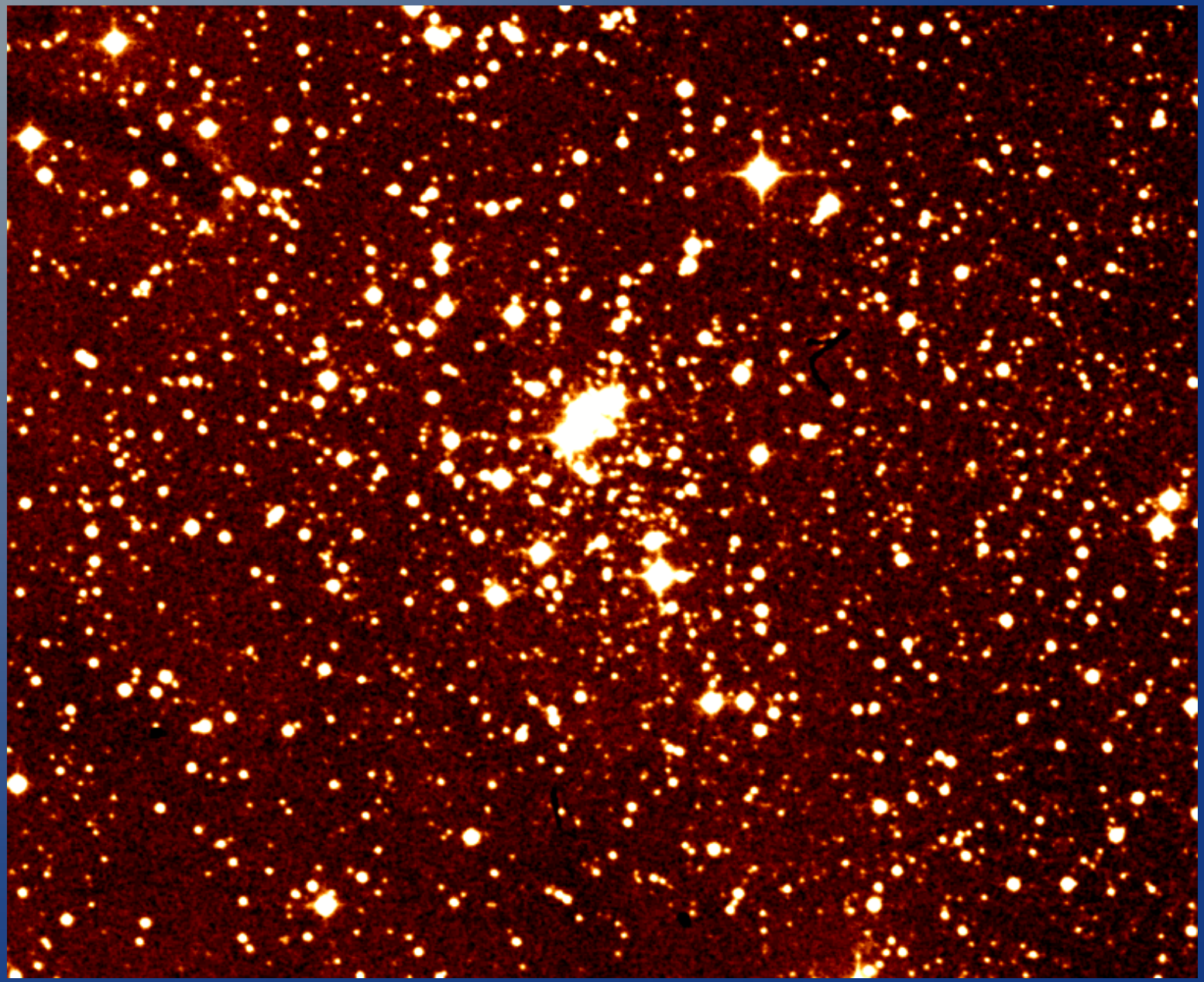
Sextractor/Scamp/URAT1 – DAOPHOT/PyRAF/Gaia-DR1



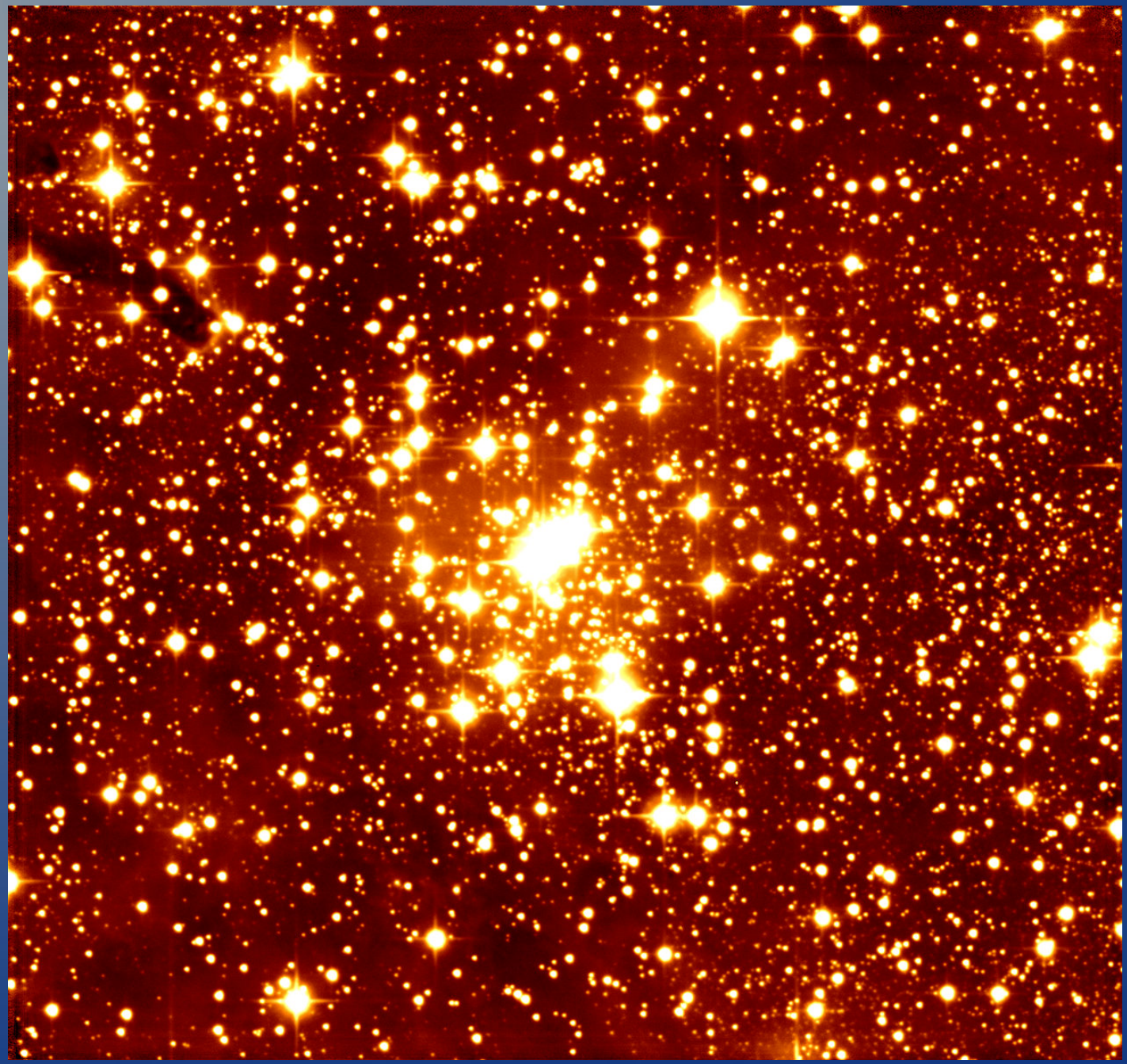
Systematic shifts of coordinates (J2000)
Gaia-DR1 - URAT1



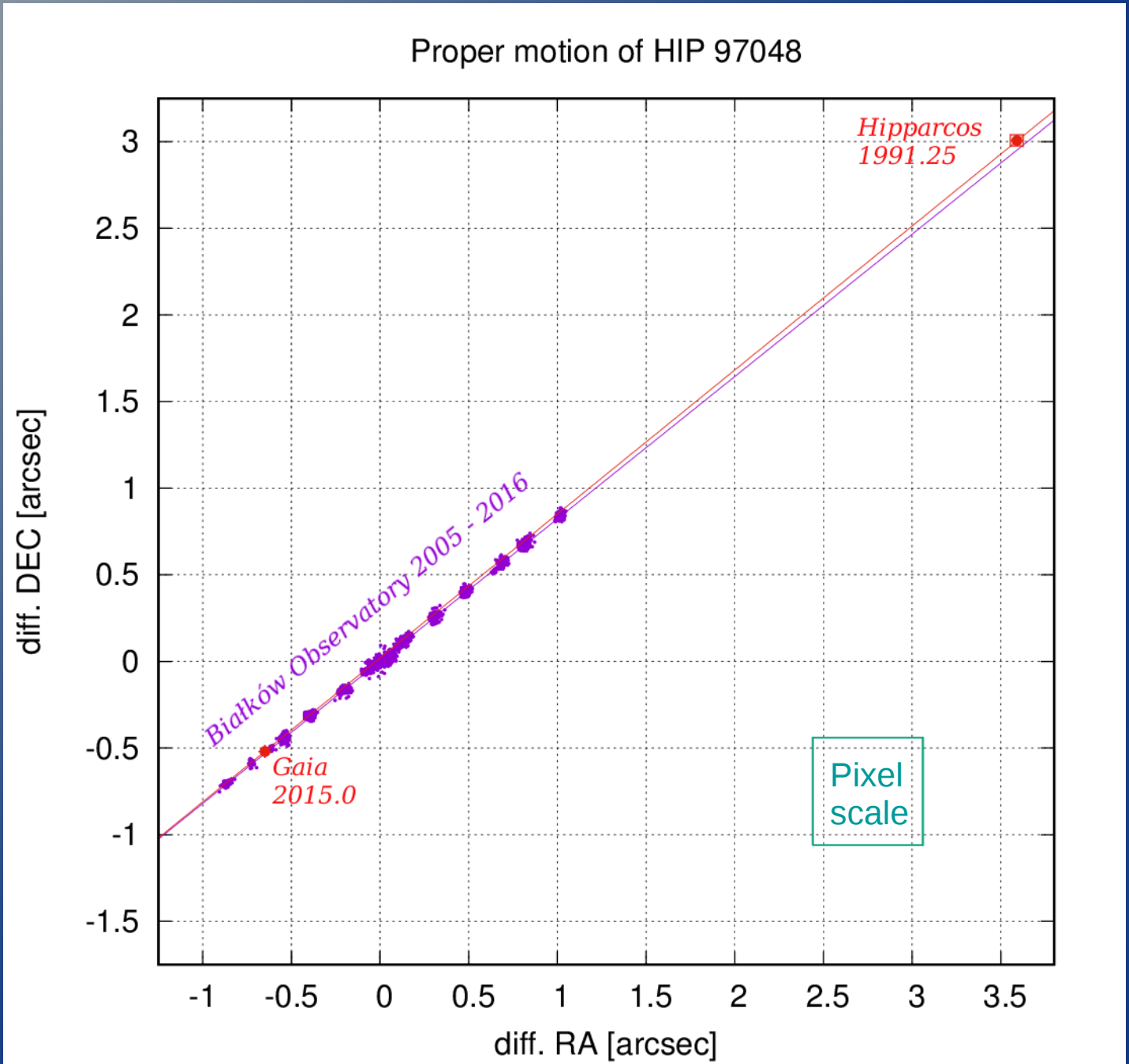
NGC6823 – DSS IR



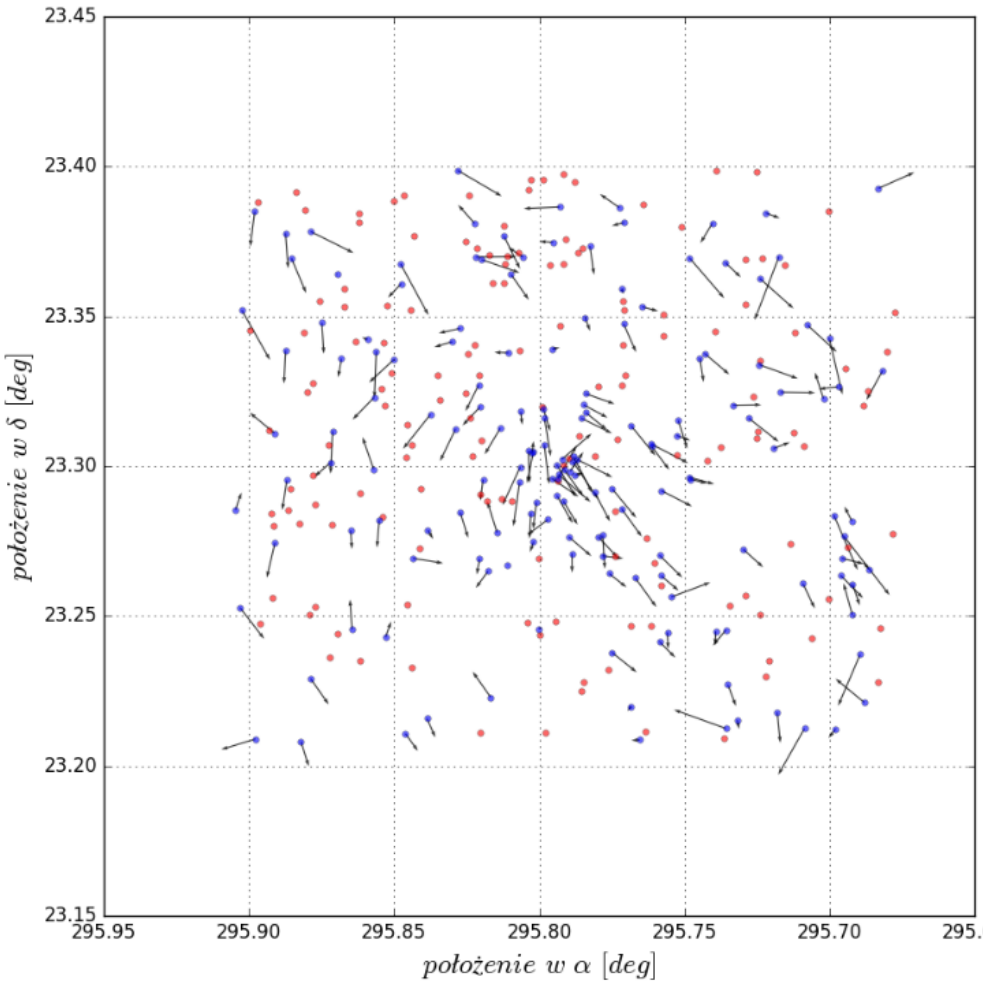
NGC6823 – deep field

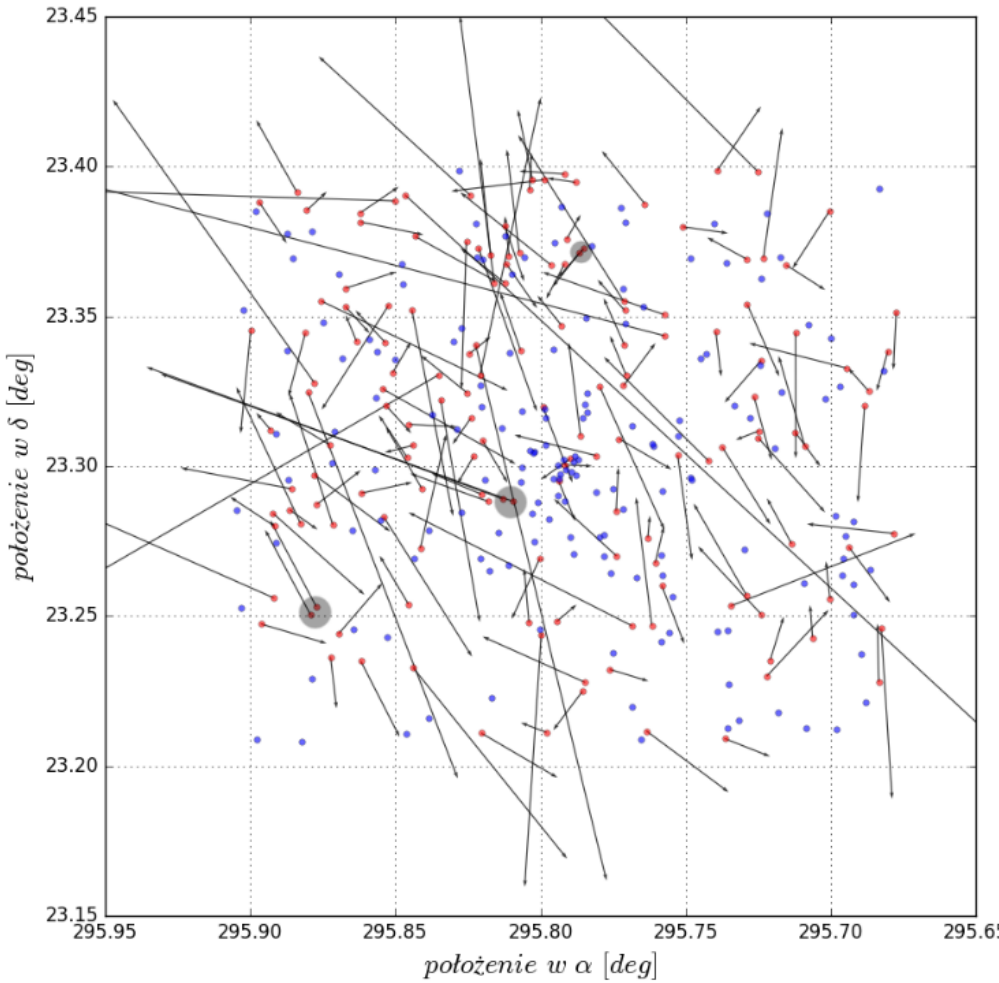


Proper motions test
Hipparcos – Gaia – ground (Białków)



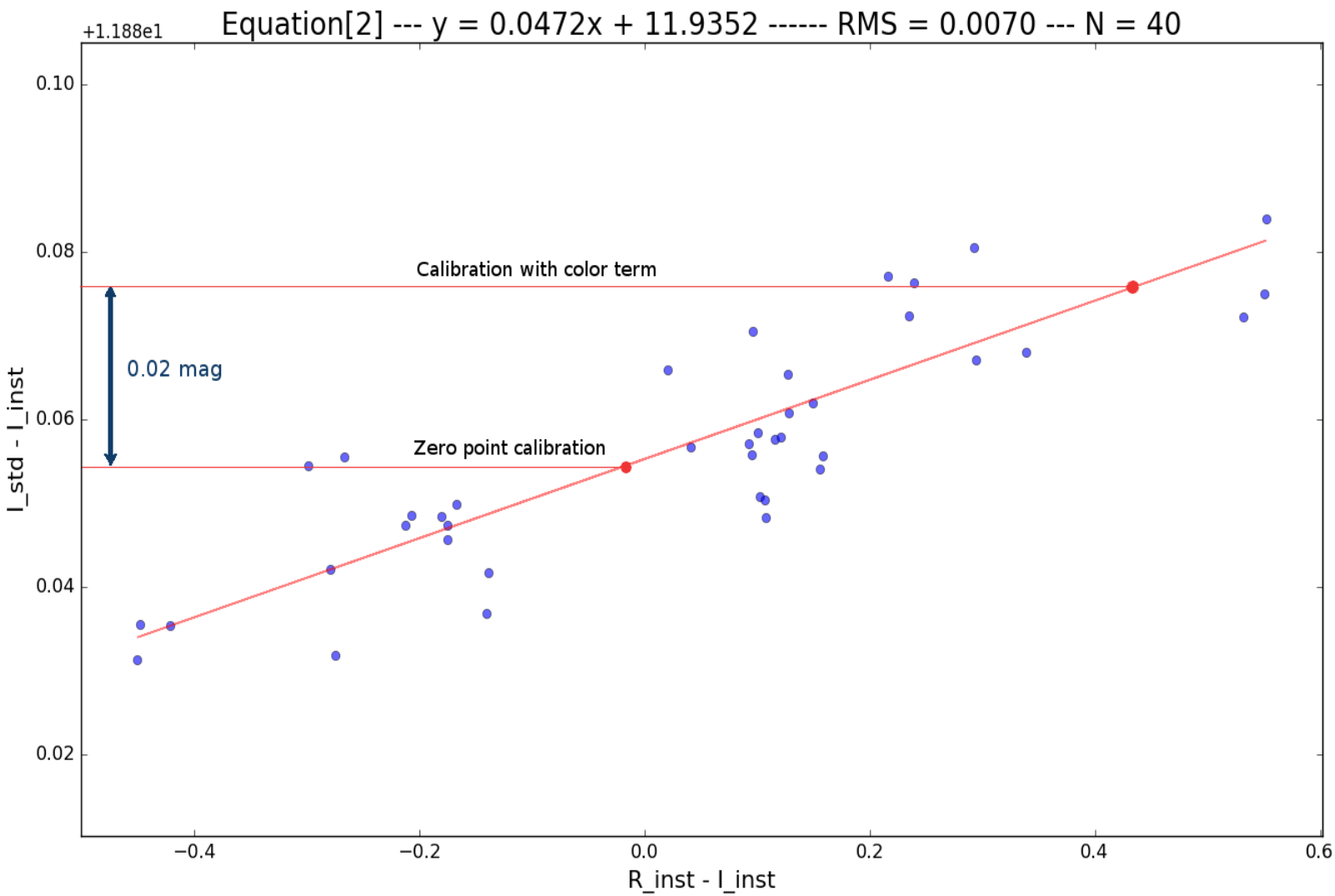
Proper motions in the field of open cluster NGC6823



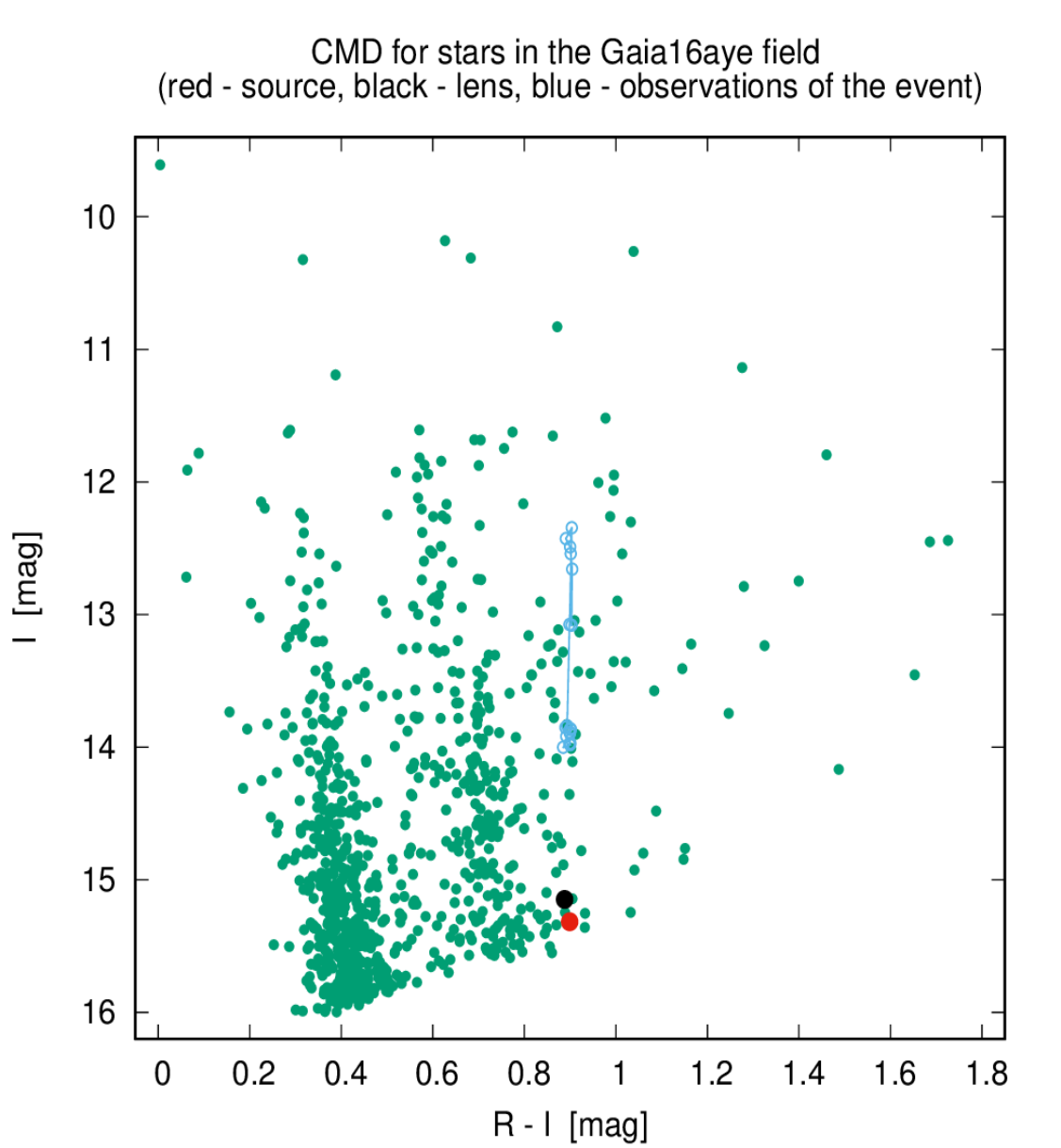


Gaia16aye field 13’ x 12’, RGB image made in Białków

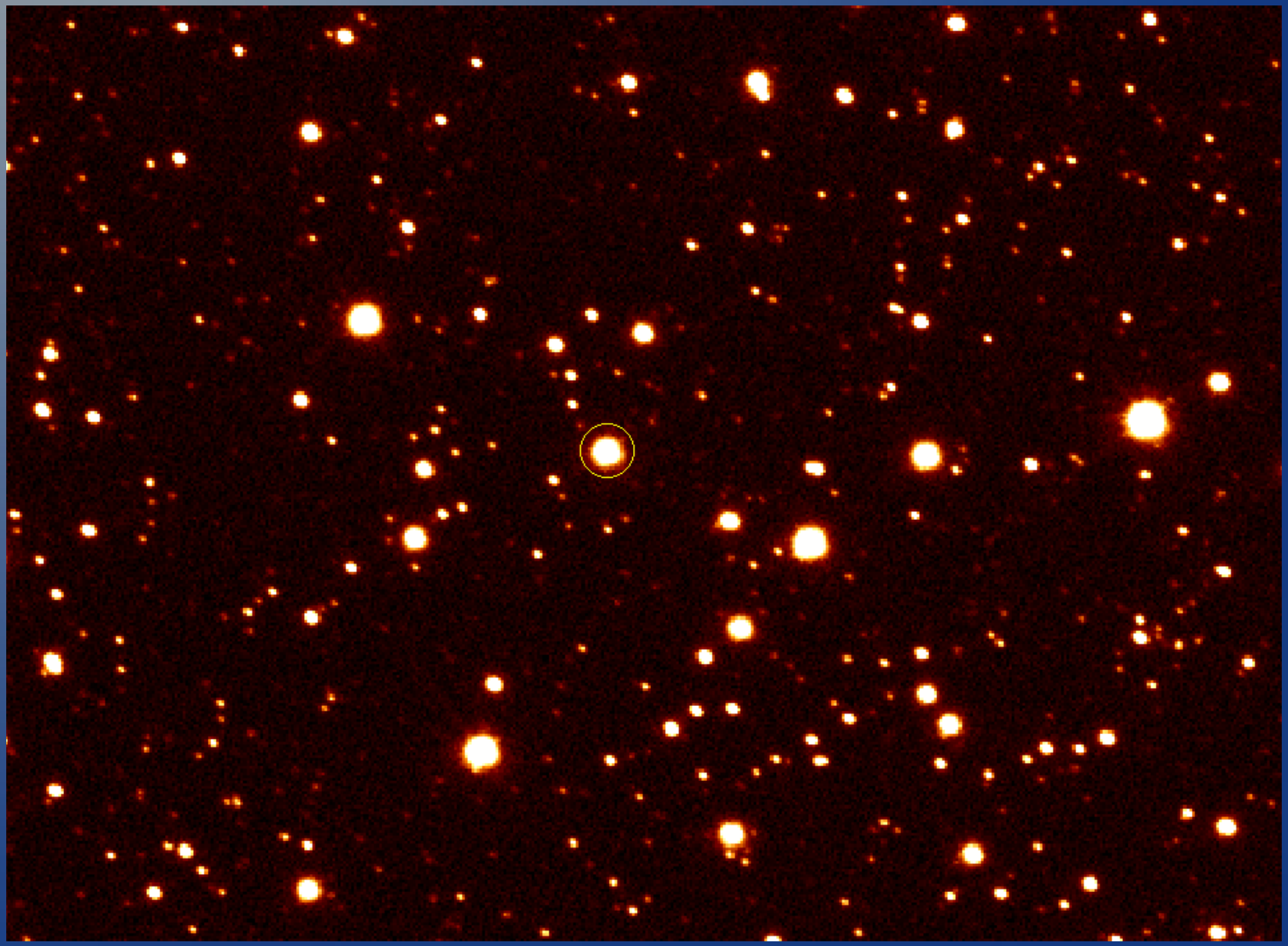
Transformation to standard photometric system



Gaia16aye
source and lens are... similar



Gaia16aye
Imaging @ Liverpool Telescope



Gaia16aye
astrometry @ Liverpool Telescope