gaia INAF

ISTITUTO NAZIONALE DI ASTROFISICA
OSSERVATORIO ASTRONOMICO DI BOLOGNA
OSSERVATORIO ASTRONOMICO DI ROMA

ASDC ASI Science Data Center

THE SPECTROPHOTOMETRIC STANDARD STARS GRID FOR THE GAIA ABSOLUTE CALIBRATION

Giuseppe Altavilla & the CU5 Bologna Gaia Team

Gaia DPAC Data Processing & Analysis Consortium

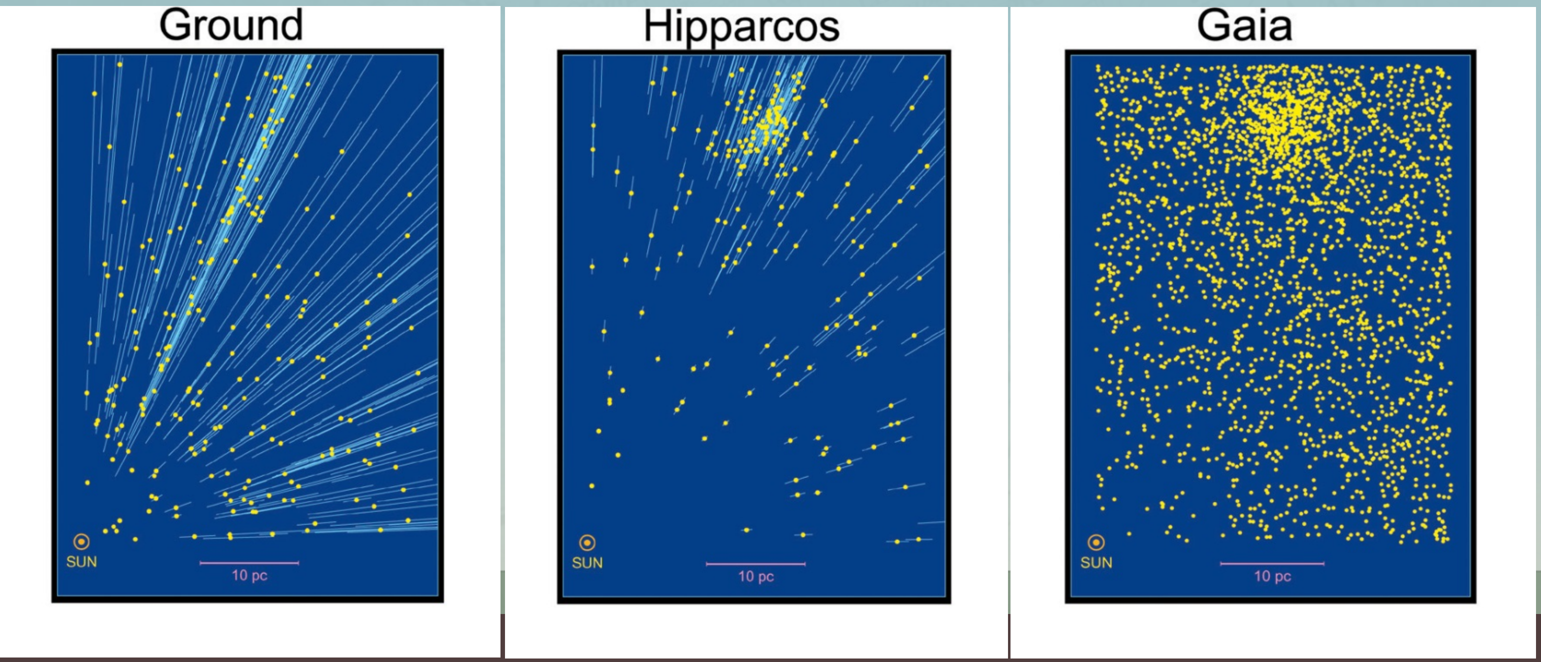
2017 ESO Calibration Workshop

esa European Space Agency

agenzia spaziale italiana

Gaia objectives

- The largest and most precise 3D chart of our Galaxy (6D space survey: α, δ, π, μα, μδ + complementary radial velocities) + astrophysical parameters
- Composition, Formation and Evolution of our Galaxy, unraveling the chemical and dynamical history of our Galaxy… And much more!

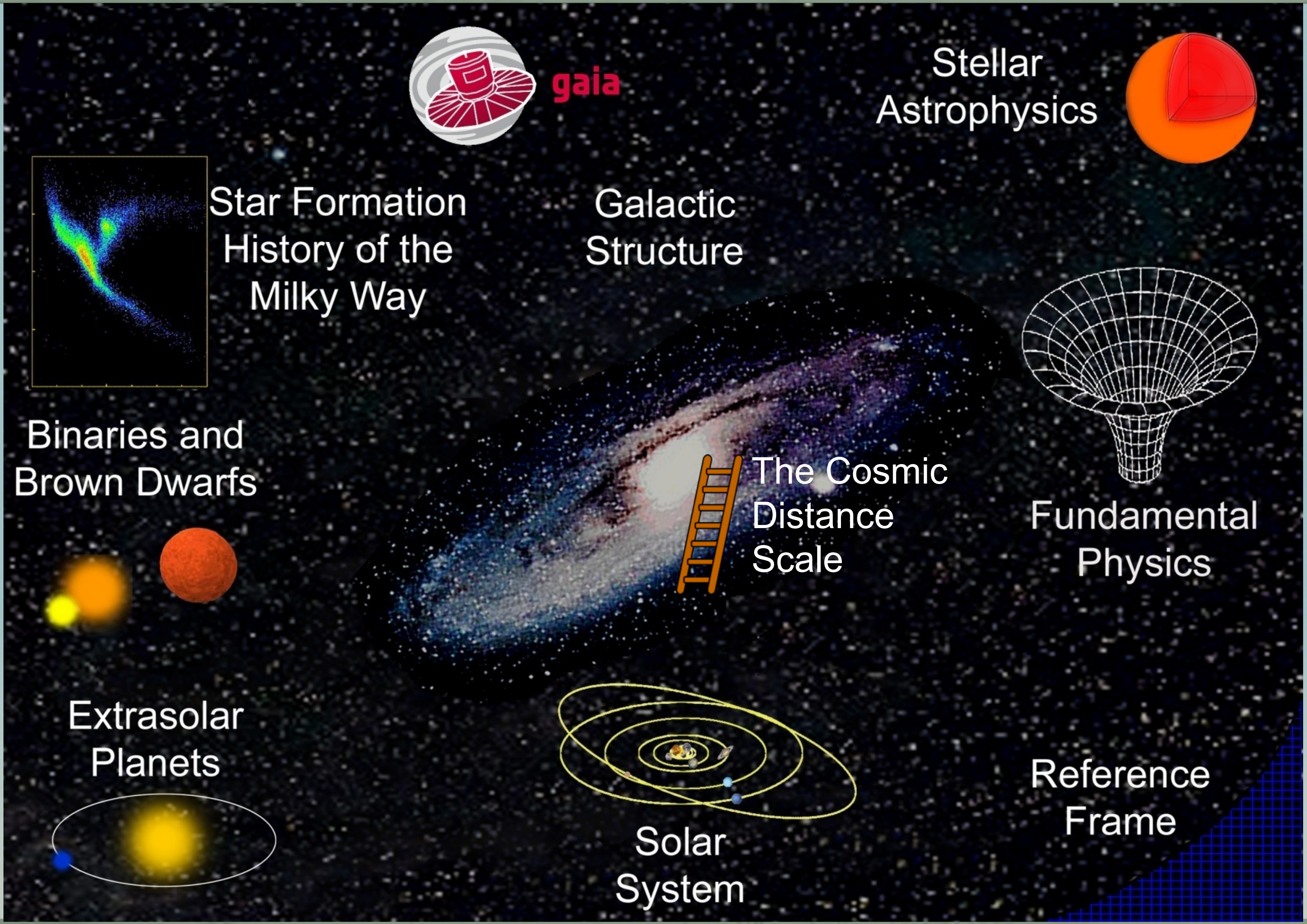


Astrometric accuracy:
the Hyades D~47 pc

Gaia will provide:

- in our Galaxy …
  - the distance and velocity distributions of all stellar populations
  - a rigorous framework for stellar structure and evolution theories
  - a large-scale survey of extra-solar planets a large-scale survey of Solar System bodies … and beyond
  - definitive distance standards out to the LMC/SMC
  - rapid reaction alerts for supernovae and burst sources QSO detection, redshifts, microlensing structure fundamental quantities to unprecedented accuracy: γ to 10-7 (10-5 present)

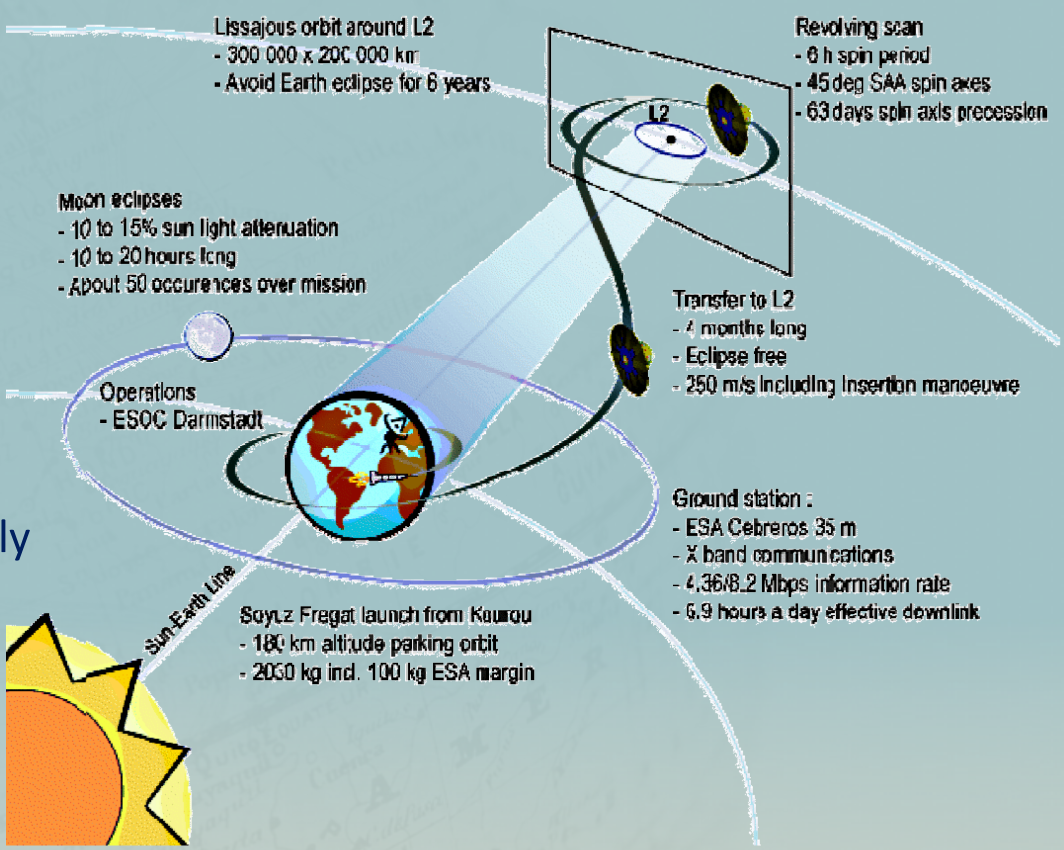
Gaia science:



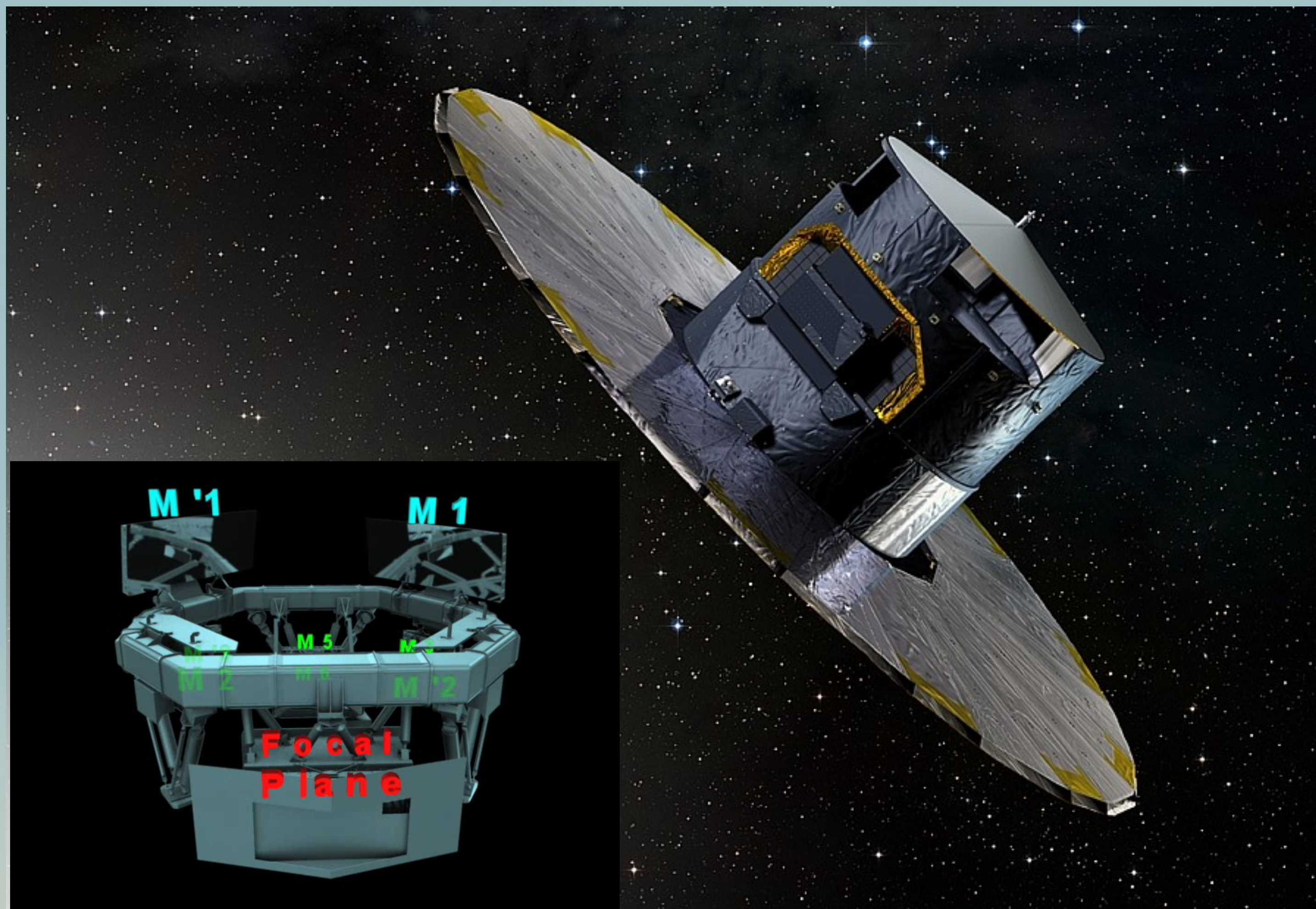
- Gaia
- The Gaia Spectrophotometric Standard Stars

Gaia

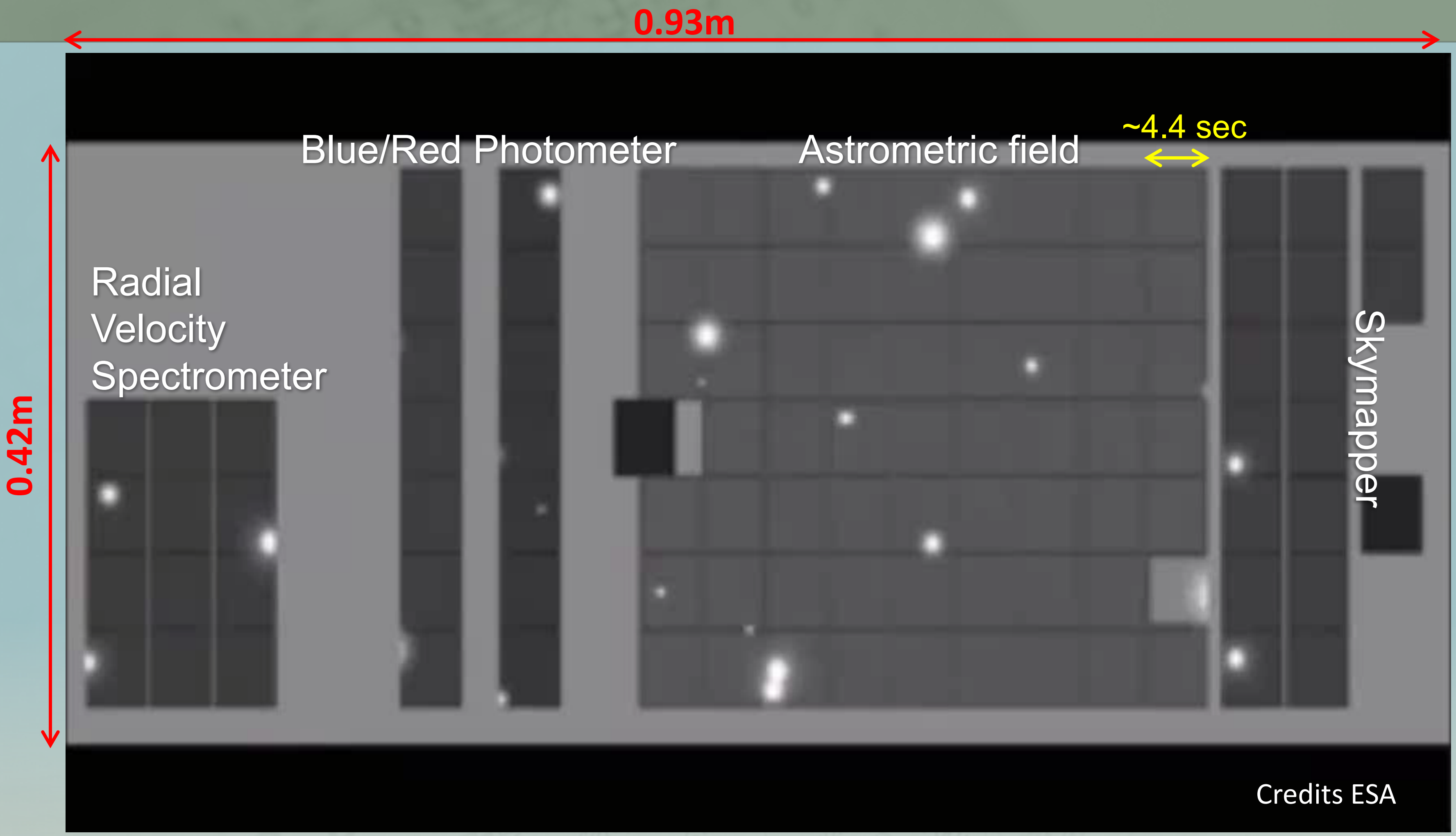
- L2, 1.5 million km from the Earth (~2 months cruise)
- stable thermal environment,
- high observing efficiency,
- moderate radiation environment (launch worst phase).
- Ground Based Optical Tracking (GBOT needed for solar system only (accuracy 20mas, 150m in L2)



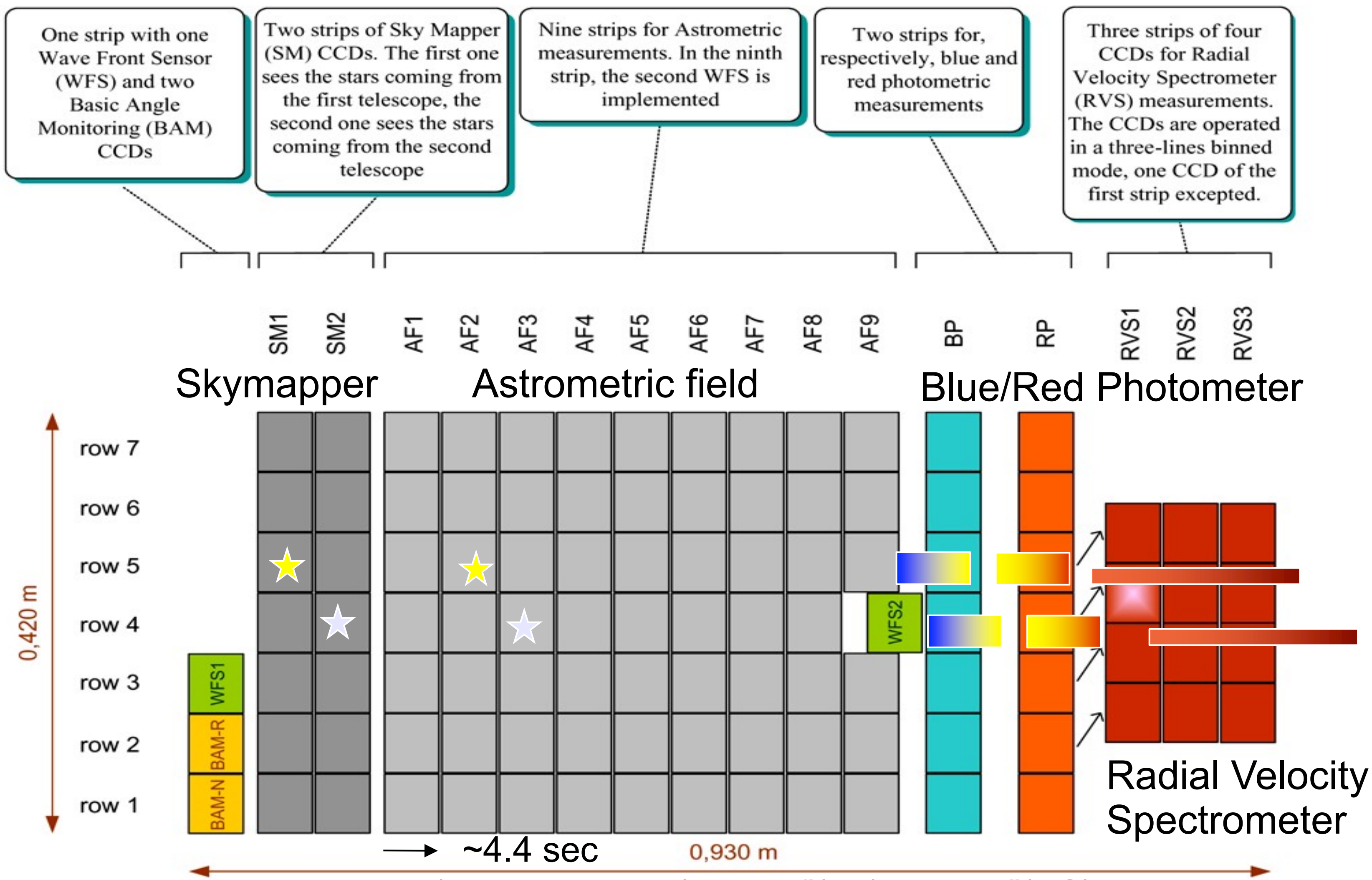
Gaia



Gaia focal plane



FoV: 0.7 deg x 0.7 deg, pixel (10 μm x 30 μm): 0.059”(AL) x 0.177”(AC)
106 CCD 4500x1966 px (TDI)



FoV: 0.7 deg x 0.7 deg, pixel (10 μm x 30 μm): 0.059”(AL) x 0.177”(AC)
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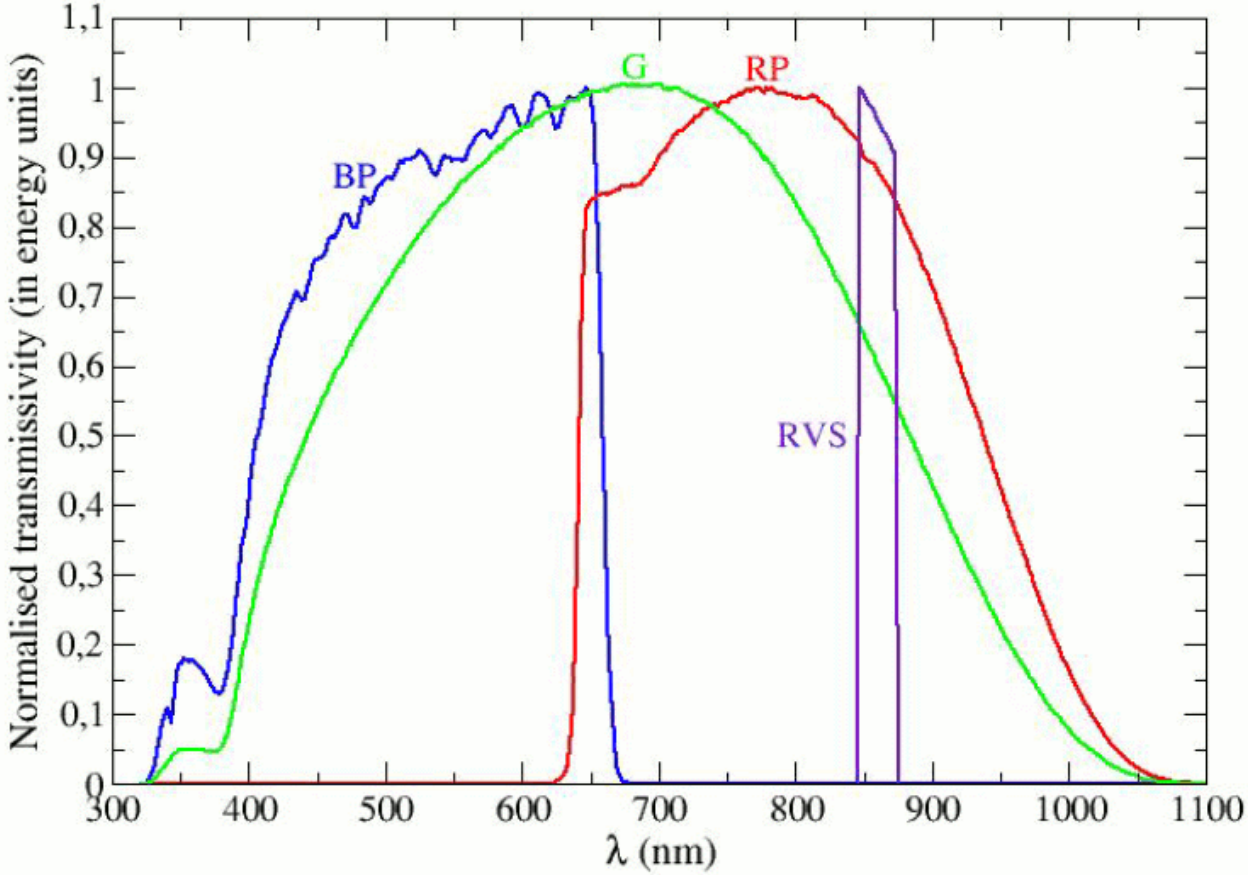
Gaia passbands



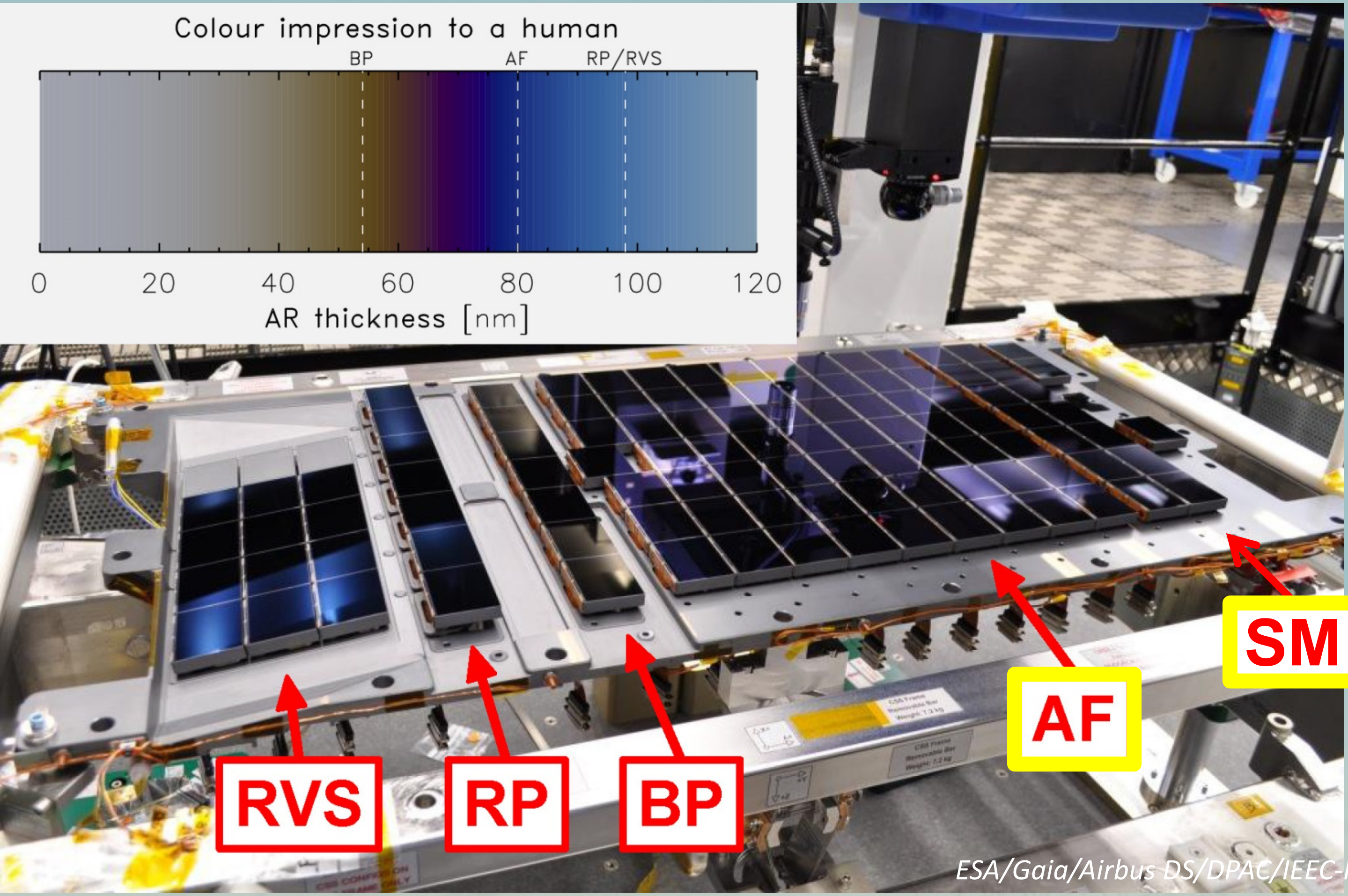
BP 3300-6800Å, R=80-20

G 3300-10500Å

RP 6400-10500Å, R=90-70

RVS 8470-8740Å, R=11500

Examples of Gaia imaging capabilities

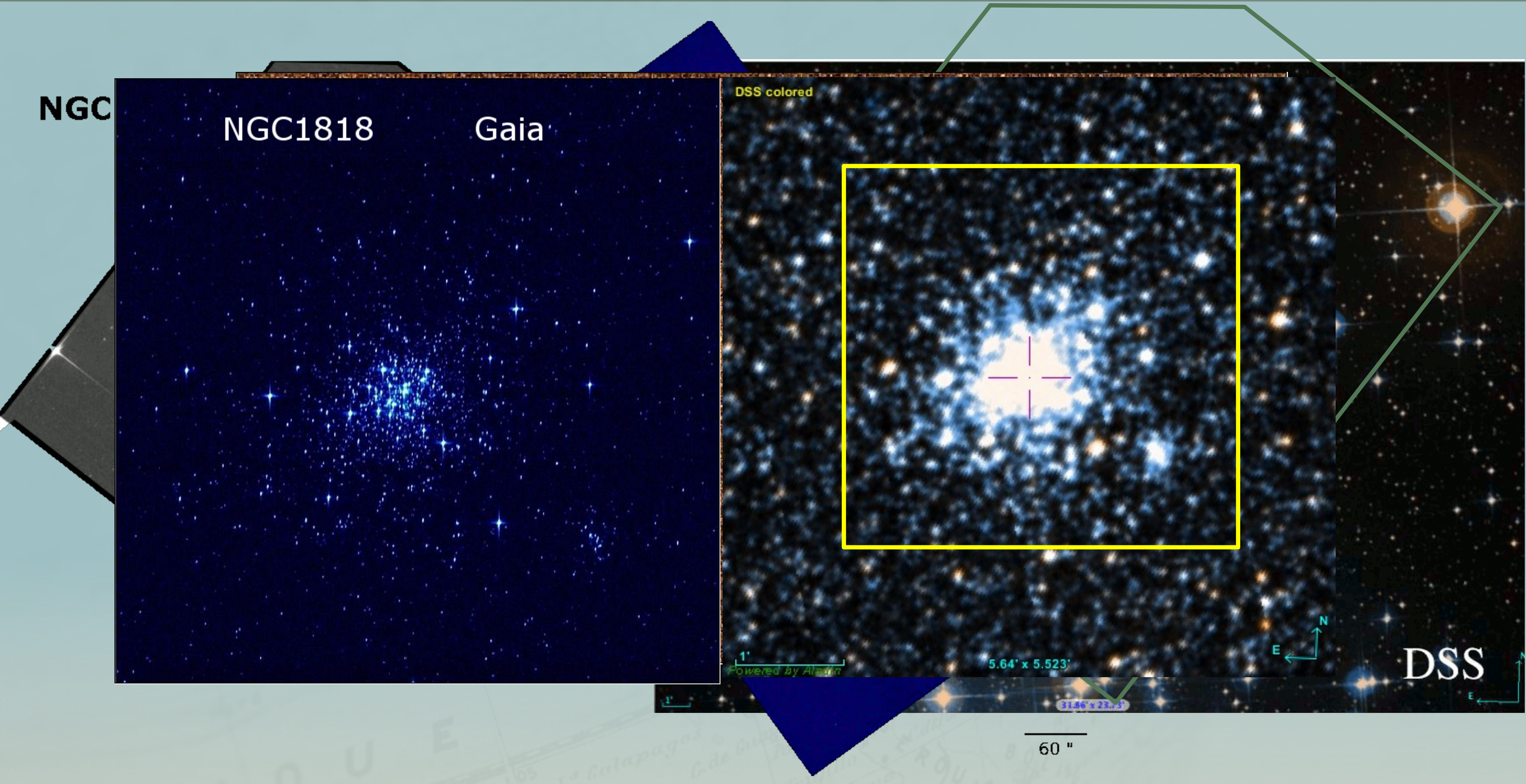


ESA/Gaia/Airbus DS/DPAC/IEEC-ICCUB/M.Weiler

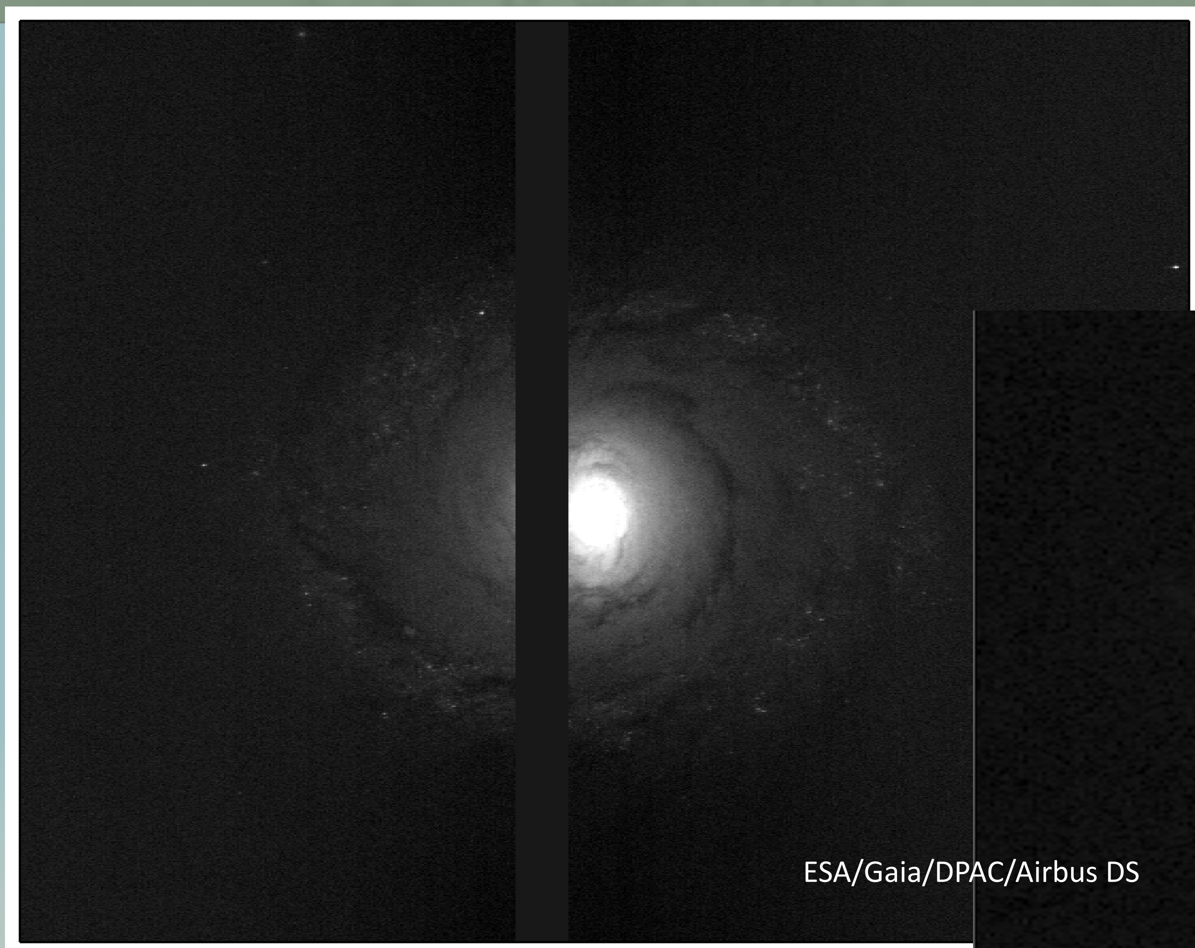
Gaia's focal plane for 2 telescopes 1.49 x 0.54 m

- Time to cross a CCD: 4.4s
- Time to cross the FOV: 45s
- Time between FOVs: 106.5m & 4h 13.5m
- Time between scans: 6h

Examples of Gaia imaging capabilities

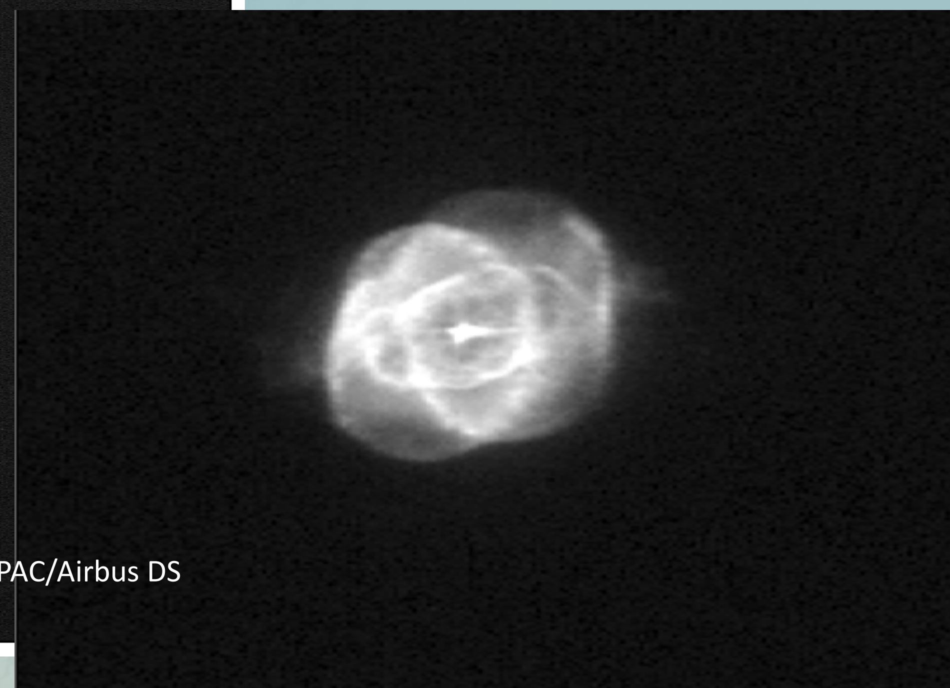


Examples of Gaia imaging capabilities

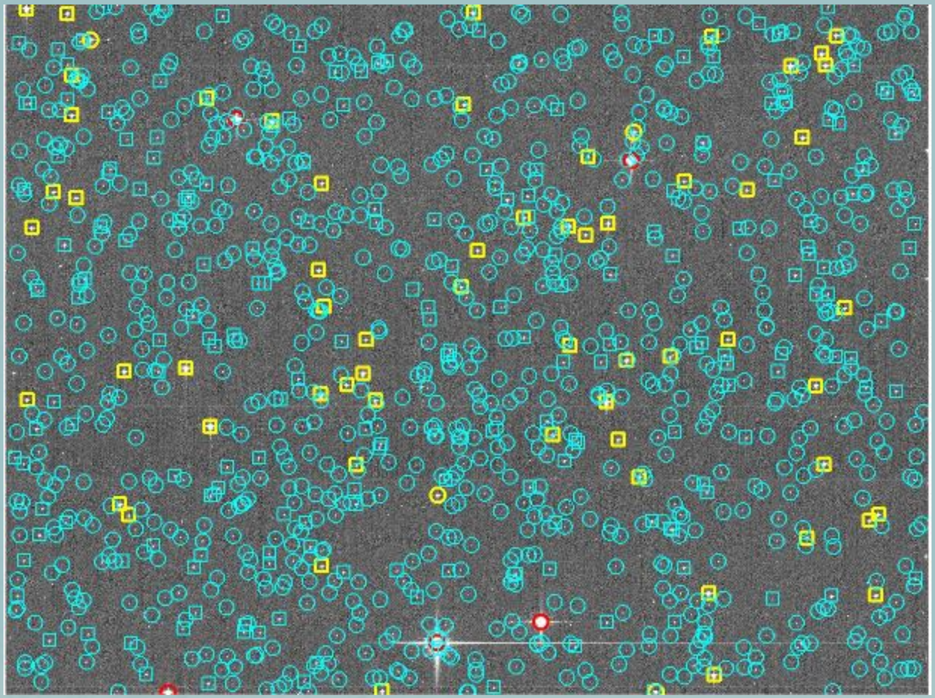


Messier 94

Cat's Eye Nebula

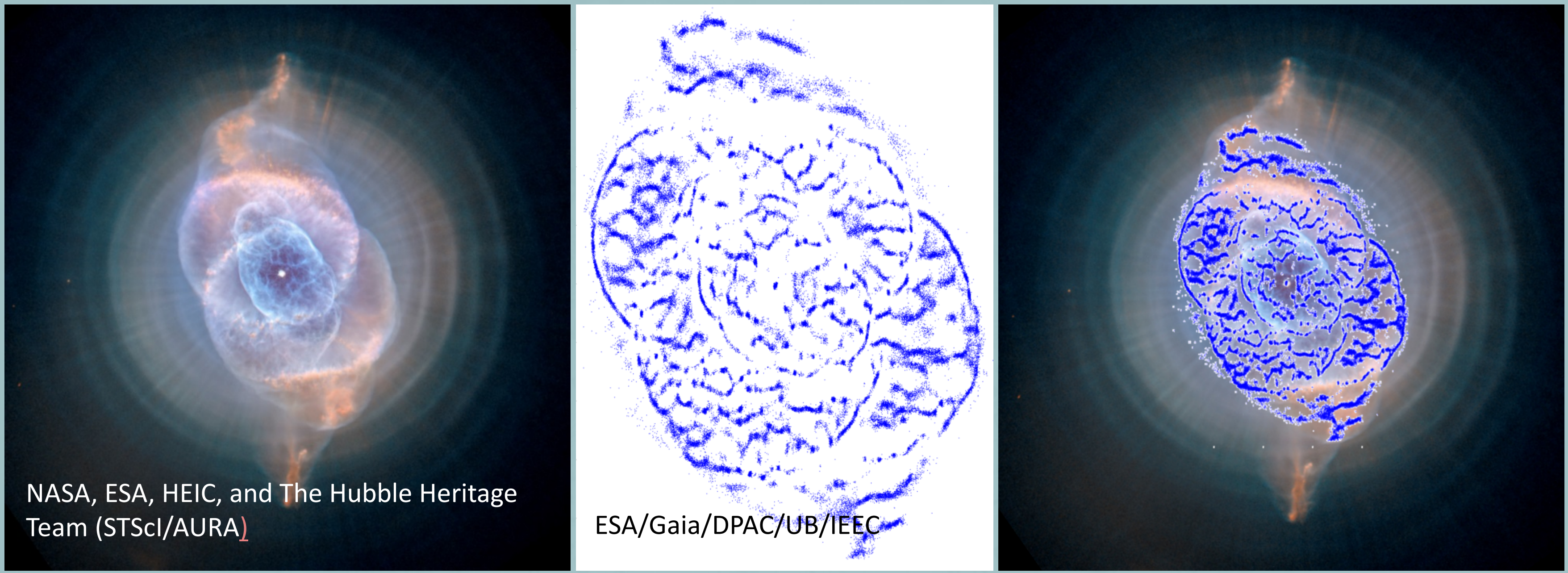


Examples of real Gaia "images"



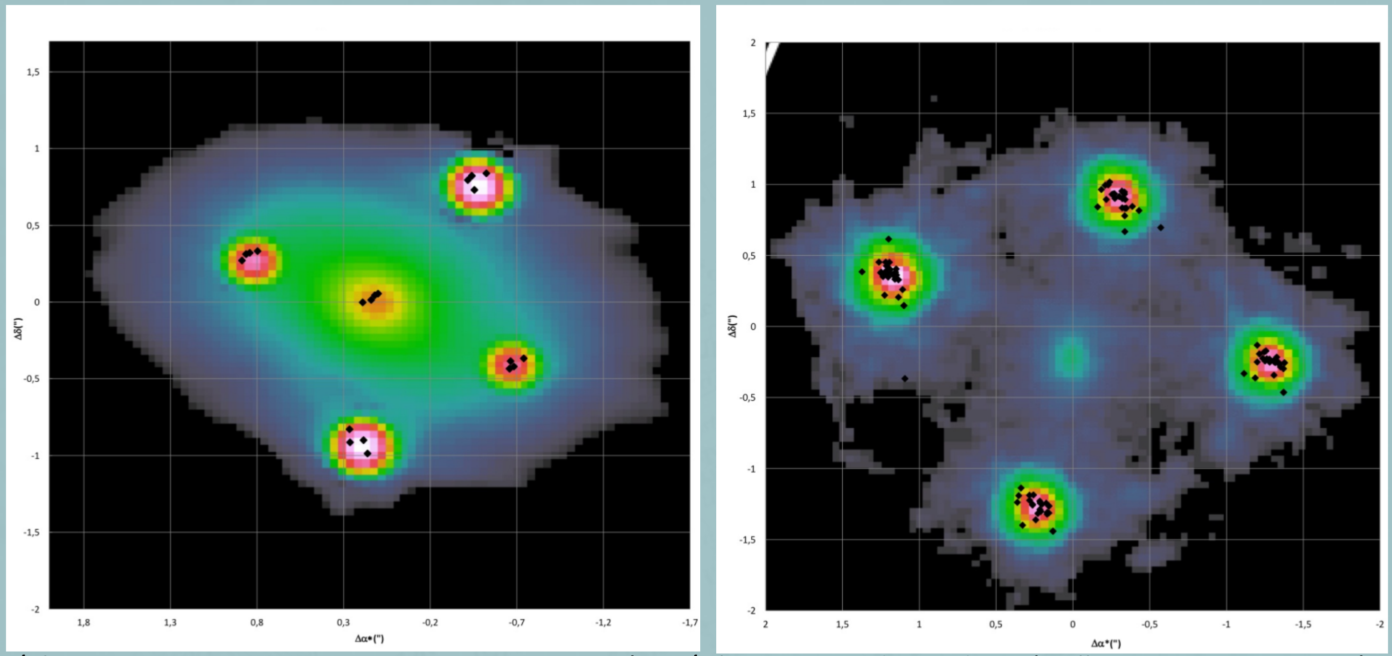
An image of the sky as recorded by one of the sky mapper CCDs and the assignment of windows to all point-like sources detected and confirmed above a given threshold. The limiting magnitude of Gaia for this image is G = 20.7. Several symbols and colours encircling the sources are used for different ranges of magnitudes

Examples of real Gaia “images”



Left: HST ACS/WFC image of the Cat's Eye nebula (integration time 1.2 h; north is up and east is left). The scale of the image is ~1 x1 arcminute. Middle: the ~84,000 Gaia detections that were made in this area from 25 July to 21 August 2014. Right: a superposition of the two images

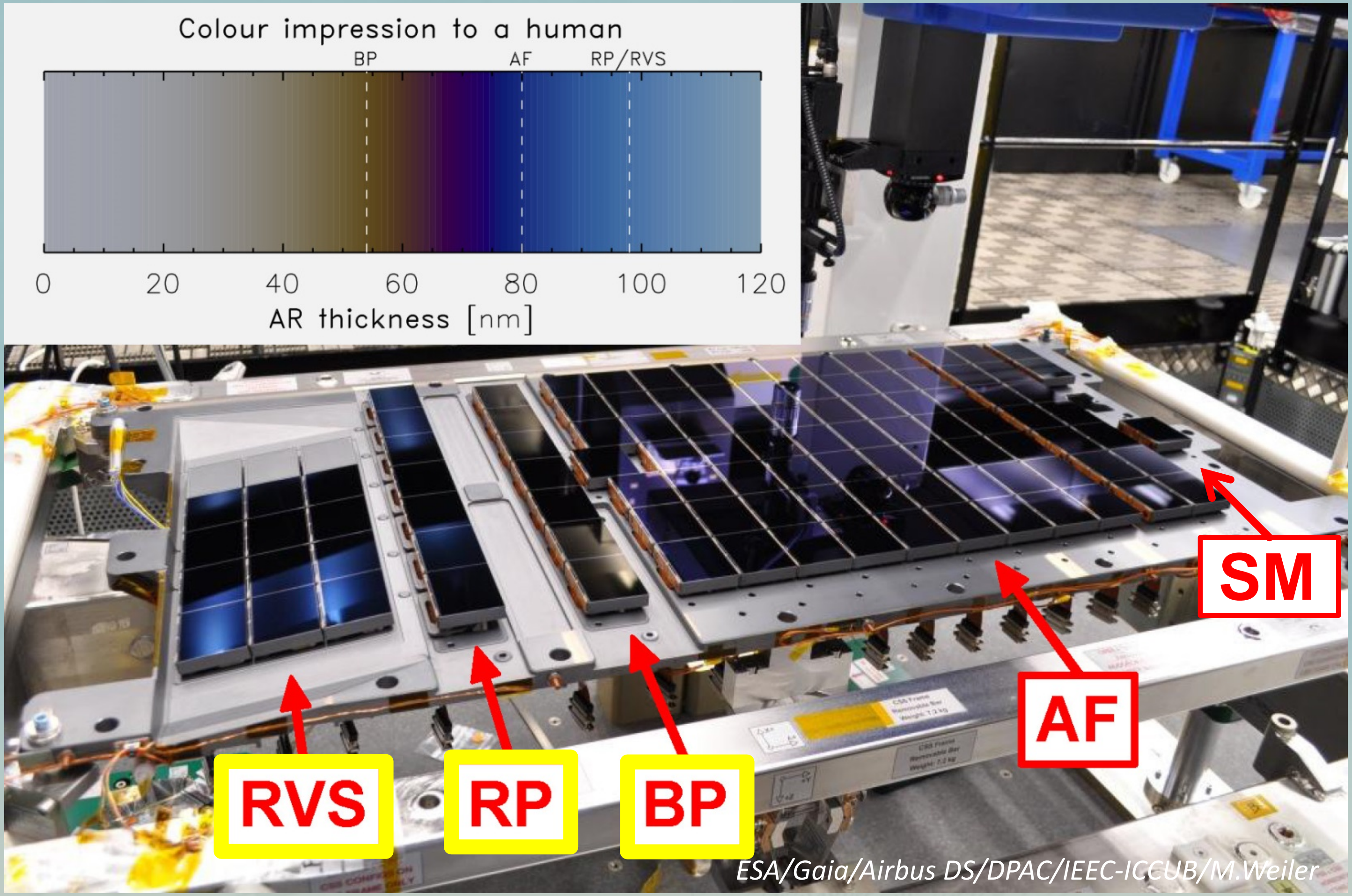
Examples of real Gaia “images”



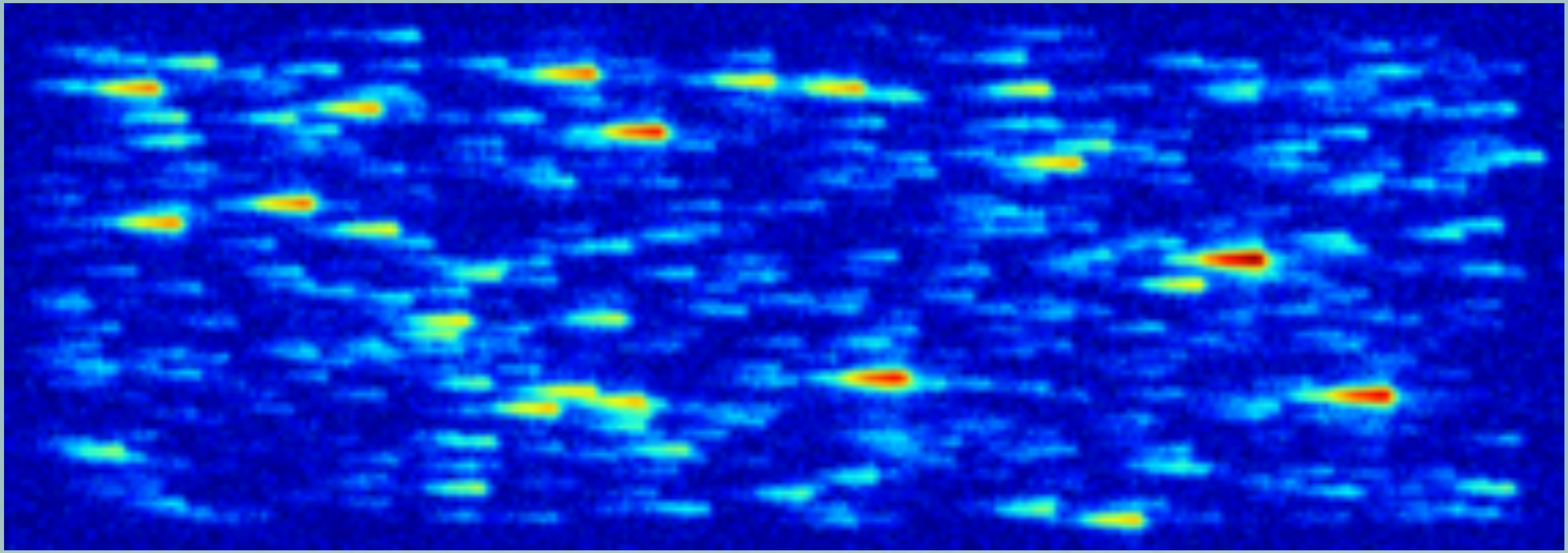
ESA/Gaia/DPAC/Christine Ducourant, Jean-Francois Lecampion (LAB/Observatoire de Bordeaux), Alberto Krone-Martins (SIM/Universidade de Lisboa, LAB/Observatoire de Bordeaux), Laurent Galluccio, Francois Mignard (Observatoire de la Côte d'Azur, Nice)

Einstein Cross (left) and HE0435-1223 (right) with Gaia astrometric positions placed over HST images. Magnitude ranges: 17 to 19 ; astrometric accuracy of each position in this preliminary reduction is ~100 mas. It will be much improved during the global astrometric processing where spacecraft attitude will also be solved together with the source astrometry.

Examples of Gaia spectroscopic capabilities

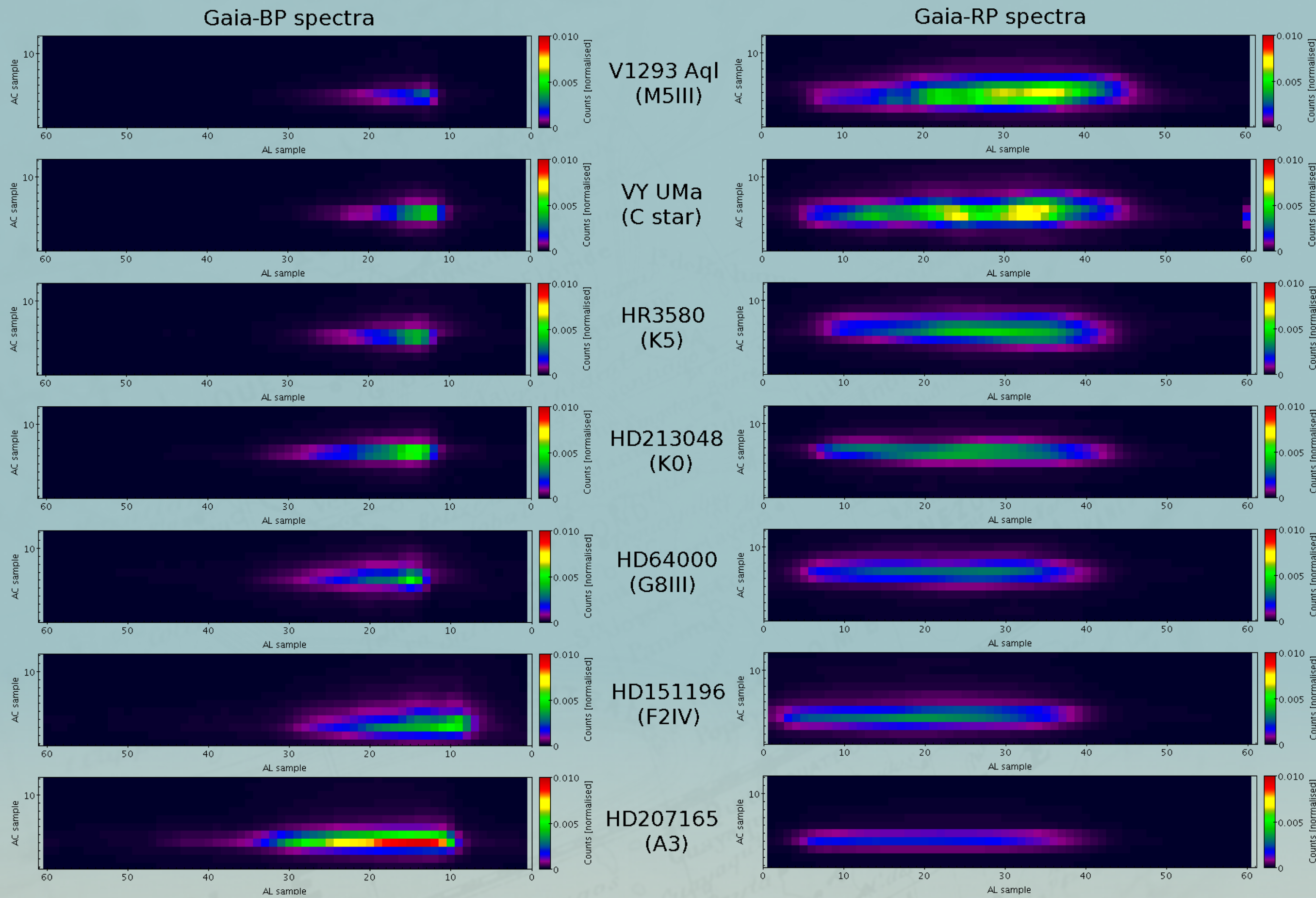


Examples of Gaia spectroscopic capabilities



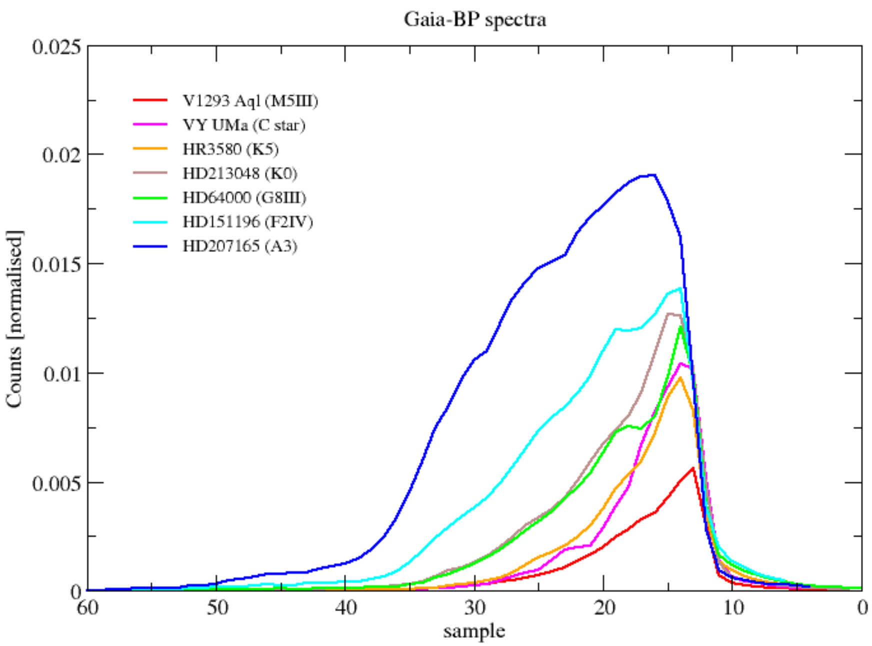
A simulation of a crowded stellar field as observed by Gaia's photometric instruments.

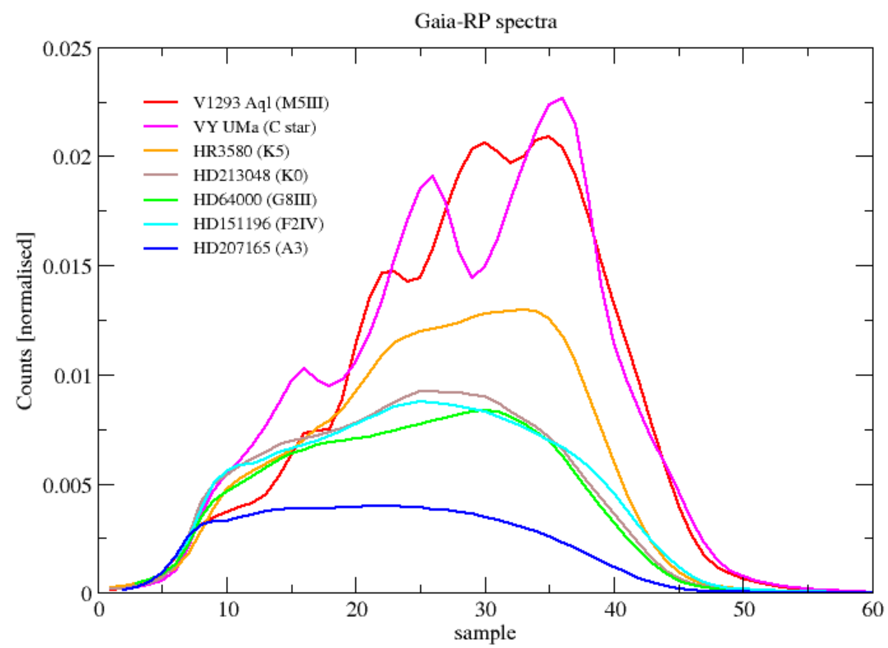
Examples of Gaia spectroscopic capabilities



Blue and Red Photometer 2D spectra for 7 bright cool (~3000°C) and hot (~8000°C) stars.

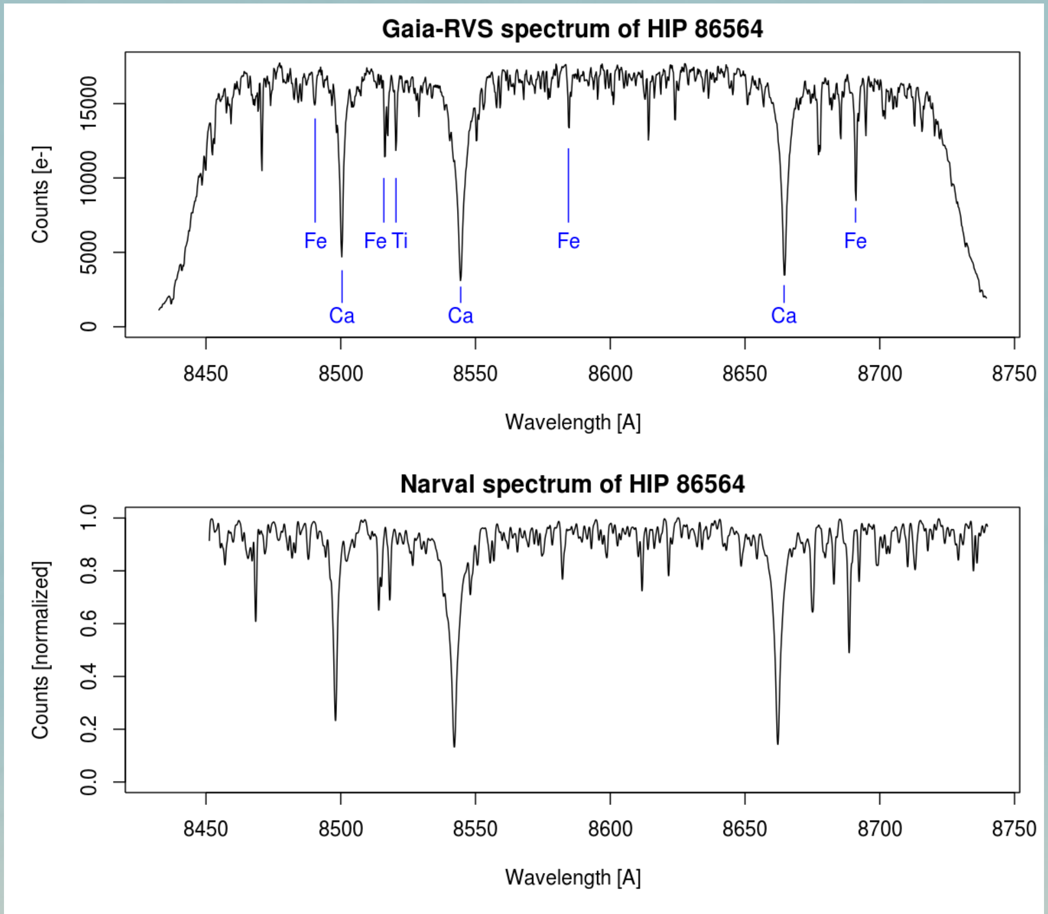
Gaia BP/RP spectra





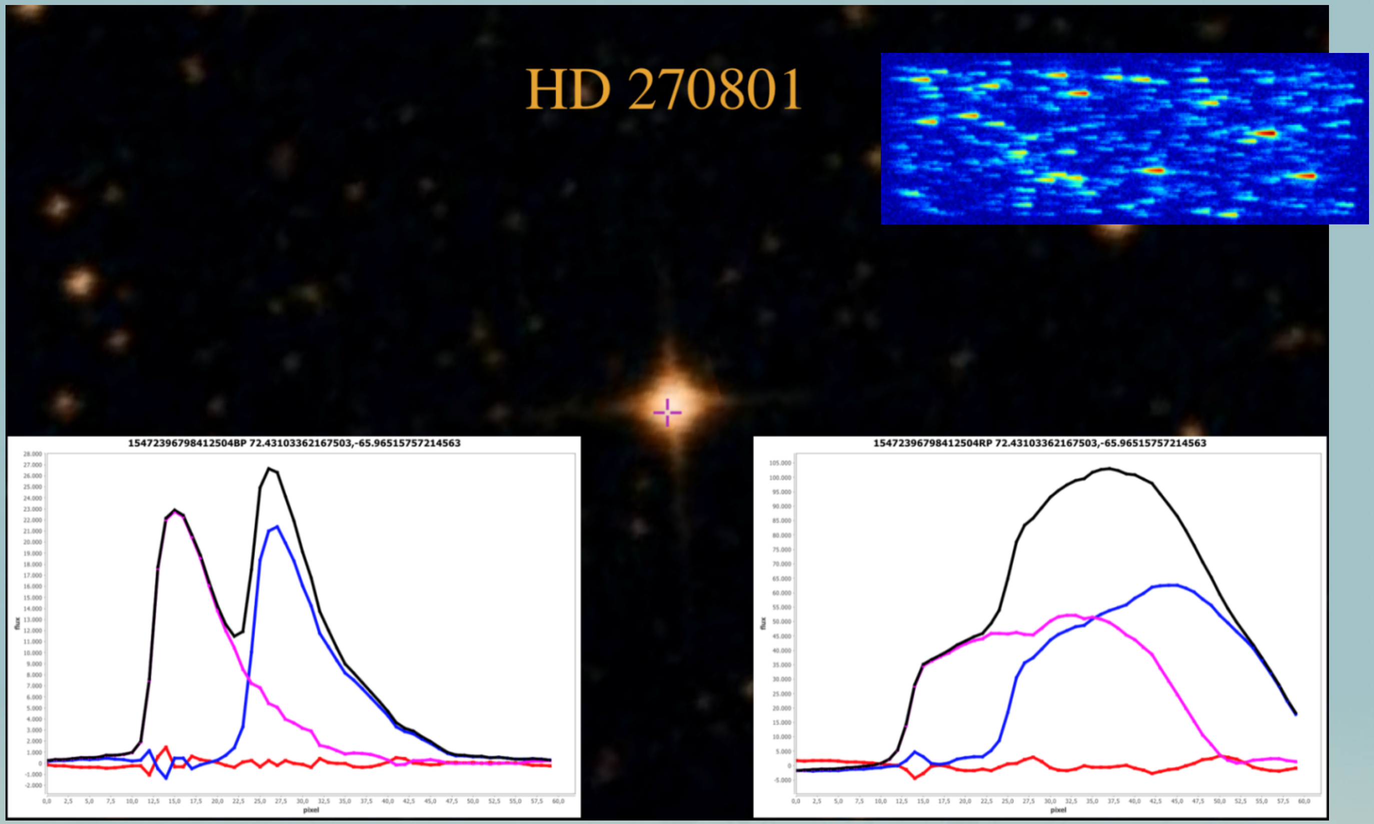
Blue and Red Photometer 1D spectra for 7 bright cool (~3000°C) and hot (~8000°C) stars.

Gaia RVS spectrum



HIP 86564 (K5, V=6.6), RVS & Narval@Bernard Lyot 2m spectra R=11500

First Gaia BP/RP deblended spectra



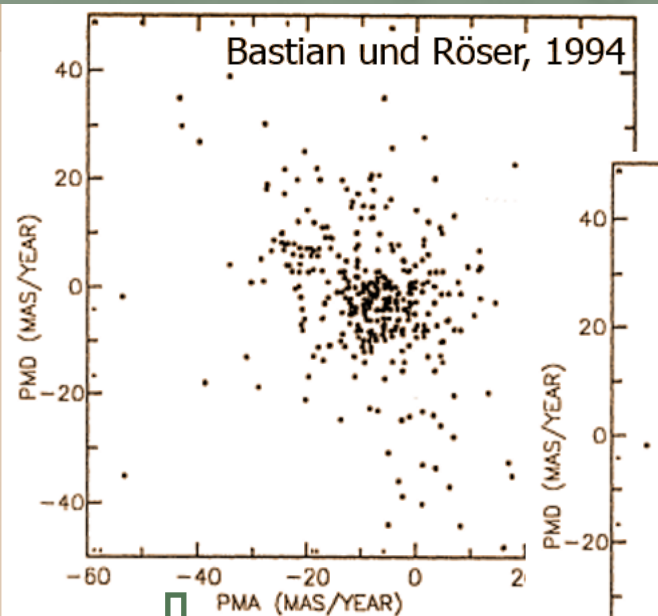
DSS coloured image of the double star HD270801. Bottom left: the observed BP spectrum in black and the two extracted spectra in magenta and blue; in red the extraction residuals. Bottom right: the same for RP

Tales of two clusters retold by Gaia

John Herschel, 1835
L. E. Dreyer , NGC2451 in 1888

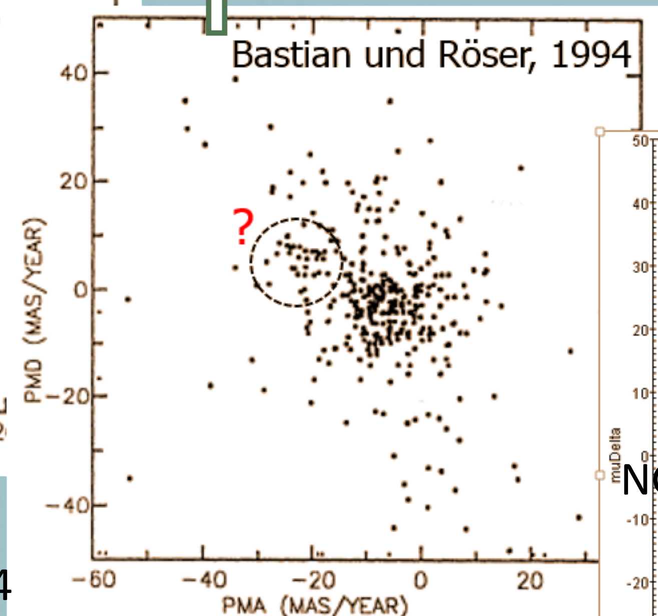
S. Röser and U. Bastian 1994
Proper Motions Catalogue (PPM)
more than 100 years of position measurements! The cluster was finally proven to be non-existent

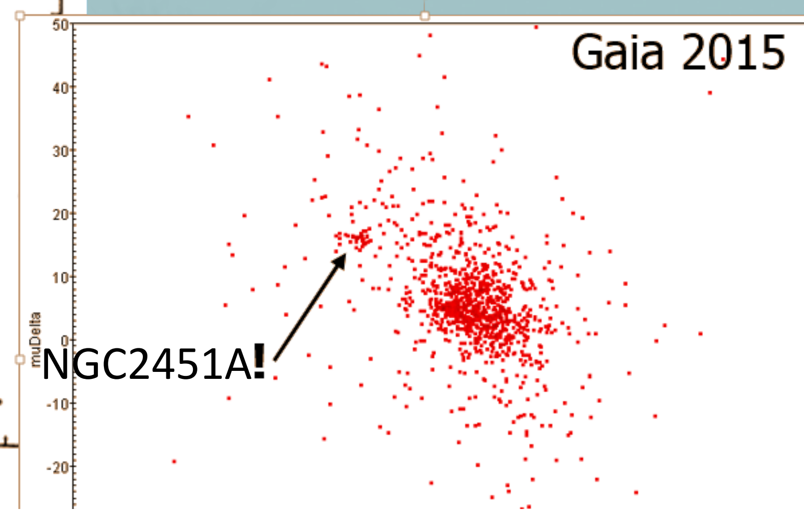
Tales of two clusters retold by Gaia



S. Röser & U. Bastian 1994
NGC2415 NON existent

A barely discernible density enhancement?





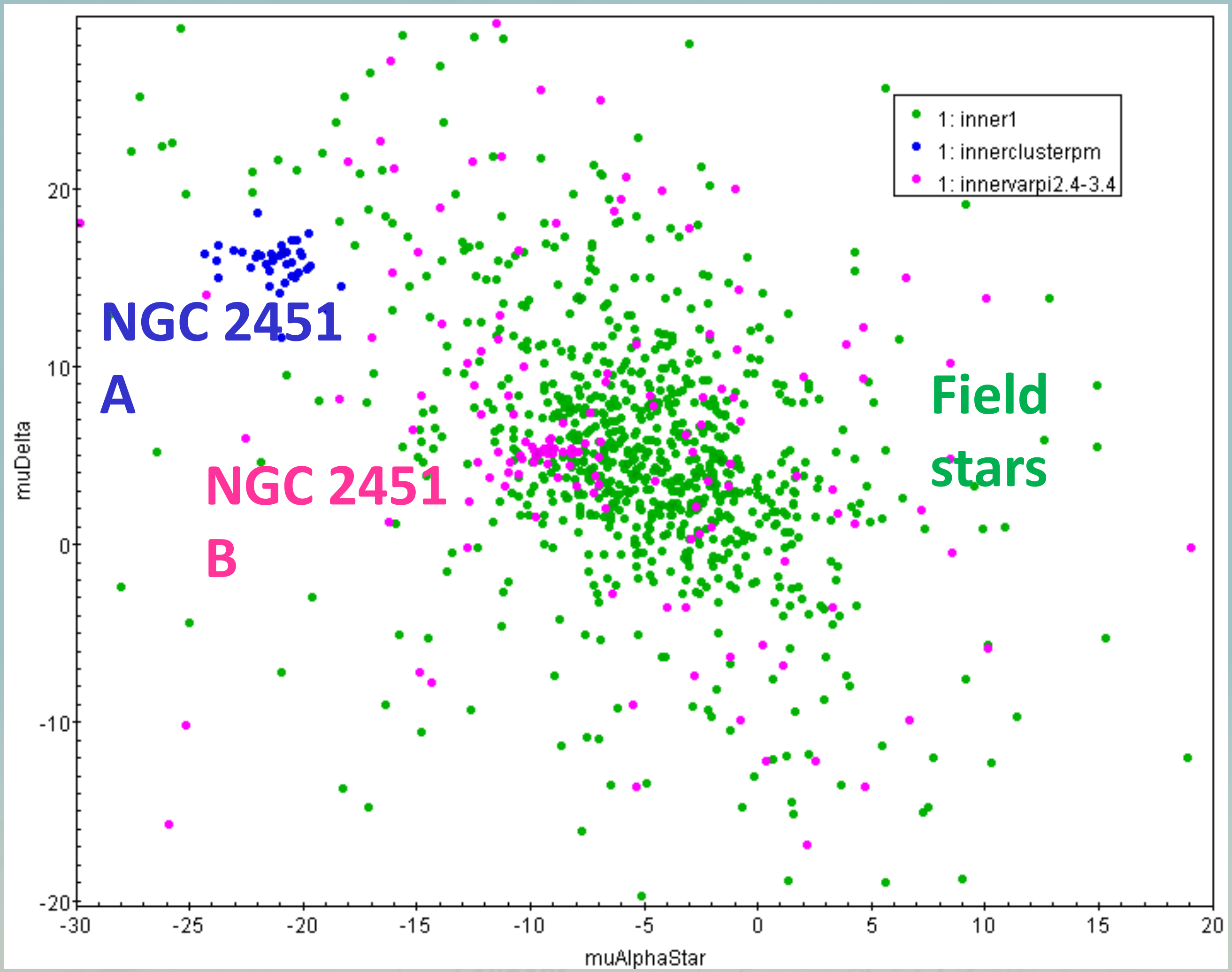
CMD
A rea
Even
indica
star c
diagra
NGC

10 months of Gaia

NGC2451 nicely pop-out in the PM diagram. No need of CMD. NGC2451B still hidden…BUT Gaia distance measurements of all 1100 stars in the NGC 2451 area indicated two slight bumps at ~190 pc, and ~360 pc (in agreement with the supposed distances of the two clusters!)

ESA/Gaia/DPAC/DPCE/DPCB/CU3/U. Bastian

Tales of two clusters retold by Gaia



Gaia DPAC

DPAC: Data Processing and Analysis Consortium

- CU1: System Architecture
- CU2: Data Simulations
- CU3: Core Processing
- CU4: Object Processing
- CU5: Photometric Processing
- CU6: Spectroscopic Processing
- CU7: Variability Processing
- CU8: Astrophysical Parameters
- CU9: Catalogue Access

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Gaia @ INAF-OABo

CU5 - photometric processing

- **DU13**: Instrument absolute response characterization: ground-based preparation (E. Pancino, G. Altavilla deputy)
- **DU14**: Instrument absolute response characterisation: definition and application (C. Cacciari)

G. Cocozza, S. Galleti, S. Ragaini,

M. Bellazzini, A. Bragaglia, L. Federici, P. Montegriffo, E. Rossetti

- **DU17**: Flux and classification-based science alerts

CU7 - variability processing (G. Clementini)

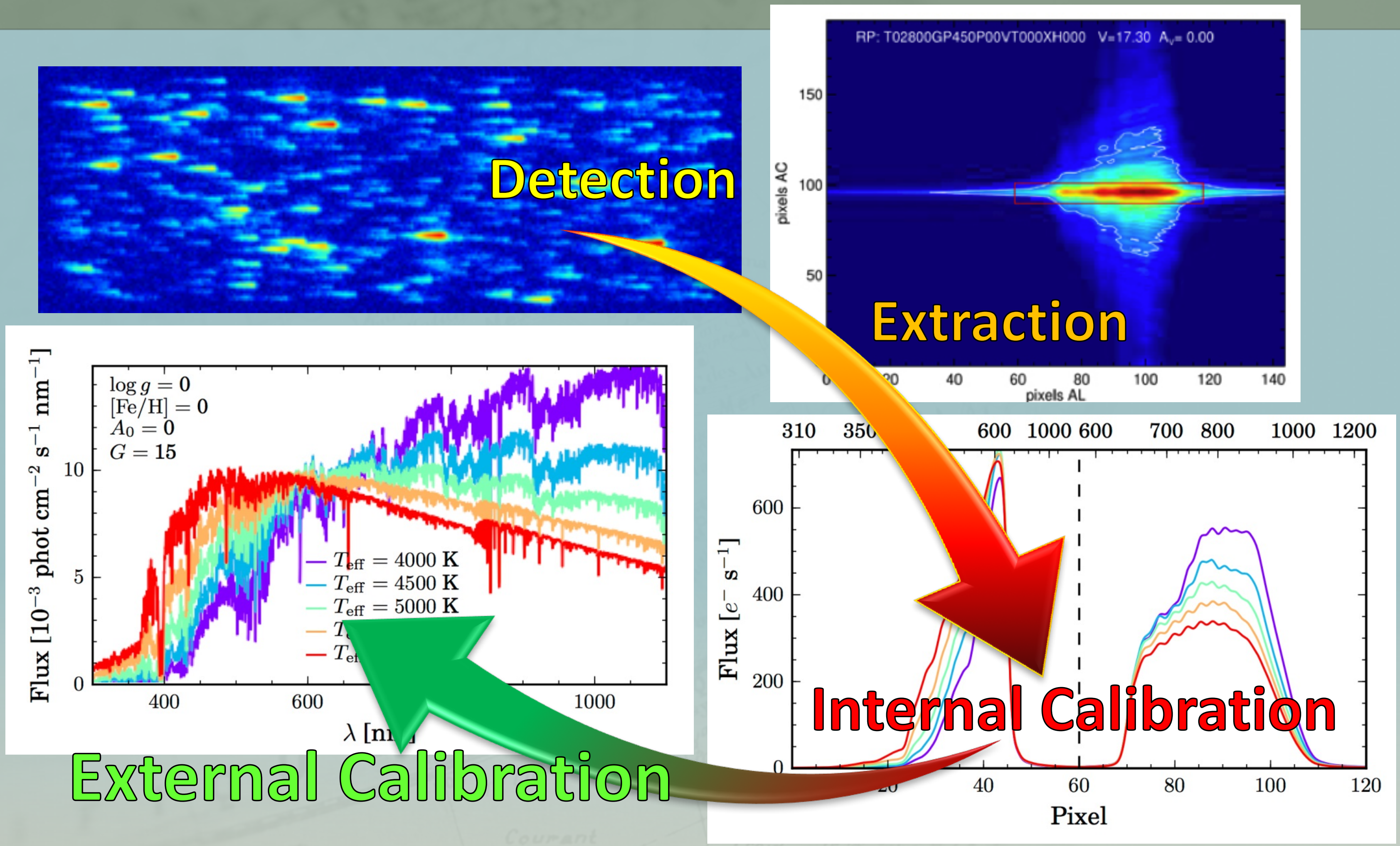
The Bologna CU5-DU13 goal

- **Provide a grid of ~200 Spectro-Photometric Standard Stars (SPSS) for the absolute spectro-photometric calibration of the Gaia G-band and low resolution (BP/RP) spectrophotometry**

- Existing grids are not sufficient, we need:
  - Spectral type coverage (all spectral types)
  - Well distributed in the sky
  - Precision and accuracy of 1-3%
  - Good statistics (100-200)
  - Full coverage of Gaia range (330-1100 nm)

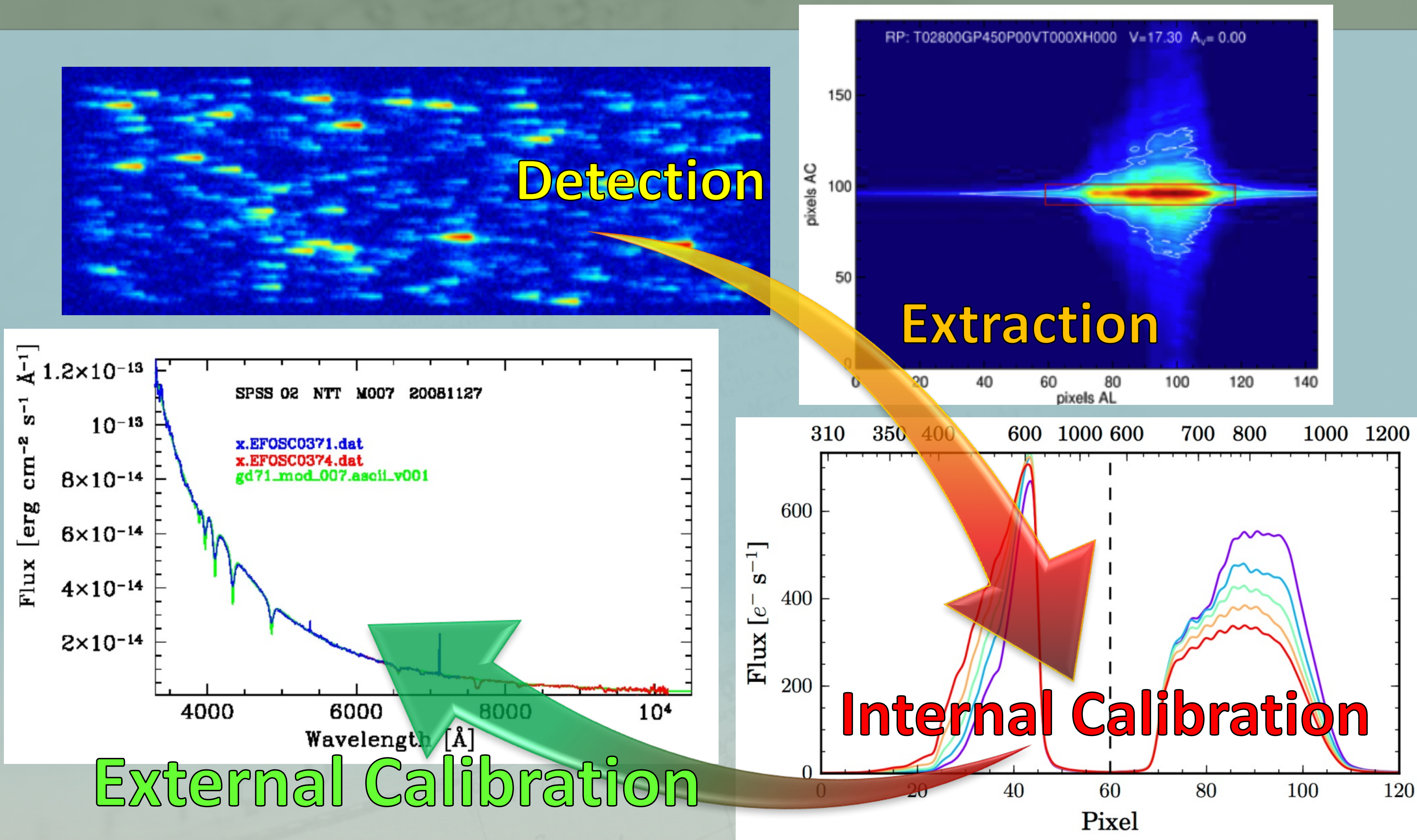
- **See Pancino et al., 2012, MNRAS, 426, 1767, Altavilla et al. 2015, AN, 336, 515**

Gaia Absolute Calibration



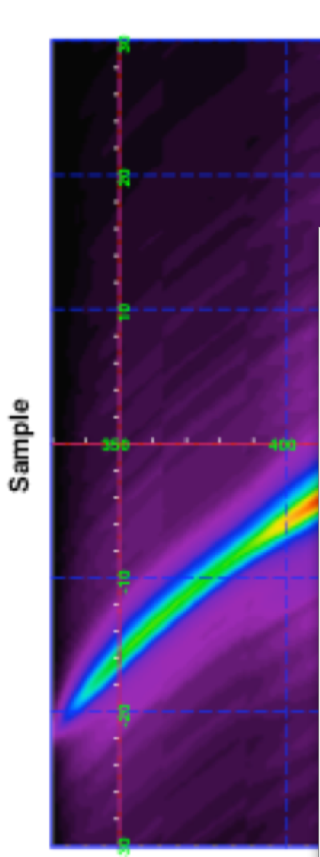
Astraatmadja, 2015, GAIA-C8-TN-MPIA-TLA-001

Gaia Absolute Calibration

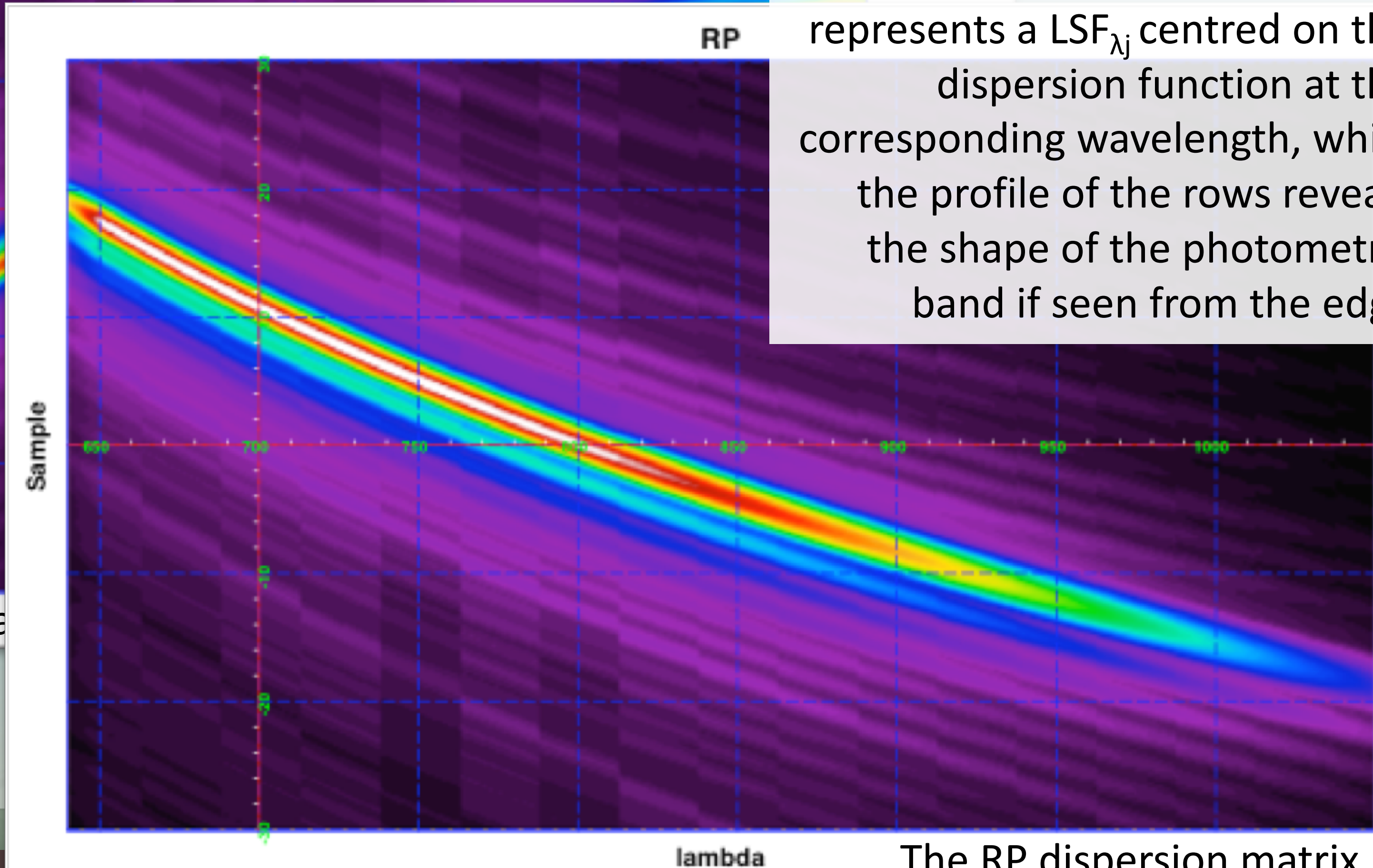


LSF smearing

Dispersion matrix for BP and RP instruments
for FoV 1 and CCD row no 4: each column of the matrices represents a $LSF_{\lambda j}$ centred on the dispersion function at the corresponding wavelength, while the profile of the rows reveals the shape of the photometric band if seen from the edge



The BP dispersion ma

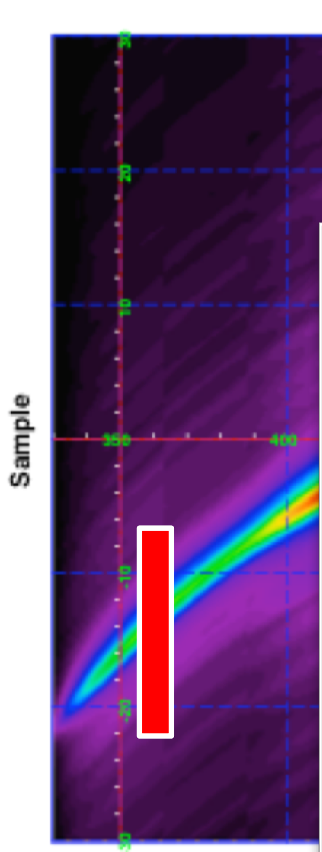


The RP dispersion matrix

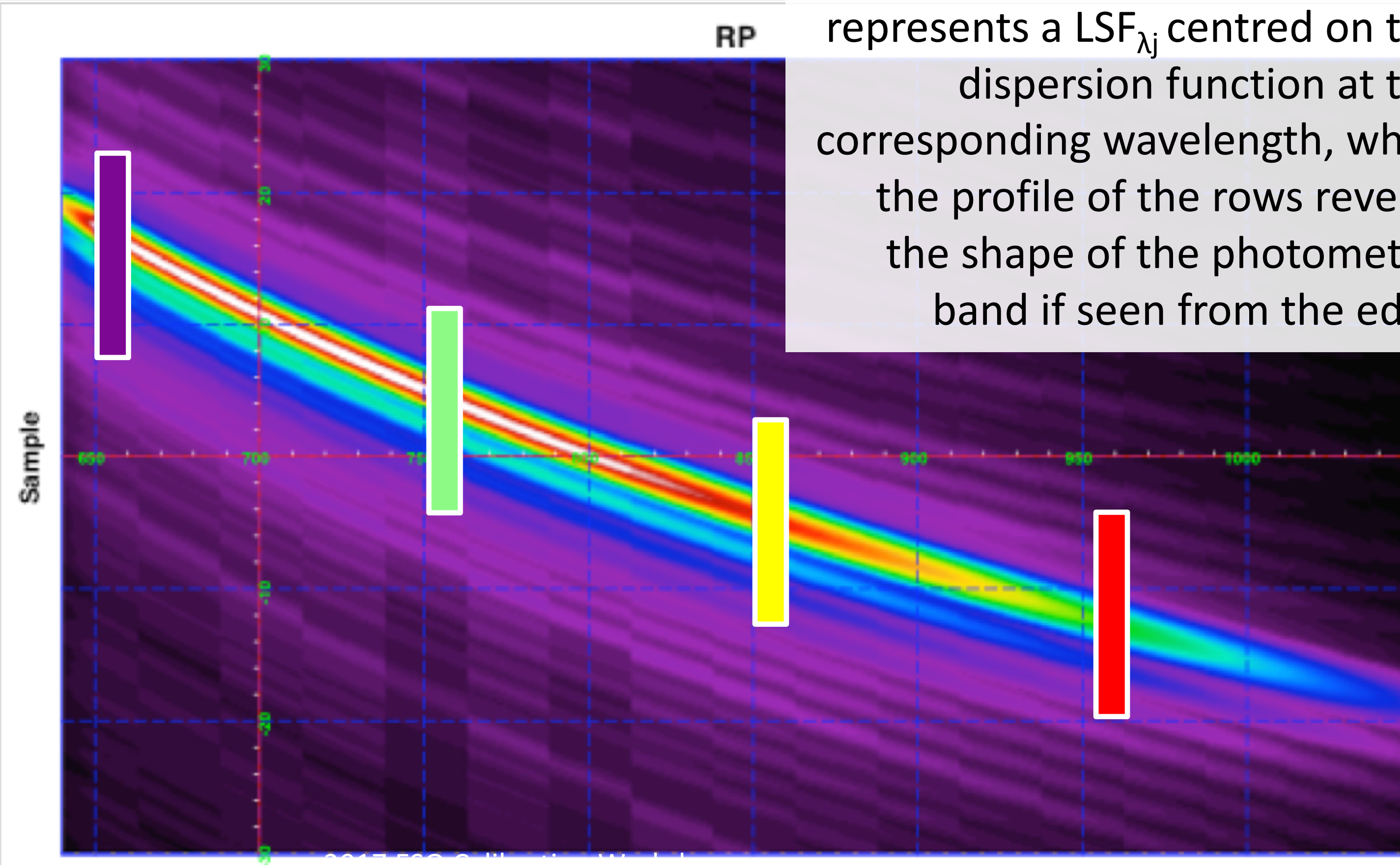
P. Montegriffo

GAIA-C5-TN-OABO-PMN-002

LSF smearing



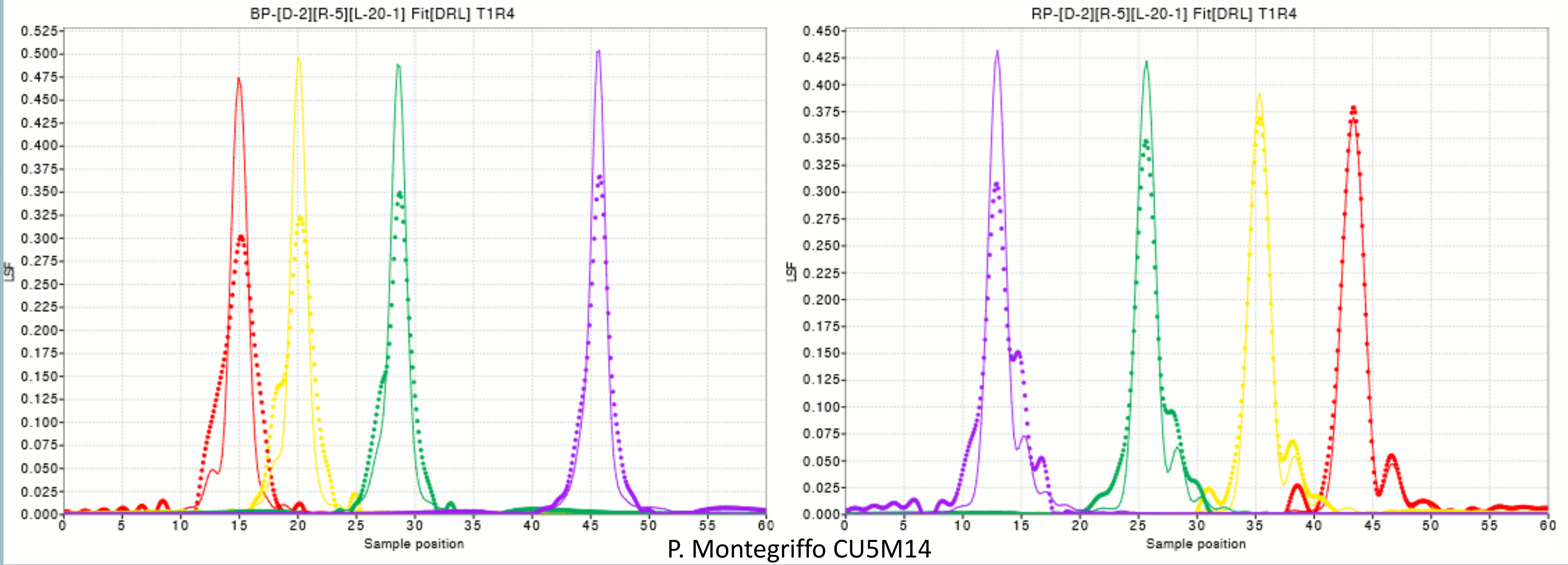
The BP dispersion ma



The RP dispersion matrix

Dispersion matrix for BP and RP instruments for FoV 1 and CCD row no 4: each column of the matrices represents a $LSF_{\lambda j}$ centred on the dispersion function at the corresponding wavelength, while the profile of the rows reveals the shape of the photometric band if seen from the edge

Gaia LSF smearing



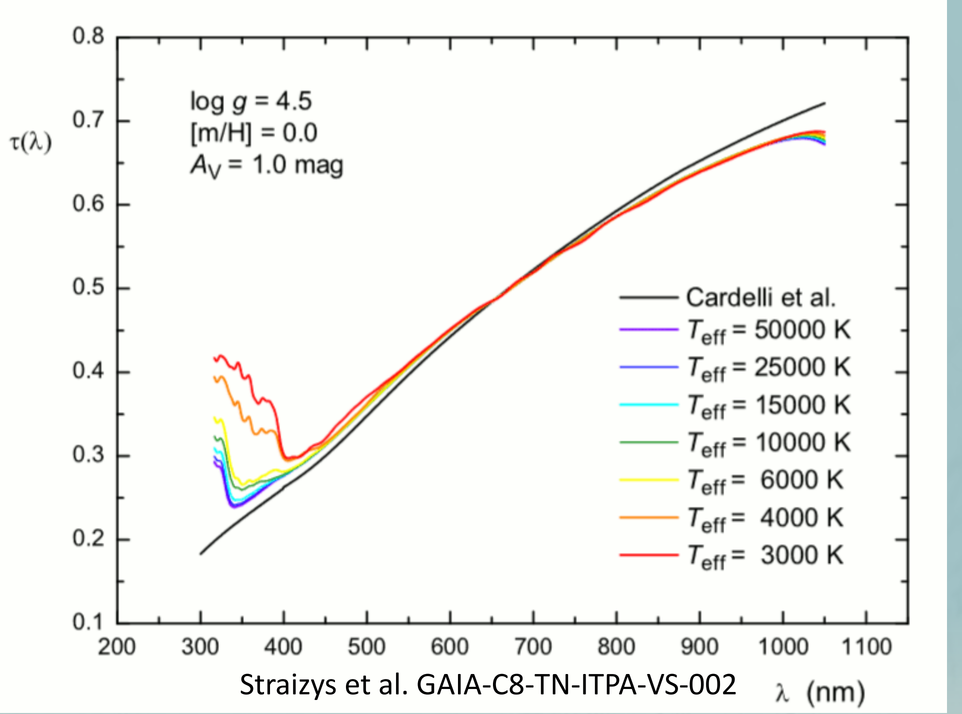
P. Montegriffo CU5M14

- 350 nm
- 450 nm
- 550 nm
- 650 nm

- 650 nm
- 750 nm
- 850 nm
- 950 nm

- line : starting model
- dots: fitted model

Gaia LSF smearing



Straizys et al. GAIA-C8-TN-ITPA-VS-002

The Gaia apparent interstellar extinction laws for different effective temperatures.

Gaia Absolute Calibration

Same principle as for classical spectrophotometry
but
much more complicated instrument model

~100-200 calibrators needed to model instrument response
mmag internal accuracy, a few % external accuracy

Gaia Absolute Calibration

- **A large observational effort to collect the required data started in 2006 and was completed in 2015**
- Almost 5000 hours (the equivalent of 500 nights)
- Spread in >900 different nights in 66 observing runs from 2006 to 2015
- Using 6(+1) different telescopes and instruments
- Comparable to one of the large modern surveys (GES)

Instruments characterization

Altavilla et al. 2015AN.336.515A

Menu: user altavilla

GAIA SPSS ARCHIVE

asdc ASI Science Data Center

Data Management *Back to home page*

Session	Data Browsing	Data Metadata Editing
Logout	SPSS Reference	File Upload
Change Password, e-mail	Browse by Night	
	Raw Data...	
	Masterframe...	
	2DPreRed...	
	Extracted Spectra...	
	Fringing Corrected Spectra...	
	Slit Loss Corrected Spectra...	
	Photometric Catalogues...	
	Short-Term Light Curves...	

Output Columns Choice

Click to select the columns to show

- Search by: Source
- Search by: Program and Scheduling

Night:	=	Observation Date / Observation Date
Run Type:	IN	P, V, M
Run ID:	=	
Sky Condition:	IN	Clear, Cloudy, Veiled, Varying
Instrument:	IN	BFOSC@Cassini, CAFOS@CAHA2.2, DoLoRes@TNG, EFOSC2@NTT
CCD:	IN	EEV1300x1340OLD, EEV1300x1340NEW, SITE1d_15, E2V4240

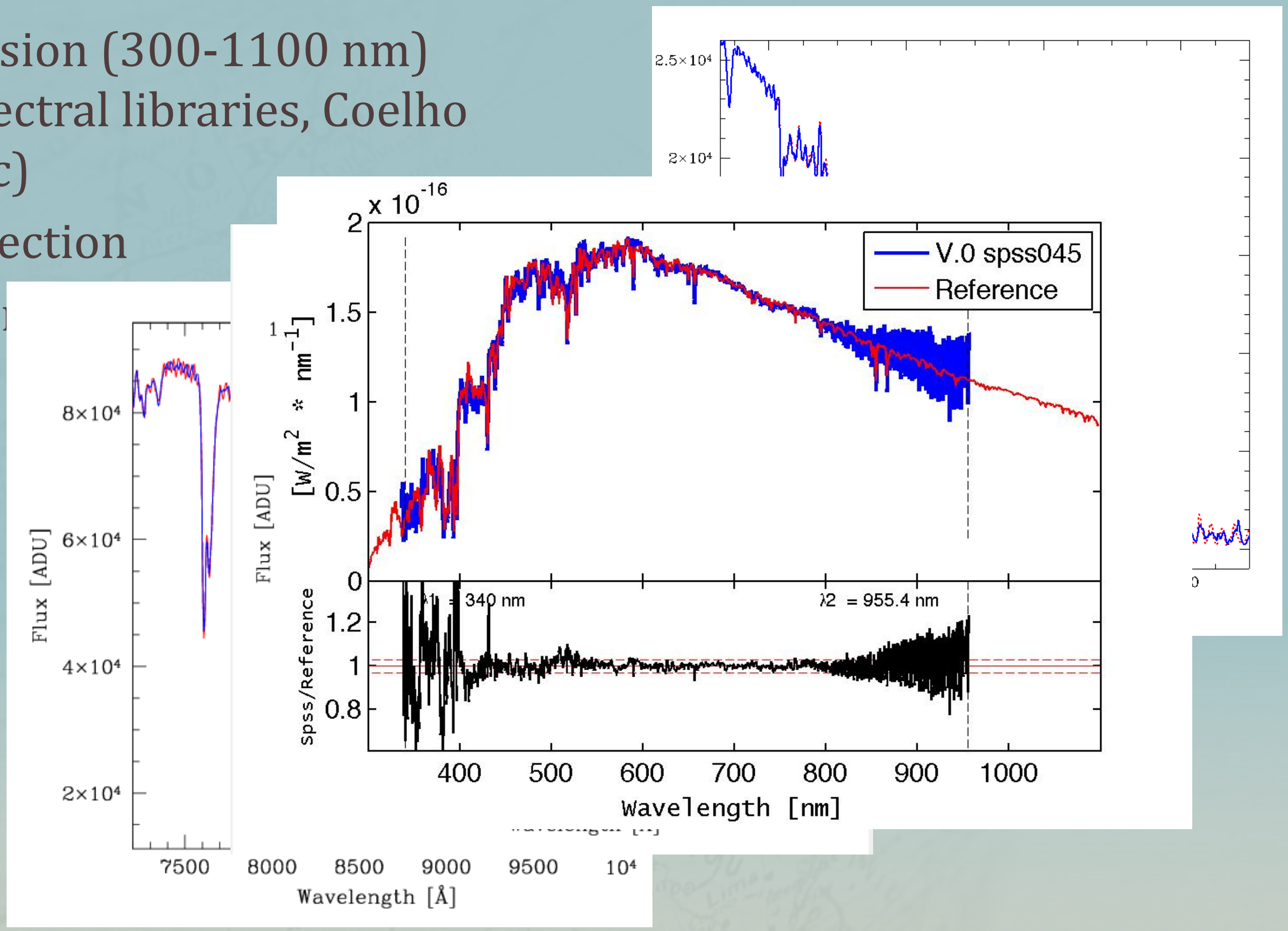
- Search by: Observing Information
- Search by: Setup Information

Reset OK

		G_TEL	G_INST	G_RUNTYP	G_RUNID	G_NIGHT	G_SKY	G_ID	FILE_THUMB	G_TYPE	G_RAhms	G_DECdms	G_DATE	G_UT	G_HJD	G_EXPT	G_EFFAM	G_SEEING
ile Download		CAHA2.2	CAFOS	M	001	2007-10-31	Clear	1		Pillar	05:06:10.31	+52:48:31.46	2007-10-31	22:04:25	2454405.42345234	10	1.511271	1.54
ile Download		CAHA2.2	CAFOS	M	001	2007-10-31	Clear	1		Pillar	05:06:06.69	+52:48:42.52	2007-10-31	22:18:33	2454405.43668268	600	1.432132	1.54
ile Download		CAHA2.2	CAFOS	M	001	2007-10-31	Clear	1		WaveLamp	05:08:47.64	+52:47:58.49	2007-10-31	22:33:58	2454405.44390024	1.5	1.403048	1.54

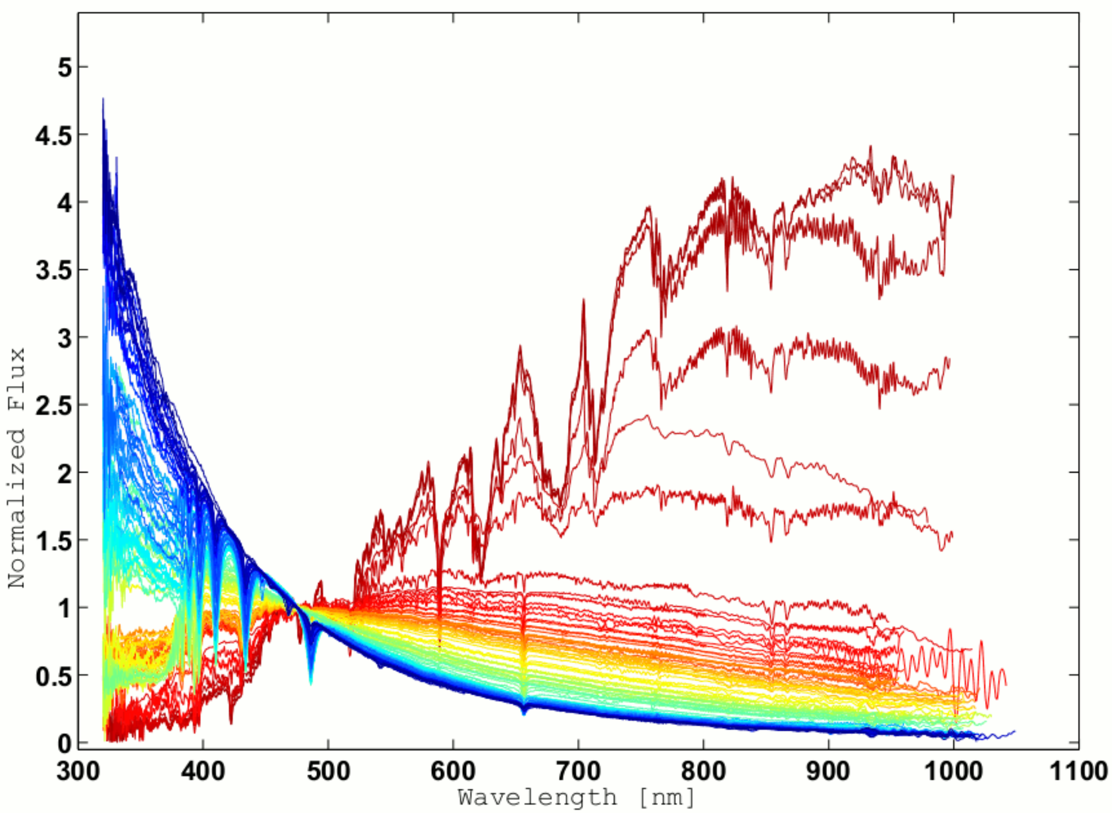
Advanced spectroscopy reductions

- Models extension (300-1100 nm) (Gaia CU8 spectral libraries, Coelho 2009, Calspec)
- Fringing correction
- Light loss cor



V0 release

The pre-launch (internal) release, October 2013



94 SPSS

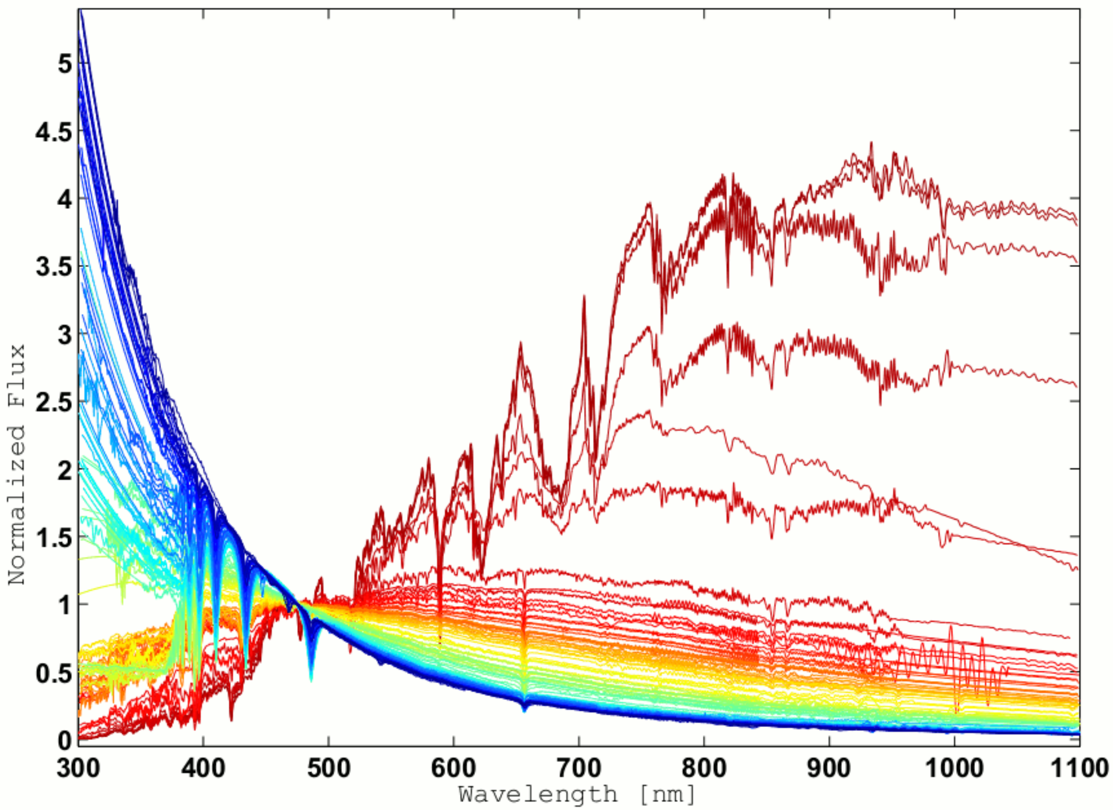
Goal:

- testing pipelines
- No fringing correction
- No narrow-slit spectra
- Cut borders (blue and red)
- Already exceeding DPAC requirements

Major problem :
Missing borders induce calibration errors > 0.1mag

V1 release

The V1 release, July 2015

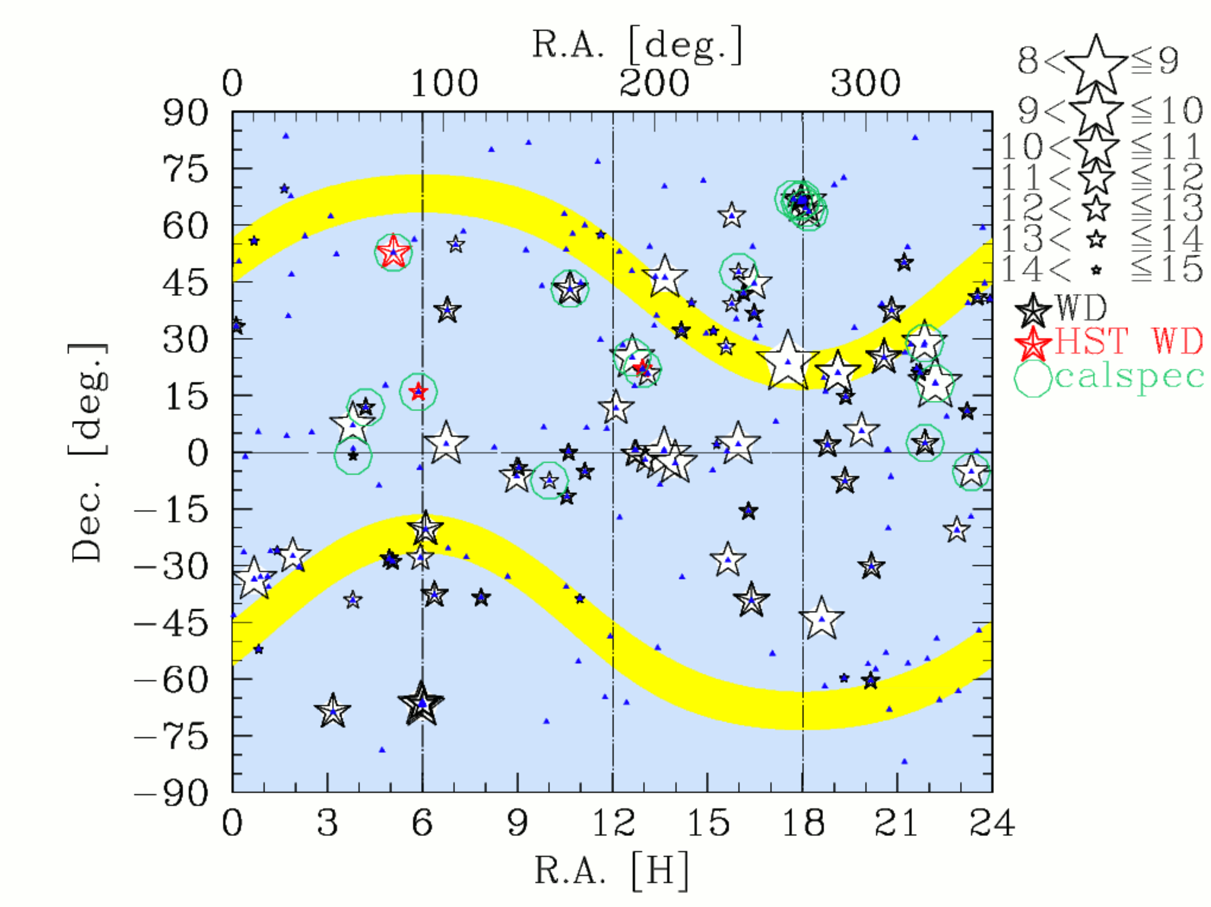


94 V0 SPSS

- Extended with theoretical or empirical template spectra (CALSPEC,
  Gaia spectral libraries,
  Public libraries)
- No new observational data
- Calibrate 1st , 2nd Gaia release
  Only G and only ZP in 1st

V1 release

July 2015

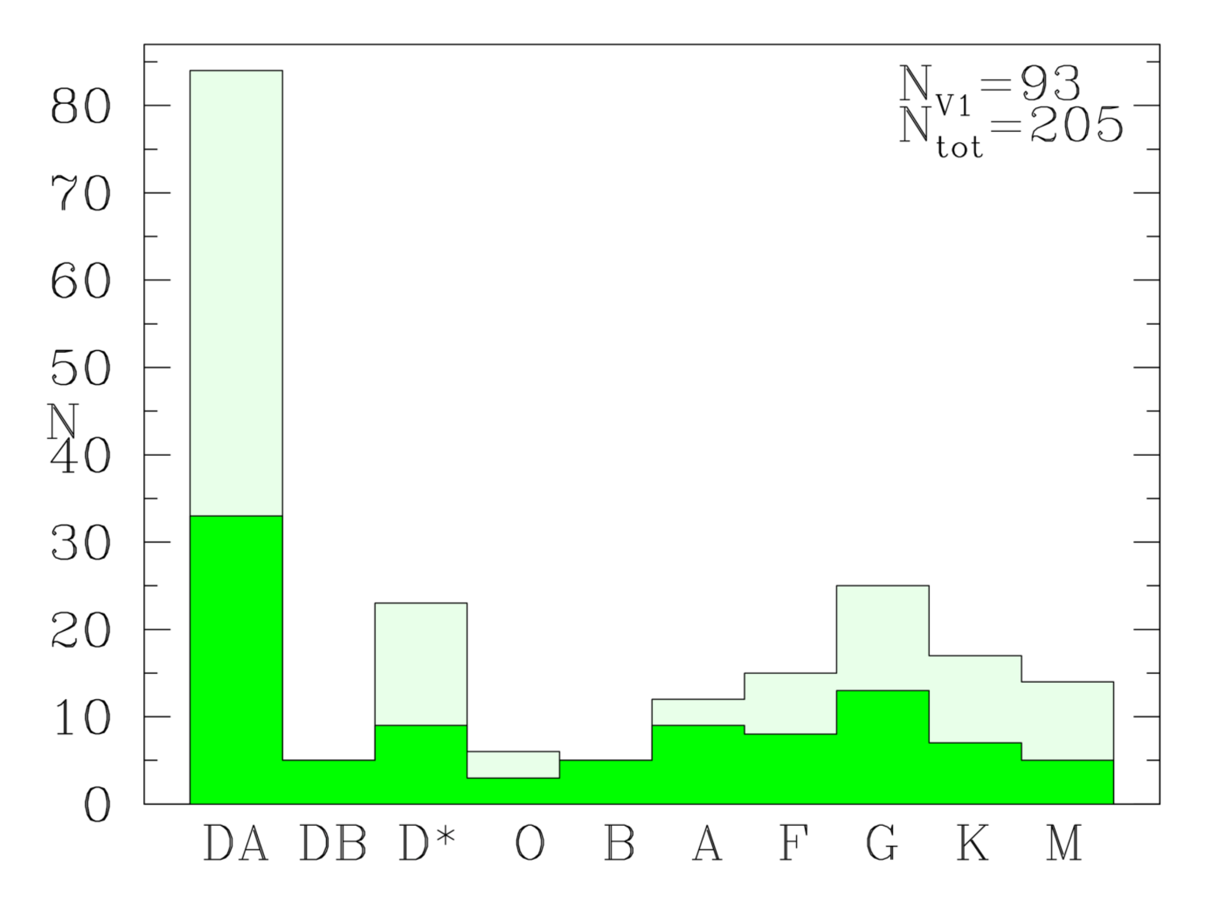


94 SPSS

- Extended with theoretical or empirical template spectra (CALSPEC, Gaia spectral libraries, Public libraries)
- Calibrate 1st Gaia release (Sept. 14 2016), G band only, and 2nd Gaia release
- Already exceeding DPAC requirements

V1 release

July 2015



94 SPSS

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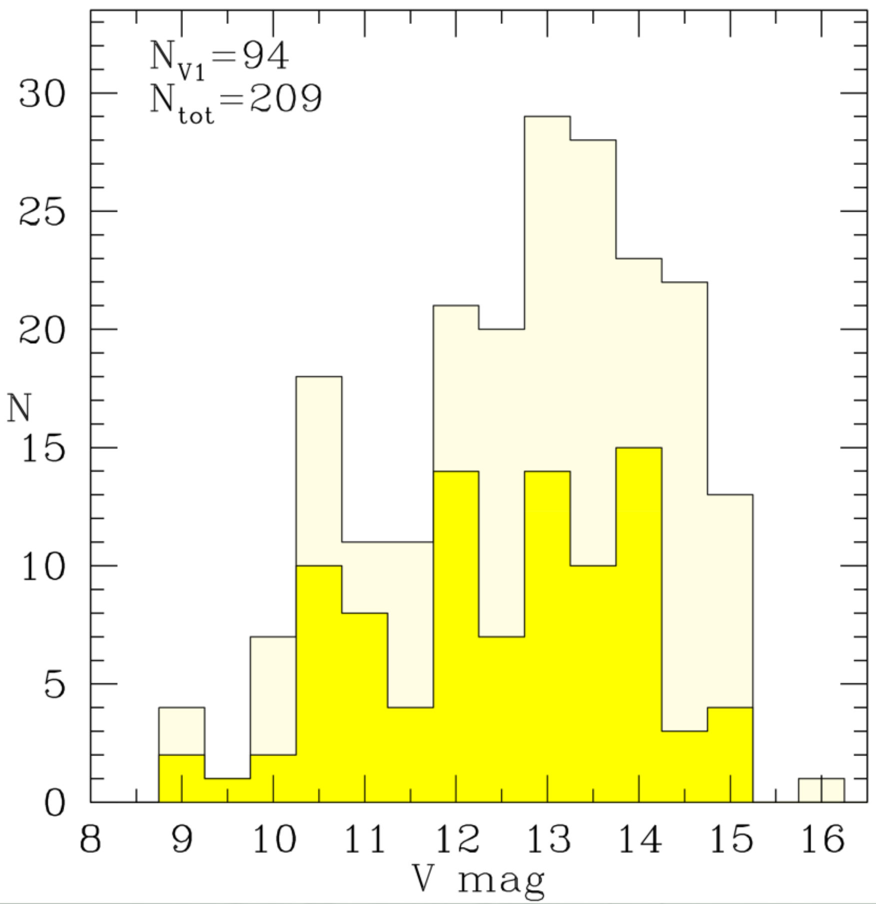
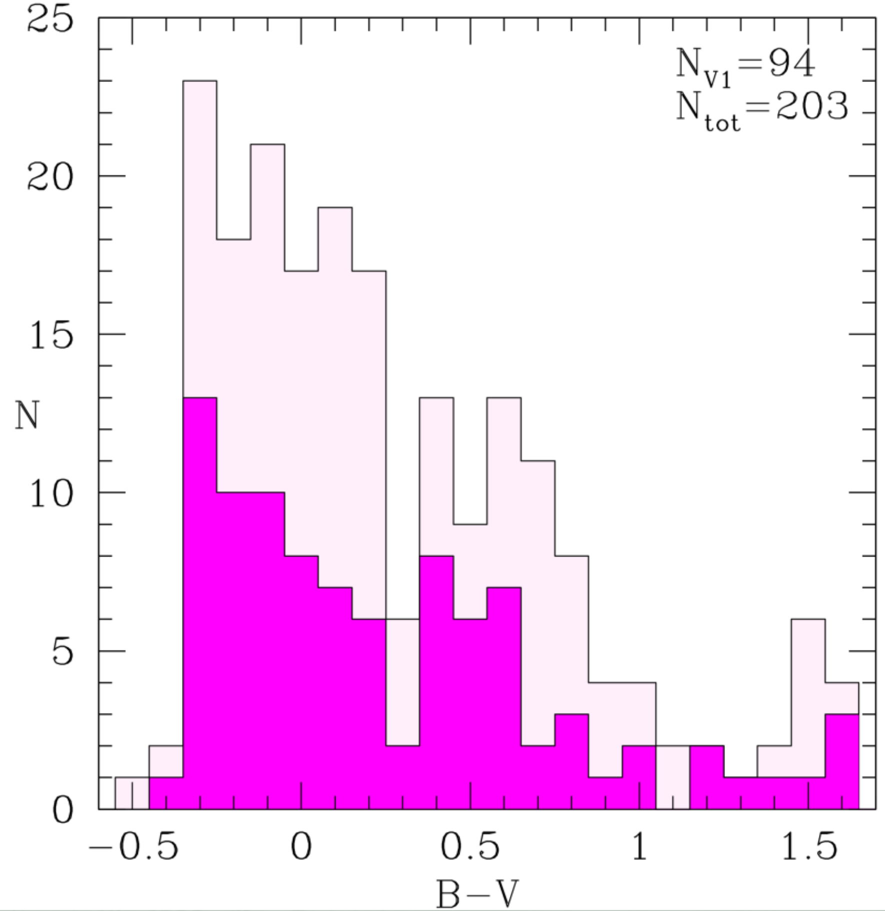
V1 release





V2 release

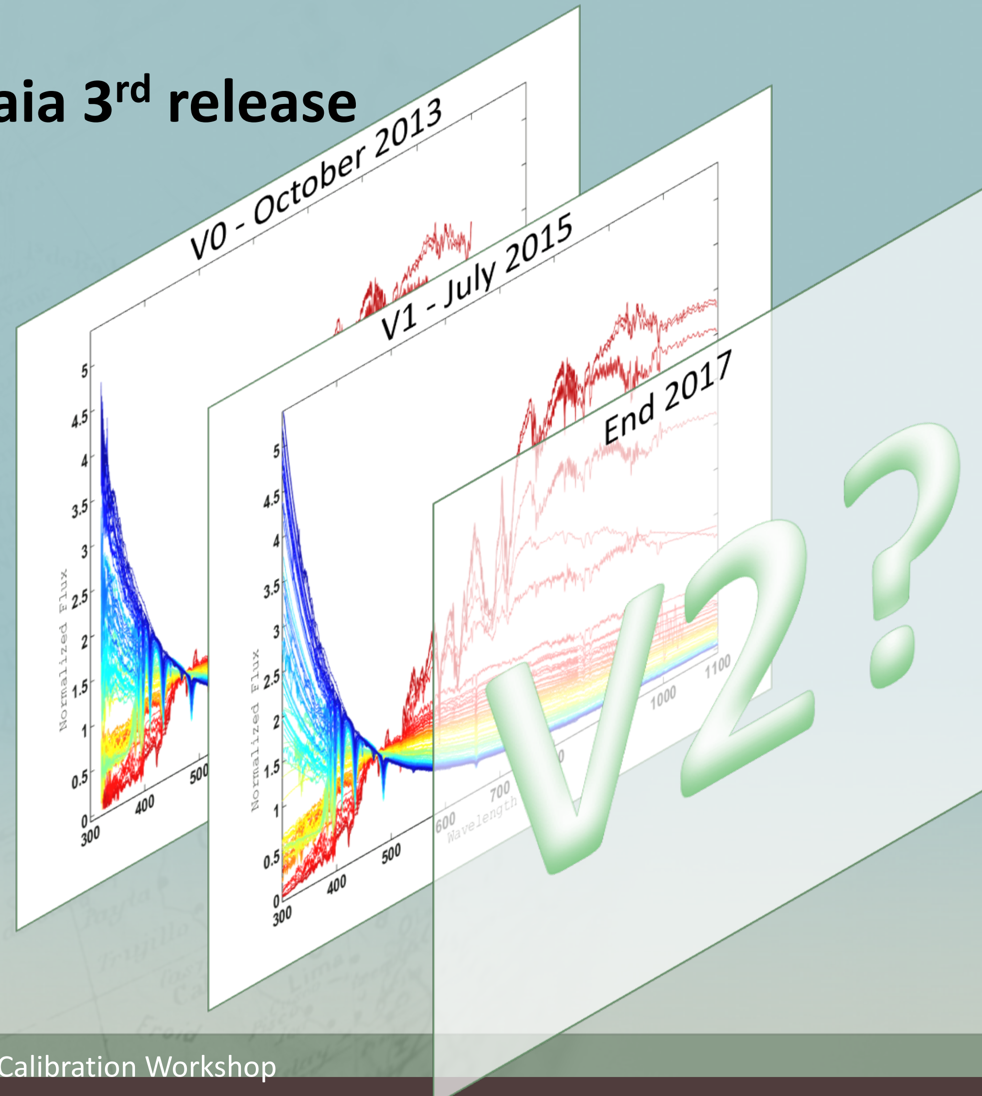
The V2 release, end 2017 for Gaia 3rd release

Including

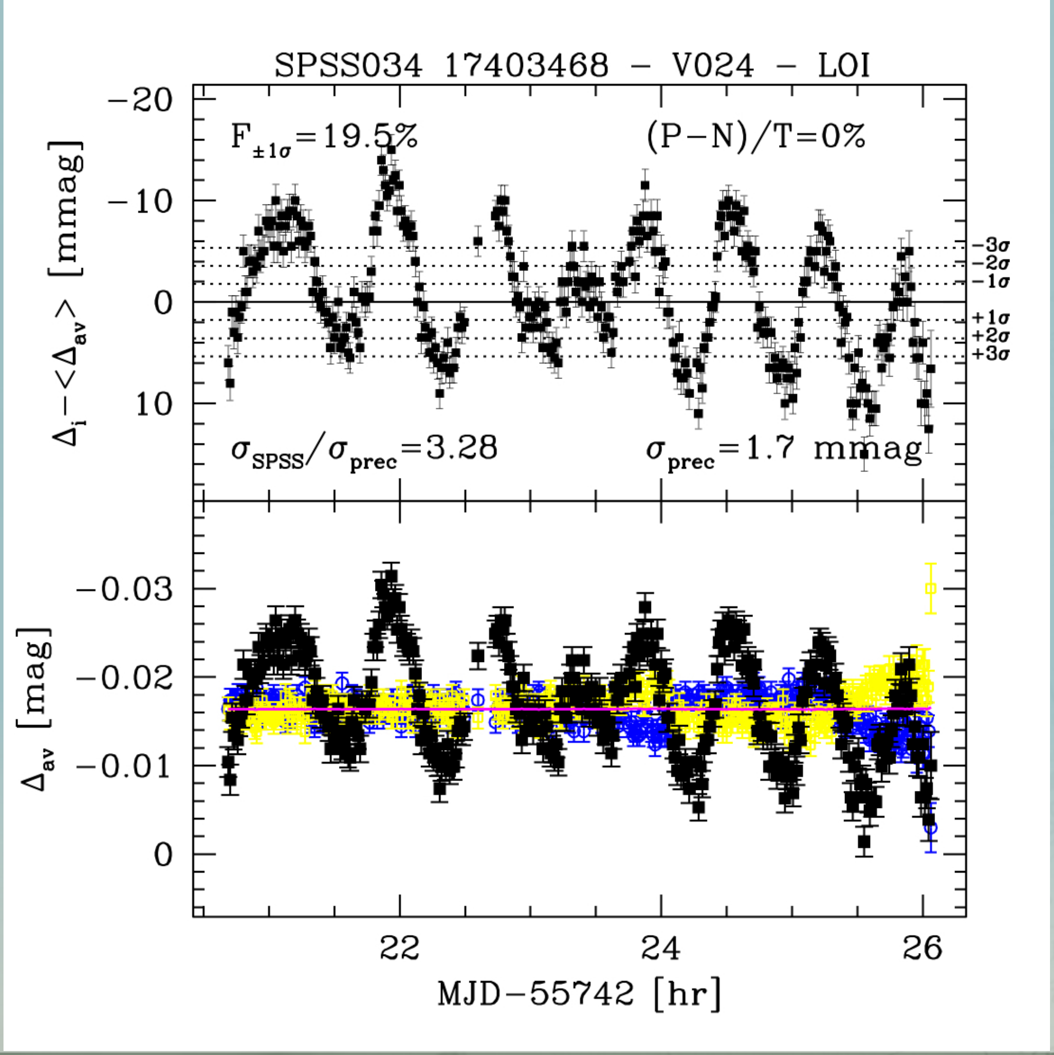
- constancy assessment
- absolute photometry

Improvements:

- Quality
- Quantity



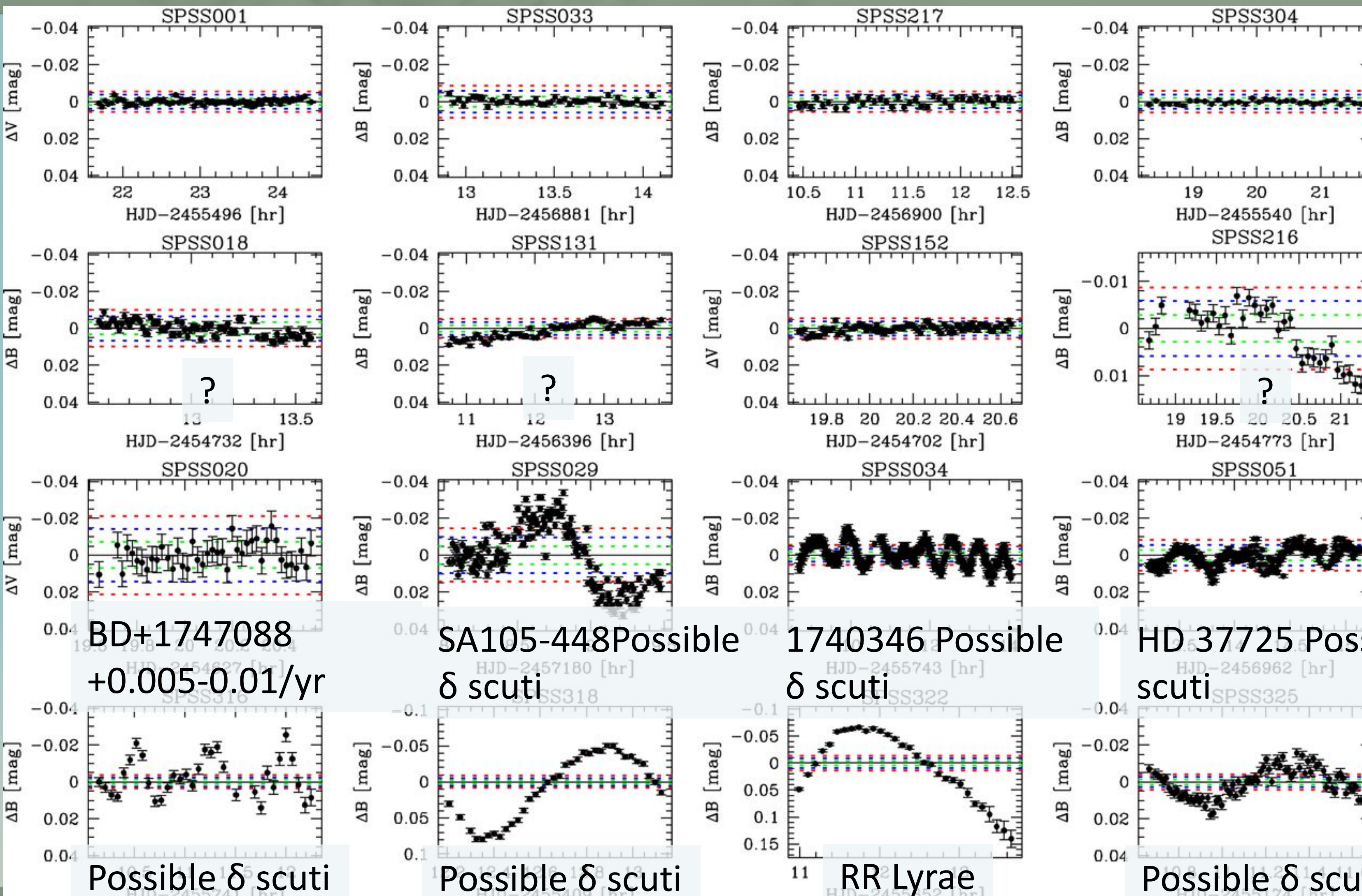
Relative Photometry



Constancy assessment:

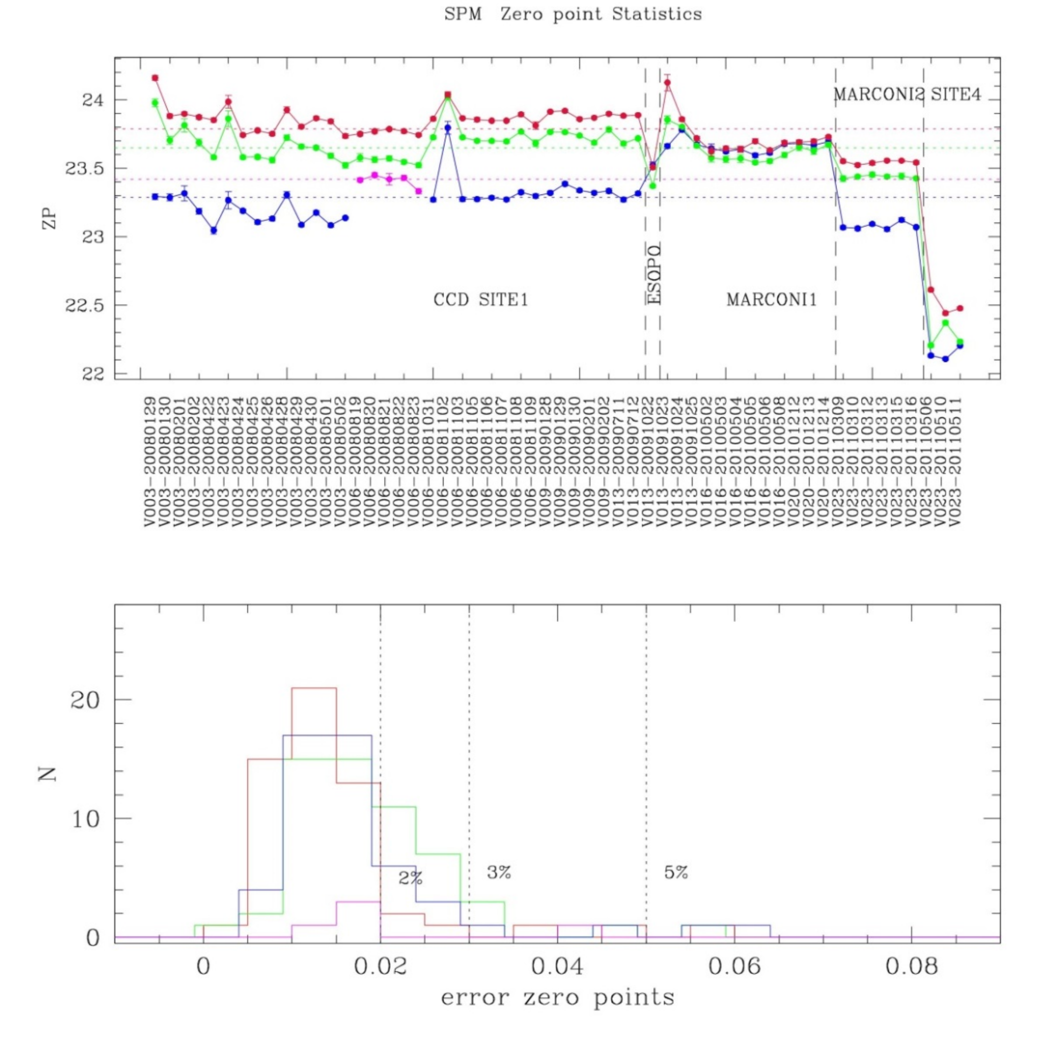
- Short-term (1-2 h series)
- 173 SPSS monitored
- Found 12 variables
- >1 good curve per SPSS (a dozen exceptions)
- Marinoni et al. 2016MNRAS.462.3616M

Relative Photometry



- Marinoni et al. 2016MNRAS.462.3616M

Absolute Photometry



ZP calibration of (grey) spectra:

- Synthetic photometry
- Night solutions
  - 32 good nights
  - 27 usable nights
  - 36 non-photometric
- Instrumental magnitudes
- First pass calibration

Now comparing internally and with literature

First release: Sept 14, 2016 ☑	Positions (α, δ) and G magnitudes (single-star and good astrometric behaviour). Photometric data of Ecliptic Poles Scanning RR Lyrae and Cepheid variable stars. The five-parameter astrometric solution - positions, parallaxes, and proper motions - for stars in common with the Tycho-2 Catalogue. The catalogue is based on the Tycho-Gaia Astrometric Solution (TGAS)
Second release: late 2017 ☐	Five-parameter astrometric solutions (single-star). Integrated BP/RP photometry. Mean radial (no radial-velocity variation).
Third release: summer 2018 (TBC) ☐	Orbital solutions, system radial velocity and five-parameter astrometric solutions, for binaries having periods between 2 months and 75% of the observing time will be released. Object classification and astrophysical parameters, together with BP/RP spectra and/or RVS spectra they are based on (well-behaved objects). Mean radial velocities (no radial-velocity and with available atmospheric-parameter estimates).
Fourth release: summer 2019 (TBC) ☐	Variable-star classifications will be released together with the epoch photometry used for the stars. Solar-system results will be released with preliminary orbital solutions and individual epoch observations. Non-single star catalogues.
Final release: 2022 (TBC) ☐	Full astrometric, photometric, and radial-velocity catalogues. All available variable-star and non-single-star solutions. Source classifications, astrophysical for stars, unresolved binaries, galaxies, and quasars. An exo-planet list. All epoch and transit data for all sources.All ground-based observations made for data-processing purposes.

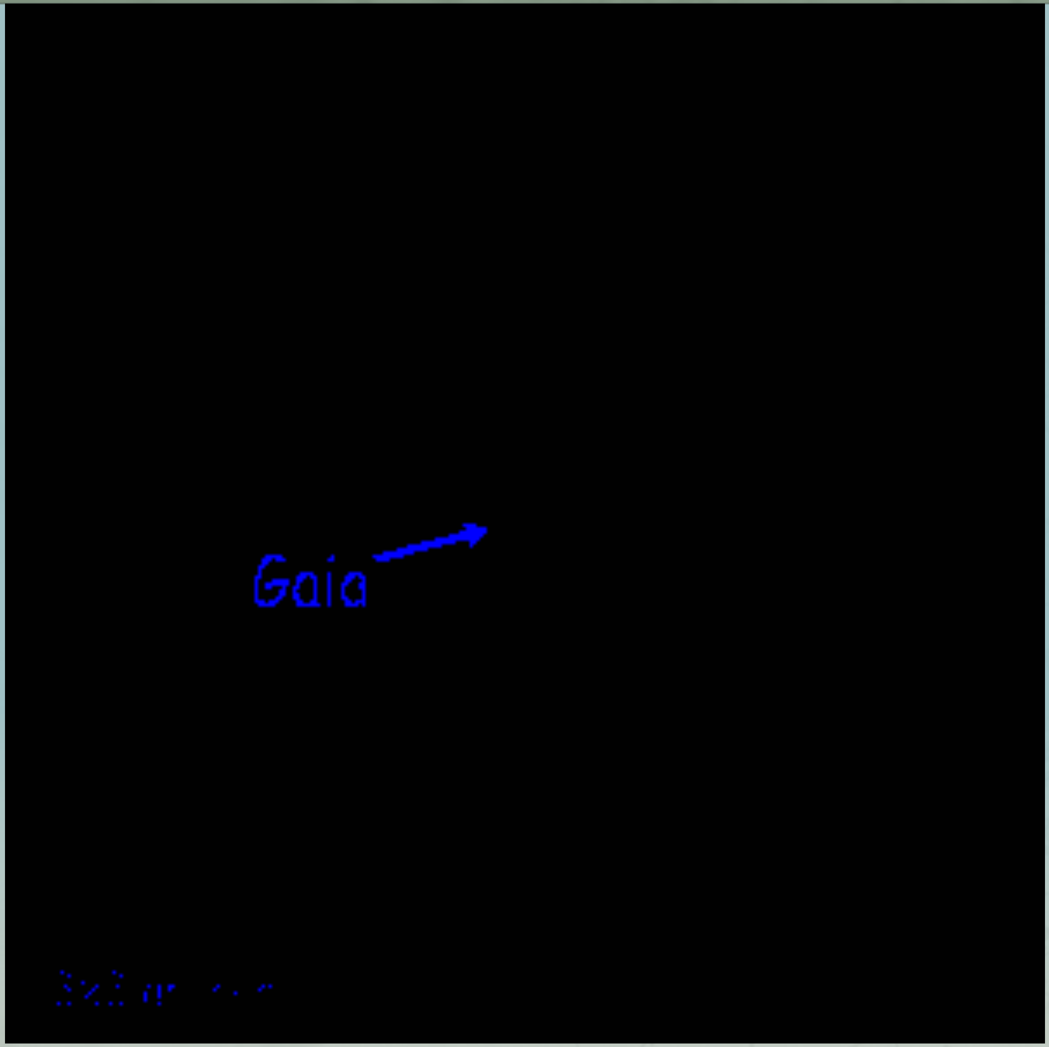
First release: Sept 14, 2016 ✅	Positions (α, δ) and G magnitudes (single-star and good astrometric behaviour). Photometric data of Ecliptic Poles Scanning RR Lyrae and Cepheid variable stars. The five-parameter astrometric solution - positions, parallaxes, and proper motions - for stars in common with the Tycho-2 Catalogue. The catalogue is based on the Tycho-Gaia Astrometric Solution (TGAS)

GDR1 available at **archives.esac.esa.int/gaia**

Also at ASDC **http://gaiaportal.asdc.asi.it/**

- Gaia data (GaiaSource, TgasSource, GaiaVariable, GaiaAuxQSO-ICRF2match);
- External Catalogues matched with Gaia (2MASS PSC, UCAC4, PPMXL, GSC2.3, SDSSdr9, AllWISE, URAT-1);
- Cross-Match Results tables;
- External Catalogues not matched with Gaia (RAVE4).
- Working at advanced science enabling tools (visualization, data analysis, statistics, data mining)

Gaia imaging… from Loiano (Italy)



Gaia Image of the Week 01 Dec 2014

www.cosmos.esa.int/web/gaia/iow_20141201

Gaia (R~21) observed with BFOSC@1.52m G.D. Cassini telescope at Loiano Observatory, Italy, on 17 October 2014

"Optical tracking of deep-space spacecraft in Halo L2 orbits and beyond: the Gaia mission as a pilot case" A. Buzzoni, G. Altavilla, S. Galleti, 2016 2016AdSpR..57.1515B

Thanks for your attention