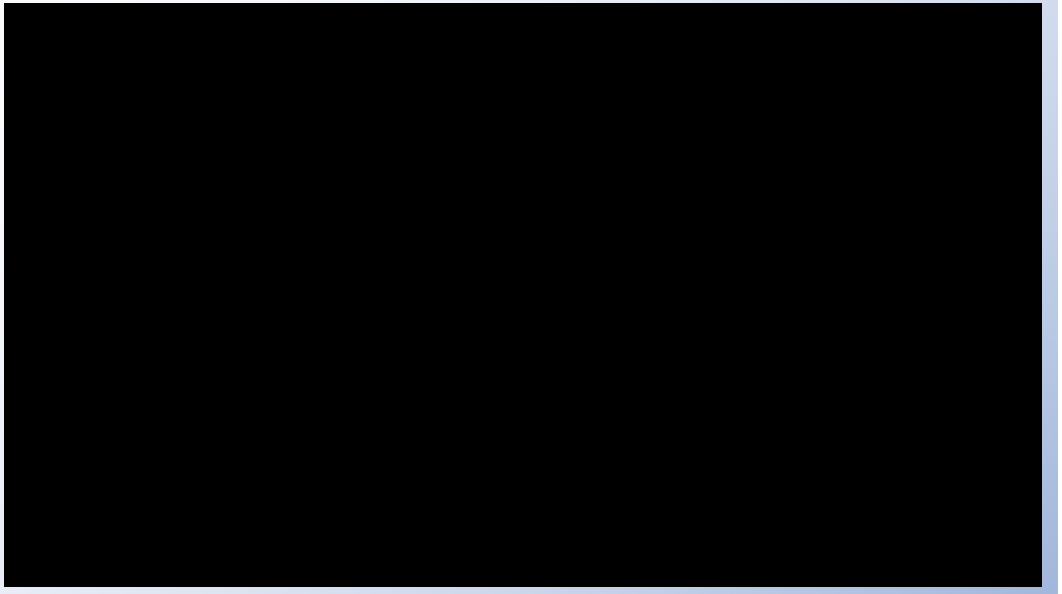
Gaia status

Timo Prusti
ESA

Gaia Summary

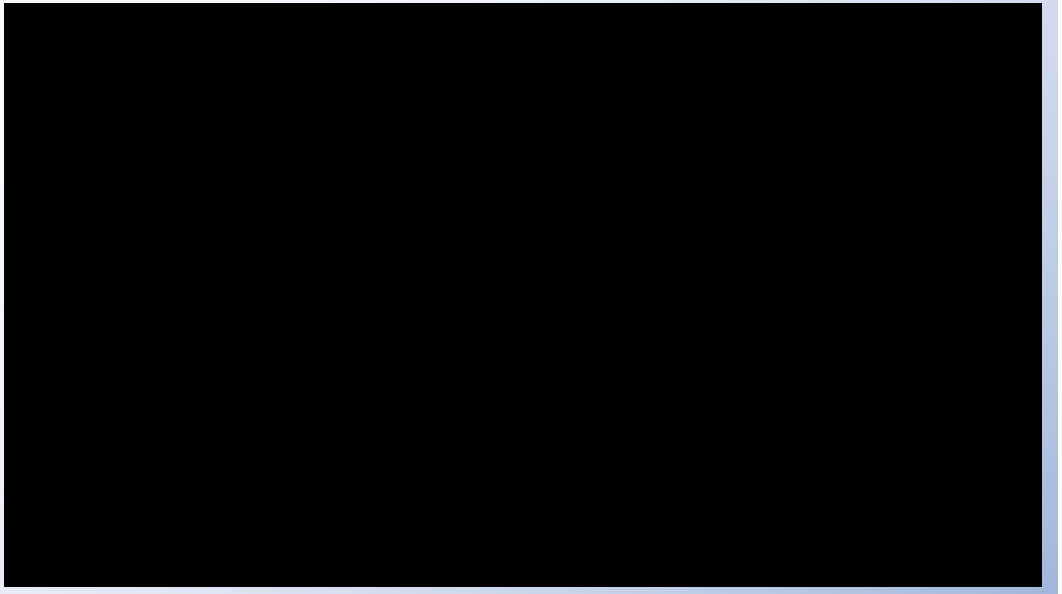
- Gaia: science with 1 billion objects in three dimensions
- ESA corner stone mission building on the Hipparcos heritage
- Astrometry, Photometry and Spectroscopy
- Satellite, including the payload, by industry, management and operations by ESA and data processing by scientists (DPAC)
- Launch 19 December 2013 with Soyuz from Kourou
- Commissioning formally completed 18 July 2014
- 5 years of operations in L2
- First intermediate data release summer 2016, but Science Alerts started



Gaia Summary

Science topics

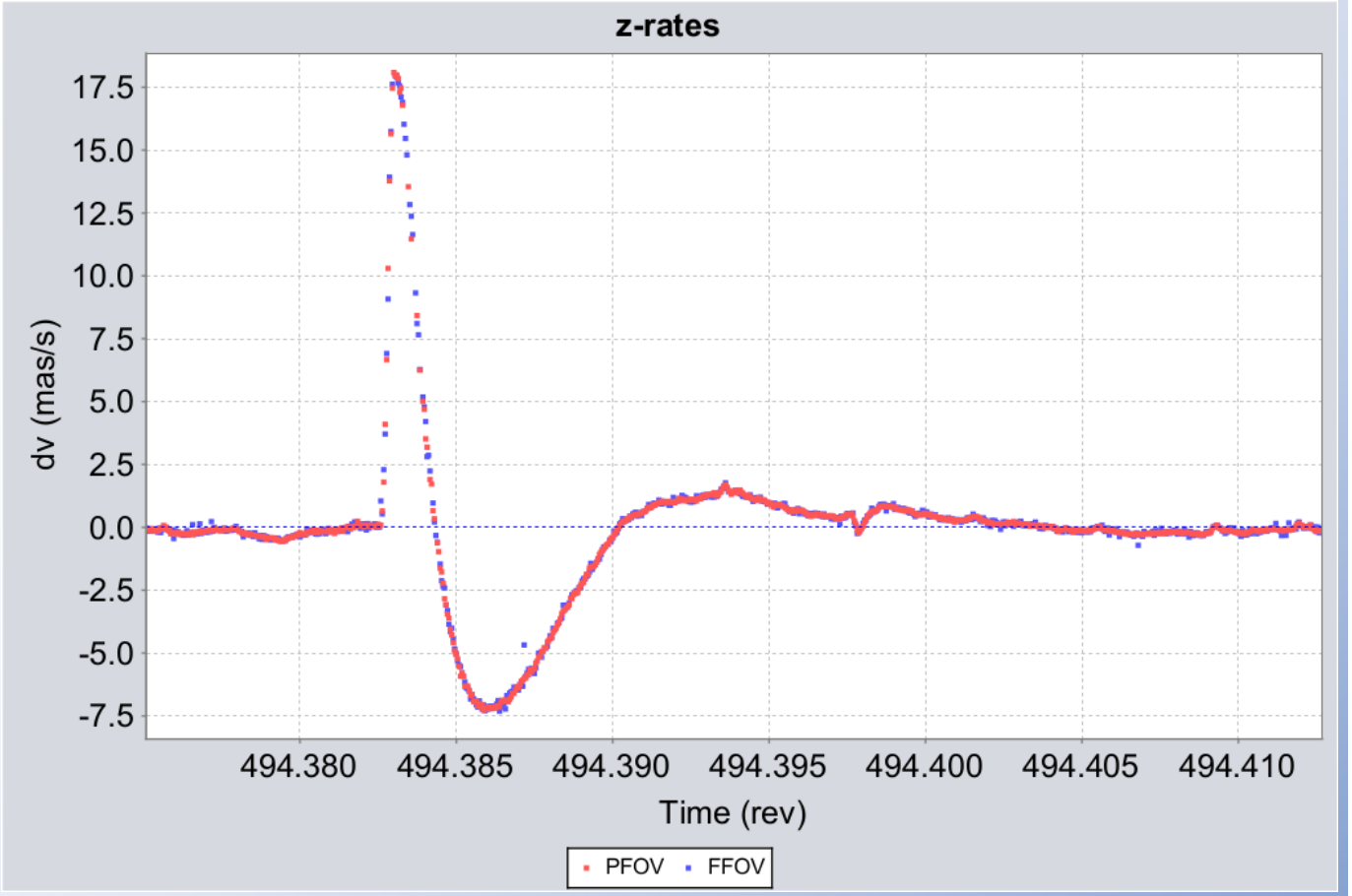
- Structure and dynamics of the Galaxy
- The star formation history of the Galaxy
- Stellar astrophysics
- Binaries and multiple stars
- Brown dwarfs and planetary systems
- Solar system
- Galaxies, Quasars and the Reference Frame
- Fundamental physics: General relativity



cosmos.esa.int/gaia

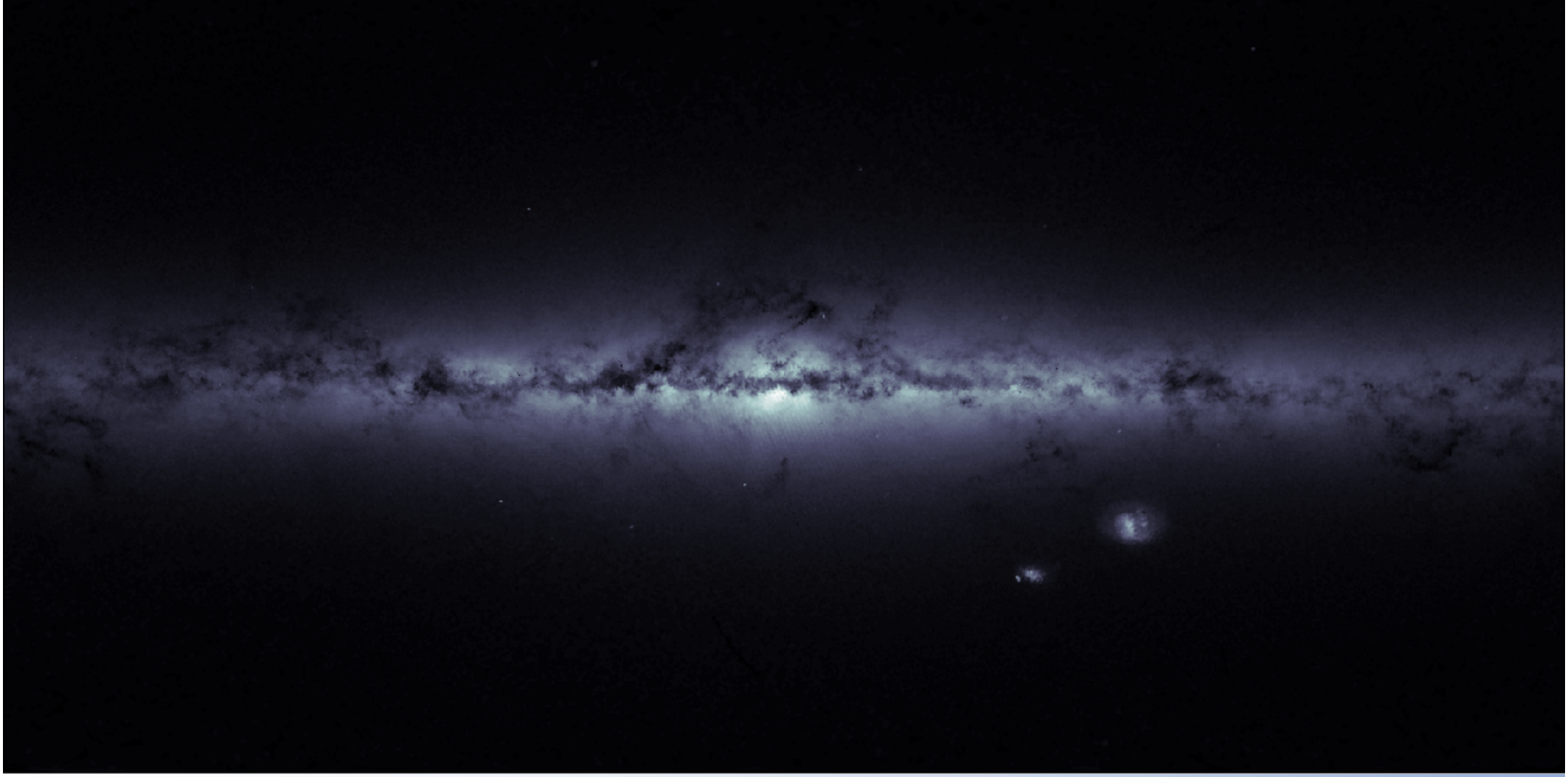
Commissioning

- Attitude and Orbit Control System working well
- Micro propulsion system working well
- Phased Array Antenna operating with healthy link budget
- Clock working at required accuracy
- 106 CCDs, electronics, data acquisition and storage all functioning



Micro-meteoroid hit example.
Figure by F. van Leeuwen

esa Gaia DPAC AIRBUS DEFENCE & SPACE



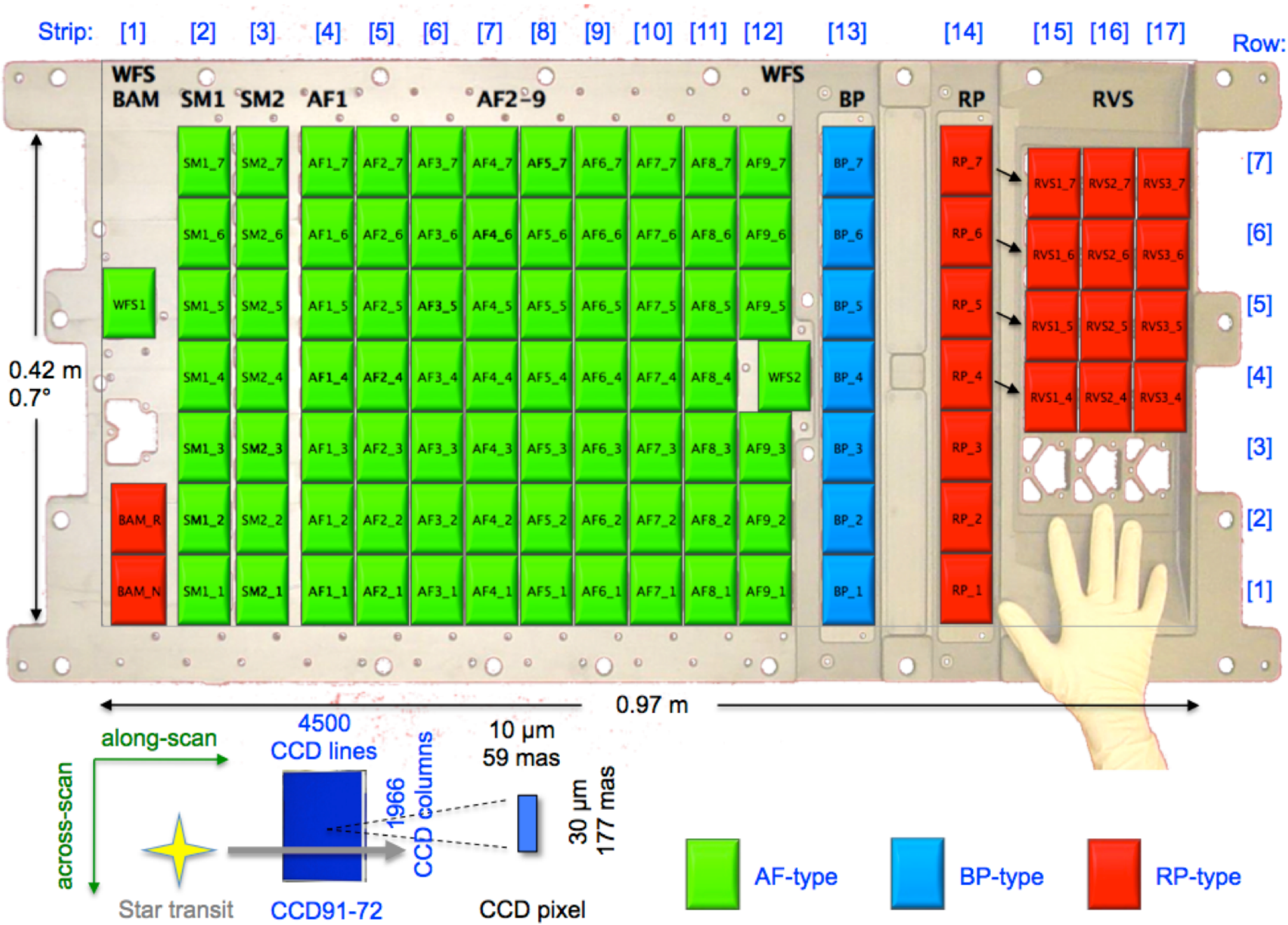
- The sky used by Gaia to keep the spin speed constant

Routine operations

- In 5-year routine phase since 18 July 2014
- Routine phase started with 1 month using Ecliptic Scanning Law before switching to Nominal Scanning Law
- Data collection:
  - 225 billion astrometric measurements
  - 45 billion photometric measurements
  - 4.4 billion spectra
- Magnitude limits
  - Astrometry and photometry between $2 < G < 20.7$ mag
  - Stars brighter than $G = 3$ mag captured with Sky Mapper imaging
  - Spectra till $G_{RVS} = 15.3 - 16.2$ mag (and $G > 2$ mag)

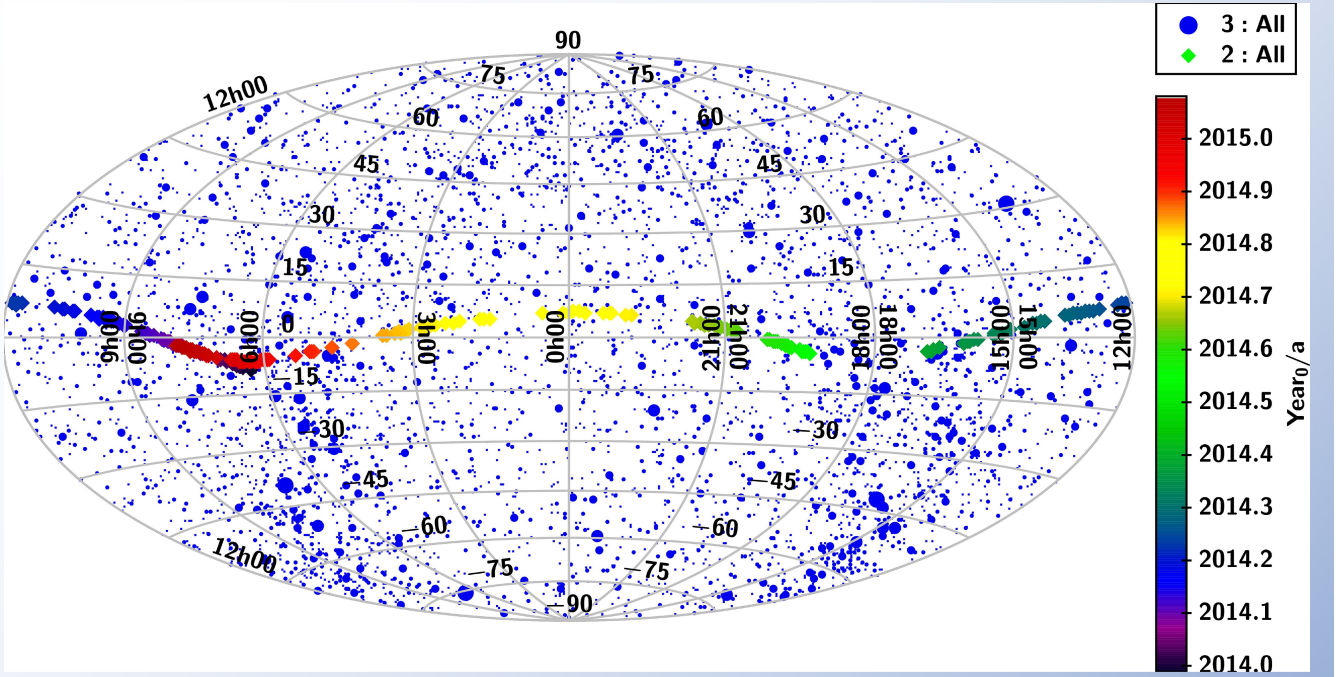
Focal Plane

Figure courtesy Ralf Kohley



Behind the scenes

- Optical tracking of Gaia for precise orbit determination
  - 1mm/s; 150m
- Relativistic corrections
  - Every observation corrected for effects by the Sun and planets (and sometimes even asteroids)
- Continuing monitoring of calibration stars



Observations of Gaia across the sky (ESO VST, Liverpool, Las Cumbres; figure courtesy of DPAC/GBOT)

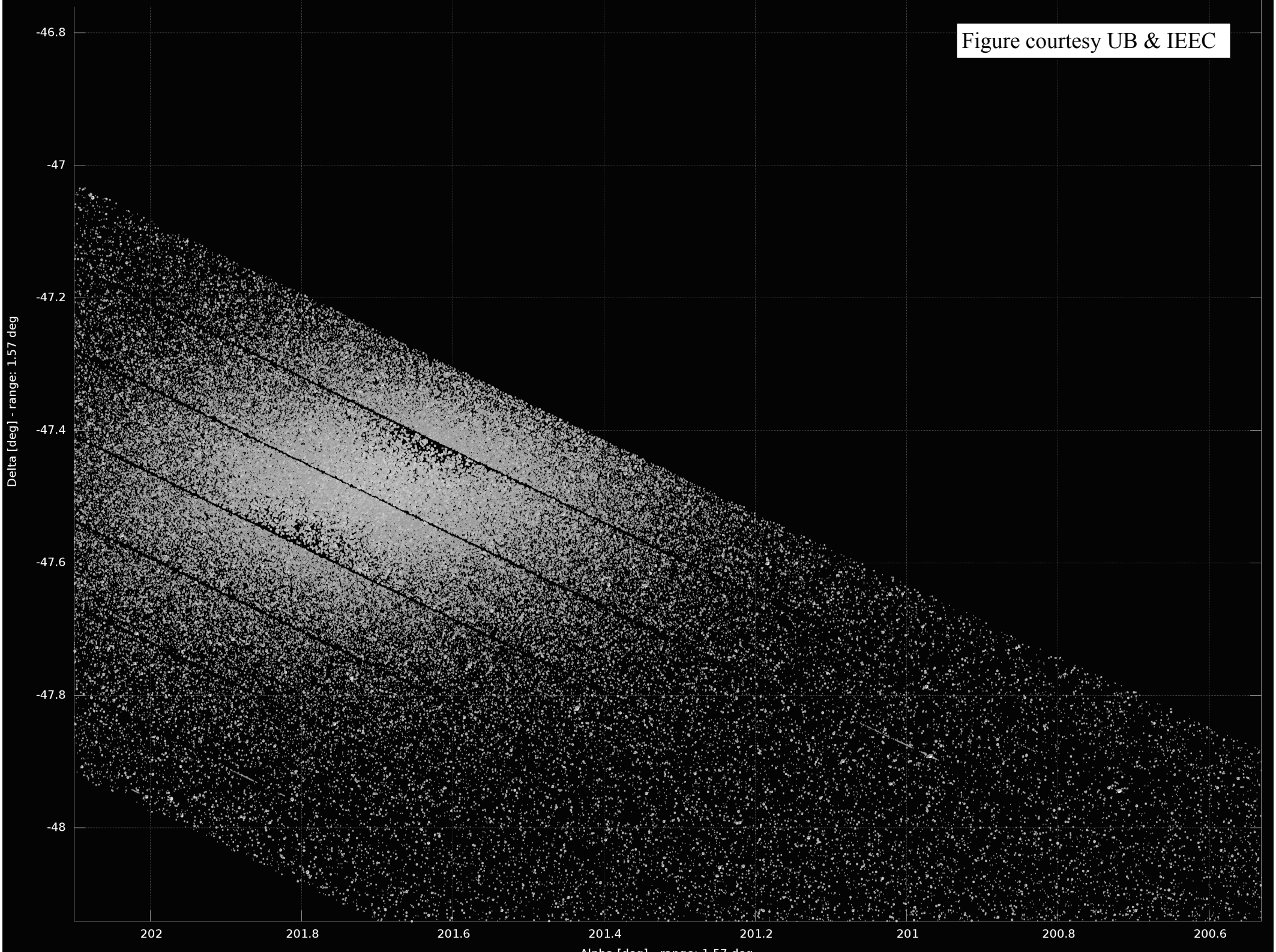
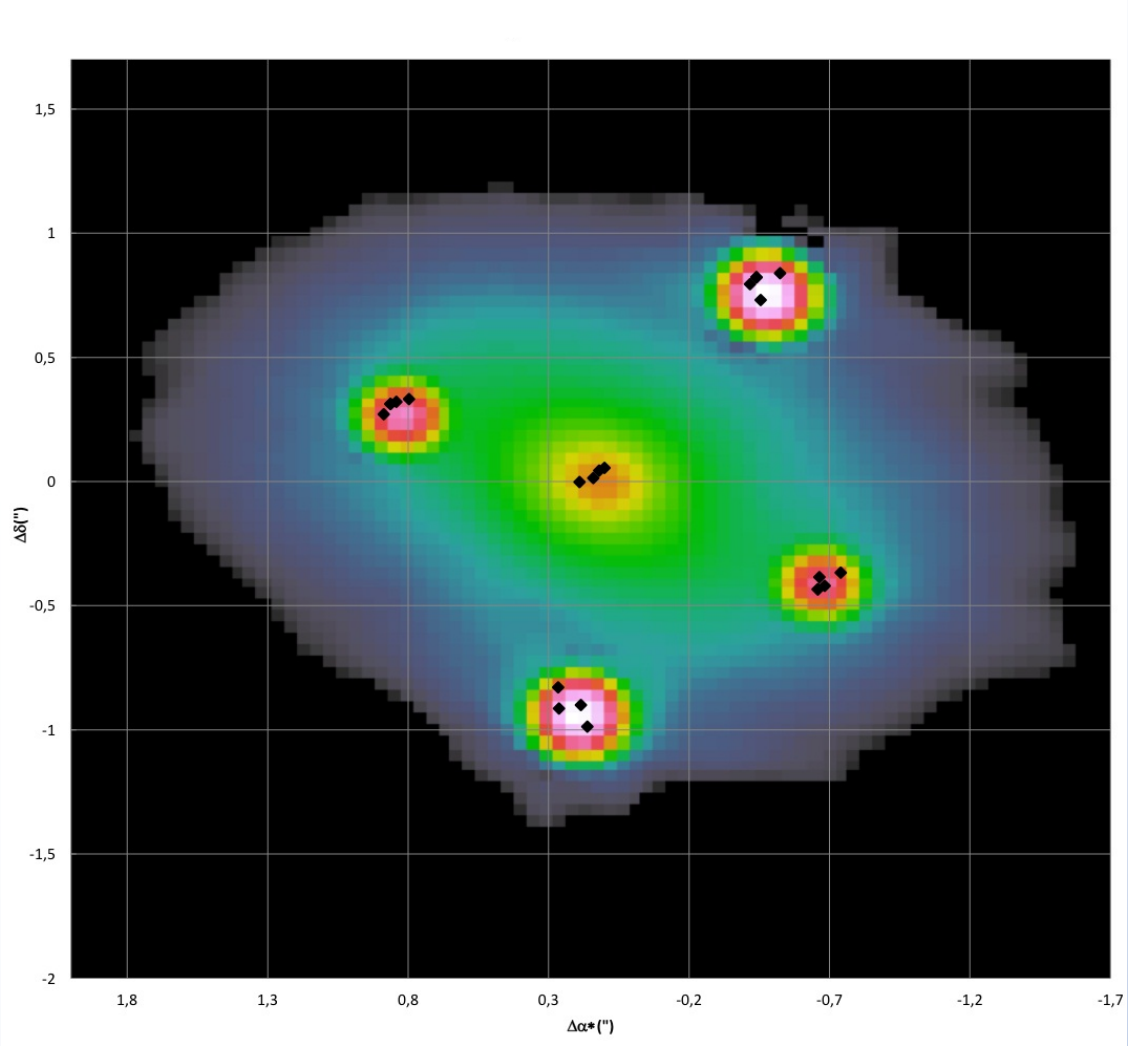


Figure courtesy UB & IEEC
-46.8
-47
-47.2
-47.4
-47.6
-47.8
-48
Delta [deg] - range: 1.57 deg
202
201.8
201.6
201.4
201.2
201
200.8
200.6

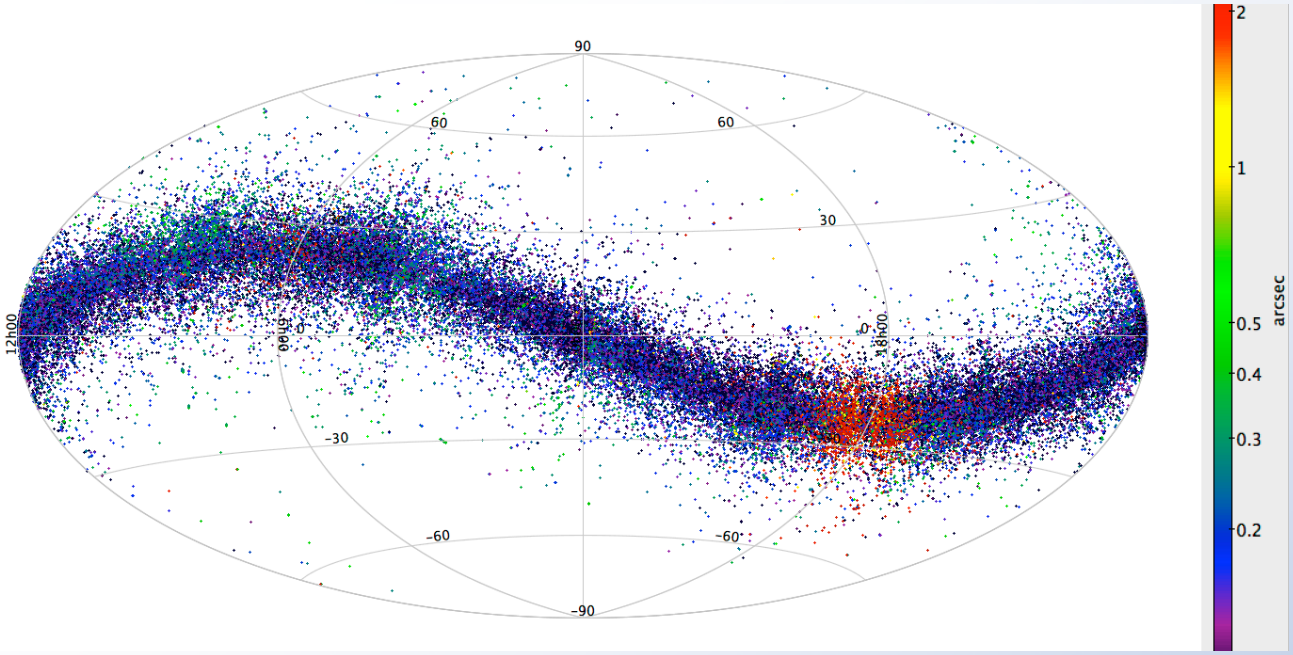
Gravitational lensing



- Einstein cross detected: the lens and the four images of the lensed object

credits: 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)

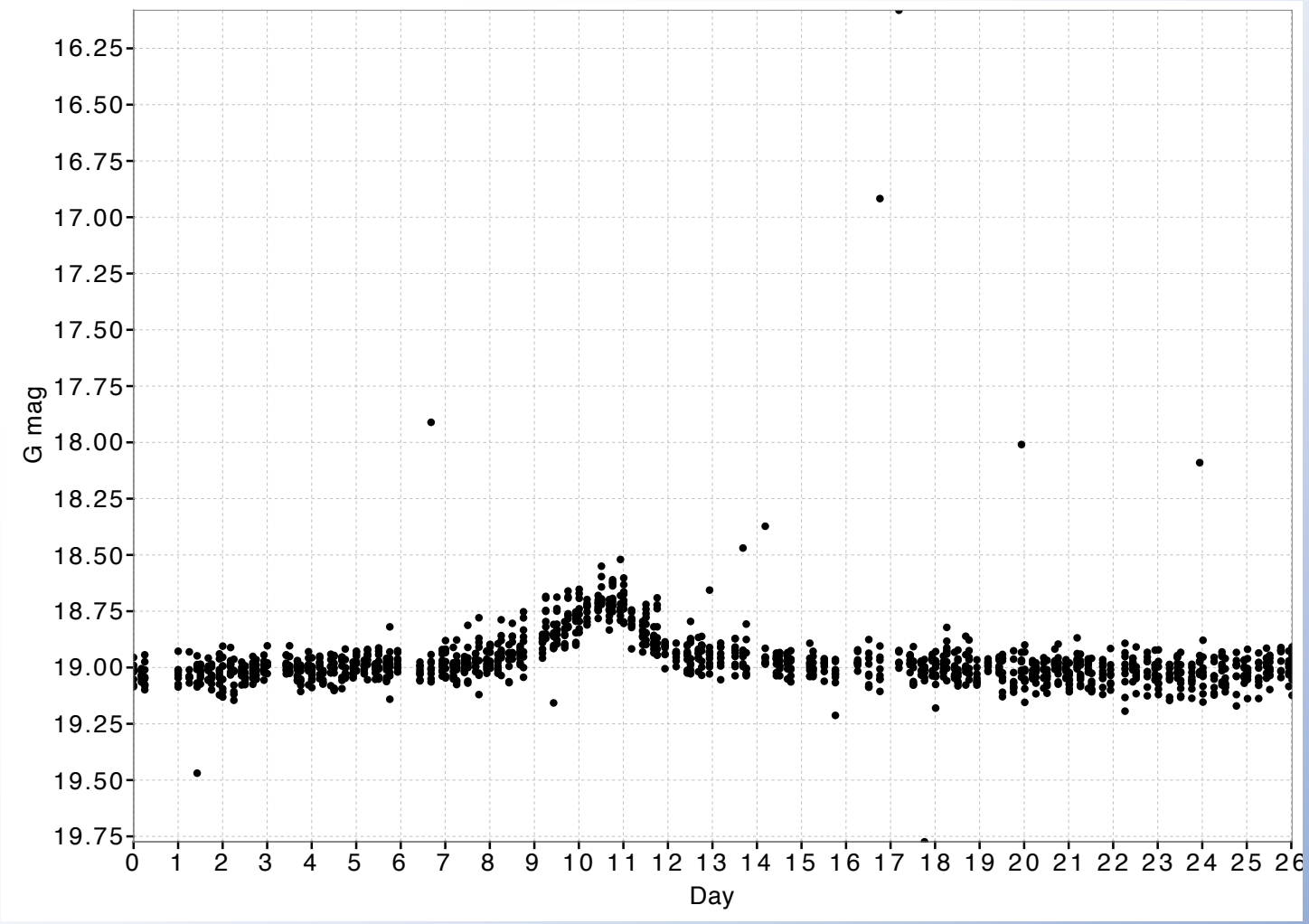
Asteroid detection



- Detection of known asteroids by Gaia

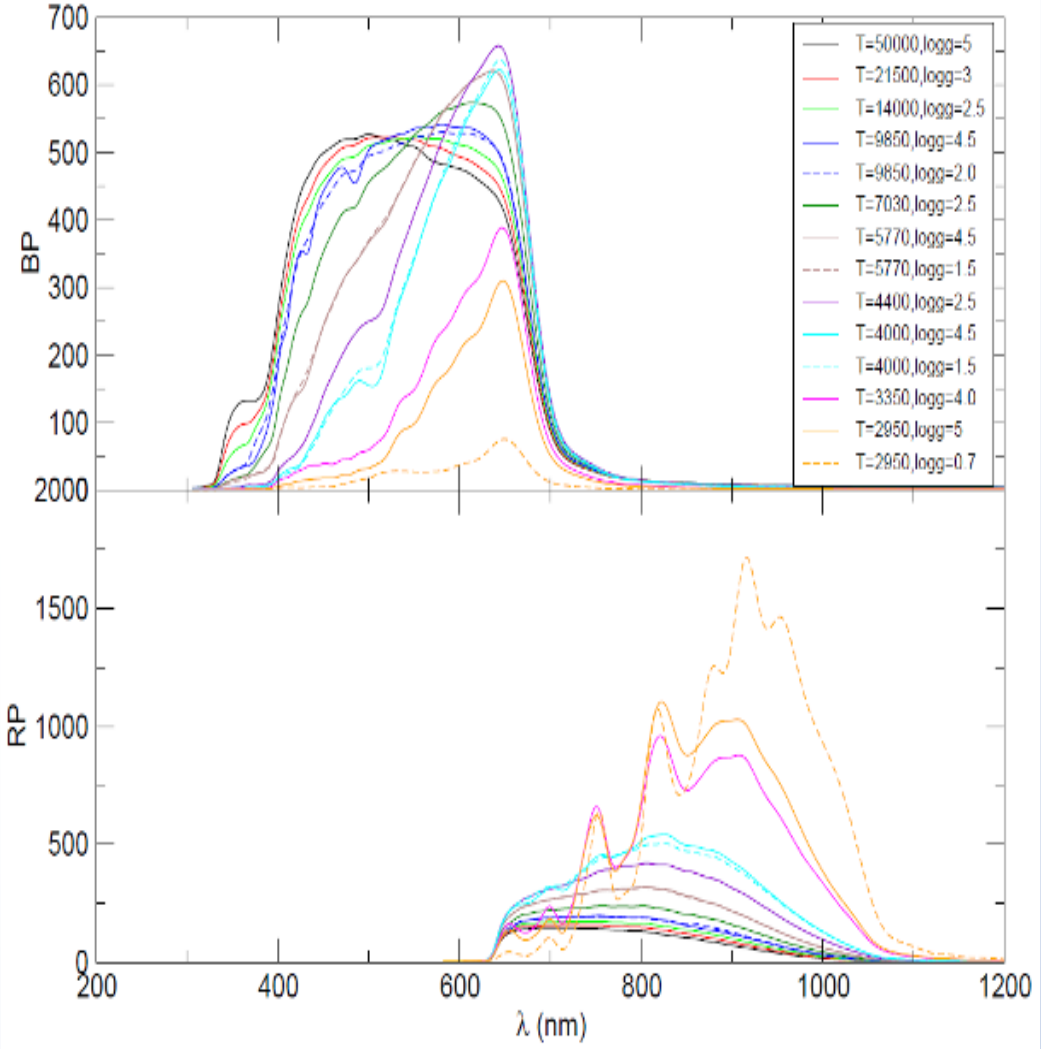
Credits: ESA/Gaia/DPAC/CU4, L. Galluccio, F. Mignard, P. Tanga (Observatoire de la Côte d'Azur)

Microlensing



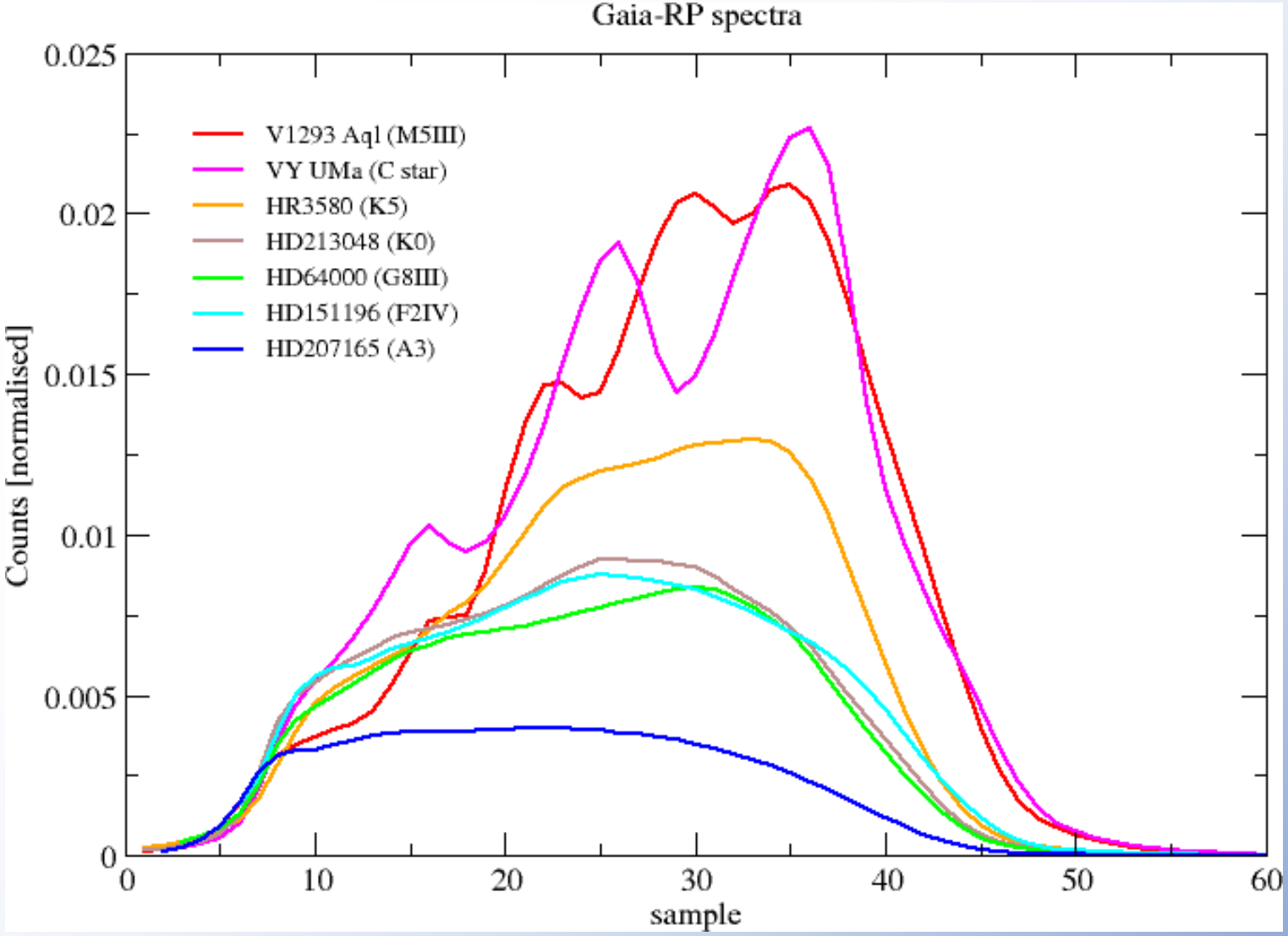
credits: ESA/Gaia/DPAC/Dafydd Wyn Evans and Marco Riello

Spectro-photometry



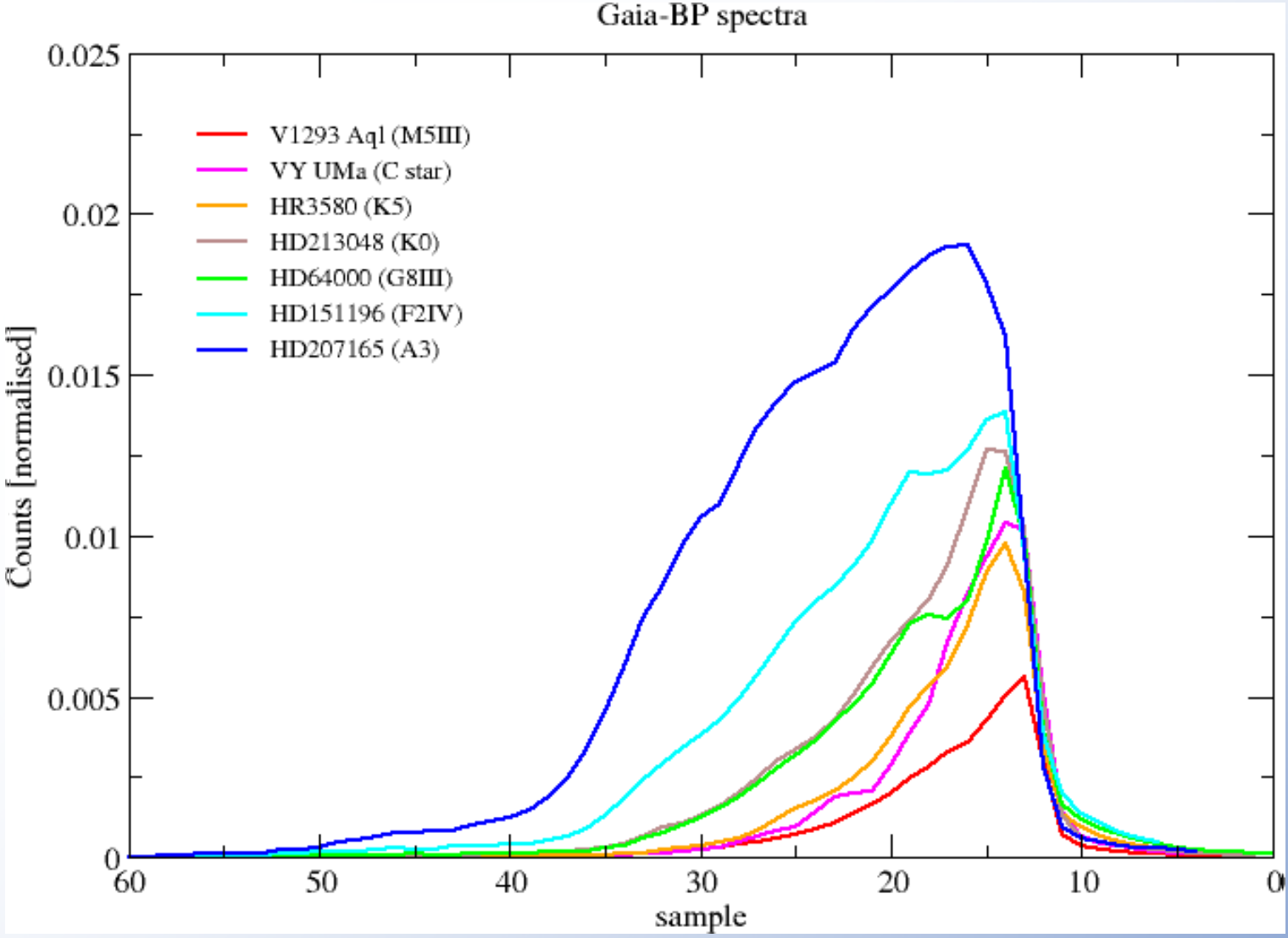
- Illustrative spectra for G=15 mag stars (Jordi et al. 2010)
- Goals at G=15 mag e.g. extinction within 0.1mag, surface gravity 0.2dex, metallicity 0.2dex and effective temperature within 200K (Bailer-Jones 2010)

Photometry



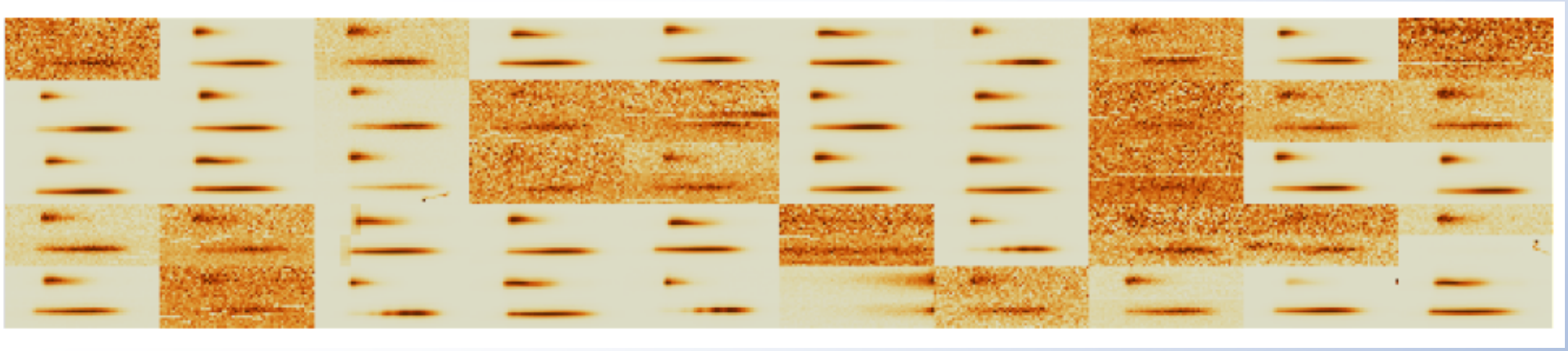
Diagrams courtesy C. Jordi and J.-M. Carrasco

Photometry

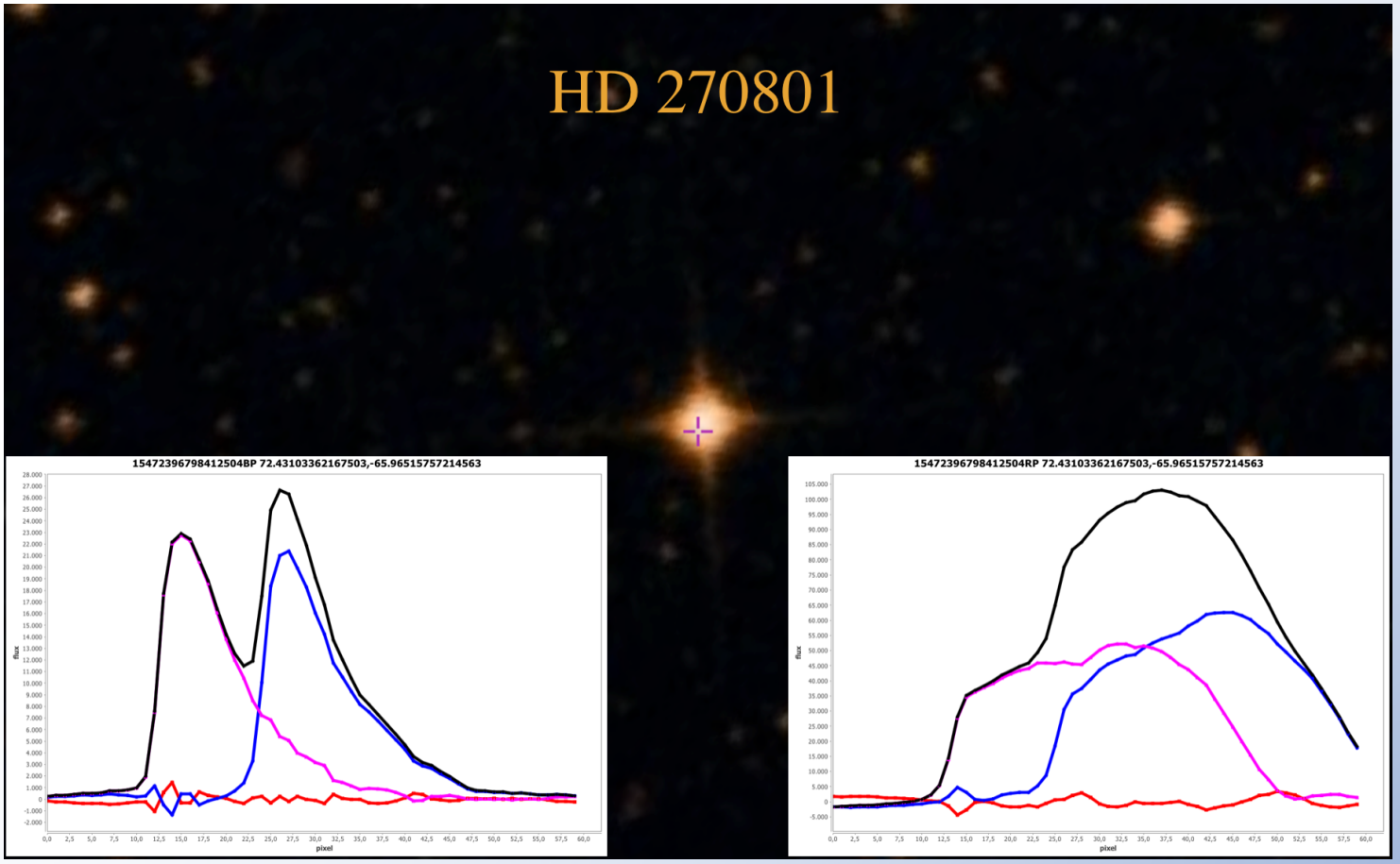


Diagrams courtesy C. Jordi and J.-M. Carrasco

Deblending



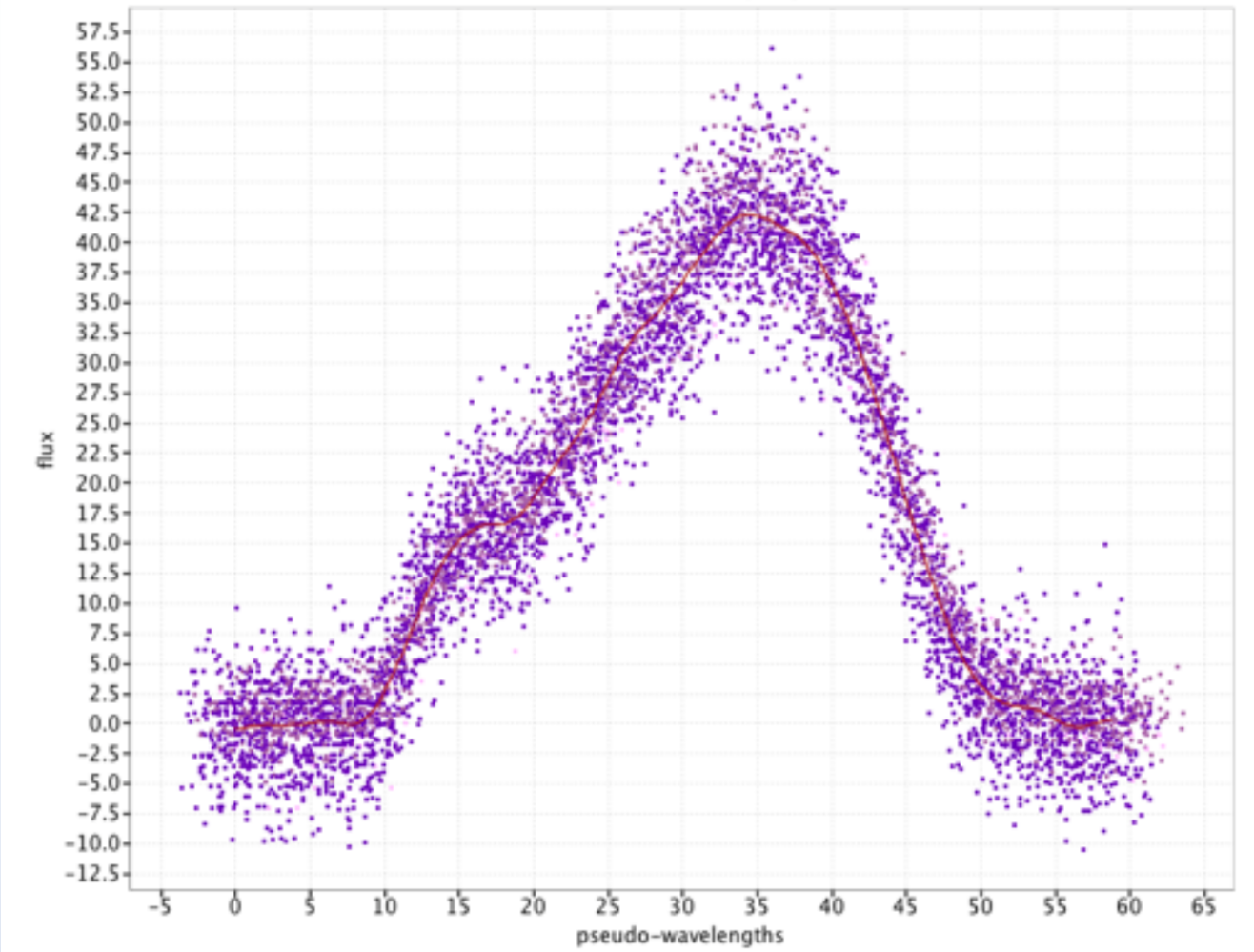
Deblending



credits: ESA/Gaia/DPAC/CU5/ASDC/INAF-OAR, Giuliano Giuffrida, Luigi Pulone, Marco Castellani

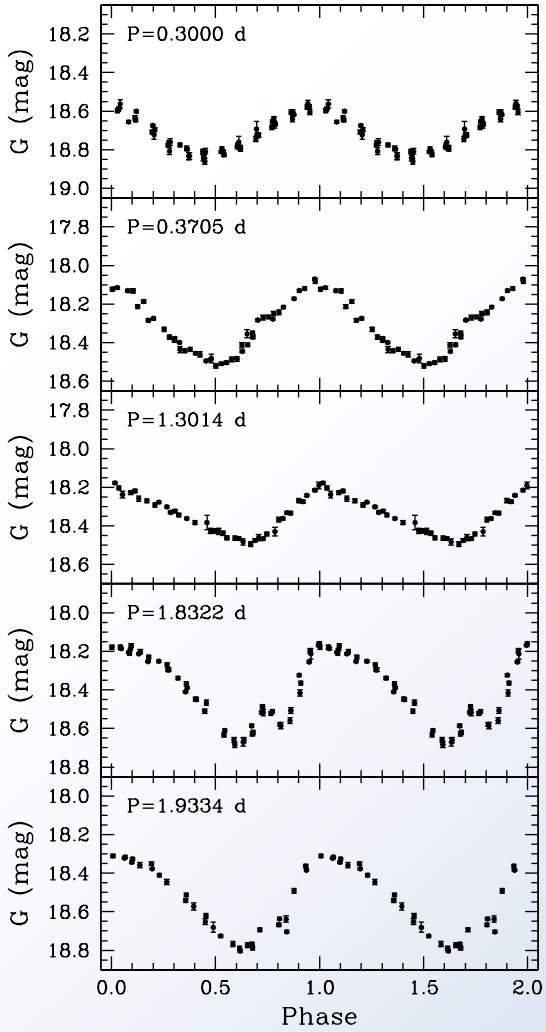
Faint sources

- Example of RP spectrum of a source with 109 transits
- Each transit consists of 60 samples
- Geometric calibration aligns each spectrum
- Mean spectrum (red line) formed from combination of all transits
- G = 18.24 mag



credits: ESA/Gaia/DPAC/CU5/D. Evans

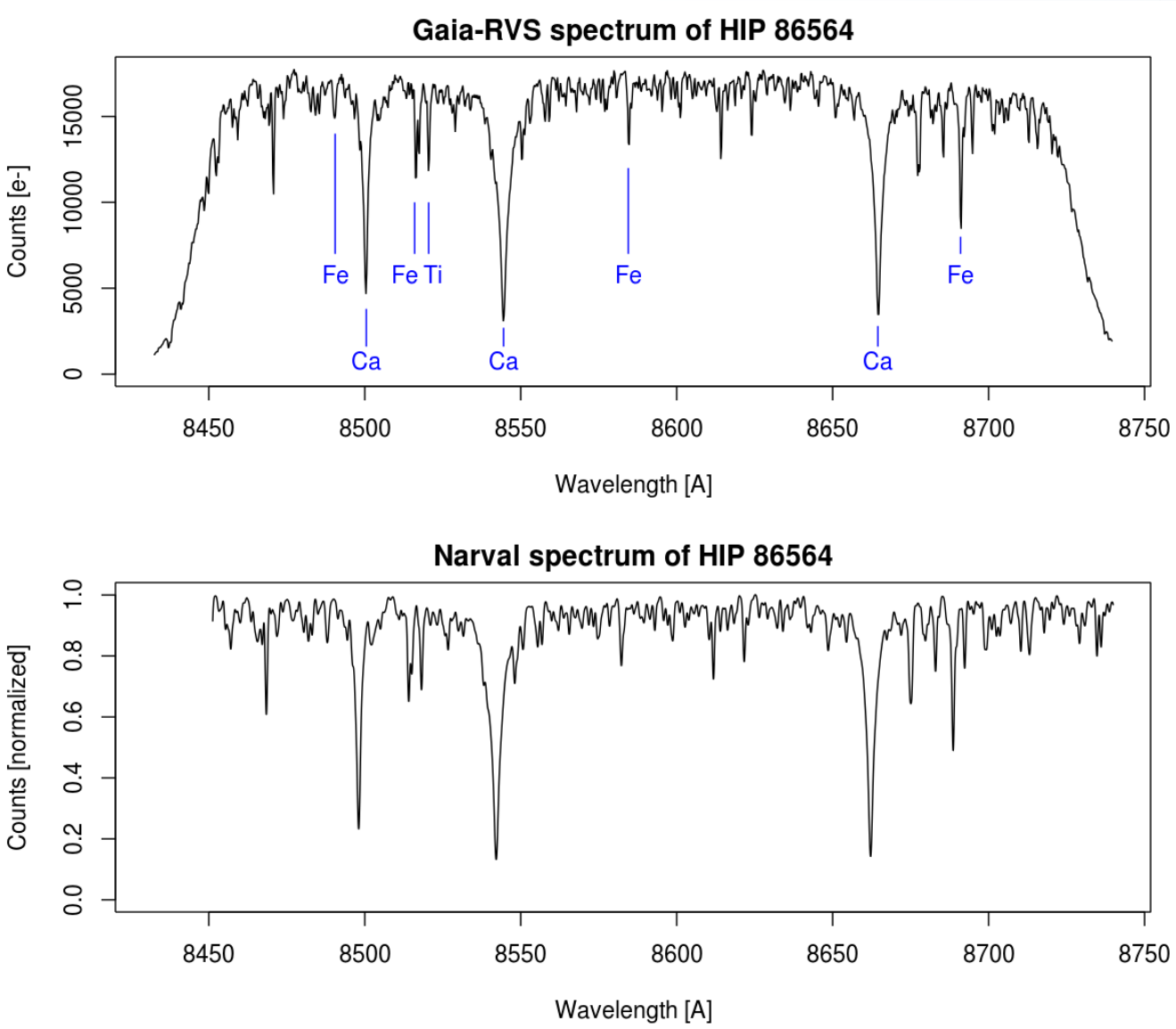
Variability



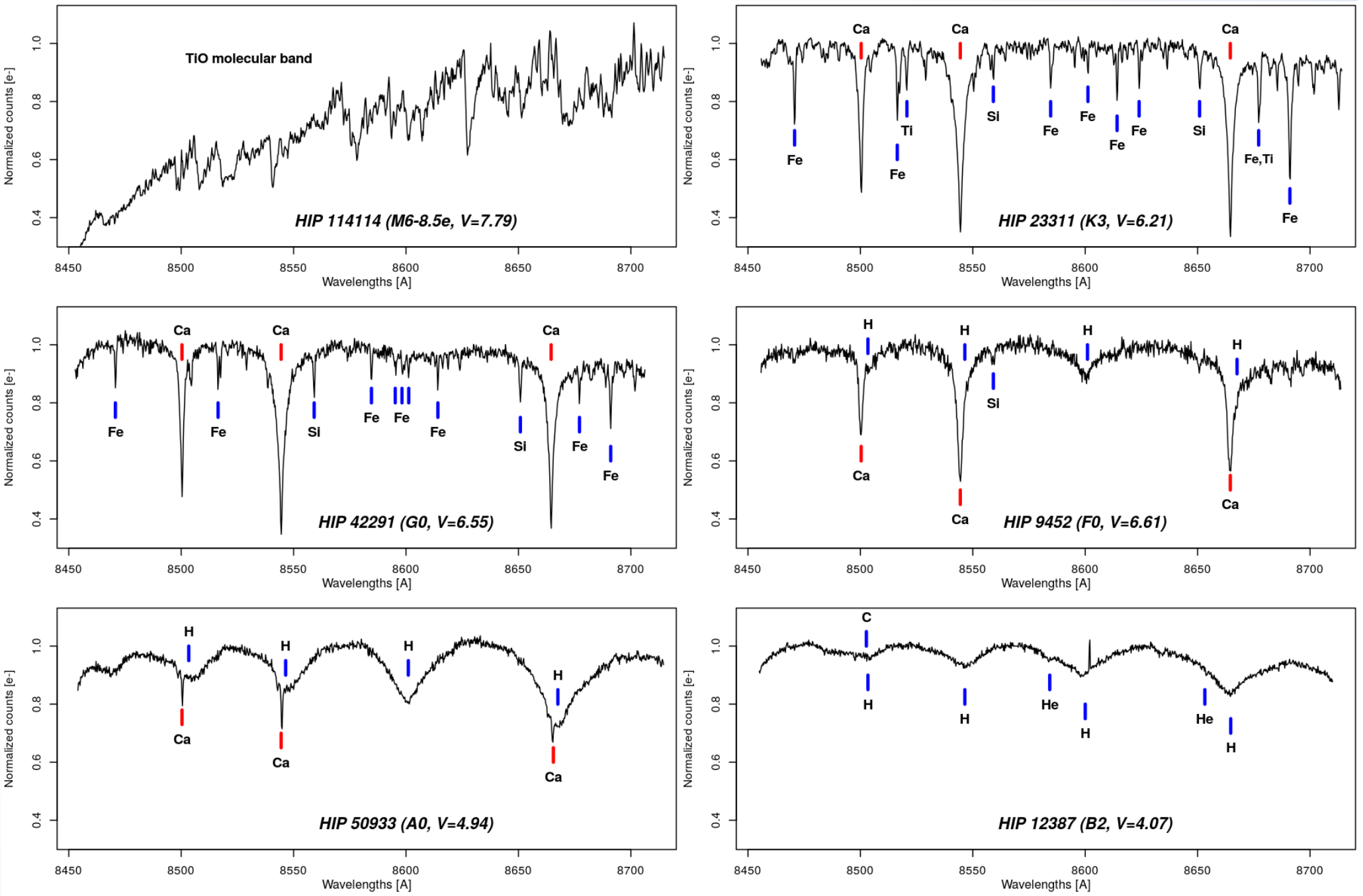
- Cepheids in LMC observed by Gaia during Ecliptic Pole Scanning
- Data processed through DPAC system with periodicity analysis as the last step

Credits: ESA/Gaia/DPAC/CU5/DPCI/CU7/INAF-OABo/INAF-OACn Gisella Clementini, Vincenzo Ripepi, Silvio Leccia, Laurent Eyer, Lorenzo Rimoldini, Isabelle Lecoeur-Taibi, Nami Mowlavi, Dafydd Evans, Geneva CU7/ DPCG and the whole CU7 team. The photometric data reduction was done with the PhotPipe pipeline at DPCI; processing data were received from the IDT pipeline at DPCE.

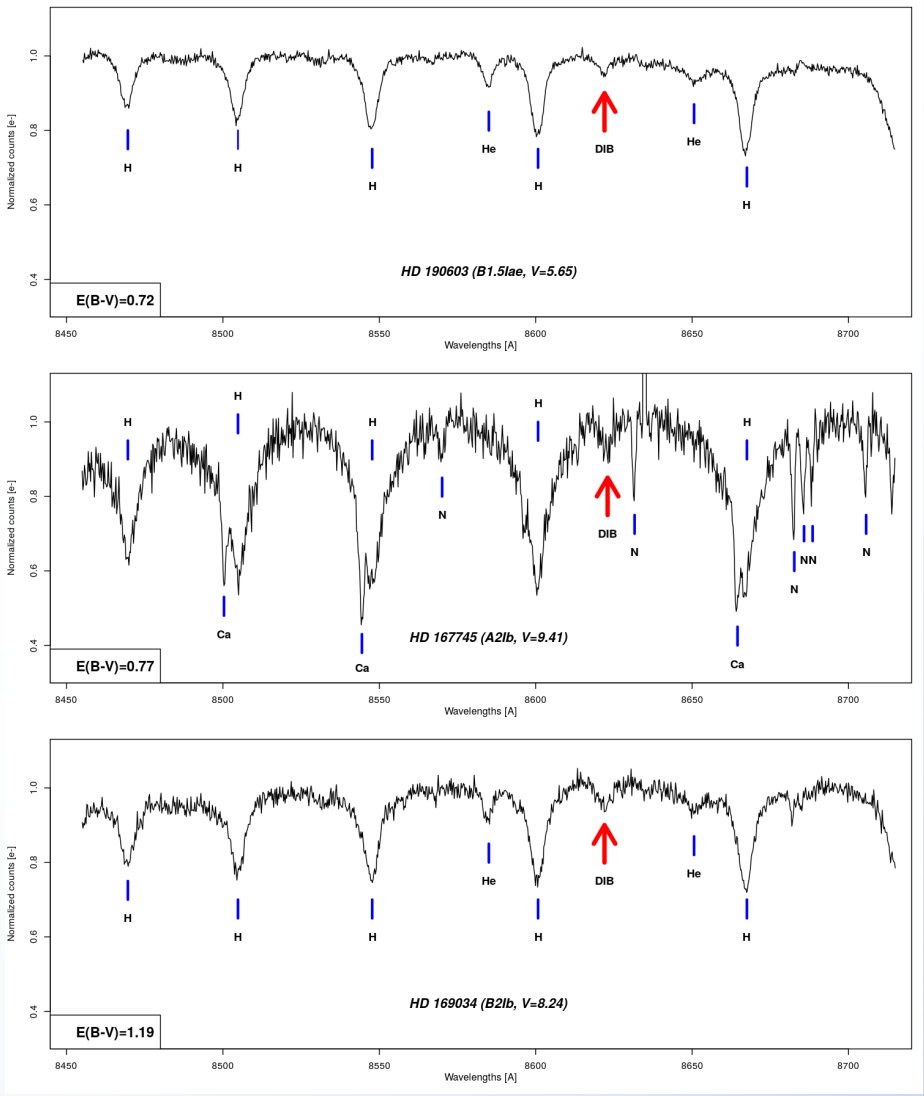
Spectroscopy



- Interstellar reddening, atmospheric parameters, and rotational velocities, for stars brighter than $G_{RVS} \approx 12$ mag (~5 million stars)
- provide element abundances for stars brighter than $G_{RVS} \approx 11$ mag (~2 million stars)

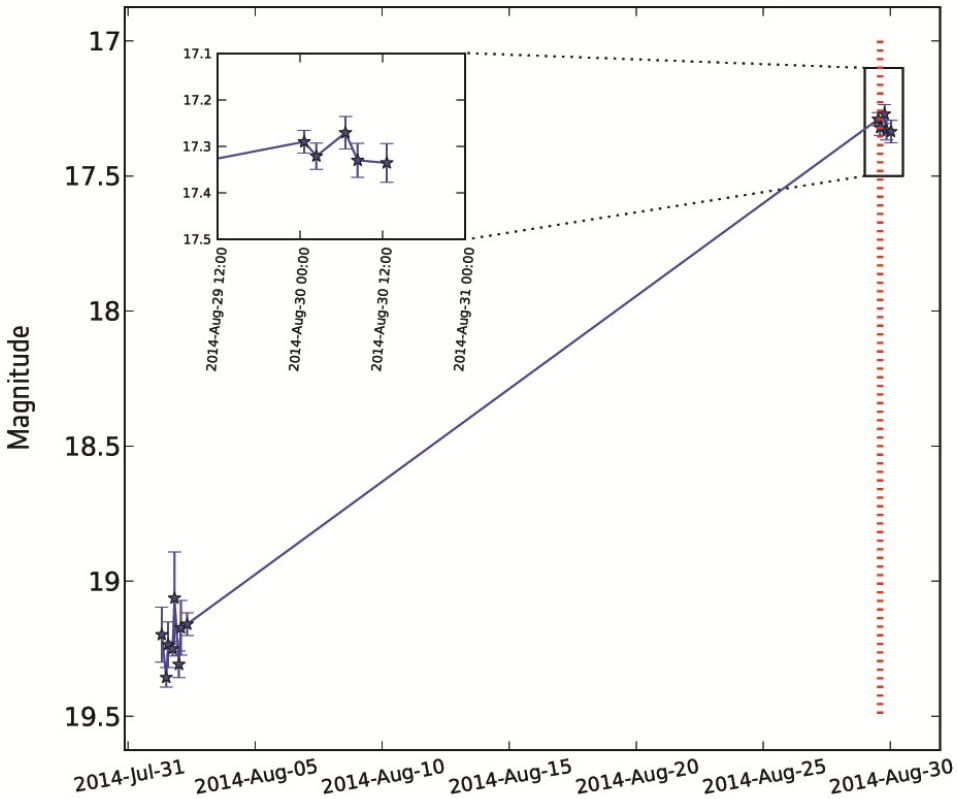

TiO molecular band
HIP 114114 (M6-8.5e, V=7.79)
HIP 23311 (K3, V=6.21)
HIP 42291 (G0, V=6.55)
HIP 9452 (F0, V=6.61)
HIP 50933 (A0, V=4.94)
HIP 12387 (B2, V=4.07)
Normalized counts [e-]
Wavelengths [A]

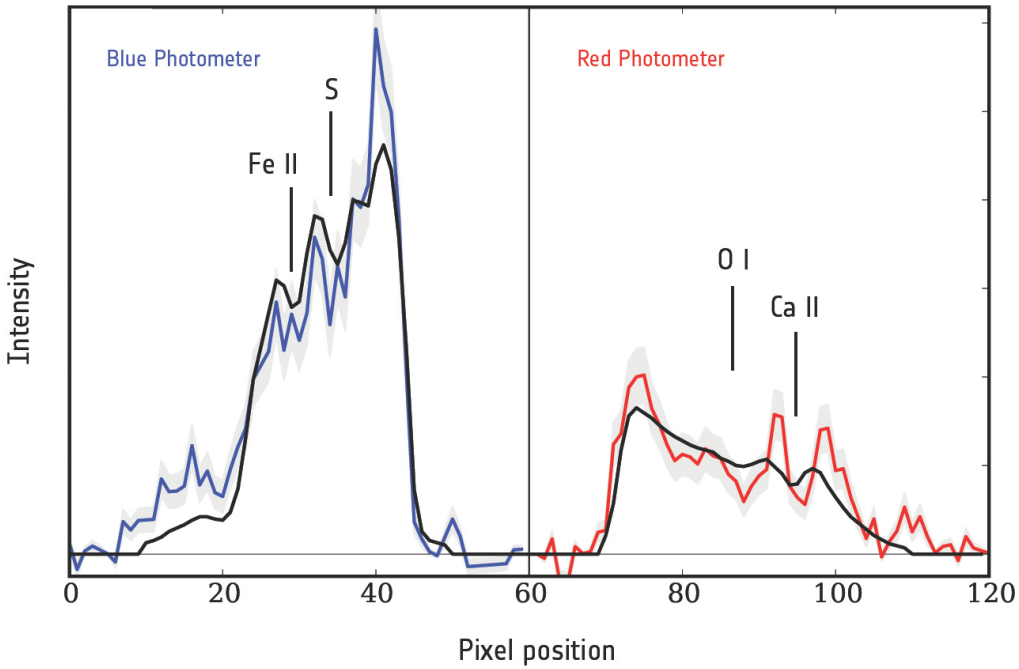
Spectroscopy



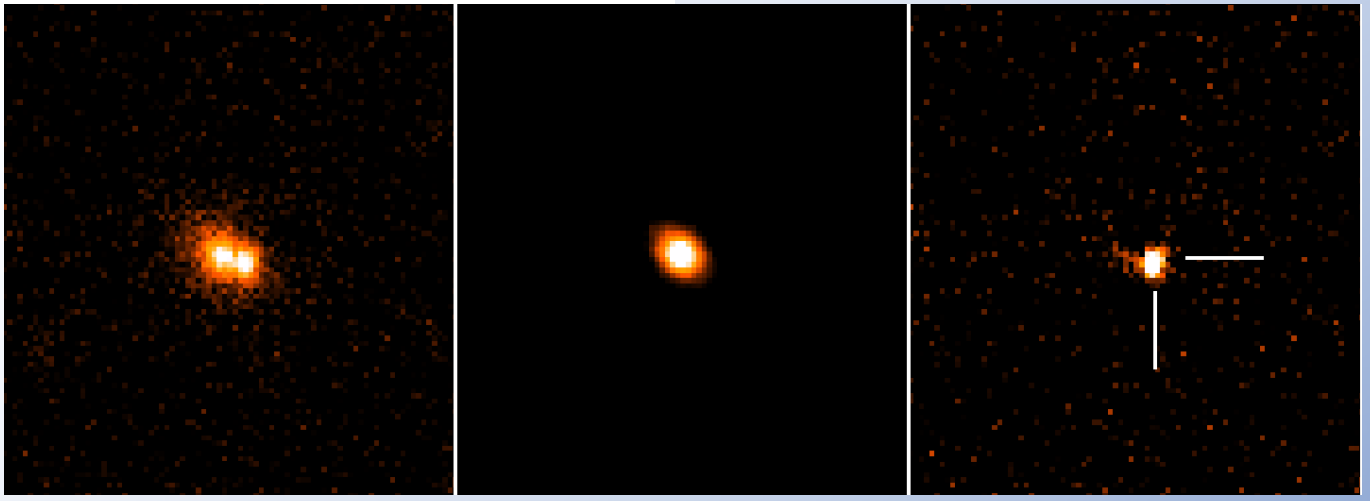
- DIBs observed toward bright stars

credits: ESA/Gaia/DPAC/CU6/Observatoire de Paris-Meudon/Olivier Marchal, Carine Babusiaux & David Katz





Credits
N.Blagorodnova
H.Campbel
M.Fraser
A.Hall
S.Hodgkin
Z.Kostrzewa-Rutkowska
G.Rixon
L.Wyrzykowski



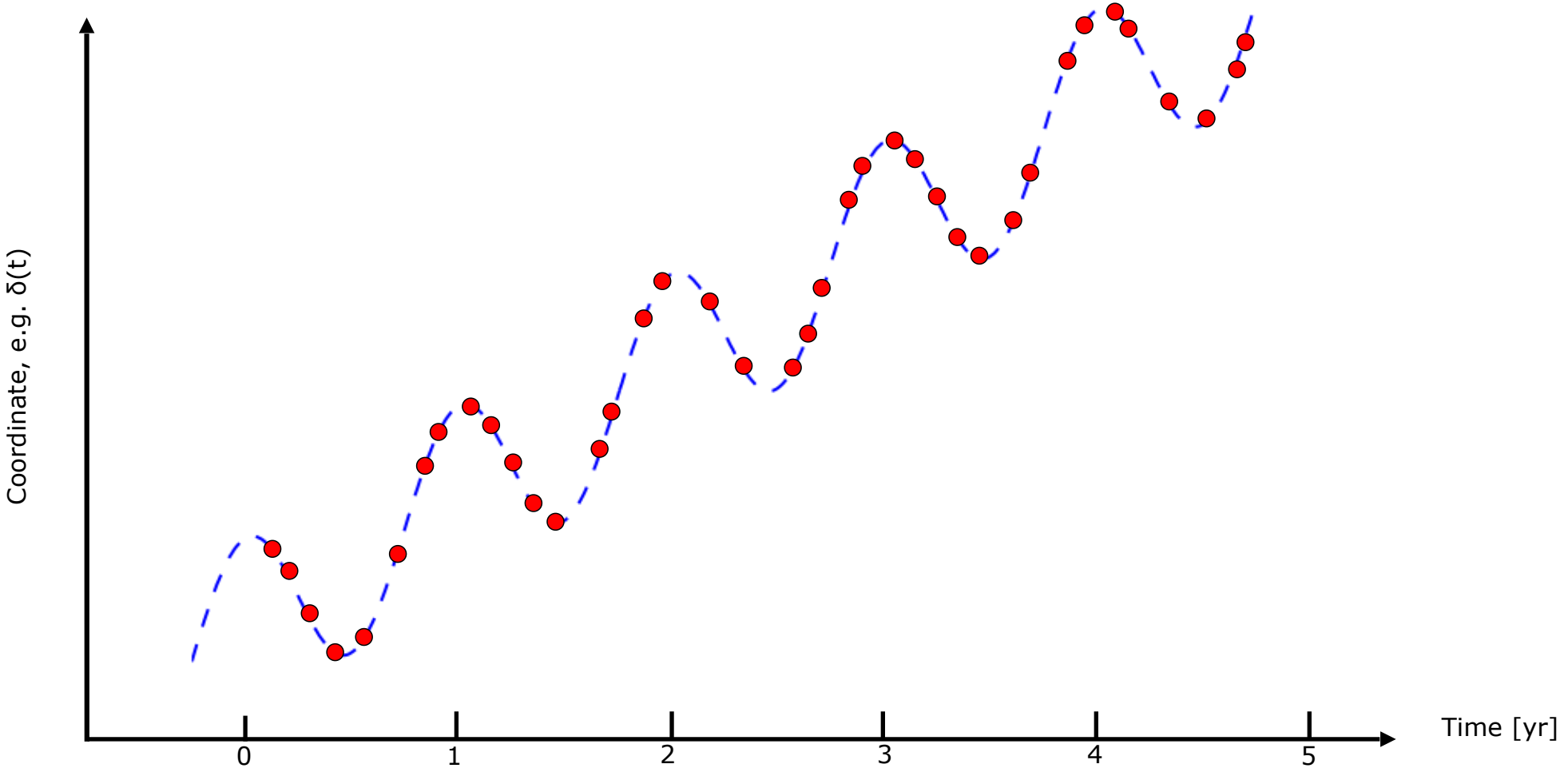
The first SN detected by gaia: gaia14aaa

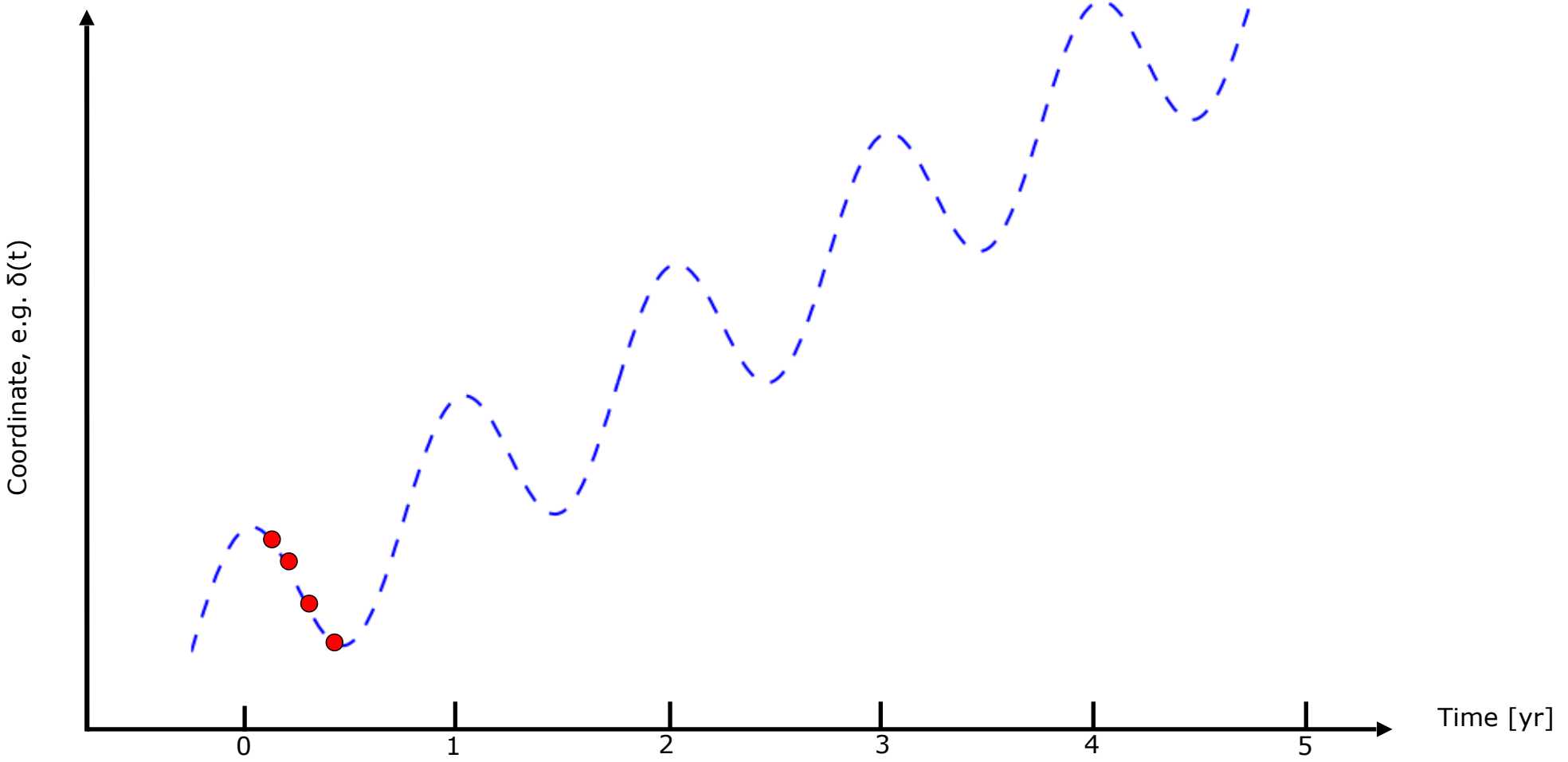
Unwanted surprises

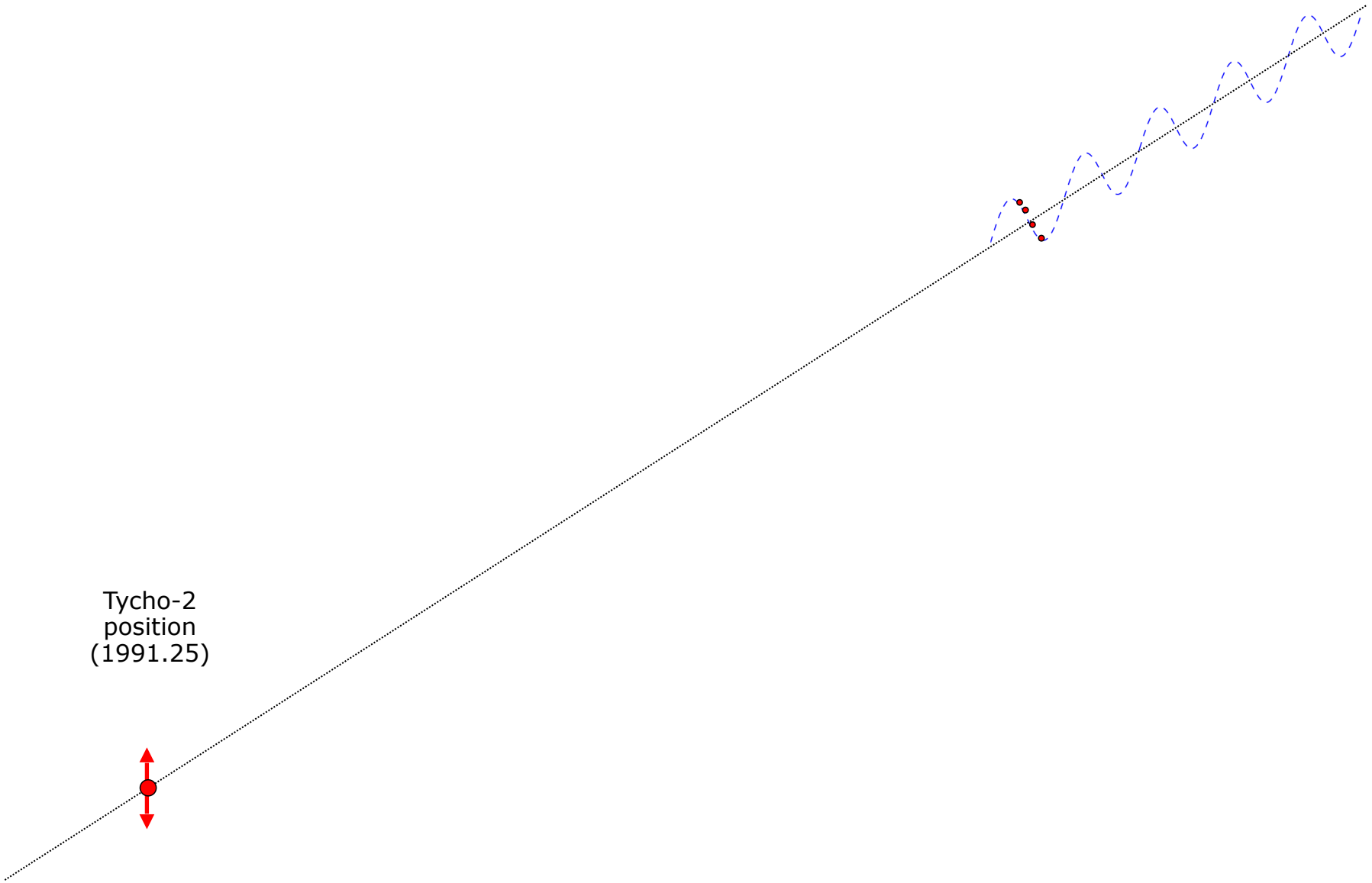
- Stray light both from astronomical sources and the Sun
  - Sun stray light due to scattering of fibres at the edge of the Sun shield
- Transmission loss due to continuing contamination of mirrors by water
  - Water source not yet exhausted although contamination rate much less than during commissioning
- Attitude disturbances
  - Micro-meteoroids and micro-clanks disturb the attitude
- Basic Angle variation larger than expected
  - Variation measured by on-board metrology device and verified at milliarsec level by astronomical sources

Next steps

- Stray light
  - On-board software modified to background dominated spectra
  - Parameter tuning on-going
- Transmission degradation
  - Decontamination conducted 3 June by heating the mirrors
- Attitude disturbances
  - Identification of micro-meteoroids and micro-clanks in the data stream
- Basic Angle variation larger than expected
  - Analysis of dedicated test measurements
  - Trial astrometric solutions with corrections based on the Basic Angle Monitor

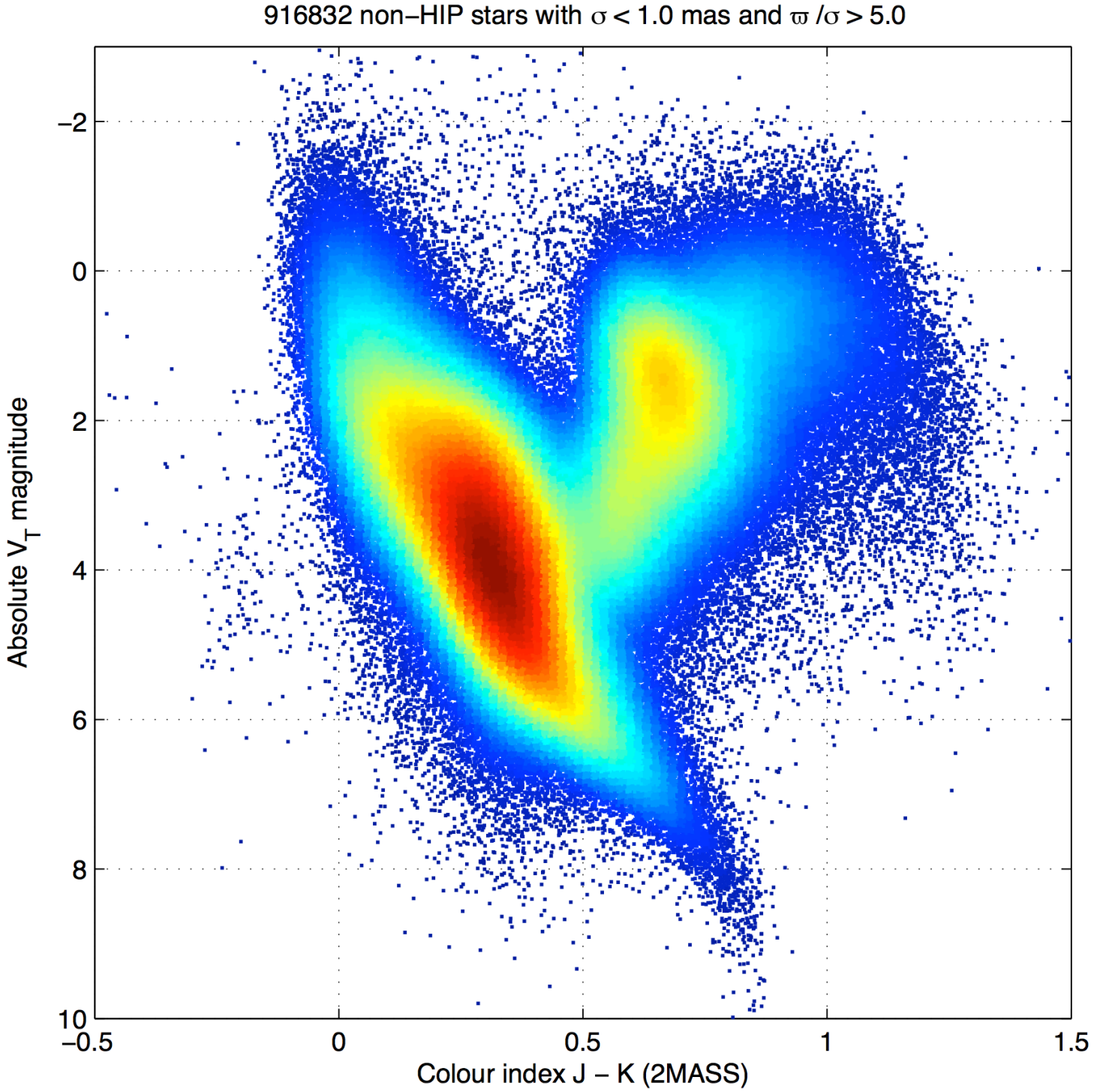

Coordinate, e.g. δ(t)
0
1
2
3
4
5
Time [yr]


Coordinate, e.g. δ(t)
0
1
2
3
4
5
Time [yr]

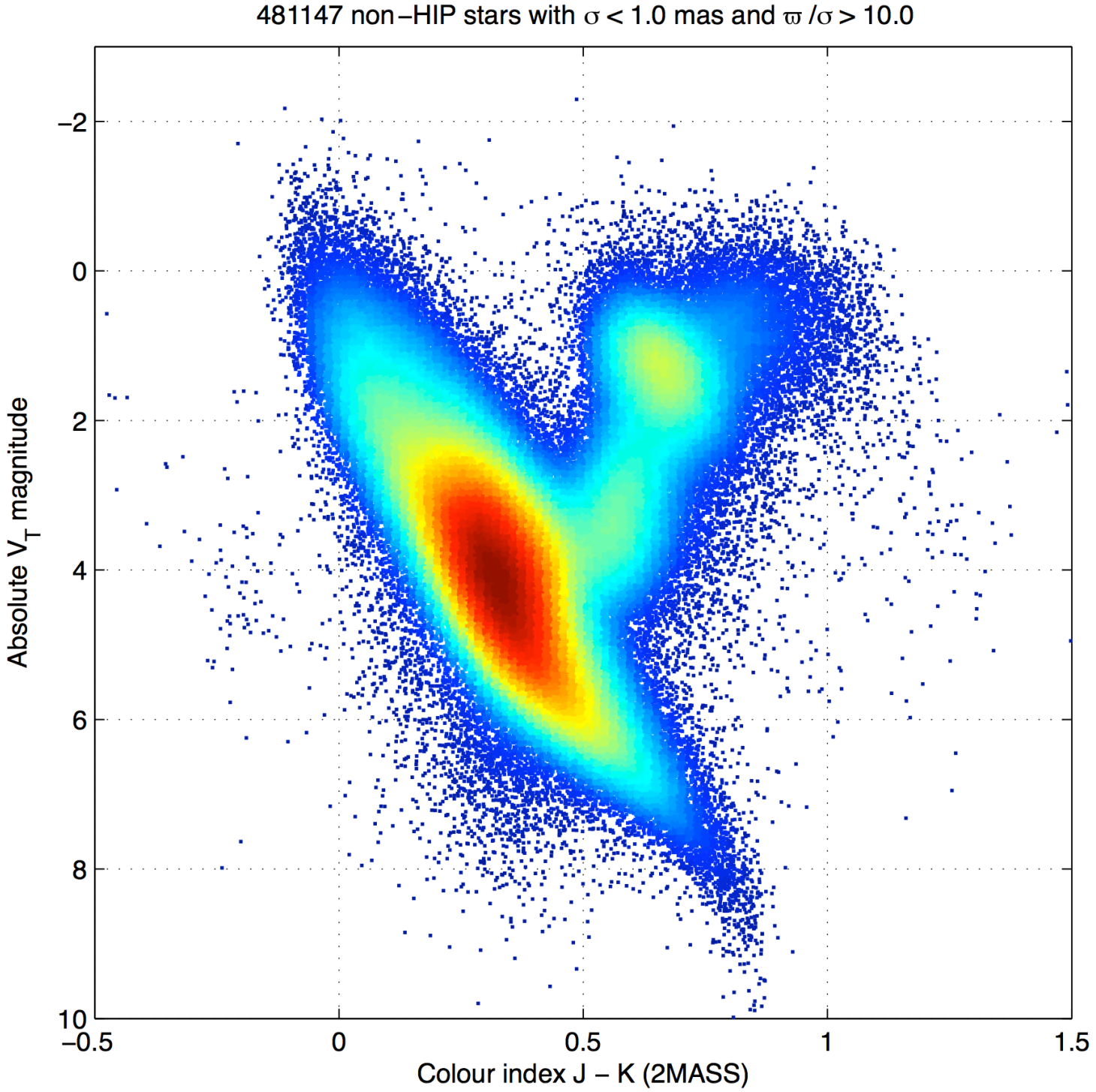

Tycho-2
position
(1991.25)

TGAS

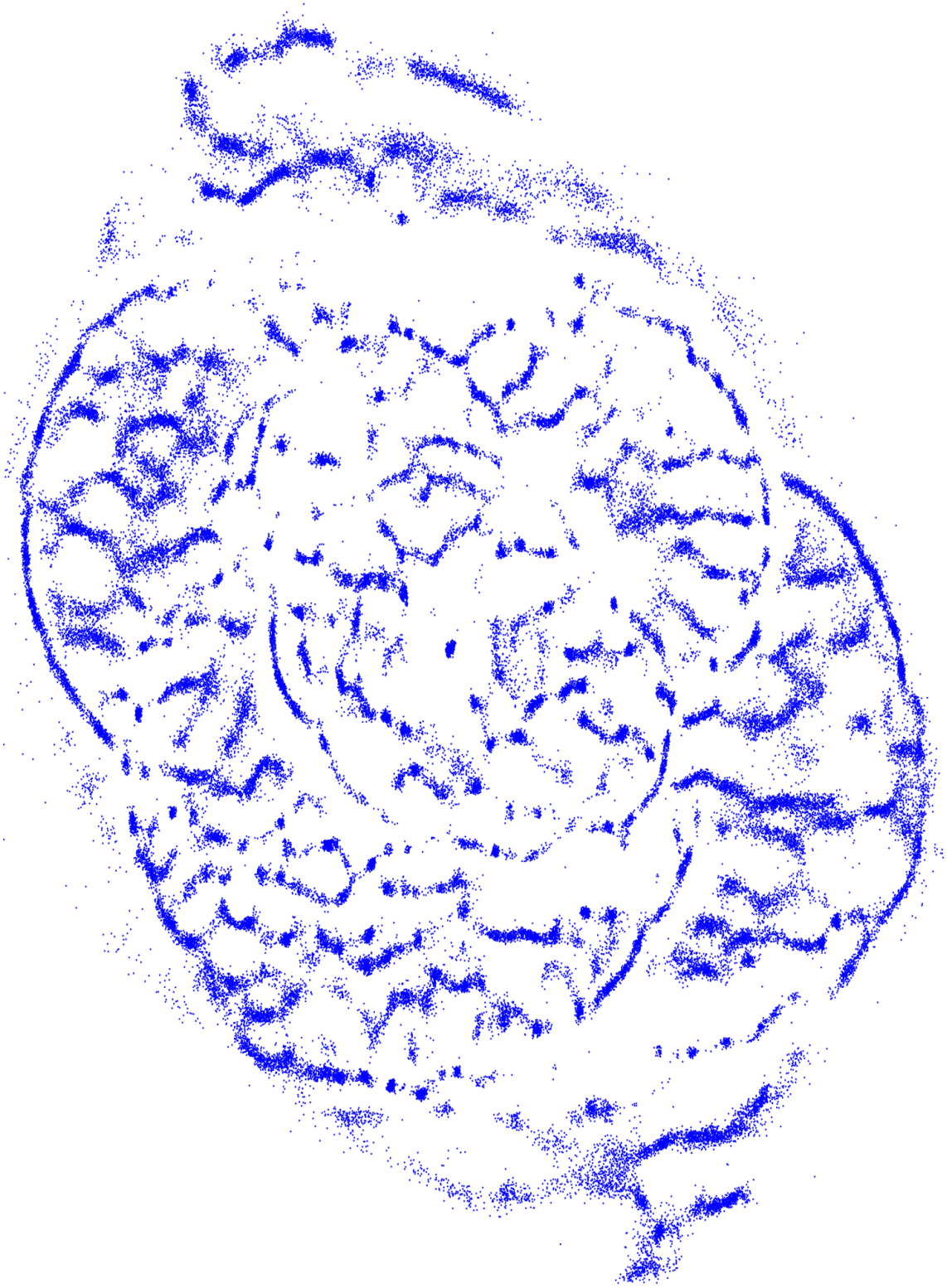
- **Time period covered:** 2014 July 25 - 2015 June 2 = data segment 0 with some additional filters applied (275 days over 10 months)
- **Number of sources:** 2,201,246 sources
  - Hipparcos: 99,070
  - Tycho-2 only: 2,102,176
- **Number of CCD observations:** 227,219,102 (most are both AL and AC)
- **Source block:** 5 parameters per source (reference epoch 2015.0)
  - Priors included (with appropriate covariances):
  - For Hipparcos stars: HIP positions @ 1991.25 + HIP proper motions (**no HIP parallax used**)
  - For non-Hipparcos stars: Tycho-2 position @ 1991.25 (no Tycho-2 proper motion used)
- Empirical correction for Basic Angle Variation using BAM data

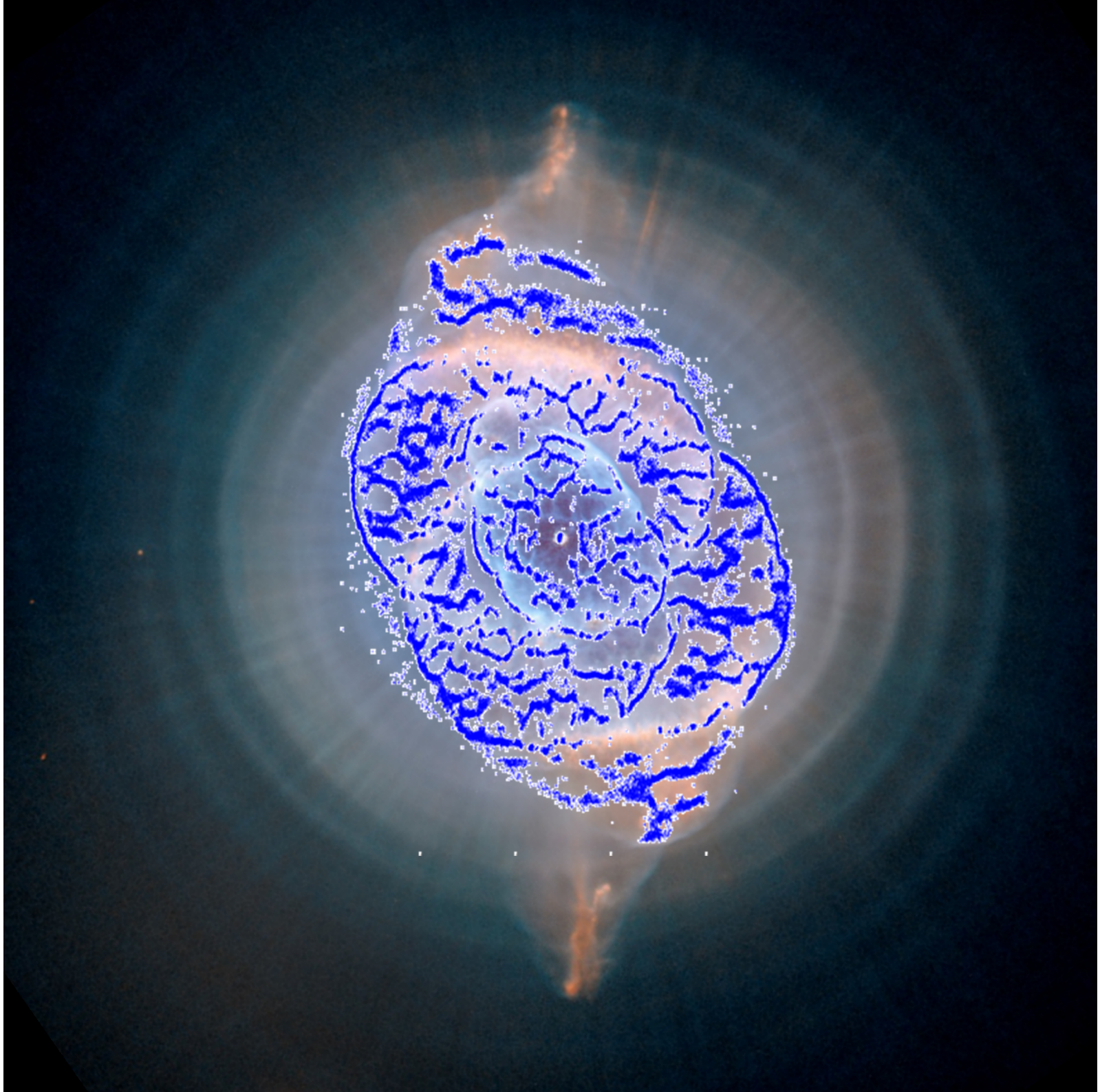


credits: ESA/Gaia/ DPAC/IDT/FL/DPCE/ AGIS



credits: ESA/Gaia/ DPAC/IDT/FL/DPCE/ AGIS





HST image credit: NASA, ESA, HEIC, and The Hubble Heritage Team (STScI/AURA)
Gaia image credit: ESA/ Gaia/DPAC/UB/ IEEC

Scientific performance

For unreddened Solar type (G2V) star

V-magnitude	*Astrometry (parallax)*	*Photometry (BP/RP integrated)*	*Spectroscopy (radial velocity)*
6 to 12	*5-14 μas*	*4 mmag*	*1 km/s*
15	*25 μas*	*5 mmag*	*13 km/s*
20	*540 μas*	*60 (RP) – 80 (BP) mmag*	

Calculations by: Airbus DS, D. Katz, C. Jordi, L. Lindegren, J. de Bruijne

esa Gaia DPAC AIRBUS DEFENCE & SPACE

Astrometric performance

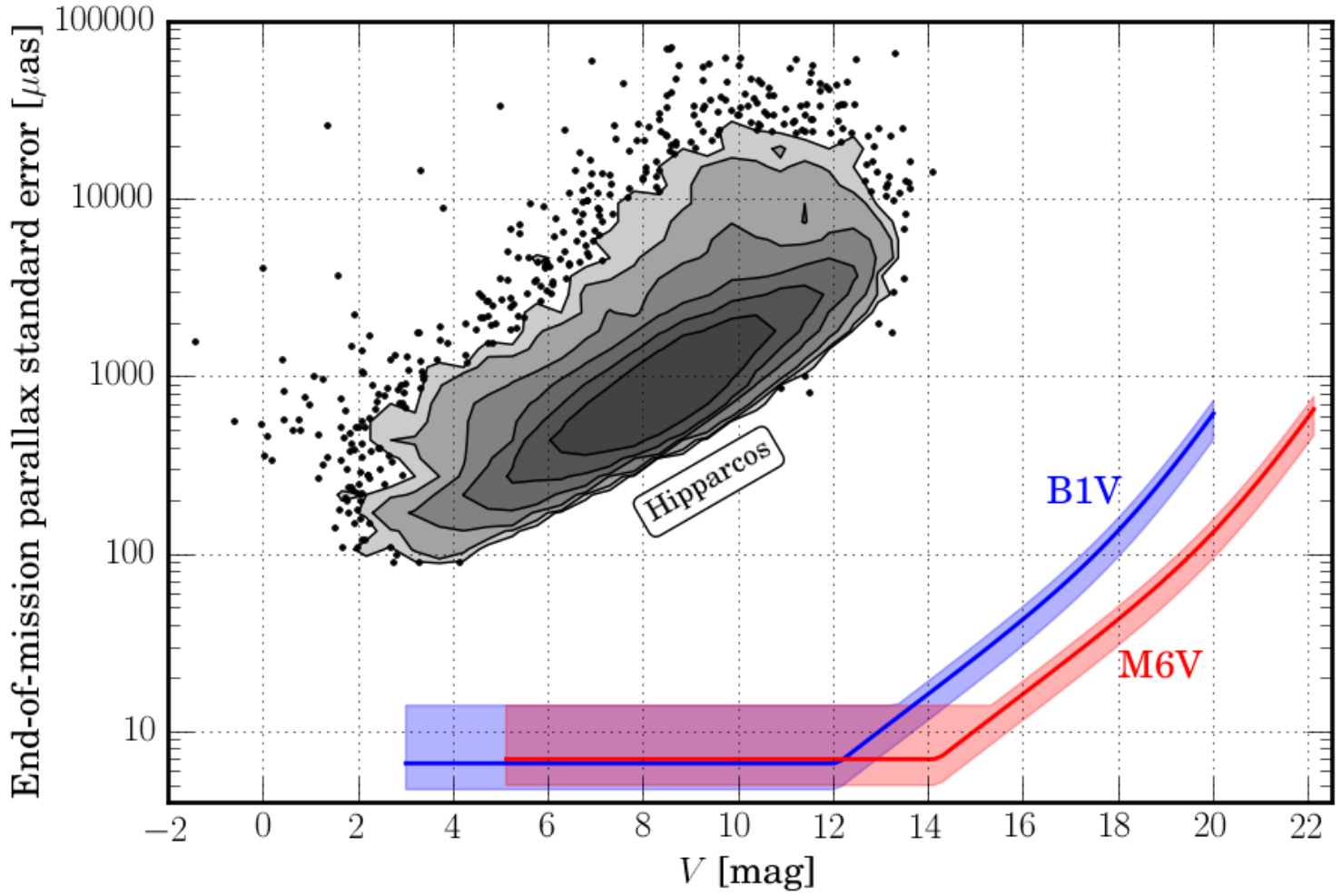


Figure courtesy of:
A. Brown

Conclusions

- Gaia is fully operational collecting data on average for 50 million stars per day (peak day above 250 million)
- Data Processing and Analysis consortium has to cope with the quantity and take into account in-orbit behaviour to ensure quality
- First intermediate release (positions and G-magnitudes complemented with proper motions to Hipparcos stars) anticipated summer 2016
    - Additional items under consideration
- First full 5 parameter astrometric Gaia solution early 2017