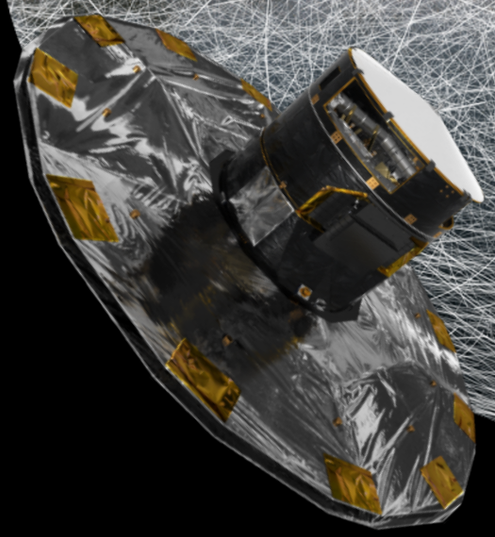
Gaia Photometric System



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Gaia Collaboration

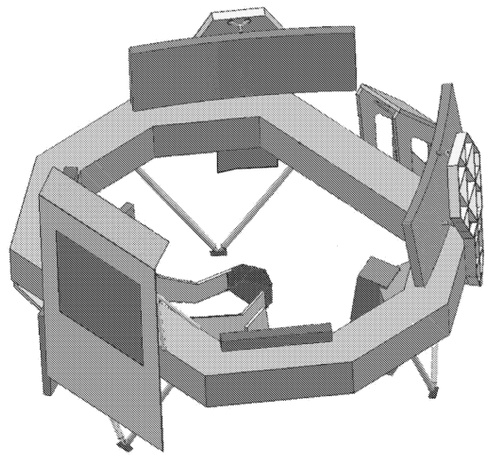
Airbus Space

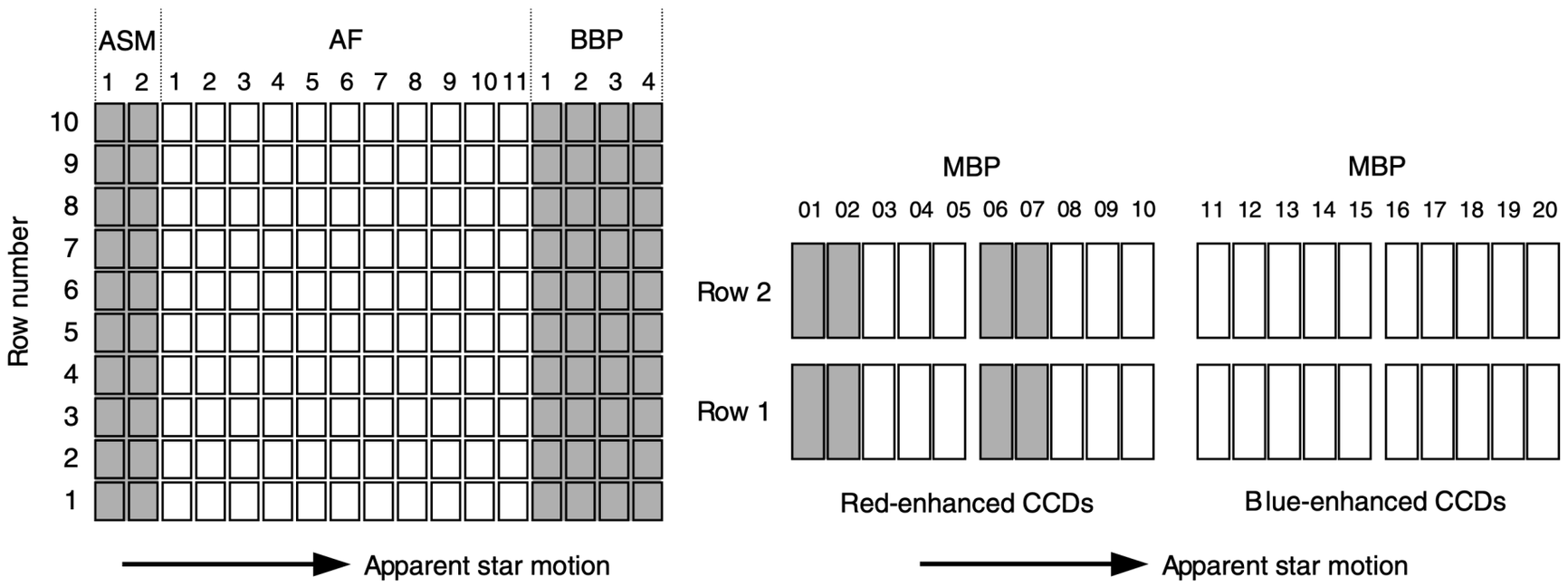
ESA/Gaia/DPAC

Why no Gaia filters?

- Early Gaia design had 3 telescopes (Gaia-2)
  - 2 Astrometric
  - 1 Spectrophotometric

- 2 focal planes





Lower resolution

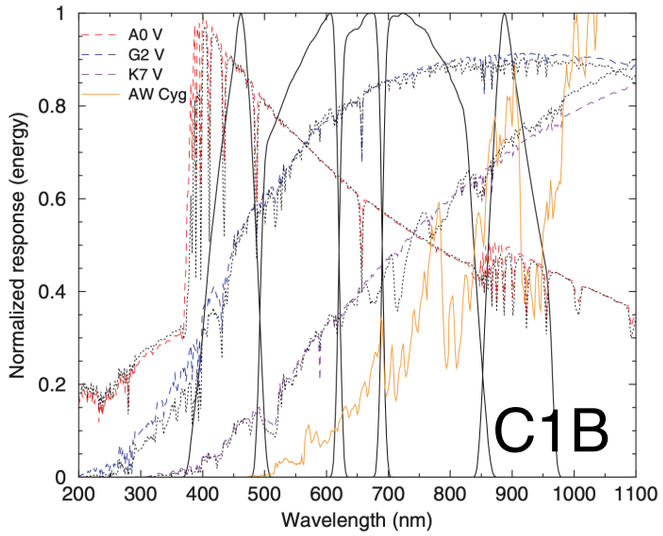
Figure 1. Schematic layout for the Astro field (left) and the Spectro/MBP field (right) in *Gaia*-2. The designations BBP1–BBP4 and MBP01–MBP20 refer to the physical locations of the CCDs in the along-scan direction within the field, independent of their functionality (e.g. for detection or photometry) and the assignment of filters between them. The Spectro sky mapper, operating without filters, is physically located at MBP01, 02, 06, and 07. ASM and AF are the Astro sky mapper and the Astro field, respectively.

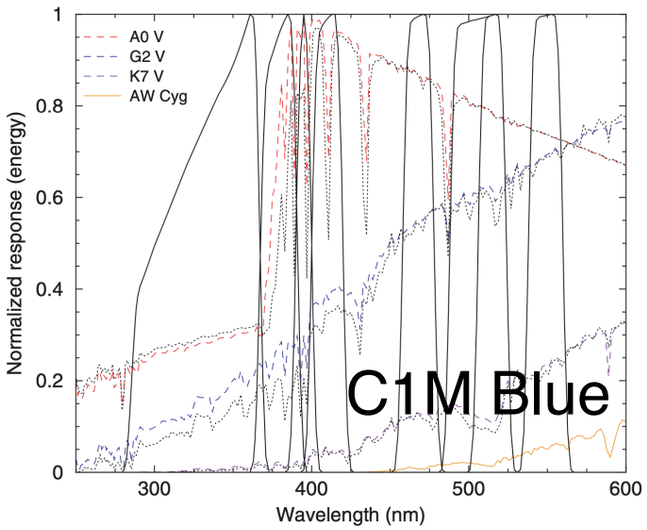
Why no Gaia filters?

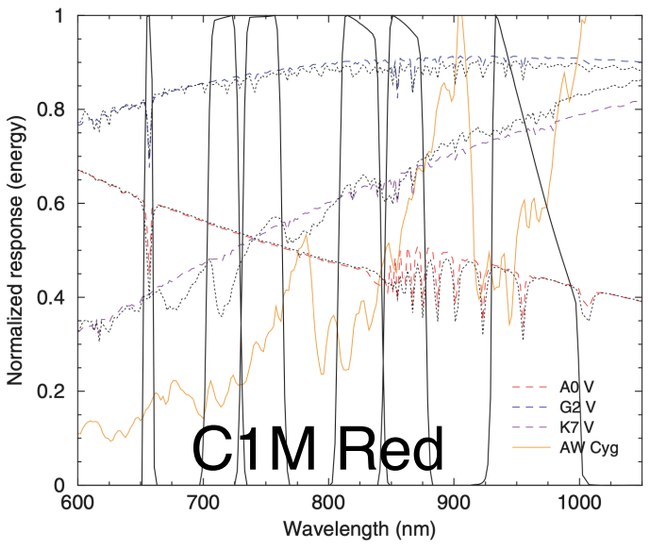
- Colour information required to correct for chromaticity
- Two filter sets C1B (broad), C1M (medium)
  - Jordi et al. MNRAS **367,** 290–314 (2006)
  - C1B designed for chromaticity correction
  - C1M designed for astrophysical parameter extraction
  - Plots show the chosen filter set overplotted with some example spectra

- Operational limitations meant scrapping Gaia-2
  - Long live Gaia-3!

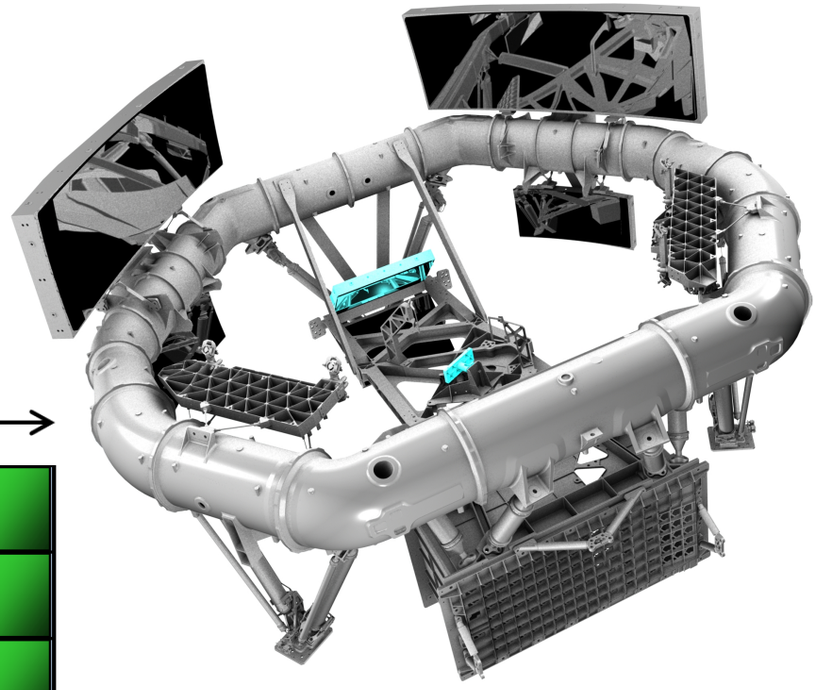
- This was unfortunate
  - Filters would have been a lot easier to calibrate!



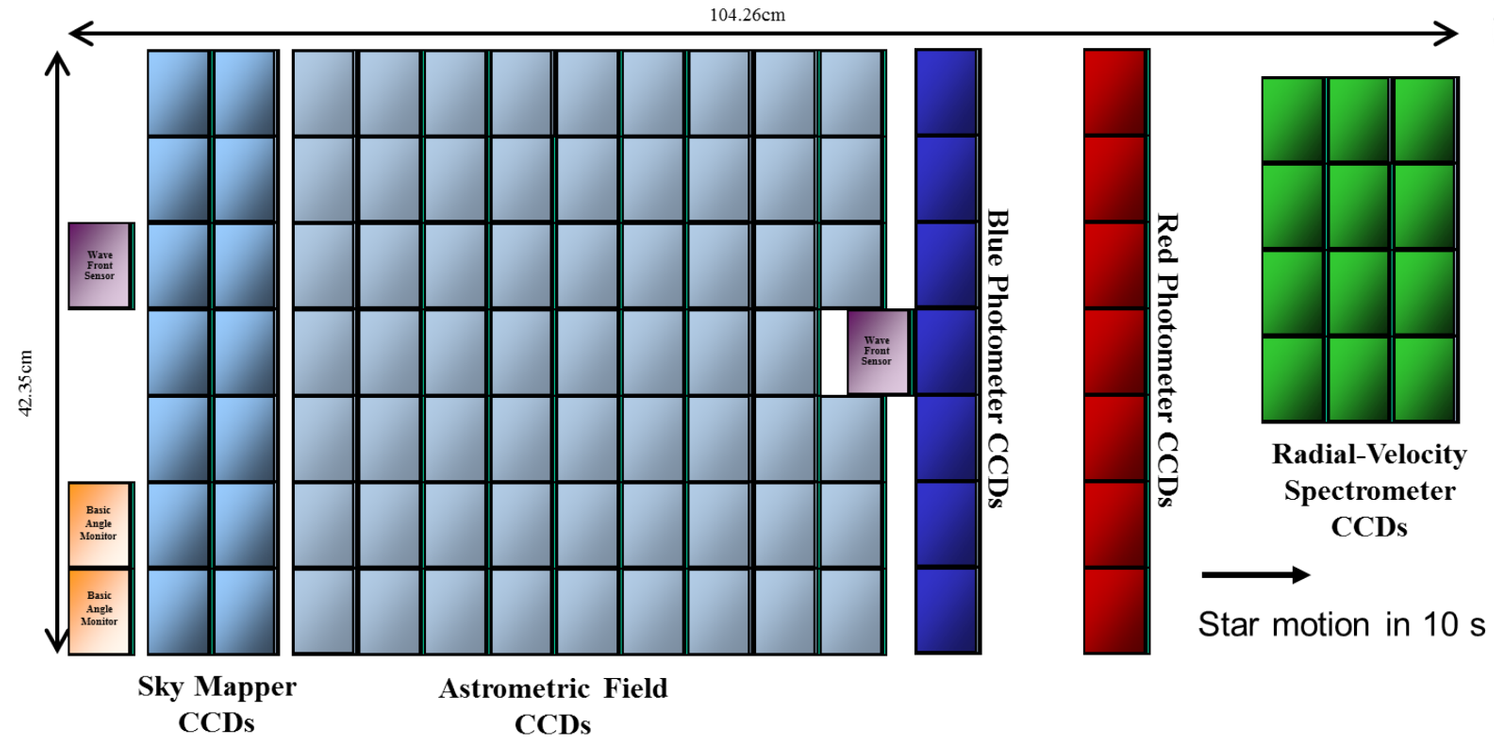




Actual Gaia design

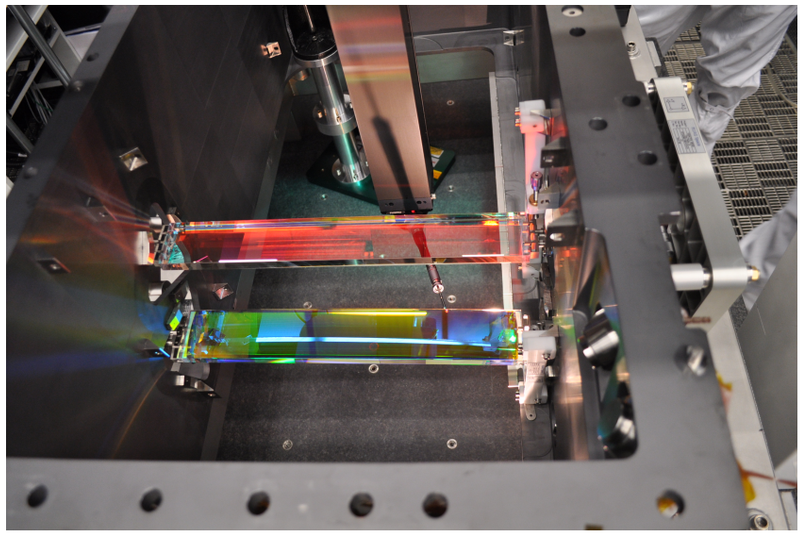


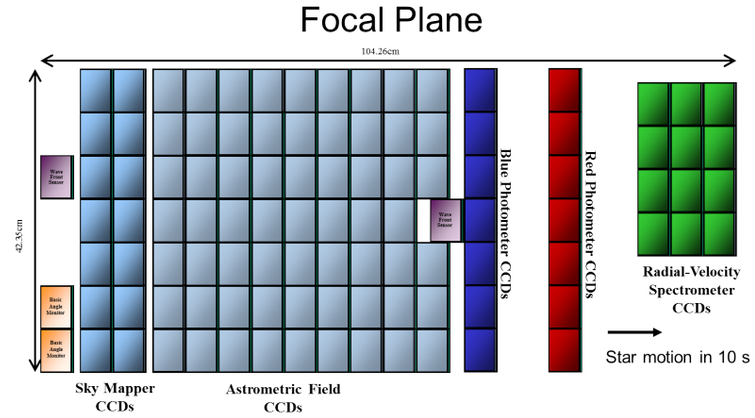
- 2 telescopes, 1 focal plane

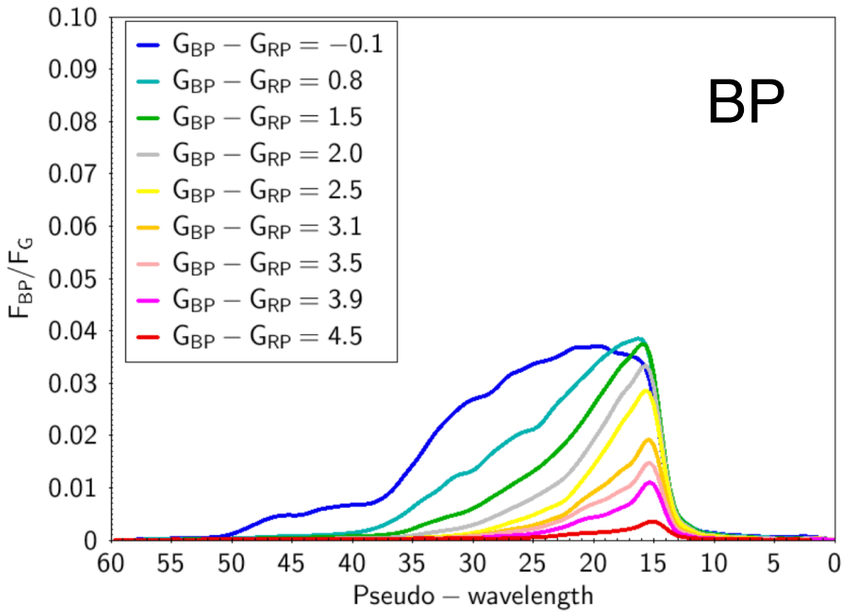


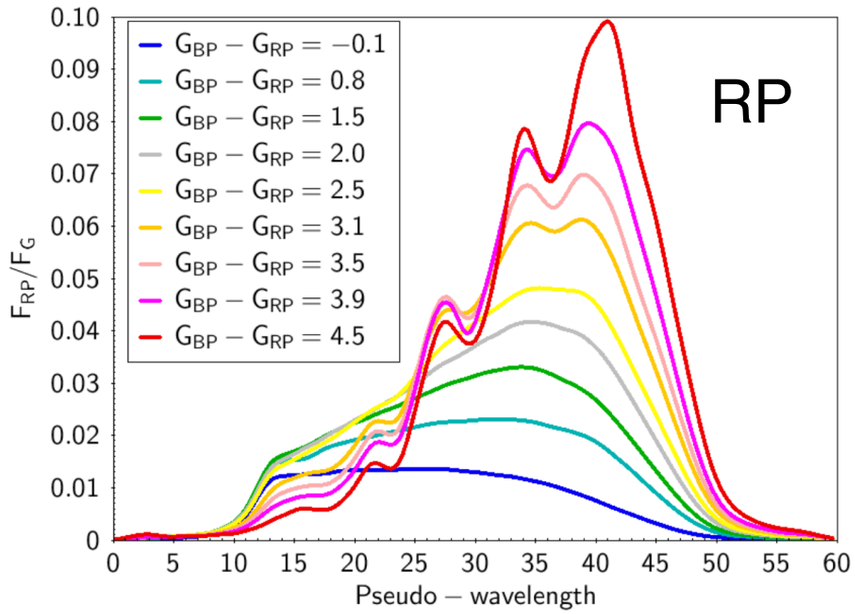
- Drift scan (TDI)
  - CCDs read out at same rate as satellite spin rate
- AF CCDs
  - G-band (no filter, just CCD and mirror response)
  - Maximize light for astrometry
- Blue and Red Photometers (BP and RP)
  - Give the colour information for chromatic correction
- Radial Velocity Spectrometer
  - Centred on Calcium triplet (845–872 nm)

Blue and Red Photometers









- No filter, but 2 prisms
  - BP 330–680 nm
  - RP 640–1050 nm
- Quite a variable dispersion
- Alien photon issue
- Complex calibration to get spectra
  - Full colour information
  - De Angeli et al. 2022 (https://doi.org/10.1051/0004-6361/202243680)
- For broad-band photometry easier to use data as a photon bucket
  - This is the source of the BP and RP photometry

Calibrating the photometry

- Where do we get the standards from?
  - There is no catalogue out there accurate or large enough or all-sky
  - It has to be self-calibrating
  - See Riello et al. A&A **649**, A3 (2021) for more details

- Simple iterative scheme
  - Generate mean photometry using raw (uncalibrated) fluxes
  - Use mean photometry to calibrate the fluxes (approximately)
  - Generate a new set of mean photometry
  - Iterate until convergence

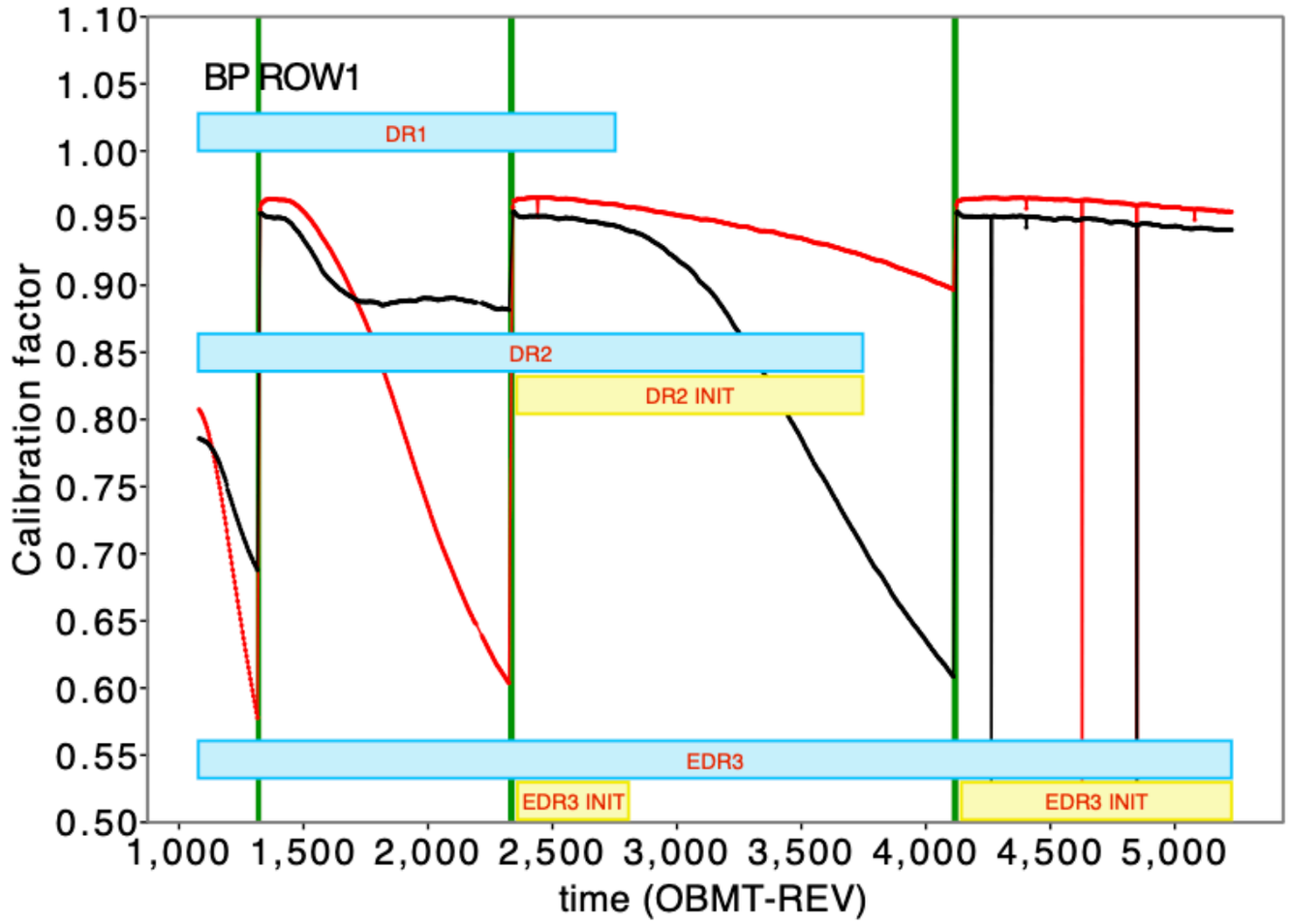
- All fluxes are calibrated to the same mean photometric system
  - Each CCD has a slightly different response

- Implies that the photometry defines the passbands

- This would be easy apart from …

Calibrating the photometry with contamination

- Contamination caused by ice condensing on mirrors and CCDs
  - Causes throughput to change a lot with time
  - Contamination acts as an additional filter (worse in BP)
  - Contamination removed by heating mirrors and focal plane
- Depending on period used for initialization, the average passband will be different
  - The photometric systems in DR1, DR2 and EDR3 are not the same

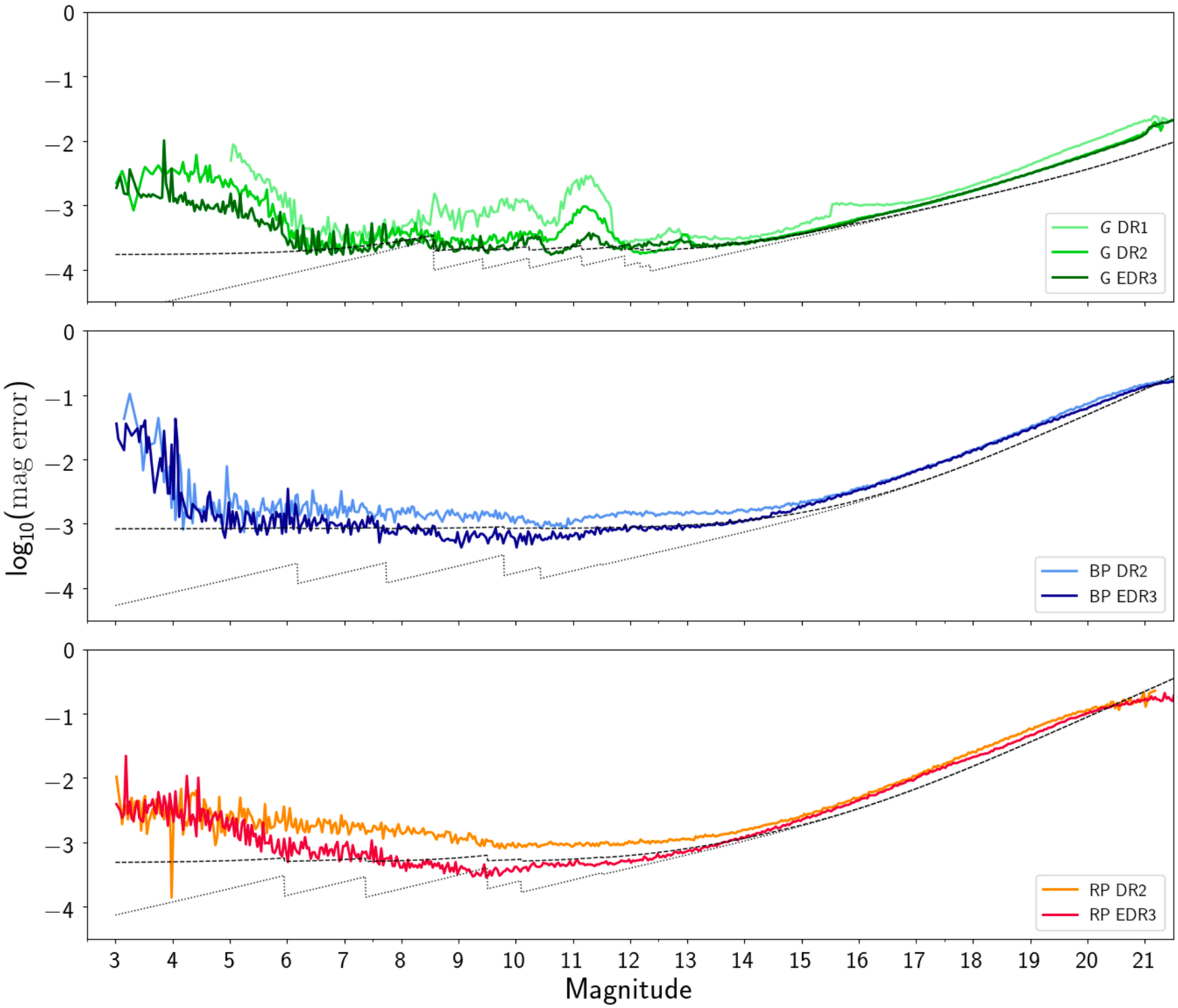


14 months

22 months

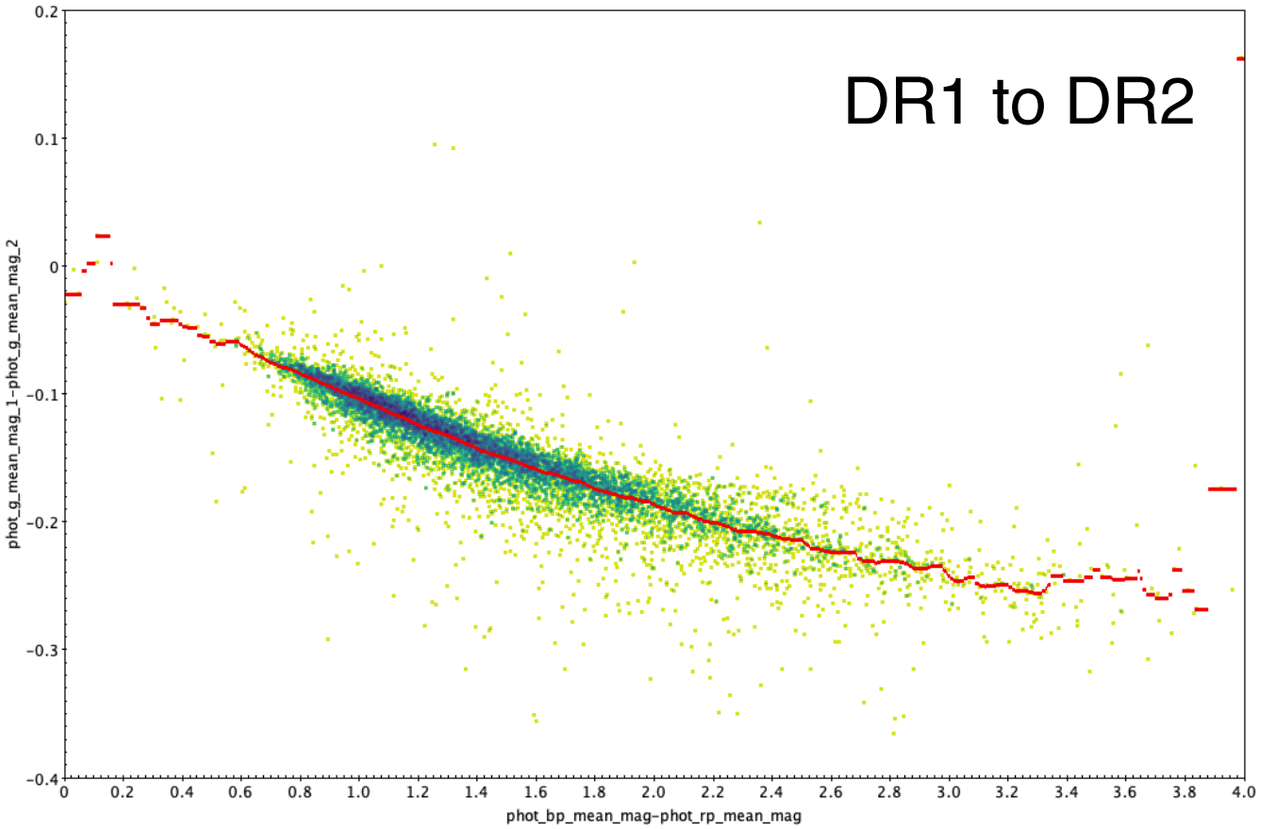
34 months

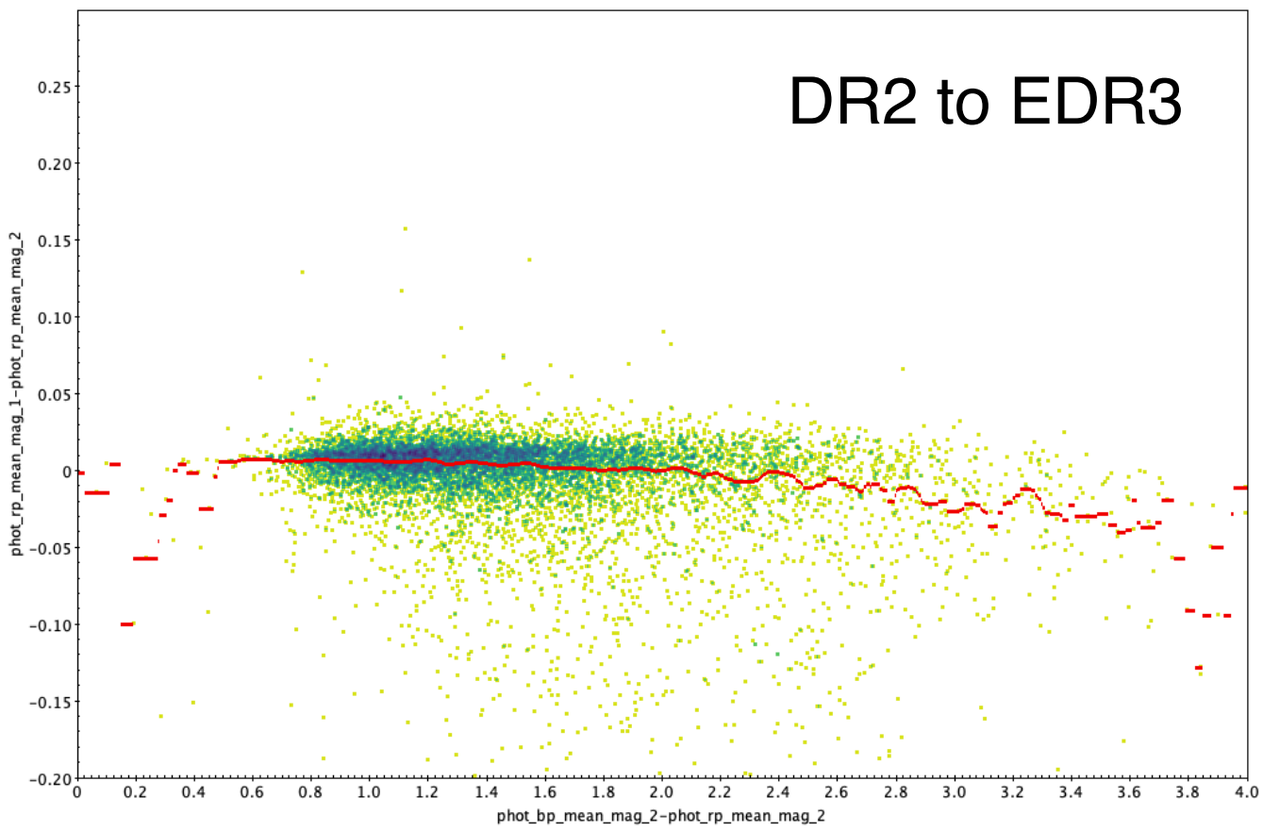
A changing system: DR1 to EDR3



- Accuracy and precision have improved

A changing system: DR1 to EDR3



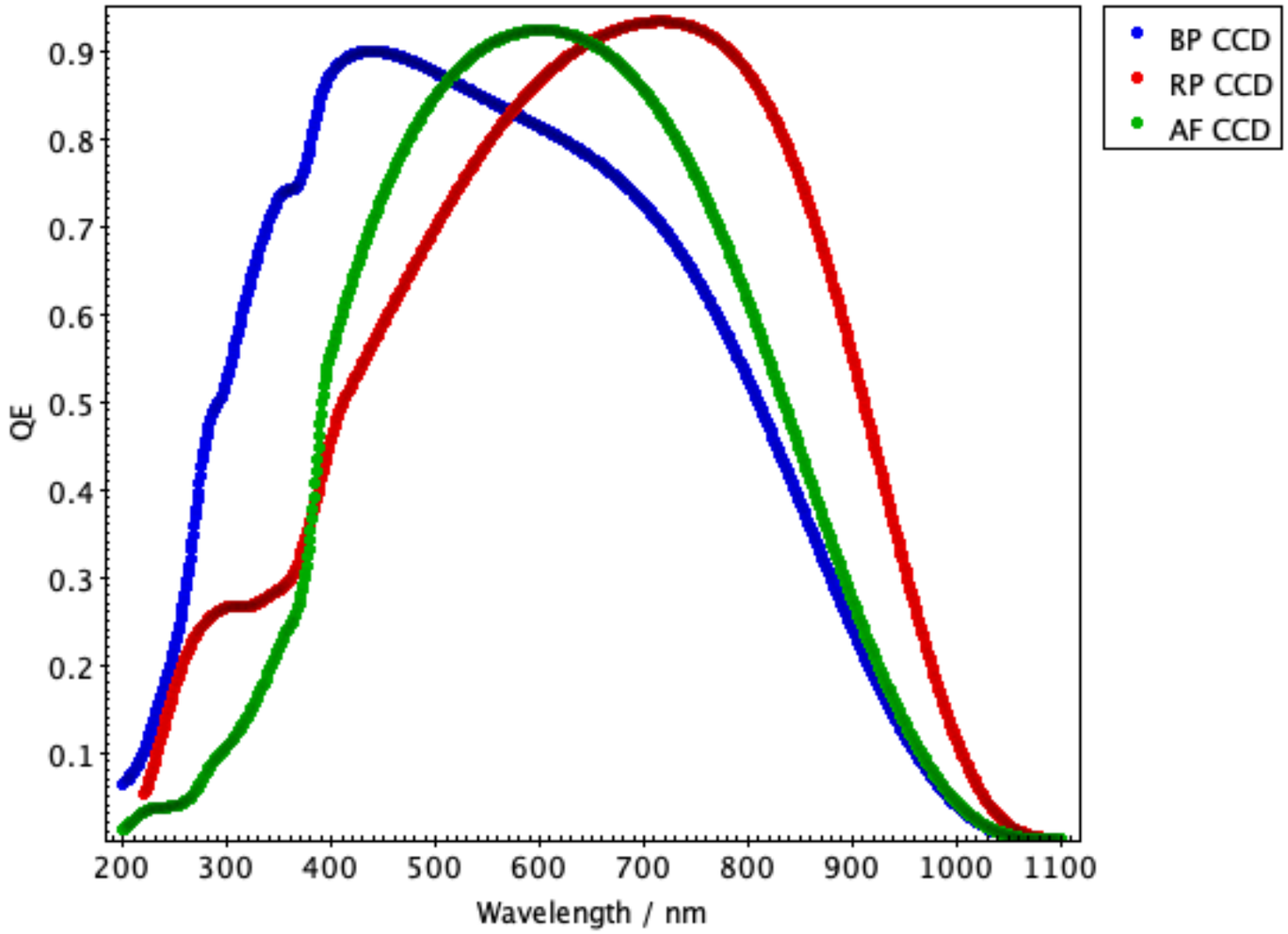


- Colour terms between releases show photometric system has changed
  - DR1 to DR2 about 0.1 mag change
  - DR2 to EDR3 about 0.01 mag change
  - Smaller change expected for DR4

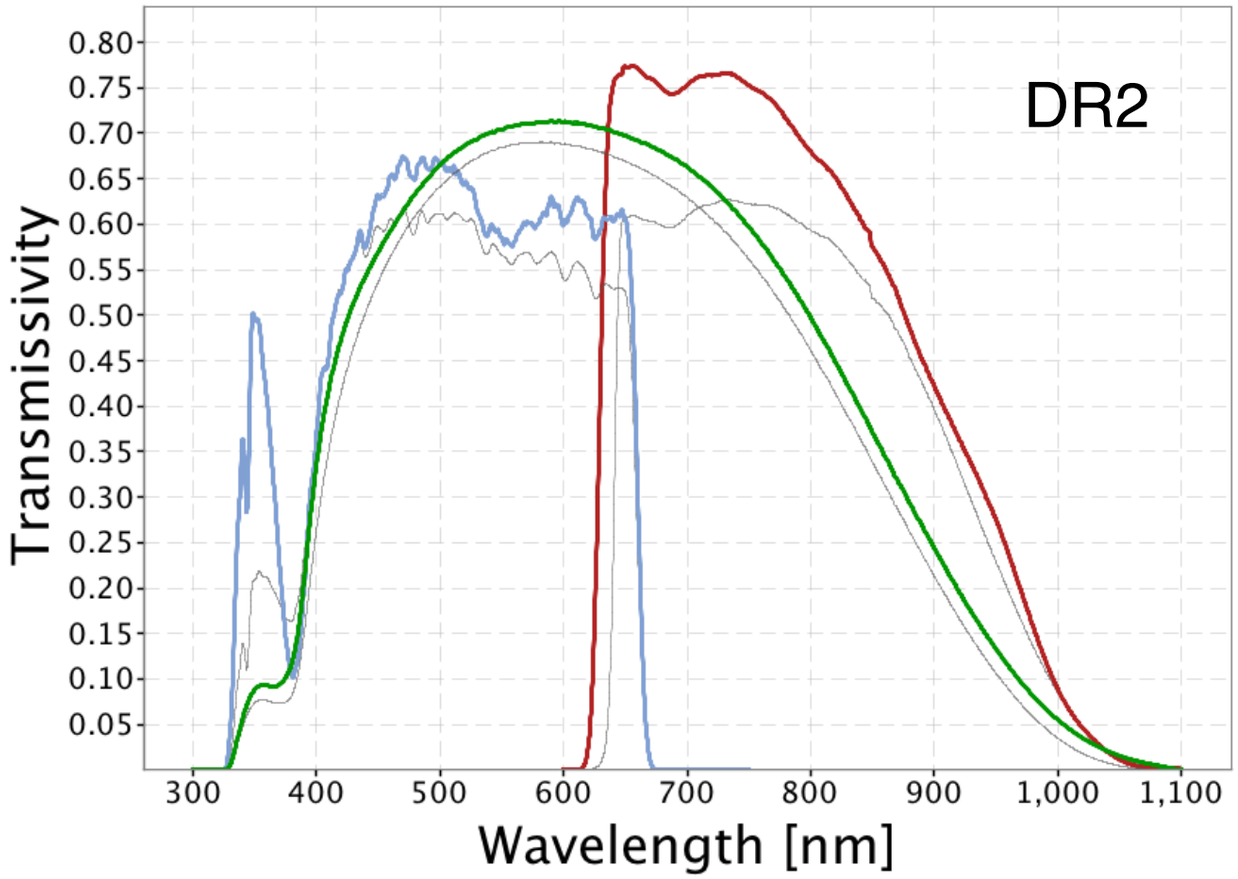
- Never try to convert from one system to another
  - Always redo the analysis using the latest release

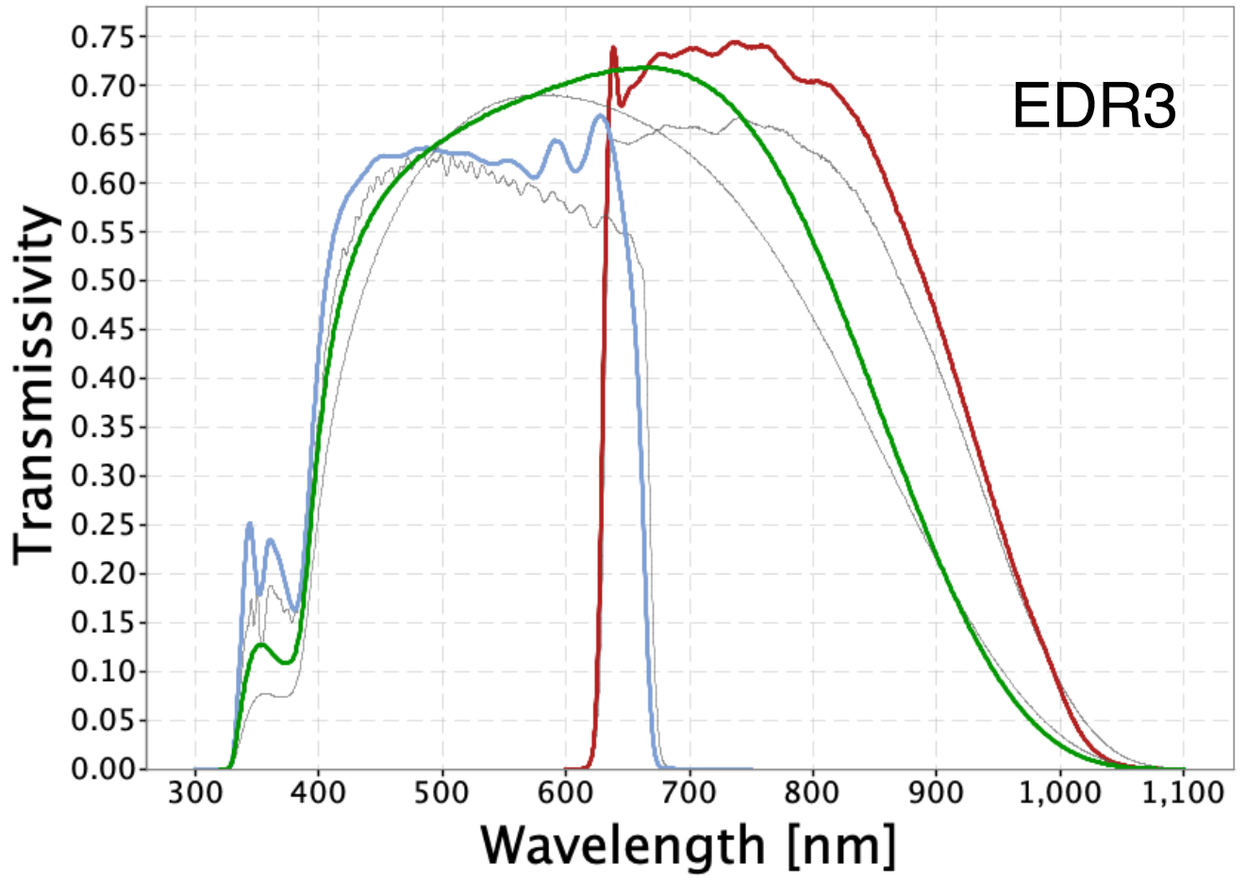
ESA/Astrium details

- GAIA-CH-TN-ESAC-RKO-003
  - CCD quantum efficiency
- Need to account for reflectivity of silver coating on mirrors
- Cut-off from prism coatings
  - BP 680 nm
  - RP 640 nm
- Nominal pre-launch passbands available at Gaia website (DR1)



Derived passbands





- Derived using ~100 spectro-photometric standard stars (SPSS)
  - Alter the passbands so that the synthetic photometry from the SPSS matches the Gaia photometry
- No G passband derived for DR1
- BP in DR2 had separate bright and faint passbands
  - Affected bright and blue stars by a percent or so
- Use the EDR3 passbands
  - Never mix passbands, zeropoints and photometry from different releases

Trying to duplicate Gaia passbands

- Start off with your CCD response
- Add effect of mirror reflectivity
- Add effect of average absorption by the atmosphere
- Ratio between this and EDR3 Gaia passbands gives the filter that you need

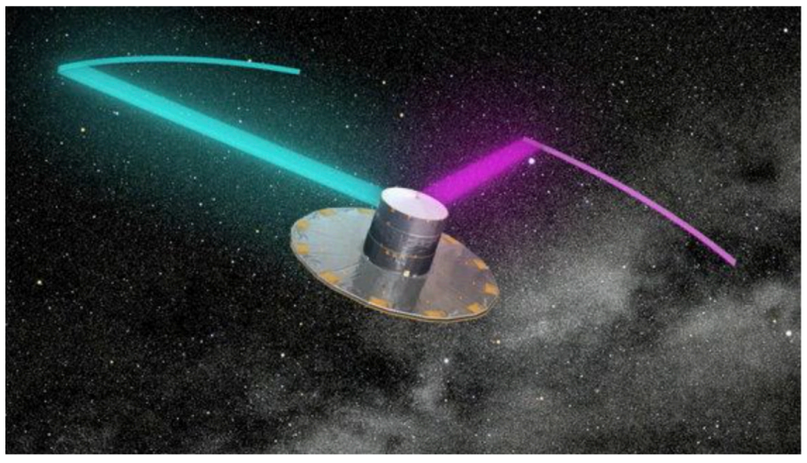
- Unlikely to get a perfect match, so you will have colour terms
  - Closer the match, smaller the colour terms

- It is not guaranteed that atmospheric extinction is grey

GaiaXPy

The Gaia BP/RP spectra package.

Get Started



About the package

BP/RP spectra will become available for the first time in Gaia Data Release 3 (DR3). In their first release, only source mean spectra will be available: these are spectra that have been generated from a number of single observations of the same object. Epoch spectra, i.e. spectra consisting of one single observation, will become available in future releases.

GaiaXPy is a Python library to facilitate handling Gaia BP/RP spectra as distributed from the Gaia archive.

Learn more

https://gaia-dpci.github.io/GaiaXPy-website/

219M spectra in DR3

Get started

Learn more about the package with the different pages available.