Stellar parameters from Gaia

Ulrike Heiter and Gaia DPAC CU8

Uppsala universitet

24 May 2016

UPPSALA
UNIVERSITET

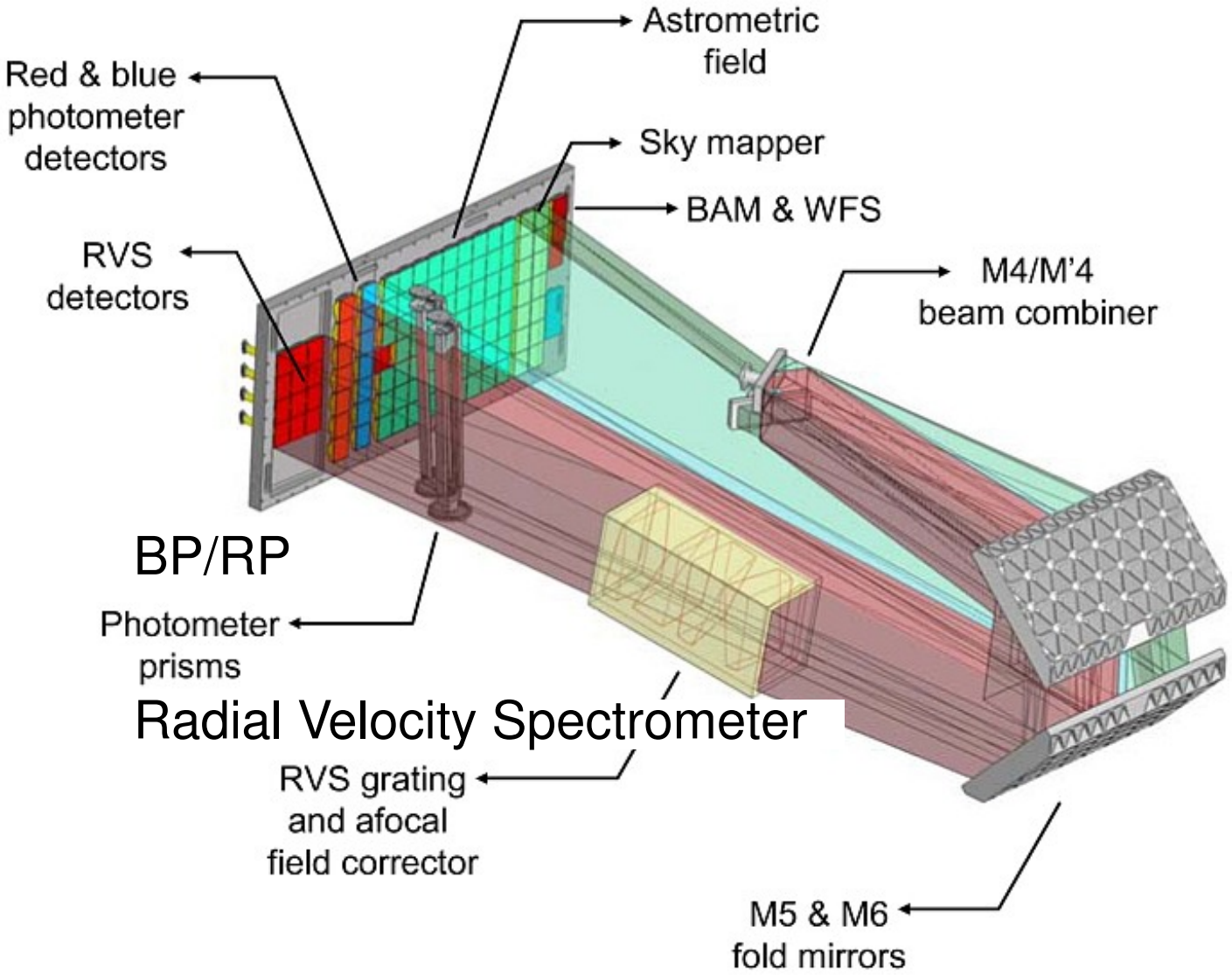
Outline

- Overview of CU8 data and processing
- Expected performance for stellar parameter estimation
- Validation and Calibration
- Stellar parameters in Gaia data releases

Classification and parameters from Gaia data

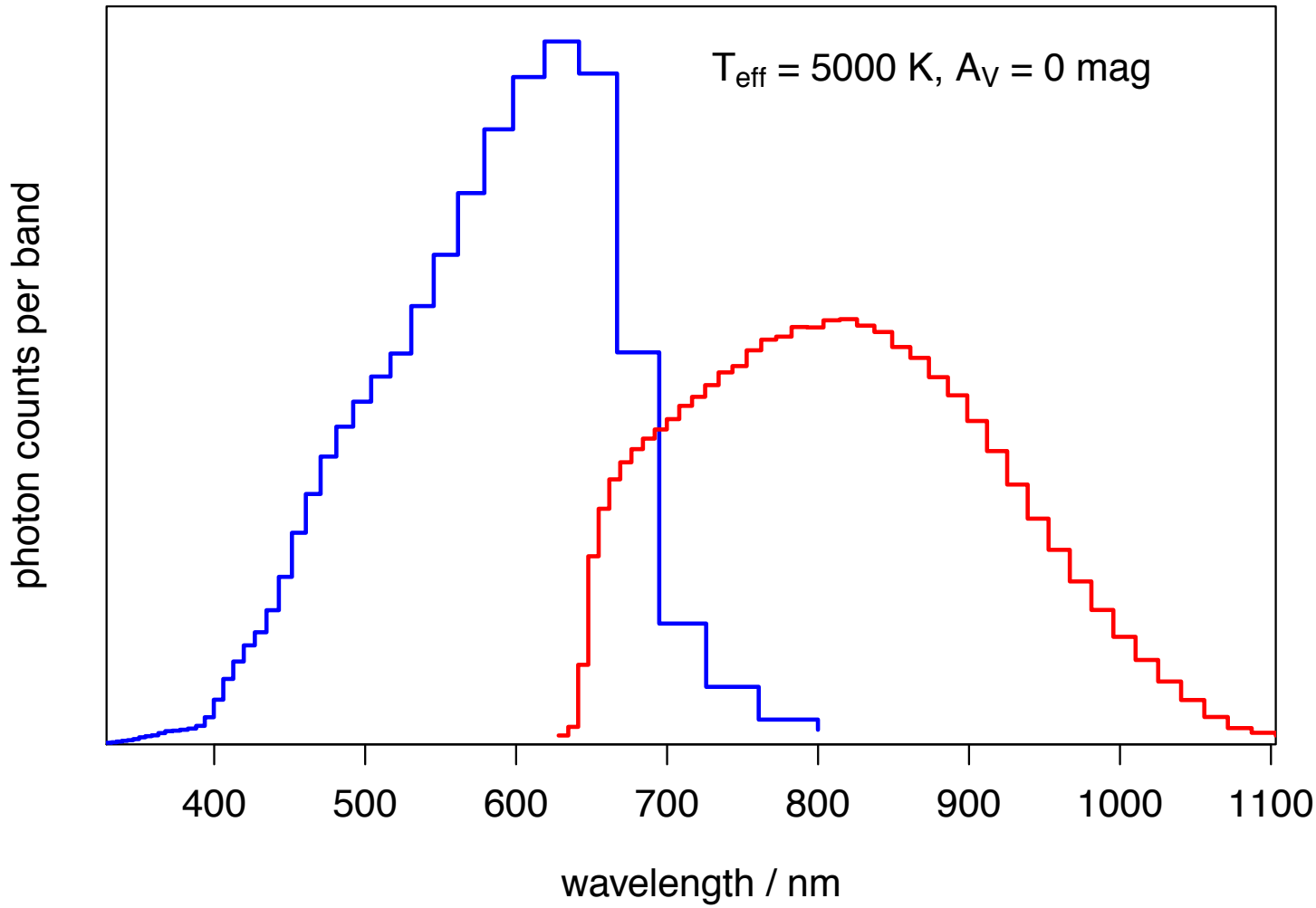
- Source classification
  - assign probabilities for belonging to different classes: star, binary, quasar, galaxy, ...
  - based on spectrophotometry (BP/RP), RVS spectra, colours, astrometry
- Astrophysical parameter (AP) estimation
  - for single and binary stars, quasars, and galaxies
  - based on spectrophotometry (BP/RP), RVS spectra, and parallax (for stars)
- Use of various libraries of synthetic spectra (plus calibration against standards)
- Novelty detection (outlier analysis)
- Described in Bailer-Jones et al. 2013, A&A 559, A74, and Recio-Blanco et al. 2016, A&A 585, A93

Gaia spectroscopy

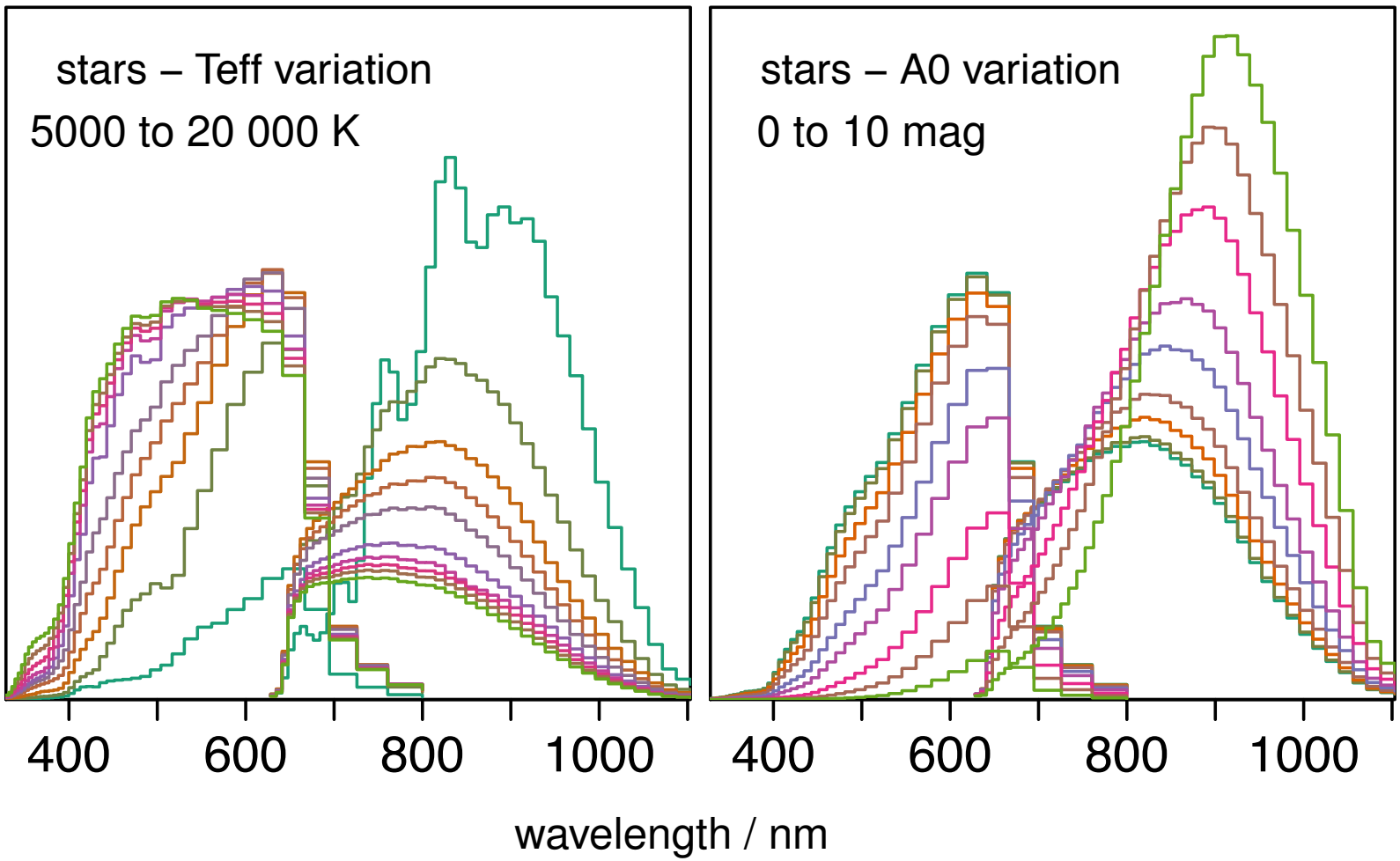


Graphics: ESA, Astrium

Simulated spectrophotometry (BP/RP)

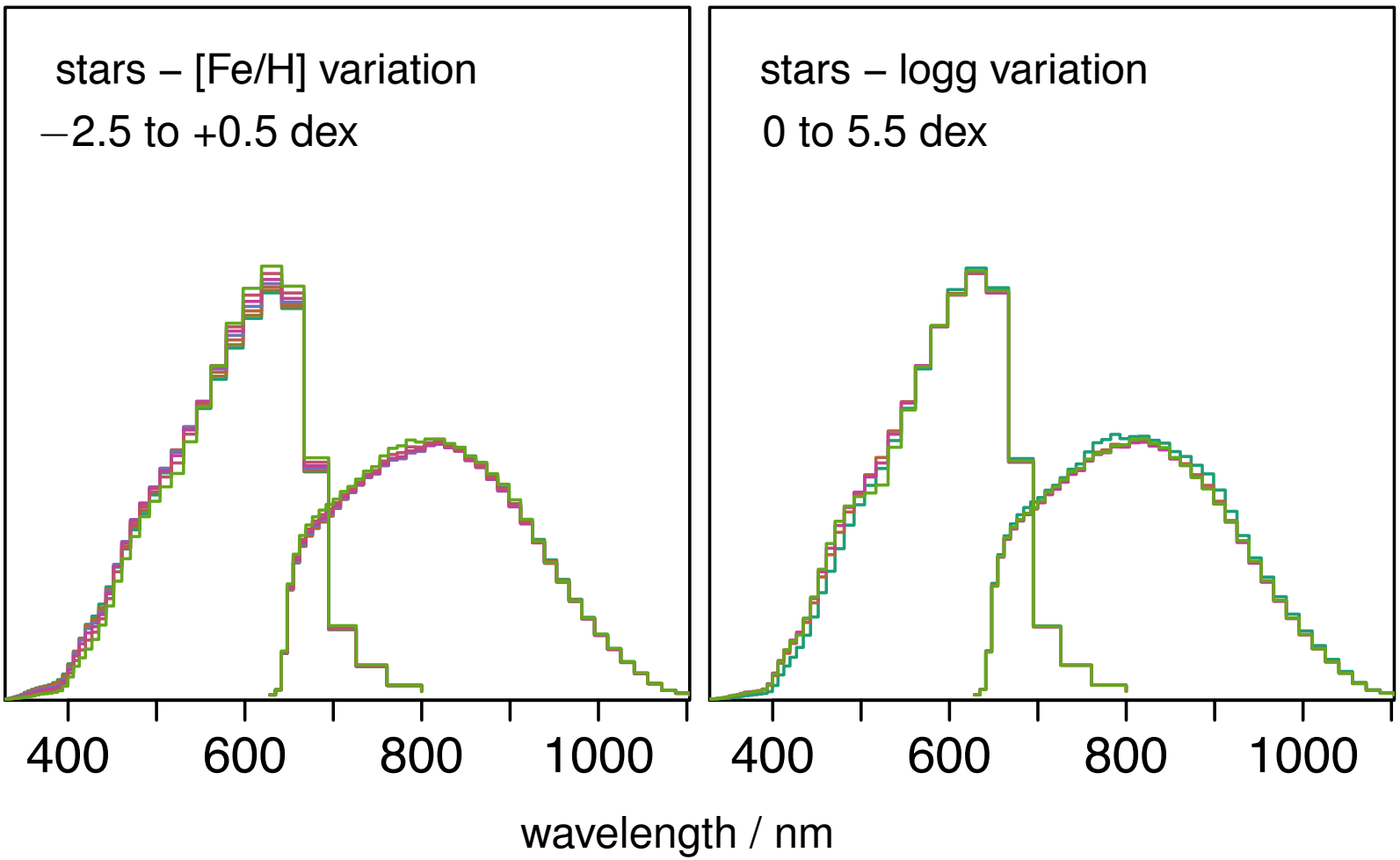


Simulated spectrophotometry (BP/RP)



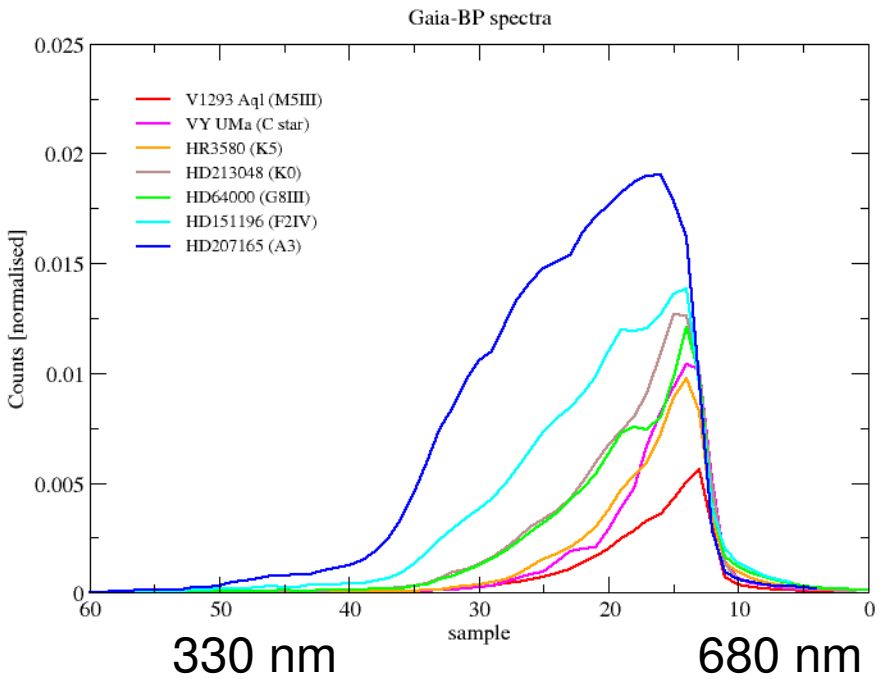
Bailer-Jones et al. (2013)

Simulated spectrophotometry (BP/RP)

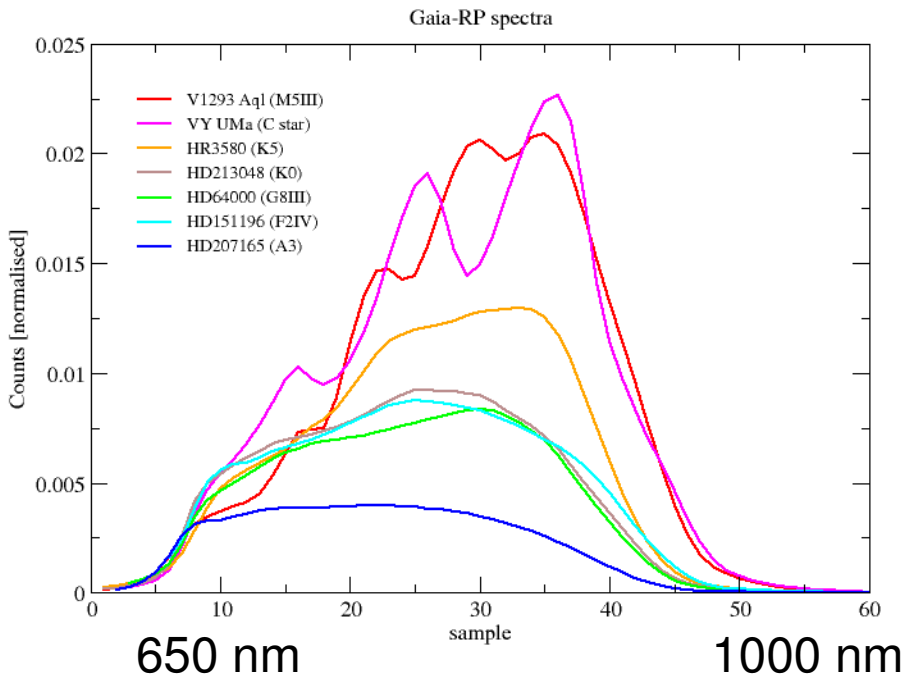


Bailer-Jones et al. (2013)

Observed uncalibrated BP/RP spectra



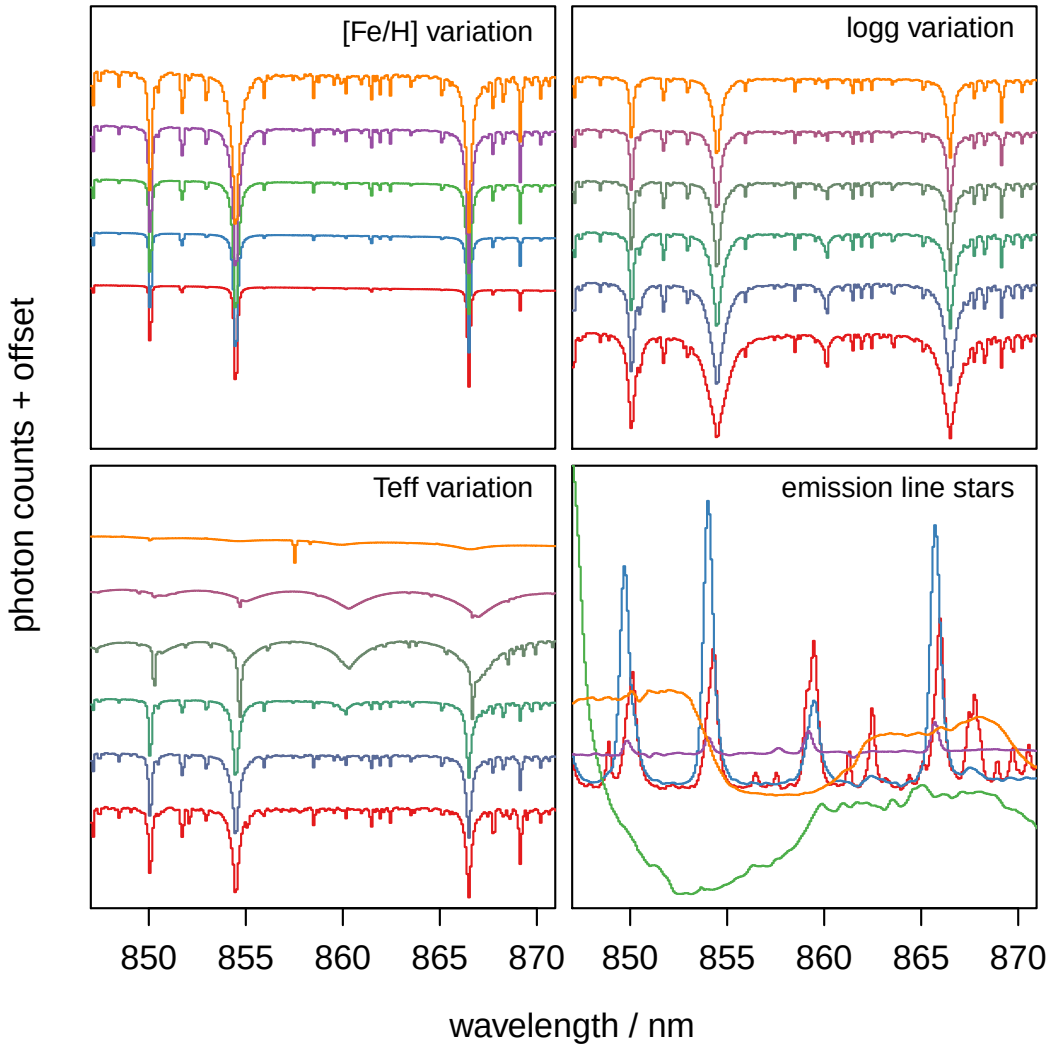
330 nm 680 nm



650 nm 1000 nm

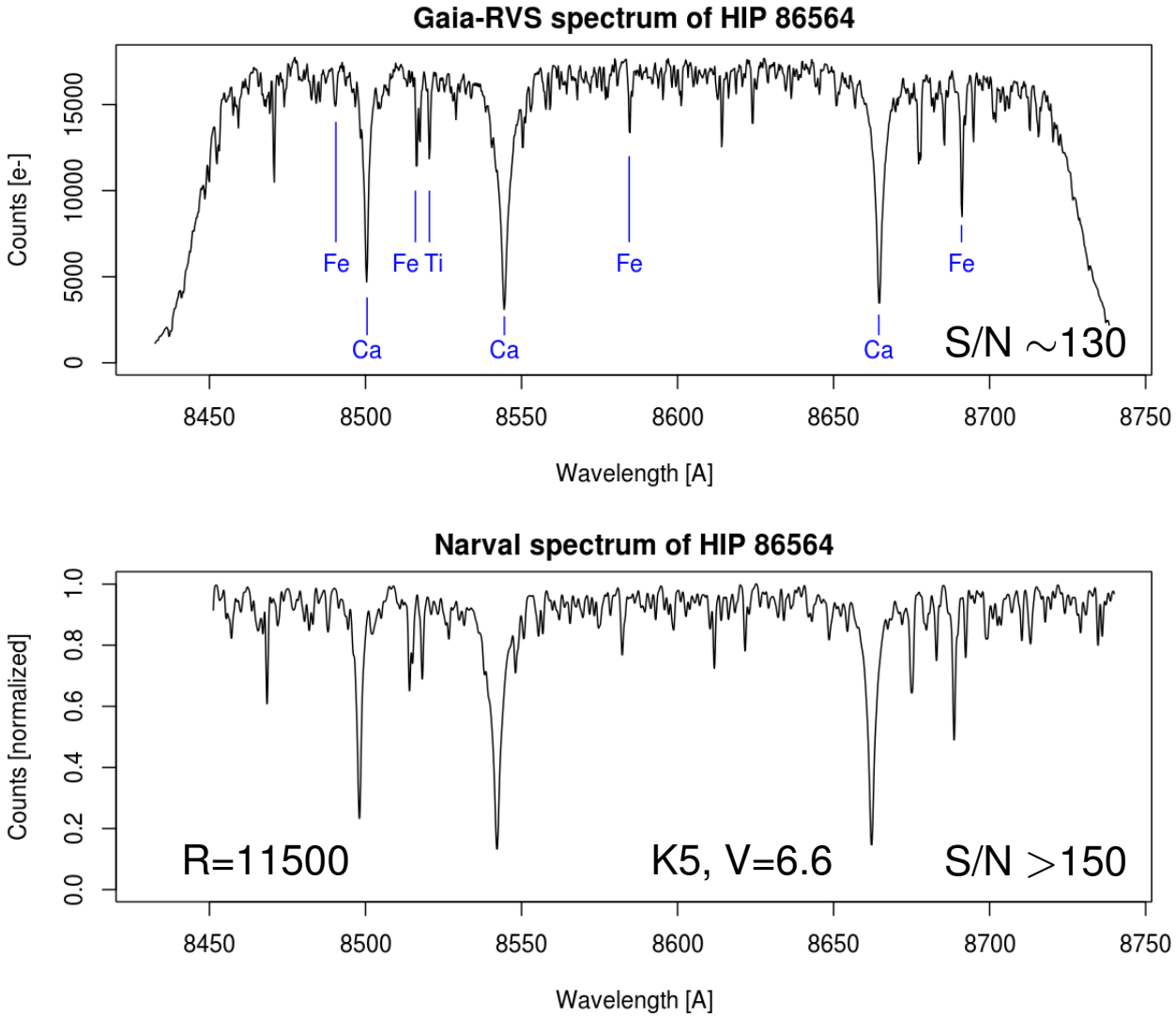
Graphics: ESA/DPAC/Astrium/ C. Jordi & J.-M. Carrasco

Simulated RVS spectra



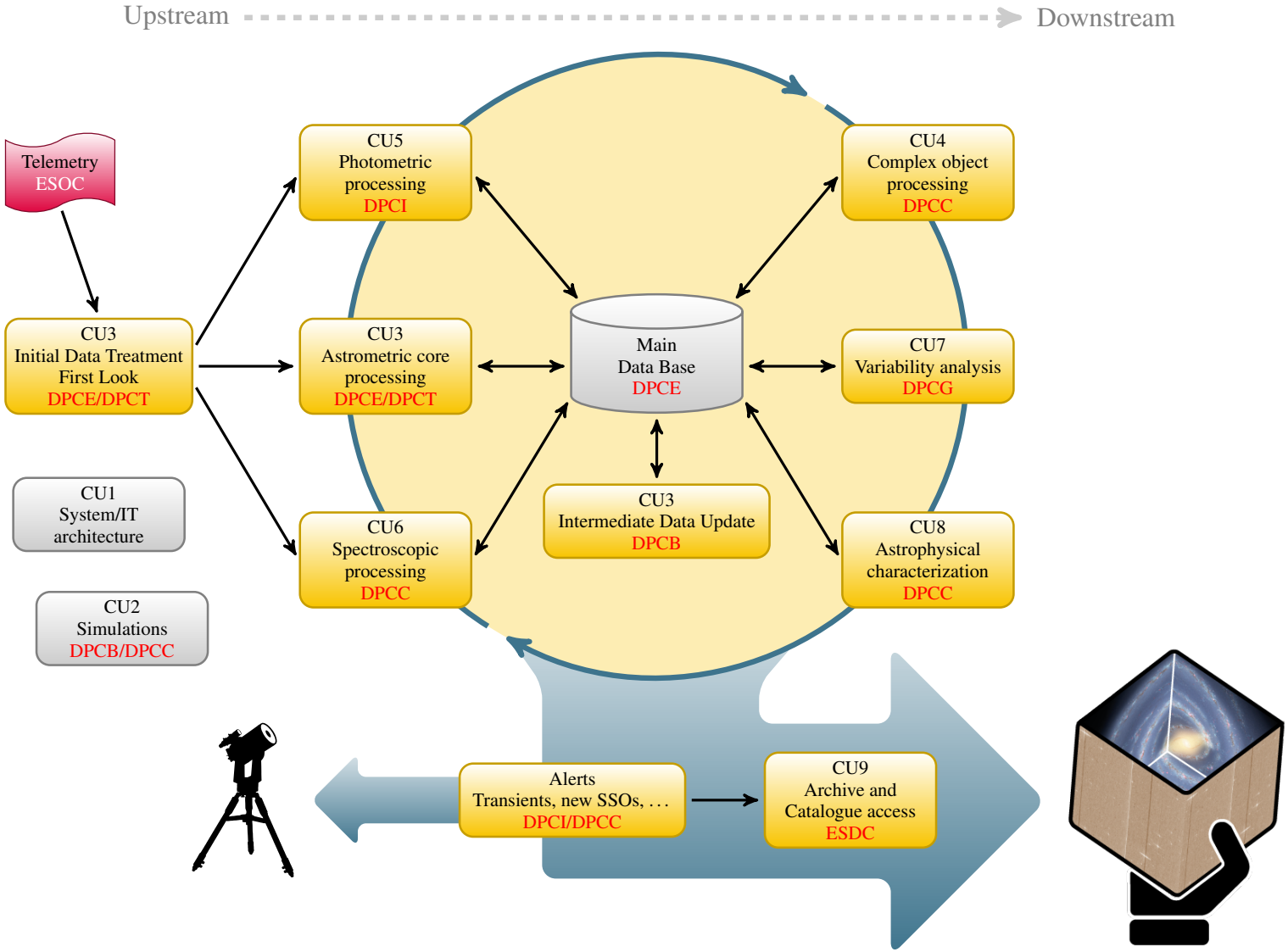
Bailer-Jones et al. (2013)

Observed early RVS spectrum

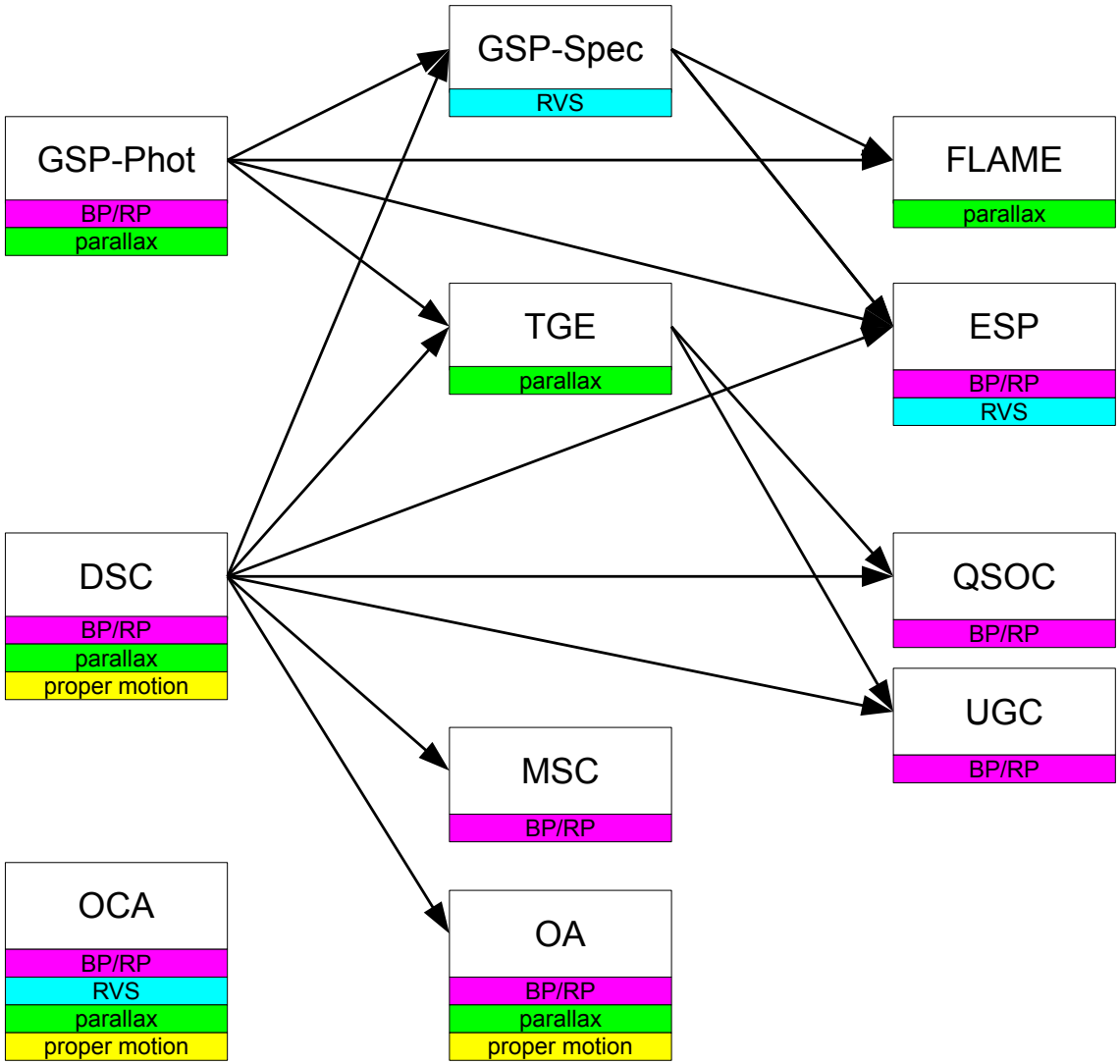


Graphics: ESA/DPAC/Astrium/ D. Katz, O. Marchal, C. Soubiran

Gaia DPAC data flow



APs inference system (Apsis) in Gaia



Acronym	Name
DSC	Discrete Source Classifier
GSP-Phot	Generalized Stellar Parametrizer – Photometry
GSP-Spec	Generalized Stellar Parametrizer – Spectroscopy
TGE	Total Galactic Extinction
MSC	Multiple Star Classifier
OA	Outlier Analysis
FLAME	Final Luminosity Age and Mass Estimator
ESP	Extended Stellar Parametrizer:
-CS	ESP – Cool Stars
-ELS	ESP – Emission Line Stars
-HS	ESP – Hot Stars
-UCD	ESP – Ultra Cool Dwarfs
QSOC	Quasar Classifier
UGC	Unresolved Galaxy Classifier
OCA	Object Clustering Algorithm

Bailer-Jones et al. (2013)

Discrete Source Classifier – preliminary performance

Bailer-Jones et al. (2013), Table 3

	DSC output class [%]				
Library	Star	WD	Binary	Quasar	Galaxy
Phoenix	92	–	7	–	1
Phoenix–R_0	90	3	7	–	–
A stars	80	–	20	–	0.1
OB stars	95	1	4	–	–
WD	17	79	4	–	–
UCDs	97	–	1	2	–
Binary stars	18	–	82	–	–
SDSS stars	94	–	6	–	–
SDSS quasars	6	3	0.1	78	13
SDSS galaxies	2	–	0.5	–	98

rows are true classes (spectral libraries)
dash means exactly zero

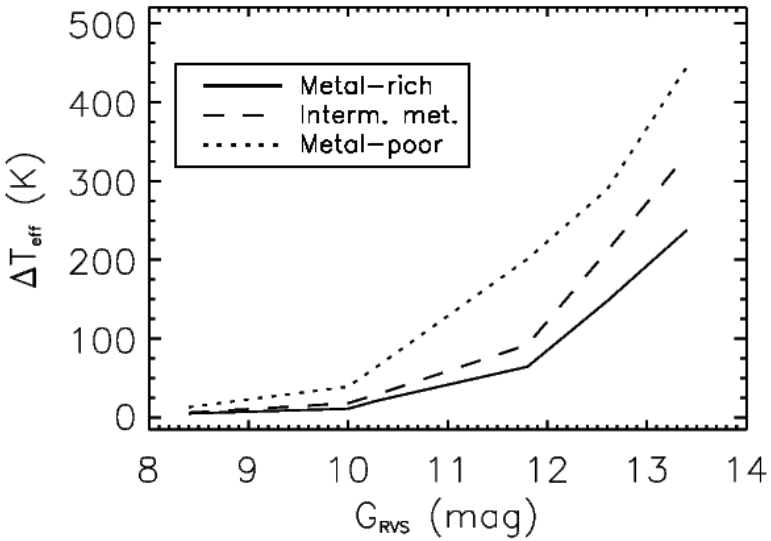
GSP-Phot/Aeneas algorithm – preliminary performance

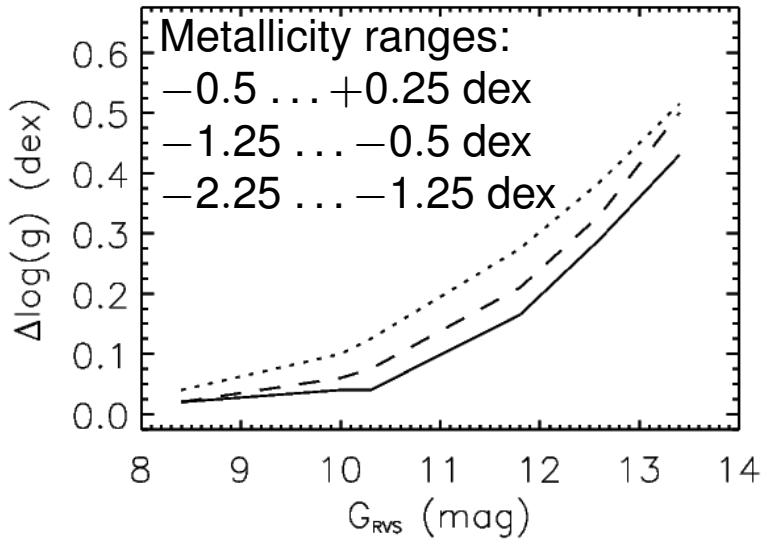
- is a function of true parameters, magnitude, number of observations
- internal RMS residuals for FGKM stars (wide range of other APs), using BP/RP and parallaxes

Bailer-Jones et al. (2013), Table 4

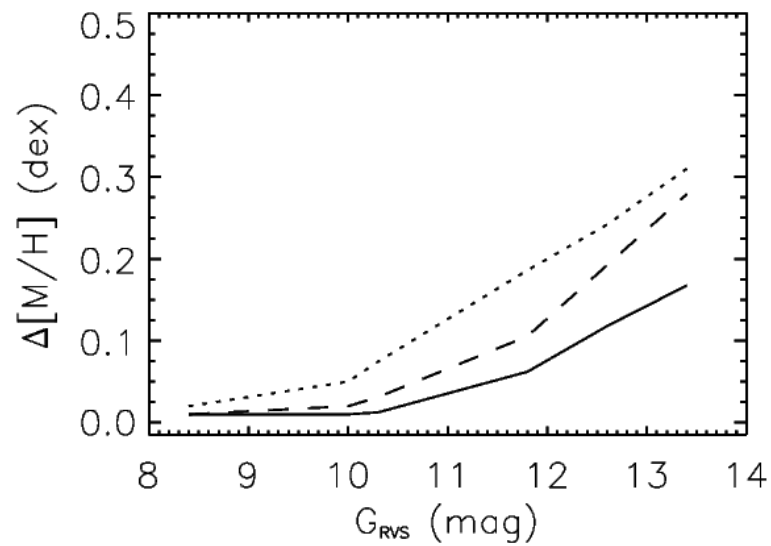
AP	G=15	G=19
$T_{\rm eff}$/ K	70 – 170	90 – 630
A_0/mag	$\sim$0.1	0.1 – 0.4
[Fe/H]/ dex	0.2 – 0.3	0.3 – 0.7
log g/ dex	0.2 – 0.4	0.2 – 0.5

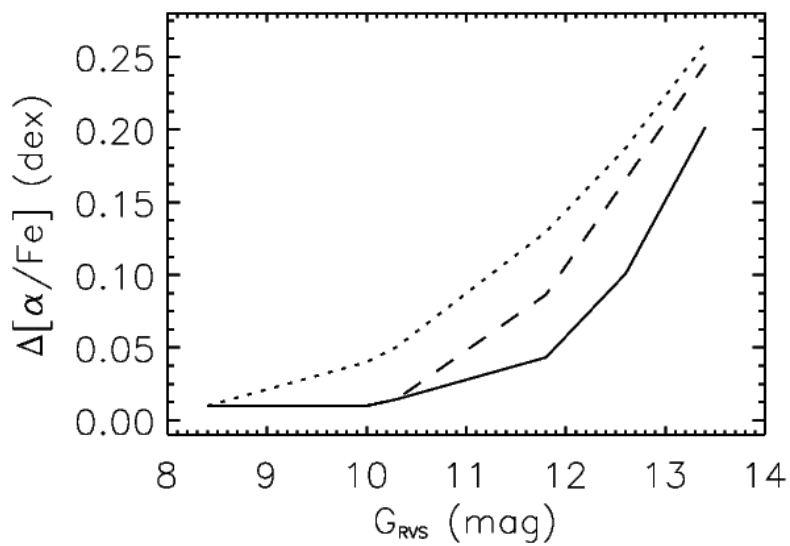
GSP-Spec – expected performance for K giants





68% quantile of residuals





Recio-Blanco et al. (2016)

GSP-Spec – expected performance for late-type stars

- internal precision based on simulations with $R = 11200$
- surface gravity is most difficult to estimate, but dwarfs and giants will be distinguishable at all magnitudes
- stars brighter than $G_{\rm RVS} \sim 12.5$ (S/N$= 20$) will be well parametrized, including good estimations of [α/Fe]
- individual chemical abundances for stars with $G_{\rm RVS} \lesssim 12$ (S/N$\gtrsim 35$) to $\sim$0.1 dex
- faintest stars will be better parametrized by GSP-Phot

Ongoing developments: validation and calibration

- **Validation**
  - *Purpose*:
    to verify accurate calibration of upstream data products and to recognise problems in software/models
  - *Procedure*:
    internal – distribution and correlation of APs and comparison between different Apsis modules,
    external – comparison of APs with non-Gaia estimates
- **Calibration**
  - *Purpose*:
    to account for mismatch between models and reality and to put Apsis stellar APs onto “useful” system
  - *Procedure*:
    either ***data-side calibration*** – modify input synthetic grids,
    or ***AP-side calibration*** – correct output APs,
    to give AP estimates consistent with calibration stars

APs in the Gaia data releases

- **Gaia-DR1** (end of summer 2016): nothing planned
- **Gaia-DR2** (end of summer 2017):
  $T_{\rm eff}$, and maybe A_0, L, R for *TGAS stars*;
  based on integrated BP/RP from Gaia-DR1
- **Gaia-DR3** (2018?):
  main APs based on BP/RP and RVS;
  BP/RP and RVS data
- **Gaia-DR4** (2019?):
  as Gaia-DR3 but with improved precision and calibration;
  more detailed APs
- **Final release** ($\sim$2022): improvement of all data products;
  ground-based auxiliary data

Stellar APs in final Gaia catalogue

- class probabilities (single star, binary, WD, etc.)
- $T_{\rm eff}$, A_0, $\log g$, [Fe/H], [α/Fe], (R_0, abundances)
  - use of parallax and priors (e.g. HRD) in some cases
  - multiple sets of estimates (different methods, data, libraries)
  - derived luminosity, mass, radius, age (variable precision)
  - uncertainty estimates, posterior PDF in some cases
- additional AP estimates
  - emission line star classes
  - rotation and activity indicators for cool stars
  - refined APs for hot stars and ultra cool dwarfs
  - brightness ratio for binaries

Summary

- The Gaia catalogue will contain
  - discrete classifications
  - star, galaxy, quasar parameters
  - novelty detection, 2D extinction map
  - multiple parameter estimates:
    different methods/data/libraries
- Large numbers of objects with APs of variable precision
  - 10^9 objects with $G < 20$ from low res. spectrophotometry over 330–1050 nm
  - 10^7 stars with $G_{\rm RVS} \lesssim 12.5$ from high res. spectroscopy over 847–871 nm
  - performance overview:
    `http://www.cosmos.esa.int/web/gaia/science-performance`