

# Stellar parameters from Gaia

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25 May 2016



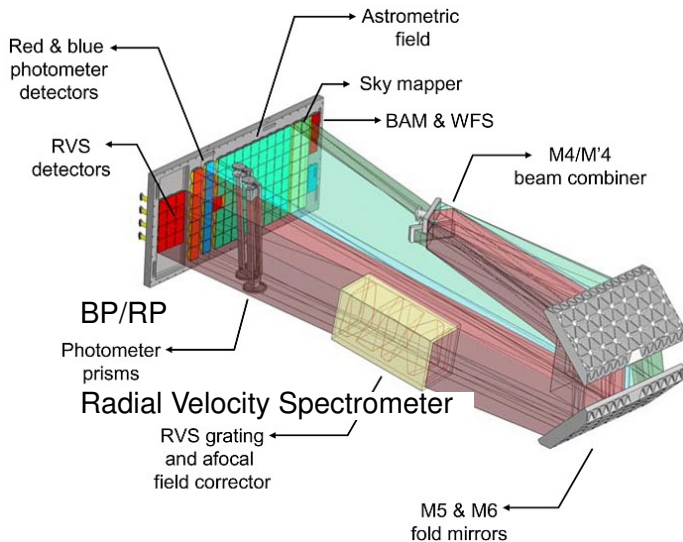
# Outline

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

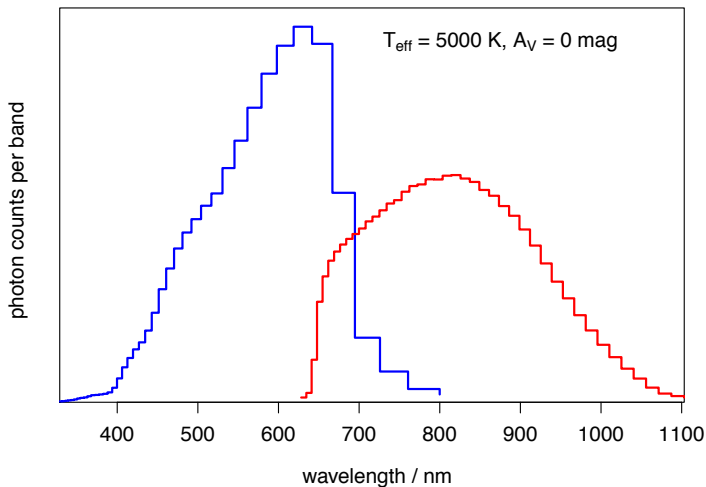
# Classification and parameters from Gaia data

- ▶ 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

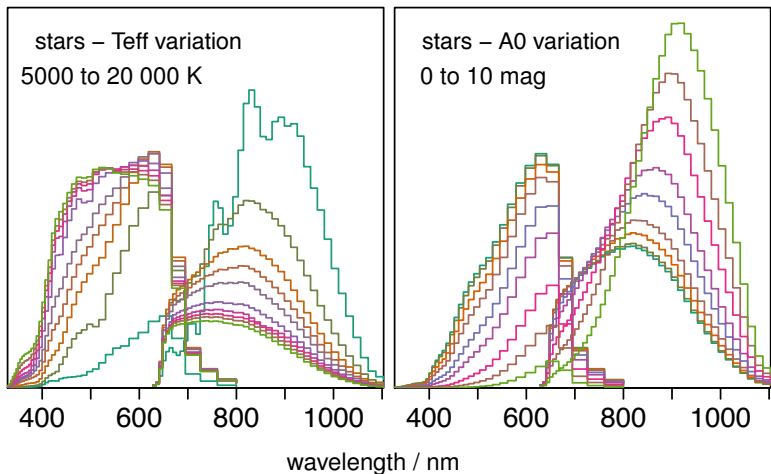
# Gaia spectroscopy



# Simulated spectrophotometry (BP/RP)

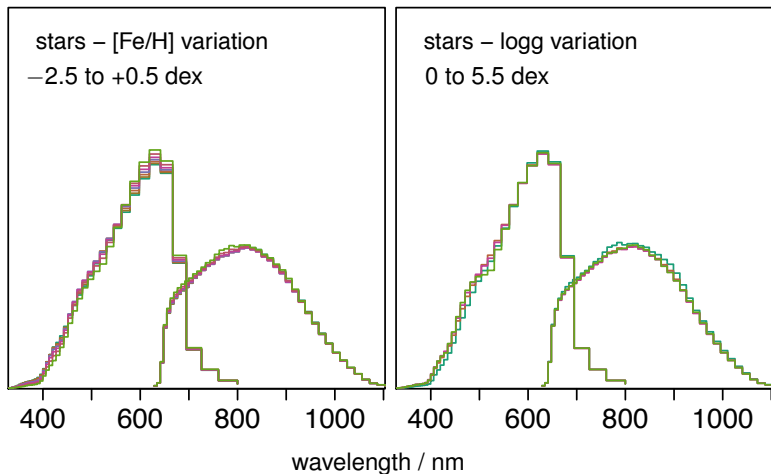


# Simulated spectrophotometry (BP/RP)



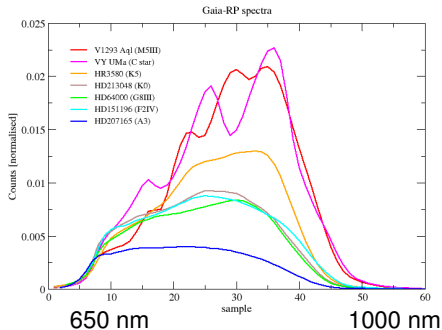
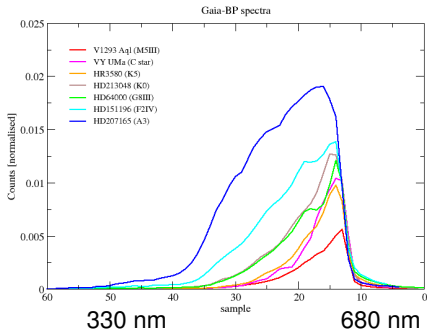
Bailer-Jones et al. (2013)

# Simulated spectrophotometry (BP/RP)



Bailer-Jones et al. (2013)

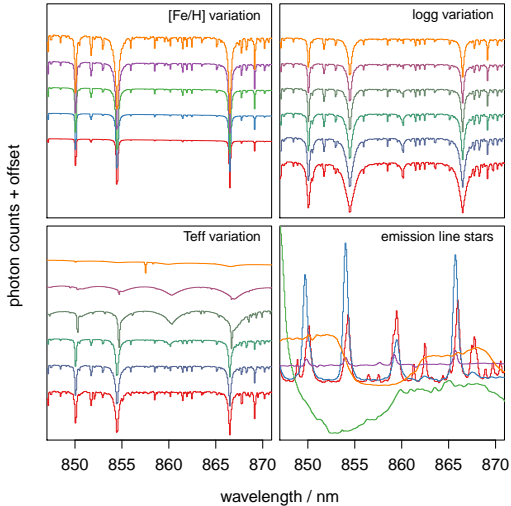
# Observed uncalibrated BP/RP spectra



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

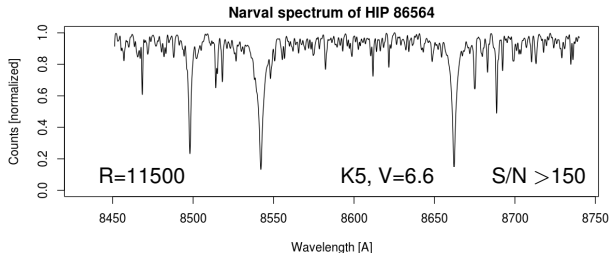
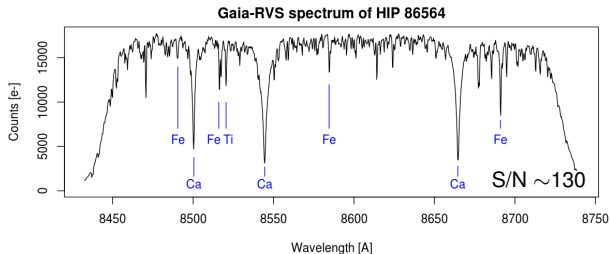


# Simulated RVS spectra



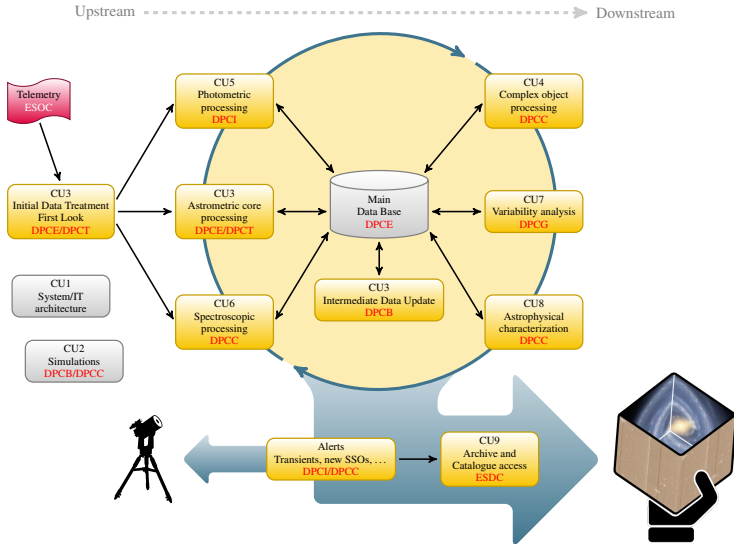
Bailer-Jones et al. (2013)

# Observed early RVS spectrum

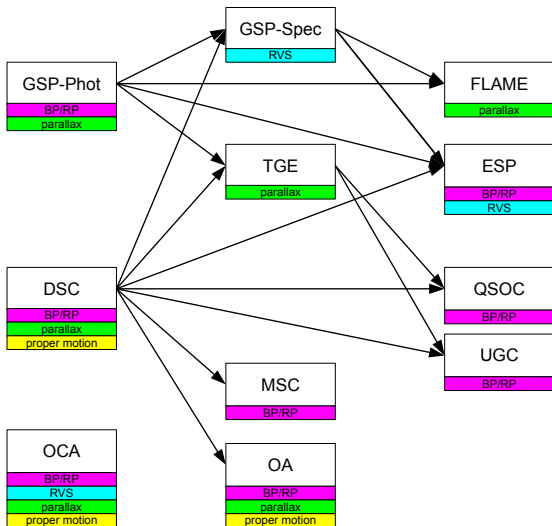


Graphics: ESA/DPAC/Astrium/ D. Katz, O. Marchal, C. Soubiran

# 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

# Discrete Source Classifier – preliminary performance

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

Library	DSC output class [%]				
	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

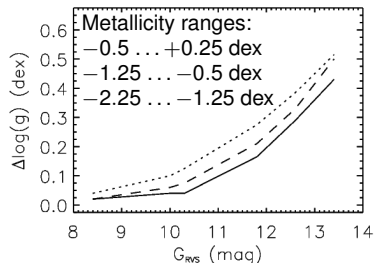
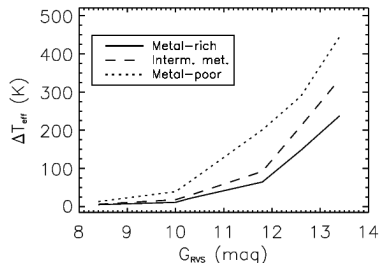
- ▶ is a function of true parameters, magnitude, number of observations
- ▶ internal RMS residuals for KM stars ( $\log g = 2.3 \dots 5.5$ ,  $[\text{Fe}/\text{H}] = -2.5 \dots +0.5$ ), using BP/RP and parallaxes

Bailer-Jones et al. (2013), Table 4			
	AP	G=9	G=15
$T_{\text{eff}}/\text{K}$		60 – 100	70 – 90
$A_0/mag$		$\sim 0.1$	$\sim 0.1$
$\log g/\text{dex}$		0.2 – 0.3	$\sim 0.3$
$[\text{Fe}/\text{H}]/\text{dex}$		$\sim 0.2$	0.2 – 0.3

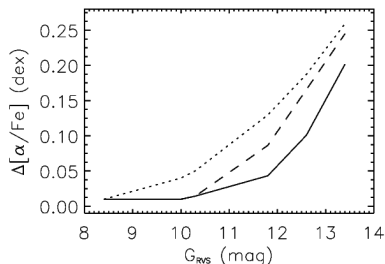
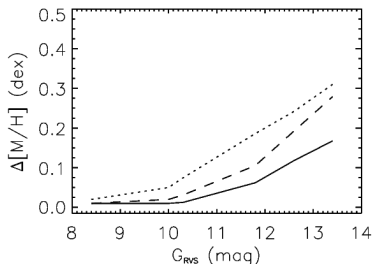
# GSP-Spec

- ▶ will parametrize several 10 million stars brighter than  $G_{\text{RVS}}=14$  ( $V \sim 15$ )
- ▶ will measure abundances of Fe, Ca, Mg, Ti, Si for a few million stars with  $G_{\text{RVS}} \lesssim 12$
- ▶ possible contribution to third Gaia data release (around 2018)
- ▶ three algorithms (optimization/projection/pattern recognition) with preferred applicability in different domains of stellar types and data quality

# GSP-Spec – expected performance for K giants

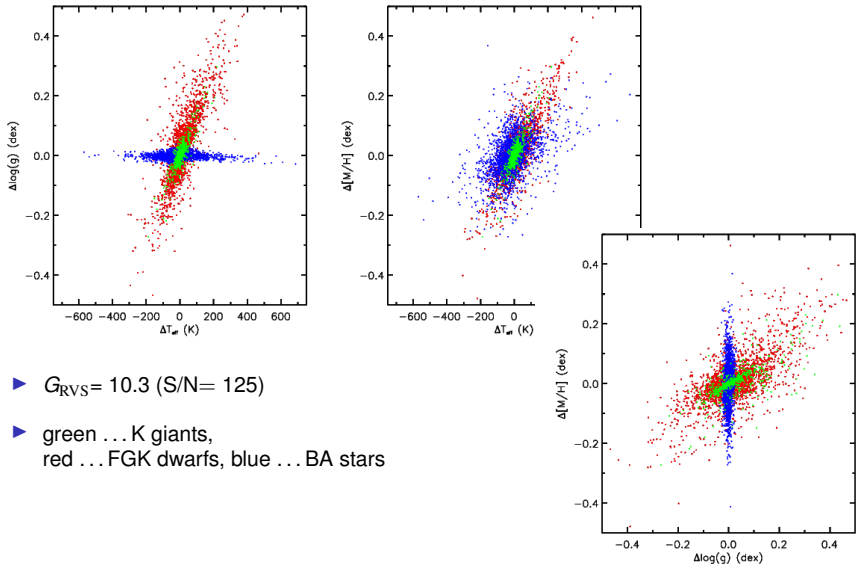


68% quantile of residuals





# GSP-Spec – correlations between residuals



- ▶  $G_{\text{RVS}} = 10.3$  (S/N= 125)
- ▶ green ... K giants,  
red ... FGK dwarfs, blue ... BA stars

## 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  $G_{\text{RVS}} \sim 12.5$  ( $S/N = 20$ ) will be well parametrized, including good estimations of  $[\alpha/\text{Fe}]$
- ▶ individual chemical abundances for stars with  $G_{\text{RVS}} \lesssim 12$  ( $S/N \gtrsim 35$ ) 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):  
 $T_{\text{eff}}$ , 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.)
- ▶  $T_{\text{eff}}$ ,  $A_0$ ,  $\log g$ ,  $[\text{Fe}/\text{H}]$ ,  $[\alpha/\text{Fe}]$ , ( $R_0$ , 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  $G_{\text{RVS}} \lesssim 12.5$  from high res. spectroscopy over 847–871 nm
  - **performance overview:**  
<http://www.cosmos.esa.int/web/gaia/science-performance>