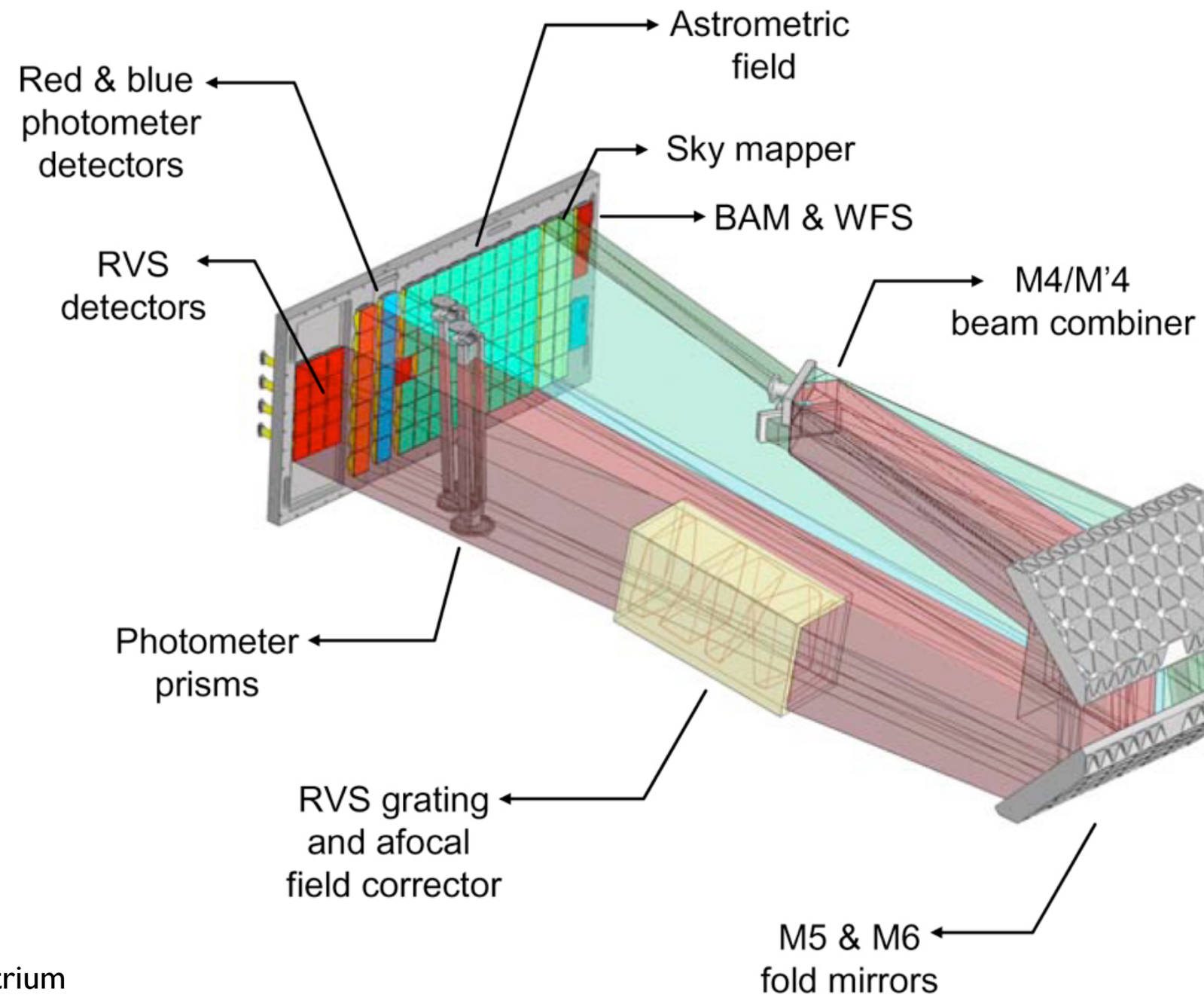
Stellar parameter estimation in the *Gaia Data Processing and Analysis Consortium*

Coryn Bailer-Jones (MPIA Heidelberg)
on behalf of DPAC Coordination Unit 8

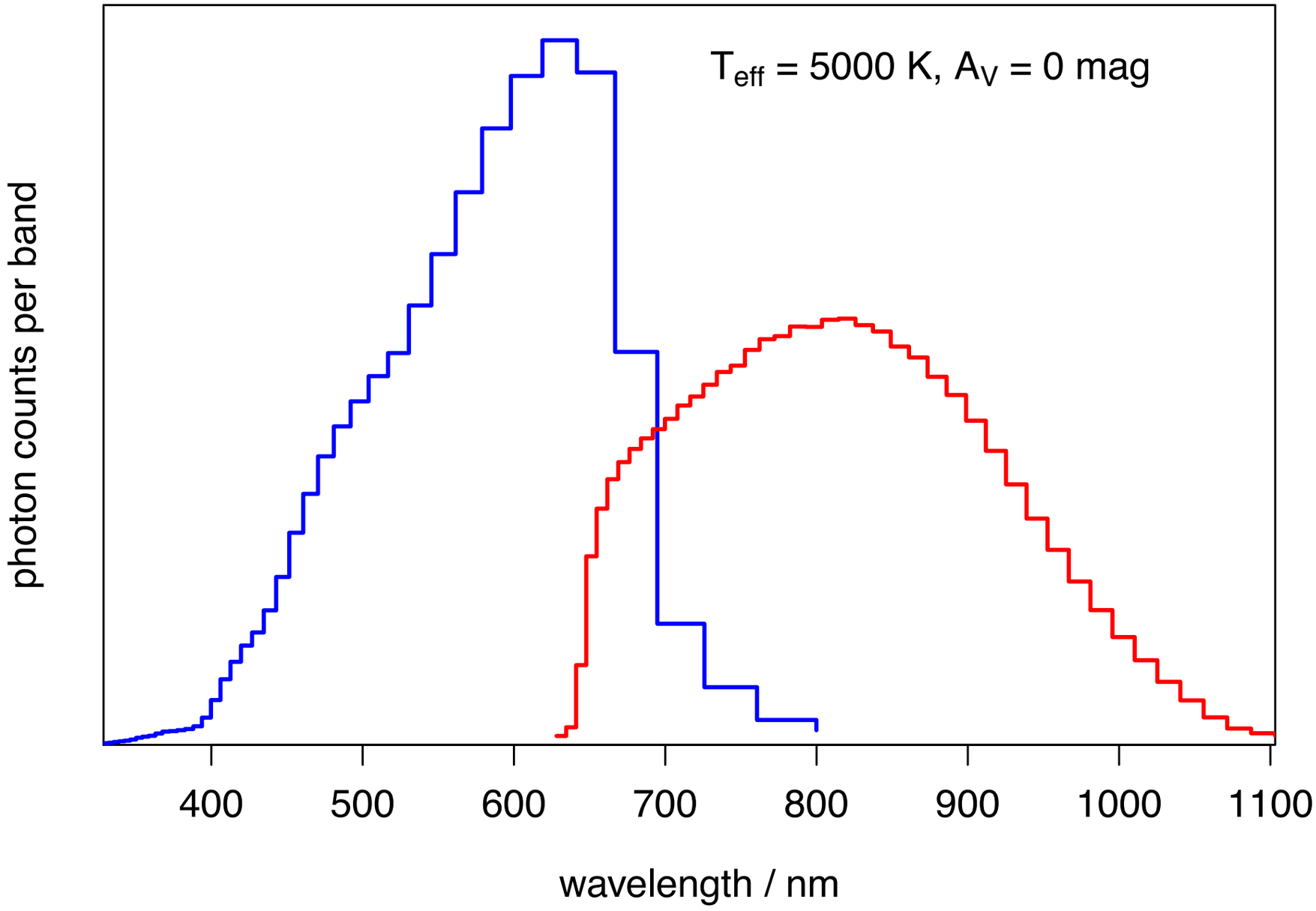
Stellar spectroscopy conference
MPIA April 2015

Gaia spectroscopy



Graphics: ESA, Astrium

Simulated spectrophotometry (BP/RP)



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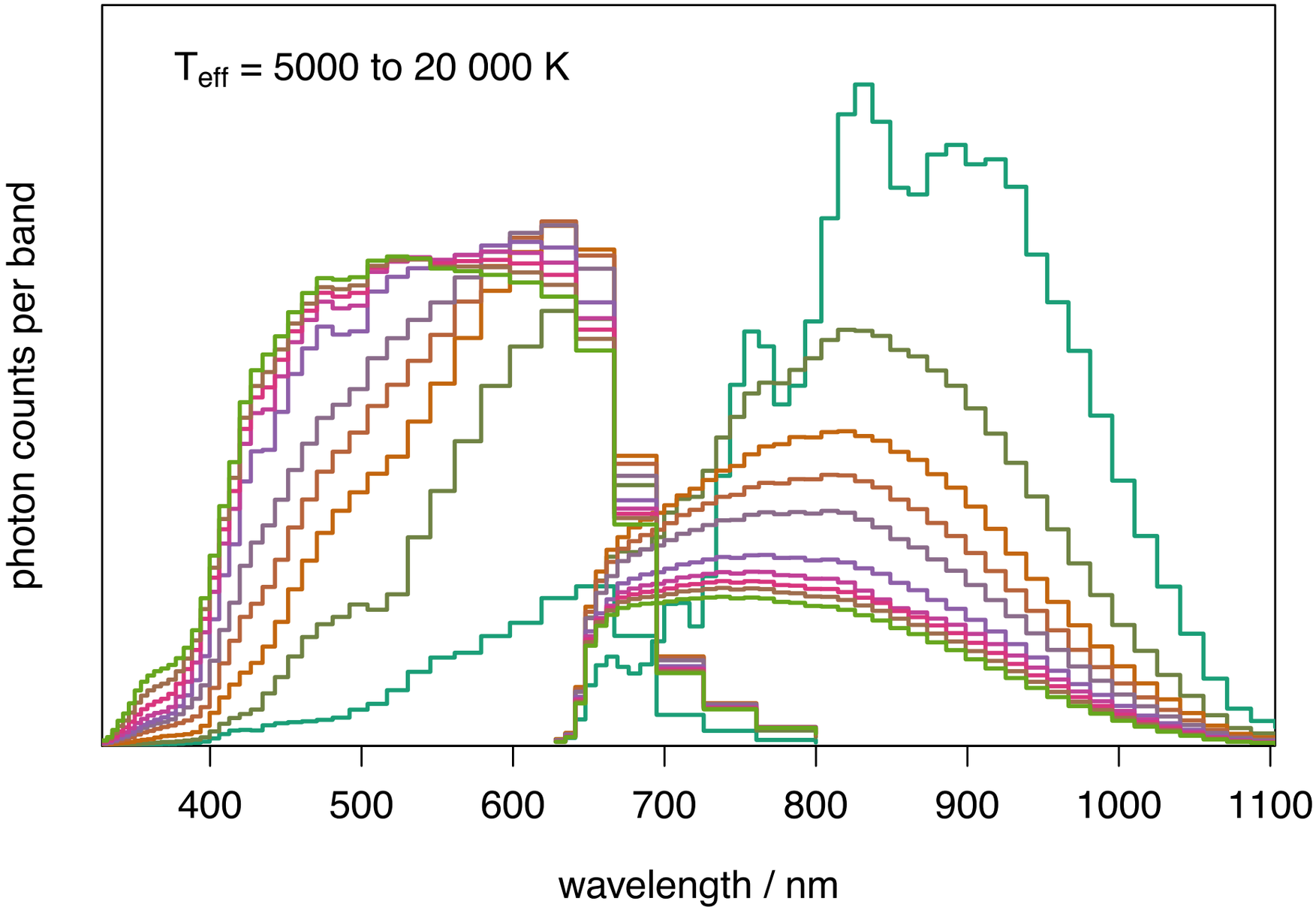
Simulated spectrophotometry (BP/RP)



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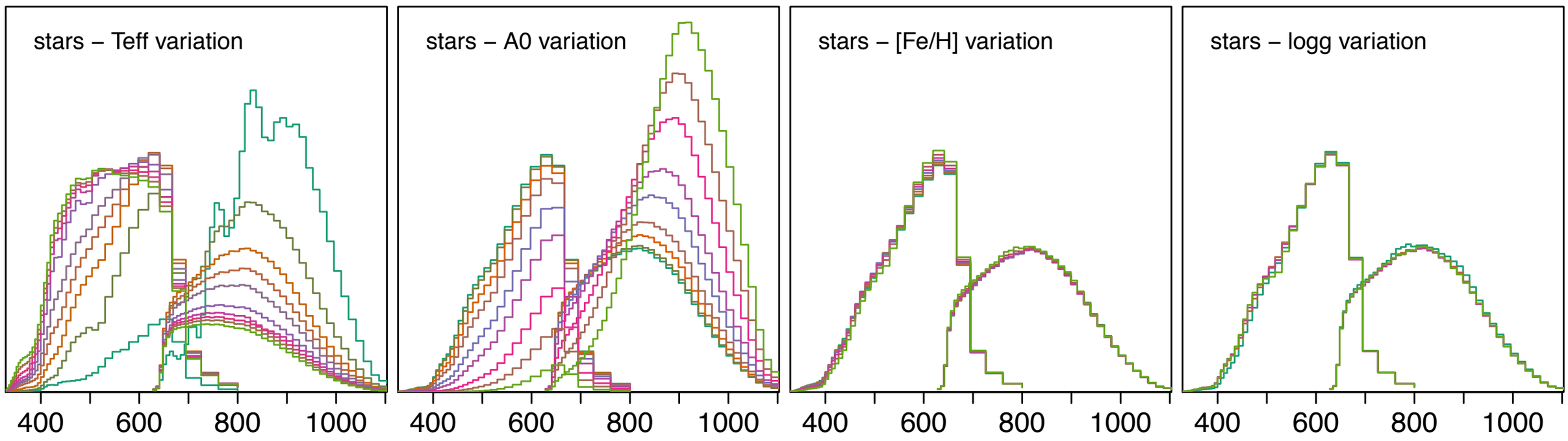
Simulated spectrophotometry (BP/RP)



5000 to 20 000 K | 0 to 10 mag | -2.5 to +0.5 dex | 0 to 5.5 dex

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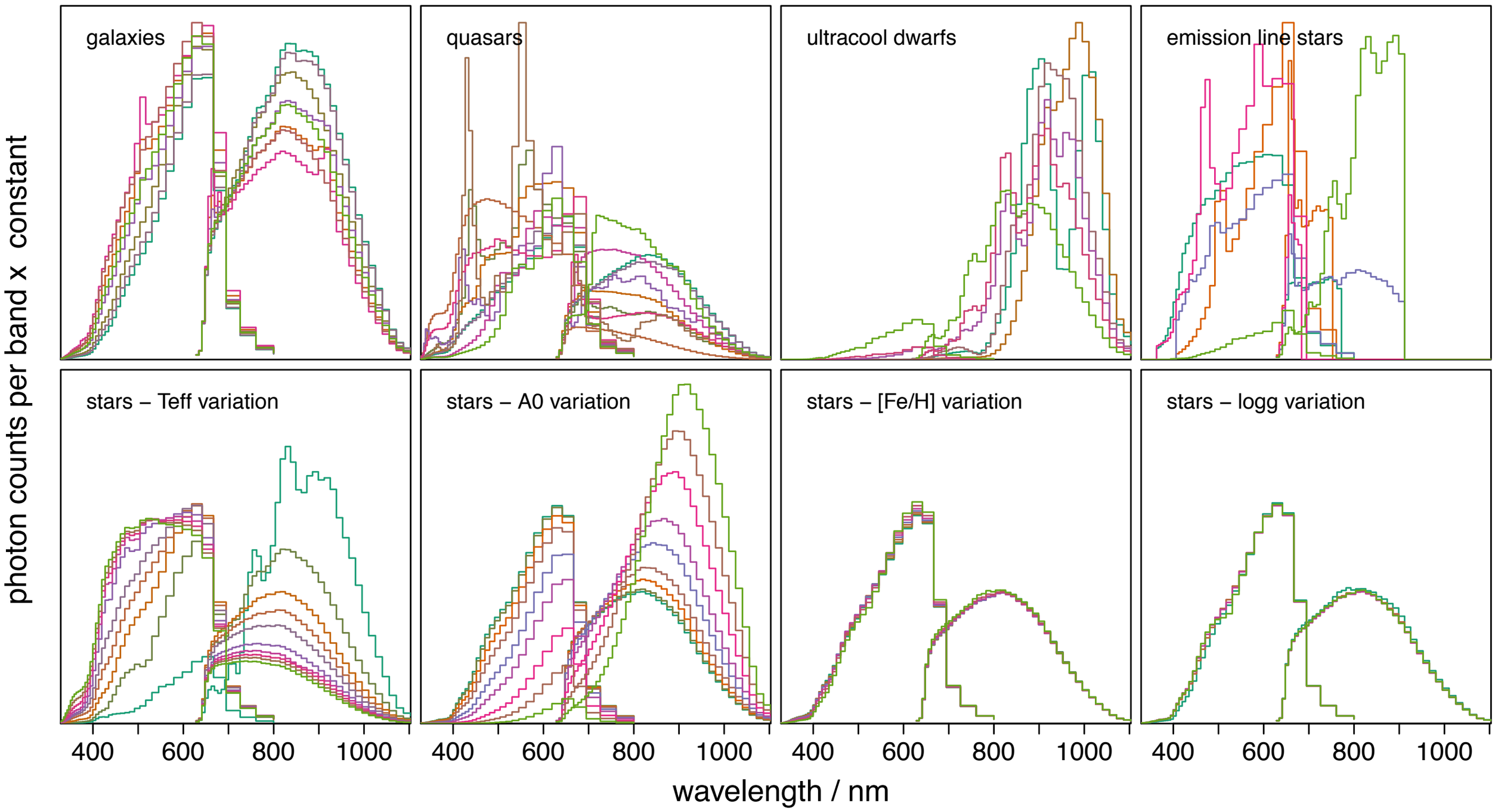
Simulated spectrophotometry (BP/RP)



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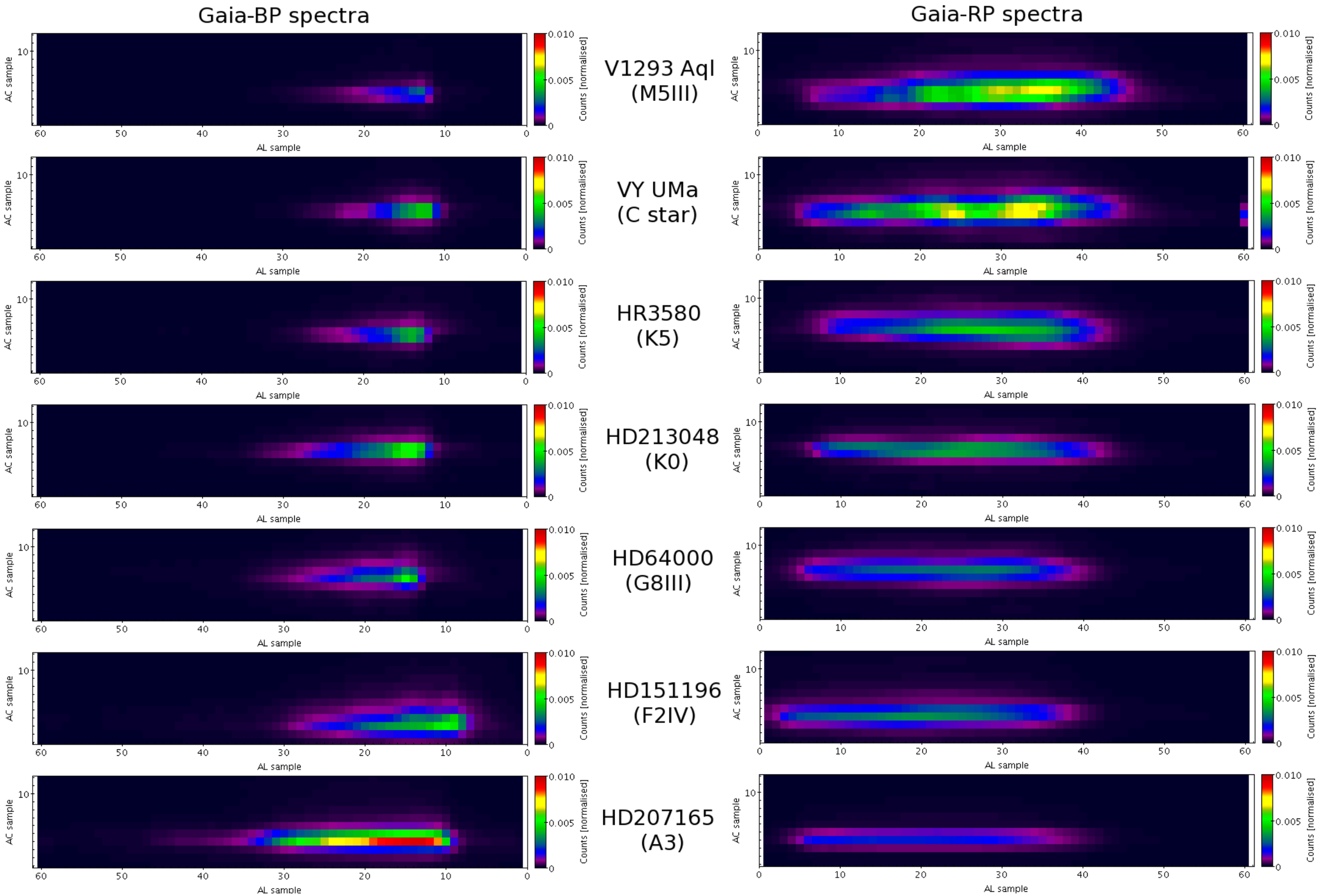
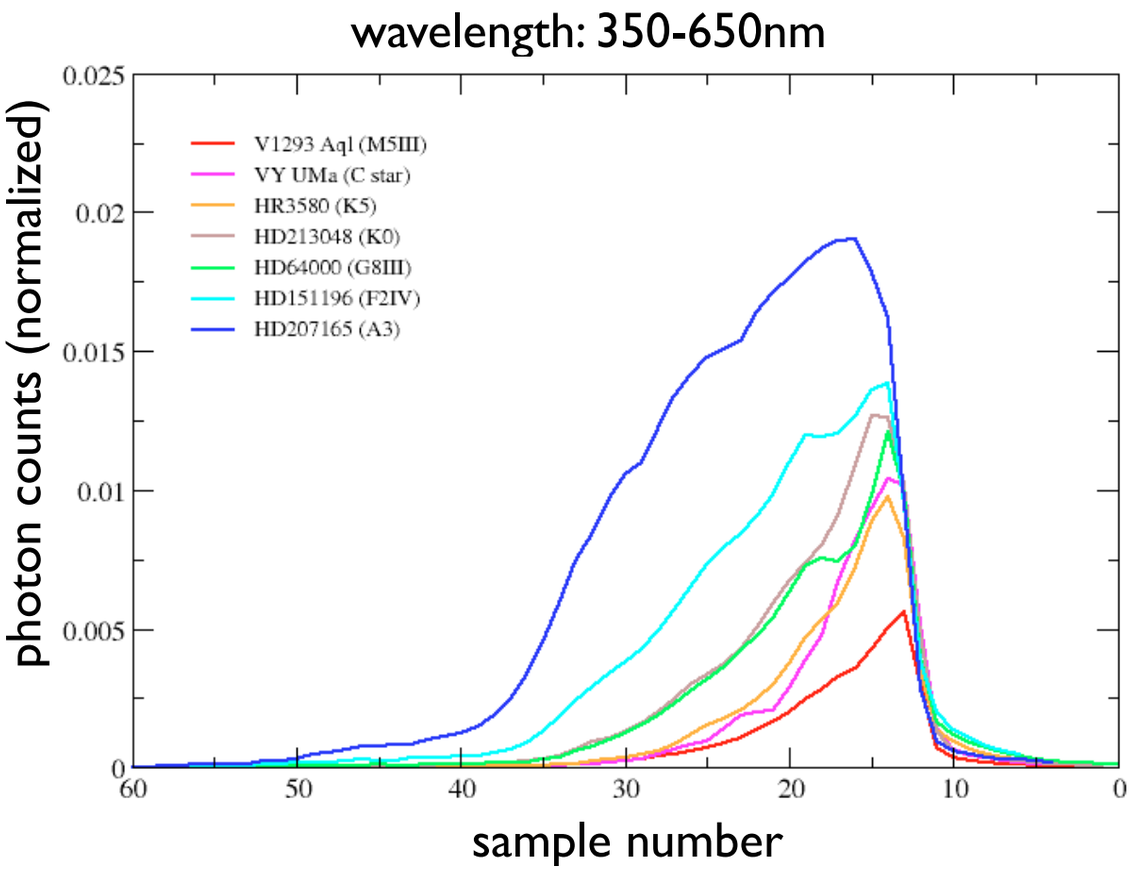
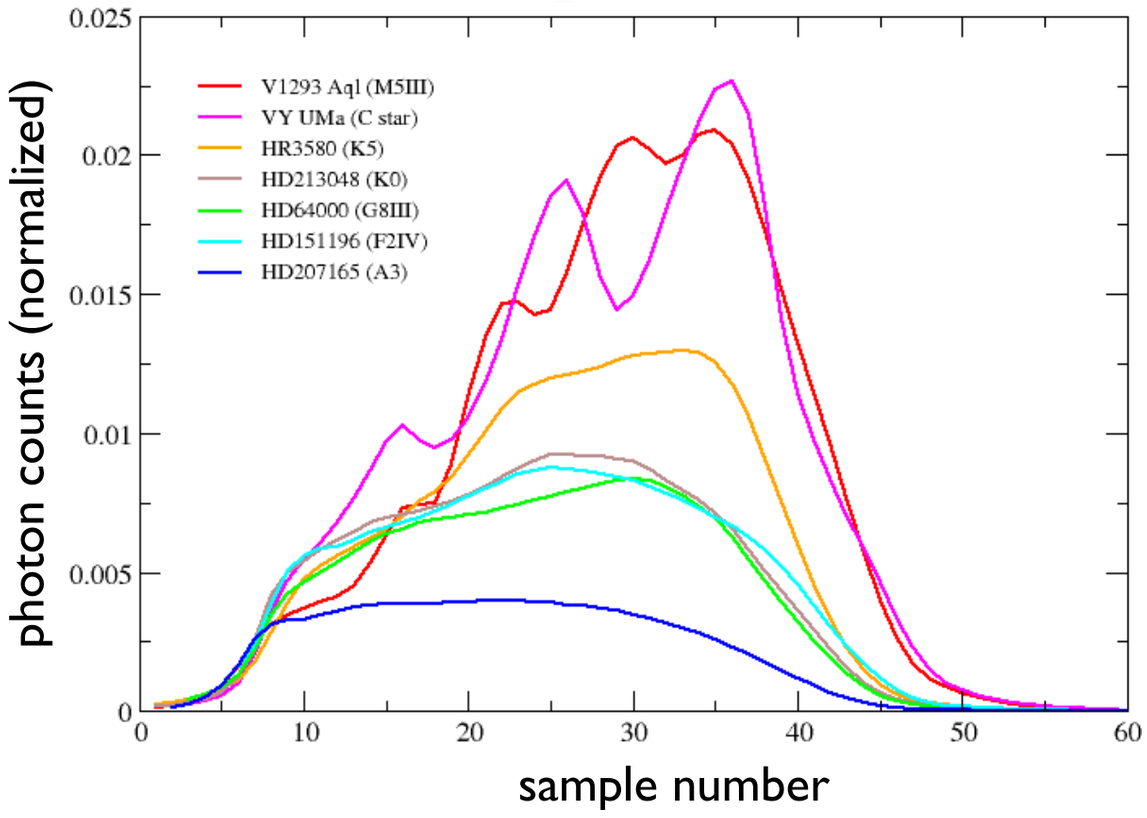
Observed uncalibrated BP/RP spectra



Graphics: ESA/DPAC/Astrium

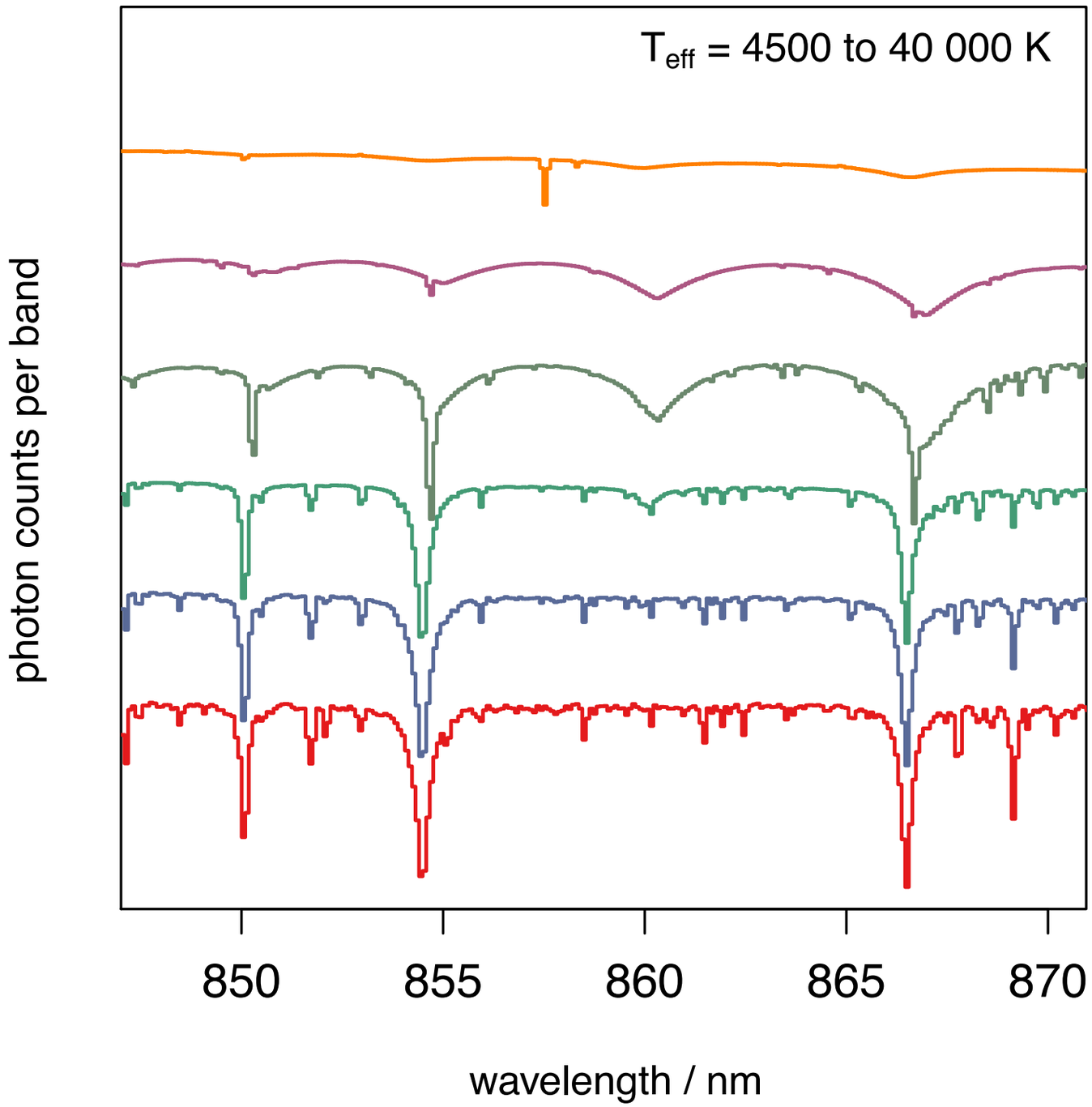
Observed uncalibrated BP/RP spectra





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

Simulated radial velocity spectra (RVS)



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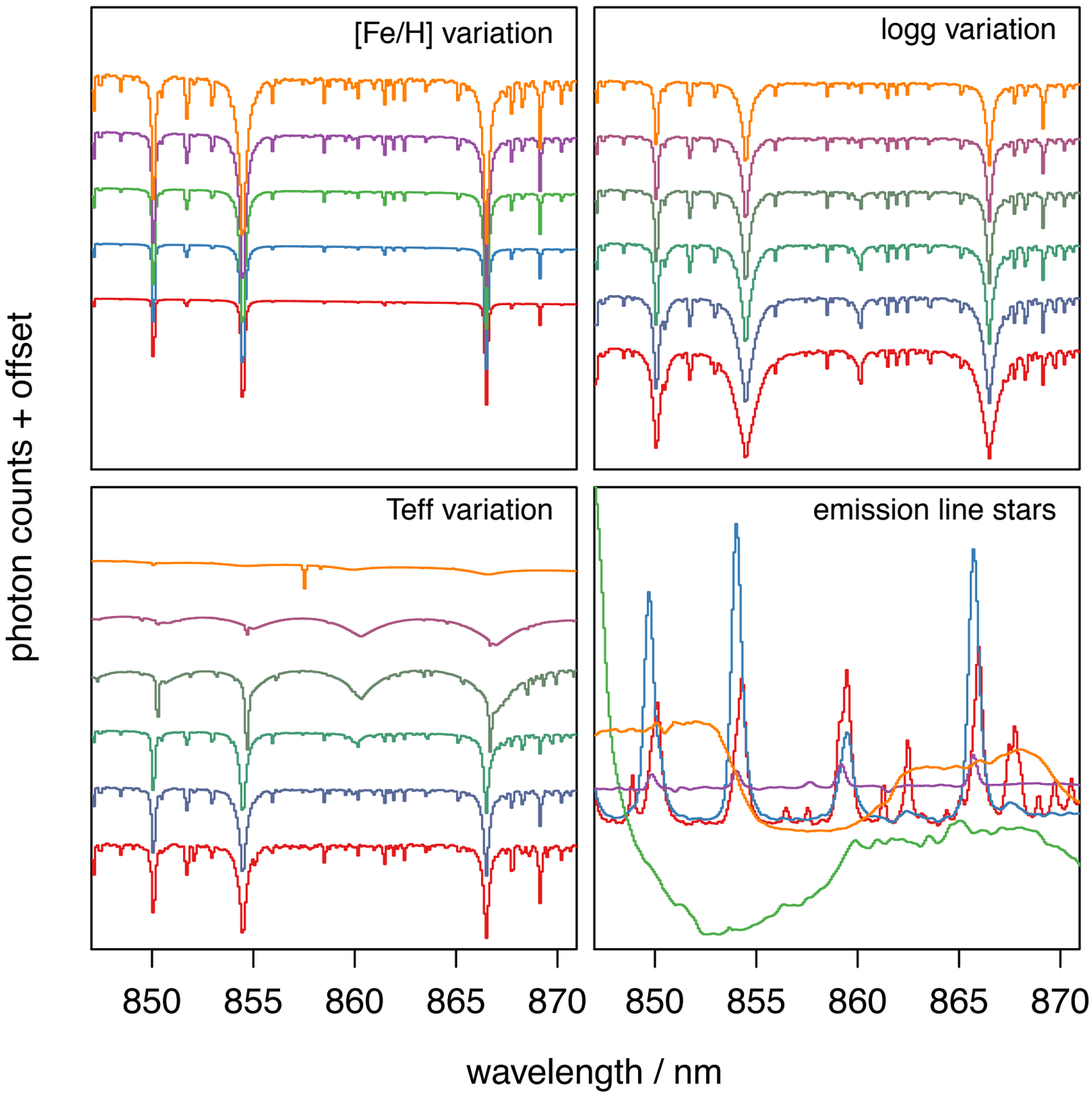
Simulated radial velocity spectra (RVS)



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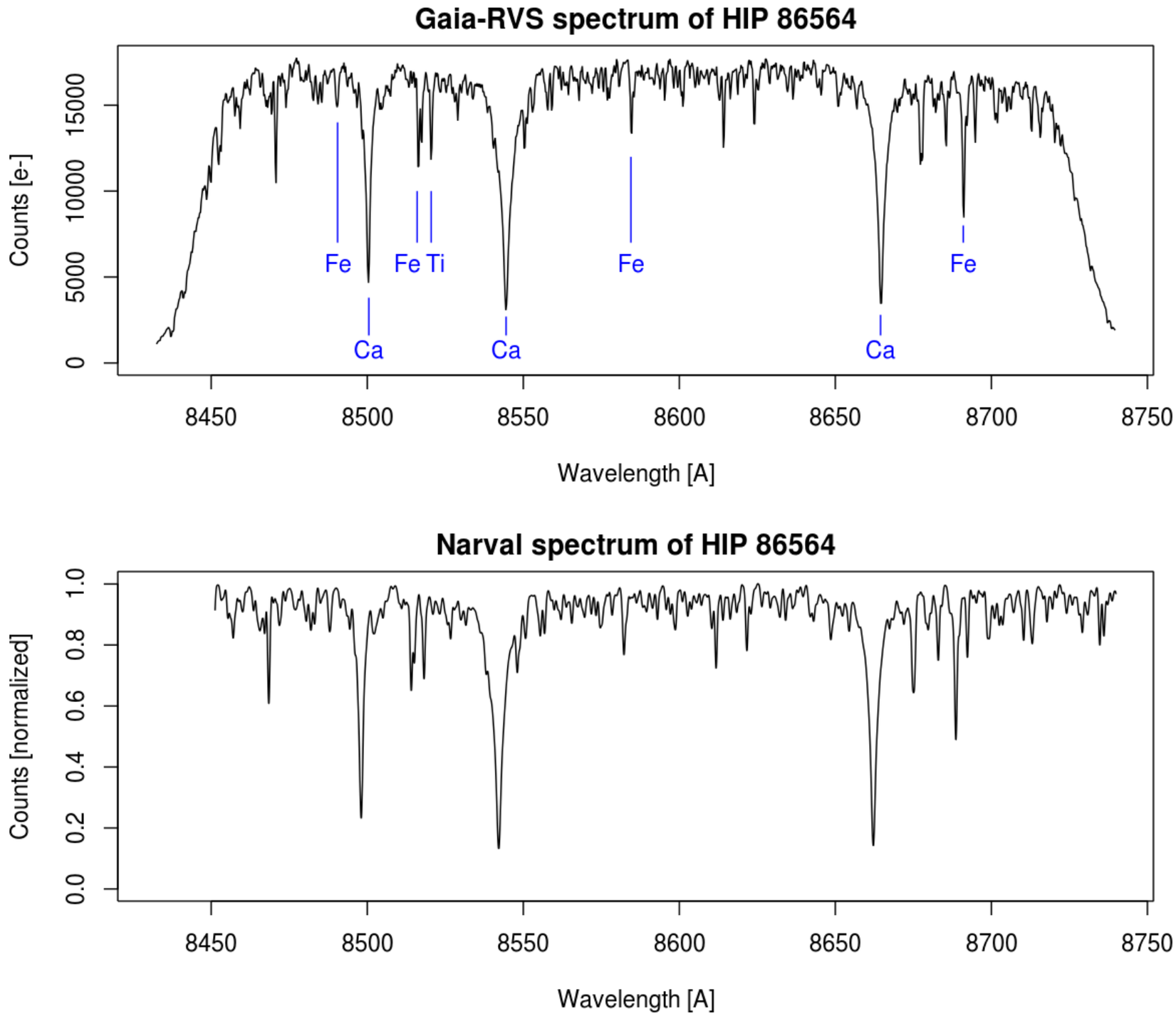
Observed early RVS spectrum



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

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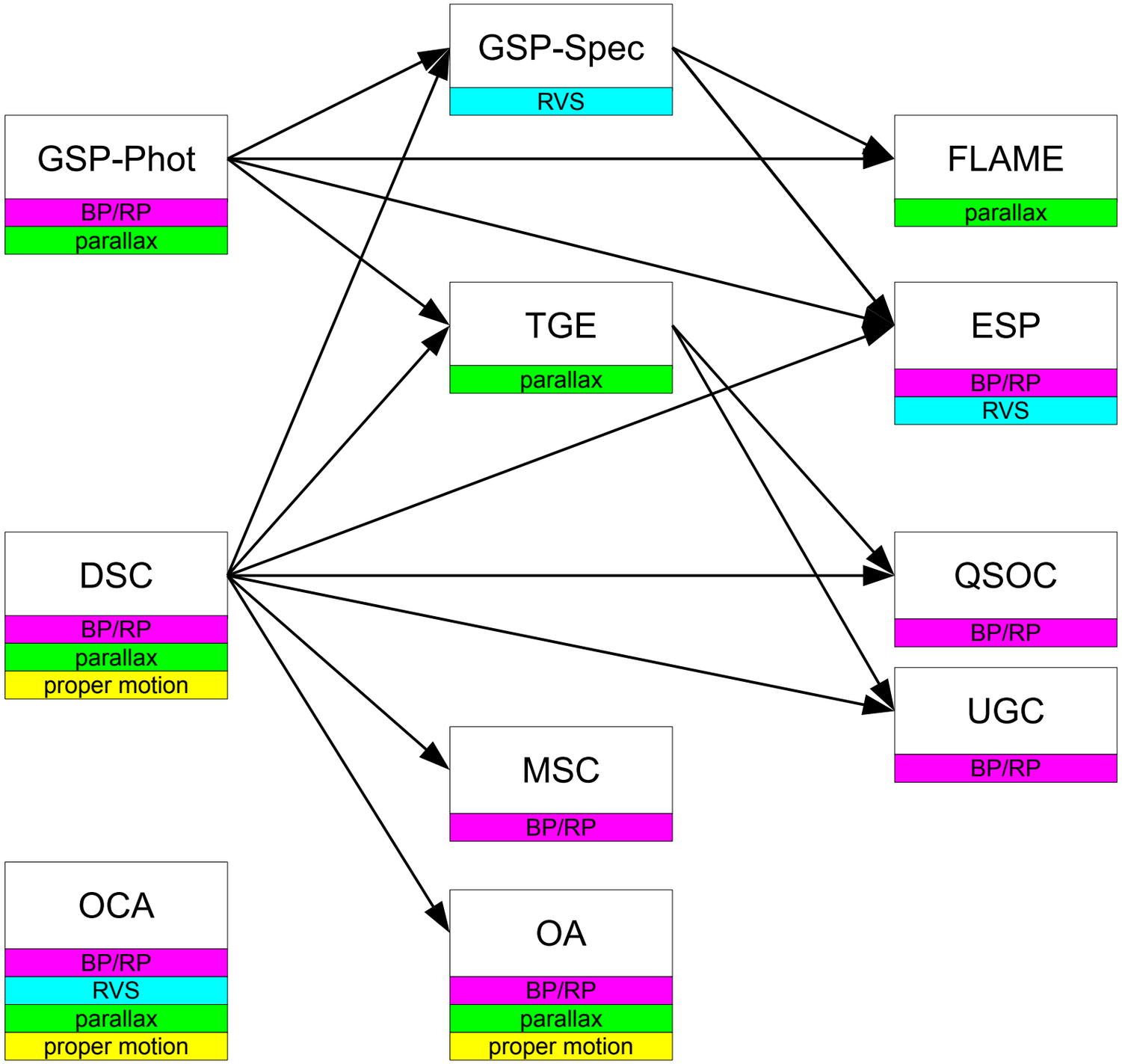
Classification and parameter estimation

- probabilistic source classification
  - classes: star, binary, quasar, galaxy, ...
  - data: BP/RP; photometry; position, parallax, proper motion
- astrophysical parameter (AP) estimation
  - for single and binary stars, quasars, and galaxies
  - data: BP/RP; RVS; parallax (for stars)
- use of various stellar libraries (plus calibration against standards)
- novelty detection (outlier analysis)

AP estimation system (*Apsis*) in Gaia

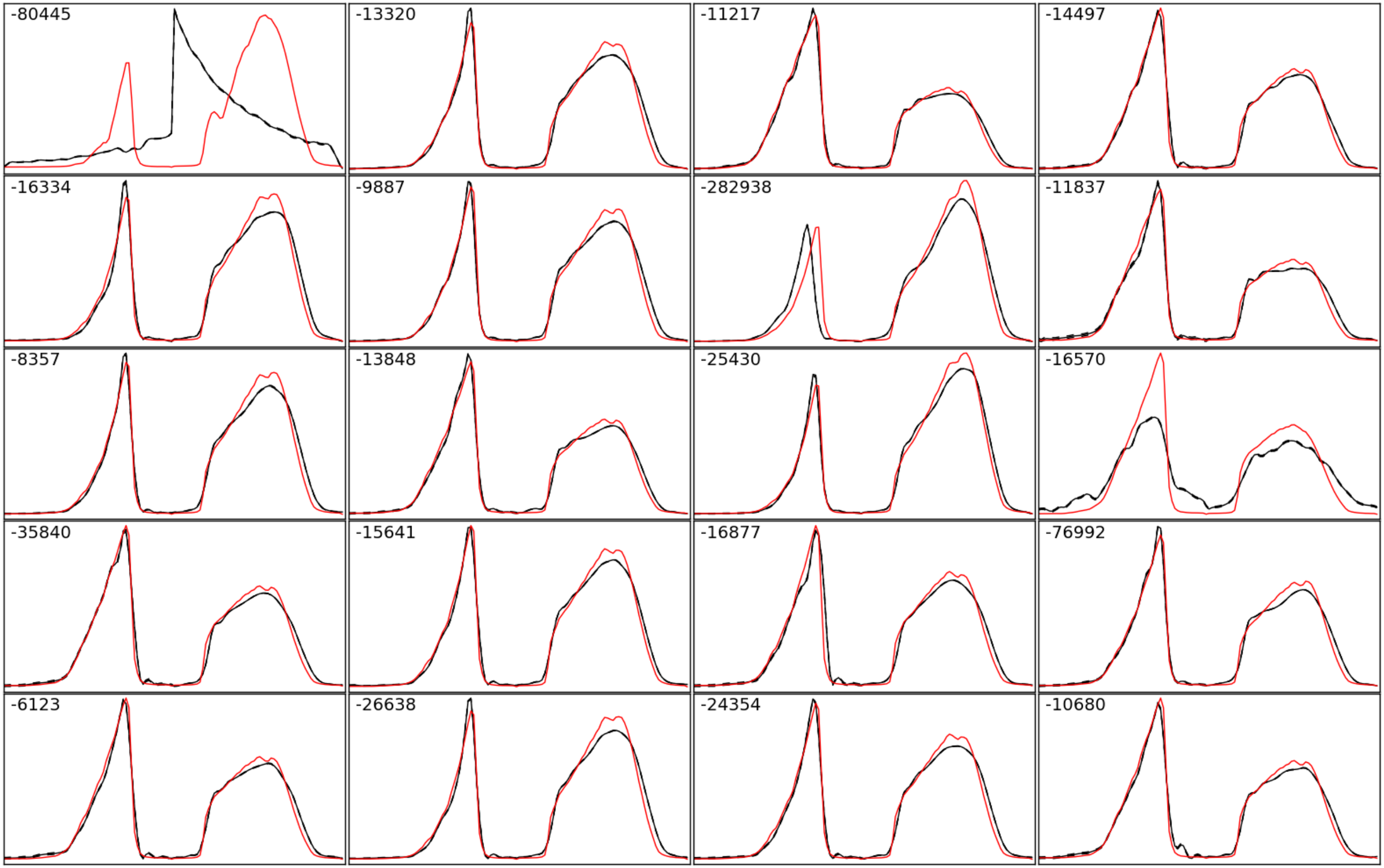


For details see:
Bailer-Jones et al. (2013)

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

Preliminary fitting of BP/RP spectra

black = Gaia data red = model fit (GSP-Phot/Aeneas with Phoenix)



Graphics: Rene Andrae (MPIA)

Expected parameter accuracy from BP/RP

- is a function of true parameters, magnitude, no. observations
- internal RMS residuals for FGKM stars (wide range of other APs)

AP	G=15	G=19
T_{eff} / K	70 - 170	90 - 630
A_0 / mag	0.07 - 0.14	0.15 - 0.35
[Fe/H] / dex	0.15 - 0.3	0.3 - 0.6
logg / dex	0.2 - 0.4	0.15 - 0.45

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Stellar APs in (final) Gaia catalogue

- class probabilities, T_{eff}, A_0, logg, [Fe/H], (R_0, [α/Fe], …)
  - derived M_G, luminosity, mass, radius, age (precision highly variable)
  - uncertainty estimates, posterior PDF in some cases
  - multiple sets of estimates (different methods, data, spectral libraries)
  - use of parallax and physical reality (e.g. HRD) in some cases
- additional AP estimates for specific types of stars
  - e.g. emission line stars, ultra cool dwarfs

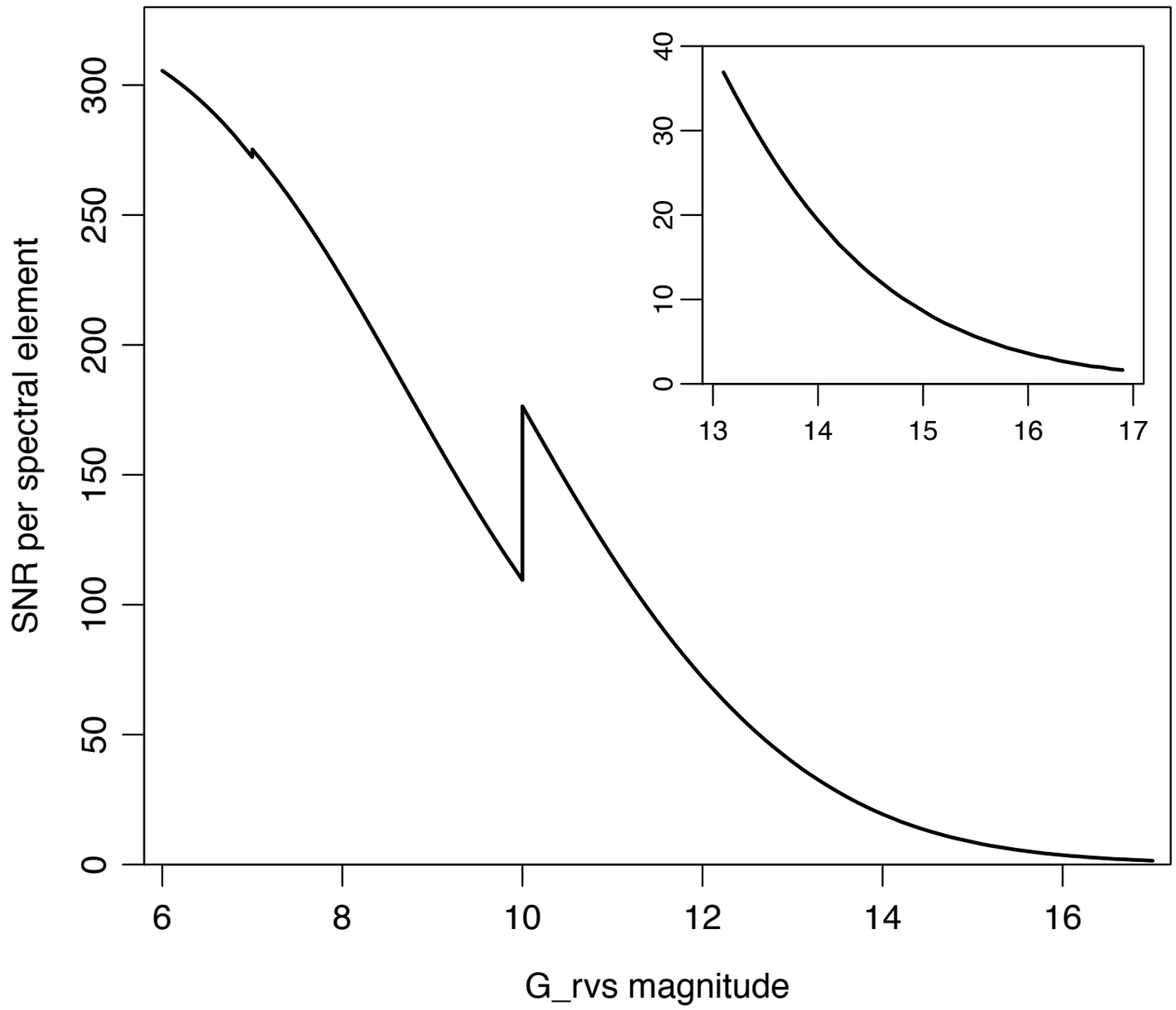
Stellar APs in the Gaia data releases

- **GR1** (mid 2016): nothing planned
- **GR2** (early 2017): T_{eff}, A_0 based on BP/RP; integrated BP/RP photometry
- **GR3** (2018): main APs based on BP/RP and RVS; BP/RP and RVS
- **GR4** (2019): as GR3 but with improved precision and calibration; more detailed APs
- **Final release** (2022): improvement of all data products; ground-based auxiliary data

Summary

- Gaia has a significant spectroscopic capability
- The Gaia catalogue will contain
  - T_{eff}, A_0, logg, [Fe/H], some individual abundances, physical parameters
  - multiple parameter estimates: different data/methods/libraries
- Large numbers of objects (variable precision)
  - 10^9 stars from low res. spectrophotometry (330-1050 nm; G < 20)
  - 10^7 stars from high res. spectroscopy (847-871 nm; G_{RVS} < 12)

RVS, end-of-mission, pre-launch, SNR



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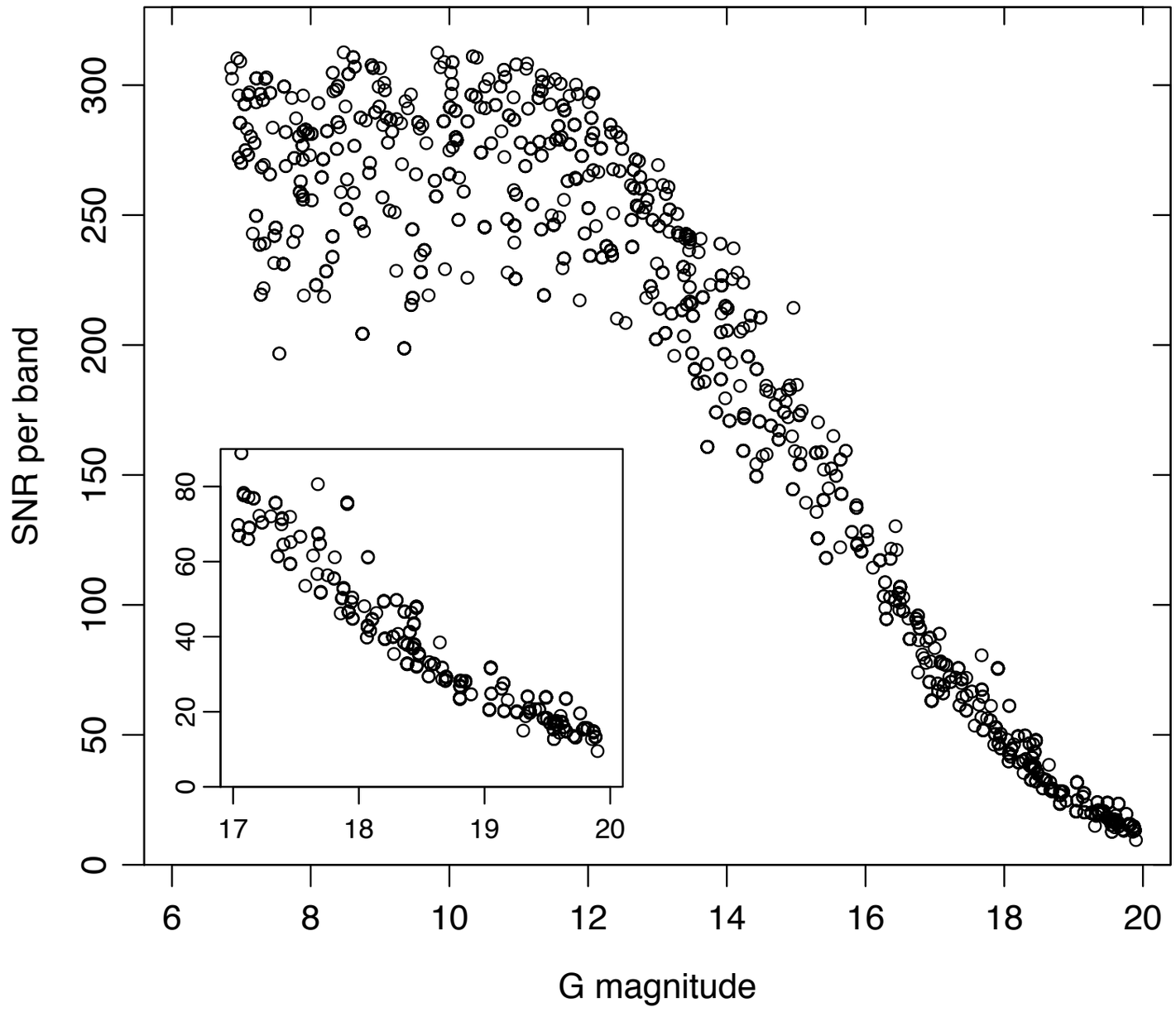
BP/RP, end-of-mission, pre-launch, SNR



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Stellar libraries

Name	N	$T_{\rm eff}$ / K	$\log g$ / dex	[Fe/H] / dex	Ref.	Notes
OB stars	1296	15 000–55 000	1.75–4.75	0.0–0.6	1	TLUSTY code; NLTE, mass loss, $v_{\rm micro}$
Ap/Bp stars	36	7000–16000	4.0	0.0	2	LLmodels code, chemical peculiarities
A stars	1450	6000–16 000	2.5–4.5	0.0	3	LLmodels code, [α/Fe] = 0.0, +0.4
MARCS	1792	2800–8000	−0.5–5.5	−5.0–1.0	4	Galactic enrichment law for [α/Fe]
Phoenix	4575	3000–10 000	−0.5–5.5	−2.5–0.5	5	$\Delta T_{\rm eff}$ = 100 K
UCD	2560	400–4000	−0.5–5.5	−2.5–0.5	6	various dust models
C stars MARCS	428	4000–8000	0.0–5.0	−5.0–0.0	7	[C/Fe] depends on [Fe/H]
Be	174	15 000–25 000	4.0	0.0	8	range of envelope to stellar radius ratios
WR	43	25 000–51 000	2.8–4.0	0.0	9	range of mass loss rates
WD	187	6000–90 000	7.0–9.0	0.0	10	WDA & WDB
MARCS NLTE	33	4000–6000	4.5–5.5	0.0	11	NLTE line profiles
MARCS RVS	146 394	2800–8000	−0.5–5.5	−5.0–1.0	12	variations in individual elements abundances
3D models	13	4500–6500	2.0–5.0	−2.0–0.0	13	StaggerCode models and Optim3D code
SDSS stars	50 000	3750–10 000	0.0–5.5	−2.5–0.5	14	semi-empirical library
Emission line stars	1620	–	–	–	15	semi-empirical library (see Sect. 5.4)

Notes. N is the number of spectra in the library. Ap/Bp are peculiar stars; UCD are ultracool dwarfs; WR are Wolf Rayet stars; WD are white dwarfs.

References. 1) Bouret et al. (2008); 2) Kochukhov & Shulyak (2008); 3) Shulyak et al. (2004); 4) Gustafsson et al. (2008); 5) Brott & Hauschildt (2005); 6) Allard et al. (2001); 7) Masseron, priv. comm.; 8), 9) Martayan et al. (2008); 10) Castanheira et al. (2006); 11) Korn et al., priv. comm.; 12) Recio-Blanco et al., priv. comm.; 13) Chiavassa et al. (2011); 14) Tsalmantza & Bailer-Jones (2010b); 15) Lobel et al. (2010).