Galactic archaeology & all-sky photometry

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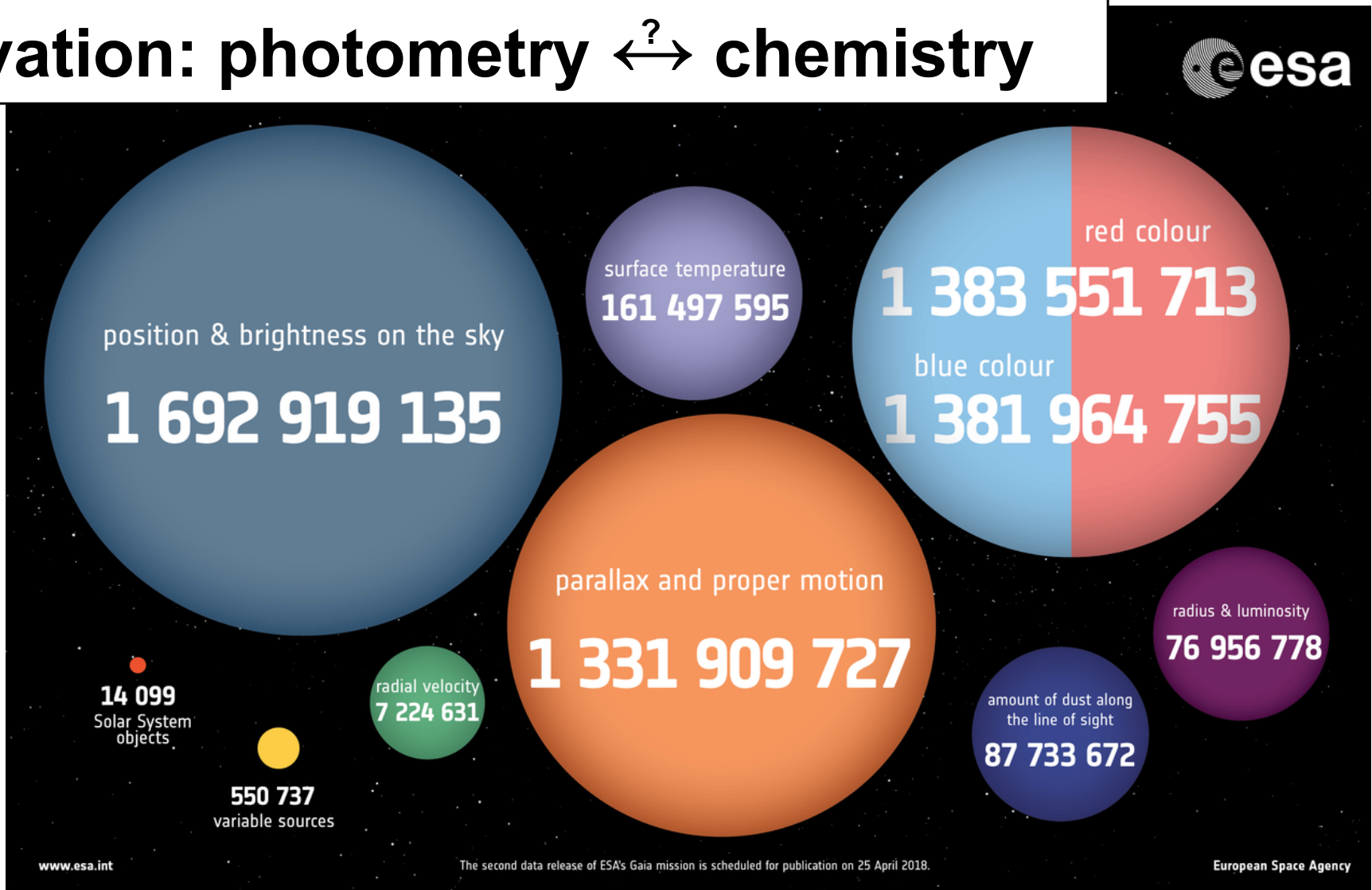
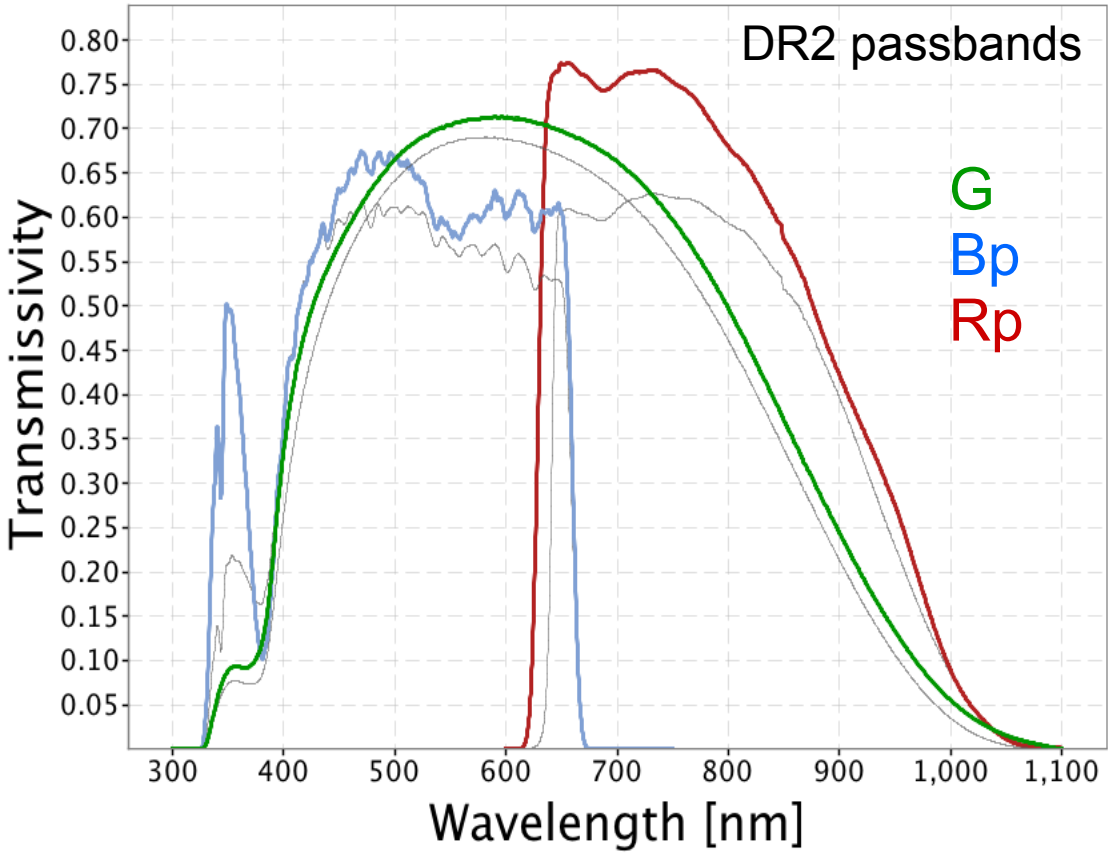
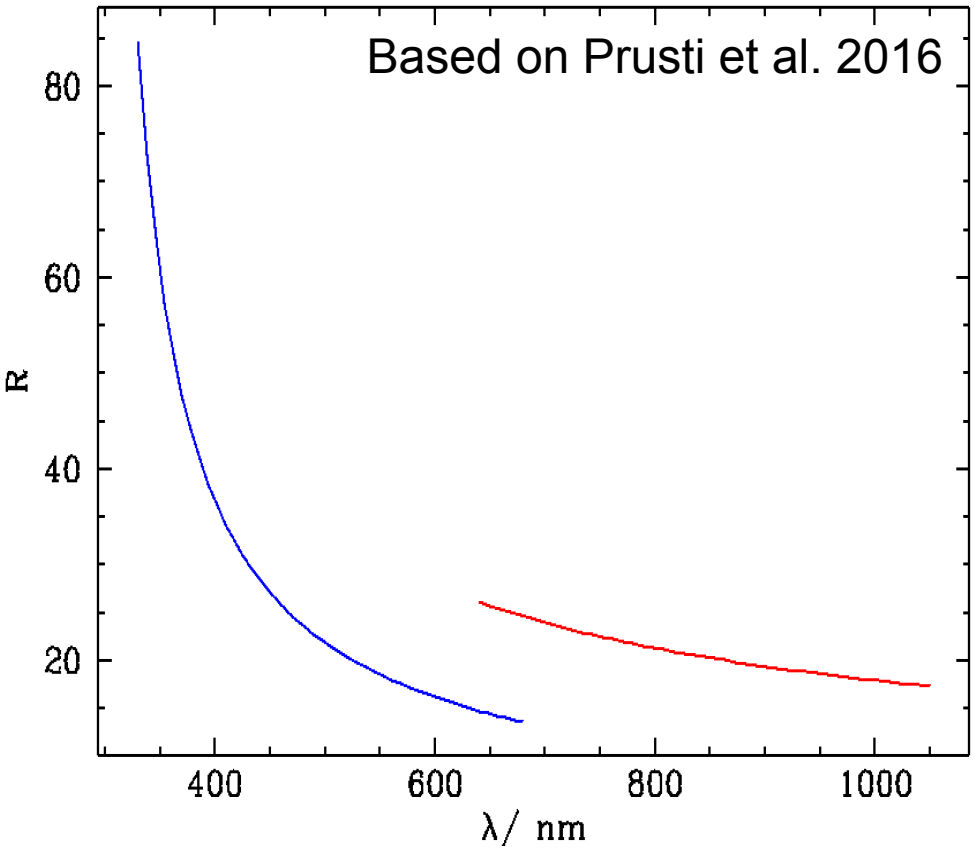
Motivation: photometry $\overset{?}{\leftrightarrow}$ chemistry



Gaia: photometric properties

- 140 epochs per 10 years on average.
- 1.44m x 0.5m primary mirror (≈ 1-m ground based telescope).
- Exp. time per epoch: 40 s (G), 4.4 s (Bp & Rp).
- Exp. time per 10 years: 5600 s (G), 616 s (Bp,Rp).





Gaia – end of mission performance

G = 17.5, 140 transits: integrated σ (G) ~ 0.0005 mag

G2 V (G = 17.5, 140 transits):

integrated: σ (Bp) = 0.0044 mag, σ (Rp) = 0.0039 mag,

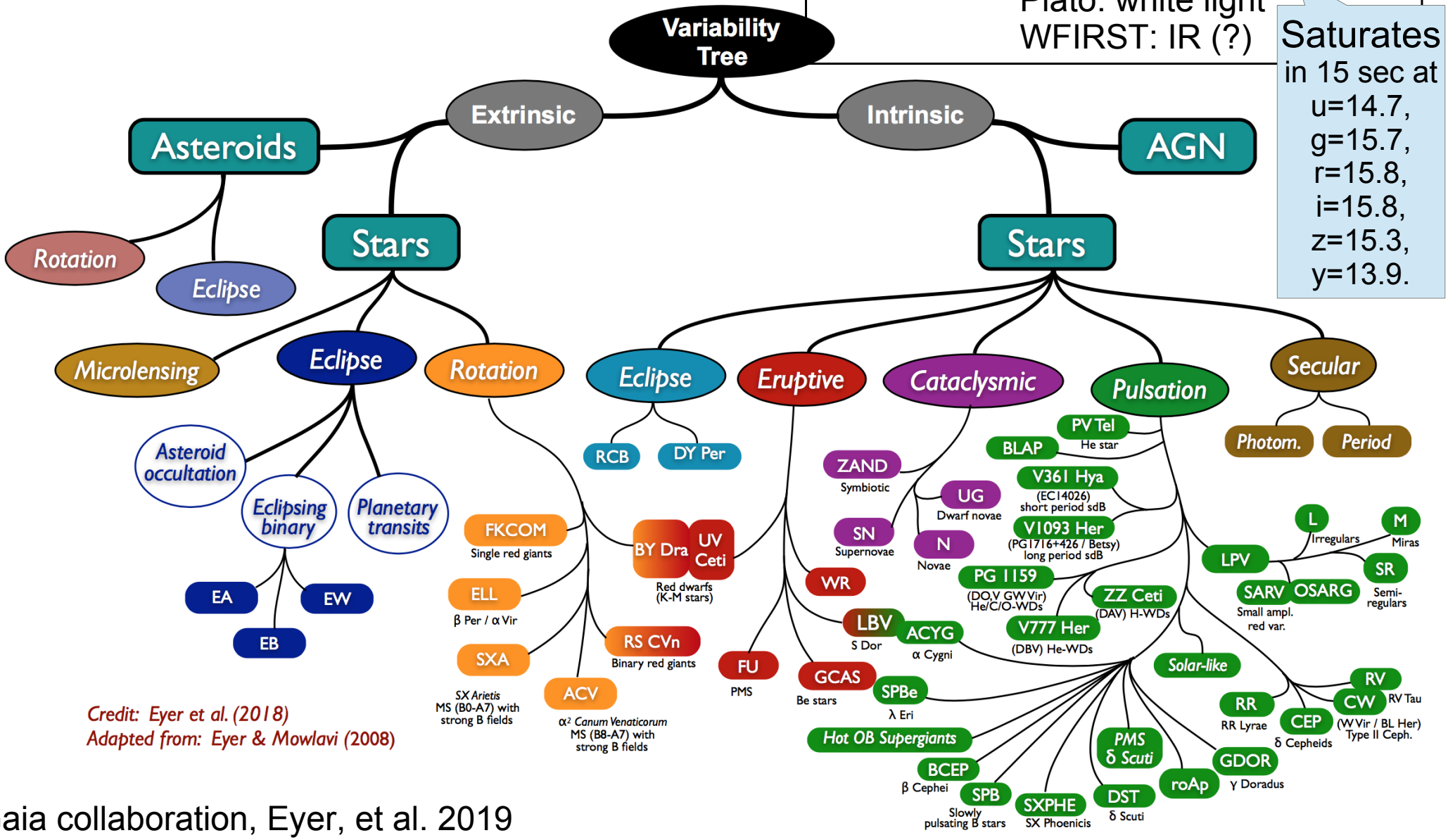
K2 III (G = 17.5, 140 transits):

integrated: σ (Bp) = 0.0048 mag, σ (Rp) = 0.0035 mag.

Exploring the variability tree

Done: OGLE, Kepler, K2
Ongoing: SkyMapper (uvgriz)
Pan-STARRS1 (grizy)
Gaia: DR3 (in 2+ years)
TESS: white light
TBD: LSST: optical ugrizy (+v?)
Plato: white light
WFIRST: IR (?)

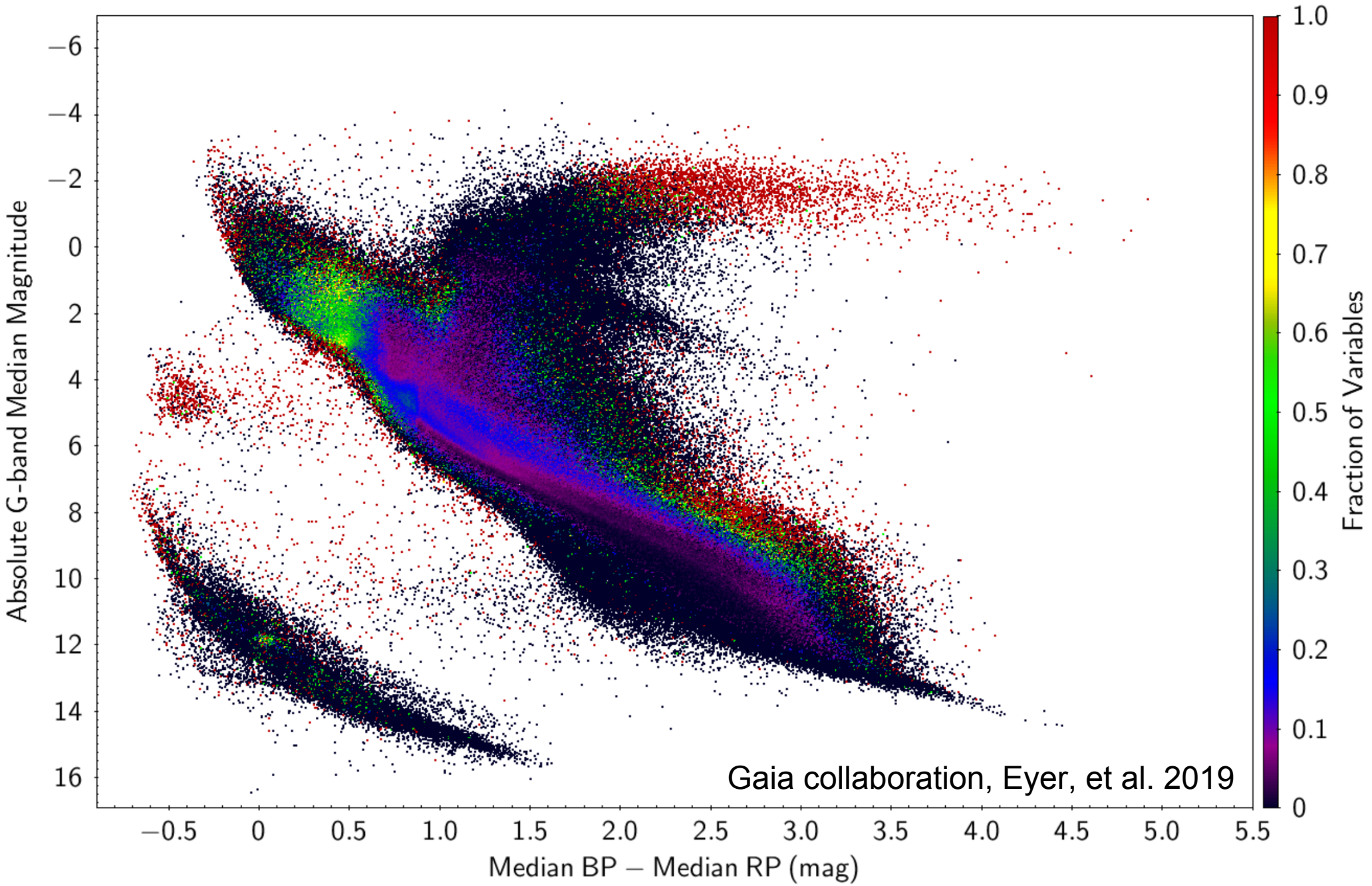
Saturates in 15 sec at u=14.7, g=15.7, r=15.8, i=15.8, z=15.3, y=13.9.



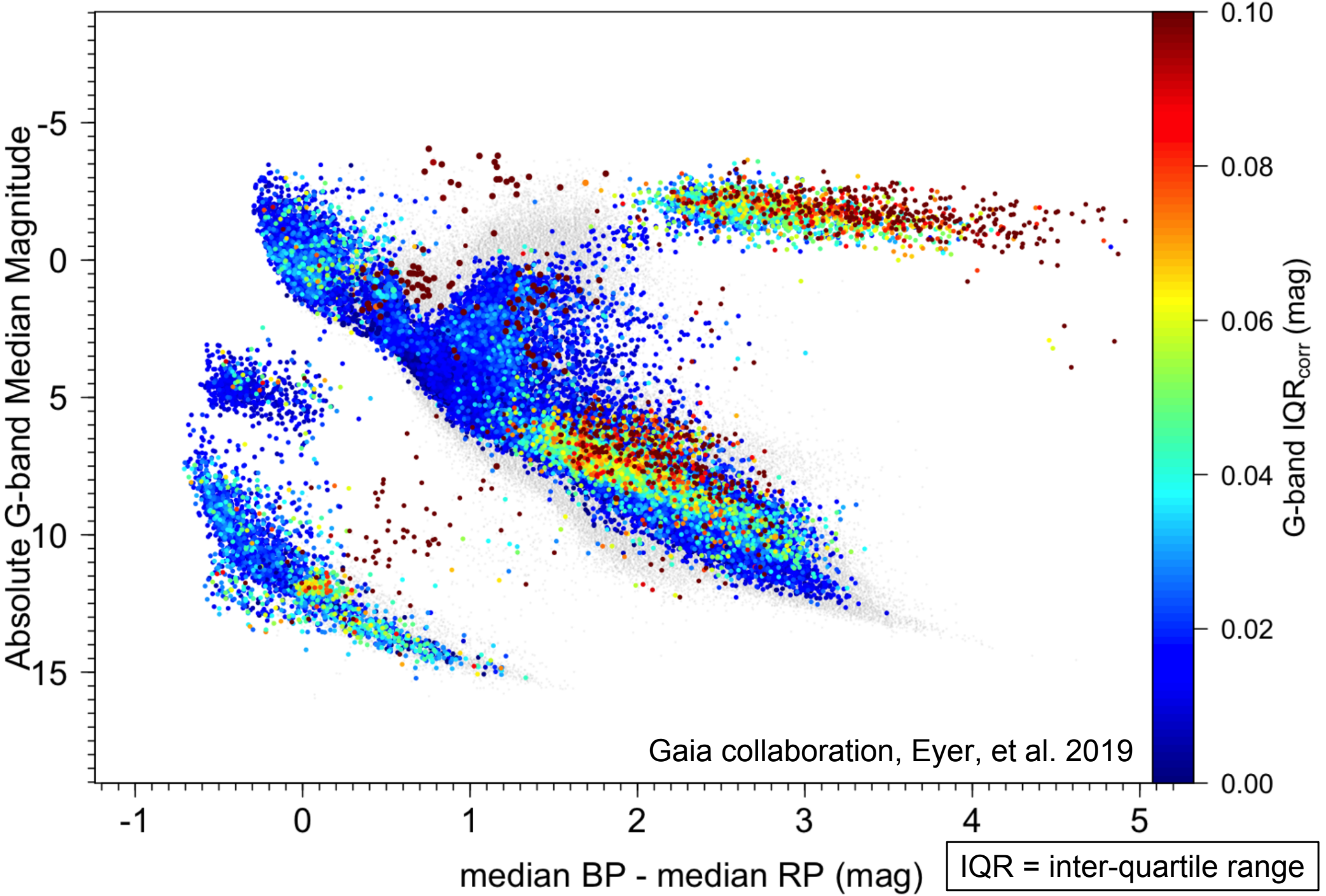
Credit: Eyer et al. (2018)
Adapted from: Eyer & Mowlavi (2008)

Gaia collaboration, Eyer, et al. 2019

Gaia: detected fraction of variables



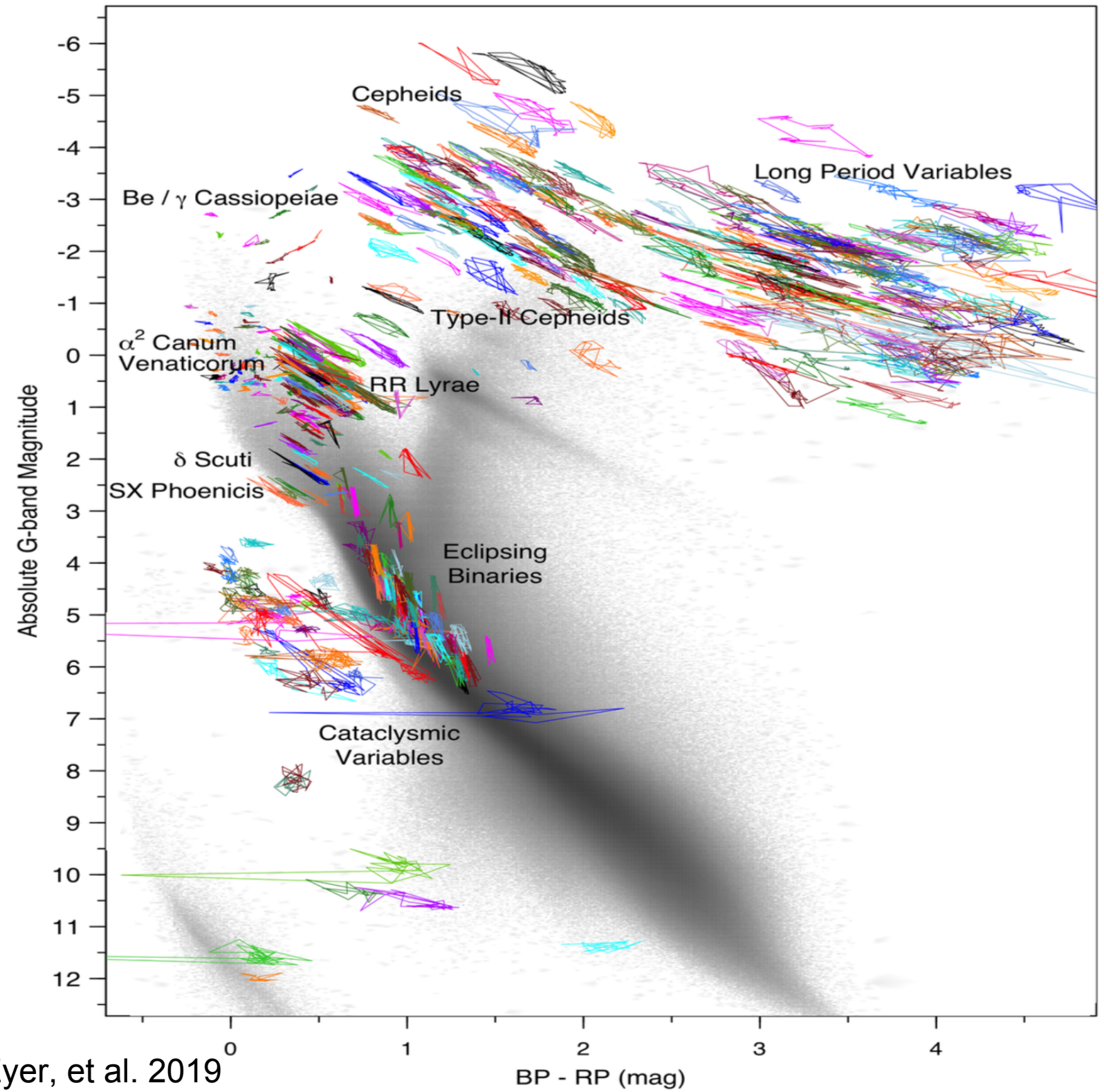
Gaia: variability amplitudes



Gaia collaboration, Eyer, et al. 2019

Gaia: wandering around

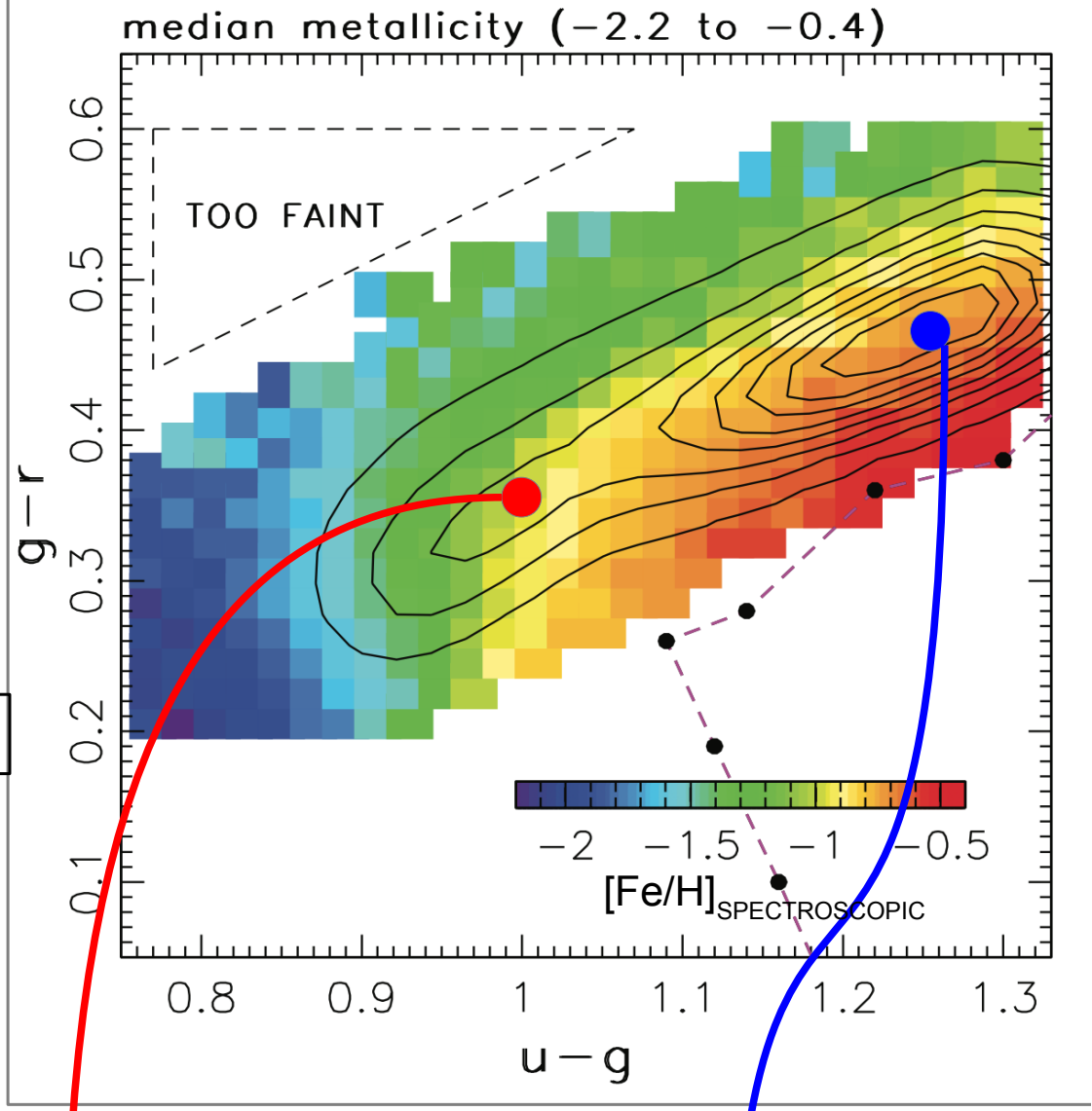
Gaia: wandering around



Gaia collaboration, Eyer, et al. 2019

Ivezić et al. 2008

Galactic archaeology: photometric [Fe/H]



Convergence may be problematic.

$$x = \begin{cases} \text{u-g, if (g-r)} \le 0.4 \\ \text{(u-g)-2(g-r)+0.8, otherwise} \end{cases}$$

$y = g-r$

$C_i = (-4.37, -8.56, 15.5, -39.0, 23.5, 20.5, 12.1, 7.33, -10.1, -21.4)$

$[Fe/H]_{phot} = C_0 + C_1x + C_2y + C_3xy + C_4x^2 + C_5y^2 + C_6x^2y + C_7xy^2 + C_8x^3 + C_9y^3$

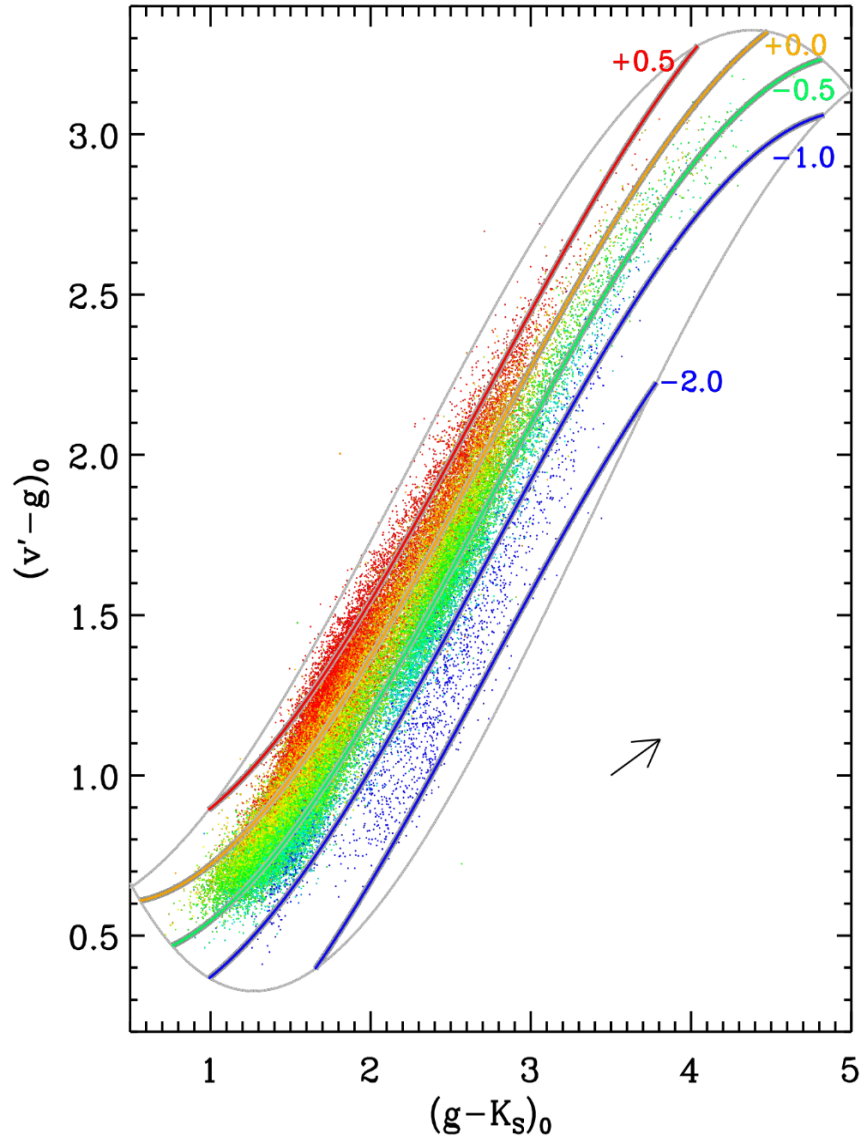
$[Fe/H]_{phot} = -4.37-9.42+5.43-15.02+28.44+2.51+5.12+0.99-13.44-0.92 = -0.68$

$[Fe/H]_{phot} = -4.37-10.70+7.29-22.91+36.72+4.52+8.89+2.02-19.73-2.22 = -0.49$

$$[\mathrm{Fe/H}] = \frac{-0.1815 + 0.1848\,(v'-g)_0 - 0.1630\,(g-K_S)_0}{0.0649} +$$
$$+ 0.8501 + 3.6086\,(g-K_S)_0 - 1.3735\,(g-K_S)_0^2 + 0.1684\,(g-K_S)_0^3$$

wide range,
moderate coefficients.
good reliability.

Photometric [Fe/H]: SkyMapper



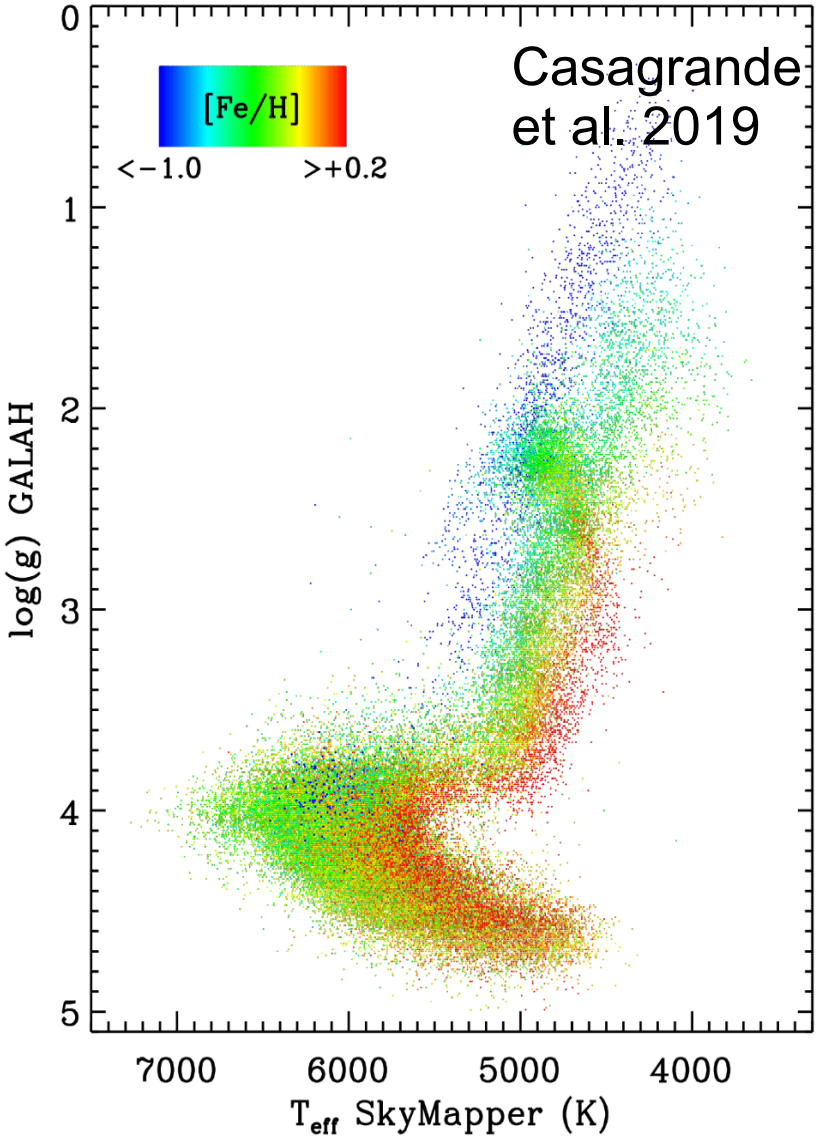
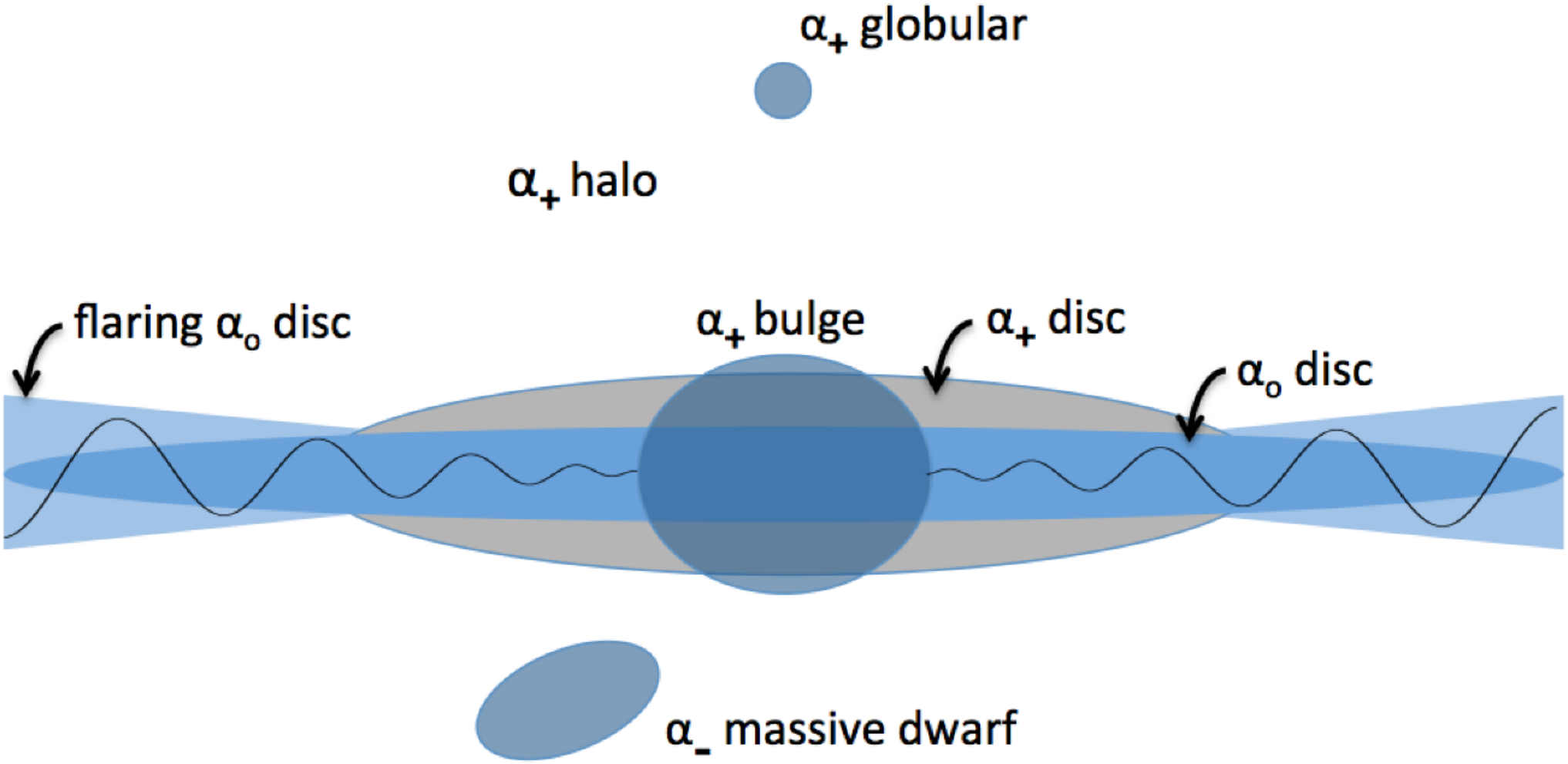


Figure 10. Left-panel: colour-colour plane with GALAH stars coded by their [Fe/H] as per inset panel on the right. Grey lines define the boundary of our metallicity calibration, while continuous coloured lines trace Eq. (12) at indicated values of [Fe/H]. The arrow shows the direction of the reddening vector with length corresponding to $E(B-V) = 0.1$. Right-panel: Kiel diagram for the same stars. In both panels, only stars with $E(B-V) < 0.05$ and $|b| > 20°$ are shown, although relaxing these conditions does not qualitatively change the plots.

Motivation: we need also [α/Fe], not just [Fe/H] from photometry



Hawthorn et al. 2019

Gaia – end of mission performance

G = 17.5, 140 transits: integrated σ (G) ~ 0.0005 mag

G2 V (G = 17.5, 140 transits):

integrated: σ (Bp) = 0.0044 mag, σ (Rp) = 0.0039 mag,

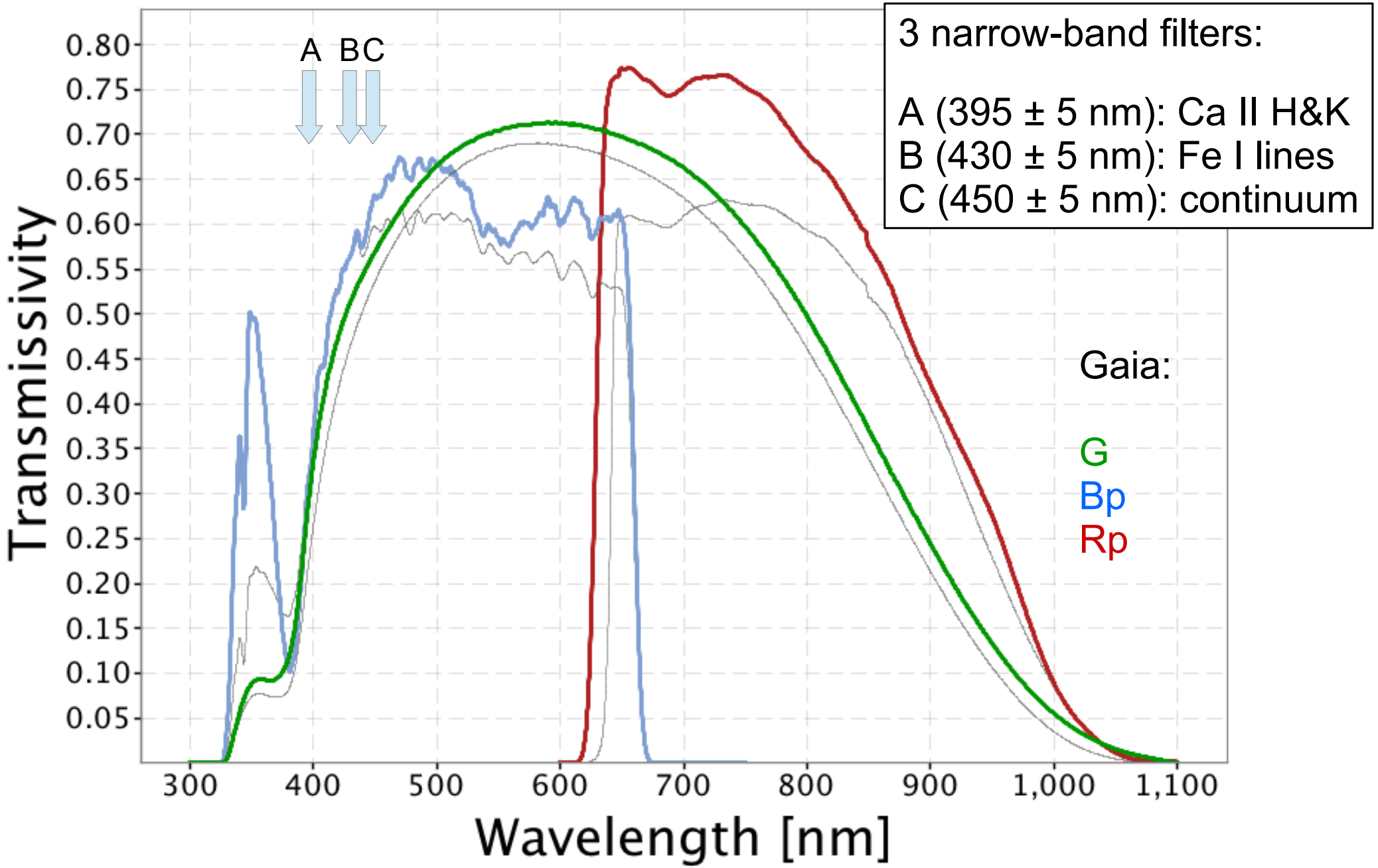
per 10 nm @450 nm: 0.025 mag, @395 nm: 0.08 mag.

K2 III (G = 17.5, 140 transits):

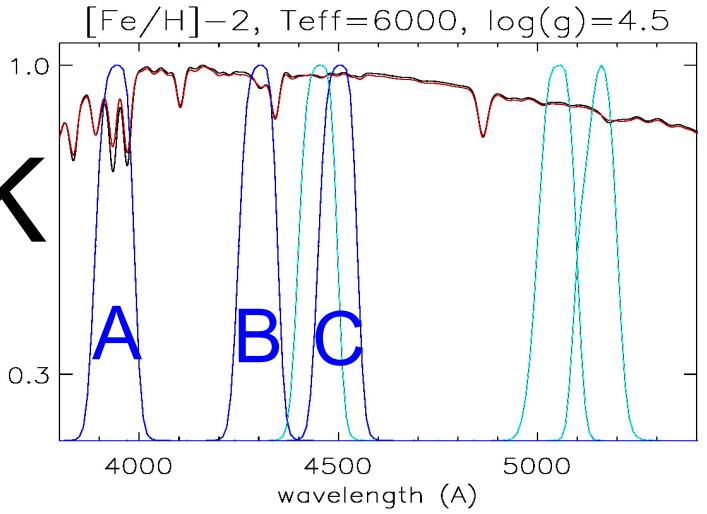
integrated: σ (Bp) = 0.0048 mag, σ (Rp) = 0.0035 mag,

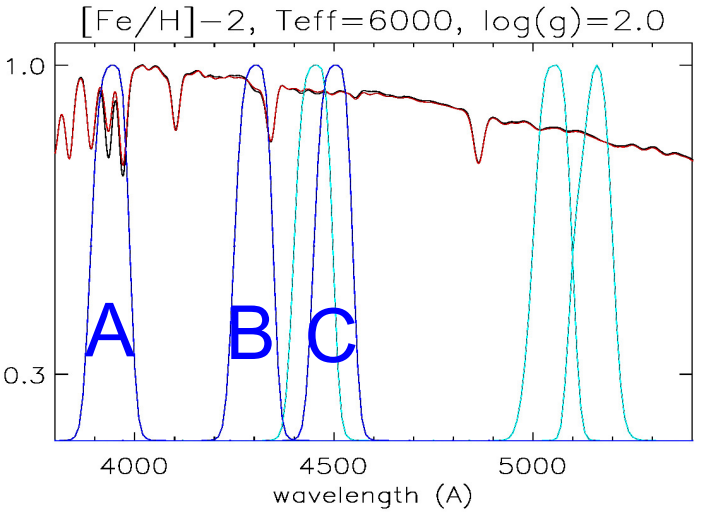
per 10 nm @450 nm: 0.03 mag, @395 nm: 0.12 mag.

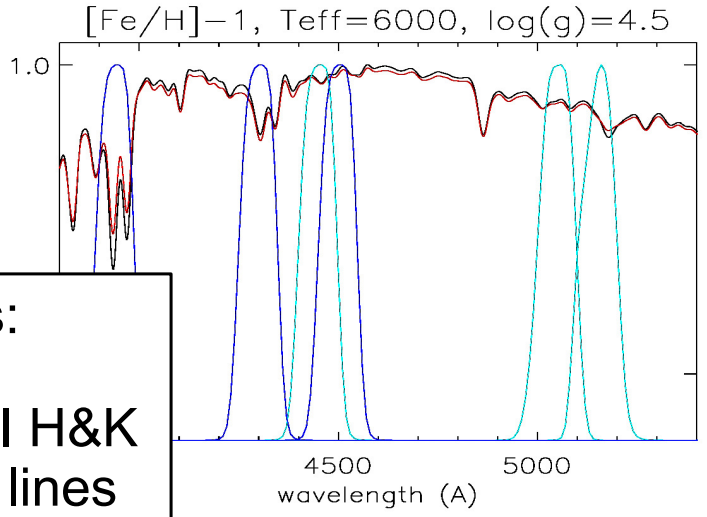
Proposing 3 narrow-band filters

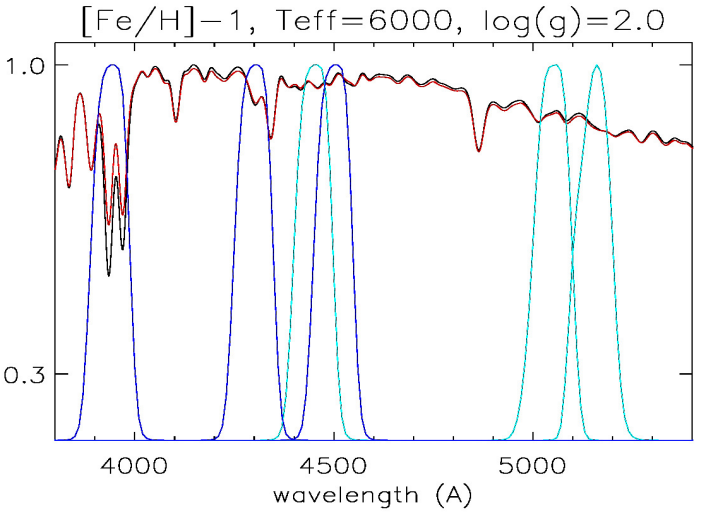


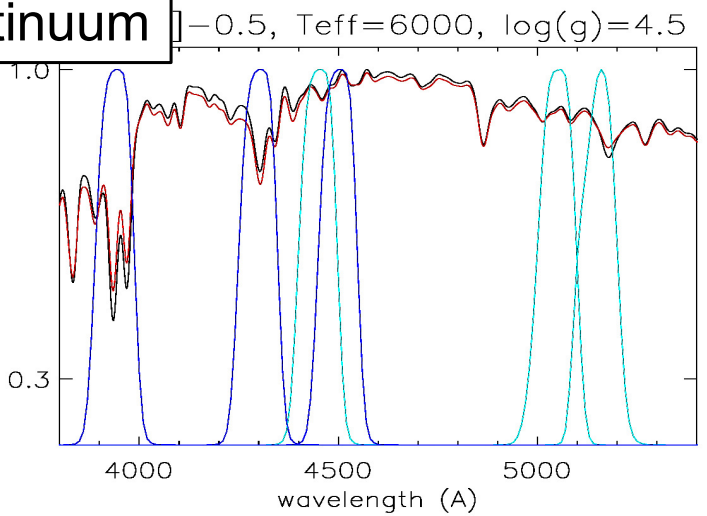
@ 6000 K

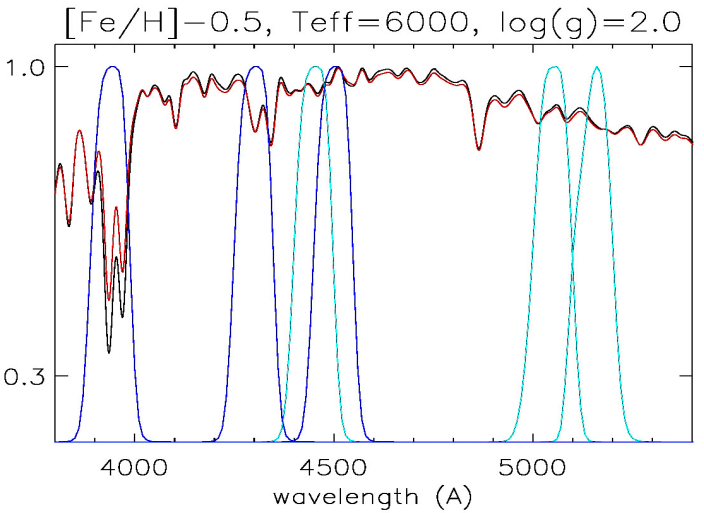








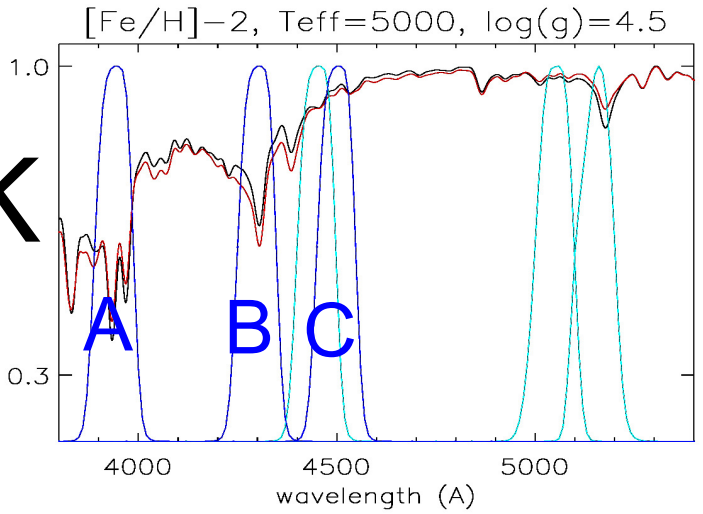


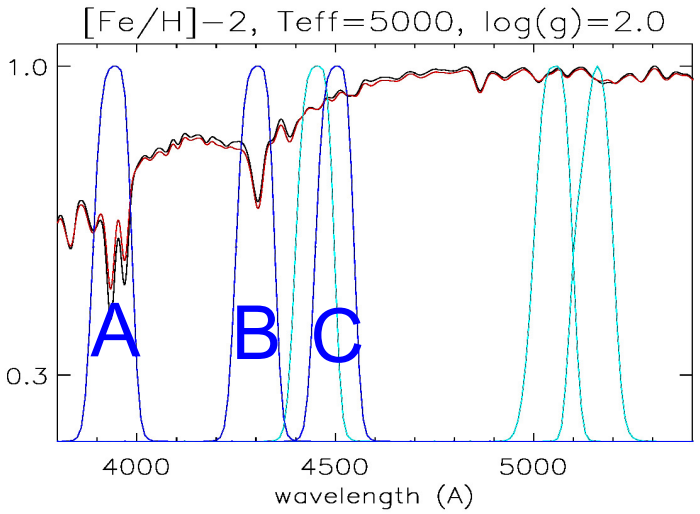


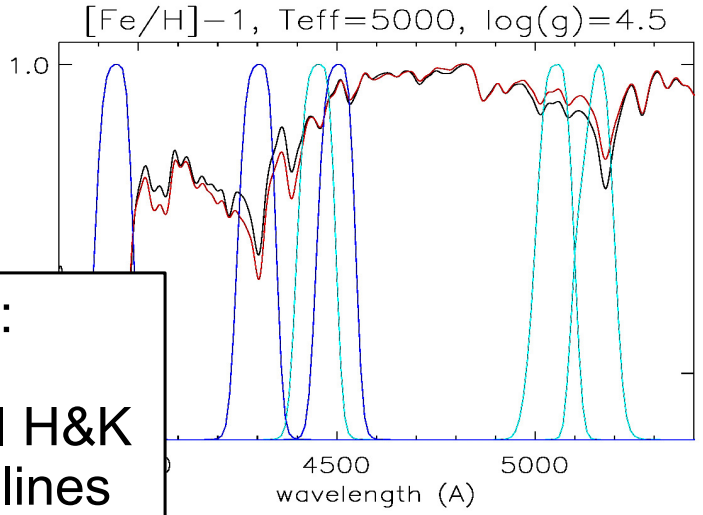
3 narrow-band filters:

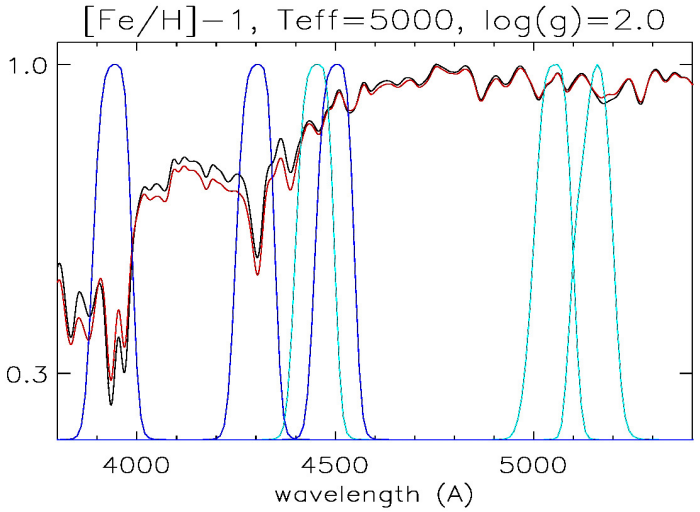
A (395 ± 5 nm): Ca II H&K
B (430 ± 5 nm): Fe I lines
C (450 ± 5 nm): continuum

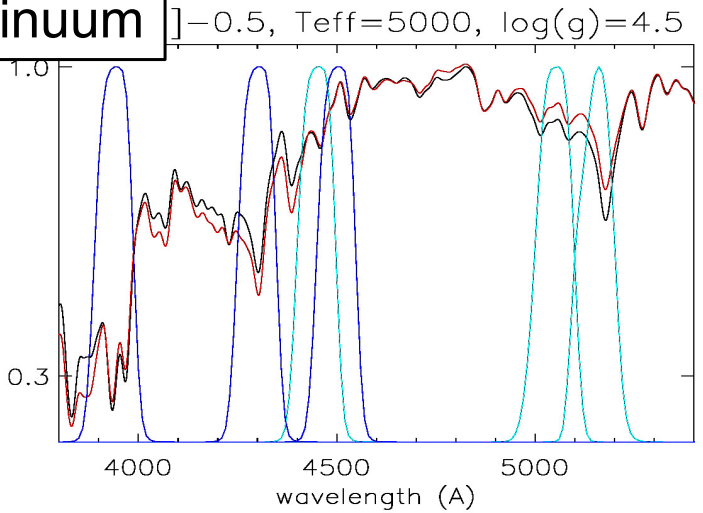
@ 5000 K

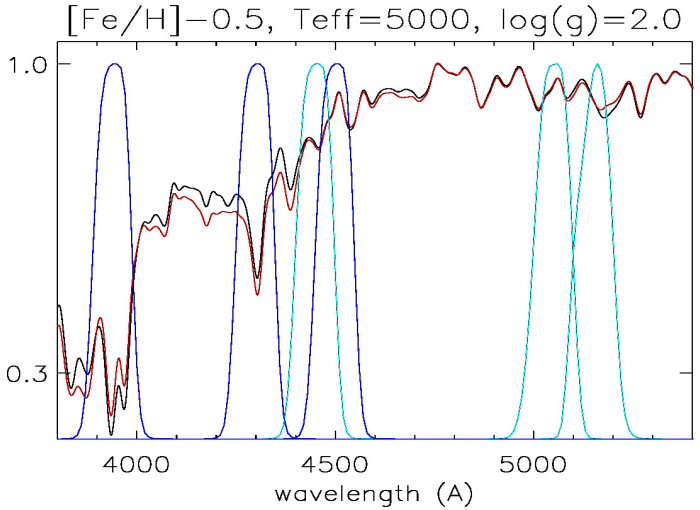












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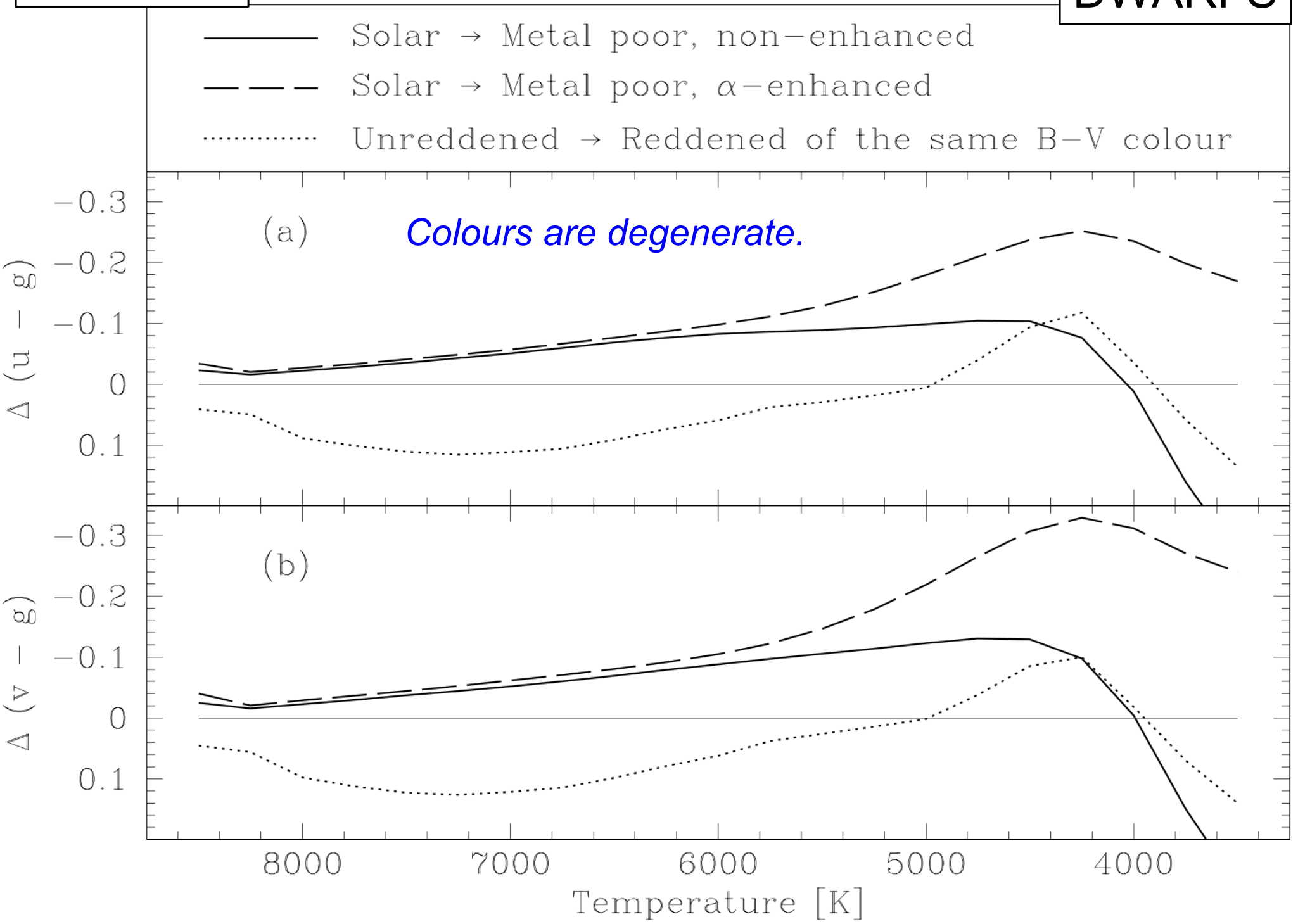
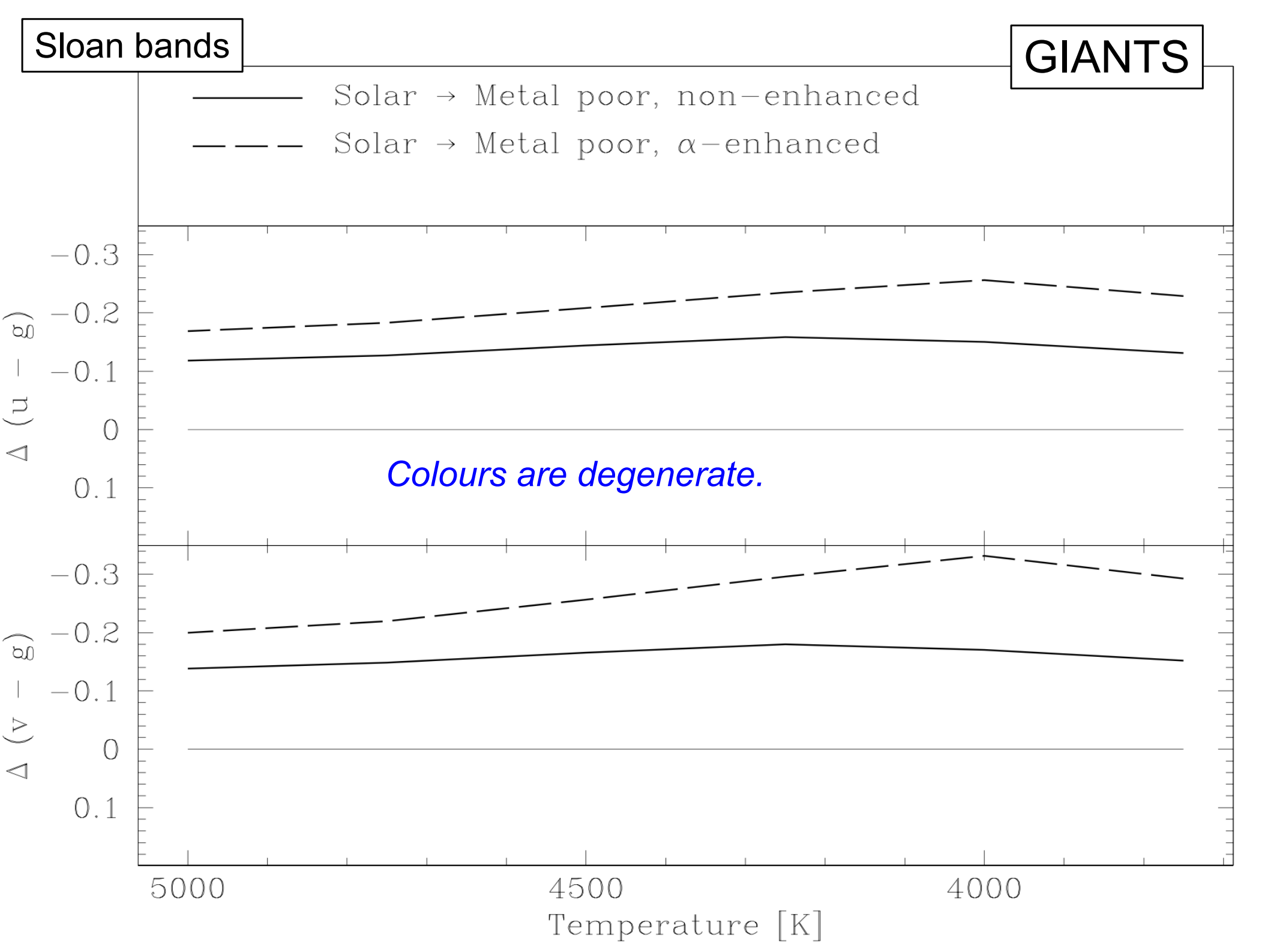
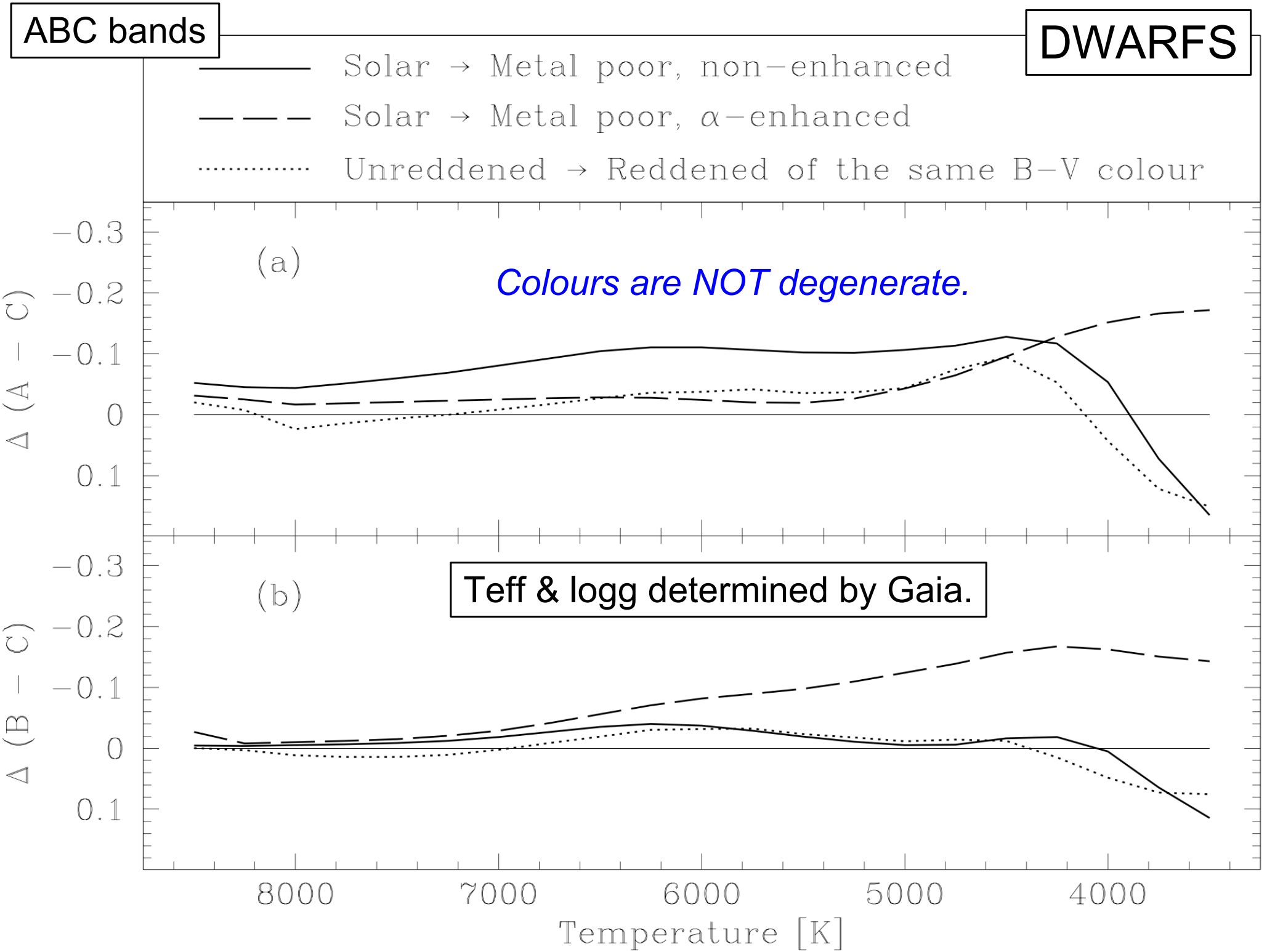
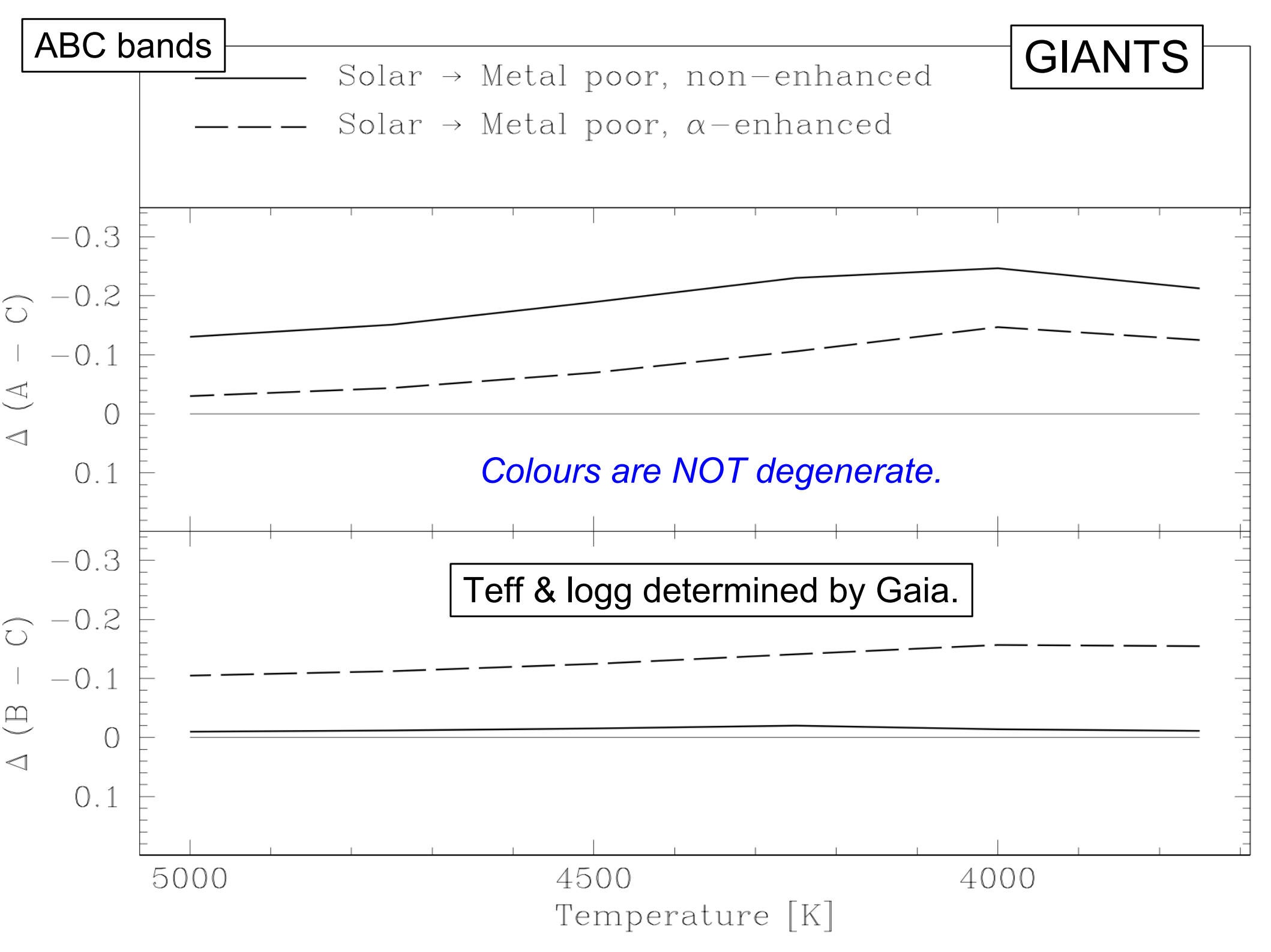
Sloan bands

DWARFS

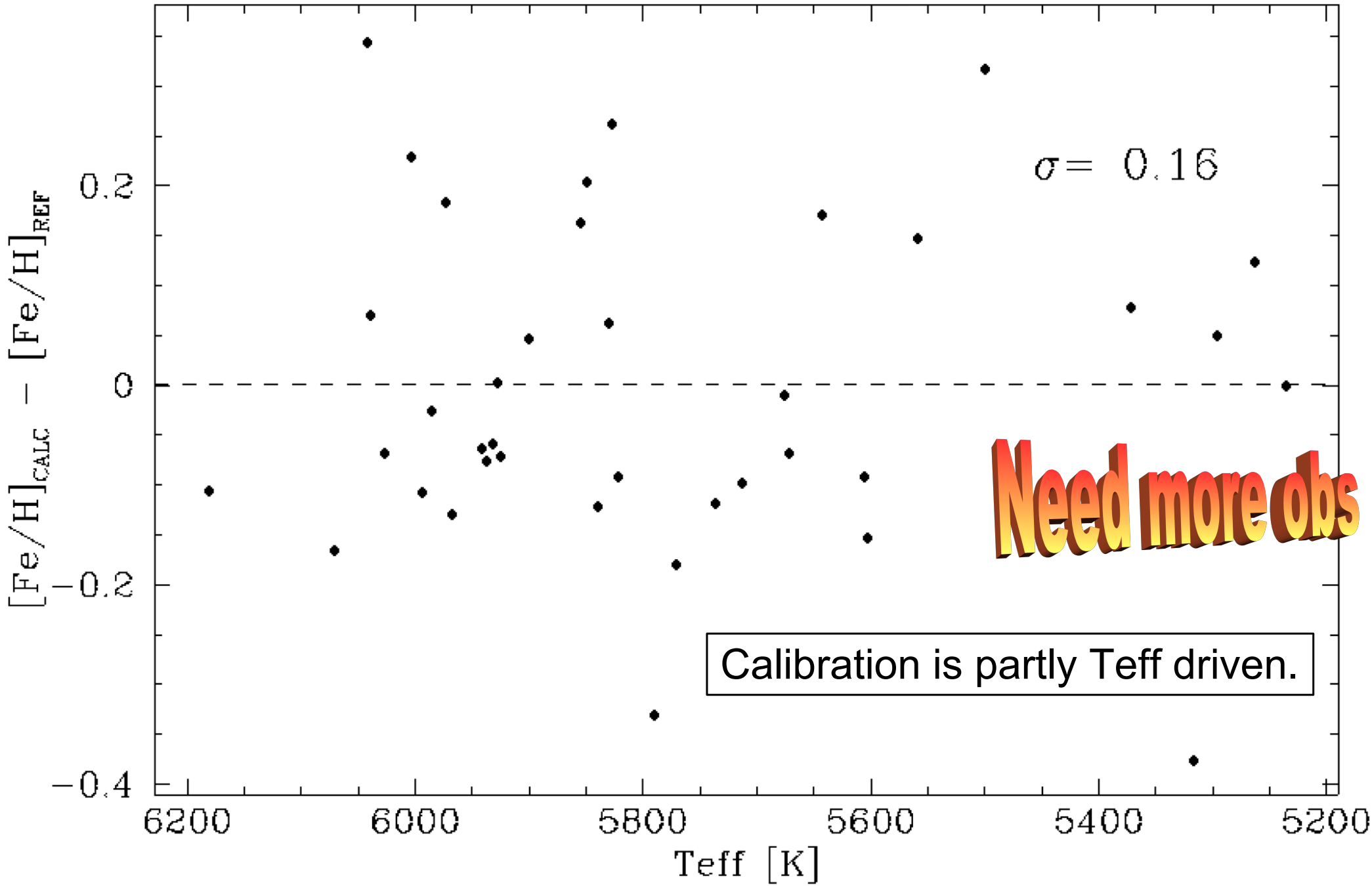



Sloan bands
GIANTS
Solar → Metal poor, non−enhanced
Solar → Metal poor, α−enhanced
Δ (u − g)
Δ (v − g)
−0.3
−0.2
−0.1
0
0.1
Colours are degenerate.
5000
4500
4000
Temperature [K]

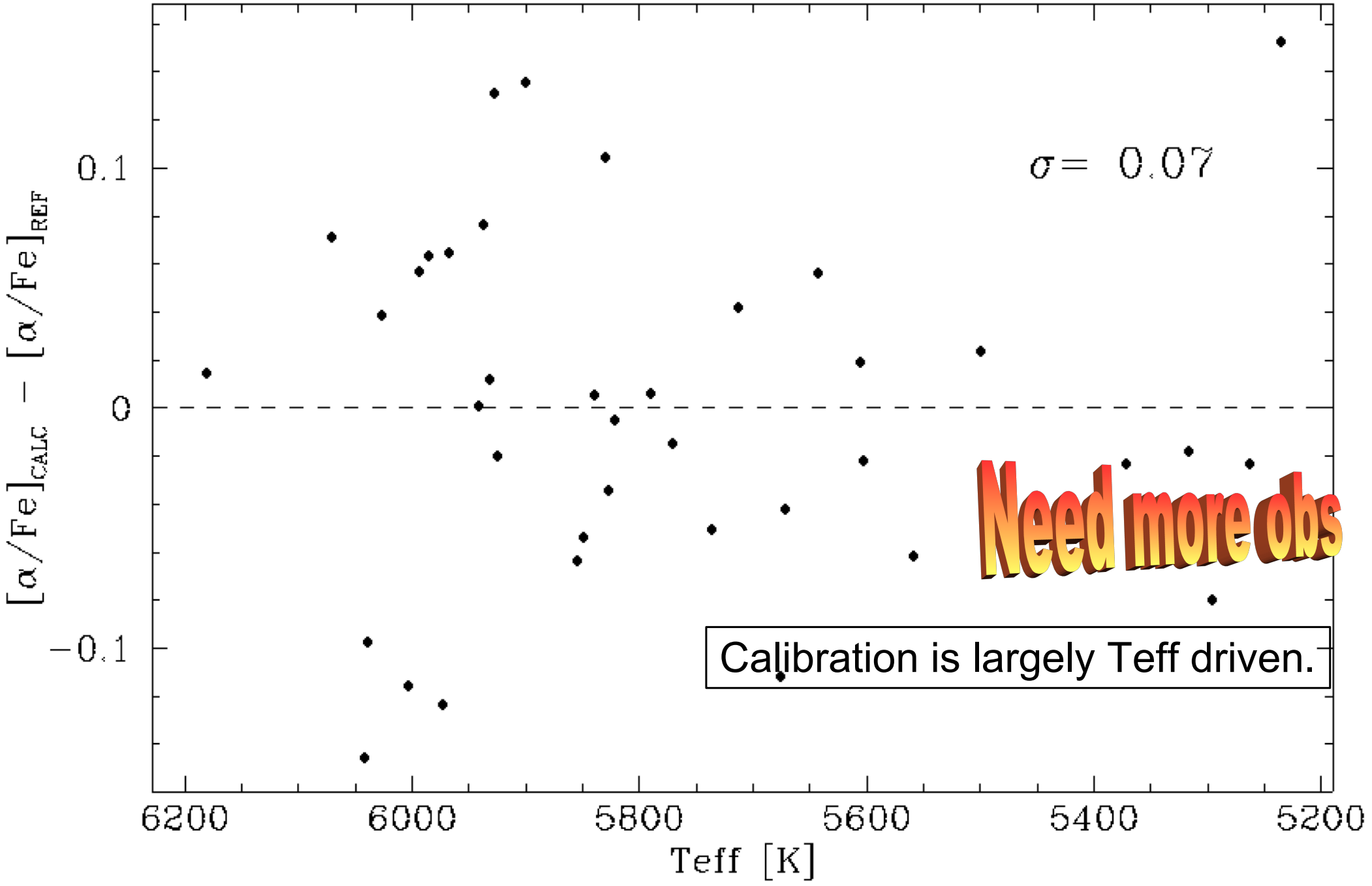

ABC bands
DWARFS
Solar → Metal poor, non−enhanced
Solar → Metal poor, α−enhanced
Unreddened → Reddened of the same B−V colour
(a)
Colours are NOT degenerate.
Δ (A − C)
−0.3
−0.2
−0.1
0
0.1
(b)
Teff & logg determined by Gaia.
Δ (B − C)
−0.3
−0.2
−0.1
0
0.1
8000
7000
6000
5000
4000
Temperature [K]


ABC bands
GIANTS
Solar → Metal poor, non−enhanced
Solar → Metal poor, α−enhanced
−0.3
−0.2
−0.1
0
0.1
Δ (A − C)
Colours are NOT degenerate.
Teff & logg determined by Gaia.
Δ (B − C)
5000
4500
4000
Temperature [K]

Results: observations of Nissen & Schuster 2011 stars @ SPM



Results: observations of Nissen & Schuster 2011 stars @ SPM



Ca II H&K and the interstellar medium

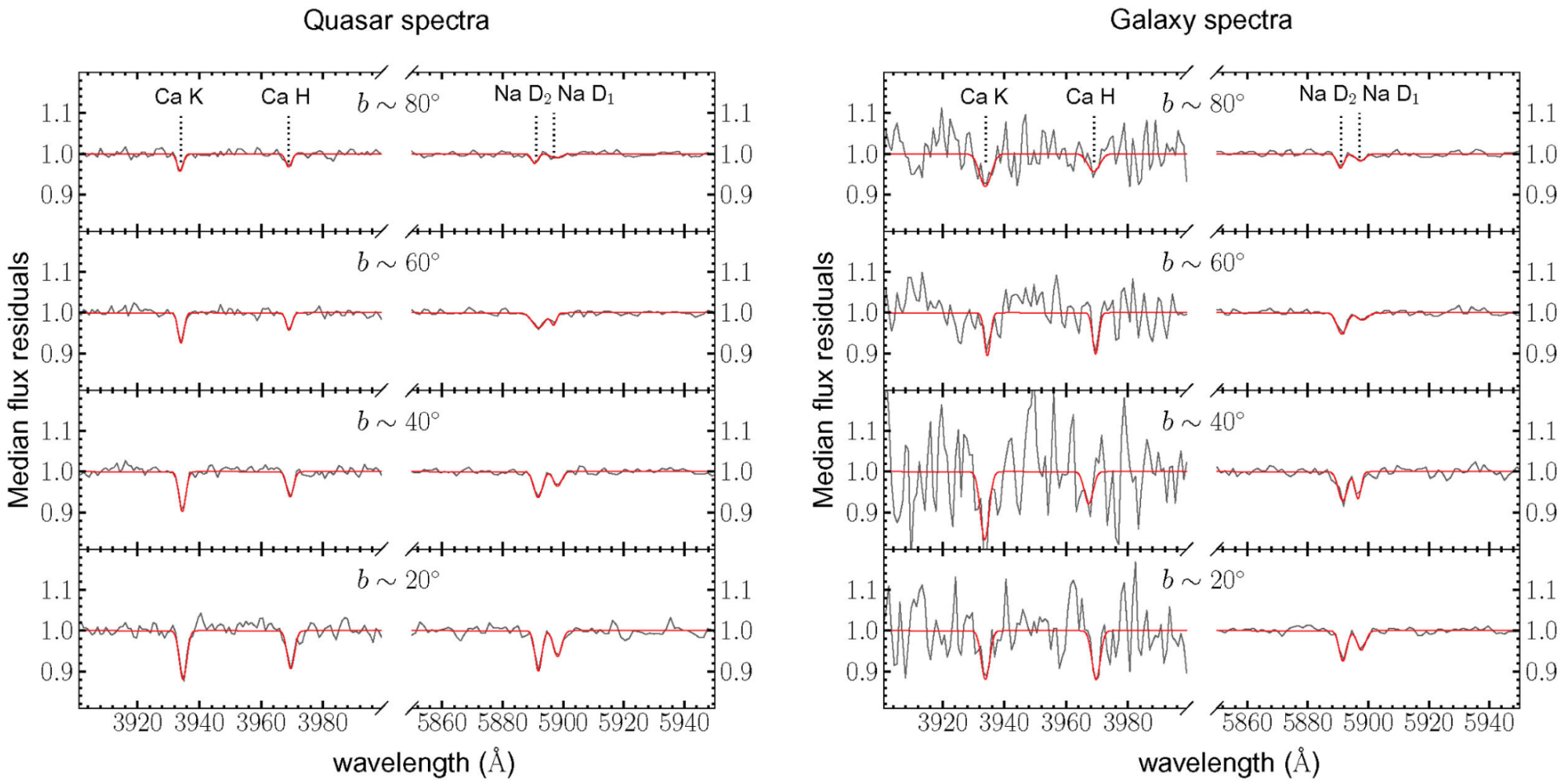
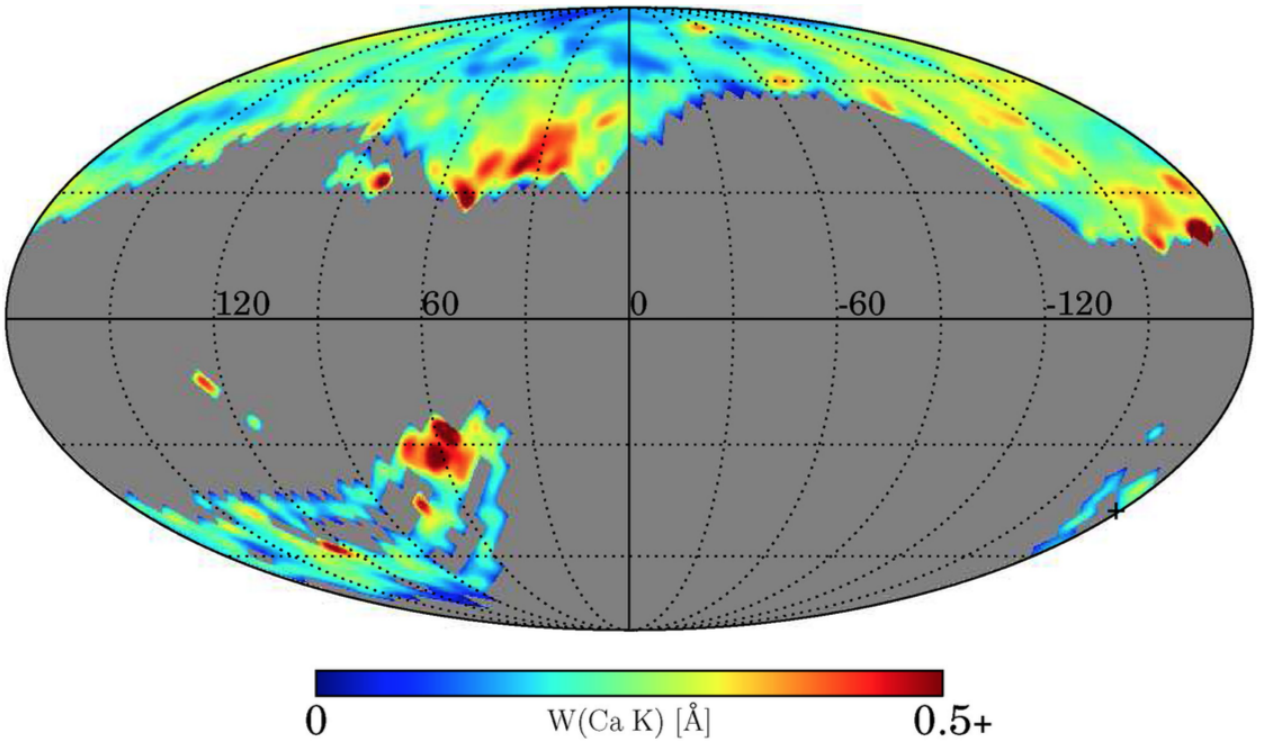
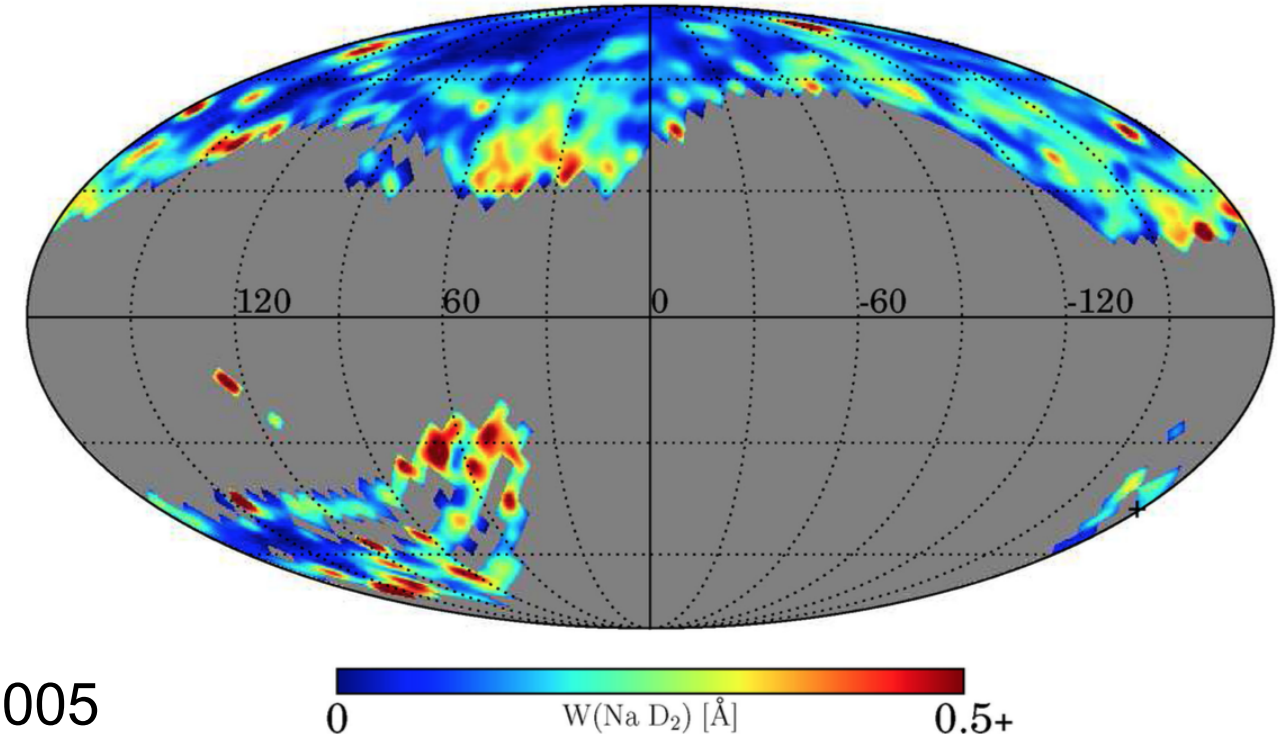


Figure 1. Examples of stacked continuum-normalized residual spectra of quasars (left-hand panel) and galaxies (right-hand panel) in four Galactic latitude bins. The red lines represent the best-fitting double-Gaussian profiles.

Maria Murga et al. 2005

Ca II H&K and the interstellar medium



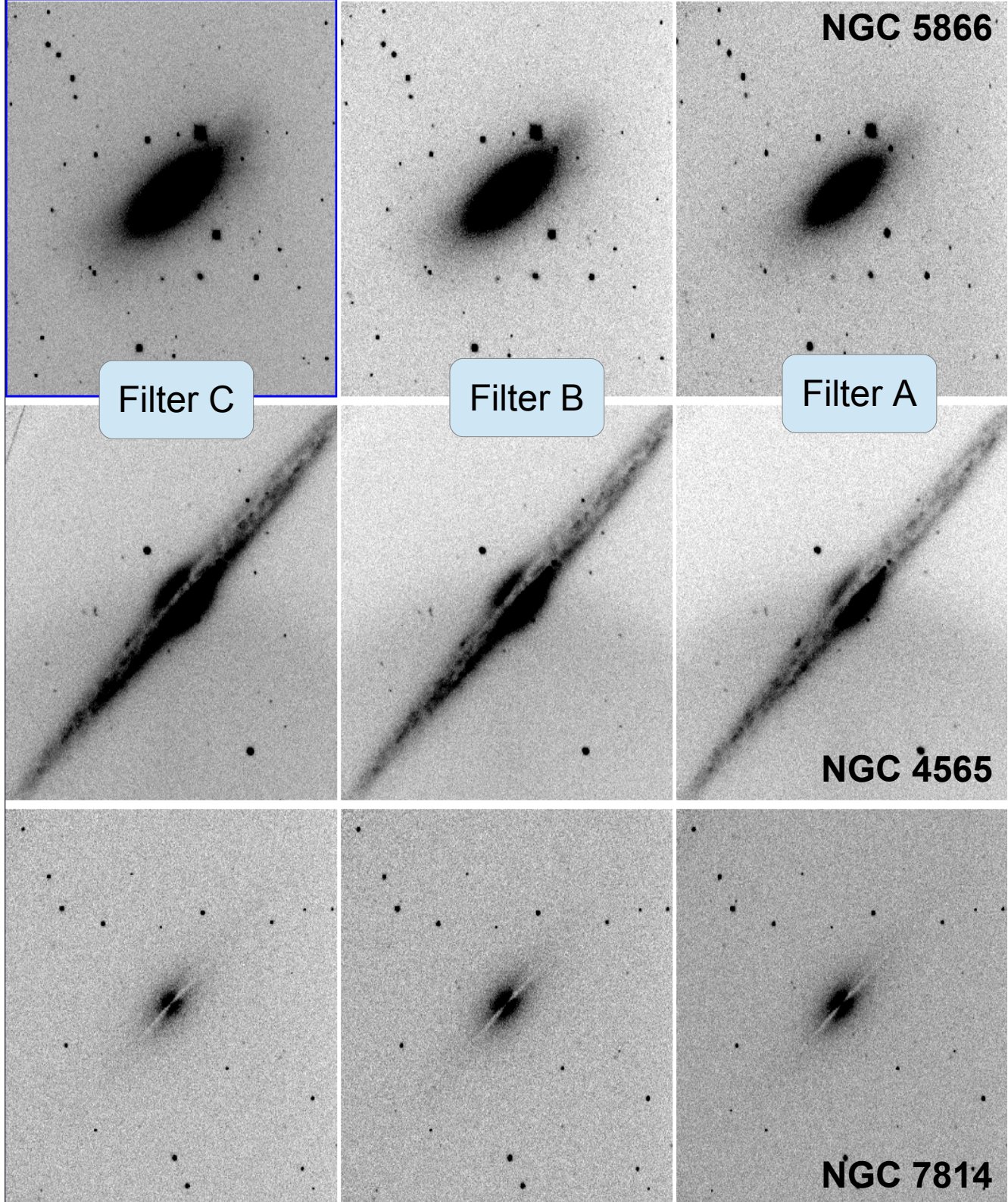


Maria Murga et al. 2005

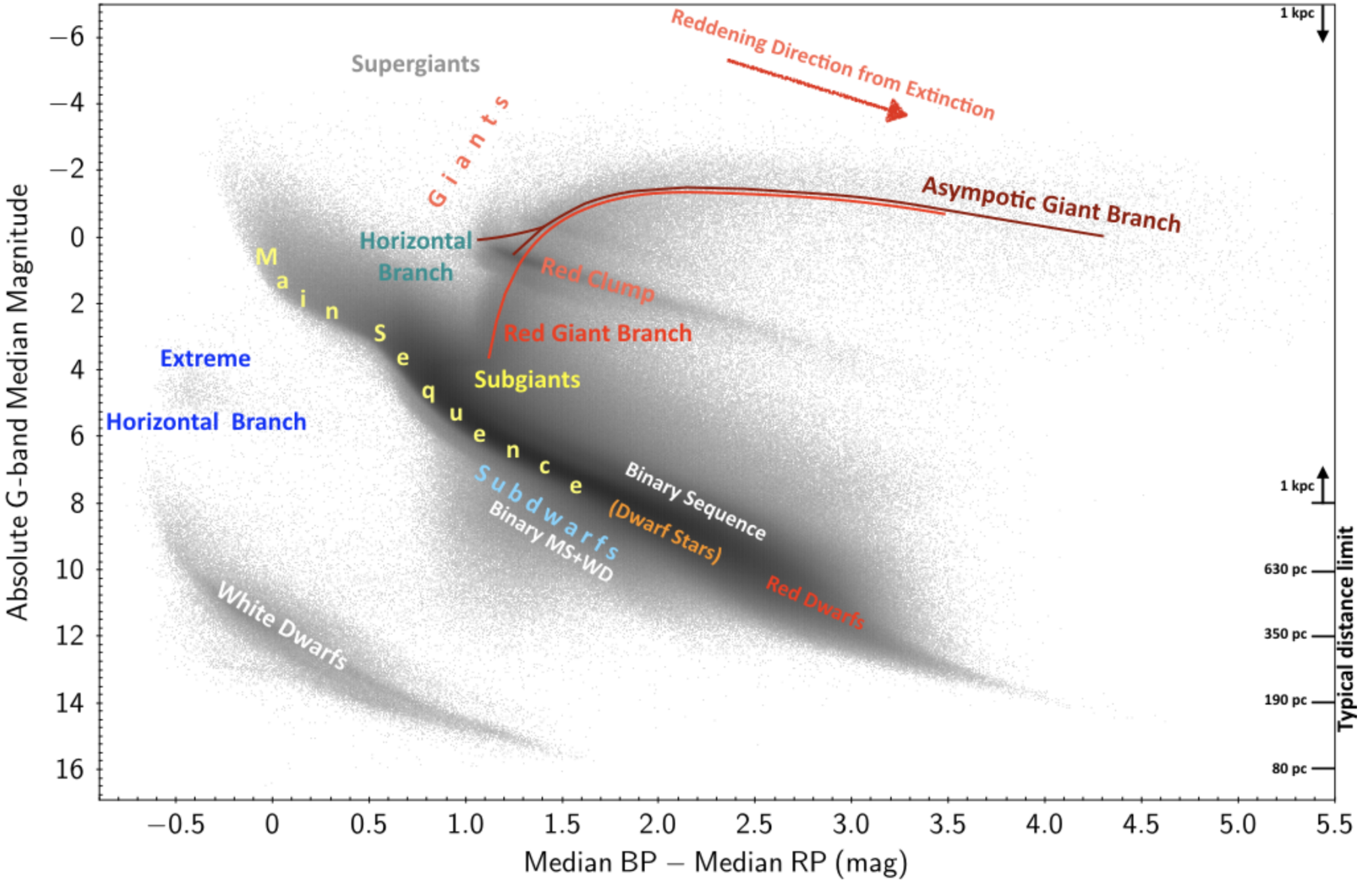
Conclusions

- Only photometry can be complete at G~17.5.
- [Fe/H] and [/Fe] estimates from narrow-band filters.
- Pilot program on its way.
- Can we study chemistry in other galaxies?

Observations @ SPM.

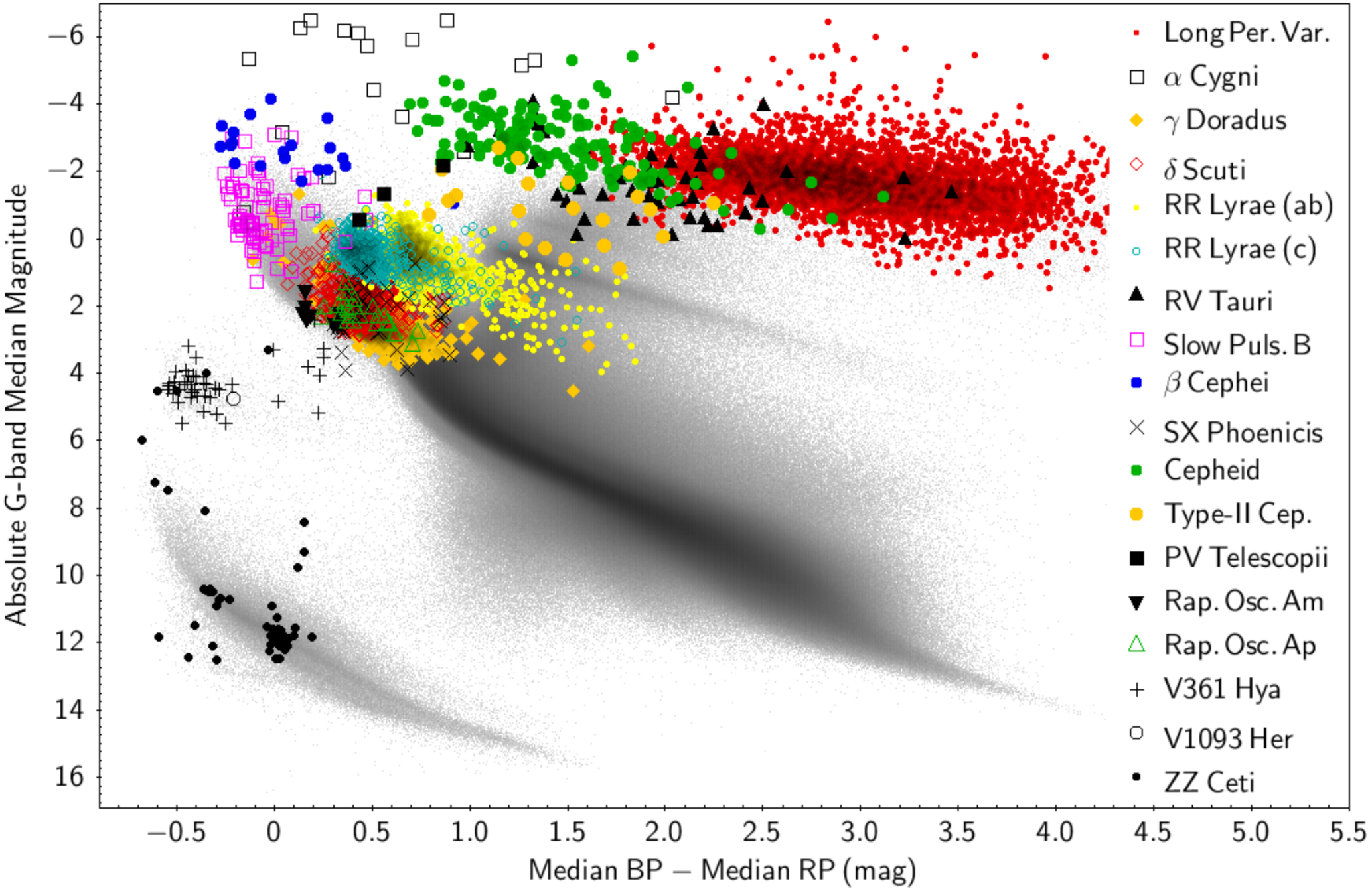


Gaia: reddened CMD

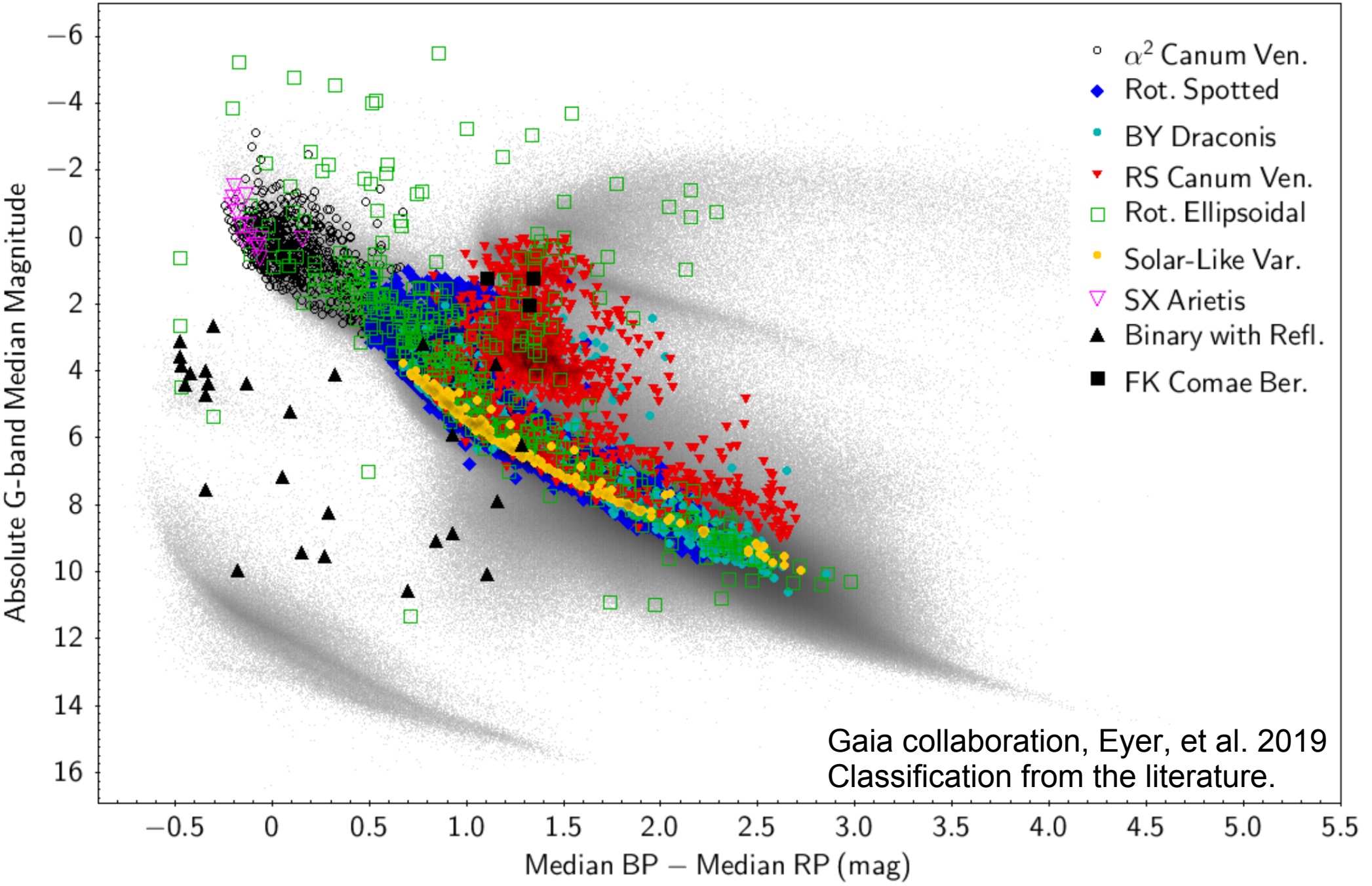


Gaia: pulsating variables

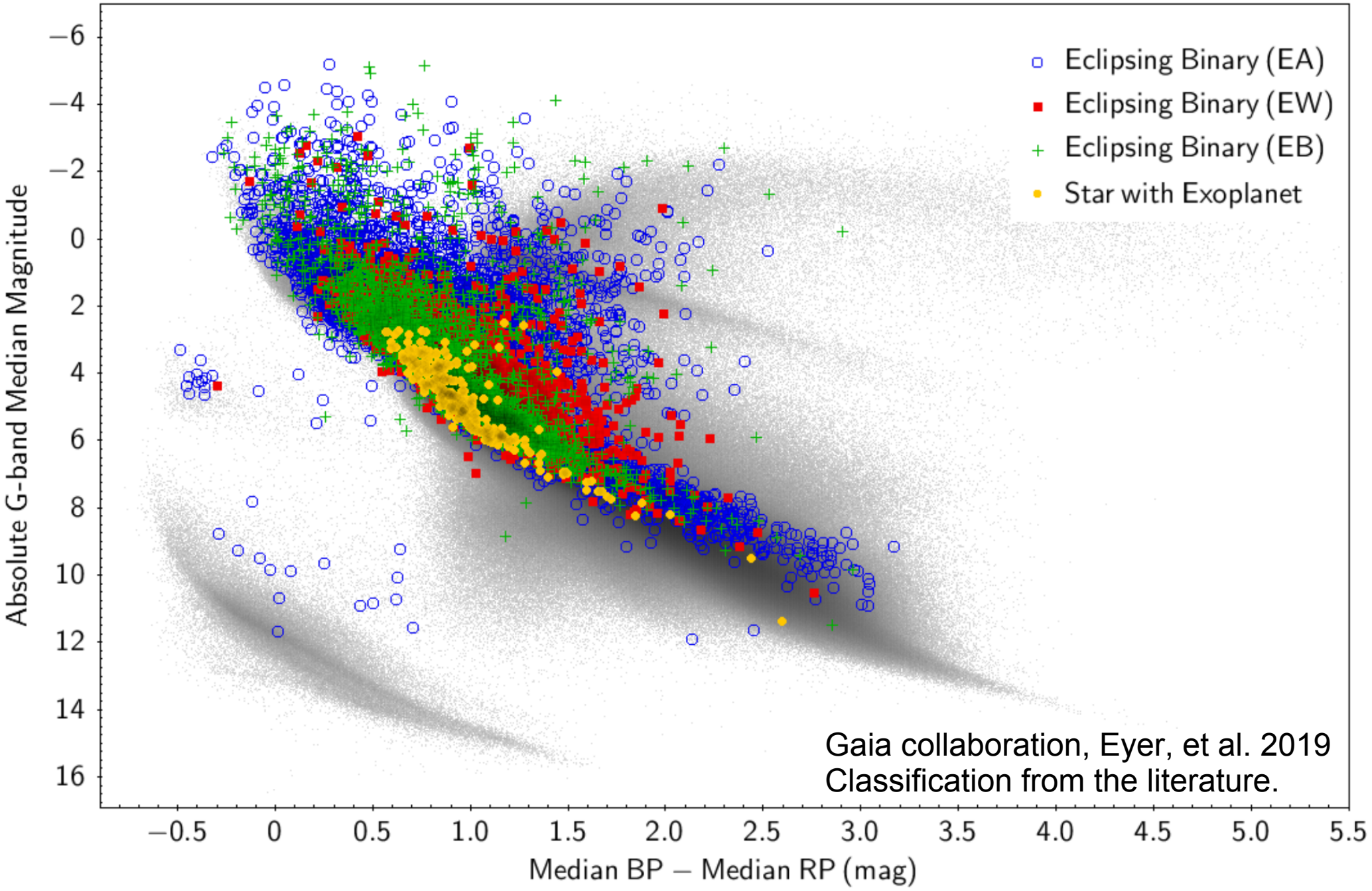
Gaia collaboration, Eyer, et al. 2019
Classification from the literature.



Gaia: rotationally induced variability

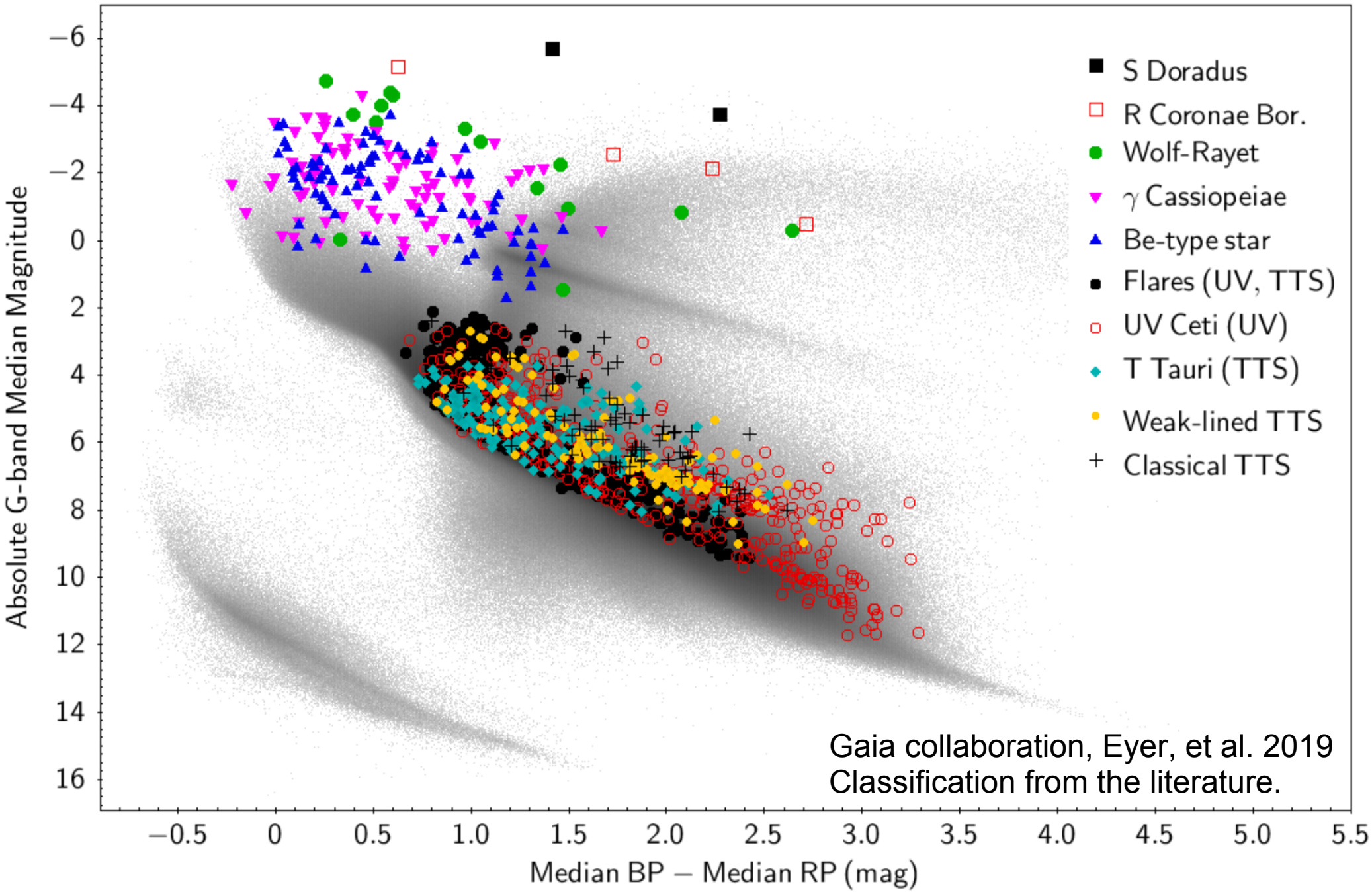


Gaia: eclipsing binaries



Gaia collaboration, Eyer, et al. 2019
Classification from the literature.

Gaia: eruptive variables



Gaia collaboration, Eyer, et al. 2019
Classification from the literature.

Gaia: cataclysmic variables