Gaia broad band photometry

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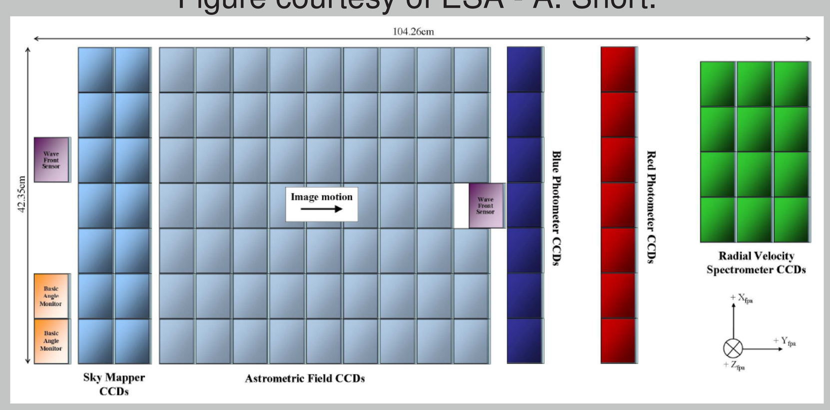
Abstract

The scientific community needs to be prepared to analyse the data from *Gaia*, one of the most ambitious ESA's space missions, to be launched in 2012. The purpose of this poster is to provide data in order to know in advance how *Gaia* photometry will be. To do so, we provide relationships among colours involving *Gaia* magnitudes (white light G, blue G_{BP}, red G_{RP} and RVS bands) and colours from other commonly used photometric systems (Johnson-Cousins, Sloan, Hipparcos and Tycho). These relationships were obtained using sources with different reddening values, range of colours, luminosity classes and metallicities. The provided dependencies among colours can be used for planning scientific exploitation of *Gaia* data, simulations of the *Gaia*-like sky, planning on-ground observations and for building catalogues with auxiliary data for the *Gaia* data processing and validation.

Gaia description

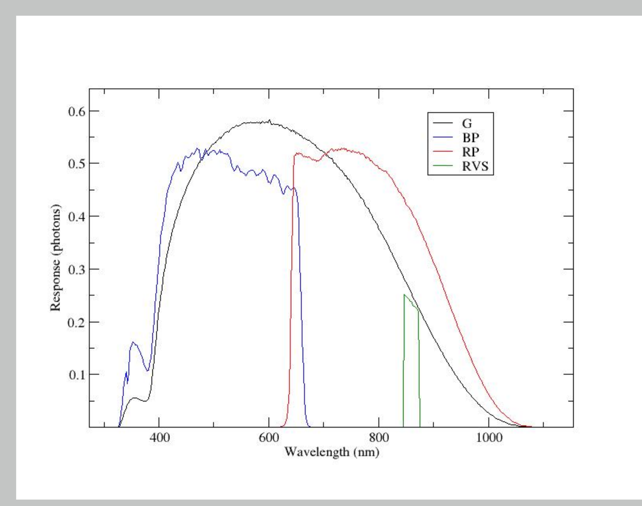
- ESA mission: Launch 2012
- Orbit: Sun-Earth L2 (Lissajous)
- Continuous scanning
- Mission lifetime: 5 years
- Two telescopes separated 106.5°
- Spin period: 6 h
- Sun/spin axis angle: 45°
- Non-deployable, 6-mirror, SiC optics
- 106 TDI CCDs (4500 × 1966 pixels)
- Astrometry, high resolution spectroscopy in Ca IR triplet and spectrophotometry (from 350 to 1000 nm)
- Astrophysically driven payload:
- faint stars, to G=20 mag (V ∼ 20–25 mag).
- radial velocities (RVS)
- spectrophotometry (BP/RP): chromaticity, astrophysics
- Complete and unbiased sample
- Average total observations/object 2 × 40

Figure courtesy of ESA - A. Short.



- Entrance pupil 1.45 × 0.5 m²
- Optical transmission > 0.86
- Pixel size 10 × 30 μm²
- Pixel size (angular) 59 × 177 mas²
- Sample size (in pixels) 1 × 12
- Number of CCDs in AF 9 × 7
- Number of CCDs in BP/RP 2 × 7
- Number of CCDs in RVS 3 × 4
- TDI integration time per chip 4.42 s

Gaia will chart a 3D map of the Milky Way. The main goal is to provide data to study the formation, dynamical, chemical and star formation evolution of the Milky Way (see Perryman et al, 2001). *Gaia* will measure positions, parallaxes, and proper motions for about 1 billion objects in our Galaxy (1% of the Milky Way stellar content) and throughout the Local Group. It will also observe the SED of the objects (BP/RP instrument) to derive their astrophysical properties (T_{eff}, $\log g$ and [M/H]).
The light rays coming from the two *Gaia* telescopes are dispersed in wavelengths, in BP/RP and RVS case. The viewing directions of both telescopes are superimposed on this common focal plane.
From unfiltered (white) light, *Gaia* will yield G-magnitudes.
The integrated flux of the two low-resolution BP and RP spectra will yield G_{BP}– and G_{RP}–magnitudes.



Band	G	G_{BP}	G_{RP}	G_{RVS}
λ_{min} (nm)	350	350	650	847
λ_{max} (nm)	1000	650	1000	874
λ_{o} (nm)	638	517	786	860
$\Delta\lambda$ (nm)	433	263	277	28

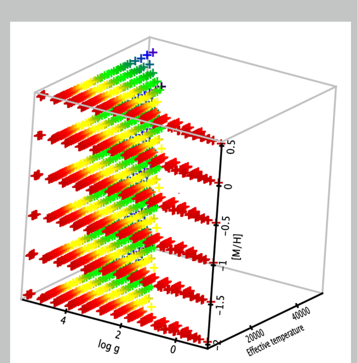
Photometric systems & Spectral libraries

We provide relationships between *Gaia*'s magnitudes and other photometric systems:

- the **Johnson-Cousins** photometric passbands (Johnson, 1963), which is one of the oldest systems used in astronomy,
- the **Sloan Digital Sky Survey** photometric passbands (Fukugita et al., 1996), and will be, used in several large surveys as UVEX, VPHAS, SSS, LSST... and
- finally, as *Gaia* is the successor of **Hipparcos**, and all its objects fainter than $V \sim 6$ mag will be observed with *Gaia*, we found it interesting to establish the correspondence between the two very broad bands of the two missions (Perryman et al, 1997).

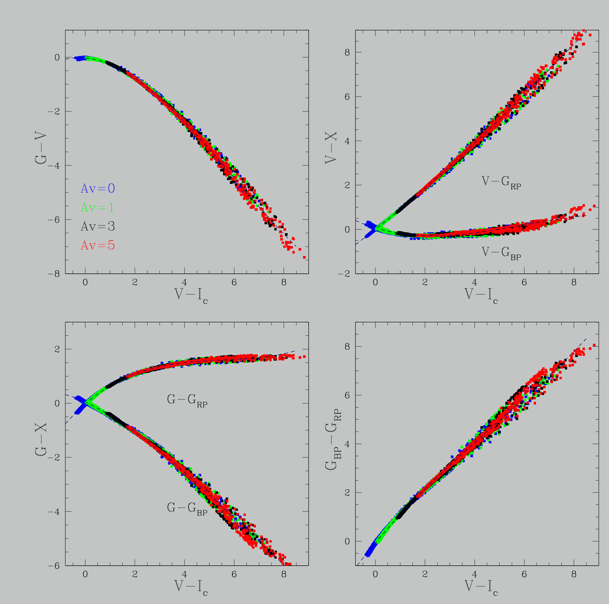
BaSeL-3.1 (Westera et al, 2002) synthetic SED library was used. The grid coverage is the following:

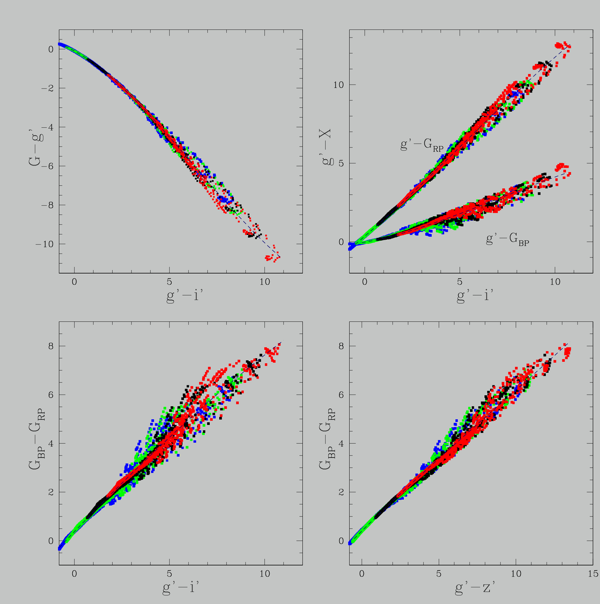
$2000 < T_{\mathrm{eff}} < 50000$ K
$-1.0 < \log g < 5.5$ dex
$-2.0 < \left[\frac{M}{H}\right] < +0.5$ dex
$\xi_t = 2$ km·s^{-1}
$9.1 < \lambda < 160000$ nm

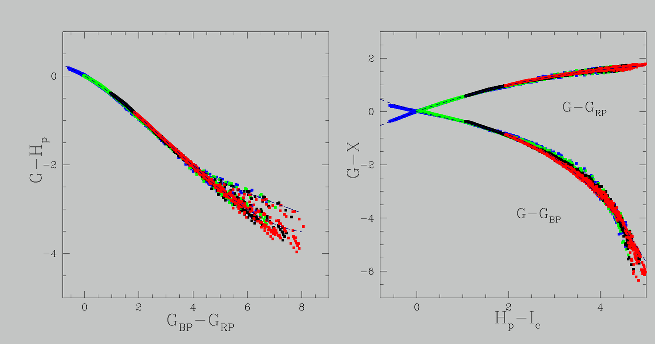


The SEDs have been reddened by several amounts ($A_{\mathrm{V}} = 0, 1, 3, 5$ mag) following Cardelli et al. (1989) reddening law and assuming $R_{\mathrm{v}} = 3.1$. Colours have been derived from synthetic photometry on all these created SEDs.

Transformations





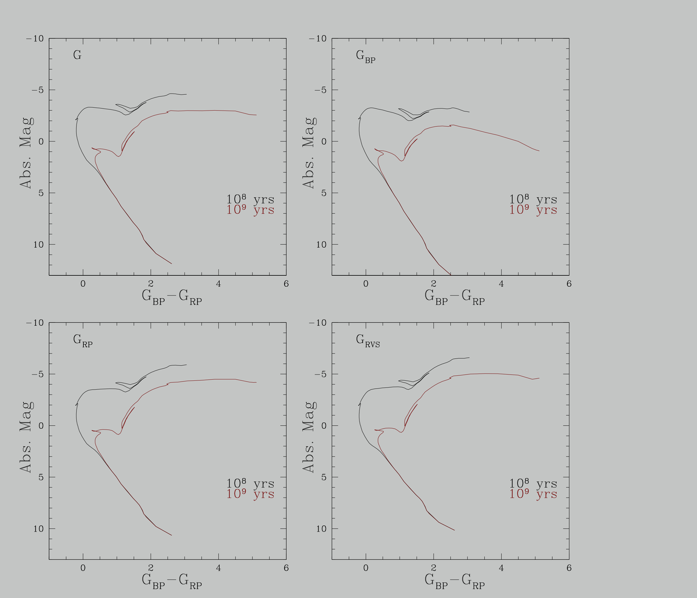


For the transformations that involve Johnson-Cousins colours, the relation with $V - I_c$ is the one that has the lowest residuals. The diagrams with the $B - V$ colour show large scatter, specially for $G - V$, $G - G_{\mathrm{BP}}$, $V - G_{\mathrm{RP}}$ and $G_{\mathrm{BP}} - G_{\mathrm{RP}}$. The same effects appears with respect to $B_T - V_T$. The residuals increase for $T_{\mathrm{eff}} < 4500$ K in all cases. Among these cool stars, scattering exists due to the surface gravity and metallicity. It is preferable not to use the transformation with $B - V$ or $B_T - V_T$ for the cool stars.

For the SDSS passbands, the relationships with $g' - i'$ colour are slightly more sensitive to reddening than with $V - I_C$. $G_{\mathrm{BP}} - G_{\mathrm{RP}}$ correlates better with $g' - z'$ than with $g' - i'$. These transformations yield residuals larger than with Johnson passbands. For stars with $T_{\mathrm{eff}} < 4500$ K, dispersions exist in gravity and metallicity for each absorption coefficient. This dispersion is more present in $g' - r'$ than in $r' - i'$.

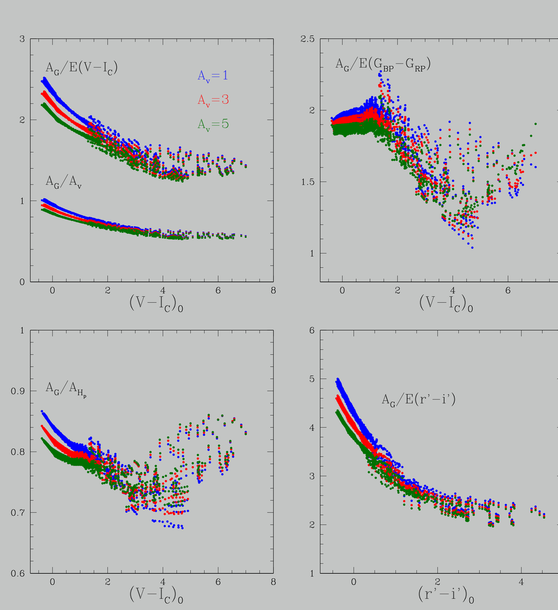
In case of Hipparcos passbands, we notice a small deviation from the main trend for $G_{\mathrm{BP}} - G_{\mathrm{RP}} \gtrsim 4$. This deviation is due to cool metal poor stars with $T_{\mathrm{eff}} < 2500$ K and [M/H]<-1.5 dex.

Isochrones



Padova isochrones (Marigo et al. 2008) computed in the *Gaia* passbands for solar metallicity and for different ages. Stellar tracks, isochrone files in the *Gaia* passbands are available as web interface at **(http://stev.oapd.inaf.it)**.

Reddening



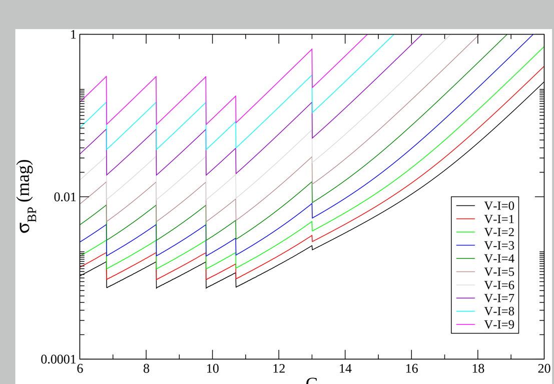
Absorption, A_G, and color excess, $E(G_{\mathrm{BP}} - G_{\mathrm{RP}})$, derived for *Gaia* magnitudes. The scattering that appears for $(V - I_C)_0 \gtrsim 1.5$ or $(r - i)_0 = 0.3$ (i.e. $T_{\mathrm{eff}} = 4500$ K) is due to the dependency in [M/H] and $\log g$.

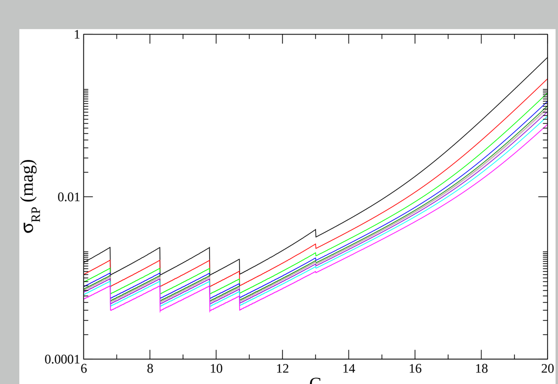
BP/RP Performances

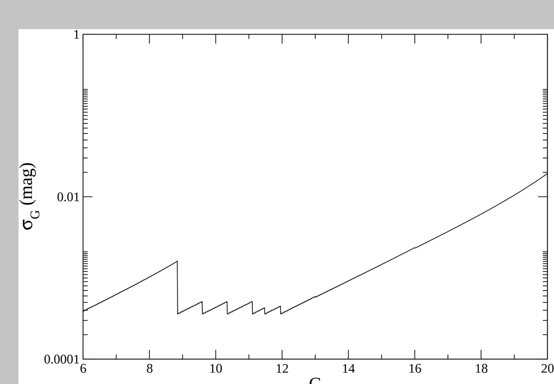
The magnitude error for a transit (σ_X) is computed taking into account:

- total detection noise per pixel (including Read-out noise),
- sky background derived from background pixels,
- contribution of the calibration error,
- total number of CCD per transit (9 for AF and 1 for BP/RP),
- total number of transits at the end of the mission derived from location in the sky (see table).

$\lvert\sin(\beta)\rvert$	β_{min} (deg)	β_{max} (deg)	N_{obs}
0.025	0.0	2.9	61
0.125	5.7	8.6	62
0.225	11.5	14.5	63
0.325	17.5	20.5	66
0.425	23.6	26.7	71
0.525	30.0	33.4	80
0.625	36.9	40.5	98
0.725	44.4	48.6	144
0.825	53.1	58.2	93
0.925	64.2	71.8	80
Mean	0.0	90.0	81







Conclusions

The characterization of the *Gaia* passbands (G, G_{BP}, G_{RP} and G_{RVS}) based on the last specifications provided by the industry was presented. Transformations between *Gaia* colours and the most commonly used photometric systems (Johnson-Cousins, Hipparcos, Tycho and Sloan) have been computed based on BaSeL3.1 stellar library and for different reddening factors. Relations involving Johnson-Cousins $V - I_C$ passbands are the one that show the lowest residuals. In case of SDSS system, the use of two colours decreases the scatter of the transformations. Independently of the choice of the passbands, some scatter exist due to metallicity and gravity effects, specially for $T_{\mathrm{eff}} < 4500$ K. The magnitude of this scatter varies from one passband to another. The shown dependences can be used to predict *Gaia* magnitudes for any star with it respective error.

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