Photometric Calibration of Astronomical Photo Plates by Gaia SED Fluxes

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Introduction

Time-domain astronomy, which studies the lifetime evolution and variability of cosmic objects, relies on long-term data collection from sources. A key focus of this field is on transients, phenomena that exhibit significant changes over time. Then, to fully leverage the valuable 140-year data captured on historic astronomical photo plates, improved photometric calibration is essential.

Aims

Improving the photometric calibration process by introducing a novel approach that addresses and overcomes the limitations and challenges associated with traditional color-term solutions.

Methods

Long-term photometry of the plates almost always lacks homogeneity and comparability of the data because of the use of different emulsions in series of observations. The difference in the color response of the emulsions makes a decisive change in the processing method of the plate in terms of color sensitivity [1].

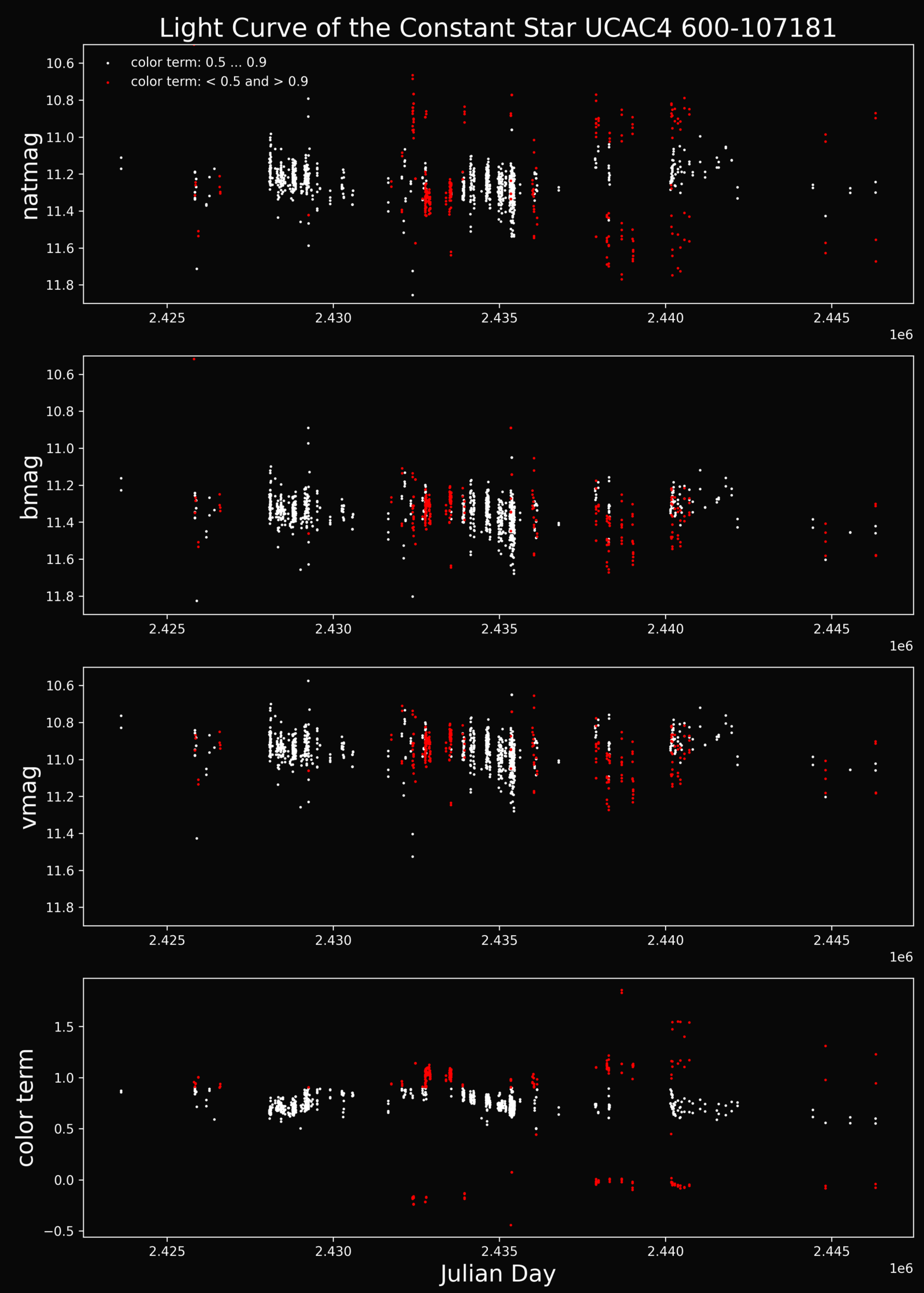
- Color Term Correction: A widely used approach

DASCH (Digital Access to a Sky Century at Harvard) project presented this method for avoiding plate offset by calibrating instrumental magnitudes to a standard system. The color term is defined as the color response of the emulsion and filter used, as described by [2]:

$$m_{cat} = B_{cat} + C\,(B_{cat} - V_{cat})$$

Where m_{cat} represents the magnitude of the stars in the reference catalog transformed into the plate system, B_{cat} and V_{cat} are the APASS Johnson B and V magnitudes, respectively, and C is the color term of the plate.

However, color term has limitations and potential sources of error that should be carefully considered.



The Figure shows the light curve of the constant star 600-107181 which obtained over 62 years of photometry using 616 photo plates from Applause DR3 archive.

The upper panel:
The calibrated magnitude of the star in the plate's natural photometric system.

The middle panels:
The star's Calibrated magnitude using UCAC4 and APASS catalog.

The lower panel:
The color terms of the plates.

The large variations of the light curve are correlated with color terms outside of the main peak.

Astrometric and photometric calibrations in this study are performed using the open-source Python package, **PyPlate** [3] .

- Synthetic Photometry: The Innovative Approach

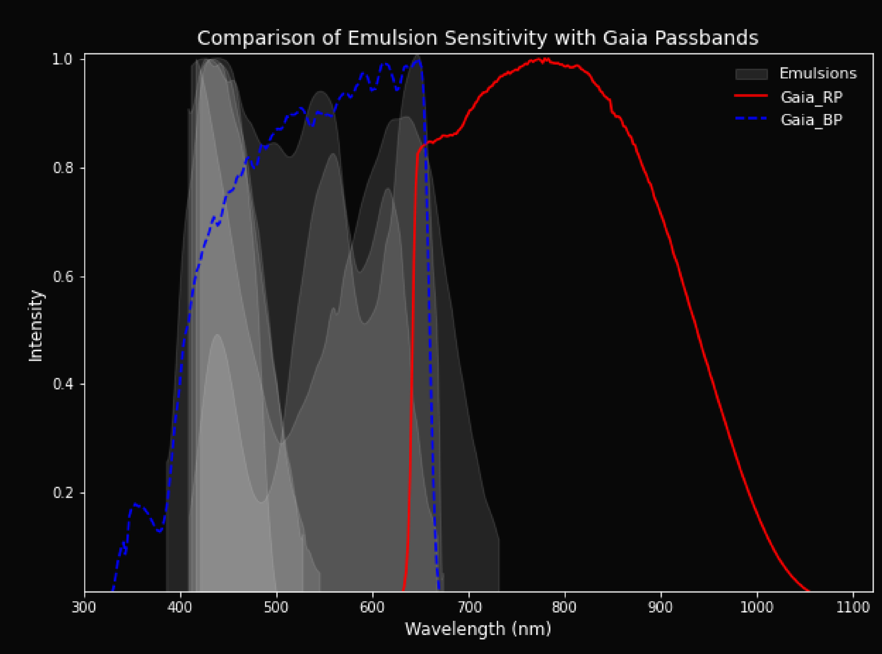
The linear correction of a color term concept is replaced with Spectral Energy Distribution (SED) data from the Gaia DR3 (ref) which includes low-resolution spectra obtained from the BP and RP spectrophotometry for over 220 million sources covering a wavelength range of 330 nm to 1050 nm (XP spectra), with magnitude G < 17.65.

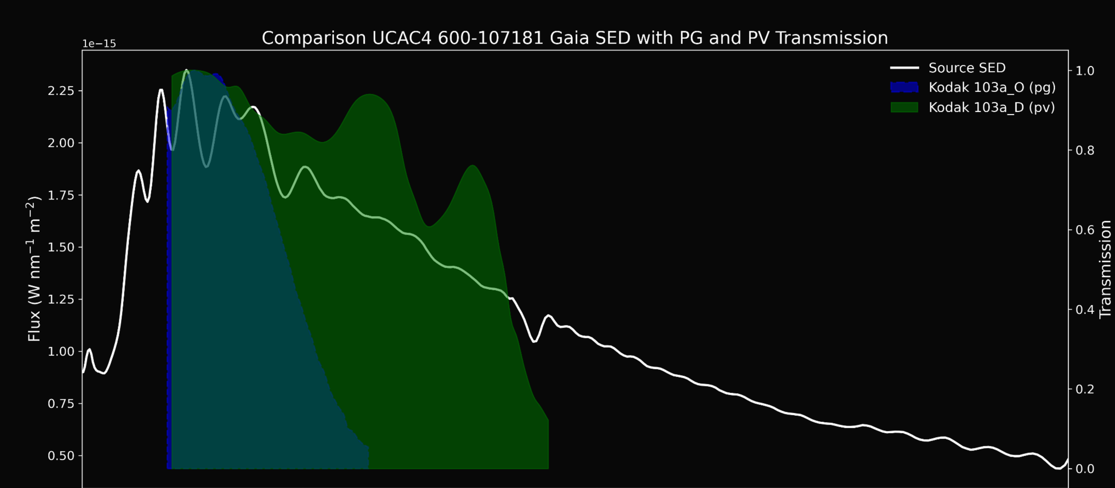
Using XP spectral data enables us to calculate the mean flux in any photometric system within the given spectral range [4].

$$< f_\lambda > = \frac{\int f_\lambda\,(\lambda)\,S(\lambda)\,\lambda\,d\lambda}{\int S(\lambda)\,\lambda\,d\lambda}$$

Where $S(\lambda)$ is the transmission curve of a plate and $f_\lambda\,(\lambda)$ the spectral energy distribution of a star. Wavelengths (λ) and energy flux per wavelength (f_λ) express in units of nm, and $W m^{-2} nm^{-1}$, respectively.

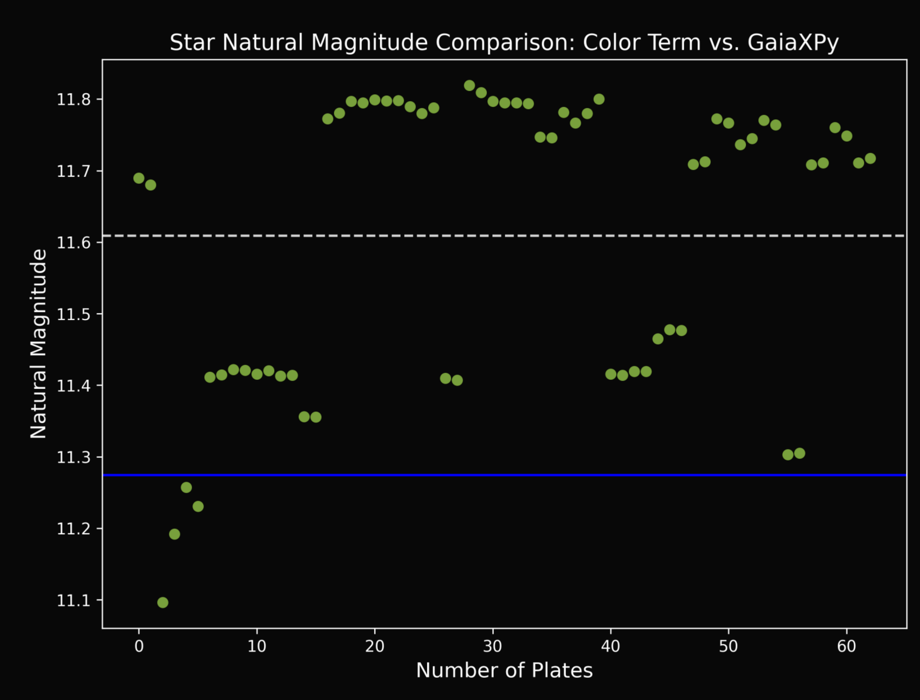
Spectral sensitivities of various PG and PV plates and the Gaia photometric system. The white area shows the spectral range of six different emulsion color responses that are sensitive to both red and blue passbands. Darker white shades indicate a higher number of emulsions, reflecting greater sensitivity at those wavelengths. The blue and red lines denote the Gaia blue and red photometer, in order.





The star SED compared with spectral sensitivity from typical pg and pv photo plates. Gaia BP/RP spectrum which is processed with GaiaXPy [5] is shown with a white line, while the filled plots in blue, represent the transmission curves of Kodak 103a_O emulsion (blue-sensitive), and the green-filled plot illustrates Kodak 103a_D emulsion (visible light-sensitive).

The plot shows the star's natural magnitude on blue-sensitive plates (green points) compared to the star's natural magnitude derived from the SED flux using GaiaXPy (blue line). A deviation of ~0.8 mag is observed, which exceeds the typical errors expected from the color term method.



Discussion

The color term concept has several limitations as relies on fitting procedures, though it is not a physical measure of the data. By applying Gaia SED flux, we dispose of color term drawbacks and resolve the problems in combining photometric results of photo plates with differing emulsions.

Star Formation Across Cosmic Time
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[1] Fröhlich H.E, et al., Astronomy and Astrophysics, v.391, p.659-663, 2002.
[2] Laycock S, et al., The Astronomical Journal, Vol. 140, p. 1062, 2010.
[3] Tuvikene T, Edelmann H, Groote D, Enke H, Astroplate proceedings, p. 127, 2014.
[4] Montegriffo P, et al., Gaia Data Release 3, eprint arXiv:2206.06215, Jun 2022
[5] De Angeli F, et al., Astronomy & Astrophysics journal, arXiv:2206.06143v1, July 2022