Delsimi: A Simulation Code for Delphini-1 Images

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1 Delsimi

This protocol forms the documentation of the author's work on the Delphini-1 satellite, a simulation of astronomy images from orbit, completed during the course *Delphini-1, Software and Satellite Operations* which the author followed as an extra-curricular project. The simulation is designed to create images with which to evaluate the potential of various photometric methods. This work describes the contemplations behind the crucial elements of the simulation.

1.1 Source Code

The delsimi Python 3 code is available at the online repository `https://github.com/jonasshansen/delsimi`. Here a README file explains the basic structure of the code and how to run it. A requirements file is included in the repository with a list of packages required for running the file. These packages can e.g. be installed in a virtual environment.

1.2 PSF and Pixel Integration

The point spread function (PSF) of Delphini-1 is unknown. As a crude approximation, a two-dimensional Gaussian is used in this simulation. The Gaussian PSF is sampled at subpixel resolution and interpolated. Smear due to the lack of pointing on Delphini-1 is introduced by convolving the subpixel PSF with a line kernel of the same dimensions. The line end and starting points are limited to integer positions in the subpixel resolution due to the package used, but this error can be reduced with sufficient oversampling.

The subpixel, smeared and normalized PSF is then interpolated and integrated at the desired subpixel location and multiplied by the stellar flux to yield the final smeared pixel response function (PRF) of a star. The Bayer filter is simulated here by scaling the pixel values depending on the color of the star and the position on the filter.

This structure, inspired by the TASOC photometry pipeline for the TESS satellite which the author is doing a master's thesis on, allows for the easy inclusion of a more accurate PSF in the future if desired.

1.3 Magnitudes

A realistic simulation of the stellar fluxes observed with Delphini-1 should take account of the Bayer RGB filter on the Aptina MT9T031 CMOS sensor of the NanoCam C1U. While summation binning of the 2×2 pixel Bayer filter structure yields greyscale images, the observed flux in each of the four RGB filtered pixels will be different for a non-uniformly colored source. Dependent on the extent of the PSF and the position of the star, this will most likely influence the flux levels in the binned pixels.

1.3.1 Absolute Flux Levels

1.3.2 Filter Transformation

A simple color transformation from the popular Johnson-Cousins UBVRI filters to RGB is applied using the results of Park et al. (2016, eqs. 1-3). Park et al. (2016) show that the Johnson-Cousins B, V and R values can be inferred from the Bayer RGB values R_B, G_B and B_B as follows:

$$B = B_{B_ZP} + B_B + C_{B,BG}(B_B - G_B) + C_{B,GR}(G_B - R_B) \ , \quad (1)$$
$$V = G_{B,ZP} + G_B + C_{V,BG}(B_B - G_B) + C_{V,GR}(G_B - R_B) \ , \quad (2)$$
$$R = R_{B,ZP} + R_B + C_{R,BG}(B_B - G_B) + C_{R,GR}(G_B - R_B) \ . \quad (3)$$

The constants found by Park et al. (2016) are repeated here for easy reference: $B_{B_ZP} = -0.291$, $C_{B,BG} = 0.280$, $C_{B,GR} = 0.600$, $G_{B,ZP} = -0.252$, $C_{V,BG} = 0.542$, $C_{V,GR} = -0.064$, $R_{B,ZP} = -0.226$, $C_{R,BG} = 0.051$, $C_{R,GR} = 0.468$. The constants are derived from ground observations of the open cluster M52, and constants B_{B_ZP}, $G_{B,ZP}$ and $R_{B,ZP}$ are the zero-points for the Bayer filters which, according to Park et al. (2016), vary with observing conditions.

The accuracy of this transformation for the purpose of estimating the scale of the Delphini-1 stellar fluxes is dubious due to the fact that Park et al. (2016) use ground-based photometry to infer relations eqs. (1) to (3). However, the inclusion of this effect is expected to have a significant effect on the final simulated image. The constant found by Park et al. (2016) are thus used for the transformation in order to include, if not the absolute, then an approximate relative flux difference between stars of different color.

Bibliography

Park, W., Pak, S., Shim, H., Le, H. A. N., Im, M., Chang, S., & Yu, J. 2016, Advances in Space Research, 57, 509 [ADS]