Converting From Gaia Magnitudes to LSST Photon Counts

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Gaia mags to SDSS mags

We start with Gaia bands G, G_{BP}, G_{RP} from the Gaia DR2 catalog. Then we use the regression from GAIA Data Release Documentation Section 5.7 to map these to the r-band SDSS magnitude m_{SDSS}:

$$\begin{aligned} m_{SDSS} = G &+ 0.12879 - 0.24662 \cdot (G_{BP} - G_{RP}) \\ &+ 0.027464 \cdot (G_{BP} - G_{RP})^2 + 0.049465 \cdot (G_{BP} - G_{RP})^3 \end{aligned}$$

SDSS mags to LSST photon counts

SDSS mags differ from an AB system at the few percent level in the r-band (SDSS Flux Calibration). In this analysis we treat it as a perfect AB system. SDSS lists magnitudes in Asinh, which asymptotically approach the classical magnitude relations for bright sourecs (SDSS Measures of Flux and Magnitude). In fact, for r-band magnitudes below 22.29, the asinh magnitude and traditional logarithmic magnitude differ by less than 1%. Since most of the sources we will use for donuts are well within this range, we employ the traditional formula in this analysis.

We start with the AB mangitude relation

$$m_{SDSS} = -2.5 \log_{10} \left(\frac{\int f(\nu)(h\nu)^{-1} S_{SDSS}(\nu) d\nu}{\int (3631 \ Jy)(h\nu)^{-1} S_{SDSS}(\nu) d\nu} \right)$$

where $S_{SDSS}(\nu)$ is the total (atmosphere + filter + detector) transmission curve for SDSS in the r-band. The zero-point magnitude is defined $m_z = 2.5 \log_{10}(\int (3631 \ Jy)(h\nu)^{-1} S_{SDSS}(\nu) d\nu)$. The value for the SDSS r-band is $m_z = 24.80$. We also make the assumption that $f(\nu) = \alpha B(\nu, T)$ where B is the spectral irradiance of a blackbody and α is constant. Then we have,

$$10^{(m_z - m_{SDSS})/2.5} = \alpha \int B(\nu, T) S_{SDSS}(\nu)(h\nu)^{-1} d\nu = \alpha h^{-1} \int B(\lambda, T) S_{SDSS}(\lambda) \lambda^{-1} d\lambda$$

We can solve for the constant f

$$\alpha = \frac{h \cdot 10^{(m_z - m_{SDSS})/2.5}}{\int B(\lambda, T) S_{SDSS}(\lambda)\lambda^{-1} d\lambda}$$

Now that we have the flux multiplier α, we can compute the LSST photon count by taking a similar integral over the bandpass and multiplying by the exposure time t_{exp} and primary mirror area A_{LSST} as follows

$$\begin{aligned} n_{LSST} &= \alpha \cdot A_{LSST} \cdot t_{exp} \cdot h^{-1} \int B(\lambda, T) S_{LSST}(\lambda)\lambda^{-1} d\lambda \\ &= A_{LSST} \cdot t_{exp} \cdot 10^{(m_z - m_{SDSS})/2.5} \cdot \frac{\int B(\lambda, T) S_{LSST}(\lambda)\lambda^{-1} d\lambda}{\int B(\lambda, T) S_{SDSS}(\lambda)\lambda^{-1} d\lambda} \end{aligned}$$

We precompute the ratio $\frac{\int S_{LSST}(\lambda)\lambda^{-1} d\lambda}{\int S_{SDSS}(\lambda)\lambda^{-1} d\lambda}$ for a range of temperature values to speed up the computation in 'transmission.py'. We interpolate between these cached values.