Algorithms to estimate infrared magnitudes of tip-tilt stars

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1 Introduction

We describe algorithms to estimate the H and K band magnitude of potential tip-tilt stars, to be implemented as a user-friendly web application available to TRICK users and other astronomers. We consider two cases. In § 2 we discuss an alogorithm of interest to the user when all they know are the coordinate of the target, and they need to find a nearby tip-tilt star based on public catalogs. In § 3 we discuss an algorithm of interest to the user when they have identified a potential tip-tilt star but they only know its magnitudes in bands other than H and K.

2 Estimate based on coordinates and public catalogs

The algorithm consists of the following steps.

1. The user enters a list of coordinates and a search radius.
2. For each set of coordinates the 2MASS database is searched. If a star is found within the search radius, its H and K magnitudes with errors are returned.
3. For each set of coordinates the SDSS database is searched. One can also search the SDSS-PT "standards" database, which extends the footprint a bit. See program findassm at

   `http://secure.lcogt.net/user/apickles/dev/assm/`

. If a star is found within the search radius, its psfmagnitudes d_j, with associated errors (σ_j) and galactic extinction g_j for each field are retrieved, where the index j identifies the filter. Note that the associated errors are typically underestimated by SDSS. Therefore we recommend multiplying the database errors by 6 4 2 3 3 respectively for the u' g' r' i' z' filters. The synthetic spectra library by Pickles (1998, PASP, 110, 863) is used to predict infrared magnitudes as follows.

For each star in the catalog i, the optimal normalization a_i is found by linear minization of the likelihood

$$a_i = \frac{\sum_j \frac{d_j - g_j - m_{ij}}{\sigma_j^2}}{\sum_j \frac{1}{\sigma_j^2}}, \tag{1}$$

where m_{ij} have been computed by Pickles & Depagne (2010, PASP, 122, 1437) and can be found here:

`http://secure.lcogt.net/user/apickles/dev/assm/LibMags`

The likelihood function of each star in the library is computed as

$$\mathcal{L}_i = \Pi_j \frac{1}{\sqrt{2\pi}\sigma_j} e^{-\frac{\left(d_j - g_j - m_{ij} - a_i\right)^2}{\sigma_j^2}} \tag{2}$$

The average predicted magnitude in the K band based on the K_i band magnitudes of each star in the library is then

$$\langle K \rangle = \frac{\sum_i (K_i + a_i)\mathcal{L}_i}{\sum_i \mathcal{L}_i} \tag{3}$$

and the associated uncertainty squared is

$$\sigma_K^2 = \frac{\sum_i (K_i + a_i - \langle K \rangle)^2 \mathcal{L}_i}{\sum_i \mathcal{L}_i}. \tag{4}$$

This procedure assumes that every star is equally probable *a priori* and could therefore be improved if one had knowledge of the stellar field in question. At this stage, however, a uniform prior appears to be sufficient for our purposes.

The same procedure yields also estimates of H and σ_H. Note that in the synthetic magnitudes files SDSS magnitudes are given in the AB system, as in the SDSS catalog, while HK magnitudes are given in the Vega system.

4. If no target is found in the SDSS footprint, the Guide Star Catalog II is searched as used as an estimate. Infrared magnitudes can be estimated to approximately 0.5 magnitude precision using the recipe developed by JWST and described by P. Chayer and E.P. Neylan in JWST technical memorandum JWST-STScI-001410.

3 Estimate from known magnitudes at other bands

A different situation is when the user has access to measurements of the tip-tilt star magnitudes in other bands and wishes to estimate the HK magnitudes. If the user provides a list of dereddened magnitudes with errors in any of the bands for which synthetic magnitudes have been computed by Pickles & Depagne (2010), the algorithm described above in step 3 of Section 2 provides an estimate of the HK magnitudes by replacing SDSS magnitudes with user supplied magnitudes.