PS1 Relative Photometric Calibration

Relative zero points for the PS1 images are determined by the photometric calibration algorithm of Schlafly et al. (2012), which refines the photometric calibration algorithm of Padmanabhan et al. (2008), used in the Sloan Digital Sky Survey. The throughput of the system is modeled with as a constant system throughput and atmospheric k-term each night. The model is determined by finding the parameters of the model that minimize the variance in flux of repeated observations of the same sources. The photometric calibration also simultaneously fits for a low resolution flat field correction vector and a trend in system throughput with PSF.

Contents

The starting point for the PS1 data archive is at The Pan-STARRS1 data archive home page.

Concept

The relative zero points for the PS1 survey are determined by minimizing the variance in the fluxes of repeated observations of the same stars, in the context of a simple model for the system throughput, as described in Schlafly et al. (2012). The relative zero points bring instrumental magnitudes onto a common scale, independent of the night on which they were taken, of the transparency of the night sky on that night, and of the location in the focal plane the star was observed.

The model has three basic terms: a nightly system zero point a; a nightly atmospheric transparency k; and a seasonal flat field f. The overall zero point is given by Z = a - k*x + f, where a is the system zero point on the night of the observation, k is the atmospheric transparency on that night, x is the airmass of the observation, and f is the term in the appropriate seasonal flat field for that observation. The terms of this model are determined by solving for the parameters a, k, and f that minimize the variance in repeat observations of the same sources over the course of the PS1 survey.

Components

The model treats the different filters completely independently, and so is, in effect, five separate independent models. Each model is composed of a set of a & k terms and a flat field vector f. Two additional parameters in each filter account for a small variation in measured flux as a function of PSF size.

"a" terms

Each night of the survey with observations in a given filter are fit with a constant "a" term, intended to give the telescope + camera throughput on that night. There are roughly 1000 nights of observations in any given filter in the PS1 survey, making for 1000 a terms fit in the model.

"k" terms

Each night of the survey with observations in a given filter are fit with a "k" term, which is intended to describe the transparency of the atmosphere on that night. The typical overall nightly zero points are determined by Z = a - k*x, where x is the airmass of a particular observation. There are again roughly 1000 k terms fit per filter, corresponding to each of about 1000 nights of observations in that filter.

Flat field

A flat field correction is fit simultaneously with the other parameters of the survey. The linear fit routines (i.e., SVD decomposition to perform matrix inversion) we adopt in the photometric calibration limits the number of free parameters we can fit simultaneously, which places a limit on the resolution we can achieve. We choose to split each PS1 chip into 4 quadrants, making for a 240 element flat field vector. We allow the flat field to vary with time, defining 5 "seasons" at which the flat field changes discontinuously: MJDs 54900, 55296, 55327, 55662, and 56110.

The rms of the overall flat field correction is about 15 mmag; the rms in the seasonal corrections to this overall flat field are only about 5 mmag.

Non-photometric data

The relative calibration model for the survey zero points is very rigid; ignoring relatively small flat field correction, it is composed of only two numbers per night. On nights where there is significant cloud coverage the atmospheric transparency varies dramatically on short time scales; such variation is not accommodated in this simple model. Accordingly, images taken in non-photometric conditions must be excluded from the simple model for the system throughput. Approximately 25% of 3pi images are excluded. These images are identified through their residuals; stars observed through clouds appear too faint relative to their mean magnitudes, and stars observed through patchy clouds additionally show high dispersion. The photometric calibration algorithm iteratively applies more and more aggressive clipping to remove images and chips with large mean residuals and large residual variances. Additionally, preliminary QA plots are inspected visually for signatures of non-photometric conditions, and non-photometric periods are marked by hand as bad, mostly to prevent the algorithm from trying to find one photometric image in a sea of non-photometric images on a night.

Some of this data can be recovered by assigning individual non-photometric images zero points that best bring them into agreement with the calibrated photometric data, though a significant amount of non-photometric data is very non-photometric, where a single zero point per exposure is not satisfactory. A night of imaging may be largely photometric with a few non-photometric periods; in this case, only the non-photometric periods are excluded from the calibration. Despite the very rigid model, for the 75% of images taken in photometric conditions, the model zero points seem to be very close to the true zero points. If we allow any individual image to float and solve for its zero point independently, forcing it to the global solution, the typical difference in zero point is <5 mmag, presumably stemming from unmodeled variations in the night sky transparency.

Application details

The operational application of relative zero points is non-trivial. PS1 single-epoch data (SMF files) are downloaded to Harvard and processed to obtain relative zero points. These zero points are adopted in the "relphot" analysis, which additionally solves for zero points of the non-photometric data by tying it to photometric data when possible, or by solving for a more relaxed photometric model (single zero point per exposure) when no photometric data is available . The relphot analysis derives zero points for the non-photometric data and together with the zero points determined above derives mean magnitudes for all stars in the survey, which eventually become the photometric portion of the PS1 reference catalog. Once a reference catalog has been constructed, future processed data is tied to the reference catalog using a single zero point per processing unit, which can be image or skycell depending on the product being analyzed. I'm not sure if the final single-epoch data making it to e.g. PSPS is calibrated in the sense that it has had the original relative zero point applied, or that it has been tied to the reference catalog, which used the original relative zero points. However, the difference between these two approaches is expected to be <5 mmag.

Absolute Calibration

The PS1 Absolute photometric calibration combines accurate measurements of the filter bandpass edges and throughput curves with measurements of HST Calspec standards with the PS1 system.