Palomar 200" LFC Reduction README

February 2015

1 Reduction

Reduction is performed in the usual way. Very few observation runs included darks, and most flats taken were dome flats. For consistency, we do not perform dark subtraction. Additionally, all flat fielding is done with dome flats, even if twilight flats were taken on a given night.

2 Astrometry, Alignment & Stacking

The astrometric solution for each field is found through two steps: (1) The *Astrometry.net* software returns a rough (though very good) WCS solution, and (2) IRAF's CCMAP task calculates a second order solution that hopefuly takes care of the small distortions and rotations at the chip's edges. We use SDSS astrometry as a reference. Astrometry was by far the most challenging step, and it is not perfect in all fields.

NOTE! The astrometry is best on the chip's top half. The astrometric solution is very poor near the bottom of the chip and can have problems very close to the chip edges. In some fields, the Palomar astrometry is significantly different from that in the WISP catalogs. **Be careful when matching Palomar and WISP catalogs. You may be missing many valid matches with a small matching radius.** Compare WISP.reg and Palomar.reg to check.

Images are stacked using IRAF's IMCOMBINE task and the crreject rejection algorithm. We only include images with perfectly consistent astrometry, at least on the upper half of the chip. We throw out images with (1) very poor seeing, (2) abnormally elongated sources, or (3) very few sources / an unusually high sky background due to clouds.

Multiplicative scale factors are calculated for each image from the airmass. The scale factor $= 10^{0.4\ \kappa_F\ X}$, where κ_F is the airmass coefficient calculated for the Palomar site[1] and filter F. Additive zero level shifts are calculated from the median value for each image. The readnoise, necessary for crreject, is estimated by binning the counts from an averaged bias frame. The mean of the resulting histogram is the bias offset and the width of the distribution is $\sigma_{ADU} =$ readnoise/gain $=$ FWHM.

If there are 2 filters observed that night, the images are aligned using the WCS in the headers and IRAF's task WREGISTER.

3 Calibration

For each field, the Palomar photometry is calibrated against the SDSS catalog. *SExtractor* is run in dual image mode on the combined Palomar images with 1σ detection and analysis thresholds. Such low thresholds are used to ensure that as much light as possible is included in each source's automatic magnitude. The Palomar catalogs are then matched with the SDSS catalog using a $1''$ matching threshold. We consider only SDSS sources with S/N$\geq$ 10 in both g and i.

Ater removing outliers, we calculate a zero point shift and – for fields observed with both g and i – a color term using the instrumental Palomar colors. The Palomar photometry is then calibrated by:

$$m_{calibrated} = m_{Palomar} + \alpha\ (g-i)_{Palomar} + zp, \tag{1}$$

[1]Taken from `http://www.ifa.hawaii.edu/~rgal/science/dposs/ccdproc/ccdproc_node3.html`, where $\kappa_g = -0.152$, $\kappa_r = -0.094$, and $\kappa_i = -0.07$.

Table 1: *SExtractor* Parameters

Parameter	Value
DETECT_MINAREA	5
THRESH_TYPE	RELATIVE
DETECT_THRESH	2.2
ANALYSIS_THRESH	2.2
DEBLEND_NTHRESH	32
DEBLEND_MINCONT	0.005
WEIGHT_TYPE	None
PHOT_APERTURES	30
PHOT_AUTOPARAMS	2.0, 3.5
PHOT_AUTOAPERS	0.0, 0.0
GAIN	GAIN $\times$ (total exptime)
BACK_SIZE	64
BACK_FILTERSIZE	3
BACKPHOTO_TYPE	LOCAL
BACKPHOTO_FILTERSIZE	24

where α is the color term and $zp = m_{SDSS} - m_{Palomar}$ is the zero point shift. Several plots are created to check the quality of the calibration. The last row shows the residuals of the calibrated data. For perfectly calibrated photometry, there would be no remaining color dependence and the solid line would have a slope of zero.

4 Final Catalog

If both filters are present, SE is run in dual image mode with the i band used for detection. SE parameters are listed in Table 1. SE is run with a zero point magnitude of 0.0, so that the zero point calculated in §3 can be applied to the photometry.

AUTO magnitudes are calibrated according to eqn. (1). We do not perform an aperture correction on the AUTO photometry. We checked the curve of growth for a variety of sources and could not determine a single correction factor for all types of sources. The percentage of light enclosed by the Kron radius depends on the Sersic index. (See, for example, Graham & Driver (2005).)

The limiting magnitude is determined for each filter by binning the flux calculated in 2.5" circular apertures placed randomly on the sky in the image. The distribution of fluxes is fit with a Gaussian and the σ is calculated. **All fluxes fainter than the 1σ limit are set to the 1σ magnitude,** and their uncertainties are set to 0.0.

The Palomar and WISP catalogs (fin_F110.cat, fin_F140.cat, fin_F160.cat) are matched with a matching threshold of 0.75". For some fields, the astrometry between the WISP and Palomar catalogs is off by more then 0.75" and 2.0" is used instead. This is indicated by a note in the field's README. In all cases, the images were visually inspected to confirm the quality of the matches.

In both output catalogs, photometry for filters that do not exist is set to 99.99 with -9.99 uncertainties. This is also true for the Palomar RA and Dec of sources in the WISP catalog there were not matched to a Palomar source.

5 Final Products

Palomar.cat Catalog of calibrated photometry. Only sources from the full overlap region of the combined image are included. Sources near the edges, where fewer input images are contributing to the combined stack, are excluded.

Palomar.reg Region file of sources in Palomar.cat

Palomar_WISPS.cat WISP catalog with matched Palomar sources. All NIR photometry available from the HST reduction is included.

README.txt Info on observations, reductions, stacking, and calibration for the given field.

result.fits SDSS catalog

sdss_calibration.dat Calibration information: color terms, zero points, and limiting magnitudes for each filter.

sdss_calibration.pdf Calibration plots showing the determination of the color terms, a comparison of the calibrated photometry with SDSS, and the residual slopes post-calibration.

(wispfield)_g_final_cat.fits Full, uncalibrated g band SE catalog

(wispfield)_g_final_seg.fits SE segmentation map, present only if g is the only filter present. If the field was observed with i as well, the images were run in dual image mode and the i band segmentation map is the only one produced.

(wispfield)_g.fits Combined g image, full chip

(wispfield)_g_WISPFOV.fits Combined g image, centered at WISP RA,Dec and trimmed to $3' \times 3'$

(wispfield)_i_final_cat.fits Full, uncalibrated i band SE catalog

(wispfield)_i_final_seg.fits SE segmentation map

(wispfield)_i.fits Combined i image, full chip

(wispfield)_i_WISPFOV.fits Combined i image, centered at WISP RA,Dec and trimmed to $3' \times 3'$

WISP.reg Region file of WISP catalog. Sources matched to Palomar are indicated by thick circles