Spacewatch 0.9m Mosaic Camera Survey, v1.0
spacewatch_data_reprocessing.pdf
Spacewatch 0.9m Mosaic Camera Survey Data Reprocessing
Document authors: Brucker, M. J.; Larsen, J. A.; Mastaler, R. A.; Bressi, T. H.; Read, M. T.; McMillan, R. S.
Date: June 23, 2021

REPROCESSING

The Spacewatch 0.9m Mosaic Camera Survey data are separated into a directory tree by year, then month, then day. All of the calibration files are together in a separate directory.

These data were reprocessed beginning in 2017. The reprocessing incorporated the following packages: SExtractor, SCAMP, SWarp, and MissFITS. In addition, the following were used: SAOImageDS9 v7.2, xpa, CDSclient, PLplot v5.9, CFITSIO and CFITSIO Perl wrappers (from a Fedora repository), PGPLOT with PGPLOT Perl wrappers, WCSTools, IRAF, Tcl/Tk (Tk-devel from a Fedora repository), and the Perl IO::Socket::INET module.

The first reprocessing step was to collect all of the exposures taken during a particular observing run, create a new directory tree structure, and copy the data to one of two computers devoted to the reprocessing effort. The reprocessing was handled using six different usernames simultaneously in order to isolate the IRAF processes. An observing run spans approximately 24 nights centered about a new moon, excluding the night of the full moon and its surrounding nights. The observing run number corresponds to the Brown lunation number (Brown 1933) that begins with the new moon in the center of the run.

To create a master flat and fringe correction for each observing run, 30 images from the run were selected randomly. They were dark-subtracted, normalized, and then median-combined. The median-combined image underwent a 200x200 pixel boxcar smoothing. The smoothed image was subtracted from the median-combined image. The smoothed image was used as the low-order master flat for the observing run. The difference image was used as the master fringe for fringe correction for the observing run.

For each image in the observing run, its underscan and overscan were used to determine dark and zero pedestal values, which were subtracted from the image. The image was flattened using the boxcar-smoothed master flat for the observing run as described above. Using the technique of Snodgrass and Carry (2013), a predefined set of “on pattern/off pattern” fringe points were scaled to the image to determine what amplitude should be used for the fringe. The scaled fringe was then subtracted from the image.

A preliminary astrometry list of objects was created by SExtractor from a rough catalog of objects with a detection threshold down to 2.5-sigma. That list was fed into SWarp along with a preliminary astrometry solution in order to generate a more refined astrometry solution. With the improved solution written to the FITS header, a final catalog was created with a detection threshold of 1.5-sigma by a second run of SExtractor.

The reported magnitude zeropoint in the headers was calculated by making a linear fit in magnitude between stars matched from our images to the USNO-B1.0 astrometry stars. The zeropoint of the fit, after two rounds of fitting the stars with 3-sigma rejection, was saved to the FITS header. An example of a very bad fringe feature on the image from one of the amplifiers and a final validation plot for each amplifier in the mosaic image that showed the x/y astrometry residual distributions were displayed so that the reviewer could evaluate manually the success of the image reduction. If an image was rejected, it was reprocessed by hand and resubmitted for validation. As a result, all images passed human validation before submission.

As a post-processing step, the mosaic images were divided into eight separate images by amplifier for archival purposes. Keywords relevant to archival storage were written to the FITS headers and XML labels were created. The nonstandard FITS header keywords included are described below.

EXTNM:
This is the pre-processing name for the amplifier extension in the mosaic CCD. Before reprocessing, the eight amplifiers were referred to as numbers 0 through 7. The XML labels refer to the amplifiers as numbers 001 through 008 where the XML amplifier number is equal to the pre-processing number plus one.

HISNSTAR, HISNXRMS, HISNYRMS, HISNCHI2:
HISNSTAR is the number of stars used to create the final astrometry solution using only stars with high signal-to-noise ratio (SNR). HISNXRMS is the root-mean-square (RMS) uncertainty in arcseconds along the x-axis for the astrometry solution using high SNR stars. HISNYRMS is the RMS uncertainty in arcseconds along the y-axis for the astrometry solution using high SNR stars. HISNCHI2 is the chi-squared value per degree of freedom for the astrometry solution using high SNR stars.

ALLSSTAR, ALLSXRMS, ALLSYRMS, ALLSCHI2:
These quantities are similar to HISNSTAR, HISNXRMS, HISNYRMS, and HISNCHI2 above but use an astrometry solution created with all stars regardless of SNR. This was not the adopted astrometric solution.

ROLLOMAG, ROLLOSNR, ROLLOFWHM:
ROLLOMAG (rollover magnitude) is the magnitude of the peak of the histogram of stellar magnitudes in the image. ROLLOSNR is the SNR at the magnitude of the peak of the histogram of stellar magnitudes in the image. ROLLOFWHM is the full width at

half maximum in arcseconds of stellar sources at the magnitude of the peak of the histogram of stellar magnitudes in the image.

Up to approximately magnitude 22, one can expect greater numbers of fainter stars than brighter stars. Due to detection limits, however, not every faint star is detected. A histogram of the magnitudes of stars detected in the image has a peak bin with the greatest number of stars in that magnitude range. Stars were binned in 0.2-magnitude-wide bins. The central magnitude of the bin with the greatest number of stars was recorded with the FITS keyword "ROLLOMAG" since the slope of the number count histogram rolls over at that magnitude. The detected object statistics were used to compute the SNR at the rollover magnitude in the image, denoted by ROLLOSNR. The FWHM was calculated using stars in the ROLLOMAG magnitude bin and was denoted as ROLOFWHM.

ROLLOMAG is highly affected by both weather and seeing. It can range from 16.0 on a miserable evening with clouds and/or high seeing to 21.7 under good conditions (this is the long-reported limiting magnitude of the survey).

LUNRPNLT in dex

The lunar penalty is a calculation of the change in sky brightness due to the moon compared to a dark sky. Using the brightness of the moonlit sky from Krisciunas and Schaefer (1991. *PASP* **103**, 1033-1039), the lunar penalty calculation also utilizes the phase angle of the moon, the angular distance between the moon and the target, and the phase of the moon.

References:

Brown, E. W. 1933. The Motion of the Moon, 1923-1931. *MNRAS* **93**, 603-619.

Krisciunas, K. and Schaefer, B. E. 1991. A Model of the Brightness of Moonlight. *PASP* **103**, 1033-1039.

Snodgrass, C. and Carry, B. 2013. Automatic Removal of Fringes from EFOSC Images. *Messenger* **152**, 14-16.