MIPS Optical Distortion Calibration

This document describes a method for calibrating the "effective" optical distortion projected onto the MIPS focal plane arrays as a function of scan-mirror angle. **This is required for the 24μm, 70μm (wide field), 70μm (narrow field) and 160μm operating modes.** The 70μm SED mode will require special treatment and will be considered later. The SSC pipeline development team will use this information to compute the distortion for arbitrary mirror angles using a robust interpolation scheme. This document does not necessarily represent a Software Interface Specification (SIS), it is primarily for peer review and feedback.

The standard FITS-compatible TNX representation for sky-projection and optical distortion will be adopted for the time-being. This will be replaced by the new and more general PV-TAN projection once it becomes ratified by the IAU. The main advantage of the algorithm below is that it computes a set of distortion model parameters in the desired TNX format *directly*. These can then be converted into the proposed PV format when needed. These parameters are defined in terms of the required standard FITS keywords for inclusion in image headers. This avoids possible uncertainties in converting (or re-mapping) from a generalized model-fit for the distortion (e.g. a low order two-dimensional polynomial fit) to the TNX format.

The current (tentative) strategy for IOC consists of acquiring dithered images of a single bright star at 9 uniformly spaced positions on the array for a *fixed scan-mirror angle.* Several scan mirror angles will be sampled for each band (and operating mode). The following algorithm is suggested for calibrating the TNX distortion parameters from this plan.

1. For a *fixed mirror angle* and given band, the pixel coordinates (to within 0.1 centroiding accuracy) of each stellar image on the array are found using IRAF, extracted interactively or otherwise.
2. Each extracted position (x, y) is associated with a sky pointing in RA and DEC provided by the PCRS. The corresponding PCRS pointings represent a set of "tangent" reference points on the sky whose offsets relative to each other are obviously not affected by optical distortion. The fact that they do not coincide with the stellar image centroids is irrelevant here. They simply define a distortion free "sky plane" onto which the "distorted" image plane is effectively mapped into.
3. The list of stellar centroids and corresponding PCRS pointings are listed in a table (for a fixed mirror angle) and used in IRAF's **"ccmap"** task to compute a plate solution. This task has various options for specifying the map projection and fitting function for the plate solution. A "TNX" projection with 2-d "polynomial" fit of order 3 should be used (10 coefficients in total).
4. The output from step 3 is a set of standard FITS keywords that specify the polynomial coefficients and type of map projection. These will be in the correct format to be used in all other downstream WCS/CFITSIO routines. Below is an example of a FITS header containing TNX distortion keywords.

5. The above process is repeated for all mirror angles over the range of interest and eventually, for all bands and operating modes.

Example of a FITS header containing TNX distortion keywords generated by the IRAF ***"ccmap"*** *task:*

```
ADECSYS= 'FK5     '
EQUINOX =                2000.
WCSDIM  =                   2
CTYPE1  = 'RA---TNX'
CTYPE2  = 'DEC--TNX'
CRPIX1  =                 128
CRPIX2  =             127.999
CD1_1   =         -0.000338152
CD1_2   =         -0.000034702
CD2_1   =         -0.000002670
CD2_2   =          0.000388354
LTM1_1  =                   1.
LTM2_2  =                   1.
WAT0_001= 'system=image'
WAT1_001= 'wtype=tnx axtype=ra lngcor = "3. 3. 3. 2. -0.01864261297364315 0.018'
WAT1_002= '64275952726732 -0.01955085100626601 0.01955152988929787 -4.339537016'
WAT1_003= '320153E-4 -1.160715148487726E-9 0.1317358092213299 -3.30519635511642'
WAT1_004= '2E-6 -0.05345735344205221 4.874350049071426 "'
WAT2_001= 'wtype=tnx axtype=dec latcor = "3. 3. 3. 2. -0.01864261297364315 0.018'
WAT2_002= '64275952726732 -0.01955085100626601 0.01955152988929787 -4.339537016'
WAT2_003= '320153E-4 -1.160715148487726E-9 0.1317358092213299 -3.30519635511642'
WAT2_004= '2E-6 -0.05345735344205221 4.874350049071426 "'
CDELT1  =          0.000389902
CDELT2  =          0.000389902
CROTA1  =          0.00000
CROTA2  =          0.00000
```