# Processing of MIPS-24μm Image Data at the *Spitzer* Science Center

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## The MIPS-24μm Detector

| Array Format | Field of View (') | Pixel Size (") | λ (μm) | F/# | λ/Δλ | QE | RN | Gain |
|---|---|---|---|---|---|---|---|---|
| 128x128 | 5.2x5.2 | 2.45 | 20.5 – 26.5 | 7.4 | 4 | 60% | 27e- | 5e/DN |

- This array was developed by Boeing and is a blocked impurity band Si:As device.
- It is continuously and non-destructively read out every 0.5 seconds until reset.
- Raw pixel data is in 16-bit signed integers
- Primary pixel data are received as slopes fit to on-board sample-up-the-ramp data (SUR mode).
- Data Collection Events (DCEs) are received as two-plane FITS cubes where plane1 = slope image, plane2 = difference of ramp sample2 - sample1, both in units of DN/0.5 sec.
- Optical layout is shown at right. PSF is sampled at a factor 1.4 above Nyquist.
- Scan mirror allows efficient dithering and mapping without overhead of moving S/C.

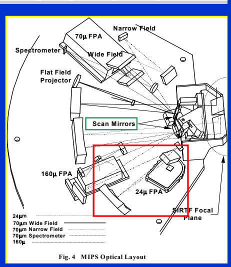
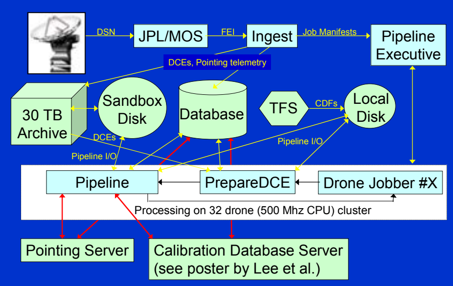
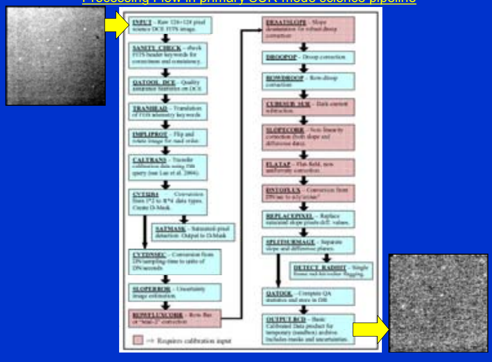



Fig. 4 MIPS Optical Layout

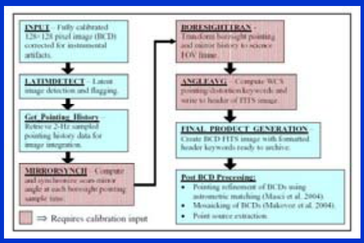
## Spitzer Downlink Data Flow at SSC




## Processing Flow in primary SUR-mode science pipeline



## Pointing Transfer Flow and Post-BCD steps



## 24μm Pipelines Summary

In total, there are thirteen (separate) automated pipeline threads for processing raw science Data Collection Events (DCEs) to produce Basic Calibrated Data images (BCDs) with pointing information:

1. SUR-mode science (2-plane DCEs input: slope + difference)
2. RAW-mode science (multi-plane DCEs: Either 6, 8, 20 or 60 plane data ramps)
3. SUR-mode dark-current calibration (pre-processing)
4. SUR-mode dark-current calibration (ensemble-processing of 3)
5. RAW-mode dark-current calibration (pre-processing)
6. RAW-mode dark-current calibration (ensemble-processing of 5)
7. Non-linearity calibration (pre-processing)
8. Non-linearity calibration (ensemble-processing of 7)
9. Flat-Field (non-uniformity) calibration (pre-processing)
10. Flat-Field (non-uniformity) calibration (ensemble processing of 9)
11. Latent image detection/flagging thread.
12. Boresight → FPA pointing transfer thread and Final Product Generator (FPG).
13. Pipe0 or "zeroth order" pipeline (for system validation and quick generation of raw translated headers with pointing.

Threads 4, 6, 8 and 10 produce calibration products required by science threads 1 and 2. The pipeline executive ensures that calibration products are made first during automated processing.

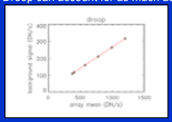
## Special Instrumental Signatures and Algorithms

"Droop" effect

This is a constant offset added to each pixel by the readouts and it not well understood. This signal is directly proportional to the total number of counts on the entire array at any given time. The constant of proportionality (termed the "droop coefficient") is derived empirically. For a droop coefficient $d$, total number of pixels on the array $N_{pix}$ and pixel signal $F_{ij}$ for pixel $i,j$ the droop signal is given by

$$F_d = \frac{1}{N_{pix}}\left(\frac{d}{1+d}\right)\sum_{i,j} F_{i,j}$$

The following shows a ground-test of the droop effect where one half of the array was covered (unilluminated) and the average signal therein was plotted as a function of the total array mean signal. Droop can account for as much as 10% of the pixel signal.



"Read-2" effect

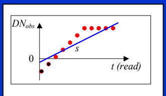
This represents a bias introduced into the SUR mode slope measurement by a small additive offset to the second read in the ramp (the first read is automatically ignored due to known reset transients). This additive offset varies across the array and has been empirically calibrated using RAW-mode (full sample) flight data.

Saturation flagging

Saturated pixels are identified and flagged in a bit mask according to the following:

**1.** If sample 2 – 1 difference ≥ *THRESHOLD VALUE* ("Soft" saturation condition).
**2.** If slope = 0 and difference = 0. This can arise if the ramp gets pegged to the maximum value allowed in the A-to-D (~30% full well) due to "immediate saturation". ("Hard" saturation condition).

In processing, saturated slope pixels are replaced with the corresponding difference value to recover more correct scan rates, at the expense however of a larger uncertainty for difference values. The following shows a ramp and slope fit for the soft-saturated case:




Non-linearity correction

Although applicable to all detectors, a simple algorithm as been developed for its correction (module SLOPECORR in science pipeline flowchart). The detector has been characterized by a quadratic non-linearity model:

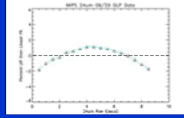
$$DN_{obs} = mt - At^2$$

The general solution for the linearized (corrected) slope in terms of the non-linear observed slope is given by:

$$m_{lin} = \frac{1-\sqrt{1-4Lm_{sur}}}{2L}$$

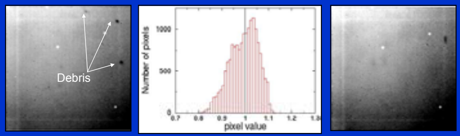
Where $L$ is a combination of non-linearity coefficients computed in the non-linearity calibration pipeline.

At right is a plot of % deviation from a linear fit to a RAW data ramp versus time. The maximum deviation is within +/- 2% of linearity for a 10 second exposure.



Scan-Mirror Dependent Flat-Fielding

- MIPS 24μm DCE images have dark spots and low-level "blotchiness" due to debris on a pick-off mirror in the scan-mirror mechanism. Consequently, these spots appear to move in images according to the position of the scan-mirror in an observation. Furthermore, these spots are smeared depending on the mirror scan rate.
- To correct the spotty images, high signal-to-noise flats are made for each scan-mirror position and applied accordingly to each image. The following are examples of some scan-mirror dependent flats. The spots and blotchiness introduce a deviation of ~20% from flatness.

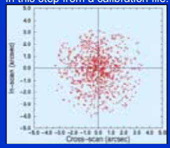



Photometry mode flat (scan rate = 0) | Photometry mode flat histogram | Medium scan rate flat

## Pointing Reconstruction & Performance

This is a four step process, all of which are carried out in a separate pipeline thread:

1. The 2-Hz sampled boresight pointing history telemetry file is searched for samples which fall within the effective integration time of the DCE (raw pointing history files span 12 hour blocks).
2. DCE scan-mirror positions are synchronized to the boresight pointing samples.
3. The detector FOV-to-boresight and FOV-to-mirror Euler angle offsets are used to transform the boresight pointing history to the FOV frame.
4. The 2-Hz pointing samples in the FOV frame are averaged to compute standard ICRS pointing keywords. Distortion keywords are also attached to FITS headers in this step from a calibration file.




Absolute pointing accuracy as measured from 24μm - 2MASS (2.2μm) astrometry is <1.2 arcsec (1σ radial). This is an upper limit since the scatter in this plot is expected to be dominated by source centroiding error.

## Processing Status Bit Mask

A 16-bit/pixel B-Mask (BCD-Mask) is associated with each BCD science product. This reports a summary of the processing steps for every pixel in the BCD. Bits are defined as follows:

| Bit # | Condition |
|---|---|
| 0 | Incomplete or questionable row-droop correction (rowdroop) |
| 1 | No row-droop correction applied (rowdroop) |
| 2 | Hard saturated (satmask) |
| 3 | Read-2 correction could not be applied (rowfluxcorr) |
| 4 | Corrected for soft saturation and slope value replaced by difference value (desatslope and satmask respectively) |
| 5 | Latent-image flag |
| 6 | Droop removed using questionable value (droopop) |
| 7 | Flat field applied using questionable value (flatap) |
| 8 | Flat field could not be applied (flatap) |
| 9 | Radhit detection (detect_radhit) |
| 10 | ----TBD---- |
| 11 | Pixel masked in pmask - bad hardware state (satmask) |
| 12 | Non-linearity correction could not be computed (slopecorr) |
| 13 | Soft saturated (satmask) |
| 14 | Data missing in downlink (cvti2r4) |
| 15 | <reserved: sign bit> |

## Archived Products and Deliverables

**Science BCD products (per processed DCE instance):**

- **tranhead.fits** (Raw DCE containing translated header with pointing)
- **bcd_main.fits** (main BCD product: slope image with saturated pixels replaced by values from difference image).
- **bmask_main.fits** (main processing status mask for main BCD image).
- **uncert_bcd_main.fits** (uncertainty image for main BCD image).
- **bcd_slope.fits** (main bcd slope image with pointing)
- **bcd_diff.fits** (slope image corresponding to above)
- **uncert_bcd_slope.fits** (uncertainty slope image).
- **uncert_bcd_diff.fits** (uncertainty for difference image)
- **bmask_slope.fits** (processing status mask for slope image)
- **bmask_diff.fits** (processing status mask for difference image).
- Processing and QA logs.

**Post BCD products (for ensemble of BCDs in a request):**

- mosaics, coverage maps, outlier masks (see presentation by David Makovoz)
- source extraction tables