MIRIS Data Analysis and Processing Status

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Outline

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**Instrument**

- **MIRIS = Multipurpose InfraRed Imaging System**
- Main payload of STSAT-3, launched on 2013 Nov. 20
- **SOC + EOC**
- **Orbit**
  - Sun-synchronous polar orbit
  - Altitude ~ 620 km
  - Eccentricity 0.002
  - Inclination 97.8 degrees
  - LTAN 22.3 o’clock
Instrument

Space Observation Camera

**Telescope**  Refractive with aperture of 8 cm

**Pixel scale**  $51''6 \times 51''6$

**Field of view**  $3^\circ67 \times 3^\circ67$

**Filters**
- Broadband: $I$ (1.1 $\mu$m) and $H$ (1.6 $\mu$m) bands
- Narrow band: Pa$\alpha$ line (1.876 $\mu$m), Pa$\alpha$ cont.
- Blank

Visible

$I$-band

$H$-band

Pa$\alpha$ line

Pa$\alpha$ cont.

<table>
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<th>$\lambda$ [nm]</th>
<th>0.2</th>
<th>0.4</th>
<th>0.6</th>
<th>0.8</th>
<th>1.0</th>
<th>1.2</th>
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<th>1.6</th>
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<th>2.0</th>
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<tbody>
<tr>
<td>$I$-band</td>
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<tr>
<td>Pa$\alpha$ cont.</td>
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<td>Pa$\alpha$ line</td>
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Origin of the cosmic infrared background

- Fluctuation
- Absolute brightness

← Survey of the pole regions (NEP, NGP & SGP) at 1.1-μm & 1.6-μm bands

Paα diffuse emission of the Galaxy

- Distribution of the ionized hydrogen gas with less extinction
- Comparison with Hα and far-IR observations

← Survey of the Galactic plane (GP) with narrow-band filters
Integration per frame: 2 seconds
- Limited due to the stability of the satellite attitude control
Integration for 10 frames, then reset the detector
- Dark current exposures for 4 (or 3) minutes, followed by sky exposures for 8 minutes
- All observations are done during the “eclipse”.
- Effective sky exposure time per observation: 8 min. × 9/11 = 6.5 min.
Main mission (2014 Mar.–2015 Mar.)
- Polar regions (NEP, NGP & SGP) wide field observations
- NEP monitoring observations
- Galactic plane Paα emission line survey

Targets-of-interest observations
- Large and Small Magellanic Clouds
- Nearby H II regions
- Star forming regions
- Comet, C/2014 Q2 (Lovejoy)

User request observations
- Dark cloud observations (Prof. Matsuura, Kwansei Gakuin Univ.)

SOC cooler stop (2015 May 22)
**Data Reduction**

- **socdr**: Data reduction pipeline for MIRIS SOC images
- **Python** and **Astropy** based
- Use external programs, *Astrometry.net, SExtractor* and *Montage*, for efficiency
- Time-consuming procedures are parallelized with MPI and Python’s multiprocessing module.

Components of socdr:
- **getfits()**: Wraps functions to query database and to convert raw data to FITS format
- **MainProcessing**: Class wrapping main processing components
- **PostProcessing**: Class wrapping post-processing components
Data Reduction

Data Retrieval

Obtain data from DB

Remove bad data

Collect 1-pointing data

Add header information

Output FITS image
**Data Reduction**

**Data Processing**

- Mask bad/saturated pixels
- Correct non-linearity
- Differentiate frames
- Remove stripe patterns
- Subtract dark current
- Correct flat-field

- Correct astrometry
- Correct temporal variation
- Stack frames
**Data Reduction**

1. **Register to DB**
   - MIRIS.dat (, ancil.)
   - Obtain data from DB
     - SOC0123456789.dat
   - Convert to FITS
     - HDUList

2. **MySQL Database**
   - obsid, observer, proposal, ...
   - Remove or fix bad frames
   - Remove data from reset frames
   - Convert raw header info. to meaningful values (time, filter, coordinates, etc.)
   - Make multi-HDU FITS file

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J. Pyo | MIRIS Data Analysis and Processing Status 11/30
Data Reduction » Main Processing

Mask bad/dead pixels
- Use pre-defined positions of bad pixels
- Set them NaNs

Mask saturated pixels
- Mask saturated (> 42,000 ADU) pixels
- Set them NaNs

Correct non-linearity
- Divide each pixel value with pre-defined correction polynomial
Mask bad/dead pixels

- Find bad/dead pixels by checking the linearity
- Also, mask out pixels with dark current > 0.5 ADU/s
- In total, 259 pixels were masked out.
Correct non-linearity

- Correction by dividing measured pixel values with 4th-order polynomial (derived from lab. data)
Differentiate frames
- Take difference between two subsequent frames

Remove stripe patterns
- FFT-based examination and removal of the stripe patterns

Subtract dark current
- Estimate dark current by fitting pre-dark data

Correct flat-field
- With templates derived from on-orbit data
Remove stripe pattern

- Unexpected stripe pattern in the on-orbit images

- Identical pattern in 4 quadrants of an image
  → Examine min.-combined quadrant to exclude sources
Remove stripe pattern

- FFT of each quadrant image

\[ \mathcal{R}(\mathcal{F}) \]
\[ \mathcal{I}(\mathcal{F}) \]
\[ |\mathcal{F}|^2 \]
Remove stripe pattern

- Subtract the FFT of min.-combined quadrant image from that of each quadrant after scaling it for each quadrant (only in the region around the peak power)

Result

Before

After
Dark subtraction

- Continuous decrease of dark current

Fitting an empirical function to pre-dark data taken during 3 min. with the filter blocked

→ Estimate dark current \((x)\) using derived parameters
Dark subtraction

- Dark “template” \((T_{ij})\) of spatial variation

- Subtract “scaled” dark template \((D_{ij})\) from images:

\[
D_{ij} = x + (0.6 + 4.4x)T_{ij}
\]
Flat-field correction templates
- Derived by median-combining observation images

$I$-band

$H$-band

PAAL filter

PAAC filter
Flat-field correction

Before

After

I-band

H-band
Data Reduction » Post-processing

**Correct astrometry**

- Use Astrometry.net and SExtractor
- Procedure is parallelized.

**Correct temporal variation**

- Correct the transient and long-term variations of background counts
- Use (MPI-enabled) Montage through montage-wrapper package
- Results are HDUs with:
  - Median-combined image;
  - Average-combined image; and
  - Image with each pixel whose value is the number of data stacked

**Stack frames**

HDUList
Correct the temporal variation of counts

- Variation of the measured (background) counts during the observation

**Data Reduction ➔ Post-processing**

**Outline**
- Instrument
- Mission
- socdr
- Issues
- Plans

**Correct the temporal variation of counts**

- **Variation of the measured (background) counts during the observation**

**Graphs**

- **MS1421157411 I-band**
  - Average count [ADU]
  - Data
  - $w/ \text{fitted par. } p_0 = 74.34, p_1 = 7.691, p_4 = 16.58$
  - $w/ \text{estimated par. } p_0 = 74.23, p_1 = 7.61, p_4 = 16.11$

- **MS1421163223 H-band**
  - Average count [ADU]
  - Data
  - $w/ \text{fitted par. } p_0 = 100.3, p_1 = 10.37, p_4 = 8.869$
  - $w/ \text{estimated par. } p_0 = 100.3, p_1 = 10.42, p_4 = 8.678$

- **MS1417288494 PAAL**
  - Average count [ADU]
  - Data
  - $w/ \text{fitted par. } D = 5.785, E = -0.002012$
  - $w/ \text{estimated par. } D = 0.913, E = 0.00202$

- **MS1417544176 PAAC**
  - Average count [ADU]
  - Data
  - $w/ \text{fitted par. } D = 9.082, E = -0.001716$
  - $w/ \text{estimated par. } D = 9.33, E = 0.002207$
Correct the temporal variation of counts

- Variation of the measured (background) counts during the observation
Correct the temporal variation of counts

- **I- & H-band**: Correct based on parameters from fitting to transient part

![Graphs showing corrected counts over time for I-band and H-band](image)

- MS1421157411 (I-band)
- MS1421163223 (H-band)
Correct the temporal variation of counts

- PAAL & PAAC: Correct based on the average of the first 50 points

![Graph showing corrected counts for PAAL and PAAC](image-url)
Issues » Stray Light

Sharp patterns due to bright stars
Sharp patterns due to bright stars

- More significant for $H$-band images
- Occurs with increase of background brightness
Background increment

- Caused by sources within $\sim 80^\circ$ from l.o.s.
Background increment

- Caused by sources within $\sim 80^\circ$ from l.o.s.
- All images with limb-to-l.o.s. angle $\lesssim 80^\circ$ are affected by Earth’s thermal radiation.
Part of some images are shadowed by the edge of filter wheel

Occurred from late March to early August, 2014

- 2014 Jul. 1
- 2014 Jul. 7
- 2014 Jul. 13
- 2014 Jul. 17
- 2014 Jul. 19
- 2014 Jul. 21
Complex, extended PSF of PAAC-filter image

Revealed in the image of Betelgeuse

- **I-band**
  - PAAL filter
  - PAAC filter

- **H-band**
  - PAAL filter
  - PAAC filter
Asymmetric, elongated PSF

- Elongated toward lower-right direction in the image coordinates

$I$-band

$H$-band
Issues » Other Issues

Absolute calibration
- Point sources
- Extended sources
- Background

Subtraction of PAAC images from PAAL
- PSF-matching between the two images
Future Plans

- Revise some components of data reduction pipeline
  - Flat-fielding templates
  - Count variation correction
- Data public release by end of June through the homepage
  - http://miris.kasi.re.kr