MIRIS Data Analysis and Processing Status

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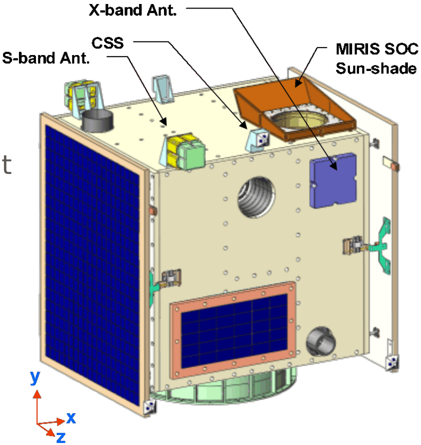
Outline

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

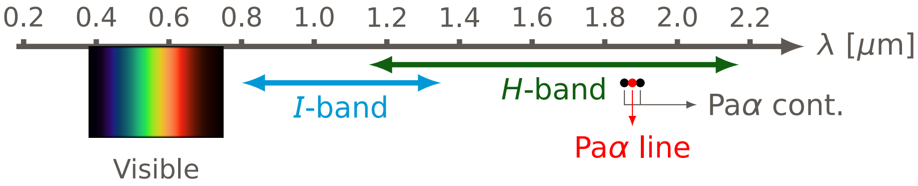
Space Observation Camera

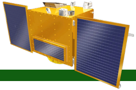
Telescope Refractive with aperture of 8 cm

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

Field of view $3^\circ.67 \times 3^\circ.67$

Filters
- Broadband: I (1.1 μm) and H (1.6 μm) bands
- Narrow band: Paα line (1.876 μm), Paα cont.
- Blank





Mission » Main Sciences

- **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

Mission » Observation Strategy

- 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: $8\,\mathrm{min.} \times 9/11 = 6.5\,\mathrm{min.}$

Mission » Status

- **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

1. Obtain data from DB
2. Remove bad data
3. Collect 1-pointing data
4. Add header information
5. Output FITS image

Data Reduction

Data Processing

1. Mask bad/saturated pixels
2. Correct non-linearity
3. Differentiate frames
4. Remove stripe patterns
5. Subtract dark current
6. Correct flat-field
7. Correct astrometry
8. Correct temporal variation
9. Stack frames

Data Reduction » Pre-processing

MIRIS.dat(, ancil.)

↓

Register to DB → **MySQL Database** (obsid, observer, proposal, ...)

Obtain data from DB ← MySQL Database

↓

SOC0123456789.dat

↓

Convert to FITS

- 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

↓

HDUList

Data Reduction » Main Processing

HDUList

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Mask bad/dead pixels

- Use pre-defined positions of bad pixels
- Set them NaNs

↓ HDUList

Mask saturated pixels

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

↓ HDUList

Correct non-linearity

- Divide each pixel value with pre-defined correction polynomial

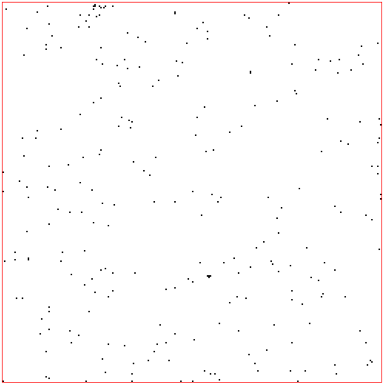
↓

HDUList

Data Reduction » Main Processing

Mask bad/dead pixels

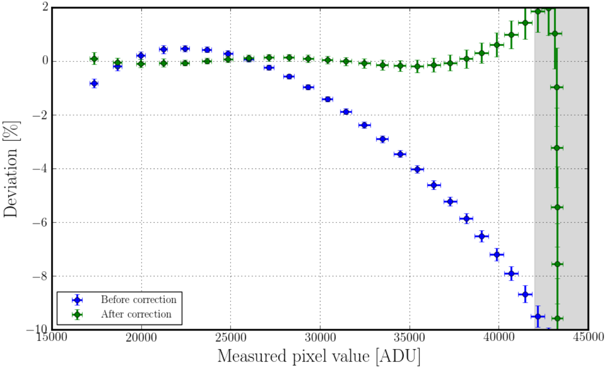
- Find bad/dead pixels by checking the linearity
- Also, mask out pixels with dark current $> 0.5\,\mathrm{ADU/s}$
- In total, 259 pixels were masked out.

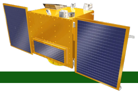


Data Reduction » Main Processing

Correct non-linearity

- Correction by dividing measured pixel values with 4th-order polynomial (derived from lab. data)





Data Reduction » Main Processing

HDUList

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Differentiate frames

- Take difference between two subsequent frames

↓ HDUList

Remove stripe patterns

- FFT-based examination and removal of the stripe patterns

↓ HDUList

Subtract dark current

- Estimate dark current by fitting pre-dark data

↓ HDUList

Correct flat-field

- With templates derived from on-orbit data

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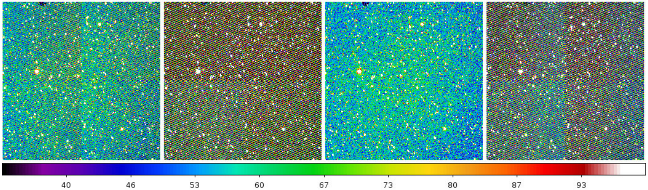
HDUList

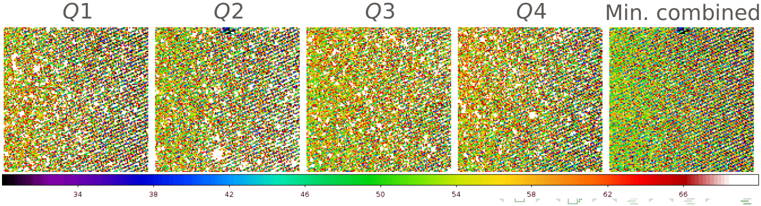
Data Reduction » Main Processing

Remove stripe pattern

- Unexpected stripe pattern in the on-orbit images



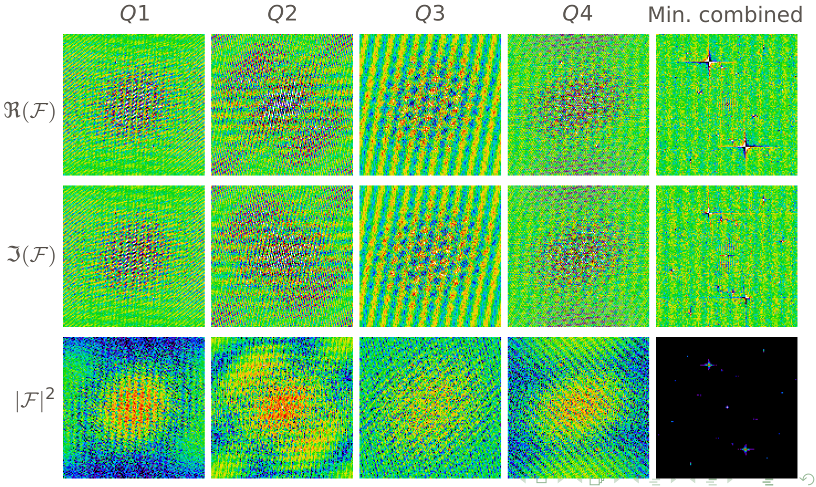
- Identical pattern in 4 quadrants of an image
  → Examine min.-combined quadrant to exclude sources



Data Reduction » Main Processing

Remove stripe pattern

- FFT of each quadrant image



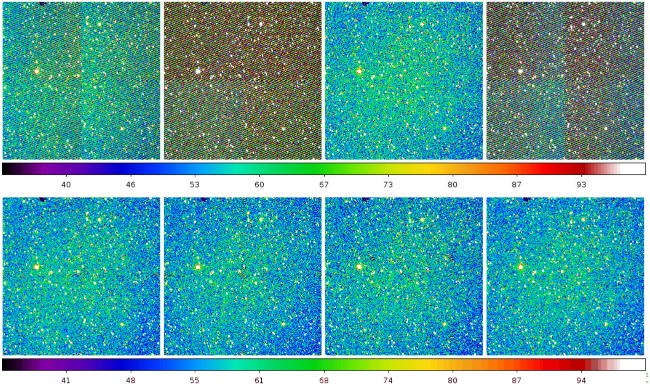
Data Reduction » Main Processing

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

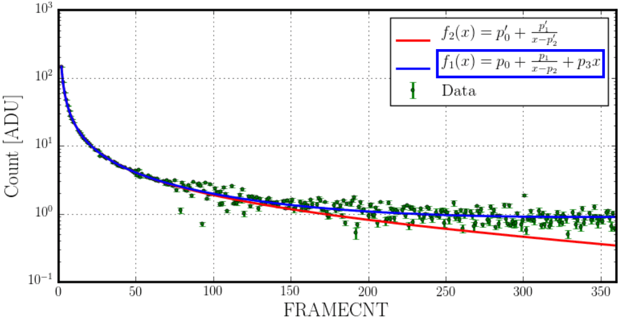
After



Data Reduction » Main Processing

Dark subtraction

- Continuous decrease of dark current

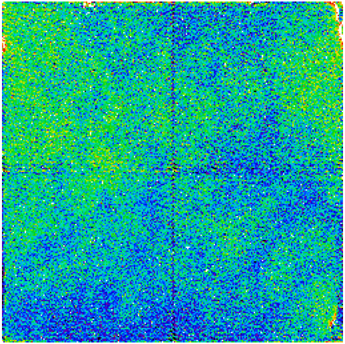


- Fitting an empirical function to pre-dark data taken during 3 min. with the filter blocked
  → Estimate dark current (x) using derived parameters

Data Reduction » Main Processing

Dark subtraction

- Dark "template" (T_{ij}) of spatial variation



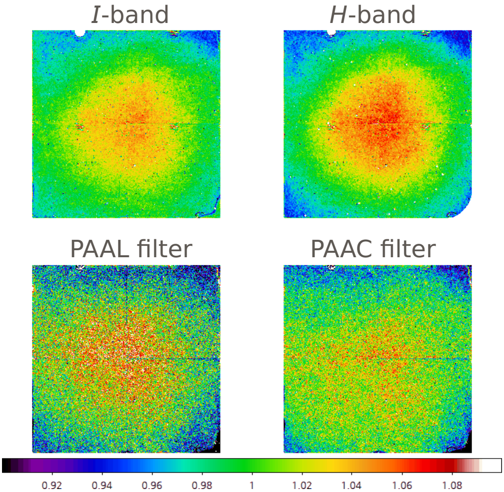
- Subtract "scaled" dark template (D_{ij}) from images:

$$D_{ij} = x + (0.6 + 4.4x)T_{ij}$$

Data Reduction » Main Processing

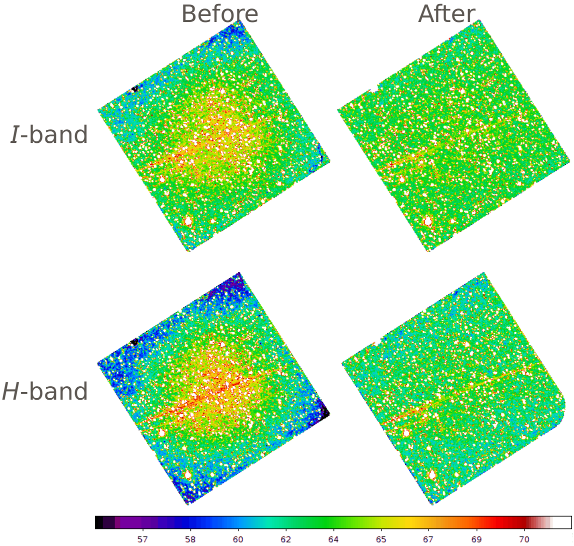
Flat-field correction templates

- Derived by median-combining observation images



Data Reduction » Main Processing

Flat-field correction



Data Reduction » Post-processing

HDUList

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Correct astrometry

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

↓ HDUList

Correct temporal variation

- Correct the transient and long-term variations of background counts

↓ HDUList

Stack frames

- 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

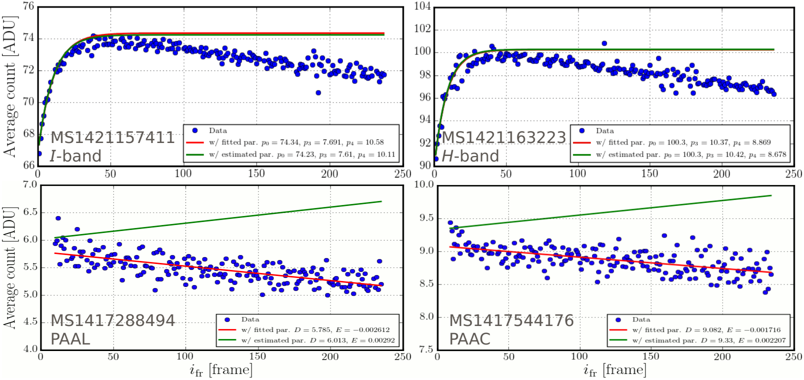
↓

HDUList

Data Reduction » Post-processing

Correct the temporal variation of counts

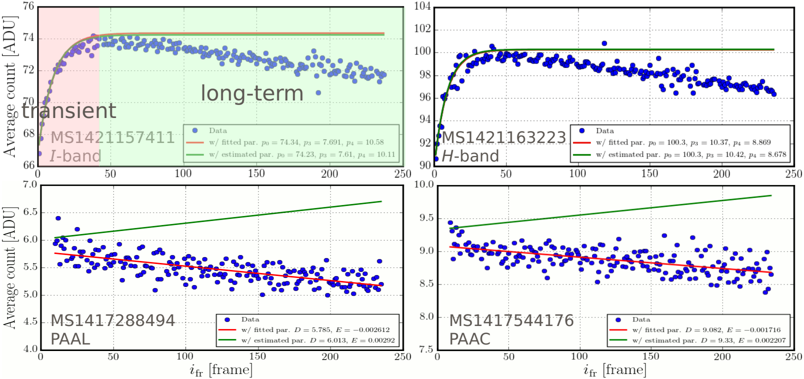
- Variation of the measured (background) counts during the observation



Data Reduction » Post-processing

Correct the temporal variation of counts

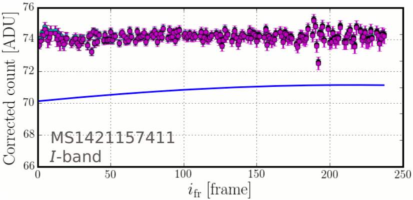
- Variation of the measured (background) counts during the observation

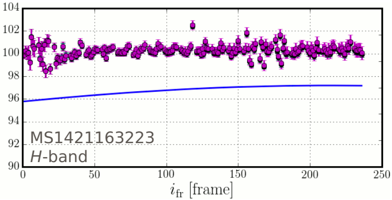


Data Reduction » Post-processing

Correct the temporal variation of counts

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

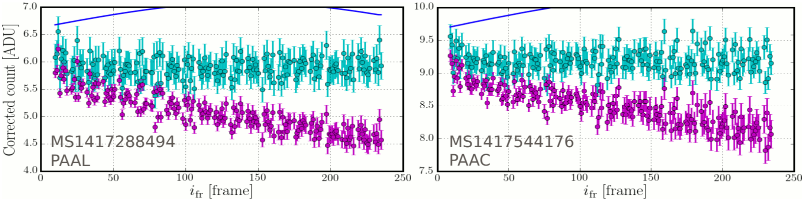




Data Reduction » Post-processing

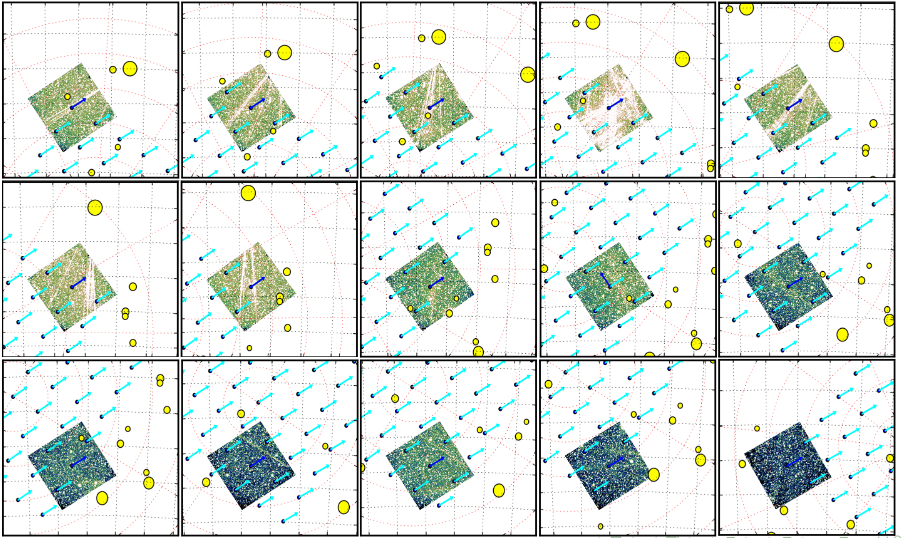
Correct the temporal variation of counts

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



Issues » Stray Light

Sharp patterns due to bright stars



Issues » Stray Light

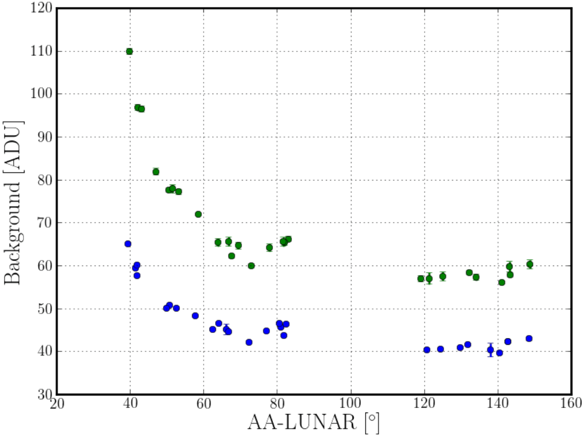
Sharp patterns due to bright stars

- More significant for *H*-band images
- Occurs with increase of background brightness

Issues » Stray Light

Background increment

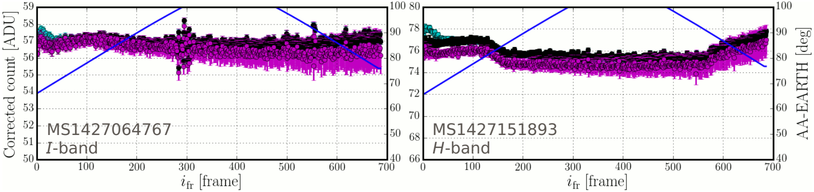
- Caused by sources within $\sim 80^\circ$ from l.o.s.



Issues » Stray Light

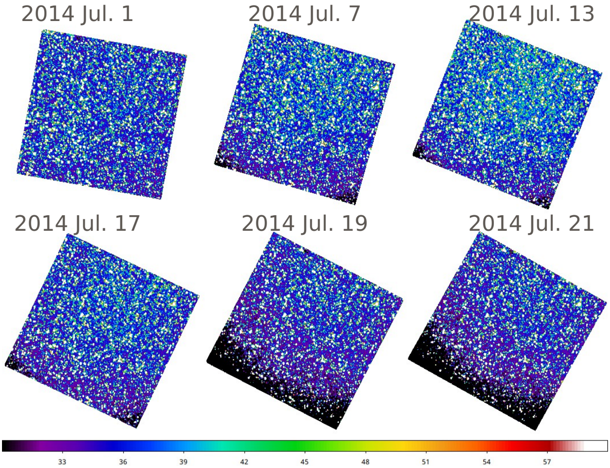
Background increment

- 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.



Issues » Filter Wheel Shadowing

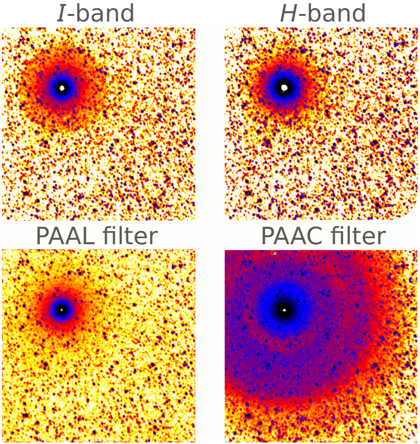
- Part of some images are shadowed by the edge of filter wheel
- Occurred from late March to early August, 2014



Issues » PSF

Complex, extended PSF of PAAC-filter image

- Revealed in the image of Betelgeuse



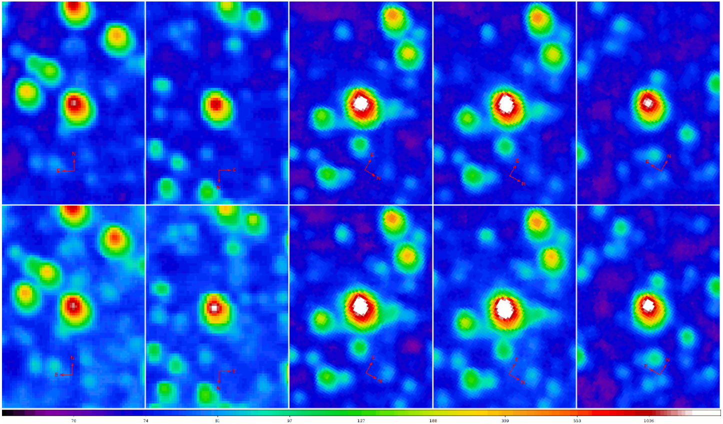
Issues » PSF

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