

STSAT-3

MIRIS System Introduction, Specification & Observation Plan

우주천문연구그룹

Korea Astronomy & Space Science Institute



MIRIS Project Summary

- **Objectives**
 - Space observation camera (SOC)
 - Pa- α emission line Galactic plane survey
 - Extragalactic Cosmic IR Background (CIB) observation
 - Earth observation camera (EOC)
 - Wide angle NIR imaging of Korean peninsula
 - Developing space IR technologies
- **Spacecraft : STSAT-3 (SaTReC, KAIST Develop)**
- **Duration : 2008. 05 ~ 2013. 11 (6 years)**
- **Participants : KASI, SaTReC, KARI, KBSI, SNU, ISAS/JAXA
Green Optics, Genesia**

MIRIS : Science Mission (1/3)

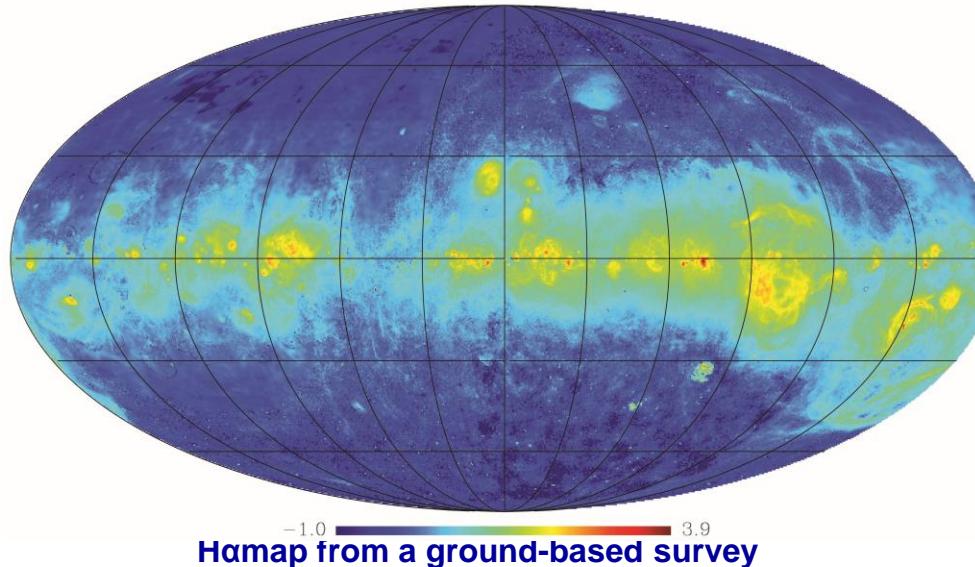
- Galactic Plane Survey (1/2)

Origin of the Warm Ionized Medium (WIM)

- Challenge to the current paradigm of the Ionization theory
- Test the effect of Dust scattering for the WIM observation

Observation : $\text{Pa}\alpha$ survey

- $\text{Pa}\alpha$ (MIRIS) vs. $\text{H}\alpha$ (Ground-based) : Scattering difference
- $\text{Pa}\alpha$ is better than $\text{H}\alpha$ in the turbulence study of the WIM because of the lower dust-extinction



Science Mission (2/3)

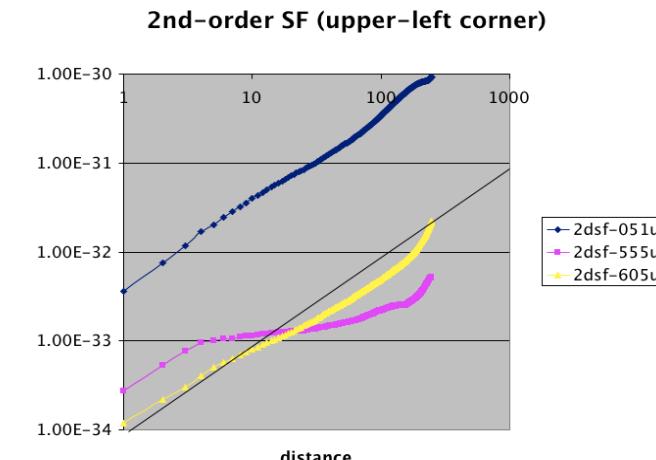
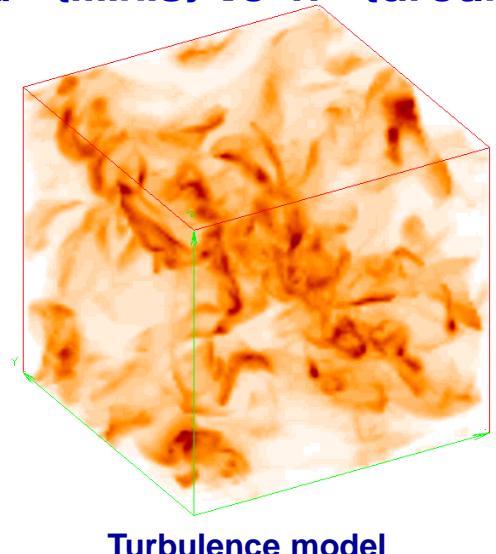
- **Galactic Plane Survey (2/2)**

Physical Properties of Turbulence in the Galaxy

- Survey the physical parameters of turbulence in the Galaxy
- Derive Magnetic field strength from the structure characteristics of turbulence

Observation : Pa α survey

- Pa α (MIRIS) vs. H α (Ground-based) : Extinction difference

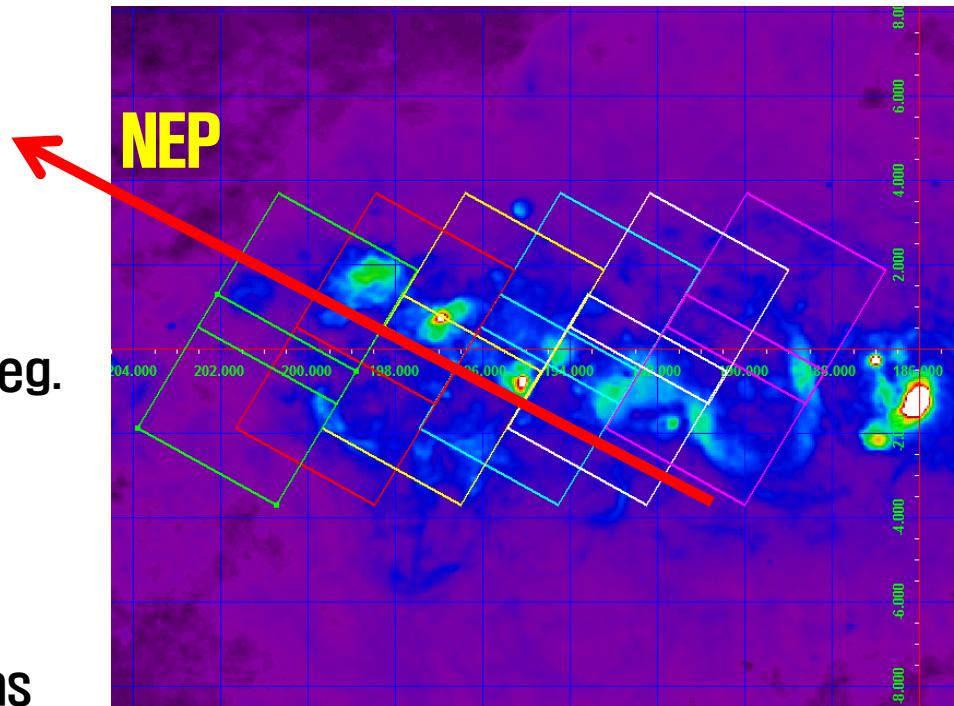


Measurement of the turbulence structure



Pa α Observation Plan

- Galactic Plane <-> Ecliptic Plane
 - Simple Satellite Control
- Current plan
 - 2 filters
 - Rotated detector FoV: 3.67 deg.
 - 20% increase of survey capability
 - ~50% overlap
 - Width: 5.9 ~ 7 deg.
 - Total survey time = 10 months



Science Mission (3/3)

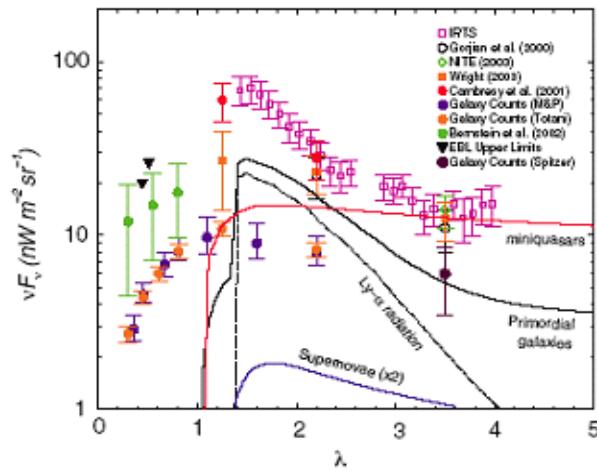
- Cosmic Infrared Background (CIB) Observation

Origin of the Near-IR CIB

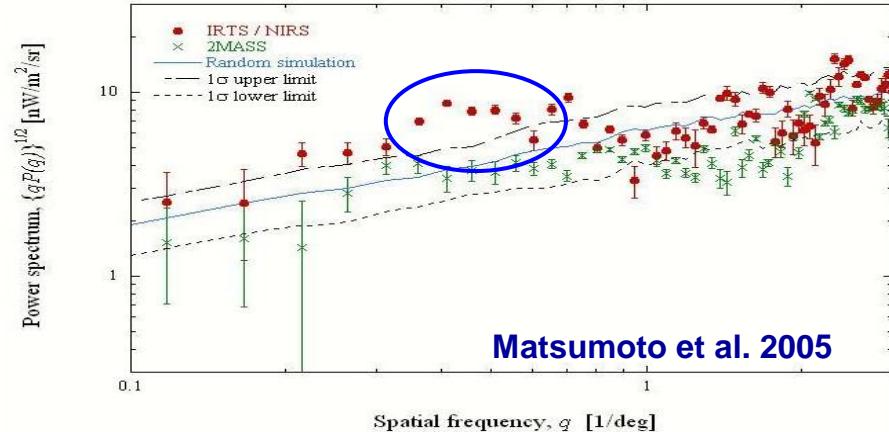
- Test the hypothesis of the Pop III origin
- Confirm the degree-scale fluctuation suggested by IRTS & AKARI and reveal its nature

Observation : I & H-band

- I-band (no Pop III) vs. H-band (Pop III star expected)



Spectral bump suspected to be redshifted from the Pop III Ly-cutoff

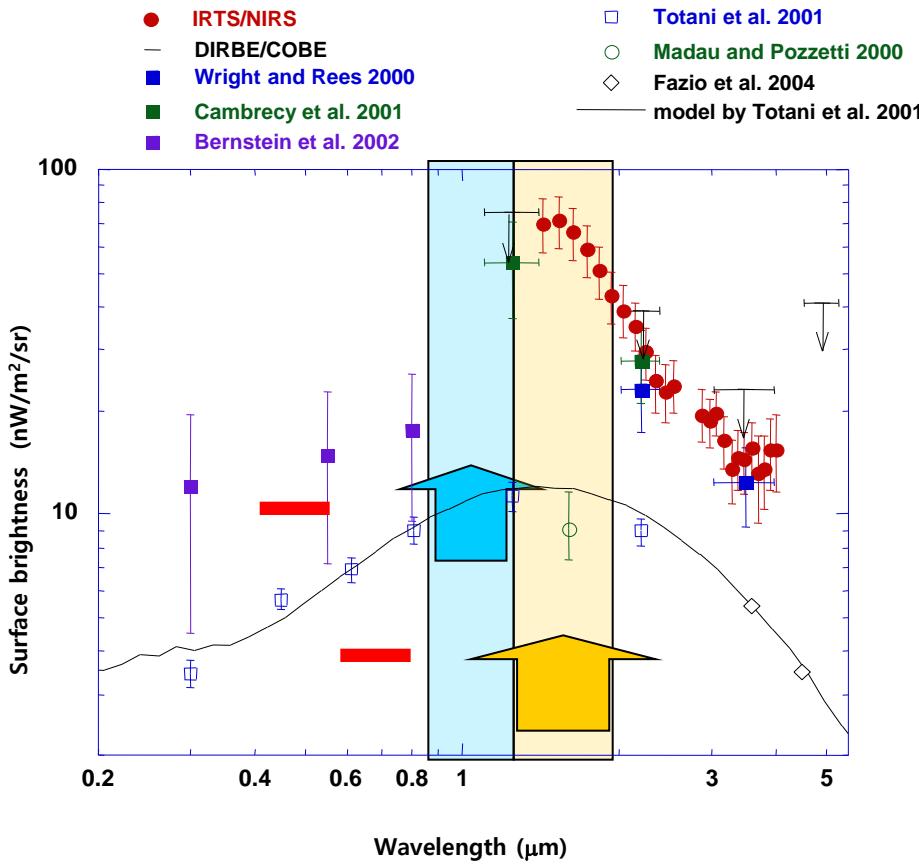


Matsumoto et al. 2005

Degree-scale fluctuation in the power spectrum from IRTS

CIB Observation

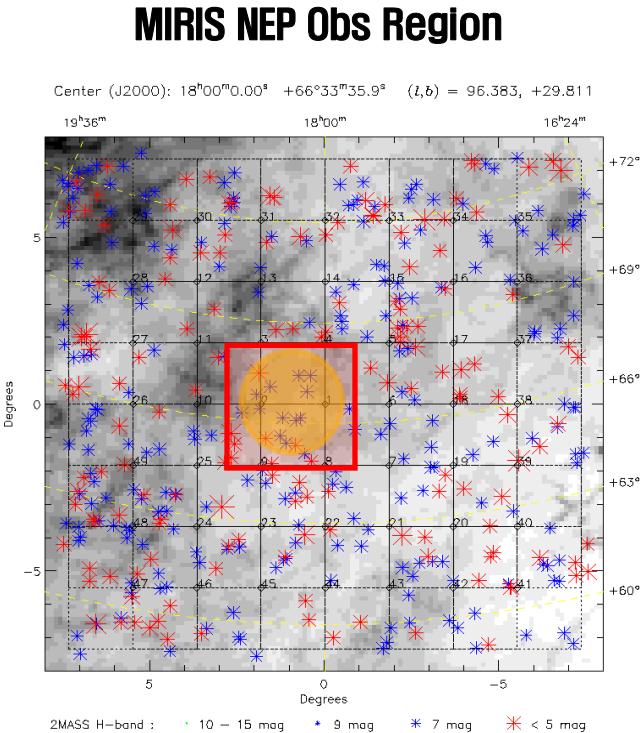
- CIB Observations:
To reveal the origin of CIB
- Expected MIRIS Sensitivity
(3σ , Instrumental noise only)
 - I band: **18.6** AB mag.
 - H band: **19.1** AB mag.
- Confusion-limited observation
- Two bands: I & H bands
→ peak of CIB?





CIB Observational Plan

- Filters: I & H bands
Blank (dark calibration)
- CIB dedicated phase: 1 month
- Primary target
NEP (North Ecliptic Pole)
 - 6.2 sq. deg. observed by AKARI
 - Whole area: $10^{\circ} \times 10^{\circ}$
 - 7 x 7 fields
 - 1 sec. integration x 600 frames
- Secondary targets
 - SEP (South Ecliptic Pole)
 - NGP (North Galactic Pole)
 - SGP (South Galactic Pole)



: AKARI Obs Region
 : MIRIS FoV



MIRIS Operation Concept

Mode	Test (3 months)	1 st Year	2 nd Year
Bus Test	10 orbits/day (1 month)	(if needed)	(if needed)
Space Observation -Galactic Plane -Cosmic Background -Calibration	(1 month) 4 orbits/day 4 orbits/day 2 orbits/day	6 orbits/day 2 orbits/day 2 orbits/day	User time (if needed)
Earth Observation	(1 month) 2 orbits/day	Regular Test & Emergency Observation	6 orbits/day
Ground Contact	4 orbits/day	4 orbits/day	4 orbits/day

Attitude Control Requirements

Item	Axis	MIRIS Req. (3σ)	Bus Spec. (3σ)	Remarks
Attitude update rate		> 1 Hz	1~4 Hz	
Pointing Knowledge	X, Z	< $\pm 0.13^\circ$	$\pm 0.12^\circ$	Refer to Mosaic overlap requirements
	y	< $\pm 0.22^\circ$	$\pm 0.15^\circ$	Field shift by rotation < 1 pixel
Pointing Accuracy	X, Z	< $\pm 0.13^\circ$	$\pm 0.13^\circ$	Refer to Mosaic overlap requirements
	Y	< $\pm 0.22^\circ$	$\pm 0.16^\circ$	Field shift by rotation < 1 pixel
Stability (Drift+Jitter)	X, Z	< $\pm 0.007^\circ/\text{sec}$	$\pm 0.007^\circ/\text{sec}$	< 1 pixel
	y	< $\pm 0.070^\circ/\text{sec}$	$\pm 0.052^\circ/\text{sec}$	Drift by rotation + x, z drift < 1 pixel



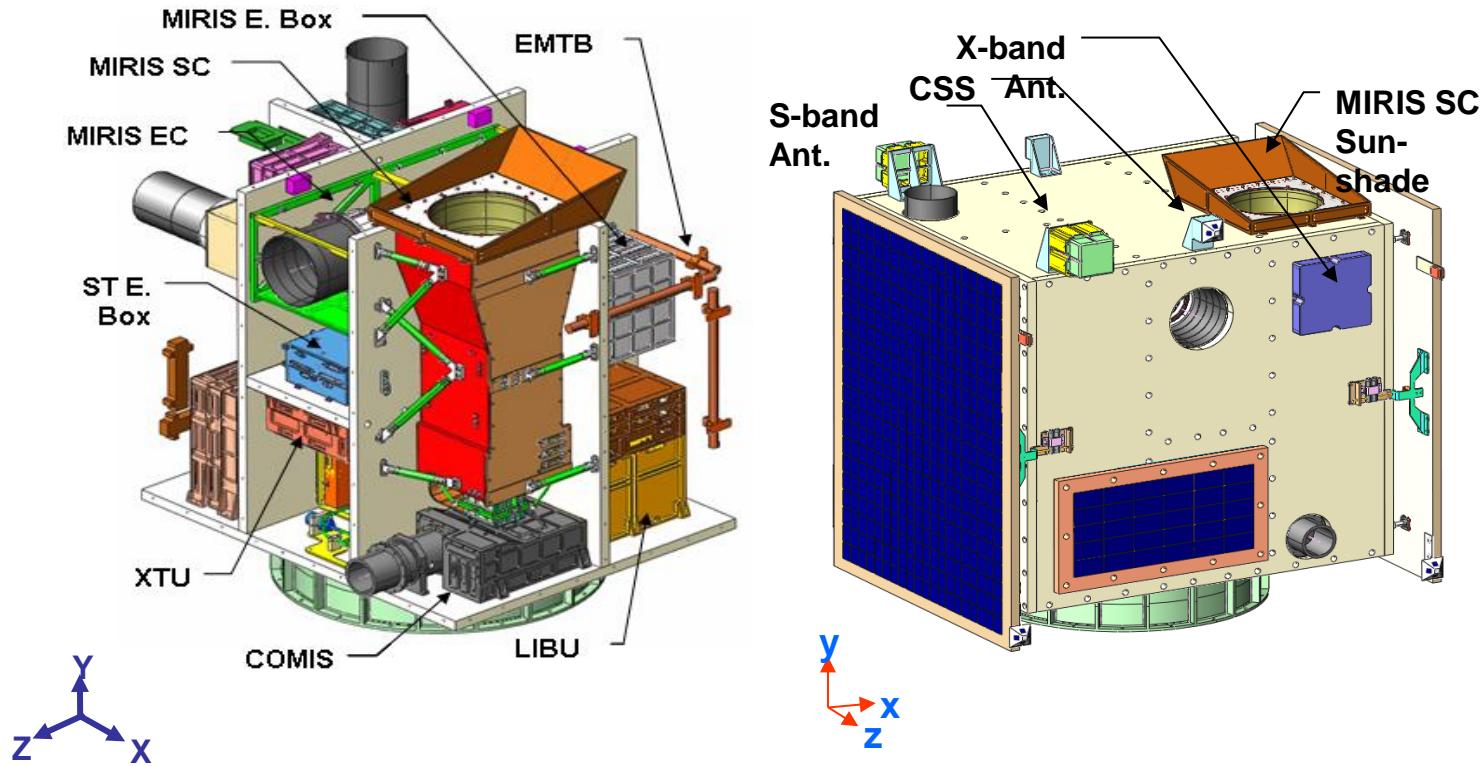
Data Communication Requirements

		MIRIS : Pa a cont. & Dual-band filter
Unit Frame Size		1.2 Mbit/frame (256x256 sensor 1, 16bit)
1 Day Obs Frame	CIB Priority Obs	6,000 frame/day (600 frame/orbit x 10 orbits)
	Normal Obs	3,600 frame/day (GP : 600 frames x 4 orbits) (CAL : 600 frames x 2 orbits)
1 day Data Production *	CIB Priority Obs	7 Gbit/day (6,000 frame/day x 1.2 Mbit/frame)
	Normal Obs	4.2 Gbit/day (3,600 frame/day x 1.2 Mbit/frame)

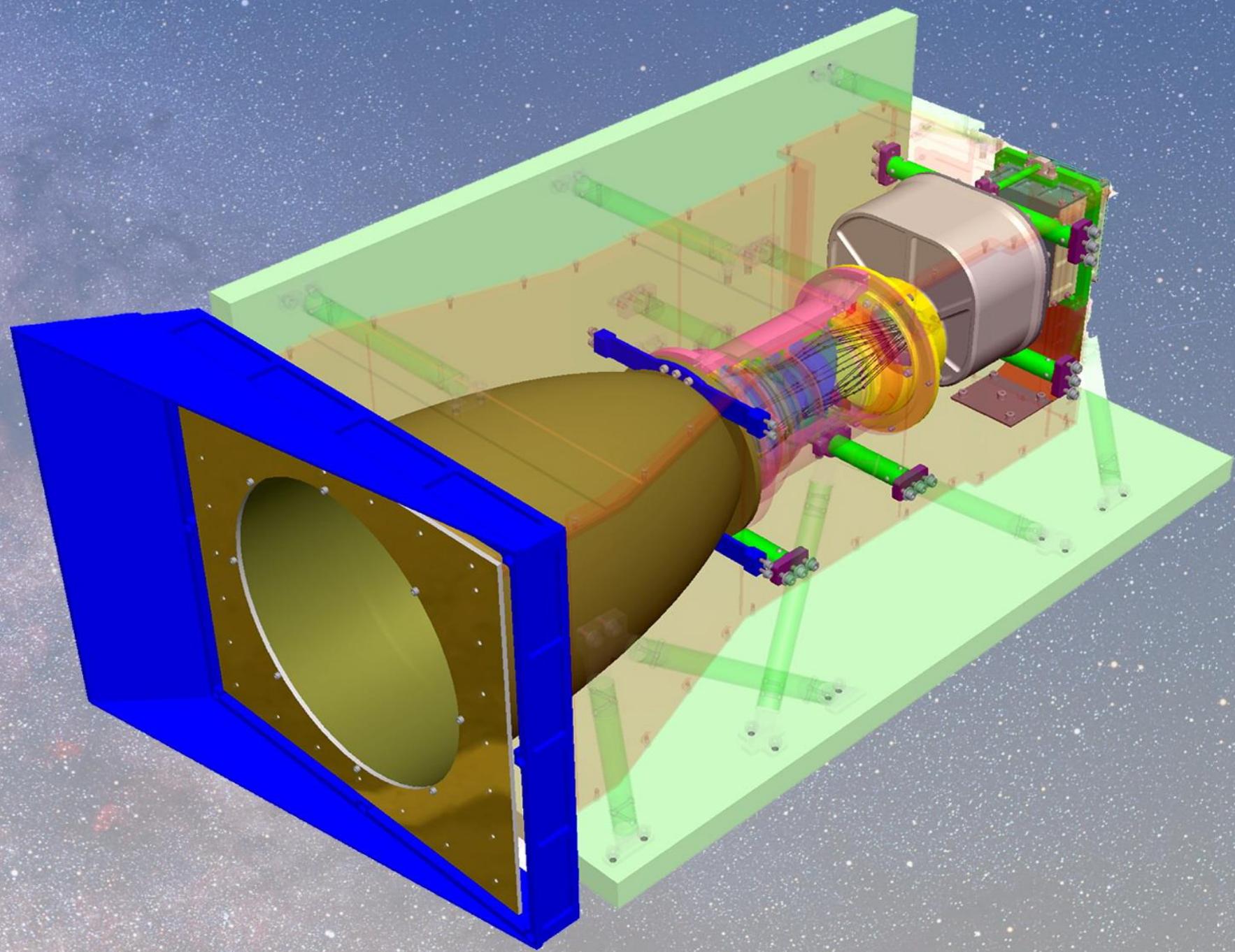
* RS Encoding & Packet frame were NOT included

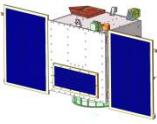


STSAT-3 Summary



Item	Specification
Mission Orbit	595 ~ 635 km, Sun synchronous
Mission Life	2 years
Satellite Mass	~ 175 kg



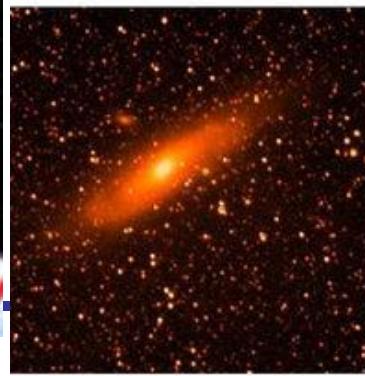
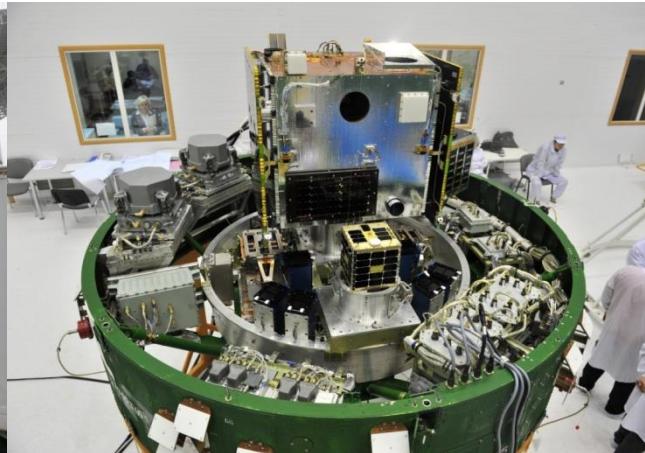


STSAT-3

STSAT-3 발사

과기3호 MIRIS 우주로

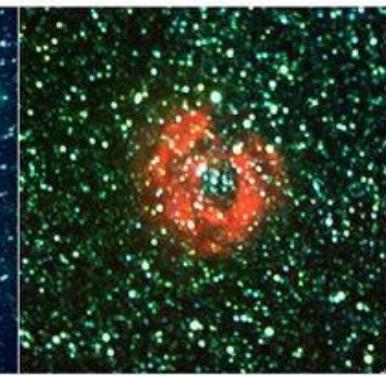
- 2013. 11. 21. 발사 (러시아 야스니 발사장)
- 2013. 12. 26. MIRIS 우주관측카메라 첫 관측영상 획득



안드로메다 은하



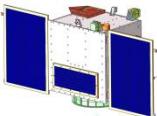
오리온 성운



장미 성운

MIRIS Workshop, 28 Jan 2015

적외선 우주망원경 촬영기법



STSAT-3

MIRIS Specifications

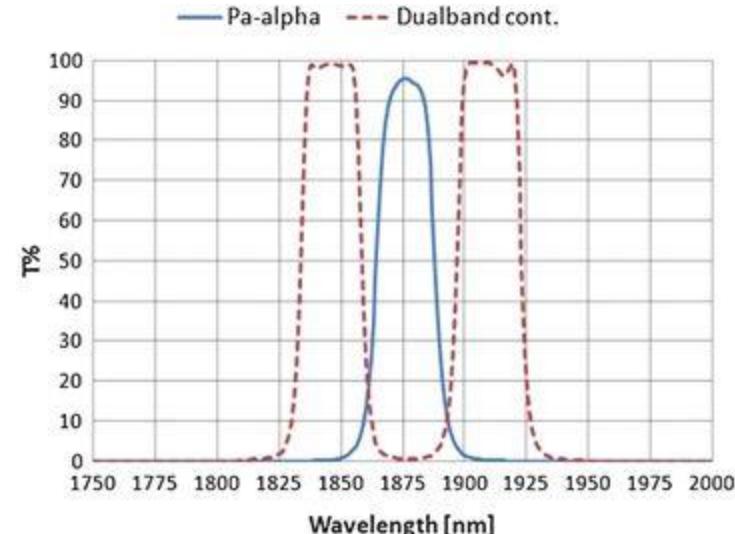
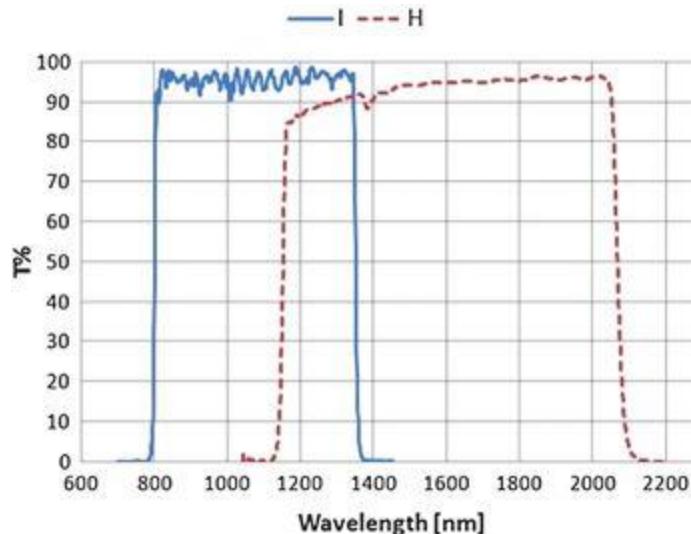
Item	Parameter	Specification	Remark
<u>Telescope</u>	Aperture	80 mm	
	F-number	F/2	
	Focal length	160 mm	
	Field of View	3.67° × 3.67°	
<u>Detector</u>	Teledyne PICNIC (HgCdTe)		
	Detector array	256 × 256	
	Pixel size	40 μm	
	Pixel scale	51.6"	
<u>Filters</u>	Broadband	1.1 & 1.6 μm	$\Delta \lambda / \lambda \gtrsim 0.5$
	Narrowband	PAAL & PAAC	
<u>Orbit</u>	Low Earth, Sun-synchronous orbit		
	Altitude	about 620 km	
	Inclination	97.8°	
	MLTAN	22.3 o'clock	

MIRIS Filter Specification

- Filters [6 filters]
 - I ($1.05\mu\text{m}$), H ($1.6\mu\text{m}$), blank
 - Pa α ($1.876\mu\text{m}$), Pa α Cont1, Pa α Cont2
 - Pa α Cont1, Pa α Cont2 → Double band filter

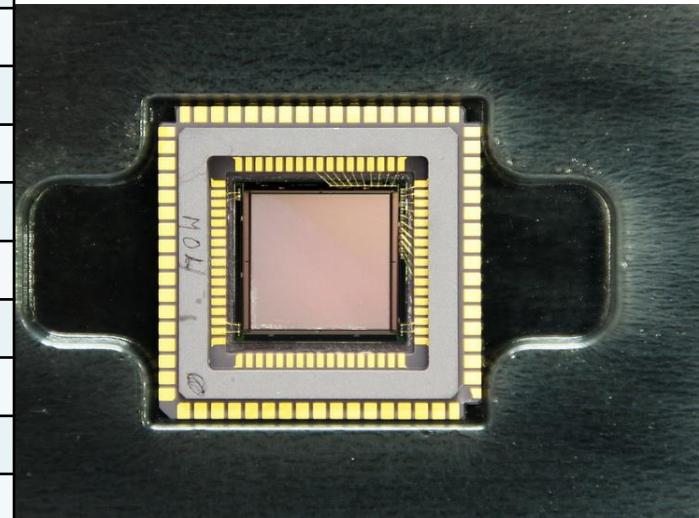


Filter	I	H	PAAL	PAAC
Nominal wavelength	$1.1\ \mu\text{m}$	$1.6\ \mu\text{m}$	$1.876\ \mu\text{m}$	$1.84 & 1.92\ \mu\text{m}$
Band width (FWHM)	$0.550\ \mu\text{m}$	$0.910\ \mu\text{m}$	24 nm	25 & 25 nm



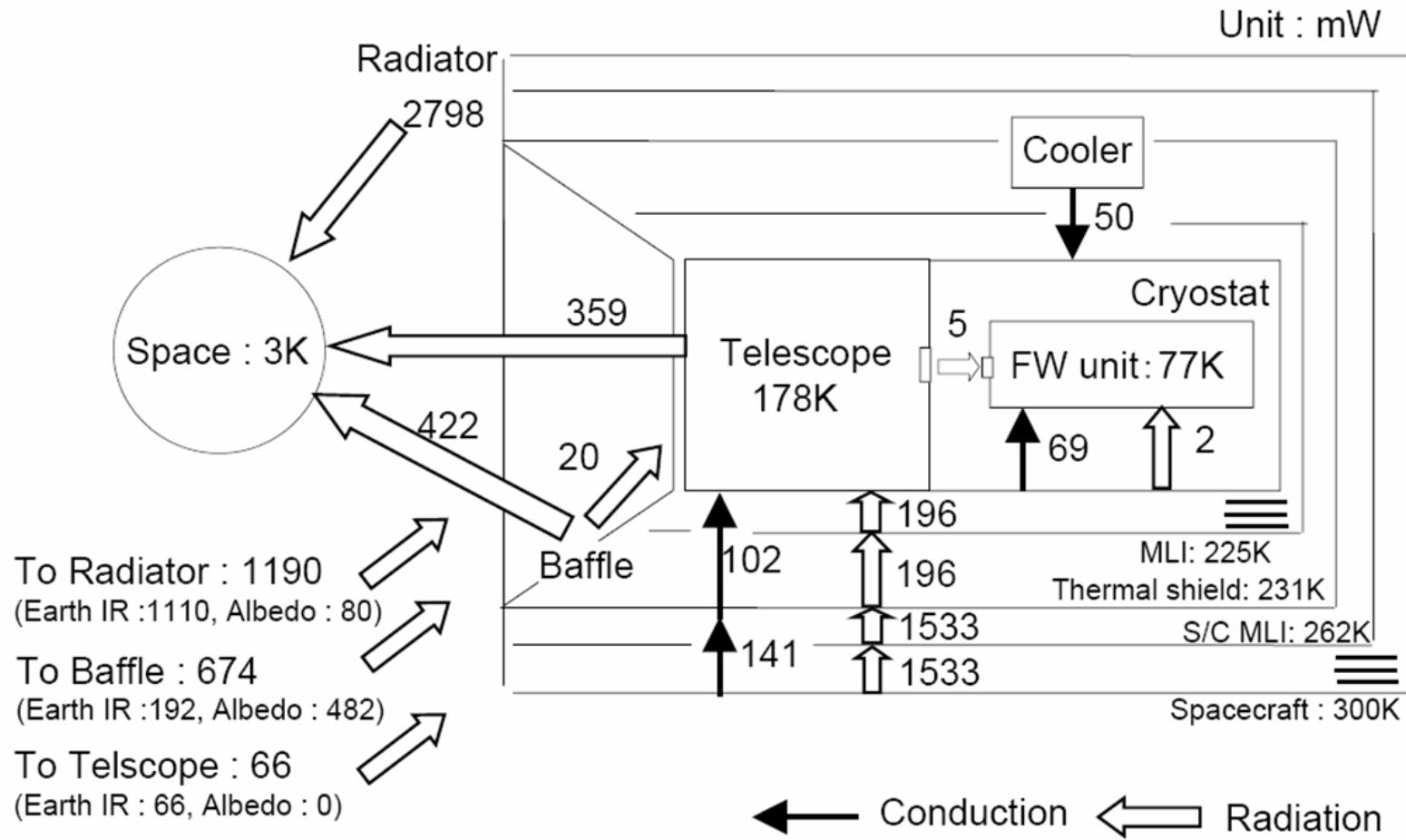
PICNIC IR Array Specification

Parameter	Specification
Detector technology	HgCdTe(PACE)
Detector input circuit	SFD
Readout mode	Ripple(per quadrant)
Pixel readout rate	Up to 200kHz
Pixel format	256x256
Pixel pitch	40um
Fill factor	>90
Output ports	4 total(1 per quadrant)
Clocks	6
Spectral range	0.9 ~ 2.5um
Quantum Efficiency @2.3um	>75%
Read noise: multiple sample	<20
Dark current	<0.2 e-/sec(@77K)
Well capacity	200,000 e-
Pixel operability	>99%



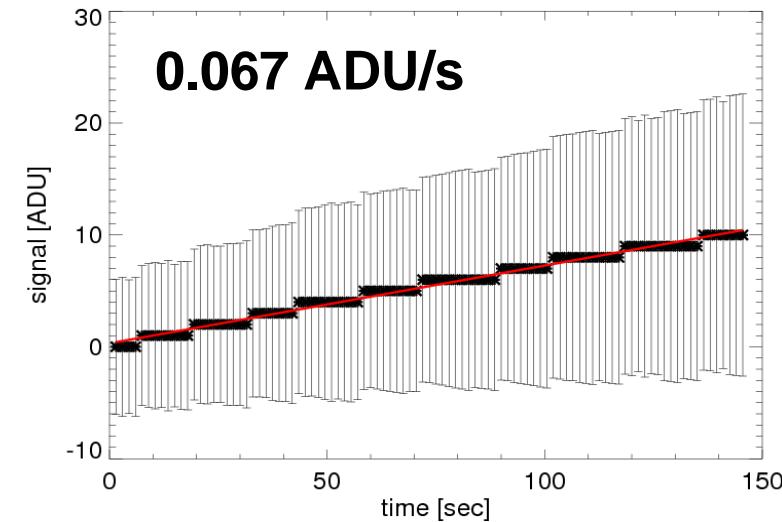
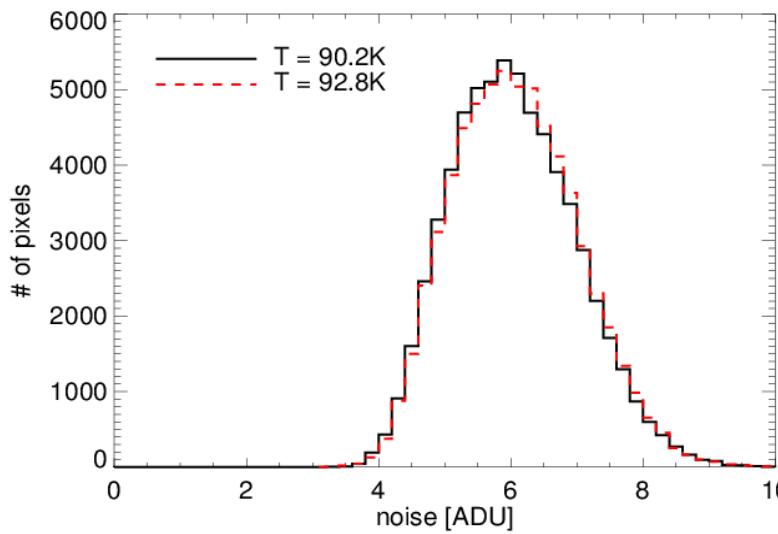
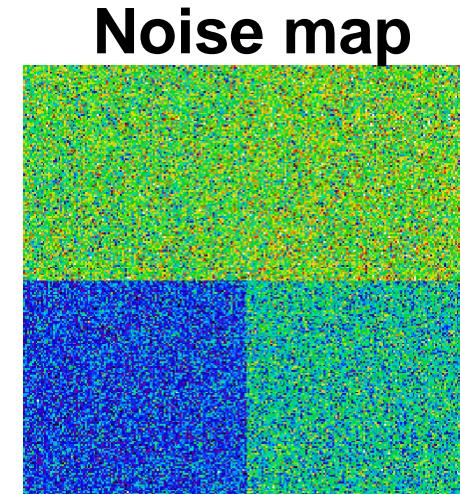
PICNIC sensor

Passive Cooling Simulation



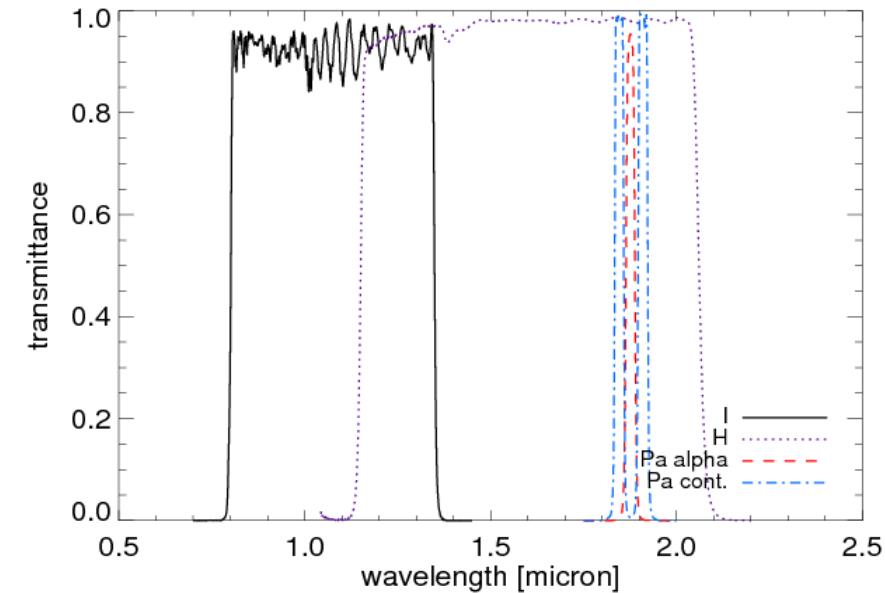
MIRIS Dark Test

- Gaussian: readout noise
- Temperature variation: $\sim 3\text{K}$
 - Increase of hot pixels: $\sim 0.26\%$
 - Increase of noise $< 1 \text{ ADU}$
 - No difference of dark on temperature variation



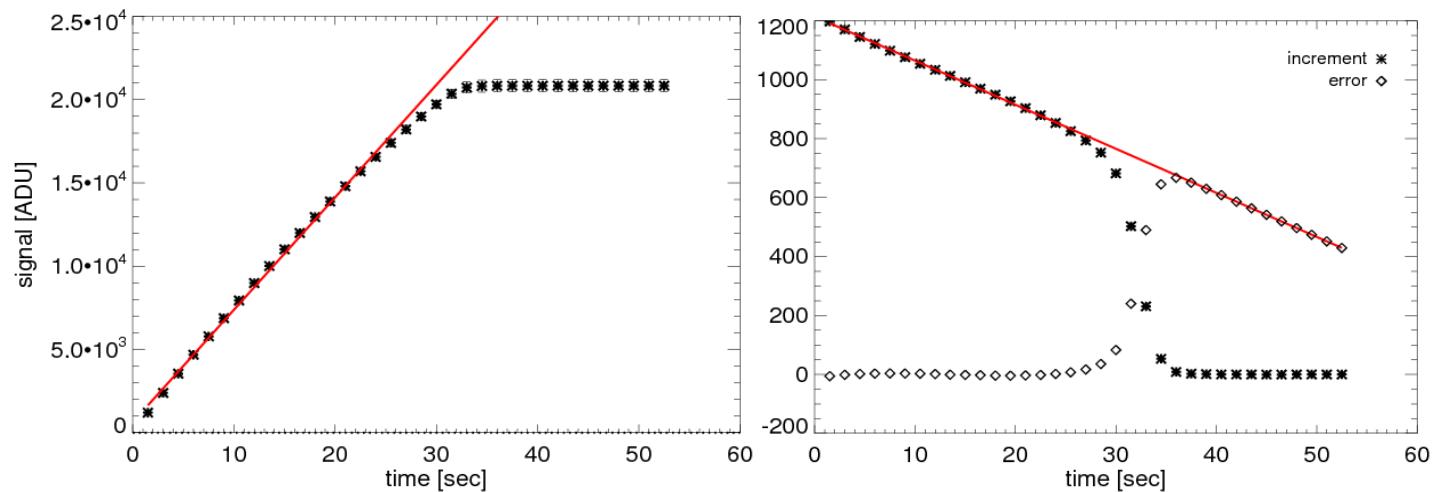
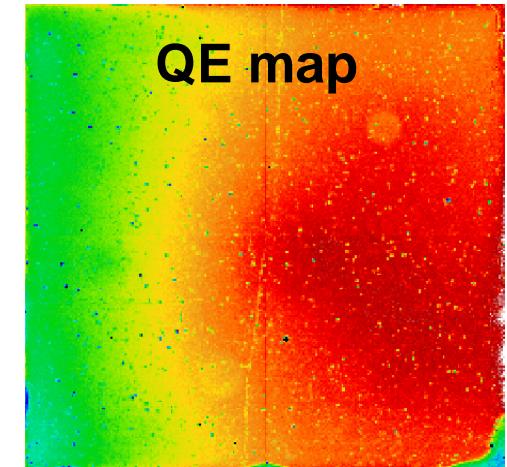
Band Response

- Band information
 - Narrow bands: Pa Cont., Pa_α
 - Wide bands: I, H
- Relative brightness
 - Source with flat energy spectrum
 - $\text{Pa}_\alpha = 1.0$ (normalized)
 - $\text{Pa cont.} = 2.2$
 - $I = 21.4$
 - $H = 37.1$
 - Uncertainty $\sim 10\%$



Linearity Test

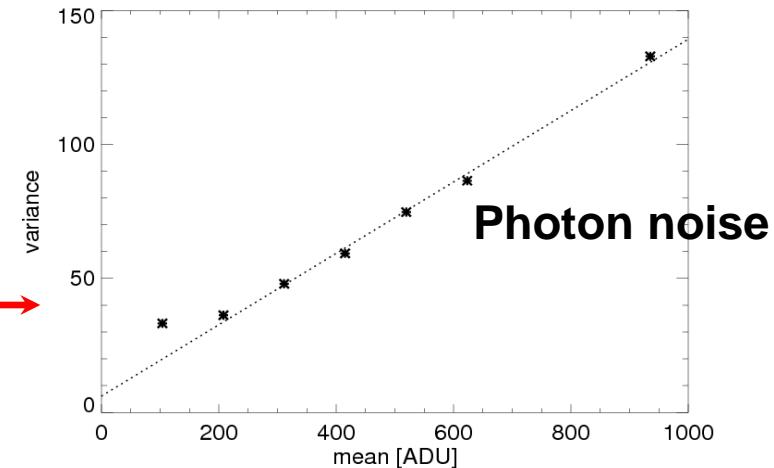
- Obtain stable integration curve
 - Use uniform source
 - Pa α band
- Linearity correction



SOC Gain Estimation

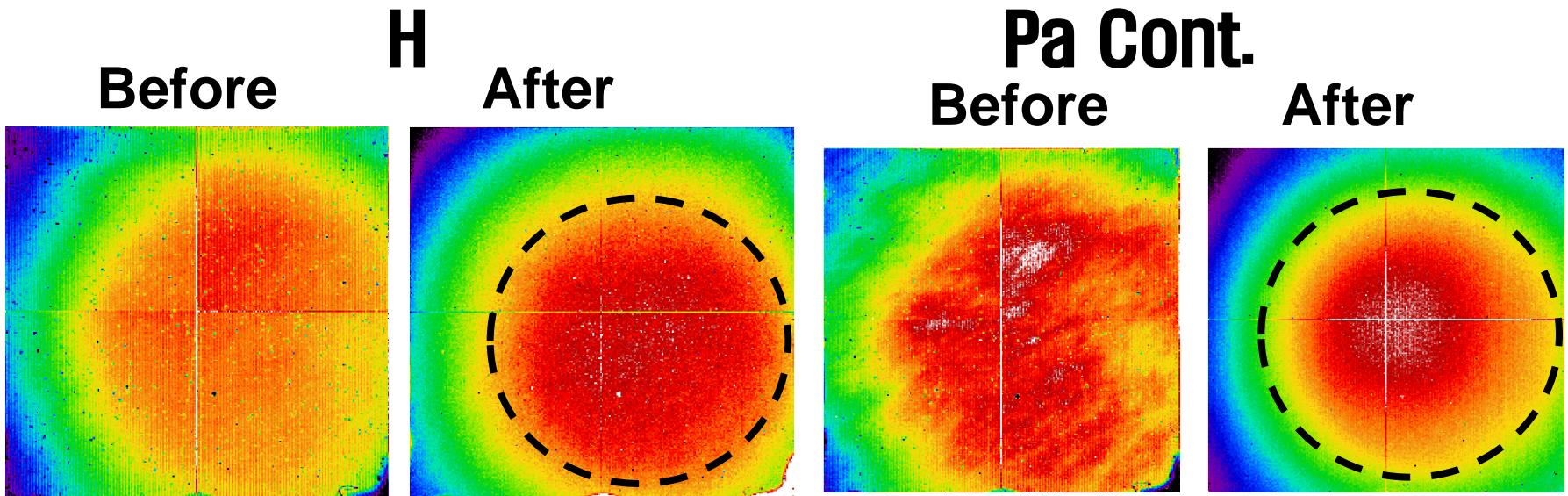
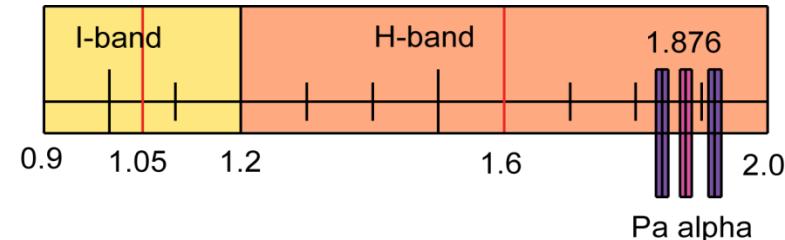
- Mean–Variance
 - Readout noise $\sim 45\text{e}^-$
 - $45\text{e}^- < 50\text{e}^-$
(performance estimation)
- Gain [e⁻/ADU]
 - Mean–Variance test: 8 ~ 11
 - Dark current: ~10
- Consistent!

Readout noise
dominant



SOC Flat Fielding

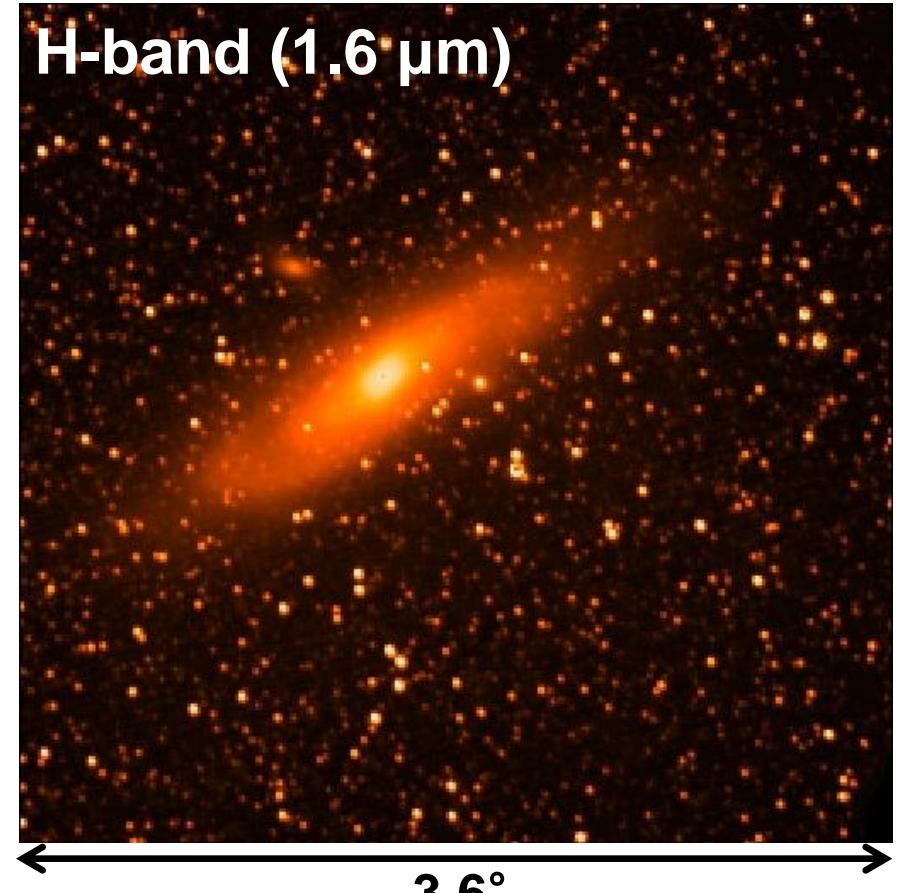
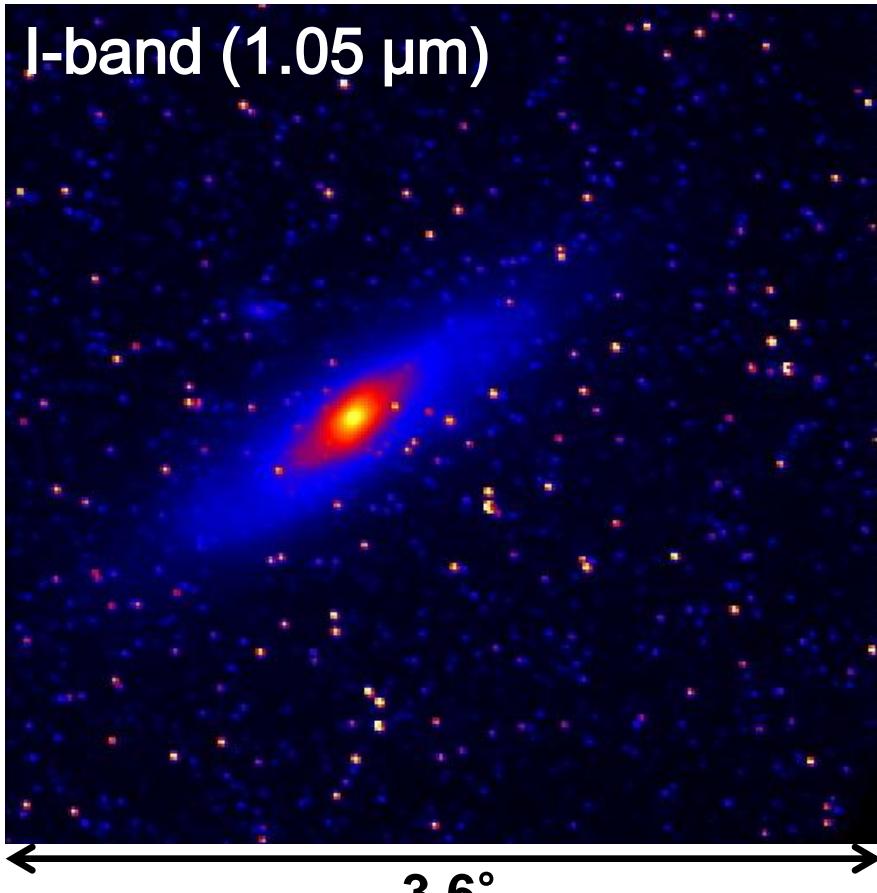
- Flat fielding for H & Pa bands
 - Deviation: reduction of 50%, 42% for H and Pa cont., respectively
 - Flatness < 1%





Performance & Enhancement

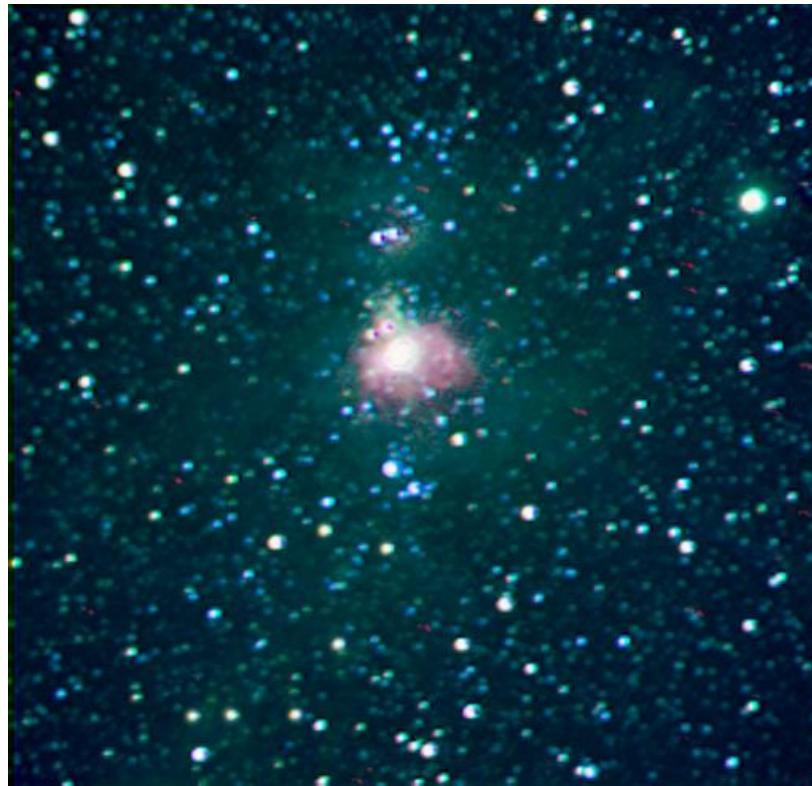
- SOC Imaging: Andromeda Galaxy (2013. 12. 17)





Performance & Enhancement

- SOC Imaging: Orion Nebula (2013. 12. 19)



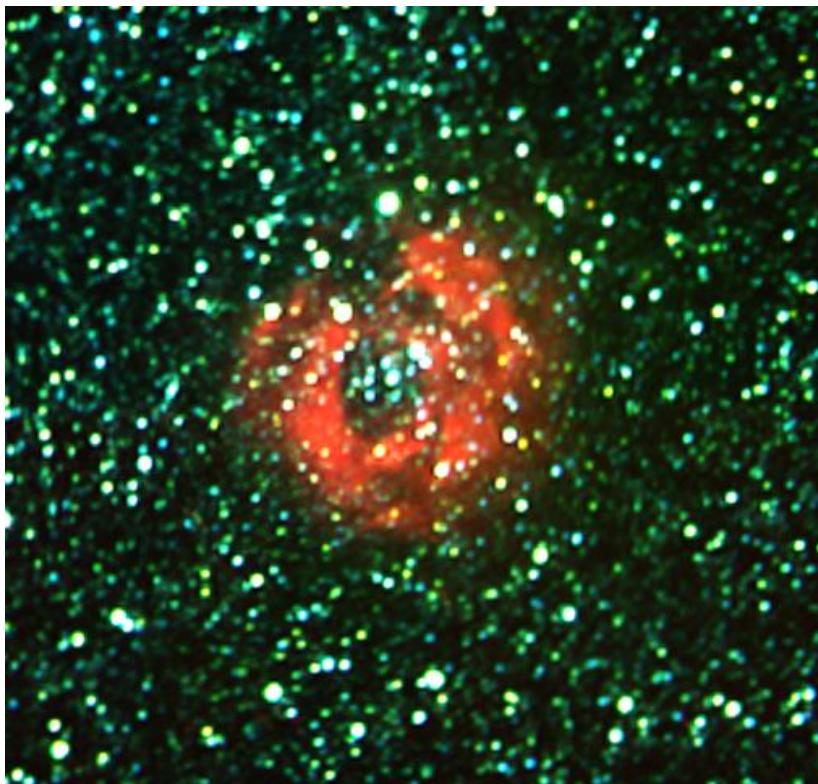
I-band
H-band
Pa- α line
(Ionized H)

* **Massive Star**
→ UV Radiation
→ Ionizes H
→ Pa- α line
→ **Star Forming Region**



Performance & Enhancement

- SOC Imaging: Rosette Nebula [2013. 12. 23]



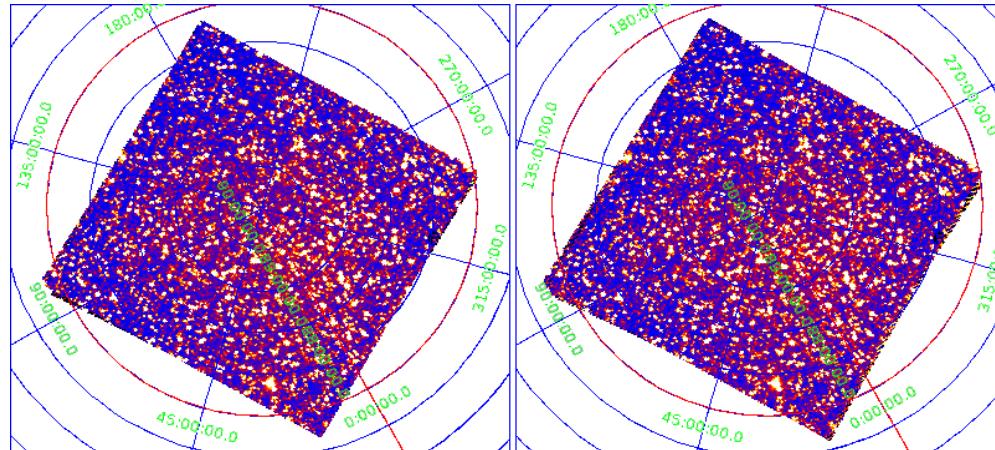
I-band
H-band
Pa α line



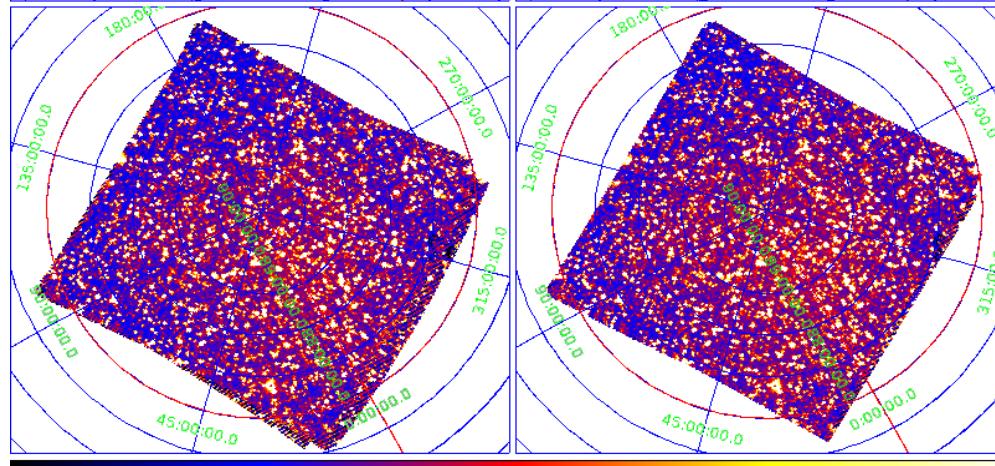
Performance & Enhancement

- SOC Imaging: North Ecliptic Pole (2014. 1. 17, I-band)

Exp 1.5 sec



Exp 2.0 sec



Exp 3.0 sec

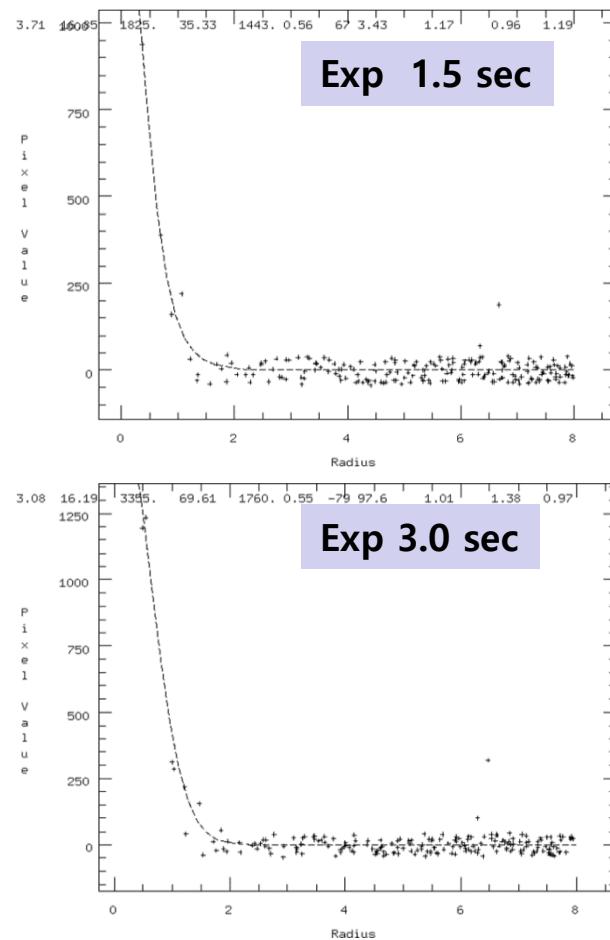
Exp 5.0 sec

24 28 31 34 38 41 44 47 51

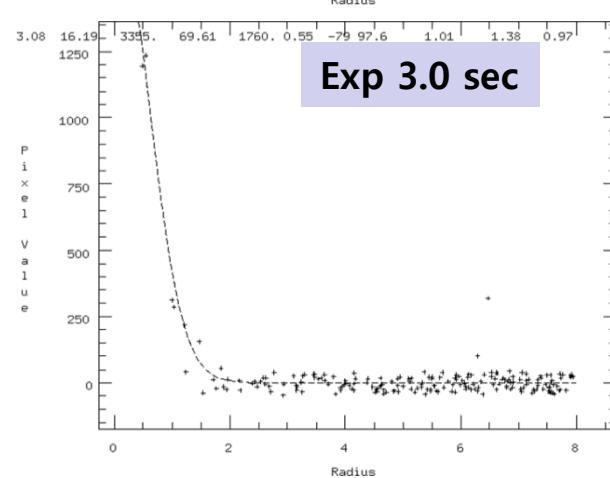


Performance & Enhancement

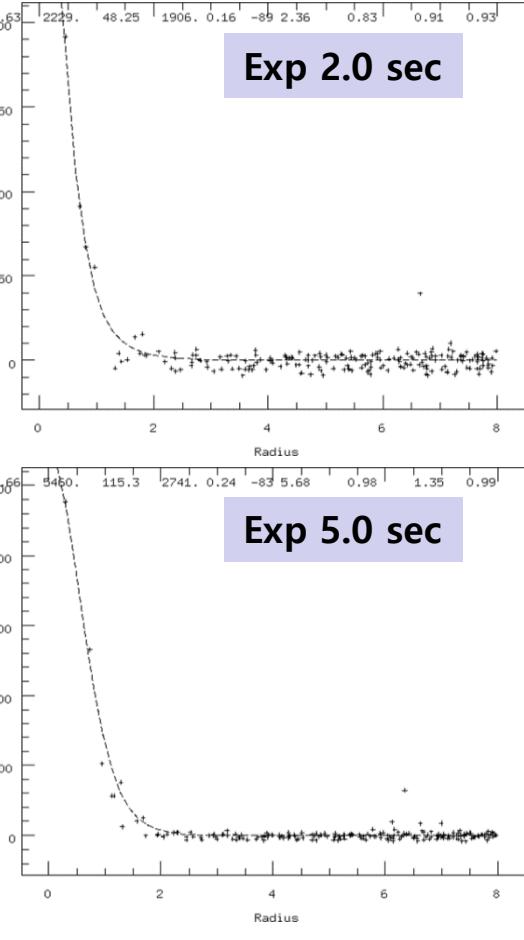
- SOC Imaging: Radial Profile of Stars



Exp 2.0 sec



Exp 5.0 sec



Exposure FWHM

1.5 s 1.19 pixels

2.0 s 0.93 pixels

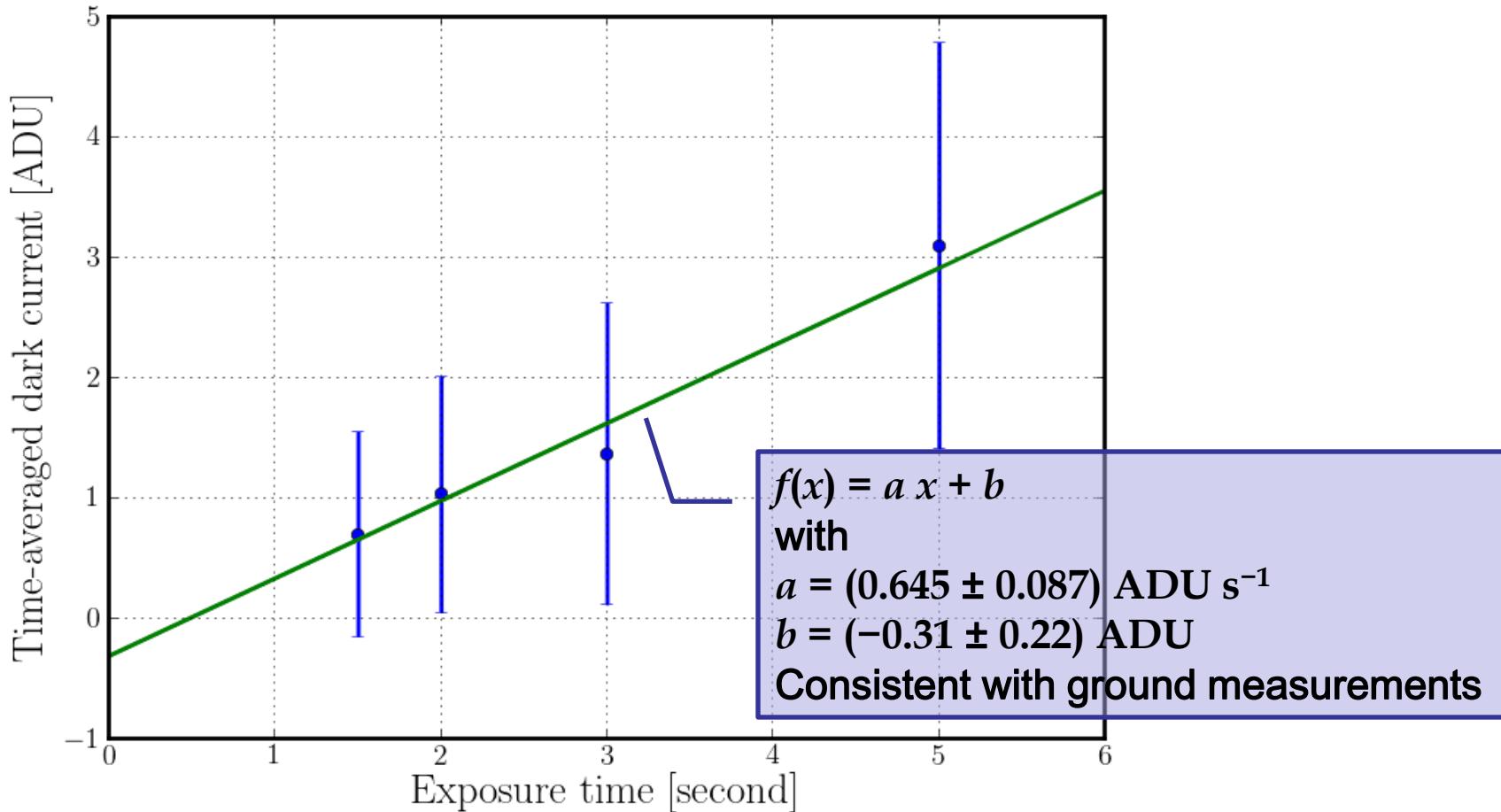
3.0 s 0.97 pixels

5.0 s 0.99 pixels

→ Indicate Good Satellite Pointing

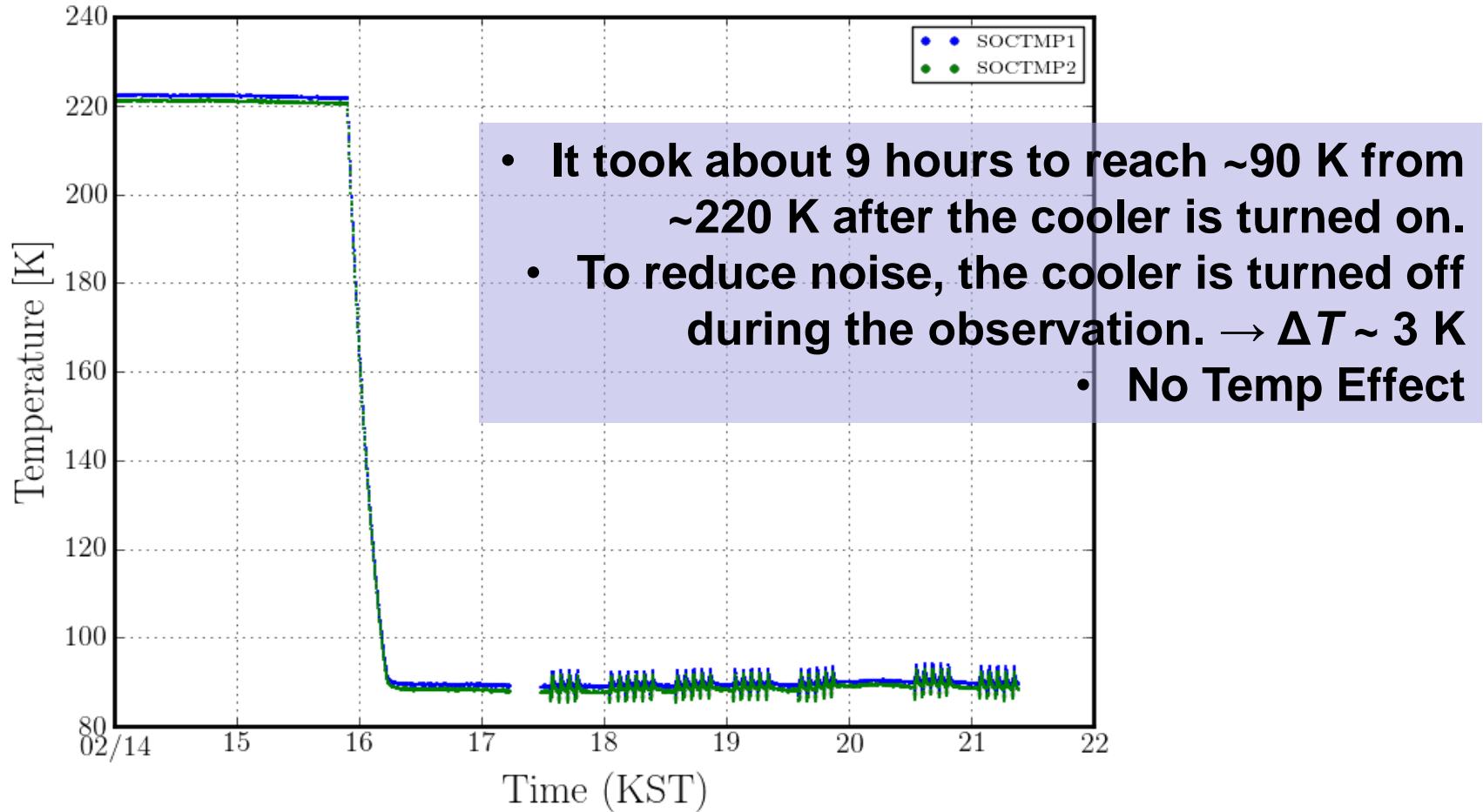
Performance & Enhancement

- MIRIS Dark Current Noise**



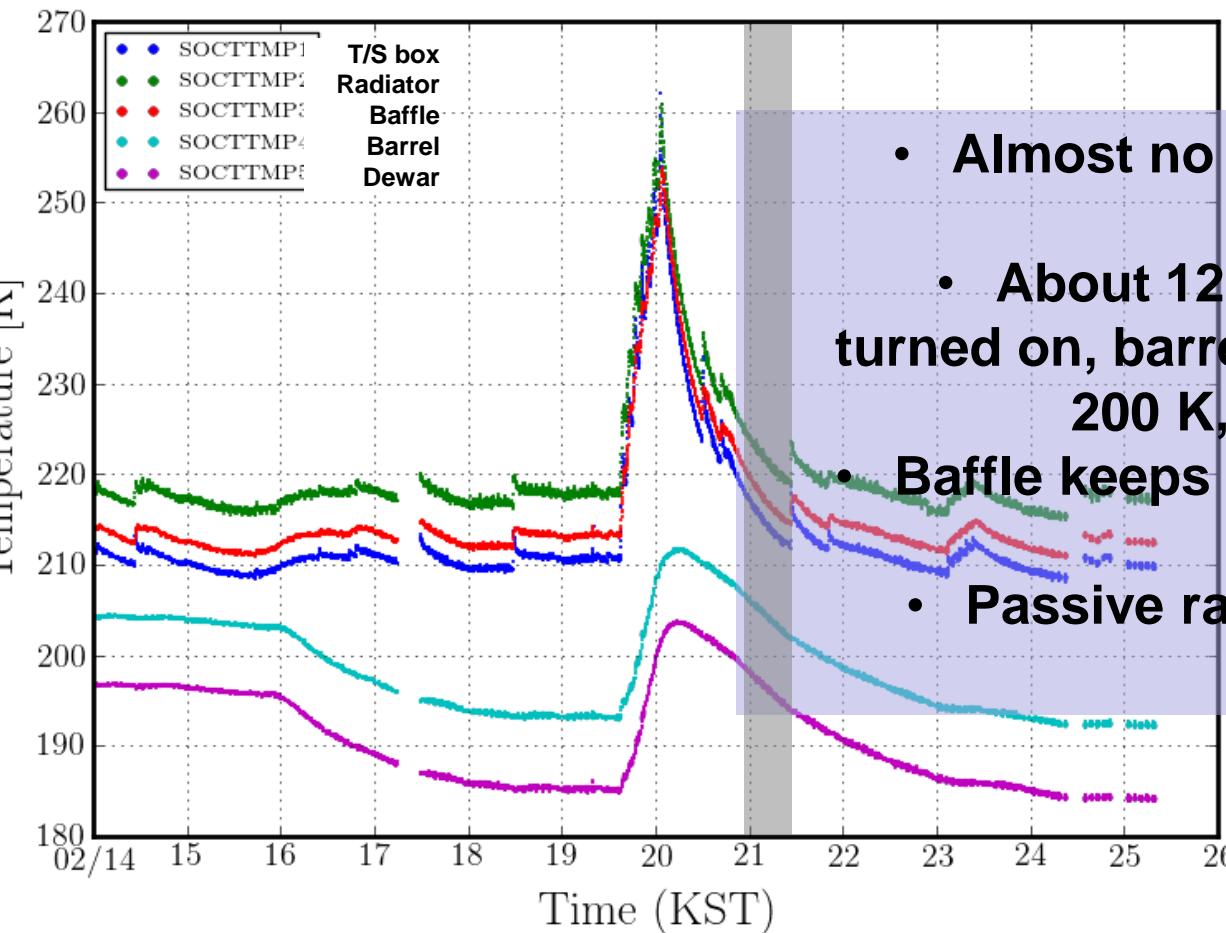
Key Telemetry Status

- ## MIRIS Detector Temperature



Key Telemetry Status

- MIRIS Structure Temperature**



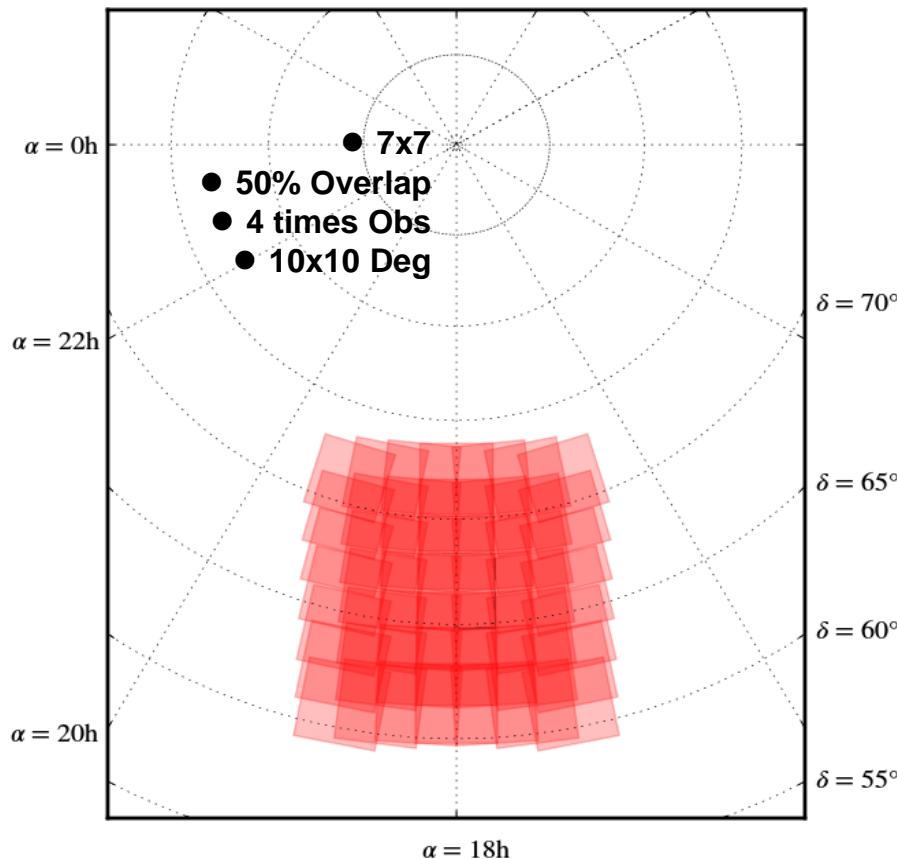
- Almost no dependency on the orbit phase
- About 12 hours after the cooler is turned on, barrel temperature reaches < 200 K, the design temperature.
- Baffle keeps the temperature < 230 K, the design temperature.
- Passive radiative cooling works as expected.



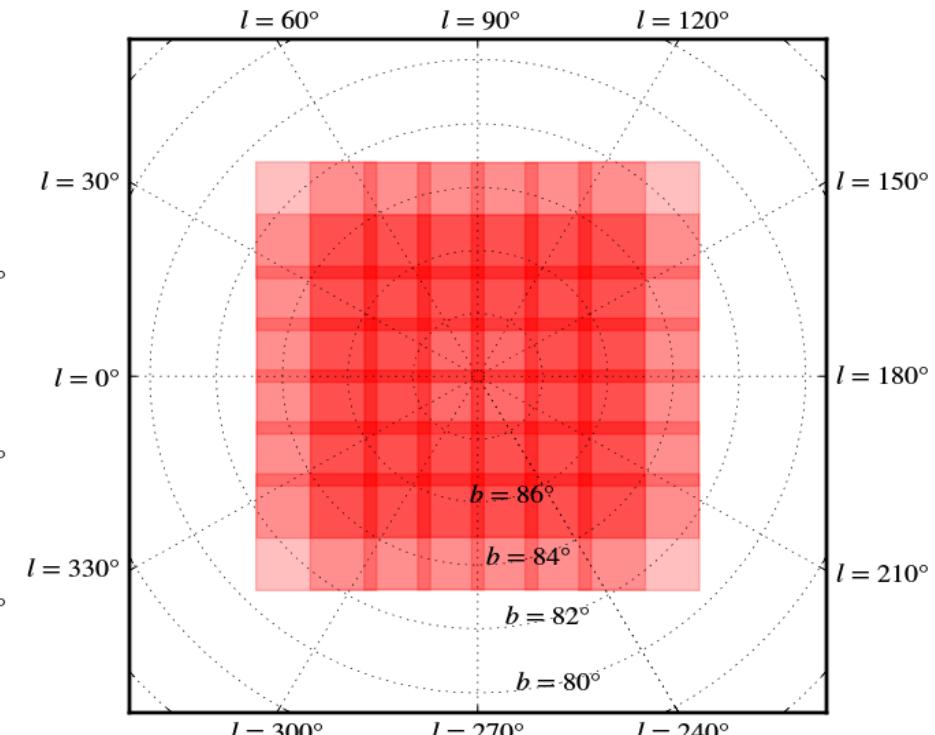
Future Plans

- Main Mission 1: Cosmic Infrared Background

North Ecliptic Pole Fields



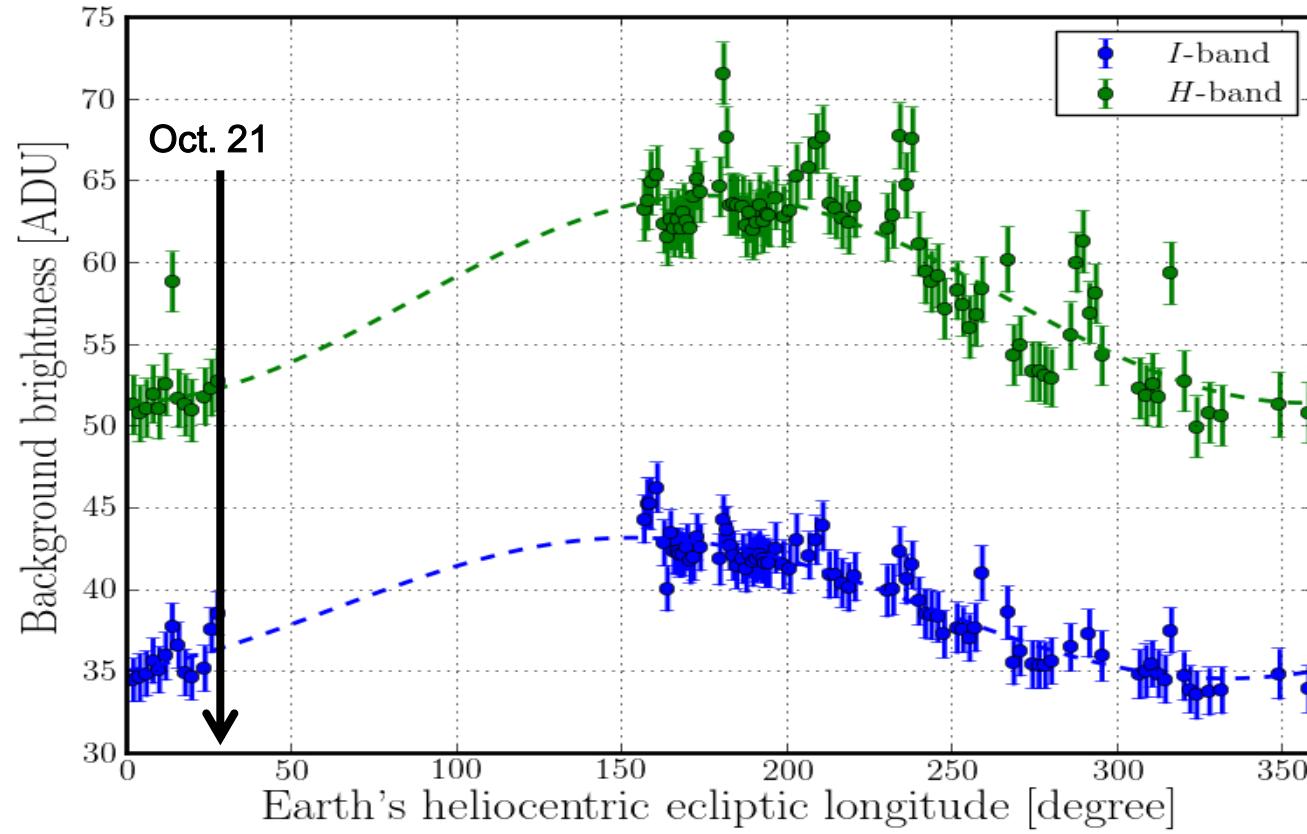
North Galactic Pole Fields



Cosmic Infrared Background

- NEP Monitoring Observations

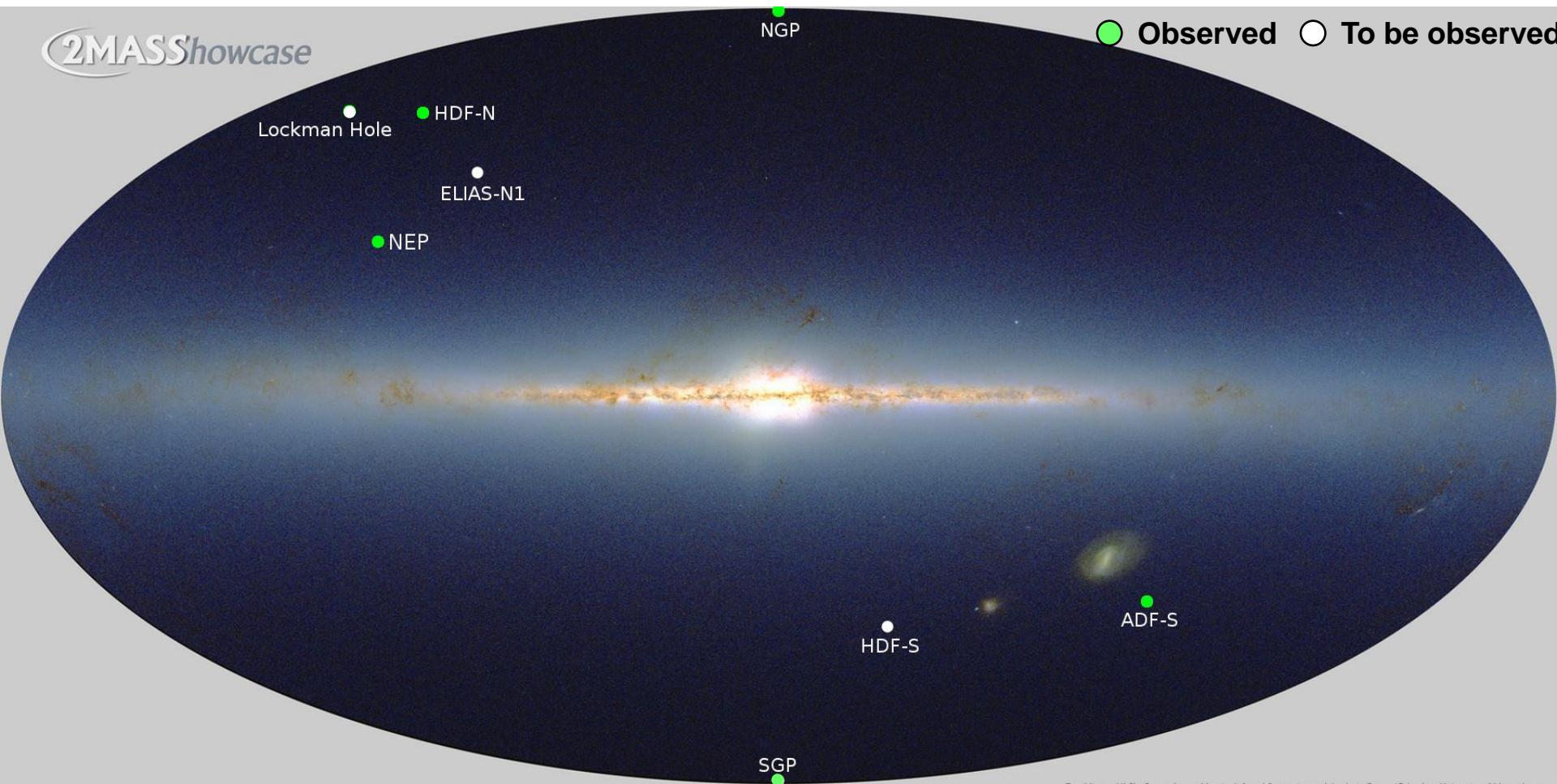
Change of NEP background brightness due to zodiacal light





Cosmic Infrared Background

- Observations of Deep Fields

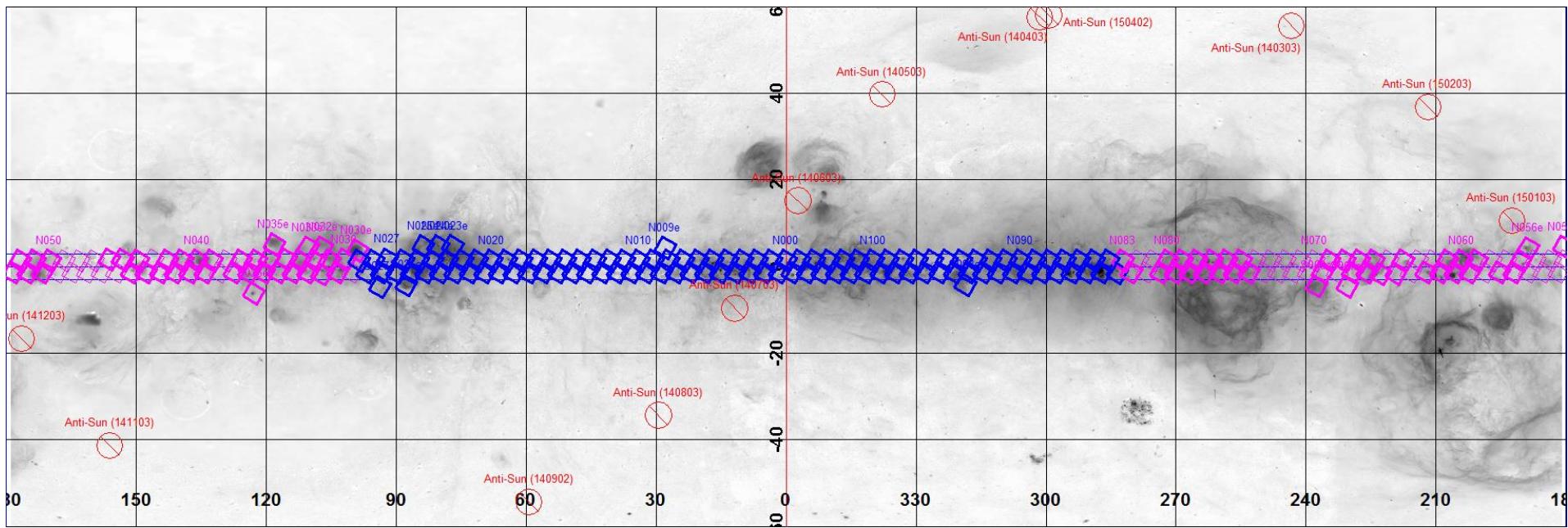




Pa α emission observations : Plan

1. Galactic Plane Survey

- ◆ Cover 360° along Galactic plane within $-3^\circ < b < +3^\circ$.
- ◆ Total 228 fields : 106 north fields + 106 south fields + 16 extended.
- ◆ Effective exposure : ~ 20 minutes (3 orbits) per field per filter



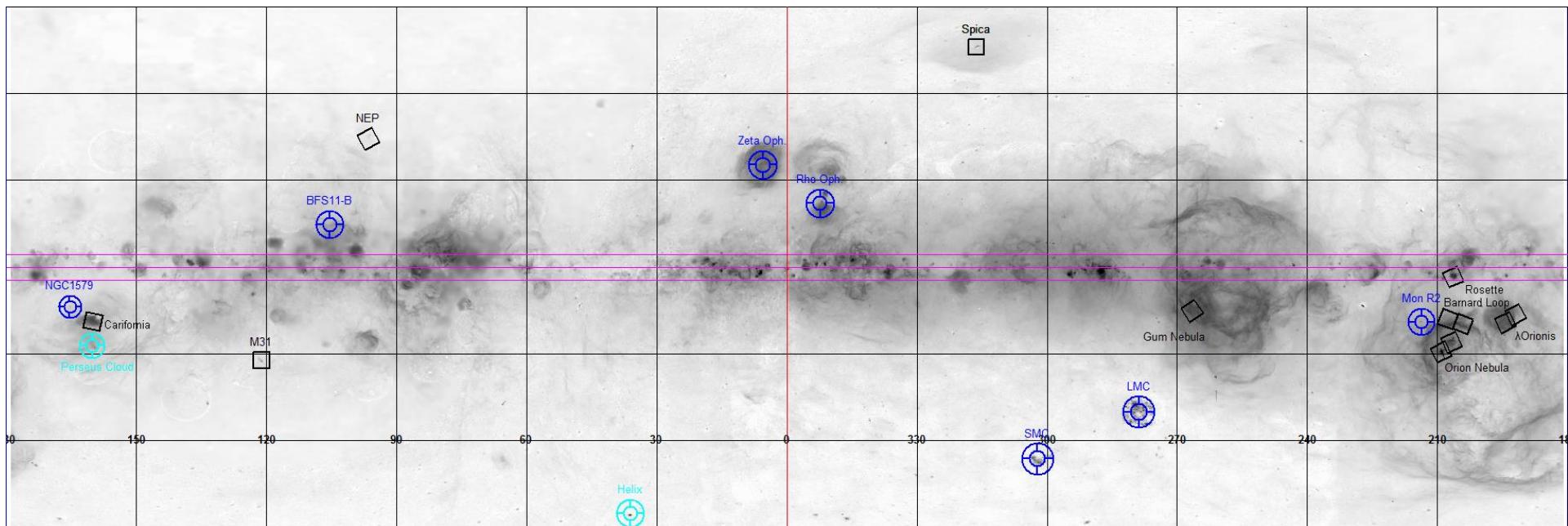
- ◆ 2014 Apr.–2014 Aug. : $/ = -80^\circ$ to $+100^\circ$ (observed).
- ◆ 2014 Nov.–2015 Mar. : $/ = +100^\circ$ to $+280^\circ$



Pa α emission observations : Plan

2. Additional Pointing Observations

- ◆ Select some interesting targets in the high galactic latitude.

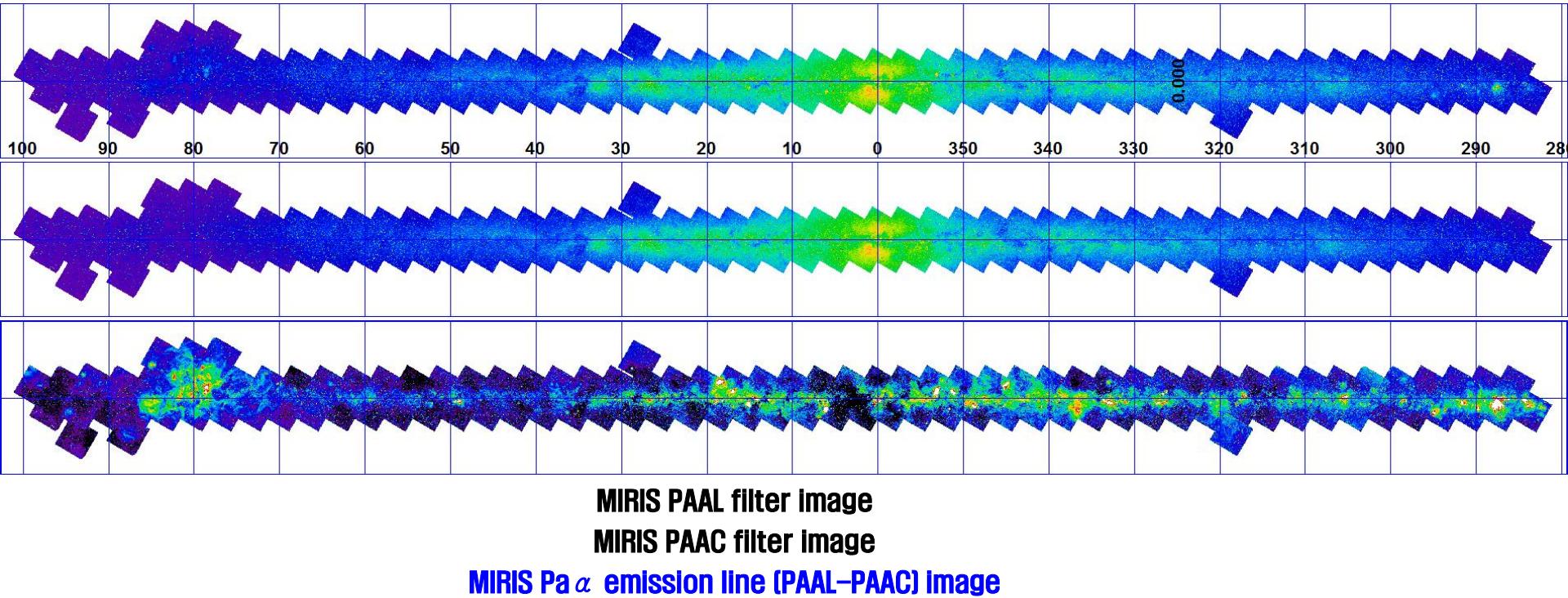


- ◆ 2013 Dec.–2014 Feb. : total 12 fields (observed).
- ◆ 2014 Apr.–2014 Aug. : Zeta Oph., Rho Oph., SMC, LMC (observed).
- ◆ 2014 Nov.–2015 Mar. : BFS11-B (Star Forming Molecular Cloud), NGC1579, Mon R2.



Pa α emission observations : Early Results

1. Galactic Plane Survey

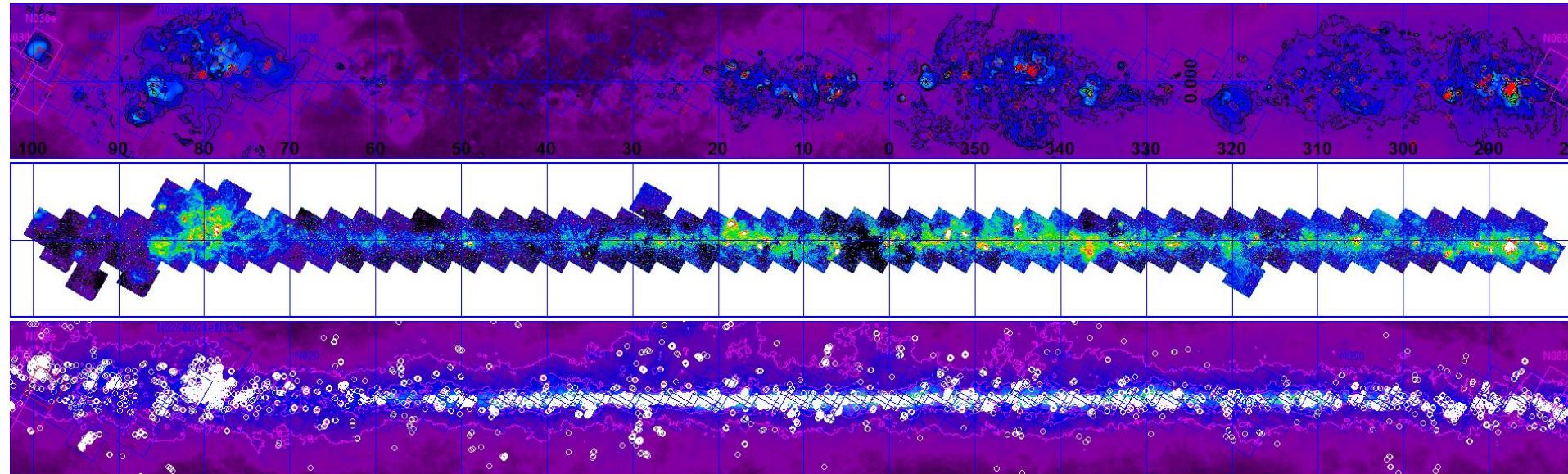


- ◆ **incompletely processed** images : no removal of detector background, no on-orbit flat field correction, no flux calibration.
- ◆ Pa α emission line image was made using fixed scale factor (0.55) subtraction : PAAL – $0.55 \times$ PAAC (NEP Obs calculated, PAAL/PAAC Filter Ratio).



Pa α emission observations : Early Results

1. Galactic Plane Survey



H α Image (Finkbeiner, 2003, ApJS, Ground Obs)

MIRIS Pa α emission line (PAAL-PAAC) Image (This Paper)

FIR + IRAS, SFD E(B-V) (Schlegel et al. 1998)

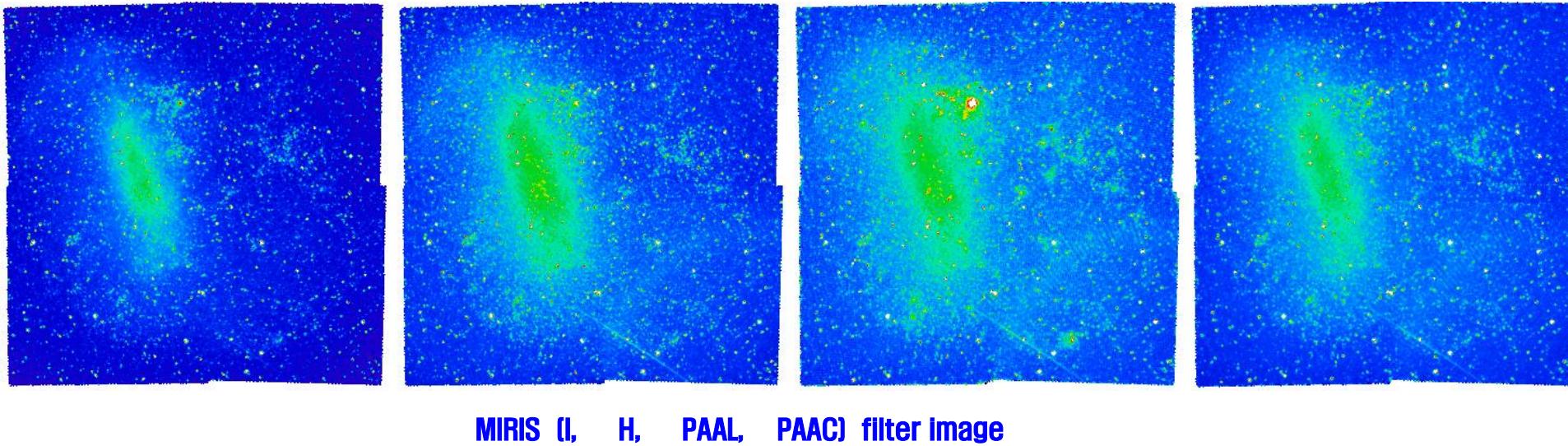
- ◆ Many of detected Pa α features are brighter than predicted by the H α observations (some of them are invisible in H α).
- ◆ Bright Pa α blobs coincide well with dense cloud regions (Star Forming Cloud).



Pa α emission observations : Early Results

2. Additional Pointing Observations

- ◆ One sample result : LMC ($7^\circ \times 7^\circ$ Field)



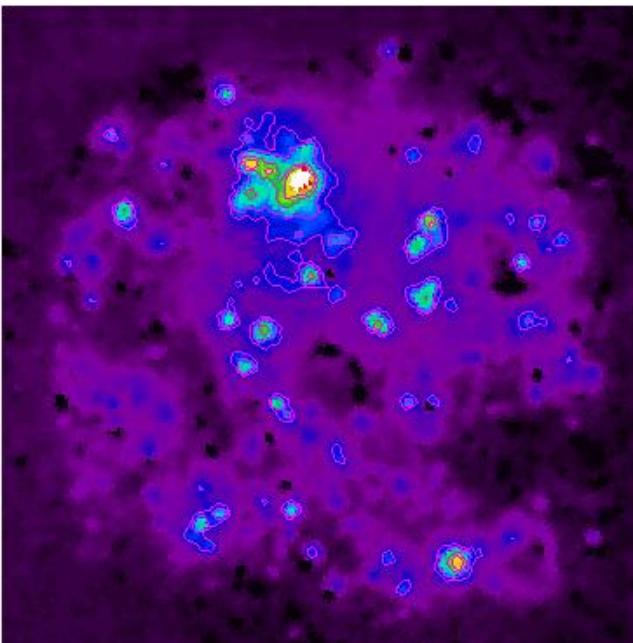
- ◆ Cover the whole LMC region with 4 field observations.
- ◆ I & H filter : 1 orbit observation per field.
- ◆ PAAL, PAAC filter : 5 orbits observations per field.
- ◆ **incompletely processed** images : no removal of detector background, no on-orbit flat field correction, no flux calibration.



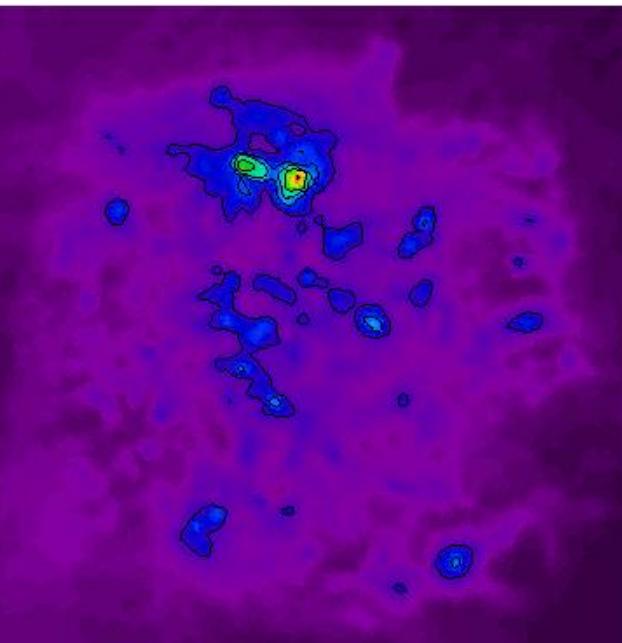
Pa α emission observations : Early Results

2. Additional Pointing Observations

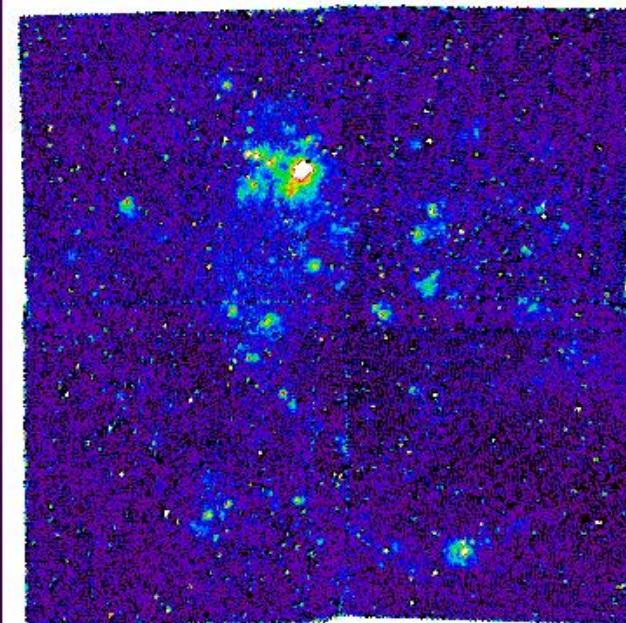
- ◆ One sample result : LMC



H α image (Finkbeiner, 2003)



SFD E(B-V) (Schlegel et al. 1998)



MIRIS Pa α emission line (PAAL-PAAC) image



Pa α emission observations : Future Work

- ◆ Cover the region of $/ = +100^\circ$ to $+280^\circ$ (2014 Nov.–2015 Mar.) and complete the whole Galactic plane survey.
- ◆ Complete basic data reduction (removal of detector background, on-orbit flat field correction, flux calibration).
- ◆ Re-estimate the scale factor of PAAL & PAAC and then apply spatially variable scale factor subtraction.
- ◆ Remove point sources and then complete diffuse Pa α emission line map.
- ◆ Compare the results with Radio survey data (radio recombination line, radio continuum) as well as H α data.
- ◆ Catalog newly detected Pa α blob sources (New Obj ?).



STSAT-3

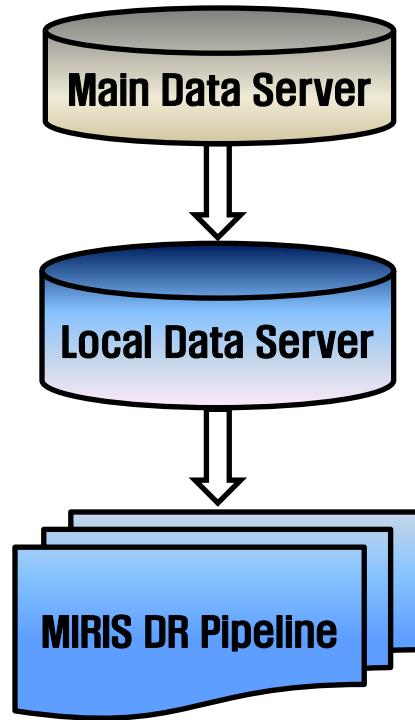
Observation Plan

Orbits / day

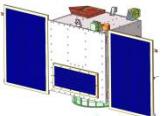
Mission	1 st Phase [1 mo] 2014 Mar.	2 nd Phase [5 mo] Apr.~Aug.	3 rd Phase [2 mo] Sep.~Oct.	4 th Phase [5 mo] Nov.~2015 Mar.	5 th Phase [8 mo] 2015 Apr.~
CIRB Survey	8		7		
Pa α Galactic Plane Survey		7		7	User time
Calibration (NEP monitoring)	2	1 (2 obs. every other day)	1	1	

Data Distribution System

- SOC
 - Data Reduction S/W Developed (Linux, Python)
 - Will Be distributed by KASI, Big Data Center



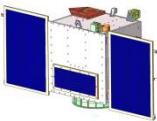
- Main data server:
Download Data from Satellite
- Local data server (inside KASI)
 - Download from Main Server
 - Header Record Obs Info such as Obs Bands, Position
 - FITS Image produce
 - Register each database
- MIRIS DR (Data Reduction)
Pipeline: Image Production for Science Analysis



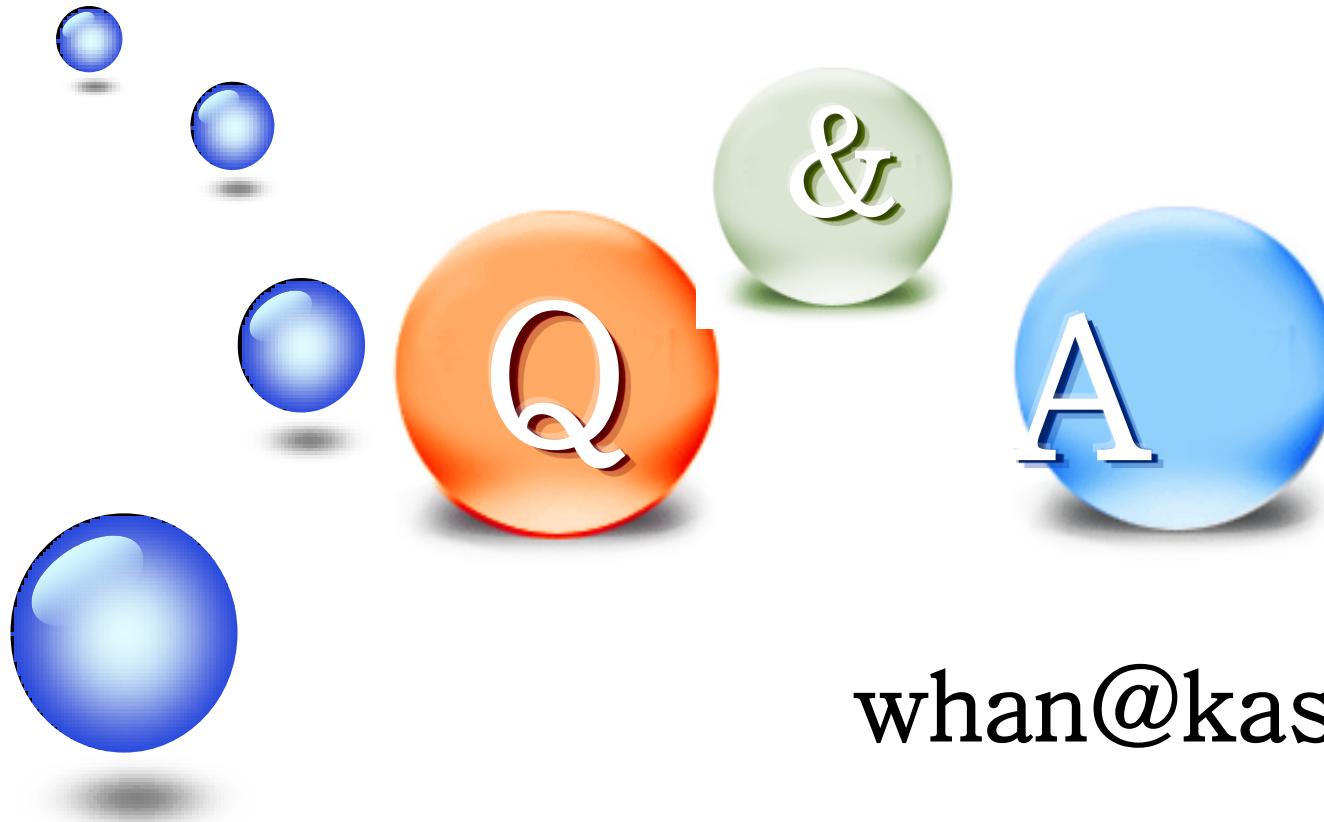
STSAT-3

Future Plans

- **Follow-Up Observation of Deep Fields**
 - Lockman Hole
 - AKARI Deep Field South
 - Hubble Deep Field North / South
 - Elias Fields
 - North / South Galactic Poles
 - *etc.*



STSAT-3



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감사합니다