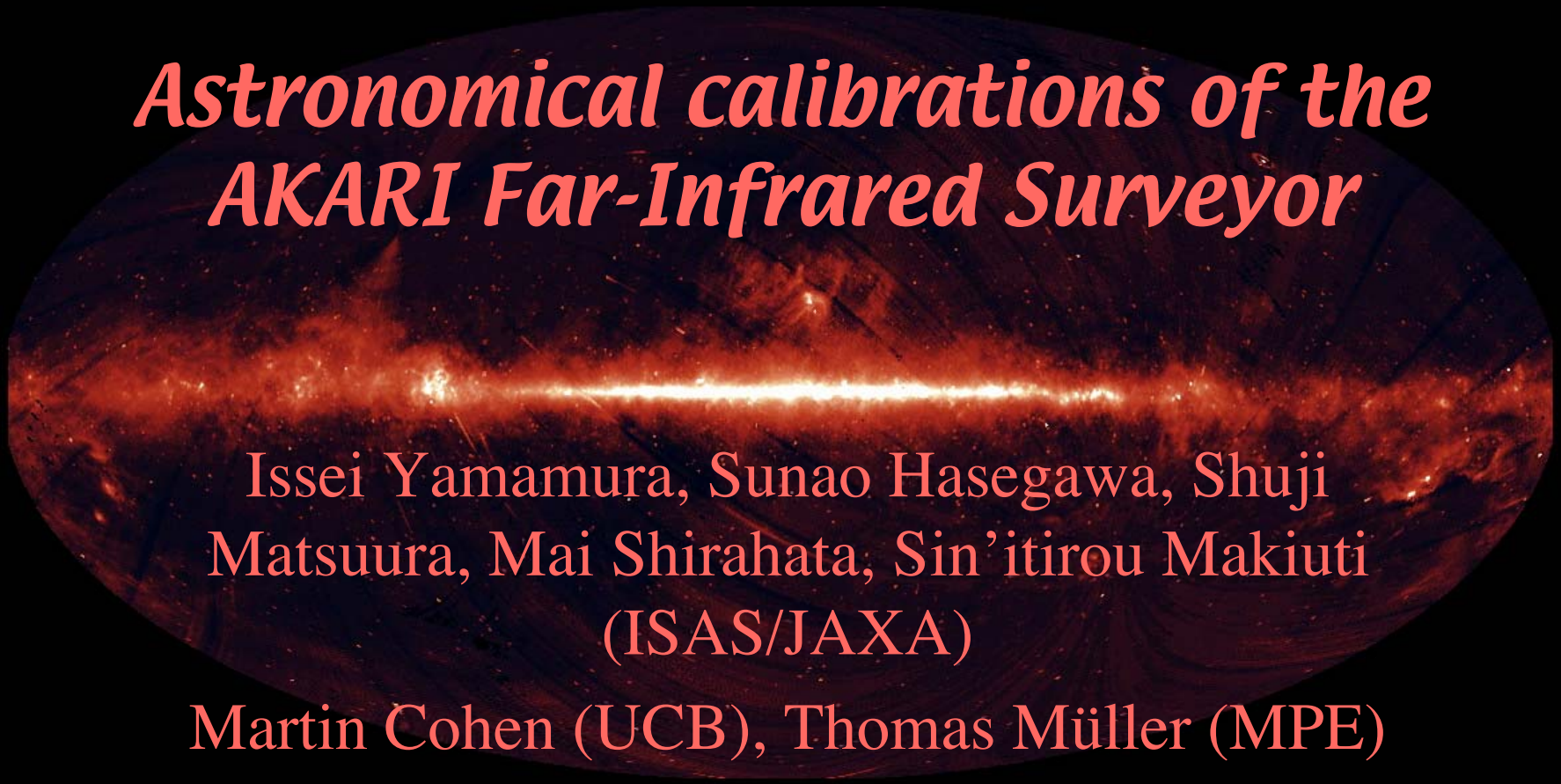
Astronomical calibrations of the AKARI Far-Infrared Surveyor



Issei Yamamura, Sunao Hasegawa, Shuji Matsuura, Mai Shirahata, Sin'itirou Makiuti (ISAS/JAXA)

Martin Cohen (UCB), Thomas Müller (MPE)

on behalf of AKARI Project / FIS team

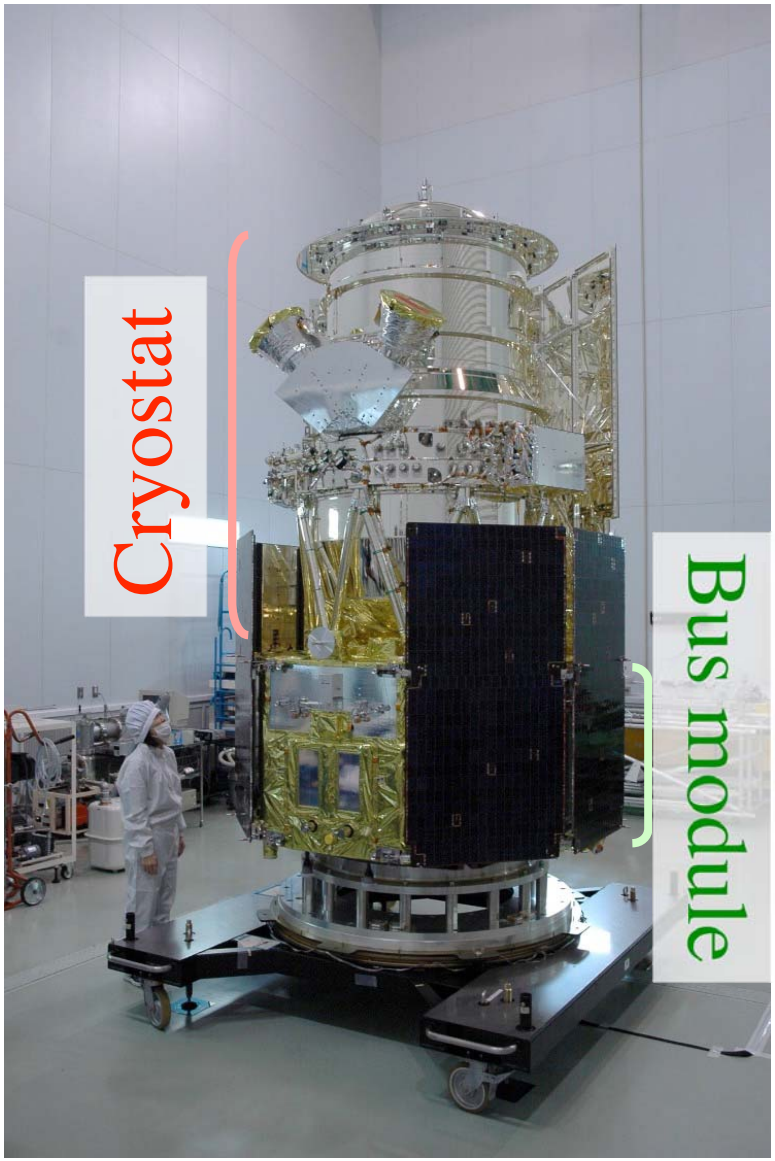
http://www.ir.isas.jaxa.jp/AKARI/

Outline of this presentation

- AKARI Mission
- Current status of the FIS (flux) calibration
- Possible contribution of AKARI data to Herschel calibration

All results we will give here are ***preliminary!***

AKARI Satellite



Height: 3.7 m

Weight: 952 kg (@Launch)

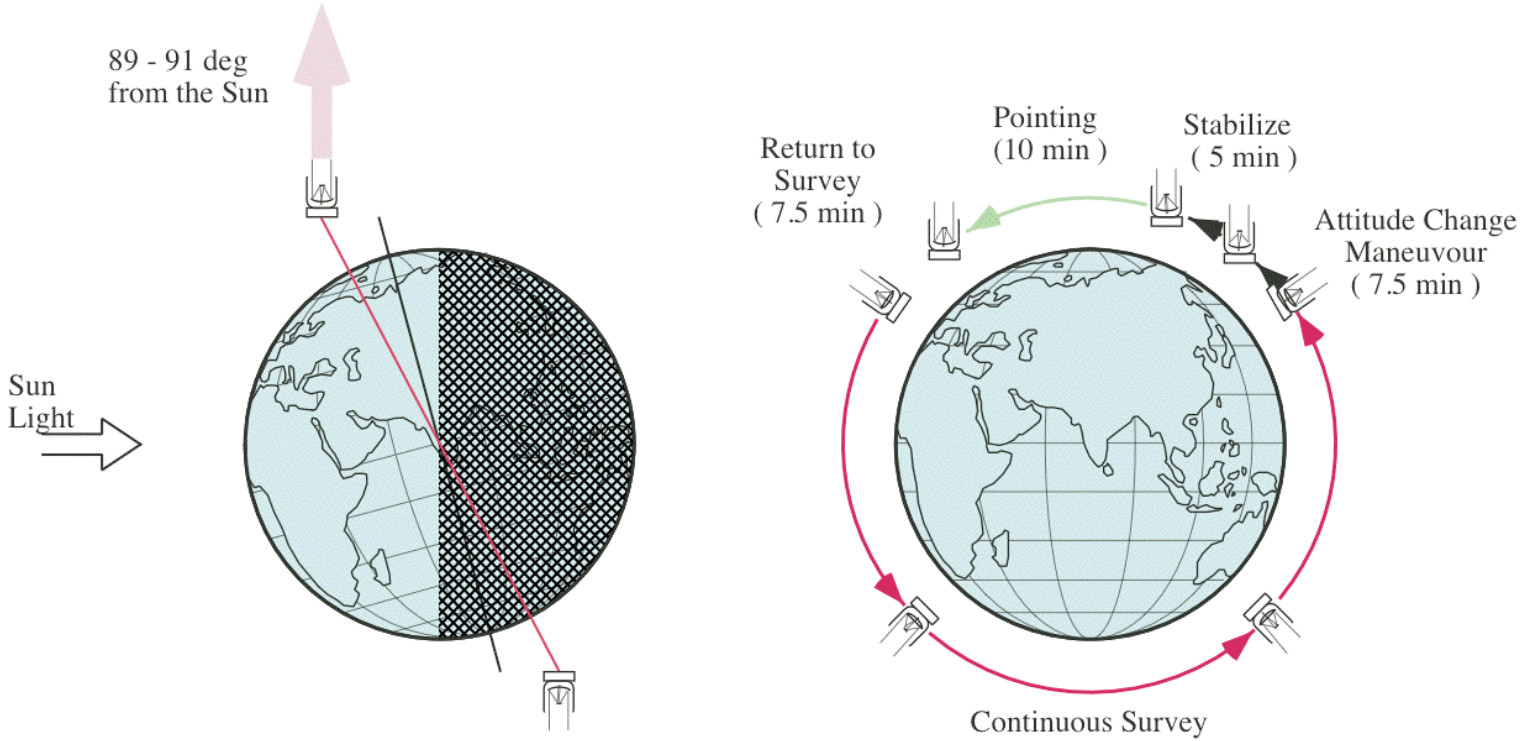
A 68.5 cm ϕ cooled telescope

Two scientific instruments covers wavelength in 1.8~180 μm

The telescope and focal-plane instruments were kept in 2~6 K by stirling coolers and liquid Helium

Orbit and Operation Modes

- Sun-synchronous polar orbit
- Altitude: 700 km
- Orbital Period: 100 min



Survey Mode & Pointing Mode

Telescope

- Aperture 68.5 cm, F/6.1 Rithcy-Chrétien system
- Mirrors were made by SiC
- Weight:
  11 kg (Primary mirror)
  42 kg (Total)

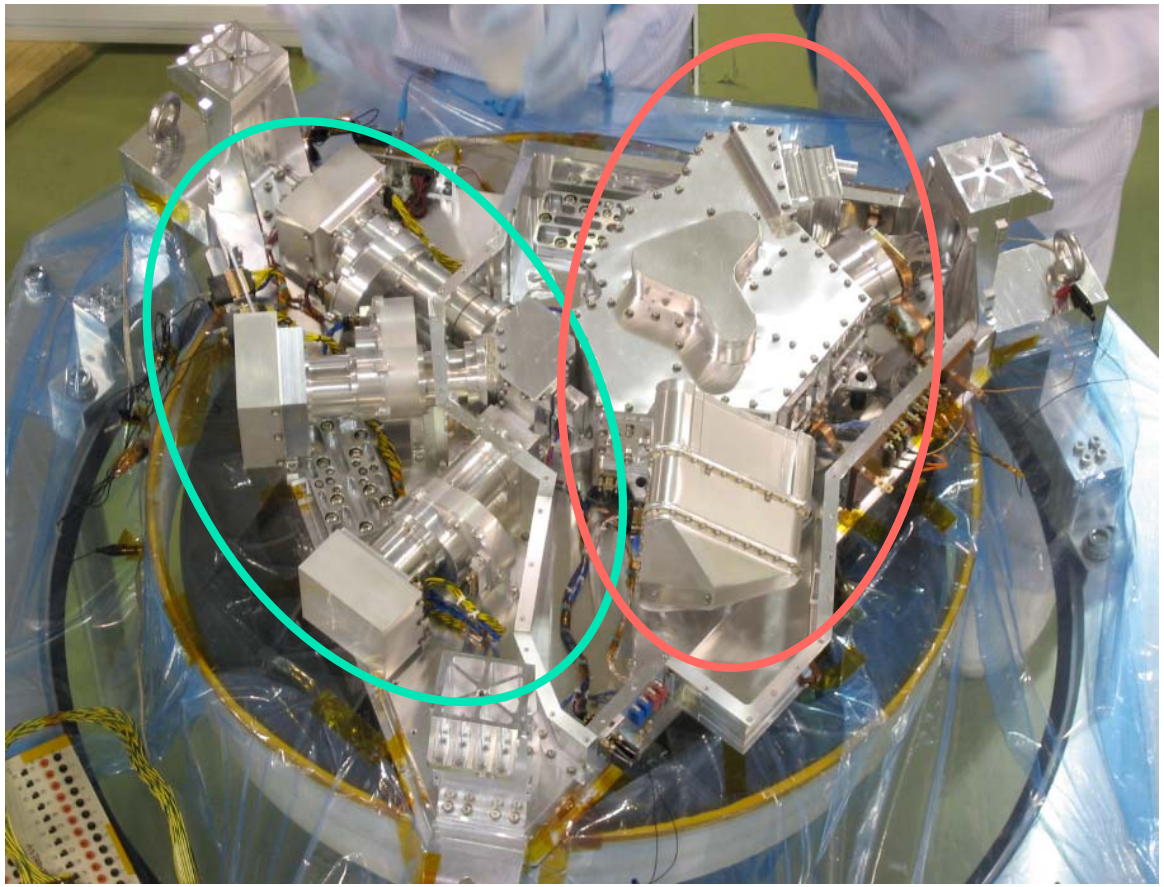
- Cooled down to ~6 K
- Diffraction limit at ~6μm

Focal Plane Instruments

(Far-Infrared Surveyor)

FIS

50–180 μm



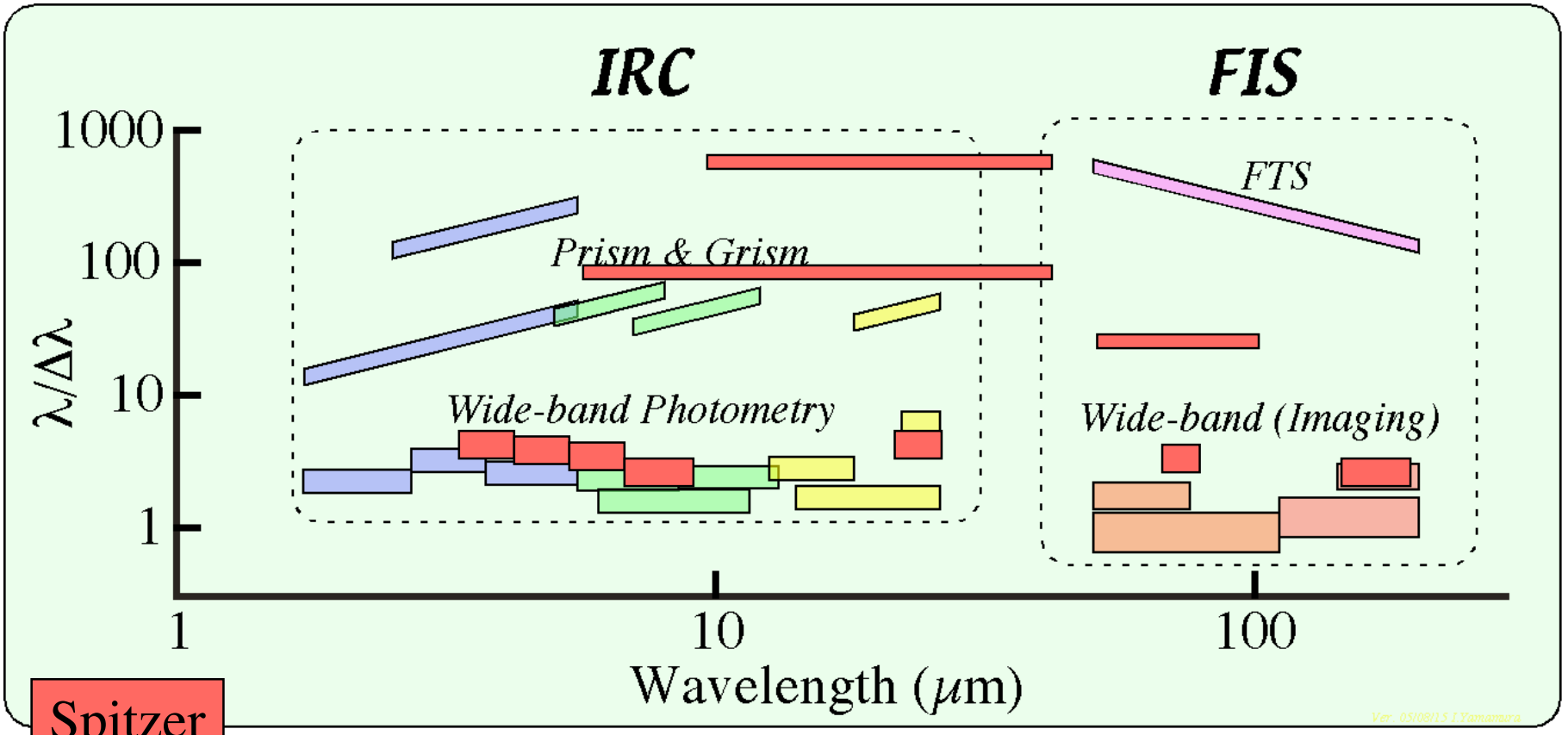
1.8–26 μm

IRC

(Infrared Camera)

Onboard Instruments

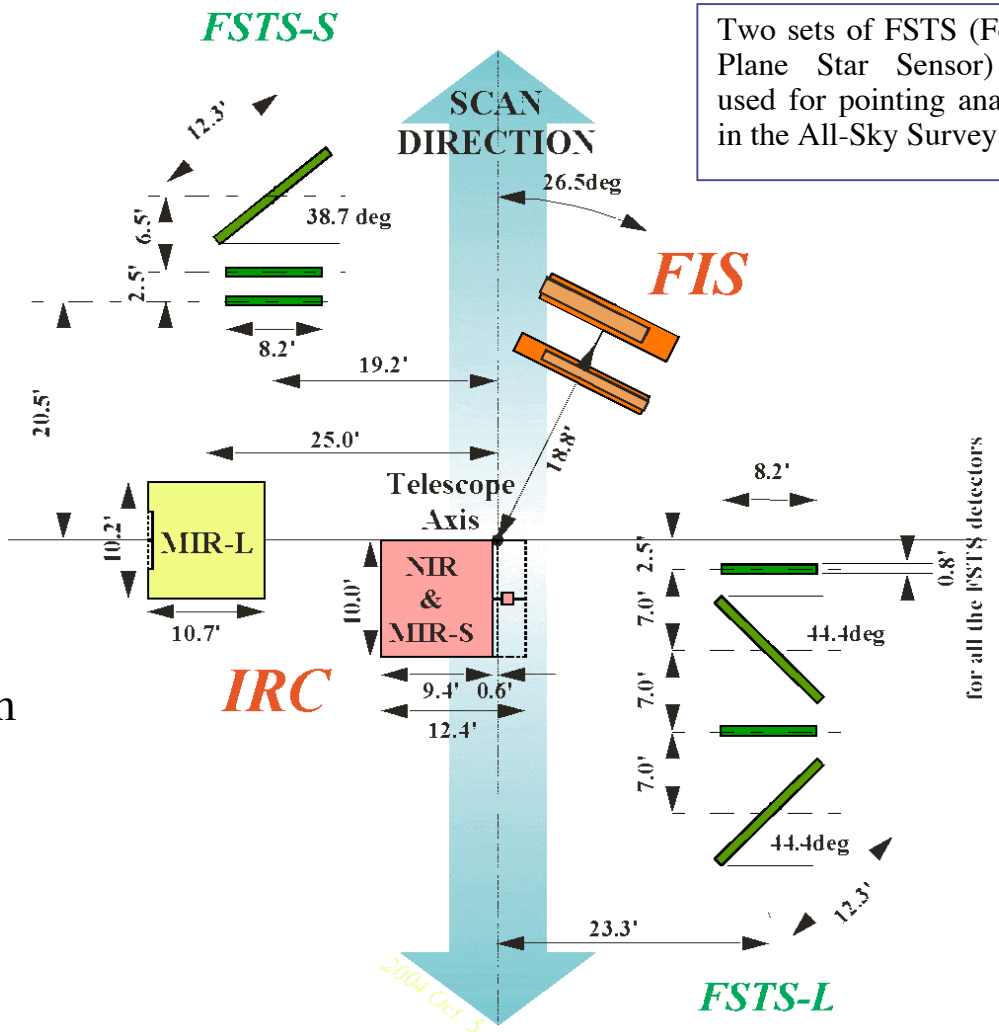
Photometric & Spectroscopic Capabilities



Field of View

- Three apertures
  - FIS (SW + LW)
  - IRC (NIR + MIR-S)
  - IRC (MIR-L)

- All instruments *can* be operated simultaneously.
  - Three apertures look at different areas of the sky.
  - FIS two channels share the same area of the sky by beam splitter.
  - IRC NIR and MIR-S share the same area of the sky by beam splitter.

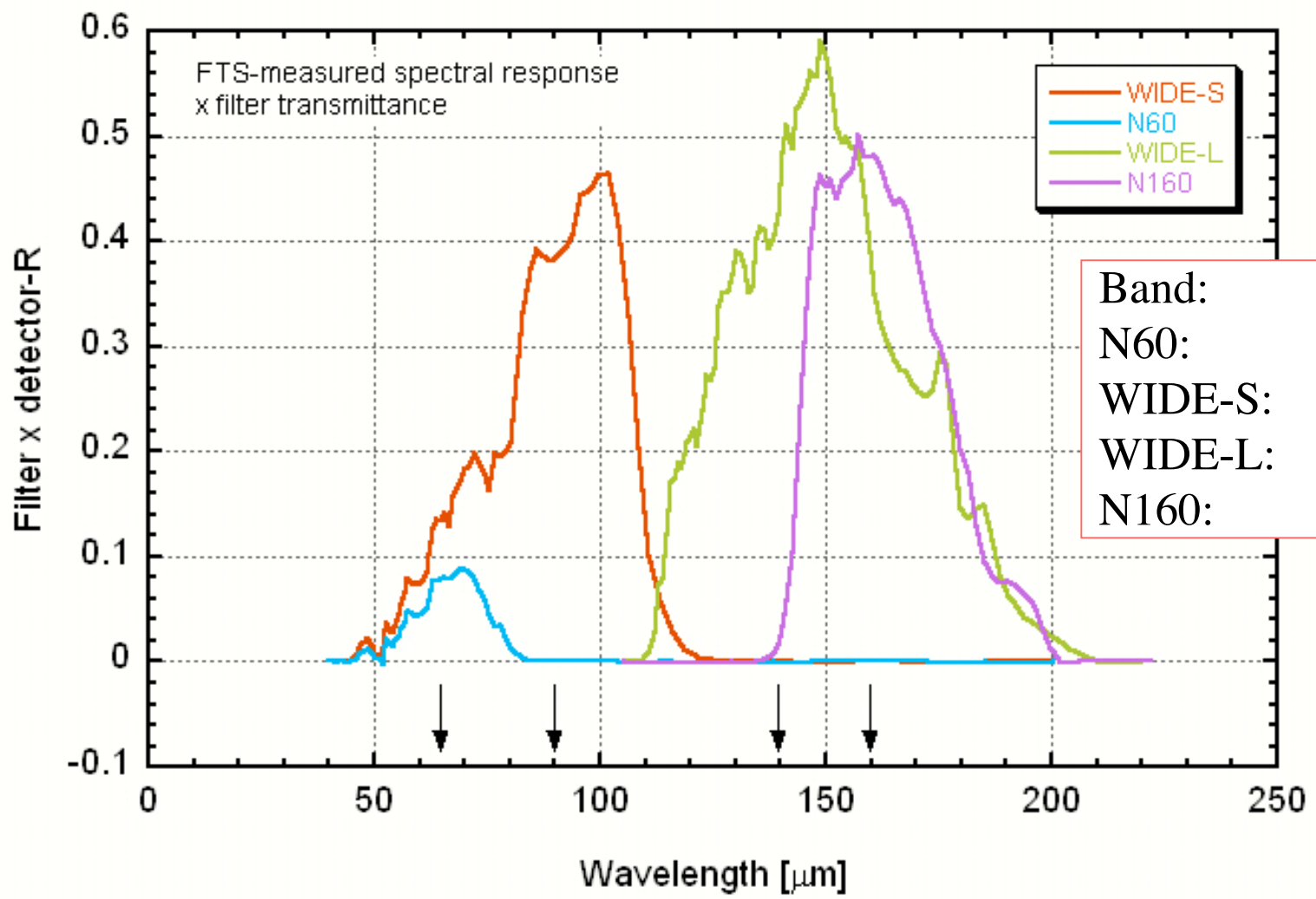


Two sets of FSTS (Focal-Plane Star Sensor) are used for pointing analysis in the All-Sky Survey.

FIS Photometric Mode

Band	N60	WIDE-S	WIDE-L	N160	
Wavelength	50–80	60–110	110–180	140–180	[μm]
Central Wavelength	65	90	140	160	[μm]
Detector	Monolithic Ge:Ga		Compact Stressed Ge:Ga		Ge:Ga chips supplied by NICT
Readout	Charge Trans-Impedance Amplifier (CTIA)				
Array format	20 x 2	20 x 3	15 x 3	15 x 2	Pixels
Pixel size (Physical size)	27 x 27 (0.5 x 0.5)	27 x 27 (0.5 x 0.5)	44 x 44 (0.9 x 0.9)	44 x 44 (0.9 x 0.9)	[arcsec^2] ([mm^2])

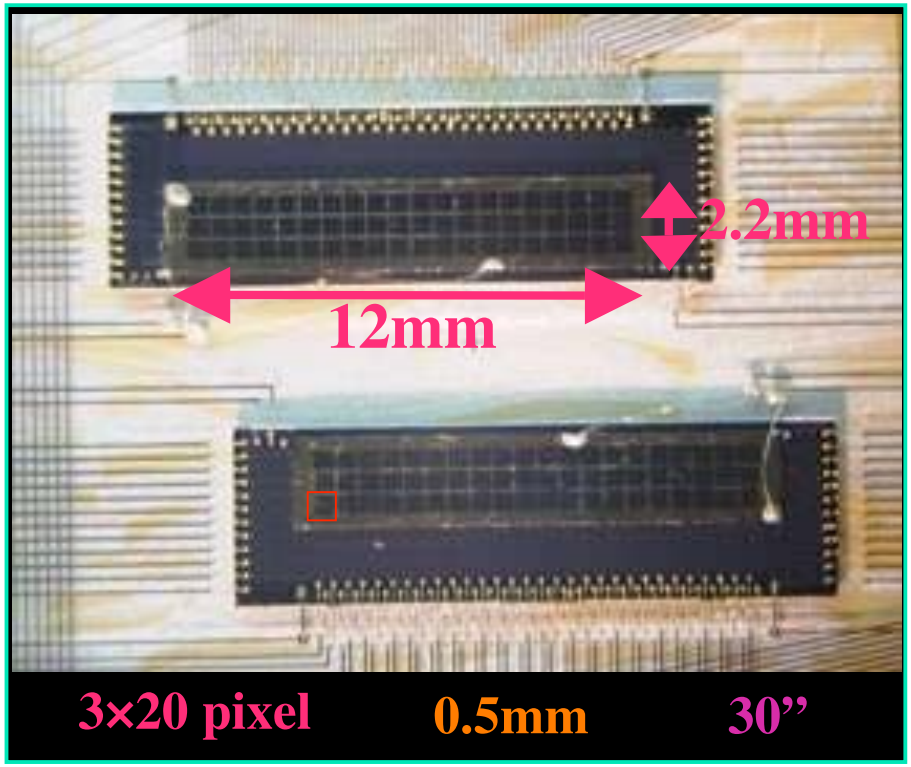
FIS RSRF



Band:	λc
N60:	65 μm
WIDE-S:	90 μm
WIDE-L:	140 μm
N160:	160 μm

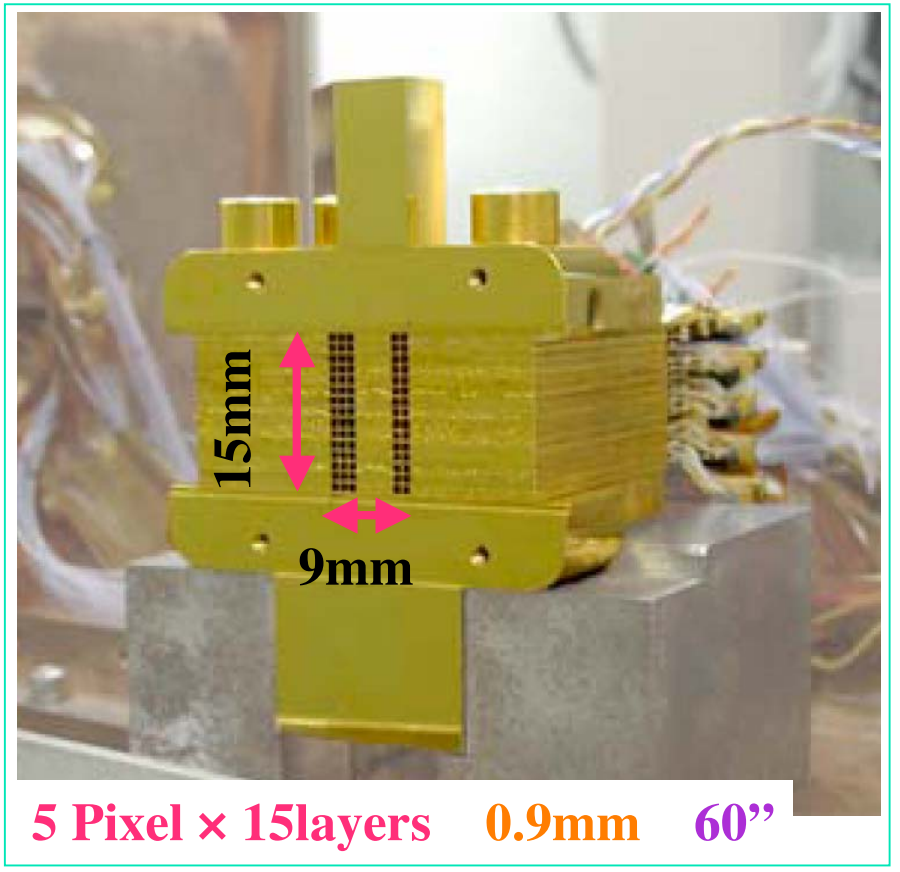
FIS detectors

Short wave band（50-100μm)



- Ge:Ga monolithic array

Long wave band(110-180μm)



- stressed Ge:Ga stacked array

**The FIS detectors were developed with the participation of NICT.*

FIS Detectors

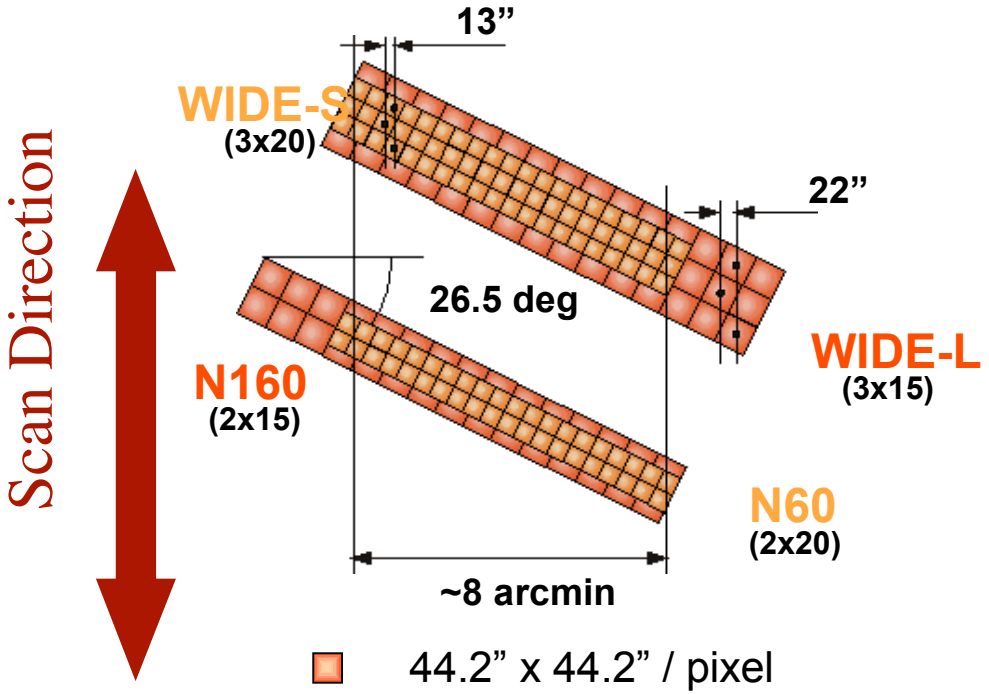
WIDE-S: 3x20

N60: 2x20

N160: 2x15

WIDE-L: 3x15

Overlap each other

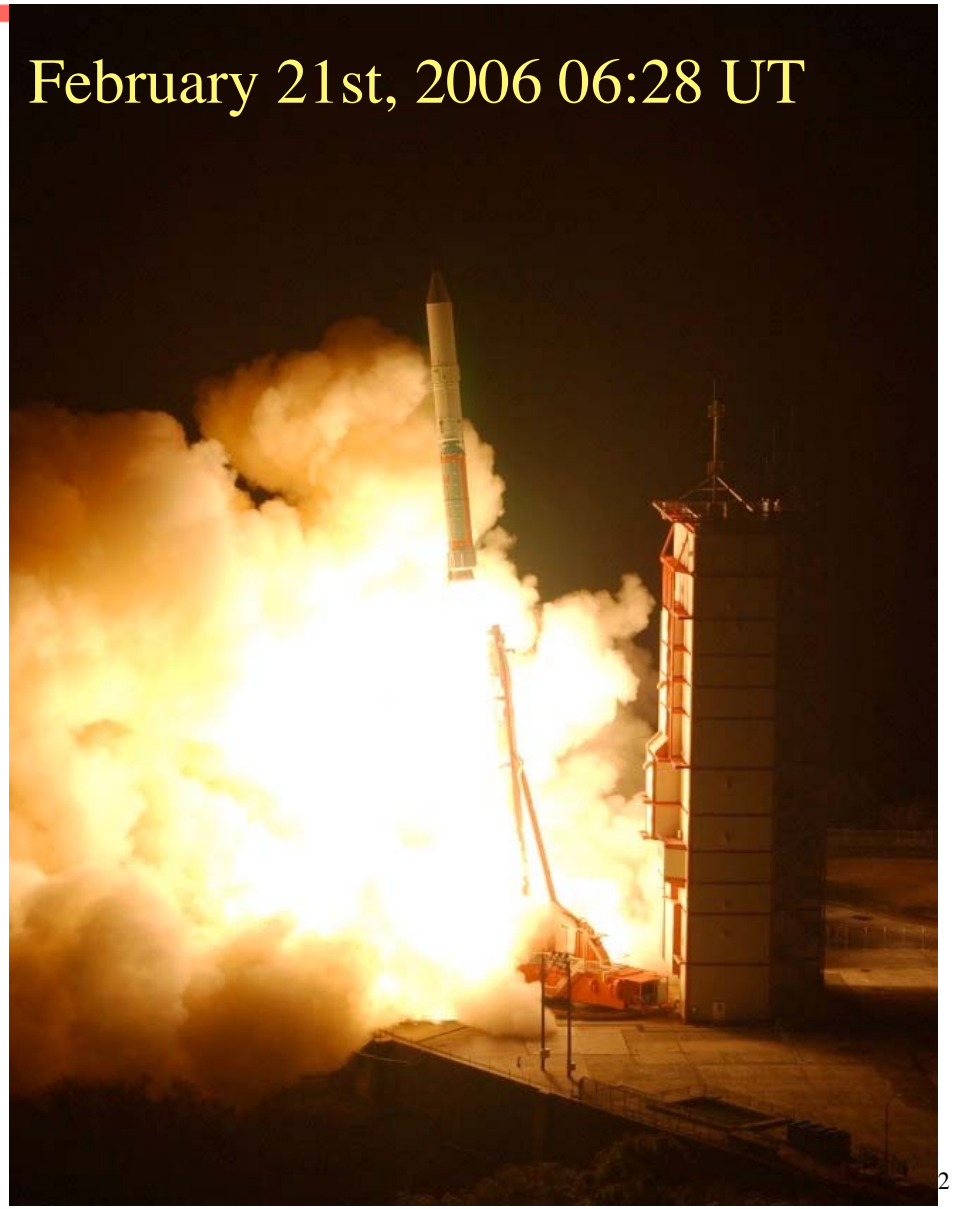


FoV of the FIS

Scan direction ~ along the constant Ecliptic longitude

AKARI Launch

M−V–8 rocket



February 21st, 2006 06:28 UT

Initial Operation

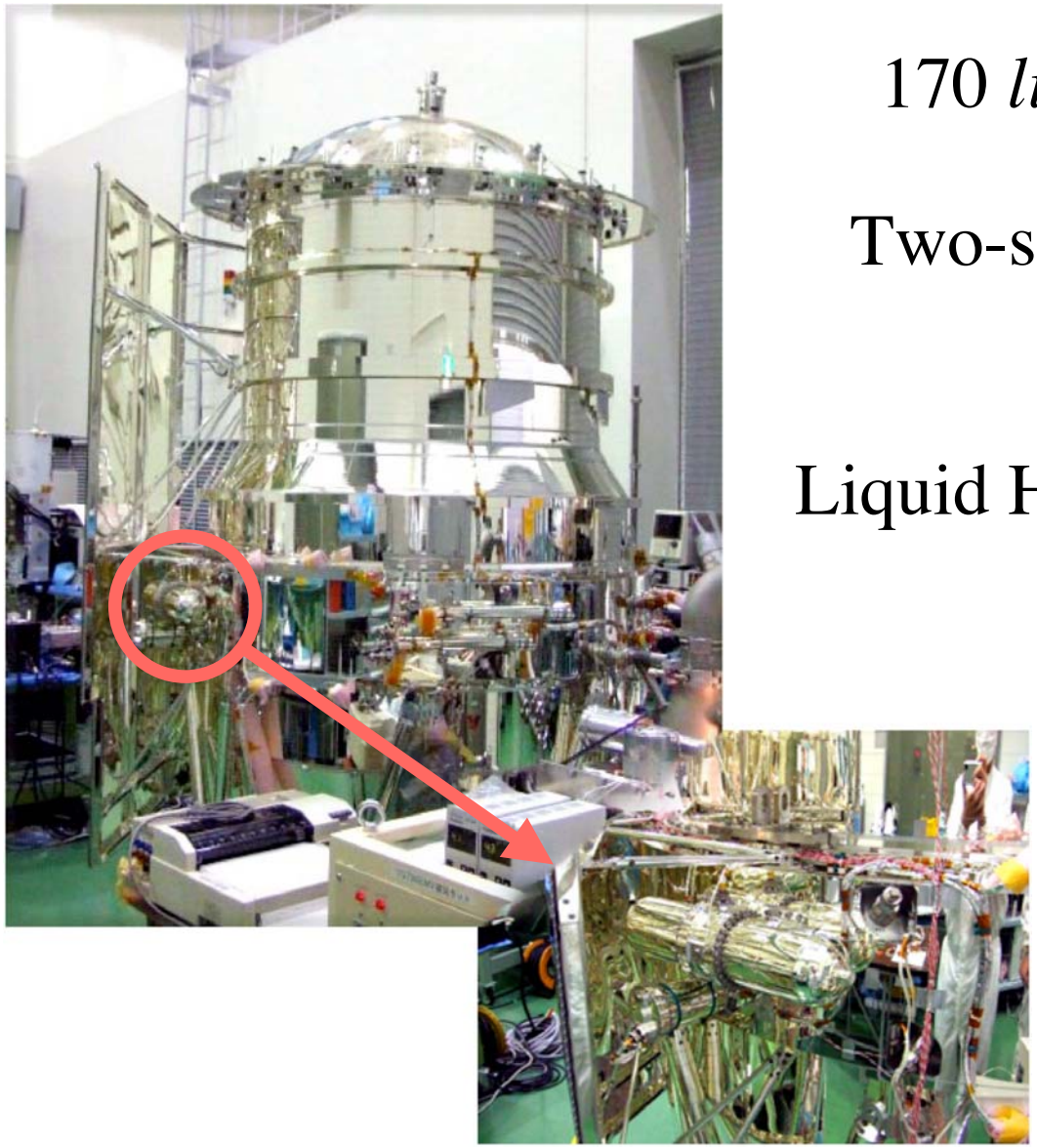
- Launch: 2006 February 22nd (JST)
- Two Sun sensors did not provide signal
  - Instruments seemed working well.
  - Also several problems on other instruments.
  - Something mask the sensors?
- Onboard attitude control program revised not to use the Sun sensors
- Aperture Lid Open = First light on April 14th (Originally March 8th)
- Extra consumption of liquid He.

AKARI Operation Phases

Launch

Checkout	Apr. 14, 2006 Checkout & Performance Verification
Phase 1 (~180 days)	May 7, 2006 FIS all-sky survey: 1st priority LS+Some MP Pointed Obs
Phase 2 (~300 days)	Nov. 10, 2006 MP + OT Pointed Obs. Supplemental FIS survey
2nd PV	LHe boil-off (Aug. 26, 2007)
Phase 3 (>365 days)	only NIR in operation MP + OT pointed Obs.

Cryogenics



170 *liter* liquid Helium

+

Two-stage Stirling Cycle Cryocoolers

=

Liquid He lifetime: 550 days

Cryogenics: Performance

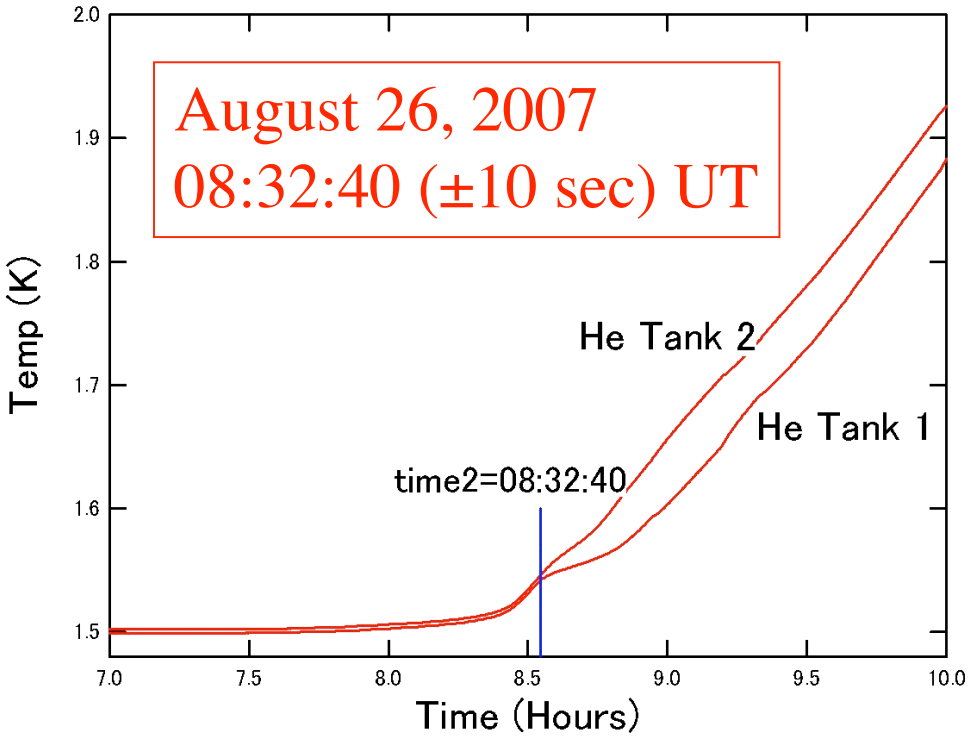
- He tank:
  - 1.5 K (pre-launch expected 1.6 K)
- Telescope
  - Primary mirror: 6.2 K (5.6 K)
- FIS
  - Body temperature : 1.7 K (1.9 K)
  - SW detector: 2.0 K (2.2 K)
  - LW detector: 1.9 K (2.1 K)
- IRC
  - NIR detector: 10 K
  - MIR-S/L: 7 K

He evaporation rate is slightly lower than expected.

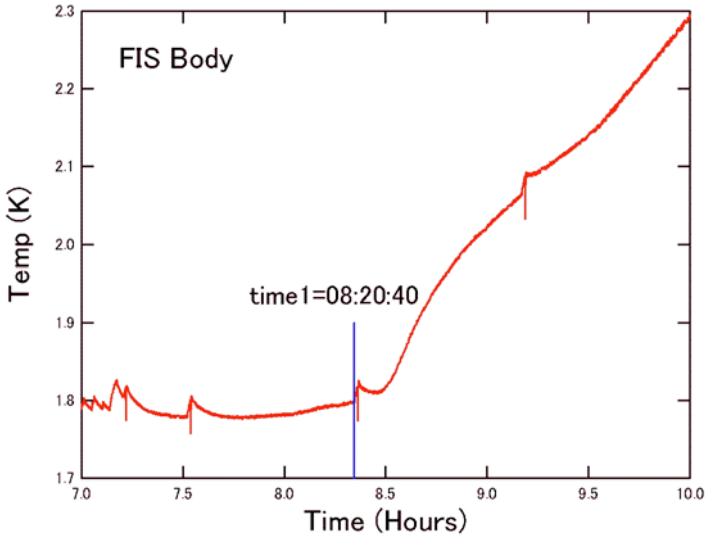
Liquid Helium boil off

- Temperature from two thermometers in the He tank started deviating = film flow broke

550.5 days since the launch



The FIS body temperature started increasing earlier.



What we have done.

- All observation instruments worked properly during the whole mission without trouble.
- Optimization of the observation sequence done during the operation.

- All-Sky Survey:
  - The FIS scanned 94 % of the entire sky more than twice.
  - The IRC scan did for more than 90 %.

- Pointed observation
  - More than 5000 pointings were carried out.

FIS Detectors

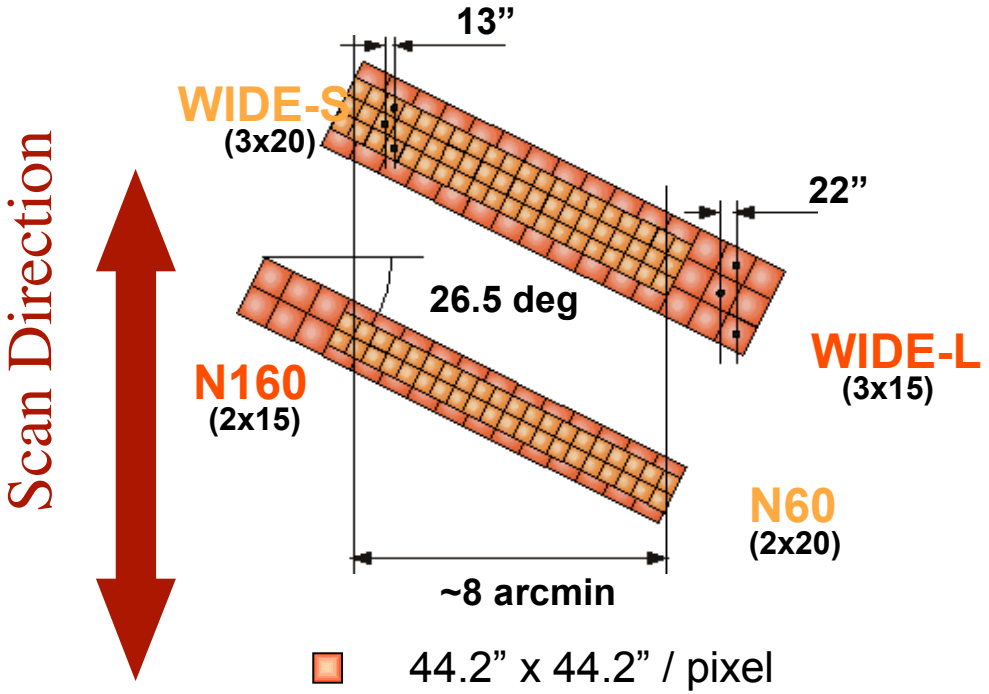
WIDE-S: 3x20

N60: 2x20

N160: 2x15

WIDE-L: 3x15

Overlap each other



FoV of the FIS

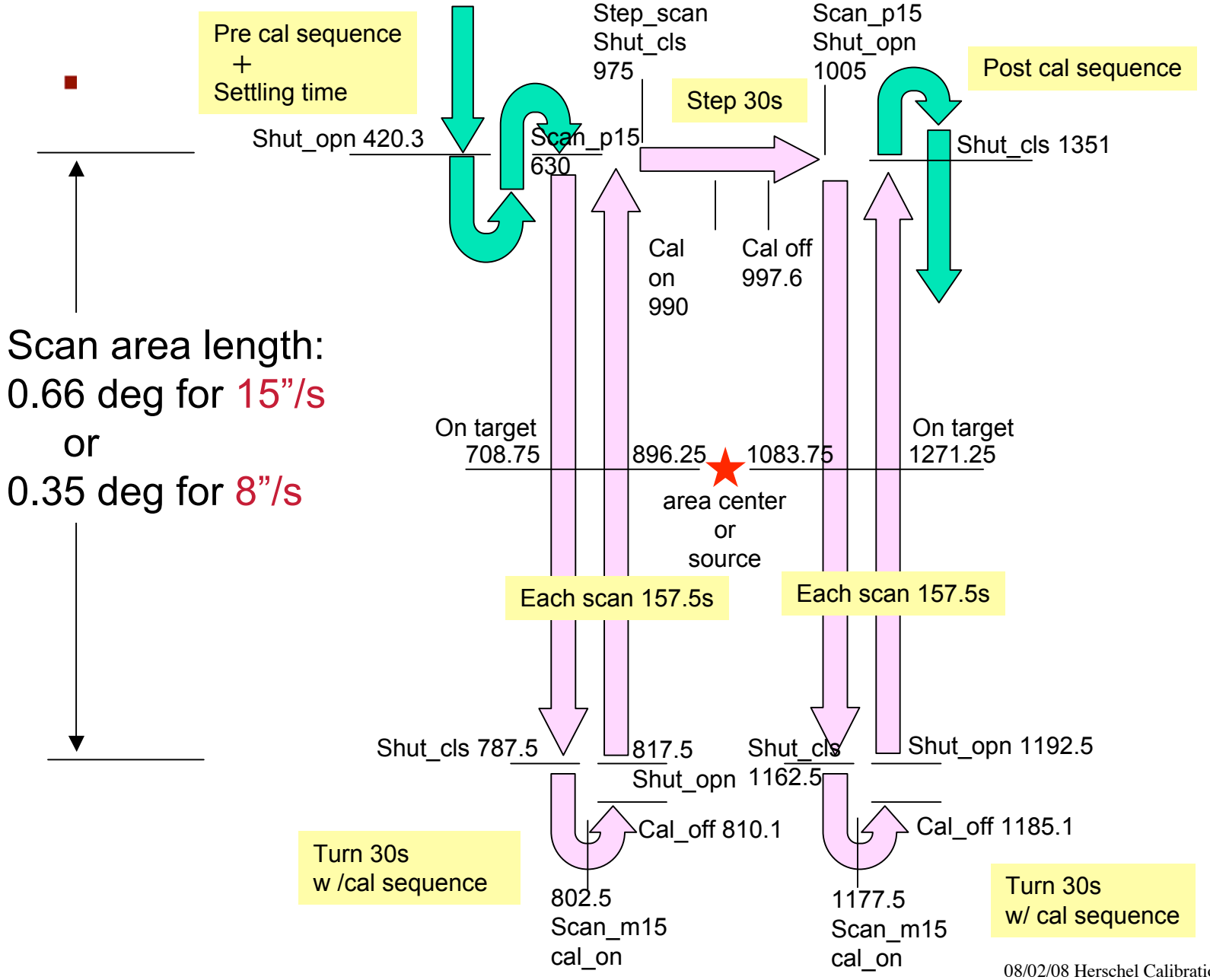
Scan direction ~ along the constant Ecliptic longitude

FIS Observation Modes

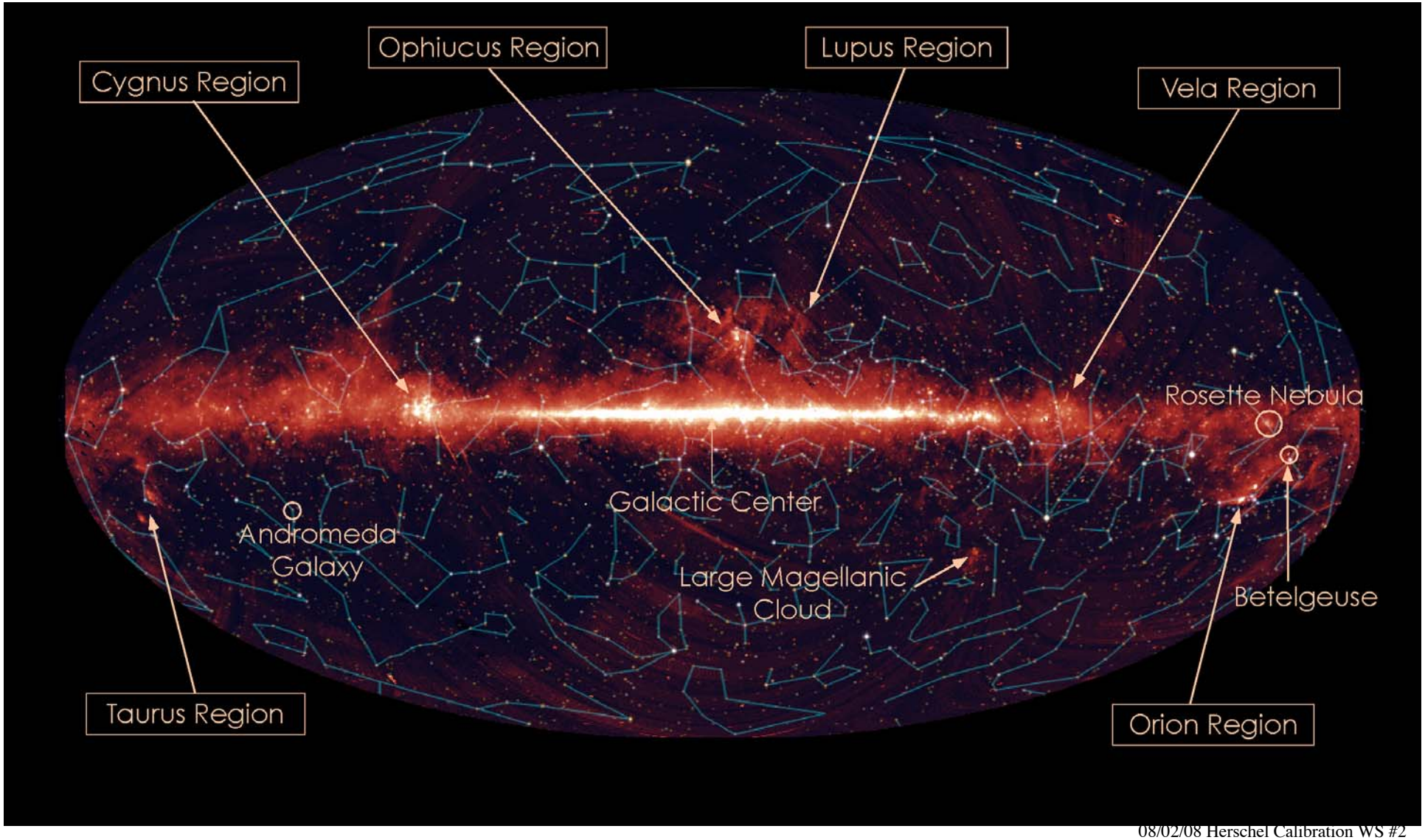
- All-Sky Survey: continuous data acquisition while the spacecraft scans the sky at 3.6 arcmin/sec.

- Pointed Observation: Observations of target positions. ~12 min exposure / obs.
  - Slow-Scan: Taking images by scanning the sky. Data acquisition is identical with the survey.
  - FTS: Data acquisition at the higher sampling rate while scan mirror is driven. Staring pointing.

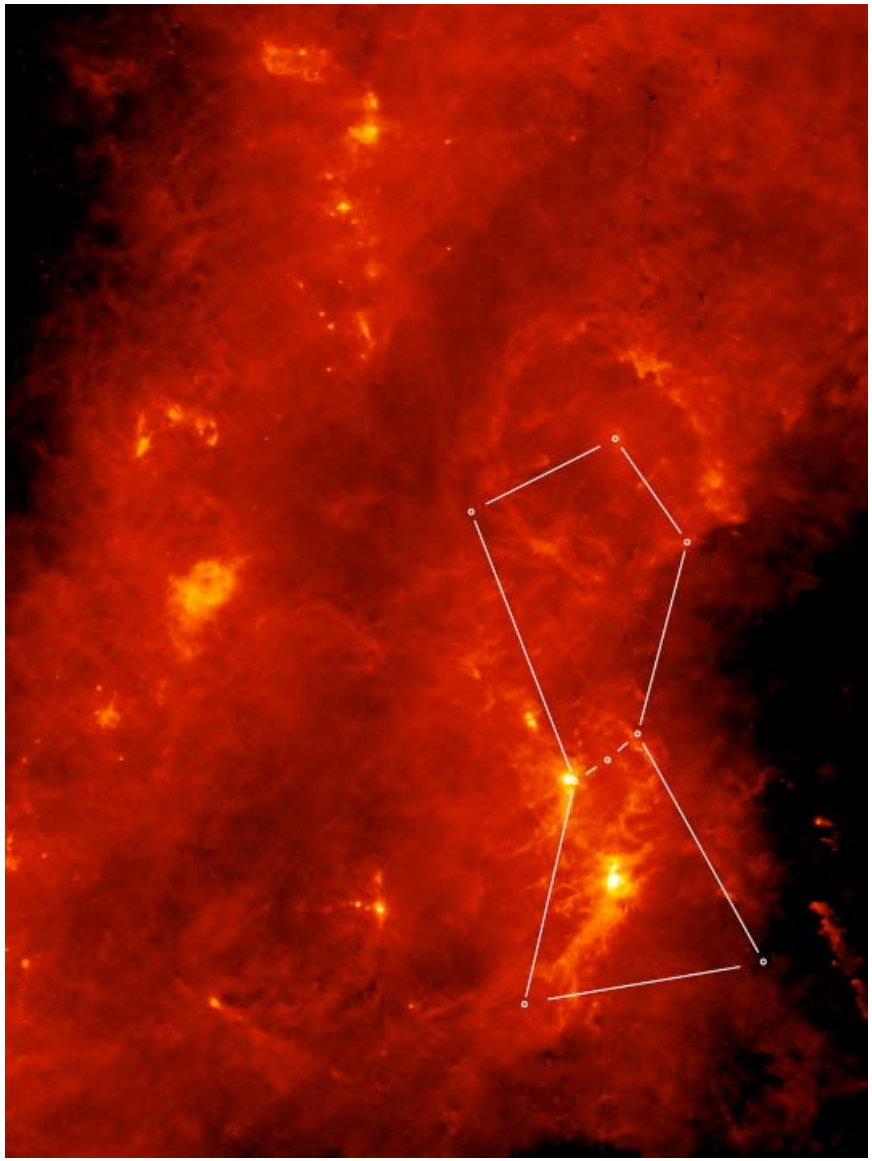
Observation Sequence (FIS01)



The entire sky at 9 μm



Orion region at 140 μm



- Reconstructed image from the FIS All-Sky Survey (WIDE-L = 140 μm).
- No scientific quality calibration has applied yet.

Doi et al.

The FIS data reduction and calibration scheme

FIS Flux Calibration Strategy

	Purpose	Requirement	Timescale	Source
Internal Calibrators	Relative	Stability	< 100 min	Cal. lamps
External Calibrators	Relative	Stability Visibility	> 100 min	Stars
Absolute Calibrators	Absolute	Accurate flux	∞	Stars Asteroids

Flight performance

	N60	WIDE-S	WIDE-L	N160
All-Sky Survey [mJy]	2400 (500)	550 (100)	1400 (100)	6300 (300)
Slow-Scan* [mJy]	130 (45)	26 (9)	67 (6)	330 (12)

- 5-sigma noise level per scan
- Slow-Scan is for the scan speed of 8 arcsec/sec and reset interval of 2.0 sec.
- Main causes of the degration:
  - Detector bias lowered (LW)
  - Detector temperature was too low (SW).
  - Glitches cause unstable signal level.

Kawada et al., 2007, PASJ 59, S389

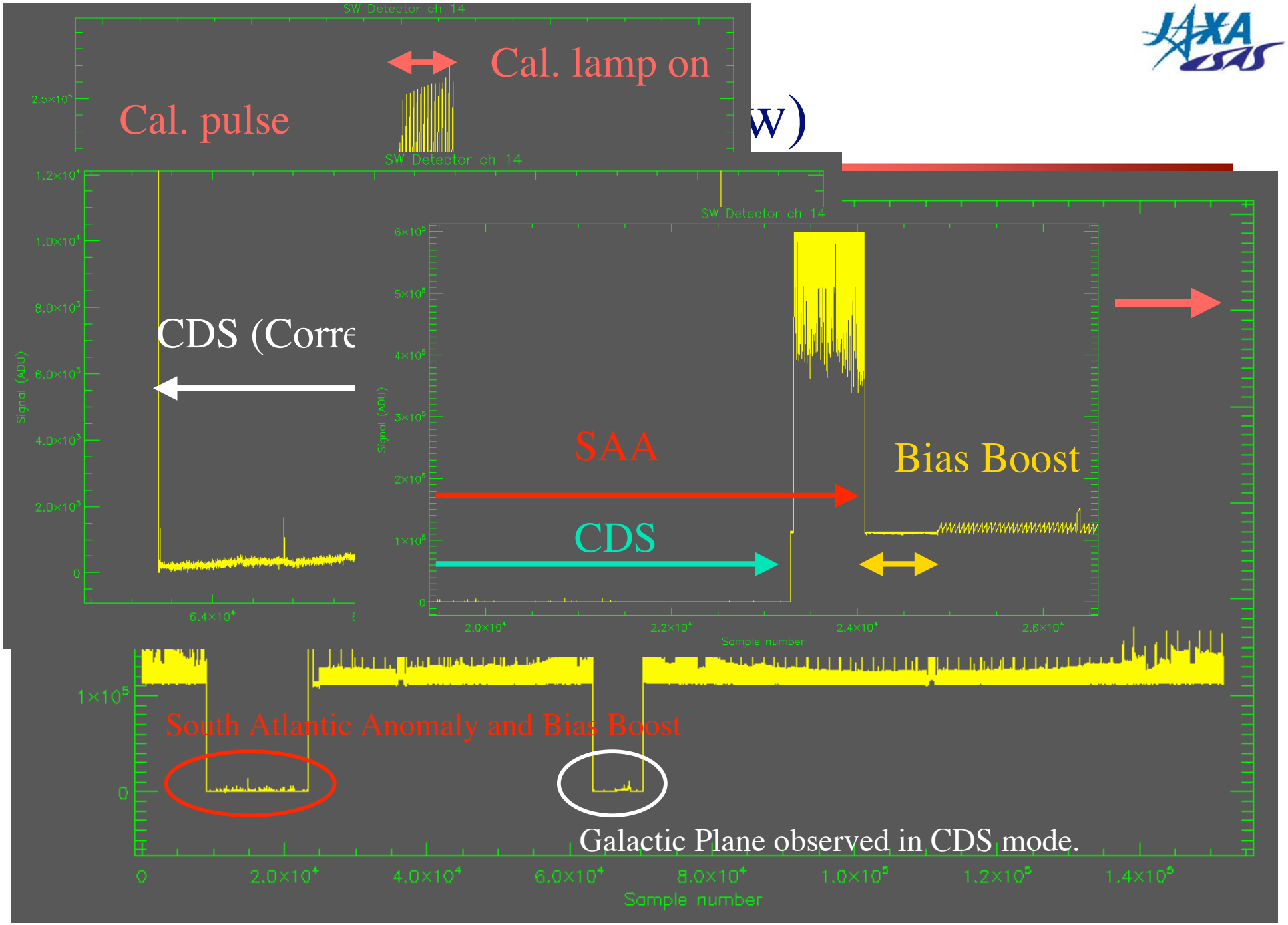
Visibility constraint

AKARI has severe constraint on visibility.

- Pre-launch design
  - Cross-scan offset was only allowed within ±1 deg.
  - cf. IRAS could have offsets of 30 deg.
- In the real operation
  - Allowance angle was even narrowed to ±0.6 deg due to trouble on Sun-sensors.
- Hard to find monitoring target.

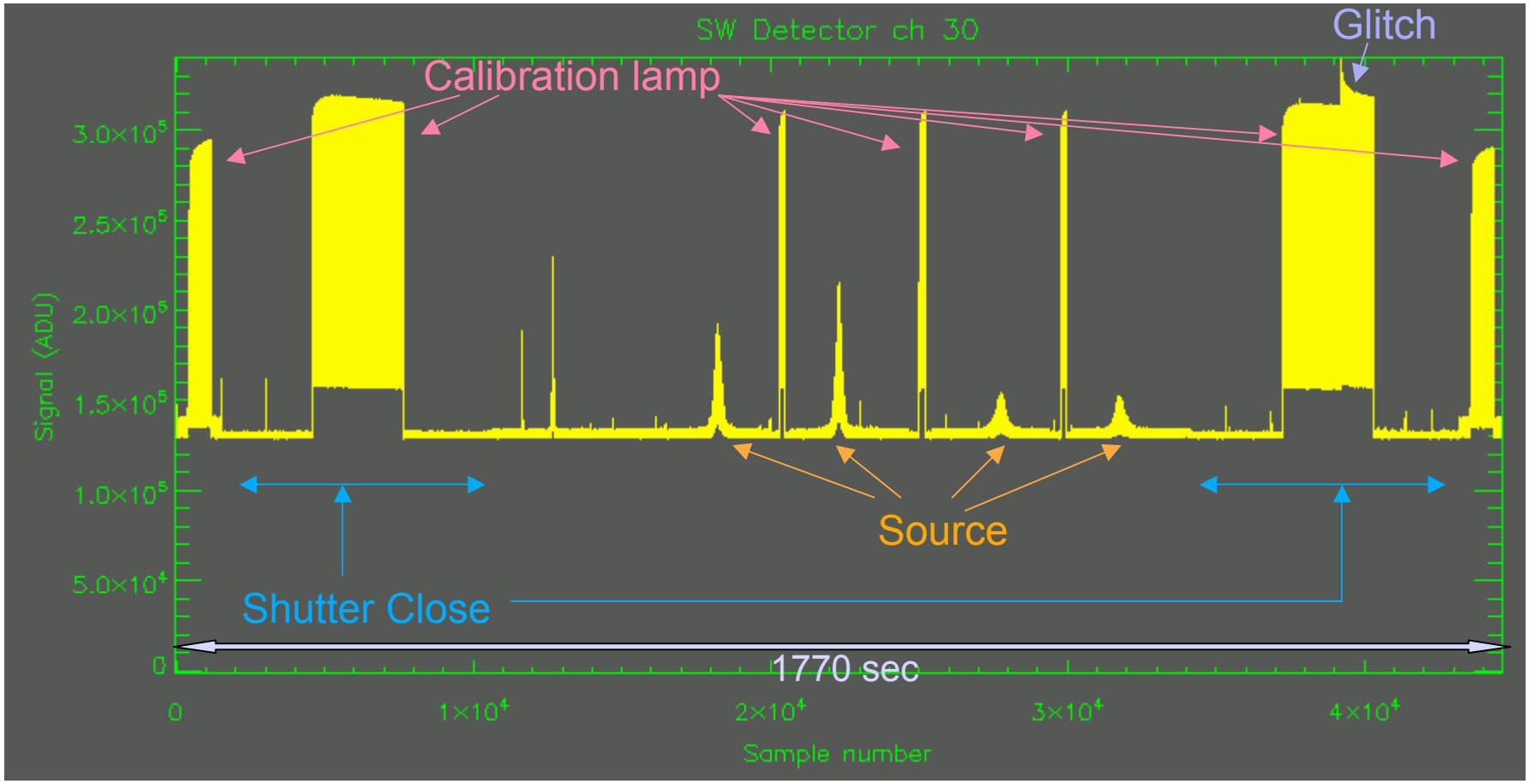
Our primary calibration standards

- Asteroids
  - In-collaboration with Thomas Müller.
  - 55 candidates of flux standard asteroids are being evaluated with AKARI data.
- Stars
  - In-collaboration with Martin Cohen.
  - All-sky standard network consisting with 614 stars.
- Planets
  - Model flux provided by courtesy of Raphael Moreno.
  - Mainly for the FTS calibration.


SW Detector ch 14
Cal. lamp on
Cal. pulse
w)
SW Detector ch 14
SW Detector ch 14
CDS (Corre
SAA
Bias Boost
CDS
Signal (ADU)
Sample number
South Atlantic Anomaly and Bias Boost
Galactic Plane observed in CDS mode.
Sample number

Slow-scan data example in TSD file

AOT : FIS01

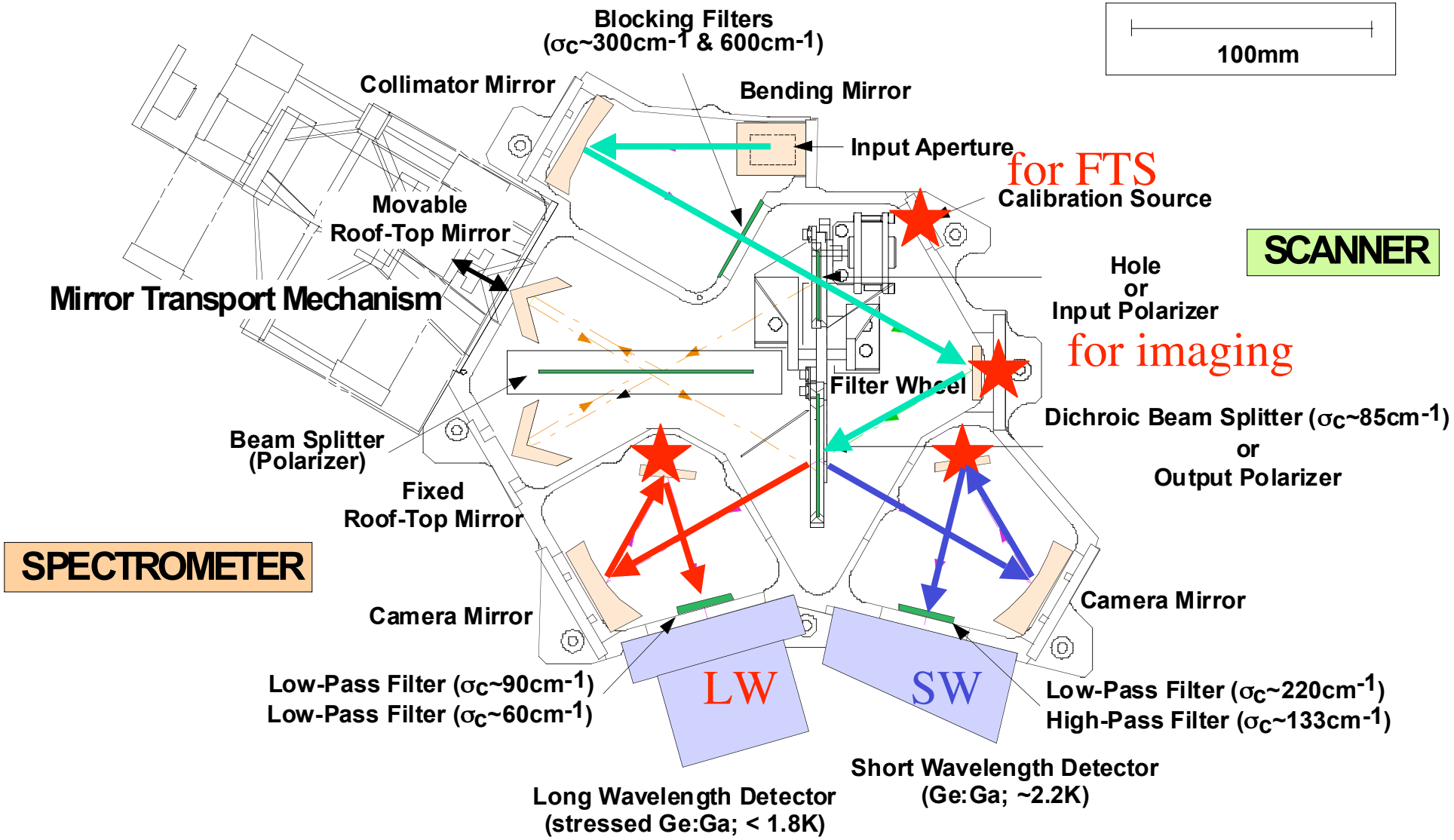


Displayed by FISv (TSD file viewer)

FIS Flux Calibration Strategy

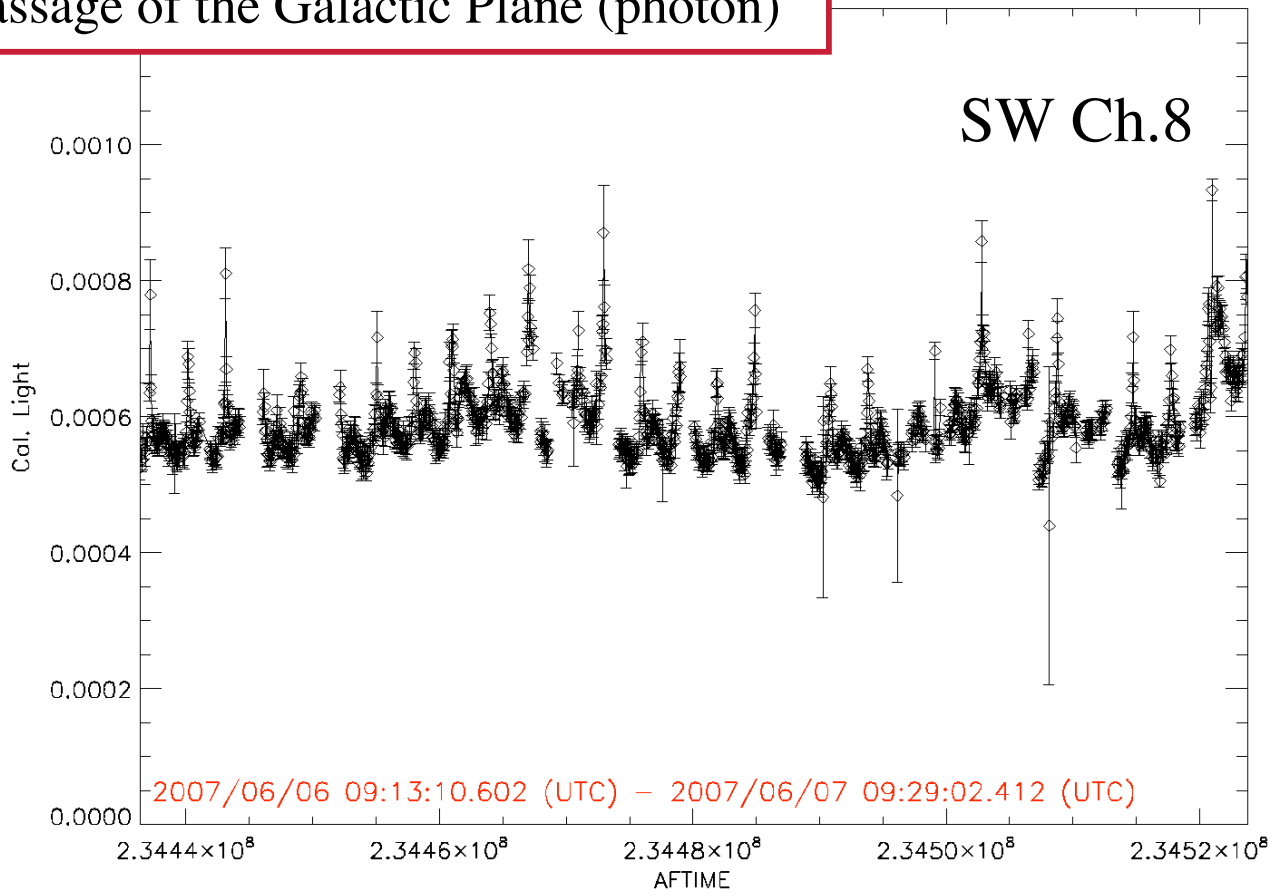
	Purpose	Requirement	Timescale	Source
Internal Calibrators	Relative	Stability	< 100 min	Cal. lamps
External Calibrators	Relative	Stability Visibility	> 100 min	Stars
Absolute Calibrators	Absolute	Accurate flux	∞	Stars Asteroids

FIS internal calibration source

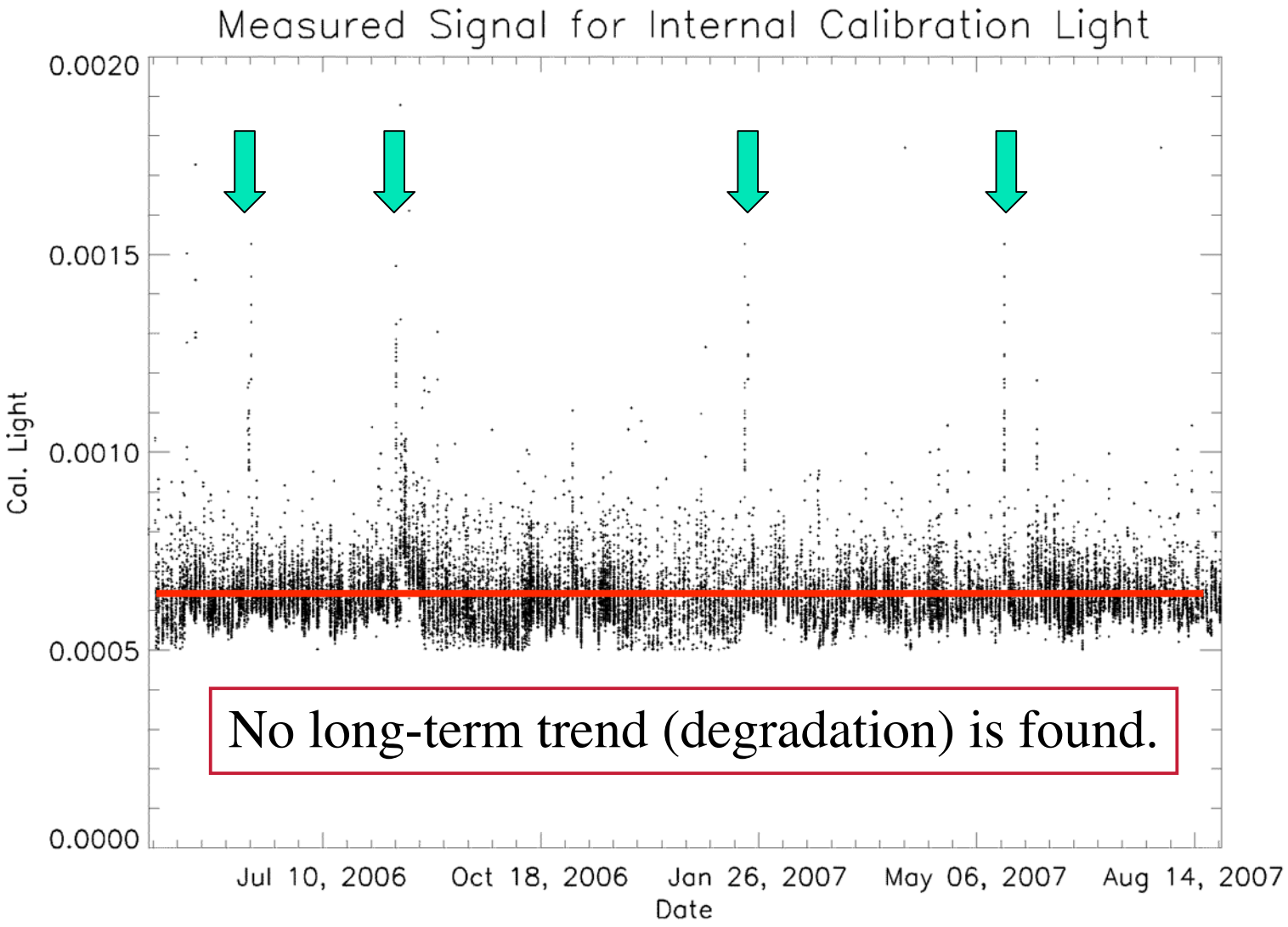


Calibration pulse signal trend (1 day)

Periodic pattern is responsivity variation by
Passage of polar-cap region (electron)
Passage of the Galactic Plane (photon)



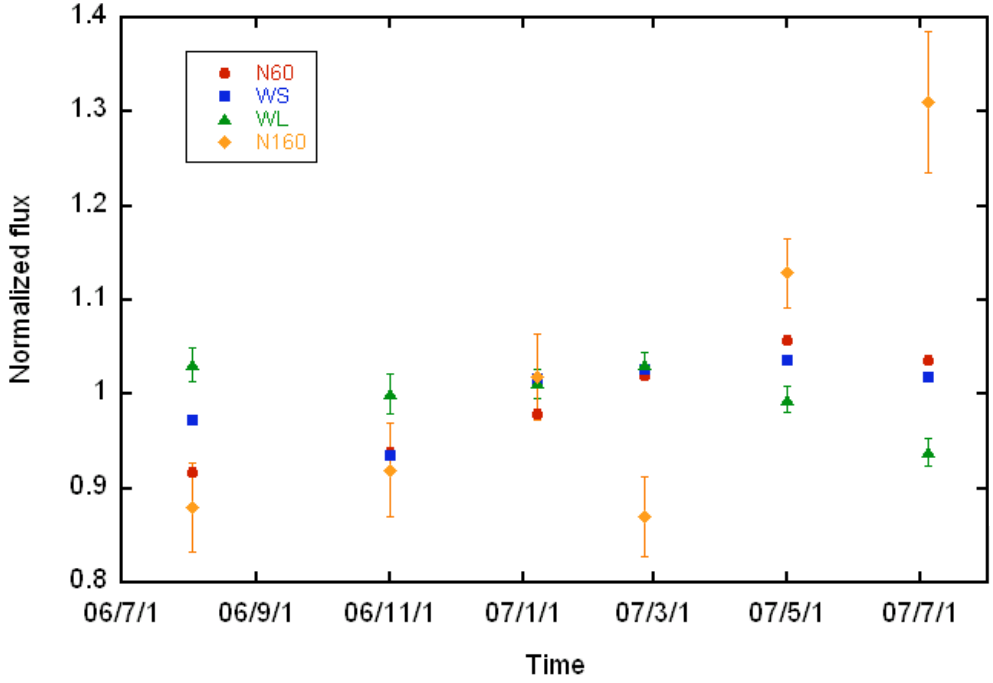
Calibration pulse signal trend (entire mission)

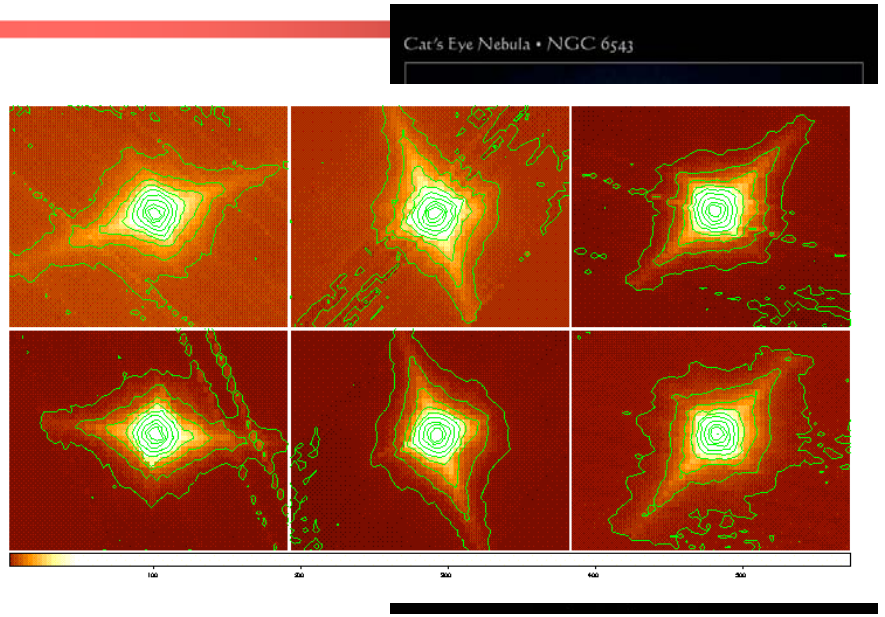


FIS Flux Calibration Strategy

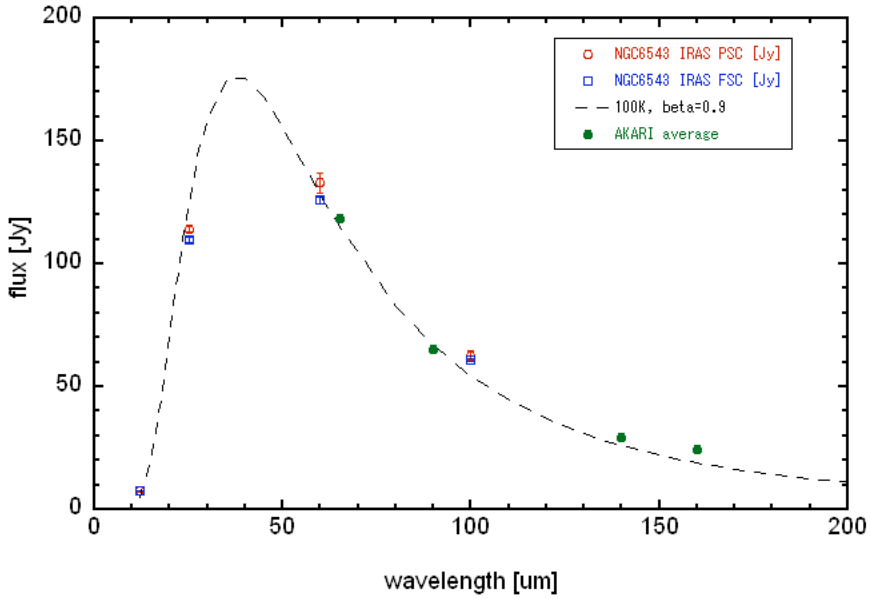
	Purpose	Requirement	Timescale	Source
Internal Calibrators	Relative	Stability	< 100 min	Cal. lamps
External Calibrators	Relative	Stability Visibility	> 100 min	Stars
Absolute Calibrators	Absolute	Accurate flux	∞	Stars Asteroids

Monitor Observation with NGC6543





- No significant time variation.



FIS Flux Calibration Strategy

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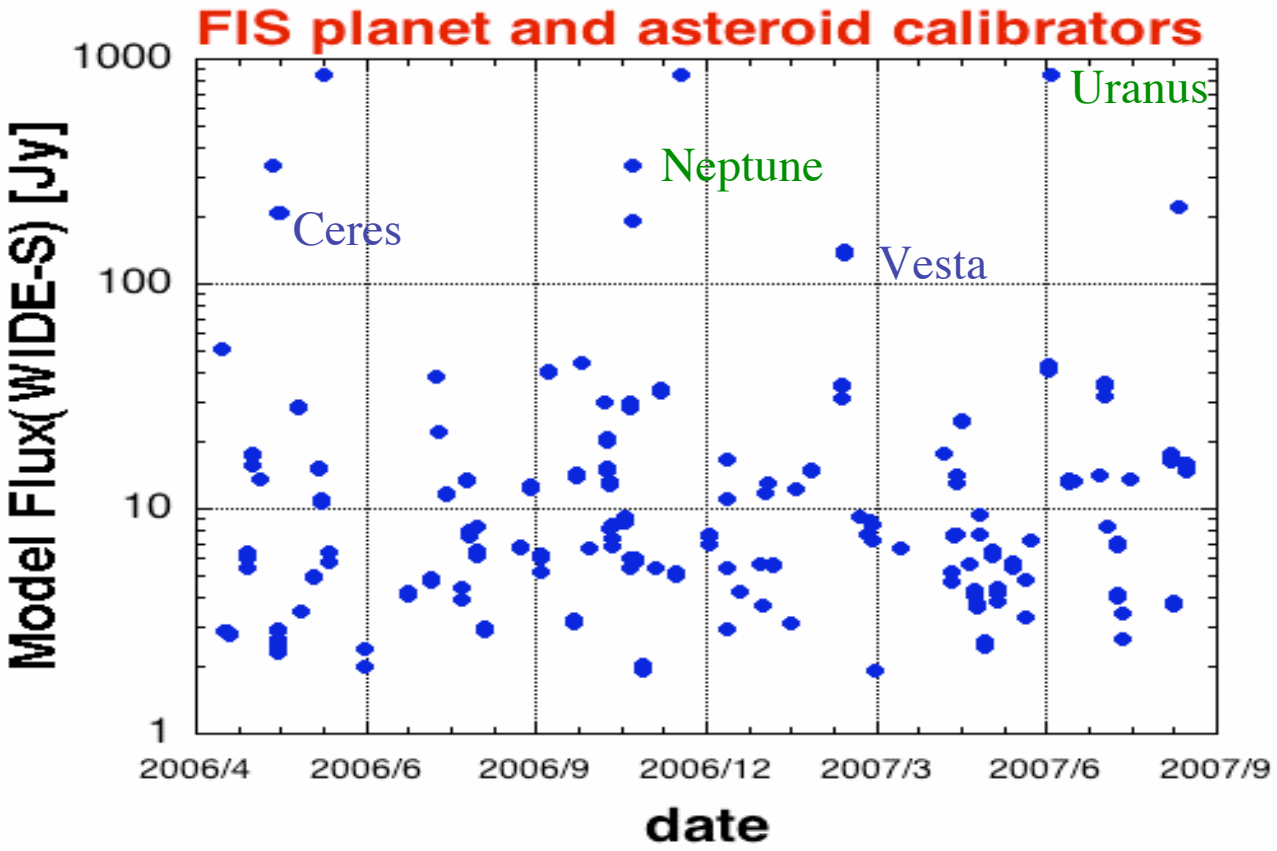
Absolute Calibrators	Absolute	Accurate flux	∞	Stars Asteroids

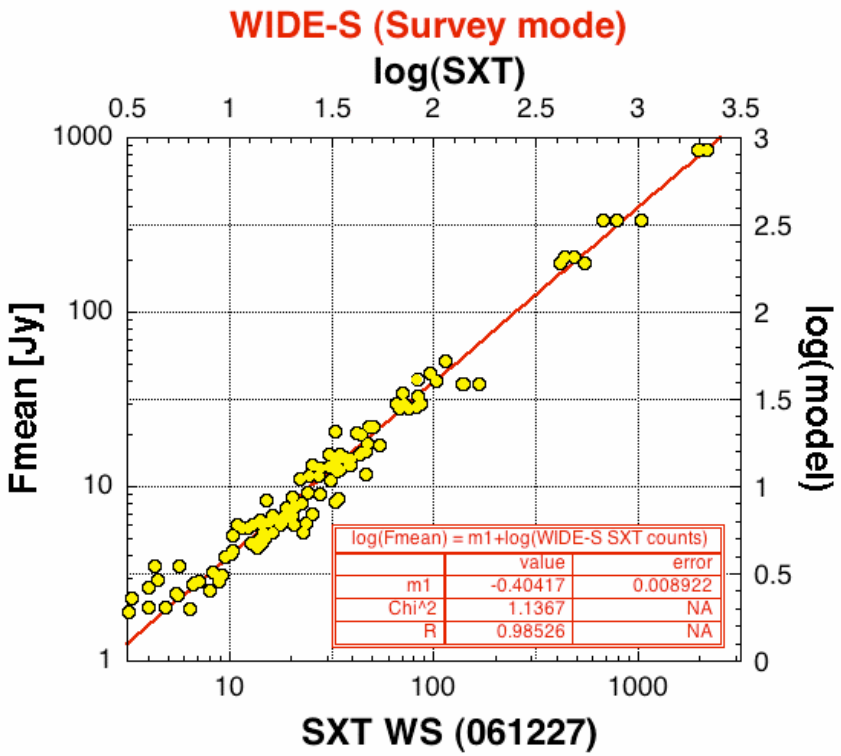
Survey observations of calibration standard asteroids and planet

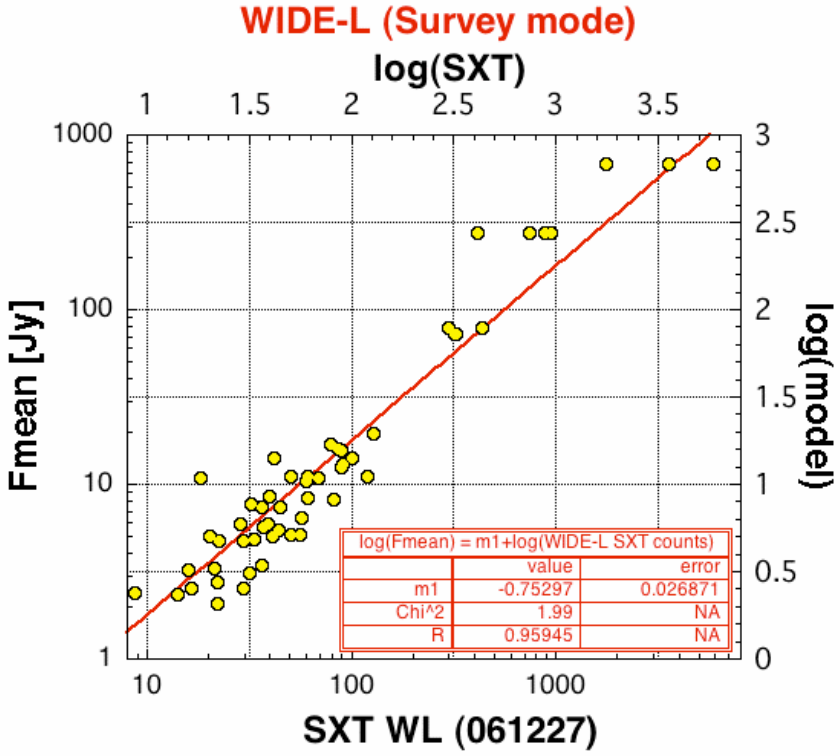
- Total 228 measurements of 51 asteroid and two planets (Uranus & Neptune) during the FIS survey.



Survey Calibration

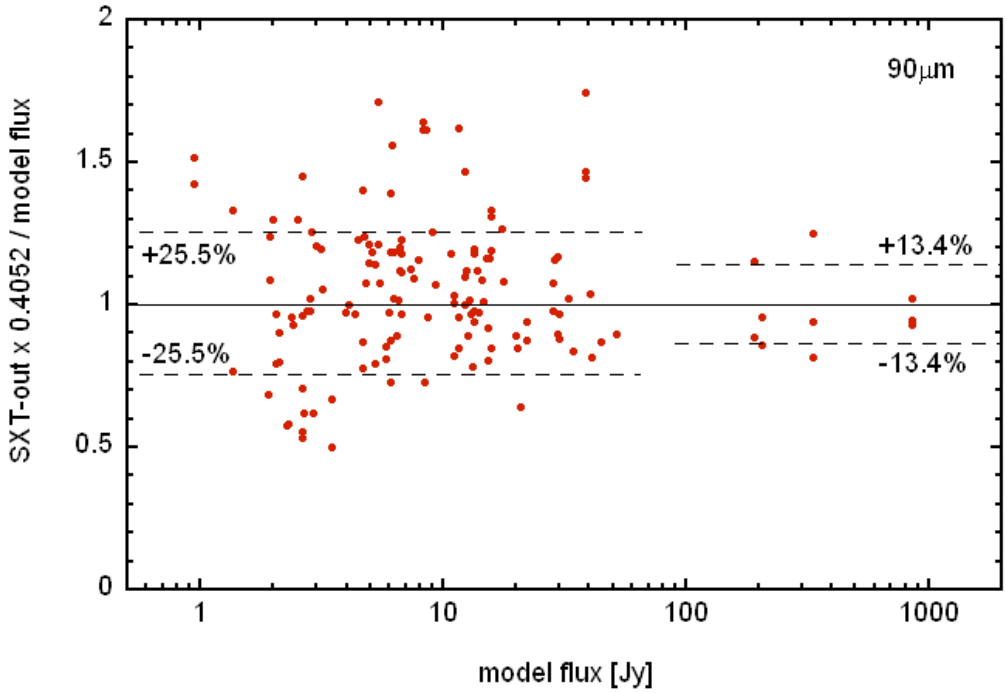
- Observation vs. Model flux
- Only asteroids are included at this moment.





Flux calibration (Asteroids ... cont.)

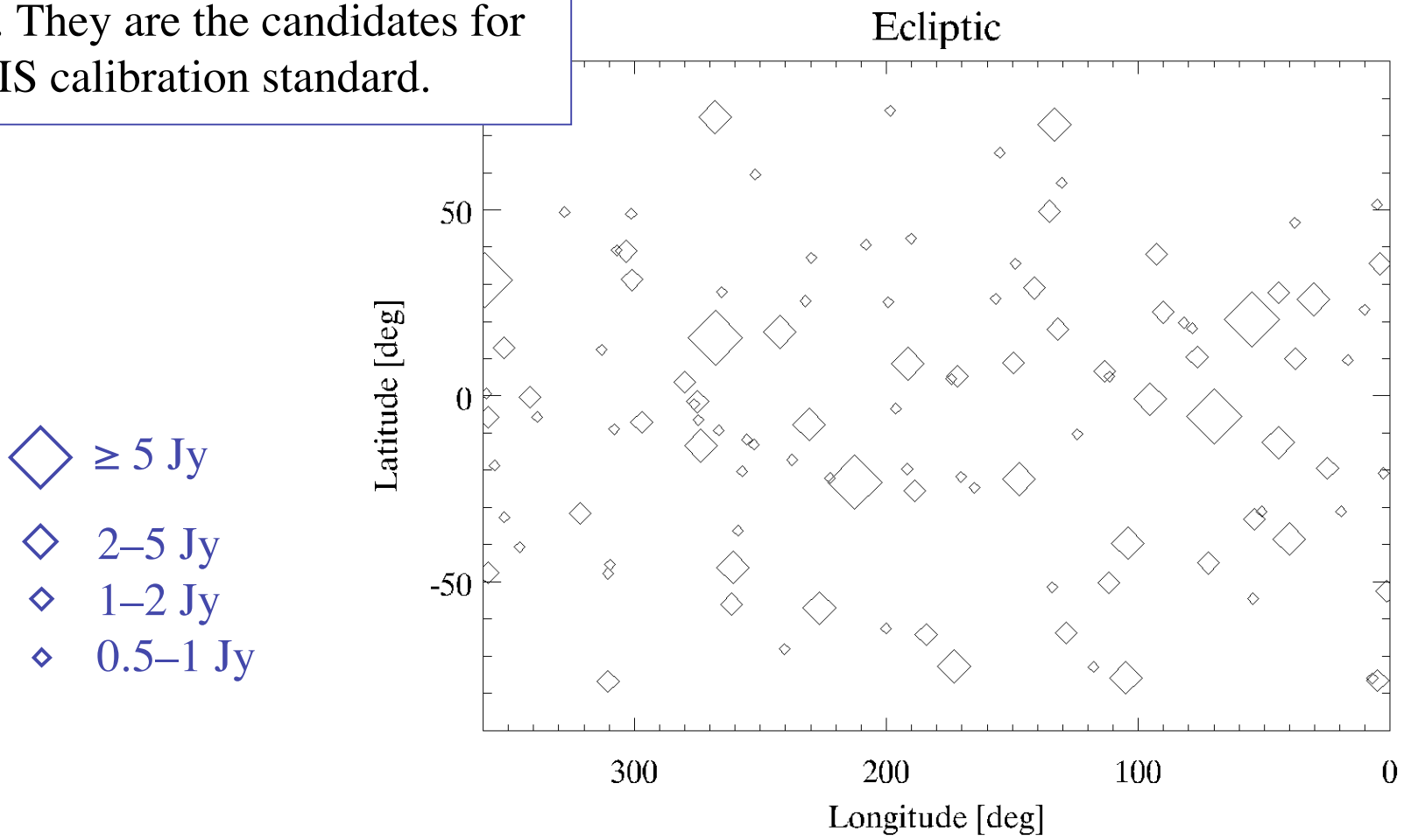
- Uncertainty: 10~30 per cent.
- The current error includes that of photometric measurement (at SXT).
- Model flux accuracy depends on stars ... 5 ~ 20 per cent.



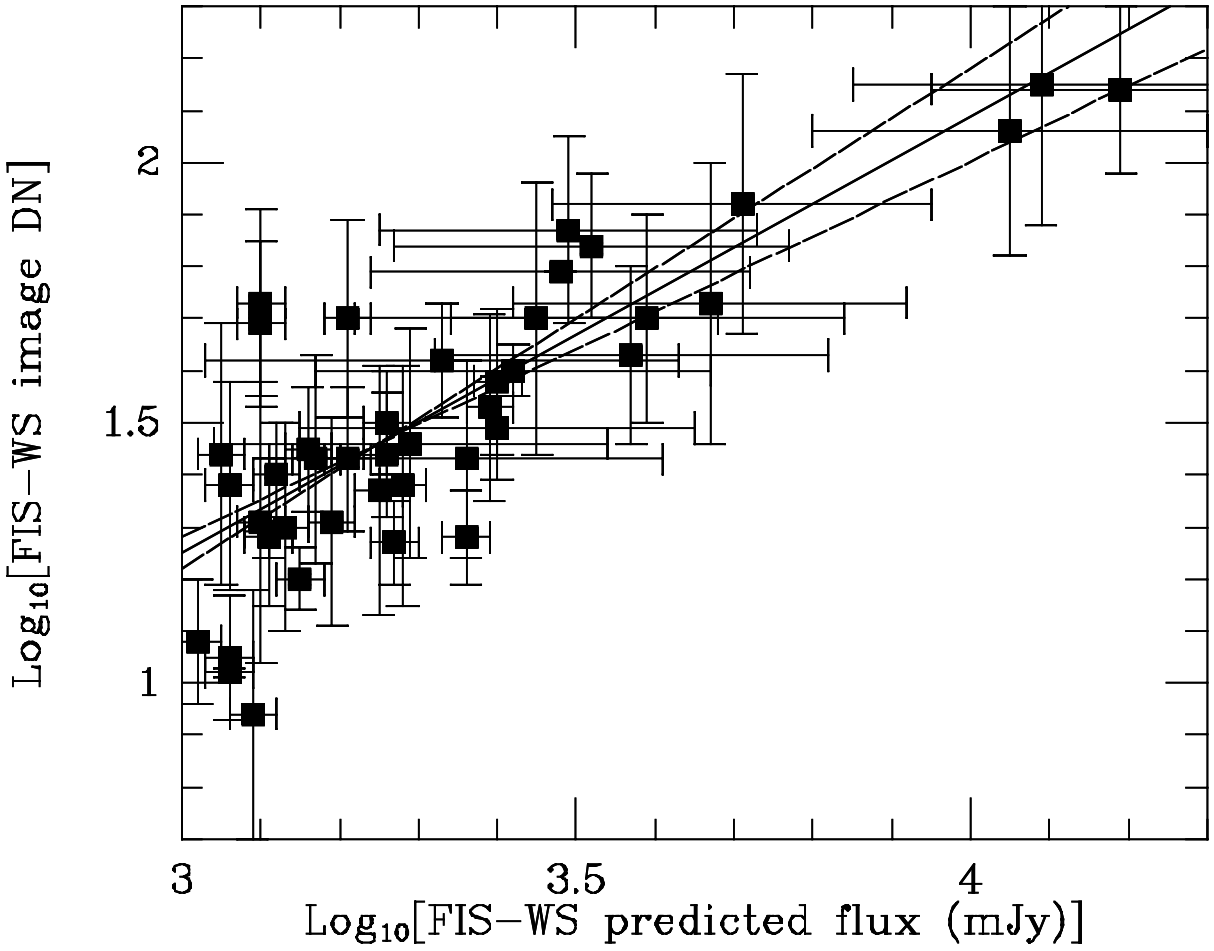
Hasegawa July 2007.

Stellar calibrators ($F_{(WIDE-S)} \geq 0.5$ Jy)

~110/614 sources have estimated flux larger than 0.5 Jy in WIDE-S band. They are the candidates for the FIS calibration standard.



Survey Calibration (Stars)



Slow-scan calibration observations

Solar System sources

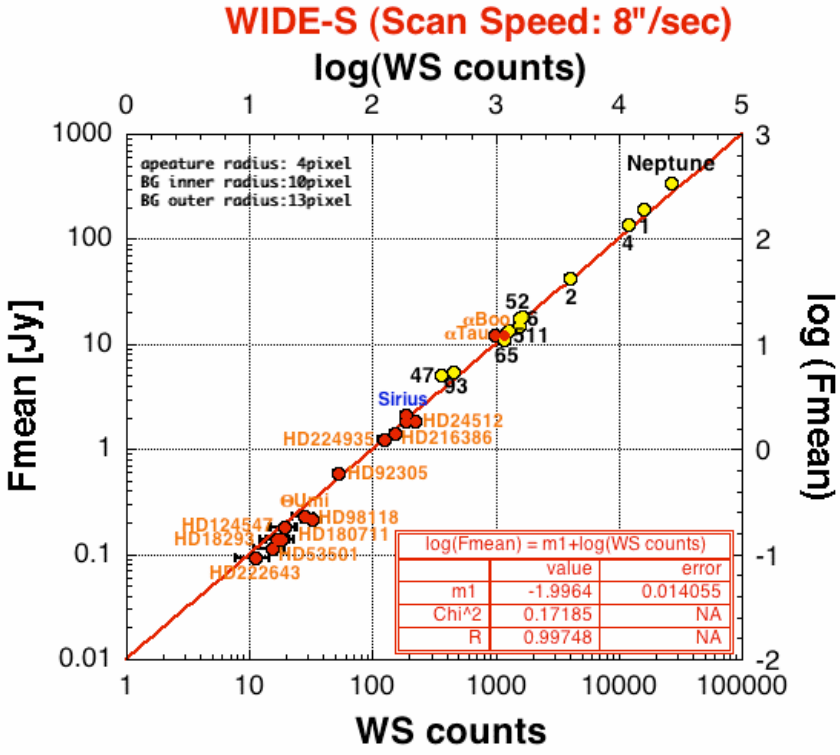
Stellar sources

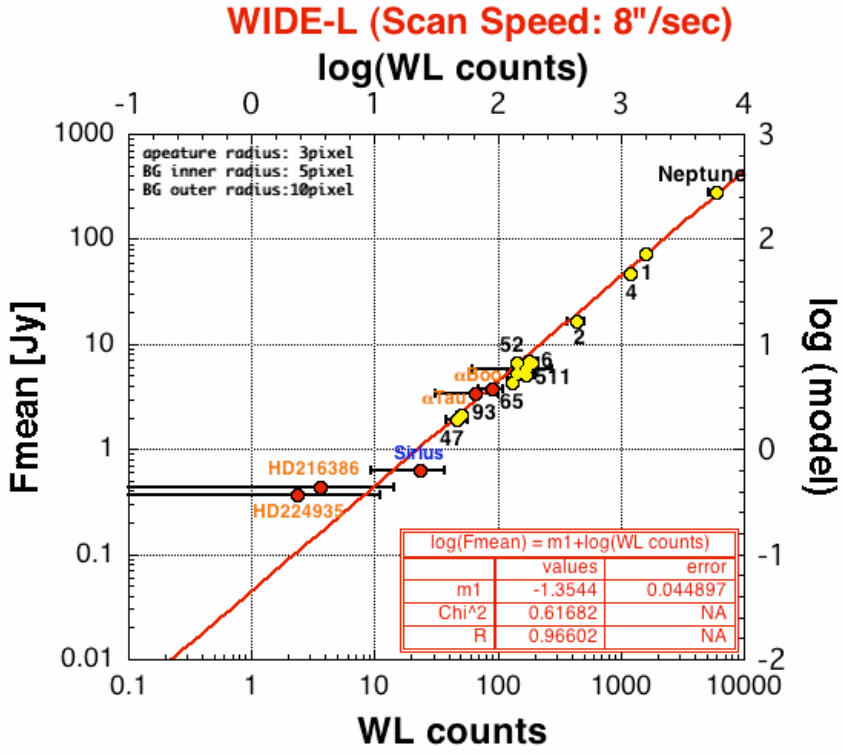
Obs.ID	Name	Obs. Date	reset [sec]	scan speed [arcsec/sec]	F(WIDE-S) [Jy]
5011066-001	6 Hebe	2006/04/30	0.5	8	18.001
5011166-001	6 Hebe	2006/05/01	0.5	8	18.296
5011067-001	511 Davida	2006/05/02	0.5	8	13.363
5011167-001	511 Davida	2006/05/03	0.5	8	13.202
5110027-001	2 Pallas	2006/09/27	0.5	8	43.074
5110032-001	1 Ceres	2006/11/08	0.5	8	191.449
5110033-001	93 Minerva	2006/11/20	1.0	8	5.455
5110038-001	65 Cybele	2006/12/28	1.0	8	11.059
5110047-001	4 Vesta	2007/02/23	0.5	8	137.319
5110046-001	4 Vesta	2007/02/24	0.5	15	138.578
5110058-001	52 Europa	2007/04/14	0.5	8	17.468
5110059-001	52 Europa	2007/04/15	0.5	15	17.592
5110066-001	Neptune	2007/05/13	0.5	8	336.443
5110067-001	Neptune	2007/05/13	0.5	15	336.725
5110078-001	47 Aglaja	2007/06/26	2.0	8	5.037
5110079-001	511 Davida	2007/07/20	0.5	8	15.024
5011072-001	HD139669	2006/04/21	2.0	8	0.220
5011069-001	HD124547	2006/04/22	2.0	8	0.179
5011069-002	HD124547	2006/04/22	2.0	8	0.179
5011068-001	HD24512	2006/04/29	1.0	8	1.865
5011071-001	HD18293	2006/04/30	2.0	8	0.139
5011071-002	HD18293	2006/04/30	2.0	8	0.139
5011068-002	HD24512	2006/05/02	1.0	8	1.865
5110034-001	HD48915	2006/10/07	2.0	8	2.132
5110039-001	HD124897	2007/01/15	1.0	8	12.211
5110045-001	HD29139	2007/02/28	1.0	8	11.103
5110068-001	HD216386	2007/06/03	2.0	8	1.417
5110072-001	HD98118	2007/06/10	2.0	8	0.215
5110075-001	HD222643	2007/06/11	2.0	8	0.092
5110070-001	HD224935	2007/06/20	2.0	8	1.217
5110076-001	HD180711	2007/07/09	2.0	8	N/A
5110077-001	HD53501	2007/07/13	2.0	8	0.113
5110092-001	HD92305	2007/08/23	2.0	8	0.591

+ UIRLGs (for comparison / LW / colour correction check)

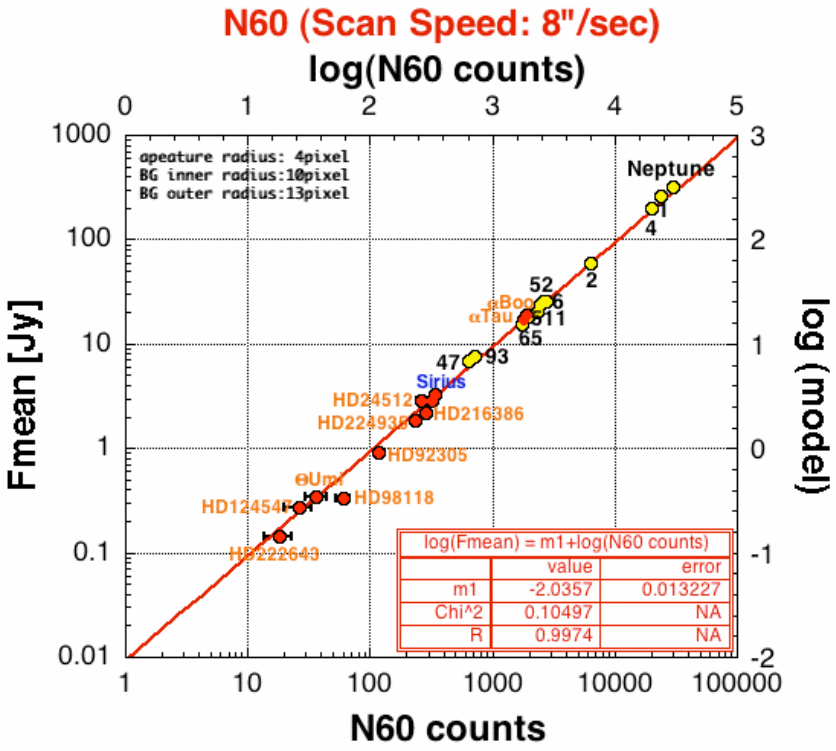
+ Vega-like star programme (44 observations)

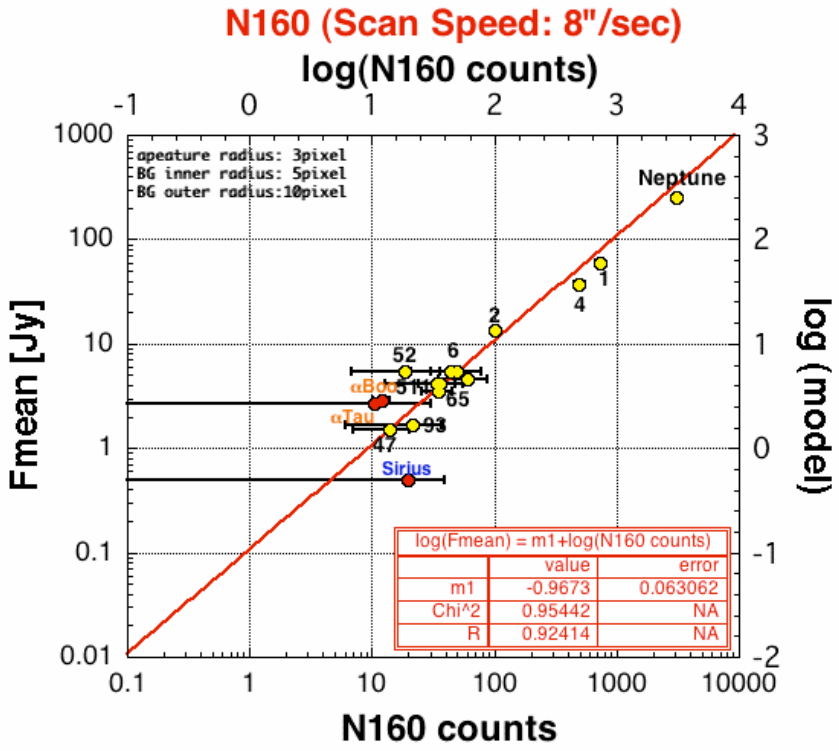
Slow-Scan Calibration





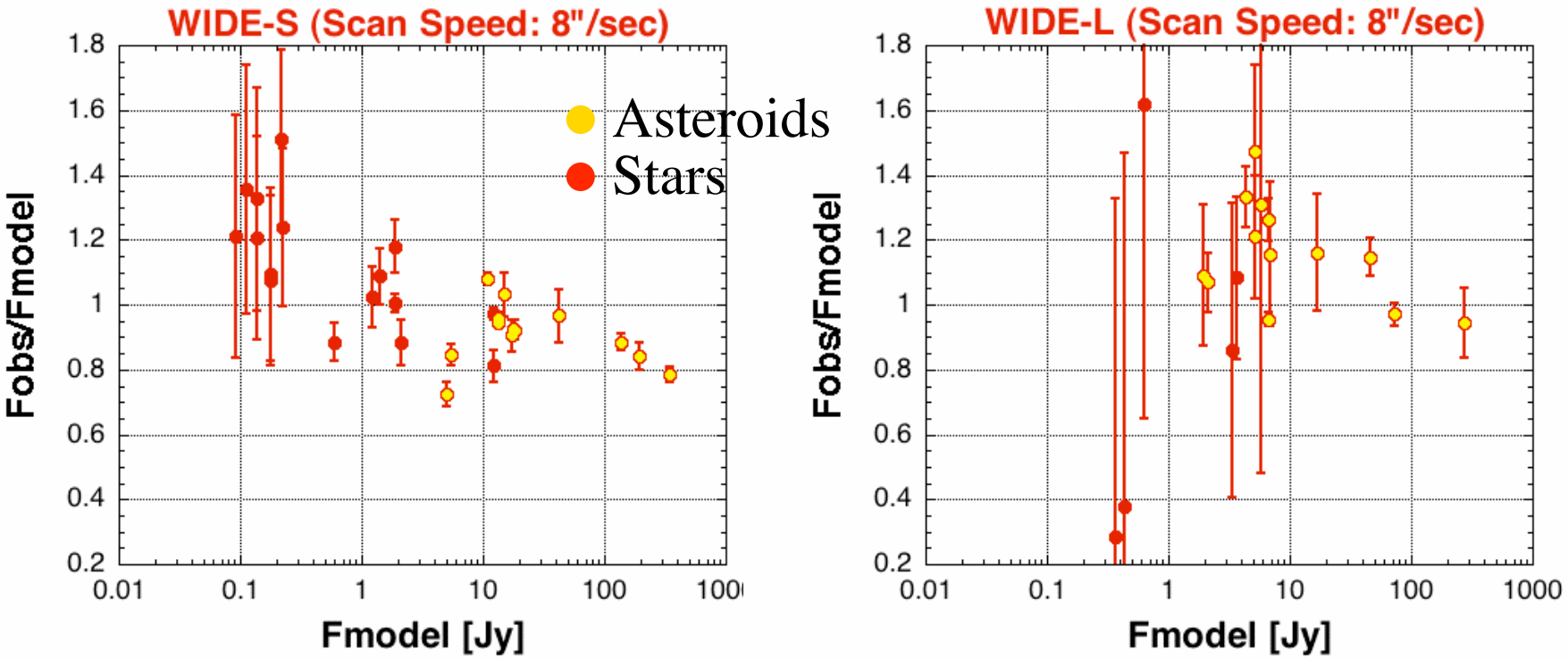
Slow-Scan Calibration





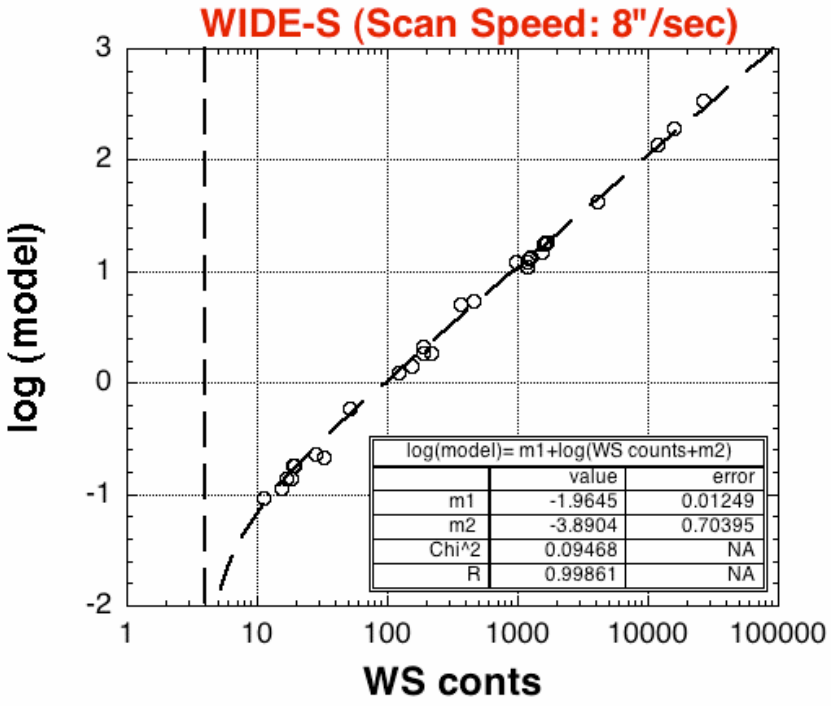
Slow-Scan Calibration

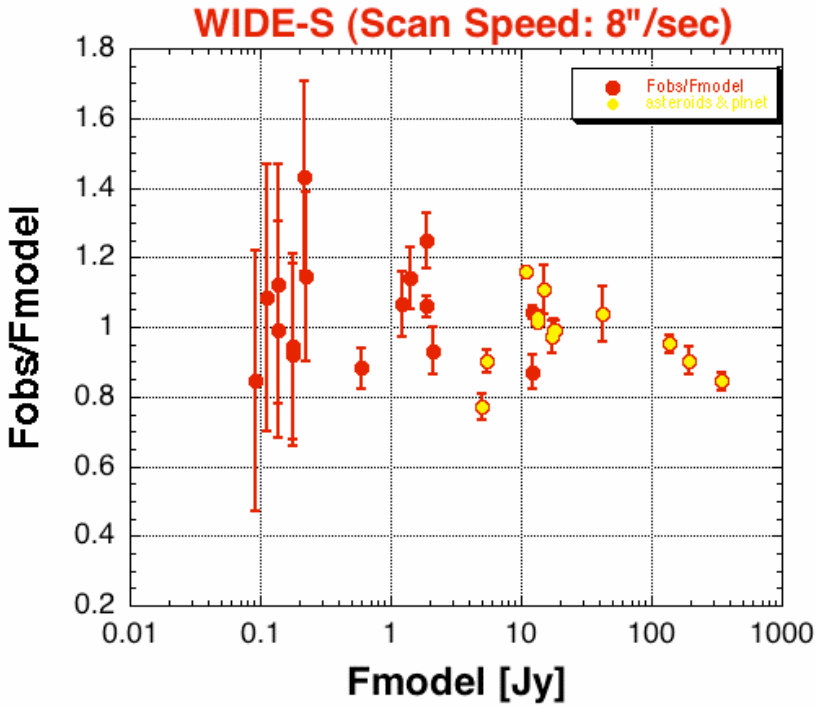
- Flux dependency ?
  - Non-linearity, Bias in photometry, ???



Slow-Scan Calibration

- Fitting with an artificial function.

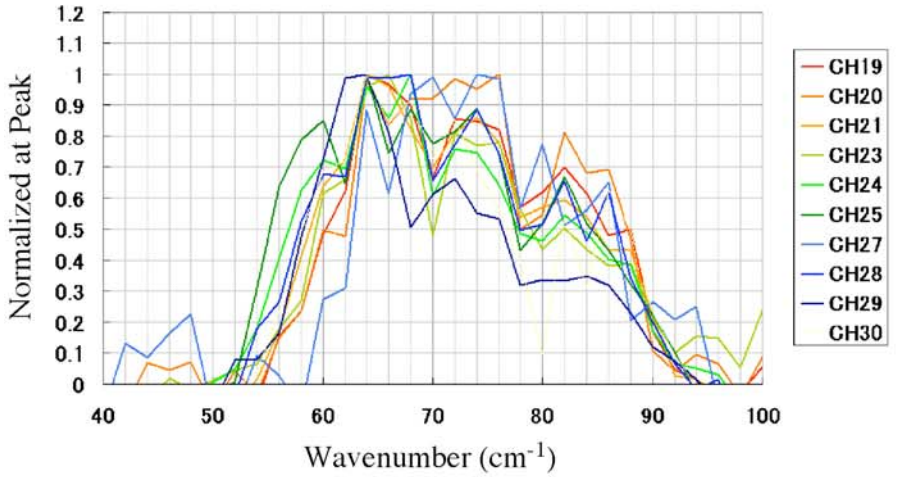




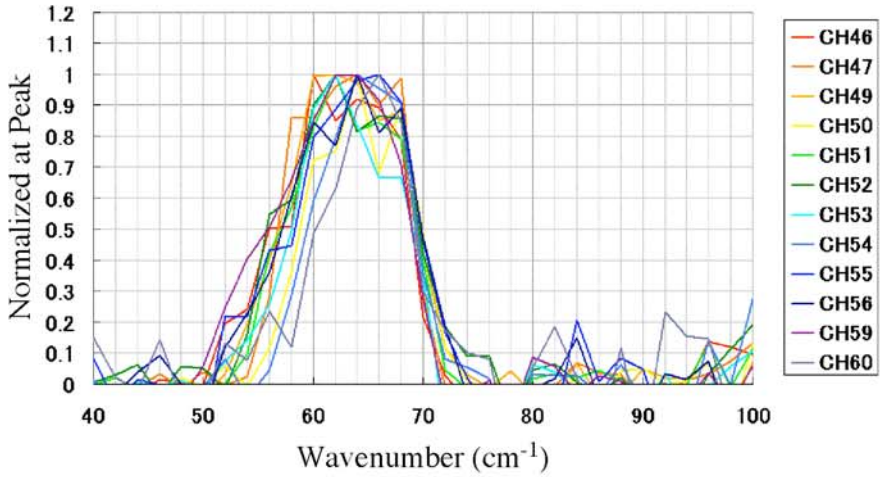
RSRF uncertainty

- The LW detector have pixel by pixel variation of spectral response.

Pre-launch measurements of RSRF by the FTS mode.



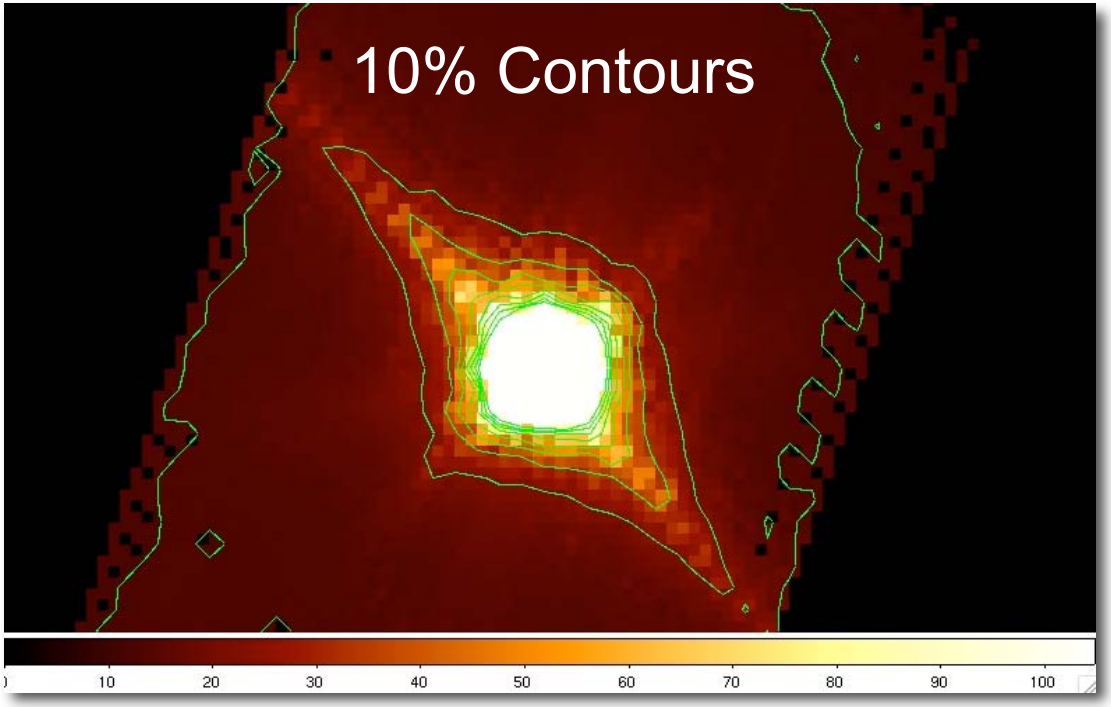
WIDE-L



N160

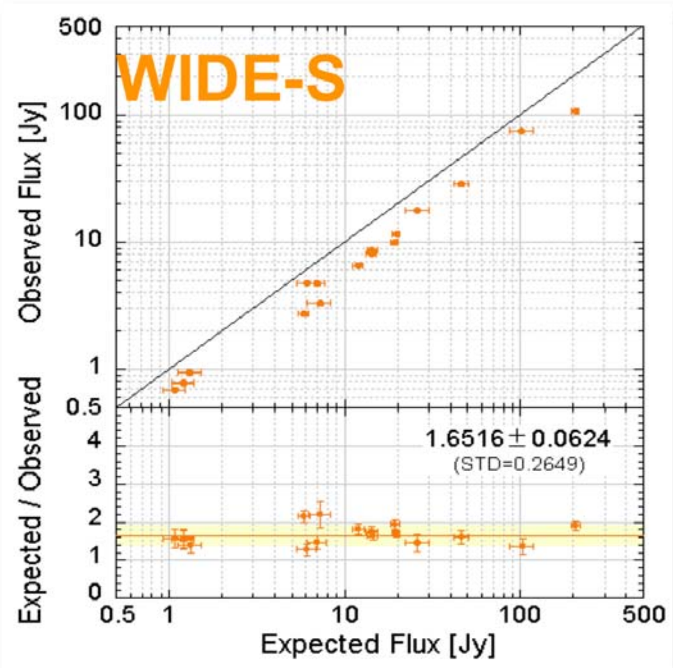
Crosstalk

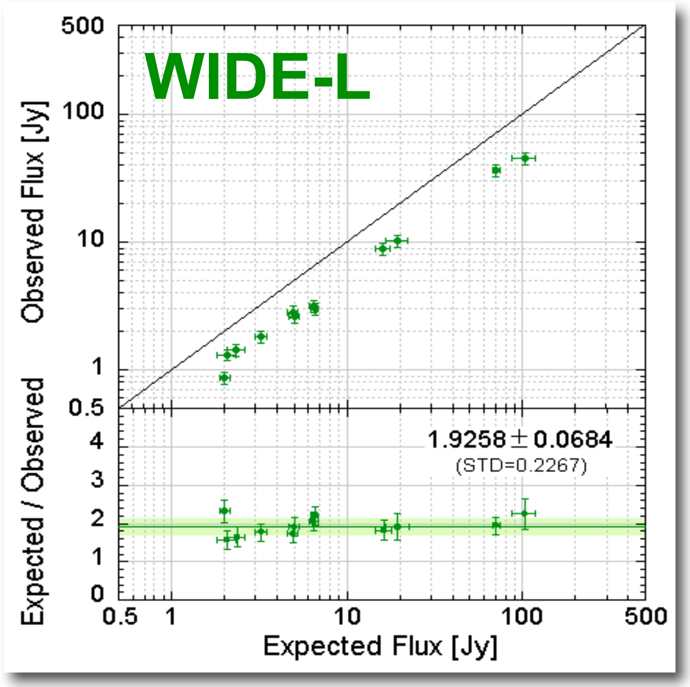
- Crosstalk between the array pixels appears in the SW detector.
  - The relative strength of the cross-talk is about 10%.
  - Cause: Photons diffuse into the monolithic Ge:Ga substrate.
  - A point source image (PSF) shows elongated substructures.



Point source vs. Diffuse source

- The Slow-scan image maps are scaled by comparing with COBE/DIRBE data at Zodiacal light and Galactic cirrus regions.





- There are systematic differences between the integrated flux of point sources with the predictions.
- This ratio seems to be constant.

  (does not depend on the source flux or the source colour.)

- The problem is still under investigation. Possible reasons are:
  - Very extended tail of the PSF.
  - Contamination from scattered light.

AKARI data

- The pointed observation data will be open to public from March 2008 (one year after data were validated and archived for the observers).
  - The data in the archive will be updated in the similar time scale (archive version 1.0 ➔ 1.1).

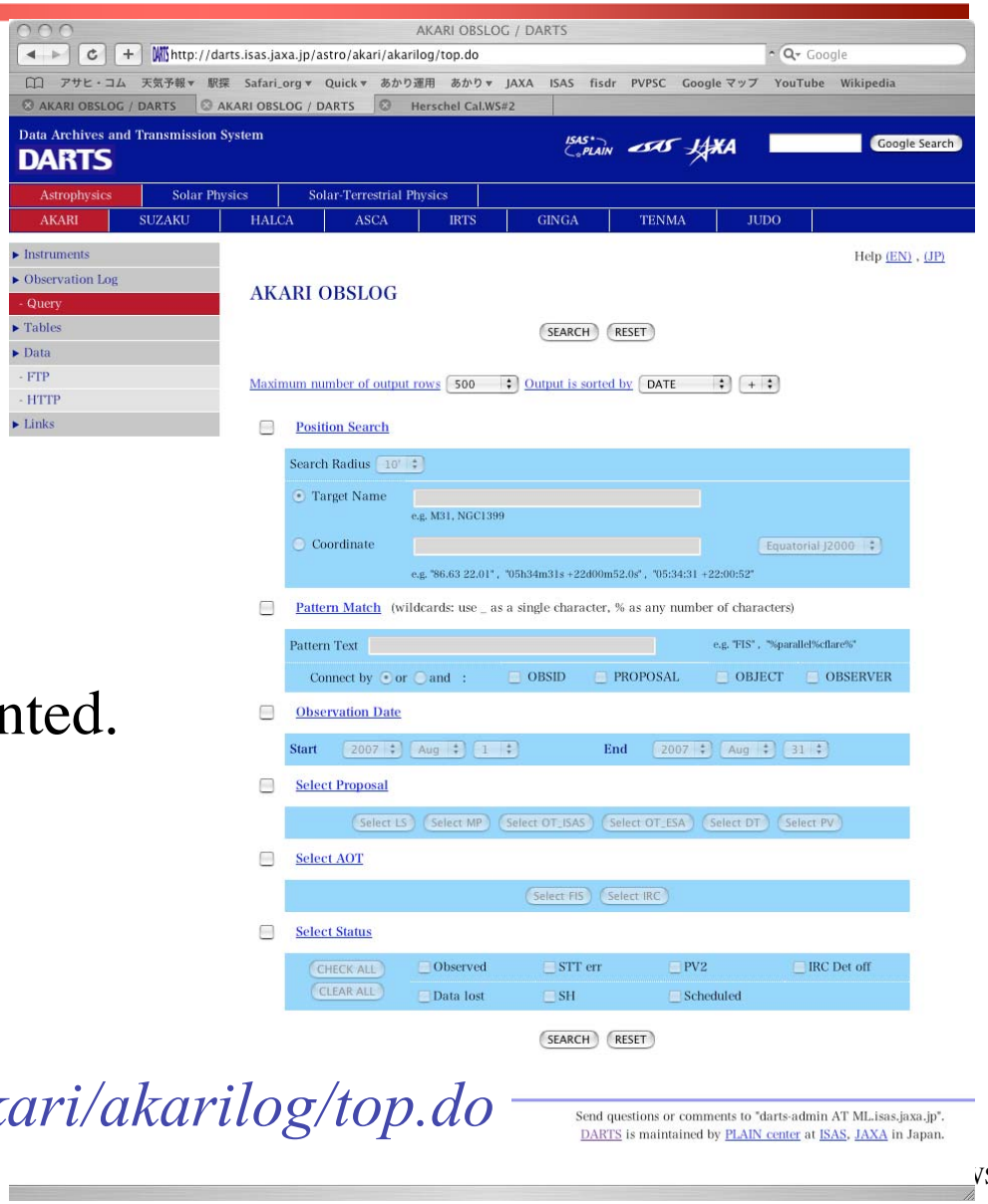
- The first version of the FIS All-Sky Survey point source catalogue will be released to the team in September 2008 for prioritized study and validation. The catalogue will be in public one year later.
  - Release of images and raw data is TBD (more than a few years?)
  - Collaborations to speed up data release / improve the calibration are welcome.

DARTS (Observation Log)

Query by:

- Position
- Target name
- Observation date
- AOT
- Proposal

VO interface will be implemented.



http://darts.isas.jaxa.jp/astro/akari/akarilog/top.do

DARTS/Search Results

Search Result

- **The number of display** 13 / **The number of hits** 13
- **Output ALL hit resords :** select an output format.
  HTML (display on browser) CSV VOTABLE PLAIN TEXT
- **Download data :** select checkboxes and then push "WGET SCRIPT" button.
  WGET SCRIPT

Status and Colors

IRC Data	Data lost	SafeHold mode	Observed	Processed	Scheduled
FIS Data			Observed	Processed	Scheduled

CHECK ALL CLEAR ALL

NO	SELECT	FTP	DATE	TIME	OBSID	OBJECT	OBSERVER	PROPOSAL	AOT	AOTPARAM	STATUS	PKGFSIZE
1	☑	ftp	2007-08-01	00:09:12	1711107-001	IRAS 15477+3943	Yamamura Issei	MLHES	FIS01	2.0;8;70	Observed	33756.8
2	☑	ftp	2007-08-02	20:00:29	1711002-001	IRAS 03172-2156	Yamamura Issei	MLHES	FIS01	2.0;8;70	Observed	33750.9
3	☑	ftp	2007-08-06	11:03:34	1711041-001	IRAS 15255+1944	Yamamura Issei	MLHES	FIS01	1.0;15;70	Observed	33708.7
4	☑	ftp	2007-08-11	01:02:08	1711106-001	IRAS 02143+4404	Yamamura Issei	MLHES	FIS01	1.0;15;70	Observed	33749.9
5	☑	ftp	2007-08-14	18:35:21	1711078-001	IRAS 02302+4525	Yamamura Issei	MLHES	FIS01	1.0;15;70	Observed	33732.1
6	☑	ftp	2007-08-15	23:02:13	1711012-001	IRAS 03463-0710	Yamamura Issei	MLHES	FIS01	1.0;15;70	Observed	33730.6
7	☑	ftp	2007-08-15	21:00:53	1711305-001	IRAS 01144+6658	Yamamura Issei	MLHES	FIS01	1.0;15;70	Observed	34027.9
8	☑	ftp	2007-08-15	17:39:45	1711293-001	IRAS 00102+7214	Yamamura Issei	MLHES	FIS01	1.0;15;70	Observed	33824.5
9	☑	ftp	2007-08-18	02:29:36	1711010-001	IRAS 04020-1551	Yamamura Issei	MLHES	FIS01	1.0;15;70	Observed	33718.5
10	☑	ftp	2007-08-18	13:50:37	1711602-001	IRAS 03019+3838	Yamamura Issei	MLHES	FIS01	1.0;15;70	Observed	33780.6
11	☑	ftp	2007-08-20	11:50:30	1711126-001	IRAS 16457+4219	Yamamura Issei	MLHES	FIS01	2.0;8;70	Observed	33722.8
12	☑	ftp	2007-08-20	15:05:25	1711221-001	IRAS 16255+2801	Yamamura Issei	MLHES	FIS01	2.0;8;70	Observed	33747.9
13	☑	ftp	2007-08-24	17:26:27	1711603-001	GK Per	Yamamura Issei	MLHES	FIS01	1.0;15;240	Observed	33761.6

CHECK ALL CLEAR ALL

Summary

- AKARI did FIS (+MIR) All-Sky Survey in more than 90 % of the entire sky with much improved spatial resolution. We also did thousands of pointed observations.
- Calibration and data reduction work are still ongoing.
- We are pleased to talk with people who are interested in our data. Please contact me!