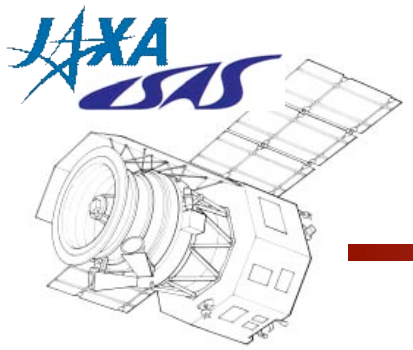
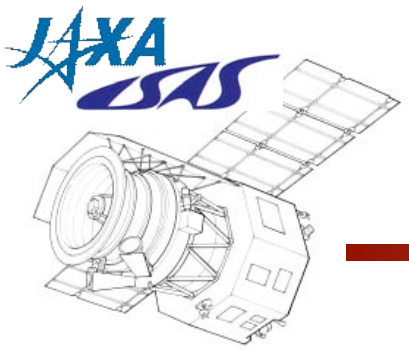

Calibration plan of the
ASTRO-F Mission
Issei YAMAMURA
(ISAS/JAXA)
ASTRO-F
http://www.ir.isas.jaxa.jp/ASTRO-F/
© Newton Press



Outline

- Overview of the ASTRO-F Mission
  - On-board Instruments
  - Operation
- Calibration strategy of the ASTRO-F/FIS
  - Requirements
  - Pre-flight measurements
  - Calibration Strategy
  - Astronomical calibrators
  - Current activity / status
  - ASTRO-F's contribution to FIR calibration.

Overview of the ASTRO-F Mission



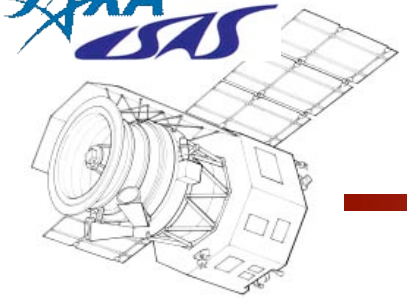
ASTRO-F Mission

- Far-Infrared and Mid-Infrared All Sky Survey.

  Better sensitivity, better resolution

- Deep Imaging / Spectroscopic Surveys of Selected Sky.

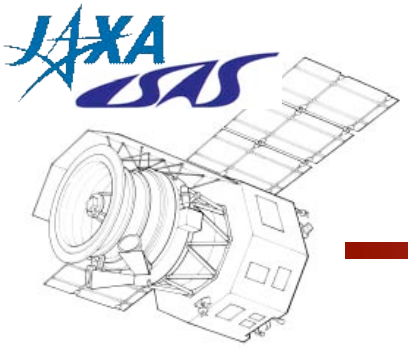
- Launch date yet TBD (we expect winter 2005–2006)
- Mission lifetime: ~ 550 days + α.



ASTRO-F Flight Model

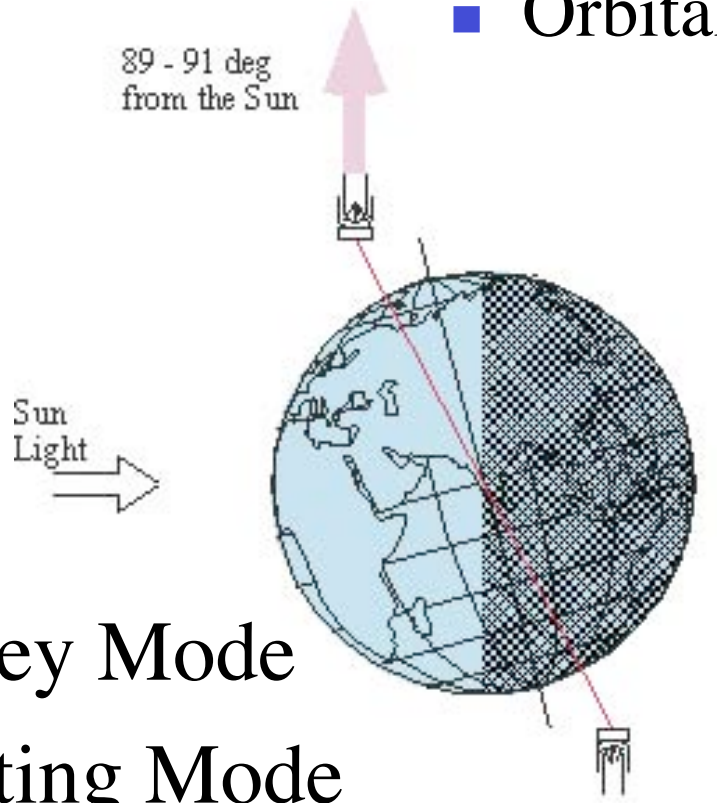
Height: 3.7 m (at the launch)
Wet Weight: 960 kg

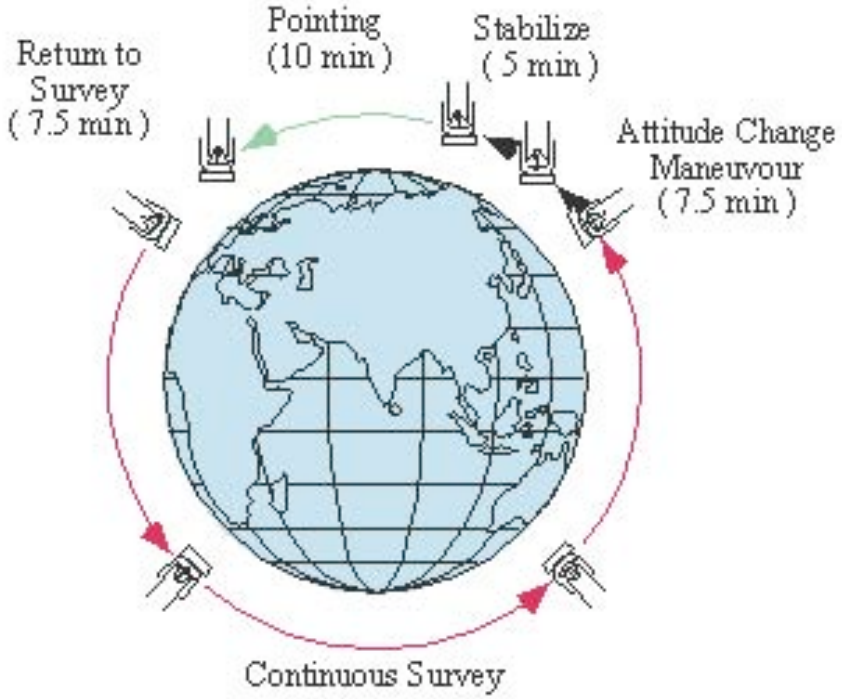
At the first integration test (June 2002).



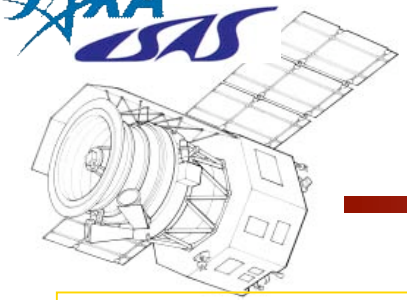
Two Operation Modes

- Sun-synchronous polar orbit
- Nominal altitude: 745 km
- Orbital Period: 100 min





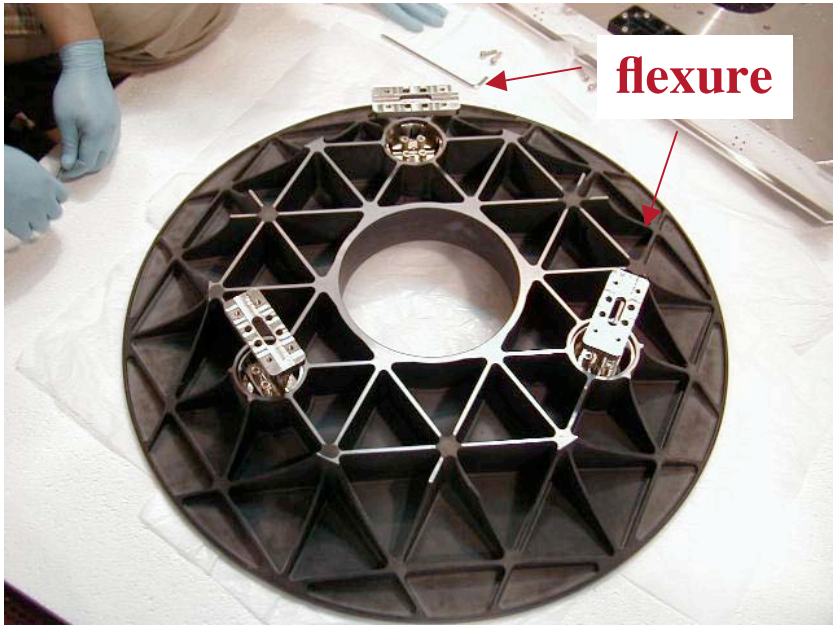
- Survey Mode
- Pointing Mode
  - ~ 10 min / operation



Telescope System

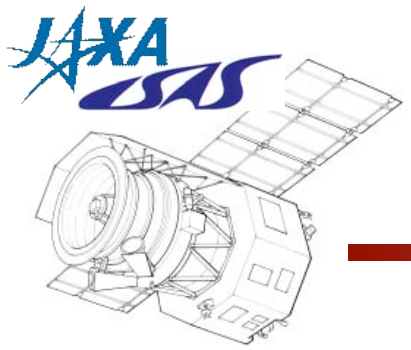
H.Kaneda (ISAS), T.Onaka (Univ. of Tokyo)

- **ϕ 685 mm**, F/6.3, Ritchey-Chretien, weight 42 kg, cooled down to **5.8 K**
- **Silicon carbide mirror**
  sandwich-type (porous SiC+CVD SiC) primary mirror: **11 kg**



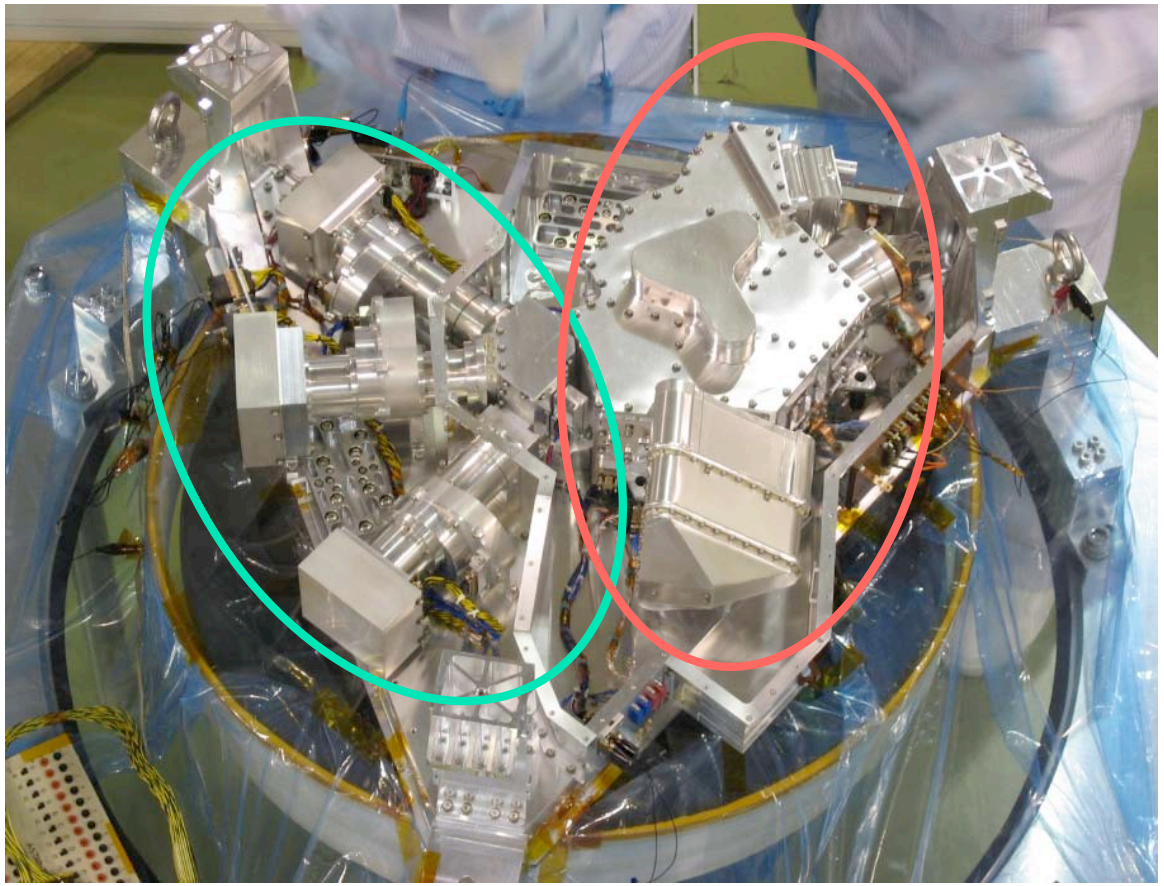
Rear surface of primary mirror

FM telescope in vibration test



Focal Plane Instruments

(Far-Infrared Surveyor)



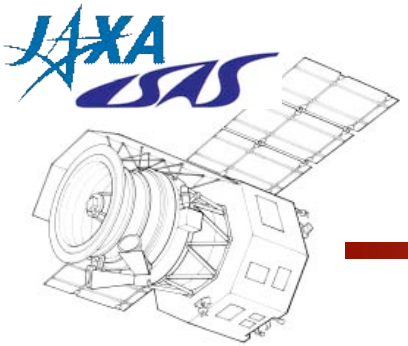
FIS

50–180 μm

1.8–26 μm

IRC

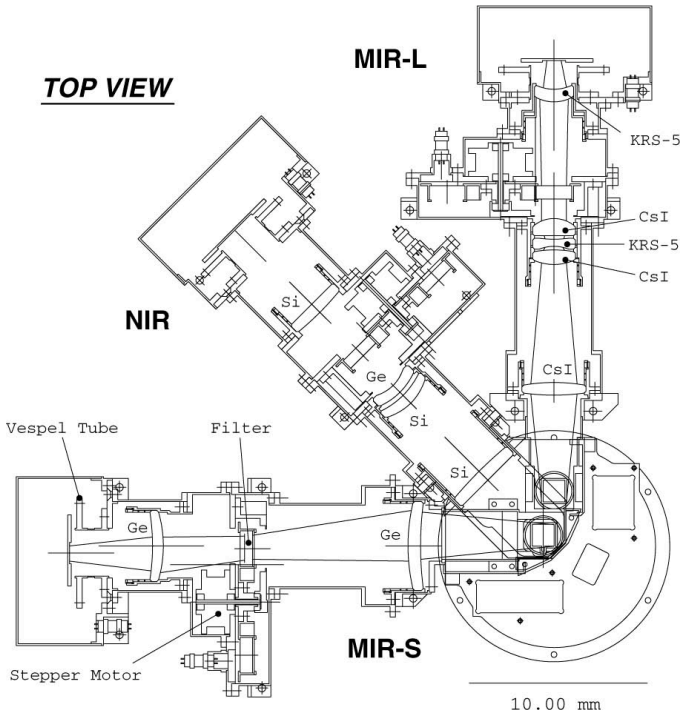
(Infrared Camera)

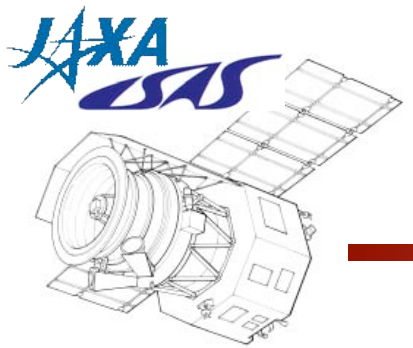


Infrared Camera (IRC)

- Three independent cameras.
- Wider FoV than Spitzer/IRAC (10'x10')
- Continuous coverage in the NIR–MIR range.

- Three filters for each camera.
- Two dispersion elements for each camera.
  - Capability of low-resolution spectroscopy.



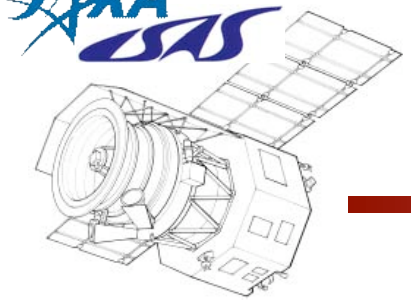


Infrared Camera (IRC)

- Three Cameras

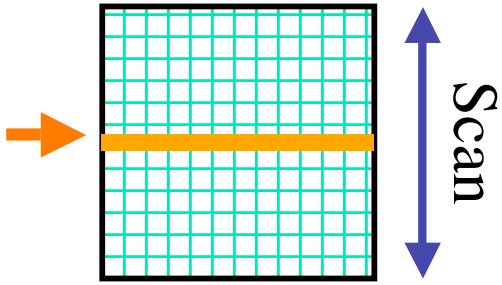
	Wavelength (μm)	Pixel Size (arcsec)	FoV (arcmin)	Detector
NIR	1.8–5.05	1.46	10 x 10	512x412 InSb
MIR-S	5–13	2.34	10 x 10	256x256 Si:As
MIR-L	11–26	2.34	10 x 10	256x256 Si:As

- NIR & MIR-S share the same FoV
- MIR-L observe at a different FoV



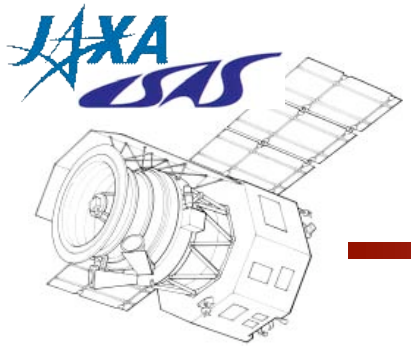
IRC Scan Survey

- Simultaneous operation with the FIS.
- Only in mid-infrared.
- By reading only a line of the arrays.



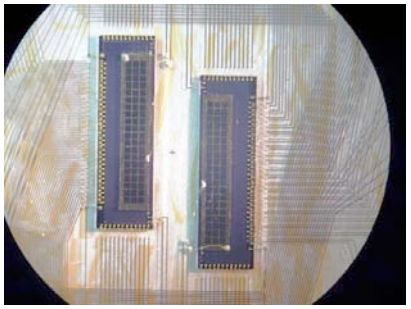
Camera	Filter	Sensitivity (5σ, mJy)	Virtual pixel size
MIR-S	S9W	80	9.36x9.36 arcsec^2 (4x4 pixel)*
MIR-L	L20W	130	

*Nominal plan. Depending on available data rate.

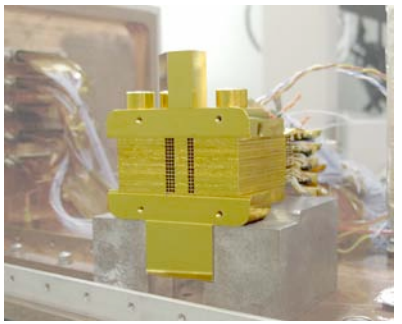


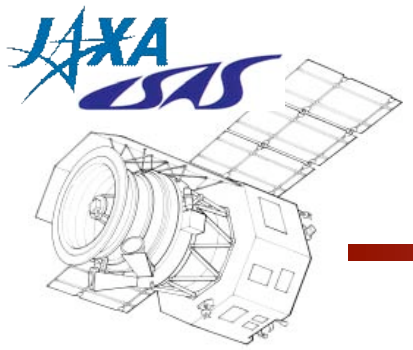
FIS: Far-Infrared Surveyor

- Simultaneous observation in four FIR bands.
- Detectors:
  - Monolithic Ge:Ga array (SW: 50–110 μm, 20x(3+2) pix)
  - Stressed Ge:Ga array (LW: 110–180 μm , 15x(3+2) pix)
- Spatial resolution of 30–75 arcsec.



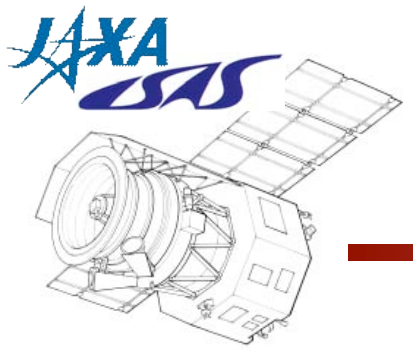
- Fourier Transform Spectrometer.
  - Martin-puplette type polarized interferometer.
  - 0.37 cm^{-1} (R=540 @ 50μm, 135 @ 200 μm)



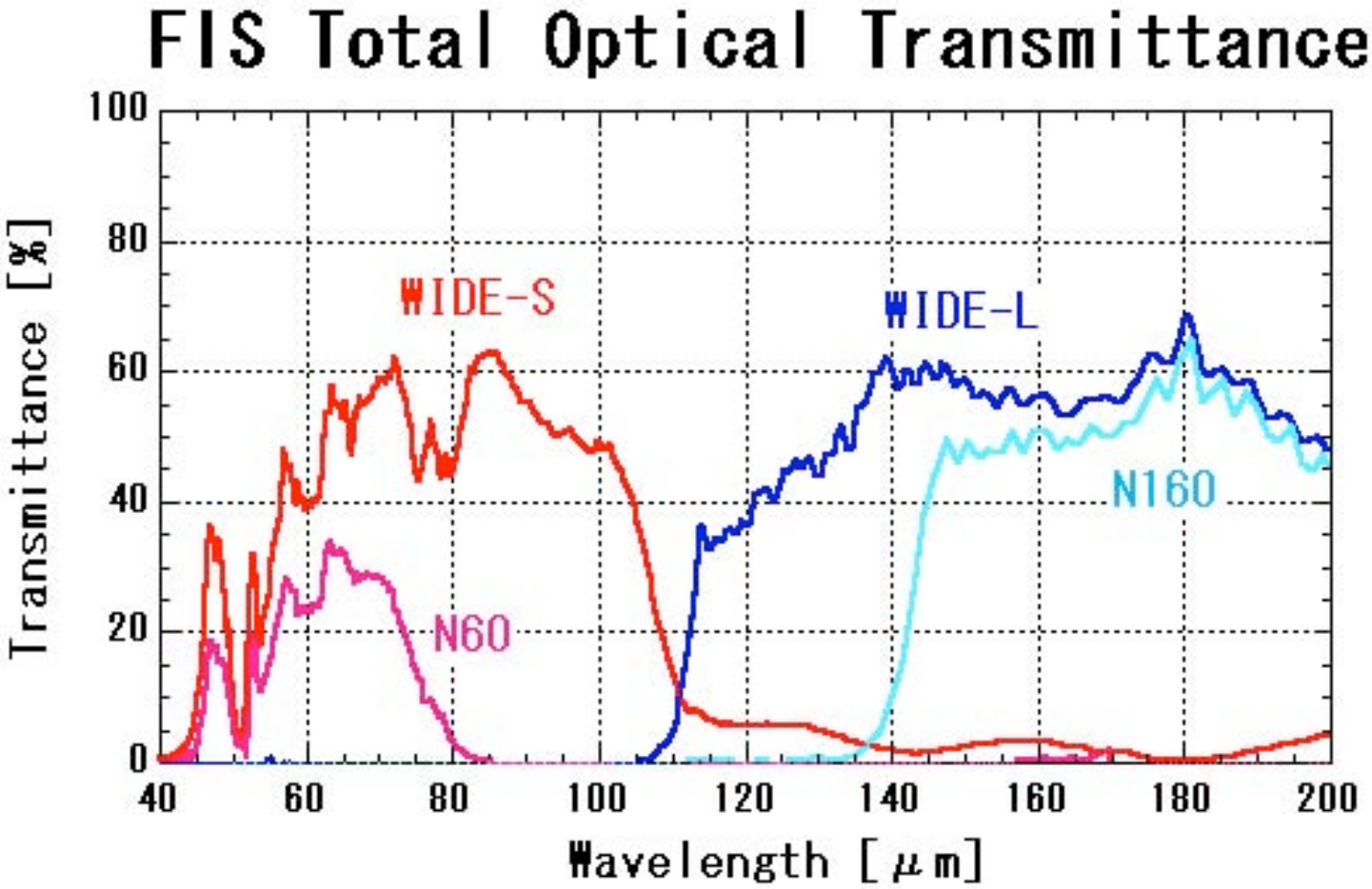


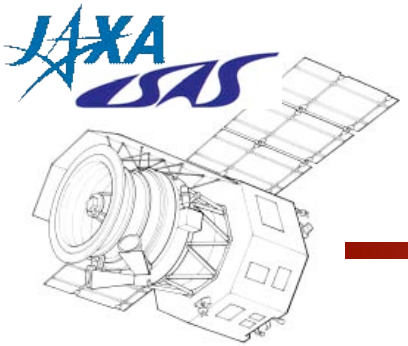
FIS Imaging Mode

Band	N60	WIDE-S	WIDE-L	N160	
Wavelength	50–75	50–110	110–180	150–180	[μm]
Central Wavelength	63	80	149	161	[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])
Detection Limit (survey)	600	200	400	800	[mJy] (1 scan; 5s)
Detection Limit (pointing)	16	5	3	6	[mJy] (8arcsec/sec)



FIS Optical Transmittance





FIS Detectors

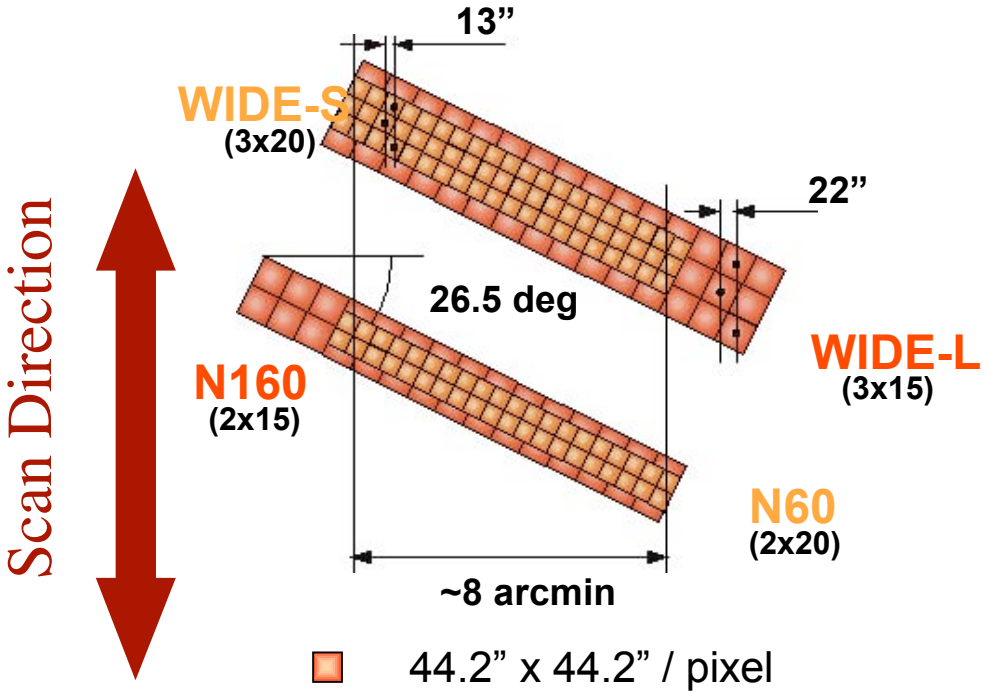
WIDE-S: 3x20

N60: 2x20

N160: 2x15

WIDE-L: 3x15

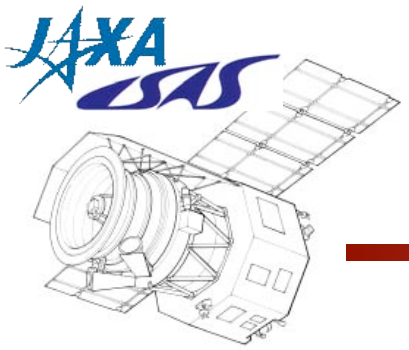
Overlap each other



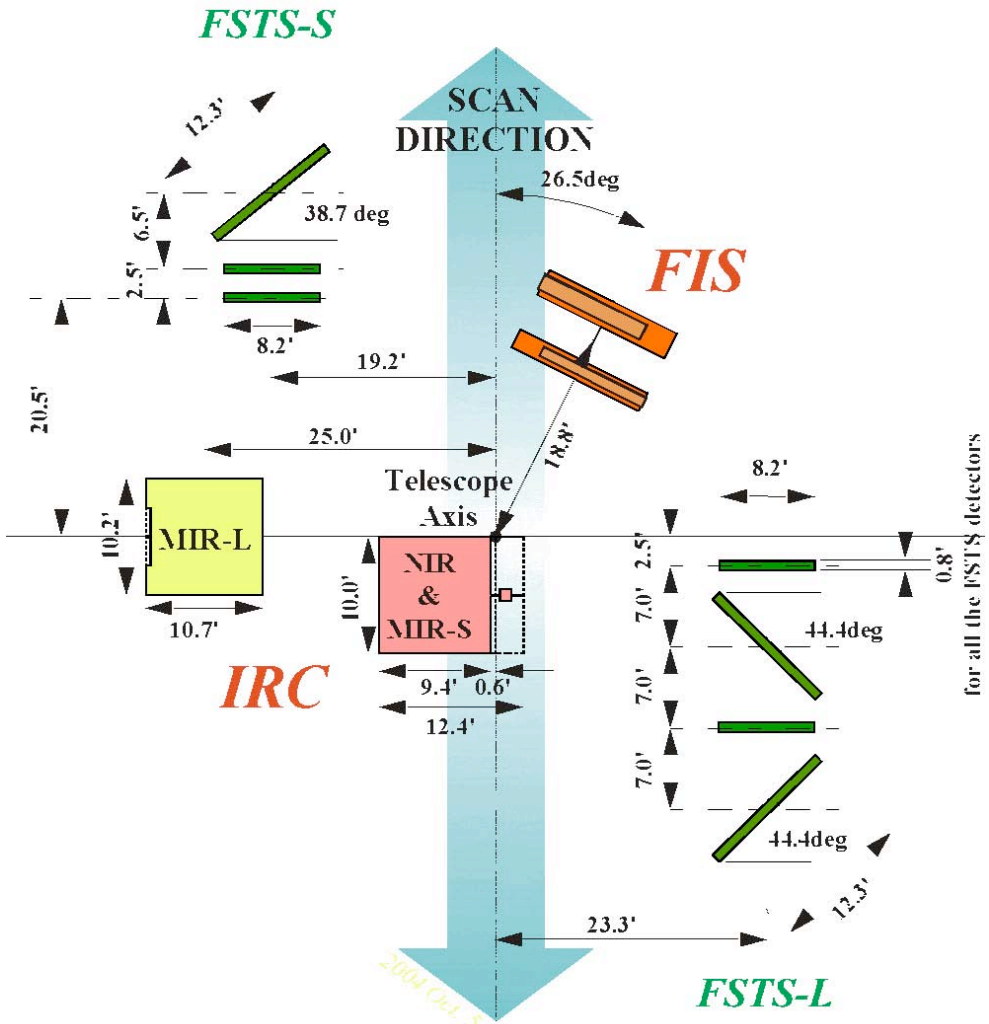
44.2” x 44.2” / pixel

26.8” x 26.8” / pixel

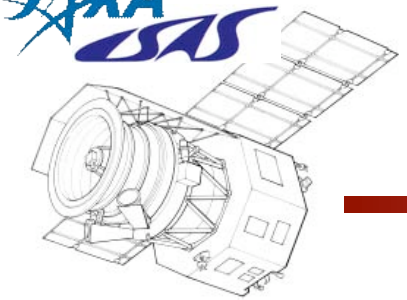
FOV of the FIS



Field of View

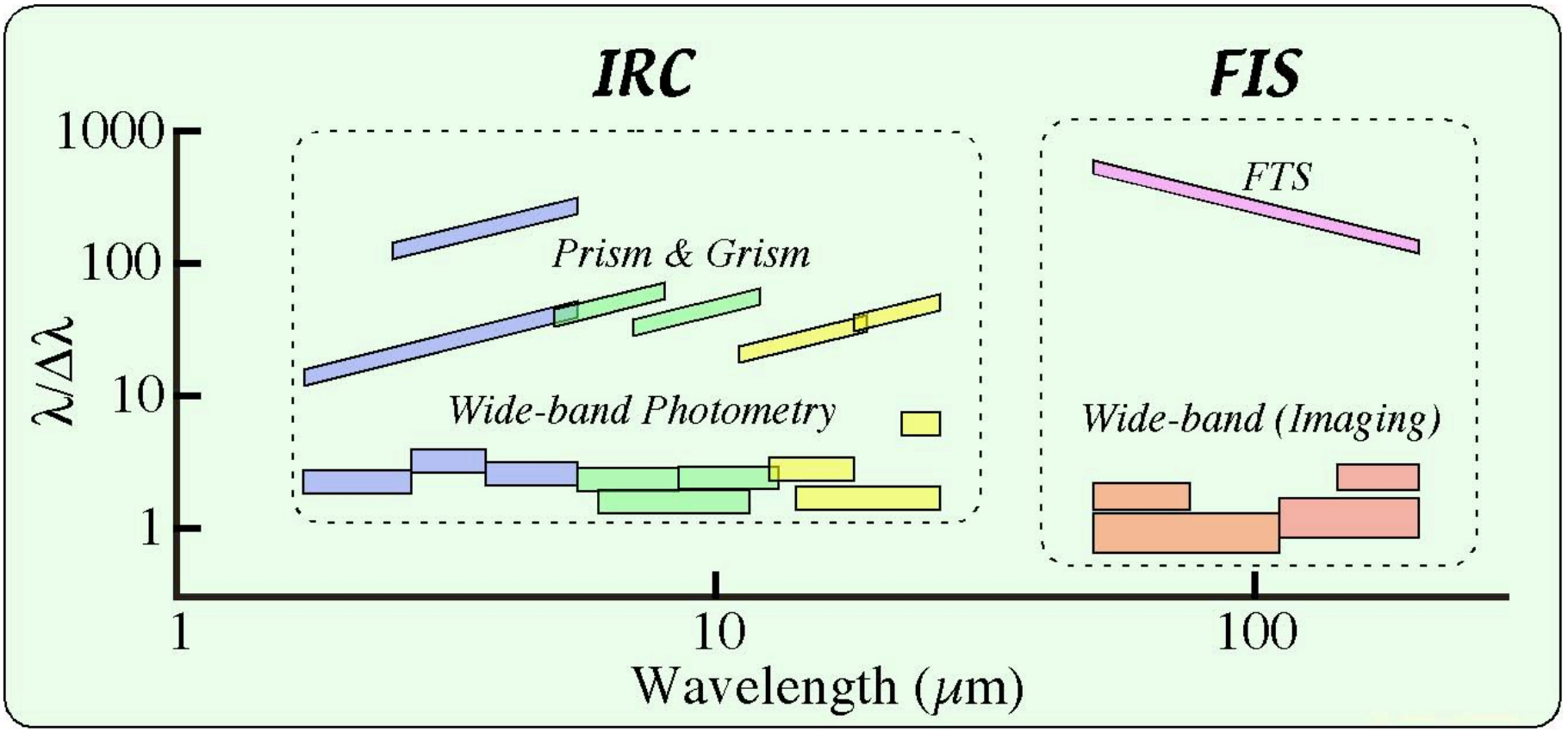


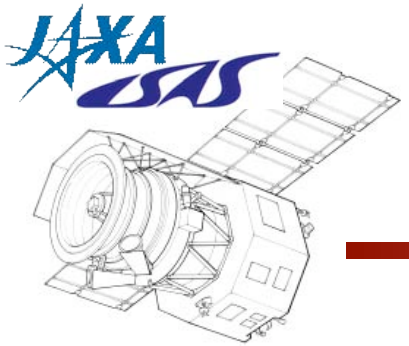
Focal Plane Configuration



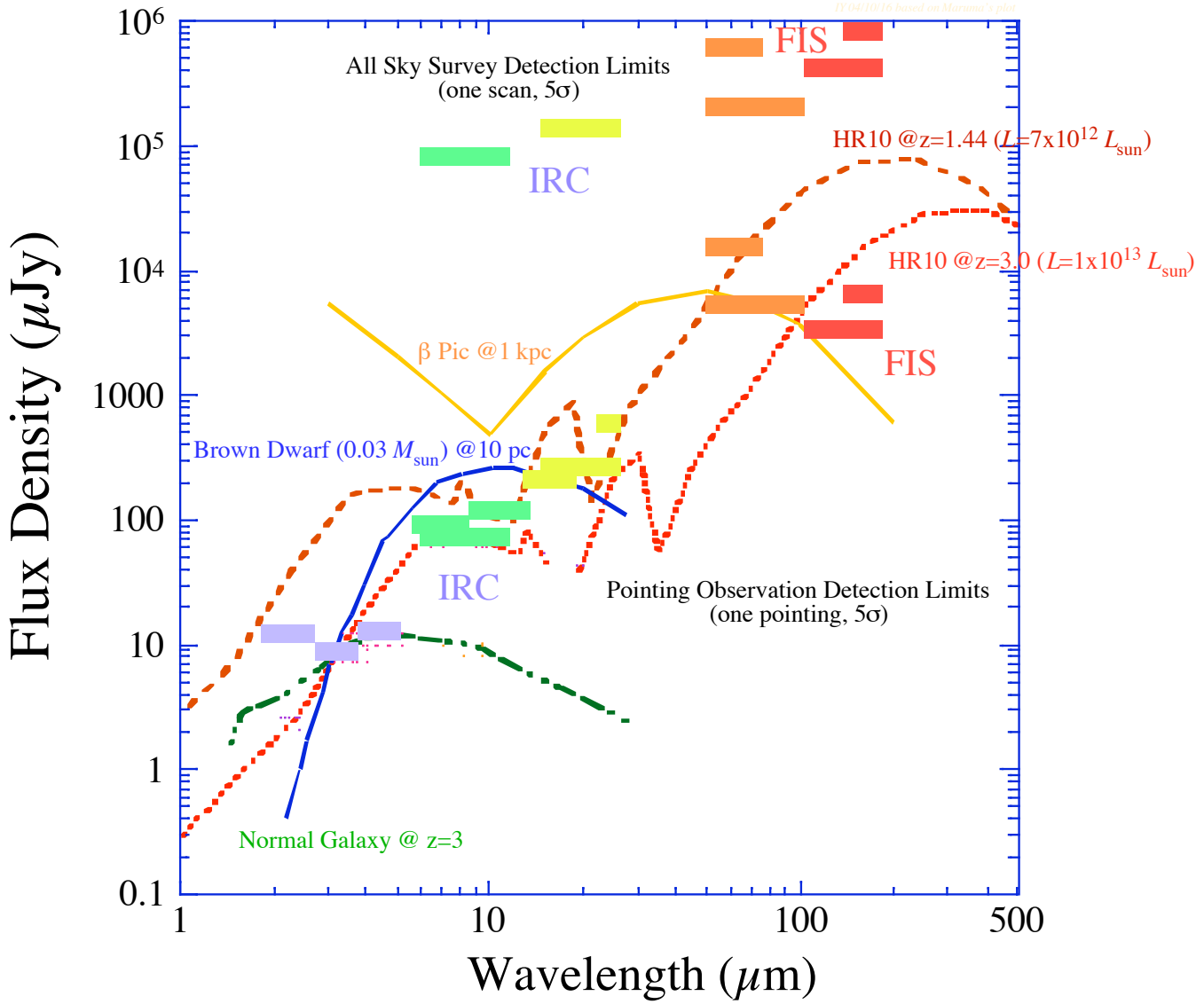
Onboard Instruments

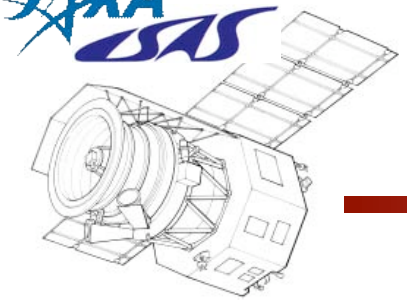
Photometric & Spectroscopic Capabilities





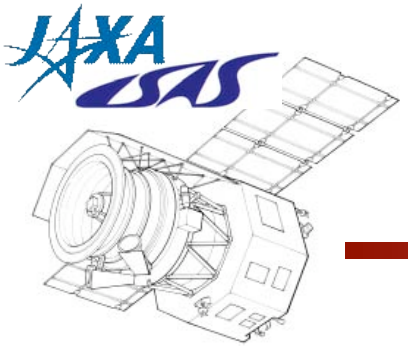
Detection Limits





Current status

- Focal-Plane Instruments
  - Intensive tests and checkout: Jun.–Jul., 2004
  - Installed in the FM cryostat: Aug.–Oct., 2004
  - Performance evaluation tests in the flight environment: This week and next year.
- Satellite system
  - Final integration & test has been paused since Nov. 2003 because of the slip of the launch due to the trouble in telescope system.
  - It is re-started in Feb. 2005 until Oct. 2005

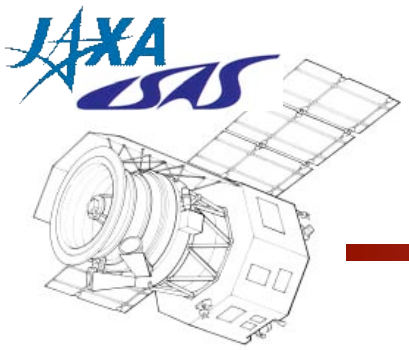


Observing Programmes

- Large Area Surveys = Operated by the project
  - All-sky survey (MIR, FIR)
  - NEP deep survey (mainly NIR–MIR)
  - LMC deep survey (NIR–MIR–FIR)
- Mission Programmes ~ Guaranteed time
  - 7 working groups for every astronomical field
  - Expected to produce legacy data set
- Open Time Programmes
  - 30 % of total pointing observation opportunity
  - 20 % for Japan/Korea, 10 % for ESA related countries.
- Director's time
  - Calibration time
  - Target of Opportunity, ...

ASTRO-F Operation Plan (preliminary)

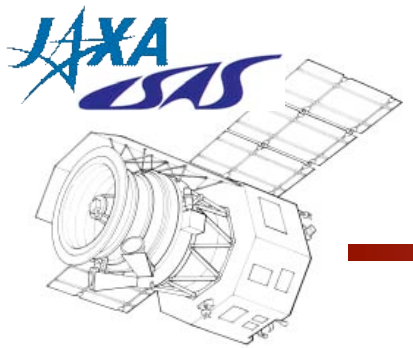
Checkout (~60days)	Launch
Phase 1 (~180 days)	FIS all-sky survey: 1st priority No. of pointings: ~2000
Phase 2 (~300 days)	Pointing + Supplemental FIS survey No. of pointings: ~6000
Phase 3 (>365 days)	LHe boil-off only NIR in operation No. of pointings: >10500



Point Sources Catalogues

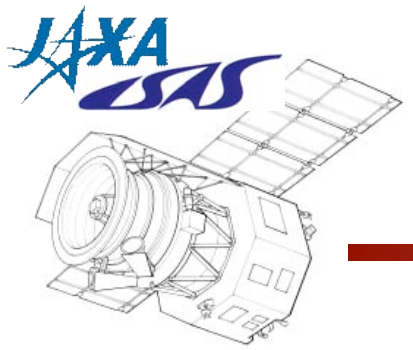
- ASTRO-F/FIS Flux of known sources
  - Flux consistency check with the IRAS PSC + additional FIR flux data.
  - Incremental release during the survey period.
  - Public release ~ mid 2008.
- The Bright Source Catalogue (BSC).
  - Uniform source extraction (Same detection limit for any area in the sky).
  - Generated consolidated data after the end of survey.
  - Public release: earlier than mid 2009.
- The Faint Source Catalogue.
  - The supplemental catalogue of the fainter sources in the region with higher redundancy.
  - Additional process after BSC.
  - Public release: expected ~ mid 2010.

Calibration of the ASTRO-F/FIS: Plan and current status



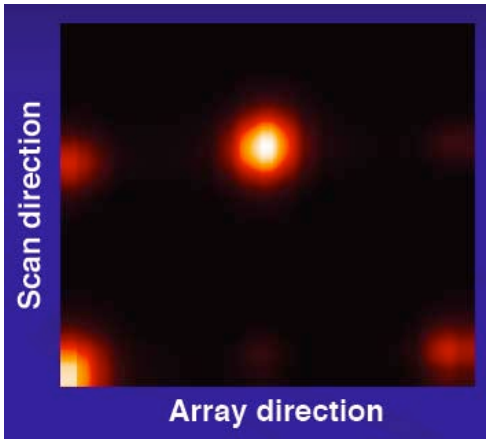
FIS Flux Calibration: *Goal*

- Absolute
  - 10 % for point sources
  - 20 % for diffuse emission
- Relative
  - 5 % for point sources
  - 10% for diffuse emission

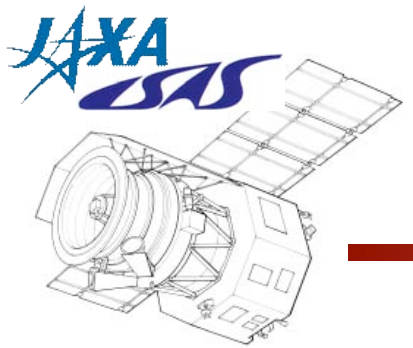


Pre-flight measurements

- Detectors
  - Absolute responsivity : ~10 A/W (SW) ~3 A/W (LW)
  - Transient: physical model correction / empirical approach
  - Ramp curve
  - Noise characteristics
  - Dark current
  - Sensitivity to the detector driving parameters / environment
- RSRF
  - End-to-end measurements of optical elements
  - Detector response not yet completed
- Imaging quality
  - Pin-hole mask image
  - Ghost removed
  - FoV distortion : by simulation



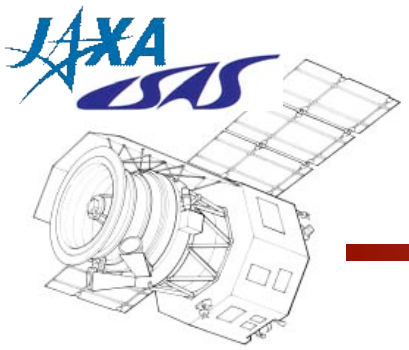
Shirahata et al. 2004



Error budget (preliminary)

- RSRF:
  - Measurement error: ~10 % (assumption)
  - ➔ Photometric error <~ 2 %
- Responsivity correction residual: ~1 %
  (Oh et al. 2004 from IRTS data)
- Transient correction: TBD
- Uniformity
  - Responsivity variation: can be corrected to < a few %
  - Long-wavelength cut-off: ~2 % after proper correction
- Ramp curve correction error: 1–10 % (current: to be improved)

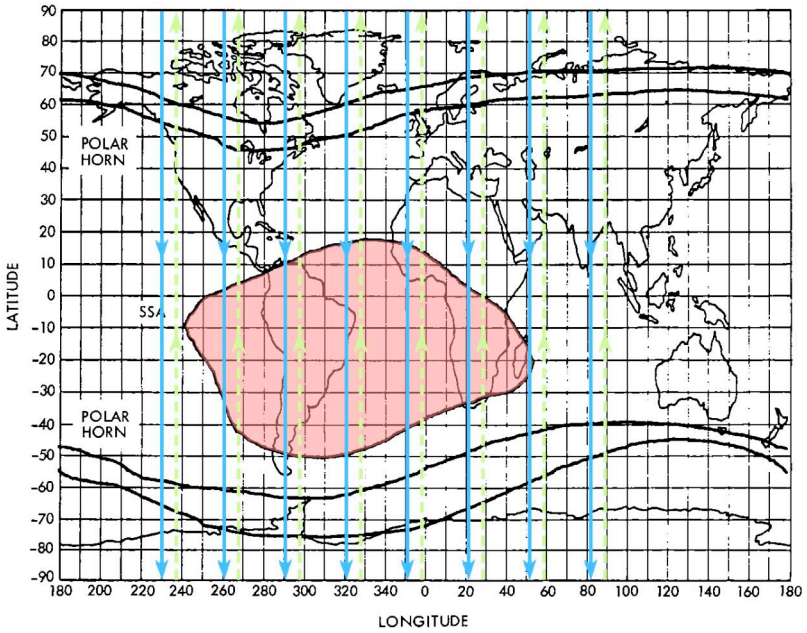
Optimistic estimates is that we can achieve the goal accuracy.



Requirements (1)

- Possible time variation of detector response.
  - Transient: seconds ~ 10 minutes
  - SAA: minutes ~ hours
  - Glitches: seconds ~ hours
  - Detector temperature: 50 min (1/2 orbital period) ~ months
- Calibration lamp intensity may change with months' time scale.

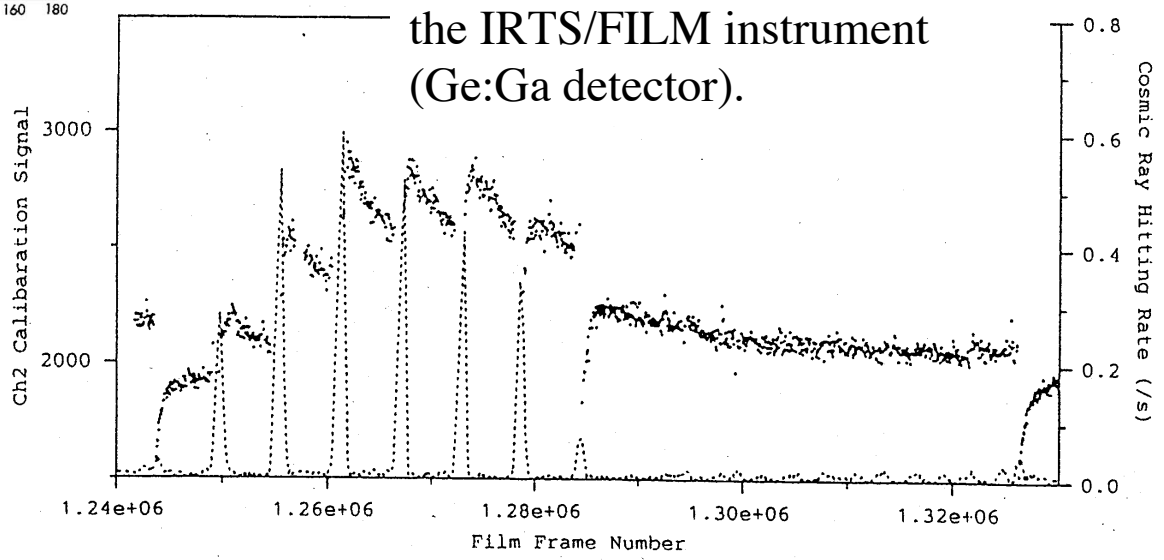
Radiation effects

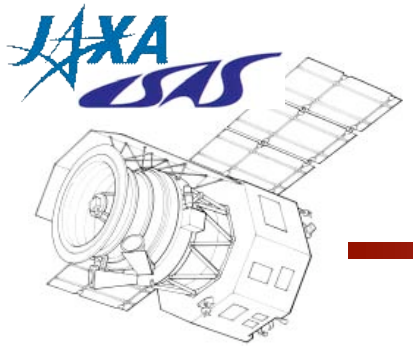


IRAS Explanatory Suplement

South Atrantic Anomary (from IRAS Explanatory suppliment. at 900 km) and the approximate orbit of ASTRO-F. ASTRO-F goes through the SAA ~10/15 orbits per day.

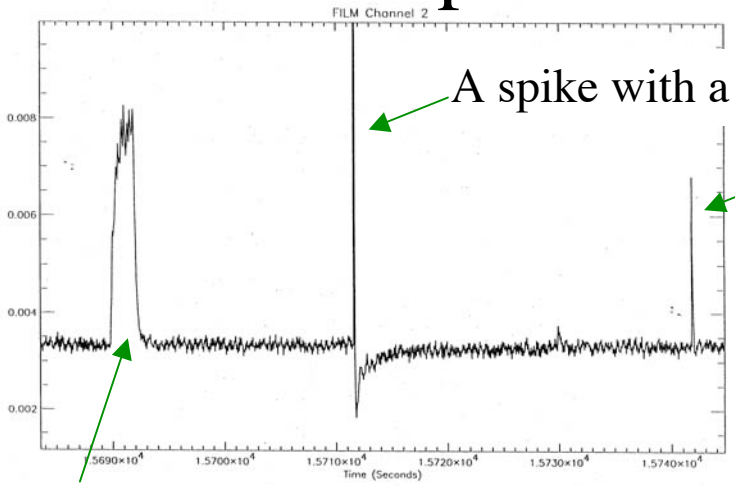
Variation of internal calibrator signal in one day observed by the IRTS/FILM instrument (Ge:Ga detector).





Charged particle hits

- Two examples

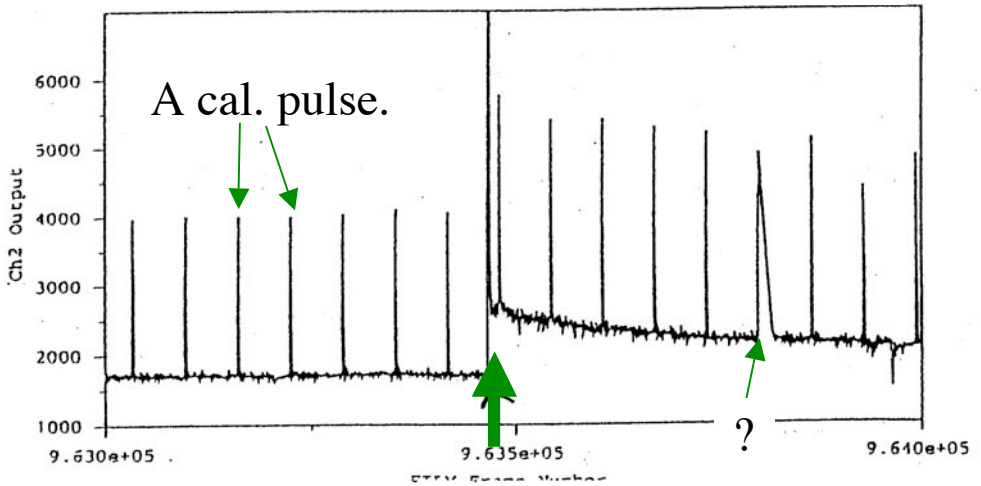


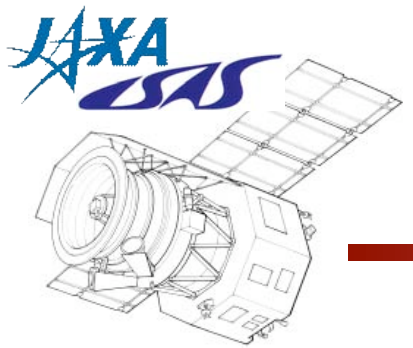
A spike with a short negative tail.

A spike.

A cal. pulse.

A spike causes a jump of responsivity with long time constant.



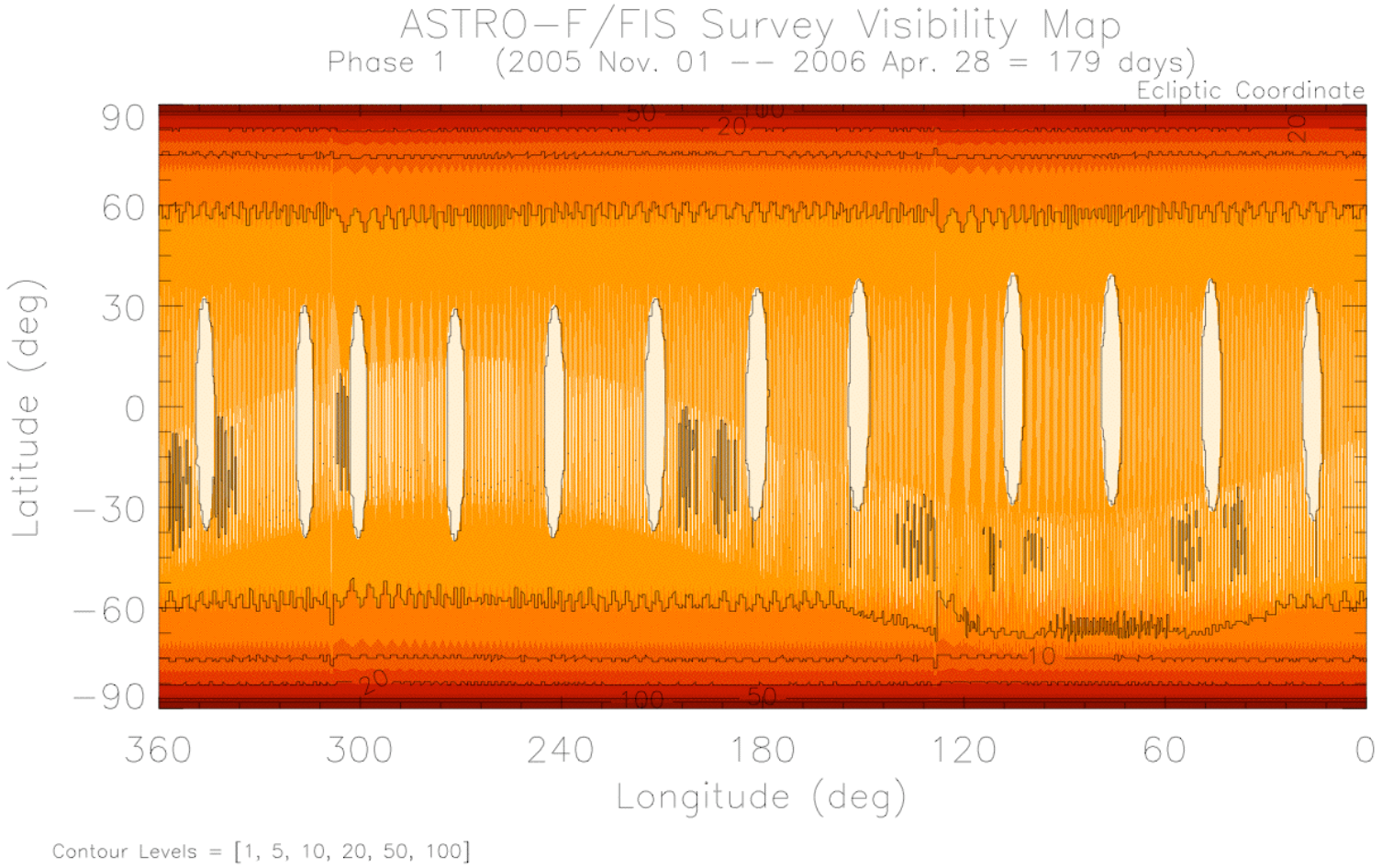


Requirements (2)

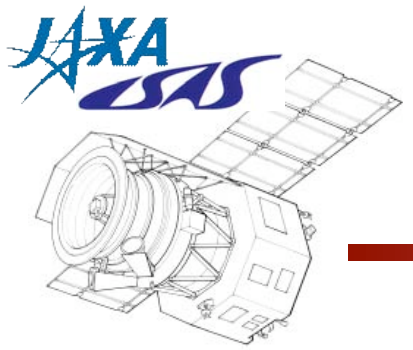
- ASTRO-F takes near-Earth orbit.
- ASTRO-F is an all-sky survey mission.
  - Scanning the sky along ecliptic meridian.
    - To cover the whole sky, a half year ~continuous observation is needed.
  - Large constraint of visibility.
    - Only ± 1 deg in cross-scan direction is visible at a time.
    - A pointing observation is limited up to 10 min exposure.

Need calibration sources everywhere in the sky!

Visibility Map (Ecliptic)



More visibility in the high-ecliptic latitude region.....

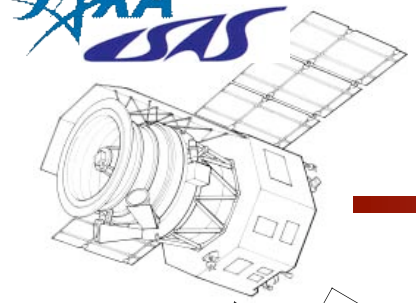


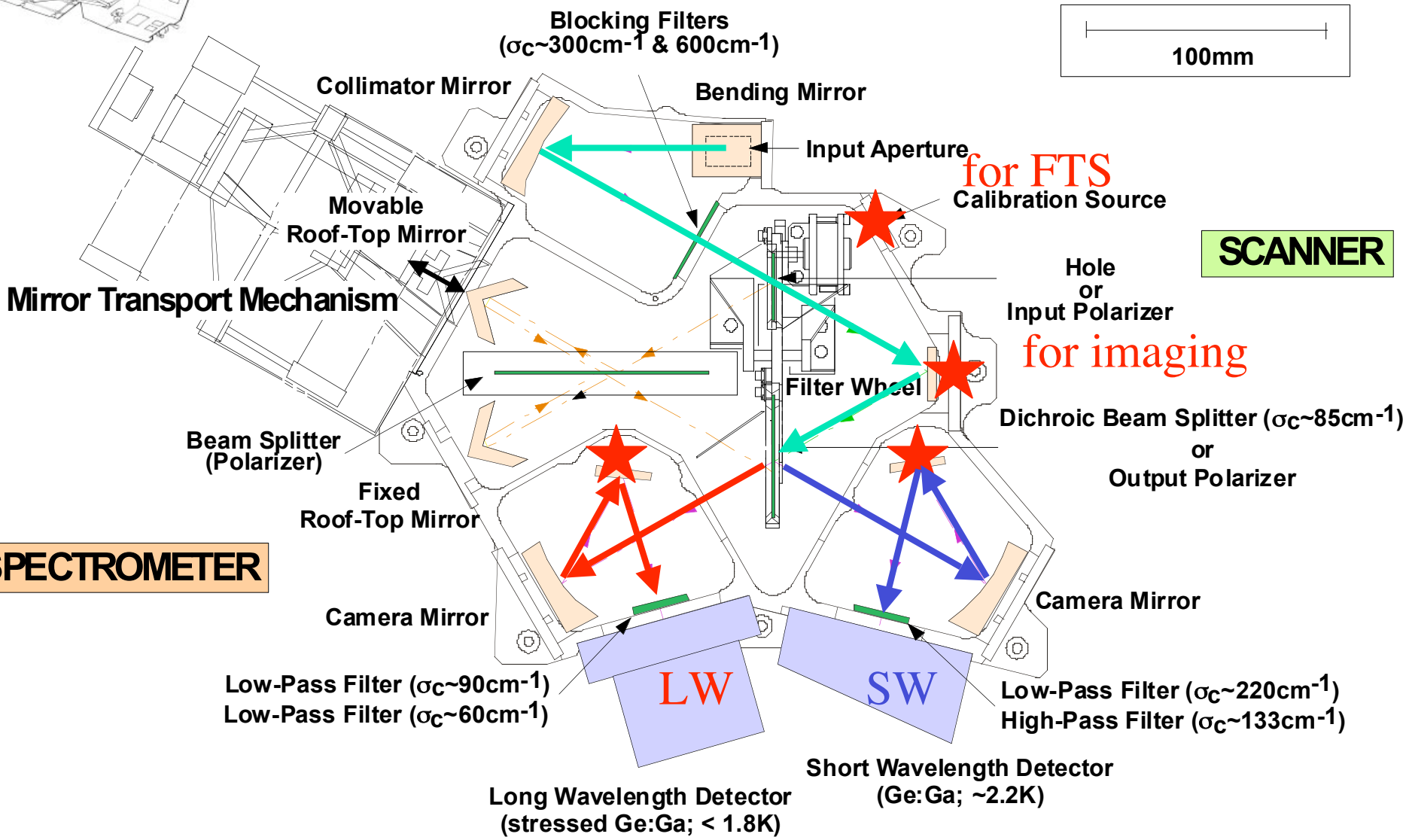
FIS Flux Calibration Strategy

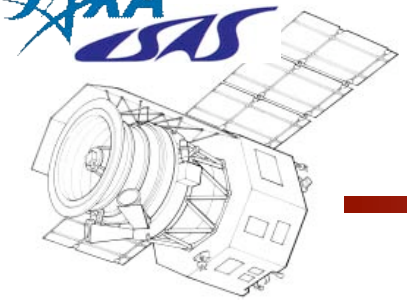
Three steps

	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	Infinity	Stars Asteroids

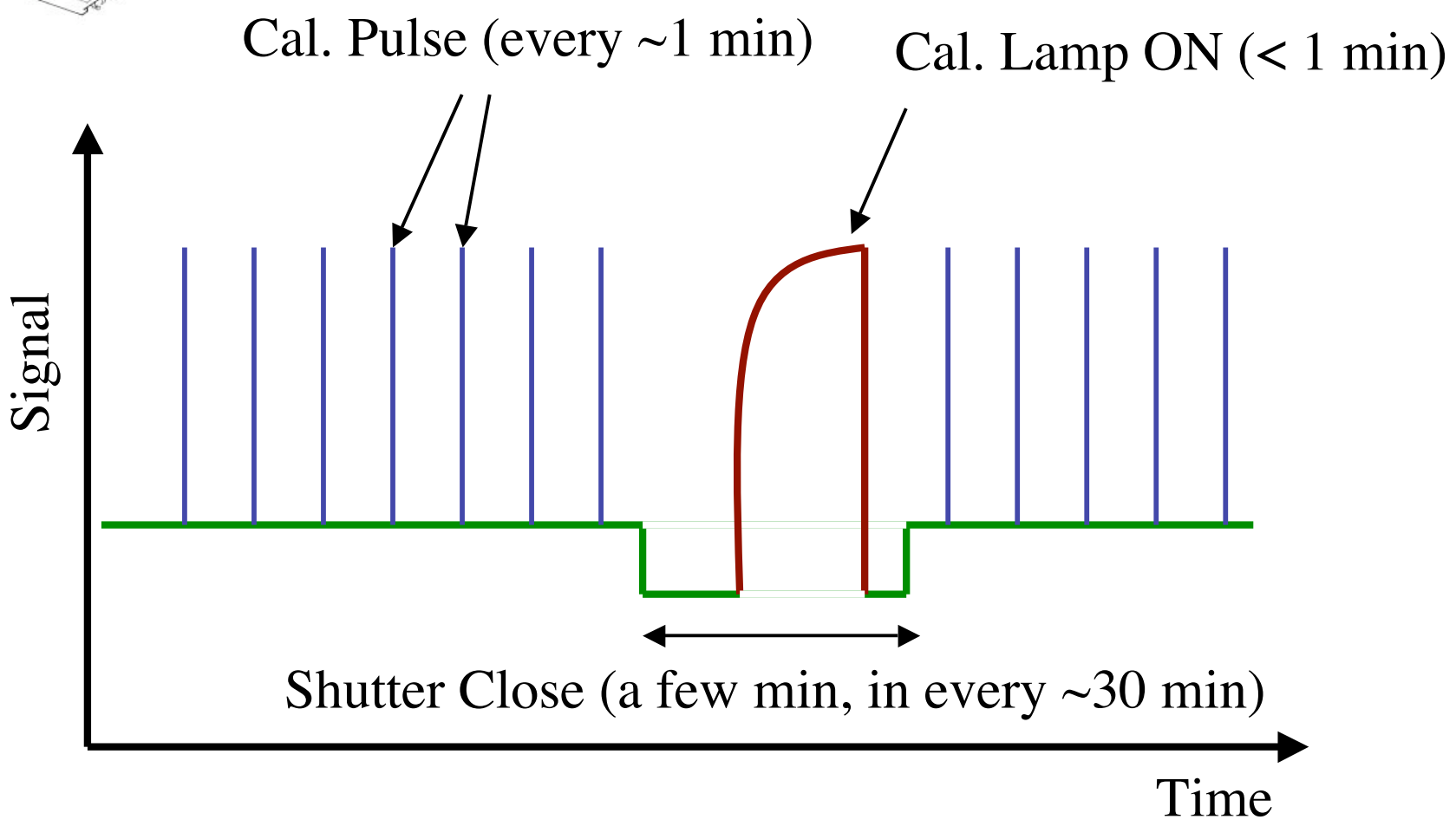
FIS internal calibration source



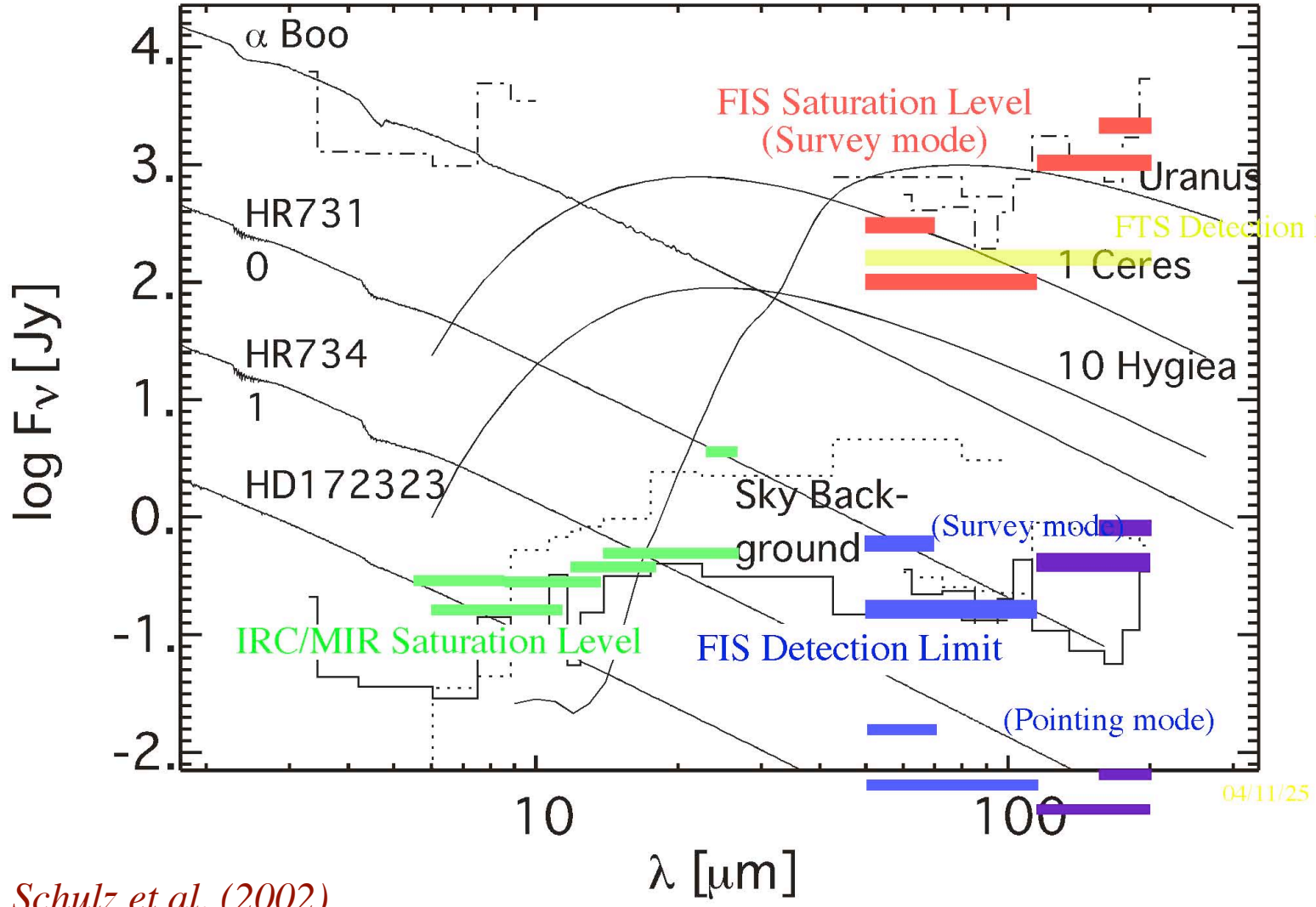




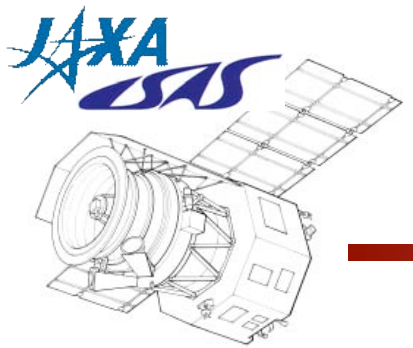
Calibration sequence (example)



FIS Calibrators



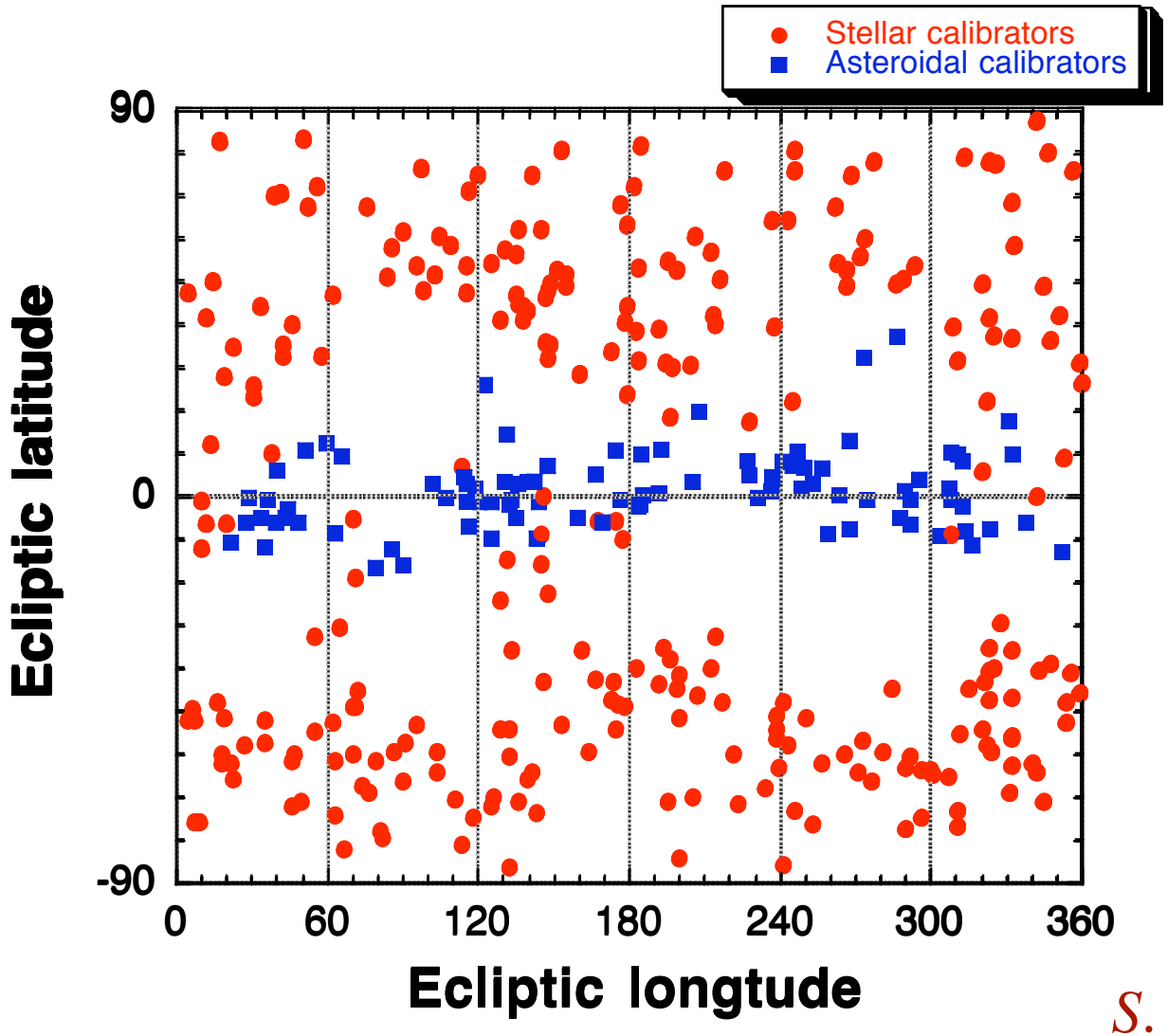
Schulz et al. (2002)



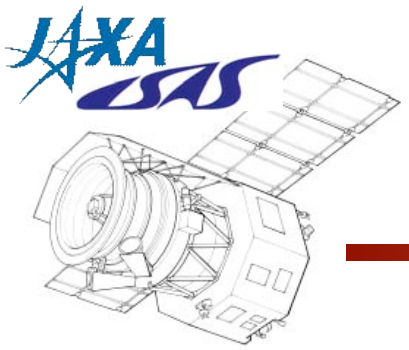
Calibration Standards for ASTRO-F

- Asteroids
  - ➔ Presentations by Thomas Müller & Ootsubo
- Stars
  - *All sky survey*: Baseline = Cohen's all sky network (614 stars)
    - 100–200 sources (SW) and 9–32 sources (LW) are bright enough
    - + ~ 200 candidate stars are selected.
      - FIS detectable, at high ecliptic latitude ($\beta >\sim 20$ deg)
      - Mostly K-giants, a few A, G dwarfs.
  - *Pointing Observations*: Baseline = NEP standard stars for Spitzer
    - About 10 stars are bright enough.
    - + Additional 11 stars ($\beta \geq 75$ deg) have been selected
    - More stars under consideration (Use of All sky network)
- Planets
  - Photometric calibration of the *FTS mode* and LW channel

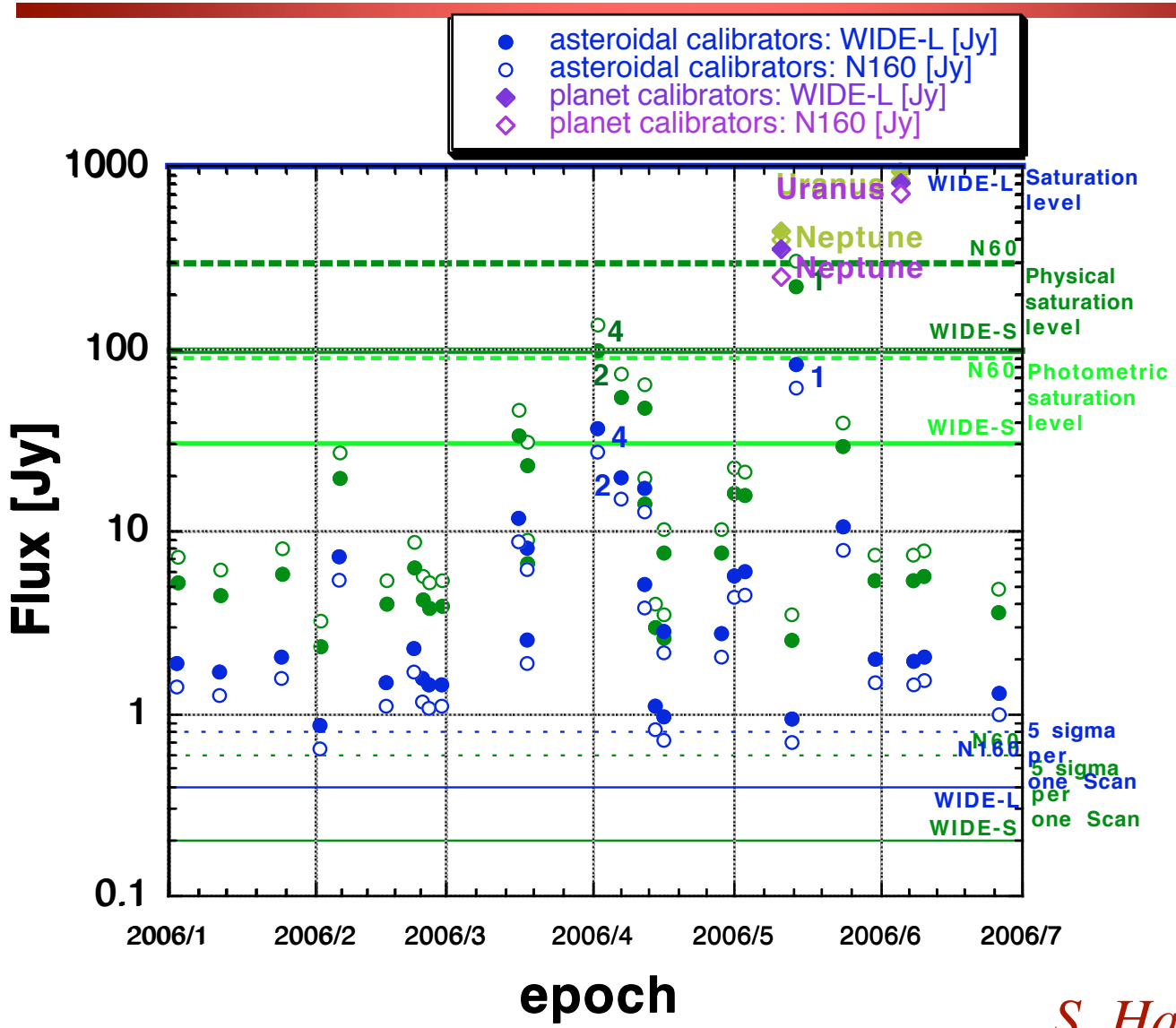
Asteroid Calibrators Visible from ASTRO-F (Jan. 2006 – Jun. 2007)



S. Hasegawa

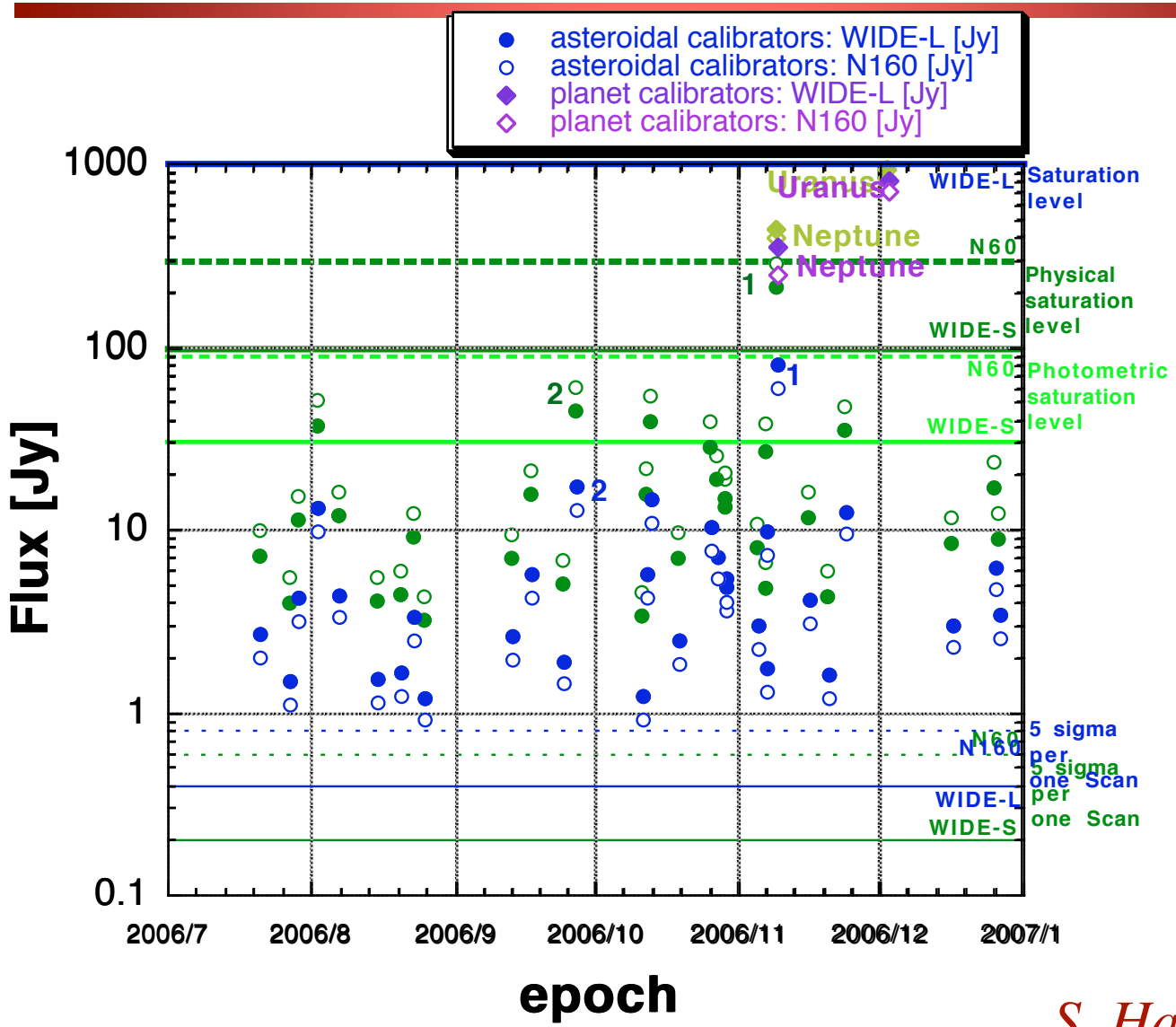


Asteroid Calibrators Visible from ASTRO-F (Jan. – Jun. 2006)



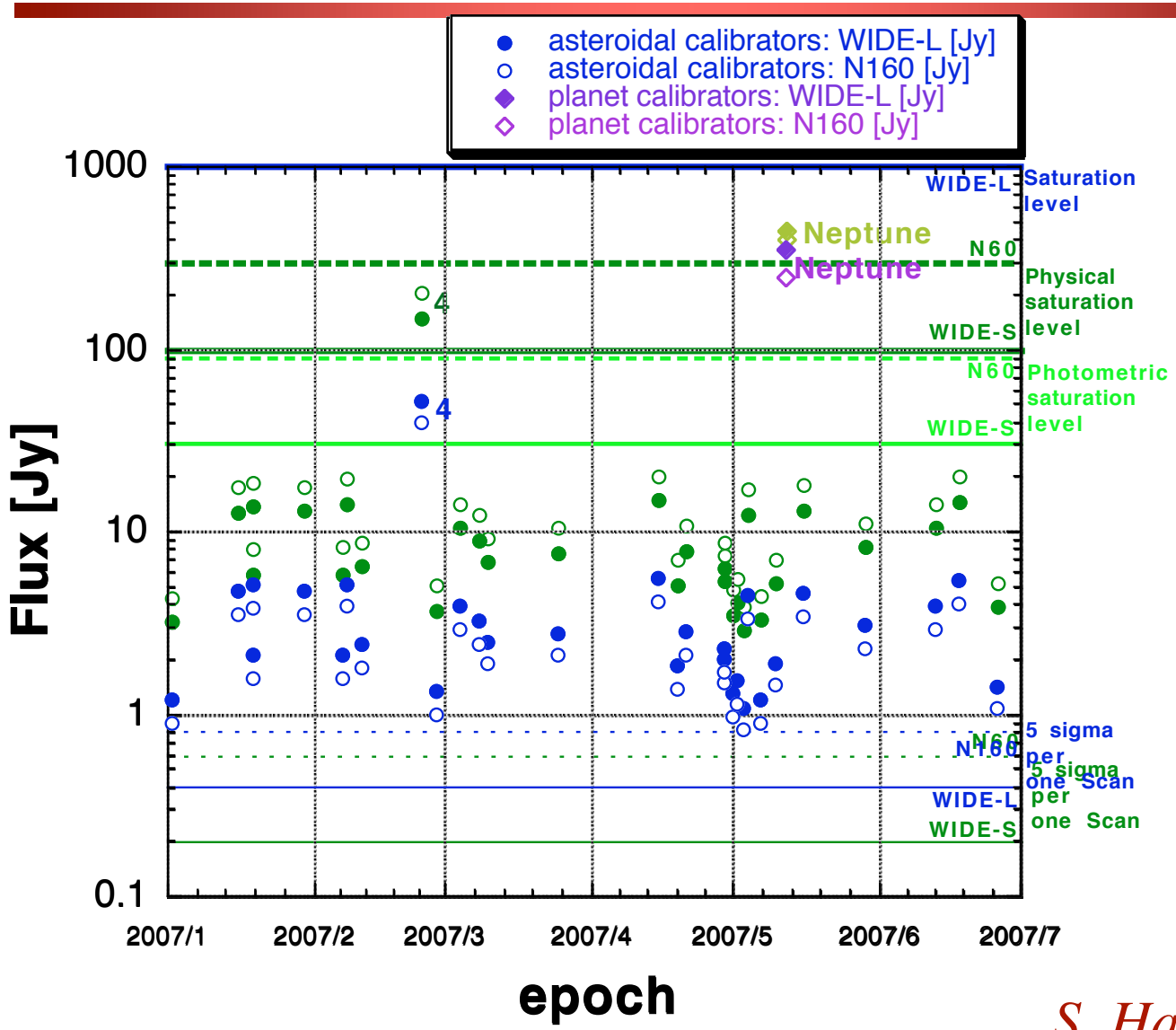
S. Hasegawa

Asteroid Calibrators Visible from ASTRO-F (Jul. – Dec. 2006)

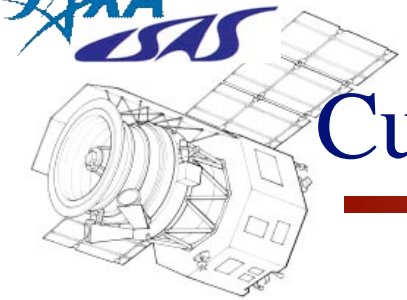


S. Hasegawa

Asteroid Calibrators Visible from ASTRO-F (Jan.– Jun. 2007)

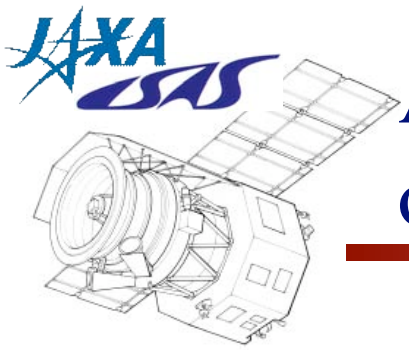


S. Hasegawa



Current activity of the calibration work

- Asteroid calibrators
  - Active team at work:
    - (T. Ootsubo, S. Hasegawa, T. Sekiguchi + Th. Müller)
    - MIR observations with Subaru/COMICS.
    - Calibration observation plan.
- Stellar calibrators
  - Not really active (only occasionally working)
  - Lack of manpower (currently I. Yamamura)



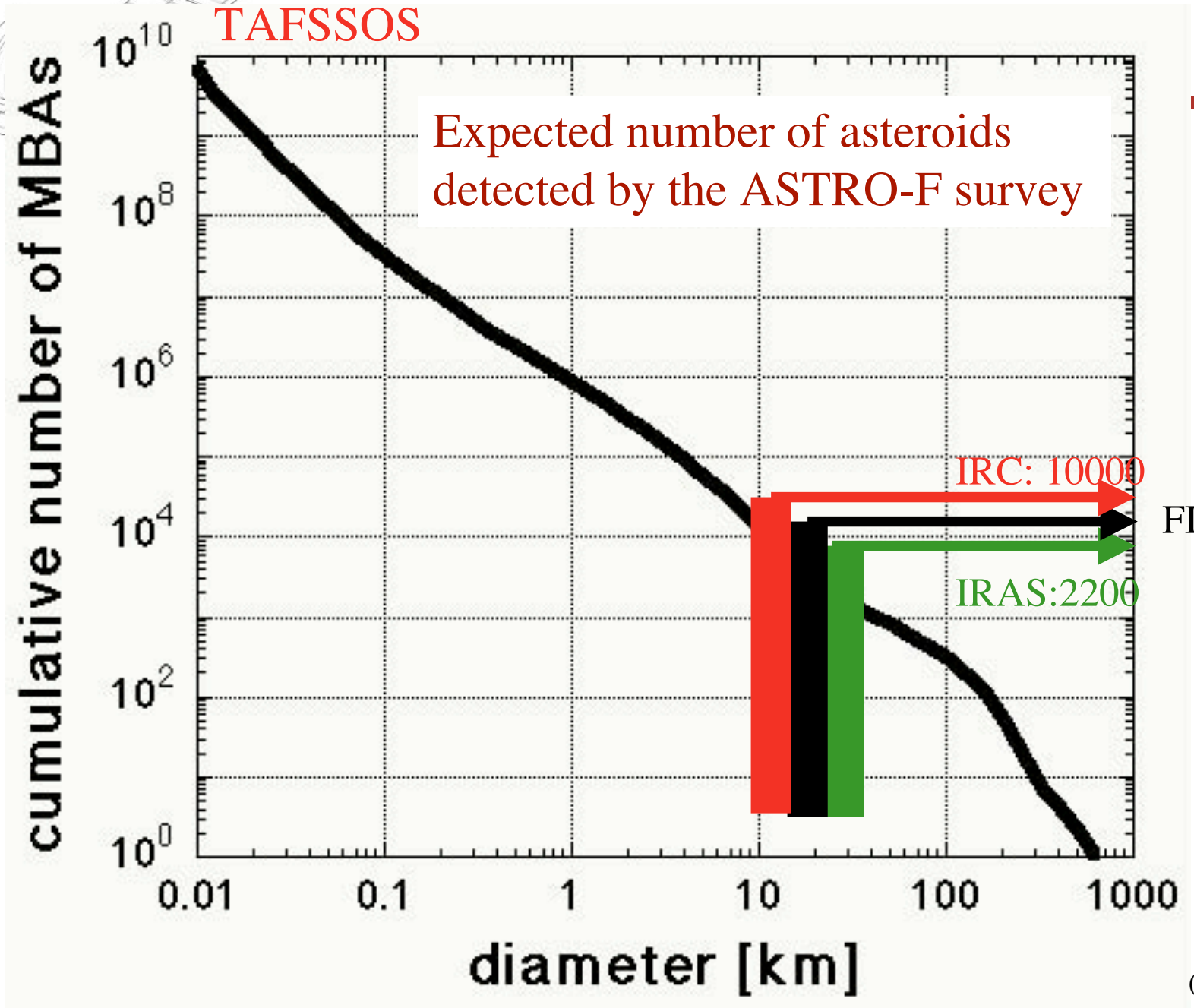
ASTRO-F's contribution to the calibration of future missions

- ASTRO-F's calibration observations will provide high-quality FIR photometry data for our calibration targets. These data will be useful to validate each sources as the calibration standard and improve the models.

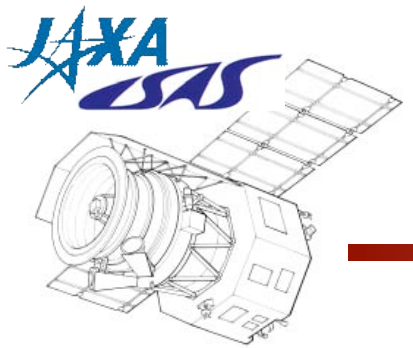
- The products of the all sky survey, the ASTRO-F catalogue will contain many stars and solar-system objects, and can be used for selecting future calibrators.

- In both cases the MIR data are also obtained. Better understanding of the calibration sources is enabled.

TAFSSOS

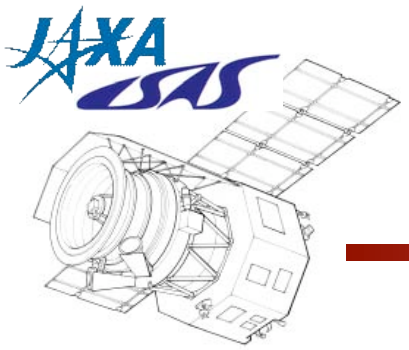


(Hasegawa 2000)



Summary

- Number of asteroids and stars are considered as the calibration standards for the ASTRO-F/FIS.
- Preparation of the asteroid calibrators are already on the same framework for ISO–Herschel.
- Preparation of stellar calibration sources is an extension of M. Cohen's all-sky network. Validation of each object is items to be considered. Concern is manpower.
- ASTRO-F will provide plenty of useful information and data for the construction of future calibration sources.



Q/A

Q: What happens when ASTRO-F looks Moon?

A: Not concrete plan so far. We may close the shutter.

Q: Any curing methods applied after SAA passage?

A: We do “bias boost” every time after the SAA passage but still large variation of the sensitivity remains.

Q: For observation of asteroid calibrators you you plan to use cross-scan offset option?

A: Probably for pointing observation. Survey mode may look them anyway. The main decision on planning is between pointing and survey. Observation planning is under investigation.

Q: Will ASTRO-F observe Trans-Neptune objects?

A: There are some science proposals for pointing observation but survey may not be sensitive enough.

Q: How many stars have you consider?

A: 641 Cohen’s network + 400 GLIMPSE targets + 200 new candidates. May be more to add.

Q: Any needs of atmospheric model?

A: Any inputs are welcome. We also wish that ASTRO-F data will be a test bench of calibration targets and models.