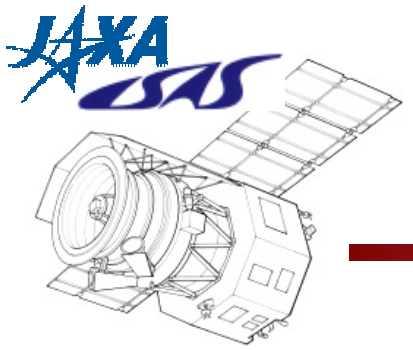
An Introduction to ASTRO-F

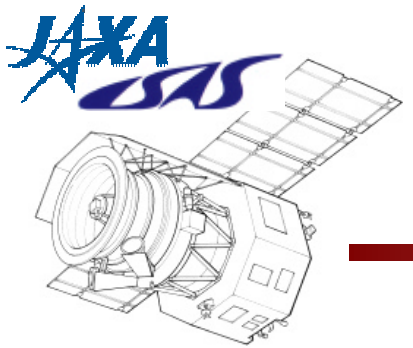
Prepared by ASTRO-F Project Team in ISAS/JAXA

and

ASTRO-F User Support Team in ESAC/ESA



Mission Overview



ASTRO-F Mission

**Formerly known as IRIS (Infrared Imaging Surveyor)*

- Far-Infrared and Mid-Infrared All Sky Survey

  The first All-Sky Infrared Survey since IRAS

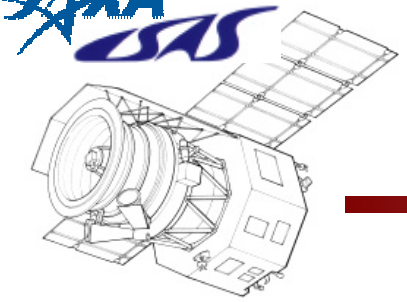
  Better sensitivity, better resolution

- Deep Imaging / Spectroscopic Surveys of Selected Sky

- Launch: January–February 2006

  By JAXA's M-V rocket

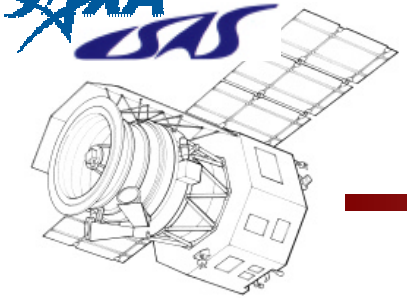
- Mission lifetime: ~ 550 days + α



ASTRO-F All Sky Survey

- Unbiased all sky survey in the Mid- to Far-Infrared range.
  - FIS: 50–200 μm (4 bands)
  - IRC: 9 & 20 μm (2 bands)
    - c.f. IRAS:12, 25, 60, & 100 μm
- High-spatial resolution
  - 30” @ 50 μm – 75” @ 200 μm.
  - ~10” @ 10 & 20 μm
    - c.f. IRAS: 2–5 arcmin
- High sensitivity
  - Detection limit ~200 mJy @ 50–110 μm, ~100 mJy @ 10&20 μm
    - c.f. IRAS PSC ~1Jy

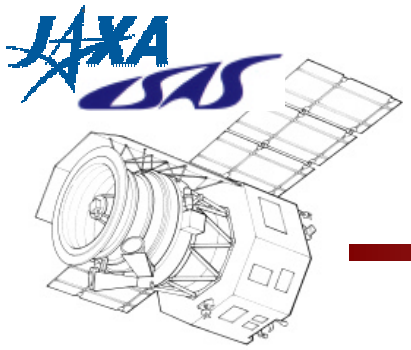
Super IRAS



ASTRO-F Flight Model

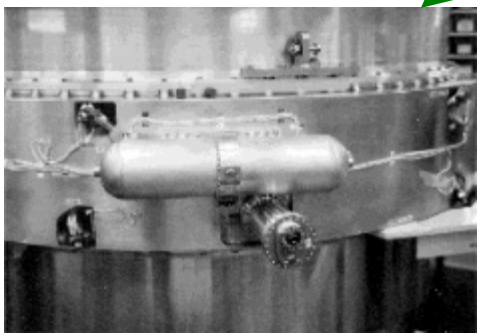
Height: 3.7 m (at the launch)
Wet Weight: 960 kg

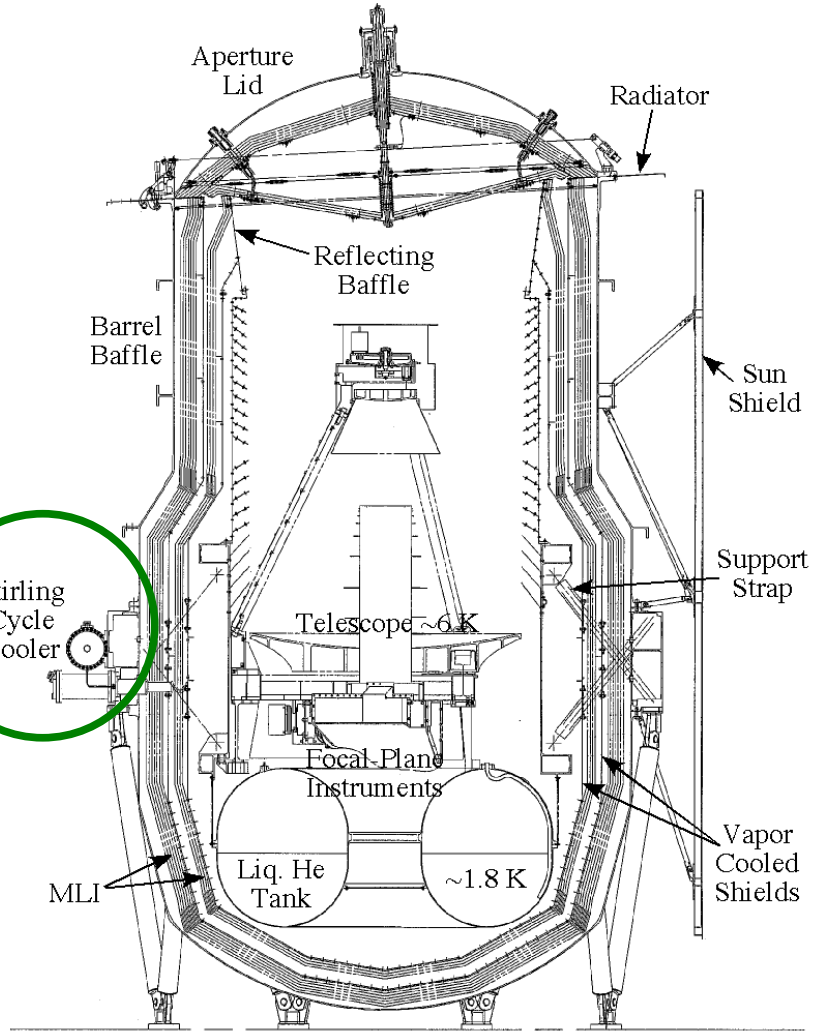
At the satellite integration test (June 2002).

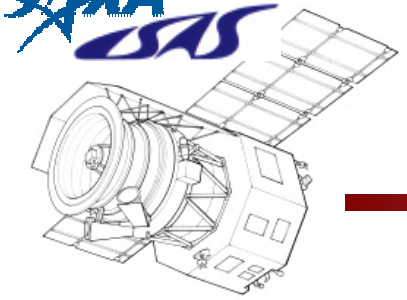


Cryogenics

- Hybrid Type
  - Liq. He (170 *l*)
  - Two-stage Stirling cryocoolers
  - Lifetime: 550 days

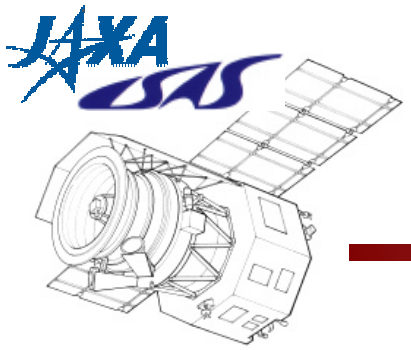






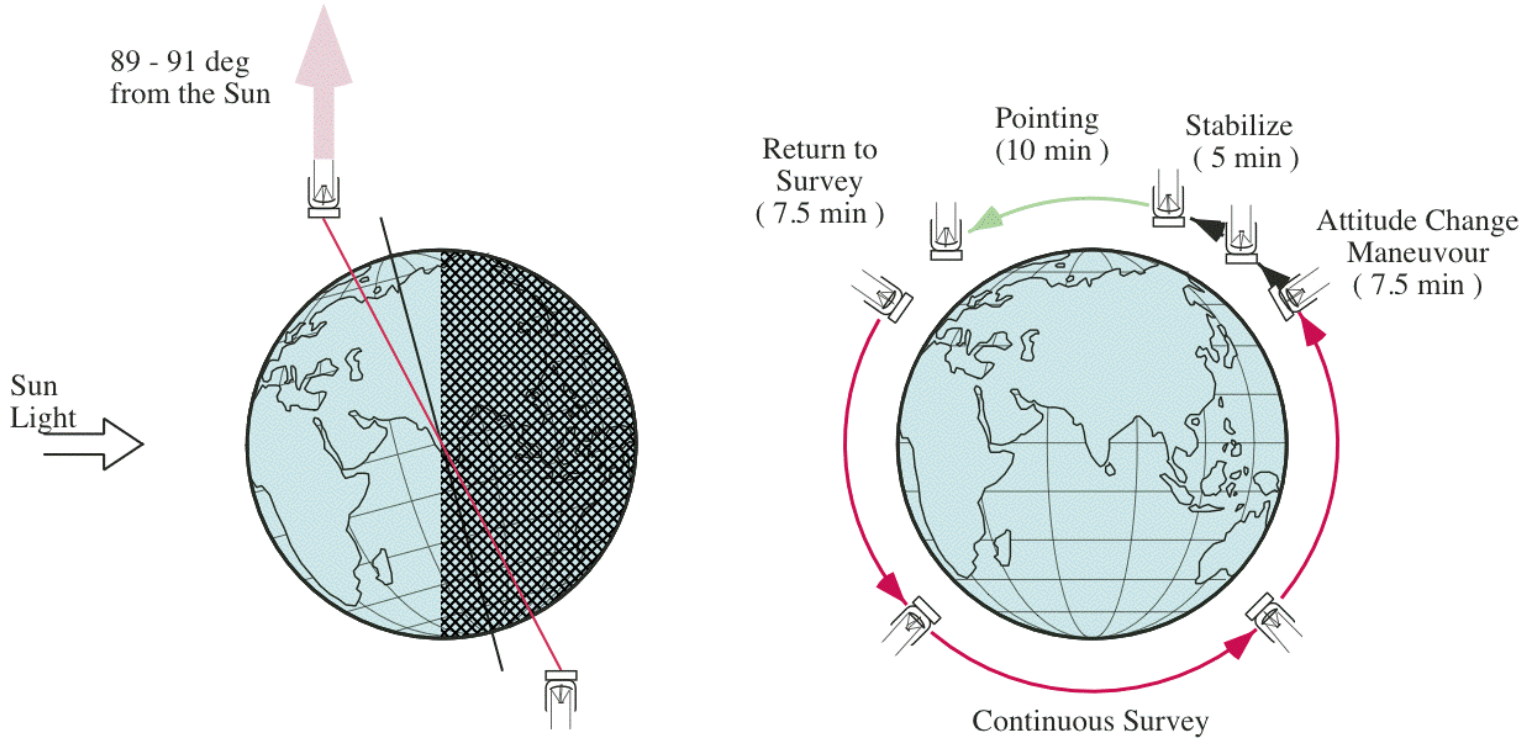
ASTRO-F Telescope

- ϕ 685 mm, F/6.3, Ritchey-Chretien,
  - Cooled down to 5.8 K
- Silicon carbide mirror
  - Sandwich-type porous SiC CVD SiC)
  - Primary mirror 11 kg, Total weight 42 kg



Orbit and Operation Modes

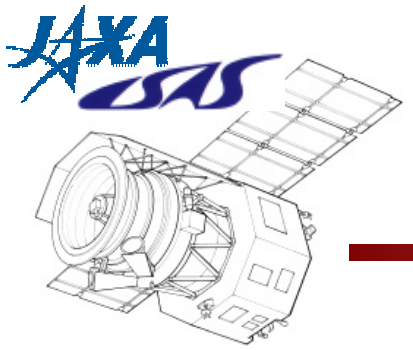
- Sun-synchronous polar orbit
- Nominal altitude: 745 km
- Orbital Period: 100 min



Survey Mode & Pointing Mode

ASTRO-F Operation Plan

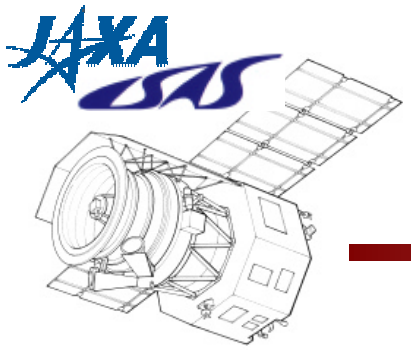
Checkout (~60days)	Launch
Phase 1 (~180 days)	FIS all-sky survey: 1st priority LS+Some MP Pointing Obs.
Phase 2 (~300 days)	MP + OT Pointing Obs. Supplemental FIS survey
Phase 3 (>365 days)	LHe boil-off only NIR in operation MP + OT pointing Obs.



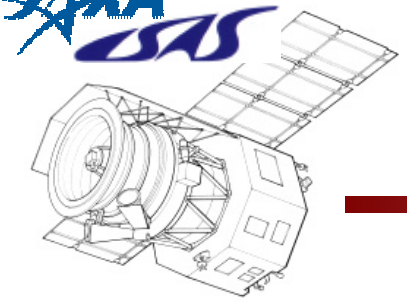
International collaboration

- ESA
  - Additional ground station.
  - Pointing reconstruction
  - User support for European open time.
- IKSG (Imperial College/ Kent/Sussex/Groningen)

  Korea (Seoul National University)
  - FIS All Sky Survey data reduction
- Personal-level collaborations
  - Photometric calibration
  - Detector characterisation



ASTRO-F Instruments



Two Scientific Instruments

- FIS (Far-Infrared Surveyor)
  - λ50–180 μm
  - Four photometric bands
  - Fourier Transform Spectrometer
- IRC (Infrared Camera)
  - λ1.8–26 μm by three cameras
  - Nine photometric bands + six spectroscopic bands
  - FoV ~10x10 arcmin^2

Spitzer

70 & 160 μm

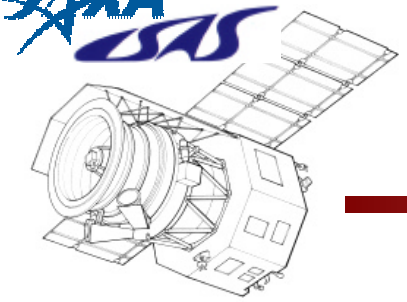
2 pht. bands

SED mode

3.6–8.0 + 24 μm

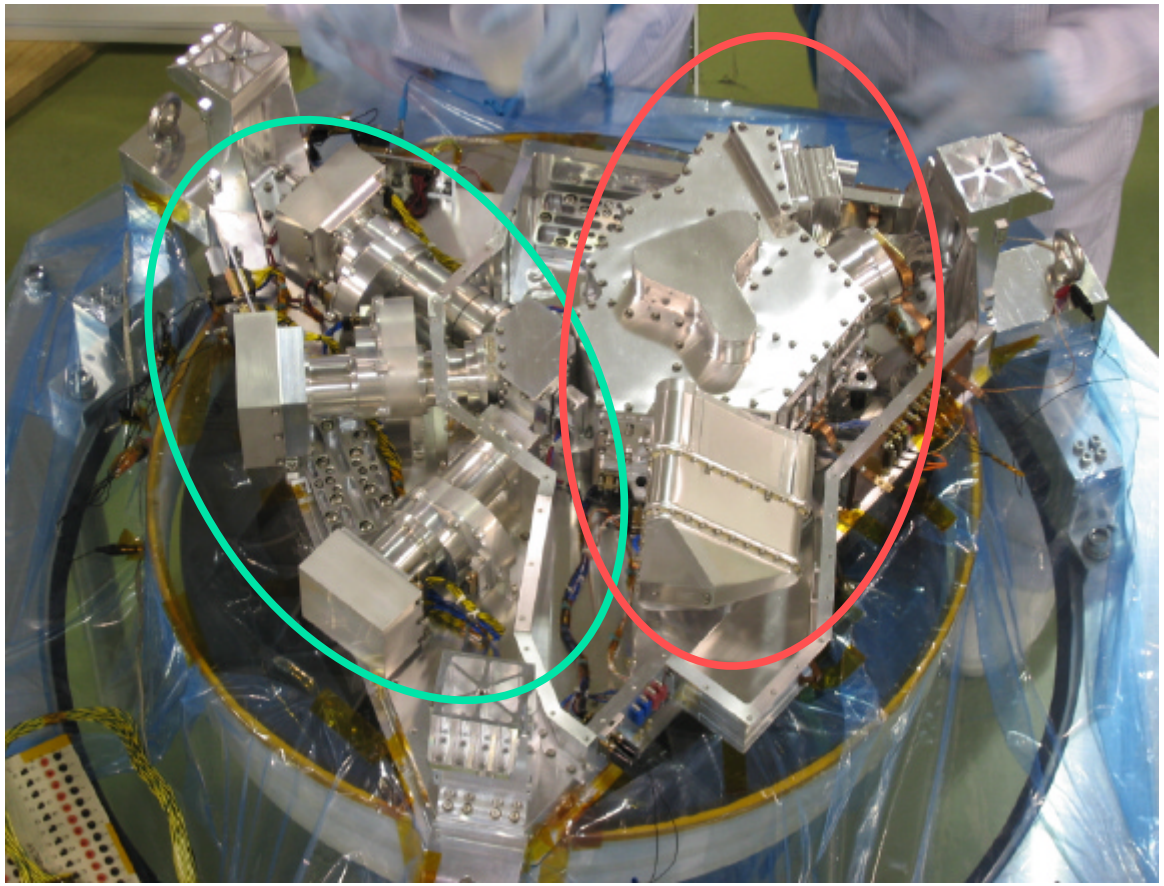
4 + 1 (imaging)

5x5 arcmin^2



Focal Plane Instruments

(Far-Infrared Surveyor)



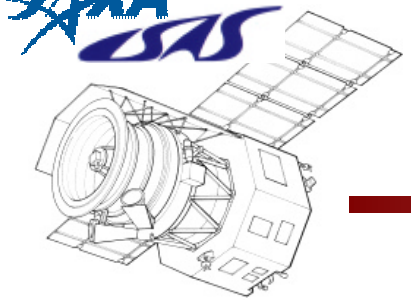
FIS

50–180 μm

1.8–26 μm

IRC

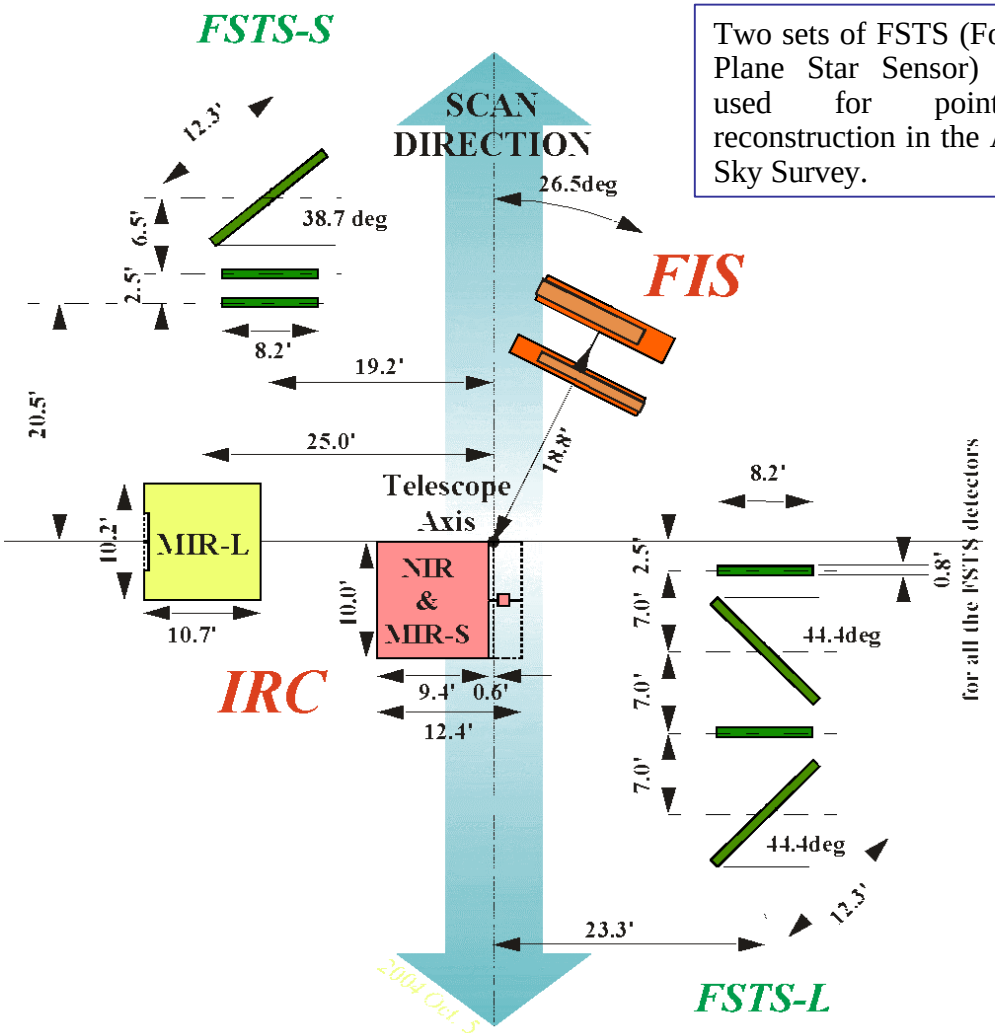
(Infrared Camera)



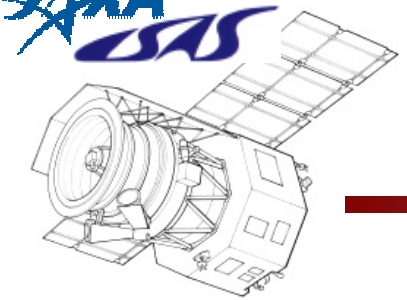
Field of View

- 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 sky by means of a beam splitter.
  - IRC: NIR and MIR-S share the same sky by means of a beam splitter.

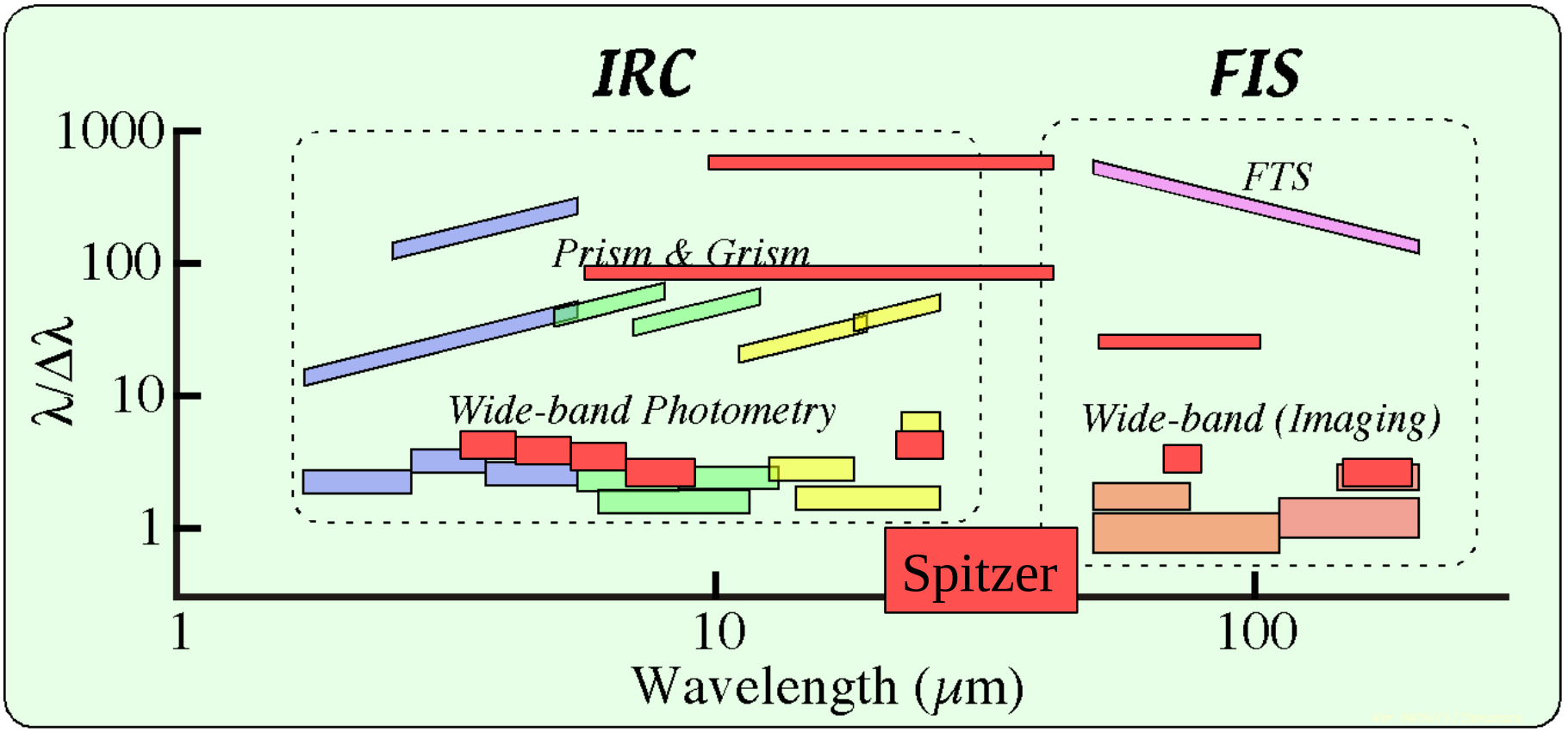


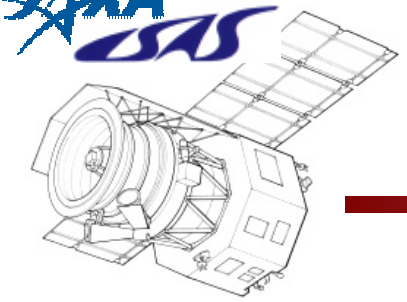
Two sets of FSTS (Focal Plane Star Sensor) are used for pointing reconstruction in the All-Sky Survey.



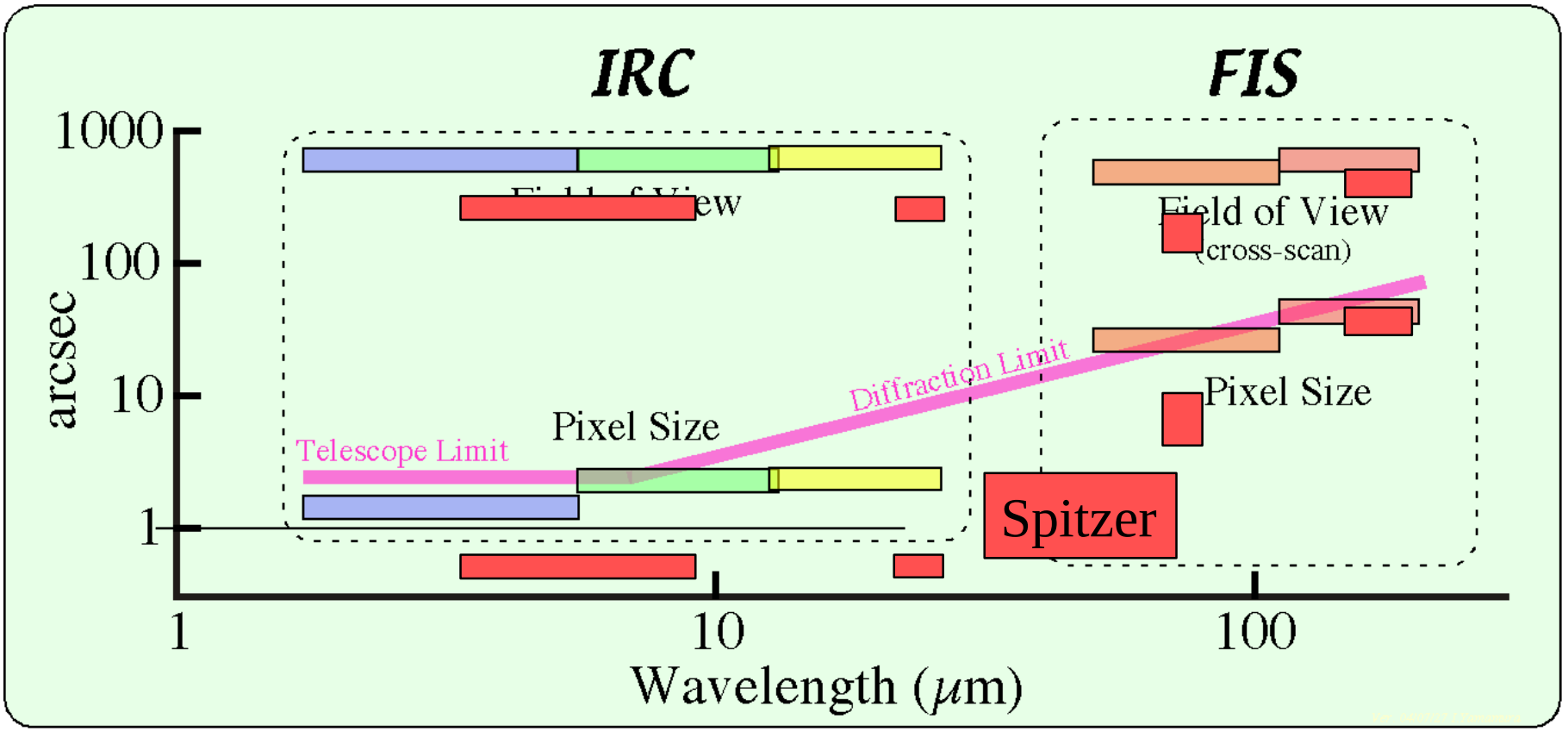
Onboard Instruments

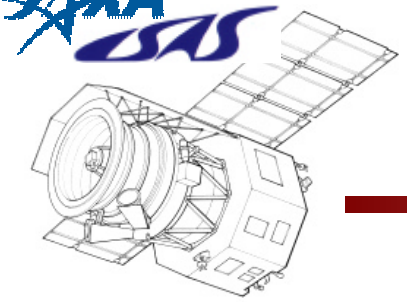
Photometric & Spectroscopic Capabilities



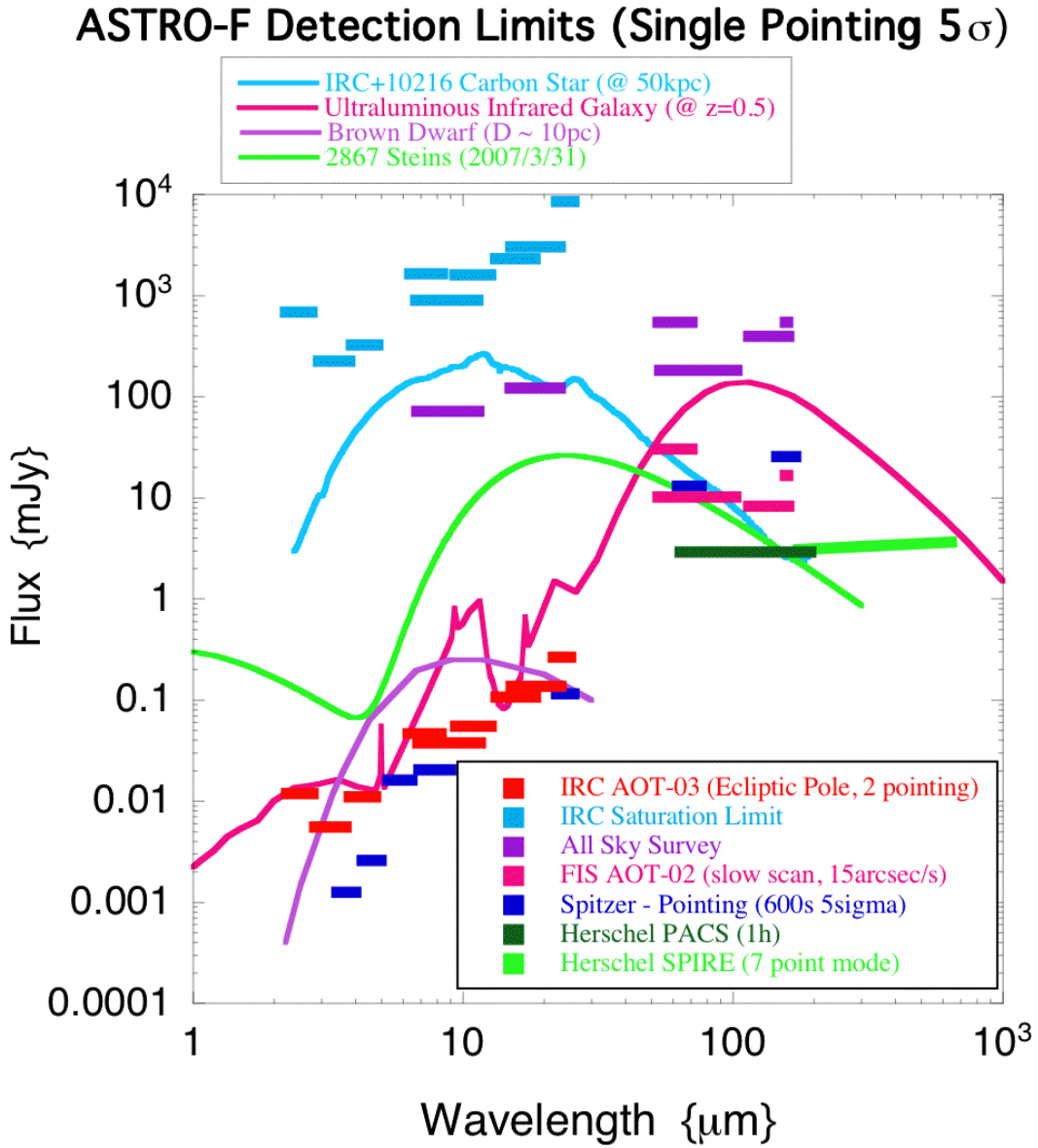


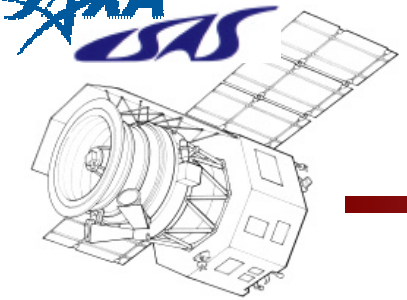
Field of View and Pixel Size





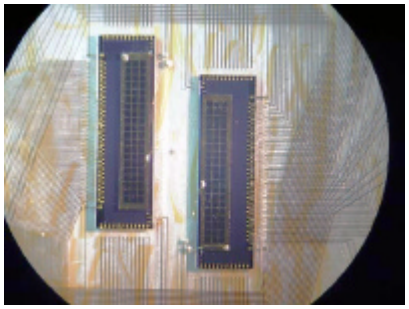
Detection Limits



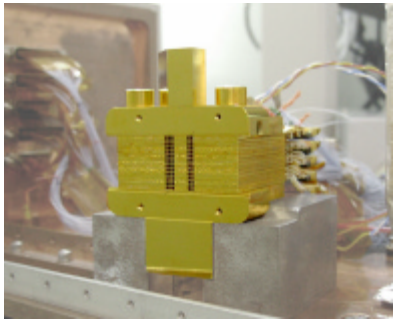


FIS: Far-Infrared Surveyor

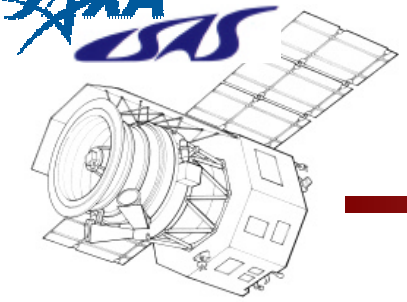
- Simultaneous observation in four FIR bands.
- Detectors:
  - Monolithic Ge:Ga array [SW: 50–110 μm, 20x(3+2) pix)]*
  - Stressed Ge:Ga array [LW: 110–180 μm , 15x(3+2) pix]
- Spatial resolution of 30–75 arcsec.



- Fourier Transform Spectrometer.
  - Martin-Puplet type polarised interferometer.
  - 0.36 cm^{-1} (R=450 @ 60μm, 170 @ 180 μm)

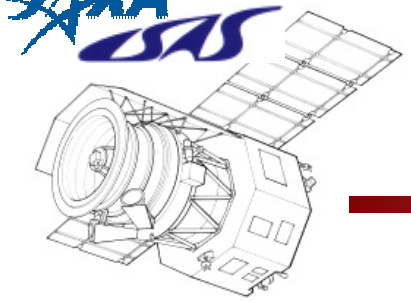


* Ge:Ga chips for the SW arrays are supplyed by NICT.



FIS Photometric Mode

Band	N60	WIDE-S	WIDE-L	N160	
Wavelength	50–75	50–110	110–180	140–180	[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 Detectors

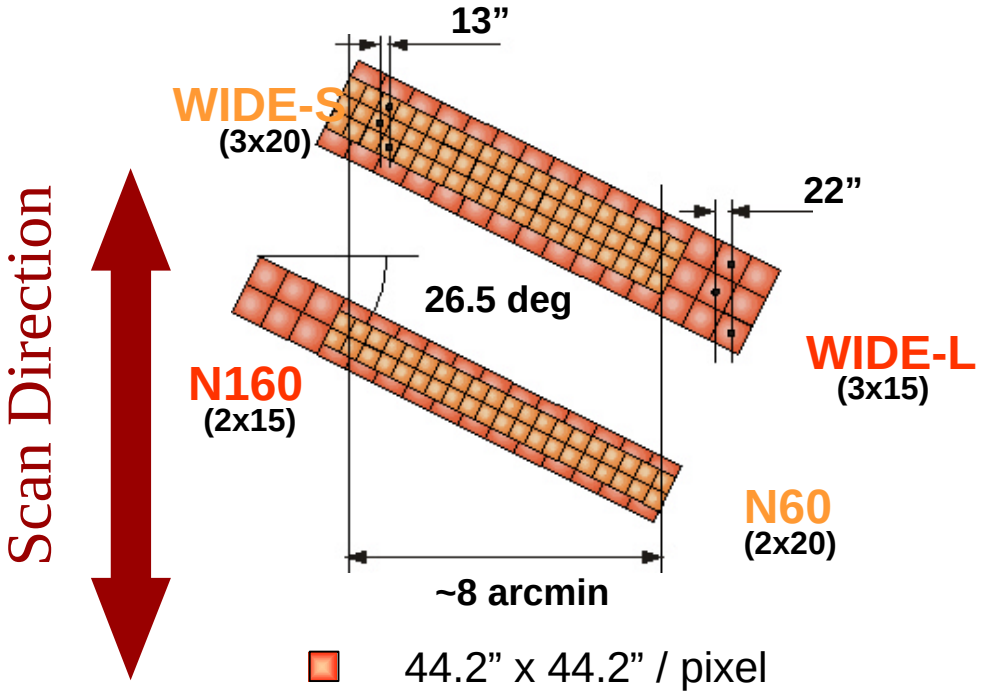
WIDE-S: 3x20

N60: 2x20

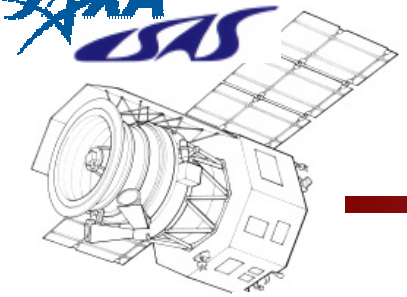
N160: 2x15

WIDE-L: 3x15

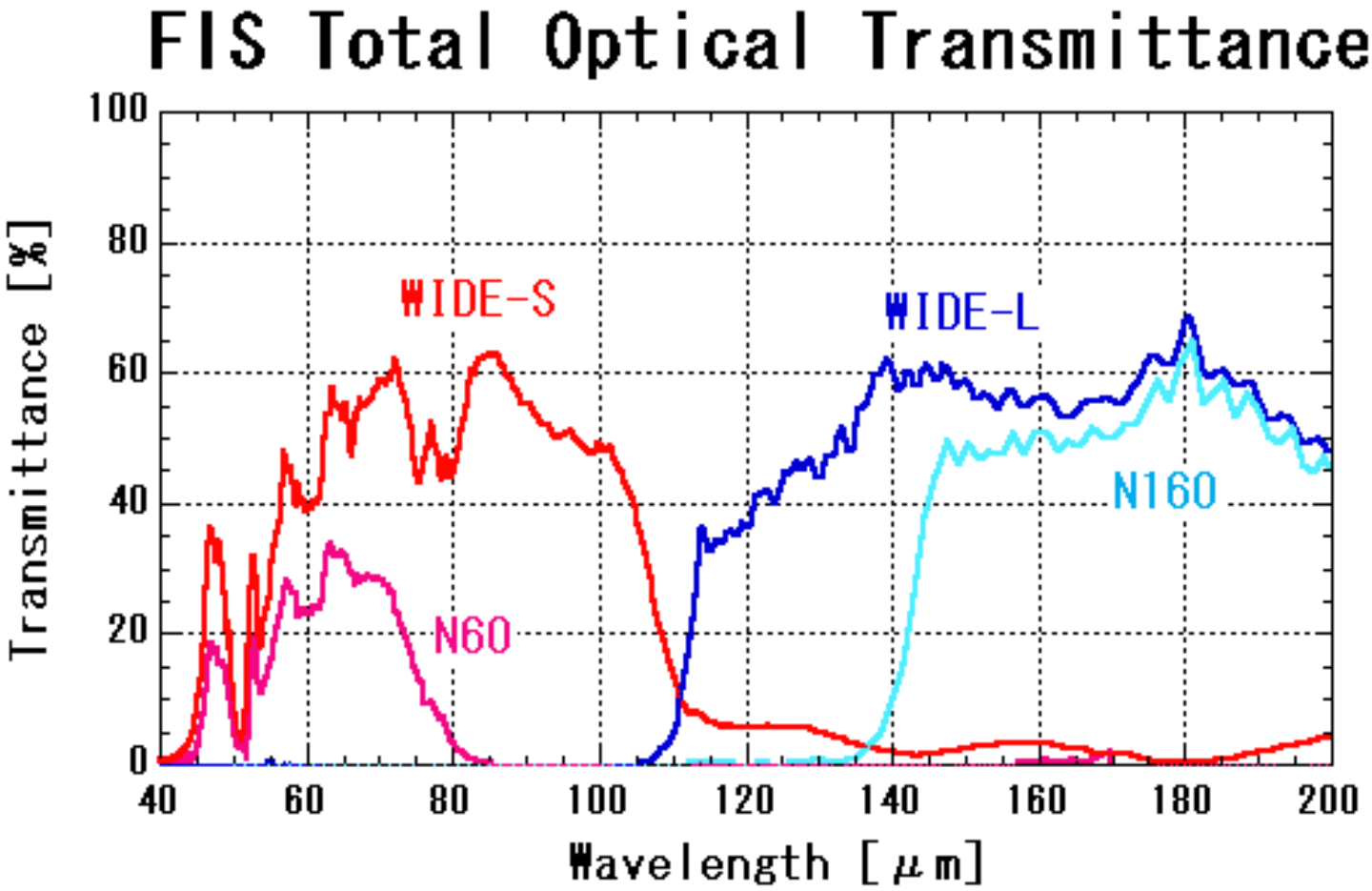
Overlap each other



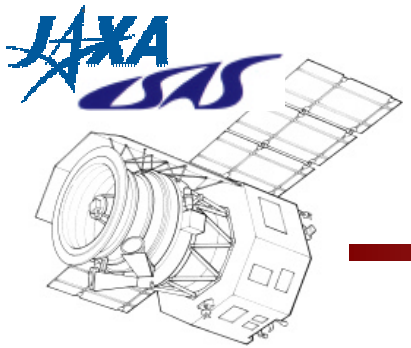
FOV of the FIS



FIS Optical Transmittance

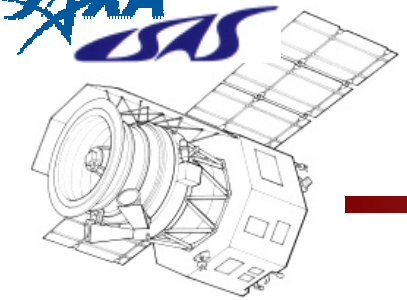


Detector responsivity has not been included.



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).
  - Consolidated data generated 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 processing after BSC.
  - Public release: expected ~ mid 2010.

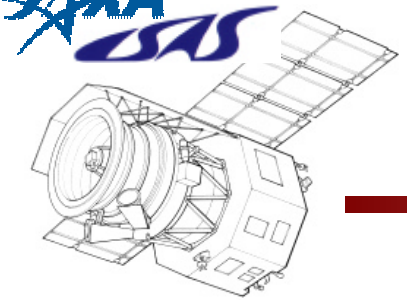


Release date: summary

Assuming the EOS = Mar. 2007

	Team Release		Public Release (Team release + 1 yr)
FIS/IRAS Catalogue	During the survey phase	Nov. 2005 – Mar. 2007	(Mar. 2008)
Bright Source Catalogue	EOS+ =1 yr	= Mar. 2008	= Mar. 2009
Faint Source Catalogue	BSC+ =1.5 yr	= Sep. 2009	= Sep. 2010

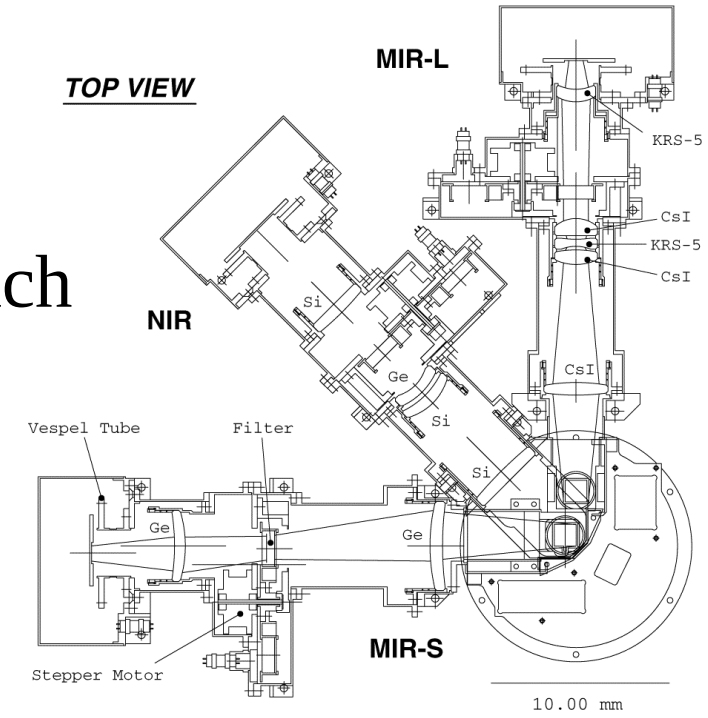
In the absence of unexpected problems, or if more manpower becomes available, the release date may be earlier.

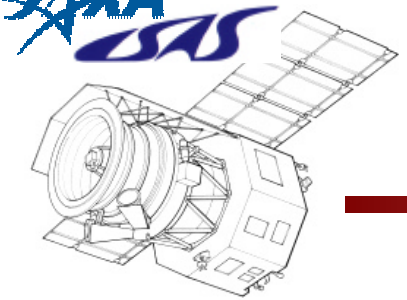


Infrared Camera (IRC)

- 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.



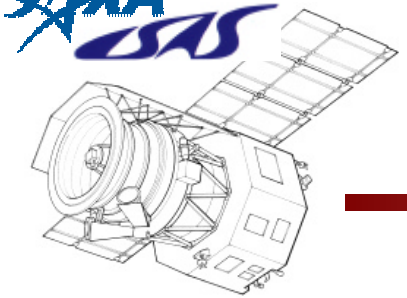


Infrared Camera (IRC)

- Overview

	Wavelength (μm)	Pixel Size (arcsec)	FoV (arcmin)	Detector
NIR	1.8–5.05	1.46	9.5 x 10	512x412 InSb
MIR-S	5.5–13	2.34	9.1 x 10	256x256 Si:As
MIR-L	12.5–26	2.51x2.39	10.3 x 10.2	256x256 Si:As

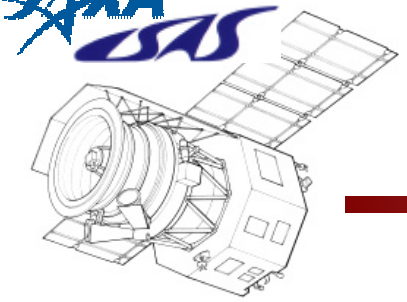
- NIR & MIR-S simultaneously observe the same FoV.
- NIR can be operated after liquid He boil-off (Phase 3)



IRC Filters for Imaging Mode

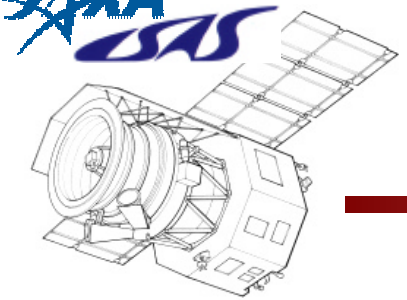
Camera	Filter Name	Wavelength (μm)	Centre (μm)	Width (μm)
NIR	N2	1.8–2.7	2.43	0.68
	N3	2.7–3.7	3.16	1.12
	N4	3.7–5.05	4.14	1.22
MIR-S	S7	5.5–8.5	7.19	2.76
	S9W	6.0–11.5	8.74	4.74
	S11	8.5–13.0	10.4	4.56
MIR-L	L15	12.5–18	15.6	6.00
	L20W	14.0–26(*)	17.8	8.86
	L24	22.0–26(*)	23.0	5.43

(*) determined by detector responsivity

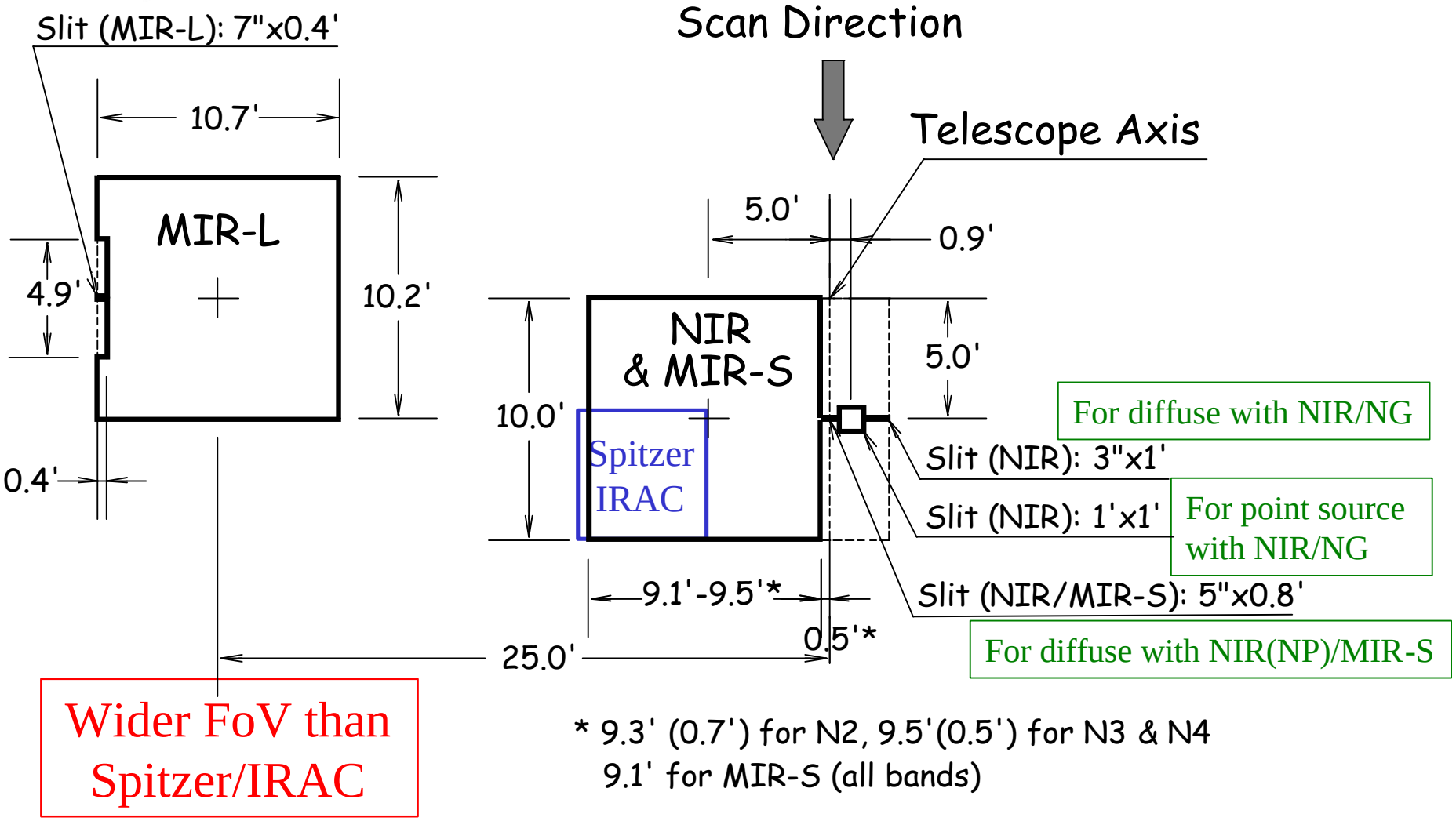


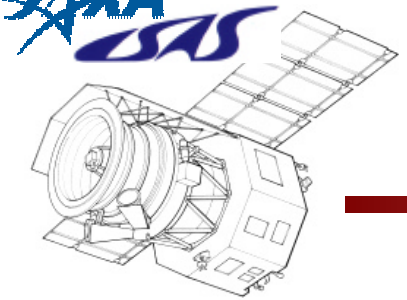
IRC Spectroscopic Mode

Camera	Name	λλ (μm)	λ/Δλ	
NIR	NP	1.9–5.0	22 @ 3.5 μm	prism
	NG	2.5–4.7	135 @ 3.6 μm	grism
MIR-S	SG1	5–8	47 @ 6.6 μm	grism
	SG2	7–12	34 @ 10.6 μm	grism
MIR-L	LG1	11–19	19 @ 14.4 μm	grism
	LG2	18–26	27 @ 20.2 μm	grism

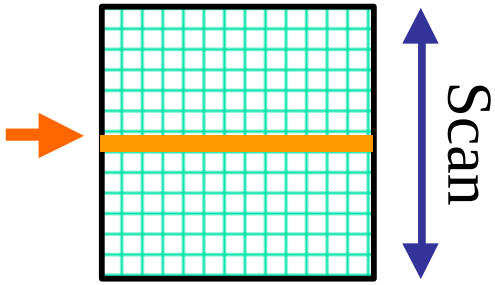


IRC Focal-Plane Layout





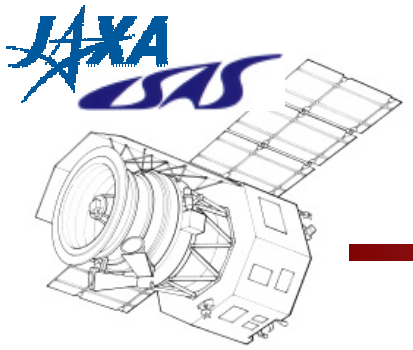
IRC Scan Survey



- Reading only one line of the array.
- Only by MIR-S/L cameras.
- Simultaneous operation with the FIS in All-Sky Survey
- Also available in the pointing mode.

Camera	Filter	Virtual pixel size (4x4 pixel)*	Sensitivity (5σ, mJy)
MIR-S	S9W	9.4x9.4 arcsec^2	80
MIR-L	L20W	10.0x9.4 arcsec^2	130

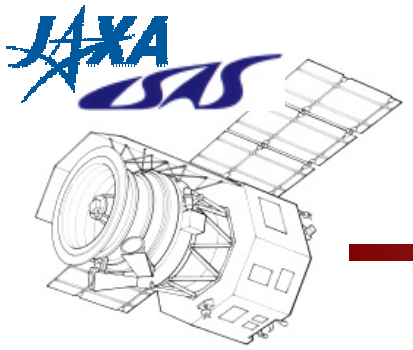
*Nominal plan. Depending on available data rate.



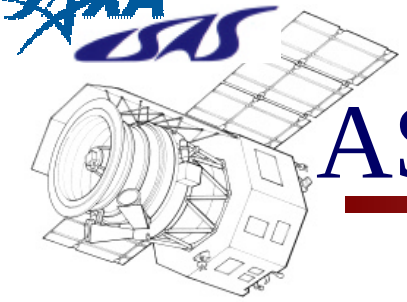
ASTRO-F Observation Modes

- All-Sky Survey
  - Continuous scanning of the sky as the satellite orbits around the Earth

- Pointing Observation
  - Staring observation of a sky region.
  - 10 minutes observation time per pointing observation at a cost of 30 minutes operation including maneuver.
  - Fine position change during a pointing observation.
    - Micro-scan: 15 x 30 arcsec stepwise shift. Needs 30 ~ 40 sec for stabilization.
    - Step-scan: 3~7 arcmin stepwise shift. Needs ~60 sec for stabilization.
    - Slow-scan: continuous scan with a speed of 1 x 15 arcsec/sec. It costs 30~40 sec for acceleration.



Observation with ASTRO-F



ASTRO-F Observation Programmes

Large Area Surveys

All-sky survey (survey mode)
NEP survey (pointing mode)
LMC survey (pointing mode)

Mission Programs (pointing mode)

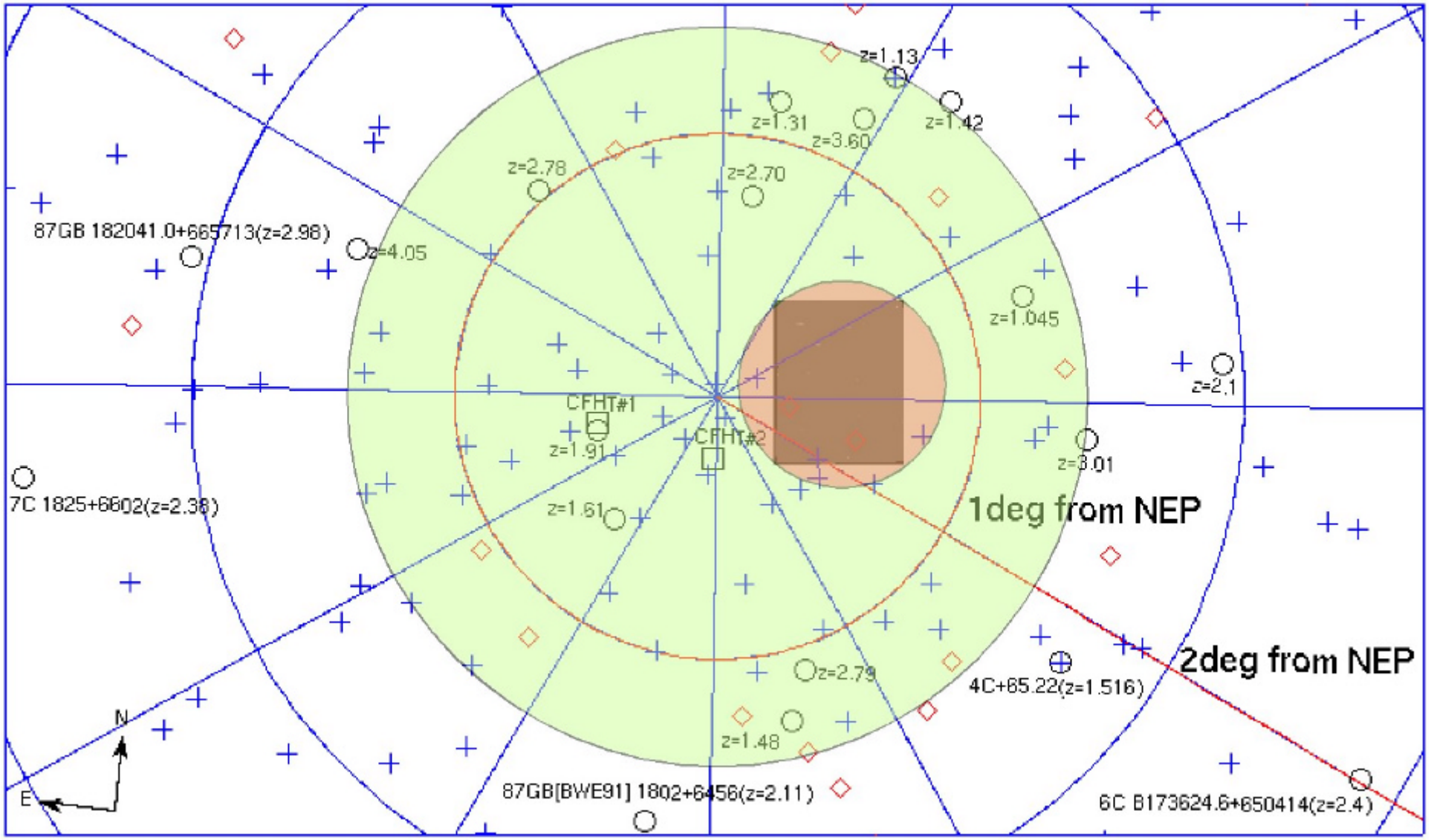
~ guaranteed time observations
Under consideration in several working groups for different astronomical fields
[Data will be public after one year prioritised use by the team members]

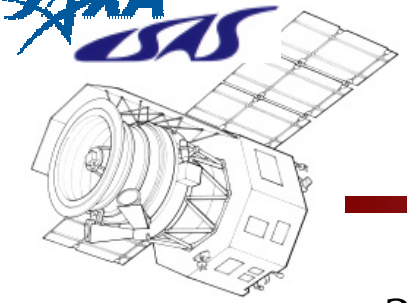
Open Time Programs

30% of pointing observations of Phase 2 & 3
Japan+Korea 20%; ESA 10%

NEP survey

DEEP (0.5deg^2) & WIDE (6.2deg^2): IRC 9 bands

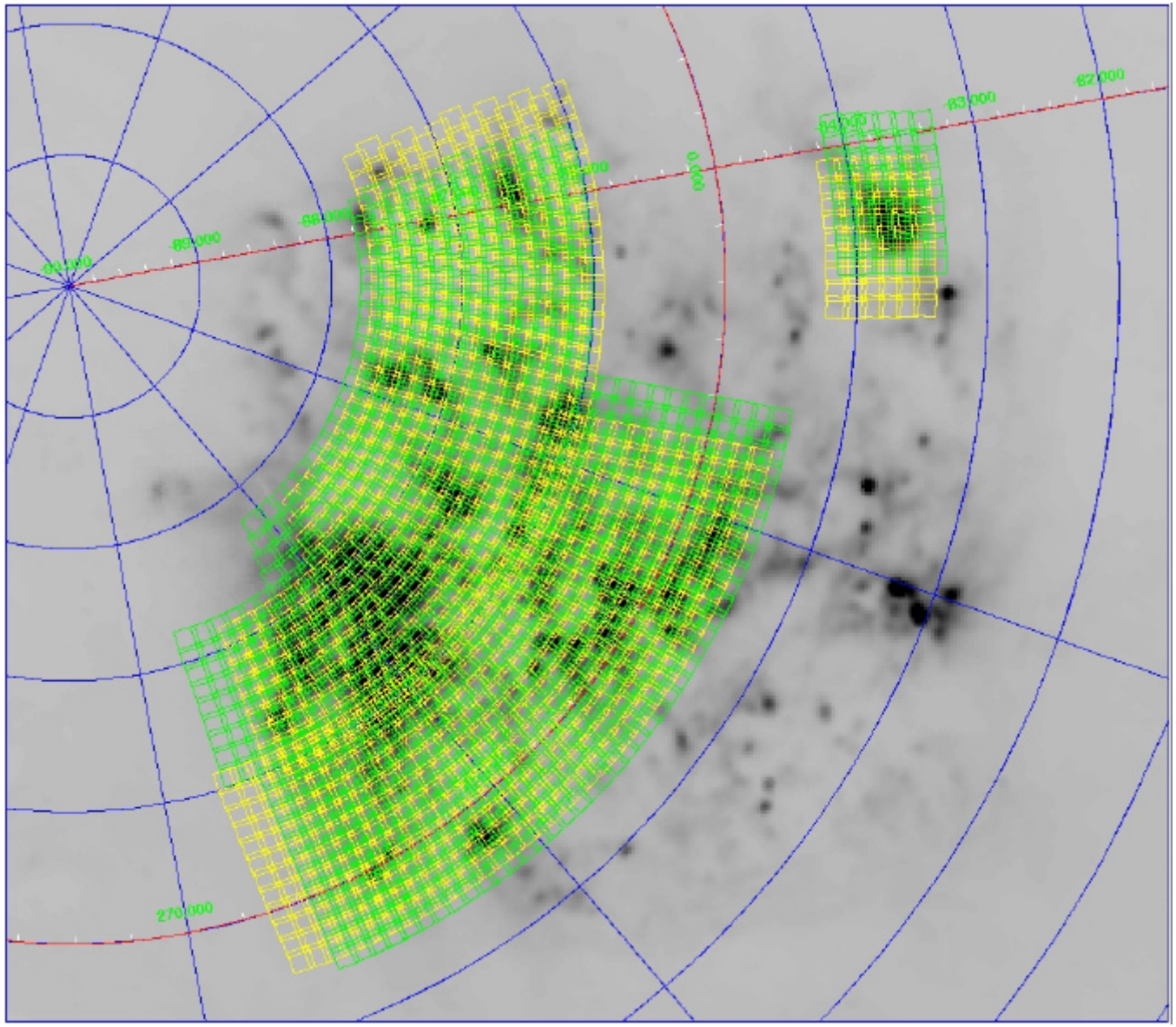


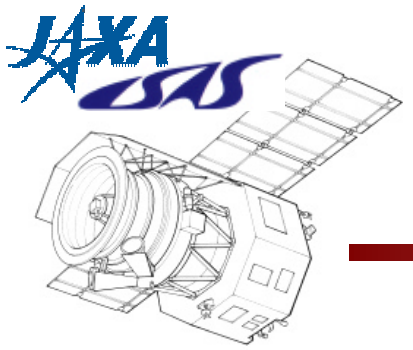


LMC survey

20 deg^2

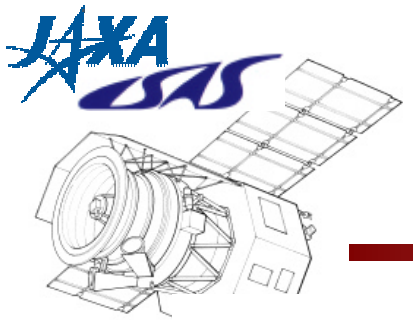
IRC 6 bands



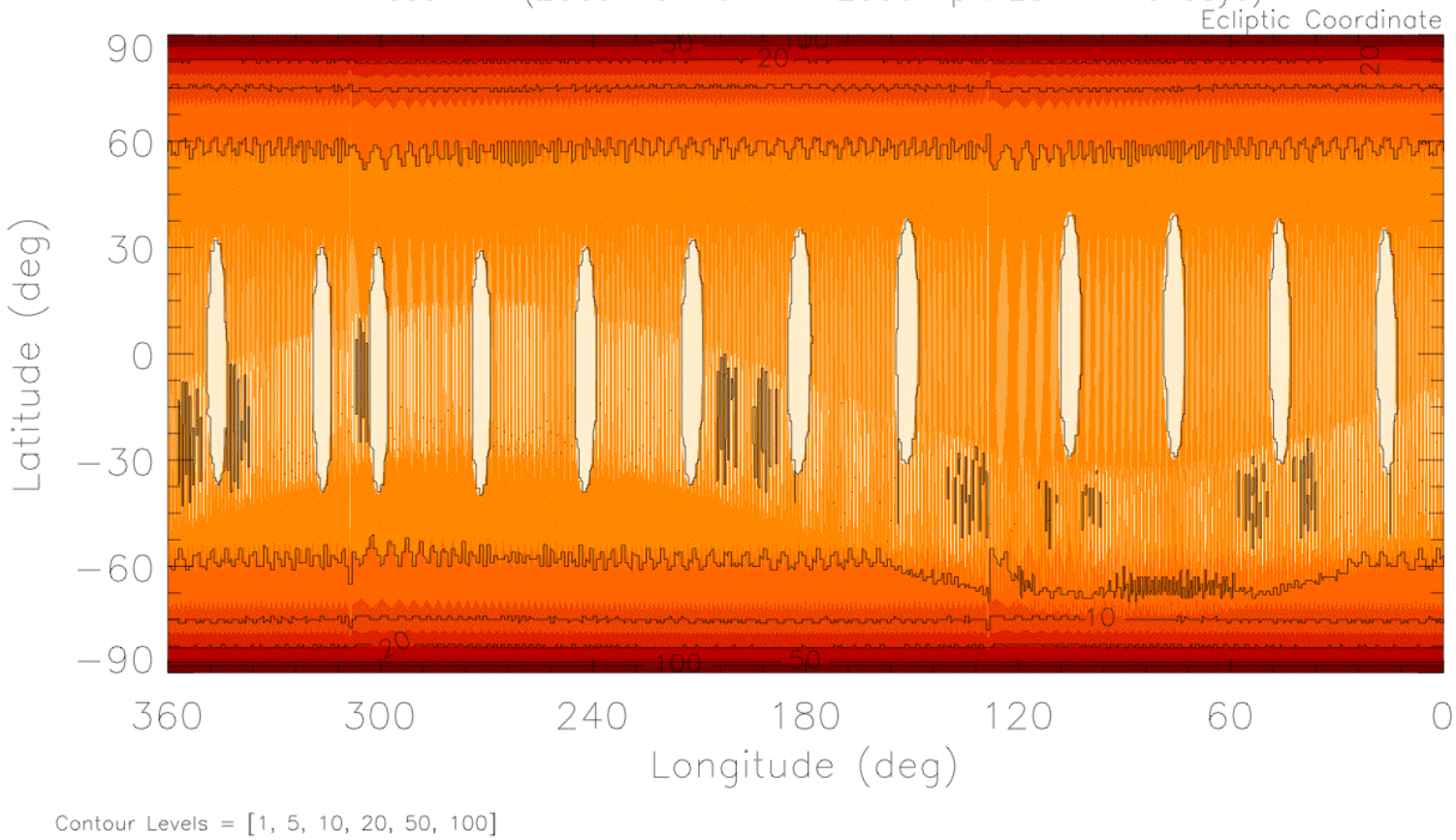


Open Time Observation

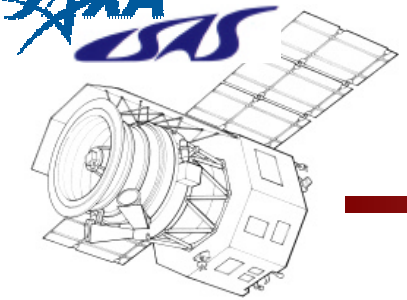
- Only in Pointing Observation Mode
  - Observation time is limited to 10 minutes per observation.
  - Stringent constraints on target visibility.



Visibility Map (Ecliptic)

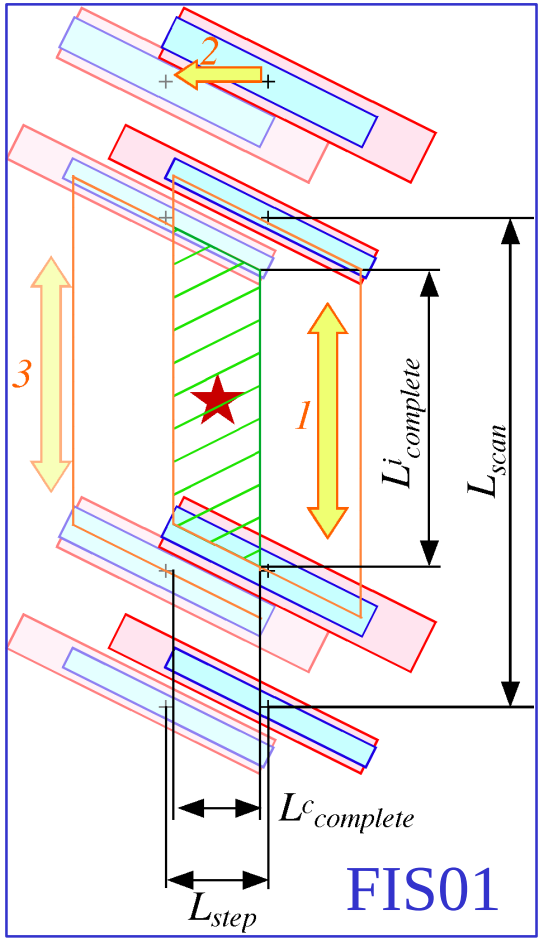


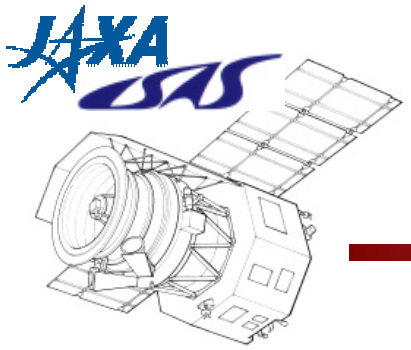
More visibility in the high ecliptic latitude region.....



FIS AOT (Preliminary for MP)

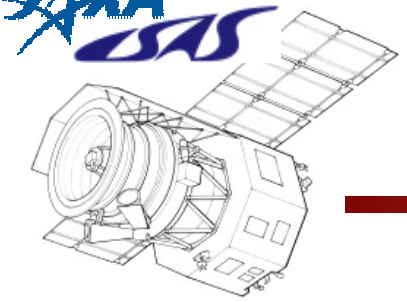
- FIS01: Photometry/Mapping of small area
  - Two round-trip Slow-scan observation with a cross-scan step.
  - 10~20 x 7 arcmin^2 per obs.
- FIS02: Mapping of wide area.
  - One round-trip Slow-scan.
  - 1 deg x 8 arcmin per obs.
  - Repeating observations in successive orbits to extend the scan area / obtain redundancy.
- FIS03: FTS spectroscopy
  - Staring integration at a target position.
  - It is not yet decided whether this mode will be opened to OT observers.





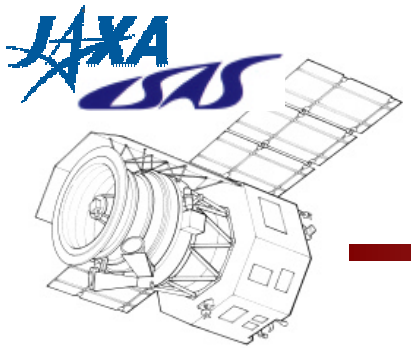
Notes on the FIS observations

- The FIS uses Ge:Ga detectors which have very complicated characteristics.
  - Transient effects, responsivity variation due to charged particle, etc.
  - Any single detector is different from the others.
  - No established data reduction methods.
  - Data reduction, especially for making images, needs very careful treatment of the data as well as patience.
  - Close contact to instrument / data reduction team via user support is encouraged.
- FTS mode has very low detection limits.
  - Also data reduction will be very difficult.
  - It is under discussion whether this mode will be opend for OT users.



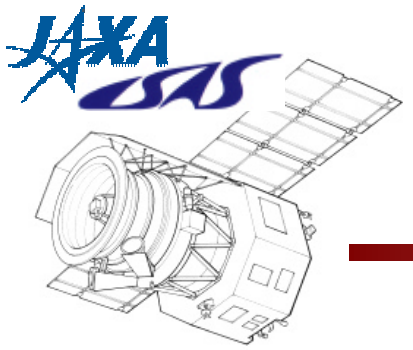
IRC AOT (Preliminary for MP)

- IRC00: Only for deep survey
  - One filter, no dithering during a pointing
    - At least 6 repeated observations are needed to have “useable” data.
    - Not yet decided whether this mode will be opened for OT.
- IRC02: General purpose (1)
  - Two filters (fixed), three dithered position in one pointing.
  - A complete data set using one pointing.
- IRC03: General purpose (2)
  - Three filters, two dithered position in one pointing.
  - At least 2 repeated observations are needed to have enough redundancy.



IRC AOT (Preliminary for MP)

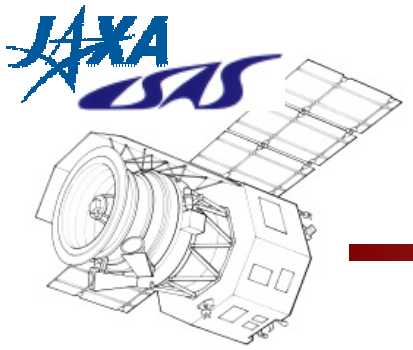
- IRC04: Spectroscopic observation
  - Choose either NP or NG for NIR camera.
  - Other two MIR cameras use the both elements.
  - No dithering. i.e. at least two observations are needed for redundancy.
- IRC11: Slow-scan observation
  - Shallow and wide area survey by Slow-scan.
  - All details are not yet defined.



Notes on the IRC Observation

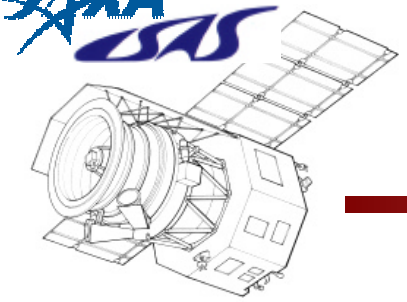
- FoVs of the NIR/MIR-S and MIR-L are different.

  ➔ Two pointings are needed to observe a sky position by all three cameras.



Observations in Open Time

- Duplicated observations with MS or LS are not allowed.
- Observations should make the best of ASTRO-F functions
  - Consider AOTs (Astronomical Observation Templates)
- Certain size proposals observing many targets are appreciated (observation of a particular target is not guaranteed due to visibility constraint).
- Data will be released to public after one year prioritised period (Same as LS and MP).

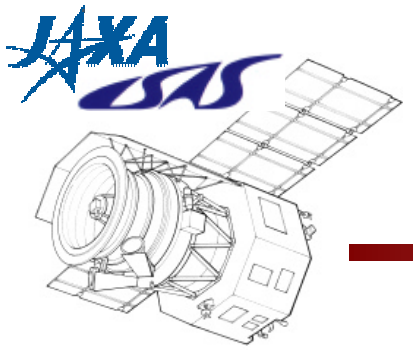


Schedule

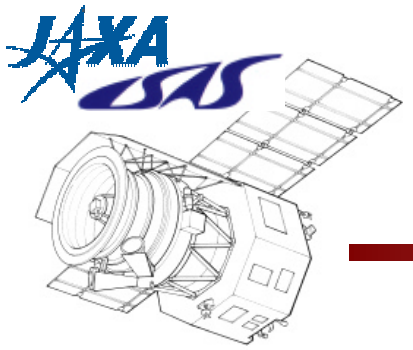
2005	April	17th	MP due
	July		MP fixed
	September	1st	Call for Open Time
	November	?	Proposal due
			screening
2006	January		Open Time fixed

Operation plan in Phase 1 & 2 fixed
[Further tuning after PV (Performance Verification)]

Phase 3 Open Time Call after Phase 2 start



Data reduction and User support

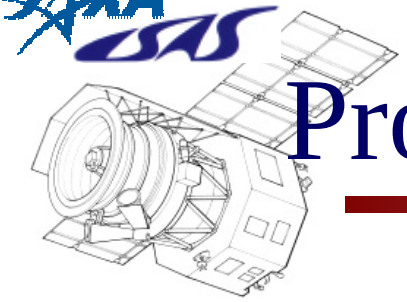


ASTRO-F Data Reduction

Policy

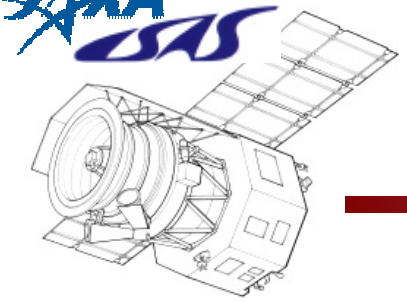
- Large Area Surveys:
  - Project is responsible for the data reduction.
  - Uniform observations (fix the observing parameters).
  - Uniform processing and unique products.

- Other Pointing Observations:
  - Observer's responsibility.
  - The instrument teams provide necessary information.



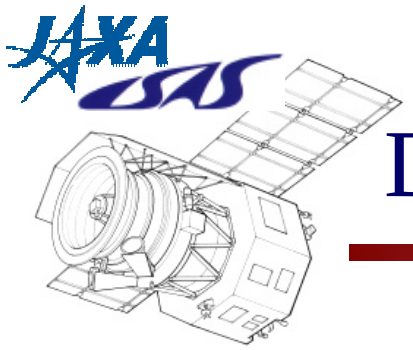
Products of the ASTRO-F Survey

- Point Source Catalogues
- Images (tbd)
- Processed Raw Data



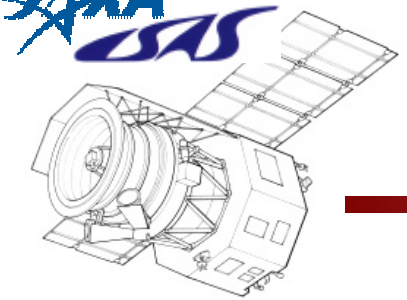
Point Sources Catalogues

- ASTRO-F/FIS Flux of known sources
  - Flux consistency check with the IRAS PSC + additional FIR flux data.
  - Incremental release during the survey period.
  - Team release: incrementally during the survey period (Phase 1 & 2).
- The Bright Source Catalogue (BSC).
  - Uniform source extraction (Same detection limit for any area in the sky).
  - Consolidated data generated after the end of survey.
  - Team release: = 1 year after the End of Survey.
- The Faint Source Catalogue.
  - The supplemental catalogue of the fainter sources in the region with higher redundancy.
  - Additional process after BSC.
  - Team release: = 1.5 year after the Bright Source Catalogue.



Data reduction of pointing observation

- Preparation of the data reduction support for pointing observations has started rather recently.
- The software system will be constructed before launch and improved in Phase 1 with the LS and (part of) MP data.
- Contributions from users are appreciated.

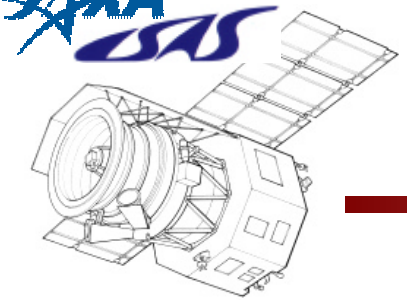


FIS data reduction support plan

(Preliminary)

- Observers will receive:
  - Raw and Basic Processed Data
  - A sample image map (no scientific quality)

- Observers have to do:
  - Correction of various detector characteristics
    - ➔ High skill and experience may be needed.
  - Making image maps, photometry.
  - Some dedicated software (in IDL) will be provided.
  - Close communication with the instrument team / data reduction specialist is desired.

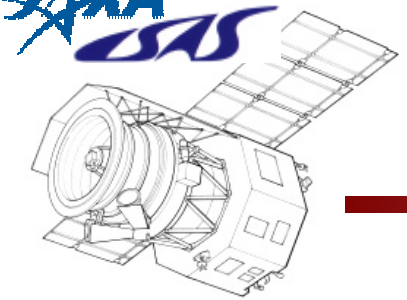


IRC data reduction support plan

(Preliminary)

- Observers will receive:
  - Raw and/or Basic Processed Data
  - Dark and flat correction will be applied by the project team or information will be provided.

- Observers have to do:
  - Deglitching, mosaicing, photometry
  - Most of the processing can be done with commonly used software packages.
  - Dedicated tools for the spectroscopic data may be provided.

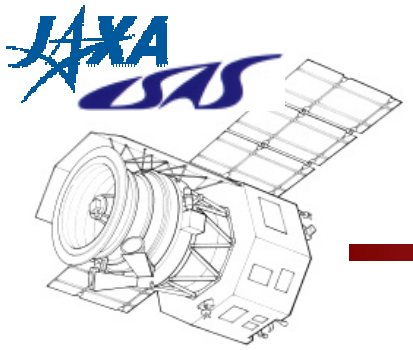


User support

- ASTRO-F European User Support Web:
  - *http://www.astro-f.vilspa.esa.int/*
- *ASTRO-F Web at ISAS/JAXA*
  - *http://www.ir.isas.jaxa.jp/ASTRO-F/*

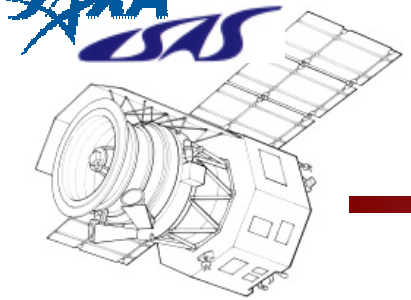
- ASTRO-F Helpdesk for European User Support:
  - *astro-f@sciops.esa.int*

- ASTRO-F Newsletters
  - Newsletter abut ASTRO-F Project (by ISAS/JAXA)
    - *http://www.ir.isas.jaxa.jp/ASTRO-F/Observation/Newsletter/*



More about ASTRO-F

- ASTRO-F Observer's Manual
  - Version 2.0 (for Mission Programmes Observers) was released on 4 April 2005.
  - Version 3.0 (for Open Time Observersion) will be released by the time of the Call for Proposal (September).



Tools

- Visibility tool
  - http://www.ir.isas.jaxa.jp/ASTRO-F/Observation/vis/

- iris_sky
  - Plots ASTRO-F FoV on IRAS images
  - Written in IDL