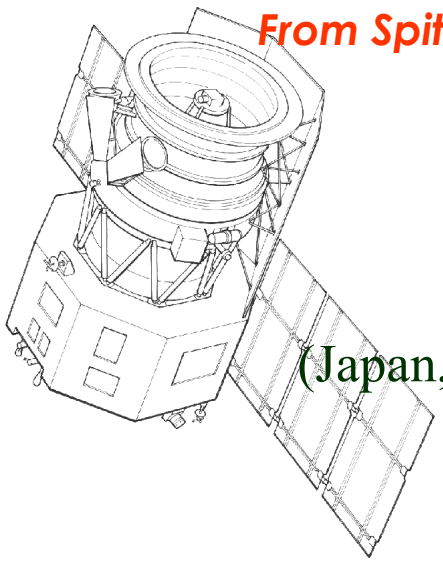
Large-Area Infrared Survey with ASTRO-F



From Spitzer to Herschel and Beyond" the future of far-infrared space astrophysics (Pasadena, June 7-10, 2004)

Hideo Matsuhara

&

ASTRO-F team

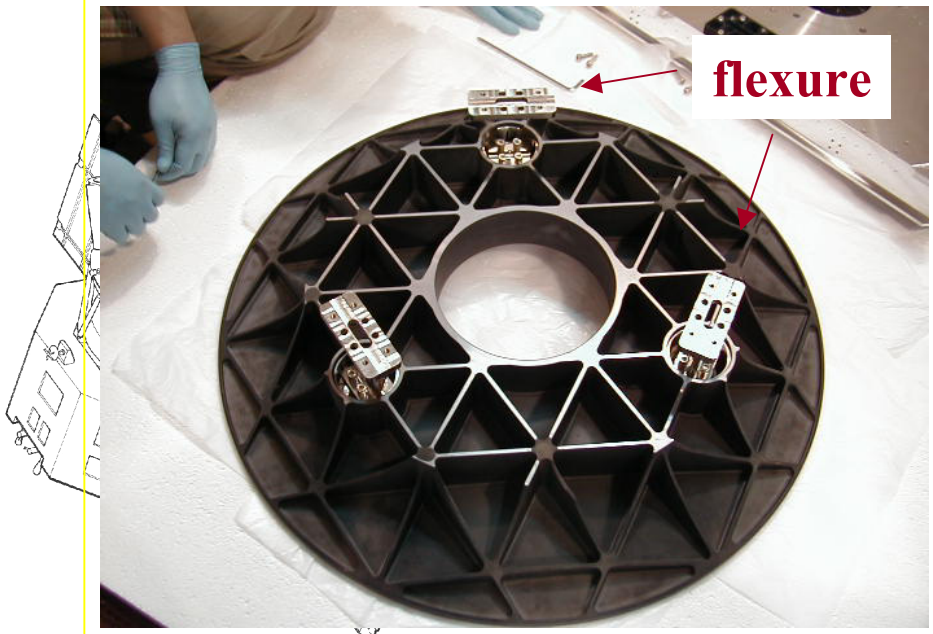
(Japan, South Korea, ESA countries (UK, Netherlands))

ASTRO-F Mission

- Dedicated for Infrared Survey with 68.5cm cooled telescope
- Far-Infrared All Sky Survey.
  - 50-200 microns, 4 band
  - Simultaneous Mid-IR (10&20 microns) data
- Pointing observations of selected sky area.
  - 10 minutes each,
  - ~8000 pointing total
- Launch in 2005 August (not yet fixed)

Telescope

- 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**



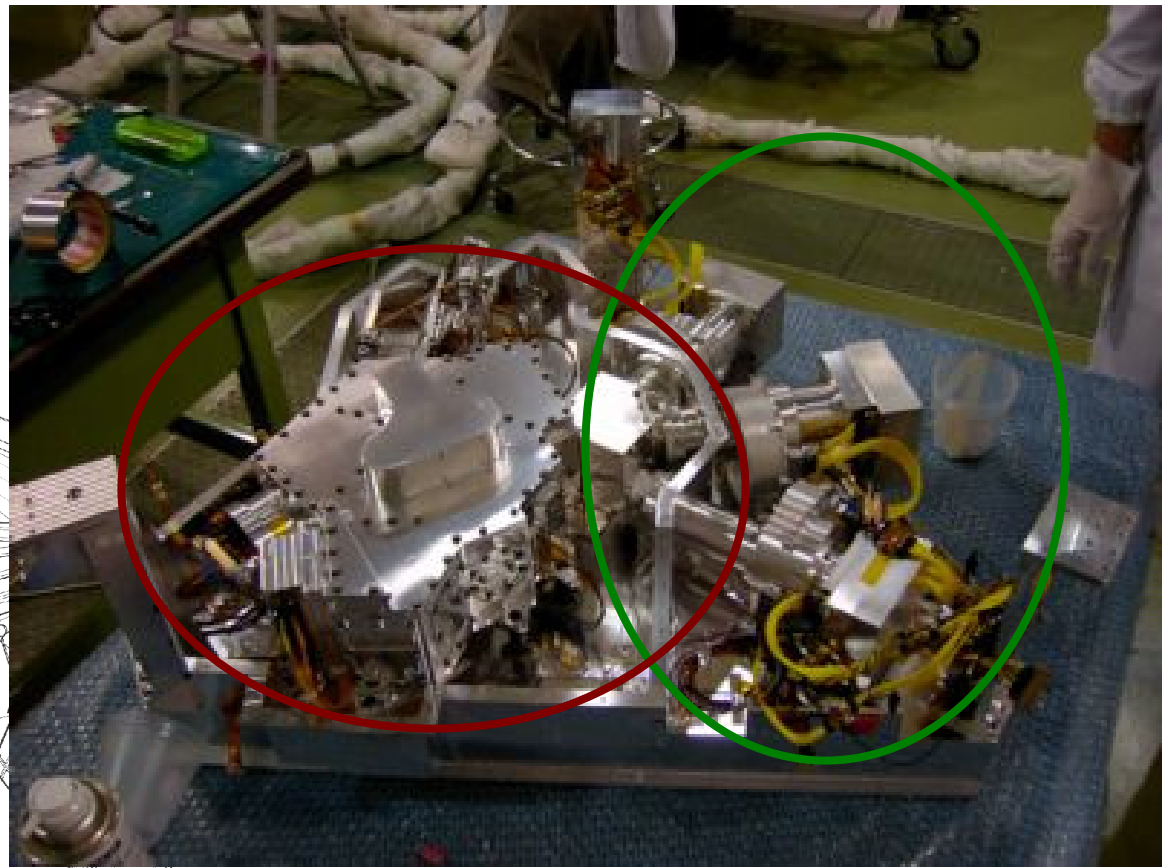
Rear surface of primary mirror

FM telescope in vibration test

Focal Plane Instruments

(Infrared Camera)

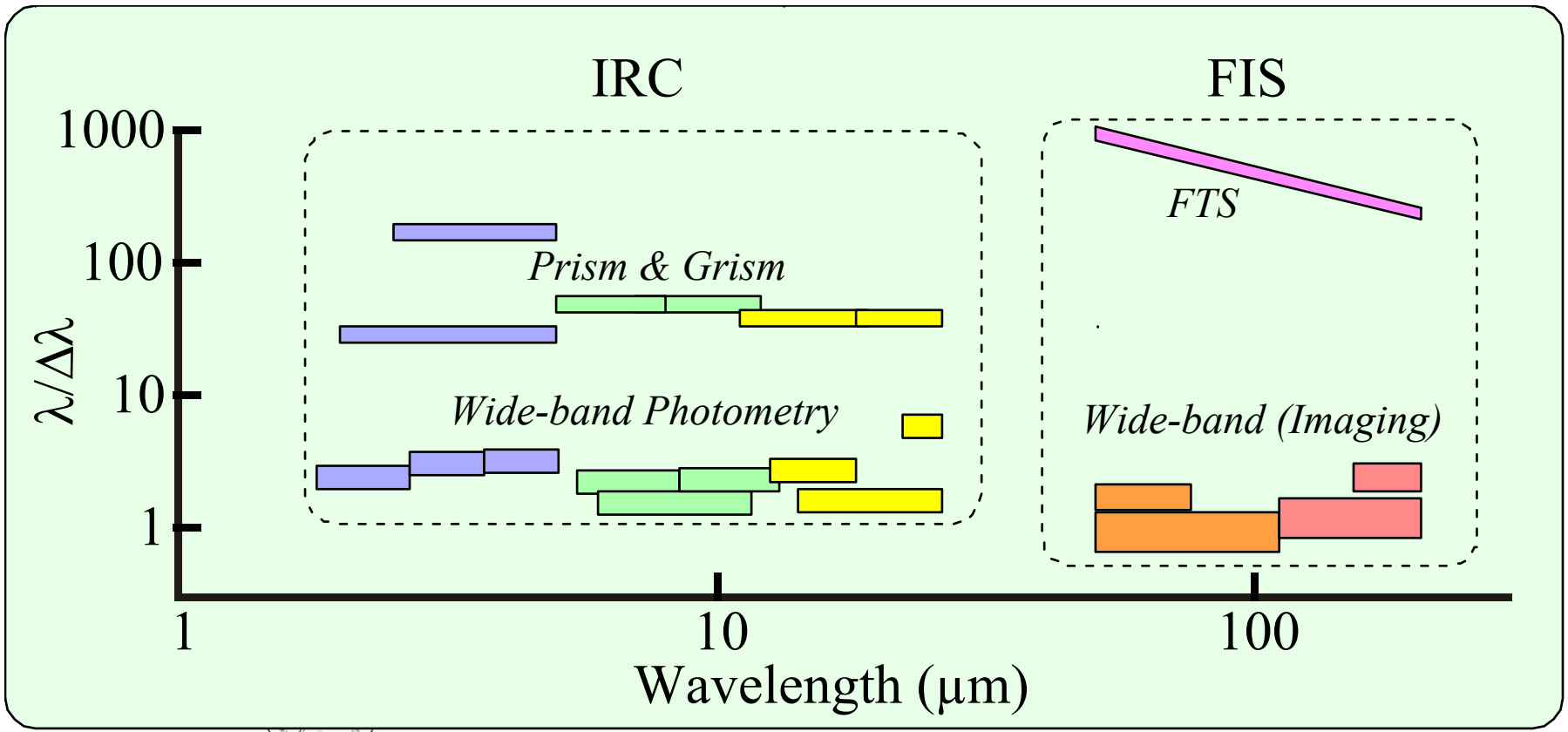
IRC



FIS

(Far-Infrared Surveyor)

Photometric & Spectroscopic Capability



FIS Detectors & FOV

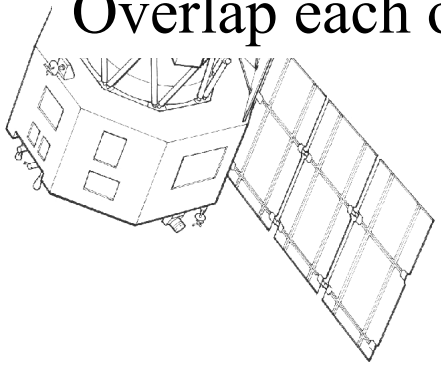
WIDE-S: 3x20

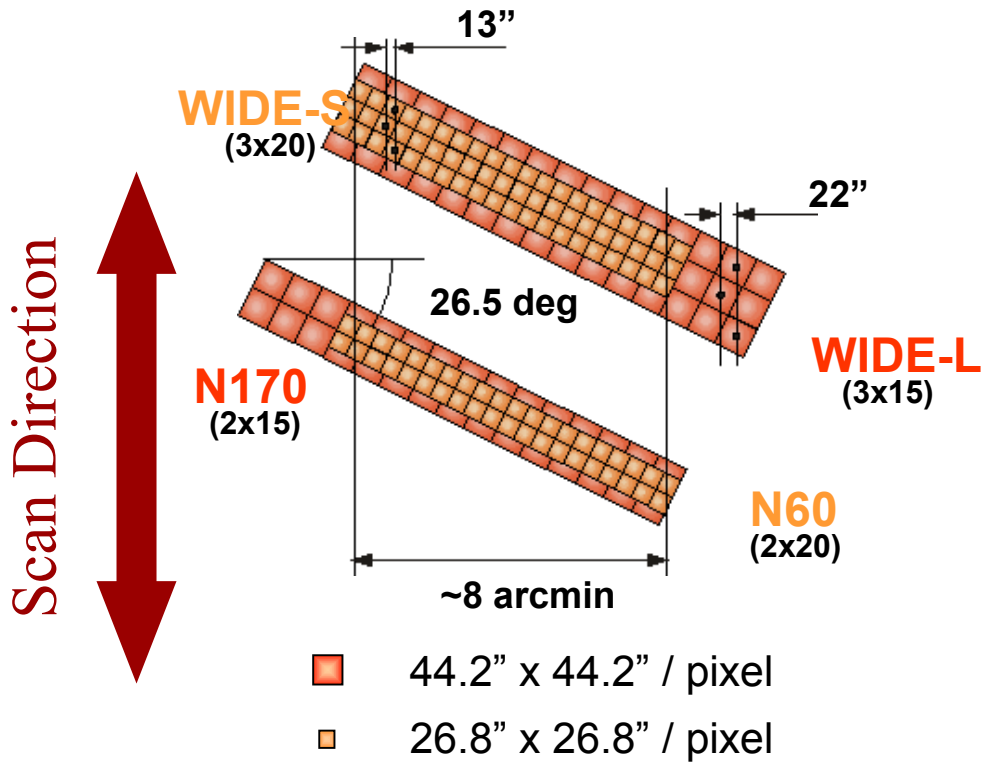
N60: 2x20

N170: 2x15

WIDE-L: 3x15

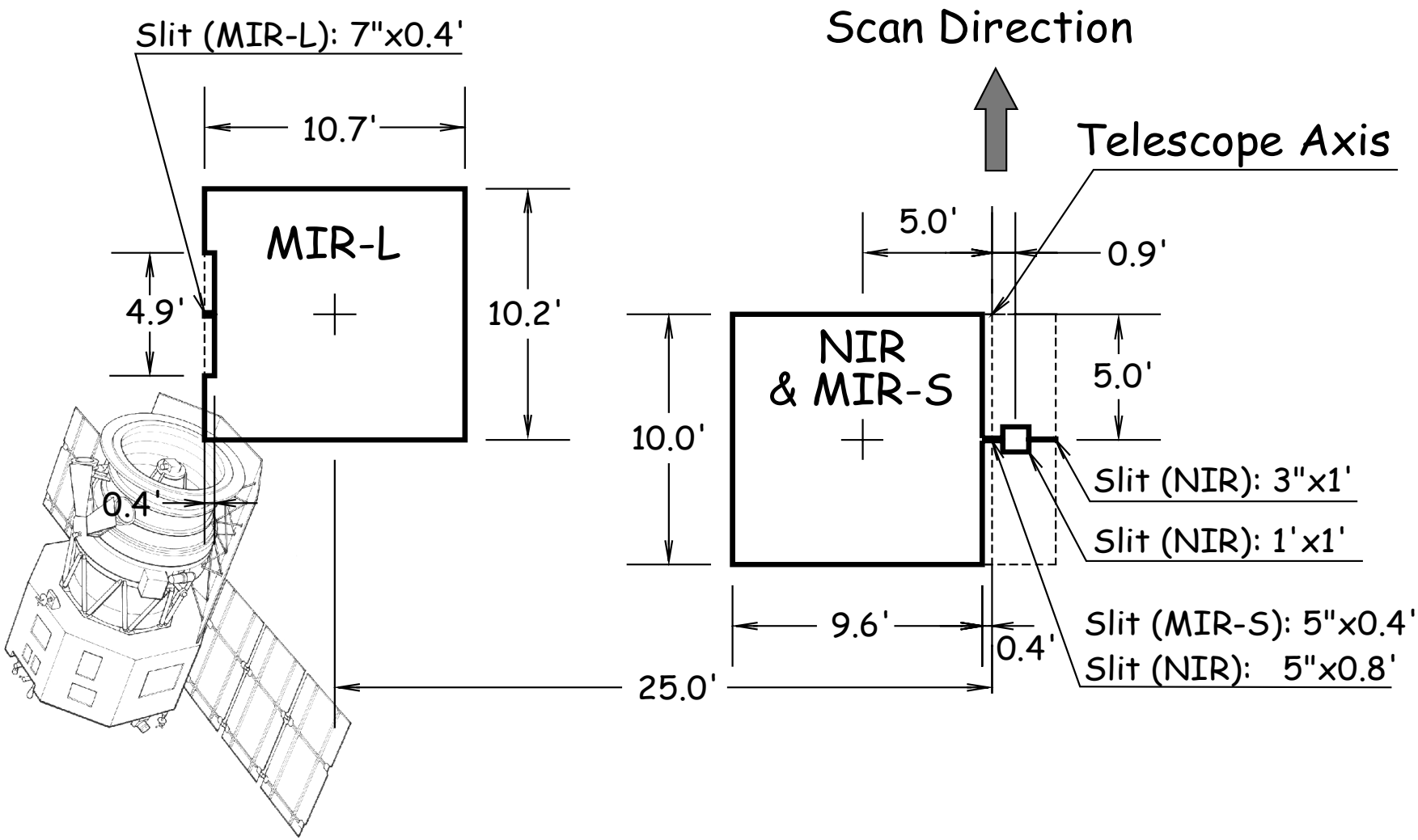
Overlap each other





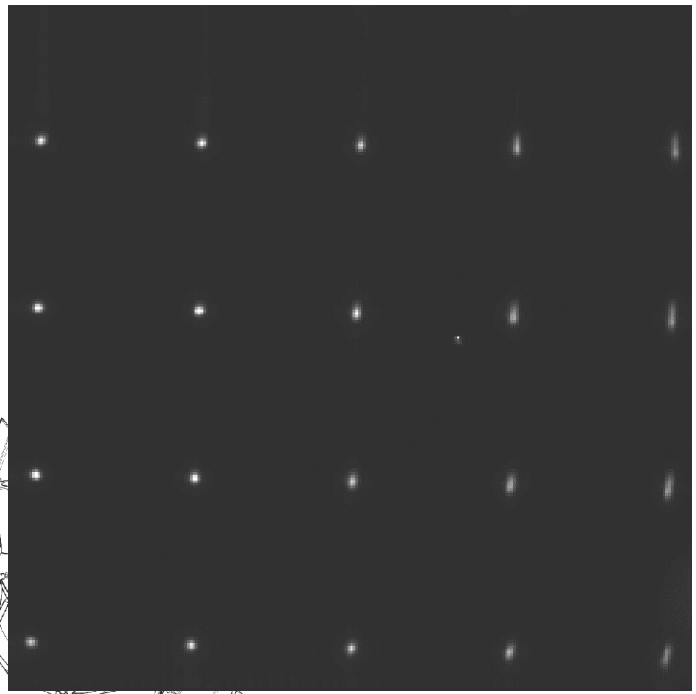
FOV of the FIS

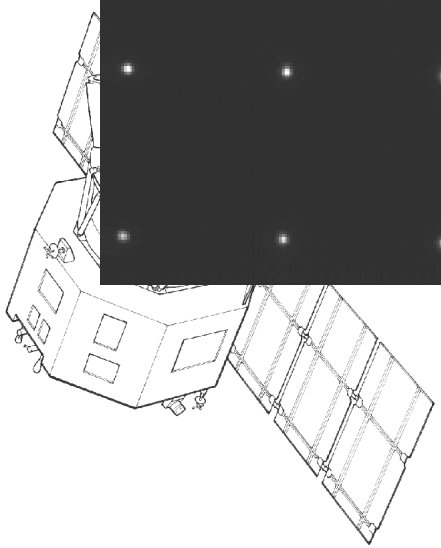
IRC FOV


Slit (MIR-L): 7"x0.4'
10.7'
MIR-L
4.9'
10.2'
0.4'
Scan Direction
Telescope Axis
5.0'
0.9'
NIR
& MIR-S
10.0'
5.0'
Slit (NIR): 3"x1'
Slit (NIR): 1'x1'
9.6'
0.4'
Slit (MIR-S): 5"x0.4'
Slit (NIR): 5"x0.8'
25.0'

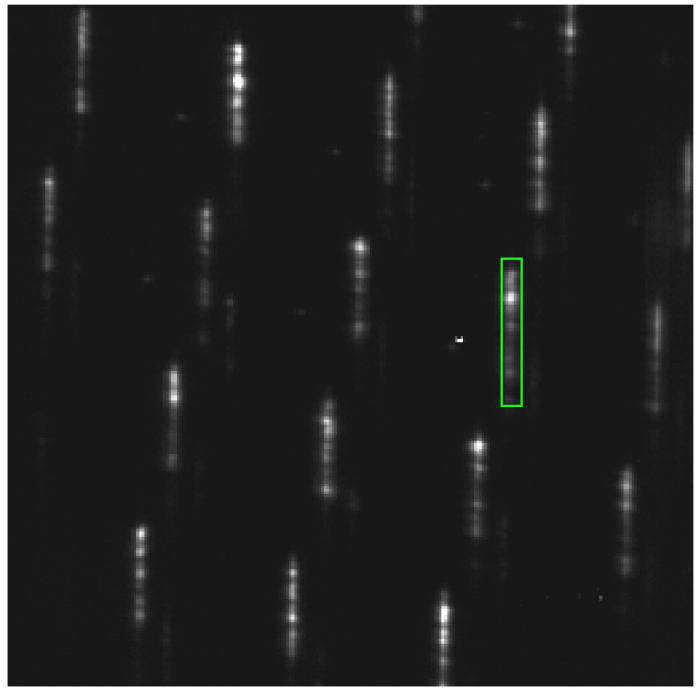
IRC-MIR-L

L15 (imaging)

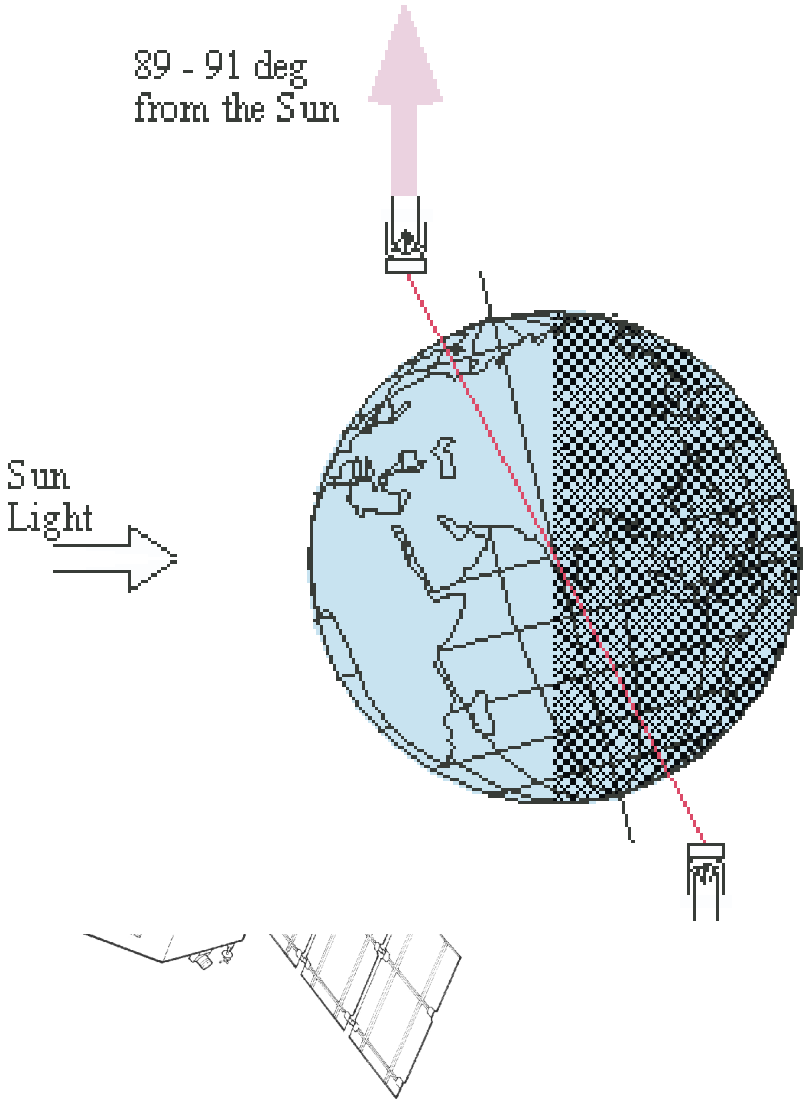




LG2 (18-26 micron grism)



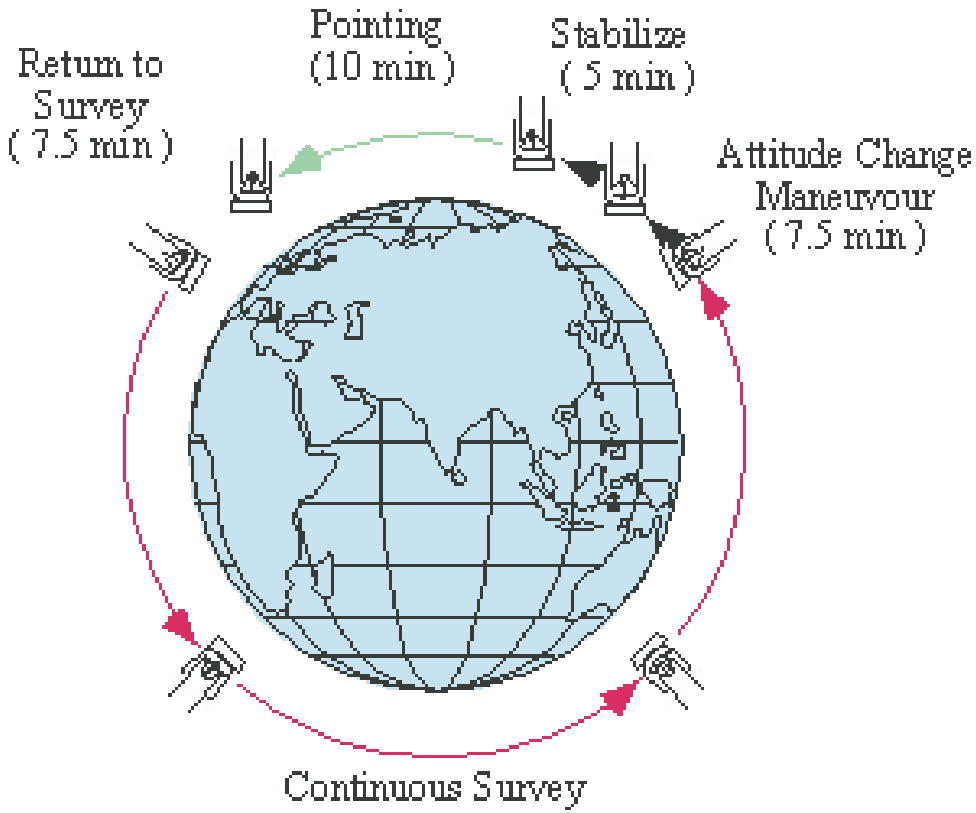
Observing mode of ASTRO-F

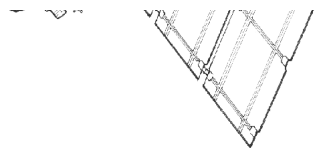


- Orbit : Sun-synchronous polar
- Survey mode
  - Telescope beam uniformly scans along the circle perpendicular to the Sun, in 100 minutes per orbit
  - Nearly all-sky will be covered in a half year

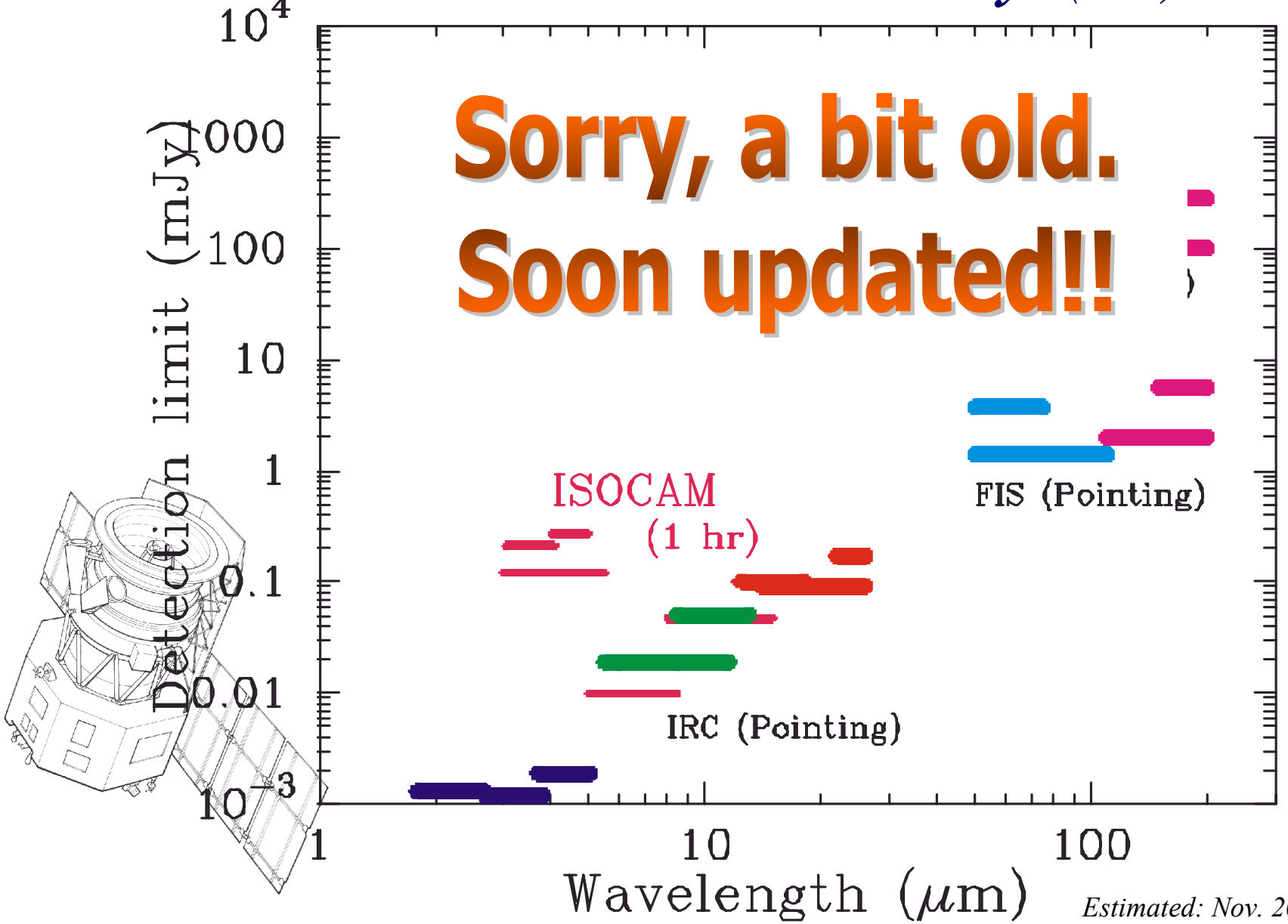
Observing mode of ASTRO-F(2)

- Pointing mode
  - 10 minutes per pointing
  - 2-3 pointing per orbit
  - "Fixed" pointing
    - 2-26 micron imaging/spectroscopy with IRC
    - FTS spectroscopy in Far IR
  - Slow-scan survey
    - 2 – 10 (or 20?) arcsec/sec
    - 5-26 micron and Far IR





Point Source Sensitivity (5σ)



Estimated: Nov. 2002

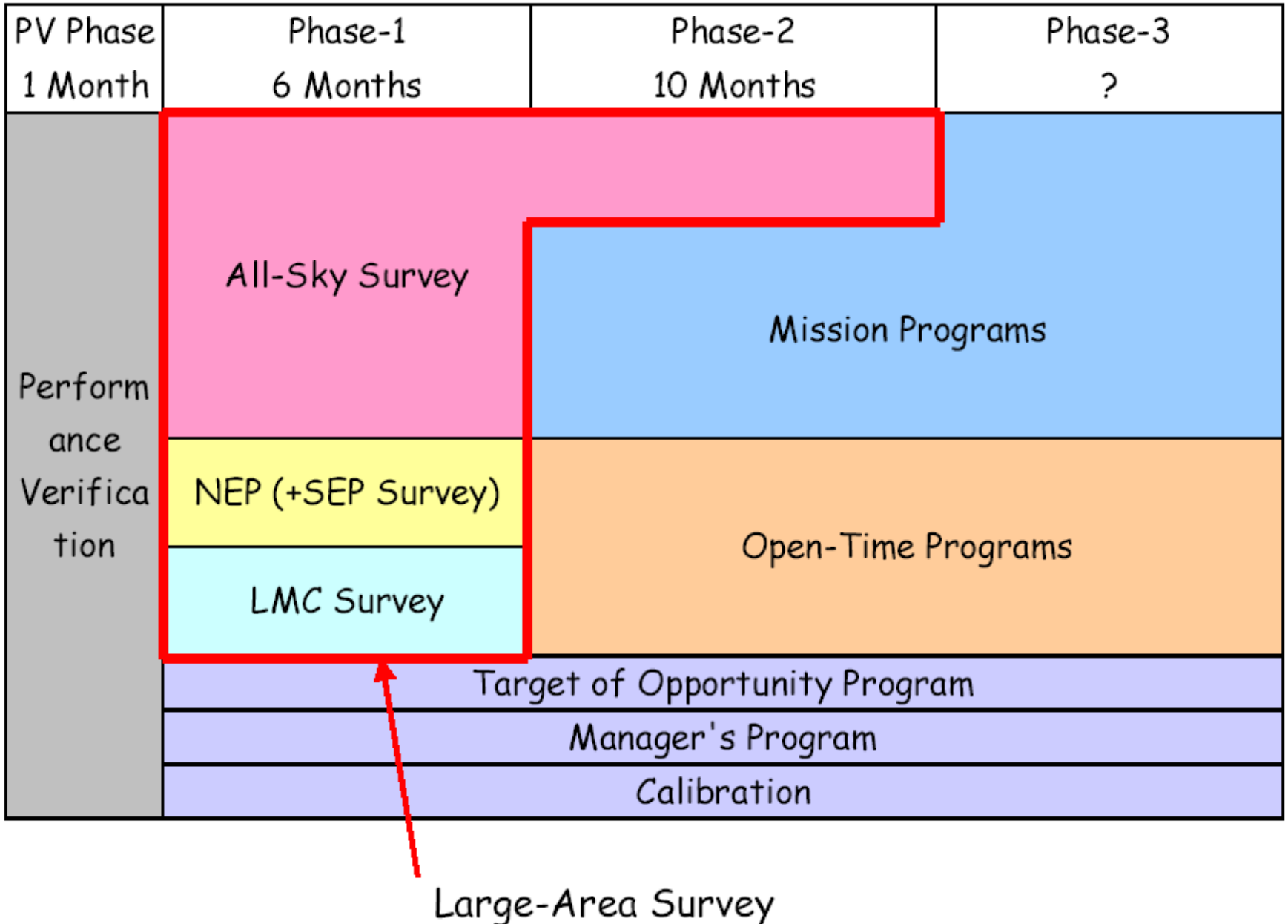
ASTRO-F Observation Programs

- Large Area Survey
  - **All-sky Far-IR(+Mid-IR) survey**
  - **NEP Survey** (Pointing mode, 1200-1800 pointing)
  - **LMC Survey** (Pointing mode, ~700 pointing)
    - ASTRO-F Project is responsible for data analysis and public data release
- Mission Program (Pointing mode)
    - MP team (ASTRO-F team + collaborators) is responsible for data analysis
- Open-time Program (Pointing mode)
    - 30 % of pointing observations in Phase-2(&-3)

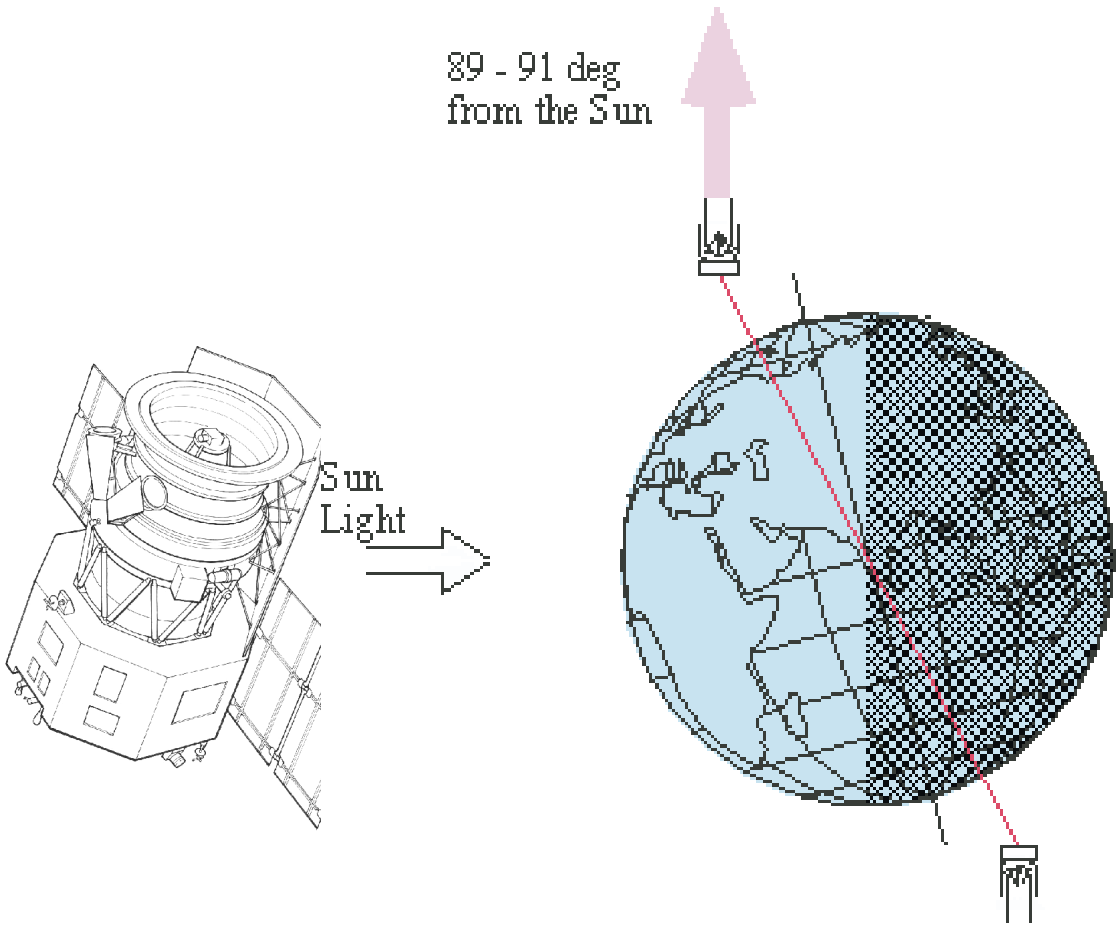
Mission life

- 18 months : PV + Phase-1(6 months) + Phase-2(10 months)
- Phase-3 : near IR observation after the LHe boil-off (> 1 year?)

Mission Phases & Observation Plan



All-sky Survey

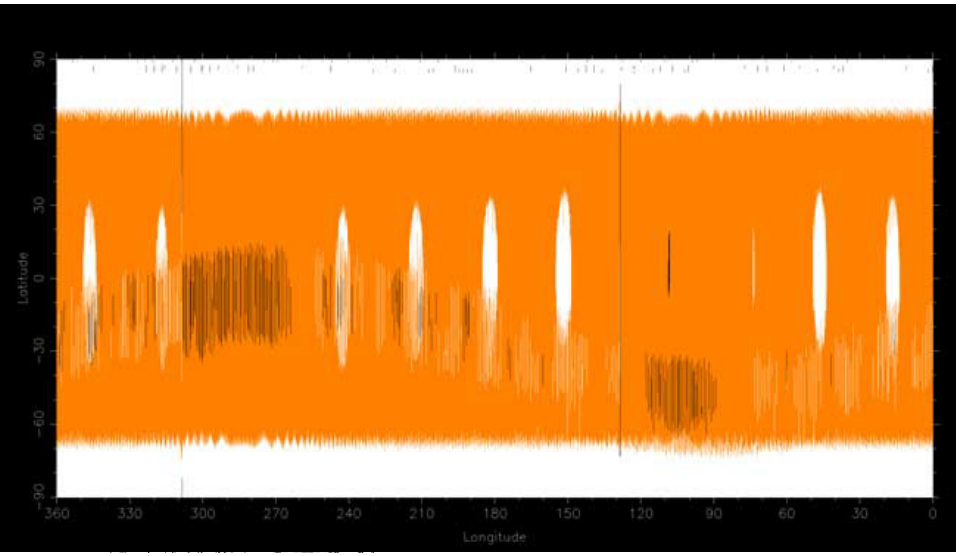


The Far-IR all-sky survey

Completeness simulation

- Nearly all-sky (goal >95%) will be covered

(with less complete mid IR(9, 20 micron) data)



MODEL-1

Survey Prioritized

Survey(N_{orb}>=2): 98.4%

N_{orb} >= 4(white), N_{orb} >= 2,

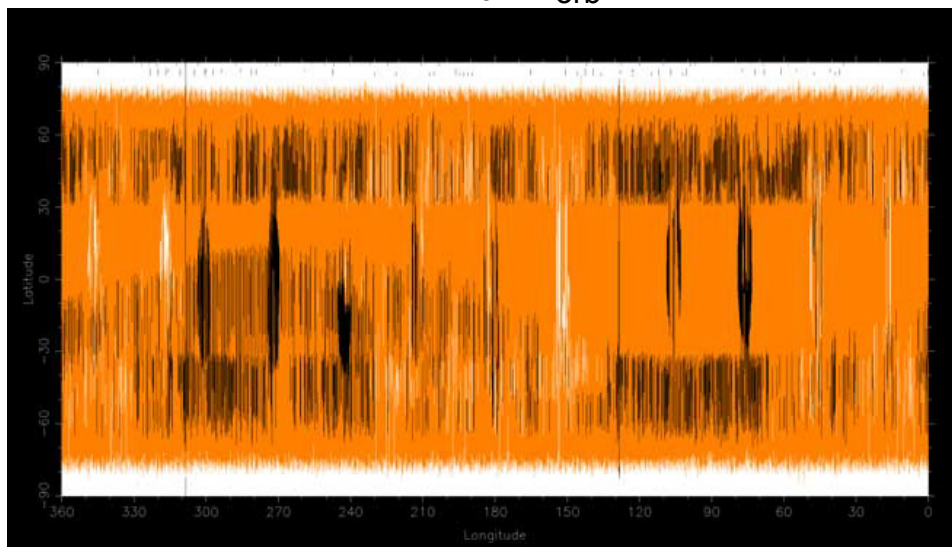
N_{orb} = 1 and 0(black)

MODEL-4

Pointing around poles on SAA orbit

Pointing prioritized

Survey(N_{orb}>=2): 87.1%



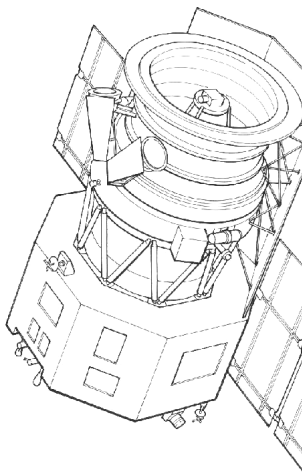
The Far IR All-Sky Survey: science goals(1)

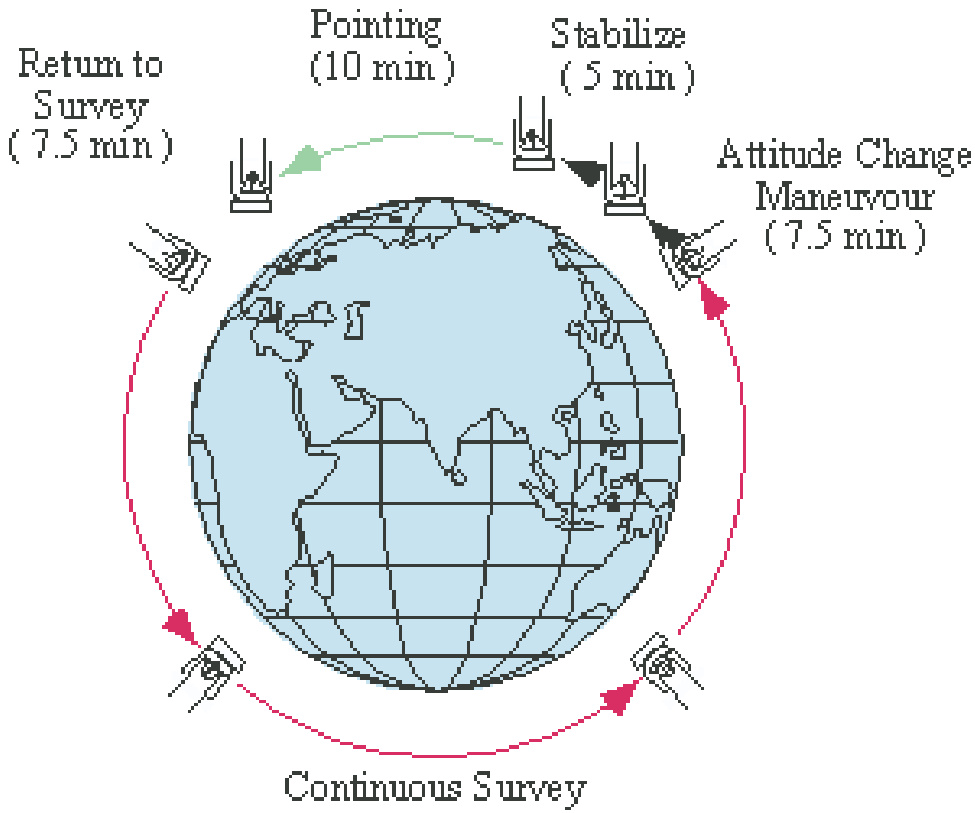
- **Obscured star formation** in the high-redshift Universe:
  - Dust enshrounded star-formation history @ z=1 – 2
- **The most luminous objects in the Hubble volume:**
  - spheroid formation in the early Universe,
  - a $10^{13.5}$ $L_{\odot}$ galaxy is detectable at z ~ 3 with ASTRO-F at 60 μm,
  - source count models predict 200 - 1200 such objects.
- **Identification of ultra-high redshift and extremely cool galaxies**:
  - Ultra-high redshift (z>3) galaxies: unusually cool observed-frame colour temperatures.
- **The all-sky large-scale structure of the Universe to z = 1**:
  - The ASTRO-F far-infrared survey will cover ~ 100 × the comoving volume of the IRAS PSC

The Far IR All-Sky Survey: science goals(2)

- **Extended cool dust in local galaxies**:
  - A cool, extended dust component heated by the interstellar radiation field (Rowan-Robinson 2000).
  - ~1000 galaxies resolved over >5 beams
- **Dust-enshrouded AGN**:
  - In areas with XMM X-ray survey coverage it will be possible to identify all but the Compton-thick AGN (NH>~10^{24} cm-^{2}) in ASTRO-F
- **Galactic science from the all-sky survey**
  - Map of Galactic Plane & nearby star-forming regions: a complete census of star formation in the whole galaxy
  - Protoplanetary systems
  - Debris discs around solar type stars
  - Planet/Disc interactions
  - Brown Dwarf stars
- **solar system science** (e.g. Kuiper belt objects).

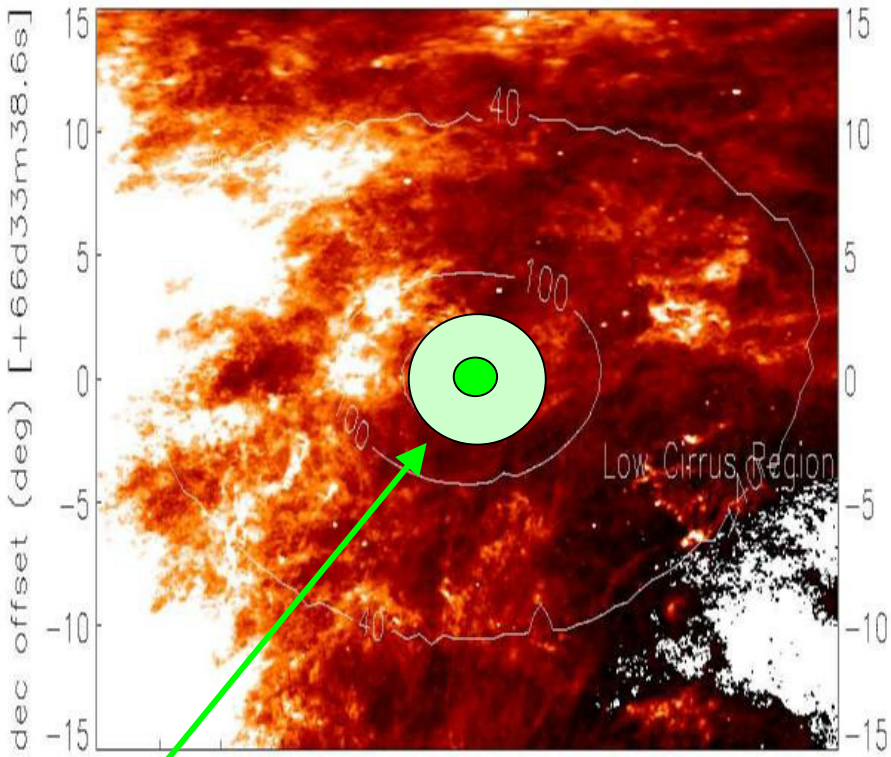
NEP (+SEP) Survey





Deep Extragalactic Survey near Ecliptic Poles (tentative)

NEP

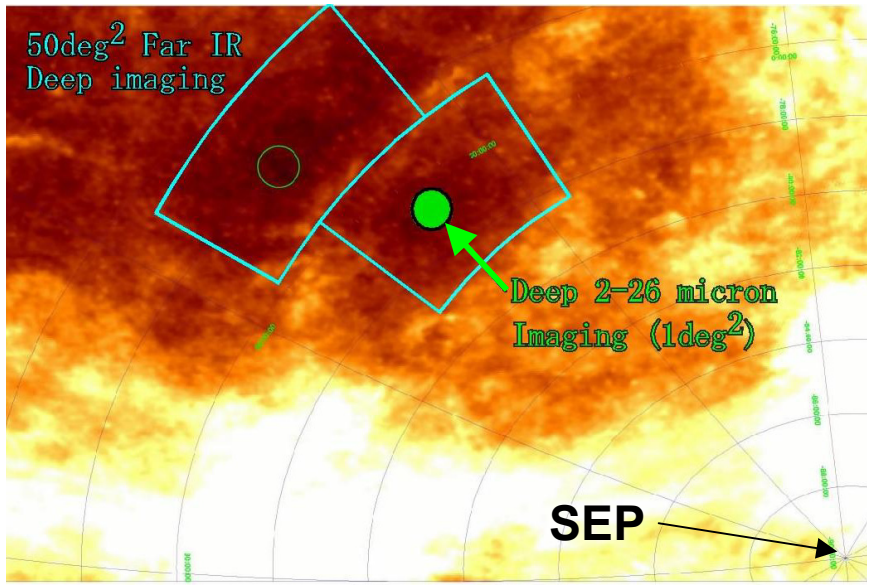


IRC imaging : 1200 + 600 pointing

1 deg^2, 10pointing/filter/FOV

4-5deg^2, 1 pointing/filter/FOV

SEP



FIS slow scan : 200 pointing

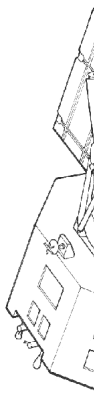
~50 deg^2, 15mJy@WIDE-S

IRC imaging : 100 pointing

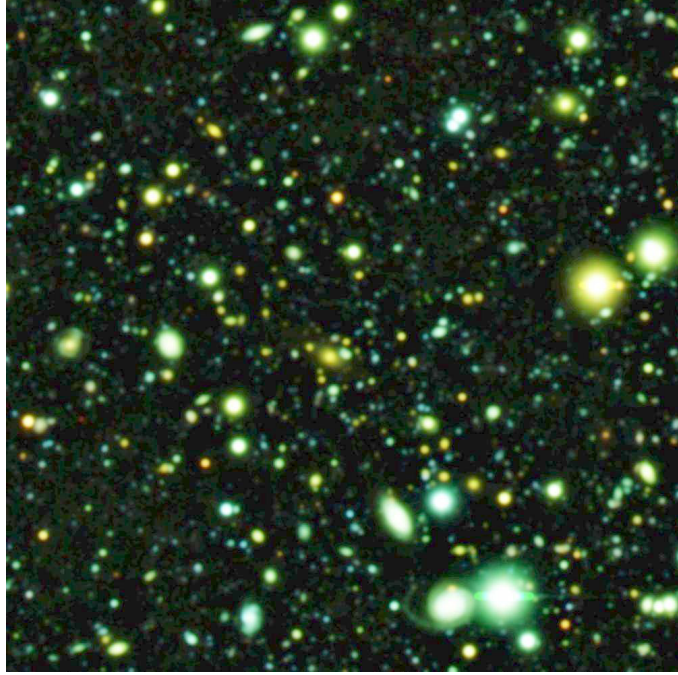
1deg^2, 1 pointing / filter/FOV

NEP(+SEP) Extragalactic Survey Science Goals

- Mass assembly history of the Universe, evolution of large scale structure
  - Near IR light (good indicator of the stellar mass) from z>2 galaxies cannot be observed from ground
- Star-formation history of the Universe at z > 1
  - Unveiling the relation among LAE/LBG, ERO, Submm galaxies
- Birth and Evolution of AGNs
  - Hidden black hole by dusty torus
- Resolving the Cosmic Infrared Backgroud
  - FIR : z=1~2 ULIRG? Fluctuation?
  - NIR : 1st stars?! – spectrum & fluctuation of CIB

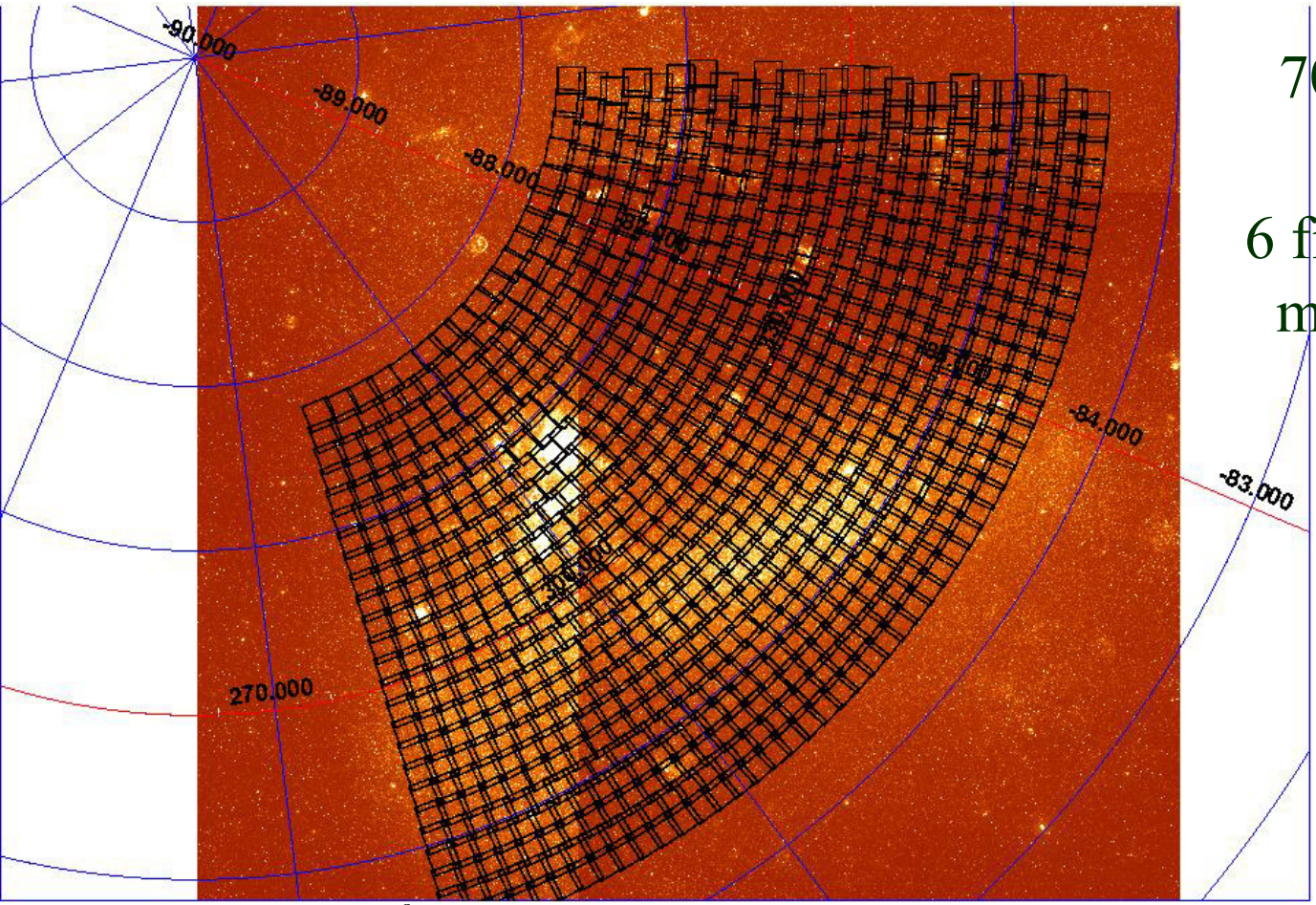


Multi-wavelength (X-ray, UV ~ radio) deep survey toward NEP



- X-ray : ROSAT catalog exists
  - Chandra: proposal submitted (cycle-6)
- UV: GALEX deep pointing survey
  - Proposal submitted (by Korean team members)
- Optical : Subaru/Suprime-cam, CFHT/Megacam
  - Subaru : BVRi'z' taken in 2003A, U,V & NB in 2004A
- Near IR(1-2 microns) :
  - KPNO 2m/FLAMINGOS in 2004A J & Ks 40'x40'
  - (WHT, KPNO 4m under consideration)
- **Mid – Far IR (2－200 microns) : ASTRO-F**
- 200-600 microns : collaboration with BLAST (under discussion)
- 850 micron & millimeter :
  - JCMT/SCUBA-2 (end of 2005) or CSO/Bolocam (not yet proposed)
- Radio : 21cm (30deg^2 0.3mJy(5σ) survey already exists)
  - WSRT: 50μJy survey, tentatively allocated in 2004B
  - VLA: 25μJy survey proposed in 2004B(not successful → try again)

LMC Survey

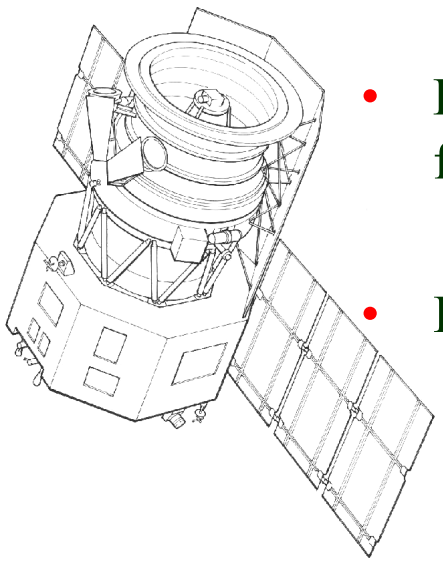


700-900 pointing observations

6 filter bands@2-26 microns per FOV

LMC Survey
Science Goals

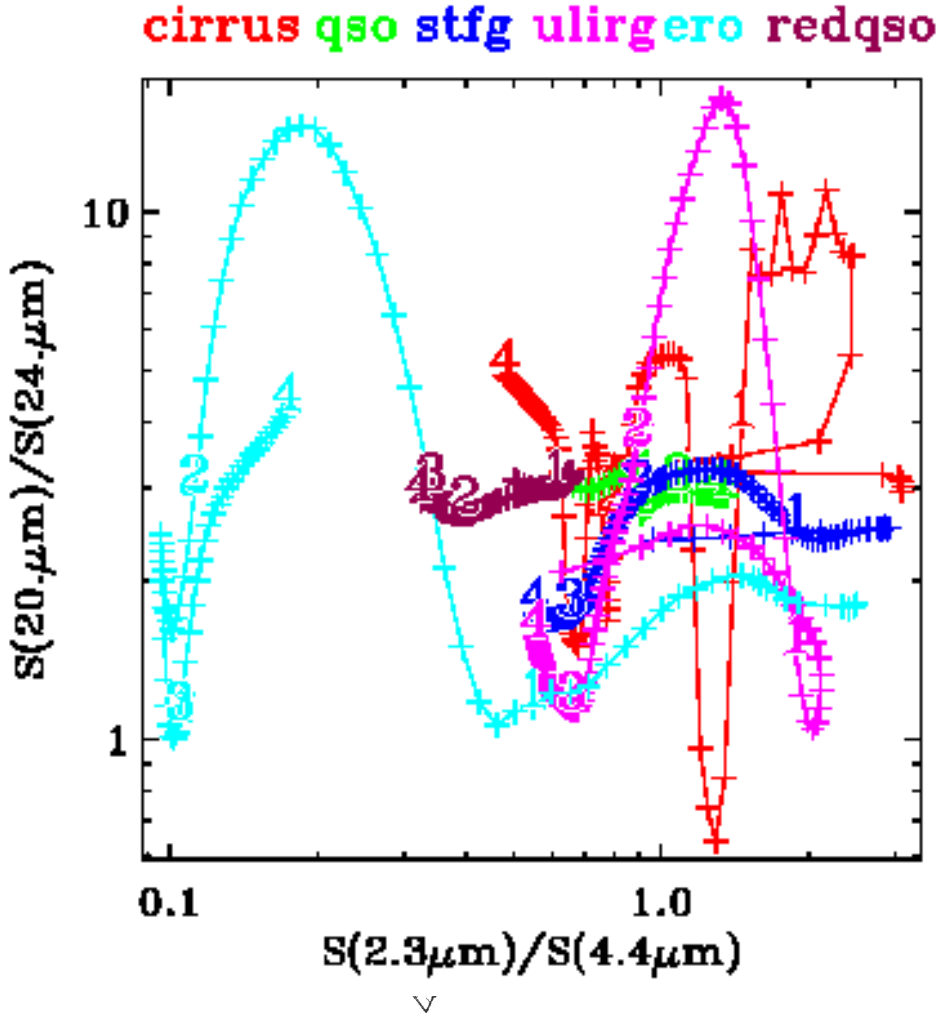
- Create volume-limited sample of high mass-loss stars(very reddened AGB)
  - ~10 000 stars per 10'x10' area of LMC central bar @ 4.5 micron, 2micro Jy
- Relationship between molecular clouds and distribution of young stars
  - collaboration with NANTEN, IRSF/Sirius
- Relationship between PAH/15-25micron excess and star-formation
  - also requires far infrared (>100 micron) images
- Interaction between SNR and its environmental gas
  - 50 SNRs, additional spectroscoic study is important

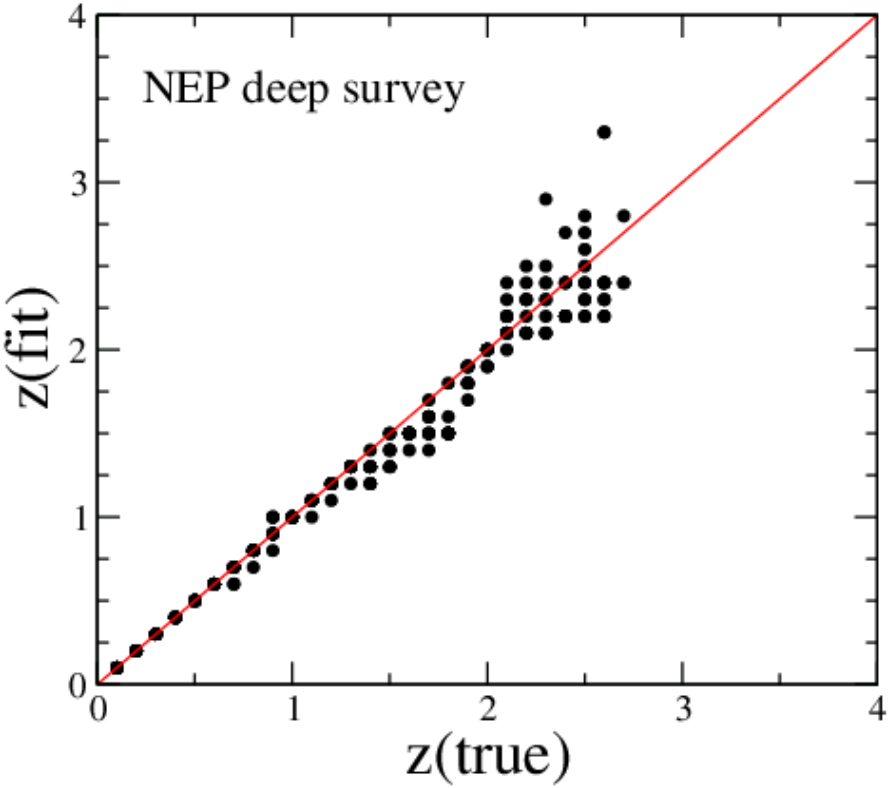


ASTRO-F is complementary to Spitzer *because..*

- Execute nearly all-sky Far-IR survey
  - But shallower than Spitzer/MIPS
- IRC has:
  - 4 times wider field per frame: 10'x10' with 412x412 format @ 2-5 micron (NIR channel can work in Phase-3: after LHe boil-off)
    - Large area(100deg^2) 2-5 micron survey in phase-3??
  - Spectroscopic Capability at 2.5-5 micron (R=180)
    - Follow-up Spitzer sources especially ULIRG or dusty AGN!!
  - Imaging Capability at K-band
    - Can address the fluctuation of the Cosmic near IR background
  - Imaging capability at 8-24 micron
    - 11, 15, 20 micron bands
    - **Photometric redshift determination solely by these bands!**
  - ***Cons*: visibility zone of ASTRO-F is quite narrow (+/- 1 deg) → deep & wide area survey is only possible toward regions near ecliptic poles**

ASTRO-F/IRC :
mid IR photometric redshift

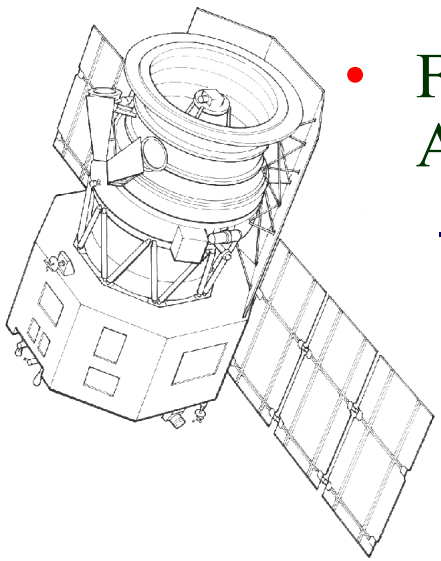




- Takagi et al. (2004) in prep.

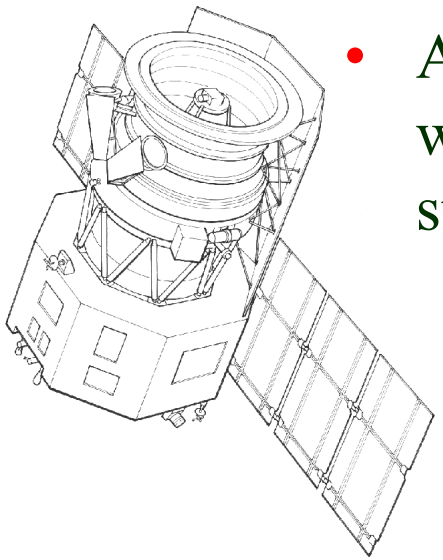
ASTRO-F follow-ups??

- ASTRO-F follow-up of Spitzer/Legacy fields (ELAIS N1, Lockman Hole, GOODS, SXDF) & COSMOS filed
- To prove the validity of mid IR photometric redshift technique :
  - Imaging by only 9, 11, 15, 20 micron bands
    - i.e. not good visibility fields with ASTRO-F
- Follow-up of z>2.5 Spitzer HLIRGs / obscured AGN candidates:
  - Near IR : 2-5 micron low-resolution spectroscopy or targetted slit-spectroscopy (R=180)



Summary

- ASTRO-F is a perfect complement to Spitzer (i.e. not rivaling each other)
- ASTRO-F follow-up of Spitzer Legacy fields is also very interesting even though ASTRO-F visibility is so low



- ASTRO-F data (especially all-sky survey catalog) will be fundamental database for future follow-up study with **Herschel**, **SPICA**, **ALMA**..