Imaging FTS with Photoconductive Detector Arrays: ~ an application to the AKARI far-IR instrument ~

Mitsunobu Kawada (Nagoya Univ.)

H. Takahashi[1], N. Murakami[2], Y. Okada[3], A. Yasuda[3],
T. Ootsubod[3], H. Kanedad[3], H. Matsuoe[4], S. Matsuurad[3], M. Shirahata[3],
Y. Doi[5], M. Fujiwara[6], I. Yamamura[3], T. Nakagawa[3] & H. Shibai[7]

[1]*Gunma Astronomical Observatory*
[2]*Bisei Astronomical Observatory*
[3]*Institute of Space and Astronautical Science, JAXA*
[4]*National Astronomical Observatory*
[5]*The University of Tokyo*
[6]*New Generation Network Research Center, NICT*
[7]*Osaka University*

2008/06/23 SPIE 7010-14

CONTENTS

- Introduction to the AKARI/FIS-FTS

  imaging Fourier Transform Spectrometer (iFTS)

  - Optics & Mechanics
  - Modulation Efficiency: optical filters & alignment

- Funny Features of the iFTS

  - Imaging Quality
  - Channel Fringes
  - Interferograms & Spectra

- Observation Summary

  - Parallel mode observations

the iFTS of AKARI/FIS

◊ **Unique Features of the iFTS**

imaging capability

boosting the observing efficiency

using photoconductive detector

high sensitivity, but thorny property – transient response

◊ **Originality**

Optical and Mechanical Design, Fabrication, Tests, Reduction, ...

optical filters are supplied by QMC Ins. Ltd.

· Mirror Driving Mechanism

based on Cassini/CIRS, but many original features

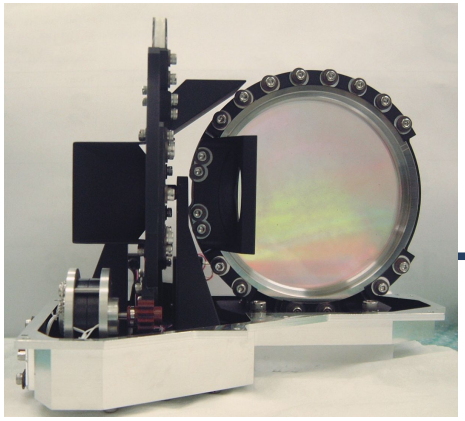
· position sensor: modified Heidenhain optical scale

· light weight roof-top mirror made by Be

· small blackbody source

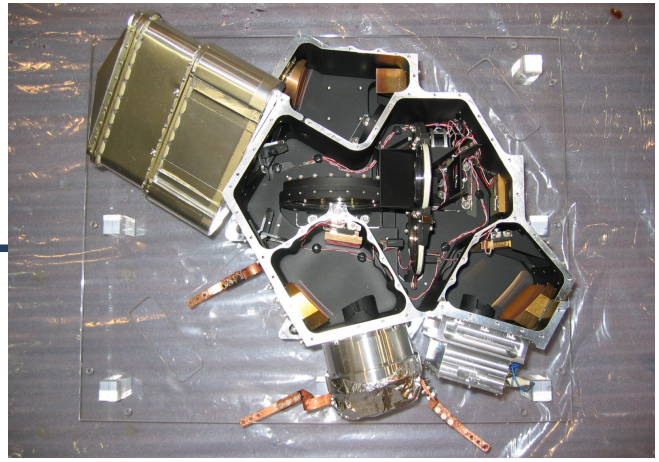
· data reduction tools

Optics

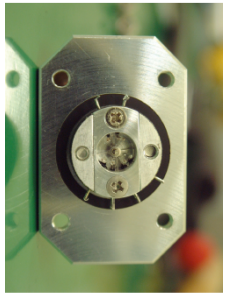


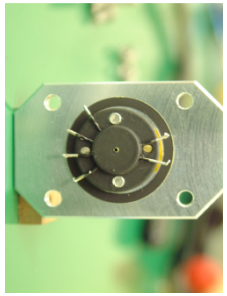
beam splitter

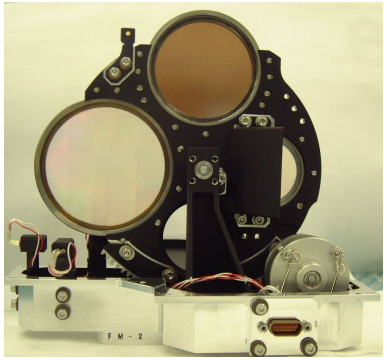
size: L 50 x W 30 x H 20 [cm]
weight: ~5.5kg



blackbody source







filter wheel

Blocking Filters
(σ_c~300cm^{-1} & 430cm^{-1})

Collimator Mirror

Bending Mirror

100mm

Input Aperture (with shutter)

Black-Body Source

Movable
Roof-Top Mirror

Hole
or
Input Polarizer

Mirror Transport Mechanism

SCANNER

Filter Wheel

Calibration Sources

Beam Splitter
(Polarizer)

Fixed
Roof-Top Mirror

Dichroic Beam Splitter (σ_c~91cm^{-1})
or
Output Polarizer

SPECTROMETER

Camera Mirror

Camera Mirror

Low-Pass Filter (σ_c~90cm^{-1})
Low-Pass Filter (σ_c~70cm^{-1})

Low-Pass Filter (σ_c~220cm^{-1})
High-Pass Filter (σ_c~133cm^{-1})

Short Wavelength Detector
(Ge:Ga; ~2.2K)

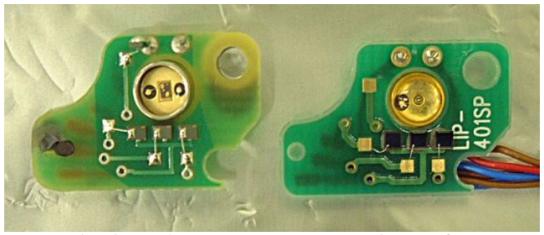
Long Wavelength Detector
(stressed Ge:Ga; < 1.8K)

Weight: ~5.5kg

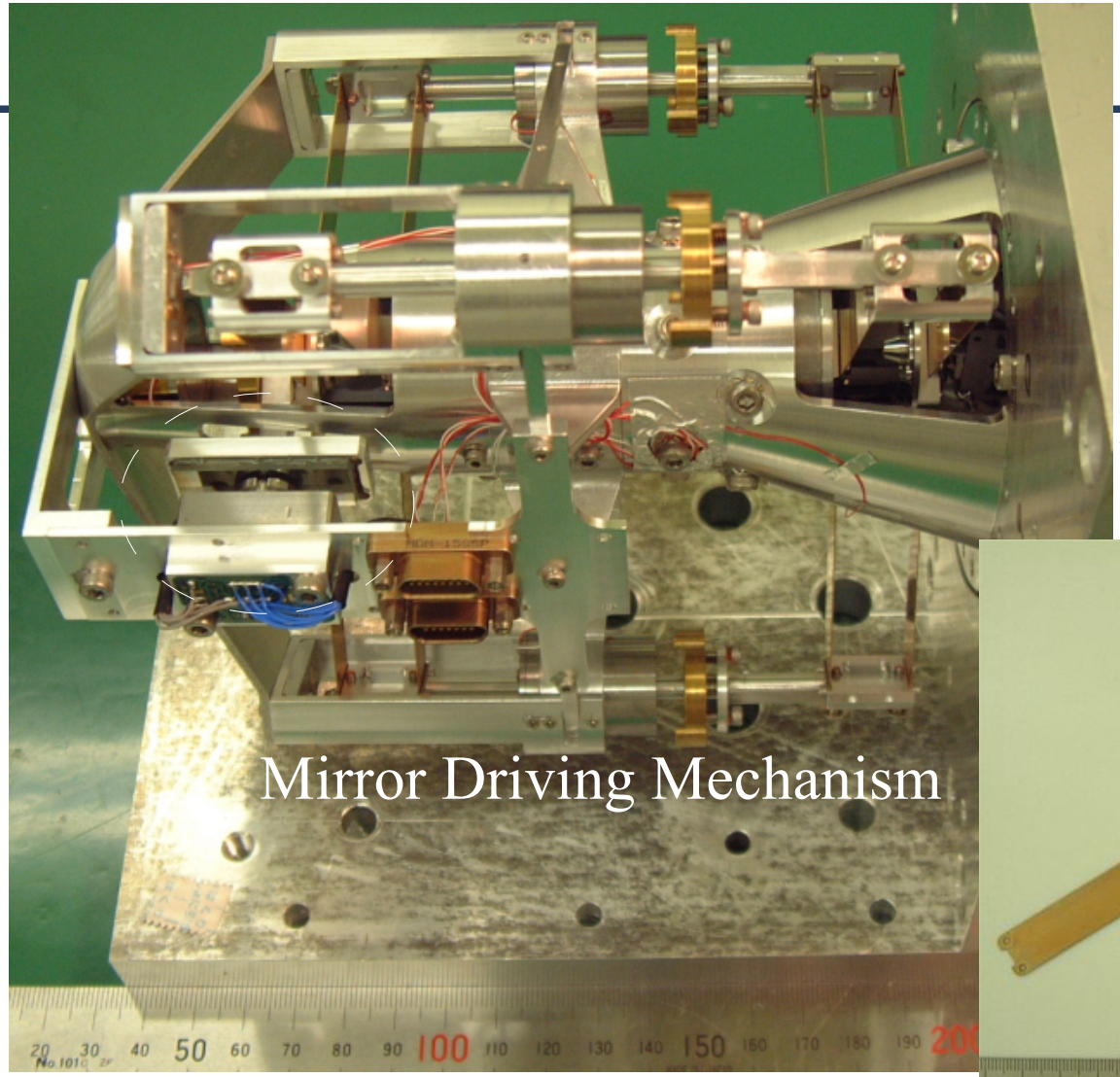
Martin-Puplett Interferometer

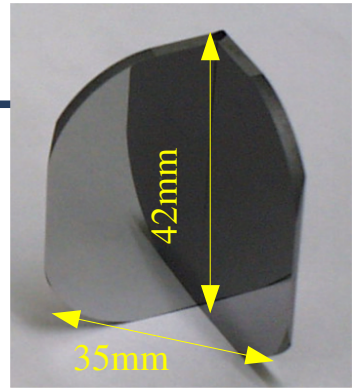
Original Components

Position Sensor Module
(originally HEIDENHAIN)

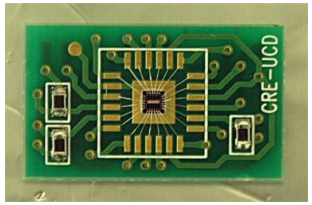


original customize for cryogenic operation

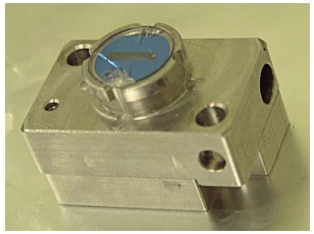


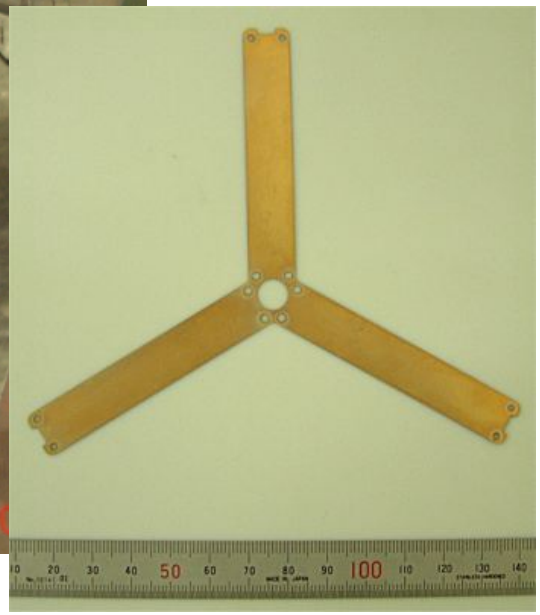


Be roof-top mirror
(weight: 8g)

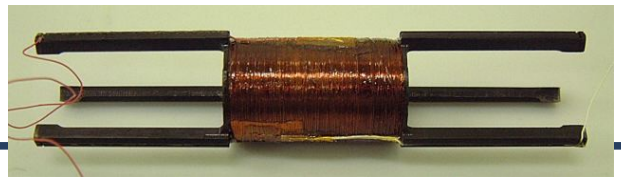


pre-amp
(not used)





106 mm

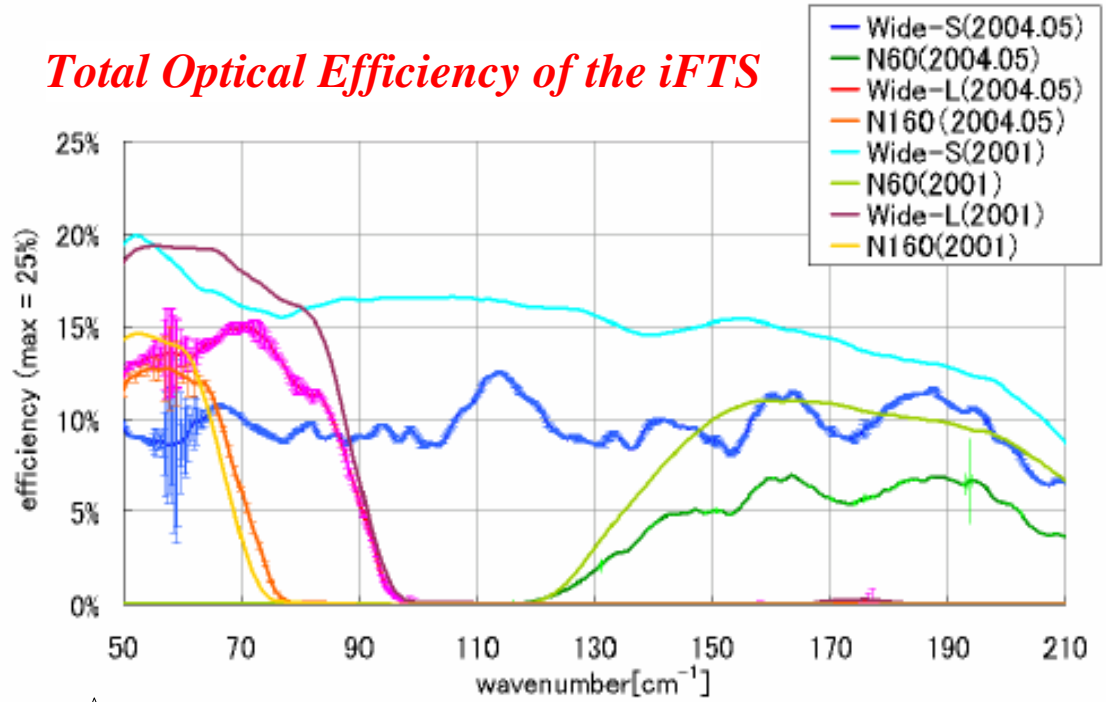


Moving Coil Shaft
- ~7000 turns
- 50 μmϕ NbTi wire

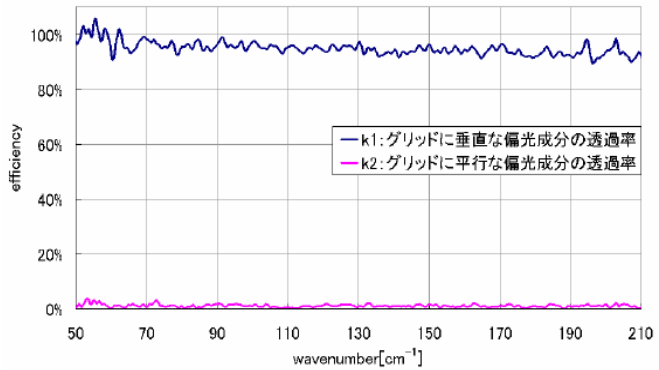
Leaf Spring
- phosphor bronze
- 0.25mm thickness

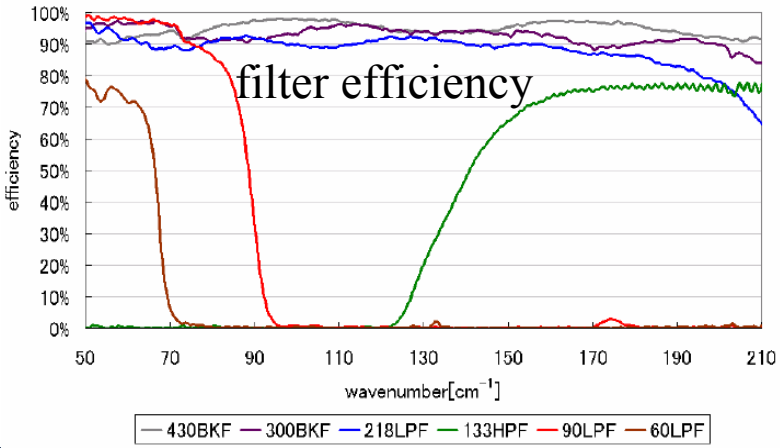
Optical Efficiency

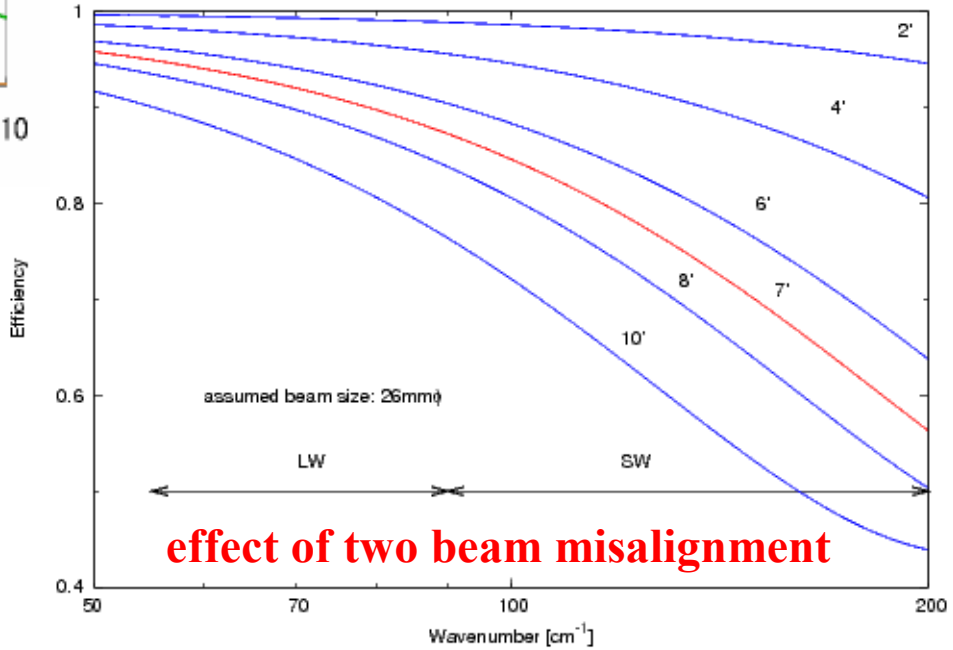
Total Optical Efficiency of the iFTS



polarization efficiency



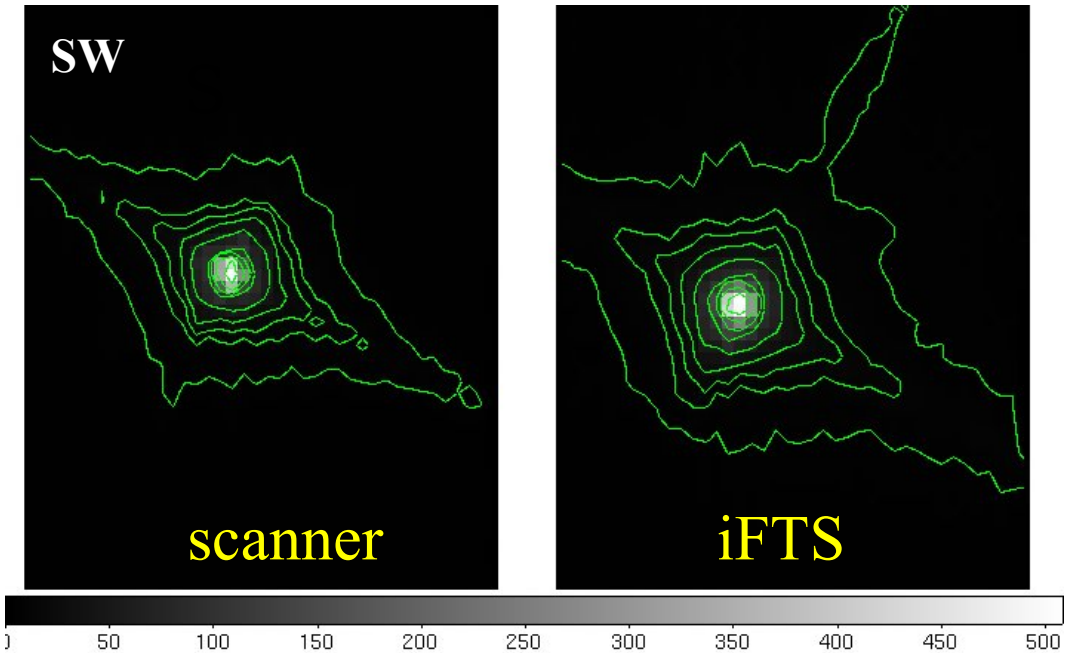


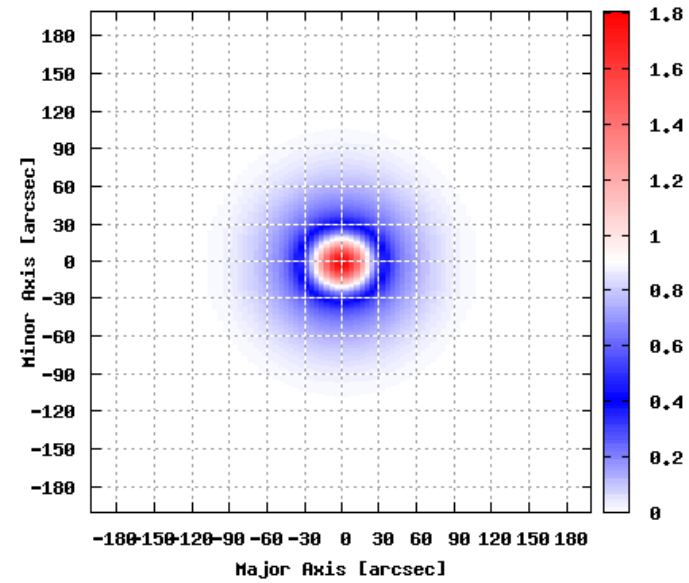


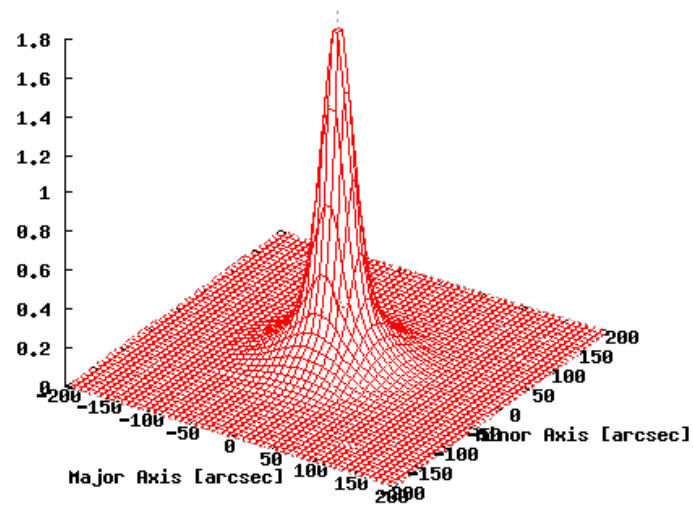
effect of two beam misalignment

Imaging Quality

scan image of *Neptune*





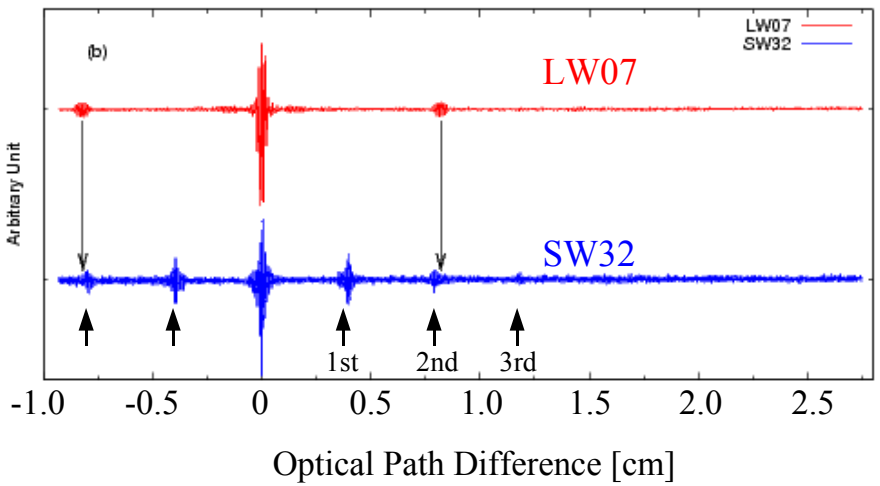


PSFs of the scanner are well fitted by double Gaussian
PSFs of the iFTS are elongated along the major axis
due to the misalignment of two beams (7')

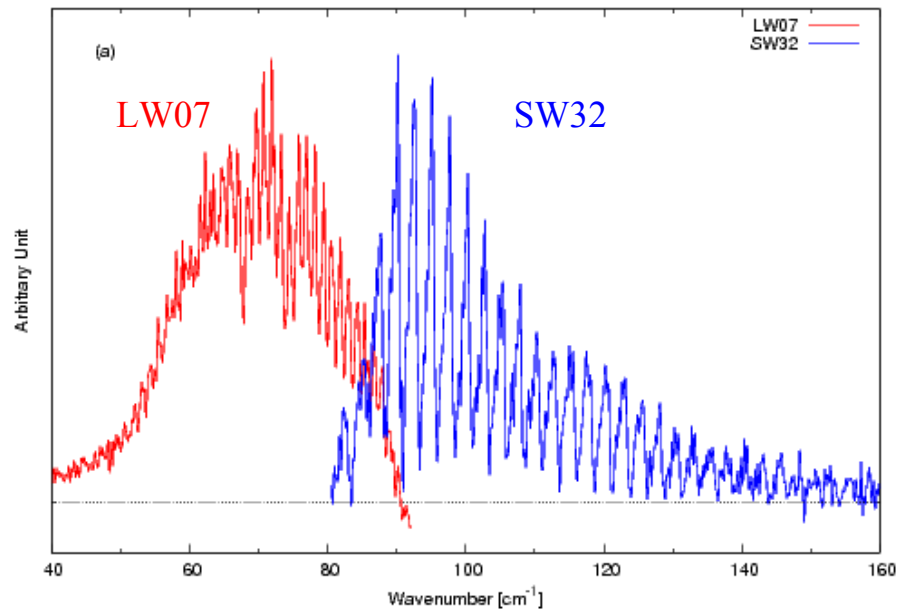
PSFs of the iFTS (FWHM) (major / minor)
SW: 44”/ 39”
LW: 57”/53”

Channel Fringes

interferograms of the aperture lid



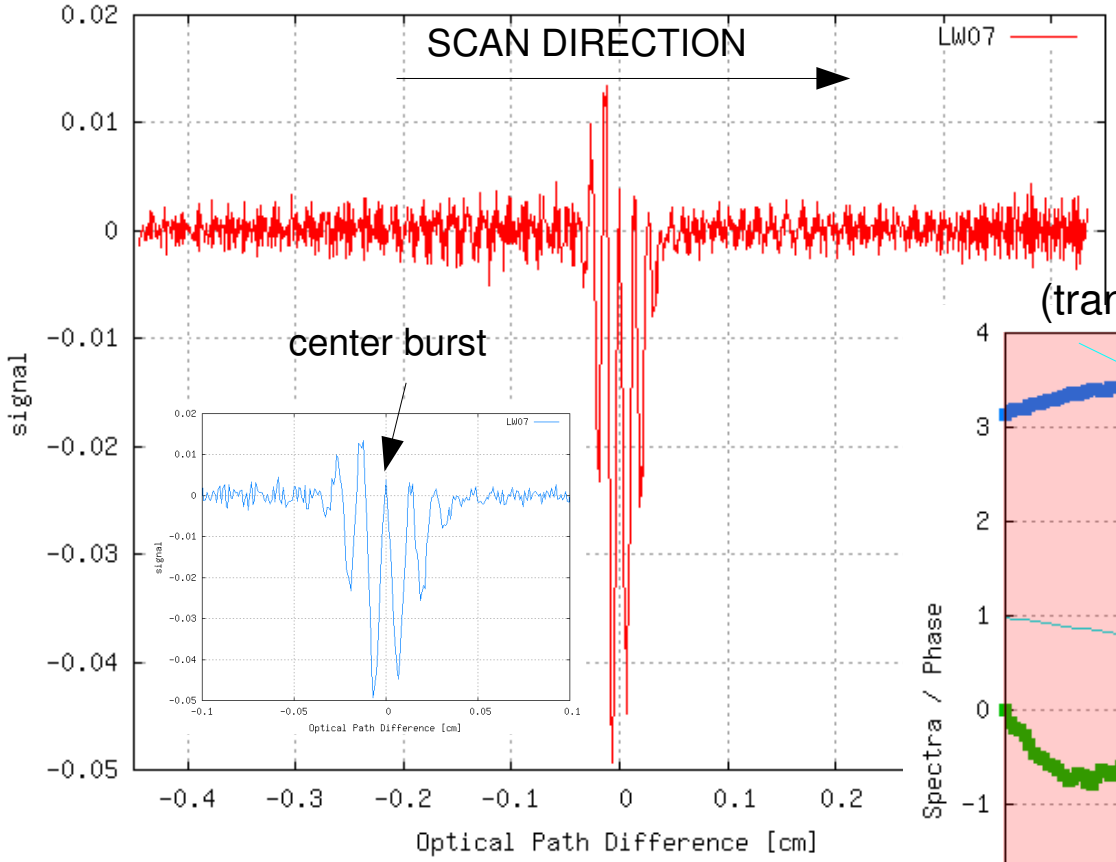
raw spectra of the aperture lid



- sub-structures seen in LW07: ~0.82 cm ↔ ~1.22 cm^{-1}
  - physical gap of two blocking filter: ~ 4 mm ► <u>0.4 cm x 2 ~ 0.8 cm</u>
    - *can be seen in SW interferograms at the same position of LW's*
  - >> multi-beam interference due to two blocking filters
- sub-structures seen in SW32: ~0.395 cm ↔ ~2.53 cm^{-1} (no in LW07)
  - multiple reflection and interference in the SW detector substrate
    - thickness: 0.5mm; refractive index of Ge: 4 ► <u>0.05cm x 4 x 2 ~ 0.4 cm</u>
  - >> multiple reflection in the Ge:Ga detector substrate (reflection efficiency: ~ 40%)

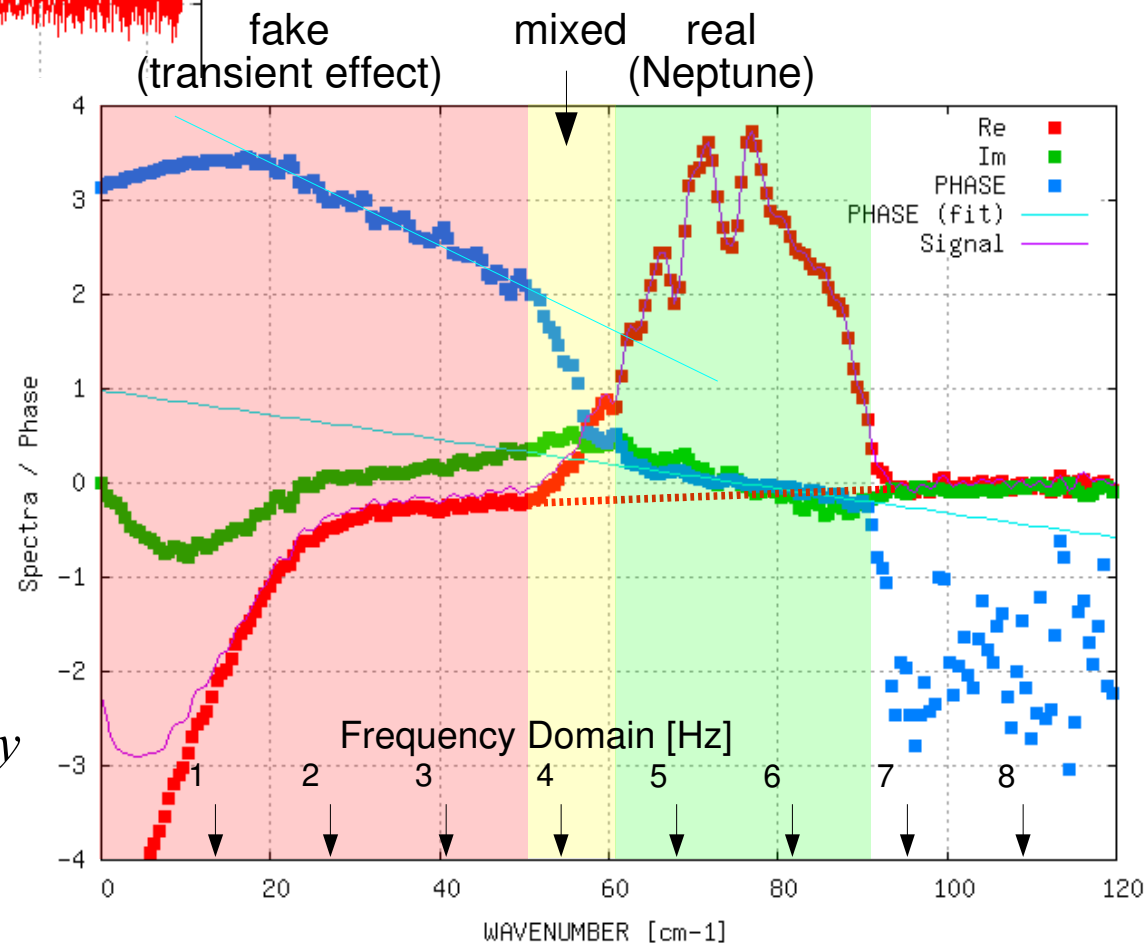
Interferogram & Spectrum

(Neptune: LW07)



averaged interferogram of 29 scnas

Fourier Transformed Spectrum



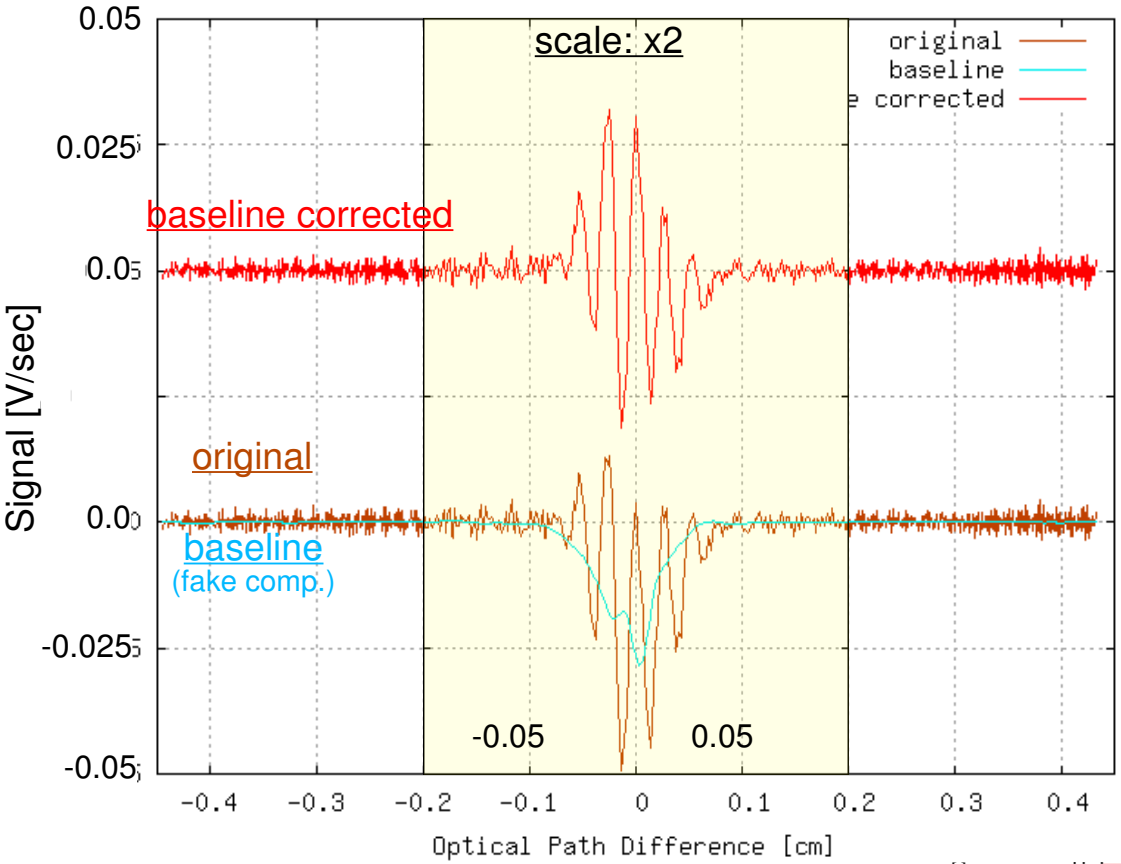
<u>conversion factors</u>

OPD/wavenumber ↔ time/frequency

1.000 cm (OPD) ↔ 13.624 sec

1.000 cm^{-1} (WN) ↔ 0.0734 Hz

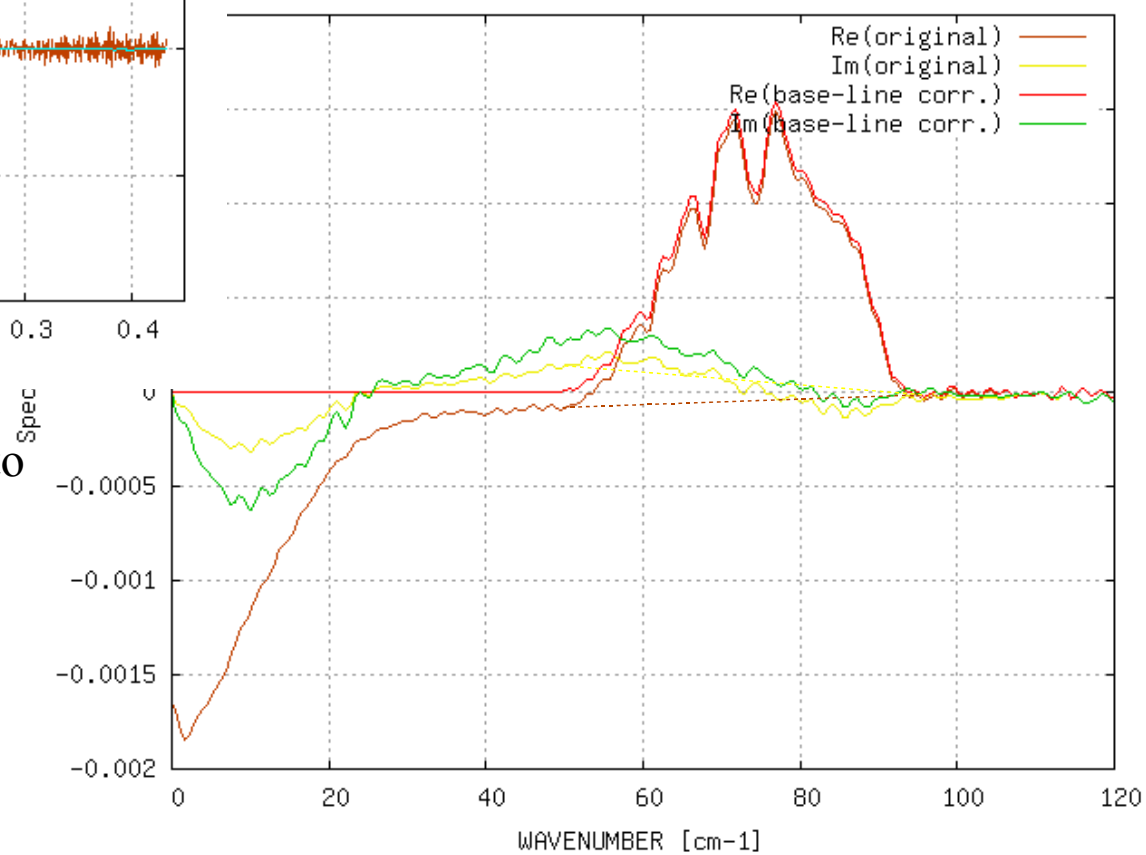
Separation of the fake component



Modulation Efficiency

- DC level: **0.084[V/sec]**
- peak value of corrected IF at ZPD: 0.030 [V/sec]
  e = 0.36
- integrated power of derived spectrum: **0.032[V/sec]**
  e = 0.38 (total modulation efficiency)
- modulation efficiency due to imperfection: **~0.75**

Detector Responsivity at 4-7 Hz
~0.5 (of DC responsivity)



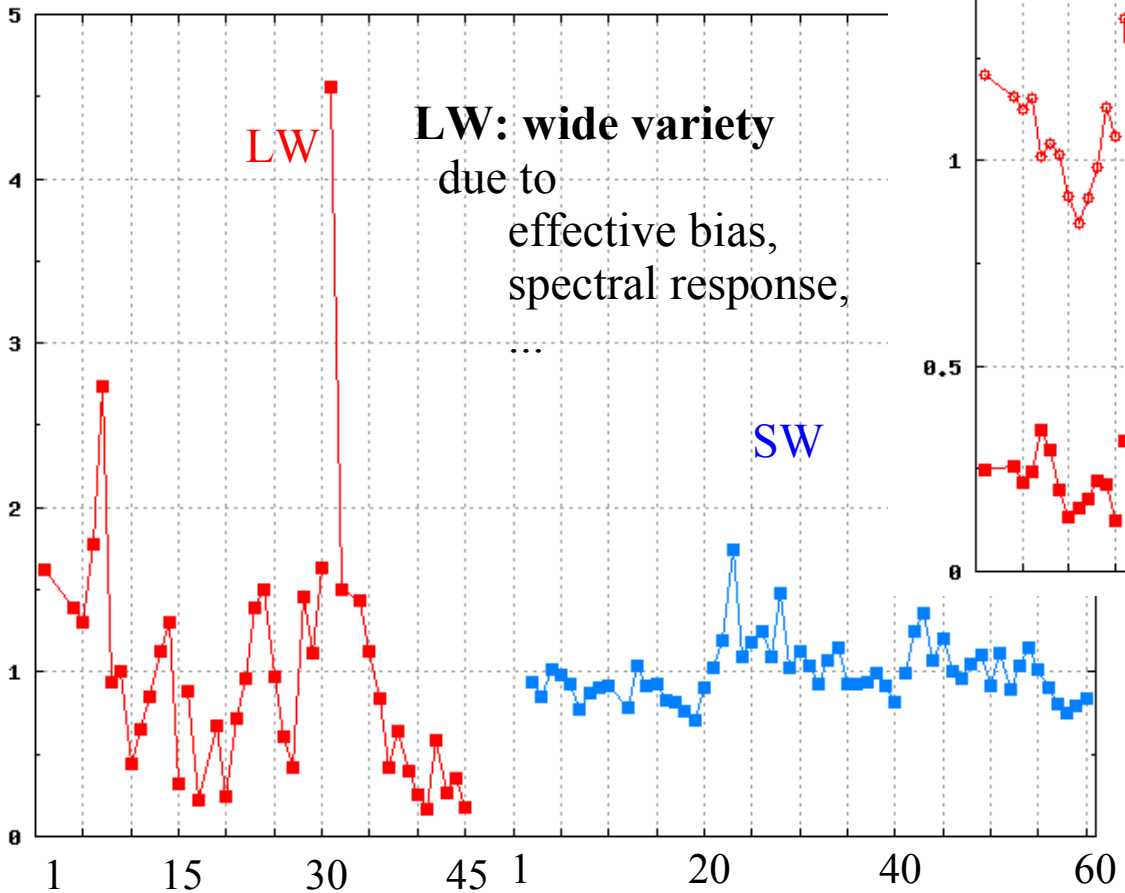
amount of contamination around 60cm^{-1} due to the transient response is depend on detector property of each pixel; some are almost separated and some are affected by factor 2.

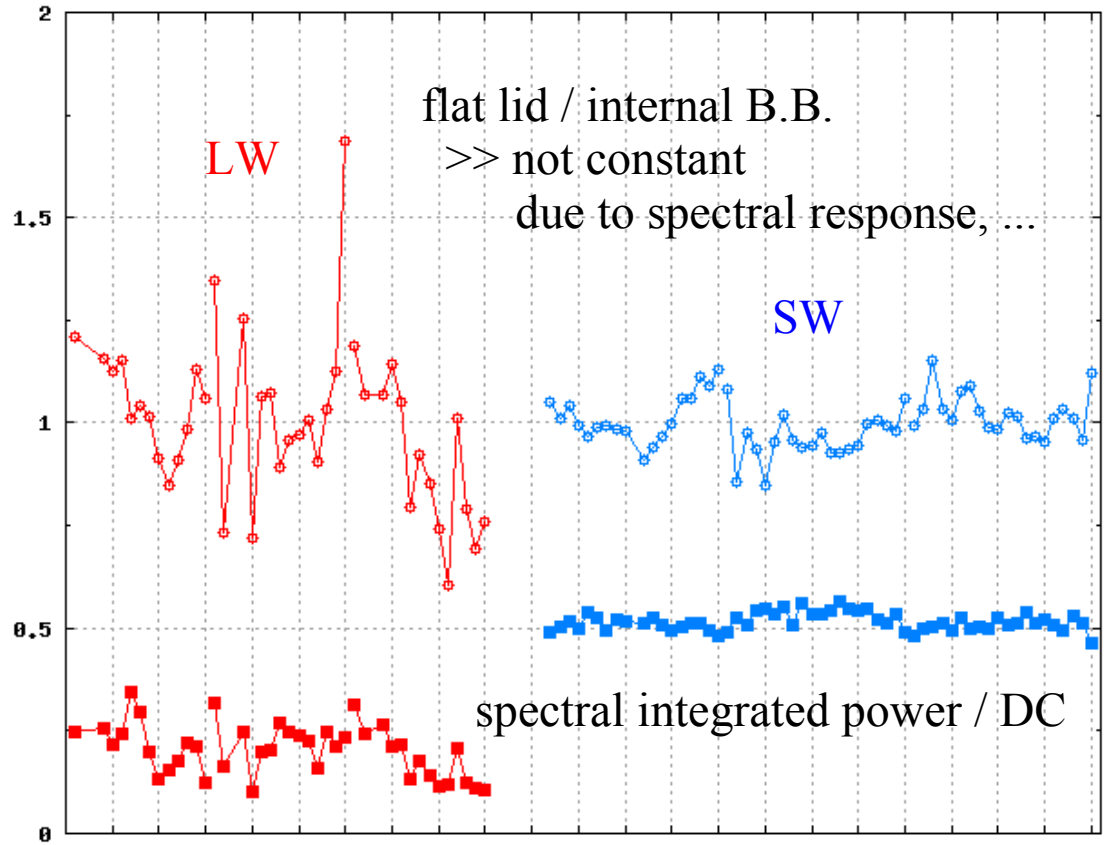
>> be careful for deriving [CII] line flux

Kawada Mitsunobu

Flat & Total Efficiency

relative pixel response to the lid flat





total modulation efficiency

LW: ~ 0.25 / SW: ~ 0.5

>> due to transient response of detector pixels

(AC/DC respons LW: ~ 0.35 / SW: ~0.8)

Summary of Observations

- Working period: 2006/04/19 – 2007/08/25
- Total number of observations: 597 points
  - PV phase : 30 points (FIS03: 18, FIS04: 12)
  - Primary obs. : 115 points (MP: 62, OT-ISAS: 7, OT-ESA: 24, DT: 22)
  - Parallel obs. : 452 points

  - SED mode : 259 points (PV: 21, FIS03: 50, FIS04: 188)
  - Full res. Mode : 338 points (PV: 9, FIS03: 65, FIS04: 264)

  (data for several obs. are lost by downlink troubles)

- Slow-scan observations using the FTS optics (for evaluation of PSF)
  - 1 observation of NGC6543 for check of the FOV direction
  - 2 observations of Neptune for PSF measurement

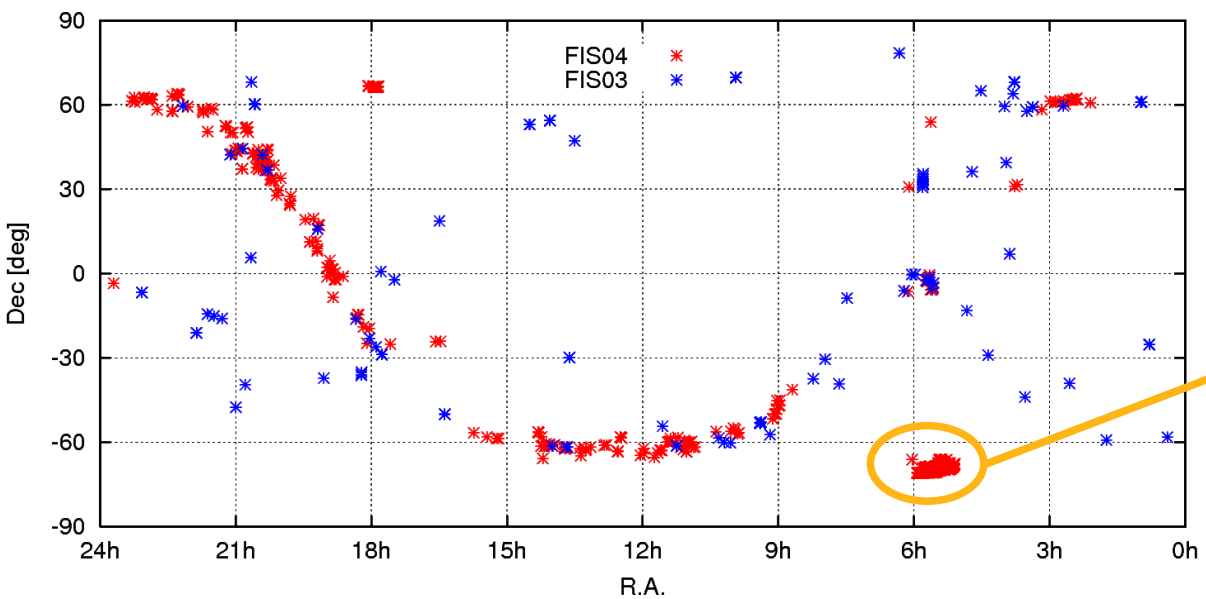
Observing Regions

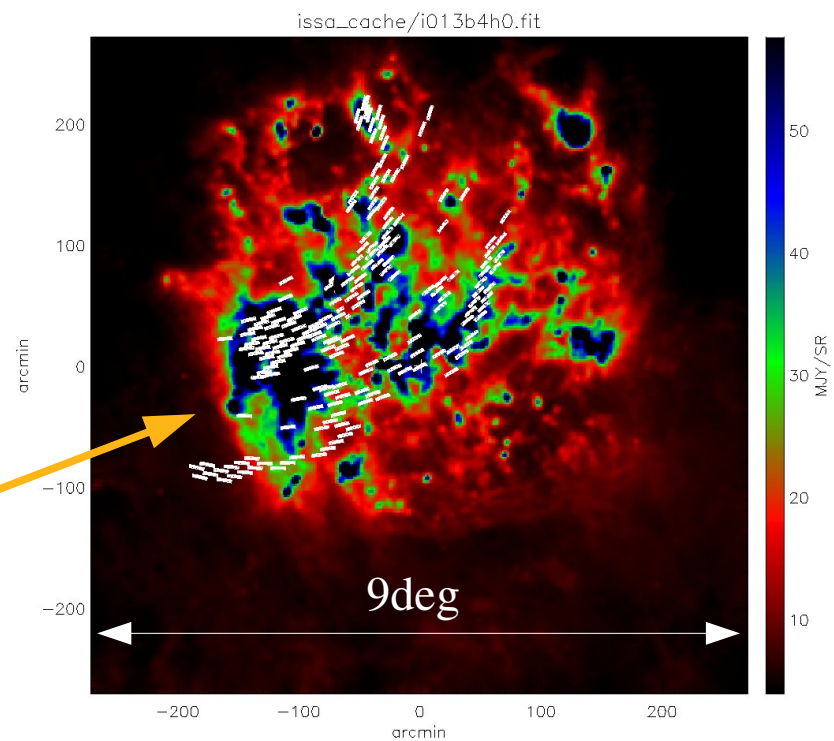
- Parallel Obs. were done on the Galactic plane
- LMC region was covered intensively by parallel obs. of LS-LMC

unfortunately, most interesting region (30 Dor) were observed by SED mode

LMC coverage by parallel obs.
188 points (SED/Full =58/130)

RED : parallel observations
BLUE : primary observations





CONCLUSION

- The iFTS of AKARI/FIS worked in orbit as well as in laboratory.
  - *imaging performance*, *spectral resolution* are good
  - *quality of spectra* is not so good

    because of ...
    - channel fringes ← *multiple reflection in detector substrate*
      multi-beam interference due to blocking filters
    - distortion of interferograms
      ← *detector transient response*

- The iFTS was operated in about 600 pointed observations
  - *~3/4 observations were operated in parallel mode with IRC*

    observing the Galactic plane, LMC, ...

    providing valuable spectral information of the intersteller medium

  and, providing valuable data for future applications

  using FTS with photoconductive detector