Measurements of atmospheric transmission using Fourier transform spectrometer in far-infrared and submillimeter-waves

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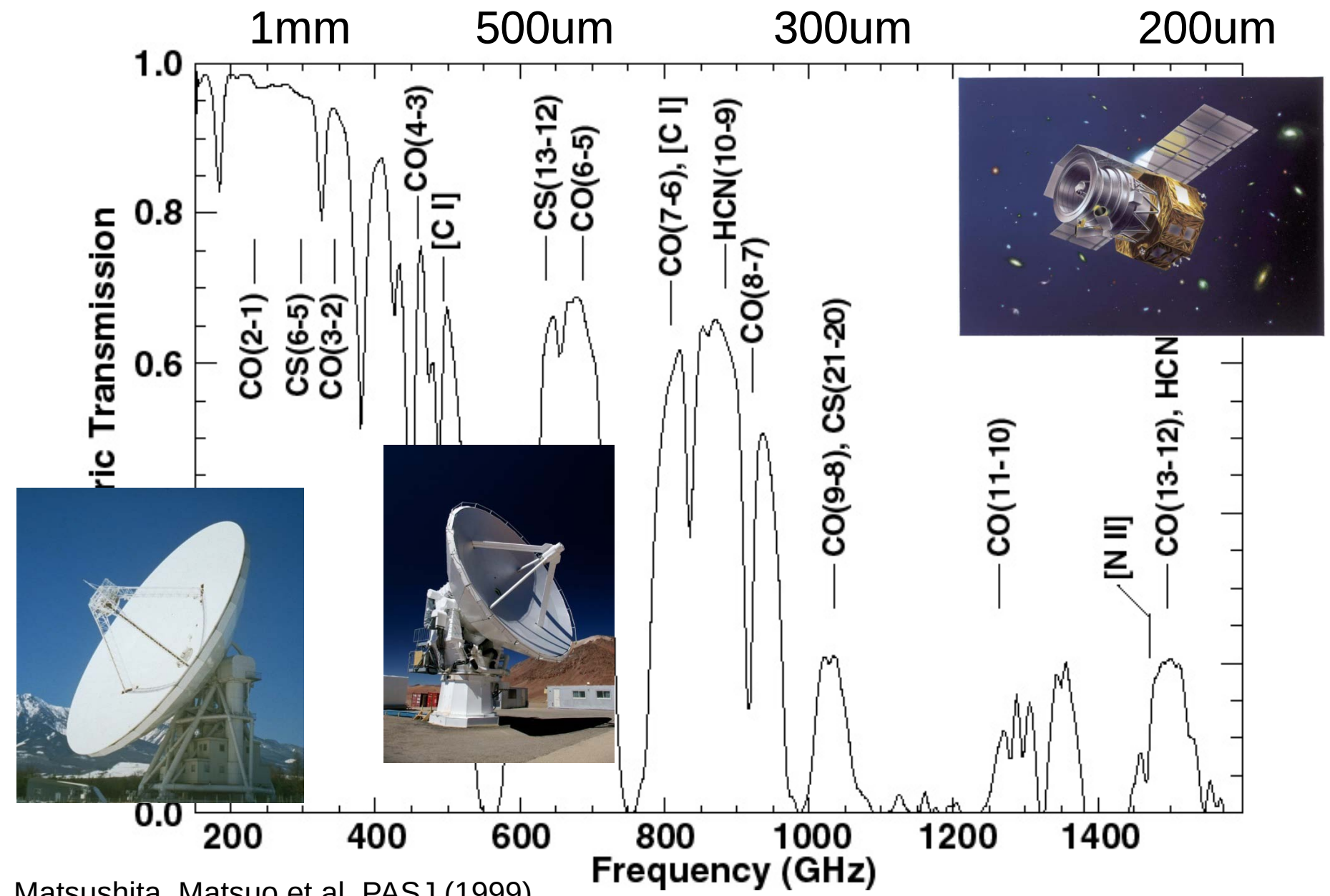
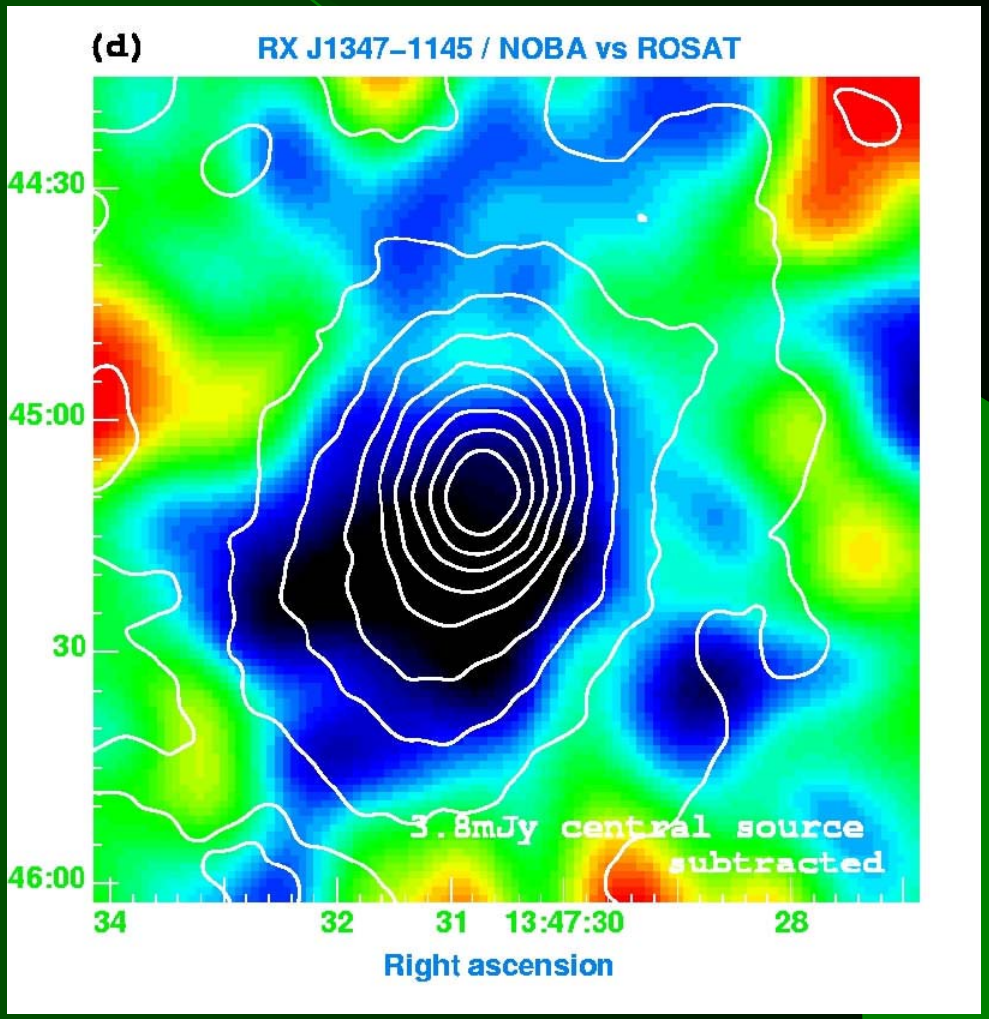
Atmospheric Transmission from Atacama（alt. 4800m）



Matsushita, Matsuo et al. PASJ (1999)

Nobeyama Bolometer Array (NOBA)
7-element NTD-Ge bolometers
λ2 mm (150GHz)
Operational during 1992 - 2008

Sunyaev-Zeldovich effect
observed with NOBA
(Komatsu et al. 2001)



AzTEC/ASTE 1100μm map of ADF-S (SEP)

Hatsukade et al. (2010)

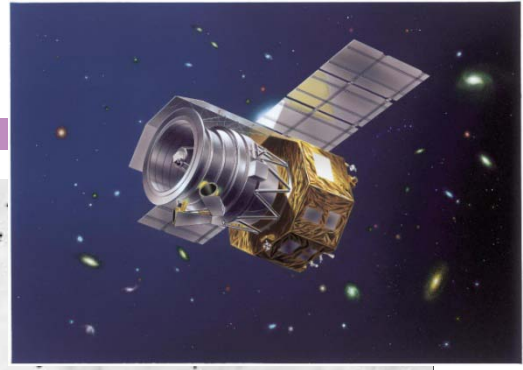
$1\sigma < 0.6$ mJy

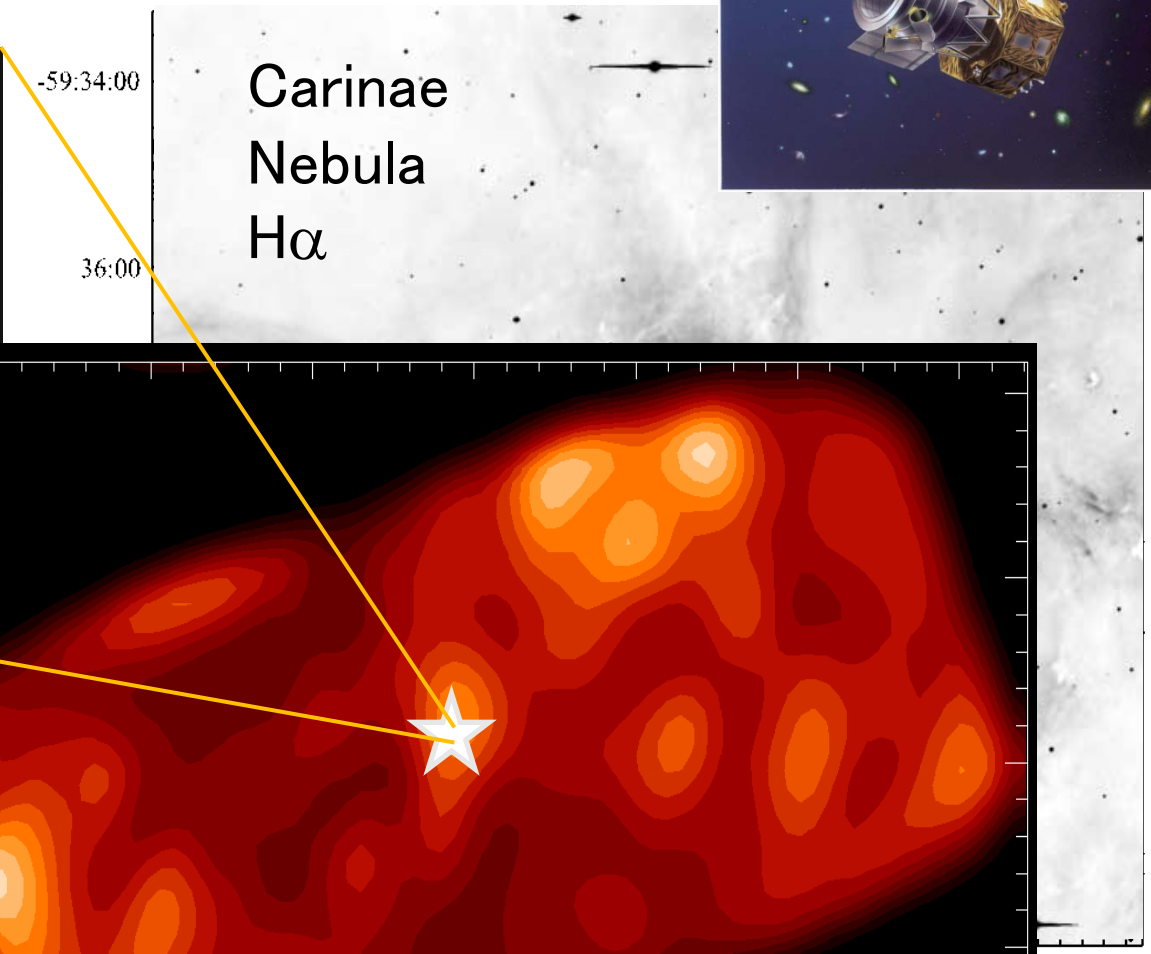
$1\sigma < 0.8$ mJy (970 arcmin^2)

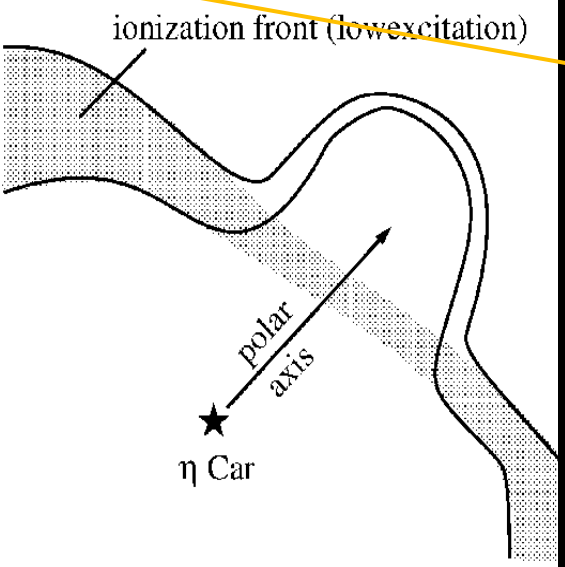
0.5 deg

- 0.25 deg^2 surveyed
- About 200 identified sources
- Only 11 AKARI sources
- $z > 1.5$

[C II] 158μm & Hα

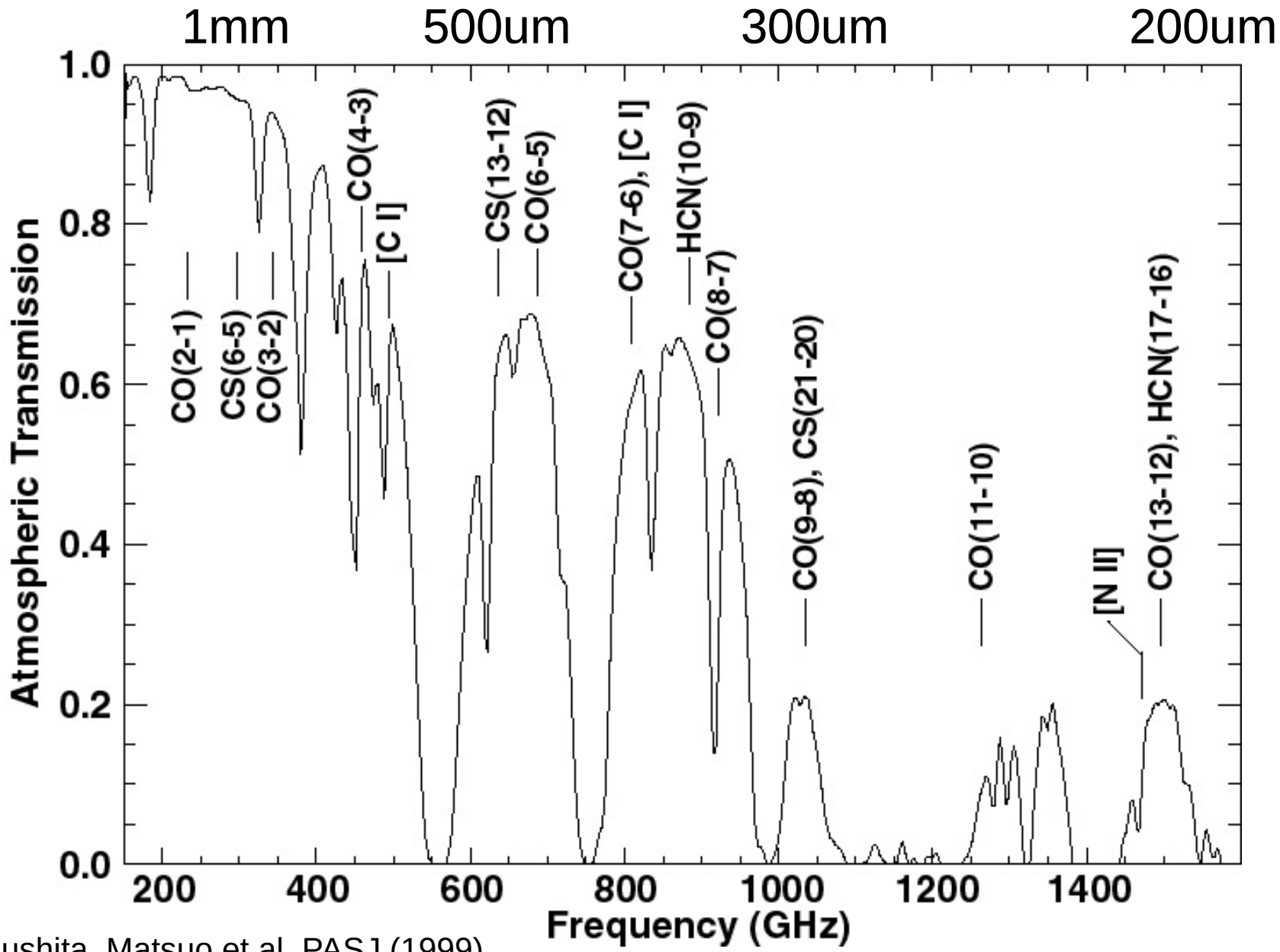






N. Smith 2002

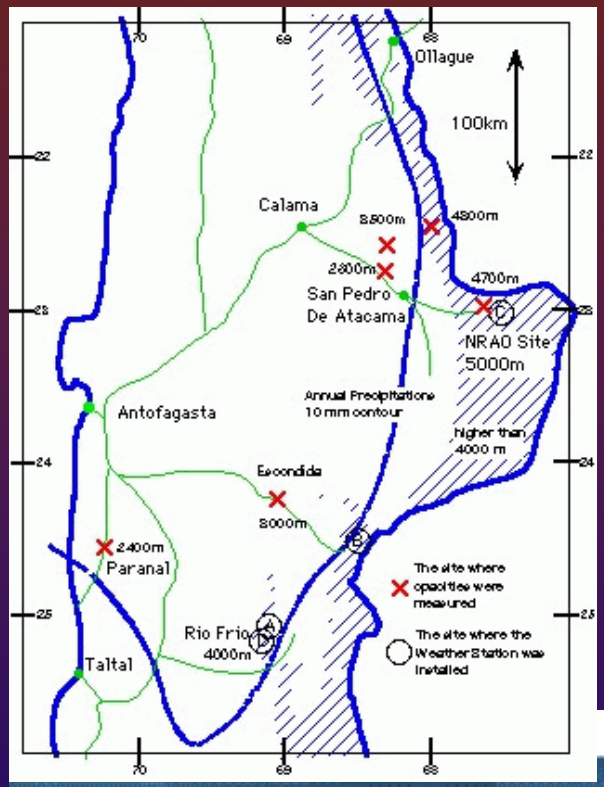
Atmospheric Transmission from Atacama（alt. 4800m）



Matsushita, Matsuo et al. PASJ (1999)

Measurements

Site

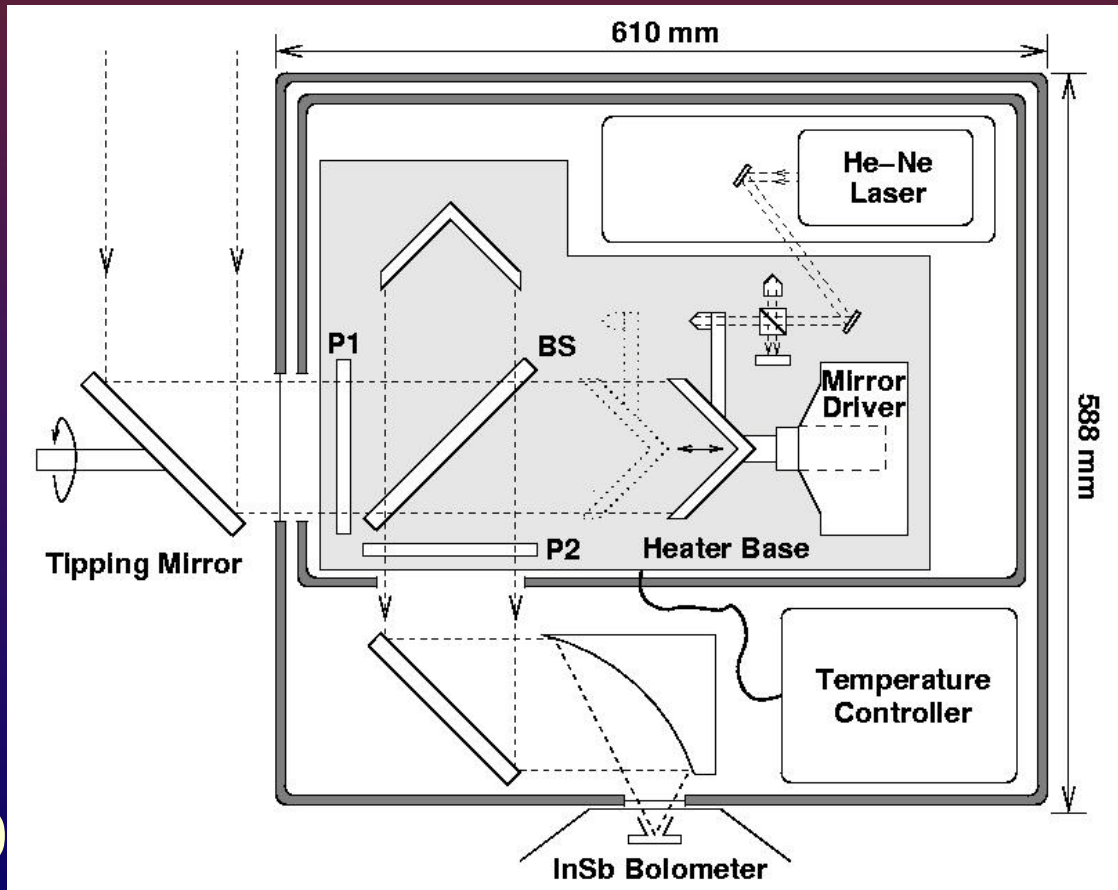


- Pampa la Bola(4800 m)
  - Atacama, Chile
  - 1.5 hr drive from San Pedro de Atacama (2800 m)
  - 7 km from Chajnantor

Measurements

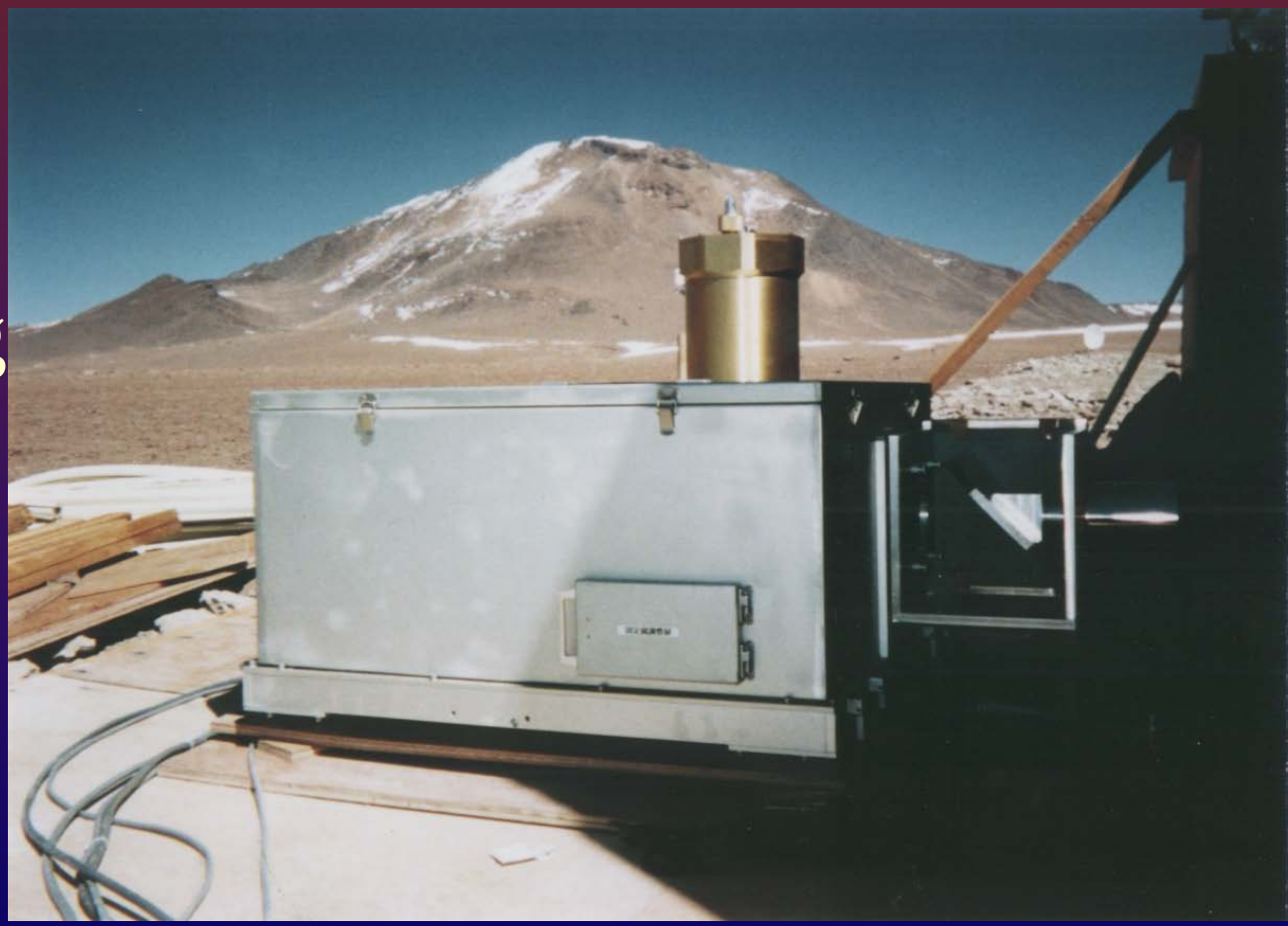
Instrument

- Fourier Transform Spectrometer (Martin-Puplett)
  - Frequency
    - 100 – 1600 GHz
      (3mm – 190μm)
  - Resolution
    - 10 GHz
  - Beam size
    - 10 deg
  - Detector
    - InSb bolometer (3.7 K)



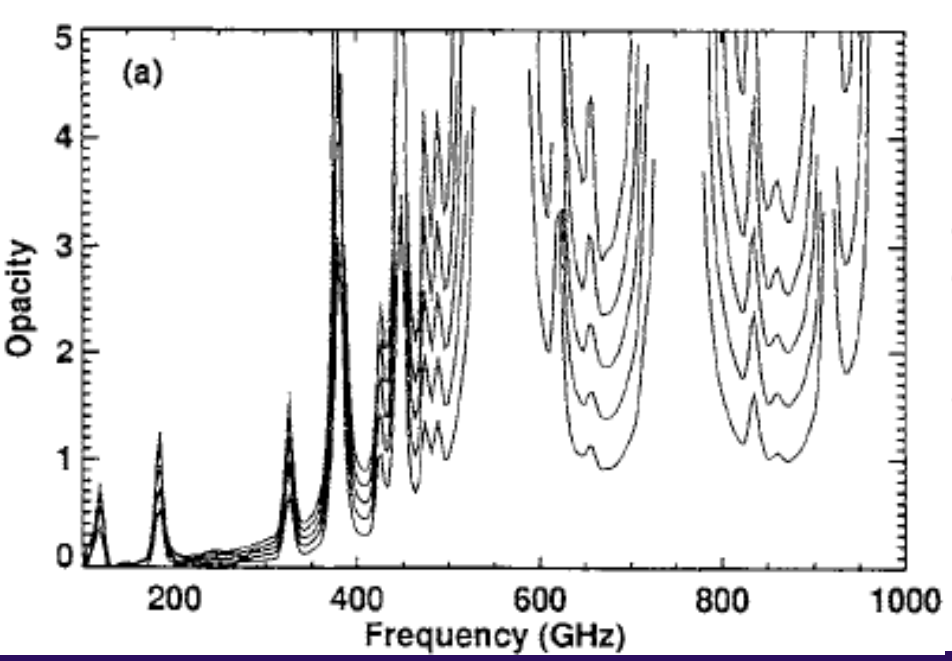
Measurements
Observing

- Period
  - 1997/9/5-12
  - 1998/6/16-18
- 12 min/tipping
- Calibration
  - Eccosorb at Ambient and 73 K



Measurements

Data



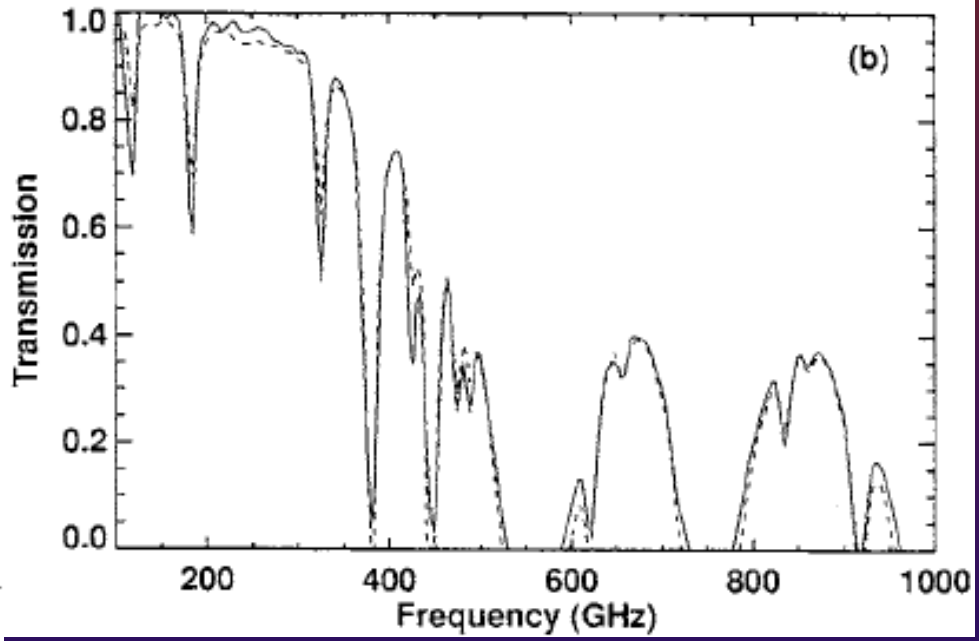
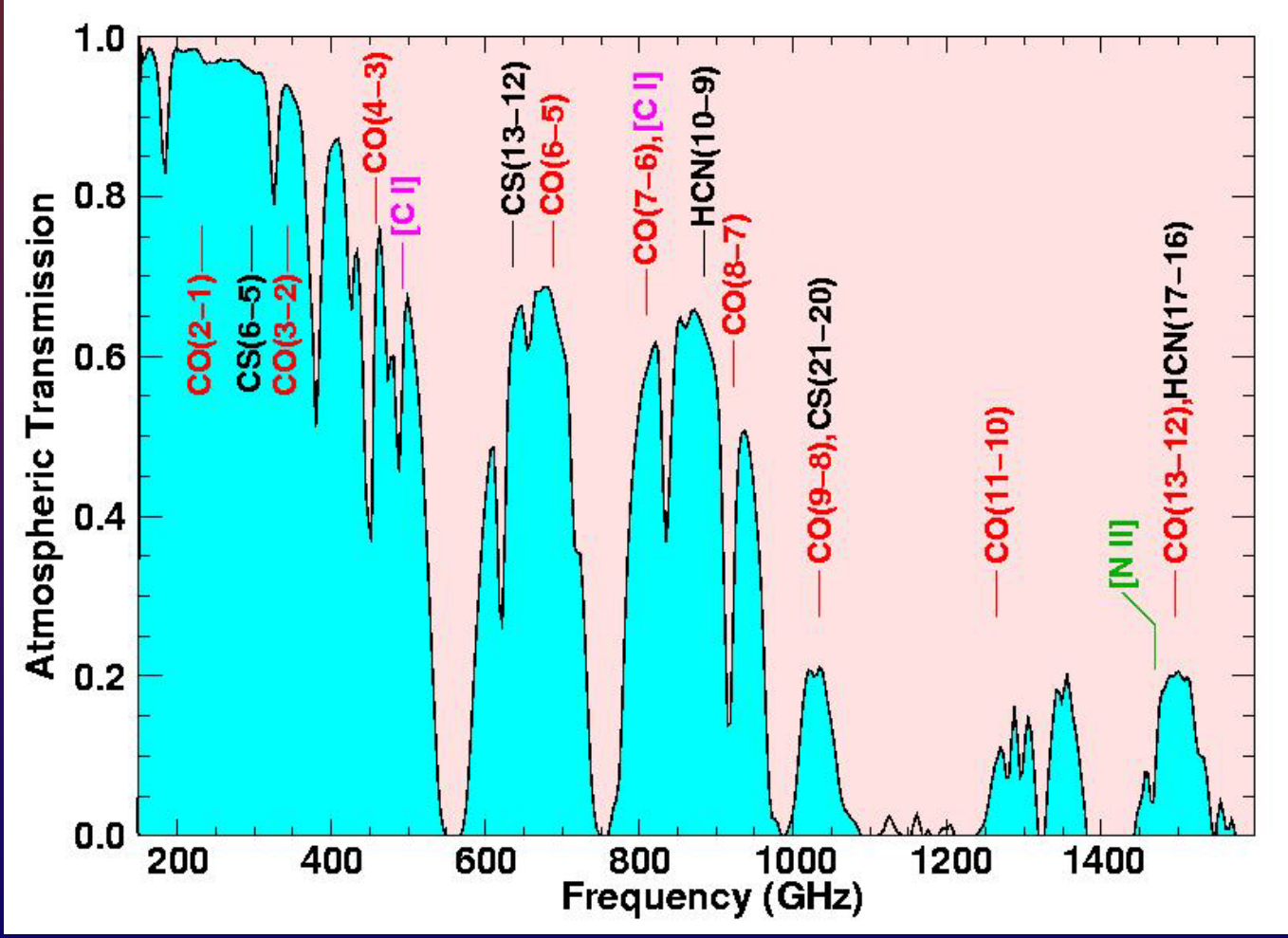


Fig. 2. (a) Atmospheric opacity spectra obtained from temperature measurements at airmasses of 1.0, 1.5, 2.0, 2.5, and 3.0 (from lower to upper curves). (b) Atmospheric transmission spectra obtained from temperature measurement (solid line) and tipping measurement (dashed line). At millimeter-wave frequencies where transmission is higher, tipping measurement is more reliable, whereas in the submillimeter-wave region with lower transmission, temperature measurement is more reliable (see text

Atmospheric Transmission Spectra

The best data

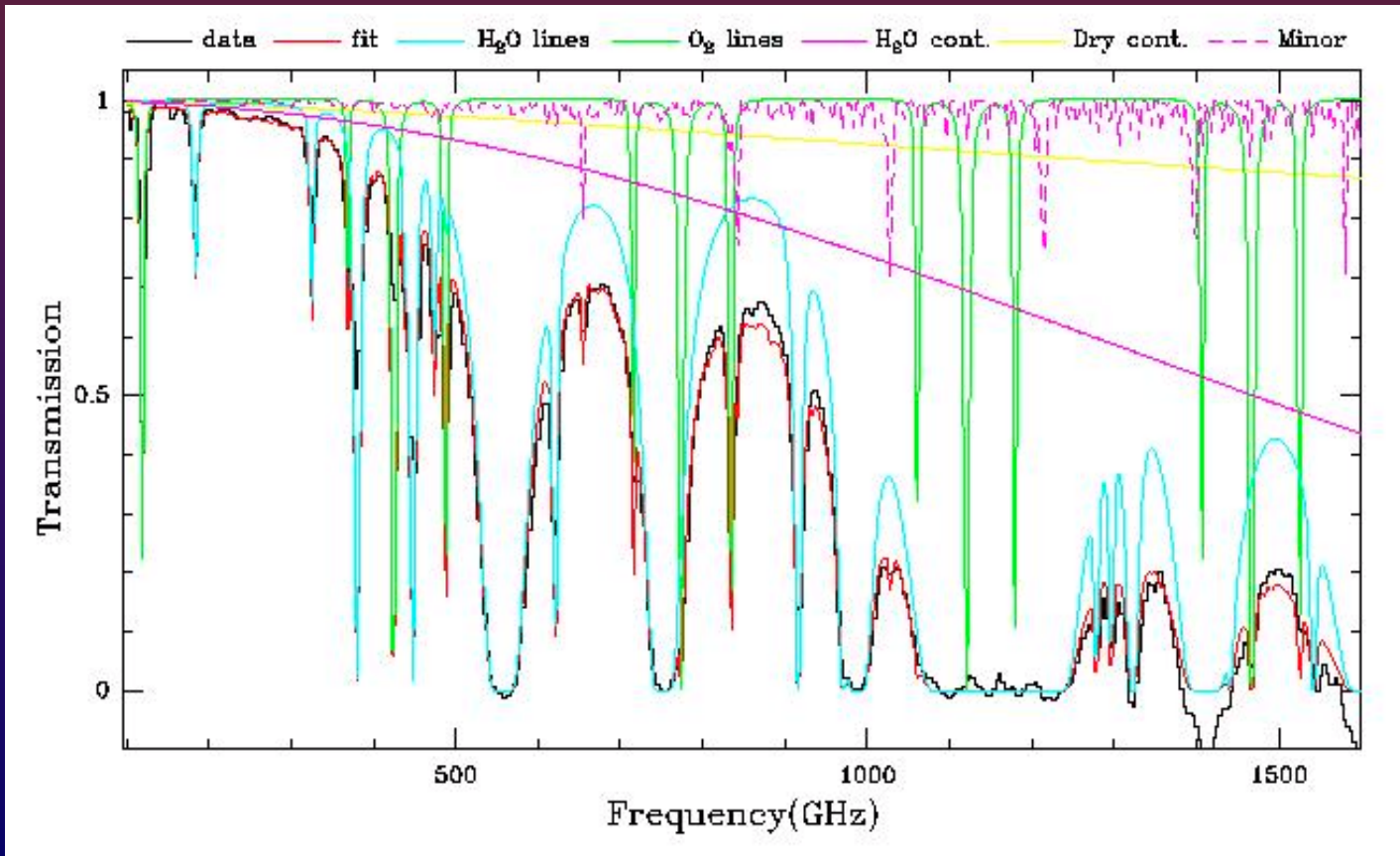
- 220 GHz
  T~ 98 %
  τ~0.016
- 650, 850 GHz
  T~ 67 %
  τ~0.40
- THz windows
  T~ 20 %
  τ~1.6



Atmospheric Transmission Spectra

Model Fit

- ATM (Atmospheric Transmission at Microwaves)
  (Pardo et al., 2001, IEEE Trans. AP.)
- pwv
  ~ 0.284 mm



Atmospheric monitors at ASTE site

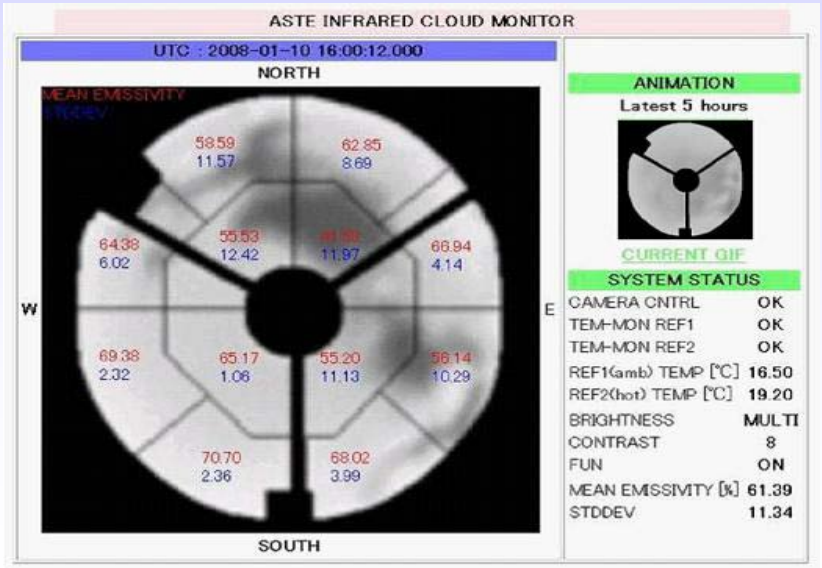
	Frequency	Area	Record every
IR Camera	8-12μm (30THz)	All sky	5 min
Radiometer	220GHz	tipping	1 min
Water line	183GHz	All sky	40 min

雲モニタ

ラジオメータ

水蒸気モニタ

IR Cloud Monitor



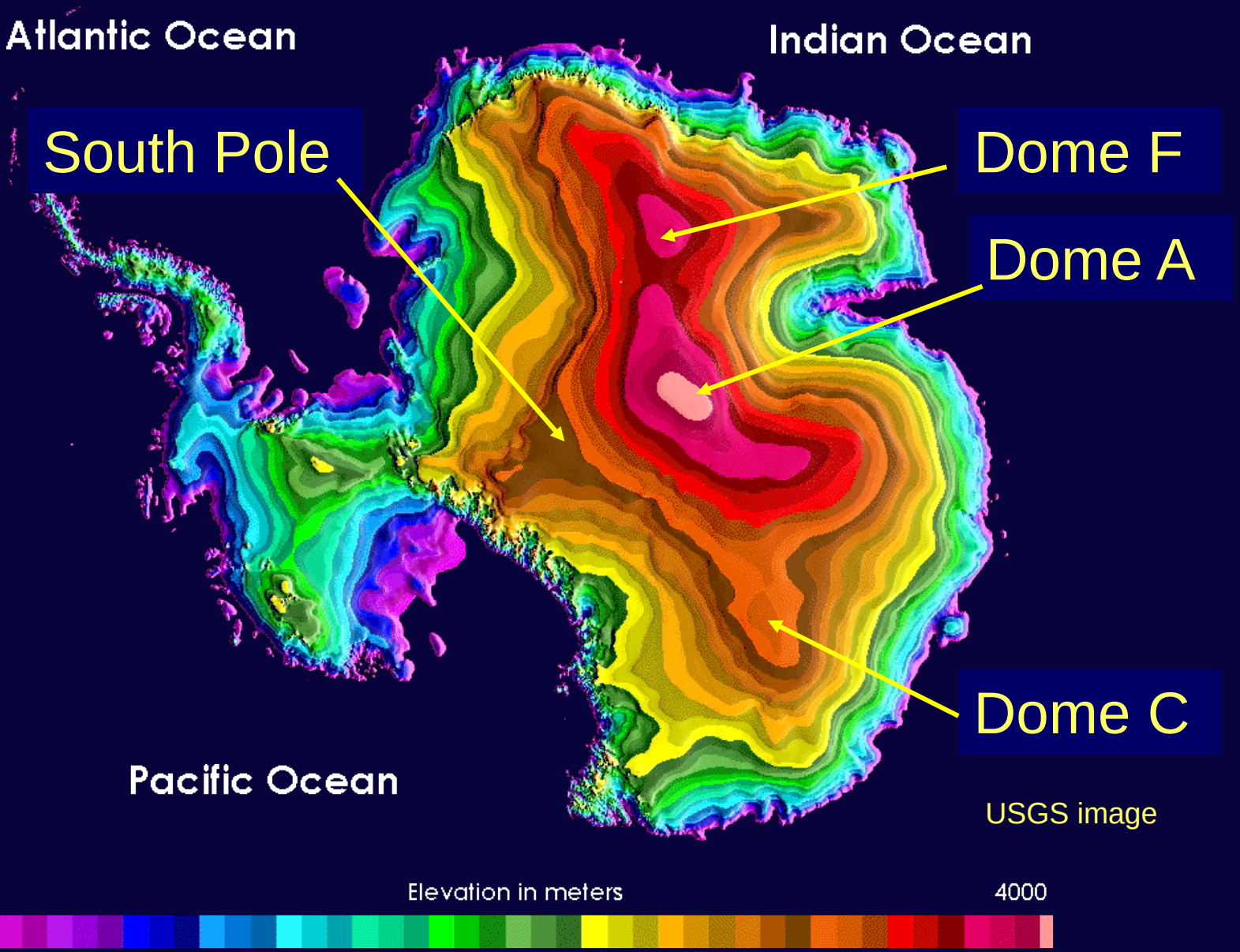
- Wavelength: 8-12 μm
- Sky coverage: 0-70° from zenith
- Recording every 5 min
- Real time monitor of clouds

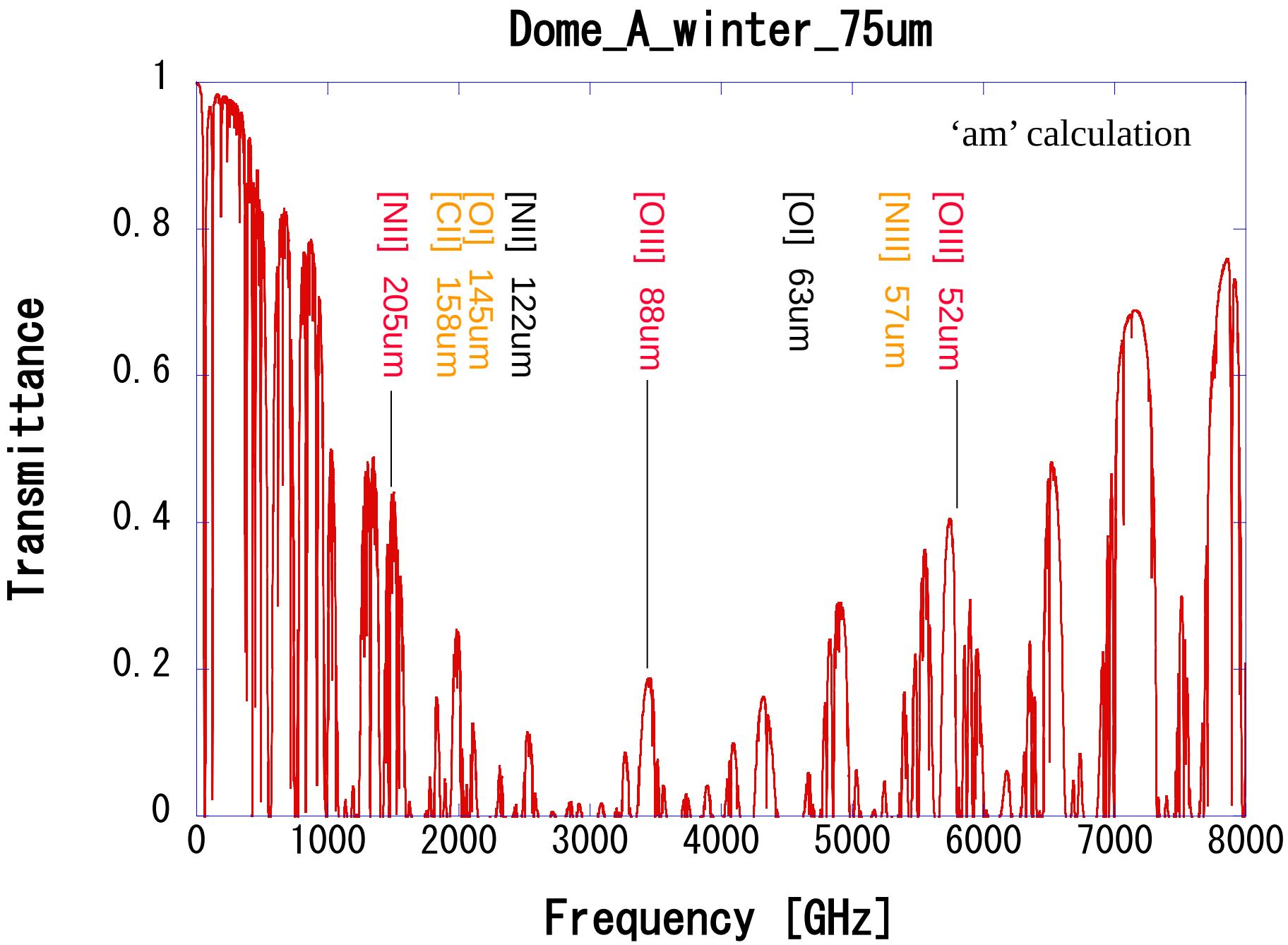
- Quantitative measure of cloud coverage and opacity

- Comparison between radio transparency

Collaboration of
Ibaraki Univ.
Univ. of Tokyo
NAOJ

南極大陸


Atlantic Ocean
Indian Ocean
South Pole
Dome F
Dome A
Dome C
Pacific Ocean
USGS image
0
Elevation in meters
4000


Dome_A_winter_75um
'am' calculation
[NII] 205um
[OI] 145um
[CII] 158um
[NII] 122um
[OIII] 88um
[OI] 63um
[NIII] 57um
[OIII] 52um
Transmittance
Frequency [GHz]
0
0.2
0.4
0.6
0.8
1
0
1000
2000
3000
4000
5000
6000
7000
8000

FIR atomic fine structure lines

			good	median
OI				
– 63.185μm	4.745THz	×	0%	0%
– 145.54μm	2.060THz	△	4%	0%
OIII				
– 51.815μm	5.786THz	○	15%	1.5%
– 88.356μm	3.393THz	○	12%	1.5%
NII				
– 121.80μm	2.461THz	×	0%	0%
– 205.30μm	1.460THz	○	35%	15%
NIII				
– 57.330μm	5.229THz	△	2%	0%
CII				
– 157.68μm	1.901THz	△	3%	0%

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– 157.68μm	1.901THz	△	3%	0%

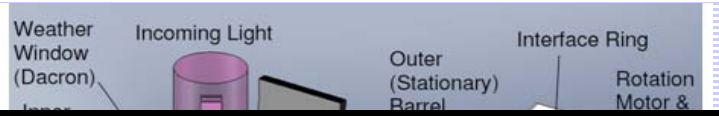
A THz FTS for Site Testing at Dome A

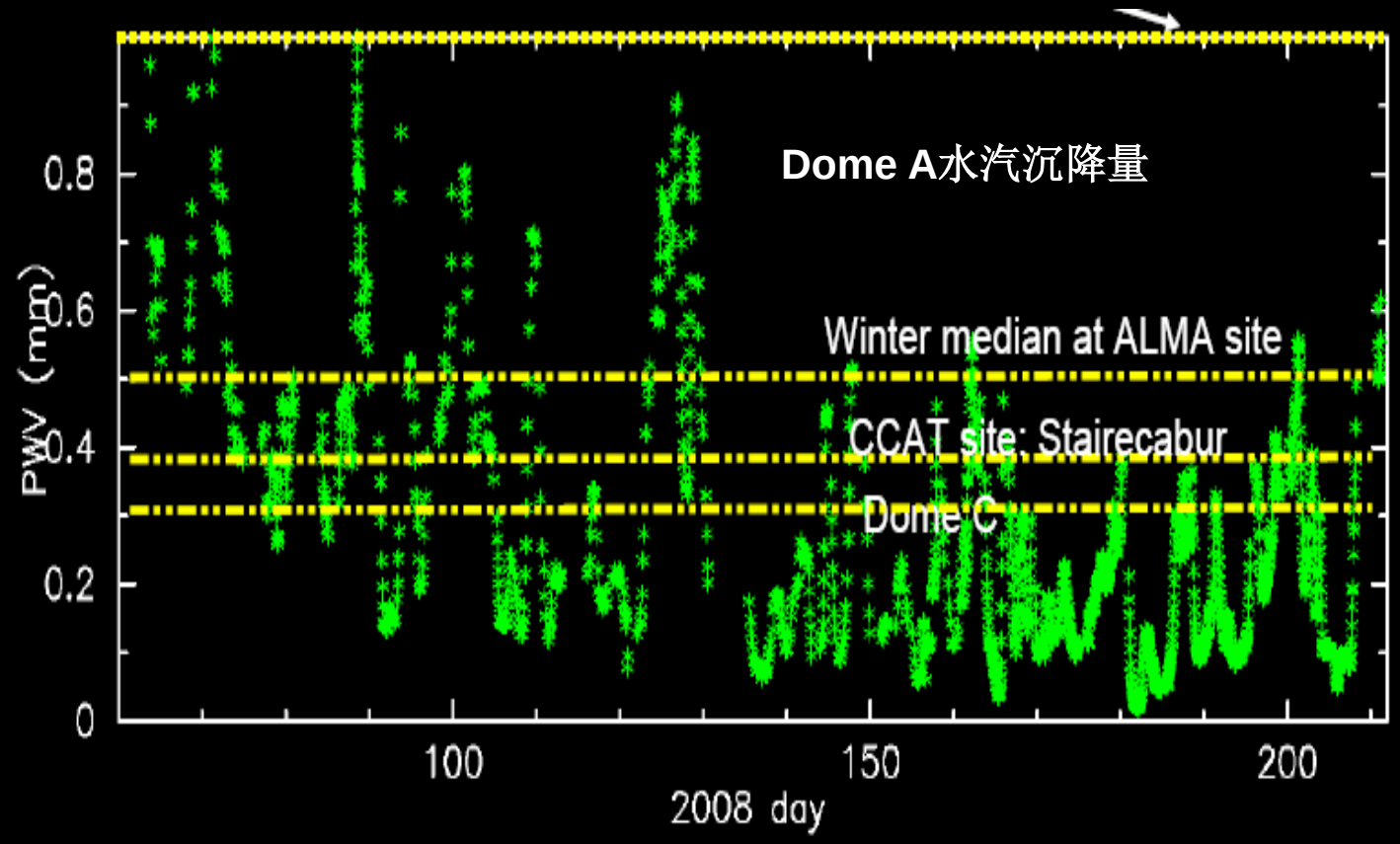
Sheng-Cai Shi[1]

S. Paine[2], Q.J. Yao[1], X.X. Li[1], X.G. Zhang[1], Z.H. Lin[1], K.M. Zhou[1], Q.G. Huang[1], H. Matsuo[3], J. Yang[1], Q.Z. Zhang[2]

A collaboration between PMO[1] and CfA[2]

Pre-HEAT
(High Elevation Antarctic THz Telescope)





SMA (25%)

ALMA (win. median)

CCAT

DomeC

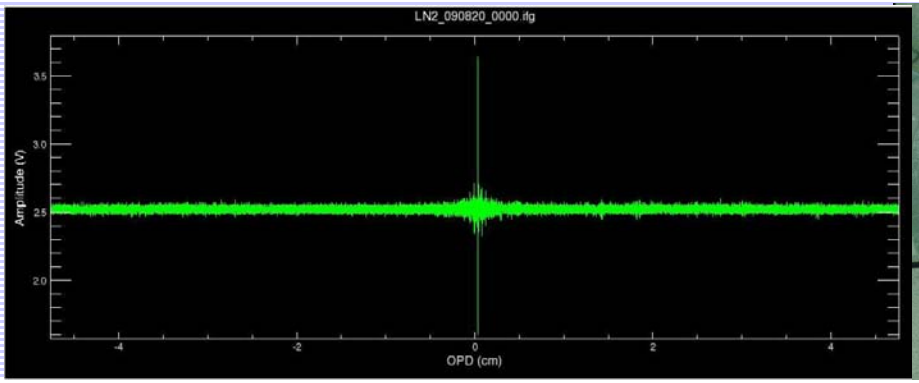
Challenges of Dome A FTS

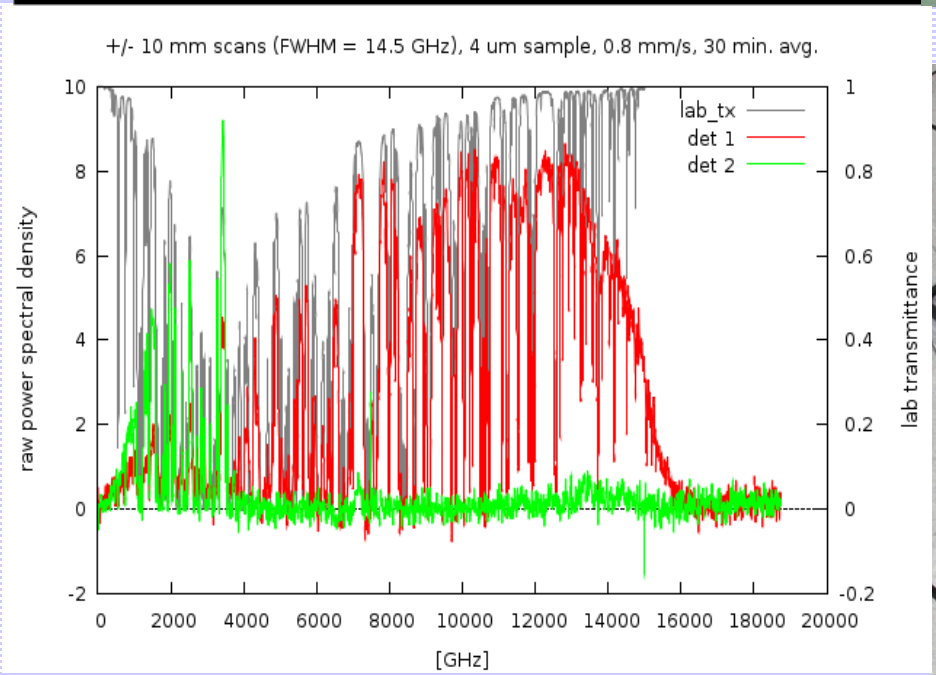
- unattended & long-duration (~1yr) operation
  - Largest bandwidth to cover THz/FIR windows
- Cryogenically cooled detectors cannot be used → *limited detection sensitivity*
- LN_2 not available → *no low-temp calibration*

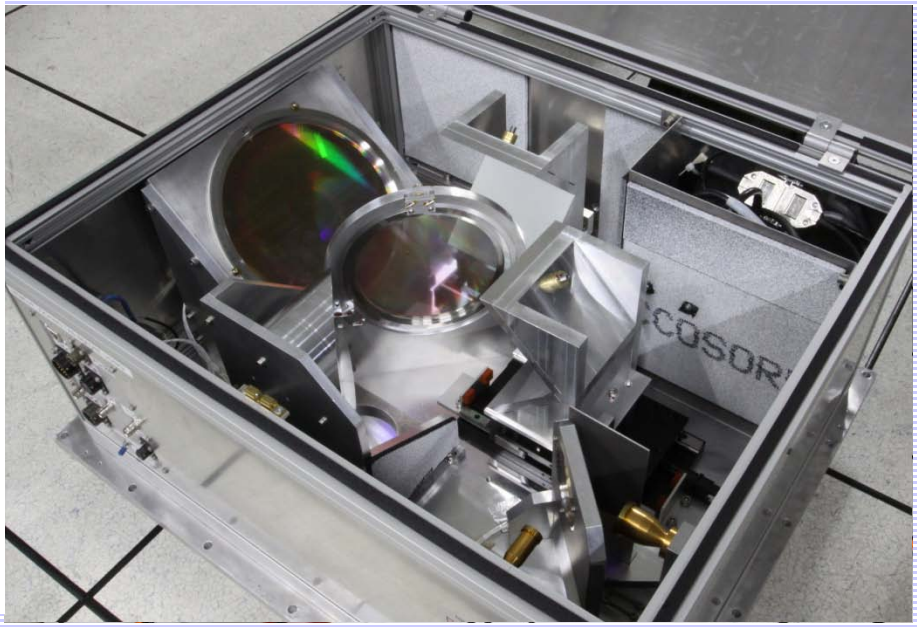
System Specs for Dome A FTS

Mode	rapid scan
Freq. Range	0.75-15THz (LB: 0.75-3.5THz, HB: 0.75-15THz)
Freq. Resolution	~10GHz
Beam Aperture	>75mm
Detector (DLATGS) NEP	~10^{-10}W/$Hz^{0.5}$
Time/Spectrum	10mins
MPI Volume	0.7mx0.7mx0.3m
Power	<200W

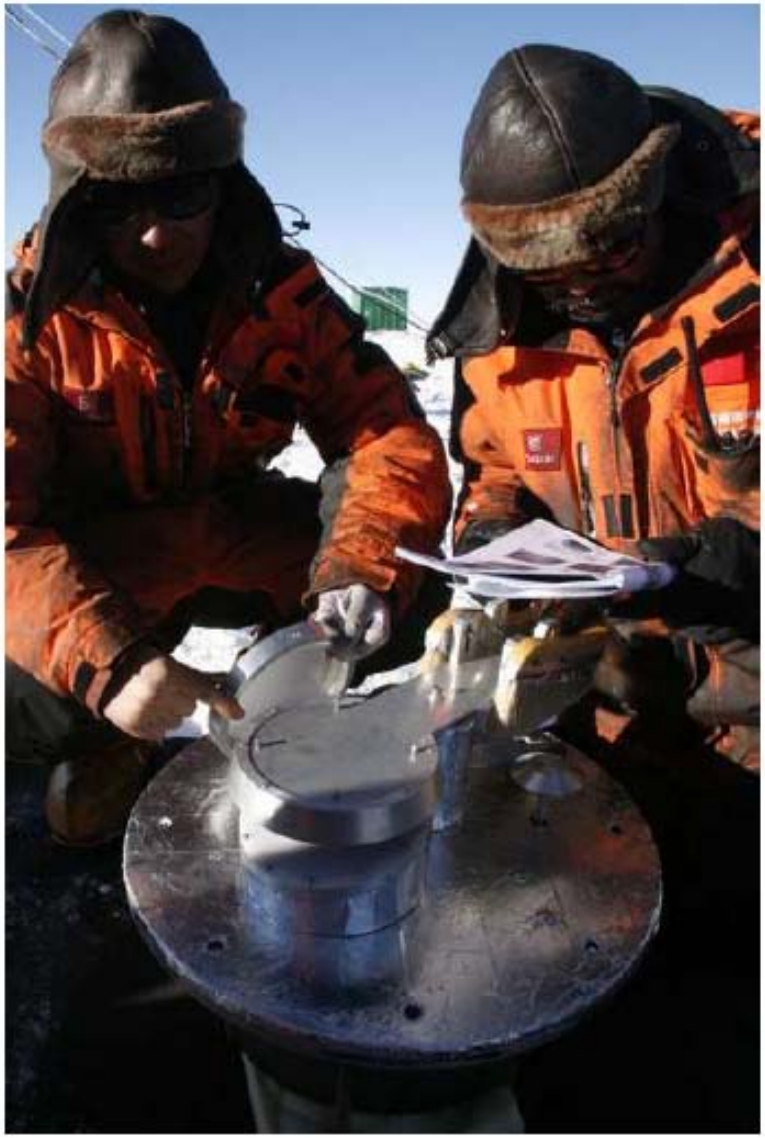
Dome A FTS


LN2_090820_0000.ifg
Amplitude (V)
OPD (cm)


+/- 10 mm scans (FWHM = 14.5 GHz), 4 um sample, 0.8 mm/s, 30 min. avg.
lab_tx
det 1
det 2
raw power spectral density
lab transmittance
[GHz]



Dome A FTS @ Dome A



Dome A FTS: Remote Monitoring

FTS status

Time of this report:

Sun Mar 21 06:01:40 UTC 2010

FTS time:

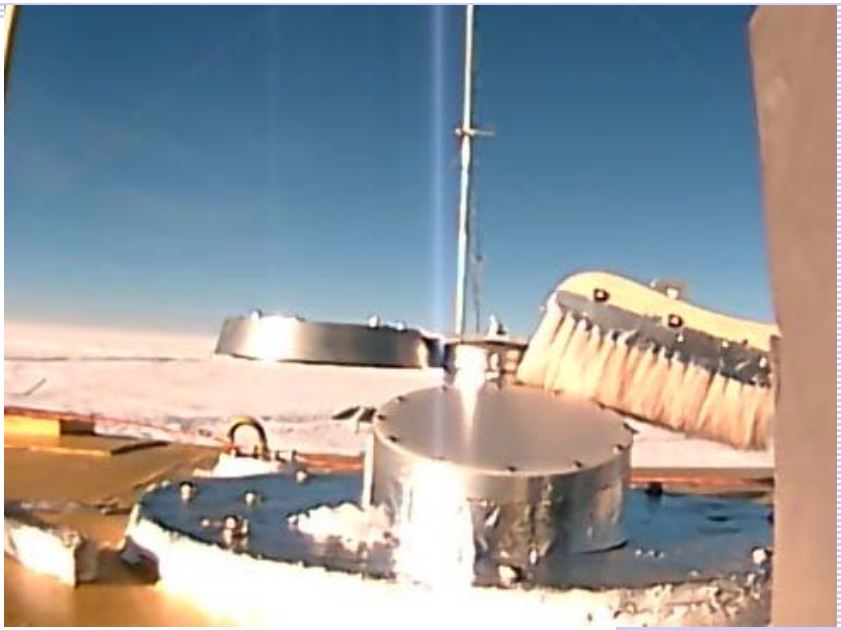
Sun Mar 21 05:51:49 UTC 2010

Most recent files in /var:

```
-rw-r--r-- 1 root root 100331 Mar 21 05:50 FTS_in_progress.igm
-rw-r--r-- 1 root root 200323 Mar 21 05:45 FTS_done.igm
drwxrwxrwt 4 root root 220 Mar 21 00:00 tmp
drwxrwxrwx 2 root root 160 Mar 20 23:30 upload
```

Data files within the last 2 hours:

```
1622043 200 -rw-r--r-- 1 root root 200323 Mar 21 03:56 ./Mar/21/2010Mar21_034728.igm
1622044 200 -rw-r--r-- 1 root root 200323 Mar 21 04:05 ./Mar/21/2010Mar21_035634.igm
1622045 200 -rw-r--r-- 1 root root 200323 Mar 21 04:14 ./Mar/21/2010Mar21_040539.igm
1622046 200 -rw-r--r-- 1 root root 200323 Mar 21 04:23 ./Mar/21/2010Mar21_041444.igm
```



5m THz Telescope — DATE5

Precedent to Space Program

	5m	Herschel
Resolution	higher	lower
Duration	long	limited
Upgrade	y	n
Cost	lower	higher

Complement to ALMA/CCAT

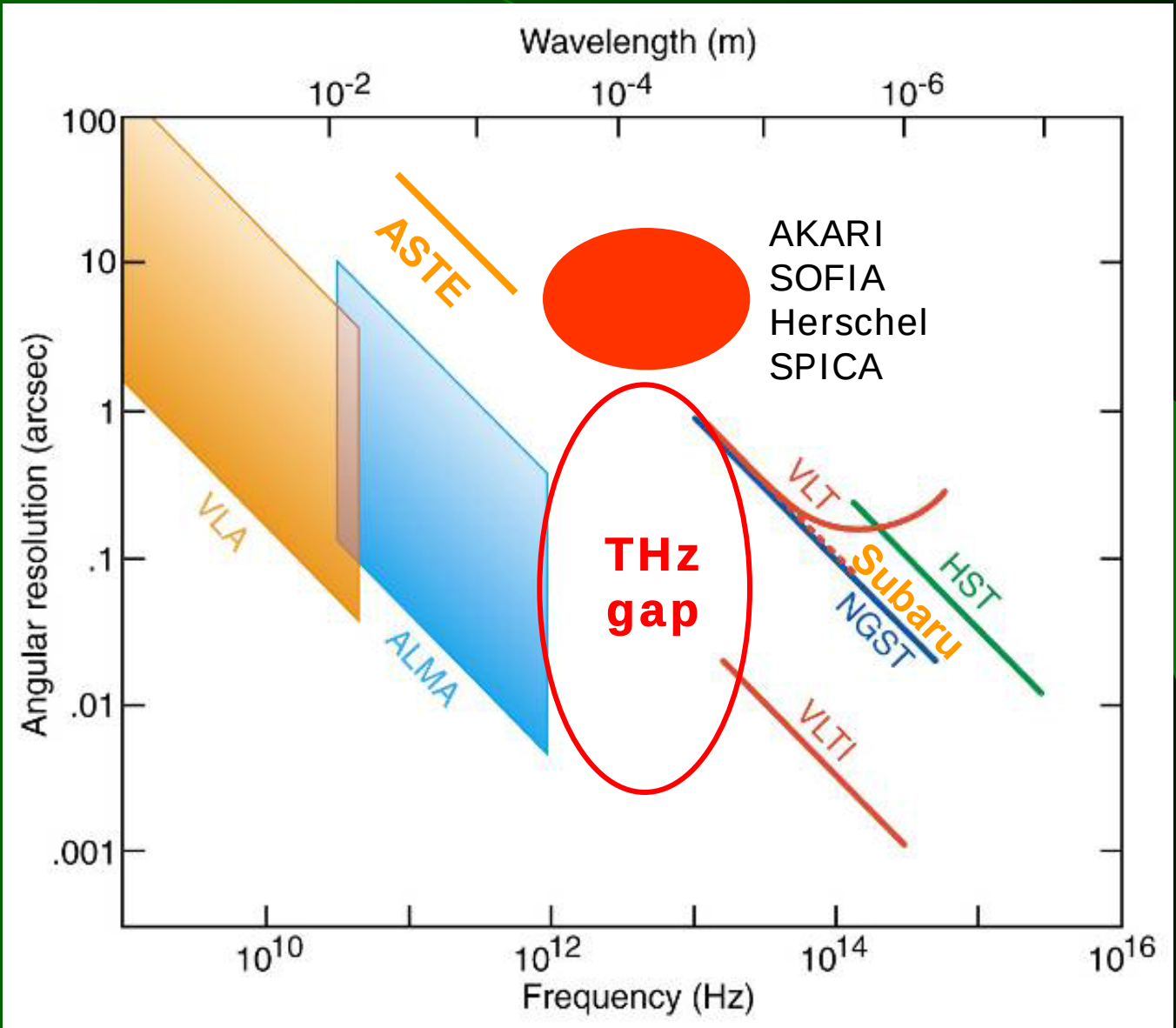
	Dome A 5m	ALMA/CCAT
Frequency (<350μm)	y	n
FoV	wide	Narrow/wide

- **Band 1: 0.9THz**
  0.78-0.9THz,
  CO (J=7-6) & CI ($^3P_2$-$^3P_1$)
  SIS混频器（Nb/ NbTiN ）
- **Band 2: 1.3THz**
  1.25-1.45THz
  high-J *CO*, H_2D^+，N^+
  SIS混频器（NbN）或
  HEB混频器
- **Low-power consumption 4K cryocooler**
  小型低功耗循环制冷机
  Cartridge型接收机

Summary of DomeA FTS

- A THz FTS system running in unmanned mode has been developed for the site survey at Dome A
- The Dome A FTS covers a large bandwidth and operates with room-temperature detectors
- The Dome A FTS started to operate from early Feb 2010 and has been in good condition since then
- Preliminary results are rather promising, detailed results will come out

THz Gap of Spatial Resolution

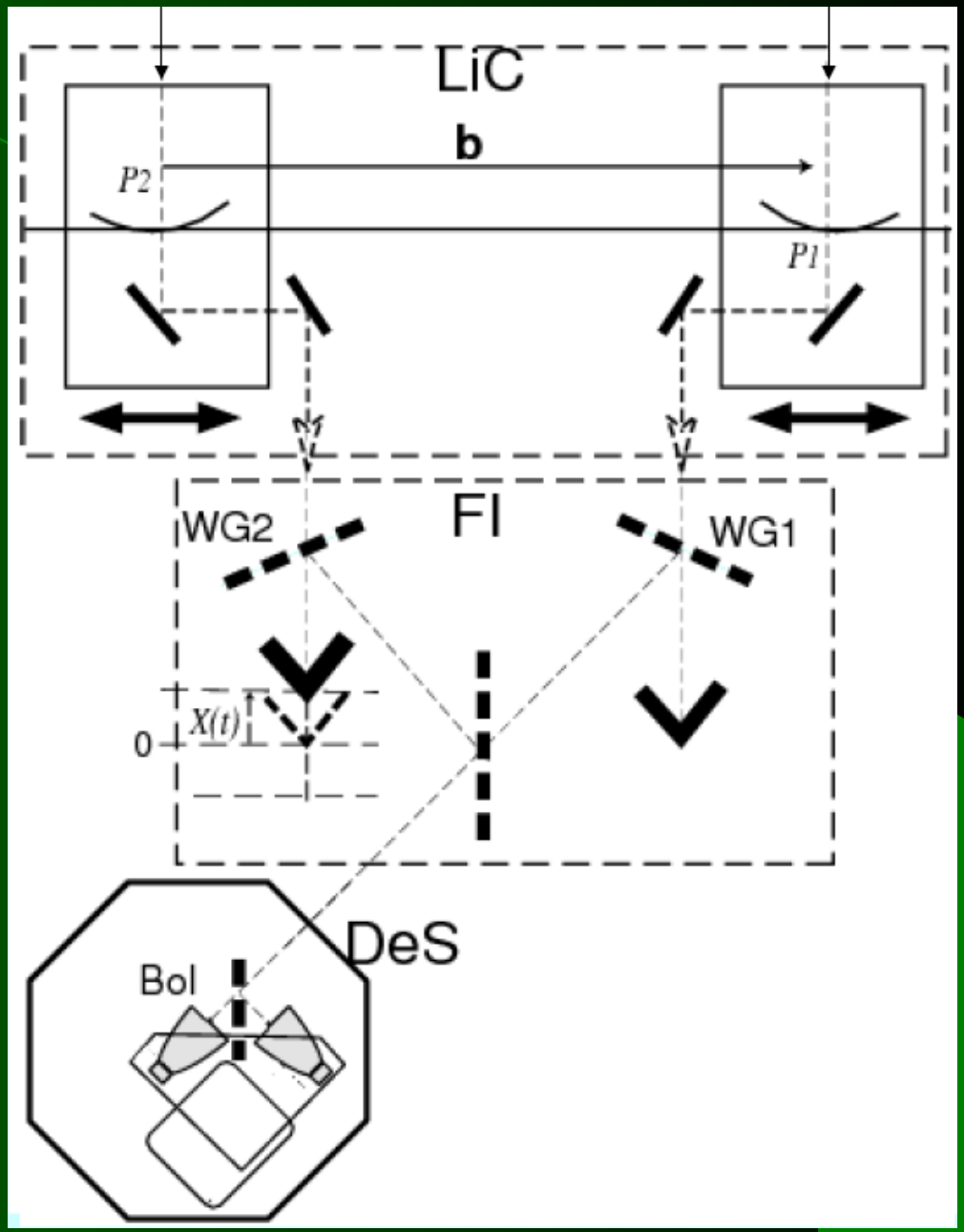


Original from W.Wild

MuFT

Multi-Fourier Transform interferometer

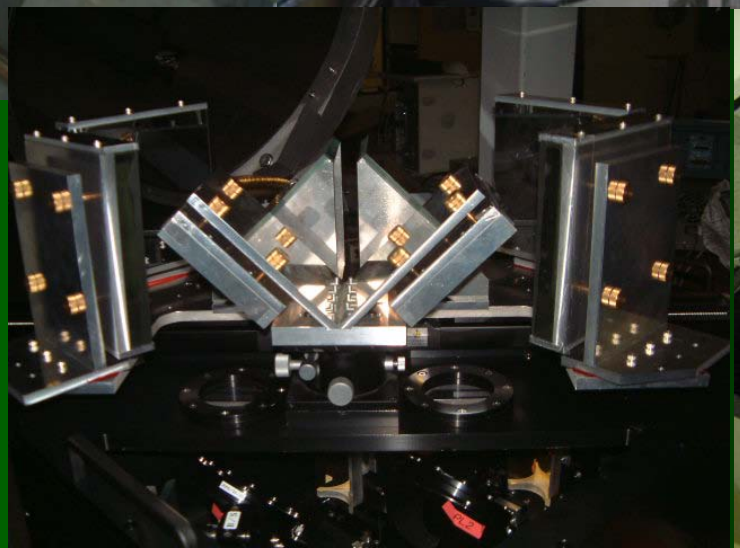
- High Dynamic Range
- Imaging Spectrometer
- Polarizing beam combiner



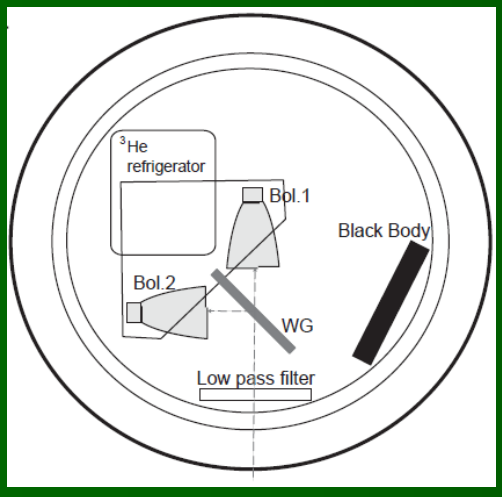
Ohta et al. Appl. Opt. 45, 2576 (2006)

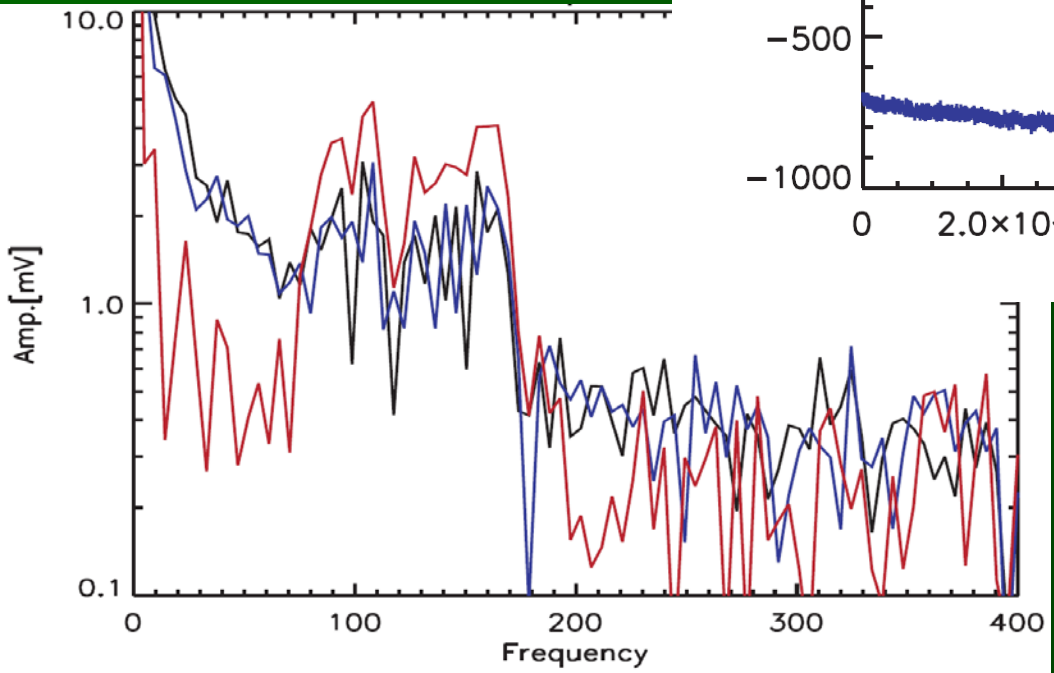
Ohta et al. Appl. Opt. 46, 2881 (2007)

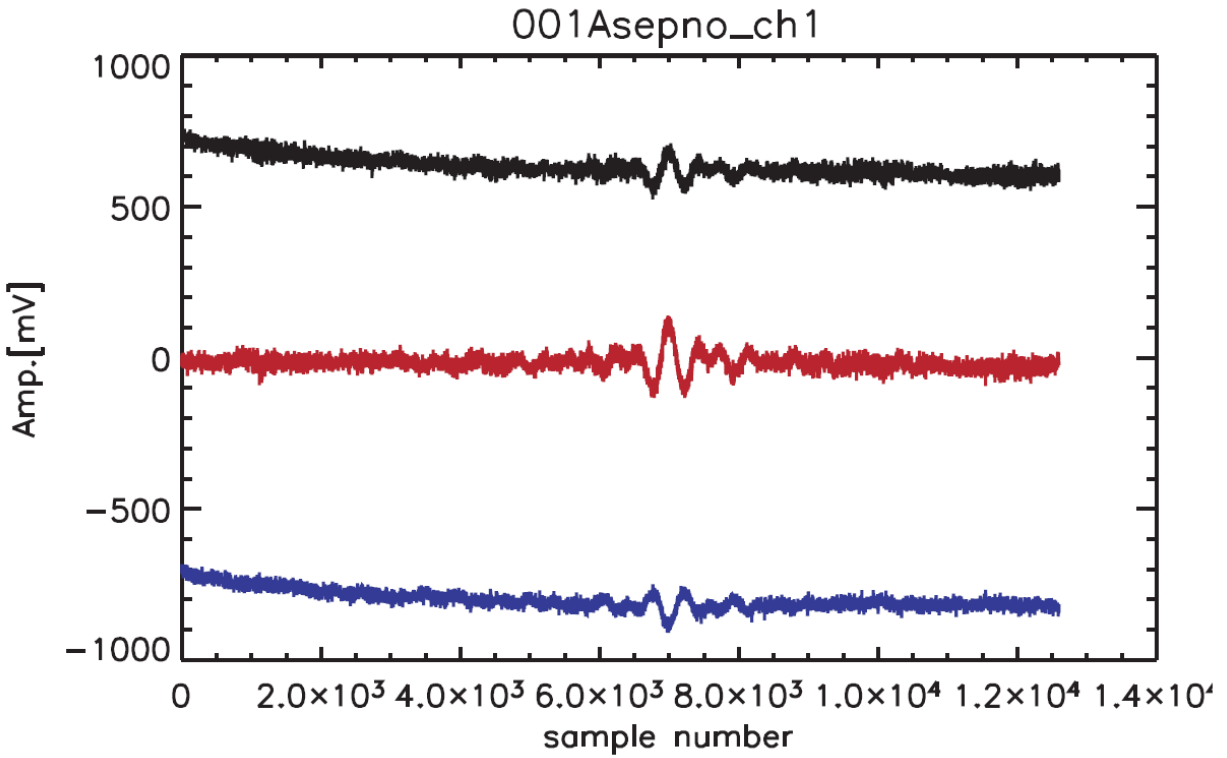
MuFT and
Heliostat
in Nobeyama
2005



Subtraction of two output ports gives cross correlated interferogram







Low frequency noise is reduced appreciably

Ohta et al. IRMMW-THz2007
Y. Luo et al. GSMM (2008)

MuFT image of the sun

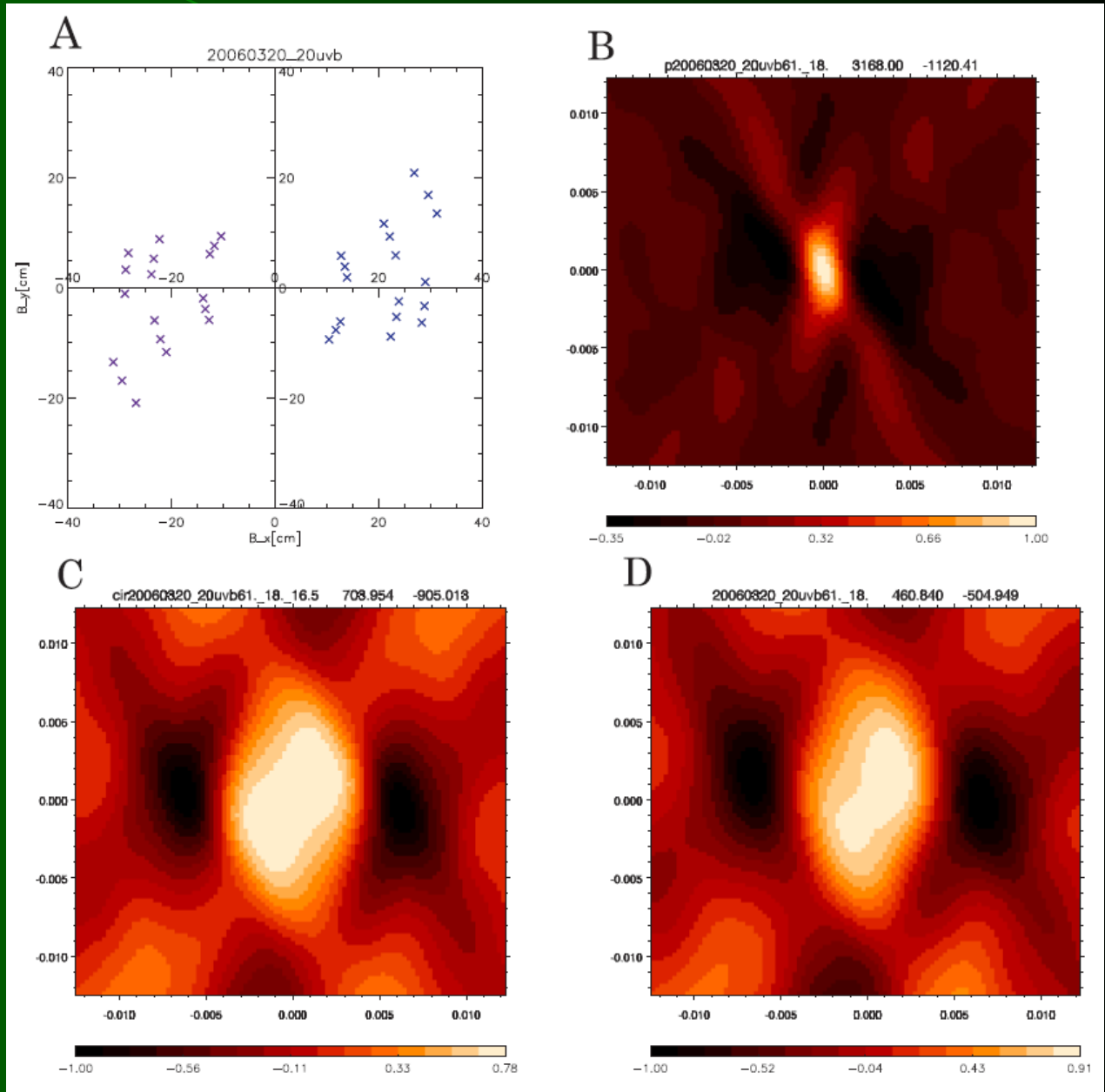
A. baselines sampled

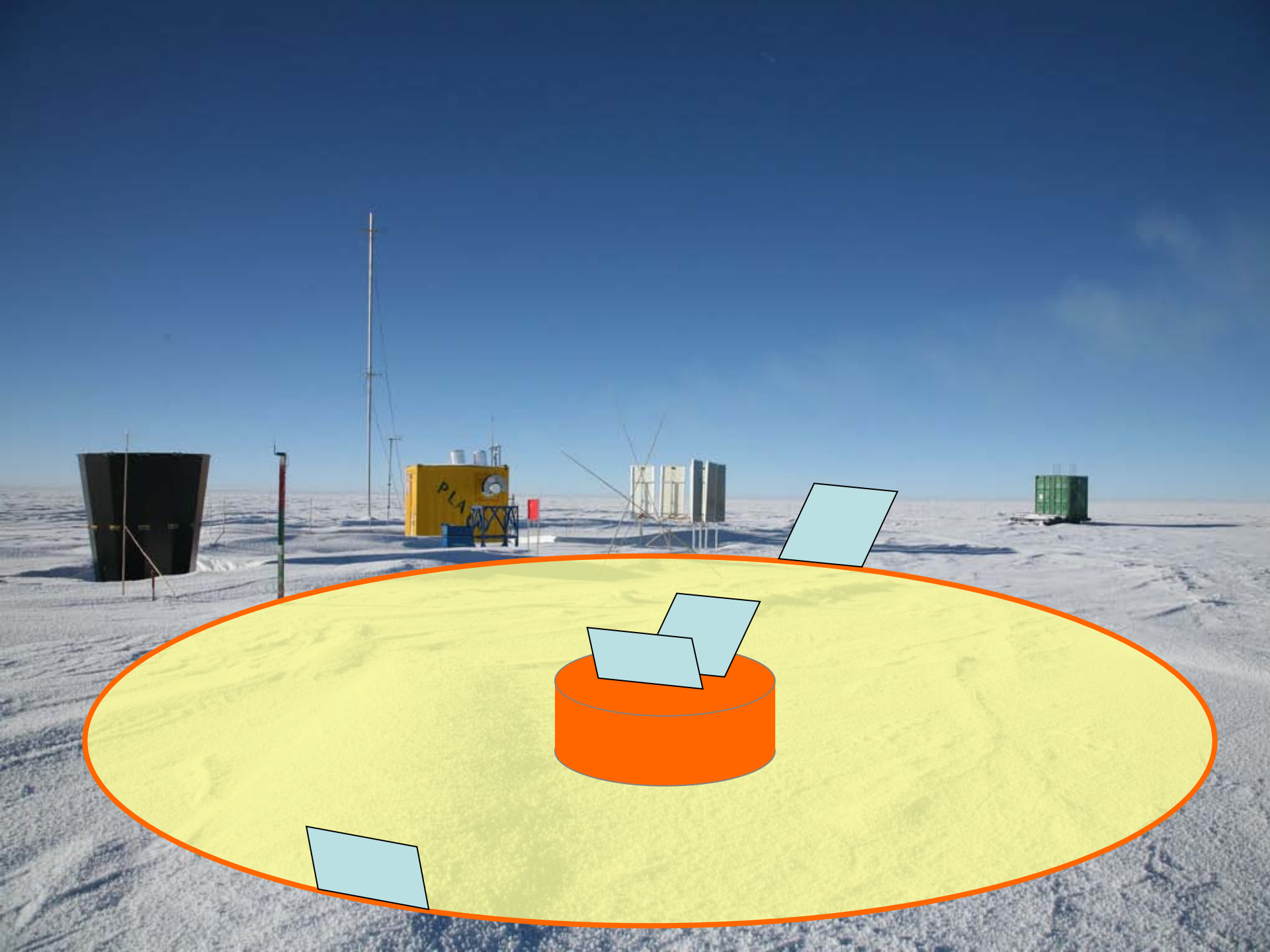
B. synthesized beam

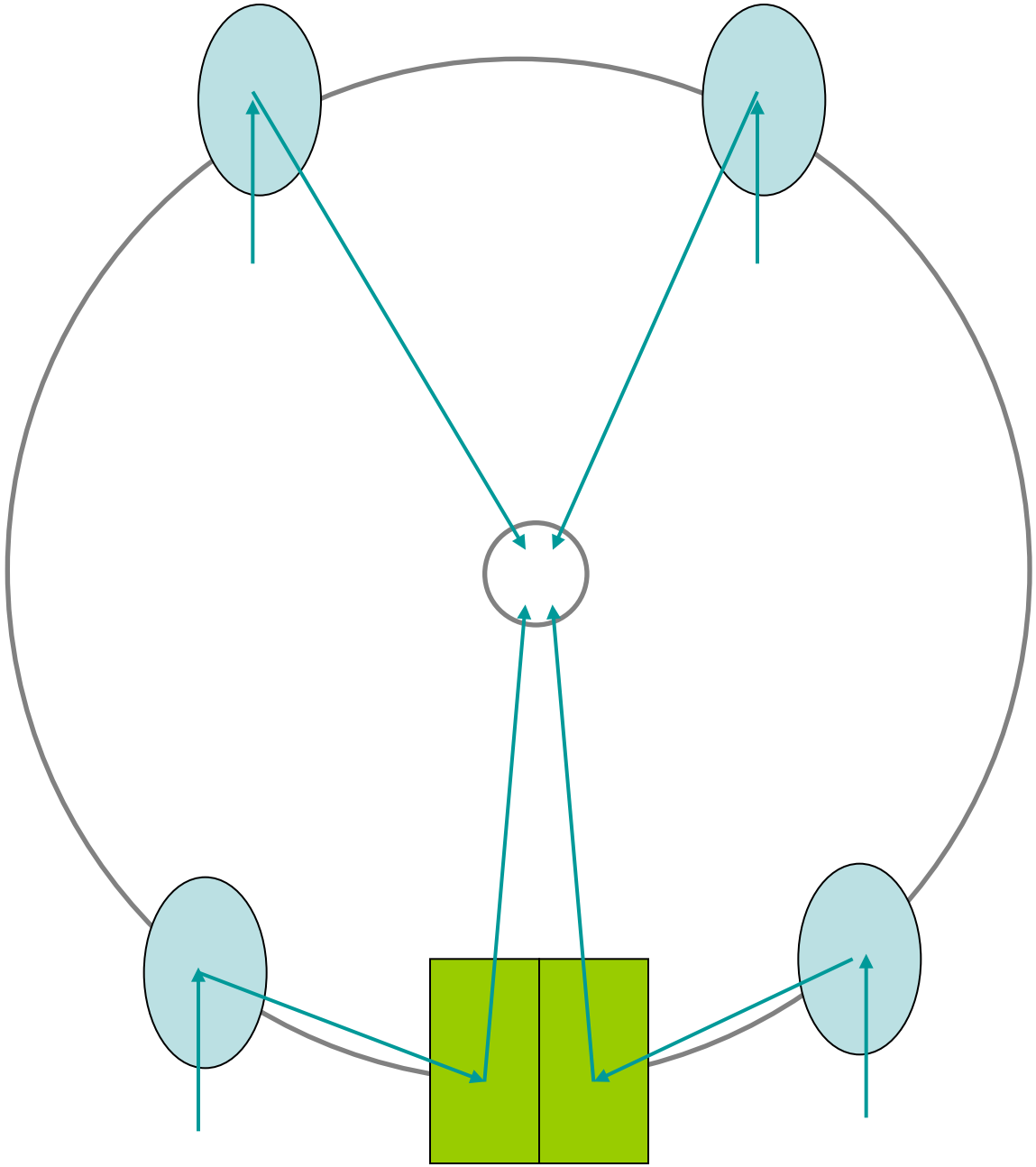
C. simulated image

D. observed image

Ohta et al.
IRMMW-THz2007







Summary

- THz Astronomy
- Atacama FTS
- IR cloud monitor
- Antarctica DomeA FTS
- THz interferometry in Antarctica