Antarctic 10-m Terahertz Telescope Project

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and Antarctic astronomy consortium

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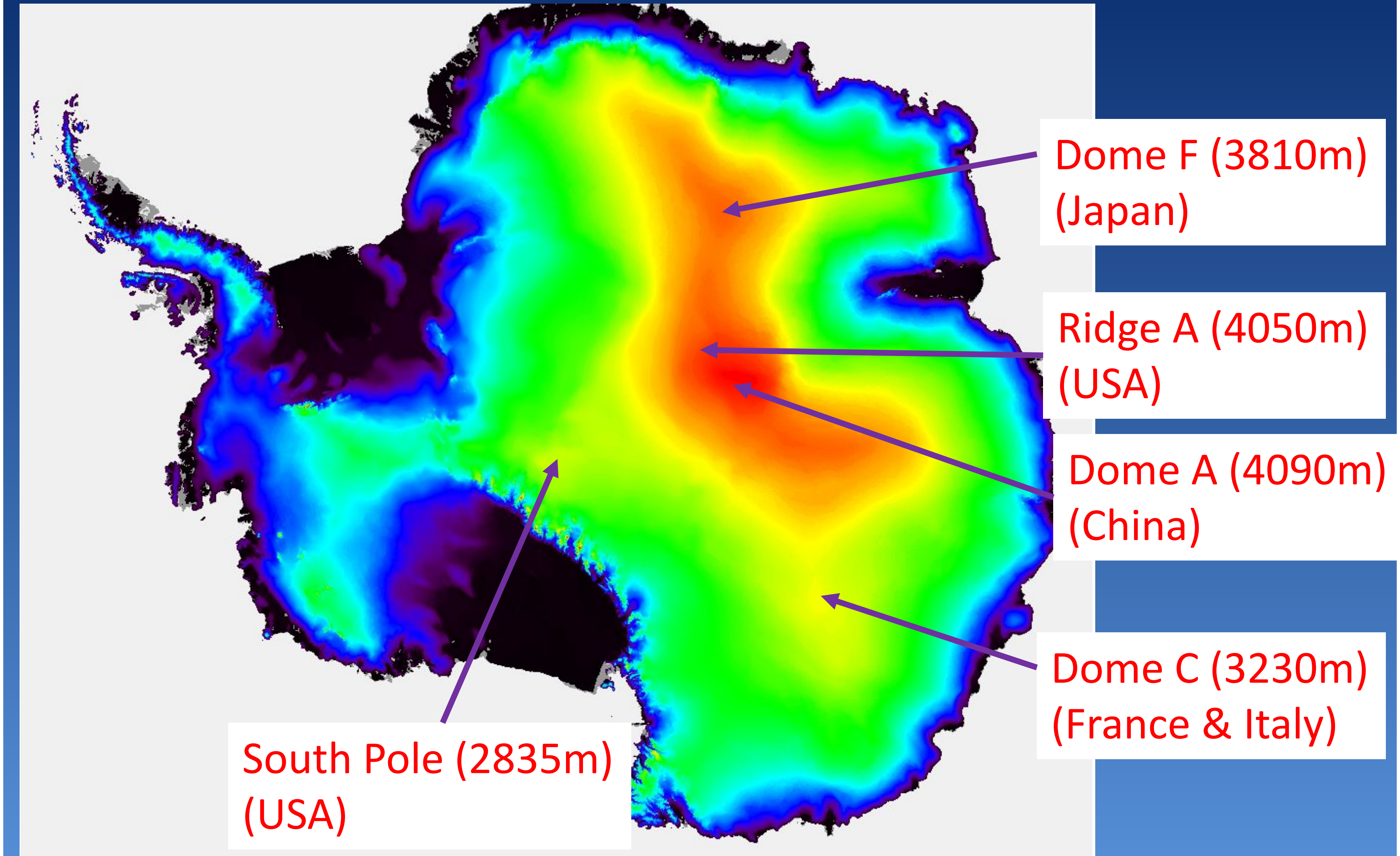
Outline

1. Astronomy from Antarctica
2. Antarctic 10-m Terahertz Telescope Project
   - 2.1 Science targets
   - 2.2 Specifications of 10-m telescope
   - 2.3 Schedule


1. Astronomy from Antarctica

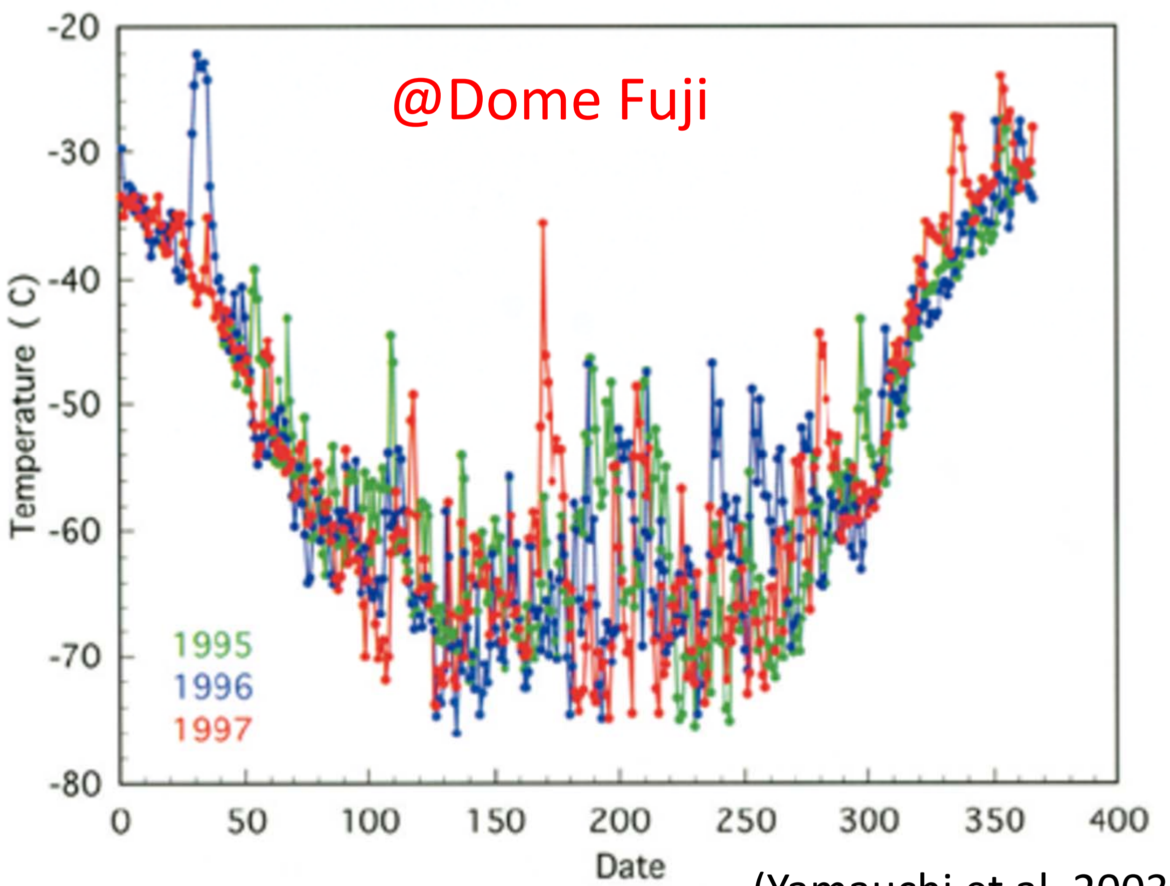
Plateau of Antarctica (>3000m)

⇒ Good place for astronomical observations



Advantages of Antarctica for Astronomy (1)

- Temperature is lowest on Earth



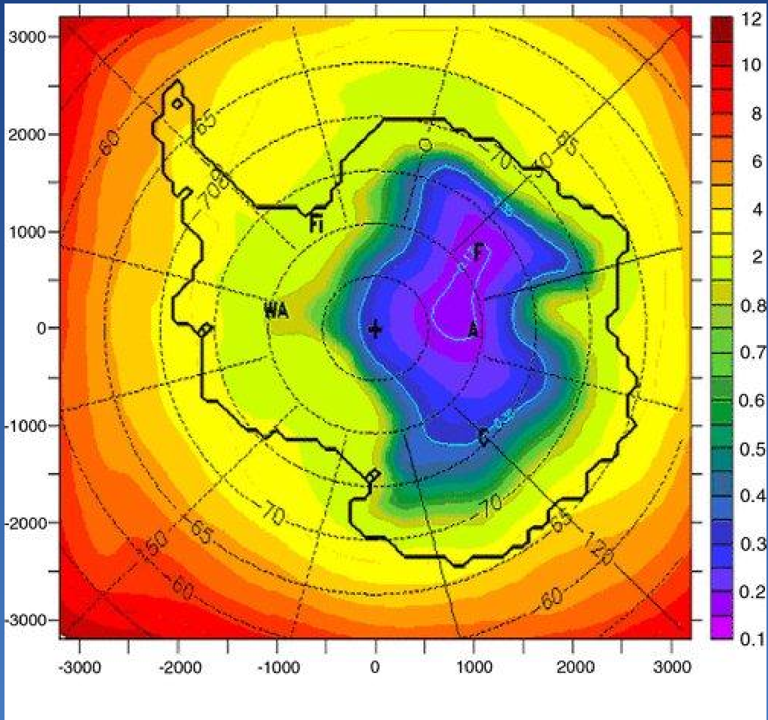
(Yamauchi et al. 2003)

⇒ Infrared sky background is lowest (2.2-30μm)

Advantages of Antarctica for Astronomy (2)

- Temperature is lowest on Earth

  ⇒ Precipitable water vapor (PWV) is lowest

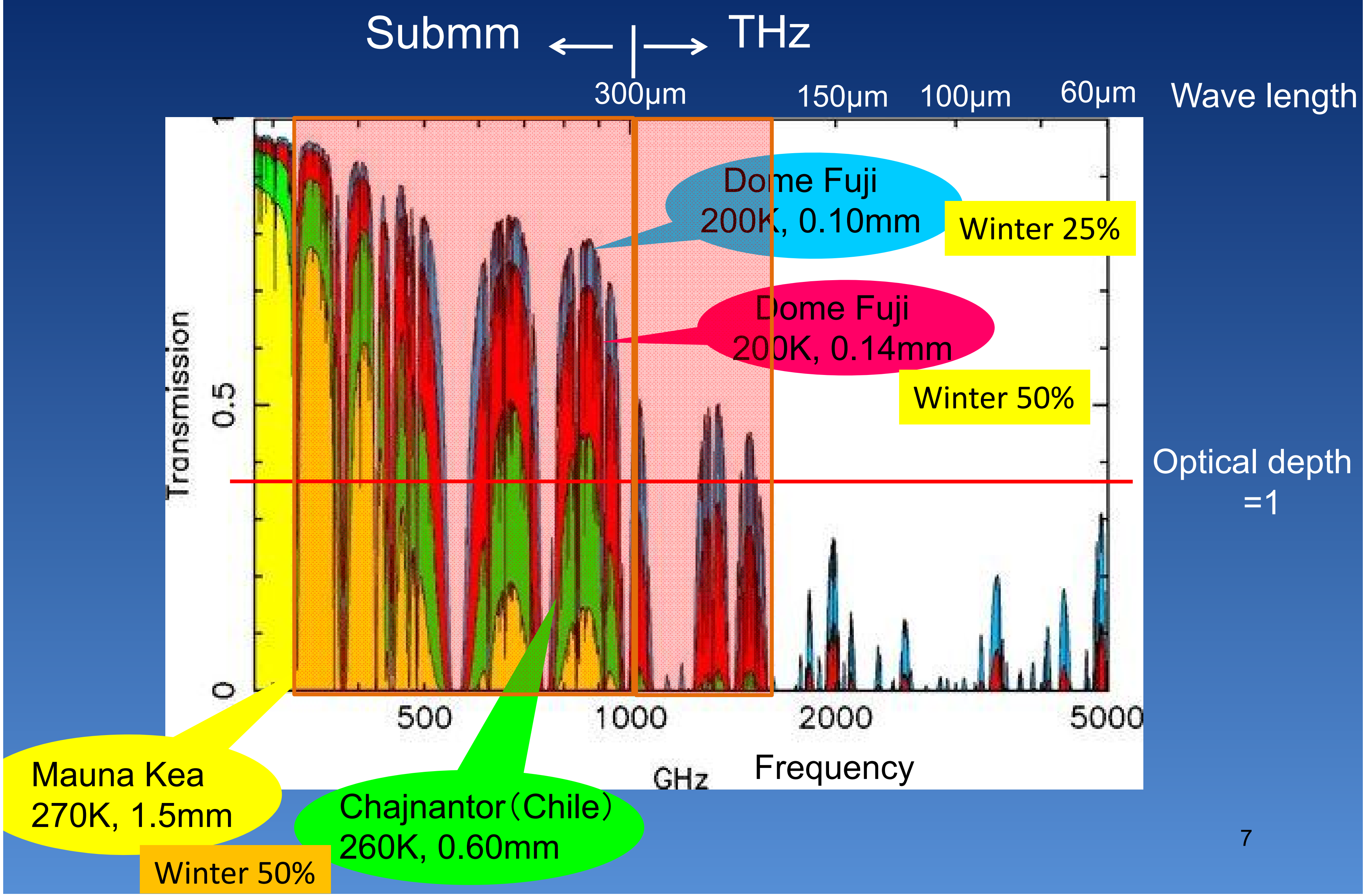


Station	PWV	
	Winter 25%	Winter 50%
Dome A	0.10 mm	0.14 mm
Dome C	0.15	0.24
South Pole	0.23	0.32
Chajnantor (Chile)	0.35	0.60
Mauna Kea	1.0	1.5

(W. Saunders, et al. 2009 PASP 121, 976)
(H.Yang, et al. 2010 PASP 122, 490)

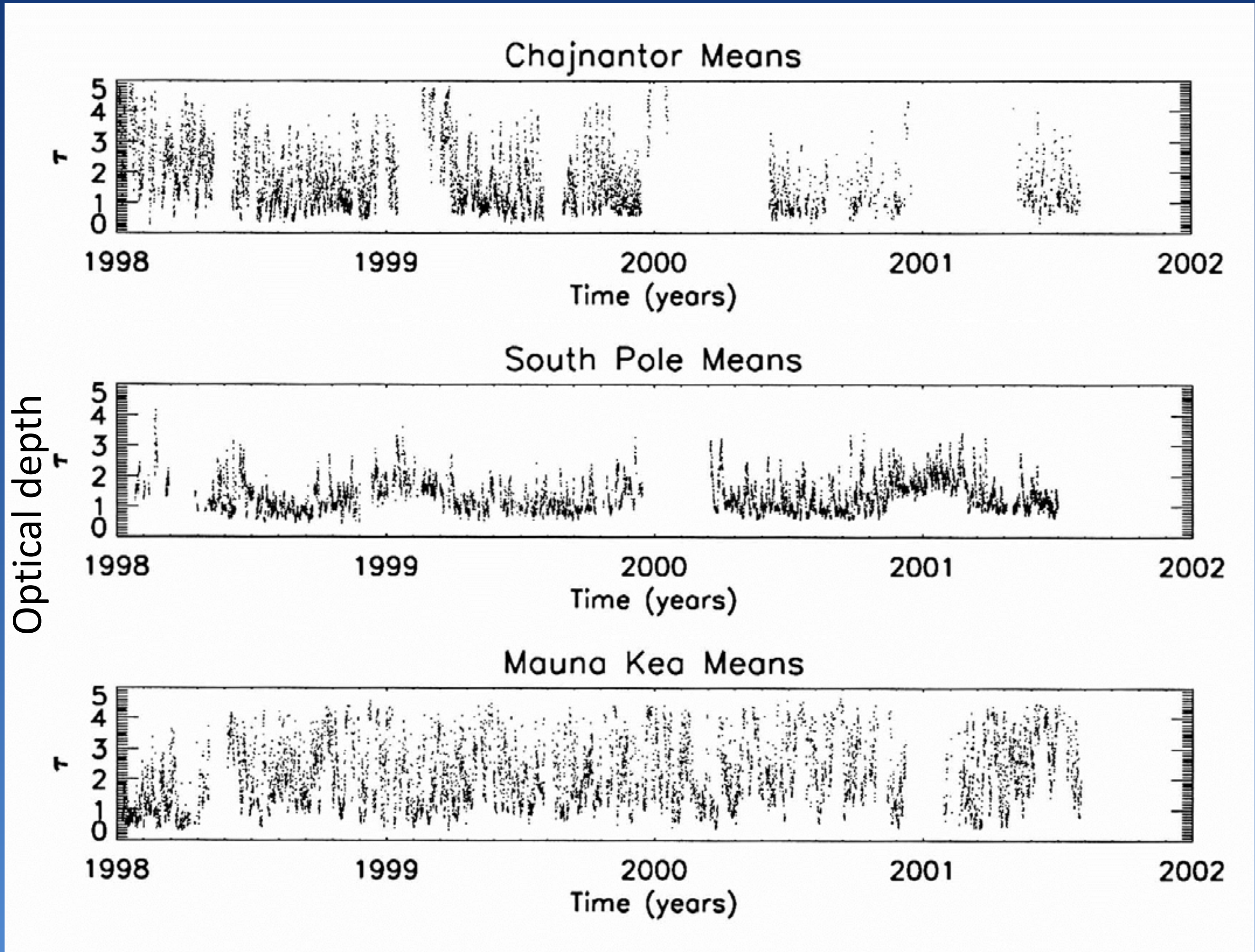
⇒ Most transparent sky (3μm-3mm)

Sky transmission (calculations)



Advantages of Antarctica for Astronomy (3)

- High stability of the sky background



Chajnantor
Chile
（5000 m）

South pole
（2840 m）

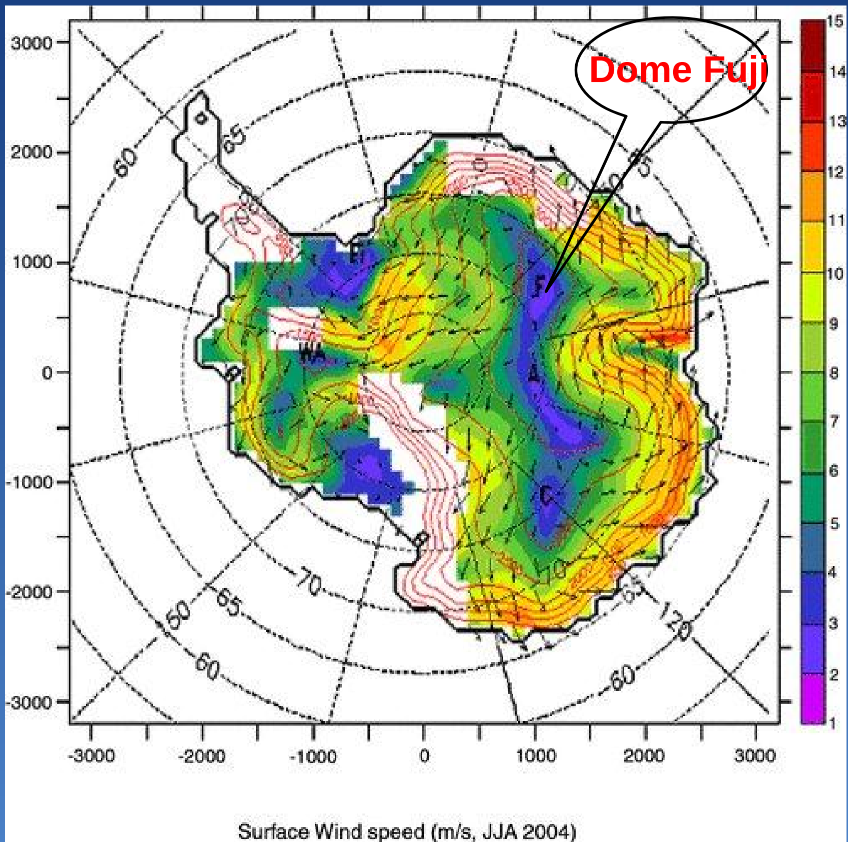
Mauna Kea
Hawaii
（4000 m）

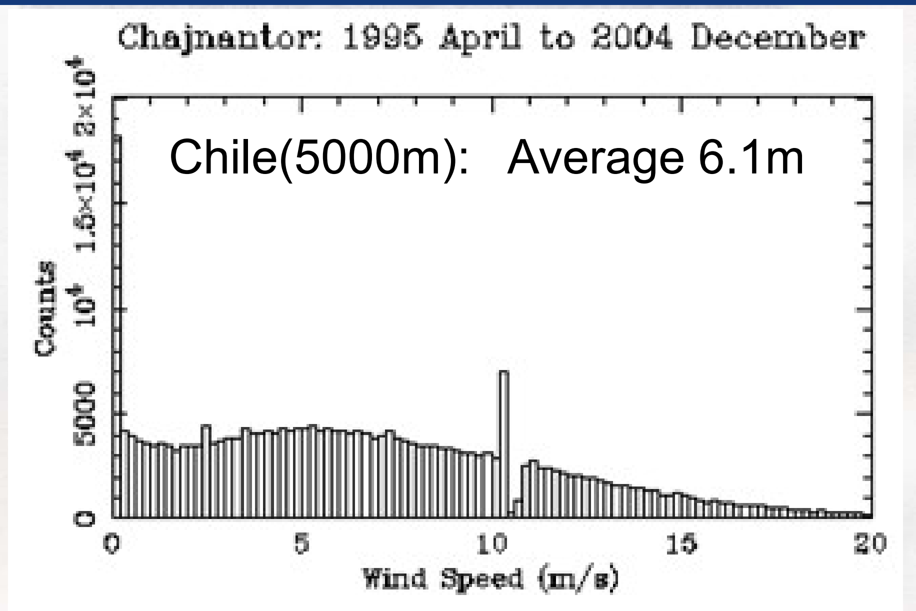
860 GHz = 350 μm(Peterson etc 2003 PASP 115, 383)

Advantages of Antarctica for Astronomy (4)

- Wind is not strong

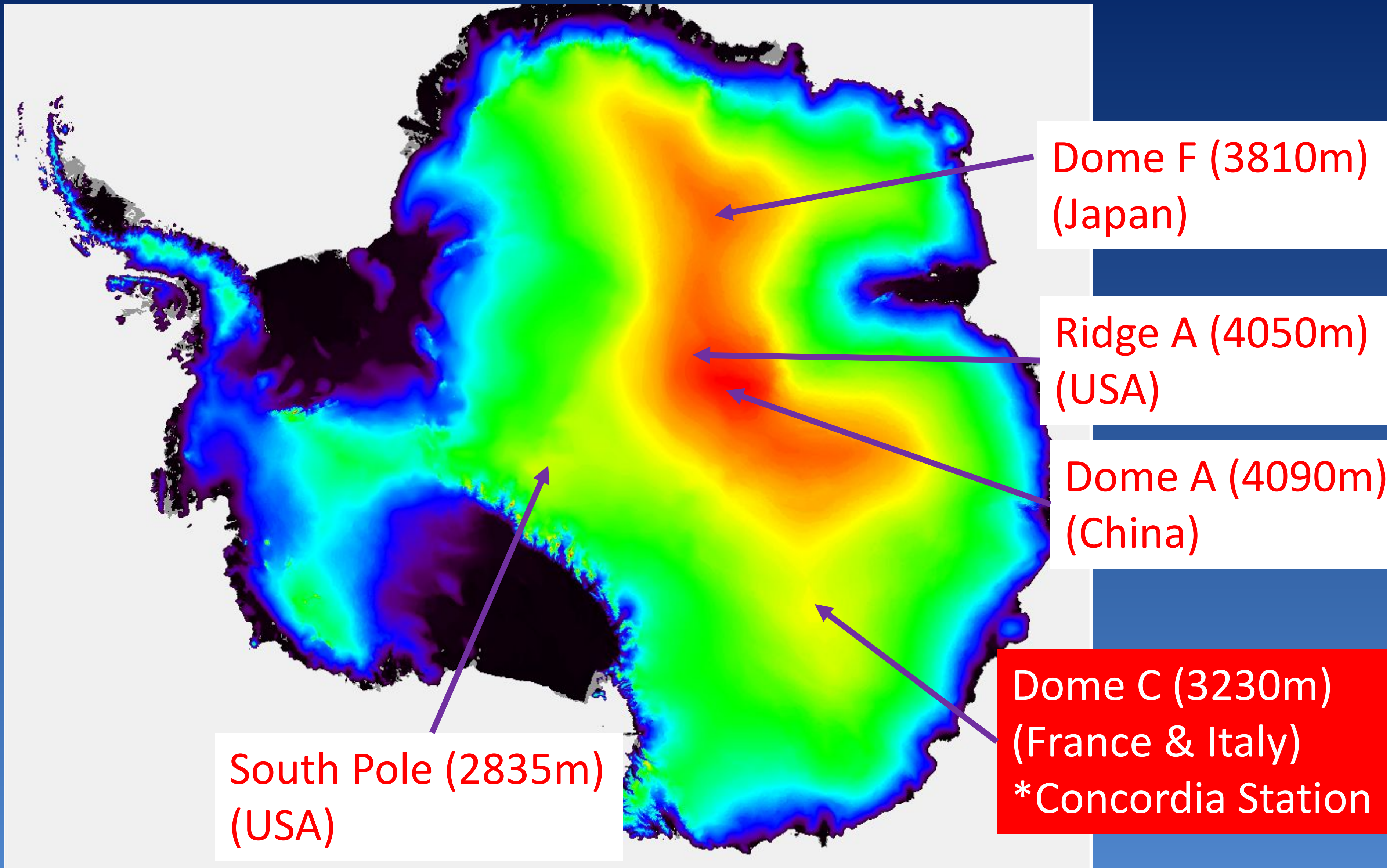
(Wind degrades pointing accuracy of telescope)





⇒ Good telescope pointing

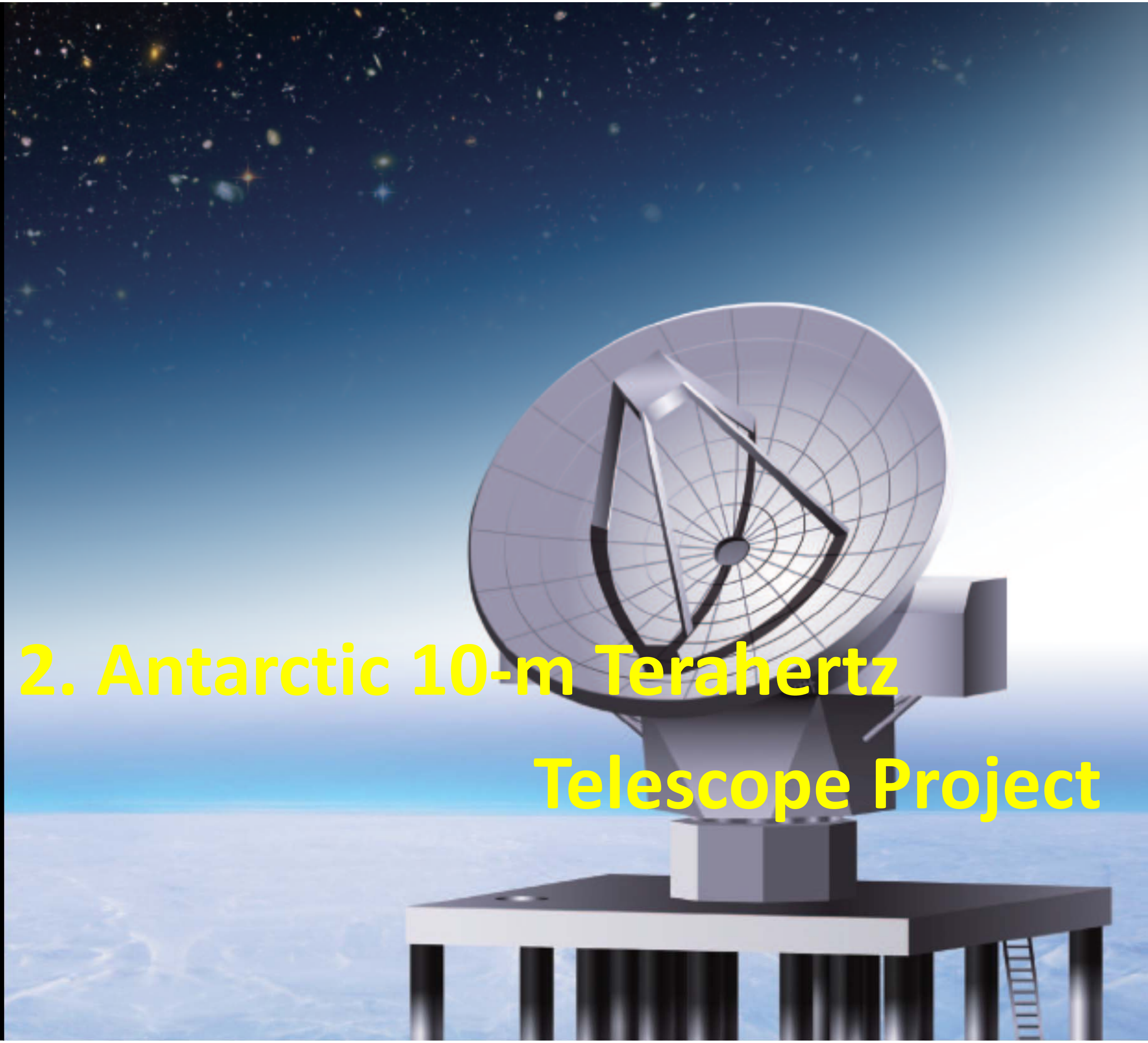
Antarctica


Dome F (3810m)
(Japan)
Ridge A (4050m)
(USA)
Dome A (4090m)
(China)
Dome C (3230m)
(France & Italy)
*Concordia Station
South Pole (2835m)
(USA)

French-Italian Concordia Station @Dome C

Hosting capability
Summer: 80 (incl. « summer camp »)
Winter: 16 (2 for our project?)

2. Antarctic 10-m Terahertz Telescope Project



2.1 Science targets

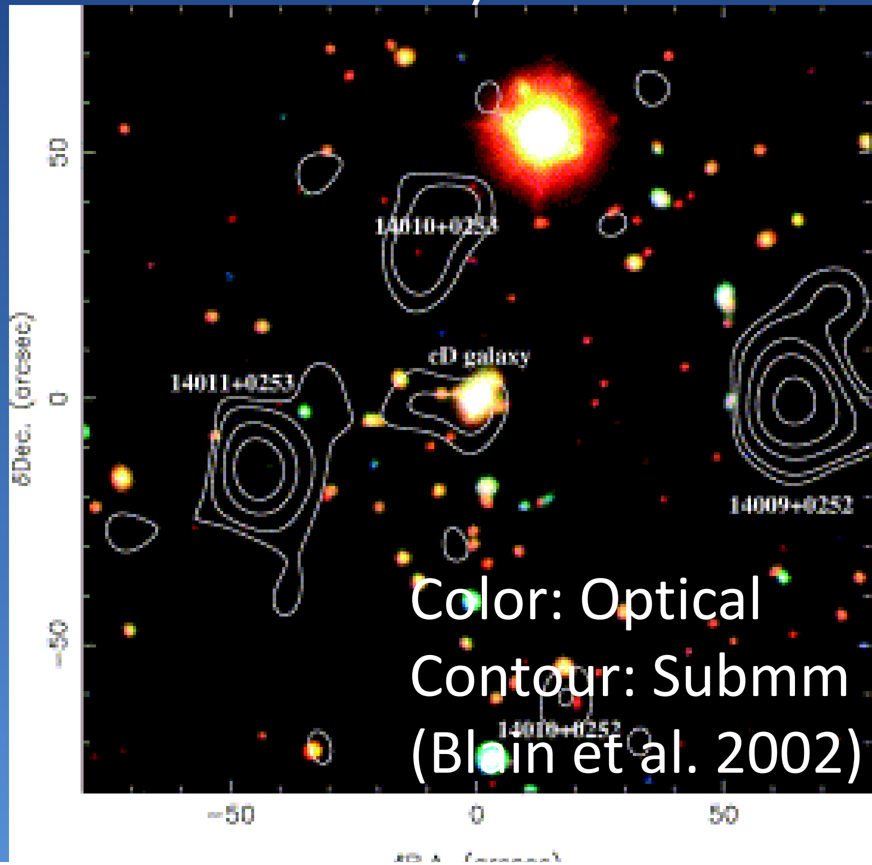
Survey of distant galaxies

- Submm galaxies
  - found at submm (dust thermal emission) but dark in optical

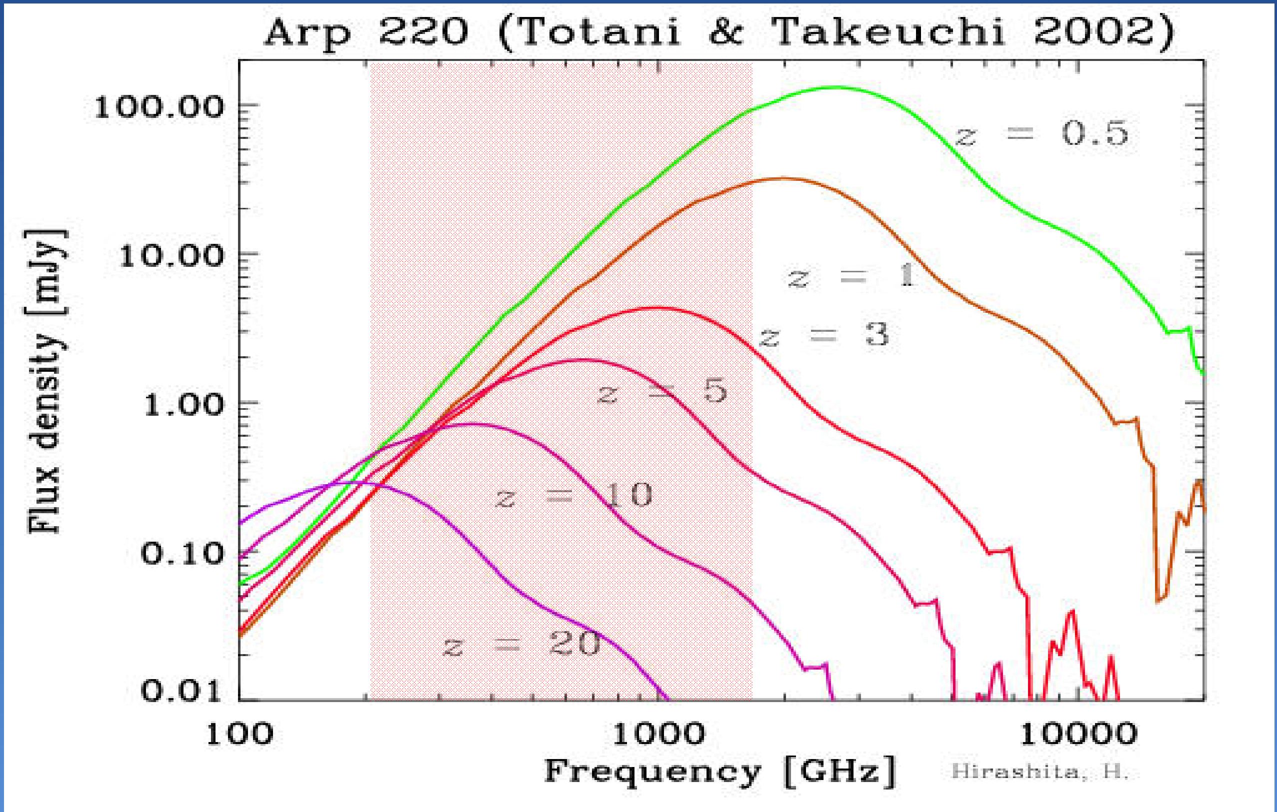
  ⇒ Young distant galaxies obscured by interstellar dust

  ⇒ evolution of galaxies

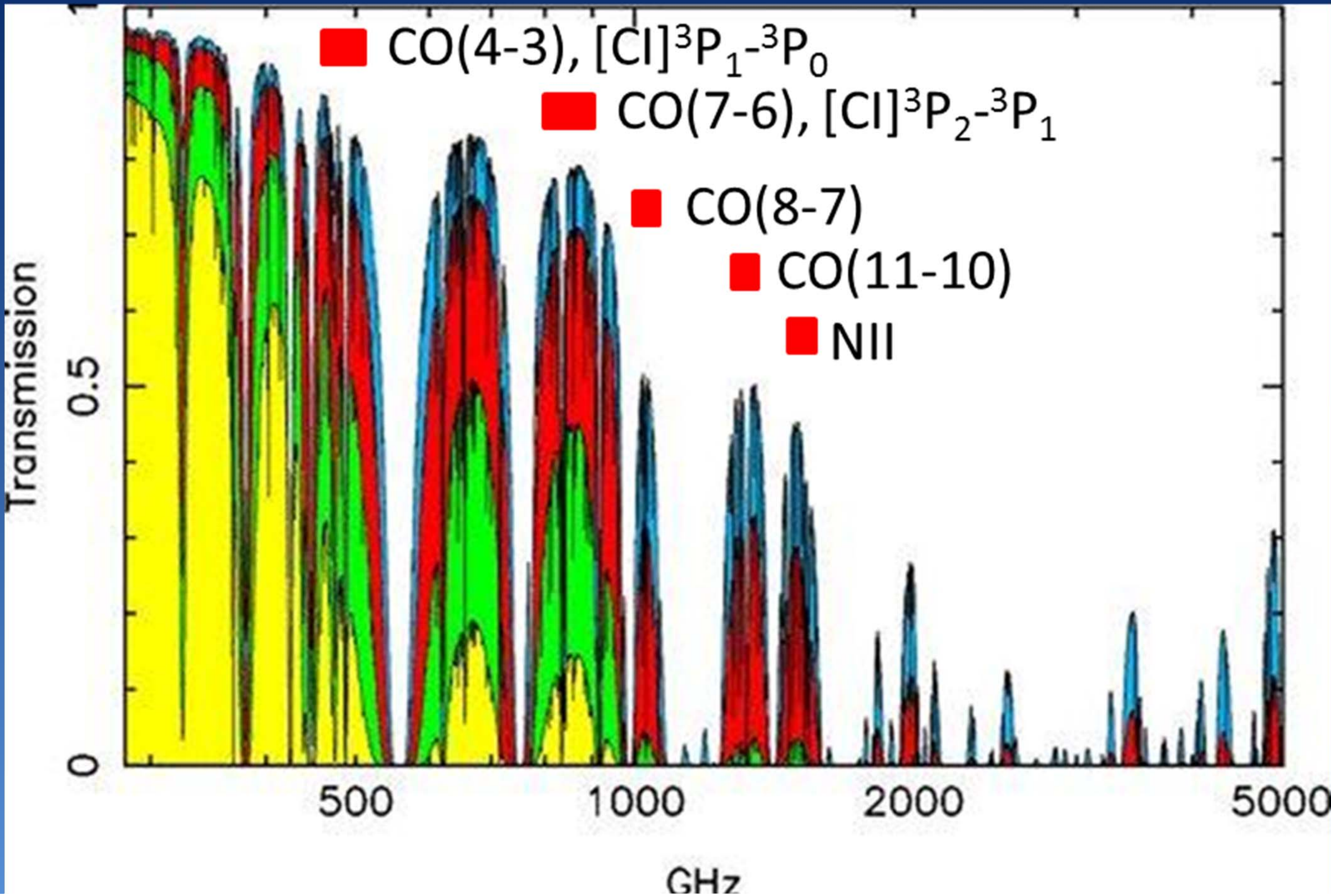
Survey at Summ & THz



- Submm & THz observations of submm galaxies
  - Dust thermal emission
  - Redshifted by cosmic expansion
    - Flux measurements in Wien regime
      - Redshift/Distance
      - Dust temperature



Atomic and molecular emission lines

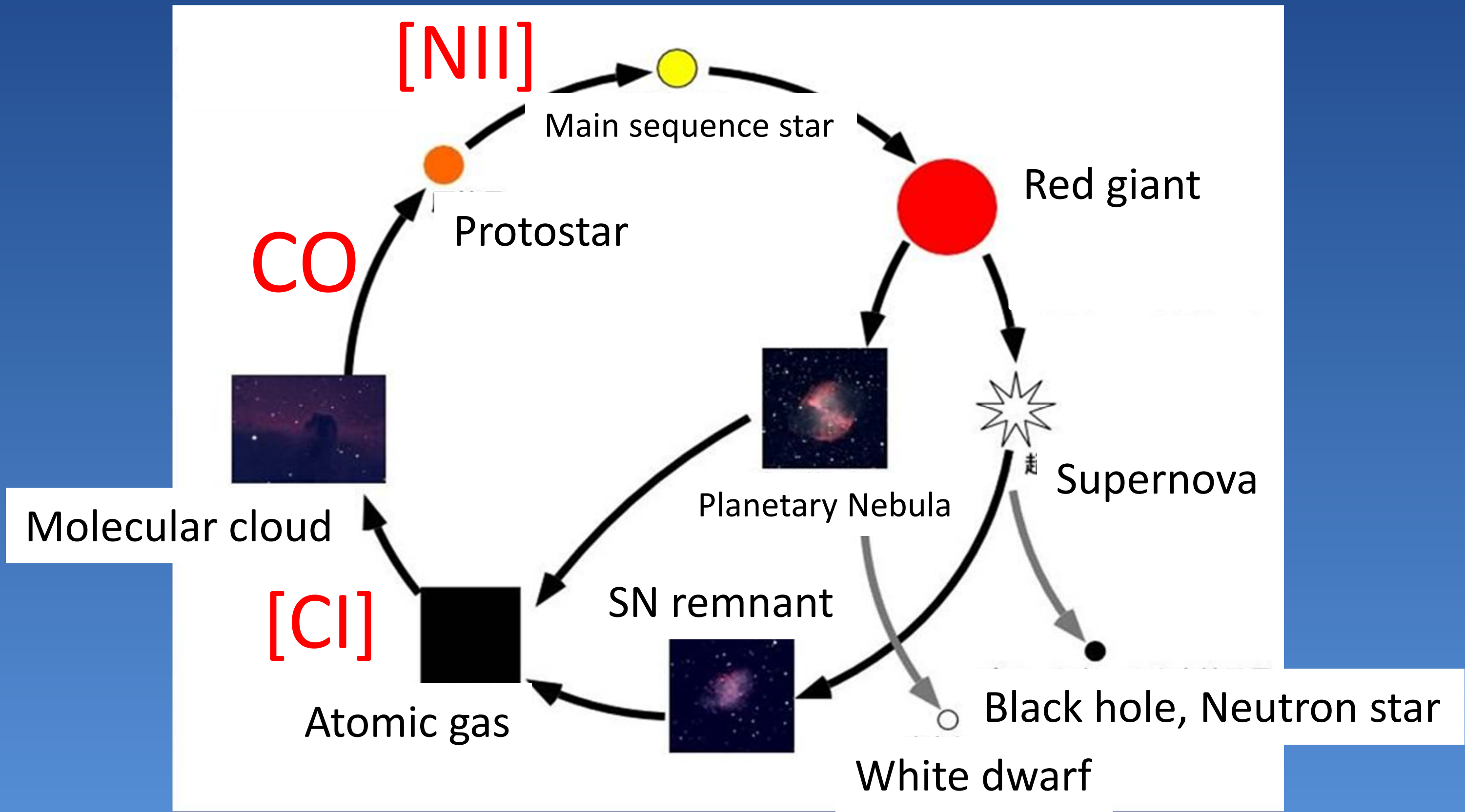


Atomic and molecular emission lines

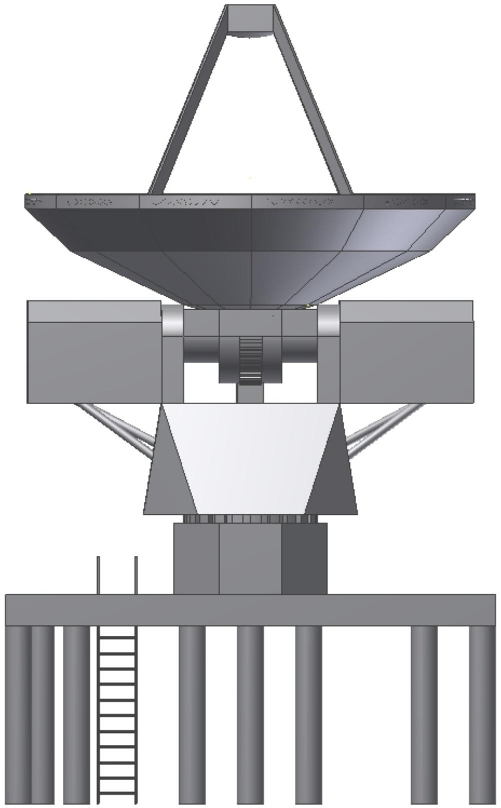
- [CI] : diffuse molecular gas → molecular cloud formation
- High excitation CO lines : warm and dense gas → star forming region
- [NII] : good indicator of star formation rate

Wide area mapping : Milky Way, nearby molecular clouds

⇒ evolutionary process of interstellar medium



2.2 Specifications of 10-m Telescope



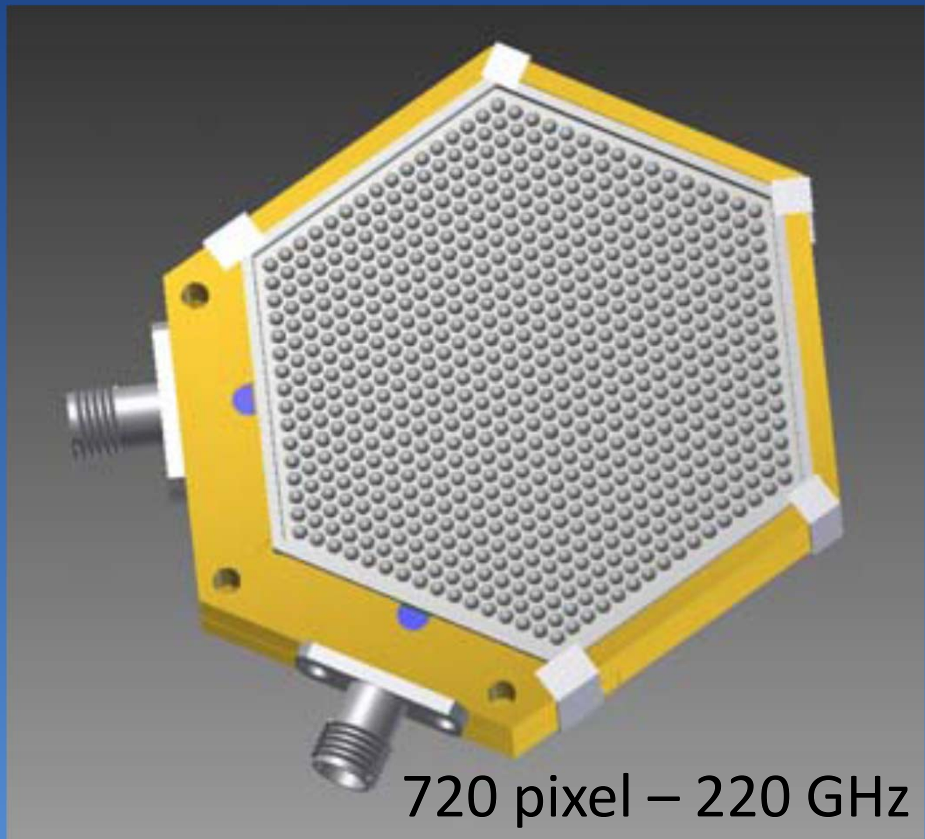
- Diameter：> 10m
- Surface accuracy：< 20μm
- Frequency：200GHz-1.3THz
- Field of view：1°
- Pointing accuracy：2″
- Tracking accuracy：0.5″

Angular resolution（10m）

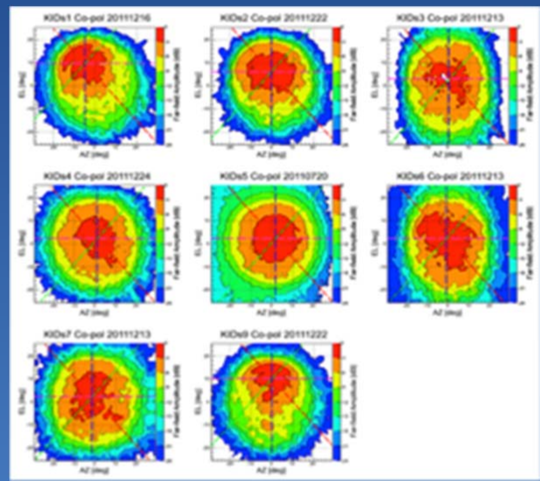
200GHz	800GHz	1.3THz
37″	9.3″	5.8″

Wide Field Radio Camera

- MKID(Microwave Kinetic Inductance Detector)
  - NEP = $6 \times 10^{-18}\ \mathrm{W}/\sqrt{\mathrm{Hz}}$



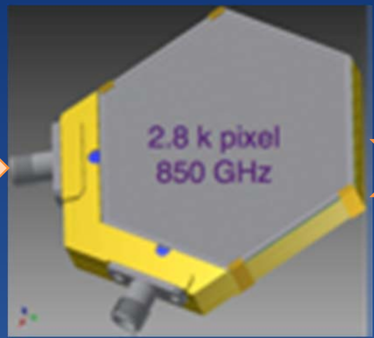
720 pixel – 220 GHz



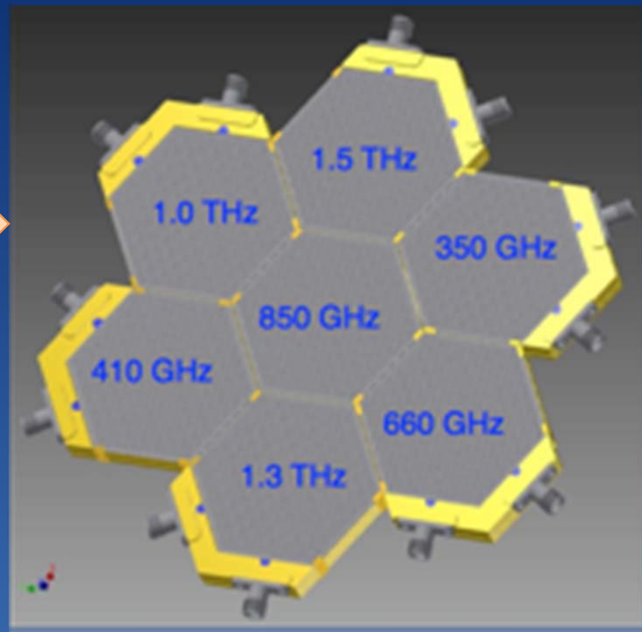
220 GHz Beam pattern (Nitta et al. 2013)

Wide Field Radio Camera

600 pixels
FOV～0.1°



3000 pixels

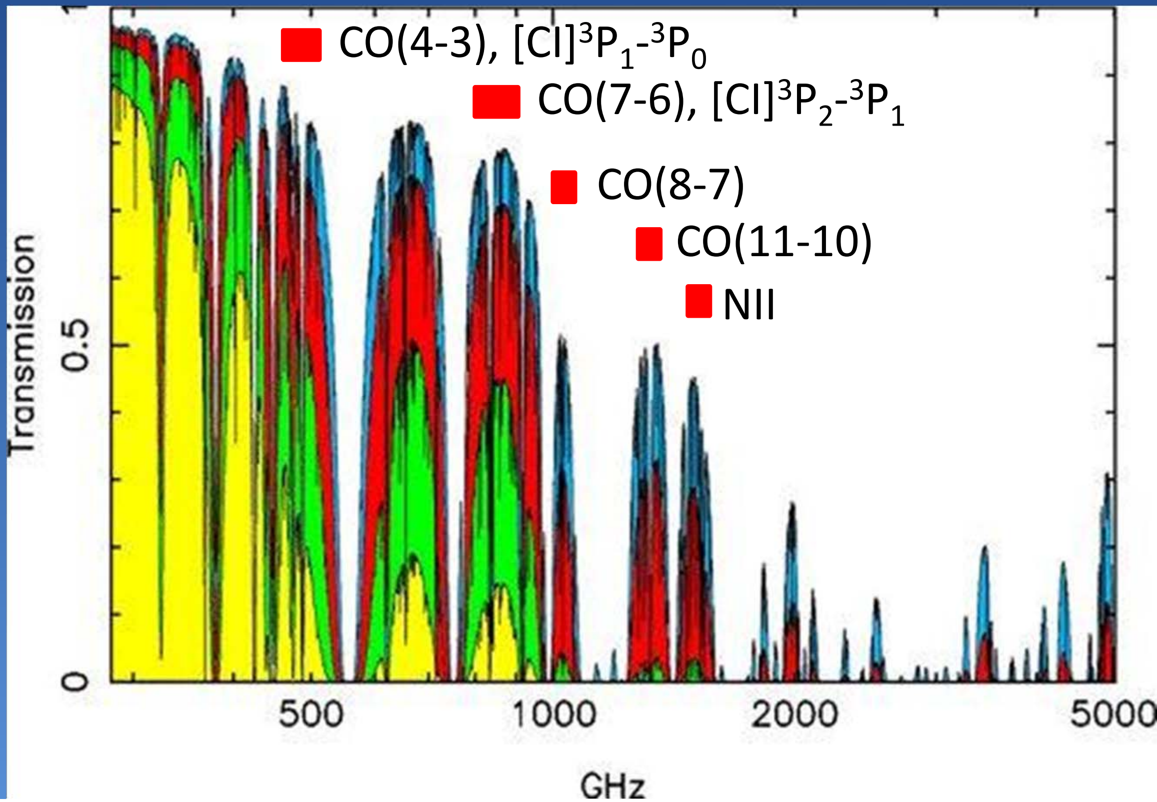


20,000 pixels
FOV～1°

- 410GHz, 850GHz, 1.3THz
  - simultaneous observations

Heterodyne receivers

- 230GHz、450GHz、800GHz、1THz、1.3THz
  - Tsys: ~280K@500GHz, ~600K@800GHz
- 2 polarization/2 band　simultaneous observation
- Single beam ⇒ multi-beam



Advantages of Antarctica 10-m Telescope

- vs. ALMA (@Chile)

  - Better transmission and stability of sky ⇒ THz obs.
  - Wide field of view (1° vs. 1’) ⇒ Wide area mapping
- vs. Hershel (Satellite)

  - 10m vs. 3.5m

    ⇒ Higher spatial resolution

    ⇒ galaxy survey : lower confusion limit

    ⇒ star forming region : more distant dense core
  - （upgrade of instruments is possible）

2.4 Schedule

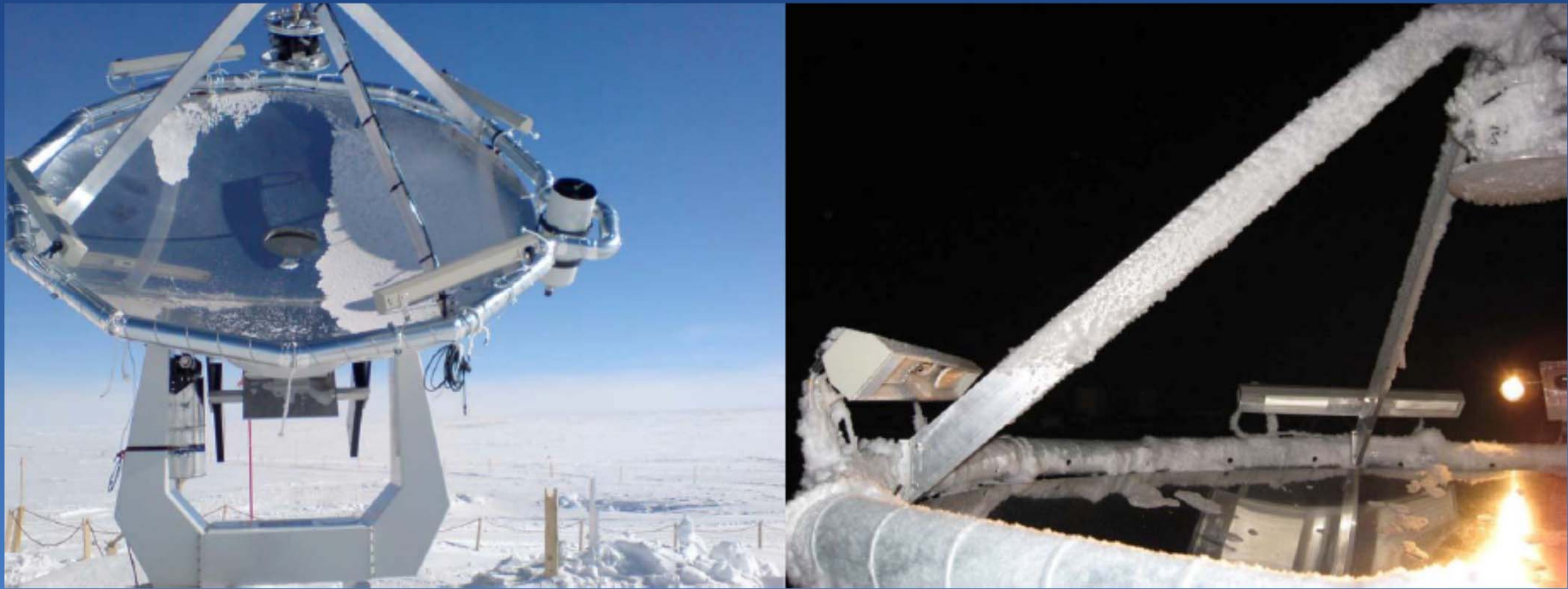
- 2016 Budget request
- 2017 Design & Fabrication
- 2018 ⬇
- 2019 Construction @ Univ. of Tsukuba
- 2020 Test & Adjustment
- 2021 ⬇
- 2022 Transport to Antarctica
- 2023 Construction @Dome C

Antarctic astronomy consortium

* ＊ Univ. of Tsukuba
* ＊ Tohoku Univ.
* ＊ National Institute of Polar Research
* ＊ National Astronomical Observatory of Japan
* ＊ Kwanseigakuin Univ.
* ＊ Hokkaido Univ.
* ＊ Saitama Univ.
* ＊ Rikyyo Univ.
* ＊ Kanazawa Univ.
* ＊ Nihon Univ.
* ＊ Niigata Institute of Technology
* ＊ Japan Aerospace Exploration Agency
* ＊ Fukushima National College of Technology

Difficulties in Antarctica (1)

- Low temperature $\Rightarrow$ ice/frost



Durand et al. (2008)

Difficulties in Antarctica (2)

- Accumulation of snow

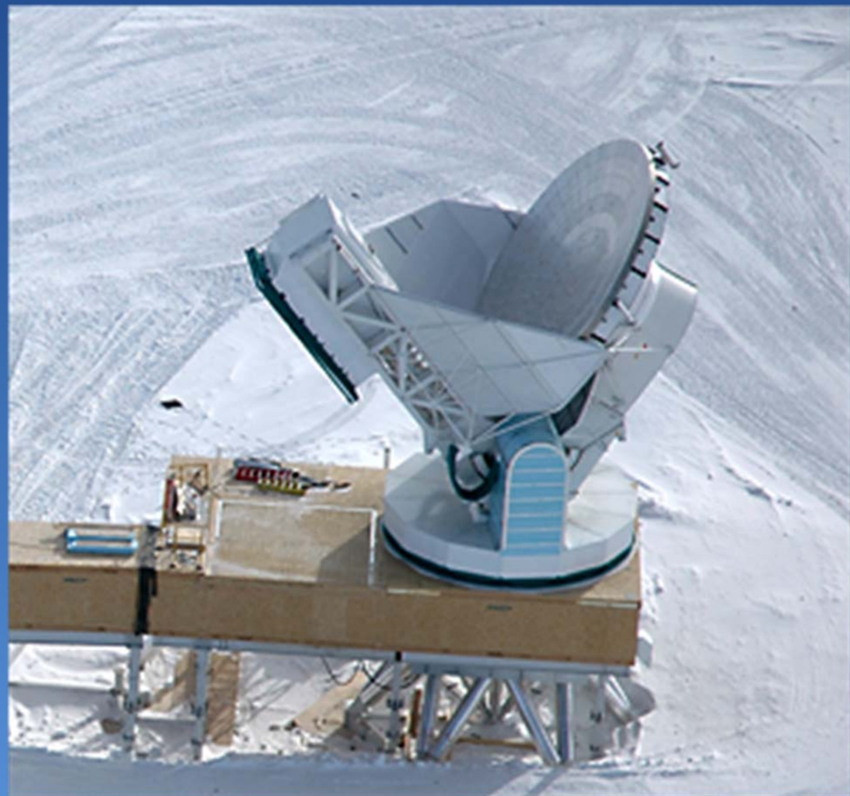
  ⇒ high-floored

AST/RO (Tothill et al. 2007)

- SPT @south pole（2007～）（USA）

  （South Pole Telescope）

  – Diameter：10m
  – Bolometer array
  – 90GHz, 150GHz, 230GHz
  – CMB、SZ、submm galaxies



- COCHISE @ Dome C（2010～）（Italy）

（Cosmological Observations at Concordia with Highsensitivity Instrument for Source Extraction）

  - D：2.6m
  - 200μm-3mm
  - 2ch bolometer @2mm、1.25mm
  - CMB

(Sabbatini et al. 2011)

- HEAT @ Ridge A（2012～）（USA, Astralia）

（High Elevation Antarctic Terahertz Telescope)

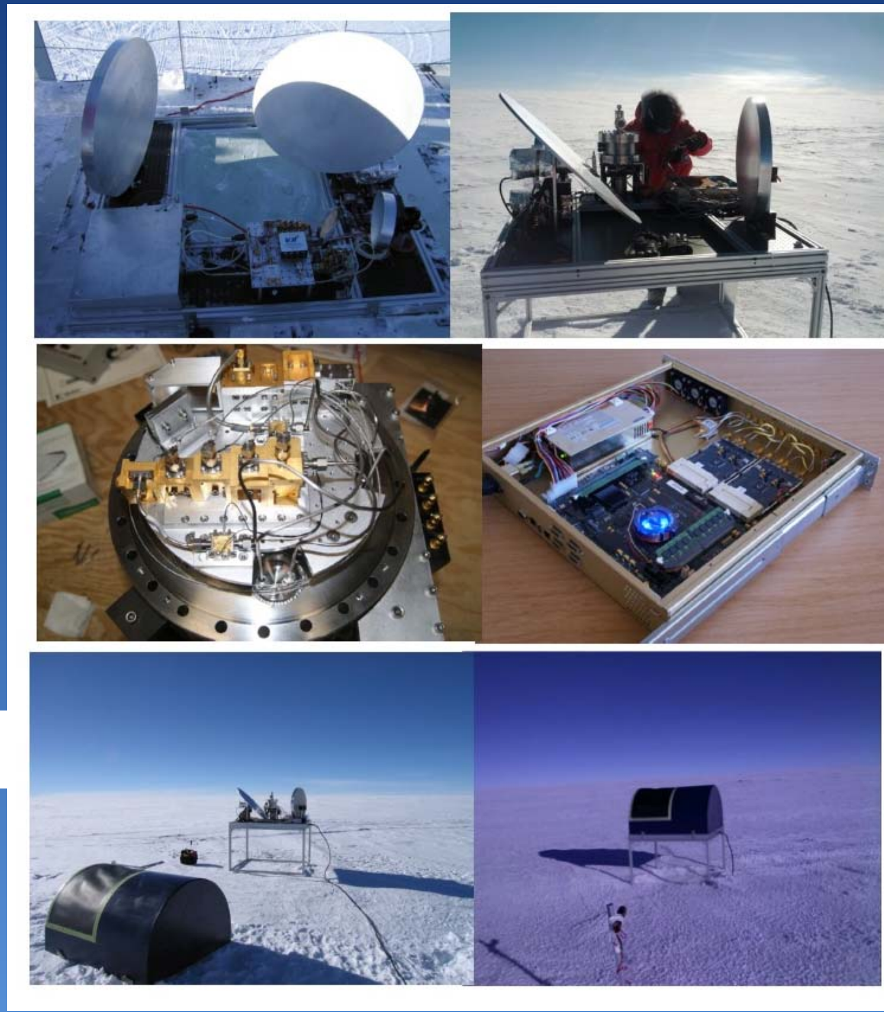
  – Remote observations

    （no station）

  – D：62㎝

  – 492GHz, 809GHz

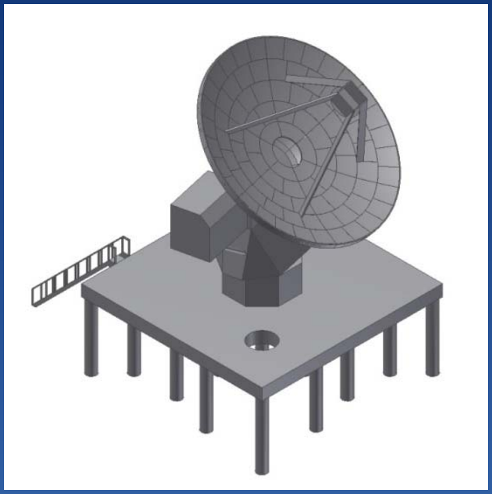
  – CO、[CI]、([CII])



http://soral.as.arizona.edu/HEAT/instrument/

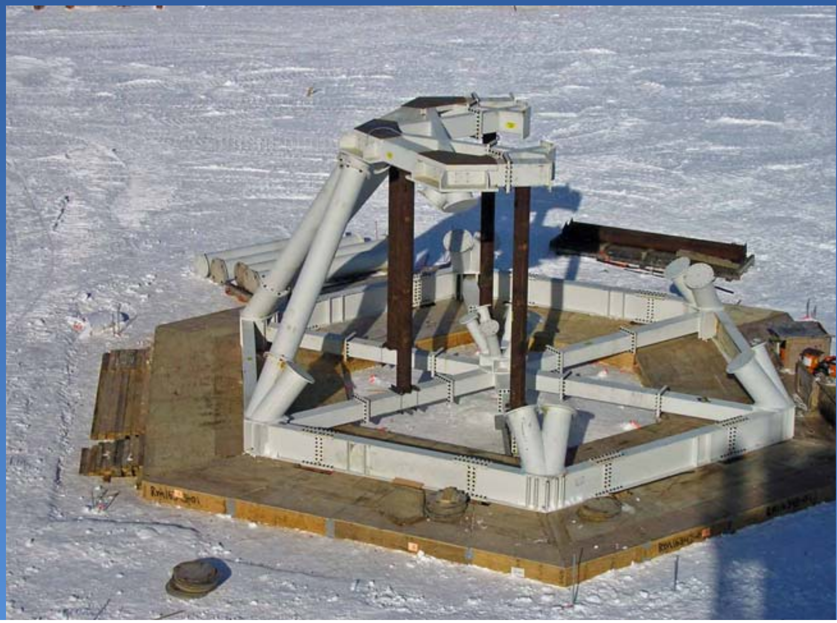
アンテナ基礎

- 吹きだまり ⇒ 高床
- 基地との位置関係
  - どこに雪がたまるか？



AST/RO (Tothill et al. 2007)

SPT（South Pole Telescope）



- 安定な基礎が作れるか？

水準測量による建設地の決定→SM112大型雪上車での十分な踏み固め（3往復）→7人の人間の足での30分間の踏み固めによる転圧→一晩養生

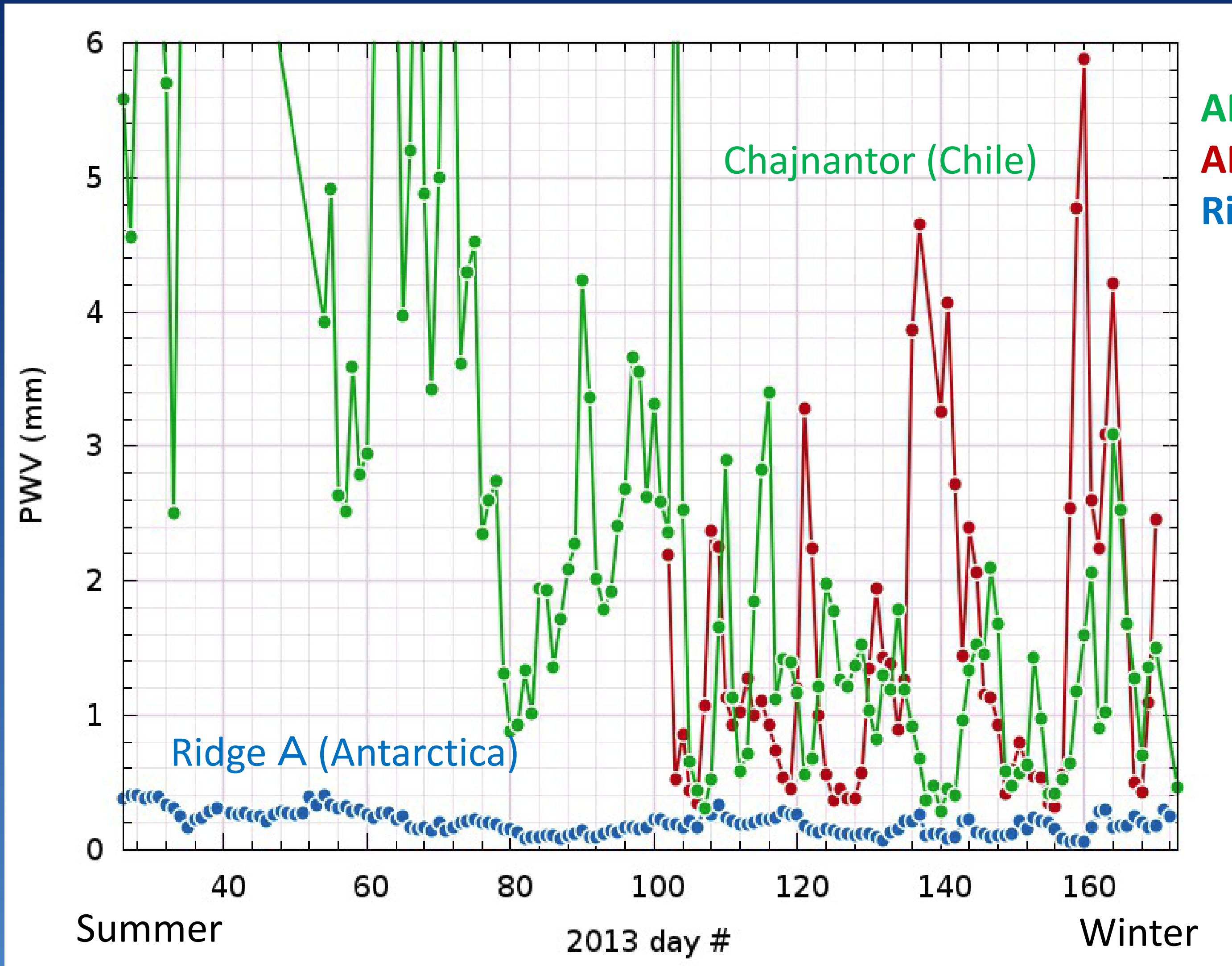
（金 極地研）

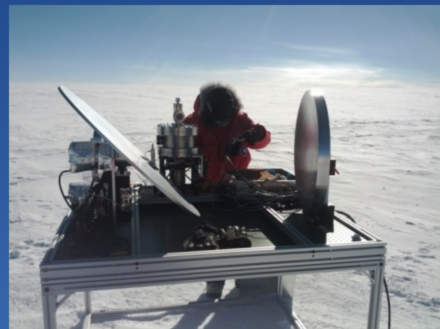
霜対策

- COCHISE
  - 赤外線ヒーター＋ブロワー＋電熱線ヒーター

- SPT
  - パネルの裏のヒーターで常に外気より1-2度高めに暖めている

Precipitable water vapor





810GHz@Ridge A

Median (Winter)
0.13mm

Kulesa (2013)

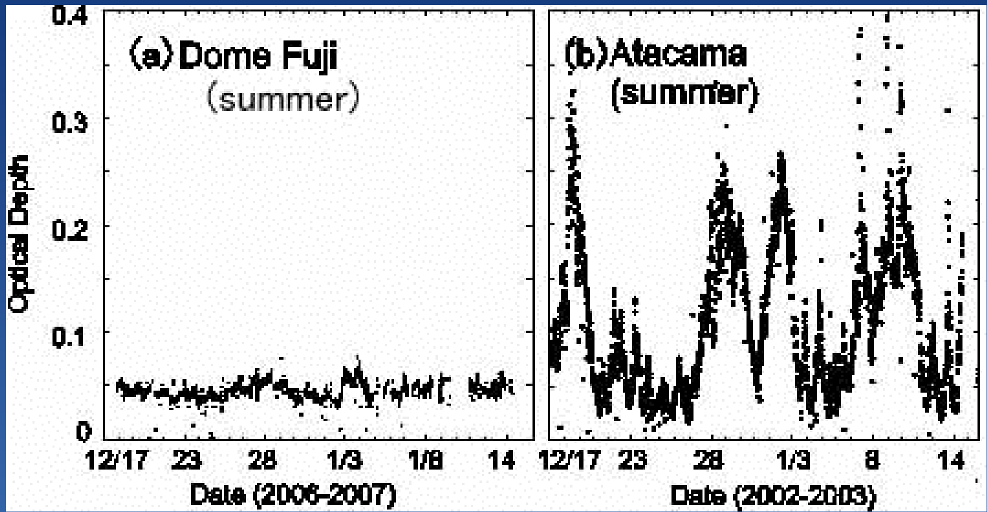
Optical depth

220GHz@Dome Fuji

measured in 2006 and 2009 summer

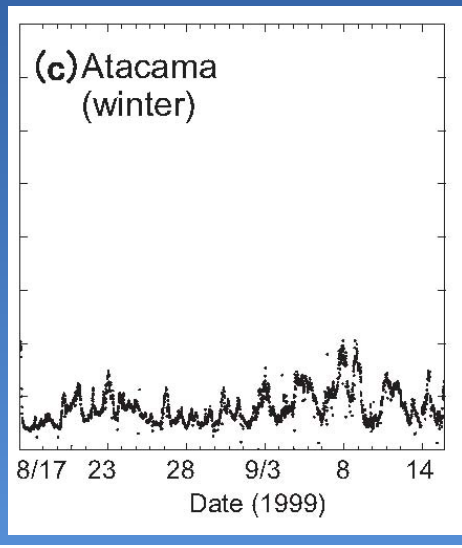
Dome Fuji　　Atacama（Chile 5000m）

Optical depth



Summer

?



Winter

Ishii et al. (2010)

Stability of sky background

860 GHz = 350 μm

(Peterson et al. 2003 PASP 115, 383)

Excellent!

→ important for continuum observations and interferometer