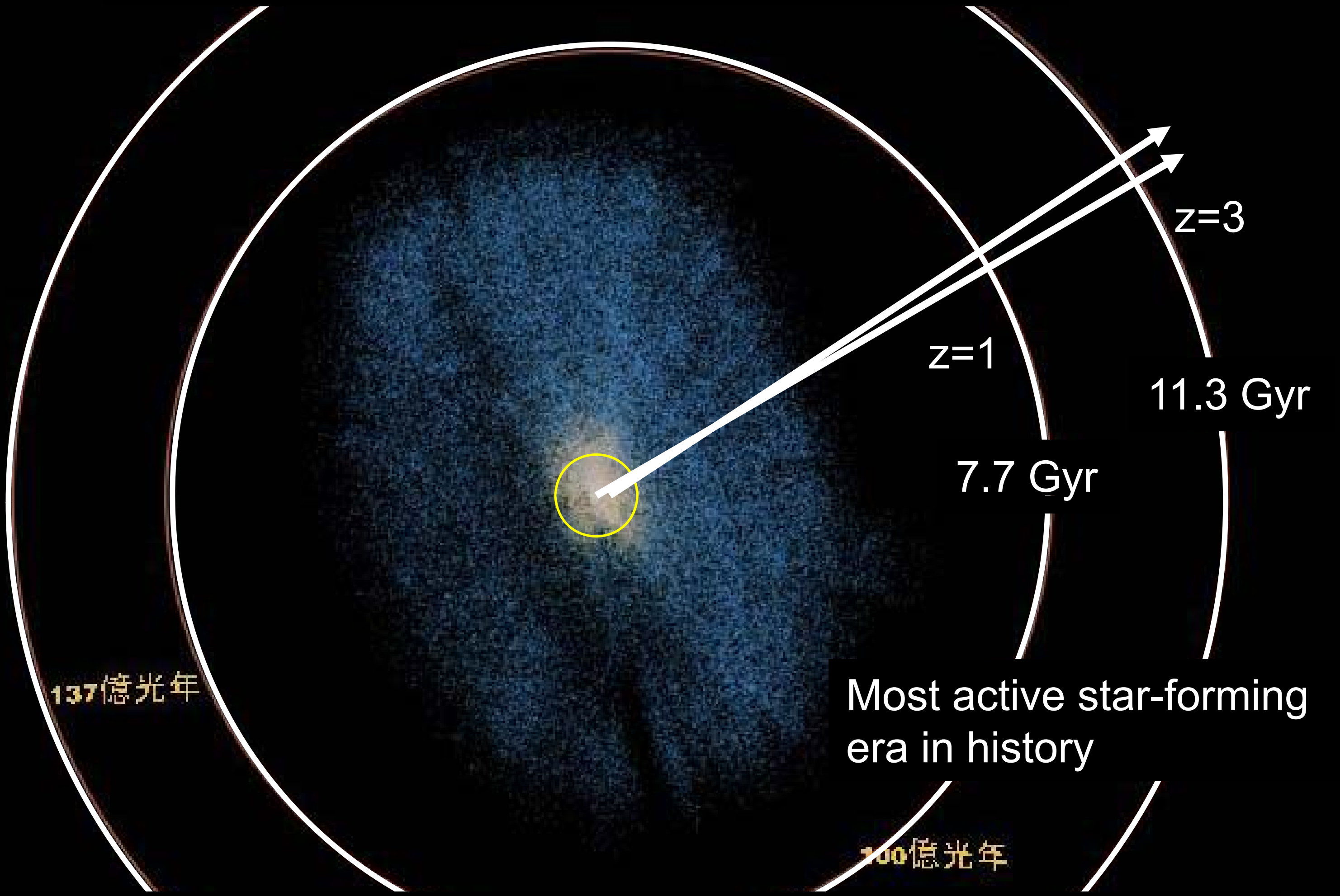
# Astronomy at Dome Fuji in Antarctica

## -background and future plan-

Tohoku University

Takashi Ichikawa

# Near-infrared wide area survey

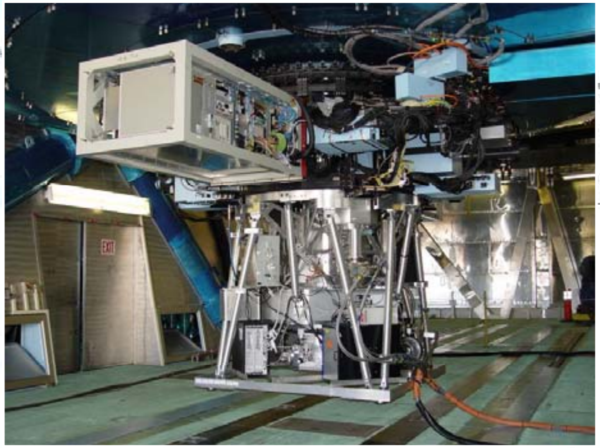


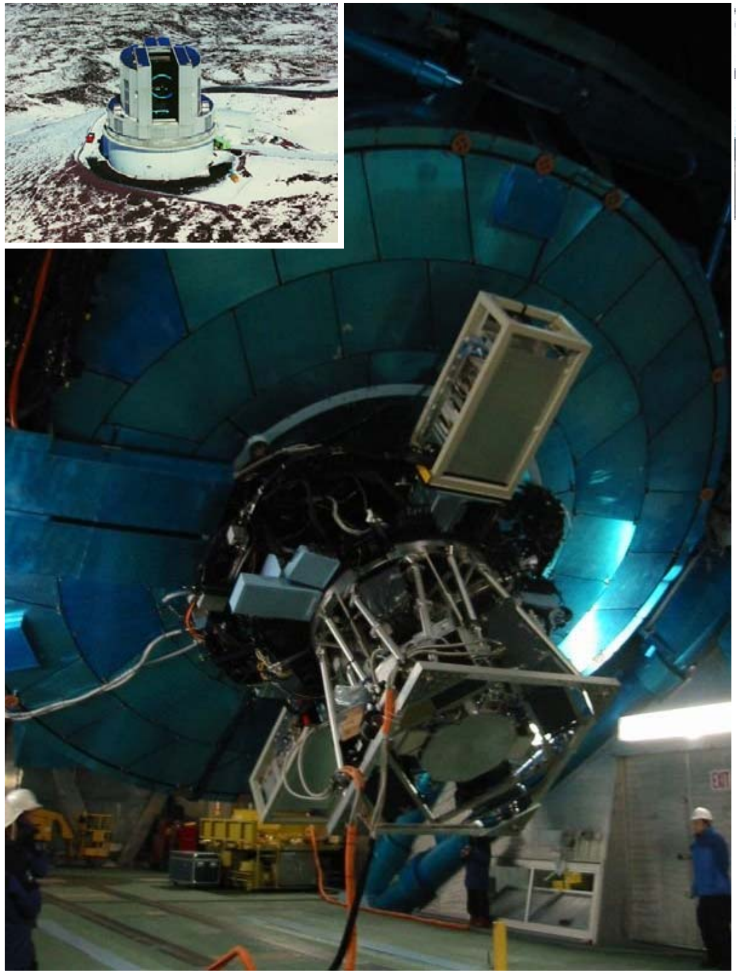

Clustering evolution of low mass galaxies (building blocks) in large scale structure is one of central issues in observational cosmology.

For the study of distant galaxies, powerful infrared camera and spectrograph are of the essence.

MOIRCS on Subaru

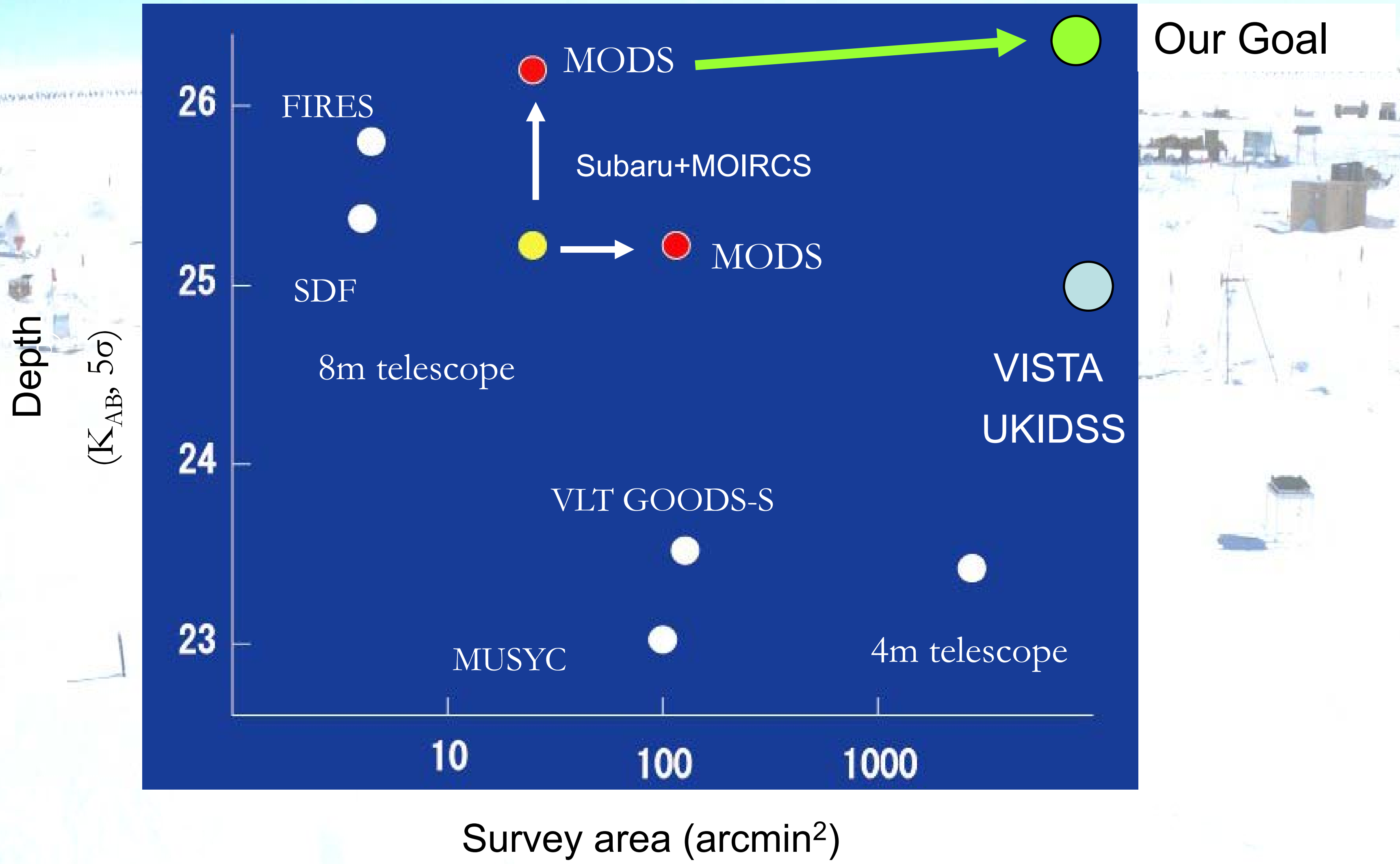
Ichikawa+(2006)





# Widest and Deepest High-Redshift Galaxy Survey in K band

Complete samples of $10^9$ $M_{sun}$ at z~3



To make a map of low-mass galaxies at high-z to study the evolution of large scale structure, a lot of telescope time is demanded (~hundreds nights).

However, telescope time of 8.2m Subaru is highly competitive.

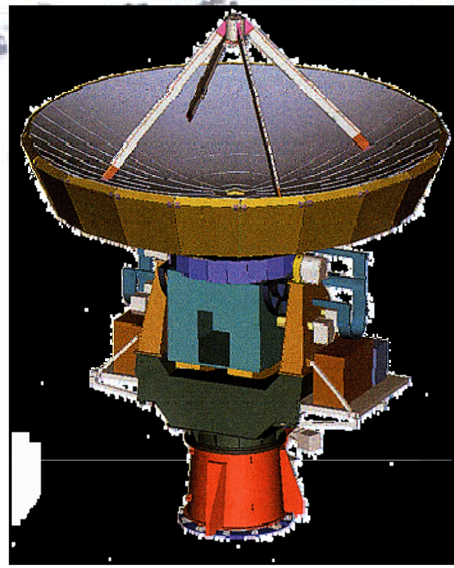
Space telescopes would be best.
However, they are quite expensive (>200 M US$).

# THz astronomy by Japanese Group

Nakai et al.

ALMA


Japan + Europe + USA



THz Radio Telescope

Chili would not be the best site for THz astronomy
to study dusty galaxies at high-z Universe.

# Consortium of Astronomy at Dome-F

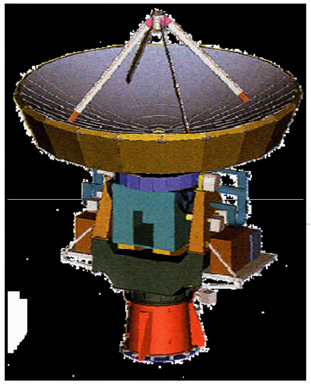
National Institute of Polar Research

Showa station


Infrared group: (PI) T. Ichikawa

~2m Infrared Telescope

THz group: (PI) N. Nakai

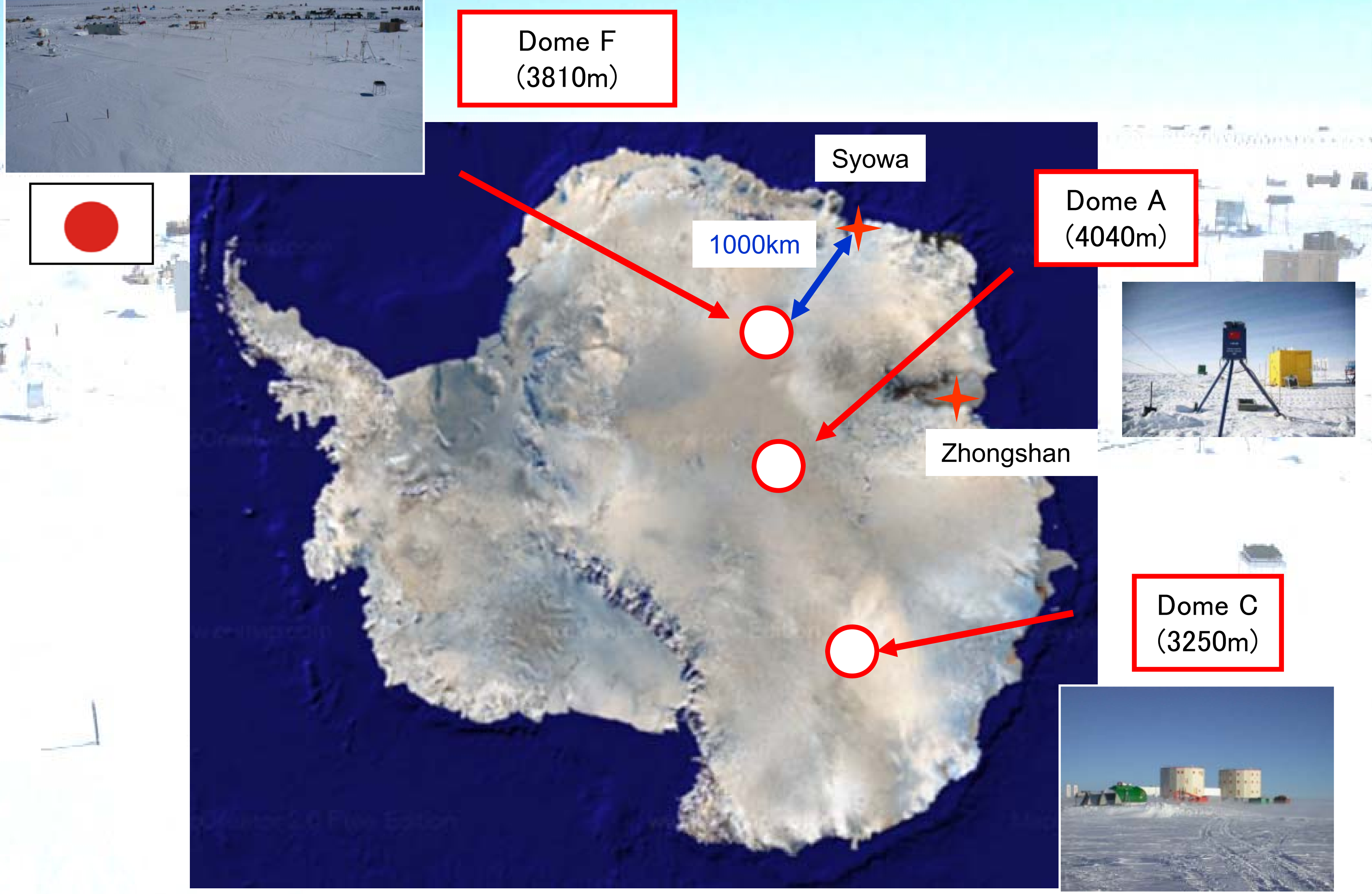


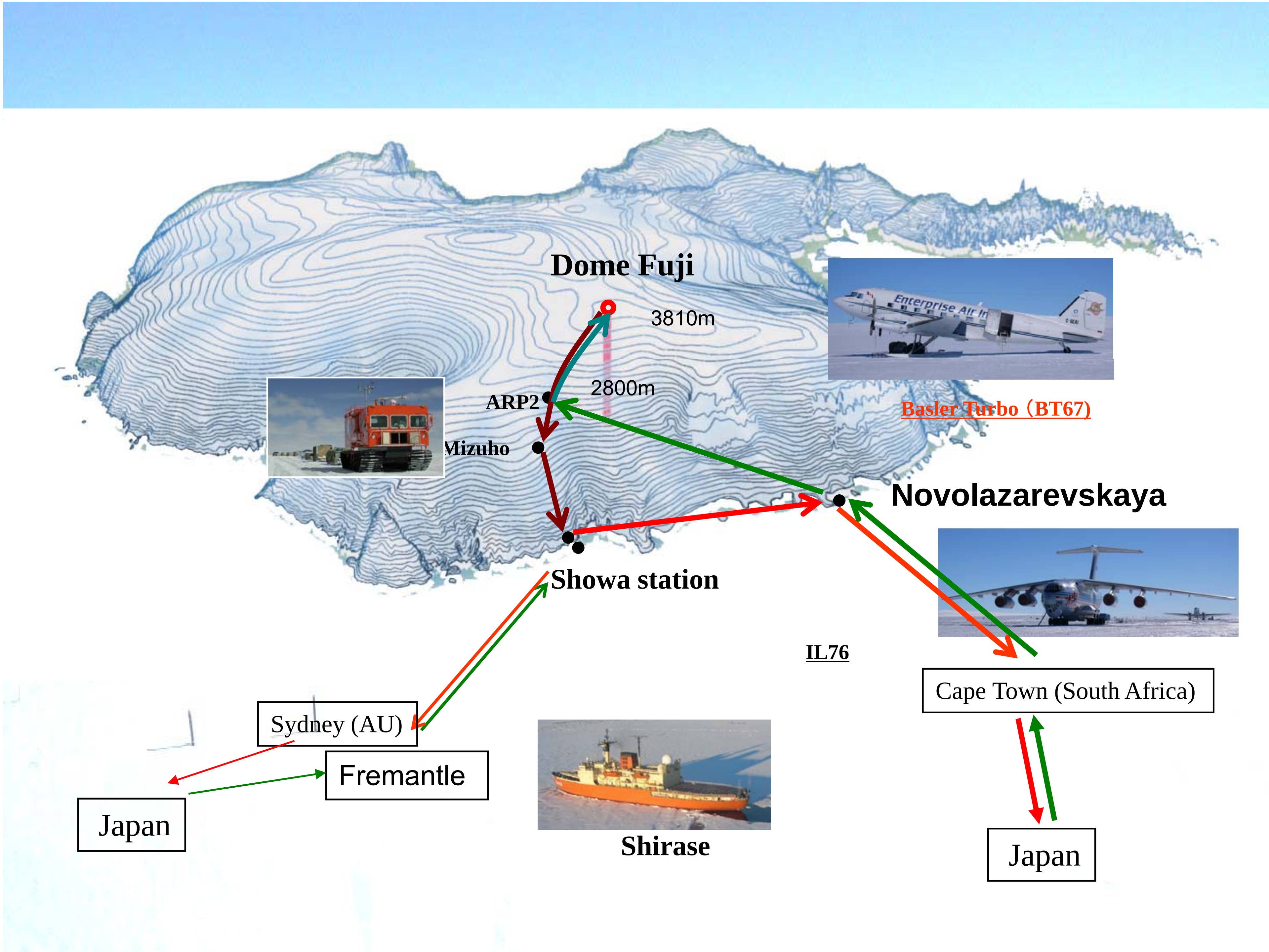
~7m THz Radio Telescope

Nakai, N., Seta M. (Tsukuba Univ.)
Ichikawa, T., Okano, S., Sakamoi, T. (TohokuUniv.)
Taguchi, M. (Rikyou Univ.)
Takato, N., Uraguchi, H., Iye, M. (NOAJ)
Kurita, M. (Nagoya Univ. )
Motoyama, H. (NIPRJ)

& collaborators

# Astronomical sites at domes

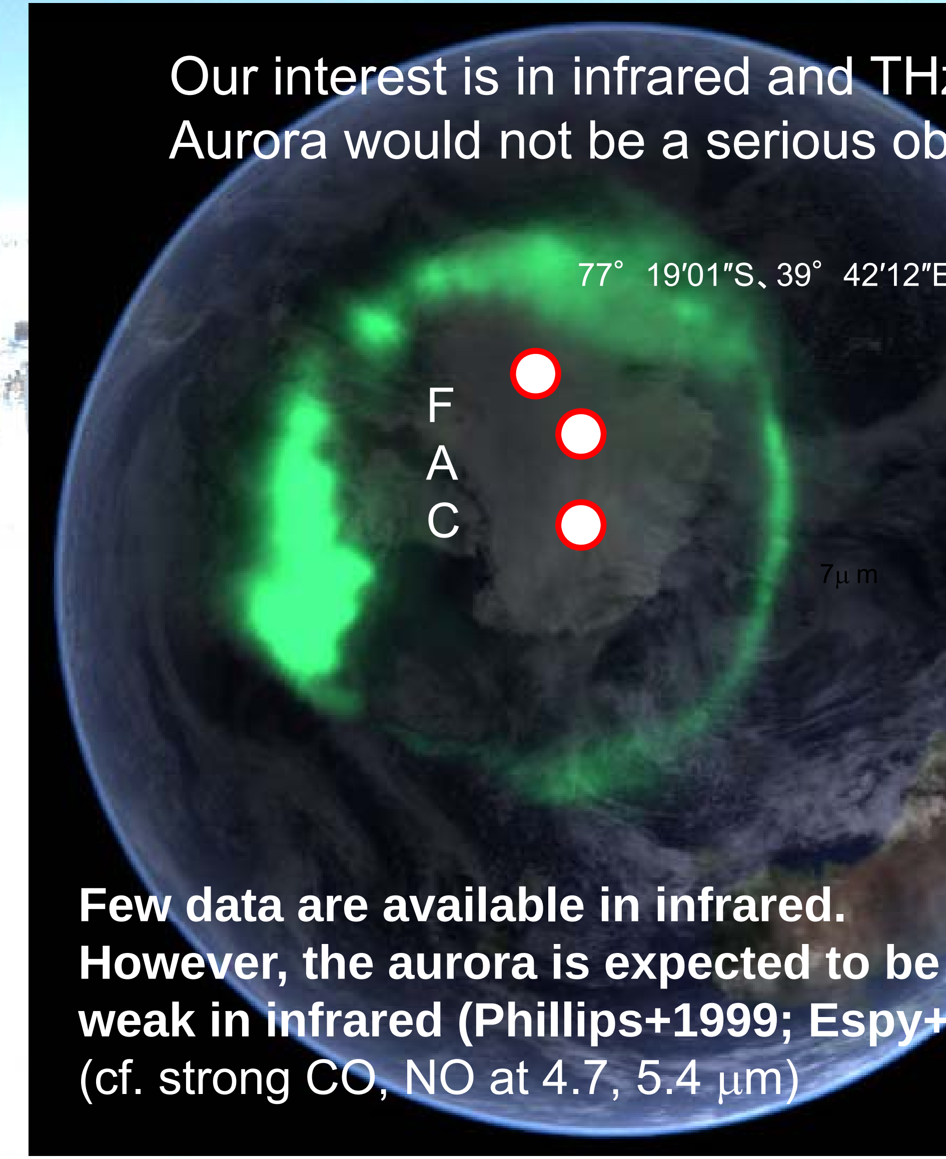




Dome Fuji
3810m
2800m
ARP2
Mizuho
Basler Turbo（BT67)
Novolazarevskaya
Showa station
IL76
Cape Town (South Africa)
Sydney (AU)
Fremantle
Japan
Shirase
Japan

# Dome F is located at the edge of the aurora oval.

Our interest is in infrared and THz.
Aurora would not be a serious obstacle.



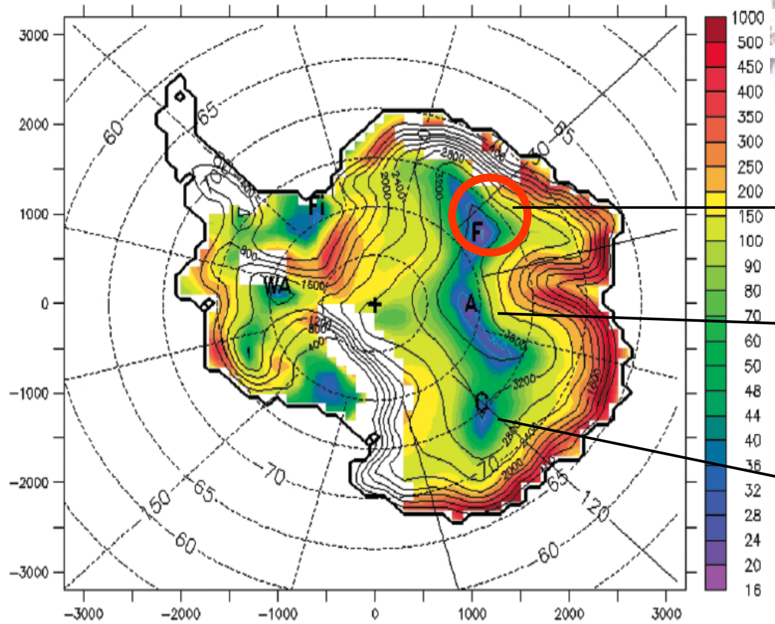

Aurora at Dome F

**Few data are available in infrared.**
**However, the aurora is expected to be very weak in infrared (Phillips+1999; Espy+ 1988).**
(cf. strong CO, NO at 4.7, 5.4 μm)

http://ja.wikipedia.org/wiki/

# Seeing strongly depends on boundary layer

Thickness of boundary layer
(simulation)




Height where the residual boundary layer seeing is 0.1" or better 50% of the time (JJA 2004)

Swain & Gallee (2006)

Simulated height of boundary layer
(model atmosphere)

**Dome F ~18m (?)**

**Dome A ~20m (?)**

**Dome C ~30m (measured)**

# Why astronomy in Antarctica? – the advantages

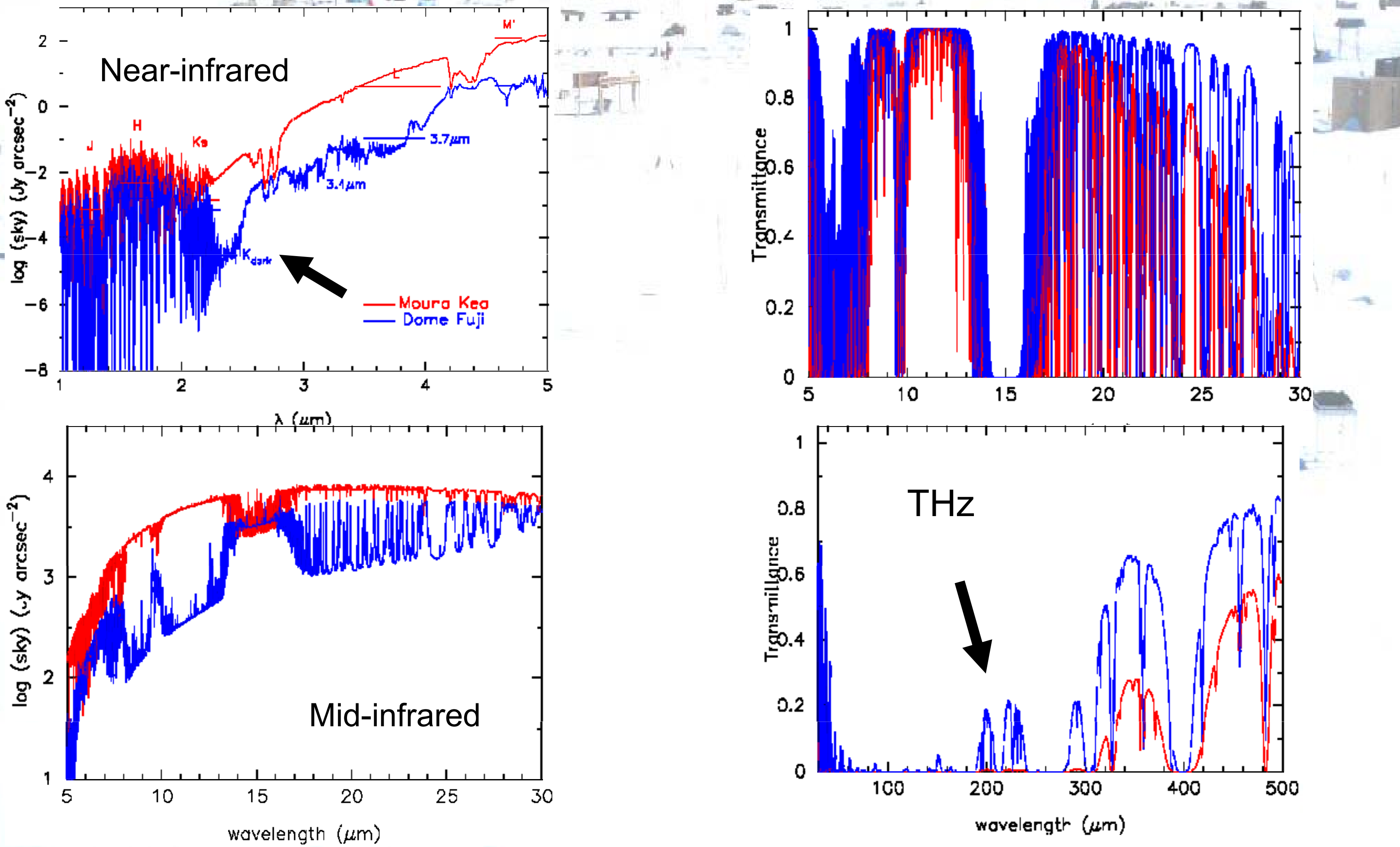
- Clear sky (photometric day > ~85%)
- Little snow (PW=2.5mm/year, 10-20cm snowfall)
- Low and stable humidity (PWV < 0.3mm)
- Low temperature (-70°C in winter)
- Very good seeing above boundary layer
- Weak wind

  3m/s on ground, 5.4m/s at 10m height

Japan has one of best astronomical sites in Antarctica

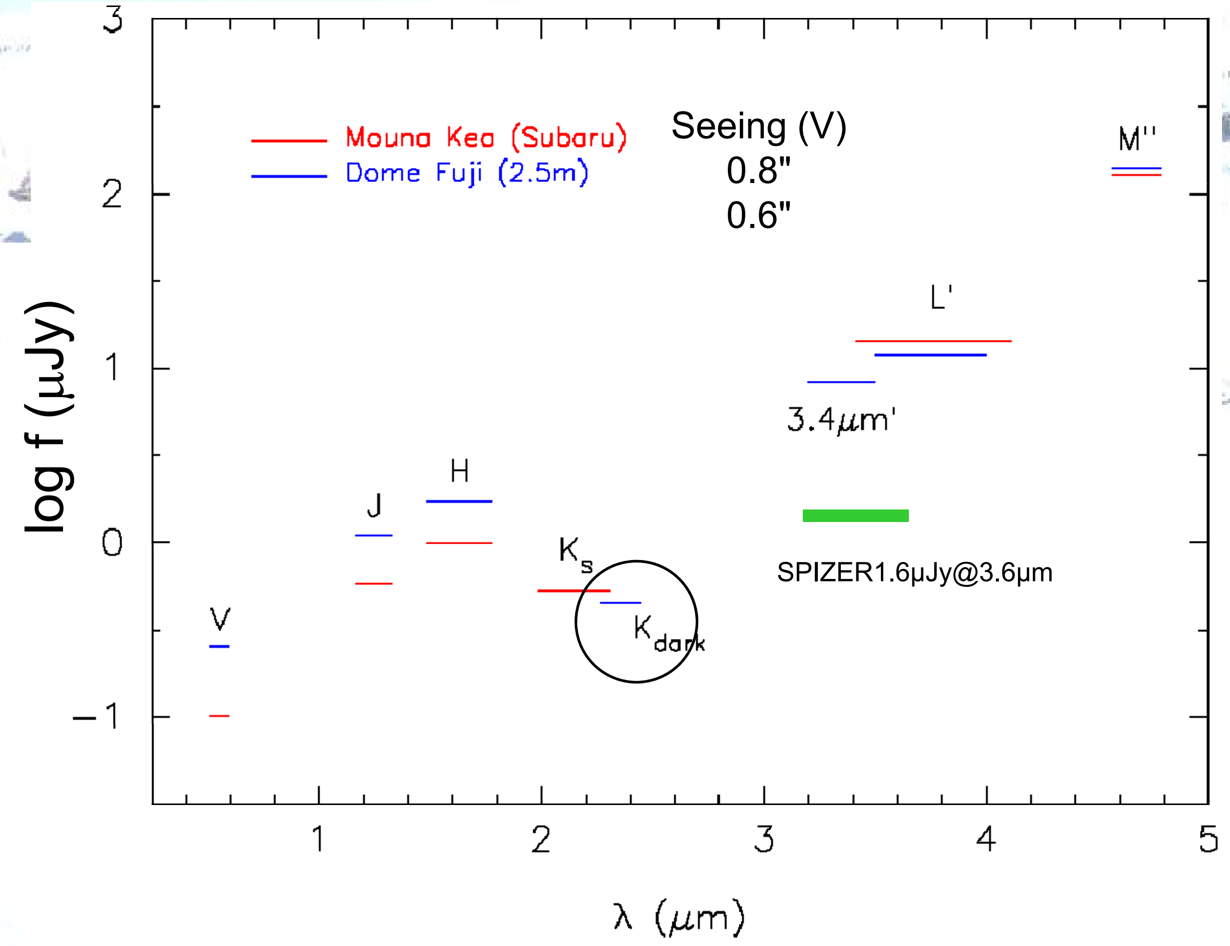
# Low sky background & High transmittance

| | | altitude | temperature | PW |
|---|---|---|---|---|
| blue | **Dome Fuji** | 3810m | -70℃ | 0.2mm |
| red | **Mounakea** | 4200m | 0℃ | 1.0mm |

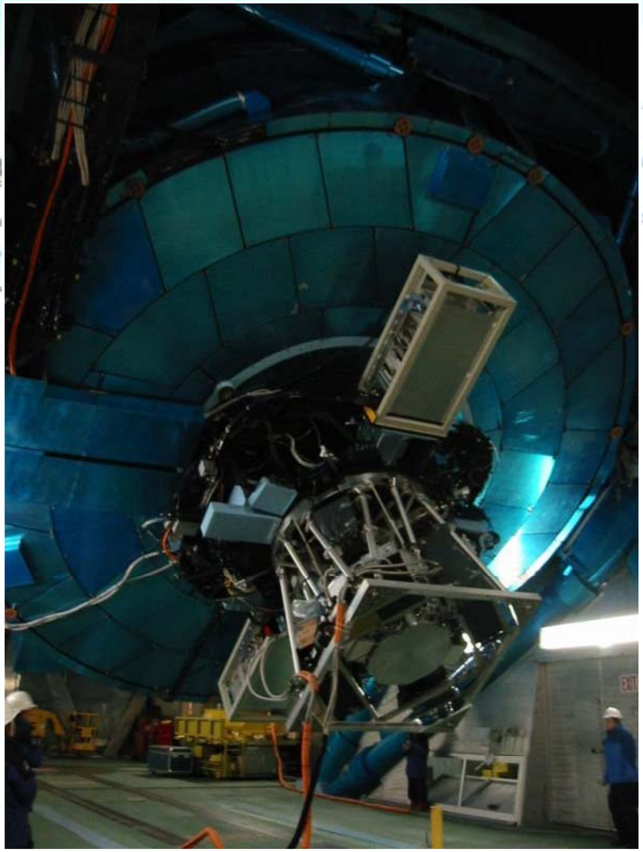


# Comparison with Subaru for 2.5m Antarctic Telescope

1 hour integration with S/N=5σ for point source



8.2mSubaru+MOIRCS



Ichikawa et al. (2005)

performance in near-infrared

1:1

Cost
100 : 1

2.5 m telescope in Antarctica

Kurita et al. (2005)

Ultra light weight mount

~5M$ (?)

# Ultra light weight 2.5m telescope

(Kurita+ 2009)

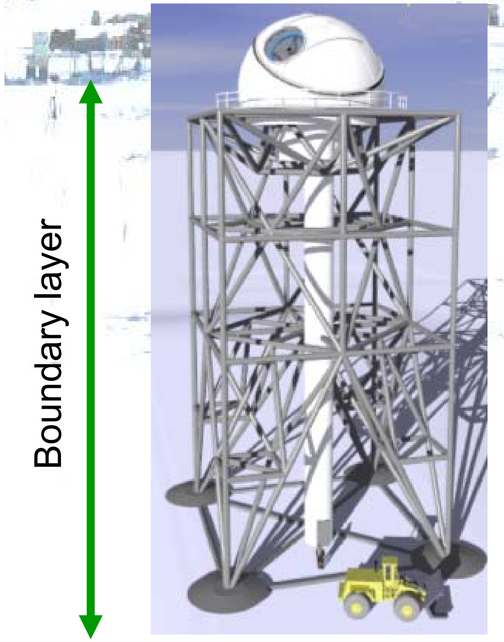
Light weight is highly appreciated for tower telescope installed above boundary layer (18m at Dome F)

Mount for <2.5m mirror

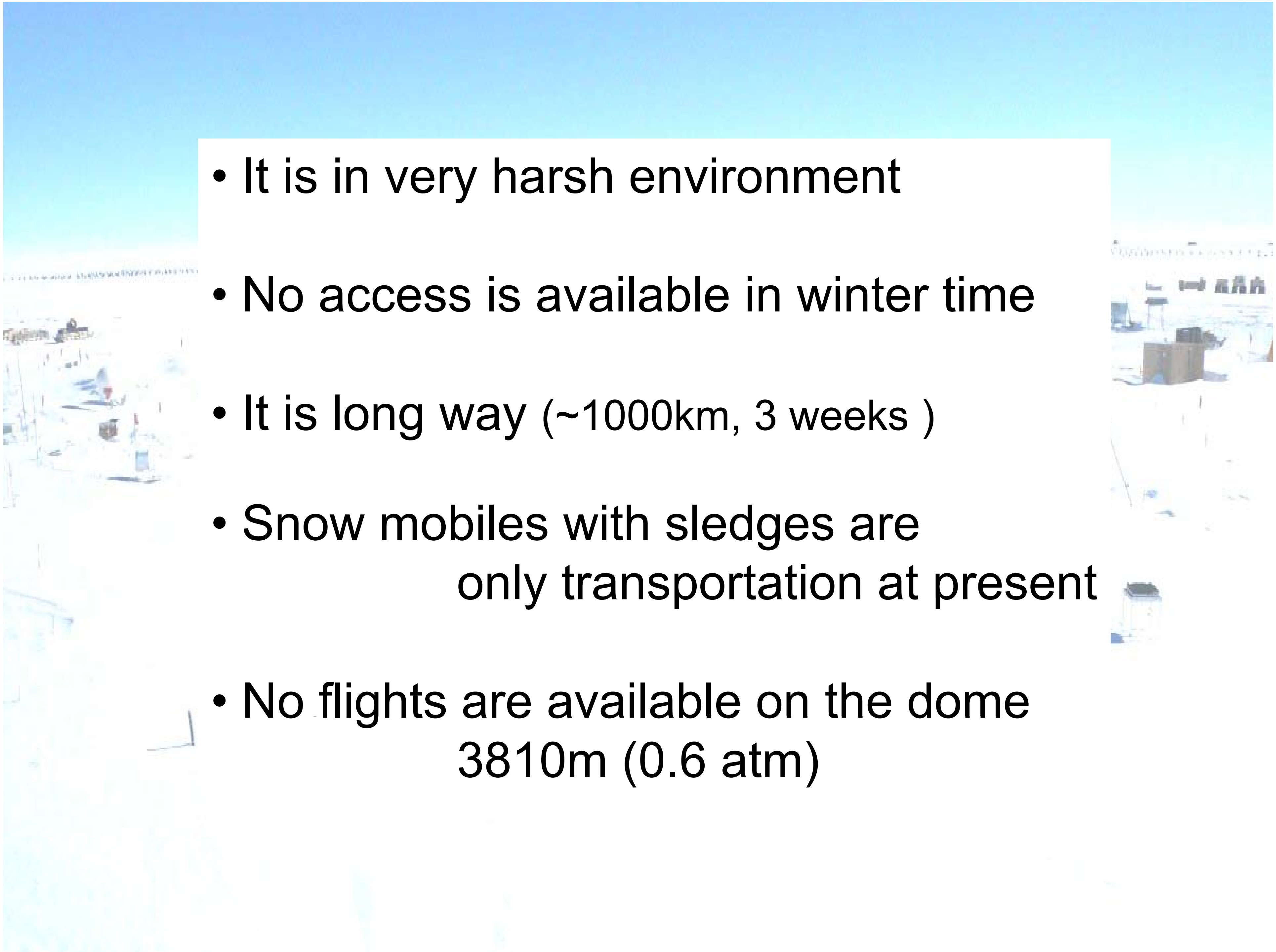
5t w/o mirror
  1/5 of conventional
3" absolute pointing error
0.5" tracking error for 5min (w/o guider)
Cass instrument $\phi$ 900x1200 (0.5t)

Cf.

PILOT2. 4m




Storey+ 2008



- It is in very harsh environment
- No access is available in winter time
- It is long way (~1000km, 3 weeks )
- Snow mobiles with sledges are only transportation at present
- No flights are available on the dome 3810m (0.6 atm)

# Sciences at Dome F

Another harsh environment:

Several scientific programs at Dome-F are proposed. Among them, the project by the astronomy group is most massive and costly. However, the astronomy is the least minority and no astronomers are in NIPR. The development of astronomy depends on the future plan of NIPR.

However, NIPR is strongly supporting astronomy program.

# Astronomy proposals by Japanese groups

**optical, Infrared**

- Wide and deep imaging survey at high redshift
  -- stellar assembly in large scale structure
- Exoplanet atmosphere by transit observations of the second eclipse
- Microlensing observations
- 3-D velocity field information on the full-disk Sun by continuous monitoring in five wavelengths around H-alpha
- Coronal Magnetic field in Sun

**THz, submm**

- Survey of proto-galaxies at high-z
- Molecular clouds and star forming region in the Galaxy

# Dome Fuji station

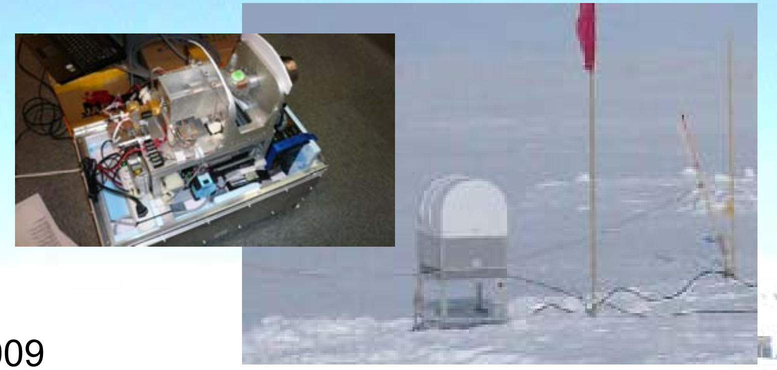
# National Institute of Polar Research

## Dome Fuji (2006/2007)

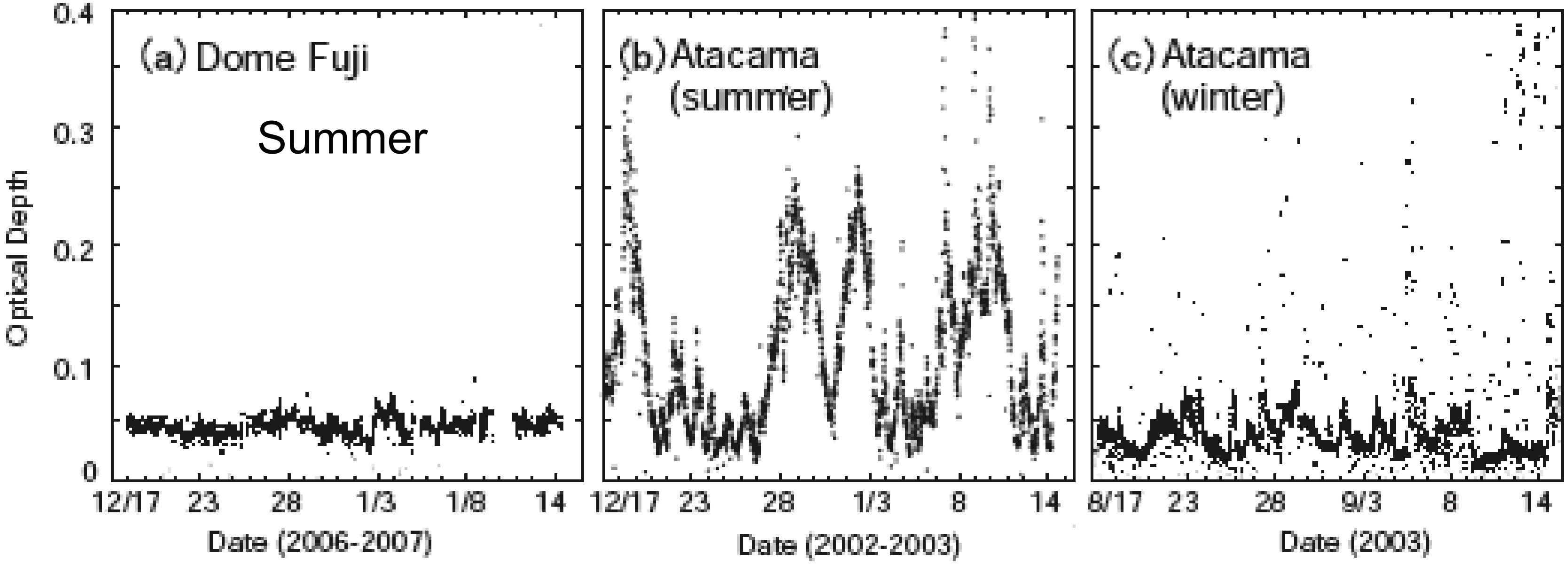
Radiometer
Transmittance of atmosphere

Doppler Sodar
Turbulence of upper atmosphere

# Transmittance in 220GHz band



Seta+ 2009

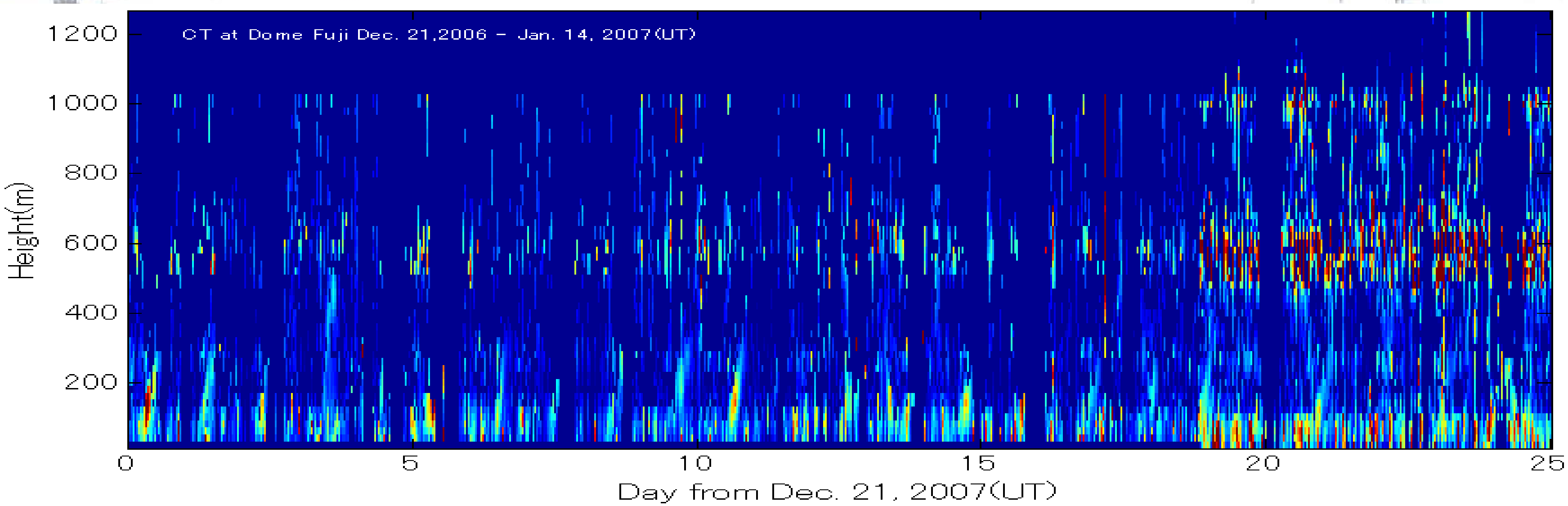



Very stable than Atakama in summer
However, higher transmittance than Atakama in the best days

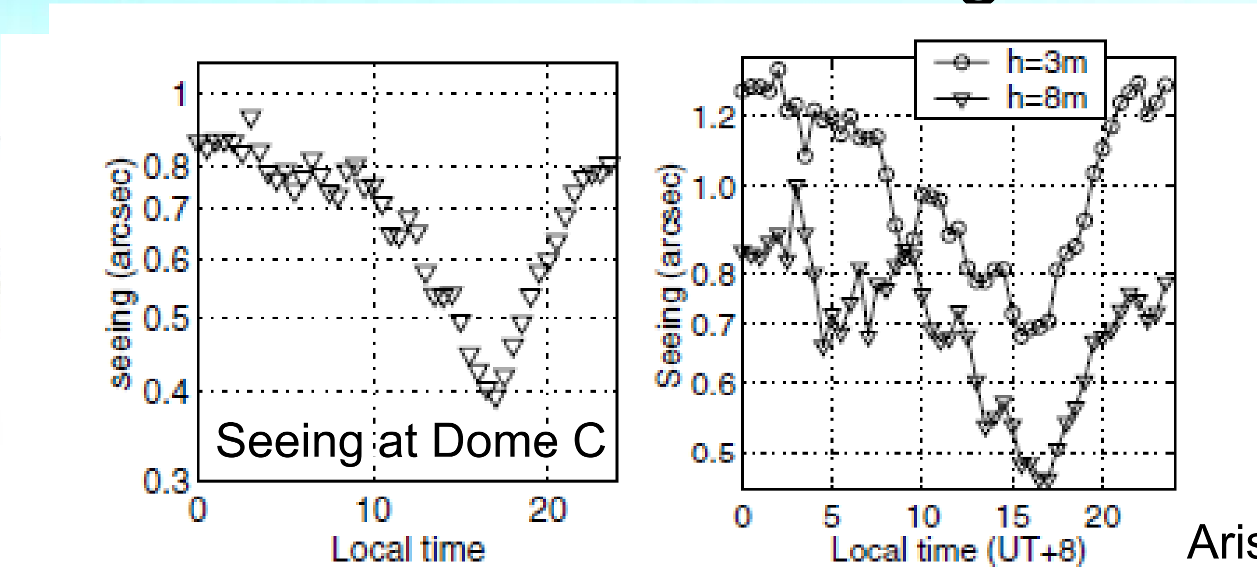
# Turbulence strength

SODAR

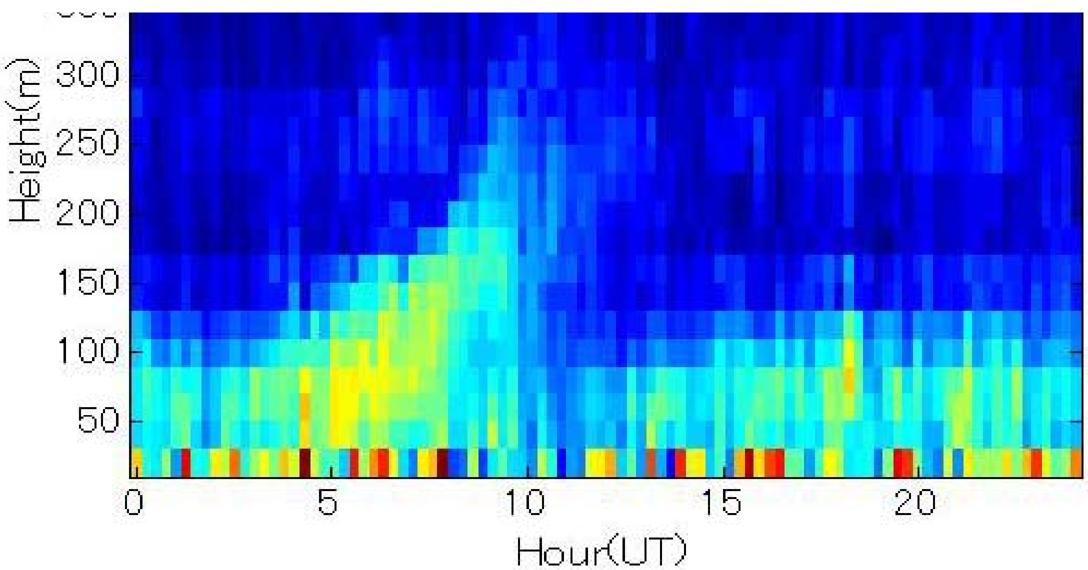
**Dome Fuji**



# Diurnal variation of turbulence strength




Aristidi + 2005



# Pilot studies with small telescopes

- 40cm Infrared telescope

  - Stellar halo in clusters of galaxies at 2.4μ m
  - Exoplanet atmosphere by second transit
  - Site test

- 30cm THz telescope

  - Survey in galactic plane
  - Site test

Seta +

at Rikubetsu (Hokkaido)
-23°C

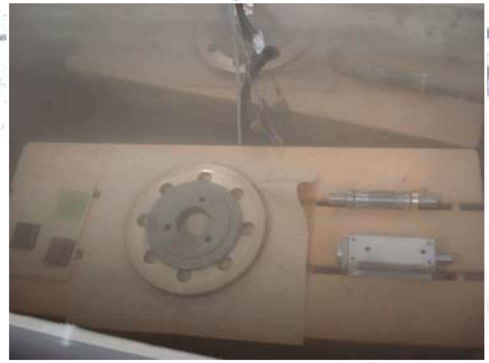
Light weight

AIR-T-40
40 cm Antarctic Infra-Red Telescope

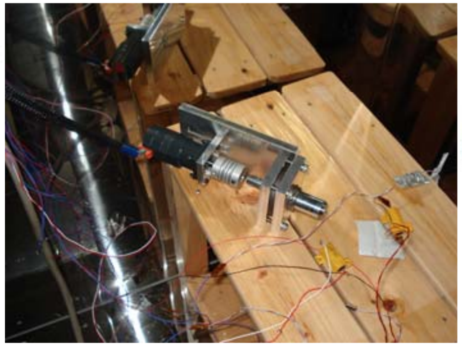
+ remote control (under developing)

Full specs for the environment at −80°C

# All parts are tested in refrigerator at −80℃

gear



motor

# 30cm THz telescope

# Jungflau in Swiss

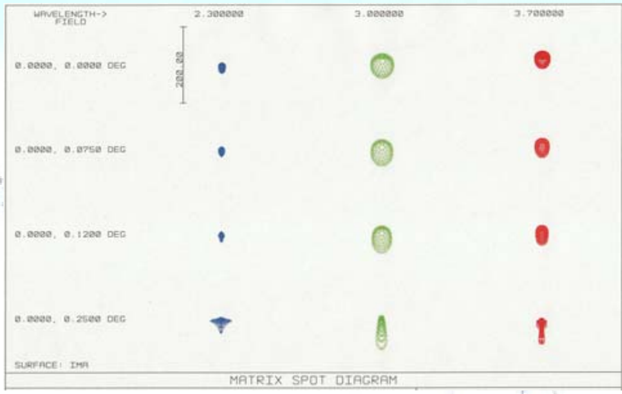
for Galactic plane survey

3580m
-28℃

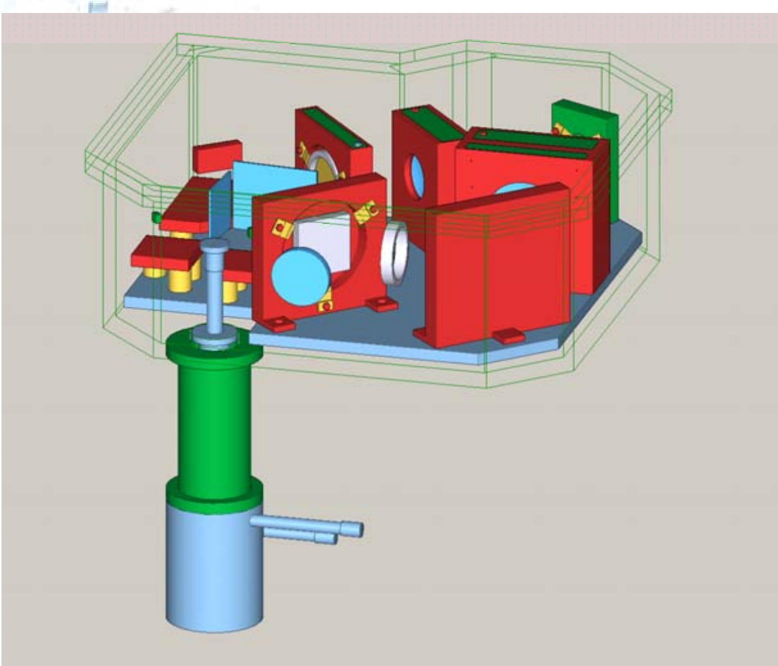
Seta et al.

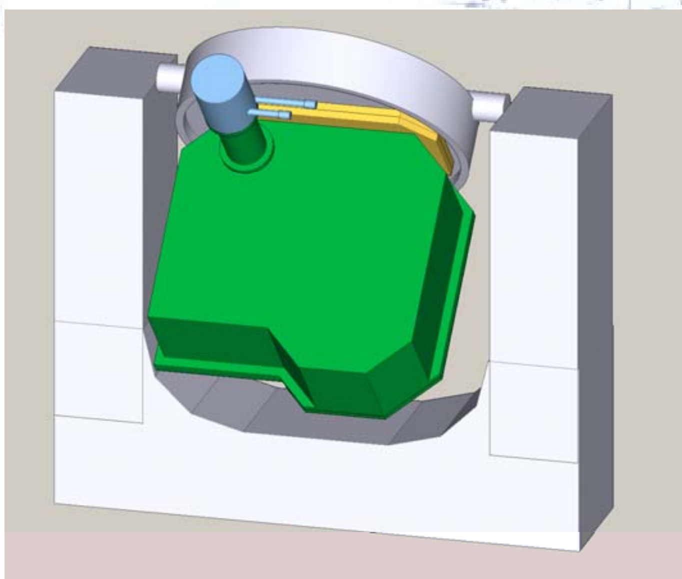
# Near-infrared three-color camera

| | | | | |
|---|---|---|---|---|
| $K_{dark}$ | (2.4μm) | 2Kx2K | MCT | 15’x15’ |
| $CH_4$ | (3.4 μm) | 256x256 | InSb | 6’x6’ |
| L' | (3.8 μm) | 256x256 | InSb | 6’x6’ |




Lundock+ (2008)

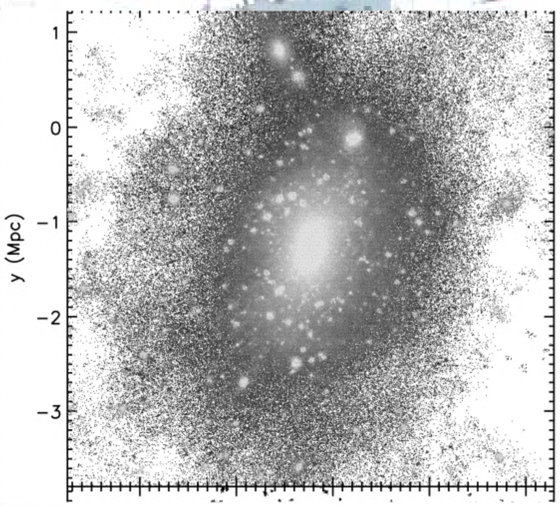




Science Program for 40cm Infrared telescope (1)

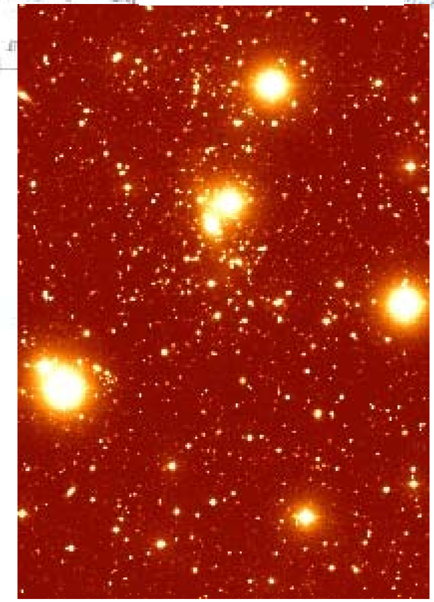
# Stellar halo in clusters of galaxies at 2.4μm

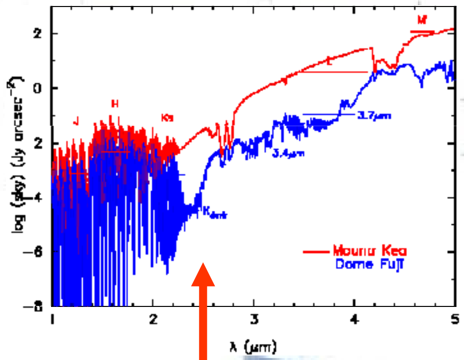
Dark halo model (Okamoto 1999)




Katsuno (2005)

Abell 1795






K band window

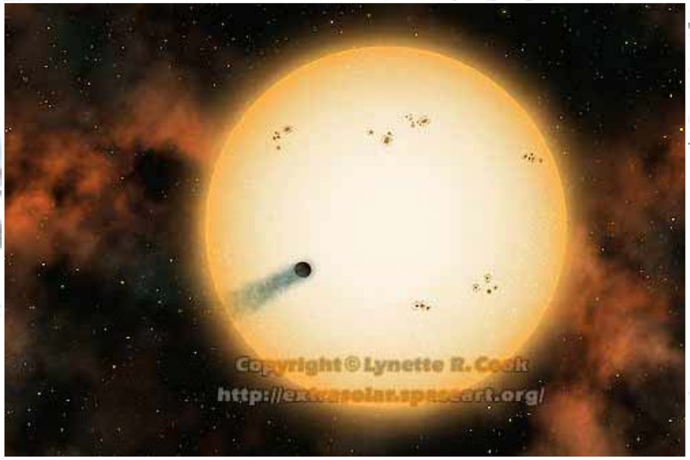
I (0.8μ m) 28.2mag/arcsec

No detection

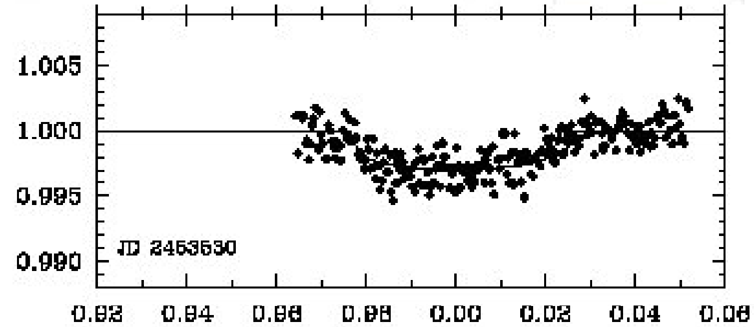
Dwarf density < 200galaxies/$Mpc^3$

Science Program for 40cm Infrared telescope (2)

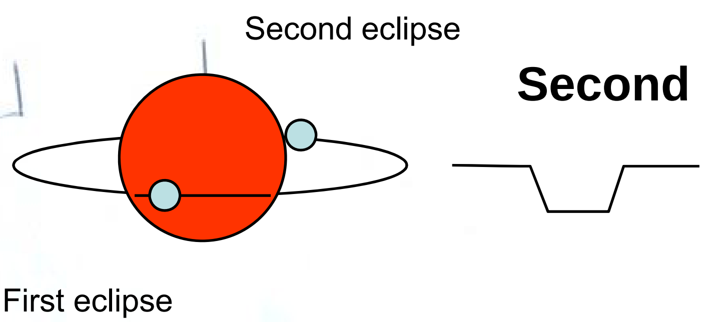
# Atmosphere of Extrasolar planets




Transit of planets in front of star or behind star



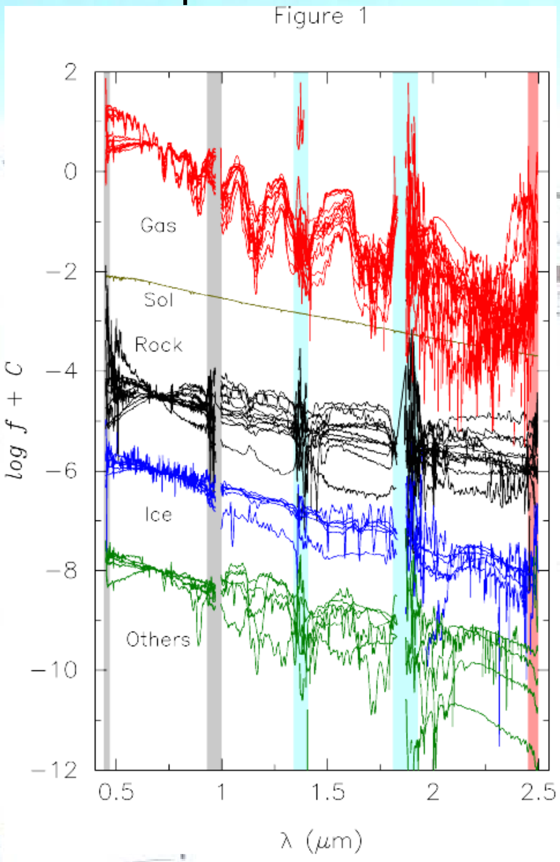

Sato+ (2005)



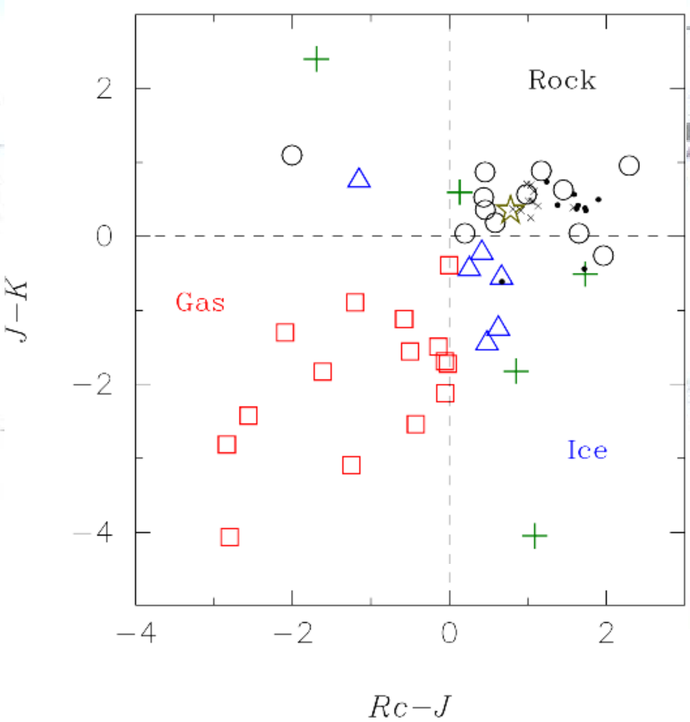

**Second eclipse hides the atmosphere of planet**

## Planet atmosphere is characterized by molecules like $CO_2$, $H_2O$ or $CH_4$.

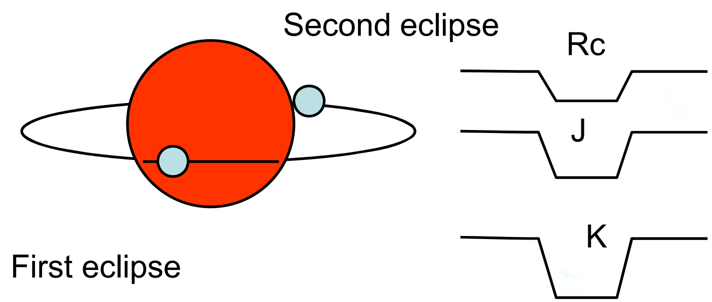
### Solar planets and moons




### Lundock & Ichikawa+ 2009




By transit observations with broad infrared at the second eclipse, we can classified the planets into Rock, Ice, and Gas planets.
$CO_2$, $H_2O$, or $CH_4$ are also observable with median-width bands.



# Collaboration with Australia group at Dome Fuji

Engine module

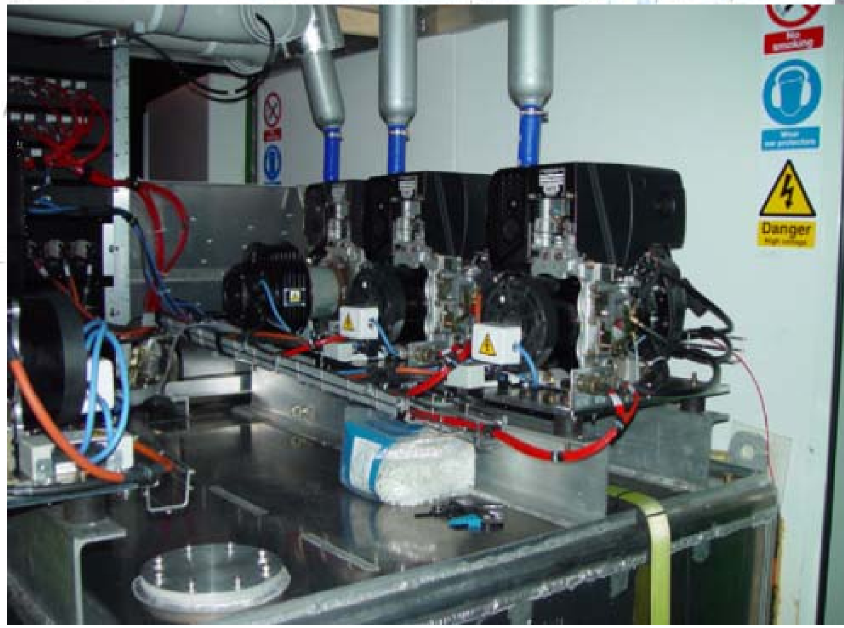
Storey+

Dome A

long-term continuous automatic operation with remote control

Engine module for Dome A

1kW for 400 days




Storey+

# Future plans

2009/12-2010/2

- A first step on Dome Fuji by a Japanese astronomer
- Transmittance measurement by handy infrared spectrograph
- Transmittance measurement by 220GHz radiometer

2010-2015 New 6-year Projects by National Institute of Polar Research

- Construction of winter-over facilities at Dome F

- our proposal for astronomy with small telescopes has been accepted for the first 3-year program (2010-2012)

2010/12-2011/2

- Deployment of 40cm-infrared and 30cm-THz telescopes at Dome Fuji
- Deployment of PLATO-Fuji by collaboration with UNSW
- Observations with small telescope over winter (remote operation)

2014?- Construction of large telescope(?)