Seeing Measurement by the Tohoku Univ. Antarctica DIMM

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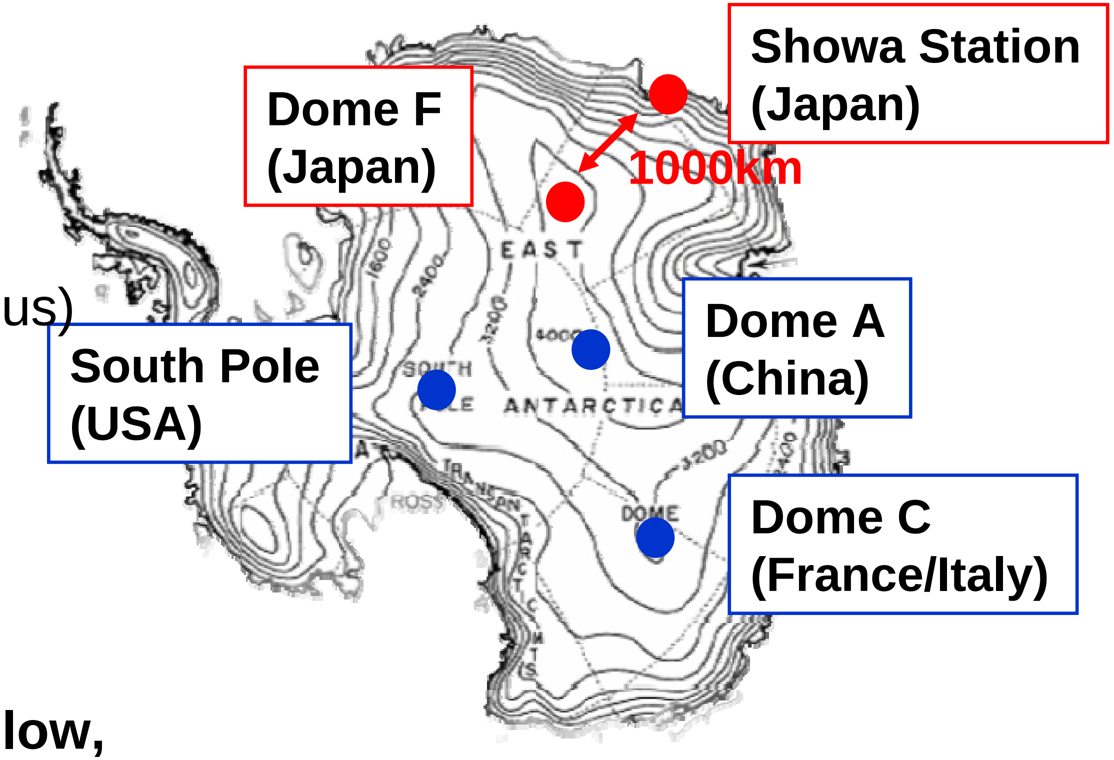
- **Introduction**
  - ~Why Antarctica?~
  - ~Seeing~
- **DIMM**
- **Making Tohoku-DIMM**
  - ~Hardware~
  - ~Software~
- **Observation**
- **Comparison**
  - ~Hiroshima DIMM~
- **Future work**

Antarctica 40cm Telescope with the DIMM

Introduction ~Why Antarctica?~

The last window toward to the Universe

☆ Plateau of Antarctica
(plateau = highland)



Cold (down to -80 degree Celsius)
about 4000m above sea level

↓

the Driest site
on the Earth

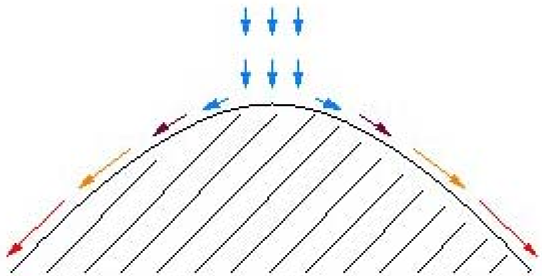
→ **IR Background is very low,**
and IR transmission is very high. (Barton et al.2005, Ichikawa's report 2008)

Advantage for InfraRed Astronomy

Introduction ~Why Antarctica?~

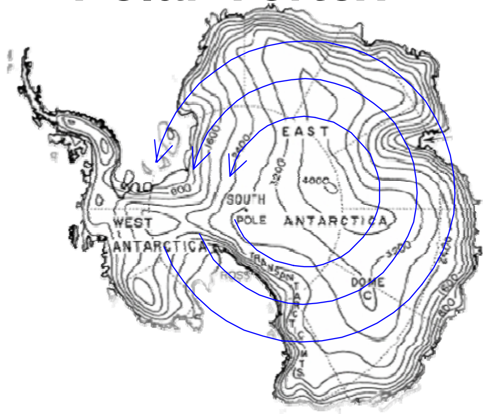
☆ Wind at Antarctica plateau

Katabatic wind



No Blizzard in the plateau

Polar Vortex



Dome C summer

Dome C winter

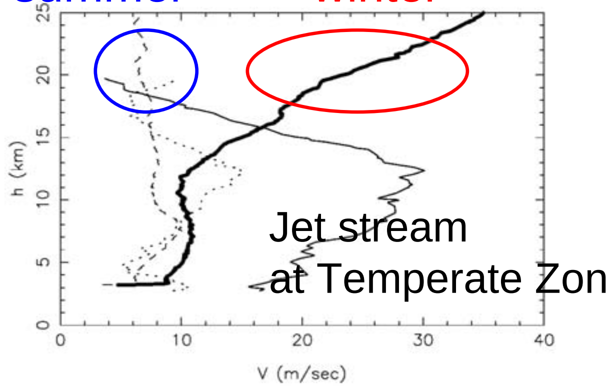
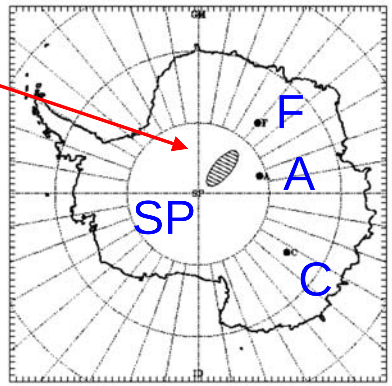


FIG. 5.—Comparison between the median wind speed profile estimated during the wintertime (*thick solid line*) and summertime (*dashed line*) above Dome C in 2003, and the median wind speed profile estimated above the San Pedro Mártir Observatory in the summer (*dotted line*) and winter (*thin solid line*). San Pedro Mártir is taken as representative of a midlatitude site.

Geissler & Masciadri 2006

Center of the polar vortex



Hagelin et al. 2008

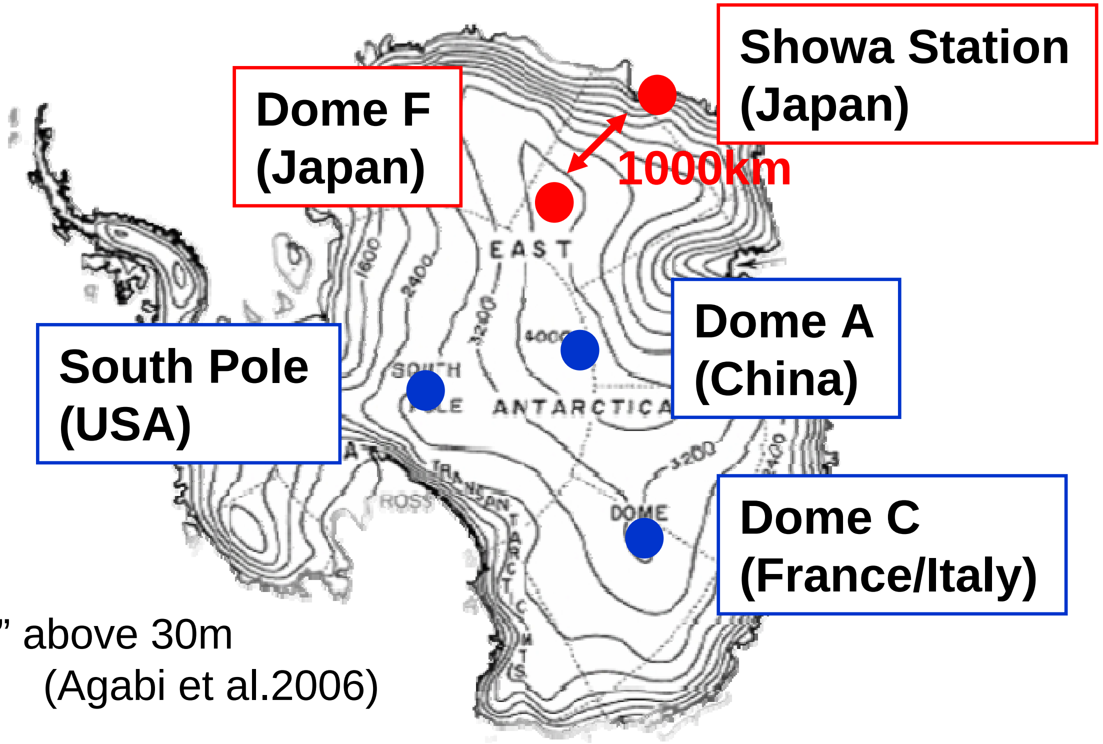
Figure 8. Antarctica map. The sites of South Pole, Dome A, Dome C and Dome F are labelled with a black point. The dashed region indicates the 'position space' of the polar high at different heights as retrieved from the Fig. 7.

Introduction ~Why Antarctica?~

Cold
high elevation
dry
weak wind
Stable weather
Downdraft

↓

Good seeing



for example, Dome C ～0.4” above 30m
at 500nm
(Agabi et al.2006)

Seeing size at Dome F ?

Introduction ~seeing~

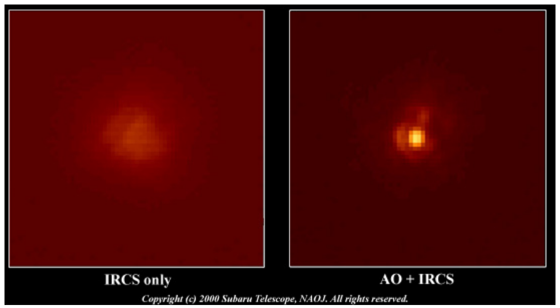
The Seeing is defined as FWHM of stars at long time exposure.

An empirical diffraction limit is "Rayleigh limit".

$$L[rad] = 1.22 \times \left(\frac{\lambda}{D}\right)$$

	Actually Seeing	Rayleigh limit	
Subaru Telescope (D = 8.2m)	**0.3"**	**0.06"**	at 2 μm
	0.7"	**0.02"**	at 500nm

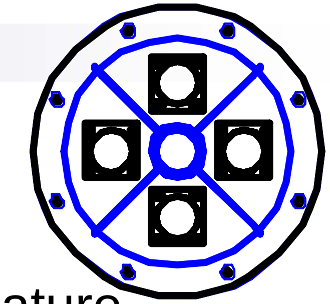
However, because the turbulent bed exists in the atmosphere, the size of stars actually grows.



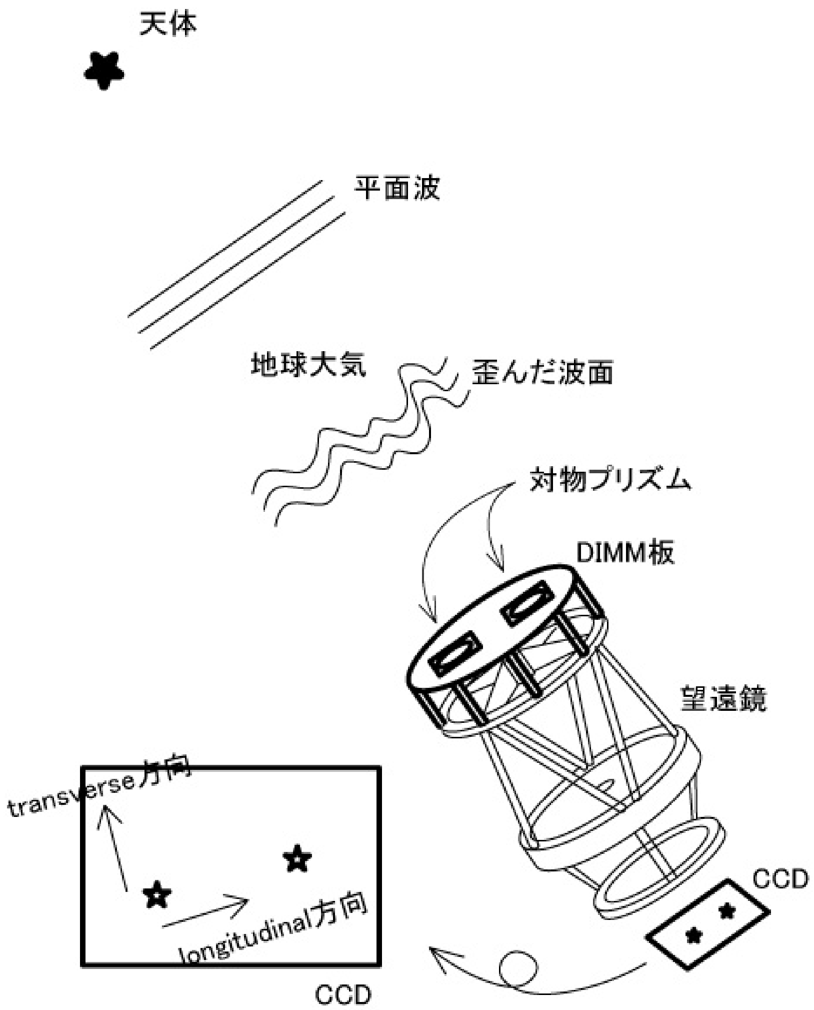
http://subarutelescope.org

It is important to choice Good Seeing Site.

DIMM



“Classical” DIMM(Differential Image Motiron Monitor) has 2 apature.



Star light

↓

The phase shifts by air turbulence

↓

DIMM

↓

Image of two stars

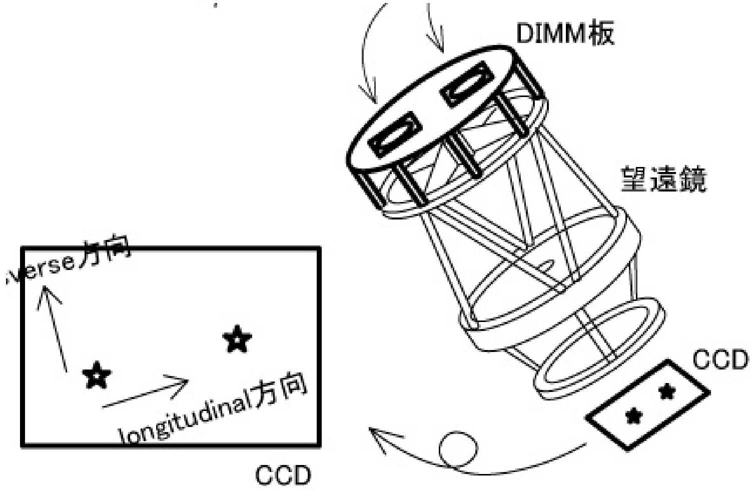
↓

Measurement of relative position

↓

Convert them into seeing value

DIMM



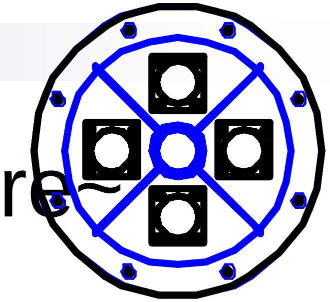
$$\theta'_l = 0.98\left[2 \times (0.179D^{-1/3} - 0.0968d^{-1/3})\right]^{-3/5} \lambda^{-1/5} \left[\sigma_l^2 \cos\gamma\right]^{3/5}$$

$$\theta'_t = 0.98\left[2 \times (0.179D^{-1/3} - 0.145d^{-1/3})\right]^{-3/5} \lambda^{-1/5} \left[\sigma_l^2 \cos\gamma\right]^{3/5}$$

D･･･Aperture Diameter
d･･･separation two aperture

→From (σ_l, σ_t)
We obtain Seeing size.

Making Tohoku-DIMM ~Hardware~



Unlike a “classical” DIMM,
Tohoku DIMM is “Four aperture DIMM”
to get more information of a turbulence layer.

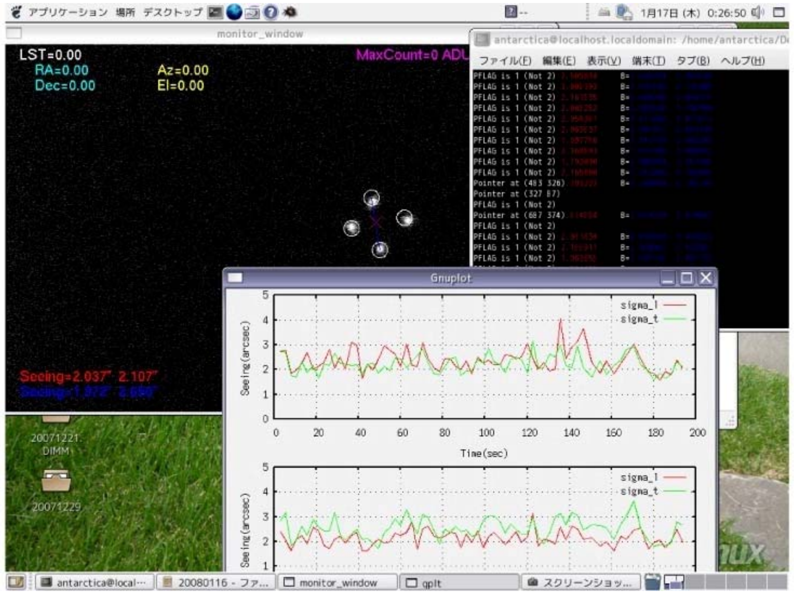
Wat-100N (Watec Co., Ltd.)
Min. 0.001 lx, and
Exp. time/gain/gamma
Manually changeable

Expose time: 1/1000s

Antarctica 40cm Telescope	
Aperture	400mm
Focal length	5190mm
DIMM	
Separation of diagonal apertures d	250[mm]
Aperture diameter D	74mm[mm]
Apex angle of Wedge prism	30[arcsec]
Pixel size	
Horizontal	0.3903[arcsec/pix]
Vertical	0.4553[arcsec/pix]

Making Tohoku-DIMM ~Software~

Software was Developed by Dr. Motohara (Research Associate, University of Tokyo)



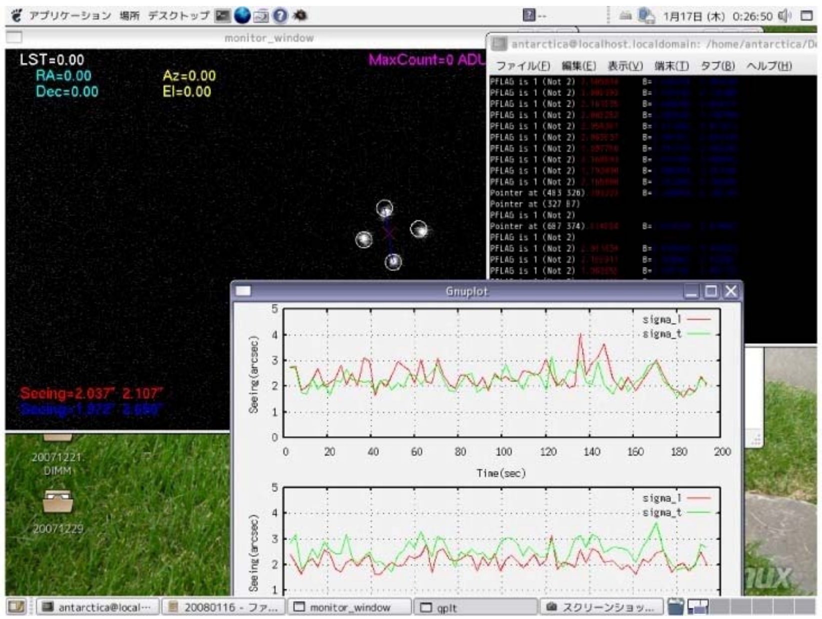
His Software

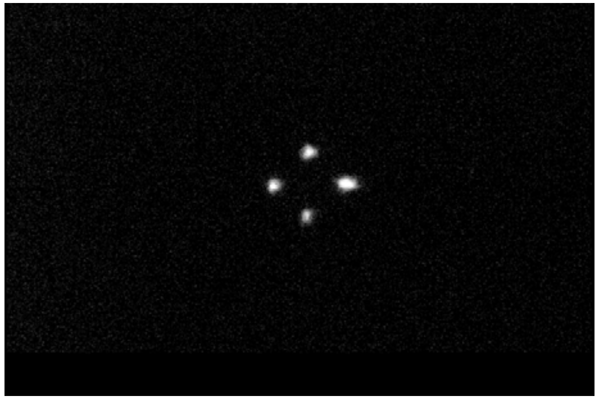
Dr.Motohara and UT-DIMM

From His software we can get analyzed data (seeing size [arcsec]) but zenith angle is not corrected, so I made some programs for zenith angle correction.

Observation

Jan 13 2008 Measurement of Pixel size
Jan 16 2008 Observation at Sendai
Feb 10 2008 Observation at Rikubetsu (Hokkaido, the North island of Japan)
Feb 14 2008 Observation at Rikubetsu





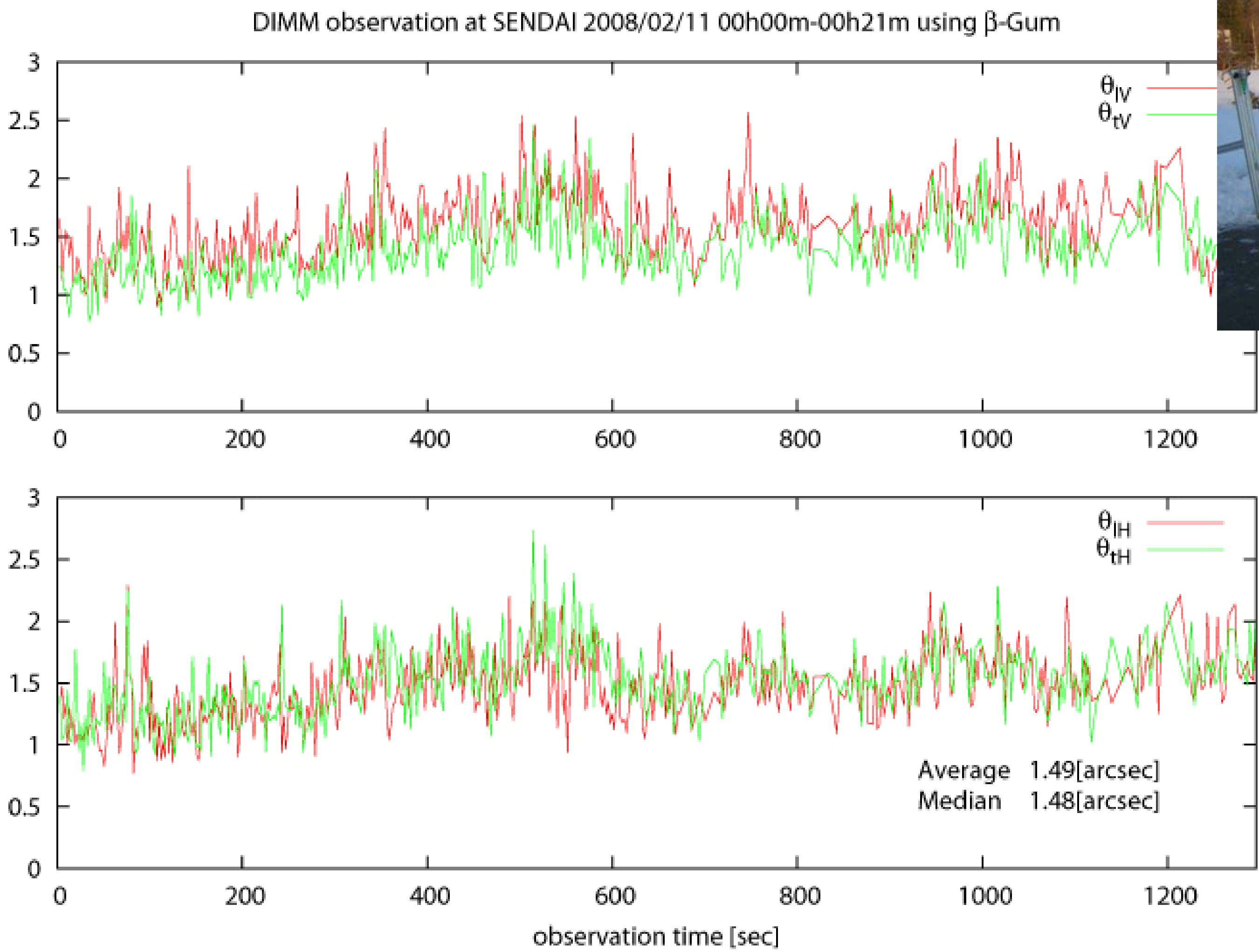
Movies

Star

Saturn

Observation

Feb 10 2008 Observation at Rikubetsu



Rikubetsu

Average 1.49”
Median 1.48”

Comparison ~Hiroshima DIMM~

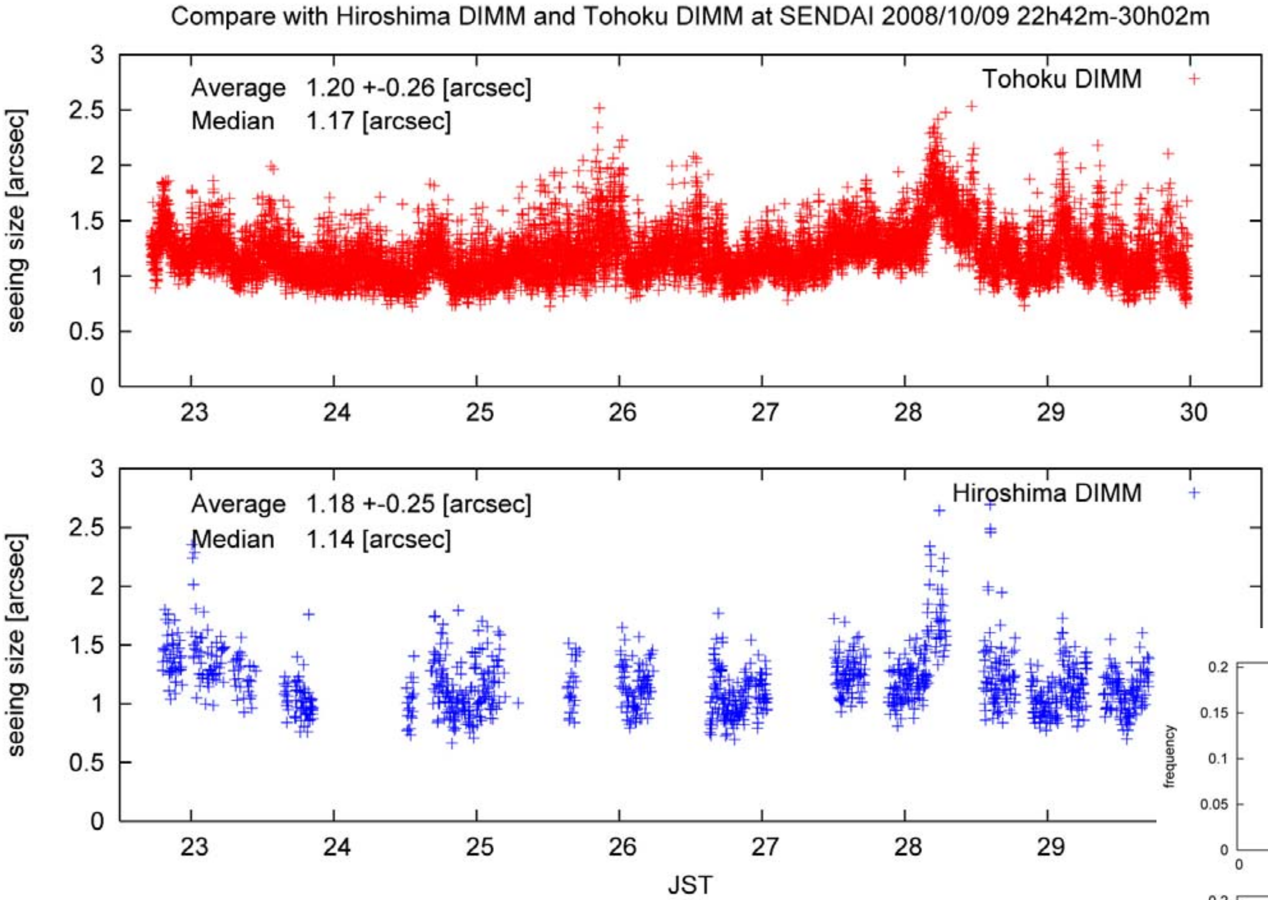
To check the Seeing Value is reasonable or not, we compare Tohoku DIMM with Hiroshima DIMM.

Hiroshima Univ. DIMM

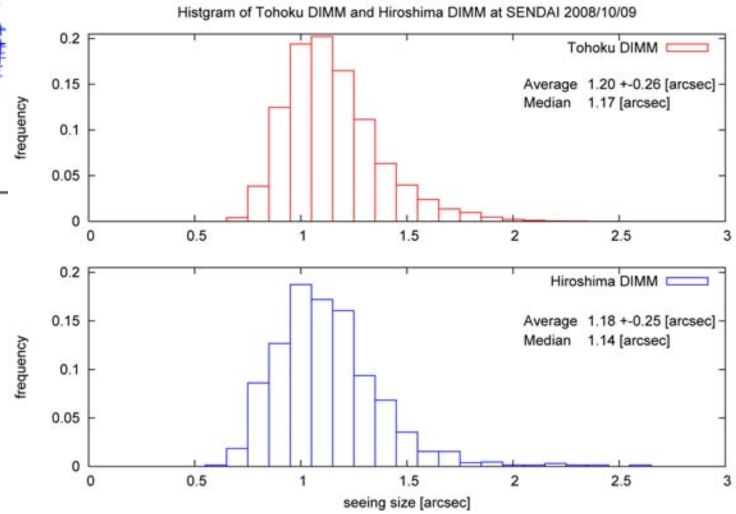
	Tohoku DIMM	Hiroshima DIMM
Telescope	AIR-T-40	Meade LX200GPS-20
Diameter[mm]	400	203
Focal Length[mm]	5190	2000
D[mm]	74	50
d[mm]	250	144
Prism[arcsec]	30	50
Pixelsize[arcsec/pixel]	0.390×0.455	0.403×0.451
Camera	WAT-100N	WAT-100N
Exp.Time[sec]	1/1000	1/1000

Jul. 13 2008, 4hour
Oct. 3 2008, 4hour
Oct. 9 2008, 7hour
Oct.13 2008, 6hour

Comparison ~Hiroshima DIMM~



Oct. 9 2008



histogram shape
Ave./Med. value → **Good agreement**

Future Work

More Observation

change in a day
change in a season

Cold Test

Camera
AD converter
PC ,etc.

We observe more and more at Sendai, and get knowhow and technique.

↓

2010 Observation at Dome Fuji

Science by AIR-T40

Antarctic Infra-Red Telescope 40cm
Telescope on the 5m tower

Aperture : 400mm
Reyleigh limit : 0".8(J-band), 1".1 (H-band), 1".4 (K-band)
Winter Seeing : 1".3(J-band), 1".2 (H-band), 1".1 (K-band)

↓

An original observation is H-band and K-band.

Because of the poor resolution and observation in the surface layer,
AIR-T-40 cannot make the best use of Antarctic good Seeing.

★Optical (0.5nm) Reyleigh limit is 0".3 and daytime seeing is 0".5
→ the Solar observation

★long time (more than 3 months) darkness during the winter
→ the Transit Search for extrasolar planets

Future

AIR-T-2K (Antarctic Infra-Red Telescope 2000mm)
on the 30m tower

Reyleigh limit : 0".2(J-band), 0".2 (H-band), 0".3 (K-band)
Winter Seeing : 0".3(J-band), 0".2 (H-band), 0".2 (K-band)

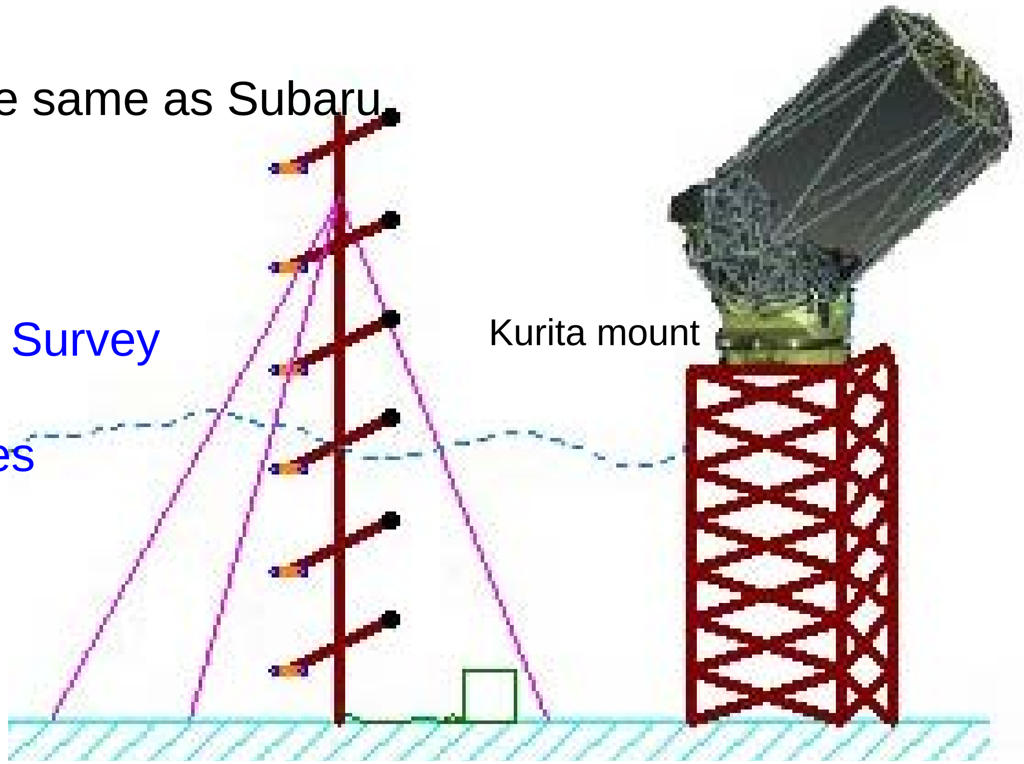
limiting magnitude (1hr, S/N=5) Ichikawa's report

J-band ~ 23mag
H-band ~ 22mag
K-band ~ 23mag

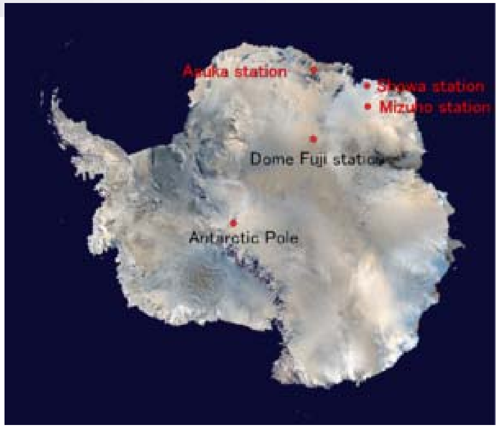
} the same as Subaru

★Wide Field Near Infra-Red Survey
- →Cosmic share
- →evolution of the galaxies
- →brown dwarf

★Transit Search



Why Antarctica?



http://en.wikipedia.org/wiki/Showa_Base

Antarctica is always Blizzard?

No, and it is only generated in the coast.

Internal Antarctic plateau is calm in all seasons.

★National Institute of Polar Research (Japan) own Dome Fuji station.

Dome Fuji station

very cord (Ave. -58℃)
high altitude 3810m
Dry < 0.6mmPWV

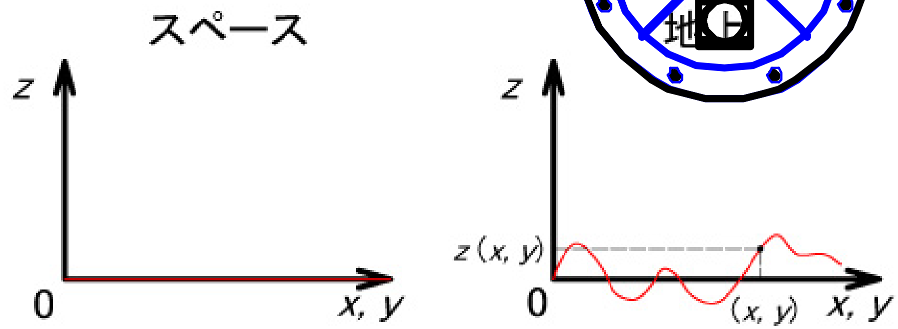
→ IR Background is very low,
and NIR transimittance is very high

calm weather
wind speed 3m/s
always downdraft

→ >75% fine days
<0".5 good seeing

Antarctic plateau is one of the best site for ground-base astronomy.

Theory (1)



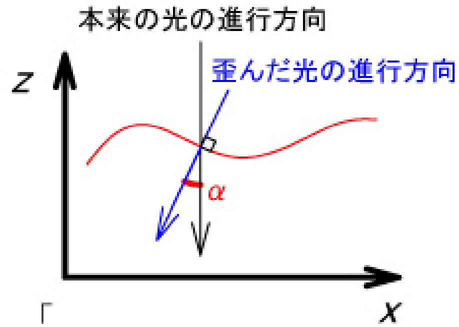
Star light at Space･･･Parallel

↓

Air turbulence･･･wavefront $z(x,y)$

$$z(x,y)=\frac{\lambda}{2\pi}\phi(x,y)$$

$\phi(x,y)$ ･･･phase error



Angle of arrival fluctuation･･･ α

$$\alpha(x,y)=-\frac{\partial}{\partial x}z(x,y)=-\frac{\lambda}{2\pi}\frac{\partial}{\partial x}\phi(x,y)$$

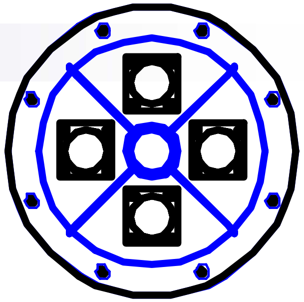
$B_\alpha(\xi,\eta)$ ･･･Covariance of α

$B_\phi(\xi,\eta)$ ･･･Covariance of ϕ

$D_\phi(\boldsymbol{r})=\langle[\phi(\boldsymbol{x}+\boldsymbol{r})-\phi(\boldsymbol{x})]^2\rangle$ ･･･Phas structure function

Kolmogorov turbulence $\rightarrow D_\phi(\xi,\eta)=6.88\left(\frac{r}{r_0}\right)^{5/3}$

Theory (2)



Change the angle of arrival fluctuation α
= Change in position of stars

$$\langle|\alpha_1 - \alpha_2|^2\rangle = \sigma^2(d)$$

Relationship between r_0 and FWHM $\theta = 0.98\,\dfrac{\lambda}{r_0}$

Zenith angle correction･･･ $\theta' = \theta \times (\cos\gamma)^{3/5}$

It calculates…

$$\theta'_l = 0.98\left[2 \times (0.179D^{-1/3} - 0.0968d^{-1/3})\right]^{3/5} \lambda^{-1/5}\left[\sigma_l^2 \cos\gamma\right]^{3/5}$$

$$\theta'_t = 0.98\left[2 \times (0.179D^{-1/3} - 0.145d^{-1/3})\right]^{-3/5} \lambda^{-1/5}\left[\sigma_l^2 \cos\gamma\right]^{3/5}$$

D･･･Aperture Diameter
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→From (σ_l, σ_t)
We obtain Seeing size.