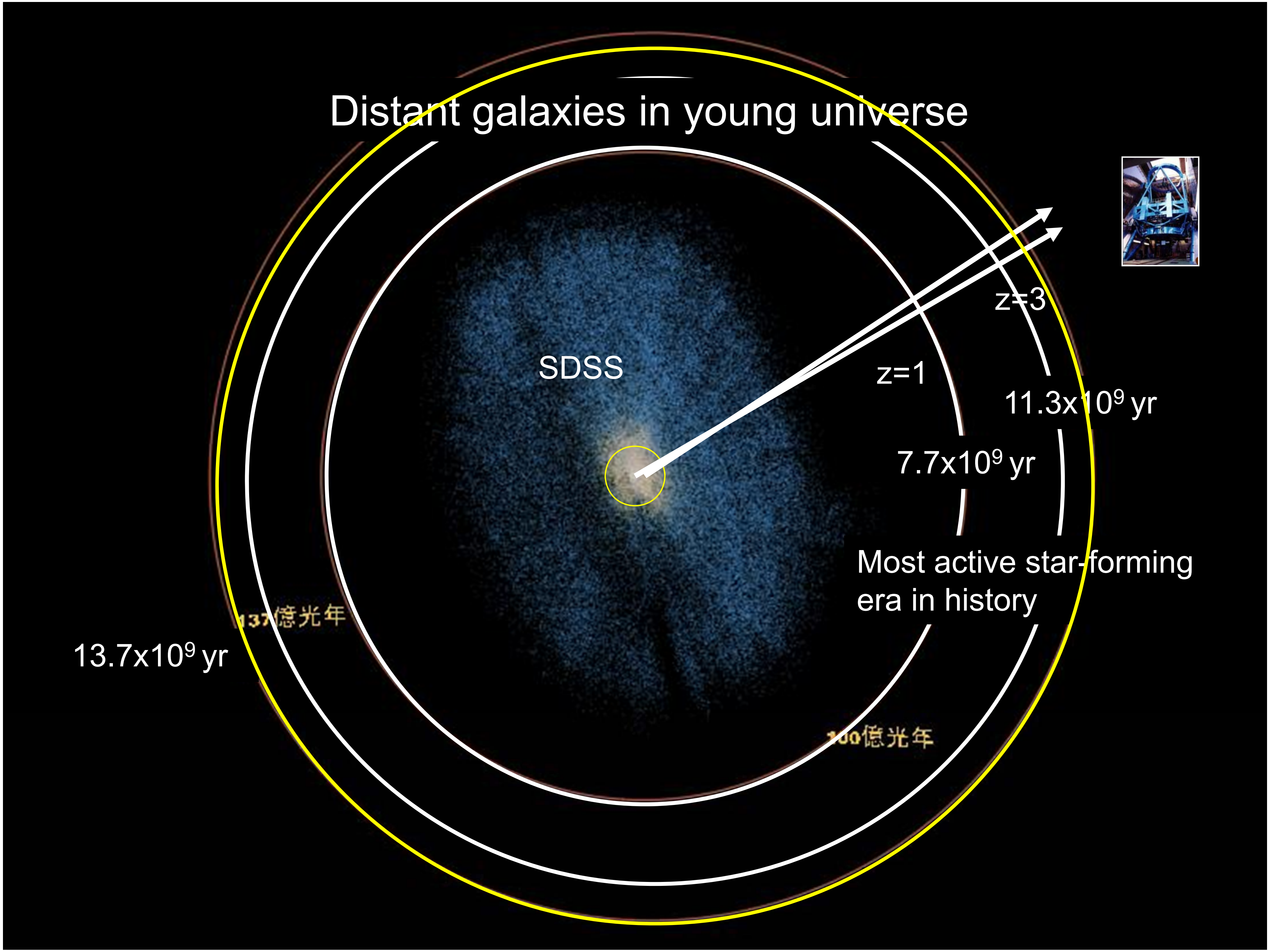
Near-Infrared Survey at Dome Fuji

motivation and future plan

Tohoku University

Takashi Ichikawa

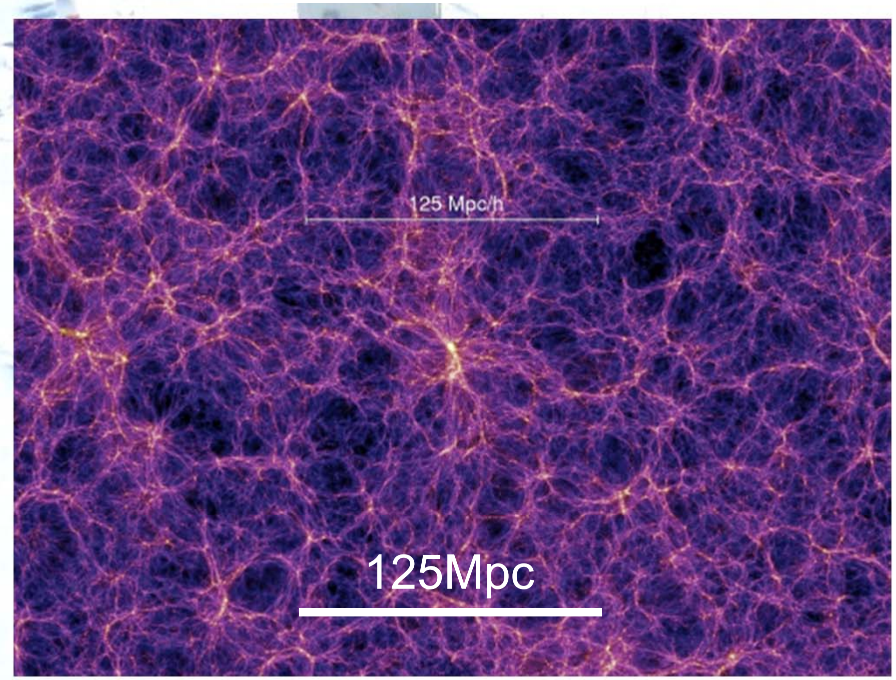
Distant galaxies in young universe



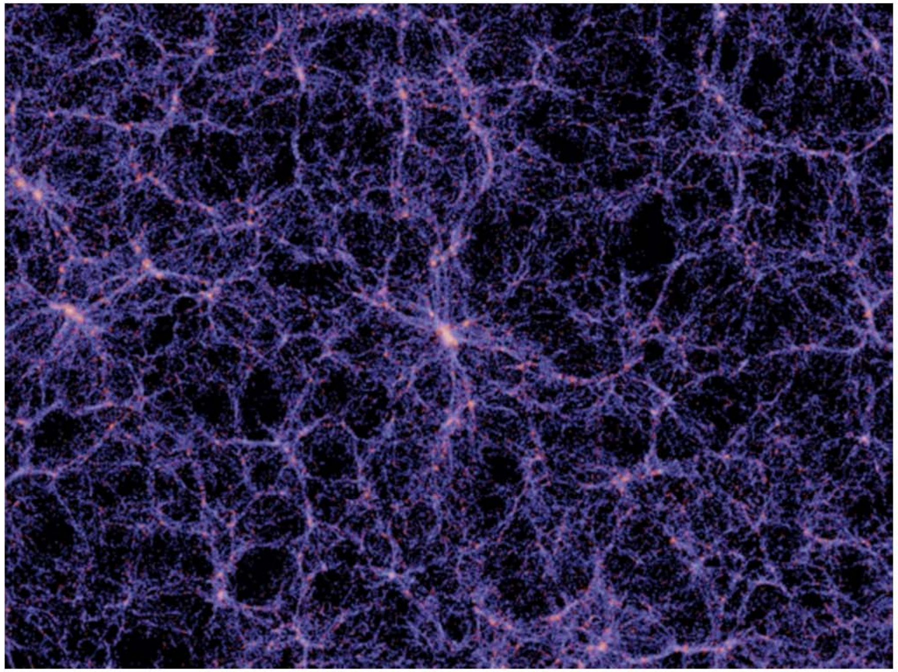
The Millennium Simulation

z=1.4 (9 Gyr)

Cold Dark Matter



galaxies



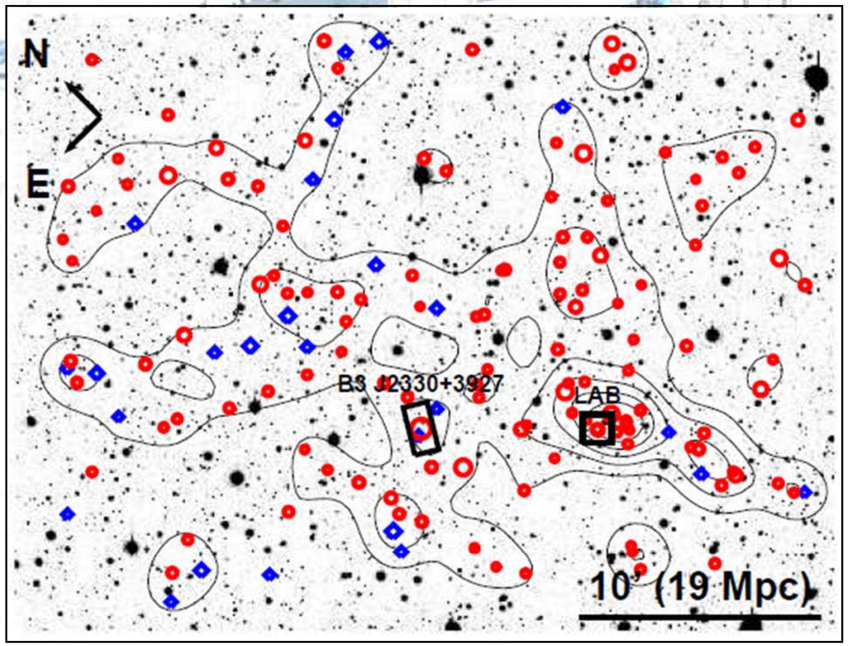
http://www.mpa-garching.mpg.de/galform/virgo/millennium/

Distribution of exotic bright galaxies

e.g., very young galaxies with strong emission lines, dusty galaxies, bright massive galaxies

z=3.1 (12 Gyr)

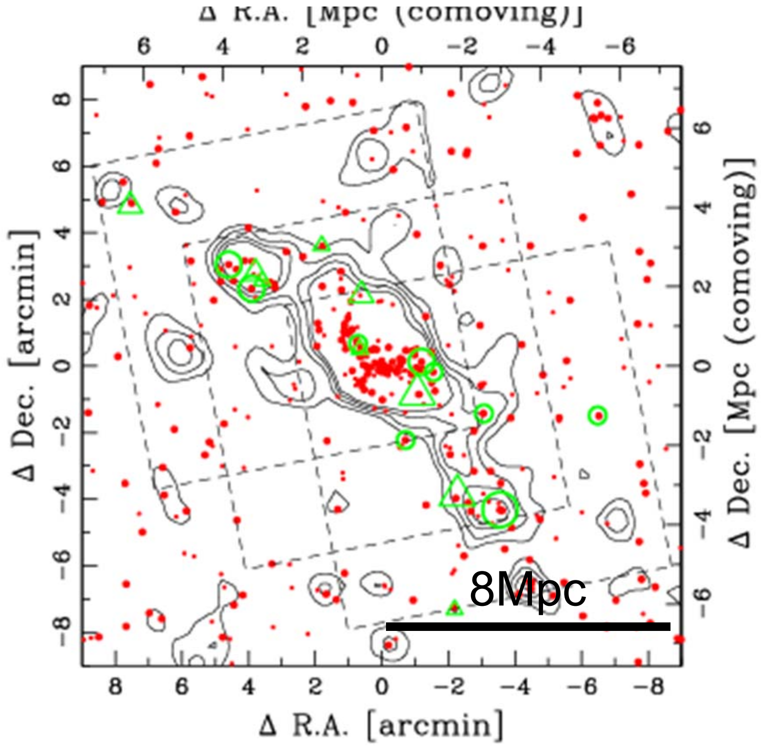
Ly α emitters



Matsuda+ 2009

z=0.8 (6.6 Gyr)

Dusty galaxies (15μm)

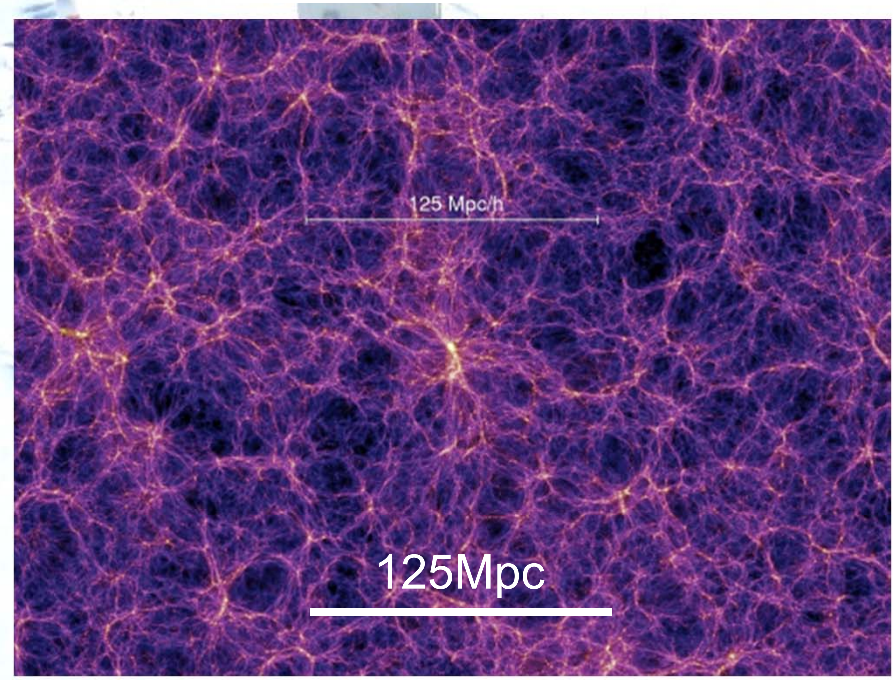


Koyama+ 2010

They are short-lived objects or temporal phenomena.

For the direct comparison of models, normal galaxies such like the Galaxy, LMC, SMC, which had been the building block for massive galaxies in early universe, we should know the distribution of normal galaxies.

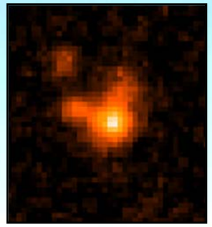
Cold Dark Matter

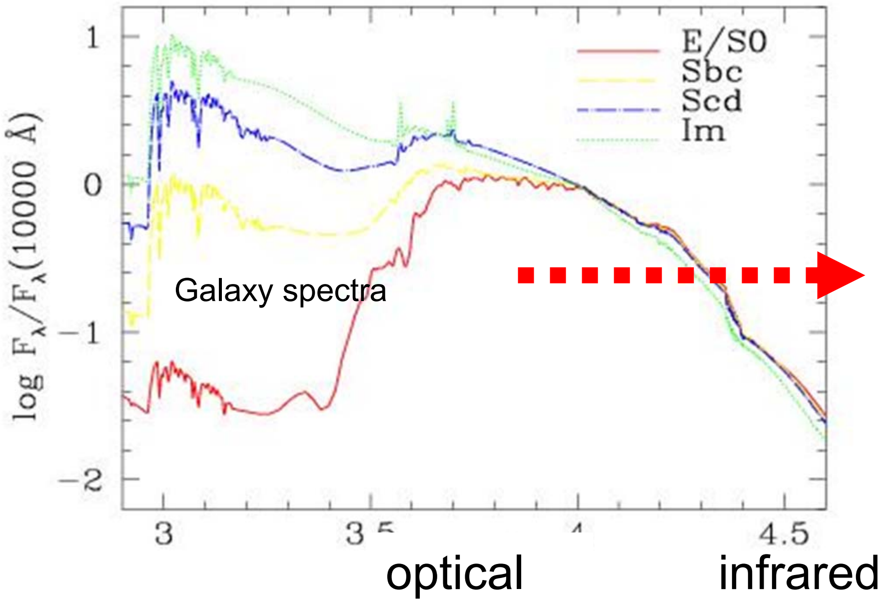


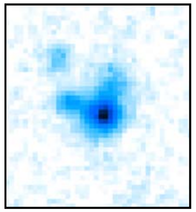
Normal galaxies

?

http://www.mpa-garching.mpg.de/galform/virgo/millennium/



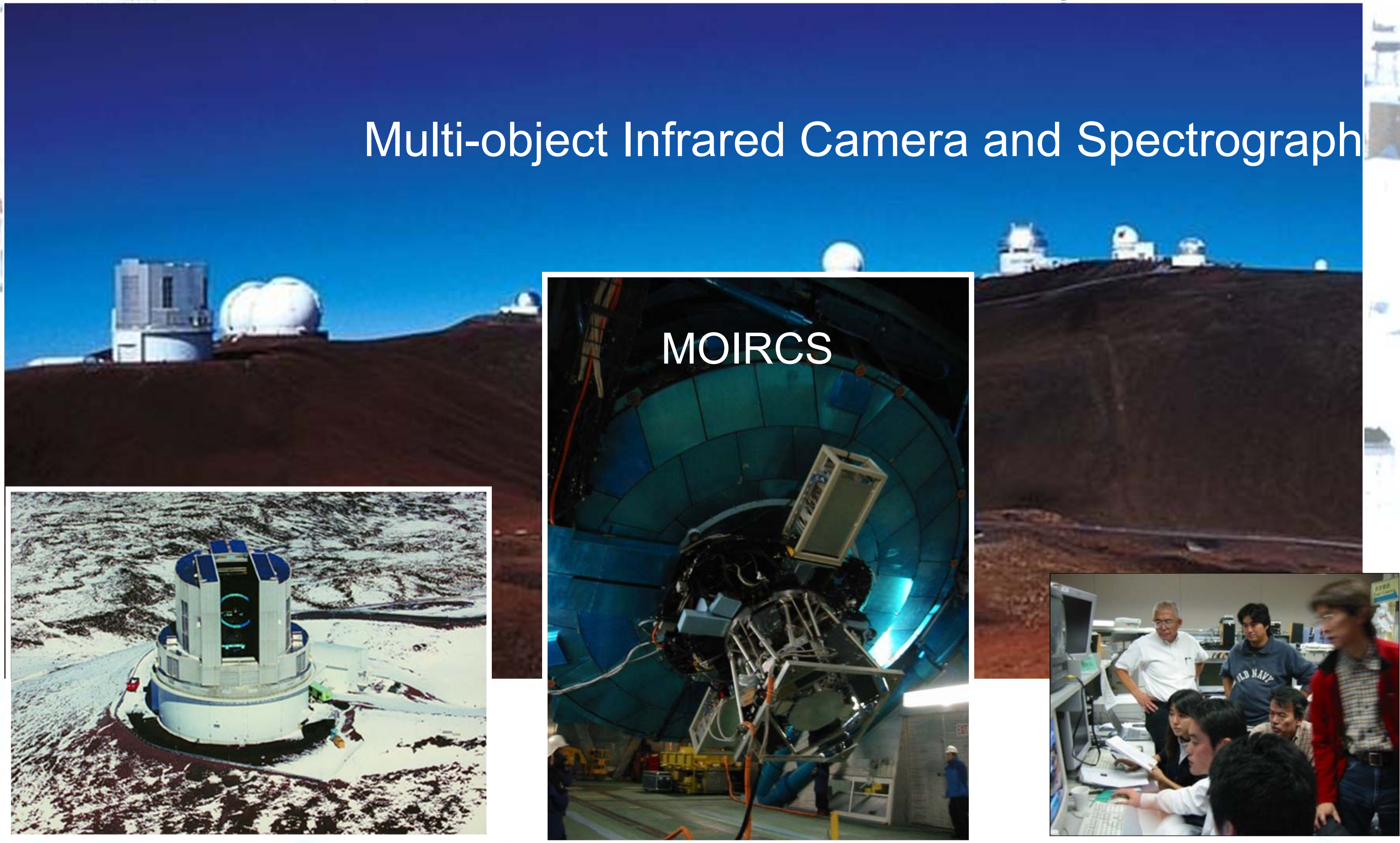




Optical spectra of distant galaxies are redshifted to infrared

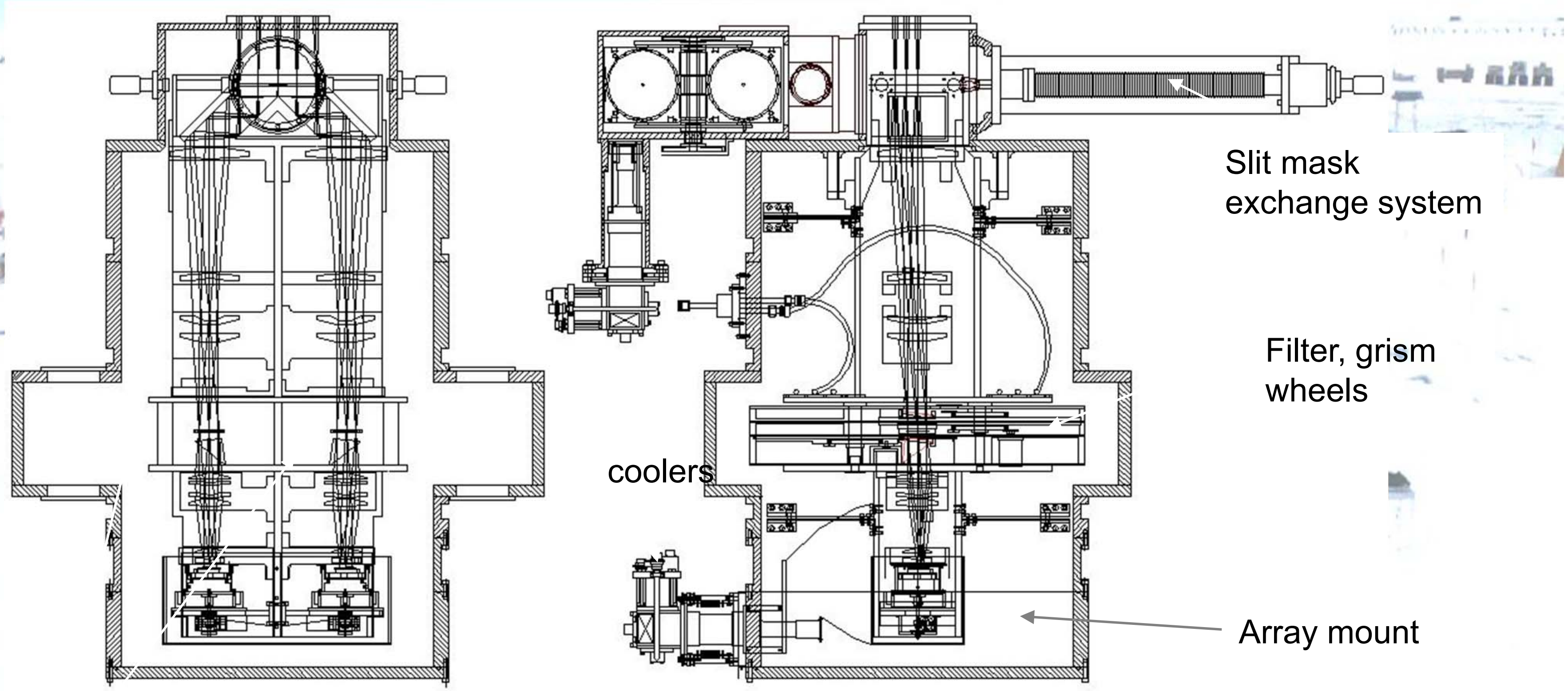
In order to study the optical properties of distant (young) galaxies, powerful telescope and infrared camera should have been constructed.

Subaru telescope



Very low cost

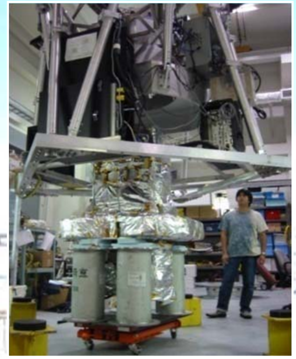
Novel structure, optics & slit mask exchanger

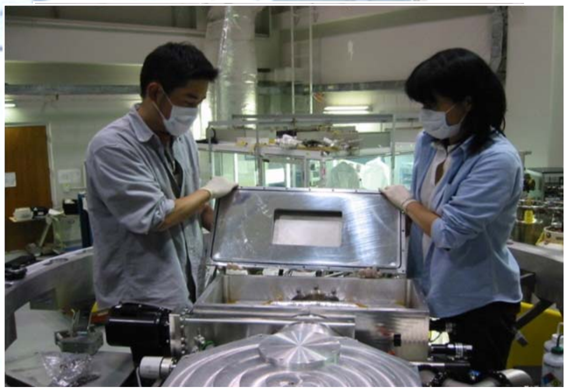


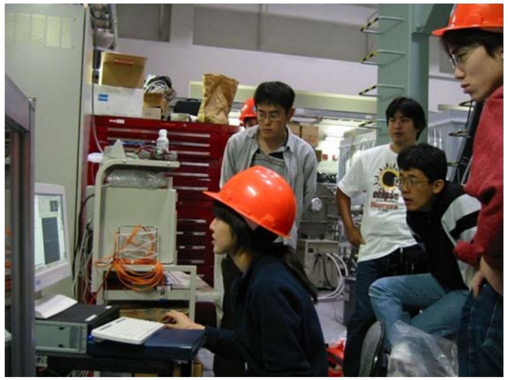
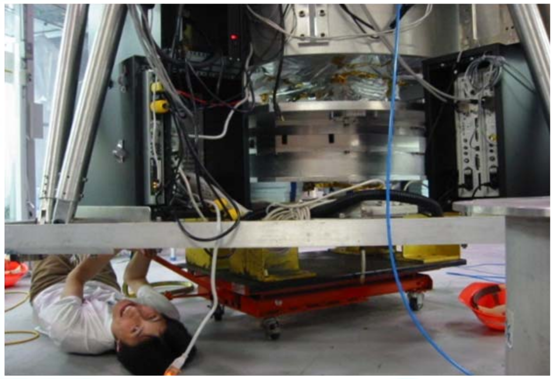
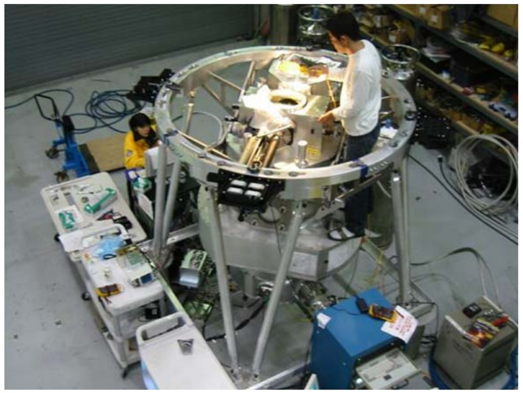
We used as many things off the shelf or self-making and self–designing components at every part as to reduce the cost.

Assembling at Hilo







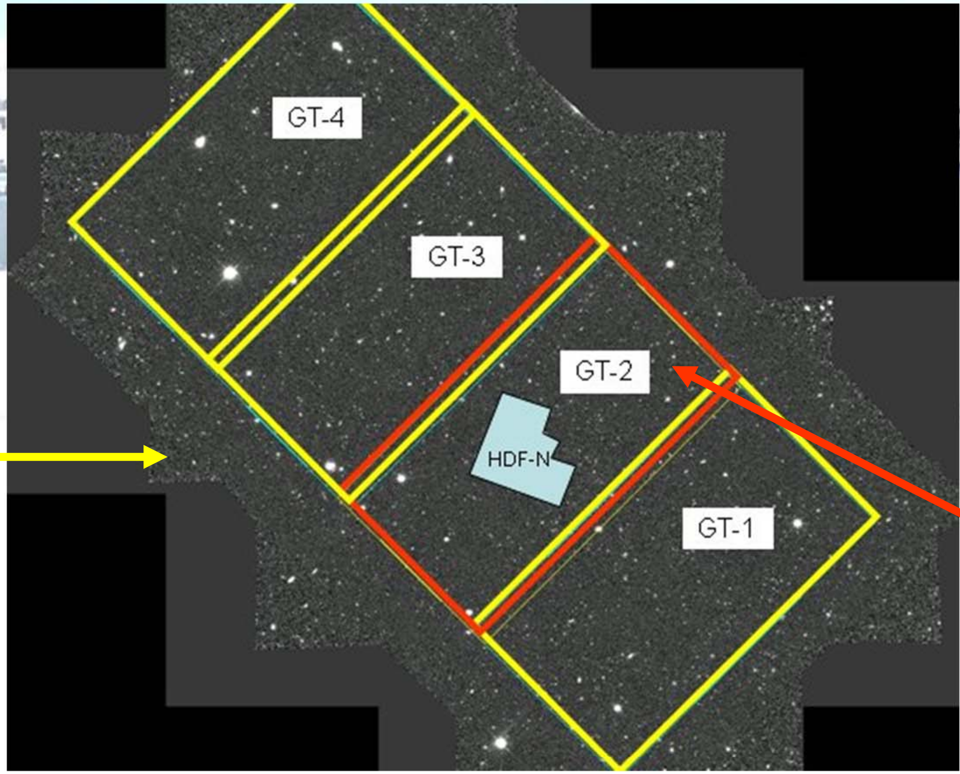
Wide field of view and superb image quality

Best image size : 0.18” (without adaptive optics)

Good image quality (~0.2”-0.3”) is always available over the field under good seeing

MOIRCS Deep Survey (MODS) Project
In GOODS-North region

Hubble ACS
SPITZER
IRAC、MIPS
Chandra
SCUBA
Subaru SuCAM



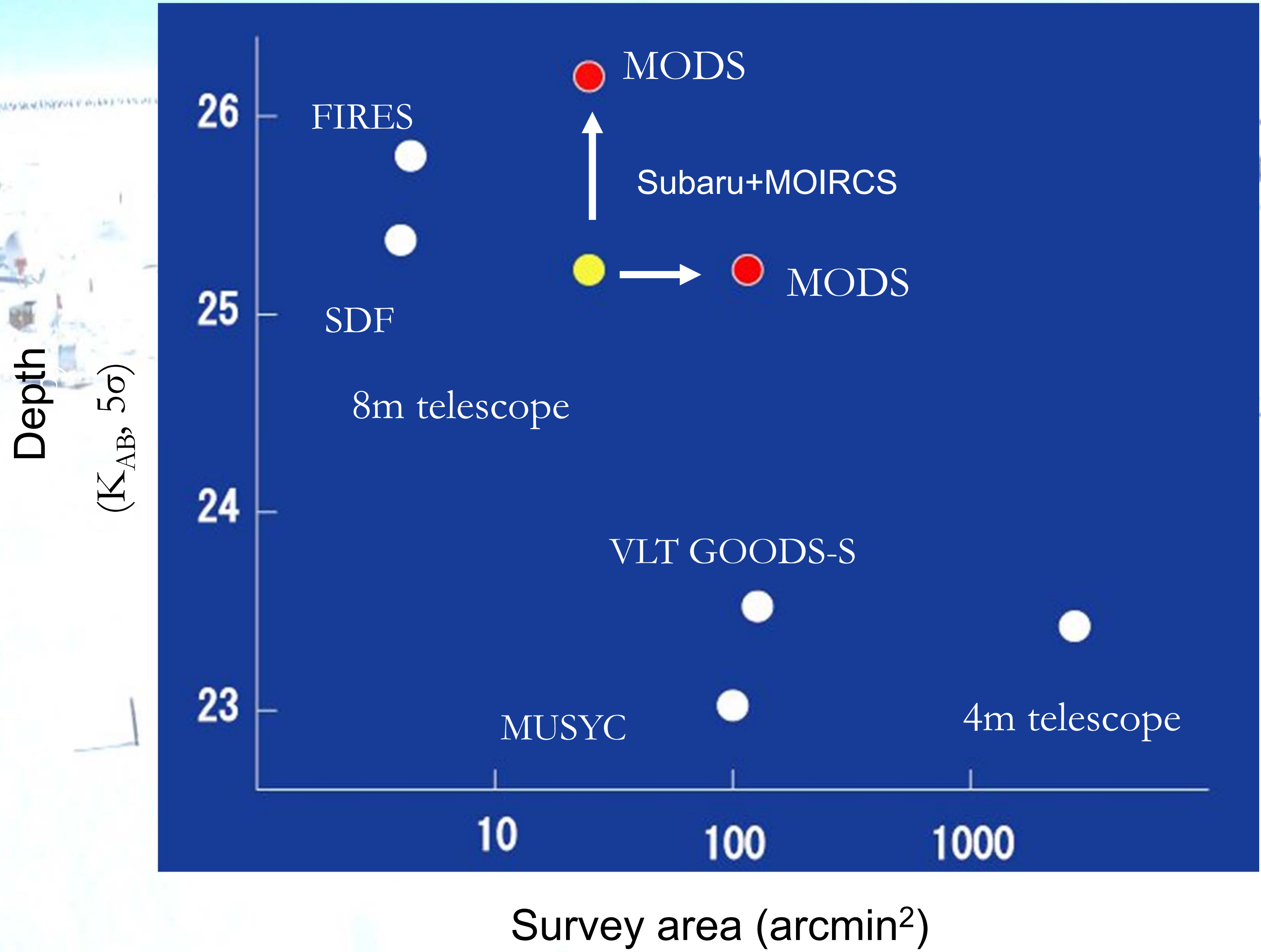
High image quality
~0.4”

28 hour integration

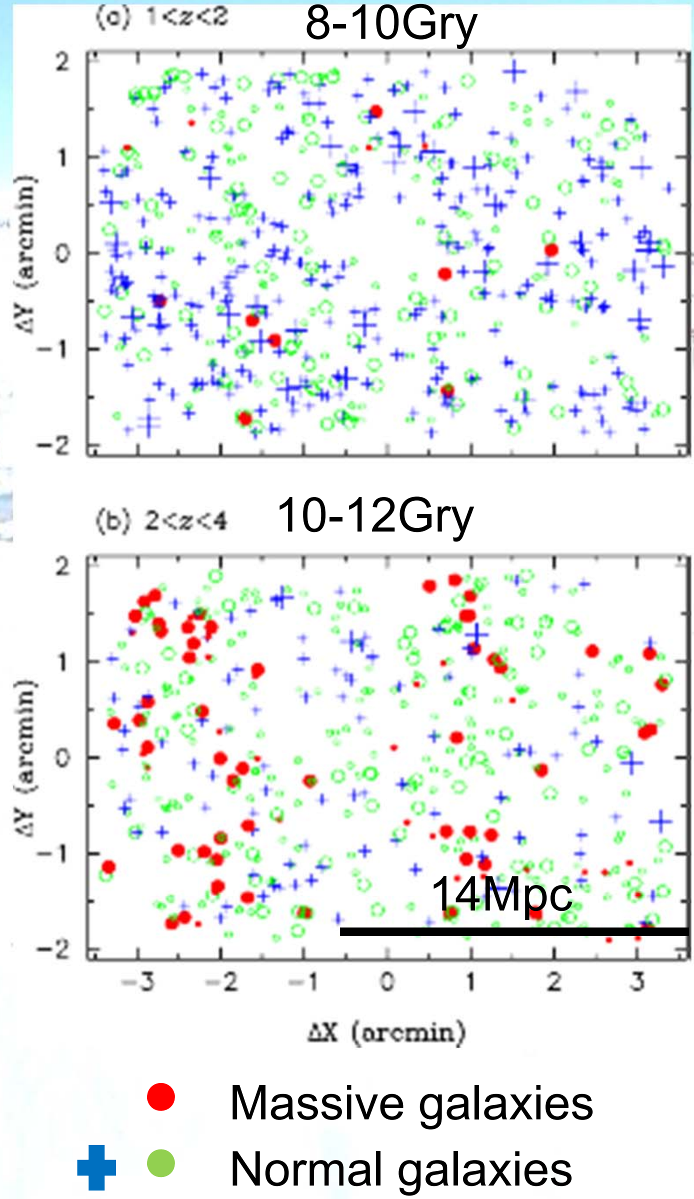
J,H, Ks-bands deep imaging

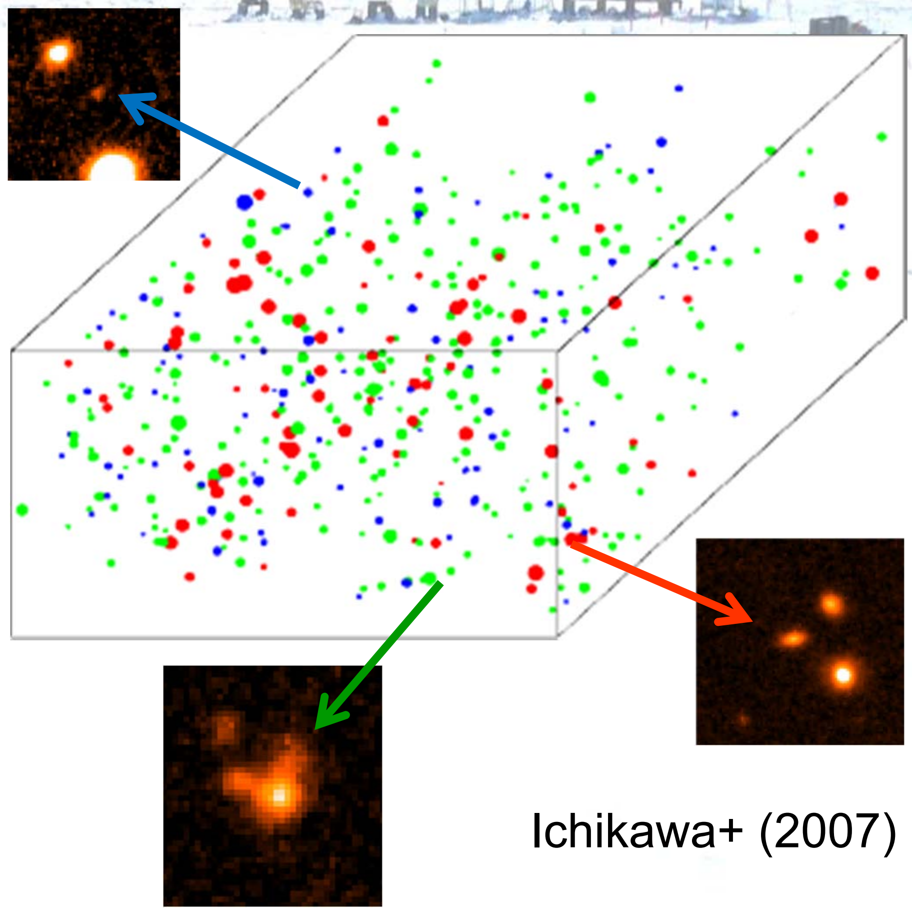
4’X7’X4’ ~ 100 arcmin^2

Near-infrared survey of High-Redshift Galaxies with ground-based telescopes



Deepest 3D distribution of normal galaxies

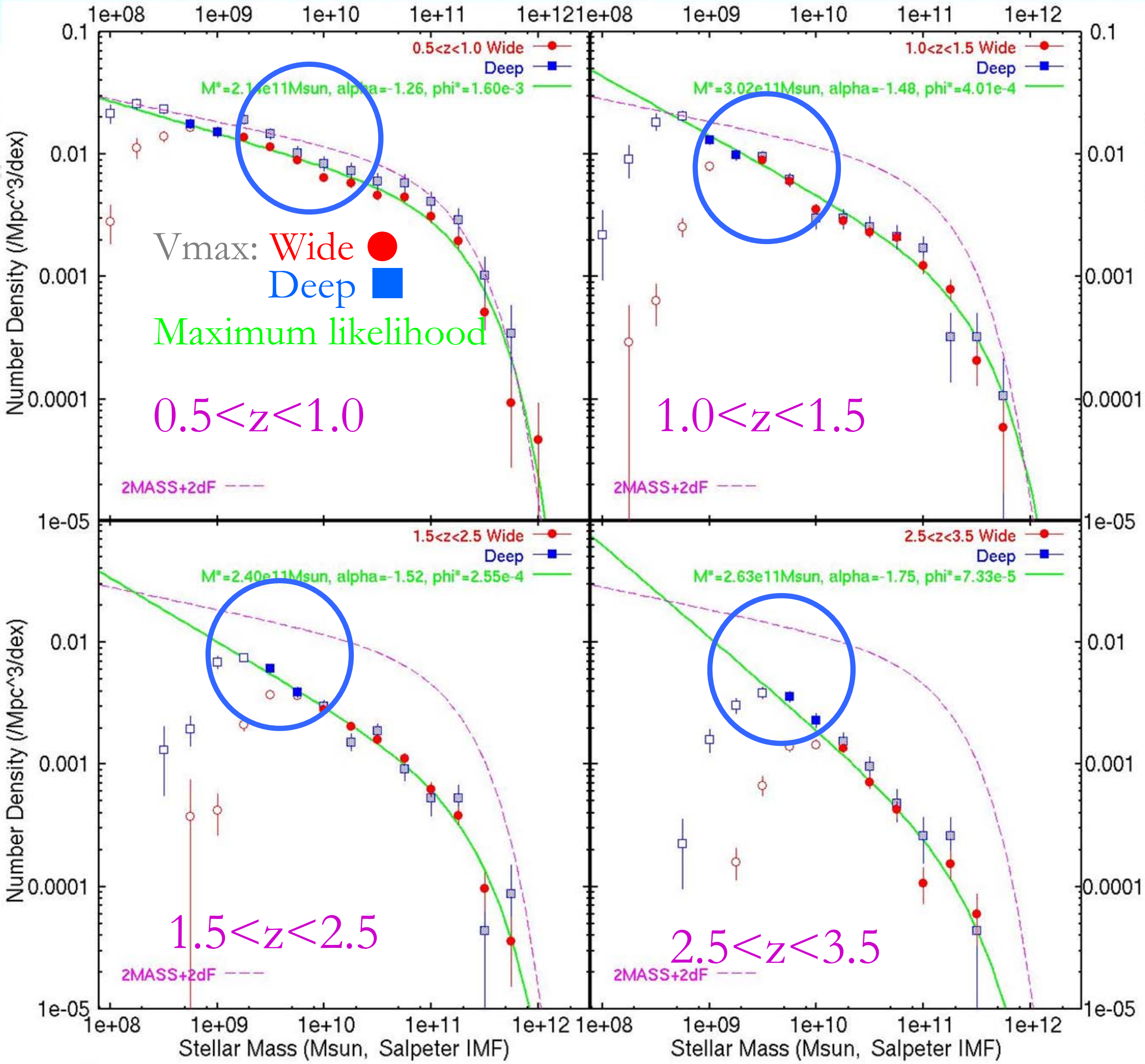




Ichikawa+ (2007)

Evolution of galaxy stellar-mass function

Kajisawa+ (2009)



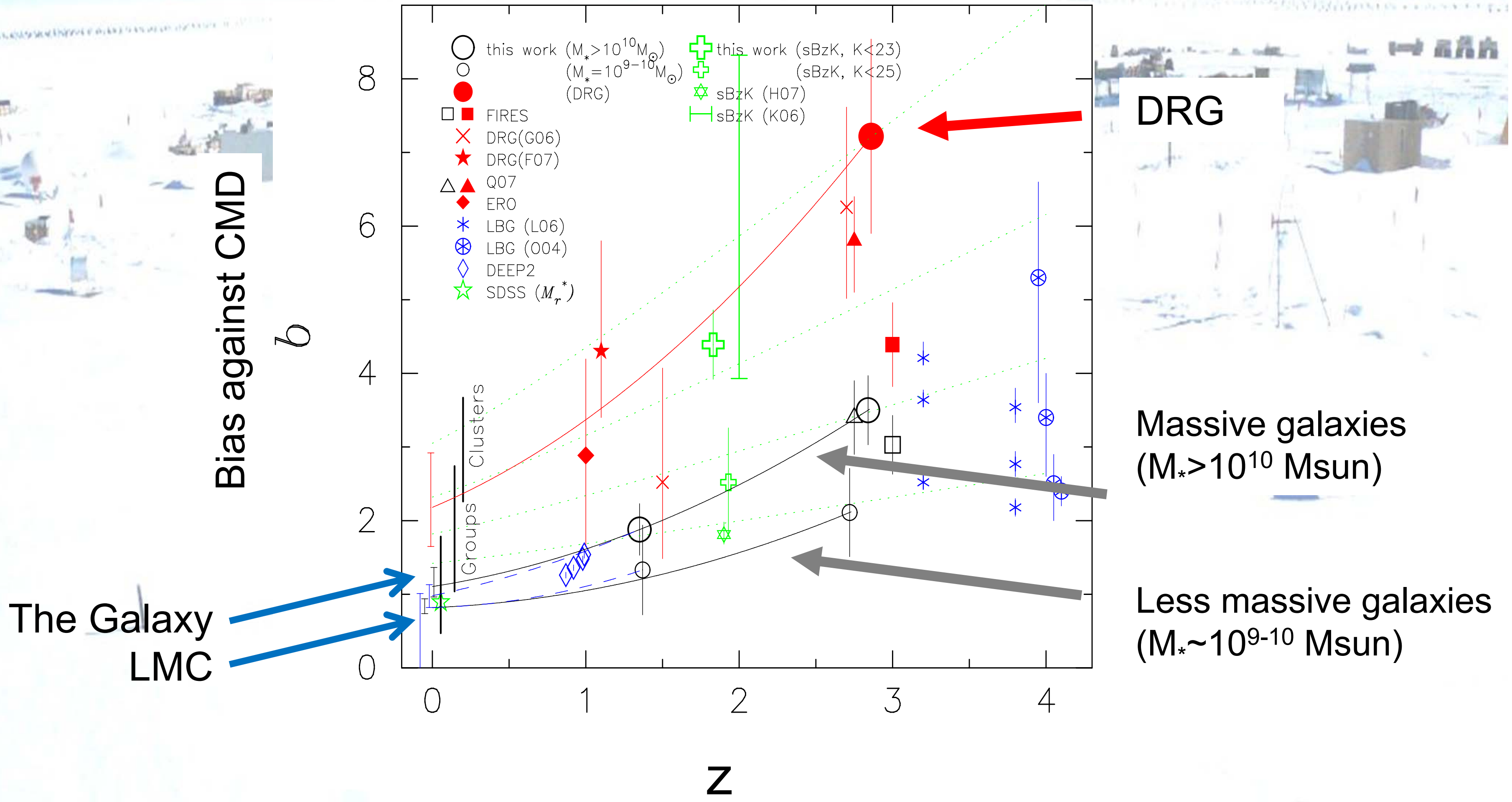
✓ Possible steeping of low-mass slope with redshift ?

Steep slope at higher redshift is expected from CMD scenario

Clustering analysis

less massive galaxies (stellar mass ~ $10^{9\text{-}10}$ Msun) evolve into normal galaxies in local universe.

Ichikawa + (2007)

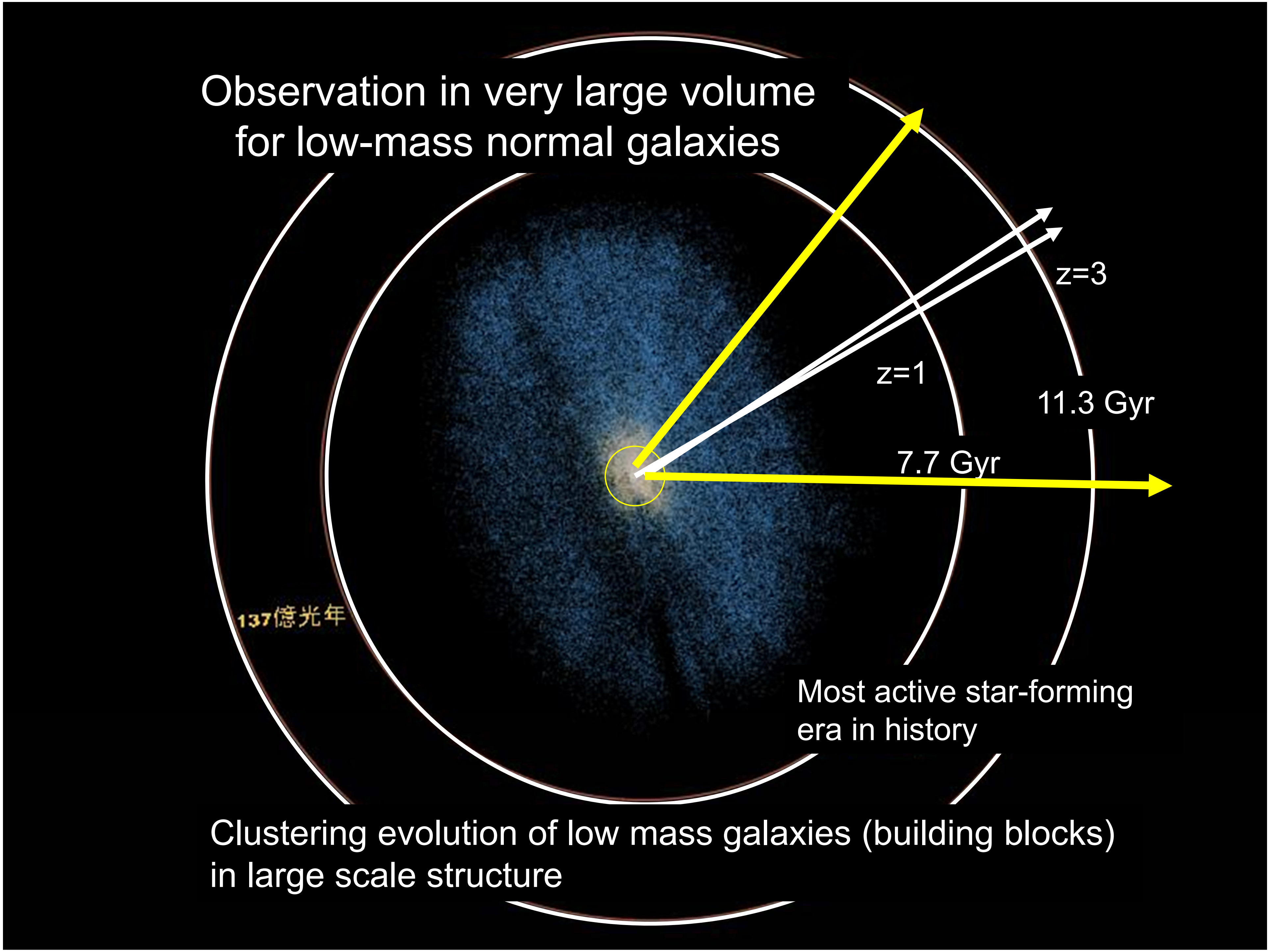


Main Results of MOIRCS Deep Survey

- Clustering evolution and stellar-mass function of normal galaxies are consistent with CDM hierarchical merging in small scale structure

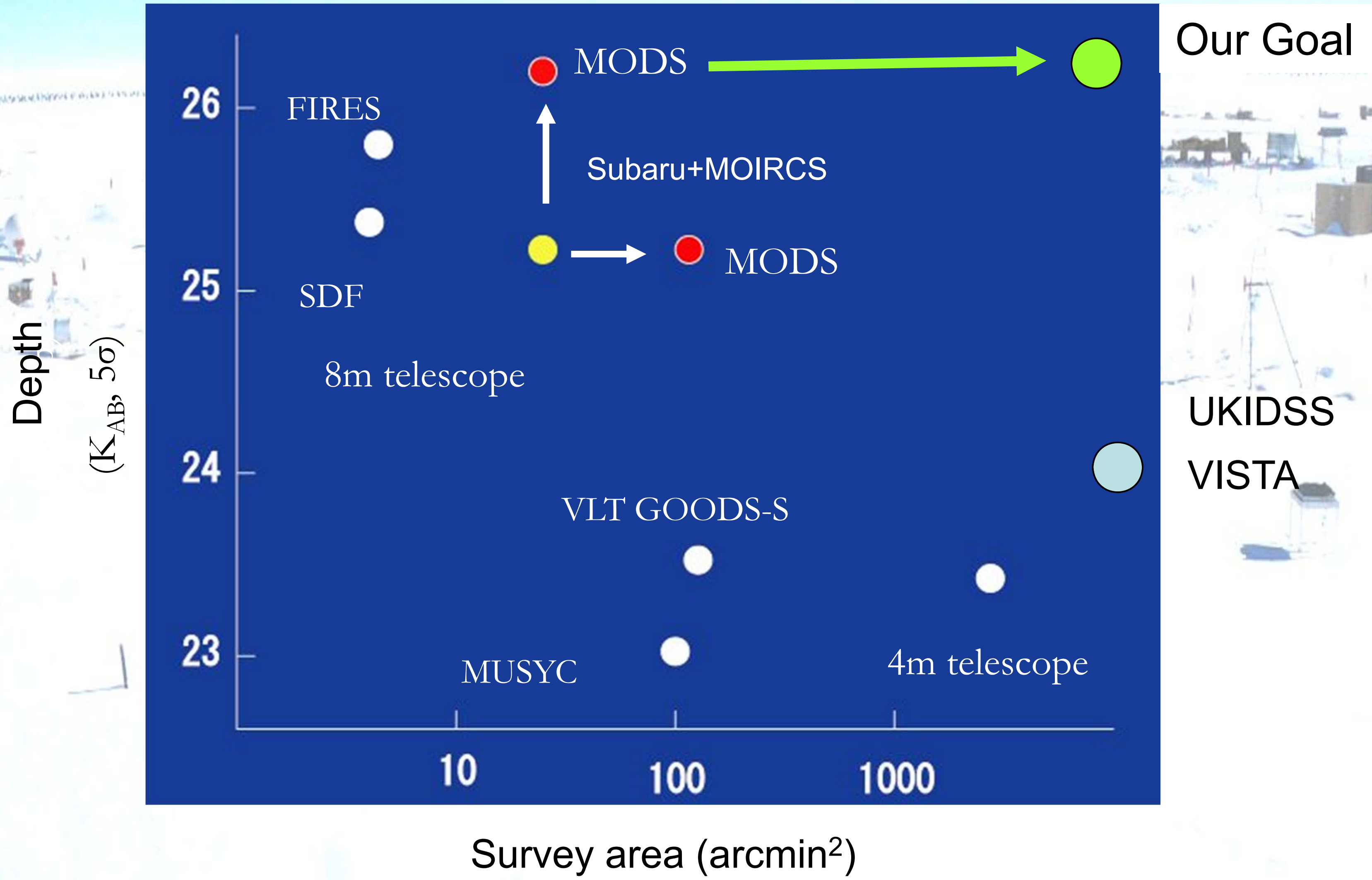
Next objective

- Evolution of normal galaxies in large scale structure

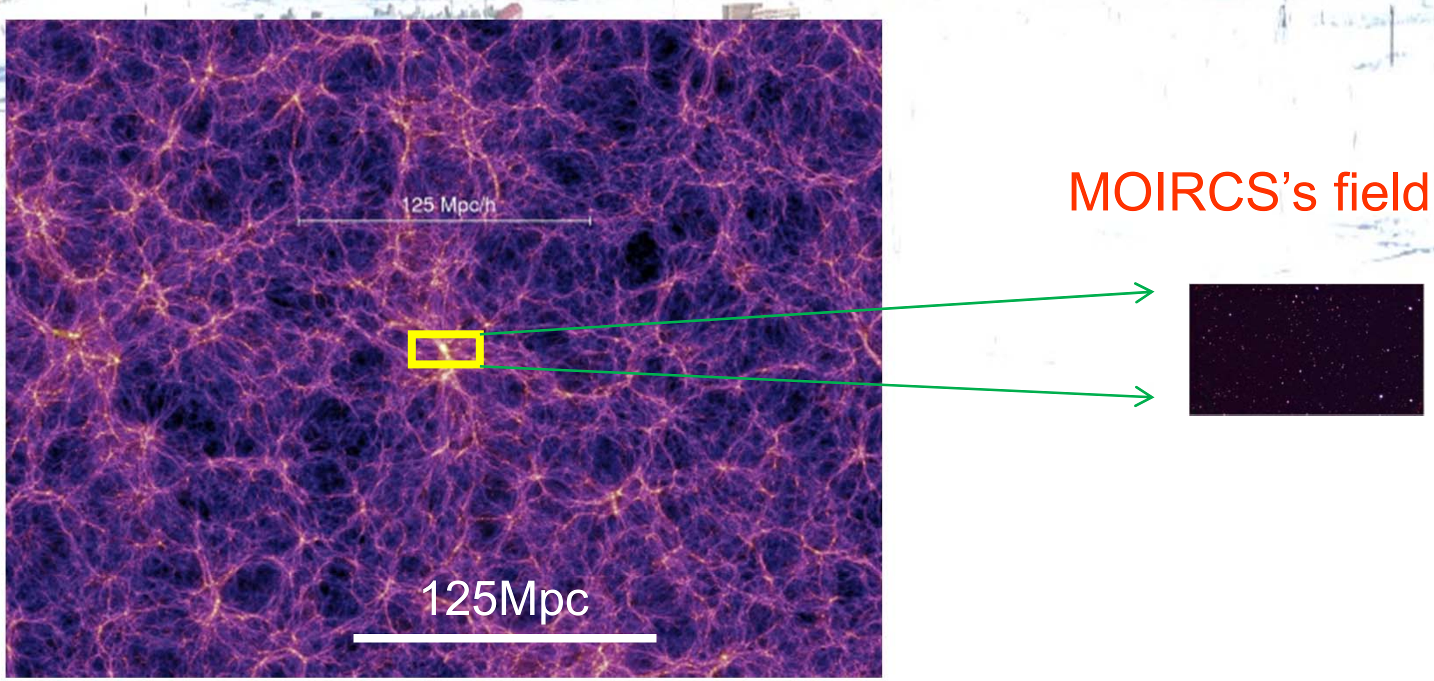

Observation in very large volume
for low-mass normal galaxies
z=3
z=1
11.3 Gyr
7.7 Gyr
137億光年
Most active star-forming
era in history
Clustering evolution of low mass galaxies (building blocks)
in large scale structure

Widest and Deepest High-Redshift Galaxy Survey

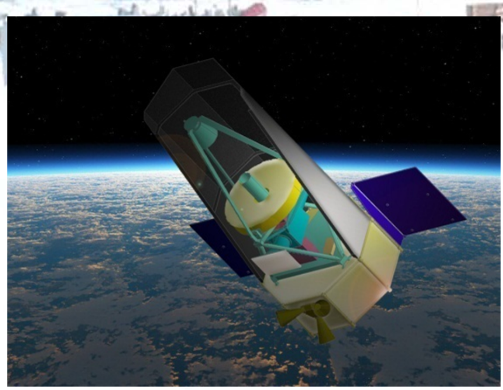
Complete samples of 10^9 M_{sun} at z~3 (11 Gyr)



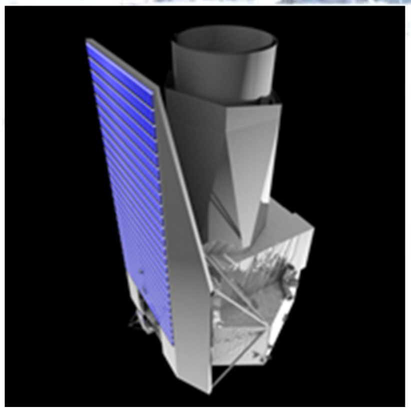
- Telescope time for 8.2m Subaru is highly competitive.



- Wide-field space telescopes would be very effective However, they are quite expensive (>200 M US$).



WISH (2020 or later)

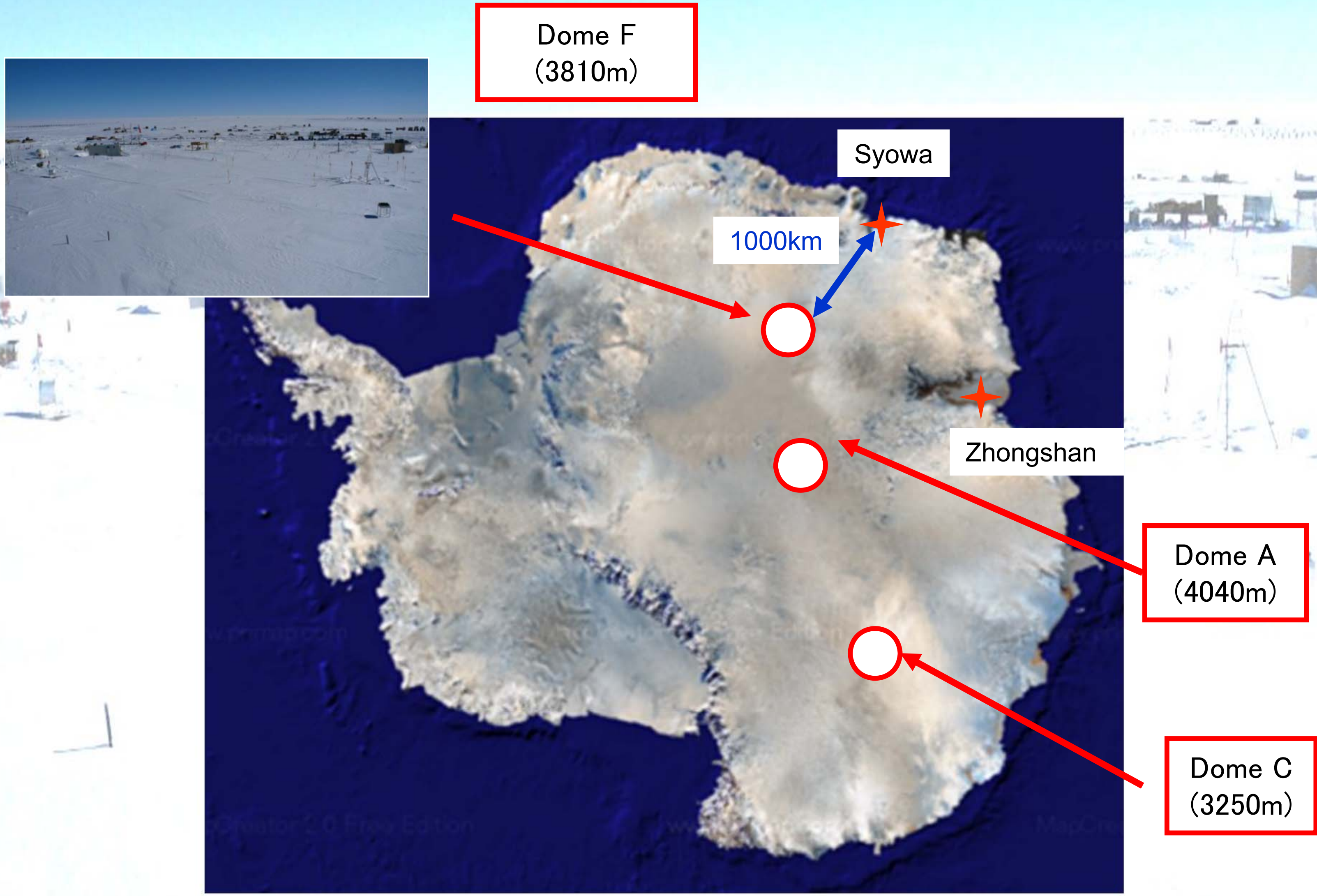


JDEM/Euclid (>2020)

Antarctica is a most promising alternative choice.

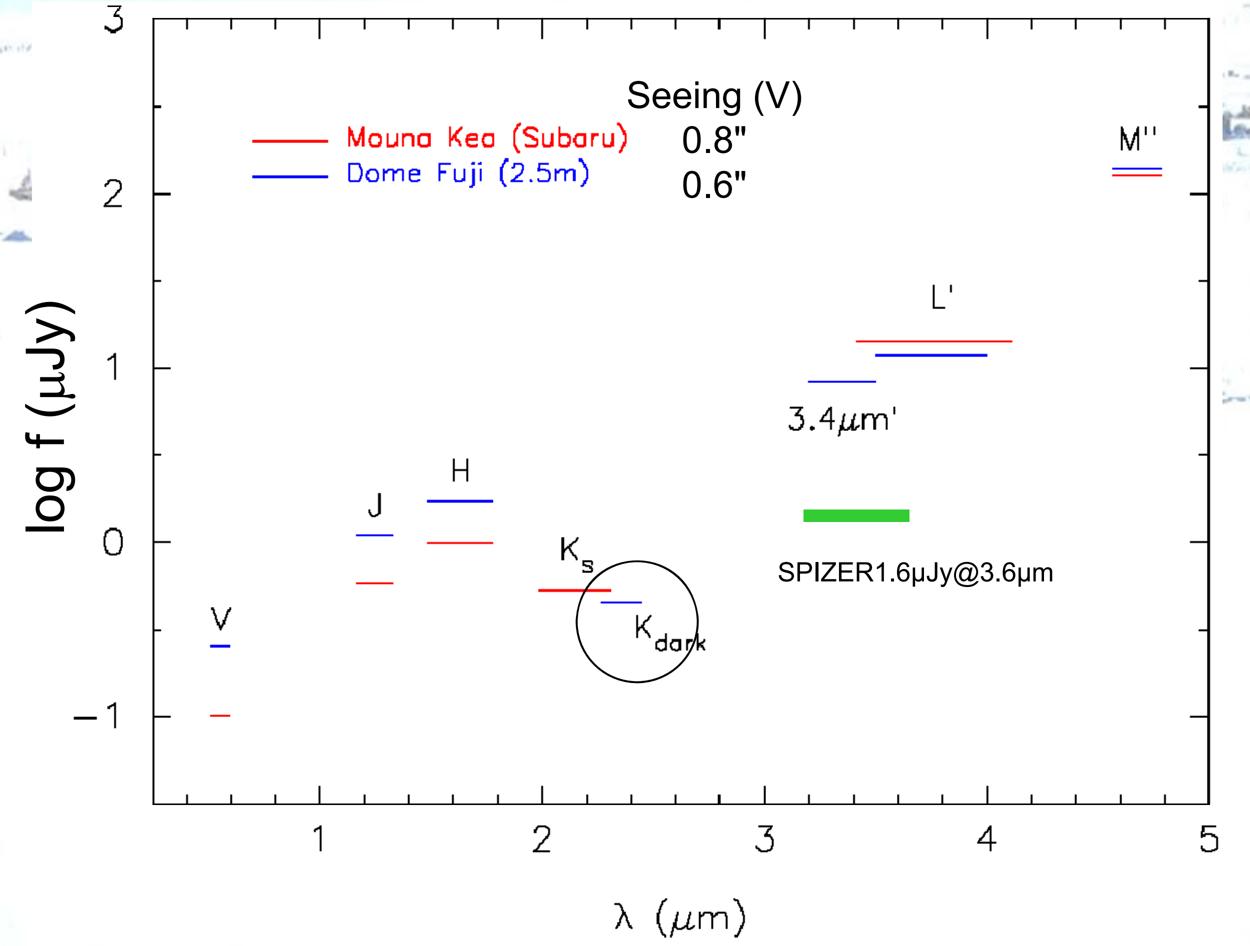
Antarctic telescopes are economical compliments (<10 M US$)

New astronomical sites in Antarctica

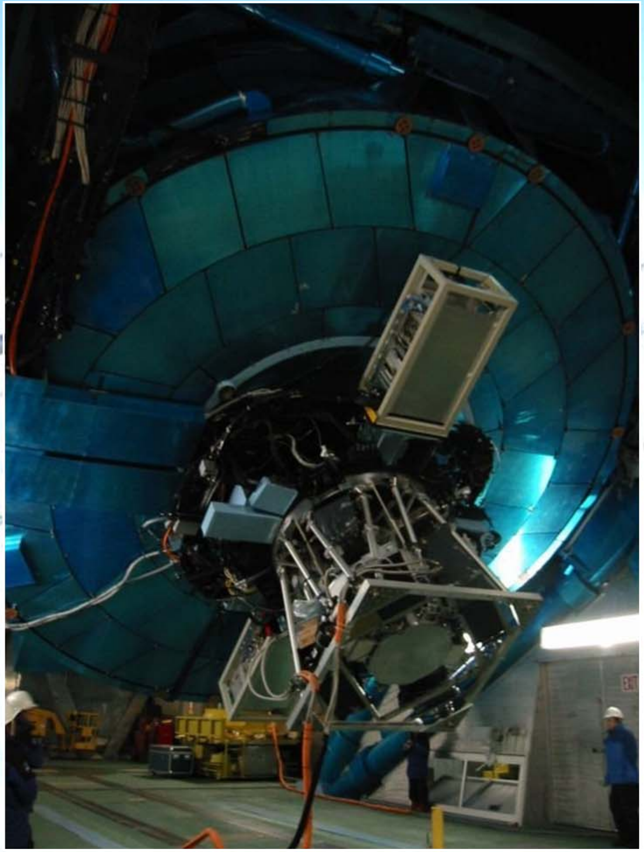


Comparison with Subaru for 2.5m Antarctic Telescope

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



8.2mSubaru+MOIRCS



Ichikawa et al. (2005)

performance in near-infrared

1:1

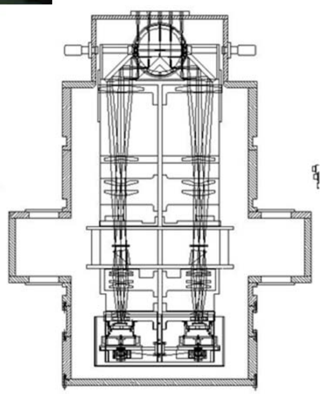
Cost
100 : 1

2.5 m telescope in Antarctica

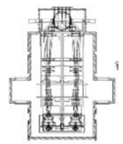
Kurita+ (2009)

~100k US$

0.037”/pixel → 0.12”/pixel



1/3 ~ 1/4 in size



0.12”/pixel
Diffraction limit =0.24”

very low cost

Innovative ultra light weight 2.5m telescope

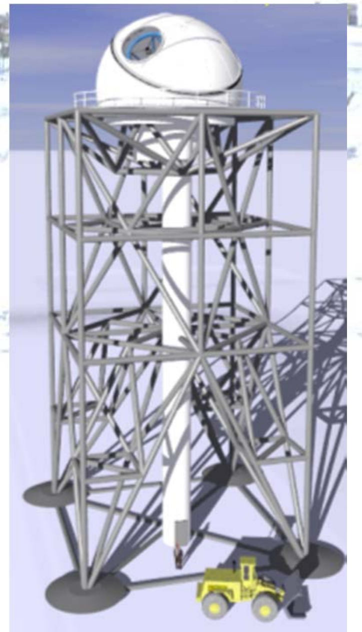
(Kurita+ 2009)

Light weight is highly appreciated for tower telescope installed above boundary layer (~15m? at Dome F)

Mount for <2.5m mirror

Storey+ 2008

Boundary layer



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

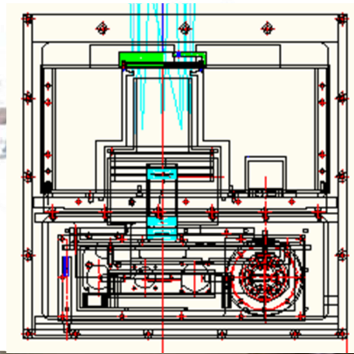
Dome Fuji station

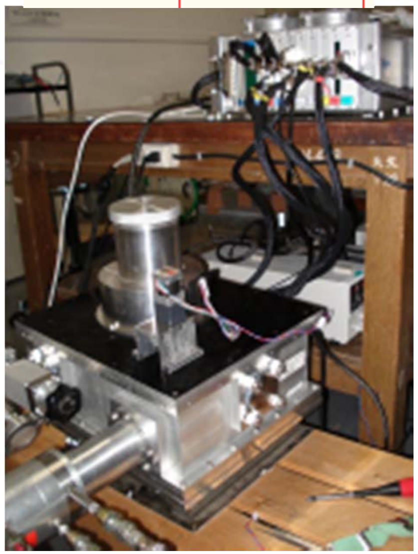
National Institute of Polar Research

Pilot Study with a Small Telescope

2011 ~

40cm IR telescope (AIR-T-40)





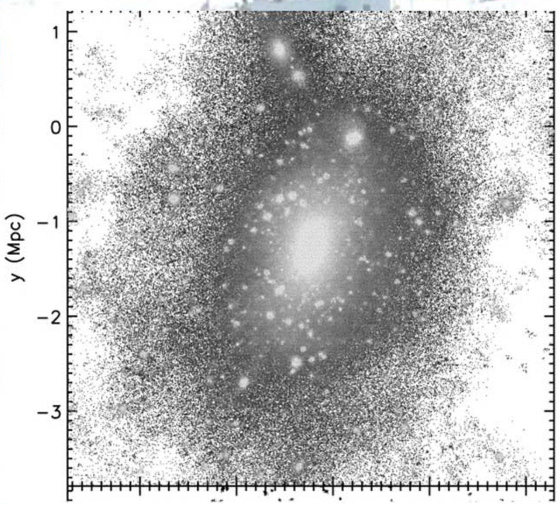
2Kx2K HgCdTe (VIRGO)

Power Supplier (PLATO)

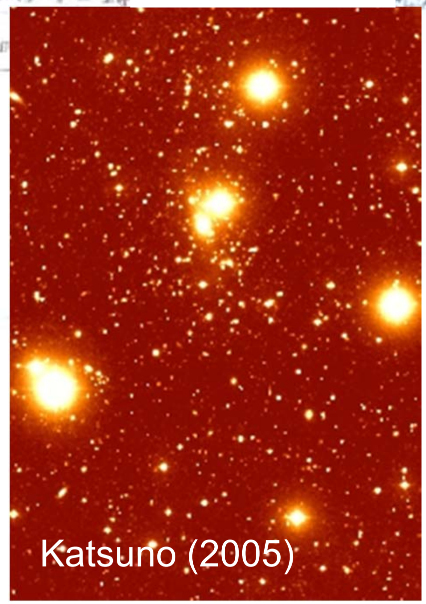
Science Program for 40cm Infrared telescope (1)

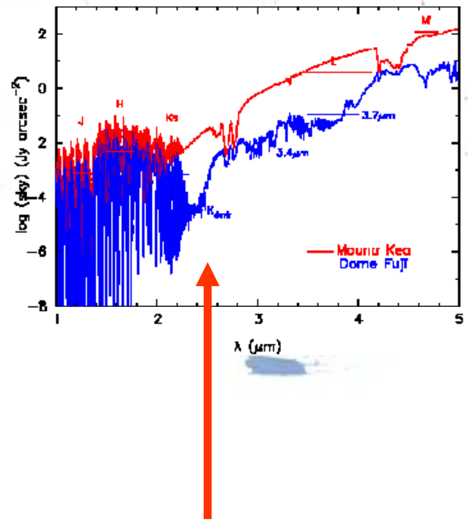
Stellar halo in clusters of galaxies at 2.4μm

Dark halo model (Okamoto 1999)



Abell 1795





I (0.8μ m) 28.2mag/arcsec

K band window

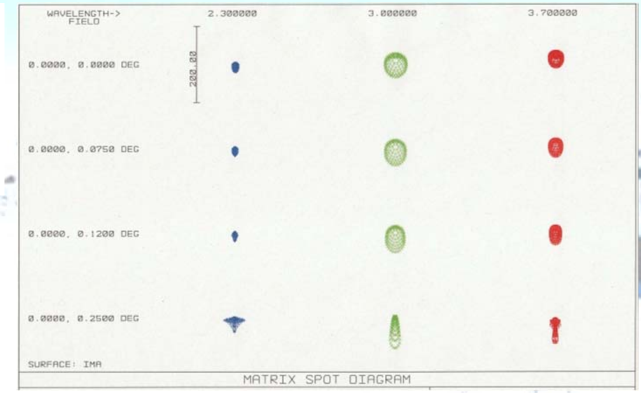
No detection

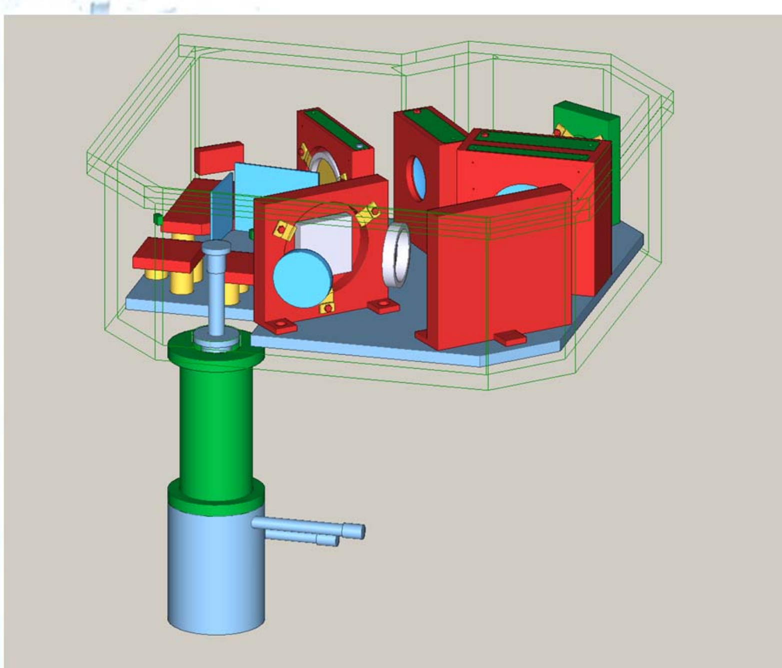
Dwarf density < 200galaxies/Mpc^3

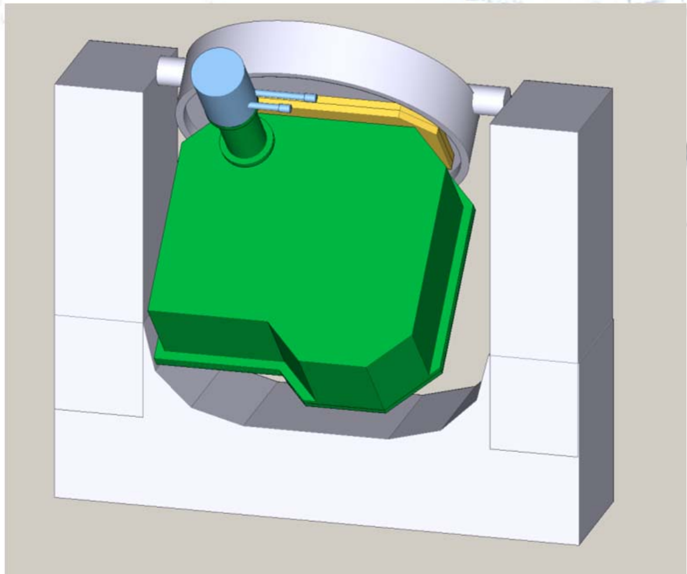
AIR-C3
three-color camera

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)







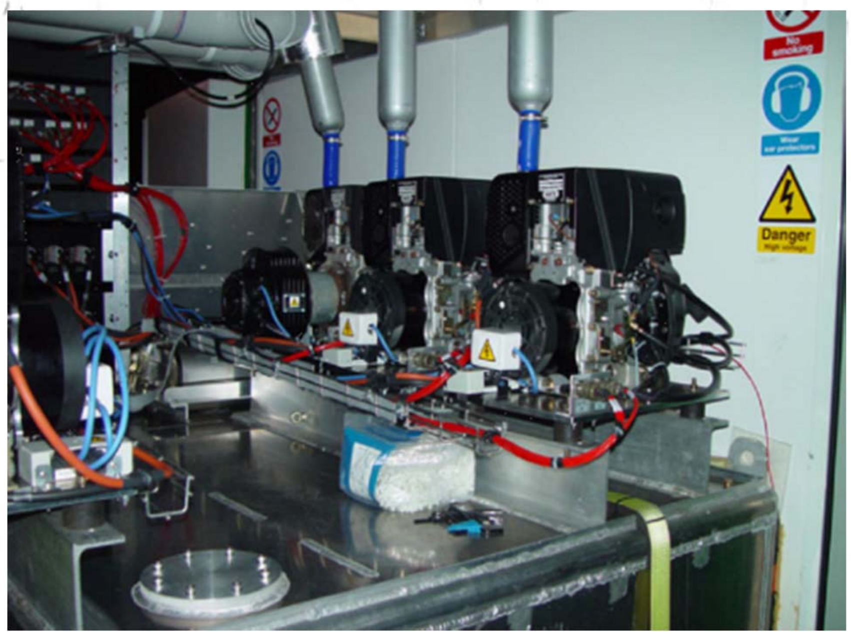
For long-term continuous observations

Automatic operation with remote control

Collaboration with Australia group at Dome Fuji

Engine module for Dome A

1kW for 400 days



Storey+

Future plane

2009/12-2010/2
- first step on Dome Fuji by a Japanese astronomer
- transmittance by handy infrared spectrograph
- transmittance by 220GHz radiometer

2010-2015 New Projects by National Institute of Polar Research
- our proposal for astronomy with small telescopes has been accepted

2010/12-2011/2
- deployment of 40cm-infrared and 30cm-THz telescopes at Dome Fuji

2010-2014 Construction of winter-over facilities by NIPR

2011-2012 deployment of PLATO-Fuji by collaboration with UNSW
- Observations with small telescope over winter (remote operation)

2014?- Construction of large telescope(?)

2. Why astronomy in Antarctica? – the advantages

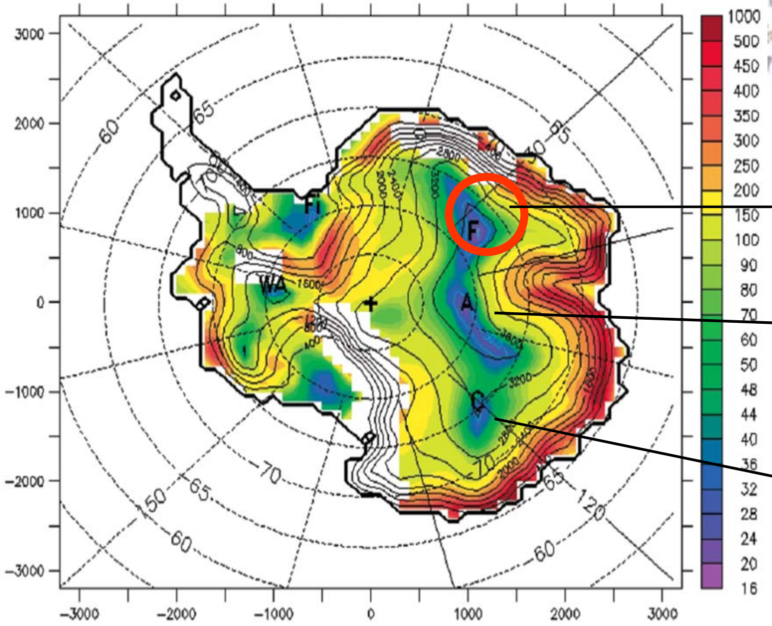
- Clear sky (photometric day > ~85%)
- Little snow (PW=2.5mm/year, 10-20cm snowfall)
- Low and stable humidity (PWV < 0.6mm)
- Low temperature (-70℃ in winter)
- Very good seeing above boundary layer
- Weak wind

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

Japan has one of best astronomical sites in Antarctica

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)

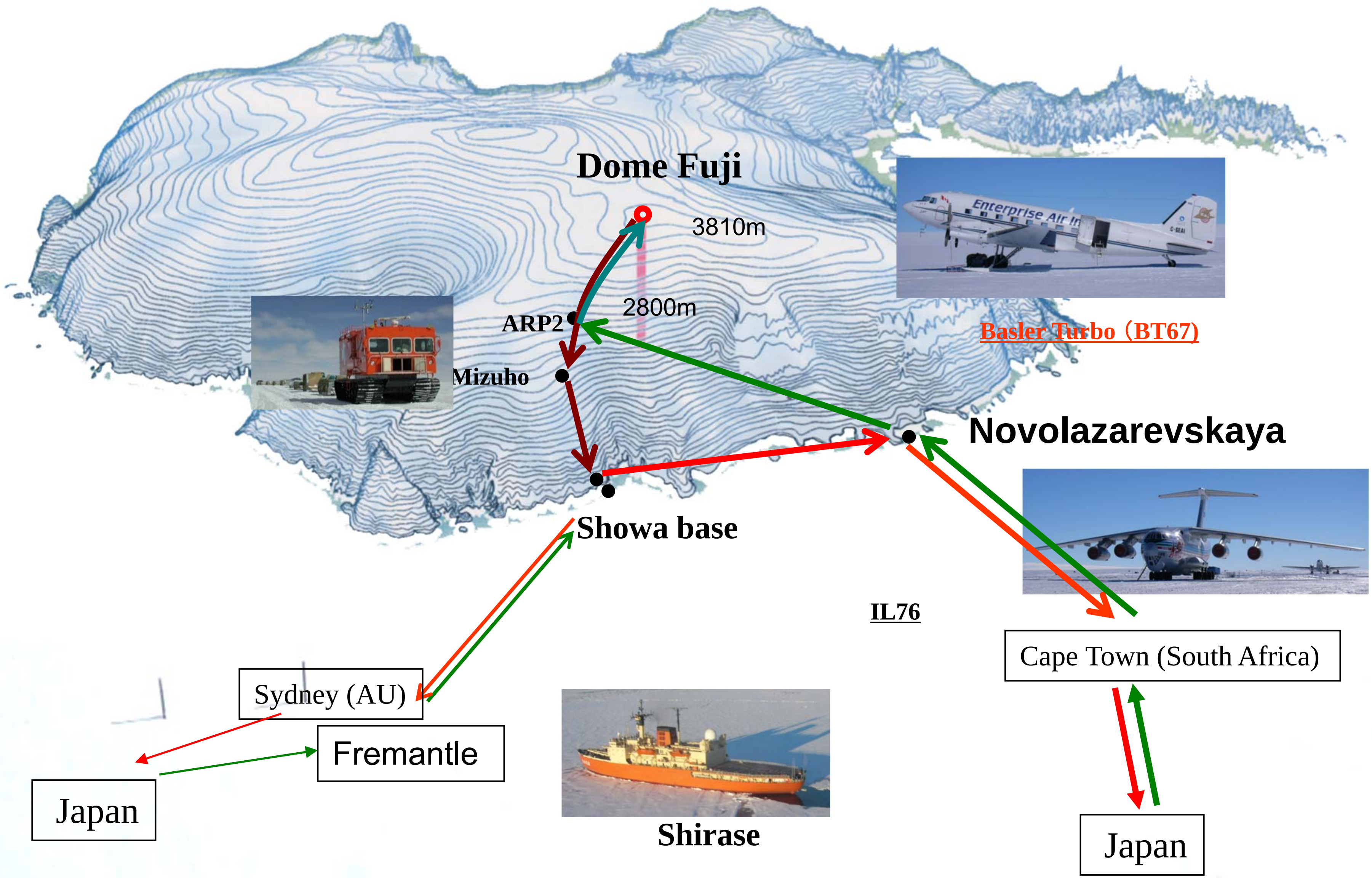
Simulated height of boundary layer (model atmosphere)

Dome F ~18m (?)

Dome A ~20m (?)

Dome C ~30m (measured)

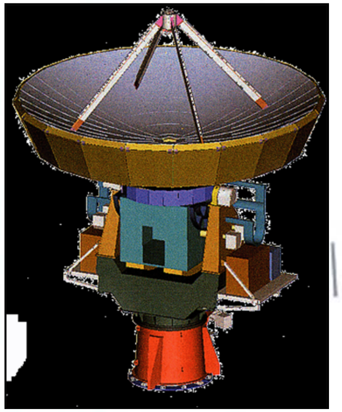
Long way to Dome Fuji



Current status of Japanese activities

Takashi Ichikawa & Japanese Consortium

2.5m Infrared 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

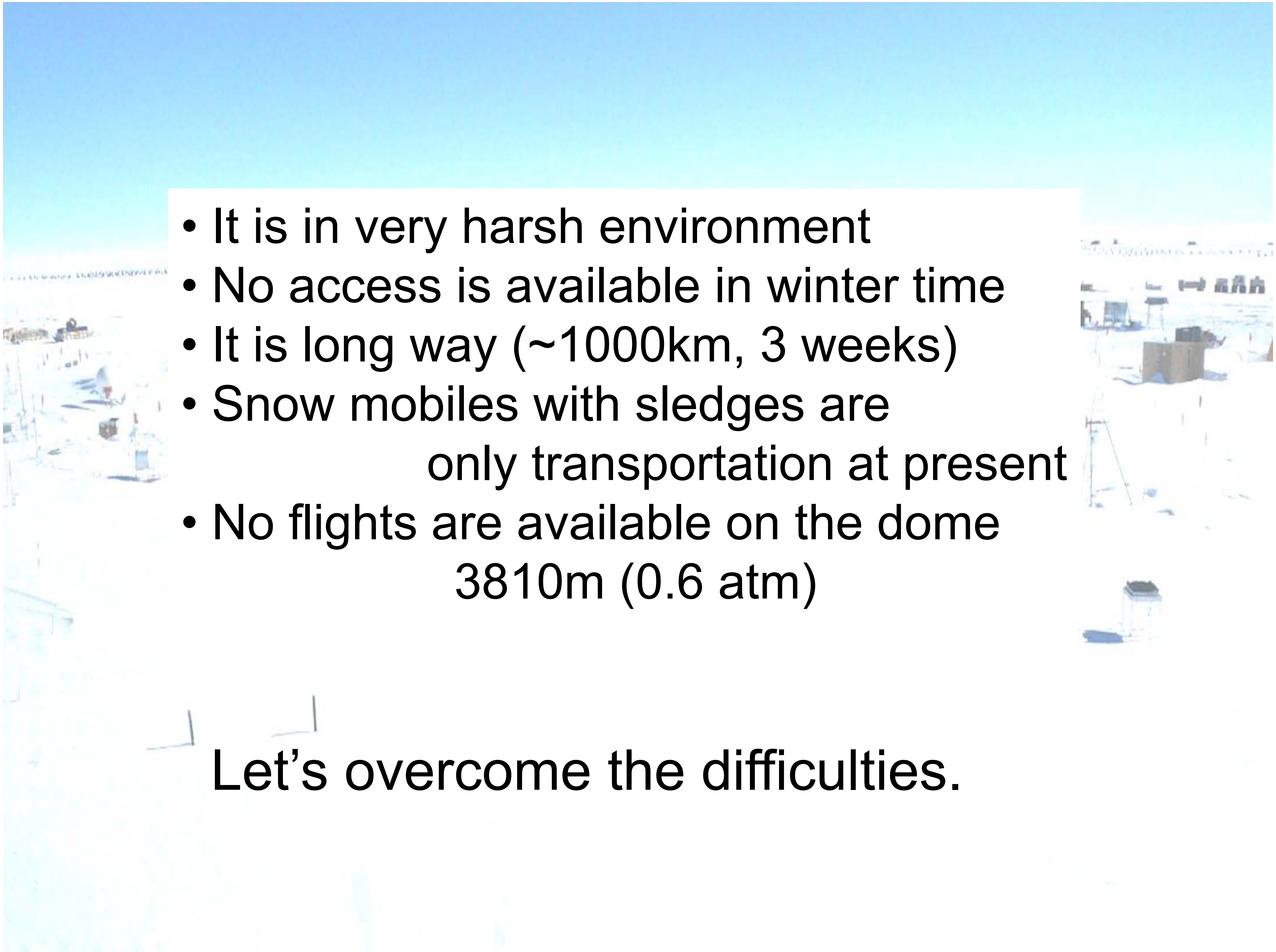
THz Radio Telescope

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

Seta +



- 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)

Let’s overcome the difficulties.

3. Scientific 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

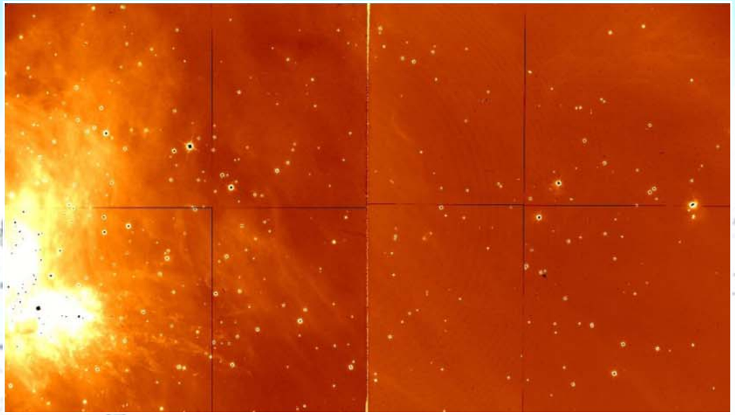
THz, submm

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

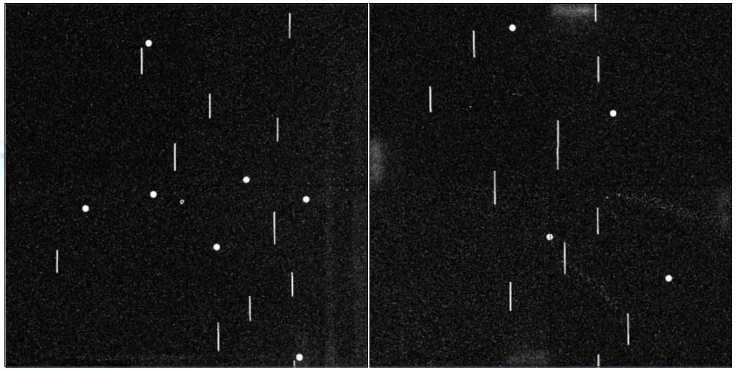
Multi-object spectroscopy

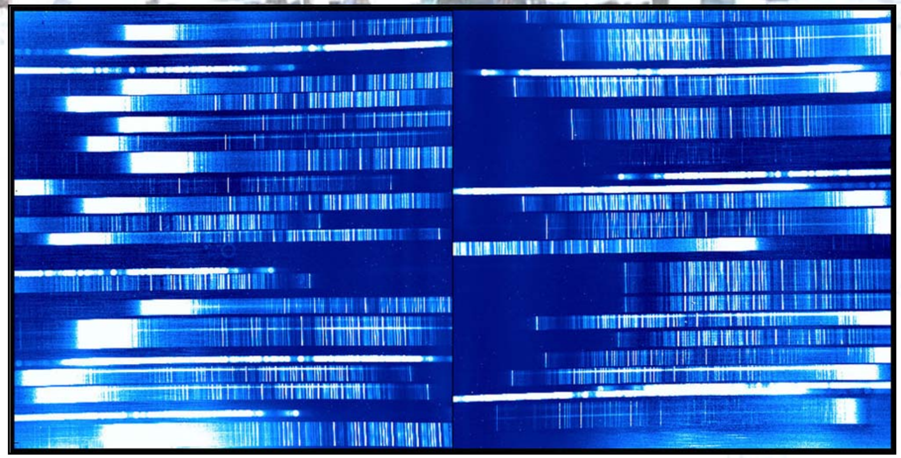
The spectra of ~60 targets can be observed simultaneously.

This is unique capability in infrared among 8-10m telescopes.

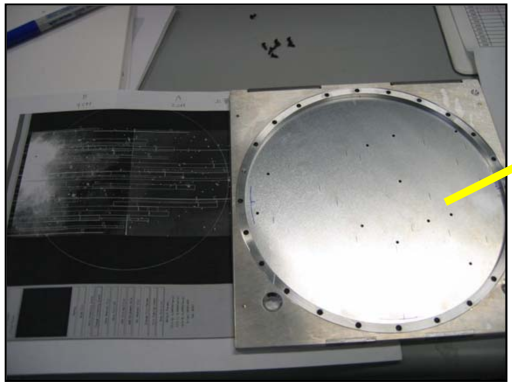


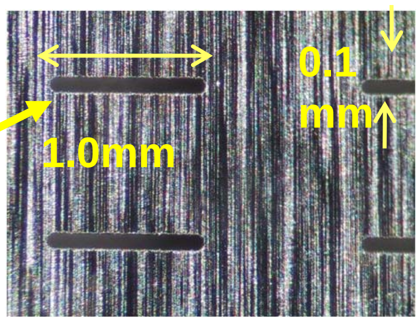
+





Aluminum plate with slits or hole cut on the targets

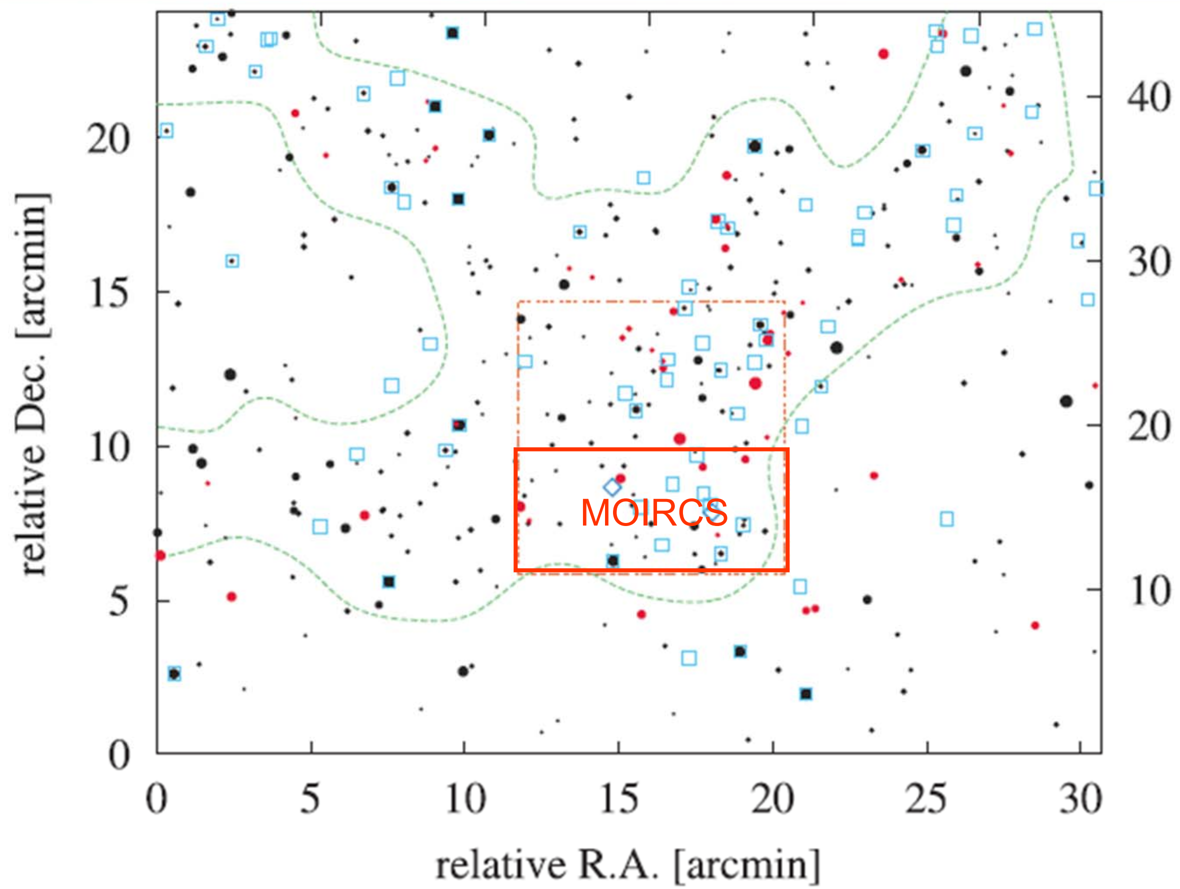




Cut by Laser

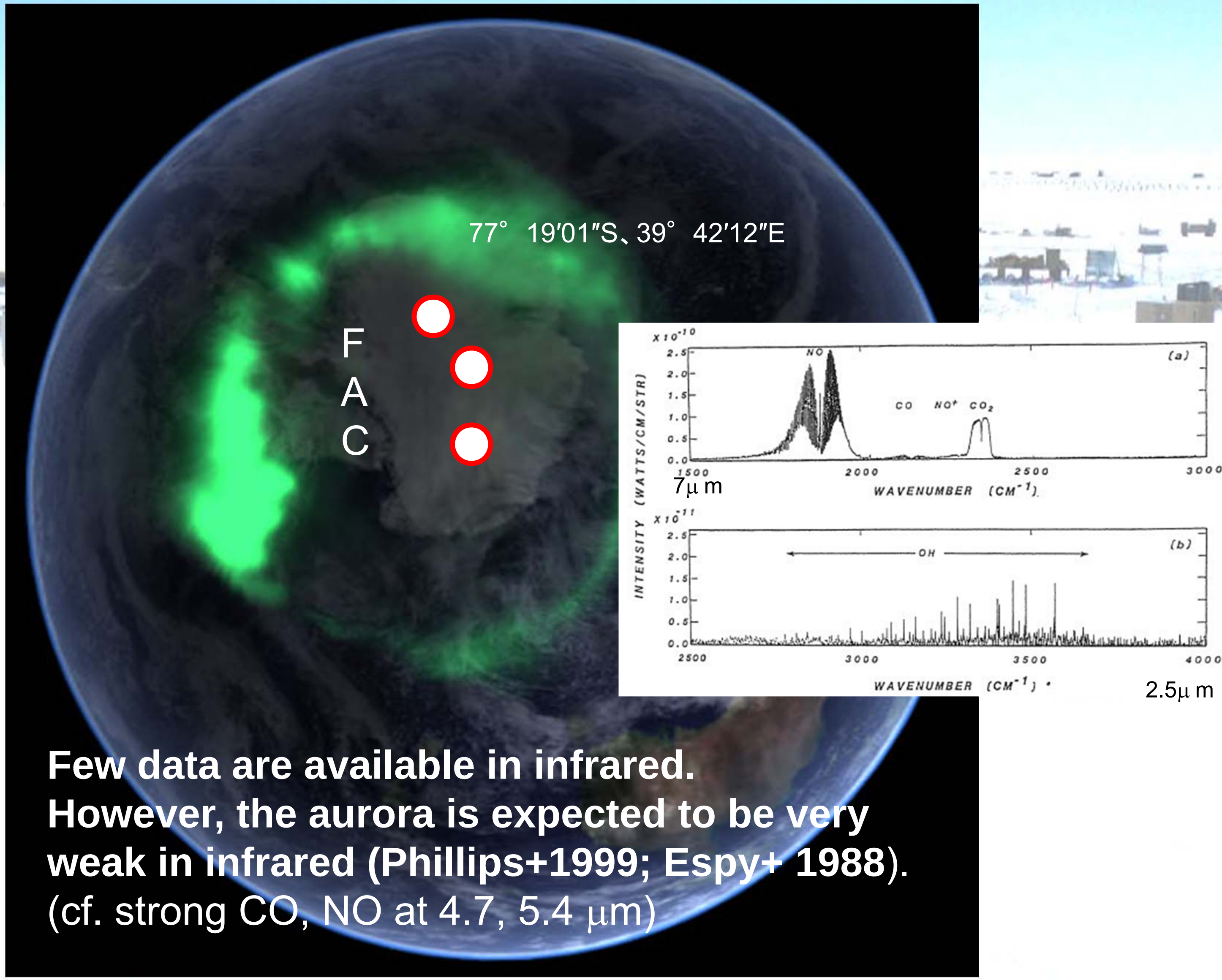
Distribution of Lyα emitters in SSA22

Optical Survey (Hayashino+ 2004)



Unbiased observations for general low-mass galaxies (building blocks) have been waited.

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



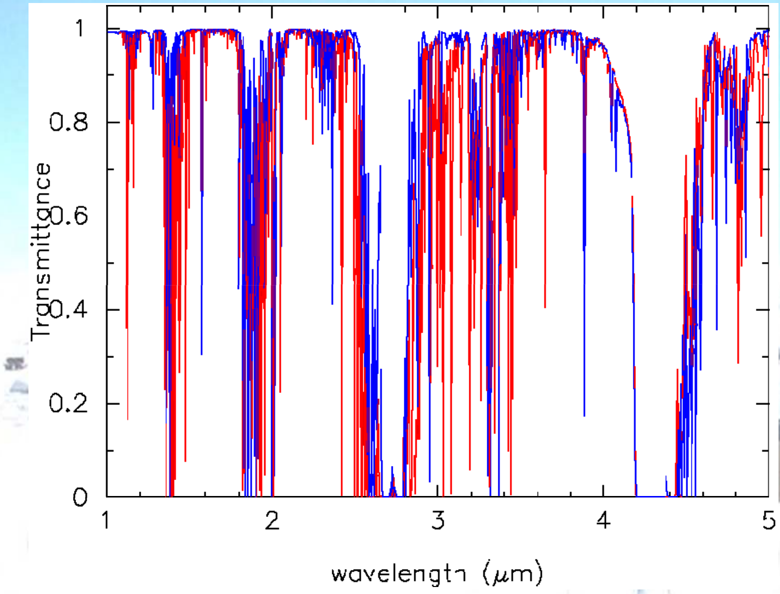
Few data are available in infrared.
However, the aurora is expected to be very weak in infrared (Phillips+1999; Espy+ 1988).
(cf. strong CO, NO at 4.7, 5.4 μm)

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

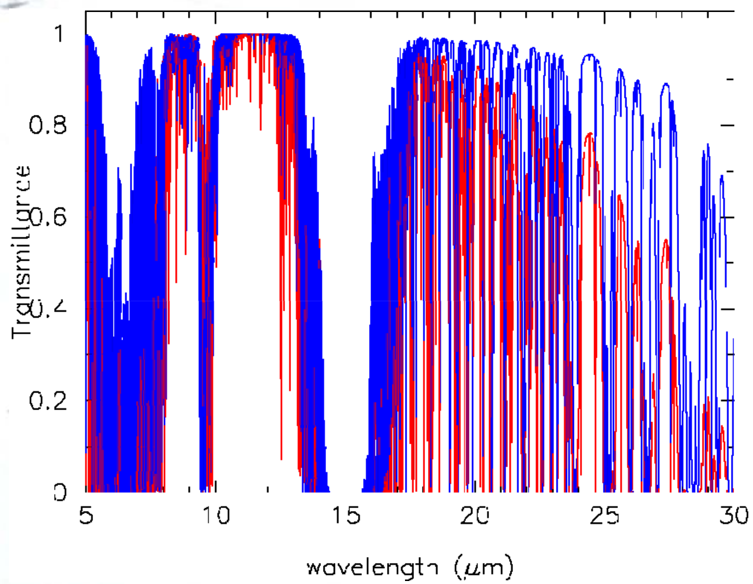
High transmittance

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

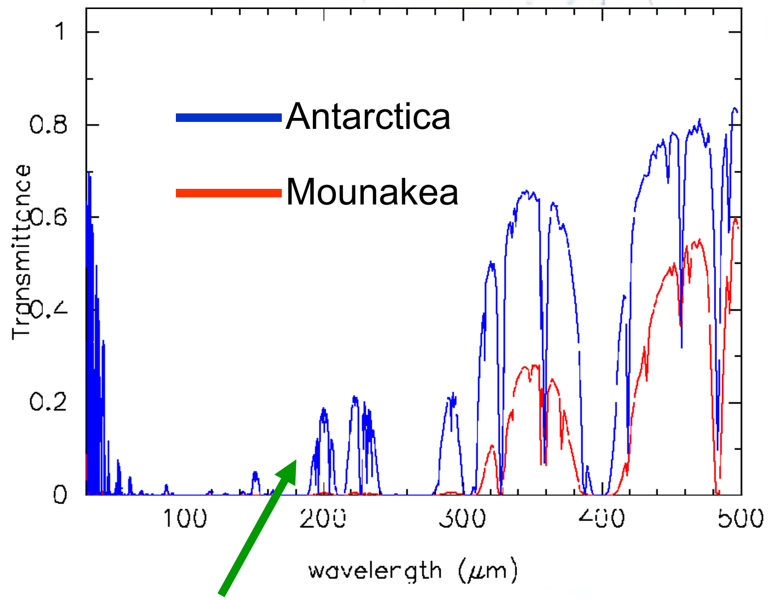
Near-Infrared



Mid-Infrared



Transmittance in THz

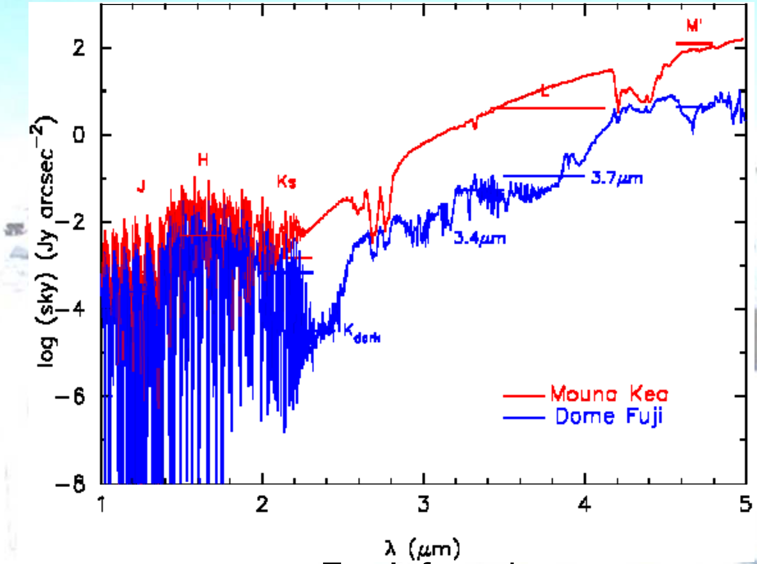


THz Windows are only available in Antarctica

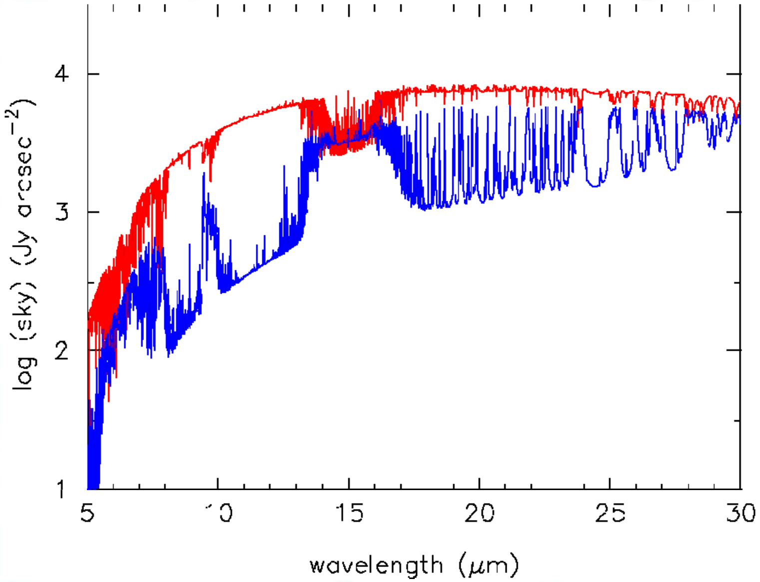
Low sky background

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

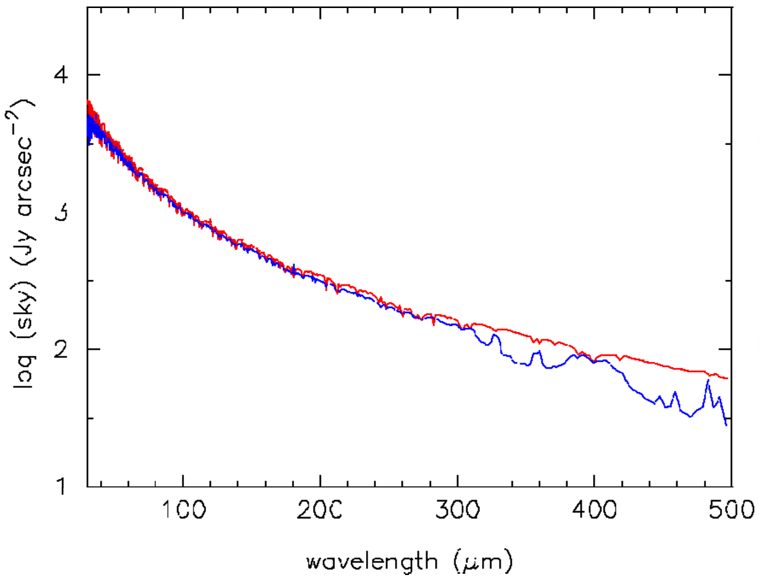
Near-Infrared



Mid-Infrared



Far-Infrared



MOIRCS

Multi-object Infrared Camera and Spectrograph

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K. Omata, R. Suzuki, C. Tokoku, Y. Uchimoto, M. Konishi

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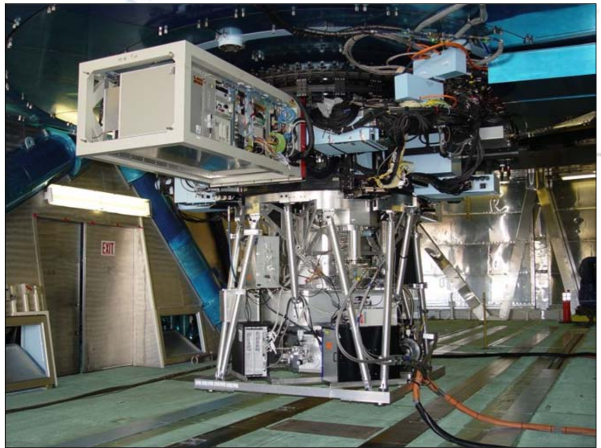

The Joint project of Tohoku University and Subaru Telescope.

MORCS has been open to common use since 2006.