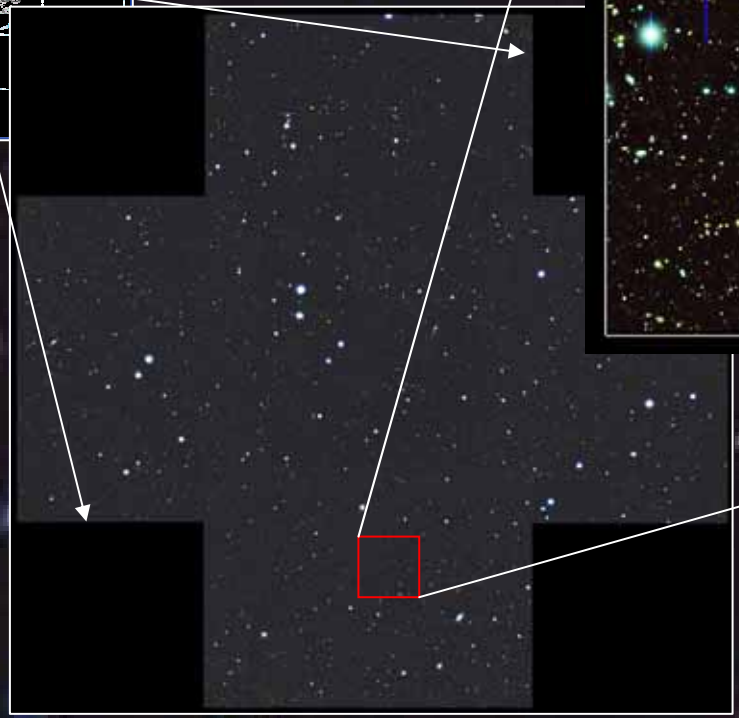
MOIRCSの開発と宇宙初期における銀河の集団化

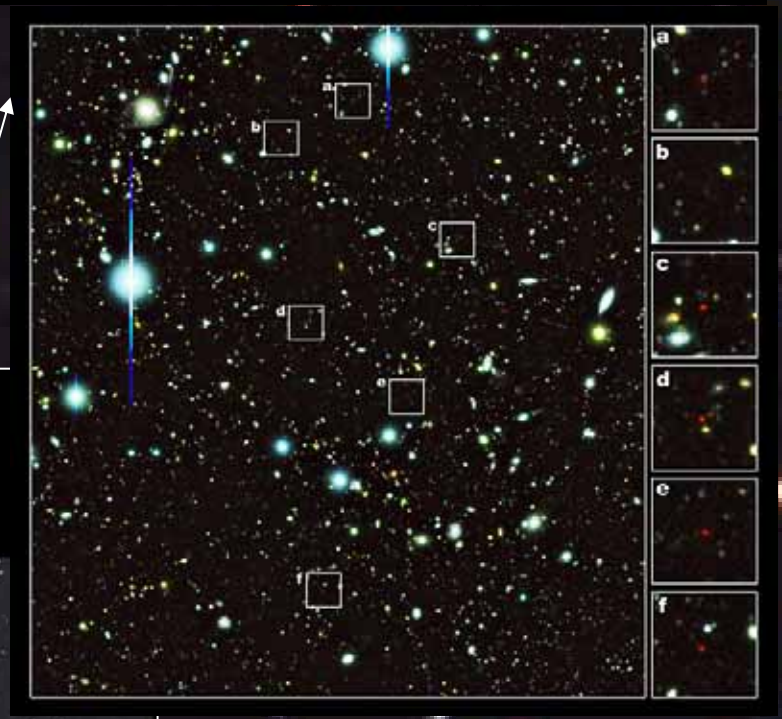
(Near-infrared Study of Stellar Mass Assembly at High-z Galaxies

市川 隆（天文学専攻）

Discovery of galaxy clusters 12.7 billion years away (= younger than 1 billion years old)

Ouchi et al. (2005)





By Optical Camera
(Subaru SuprimeCAM)

Group

1 milion
light years

10 milion
light years

Cluster

1 giga LY

Large scale
structure

Jenkins et al.

100 milion
LY

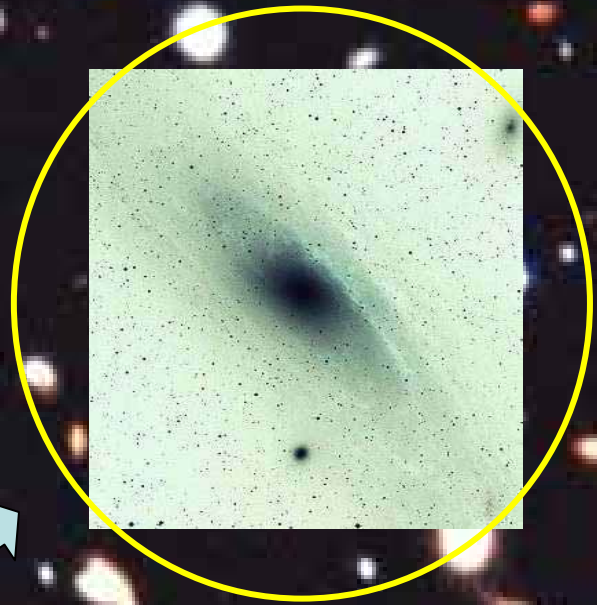
supercluster

Clustering of galaxies
in dark matter
universe

Formation of proto galaxies

When and how did the nearby galaxies acquire the present shape?

Dark halo



Merging?

Growth of dark matter halo and stellar mass

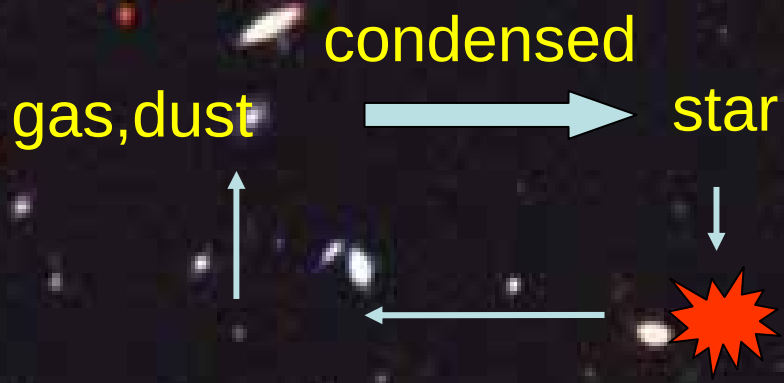
Stellar mass assembly in galaxy clustering

distribution and growth of dark matter halo


Why infrared?

Gas condense into stars

Decrease of gas with the age of universe



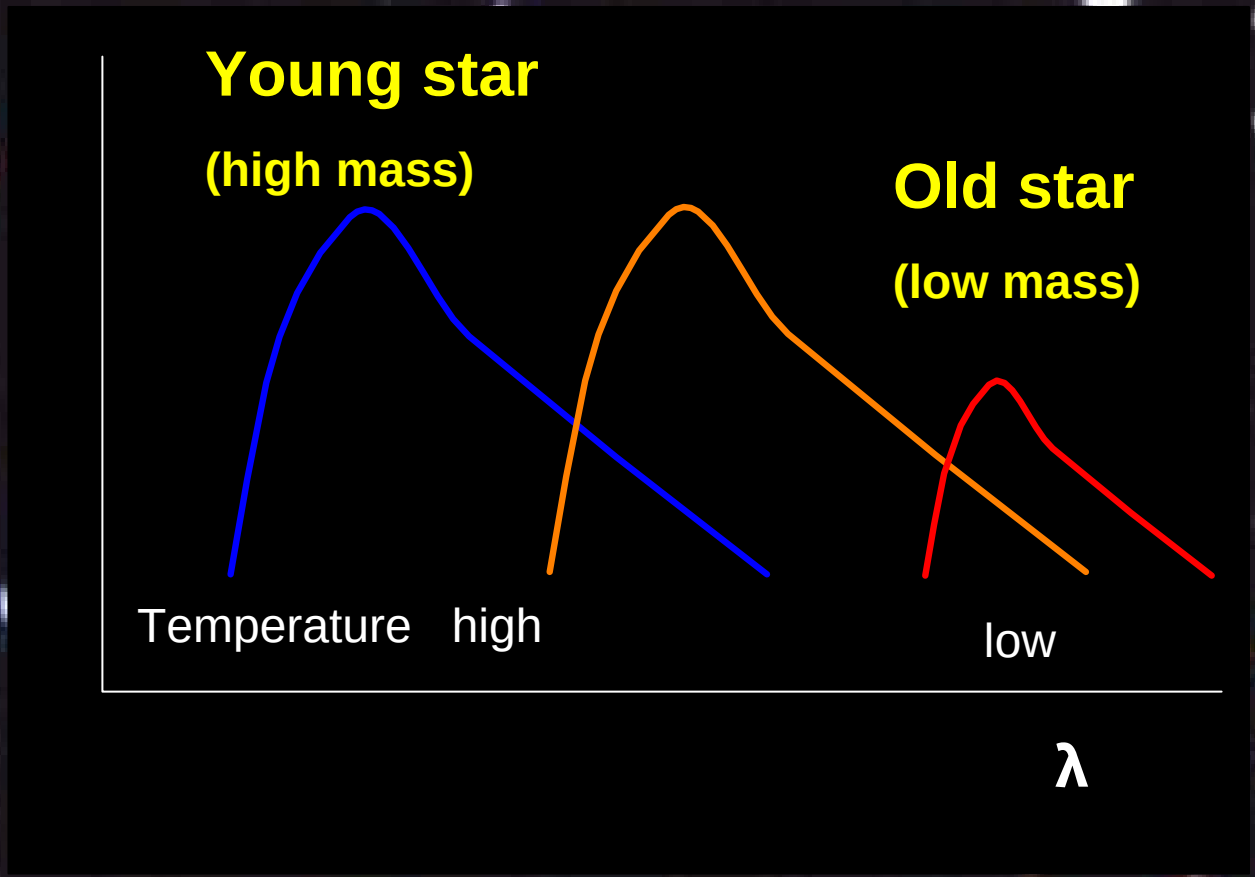
Accumulate of low mass stars

Growth of galaxy structure

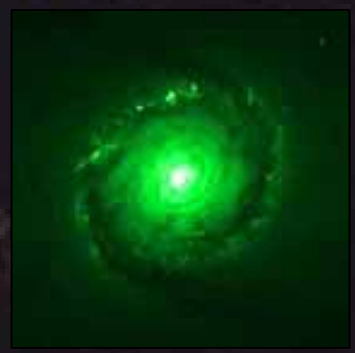
Stellar age $=1/\text{mass}^4$

High mass star -> short lifetime, high temeprature

Stellar spectra



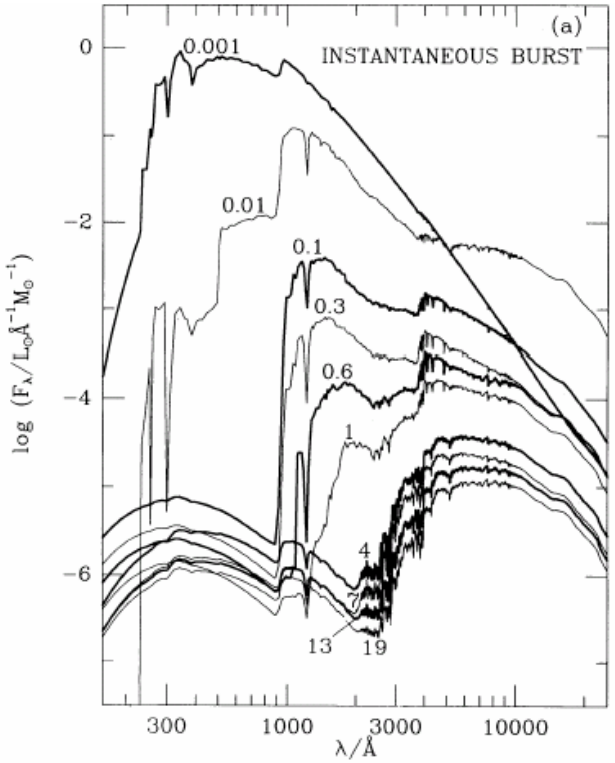
De-composition of galaxy stellar image in wavelength



	ultraviolet	**optical**	near-infrared
Stellar mass	> 1 M (sun)	~ 1 M (sun)	< 1 M (sun)
age	< 10 million	~ 10 billion	**>> Age of universe**
Total mass	very small		~ galaxy stellar mass

evolution of spectral energy distribution

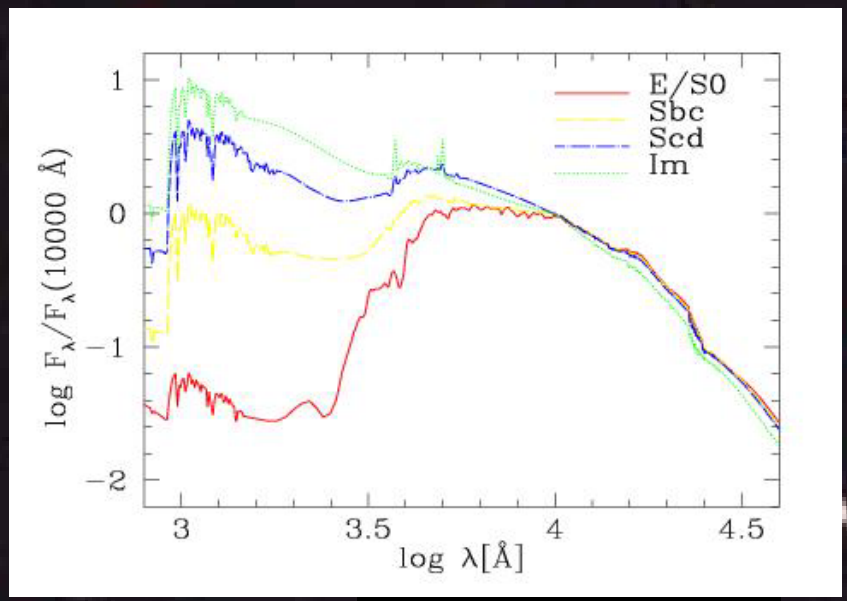
Burst star-forming galaxy



UV Op IR

Bruzual and Charot (1993)

Near-by local galaxies



UV Op IR

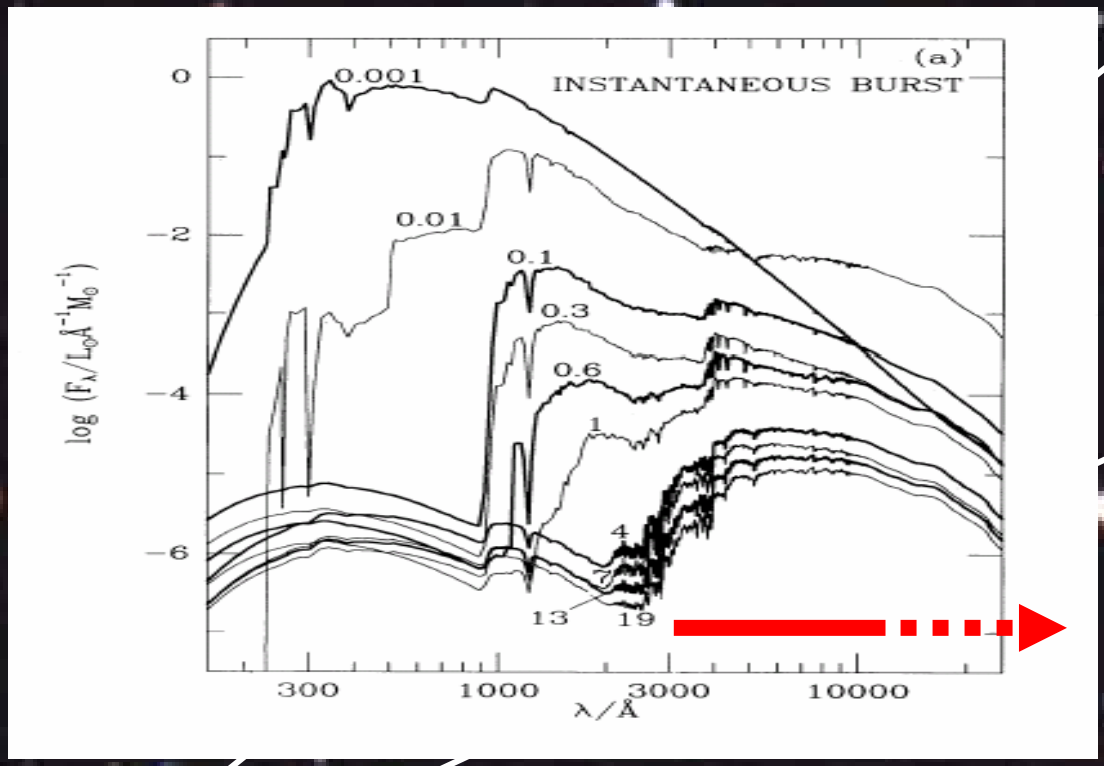
Bolzonella et al. (2000)

Active galaxy M82

Optical
(0.44 μm)

Infrared 1.6 μm

redshift



Due to expansion of universe, spectra of distant galaxies in early universe are redshifted.

The spectra at 0.3 μm or longer of galaxies 10 billion years away are red-shifted to near-infrared (>1.2 μm).

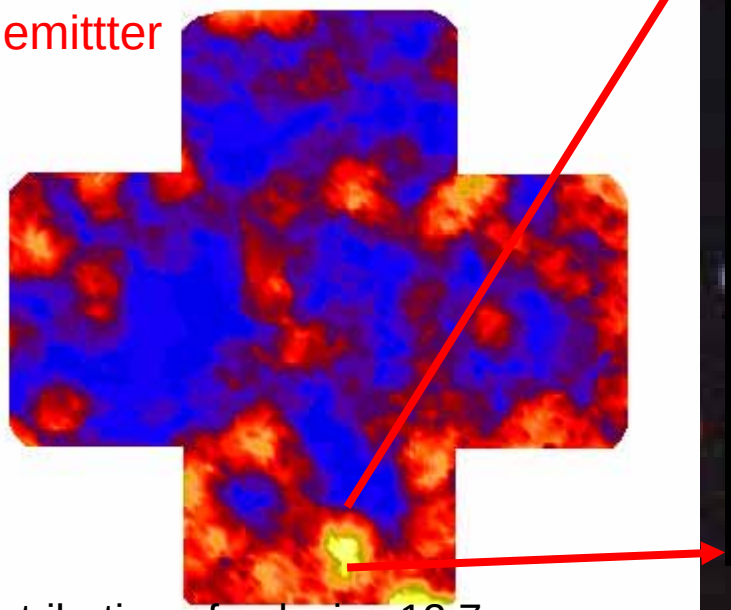
Ouchi et al. (2005)

Observation in optical

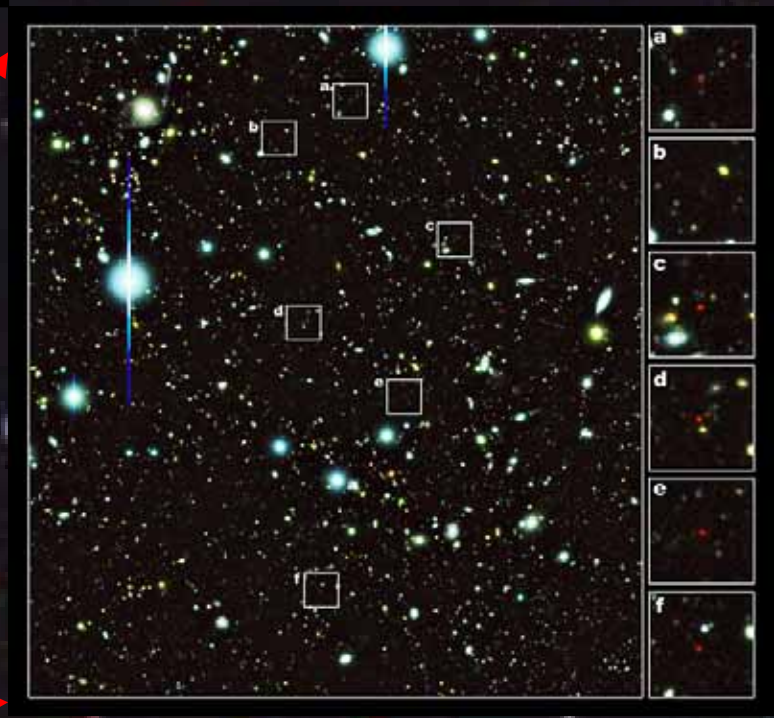
= far UV at rest wavelengths

Distribution of

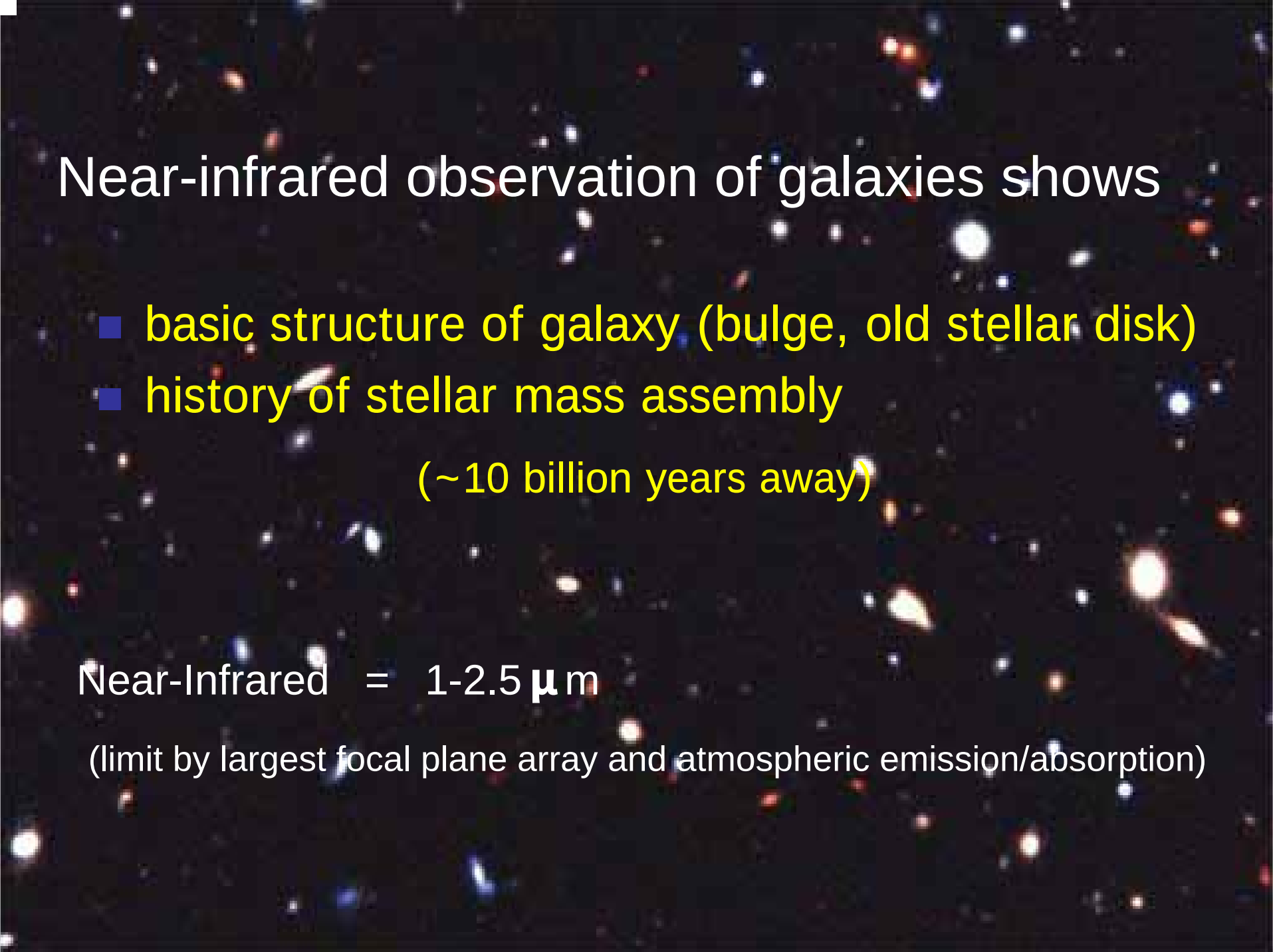
burst Star formation galaxies



Distribution of galaxies 12.7 billion years away



It does not mean the stellar mass assembly.



Near-infrared observation of galaxies shows

- basic structure of galaxy (bulge, old stellar disk)
- history of stellar mass assembly

(~10 billion years away)

Near-Infrared = 1-2.5 μm

(limit by largest focal plane array and atmospheric emission/absorption)

MOIRCS Project

Multi-Object InfraRed Camera and Spectrograph (モアックス)

The joint project of Tohoku University and Subaru Telescope for a new generation near-infared instrument for Subaru

1999	Research and Development started
2001	Approved by Subaru advisory committee
2004	First light with Subaru telescope

MOIRCS Team

P.I. Takashi Ichikawa（Tohoku Univ.）

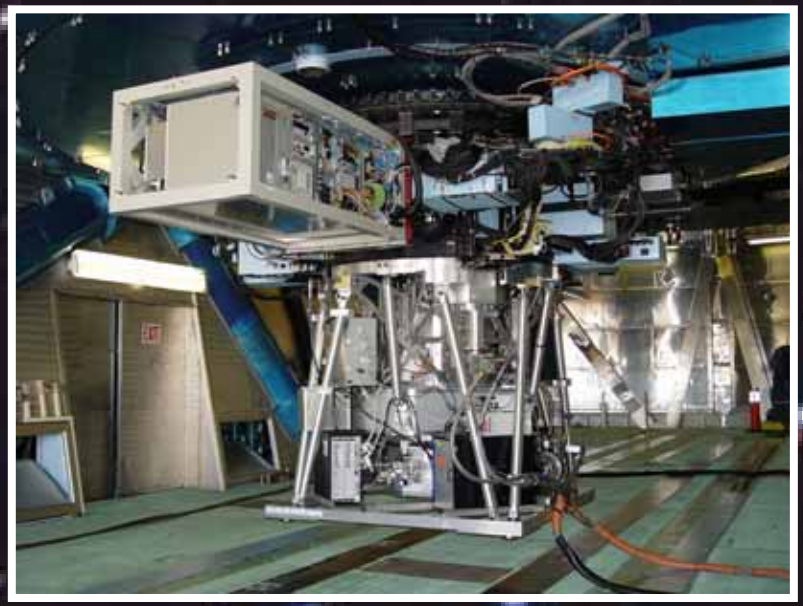
Ryuji Suzuki, Chihiro Tokoku, Katsuno Yuka, Masahiro Konishi

(Subaru Telescope, Tohoku Univ.）

Tomohiro Yoshikawa, Ichi Tanaka (Tohoku Univ.)

Yamada Toru (NAOJ)

Kohji Omata, Tetsuo Nishimura (Subaru Telescope)



学生の教育の観点から

ものづくりに基づく天文学の教育基盤の整備

実験室、実験環境の整備

大学院生を中心として、すべて自分たちで設計、基礎実験

海外拠点の形成

現地での組み上げ、実験
外国の一流望遠鏡環境の中での開発

世界最高性能への挑戦

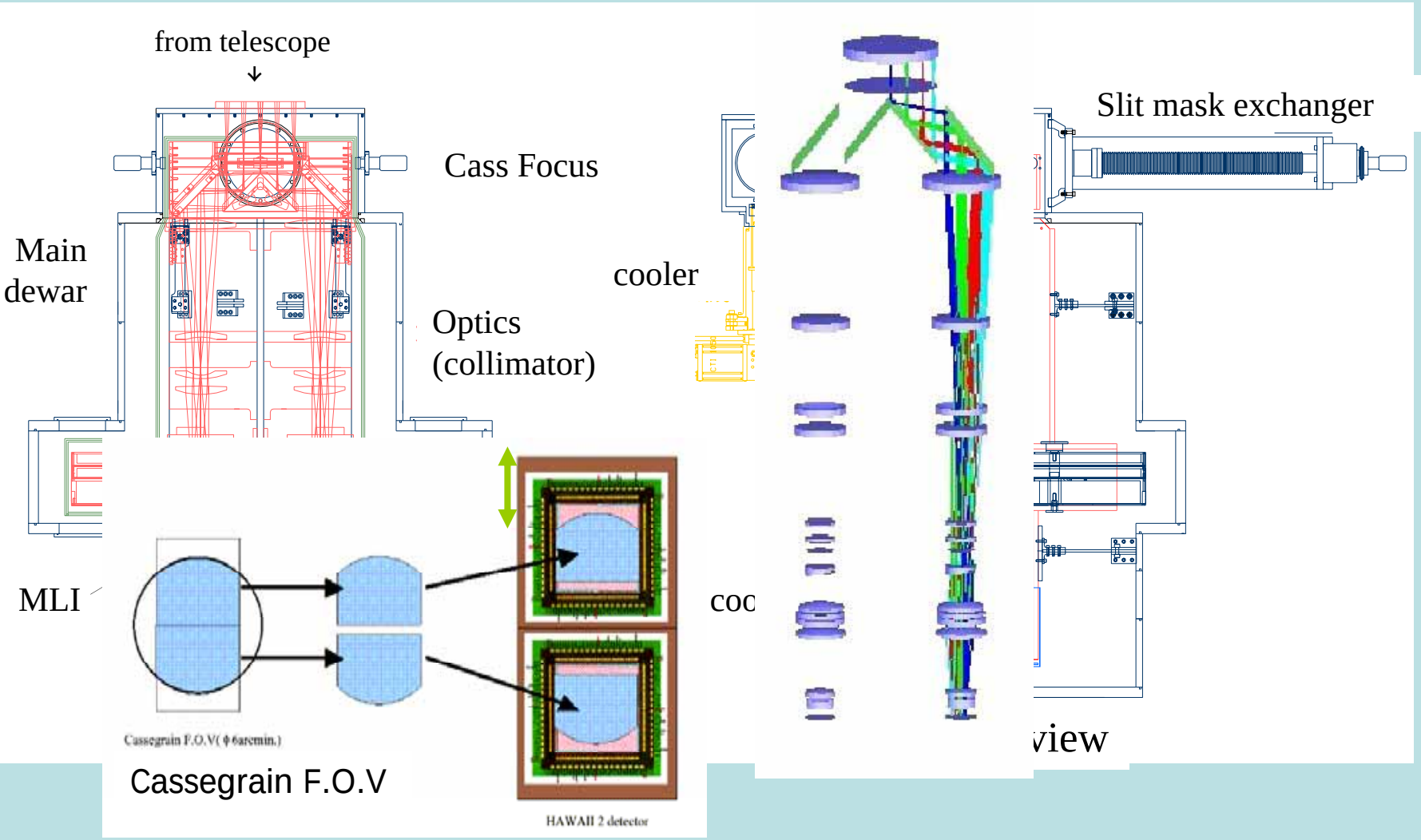
Wide field of view → Clustering evolution

Discovery of rare objects

Deep → Early universe

High resolution → Evolution of shape

Schematic View



Specifications

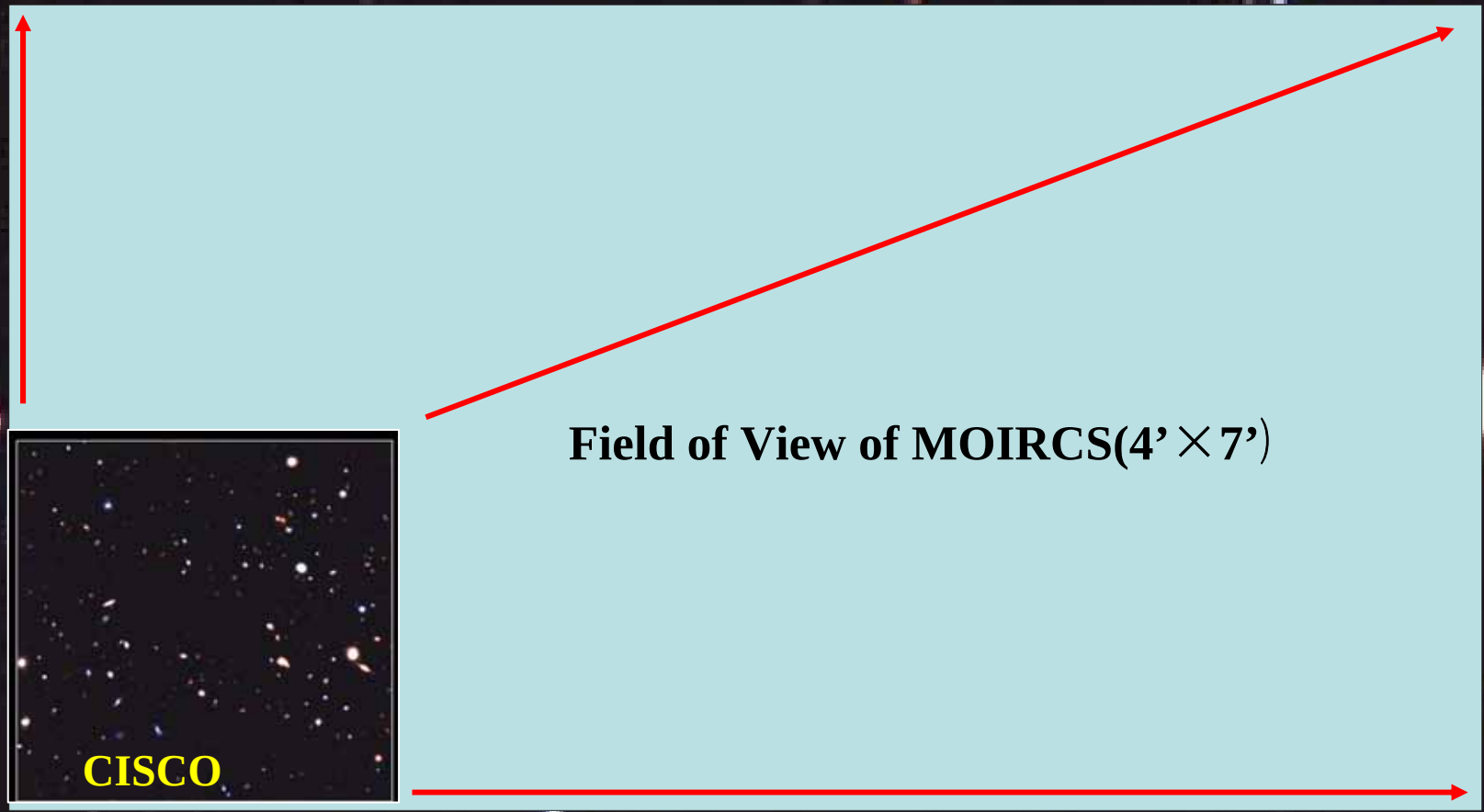
Wide filed & MOS in K band

Observation modes	Imaging & Multi-object Spectroscopy
Field of View	7'×4' (Imaging), 6'×4' (Spectroscopy)
Wavelength Coverage	0.85 ～ 2.5 μm
Scale	0.117"/pixel
Spectral resolution (R)	500, 1300 (grism) (3000? VPH)
Filters	J, H, K', K, H_2, Kcont
Number of filter holders	>20
Detector	2 x 2048 × 2048 HgCdTe (HAWAII2)
Pixel size	18μm
QE	0.65 – 0.85 (0.85～2.5 μm)
Readout noise	20 e−
Cut of slit	Laser Cutter at the summit
Number of slit masks	9 (20)
Number of slits	～50 slits/mask

Challenge of MOIRCS (I)

Wide field of View (4'x7') with high spatial resolution(0.12"/pixel)

Largest among the IR instruments of 8-10m telescope



state-of-the-arts Near-Infrared Focal Plane Array

HAWAII2（2Kx2K HgCdTe）

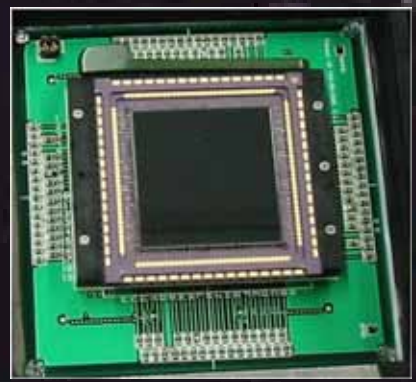
Tohoku Univ. Focal Plane Array Controller

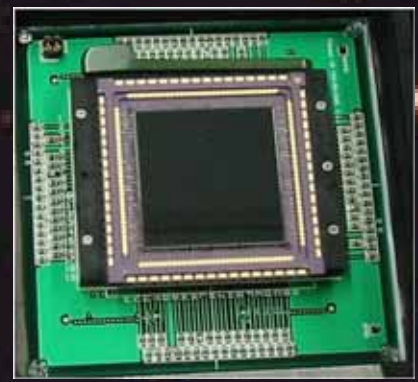
(TUFPAC)

PC+Linux+DSP

front-end electronics

HAWAII2 science grade

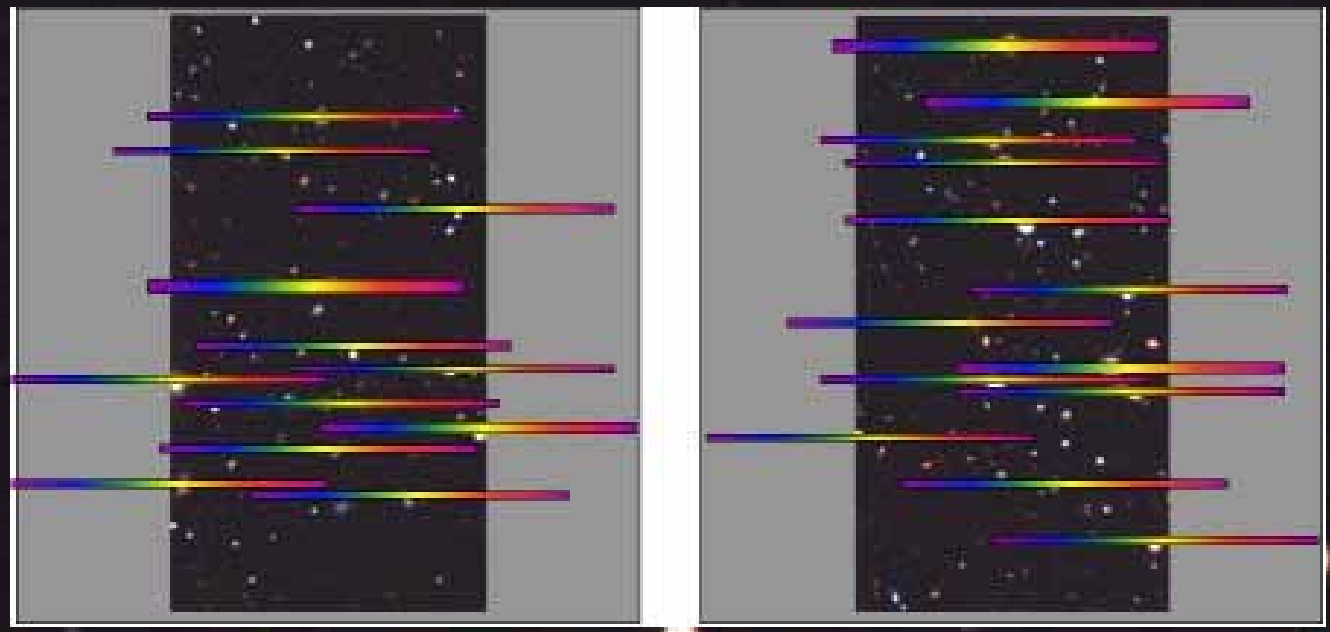




Ichikwa et al. 2002

Challenge of MOIRCS **(II)**

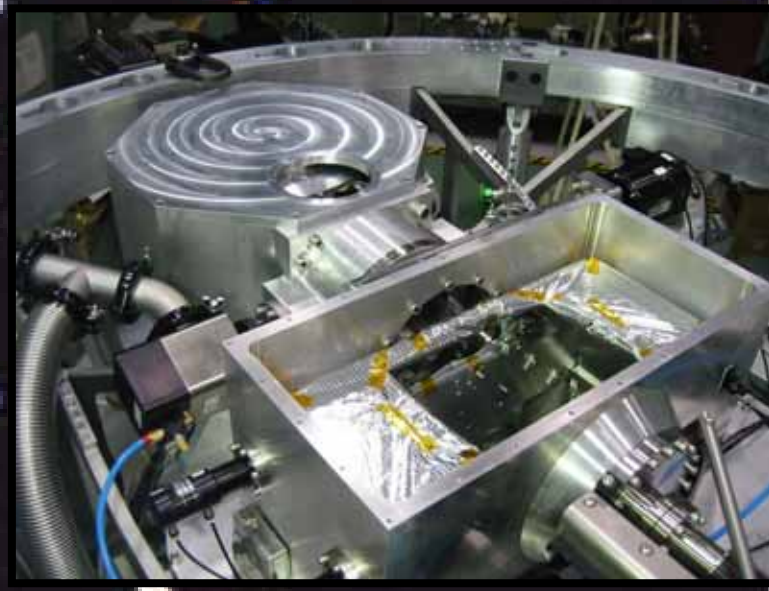
Slit masks cooled at about 100 K enable the multi-object spectroscopy in *K* band (2.5μm)

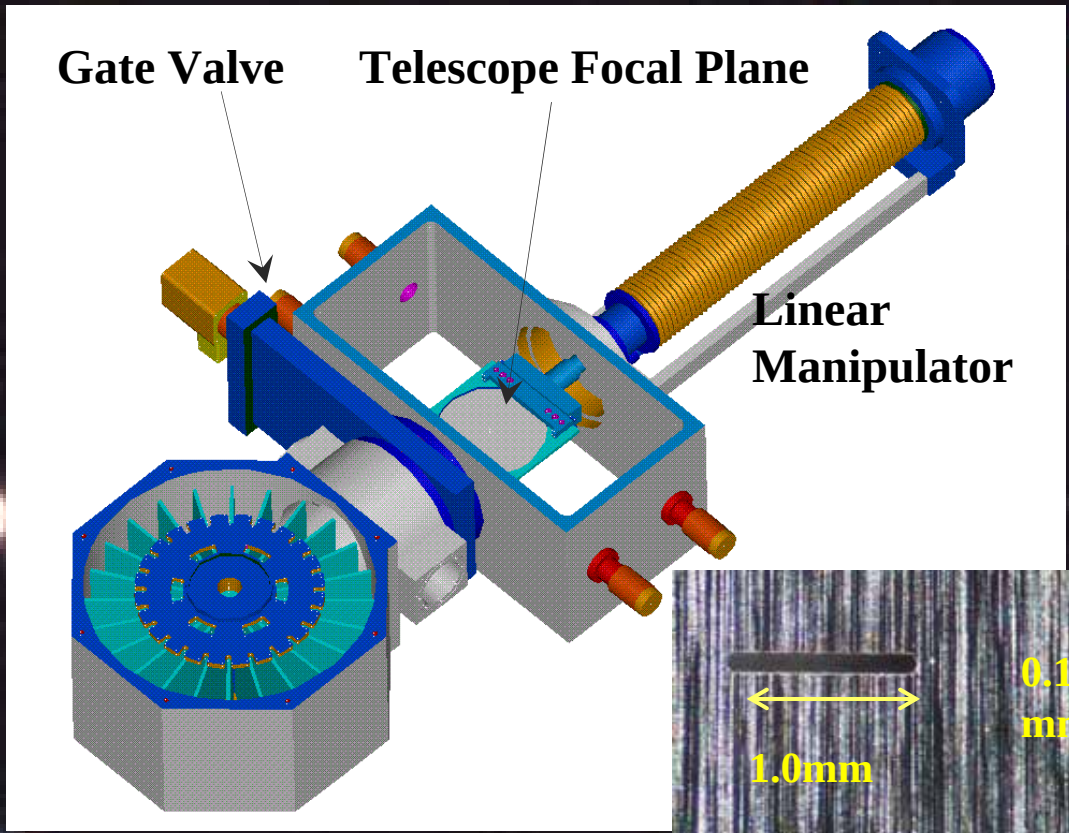


Not established for 8-10 m telescope yet

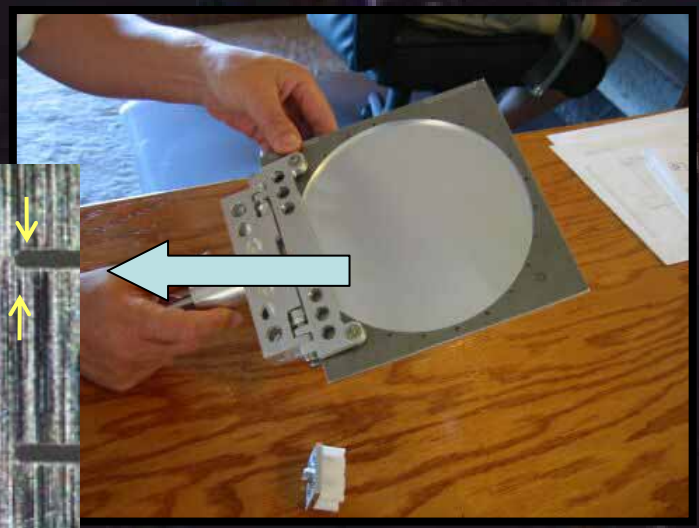
50 times more efficient than previous instruments

Slit Mask Exchange System





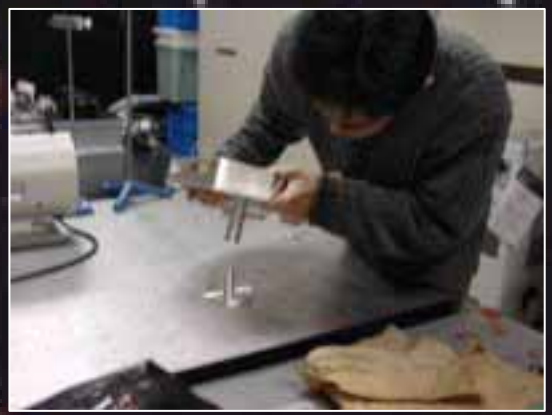
Mask Dewar (Carrousel)

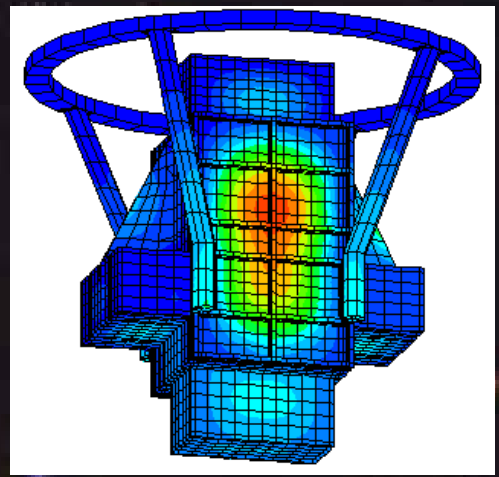


Aluminum slit mask

Development at Sendai 1999~

Preliminary design, prototype model, and laboratory test





Assembly and laboratory test at Hilo in Hawaii Subaru Office 2001-

optics

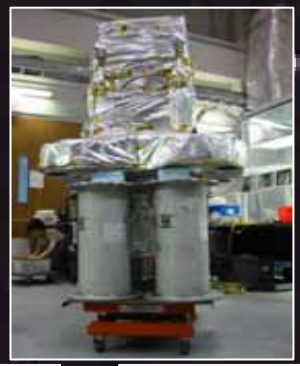
ZnSe lens

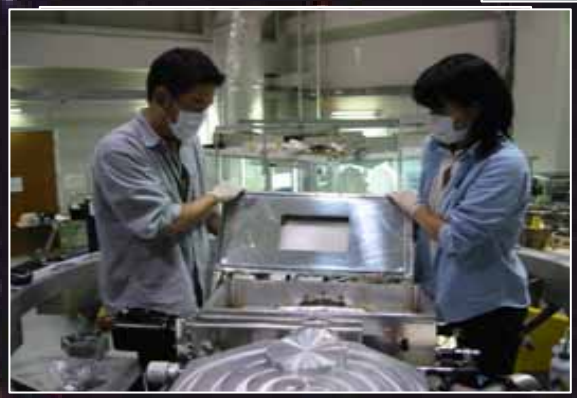
ϕ152mm

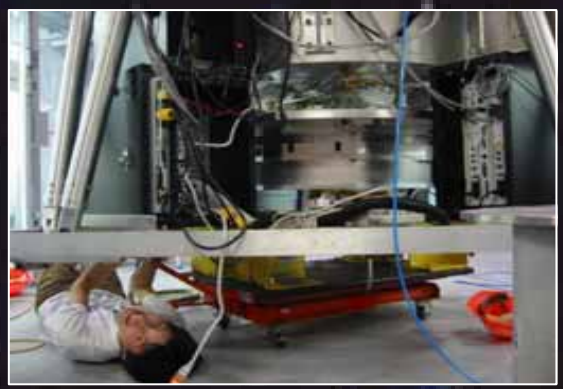
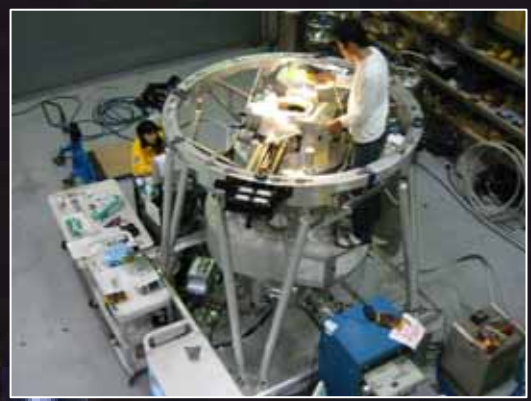
CaF_2 lens

ϕ208mm

Simulator test

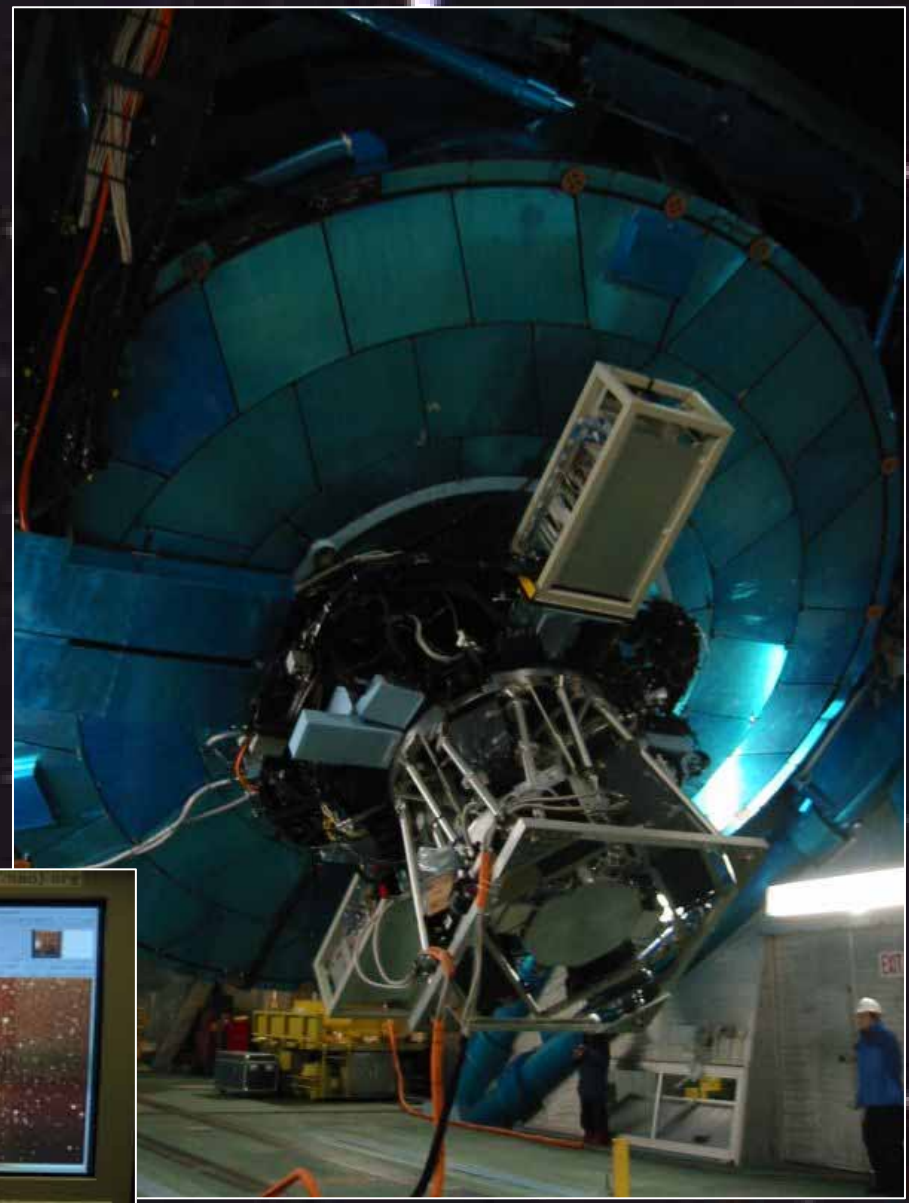




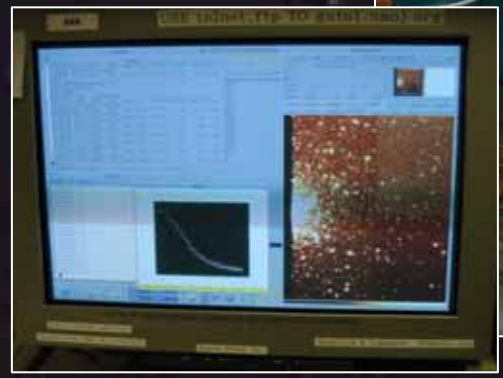
Mount on Subaru Telescope

ハワイ・マウナケア山頂の望遠鏡群（空撮）

Engineering Runs

Sep 20-22, 2004
Imaging
42 tests
(870 shots, 1740 frames)
Jan 25-27, 2005
MOS, spectroscopy, imaging
20 tests
(986 shots, 1972 frames)





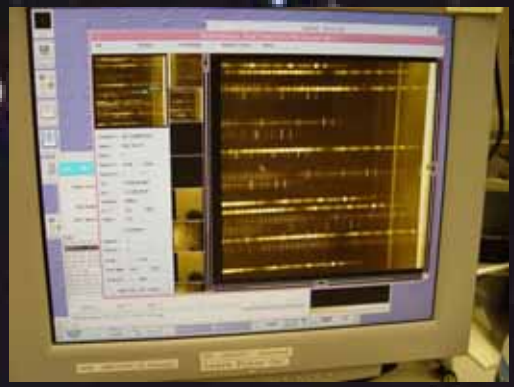
Near-infrared image of Orion from first light images

In 2.2 μm band, the efficiency of MOIRCS is 16 times that of CISO.

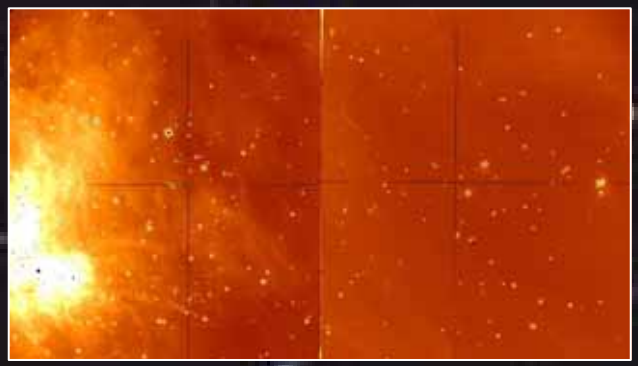
8 times in field of view

1/2 times in exposure time

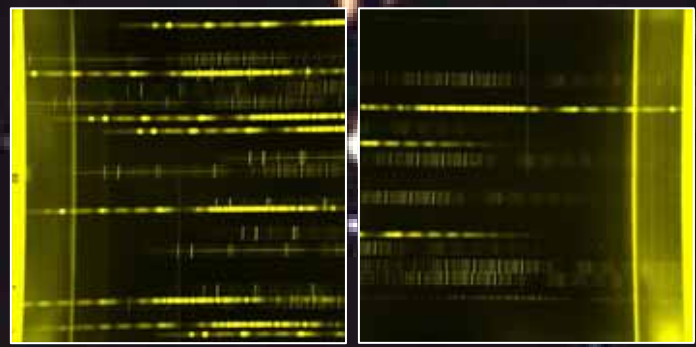
Multi-object spectra



About 30 stars hit just on the slits or guide holes.



Pre-image



MOS raw image

data analysis in progress

GT program

Deep Survey for Blank Fields in 50 nights

(proposed)

Background

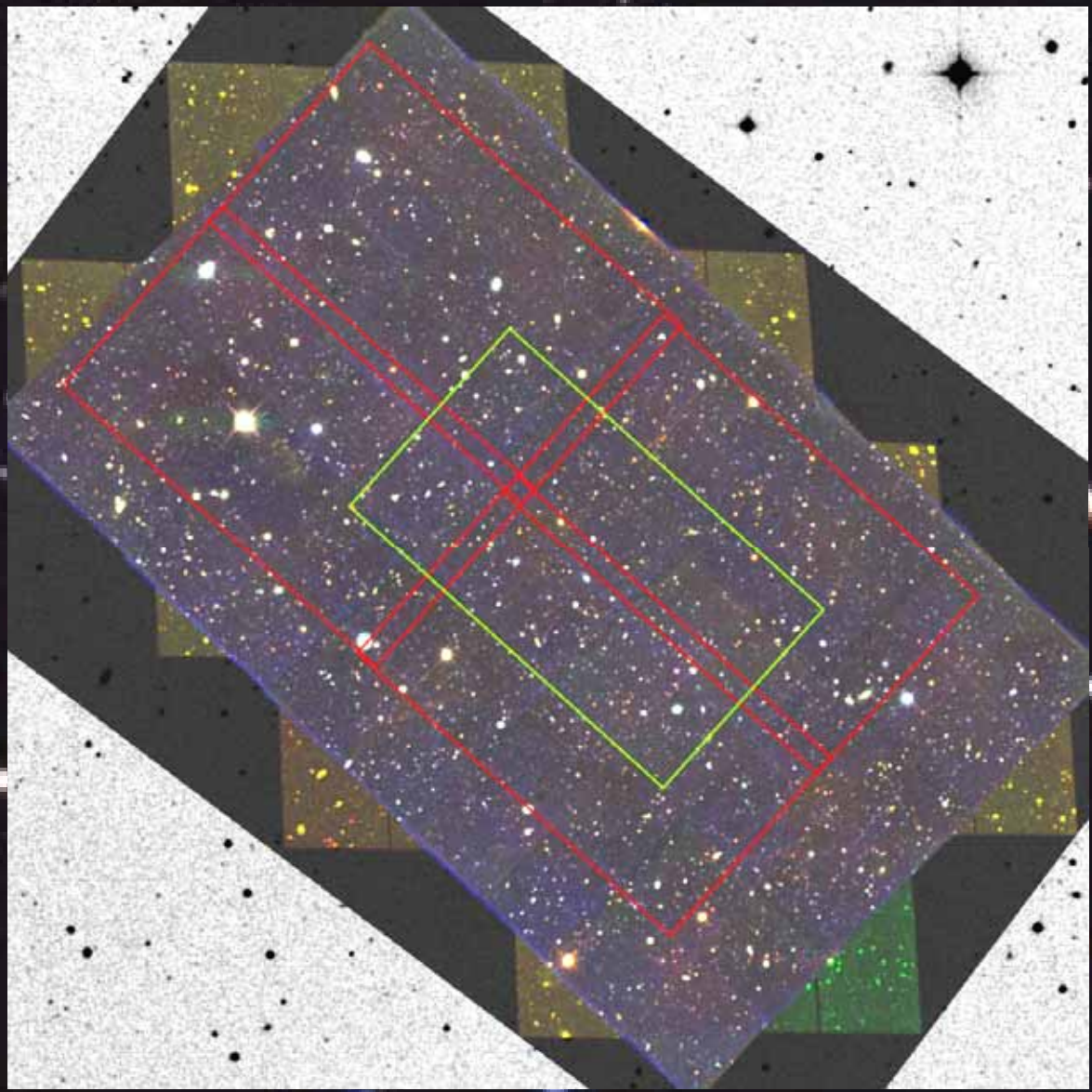
Rival instruments will be in operation in ～2 years.

Legacy projects for MOIRCS

Near-Infrared Camera and Spectrograph for 8-10m Telescopes

Instrument	Telescope	FOV	Scale	Operation
ISAAC	VLT 8.2m	2.5' x 2.5'	0.15"/pixel	
CISCO	Subaru 8.2 m	1.8' x 1.8'	0.105"/pixel	
MOIRCS	**Subaru 8.2 m**	**4' x 7'**	**0.117"/pixel**	**in eng run**
EMIR	GTC 10.4 m	6' x 6'	0.2"/pixel	Construction in progress
HAWK-I	VLT 8.2 m	7.5' x 7.5'	0.106"/pixel	PDR, 2004
KIRMOS	Keck 10 m	11.3' x 11.3'	0.16"/pixel	(?)

GOODS=The Great Observatories Origins Deep Survey



Deepest near-infrared imaging and spectroscopy by MOIRCS in 40 nights

Test observation at SSA22 Proto-cluster fields

Katsuno (PhD thesis)