International Collaboration in Astronomy for Asia

Strategy of Subaru Telescope

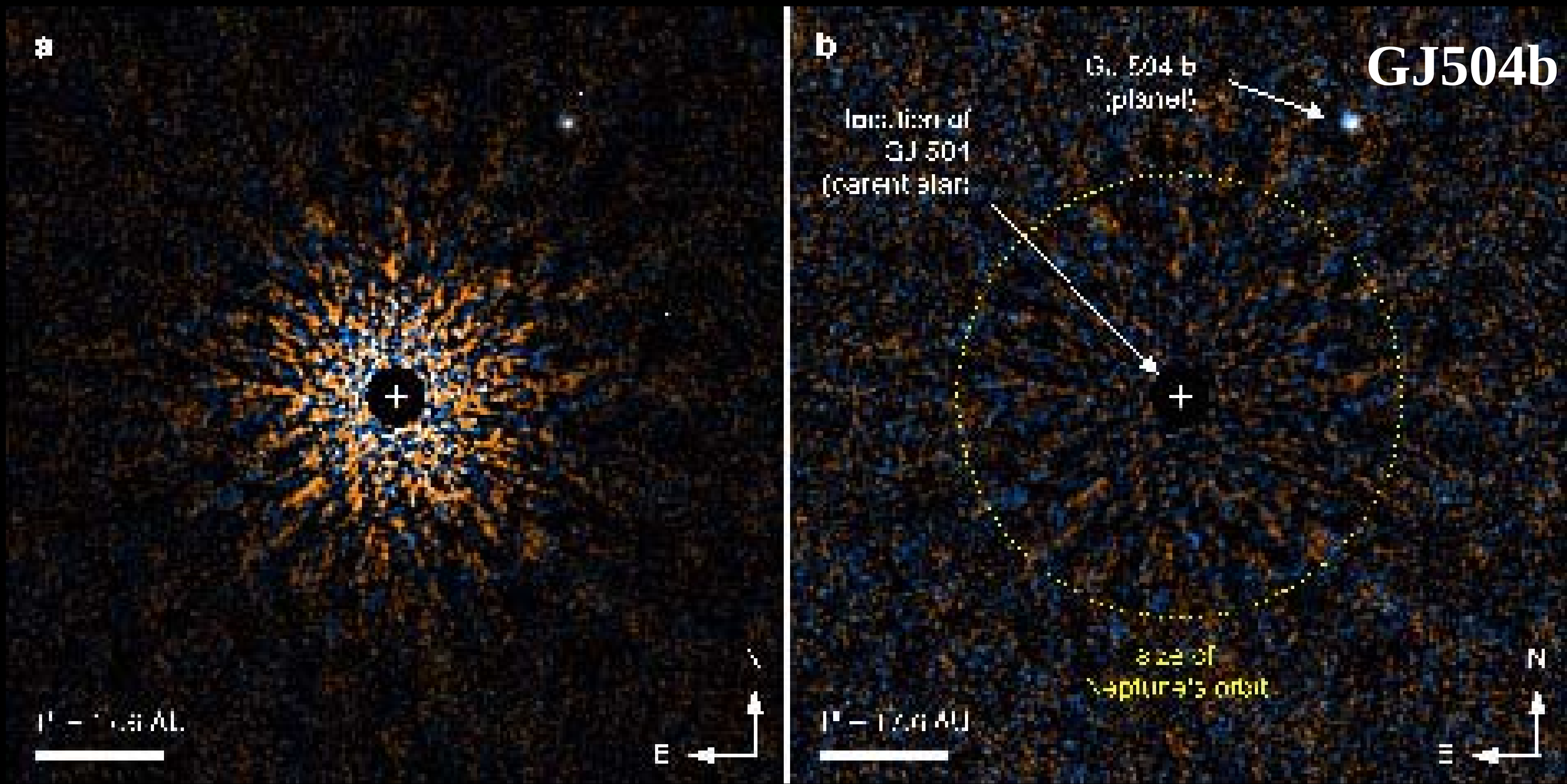
Nobuo ARIMOTO
Subaru Telescope

Subaru Telescope Science Topics

Subaru Telescope

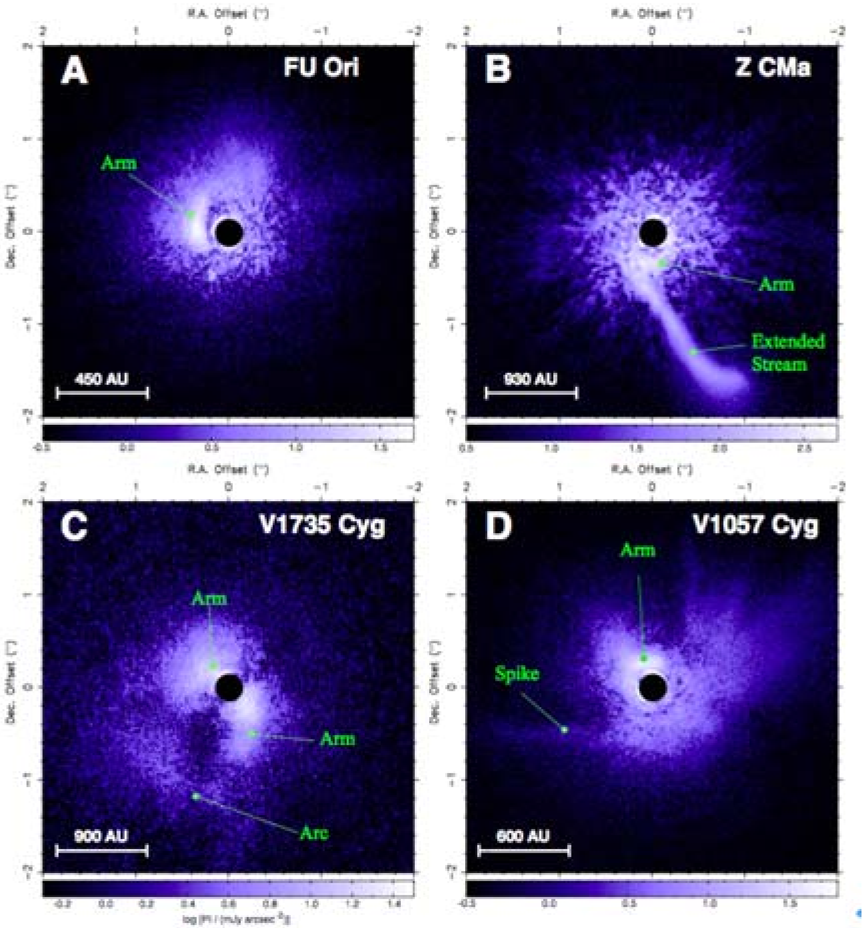
Direct Discovery of a Second Jupiter Shows the Power and Significance of the SEEDS Project

(Kuzuhara et al. 2013)



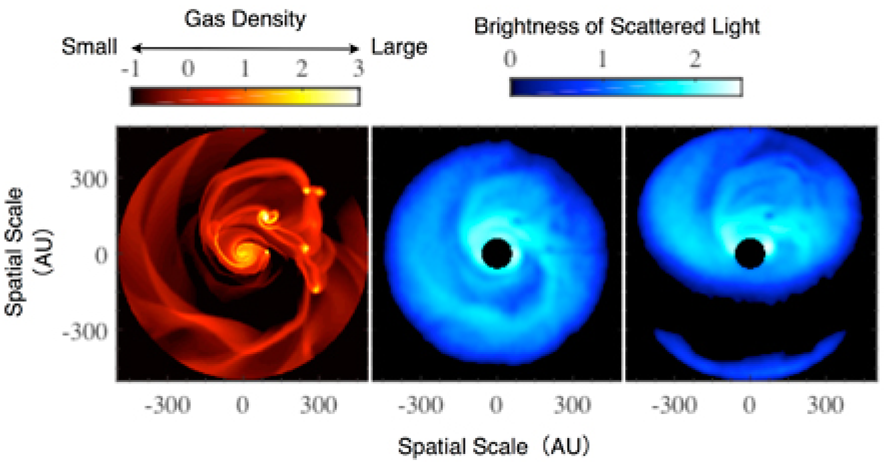
Subaru Telescope

Subaru-HiCIAO Spots Young Stars Surreptitiously Gluttonizing Their Birth Cloud (Liu et al. 2016)



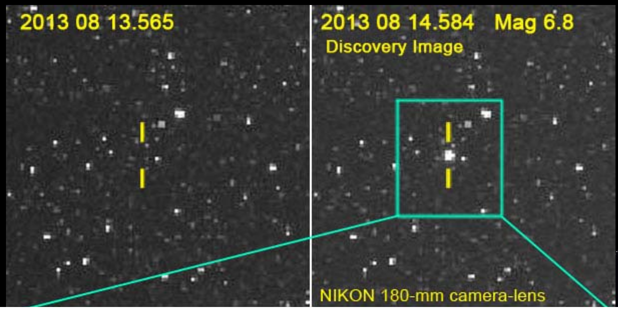
Circumstellar structures of young stars

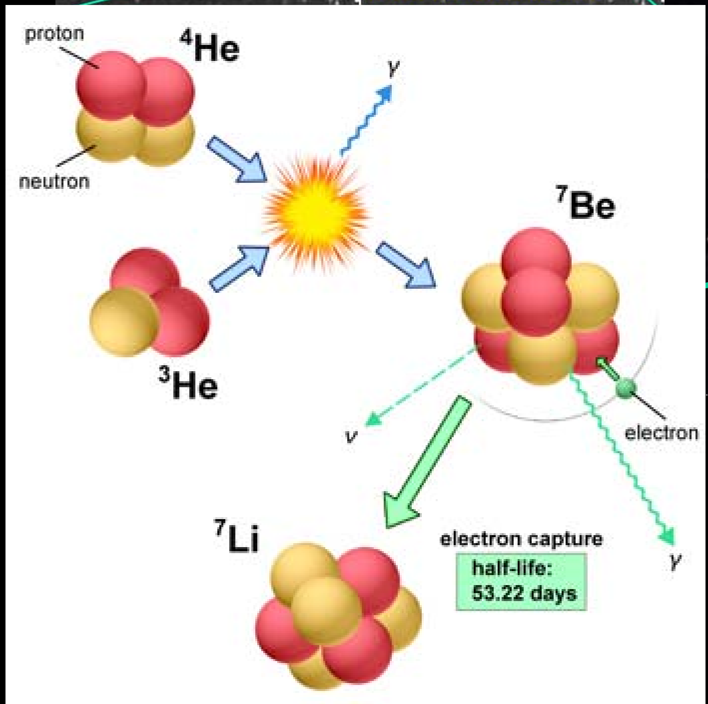
Images made from computer simulations based on one theory for violent growth of a star. (Left) Simulations of the motion of circumstellar materials falling onto a baby star. (Middle and right).

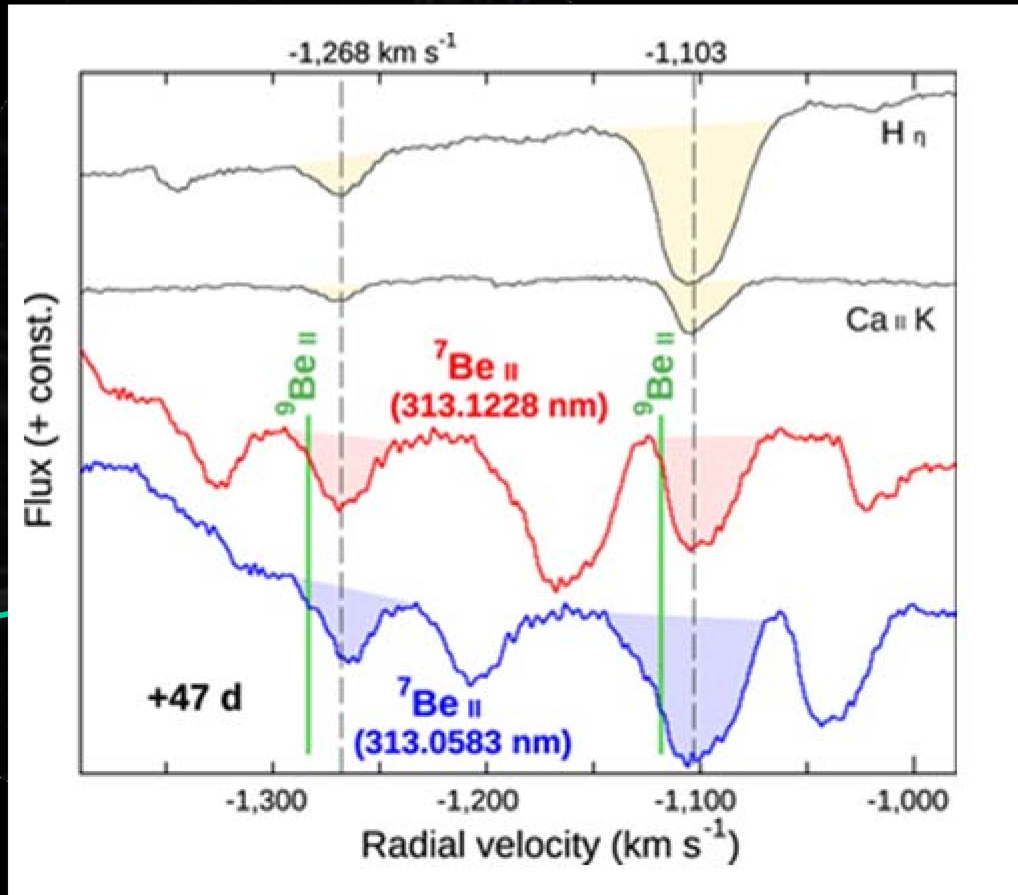


Subaru Telescope

Classical Nova Explosions are Major Lithium Factories in the Universe (Tajitsu et al. 2015)

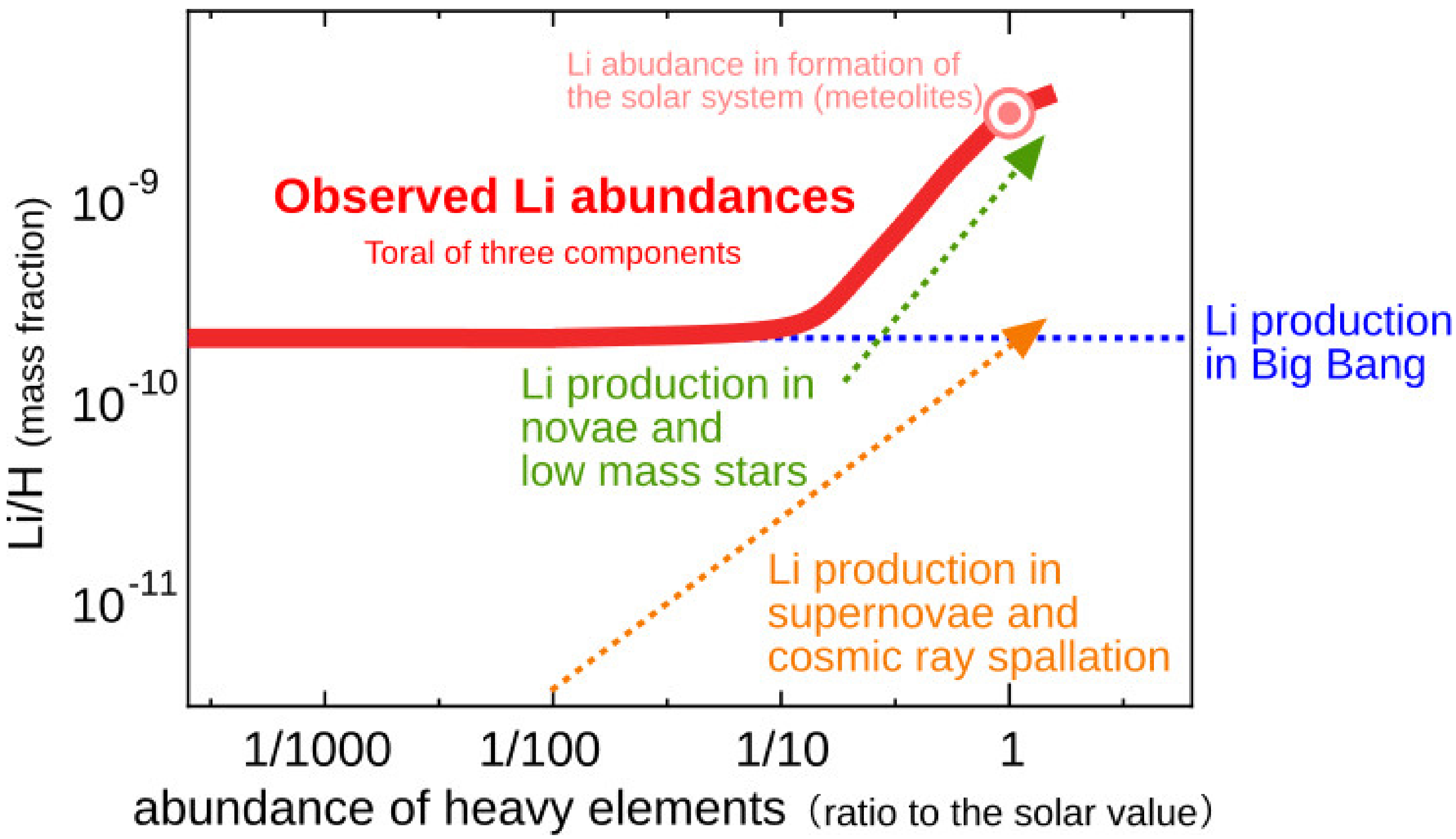






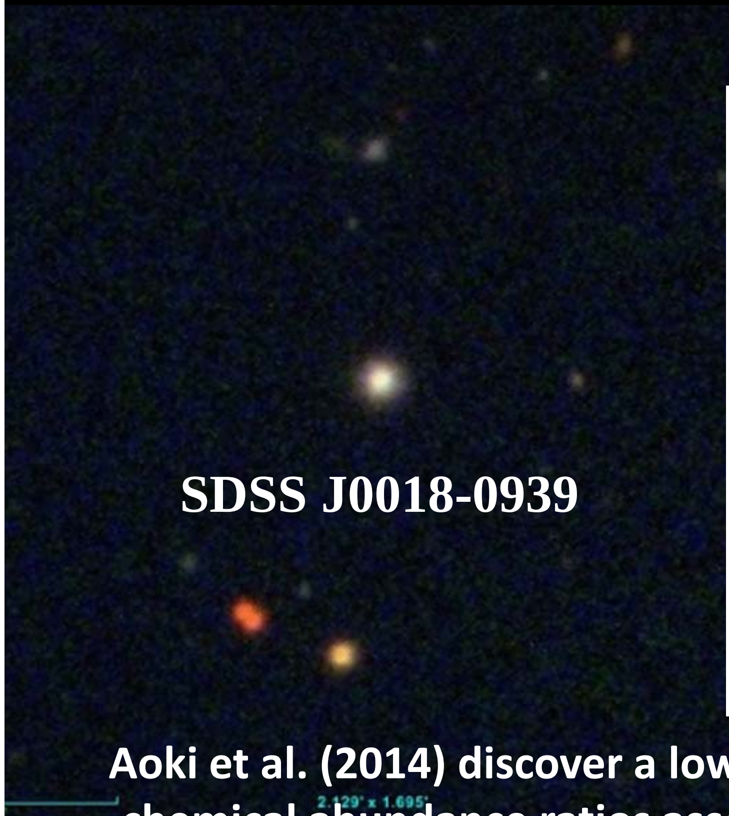
Classical novae are strong candidates as suppliers of Li in the universe.

Schematic Evolution of Li^7 in the Universe

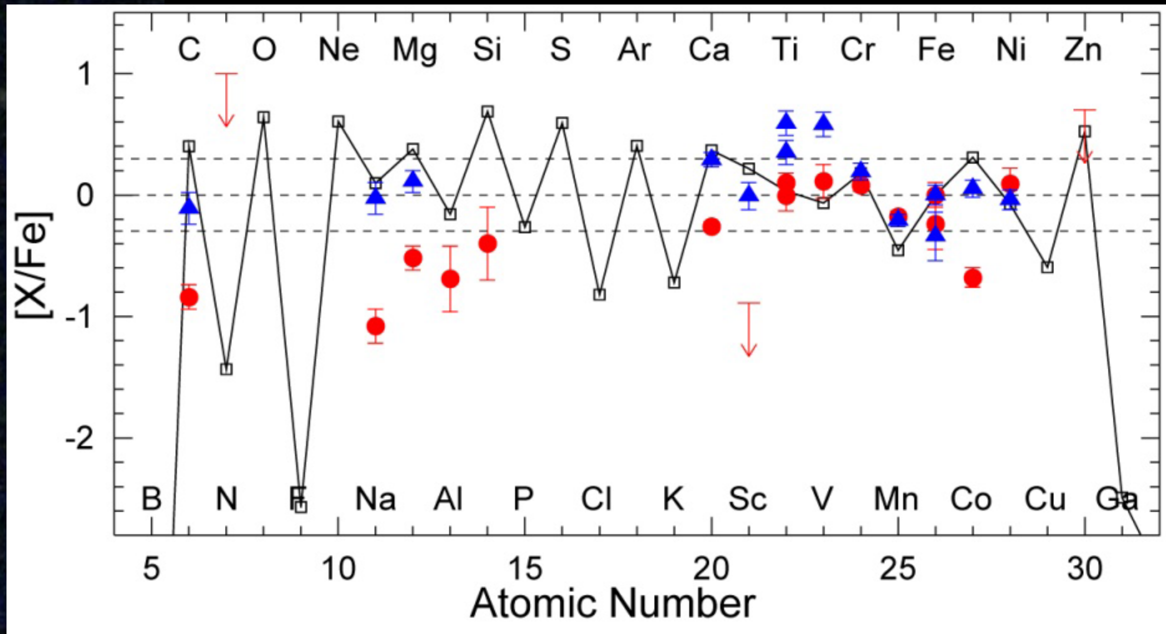


Subaru Telescope

Chemical Signature of First-Generation Very-Massive Stars



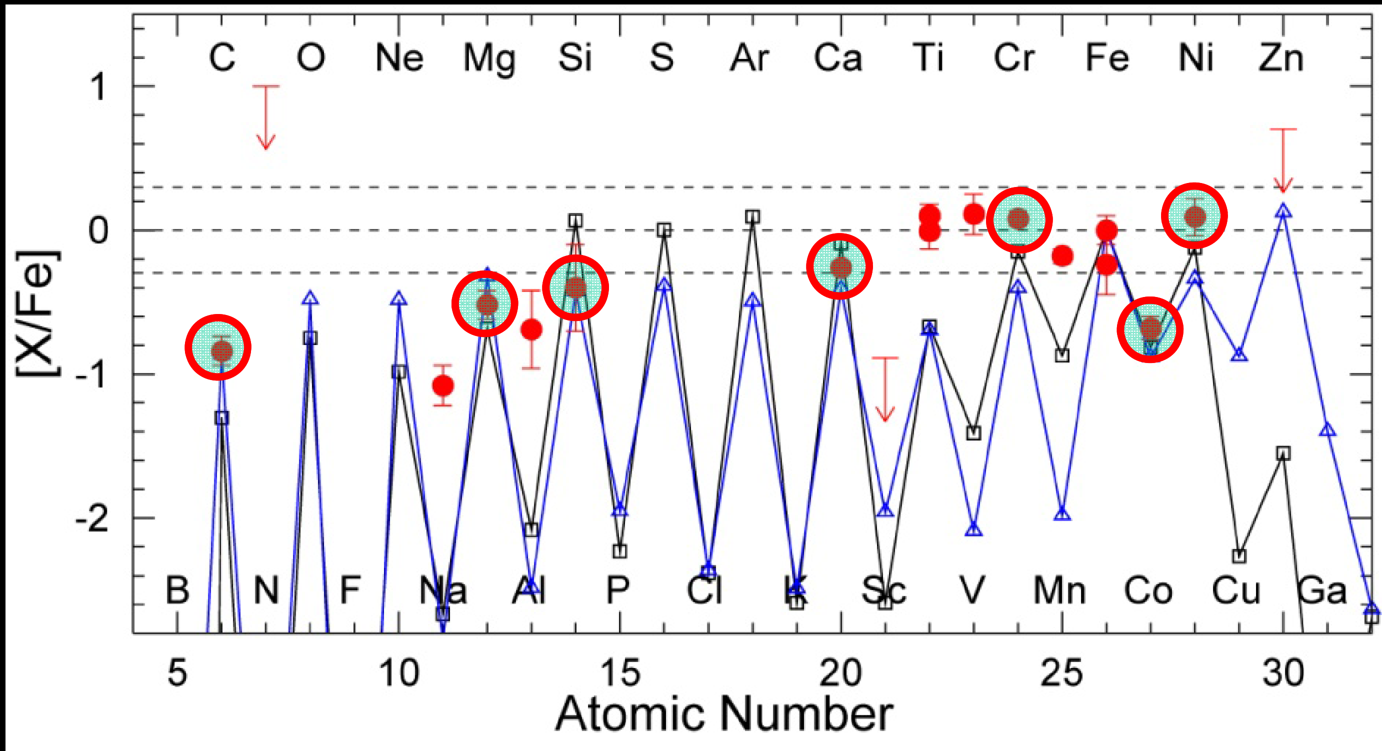
The chemical abundance ratios (with respect to iron) of SDSS J0018-0939 (red circles) compared with model predictions for a supernova explosion of a massive star.



Aoki et al. (2014) discover a low-mass star, SDSS J0018-0939, that exhibits the peculiar chemical abundance ratios associated with the process of creating new atomic nuclei (nucleosynthesis) in a first-generation very-massive star. Until now, no observational evidence has supported numerical simulations of the existence of very-massive stars among the first generation of stars formed after the Big Bang.

Subaru Telescope

Chemical Signature of Pair-Instability Supernovae



The chemical abundance ratios (with respect to iron) of SDSS J0018-0939 (red circles) compared with model prediction for explosions of very-massive stars. The black line indicates the model of a pair-instability supernova by a star with 300 solar masses, whereas the blue line shows the model of an explosion caused by a core-collapse of a star with 1000 solar masses.

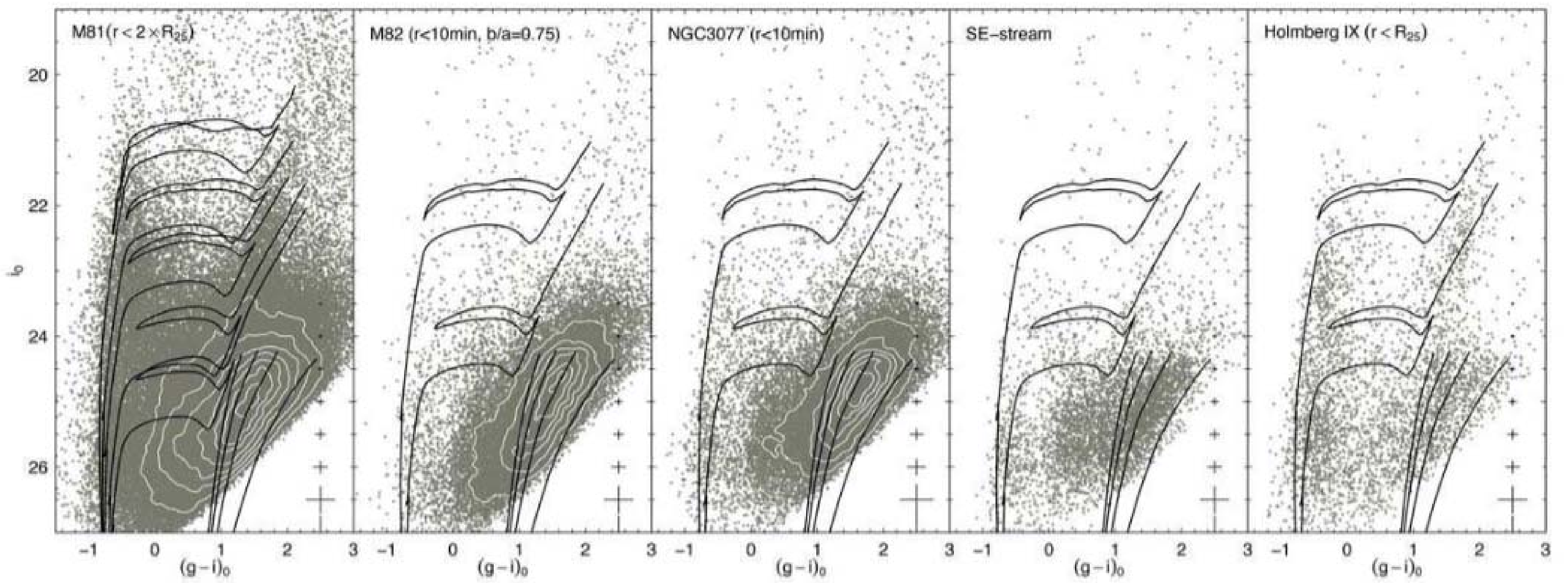
Subaru Telescope

The Ghostly Remnants of Galaxy Interactions Uncovered in a Nearby Galaxy Group M81

Okamoto et al. (2015)

Subaru Telescope

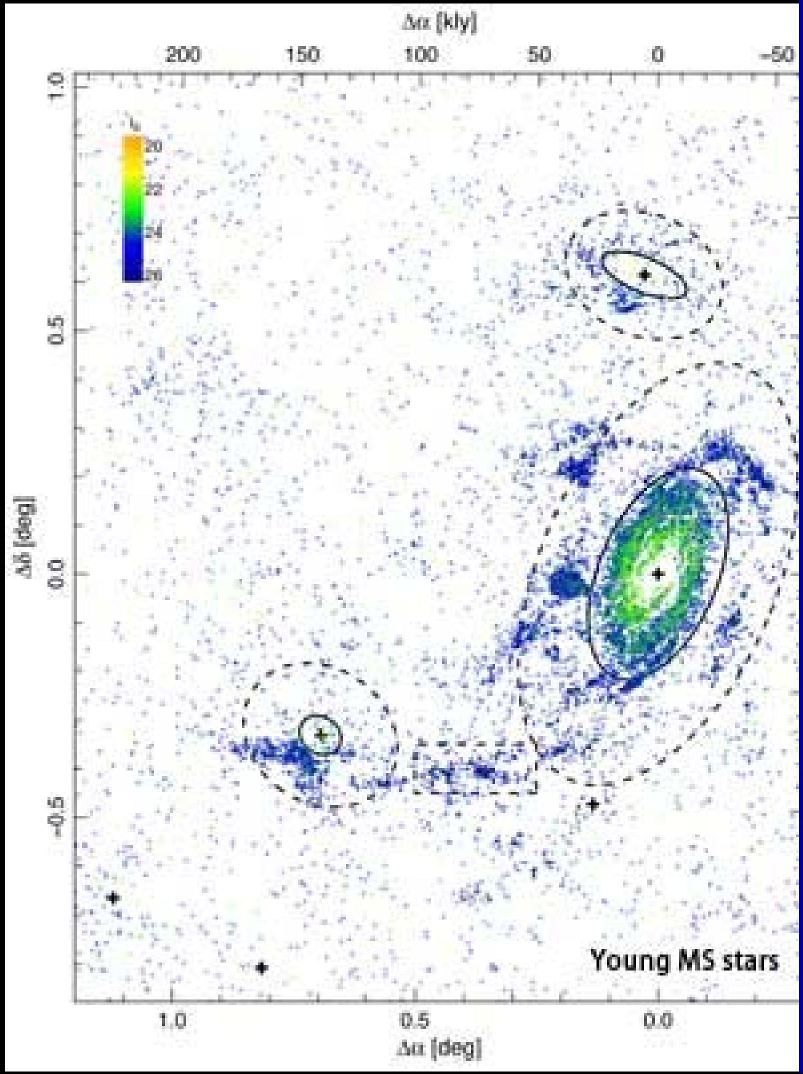
The Ghostly Remnants of Galaxy Interactions Uncovered in a Nearby Galaxy Group (Okamoto et al. 2015)

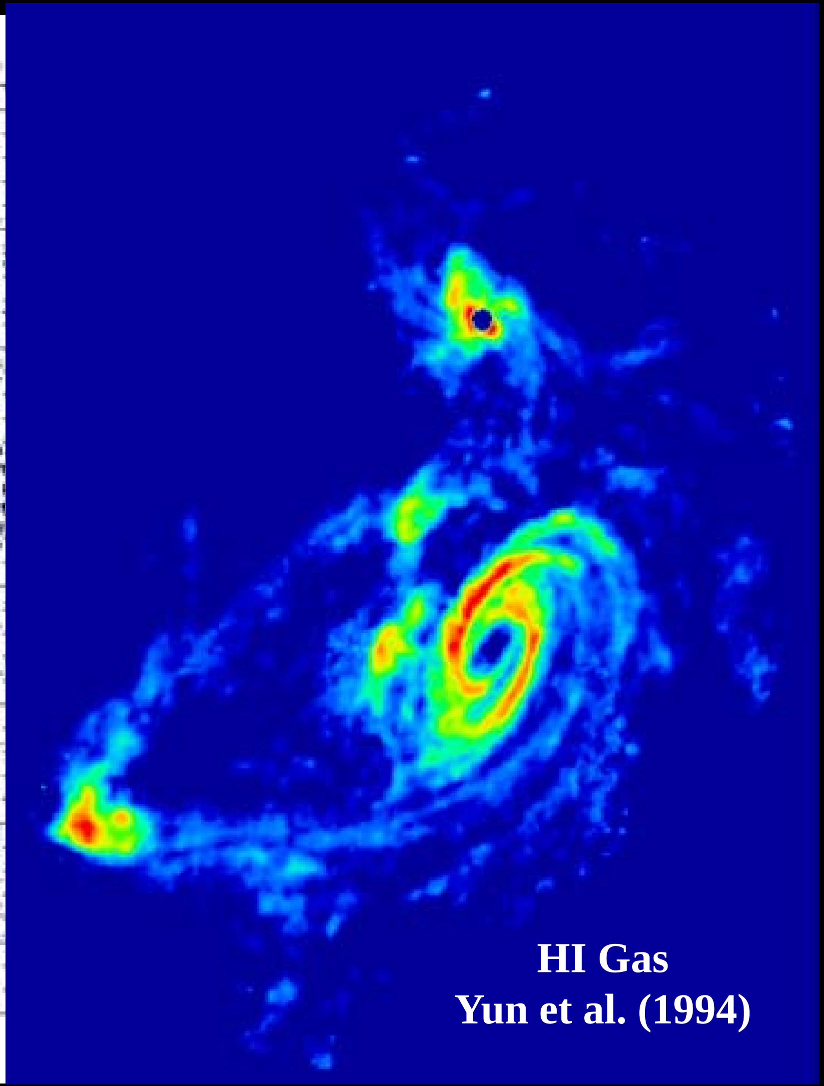


M81 **M82** **NGC3077** **SE-stream** **Ho IX**

Subaru Telescope

Young main-sequence (MS) stars and red-giant branch (RGB) stars around M81, M82, and NGC 3077

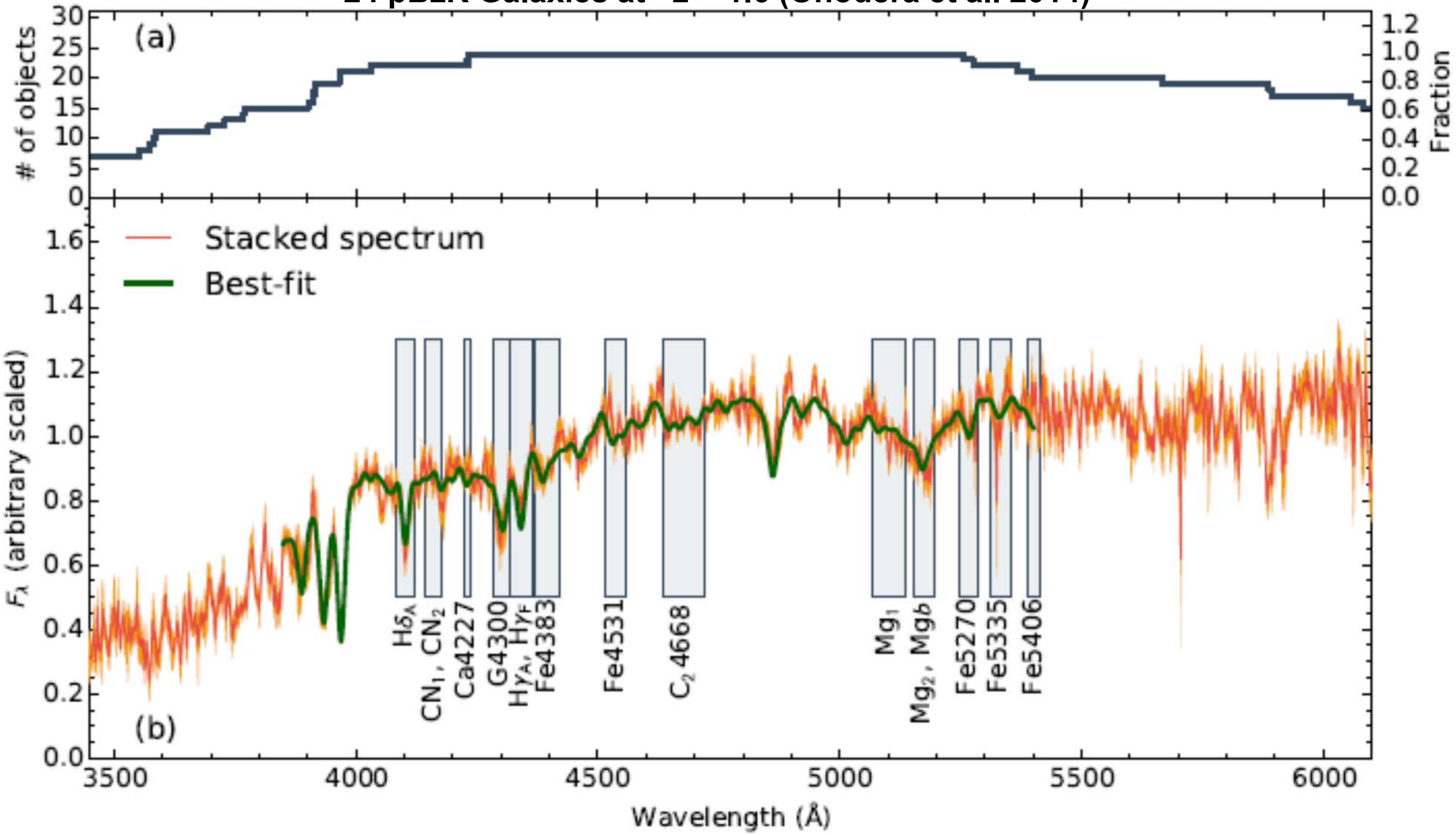




Subaru Telescope

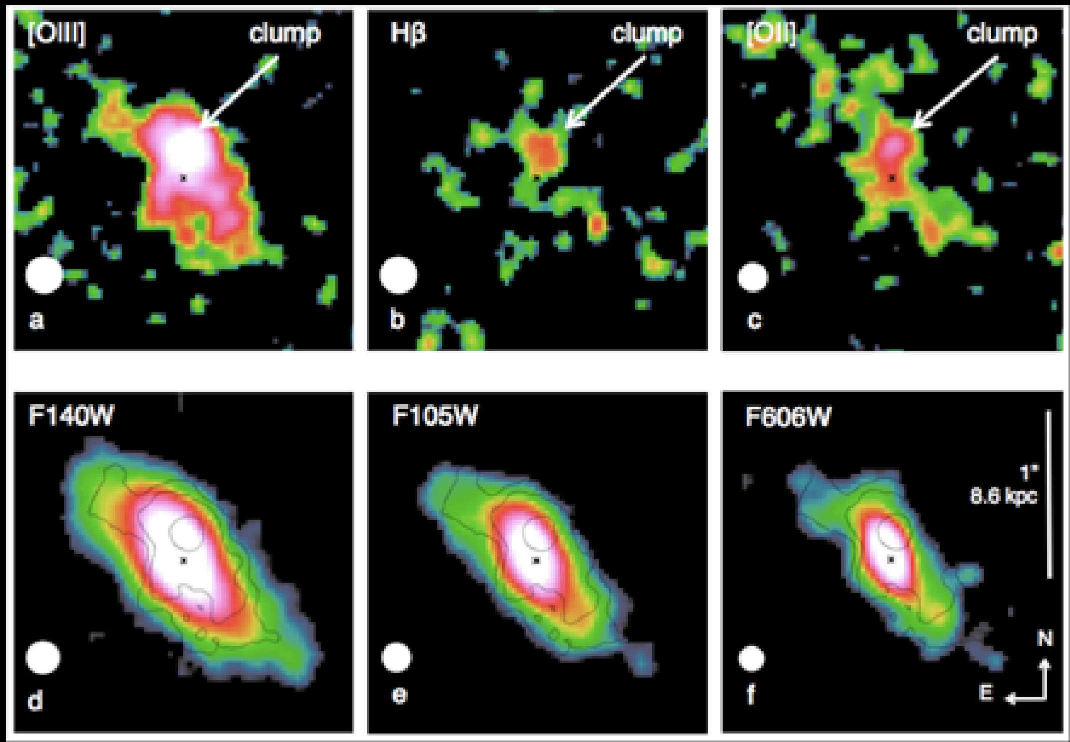
Rapid evolutionary transition revealed in massive quenched galaxies

Composite Rest-frame Optical Spectrum of 24 pBzK Galaxies at <z>=1.6 (Onodera et al. 2014)

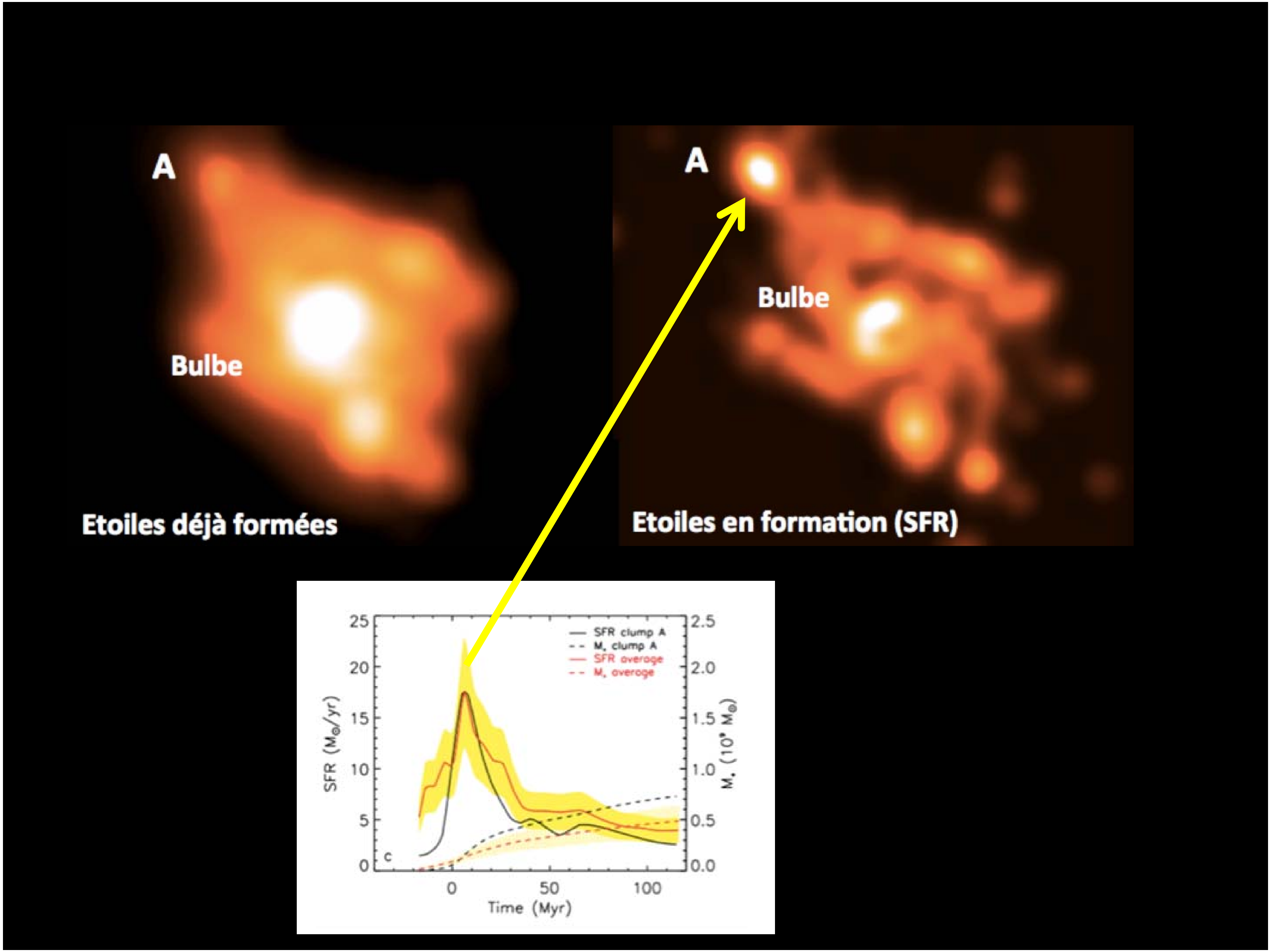


Subaru Telescope

Discovery of an Extremely Young Stellar Clump in the Distant Universe (Zanella et al. 2015)



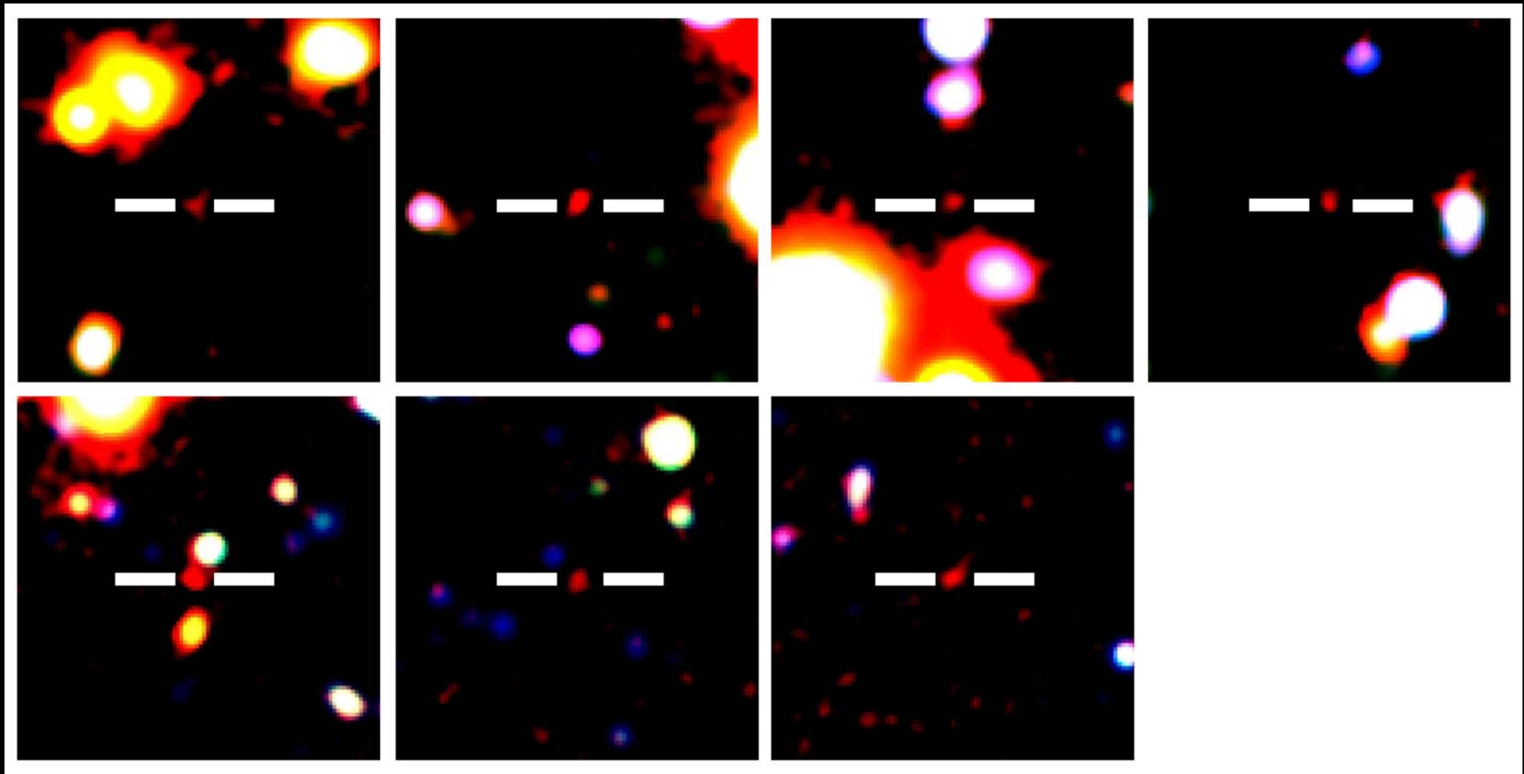
A group of French researchers discovered the birth cry of a massive star-forming clump in the disk of a very distant galaxy. This giant clump is less than 10 million years old, and it is the very first time that such a young star-forming region is observed in the distant Universe.



A
Bulbe
Etoiles déjà formées
A
Bulbe
Etoiles en formation (SFR)
SFR clump A
M* clump A
SFR average
M* average
SFR (M⊙/yr)
M* (10⁹ M⊙)
Time (Myr)
c

Subaru Telescope

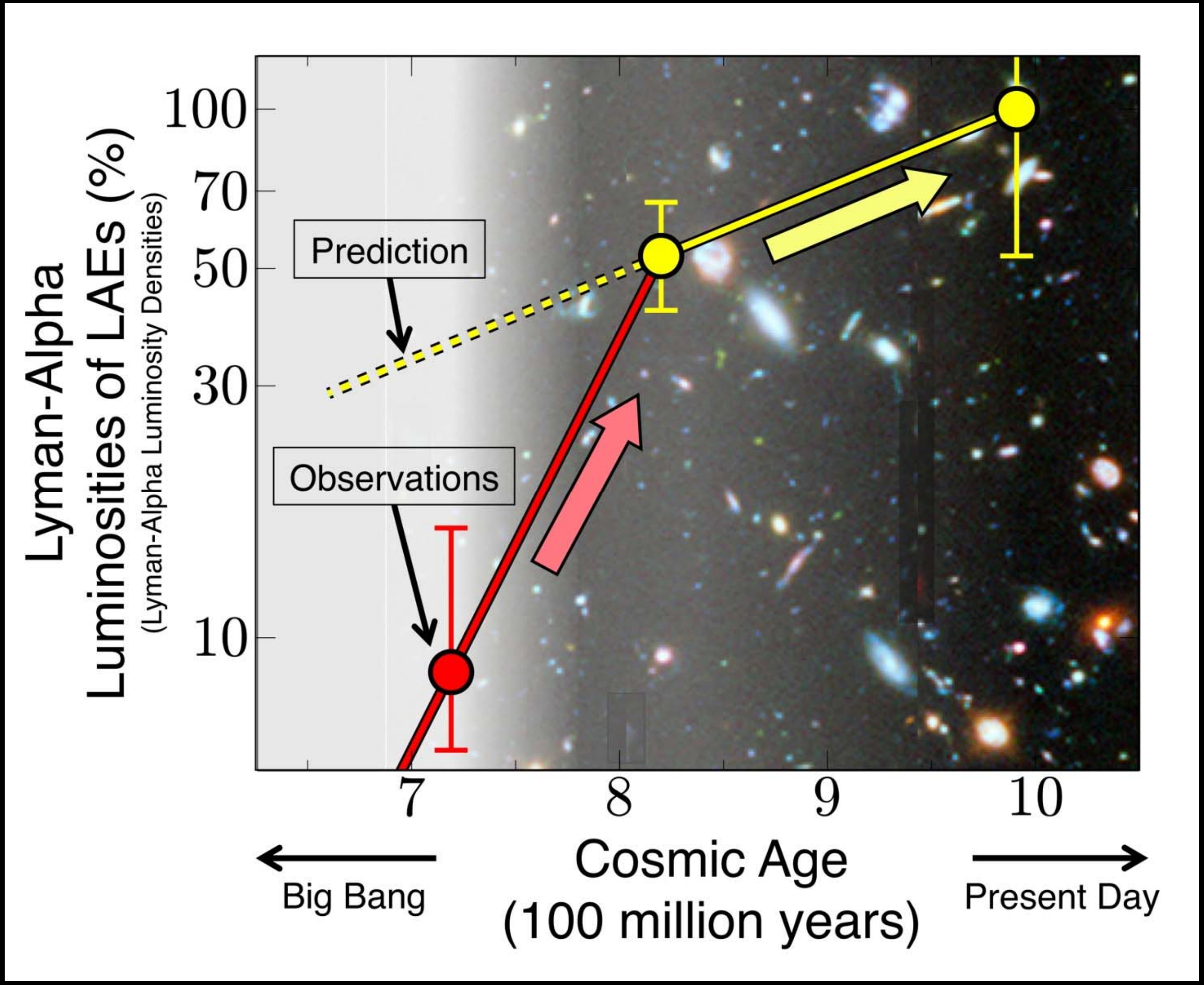
Subaru Telescope Detects Sudden Appearance of Galaxies in the Early Universe (z=7.31)



A team of astronomers using the Subaru Telescope's Suprime-Cam to perform the Subaru Ultra-Deep Survey for Lyman-alpha Emitters have looked back more than 13 billion years to find 7 early galaxies that appeared quite suddenly within 700 million years of the Big Bang (Konno et al. 2014).

Subaru Telescope

Why Only 7 LAEs?



Subaru Telescope Instruments

Change of Subaru Operations

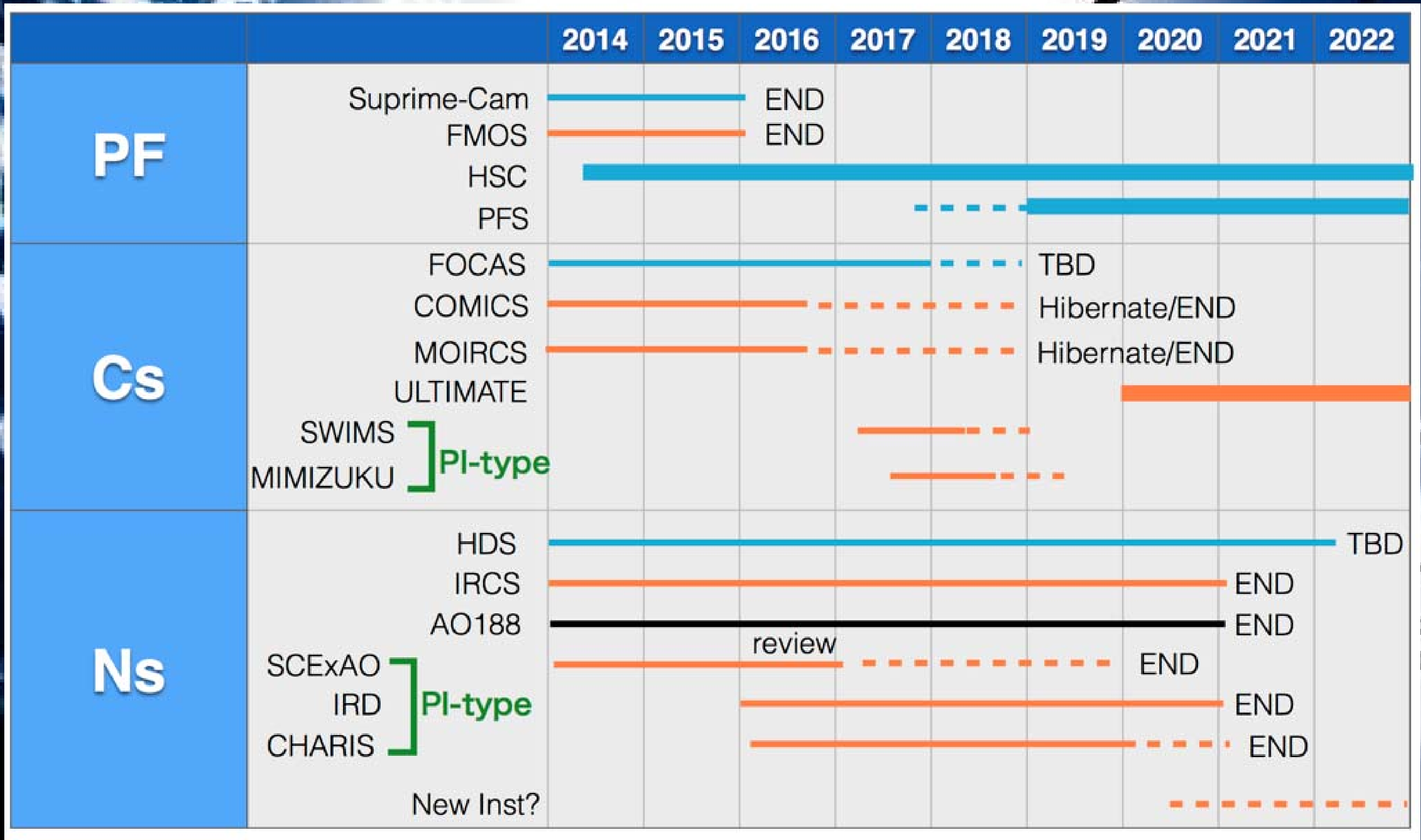
Current
Wide variety of instruments
Classical observations
<5 nights per program
Frequent instrument exchange

Future
Emphasis on surveys
Queue observations
Large programs
Smaller number of instruments

Change of Subaru Operations

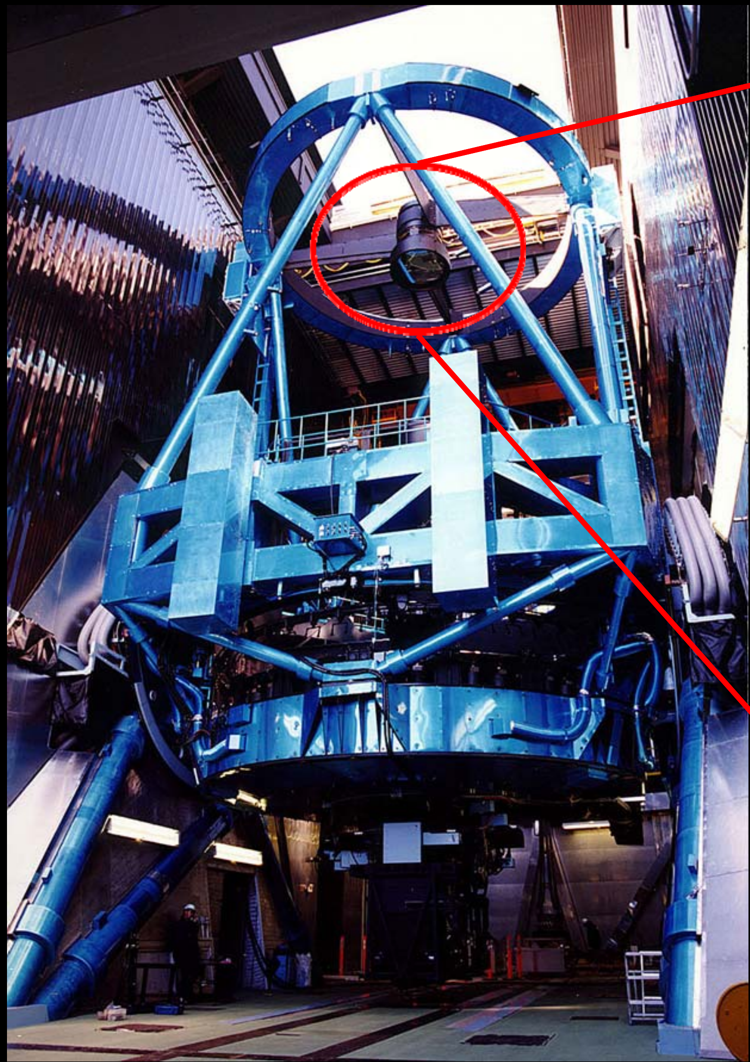
- Synergy with TMT - Subaru will conduct large surveys to feed targets to TMT.
- New generation instruments are very large and expensive. We cannot keep whole suite of instruments competitive to newer generation instruments in other telescopes.
- Strong pressure to reduce budget in the era of TMT operation.
- Accepting PI-type instruments
  - Subaru as a development platform
  - Cutting-edge technologies, sharp science cases

Instrument Timeline
(Preliminary Decommission Plan)



Hyper Suprime-Cam has started Open-use in March 2014

Hyper-Suprime-Cam (HSC)



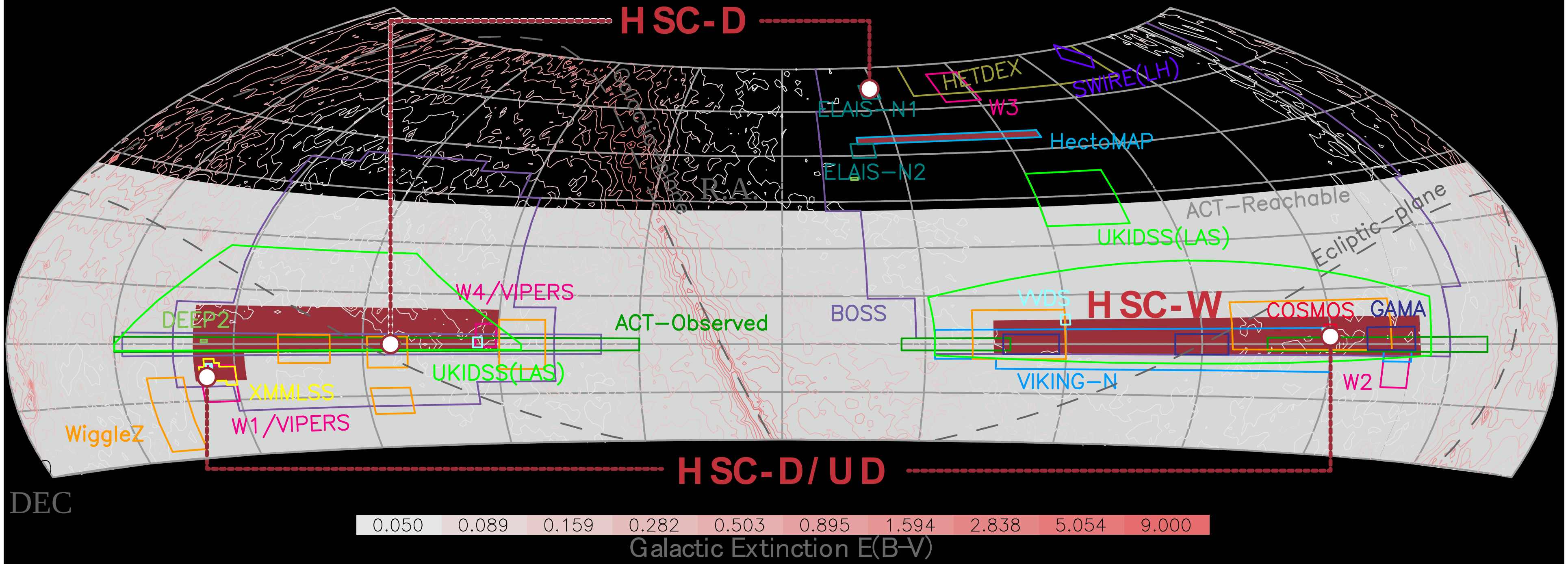
HSC

S
Wide Fi

- **Quicker, Wid**

HSC
Field of Vie

HSC Survey Area



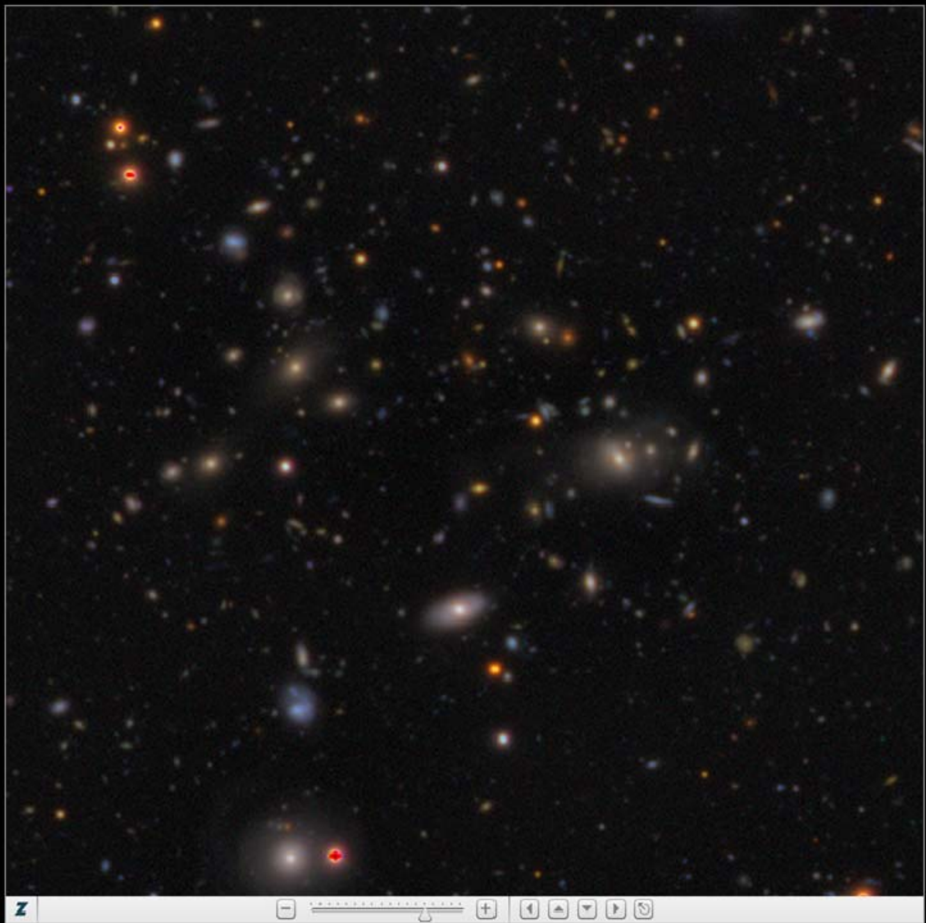
- **HSC Survey Area**
  - **Include the previous surveis**
  - **Little absorption by dust**
  - **Observable whole year**

Subaru Strategic Program
2014–2020
300 Nights

Image Quality of HSC

So far ~1.5 nights (Subaru has 8 instruments), but soon ~15nights

Subaru HSC image (riz: ~2.5hrs)

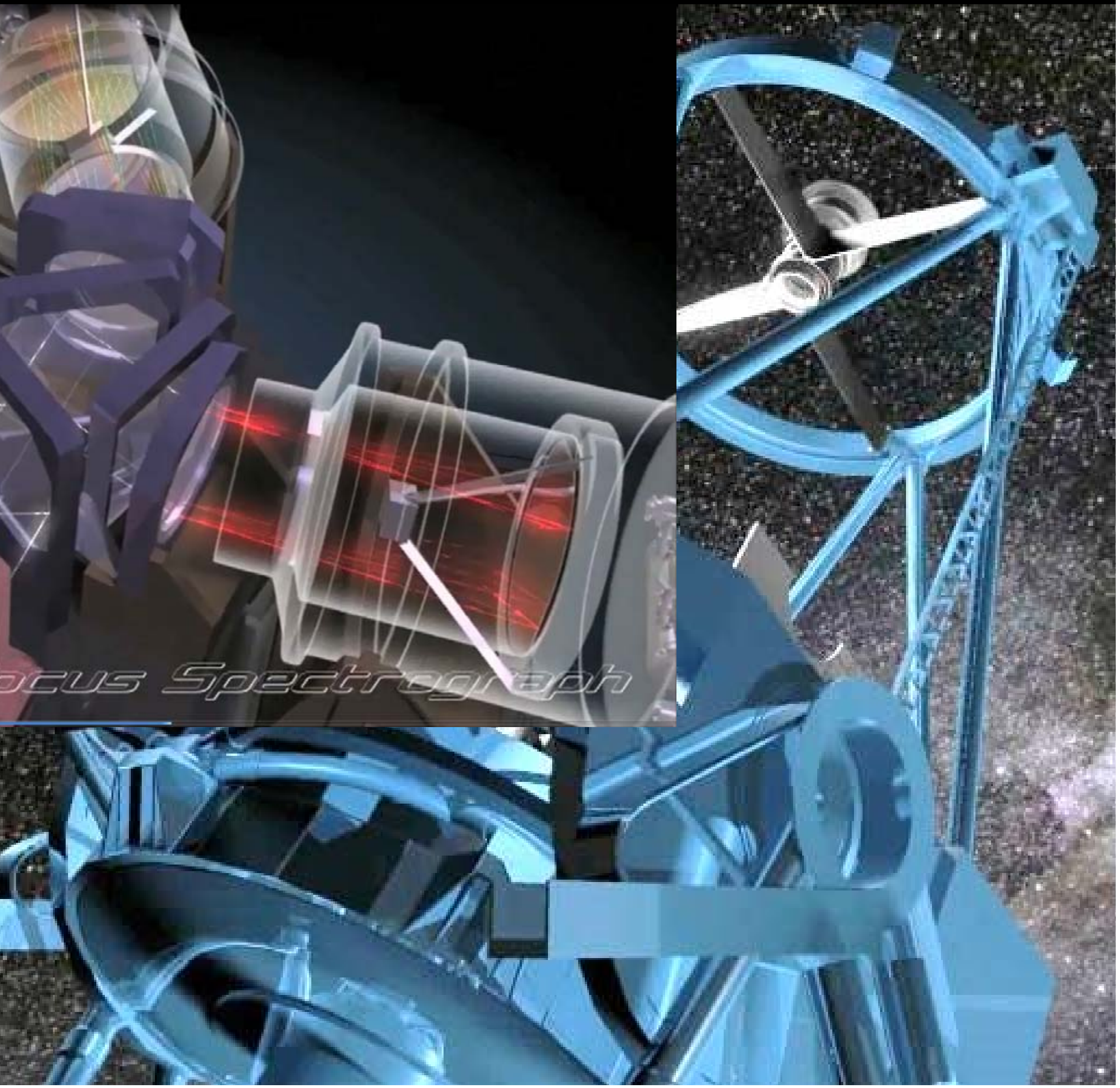


Data reduced by HSC pipeline
(NAOJ, Princeton, Kavli IPMU)

COSMOS HST (640 orbits: ~500hrs)

Hubble Telescope

SUBARU PRIME FOCUS SPECTROGRAPH

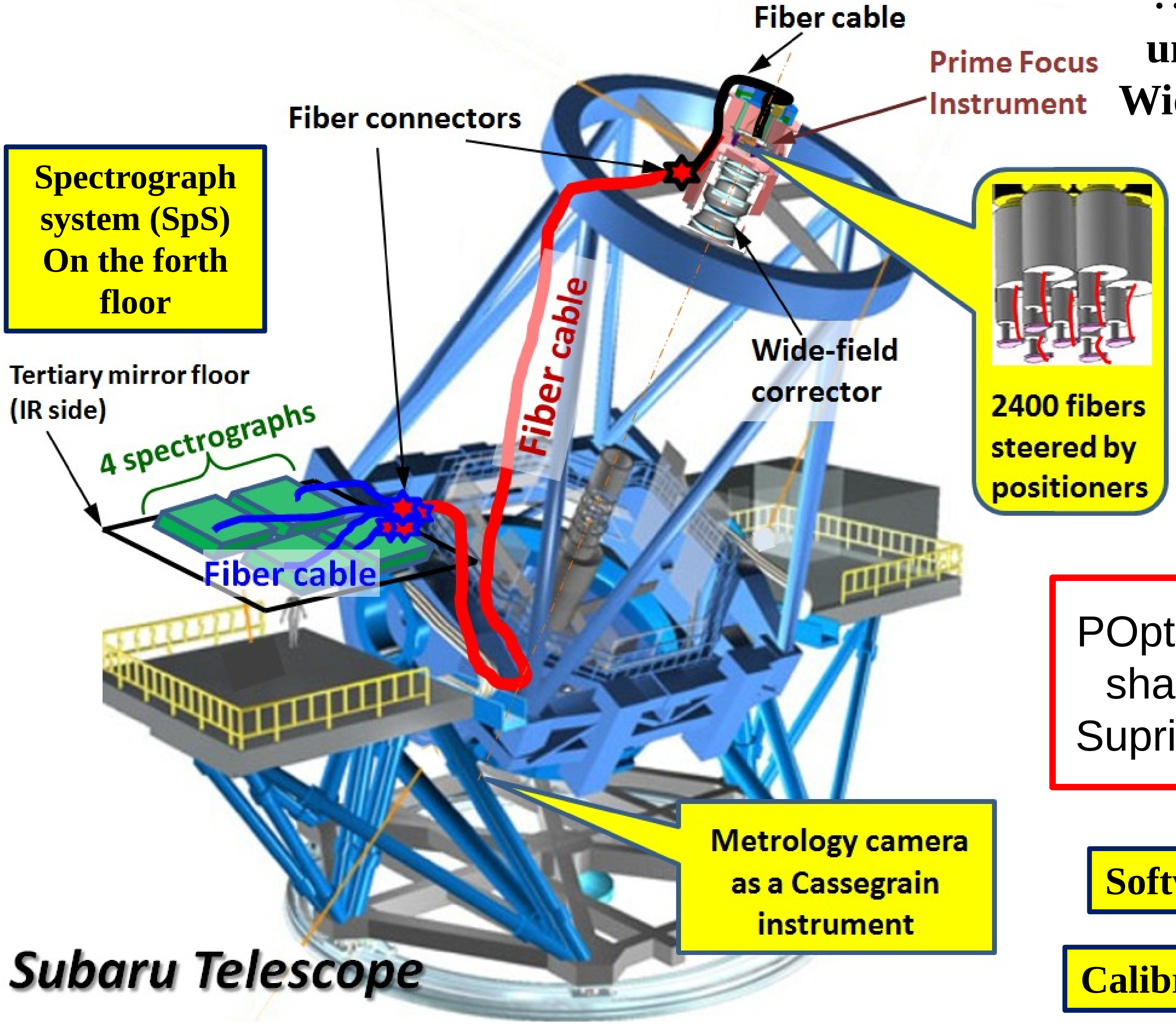


Kavli IPMU,

U. Tokyo

PFS project office

… in Prime focus unit "POpt2" with Wide Field Corrector "WFC".

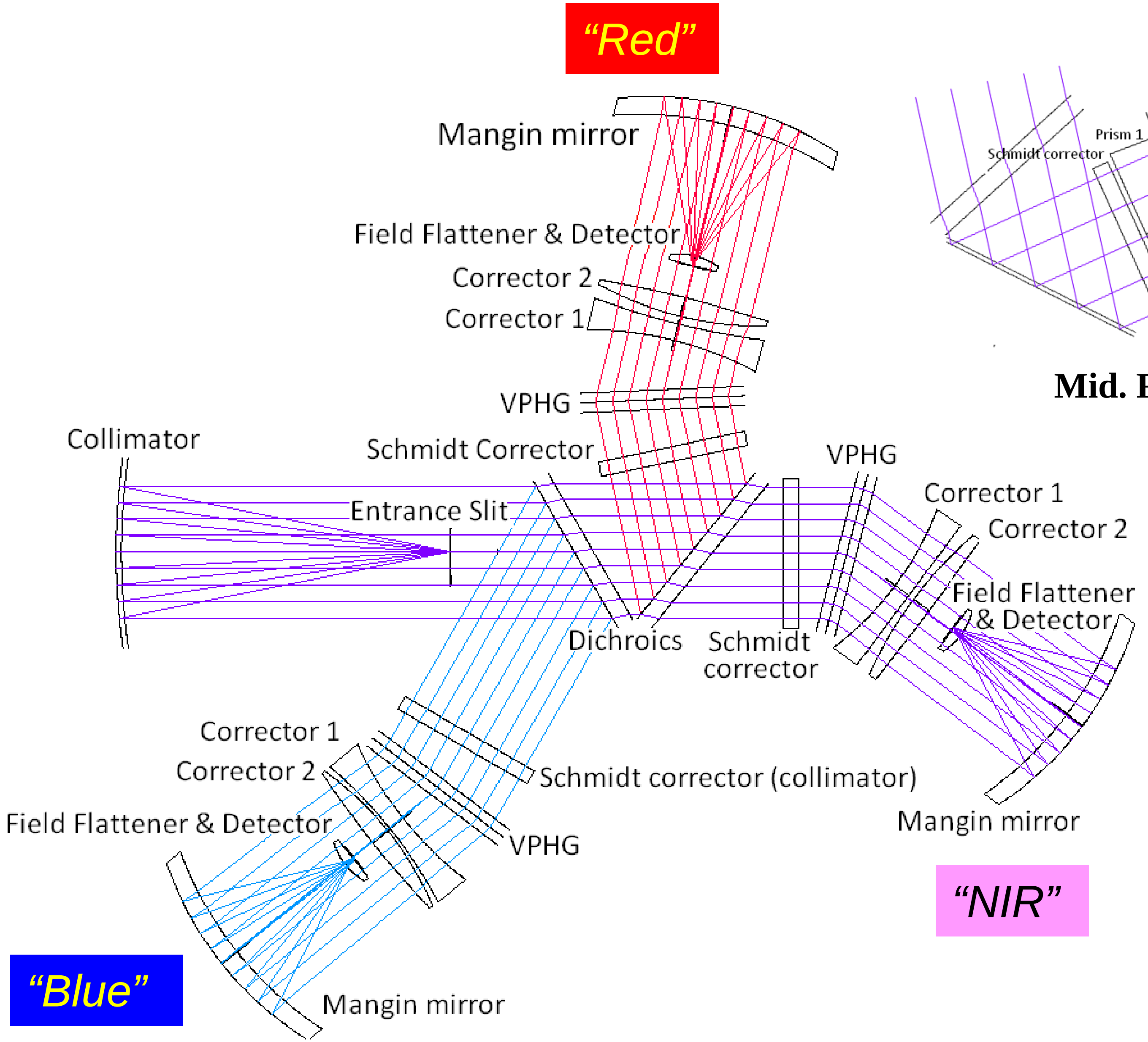


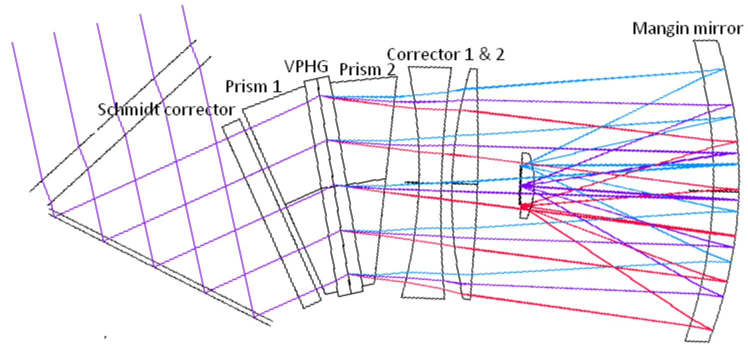
POpt2 & WFC will be shared with Hyper Suprime Cam (HSC).

Software system

Calibration system

Spectrograph System



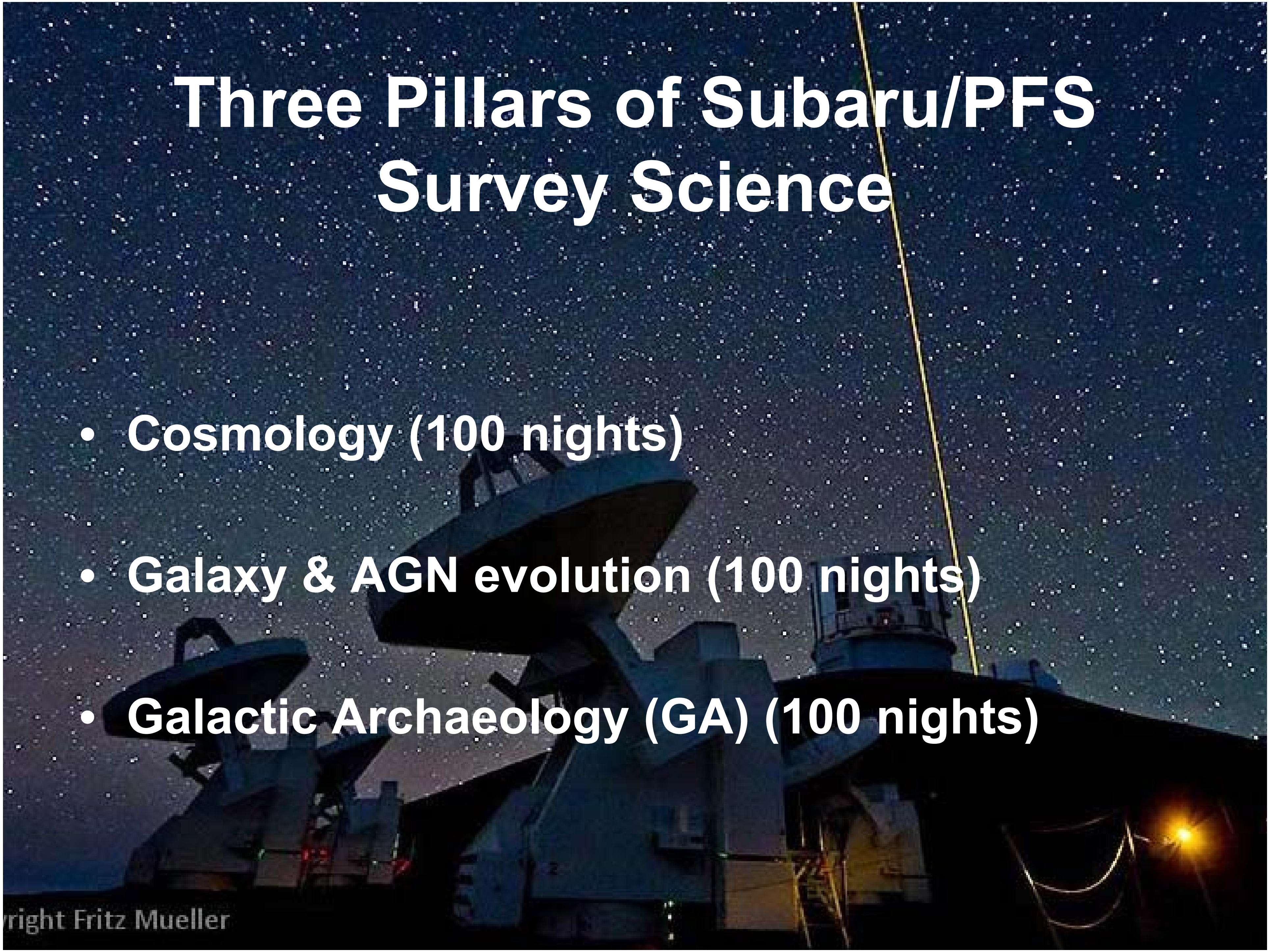


Mid. Res. Mode in the Red Arm

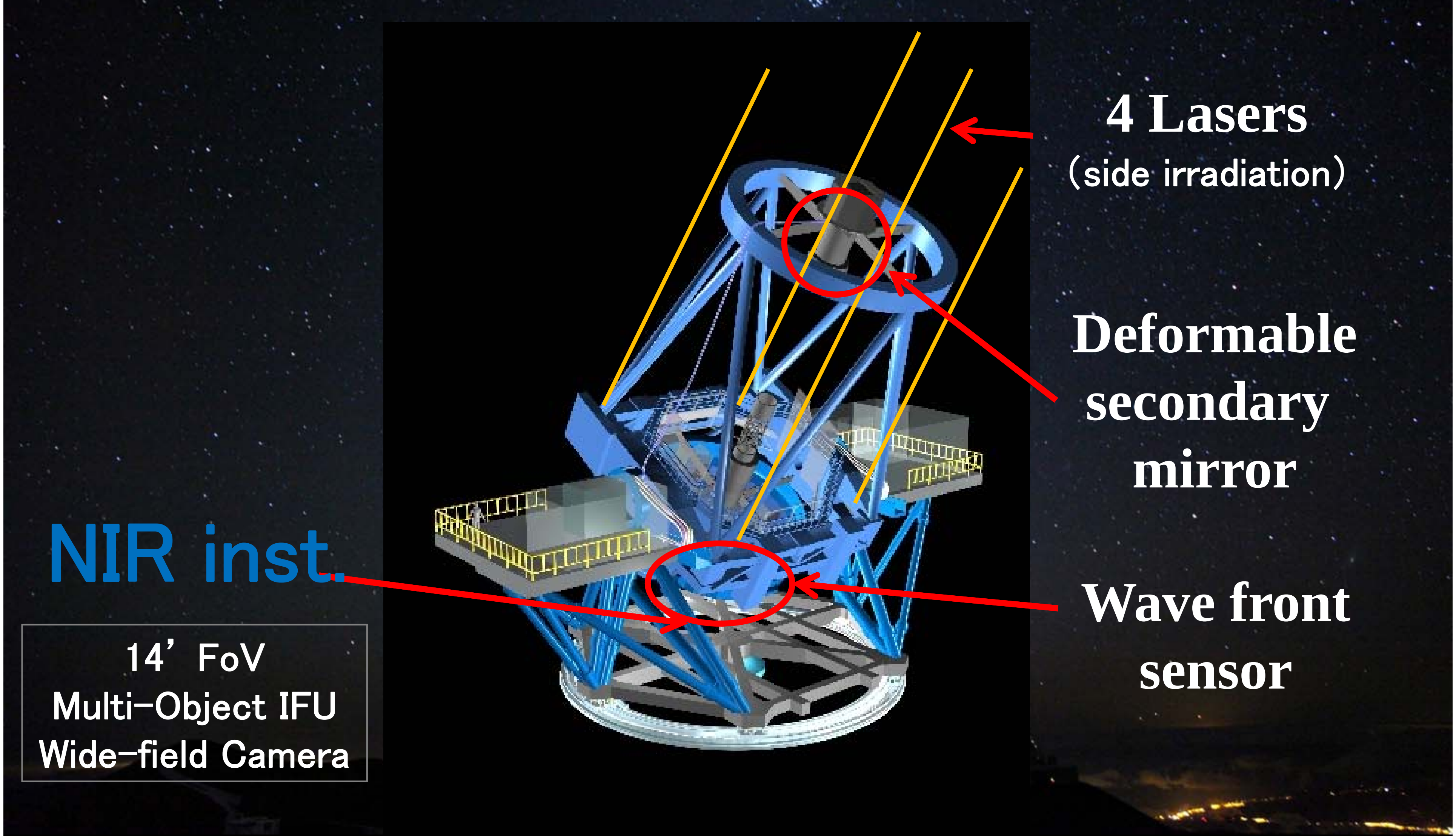
		Blue	Red		NIR
			Low Res	Mid Res	
Collimator F/#		2.5			
Camera F/#		1.1			
# of science fibers		597 or 600			
Operating temperature		3 +/- 0.5 degC			
Input fiber core diameter		129um			
Wavelength coverage		380-650nm	630-970nm	710-885nm	940-1260nm
Resolving power		~2300	~3000	~5000	~4300
Detector	Type	CCD (Hamamatsu, with a new blue coating)	CCD (Hamamatsu, with the same coating as HSC)		H4RG (Teledyne, 1.7um cutoff)
	Format	(4K x 2K) x 2	(4K x 2K) x 2		4K x 4K
	Pixel size	15um			
	Readout noise	~4 e-/pix			4 e-/pix
	Dark	~0.4 e-/pix/hour			0.01 e-/pix/s
Thermal background		None			0.006 e-/pix/s

Three Pillars of Subaru/PFS Survey Science

- Cosmology (100 nights)
- Galaxy & AGN evolution (100 nights)
- Galactic Archaeology (GA) (100 nights)

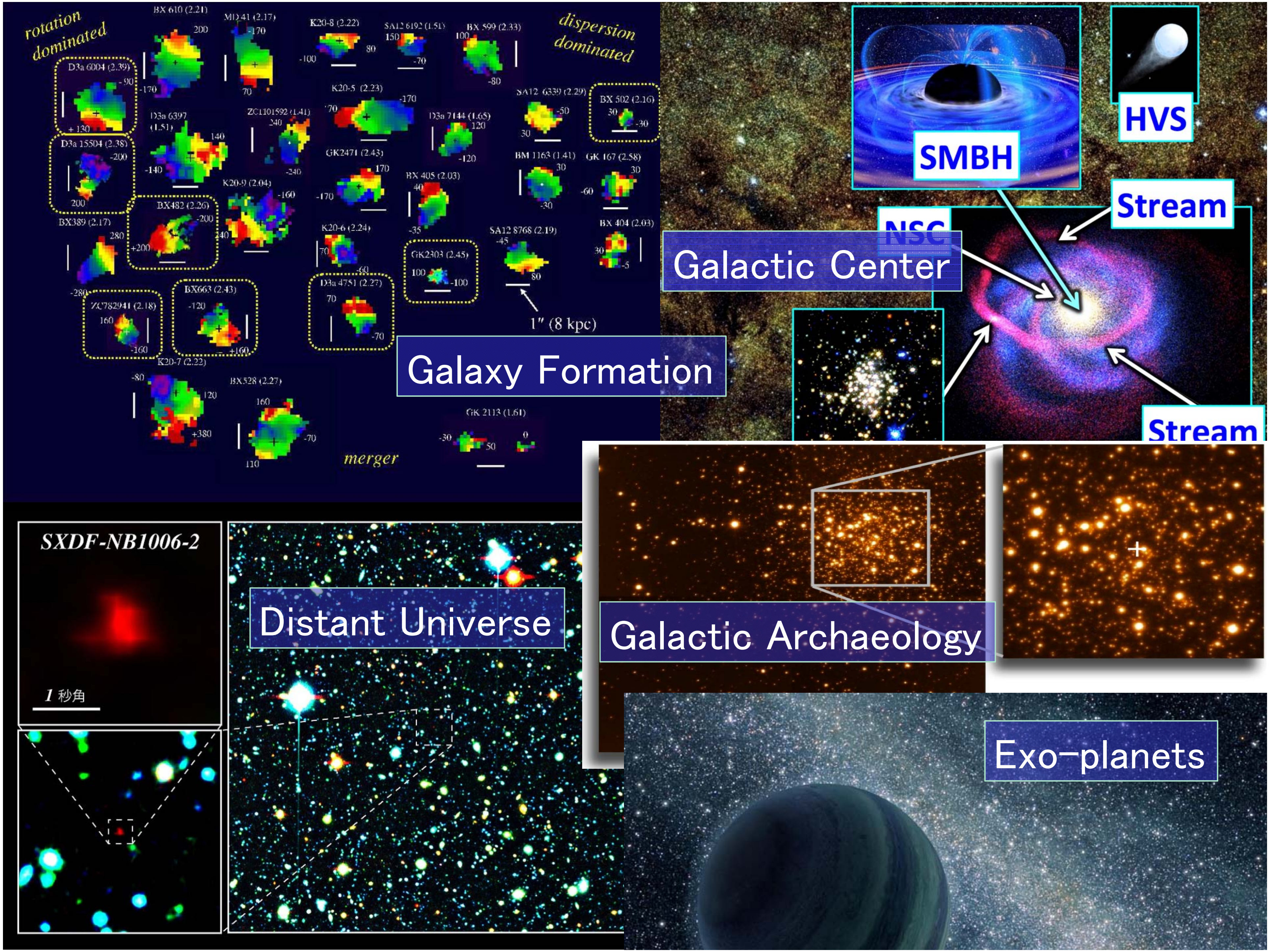


ULTIMATE-Subaru



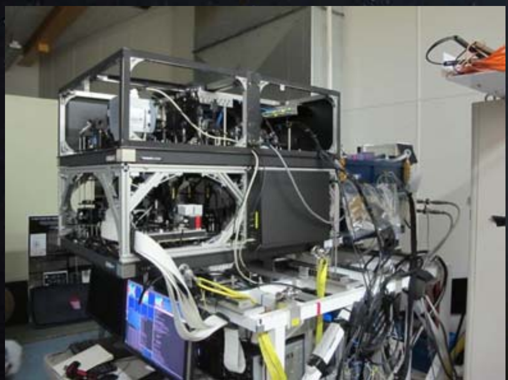
Science of ULTIMATE Subaru

- Dissect the Galactic Evolution of the Golden Age
  - Sample of a few 1000 galaxies at $1<z<3$ - morphology, dynamical structure, physical parameters, environmental effects, internal motion of stars/gas, AGN contribution, heavy elements distribution
- Discover Galaxies at the Edge of the Universe
  - Search for highest-redshift galaxies with highly sensitive narrow band imaging ($z>10$)
  - Discover galaxies at $z>7.5$, physical process of cosmic re-ionization
- → Subaru Original Samples for TMT
    - Sampling of the most interesting targets cannot be done by HSC + PFS alone.
- Improvement of Telescope Performance - contributing to various science

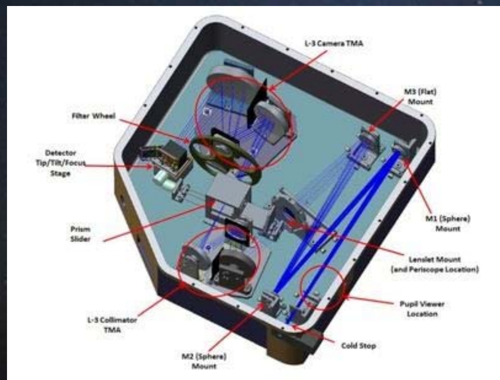

rotation dominated
dispersion dominated
merger
1″ (8 kpc)
Galaxy Formation
SMBH
HVS
Stream
NSC
Galactic Center
Stream
SXDF-NB1006-2
1 秒角
Distant Universe
Galactic Archaeology
Exo-planets

PI-type Instruments for Exoplanets

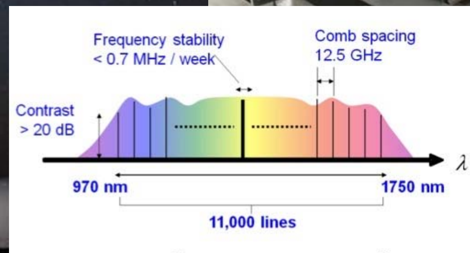
- SCExAO: Coronagraphic Extreme-AO (direct imaging)
- CHARIS: Integral Field Spectrograph (discover and characterization)
- IRD: Near-IR High-dispersion Spectrograph (Earth-mass planets around M-dwarfs)
- Short time-scale of Cycles (Development-Commissioning-Science) to catch-up this rapidly evolving research field



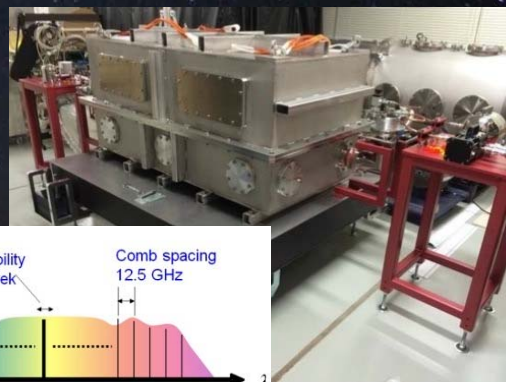
SCExAO



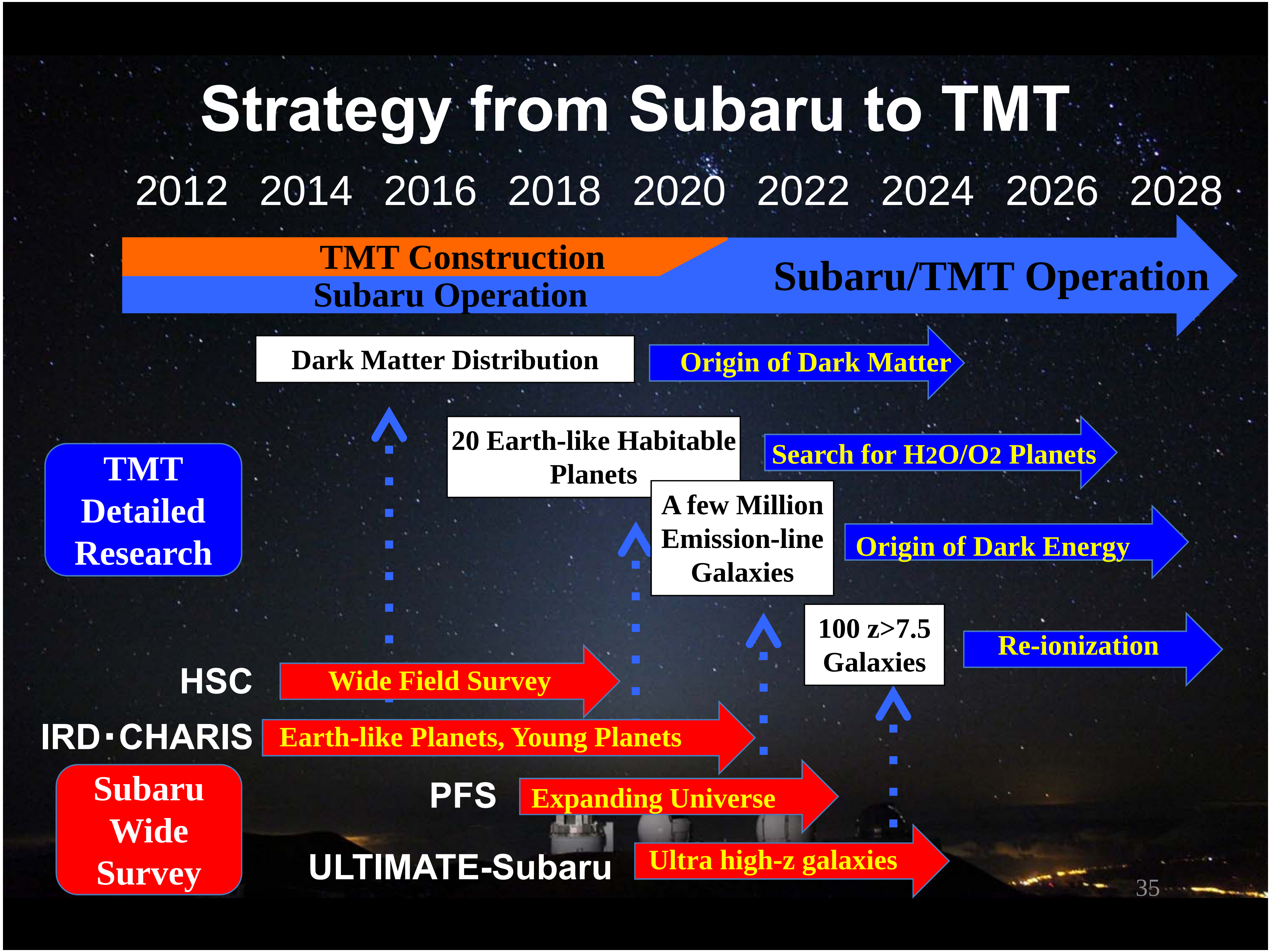
CHARIS



Laser frequency comb



IRD


Strategy from Subaru to TMT
2012 2014 2016 2018 2020 2022 2024 2026 2028
TMT Construction
Subaru Operation
Subaru/TMT Operation
Dark Matter Distribution
Origin of Dark Matter
20 Earth-like Habitable Planets
Search for H2O/O2 Planets
TMT Detailed Research
A few Million Emission-line Galaxies
Origin of Dark Energy
100 z>7.5 Galaxies
Re-ionization
HSC
Wide Field Survey
IRD･CHARIS
Earth-like Planets, Young Planets
PFS
Expanding Universe
Subaru Wide Survey
ULTIMATE-Subaru
Ultra high-z galaxies

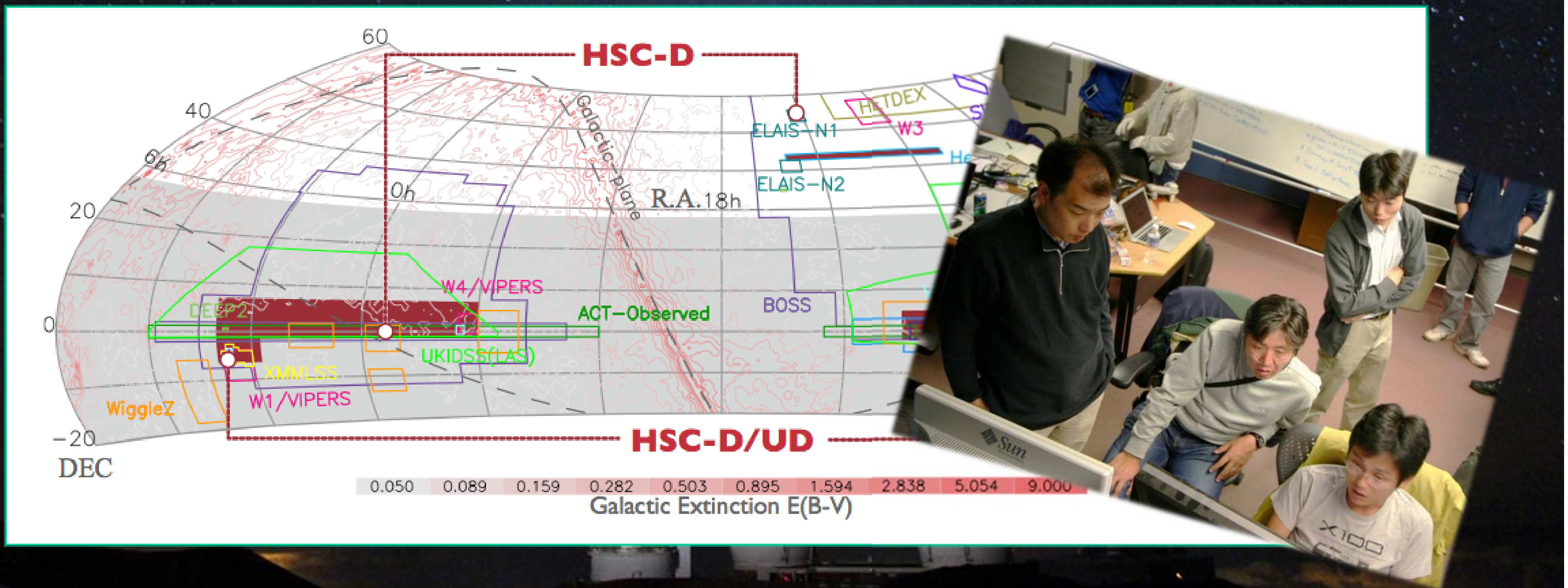
Subaru Strategic Program

Subaru SSP ③

HSC Subaru Strategic Program

"Wide Field imaging with Hyper Suprime-Cam"
"Cosmology and Galaxy Evolution"

S.Miyazaki (PI) 300 nights（2014 - 2018）

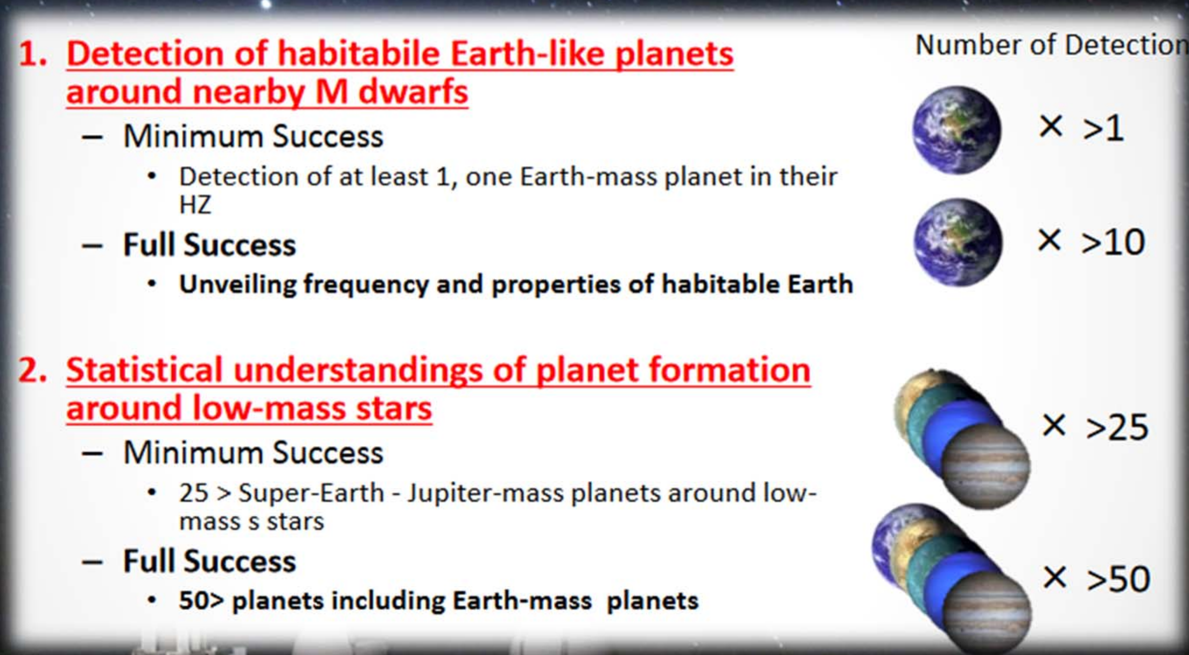


Subaru SSP ④

IRD Subaru Strategic Program

“Search for the Earth in Habitable Zone

T.Kotani (PI) 150 (?) nights（2017 - 2021）



Subaru SSP ⑤

PFS Subaru Strategic Program

“Galactic Archaeology, AGN & Galaxy Evolution, and Cosmology”

H.Murayama (PI) 300 nights（2019 - 2023）

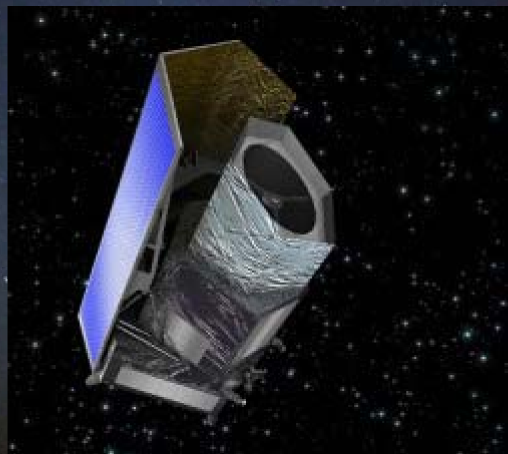
Synergy with Space Missions

Subaru Strategic Program (?)

WFIRST 100-400 nights（2025 – 2030）

Euclid 100 nights (2019 – 2022)

TESS 40 nights (2017 – 2020)



International Collaboration in Astronomy for Asia

- Subaru can offer opportunities for students in Asian countries to have an access to Subaru Data.
- ① Apply for Open Use Program jointly with Japanese PI’s.
- ② Contact CoIs of SSP and have an access to HSC/PFS/IRD data
- ③ Use Subaru Archive Data.

Subaru Winter School in Korea

2014/02/25 – 2014/02/27 (KASI)


天文大厦
1st China-Subaru WS (Shanghai)
2014/11/29 – 2014/12/01

SOKENDAI Asian Winter School

Subaru Internship