Galaxy evolution science with Hyper Suprime-Cam, Prime Focus Spectrograph, and ULTIMATE

Masayuki Tanaka

Hyper Suprime-Cam and the SSP Survey

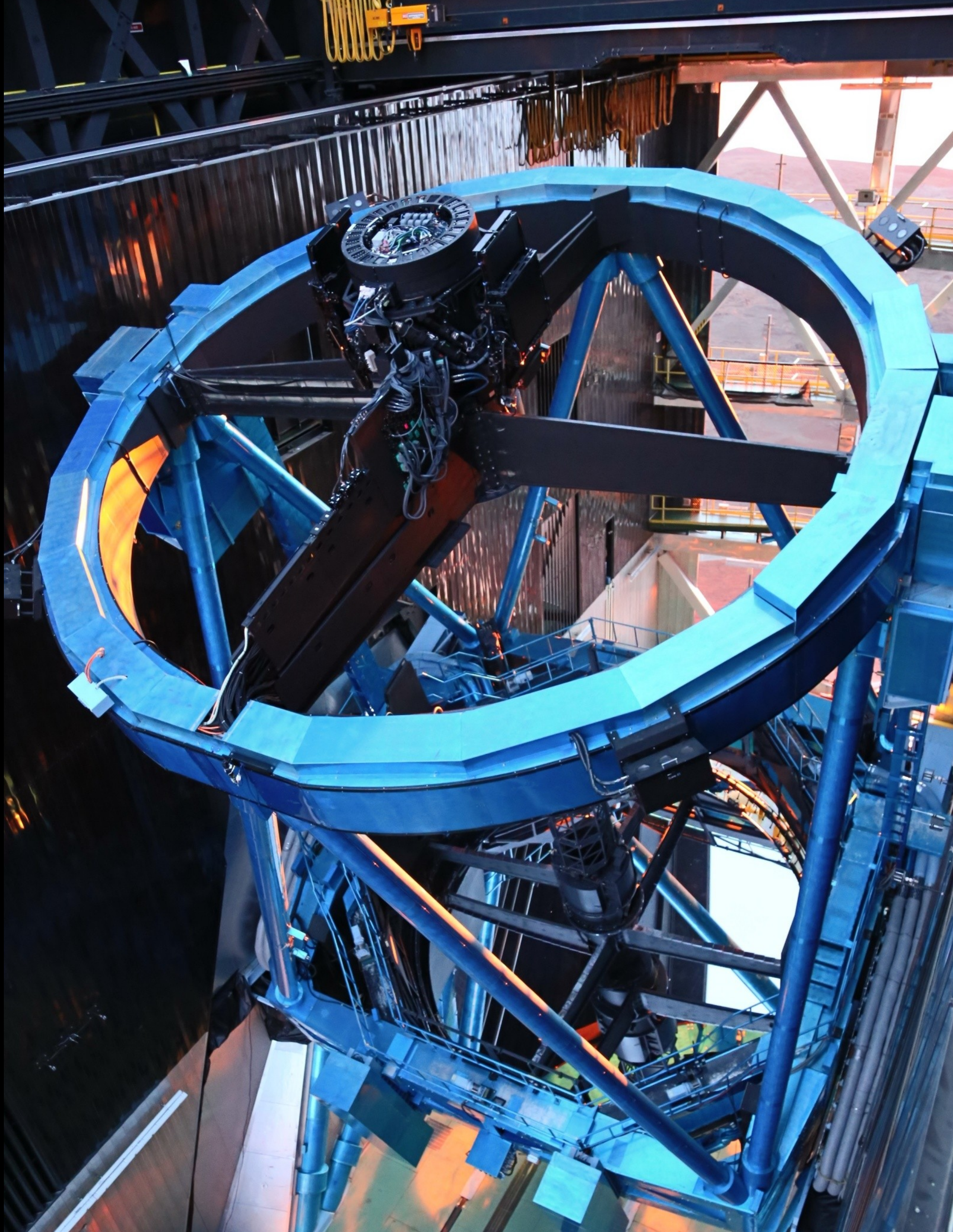
A website will be launched very soon!

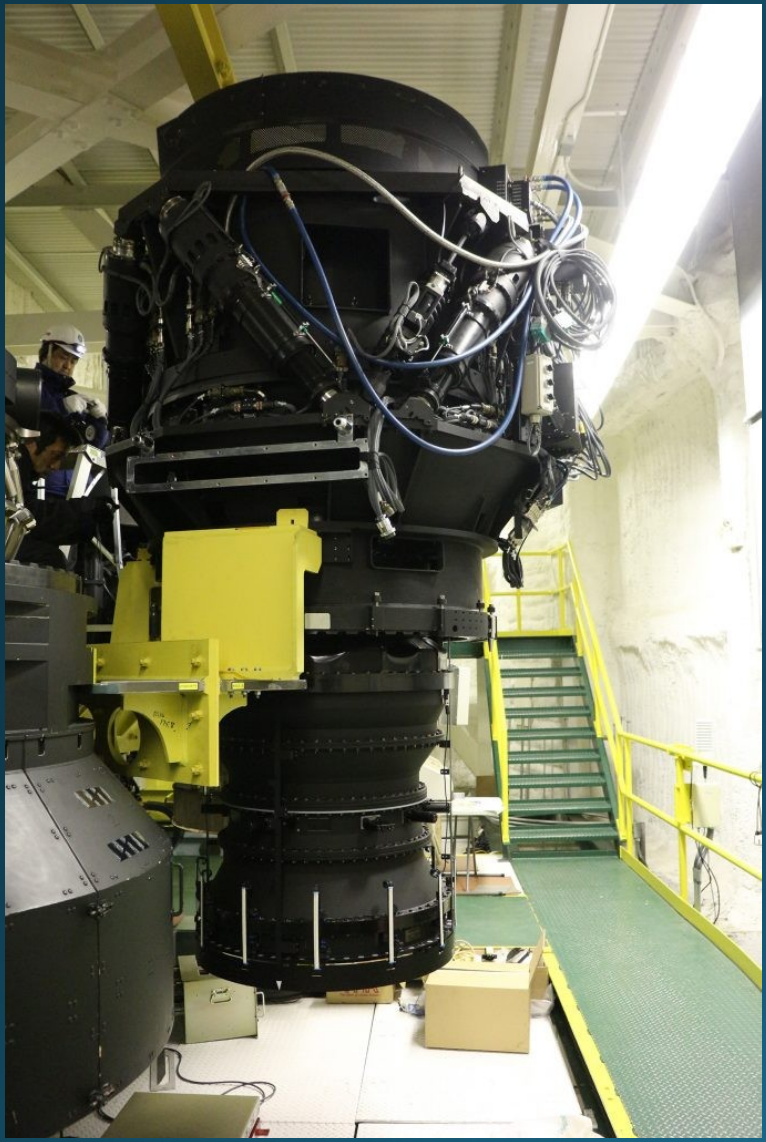
Hyper Suprime-Cam is a wide-field imager installed at the prime focus.

– 104 full depletion science CCDS plus 12 CCDs for guiding and focusing.

– It covers a 1.5 deg diameter field of view.

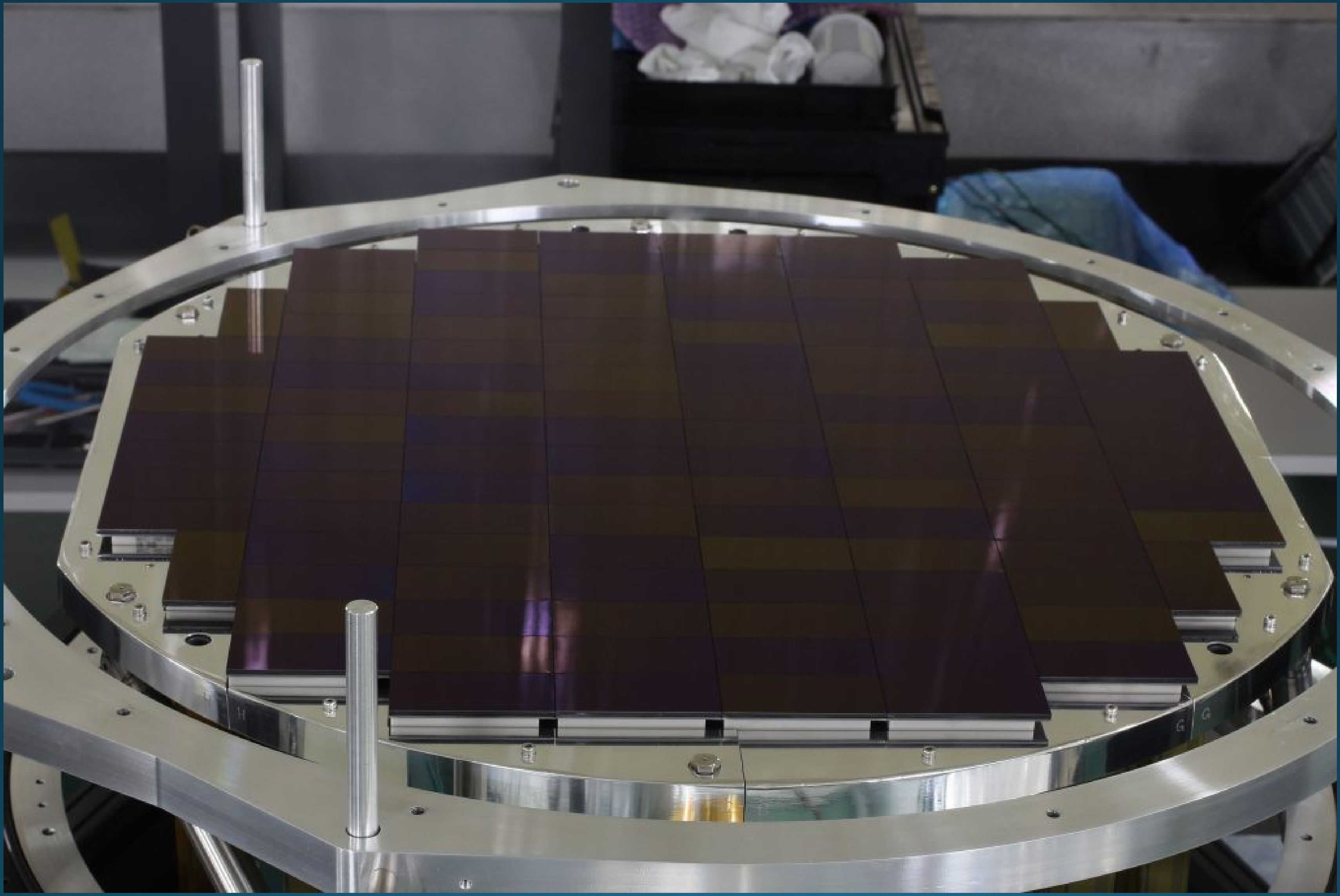
– 5 broad-band filters (grizy) and several narrow-bands are available.



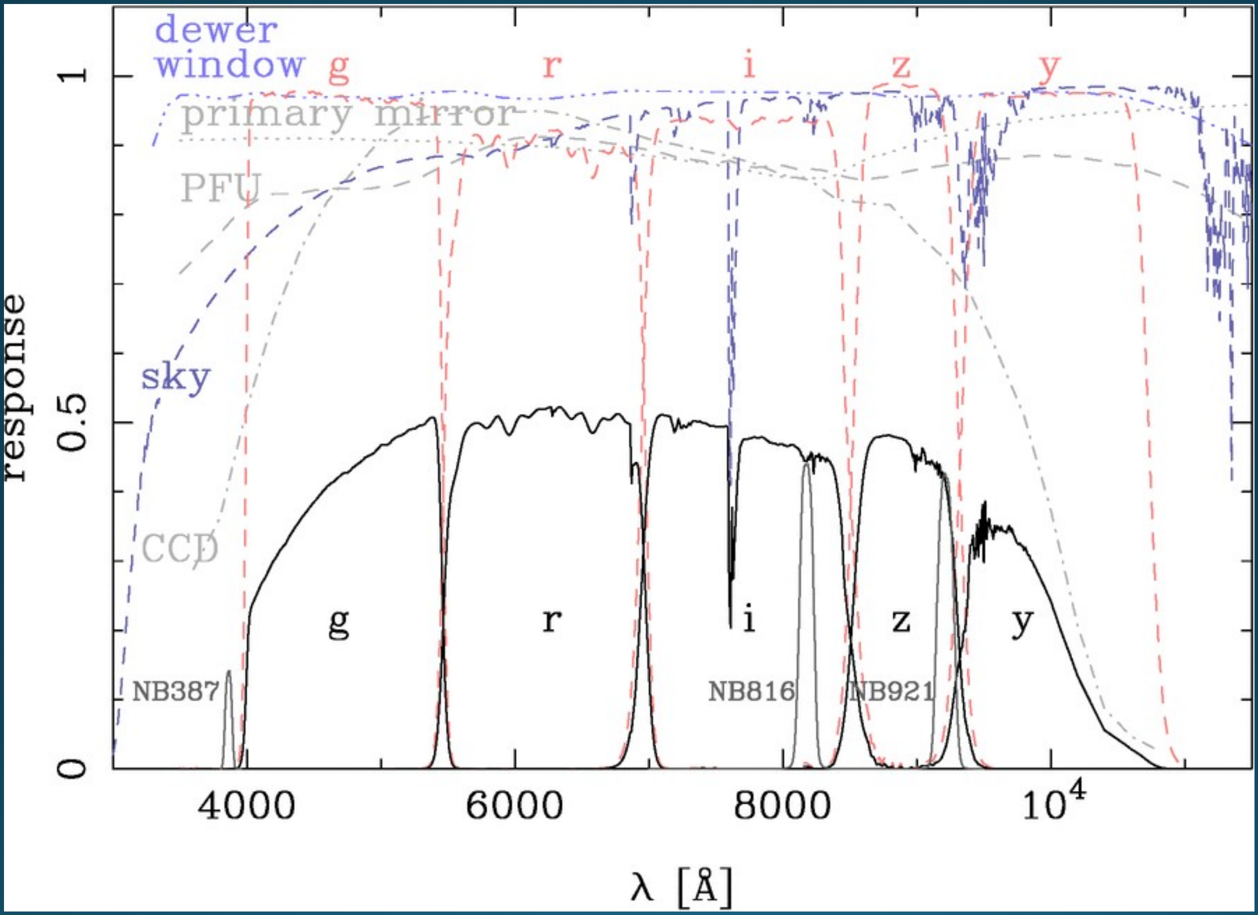


Camera body

Wide-field corrector



Focal plane tiled with 116 CCDs



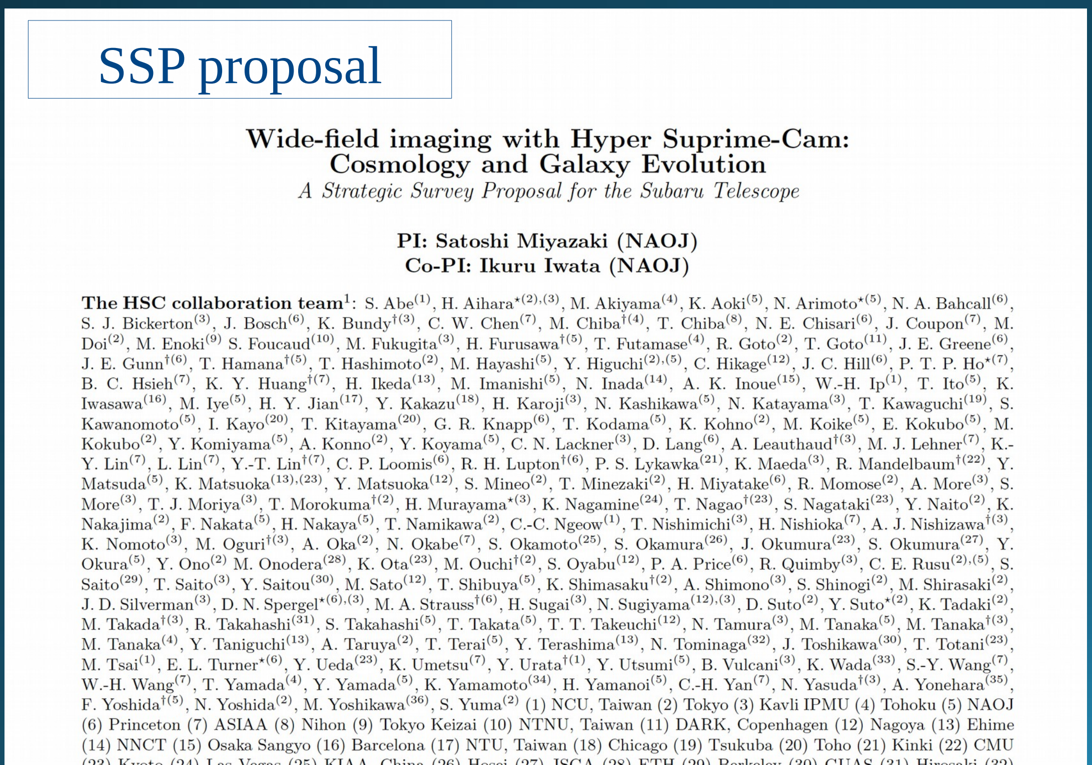
HSC filter system

Subaru Strategic Survey

International collaboration of **all Japan**, Princeton, and Taiwan.

Over 170 scientists put together efforts in a huge observing program of 300 nights over 5-6 years. The survey started in March 2014 and it is about 25% done.

SSP proposal



Wide-field imaging with Hyper Suprime-Cam:
Cosmology and Galaxy Evolution
A Strategic Survey Proposal for the Subaru Telescope

PI: Satoshi Miyazaki (NAOJ)
Co-PI: Ikuru Iwata (NAOJ)

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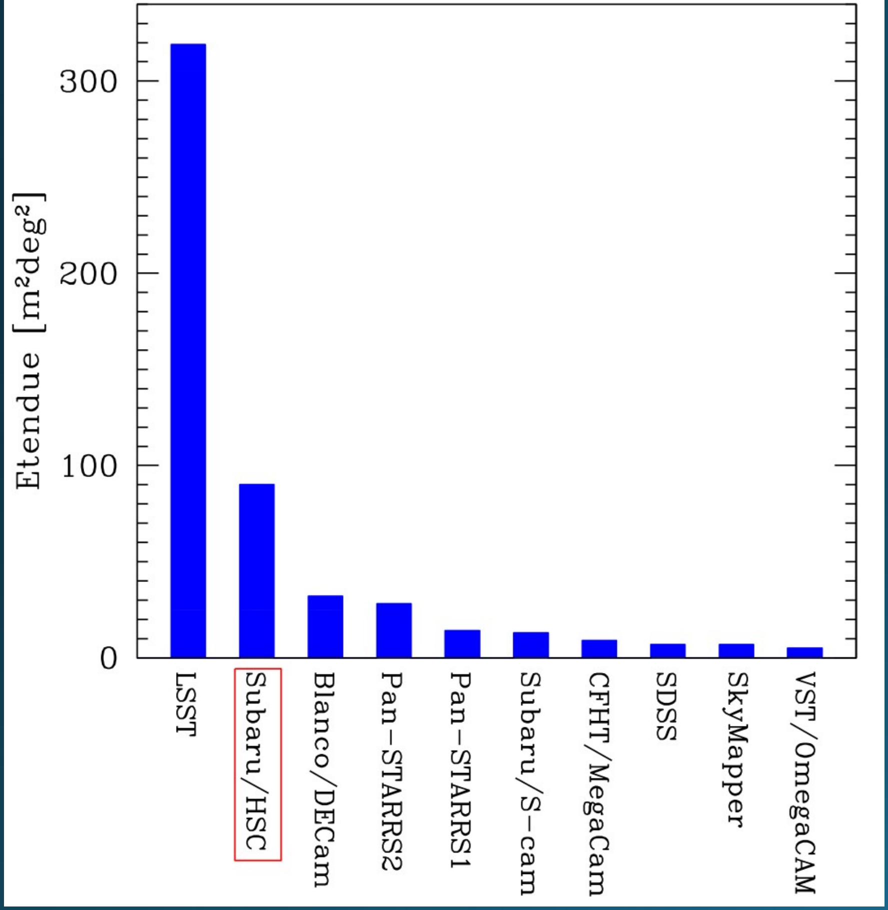
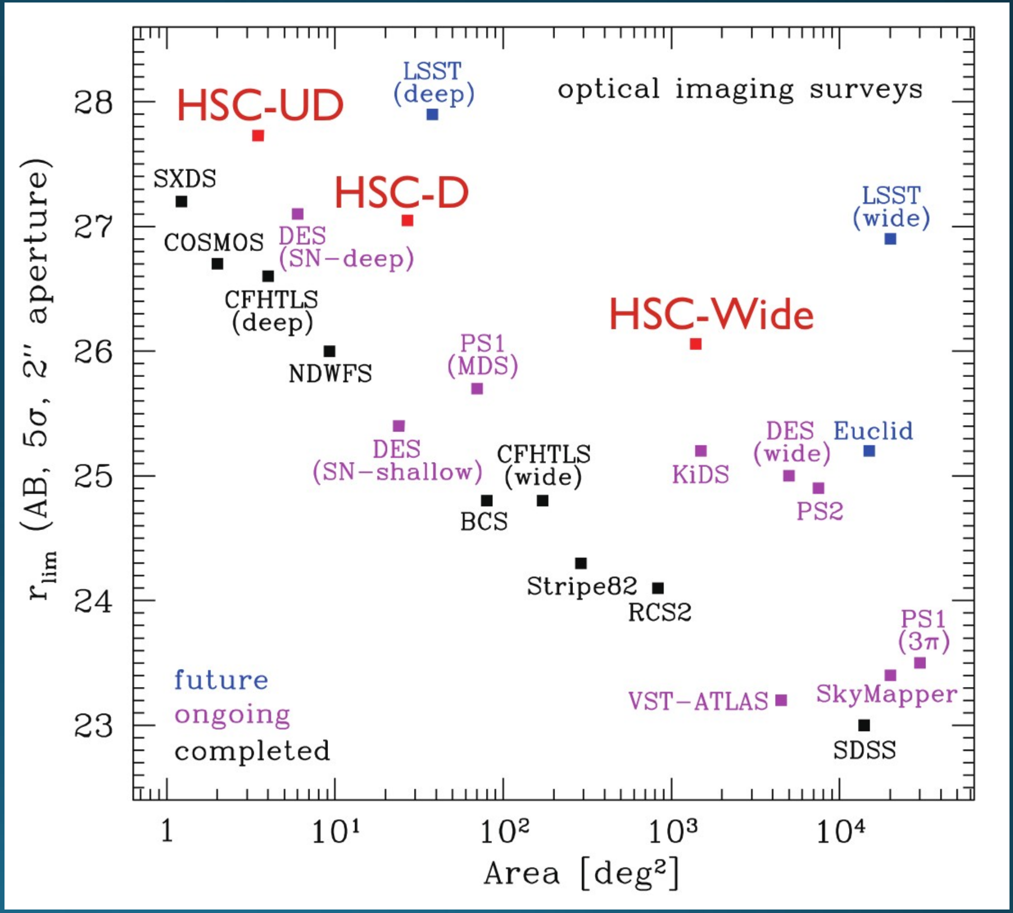
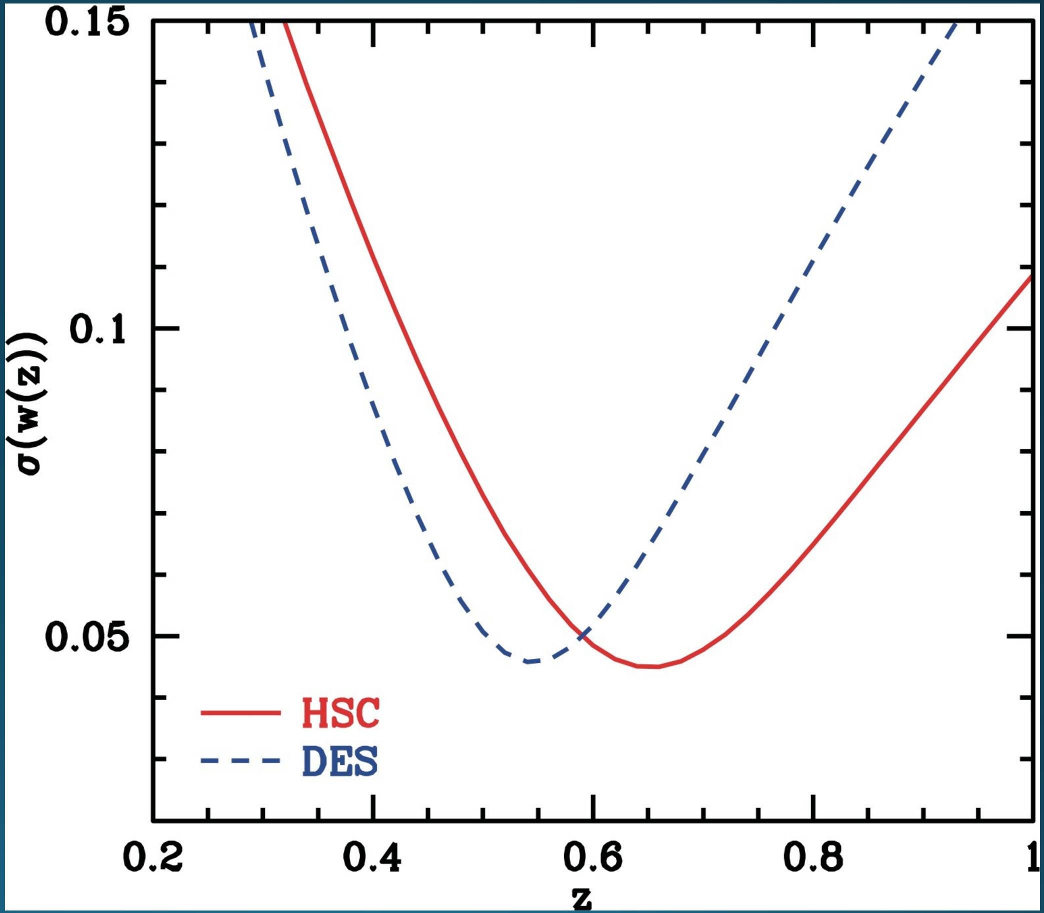
Survey power





Science goals

- **Weak-lensing cosmology**
- High-redshift galaxies
- Galaxy evolution
- Clusters of galaxies
- Transient objects
- Solar system bodies
- AGN/QSO
- MiklyWay
- Strong lensing
- ...



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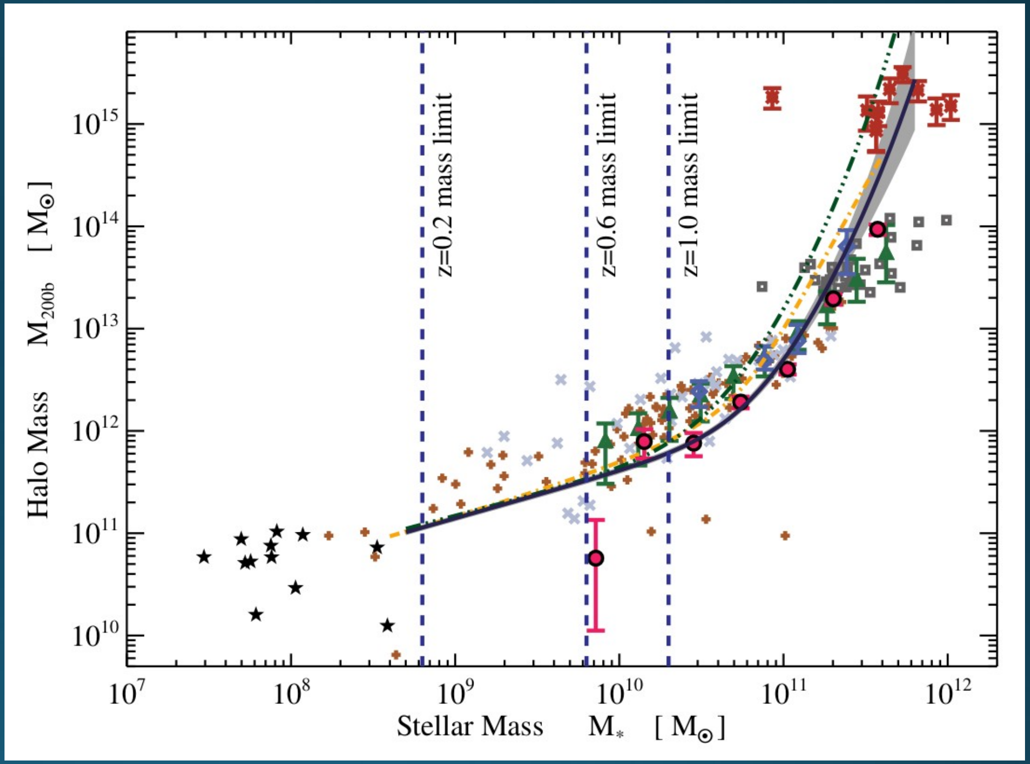

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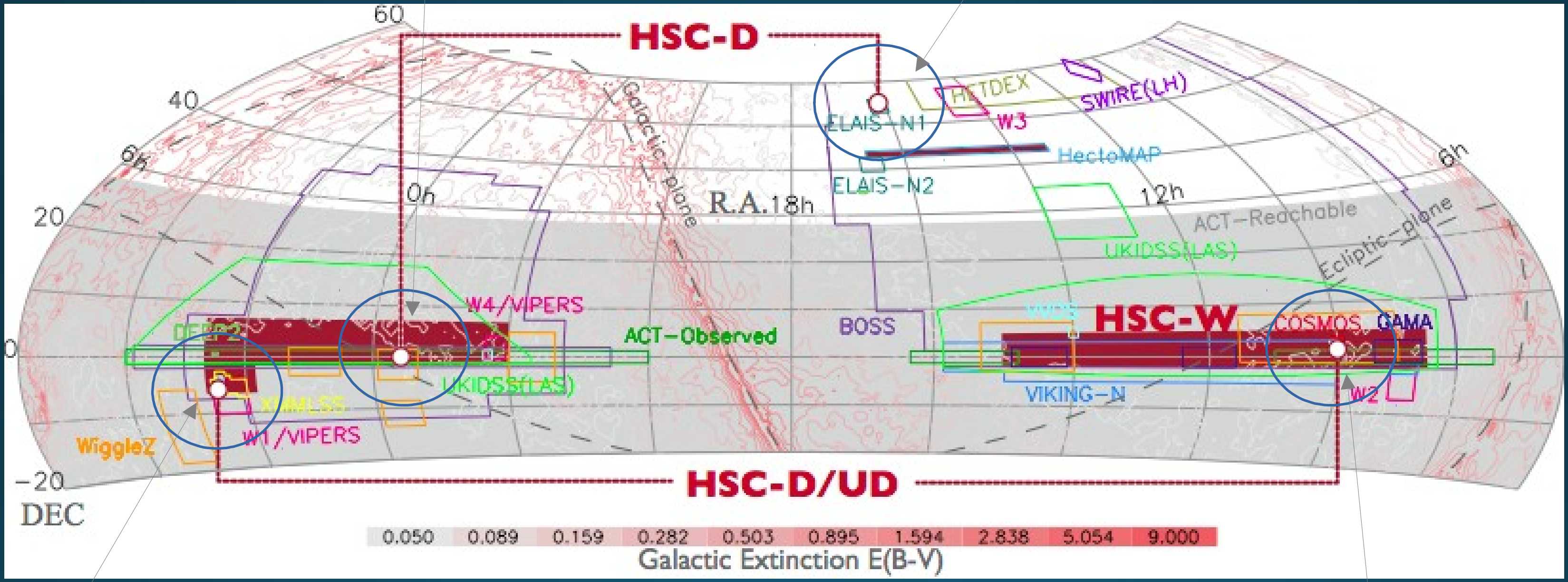
Tanaka, Wong, et al. ApJL submitted

Survey fields

DEEP2-F3 (D)

ELIAS-N1 (D)



SXDS (UD)
XMMLSS (D)

- Full overlap with SDSS
- Low dust extinction
- Wide R.A. range
- Overlap with other NIR, spec, etc surveys.

COSMOS (UD)
E-COSMOS (D)

Survey depths

Layer	Filter	Exptime (# of epochs)	Total nights	Lim. mag.	Moon phase
Wide	*g,r*	10min (4)	53	26.5, 26,1	dark
Wide	*i*	20min (6)	53	25.9	dark
Wide	*z,Y*	20min (6)	108	25.1, 24.4	gray
Deep	*g,r*	1.4hrs (10)	7.3	27.5, 27.1	dark
Deep	*i*	2.1hrs (10)	5.4	26.8	dark
Deep	*z*	3.5hrs (10)	9.1	26.3	gray
Deep	*Y*	2.1hrs (10)	5.4	25.3	gray
Deep	*N387*	1.4hrs (10)	3.6	24.5	dark
Deep	*N816*	2.8hrs (10)	7.2	25.8	gray/dark
Deep	*N921*	4.2hrs (10)	11	25.6	gray/dark
UD	*g,r*	7hrs (20)	4.8	28.1, 27.7	dark
UD	*i*	14hrs (20)	4.8	27.4	dark
UD	*z,Y*	18.9hrs (20)	13	26.8, 26.3	gray
UD	*N816*	10.5hrs (10)	3.6	26.5	gray/dark
UD	*N921*	14hrs (10)	4.8	26.2	gray/dark
UD	*N101*	17.5hrs (10)	6.1	24.8	gray/dark

S15B (Release Date: 2016.01.29)

This data release is the fourth full release and considered to be a candidate for the world-public release schedule in early next year. The data set involves all the SSP data taken in 2014.3 to 2015.11.

> Data Status and Important Notices (Please read this page first.)

NOTE To publish papers, please follow the requirements listed in **this page**

Getting Catalog Products

*Catalog Archive Server (CAS):*SQL search for the catalog sources *(Please go to the following pages for getting source list!)*

> S15B Release Database: Information on Catalog Database Tables

Search by Form

Direct SQL Search

Schema Browser

hscMap (Sky Explorer)
(*) If the hscMap does not display any pseudo color image with a recent version of Firefox, please use a different browser in the meantime.

The latest internal release includes ~100sqdeg of full-color, full-depth data. Over 20 million objects and 10TB of catalog data.

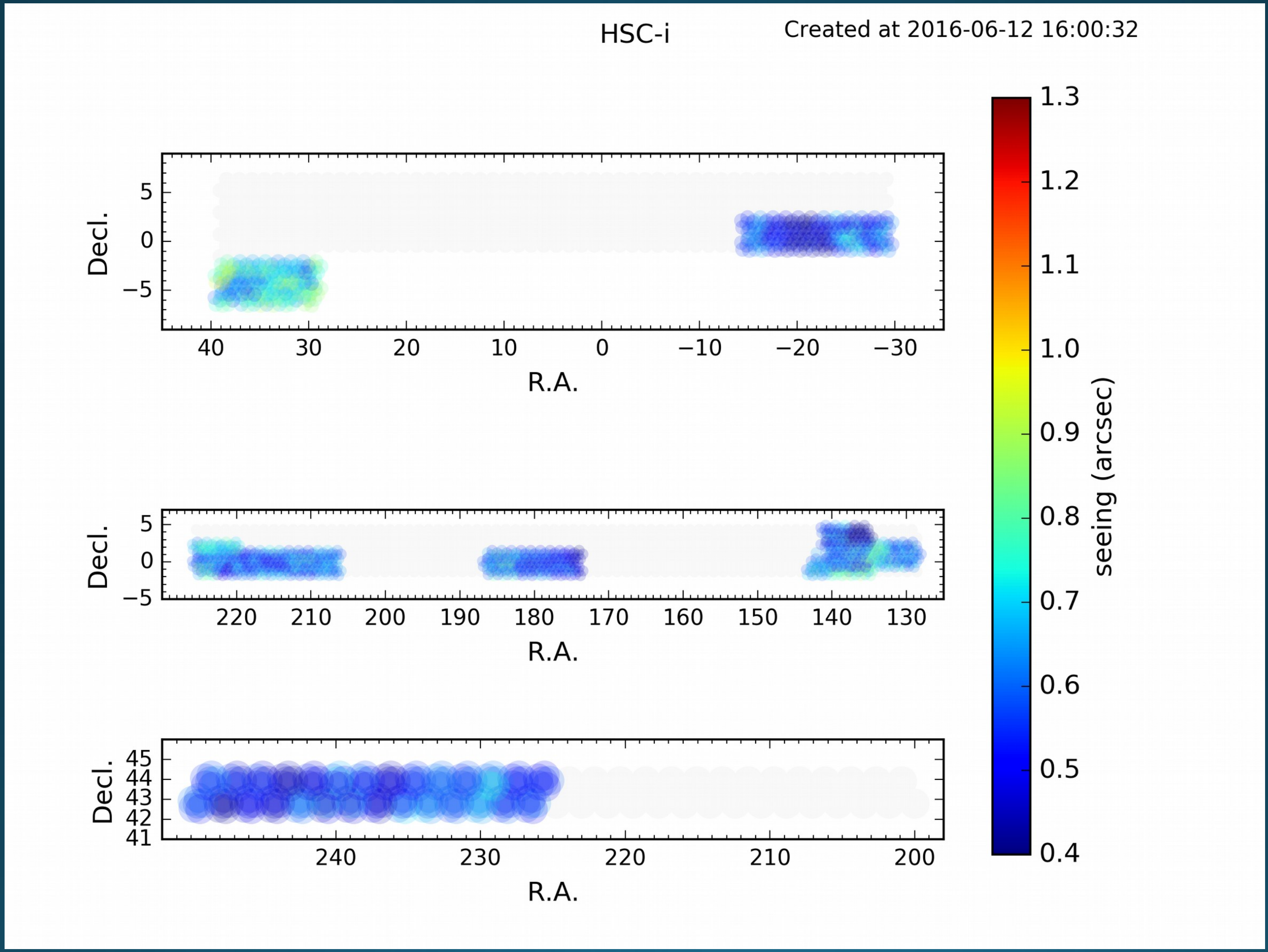
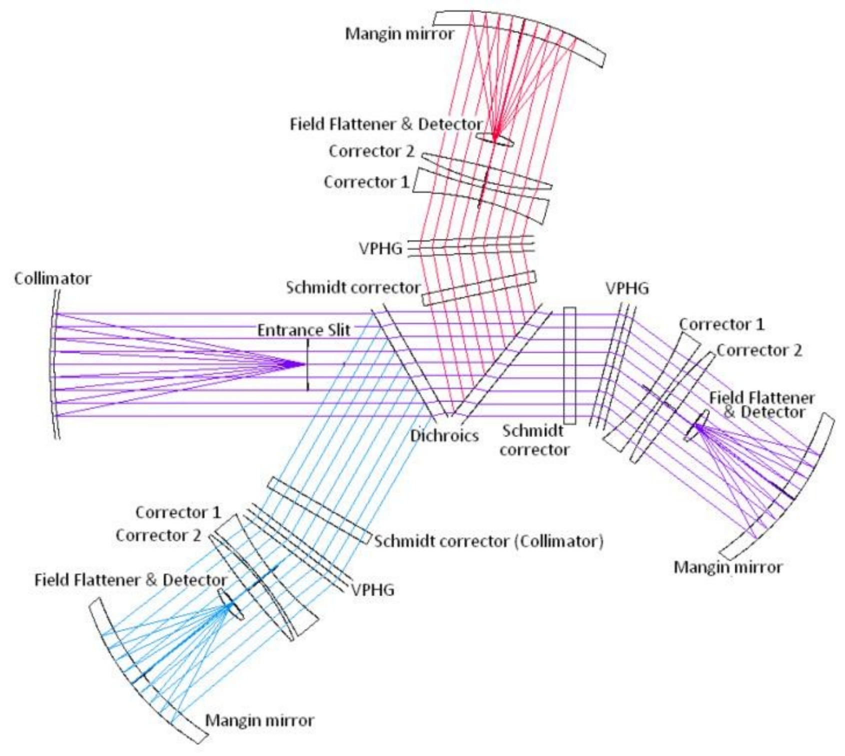


Figure courtesy: Yasuda-san. Note the excellent seeing!

PFS-Galaxy Survey

(see talk by Tamura-san + Yabe-san later today)

Collaboration and Instrument



From Tamura-san's slide

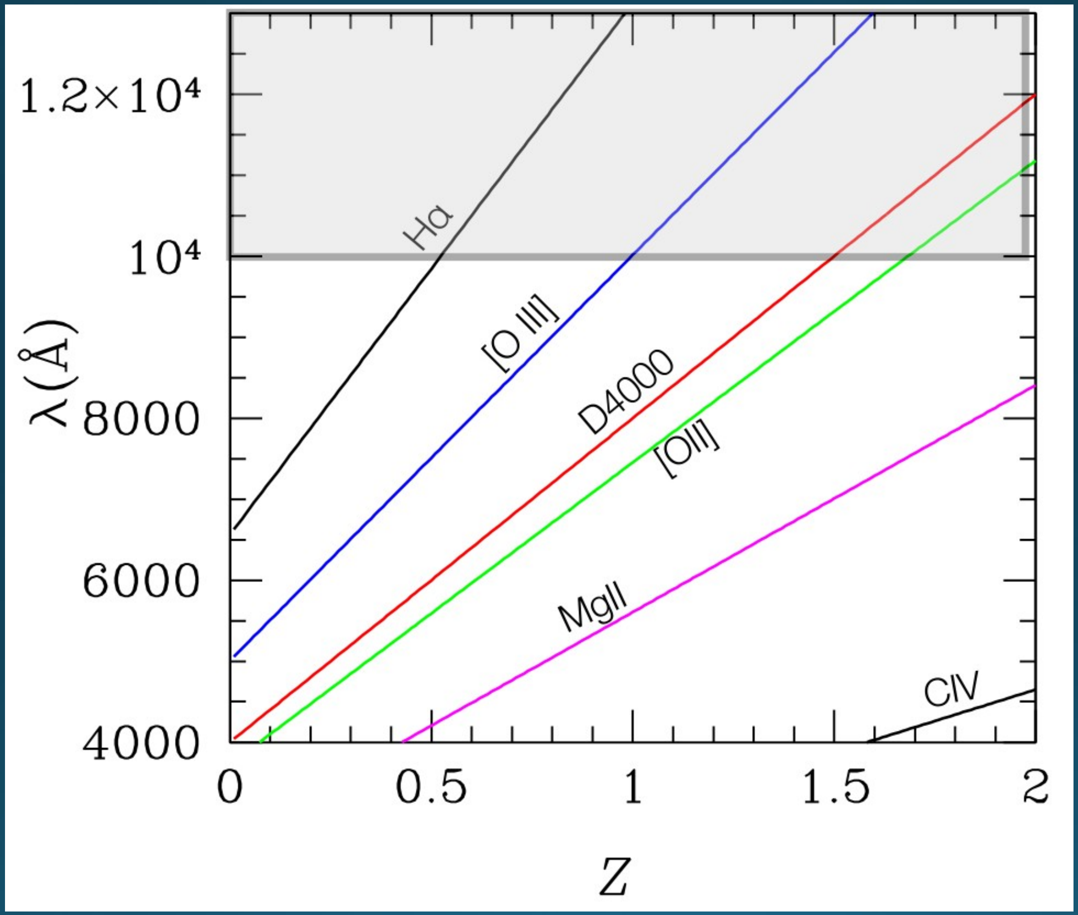
Will be available for open-use observations in mid-late 2019

PFS Instrument Parameters

Prime Focus Instrument				
Field of view	~1.4 deg (hexagonal - diameter of circumscribed circle)			
Field of view area	~1.2 deg^2			
Input F number to fiber	2.8			
Fiber core diameter	127 μm (1.12 arcsec at the FoV center, 1.02 arcsec at the edge)			
Positioner pitch	8 mm (90.4 arcsec at the FoV center, 82.4 arcsec at the edge)			
Positioner patrol field	9.5 mm diameter (107.4 arcsec at the FoV center, 97.9 arcsec at the edge)			
Fiber minimum separation (1)	~30 arcsec			
Fiber configuration time	~60-70 sec. [TBC]			
Number of fibers	Science fibers		Fixed fiducial fiber	
	2394		96	
Fiber density	~2000 deg^{-2} / ~0.6 $arcmin^{-2}$			
Number of A&G camera (2)	6			
Field of view of A&G camera	~5.1 $arcmin^2$ per one camera			
Sensitivity of A&G camera	r'~20.0 AB mag for S/N~30 (100) in 1 (10) sec. exposure			

Spectrograph				
Spectral arms	Blue	Red		NIR
		Low Res.	Mid. Res.	
Spectral coverage	380 - 650 nm	630 - 970 nm	710 - 885 nm	940 - 1260 nm
Dispersion	~0.7 Å/pix	~0.9 Å/pix	~0.4 Å/pix	~0.8 Å/pix
Spectral resolution	~2.1 Å	~2.7 Å	~1.6 Å	~2.4 Å
Resolving power	~2300	~3000	~5000	~4300
Spectrograph throughput (3)	~58% (@500nm)	~55% (@800nm)	~52% (@800nm)	~52% (@1100nm)

Unique instrument for z~1 galaxy science



PFS covers all the important emission/absorption features of galaxies around z<~1. Above z=2, Lyman alpha line comes in the wavelength coverage. We have no redshift desert.

PFS-SSP: Science goals

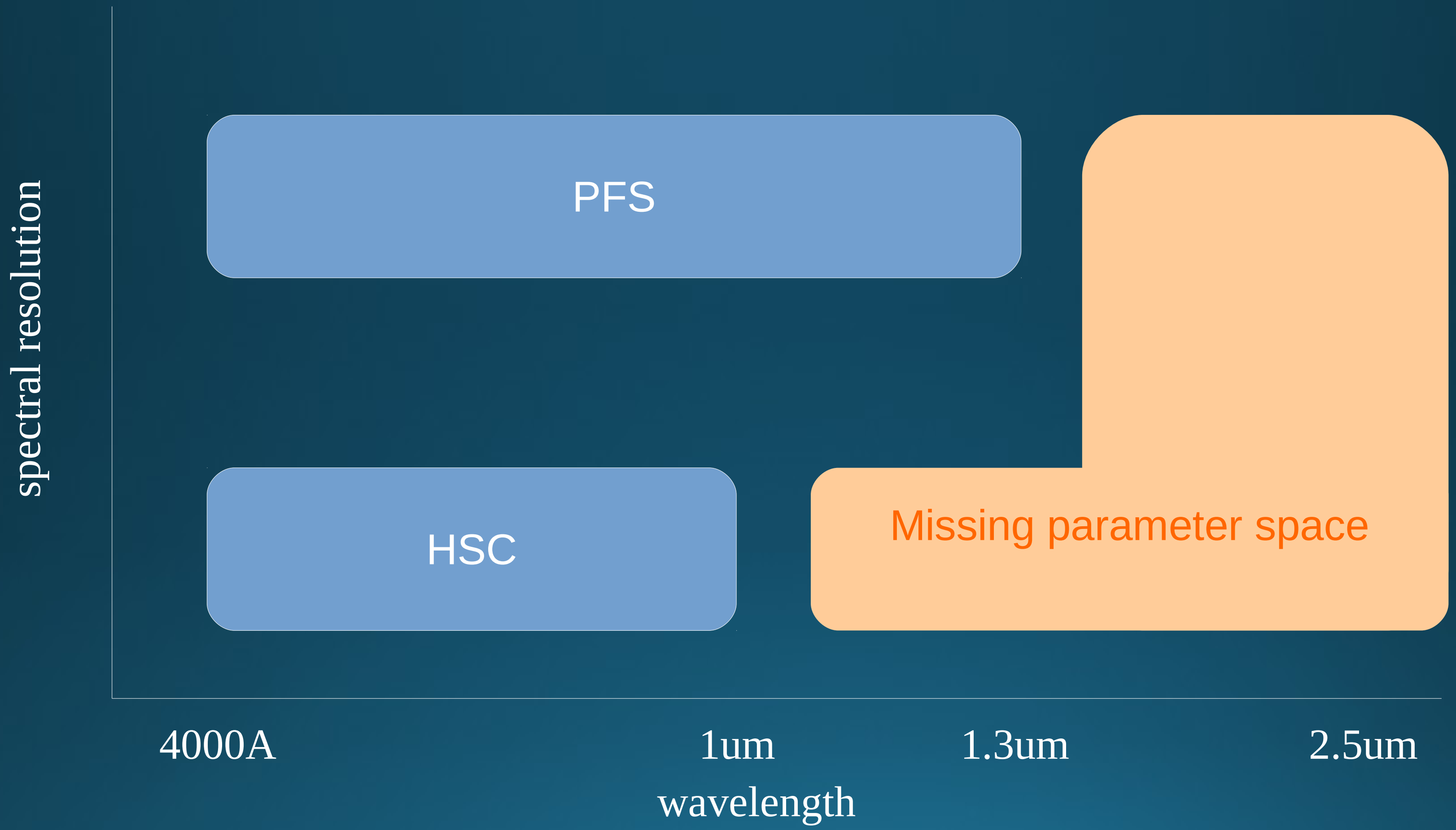
- Cosmology (BAO at 1<~z~<2)
- Galaxy evolution at all redshifts
- Galactic archeology

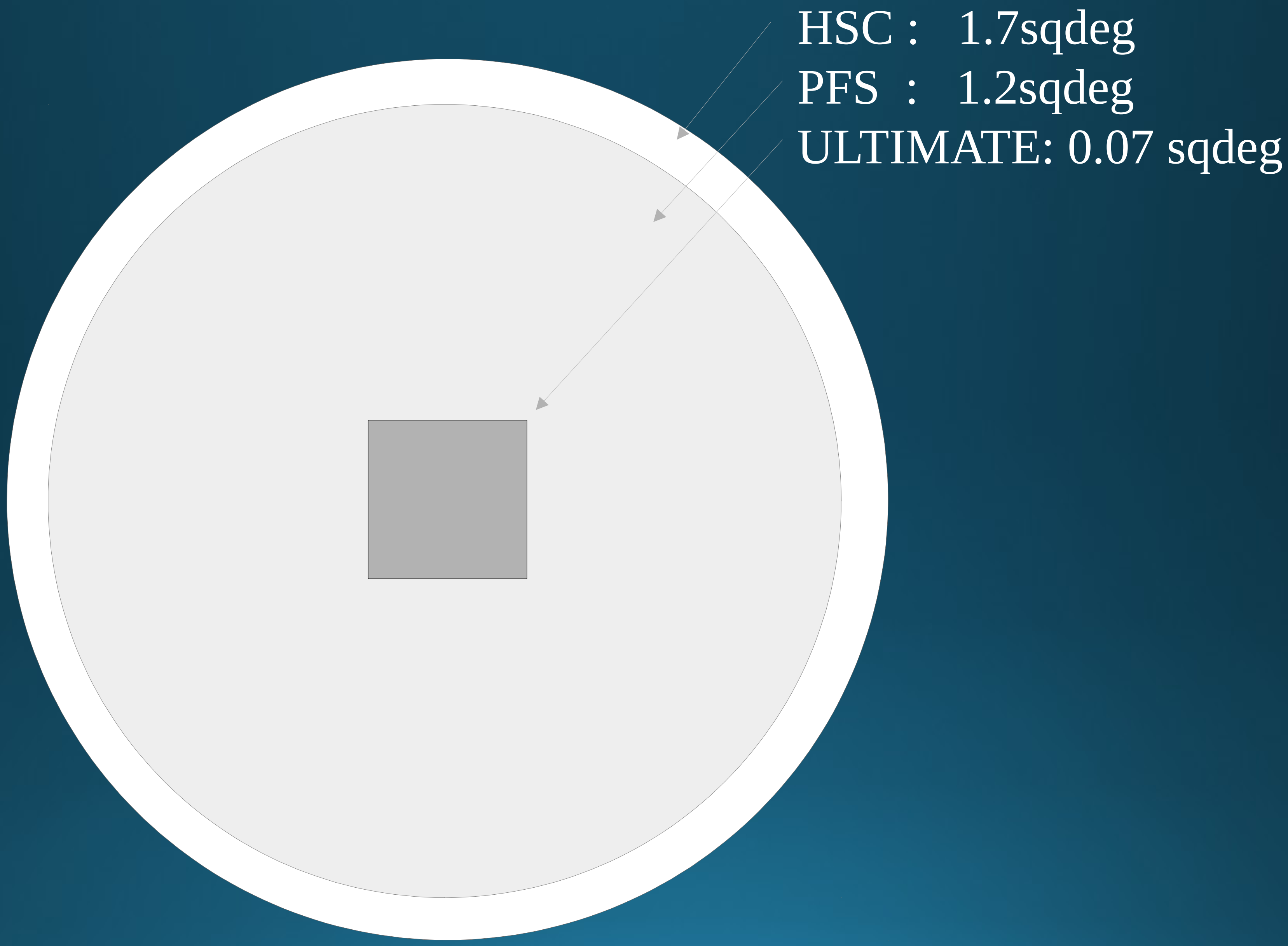
Resulting Survey Design

25 deg^2	~9 deg^2
~200k color- selected galaxies with $0.5 < z < 1.5$ (2hr exp)	~170k color- selected galaxies with $1 < z < 2$ (3 hr exp)
~82k drop-out selected galaxies with $2 < z < 6$ (3 hr exp)	
~20k LAEs with z=2, 6 (5hr exp)	

Current tentative galaxy survey design. The target fields are HSC-Deep fields.

Synergy with ULTIMATE-Subaru

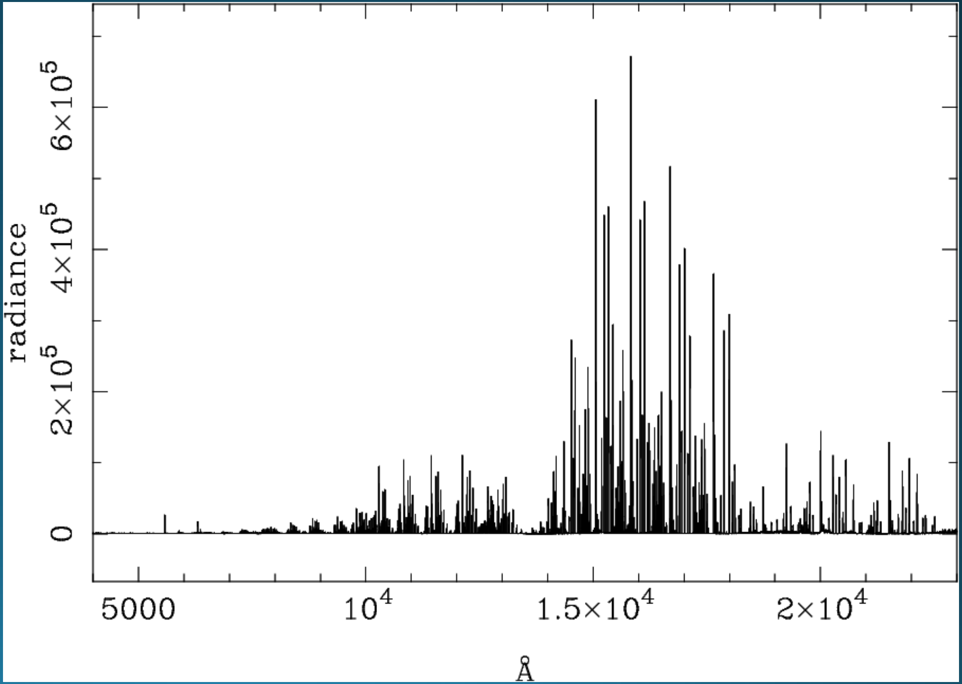

spectral resolution
PFS
HSC
Missing parameter space
4000A
1um
1.3um
2.5um
wavelength



HSC : 1.7sqdeg
PFS : 1.2sqdeg
ULTIMATE: 0.07 sqdeg

Imaging capability of ULTIMATE

- Night sky emission is a real killer.
- JWST will start to deliver excellent IR data in a few years.
- WFIRST will deliver near-IR (up to H?) data with image quality better than ULTIMATE over a much wider area.
- No way we can compete with LSST + WFIRST.
- NB imaging might be an option but science is quite limited.



Spectroscopic capability of ULTIMATE

- Jim Gunn says “spectroscopy is faster than imaging in nearIR. “
- PFS stops at ~1.3um. If we observe the same objects with ULTIMATE, then we will have a complete coverage of optical-nearIR spectra for many thousand objects.
- The target selection in PFS-SSP is quite heterogeneous, but there is a flux-limited component. So, we can build upon PFS-SSP.
- I am not against IFU – it will be interesting. But, from the point of view of synergy with HSC and PFS, I think MOS is good.

Request for the MOS capabilities

- It would be nice to make it a survey instrument. It should be efficient in terms of both throughput and observing overhead.
- Cover the entire JHK bands in one go at R~4000. H+K at minimum.
- FoV should be as large as possible.
- Should be more sensitive than MOSFIRE – it WILL be thanks to GLAO.
- No plate masks please. Use MOSFIRE-like mechanical slitlets.
- Make a sophisticated and automated 2d pipeline. Reduction software is as important as an instrument.

Q1: What do you think is the "KEY" science/observations for ULTIMATE in your research field? We hope to establish the very best science cases which are unique enough even in mid-late 2020's.

I think it is very hard to identify the very best science cases in the mid-late 2020's at this point because JWST is going to completely change the game. My suggestion here would be to design a survey for the first few years with MOIRCS+GLAO and design another survey later.

The first survey would be NB and/or Ks-band survey because the observing efficiency of MOIRCS is not very high in MOS mode and the spectral resolutions are too low. But, I do not have an excellent idea for the major science goals. The 2nd survey would be MOS follow-up of the PFS sources to obtain complete optical+nearIR spectra of many objects. The target selection should be defined after the JWST era.

Q2: Which instrument, WFC/MOS/IFU, is the 1st priority?

I am interested in extending the PFS spectra to H+K, so I would vote for MOS.

Q3: Good science case with MOIRCS+GLAO in 2020-2023?

Not really… As I said, NB and Ks-band imaging is perhaps what we should be doing, but I am not so enthusiastic about such a survey.

MOIRCS+GLAO does not seem to be as interesting as HSC and PFS. Perhaps we could use HSC and PFS on as many bright nights as possible?

Q4: Which survey design looks good for you?

NB and/or K-band imaging might be an option for the first few years with MOIRCS+GLAO. For the 2nd survey, intensive MOS follow-up of PFS sources is I thnk interesting. This will deliver data products with a lot of legacy value.

Summary

- A small NB and/or Ks-band survey with MOIRCS+GLAO, but should use as many bright nights as possible with HSC and PFS.

- The 2nd survey could be MOS follow-up of PFS sources. Make the MOS instrument as efficient as possible.