

Prime Focus Spectrograph (PFS)
for Subaru Telescope

Hitoshi's life

My life

The intersection of my life with the Hitoshi's

Naoyuki TAMURA

Subaru Telescope, NAOJ

Professor & an Associate Director (Instrument Engineering)

(Ex. IPMUer in 2012-2023)

Hitoshi Fest at Kavli IPMU, Dec 18 2024

The cupids appeared in 2009-2010.



Prof. Masahiro Takada



Prof. Hiroshi Karoji

The meeting by three of us in Ochanomizu.

飛んで火に入る夏の虫 / It's like a moth flying into the flame.



The first PFS collaboration meeting at IPMU in July 2011.

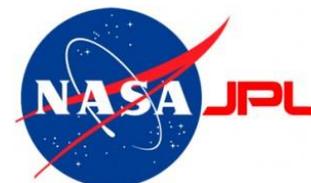


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IPMU INSTITUTE FOR THE PHYSICS AND
MATHEMATICS OF THE UNIVERSE



Caltech

国立天文台
NAOJ



LAM
LABORATOIRE D'ASTROPHYSIQUE
DE MARSEILLE

PRINCETON
UNIVERSITY



JOHNS HOPKINS
UNIVERSITY

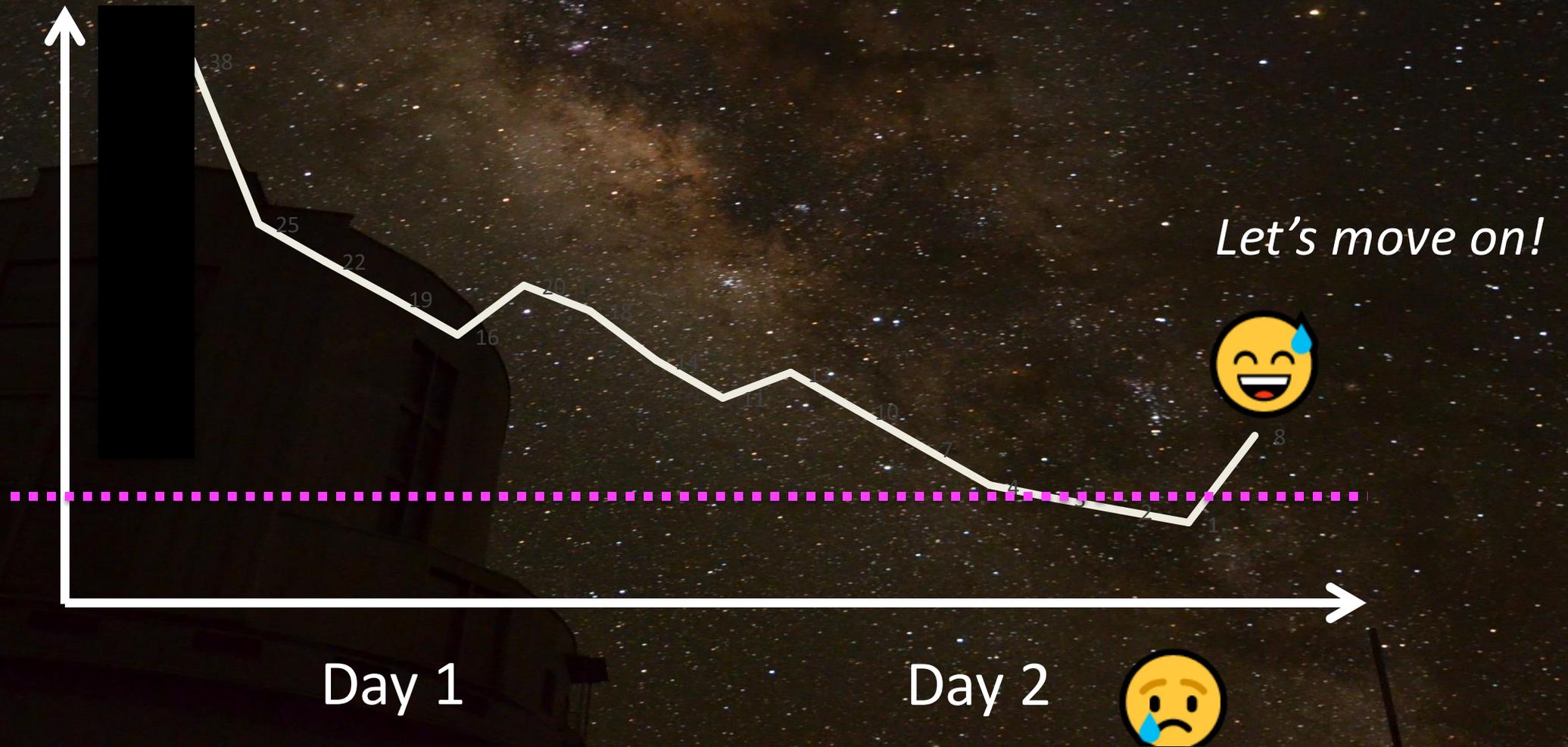
LNA LABORATÓRIO
NACIONAL DE ASTROFÍSICA



In 2014, Hitoshi bravely assigned me (a non-tenured project assistant professor) to a Project Manager. (I was already a Project Systems Engineer, so I have been on the double duties since then.)

Hitoshi is the PI, and I am the Project Manager.

The mood of the collaborators during a 2-day collaboration meeting



2011, IPMU



2014, ASIAA



2015, LAM



PFS 10th Collaboration Meeting in Shanghai

Dec 10-14, 2018

2018, Shanghai Jiao Tong



2016, JHU



2017, IPMU



2019, Caltech



2022, Online



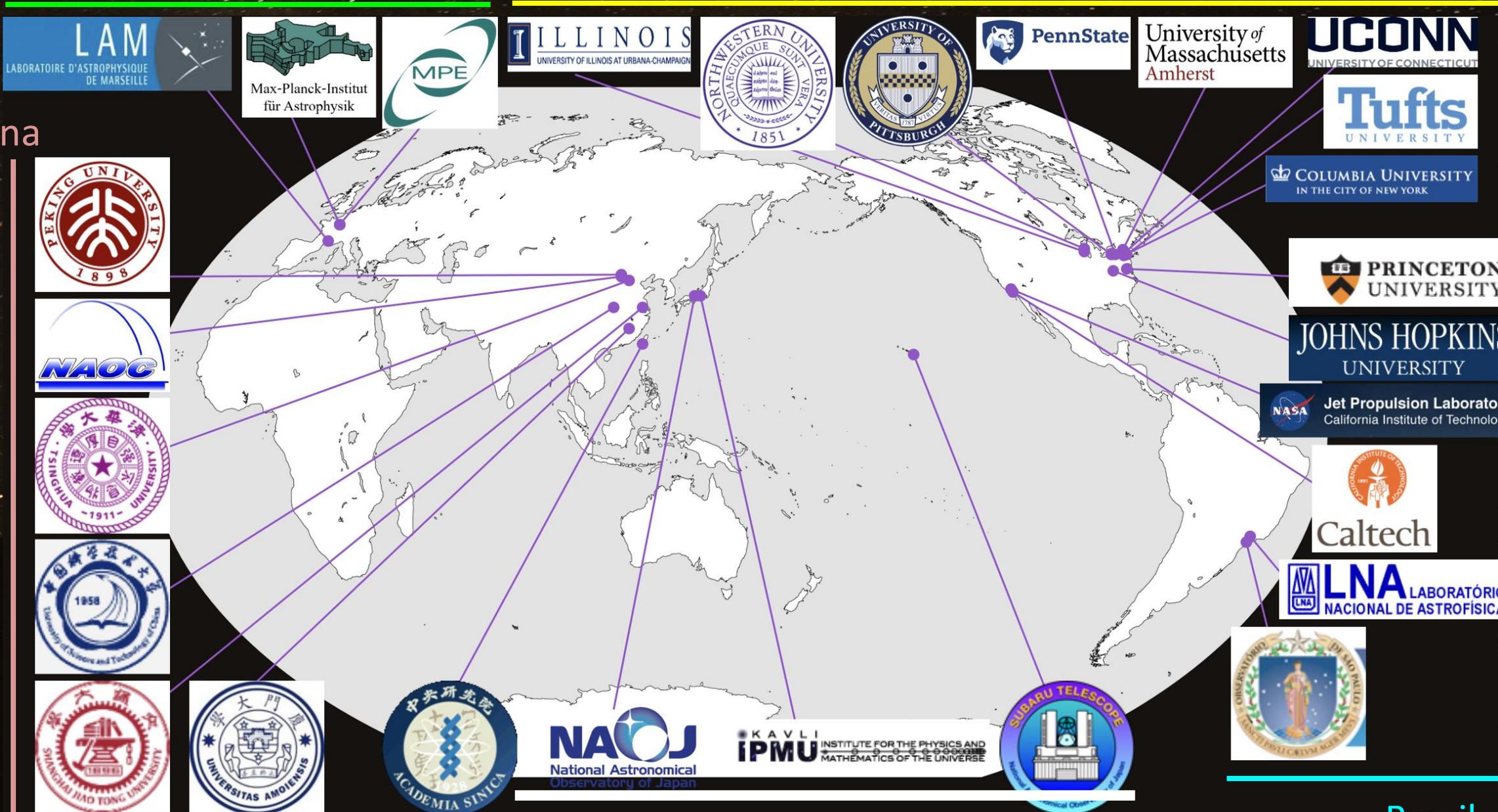
14th collaboration meeting
Jan 7-9 2025
@Kavli IPMU

France & Germany

The international collaboration for PFS

USA

China



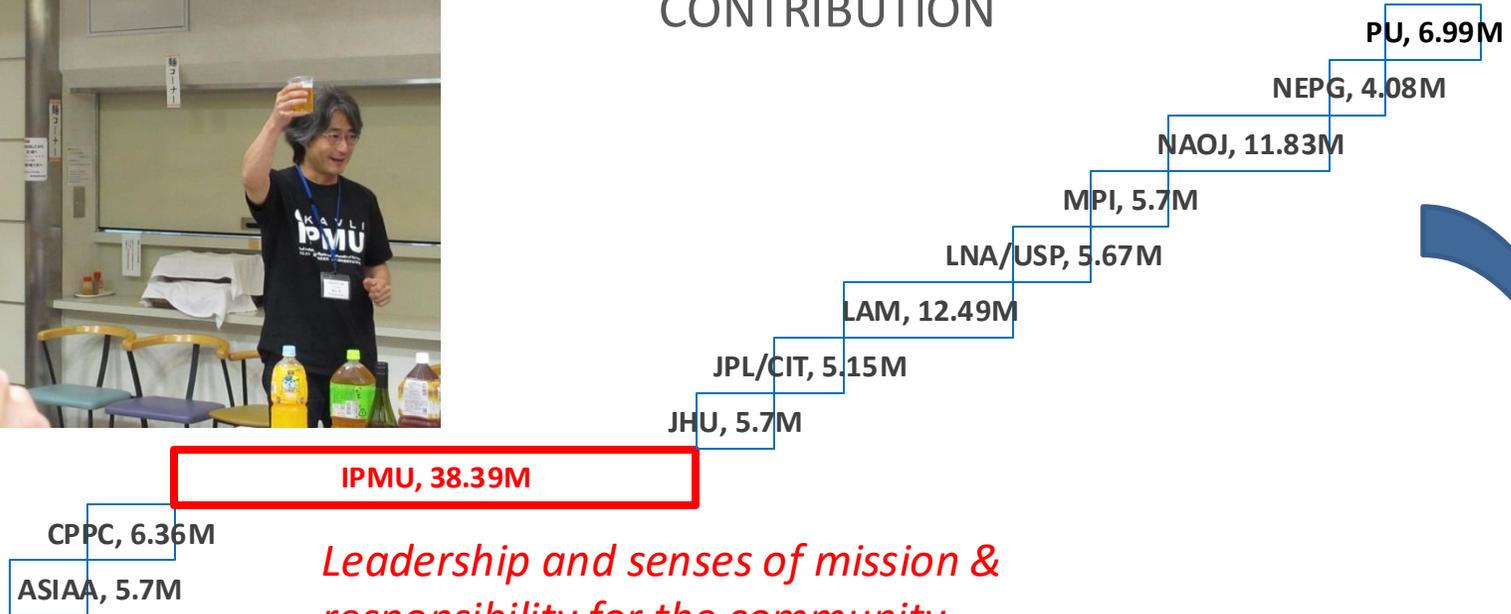
Taiwan

Japan

Brazil

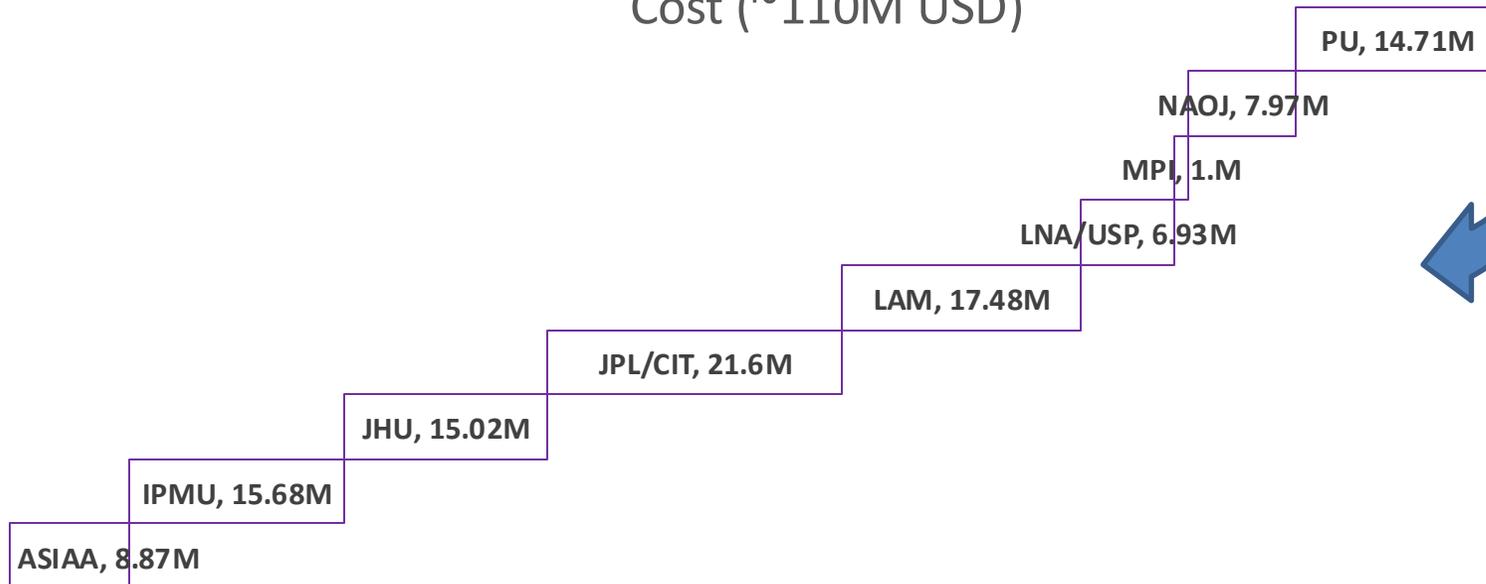


CONTRIBUTION



Leadership and senses of mission & responsibility for the community

Cost (~110M USD)

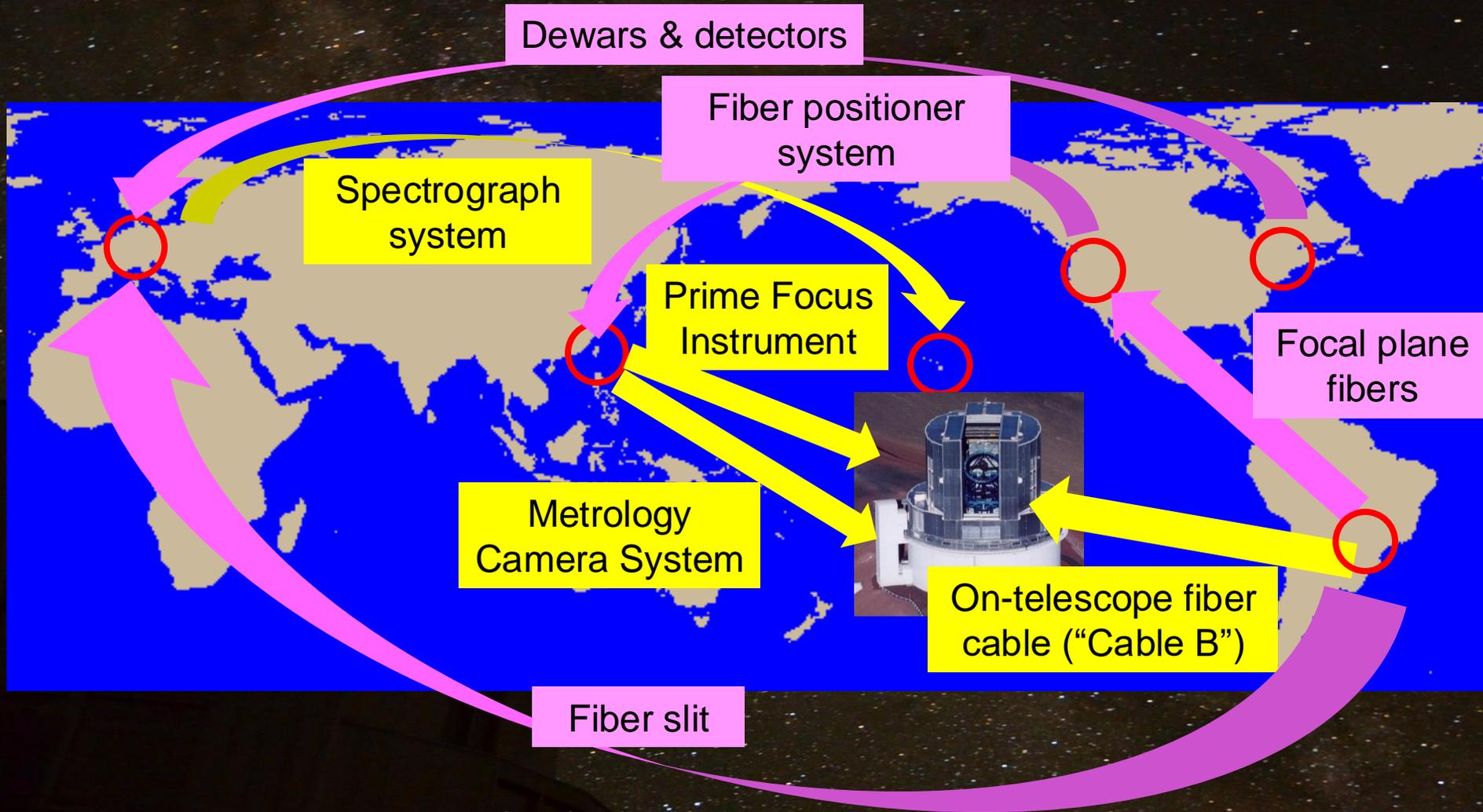


“Budget”

- The contribution from each institute is often insufficient to cover the entire cost of the developments.
 → *Filling the gap is the project’s responsibility.*
- Cash flow**, which does not appear in this chart, has also been a challenge.

“Spending”

Logistics for PFS system integration

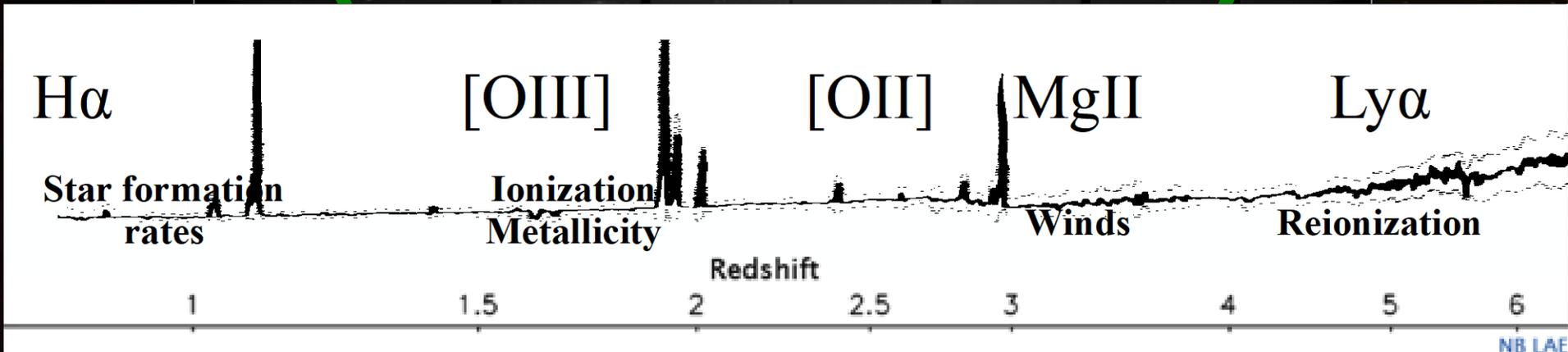


- Systems engineering is clearly the key.
- Parts/components/subsystem are validated at each site before their delivery to other places for higher-level integration & finally to Subaru.

M31 on a single shot
by HSC

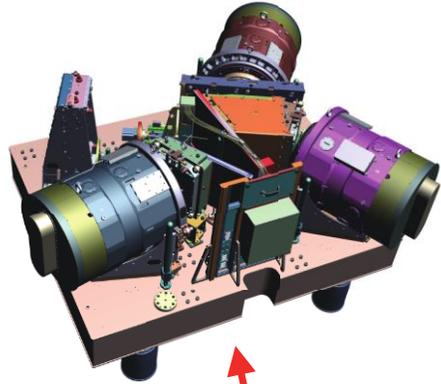
PFS will configure
2386 individual fibers
for simultaneous spectroscopy
over this hexagonal field.

Wide in wavelength coverage too:
380-1260nm at once with 3 arms

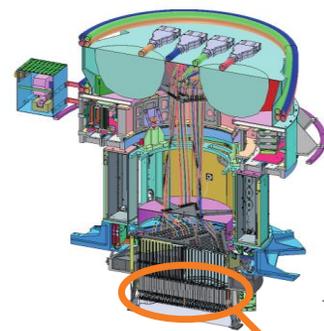


Subaru Prime Focus Spectrograph (PFS)

Spectrograph System (SpS)



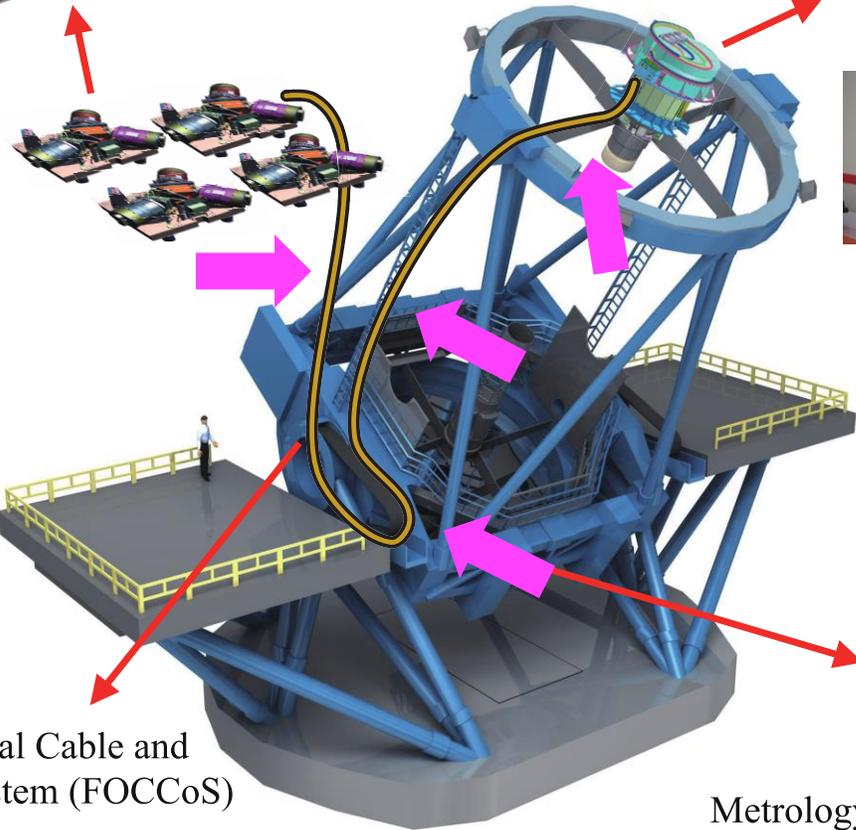
Prime Focus Instrument (PFI)



+



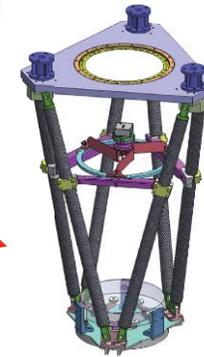
Wide Field Corrector (WFC)



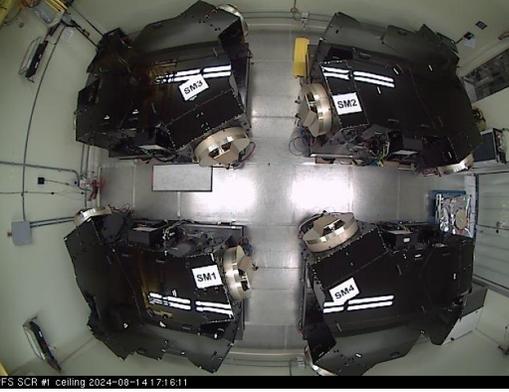
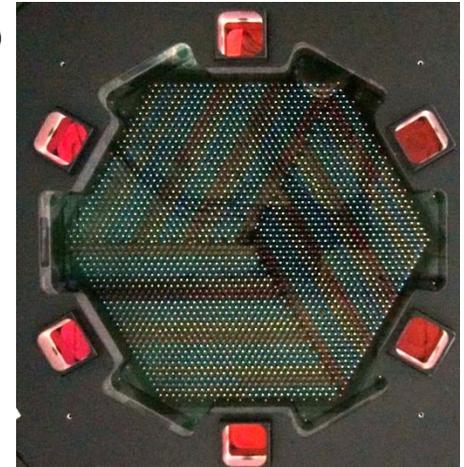
Fiber positioner "Cobra"



Fiber Optical Cable and Connector System (FOCCoS)



Metrology Camera System (MCS)

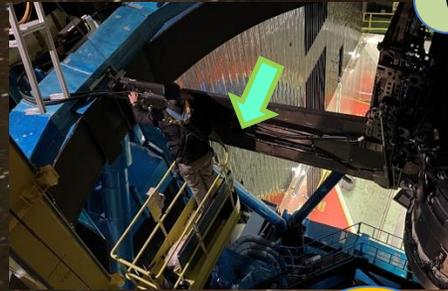


PFS commissioning *for quite some time*

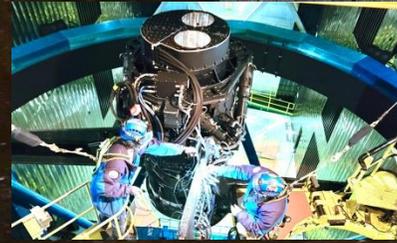
Metrology Camera System installed 1st time on the Cs focus (Jun 2018).



1st Fiber Cable (Cable B1) was installed (Feb 2021).



1st system test on the telescope (Sep 2021).



2nd Fiber Cable (Cable B2) on Telescope (Apr 2022).



2018

2019

2020

2021

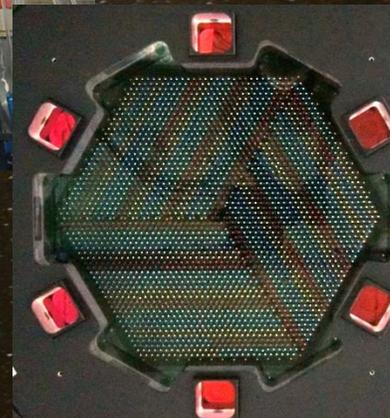
2022



1st Spectrograph Module (SM1) was installed (Dec 2019).

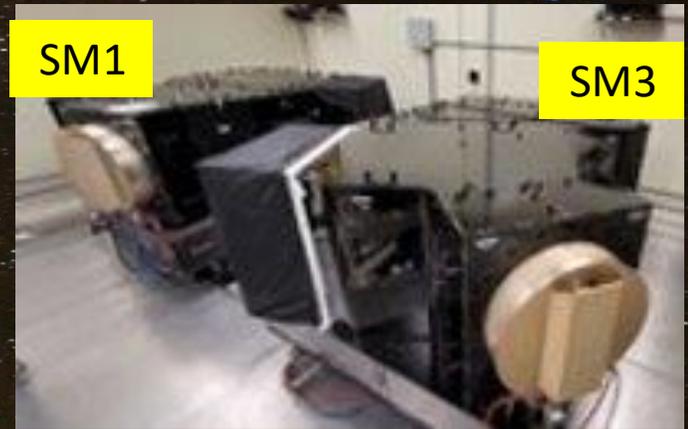


Prime Focus Instrument (PFI) was delivered & re-validated (Jun-Sep 2021).



SM1

SM3



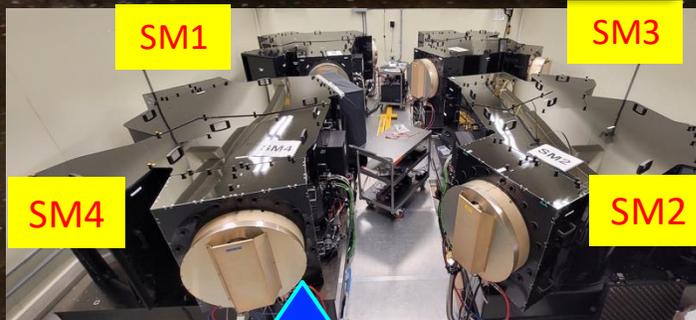
2nd Spectrograph Module (SM3) was installed (Nov 2022).

Integration kept going on and on ... *And finally!*

3rd & 4th Fiber Cable (Cable B3 & B4) on Telescope (Feb & May 2023).



3rd & 4th Spectrograph Modules (SM2 & SM4) (Nov 2023).



Having the arrival & return of NIR cameras in Jun-Aug, all the hardware is finally in place since Aug 2024.

Q1 2023

Q2 2023

Q3 2023

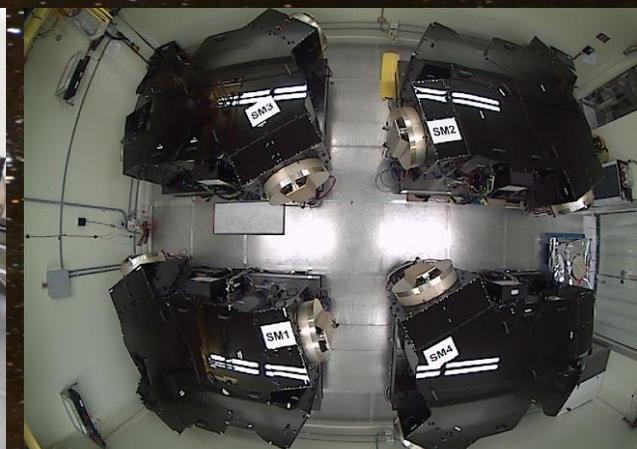
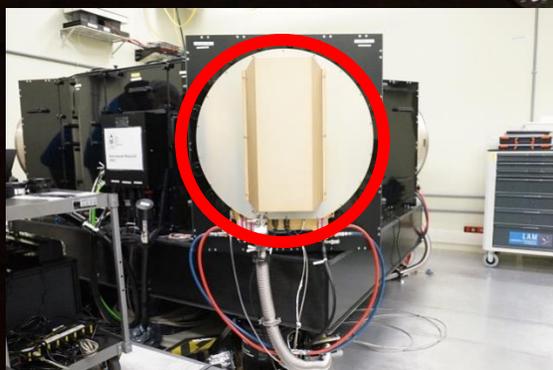
Q4 2023

Q1 2024

Q2 2024

Q3 2024

Q4



1st & 2nd NIR cameras on Spectrograph Modules (Mar & July 2023).

Engineering First Light in Sep 2022

Successfully observed many stars simultaneously by intentionally positioning the fibers on the targets.

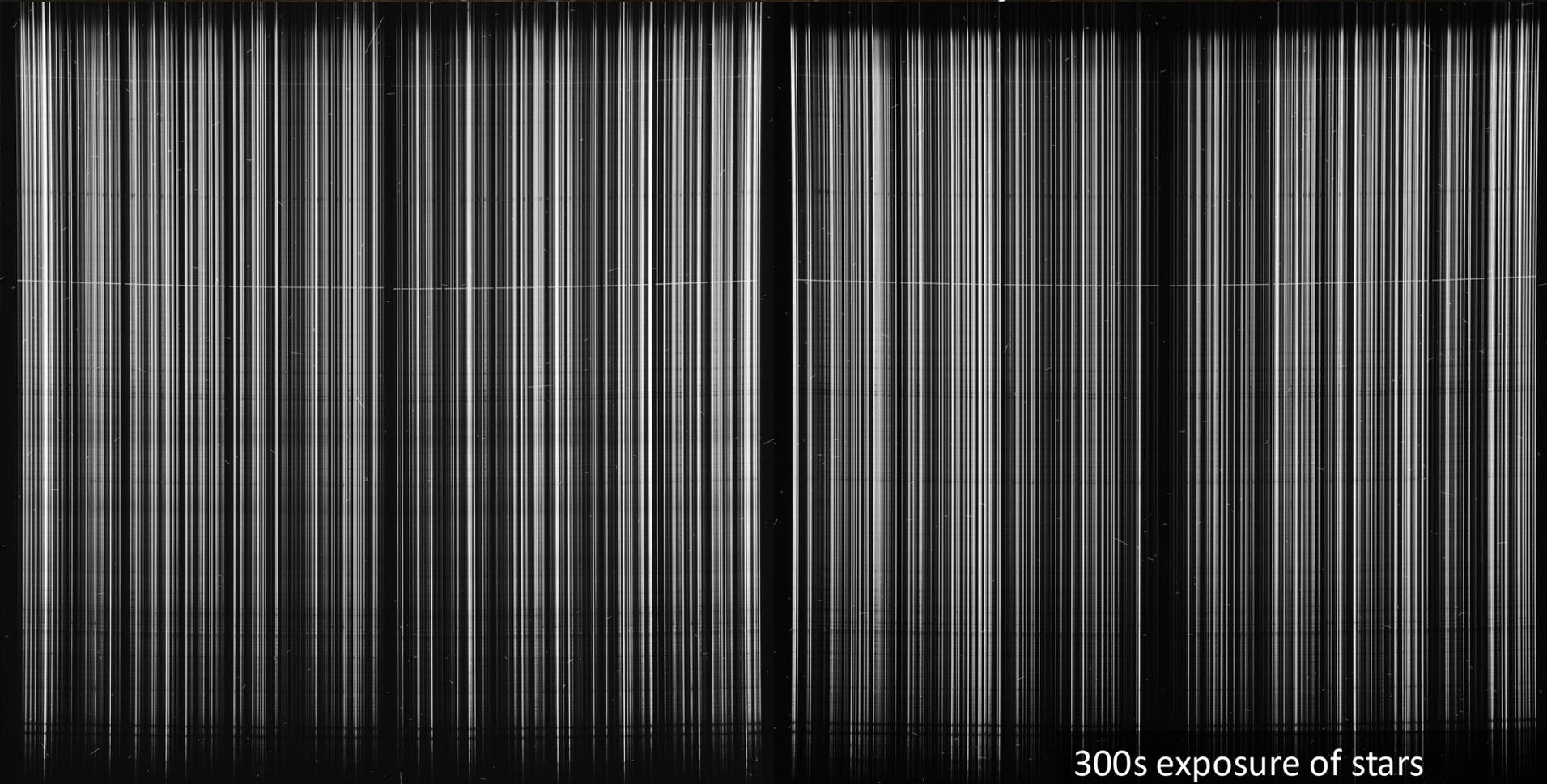
Wavelength
(630-970nm)



~600 fibers

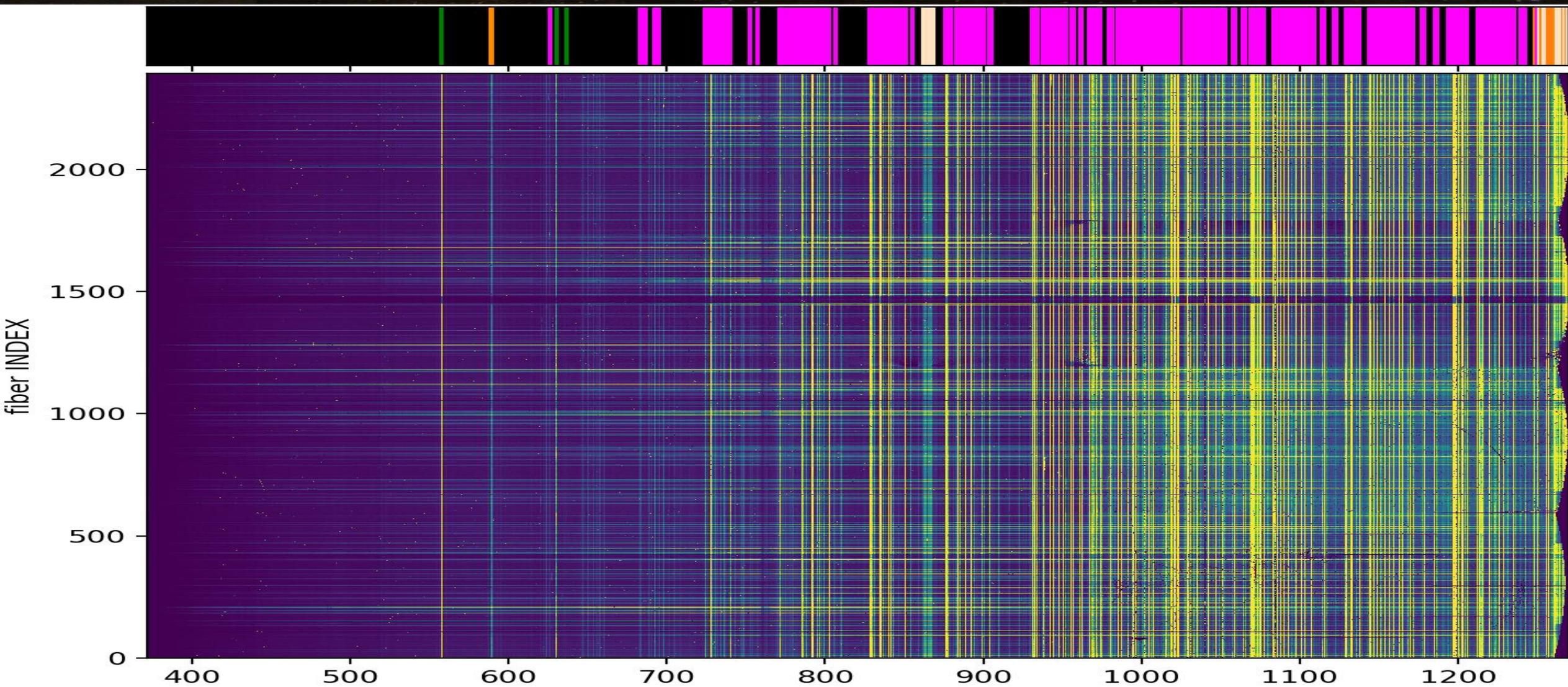
300s exposure of stars
in an NGC 1980 field
w/ SM1 red camera

The observation in Nov 2022 with
doubled multiplicity: $\sim 600 \rightarrow \sim 1200$



300s exposure of stars
in an NGC 1980 field
w/ SM1 & SM3 blue cameras

The observation on 8/27-9/2 with the full set of hardware



Call for Proposals

Semester S25A: February 1, 2025 -- July 31, 2025

Subaru Telescope, National Astronomical Observatory of Japan

Important Notice for S25A

Notice for **PFS Observation**

The Prime Focus Spectrogra
We note that the [PFS SSP pr](#)
applicants, please describe t

Instruments

Subaru Telescope has a suite of eight facility instruments providing imaging and spectroscopic c from optical to mid-infrared.

- **AO** - Subaru Adaptive Optics system
 - [AO188](#) - Subaru 188-elements Adaptive Optics system - delivers diffraction-limited images in the near-infrared com curvature wavefront sensor (CWFS).
 - [AO3K](#) - Subaru 3,228-elements Adaptive Optics system - delivers diffraction-limited images combined with near infr sensor ([NIR-WFS](#)).
- **FOCAS** - Faint Object Camera And Spectrograph - provides optical imaging and longslit and multi-slit spectroscopy over view.
- **HDS** - High Dispersion Spectrograph - provides extremely high-resolution optical spectroscopy.
- **HSC** - Hyper Suprime-Cam - provides optical imaging over a very large field of view (1.5 degree diameter) with a mosaic
- **IRCS** - Infrared Camera and Spectrograph - provides high-angular resolution imaging combined with AO188, low-resolut resolution echelle spectroscopies over 0.9-5.6 microns.
- **MOIRCS** - Multi-Object Infrared Camera and Spectrograph - provides imaging and low-resolution spectroscopy from 0.9 4 arcmin x 7 arcmin field of view.
- **PFS** - Prime Focus Spectrograph - allows simultaneous observations of approximately 2,400 targets using multiple fiber of about 1.25 square degrees and covers a broad wavelength range from 0.38 to 1.26 microns with a single exposure.

The screenshot displays the PFS-OBSLOG interface. On the left, a list of observation targets is shown with columns for ID, coordinates, and instrument configurations. The targets listed include:

- None, None, dcb(blue;yellow;orange), dcb2(blue;yellow;orange)
- dcb(blue;yellow;orange), dcb2(blue;yellow;orange), None, None
- dcb(red1;red4;red8;blue), dcb2(red1;red4;red8;blue), None, None
- dcb(red1;red4;red8;blue), None, None, dcb2(red1;red4;red8;blue)
- None, None, dcb(red1;red4;red8;blue), dcb2(red1;red4;red8;blue)

On the right, a star field visualization is shown with a grid of fiber markers overlaid on the sky. The interface includes a 'Target Type' dropdown menu and a 'configure to allHome' button.

Queue mode operation by default where targets from multiple observing programs (including fillers) share a single focal plane to make the best use of the wide field and high multiplicity.

PFS scientific operations will start from Feb 1 2025!

Schedule for March 2025

Sun	Mon	Tue	Wed	Thu	Fri	Sat
						Mar 01
						S25A-TE193-K Weisz HSC
Mar 02	Mar 03	Mar 04	Mar 05	Mar 06	Mar 07	Mar 08
S25A-UH027-A(0.6) de Boer HSC	Queue HSC				S25A-026 Hashimoto CRS+SCExAO+NIRWFS+NGS	S25A-TE009-G Jiang VAM+SCExAO+NIRWFS+NGS
Queue(0.4) HSC					Eng SCExAO	Eng SCExAO
Mar 09	Mar 10	Mar 11	Mar 12	Mar 13	Mar 14	Mar 15
S25A-026 Hashimoto CRS+SCExAO+NIRWFS+NGS	S25A-026 Hashimoto CRS+SCExAO+NIRWFS+NGS	S25A-026 Hashimoto CRS+SCExAO+NIRWFS+NGS	S24A-023I Currie CRS+SCExAO+NIRWFS+NGS		S25A-040 Ichikawa MOIRCS	S25A-025 Takeda MOIRCS
SSP IRD+NGS-AO	S24A-023I Currie CRS+SCExAO+NIRWFS+NGS	S24A-023I Currie CRS+SCExAO+NIRWFS+NGS			Eng AO188+LLT	
Mar 16	Mar 17	Mar 18	Mar 19	Mar 20	Mar 21	Mar 22
TBD	S24A-113 Matsumoto MOIRCS	Obs IRCS+NGS-AO	Eng PFS			S25A-UH006-B(0.75) Sanders PFS
	Obs MOIRCS	SSP IRD+NGS-AO				Queue(0.25) PFS
Mar 23	Mar 24	Mar 25	Mar 26	Mar 27	Mar 28	Mar 29
S25A-UH006-B(0.75) Sanders PFS	S25A-039 Lee PFS	Queue PFS		Queue PFS	Queue PFS	Queue PFS
Queue(0.25) PFS				SSP PFS	SSP PFS	SSP PFS
Mar 30	Mar 31					
Queue PFS	Queue PFS					
SSP PFS	SSP PFS					

(The first observations have been allocated in March actually while the semester will start from Feb 1.)

*How exciting!
(and a little scary!!)*

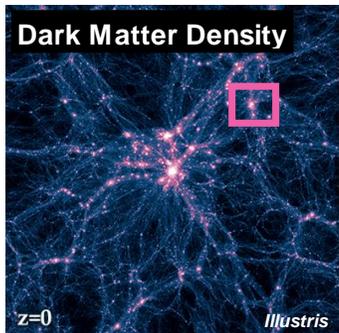
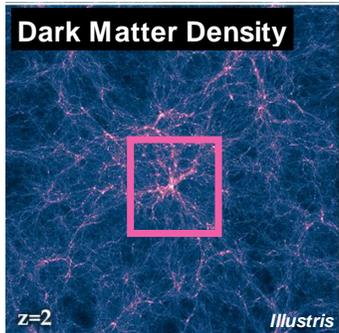
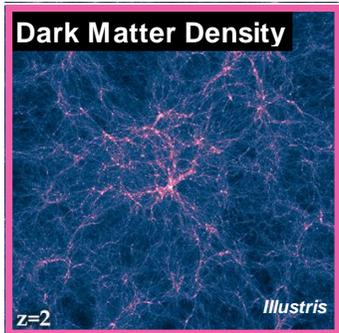
The 360 nights have been fully approved

(progresses will be discussed with the authority at times during the survey).

PFS SSP (Subaru Strategic Program) Survey: “Cosmic evolution and the dark sector”

The observation will begin from S25A.

PI: Hitoshi Murayama (Kavli IPMU/UC Berkeley)
 Science WG co-chairs: Masahiro Takada (Kavli IPMU),
 Richard Ellis (UCL)



	Testing Λ CDM	Assembly history of galaxies	Importance of IGM
CO	<ul style="list-style-type: none"> Nature & role of neutrinos Expansion rate via BAO up to $z=2.4$ PFS+HSC tests of GR 	<ul style="list-style-type: none"> PFS+HSC galaxy association Absorption probes with PFS/SDSS QSOs around PFS/HSC host galaxies 	<ul style="list-style-type: none"> Search for emission from stacked spectra
GA	<ul style="list-style-type: none"> Curvature of space: Ω_K Primordial power spectrum 	<ul style="list-style-type: none"> Stellar kinematics and chemical abundances – MW & M31 assembly history 	<ul style="list-style-type: none"> dSph as relic probe of reionization feedback Past massive star IMF from element abundances
GE	<ul style="list-style-type: none"> Nature of DM (dSphs) Search of MW dark halo Small-scale tests of structure growth 	<ul style="list-style-type: none"> Halo-galaxy connection: M_*/M_{halo} Outflows & inflows of gas Environment-dependent evolution 	<ul style="list-style-type: none"> Physics of cosmic reionization via LAEs & 21cm studies Tomography of gas & DM

Cosmology (CO) (~1200 sq. degs.): ~4M emission-line galaxy spectra

Galactic Archaeology (GA): stars in dSphs, streams and disk in MW and M31

Galaxy Evolution (GE) (~15 sq. degs.): ~a few 10^5 high S/N galaxy spectra

Target selection is based on the **HSC data**

Competition: DESI (4m; see David’s talk), Euclid, VLT MOONS

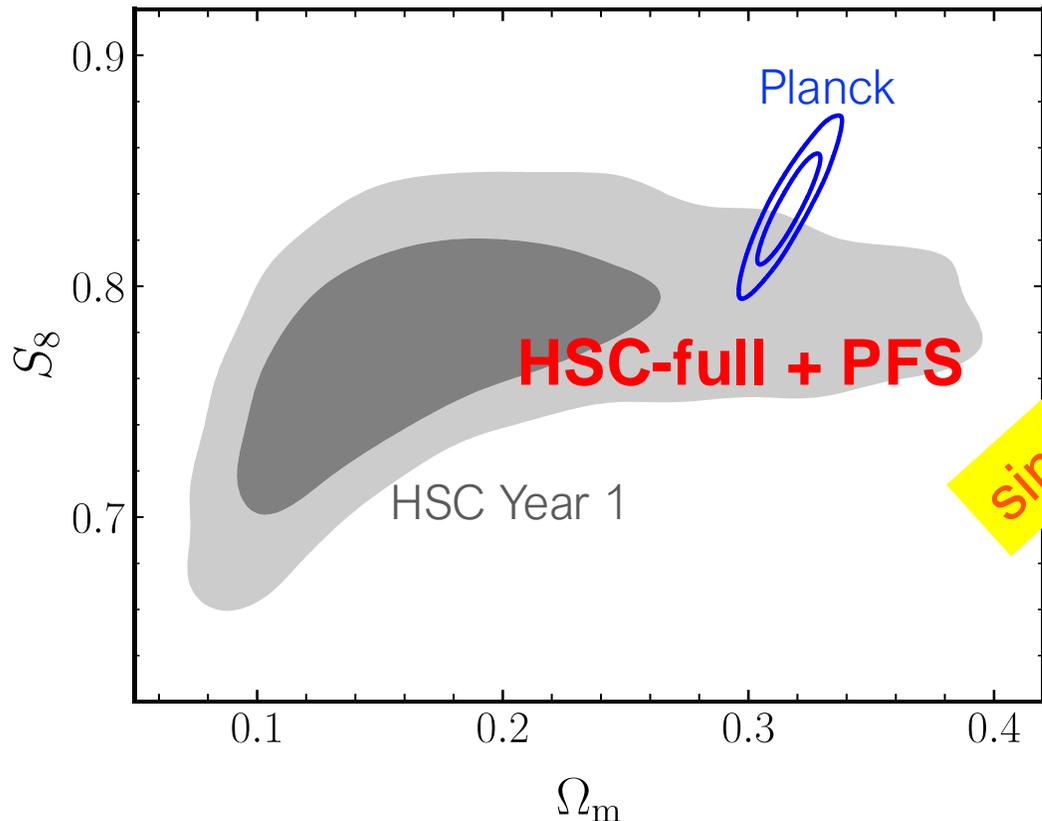
(By courtesy of M. Takada)

Complementarity of HSC and PFS

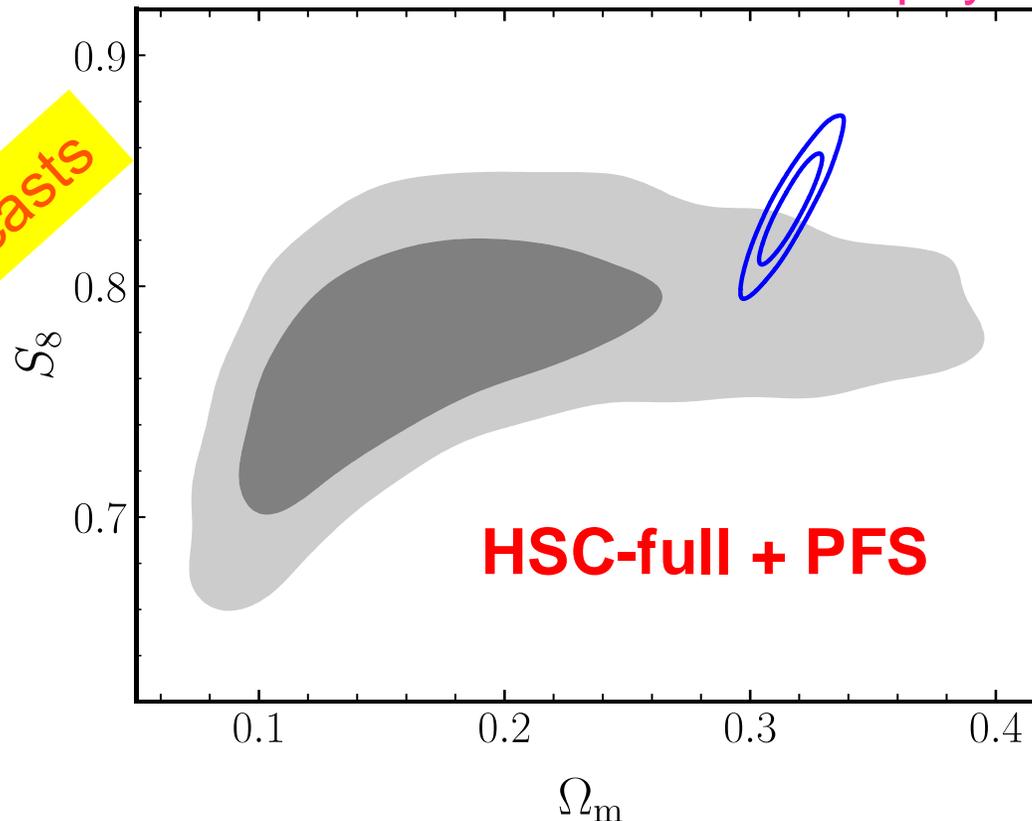
(By courtesy of M. Takada)

- PFS spectroscopic catalog of galaxies at $z > 1$ will be a perfect calibration data of HSC photo- z 's at $z > 1$
- PFS will then improve the HSC-only's constraints A LOT.

Case 1: tension resolved



Case 2: tension confirmed \Rightarrow New physics?



simulated forecasts

Refs. to HSC Year 3 results: Dalal+ 23, Li+ 23, More+ 23, Miyatake+ 23, Sugiyama+ 23, etc.

Congratulations & thanks Hitoshi!

- Not just from me but from all PFSers including the ex. IPMUsers as follows who continue to be in the middle of PFS.
 - M. Ishigaki, Y. Ishizuka, Y. Moritani, T. Sunayama, M. Tanaka, K. Yabe.
 - Without any single piece of Hitoshi's efforts, we wouldn't see PFS as we see today (it wouldn't even exist).
- Indeed, it is an important milestone, but things continue.
 - E.g. PFS: Development → Operations and science
- So, my concluding phrase is:

We find you wherever you are!

Like Kavli IPMU, Subaru needs good people!

- Job opportunity is open for **Support Astronomer**
 - Key person of data acquisitions leading nighttime astronomical observations by operating the telescope and scientific instruments.
 - Location: Hilo, Hawaii
 - Closing date: Jan 15
 - <https://subarutelescope.org/jp/news/employment/2024/11/27/3482.html>

Please share this with those who may be good candidates.