

Subaru 3 (FY2032-)

- [5] Summary of Subaru 3 activities (Morokuma)
- [35=5x(6+1)] current thoughts in each science subWG
 - [5] cosmology (Osato)
 - [5] MMA (Tominaga)
 - [5] exoplanets (Nugroho)
 - [5] galactic archeology (Hirai)
 - [5] Milky Way (Morihana)
 - [5] galaxy evolution (Ito)
 - [5] new operation/proposal scheme (Tanaka)
- [10] timeline/discussion
 - [5] TMT-ACCESS - Subaru 3 WS (Momose)
 - [5] discussion

Tomoki Morokuma

(Chiba Institute of Technology)

on behalf of Subaru 3 WG / Subaru SAC

Subaru 3 WG members: M. Oguri (Chiba U.), Y. Koyama (NAOJ), M. Ishigaki (NAOJ), M. Kubo (Kwansei Gakuin U.), B. Sato (Science Tokyo), T. Morokuma (Chibatech)

Towards Subaru 2 (around 2010)

= 光赤外専門委員会への提言 =

2020 年へのすばるの戦略 “天・地・人”

～スペースと地上観測の連携そして人材育成を軸に～

2009 年 3 月 9 日

すばる小委員会

https://subarutelescope.org/Science/SACM/sacreport/SAC_teigen_2008.pdf

2026/06/17-19

Subaru Users Meeting 2026 @ NAOJ/Mitaka

= ハワイ観測所への提言 =

2020 年代に向けたすばるの戦略

～次世代地上・スペース望遠鏡を見据えた運用と人材育成～

2012 年 6 月 30 日

すばる小委員会

https://subarutelescope.org/Science/SACM/sacreport/SAC_teigen_2012.pdf

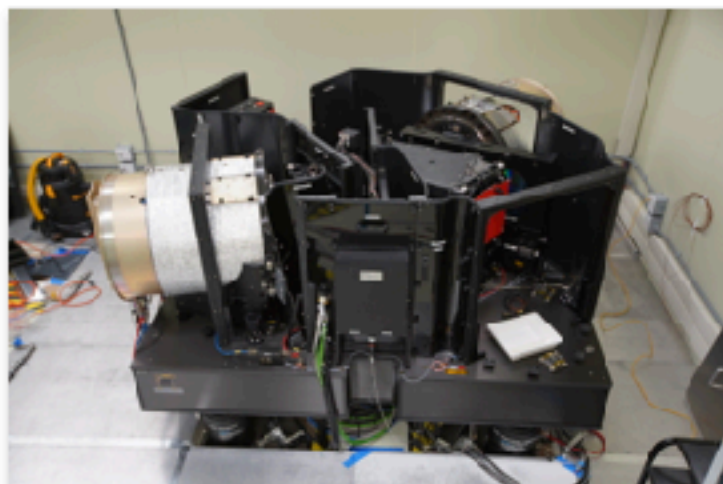
Tomoki Morokuma

Subaru 2

— Key Instruments —



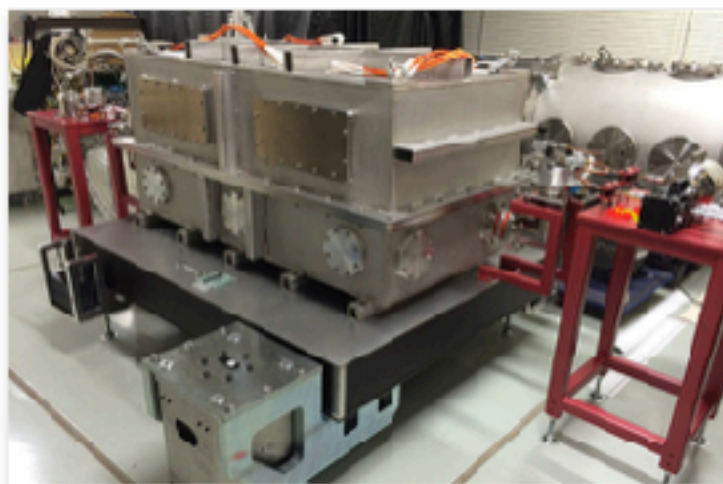
Hyper Suprime-Cam (HSC)



'Ōnohi'ula Prime Focus Spectrograph ('Ōnohi'ula PFS)



Ultra-wide Laser Tomographic Imager and MOS with AO for Transcendent Exploration (ULTIMATE-Subaru)



InfraRed Doppler (IRD)

Key Instruments

Science Goals

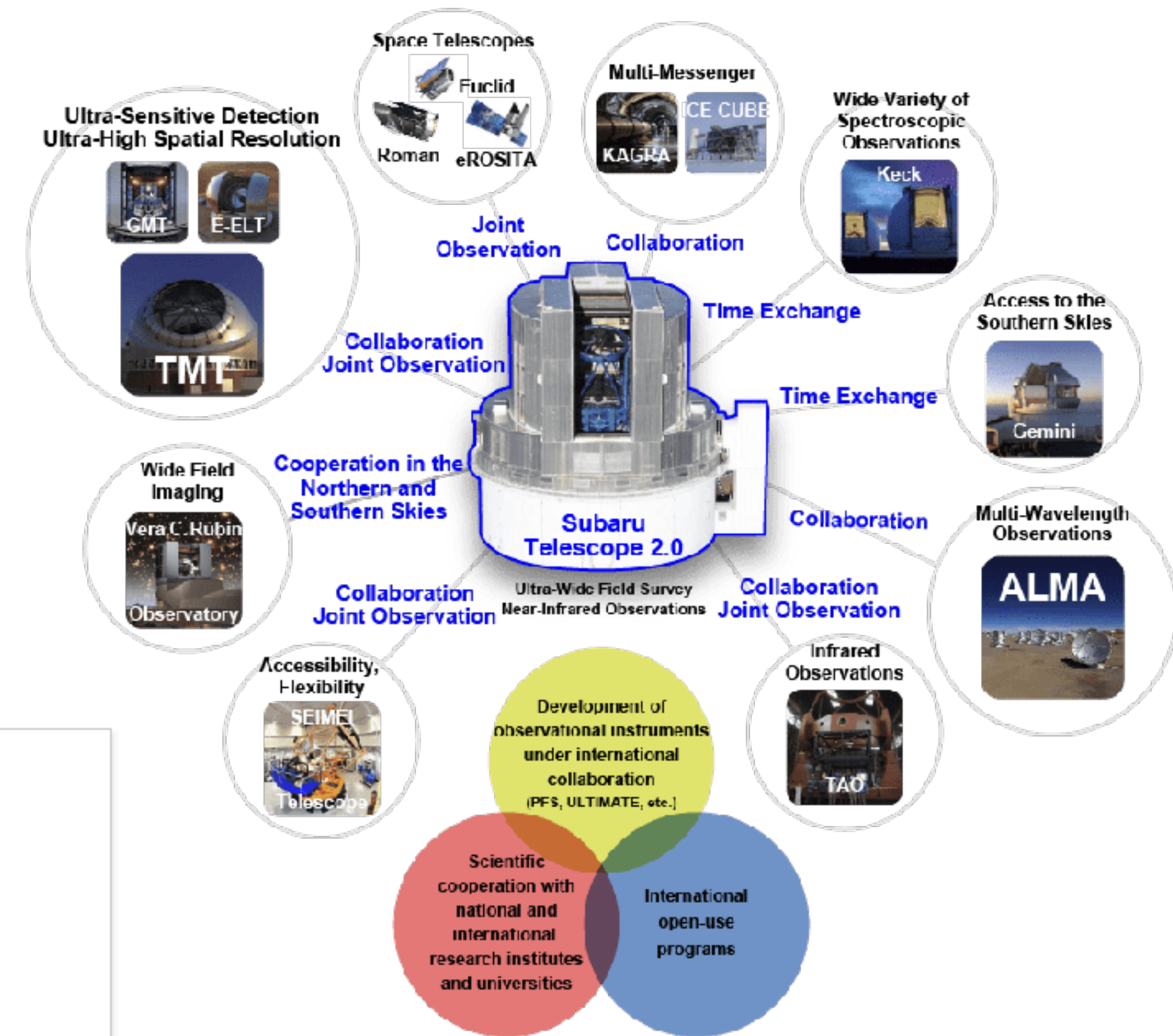
— Science Goals —

To probe the nature of dark matter and dark energy, and determine the neutrino mass

To understand structure formation in the Universe and the physical process of galaxy formation and evolution

To contribute to multi-messenger astronomy

To identify Earth-like exoplanet candidates

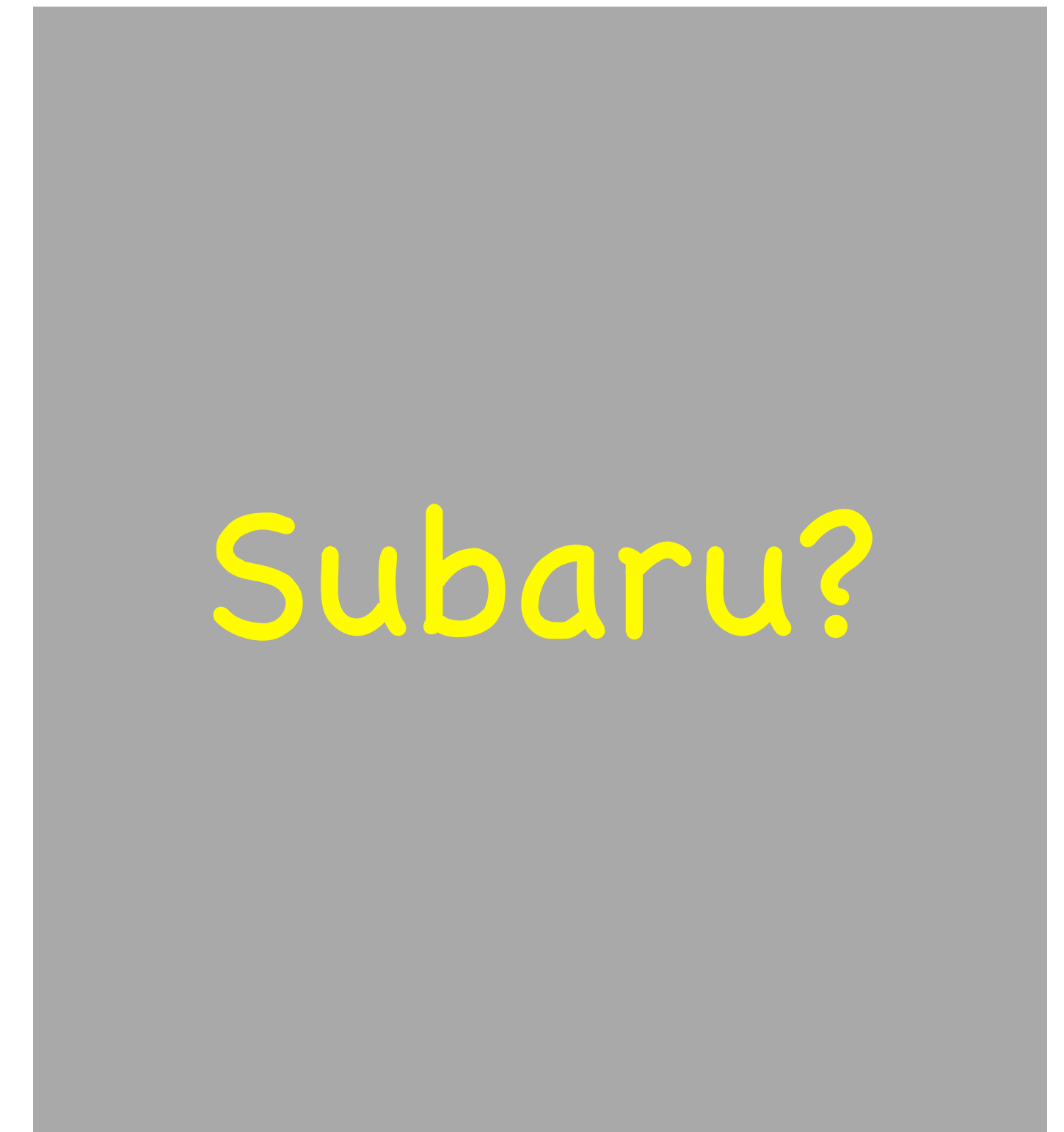
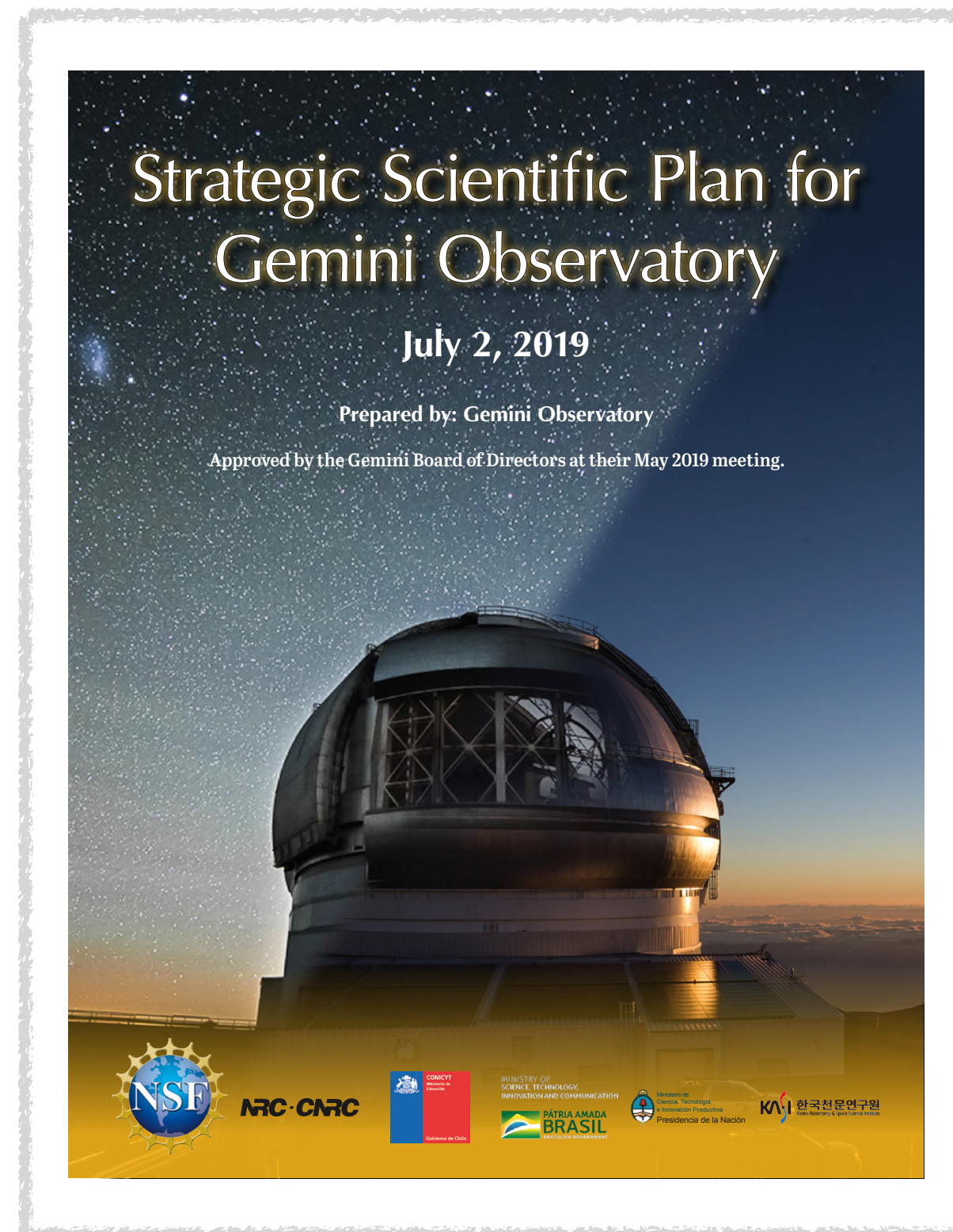
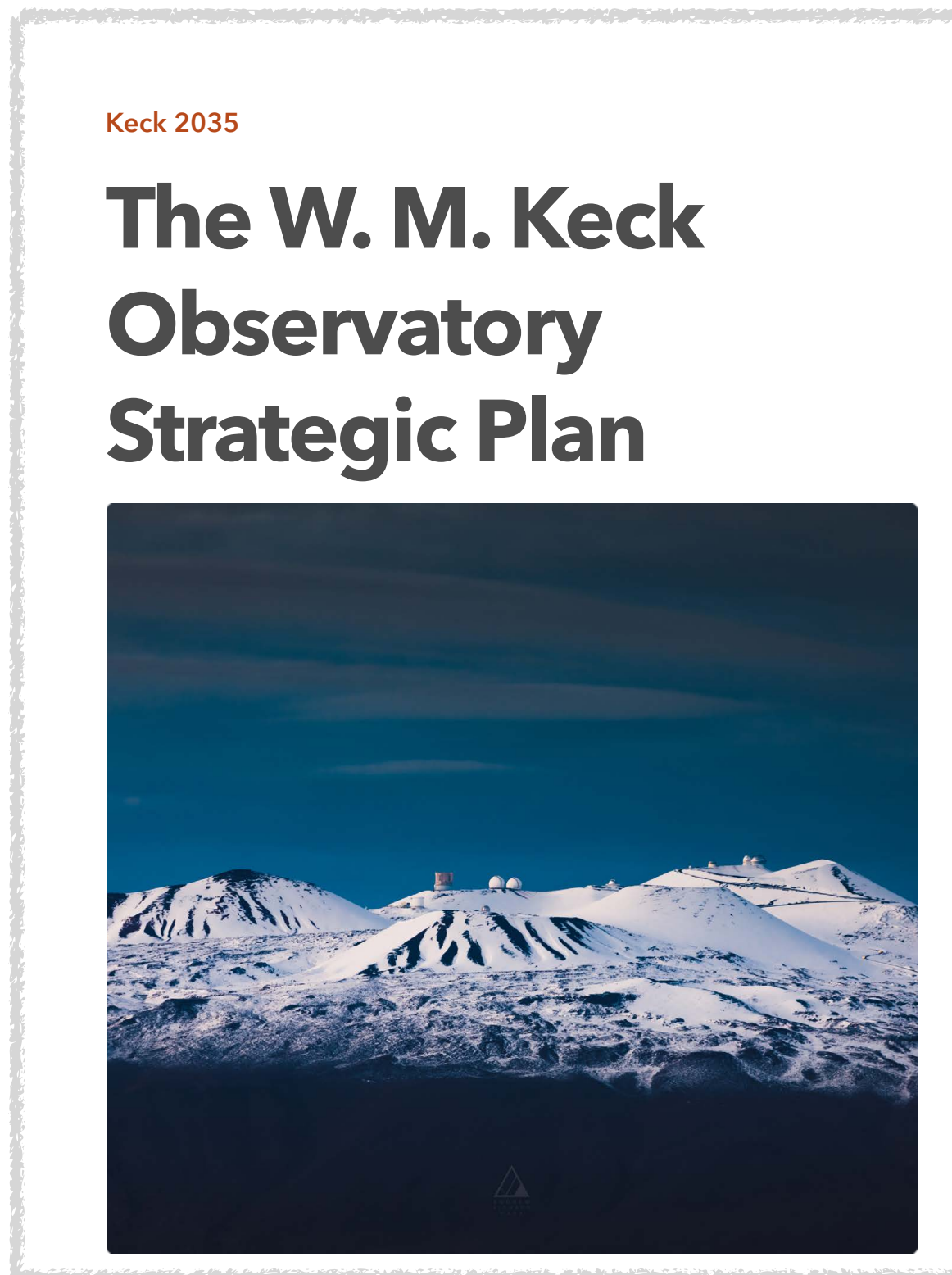


Collaborations w/ Cutting-Edge Telescopes

<https://subarutelescope.org/en/subaru2/>

Subaru 3 (booklet)

- Workshop (Aug. 2024), Subaru UM FY2024 (Jan. 2025), Workshop #2 (Mar. 2026)
- Other observatories (incl. Keck, Gemini) issued 30–40–page books for their future.
- Anybody welcome to join the subWGs (please contact the WG members)
 - Exoplanets, Nearby galaxies, Galaxy evolution, Cosmology, MMA, Milky Way



Subaru 3 WG: M. Oguri, Y. Koyama, M. Ishigaki, M. Kubo, B. Sato, T. Morokuma

2026/06/17–19

Subaru Users Meeting 2026 @ NAOJ/Mitaka

Tomoki Morokuma

Subaru 3 Science subWGs

- Exoplanets: Stevanus Kristianto Nugroho (Science Tokyo)
- Milky Way: Kumiko Morihara (NAOJ/Subaru)
- Galactic archeology: Yutaka Hirai (Tohoku University of Community Service and Science), Tadafumi Matsuno (Heidelberg Univ.)
- Galaxy evolution: Kei Ito (Cosmic Dawn Center), Yuichi Harikane (Univ. of Tokyo)
- Cosmology: Ken Osato (Chiba Univ.), Hironao Miyatake (Nagoya Univ.)
- Multi-messenger: Nozomu Tominaga (NAOJ), Takashi Moriya (NAOJ)

Discussion is being made via MLs, Slack, and meetings in each subWG and across multiple subWGs.

Goals of Subaru 3 WS #2 (March 11-12 2026)

- This workshop serves as an **interim report and discussion** toward clarifying the vision of the Subaru Telescope in the Subaru 3 era and preparing the Booklet. It is an opportunity to reconfirm and share our objectives and the roles of each subWG.
- This WS is the **first opportunity** to learn about the **progress in other subWGs**. We strongly encourage **active information sharing and open, constructive discussion**.
- We would also like to use this workshop as a **kickoff for examining the technical and operational feasibility** of the proposed plans. In particular, some aspects will require detailed consideration by the observatory. Ultimately, the Booklet should include concepts that are reasonably realistic and technically feasible.

Day 1: March 11			
10:30-10:45 (15)	01	Workshop Background and Purpose	Tomoki Morokuma
10:45-11:00 (15)	02	TMT	Wako Aoki
Progress reports		Progress Reports from Sub-Working Groups	
10:45-10:55 (10)	03	Exoplanets	Exoplanets subWG
10:55-11:05 (10)	04	Milky Way	Milky Way subWG
11:05-11:15 (10)	05	Galactic Archeology	Galactic Archeology subWG
11:15-11:25 (10)	06	Galaxy Evolution	Galaxy Evolution subWG
11:25-11:35 (10)	07	Multi-Messenger	Multi-Messenger subWG
11:35-11:45 (10)	08	Cosmology	Cosmology subWG
11:45-13:30 (105)		lunch	
13:30-15:00 (90)		09	Discussion in each subWG -
15:00-15:20 (20)		break -	
15:20-16:30 (70)		10	Discussion across subWGs -
16:30-17:00 (30)		11	Today's Summary -
Discussion			

Day 2: 3/12				Discussion reports	
10:00-12:00		Summary of subWGs' Discussion			
10:00-10:30 (30)	12	Exoplanets	Exoplanets subWG		
10:30-11:00 (30)	13	Galaxy Evolution	Galaxy Evolution subWG		
11:00-11:30 (30)	14	Milky Way	Milky Way subWG		
11:30-12:00 (30)	15	Cosmology	Cosmology subWG		
12:00-13:30 (90)		lunch			
13:30-14:30		Summary of subWGs' Discussion			
13:30-13:00 (30)	16	Galactic Archeology	Galactic Archeology subWG		
14:00-14:30 (30)	17	Multi-Messenger	Multi-Messenger subWG		
14:30-16:00 (90)		18	Future Plans and Discussion		

Keywords discussed in Subaru 3 WS #2 (March 11-12 2026)

- Instruments
 - PFS high-R($\sim 20,000$ – $100,000$) mode
 - PFS multi-IFU
 - PFS extension to longer wavelengths
 - ULTIMATE multi-IFU
 - CMOS imaging camera & spectrograph
 - Simultaneous coverage in optical/NIR high-R spectroscopy
 - Ultra-Doppler, exo-NINJA, HDS 2.0, IRD, T-SHIRT, SCExAO
 - HSC w/ medium-band filters, MOIRCS, wide-field IFU, NINJA
- Telescopes
 - Secondary mirror on Wide Field Corrector at Prime focus (HSC/PFS)
- Operation
 - Flexible observations (scheduling, queue, instrument exchange, ToO etc.)
 - “Smart Subaru”, “AI Subaru”
 - New proposal category
 - SSP-like ($\gg$ intensive) w/ existing instruments, over ~ 10 years (talk by M. Tanaka)

Timeline

- Sep/Oct 2025: Call for subWG members ==> started discussion
 - Oct 2025: Subaru 3 Discussion @ Subaru UM FY2025
 - Mar 2026: Subaru 3 WS #2 (this WS)
 - Jun 2026: Subaru UM 2026
-
- [Technical discussion soon started]
 - Late FY2026: Subaru 3 WS #3 (and TMT-ACCESS-Subaru3 WS?)
 - [define the key science cases etc. in SAC]
 - [finalize the booklet structure]
 - From late FY2026?: Writing & Editing
 - FY2027? (before mid-term review for Subaru 2): Subaru 3 Booklet Issued
 - FY2028?: gopira roadmap (renew)

目的 / Purposes

- すばる3時代に向けた科学的展望を明示し、外部への説明資料および内部の交通整理資料として活用

Clearly present the scientific vision in the Subaru 3 era, and utilize it both as material for external communication and as an internal reference document.

- 以下の読者を想定する: 国内外の天文学コミュニティ (光赤外以外も含む)、他分野の研究者、政策決定・予算措置に関わる方々、一般の方々

Intended audience includes: astronomical community (not limited to optical and infrared fields), researchers in other disciplines, policymakers and funding authorities, and the general public.

構成案 / Booklet Structure (draft) To be discussed seriously in late FY2026

- すばる3時代におけるサイエンスの展望 (キーサイエンス+その他)

Scientific vision in the Subaru 3 era (emphasis on key sciences)

- マウナケアを取り巻く状況・環境 / Current situation/environment surrounding Maunakea

- 望遠鏡の運用方針 など / Telescope operation policies, etc.

Comments in Subaru UM FY2024

- Relationship w/ local community
- Sustainable operation model

Subaru 3

Cosmology subWG

Ken Osato (Chiba Univ.)
on behalf of Cosmology subWG

Members

- Shun Arai (Daiichi Institute of Technology)
- Yuichi Harikane (ICRR, Univ. of Tokyo)
- Hironao Miyatake (Nagoya Univ., **co-chair**)
- Fumihiro Naokawa (Tohoku Univ.)
- Atsushi J. Nishizawa (Gifu Shotoku Gakuen Univ.)
- Ippei Obata (KEK)
- Masamune Oguri (Chiba Univ., **Subaru 3 WG member**)
- Ken Osato (Chiba Univ., **co-chair**)
- Masami Ouchi (ICRR, Univ. of Tokyo; NAOJ)
- Sunao Sugiyama (Kavli IPMU, Univ. of Tokyo)
- Tomomi Sunayama (ASIAA)
- Masahiro Takada (Kavli IPMU, Univ. of Tokyo)
- Daisuke Yamauchi (Okayama Univ. of Science)
- Hiroto Yanagisawa (ICRR, Univ. of Tokyo)
- Shitaro Yoshiura (Nagoya Univ.)

So far, we have had 7 monthly meetings to discuss science projects in Subaru 3 era.

If you are interested, feel free to join!

Current status: Stage-III/IV Cosmological Surveys

- **Spectroscopic surveys**
Science: Galaxy clustering



	eBOSS	DESI	PFS	<i>Euclid</i>	<i>Roman</i>
Instrument	1000 fibers	5000 fibers	2400 fibers	Slitless	Slitless
Redshift	0.7-1.1	1.1-1.6	0.8-2.4	0.7-2.1	1.0-2.8
Survey area [deg ²]	9,000	14,000	1,200	14,000	2,000

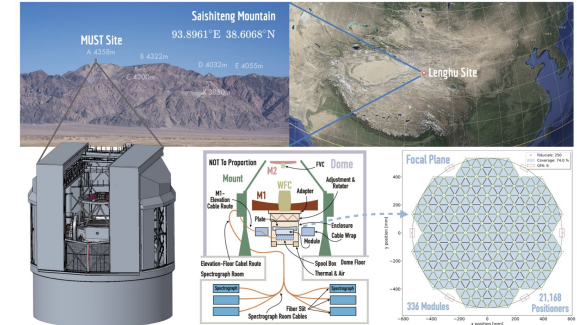
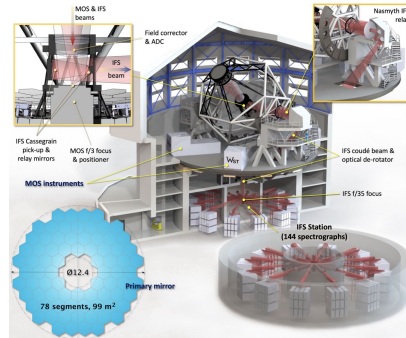
- **Imaging surveys**
Science: Weak lensing



	KiDS	DES	HSC	<i>Euclid</i>	LSST	<i>Roman</i>
Mirror diameter [m]	2.6	4.0	8.2	1.2	8.4	2.4
Galaxy density [arcmin ⁻²]	11	25	25	30	30	50
Survey area [deg ²]	1,500	5,000	1,400	14,000	18,000	2,000

Future planned surveys: Stage-V spectroscopic surveys

- **Spec-S5** (~mid 30's)
Pair of 6m telescopes
3.8 deg² FoV
12,852 fibers each
- **WST** (~ 40's)
12m class telescope
3.1 deg² FoV
30,000 fibers
3x3 arcmin² IFS
- **MUST** (~ 30's)
6.5m telescope
5 deg² FoV
20,000 fibers



Strategy

- Cosmology science cases with and without upgrades of Subaru instruments
 - Without upgrades
 - Cosmology with high-redshift ($z = 3.1 - 3.8$) large scale structure (HSC-MB+PFS)
 - **Synergy** between PFS and LSST = A **strategic investment** in the future time-domain astronomy
 - Multi-probe cosmology using PFS, LSST, CMB SO, ...
 - Characterizing the physical properties of a new class of fast-variable LSST transient objects with PFS follow-up observations (a coordinated observing campaign of LSST and PFS)
 - With upgrades
 - HSC upgrades: time domain cosmology with CMOS
 - PFS upgrades: improve localizations of GW sources by adding multi-object IFU to PFS

Summary

- Benefit from Subaru's character = high sensitivity, large FoV, northern sky, ...
Need new instruments which reinforces the strong points (CMOS, multi-object IFU, ...)
- HSC and PFS are very unique instruments for cosmological (wide) surveys.
HSC-SSP has finished and PFS-SSP is ongoing. But for Subaru 3, we keep thinking about the successor of these surveys with(out) upgrades of instruments.
- Physics driven survey design is desirable, inputs from theorists are appreciated. Ideas are welcome!

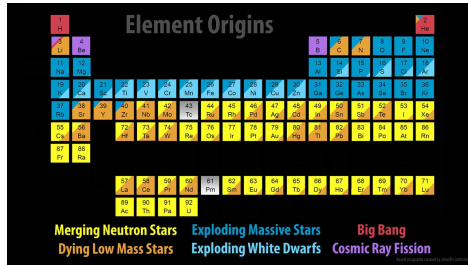
Subaru 3

Multi-messenger astronomy subWG

Nozomu Tominaga (NAOJ), Takashi J. Moriya (NAOJ), Koji S. Kawabata (Hiroshima U.), Yutaka Komiyama (Hosei U.), Keiichi Maeda (Kyoto U.), Tomoki Morokuma (Chiba Tech), Masaomi Tanaka (Tohoku U.), Seiji Toshikage (Tohoku U.)

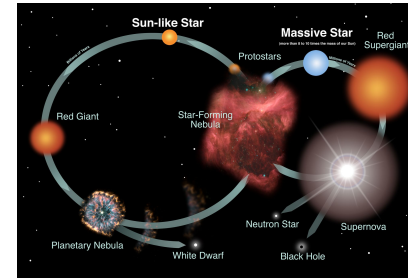
Science goals

Origin of matter and elements



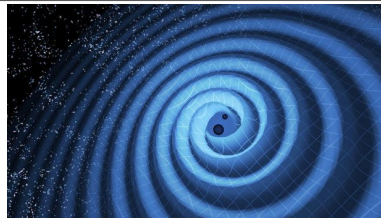
(C) J. Johnson/SDSS

Evolution of matter in the Universe



(C) NASA

Basic laws of physics

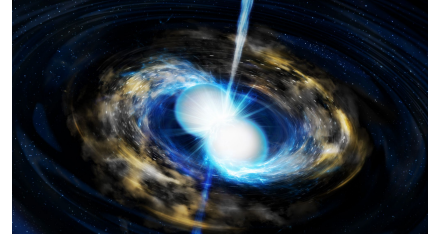


(C) LIGO

Three major scientific targets

1. Gravitational wave sources

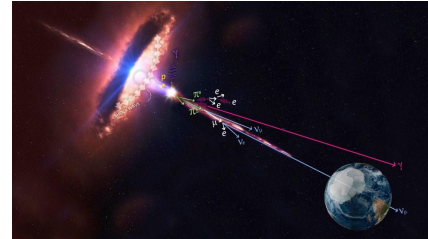
- Neutron star mergers
- (Massive) black hole mergers



(C) Tohoku U.

2. Neutrino sources

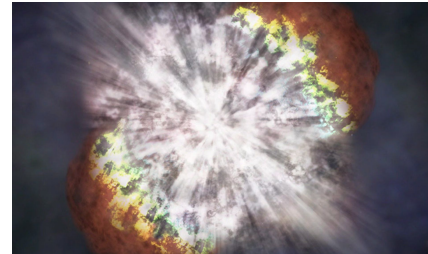
- Unknown high-E neutrino sources
- Galactic supernovae



(C) IceCube/NASA

3. Astronomical transients

- High-redshift supernovae / GRBs
- Infant supernovae
- Fast transients (FRBs, ...)



(C) Nasa/Chandra/
X-Ray Centre/M
Weiss/Ho/EPA

1. Gravitational wave sources

Landscape in 2030

Objectives

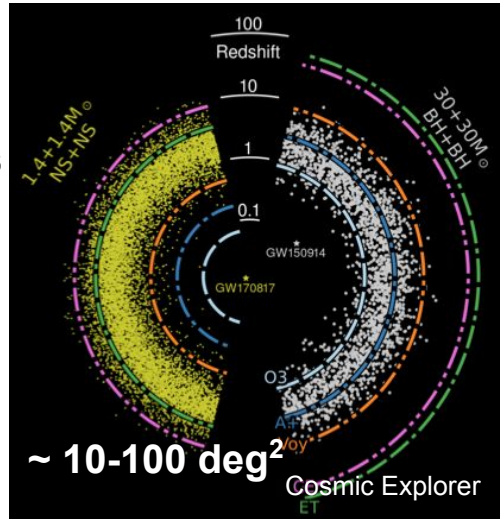
Astrophysics

- Identification of EM counterparts
- Origin of r-process elements
- Evolution of massive BHs

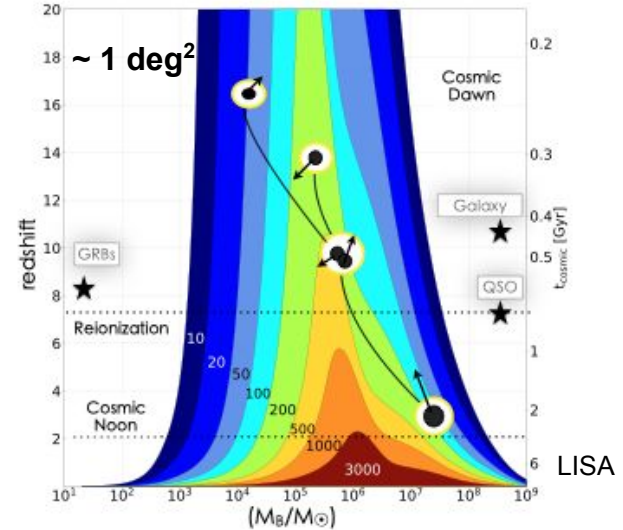
Physics

- Cosmology
- Equation of state of NS
- Test of general relativity

Next-gen GW detector (Stellar mass objects)



Space GW detectors (Massive BH, ~10⁶ Msun)



Subaru 3

- Immediate ToO observation (< 1 hr)
- Wide and deep imaging capability
- Deep spectroscopy (low-resolution)

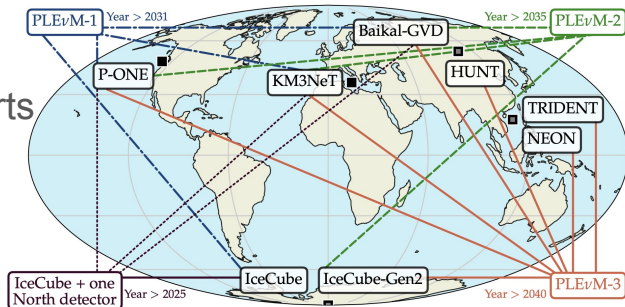
2-1. High-energy neutrino sources

Landscape in 2030

Objectives

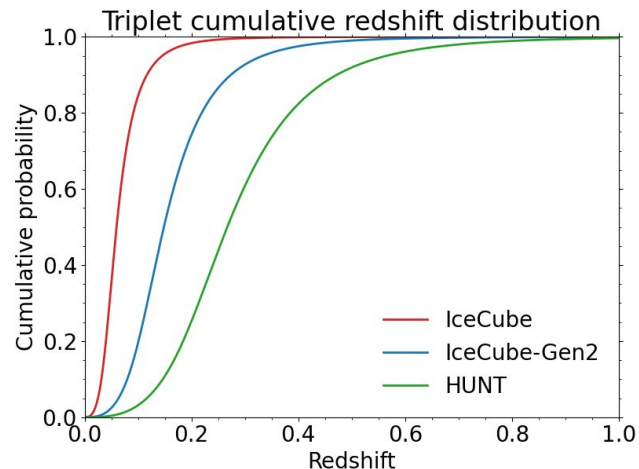
- Identification of EM counterparts
- Origin of high-energy particles
- Acceleration mechanism

Next-gen neutrino detectors



Schumacher + 2025

Sensitivity for neutrinos



Multiple cubic-kilometer-scale neutrino detectors

increase the global rate of neutrino detection by up to 30 times

Subaru 3 - Wide imaging ($\lesssim 1$ sq. deg)
- **Deep spectroscopy**
single ν event : $z \lesssim 2$, multiple ν : $z \lesssim 0.5$

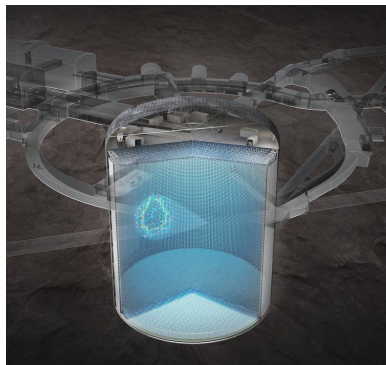
2-2. MeV neutrino sources

Landscape in 2030

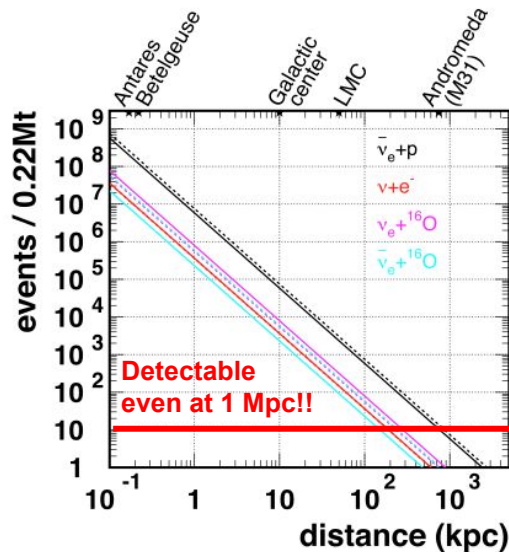
Objectives

- “All messenger” observations
- Explosion mechanism of supernovae
- Equation of state
- End point of stellar evolution (precursor neutrino for extremely nearby Galactic events)

SK-Gd & Hyper-Kamiokande



(C) ICRC



Abe+2021

Extremely rare event (1 event per > 30 years)

But needs Subaru depth if SN occurs behind the Galactic center

Subaru 3

- Immediate ToO observation (< 1 min)
- Continuous observations (flexible scheduling)
- Deep imaging and spectroscopy (high-resolution)

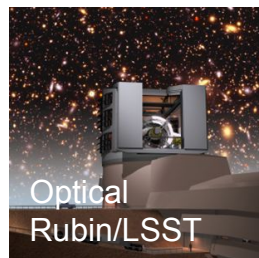
3. Transients

Landscape in 2030

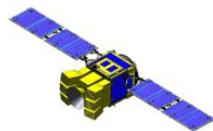
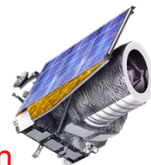
Objectives

- Census of transients
 - Any redshift, timescale, brightness
- High-redshift transients
 - Origin of elements
 - Evolution of the Universe
- Cosmology
 - Missing baryon
 - Cosmological params.

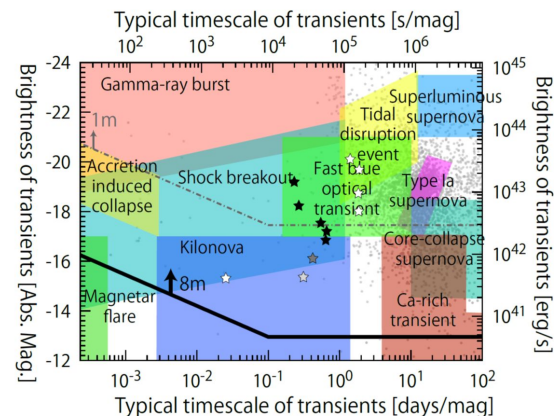
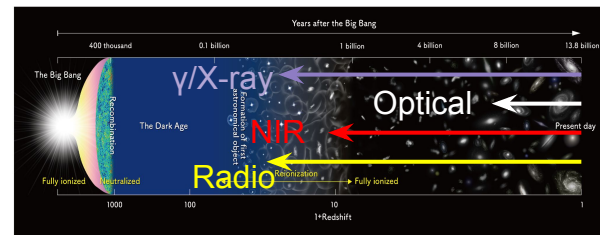
Next-gen transient surveys



NIR
Euclid
Roman



y/X-ray
High-z GUNDAM



Subaru 3

- Immediate spectroscopy (<1hr)
- Continuous follow-up (> 1yr)
- Simultaneous high-time-resolution imaging observation

Scientific targets: Summary

Targets	Alert rate	Area	Timescale	Instruments	Observing mode
1. GW Stellar mass	~10 per yr	~10-100 deg ²	~ hr - weeks	HSC, PFS, NINJA	Imaging Spectroscopy (low-res)
1. GW Massive BH	??	~1 deg ²	~ yr	HSC, PFS	Imaging Spectroscopy (low-res)
2-1. High-E ν	~10 per yr	~1 deg ²	~month	HSC, PFS, NINJA	Imaging Spectroscopy (low-res)
2-2 MeV ν (Galactic SNe)	~1 per 30 yr	~3 deg ²	~ min - yr	HSC, HDS	Imaging Spectroscopy (high-res)
3. Transients	~10-100/deg ²	—	~ min - yr	NINJA, PFS	Imaging Spectroscopy (low-res)

Subaru 3 x Multi-messenger/time-domain astronomy

Scientific requirements

- **Immediate target-of-opportunity observation / 即時追観測 (ToO)**
- Continuous observation / 継続観測

Instruments

- **Secondary mirror on WFC**
 - Make available other focus even with HSC or PFS
主焦点装置と他焦点装置の同日使用
- **CMOS S-Cam**
 - Simultaneous sub-second transients
秒スケール突発天体の同時観測

Flexible operation

- **Make all instruments immediately available
全装置即時使用可能に**
 - Uniformize the operation and user interface of all instruments / 全装置の観測UI統一
 - All queue observation / 全キュー観測
- Fiber-based ToO with PFS / PFSファイバーToO
- Optimization of scheduling/operation/network/data policy and scheme / ポリシー、オペレーションの最適化
- Collaboration with other telescopes/他望遠鏡との連携

One of new
“instruments”
新装置開発と
同等に重要

Subaru 3 as “Smart Subaru” / “AI Subaru”

These would benefit other science cases. 他のサイエンスにも有益

Subaru User Meeting FY 2026
NAOJ, June 19, 2026

Subaru 3 Exoplanet SubWG

On behalf of Exoplanet SubWG
Stevanus K Nugroho (Science Tokyo; ABC)

Members

- Bunei Sato (Science Tokyo; Subaru3 WG, Subaru SAC)
- Masashi Omiya (ABC)
- Motohide Tamura (U. Tokyo/ABC/)
- Noboru Ebizuka (RIKEN)
- Olivier Guyon (NAOJ)
- Stevanus Kristianto Nugroho (Science Tokyo) Chair
- Takayuki Kotani (ABC)
- Teruyuki Hirano (ABC)

Key open questions in exoplanet science

✳️ How common are true Earth analogues?

Can we detect Earth-twins around nearby stars?

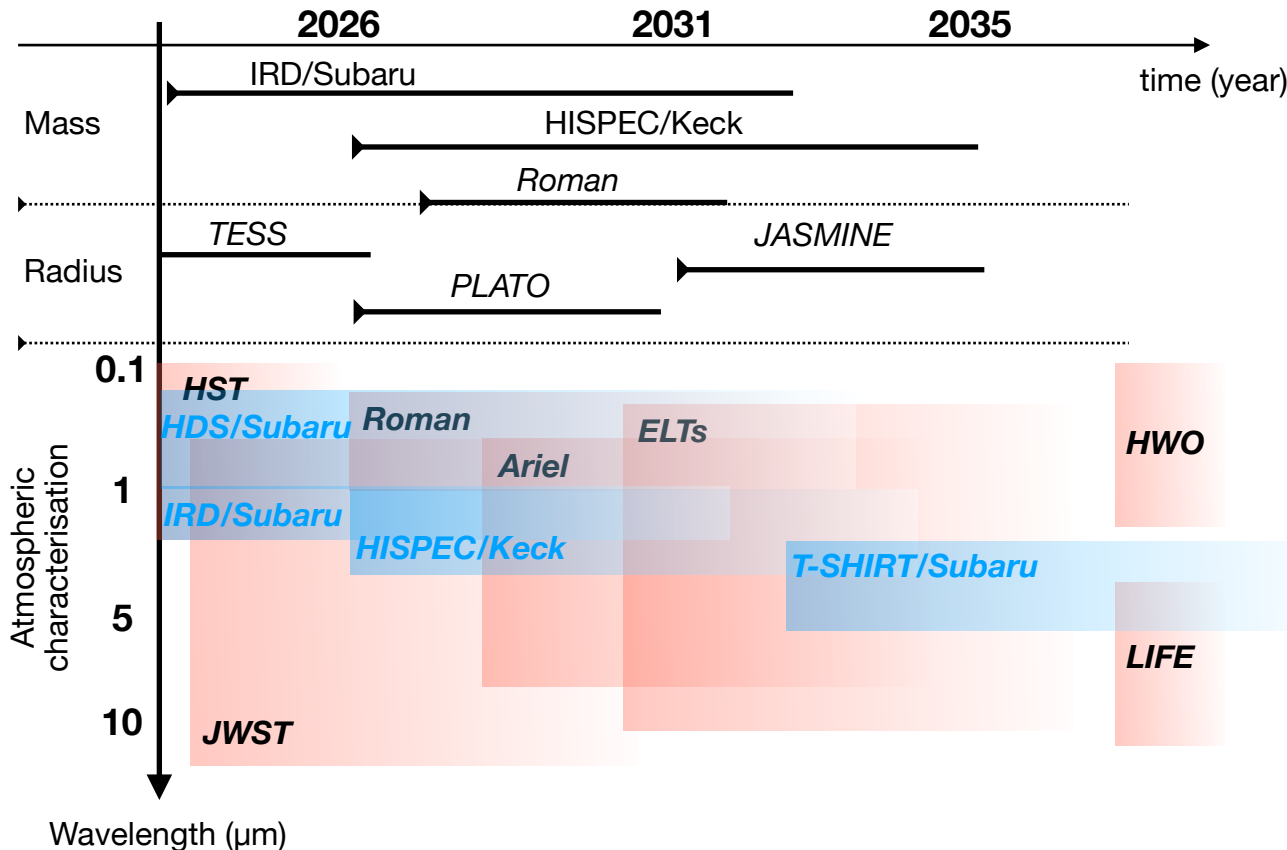
✳️ How do planetary systems form and evolve?

How do young planets connect to mature planetary systems?

✳️ What controls atmospheric physics in exoplanets?

How do chemistry, dynamics, and irradiation shape planetary atmospheres?

Exoplanet Landscape in the 2030s

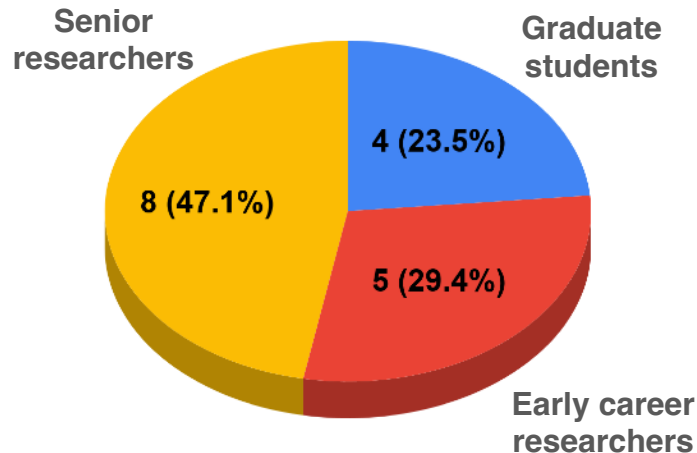


- PLATO will find transiting **small planets** and **long-period planets ($P > 150$ days)** around **bright stars ($V < 11$)**.
- ARIEL will explore the **atmospheres of hundreds of exoplanets** (at low spectral resolution)
- HWO will **directly image potentially habitable worlds**
- LIFE will measure the **atmospheric composition of dozens of temperate terrestrial exoplanets**

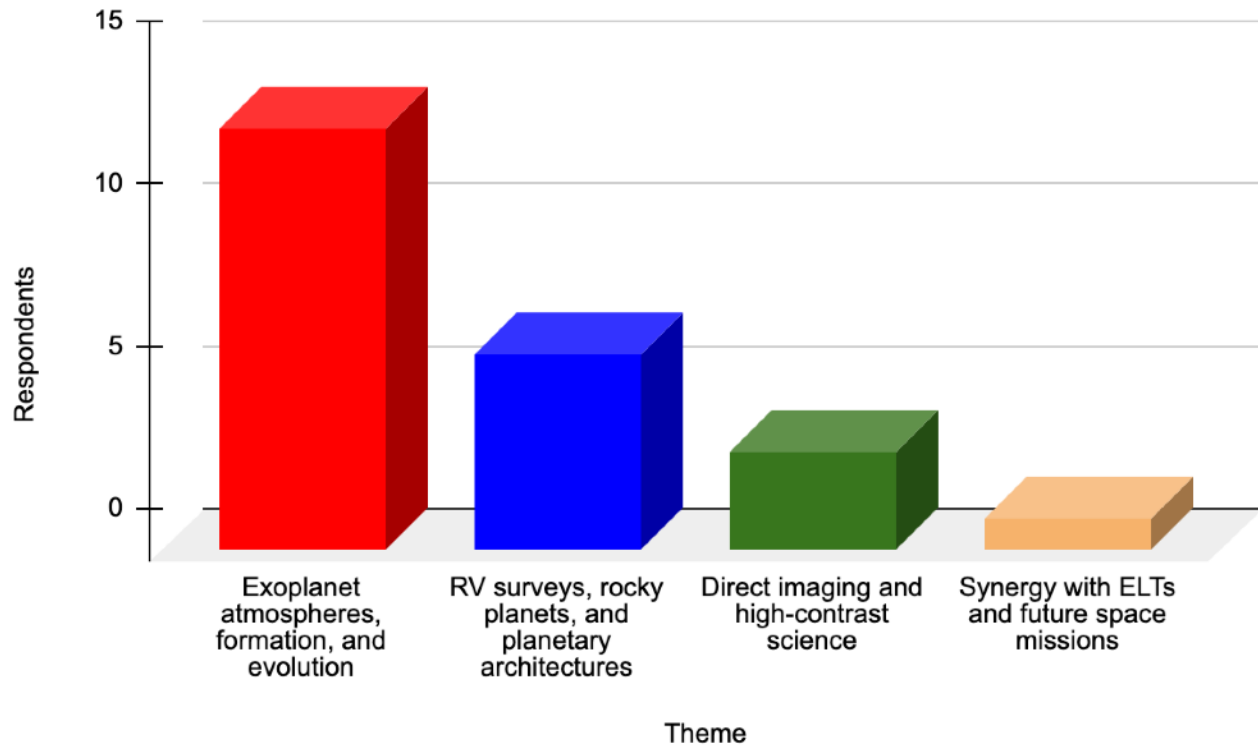
Community survey

- Survey aimed to collect views from the Japanese **exoplanet community (only)** on future Subaru 3 science.
- Total responses: 17 (JAXA/ISAS, Kyoto University, University of Tokyo, NAOJ, ABC, Science Tokyo, University of Hawaii). Thank you very much for your contribution!!
- **Questions:**
 - Q1: What exoplanet science do people personally want to pursue?
 - Q2: What should Subaru 3 focus on?
 - Q3: Why should Subaru 3 focus on those areas?
- Categories are not mutually exclusive.
- Each respondent is counted at most once per theme.

*Because of the small sample size, **career-stage trends** should be interpreted qualitatively rather than statistically.



Overall Q1 result: personal science interest



- **Atmospheres & spectroscopy**
Hot Jupiters, sub-Neptunes, brown dwarfs, chemistry, dynamics, high-resolution spectroscopy
- **Planet formation & evolution**
Formation pathways, atmospheric abundances, internal structure, population studies
- **Small planets & Earth twins**
RV/transit searches, rocky planets, long-period planets, Earth analogues
- **Orbital architecture & dynamics**
Transit follow-up, obliquity, migration history
- **Direct imaging & substellar companions**
Young planets, brown dwarfs, future ELT/HWO/Roman/LIFE targets



What Subaru 3 should do - and why

Subaru 3 science priority	Q2 support	Main Q3 reasoning
Exoplanet atmospheres, formation, and evolution	11 / 17	Subaru can provide high-resolution/high-dispersion atmospheric characterisation complementary to JWST, ARIEL, and ELTs
RV surveys, rocky planets, and planetary architectures	8 / 17	Long-term RV surveys can map nearby planetary systems and prepare targets for HWO/LIFE
Direct imaging and high-contrast science	6 / 17	Builds on Subaru's AO/high-contrast heritage and connects to reflected-light, ELT, and future space-mission science

Strategic priority	Q2 support	Main Q3 reasoning
Synergy with ELTs and future space missions	6 / 17	Subaru can provide precursor observations, target screening, and flexible follow-up before expensive ELT/HWO/LIFE observations
Instrumentation and technology development	8 / 17	Subaru 3 can serve as a technology platform for HRS, RV precision, AO/ExAO, calibration, and high-contrast science

Example of related projects

✳️ **Super precise HRS** ($R > 300,000$)

- HDS upgrade+visible Nasmyth focus AO+**HDS-comb**
 - $R > 300,000$, $\sigma_{RV} < 10$ cm/s, >UV efficiency, +infrared channel (red optical), temporal resolution $< \sim 10$ s
- HDS comb (astrocomb for HDS) **P25**
- HIDES-F ($R \sim 300,000$ is already on 188m Okayama telescope)

✳️ **Ultra-Doppler** ($R \sim 100,000$, $\sigma_{RV} \sim 1-3$ cm/s) **P05**

- ExAO in the visible is the key instrument to get the extreme precision and compact spectrograph
- Needs 10 years of survey targeting selected 100 stars ($V \sim 2.82-7.67$, *preliminary*) -> expected outcome is 10 Earth-twins (based on Kepler data)

✳️ **T-SHIRT** (KL(M), $R \sim 100,000$) **P19**

- Add crucial capabilities to Subaru to :
 - Detect **C-, S-, N-bearing molecules**
 - Atmosphere of cooler planets, $T < 1000$ K) targetting HCN, CO₂, C₂H₂, NH₃, SiO, etc
 - C/O ratios, volatile-to-refractory ratios, ¹²CO/¹³CO for planet formations

✳️ **SCEXAO** **P28, 29, 30, 31, 32, 33, 35**

- GAIA DR4 end of 2026 -> GAIA-assisted survey
- The long-term plan is to move to TMT
- ExAO in the visible will take quite some time to work on the TMT
- Disk science at short wavelength around nearby stars is best on 8-m class telescope

Draft of exoplanet science goal for Subaru 3*

Goal:

“To explore planetary diversity, origins, and potential Earth analogs around Sun-like stars for signs of life”

Objectives:

1. **Reveal the chemical composition, climate, and dynamics of exoplanets and substellar objects for different mass, temperature, and age regimes** using high-resolution spectroscopy and/or high-contrast observations in synergy with JWST and Ariel
2. **Reveal the architecture and formation history of planetary systems** by measuring their obliquity and/or searching for possible long-period companions *using an ultra-precision radial velocimeter* through collaboration with PLATO and GAIA
3. **Detect Earth analogues around nearby Sun-like stars** *using an ultra-precision radial velocimeter* and establish the foundation for future habitability studies with HWO, LIFE, and TMT
4. **Develop the technology and observing strategies** required for the next stage of exoplanet exploration using Subaru as a testbed

*a working progress

Three key extreme pillars+queue mode

Exoplanet science in Subaru 3



**Extreme high-resolution
spectrograph**

Ultra-Doppler, HDS 2.0,
IRD, T-SHIRT



Extreme AO

SCExAO



**Extreme high-contrast
spectrograph**

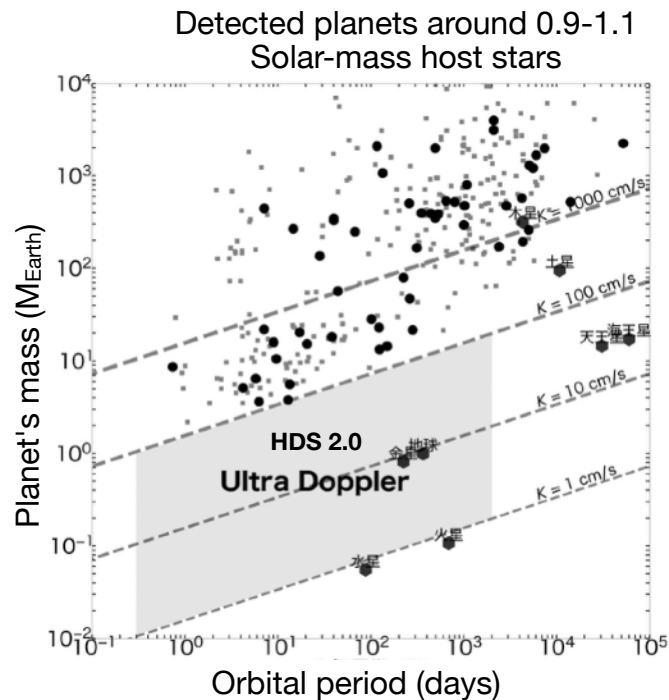
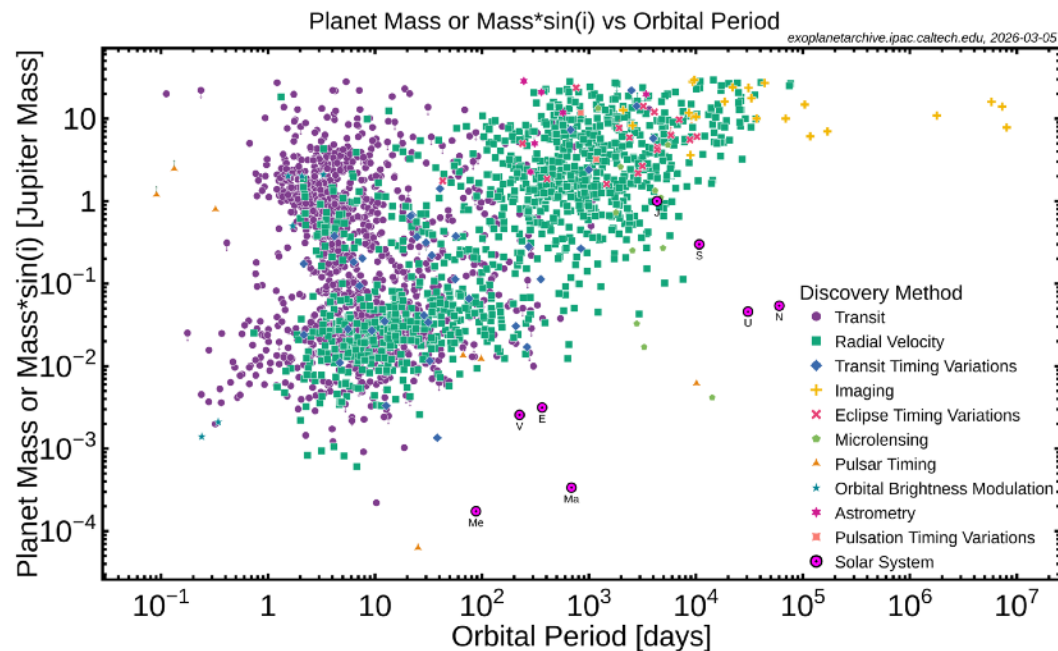
CHARIS, REACH, K-REACH,
FIRST-PL, NIR-PL, Exo-Ninja

Backup

Where Subaru 3 can lead

Discover nearby Earth analogues

- How common are **Earth-twins around nearby Sun-like stars**?
- Small planets around nearby Sun-like stars are unexplored
- Creating target lists for HWO and LIFE



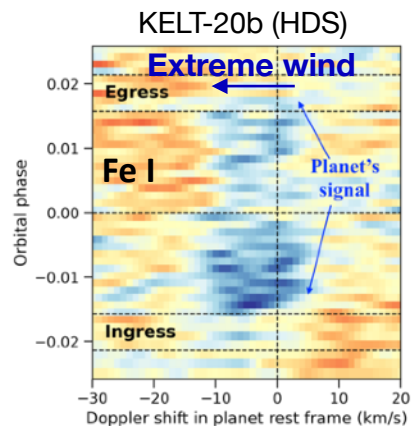
Where Subaru 3 can lead

Understand diversity exoplanetary atmospheres across the population

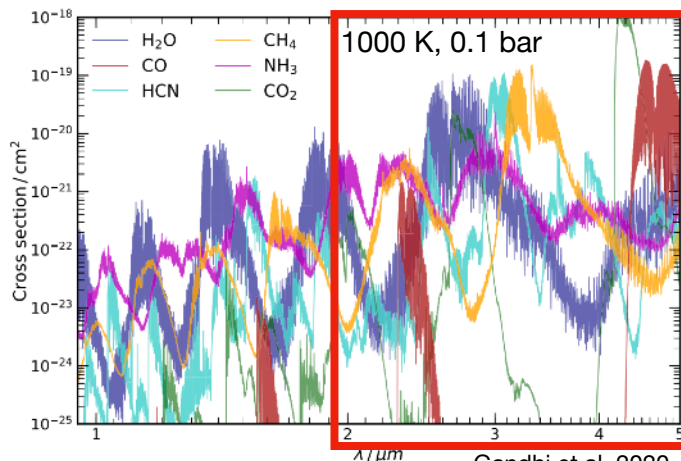
- What controls atmospheric chemistry and dynamics?
- How do atmospheres vary across different planet types?
- Mini-Neptune vs Super-Earth; hot-start vs cold start?

Understand how planetary atmosphere evolve?

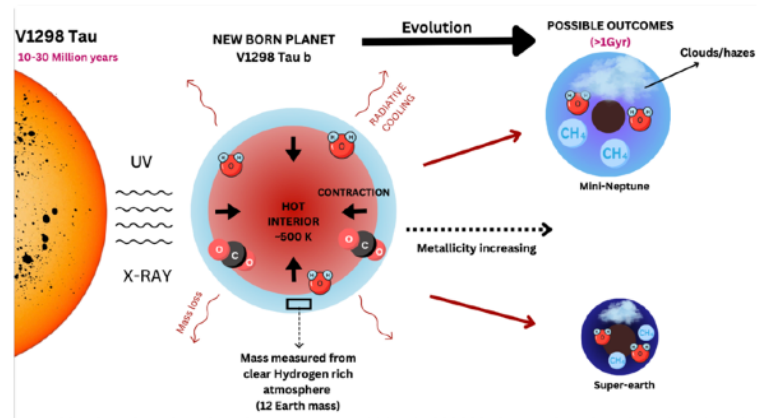
3D atmospheric dynamics & chemistry of hot gas giants



Seeing through the clouds of longer-period exoplanets (cooler planets)

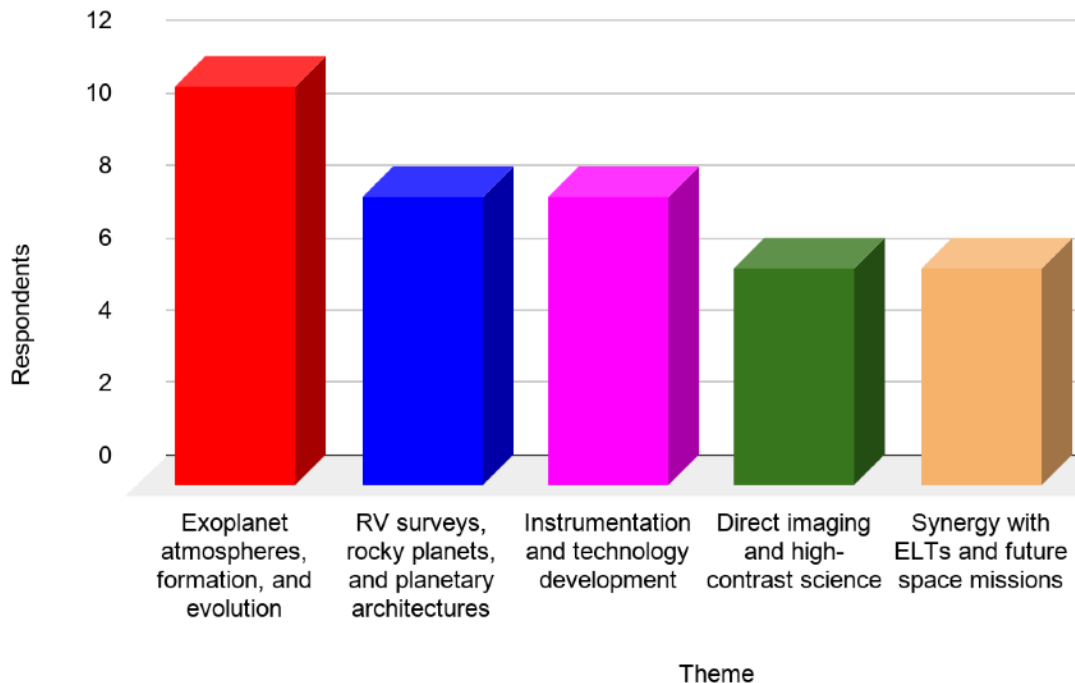


How planetary atmosphere evolve? (Young transiting+direct imaged exoplanets)



Adapted from materials written by the Netherlands Research School of Astronomy (NOVA) and Marieke Baan.

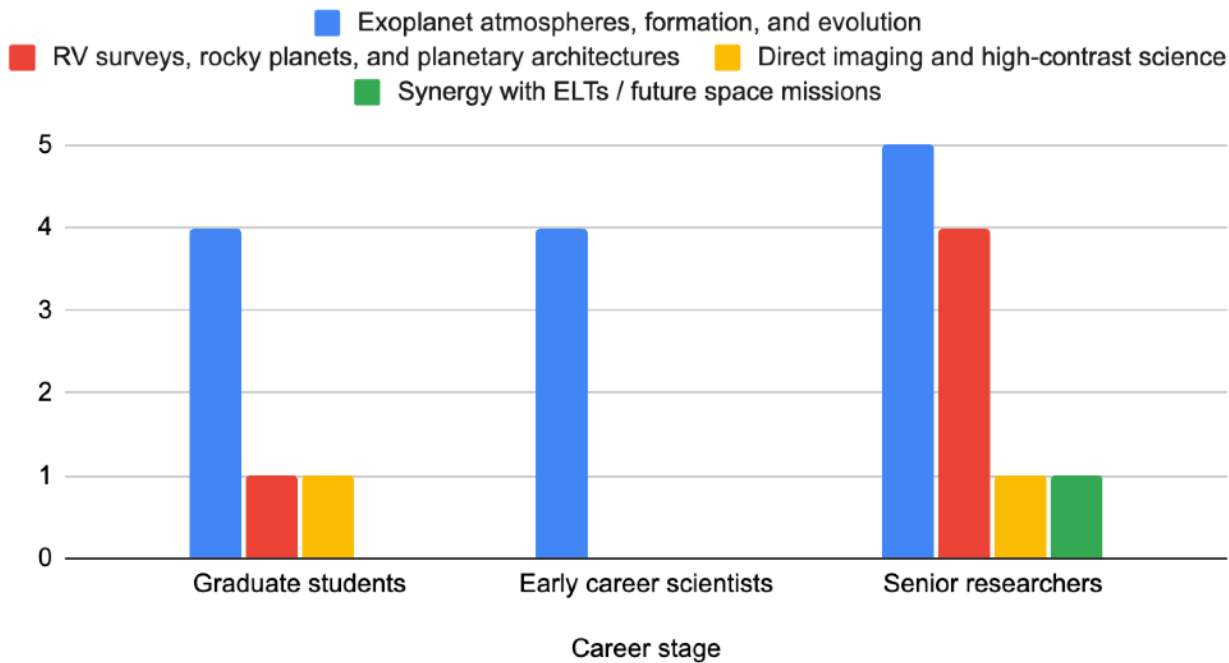
Overall Q2 result: Subaru 3 priorities



- **Atmospheres & spectroscopy**
Atmospheric chemistry of cool planets, young planets; dynamics, and 3D structure of hot Jupiters
- **Small planets & RV**
Earth twins, low-mass planets, mass measurements, HWO/LIFE target preparation
- **Instrumentation development**
Ultra-Doppler, T-SHIRT, IRD upgrades, precision RV, multi-wavelength capability
- **Direct imaging & ExAO**
Young planets, protoplanets, substellar companions, high-contrast technology
- **Bridge to future facilities**
Follow-up and target selection for ELTs, Ariel, PLATO, JWST, Roman, HWO, and LIFE

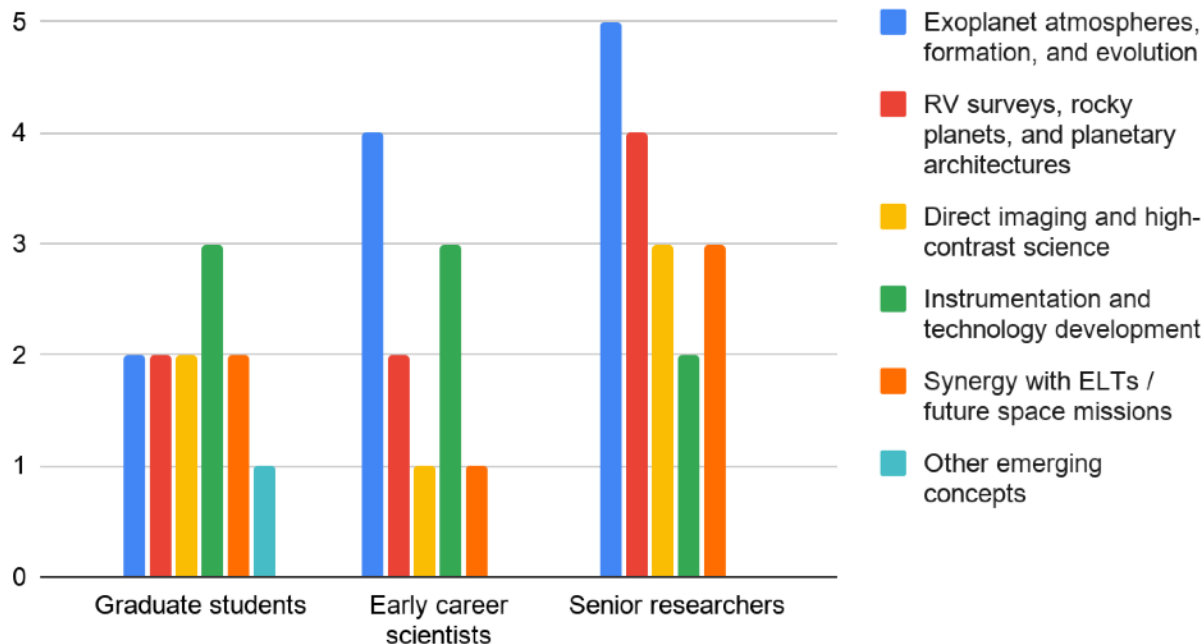
By career stage (please take it with a big grain of salt)

Personal exoplanet science interest

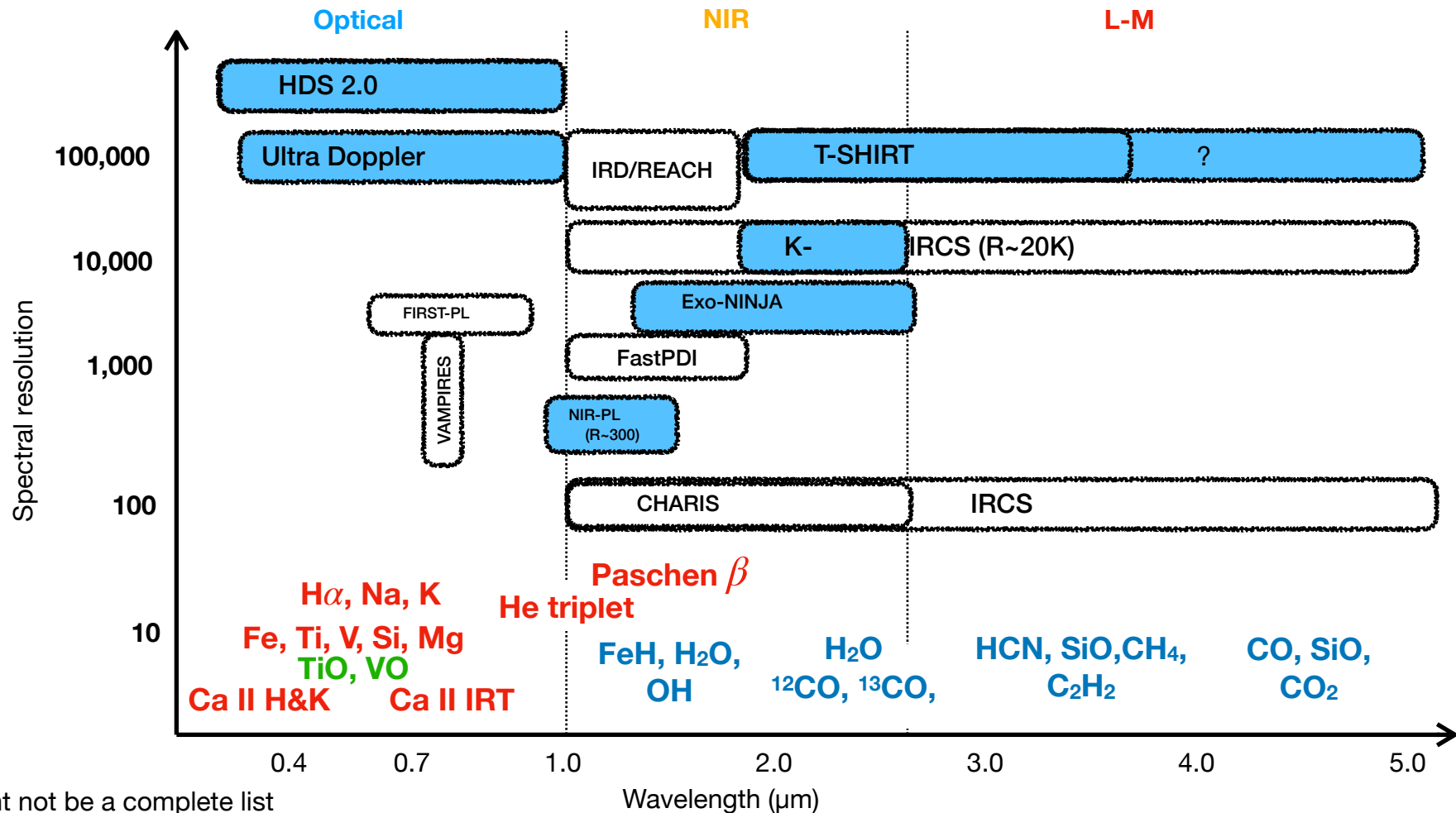


By career stage (please take it with a big grain of salt)

Priorities for Subaru 3

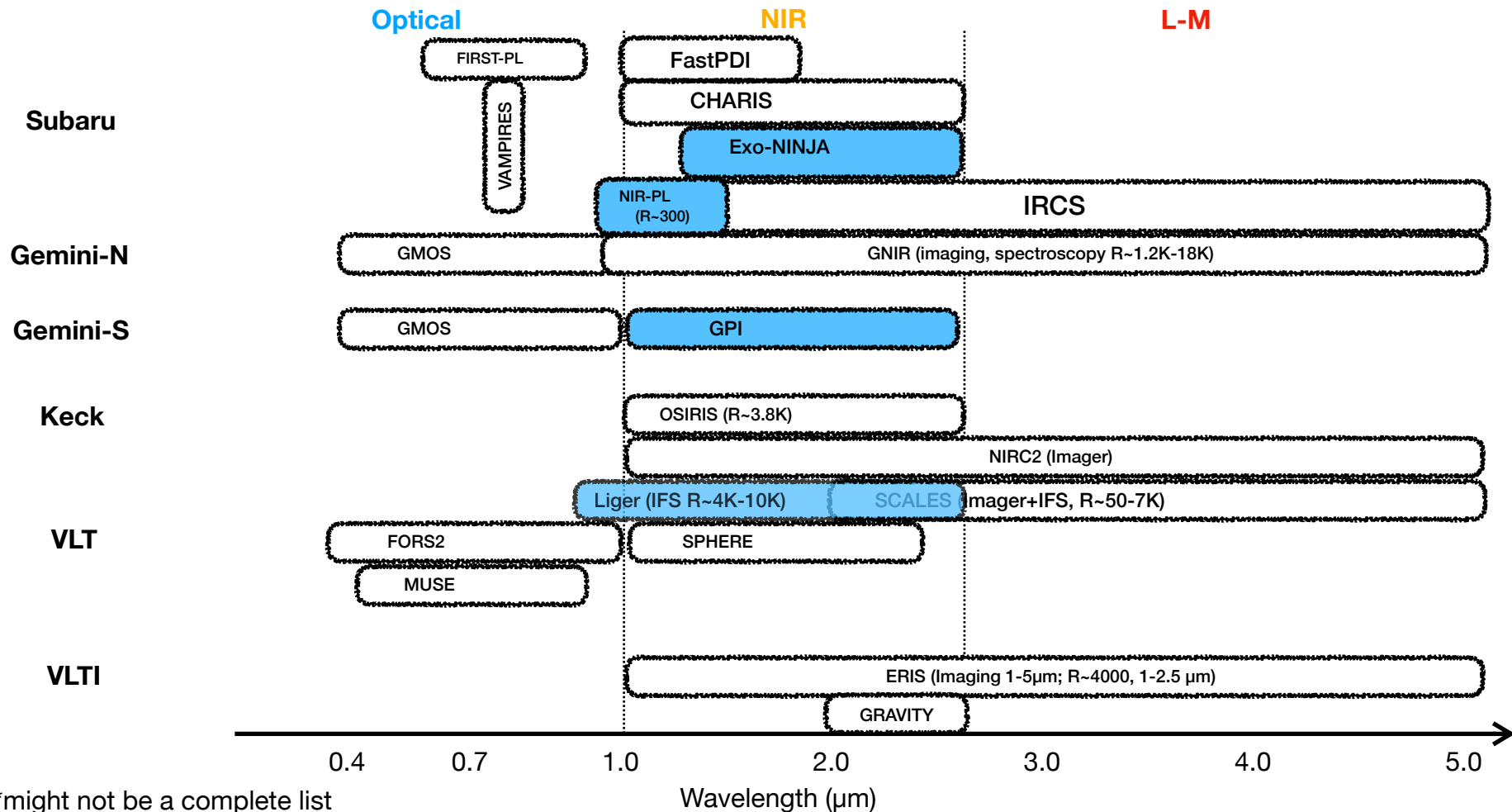


Current and planned: exoplanet-related instruments on Subaru

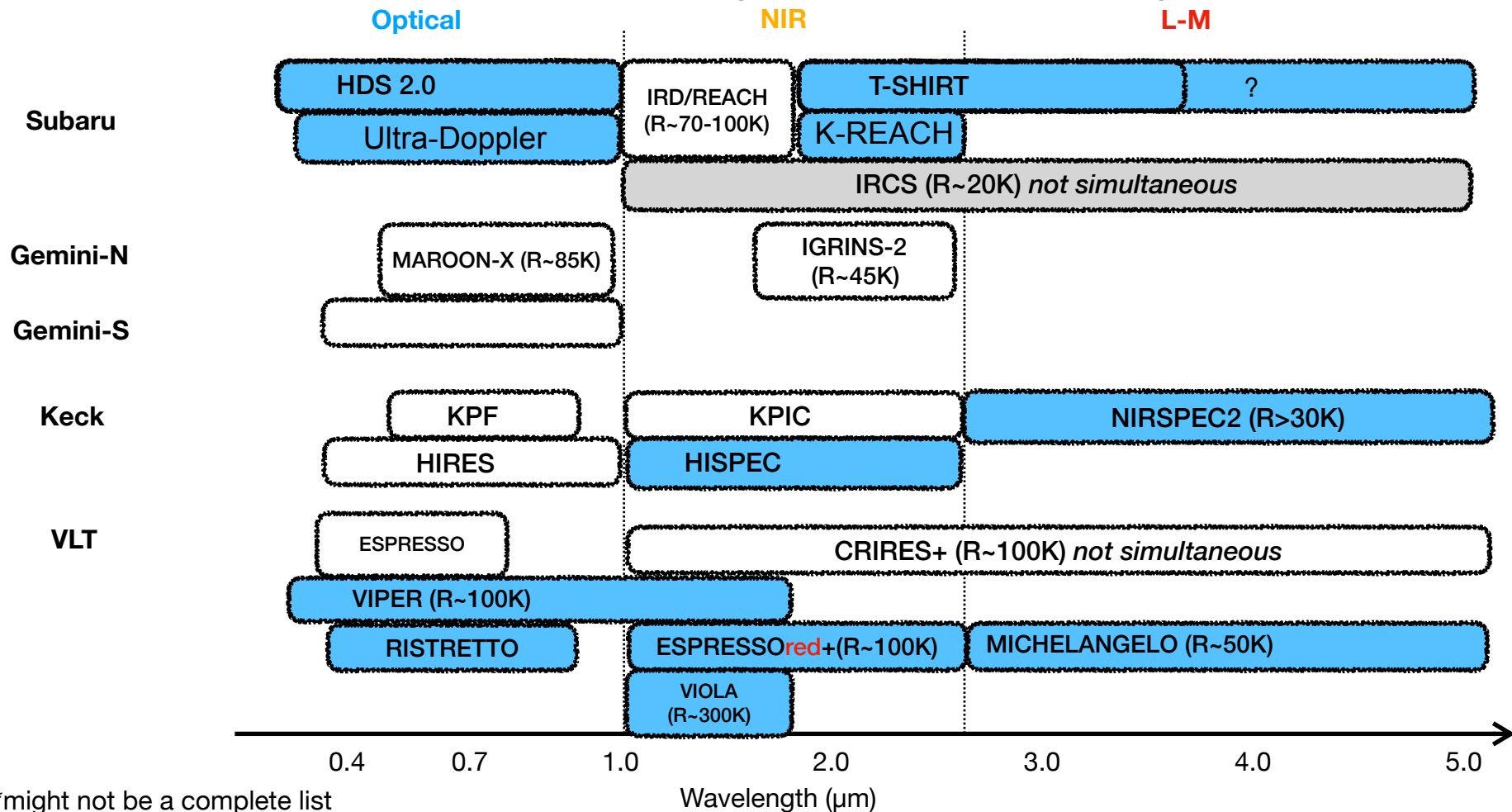


*might not be a complete list

Current and **planned**: high-contrast imager and low-res. spectrograph



Current and **planned**: high-resolution spectrographs



Status of the Subaru 3 Galactic Archaeology subWG

**Yutaka Hirai, Tadafumi Matsuno, Miho Ishigaki, Masashi Chiba,
Yutaka Komiyama, Naoyuki Tamura, Nozomu Tominaga,
Itsuki Ogami, Yoshihisa Suzuki, Kyosuke Sato, Ryo Ishikawa,
Kohei Hayashi, Sakurako Okamoto**

Science Goal in Galactic Archaeology sub WG

Understand the formation of the Milky Way and nearby galaxies, as well as the origin of elements

Wide-field survey



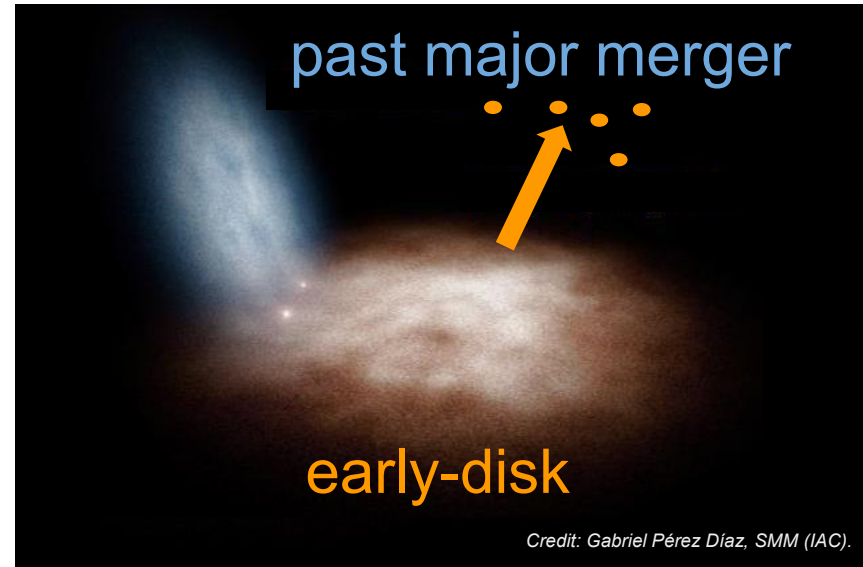
- Chemo-dynamical structures and the assembly history of the Milky Way
- Star formation and metal enrichment of dwarf galaxies and globular clusters
- The origin of elements from Li to Th

Milky Way

Scientific Objective

Reconstructing a unified formation history of disk, halo (and bulge) based on stars

- I. In-situ formation: Disk (and Bulge)
- II. Interface: In-situ and Accreted populations
- III. Assembly history: Halo



Dwarf galaxies

Scientific Objective

Understanding chemical evolution and the structures of dwarf galaxies

- I. Detailed chemical abundances encoding early star formation histories**
- II. Structures of dwarf galaxies as a probe of the nature of dark matter**



Globular clusters

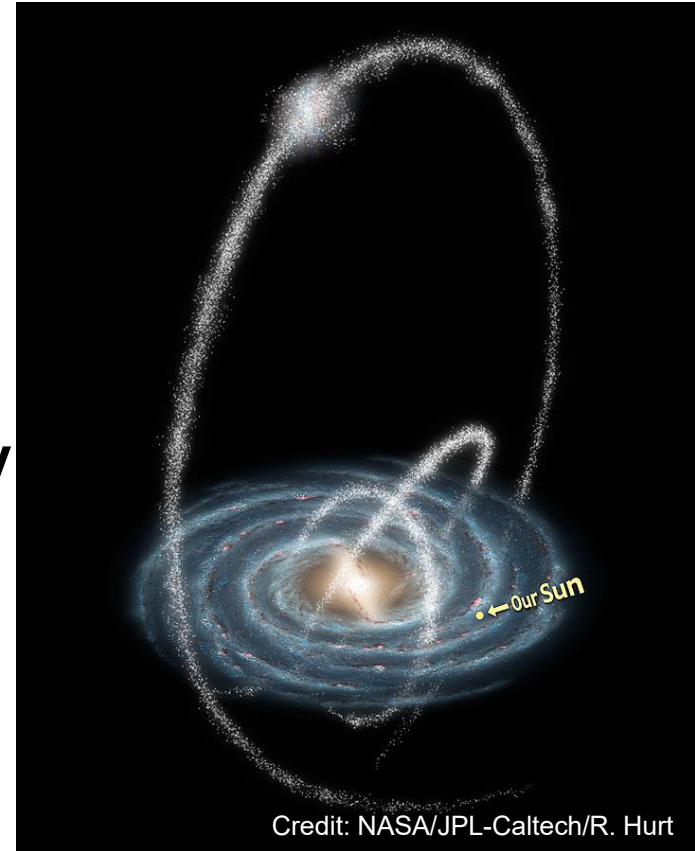
Scientific Objective

Unveiling the assembly history of the Milky Way and properties of globular clusters

I. Dynamical evolution of the Milky Way

II. Constraints on the Galactic potential from globular cluster streams

III. Origin of globular clusters

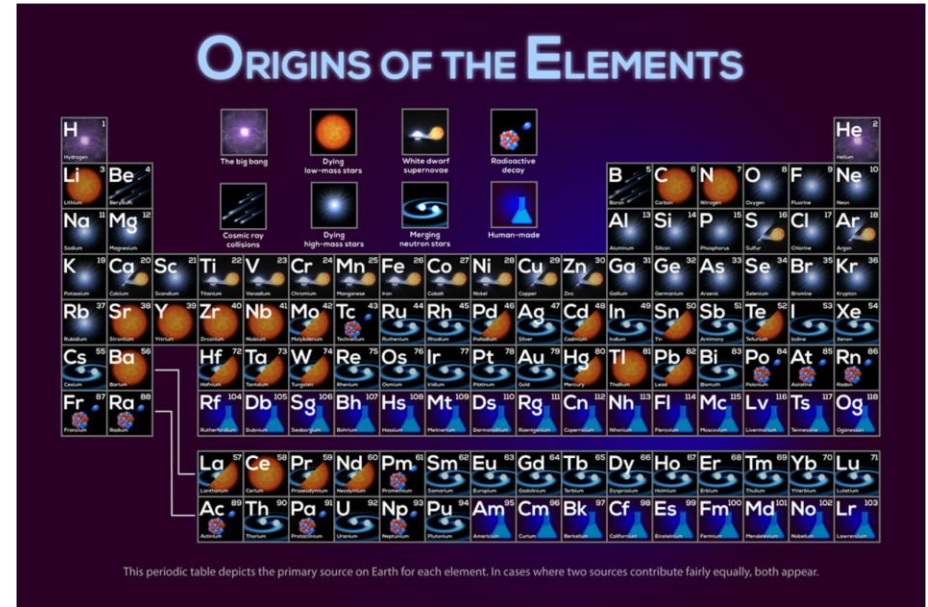


Nucleosynthesis

Scientific Objective

Clarifying the origin of elements and chemical evolution in the Universe

- I. What synthesizes elements?
- II. When are elements synthesized?
- III. Where are elements synthesized?



PFS High Resolution Mode

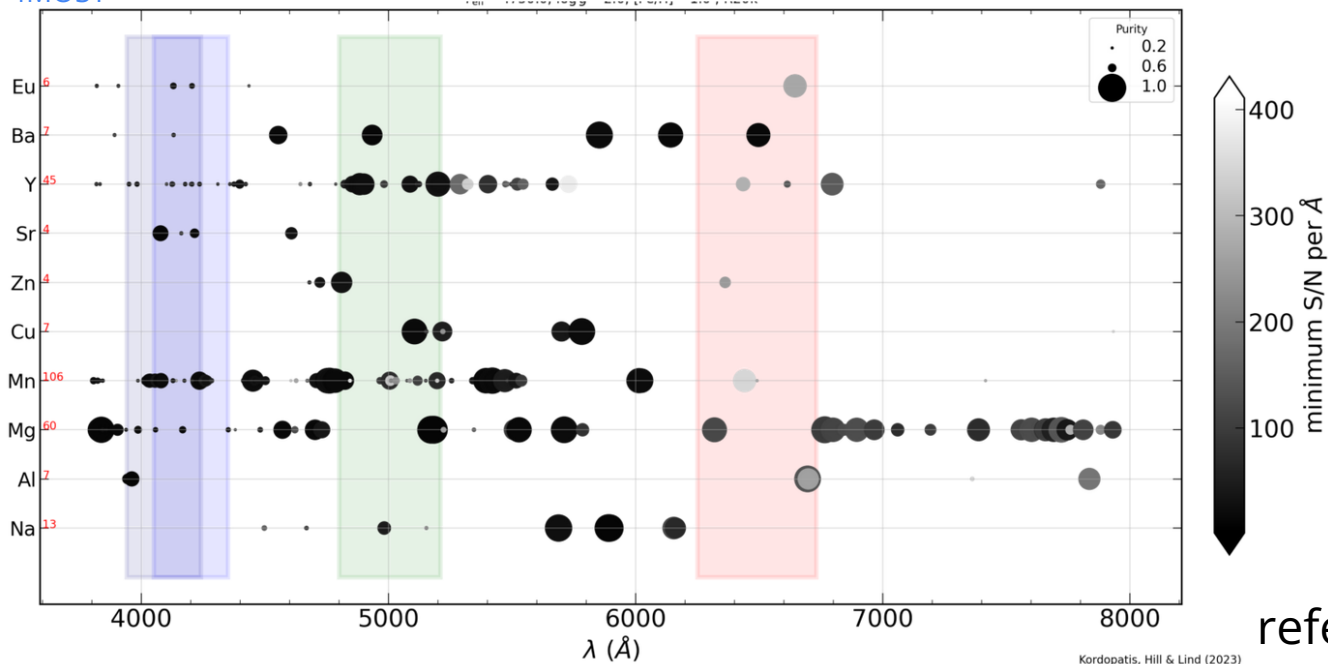
Resolution: $R \sim 20,000$

Fibers: $\sim$ a few hundred

Chemical abundances of stars with $g < 17$ mag

Potential wavelength coverage

CCD: 4k x 4k, a few spectrographs, wavelength sampling: FWHM / 2.7



reference: Kordopatis +23

Example setup

Wavelength: 407.7, 421.5 nm (Sr), 454.4, 619.6 nm (Ba II), 664.5 nm (Eu II), N, Na, Al, CN, CH

Blue: CH or Al, CN, Mg, Mn, Sr, (Y), (Ba), Eu

Green: (Na), Mg or Zn, Cu, Y, Ba, H β

Red: (Al), (Mg), Ba, (Eu), H α

2 spectrographs: Blue + Green

3 spectrographs: potentially broader application with H α

4 spectrographs: Na D lines (between G and R), O triplet (~770 nm), or NIR?

Summary

The goal of the Galactic Archaeology subWG is to understand the formation of the Milky Way and nearby galaxies, as well as the origin of elements.

We are proposing PFS high-resolution mode

Subaru3 Milky Way sub-working Group

Kumiko Morihana

on behalf of the Milky Way sub-working group

Members

- The Milky Way sub-group was launched in Jan. 2026, and we did online meetings (Jan. 15, 21, Feb. 12, 17)
- As of today, our group has collected members' science and instrument ideas for the Subaru 3 era.

Members (As of 06.14.2026) ※no particular order

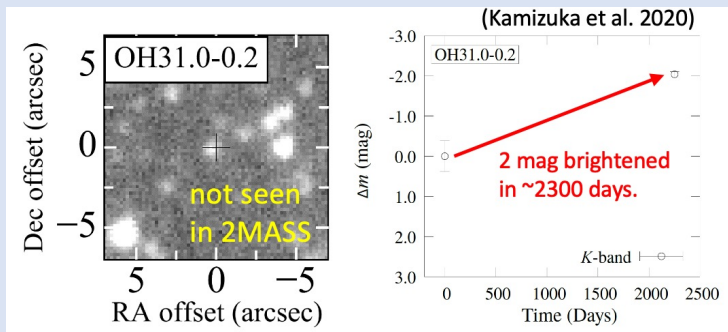
Kumiko Morihana, Rei Enokiya, Ryou Osawa, Masao Saito, Yuhei Takagi, Rin Yamada (NAOJ), Hiroki Onozato (National Institute of Technology, Fukushima College), Takafumi Kamizuka, Noriyuki Matsunaga (Univ. of Tokyo), Takuma Kokusho (Nagoya Univ.), Shogo Nishiyama (Miyagi University of Education)

- Motivation
 - Exploring the individual stellar populations that make up our Galaxy and investigating the distribution of stars at various evolutionary stages contributes to our understanding of **when and how our Galaxy formed**.
- Science Targets
 - Stars: Dwarfs, AGB–phase, post-AGB phase, Cataclysmic Variables etc.
 - Diffuse phenomena
 - Star formation
 - Synergy with radio astronomy

Science Ideas

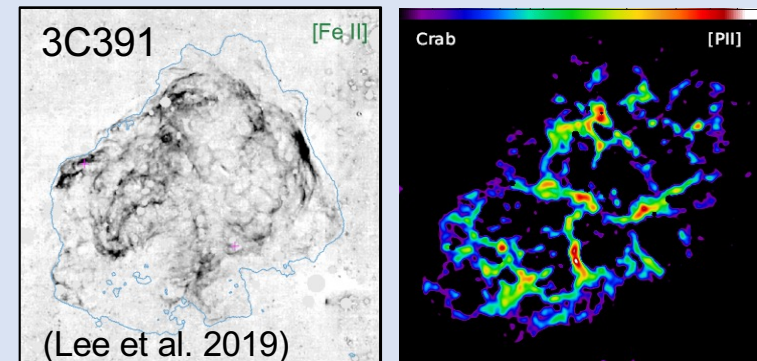
Find Non-variable OH/IR stars (by Kamizuka)

- NIR unexpected brightening has been discovered for these objects, which can be related to their rapid evolution



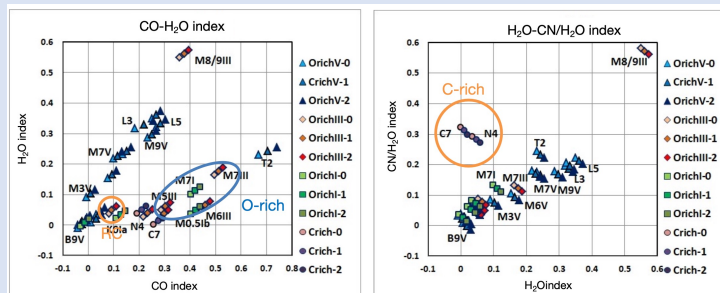
NB filter image mapping of SNRs (by Kokusho)

- A study of dust processing in SNRs
- Detection of Phosphorus in SNRs



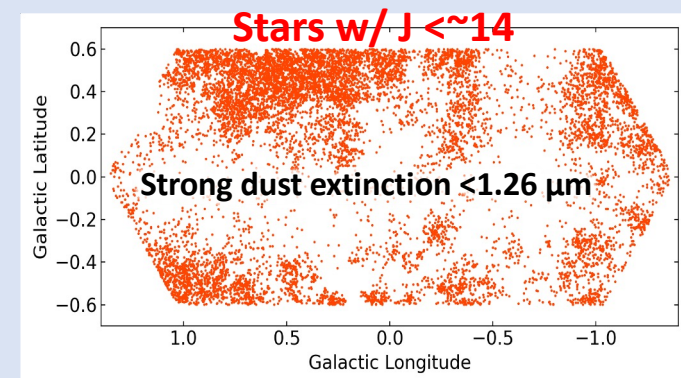
Stellar classification & distribution (by Onozato)

- Investigate the structure of the galactic plane and the history of star formation
- Classify RC, late-type main sequence stars, C-rich/O-rich AGB **medium-band filters**



Observe the Nuclear Stellar Disk to reveal the bar and secular evolution (by Nishiyama)

- Spectroscopy of stars of NSD

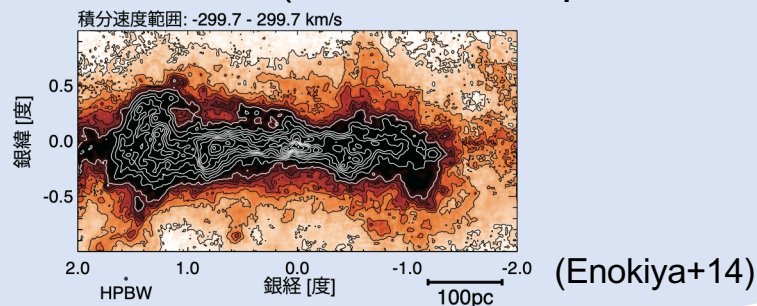


Science Ideas

Magnetic fields in MW center

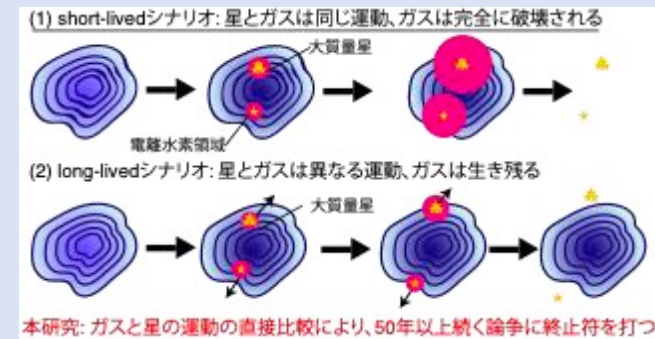
(by Enokiya)

- Vertical B fields associated with molecular gas are not observed so far
- Deep and large-scale magnetic field in the Galactic Center (ULTIMATE + polarimetry)



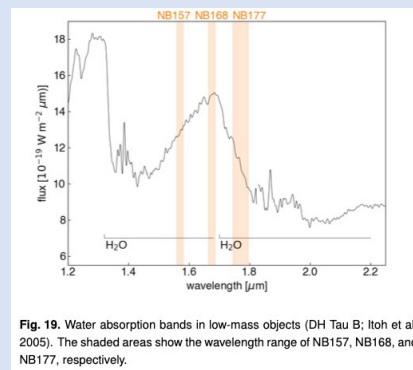
Investigating Star Formation through Gas and Stellar Kinematics & distribution (by Yamada)

- Search evolution time scale of Galactic molecular clouds



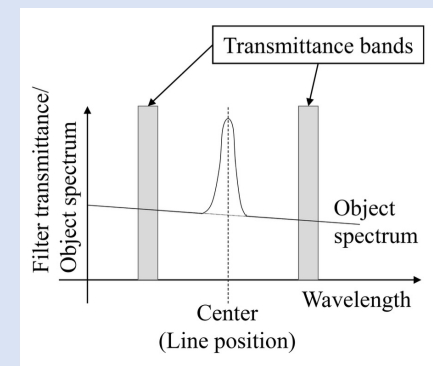
Exploring Star and Planet Formation Processes (by Takagi)

- Reveal the Initial Mass Function (IMF) for each star-forming region
- Statistical Discussion of Protoplanetary Disk Formation and Evolution



Search for faint Cataclysmic Variables along the Galactic Plane (by Morihana)

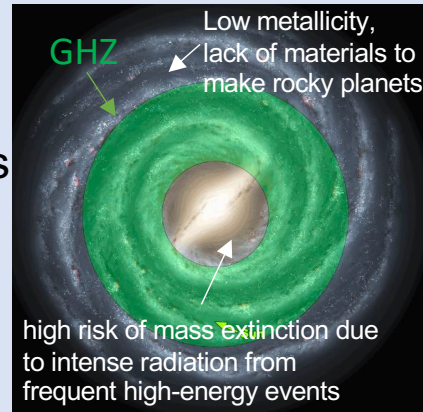
- Detecting faint CVs with small equivalent-width lines using dual-band narrow-band filters



Science Ideas

Galactic Habitable Zone study based on dwarf star observations (by Matsunaga)

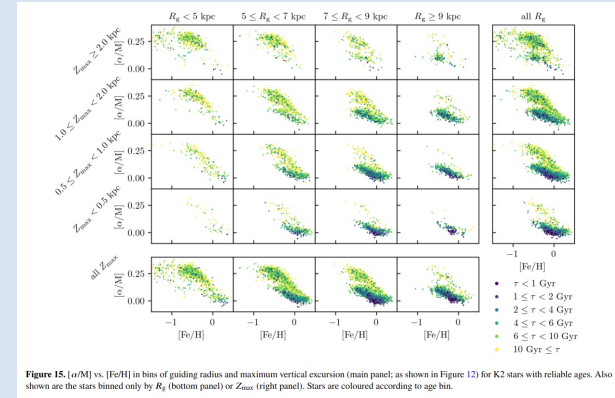
- Elemental composition obtained from giant star spectroscopic surveys is used to discuss → should be discussed with dwarfs
- NIR spectroscopy



Lineweaver et al. (2004)

Understanding stellar evolution requires precise age determination (by Ozawa)

- Asteroseismology : reliable method for determining individual stellar ages.

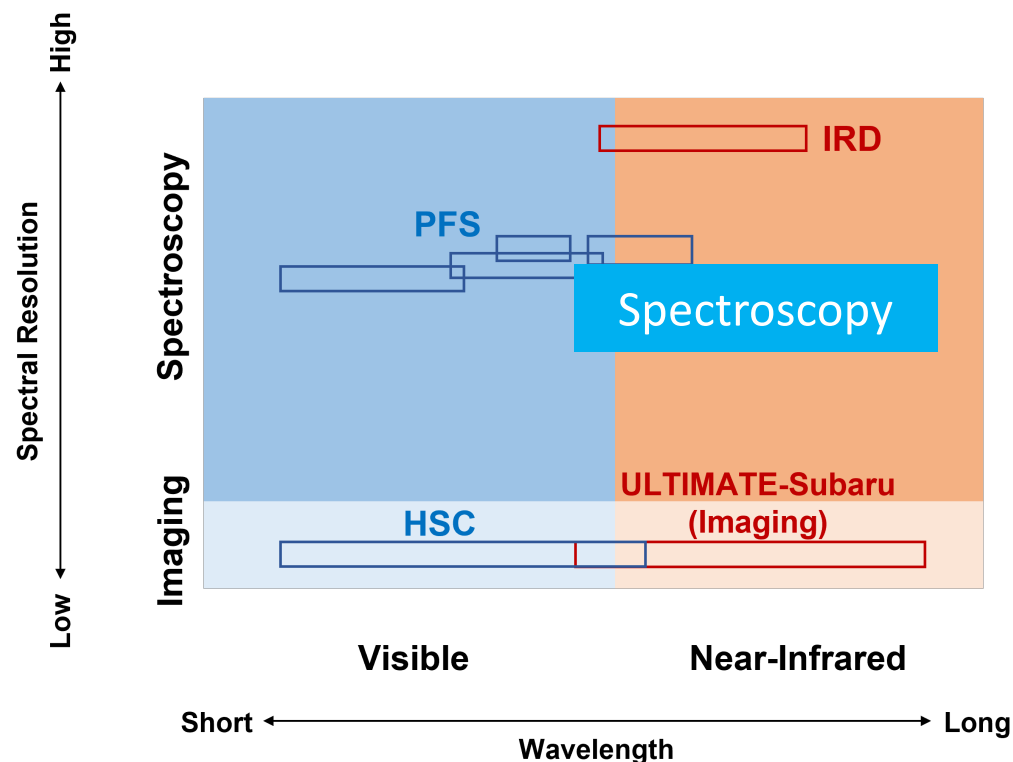


Software System for Maximizing Science Output (by Saito)

- Implement a suite of functions that bridge the gap between vast observational data and physical insights, supporting everything from observation preparation to physical modeling
- Real-time collaboration with other telescopes

Upgrade of Instruments

- Based on our scientific ideas, the following instrument upgrades are requested for the Subaru 3 era.
- Upgrade of PFS
 - **High-resolution** ($R \sim 20,000$)
 - Effective temperature
 - Elemental composition measurements
 - Chemical age indicators
 - Stellar activity indicators
 - Extend to H- and K-band
- GLAO+MOIRCS
 - NIR Multi-Object Spectroscopy + AO
 - $R \sim 2000 - 3000$
 - ※MOIRCS is planned to be decommissioned after the coming of ULTIMATE/WFI at Cs.
- High-dispersion polarimetric spectroscopy



Demand for NIR Spectroscopy (up to K-band)

Summary

- As an initial step, we have synthesized each member's science ideas and specific requirements for the upcoming Subaru 3-era instrumentation.
- The proposed science cases span a diverse range of scales, from point sources to extended celestial phenomena:
 - Stars: Includes spectroscopic surveys of dwarf stars to define the Galactic Habitable Zone , as well as the detection of faint Cataclysmic Variables (CVs).
 - Stellar Evolution: Detailed studies of non-variable OH/IR stars transitioning between evolutionary phases.
 - Star-Forming Regions: Investigations into GMC lifetimes and the Initial Mass Function (IMF) across various molecular cloud environments.
 - Extended/Large-scale Phenomena: Mapping of SNRs to study dust processing and exploring the Central Molecular Zone (CMZ) and Nuclear Stellar Disk (NSD).
 - Magnetic Fields: Large-scale mapping of magnetic field configurations within the Galactic Center.
- There was a demand for **H- and K-band spectroscopy** (both medium and high resolution) as essential capabilities for Subaru 3-era instrumentation.
- Moving forward, the Milky Way group will focus on discussing how to integrate these diverse science cases into a cohesive scientific narrative

If you want to join MilkyWay sub working group, please contact me (Morihana@naoj.org)

Subaru3 Galaxy Evolution subworking group

-current status-

Kei Ito (Cosmic Dawn Center) on behalf of Subaru3 GE subWG

Subaru3 Galaxy Evolution subworking group

- **Current status**
 - 19 members
 - chairs: Kei Ito (DAWN / DTU) & Yuichi Harikane (U.Tokyo / ICRR)
 - Seven meetings so far.
- **Overall plans**
 - **Science leveraging Subaru's large-survey capability and high sensitivity.**
 - Under consideration
 - wide-field IFU
 - multi-object IFU for Cosmic Noon galaxies
 - high-z science with wide-field observation
 - new proposal category for more flexible observation
 - Started to be considered
 - SMBH/AGN



Wide-field IFU observation for IGM and CGM

[Goal]

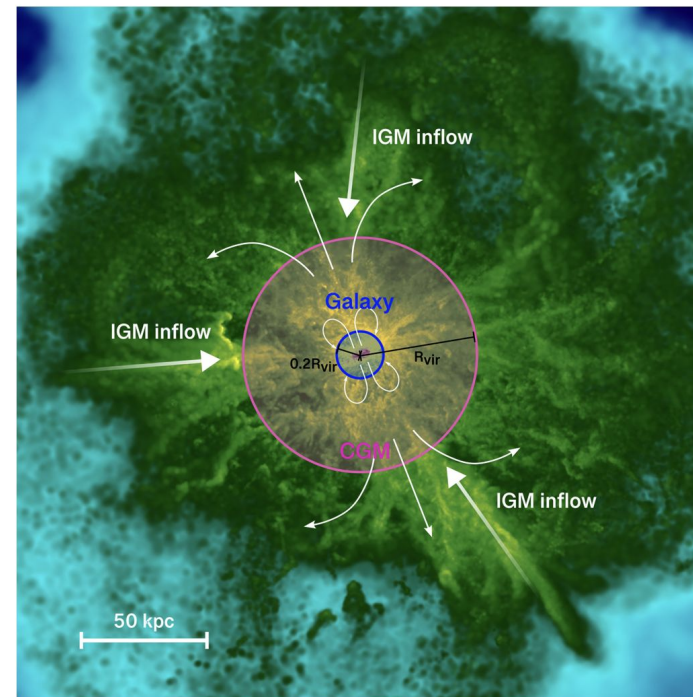
- Evolution of CGM around evolving galaxies
- Baryon cycle from Cosmology-scale to galaxy-scale
- Chemical evolution of CGM/IGM

[Observation/Instrument we need]

- Wide-field (larger than $3' \times 3'$?) IFU with spatial sampling of $\sim 0.2'' \times 0.2''$
- IFU with a wide-wavelength range with high spectral resolution.

[Impact]

- Tracing the gas distribution in the large-scale structure



6 times larger scale than this field of view.

Multi-object IFU observation of galaxies at Cosmic Noon

[Goal]

- Examining the spatially resolved properties of galaxies at Cosmic Noon

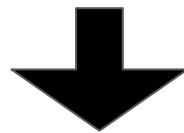
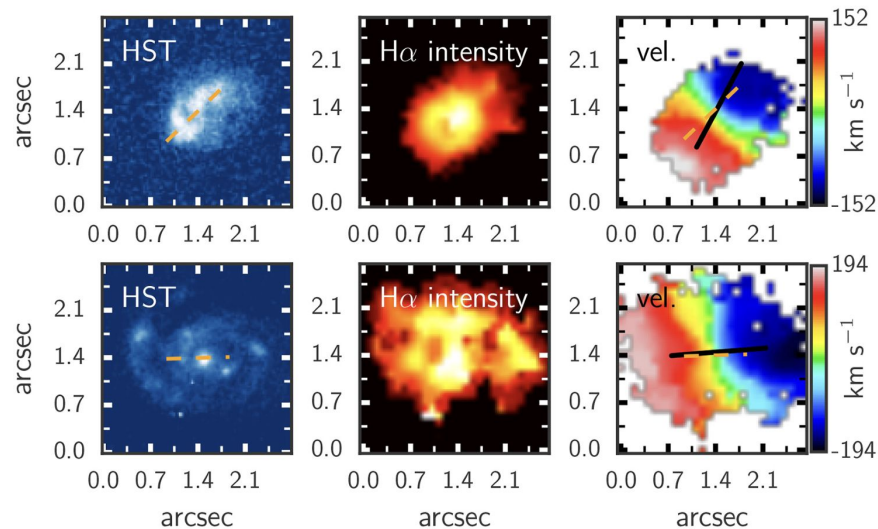
[Observation/Instrument we need]

- A large sample of spatially resolved observations of >1000 galaxies at Cosmic Noon
- AO-fed multi-object IFU (as part of ULTIMATE?)

[Impact]

- JWST/30-m telescopes only provide a small number of objects due to the small field of view.

Spatially-resolved line map from VLT/KMOS (Tiley+19)



- Larger sample ($N>1000$)
- better resolution with AO

Wide-field observation for high- z galaxies

[Goal]

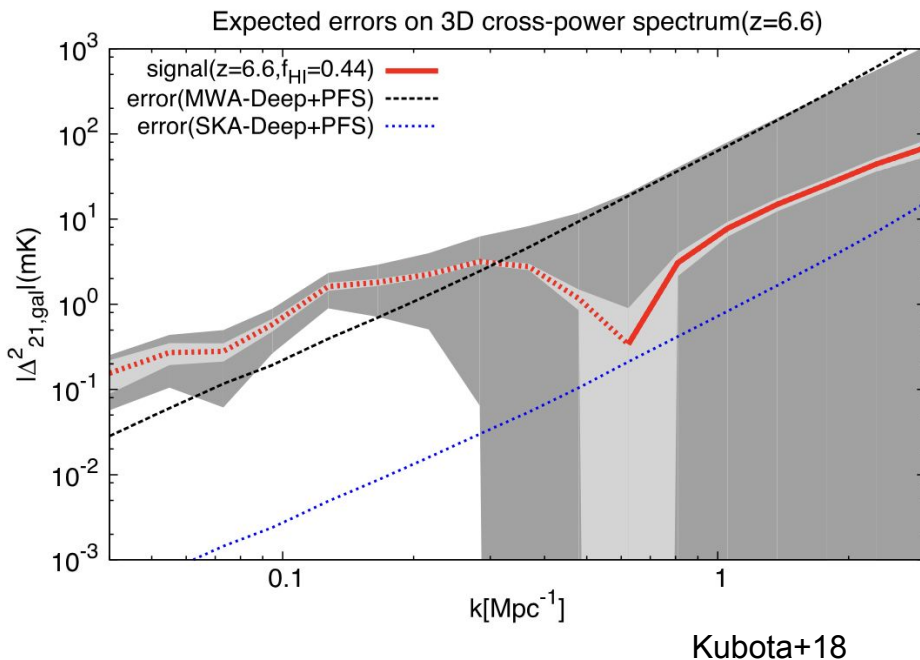
- Finding bright Pop-III galaxy candidates from wide-field imaging
- Mapping the reionization

[Observation/Instrument we need]

- Large NB imaging with ULTIMATE to select Lyman α emitters at high redshift ($z \sim 8-9$)
- Cross-correlation between PFS LAE sample at $z \sim 7$ and SKA HI 21cm map.

[Impact]

- Providing targets for spectroscopic follow-up with JWST or 30m telescopes



More flexible observation programs with current instruments

[Goal]

- Making Subaru's legacy value by allowing more flexible time allocations, such as very large observing programs that are not possible in the current framework.

[Observation/Instrument we need]

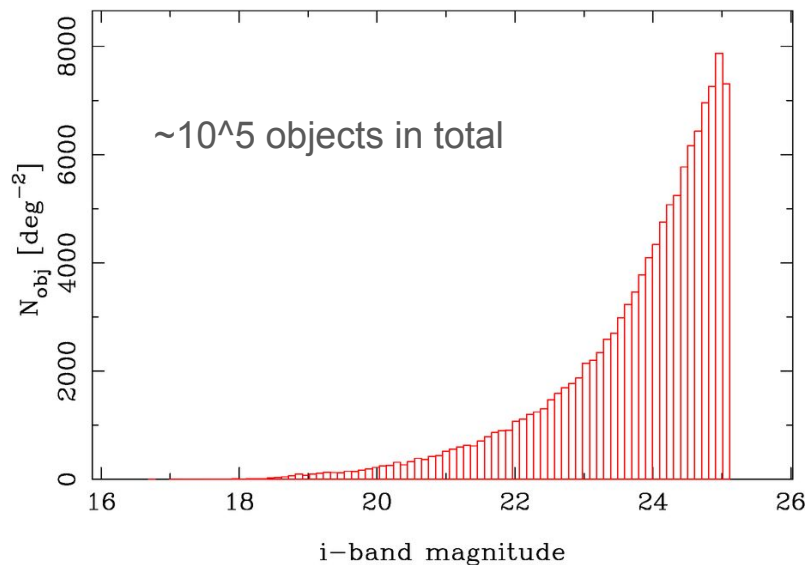
(some examples)

- Maximum 100 nights with multiple instruments for an intensive program.

[Impact]

- It will allow more impactful observations.

Discussion in the all Subaru 3 WG has started (led by Masayuki Tanaka-san), more on later talk.



Example of a massive program: Observing flux-limited sample of galaxies in famous cosmological fields (50-100 nights in total).

Others, Summary

We are discussing the science case leveraging Subaru's wide-field capacity and high sensitivity.

[Ideas of new instruments / observations]

- Wide-field IFU
- Multi-object AO-fed IFU
- Wide-field observation for high-redshift galaxies (ULTIMATE, PFS)
- More flexible observational programs

[Other ideas]

- IFU mode of the PFS
- Longer wavelength extension of the PFS
- Larger HSC-MB survey

New observing proposal scheme

- The discussion started in the galaxy WG. Now, all WGs are involved.
- A new scheme to allow flexible & larger time allocations will strengthen Subaru 3's capabilities. It will be a good way to compete with larger telescopes.
- Taking this opportunity, we will revisit the current rules and policies (many of them are from ~25 years ago...) and make changes to improve science output.
- Please join our discussion! It is crucial to incorporate input from you! Some of the discussion items on the overall framework include:
 - Why not switch from a semester system to a yearly system?
 - Can we make queue observing default for all instruments?
 - Shall we revisit the balance between different science categories?
 - How best we can/should use DDT?
 - Etc, etc.

New observing proposal scheme

プログラム	最大観測夜数	期間	LOI (事前連絡)	締切	装置利用	規模・参加人数	審査	採択後レビュー	備考
SSP	最大 500 夜	最長 5 年	1-2 年前	なし (随時)	複数可	日本コミュニティ 全体 (約 200 人) 必須	TAC+外部	毎年レビュー (不通過で終了)	大規模共同研究
Intensive (Large)	最大 100 夜	最長 3 年	1 年前	通常 締切	複数可	約 50 人規模 (広い参加推奨)	TAC+外部	毎年レビュー (不通過で終了)	SSP より小規模
Normal	最大 20 夜	1 年	不要	通常 締切	複数可	チームレベル (約 10 人)	通常審査	なし	標準的プログラム
Small	最大 5 夜	1 年	不要	通常 締切	複数可	個人レベル (1-3 人)	通常審査	なし	小規模研究
ToO (fast-track)	最大 5 夜 (目安)	単発	不要	なし (随時)	複数可	個人～研究室 (1-10 人)	TAC のみ	なし	時間制約のある 観測、queue 観測 推奨

More detailed proposal categories are here. This is just a table to start with, but it should give you an idea. We will discuss science operations, etc, down the road as they are tightly related to the proposal categories.

Join our discussion here:

<https://docs.google.com/document/d/1H9mDrRNli06y0IRD CWU2NsT9sQYHHJBPTM7FyaF6Qrs/edit?usp=sharing>

(the link is available from the UM's google doc)

About Subaru 3.0 x TMT-ACCESS Workshop

Rieko Momose (Carnegie Observatories)

Taichi Uyama (ABC), Hiroki Onozato (Fukushima KOSSEN), Tomoya Kinugawa (Shinshu U.),
Ryuji Suzuki (NAOJ), Haruhisa Tabata (JAXA/ISAS), Shota Notsu (U. Tokyo),
Yasuhiro Hasegawa (JPL), Mayuko Mori (ABC), Yoneta Kenta (TUAT)



What is TMT-ACCESS?

TMT-ACCESS = TMT eArly Career Centered, Engineers-Scientists Synergy

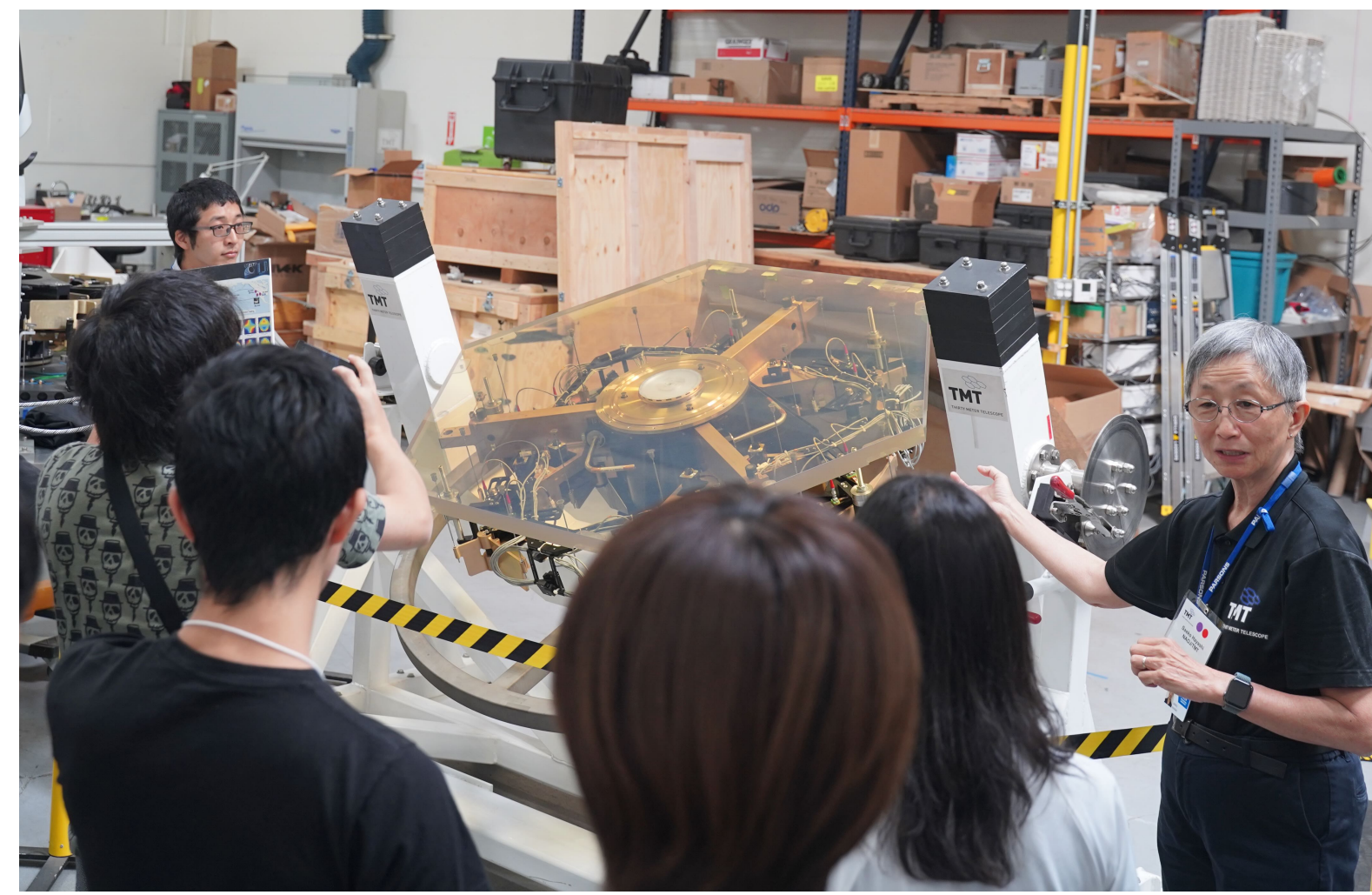
A TMT workshop series led by **early-career researchers**,
aiming to create new TMT science cases
and propose next-generation TMT instruments.

Interdisciplinary

Discussion-Oriented

**Early-career
Centered**

**Science—
Engineering
Collaboration**



What is TMT-ACCESS?

We have **3** workshops in Japan and the US, bringing together **111** participants and exploring more than **10** future TMT instruments.

◆ 2023

Date : September, 2023
Venue. : TIO Office
Participants : 30

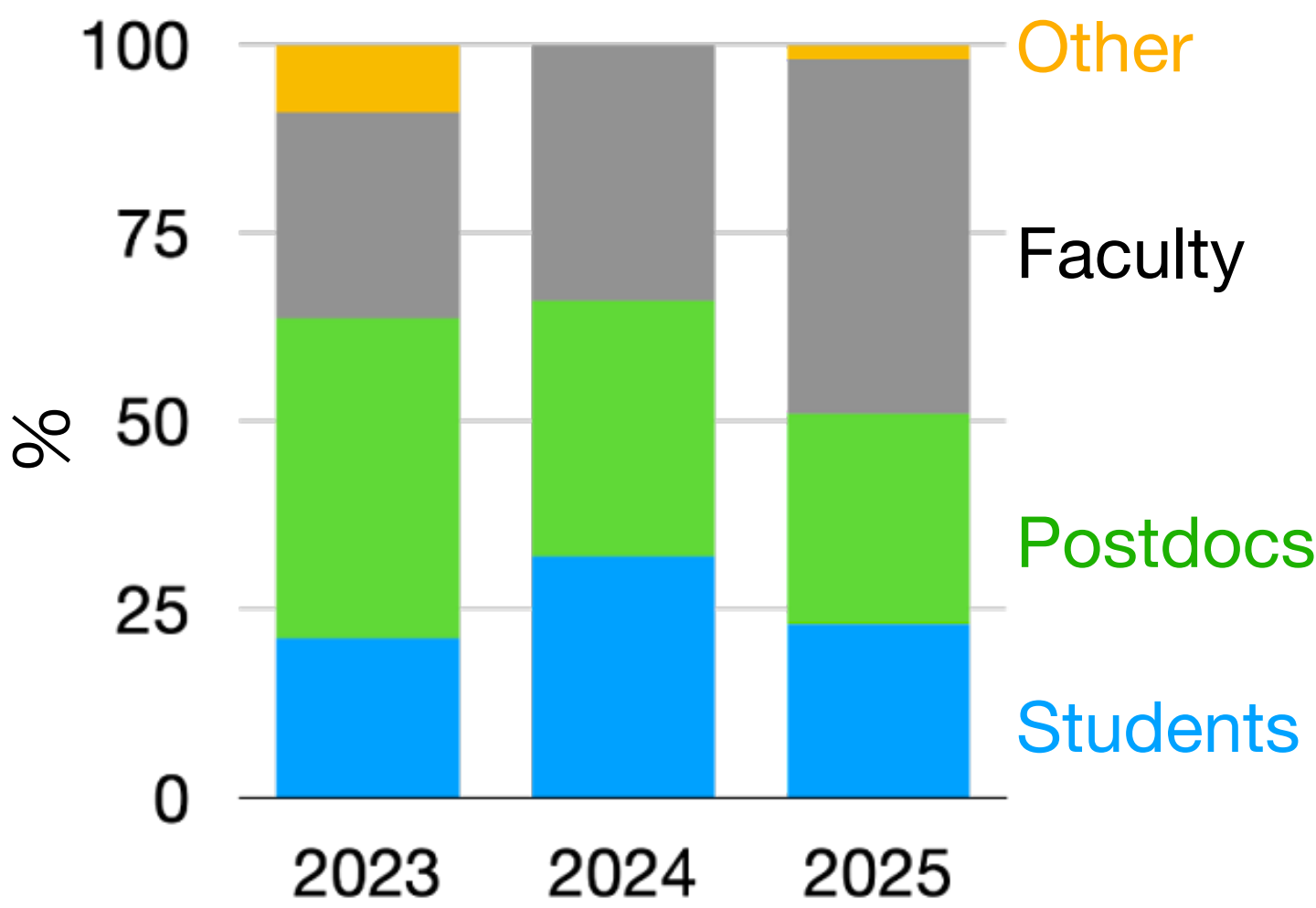
◆ 2024

Date : June, 2024
Venue. : Tohoku University
Participants : 38

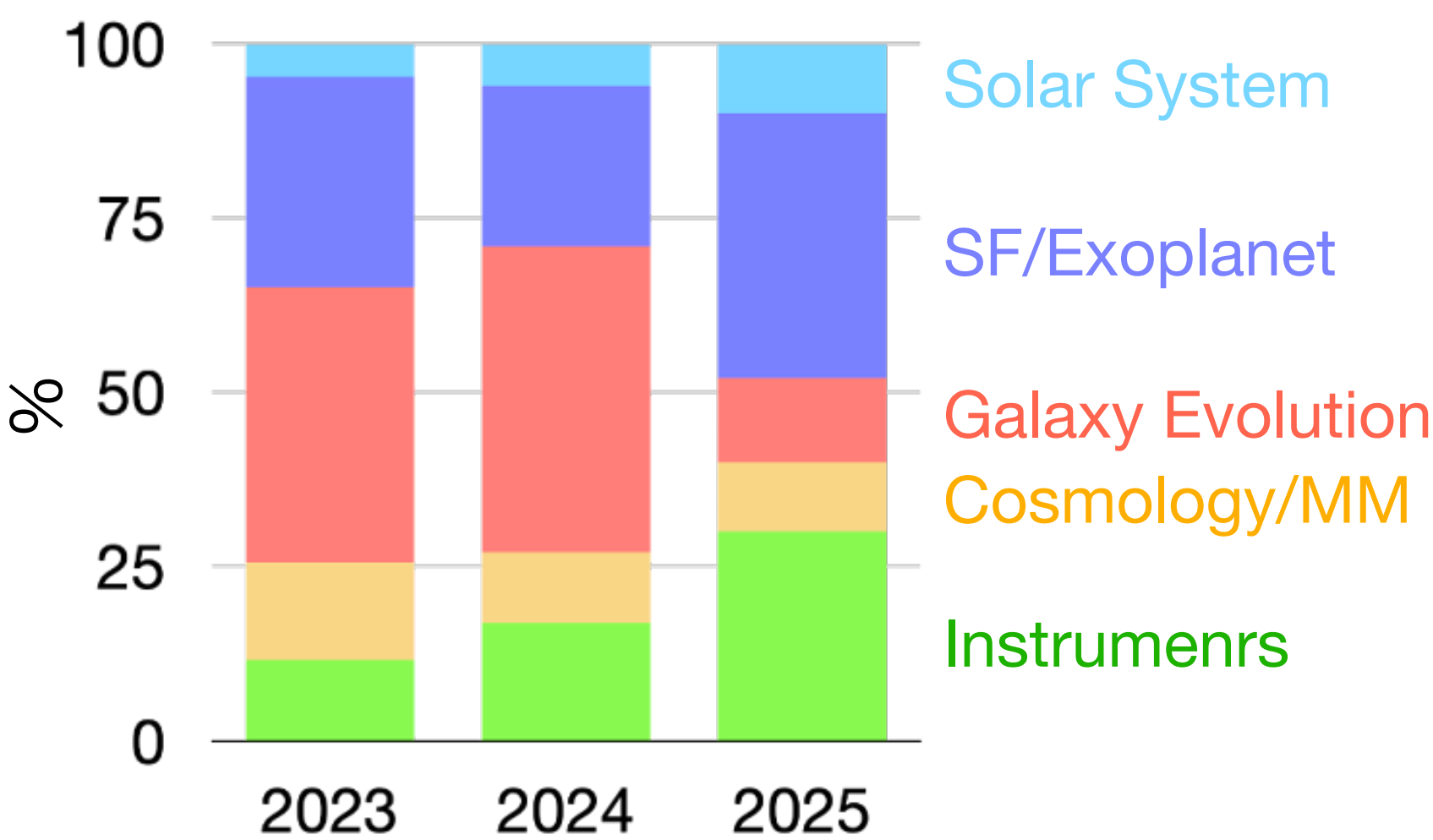
◆ 2025

Date : July, 2025
Venue. : NAOJ
Participants : 43

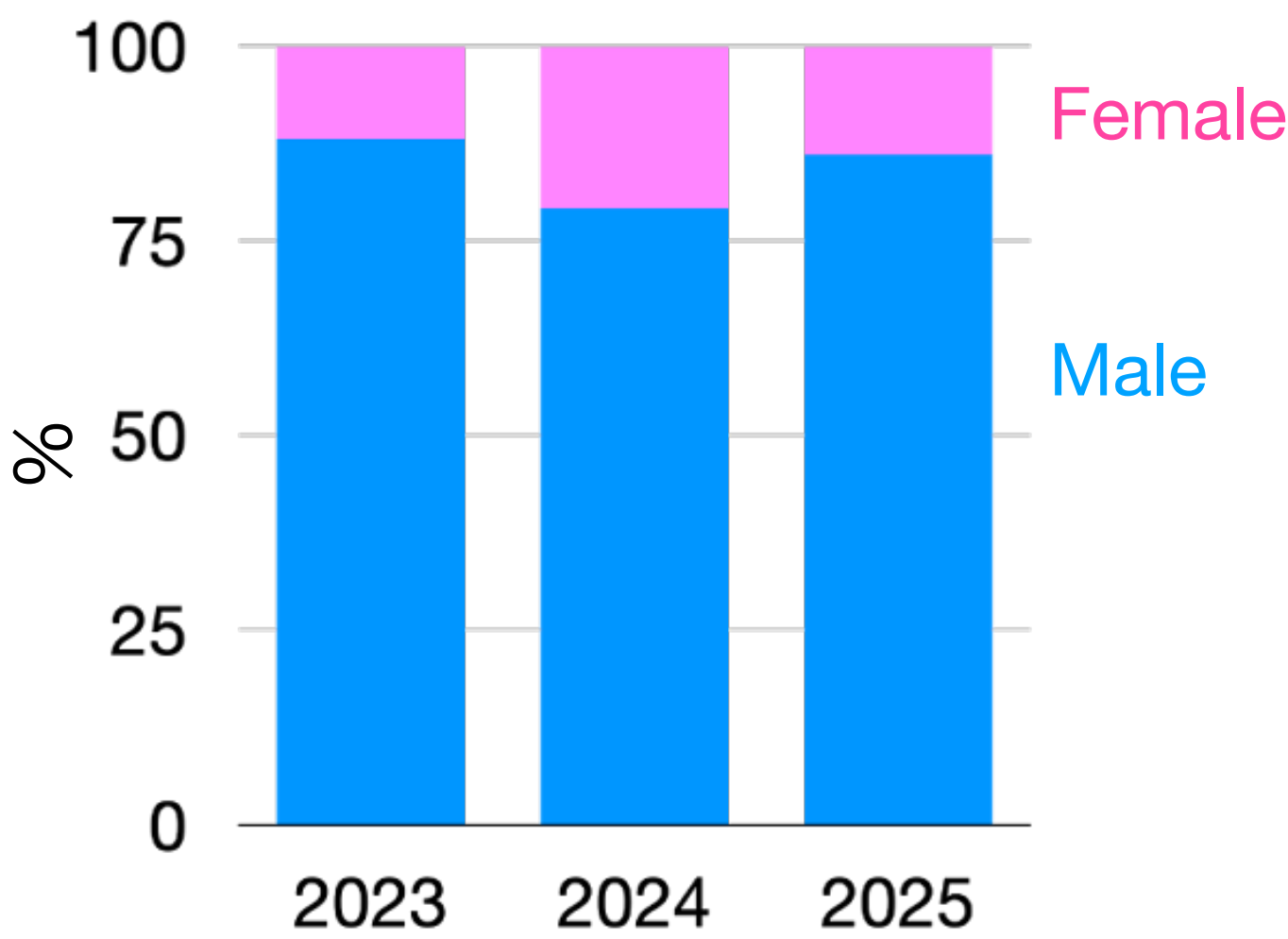
Career



Science Categories



Gender



Propose of joint Subaru 3.0 x TMT-ACCESS Collaboration Workshop

