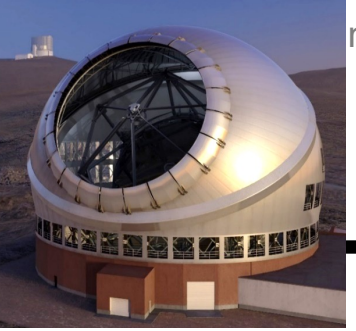
TMT
THIRTY METER TELESCOPE

国立天文台
NAOJ
National Astronomical Observatory of Japan

Progress on Thirty Meter Telescope (TMT) Project

January 24, 2024 (JST)

Tomo Usuda
(TMT Project Manager
National Astronomical Observatory of Japan)



TMT: Thirty Meter Telescope

Optical/infrared telescope with 30m aperture to be built on Maunakea, Hawai‘i by international Collaboration

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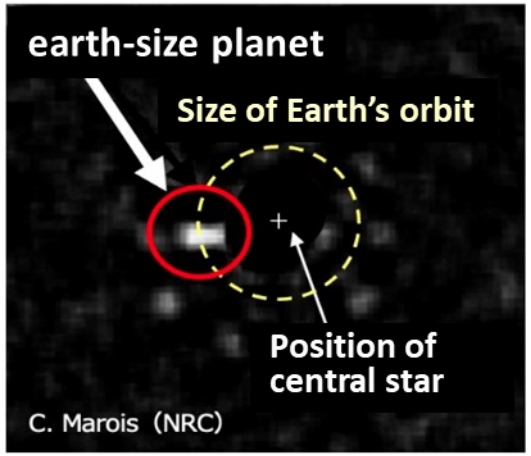
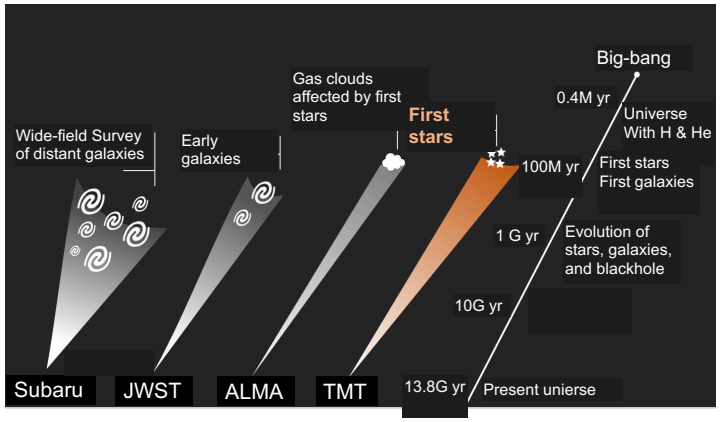
Searches for signature of life in exoplanets



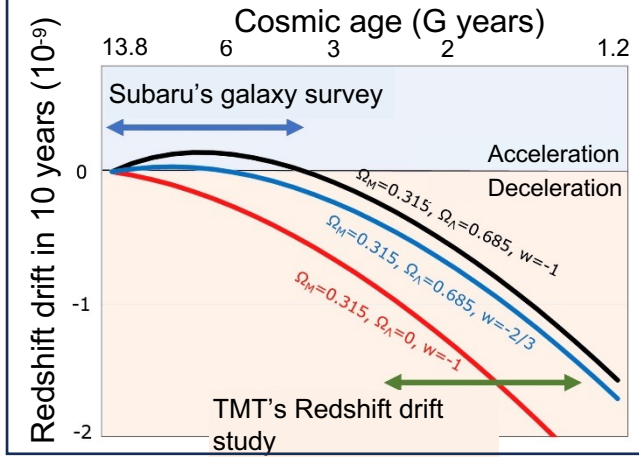
TMT will challenge detection of molecules related to life (e.g., O_2, O_3, CH_4) through direct imaging of earth-like exoplanets and spectroscopic study of their atmosphere.

Detection of light from first stars



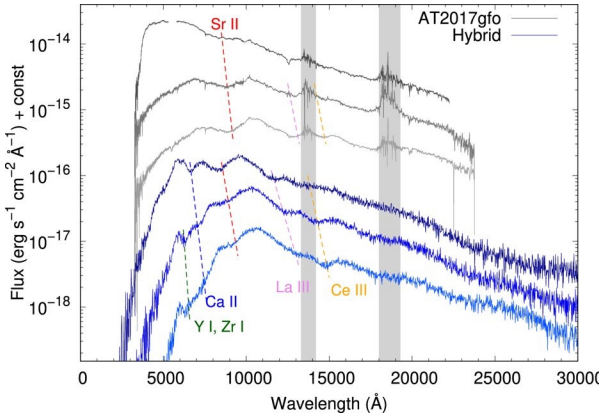
Detection of He emission line expected from first stars will constrain the timescale of first star formation as well as their nature and role in galaxy formation.

Constraining the nature of dark energy



Direct measurement of the universe expansion by the redshift drift of intergalactic matter will constrain the nature of dark energy.

Multi-messenger astronomy



TMT will play crucial role in optical-infrared spectroscopy for events detected by gravitational wave or neutrino to explore physics in extreme environment and origins of heavy elements

Advantages of TMT over E-ELT

High altitude of Maunakea
→ advantage in UV and IR observations
Large Isoplanatic angle and coherence time
→ preferable conditions for AO observations.
Quick Switching instruments in <10 min
→ rapid reaction to Targets of Opportunity

	TMT	E-ELT
Primary mirror	30m	39m
FoV (no vignetting)	20 arcmin (15 arcmin)	10 arcmin (5 arcmin)
Number of reflections	3	5
Site (altitude)	Maunakea(4012m)	Armazones(3064m)

Site characteristics Red: best site between the two	Maunakea (MK-13N)	Armazones (E-ELT site)	Ref.
Altitude (m)	4012	3064	1,4
Seeing at 60m above ground (arcsec)	0.50	0.50	1,3
Isoplanatic angle (arcsec)	2.55	2.05	1,3
Atmospheric coherence time (ms)	7.3	5.0	1,3
Precipitable Water Vapor (PWV) (mm)	1.86	2.87	2
Mean UV transmission (0.30-0.38μm)	0.47	0.43	2
Fraction of Clear night	0.72	0.86	1

Ref. (1) CATAC report Apr. 16, 2017 (draft), (2) TMT.PSC.TEC.16.008.DRF01, (3) https://www.tmt.org/page/site, (4) Schöck et al. 2009, PASP 121, 384

Declination (deg)

90

GOODS-North (62 deg)

Deep field survey.
Hosts one of the most distant galaxies, GN-z11.

45

Andromeda Galaxy (41 deg)

Nearest massive spiral. Close proximity allows for detailed studies of the stellar composition, structure, and physical properties.

COSMOS (2 deg)

0

Subaru/XMM-Newton (-5 deg)

Deep field surveys

GOODS-South (-27 deg)

Galactic Center (-29 deg)

Hosts a supermassive blackhole and the nearest laboratory to study extreme conditions and associated phenomena.

-45

Alpha Centauri (-62 deg) Nearest star-planet.

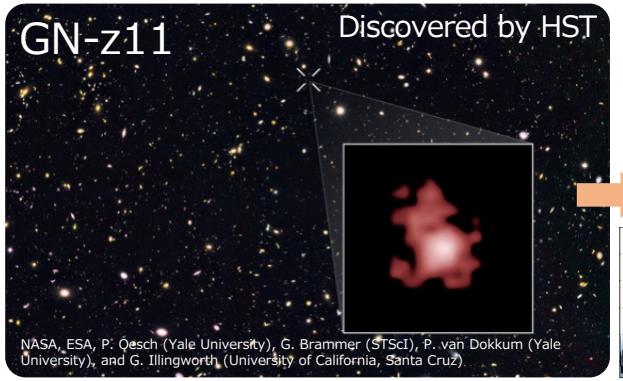
Large/Small Magellanic Cloud (-69 deg)

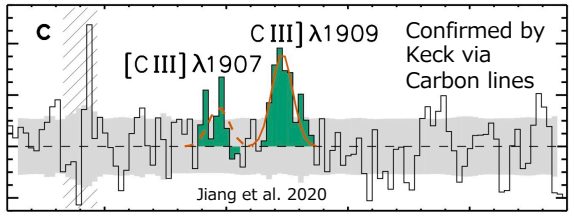
Satellite galaxies of the Milky Way and relics of early galaxy formation.

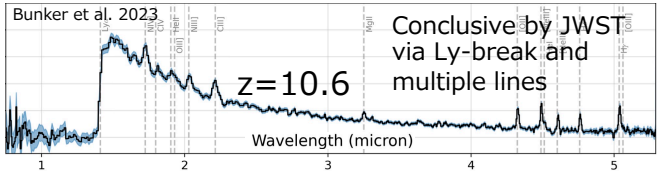
-90

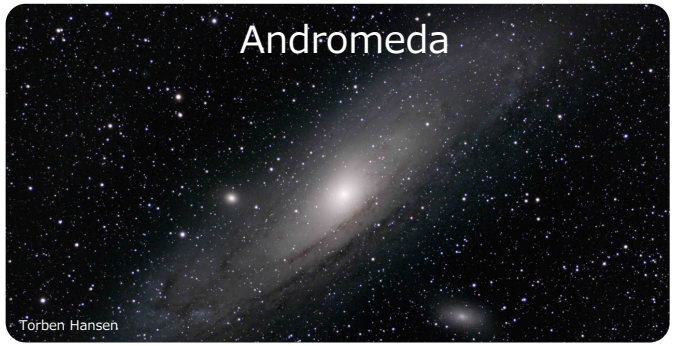
TMT visibility

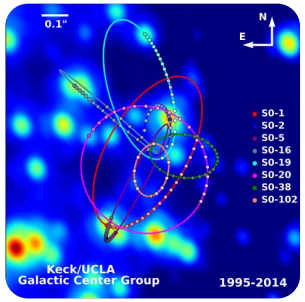
E-ELT/GMT/ALMA visibility

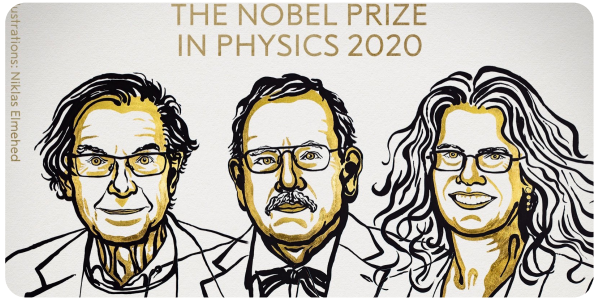












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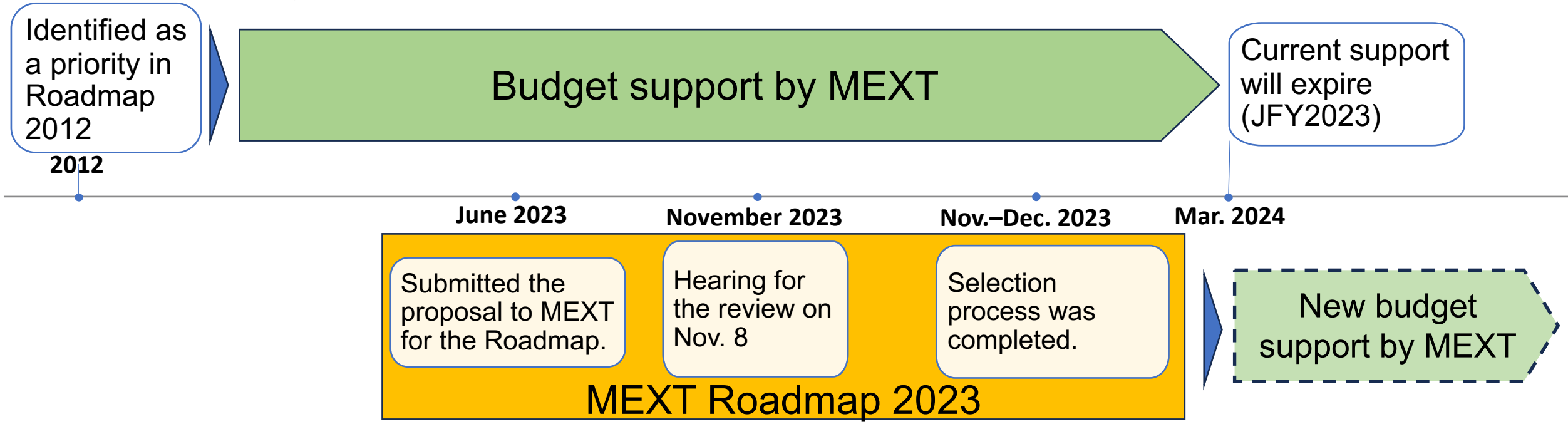
Positive Outcomes in Japan

Importance of MEXT Roadmap 2023 for completion of TMT Project

- TMT Project was selected in the “MEXT Roadmap* 2012” and the construction budget was supported from FY2013. The term-end review was successfully done in June 2023 (Summary report page 7~8).
- NAOJ/NINS submitted a proposal to “**MEXT Roadmap 2023**” in order to continue the project after JFY2024 and beyond, and to address the increased construction costs to complete Japan's contribution.



* Fundamental Concepts for Promoting Large Scientific Research Projects – MEXT Roadmap is formulated by the Working Group** under MEXT every three years to identify the nation’s priorities for large projects and provide grants.
Both Subaru Telescope and ALMA Project were re-selected in the MEXT Roadmap 2020 as Subaru2 (Super Wide Field Large Optical-IR Telescope) and ALMA2 (A Giant Millimeter/submillimeter Telescope in Search of our Cosmic Origins).

** The Working Group on Large Scientific Research Projects, Research Environment Infrastructure Subcommittee, Science Committee, Council for Science and Technology
cf) https://www.mext.go.jp/content/20210511-mxt_gakkikan1388523_2.pdf

TMT End-term Evaluation Report, Aug. 21, 2023

Working Group on Large Scientific Research Projects, Council for Science and Technology MEXT (1/2)

- In the annual plan previously submitted, the project was scheduled for start of 9-year-long construction in FY2013 with completion in FY2021. However, **due to unforeseen circumstances for the executing institution, on-site construction have been stalled since April 2015**. Please note that, **based on the understanding that heteronomous factors have delayed the project**, the WG reviewed the executing institute's role and achievement in accordance with criteria defined related to the evaluation of management.
- **Despite delays in the entire project due to a series of unexpected events, NAOJ has steadfastly assumed the responsibilities for its in-kind work to the extent possible**.
- The WG acknowledges that **NAOJ has significantly contributed to the overall project**. NAOJ introduced such measures for improving TIO's operational structure as a shift of the headquarters to Hawai'i and a reshuffle of its Hawai'i engagement team. Furthermore, starting with relocation of NAOJ TMT Project Manager and other staff members to Hawai'i, NAOJ's broad range of activities have helped to gain the local communities' understanding of the project.

TMT End-term Evaluation Report, Aug. 21, 2023

Working Group on Large Scientific Research Projects, Council for Science and Technology MEXT (2/2)

- The WG recognizes **NAOJ's key role in advancing the project has strengthened the nation's trust and presence.** NAOJ has been fully participating in the project, taking the initiative in strengthening TIO's governance and reorganizing the project management structure, as well as assigning some staff members to Hawai'i to actively carry out the community engagement activities to deepen trust and to continuously help with the communities' needs.
- Notwithstanding the suspension of on-site construction work, **the TMT project remains academically significant. It is expected to deliver scientific results which will be critical not just for astronomy but also for other areas of physics and Earth and planetary science.**
- **The issues surrounding the construction site in Hawai'i are not project-specific matters, but has a major impact on consideration of the role of science in the society. The WG hopes lessons learned from this project will be widely shared with other large-scale projects under international collaboration.**

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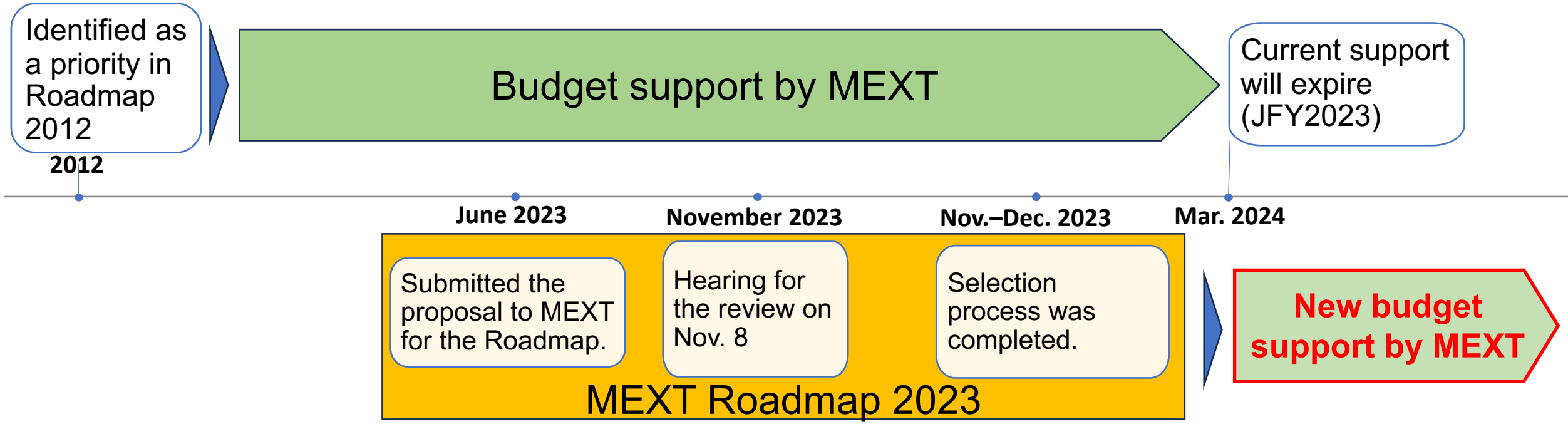
- TMT Project was selected in the "**MEXT Roadmap 2023**", which enable to continue the project for 10 years after JFY2024, and to address the increased construction costs to complete Japan's contribution.



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cf) https://www.mext.go.jp/content/20210511-mxt_gakkikan1388523_2.pdf

ロードマップ2023　掲載計画概要

※カッコ内は実施主体（中核機関）
※＊はロードマップ2020からの継続掲載（５計画）

BSL-4施設を中核とした感染症研究拠点の形成＊（長崎大学）

BSL-4施設を中核とした世界トップレベルの感染症研究拠点を形成し、感染症の病態解明、診断・治療法の確立、有効な予防法の構築による国民の安全・安心の確保、WHO 等による国際的な感染症管理体制への貢献を通じ、世界の保健向上に資する。

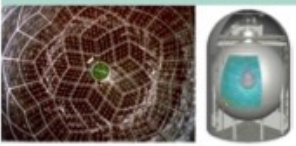
スピントロニクス・量子情報学術研究基盤と連携ネットワーク＊（東京大学）

将来の量子科学・量子情報技術の中核となる分野である「スピントロニクス」について、卓越した研究機関のネットワークによる国際共同研究拠点を形成・強化し、革新的省エネルギーデバイス、古典・量子情報融合デバイスなどの新しい情報処理技術の実現に向けて不可欠の科学技術基盤を提供する。

多様な知が活躍できるパワーレーザー国際共創プラットフォーム：J-EPoCH計画（大阪大学レーザー科学研究所）

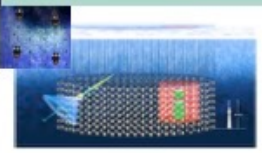
我が国の強みを活かした世界一の高繰り返し大型パワーレーザーによる国際共創プラットフォームをオールジャパン体制で構築し、量子真空の探査（場）、核融合エネルギーの探求（プラズマ）、超高圧新奇量子物質の創生（固体）を通して、エネルギー密度の高い極限的な量子科学の開拓で世界を先導する。

極低放射能環境でのニュートリノ研究（東北大学ニュートリノ科学研究センター）



神岡地下に建設したカムランド実験装置の高性能化により、素粒子原子核研究の最重要課題に挙げられる二重ベータ崩壊研究や、地球内部の組成や活動様式解明に挑む地球ニュートリノ観測、特徴的な低エネルギーニュートリノ天文学等を展開する。

IceCube-Gen2 国際ニュートリノ天文台による高エネルギーニュートリノ天文学・物理学研究（千葉大学ハドロン宇宙国際研究センター）



南極点直下に設置したIceCube検出器を世界15か国の連携により高度化し、世界最大のニュートリノ観測装置により高エネルギー宇宙ニュートリノの高感度観測を行う。電波からガンマ線まで分布する電磁波及び重力波との統合観測によるマルチメッセンジャー天文学を展開し、宇宙線の統合的理解、遠方宇宙や天体内部の探求に貢献する。

CTA国際宇宙ガンマ線天文台（東京大学宇宙線研究所）

次世代の国際宇宙ガンマ線天文台CTAにより、超高エネルギーガンマ線領域の世界唯一の天文大型施設として、極限宇宙の姿を捉え、ブラックホール、宇宙線の起源、暗黒物質などの解明を目指す。さらに、従来の電磁波・宇宙線観測に加え、重力波やニュートリノ観測と連携し、マルチメッセンジャー天文学の重要な一つの柱となる。

強磁場コラボラトリー：統合された次世代全日本強磁場施設の形成＊（東京大学物性研究所）

全日本的な強磁場施設の連携の下で世界最高性能の設備を組み合わせた独創的な戦略により、我が国が強みを持つ物質・材料科学-とりわけ、半導体、磁石、超伝導材料などの研究で世界を先導する。情報、エネルギー、医療等の課題解決に貢献するとともに、1200テスラ超強磁場下の学際的研究により宇宙、生命、化学などにおける未知現象を発見する。

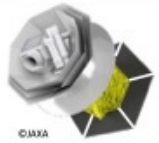
30m光学赤外線望遠鏡計画TMT（自然科学研究機構国立天文台）

ハワイ島マウナケア山頂域に口径30m光学赤外線望遠鏡TMTを建設し、すばる望遠鏡の広域探査と連携して地球型系外惑星や宇宙の初代星等の観測を行う。膨張宇宙における星、銀河、元素生成等の全貌を理解し、惑星の形成や生命誕生という人類究極の課題に挑む。

超高温プラズマの「ミクロ集団現象」と核融合科学（自然科学研究機構核融合科学研究所）

超高温プラズマを高精度で制御・操作し、世界最高の分解能で計測する実験システムを構築することで、核融合炉のみならず宇宙・天体にも共通するプラズマに独特な揺らぎの発生原因とその影響を解明する。計測と理論・シミュレーションを連携し、核融合イノベーションを駆動する科学的指導原理の構築を目指す。

LiteBIRD－熱いビッグバン以前の宇宙を探索する宇宙マイクロ波背景放射偏光観測衛星＊（宇宙航空研究開発機構）



熱いビッグバン以前の宇宙に関する最有力仮説である「インフレーション宇宙理論」を検証するため、LiteBIRD衛星による宇宙マイクロ波背景放射の全天偏光観測から原始重力波を探索する。代表的インフレーション宇宙理論を検証することで、宇宙創生の謎に挑む。

アト秒レーザー科学研究施設＊（東京大学）

我が国で長年にわたって培われてきた先端レーザー技術と自由電子レーザー技術を集約し、アト秒レーザー科学研究施を建設する。物質中の電子の動きを実時間で捉えることにより、物理学、化学、生物学、工学、薬学、医学等の幅広い分野でイノベーション創出を目指す。

統合全球海洋観測システムOneArgoの構築と海洋融合研究の推進（東北大学）

全球海洋の深度2000mまでの水温・塩分を常時計測する現行のArgoフロート観測網を、海底まで、かつ、生物地球化学変数の計測にまで拡張する統合全球海洋観測システムOneArgoを構築する。海洋全層における気候変動シグナルの検出や、海洋酸性化・貧酸素化の実態把握と生態系の応答の解明等により、海洋融合研究を推進する。

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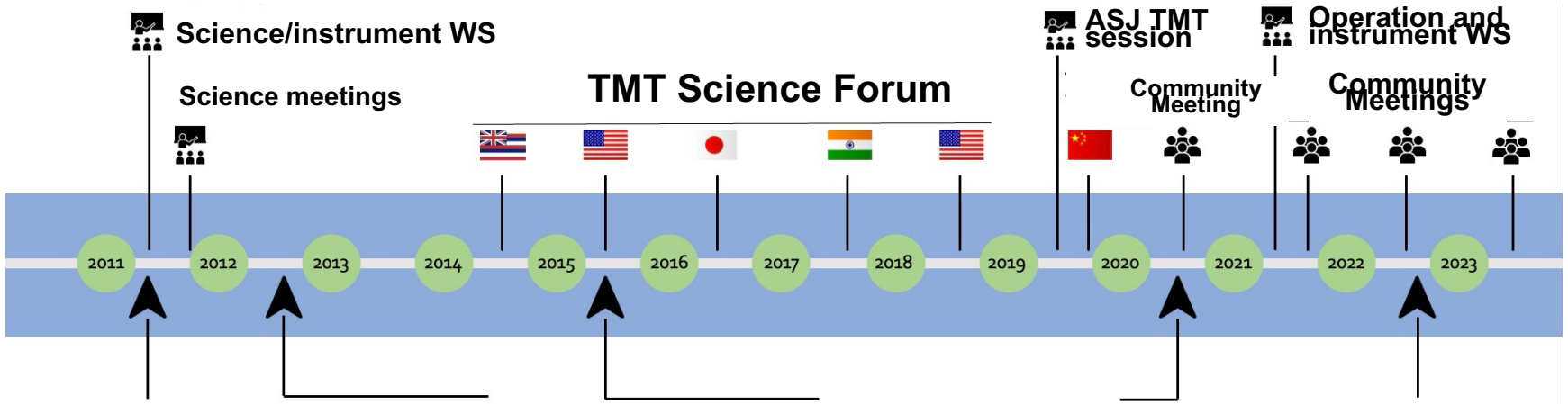
MEXT Roadmap 2023 (https://www.mext.go.jp/content/20231222-mxt_gakkikan-000033259_1.pdf)

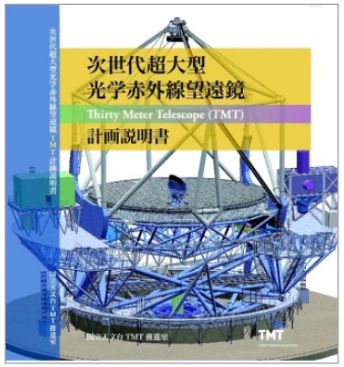
The WG accepted screening applications for a total of 47 projects. As a result of the document screening, the WG decided to conduct hearings for 18 projects. As a result, a decision was made to post 12 projects on the roadmap.

TMT Science Activities in Japan

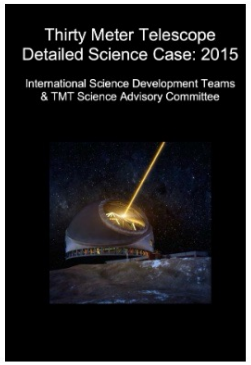
TMT Science cases have been studied in wide community in Japan in the past decade through a variety level of meetings, resulting in **science books**. Many researchers have been contributing to the international discussion on TMT science, e.g., 43 contributed to the updated **TIO's Detailed science Case**.



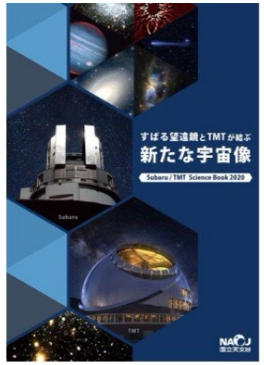
2011 TMT-Science Book



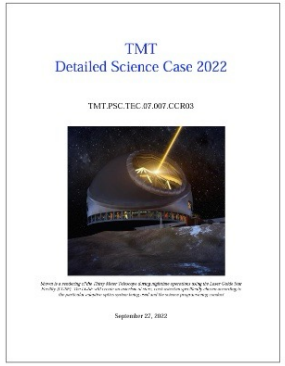
2012 TMT-J Blue Book



2015 TIO Detailed Science Case



2020 Subaru/TMT Science Book *



2022 TIO Detailed Science Case

*2020 Science Book: https://tmt.nao.ac.jp/researchers/science/

Recent and ongoing activities

TMT ACCESS: TMT eArly Career Centered, Engineers-Scientists Synergy: a workshop organized by young scientists and engineers (Sept. 11-15, Pasadena).

Series of workshops on ELTs (incl. TMT) and JWST

TMT-ACCESS (TMT eArly Career Centered, Engineers-Scientists Synergy)

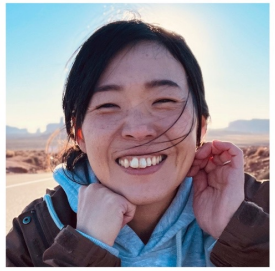
Sep 11-15, 2023 (TIO, Pasadena)

A workshop proposed, planned, and executed by Japanese early career researchers, with a forward-looking motivation to actively participate in TMT science. NAOJ fully endorsed it for the purpose of fostering the next-generation of astronomers and engineers for TMT.

- **Scope**: Discuss/materialize new science cases and formulate ideas for the 2nd generation instruments for TMT
- **Format**: Lectures (mainly on first two days), group discussion (a good fraction of the time), report-writing/summary
- **Output**: White paper with ideas on new science and synergies
- **Budget**: NAOJ/TMT Research and Development Expenses for Strategic Foundation Development, SUPER-IRNET

Organizers


T. Uyama (NAOJ/Caltech)


R. Momose (Carnegie)


Y. Hasegawa (JPL)


T. Nakamoto (NAOJ/TIO)

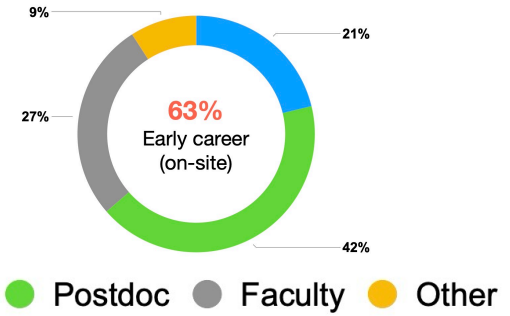

T. Sunayama (Arizona)


T. Kinugawa (Shinshu)


A. Takahashi (NAOJ)


H. Umehata (Nagoya)

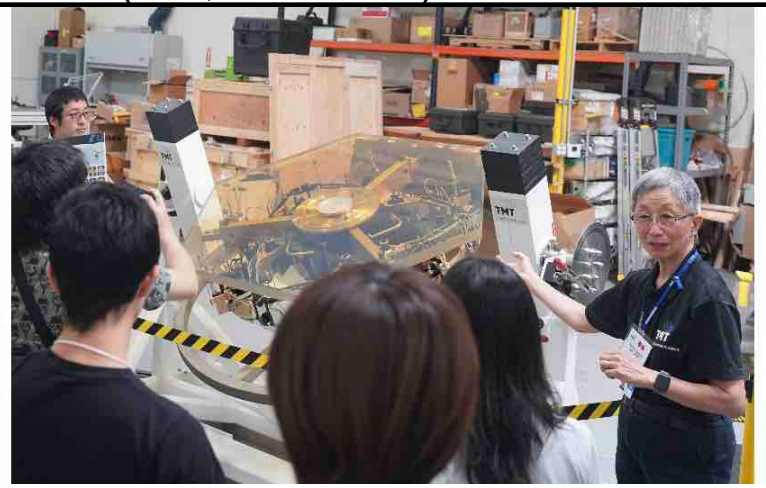
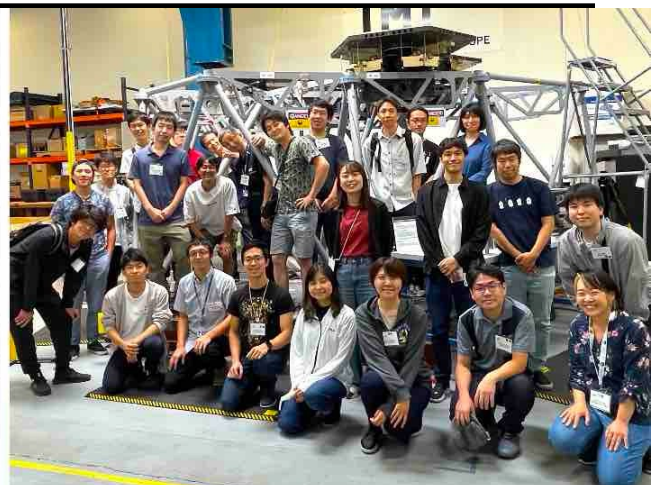
- ~30 participants traveled from Japan to attend the meeting
- 63% were early career (students and postdocs)
- female : male =0.18 : 0.82
  - efforts are underway in the community to improve the gender balance



TMT-ACCESS (TMT eArly Career Centered, Engineers-Scientists Synergy)

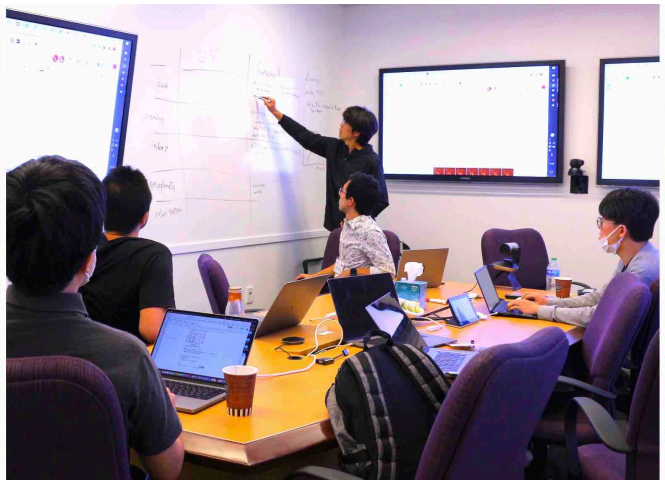
Sep 11-15, 2023 (TIO, Pasadena)



Group discussion:

- UV science and 1st generation instruments on TMT
- Synergy with Subaru Telescope 3.0 (e.g., next-generation HSC, wide FoV UV camera)
- Synergy with JWST (deep, high-spatial/spectral resolution follow-up with TMT)


Next TMT-ACCESS:
In June 10-12, after the "ELT science in light of JWST" conference to be held in Tohoku University.

ELT Science in Light of JWST

Part 2 in Asia: June 3~7 @Tohoku Univ.

SOC:

- Co-chairs: Masaomi Tanaka (Tohoku U.) & Narae Huang (KASI)
- Norio Narita (U.Tokyo), Miho Ishigaki (NAOJ), Fumi Yoshida (U. Occupational and Environmental Health), Hironao Miyatake (Naoya U.), Myunshin Im (Seoul National U.), Young Sun Lee (Chungnam National U.), Sree Oh (Yonsei U.), Yujin Yan (KASI), Sarah Brough *UNSW), Surhun More (IUCAA), Tommaso Treu (UCLA), Eric Peng (NOIRLab)

Status of Hawai‘i
TMT’s Community Outreach in Hawai‘i

- The TIO Project Manager (Fengchuan Liu) and NAOJ TMT Project Manager (TU) have relocated to Hilo in 2021. Together with NAOJ employees (Yuko Kakazu) there, the Project Manager has met in small groups with more than 400 stakeholders in the local community.

Issue: Past community engagement reached out to the communities familiar to us and supporting us, but missed the majority of Native Hawaiians, social-economically struggling, and rural communities.

New Approach: Proactively reach out to people who traditionally oppose the project, respect, listen and learn, build trust and relationships with Native Hawaiian communities.

- TIO’s outreach activities are consistent with Astro2020 report’s recommendation of community-based astronomy, and partnership with indigenous community. These are essential not only for TMT but also for MKOs including Subaru Telescope.

TMT THIRTY METER TELESCOPE

Positive Development surrounding TMT

国立天文台 NAOJ National Astronomical Observatory of Japan

TIO's direct engagement and educational assistance in Hawai'i help to build trust with wider communities. Hawai'i State's establishment of MKSOA and NSF's start of the process have speeded up the progress toward on-site construction in Hawai'i.

From June 2021

TIO's direct dialogue in Hawai'i

- Relocated TIO Project Manager to Hawai'i to start grassroots community engagement through listening and respect, and to provide educational support in response to their needs, which has led to trust-building ➡ Substantive change in wider Native Hawaiian communities' stance on TMT.
- e.g., Developed rapport with five elderly leaders who had been once opposed to TMT and arrested for road blockage in 2019. They now support TMT.

November 2021

Astro2020's top priority

- The U.S. National Academies of Sciences' Astro2020 identified a joint program of TMT and GMT, called the US Extremely Large Telescope Program, as a top priority for ground-based astronomy.

From July 2022

Native Hawaiians' participation in Maunakea decision making

- The state's new law established new Maunakea management (MKSOA) that enables Native Hawaiians to have seats to represent their community groups, whose voices have been long ignored, and to equitably share benefits (rent revenue and observing time) ➡The policy direction is now focused on Maunakea management and reconciliation with Native Hawaiians which transcends the issue of TMT.

From July 2022

NSF started the process for federal budget

- **Process for evaluating impacts on the environment and historic properties started from July 2022.**
- **NSF Preliminary Design Review (PDR) was successfully done in March 2023**
- **NSF awarded $6.5M for Design & Development in September 2023**

Progressing toward restart of onsite construction in Hawai'i

U.S. federal budget

TMT
THIRTY METER TELESCOPE

Status of CSO Decommissioning

国立天文台 NAOJ National Astronomical Observatory of Japan

- CSO operations was terminated in 2014, and CDUP authorized 2022
- Telescope (dish and mount) was removed for shipping to Chile in August 2023

Future Steps:

- Removal of above/below ground structures will commence Spring
- Site restoration will be done next summer
- Careful to be transparent and communicate status with MKSOA, CMS and all interested parties.

Summary

- TMT will play an essential role in the 2030s to deepen the human perception of the Universe.
- NAOJ's TMT Project has been successfully selected as a priority project in the MEXT Roadmap 2023 which serves as a guideline for implementation of related policies.
- The roadmap is one of the essential elements in assessing NAOJ's annual budget request to cover the increased construction costs.
- The JFY2024 Budget is more than doubled from JFY2023, with great understanding and successful work by MEXT.
- New TIO/NAOJ outreach team based in Hilo are proactively reaching out to people who were not heard before. We are listening to and learning from the community, in particular Native Hawaiian communities. We recognizes that in order to build an enduring community-based observatory, the focus must be on creating genuine, long-term partnerships with local communities based on respect, trust, and protection of nature and heritage.
- NSF awarded $6.5M for Design & Development in September 2023
- NSF's review processes (Design Review, EIS, NHPA) are on going.