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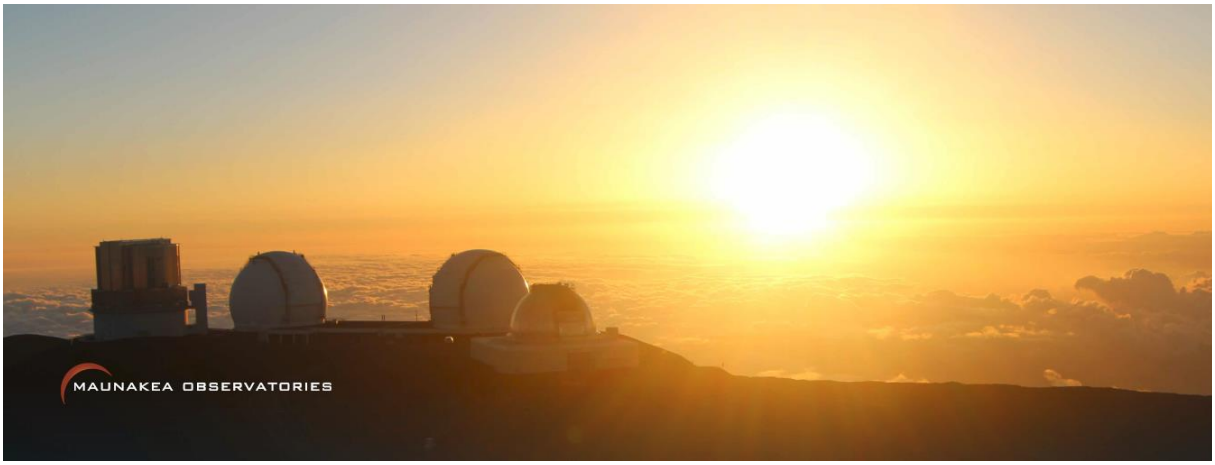
Abstract

Given the importance of the Maunakea Observatories to the field of astronomy in the 21st century, ensuring a robust future for this billion-dollar research complex has broad impact. Of particular importance is land authorization renewal of the Maunakea Science Reserve (MKSR), which expires in 2033. Planned facilities including TMT and MSE, not to mention most of the existing observatories, fundamentally require MKSR land authorization well beyond 2033. This White Paper summarizes challenges, scientific opportunities and various strategies that build on the 50 years of astronomy on Maunakea. A range of programs are underway now to build broad community support for Maunakea astronomy long-term. Solutions to on-going conflicts will be established through multilateral dialog, open minded and open hearted listening, and a community wide sense of ownership and pride in the future of Maunakea as a whole.

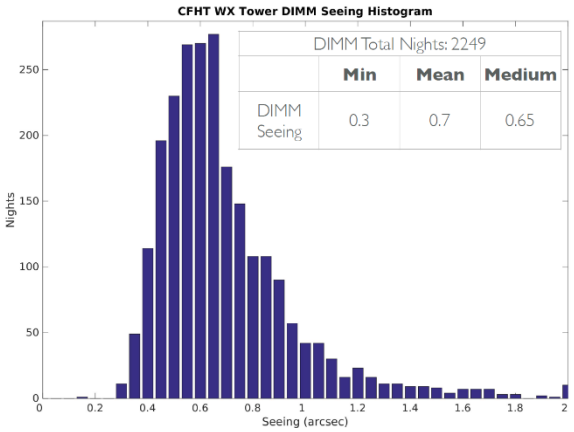
Background

A large fraction of ground based astronomical observatories are located in Hawaii and Chile which together provide all-sky research capabilities using a variety of advanced technologies. They are an essential complement to space based facilities, which have been steadily growing in number and sophistication for decades. Combined these ground based observatories include 8-10 m O/IR telescopes, ALMA, essential elements of the Event Horizon Telescope, panoramic and high-resolution facilities, detector sensitivities from UV to radio, the largest collection of laser AO systems in the world, and more. While geographic clustering of facilities often leads to efficiency gains, it can also leave ground based astronomy vulnerable in the event these clusters are no longer part of the global network due to natural disasters, geopolitical dynamics, funding or legal/permitting restrictions, etc. In Hawaii, the Maunakea Observatories collectively provide a large fraction of the leading astronomical research capabilities in the northern hemisphere and due to a confluence of events, their long-term futures are rather vulnerable. This white paper outlines the challenges and multifaceted strategies underway now to help ensure the Maunakea Observatories will thrive well into the 21st century.



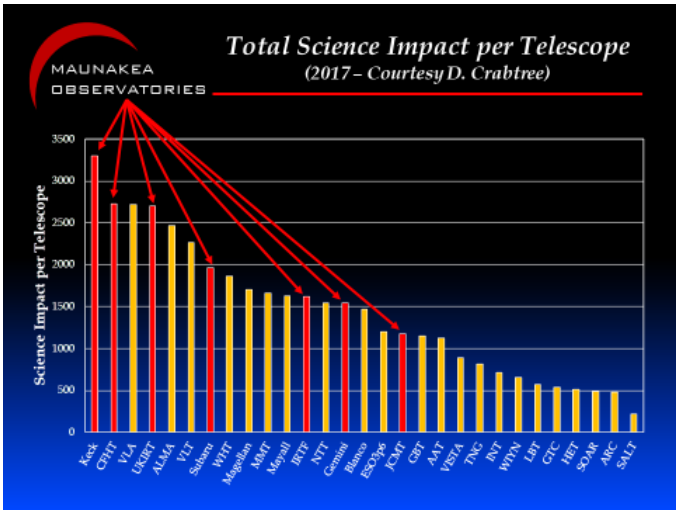
The Maunakea Observatories will play a critical role in the future of 21st century astronomy. It is important to take steps in the next decade and beyond to ensure a bright future for these facilities.

Site Properties



Over 2000 nights of seeing data using a DIMM on the upper ridge of Maunakea is plotted. Median seeing (r-band) is 0.65 arcsec. (priv. comm. – Maunakea Weather Center)

After being essentially "discovered" by Gerard Kuiper and his associate Alika Herring in 1964 as a premier site for astronomical research, the summit of Maunakea steadily attracted international attention and investment for the next 50+ years. The smooth topography of this ~14,000 foot shield volcano, combined with prevailing trade wind flows from the Pacific Ocean, helps provide seeing conditions on Maunakea that are nearly unrivaled. Most of the turbulence above Maunakea is contained within ~100 m of the summit in the form of "ground layer seeing", rendering a site that is particularly amenable to ground layer adaptive optics. The median seeing is 0.65 arcsec at ~0.6 um. Combined with exceptionally dark skies, dry air, and photometric conditions ~70% of the time, the Maunakea Observatories enable a large fraction each year of the peer reviewed publications in astronomy. The combined "science impact" of the Maunakea Observatories (a metric that gauges the number of papers published and their citation rates) is collectively world leading. This combination of site properties, diverse facility capabilities, and scientific collaboration across the Maunakea Observatories is an important distinction worldwide.

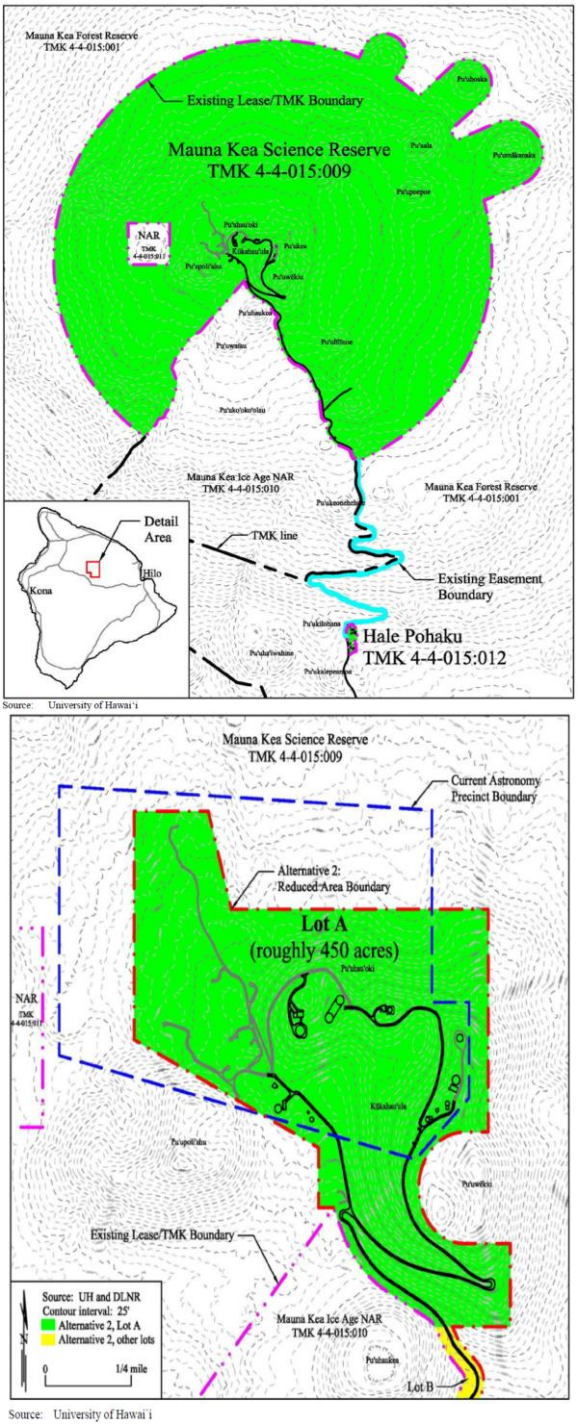


Science impact, a metric that tracks the quantity of publications and their citation rates (quality) is plotted for ground-based observatories worldwide. The Maunakea Observatories consistently rank among the best in the world by this metric. (priv. comm. – Dennis Crabtree)

Maunakea Science Reserve

In 1968 the University of Hawaii (UH) received a 65 year "Master Lease" from the State of Hawaii to manage a ~13,000 acre region centered on the summit of Maunakea. A few years later the first major telescope on Maunakea was built by the University of Hawaii, a 2.2 m O/IR facility that in turn helped leverage the formation of the UH Institute for Astronomy. This telescope helped demonstrate worldwide the exceptional image quality possible from Maunakea, and ultimately helped attract internationally funded facilities that would be operated through subleases to the UH held Master Lease. In 1979 the Canada-France-Hawaii telescope (CFHT), United Kingdom Infrared Telescope (UKIRT), and NASA's Infrared Telescope

Facility (IRTF) were commissioned in fairly rapid succession. During the 1980's these facilities, combined with Maunakea's site properties, put Maunakea "on the map" globally as an astronomical research site. Next came sub-mm facilities including the 10 m Caltech Submillimeter Observatory (now being decommissioned) and the 15 m James Clerk Maxwell Telescope, followed by Keck I and II in the early 90's, which enabled breakthrough research throughout that decade given their enormous light gathering power. The 8 m Subaru and Gemini-North telescopes came next, followed by the Submillimeter Array. Road, fiber optics, commercial power, and the Hale Pohaku mid-level facility built by UH helped round out essential infrastructure, the cost of which has been shared across the Maunakea Observatories. During the 1980's ~3000 acres was removed from the Science Reserve to become part of the Mauna Kea Ice Age Natural Area Reserve. In 2000, a ~600 acre "Astronomy Precinct" was designated as the area within which all summit-level astronomy facilities were to be located. By the turn of the century, this combination of facilities and their diverse capabilities, supported by shared infrastructure, left Maunakea as the preeminent site in the northern hemisphere for astronomy research. With the MKSR Master Lease due to expire in 2033, it is of paramount importance that UH obtain new land authorization that will allow these observatories to continue well into the future.



Top – The MKSR is shaded green in this topo-map of Maunakea. Bottom – Blue dashed line indicates the current astronomy precinct within the MKSR while the green area indicates the proposed new, smaller astronomy precinct.

Numerous steps are underway now, principally led by UH, to secure MKSR land authorization. It is important that these steps be taken soon, since the planning horizons for new instrumentation, yet alone new observatories, now arguably exceed the remaining duration of the Master Lease. The documents that substantially underpin the management of the MKSR including the Comprehensive Management Plan (CMP), its numerous sub-plans, and the 2000 Master Plan.

Implementation of the CMP falls onto the UH Office of Maunakea Management (OMKM), which is overseen by the Maunakea Management Board, with guidance on cultural matters provided by Kahu Kū Mauna. Significant portions of the sub-plans, which cover public access, culture resources, natural resources, and eventual telescope decommissioning, were written by experts on Hawaii Island, part of the overall community management model that has worked well since OMKM was formed nearly 20 years ago.

Steps underway now to secure land authorization of the MKSR include –

- Establishing UH Administrative Rules for Public and Commercial Use of Maunakea (2019)
- Generating Environmental Impact Study for Land Authorization (2020)
- Comprehensive Management Plan Update (2020)
- Master Plan Update (2020)
- UH-Maunakea Observatory Terms & Conditions Negotiations (rent, UH access, etc.) – occurring now

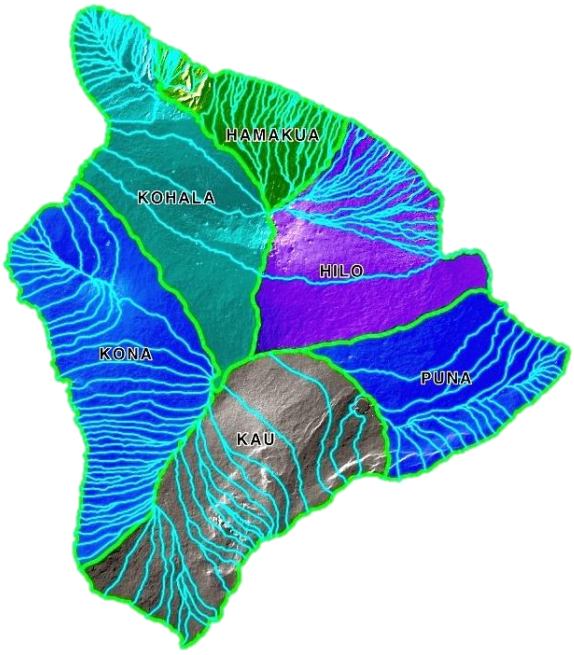
All of this activity is phased to bring before the Board of Land and Natural Resources a proposal to secure MKSR land authorization (probably in the form of a new Master Lease) in early 2021.

The Hawaiian Cultural Renaissance

At about the same time as development occurred on Maunakea during the latter half of the 20th century, the "Hawaiian Cultural Renaissance" began – a time of cultural reawakening since the overthrow of the Hawaiian Kingdom roughly a century before. This included landmark efforts to renormalize the Hawaiian language, reinvigorate cultural practices including hula and music, and restore the ancient craft of sea wayfaring, in which canoes are navigated across the ocean without the use of modern navigational aids, instead relying on the stars, winds, and currents to accurately guide craft long distances across the open ocean. Hawaiian immersion schools also started during this period, in which students are taught in schools where only the Hawaiian language is spoken, giving students a solid basis in both Hawaiian culture and contemporary education. A cultural anchor for many in the Hawaiian community is Maunakea, which has long been regarded as the place of the akua (gods) and aliʻi (royalty). Several hundred culturally sensitive sites around the summit of Maunakea have been identified, with few actually on the summit itself, consistent with the ancestral regard many Hawaiians have had for the summit for centuries.

The Hōkūleʻa voyaging canoe that sailed around the world without the use of modern navigational aids is pictured. This impressive feat gave Hawaii residents an enormous sense of pride and is one of the most visible aspects of the modern Hawaiian cultural renaissance.

Maunakea is therefore at the intersection of modern astronomy and the resurgence of Hawaiian culture. There remains a broadly shared sense of injustice when the Hawaiian Kingdom was overthrown, and subsequent social inequities many Hawaiians have felt as they become a smaller fraction of an otherwise incredibly diverse, multicultural community in Hawaii. There are many layers and nuances to this complex situation, which cannot be adequately explained in the confines of this white paper. Regrettably, as a result of the conflict over TMT and Maunakea, some misconceptions have emerged. The Hawaiian community is not anti-astronomy or anti-science. On the contrary, they were demonstrably some of the best astronomers and scientists of their time. Their acute observational skills allowed trade across the vast Polynesian seas and before western contact sustained over a million people in Hawaii with sophisticated fish ponds and land management techniques (ahupua`a). In the late 1800's over 90% of the Hawaiian population was literate, as 'olelo Hawaii (Hawaiian language) evolved from an oral means of communicating across generations by chants to a written language. There is no single reason behind the conflict over TMT and Maunakea and both have become proxies for broader social unrest in the Hawaiian community. That said surveys indicate most of Hawaii's residents (including Native Hawaiians) support Maunakea astronomy and TMT, recognizing the numerous benefits these facilities bring, particularly to the residents of Hawaii Island. Vocal opposition to TMT has nonetheless delayed its construction in Hawaii, and in general many opposed to TMT probably will not support MKSR land authorization by UH beyond the 2033 duration of the current Master Lease.



The historic districts and numerous ahupua`a across Hawaii Island are shown. While land was never formally owned in Hawaiian culture, it was divided and managed based upon rank and standing within communities.

The conflict over Maunakea is therefore multifaceted and includes concerns about culture, environment, religion, public access, commercial activities, finance, sovereignty, indigenous rights, land management, stewardship, legalities, etc. Furthermore, unlike many Native American organizations in North America, there is no single entity recognized to formally represent Hawaiian interests in these complex social movements. Unraveling these complexities, which span generations and stem from issues far beyond telescopes on Maunakea, is unlikely to succeed on a short timescale. This is a long-term (generational) challenge and needs to be addressed at the grass roots, community level, through long-term, fully committed engagement with integrity. That is the subject of the remainder of this white paper.

Community Engagement

The Maunakea Observatories have always supported education, outreach, and workforce development programs. Coordination and resource sharing is generally handled through the Maunakea Astronomy Outreach Committee, which meets monthly and has representation from all observatories. In addition many observatories spearhead major programs on a recurring basis. Given the diversity of Hawaii's community (among the most ethnically diverse regions in the US), no single approach connects effectively to the entire community. Both STEM and place based educational opportunities that are culturally engaging are needed. In some cases, completely "out of the box" approaches are used. These pilot programs are among the most revolutionary in astronomy today and stem from unique circumstances and needs in Hawaii. Taken in their entirety, these programs are doing more than providing astronomy related education. They are defining the relationship between the Maunakea Observatories and the community from which they come.

Top - Community members participating in a recent Kama'āina Observatory Experience at the summit of Maunakea. Middle - Maunakea Scholars being interviewed live on KHNL, where they described their research projects on the Maunakea Observatories. Bottom – Hawaiian immersion school students from Hawai'i Island and Maui proudly hold their chosen names (later accepted by the IAU) for a pair of unusual asteroids discovered by Hawai'i observatories stemming from the A Hua He Inoa program.

Some of the larger programs that include involvement from most or all of the observatories include –

Journey Through the Universe – This program is led by Gemini Observatory and brings >70 astronomy educators into classrooms in East and North Hawaii Island, engaging thousands of students in grades 2-12 over a weeklong period. It also includes teacher workshops, career panels, public colloquia, and numerous forms of community engagement over the course of the year. Now in its 15th year, Journey Through the Universe is the largest outreach program in Hawaii astronomy in terms of numbers of students reached.

AstroDays – Held once a year in Hilo and Kona at major shopping malls, these events are a major draw and generally involve thousands of residents on each side of the island. All observatories set up booths and displays, engaging kids and their parents alike. They also feature a coin contest in which students from numerous schools enter their designs, one of which is chosen to be used to design a custom coin that is broadly distributed.

Kamaʻāina Observatory Experience – The third Saturday of every month, Hawaii residents converge on Hale Pohaku where they are provide with presentations on the cultural importance and environmental sensitivity on Maunakea before being brought to the summit to get "behind the scenes" tours of two telescopes. These tours, which are provided free to the public, have been spectacularly well received by the community.

Solar System Walk – Each fall Keck, CFHT, UH, ʻImiloa, and other organizations create stations stretching across Waimea from Keck Observatory's front lawn to CFHT's, scaled to represent the position of the planets in the solar system. Children receive a lesson about each planet by visiting the booths, with themes drawn from recent research about the planets from Maunakea. Hundreds of people participate and everyone is provided with a free BBQ lunch at the "end of the solar system" at CFHT's front lawn.

Akamai Intern Program – The "gold standard" among observatory internship programs and led by the ISEE program at UCSC, 30-40 college students that reside in Hawaii (but can go to college anywhere) are paired with mentors across the Maunakea Observatories in this intensive 8-10 week program each summer. Each student finishes their project with a public presentation, giving the community valuable insight into the remarkable projects these students complete each summer.

Maunakea Scholars – The only statewide astronomy education program in Hawaii, Maunakea Scholars is a collaboration between the Maunakea Observatories (who provide observing time), Department of Education (who provide links into classrooms), and the University of Hawaii (who provide student mentors through the UH, Institute for Astronomy). High school students submit observing proposals that are evaluated by professional astronomers. Those that pass this review process receive time in award ceremonies. All students are provided with summit tours and cultural education through ʻImiloa's MANU program.

A Hua He Inoa – Also the first of its kind, this program links discoveries made with Hawaii observatories with Hawaiian names created through experts in ʻolelo Hawaii (Hawaiian language). Originated by Hawaiian kupuna, A Hua He Inoa helps connect the long standing tradition of naming in Hawaiian culture with local discoveries. The interstellar asteroid name ʻOumuamua, black hole name Pōwehi, and the unusual asteroids recently officially named Kamoʻoalewa and Kaʻepaokaʻāwela by Hawaiian students are all products of this program. Many more will emerge in the years ahead.

Counting other programs, classroom visits, dedicated tours of base and summit facilities, and much more, the Maunakea Observatories organize and sponsor nearly 100 events annually

within the community. This steadfast commitment to community engagement is the core of our approach to ensuring long-term community support for Maunakea astronomy. In addition, UH and Maunakea Observatory strategic communications includes a multitude of media engagements, including newspaper, TV, magazine, and various social media formats. This has been particularly effective with local evening news features about the Maunakea Scholars, and morning live interviews with students that allow them to share their experiences using some of the most powerful telescopes in the world to conduct their own research projects. These projects have been used in numerous science fair projects, senior research projects, etc. All of this is part of a workforce development program designed to cultivate local talent at the grade school level, carry students through college via internships and scholarships, and ultimately hire them at the observatories. The bond this makes between the observatories and the local community, as parents watch their keiki (children) engage observatory opportunities in their youth and discover a passion that leads to careers at the Maunakea Observatories is powerful. Such a bond requires time and patience though. As mentioned before, this is a generational challenge but with such a long-term investment, generational support will be achieved, for the betterment of everyone.

Recommendations

The various administrative steps needed to secure MKSR land authorization are largely confined within the State of Hawaii and are, accordingly, mostly beyond the reach of NSF or other Federal agencies that might influence outcomes. Nonetheless tangible help could be provided by Federal agencies consistent with the approaches outlined earlier to further build community support in Hawaii for the Maunakea Observatories. Some steps include –

- Support astronomy related indigenous programs in Hawaii through grants to ʻImiloa Astronomy Center and the Ka Haka ʻUla O Keʻelikōlani College of Hawaiian Language at the University of Hawaii-Hilo. These UH-Hilo units serve has hubs for advancing ʻolelo Hawaii (Hawaiian language), as it links to STEM education, and build bridges between Hawaiian culture and Maunakea astronomy.
- Sponsor internships (e.g., Akamai Workforce Initiative) and burgeoning apprenticeship programs that help place students in STEM careers, including within the Maunakea Observatories.
- Through conferences, workshops, and professional development further enroll the astronomy community in the importance of advancing indigenous cultures together with astronomy. This can be part of a worldwide movement in science, led by astronomy.
- Encourage more involvement in Maunakea astronomy in US strategic planning at various agencies and organizations that support astronomy. By a considerable margin Maunakea is host to the largest collection of telescopes based in the US, but strategic planning often tends to focus Chile or the US mainland. As a result, US entities might be

missing opportunities for collaboration, research, tech-dev, education/outreach, cultural advancement, etc.

Conclusions

History is replete with examples of conundrums that seemed impossible to overcome at the time, which spawned new thinking, new perspectives, and new solutions driven by the need to survive and, if fortunate, thrive. The Maunakea controversy is no different. This white paper is being submitted not long before the launch of TMT construction on Maunakea, after a lengthy legal battle to secure support for the project. If TMT succeeds, that will build crucial confidence in international funding for the future of the Maunakea Observatories. If TMT fails, that will call into question future major investments for many years on Maunakea. In either case, the foundation of Maunakea astronomy is built on the state of Hawaii's only billion-dollar research complex, as it exists today. Coupled with the singular properties of Maunakea as an astronomy site, the basis for the future of Maunakea astronomy is strong, long-term. MKSR land authorization will likely be granted given the 50+ years of momentum behind Maunakea astronomy. The main uncertainties are the terms and conditions of that land authorization and how many telescopes will remain on the summit, well into this century.

That said, the future of Maunakea astronomy should not be predicated on government sanctioned arrangements, forged in controversy. For people who work on the mountain, people who practice their culture and religion on the mountain and people who visit the mountain, we should look to a future beyond coexistence because coexistence still implies barriers. We should look to a future in which knowledge, culture and worldviews hybridize to create a reality more beautiful and resilient than its progenitors. We should look to a future for Maunakea where studies of the universe are buoyed by the wisdom of Hawaiian kupuna, and grounded in the genius of Hawaiian culture.