The Mauna Kea Observatory

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Abstract

Mauna Kea is a tremendous asset to the US community representing a site with decades of investment. Building on this investment in the next decade is critical to retaining a competitive US position in ground-based astronomy. TSIP has been a widely recognized success in providing community access to unrivaled private facilities as well as enabling those facilities to develop in a manner that is coordinated nationally. The Mid-scale Innovation program was highly ranked in the Decadal Survey and its realization is key to maintaining front-line capabilities on our observatories. Mauna Kea offers the potential for cost-savings at a time of financial hardship through new international partnerships, shared instrument development and better coordination of operations.

Background

Mauna Kea hosts the largest astronomical observatory in the world. The exceptionally dry and stable atmospheric conditions at its 4200-m altitude combined with its dark sky make this the northern hemisphere's premier site for ground-based astronomy. Currently there are thirteen telescopes operating on Mauna Kea enabling observations of the universe from the radio to the ultraviolet part of the electromagnetic spectrum. In terms of collecting area of optical and infrared (OIR) telescopes, Mauna Kea is quite comparable to the facilities of the other major player in ground-based astronomy, the European Southern Observatory in Chile. This similarity may extend well into the future, if both the European Extremely Large Telescope (E-ELT) in Chile and the Thirty-Meter-Telescope (TMT) on Mauna Kea are built. However, it will be a decade or more before this next generation of large telescopes is available. In the meantime it is imperative that we keep the most powerful US 8-10 m telescopes at the international forefront of research, in particular with upgraded instrumental capabilities.

The governance and funding organization of the telescopes on Mauna Kea is substantially more complex and internationally diversified than that of ESO. This presents challenges but also opportunities for future development on Mauna Kea. In particular, the international scene is changing rapidly. The new economies around the Pacific Basin are aspiring to become major players in science and technology, including astronomy. Mauna Kea is in an excellent position to embrace and capitalize on this emerging interest. <u>We suggest that strategic cooperation among the OIR telescopes on Mauna Kea, enabled by appropriate seed funding for competitive instrument development, could help US astronomy to achieve some of the highest scientific priorities laid out in the Astro2010 decadal survey despite the highly constrained budget conditions.</u> A key element of our plan is the intelligent combination of public, private and university resources with international partnerships to provide the US community with enhanced observational capabilities.

Building on existing structures: the observing time exchange program.

For almost one decade now there has existed an observing time exchange program between the 8-10m telescopes on Mauna Kea: Keck, Subaru and Gemini. This program provides access to these large telescopes and provides links between the various distinct communities. In particular it allows access to unique capabilities on the individual telescopes. This program, although kept at a rather modest level, has been a great success, and it has the potential to expand considerably in the future. No exchange of funds is involved and each observatory uses its existing Phase 1 proposal system to support proposals. As a result the management overhead is small. The oversubscription from the Gemini and Subaru communities for access to each other's telescope has been very healthy in the last few years, sometimes reaching factors of 5-6. The number of nights offered has been capped at 5 per semester to ensure minimal disruption to baseline operations. Both observatories place no restrictions on which instruments are offered through this program. The exchange time program between Keck and the other 8m-telescopes is somewhat more restricted and consequently has been less in demand. The scope of observing time exchange on Mauna Kea could be expanded significantly in the future, involving more nights, and perhaps also other telescopes. This would allow US astronomers access to unique capabilities. It would become particularly attractive if the cooperative strategic planning and joint instrument development concepts discussed below were instituted.

Strategic planning for major new instrumentation

Modern-day astronomical instruments are far more capable, complex and expensive than those of 20 or 30 years ago. Today, the cost of a competitive instrument can easily be 20% or more of the cost of the telescope on which it is used. This is a qualitative change in relative cost, and it calls for a qualitative change in how we do strategic planning for instrumentation. Astronomers have long abhorred the thought of a telescope sitting idle on a clear night, but nowadays an idle instrument should elicit a similar reaction. In the strategic planning for new instrumentation, we must avoid duplication and must arrange for these expensive instruments to be used as much of the time as possible. Such a strategy of course meshes perfectly with the time-exchange programs introduced above - in fact the two are interdependent.

Given the variety of organizations on Mauna Kea, and the different international funding bodies, it is impossible to harmonize the long-term strategic planning for new instruments in the same way as ESO can. However, some coordination and specialization has already been going on among the Mauna Kea 8-10m telescopes, as each has been developing its own special capabilities. Subaru, for instance, has the unique aspect of wide-field imaging and spectroscopy, with the new instruments HyperSuprimeCam (HSC) and the fiber-fed PrimeFocusSpectrograph (PFS) coming online in the near future. Keck is exploiting faint multi-object spectroscopy with the pioneering instruments LRIS, DEIMOS and MOSFIRE. Gemini is optimized for the infrared and is the only 8m telescope performing efficient queue observing, with ~25% dedicated to targets of opportunity. Each observatory community has its own traditions and procedures for the strategic planning for new instrumentation, and also its own funding boundary conditions.

Here we propose to harmonize these processes in two different ways. First, we will hold larger grassroots community meetings exchanging views about future scientific priorities at regular intervals. Second, we will include a strategic planning element in the regular meetings of the Mauna Kea observatory directors. One could start by attempting to coordinate the design and construction of major new instrument capabilities and ensuring that they will be commissioned on the telescopes that can best accommodate and operate them.

Eventually, consideration should be given to shared services to reduce operations and maintenance costs. This will introduce an additional incentive for coordinated instrument development. One positive concrete example can be seen in the Joint Astrometry Centre in Hilo, which is responsible for operating both JCMT (governed by the UK, Canada, and the Netherlands) and UKIRT (a telescope governed by the UK alone). Substantial cost savings have been achieved in recent years through coordination of JAC resources supporting both telescopes. This has been essential to continued operation of UKIRT and demonstrates that such arrangements are possible even with multi-national funding and governance logistics.

<u>NSF could play a major role in persuading and funding the US observatories on Mauna Kea to investigate more efficient, coordinated development and operation in return for funding upgrades and new capabilities.</u> A well-organized federation among the different telescopes on Mauna Kea will also allow a more efficient inclusion of new partners and potential new funding sources ultimately paving the way to an international Pacific Observatory Federation.

Cross-Observatory instrumentation cooperation

Beyond the observing time exchange program, a number of other highly successful inter-observatory cooperative efforts already exist on Mauna Kea, e.g. the Hale Pohaku mid-level facility, which provides food and lodging for all observatories, and the extremely important Mauna Kea Weather Center (http://mkwc.ifa.hawaii.edu/), which gives crucial atmospheric information and summit forecasts to all observers using sensors from nearly all observatories.

Looking ahead, there is great potential for inter-observatory instrument development. This is crucial to avoid duplication of efforts, to maximize return from a given instrument, and to optimally support time exchange programs. Arguably, the Gemini-Subaru idea of building the WFMOS wide-field spectrograph at the prime focus of Subaru, using joint Gemini and Subaru funding, has been the most ambitious attempt at inter-observatory collaborative development to date. In addition to developing the technical studies for WFMOS, an extensive draft inter-observatory agreement was negotiated between Gemini and NAOJ, which included terms for joint surveys using this remarkable system. Unfortunately the cost for WFMOS proved to be too large for the Gemini Partnership, so the project was terminated after the design study phase.

To be better prepared for future opportunities, it is important to understand why this project did not succeed. The basis for this collaborative development came from observatory staff in response to science initiatives that were broadly supported by the user communities of Gemini and Subaru (e.g., dark energy and galactic archeology). It was recognized that the same wide-field corrector and prime-focus facilities that were being developed for HSC could also support WFMOS, representing considerable cost savings and scientific synergy. On that basis WFMOS was supported at the agency level but in a funding environment that, in the end, proved to be unrealistic and unable to support a price tag of more than $70M for the instrument. Grounding such major new initiatives in realistic levels of funding from various agencies will be crucial to ensure their success in the future. Nevertheless Japan, in a new international partnership, is going ahead with a new version of the wide field spectrograph concept via the PFS project for the Subaru telescope. If the CFHT Corporation succeeds in upgrading its telescope to a 10m next-generation telescope (ngCFHT), uniquely dedicated to wide field spectroscopy, this spectrograph could conceivable be the workhorse of this new facility. So while WFMOS may have been too ambitious in its time, we can see that future international collaborations are a powerful and natural means to realize the next generation of facilities.

On a smaller scale, a new inter-observatory collaboration currently underway between Gemini and CFHT serves as a good example of innovative resource sharing. The GRACES project will fiber feed the CFHT high resolution optical spectrometer ESPaDOnS from Gemini-N. A deployable fiber feed module will be built into the Gemini GMOS-N spectrograph, feeding a ~300 m run of high performance optical fiber that will be coupled to the ESPaDOnS entrance image slicer at CFHT. The first implementation of this hybrid telescope/instrument system will be used to demonstrate the anticipated performance of the system before it is further developed into a full facility class system. Gemini is funding this new capability, at a cost which is an order of magnitude below what Gemini would spend to develop its own comparable system. This type of innovative collaboration yields millions in cost savings for new instrumentation, while opening up new avenues of research for the broader international community on Mauna Kea, including Gemini's community.

TSIP and Mid-Scale funding for future instrumentation

The NSF TSIP program has had a major positive impact on the Keck telescopes in the past decade, having partly funded OSIRIS, MOSFIRE, KCWI etc. The users of Keck benefit from new instruments, which have a huge reach and new capabilities while the broad US community gets access to a leading edge facility. Unfortunately, the TSIP program has been cancelled because of funding pressure at NSF. We argue here, that an adapted NSF funding scheme is essential to keep the telescopes on Mauna Kea at the leading edge of research in the coming decade to the benefit of the US community.

We discuss here the use of cross-observatory, next-generation adaptive optics (AO) development systems as an example of how large synergies could be exploited. Next-generation AO systems are one of the highest priorities in the Astro2010 Decadal Survey. Adaptive optics systems are commonplace on all of the large aperture ground-based astronomical telescopes in the world with no fewer than five first-generation "classical AO" systems on Mauna Kea. A wave of next generation approaches is being developed to address key deficiencies in the classical approach: anisoplanatism that leads to the variation of the point-spread function across the field of view with the resulting inability to access large portions of the sky and the relatively modest corrections that current systems achieve that are insufficient for very high-contrast studies. On Mauna Kea: (1) Subaru has deployed a 188-element curvature system along with an extreme-AO system coronagraph, (2) Keck's next-generation AO system (NGAO) will bring better correction, sky coverage, point spread function uniformity, sensitivity and contrast, and (3) CFHT, Gemini and Subaru are exploring seeing improvements via ground-layer AO with on-sky tests and characterization planned on the UH 88-inch telescope. The collaborative use of the UH 88-inch as a technology development platform, as part of a coordinated strategy for demonstrating and prototyping new AO technologies, illustrates the type of resource leveraging possible across the Mauna Kea observatories.

An approach that would enable new AO systems, with considerable benefit to the broader community, would involve the use of "mid-scale" funding from the NSF. Under this approach the University of Hawaii would offer to coordinate the cross-observatory development of these systems, providing lab, shop, on-sky demonstration with the 88-inch telescope, and administrative infrastructure in their existing building on the UH-Hilo campus. Although the general concepts of next-generation AO systems have substantial differences, there are many common elements and needs for technology development, e.g., photon-counting NIR wave-front sensing arrays, adaptive secondary mirrors, advanced Raman fiber lasers, etc. It is obvious that for the Keck NGAO most of the development is being done by strong groups in California (e.g. UCSC/Lick/CfAO and Palomar/JPL/ Caltech), with a small but strong contingency at the Keck headquarters in Hawaii. However, almost all of the first generation AO systems on Mauna Kea required a significant period of commissioning and optimization. That expertise has been developed in the observatories, since it was largely done by the observatory teams and not the instrument builders. Maintaining a team of experienced AO instrumentalists across the observatories in Hawaii therefore would be beneficial to all the groups.

Participating Mauna Kea observatories would exchange technical expertise to help implement a number of advanced AO systems at different facilities. In exchange for financial support, participating observatories would agree to provide access to the US community in a program akin to the TSIP program specifically tailored to AO development, consistent with the US AO Roadmap (http://www.noao.edu/system/aodp/AO_Roadmap_2008_Final.pdf). This win-win strategy would capitalize on the exceptional AO talent and singular investments in Hawaii now, while yielding exciting new capabilities and enabling access to all US astronomers. It is fair to say that no other site is better positioned today to leverage past investments and unique expertise in adaptive optics than the Mauna Kea observatories. This approach would make a large range of instruments on Mauna Kea available to the entire US community at an unprecedented level and in a cost-effective manner.

Summary

The National Science Foundation should play a major role in enabling a strategic cooperation among the Mauna Kea telescopes and funding upgrades and new capabilities for the US community. Appropriate seed funding for a TSIP-like competitive instrument development, e.g. using the midscale funding scheme, is necessary to keep the telescopes on Mauna Kea at the leading edge of research in the coming decade and would allow the US astronomy community to achieve some of the highest scientific priorities laid out in the Astro2010 decadal survey despite the highly constrained budget conditions. Ultimately, NSF could lay the foundation for a truly international Pacific Observatory Federation on Mauna Kea.