OHANA Phase III: Scientific operation of an 800 meter Mauna Kea interferometer.

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ABSTRACT

Once the proof of concept of the OHANA Array has been demonstrated, the Phase II capabilities can be put into regular science operation, and the OHANA facility can be upgraded to extend interferometric operation to include all of the telescopes of the OHANA Consortium member observatories. This will constitute the Phase III of OHANA.

The technical developments required will be relatively straight-forward. Longer fiber sets will be procured (fiber losses are not a limiting factor at the OHANA scale). An enhanced delay line capability will be needed in order to exploit longer baselines with good sky coverage and ample super-synthesis (several compact, multi-pass long optical delay concepts are under investigation).

The scheduling and operational modes of an instrument such as OHANA present interesting opportunities and complications. We envision a place for both collaborative consortium science, based on mutual allocation of facility access, and PI-driven access, based on telescope access exchange between consortium members. The most potentially successful mode of operation would imply a community driven model, open to proposals from the different time allocation committees. This poster looks at possible methods of allocation and operation, inspired by the UKIRT infrared survey (UKIDSS), the European VLBI, and the very interesting possibility of a Mauna Kea telescope time exchange scheme.

The issue of data property is of course intimately tied with the proposal/operation system, and means of data availability and distribution are discussed, along with data interpretation tools, which may be modeled on existing systems such as the ISC at Caltech or the JMMC in France.

When weighed against the UV coverage, the potential science and the uniqueness of this project, all these issues are worth an in depth study. Discussions are starting as to an OHANA Operation Committee, the goal of which would be to discuss, define and eventually carry out operational modes. The goal, of course, is for the Operation Committee to handle the details of multi-telescope scheduling in a way that will be transparent to the scientist who merely seeks the observational results.

Keywords: Interferometry, operations, observing methods

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1. INTRODUCTION TO THE OHANA ARRAY

OHANA (Optical Hawaiian Array for Nanoradian Astronomy) will link the major existing optical telescopes on Mauna Kea with single mode optical fibers for interferometric operation. Injection of star light into fibers is now well understood (Ref. 1), and the large Mauna Kea telescopes are equipped with adaptive optics (AO) enabling a high injection efficiency (Ref. 2). Several fiber types are available in single mode for operation in the spectral range visible through near-IR and into the mid-IR. The linking of pre-existing telescopes which were not designed for interferometry has been demonstrated (Ref. 3). Fiber beam combination is a well established technique which has been shown well suited for precision visibility measurement (Ref. 4).

OHANA will be developed in three phases. Phase I, now underway, will demonstrate injection of starlight into the fibers which will be used in Phase II. Phase II, now in preparation, will demonstrate interferometric operation between selected Mauna Kea telescopes (Ref. 5). Phase II may be continued indefinitely for initial science operation. In Phase III, the OHANA capability will be extended to additional telescopes, and science operations will become regularized (Ref. 6)

1.1. Memorandum of Understanding

A Memorandum of Understanding covering Phases I and II is currently being reviewed and signed by participating organizations. The approach taken for Phases I and II is that of a prototype instrument, and the purpose of the MoU is to grant visitor instrument status to ‘OHANA for a number of technical nights. The work required to turn the sub-components and the operations of ‘OHANA into facility instrumentation are not covered by the Memorandum of Understanding, and are part of the planning in progress for Phase III.

2. SENSITIVITY LIMITS

Estimating the sensitivity limit for OHANA is fraught with difficulty, as the array will incorporate various telescopes and AO systems in its operation. One of the results of Phase II will be some experience with fiber injection efficiencies on the sky. For one particular (relatively conservative) set of assumptions, we estimate the following for the instantaneous (single atmospheric time constant) sensitivity. (Note that the fiber technology is not equally developed and demonstrated in all wavelength regions.)

Waveband	Strehl	M_{lim}
V	.01	10
R	.02	10
I	.05	11
J	.21	12
H	.41	12
K	.61	12
L	.85	7
M	.93	4

These numbers show a relatively bright visible and thermal infrared limit (due, respectively, to AO performance and thermal background emission) and a fairly deep capability in the near IR (possibly up to several magnitudes deeper than shown in the table, according to more optimistic calculations[7] .)

3. SCIENCE OPPORTUNITIES AND THE RATIONALE FOR OHANA

The basic OHANA concept is to link existing large Mauna Kea telescopes with fibers. This is obviously not a trivial exercise, and should only be undertaken for clear and compelling reasons.

At the same time, the OHANA linkage offers very interesting and unique capabilities. It will simultaneously offer the largest collecting apertures available, with the largest interferometric baselines. The combination is attractive, for obvious reasons. Astronomy is replete with many examples of small sources (e.g., galactic cepheids, brown dwarfs, microlenses), that are both difficult to resolve and typically faint. It is reasonable that in some cases, their study may offer such interest that they merit special effort. While a dedicated large telescope array may be developed at some future time, OHANA offers an interim opportunity, at low incremental cost, to enable selected high priority science programs.

In order to evaluate the science opportunity, members of the OHANA consortium examined a number of possible programs. Of particular interest are those which are of high scientific interest to a broad community, and which appear to be distinctly beyond the capability of array facilities currently in operation or under development. In comparison to such very capable arrays as the Keck interferometric facility and the VLTI, OHANA differs mainly in offering angular resolution up to $2-4\times$ higher.

Examples of programs which met the criteria of high priority and uniqueness are (Ref. 7): the physical characterization of brown dwarfs (direct determination of effective temperatures and diameters), AGN's (measurement of nuclear size and shape), cepheids (full characterization of a broad selection of population and abundance, with measurement of limb darkening), YSO's (characterization of the accretion disk size and shape), and selected microlensing events (characterization of the lensed image). Examples of other potential programs, which are within the capability of OHANA but have not been studied, include cataclysmic variable systems, the relativistic system SS433, and the broad line region of bright QSO's.

These science examples are selected to explain the interest in an OHANA capability. They are developed in further detail in Ref. 7). The choice of topics is meant to be representative and illustrative, and their publication is not intended in to preempt these topics for the current OHANA consortium members.

4. SCIENCE AND PHASE II

The primary purpose of Phase II is the demonstration of feasibility. The present MoU calls for two technical nights from each participating telescope for phase II. If we consider the two triplets of telescopes (and baselines) [CFHT-GEMINI-UKIRT] and [IRTF-KECK-SUBARU], irrespective of how these nights are eventually allocated and divided, this means that there is effectively ONE NIGHT PER BASELINE in the initial allocation for Phase II. Realistically, after having found the fringes, and done a few unresolved and (known) resolved sources, and maybe a few photometric standards, this would not leave enough time to carry out more than one or two trial measurements for the demonstration science programs. This illustrates the goal of the science cases developed in Ref. 7, namely to show examples of the type of science that will be possible and how it might be attempted, not as any definitive scientific observing plan.

5. TECHNICAL REQUIREMENTS FOR PHASE III

While Phase II will demonstrate interferometric operation, the science potential will be limited by the use of moderate fiber lengths and limited optical delay capability. The outstanding technical issue for Phase III will be production and installation of longer fibers, offering an adequate range of spectral access, and delay lines with sufficient total path. Since only pairwise telescope combination is planned for Phase III at this time, all other OHANA equipment from Phase II will carry-over directly to Phase III, including beam combination, detectors and control systems. This equipment is currently under construction, illustrating that OHANA is under active development. The required fibers for Phase III are commercially available. The prices may be high, in some cases, however, and so present a non-technical, but significant, challenge.

The required total optical delay is of order 800 meters. This is not intrinsically a problem, but for environmental and cost reasons, it must be provided within existing structures without new construction. A number of concepts are available, which do not present particular problems or require significant innovation. This topic is the subject of a separate poster paper at this conference (Ref. 8)

6. HOW COULD THE OHANA ARRAY BE OPERATED IN PHASE III?

As technical progress is being achieved and single mode fiber interferometry is becoming a reality, it is timely to raise the important and interesting issue of how could the OHANA interferometer be operated in phase III. This issue has to be addressed early because a clear vision at this stage will give a solid foundation to the later phases of the project. This will facilitate obtaining support and/or commitment from our respective communities.

This instrument has to deal with a very particular set of circumstances. The array is common to many telescopes, each one serving its own community. In effect, each community would be giving up some valuable telescope time for OHANA if it were to be operated on a somewhat regular basis. Therefore the communities need to be involved in - and must have access to - the OHANA interferometer in appropriate measure to justify their interest and commitment.

Since OHANA will require coordination of some number N of large telescopes for its operation, where $N > 1$, it may be expected that the potential complexity of operation might scale as N^2. A significant challenge of Phase III is to identify and implement operating policies and practices which are acceptable to all OHANA consortium members, and which are effective scientifically.

7. OPERATIONAL AND POLICY ISSUES

The OHANA consortium membership currently has representatives from most Mauna Kea observatories, including: Andy Adamson (UKIRT), Rolf Kudritzki (IfA, UH), Olivier Lai (CFHT), Pierre Léna (Observatoire de Paris), Jun Nishikawa (NAOJ), Guy Perrin (Observatoire de Paris), Steve Ridgway (NOAO), François Rigaut (Gemini), Alan Tokunaga (IRTF) and Peter Wizinowich (Keck).

The major practical operational issue concerns coordinated scheduling of telescopes operated by independent organizations, some of which may have a stronger history of healthy competition than of intertwined science programs. This could be a formidable issue - however, the very existence of the OHANA consortium, with its broad membership, shows that member observatories are motivated to find solutions to operational matters.

Interesting policy issues concern the procedures for bringing telescope time into the OHANA consortium, and for allocating it to users. As each observatory will presumably contribute time strictly according to its own evaluation of scientific priorities, it is clear that OHANA policies must fully support and serve the individual Mauna Kea communities as well as, and even before, the consortium *per se*.

8. OPERATIONAL SOLUTIONS?

The envisioned mode of operations therefore needs to be open to proposals from the communities. How this could be achieved still remains to be determined but there are precedents either with large scale projects such as the UKIRT surveys, European VLBI or some form of telescope time exchange agreement. The operational model of each is very different, and each is well adapted to the structure being managed.

8.1. UKIDSS

The suggestion that UKIRT's wide Field Infrared Camera, WFCAM, should be used for a set of ambitious public surveys originated from Andy Lawrence, who is the PI of the UKIRT Infrared Deep Sky Survey (UKIDSS)[9] .

In 2000, a call was made to the UK astronomical community for volunteers to form a consortium which would

- design a set of surveys,
- prepare a request for telescope time for approval by the UKIRT Board, and
- undertake the observing.

Membership of the consortium is, and has always been, open to all UK professional astronomers. The processed survey data will be made available to the UK community immediately it enters the archive, and consortium members have no privileged data rights. However, joining the consortium is the only way to affect what scientific programs will be carried out. The purpose of the consortium is to represent the survey interests of the community, and to undertake the surveys on behalf of the community. This is illustrated by the fact that there are currently over 70 consortium members, a significant fraction of the UK optical/near-IR astronomical community.

However, membership of the consortium implies an obligation to provide a substantial contribution in effort towards the completion of the surveys. For most members, this would take the form of actual observing at the telescope during the survey (up to 7 nights per year), but the contribution could take other forms.

It can therefore be seen that the UKIDSS survey (somewhat in the same way as the CFHTLS, the CFHT Legacy Survey[10]) is a "grass–roots" effort, relying on community support and involvement.

8.2. European VLBI structure

The European VLBI Network (EVN) is a collaboration of the major Radio Astronomical Institutes in Europe and Asia. It has been performing high angular resolution observations of Cosmic radio sources since 1980 and manages 14 major institutes. Due to the scope of this project, it is very well structured and managed, as a facility instrument. As such, it could therefore be a very good operational model for the Phase III of OHANA.

The overall policy of the network is set by a "Consortium Board of Directors", which is composed of the directors of the participating institutes. There is then a "Technical and Operations Group", which is responsible for advising the Consortium Board of Directors on all aspects of technical and operational issues relevant to the reliability and performance of the network. This group is also the body which implements technical and operational upgrades across the network.

Observing programs are open to astronomers from all over the world, as the EVN is an open facility and the observing time is awarded on scientific merit and technical feasibility. Observing proposals are submitted to a Programme Committee, which consists of astronomers internal AND external to the EVN. Both the Technical and Operations Group and the Programme Committee report to the Consortium Board of Directors.

The observing of the European VLBI Network takes place in campaign mode: There are four 3-4 week long periods per year, known as "VLBI sessions", where the array is operated at 3 or 4 different frequencies. A scheduler ensures that all the telescopes follow the same observing schedule.

The EVN actually encourages use of the Network by astronomers not specialized in the VLBI technique. As such, a special facility, the Joint Institute for VLBI in Europe (JIVE) has been set up to provide support for proposal preparation, scheduling and correlation of EVN projects. JIVE support scientists are also available to support users with data analysis.

8.3. Telescope Time exchange

Somewhere in between the community driven UKIDSS model and the facility level management of the EVN, one could conceive a Mauna Kea specific model, that could be used outside of the OHANA project to foster collaborations across the Mauna Kea communities, but which would also allow interferometric observations with specific proposals. This would require a scheme by which telescope time could be exchanged between observatories.

It has been argued that it is not optimized, nor cost-effective, to develop (let alone operate) similar instruments on adjacent telescopes. An apparently simple solution to this objection would be to develop instruments particularly suited to each telescope, but allowing telescope time to be exchanged between various observatories.

The theoretical case would be if two observatories agree that, for example, one is more efficient in the visible, the other in the infrared. Each develops an instrument optimized for its spectral range coverage, with the agreement to give half of their observing time to each other. A scientific evaluation committee can be set up at each observatory to assess the proposals of their own community, while a technical evaluation committee will evaluate the proposals for their respective telescopes.

In practice, instruments already exist and such agreements don't. Most observatories have separated (or could separate) the technical from the scientific justification and review. To implement such a practice, two key elements are needed. The first one would be a currency of telescope time, to assess the question of telescope time equivalence. Whether this would be proportional to linear time, to telescope diameter or to operating costs is well beyond the scope of this paper. The second one is accountability of such a currency. Ideally, this could be a task for the Mauna Kea Directors. The advantage of such a scheme is that each observatory can participate to OHANA at a level which is proportional to the community involvement and support.

8.3.1. Opticon network

There is a precedent to the telescope time exchange scheme, in the European Opticon Network, which aims at coordinating medium-sized, ground-based, optical/IR observational astronomy facilities all over Europe in the COMET project (Co-operative Operation of Medium-Sized European Telescopes). With the long-term aim of introducing all European astronomers to state-of-the-art research facilities and developing scientific collaborations across Europe, the immediate intention is to provide access to facilities based on scientific merit in a way not limited by the geographical location of a particular facility or individual.

A strong driver for this program is to emphasize the provision of new opportunities to develop European science. This will take the form of opening existing facilities to a wider range of users and for a wider range of projects. The opportunities for gifted individuals to develop their ideas fully without being limited to only those national facilities to which they normally have access will increase dramatically. At the same time, the network can provide a synthetic view to rationalize facilities while ensuring the full range of capabilities is retained for the community as a whole.

Note that a major difference between the COMET/Opticon Network and OHANA is the difference in the range of telescope diameters, operating costs and pressure for telescope time amongst the participants.

8.4. Potential application to OHANA

At least three distinct modes of scheduled access to OHANA could be imagined. First, scientists from one community could propose for access to their community facilities, requesting sufficient time to fully carry out an OHANA project - that is, including time from the community's telescope for the OHANA observations, and also enough additional time to swap with other OHANA telescopes in order to enable the observation.

Second, consortium members could agree, based on a level of expected and agreed activity, to commit some number of telescope nights to the consortium in exchange for priority access to some number of nights of OHANA operation. In each of these two cases, scientific review and allocation could be entirely within the home community allocation process of the scientist.

A third possible avenue could be for consortium members to initiate collaborative proposals, with review by allocation committees of all impacted telescopes.

Since OHANA is a consortium of scientists driven by science interests, we are most interested in the allocation and scheduling scenarios which contain an element of scientific collaboration as well as technical and facility sharing between communities. Thus we hope and expect that the reality may be a blend, with most projects having some collaborative elements - some based on initiative within member observatories and some based on initiative within the consortium. However, we would like for OHANA to be able to support a wide variety of proposal types, including PI programs from a single community. If OHANA is as successful as we believe possible, then there will be a significant number of interferometric nights each year, and the operations support will have the resources and experience to respond flexibly.

One thing we may be sure of - because of the high price (in large telescope nights) of OHANA observing, only the highest priority and most compelling proposals are likely to survive.

9. POTENTIAL OPERATIONS COMMITTEE

Finally, to be able to achieve this, a vehicle needs to be set up to discuss and eventually carry out the operational ideas and/or modes. It seems that a campaign mode could be appropriate, with some identified key programs and some community proposals (ideally with an encouragement for collaborative efforts). Such a coordinating committee could have three roles: one user oriented, one technical, and one operational.

- "User oriented" means that it would somehow solicit, coordinate or otherwise generate community input (in the form of proposals, key programs, etc.), weighing the scientific value and merit of programs as a function of the time required to carry them out. Such a committee might need to be impartial and independent of 'OHANA, yet well aware of its specifications. Of course the committee would have time to allocate only at the pleasure of the different OHANA communities, and so a vital role for the committee would be advocating proposals and supporting them in reviews by the existing community TACs. This is not a casual issue, since a TAC would be understandably reluctant to allocate a number of nights to a program involving third party support unless reliably assured that the program could be carried out as proposed.

- "Technical" means being able to judge feasibility from an interferometry standpoint but also sufficient knowledge of and interaction with the operations of the telescopes on the mountain to be able to review the technical details, or even iterate with the PI in developing the technical program.

- "Operational" refers to the myriad of issues involved in organizing and operating OHANA, starting with coordination of telescope schedules to enable the execution of mutually approved programs, and continuing to proper staffing of the OHANA equipment and coordination of the observing activity.

Such a committee would not be solely aware of scientific issues but also sensitive to the balance of the communities in the programs. Clearly there must be an approximate balance among the communities, between the input to output of a given community and between a community involvement and its representative telescope's involvement and/or amount of telescope time contributed. Initially, it may be necessary to maintain a quite accurate balance even over the short term. As the consortium activity becomes a familiar and stable, it would be unreasonable to expect such a balance on a short term basis, but a sensitivity of the decision-making process to long term averages would be essential to serve the interests of all consortium members.

10. DATA REDUCTION AND DISTRIBUTION AND DATA RIGHTS

The processing of interferometric data is not necessarily mysterious, but it remains a somewhat specialized activity. It is likely that data reduction will be undertaken by OHANA participants who have experience with the facility and its operation. Tapping this expertise will also be a natural motivation for developing multi-institutional collaborations. The growing number of national facilities with expertise in optical interferometry data processing (eg, the ISC and the JMMC) are also potential sources of support.

The issue of data property rights is intimately linked to the consortium concept. In a sociologically diverse community such as OHANA serves, flexibility is certainly required and OHANA should be responsive to the needs of the communities, while respecting the legitimate interests of the consortium members. We are most comfortable with collaborative programs in which results will be shared between participants within the context of the project.

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