Flexible Scheduling of the UK Infrared Telescope (UKIRT)

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ABSTRACT

We present a summary of a short experiment in flexible scheduling of the UKIRT telescope in Hawaii. This was accomplished by asking visiting observers to alternate between projects based on specified environmental conditions. This limited experiment delivered more time on target in the required conditions than would have been achieved by classical scheduling. We find there is a need to accurately estimate overheads during observation planning, to deliver unambiguous measurements of observing conditions on which decisions can be made, to have software to reduce the administrative overhead when accounting for time used and distributing data taken during flexible observing.

Keywords: flexible scheduling, queue scheduling, observatory operations

1. INTRODUCTION

1.1. Why flexible scheduling?

There is an increasing desire to maximise telescope productivity by moving away from traditional scheduling in order to take advantage of specific, but rare, conditions which certain types observations require. Typical of these desirable but sometimes rare conditions are good seeing (generally for imaging projects) and low water vapour column for most kinds of mid-infrared and sub-millimetre observing. Thus many observatories are implementing various flexible, or queue scheduled, observing strategies. Typical of these are the WIYN telescope,[1] Gemini[2] and the JCMT.[3]

Flexible scheduling schemes may range from fully queue-scheduled operations in which observations are drawn from a large pool of approved but not yet executed observations according to some algorithm which balances scientific grade, match to conditions and other observatory specified parameters (such as national share or project completion criteria), to a system where observers select between a limited range of projects based on simple criteria such as water vapour column or seeing. To be effective, fully queue-scheduled schemes may need complicated processes to ensure that at any given time the correct observation is selected, that it is executed in the manner specified by the Principal Investigator, that it meets observatory quality control criteria, that the data is duly transmitted to the appropriate investigators in a timely manner and that the observation is then removed from the queue.

1.2. Background to the UKIRT experiment

The United Kingdom Infrared Telescope (UKIRT) is a 3.8m infrared-optimised telescope operated by the Joint Astronomy Centre for the astronomical community. Although conceived in the 1970's as a simple "flux collector" UKIRT has undergone a series of upgrades to both the telescope and its environment which allow it to routinely deliver both good-quality images (Median FWHM approximately 0.5 arc seconds[4]) and outstanding performance in the thermal infrared. The telescope will shortly receive a new mid-infrared camera spectrometer (Michelle[5,6]) a new near infrared camera-spectrometer UIST[7] and in the somewhat longer term it will be equipped with a wide field camera able to conduct deep surveys in the near infrared (JHK) bands.

To take full advantage of these new facilities, especially Michelle for which specific weather conditions will be needed if its 20 micron capabilites are to be exploited, UKIRT would gain enormously from moving away from its present "classical" block scheduling towards a more flexible approach. There are numerous issues, both financial and sociological, concerning all-up queue scheduling. These have been reviewed by Robson[8] and include the fact that such schemes can be very staff intensive (and are hence likely to be expensive), the need to make the users comfortable with the process and to ensure a regular throughput of visitors and students to remote observatory sites. For these reasons some facilities, notably the James Clerk Maxwell Telescope have operated a flexible scheduling scheme using visting scientists as observers,[9] Tilanus00. These visitors may make observations for their own project

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or may, in the event of specific weather conditions, be required to observe as a proxy for an absent investigator. A move towards this type flexible scheduling of UKIRT is likely to require considerable investment in both observing and queue management tools and in user education. In order to gain some experience with these issues, UKIRT was directed to carry out a limited flexible scheduling experiment during the 99B semester (August 1999- Jan 2000). The objective was to test protocols, observing tools and human factors which interact during a period of flexible scheduling using visiting, rather than local staff, observers.

For this experiment UKIRT users were not invited to nominate specific projects but rather, at the time allocation meeting, three pairs of projects which appeared to have complementary observing requirements were identified and linked as having potential for flexible scheduling. The intention was that the pairs of projects would be scheduled contiguously and that only one observer would come to the telescope. This observer was expected to be the one whose project demanded the most stringent conditions and the observer would then "Flex" between projects according to the conditions *.

Note that this is a project to "match to conditions" and took no account of the relative scientific ranking of each proposal. A related "Reactive Scheduling" scheme[10] which has been underway at UKIRT for some time attempts to ensure the full allocation of observing time is made available for the most highly ranked projects whatever the weather.

2. THE RULES

Experience[11] at UKIRT with the Reactive Scheduling scheme has shown that, given any "fuzziness" in the selection criteria, observers faced with a decision to switch projects will generally err on the side of whatever gets the most data for projects in which they have an interest. This is understandable given the intense competition for telescope time, the difficulty of quantifying observing conditions with high precision and the uncertainty of knowing how much, if any, time will be repaid if the observer's own project is subjugated to another †. In an attempt to resolve this difficulty the UKIRT staff defined, in as great a detail as possible, specific rules on how conditions were to be measured, for how long they must be stable before initiating a change of project and how time would be accounted for in the event of bad weather, system failures or the triggering of other pre-approved observatory over-rides (such as a Gamma-Ray Burst). The objective of these rules was to miminise the amount of interpretation required during the middle of the night when the observer was already under considerable stress due to altitude and a natural desire to press on and obtain data. Note that to avoid any post-facto dispute about conditions, it was agreed that once an observer started to observe their project the clock was ticking and the time used was being counted against their allocation.

3. THE PROJECTS

The three pairs of projects chosen for the experiment were as follows.

Pair 1. Two projects to image galaxy clusters. One of these required seeing better than 0.5 arc second, the other was less demanding in terms of image quality. This was a fairly straightforward test of switching between similar projects based on a single criterion.

Pair 2. A project to identify the morphology of distant galaxies with high spatial resolution which was flexed against a mixture of Director's Discretionary Time and Service Observing with no specific environmental requirements. This was a more demanding test since while the seeing conditions for switching between projects were clear, the alternate observing programme was an eclectic mixture of different projects, some of which required changing instruments. This simulated queue observing where the observer may be presented with a variety of different options with only limited time to consider the details and implementation of each observation before making a decision as to which to adopt.

Pair 3. An imaging project requiring good seeing and a 3 micron spectroscopy project for which seeing was not critical, but which did require low humidity in order to maximise sensitivity in the wavelength region of interest. This tested our ability to test one condition (eg seeing) when observing with a non-imaging instrument with quite different constraints.

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*In one case the observer requiring the most demanding conditions had the shorter run and various travel commitments which required that the run was executed by representatives of the other proposal.

†This is likely to be less of a concern for telescopes which are fully, or at least largely, queue or flexibly scheduled and so will generally still have large blocks of time uncommited.

4. THE TOOLS

Although the UKIRT observatory has a conventional weather station it does not at present have access to any more sophisticated tools (such as an all-sky IR camera for detecting clouds during dark nights or a dedicated Differential Image Motion Monitor for seeing measurements). For determination of the seeing two options were available. Provided suitably bright guide stars were accessible it was possible to use the output from the Shack-Hartmann system which forms part of the facility fast-guiding system. This operates in the optical regime and its output has been calibrated in terms of seeing in the near-infrared during the upgardes project.[4] If suitable stellar images were available in the fields being observed, it was also possible to make seeing measurements directly on the infrared images taken as part of the science programme.

There was also access to a local humidity meter and to a measurement of the CSO tau, effectively a measurement of the opacity at 1.3mm which is provided to the Mauna Kea observatories courtesy of the Caltech Sub-millimetre Observatory. CSO tau is used by the JCMT to define weather bands for its flexible scheduling programme[12] although a decision was taken not to use this during the UKIRT experiment since UKIRT does not yet have a calibrated relationship between CSO tau and 3 micron transmission.

5. RESULTS

There are two possible approaches to assessing the results of the test. Each member of the paired runs had a nominal scheduled date range in the original UKIRT schedule and since the conditions during the experiment are known, it is possible to assess how each project would have fared if they had been scheduled classically. It is also possible to attempt to distill the experiences of the individuals involved as recorded by both their written post-observing reports and by interviews carried out after the runs.

5.1. Quantitive results

TABLE I.

Statistics of flexed UKIRT proposals.

Project	Allocation (nights)	Percent of allocation within requirments (classical)	Percent of allocation within requirements (Flexed)	Percent Gain by Flexing
1A	1	17	79	460
1B	4	77	82	106
2A	2	2	2	0
2B	2	0.25	0.5	50
3A	3	36	53	147
3B	2	50	58	116

Within the fairly small number statistics, Table 1 shows that most of the flexed runs achieved more time on target in conditions within their criteria than would have been achieved otherwise. Run 2B, which required better than 0.5 arc second seeing did not achieve much additional time on target since at no time during the four day period was there a long period of significantly good seeing at better than the required level.

5.2. Qualitative feedback

The observers who benefited from the experiment recognised that the experiment did allow them to obtain more time on target in conditions suited to their project.

When seeing was close to the specified value for switching projects, the inevitable noise in the seeing measurements (a problem often compounded by a shortage of suitable guide or PSF stars at high galactic lattitude) made it difficult to decide when to change programmes.

Two of the observers admitted ‡ to a temptation to interpret the present conditions in a manner that would bias the data taking in favour of projects in which they had an interest. For example, the knowledge gained from a

‡rather courageously

long range weather forecast that severe weather was approaching meant that one observer was faced with observing for some-one else in the near certain knowledge that the remainder of the run, and hence the rest of their own anticipated observing time, would be lost. The other observer was strongly tempted to aquire data when the seeing was 0.55 arcsec, close to but not quite at the level specified, on the grounds that data taken under these conditions was "probably good enough" especially since the determination of the seeing was a bit noisy and "perhaps the seeing was a bit better than indicated". It would also be possible, although there is no suggestion that this was done during these observations, for a devious observer with relaxed seeing criteria to work at high airmass or with the telescope pointing into wind in order manipulate the measured image quality to their advantage. We beleive that all of these result from the limited observing time available for the experiment and would be much less likely to occur during fully queue-scheduled operations when the likelihood of ultimately achieving the desired conditions would be much higher.

6. LESSONS LEARNED

At present UKIRT uses a data aquisition system which allows the data taking process to be specified in advance via a number of files called "EXEC"s and "CONFIGS".[13] Accordingly an investigator, whether present at the telescope or not, has a means of specifying some observation parameters, such as exposure time, filters and jitter (dither) patterns in detail. However the absent Principal Investigator is still dependent on the actual observer and telescope system specialist to acquire the correct field and to execute the specified observations in the correct order. The present system also requires a reasonably detailed understanding of how the telescope and instrument operates before it is possible to specify the EXEC and CONFIG files. The soon-to-be implemented ORAC observation preparation system[14] is rather more sophisticated and provides the observer with a preview of the area to be observed projected onto, for example, a Digital Sky Survey image and allows them to specify specific guidestars and telescope offsets from that star. This system will place the onus of ensuring correct pointing, adequate jitter patterns etc firmly on the shoulders of the Principal Investigator.

However, neither of these observation preparation systems takes account of observatory overheads such as slewing the telescope, moving the telescope and dome or for time spent focussing and peaking up a spectrometer. Nor do these tools force the aquisition of observations of appropriate standards. As a result it is very easy for an observer to specify a programme which has approximately the allocated amount of integration time, or time on target, but which simply cannot be executed in the number of real hours allocated to the project by the time allocation committee. This puts the proxy observer in a very difficult position, having a choice between either starting to execute the observations as specified in the near certain knowledge that the programme will run out of time before it is completed or modifying someone elses project in near real time based on what one observer "thinks" the other one actually wants.

- Lesson 1. In this flexible-scheduling mode the observation preparation tool must make due allowance for overhead, either by calculating specific overheads for each observation or applying an average fraction of each night to overhead.

Observers found that flexing between two broadly similar projects, such as two galaxy imaging projects which differed mainly in terms of the seeing which they required, was fairly straightforward since the basic issues concerning the data were understood by both observers. However, switching between imaging and spectroscopy, or between a specific imaging project and a service queue in which each observation was very different, was more demanding since it required a switch of mindset and perhaps expertise with an instrument and/or observing technique which the observer did not have.

- Lesson 2. The observation preparation tool should specify each observation in sufficient detail that an observer inexperienced in a specific observational technique can execute it without the need for special skills or experience.

Observers needed to have a real-time, or quasi real-time, display of the data with which to make judgements about data quality. For example, a data-reduction pipeline which produces images good enough to determine whether the image quality required by a specific project is in fact being achieved. Absent observers must be able to specify simple tests which can be done on such pipeline-reduced data in order to provide quality assurance to the proxy observer and convince all concerned that the project is acquiring useful data.

- Lesson 3. A robust data reduction pipeline with adequate diagnostic tools is essential.

Monitoring the progress of the experiment was very labour intensive for the observatory staff. There was a need to review each night's observing and to immediately modify or update target lists based on what had been done. Data distribution was complicated by the fact that a single night contained data for more than one group so the data had to be sorted and packaged before it could be circulated. Accounting for time used had to be done on a night by night basis to ensure that the time available was distributed equitably. This staff overhead was tolerable for the small number of nights allocated to this experiment but to have run an entire semester in this way would not have been practical.

- Lesson 4. Computerised data management tools are required for accounting and data distribution.

Despite the logic that observations should be done only when the conditions were good enough for the scientific observations to be achieved successfully, it was clear that in the minds of some observers they had been allocated a specific amount of time, and that if conditions were less than optimum then they should be permitted to revert to a less demanding back-up project of their own rather than observe on a project in which they were not stake-holders. In one case the proposed back-up project amounted to observing the same fields in poorer seeing to achieve a different scientific objective. In the context of this experiment this was understandable since the flexing aspects had been imposed on projects which had already been submitted to a time allocation committee without any prior knowledge that they might be flexed. Furthermore the present application form requires that a poor weather back-up project be specified. This line of thinking manifested itself again in semsester 00A when attempts to organise further flexing runs proved impossible. Although suitable pairs of projects were identified, there were insufficient groups willing to be flexibly scheduled, several individuals stating a preference to "take their chances" or regarding conditions as "the luck of the draw".

- Lesson 5. There is a need to change the mindset of observers that an allocation of observing time is immutable whatever the conditions.

Finally there is the issue of how such a scheme is to be arbitrated. It is not hard to envisage a situation where an observer might ignore, or flagrantly mis-interpret, the guidelines in order to obtain some data to which they were not formally entitled. It is not clear what sanctions, other than peer displeasure, could be applied to such individuals. It is easy to argue that having agreed to a set of rules then everyone should follow them, but it would be wise to consider what steps might be available should individuals cross the line. However we note that in this experiment all the observers cooperated fully with the observatory in order to make the experiment work and all benefited as a result of their professionalism.

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