SELECTING, SCHEDULING, AND CARRYING OUT OBSERVATION PROGRAMS AT THE SUBARU TELESCOPE

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Abstract. I explain the current systems for evaluating and selecting observation programs at the Subaru telescope, and how individual programs are scheduled and executed, to maximize scientific outputs.

1. Subaru Proposal Systems

The Japanese-built Subaru telescope is one of the world’s largest optical and infrared telescopes (with a primary mirror diameter of 8.2 m), located on the summit of Mauna Kea, Hawaii. The telescope is equipped with highly competitive observing capabilities, including wide-field imaging and spectroscopy, high-spatial-resolution imaging and spectroscopy, and various dispersion long-slit and multi-object spectroscopy, from optical to mid-infrared wavelengths. Tables 1 & 2 and Fig. 1 summarize the current instrumentation of the Subaru telescope. More detailed descriptions are found in Iye et al. (2004).

The Subaru telescope has produced many important scientific discoveries, extending from our solar system, through the Milky Way galaxy, to nearby galaxies and active galactic nuclei, as well as very distant objects in the early universe, only 800 million years after the Big Bang. This article explains the current systems for evaluating and selecting observation programs at the Subaru telescope, and how individual programs are scheduled and executed.

Of the available Subaru telescope time, 65% is for open-use programs, and 52 nights per year (~15%) are allocated to astronomers at the University of Hawaii. The remaining ~20% is reserved as director discretionary time (DDT) for performing necessary engineering work on the telescope.
TABLE 1. A brief description of the imaging capabilities of Subaru facility instruments*.

<table>
<thead>
<tr>
<th>Semester</th>
<th>Field of view</th>
<th>Pixel scale</th>
<th>Filters</th>
</tr>
</thead>
<tbody>
<tr>
<td>COMICS</td>
<td>42′′ × 32′′</td>
<td>0.133′′</td>
<td>15</td>
</tr>
<tr>
<td>FOCAS</td>
<td>6′ diameter</td>
<td>0.1′′</td>
<td>14</td>
</tr>
<tr>
<td>IRCS</td>
<td>21′′, 54′′</td>
<td>0.020′′, 0.052′′</td>
<td>18</td>
</tr>
<tr>
<td>MOIRCS</td>
<td>4′ × 7′</td>
<td>0.117′′</td>
<td>3</td>
</tr>
<tr>
<td>Suprime-Cam</td>
<td>34′ × 27′</td>
<td>0.20′′</td>
<td>12</td>
</tr>
</tbody>
</table>


TABLE 2. A brief description of the spectroscopic capabilities of Subaru facility instruments**. Spectral resolutions in the second column are for given slit widths shown in parentheses.

<table>
<thead>
<tr>
<th>Instrument</th>
<th>Resolution</th>
<th>Slit length</th>
<th>Pixel scale</th>
</tr>
</thead>
<tbody>
<tr>
<td>COMICS</td>
<td>10000 (0.33′′)</td>
<td>40′</td>
<td>0.165′′</td>
</tr>
<tr>
<td>FMOS</td>
<td>500-2200 (1.2′′ fiber)</td>
<td>30′, multi</td>
<td>—</td>
</tr>
<tr>
<td>FOCAS</td>
<td>250-7500 (0.4′′)</td>
<td>6′, multi</td>
<td>0.1′′</td>
</tr>
<tr>
<td>HDS</td>
<td>100000 (0.38′′)</td>
<td>10′, 60′</td>
<td>0.13′′</td>
</tr>
<tr>
<td>IRCS (grism)</td>
<td>50-1400 (0.15-0.90′′)</td>
<td>21′′, 54′′</td>
<td>0.020′′, 0.052′′</td>
</tr>
<tr>
<td>IRCS (echelle)</td>
<td>5000-20000 (0.14-0.55′′)</td>
<td>4.8-9.6′′</td>
<td>0.060′′</td>
</tr>
<tr>
<td>MOIRCS</td>
<td>640-1600 (0.5′′)</td>
<td>multi</td>
<td>0.117′′</td>
</tr>
</tbody>
</table>


and existing instruments, and for commissioning new instruments. If time is available, scientific observations may be carried out by the Subaru staff during DDT.

Subaru open-use observations are divided into two semesters. Semester A starts in February and ends in July. Semester B extends from August to January of the following year. Calls for proposals regarding Subaru open-use telescope time are issued twice annually, usually in early August for semester A and early February for semester B.

Four types of proposals are considered for Subaru open-use time: (1) normal, (2) service, (3) intensive, and (4) Subaru strategic program (SSP).

1. Normal program
   - The most common type of proposal is a “normal” proposal. Applicants can request up to five nights, generally in whole nights. However, a 0.5 night request is possible and is acceptable if a
suitable program is found for the other half night. The proposal submission deadline is usually about one month after the call has been issued, namely in early September for semester A and early March for semester B. Approved normal programs are executed in a classic mode, so that at least one observer must be present for actual observations at the Subaru telescope atop Mauna Kea, Hawaii, or at the Subaru base facility in Hilo, Hawaii. Astronomers throughout the world are eligible to apply for normal programs, regardless of their nationalities or affiliations.

2. Service program

- Some types of science may not require a full night and can be accomplished with shorter exposure time. A “service” program is more suitable in such cases, for which a maximum of four hours can be requested, including observation overhead. Service programs are
also useful for finishing previously uncompleted observations that were interrupted by, e.g., bad weather. Accepted service programs are executed by the Subaru observatory staff, and the researchers themselves need not be present. If observations are successfully carried out under good weather conditions, the resulting data are delivered to the researchers. Any astronomers can submit service proposals.

3. Intensive program

- There has been an increasing demand for telescope time allocation of more than five nights to perform systematic studies on astronomically interesting scientific topics. The “intensive” proposal concept was developed for this purpose. Up to 10 nights per semester, and a maximum of 20 nights over four semesters, can be requested. Accepted intensive programs are executed in a classic mode. The submission of intensive proposals is basically restricted to Japanese principal investigators (PIs) who satisfy one of the following criteria: (a) astronomers of Japanese nationality, either working in Japan or in foreign institutes outside Japan, or (b) non-Japanese astronomers affiliated with Japanese institutes. However, an exception is made for FMOS. Since FMOS was developed under a collaboration between Japan and the United Kingdom (UK), astronomers affiliated with UK institutes are allowed to submit intensive proposals for the use of FMOS as PIs.

4. Subaru Strategic Program (SSP)

- Because more than 10 years have passed since 8-10m class large telescopes were put into operation, the Subaru advisory committee (SAC) has established a proposal system for performing legacy-type observations using more than 100 nights called the Subaru Strategic Program (SSP). SSP applicants are limited to Japanese PIs, and SSP observations are executed in a classic mode. The fraction of telescope time used for SSP per semester is currently limited to no more than 25% of the Subaru open-use time (i.e., a maximum of ∼30 nights per semester) to ensure that opportunities will be available for a variety of scientific topics by a wide range of astronomers within the framework of Subaru open-use.

Table 3 summarizes these proposal submission schemes for Subaru open-use time.
TABLE 3. A brief summary of the current Subaru open-use time proposal system, consisting of normal, service, intensive, and SSP proposals.

<table>
<thead>
<tr>
<th>Proposal</th>
<th>Nights</th>
<th>PI</th>
</tr>
</thead>
<tbody>
<tr>
<td>Normal</td>
<td>up to 5 nights</td>
<td>Any astronomer</td>
</tr>
<tr>
<td>Service</td>
<td>up to 4 hours</td>
<td>Any astronomer</td>
</tr>
<tr>
<td>Intensive</td>
<td>up to 20 nights over 4 semesters</td>
<td>Basically Japanese ***</td>
</tr>
<tr>
<td>SSP</td>
<td>up to 300 nights over 5 years</td>
<td>Japanese</td>
</tr>
</tbody>
</table>

*** UK astronomers can exceptionally become the PIs of intensive proposals using FMOS.

2. Proposal evaluation

2.1. SUBARU TIME ALLOCATION COMMITTEE (TAC)

2.1.1. Normal program

A normal proposal consists of a two-page scientific justification section, cover pages for the applicant and observation information, as well as a technical description. All normal proposals are evaluated by the Subaru Time Allocation Committee (TAC). The Subaru TAC consists of about 10 astronomers from various research fields. Members of the TAC usually serve for 2+2 years and review proposals 4 + 4 times every six months (semesters A and B). Since the telescope time requested generally exceeds the available nights (Fig. 2), the Subaru TAC must carefully select the programs that will be executed on the given available nights.

First, the applicant must select a scientific category that is most relevant to the objective of the proposal. Soon after the proposal submission deadline for each semester, the Subaru TAC meets and divides the proposals into several groups based on scientific category. The basic policy is that proposals with similar scientific goals be reviewed by the same referees. If necessary, some proposals are transferred to categories other than those specified by the applicants. The total number of proposals in each group is usually <30, so that reviewers can read each proposal carefully and provide sufficient feedback. Since the total number of submissions has ranged from 100 to 150 during the past several years (Fig. 3), proposals are categorized into several groups. Principal and secondary TAC members are then assigned to each group, and these are responsible for selecting referees from outside the Subaru TAC (typically five, but in some cases six). The referees include Japanese and non-Japanese researchers from various fields, including γ-ray, X-ray, optical, infrared, and radio observational astronomers, as well as theorists.
The selected referees are asked to rank the proposals and provide feedback within one month. Ranking is based mainly on scientific merit, but technical feasibility can also be taken into account. Parallel to the referee’s review, an expert technical evaluation is provided by the support astronomers for the proposed instruments at the Subaru telescope.

After the referee reports and technical comments have been received, the Subaru TAC meeting is held about two months after the proposal submission deadline, usually in early November for semester A and early May for semester B. The meeting lasts two full days. The primary and secondary TAC members of each group review the overall referees’ scores and scientific/technical comments, and then decide which programs will be accepted, so that the maximum scientific output can be obtained from the Subaru telescope. The night allocation for each group is roughly proportional to the total requested nights of the normal and intensive proposals assigned to that group. In previous semesters, many applications have come from

\begin{figure}
\centering
\includegraphics[width=\textwidth]{figure2.png}
\caption{Normal and intensive proposal statistics per semester since the start of Subaru open-use operation in 2000 (S00). Service and SSP programs are not included in the statistics. Filled triangles: The number of requested nights (left label). Filled squares: The number of approved nights (left label). Open circles: Oversubscription rate on a per-night basis (right label). The total number of approved nights can vary per semester, depending on factors such as telescope down time for primary mirror re-aluminization and commissioning of new instruments, guaranteed time observations for Subaru facility instrument development teams (20 nights for each, distributed over a few semesters), and nights used for SSP.}
\end{figure}
non-Japanese PIs (non-Japanese astronomers working at foreign institutes) (Fig. 4), and Subaru open-use telescope time was actually assigned to such individuals if their proposals receive high scientific rankings and are judged to be technically feasible (Fig. 5), demonstrating the international nature of the Subaru telescope.

2.1.2. Service program

For service proposals, since the requested time is shorter than 4 hours, scientific justification is limited to one page, and cover pages are simpler than those of normal proposals. The submission deadline for service proposals is usually about 1 month later than that of normal proposals. Service proposals are evaluated by Subaru TAC members themselves, rather than outside referees. Generally, three TAC members read the individual service proposals and assign scores based on scientific merit. After considering the technical comments provided by the instrument experts, final rankings are given to the service proposals.
Figure 4. Application of Subaru open-use time. The category “Oversea” includes astronomers working at foreign institutes, and the bulk of them are non-Japanese (non-Japanese PIs). The other categories pertain to Japanese institutes. A large number of applications come from non-Japanese PIs.

Figure 5. Allocation of Subaru open-use telescope time. The symbols are the same as in Fig. 4. A significant fraction of Subaru open-use telescope time is allocated to non-Japanese PIs.
2.1.3. **Intensive program**

For intensive proposals, the length of the scientific justification can be a maximum of five pages, since more detailed scientific information is necessary to carefully judge whether such a proposal deserves an allocation that may entail >5 Subaru nights. Among the 100-150 proposals for Subaru open-use time submitted during recent years (Fig. 3), only a few have been intensive programs. Intensive proposals are also reviewed by outside referees, in a manner similar to normal proposals. However, unlike normal proposals, final acceptance of an intensive proposal requires an oral presentation to Subaru TAC members during the Subaru TAC meeting. Based on the referees’ scores, the Subaru TAC preselects highly ranked intensive proposals and holds a special hearing for them. This oral interview is important for the Subaru TAC to better understand the feasibility of, and strategy for, achieving the proposed scientific goals, and make a final decision on whether so many (>5) Subaru nights should be allotted.

2.1.4. **Subaru Strategic Program (SSP)**

For proposals that require >20 nights, the Subaru Strategic Program (SSP) has been established. Since an SSP proposal involves a large number of observation nights (>100), a very careful review process is required. The basic SSP selection policy is as follows.

1. The SSP was recently initiated with the intent of producing unprecedented and outstanding scientific outcomes by using unique/expedient observing instruments, while also bringing out the capabilities of the Subaru telescope as much as possible, so that a decisive leadership position may be established in the relevant fields of astronomical science.
2. The SSP is intended for systematic observations to collect a large and controlled volume of scientific data, based on an exceptionally large amount of allocated nights, over a time span of several years (e.g., up to 200-300 nights over 3-5 years).
3. Because of the extraordinary character of the program, an SSP proposal should be outstanding and unprecedentedly creative. Preferably, either of the following descriptions should apply.

   (a) Category A
   
   − Heritage/Treasury Database (excellence of the ‘data’)
     
     • Subaru telescope time will be intensively or continually devoted to strategic survey observations, with the intent of systematically collecting a large amount of data to achieve an epoch-making scientific end. That is, the prospective data will remain an invaluable treasure and will be widely used by researchers far into the future.
(b) Category B
   - Decisive Scientific Impact (excellence of the expected ‘discovery’)
     • Systematic observations will be intensively or continually conducted, with the solid and sustained intent of accomplishing a definite and challenging objective that will clarify unresolved astronomical problems of enormous scientific importance. That is, the outcome of the project is expected to be so important that it will have a major impact on our knowledge about the universe.

4. Call for Proposals
   - A call for the SSP proposals will include the following requirements and remarks.
     • Requirements
       * Since the SSP should be executed in close collaboration with the Subaru telescope staff, the PI (who is responsible for the overall project) must be in close contact with the director of the Subaru observatory prior to submitting the proposal. Also, at least one Subaru staff member must be included as a co-PI who, as a resident staff member in Hawaii, will share the PI’s responsibility for managing the project.
     • Remarks
       * For the time being, at most one SSP project may be approved for each newly commissioned instrument, no matter how many proposals are submitted. While no strict limitation exists on the size of a project, the typical period is expected to be ~3 years (the maximum duration would be ~5 years or so). The allocation of telescope time per semester (6 months) will be restricted to about 30 nights.

5. Review Process
   (a) First Screening Process
      - Review by prominent Japanese astronomers + the Subaru advisory committee (SAC)
        • At most, two proposals will be accepted for the second review process. The accepted proposals will be immediately announced and made available to the Japanese Subaru community.
   (b) Second Review Process
– Accepted proposals will be reviewed by ~20 referees, and the TAC will review the proposals from the point of view of astronomy and astrophysics.

– TAC may recommend at most one proposal to the SAC as the SSP.

– The PI of the accepted SSP proposal immediately reorganizes the project team, which should include all Japanese astronomers who want to participate in the project.

(c) Third Review Process

– The SAC will review the SSP proposal to determine whether the project is well organized (science, team members, and cooperation with Subaru).

– The SAC may approve one SSP project.

– If the project is not well planned, the SAC can reject the SSP proposal, even if it was recommended by the TAC.

(d) Final Decision

– The PI of the SSP submits the final version of the proposal, which includes a detailed schedule of observational runs and a list of all team members, including the Hawaii Subaru staff.

– The SAC will make a final decision on the starting semester of the approved SSP.

2.2. TELESCOPE TIME EXCHANGE WITH KECK AND GEMINI

Since 2008, Subaru and Keck, and Subaru and Gemini, have been exchanging their telescope time, so that the Subaru community can have access to the unique observing capabilities of Keck and Gemini, and vice versa. For example, since classic runs are the basic observing mode of the Subaru telescope, accommodating programs that require repeated observations with short exposure in each run is difficult. Such programs are more easily managed with the Gemini telescope, since the queue observing mode occupies the dominant fraction of Gemini telescope time. Other advantages of this telescope time exchange program for the Subaru community include (but are not limited to) access to

(1) multi-object optical spectroscopy with a wider field of view than that available at the Subaru telescope (Keck DEIMOS),

(2) objects in the Southern Hemisphere (Gemini South), and

(3) infrared integral field unit observing capability (Keck OSIRIS and Gemini NIFS).

On the other hand, the Keck and Gemini communities can make use of
Subaru’s unique capabilities for wide-field imaging and spectroscopy at the primary focus (Suprime-Cam and FMOS). Thus, this program is very important to each community for enlarging scientific output.

The Subaru TAC selects the programs from the Subaru community that use Keck and Gemini. The Keck and Gemini TACs are responsible for selecting the respective Keck and Gemini community programs that use Subaru. So far, the exchange time per semester ranges from few to several nights for both Keck and Gemini, and this amount is variable, depending on the demands of each community in a given semester. The exchange is made within the framework of the Subaru open-use programs. Specifically, if we use five Keck nights and five Gemini nights in a semester, $10 (= 5 + 5)$ nights are subtracted from the Subaru open-use time and are made available to Keck and Gemini observers.

2.3. UNIVERSITY OF HAWAII TIME

Twenty-six nights per semester are allotted to astronomers at the University of Hawaii (UH). The UH TAC selects the programs and sends the list to the director of the Subaru telescope. Accepted programs are distributed into dark, gray, and bright nights, at roughly one-third each. Observation dates should also be reasonably divided into six months in individual semesters.

3. Proposal Scheduling

Subaru has four foci: Cassegrain, infrared Nasmyth, optical Nasmyth, and primary focus (Fig. 6). Currently, seven facility instruments are attached to one of the four foci (Fig. 7). These instruments are Suprime-Cam (primary focus), FOCAS (Cassegrain), HDS (optical Nasmyth), FMOS (primary focus), IRCs (infrared Nasmyth), MOIRCS (Cassegrain), and COMICS (Cassegrain). The PI instrument\(^1\) HiCIAO (Tamura et al. 2006) is regularly used two or three times per semester at the infrared Nasmyth focus. IRCs and HiCIAO can be combined with the Subaru adaptive optics (AO) system to obtain images with higher spatial resolution.

In principle, optical observations of faint objects, particularly imaging and low-resolution spectroscopy at the blue optical wavelength, should be allocated to the darkest nights, since lunar effects are severest under these conditions. Suprime-Cam imaging and FOCAS spectroscopy are best assigned to nights around the new moon. Infrared observations and high-resolution optical spectroscopy can be performed on brighter nights, since lunar effects are less troublesome in these cases. Among infrared observations, those using laser-guide-star adaptive optics (LGS-AO) should be

\(^1\)Maintenance is generally performed by the instrument teams, not by Subaru staff.
scheduled on darker nights, since moonlight causes degradation of LGS-AO performance due to the gradient of sky brightness as a function of the distance from the moon.

In reality, Subaru telescope time allocation is not so simple because we cannot change a secondary mirror and an instrument at the same focus during the night, or on weekends and holidays. For Nasmyth and Cassegrain observations, three secondary mirrors are prepared: optical Cassegrain, optical Nasmyth, and infrared. At the primary focus, no secondary mirror is used; instead, an individual primary focus unit, including an image corrector, must be attached for both Suprime-Cam and FMOS. These secondary mirrors and primary focus units can be switched only in the daytime on weekdays, excluding holidays. Accordingly, once an instrument is selected for a Friday night, the same secondary mirror or primary focus unit must be used on the subsequent Saturday and Sunday nights. For example, if Suprime-Cam is attached on a Friday night, the instrument used on the subsequent Saturday and Sunday must be Suprime-Cam. The situation is the same for FOCAS, HDS, and FMOS. The same policy is applied on the
night before a holiday and the night of the holiday.

For infrared instruments at the Cassegrain and infrared Nasmyth foci, we provide slightly more flexibility. Specifically, an infrared instrument at the Cassegrain focus can be switched to an instrument at the Nasmyth focus during a night or weekend, since we can use the same infrared secondary mirror and only need to remove or insert a tertiary mirror, which takes ~20 minutes. For example, we can combine observations using MOIRCS or COMICS at the Cassegrain, and IRCS+AO or IRC without AO or HiCIAO+AO at the infrared Nasmyth focus, on Fridays and weekends. Some types of HDS observations of bright objects may be performed using an infrared secondary mirror, instead of the original optical Nasmyth secondary. In this case, HDS programs can be combined with a Cassegrain infrared instrument (MOIRCS or COMICS) and a Nasmyth infrared instrument (IRCS+AO or IRC without AO or HiCIAO+AO) on Fridays and weekends.

Changing instruments at the same focus, namely FOCAS, MOIRCS, and
COMICS at the Cassegrain, requires one daytime work on a weekday. IRCS and HiCIAO share the same infrared Nasmyth and can only be exchanged during the daytime on a weekday. Since switching these instruments at the infrared Nasmyth focus entails a lot of work and resources, ideally, more than one night interval is desirable. As for the primary focus instruments, Suprime-Cam and FMOS, since exchanging them in only one daytime is difficult, their consecutive allocation should be avoided.

After taking into account these complicated restrictions on instrument exchanges, the Subaru telescope schedule is determined. Telescope time allocation for some proposals on the borderline between approval and rejection at the Subaru TAC meeting can be affected by these limitations.

Only after finalizing the schedule of accepted normal, intensive, and SSP programs, as well as necessary engineering/commissioning work on instruments/telescope, service programs are assigned in the remaining available time slots. For this reason, some service programs with high scientific rankings may not receive time allocations.

4. Program Execution

All normal, intensive, and SSP programs are executed in a classic mode. At least one observer must be present during the actual observations at the Subaru telescope atop Mauna Kea, Hawaii, or at the Hilo Subaru base facility, from which remote observations are possible for some instruments. For normal and intensive programs, at least one telescope operator and one instrument support scientist are on duty on all classic nights and assist with observations throughout the night. Because of this extensive support, classic observations at the Subaru telescope proceed very smoothly, minimizing the loss of precious telescope time due to the unfamiliarity of observers with actual instrument operational procedures. The basic task of the observers is to establish an observation strategy. By consultation with support astronomers and telescope operators, observers can verify whether the telescope is pointed at the desired objects, and then set each exposure time so that the signal level is kept within the linearity limits of the array of applied instruments. Appropriate calibration data should also be collected. Since weather conditions are variable, observers should inspect the quality of the data obtained in previous exposures, judge when to slew the telescope to a next desired object, and provide this information to the telescope operator and instrument scientist. For SSP programs, although a telescope operator is assigned, no instrument support scientist is provided. Hence, SSP proposals must include experts on the instruments used for the observations. This is based on the policy that SSP programs should proceed according to the all-Japan system, making it comparatively unnecessary to
Figure 8. Subaru operating statistics, excluding bad weather. The category “Others” includes telescope down time due to earthquakes and re-aluminization of the primary mirror. Under normal circumstances, a very high percentage of trouble-free operation is achieved.

assign a support scientist.

Fig. 8 shows the time percentages actually used for astronomical observations. Subaru operation has proved to be very stable and efficient, with a minimal amount of time loss due to telescope/instrument/software troubles.

Fig. 9 shows publication statistics for research based on observations using the Subaru telescope. The number of refereed papers is steadily increasing, demonstrating that the Subaru telescope has achieved a high production rate for scientific papers with the current systems of proposal evaluation and operation. Of course, these systems are subject to future changes. The hope is that the Subaru telescope will continue to be at the forefront of many research fields in observationally uncovering the mysteries of the universe.

Acknowledgments

I would like to thank all of the Subaru staff members and proposal reviewers for their tremendous efforts, which make the present sophisticated level of Subaru operation possible. I am grateful to Yoichi Takeda and Hiroshi Terada for their useful comment on this manuscript, and to Chie Yoshida and Tomoko Fuselier for kindly providing me with Subaru open-use statistical data and assisting with the preparation of some figures.
Figure 9. The number of refereed papers based on Subaru observations in each year from 2000 to 2011. See http://www.naoj.org/Observing/Proposals/Publish/index.html for more details.

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