Recommendation on the approval of the SCExAO project

Jan. 20, 2010
Subaru internal review committee
Motohide Tamura, Shin Oya, Hiroshi Terada and Naruhisa Takato (chair)

We have reviewed the merit and feasibility of installing the SCExAO to Subaru telescope and concluded that **we recommend approving phase 1 of the SCExAO project on condition that SCExAO group will learn necessary operation skills for AO188/HiCIAO and minimize the load of relevant group.**

The SCExAO project is divided into three development phases; phase 1 includes basic functions of PIAA coronagraph and non-redundant aperture masking, phase 2 is an upgrade of these functions and phase 3 will be the installation of IFU (please see the project proposal). We have reviewed mainly on the phase 1, and the recommendation is only for this phase. The phase 2 and 3 will be discussed when it become ready.

[Science merit]
The SCExAO will be a competitive instrument; it will improve the imaging contrast 10 to 100 times better compared to the HiCIAO in the field between 0.1 and 0.5 arcsec from the central star. The competitors are VLT-SPHERE and GEMINI South GPI, both are planed to deliver the first light around the end of 2010 to early 2011. Thus we recommend early commissioning of the SCExAO in order to keep it competitive.

[manpower and feasibility]
The reviewers' main concerns were (1) shortage in man-power of AO188 and HiCIAO group, (2) little amount of available DDT. However, SCExAO group agreed to learn the skills of AO188/HiCIAO operation and AO188/HiCIAO group agreed to offer the necessary training in order to reduce the load of AO188/HiCIAO group. Also, SCExAO group understood the prospected small amount of telescope time for their engineering and agreed to adjust their schedule.

[SOSS/STARS]
Reviewers do not impose the condition of utilizing SOSS/STARS because this approval recommendation is for the phase 1 and operational difficulties may not be a big problem

compared to the work load of implementing SOSS/STARS functions. Since the data produced by the HiCIAO will be archived by STARS, only the data from visible camera will not be archived by STARS.

[potential use as stand-alone]
Since there are small risks for HiCIAO project in installation of the new frame, it might be worth considering to build the support frame for SCExAO stand-alone mode. This could allow us to use the SCExAO system as a pure upgrade of the AO188 for the other science instruments such as IRCS.

[detailed discussion]
Please see attached Q and A.

Reviewers' comments on installing SCExAO to Subaru telescope

Dec. 21, 2009
Subaru internal review committee
Motohide Tamura, Shin Oya, Hiroshi Terada, and Naruhisa Takato (chair)

Reviewers understand the scientific merit and uniqueness that will be provided by the SCExAO installed to the Subaru telescope. However, following points should be clarified before proceeding to approval. This review is only for phase A of SCExAO project, but comments for phase B and C are included for better understanding of the project plan as a whole.

[C]: comment
[Q]: question

1. Man-power from the observatory

[Q] How much man-power do you expect from the observatory to complete each phase?

2. Man-power from AO

[C] Baseline Policy:

First off AO188 group always welcomes research cooperation with SCExAO project. However, it is difficult for AO188 group to contribute to any commissioning work of SCExAO. LGS-related works has highest priority to start open-use observation on schedule. Impact on open-use observation should be as small as possible.

The function of AO188 will be provided as is, namely, no special upgrade of any part of AO188 is expected just for SCExAO. Work items to open the cover of AO188 bench is basically not acceptable. In case of unavoidable necessity, SCExAO group must discuss as soon as possible with the responsible persons of AO188 group, Dr. Hayano or Dr. Minowa, to obtain agreement of AO188 group. Submission of concrete plan for AO188-related work well in advance, is desired. It will be considered as a part of work/upgrade plan of an open-use observation instrument. When a member of AO188 gets involved in the work/upgrade item, he/she should be included in SCExAO group as a co-investigator.

[C] Support:

AO188 group will provide any calibration/engineering data already obtained,

upon request. However, AO188 group does not expect to prepare any special calibration/engineering data required just for SCExAO. If daytime calibration data is necessary, a member of SCExAO should learn to operate AO188 in calibration mode and acquire data by him/herself. AO188 group will assign a person for instruction. Nighttime operation by SCExAO members is also encouraged; however, it is difficult, AO188 group will assign a person to operate AO188 to support SCExAO observations. When a member of AO188 supports nighttime observation, he/she should be included in SCExAO group as a co-investigator.

3. Man-power from HiCIAO

[C] Two persons with Suzuki-san's technical advices seem indispensable for the manpower from HiCIAO side. HiCIAO needs to discuss who will be there.

4. Technical issue

[C] Must be careful enough for optical shielding of SCExAO itself and connection between AO188 and SCExAO, or AO188 cannot be used in closed-loop for daytime calibration work because APD cannot be turned on.
[C] A document describing interface between SCExAO and AO188 (optical, mechanical, electronics, software and so on) must be provided by SCExAO group in advance.
[C] When operating AO188 for calibration, always ask the responsible persons of AO188 group, Dr. Hayano or Dr. Minowa, for permission.
[Q] Does SCExAO have own calibration light source dedicated for high-contrast observation?
[Q] What is the procedure of calibration of SCExAO?

5. Schedule

[C] The three step procedure is fine for HiCIAO team.
[Q] At this point, no vacancy can be found in S10A semester for SCExAO night time testing. Although the telescope schedule is still fluid, it is expected that the S10B semester will start from 2010 September. Would you update the schedule accordingly?
[Q] In this update, could you make "gannt chart" for us to easily understand it?
[Q] Is the latest SEEDS schedule considered in the description of the Project schedule, commissioning plan?
run 2: Dec 22-25
run 3: Jan 22-24
run 4: Feb 26-28

run 5: Apr 19-22

run 6: Jun 2-4

Jun 5-8 (4 half-nights)

[Q] When is the best timing for frame change and first light run?

After the Feb run is most realistic?

+ only 1 month interval between Dec and Feb

+ while Suzuki-san is still in Hilo

[Q] When and how much time does SCExAO need AO188 calibration light source?

[C] At least until Feb. 5, 2010 there is no room for SCExAO related work, because of LGS engineering and preparation for that. LGSAO188 schedule is updated by Dr. Hayano in Google Calendar with account name of 'ao@subaru.naoj.org'. Please refer to the schedule by importing it to your account if you have.

[C] Basically, 1 week margin is desirable for AO188 group before open-use observations or other PI instrument run (negotiable, case-by-case).

6. Current SCExAO status

[Q] Would you show us the laboratory results with figures which you have achieved?

7. Science

[C] The SEEDS discovered planets/disks or well known other targets whose inner structures are not yet explored are the first targets I agree.

[Q] Do you need PDI mode for disk science?

8. Open-use

(You might have expressed a possibility for SCExAO open-use in the proposal because Takato requested you to write your possible plan. The following comments and question are just our concern. These issues should be discussed in a review for phase B or C.)

[Q] In view of operation at the NsIR platform, the frequency of HiCIAO attachment onto the focus will be limited to be twice a semester. It might be difficult to fit to that limitation in some cases if the SCExAO will be widely open. (for example, in good seasons for extragalactic targets HiCIAO will not be most likely at the focus.)

Do you have any other specific science cases than extrasolar planet study?

[C] Unless HiCIAO becomes an Open use instrument, it seems to be difficult to use SCExAO+HiCIAO for open use.

[Q] Who will maintain and support for optical mode in open use?

SCExAO installation on Subaru Telescope

1. Man-power from the observatory

[Q] How much man-power do you expect from the observatory to complete each phase?

Task 1 (frame commissioning: replace HiCIAO frame)

- Support from Doi-san, HiCIAO group and telescope group to ensure proper mechanical fit
- 3 days of daytime observatory support at summit
  crane operation
  move all HiCIAO electronics to new frame
- Daytime & Nightime HiCIAO tests for alignment work at summit

Task 2 (Day time commissioning of SCExAO bench with AO bench)

- AO188 operation (internal source, on-axis)

Task 3 (Night time engineering for SCExAO with AO188+HiCIAO)

- AO188 operation (NGS, on-axis)
- HiCIAO operation

2. Man-power from AO

[C] Baseline Policy:

First off AO188 group always welcomes research cooperation with SCExAO project. However, it is difficult for AO188 group to contribute to any commissioning work of SCExAO. LGS-related works has highest priority to start open-use observation on schedule. Impact on open-use observation should be as small as possible.

The function of AO188 will be provided as is, namely, no special upgrade of any part of AO188 is expected just for SCExAO. Work items to open the cover of AO188 bench is basically not acceptable. In case of unavoidable necessity, SCExAO group must discuss as soon as possible with the responsible persons of AO188 group, Dr. Hayano or Dr. Minowa, to obtain agreement of AO188 group. Submission of concrete plan for AO188-related work well in advance, is desired. It will be considered as a part of work/upgrade plan of an open-use observation instrument. When a member of AO188 gets involved in the work/upgrade item, he/she should be included in SCExAO group as a co-investigator.

No special upgrade of AO188 is required. SCExAO does not have any software link with AO188. SCExAO only requires on-axis NGS mode. SCExAO has flexibility to align to AO188 beam (translation, rotation).

Note: Only requirement from SCExAO is Kyoto-3D dichroic.

[C] Support:

AO188 group will provide any calibration/engineering data already obtained, upon request. However, AO188 group does not expect to prepare any special calibration/engineering data required just for SCExAO. If daytime calibration data is necessary, a member of SCExAO should learn to operate AO188 in calibration mode and acquire data by him/herself. AO188 group will assign a person for instruction.

Nighttime operation by SCExAO members is also encouraged; however, it is difficult, AO188 group will assign a person to operate AO188 to support SCExAO observations. When a member of AO188 supports nighttime observation, he/she should be included in SCExAO group as a co-investigator.

Daytime operation will be necessary.

[Q] Should a member of SCExAO be trained to operate AO188 soon ?

3. Man-power from HiCIAO

[C] Two persons with Suzuki-san's technical advices seem indispensable for the manpower from HiCIAO side. HiCIAO needs to discuss who will be there.

[Q] We would like HiCIAO to be operated in the guide window mode (not required for first light, but will be required to improve contrast performance). Will this mode be available in the future ? If not, we will rely more heavily on SCExAO internal near-IR camera with fast readout.

4. Technical issue

[C] Must be careful enough for optical shielding of SCExAO itself and connection between AO188 and SCExAO, or AO188 cannot be used in closed-loop for daytime calibration work because APD cannot be turned on.

Thank you for this useful comment.
Action items for SCExAO: Shielding of SCExAO bench is provided by covers. We will need to add soft tube between SCExAO and AO188, and between SCExAO and HiCIAO. Lights from LEDs inside SCExAO will be blocked by tape.

[C] A document describing interface between SCExAO and AO188 (optical, mechanical, electronics, software and so on) must be provided by SCExAO group in advance.

We will provide this document.
Optical: optical design will be provided, along with alignment procedures. SCExAO is designed with sufficient flexibility to align to AO188 beam without requiring AO188 alignment.
Mechanical: Interfaces are provided by frame
Electronics/software: No interface between AO188 & SCExAO. No interface between SCExAO and HiCIAO at first light, but future software interface between SCExAO & HiCIAO is highly desirable.

[C] When operating AO188 for calibration, always ask the responsible persons of AO188 group, Dr. Hayano or Dr. Minowa, for permission.

OK.

[Q] Does SCExAO have own calibration light source dedicated for high-contrast observation?

SCExAO has visible and near-IR calibration light sources suitable for high contrast tests, but no turbulence generator (although it could be implemented on MEMs DM).

[Q] What is the procedure of calibration of SCExAO?

Calibration is initially done on SCExAO internal source (SCExAO internal alignment, DM control matrix, LOWFS).
SCExAO alignment to AO188 requires moving 2 mirrors at entrance of SCExAO (pupil alignment, focal plane translation and focus). SCExAO to HiCIAO alignment: focus only (no dithering of focal plane mask on HiCIAO detector planned initially, although possible through actuators on focal plane mask if using Lyot type coronagraph).

[C] The three step procedure is fine for HiCIAO team.
[Q] At this point, no vacancy can be found in S10A semester for SCExAO night time testing. Although the telescope schedule is still fluid, it is expected that the S10B semester will start from 2010 September. Would you update the schedule accordingly?
[Q] In this update, could you make "gannt chart" for us to easily understand it?

Small amount of on-sky observing time before 2010 september would be valuable to test SCExAO on-sky performance and identify issues that need to be solved early on. Visible AO imaging channel would benefit from this, providing PhD student Garrel with real data to work on.
If not possible to secure time before Sept 2010, schedule will be modified with more daytime work and calibration ahead of on-sky observation.

[Q] Is the latest SEEDS schedule considered in the description of the Project schedule, commissioning plan?

run 2: Dec 22-25

run 3: Jan 22-24

run 4: Feb 26-28

run 5: Apr 19-22

run 6: Jun 2-4

Jun 5-8 (4 half-nights)

[Q] When is the best timing for frame change and first light run?

After the Feb run is most realistic?

+ only 1 month interval between Dec and Feb

+ while Suzuki-san is still in Hilo

Between Feb and Apr run (almost 2 months) is longest, but between Jan and Feb runs is also possible. 1 month switching time should be sufficient with good planning.

During frame upgrade, we will keep time to install old frame back before next observation in case of unexpected trouble.

[Q] When and how much time does SCExAO need AO188 calibration light source?
[C] At least until Feb. 5, 2010 there is no room for SCExAO related work, because of LGS engineering and preparation for that. LGSAO188 schedule is updated by Dr. Hayano in Google Calendar with account name of 'ao@subaru.naoj.org'. Please refer to the schedule by importing it to your account if you have.

Internal SCExAO calibration will be done without AO188.
Light source from AO188 required to
(1) alignment procedure validation
(2) performance verification with turbulence and identification of possible issues with AO +SCExAO performance

We would like to perform thorough work with internal light source. We want to avoid testing new modes on sky if they have not been fully verified with AO188 calibration light source.

We would like frequent tests with AO188 calibration light source (rough estimate: total of 10 days, 4 hr per day before going on sky).
Note: Use of AO188 calibration light source and on-sky commissioning will overlap as we keep testing new modes/improvements.

No work with calibration source can begin before new frame is installed. We will not begin AO188 calibration light source tests before end Feb 2010 at the earliest.

[C] Basically, 1 week margin is desirable for AO188 group before open-use observations or other PI instrument run (negotiable, case-by-case).

OK. This is reasonable and we will plan accordingly.

[Q] Would you show us the laboratory results with figures which you have achieved?

Basic techniques and wavefront control algorithms have been tested in clean room lab since 2003. Reached 2e-7 raw contrast at 1.65 lambda/D (100x better than possible on SCExAO due to residual WF error). Coherent detection (core of SCExAO detection technique) demonstrated to 3.5e-9 in visible.
NOTE: THESE RESULTS ARE FOR NO TURBULENCE CASE.

SCExAO coronagraph has been tested in visible (Lozi et al. 2009). Less challenging near-IR tests will begin in ~1 week (we just received second near-IR camera required for tests).

Visible EMCCD channel under final integration. Software and basic data processing is ready (V. Garrel). Optical layout is quite simple & provides field selection, focus, and plate scale choice.

Lab integration update will be given by Frantz, with short visit of lab.

[C] The SEEDS discovered planets/disks or well known other targets whose inner structures are not yet explored are the first targets I agree.
[Q] Do you need PDI mode for disk science?

SCExAO will add CDI (Coherent Differential Imaging) for detection of companions at very close angular separation. Use of PDI would be very valuable for disk science, but impact of SCExAO on PDI performance has not be estimated (instrumental polarization issues ?).

SCExAO can be used with SDI or PDI to augment performance.
For disks and companions at large separation (> 0.4" radius approximately), SCExAO will provide little improvement over HiCIAO: SCExAO should be used for <0.4" radius observations.

8. Open-use

(You might have expressed a possibility for SCExAO open-use in the proposal because Takato requested you to write your possible plan. The following comments and question are just our concern. These issues should be discussed in a review for phase B or C.)

[Q] In view of operation at the NsIR platform, the frequency of HiCIAO attachment onto the focus will be limited to be twice a semester. It might be difficult to fit to that limitation in some cases if the SCExAO will be widely open. (for example, in good seasons for extragalactic targets HiCIAO will not be most likely at the focus.)

Do you have any other specific science cases than extrasolar planet study?

Visible imaging science will be diverse and unique thanks to unique angular resolution:

- planetary system (asteroids, satellites and planets)
- star/planet formation (disks, jets)
- stellar surface imaging
- extragalactic astronomy (AGNs)

Near-IR channel more limited in non extrasolar planets science

- AGNs (to be explored)
- planetary system astronomy

Notes:

- Fast near-IR camera (>100Hz) provides image quality enhancement over long exposure AO188.
- aperture masking provides sub-lambda/D resolution

[C] Unless HiCIAO becomes an Open use instrument, it seems to be difficult to use SCExAO+HiCIAO for open use.
[Q] Who will maintain and support for optical mode in open use?

Note: Visible imaging science does not need HiCIAO, and some near-IR science possible without HiCIAO.

Optical mode can be maintained by SCExAO group in open use with simple setup (no support for new modes). Simple data reduction pipeline can be provided (part of V Garrel PhD).
We will need to follow closely progress of optical mode and assess operation / support needs to decide when/if open use.

Overview of the Subaru Coronagraphic Extreme-AO project

by Olivier Guyon and Frantz Martinache
project URL: http://www.naoj.org/Projects/SCEXAO/

Abstract

The Subaru Coronagraphic Extreme AO (SCExAO) Project is an upgrade to the newly commissioned coronagraphic imager HiCIAO for the Subaru Telescope. SCExAO combines a high-performance coronagraph PIAA coronagraph and non-redundant aperture masking interferometry to a MEMS-based wavefront control system to be used in addition to the 188-actuator Subaru Adaptive Optics (AO188) system.
The upgrade is designed as a flexible platform with easy access to both pupil and image plane to allow quick implementation of new high-angular resolution techniques, using a combination of interferometry and coronagraphy.
The SCExAO system will enhance SEEDS by offering access to smaller separations and improved PSF calibration, and will therefore allow high quality follow-up observations of challenging SEEDS candidates. SCExAO will also enable new science investigations requiring high contrast imaging of the innermost (< 0.2 arc second) surrounding of stars.

SCExAO uniqueness

Flexibility
High contrast Extreme-AO coronagraphic imaging instruments currently under construction for 8-m class telescopes (SPHERE for VLT, GPI for Gemini) are build as a whole, delivered to the observatory and used to conduct a large survey. There is little room for flexibility and upgrades once the instrument is delivered. SCExAO will be uniquely flexible and will rely on this flexibility to remain scientifically competitive. Flexibility is key in this relatively immature field where ideas and techniques rapidly change.
SCExAO's flexibility also allows other groups to participate to SCExAO's development. It is relatively easy for an instrument or coronagraph builder to include hardware on the HiCIAO/SCExAO system. For example, Princeton University is currently applying for funds to augment HiCIAO/SCExAO with an integral field spectrograph.

Small inner working angle
Technical choices (PIAA coronagraph, non-Redundant Masking Interferometry) made for SCExAO enable high contrast imaging in the 0.5 to 3 lambda/D separation. This range of separation is not probed by GPI, which will have a 3 lambda/D radius focal plane mask. SPHERE has an option for low inner working angle coronagraph, but was not optimized for small angular separations. This capability offers unique science capabilities for SCExAO which will not be available to other projects.

New schemes for speckle calibration

SCExAO will be the first ExAO system to use coherent speckle calibration. This new technique is extremely powerful to separate speckles from planets: our PIAA laboratory experiment demonstrated an improvement of the contrast by a factor 100, and brought achievable contrast four orders of magnitude beyond SCExAO's current objective. Unlike ADI, this technique can be used for very small angular separation.

Visible light access
Among unique capabilities offered by SCExAO is visible diffraction-limited imaging. The SCExAO instrument configuration may allow observations simultaneously in both NIR and VIS. For visible observations, SCExAO uses an internal EMCCD detector already interfaced to our system and will have no impact on Subaru's work force. This visible part of the SCExAO project is forming the bulk of Vincent Garrel's PhD dissertation.

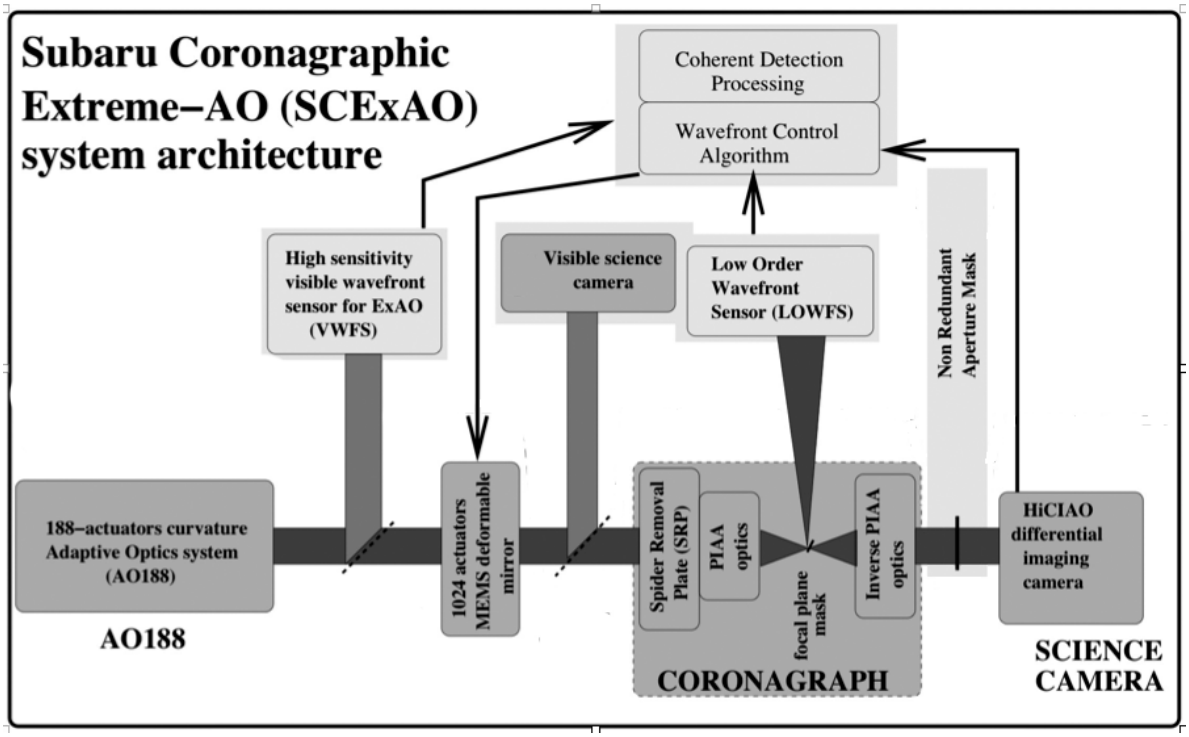
Science Case

The validation of planet formation scenarios and evolutionary theories requires the identification of a large population of young planetary systems whose orbital and atmospheric properties can be directly measured, independently of the use of a model. Conventional AO observations and the use of the successful Angular Differential Imaging (ADI) technique that lead to the discovery of the HR 8799 system on Gemini and Keck can only efficiently probe for objects at angular separations greater than 0.5 arc second and reach maximum sensitivity around 1 arc second (current HiCIAO performance estimate respectively give contrasts of 9.5 and 12 magnitudes for separations of 0.5 and 1 arc second respectively on a m$_V$=6 star).

Even for the nearest populations of young stars, at distances of 30 pc, the current AO performance translates into projected orbital separations greater than 30 AU. While some potentially planetary mass objects do seem to form at such large radii, RV surveys and the structure of our own Solar system suggest that most planet formation occurs at a smaller separation. Moreover, for most of the directly imaged extrasolar planet candidates, orbital periods are too long to allow significant orbital coverage, which would lead to dynamical masses, a most important piece of information in the puzzle of planet formation. The planetary status of such candidates remains model-dependent and in some cases controversial.

The Subaru Coronagraphic Extreme AO (SCExAO) project was designed to palliate this flaw and implements the necessary techniques to probe the innermost parts of extrasolar planetary systems, in fact going as far providing access to their habitable zone. The SCExAO project benefits from the most recent developments in coronagraphy, interferometry and advanced wavefront control techniques, many of which have been pioneered by our group at Subaru. It builds upon recent successful developments at Subaru Telescope: the AO188 Adaptive Optics system and the coronagraphic imager HiCIAO. SCExAO's access to small angular separations and its location in the Northern hemisphere make it scientifically complementary to ESO's SPHERE and Gemini's GPI projects. The flexible layout of SCExAO allows use of high performance techniques which were not available when SPHERE and GPI were designed, and continuous upgrades of the system will keep SCExAO highly competitive for the next decade.

SCExAO System Architecture



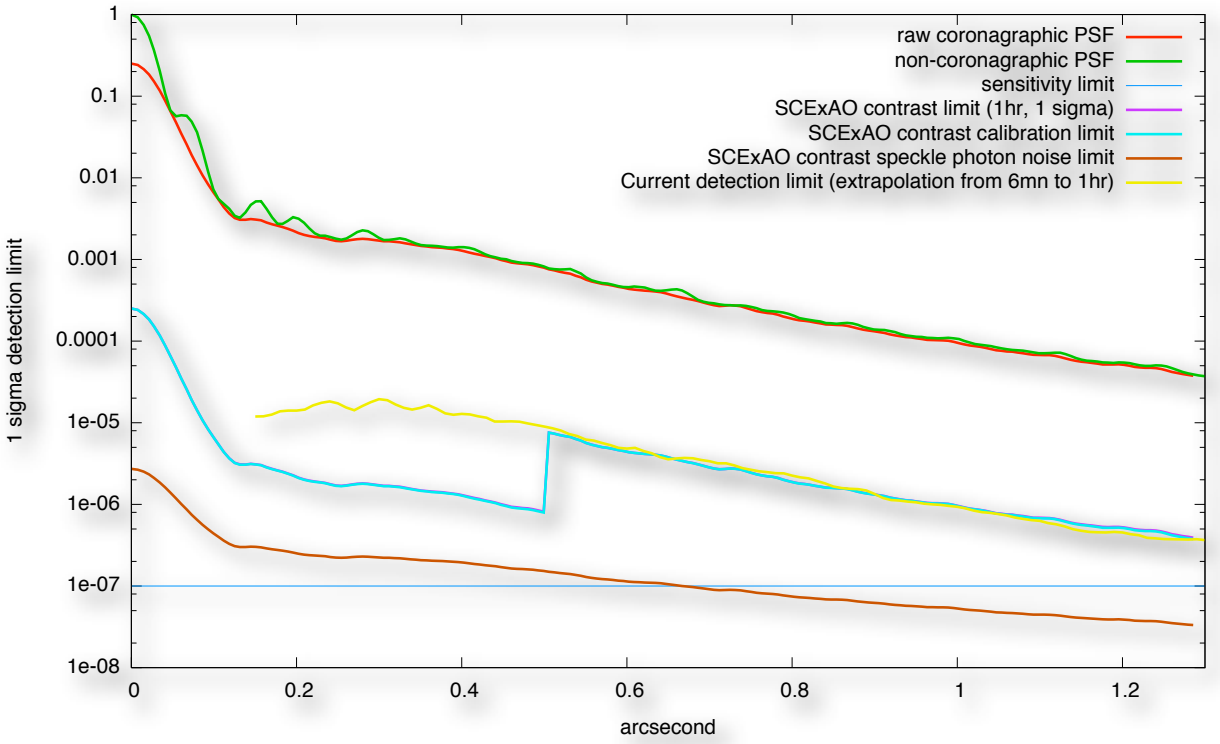
SCExAO is designed as a flexible, easy access, warm optics, platform providing access to both image and pupil plan to welcome guest coronagraphs and attractive wavefront control schemes. A MEMS-type deformable mirror will allow active speckle calibration without relying on expected planet properties (spectral differential imaging).

For the its first version, currently being assembled in the Subaru simulation lab, the choice of a Phase Induced Amplitude Apodization (PIAA) Coronagraph and the implementation of non-redundant aperture masking interferometry (NRM) make of SCExAO the instrument that will provide the best inner working angle (respectively 40 and 20 mas) of the coming generation of ground based planet finders on the 8 to 10 meter class telescopes.

Key SCExAO modes / components are listed in the table below. The table shows the components/modes which will be ready for the Phase 1 of the project (early 2010) as well as upgrades / components which will be completed in later phases.

SExAO component/mode	Role	Status / readiness
Phase 1 (ready for on sky engineering in feb 2010)		
PIAA coronagraph	high efficiency coronagraphy at 1 lambda/D	Tested in visible light. Integrated in SCExAO.
Non-redundant aperture mask	moderate contrast imaging down to 0.5 lambda/D	Low impact on hardware. Masks can be laser-cut in house.
Low order wavefront sensor (30 Hz)	pointing control in coronagraph	Hardware tested. Software will duplicate LOWFS built in clean room.
Visible imaging	diffraction limited VIS imaging	Photon-counting camera tested and working. Requires Kyoto 3D dichroic in AO188.
Coherent speckle calibration (slow)	removes slow/static speckles	Validated to 3.5e-9 contrast in clean room.
1024 actuator MEMs	required for coronagraph and coherent speckle calibration	Mounted in SCExAO system, component is tested and working
Phase 2 (approximately 1 year after phase 1, schedule subject to funding)		
Low order wavefront sensor (~1 kHz)	Improved pointing control essential for high contrast at 1 lambda/D	Requires new near-IR camera. Possible seller identified.
High sensitivity fast visible WFS for ExAO	Improved contrast at all separations	In R&D. First prototype under design.
SCExAO relay optics upgrade	Enable all current HiCIAO observation modes with SCExAO frame. Eliminate need to remove SCExAO table for “conventional” HiCIAO observations	Relay optics not designed yet
Phase 3 (approximately 2-3 year after phase 1, schedule subject to funding)		
Integral Field Spectrograph	Spectroscopy	Proposal submitted to NSF by Princeton University

SCExAO's performance in phase 1

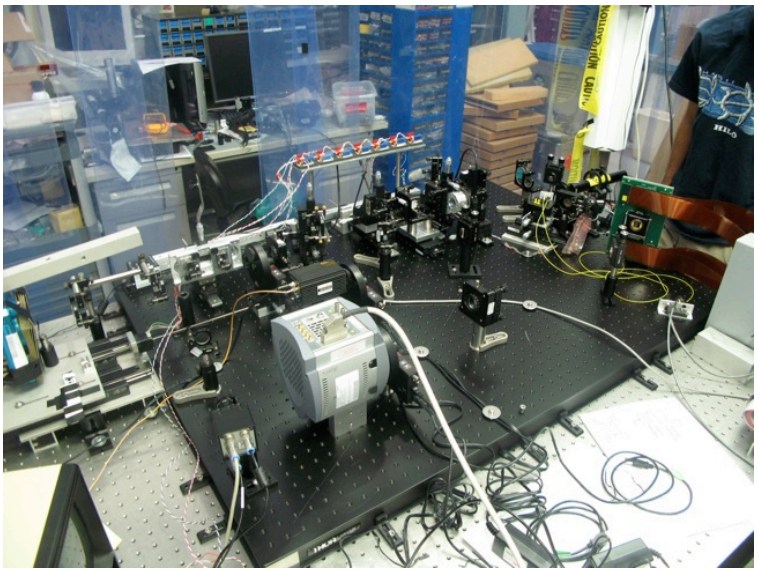


During phase 1, the absence of internal fast high-order wavefront sensor will prevent from actually running the system in extreme AO mode. The 1024-actuator MEMS mirror will instead be used with the two following purposes:

- cancel out the non-common path errors in the system responsible for the presence of quasi-static and slow speckles in the field. Although this requires a preliminary calibration procedure (using phase-diversity or interferometric algorithms) before the actual observing, this active suppression of the speckles offers a significant advantage over classical ADI in overhead.
- calibrate the speckles by measuring their coherence. To keep track of the slow speckles, the DM can be used to actively probe the coherence of the speckles while observing. The efficiency of this method was validated in an experiment conducted in the clean room at the 3.5e-9 contrast level, that is more than three orders of magnitude deeper in contrast than what can really be achieved from the ground.

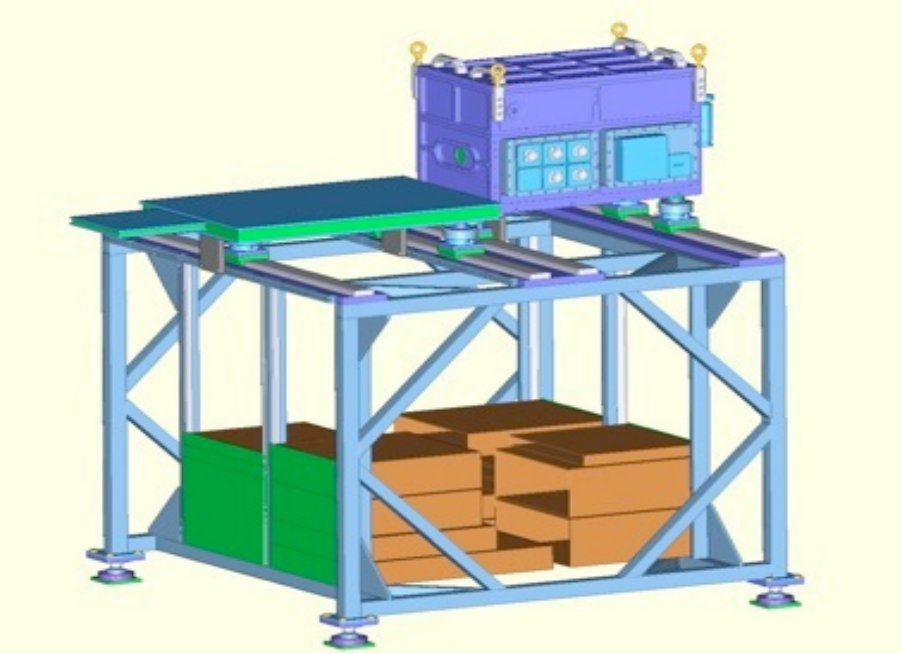
Expected performance of the SCExAO system in this phase 1 mode is plotted on the figure at the top of this page. The most important curves are the yellow (current HiCIAO detection limit) and cyan (SCExAO contrast calibration limit). For angular separations smaller than 0.5" (cut-off frequency of the DM), SCExAO will outperform the current ADI contrast by a factor 10.

Current status



The SCExAO bench is shown in the picture (left). All key components have been integrated and tested. We are currently finalizing alignment, and developing software for calibration and data collection. The major activity for the next 2/3 months is to test the AO control loop which is a duplicate of the control loop which was developed in the PIAA testbed in the clean room (which achieved 1e-7 raw contrast and measured speckles to 1e-9 contrast).

The new frame, which will hold both HiCIAO and the SCExAO bench, has been designed by Yoshi Doi with input from the SCExAO team (see picture on the right). We are currently working with Steve Colley to identify where it will be fabricated, with a goal of taking delivery at the end of the calendar year 2009.



SCExAO operation, impact on observatory, HiCIAO and AO188

SCExAO requires both AO188 and HiCIAO for normal operation. The visible imaging mode of SCExAO is the only mode which can be performed without HiCIAO.

To accommodate both SCExAO and HiCIAO, the current frame bearing HiCIAO has been redesigned, and the replacement of the frame early 2010 will be the first step for the deployment of SCExAO at the summit.

SCExAO status in Subaru: PI instrument vs. open use

SCExAO is currently a PI-type instrument, but we hope to offer several observing modes to be open-use. The SCExAO team would like to discuss with Subaru and HiCIAO how to proceed on this.
Observing modes which are likely to attract strong interest to a wide community, and will be technically ready in the near future (easier to commission for science use) are the first candidates to be offered for open use:

- visible imaging with AO is the first candidate for open use. It could be ready to be offered for open use in ~1 year from SCExAO first light. The SCExAO team would provide some minimal pipeline for data reduction ("Lucky imaging" select, shift and coadd), and the observer could develop more powerful data reduction.
- enhanced HiCIAO observing modes for coronagraphy at small angular separation. This will need to be coordinated with HiCIAO team. Since HiCIAO is a PI-type instrument, can an observing mode of HiCIAO be offered for open use ?

SCExAO and SEEDS

From the SEEDS perspective, the SCExAO upgrade is perceived as a tool for follow-up observations of interesting targets already observed with HiCIAO, that would benefit from deeper coronagraphy and/or better AO correction.

From the ExAO group perspective, the upgrade also provides access to a unique fraction of the discovery space, and therefore should deserve to be allocated telescope time outside from the SEEDS collaboration.

In order to minimize the impact on the Subaru work force during the commissioning of the SCExAO bench, a Linux-compatible Xenics near-IR camera has been purchased to substitute for HiCIAO. While the primary objective of this new camera is to be used for commissioning, if readout noise proves satisfactory, it might be usable for actual observations. Our group is currently running simulations to explore this possibility.

Project Schedule, commissioning plan

Note: 1 day time = 8 am to 4 pm
All dates shown will need to refined with telescope schedule

Task 1: Commissioning the SCExAO frame for HiCIAO but without SCExAO bench to ensure that SEEDS observations can continue with the new frame.
•mid January 2010 (3 days): replace the current HiCIAO frame on the IR Nasmyth floor by the SCExAO frame. HiCIAO in front position can pursue its current observing mode.
Estimated time required: 3 days (daytime), with AO188 internal source on.

Task 2: Day time commissioning of SCExAO bench with AO bench.
•end Jan 2010 (3 days): daytime commissioning of SCExAO, part 1. Interfacing with AO. This requires the use of internal source of AO188 for basic functionalities checking: global alignments, stability of DM flat map, tip tilt residuals. All these tests can be done with the Xenics camera and do not require HiCIAO camera.
•early Feb 2010 (4 days): daytime commissioning of SCExAO, part 2. SCExAO performance evaluation: coronagraphic rejection. This requires AO188 running with the turbulence simulator. These tests will also use the Xenics camera.
•mid Feb 2010 (5 days): daytime commissioning of SCExAO, part 3. Interfacing with HiCIAO. Measure changes of plate scale, image quality, determine the deformable mirror flat map with HiCIAO.

Task 3: Night time engineering for SCExAO with AO188 + HiCIAO
From late feb 2010 to HSC telescope shutdown (2 nights, ideally two 1/2 nights + one full night, separated by >1 week if possible).
•Run #1 (1/2 night): On sky tests of HiCIAO imaging without coronagraph (DM set to flat) and visible. Verify alignment of both visible and near-IR channel. Acquire first data set in visible on a few moderately bright targets. Acquire fist set of non-redundant masking data with HiCIAO.
•Rub #2 (1/2 night): On sky test with HiCIAO + coronagraph. Align coronagraph, run LOWFS.
•Run #3 (1 night): First performance verification with simultaneous imaging in near-IR with HiCIAO and SCExAO coronagraph and in visible with EMCCD. Run coherent speckle modulation loop.

OUTSTANDING ISSUE: SCExAO frame construction schedule, delivery date for Kyoto 3D dichroic.

NOTE:
During phase 1 of the project, the position of HiCIAO on the new frame would alternate between front position (emulating the current frame setup) and the back position (using the SCExAO upgrade).

Possible collaborations, ongoing discussions with other groups

SCExAO's open and flexible architecture generates much interest from the community. Multiple collaborations have already been discussed. We will need to establish how to decide which collaborations are beneficial to Subaru Telescope and how to proceed if we decide to move forward.

Institutions
- Princeton University, USA (IFS proposal)
- Herzberg Institute for Astrophysics, Canada (construction of WFS for SCExAO, ExAO control loop)
- Meudon Observatory, France (Coherent speckle calibration)

Individuals, small groups
- Eugene Serabyn, NASA JPL, USA (Vortex coronagraph)
- Peter Tuthill, University of Sydney, Australia (super-narrow band tunable filter for visible masking)
- Ren Deqing, California State Univ. Northridge, USA (step-transmission apodizer)