

Memorandum of Understanding Between the Subaru/HSC and Steward/UKIRT Teams

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I. Background

Hyper Suprime-Cam (HSC) is Subaru's new prime-focus camera with a circular field of view of $D=1.5$ deg. The Subaru Observatory will allocate ~ 300 nights of observing time over the next 5 years to three large extragalactic surveys: **Wide** (1400 deg^2 ; $r \sim 26$ AB mag), **Deep** (27 deg^2 ; $r \sim 27$ AB mag; XMM-LSS, E-Cosmos, ELAIS-N1, DEEP2-F3), and **Ultradeep** (3.5 deg^2 ; $r \sim 28$ AB mag; SXDS/UKIDSS & COSMOS). Although good complementary near-infrared imaging data already exist for the **Wide** and **Ultradeep** surveys (e.g., from UKIRT/UKIDSS and VISTA/VIKING), only half of the **Deep** survey area ($\sim 12\text{-}13 \text{ deg}^2$ out of 27 deg^2 in total) has good near-infrared data. To fully realize the great scientific potential of the **Deep** survey (HSC-Deep hereafter), it is highly desirable to extend the near-infrared imaging coverage to the remaining half of the HSC-Deep fields. Scientifically, near-infrared data will be crucial for improving photometric redshifts, deriving galaxy stellar masses, and detecting optically-faint red objects. The Steward UKIRT program described here will therefore be essential for a wide array of key HSC science goals. In the long run, the same near-infrared data will also aid the target selection for the Subaru/PFS survey.

II. Purpose

The purpose of this memorandum is to define the framework of collaboration between the Subaru/HSC and Steward/UKIRT teams toward the following goals:

- 1) To increase significantly the near-infrared imaging coverage for the HSC-Deep fields.
- 2) To promote and establish a scientifically stimulating and productive partnership between the two teams through various collaborative projects using the HSC-Deep data.

III. Roles & Responsibilities

- 1) Steward/UKIRT team
 - i) The Steward/UKIRT team will obtain J-, H-, and K-band images covering the E-COSMOS field (four flanking fields; $4 \times 0.75 \text{ deg}^2$) and DEEP2-F3 field ($6 \times 0.75 \text{ deg}^2$) using WFCAM with a depth of ~ 2 hours/pixel per filter. With a total imaging area of 7.5 deg^2 , this program will increase the HSC-

Deep near-infrared coverage from the current $\sim 12\text{-}13\text{ deg}^2$ to $\sim 20\text{ deg}^2$. To carry out this program, the Steward team will commit ~ 240 hours of UKIRT *science open-shutter* time.

- a) The Steward team has already obtained 189 hours of UKIRT observing time in 2014, 49 hours in 2014A and 140 hours in 2014B. However, the 2014A allocation was unused because the HSC pointings for the E-COSMOS field were not finalized in time.
- b) This commitment should be understood as that of “good-faith” and “best-effort”. Although the Steward team will do their best to fulfill the stated commitment above, there will always be a possibility that something happens and prevents the Steward team from collecting the promised amount of data (e.g., telescope/instrument failures, a long spell of bad weather making it impossible to schedule all the observations within a given time frame). In such cases, the terms of collaboration will be reassessed and renegotiated.
- c) The promised open-shutter time of 240 hours should be regarded as a soft limit with an uncertainty of a few percent. For example, our preliminary UKIRT observing scripts indicate that the final integration time per pixel may be 1.96 hours rather than 2 hours.
- ii) The Steward/UKIRT team will make available the data products described in VI to the Subaru/HSC team in a timely manner. They will also release these products publicly in coordination with the HSC public data releases (see VII).
- iii) The Steward/UKIRT team members will actively participate in science discussions/projects, and will help enhance the impact/productivity of the HSC-Deep survey.

2) Subaru/HSC team

- i) In exchange for receiving the UKIRT data, the Subaru/HSC team will accept eligible Steward/UKIRT team members as External Collaborators (“Steward Collaborators” as defined in VIII) with “Limited Data Access”¹, giving them opportunities to collaborate by joining existing research projects and/or initiating new ones
- ii) To execute such collaborative projects, Steward Collaborators will have access to the full HSC-Deep and Ultradeep broad-band data as well as ancillary ones, following the collaboration policy (see IV). Although the Steward UKIRT program will obtain near-infrared data only for part of the HSC Deep fields, giving Steward Collaborators a full access to the HSC-Deep and Ultradeep data is considered desirable as well as reasonable for the following reasons:

¹ “Access to the Survey data needed to carry out a specific, announced scientific investigation.” (HSC collaboration policy 3.3.4).

- a) Although the Steward UKIRT program will bring in a substantial amount of near-infrared data to HSC-Deep, its total area coverage is limited to 7.5 deg^2 over those areas where multi-wavelength ancillary data are scarce. Since $12\text{-}13 \text{ deg}^2$ of the HSC-Deep fields already has similar near-infrared data with more abundant multi-wavelength coverage, it will likely be difficult for Steward researchers to come up with projects that are new, unique, and exciting if their data access is limited to the 7.5 deg^2 area they observe.
 - b) It is expected that in the early stage, HSC-Deep will preferentially observe those fields that already have near-infrared and other multi-wavelength ancillary data. Therefore, the arrival of HSC data will likely lag for those fields that the Steward UKIRT program will cover. This will cause a significant delay with science activities on the Steward side, and could result in a significant wait time for the arrival of the HSC data covering the Steward UKIRT fields.
 - c) One important purpose of this collaboration is to promote and establish a scientifically stimulating and productive partnership between the two teams (II.2). In this sense, Steward researchers are keen to work with HSC team members closely, but such a collaboration will become in practice difficult if the data are not fully shared between the two sides.
 - d) The existing HSC-Deep science projects are strongly protected under the collaboration policy as detailed in IV. Steward Collaborators are simply not allowed to compete with science projects that already exist on the HSC side.
 - e) While this policy originally limited the Steward collaborators to data to the Deep layer depth in the ultradeep fields, this required the generation of separate coadd images to that depth just for this purpose, which caused inefficiencies in processing and distributing of data.
- iii) UKIRT near-infrared data are expected to provide only a limited scientific opportunity for the HSC-Deep narrow-band survey because the UKIRT data will detect only a small fraction of the HSC narrow-band-selected sources individually. Because of this, an access to the HSC-Deep narrow-band survey information will be granted to Steward Collaborators only when the following conditions are met:
- Proposed sciences are driven by the use of near-infrared data (e.g., near-infrared study of narrow-band-selected sources).
 - Proposed projects are focused on the use of the Steward/UKIRT data.

In other words, the primary purpose of such projects must be the exploitation of the Steward/UKIRT data. It is not appropriate for Steward

researchers to use their UKIRT data simply as a leverage to access and exploit the HSC-Deep narrow-band data.

IV. Collaboration Policy

- 1) Regarding the framework of the collaboration, the Steward team will follow that of the SDSS external collaborators as adopted by the HSC team (the HSC Collaboration Policy version 15 issued on Oct., 3 2012).
- 2) More specifically, Steward participants will enter the collaboration by either joining existing projects or proposing new ones, both of which will require an approval from the HSC board.
- 3) **This collaboration does not provide Steward participants a free unlimited data access;** They will always have to propose to collaborate on specific projects, and will seek for data access only to those products that are directly relevant to the proposed projects (including multi-wavelength ancillary data).
- 4) The Steward team will follow the existing HSC team policies (e.g., collaboration, publication), and will seek for an approval from the HSC board when necessary. The following are a few specific examples of the protocols:
 - i) All projects using HSC data will be announced to the HSC collaboration when they start, and HSC SSP (Strategic Survey Program) participants are welcome to request to join any such project.
 - ii) All papers will be posted to the HSC collaboration for a minimum of 3 weeks before submission. During that time, those HSC scientists who have contributed significantly to the instrument, software, survey design, and/or particular scientific analysis have the right to add their names as co-authors.
- 5) The Steward team will respect the rights of the current HSC team members regarding the existing projects, meaning that Steward participants will not independently attempt to conduct a program that would directly conflict with the existing ones. Instead of proposing competing projects, Steward researchers are encouraged to join and help existing projects of their interest.
- 6) The policies described above will also apply to the use of the Steward UKIRT data in reciprocal ways. In particular, HSC team members wishing to lead projects that make use of the Steward UKIRT near-infrared data should seek permission from the Steward/UKIRT team just as Steward/UKIRT team members wishing to lead projects involving HSC data should seek permission from the HSC Board. When using Steward UKIRT near-infrared data, HSC team members will follow the HSC publication procedures in such a way that Steward/UKIRT team members have the opportunity to participate in these

papers, similarly to what is described in IV.4.ii above.

- i) A Steward researcher joining an existing HSC research project does not carry with him/her an access right to the Steward/UKIRT data for that project. If the project needs such an access, the project proposal needs to be modified and approved by the Steward/UKIRT team.
- 7) When conflicts arise, both sides will attempt to address and resolve issues in a respectful and collegial manner. More specifically, every effort will be made to discuss and resolve conflicts at the earliest opportunity and at the lowest level possible within the framework of this collaboration. Whenever possible, discussions related to particularly sensitive and/or conflicted issues should be conducted via tele- or video-conferencing as opposed to engaging in dialogue via email. Only if the involved parties are unable to find a solution on their own will the HSC board and Steward/UKIRT team representatives impose a common decision.
- 8) Approved Steward Collaborators will be eligible for joining HSC working groups and mailing lists as well as accessing web/wiki pages that are relevant for their research projects. HSC Collaborators will have a similar access to the internal information on the Steward side.

V. UKIRT Observations

- 1) The Steward team will provide the J/H/K-band coverage for two HSC-Deep fields, E-COSMOS and DEEP2-F3 (see Figure 1).
- 2) The integration time will be 2 hours/pixel per filter, achieving 5σ point-source limiting magnitudes (in AB mag) of 23.6 (J), 23.2 (H), and 23.1 (K), respectively (based on the WFCAM ETC with 0.9" seeing, D=2" aperture, airmass=1.2, and average sky brightness).
- 3) When four separate adjacent pointings are combined, WFCAM will produce a filled square image of 0.75 deg^2 . Therefore, to image one 0.75 deg^2 field in the three filters, 24 hours of open-shutter time is required (= 2 hours/filter * 3 filters * 4 pointings).
- 4) Four 0.75 deg^2 flanking fields will be observed for E-COSMOS with a total open-shutter time of 96 hours while six 0.75 deg^2 fields will be observed for DEEP2-F3 with a total open-shutter time of 144 hours (Figure 1). The total open-shutter time for the two target fields is therefore 240 hours with a total area coverage of 7.5 deg^2 .
- 5) **What is promised here is the commitment of a total science open-shutter time to complete the program (i.e., 240 hours).** With an expected overhead rate of $\sim 35\%$, the total observing time will be ~ 324 hours, roughly corresponding to one month of UKIRT time. Neither the targeted depth nor the area coverage is guaranteed. Since UKIRT is run in the queue observing mode, it is not necessary to take into account time losses due to bad weather, telescope problems, etc. in the calculation of this time request.

- 6) The Steward team is also open to the possibility of conducting an even more ambitious survey with a wider and/or deeper coverage. For example, one possibility is to fill the gaps between the WFCAM E-COSMOS coverage (the WFCAM 5-8 pointings in Figure 1). At the conclusion of the program described above, the two teams will review what has been achieved, and will discuss the possibility of conducting any additional observations.

VI. UKIRT Data Products

- 1) The Steward/UKIRT team will process WFCAM data with the help of the Cambridge Astronomy Survey Unit (CASU) in the UK. The data processing procedure will therefore be similar to that of the UKIDSS survey. Through the data repository either in the UK or in Arizona, the Steward/UKIRT team will make the following products available to the Subaru/HSC team:
 - i) Fully calibrated and combined images
 - ii) Individual calibrated frames
 - iii) Raw frames including calibration data (if necessary)
 - iv) Near-infrared source catalog with coordinates and J, H, K magnitudes
- 2) The Steward/UKIRT team will specifically support the effort to process the UKIRT/WFCAM data using the HSC pipeline, and will provide the necessary data files/products to make this effort possible.

VII. UKIRT Data release

- 1) The Steward team will coordinate the public releases of the UKIRT data with those of the HSC data. In general, whenever the HSC team makes a public data release, the Steward team will release the corresponding UKIRT data covering the same fields.
- 2) However, there should be at least a 6-month proprietary period for any fully calibrated and combined images produced by the Steward team before they are made public.
- 3) We anticipate the first public data release to take place in 2016.

VIII. Steward Collaborators

- 1) Only those Steward researchers who have the right to request Steward UKIRT observing time are eligible for joining this collaboration. They are considered to be contributing UKIRT time to this project jointly.
- 2) Eligible Steward researchers become HSC External Collaborators (= "Steward Collaborators") only after they have started new projects or have joined existing projects with the approval of the HSC board.
- 3) The Steward/UKIRT team representatives include Eiichi Egami, Xiaohui Fan, and Buell Jannuzi (Steward Director). Jannuzi may appoint other Steward Senior Personnel, such as Dennis Zaritsky (Deputy Director; Steward TAC Chair) and Richard Green (UKIRT Director), as his substitute when

necessary. Richard Green will play an advisory role for the Steward/UKIRT program as the UKIRT Director.

- 4) The Steward representatives E. Egami and X. Fan will be part of the collaboration from the start for various program coordination purposes. Egami is already an HSC Survey Member, so no special arrangement is required; Fan will become a Steward Collaborator without submitting any specific research project proposal.
- 5) Steward researchers can be part of the Steward UKIRT program without being HSC external collaborators if their projects do not use any HSC data.
- 6) When adding *new* members to the collaboration, the Steward team will follow the following procedure:
 - i) Before each HSC team meeting (i.e., every 6 months), Egami and Fan will collect requests for the HSC external collaborator status from interested Steward researchers. These requests will be made with specific science proposals.
 - ii) These requests will be submitted to the HSC team/board for their evaluation and approval. Based on the submitted information, the HSC team/board will accept/deny the requests.
 - iii) If a particular request is denied, Steward researchers involved in the denied request may appeal to the decision through the Steward representatives, who will then try to work out a solution with the HSC team/board.
 - iv) Students and postdocs of approved faculty members are expected to be included in the collaboration, but will still have to obtain an approval from the HSC board following the HSC collaboration policy (3.2.3).
 - v) Once inside the collaboration, Steward Collaborators can submit project proposals any time as HSC Collaborators can.
 - vi) The first batch of requests will be an exception, and may be submitted soon after this MOU is approved.
- 7) The following are the Steward and associated researchers who have expressed interest in this collaboration as of August 2014. They will officially become Steward Collaborators after their involvement in a new/existing project is approved:
 - i) Senior members (17): Eiichi Egami, Xiaohui Fan, Timothy Axelrod, Brenda Frye, Richard Green, Buell Jannuzi, Ian McGreer, George Rieke, Brant Robertson, Daniel Stark, Rodger Thompson, Benjamin Weiner, Christopher Willmer, Ann Zabuldooff, Dennis Zaritsky; Arjun Dey (NOAO & Steward adjunct faculty member), Dave Thompson (LBT).
 - ii) Postdocs (1): Rachel Bezanson (Hubble Fellow)

Note that this is just a preliminary, incomplete list of potential Steward Collaborators. As long as the eligibility condition (VIII.1) is met, any Steward researcher may request to join this collaboration later by following the process outlined above.

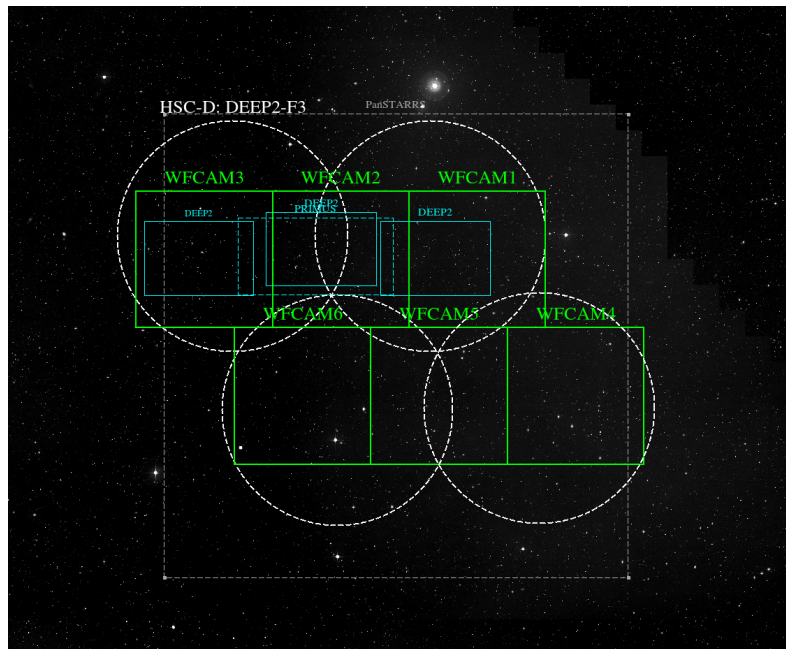
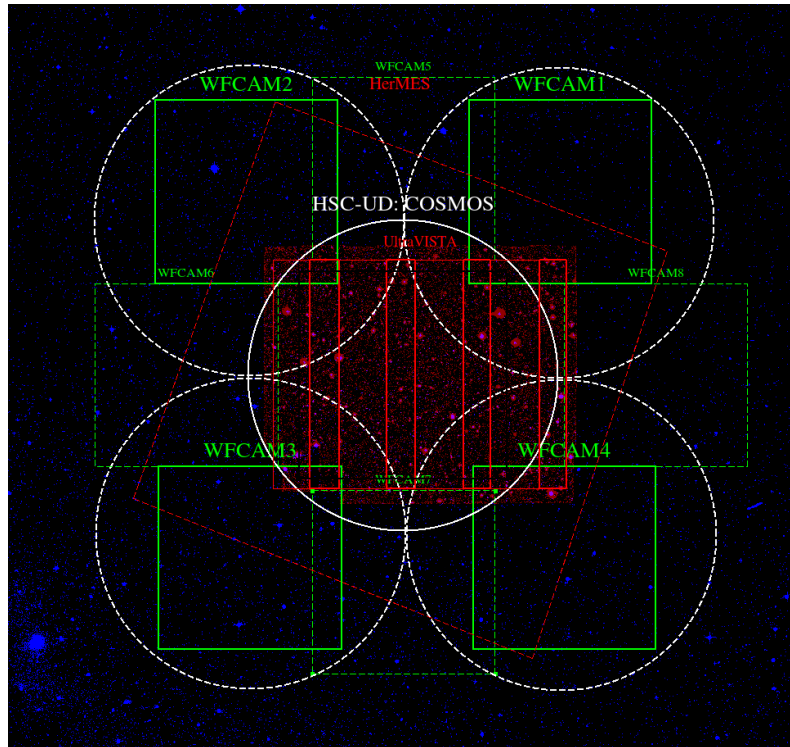


Figure 1: The planned UKIRT/WFCAM pointings (green squares) for the E-COSMOS (top; WFCAM 1-4) and DEEP2-F3 (bottom; WFCAM 1-6) fields. The white circles indicate the planned Subaru/HSC pointings (solid: HSC-Ultradeep; dashed: HSC-Deep). The locations of other existing data are also shown (figures by M. Tanaka).