UKIRT under new management: status and plans

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UKIRT under new management: status and plans

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ABSTRACT

The United Kingdom Infrared Telescope (UKIRT) observatory has been transferred to the ownership of the University of Hawaii (UH) and is now being managed by UH. We have established partnerships with several organizations to utilize the UKIRT for science projects and to support its operation. Our main partners are the U.S. Naval Observatory (USNO), the East Asian Observatory (EAO), and the UKIRT microlensing team (JPL/IPAC/OSU/Vanderbilt). The USNO is working on deep northern hemisphere surveys in the H and K bands and the UKIRT microlensing team is running a monitoring campaign of the Galactic bulge. EAO, UH, and USNO have individual P.I. research programs. Most of the observations are using the Wide Field Camera (WFCAM), but the older suite of cassegrain instruments are still fully operational. Data processing and archiving continue to be done CASU and WSA in the UK. We are working on a concept to upgrade the WFCAM with new larger infrared detector arrays for substantially improved survey efficiency.

Keywords: UKIRT, telescope operation, sky surveys, wide-field imaging, infrared instrumentation

1. INTRODUCTION

The United Kingdom Infrared Telescope, a 3.8m infrared telescope on Maunakea, Hawaii, saw first light in 1979 and was operated by the UK Science and Technology Facilities Council through October of 2014, when funding by the UK ceased and ownership was transferred to the University of Hawaii (UH) on Nov. 1. From then through May of 2017, the telescope was operated by the University of Arizona and Lockheed Martin Advanced Technology Center under an agreement with UH. After this collaboration ended, the UH took over the management of UKIRT directly on 2017 June 1 and named a UH director of the telescope. The first incumbent was R. McLaren, who managed the transition period until he became interim director of the Institute for Astronomy. On February 1, 2018, K. W. Hodapp succeeded him as the UKIRT director. The University of Hawaii decided to keep the historical name of UKIRT, irrespective of the change in ownership. In the last years of British operation, UKIRT ranked as the most productive ground-based telescope in a bibliographic analysis[1] done by D. Crabtree. This is a testament to the impact of the UKIDSS [2] survey programs whose data are now publicly available and being used by the international community. In response to a reduction in funding, UKIRT had been operating in a "minimalist" operating mode since 2010 [3] for the last years of operation by the British Science and Technology Facilities Council. This mode involved a concentration on near-infrared

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imaging with WFCAM[4], no support of the suite of Cassegrain instruments, and reliance on James Clerk Maxwell Telescope (JCMT) staff for maintenance on an as-needed basis. This is the mode of operation that the University of Hawaii "inherited" when ownership of the telescope was transferred to them in 2014, and that was maintained through the years of operation of the telescope by the University of Arizona, except that the use of the Cassegrain instruments was reinstated. The UKIRT is operated fully remotely from the offices in Hilo, without anybody at the telescope during nighttime.

2. PARTNERSHIPS FOR UKIRT OPERATION

The University of Hawaii does not have the funding to fully operate UKIRT on its own, so we have established partnerships for the scientific operation of UKIRT with other organizations who wish to use the telescope for their scientific research. Currently, the main partner organization is the US Naval Observatory who are interested in completing the northern hemisphere near-infrared survey work initiated with the UKIDSS [2] surveys.

The East Asian Observatory (EAO) was incorporated in 2015 as a joint venture between the primary astronomical institutes in China (NAOC), Japan (NAOJ), Korea (KASI) and Taiwan (ASIAA). EAO's main project is to operate the 15 m single-dish sub-mm JCMT following the defunding of the joint UK/Canada/Netherlands partnership. It also continues to provide the engineering, software and technical support for UKIRT, in a similar way as was done in the final few years of British management [3] of this telescope. The jointly shared staff made the operational transition smooth and cost-effective. In the new UH-led partnership, this has enabled opportunity for PIs from the EAO partners to access UKIRT for a portion of the available time and there has been strong interest. Key science goals in the first round of EAO projects include periodic monitoring of AGNs, Y and J quasar surveys, an ambitious J & K pre-survey of the planned Subaru PFS fields, as well as varied interests in the use of the Cassegrain instruments.

The UKIRT microlensing team is conducting a monitoring campaign for micro-lensing events in the Galactic bulge.

The major projects are described in some detail in Section 3.

We continue the established collaboration with the Cambridge Astronomy Survey Unit (CASU) and the Wide Field Astronomy Unit (WFAU) in Edinburgh who run the data reduction pipeline for WFCAM data and the WFCAM Data Archive (WSA), respectively.

Three of our partner organizations accept individual research proposals from within their communities: EAO, UH, and USNO. Each organization evaluates their proposals for scientific merit, selects and ranks them. Each partner organization is entitled to a fraction of the total available observing time in proportion to their contribution to the operation of the telescope. Since the number of usable observing hours is not known with certainty, we base the number of assigned observing hours on the average of past years, and ask the partner organizations to overfill their estimated allotment of observing time to ensure that we don't run out of programs in the event of better than average weather.

Every observing project, including those using the older Cassegrain instruments, is defined by a set of MSBs, these "minimum schedulable blocks" are generated by the P.I.s from existing templates, with some advise from the UKIRT support scientists, who check the submitted MSBs before activating them in the Observatory Management System (OMP). Based on the scientific merit ranking, the observing condition specifications, the prevailing weather conditions, and the local sidereal time, the OMP will present a list of priorities to the Telescope System Specialist during the night, who conducts the actual observations. In general, UKIRT gives the highest priority to a small number of projects with override privilege, for example gamma-ray burst follow-up observations. The second level of priority is for projects with critical schedule or cadence requirements, such as, for example, microlensing or other variability monitoring. In order not to crowd out all other programs, priority projects are limited in their total time allocation. After these priority projects, all other projects are carried out in order of scientific ranking.

3. MAJOR PROJECTS

3.1 The USNO northern hemisphere near-infrared surveys

In July 2017, UKIRT began taking data as part of a new collaboration to produce a northern hemisphere survey of the sky at near-infrared wavelengths. The collaboration is led by the United States Naval Observatory (USNO) in conjunction with the Institute for Astronomy (IfA), University of Hawaii (UH) with continued support from the Cambridge Astronomy Survey Unit (CASU) and the Wide Field Astronomy Unit (WFAU) in Edinburgh. The principal objective of this survey is to produce continuous coverage of the northern celestial hemisphere in the K and H bands over the declination range from δ=0º to +60º (the upper limit being set by UKIRT's mechanical constraints). This will be accomplished by combining over 12,700 deg^2 of new imaging with existing survey data from the UKIRT Infrared Deep Sky Survey (UKIDSS; Lawrence et al. 2007) Large Area Survey (LAS), Galactic Plane Survey (GPS) and Galactic Cluster Survey (GCS). The expected 5-σ point source sensitivity is K~18.4 and H~19.0 (Vega), which is over three magnitudes deeper than the Two Micron All Sky Survey [6] (2MASS).

The USNO-UKIRT Hemisphere Survey in K-band (UHSK) employs the Wide Field Camera (WFCAM) on the infrared-specific UKIRT telescope, which together yield an impressive étendue of ~2.4 m^2deg^2. The fast tip-tilt secondary on UKIRT combines with the high efficiency of WFCAM to make it a highly optimized facility for infrared surveys. The design of the UHSK is based on that of the J-band UKIRT Hemisphere Survey (UHS [5]). The UKIRT Survey Definition Tool (SDT) was used to plan out and form contiguous areas which overlap by 30" in both right ascension and declination to fill in all areas not imaged by the UKIDSS surveys. When developing the tile pattern, the SDT was constrained by the WFCAM detector layout, discussed in detail in Section 6 and Figure 4, as well as the availability of adequate guide stars detectable in the R band with the guide CCD.

The individual UHSK observations are comprised of four 10s exposures, offset in a rhombic dither pattern which is 6.4" across at its largest extent. The observations have the same pointing coordinates and exposure times as the UHS J-band survey, and the only change for the H-band (UHSH) observations will be to co-add two 5s exposures at each of the four dither points. The observing strategies have been chosen with a number of considerations in mind, including minimizing saturation from bright sources, reducing read noise and maintaining low observing overheads.

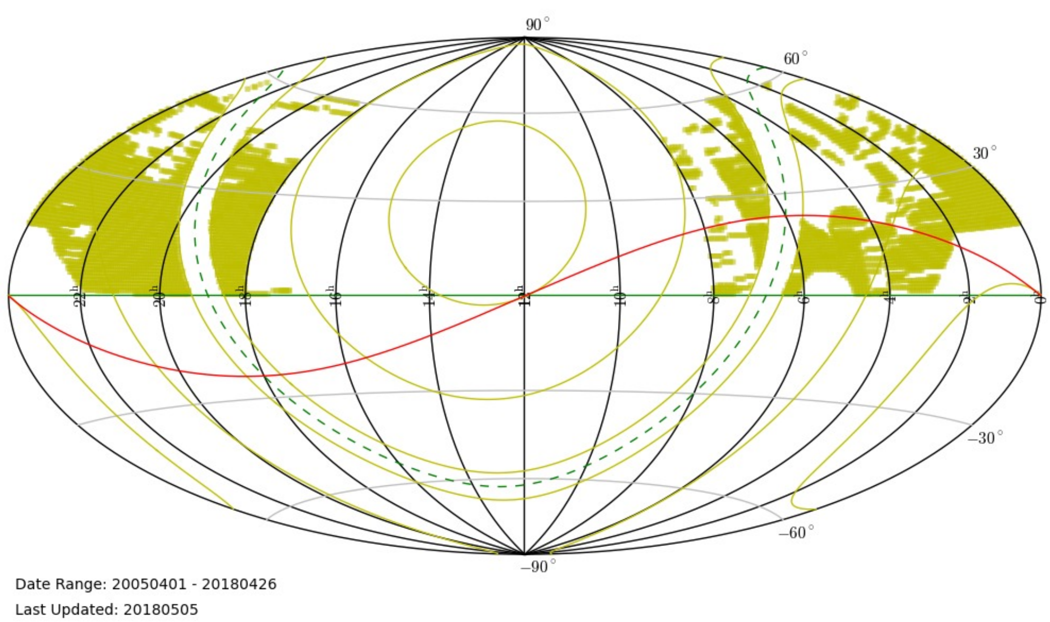

Figure 1. Completion map of the USNO-UKIRT Hemisphere Survey in K-band (UHSK)

All survey data are initially transferred from UKIRT to CASU and processed via the WFCAM data reduction pipeline. Raw images are flattened, sky-subtracted and stacked before catalogs are generated. CASU processing includes source extraction and distortion corrections to produce astrometric solutions that range from a precision of ~0.01" at low Galactic latitudes to ~0.03" by a latitude of *b*=80º, where there are fewer 2MASS [6] stars for reference. Photometric calibration is completed using 2MASS magnitudes, achieving a photometric accuracy of ~2%. After CASU, the processed images and catalogs are transferred to the WFAU in Edinburgh where the catalogs are merged. The processed images and final photometric catalogs are archived on the Wide Field Science Archive managed by WFAU, and will be publicly released in the future (URL: http://wsa.roe.ac.uk).

The UHSK is currently 40% complete (Figure 1), and data collection for the UHSH will begin in the summer of 2018. The UHSK and UHSH contributions are meant to complement and combine with the recently obtained J-band UHS which is expected to be released in August, 2018. These combined UKIRT surveys will create an unprecedentedly-deep near-infrared northern hemisphere survey up to δ=60º. The coverage of these UKIRT surveys will also complement the Visible and Infrared Survey Telescope for Astronomy (VISTA) Hemisphere Survey (VHS [7]), which is a very comparable near-infrared survey of the southern hemisphere, in terms of survey design, coverage and depth.

3.2 The UKIRT microlensing survey

The Wide Field InfraRed Survey Telescope (WFIRST) flagship mission [8] is scheduled to launch in the mid-2020s, with ~25% of its lifetime dedicated to a microlensing survey. This survey will discover thousands of exoplanets near or beyond the snowline via their microlensing light curve signatures, enabling a Kepler-like statistical analysis of planets at ~1–10 AU from their host stars and potentially revolutionizing our understanding of planet formation. In addition to the superb photometry, high cadence, and continuous observations, the survey will be conducted in the near-infrared (NIR). An NIR microlensing survey suffers from less extinction than traditional optical surveys, enabling observations closer to the Galactic plane and center, where the stellar surface density of sources and lenses, and thus the microlensing event rate, is highest. However, until recently no dedicated NIR microlensing survey has been conducted, and so the event rate in the NIR has not been measured, which is crucial for WFIRST field optimization [9].

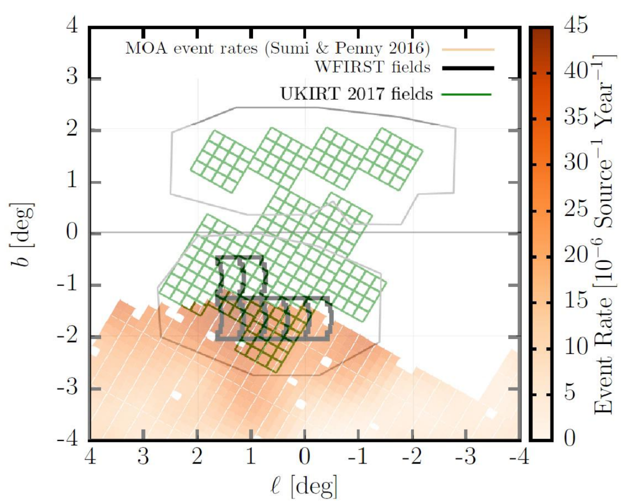

Figure 2. UKIRT 2017 fields (green) cover the regions near the Galactic center that are not covered by the state-of-the-art event rate maps [12] (orange shades). The currently suggested WFIRST fields (black) and their range of possible alternative fields (gray) are only partially covered by the known event rate. The UKIRT survey is thus essential for covering the remaining regions where WFIRST might observe.

In order to map the unknown NIR event rate, we have started a NIR survey with the UKIRT. During the 2015 and 2016 seasons, we conducted the first NIR microlensing surveys, in support of the Spitzer and Kepler (K2C9) microlensing campaigns. In 2017 we initiated a full NIR microlensing survey with UKIRT, covering all potential WFIRST fields, including the Galactic plane and center, which are inaccessible to optical surveys due to the high extinction. The fields (Figure 2) were observed with a daily cadence [10], allowing for straightforward detection of microlensing events with their typical timescale of ~20 days, and with a cadence of 3 epochs/night in the central fields, which are expected to have an excess of short-timescale events whose source and lens both reside in the Galactic bulge [11].

The state-of-the-art event rate map [12], derived from optical surveys, does not adequately probe the Galactic center, and in particular it does not include the currently suggested WFIRST fields. From examination of 5% of the 2016 UKIRT fields (overlapping with optical survey fields), we discovered five highly extinguished, low-Galactic latitude microlensing events [10] . These events were not detected by optical surveys, likely due to the high extinction. Combining these detections with additional events that were also detected by optical surveys in this region, we showed that the event rate is indeed higher closer to the Galactic plane. From preliminary examination of the full 2015–2017 datasets we have detected nearly 200 additional microlensing events, ~65% of which were not detected by optical surveys (Bryden et al., in preparation).

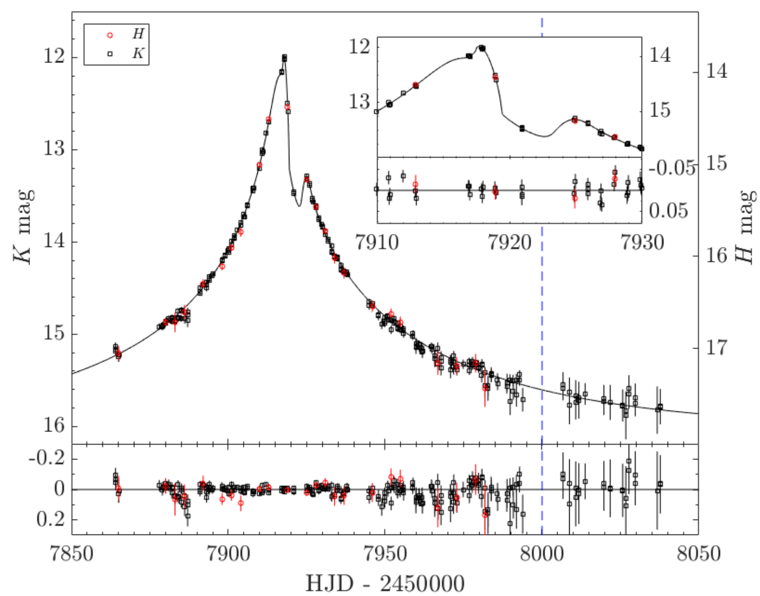

Figure 3. Light curve of UKIRT-2017-BLG-001Lb, the first NIR microlensing planet [13]. The planetary anomaly (inset) over the peak, which is due to a Jupiter-mass planet orbiting at ~4 AU around a solar-type star, is clear and covered sufficiently well with our 3 epochs/night cadence.

In parallel with the event rate study, we have also used our data to detect and characterize the first NIR microlensing planet [13] (Figure 3) and five additional planets [14,15,16,17,18]. This represents ~10% of the total number of planets detected by microlensing to date. In addition, we used our data to detect and measure a massive remnant (likely a neutron star) in a well-separated binary [19].

Light curves for more than 50 million targets are available through the NASA Exoplanet Archive. These light curves were obtained in 2015, 2016 and 2017. In addition to yielding numerous microlensing events, the light curves are a valuable resource for the study of a wide variety of variable sources toward the Bulge. Information on the survey is available at https://exoplanetarchive.ipac.caltech.edu/docs/UKIRT_figures.html and data are accessible at https://exoplanetarchive.ipac.caltech.edu/index.html.

4. CASSEGRAIN INSTRUMENTATION

UKIRT currently has a suite of four Cassegrain instruments, three of which are in operation and the fourth is operable but not in active use. These instruments require access to UKIRT's f/36 beam which means WFCAM needs to be removed from the telescope and the f/36 secondary mirror installed. Downtime for such an operation is approximately three days at the start of a Cassegrain run and three days after. Therefore these runs must be scheduled in advance and are only carried out if there is sufficient demand from the community. Regular Cassegrain observing ceased in early 2009 when the observatory streamlined operations to ensure completion of the UKIDDs survey, but blocks of Cassegrain instrument use were reintroduced in the second half of 2014 when UKIRT started undertaking observations of orbital debris. These observations finished in 2016 but a new session of Cassegrain observing is scheduled for August 2018, mainly for PI-based projects. We plan to offer one Cassegrain run per semester, if we have enough proposals for at least a 20 night run, so that the substantial effort for the switchover is justified.

The current Cassegrain instruments are CGS4, Michelle, UFTI and UIST satisfying imaging, spectroscopy and polarimetry requests and covering wavelengths from approximately 1.0 to 25 μm. The instruments are described below:

CGS4 [20]: This is a cooled grating spectrometer covering the 1 to 5 μm regime with resolving powers of approximate 400 to 40000. It can also be used in conjunction with the UKIRT polarimetry module (IRPOL) to carry out spectropolarimetry although only in at low resolution. CGS4 has not been in use since 2009 and was not in demand during recent Cassegrain runs as it has no slit viewer and was therefore difficult to use for orbital debris observations where positions can be very uncertain. CGS4 is currently stored under vacuum and is available for use if there is demand, but would require a period of re-commissioning.

Michelle [21]: The 7 to 25 μm range is covered by Michelle, an imager/spectrometer that also contains an echelle grating for high-resolution spectroscopy. It has an inbuilt polarimetry unit so that it can do imaging polarimetry as well as spectropolarimetry. Michell offers an imaging mode with a number of broad and narrow-band filters and a spectroscopy mode with resolving powers that range from 100 to 30000. This instrument was under heavy demand during Cassegrain runs since 2014 and is currently fully operational.

UFTI [22]: This is a relatively simple 1 to 2.5 μm imager offering a plate scale of 0.09 arcsec per pixel and a field of 92"×92". This is well matched to to UKIRT's diffraction limit so it is best used for observations that require excellent image quality. This instrument can be used in conjunction with IRPOL for imaging polarimetry but this mode is not currently offered as IRPOL has not be re-commissioned for remote observing. We did not have any proposals for UFTI for the upcoming cassegrain run.

UIST [23]: Currently the workhorse of UKIRT's Cassegrain instrument suite, UIST operates in the 1 to 5 μm region and offers imaging, spectroscopy and IFU spectroscopy. In imaging mode the wavelength regime is covered by both broad and narrow-band filters while in spectroscopy mode UIST employs several grisms with resolving powers of approximately 500 to 3500. The IFU enables integral field spectroscopy of a 3.3"×6" region of the sky. UIST can also carry out imaging polarimetry and spectropolarimetry in conjunction with IRPOL, but, as is the case for UFTI, this mode is not currently offered.

5. MAINTENANCE AND UPGRADES

The years of "minimalist" operation have led to a backlog of maintenance tasks. In particular, have been monitoring a steady decline in the telescope throughput due to slowly deteriorating mirror conditions, despite regular CO_2 cleaning of the telescope primary mirror. We are now planning a technical shutdown of the telescope in August and September of 2018 to re-aluminize the primary in CFHTs coating chamber, and to re-coat the secondary mirror for WFCAM with a silver coating in Gemini's magnetron coating chamber. In the coming years, all our computers need to be replaced with state-of-the-art 64-bit machines, since our existing systems are becoming difficult to maintain.

6. WFCAM UPGRADE PLAN

The most frequently used instrument, and the one responsible for most publications in the past decade is the Wide Field Camera WFCAM[3]. This is a near-infrared camera using four Teledyne Imaging Sensors (formerly Rockwell Scientific Co.) HAWAII-2 devices in a sparsely filled focal plane. The detectors are now over 20 year old technology that had already been surpassed in many ways by the HAWAII-2RG devices developed for the JWST project. Recently the HAWAII-4RG-15 devices [24] developed by Teledyne in collaboration with UH and funding from the National Science Foundation (NSF) under grant AST 6659337 have provided the technology for a substantial upgrade of the WFCAM capabilities with minimal changes to the optics and mechanics of the instrument. Upgrading WFCAM with these new H4RG-15 detector arrays will quadruple the pixel count of WFCAM and significantly increase the quantum efficiency, in particular at shorter wavelengths.

The detector arrays used for WFCAM were the HAWAII-2 arrays from then Rockwell. These were the first detector arrays in 2048×2048 format and have 18 μm pixels. Similar to the earlier NICMOS-3 and HAWAII-1, the HAWAII-2 detectors were arranged in electrically independent quadrants, and had control and signal pinouts all around their periphery. As a consequence, it was not possible to place these in a closely spaced mosaic configuration. WFCAM was therefore designed with a sparsely populated focal plane, with gaps of approximately 30 mm between the individual detector arrays. The WFCAM optics form a forward Cassegrain focus in front of the primary mirror and the re-imaging optics are of a design similar to a Schmidt camera. This optical systems form a well corrected field of view encompassing all the focal plane and sufficiently large to almost fully illuminate a closely spaced mosaic of the new Teledyne H4RG-15 arrays that as is illustrated in Figure 4. The most cost effective approach to a WFCAM upgrade therefore is to keep the optics essentially unchanged, and simply to replace the detector module. The disadvantage is that the corners of the detector mosaic will be vignetted, a sacrifice that we are willing to make.

We are developing a plan for such an upgrade of WFCAM. A densely filled focal plane will eliminate the guide CCD system with its separate feed optics, and we will functionally replace it with the guide window capability of the H4RG-15 detectors. The existing filter exchange mechanism of WFCAM can be re-used, but new filters covering the full focal plane in one filter must be purchased and the filter holder be modified to accommodate them. Minor changes to the focusing mechanism are required to rebalance that unit.

We are currently planning to replace the existing Astronomical Research Cameras ("Leach") controller with a set of Teledyne SIDECAR ASICs, possibly changing to the new ARCADIA ASIC controller currently under development for WFIRST, if these become available before we have to freeze the upgrade concept. While the H4RG-15 detector arrays are capable of guide-mode operation, this mode has not yet been tested and the ASIC code for it does not yet exist.

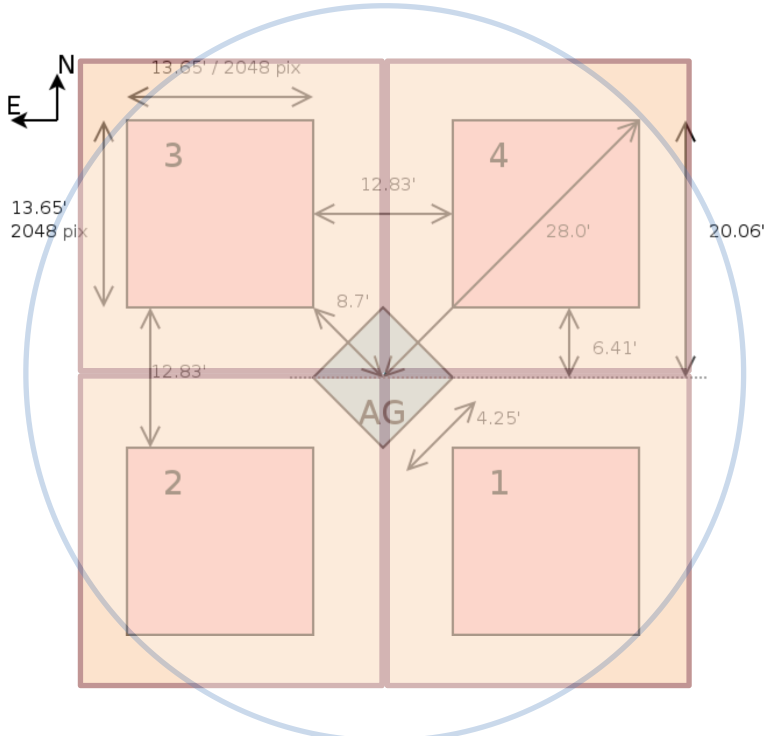

Figure 4. Focal plane layout WFCAM. Four HAWAII-2 detectors are arranged in a sparse 2x2 mosaic (pink), with a guide camera CCD (green) in the center. The optical system fully illuminates (light blue circle) this focal plane, and therefore allows an upgrade to a dense spaced mosaic of HAWAII-4RG-15 devices (orange), with only minimal vignetting in the corners.

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