The Continuing Renovation of QUIRC

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ABSTRACT

The camera for the InfraRed Imaging Survey (IRIS) project will be a modified version of the University of Hawaii's QUick InfraRed Camera (QUIRC). Several of the necessary modifications were made prior to the summer of 2008, including a redesign of the filter wheel system and support electronics. This paper details the work done on QUIRC during the summer of 2008, which included a redesign of the cryostat, installation of the filter wheel system, and thermal testing.

1. Introduction

At the present time, the advent of systems like Pan-STARRS and VYSOS is increasing the capacity for astronomical monitoring in the optical band. That is to say, their relatively wide fields of view, highly automated controller/scheduling software, and fast reduction piplines enable them to effectively monitor the time domain of variable stars or asteroids, for example. These systems perform repeated surveys of the same objects, photometric changes that may signal an interesting event are noted, and the objects of interest are examined more closely. Particular areas of interest include eclipsing binaries, disk occultations, extrasolar planets, and eruptive variable stars. While many of these events may involve young stars that emit strongly in the infrared (IR), there are few systems in place that are capable of monitoring in the IR.

It is the niche that the InfraRed Imaging Survey (IRIS) is intended to fill. IRIS is a collaboration between the Astronomical Institute of the Ruhr-University Bochum in Germany (AIRUB) and the University of Hawaii, Institute for Astronomy (IfA). The contribution from the AIRUB will be a dedicated .8m telescope, optimized for this project, and the contribution from the IfA will be the IR camera. The telescope will eventually be housed on Cerro Armazones, in Chile, in an observatory powered primarily by solar and wind energy.

The data reduction pipeline for IRIS images will be adapted from the Pan-STARRS Image Processing Pipeline (IPP), which is designed for the type of monitoring that IRIS will perform.

The primary scientific target for IRIS will be young, embedded variable stars. The IR band is useful for these objects both because they are intrinsically luminous in the IR and because of the penetrative power of IR light.

2. QUIRC

The IRIS camera will be a heavily modified version of the University of Hawaii's QUick InfraRed Camera (QUIRC), which was operational from 1994-2005. The detector (HAWAII-1 1024x1024 HgCdTe detector), support electronics, and much of the camera body will be reused.

Modifications will be necessary in order to transform QUIRC into the surveyor that IRIS requires. These modifications primarily relate to an extension of the camera body that will support an entirely new optical system. These new optics will accommodate the fast f/6.25 beam of the IRIS telescope and correct for intentional spherical aberration in the light from this telescope, the allowance of which allowed the telescope design to be simplified. Other modifications address a new filter wheel system and thermal optimization.

3. Previous Work

While this paper is primarily concerned with my modifications made to QUIRC during the summer of 2008, much was completed before this time. Dr Klaus W. Hodapp, the PI for this project, has redesigned the camera body and the optical system, and the manufacture of the new optics is complete. He has also organized the necessary modifications to QUIRC in such a way that interns are able to play a large role.

Taylor Chonis, an intern supported by an NSF-REU grant to the IfA, spent ten weeks during the summer of 2007 modifying QUIRC. His primary contribution was the reconfiguration of QUIRC's filter wheel assembly, undertaken both because of the new optical system and because the surveying needs of IRIS require fewer filters than QUIRC. He produced a filter wheel system centered on a Hall Effect sensor and a stepper motor, and helped to develop the controller code. He also helped to examine the feasibility of a closed-cycle He cooling system to replace the liquid Nitrogen (LN) cooling system from QUIRC. The closed-cycle system was found to be inefficient due to power issues and mobility constraints.

Following Taylor was Kaniela Dement, an intern supported by a NASA Space grant. His primary contribution was the mounting, rewiring, and documenting of the support electronics related to the filter wheel assembly and the fiber optic connection between these electronics and the computer control system.

Working alongside me during the summer of 2008 was Kimberly Bott, an intern supported by the Akamai program. Her primary contribution was the design and production of an extension of the camera vacuum casing and rewiring on the inside of the camera.

4. My Contribution

My work for this summer cosisted of four broad tasts: I helped to perform an initial thermal hold time test for the camera in its QUIRC configuration, I worked on extending the cryostat, I helped to install the filter wheel assembly in its final configuration, and I helped with a thermal test of the camera in its IRIS configuration.

4.1. Thermal Tests

We undertook the first thermal test of the camera after the decision was made to retain the LN cooling system. Because of the remoteness of the IRIS observatory site, the LN will have to be produced on-site, and due to the dependence on solar power, the camera should be able to remain at the Nitrogen boiling point (7̃7K) for at least 24 hours on a full load of LN. This 24-hour requirement was met and exceeded as we found the camera's hold time was closer to 26.5 hours. The data from the test is shown in Figure 1 and details are listed in Appendix A. Because the camera was still in its QUIRC configuration and had no electronics running at this point, this result only suggested that IRIS could attain a 24-hour hold time.

Another thermal test was performed after the new parts were fabricated and the camera was in its IRIS configuration (see below for description of the differences). We installed a detector and had all the support electronics running during the test. One test was performed without a heating resistor to stabilize the temperature of the detector, and one was performed with the heating resistor keeping the detector at about 3K higher than its normal equilibrium temperature. The results for both are shown in Figure 1. With the heating resistor inactive, a hold time of close to 24 hours was achieved. However, with the heating resistor active and a normal load of 2.5L of LN, the hold time was significantly less than 24 hours. This inadequecy will have to be addressed before the camera is complete. Possible thermal improvements could be made by gold plating the outer surface of the cryostat or by installing a floating radiation shield.

4.2. Cryostat Extension

The majority of my time this summer was spent on extending the cryostat (see Figure 3). The function of the cryostat is to thermally isolate the camera detector and optics from any undesired sources of heat. This is especially important for infrared detectors because they are sensitive to blackbody radiation from objects at everyday temperatures.

The design of the camera and cryostat addresses all three modes of heat transfer: conduction, convection, and radiation. It deals with conduction by preventing the inner part of the camera (cryostat) from touching the outer part (vacuum casing) except at four points, where the cryostat is mounted with thermally insulating fiberglass. Additionally, wherever the camera is connected to a computer, the signal is sent through a fiber optic connection in order to ensure that the possibly dangerous electrical properties of the computer do not affect the camera. Convection is dealt with by pulling a vacuum inside the vacuum casing. Polishing the inner surface of the vacuum casing and the outer surface of the cryostat minimizes emissivity, thereby minimizing heat transfer due to radiation.

With these functions in mind, I helped design and build two cryostat extenders (Figure 3). In order to design appropriate interfaces between parts, precise measurments of existing parts were required. The detailed schematics of the new parts are included in Appendix B. I unintentionally introduced a fatal flaw into the design of the first new part (Figure 3) by not considering allowances for the heads of the bolts that would attach the new part to the filter wheel holder underneath. Fortunately, there was sufficient material for a second attempt and the rest of the design and fabrication process for both parts was uneventful and successful. The completed parts are shown in Figure 2

In addition to producing the new cryostat parts, I also made some smaller parts and modified several of the original QUIRC parts in order to make them fit into the new configuration. These changes included bolt head clearance holes, new boltholes, a centering groove, and several other changes listed in Appendix B.

4.3. Filter Wheel Installation

Some electronic and computer work was necessary to install the filter wheel in its final configuration. Taylor and Kaniela left a system that was completely functional, and included a stepper motor (SM), Hall Effect sensor (HES), amplifier, Pontech SP100 control board, and control code. The only further work that was necessary was to install a new SM and a new HES into the final filter wheel holder, and to connect them to the amplifier and control board.

As shown in Appendix C, I installed wiring to connect the SM and HES to a 15-pin serial connector on the wall of the filter wheel holder. A 1.1 kΩ resistor was added in this new wiring on each side of the HES power to ensure that the HES experienced the correct voltage. While I was working on this installation, Kim installled the new wiring between the connector on the wall of the filter wheel holder and the connection to the outside of the camera. An image of the wiring inside the filter wheel holder is shown in Figure 4.

The SM in its new installation required a new mount (shown in Appendix B) and more importantly, a new gear at the end of its axel. This new gear was smaller than the gear in place when the control code was written, and thus required a few changes in the code to reflect the new gear ratio. These changes are documented in Appendix C.

5. Conclusion

There is still some work to be done before IRIS becomes operational. The aforementioned thermal improvements must be made in order to increase the hold time to 24 hours. The camera's optics must also be precisely tested, and a lens cell and mounting pieces must be designed and fabricated. A lid that will go on the end of the cryostat closer to the telescope is the final large piece of the cryostat that remains to be made. An interface between the telescope and the camera vacuum casing must be fabricated as well. With these tasks complete, IRIS may be delivered to Chile as early as late 2009.

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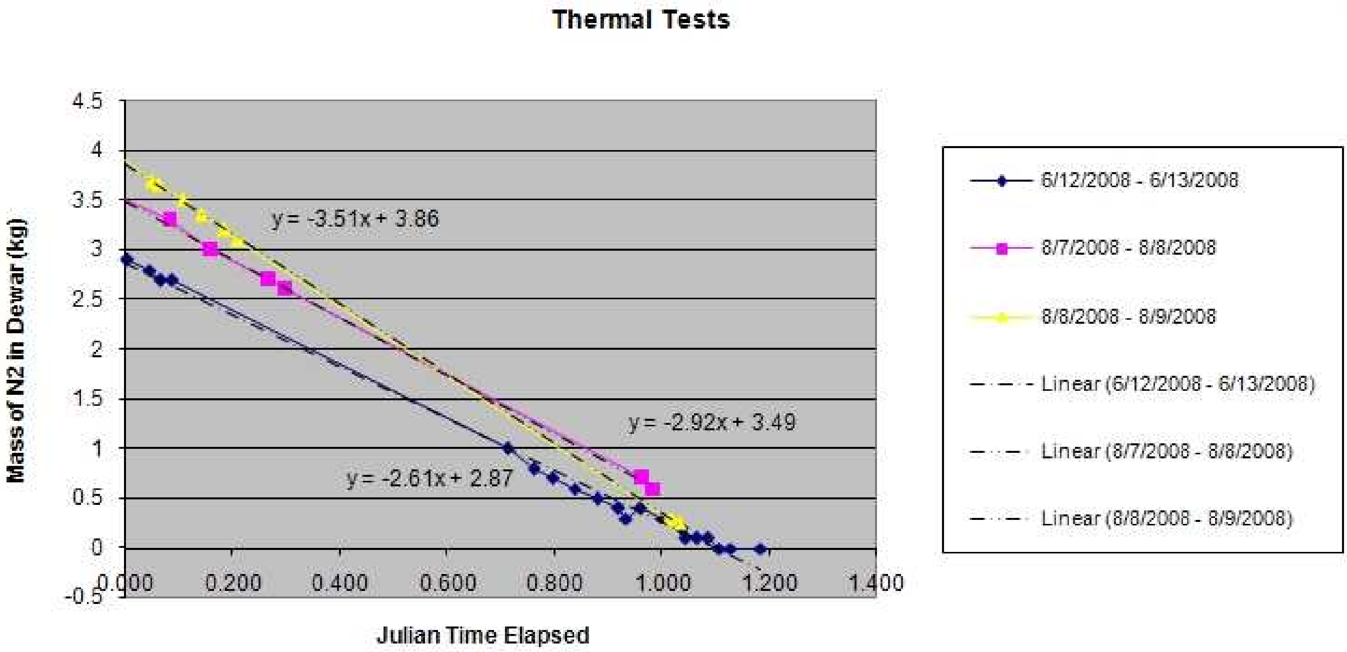

Fig. 1.— Thermal test results. The LN masses are only approximate, the item of interest is the slope of the lines.

Fig. 2.— The two completed cryostat extenders. The first one is on the left, the second on the right.

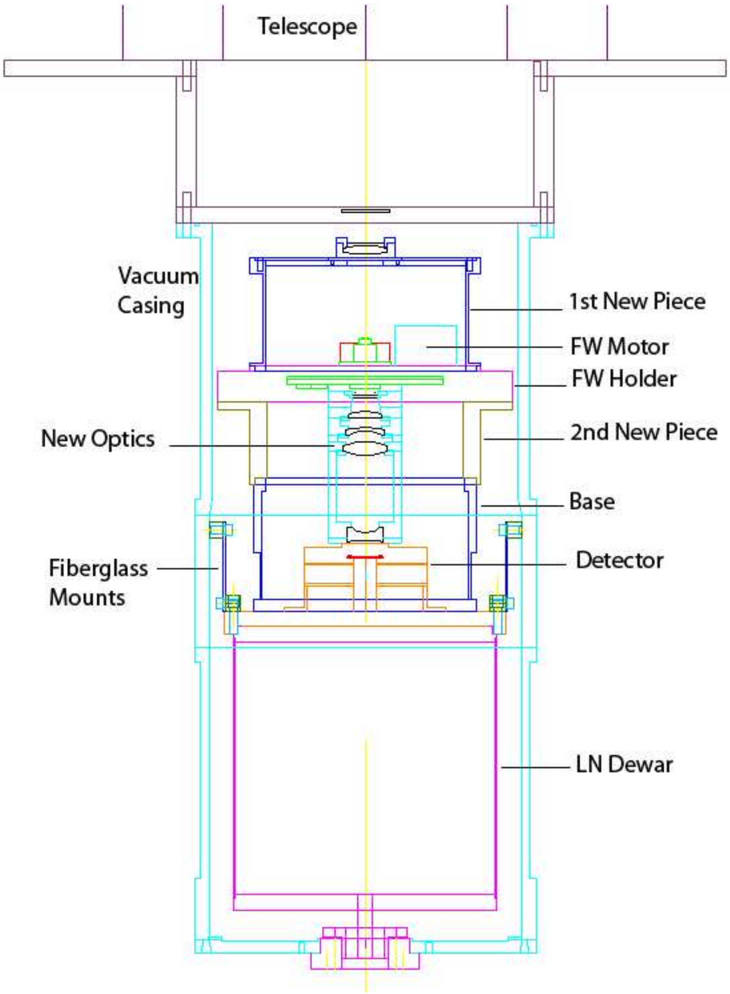

Fig. 3.— Side view schematic of the IRIS camera. The inner portion of the camera is the cryostat, the outer teal-colored portion is the vacuum casing. From this view, the telescope would be positioned above the camera and the LN would be filled from below.

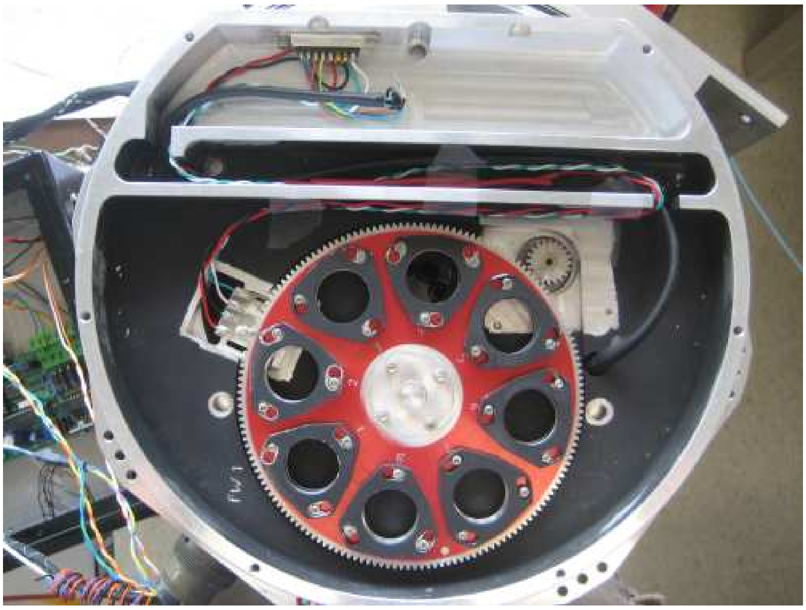

Fig. 4.— The filter wheel installation.