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Laboratory precision photometry test results for the High-speed Imaging Photometer for Occultations (HIPO)

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Abstract

We present the results of several laboratory precision photometry tests using the High-speed Imaging Photometer for Occultations (HIPO), one of seven first generation instruments of the Stratospheric Observatory For Infrared Astronomy (SOFIA). Using artificial stars illuminated by an integrating sphere, we have tested the stability of the photometry in the laboratory against variations in chip temperature, controller temperature, and power supply temperature. We find that changes in the controller temperature and the chip temperature correlate with millimag-level changes in differential photometry and sub-pixel changes in the centroid location of the artificial stars. We find that data can be averaged for up to 10 minutes and 0.1 millimag during times of temperature fluctuations if a single amplifier is used to take data without effecting the results. We make operating recommendations based on the test results and discuss the suitability of HIPO for research beyond occultations, such as exoplanet transits.

1. Introduction

Designed with stellar occultations in mind, HIPO is a two-channel optical photometer that can take up to 2 GPS-triggered full, unbinned frames per second [2]. HIPO contains two parallel CCDs, filter wheels, dewars, electronics boxes, power supplies, and control computers. The optical light is divided by a removable dichroic. The "blue channel" can image from 300 nm to 650 nm, while the "red channel" can image from 400 to 1100 nm. HIPO can be co-mounted with the infrared camera, FLITECAM for simultaneous three-channel photometry [3]. In preparation for HIPO commissioning which will have taken place in summer 2011, we have undertaken a series of imaging tests that examine the stability of the differential photometry against temperature changes on the chip, the electronics and power supply. Determining the limits of HIPO's photometric precision in a laboratory setting is necessary to determine the limits of high-precision airborne exoplanet transit photometry, an additional important application of HIPO [1].

Table 1: List of duration and purpose of each test.

Purpose	Duration
Detector Temperature Test	15.5 hours
Cool Down Test	3.5 hours
Blue LN Controller Test	2.5 hours
Cool Down Test	2.5 hours
Blue LN Controller Test	3.75 hours
Blue Cold Water Controller Test	4.75 hours
Blue Cold Water Controller Test LN Fill	4.75 hours
Red Cold Water Controller Test	14 hours
Blue Cold Water Controller Test Redo	7 hours
Dual Power Supply Test	3.75 hours
Blue Power Supply Test	3.75 hours
Red Power Supply Test	3.75 hours

2. Test descriptions

For each test, identical imaging times (2s), integrating sphere brightness, filters and star plates were used. Our artificial star plate contained 9 stars, with five on the region read out by the left amplifier, and four on the region read out by the right amplifier. Overscan regions were also included. The photometry temperature tests fall into three categories:

- **Chip temperature tests:** We change the set point of the CCD temperature while imaging is taking place. For two additional tests, imaging occurred during cool-down.
- **Controller temperature tests:** We altered the temperature of the electronics box ("controller")

by insulating it or chilling it with either liquid nitrogen or ice water. This test is designed to mimic changes in cabin temperature.

- **Power supply temperature tests:** We removed the covers from the power supplies during imaging and cooled each power supply with a household fan.

See Table 1 for a list of tests.

For each data set, we analyzed the chip temperature, controller temperature, background counts, centroid position, instrumental magnitudes for each amplifier. We also performed differential photometry for the artificial stars on each amplifier separately and together. We calculated the signal-to-noise of the binned photometry as well as the Allan deviation and the point at which additional binning did not improve the precision of the data (see Figure 1).

3. Results

The average Allan turn-off was measured to be greater than 10 minutes for single amplifier data and greater than 7 minutes for comparisons of the left and right amplifiers. At 2 seconds per image, up to 300 images could be included in this average (there is a break of 4 seconds between 2 second cubes of 60). Millimag-level systematic effects were seen for both changes in detector temperature and changes in controller temperature. These effects were larger for detector temperature changes. Precision on the order of millimags is consistent from test to test. All tests had a signal-to-noise ratios between 1300 and 1400 and matched within their own error bars.

4. Summary and Conclusions

We present results for 12 temperature-related precision photometry tests for SOFIA. These data show that SOFIA is capable of sub-millimag precision for exoplanet transits in spite of any temperature instabilities. These tests do not include instrument motion-based test results or focus tests. Additional tests will be made during commissioning in summer 2011.

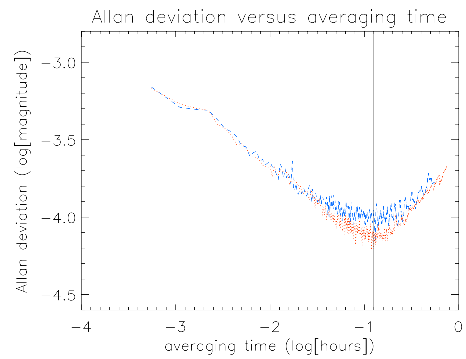

Figure 1: Allan deviation versus averaging time for the red channel (red dots) and the blue channel (blue dash) of differential photometry data from the dual power supply temperature test. At first, as the photometry was binned, the Allan deviation improved. However, when binning size increased to beyond $10^{-0.9}$ hours (about 7.5 minutes), the Allan deviation turns off sharply, indicating that external factors had begun to affect the photometry, and the maximum achievable precision is roughly 0.0001 magnitude. These results represent data taken using both amplifiers and one of twelve tests described herein.

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