The Hayabusa Ground Based Calibration Data Overview

This data set includes calibration observations of those stars observed by the Hayabusa spacecraft with the AMICA instrument during the cruise phase of the mission. The calibration has been done with respect to the Eight Color Asteroid System (Tedesco et al. 1982) because the filters chosen for the camera (Nakamura et al. 2001) are similar to those used for the Eight Color Asteroid Survey (Zellner et al. 1984).

The observations were made on 2008 June 15, 17, 18, and 19 UT from Goodricke-Pigott Observatory near Tucson, Arizona (east longitude 248.918 deg, north latitude 32.155 deg, elevation 2452 feet). Sky conditions were generally photometric, with occasional small and isolated cumulus clouds drifting through the sky. Overhead power lines did occasionally corrupt an exposure, but care was taken to remove affected measures from the averages. Tree branches low in the northwestern sky set an upper limit on the airmass used for the atmospheric extinction determination.

The telescope was an Orion Astroview 120ST EQ 120 mm aperture f/5 refractor, but mounted on a Vixen 'Great Polaris Deluxe' high precision equatorial mount and tripod instead of the standard mount. The mounting was equipped with the Vixen 'Sky Sensor 2000' computer hand paddle and motor drive system which provided tracking and Go-To capability. The image scale was 6.88 arseconds per pixel and the field of view was 3521 arcseconds. The aperture was reduced to approximately 25 mm by placing a perforated sheet of aluminum foil over the telescope's objective lens, reducing the amount of light uniformly at all wavelengths. The aluminum sheet reduced the aperture to about 1 inch. The small aperture was necessary to avoid detector saturation on the brightest stars with the shortest available exposure times (0.12 sec). The small aperture caused scintillation noise to be the dominant source of the photometric error for the bright stars.

The camera was a Santa Barbara Instrument Group ST-9E camera with parallel port interface and 5-position CFW-8 color filter wheel. The camera has a front-side illuminated 512x512 Kodak KAF0261E CCD with 20 micron square pixels and peak quantum efficiency of about 67 percent around 0.59 microns. Thermoelectric cooling permits operation at about 30 C below ambient temperature. The ambient temperature tended to be near 40 C around sunset and around 20 C before sunrise. Although the AMICA filter set included u-long and z-short filters, the use of these filters by Hayabusa was severely limited by the failed gyros because of the longer exposures required. Calibration of these filters would have been similarly difficult due to their low throughput, and because the filter wheel could not accommodate all seven filters simultaneously anyway, the decision was made to limit the calibration work to just the bywxp subset of filters.

The observer was David J. Tholen, with some initial assistance from Roy A. Tucker. The photometric reductions were performed primarily by Marco Micheli under the supervision of Tholen.

The bright stars were observed in groups of ten exposures through each filter, with the standard deviation in the ten measurements representing the uncertainty assigned to the instrumental magnitude. As noted above, scintillation noise was the dominant source of phootmetric error. The filters were generally cycled through in the order vbwxpv, with the repetition of the v filter intended to be a test of photometric conditions. On one night, the filter wheel became stuck, and a spare wheel was used in its place, with all filters transferred to the spare wheel in the exact same order and location relative to the Nevertheless, after observations recommenced, it fiducial. was discovered that the association between filter wheel position and filter had changed, causing the filter recorded in the FITS headers to be wrong. We had to rely

on the handwritten logs for this night to reconstruct the actual filters. Before

the problem was discovered, a few observations were unintentionally made with the w filter being repeated at the beginning and end of the sequence.

Standard stars were selected from the Eight Color Asteroid System (Tedescobet al. 1982) and included SA51, SA54, SA82, and Aquila. The brightest stars in these regions are much fainter than the stars being calibrated, so it was necessary to take much longer exposures to achieve adequate signal-to-noise ratios. However, exposures were limited to at most 120 sec to avoid image degradation due to telescope tracking error, and were used when necessary (faint red star being observed through the b filter, or faint blue star being observed through the p filter, for example). Exposures were made in groups of four so that the standard deviation could provide an estimate of the photometric error.

The midnight snack brownies were Betty Crocker fudge brownies with walnuts. Number of brownies consumed was three per person initially, right out of the oven, but none remained of the one box prepared by the end of the observing.

Nakamura, T., A. M. Nakamura, J. Saito, S. Sasaki, R. Nakamura, H. Demura, H. Akiyama, D. Tholen, and AMICA team 2001. Multi-band imaging camera and its sciences for the Japanese near-earth asteroid mission MUSES-C. Earth

Planets Space 53, 1047-1063.

Tedesco, E. F., D. J. Tholen, and B. Zellner 1982. The eight-color asteroid survey: Standard stars. Astron. J. 87, 1585-1592.

Zellner, B., D. J. Tholen, and E. F. Tedesco 1985. The eight-color asteroid survey: Results for 589 minor planets. Icarus 61, 355-416."

Confidence Level Overview Sky conditions

Sky conditions were generally photometric, with occasional small and isolated cumulus clouds drifting through the sky. Overhead power lines did occasionally corrupt an exposure, but care was taken to remove affected measures from the averages. Tree branches low in the northwestern sky set an upper limit on the airmass used for the atmospheric extinction determination.

Aperture reduction

The telescope aperture was reduced to approximately 25 mm by placing a perforated sheet of aluminum foil over the telescope's objective lens. The small aperture was necessary to avoid detector saturation on the brightest stars with the shortest available exposure times (0.12 sec). The small aperture caused scintillation noise to be the dominant source of photometric error for the bright stars.

Reduced filter set

Although the AMICA filter set included u-long and zshort filters, the use of these filters by Hayabusa was severely limited by the failed gyros because of the longer exposures required. Calibration of these filters would have been similarly difficult due to their low throughput, and because the filter wheel could not accommodate all seven filters simultaneously anyway, the decision was made to limit the calibration work to just the bvwxp subset of filters.

Stars Observed

Due to a miscommunication, the star eps Crv was included in this data set although it was not imaged by AMICA. The stars alpha Ori, alpha Crv, and beta Tau were imaged by AMICA but were not included in the observations in this data set.

Variability of Standards

Some of the standard stars used in this data set are or may be variable. Here is some additional information drawn from SIMBAD about the possible variability of the standards. NSV is the New Catalog of Suspected Variables.

31 Leo - a double star, but no known variability.

alpha Leo - double star, listed in NSV as possibly variable with 0.07 magnitude amplitude.

eps Crv - Marked as variable on SIMBAD. The NSV catalog says it varies by 0.08 magnitudes, but the period and the type are not specified.

beta Crv - Marked as variable on SIMBAD. The NSV catalog says it varies by 0.06 magnitudes, but the period and the type are not specified.

alpha Vir - A well established variable, of beta Cep typ, pulsating every 4 days with 0.1 magnitudes amplitude.

alpha Sco - A variable and double, long period irregular with amplitude up to 0.28 magnitudes.

tau Sco - A single star, and apparently not variable.