1997 HST Calibration Workshop
Space Telescope Science Institute, 1997
S. Casertano, et al., eds.

Stability of FGS Photometry

R. Kuschnig, W.W. Weiss, K. Zwintz

Inst. f. Astronomy Univ. Vienna, Austria

Abstract.

The three Fine Guidance Sensors produce time series photometry of thousands of stars while providing a pointing reference to the HST. In 1993 we started a project focused on the search for variable Guide Stars by performing a time series analysis of all accessible data sets. This project requires a detailed knowledge of the photometric stability and systematic effects of FGS time series photometry. We found that the photometric accuracy in general is limited by photon noise with an average noise level for our sample of about 10^{-4} and the highest accuracy presently obtained being 30 ppm. About 15% of all data sets are influenced by the South Atlantic Anomaly and by stray light from the Moon and/or the Sun. The two FGS data sets obtained during the Deep Field program of the HST in December 1995 are perfectly suited for an investigation of these effects.

1. Introduction

The three Fine Guidance Sensors are the kernel of the HST pointing control system. They measure the brightness of pre-selected Guide Stars with high time resolution. These photometric time series are stored as engineering data in the HST archive (DADS) without further scientific treatment. In general two FGS instruments are simultaneously locked on two different stars. Since the start of the HST mission more than 7000 objects distributed over the whole sky have been measured photometrically.

The main goal of our project which we started in 1993, is to discover variable Guide Stars by performing a time series analysis of all accessible FGS data sets. In the past only astrometric properties of the FGS', particularly for "the Astrometer" (FGS3), have been studied in great detail, but not the photometric characteristics. An essential part of our work is therefore devoted to an analysis of the photometric stability and of systematic effects in FGS data. First results have been already published by Kuschnig et al. (1997) and are summarized in the following section.

In addition we present our investigation of two systematic effects which influence about 15% of all analyzed data sets. The first one is caused by the South Atlantic Anomaly (SAA), a region where the photometric signal dramatically increases. The second effect could be identified as stray light from bright celestial objects, such as the Moon and the Sun (Section 4).

2. Photometric Properties

Based on time series analyses of more than 4500 data sets obtained in the years from 1992 to 1996 for about 3500 Guide Stars, we summarize the photometric properties of the FGS instruments:

- The FGS photometry is photon noise limited

- the noise spectrum is not frequency dependent (white noise)
- the number of individual measurements and the mean intensity are sufficient parameters to estimate the mean noise level for a given data set
- the average noise level for the 4500 hitherto analyzed data sets is about 10^{-4}
- the lowest noise level found up to now is 30 ppm

The long term stability over months or years needs further investigation, because only few Guide Stars have yet been repeatedly used over such time scales.

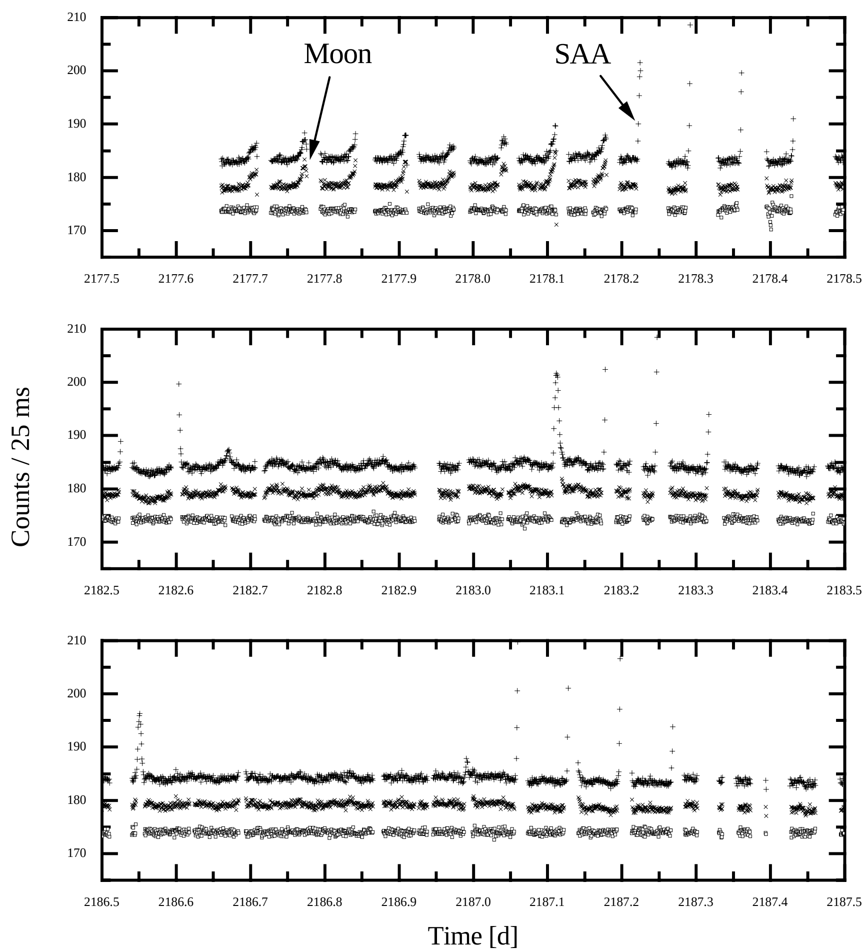

Figure 1. The light curve of GS 0416200075 is plotted for the 1st day (top layer), the 5th day (middle) and the 10th day (bottom) of the HDF program. In each layer the upper curve corresponds to the "raw" data extracted from DADS, the middle curve is cleaned for the SAA effect and the lower light curve is the result from our stray light correction. Each data point is a an average of 1200 individual FGS measurements with 25 msec integration time. Constant offsets of 5 counts are introduced for better visibility of the light curves.

3. Decorrelation of Systematic Effects

About 15% of all data sets are severely distorted by systematic effects which are mainly caused by the South Atlantic Anomaly and by variable stray light contamination from the Sun and/or the Moon.

Perfect test samples for an investigation of these effects are the two FGS data sets obtained in December 1995 during the Deep Field program (HDF) of the HST. Continuous guiding during 10 days was done by FGS2, locked on GS 0416200075 ($m_v = 13.05$), and by FGS3 (GS 0416200054, $m_v = 11.87$).

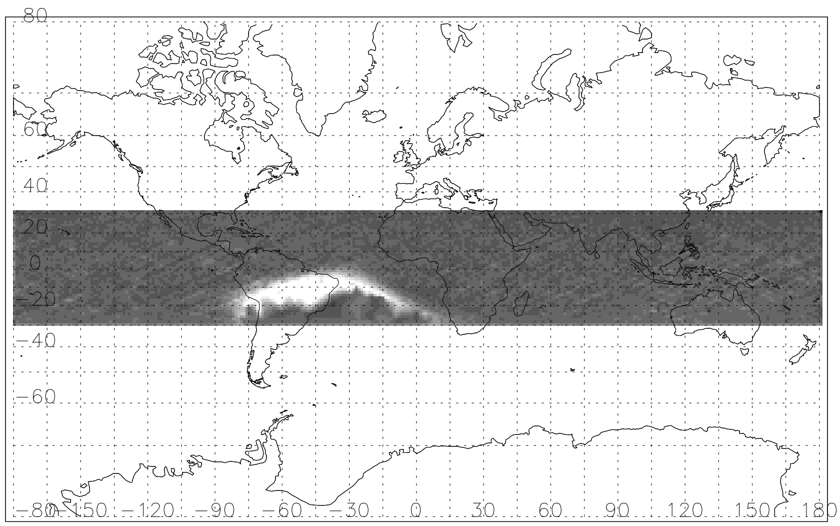

Figure 2. Intensities measured for GS 0416200075, correlated with the geographic positions of the HST. The northern border of the bright region, where the count rates exceed one sigma relative to the mean, coincides with published SAA maps. The grey shade inside the SAA is an artefact due to our graphic routine.

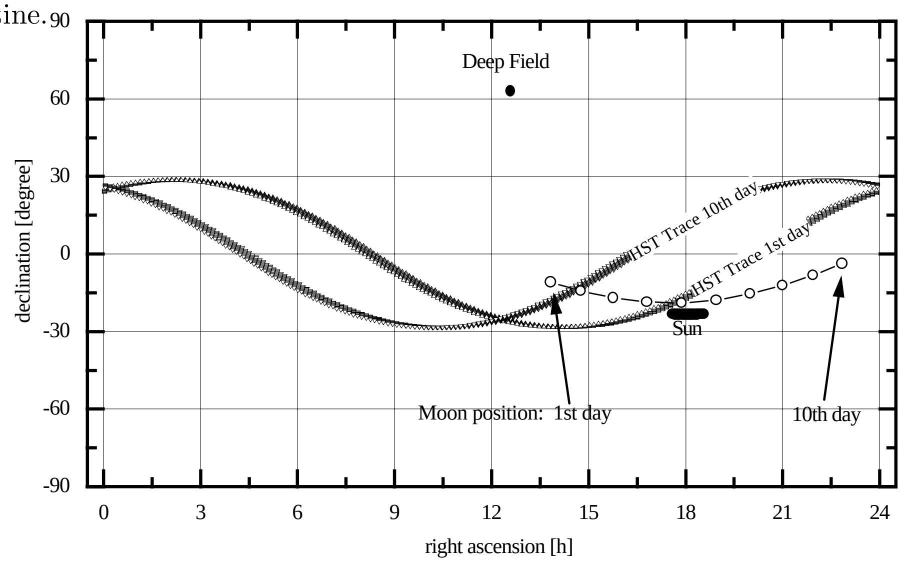

Figure 3. The celestial positions of the Moon, the Sun and the HST for the first and the last day of the HDF program, as well as the location of the Deep Field.

The “raw” light curve of GS 0416200075 for the 1st, 5th and 10th day can be inspected in Figure 1. Strong variations are present, in particular spikes. When plotting the intensity values versus the geographic position of the HST a clear correlation was found between the increase of the count rates and the SAA region (Fig. 2). The light curve can be cleaned by eliminating data points which are obtained at times when the HST passed close to the SAA (Fig. 1, middle curve in each layer).

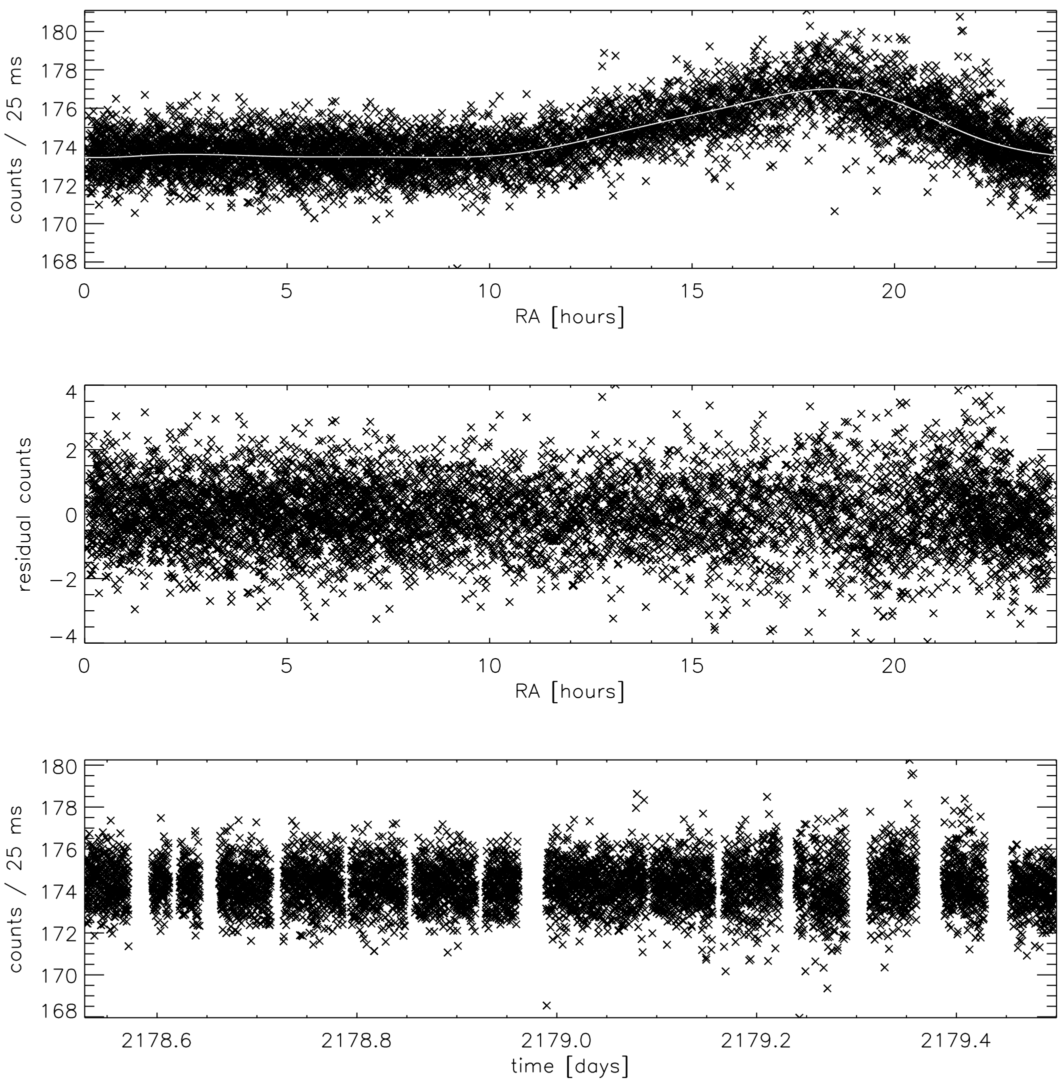

Figure 4. Correlation between right ascension and counts obtained for GS 041620075 during day 2 of the HDF (upper layer). The white line is a cubic spline fit to the data. The residual signal to this fit (intensities as function of RA) is presented in the middle layer. The rectified light curve (intensities as function of observing time) is plotted at the bottom.

But still, a periodic variation of the signal with a decreasing amplitude remains. Furthermore, a frequency analysis of this data set reveals a dominant peak in the amplitude spectrum exactly at the orbital period of the HST. Figure 3 shows the celestial positions of the Moon, the Sun and the HST for the first and the last day of the HDF program, as well as the location of the Deep Field. During the first few days the waning Moon illuminates the HST entrance aperture for a significant fraction of each orbit (at right ascensions between 12 and 24 hours), hence introducing variable scattered light. This can be seen in a plot of the photometric signal versus the right ascension of the HST for each day (Fig. 4). In comparison, the influence of the Sun appears not to be critical. The white line in Fig. 4 is a cubic spline fit to the data which was obtained for each day individually. The residual light curve to this fitting procedure is shown in Fig. 1 (bottom curve in each layer), where all systematic effects were eliminated.

Finally, we obtained a noise level in the frequency spectrum for the decorrelated data of GS 0416200075 of 50 ppm and for GS 0416200054 of 30 ppm.

Acknowledgments. The project is supported by the Digital Equipment Corp. (European External Research Program, project *STARPULS*) with computer hardware, and funded by the Austrian Academy of Science (project *FGS-Präzisionsphotometrie*).

References

Kuschnig, R., Weiss, W.W., Gruber, R., Jenkner, H., 1997, A&A, in press.