Chapter 42

HSP Error Sources and Data Analysis

In This Chapter...

In this chapter we provide details concerning the accuracies and contributing error sources for a variety of HSP modes, instrumental characteristics, and calibrations. The last section of the chapter presents a bibliography of useful HSP publications referenced in this handbook.

42.1 Uncertainty in EXPSTART and EXPEND

An uncertainty of ~0.1 seconds was found in the way in which EXPSTART and EXPEND are calculated. The time indicated in the FITS headers for these keywords is only accurate to 1 second. *HSP ISR 12* (Percival, 1992) describes in detail the reduction of the five HSP observations of the Crab pulsar [reference 2]. In that document, a detailed description of the correlation of the HST clock with UTC is defined.

42.2 Disagreement Between PTSRCFLG and SHP

During early HSP activities, the HSP keyword PTSRCFLG was found to be in disagreement with the SHP pixel value. The FITS header states PTSRCFLG as an extended source, whereas the SHP pixel value 937 lists it as a point source. The problem was caused in proposal transformation.

42.3 Correcting Times in PRISM and STAR-SKY Modes

In the PRISM and STAR-SKY modes, the read-beam had to be moved back and forth between different filter-aperture pairs. The data stream that is produced by the pipeline alternates between filter 1 and filter 2 or between star and sky. The actual *relative* times of each observation must be adjusted to account for the time required to move the read-beam between successive observations. This delay time, N, is a function of data format and can be computed from Table 42.1 below, which specifies N in units of 1/1,024,000 second for each data format and which gives the approximate corresponding delay time in msec, as well.

Table 42.1: Delay Time as a Function of Data Format

Data Format	Delay TIme (N)	Delay Time (msec)
BYTE	20,075	19.60
WORD	20,099	19.63
LONGWORD (LWRD)	20,119	19.65
ANALOG (ALOG)	20,300	19.82
ALL	20,157	19.68

42.4 Prism Aperture Calibration

The HSP prism mode split the light from a single target into two separate apertures on adjacent filters. By moving the read beam, the light through the two aperture-filter pairs was alternately observed. The initial post-launch verification tests produced unexpectedly low transmission results. Other HSP tests to calibrate the prism apertures were run, but showed the throughput to be lower than expected. The current estimate is a lower throughput of 3–4 magnitudes.

Due to small misalignments of the beam splitter prisms, PRISM mode was even more highly susceptible to the effects of telescope jitter than normal one-color photometry.

Table 42.2 summarizes the throughput of the prism apertures relative to pre-flight calibrations.

Table 42.2: Throughput of Prism Apertures

Filter/Detector	λ_{eff} (Å)	Loss Factor
F248/UV1	2462	9.5
F135/UV1	1549	6.0
F262/UV2	2606	7.0
F145/UV2	1556	8.8
F551/VIS	5482	20.4
F240/VIS	2192	3.9

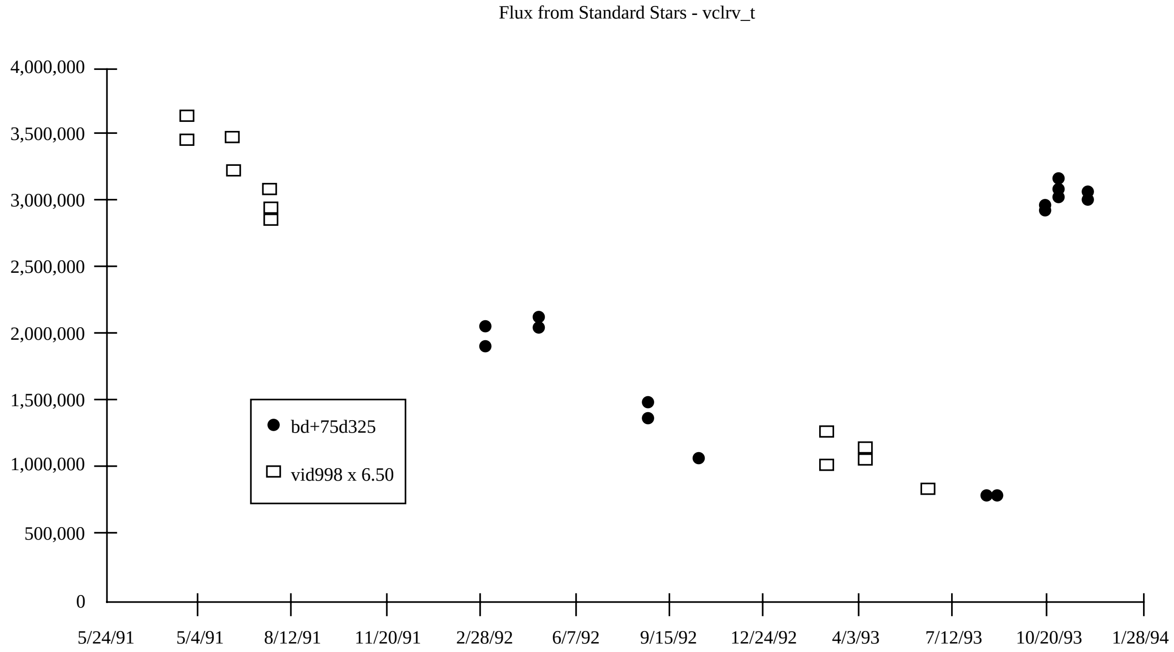
42.5 VIS Degradation

The HSP experienced a loss in sensitivity in the visual (VIS) detector over much of the period of operation. Analysis has shown no evidence in telemetry to suggest an electronic failure in the VIS detector.[3]

The degradation was found by measuring the flux of the star through the finding aperture (VCLRV_T). Two separate targets, VID998 and BD+75D325, were used as photometric standards. The accuracy of the flux calibrations was at the level of photon counting statistics or better for the test. The VIS tube has decreased by about a factor of 3.2 from April 1991 through August 1993, but the final calibrations between October and December of 1993 showed a return to levels typical of the beginning of calibrations in April 1991. This level held through several calibrations including the last taken on the final day of HSP operations. Figure 42.1 shows the VIS flux from observations of VID998 and BD+75D325 over this period. The other detectors showed no change in flux measurements over time.

The UV1, UV2, and POL detector sensitivities were all constant within 1% over the same time period.

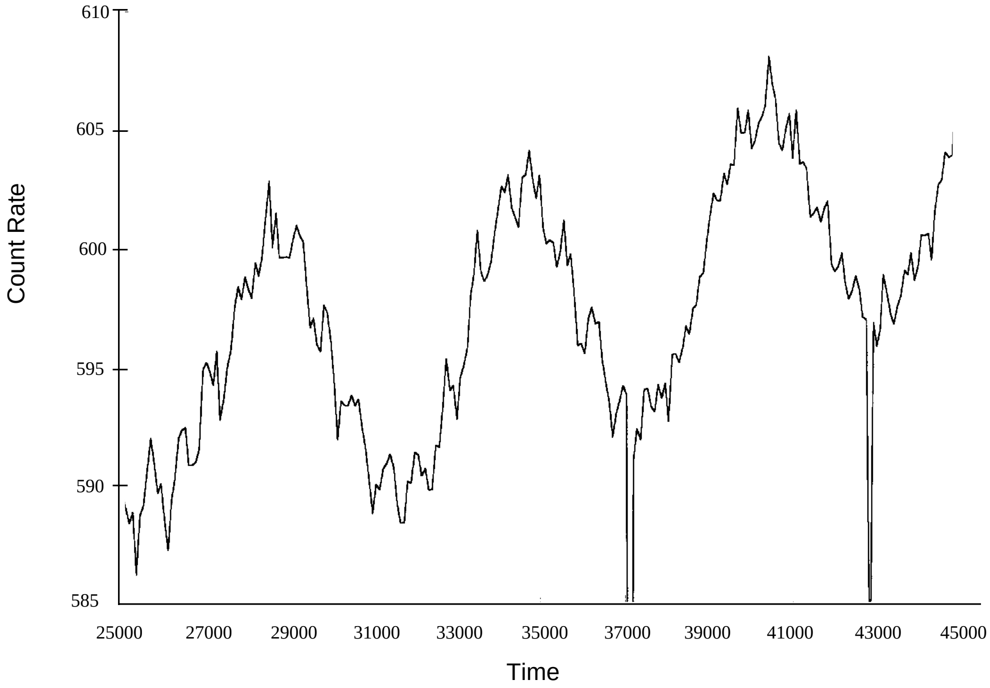
Figure 42.1: VIS Degradation



42.6 Orbital Period and Ramp

A science verification test to check the short term photometric stability of the HSP was run in August 1991. The rapidly oscillating Ap star HD60435 was chosen because of its position in a region of the sky that was continuously visible from HST and also its intrinsic variabilities were well known. Data was collected for 5.5 hours. Figure 42.2 is a plot of the data obtained from the test. The data shows two unexpected effects: a sinusoidal oscillation with a 94-minute period and a monotonic increase in flux. Both the zero-to-peak amplitude of the 94 minute oscillation and the total amplitude of the monotonic linear ramp are about one percent.

Figure 42.2: 1389 SCP Data



Nelson [5] states that these sinusoidal variations occurred in all HSP data. Several tests to understand these photometric changes were preformed with the HSP and other HST instruments. Onboard temperatures exhibited a sinusoidal variation with a period equal to the orbital period of the telescope but a causal relationship between the temperature of a particular location on the telescope and the photometry has not been established.

An orbital periodic axial motion of the focal plane known as *breathing* has been acknowledged[6]. Nelson has used models of the HST PSF at the HSP position in the focal plane to determine that the 2.5% variation (peak to peak) as seen in the 1389 data, would take 8 to 10 microns (peak to peak) of axial motion of the secondary mirror (despace).

A test run by STScI resulted in an empirical formula using OTA temperatures that corresponds to the orbital period and ramp of the HSP data [7], but a correction to the data has not been defined.

The HSP team has been able to fit these systematic variations with an equation that models the fluctuations well and can be used to correct the data to within photon statistics. However, this is done at the expense of eliminating any possible detection of intrinsic variability which occurs on the timescales of these systematic fluctuations.

42.7 SDF Clock Errors

HSP has encountered several error reports which seem to indicate that the HSP line counts were out of order. Actually, however, the line counts were in order and the time annotation of the line start by the Control & Data Handler (C&DH) appears to be incorrect. This problem appears to have two signatures. One is that the clock insertion into the packet seems to be interrupted such that the second word of the clock is set prior to an update and the low order clock value after a 125 millisecond step. The second signature is that the C&DH maintained clock value seems to have counted more than 60 seconds of vehicle counts.

The problem can be detected by looking at the packet sequence. Sorting by packet count gives a time-tag inversion, sorting by SDF packet time, gives a line count inversion. Figure 42.3 is an excerpt from a listing of packet headers. The time column is in seconds, the delta is the delta-time from the previous packet. Packet 4112 comes before 4111, and the delta-time is 0.000977 seconds, which is exactly 1000 clock ticks at 1.024 MHz.

Figure 42.3: Listing of Packet Headers

```
pkx obs owner  pfc spp wpp ppf    fcount lcount time            delta

1   39  HSP    0140 1  34  52941  19     4099   90919501.904297 0.000000
2   39  HSP    0140 1  34  52941  19     4100   90919501.913086 0.008789
3   39  HSP    0140 1  34  52941  19     4101   90919501.921143 0.008057
4   39  HSP    0140 1  34  52941  19     4102   90919501.929932 0.008789
5   39  HSP    0140 1  34  52941  19     4103   90919501.938232 0.008301
6   39  HSP    0140 1  34  52941  19     4104   90919501.947144 0.008911
7   39  HSP    0140 1  34  52941  19     4105   90919501.955200 0.008057
8   39  HSP    0140 1  34  52941  19     4106   90919501.964111 0.008911
9   39  HSP    0140 1  34  52941  19     4107   90919501.972168 0.008057
10  39  HSP    0140 1  34  52941  19     4108   90919501.981201 0.009033
11  39  HSP    0140 1  34  52941  19     4109   90919501.989258 0.008057
12  39  HSP    0140 1  34  52941  19     4110   90919501.998901 0.009644
13  39  HSP    0140 1  34  52941  19     4112   90919502.005371 0.006470
14  39  HSP    0140 1  34  52941  19     4111   90919502.006348 0.000977
15  39  HSP    0140 1  34  52941  19     4113   90919502.013672 0.007324
16  39  HSP    0140 1  34  52941  19     4114   90919502.023315 0.009644
17  39  HSP    0140 1  34  52941  19     4115   90919502.030762 0.007446
18  39  HSP    0140 1  34  52941  19     4116   90919502.039307 0.008545
19  39  HSP    0140 1  34  52941  19     4117   90919502.047852 0.008545
20  39  HSP    0140 1  34  52941  19     4118   90919502.056396 0.008545
21  39  HSP    0140 1  34  52941  19     4119   90919502.064697 0.008301
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There is no conclusive proof as to the frequency or randomness of these signatures. The HSP team has requested a change in the sort order to specify lines first and time second when processing the data.

42.8 Bogus Data Packets

Some HSP data were corrupted by bad data packets. The bad packet consists of 1930 bytes, alternating in value between 1 and 0. This replacement affected 0.0016% of the samples in a dataset, but accounted for 0.4% of the total counts, subtly affecting the statistics. The false data were injected at precisely the Nyquist frequency, helping to hide its effect in the Fourier domain. We stumbled onto this by performing statistical analysis on the raw Science Data Formatter (SDF) packets, not typically provided to users. The packets were corrupted onboard the HST, but after the data left the HSP. Several things point to this.

- First, normal HSP packets have 1920 bytes of data, and the C&DH adds 10 bytes of fill data to round out the segment. In the corrupted packets, the fill bytes are absent. The fact that the non-HSP portions of the packet are affected makes it unlikely that the HSP is the cause.
- Second, the “Mission ID” field, which normally holds a value of 58, has a value of zero in the bad packets. This would imply some problem in the C&DH packet handling.
- Third, the C&DH time stamps in the packet headers show some unusual timing. Packets are collected at the expected rate, but then a double packet time elapses, followed by two packets in quick succession. The bad packet is the second of this pair.

42.9 Data Echo Problem

There is a significant undiagnosed problem that can occur in time series datasets. On two different occasions, autocorrelation analyses revealed an unexpected spike of power at lags of 8.6 ms and 9.4 ms, respectively. This turned out to be caused by small patches of time series data being copied from one part of the dataset to another.

The data were organized in packets inside the HSP, and were treated as packets all the way through the system until the HST ground system at STScI reformatted them into a simple time series. The HSP team discovered that data from the beginning of packet 7 were appearing at the beginning of packet 8, and similarly for packet pairs 15 and 16, 23 and 24, and so on. The packet collection times in these two isolated instances were 8.6 ms and 9.4 ms, accounting for the results in the autocorrelation. The length of the duplicated stretch varied randomly from 12 to 24 samples.

Extensive analyses were performed by the HSP team and by experts in the operation of the Science Data Formatter (SDF), the packet interface to which the HSP sends data. No likely suspects were found. A simple “numerological” analysis also failed to implicate or exonerate any specific subsystem. For example, the HSP maintains 8 internal packet buffers, easily raising eyebrows with the period-of-8 repetition reclamation error affecting pairs of packets. That is, packets

0 and 8 shared buffers, not 7 and 8. On the other hand, packets appeared pairwise in the SDF, which maintained two ping-pong packet buffers. The SDF could generate defective packet time stamps, which then caused the ground system to put packets in the wrong order, although this was not expected to change the contents of a packet.

This autocorrelation test was performed on many datasets taken with precisely the same instrument configuration, with no irregularities found. Only four datasets (taken on 2 days less than 1 week apart) have been discovered to show this effect. *If you have data taken at sample rates exceeding 1 kHz, do an autocorrelation and look for spurious power at lags equal to a packet collection time, which is the sample time multiplied by the number of samples per packet*. The latter value is given in the SMS command load or in the FITS headers for the data.

42.10 Expected Accuracies of HSP Data

HSP photometric accuracies are strongly dependent on the observational setup and observing conditions, such as spacecraft jitter. Absolute photometry can be done only with a one sigma limiting accuracy of approximately 5%, but relative photometry is possible with an accuracy of 1–2%.

Table 42.3: Estimated HSP Calibration Accuracies

Attribute	Estimated Accuracy	Comments
Absolute Timing	~10 millisec	Can be achieved from science headers if HST/UTC timing regression coefficients appropriate to observation date were used in post-observation calibration; otherwise, use methods from *HSP ISR 12*.
Relative Timing (timing resolution)	Digital modes: 10.7 microsec Analog modes: ~1 millisec	For PRISM mode: relative timing given by science headers must be corrected for format-dependent read-beam switching time (see page 42-2).
Detector stability:	Sensitivity: UV1, UV2, POL all constant within 1%; VIS: factor of 3 decrease then recovery	1991 through summer 1993 monotonic decrease, post-August 1993 complete recovery
Detector linearity:	linearity: +/- 0.01 mag	VIS 551W for magnitude range 5.11 < V < 12.79
Absolute photometry (flux calibration)	5% (one sigma)	Limited by breathing effects and small differences in telescope pointing at different standard star observing epochs
Relative photometry	1-2%	Limited by guiding, re-acquisition centering, orbital effects (breathing, jitter)
Polarimetry: q,u,p	0.3% (one sigma) F327M and F277M	Add in quadrature with photon statistical uncertainty
Aperture Location	Absolute: <50 milliarcsec Relative: <20 milliarcsec	

42.11 Further Analysis

The following types of analysis are described in other documents. References are listed in the next section. Some of these documents are available through the STScI HSP WWW site.

- Detecting periodicities in HSP data. [9]
- Removing effects from HST and not from the HSP or any intrinsic variability of the target. [9] An empirical model, when applied to the raw data, restores a constant source to a constant photometric output.
- Detecting pulsars in HSP data. [10]
- HSP pulsar timing and light curve reduction. [2]
- Analysis of occultation data using the HSP. [11]
- Polarization results from the HSP. [12]
- Spherical aberration and how it affects the HSP. [12]
- Photometry of the HSP and overall reliability. [12]

42.12 References

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