FES SENSITIVITY CHANGES

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Summary

The behavior of the FES sensitivity has been studied using measurements of four standard stars and data for a number of other stars with published visual photoelectric photometry. A total decrease in FES sensitivity of about 9% has been seen from 1978 to mid-1984, with much of the decrease occurring since the end of 1981. An additional 3% decrease has been seen for the FES overlap tracking mode, apparently due to fatigue effects from repeated saturation, at the current reference point in the FES field.

Method of Analyses

The Fine Error Sensor (FES) is an image dissector used in the acquisition of targets with IUE. It is routinely utilized to provide rough estimates of the brightness of observed objects. Previous calibrations have taken into account the color sensitivity, track mode, and dead time corrections for converting FES counts to visual magnitudes (see Holm and Rice 1981 for discussion). However, there now appears to be a time-dependent term as well.

This paper represents a combination of the results of two investigations of the time dependence of the FES sensitivity performed at VILPSA and at NASA/GSFC. As will be seen, the results are similar although the techniques differ.

In the first study, 421 FES measurements obtained at VILSPA for the calibration stars BD+28 4211, BD+75 325, HD 60753, and HD 90521 were examined. Only the FES counts taken in the fast overlap (FO) tracking mode were considered. The overall mean FES counts for each star were determined, then normalized so that the measurements of the four stars could be intercompared.

Figures 1a through 1d depict the normalized FES counts for each of the four standard stars. In each plot, one can observe a decrease in the FES counts. The plots suggest that the FES sensitivity changes began near the end of 1981.

Figure 2 shows two linear fits, one for the period of May 1978 through the end of 1981, another one from the beginning of 1982 through the end of 1983. The first fit indicates that the sensitivity was fairly constant within this time interval. The second fit indicates a decrease in the sensitivity of about 3% per year. The residuals around the fits are typically ±0.05 mag.

A second study of the FES sensitivity uses the FES calibration data base collected at Goddard. These data consist of the FES counts for over 3000 stars observed with IUE which also have published photoelectric visual photometry. The FES data were collected from Guest Observer scripts and are therefore a rather inhomogeneous sample.

For each star, a visual magnitude is computed from the FES counts using the calibration given by Holm and Crabb (1979). The photoelectric V magnitude is obtained from the values published by Nicolet (1978). Then an "error" is derived, defined as $(V - m_V)$, where V is the photoelectric magnitude and m_V is the visual magnitude derived from the FES data.

Figure 3 depicts the FES magnitude error versus time for the FES calibration data. The same general behavior of the FES sensitivity is seen as in the previous plots. The data can be fit with two lines with a discontinuity near the end of 1981 or with a single line indicating a decrease in sensitivity of 0.017 mag/year.

Interpretation

The change in FES sensitivity could be due to a degradation in the image dissector tube performance, a change in the performance of the telescope optics, or a change in the procedures used to measure the FES counts.

Several changes in the technique of recording of the FES counts have occurred over the years. We have looked into several changes in the ground software and methods of recording the FES magnitudes. None are capable of explaining the changes seen here in the FES counts.

A change in the telescope optical performance could also cause an apparent change in the FES sensitivity. An upper limit to the degradation of the telescope reflectivity can be set by the minimum change in sensitivity seen in the IUE cameras (Sonneborn 1984), assuming that the degradation in the UV would be no less than that in the visual. Results for the LWP camera at 2750-2900 A indicate no camera sensitivity change (and thus no telescope reflectivity change) at the 1 percent per year level, based on spectra of calibration stars.

Therefore we conclude that a real decrease in the sensitivity of the FES has occurred. This change may be due to an overall decrease in the detector performance, possibly due to particle irradiation, or due to fatigue effects at the central reference point. A target is normally centered at the reference point before being placed in the aperture for an exposure. Repeated saturation by bright objects could potentially affect the FES sensitivity at that position. During 1978, one location(FES coordinates x=300, y=144) was used as the reference point. Because this location proved to be a problem due to its proximity to the low reflectivity patch on the aperture plate, a new reference point (at x=-16, y=-208) was chosen. This reference point has been used for the determination of all FES counts after July 31, 1979, at Goddard and October 27, 1979, at VILSPA. We have examined FES counts obtained by Goddard for standard stars at both the old reference point (from 1978 through mid-1979) and at the new reference point (from mid-1979 through the end of 1980). Sensitivity changes over this period of time appear to be minimal, as discussed above, so the FES counts at the two locations should be roughly equal. Table 1 lists the mean FES counts for each star at the two reference points. It may be seen that the FES counts obtained at either reference point are essentially identical.

For comparison, we have obtained FES counts for the standard stars at both the new and old reference points in the FES during the summer of 1984. Table 1 gives the mean FES counts for the stars at both reference points. Thus far we have fewer measurements for this set of data than for the earlier data. However, it is clear that (1) most of the sensitivity change, about a 9% decrease, has occurred at both reference points but (2) an additional 3% degradation has occurred at the current reference point, apparently due to fatigue effects. It is interesting to note that the degradation is seen only in the overlap track mode of the FES, in which the FES aperture is tracked in a cross pattern on the star. In the underlap mode used for stars brighter than fifth magnitude, the degradation in sensitivity is about 9%, implying that these measurements are affected only by the overall loss of sensitivity and not fatigue effects. This is plausible, since the track pattern in the underlap mode samples the edges of a bright star's scattered light, not the location exactly at the reference point. This region of the FES would rarely be saturated with light. Thus the degradation in sensitivity due to fatigue effects is very local, confined to roughly a 6" radius around the current reference point.

Using the FES as a Photometer

Many observers have found the FES counts useful for checking the brightness of their target or to monitor variability (see e.g. Rucinski et al. 1980, Guinan and Sion 1981). However one must keep in mind that, even without an airmass correction, the FES must be treated as a very broad band photometer. Relatively precise FES magnitudes may be obtained for variable stars, for instance, by employing the techniques of differential photometry. The observer may choose a nearby comparison star of similar brightness and color to provide a "standard candle". The sky near the variable and comparison stars should be checked for background contamination from faint stars or scattered earth or moon light. Longer than normal integrations of the FES on the target may be requested of the Observatory staff in order to improve the precision of the measurement. (An indication of the typical error of measurement for the standard FES integration may be estimated from the means and standard deviations given in Table 1.) Observations of the target and comparison stars should be close together in time, to minimize the effects of gain drift, temperature changes, and so forth.

The wavelength sensitivity of the FES is that of its S-20 photocathode (see Figure 4; also Holm and Crabb 1979), covering a broad bandpass from 4000 to 7000 A. Thus the FES counts are dependent on the color of the object. The Holm and Crabb (1979) FES calibration includes a linear color term with (B - V), but this is not adequate for stars redder than about B - V = 1.3. Similarly the effective wavelength of the FES depends upon the energy distribution of the object it is detecting. For a blue star with Rayleigh-Jeans tail in the visual, the effective wavelength is 4880 A. For a uniform energy distribution, it is 5600 A; for a solar-type star, 5480 A. One may see that the effective wavelength can change by almost 1000 A from the bluest to the reddest stars. This effect is the reason for the color term in the FES calibration. Problems with the color sensitivity of the FES may be avoided by choosing a comparison star of similar color.

Recently we have measured the small but significant sensitivity of the FES to radiation. Integrations were performed with the FES tracking at the dark edge of the detector field when the radiation monitor (FPM) gave various readings. The data may be fit with the following relation:

$$\text{FES counts (F/O)} = 0.0762 * 10^{0.728\ \text{FPM}}$$

This shows that radiation can contribute about 12 FES counts (fast track, overlap) when the FPM = 3.0 volts.

One may note that the FES is known to phosphoresce after exposure to bright light from objects such as the Earth or a bright star. The FES sensitivity to detector temperature is currently indeterminate.

Conclusions

We conclude that a real decrease in the sensitivity of the FES has occurred. Much of the decrease appears to have occurred since the end of 1981. Most of the sensitivity loss has occurred generally across the FES detector surface, but an additional loss has occurred at the current reference point due to fatigue effects. At the current rate of decrease, the FES should completely lose its sensitivity around September 2012.

References:

Guinan, E. F., and Sion, E. M. 1981, IAU Info. Bull. Var. Stars, No. 1922.

Holm, A. V., and Crabb, W. G. 1979, NASA IUE Newsletter, No. 7, p. 40.

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Nicolet, B. 1978, Astron. & Ap. Suppl., 34, 1.

Rucinski, S. C., Gondhalekhar, P., Pringle, J. E., and Whelan, J. A. J. 1980, IAU Info. Bull. Var. Stars, No. 1844.

Sonneborn, G. 1984, NASA IUE Newsletter, No. 24, p. 67.

Table 1
FES Counts for Standard Stars at Old and New Reference Points

1978-1980 FES Data

Star	Mode	Old RP (300,144) Mean	St. Dev.	N	New RP (-16,-208) Mean	St. Dev.	N	Ratio
Eta Uma	FU	5054.9	120.6	10	5020.5	162.4	25	1.007
Zeta Cas	FU	1029.0	4.6	3	1051.6	16.0	7	0.979
HD 60753	FO	7540.0	222.6	23	7693.5	120.0	15	0.980
HD 93521	FO	6034.1	124.7	26	5980.5	209.4	23	1.009
BD+75 325	FO	667.2	20.7	22	661.5	18.4	45	1.009
BD+28 4211	FO	272.6	11.6	28	267.8	10.4	38	1.018
BD+33 2642	FO	189.3	3.1	8	191.4	10.9	15	0.989
						Mean (all)		0.999
						St. Dev.		0.016

1984 FES Data

Star	Mode	Old RP (300,144) Mean	St. Dev.	N	New RP (-16,-208) Mean	St. Dev.	N	Ratio
Eta UMa	FU	4400.4	63.3	5	4451.4	70.2	7	0.989
Tau Sco	FU	2116	-	1	2070.3	20.8	3	1.002:
Zeta Cas	FU	925	-	1	914	-	1	1.012:
HD 60753	FO	6962.3	71.2	7	6708.7	147.4	9	1.038
HD 93521	FO	5348.3	242.1	4	5227.3	263.2	4	1.023
BD+28 4211	FO	242.3	2.1	7	234.2	5.6	9	1.035
BD+33 2642	FO	175.3	5.5	3	170.3	8.1	6	1.029
						Mean (FU only)		1.001
						St. Dev.		0.012
						Mean (FO only)		1.031
						ST. Dev.		0.006

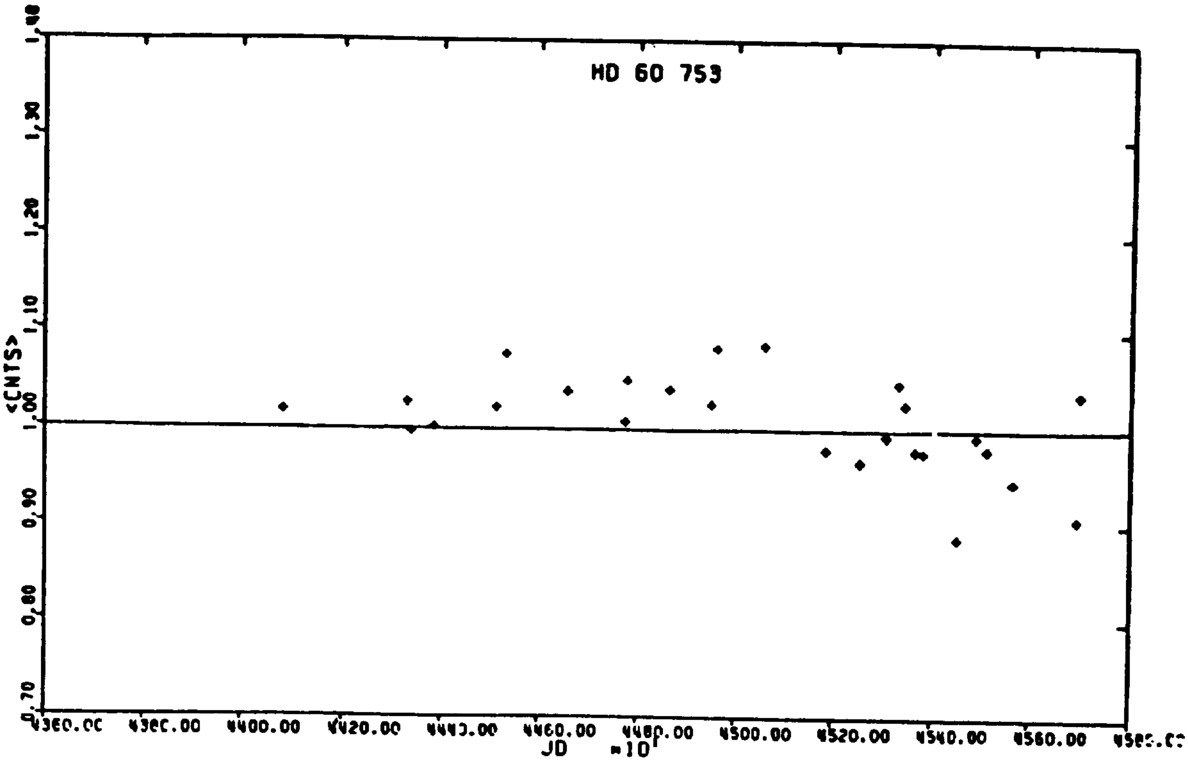

Fig. 1a. The FES counts of HD 60753 normalixed to the mean (7323).

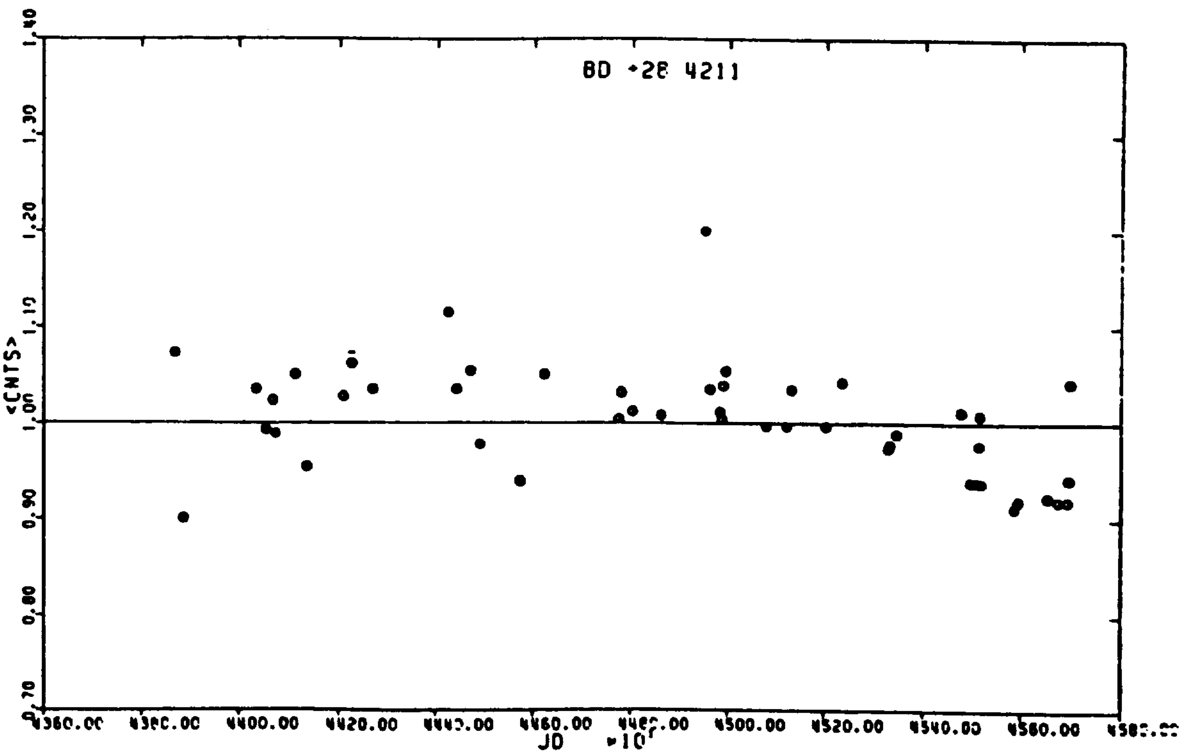

Fig. 1b. The FES counts of BD+28°4211 normalized to the mean (261).

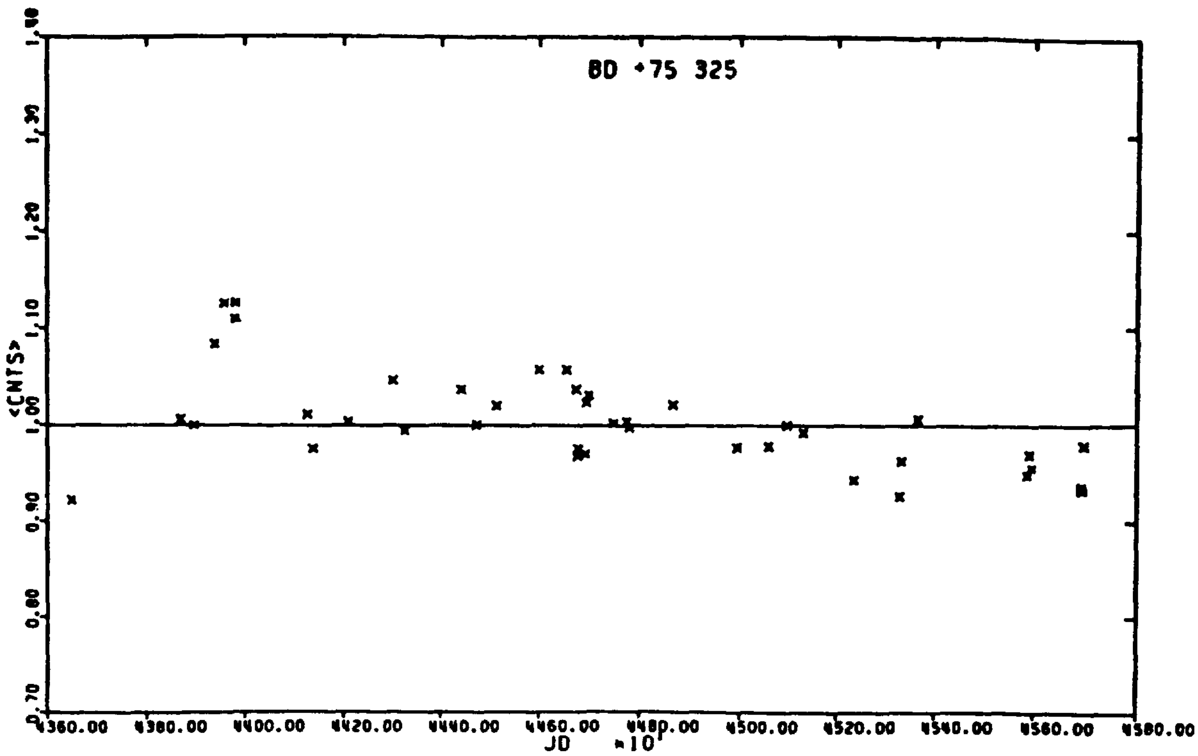

Fig. 1c. The FES counts of BD+75°325 normalized to the mean (651).

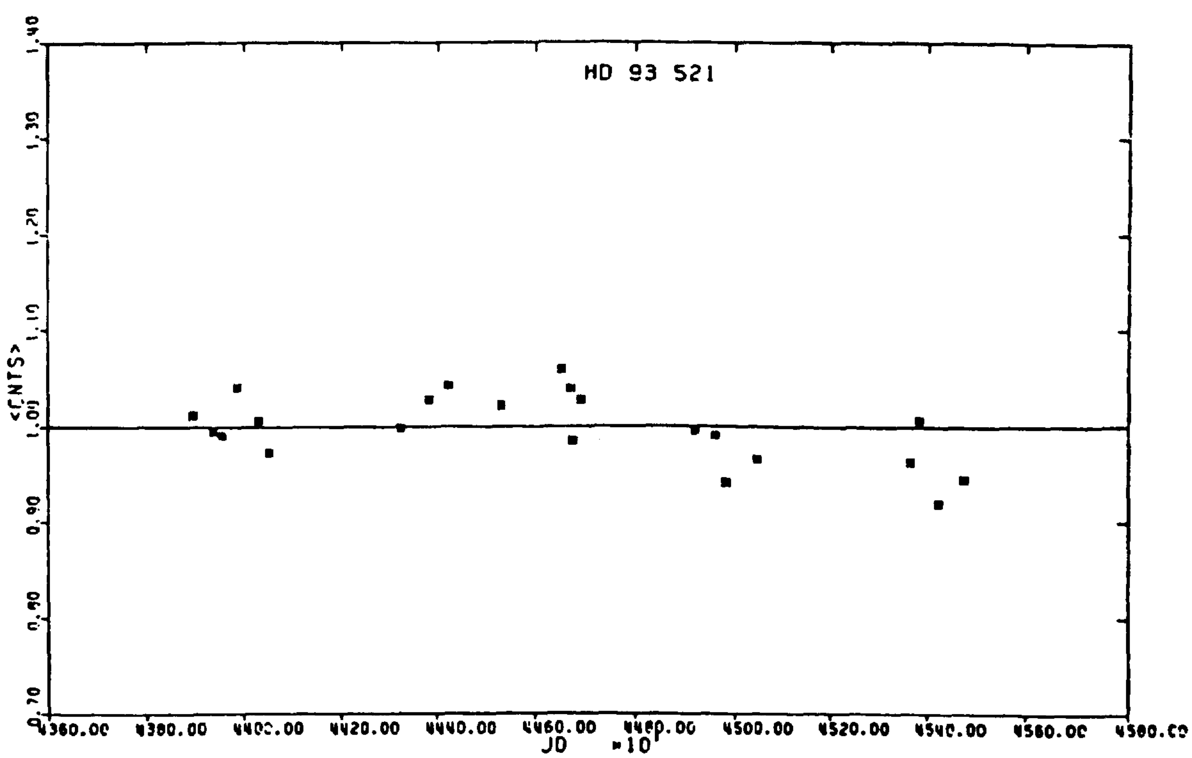

Fig. 1d. The FES counts of HD 93521 normalized to the mean (6059)

Fig. 2

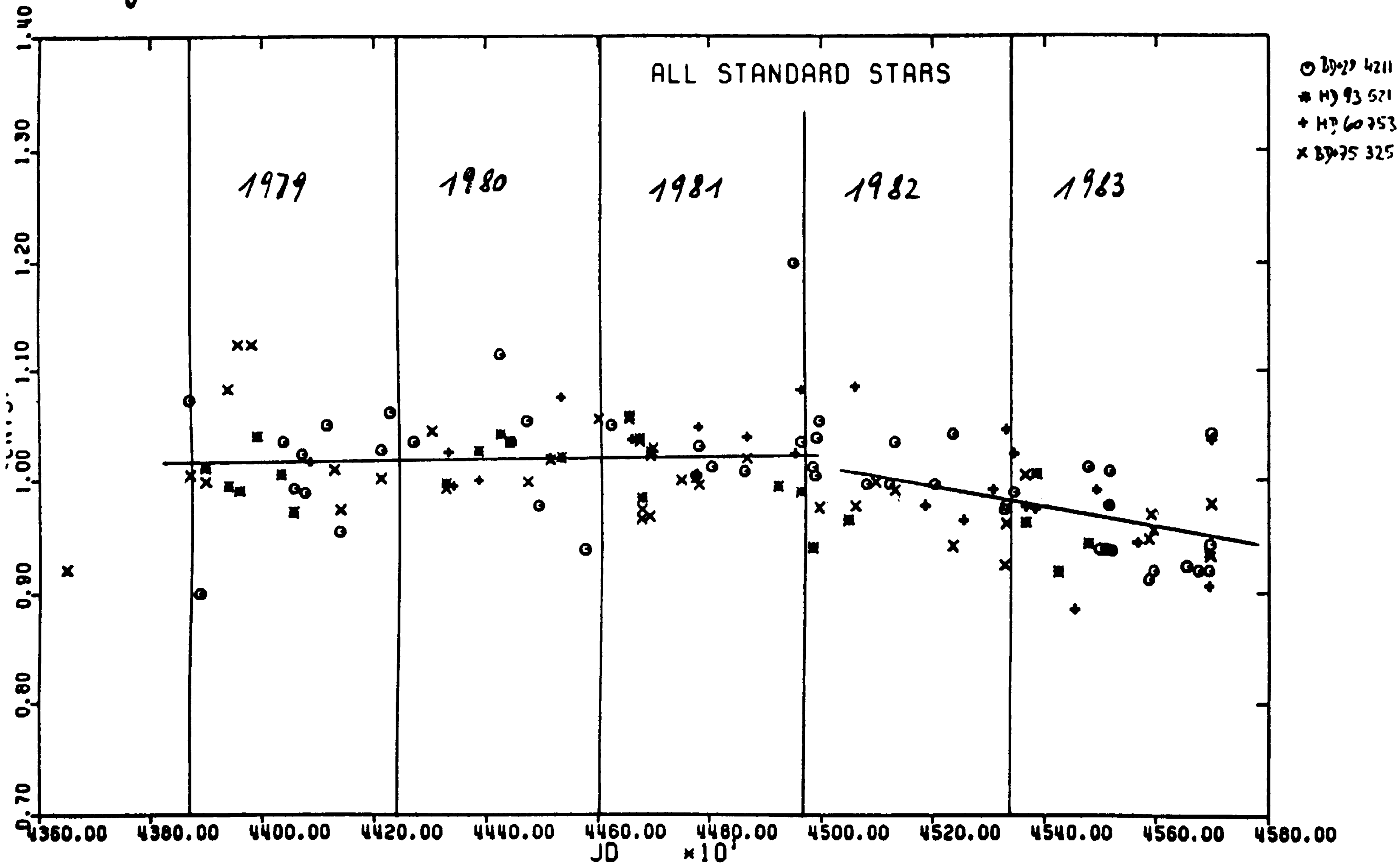

Fig. 2. FES count of the four standard stars normalized to their mean.

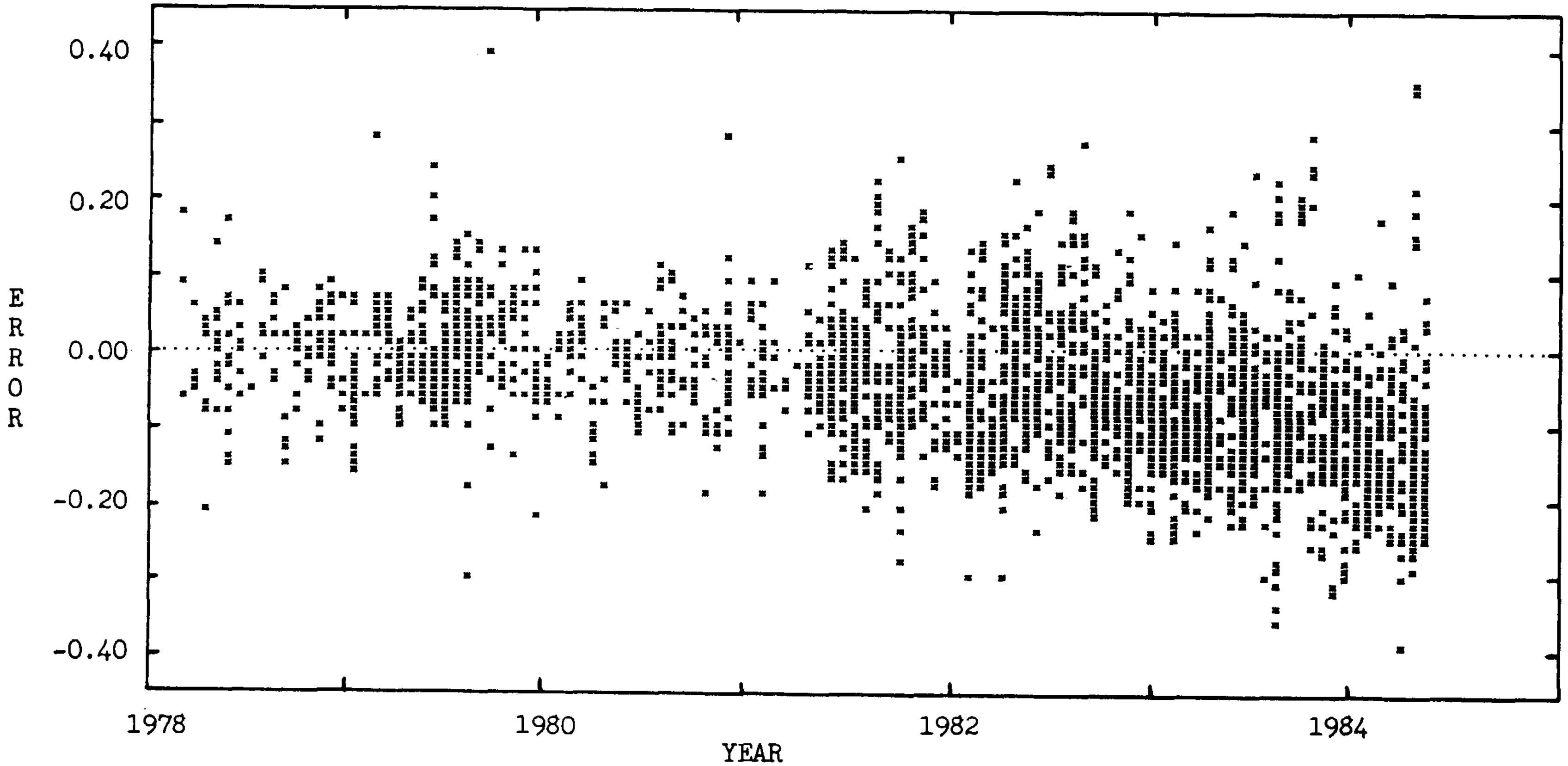

Figure 3. FES magnitude error, defined as photoelectric V magnitude minus visual magnitude computed from Holm and Crabb (1979), versus time for various stars observed at Goddard. The line of small dots represents an error of zero.

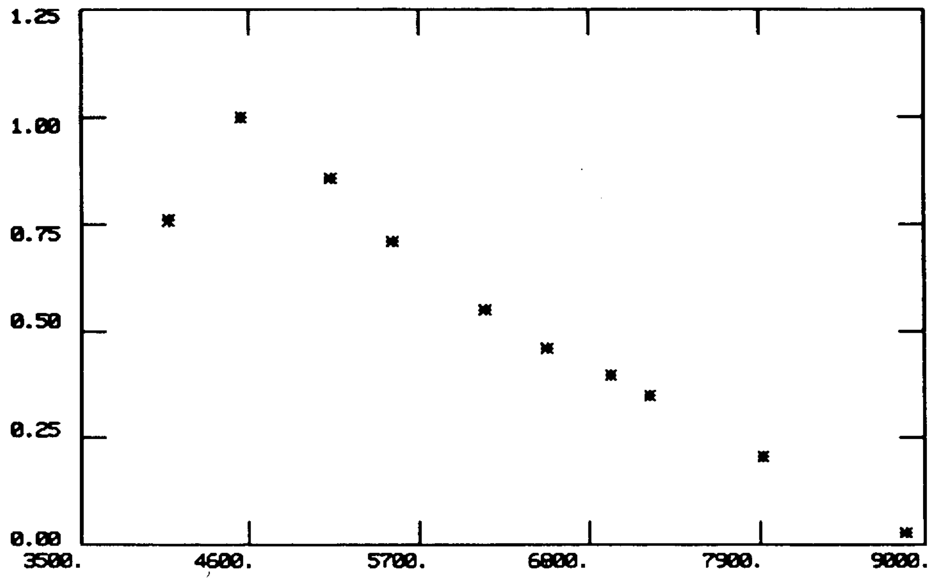

Figure 4. Relative sensitivity of the FES as a function of wavelength. Values from Holm and Crabb (1979) are plotted.