ASTRONOMY & ASTROPHYSICS
SUPPLEMENT SERIES

Astron. Astrophys. Suppl. Ser. **145**, 481–490 (2000)

Variable HST guide stars (I)*

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Received April 19; accepted July 4, 2000

Abstract. We have performed time series analyses on more than 4500 sets of Hubble Space Telescope (HST) Fine Guidance Sensor (FGS) data, obtained from about 3600 guide stars in the period from August 1992 to December 1995. We discuss here a subset of 20 stars that were found to be variable at a high confidence level. This subset contains *all* definite variables in our sample for which at least spectral type, $B-V$, or Strömgren colors, respectively, are available.

Our variability survey is characterized by comparably high photometric accuracy and high time resolution. The time base of a data set for a given guide star can range from half an hour to several days and even up to years in some cases. The elimination of scintillation noise in a space-borne experiment and the usage of the identical instrument throughout the survey results in very homogeneous data with a typical photometric precision of about 500 ppm, and with a best case of 50 ppm. Half of the cases discussed here are probably δ Sct variables, and two are eclipsing binaries. We have also found four K-type stars with a photometric period of a few hours, which is difficult to interpret as rotation.

Currently, several space missions are in preparation, dedicated to high precision photometry with the goal of applying asteroseismic techniques to a significant sample of stars. The HST-FGS data provide an excellent testing ground for modelling the photometric characteristics of such space experiments and for gaining experience in handling the issues related to the respective data and algorithms.

Key words: instrumentation: photometers — surveys — stars: general — stars: oscillations — δ Scu — stars: variables: other

1. Introduction

The three Fine Guidance Sensors (FGSs) are photometric instruments that allow to point the Hubble Space Telescope (HST) with high precision to almost any point in the sky by locking on to a pair of stars taken from the Guide Star Catalog or GSC (Lasker et al. 1990; Russell et al. 1990; Jenkner et al. 1990). During a typical HST observing sequence, two FGSs measure simultaneously and with high time resolution the brightness of these guide stars. A detailed description of the instruments can be found in Bradley et al. (1991) and in Kuschnig et al. (1997), the latter being an investigation of the suitability of FGS photometric data for micro-variability surveys.

Since the start of the HST mission in April 1990 till the end of 1999, about 22 000 stars have been used for guiding. The corresponding FGS data are available in the Engineering Subset Data Files of the Hubble Data Archive. The goal of our project is to perform a time series analysis for all useful data obtained by the FGSs, possibly

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* Based on observations made with the NASA/ESA Hubble Space Telescope, obtained from the data archive at the Space Telescope Science Institute, which is operated by the Association of Universities for Research in Astronomy, Inc., under NASA contract NAS5-26555.

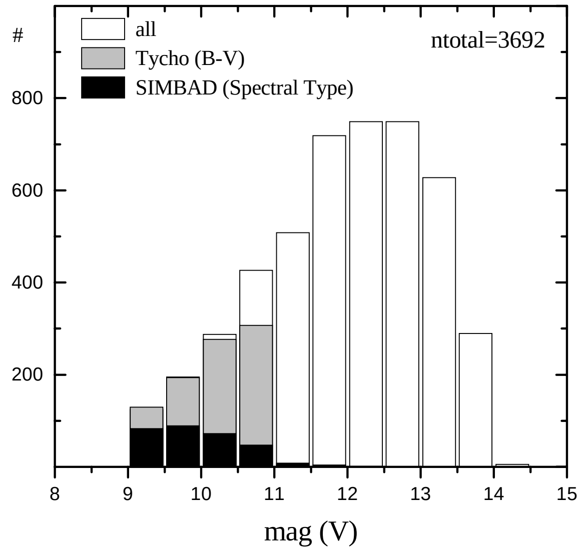

Fig. 1. Brightness distribution of total sample of 3692 guide stars analyzed to date (white columns), of guide stars with TYCHO $B-V$ values (grey columns), and of guide stars with published spectral types (black columns)

until the end of the HST operational life time. Each FGS is an assembly of two interferometers with two channels each. The signal of 4 PMT's per FGS instrument was averaged to a single data point for our analysis. Presently, we have investigated about 4500 individual data sets recorded from more than 3600 guide stars.

With a basic integration time of 25 msec the FGS photometry has a high time resolution[1], but about half of the FGS light curves are shorter than 45 min, corresponding to about half an HST orbit. Fortunately, there are numerous cases where guide stars have been observed continuously for more than a day, or were revisited by HST after months or even years. Prominent examples are the two guide stars used continuously over more than ten days during the northern Hubble Deep Field program (Zwintz et al. 1999).

As the brightness of guide stars ranges from about $V = 9$ to 14.5, spectral types and photometric colors are available from the SIMBAD archive only for the brightest guide stars, or 7% of the entire sample (Fig. 1). The TYCHO catalog (ESA 1997) provided Johnson $B-V$ values for about 20% of our sample. In addition, Strömgren *uvby* measurements were obtained with the Danish 0.5 m telescope at ESO (La Silla, Chile) for about a hundred guide stars. Figure 1 illustrates the fact that little or no additional information can be retrieved for guide stars fainter than 11$^{\rm th}$ mag from existing archives.

In this paper we present 20 variable stars for which spectral types or TYCHO $B-V$ values are available.

[1] Prior to 1 Jan. 1995 all FGS data were telemetered to the ground with a lower time resolution (1 Hz).

2. Classification of the FGS photometry

The period search was carried out with a standard Fourier technique (Deeming et al. 1975). All FGS data sets were reduced and analyzed as described in Kuschnig et al. (1997), where a significance criterion for variability, based on extensive numerical simulations, is defined. A probability of 99.9% for an intrinsic variability was found for synthetic data sets simulating real FGS data, if the corresponding amplitude in the frequency spectrum was higher than four times the noise level, which is basically determined by the mean amplitude of the whole frequency spectrum (0 to Nyquist limit). For purely white noise data, such a S/N ratio was found in only 0.1% of the simulations.

We established the following data set classes, based on the signal-to-noise ratio (S/N) as the principal criterion:

v: Variable data sets, showing a significant amplitude above $4.0 \times S/N$, excluding trend (see "t" class) and orbital modulations (see "o" class);
s: Suspected variable data sets, having amplitudes in the frequency spectrum ranging between $3.0 \leq S/N \leq 4.0$ (85% to 99.9% probability of not being a chance occurence);
t: Trend data sets, where the highest significant amplitude corresponds to the lowest resolvable frequency;
o: Orbit-modulated data sets, where significant amplitudes ($S/N > 4$) appear at frequencies which coincide with the orbit period or are in resonance with it;
c: Constant data sets, showing no amplitudes with a S/N ratio above 3.0 in the entire frequency range (0 to Nyquist limit);
u: Unusable data sets, having a time base that is too short (< 20 min).

For each of the above classes, four categories reflecting the noise level were defined:

Category 1:		$<$	250 ppm
Category 2:	250	–	500 ppm
Category 3:	500	–	1000 ppm
Category 4:		$>$	1000 ppm.

Following the above classification scheme, a variable data set (v) with a noise level of 450 ppm (category 2), will be classified as v2.

With 4566 photometric data sets obtained by the three FGS instruments between August 1992 and December 1995, cross references with the HIPPARCOS and TYCHO catalog and the SIMBAD data base were performed to extract relevant information for the respective guide stars, yielding additional information for 1060 data sets.

Of these, 59 sets are classified as variable (v), 112 show a trend (t), 39 are suspected to be variable (s), 161 show orbital modulation (o), and for 102 data sets the time base is too small (< 20 min), so that they were excluded from further analysis (u). The remaining 587 data sets show no significant variability and are classified as constant (c).

Spectral types for 292 guide stars in our sample have been published, and for only 10% of these a luminosity class was available. For less than 5% of this sample of guide stars the SIMBAD database provided references to the literature, frequently with contradicting evidence. Hence, for an individual star even the spectral information may be incorrect. Our sample still is too small to draw definitive conclusions; however, it is worth mentioning that at noise levels below 100 ppm all stars show variability, almost independent of spectral type. Furthermore, the highest percentage of variability is found for G and K type stars.

For the 20 most interesting variables presented here, at least one data set was found to be variable with high confidence and, in addition, spectral type or $B-V$ are available. This information is summarized in Tables 1, 2 and 3. Note that it was not possible to perform a simultaneous (multi-component) sine fit for all guide stars (see Sect. 5).

3. Comparison with other surveys

Some ground-based stellar variability surveys, covering most of the HR diagram parameter space, have been carried out over the last years, but with poorer time resolution than can be achieved with FGS photometry. Frequently, the discovery of new variable stars is a by-product of the search for brown dwarfs and planets. Many projects (e.g., MACHO, EROS, OGLE, MEGA, AGAPE, PLANET) are monitoring photometrically several million stars to detect gravitational microlensing effects, for example in the Large Magellanic Cloud, the Galactic Bulge of the Milky Way and the Andromeda Galaxy. With these large-scale surveys it is possible to discover an enormous amount of new variables, such as RR Lyrae, eclipsing binaries, Cepheids, Miras and δ Scuti stars. As an example, the *Catalog of Periodic Variable Stars in the Galactic Center* (Udalski et al. 1997) contains more than 2000 objects and is one of the results from the Optical Gravitational Lensing Experiment (OGLE).

Other projects are dedicated to all-sky variable star studies like the All-Sky Automated Survey (ASAS), which monitors about 10^7 stars brighter than $14^{\rm th}$ magnitude over the entire sky, but with a temporal resolution of only about one hour. The Robotic Optical Transient Search Experiment (ROTSE) recently reported 1950 variable star detections; 90% of these are not present in the General Catalog of Variable Stars.

Two other very interesting surveys are the ground-based Geneva Photometric Survey (Grenon 1990) and the HIPPARCOS/TYCHO space missions (Eyer & Grenon 1997). The Geneva Photometric Catalog contains about 29 000 stars that were observed more than three times, typically separated by several days, with a precison of about 10 mmag for a $6^{\rm th}$ magnitude star. Stars with larger than expected variance were systematically re-observed to confirm their variability.

The HIPPARCOS photometry is a complete survey of stars brighter than $8^{\rm th}$ magnitude and contains 118 218 objects with an accuracy of 0.2 (6) mmag for a $5^{\rm th}$ ($9^{\rm th}$) magnitude star. The detectable periods range from one hour up to 1.5 years. On the same spacecraft, the TYCHO (star mapper) experiment obtained brightness measurements for more than a million stars (complete down to $10^{\rm th}$ magnitude), but with lower intrinsic accuracy (25 mmag for a $9^{\rm th}$ magnitude star). Spectral types are known only for a few percent of the TYCHO target stars, but the $B-V$ values could be used to estimate the spectral classification of the other HST guide stars.

Compared to these programs, the FGS data provide a survey of stellar variability which is complementary in the sense that it is focused on short time scale brightness changes of on average fainter stars. Photometric accuracies of better than 500 ppm (0.5 mmag) are obtained for stars down to $11^{\rm th}$ magnitude, if observed for a few hours. The extremely high sampling rate allows to detect short time scale variations such as rapid oscillations, found for instance in a certain group of Ap stars (roAp, Kurtz 1990). However, a statistical investigation on the occurence of micro-variability in the HR diagram can only be done if spectral types and luminosities (or $T_{\rm eff}$ and $\log g$ values) are known.

4. Instrumental effects

Systematic photometric effects in FGS archival data were studied by Zwintz et al. (1999) as part of an analysis of the northern Hubble Deep Field program. Not surprisingly, brightness variations modulated by the HST orbit frequency, or in resonance to it, were detected. These orbit-induced variations are caused by scattered light from the illuminated Earth visible from the spacecraft. This occurs in about 15% of the high quality data sets with noise levels below 100 ppm. A further significant source for increasing noise levels are the wings of the South Atlantic Anomaly (SAA). During the passage through the actual SAA, however, the FGS instruments are switched off to protect the sensitive PMTs. A full correction of the FGS photometry for stray light effects will probably shift most of the guide star data sets classified as "o" to one of the other three variability groups.

Compared to the stray light contamination, the nature of "t" group variables cannot be unambiguously interpreted yet. For example, some of the data sets reveal strong intensity offsets between consecutive orbits. Other data sets show abrupt drops in intensity, which turn out to be limited to the X or Y channel of the FGSs (Fig. 2) and which last for one or more orbits with occasional rise to the previous value (Zwintz et al. 1999). In some cases we have "saved" these observations by eliminating the faulty channel, but taking an increase of the noise level into account.

While a detailed analysis of the source of these effects remains to be undertaken, it appears likely that they are

Table 1. Parameters for 20 variable guide stars (VGS) discussed in this paper based on an automatic analysis and classification: VGS number, Guide Star Catalog number (GSC), time at start of observations in Julian Date (JD_{start}), magnitude given in the Guide Star Catalog (mag(V)), Fine Guidance Sensor used for a given data set (FGS), number of measurements for each data set (n_{dat}), frequency at maximum amplitude ($f_{max\,amp}$) in mHz, noise level in ppm, maximum amplitude (A_{max}) in ppm, time base (t_{base}) in hours, classification (Cl) due to criteria described in Sect. 2

VGS #	GSC #	JD_{start} 2447892+	mag(V) (GSC)	FGS #	n_{dat}	$f_{max\,amp}$ (mHz)	noise (ppm)	A_{max} (ppm)	t_{base} (h)	Cl
1	0097301351	2099.3530	9.95	3	164505	0.4383	199.1	6027.55	5.46	v1
2	0127000385	2136.4435	10.91	2	92239	0.1239	861.2	27037.14	3.92	v3
3	0199501825	2026.8960	11.64	2	501487	0.0505	226.2	1808.57	15.12	v1
4	0199502185	2026.8960	11.32	3	501482	0.0184	177.8	2367.63	15.12	t1
5	0229301267	1640.2523	10.53	1	534	0.7812	3738.5	11029.32	0.22	u
		1663.7676		1	1047	0.0967	3643.9	45669.00	1.79	o4
		1793.2235		2	4680	0.2635	1403.0	11956.37	6.32	v4
6	0229301382	1809.6279	11.00	3	4340	0.1182	1844.6	44014.00	3.82	o4
7	0299600003	2114.8113	10.10	3	97550	0.2907	376.6	11345.90	2.27	o2
		2128.4744		2	299247	0.1986	514.3	32886.26	12.24	v3
8	0341102017	1822.1891	9.25	1	3267	0.3929	840.7	5793.26	3.36	v3
		2128.0731		1	99097	0.3703	258.4	9819.23	2.34	o2
		2134.7148		1	3202	0.1045	824.7	8703.16	1.99	o3
		2142.4898		1	86004	0.2199	292.6	10206.53	48.94	v2
		2146.4453		1	130984	0.2365	229.2	7685.45	73.12	v1
		2151.8065		1	42636	0.3178	442.4	10289.50	0.65	o2
9	0454701381	1484.1282	9.99	3	7479	0.0257	5538.1	409337.59	66.12	v4
		1494.7273		3	12779	0.0219	4488.0	445595.57	14.24	t4
10	0477400822	2112.5192	11.64	3	178750	0.0234	1853.9	115505.39	11.85	t4
11	0495601167	1616.3419	11.48	1	7289	0.0610	1659.4	42628.33	6.82	t4
12	0502500568	1349.0033	9.55	1	10149	0.1351	591.7	4263.78	14.65	v3
13	0685403208	2070.2648	11.25	2	168228	0.1310	3012.4	327478.00	3.97	v4
14	0685601078	2123.0837	11.07	3	159887	0.0448	373.5	13800.46	5.42	t2
15	0739300128	955.0155	9.49	1	283177	0.0128	286.0	26431.53	24.48	t2
		1366.2859		1	11984	0.0893	1001.1	5957.05	1.94	o4
16	0739300524	955.0155	10.62	2	283165	0.0099	2426.8	260808.20	24.48	t4
17	0742602146	2133.0724	11.34	3	241567	0.1413	808.8	33970.41	8.60	v3
18	0779501427	1317.2010	9.51	3	149855	0.0077	307.5	7550.78	107.88	v2
19	0781801912	2045.3953	10.83	3	252575	0.3217	388.8	2352.89	5.39	o1
20	0825203215	980.2662	9.28	3	3873	0.2755	867.0	6144.30	3.65	v3
		1587.1031		2	41863	0.2010	451.0	2691.84	8.63	v2
		1950.6203		2	48187	0.2037	552.6	2520.30	5.45	v3
		1980.1877		2	234443	0.2481	132.9	4320.52	5.17	v1

due to double S-curves, leading to slightly different fine lock positions and correspondingly different photometric sensitivity. It is known that in certain areas of FGS2 such double S-curves occur. They may also be caused by unresolved binaries; depending on their position angle, they can influence either or both channels of the FGS in question.

We do not discuss instrumental effects caused by different sensitivity, dead time correction and color transformation of the FGS instruments involved in our study but refer to Weiss et al. (1999) and to a paper in preparation on probably constant Guide Stars.

5. Discussion

All frequencies, amplitudes and phases of the variable guide stars are listed in Table 4. The corresponding light curves, fits and phase plots are shown in Figs. 3 and 4. In the remainder of this section, we present detailed information on the guide stars found to be variable.

VGS 1, `GS0097301351`: The light curve was simultaneously fitted with two frequencies (38.16740 c/d and 32.00760 c/d). The first cycle calls for a slight zero point correction for which, however, no justification can be found. This star is flagged as a variable in the TYCHO catalog and the light curve resembles a multiperiodic

Table 2. Right Ascension (RA) and Declination (DEC) for Epoch 2000 from the Guide Star Catalog (GSC); name; spectral type (Sp); V and $B-V$ from TYCHO catalog; number in the HIPPARCOS catalog (HIP); spectral types (sometimes not consistent with $B-V$!) from the TYCHO catalog; merged $V_{\rm simbad}$ from the SIMBAD data base; preliminary identification of variability type (comment)

VGS	GSC	RA	DEC	Name	V	$B-V$	HIP	Sp	$V_{\rm simbad}$	comment
		hh:mm:ss	°:′:″		TYCHO			SIMBAD		
1	0097301351	16:36:27	14:11:36	SAO 102269	9.88	0.22		A2		δ Sct
2	0127000385	04:32:10	17:43:18	HD 285850	10.88	0.475		F3		δ Sct
3	0199501825	13:01:45	27:57:40	Weis 63150				K2Ib	11.45	K
4	0199502185	13:00:48	27:48:03	Weis 63301				K2III-IV	11.62	K
5	0229301267	01:34:42	30:25:28		10.43	0.501			10.44	?
6	0229301382	01:32:00	30:21:56		11.39	−0.017				?
7	0299600003	09:56:56	41:26:41		10.36	0.128				δ Sct
8	0341102017	08:14:50	48:49:15	HD 68500	9.13	0.244	40395	F0		δ Sct
9	0454701381	09:14:38	81:56:30	SAO 1470	9.9	0.274		A5	10.3	EB
10	0477400822	05:35:51	−5:08:08	UBV M 51750				K2	12.34	K
11	0495601167	12:55:36	−5:38:35							δ Sct
12	0502500568	15:37:54	−4:44:19	HD 139377	9.75	0.348		A3	9.75	δ Sct
13	0685403208	18:03:57	−29:56:59	BMB 224				M6		RR Lyr
14	0685601078	18:19:23	−28:28:56	V* V1592 Sgr				Me		δ Sct
15	0739300128	18:23:29	−30:15:30	HD 168922	9.8	0.192		B8IV	9.81	δ Sct
16	0739300524	18:24:57	−30:24:42	HD 317508	11.17	0.168		A0	11.2	EB
17	0742602146	19:40:00	−31:13:16							δ Sct
18	0779501427	13:24:33	−43:05:00	HD 116466	8.92	1.516	65421	K4III		K
19	0781801912	14:32:00	−44:26:29		10.99	0.54			11.0	δ Sct
20	0825203215	13:28:01	−47:23:19	HD 116979	9.46	0.568		G8/K0III+	9.41	?

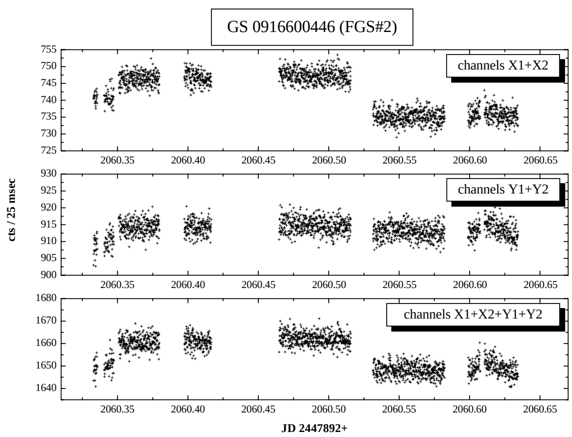

Fig. 2. GS0916600446, an example for the "dropping channel" problem

Table 3. Strömgren photometry obtained at ESO by S.F.: variable guide star number (VGS); Guide Star Catalog number (GSC); Johnson V magnitude; Strömgren $b-y$, $m1$ and $c1$ values

VGS	GS	V	$b-y$	$m1$	$c1$
11	0495601167	11.62	0.321	0.119	0.411
12	0502500568	9.80	0.219	0.173	0.932
13	0685403208	11.46	0.310	0.104	0.784
14	0685601078	11.28	0.119	0.065	0.636
15	0739300128	9.97	0.229	−0.017	0.884
17	0742602146	11.66	0.206	0.164	1.017
18	0779501427	8.89	0.965	0.903	0.201
19	0781801912	11.15	0.179	0.243	0.751
20	0825203215	9.54	0.445	0.220	0.668

δ Sct star. The SIMBAD archive gives a spectral type of A2, while the TYCHO color suggests A8, which would be commensurate with a δ Sct variable.

VGS 2, `GS0127000385`: The time base of the observations for this F3 star is rather short and hence a (formal) fit of the data was limited to two frequencies (8.55345 c/d and 26.49273 c/d). SIMBAD archive and TYCHO color agree in an early F classification which would be consistent with δ Sct variability.

VGS 3 and 4, `GS0199501825 and GS0199502185`: These two guide stars were observed simultaneously with FGS 2 and FGS 3, respectively. With a time base of 15.12 hours and homogeneous data, it is possible to study even low amplitude variability. The open squares in Fig. 3 show the mean intensity for each block of data (i.e., HST orbit) and the symbol size corresponds to the standard deviation. For `GS0199501825` a simultaneous fit with two frequencies was performed whereas for `GS0199502185` a fit with a single frequency seemed to be sufficient (see

Table 4. Frequencies and amplitudes derived by a (multi-component) sine fit: variable guide star number (VGS), Guide Star Catalog number (GSC), frequency in mHz, amplitude in mmag

VGS #	GSC #	freq (mHz)	ampl (mmag)
1	0097301351	0.4417523	2.8164
		0.3704583	1.4488
2	0127000385	0.0989983	19.3090
		0.3066288	4.3830
3	0199501825	0.0505502	0.7653
		0.0011560	49.3609
4	0199502185	0.0182455	0.3170
5	0229301267	0.2572485	5.9219
		0.2927831	4.9748
6	0229301382	0.1110136	20.7980
		0.1987356	7.2022
7	0299600003	0.1978063	18.3684
		0.2403626	3.5217
		0.3337519	4.1131
10	0477400822	0.0132634	84.0723
11	0495601167	0.0621893	27.0865
12	0502500568	0.0375865	1.8812
13	0685403208	0.1362797	155.6936
		0.2725595	43.7994
		0.3975123	20.5502
14	0685601078	0.0516593	8.1490
15	0739300128	0.0122166	18.0785
17	0742602146	0.1373600	20.9450
18	0779501427	0.0076560	2.9164
19	0781801912	0.3195616	1.4698

also Table 4). These stars are examples of cool stars with periods that are too short to be explained by rotation.

VGS 5, `GS0229301267`: For this guide star three different data sets were obtained with FGS 1 and FGS 2 in 1994, but archived in a telemetry format that increases the noise level. An offset affects the second block of data in set *b* (see Fig. 3) and we excluded it from further analysis. The reason is unknown, but the intensity drop seems to be of instrumental origin. Two frequencies (22.22627 c/d and 25.29656 c/d) fit the light curve well. This guide star is also a good example to demonstrate that three individual data sets can have different classifications. Data set *a* has a time base of 0.22 hours (13.2 min) and hence is classified as "unusable". The frequency of the highest amplitude of data set *b* is close to the orbital frequency, and the set was classified as "o4". The third observation (*c*) is of better quality and was classified as variable. The two-frequency fit would be consistent with δ Sct variability, but the TYCHO color indicates F7.

VGS 6, `GS0229301382`: A fit with 2 frequencies (9.59158 c/d and 17.17075 c/d) was found to be the best solution. This star is clearly variable, but is too hot for a δ Sct star, if the suggested TYCHO color (A0) is correct.

VGS 7, `GS0299600003`: The two data sets were obtained within 14 days. The first of the ten orbits does not fit the model very well, probably due to instrumental effects. For the frequency analysis this first orbit was ignored. The larger scatter for the middle part of the second set is caused by a different telemetry format, inducing larger noise. This is probably a multiperiodic δ Sct star, with a TYCHO color of about A5.

VGS 8, `GS0341102017`: This guide star was observed during 1994 and 1995 on six occasions (see Fig. 3, plots a-f) with FGS 1. Although the quality of the data is quite good, it was not possible to determine a reasonable sine fit to the data. This may be a cool δ Sct star.
Note: Data sets *d* and *e* are split for this plot, because of gaps of about two days between observations.

VGS 9, `GS0454701381`: The two observations of the eclipsing binary system AZ Cam have been performed during January 25 and February 5, 1994 (see Kuschnig et al. 1997). The light curve is given here for completeness.

VGS 10, `GS0477400822`: A trend with a frequency of about 1.14596 c/d is clearly present, with a sudden intensity increase for a small period of time during the sixth orbit. This increase does not happen during a passage of the SAA by the HST (see Zwintz et al. 1999) and it also does not seem to be of instrumental origin. A possible interpretation could be that microlensing due to a planet passage or a flare was detected. This is another example for a K-type star with a period too short to be caused by rotation.

VGS 11, `GS0495601167`: This data set first was formally classified as "t", but closer scrutiny revealed a clear signal with a frequency of 5.37315 c/d and an amplitude of 0.02709 mag. The light curve and TYCHO color would be consistent with a cool δ Sct variable, but Strömgren indices indicate an F-type spectrum.

VGS 12, `GS0502500568`: This guide star was flagged as "v3" with a noise level of about 592 ppm and it is again a candidate for microvariability. We present the light curve together with the mean intensities per data block (open squares). A fit with a frequency of 3.24747 c/d is also shown. TYCHO color as well as Strömgren photometry are consistent with a (very small amplitude) cool δ Sct variable, but SIMBAD archive gives A3.

VGS 13, `GS0685403208`: VGS 13 is an interesting new variable because its spectral type is listed as M6. It is included in the BMB catalog (Blanco et al. 1984) as BMB 224. Strömgren photometry indicates spectral type F, which contradicts the SIMBAD archive classification. Considering the main period and a probable F spectral type, we propose a δ Sct variability classification. Large amplitudes usually are associated with non-harmonic light curves and result in overtones for Fourier spectra. Hence, we investigated $f1 + 2 \cdot f1$ solutions and found a third frequency close to $3 \cdot f1$ to reproduce the

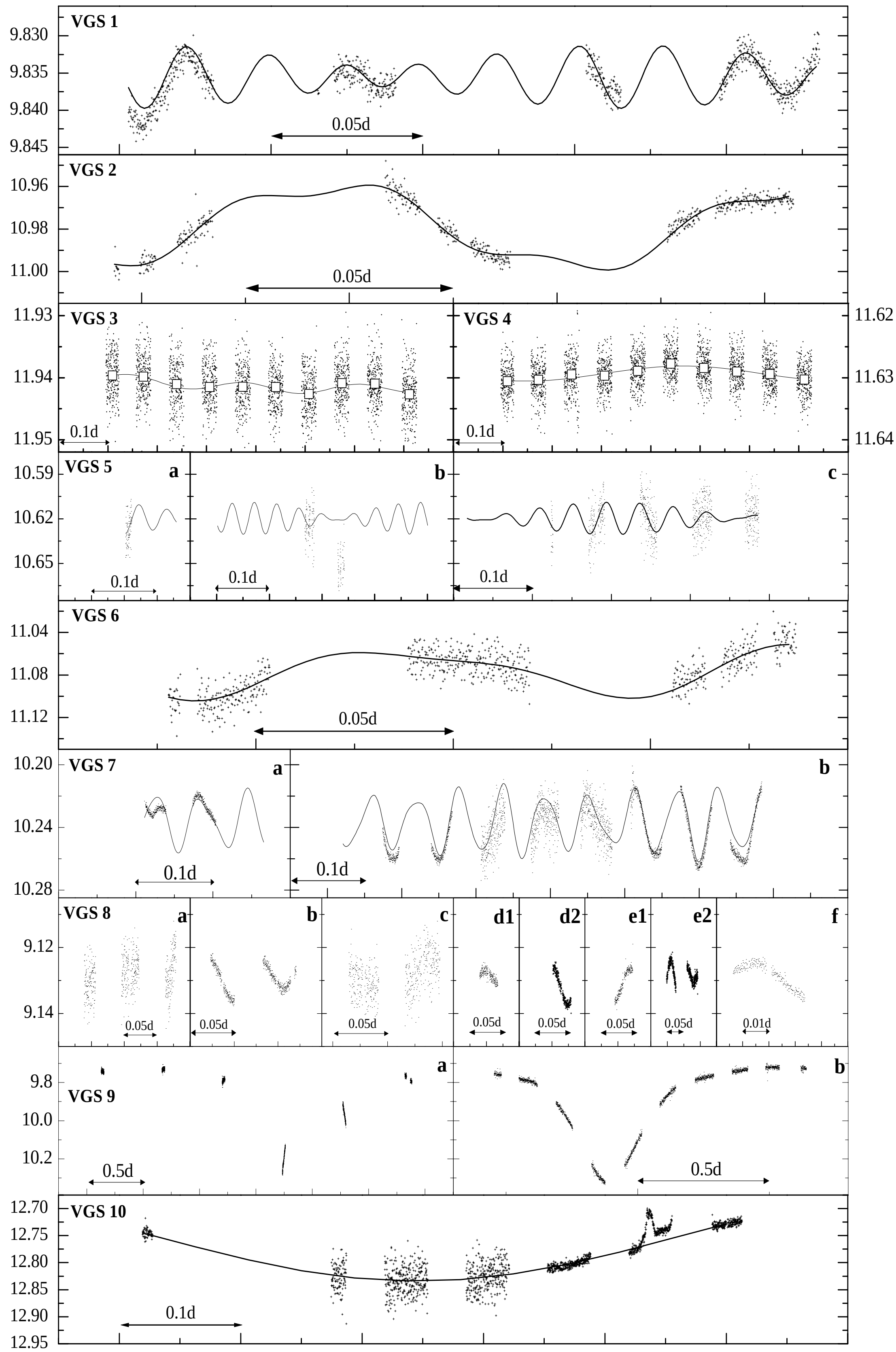

Fig. 3. Variable guide stars #1 − #10

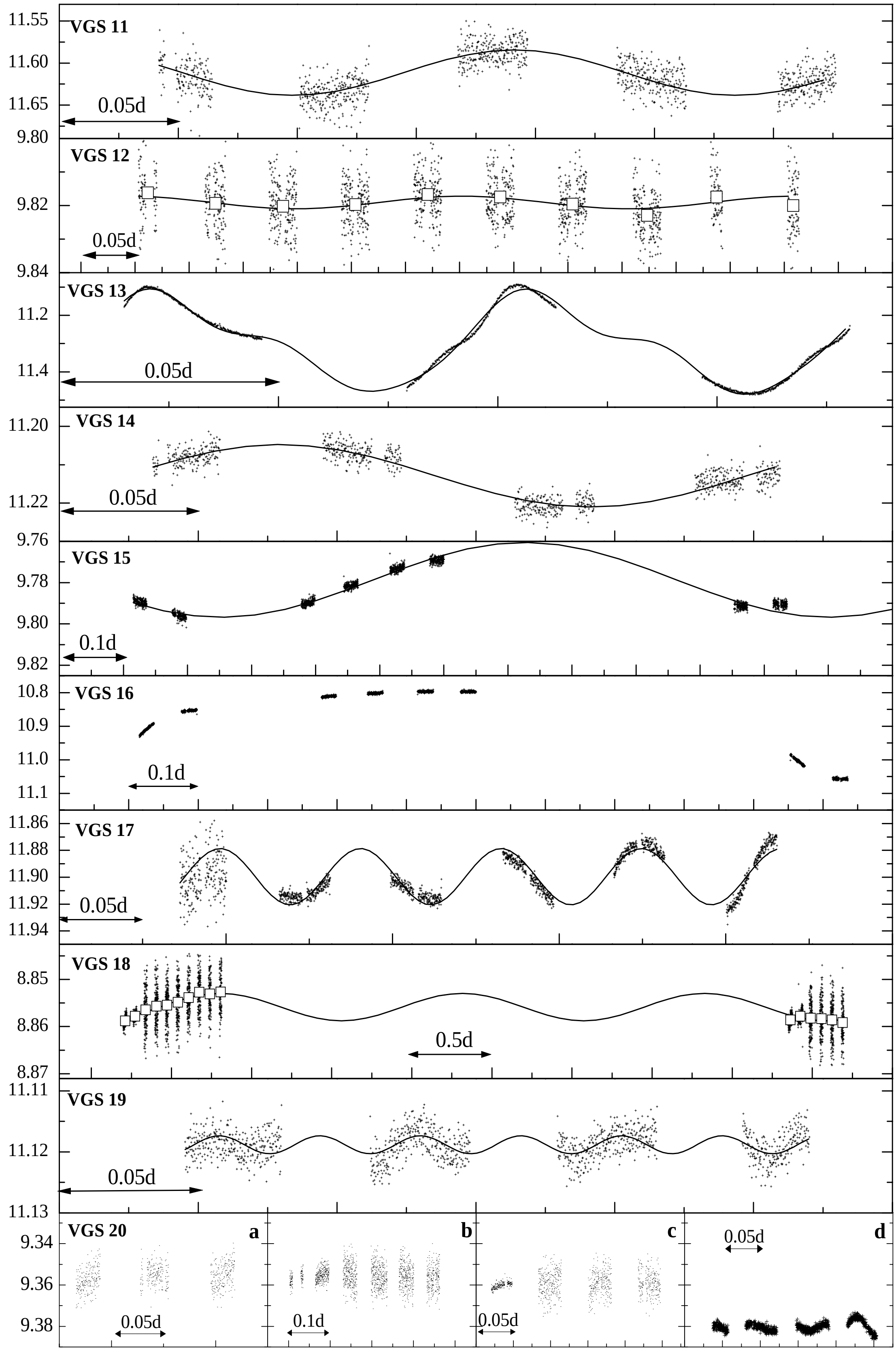

Fig. 4. Variable guide stars #11 − #20

observations to first order. Considering the short data set a more detailed frequency analysis does not seem to be justified. Follow-up observations from ground are needed.

VGS 14, GS0685601078: The frequency of 4.46337 c/d fits the data reasonably well, but with systematic residuals. The number of data points does not allow a more detailed analysis. SIMBAD archive claims that star to be a Mira variable with a period of 218 days, but the FGS light curve looks more like a δ Sct variable, which would also fit the Strömgren photometry (late A type).

VGS 15, GS0739300128: There are two data sets observed in 1992 and 1993, respectively, where the second set has a rather short ($\sim$ 2 hours) time base. A frequency of 1.05551 c/d fits the data from both years well, but Fig. 4 shows only the observations from 1992. A δ Sct light curve would be consistent with the TYCHO color and Strömgren photometry (late A), but not with B8 given in the SIMBAD archive.

VGS 16, GS0739300524: This star was observed in 1992 simultaneously with GS0739300128. It appears to be a new eclipsing binary.

VGS 17, GS0742602146: A fit with the frequency of 11.86790 c/d and an amplitude of 21 mmag is shown together with the data, archived with two different telemetry formats. The light curve resembles a multiperiodic δ Sct variable, which would fit the late A type classification from Strömgren photometry.

VGS 18, GS0779501427: VGS 18 is again a candidate for microvariability with a period of about 1.5 days and an amplitude of 3 mmag. The open squares show the mean intensities per block (HST orbit). This may be a cool K type star with a very short period.

VGS 19, GS0781801912: The formal classification of this guide star is "o1", but after a careful stray light correction of the entire data set the lightcurve shown in Fig. 4 remained. The period of about 52 min is close to half of the orbital period of the HST, but definitely seems to be intrinsic. The light curve resembles δ Sct variability which would fit to the Strömgen photometry, but the TYCHO color is too cool.

VGS 20, GS0825203215: All four data sets of VGS 20 have been classified as variable, but unfortunately the last set (d), transmitted with the low noise telemetry format, shows an intensity offset of unknown origin. It was impossible to find a proper fit for all four data sets simultaneously, even after applying a zero point correction for the last set. The last data set resembles δ Sct variability, but the TYCHO color and even more so the spectral type given in the SIMBAD archive are too cool.

6. Conclusion and perspective

In this first catalog we present 20 variable guide stars discovered in the HST-FGS archive with large to submmag amplitudes. This group is a small subset of a potentially much larger set of variables, because it is restricted to those stars for which spectral types from the SIMBAD archive and/or $B-V$ values from the TYCHO catalog are available.

Our current program consists of a survey for microvariability among guide stars with an accuracy of typically $5\ 10^{-4}$ and in the best cases even of less than 50 ppm. A severe limitation for a sound statistical analysis of the occurence of variability in the HR diagram is the small number of guide stars with known spectral classification; this is caused by the relative faintness of the guide stars used by HST. Intermediate band photometric data (e.g., Strömgren, Geneva), that would allow to estimate $\log g$ and $T_{\rm eff}$, are very rare for such faint stars and we therefore had to arrange for dedicated Strömgren photometry at ESO, as included in this paper.

Future activities will be devoted to better modeling of the photometric properties of HST, in particular with regard to stray light effects, which cause intensity variations modulated by the spacecraft orbit. Such an improved model will allow us to reduce the number of stars classified as "o" considerably. Furthermore, data sets which presently are classified as "t" will also be explored in more detail in order to separate intrinsic long term variability from instrumental or guiding effects. In summary, we expect the percentage of variable stars discovered in our survey to increase.

Currently, several space missions are in preparation, that are dedicated to high-precision photometry with the goal to apply asteroseismic techniques to a significant sample of stars. The HST-FGS data provide an excellent testing ground for modelling the photometric characteristics of such space experiments. Our extensive usage of the FGS archive (Kuschnig et al. 1997; Weiss et al. 1999; Zwintz et al. 1999, and this paper) is motivated in part by this argument.

Follow-up ground-based spectroscopic and/or photometric observations of guide stars are definitely needed and will provide essential information for better and more complete astrophysical interpretation of the effects seen in the data.

Acknowledgements. The authors thank Ed Nelan of the Space Telescope Science Institute for enlightening discussions about the technical intricacies of the FGSs. In addition, we would like to thank Martin Sperl for providing us with his program Period98. This project received funding from the *Österreichische Nationalbank* (project 8014) and the *Fonds zur Förderung der wissenschaftlichen Forschung* (project S-7303 AST).

References

Blanco V.M., McCarthy M.F., Blanco B.M., 1984, AJ 89, 636
Bradley A., Abramowicz-Reed L., Story D., Benedict G.F., Jeffreys W., 1991, PASP 103, 317
Deeming T.J., 1975, Ap&SS 36, 137

ESA, The Hipparcos and Tycho Catalogs, 1997, ESA SP-1200
Eyer L., Grenon R., 1997, ESA SP-402
Grenon M., 1993, Weiss W.W., Baglin A. (eds.), in: Inside the Stars, ASP Conf. 40, 693
Jenkner H., Lasker B.M., Sturch C.R., McLean B.M., Shara M.M., Russell J.L., 1990, AJ 99 (6), 2081-2154
Kuschnig R., Weiss W.W., Gruber R., Bely P.Y., Jenkner H., 1997, A&A 328, 544
Kurtz D.W., 1990, ARA&A 28, 607
Lasker B.M., Sturch C.R., McLean B.M., Russell J.L., Jenkner H., Shara M.M., 1990, AJ 99 (6), 2019-2058
Russell J.L., Lasker B.M., McLean B.M., Sturch C.R., Jenkner H., 1990, AJ 99 (6), 2059-2081
Udalski A., Olech A., Szymanski M., et al., 1997, Acta Astron. 47, 1
Weiss W.W., Zwintz K., Kuschnig R., Witeschnik A., 1999, Comm. Asteroseismology, No. 129
Zwintz K., Kuschnig R., Weiss W.W., Gray R., Jenkner H., 1999, A&A 343, 899