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PREPARING THE *COROT* SPACE MISSION: NEW VARIABLE STARS IN THE GALACTIC ANTICENTER DIRECTION¹

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ABSTRACT

The activities related to the preparation of the asteroseismic, photometric space mission *COROT* are described. Photoelectric observations, wide-field CCD photometry, *uvby* β calibrations, and further time series have been obtained at different observatories and telescopes. They have been planned to complete the *COROT* program in the direction of the Galactic anticenter. In addition to suitable asteroseismic targets covering the different evolutionary stages between zero-age main sequence and terminal-age main sequence, we discovered several other variable stars, both pulsating and geometric. We compared results on the incidence of variability in the Galactic center and anticenter directions. Physical parameters have been obtained, and evolutionary tracks fitting them have been calculated. The peculiarities of some individual stars are pointed out.

Key words: binaries: eclipsing — δ Scuti — stars: oscillations — stars: statistics — stars: variables: other

1. INTRODUCTION

The definition of the observing program of the asteroseismic space mission *COROT* (CONvection, ROTation and planetary Transits; Baglin et al. 2002) requires a careful evaluation of all the potential targets included in the accessible field of view. One at a time, the satellite will monitor six primary targets located in two circles centered at $\alpha = 18^{\text{h}}50^{\text{m}}$, $\delta = 0^{\circ}$ (i.e., in the direction of the Galactic center) and $\alpha = 6^{\text{h}}50^{\text{m}}$, $\delta = 0^{\circ}$ (anticenter direction). No more than 10 stars for each 150 day run can be monitored in the Seismo CCDs; therefore, for each pointing we have one primary target and nine secondary targets. Secondary targets have to be found close to the primary ones in a $1.4^{\circ} \times 2.8^{\circ}$ area, and they should maximize the coverage of the Hertzsprung-Russell (H-R) diagram. Indeed, to match the scientific profile of the mission, the asteroseismic targets (solar-like, γ Dor, δ Sct, β Cep, slow pulsating B stars, etc.) have to be chosen along the zero-age main sequence (ZAMS). In this respect, it is expected that ground-based observations would allow us to choose pulsators located in the lower part of the instability strip, avoiding the too-dense frequency spectrum shown by the evolved stars. Ideal *COROT* candidates should be located between the ZAMS and the terminal-age main sequence (TAMS).

Poretti et al. (2003, hereafter Paper I) described how primary targets were searched in the center direction. In the anticenter direction the request was to find suitable secondary targets around already fixed primary ones in such a way as to minimize the impact on the whole program. Regarding the specific goal to map the lower part of the instability strip, we describe here how we matched it by using a limited number of targets. We also detected several new variable stars in the *COROT* fields.

2. OBSERVATIONS AND DATA REDUCTION

The anticenter direction was monitored with four different instruments on different occasions. The first photoelectric results were obtained for a preliminary list of candidate secondary targets using the Mercator telescope in 2002 February. Three to five measurements per night were obtained on several targets, and some variables could be proposed. Dedicated CCD observations obtained with the STARE telescope (T. Brown et al. 2005, in preparation) in 2002 March allowed us to sharpen our approach. Covering a wider area around the targets ($6.1^{\circ} \times 6.1^{\circ}$), the STARE monitoring (typically one night for each field) allowed us to identify many suspected variable stars. Therefore, these suspected variables became the targets of future observations. The main differences from the data reduction pipeline described in Brown et al. are the use of a V filter and different exposure times. These were optimized for bright stars, and accurate photometry is available for stars brighter than $V = 11.0$. The original time sampling of the STARE images was less than 1 minute; therefore, seven consecutive images were averaged to give more accurate mean magnitudes. The differential magnitudes were transformed into an instrumental V system. Table 1 is the inventory of the new variables we found.

On the basis of the results obtained by the analysis of the STARE data, new photoelectric measurements were carried out at San Pedro Martír (SPM; 2002 December 3–10 and 2003 November 14–23) and at Sierra Nevada Observatory (OSN; 2002 December 20 and 2003 February 16). In both observatories a simultaneous *uvby* photometer was used. These observations were performed to confirm the variability of selected targets on a longer time baseline, to clarify doubtful cases, and

¹ Based on observations collected at the San Pedro Martír, Sierra Nevada, Teide, La Silla, Haute-Provence, and Roque de Los Muchachos (Telescopio Nazionale Galileo and Mercator telescopes) observatories.

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TABLE 1
NEW VARIABLE STARS DISCOVERED IN THE ANTICENTER DIRECTION

Star	V^a	Spectral Type	Amplitude ^b (mmag)	Type ^c and Remarks
Potential Secondary Targets				
HD 43021	7.84	A0	45	δ Sct
HD 43286	7.02	B5	35	Geometric?
HD 44195	7.56	F0	30	δ Sct, γ Dor too?
HD 44283	9.36	F5	<50	δ Sct, small $v \sin i$, small frequency range
HD 44562	8.63	A3	20	δ Sct
HD 44872	8.40	A3	20	δ Sct
HD 45196	8.33	...	14	Geometric, fast rotator
HD 48719	9.19	A5	30	δ Sct, evolved but fast rotator
HD 50844	9.10	A2	80	δ Sct, highest amplitude
HD 50870	8.88	F0	70	δ Sct
HD 55113.....	8.70	K5	~20	Red variable
HD 291684	9.83	A0	60	δ Sct, ZAMS object
HD 293340	9.53	F0	40	δ Sct
Too Faint to Be Secondary Targets				
HD 54780	10.17	A0	~220	E
HD 289732	10.8	B8	105	β Cep? multiperiodic
HD 291635	10.4	B	400	E
HD 291791	10.5	F0	~80	δ Sct
HD 292402	10.10	F0	120	δ Sct
HD 292525	10.36	F2	150	δ Sct
HD 292864	10.45	A2	75	δ Sct
HD 292930	10.33	F0 V	40	δ Sct
HD 292971	10.12	F2 V	100	δ Sct
GSC 00142-00022	10.3	...	65	δ Sct
GSC 00143-01718	10.3	...	~200	HADS or E
GSC 00144-03031	10.1	...	>400	HADS, double mode
GSC 00143-00139	10.8	...	~120	HADS or E
GSC 04784-00830	11.5	...	600	E
GSC 04814-00028	11.1	...	~100	Red variable
Too Far to Be Secondary Targets				
HD 41641	7.86	A5	70	δ Sct, SB2?
HD 42561	8.89	A2	60	δ Sct
HD 44333	6.31	A4.5 V	...	E+SB2
HD 45135	8.82	A2	100	δ Sct
HD 48866	9.0	A0	~300	E
HD 52239	9.06	A5	55	δ Sct
HD 54331	7.94	A0	~40	Long period
HD 292962	9.89	F0 V	200	δ Sct
HD 293031	10.48	F8 III	>200	E
HD 293622	9.98	A	35	δ Sct

^a Values reported in the SIMBAD and/or GAUDI databases; in particular, for GSC stars, see GSC ver. 1.2.

^b Peak-to-peak amplitudes are in the V STARE instrumental system; for HD 44195 it is in y light, and for HD 43286 it is in the V light of the Geneva system.

^c HADS: High-amplitude δ Sct star; E: eclipsing binary.

to characterize a little more the pulsational behavior of well-established ones. The reduction of the photometric data and their transformation into the standard system were done following the procedures described in Olsen (1993) and references therein. The results of these procedures applied to our data set will be presented in a future work (P. J. Amado et al. 2005, in preparation).

To complete the target characterization, the data from the extensive ground-based survey carried out at OSN ($uvby\beta$ photometry of all stars brighter than $V = 8.0$) were used to build a color-magnitude diagram (CMD), as we did in Paper I. In a second step, we also considered spectroscopic observations obtained

at the Haute-Provence Observatory (ELODIE and AURELIE instruments on the 193 and 152 cm telescopes, respectively), La Silla Observatory (FEROS instrument on the 152 cm telescope), and the Italian Telescopio Nazionale Galileo (SARG instrument). All these data were used to build up the GAUDI archive (Solano et al. 2005). Line profile variations and double lines were searched in the high-resolution spectra. Moreover, $v \sin i$ determinations were performed; resulting uncertainties are of the order of a few km s^{-1} .

To complete the coverage of the H-R diagram, we also searched for COROT targets among B stars using the Mercator telescope. The time sampling of these data is very different than that of

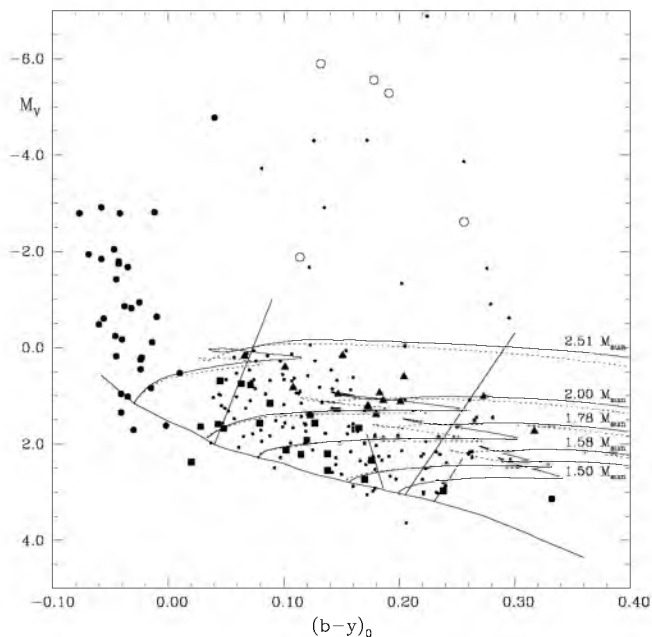


FIG. 1.—Absolute magnitude M_V vs. $(b-y)_0$ color index for stars located in the anticenter direction. Dotted and solid lines indicate evolutionary tracks for $d_{\text{over}} = 0.1$ and 0.2 , respectively. Solid squares represent stars that are certainly unevolved, independent of overshooting influence. Solid triangles represent stars whose evolutionary status depends on the importance of overshooting. Open circles represent stars too advanced on their evolutionary tracks. Large filled circles indicate blue stars. Small filled circles indicate stars located in the instability strip but too far from the primary targets and therefore not investigated for photometric variability. The borders of the δ Sct (*longer lines*) and γ Dor (*shorter lines*) instability strips are also indicated.

δ Sct data, as the data were taken in the general framework of a long-term monitoring program with a time spread of 2 yr (C. Aerts et al. 2005, in preparation). This type of monitoring is much better suited to discovering gravity mode oscillations in B stars (see, e.g., Aerts et al. 1999).

3. THE IDENTIFICATION OF POTENTIAL TARGETS

By considering stars belonging to the B, A, and F spectral types, the merging of the *uvby β* OSN survey and STARE photometry resulted in an initial sample composed of 223 objects. Figure 1 shows the CMD as obtained from *uvby β* photometry performed at OSN. The same procedures described in Paper I are used to deredden color indices and apparent magnitudes and to determine absolute magnitudes. ZAMS, δ Sct instability strip borders, evolutionary tracks, and models are taken as in Paper I, and the same symbols as in Figure 1 of Paper I have been used; the borders of the instability strip for γ Dor variables are those reported by Handler & Shobbrook (2002).

Taking into account the list of potential primary targets in the anticenter direction, 150 stars were not considered for further investigation, as they are located too far from the possible satellite pointings. This decision implied that we were obliged to neglect the variables we found among them. They are listed in Table 1 as “Too Far to Be Secondary Targets.” Some of them can be considered for further studies. For example, the ELODIE spectrum of HD 44333 shows that the star is a spectroscopic binary; moreover, an eclipse with a minimum light at HJD 2,452,963.92 has been observed at SPM. In addition, HD 292962 is noted as a double or multiple star in SIMBAD; the star can be used to investigate the connection between pulsation and duplicity.

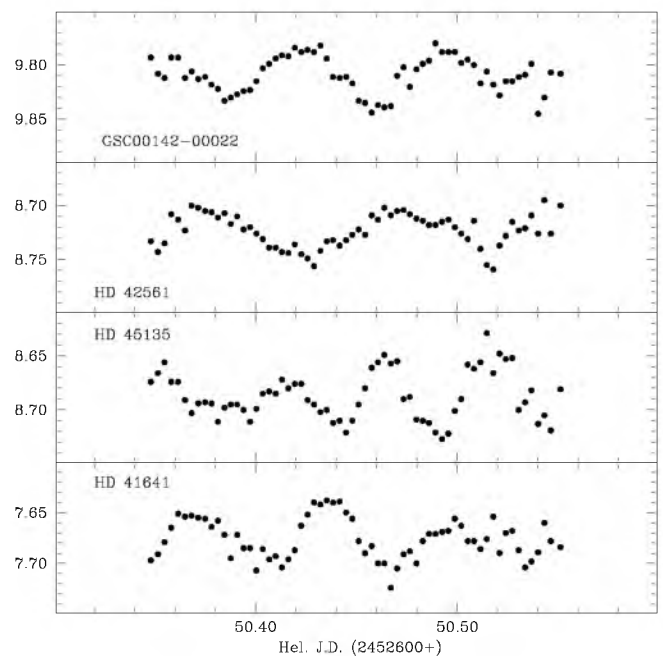


FIG. 2.—Light curves of some new δ Sct stars discovered by STARE in the anticenter direction. Magnitude scale is the STARE V instrumental system.

The remaining 73 stars fall close to the primary targets. However, some of them are too faint to be monitored in the *COROT* Seismo CCDs; a magnitude fainter than $V = 9.5$ will result in a low signal-to-noise ratio, precluding the possibility of doing asteroseismology at the micromagnitude level. They are listed in Table 1 as “Too Faint to Be Secondary Targets.” We note that GSC 00144–03031 is a double-mode pulsator (E. Poretti et al. 2005, in preparation). Figure 2 shows some examples of light curves of pulsating stars discovered in our survey that cannot be included in the list of secondary targets, as they are too faint and/or too far from primary ones. The variable stars that fit the requirements about brightness and distance from the primary targets are listed in Table 1 as “Potential Secondary Targets.”

We stress the fact that all doubtful cases have been omitted to avoid producing false alarms. This means that small-amplitude pulsating stars with a poorly defined light curve, as well as geometric variables simply showing a drift, are not considered, as both effects can be due to random and systematic effects in the wide-field STARE photometry. On the other hand, long-period and red variables are stars showing a well-defined nightly drift or different mean magnitudes (one field was monitored on two nights separated by 2 days). To illustrate a few other examples of variables, Figure 3 shows light curves that strongly support the eclipsing binary hypothesis. Of course, no period can be given, as most of the stars were monitored on one night only. The whole STARE photometry, as well as the *uvby β* one, will be available in the GAUDI archive (Solano et al. 2005).

4. THE CHARACTERIZATION OF THE NEW VARIABLES

As a further step, the rapid variability of the most interesting cases was investigated at the OSN and SPM sites in dedicated observing runs; among these cases, none was previously known as variable, and therefore their characterizations are interesting on their own, independently from their use as *COROT* targets. Unfortunately, for some stars (HD 44562, HD 44872, HD 54277, HD 293340, HD 50870, HD 55113, and GSC 00143–01718) the

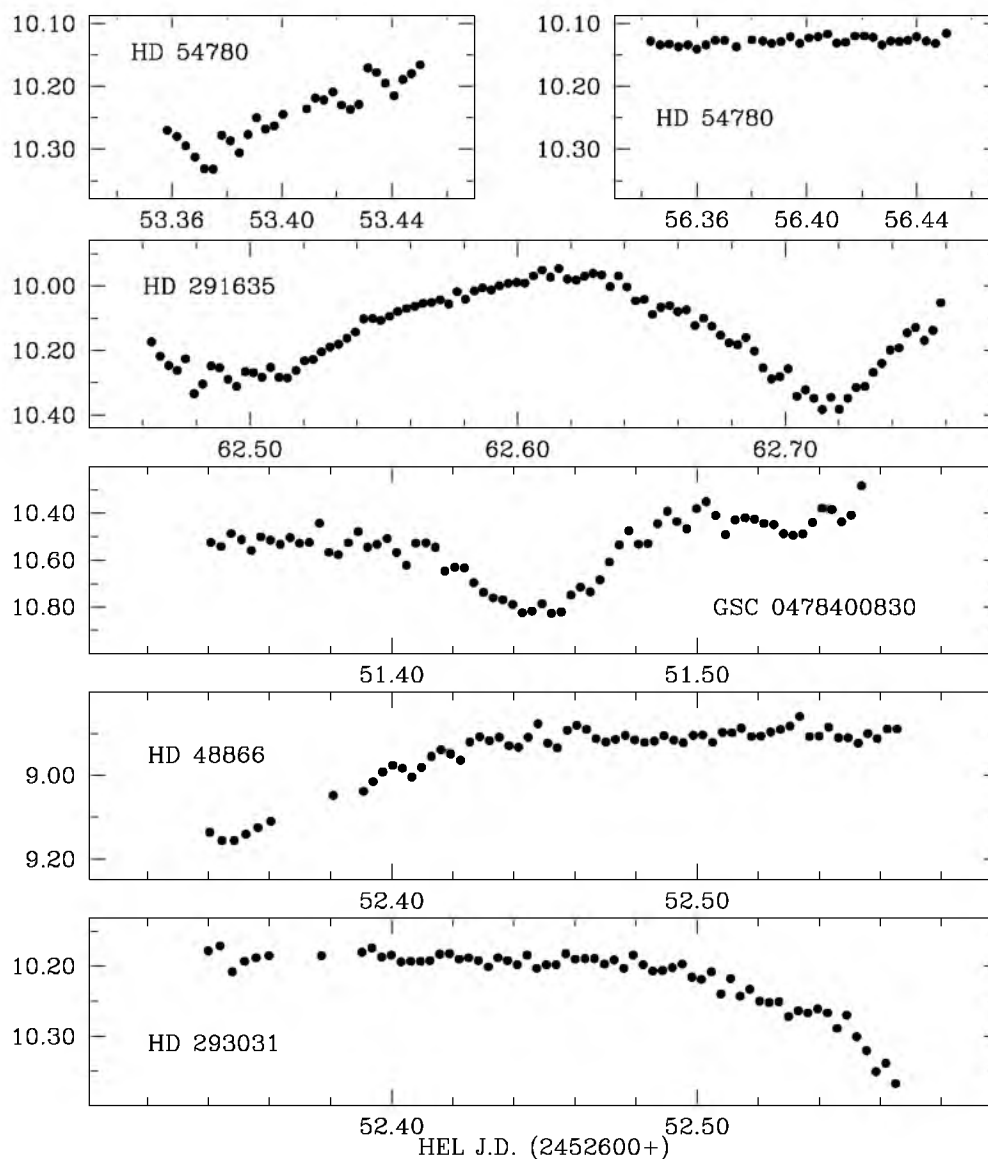


Fig. 3.—Light curves of some new eclipsing binaries discovered by STARE. Magnitude scale is the STARE V instrumental system.

detection of variability on the STARE frames remains the only (but well-proven) evidence. Both STARE and Mercator photometry support the variability of HD 43021. The time series collected on other stars are more numerous, and they allowed us a more complete characterization of their variability. The time series have been analyzed using the least-squares power spectrum method (Vaniček 1971). Moreover, $wby\beta$ photometry has been extended to δ Sct stars fainter than $V = 8.0$, either with dedicated observations at OSN or after the Hauck & Mermilliod (1998) catalog. The physical parameters for the new δ Sct stars in the anticenter direction (Table 2; stars in the upper part plus HD 44195, HD 44283, and HD 50870) have been derived from $wby\beta$ photometry only (TEMPLOGG method; Rogers 1995; see also Kupka & Bruntt 2001), disregarding for the moment other methods such as M_V determinations from *Hipparcos* parallaxes or T_{eff} values from spectroscopy. Uncertainties on the parameters derived from Strömgren photometry are ± 200 K, ± 0.2 dex, and ± 0.2 dex on T_{eff} , $\log g$, and $[\text{Fe}/\text{H}]$, respectively. Our high-resolution spectroscopy shows that HD 41641 could be a double-lined spectroscopic binary, and therefore the physical parameters in Table 2 are uncertain.

Figure 4 shows the position of the new pulsating stars in the CMD.

4.1. HD 50844

High-resolution spectroscopy reveals that the line profiles are very perturbed; the star is a multiple one or, more probably, a δ Sct showing high-degree modes. The considerable photometric amplitude (Fig. 5, *top panel*) also suggests the presence of a dominant low-degree mode. It is a $2 M_{\odot}$, slightly evolved object (star 14 in Fig. 4).

4.2. HD 44283

The intensive monitoring carried out in 2003 November at OSN and SPM allows us to detect a dominant peak at $f_1 = 15.00 \text{ day}^{-1}$ (Fig. 6). Other peaks in the $14\text{--}16 \text{ day}^{-1}$ interval are noted after introducing f_1 as a known constituent. No other term at the highest or lowest frequencies is detected; thus, the excited modes are confined in a well-defined region. The $v \sin i$ value is quite low (19 km s^{-1}), and the star is located in the middle of the instability strip, in a position compatible with both an evolved

TABLE 2
PHYSICAL PARAMETERS OF THE NEW PULSATING STARS

ID ^a	Star	$v \sin i$ (km s ⁻¹)	M_V^b	T_{eff} (K)	$\log g$	[Fe/H]
δ Sct Stars in the Anticenter Direction ^c						
11.....	HD 41641	29	1.92	7700	3.9	-0.2
12.....	HD 43021	80	2.16	7850	4.0	-0.5
13.....	HD 48719	197	1.21	7250	3.5	0.0
14.....	HD 50844	...	1.31	7500	3.6	-0.4
15.....	HD 291684	...	2.12	7600	4.0	0.0
δ Sct and γ Dor Stars: <i>COROT</i> Targets ^d						
1.....	HD 44195	58	2.72	7650	4.2	-0.3
6.....	HD 44283	19	1.31	7250	3.6	0.2
9.....	HD 49434	90	2.63	7250	4.1	-0.1
3.....	HD 50870	17	1.67	7600	3.9	0.2
4.....	HD 170782	198	1.35	7900	3.8	-0.4
5.....	HD 170699	>200	1.15	7400	3.5	-0.4
7.....	HD 172189	...	0.90	7700	3.6	-0.3
10.....	HD 171834	72	2.64	6550	4.0	-0.2
2.....	HD 181147	...	1.70	7850	3.9	-0.3
8.....	HD 181555	170	1.20	7200	3.5	-0.1

^a Identification for Figs. 4 and 9.

^b Absolute magnitudes calculated from *uvby* β photometry.

^c Variables far from *COROT* primary targets.

^d *COROT* targets selected in both the anticenter and center directions.

and an unevolved status (star 6 in Fig. 4); the frequency regime is more compatible with the latter hypothesis. Erroneously reported as a K0 star in SIMBAD, it is actually an F5 star.

4.3. HD 45196

The frequency analysis of the OSN and SPM data shows a power spectrum in which the signal is confined in the $f \leq 6 \text{ day}^{-1}$ region; small-amplitude, long-period fluctuations are detectable in the light curves. The star is a very fast rotator ($v \sin i = 200 \text{ km s}^{-1}$; ELODIE and AURELIE spectra). It is probably a geometric variable, maybe an ellipsoidal one, as also suggested by the frequency analysis of the $b - y$ color index.

4.4. HD 291684

Both STARE and OSN data show a well-defined light variability (Fig. 5). The star is located very close to the ZAMS (star 15 in Fig. 4). A rapid, well-defined variability (0.04–0.05 days) can be inferred from the STARE night, but the OSN night shows the action of other terms changing the light-curve shape from one cycle to the next.

4.5. HD 48719

Its position in the CMD is close to the TAMS and superposed on the zigzags of the evolutionary tracks of $2 M_{\odot}$ models (star 13 in Fig. 4). The detected frequency is compatible with an evolved stage ($f_1 = 10 \text{ day}^{-1}$), but the rotational velocity is still fast ($v \sin i = 197 \text{ km s}^{-1}$). The star also seems to be multiperiodic (Fig. 5).

4.6. HD 44195

The power spectrum of the SPM data is quite peculiar, as it shows peaks at low frequencies and a well-defined peak at around 20 day^{-1} (Fig. 7, top). The $v \sin i$ value is moderate (58 km s^{-1}), and the star is located in the middle of the instability strip,

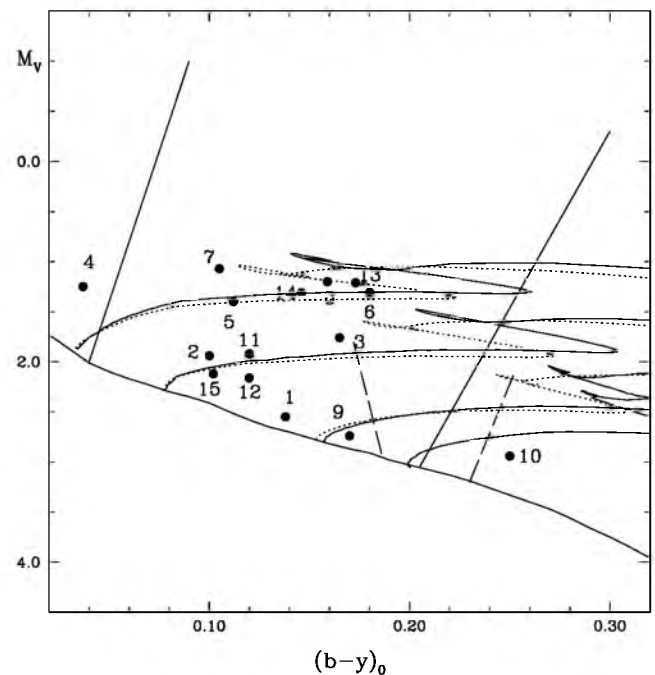


FIG. 4.—The δ Sct variables (1–8) and suspected γ Dor variables (9 and 10) accepted as targets in the *COROT* program, shown in the CMD. The new pulsating stars discovered in the anticenter direction (11–15) are also shown.

very close to the ZAMS (star 1 in Fig. 4). It is a good candidate to be a combined γ Dor and δ Sct variable. The ELODIE high-resolution spectra confirm the presence of bumps all along the lines, which was already suspected from the AURELIE spectra (Mathias et al. 2004). It should be noted that the star's light variability has been investigated at SPM to confirm the spectroscopic variability, since the STARE light curve did not give a definitive result (the full amplitude of the rapid pulsation is less than 0.01 mag). Figure 7 (bottom) shows the light curves; the mean magnitude is also indicated to evidence the night-to-night variations originating the peaks at low frequencies in the power spectrum.

5. PROBING THE ANTICENTER DIRECTION USING δ SCT STARS

The sample in the anticenter direction is homogeneous up to $V = 8.0$, i.e., the limit for which the *uvby* β sample is complete. Therefore, we cannot evaluate the incidence of variability, since we have only three variables and 15 constant stars brighter than $V = 8.0$ (Fig. 8).

On the other hand, we can study the positions of δ Sct stars inside the instability strip by also considering fainter stars, since we performed *uvby* β photometry for variable stars. They are concentrated in the central part, in the narrow range $0.10 < (b - y)_0 < 0.16$. This confirms the result described in Paper I: we have a higher probability of finding δ Sct variables in the middle of the instability strip than close to the borders. In the anticenter direction the δ Sct stars (Fig. 8, filled circles and crosses) have a distribution similar to that of the whole Galaxy (see Fig. 5 in Paper I). Moreover, no variable has been found close to or outside the blue border; the two cases found in the center survey (HD 170782 and HD 183324; Paper I) still remain isolated. However, we note that very short period δ Sct stars should populate that region; recently, Amado et al. (2004) discovered an 18 minute pulsation in HD 34282, finding evidence

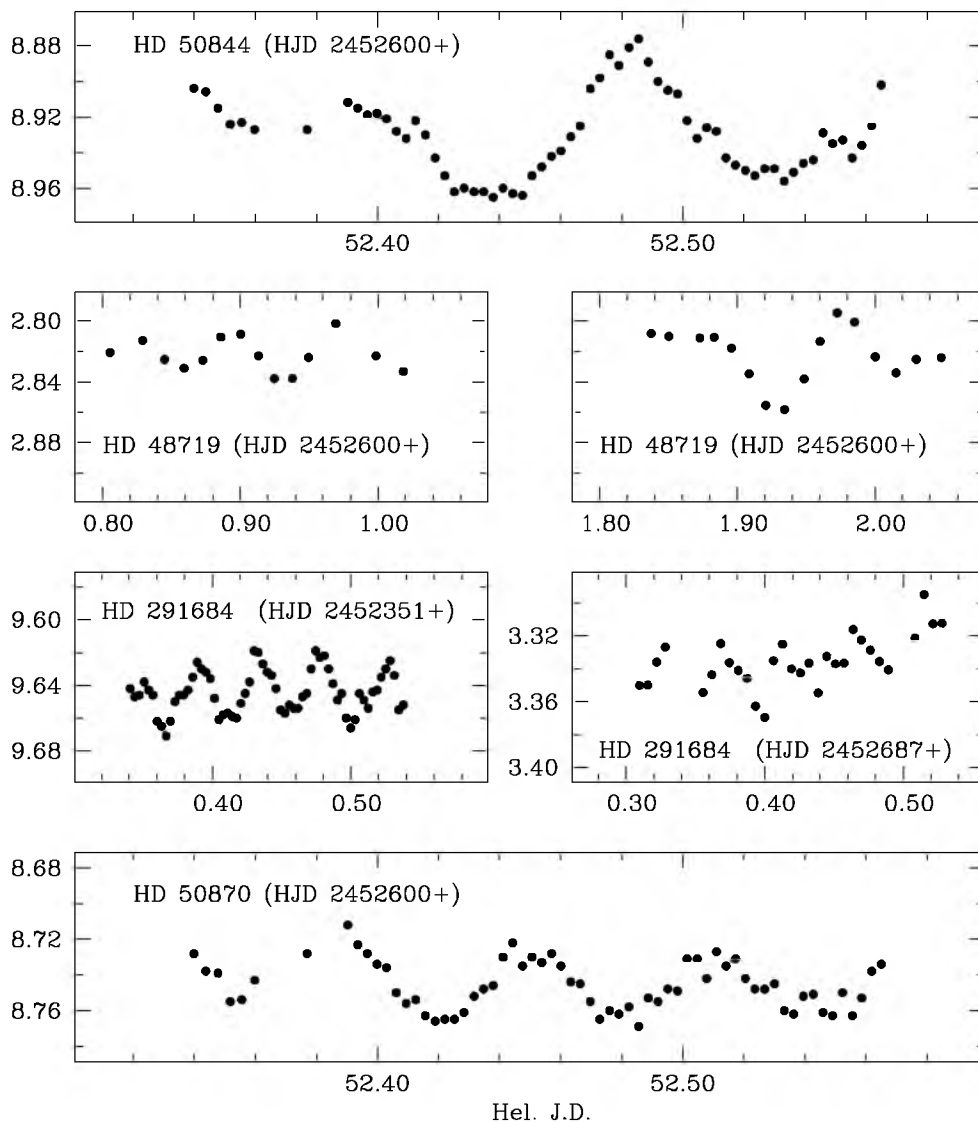


FIG. 5.—Light curves of some new δ Sct stars that are potential *COROT* targets. The magnitude scale of HD 50844, HD 291684 (JD 2,452,351), and HD 50870 is the STARE V instrumental system; the magnitude scale of HD 48719 and HD 291684 (JD 2,452,687) is differential Δv photometry.

that high radial order pulsators can be located close to/outside the blue border. Moreover, we remind the reader that we found an overabundance of variables in the half toward the blue border when observing in the center direction (see Fig. 4 in Paper I); not being found here, that overabundance still seems to be a peculiarity of the solar neighborhood in the center direction. *COROT* photometry from Exoplanetary CCDs, which will be obtained in both directions within the same magnitude limits, should supply more consistent statistics to evaluate this different abundance.

The CMD shown in Figure 1 is also characterized by a plume of B stars at $b - y < 0.0$. Most of the time series consist of one night of monitoring by STARE only. Such a survey should be able to detect rapid variability, while slow variability should remain undetectable. Actually, only the faint star HD 289732 shows rapid variability; its light curve suggests multiperiodicity. The distribution of the $v \sin i$ values is quite uniform, with a preference for slow rotation ($v \sin i < 50 \text{ km s}^{-1}$).

6. CONCLUSIONS

Using the TEMPLOGG method (see § 4), we also calculated the physical parameters for targets in the center direction (Table 2):

the variabilities of HD 181555,¹¹ HD 170782, and HD 170699 have been reported in Paper I, while those of HD 181147 and HD 172189 have been detected when observing these fields. The case of HD 49434 is described by Bruntt et al. (2002). We also note that HD 171834 is photometrically constant from the ground (see Table 2 in Paper I), but a new, dedicated spectroscopic time series (35 spectra in 4 hr) allowed us to detect line profile variations having a relative amplitude of 3×10^{-4} ; such very weak line profile variations are also reported by Mathias et al. (2004). The slightly metal-poor content of the variables listed in Table 2 is in agreement with the distribution of metallicities observed in the solar neighborhood (Nordström et al. 2004).

To give a different picture of the evolutionary scenario covered using these targets, we compared the physical parameters derived from $uvby\beta$ photometry with the evolutionary tracks

¹¹ The position of this star in the CMD has been revised (see Fig. 8 in Paper I) on the basis of a more accurate set of $uvby\beta$ photometry. However, there is a large discrepancy between the Strömgren M_V and *Hipparcos* parallaxes. They can be reconciled by admitting an error of 0.065 mag in the β value, which seems huge for such an index. On the other hand, the parallax measurement could be inaccurate owing to two objects that appear very close to HD 181555 in the Guide Star Catalog.

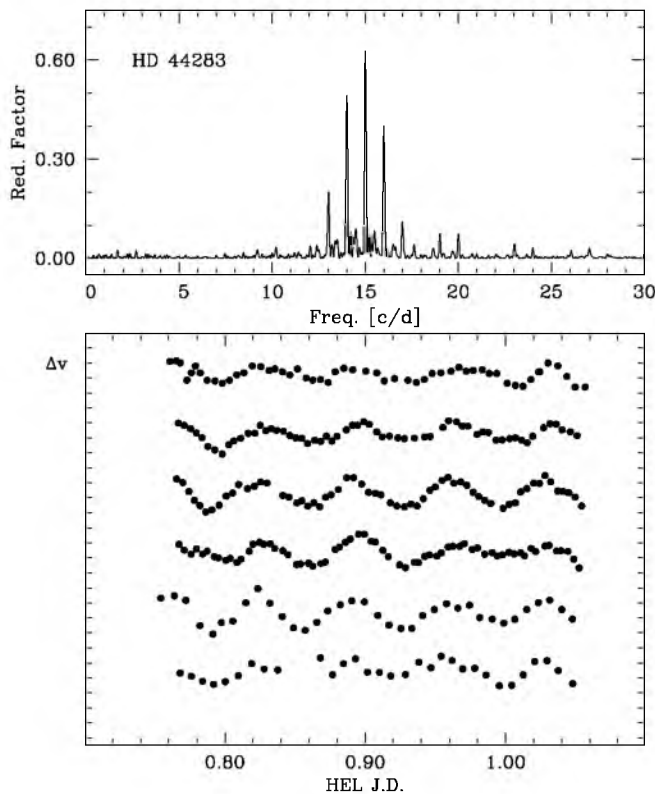


FIG. 6.—Power spectrum and light curves of the new δ Sct variable HD 44283. Light curves were obtained at SPM on JD 2,452,960; 2,452,961; 2,452,962; 2,452,964; 2,452,966; and 2,452,967 nights (top to bottom); the tick size on the Δv magnitude axis is 0.02 mag.

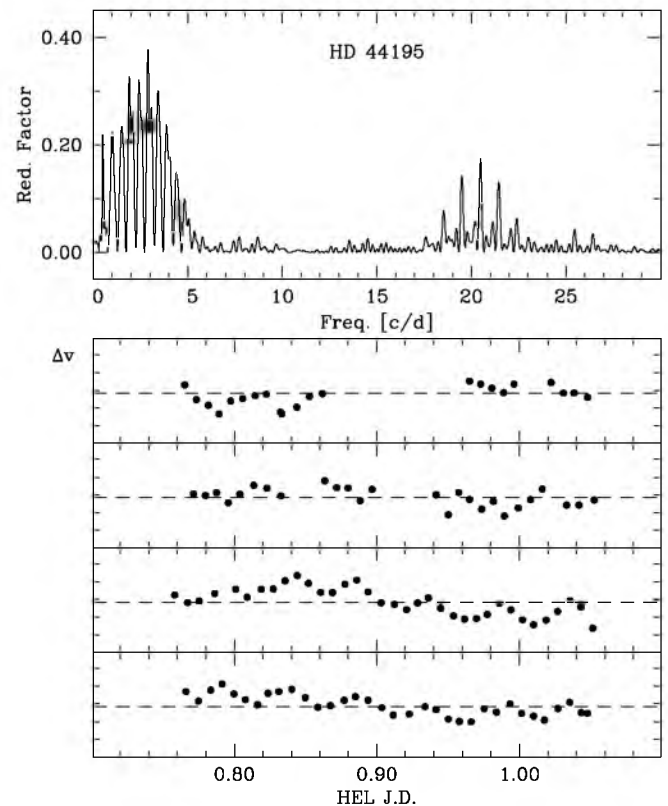


FIG. 7.—Power spectrum and light curves of the new δ Sct variable HD 44195. Peaks at low frequencies also suggest a γ Dor pulsation. Measurements were obtained at SPM on JD 2,452,963; 2,452,964; 2,452,966; and 2,452,967 nights (top to bottom); the tick size on the Δv magnitude axis is 0.01 mag. The dotted line in each panel indicates the mean magnitude of the whole data set.

calculated with the CESAM code (ver. 4; Morel 1997). In Figure 9 the $\log T_{\text{eff}}$ and M_{bol} values of each variable star are plotted together with the evolutionary tracks calculated for $[\text{Fe}/\text{H}]$ values similar to those of the variables. An overshooting parameter $d_{\text{over}} = 0.2$ has been considered, and the (small) bolometric corrections have been introduced (VandenBerg & Clem 2003). All the stars are between ZAMS and TAMS, and most of them have mass greater than $1.50 M_{\odot}$. The presence of some fast rotators among the targets (HD 181555, HD 170782, and HD 170699) will constitute a severe test for the recent progress in the treatment of pulsation and fast rotation (Suárez et al. 2004). The two γ Dor variables HD 49434 and HD 171834 (stars 9 and 10) are the less massive stars; the latter is more evolved than the former. Their spectroscopic variability, as well as the photometric variability of HD 44195, has some theoretical implications regarding the location of the borders of the γ Dor instability strip (see Fig. 7 in Handler & Shobbrook 2002 and Fig. 1 in Kaye et al. 2004).

All the evolutionary stages between and including ZAMS and TAMS are covered (Fig. 9) by considering only stars brighter than $V = 9.5$ and located in two arbitrary directions. Since this task has been fulfilled using only 10 objects, the other parts of the ZAMS can be adequately covered by the remaining 83% of the *COROT* targets. This proves that unevolved or slightly evolved pulsating stars are quite common and that they can be included as a solid, ground-based tested baseline in any asteroseismic mission from space. We can look at the different targets as sort of key steps along the stellar evolution path; the possibility of sounding their interiors by detecting oscillations at the micro-magnitude level in the *COROT* time series will result in great improvement in stellar physics knowledge.

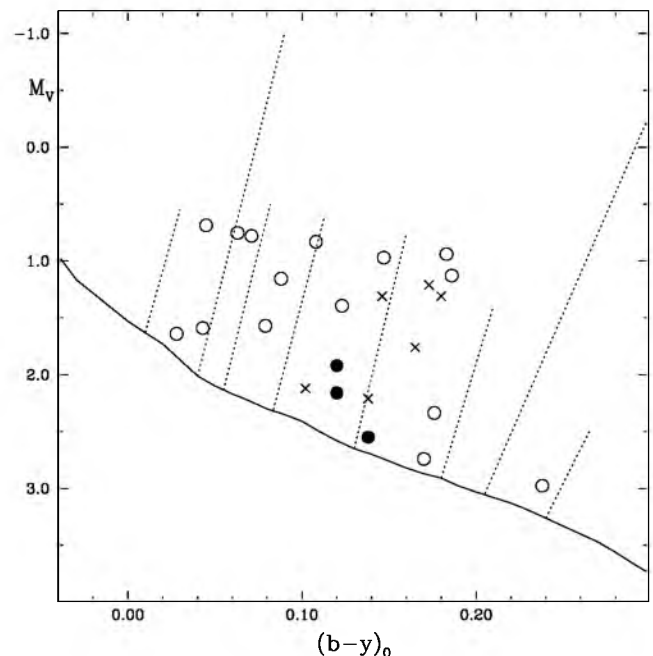


FIG. 8.—Incidence of δ Sct variability in the anticenter sample. The spacings are selected as in Paper I, i.e., by taking the borders roughly parallel to the blue and red borders (the longest ones) of the instability strip. Filled circles represent variable stars brighter than $V = 8.0$, crosses represent variable stars fainter than $V = 8.0$, and open circles represent constant stars.

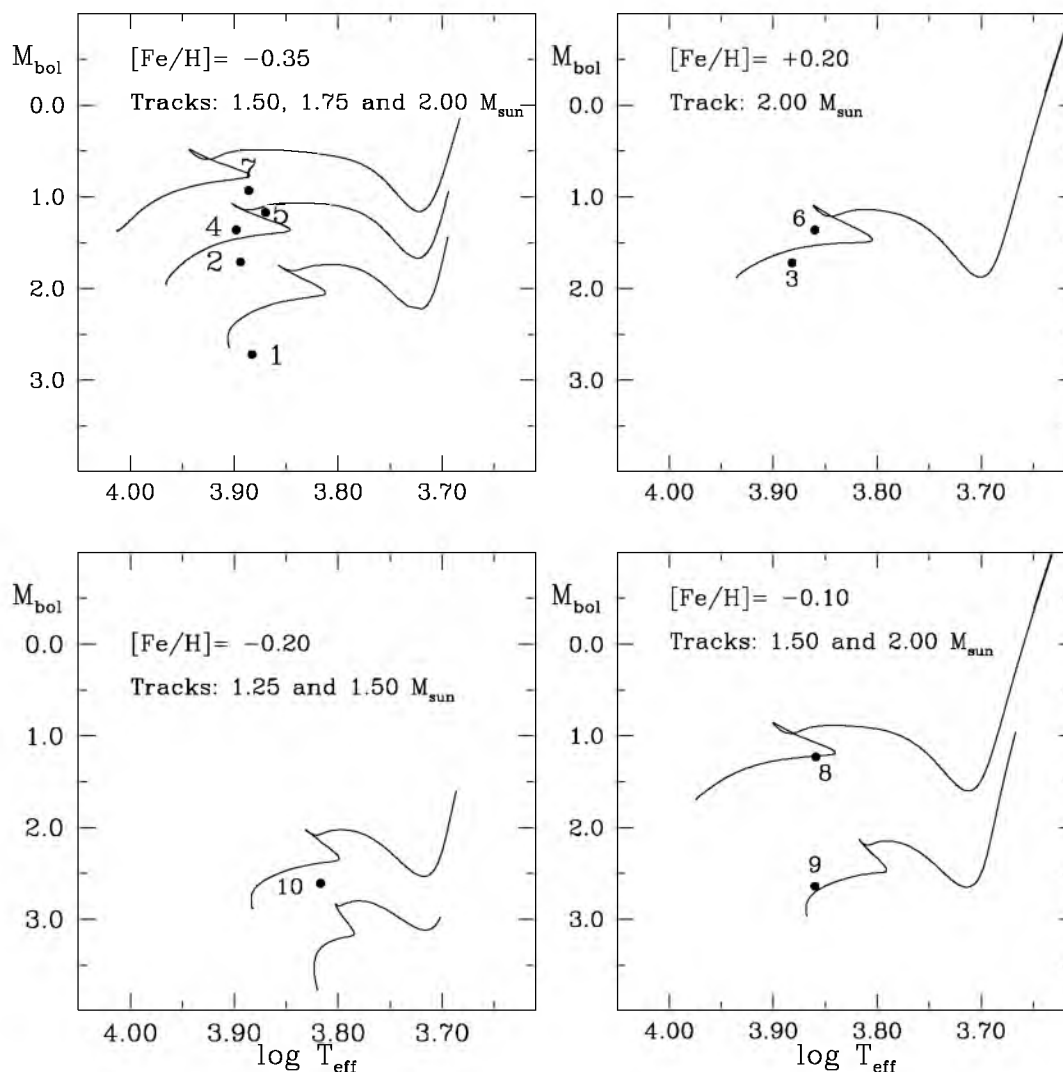


FIG. 9.—*COROT* targets in the $T_{\text{eff}}-M_{\text{bol}}$ plots. The evolutionary tracks were calculated for the value of $[\text{Fe}/\text{H}]$ indicated in the top left corner of each panel. The lower track indicates the model with the lower mass. For identification of the stars, see Table 2.

This research has made use of the SIMBAD, VizieR (Guide Star Catalog 1.2), and Aladin databases, operating at CDS, Strasbourg, France, and of GAUDI, the data archive and access system of the ground-based asteroseismology program of the *COROT* mission. The GAUDI system is maintained by LAEFF, which is part of the Space Science Division of INTA. The authors wish to thank the STARE team for the attribution of observing time to the *COROT* project. The authors also wish to thank G. Handler for useful comments and J. Vialle for the careful proofreading of the first draft of the manuscript. R. A. and J. A. B. acknowledge financial support from grants AyA2001-1571 and ESP2001-

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REFERENCES

- Aerts, C., et al. 1999, *A&A*, 343, 872
 Amado, P. J., Moya, A., Suárez, J. C., Martín-Ruiz, S., Garrido, R., Rodríguez, E., Catala, C., & Goupil, M. J. 2004, *MNRAS*, 352, L11
 Baglin, A., et al. 2002, in First Eddington Workshop on Stellar Structure and Habitable Planet Finding, ed. B. Battrick (ESA SP-485; Noordwijk: ESA), 17
 Bruntt, H., et al. 2002, *A&A*, 389, 345
 Handler, H., & Shobbrook, R. R. 2002, *MNRAS*, 333, 251
 Hauck, B., & Mermilliod, M. 1998, *A&AS*, 129, 431
 Kaye, A. B., Warner, P. B., & Guzik, J. A. 2004, in ASP Conf. Ser. 310, Variable Stars in the Local Group, ed. D. W. Kurtz & K. R. Pollard (San Francisco: ASP), 474
 Kupka, F., & Bruntt, H. 2001, in First *COROT/MONS/MOST* Ground Support Workshop, ed. C. Sterken (Brussels: Vrije Univ.), 39
 Mathias, P., et al. 2004, *A&A*, 417, 189
 Morel, P. 1997, *A&AS*, 124, 597
 Nordström, B., et al. 2004, *A&A*, 418, 989
 Olsen, E. H. 1993, *A&AS*, 102, 89
 Poretti, E., et al. 2003, *A&A*, 406, 203 (Paper I)
 Rogers, N. Y. 1995, *Commun. Asteroseismology*, 78, 1
 Solano, E., et al. 2005, *AJ*, 129, 547
 Suárez, J. C., Goupil, M. J., Michel, E., Dziembowski, W. A., Lebreton, Y., & Morel, P. 2004, in Second Eddington Workshop on Stellar Structure and Habitable Planet Finding, ed. F. Favata, S. Aigrain, & A. Wilson (ESA SP-538; Noordwijk: ESA), 431
 VandenBerg, D. A., & Clem, J. L. 2003, *AJ*, 126, 778
 Vaniček, P. 1971, *Ap&SS*, 12, 10