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New multi-site observations of the δ Scuti stars BS and BT Cancri

Results of the STEPHI VII campaign on the Praesepe cluster

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Abstract. New observations of BS and BT Cnc were performed during the STEPHI VII campaign in 1996 February. An overall run of 115 hours of data was collected. Different methods have been used to analyse the time series, bringing the detection of 2 frequencies for BT Cnc and 3 frequencies for BS Cnc above the 99% confidence level. A comparison with the literature reveals that the dominant mode of BT Cnc ($\sim$ 9.8 c/d) has kept excited over tens of years, while the secondary modes have not been the same all the time. However, during the very last years the two frequencies detected by us have been the only ones noticeably excited in the spectrum.

Key words: stars: oscillations – δ Scu – open clusters and associations: individual : Praesepe – stars: individual: BS Cnc; BT Cnc

1. Introduction

Multi-site observations by means of international networks have produced a revolution in the seismology of δ Scuti stars over the last decade. Several networks have contributed to the improvements of our understanding of these stars. Two of them, STEPHI (Michel et al. 1995) and STACC (Frandsen et al. 1996), have concentrated their efforts mainly on the observations of δ Scuti stars in clusters, where the potential amount of information obtainable is larger.

The Praesepe cluster is probably the best target to study due to its proximity and the large set (14) of δ Scuti stars detected. With this campaign, the STEPHI network (STEllar PHotometry International) completes a sample of 6 δ Scuti stars in this cluster (BN and BU Cnc, Belmonte et al. 1994; BQ and BW Cnc, Álvarez et al. 1998; BS and BT Cnc, this paper) which offers for a first time the opportunity of having so many stars in the same cluster, observed simultaneously from different sites and for a long time (typically 3 weeks). Theoretical work is currently being developed by using this information on different topics, such as the effect of fast rotation on modelling and growth rates versus observations (Michel et al. 1998), joint identification of the possible radial modes present in each star (Hernández et al. 1998c), etc.

In Sect. 2, the target stars and their characteristics are described. Sect. 3 will cover the different observatories involved, the observing programme and data reduction to get the final time series for analysis. The spectral analysis of these data by different methods is shown in Sect. 4. Discussion of results compared to previous publications is presented in Sect. 5. Finally, conclusions are given in Sect. 6.

2. The target stars: BS and BT Cnc

In this 1996 campaign, BS and BT Cnc (HD 73450, KW 154; HD 73575, KW 204, 38 Cnc), two δ Scuti stars belonging to the Praesepe cluster, were chosen as target stars for STEPHI VII. As we have mentioned in the introduction, Praesepe (NGC 2632, M 44; $\alpha_{2000} \sim 8^{\rm h}40^{\rm m}, \delta_{2000} \sim +19°40'$) is potentially one of the most useful clusters in terms of asteroseismology. It is known as a Population I ($0 \lesssim$ [Fe/H] $\lesssim 0.2$; Cayrel de Strobel et al. 1992), intermediate-age open cluster. Recent parallax determinations by *HIPPARCOS* have given a precise value of its distance ($177\pm^{10.3}_{9.2}$ pc; Mermilliod et al. 1997). The age estimates of this cluster depend mainly on the introduction of overshooting proccesses. They range from 500 to 900 Myr without overshooting (Table V, Tsvetkov 1989) to more than 1

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Table 1. Observational properties of the target stars in STEPHI VII.

Star	KW	HD	ST	m_V	$B-V$	$U-B$	$v \sin i$ (km s^{-1})	Period (d)	Ampl. (mmag)
BS Cnc	154	73450	A9V	8.50	0.251	0.072	135	0.051	20
BT Cnc	204	73575	F0III	6.66	0.241	0.159	154	0.11	30
Comp. star	150	73449	A9Vn	7.45	0.255	0.137	235		

Gyr when overshooting is taken into account (Mazzei & Pigatto 1988; Tsvetkov 1993). Correction for rotational effects on the stellar position in the HR diagram due to centrifugal oblateness seems to lead Praesepe to a younger stage, coming back to an age less than 1 Gyr (Michel et al. 1998).

Our two stars represent the two extremes of the evolutionary stages of the Praesepe δ Scuti stars. While BS Cnc remains on the main sequence, in the core hydrogen burning phase, BT Cnc is a rather evolved star leaving the main sequence, if it is not already off, and finishing the hydrogen burning in the core or beginning the shell burning. This uncertainty in the evolutionary stage of BT Cnc is evident in the literature. It is classified as a shell hydrogen burning star by Tsvetkov (1993) with an F0III spectral type (SIMBAD database), while Abt (1986) considers it as an A8IV star. In contrast, no discrepancy is found by the previous authors when classifying BS Cnc as a core hydrogen burning A9V star. These different scenarios for the stellar structure should have a consequence in the distribution of the modes in the spectrum, besides the known trend to lower frequencies when the mean density decreases along the evolution. One of our aims is to confirm this with these new observations, in comparison with previously obtained spectra for other cluster stars.

As a comparison star, we have chosen HD 73449 (KW 150), another cluster star with similar colour (A9Vn) to that of the target stars and located close enough to permit the simultaneous monitoring of all the stars within the field of view of the photometer ($\sim 12'$x$16'$). There are some indications of spectral variability in this star (Wilson & Joy 1950; Treanor 1960), but to the best ot our knowledge no confirmation of this behaviour has been found in the literature. KW 150 has been included in the *New Catalogue of Suspected Variable Stars* (Kholopov 1982) with the number NSV 4163. This catalogue refers the photometric variability of this star from a marginal note in a paper of infrared observations of Praesepe by Eberlein (1962), without any indication of the size of the fluctuations. However, further observations by Breger (1970) found KW 150 stable up to 1 mmag in 2.8 h. Lunar occultations (Peterson & White 1984; Peterson et al. 1989) and speckle interferometry (Mason et al. 1993) discount the possibility of its also being a binary, within the given resolution.

Table 1 shows the observational parameters and nomenclature corresponding to the target and comparison stars. KW nomenclature comes from the proper motion work by Klein-Wassink (1927). Magnitude, colour indices, spectral types and rotational velocities for each star were obtained from the SIMBAD database operated at CDS (Strasbourg, France). The pulsation period and peak-to-peak amplitude of the dominant mode come from Breger (1973). Other observational campaigns on our target stars and their spectral analysis will be discussed in Sect. 5 together with our own results.

3. The observations

The observations in this campaign spanned 1996 February, more specifically, the period February 7–29. As in other STEPHI campaigns, three observatories well distributed in longitude around the Earth were in operation at the same time during the observations. The aim of this cooperation is to suppress systematic gaps in the monitoring of the light curves of our target stars, avoiding the formation of aliasing through side lobes of the spectral window in the Fourier spectrum. These three observatories are: San Pedro Mártir (SPM) in Baja California, Mexico; Xing Long Station (XL) in Beijing, China; and Observatorio del Teide (OT) on Tenerife, Spain. The log of observations for every site is displayed in Table 2. Bad weather conditions at all the sites thwarted observations during February 18–24. Nevertheless, a total amount of 116.8 hours of useful data were collected. Taking into acount overlapping between observatories, this amount is reduced to 115 hours. This gives a duty cycle of 21% during the whole period. This coverage is significantly lower than what is currently obtained with STEPHI ($\sim$40%) due to very poor weather conditions. However, if we consider the data set only from February 7 to 17, the duty cycle increases to 35%. The better coverage in this period implies a better spectral window in the Fourier spectrum, so in Sect. 4.1.1 we will carry out a complementary analysis with these data in addition to the whole campaign analysis.

The observational procedure was the same as in the previous campaigns (for a description, see Álvarez et al. 1998). Four-channel photometers were used at each site. Three of the channels were employed to monitor the stars (targets and comparison), while the fourth channel was devoted to measure the adjacent sky. Interferometric blue filters ($\lambda \sim 4200$ Å, $\Delta\lambda \sim 190$ Å) were implemented individually in each channel. In one of the sites (OT), no filter was used because they were accidentally damaged at the beginning of the observations. Potential effects, due to this non-uniformity in the filter system, on the final detected frequencies will be discussed in Sect. 4.2. As a novelty, simultaneously with the observations, temperature measurements inside the photometer were made automatically to determine the potential effects of temperature changes in the efficiency of the detectors. At the level of precision of the thermometer (± 0.05

Table 2. Log of observations. Observing time is expressed in minutes for each site.

Day	Date 1996	SPM	XL	OT	
1	Feb 7		210		
2	Feb 8	323 [a]	401		
3	Feb 9	341 [a]	411		
4	Feb 10		251		
5	Feb 11	93	407	268	
6	Feb 12	32	153	327	
7	Feb 13		197	379	
8	Feb 14		84	90 [b]	
9	Feb 15	449 [a]	487		
10	Feb 16	68			
11	Feb 17	135		322	
12 to 18	Feb 18–24				
19	Feb 25	400			
20	Feb 26			217	
21	Feb 27			299	
22	Feb 28			355	
23	Feb 29			308	
Total	Feb 7–29	1841	2601	2565	7007
	Feb 7–17	1441	2601	1386	5428

Total observing time: 116.8 h.
Overlap during the observations: 1.8 h.

[a] Overlap between SPM and XL observations.
[b] Overlap between OT and SPM observations.

K), no correlation was found between the fluctuations in the efficiency of the instruments and the temperature.

The original light curves were obtained after removing bad points (clouds, electronical malfunctions, pointing and guiding problems, etc) and subtracting the sky background from each channel. Light curves were expressed in differential form to avoid the major part of the extinction effects. In this way, we produced three curves in magnitudes: BS-Comp, BT-Comp and BT-BS. This last curve allows us to detect possible frequency peaks not intrinsic to the target stars in the two first light curves. A least-squares fit to a parabola is then applied and subtracted from every light curve each night. This is done in order to remove additional low-frequency trends which can affect the detection of the oscillation modes at higher frequencies, through the side lobes of these low-frequency peaks. In the cases of nights with a small number of points, the mean is used instead. Finally, the mean of the residuals is subtracted for each night in each curve, deriving the definitive time series. Overlap between sites is handled by making the mean between the common data.

4. Frequency analysis of the time series

4.1. Comparative analysis of different methods

Different methods have been used to obtain the Fourier amplitude spectrum of the time series previously derived in Sect. 3. In our case, iterative sine wave fitting (ISWF), ISWF with statistical weights and the MUFRAN (MUlti FRequency ANalysis) packages were used for this purpose. We will discuss now the results achieved with each method.

4.1.1. ISWF

For the ISWF method we will follow the same procedure as that used in Álvarez et al. (1998), fitting the light curve to a sinusoidal function, $A\cos(2\pi\nu t - \phi)$, for a given set of frequencies, ν, in the range of interest.

The spectral window corresponding to our observations using ISWF is shown in Fig. 1a. A large reduction of the side lobes is reached by the use of the three observatories, obtaining a 1-day alias of only 31% of the main lobe amplitude. We will consider the resolution in frequency, $\Delta\nu$, as the FWHM of the main lobe, which in this case is 0.63 μHz.

The spectra of the three light curves obtained through this method are given in Fig. 2. A 99% confidence level is applied to each spectrum, extracting the frequencies we will consider intrinsic to the global oscillations of the target stars. As is explained in Álvarez et al. (1998), we will apply the prewhitening method in which the frequency peaks above this confidence level are selected and subtracted iteratively from the original time series until the whole spectrum is below this level.

In the reference mentioned above, it was demonstrated that the 3.7 times the mean noise level in the spectrum derived in boxes of 100 μHz can represent very fairly the 99% confidence level given by statistical tests, such as Fisher's (Fisher 1929; Nowroozi 1967; Koen 1990) or Scargle's test (Scargle 1982). This makes the application of these tests easier and will therefore be applied to get the set of detected frequencies for all the methods discussed in Sect. 4.1. From the confidence level, it can be seen that the noise in our spectra is not white but rather has a typical $1/f$-noise behaviour truncated at lower frequencies by the parabola fit. In fact, for BT Cnc the mean noise level at 200 μHz is 530 μmag and 200 μmag at 600 μHz. For BS Cnc, this level reaches 530 μmag and 190 μmag at the same frequencies, respectively.

Table 3 gives the detected frequencies with their corresponding amplitudes and phases for each light curve. It can be seen that for the series BT-BS the set of detected frequencies is essentially the combination of those detected in the other series with the comparison star. Amplitudes are very similar while the phases for the common frequencies between the series BT-BS and BS-Comp logically differs by π radians since the contribution of BS to the series BT-BS is preceded by a minus sign.

The peak at 481.8 μHz present in BS Cnc was not found above the 3.7-mean-noise level in the BT-BS curve. To determine whether this peak could be intrinsic to the comparison star rather than to the target one, close inspection at that frequency in the curves BT-Comp and BT-BS was made. The peak was found in the BT-BS curve but with a smaller significance (S/N$\sim$3) and similar phase, while no indication was obtained from BT-Comp, thereby discounting its origin in the comparison star. The peak at 398.2 μHz in BT-BS was found at the limit of the detection level, so interference from nearby peaks or slight increases in the

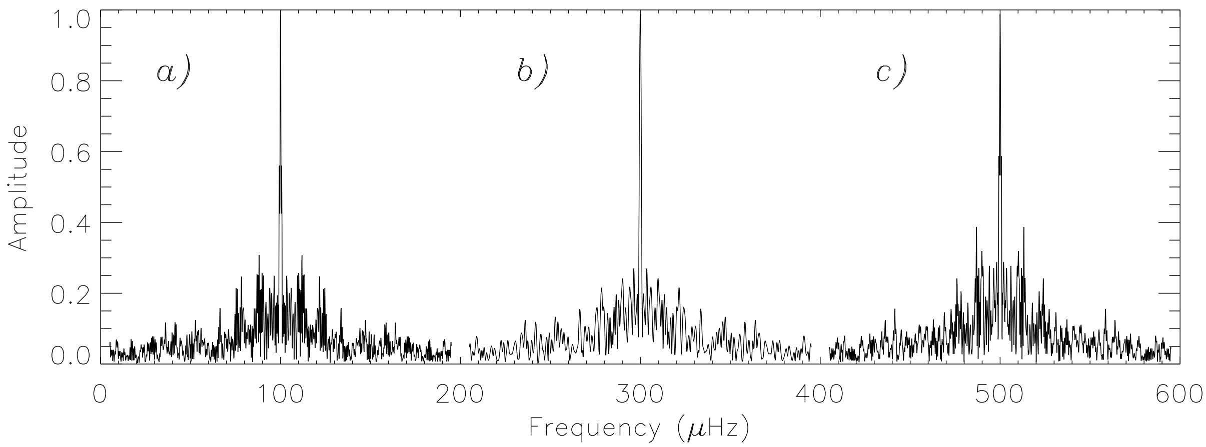

Fig. 1a–c. Spectral windows belonging to: **a** whole series (February 7–29) using ISWF, **b** short series (February 7–17) using ISWF and **c** whole series using ISWF with statistical weights.

noise level can place it below the detection level in other curves. The fact of having peaks above the 99% confidence level in one curve and not in the other, just demonstrates the uncertainty in amplitude of such peaks and is especially important in cases of low S/N.

As we mentioned in Sect. 3, there is a gap of seven days (February 18–24) with no data during the observations. A new inspection to the spectrum using only the data previous to this gap (February 7–17) will allow a better duty cycle (35%) and, therefore, a reduction of the side lobes (1-day alias at 24% of the main lobe amplitude, see Fig. 1b) while the frequency resolution, $\Delta\nu$, will approximately double (1.36 μHz) the resolution for the whole campaign. In our case, this new inspection just confirms the frequencies detected with the whole set of data, as is shown in Table 3. Since the number of points is smaller in this new set of data, the noise level present in the spectra increases. For instance, the mean noise level at 200 and 600 μHz is 600 and 240 μmag for BT Cnc, and 590 and 220 μmag for BS Cnc, respectively. This puts the peaks at 396.2 and 398.2 μHz below the 99% confidence level in the BS-Comp and BT-BS curves. The peak at 481.8 μHz in BS Cnc is also found in this shorter serie of the BT-BS curve, but with a lower significance.

4.1.2. ISWF with statistical weights

In the previous section, all the points had the same importance in the calculation of the frequency spectrum. Statistically, this means that we have attached a weight equal to one to all the points. In this section we will include the results of using the ISWF with statistical weights in BS Cnc as an example.

To each data point has been assigned a statistical weight according to its quality, calculating a weighted sine wave fit (Frandsen et al. 1995) to each light curve. The weight of each data point is calculated as the inverse of the local variance measured in a high-pass filtered time series. In this way, the weights are calculated in a part of the spectrum where no signal is expected. In some cases, a re-scaling of these weights is implemented to take into account the different qualities of the observing nights. For more details of this method, we refer to Arentoft et al. (1998) where it has been applied to the two stars observed in the STEPHI IV campaign, BN and BU Cnc.

One of the features of this method is that it offers a lower noise level, mainly at low frequencies, and a flatter spectrum (see Fig. 3), since it weights the good-quality data more, ignoring the noisier segments of the light curve. The mean noise levels at 200 and 600 μHz are 390 and 140 μmag, respectively. This represents a reduction of about 25% in the noise level with respect to the spectrum obtained in Sect. 4.1.1 at these frequencies. Just by chance, this reduction is the same at both frequencies. In contrast, the spectral window is deteriorated because the low-weighted data can be considered almost as data omitted from the analysis, and therefore new gaps are produced. Fig. 1c shows that the side lobes are slightly increased (39% of the main lobe), and that the peak width is enlarged (1.55 μHz). Consequently, this method is more powerful in time series where the data quality throughout the series changes considerably (an example of this can be seen in Arentoft et al. 1998). In our case, the effect is not so relevant since the quality of the data is more uniform throughout the campaign. The modes detected above the 99% confidence level in BS Cnc are also shown in Table 3. Same peaks as in Sect. 4.1.1 are found above the 3.7-mean-noise level, except for the p eak at 396.2 μHz which is now found with a slightly smaller S/N of 3.5.

4.1.3. MUFRAN

The MUFRAN package (MUlti FRequency ANalysis) consists of a set of programs for period determinations in observational light curves with graphics routines for the visualization of the results. At each step, all previous frequencies were computed and successive prewhitening was avoided. This package was developed at the Konkoly Observatory in Hungary by Kolláth (1990) and introduced for our purpose by one of us (M.P.). For more details about its application, see, for example, Paparó et al. (1996).

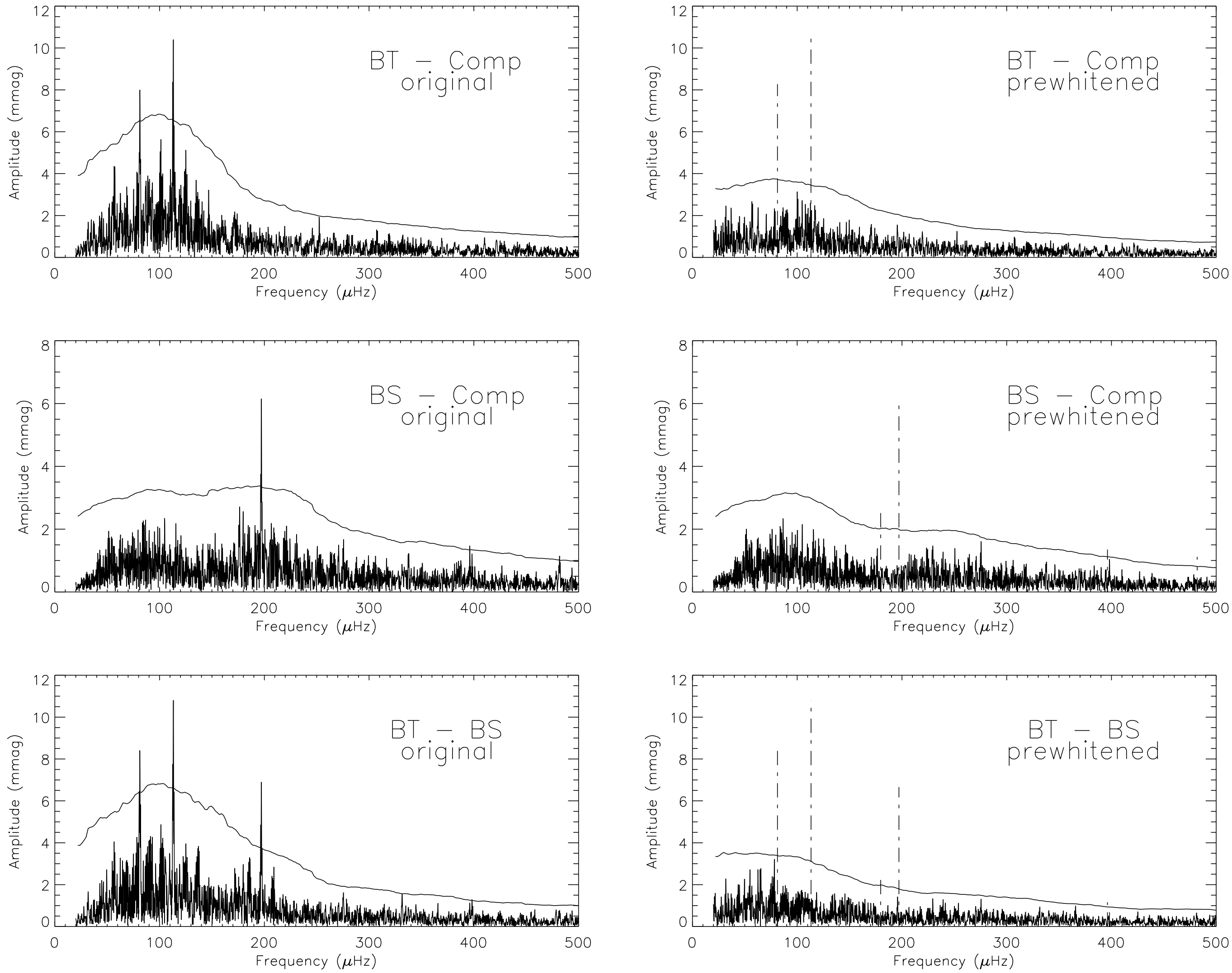

Fig. 2. Left: original spectra of the three light curves under study. Right: the prewhitened spectra after removing all the peaks above the 99% confidence level (solid line). Frequencies detected (two, four and six from upper to lower panel, see Table 3) are indicated with dot-dashed lines. Whole series and ISWF method was used.

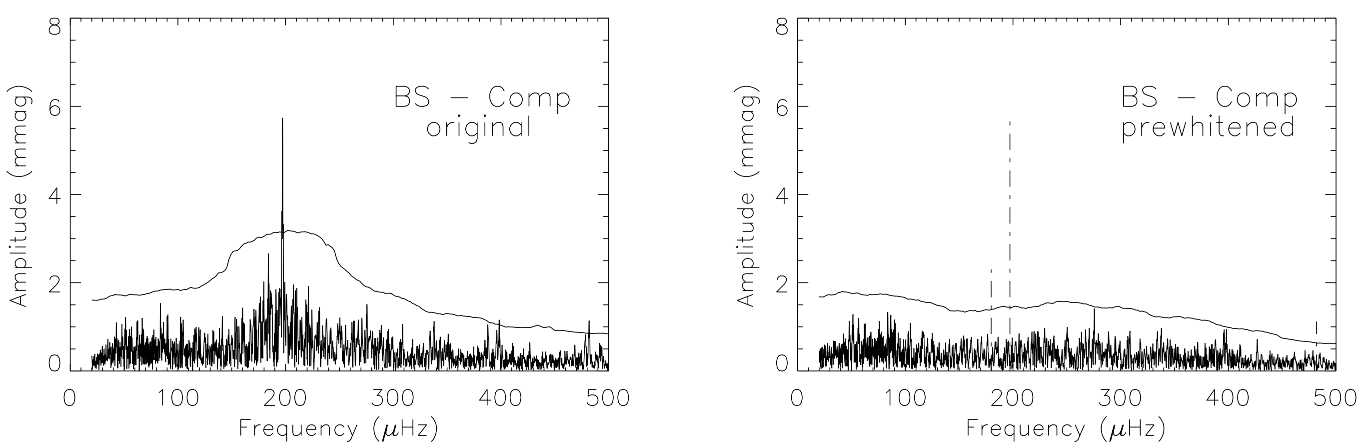

Fig. 3. Same as Fig. 2 for BS-Comp analysed with the ISWF method using statistical weights. Note the noise reduction at low frequencies compared to the same spectrum in Fig. 2.

Table 3. Frequencies detected in the three light curves (BT-Comp, BS-Comp, BT-BS) above a 99% confidence level by different methods. For the ISWF method, a shorter data set with a better duty cycle is also considered. The signal-to-noise ratio is calculated from the prewhitened spectra. The origin of ϕ is at HJD 2450132.0.

	ISWF						ISWF + stat. weights		MUFRAN	
	Whole data set (Feb 7–29)				Short data set (Feb 7–17)		Whole data set		Whole data set	
Series	ν (μHz)	A (mmag)	ϕ (rad)	S/N	ν (μHz)	A (mmag)	ν (μHz)	A (mmag)	ν (μHz)	A (mmag)
BT Cnc–Comp	113.156	10.552	–2.093	11.3	113.050	9.378			113.165	10.93
	81.196	8.275	+2.540	8.2	81.139	8.961			81.187	8.39
BS Cnc–Comp	197.167	6.141	–0.041	11.4	197.088	6.154	197.167	5.772	197.181	6.30
	179.683	2.676	+0.228	4.9	179.692	2.642	179.675	2.303	179.683	2.73
	481.829	1.116	–1.300	5.1	481.783	1.122	481.797	1.121	481.829	1.07
	396.165	1.353	+2.659	4.5					396.164	1.34
BT Cnc–BS Cnc	113.177	10.792	–2.133	12.8	113.113	10.531			113.188	10.86
	81.187	8.574	+2.537	9.4	81.081	8.507			81.183	8.59
	197.167	6.658	–3.097	13.7	197.133	6.310			197.166	6.77
	179.712	2.459	–2.989	4.6	179.848	2.557			179.725	2.50
	396.181	1.159	–0.673	4.6					396.162	1.19
	398.187	1.002	–0.141	4.0						

Table 4. Comparison between the parameters obtained from the whole series for BT-Comp and BS-Comp and those belonging to split subseries (OT and SPM-XL) to measure the effect of not using filters at the OT. Errors estimates in frequency and phase are indicated between parentheses. The phase origin is the same as in Table 3.

BT Cnc	ν (μHz)	A (mmag)	ϕ (rad)	ν (μHz)	A (mmag)	ϕ (rad)
OT	113.166 (0.009)	11.188	–2.086 (0.030)	81.215 (0.010)	8.129	+2.449 (0.002)
SPM-XL	113.134 (0.007)	9.967	–1.981 (0.025)	81.148 (0.006)	8.595	+2.744 (0.019)
Whole series	113.156 (0.004)	10.552	–2.093 (0.004)	81.196 (0.004)	8.275	+2.540 (0.009)

BS Cnc	ν (μHz)	A (mmag)	ϕ (rad)	ν (μHz)	A (mmag)	ϕ (rad)	ν (μHz)	A (mmag)	ϕ (rad)	ν (μHz)	A (mmag)	ϕ (rad)
OT	197.224 (0.011)	6.982	+0.161 (0.016)	179.702 (0.030)	2.582	+0.265 (0.060)	481.841 (0.086)	0.907	–1.169 (0.253)	396.181 (0.039)	1.960	+2.770 (0.070)
SPM-XL	197.167 (0.008)	5.911	–0.138 (0.026)	179.673 (0.018)	2.647	+0.280 (0.054)	481.876 (0.037)	1.246	–1.517 (0.134)	396.165 (0.049)	0.949	+2.548 (0.127)
Whole series	197.167 (0.006)	6.141	–0.041 (0.008)	179.683 (0.012)	2.676	+0.228 (0.016)	481.829 (0.029)	1.116	–1.300 (0.049)	396.165 (0.024)	1.353	+2.659 (0.004)

In Table 3, the modes detected by using this package are listed, confirming the previous estimates with ISWF, both with and without statistical weights.

After these comparisons, we will consider as definitive only the frequencies above the 99% confidence level for each target star if they are found in both the curve with the comparison star and the BT-BS curve, using the whole data set analysed by ISWF. That is, 113.2 and 81.2 μHz for BT Cnc, and 197.2, 179.7 and 396.2 μHz for BS Cnc. The peak at 481.8 μHz in BS Cnc is considered as possible.

4.2. *Effect of using different filters in the same time series*

As mentioned in Sect. 3, filters were unavailable for the observations on Tenerife (OT). In principle, this might imply a change in phase and amplitude with respect to the observations at the other observatories (Stamford & Watson 1981; Watson 1988), while the oscillation frequency should remain the same. The change in amplitude and phase will obviously depend on the difference in the spectral response of the optical system (mirror, filter, detector, etc) with and without filter. In Sect. 4.1, the time series analysed include this inhomogeneity. To have an estimate of the potential effect of this mixing in the results shown in Table 3, we have split the whole time series into two parts: in the first we used filters (SPM and XL), and in the other no filters were used (OT). These two subseries have been analysed separately in order to compare the results. Of course, the spectral window of each subseries will be much worse than that derived from the whole campaign. This fact would make the detection of the real frequencies among the aliases more difficult if no information from the global analysis was given, especially for the OT subseries with only one site. Since the effect on the frequency is expected to be small, we will search in the spectra of the subseries around the frequencies detected in the global analysis. In Table 4, the results for each subseries, coming from the curves BT-Comp and BS-Comp, are listed. They have been analysed following the procedure described in Sect. 4.1.1 except for the confidence level application to extract the frequencies. Amplitude, frequency and phase at the same origin of time as for the whole series are shown for each mode.

Rough estimates of errors in frequency are derived following Kovács (1981) and Horne & Baliunas (1986) for evenly spaced time series with a single mode and white noise. These values are merely indicative of the error size and probably underestimate it. Errors in phase were calculated from the phases corresponding to the edges of the errors in frequency. As was to be expected, no significant differences were found between the frequencies detected in the split subseries and those in the whole series (mean absolute difference of 0.022 μHz). Neither was any systematic trend found in the amplitudes for each subseries.

Apart from the spectral response of the optical system, the differences in phase will also depend on the observational characteristics of the star and its atmosphere, and on the angular degree, l, of the oscillation (Watson 1988). The mean phase separation between the split subseries is not large (0.214 radians) but is well above the typical uncertainty displayed in Table 4, so it might possibly be due to the inhomogeneity in the filter system.

In any case, it can be concluded that the results belonging to the subseries separately are very close in all aspects, and that the final determination of frequency, amplitude and phase for the whole series is not strongly affected by the absence of a filter at the OT.

5. Discussion of results

In this section, we will compare our results with those reported in previous publications. The quantity of literature on these two stars and related topics has hitherto been modest, and the results have been often contradictory. This campaign has been the most extensive in terms of the time, data points and observatories involved, working on BS and BT Cnc, so we expect to throw light on the better determination of the frequency spectra of these stars.

5.1. BT Cnc

First detection of variability in BT Cnc was reported by Breger (1970); pulsation period and V amplitude were published later (Breger 1973; see Table 1). This is well within the period of the modes detected by us for this star ($P_1 = 0.102284$ d, $\nu_1 = 9.77668$ c/d; $P_2 = 0.142545$ d, $\nu_2 = 7.01533$ c/d). Gupta & Bhatnagar (1974) gave a peak-to peak amplitude of 0.07 mag in B and a period of 0.108 d after one night of observations. Some years after, Guerrero et al. (1979, hereafter GMS) merged twelve observing nights from one site in Johnson UBV filters with the four nights already reported by Guerrero (1975) and they got three frequencies at 7.14417, 7.17378 and 9.77704 c/d. They catalogued them as non-radial modes after negative comparison with period ratios, pulsation constants, Q, and P-L-C relations.

Breger (1980) re-analysed the data set obtained by GMS with a multiple-frequency, non-linear, least-squares fit. He found a different set of frequencies, except for the dominant mode: 9.77713, 7.8811 and 5.9465 c/d. This frequency set reduced slightly more the dispersion of the residuals in each filter, not only in the GMS data but also in his own data from 1970. Surprisingly, on this occasion the three frequencies were identified as radial modes (2H, 1H and F, respectively) through period ratios and pulsation constants obtained from suitable models.

Freyhammer et al. (1997) made new CCD observations in the B filter and found two modes at 9.783 and 7.005 c/d, in very good agreement with our results, within the resolution given by the three nights of observations. In fact, they compare their results with a preliminary list of ours (Hernández et al. 1998a). They also find that Breger's frequency set does not fit their measurements. The period ratio indicates a possible pair of radial modes, 2H and 4H, but without taking into account rotational effects on the frequency. This is implemented in a latter work by Hernández et al. (1998b), where rotational effects on pulsation frequency and on position in the HR diagram are considered. Hernández et al. (1998b) arrived at the same identification, valid for a rotation rate of 11-12 μHz.

Peña et al. (1998) reported a new spectral analysis for BT Cnc by comparing several methods. 10 nights of observations in Johnson V and Strömgren filters made in 1982, 1985 and 1997 from different sites were included in the analysis. Frequency determinations in different sets of data differ substantially except for the dominant mode (~ 9.8 c/d). Discrepancies are also found between the different methods analysing the same data set, except in the mentioned mode. Adding GMS to their data, they find that the dominant frequency by itself reproduce the whole set of observations better than any frequency set determined in any subset. A final frequency of 9.78007 c/d is reported.

The aforementioned comments reveal a poor current understanding of the pulsation modes of this star. Even considering the uncertainties in the frequency determination of previous observations, the spectrum of noticeably excited frequencies in BT Cnc seems to have changed over recent decades. This is probably due to the different S/N ratio of the excited modes reached in each observing period. Our work, together with Freyhammer et al. (1997), confirms a stability in the detected frequencies in the last few years, but not in the amplitudes reported. The finding of the same dominant mode during all the observing periods is the reason of the conclusion made by Peña et al. (1998) but, as we have confirmed beyond doubt, there are at least two modes excited in the spectrum of BT Cnc. In fact, the correlation factor found by them (0.78), for the largest series analysed, gives room enough for the presence of secondary modes which have changed over time.

5.2. BS Cnc

To the best of our knowledge, there is no new information about frequency detection in this star after Breger's first report (1973) except for the very recent communication by Peña et al. (1998) who report new measurements on BS Cnc, indicating the presence of two modes at 17.03 and 16.30 c/d. The first agrees with our dominant mode for BS Cnc in Table 3 (17.03523 c/d), while the second could be a 1-day alias of our second dominant mode (15.52461 c/d). In any case, the spectral resolution reached and the S/N ratio obtained by us offer a conclusive solution of at least 3 modes oscillating in this star.

6. Conclusions

BS and BT Cnc, two stars belonging to the Praesepe cluster, were the target stars of the seventh STEPHI campaign during 1996 February. This completes a sample of six Praesepe stars at different evolutionary stages observed by the STEPHI network. This sample tries to provide the largest possible amount of material to establish a better knowledge of the Praesepe cluster by means of asteroseismology. A duty cycle of 21.3% is reached in the whole campaign, representing a global run of 115 hours. This coverage is significantly lower than what is currently obtained with STEPHI ($\sim$40%) due to very poor weather conditions.

The three light curves derived (BT-Comp, BS-Comp and BT-BS) have been analysed by different methods: ISWF (Iterative Sine Wave Fitting), ISWF with statistical weights and MUFRAN (MUlti FRequency ANalysis). Two frequencies for BT Cnc and three frequencies for BS Cnc were confirmed above confidence level of 99%. Potential effects of the absence of a filter at the OT has been shown to be negligible in our final results.

Comparison with previous sources confirms BT Cnc as a star whose spectrum of noticeably excited frequencies has changed over tens of years, with a dominant mode around 9.8 c/d (113 μHz) present in all the observing periods. Our results, together with those of Freyhammer et al. (1997), show a stability in the detected frequencies in recent years. This latter work and Hernández et al. (1998b), which take into account rotational effects, identify them as a possible pair of radial modes, 2H and 4H.

The distribution of the modes in the spectrum follows the trend shown in Belmonte et al. (1997), where less massive stars present a spread frequency spectrum while the modes of the more massive stars are grouped into a narrower range at lower frequencies.

Theoretical work making use of this sample of six Praesepe stars is currently being undertaken (see Michel et al. 1998, Hernández et al. 1998c).

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