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Pulsational frequencies of the eclipsing δ Scuti star HD 172189. Results of the STEPHI XIII campaign⋆

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ABSTRACT

Context. The eclipsing δ Scuti star HD 172189 is a probable member of the open cluster IC 4756 and a promising candidate target for the CoRoT mission.

Aims. The detection of pulsation modes is the first step in the asteroseismological study of the star. Further, the calculation of the orbital parameters of the binary system allows us to make a dynamical determination of the mass of the star, which works as an important constraint to test and calibrate the asteroseismological models.

Methods. We performed a detailed frequency analysis of 210 hours of photometric data of HD 172189 obtained from the STEPHI XIII campaign⋆⋆.

Results. We have identified six pulsation frequencies with a confidence level of 99% and a seventh with a 65% confidence level of 65%, in the range between 100−300 μHz. In addiction, three eclipses were observed during the campaign, allowing us to improve the determination of the orbital period of the system.

Key words. stars: oscillations – stars: variables: δ Sct – stars: binaries: eclipsing – stars: individual: HD 172189

1. Introduction

HD 172189 (IC 4756 93 = SAO 123754) is a binary star of visual magnitude $m_V = 8.85$ and spectral type A2 ($\alpha_{2000} = 18^h38^m37.554^s$, $\delta_{2000} = +05°27'55.34''$) in the galactic cluster IC 4756. Recently, Martín-Ruiz et al. (2005) (M-R, hereafter) showed that HD 172189 is an eclipsing binary star with an orbital period of 5.71 days and with δ Scuti-type pulsations with a clear frequency of 19.5974 cd^{-1} (226.8 μHz), and evidence of more modes in the range 208−232 μHz.

The δ Scuti variables are stars with masses from 1.5 to 2.5 $M_\odot$, located at the intersection of the lower part of the classical Cepheid instability strip with the main sequence. They consist of main sequence objects, pre-main sequence ones, and also objects that have evolved off the main sequence, in the hydrogen shell burning phase. Most of the δ Scuti stars are multiperiodic, with frequencies between 50 and 600 μHz. The pulsation modes are radial as well as non-radial due to κ-mechanism associated with the zone where He is partially ionized. Thus, δ Scuti stars provide a good opportunity to apply asteroseismology and study key mechanisms at work in the main sequence stage, among which are transport of angular momentum, transport of chemical species at the edge of convective cores (overshooting), and large-scale circulations.

A few weeks of observations are usually required to resolve their rich spectra, often showing close pairs of peaks with a spacing of ∼0.5 μHz. Three week-long multisite observational campaigns are regularly organized within the STEPHI network (Michel et al. 1992, 2000), trying to minimize the problem of missing data due to the day-night cycle, which induces strong side lobes of the spectral window in the Fourier spectrum.

The frequency analysis of HD 172189 shows that it is a δ Scuti with at least six pulsation frequencies. Eclipses that occurred during the campaign were observed, allowing us to refine the period of the binary system.

The star HD 172189 was found to be a "likely member" of the open cluster IC 4756 by Kopff (1943). Herzog et al. (1975) updated the results of a previous work of Seggewiss (1968), concluded that the probability of the membership to the cluster for HD 172189, based on its proper motion alone, is 92%. Missana & Missana (1995) re-studied the cluster IC 4756, estimating the probability of membership of each stars and arrived to a similar result for the case of HD 172189: 95% of probability of being a member of the cluster.

The interest of pulsating stars in cluster and/or in well characterized binaries for asteroseismology studies has been stressed for long and by several authors. As mentioned in a recent review by Aerts (2006) (see also Aerts & Harmanec 2004), beside the perspective to study processes specific to binarity, like the influence of tidal forces on angular momentum transport or eventual mass transfer, the possibility to determine precisely global parameters (like individual masses, radii, chemical composition or age) allows to reduce significantly the parameters space to

⋆ Table 1 is only available in electronic form at http://www.aanda.org

⋆⋆ The HD 172189 reduced light curves are available in the CDS via anonymous ftp to cdsarc.u-strasbg.fr (130.79.128.5) or via http://cdsweb.u-strasbg.fr/cgi-bin/qcat?J/A+A/468/637 explore in the necessary stellar modeling work. The seismic interpretation is thus expected to become more constraining in terms of diagnostics on physical processes.

In this spirit, Brown et al. (1994) applied singular value deconvolution technique to study the relative impact of precision on eigenfrequencies and global parameters in the illustrative case of two solar-like pulsators in a visual binary. They considered the optimal case of the close Alpha Cen binary. Their conclusions necessarily remained theoretical, since no oscillations were detected at that time neither in Alpha Cen A nor in Alpha Cen B. But this seminal work found a great development in Miglio & Montalbán (2005) where an optimization using Levenberg-Marquardt algorithm is applied to Alpha Cen A+B, considering all available observables, including oscillation frequencies now detected in both objects. This work confirms that satisfying all the observables with present physical assumptions is becoming more and more challenging and ineluctably leads to question the description of key-physical processes like mixing length theory versus full spectrum theory. Miglio and Montalbán however conclude that the present seismic data do not allow to go further and discriminate between different physical options for the equation of state or element diffusion descriptions.

In the specific case of δ Scuti stars, Creevey et al. (2006) proposed to develop the approach of Brown et al. (1994), in the specific case of eclipsing binaries featuring a δ Scuti. Their work is however, so far limited only to non seismic observables.

A few δ Scuti pulsators in eclipsing binaries have already been intensively searched for oscillations. For RZ Cas and AB Cas (Rodríguez et al. 2004a,b), these observations only brought one oscillation frequency, and they did not lead to a seismic interpretation so far. RS Cha is another example of eclipsing binary featuring pre-main sequence objects, one of them showing δ Scuti type oscillations (Alecian et al. 2006). Recently, new observations have been organized successfully, showing apparent multiperiodicity of both component (Bohm et al. In prep.).

The fact that HD 172189 is a δ Scuti star and at the same time a binary system and a member of the open cluster IC 4756 makes it a very interesting target for the CoRoT mission.

2. The observations

The STEPHI campaigns include three observatories around the world: Observatorio del Teide (Izaña, Tenerife Island, Spain), Observatorio Astronómico Nacional de San Pedro Mártir (Baja California, Mexico) and the Xinglong Station of the Beijing Observatory (China). The observations were carried out for 21 days over the period 7–28 June 2004. The B9 star HD 172248 (IC 4756 117 = SAO 123762) was used as the primary comparison star (comp1) with a brightness of $m_V = 8.91$. Two secondary comparison stars (comp2) were observed: IC 4756 142 at the Mexican observatory and IC 4756 115 at the Spanish observatory. The first one is an A3 star with $m_V = 9.51$ while the latter is a star of spectral type G0 with $m_V = 10.43$.

We used a four-channel Chevreton photometer at each site. Three of the channels are employed to monitor the stars (target + comparison 1 + comparison 2), and the fourth channel is devoted to measuring the sky level.

A total of 210 h of photometric data were obtained during the 21 days of the campaign. The integration time was 1 second. This corresponds to a duty cycle of 40% which is typical for the STEPHI campaigns.

A log of the campaign is given in Table 1. The digits in the data set names (in the first column) indicate the date of the start of the observations and the two last letters indicate the site of observation: XL = Xinglong, ZN = Obs. del Teide (Izaña), and SP = San Pedro Mártir. Hereafter, we will use these three abbreviations to represent the three sites. Column 2 gives the UT date at the start of the observations and Cols. 3 and 4 give the HJD time (Heliocentric Julian Date) at the start and end of the observations. The last two columns show the number of useful measurements and the observation length (in hours). The coverage diagram of the campaign is shown in Fig. 1. The letters in the top of the figure indicate the positions of the observations from the three sites. The rectangular strips represent the duration (in hours) of the observations in relation to 0h UT of the date in the vertical axis. The diagram was made this way to be consistent with Table 1. Note that the observations from each site are aligned inside the same approximate range of time. The times of minimum of the primary eclipses discussed in Sect. 5 are indicated in the figure.

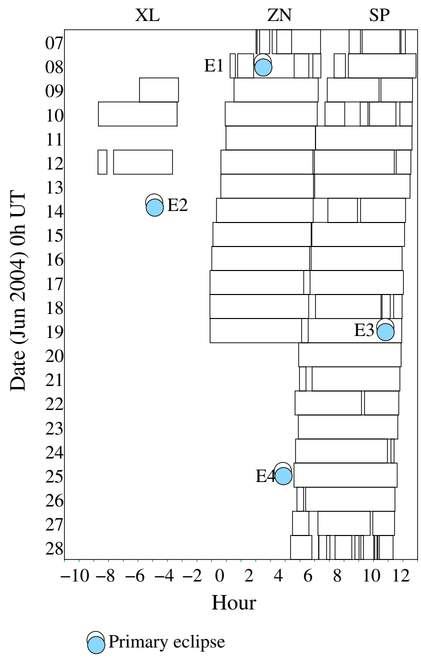

Fig. 1. Coverage diagram of the STEPHI XIII campaign. Each rectangular strip represents a night of observation. The labels XL, ZN and SP indicate the three observatories. The total number of hours of photometric data is 210 with an effective coverage of 40%. The times of minimum of the primary eclipses are indicated by E1, E2, E3 and E4.

3. Data reduction

The data reduction followed similar steps as reported in previous STEPHI campaigns (see, for instance, Hernandez et al. 1998). We start with the inspection of the light curve and, when necessary, elimination of bad points and anomalous parts of the dataset (including the parts where the eclipses are occurring). In the second step we proceed to the calibration using measurements of the sky background simultaneously taken by all the four channels, usually taken at the beginning and at the end of the observations. The third step is the subtraction of the sky background. The measurements of the sky background are subtracted from the light curve of each channel. However, due to technical problems, in this campaign the photometer sky channel could not be used for the sky monitoring on some nights. The fourth step is the division of the light curve of the variable star (var) by the primary comparison star light curve, var/comp1, and by the secondary comparison star light curve, var/comp2. The

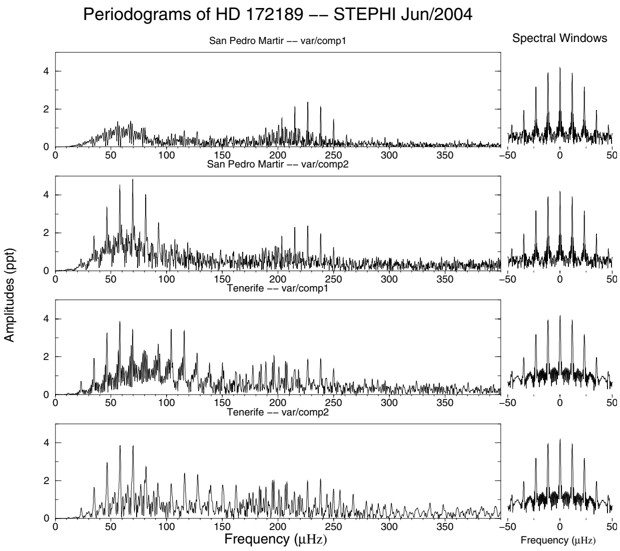

Fig. 2. Periodograms of the one-site light curves of var/comp1 and var/comp2 for the San Pedro Mártir and Tenerife data. In the right side are shown the respective one-site spectral windows.

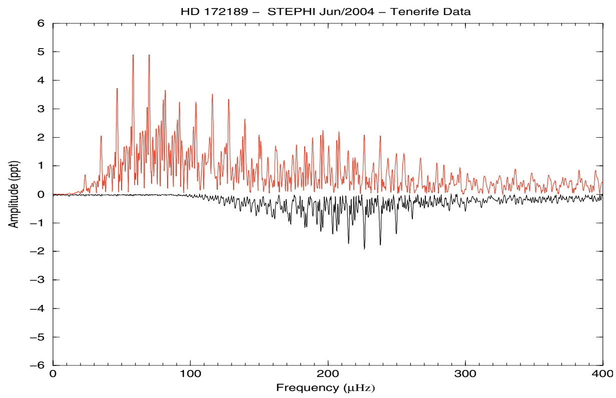

Fig. 3. Periodograms of the Tenerife data obtained with polynomial fitting of order 2 (*top*) and order 3 (*bottom*).

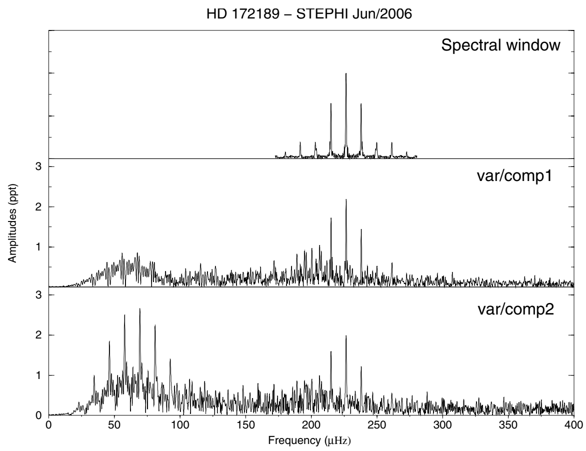

Fig. 4. Spectral window (*top*) and periodograms of the whole light curves of HD 172189 of var/comp1 (*middle*) and var/comp2 (*bottom*).

purpose of this step is to minimize the effect of changes in the sky transparency on long time scales.

In order to remove low-frequency trends which affect the detection of pulsation modes, the next step is to fit and subtract a polynomial of low-order (order ≤2) from the light curve. The last step is to divide the whole light curve by the average value and subtract 1. The resulting light curve is the relative variation in the magnitude of the star in relation to its mean magnitude. Most of the light curves show maximum variations around 0.05 mag, which corresponds to ~5% relative to the mean intensity. Finally, all times are converted to heliocentric Julian dates (HJD).

4. Frequency analysis

In Fig. 2 we show the periodograms of the light curves of var/comp1 and var/comp2 for San Pedro Mártir and Tenerife data sets for the range of 0–400 μHz with amplitudes given in ppt (part per thousand). The respective spectral windows are shown on the right side.

To our surprise, the periodogram of the light curve of the Tenerife data shows the presence of a series of at least 12 harmonics of the frequency of 1 cd^{-1} ($f_{\rm d}$ = 11.605 μHz). This is not the case for the San Pedro Mártir data, although the reduction procedure is the same for the two data sets. We discarded the possibility of these harmonics being an artifact of an electronic problem in one of the channels because they are present in the periodograms of the light curves of var/comp1, var/comp2 and comp2/comp1. The harmonics, perhaps, are resulting of an occasional change in the sky transparency at Izaña during the campaign.

In the periodogram of the SP light curve var/comp1, we can clearly see peaks of pulsation modes with high amplitudes and frequencies within the range 150–300 μHz, completely separated from the bump of peaks of low frequencies (f < 150 μHz). The same peaks appear in the periodogram of the light curve of var/comp2 of the same site, proving that they are related to the target star and not to the comparison star. The difference between the relative heights of the bumps in the two cases can be explained by the difference in spectral type: the variable star HD 172189 is an A2 star and the first comparison star (comp1) is of spectral class B9, while the second one (comp2) is a G0 star.

The presence of the harmonics complicates the identification of the peaks of pulsation frequencies in the spectrum. We tried a new modification in the data reduction procedure: we fitted and subtracted a polynomial of order three (instead of order two) from the Tenerife data from each night. This procedure was effective in eliminating all the peaks with high amplitude in the low-frequency region of the periodograms (0–100 μHz) and the harmonics of the frequency of the day, without any apparent effect over the peaks with higher amplitude in the pulsation range of frequencies (100–300 μHz) as can be seen in Fig. 3.

In Fig. 4 we show the spectral window (top) and the periodograms of the whole light curve (ZN + SP + XL) of var/comp1 (middle) and var/comp2 (bottom), where we can see the presence of pulsation modes in both cases. The central peak of the spectral window was arbitrarily positioned to coincide with the position of the highest peak in the periodogram. The *FWHM* of the central peak is 0.54 μHz and the two nearest sidelobes have ~40% of its amplitude. All subsequent sidelobes have heights below ~4% of the amplitude of the central peak. The pulsation frequencies appear in both periodograms, in the range 150–250 μHz.

To find pulsation frequencies we used the usual iterative approach: starting with an empty list of candidate frequencies and the periodogram of the original light curve (var/comp1); (1) inside the region of interest in the amplitude spectrum we identify the peaks with the highest confidence levels (taking care to

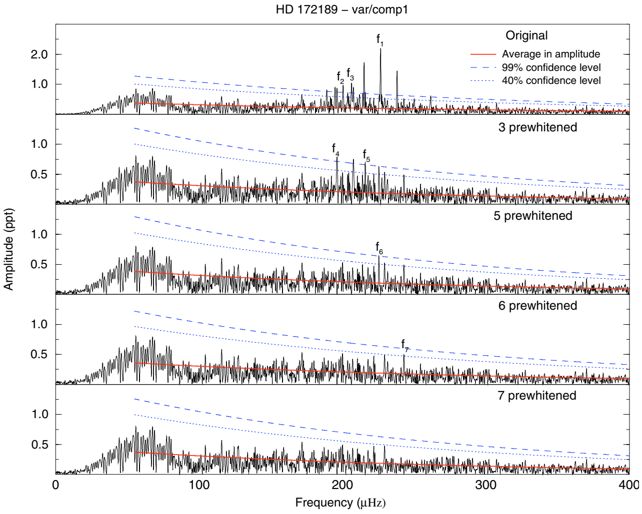

Fig. 5. Prewhitening process in HD 172189 (var/comp1). In each panel the peaks above the 99% confidence level (dashed line) are selected and removed from the original light curve, together with all previous selected frequencies, and a new periodogram is obtained. The selected peaks are indicated by f_1, f_2, etc. The lower level of 40% is indicated by the dotted curve and the solid curve represents the average amplitude.

discard aliases). If there is no peak with a significant probability the algorithm stops. (2) Put the selected frequencies in the list of candidate frequencies; (3) using a non-linear method, fit sinusoidals with *all* frequencies of the list of frequencies to the original light curve. The fitting refines the values of the initial frequencies and calculates the amplitudes and phases, as well as the respective uncertainties. (4) The fitted sinusoidals are subtracted from the original light curve and the periodogram of the residual light curve is calculated, and return to step (1) to search for additional possible pulsation frequencies.

Before applying the algorithm on the light curve var/comp2, we used a high-pass filter to remove signal at low frequencies (<100 μHz). As in previous STEPHI articles (e.g. Álvarez et al. 1998; Fox-Machado et al. 2002), the confidence levels are calculated with Fisher's test as prescribed by Nowroozi (1967). We search for oscillation peaks in the range 100−600 μHz, which in Nowroozi's description corresponds to around $m = 1000$ "independent" frequency bins. This sets the 99% confidence level at 3.4 times the local square-root of the mean power spectrum $\sqrt{\bar{A}_f^2}$, which is fitted by the exponential $\bar{A}_f^2 = c_0 \exp(c_1 f)$, where c_0 and c_1 are constants and f is the frequency.

The result of the prewhitening process in HD 172189 is shown in Fig. 5. The dashed curve in each graph indicates the 99% confidence level, adopted as a detection limit while the dotted curve indicates the position of the 40% confidence level. In the periodogram of the original light curve, we found three peaks above the 99% confidence level, indicated in the first graph (top) as f_1, f_2, and f_3. In the two successive prewhitened periodograms we found three more frequencies above this level, f_4, f_5 and f_6. After the prewhitening of the six frequencies, only one peak was found with a confidence level upper the 40% probability limit, with a 65% confidence level. The six detected pulsation frequencies and the seventh frequency with lower probability are given in Table 2.

We search for the seven detected peaks in the periodogram of the light curve of var/comp2 and using a least square fitting we estimated the probability of each peak not being due to noise

Table 2. Detected pulsation frequencies in HD 172189 with confidence levels ≥40%.

f_i	Frequency (μHz)	Amplitude (ppt)	Confidence Level
f_1	226.641 ± 0.003	2.19 ± 0.02	99%
f_2	200.506 ± 0.006	0.99 ± 0.02	99%
f_3	206.270 ± 0.006	0.98 ± 0.02	99%
f_4	196.244 ± 0.008	0.81 ± 0.02	99%
f_5	215.892 ± 0.010	0.69 ± 0.02	99%
f_6	225.446 ± 0.010	0.67 ± 0.02	99%
f_7	242.853 ± 0.012	0.50 ± 0.02	65%

in the periodogram of this light curve: 99.9% for f_1; 92% for f_2; 96% for f_3; 80% for f_4; 30% for f_5; 45% for f_6; and 35% for f_7. As expected, the probabilities found here are lower than those ones found for the case of var/comp1 because the light curve of var/comp2 is more noisy. Even so, the four highest peaks are clearly confirmed in this test.

M-R found two pulsation modes in HD 172189: 226.82 μHz and 218.51 μHz. The first mode is in agreement with f_1, but the second one does not agree with our frequencies. However, we identify the peak at 218.51 μHz as an alias of f_3.

5. Eclipses in HD 172189

The binarity of HD 172189 was discovered from analysis of the data of a campaign carried out in 1997 for detecting γ Doradus pulsating stars in the cluster IC 4756 (Martín 2000, 2003). M-R analyzed Strömgren $uvby-H_\beta$ observations obtained in different campaigns during 1997, 2003, and 2004, showed the presence of three light minima due to eclipses, but only one of the eclipses was followed past the minimum in brightness with a depth of ∼0.12 mag. From the data analysis, they found a period of P = 5.70198 days. The ephemeris obtained from the data is $T_{\min I}$ = 2 452 914.644(3)+5.70198(4)·E (in HJD), where E is the integer number of primary eclipses since the epoch 245 2914.644 HJD. The results indicate a system with an orbital eccentricity of $e \simeq 0.24$, a longitude of the periastron of $\omega \simeq 68°$ and an inclination of $i \simeq 73°$. The analysis also suggests that the two stars have different radii ($r_2/r_1 \simeq 0.6$), but similar temperatures $T_{\rm eff;1} \simeq 1.05\, T_{\rm eff;2}$.

According to the ephemeris, there were four primary eclipses during the present campaign, but, as shown in Fig. 1, only the eclipses $E1$, $E3$ and $E4$ occurred while the star was being observed. The first one by the Tenerife observatory and the last two by the Mexican observatory, in the data sets `IC0608ZN`, `IC0619SP` and `IC0625SP`, respectively (cf. Table 1).

Figure 6 shows the positions of the eclipses in the light curve of HD 172189. The seven detected pulsation frequencies were subtracted and points collected within 60 s were binned. The three primary eclipses are clearly visible.

Figure 7 shows the light curves during the eclipse. In the first two panels we see the light decreasing, passing through a minimum in brightness and then increasing. The primary eclipse $E1$ has its minimum at 2 453 165.520 (HJD). Unfortunately, the observations were interrupted several times during the night of this eclipse and the reduction of the data presented some difficulties.

A better scenario is shown in the second graph of Fig. 7 for the primary eclipse $E3$, where the light curve changes slowly and the minimum is well defined. Fitting a polynomial curve of degree 3 to the eclipse part of the light curve, we obtain $T_{\min I}$ = 2 453 176.920(2) (HJD), which differs by ∼9σ from

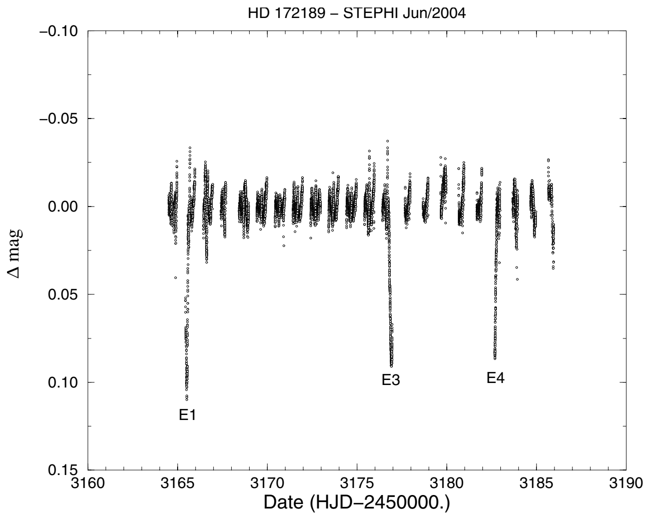

Fig. 6. Light curve of HD 172189. The measurements were binned to 60 s. Three primary eclipses, *E*1, *E*3 and *E*4 are clearly visible.

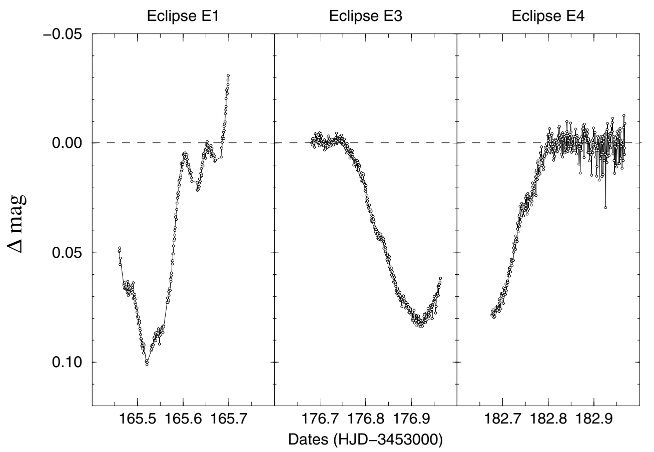

Fig. 7. The three primary eclipses (*E*1, *E*3 and *E*4) observed during the campaign. The points were binned and the pulsation frequencies were subtracted.

the predicted value using the ephemeris from M-R, indicating that the uncertainty in the orbital period is underestimated. Using this new minimum and the previous ephemeris, we recalculated the orbital period to obtain $P = 5.70165(8)$ days. Adopting the instant of the primary eclipse *E*3 as the new epoch, the new ephemeris is:

$$T_{\min \mathrm{I}} = 2\,453\,176.920(2) + 5.70165(8) \cdot E \quad \text{(in HJD).} \tag{1}$$

Table 3 shows the ephemeris dates for the four eclipses. The calculated date for the eclipse *E*1 is 2 453 165.518(2), consistent with the minimum observed in the light curve. The maximum in depth for the primary eclipses *E*1 and *E*3 are Δmag = 0.10(3) and Δmag = 0.08(3), respectively, in agreement with the minimum of Δmag = 0.12 for the eclipse observed by M-R.

The light curves show that the duration of each primary eclipse is ~seven hours and the half-depths occur around one hour before and after the instant of minimum. From the orbital elements calculated by M-R, we calculated a phase of ~0.132 for the secondary eclipse, i.e., the secondary eclipses would occur ~0.75 days (~18 h) after each primary eclipse and have the same duration. We searched for minima in the light curve around these dates, but as was remarked by M-R in their analysis, no minimum with an unequivocal and statistically significant depth was found.

Table 3. Primary eclipses of HD 172189.

Eclipse	Date (HJD)
E1	245 3165.517(2)
E2	245 3171.218(2)
E3	245 3176.920(2)
E4	245 3182.612(2)

6. Conclusions

The STEPHI XIII campaign carried out in June 2004, allowed a study of the pulsating behavior of the δ Scuti star HD 172189. The Fourier analysis of the light curve from three sites shows the presence of six pulsation frequencies with a confidence level of 99%. An additional frequency with a lower probability of 65% was also found. The observation of three eclipses during the campaign – two of them including the minimum in intensity – allows us to refine the previous value for orbital period of the system, obtaining 5.70165(8) days.

With the detection of six pulsation frequency with a high confidence level, our present campaign confirms the interest of HD 172189 as eclipsing binary featuring a δ Scuti pulsator for seismology. Besides the number of modes detected, the interest of HD 172189 Compared with other objects like RZ Cas (Rodriguez et al. 2004a) or AB Cas (Rodriguez et al. 2004b) is also associated with its orbital period. Both, AB Cas and RZ Cas, reveal a short orbital period (~1d). This suggests possible important effect of tidal forces on the star shape and structure, potential effects on oscillations. In fact, both these objects are considered Algol-type binaries, which supposes that mass transfer occurred between companions and changed their evolution compared with single stars. With a 5.7d orbital period, HD 172189 is expected to be more representative of a "normal" single star, both for its pulsational behavior and for its evolution history.

Dedicated spectroscopic and photometric observations are under way to characterize precisely the orbital parameters and radii of HD 172189 members. These results when available, completed by our present oscillation frequencies analysis will allow to start the modeling and seismic analysis of this object taking advantage of these numerous constraints. In addition to this, within a few years now, it is planed to observe HD 172189 with CoRoT for five months. This is expected to allow detection of many more oscillation modes by pushing down the noise level by a factor 500 in the power spectrum (see Michel et al. 2006). Beside this, the fact that HD 172189 belongs to the cluster IC 4756, even if this one is not so well studied yet, offers an interesting potential source of complementary information for further developments.

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Online Material

Table 1. Log of the observations of the STEPHI XIII campaign. The letters XL, ZN and SP in the data set names indicate the site of observation.

Data set name	Date	T_{begin} 245 0000.+ (HJD)	T_{end} 245 0000.+ (HJD)	Number of points	Duration (h)
IC0607ZN	07-Jun.-2004	3164.51865	3164.70145	18111	5.05
IC0607SP	07-Jun.-2004	3164.78305	3164.94251	11327	3.61
IC0608ZN	08-Jun.-2004	3165.44773	3165.70545	10067	2.97
IC0608SP	08-Jun.-2004	3165.74305	3165.97506	19082	5.37
IC0609XL	09-Jun.-2004	3166.19328	3166.30368	9499	2.65
IC0609ZN	09-Jun.-2004	3166.46177	3166.70003	20586	5.72
IC0609SP	09-Jun.-2004	3166.72632	3166.96818	20407	5.67
IC0610XL	10-Jun.-2004	3167.07915	3167.30217	19267	5.35
IC0610ZN	10-Jun.-2004	3167.43952	3167.69994	22485	6.25
IC0610SP	10-Jun.-2004	3167.72274	3167.97030	16098	4.50
IC0611ZN	11-Jun.-2004	3168.44450	3168.69808	21910	6.09
IC0611SP	11-Jun.-2004	3168.69851	3168.97172	23592	6.56
IC0612XL	12-Jun.-2004	3169.08350	3169.29475	16178	5.07
IC0612ZN	12-Jun.-2004	3169.43251	3169.69744	22884	6.36
IC0612SP	12-Jun.-2004	3169.69386	3169.97170	23435	6.52
IC0613ZN	13-Jun.-2004	3170.43495	3170.70100	22986	6.39
IC0613SP	13-Jun.-2004	3170.69817	3170.97177	23591	6.57
IC0614ZN	14-Jun.-2004	3171.42569	3171.69950	23605	6.57
IC0614SP	14-Jun.-2004	3171.74160	3171.96188	18238	5.07
IC0615ZN	15-Jun.-2004	3172.41819	3172.69828	24191	6.72
IC0615SP	15-Jun.-2004	3172.69699	3172.96155	22845	6.35
IC0616ZN	16-Jun.-2004	3173.41763	3173.69907	24256	6.75
IC0616SP	16-Jun.-2004	3173.69528	3173.95722	22574	6.29
IC0617ZN	17-Jun.-2004	3174.41541	3174.69871	24476	6.80
IC0617SP	17-Jun.-2004	3174.68134	3174.96363	24302	6.77
IC0618ZN	18-Jun.-2004	3175.41786	3175.69765	24172	6.72
IC0618SP	18-Jun.-2004	3175.71757	3175.96352	20072	5.58
IC0619ZN	19-Jun.-2004	3176.42122	3176.69892	23990	6.67
IC0619SP	19-Jun.-2004	3176.68105	3176.96442	24959	6.96
IC0620SP	20-Jun.-2004	3177.67549	3177.96542	24959	6.96
IC0621SP	21-Jun.-2004	3178.68041	3178.96473	22922	6.40
IC0622SP	22-Jun.-2004	3179.67059	3179.96465	24506	6.84
IC06S3SP	23-Jun.-2004	3180.68252	3180.96416	24180	6.76
IC0624SP	24-Jun.-2004	3181.67754	3181.95713	23220	6.46
IC0625SP	25-Jun.-2004	3182.67586	3182.96803	25104	7.01
IC0626SP	26-Jun.-2004	3183.68674	3183.70567	23307	6.52
IC0627SP	27-Jun.-2004	3184.67712	3184.89731	21940	6.14
IC0628SP	28-Jun.-2004	3185.67427	3185.96532	14789	4.34