Abstract In this study, pulsational and physical characteristics of two δ Scuti stars, V775 Tau and V483 Tau, are analysed by using four-year high-precision photometric data of the STEREO satellite. Thus, it is aimed to gain new insights into behaviours of these pulsators and evolution of δ Scuti, γ Dor and Am type stars. The data are taken between 2007–2011 and examined with the help of the Lomb-Scargle method. The detection precision in the four-year combined data is around $10^{-5}$ cd$^{-1}$ in frequency and $10^{-5}$ mag in amplitude. It is revealed that V775 Tau exhibits weak pulsation characteristic which is interpreted as the existence of the interaction between the helium loss in the partial ionization zone and pulsation intensities. It is also considered that the absence of strong pulsations is also related to the evolution status of the star. Further, its periodogram shows low-frequency peaks. If these oscillations are g-modes, V775 Tau can be thought to be one of the rare stars that show all γ Dor, δ Scuti and Am type variations. V483 Tau is comparatively more luminous, hotter and has higher rotational velocity. Therefore, although it shares the same region with V775 Tau in the H-R diagram, it is not considered to be an Am star. Yet, it exactly overlaps with the γ Dor stars. These clues as well as g-modes detected in its periodogram indicate that V483 Tau is a hybrid star. Finally, both V775 Tau and V483 Tau display period changes whose rates are between $10^{-3}$ and $10^{-4}$ yr$^{-1}$. Considering the δ Scuti nature, it may be speculated that these changes are non-evolutionary.

Keywords V775 Tau; V483 Tau; δ Scuti; Hybrid stars; Data Analysis

1 Introduction

δ Scuti stars are located at the intersection of the classical Cepheid instability strip and the main sequence on the H-R diagram. Their luminosity classes vary between V and III, since some massive samples evolve towards the giant region and across the strip at higher luminosities. Hence, they are generally referred as dwarf or sub-giant stars (Alcock et al. 2000). Spectral types of these stars range from A2 to F0 in the main sequence and from A3 to F5 in the giant region (Kurtz 2000). Also, the mass values are between 1.5 and 2.5 M$_\odot$ for δ Scuties with solar metal abundance and 1.0–2.0 M$_\odot$ for metal-poor samples (Silva 2011). Therefore, it is known that these stars are either at the core or shell hydrogen-burning stages.

δ Scuti stars display small amplitude and regular multi-periodic light curve variabilities with periods ranging from 0.02 to 0.25 days. The typical amplitude is around 0.02 mag, but the brightness variations in the V-band are between 0.003 and 0.9 mag (Breger 1979). Although most δ Scuti stars pulsate in several non-radial p-modes, some of them have radial oscillations. As stated by Breger (2000), the excitation in the He II ionization zone with temperatures around 48 000 K is enough to counterbalance the damping in the underlying layers. For this reason, the origin of the oscillations is believed to be the κ-mechanism excited by the He II partial ionization zones. Due to the pulsational varieties of δ Scuties, they are considered to be the representatives of the transition between Cepheid-like large amplitude radial pulsation seen in the classical instability strip and the non-radial pulsations taking place in the hot part of the H-R diagram (Breger 2000).
δ Scuti stars share same location with other pulsating variables such as RR Lyrae, roAp, Am, and γ Dor stars in the instability strip. To distinguish them from the star types mentioned above, physical and chemical parameters such as period, age, luminosity, and chemical composition can be considered. For example, RR Lyrae stars are less massive (between 0.4 M⊙ and 0.6 M⊙), more evolved, and brighter than δ Scuties even though their periods overlap. On the other hand, the period values of δ Scuties provide a unique differentiation from γ Dor stars (0.5 days < PγDor < 3.0 days; Oldershaw (2004)). Also, there are many chemically peculiar (CP) stars situated in the δ Scuti instability domain. Among them, evolved Am stars (known as δ Del or ρ Pup stars) pulsate within the same frequency interval with δ Scuties, yet they differ by their chemical peculiarities due to over-abundance of some metals (Aerts et al. 2010).

In terms of gaining new insights for understanding the seismic behaviour of δ Scuti stars, observations taken from the space missions MOST, CoRoT, and Kepler have been major breakthroughs. These missions provide determination of long-period oscillations and resolution of beat frequencies with the help of long-term continuous monitoring. Also, their high photometric precision from mmag to μmag enables the detection of low-amplitude variations that are not easily observed from the ground. In line with these examples, in this study, I use high-precision and long-term photometric data (four years of data obtained between 2007 and 2011) of another space mission, the STEREO satellite, to investigate and characterize the pulsational behaviour of two δ Scuti stars, V775 Tau and V483 Tau.

| Star     | Ra. (°) | Dec. (°)  | Mag. (″) | Type |
|----------|---------|-----------|----------|------|
| V775 Tau | 65.51466| 14.07720  | 5.72     | A9V  |
| V483 Tau | 64.99043| 14.03520  | 5.57     | F0IV |

Table 1 Target stars and their characteristics in the literature.

V775 Tau (HD 27628; 60 Tau; HIP 20400; HR 1368) is a metallic-lined spectroscopic binary and an important object since it fills an asteroseismologically important gap between Am stars and δ Scuti variables on the H-R diagram.

V483 Tau (HD 27397; 57 Tau; HIP 20219; HR 1351) is a member of the well-populated Hyades open cluster and forms a binary system with another δ Scuti, 58 Tau (Fu et al. 1996). It is located in the red edge of the instability strip in which γ Dor stars exist (Morgan and Hiltner 1963). Due to being a multiperiodic variable in a cluster and interacting with another pulsator, it is considered to be an asteroseismologically important object.

Some of the characteristics of the stars are given in Table 1.

2 Literature Review

2.1 V775 Tau

The orbital period of the system was determined by Abt (1961) as 2.14328 days, and Horan (1979) gave a variability period of around 1.5 hours. He also confirmed that the star was located at the red edge of the instability strip. This result was quite remarkable since it was very well known that Am-type variables in both field stars and galactic clusters did not pulsate. Cox et al. (1974) illuminated this situation by suggesting that there might be an instability strip for cool Am stars in the red edge of the normal δ Scuti strip, and that V775 Tau fell in this region.

Zhijing (2000) photoelectrically observed the star for 30 hours and detected two significant frequencies at 13.0364 cd−1 and 11.8521 cd−1 with the SNR of 10.2 and 5.8, respectively. He calculated the Q values of f₁ and f₂ to be around 0.032 and 0.035 days. He also noted that residuals of the amplitude spectrum still had variability. In addition, it was verified that all Am stars (from evolved and marginal to classical Am stars) could be δ Scuti variables in that study.

2.2 V483 Tau

The photometric variability of the star was first discovered by Millis (1967), who gave its period as 0.054 days (18.5185 cd−1, A = 0.03 mag). These variations were then confirmed by Horan (1979) by determining a period value of around 1.3 hours (18.4615 cd−1, A = 0.02 mag). Later, Lopez de Coca et al. (1990) derived a similar frequency at 18.5185 cd−1 with an amplitude of 0.08 mag using the P-L-C relation for Scuti stars.

The first, and one of the most detailed, photoelectric photometry of the star was performed by Fu et al. (1996). They obtained 863 measurements after a 10-day observation run, and detected two reliable frequencies with very small amplitudes in time series. With the help of rotational velocity, inclination angle and frequency difference (v sin i = 100 km s−1, i = 90°, f₁ − f₂ = 2.217 cd−1), they assumed that these peaks were a doublet separated due to stellar rotation.

Combining all available data from the literature, Paparó et al. (2000) derived a 54-night observation (232 hours) covering the period between 1981 and 1995. They found many individual frequencies by composing
different data sets, and identified 12 modes using the entire set of data. Even though four of these were in the low frequency region, which might be produced by misalignments of different subsets, two peaks were proposed as being generated by binarity or g-modes, as in γ Dor stars. This result was quite interesting, because if it was true, the star would be the first δ Scuti variable exhibiting both p- and high overtone g-modes. Furthermore, Kavel (1999) obtained a spectroscopic orbital period of around 2.4860 (17) days and noted that some of the low frequencies determined by Paparó et al. (2000) were most likely due to binarity such as geometric or proximity effects.

3 STEREO Satellite and Data Analysis

The data are provided from the HI-1A instrument on-board the STEREO-A satellite. The HI-1A is capable of observing background stars with the magnitude of 12m or brighter for a maximum of 20 days and a useful stellar photometer which covers the region around the ecliptic (20% of the sky) with the field of view of 20° × 20°. The nominal exposure time of the camera is 40 seconds, and putting 30 exposures together on board, a 40-minute integrated cadence is obtained to transmit for each HI-1 image (For details of the HI instruments refer to Eyles et al. (2009)). Therefore, the Nyquist frequency of the data is around 18 cd−1. Light curves mostly affected by solar activities are cleaned with a 3rd order polynomial fit. Observation points greater than 3σ are clipped with a pipeline written in the Interactive Data Language (IDL) (For a more detailed description of the data preparation, refer to Whittaker et al. (2013) and Sangaralingam and Stevens (2011)).

After the light curve refinement, I analyse all seasonal and four-year combined time series using the Lomb-Scargle method (Lomb 1976; Scargle 1982) and obtain the most dominant frequencies to gain an idea about variations. To do this, a recursive method is applied to the light curves to detect every significant frequency; the Fourier spectrum of the original data is initially derived, and the frequency with the highest amplitude is identified. If this peak is higher than a specific significance level, it is subtracted from the time series by using a least-squares fit. In the next step, the same procedure is applied to the pre-whitened data. At this point, the next significant frequency with the highest amplitude is removed: this routine is continued until the last significant frequency is found.

To extract the significant frequencies in seasonal and combined amplitude spectra, the conventional method of signal-to-noise ratio (SNR) ≥ 4.0 (or SNR ≥ 3.5 for combinations and harmonics of frequencies), suggested by Breger et al. (1993), is put aside, since the significance of a single frequency peak is underestimated by the 4σ rule. In other words, there are peaks of lower amplitude which are significant, but which are considered to be noise by the 4σ rule (Koen 2014). Therefore, regional noise values are calculated for every 0.5 cd−1 frequency interval up to the Nyquist frequency. In this way, a variable noise profile is determined for each periodogram. Based on this noise characteristic, the specific significance level is then found with the help of the equation given by Scargle (1982), as,

\[
\sigma = -\sigma_0^2 \ln \left( 1 - (1 - P(z))^{1/N_{\text{id}}} \right) .
\]

In this equation, \( \sigma_0 = A_m \sqrt{N}/2 \); where \( A_m \) is the mean amplitude of the amplitude spectrum where there is no significant signal (pure white noise) and \( N \) is the number of observation points. Scargle’s significance test is established on the assumption that I can identify a set of frequencies at which the periodogram powers are independent random variables (Frescura et al. 2008). In the case where the time series are evenly spaced, it is guarantee to find such a set. These are called the natural frequencies or the standard frequencies (Scargle 1982). \( N/2 \) is the maximum number of natural (independent) frequencies (\( N_{\text{id}} \)) expected in a periodogram.

| Star    | Time (year) | Observation Points | Observation Duration (day) | Observation Duration (hour) | \( f_{\text{Nyq}} \) (cd−1) |
|---------|-------------|--------------------|-----------------------------|----------------------------|-----------------------------|
| V775 Tau| 2007        | 583                | ~ 17                        | ~ 410                      | 17.9979                     |
|         | 2008        | 612                | ~ 17                        | ~ 414                      | 17.9989                     |
|         | 2010        | 673                | ~ 19                        | ~ 461                      | 17.9938                     |
|         | 2011        | 483                | ~ 14                        | ~ 331                      | 18.0001                     |
|         | Combined    | 2351               | ~ 67                        | ~ 1615                     | 18.0005                     |
| V483 Tau| 2007        | 582                | ~ 17                        | ~ 412                      | 17.9899                     |
|         | 2008        | 611                | ~ 17                        | ~ 412                      | 17.9989                     |
|         | 2010        | 676                | ~ 19                        | ~ 460                      | 17.9938                     |
|         | 2011        | 472                | ~ 14                        | ~ 340                      | 18.0001                     |
|         | Combined    | 2341               | ~ 68                        | ~ 1624                     | 18.0005                     |

Table 2 Details of the annual observations.
of evenly spaced data. In other words, the number of independent frequencies in the spectrum is only well
determined in the case of evenly spaced data without
gaps, with \( N/2 \) independent frequencies between 0 and
the Nyquist frequency \( (\sim 18 \text{ cd}^{-1}) \) for a time series of \( N \)
points [Frescura et al. 2008]. Since STEREO provides
equally spaced data with the cadence of around 40 min-
The extracted frequencies, their amplitudes, SNR and
noise \( (\sim \text{gaps, with g}) \) are calculated in the case of evenly spaced data without
independent frequencies in the spectrum is only well
determined in the case of evenly spaced data. In other words, the number of
independent frequencies between 0 and the Nyquist frequency \( (\sim 18 \text{ cd}^{-1}) \) for a time series of \( N \)
points [Frescura et al. 2008]. Since STEREO provides
equally spaced data with the cadence of around 40 min-
utes, \( N_{\text{id}} \) is calculated from \( N/2 \). In the equation, \( z \) is in
the unit of power, and hence the corresponding amplitude is derived from
\( A_1 = 2\sqrt{z/N} \) [Balona 2014]. Since the significance level varies according to noise, it allows
me to be more selective and also enables the detection of frequencies with low SNR. These noise and related
significance levels are presented with red dash-dot and red dashed lines in periodograms, respectively. For a
comparison, the constant significance level calculated from the mean noise value of the periodogram is shown
with a blue dashed line in the same figures. The false alarm probabilities are assumed to be 99\% \((P_0 = 0.01)\).

Apart from these, signals are sought between the frequency range of 0.05 - 18 \text{ cd}^{-1}, and variabilities greater
than the Nyquist frequency are not taken into account. The extracted frequencies, their amplitudes, SNR and
noise \( (A_m) \) values are given in the relevant tables.

With the detected frequencies, pulsation constants are calculated in order to identify the pulsation modes
with the help of the equation [Breger and Bregman 1972]:

\[
\log Q = -6.456 + 0.5 \log g + 0.1 M_{\text{bol}} + \log T_{\text{eff}} + \log P, \tag{2}
\]

where \( \log g \) is the surface gravity, \( M_{\text{bol}} \) is the bolometric magnitude, \( \log T_{\text{eff}} \) is the logarithm of the effective
temperature, and \( \log P \) is the period. Radial and non-
radial modes are distinguished by using observational and experimental approximations, which are given as:
\( Q_0 = 0.032 - 0.036 \) days, \( Q_1 = 0.024 - 0.028 \) days,
\( Q_2 = 0.0195 - 0.0225 \) days, and \( Q_3 = 0.016 - 0.0185 \) for the fundamental mode and the first three overtones
[Fitch 1981]. To separate the radial modes, the ratios between the radial frequencies are found by comparing
the observed and the calculated period ratios:
\( P_1/P_0 \sim 0.761, P_2/P_1 \sim 0.810 \) and \( P_3/P_2 \sim 0.845 \)
[Breger 1979]. In light of these estimations, the relations of the significant frequencies are evaluated.

4 Results

4.1 V775 Tau

I obtain a four-year time series of the star covering the
interval from 2007 to 2011. The overall observations
consist of 2351 photometric measurements, correspond-
ting to a data of around 1615 hours. Properties of the
combined and individual light curves are given in Table 2.

Frequency analysis of the entire set of data shows that there are at least five significant peaks in the com-
combined light curve (Fig. 1 and Table 3). Among the
frequencies detected, 11.07 and 14.04 \text{ cd}^{-1} are at the edge of
the significance limit, whereas 0.93, 5.60, and 13.08 \text{ cd}^{-1} are above this level. All frequencies, except for
0.93 and 13.08 \text{ cd}^{-1}, have an SNR between 3.0 and 4.0. The most dominant peak in the periodogram is 0.93
\text{ cd}^{-1}, which is twice the orbital period given by Abt (1961) as 0.4666 \text{ cd}^{-1}. Even though one of the two fre-
quencies (13.0364 \text{ cd}^{-1}) discovered by Zhiping (2000)
is confirmed, the one at 11.8521 \text{ cd}^{-1} is detected nei-
er in the combined nor in the seasonal light curves;
the light curve taken in 2007, however, exhibits some
variabilities between 11 and 12 \text{ cd}^{-1} (Fig. 2).

Further, I observe that \( \delta \) Scuti type variations are mostly accumulated between 10 and 15 \text{ cd}^{-1}, I am
able to extract only three frequencies within this re-
gion since the noise level is quite high, but it is clear
that residuals of the amplitude spectrum still have other
peaks. There are also some activities between 16 and
18 \text{ cd}^{-1} that are quite below the significance level. Addition-
ally, another variability at around 5 \text{ cd}^{-1} attracts the attention. The main \( \delta \) Scuti type frequency (13.08
\text{ cd}^{-1}) in the combined data set is weaker than many
other frequencies in the amplitude spectrum of 2007,
Table 3  Frequencies derived from the combined data of V775 Tau.

| No | Freq. (cd⁻¹) | Amp. (mmag) | SNR | Amplitude (mmag) | Q (days) | Comments |
|----|--------------|-------------|-----|------------------|---------|----------|
| f₁ | 0.93295(3)   | 1.09(8)     | 8.14| 0.13             |         |          |
| f₂ | 13.08085(6)  | 0.47(8)     | 4.06| 0.12             | 0.033(8)|          |
| f₃ | 11.06751(7)  | 0.43(8)     | 3.37| 0.13             | 0.039(9)| 24f₀orb |
| f₄ | 14.03945(8)  | 0.38(8)     | 3.45| 0.11             | 0.031(7)| 30f₀orb |
| f₅ | 5.60174(12)  | 0.25(7)     | 3.87| 0.06             | 0.078(18)|         |

2008, and 2010 although it is quite strong in the 2011 data (Fig. 2). Beside this, I realize that the dominant pulsation mode of V775 Tau varies year by year. For instance, the main peak is 14.12 cd⁻¹ in 2007 while it is respectively 13.80, 10.98, and 13.09 cd⁻¹ for the time series obtained in 2008, 2010, and 2011. The exact reason for this variability is unclear, but it is suspected that some of these frequencies may be combinations of others. For example, 14.12 ≈ f₁ + 1.63 + 11.58, where 1.63 and 11.58 cd⁻¹ are observable but insignificant frequencies in 2007, and 13.80 ≈ 3f₁ + 10.98, where 10.98 cd⁻¹ is quite strong but remains under the significance level in 2008 (Table 4).

Since I am able to detect only a limited number of frequencies, it is not possible to track spacing patterns between the frequencies determined. However, I attempt to examine the effect of the orbital motion on these frequencies. Thus, I calculate the harmonics of the orbital period value and plot them with black vertical lines in Fig. 2. The observable peaks above and under the significance level are quite consistent with these harmonics. This might be the indication that amplitudes of the most peaks in the periodogram are intensified due to orbital motion.

Moreover, I compute pulsation constants of the δ Scuti type frequencies in the amplitude spectrum. As given in Table 3, the Q values of f₂ and f₄ are in agreement with the fundamental mode of a typical δ Scuti star, given by Breger (1979). If the frequency at 13.08 cd⁻¹ is considered to be the fundamental mode, the first overtone is predicted as approximately 16.67 cd⁻¹ by using the ratio of P₁/P₀ = 0.785 suggested by McNamara (1983) for δ Scuti stars located in the red edge of the instability strip. Further, the error value estimated for the pulsation constant of 13.08 cd⁻¹ is slightly large; this reveals another possibility that 13.08 cd⁻¹ might be the corresponding first overtone. Based on this, the fundamental mode is found to be around

Table 4  Frequencies derived from the individual data of V775 Tau.

| No | Freq. (cd⁻¹) | Amp. (mmag) | SNR | Amplitude (mmag) | Comments |
|----|--------------|-------------|-----|------------------|----------|
| f₁ | 0.93287(7)   | 0.76(15)    | 4.66| 0.19             | 2f₀orb   |
| f₂ | 14.124(8)    | 0.62(15)    | 3.28| 0.19             |          |
| f₃ | 3.372(8)     | 0.61(15)    | 3.55| 0.17             |          |

2008 Frequencies

| No | Freq. (cd⁻¹) | Amp. (mmag) | SNR | Amplitude (mmag) | Comments |
|----|--------------|-------------|-----|------------------|----------|
| f₁ | 0.935(4)     | 1.23(14)    | 7.52| 0.16             | 2f₀orb   |
| f₂ | 13.797(8)    | 0.61(15)    | 3.32| 0.18             |          |
| f₃ | 7.388(13)    | 0.28(14)    | 3.05| 0.12             |          |

2010 Frequencies

| No | Freq. (cd⁻¹) | Amp. (mmag) | SNR | Amplitude (mmag) | Comments |
|----|--------------|-------------|-----|------------------|----------|
| f₁ | 0.934(3)     | 1.36(14)    | 7.23| 0.19             | 2f₀orb   |
| f₂ | 14.434(5)    | 0.86(14)    | 3.28| 0.26             |          |
| f₃ | 10.981(7)    | 0.64(14)    | 3.31| 0.19             |          |

2011 Frequencies

| No | Freq. (cd⁻¹) | Amp. (mmag) | SNR | Amplitude (mmag) | Comments |
|----|--------------|-------------|-----|------------------|----------|
| f₁ | 0.939(7)     | 1.04(16)    | 7.52| 0.18             | 2f₀orb   |
| f₂ | 13.099(8)    | 0.97(16)    | 5.53| 0.18             |          |
| f₃ | 13.522(11)   | 0.67(16)    | 4.48| 0.19             |          |

Fig. 2  Annual light curves of V775 Tau and their amplitude spectra.
Table 5 All archival frequencies of V483 Tau.

| Time (year) | Frequency (cycle per day) | Authors                        |
|-------------|---------------------------|--------------------------------|
| 1981-1995   | 0.16208, 0.65745, 0.8025, 1.11933, 7.22323, 14.16131, 16.73835, 17.25689, 18.2086, 20.2181, 20.44054, 24.55519 | Paparó et al. (2000)          |
| 1981        | 0.654, 0.804, 1.021, 7.232, 14.762, 16.594, 19.048, 18.260, 20.406, 25.556, 29.837 |                                |
| 1986        | 0.659, 0.845, 6.262, 16.626, 20.202, 20.411, 25.843                                      |
| 1989        | 0.626, 0.802, 1.119, 8.002, 16.493, 21.434, 29.527                                      |
| 1995        | 0.665, 0.813, 7.237, 14.173, 16.214, 20.446, 29.843                                      |
| 1967        | 18.5185                                                                | Millis (1967)                 |
| 1973        | 18.5185                                                                | Fu et al. (1996)              |
| 1989        | 18.221(3), 20.4389(4)                                                  | Horan (1979)                  |
| 1978        | 18.4615                                                                |                                |
| 1998        | 0.4022530(2751)                                                        | Kaye (1999)                   |

10.27 cd$^{-1}$, corresponding to 22$f_{\text{rot}}$. The second overtone would be around 16.15 cd$^{-1}$ (≈ 35$f_{\text{rot}}$).

In order to see the general frequency profile, I add two frequency values determined by Zhiping (2000) to the STEREO data. As previously mentioned, frequencies are accumulated between 10 and 15 cd$^{-1}$, but they do not show any regular variation. The most consistent variation is seen in the frequency at 0.93 cd$^{-1}$. Although there is not a significant change in the stellar orbital period between 2007 and 2011, I determine that it shows a decrease of about $-5.71(2.5) \times 10^{-3}$ yr$^{-1}$. Besides, its amplitude displays a remarkable inverse parabolic variation. Moreover, the comparison of the δ Scuti type pulsation at 13.0809 cd$^{-1}$ in the combined periodogram with 13.0364 cd$^{-1}$ given by Zhiping (2000) [255] shows that the pulsation period of the star also decreases between 2000 and 2009 (the mean time value of the four-year mission). The rate of this variation is around $-3.78(54) \times 10^{-4}$ yr$^{-1}$.

4.2 V483 Tau

In order to analyse the interior structure of V483 Tau, a data set consisting of 68 days from 2007 to 2011 is obtained in this study. This data contain 2341 photometric measurements equivalent to 1624 hours of observation (Table 2). Frequency analysis of the combined light curve shows that there are at least 14 substantial frequencies hidden within the time series (Fig. 3). Eight of these frequencies have an SNR greater than 4.0, two of which are low frequencies at around ∼ 0.7975 and ∼ 2.1396 cd$^{-1}$. Instead of two certain peaks at 0.8025 and 0.6575 cd$^{-1}$ as reported by Paparó et al. (2000) (Table 5), I observe only one strong frequency at 0.7975 cd$^{-1}$, which is nearly twice the orbital period ($f_{\text{orb}} = 0.4023$ cd$^{-1}$; orbital period of 57 and 58 Tau binary system) calculated by Kaye (1999) (Table 5).

Moreover, I detect that main variations start after 15 cd$^{-1}$ as indicated in the literature. Even though the most dominant frequency in the 1980s - 90s data is found at 17.2569 cd$^{-1}$ (Paparó et al. 2000), it appears at around 17.2422 cd$^{-1}$ for the current data. However, it is not possible to identify other variations reported at 18.22, 20.22, 20.44, and 24.56 cd$^{-1}$ since the Nyquist frequency of the combined light curve is 18.0005 cd$^{-1}$. Also, there are distinctive frequencies between 5 and 15 cd$^{-1}$ in the amplitude spectrum (Fig. 3). I detect six frequencies in this region, but almost none of them are consistent with previous results. The peaks close to the

Fig. 3 The amplitude spectrum of V483 Tau obtained from four-year combined light curve. The variable noise level, corresponding significance level and mean significance level are shown with red dash-dot, red dashed and blue dashed lines, respectively. The vertical black dotted lines are the harmonics of the orbital period ($P_{\text{orb}} = 0.4023$ cd$^{-1}$) calculated by Kaye (1999)
Table 6  Frequencies derived from the combined data of V483 Tau.

| No | Freq. (cd$^{-1}$) | Amp. (mmag) | SNR | $A_m$ (mmag) | $Q$ (days) | Comments |
|----|------------------|-------------|-----|-------------|-----------|----------|
| f1 | 17.24223(2)      | 1.13(07)    | 8.86| 0.13        | 0.032(1)  | 43$f_{rot}$ |
| f2 | 0.79752(3)       | 1.06(07)    | 9.67| 0.11        | 2$f_{rot}$ |
| f3 | 16.77804(3)      | 0.85(07)    | 5.91| 0.14        | 0.033(1)  | 42$f_{rot}$ |
| f4 | 16.18334(3)      | 0.81(07)    | 6.18| 0.13        | 0.034(1)  |
| f5 | 15.55500(5)      | 0.51(07)    | 4.80| 0.11        | 0.036(1)  | 39$f_{rot}$ |
| f6 | 2.13956(6)       | 0.51(07)    | 3.51| 0.15        |
| f7 | 16.48345(6)      | 0.50(07)    | 3.58| 0.14        | 0.034(1)  |
| f8 | 6.16719(7)       | 0.42(07)    | 4.78| 0.09        | 0.090(4)  |
| f9 | 12.32198(7)      | 0.39(07)    | 4.91| 0.08        | 0.045(2)  |
| f10| 15.17151(7)      | 0.39(07)    | 3.88| 0.10        | 0.036(1)  |
| f11| 9.65906(7)       | 0.38(07)    | 4.56| 0.08        | 0.057(2)  |
| f12| 14.79548(8)      | 0.36(07)    | 3.98| 0.09        | 0.037(1)  |
| f13| 9.08919(9)       | 0.32(07)    | 3.67| 0.09        | 0.061(2)  |
| f14| 11.43619(9)      | 0.30(07)    | 3.88| 0.08        | 0.048(2)  |

Fig. 4  Annual light curves of V483 Tau and their amplitude spectra

previous findings are the frequencies at 6.17 and 14.79 cd$^{-1}$.

As this star is a rapidly rotating δ Scuti ($v \sin i = 100$ km s$^{-1}$, Fu et al. 1996), it is possible to observe some split frequencies due to stellar rotation. With the help of the Kolmogorov-Smirnov (K-S) test (Kolmogorov 1933; Smirnov 1948), I calculate spacings between frequencies and check whether there is any perturbed peak (Özvan 2015). Although this is not the usual application of the K-S test, it provides a measure of the probability that a set of numbers is drawn from a chosen distribution. In this context, Kawaler (1988) states that if a star shows many g-modes with the same value of $l$ but different values of $n$, the differences between the modes should be integer multiples of a minimum period interval. Any such statistically significant minimum period interval in the periodogram of a star allows the full power of the theoretical analysis of the adiabatic pulsation properties to make fundamental statements about the star and its pulsations (Kawaler 1988). On the basis of this, K-S test can be used to verify constant period intervals in the periodogram of a pulsating star.

Based on the K-S test done for V483 Tau, I find a regular spacing of around 0.4643 cd$^{-1}$ between frequencies in the combined periodogram. The probability of this result is 0.99, which is greater than the significance level of 95% ($p = 0.05$). However, it is not precisely possible to explain the relation between some of the detected frequencies and this value. For this reason, I compute the harmonics of the orbital period ($\sim 0.40$ cd$^{-1}$), and present them with black vertical dotted lines in Fig. 4 as well as in Table 6. As seen in the figure, almost all observable peaks over and under the significance level are in good agreement with the harmonics. For example, the frequencies at around 14.79, 15.17, 15.55, 16.77, and 17.24 cd$^{-1}$ are clearly consistent with the harmonics of the orbital period. They may be a result of the interaction between the orbital motion and the δ Scuti type variation previously reported to be at around 18.5 cd$^{-1}$ (Millis 1967; Horan 1973 and Lopez de Coca et al. 1990), which is however greater than the Nyquist fre-
quency in this study. On the other hand, the frequencies at 2.14, 6.17, and 16.18 cd$^{-1}$ seem to be inconsistent with the harmonics.

Subsequent to these investigations, I also derive pulsation constants of the frequencies within δ Scuti variability region. It is seen that Q constants of V483 Tau are considerably greater than expected values and vary from 0.03 to 0.09 days for frequencies between 5 and 18 cd$^{-1}$. Considering the frequencies obtained only from the STEREO data (up to its Nyquist frequency), I find six frequencies (17.24, 16.78, 16.18, 15.56, 16.48, and 15.17 cd$^{-1}$) in the fundamental mode interval given by [Breged (1979)]. Among them, only 16.18 cd$^{-1}$ satisfy the relation of $P_f / P_0 = 0.761$, together with the frequency of 12.32 cd$^{-1}$. However, this relation is reached if 16.18 cd$^{-1}$ is assumed to be the corresponding first overtone of the frequency at 12.32 cd$^{-1}$. In this case, the second overtone matches with $\sim 50 f_{rot}$ (19.98 cd$^{-1}$). I am also able to derive the ratio of $P_2 / P_1 = 0.810$ by using the frequencies 15.17 and 12.32 cd$^{-1}$. If 12.32 cd$^{-1}$ is the first overtone, then the fundamental mode and the third overtone will be 9.38 cd$^{-1}$ ($\sim f_{11}$ or $f_{13}$) and 17.97 cd$^{-1}$ ($\sim 50 f_{rot}$). In addition, the ratio between the frequencies of 14.79 and 17.24 cd$^{-1}$ yields $P_3 / P_2 \approx 0.845$. According to this, the fundamental mode and the corresponding first overtone are calculated to be around 11.98 cd$^{-1}$ (30 $f_{rot}$) and 9.12 cd$^{-1}$ ($f_{13}$).

Frequency analyses are also performed for individual light curves to study annual frequency and amplitude variations (Fig. 4). Only four frequencies (0.80, 16.18, 16.78, and 17.24 cd$^{-1}$) are found to be detectable in each year. However, neither their frequencies nor their amplitudes exhibit significant variation during four years; their changes are within the acceptable error margins.

Further, a frequency profile of the star is constructed to search for long-term variations by collecting all available findings from the literature (Table 5) and integrating them with STEREO data (Table 7). Based on this overall profile given in Fig. 5, three frequencies (16.2140, 17.2569 and 0.8025 cd$^{-1}$) close to my findings are determined, and their variations carrying on over two decades are examined in detail as shown in Fig. 5. It is determined that the most dramatic changes occurred in the frequencies at 16.18 and 17.24 cd$^{-1}$. However, apart from having no error value, the frequency at 16.2140 cd$^{-1}$ found by [Paparó et al. (2000)] exists only in the data derived in 1995 and is not seen in the combined data taken between 1981-1995. Therefore, its accuracy is suspected. Considering this, the period variation at around 16.18 cd$^{-1}$ is calculated to be $dP / dt = 1.35(44) \times 10^{-4}$ yr$^{-1}$. Unlike this, the accuracy of the frequency at 17.2569 cd$^{-1}$ is quite high since it is detected in [Paparó et al.'s (2000) combined

Table 7  Frequencies derived from the individual data of V483 Tau.

| No | Freq. (cd$^{-1}$) | Amp. (mmag) | SNR | $A_m$ (mmag) | Comments |
|----|------------------|-------------|-----|-------------|----------|
| $f_1$ | 17.246(4) | 1.09(15) | 5.52 | 0.21 | $2f_{rot}$ |
| $f_2$ | 0.798(5) | 1.04(15) | 4.55 | 0.23 | $2f_{rot}$ |
| $f_3$ | 16.184(6) | 0.84(15) | 4.08 | 0.21 | $f_1 - f_2$ |
| $f_4$ | 16.470(6) | 0.85(15) | 4.02 | 0.21 | $f_1 - f_2$ |
| $f_5$ | 3.079(6) | 0.80(15) | 3.28 | 0.24 | $f_1 - f_2$ |
| $f_6$ | 16.772(7) | 0.77(15) | 3.70 | 0.21 | $2f_4 - 4f_3$ |

Fig. 5 All available frequencies of V483 Tau, up to the Nyquist frequency. Black diamonds and red filled circles represent the STEREO and literature data, respectively. Blue dotted lines indicate the frequencies at 0.8025, 16.2140 and 17.2569 cd$^{-1}$, which have been observed since the 80’s and 90’s.
data (shown by a black point with 14-year error bar in Fig. 6 (bottom left), and its variation ratio is derived as 4.05(28) × 10^{-5} yr^{-1}.

Archival orbital period values of the star are also compared to STEREO results. I find four different literature values as seen in Fig. 6 (top left). However, two of these frequencies (0.8020 and 0.8040 cd^{-1}) are ignored and the variation ratio is calculated according to the frequency value at 0.8025 cd^{-1} since this one represented 14-year combined data. Moreover, another variation rate is also computed for the data obtained in 1995 due to its being within the error limits. Thus, I find a rate of 2.96(59) × 10^{-4} yr^{-1} for the former and 1.37(100) × 10^{-3} yr^{-1} for the latter period.

5 Summery and Discussion

In this study, photometric data of two δ Scuti stars – V775 Tau and V483 Tau – are derived from the HI-1A instrument of the STEREO satellite. The data are collected between 2007 and 2011 for the purpose of investigating the internal structures and evolution stages of the target stars. Four years of seasonal and combined light curves are examined with the help of the Lomb-Scargle method. For each periodogram, regional noise levels are determined by averaging the noise values in every 0.5 cd^{-1}, and a specific noise characteristic is thus established. Based on this characteristic, a significance level is calculated with 99% probability. Frequencies whose amplitudes are greater than this level are then detected. The detection precision in four-year combined data is around 10^{-5} cd^{-1} in frequency and 10^{-5} mag in amplitude.

In order to identify oscillation modes, significant STEREO frequencies and the Eqn. 2 provided in Section 3 is used. In the equation, temperature and surface gravity, as well as luminosity and mass values of the sample stars, are adopted from the literature. The bolometric magnitude of the targets are estimated due to a lack of archival data: bolometric correction (BC) is approximated from Flower (1996) by using the $B-V$ colour index. Bolometric and absolute magnitudes are found from:

$$M_{bol} - M_{⊙(bol)} = -2.5 \log(L/L_⊙),$$

where $M_{bol} = M_V + BC$ and $M_{⊙(bol)}$ equals to 4.81 mag, and

$$M_V = m_V + 5 - 5 \log d - A_ν,$$

where $m_V$ and $d$ are the apparent magnitude and the distance values, adopted from the Simbad Database. $A_ν$ is the interstellar extinction derived from Fitzgerald (1970). $E(B-V)$ where $E(B-V) = (B-V) - (B-V)_0$ where $(B-V)_0$ is the intrinsic colour index and taken from Fitzgerald (1970).

Table 8 Target stars and their physical properties.

| Star ID | V483 Tau | V775 Tau |
|---------|----------|----------|
| vsini (km s^{-1}) | 102^a | 32^a |
| Period (day) | 0.05799717(9) | 0.0764476(4) |
| Q (day) | 0.0321(1) | 0.033(8) |
| $M_{bol}$ (mag) | 2.37(4) | 1.79(5) |
| log$g$ | 4.169(33)^b | 4.120(200)^c |
| log$T_{eff}$ | 3.878(4)^b | 3.857(4)^b |
| log$(L/L_⊙)$ | 0.955(14)^b | 0.900(14)^b |
| $R$ (R_⊙) | 1.76(4) | 1.83(4) |
| $M$ (M_⊙) | 1.67^b | 1.71(12)^d |
| $m_1$ (mag) | 0.194^e | 0.204^e |

Note: The estimated errors of the parameters (in particular on the radii) given in the table are statistical errors only. The true errors will be rather larger.

Note: The estimated errors of the parameters (in particular on the radii) given in the table are statistical errors only. The true errors will be rather larger.

Table 8 Target stars and their physical properties.

| Star ID | V483 Tau | V775 Tau |
|---------|----------|----------|
| vsini (km s^{-1}) | 102^a | 32^a |
| Period (day) | 0.05799717(9) | 0.0764476(4) |
| Q (day) | 0.0321(1) | 0.033(8) |
| $M_{bol}$ (mag) | 2.37(4) | 1.79(5) |
| log$g$ | 4.169(33)^b | 4.120(200)^c |
| log$T_{eff}$ | 3.878(4)^b | 3.857(4)^b |
| log$(L/L_⊙)$ | 0.955(14)^b | 0.900(14)^b |
| $R$ (R_⊙) | 1.76(4) | 1.83(4) |
| $M$ (M_⊙) | 1.67^b | 1.71(12)^d |
| $m_1$ (mag) | 0.194^e | 0.204^e |

Note: The estimated errors of the parameters (in particular on the radii) given in the table are statistical errors only. The true errors will be rather larger.
The theoretical values for stars in the main sequence, and cover the mass range of 1.5 and 2.3 \( M_\odot \). Initial hydrogen and heavy metal abundances are assumed to be \( X = 0.70 \) and \( Z = 0.02 \), respectively. The red and blue solid lines are the theoretical blue edge for the radial mode and the empirical red edge of the instability strip. The dashed line marked as \( BE_F \) is the theoretical blue edge for the radial fundamental mode. The logarithmic luminosity values are adopted from de Bruijne et al. (2001), who determined these parameters from the measurements of \( M_V \) and \( (B-V) \) values, respectively. The uncertainty of the luminosity value comes from the combination of \( \sigma_{M_V} \) and \( \sigma_{BE_V} \), which include \( \sigma_V \), \( \sigma_\pi \) and \( \sigma_{logT_{eff}} \). Additionally, \( \sigma_{logT_{eff}} \) is affected by \( \sigma_{(B-V)} = \min(\sigma_{(B-V)}^{observed}, 0.010 \, \text{mag}) \) and \( \sigma_M = 0.10 \, M_\odot \) (Perryman et al. 1998). For the calculation of the luminosities, \( \pi \) parallax values of 21.88(36) mas for V483 Tau and 22.53(55) mas for V755 Tau are taken from de Bruijne and Eilers (2012). These parallaxes are derived from Tycho-2 proper motions since Hipparcos data have greater error values (\( \sigma_\pi(\text{Hip}) = 0.92 \) for V483 Tau and \( \sigma_\pi(\text{Hip}) = 0.96 \) for V483 Tau).

In the region where the Cepheid instability strip intersects with the main sequence on the H-R diagram, the positions of \( \delta \) Scuti variables are normal abundances. The most stars observed in this intersection are normal abundance \( \delta \) Scuti variables with relatively high rotational velocities, \( v_{\sin i} \geq 100 \, \text{km s}^{-1} \) (Smalley et al. 2011). \( \delta \) Scuties overlap with Am stars, as they overlap with many other variables such as A and F type peculiar stars (Ap and Fp), \( \gamma \) Dor, and \( \delta \) Boo stars in this region. Am stars mostly exist in short-period binary

---

9http://owww.phys.au.dk/ jcd/emdl94/eff_y6/
systems \((P = 1 \sim 10\) days), and their rotational velocities are lower than \(100 \text{ km} \text{s}^{-1}\) due to a tidal brake between components \(\text{Abt 2003}\). These stars show ab-normal metal abundance on their surfaces. The origins of this peculiarity are thought to be atomic diffusion, radiative levitation, and the gravitational settling that occurred depending on slow rotation. Also, the lack of an effective mixing mechanism and turbulence negligible below rotational velocity of \(100 \text{ km} \text{s}^{-1}\) are other factors that cause abnormal metal abundance on the surface \(\text{Murphy et al. 2015}\).

As known, the pulsation source of the \(\delta\) Scuties is the \(\kappa\)-mechanism driven in the He II ionization zone, which means helium is the key element in these stars. Yet, \(\delta\) Scuti type pulsations are inhibited due to the gravitational settling of helium in slowly rotating stars such as Am types. It was therefore thought for many years that Am stars did not pulsate. However, the detection of the \(\delta\) Scuti type pulsations in HD 1097 revealed that many Am stars in fact pulsated. These discoveries have been rapidly increasing through space missions such as CoRoT (HD 51844, Hareter et al. 2014), MOST (HD 114839, King et al. 2000), and Kepler (KIC 3429637, Murphy et al. 2012). In this context, V775 Tau is another example of an Am-\(\delta\) Scuti type star. I believe that the position of the star between Am and \(\delta\) Scuti types has been better understood with the help of \textsc{Stereo} data. V775 Tau shows all typical properties given for Am stars. It is known that the star is a spectroscopic binary, and its projected rotational velocity is around \(32\) \(\text{km} \text{s}^{-1}\), which is most probably due to binarity. Its metallicity index \(m_1\) is around \(0.204\) mag \(\text{Rodriguez et al. 2000}\).

It is stated that pulsating Am stars are cooler than normal \(\delta\) Scuties and produce lower amplitude compared to \(\delta\) Scuti stars \(\text{Smalley et al. 2011}\). Referring to the Fig. the star is also located quite close to the cool edge of the instability strip on the H-R diagram. Moreover, it can be seen from Fig. that indeed the star does not exhibit strong pulsations. This situation indicates that the loss of helium in the partial ionization zone does not suppress pulsations but reduces their intensities. Additionally, the absence of strong pulsations in the amplitude spectrum might be related to the evolutionary status of the star. As shown on the H-R diagram, the star is still on the main sequence. According to Turcotte et al. 2000, the position of stars on the H-R diagram and their pulsation characteristics are directly related, i.e., it is suggested that pulsation amplitudes intensify as stars evolve or begin to leave the main sequence.

Further, for the lack of p-modes, energy transferring between modes should also be considered, as speculated by Murphy et al. 2013. Mode coupling is estimated between frequencies in \(\delta\) Scuti stars. Due to the instability of a linearly driven mode, two other modes grow stronger. This phenomenon is known as the parametric resonance. As a result of these non-linear effects, the amplitude of a linearly-driven p- or g-modes decreases while other g-modes increase \(\text{Dziembowski 1982}\). These g-modes can be trapped in the deep interior and are not observable on the surface. If this is the case for V775 Tau, the abnormal frequency variations seen in its seasonal light curves and the frequency at \(11.85\) \(\text{cd}^{-1}\) observed by Zheng (2000) but not observable in the \textsc{Stereo} data might be explained.

The other sample, V483 Tau, forms a binary system with another \(\delta\) Scuti star, and thus has a different amplitude spectrum. The main variations are observed after \(15\) \(\text{cd}^{-1}\), and the maximum pulsation oscillation is at around \(18.22\) \(\text{cd}^{-1}\) \(\text{Fu et al. 1996}\), which is beyond the \textsc{Stereo} Nyquist frequency. V483 Tau is situated close to the red edge of the instability strip on the H-R diagram. Although the star shares the same location with V775 Tau, it is more luminous, hotter, and, above all, its rotational velocity is significantly higher \(\text{vsini} = 100\) \(\text{km} \text{s}^{-1}\). For these reasons, it is not considered to be an Am-type star as is V775 Tau. However, the location of the star exactly overlaps with the \(\gamma\) Dor stars, and it is reported that the star pulsates in g-modes in addition to p-modes \(\text{Paparó et al. 2000}\). These low-frequency structures are also seen in the \textsc{Stereo} periodogram. If these have not occurred due to binarity such as geometric and proximity effects, V483 Tau might be thought to be a hybrid star.

Further, it should be noted that similar low frequencies are also detected in the amplitude spectrum of V775 Tau. If these oscillations are indeed g-modes, V775 Tau would be one of the rare stars that show all \(\gamma\) Dor, \(\delta\) Scuti and Am type variations at the same time. The MOST star HD 114839 \(T_{\text{eff}} = 7,400\) K, \(\log g = 4.20\), \(V\text{sin}i = 68(2)\) \(\text{km} \text{s}^{-1}\) can be given as another example for such a type \(\text{Hareter et al. 2011}\). It is the fourth-known such hybrid pulsator that shows both p- and g-modes as well as Am-type properties in the amplitude spectrum \(\text{King et al. 2000}\). Recently, the Am star KIC 11445913 \(T_{\text{eff}} = 7,250(100)\) K, \(\log g = 3.50(20)\), \(V\text{sin}i = 51(1)\) \(\text{km} \text{s}^{-1}\) has been also classified as a \(\delta\) Scuti/\(\gamma\) Dor hybrid with a very rich frequency spectrum \(\text{Balona et al. 2011}\).

As previously discussed, period changes in \(\delta\) Scuti stars are directly proportional to the changes in the stellar radius, i.e., a period increase is observed with increasing radius for the vast majority of stars in the lower instability strip of the H-R diagram. Breger et al. 1998 give the variation rates in periods as \(dP/Pdt = \)
$10^{-10}$ yr$^{-1}$ and $10^{-7}$ yr$^{-1}$ for the main sequence and the longer-period evolved stars, respectively. However, due to the inconsistencies between the theoretical and the observational findings, it is assumed that the period changes observed in population I, $\delta$ Scuti stars are not caused by stellar evolutionary changes, but produced by non-linear mode interactions that is explained above. For $\delta$ Scuti models in a wide range of oscillation parameters, the rates of these period changes are found to be between $7.00 \times 10^{-4}$ and $1.00 \times 10^{-3}$ yr$^{-1}$ (Breger et al. 1998). The latter estimations, which are given for the non-evolutionary period changes, are significantly consistent with the result found in the STEREO data.

As seen in previous sections, the rates calculated for V483 Tau and V775 Tau mostly vary between $10^{-3}$ and $10^{-4}$ yr$^{-1}$.

At last but not least, from Fig. 1 and Fig. 3 I infer that most of the observable peaks above and under the significance level are quite consistent with the harmonics of the rotational periods of the sample stars. In order to support such a result, numerous studies in the literature can be given as an example. According to Liakos and Niarchos (2017), binarity affects pulsation period for the systems with $P_{\text{orb}} < 13$ days, such that these systems show an explicit linear correlation between orbital and pulsation periods. Also they state that in short-period ($P_{\text{orb}} < 13$ days) detached systems, the tidal effects may play an important role to the pulsation frequency modulation. Although tidal potential excites g-mode pulsations (Zahn 2013; Hambleton et al. 2010), there is probably an influence to the p modes and/or to the radial mode of the pulsating member of the system. In oscillating eclipsing systems of algol type stars, this dependence seems to be more complicated because the mass transfer rate may be also a determining parameter additionally to the tidal interaction influence in the pulsations likely in detached systems (Liakos and Niarchos 2017). This suggestion is also given in Liakos and Niarchos (2015). Accordingly, a strong correlation appears to exist between $P_{\text{orb}}$ and $P_{\text{puls}}$. However, it seems that binarity does not affect the pulsation properties in systems with $P_{\text{orb}} > 13$ days.

Similar to the findings of Liakos and Niarchos (2017), Zhang et al. (2013) propose that the $P_{\text{puls}}/P_{\text{orb}}$ ratio could be a criterion to approximately distinguish whether the star in a close binary pulsates in p-modes. If $P_{\text{puls}}/P_{\text{orb}} > 0.1$, the star does not pulsate in p-modes, while if $P_{\text{puls}}/P_{\text{orb}} < 0.07$, the pulsation could be of p-modes. The studies which claim that there is an exact relation between pulsation and orbital periods can be increased with the samples of Soydugan et al. (2006) and Cakirlı and Ibanoglu (2016).

In the case of V483 Tau and V775 Tau, the orbital periods of the stars are given as 2.4860 and 2.14328 days, respectively. Also, from the pulsation periods found in this study, the ratios of the pulsation periods to the orbital periods ($P_{\text{puls}}/P_{\text{orb}}$) are between 0.03 and 0.07 for V483 Tau, 0.03 and 0.08 for V775 Tau. These results indicate that pulsations are in p-modes. Based on the fact that the orbital periods of the stars are smaller than 13 days and they pulsate in p-modes, it may be concluded that the $\delta$ Scuti type pulsations observed in the stars are correlated with their rotation periods, as suggested in Sect. 4.

The micro-magnitude precision of the space missions such as KEPLER, CoRoT, and MOST is quite sufficient to detect the $\delta$ Scuti type pulsations. For stars of spectral types A-F, these telescopes offer several perspectives: the CoRoT satellite revealed more candidate hybrid $\delta$ Scuti/$\gamma$ Dor stars (Hareter et al. 2010); the KEPLER found that the $\delta$ Scuti or $\gamma$ Dor stars were in fact hybrid pulsators (Grigahcène et al. 2010); the MOST satellite discovered two bright hybrid candidates (King et al. 2006; Balona et al. 2011) analysed the Kepler data of ten known Am stars and found that six of them exhibit $\delta$ Scuti pulsation; and Breger et al. (2012) observed $\delta$ Scuti stars in the Praesepe cluster by the MOST satellite and discovered different pulsation behaviours.

As seen from the examples, the space missions provide new insights into behaviours of $\delta$ Scuti pulsators and also valuable information about the evolution among $\delta$ Scuti, $\gamma$ Dor and Am type stars. In this context, I believe that the STEREO HI-1A is also a valuable source for gaining a better understanding of the nature of $\delta$ Scuties and their evolution status. Its high-precision and long-term observation capability provided a unique opportunity to detect the smallest variations in $\delta$ Scuti light curves and study period changes seen in the selected $\delta$ Scuti stars.

Acknowledgements

I acknowledge assistance from Prof. Dr. Ian R. Stevens, Dr. Vino Sangaralingam and Dr. Gemma Whittaker in the production of the data used in this study.
