Stellar Variability with Photometric and Spectroscopic Analysis of five Am Field Stars

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Abstract

The spectroscopic and photometric analysis of sample Am stars are carried out to determine the stellar characteristics of each studied star. The CCD photometric analysis of HD 98851 and HD 207561 show clear evidence of pulsation variability of 1.55 hr and 5.8 min respectively. Similarly, a clear evidence of the photometric variability is also found for an Am star HD 73045 which is likely to be pulsating in nature with a period of about 36-min. We are also found dissimilar behaviour of elemental abundances of various ions for HD 113878 and HD 118660. The basic stellar parameters (mass, luminosity, radius, life time, distance, proper-motion etc.) are determined for each sample stars. The tidal radius and boundaries of habitable zone of each star are also computed to search the extra-terrestrial life. Astero seismic mass scale test shows greater stellar masses compare to the solar mass.

Keywords: astronomy: photometric methods – database – telescopes – astronomical reduction – HD 73045, HD 98851, HD 113878, HD 118660, HD 207561, stellar variability

1. Introduction

The metallic-lined Am stars are a well-known subgroup of the chemically peculiar (CP) stars on the upper main sequence (MS) (Budaj & Iliev, 2003). The Am stars along with A-peculiar(Ap) are main classes of CP stars and they are important tools for the asteroseismological study because some of them exhibit multi-periodic pulsational variability. They show strong and/or weak absorption lines of certain heavy and rare-earth elements in their optical spectrum in comparison to the normal stars of similar spectral type. Their peculiarity is interpreted as atmospheric under-abundance and/or over-abundance of different chemical elements, and is explained by the diffusion process (Vauclair, 2004). The atmospheres of these stars have an inhomogeneous distribution of chemical elements which are frequently seen as abundance spots on stellar surfaces and as clouds of chemical elements concentrated at certain depths along the stellar radius (Ryabchikova et al., 2006). Am stars exhibit overabundance of the iron peak and heavy elements such as Zn, Sr, Zr, Ba and underabundance of the elements

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such as Ca, Sc (Gray & Corbally, 2009). The strengths of metal lines of Am stars are more typical of an F star rather than an A star (Balona et al., 2011). The Am stars are very weak magnetic and found generally in the binary system and many of them are now known to exhibit low-amplitude pulsational variables of period range similar to the δ-Scuti variables. The pulsations in Am stars are important astrophysical tools to study the complex relationship between stellar pulsation and magnetic field in the presence of atmospheric abundance anomalies. They are also excellent test objects for astrophysical processes like diffusion, convection, and stratification in stellar atmospheres in the presence of rather strong magnetic fields.

2. Sample Stars and their previous study

2.1. Characteristic properties of stars

In the present work, author has taken a sample of Am field stars, having five members as HD 73045, HD 98851, HD 113878, HD 118660 and HD 207561. The present analysis is carried out using existing catalogue and literature data with the gathered data of author through the collaboration of ARIES, Nainital. The detail of basic parameters of selected stars are given in the Table 1 and their corresponding finding charts (FCs) have been shown in the Figure 1. These FCs of target stars are helpful to decide the nature of observations as well as the perform accuracy of analysis of gathered data. The brief discussion of available characteristic data of each sample star is given as below,

| Parameter Name | HD 73045   | HD 98851   | HD 113878  | HD 118660  | HD 207561  |
|----------------|------------|------------|------------|------------|------------|
| R. A. (α)     | 08h36m48s  | 11h22m51.17s | 13h06m0.7s | 13h38m0.8s | 21h48m16s |
| Declination (δ)| +18°52'58" | +31°49'41"  | +48°01'41" | +14°18'07" | +54°23'15" |
| Distance (pc)  | 218.34 ± 0.21 | 160.51 ± 0.09 | 401.61 ± 0.31 | 73.26 ± 0.03 | 116.69 ± 0.07 |
| Radial Velocity (km/s) | 35.20 ± 0.07 | -1.86 ± 0.89 | -18.10 ± 0.9 | -1.7 ± 2  | -15.10 ± 3.6 |
| Redshift z (order of 10⁻⁶) | 117  | -0.6 ± 0.3 | -6 ± 0.3 | -0.06 ± 0.03 | -50 ± 12 |
| Parallaxes     | 3.54 ± 0.14 | 6.64 ± 0.06 | 3.50 ± 0.04 | 14.18 ± 0.05 | 7.63 ± 0.04 |
| Spectral Type  | Am C       | F2 D       | A5 D       | A9Vs C     | F0III C    |

2.1.1. HD 73045

The spectral type of HD 73045 is given as A7.2 (Kraus & Hillenbrand, 2007), Am-var (Bertaud, 1960) and Am (Bidelman, 1956). This star belongs to Praesepe open star cluster (Fossati et al., 2008) and classified as Am star in which Ca and Sc are underabundant and the Fe-peak elements are overabundant (Fossati et al., 2008).
Figure 1: The finding charts of HD 73045, HD 98851, HD 113878, HD 118660 and HD 207561 are shown in the panel A, B, C, D and E respectively. Size of each FC is $15 \times 15$ arcmin$^2$ and constructed by “fits” file as extracted from the DSS1 server of ESO. These finding charts are effectively used to identify the target stars during their time series observation through fast photometer and CCD camera of the 1.04 telescope. The most centered and brighter star of each panel represents the corresponding target object.
analysis of high spectral resolution and high signal-to-noise ratios observation gives the values of $T_{\text{eff}}$, $\log g$ and $F_{\text{H}}$ as 7500 K, 4.00 and 0.35 respectively. Similarly, the high resolution spectroscopic work (Hui-Bon-Hoa et al., 1997) provide the values of $T_{\text{eff}}$, $\log g$ and $F_{\text{H}}$ as 7520 K, 4.27 and 0.59 respectively. Masana et al. 2006 (Masana et al., 2006) provides the value of $T_{\text{eff}} = 7524$ K. Its velocity ($v$) given as 35.20±0.07 (Pourbaix et al., 2004), 22.8 (Duflot et al., 1995), 48.5 (Dickens et al., 1968), 22.8±2.0 (Wilson, 1953) and 22.8 (Wilson & Joy, 1950).

2.1.2. HD 98851

It describes as F2 spectral type (Olsen, 1980) and marginal Am stars (Abt, 1984). Its velocity is found to be $-6.60\pm3.50$ (Gontcharov, 2006). Its luminosity class is designed to be F3III (Grenier et al., 1999). The proper motion values ($\mu_x$, $\mu_y$) of HD 98851 are $(-46\pm10,-21\pm10)$ (Luyten, 1971). The main pulsating frequencies of HD 98851 found to be 0.208 and 0.103 mHz and its equivalent H-line spectral class is F1-IV (Joshi et al., 2003).

2.1.3. HD 113878

HD 113878 is an A5 spectral type star with metallic lines (Olsen, 1980) and also Am star (Grenier et al., 1999). It shows δ − Sct behavior with pulsation period of 2.31hr ($f_1 = 0.12$mHz) (Joshi et al., 2006). The $\log g$ values are given to be 3.36 (Casagrande et al., 2011) and 3.84 (Bailer-Jones, 2011). The value of $[Fe/H]$ is 0.74 for this star (Casagrande et al., 2011). Its parallax values are $2.67\pm0.99$ (Perryman et al., 1997) and $2.49\pm0.77$ (van Leeuwen, 2007). The proper motion values ($\mu_x$, $\mu_y$) of HD 113878 are $(-14\pm8,-25\pm8)$ (Luyten, 1971). Its velocity is $-18.10\pm0.9$ (Gontcharov, 2006).

2.1.4. HD 118660

The spectral class of HD 118660 is A9Vs (Barry, 1970) and A9III-IV (Appenzeller, 1967). The calculated values of its velocity are $-1.70\pm2.90$ (Gontcharov, 2006), -1.7 (Duflot et al., 1995), -1.7 (Wilson, 1953) and $-1.7\pm2.0$ (Harpey, 1937). It also shows δ − Sct behavior with multi-periods (1 hr, 2.52hr etc.) (Joshi et al., 2006).

2.1.5. HD 207561

It has described to be F0III (Cowley & Cowley, 1965) or F0IV (Floquet, 1975) spectral star. The period of HD 207561 is found to be 6min. The null results of $B_z$ indicates that 6 min periodicity of HD 207561 through fast photometer and CCD photometry may be arisen due to the instrumental or other reasons (Joshi et al., 2015). According to Cunha, 2002 (Cunha, 2002), the possible rapid pulsation in the atmosphere of HD 207561 could have non-stable modes. The rotational velocity (74±5 $kms^{-1}$) of HD 207561 have been found through the analysis of high-resolution spectroscopic observations. Its proper motion values ($\mu_x$, $\mu_y$) are derived to be $(+39\pm7,+40\pm8)$ by Luyten 1971 (Luyten, 1971). Its velocity is $-15.10\pm3.60$ (Gontcharov, 2006).
2.2. Previous observations of high resolution of spectroscopy

The high resolution spectroscopic data of HD 73045 has been acquired by Fossati et al. 2007 (Fossati et al., 2008) through Echelle Spectro-Polarimetric Device for Observations of stars (ESPaDOnS) spectrometer at the Canada-France-Hawaii Telescope (CFHT). The ESPaDOnS spectrometer covers the wavelength range from 3700 Å to 10400 Å with a resolving power of about 65000. The high resolution spectral data of HD 98851, HD 113878, HD 118660 and HD 207561 have acquired by Joshi et al. 2015 (Joshi et al., 2015) and Joshi et al. 2012 (Joshi et al., 2012). The prescribed data were collected through the Nasmyth echelle spectrometer (NES) of the 6-m Big Telescope Alt-Azimuthal (BTA) telescope at Special Astrophysical Observatory (SAO), Russian Academy of Sciences (RAS). It also includes the Main Stellar Spectrograph (MSS). The MSS has been applied to register the circularly polarized spectra within 500 Å range, have centered on 4700 Å. These instruments share the common block of preslit devices, including a set of calibration lamp. The mean resolving power \( \frac{\lambda}{\Delta \lambda} \) of about 14000 in spectropolarimetric mode and 39000 in echelle spectroscopy. The detail of used spectra format and their quality is summarized in the Table 2.

In this connection, the abundances results of high resolution spectroscopic observations of HD 113878 and HD 118660 are also available with the SARG (Spettrografo ad Alta Risoluzione del Galileo) spectroscope at the Telescopio Nazionale Galileo (TNG), La Palma (Catanzaro & Ripepi, 2014). SARG covers a spectral wavelength range from 3600 Å to 10000 Å, with a resolution ranging from 29000 to 164000 (Gratton et al., 2001).

### Table 2: High resolution spectroscopic observation log for the sample Am stars as extracted from the literature.

| HD number | JD, 2450000+ | Instrument | Sp. range, Å | SNR | References |
|-----------|--------------|------------|--------------|-----|------------|
| 73045     | 3745.091     | ESPaDOns   | 3850-6800    | 290 (5000 Å) | (Fossati et al., 2008) |
| 98851     | 5025.265     | NES        | 4840-6250    | 250 (5500 Å) | (Joshi et al., 2015) |
| 113878    | 5025.312     | MSS        | 4428-4980    | 370 (4700 Å) | (Joshi et al., 2015) |
| 5615.676  | 3600-7900    | SARG       | 4428-4980    | 100 (5750 Å) | (Catanzaro & Ripepi, 2014) |
| 6381.497  | MSS          | 4428-4980  | 180 (4700 Å) | (Joshi et al., 2015) |
| 6383.486  | MSS          | 4428-4980  | 250 (4700 Å) | (Joshi et al., 2015) |
| 5615.649  | SARG         | 4600-7900  | 100 (5750 Å) | (Catanzaro & Ripepi, 2014) |
| 6408.505  | NES          | 3950-6860  | 130 (5500 Å) | (Joshi et al., 2015) |
| 6383.521  | MSS          | 4428-4980  | 350 (4700 Å) | (Joshi et al., 2015) |
| 6383.538  | MSS          | 4428-4980  | 330 (4700 Å) | (Joshi et al., 2015) |
| 207561    | 5702.506     | NES        | 4426-4978    | 230 (5500 Å) | (Joshi et al., 2012) |
| 5764.342  | NES          | 44204974   | 250 (5500 Å) | (Joshi et al., 2012) |
| 5764.508  | NES          | 44204974   | 200 (5500 Å) | (Joshi et al., 2012) |
2.3. Hβ profile of HD 113878 and results for other stars

The absorption lines of Balmer series of gathered stellar spectrum is effectively useful in the stellar astronomy due to their appearances in numerous stellar objects as a function of abundances of hydrogen. These lines are strong compared to other lines from other elements and used to determine radial velocity and surface temperature. The Hβ absorption line of Balmer series has a strong indicator of temperature. As a result, the stellar parameters such as $T_{\text{eff}}$ and $\log g$ have estimated through the best fit computed spectra with the observed spectrum of each sample star.

In the Figure 1.3, author represents the comparison of synthetic profile of Hβ line computed for $T_{\text{eff}} = 7000 \pm 200$ K and $\log g = 3.7$ with an observed spectrum of HD 113878 to show the best fitting of adopted synthetic Hβ profile on actual spectrum. Black thin lines of this figure represents the synthetic profiles as computed for the two values of $T_{\text{eff}} = 7000 \pm 200$ K which are reflecting the accuracy of procedure of $T_{\text{eff}}$ determination. These results are close to the results of Catanzaro & Ripepi (2014) (Catanzaro & Ripepi, 2014), which are $T_{\text{eff}} = 6900 \pm 200$ K and $\log g = 3.4 \pm 0.1$ dex. Similarly, Casagrande et al. (2011) (Casagrande et al., 2011) have derived the following astrophysical parameters for HD 113878 thorough the spectroscopic observations: $T_{\text{eff}} = 7072 \pm 210$ K, $\log g = 3.36$, and $[Fe/H] = 0.74$.

The $H_{\alpha}$ and $H_{\beta}$ line wings of high-resolution spectrum of HD 73045 have given the value of effective temperature ($T_{\text{eff}}$) and $\log g$ as 7570 K and 4.05 respectively (Fossati et al. 2008). Based on the low-resolution spectroscopy, the $T_{\text{eff}}$ and $\log g$ for the star HD 98851 are determined to be 7000$\pm$250 K and 3.5$\pm$0.5 respectively (Joshi et al. 2003). The best fitted $H_{\alpha}$ and $H_{\beta}$ profiles of high resolution spectrum of HD 118660 provide atmospheric parameters as $T_{\text{eff}} = 7200 \pm 200$ K, $\log g = 3.9 \pm 0.1$.
dex and $v \sin i = 100 \pm 10$ km s$^{-1}$ (Catanzaro & Ripepi 2014). After best fitted $H_\beta$ profile on the high resolution spectrum of HD 207561, the values of $T_{\text{eff}}$ and surface gravity ($\log g$) have found to be $7300 \pm 250$ K and $3.7 \pm 0.1$ dex respectively (Joshi et al., 2012).

On the basis of spectroscopic analysis of new gathered data, the values of a set ($T_{\text{eff}}$, $\log g$) of HD 98851, HD 113878 and HD 118660 are found to be $(7000 \pm 200, 3.65 \pm 0.15)$, $(7000 \pm 200, 3.70 \pm 0.10)$ and $(7550 \pm 150, 4.00 \pm 0.10)$ respectively (Joshi et al., 2017).

2.4. Fast Photometry

The used Photometric data of HD 73045 was collected on the date 07 February 2009 (HJD 2454870). The photometric observations were carried out from 1.04-m telescope of ARIES in the high-speed photometric mode with a continuous 10-sec integrations through a Johnson B filter and 30′′ diaphragm aperture. The data reduction process comprises of visual inspection of the light curve to identify and removal of the bad data points; correction for coincident counting losses; subtraction of the interpolated sky background and correction for the mean atmospheric extinction. The left panels of Figure 3 show photoelectric light curve and their corresponding Discrete Fourier Transformation diagram of each star are represent in right panels of Figure 3. The photoelectric light curve of HD 98851 has contained alternating high and low magnitudes, nearly harmonic period ratio, high pulsating overtones. The $\delta$ Sct nature of HD 113878 and HD 118660 has not found many observation nights due to the short duration and large time gaps between the runs. The 6-min oscillation detection of HD 207561 have found in two consecutive nights and not other observed nights, therefore, it is not claimed as roAp star.

3. Photometric Analysis of Sample Stars

3.1. CCD Photometric Study of HD 98851 and HD 207561

The CCD observations have been acquired for HD 98851 and HD 207561 only because the field of view of other two stars have no comparison star. The photometric observation of sample stars HD 98851 and HD 207561 have been acquired through 1.04-m Sampurnanand telescope at Manora Peak, Nainital. We used 2K $\times$ 2K CCD detector of 2048 x 2048 pixel$^2$, each of which has a square size of 24 $\mu$m on a side. The field of view of the CCD camera is approximately 13$\times$13 arcmin$^2$. The read noise and gain per pixel of the CCD are 5.3 e$^-$ and 10 e$^-$/ADU e$^{-1}$, respectively. A total of 38 frames of HD 98851 are acquired in Johnson V-band filter in various 22 nights (Observation detail in Table 3) while 87 frames of HD 207561 are observed on the night of 30Sep, 2008 with the exposure time 3 sec. The bias frames and flat frames are also acquired in the systematic way for each night which used to zero bias correction and pixel sensitivity correction for each science frame. Thus obtained science frames further used to aperture magnitude estimation of stars through "DAOPHOT" package. In the differential photometry, the same aperture of target star and comparison star is required because the differential photometry has performed for similar magnitude type of stars which are situated as close to each other in the field of view of science frame. Due to the limiting field of view of 1.04m telescope, we have found 1 comparison star
Figure 3: The fast photometric light curves and their corresponding DFT of sample stars are shown in left and right panel respectively.
in the observing field of both stars. The smoothness of phase diagram of each star found by the moving average of each further five magnitude points as depicted in Figure 1.2. The period of HD 207561 and HD 98851 found as 5.8 min and 1.55 hr respectively.
4. Extraction of stellar magnitudes

The stellar magnitudes of selected Am field stars with effective wavelength of filters has been listed in the Table 4. Author does not find stellar magnitudes of HD 207561 in SDSS photometry. Similarly, HD 73045 and HD 113878 have also stellar magnitudes in filters of GALEX. Author has been noticed the descending stellar magnitudes with increment effective wavelength from filter $z$ to filter $R$ and stellar magnitude of $G$ filter of each sample stars is greater than its stellar magnitude of $R$ filter. In this connection, the stellar magnitudes further decrease with effective wavelengths from filter $G$ to filter $K$. Author does not obtain any generalized feature of sample members below the effective wavelength of filter $z$ and above the effective wavelength of filter $K$. Thus, author obtains a bump of stellar magnitude at the effective wavelength of filter $G$ for each Am star of the sample.

| S.N. | Filter | $\lambda$ | HD 73045 | HD 98851 | HD 113878 | HD 118660 | HD 207561 |
|------|--------|----------|----------|----------|-----------|-----------|-----------|
| 01   | FUV    | 153.8    | 16.090   | --       | 16.514    | --        | --        |
| 02   | NUV    | 231.6    | 12.418   | --       | 12.467    | --        | --        |
| 03   | u      | 354.3    | 14.474   | 9.364    | 9.959     | 8.375     | --        |
| 04   | g      | 477.0    | 9.031    | 11.419   | 8.401     | 7.275     | --        |
| 05   | r      | 623.1    | 8.620    | 10.933   | 8.257     | 10.485    | --        |
| 06   | i      | 762.5    | 12.032   | 11.065   | 12.683    | 7.058     | --        |
| 07   | z      | 913.4    | 9.193    | 7.909    | 9.096     | 7.139     | --        |
| 08   | B      | 440.0    | 8.906    | 7.729    | 8.596     | 6.739     | 8.078     |
| 09   | V      | 550.0    | 8.622    | 7.415    | 8.249     | 6.496     | 7.846     |
| 10   | R      | 650.0    | 8.430    | 7.220    | 8.020     | 6.350     | 7.710     |
| 11   | G      | 715.0    | 8.512    | 7.295    | 8.116     | 6.398     | 7.752     |
| 12   | J      | 1235.0   | 8.036    | 6.741    | 7.581     | 5.973     | 7.377     |
| 13   | H      | 1662.0   | 7.947    | 6.673    | 7.465     | 5.890     | 7.363     |
| 14   | K      | 2159.0   | 7.944    | 6.610    | 7.407     | 5.853     | 7.314     |
| 15   | W₁     | 3400.0   | 7.861    | 6.626    | 7.313     | 5.826     | 7.220     |
| 16   | W₂     | 4600.0   | 7.887    | 6.549    | 7.402     | 5.750     | 7.327     |
| 17   | W₃     | 12000.0  | 7.907    | 6.628    | 7.407     | 5.886     | 7.303     |
| 18   | W₄     | 22000.0  | 7.587    | 6.530    | 7.156     | 5.815     | 7.122     |
| 19   | $\beta$ | 2.759    | --       | --       | 2.745     | 2.778     | 2.825     |
| 20   | $(b - y)$ | 0.218    | 0.199    | 0.219    | 0.150     | 0.142     |           |
| 21   | m₁     | 0.195    | 0.222    | 0.257    | 0.214     | 0.220     |           |
| 22   | c₁     | 0.749    | 0.766    | 0.728    | 0.794     | 0.819     |           |

4.1. Atmospheric parameters through Strömgren photometry

The values of temperature, logarithm gravity and BC are used to estimate the basic atmospheric parameters of any star. The values of bolometric corrections (BC), logarithm temperature and logarithm gravity are calculated through the Balona’s relations.
The values of $[\beta]$ and $[c]$ are estimated as $[\beta] = \log(\beta - 2.5)$ and $[c] = \log(c + 0.2)$. Moon & Dworetsky 1985 ([Moon & Dworetsky, 1985]) introduced the dereddened value ($a_0$) and reddening free parameters ($r$) to calibrate these parameters. These estimated terms are defined as below,

$$a_0 = 1.36(b - y) + 0.36m + 0.18c - 0.2448 \quad \text{and} \quad r^* = 0.35c - 0.07(b - y) - \beta + 2.565.$$

These estimated parameters are used to estimated the value of $M_V = 1.5 + 6a + 17r$ (Moon & Dworetsky, 1985), here $r^* = -r$. Moon & Dworetsky 1985 (Moon & Dworetsky, 1985) are also published a grid according synthetic $uvby$ indices to determine the values of effective temperature $T_{MD}$ and $g$ in the range 600K $\leq T_{MD} \leq 20000$K. The calibrations of effective temperature ($T_{eff}$) and logarithm gravity are further carried out through the relation of Napiwotzki et al. 1993 (Napiwotzki et al., 1993) as, $T_{eff} = 1.007 \pm 0.008$ and $\log g = \log g_{MD} - 2.9406 + 0.7224 \log T_{eff}$.

In the case of HD 98851, indices $\beta$ misses in literature. In this connection, the value of $r^*$ of HD 98851 is estimated through a relation $a = 2([m] - 0.179) + 0.8r^*$ (Strömgren, 1966) and value of $[m]$ is given as $[m] = m + 0.30(b - y)$ ([Grobben, 1978]). Author found the values of $[m]$, $r^*$ and synthetic $\beta$ indices for star HD 98851 as 0.282, 0.0478 and 2.784 respectively. The estimated value of $\beta$ indices of HD 98851 has utilized to estimate the $T_{eff}$ through above prescribed relations. All computed parameters of studied Am stars through the Strömgren photometry are listed in the Table 5. The values of $T_{eff}$ and $\log g$ of this table are the initial derived set of sample stars.

### 4.2. Measurement of stellar reddening

The absolute value of $M_V$ is also estimated through the relation $M_V = V + 5 + 5\log \pi - A_V$, in which $\pi$ and $A_V$ are the stellar parallax and visual absorption. The
values of visual absorption of nearby and high galactic latitude stars are estimated as $A_V = 3.1E(B-V)$ (Savage & Mathis, 1979) and $E(B-V)$ is the reddening value for studied star. The Hipparcos catologue provides the parallax values of HD 73045, HD 98851, HD 113878, HD 118660 and HD 207561 as 4.97±1.22, 5.84±0.87, 2.67±0.99, 13.95±0.85 and 7.86±0.70 mas respectively (van Leeuwen, 2007). These values are providing the reddening values as -0.012, -0.37, -0.413, 0.19 and 0.75 for HD 73045, HD 98851, HD 113878, HD 118660 and HD 207561 respectively.

5. Abundance Analysis

5.1. Results of spectroscopic studies from literature

The abundance of various element have been estimated through the spectrum synthesis method of observed spectrum while the theoretical spectra were computed in LTE approach with Synth3 Software (Kochukhov, 2007). Analysis of stellar spectra are based on the principle that different spectral lines of a certain chemical yield the same element abundances, independent of their equivalent width (Hundt, 1973). The spectroscopic abundance results of various elements for each star are depicted in the Figure 5(A) and listed in the Table 6. The high-resolution spectroscopic analysis of sample stars are showing following features,

(1) The abundances of C, N, O, Ca and Sc are underabundant for HD 73045. Other hand, Fe-peak and rare earth elements are found overabundant for it.

(2) Abundances of half of the elements HD 98851 are similar to solar one within error.

(3) In the case of HD 113878, author found deficiency in abundance of Ca, Sc, and Ti compare to solar values and excess in abundance of heavy elements.

(4) In the case of HD 118660, abundance of Ca and abundance of the group of lanthanide elements are found to be underabundant and overabundant respectively.

(5) The small underabundance of C, O, Ca, and Sc are reported for HD 207561 (Joshi et al., 2015). Similarly, the mild Am character and normal star abundances of HD 207561 have confirmed through moderate excess of the other 10 chemical elements (Na, Mg, Si, Ti, Cr, Mn, Fe, Ni, Y, Ba).

5.2. Dissimilarities of Analytic results of elemental abundances

The individual discussion of elemental abundance can help to understand the atmospheric dynamics of Am stars. A typical analysis of abundance of each element for HD 113878 and HD 118660 are carried out by both Joshi et al. (2015) [hereafter, JO15] and Casagrande et al. 2011 [hereafter, CA11]. We have found dissimilar properties of elemental abundances of some ion for HD 113878 and HD 118660 as shown in the Figure 5(B). A brief description of dissimilar properties of ion abundances are given as below.

Carbon Abundances:- According to the data of Table 1.6 and Table 1.7, the value of carbon abundances of each star is found to be maximum. On the basis of comparison of work JO15 and CA11, the difference of carbon abundance for HD 118660 is found to be maximum with respect to the other elements. However, these work also indicate
Figure 5: In the panel A:- Derived atmospheric abundance of HD 98851, HD 11378 and HD 118660 by JO15 for the various element relative to the Sun. Atmospheric abundance values for HD 73045 and HD 207561 are extracted from the FO08 and Joshi et al. JO12 (Joshi et al., 2012) respectively. In the panel B:- Author represents the differences of atmospheric abundances as derived by Joshi et al. (2015) (Joshi et al., 2015) and Casagrande et al. 2011 (Casagrande et al., 2011) with respect to the derived atmospheric abundances of the former work.
that said difference for HD 113878 is larger except Na and S. JO15 found carbon abundance is under-abundant for HD 113878, however it comes nearly equal to the solar one in the work of CA11. In the case of HD 118660, carbon abundance is found to be under-abundant for HD 113878, whereas it is reported to overabundant by CA11.

**Magnesium Abundances:** JO15 found the Mg overabundant for HD 118660, whereas it is found to be under-abundance in the analysis of CA11.

**Silicon Abundances:** CA11 found the Si overabundant for HD 113878, whereas it is found to be under-abundance in the analysis of JO15.

**Calcium Abundances:** According to the CA11, the elemental abundance of Ca for HD 113878 are found to be similar of Ca abundances of Sun. Other hand, results of JO15 show under-abundances of Ca ion for HD 113878. Both studies are showing under-abundances of Ca ion for HD 118660.

### Table 6: Individual abundance of chemical elements in the atmosphere of stars with solar chemical composition.

The colon sign denotes doubtful measurements due to the small number of lines or others. The actual accuracy for the most of elements should be setted up to 0.20-0.25 dex as depend in changes in log $\frac{N}{N_{\text{tot}}}$ caused by the accuracy of atmospheric parameters.

| Ion  | At. No. | HD 73045 F08 | HD 98851 JO15 | HD 207561 JO15 | Sun I | Sun II | AS09 | SUN |
|------|---------|--------------|--------------|----------------|-------|--------|------|-----|
| $C_I$ | 06      | -4.37±0.04  | -3.94±0.17   | -3.78±0.10     | -3.61 | -3.65 | -3.63 |     |
| $Na_I$ | 11      | -5.32±0.03  | -5.25±0.32   | -5.22±0.19     | -5.80 | -5.87 | -5.84 |     |
| $Mg_{II}$ | 12    | -4.52±0.04  | -4.59±0.06   | -4.27±0.03     | -4.44 | -4.51 | -4.48 |     |
| $Mg_{III}$ | 12    | -4.18(1)    | -4.51        | -4.51          | -4.51 |       |      |     |
| $Si_{II}$ | 14     | -4.21±0.05  | -4.42±0.12   | -4.29±0.16     | -4.53 | -4.53 | -4.53 |     |
| $Si_{III}$ | 14    | -4.45(1)    | -4.23(1)     | -4.53          | -4.53 | -4.53 | -4.53 |     |
| $S_I$ | 16      | -4.67±0.09  | -4.47(1)     | -4.91          | -4.90 | -4.91 |       |     |
| $Ca_{II}$ | 20     | -6.46±0.04  | -5.53±0.16   | -5.69±0.24     | -5.70 | -5.73 | -5.72 |     |
| $Ca_{III}$ | 20     | -5.64±0.03  | -5.68(1)     | -5.70          | -5.73 | -5.72 |       |     |
| $S_{II}$ | 21      | -9.39±0.01  | -8.65±0.03   | -8.74±0.10     | -8.89 | -8.99 | -8.94 |     |
| $Ti_{II}$ | 22     | -6.91(1)    | -6.26±0.37   | -7.09          | -7.14 | -7.12 |       |     |
| $Ti_{III}$ | 22    | -6.95±0.04  | -7.19±0.17   | -6.69±0.29     | -7.09 | -7.14 | -7.12 |     |
| $V_I$ | 23      | -7.60±0.00  | -7.55(1)     | -8.11          | -8.04 | -8.08 |       |     |
| $Cr_{II}$ | 24     | -5.63±0.16  | -6.38±0.25   | -5.97±0.07     | -6.40 | -6.40 | -6.40 |     |
| $Cr_{III}$ | 24     | -5.82±0.26  | -5.88±0.09   | -6.40          | -6.40 | -6.40 |       |     |
| $Fe_{II}$ | 26     | -4.03±0.04  | -4.23±0.22   | -4.09±0.15     | -4.54 | -4.59 | -4.57 |     |
| $Fe_{III}$ | 26    | -4.17±0.25  | -4.07±0.10   | -4.54          | -4.59 | -4.57 |       |     |
| $Ni_{II}$ | 27     | -4.93±0.06  | -5.39±0.25   | -5.23±0.18     | -5.82 | -5.81 | -5.82 |     |
| $Y_{II}$ | 39      | -8.91±0.09  | -9.24±0.15   | -9.47±0.09     | -9.83 | -9.83 | -9.83 |     |
| $Zr_{II}$ | 40     | -9.05±0.01  | -8.73(1)     | -9.46          | -9.45 | -9.46 |       |     |
| $Ba_{II}$ | 56     | -8.50±0.00  | -9.02±0.22   | -9.00          | -9.86 | -9.87 | -9.87 |     |
| $La_{II}$ | 57     | -9.61±0.09  | -9.80±0.20   | -10.94         | -10.91 | -10.93 |      |     |
| $Ce_{II}$ | 58     | -9.26±0.04  | -10.46        | -10.46         | -10.46 | -10.46 |      |     |
| $Nd_{II}$ | 60     | -9.48±0.03  | -10.62        | -10.59         | -10.61 |       |      |     |
Iron Abundances: According to the JO15, the elemental abundance of Fe for HD 118660 are found to be similar of Fe abundances of Sun. Other hand, results of CA11 show overabundant of Fe ion for HD 118660. In the case of HD 113878, under-abundances of Fe ion is reported by CA11 and overabundant of Fe ion is confirmed by JO15.

6. Stellar properties

6.1. Effective temperature and Surface gravity

The effective temperature ($T_{\text{eff}}$) of a star is the temperature of a black body of the same size as the star and that would radiate the same total amount of electromagnetic power as emitted by the temperature (Rouan, 2011). According to the comparative result of BT-SETTL atmospheric model with spectral energy distribution, the $T_{\text{eff}}$ values of HD 73045 and HD 99851 are found to be 7268 K and 6800 K, respectively.
On the basis of principle component analysis (PCA) approach, the value of $T_{\text{eff}}$ for HD 73045 comes to be 7199 K (Munoz et al., 2013). The experimental values of $T_{\text{eff}}$ of HD 113878 are 6800 K (McDonald & Zijlstra, 2012), 7328 K (Balona et al., 2011), 6900 K (Bailer-Jones, 2011), 7072 K (Casagrande et al., 2011) and 7263 K (Joshi et al., 2006). The computed values of $T_{\text{eff}}$ for HD 118660 are 7772 K (Masana et al., 2006), 7500 K (Joshi et al., 2006), 7638 K (Balona et al., 2011), 7177 (McDonald & Zijlstra, 2013), 7447 (Zorec & Royer, 2012) and 7340 K (Catanzaro & Ripepi, 2014). Similarly, surface gravity of a rotating stellar object is the experienced gravitational acceleration at the equator of its surface. In astrophysics, the surface gravity is measured in the logarithm scale of its value in cgs system and expressed by $\log g$. The derived and extracted values of $T_{\text{eff}}$ and $\log g$ through Strömgren photometry, spectroscopic analysis and literature are used to determine the average values of effective temperature and logarithm gravity of each sample Am star. The computed values of $T_{\text{eff}}$ and $\log g$ of each sample star are given in the Table 9 and these resultant values are used to further analysis of stellar dynamics.

### 6.2. Micro-turbulence Velocity

The microturbulent velocity is defined as the microscale non-thermal component of the gas velocity in the region of the spectral line formation (Cantiello et al., 2009). The theoretical microturbulence velocity ($v_{\text{mic}}^{h}$) of each star has determined using the following relation (Gebran et al., 2014),

$$v_{\text{mic}}^{h} = 3.31 \times \exp \left( -\frac{T_{\text{eff}}}{8071.03} \right) \sqrt{0.01405}.$$ 

The $v_{\text{mic}}^{h}$ of HD 73045, HD 98851, HD 113878, HD 118660 and HD 207561 are found to be 3.01, 2.63, 2.60, 3.04 and 3.16 km s$^{-1}$ respectively and also listed in the Table 9.

### 6.3. Stellar Luminosity

The value of logarithm luminosity of each star has calculated through the relation,

$$\frac{L}{L_{\odot}} = - \frac{M_{V} + BC - M_{\text{bol,}\odot}}{2.5}.$$ 

The value of $M_{\text{bol,}\odot}$ is given as 4.74. After using the values of $M_{V}$ and $BC$ as estimated in the Section 8.5.1, the values of prescribed logarithm luminosity for HD 73045, HD 98851, HD 113878, HD 118660 and HD 207561 are found to be 1.32, 1.30, 1.53, 1.49 and 1.21 respectively.

### 6.4. Stellar Radius

The stellar parameters $T_{\text{eff}}$ of a star is physically related to the total radiant power per unit area at stellar surface ($F_{\odot}$) (Smalley, 2005):

$$\sigma T^{4} = \int_{0}^{\infty} F_{\nu} d\nu = F_{\odot} = \frac{L}{4\pi R^{2}}.$$ 

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It is allow us to estimate the stellar radius by using the values of $T_{\text{eff}}$ and luminosity of the investigate objects. In this connection, author used the following relation to estimate the stellar radius,

$$ R = R_\odot \left( \frac{L}{L_\odot} \right)^{1/2} \left( \frac{T}{T_\odot} \right)^2 $$

The value of effective temperature ($T_\odot$) is 5777 K. The radius of HD 73045, HD 98851, HD 113878, HD 118660 and HD 207561 are computed as 2.77 $R_\odot$, 2.97 $R_\odot$, 3.89 $R_\odot$, 3.34 $R_\odot$ and 2.32 $R_\odot$ respectively. The result of HD 73045 is close to the literature $2.124\pm0.522\ R_\odot$ (Masana et al., 2006).

6.5. Distance and stellar parallax

If, the units of stellar parallax ($\pi$) and distance ($d$) are milli-arcsec ($\text{mas}$) and parsecs ($\text{pc}$), then the stellar parallax is equivalent to the reciprocal of the stellar distance. The listed stellar distances and parallax of Table 1 are extracted from the work of McDonald et al. (McDonald & Zijlstra, 2012) and GAIA collaborations respectively. These values are different that of given in the Hipparcos catalogue (van Leeuwen, 2007) as given in the Section 8.3.2. After utilizing these values, author assigned the average parallax values for HD 73045, HD 98851, HD 113878, HD 118660 and HD 207561 as 4.36, 6.24, 2.89, 13.93 and 8.02 mas respectively. These values are listed in the Table 9 with the corresponding values of stellar distances.

6.6. Stellar Proper Motions and Transverse Velocities

The proper motion of any star shows the rate of angular drift across the sky. The proper motion values of sample stars are extracted from the various previous works, as listed in the Table 8. Author computed the proper motion values of each star as an average value of these extracted proper motion values. The proper motion of each star is determined through the following relation,

$$ \mu = \sqrt{\mu_x^2 + \mu_y^2}. $$

Author has found the proper motion values of HD 73045, HD 98851, HD 113878, HD 118660 and HD 207561 as 37.30±1.05, 44.32±0.88, 22.84±0.91, 43.70±0.93 and 48.05±0.78 mas/yr respectively. A perpendicular component of velocity of stellar objects with line of sight, is expressed as the Transverse Velocity ($v_T$). The value of $v_T$ has been obtained through the following relation,

$$ v_T = 0.21 \mu D \ km \ s^{-1}. $$

In the above relation, units of $\mu$ and $D$ are the $\text{mas/yr}$ and $\text{kpc}$ respectively. This formula leads the values of $v_T$ for HD 73045, HD 98851, HD 113878, HD 118660 and HD 207561 as 8.55, 7.10, 7.90, 3.14 and 5.99 km/s respectively.
Table 8: The stellar proper motion values through various catalogues.

| Catalogue            | HD 73045     | HD 98851     | HD 113878    | HD 118660    | HD 207561    |
|----------------------|--------------|--------------|--------------|--------------|--------------|
| Frouard et al. (2015) | $\mu_x = -34.26 \pm 0.31$ | $\mu_y = -12.26 \pm 0.31$ | $\mu_x = -39.53 \pm 0.35$ | $\mu_y = -22.93 \pm 0.27$ | $\mu_x = 42.92 \pm 0.35$ |
| Perryman et al. (1997) | $\mu_x = -35.80 \pm 1.19$ | $\mu_y = -10.58 \pm 0.94$ | $\mu_x = -41.91 \pm 0.76$ | $\mu_y = -15.53 \pm 0.63$ | $\mu_x = 41.01 \pm 0.79$ |
| Roeser et al. (2010)  | $\mu_x = -35.70 \pm 0.90$ | $\mu_y = -11.40 \pm 0.80$ | $\mu_x = -41.80 \pm 0.70$ | $\mu_y = -15.50 \pm 0.60$ | $\mu_x = 40.60 \pm 0.70$ |
| Van Leeuwen (2007)    | $\mu_x = -35.71 \pm 0.95$ | $\mu_y = -11.79 \pm 0.78$ | $\mu_x = -41.59 \pm 0.44$ | $\mu_y = -16.43 \pm 0.37$ | $\mu_x = 41.01 \pm 0.79$ |
| Zacharias et al. (2013) | $\mu_x = -35.60 \pm 0.50$ | $\mu_y = -12.50 \pm 0.70$ | $\mu_x = -41.60 \pm 1.00$ | $\mu_y = -16.40 \pm 1.00$ | $\mu_x = 40.50 \pm 1.00$ |
| Average Values        | $\mu_x = -35.41 \pm 0.77$ | $\mu_y = -11.71 \pm 0.71$ | $\mu_x = -41.29 \pm 0.65$ | $\mu_y = -16.10 \pm 0.59$ | $\mu_x = 41.21 \pm 0.73$ |

6.7. Stellar Lifetime

The lifetime of a star on the main sequence can be estimated through the solar evolutionary models. In this connection, the lifetime ($\tau_{MS}$) of a star is expressed as,

$$\tau_{MS} \approx \left(\frac{M}{M_\odot}\right)^{-2.5} \times 10^{10} \text{ years},$$

where $M$ and $M_\odot$ are the stellar and solar masses, respectively. The values of $\tau_{MS}$ of HD 73045, HD 98851, HD 113878, HD 118660 and HD 207561 are found to be 14.07, 13.42, 14.32, 14.14 and 13.71 Gyr, respectively.

6.8. Stellar tidal locking radius

An orbital state, where the planet rotates around its own axis with the same speed as it orbits its host star is called 1:1 spin-orbit resonance (Eggle et al., 2013). To calculate the value of distance up to which a planet would be tidally locked in a time span equal to age of the Solar system, the following relation of tidal radius is used (Kasting et al., 1993),

$$r_{TL} \approx 0.46\left(\frac{M}{M_\odot}\right)^{1/3} \text{ AU}.$$ 

Applying above relation, author estimated the value of $r_{TL}$ of HD 73045, HD 98851, HD 113878, HD 118660 and HD 207561 as 0.578, 0.559, 0.584, 0.580 and 0.568 AU, respectively.
6.9. Stellar habitable zones

The circum-stellar habitable zone of a star is a range of orbits around it within which a planetary surface can support liquid water given sufficient atmospheric atmosphere (Huang Su-Shu, 1959; Cruz & Cooray, 2013). The approximate inner radii \( r_i \) and outer radii \( r_o \) of boundaries of the host star’s habitable zones are expressed as (Whitmire & Reynolds, 1996),

\[
   r_i = \sqrt{\frac{L}{L_{\odot}}} \quad \text{and} \quad r_o = \sqrt{\frac{L}{L_{\odot}}}^{-0.53}
\]

where \( r_i \) and \( r_o \) are measured in astronomical units (AU). The inner radii of HD 73045, HD 98851, HD 113878, HD 118660 and HD 207561 are estimated as 1.095 AU, 1.087 AU, 1.179 AU, 1.164 AU and 1.049 respectively. Similarly, the outer radii of HD 73045, HD 98851, HD 113878, HD 118660 and HD 207561 are computed as 1.578 AU, 1.566 AU, 1.699 AU, 1.677 AU and 1.511 respectively.

7. Correlations among stellar parameters

7.1. Stellar locations in temperature-luminosity HR diagram

The precise location of each star in Hertzprung Russell (HR) diagram effectively useful to know the evolutionary status of a star and positions of present sample stars in temperature-luminosity HR diagram are depicted in the Figure 1.5. The estimation procedure of most accurate values of effective temperature and luminosity have an error of 150 K in the determination of \( T_{\text{eff}} \) leads to an error of about 0.20 mag in the bolometric magnitude (Casagrande et al., 2011; Neiner & Lampens, 2015). The location of sample stars in the HR diagram consistent with the theoretical work of Turcotte et al. 2000 (Turcotte et al., 2000) leads to as young stable Am star against the \( \kappa \)-mechanism pulsation. The positions of HD 98851, HD 113878 and HD 118660 indicates that they become unstable due to their evolution towards the red edge of the instability strip. The location of HD 207561 and HD 73045 in the HR diagram is indicates that it is slightly evolved from the main sequence and lies within the \( \delta \)-Scuti instability strip. Their evolution track is follow the path of Henry Track in luminosity-temperature HR diagram. On the basis of position of stars in HR diagram, author also estimated the masses of HD 73045, HD 98851, HD 113878, HD 118660 and HD 207561 as 1.99 \( M_{\odot} \), 1.80 \( M_{\odot} \), 2.05 \( M_{\odot} \), 2.00 \( M_{\odot} \) and 1.88 \( M_{\odot} \) respectively.

7.2. An accuracy test of Surface gravity

The surface gravity of all stars can also be derived from the fundamental relation (Casagrande et al., 2011)

\[
   \log g = \log \frac{M}{M_{\odot}} + 4 \log \frac{T_{\text{eff}}}{T_{\odot}} - \log \frac{L}{L_{\odot}}
\]

where \( L \) and \( M \) are the bolometric luminosity and mass of the studied stars. This relation gives the value of logarithm of surface gravity for HD 73045, HD 98851, HD 113878, HD 118660 and HD 207561 as 3.60, 3.49, 3.47 3.56 and 3.66 respectively.
Figure 6: The location of sample stars in HR diagram.
Notice that in above relation mass plays only a secondary role: varying it by 10% changes \( \log g \) by 0.4 dex (Casagrande et al., 2011). Author has been estimated standard deviation from given values in the table as 10.9%, 4.9%, 5.7%, 10.3% and 4.7% for HD 73045, HD 98851, HD 113878, HD 118660 and HD 207561 respectively. The values of standard deviation of surface gravity of studied stars confirm the role of mass in the variation value of surface gravity.

### 7.3. Maximum rotational from the Asteroseismic mass scale

Stellar rotation is observed to be both a strong function of mass and evolutionary state and measurement of rotation period could serve as useful diagnostics in the context of asteroseismology (van Saders &Pinsonneault, 2013). The location of the peak (in power) of the envelop of oscillation modes is defined as the frequency of maximum power \( (\nu_{\text{max}}) \). The value of \( \nu_{\text{max}} \) of a star is estimated through the following relation (Kjeldsen & Bedding, 1995),

\[
\nu_{\text{max}} = \frac{M/M_\odot}{(R/R_\odot)^2 \sqrt{T_{\text{eff}}/T_\odot}}
\]

This scaling relation is model independent and an extremely useful to determining stellar parameters. The values of \( \nu_{\text{max}} \) for HD 73045, HD 98851, HD 113878, HD 118660 and HD 207561 are found to be 0.228, 0.184, 0.123, 0.158 and 0.304 \( \text{d}^{-1} \) respectively. All stars, having range of \( P < 10 \text{ days} \), are either above a solar mass (on the MS or the SGB) or young, rapidly rotating solar mass objects (van Saders & Pinsonneault, 2013). Thus, the estimated values of periods of sample Am stars confirm their masses above the solar mass.

### 8. Conclusions

Author obtained a decreasing pattern of stellar magnitudes with increment effective wavelengths from filter \( z \) to filter \( K \) and also found a bump of stellar magnitude at filter \( G \). The period of pulsation variability of HD 73045 is found to be \( \sim 36.23 \text{ min} \) through fast photometry. On the background of differential photometric analysis of CCD photometric observation, author found the period of HD 98851 and HD 207561 as 1.55 hr and 5.8 min respectively. The late A type spectral class of the stars HD 98851 and HD 113878 has confirmed through the results of photometric indices of the sample stars. The mild deviation and nearly solar abundance of elements indicates that they belong to the subclass of marginally Am stars or close to the normal ones as supported by the spectropolarimetry-measurements of circularly polarized spectra. Thus, the abundances analysis of these stars confirm their CPI (i.e. Am) spectral class. The effective temperature, surface gravity, mass, distance, luminosity, transverse velocity, proper motion and micro-turbulence velocity of selected stars are estimated by author and results are summarized in the Table 1.8. Further, the surface gravity value (\( \log g \)) value for each star indicates that they are significantly evolve in HR diagram.

The present analysis of sample stars indicate that the new results of mass and radius are large compare to the previous ones. To see the importance of liquid water to Earth’s
Table 9: New computed results for the sample Am stars.

| Parameter Name | HD 73045 | HD 98851 | HD 113878 | HD 118660 | HD 207561 |
|----------------|----------|----------|-----------|-----------|-----------|
| $T_{\text{eff}}$ (K) | 7418     | 7082     | 7059      | 7452      | 7614      |
| log g          | 4.04     | 3.67     | 3.68      | 3.97      | 3.84      |
| $v_{\text{mic}}$ (km s$^{-1}$) | 3.01 | 2.63 | 2.60 | 3.04 | 3.16 |
| log R$_{g}$    | 1.32     | 1.30     | 1.53      | 1.49      | 1.21      |
| $E(B-V)$       | -0.012   | -0.37    | -0.413    | 0.183     | 0.75      |
| Mass ($M_\odot$) | 1.98    | 1.80     | 2.05      | 2.00      | 1.88      |
| Radius ($R_\odot$) | 2.77   | 2.97     | 3.89      | 3.34      | 2.32      |
| $\mu$ (mas/yr) | 37.30±1.05 | 44.32±0.88 | 22.84±0.91 | 43.70±0.93 | 48.05±0.78 |
| $\pi$ (mas)    | 4.36     | 6.24     | 2.89      | 13.93     | 8.02      |
| $d$ (pc)       | 229.36   | 160.26   | 346.02    | 71.78     | 124.69    |
| $v_T$ (km/s)   | 8.55     | 7.10     | 7.90      | 3.14      | 5.99      |
| $\tau_{\text{MS}}$ (Gyrs) | 14.07 | 13.42 | 14.32 | 14.14 | 13.71 |
| $r_{\text{T L}}$ (AU) | 0.578 | 0.559 | 0.584 | 0.580 | 0.568 |
| $r_i$, $r_o$ (AU) | 1.095-1.578 | 1.087-1.566 | 1.179-1.699 | 1.164-1.677 | 1.049-1.511 |
| $v_{\text{max}}$ | 0.228 | 0.184 | 0.123 | 0.158 | 0.304 |

biosphere, the estimated values of boundaries ($r_i$, $r_o$) of habitable zones and tidal radius ($r_{\text{T L}}$) of each star is effectively useful to search the Earth like Extra-terrestrial life and intelligence. Asteroseismological mass scale test of sample Am stars confirm their mass, having the greater than the solar mass.

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