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TESS observations of the Pleiades cluster: a nursery for δ Scuti stars

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ABSTRACT

We studied 89 A- and F-type members of the Pleiades open cluster, including five escaped members. We measured projected rotational velocities ($v \sin i$) for 49 stars and confirmed that stellar rotation causes the broadening of the main sequence in the color-magnitude diagram. Using time-series photometry from NASA's *TESS* Mission (plus one star observed by *Kepler*/K2), we detected δ Scuti pulsations in 36 stars. The fraction of Pleiades stars in the middle of the instability strip that pulsate is unusually high (over 80%), and their range of effective temperatures agrees well with theoretical models. On the other hand, the characteristics of the pulsation spectra are varied and do not correlate with stellar temperature, calling into question the existence of a useful $\nu_{\rm max}$ relation for δ Scutis, at least for young stars. By including δ Scuti stars observed in the *Kepler* field, we show that the instability strip is shifted to the red with increasing distance by interstellar reddening. Overall, this work demonstrates the power of combining observations with Gaia and *TESS* for studying pulsating stars in open clusters.

Keywords: Asteroseismology

1. INTRODUCTION

Explaining the excitation and mode selection in δ Scuti stars is one of the major unsolved challenges in stellar pulsations (see reviews by Goupil et al. 2005; Handler 2009; Lenz 2011; Guzik 2021; Kurtz 2022). Why do only a subset of stars in the instability strip show δ Scuti pulsations? And how can two stars occupy essentially the same position in the H–R diagram, but only one shows pulsations?

One obvious explanation is that some stars have pulsations too weak to be detected. However, *Kepler* pushed the detection threshold down to extremely low levels (Balona et al. 2015; Bowman & Kurtz 2018; Guzik 2021), and it is still the case that only about half the stars in the central part of the instability strip are pulsating (Murphy et al. 2019).

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Another possible factor is chemical composition. Stars with different metallicities can pass through a given location in the H–R diagram at different ages, and with different opacities in the driving zone. This will affect pulsations driven by the κ (opacity) mechanism (Guzik et al. 2018), and even more so for chemically peculiar stars (Murphy et al. 2015; Guzik et al. 2021), so it is likely that chemical composition is part of the explanation. But even in open clusters, which are assumed to have a uniform metallicity (De Silva et al. 2006; Sestito et al. 2007; Bovy 2016), the pulsator fraction is much less than one. In the Pleiades, for example, Breger (1972) found four δ Scuti stars and three decades later, that number still only stood at six (Koen et al. 1999; Li et al. 2002; Fox Machado et al. 2006). Kepler/K2 observed five of these in short-cadence (1-min) mode (Murphy et al. 2022), and the long-cadence (30-min) data hinted at more variables (Rebull et al. 2016).

NASA's *TESS* Mission (Ricker et al. 2015) is producing high-precision, rapid-cadence light curves over most of the sky, opening up new possibilities for studying large samples of δ Scuti stars (e.g., Antoci et al. 2019; Balona & Ozuyar 2020; Barceló Forteza et al. 2020; Bedding et al. 2020; Murphy et al. 2020). In this *Letter*, we use data from Gaia and *TESS* to perform the most detailed search to date for δ Scuti pulsators in the Pleiades.

2. SAMPLE SELECTION AND GAIA PHOTOMETRY

We selected an initial list of likely Pleiades members using Gaia DR2 astrometry and the BANYAN-Σ code (Gagné et al. 2018). We used the default Pleiades parameters and did not include any radial velocity information (to avoid biasing against binaries). We selected all stars with BANYAN membership probabilities above 90% and Gaia colors $0.0 < G_{BP} - G_{RP} < 0.7$, which corresponds approximately to spectral types in the range A0 V to F8 V. This gave a list of 83 stars. We note that our membership selection was not altered by updating to Gaia DR3.

We also included five stars listed by Heyl et al. (2022) as escaped Pleiades members (HD 17962, HD 20655, HD 21062, HD 23323 and HD 34027). These stars are too distant from the Pleiades core to have been included in our BANYAN-Σ selection. We note that a cross-check of the G and early K dwarfs in the Heyl et al. (2022) sample with *TESS* indicated most of the suggested escapees have < 10 day rotation periods, which is consistent with expectations for Pleiades membership (Curtis et al. 2019).

Our final sample of 89 stars is listed in Table 1. V1229 Tau (HD 23642) is a well-studied eclipsing and spectroscopic binary that consists of two A-type stars with an orbital period of 2.4611 d (see Groenewegen et al. 2007, and references therein). Both components are A-type stars, so we have listed them separately in the table (see Sec. 4.1 for details).

Ten stars in Table 1 are named variables (column 1). These include the six δ Scuti stars previously known from ground-based observations (V534 Tau, V624 Tau, V647 Tau, V650 Tau, V1187 Tau and V1228 Tau; Breger 1972; Koen et al. 1999; Li et al. 2002), together with two γ Doradus stars (V1210 Tau and V1225 Tau; Martín & Rodríguez 2000) and both members of the eclipsing binary V1229 Tau (HD 23642).

The photometry in Table 1 (columns 5–7) is based on magnitudes and parallaxes from Gaia DR3 (Gaia Collaboration 2021; Lindegren et al. 2021; Riello et al. 2021). In Fig. 1 we show the color-magnitude diagram (CMD) of the sample. No correction for extinction or reddening was made. We have included a PARSEC isochrone (Marigo et al. 2017), with a metallicity of $Z = 0.017$ and an age of 110 Myr, which are appropriate for the Pleiades (Gaia Collaboration et al. 2018). We shifted the isochrone to account for extinction and reddening, using values of $A_G = 0.11$ and $E(G_{BP} - G_{RP}) = 0.055$ (Andrae et al. 2018).

Some of the spread in the cluster main sequence is probably from binarity. This is confirmed by Fig 1a, which shows several stars above the main sequence with values of Gaia RUWE (renormalised unit weight error) significantly greater than 1.0, indicating they are likely to be binaries (Evans 2018; Belokurov et al. 2020; Stassun & Torres 2021; Torres et al. 2021). The remaining spread in the observed sequence can be attributed to binaries that do not show elevated RUWE (such as very close systems) or to the presence of rapid rotators, as discussed in the next section.

3. PROJECTED ROTATIONAL VELOCITIES

We have measured $v \sin i$ for 49 stars in our sample using spectra collected by the Center for Astrophysics (CfA) survey (Torres 2020; Torres et al. 2021). These were gathered with the Tillinghast Reflector Échelle Spectrograph (TRES), a high-resolution ($R = 44,000$) fiber-fed échelle mounted on the 1.5m reflector at the Fred Lawrence Whipple Observatory, Arizona. Following Zhou et al. (2018), we extracted line profiles from each spectrum via a least-squares deconvolution (Donati et al. 1997) against a synthetic non-rotating ATLAS9 template (Castelli & Kurucz 2003). The broadening profile was then modeled as a combination of kernels describing the effects of rotational, macroturbulent, and instrumental broadening (Gray 2005). The resulting $v \sin i$ values are listed in Column 8 of Table 1 and are indicated as source 1 in Column 9. For an additional 10 stars, we used $v \sin i$ measurements from Gaia RVS spectra (Creevey et al. 2022), which are indicated as source 2 in the table. By way of validation, we note there is good consistency for 15 stars with $v \sin i$ measurements from both sources.

The color-magnitude diagram in Figure 1b is color-coded by $v \sin i$. It is well-known that rotation causes stars to move in the CMD (Pérez Hernández et al. 1999; Fox Machado et al. 2006; Espinosa Lara & Rieutord 2011; Lipatov & Brandt 2020). This is at least partly responsible for the extended main-sequence turn-offs seen in the CMDs of young and intermediate-age clusters (Bastian & de Mink 2009; Yang et al. 2013; Brandt & Huang 2015; Goudfrooij et al. 2017; Gossage et al. 2019; Sun et al. 2019; de Juan Ovelar et al. 2020; Kamann et al. 2020; Chen et al. 2022a; He et al. 2022). Rotation does not only affect the turn-off, but also broadens the main sequence itself, and we are seeing good evidence for this in the Pleiades in Fig. 1b.

4. *TESS* OBSERVATIONS AND ANALYSIS

Observations with *TESS* are made in 27-d sectors (Ricker et al. 2015). The Pleiades were observed in the fourth year of the mission, in Sectors 42–44 (2021 August 20 to November 6). Most Pleiades stars have *TESS* data in all three sectors and a few were also observed in Sectors 18 or 19. All stars in our sample with *TESS* observations have light curves with 120-s cadence, and we used the `lightkurve` package (Lightkurve Collaboration et al. 2018) to download the PDCSAP[1] light curves that were provided by the SPOC (Science Processing Operations Center). Only one star in our sample has no *TESS* observations, namely HD 23028, which fell just off the edge of the detector. For this star, *Kepler*/K2 long-cadence (30-min) observations show pulsations and we have included it as a δ Scuti star in the table and figures (apart from Fig. 2).

In total, we detected δ Scuti pulsations in 36 of the stars in our sample, as flagged in Table 1

[1] Pre-search Data Conditioning Simple Aperture Photometry

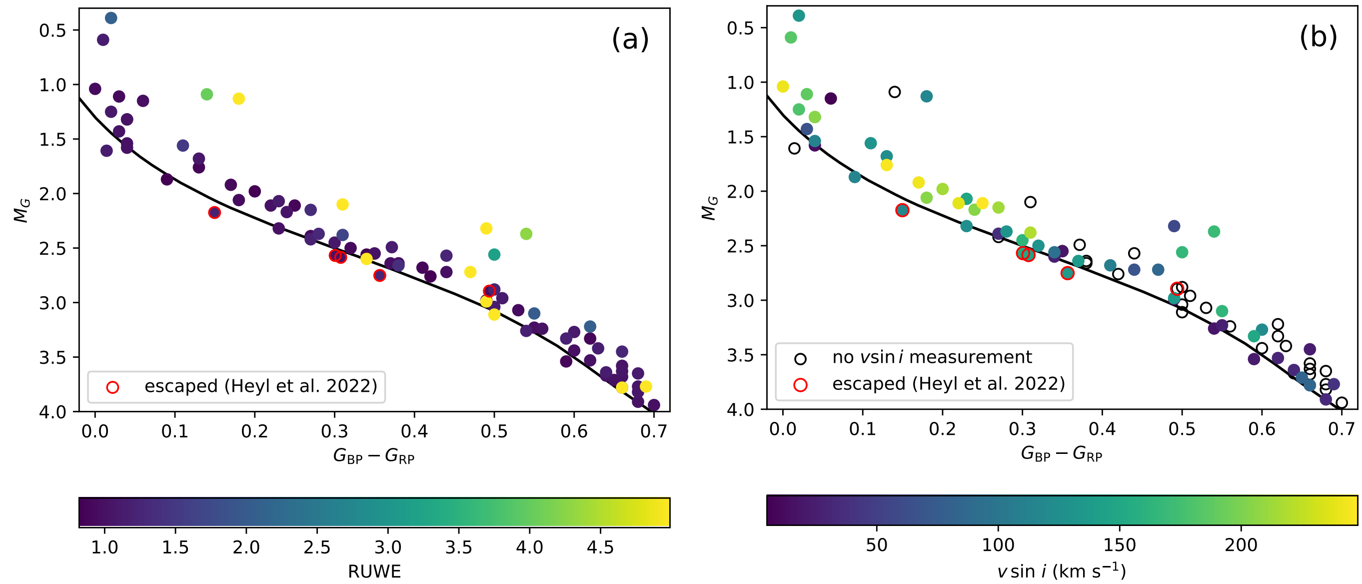

Figure 1. Color-magnitude diagram of 89 A and F stars in the Pleiades, based on photometry and parallaxes from Gaia DR3. Photometry has not been corrected for extinction and reddening. (a) stars are color-coded by RUWE (clipped at RUWE = 5, although some stars have greater values); (b) color-coded by $v \sin i$ (see Table 1). Red circles indicate five stars listed as escaped members by Heyl et al. (2022). The black line is a PARSEC isoschrone, corrected for extinction and reddening (see text).

(Column 10). These include the six previously known from ground-based observations (V534 Tau, V624 Tau, V647 Tau, V650 Tau, V1187 Tau and V1228 Tau), plus 30 additional detections.

The amplitude spectra for the 35 δ Scuti stars observed by *TESS* are shown in Fig. 2, ordered according to Gaia $G_{BP} - G_{RP}$. The detections include four of the five escaped members (Heyl et al. 2022), and the similarity of those oscillation spectra to confirmed members of the Pleiades lends support to their status as escaped members.

4.1. *V1229 Tau (HD 23642)*

V1229 Tau is a well-studied eclipsing and spectroscopic binary, with a period of 2.4611 d (see Groenewegen et al. 2007, and references therein). Both components are A-type stars, and so we have treated them separately.

The Gaia photometry ($G = 6.82$ and $G_{BP} - G_{RP} = 0.10$) measures the combined light of the system. In order to plot both components separately, we have estimated values in the table using the published effective temperatures (9750 ± 250 K and 7600 ± 400 K; Southworth et al. 2005) and a luminosity ratio of 0.355 ± 0.035 (David et al. 2016). The photometry given in columns 5–7 of Table 1 are estimates if the two components were measured separately, also taking into account the reddening and extinction of the cluster. In Fig. 3a, the black circles show (from left to right) the A component, the combined system, and the B component.

In addition to the eclipses, the *TESS* light curve shows high-frequency δ Scuti pulsations. The amplitude spectrum in Fig. 2 was made after fitting and subtracting an eclipse model. Given the colors of the components (see Fig. 3a), it is reasonable to conclude that the pulsations occur in the B component. To verify this, we examined the scatter in the time series after fitting and removing the five highest peaks in the amplitude spectrum. We found the scatter to be reduced everywhere in this

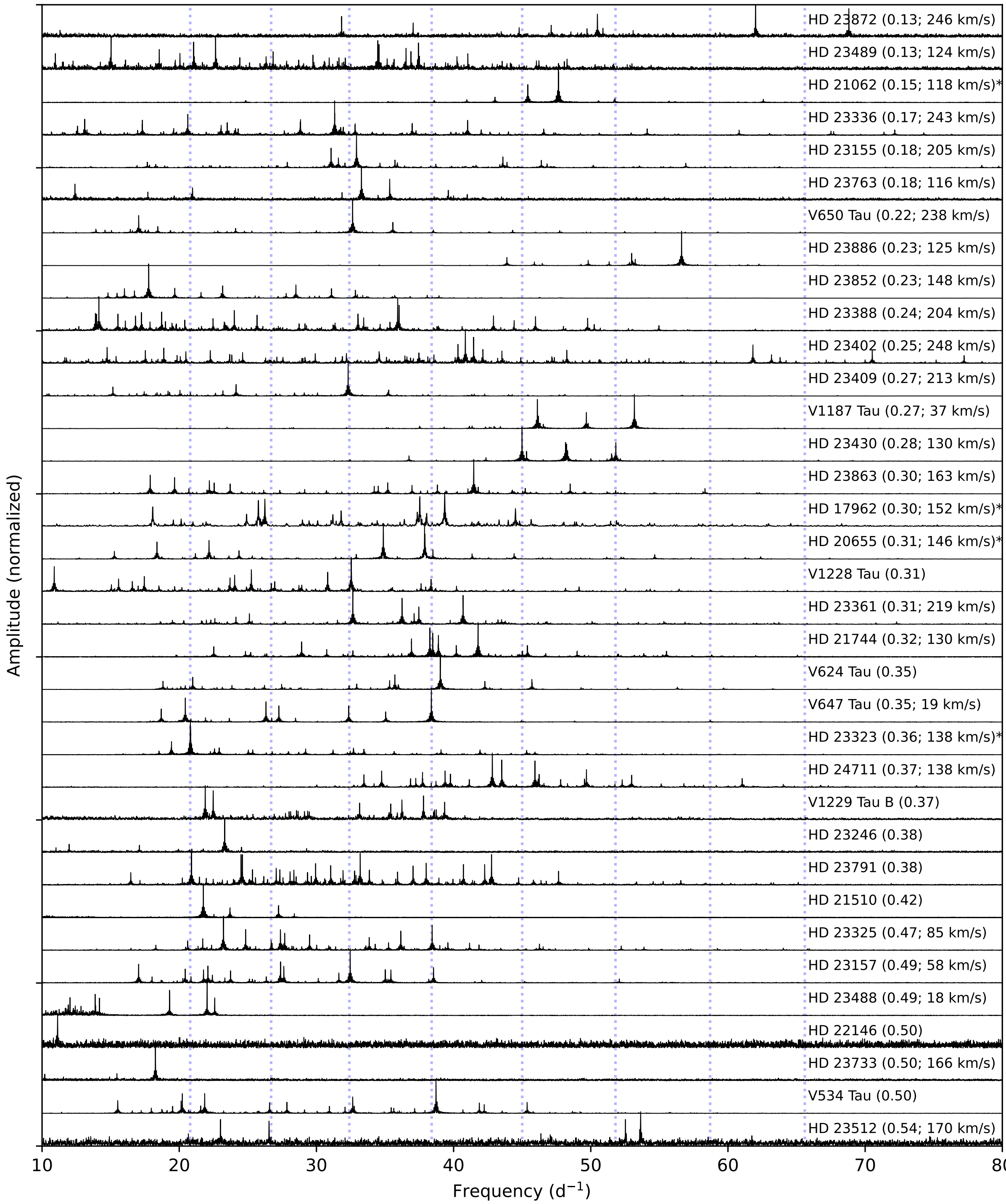

Figure 2. Pulsation spectra of 35 δ Scuti stars in the Pleiades observed with *TESS*. Stars are ordered according to the Gaia $G_{BP} - G_{RP}$ color index, whose values are given in parentheses, together with $v \sin i$ (if available). Asterisks indicate four stars listed by Heyl et al. (2022) as escaped members. The blue dotted lines show approximate frequencies of the first 8 radial modes (Murphy et al. 2022).

prewhitened light curve, but the reduction was less during secondary eclipses because the five-peak fit is a poorer fit when part of the pulsating star is being eclipsed (note that the inclination of the system is about 78° and the eclipses are not total; David et al. 2016). We can therefore confirm that it is the secondary component (V1229 Tau B) that is undergoing pulsations.

Chen et al. (2022b) noted pulsations in V1229 Tau (which they referred to as TIC 125754991) and suggested that it is hotter than typical δ Scuti stars, because they assumed the primary is the pulsator. Once we accept that the secondary is the pulsating component, this star becomes typical. A more detailed study of the pulsations of V1229 Tau (HD 23642) using the *TESS* light curve has been made by Southworth et al. (in prep.).

5. THE δ SCUTI INSTABILITY STRIP

Figure 3 shows the δ Scuti detections as a function of Gaia $G_{BP} - G_{RP}$ color index (without correcting for the reddening of the Pleiades, which is about 0.055; Andrae et al. 2018). We see in the CMD (Fig. 3a) and the accompanying histogram (Fig. 3b) that the pulsators lie within a strip that spans from about 0.10 to 0.55 in $G_{BP} - G_{RP}$. In this color range, the fraction of stars that pulsate is 36/50 (72%), and in the middle of the instability strip (0.20–0.40) it is 21/25 (84%). This pulsator fraction is significantly higher than the 50–60% found in the *Kepler* δ Scuti sample by Murphy et al. (2019).

Although the Pleiades cluster is unusually rich in δ Scutis (with peak amplitudes in the range 50–3000 ppm, depending on the star), there are still several stars within the instability strip that are not pulsating (down to a sensitivity limit of 10–20 ppm). One possible explanation is chemical peculiarity, which typically occurs in slow rotators because helium sinks out of the He II driving zone (Baglin et al. 1973; Deal et al. 2020). Slow rotation can be caused by

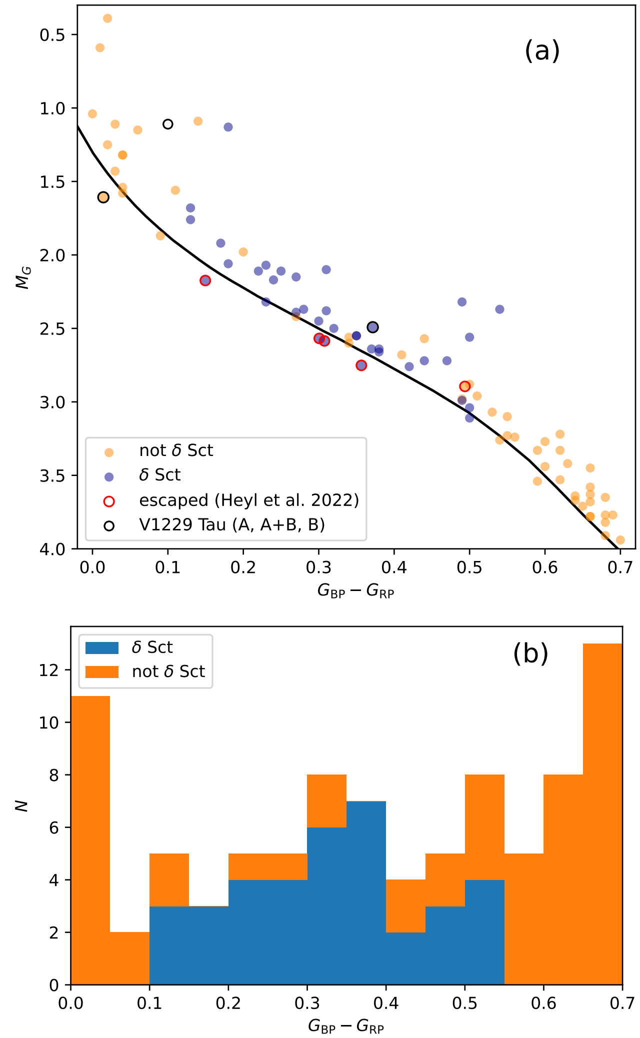

Figure 3. Sample of 89 A and F stars in the Pleiades, of which 36 have δ Scuti pulsations. (a) Color-magnitude diagram, where red circles are the five escaped members (Heyl et al. 2022). For the eclipsing binary V1229 Tau (HD 23642), black circles show (from left to right) the A component (not pulsating), the combined system, and the B component (pulsating; see text). The black line is a PARSEC isochrone (corrected for extinction and reddening; see text). (b) Histogram as a function of Gaia color.

tidal interactions with a binary companion (e.g., Fuller et al. 2017, and references therein), which is thought to be responsible for the Am stars ('m' for 'metallic-lined'; e.g., Abt 1967; North et al. 1998; Debernardi et al. 2000; Stateva et al. 2012).

Eight stars in our sample were listed by Renson & Manfroid (2009) as being Am stars (see column 10 in Table 1). One of these is the eclipsing binary V1229 Tau, for which Abt & Levato (1978) give the spectral type as A0 Vp(Si) + Am, indicating that the B component is an Am star. Overall, seven of the Am stars in our sample have colours that place them within the δ Scuti instability strip, and five of these are pulsating. The conclusion is that chemical peculiarity can only account for two of the non-pulsators in the Pleiades.

Figure 4 shows our sample in an H–R diagram. To construct this, we first corrected the observed Gaia photometry for extinction and reddening using the values given above. We estimated effective temperatures from the de-reddened $G_{BP} - G_{RP}$ colors using an updated version of Table 5 of Pecaut & Mamajek (2013)[2]. We estimated stellar luminosities from G magnitudes and Gaia DR3 parallaxes, using V bolometric corrections and $G-V$ colours from the same source.

The solid blue lines in Fig. 4 show the theoretical instability strip (Dupret et al. 2005). We see that the observed δ Scuti strip in the Pleiades is very well matched to the theoretical calculations.

The dashed purple lines in Fig. 4 mark the instability strip for δ Scuti stars observed with *Kepler* (Murphy et al. 2019). The offset with respect to the Pleiades might come from a combination of: (1) different $T_{\rm eff}$ scales being used; (2) having a homogeneous composition among Pleiades members, rather than the heterogeneous *Kepler* sample; (3) perhaps from having a slightly higher overall metallicity in the Pleiades; (4) from the Pleiades being ubiquitously young, as opposed to the Kepler sample where even stars that appeared near the ZAMS were probably older stars of lower metallicity.

[2] http://www.pas.rochester.edu/~emamajek/EEM_dwarf_UBVIJHK_colors_Teff.txt

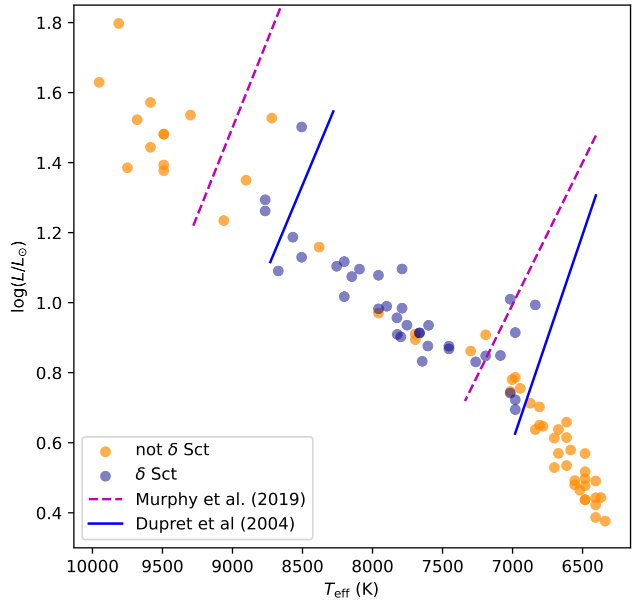

Figure 4. H–R diagram of the Pleiades, corrected for extinction and reddening, showing the location of the δ Scuti pulsators. Sloping lines indicate both the theoretical instability strip (solid blue lines; Dupret et al. 2005) and the observed strip from *Kepler* (dashed purple lines show the region in which at least 20% of *Kepler* stars pulsate; Murphy et al. 2019).

Figure 5 shows the effect of reddening on the δ Scuti instability strip by plotting the distance to each star versus its Gaia color index. The red points at the bottom show the Pleiades and the blue points show δ Scuti stars detected by *Kepler* (Murphy et al. 2019). As expected, the observed instability strip shifts to the red with increasing distance. Note that we have restricted the *Kepler* sample to stars more than 10 degrees from the Galactic plane, in order to see the dependence on distance more clearly. We also show the sample of γ Doradus stars in the *Kepler* field studied by Li et al. (2020), again restricted to $b > 10°$ (orange points). Overall, Fig. 5 displays very nicely the effect of inter-

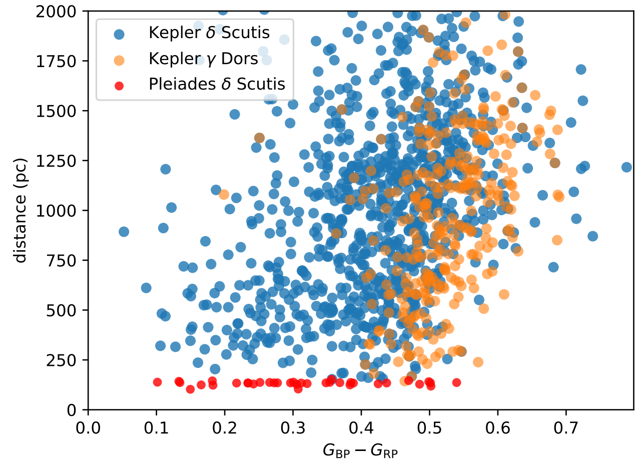

Figure 5. The effect of reddening on the pulsation instability strip. The *Kepler* samples of δ Scuti stars (from Murphy et al. 2019) and γ Doradus stars (Li et al. 2020) are restricted to Galactic latitude $b > 10°$.

stellar reddening on the pulsational instability strips.

6. IS THERE A $\nu_{\rm max}$ SCALING RELATION FOR δ SCUTI STARS?

The quantity $\nu_{\rm max}$ is defined for solar-like oscillations as the centroid of the power envelope (Kjeldsen & Bedding 1995). Solar-like oscillations are excited stochastically by near-surface convection, and the observed modes cover a broad range of frequencies centred at $\nu_{\rm max}$. It was suggested by Brown et al. (1991) that when scaling from the Sun to other stars, $\nu_{\rm max}$ should be a fixed fraction of the acoustic cutoff frequency. The latter is the frequency above which waves are no longer reflected at the surface, and is expected from simple arguments to scale as $g/\sqrt{T_{\rm eff}}$. That line of reasoning underlies the scaling relation

$$\nu_{\rm max} \propto g/\sqrt{T_{\rm eff}}, \qquad (1)$$

which is widely used in the study of solar-like oscillations, although its physical basis is not well understood (Belkacem et al. 2011; Kjeldsen & Bedding 2011; Chaplin & Miglio 2013; Hekker 2020).

There have been suggestions that $\nu_{\rm max}$ is a useful observable for δ Scuti stars, given that it shows a correlation with $T_{\rm eff}$ (Balona & Dziembowski 2011; Zwintz et al. 2014; Barceló Forteza et al. 2018; Bowman & Kurtz 2018; Barceló Forteza et al. 2020; Hasanzadeh et al. 2021). However, the oscillation spectra of δ Scuti stars in the Pleiades (see Fig. 2, which is ordered by color index) show the correlation to be weak or nonexistent for this sample of young stars. In particular, we do not see a shift to higher radial orders with increasing $T_{\rm eff}$, as predicted by theoretical models. Different theoretical treatments give slightly different predictions, but they all agree that we expect the excitation of higher radial order modes δ Scuti stars as we move to higher temperatures within the instability strip (Dziembowski 1997; Houdek et al. 1999; Pamyatnykh 2000; Dupret et al. 2005; Houdek & Dupret 2015; Xiong et al. 2016; Xiong 2021).

The variety of oscillation spectra in Fig. 2 is quite remarkable, although there is also the similarity between some stars. Some of the variation could be attributed to differences in rotation, but it is difficult to see much in the way of systematic trends. On balance, our results seem to raise more questions than they answer. On the one hand, the very high fraction of pulsators in the Pleiades means we are not left wondering why some pulsate and others do not. On the other hand, we cannot explain why stars with similar properties have such different pulsation spectra. The question of mode selection in δ Scuti stars remains as elusive as ever.

7. CONCLUSIONS

Using Gaia photometry and astrometry, we constructed a list of 89 probable members of the Pleiades with spectral types A and F. We measured projected rotational velocities ($v \sin i$) for 49 stars and confirmed that stellar rotation is a significant cause of the broadening of the main sequence in the color-magnitude diagram (Fig. 1b). Using time-series photometry from

NASA's *TESS* Mission (plus one star observed by *Kepler*/K2), we detected δ Scuti pulsations in 36 stars. Some stars suggested as being escaped members of the Pleiades by Heyl et al. (2022) have similar pulsation properties to confirmed members, which supports their identification as former members.

The fraction of Pleiades stars in the middle of the instability strip that pulsate is unusually high (over 80%), and their range of effective temperatures agrees well with theoretical models (Fig. 4). On the other hand, the characteristics of the pulsation spectra are very varied and do not correlate very strongly with stellar temperature (Fig. 2), calling into question the existence of a useful $\nu_{\rm max}$ relation for δ Scutis, at least for young stars. By including δ Scuti stars observed in the *Kepler* field (Fig. 5), we show that the instability strip is shifted to the red with increasing distance by interstellar reddening. In summary, this works demonstrates the power of combining observations with Gaia and *TESS* for studying pulsating stars in open clusters.

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This work has made use of data from the European Space Agency (ESA) mission Gaia (https://www.cosmos.esa.int/gaia), processed by the Gaia Data Processing and Analysis Consortium (DPAC, https://www.cosmos.esa.int/web/gaia/dpac/consortium). Funding for the DPAC has been provided by national institutions, in particular the institutions participating in the Gaia Multilateral Agreement. This work also made use of ARI's Gaia Services at http://gaia.ari.uni-heidelberg.de/ for RUWE values.

Facility: TESS

Table 1. Sample of A and F stars in the Pleiades. Column 9: source for $v \sin i$ is 1 (this work) or 2 (Gaia DR3). Column 10: 1 indicates δ Scuti star. Column 11: 1 indicates Am star (Renson & Manfroid 2009). For V1229 Tau A & B, the magnitudes and colors (Columns 5–7) are estimates (see Sec. 4.1)

Name	HD	HIP	TIC	G	M_G	$G_{BP} - G_{RP}$	$v \sin i$ $\mathrm{km\,s^{-1}}$	$v \sin i$ source	δ Sct	Am
(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)	(10)	(11)
	22578	17000	113956708	6.70	1.04	0.00	242	1	0	0
24 Tau	23629		405484171	6.30	0.59	0.01	184	1	0	0
V1229 Tau A	23642	17704	125754991	7.32	1.61	0.01			0	0
	23410	17572	67830155	6.90	1.25	0.02	180	1	0	0
	23950	17921	440695282	6.04	0.39	0.02	133	1	0	0
	24899	18559	149980785	7.20	1.43	0.03	67	1	0	0
	23568	17664	405484416	6.80	1.11	0.03	188	2	0	0
	22614	17034	427545204	7.10	1.54	0.04	114	1	0	0
	23631		440681316	7.29	1.58	0.04	13	1	0	1
	23632	17692	440681358	7.00	1.32	0.04	194	2	0	0
	23913	17892	440691760	7.00	1.32	0.04	205	1	0	0
	23964	17923	440695975	6.81	1.15	0.06	5	1	0	0
	23948		35159593	7.55	1.87	0.09	115	2	0	0
	22637	17043	113981021	7.27	1.56	0.11	131	1	0	0
	23872		346626001	7.53	1.76	0.13	246	2	1	0
	23489		125736946	7.35	1.68	0.13	124	1	1	0
	24076	17999	35205647	6.93	1.09	0.14			0	0
	21062	15902	29058513	7.11	2.17	0.15	118	2	1	0
	23336	17547	385554826	7.40	1.92	0.17	243	2	1	0
	23763	17791	35156298	6.94	1.13	0.18	116	1	1	0
	23155	17403	405483425	7.51	2.06	0.18	205	1	1	0
	24178		84336172	7.65	1.98	0.20	214	1	0	0
V650 Tau	23643		440681425	7.75	2.11	0.22	238	1	1	0
	23886		346626099	7.96	2.32	0.23	125	2	1	0
	23852		440691730	7.71	2.07	0.23	148	1	1	0
	23388	17552	67828699	7.73	2.17	0.24	204	1	1	0
	23402		67830321	7.80	2.11	0.25	248	1	1	0

Table 1 *continued*

Table 1 *(continued)*

Name	HD	HIP	TIC	G	M_G	$G_{BP}-G_{RP}$	$v\sin i$ $\mathrm{km\,s^{-1}}$	$v\sin i$ source	δ Sct	Am
(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)	(10)	(11)
V1187 Tau	23194		405483707	8.04	2.39	0.27	37	1	1	1
	23924		440695768	8.09	2.42	0.27			0	1
	23409		385589694	7.83	2.15	0.27	213	1	1	0
	23430	17583	385558439	8.02	2.37	0.28	130	1	1	0
	23863		346626294	8.10	2.45	0.30	163	1	1	0
	17962	13522	77568727	8.15	2.57	0.30	152	2	1	0
	20655	15552	402366726	7.55	2.59	0.31	146	2	1	0
	23361		385552144	8.02	2.38	0.31	219	1	1	0
V1228 Tau	23628		125754823	7.63	2.10	0.31			1	0
	21744	16407	46476992	8.09	2.50	0.32	130	1	1	0
	23664	17729	125754460	8.27	2.56	0.34	96	1	0	0
	23610	17694	440681752	8.12	2.60	0.34	26	1	0	1
V624 Tau	23156		405483817	8.20	2.55	0.35			1	0
V647 Tau	23607		405484188	8.24	2.55	0.35	19	1	1	1
	23323		385553714	8.55	2.75	0.36	138	1	1	0
	24711	18431	14111056	8.30	2.64	0.37	138	1	1	0
V1229 Tau B	23642	17704	125754991	8.20	2.49	0.37			1	1
	23246		348639016	8.12	2.64	0.38			1	0
	23791		440690782	8.34	2.66	0.38			1	1
V1210 Tau	23585		405484093	8.33	2.68	0.41	108	1	0	0
	21510	16217	405461432	8.33	2.76	0.42			1	0
	23479		385589599	8.23	2.57	0.44			0	0
	23028	17325	114083179	8.36	2.72	0.44	68	1	1	0
	23325		385509282	8.55	2.72	0.47	85	2	1	1
	23157	17401	67768222	7.86	2.32	0.49	58	1	1	0
V1225 Tau	22702		427580304	8.75	2.98	0.49	137	1	0	0
	23488	17625	125736216	8.65	2.99	0.49	18	1	1	0
	34027	24808	82969878	8.85	2.89	0.49			0	0
	23375		385552372	8.55	2.88	0.50			0	0
V534 Tau	23567		405484574	8.48	3.11	0.50			1	0
	23733		35155873	8.21	2.56	0.50	166	1	1	0
	22146		26126738	8.79	3.04	0.50			1	0

Table 1 *continued*

Table 1 *(continued)*

Name	HD	HIP	TIC	G	M_G	$G_{BP} - G_{RP}$	$v \sin i$ km s^{-1}	$v \sin i$ source	δ Sct	Am
(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)	(10)	(11)
	23290	17481	67788829	8.63	2.96	0.51			0	0
	24132	18050	84331341	8.77	3.07	0.53			0	0
	23326		67829720	8.89	3.26	0.54	19	1	0	0
	23512		61139371	8.04	2.37	0.54	170	1	1	0
	23792		440690206	8.31	3.10	0.55	164	1	0	0
	23289	17497	67787772	8.89	3.23	0.55	26	1	0	0
		16423	26078071	8.78	3.24	0.56			0	0
	24655		14109779	8.98	3.54	0.59	22	1	0	0
	23912		440691379	9.03	3.33	0.59	151	1	0	0
	22887	17225	114060256	9.07	3.44	0.60			0	0
	23133		114166637	8.89	3.27	0.60	122	1	0	0
	23351		385552643	8.90	3.22	0.62			0	0
	23511		125736995	9.20	3.53	0.62	30	1	0	0
	24086		84331854	9.01	3.33	0.62			0	0
	22977	17289	114084434	9.06	3.42	0.63			0	0
	24302	18154	427735820	9.34	3.67	0.64			0	0
	23513		61145701	9.30	3.64	0.64	32	1	0	0
	23584		405484278	9.38	3.71	0.65	82	1	0	0
	23312	17511	67788288	9.36	3.63	0.66			0	0
		17125	353928999	9.50	3.78	0.66	85	1	0	0
	23514		61145611	9.31	3.58	0.66			0	0
		18544	14177821	9.29	3.78	0.66	72	1	0	0
	23732		35155396	9.12	3.45	0.66	23	1	0	0
	23061		258067594	9.37	3.68	0.66			0	0
SAO 93581			67789284	9.30	3.65	0.68			0	0
	23975		35204900	9.52	3.82	0.68			0	0
		16639	46538779	9.43	3.77	0.68			0	0
	23352		385552619	9.57	3.91	0.68	34	1	0	0
	23158		67768242	9.43	3.77	0.69	40	1	0	0
	24463		348769726	9.60	3.94	0.70			0	0

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