TESS observations of Am stars

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Pulsating Am stars

It has long been held that metallic-lined (Am) stars have a much lower incidence of pulsation than normal stars, yet when Am stars were observed in large numbers by the WASP survey, many pulsating examples were found (Smalley et al., 2011, A&A 535, A3; 2017, MNRAS, 463, 2662). The mechanism causing the lower incidence of pulsation among Am stars is atomic diffusion of helium out of the He II partial ionisation zone where δ Sct pulsations are predominantly driven. The Am stars are slow rotators, and without large-scale surface convection zones or rotationally-induced mixing, He gravitationally settles towards the core whilst Fe-peak elements levitate to the surface. Pulsating Am stars presented a puzzle, until two additional contributions to the driving were revealed. Firstly, it appears that turbulent pressure adds considerably to the driving of pulsations at radial orders $\gtrsim 4$ and is likely to be responsible for driving pulsations in some Am stars. Secondly, even in the complete absence of helium in the driving zone, the 'edge-bump mechanism' is able to drive pulsation in Am stars. This driving is weaker than driving from the κ-mechanism operating on He II, hence the pulsator fraction should be lower than for normal stars. A direct evaluation of the effect of the Am peculiarity on pulsations is now possible because TESS gives us a high-precision and homogeneous view of the pulsations of Am stars. Observations at 2-minute cadence of about 600 Am stars with TESS constitute a unique dataset to make a meaningful analysis.

Pulsation classifications

Our objectives require that we measure which stars in our sample are pulsating as δ Sct stars. Two of us (BS & EN) independently manually classified the sample into a Boolean list (δ Sct/non-δ Sct). Since manual classifications can be subjective in borderline cases, we also used an objective metric. Murphy et al. (2019, MNRAS, 485, 2380) showed that automated pulsator classifications reliably replicated the manual classifications of a sample of $\sim$2000 *Kepler* stars with a threshold of $\log(\mathrm{skewness}) = 1$ being one of the suggested thresholds. We calculated the skewness of the Fourier amplitude distribution for each star in our TESS sample and the signal-to-noise ratio of the strongest peak. We found that the $\log(\mathrm{skewness}) = 1$ threshold matches reasonably well with the manual classifications of TESS light curves, and SJM visually validated every light curve whose manual class was discrepant with the automated one. We ultimately adopted these revised manual classifications.

Preliminary Results

Figure 1 shows that almost all of the pulsating Am stars lie inside the theoretical instability strip, but it is known that the pulsator fraction of the overall A/F star population is not constant across the instability strip (Murphy et al. 2019, MNRAS, 485, 2380). By using the known pulsator-fraction distribution for A/F stars, we modelled the expected pulsator fraction of Am stars to be $46 \pm 5\%$. However, our observations show that 28% of the 'single' (non-eclipsing) stars actually pulsate, suggesting that Am stars are 40% *less* likely that normal stars to pulsate as δ Sct stars. The exclusion of eclipsing binaries does not significantly change the results: the raw pulsator fraction (including EBs) in our sample was 26%. However, we do find that the pulsator fraction of the EBs (15%) is different, which could be due to the difficulty in detecting low-amplitude pulsations against the strong Fourier series in the amplitude spectrum of an eclipsing binary.

We also evaluated whether the pulsator fraction is a function of the strength of the peculiarity, as indicated by the Δ (metallicism) index, which is defined as number of spectral sub-types difference between the k and m spectral types (Figs. 2 & 3). For single, strong Am stars ($\Delta \geq 5$), 23% of the stars pulsate, whereas for mild Am stars this increases to 39%. To make sure this doesn't reflect a preference for stronger peculiarities away from the peak of the pulsator fraction distribution, we modelled the expected pulsator fractions individually, finding 56% for the strong Am stars, and 44% for the mild Am stars. This suggests that the difference in pulsator fraction between strong and mild Am stars is real.

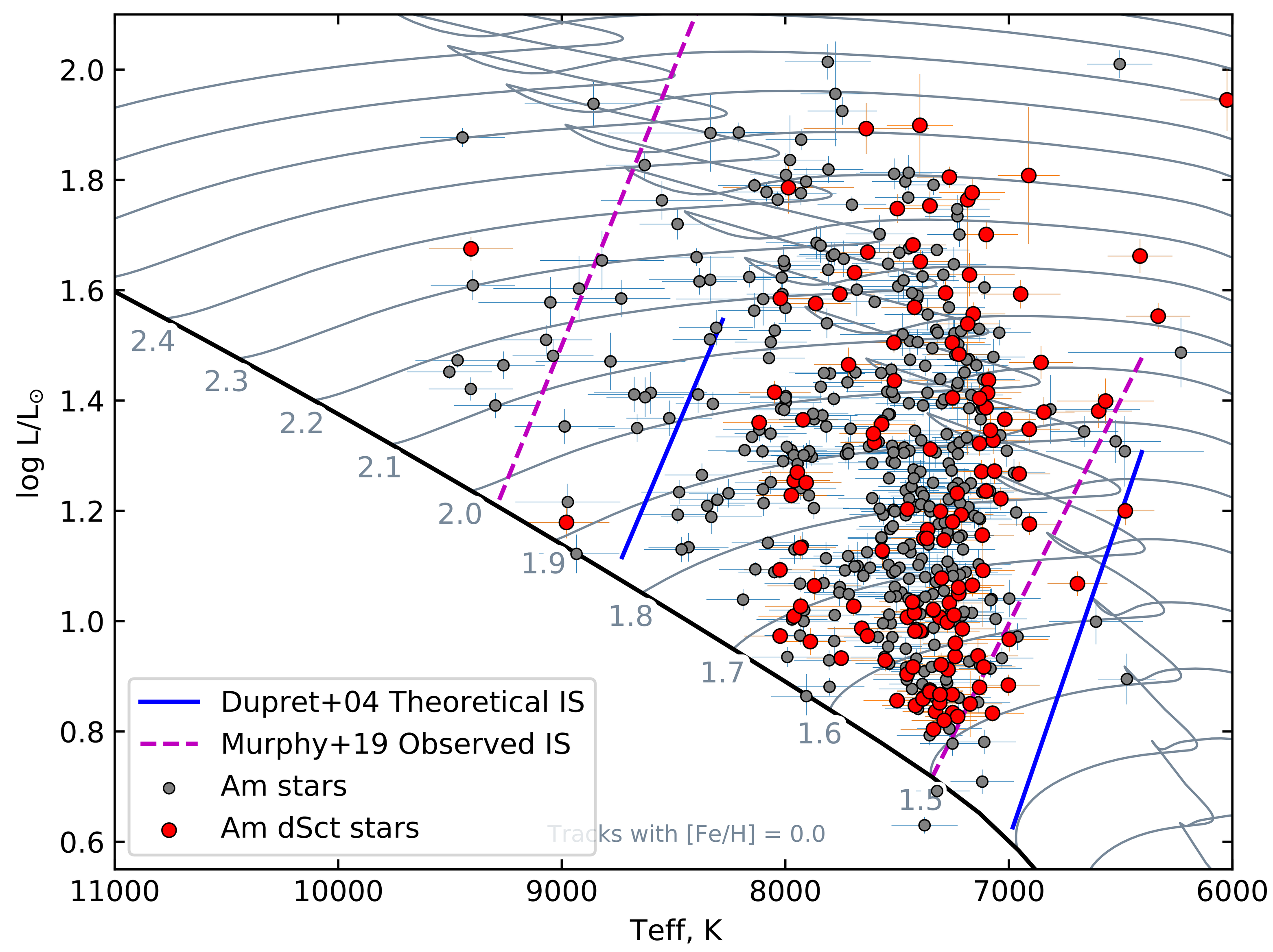

Figure 1: Location of Am stars in the HR Diagram. The stars with identified pulsations are shown in red.

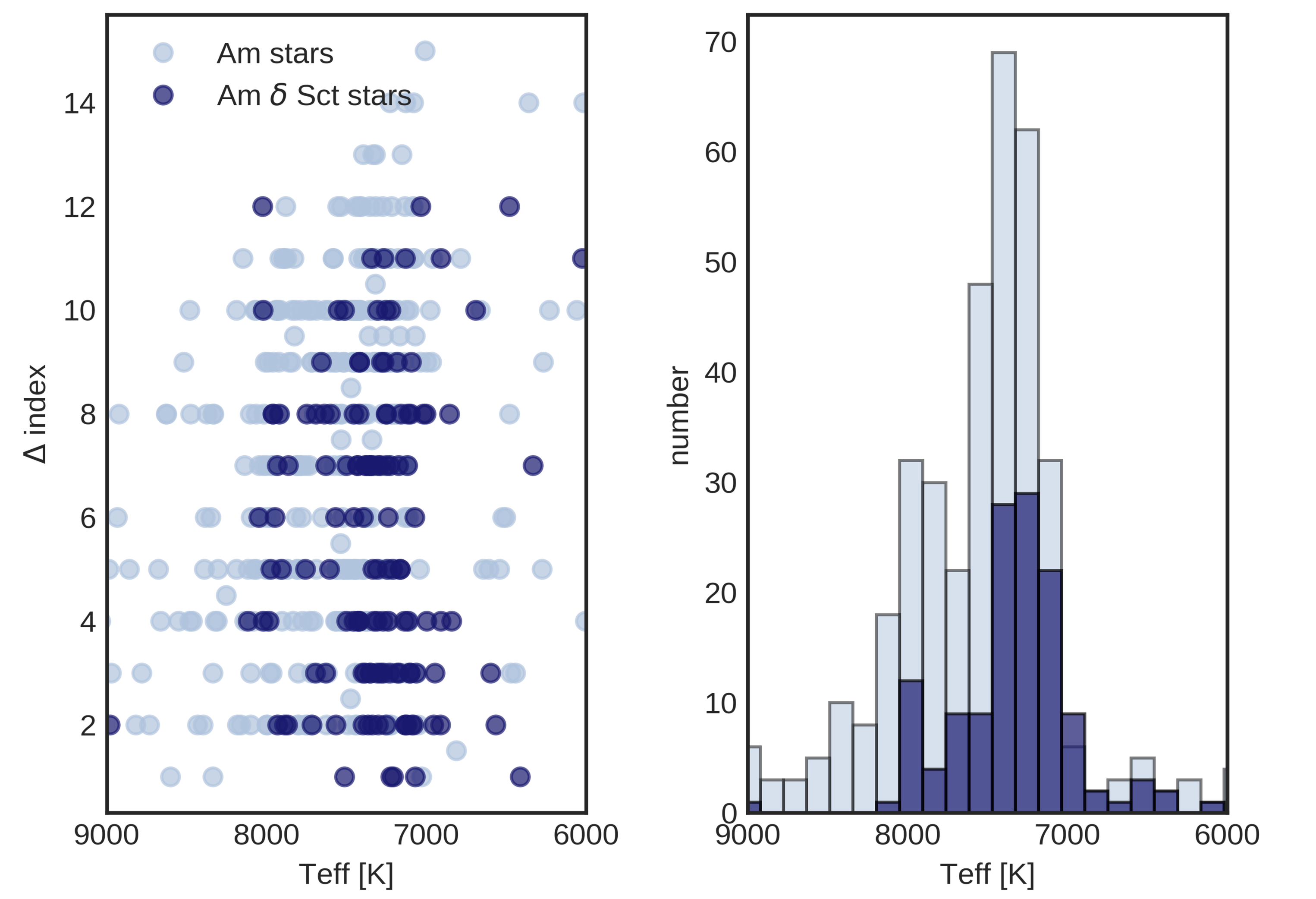

Figure 2: Variation of pulsation incidence with effective temperature. The left panel shows the Δ metallicism index as a function of $T_{\rm eff}$. The right panel shows the number the of Am stars with a given $T_{\rm eff}$.

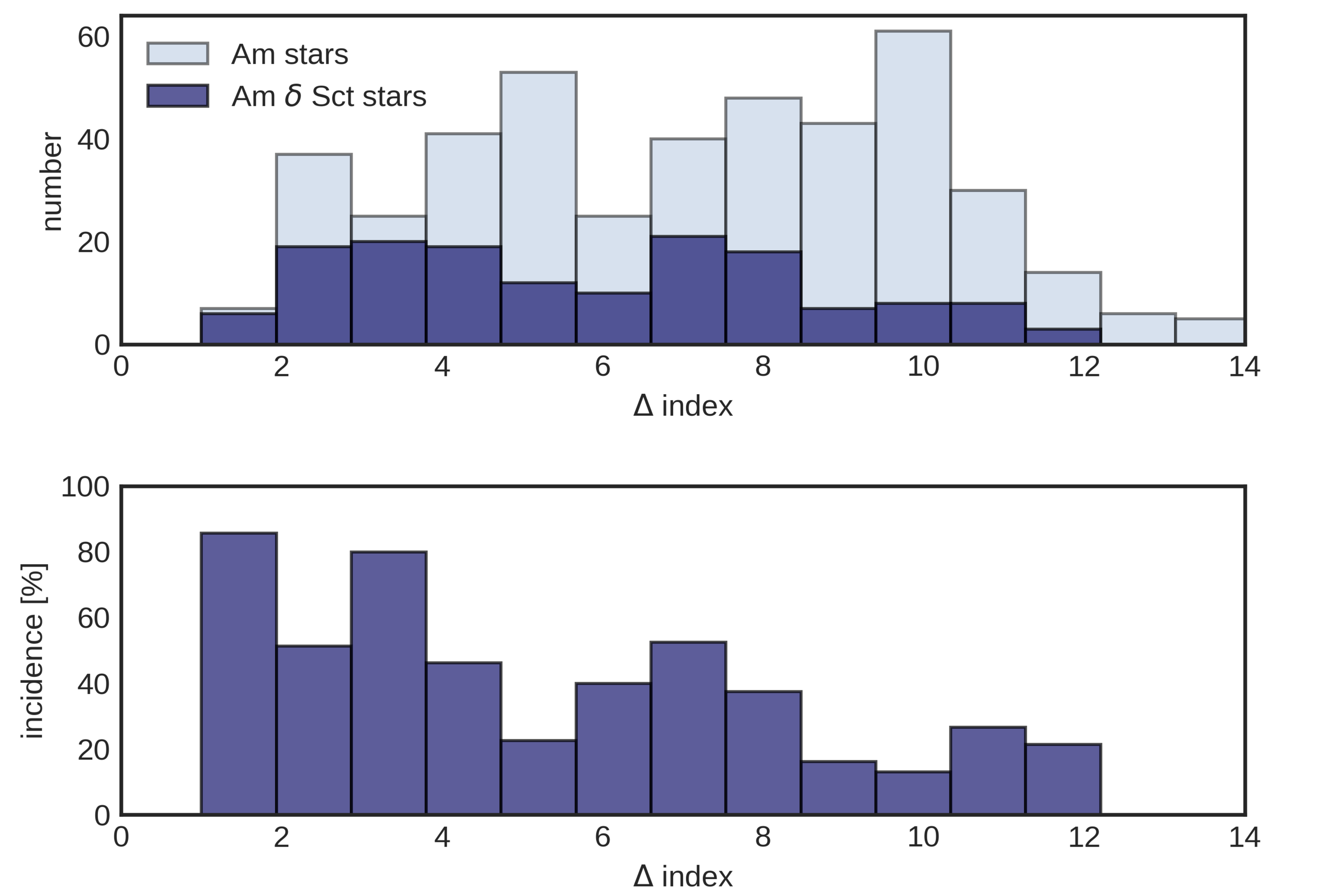

Figure 3: Variation of pulsation incidence with the Δ metallicism index. The upper panel shows the number of Am stars with a given Δ index, with the black bars indicating those with identified δ Sct pulsations. The lower panel shows the variation of incidence of δ Sct pulsations with Δ index.