# Are the constant stars in the delta Scuti instability strip chemically peculiar?

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## Introduction

The delta Scuti instability strip is located at the foot of the classical Cepheid instability strip where it meets with the main sequence, covering spectral types from early-A to mid-F. Delta Scuti stars pulsate via the opacity mechanism operating on the second ionisation zone of helium, and show pulsation amplitudes ranging from tenths of a magnitude right down to the noise levels of photometric observations, which with *Kepler* approach 1 μmag in some cases. Not all stars in the delta Scuti instability strip are pulsating, however; some appear to be constant at the detection limit of *Kepler*.

The metallic-lined A-stars (Am stars) coincide with the delta Scuti stars in the Hertzsprung-Russell diagram and account for about 50% of A-stars at A8 (Smalley et al. 2011). These stars are identifiable spectroscopically by having metal-line types that do not match their hydrogen line types. Specifically, classical Am stars are defined as having Ca II K-line types that differ from the metal lines by more than five spectral subclasses.

The chemical peculiarity of the Am stars can be attributed to their slow rotation: Am stars rotate more slowly than normal A-stars (Abt & Morrell 1995) – slowly enough that meridional circulation is non-turbulent. Under these conditions helium sinks gravitationally (Baglin et al. 1973), and ions with absorption lines near the peak wavelength of the photon energy distribution are radiatively levitated – accounting for the peculiar metal abundance. The sinking of helium towards the core partially drains the ionisation zone, impeding pulsation in these stars. Nevertheless, six of the ten known Am stars in the *Kepler* field of view are observed to pulsate (Balona et al. 2011).

Almost 70% of non-chemically-peculiar A-stars are delta Scuti stars (Turcotte et al. 2000), based on ground-based detection capabilities of around 1 mmag. We ask the inverse question: are the constant stars of the delta Scuti instability strip chemically peculiar?

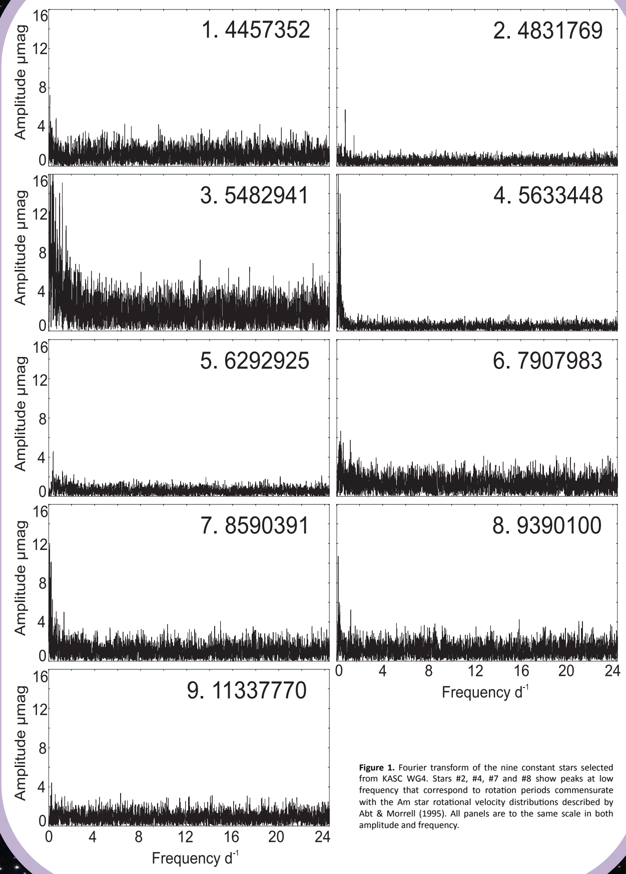


**Figure 1.** Fourier transform of the nine constant stars selected from KASC WG4. Stars #2, #4, #7 and #8 show peaks at low frequency that correspond to rotation periods commensurate with the Am star rotational velocity distributions described by Abt & Morrell (1995). All panels are to the same scale in both amplitude and frequency.

## Method

Target selection was performed by eye on the stars of KASC WG4 (delta Scuti stars). Those stars with peak Fourier amplitudes below 30 μmag in Pre-search Data Conditioned (PDC) flux were compared, and the nine stars with the flattest looking spectra were adopted. The target number was kept small to facilitate spectroscopic observations, and for this reason selection was weighted against faint stars.

Long-cadence *Kepler* data from Q3 were inspected for low-frequency peaks that could be attributed to rotation. Fourier transforms of the stars are shown in Fig. 1. The spectroscopic side of the study is still ongoing. The spectra are investigated for chemical peculiarity by evaluating the α and α′ values described by Smith (1970), which compare the relative strengths of some metal lines, namely, α = (Sc II λ4246.8)/(Sr II λ4215.5) and α′ = (Sc II λ4320.7)/(Y II λ4309.6). These criteria are particularly sensitive to the Am phenomenon because Sc is typically underabundant and Sr overabundant in these stars. The location of a star in log α / log α′ space is a strong indicator of chemical peculiarity, as shown in Fig. 2 (Smith 1970).

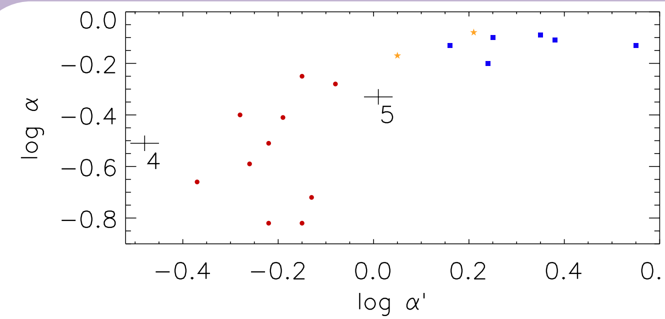


**Figure 2.** The spectroscopic criteria, α and α′, are plotted with errors (black crosses) for the target stars for which we currently have spectra. They are labelled numerically as in Fig. 1 and plotted alongside a sample of stars presented in Smith (1970). In this reproduction, the Am stars are red circles, the normal stars are blue squares, and the objects represented by orange star-shaped symbols have been classified as Am and normal in two separate studies.

## Results

Four of the nine stars (#2, #4, #7, #8) have a low frequency peak and a harmonic that might be interpreted as rotation (Balona 2011). Their estimated rotation velocities are 128, 46, 125, and 36 km s$^{-1}$, respectively. These values fall in the range expected from Abt & Morrell (1995), but need to be confirmed with spectroscopy. Spectra are available for stars #2, #4 and #5. Preliminary results show stars #4 and #5 to be Am stars. Star #2 rotates quickly ($v \sin i$ = 73 ± 5 km s$^{-1}$) making the star hard to place accurately in Fig. 2.

## Conclusions

The study is still in its early stages, but it appears that there is a high incidence of chemical peculiarity in the constant stars in the delta Scuti instability strip, as expected. The rotation velocities inferred from Fourier transforms appear high for Am stars, which have a modal rotation velocity of 65 km s$^{-1}$ (Abt & Morrell 1995), but do fall within the expected distribution. This method of inferring rotation velocities will be tested when spectroscopic data are available for each star.

## References

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## Future Work

Each star for which spectra are not yet available is on target lists for the next observing season. A full abundance analysis and atmospheric parameter determination will be carried out on each spectrum. Target selection for an extended study is nearing completion.