

## Close Frequency Pairs in Delta Scuti Stars<sup>1</sup>

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**Abstract.** The power spectra of several  $\delta$  Scuti stars show close peaks with similar frequencies and amplitudes. Apart from possible observational problems, this can be interpreted in terms of two separate pulsation modes with similar, close frequencies or an artifact of amplitude variability of a single pulsation mode. If sufficient data are available, it is possible to distinguish between the two hypotheses on the basis of expected systematic phase changes associated with the amplitude variations of an assumed single frequency. This phase-shift test has been applied to modes found for BI CMi. In this paper we present the evidence for one of the close frequency pairs found in this star.

### 1. Motivation

We made a literature survey of all stars listed in the  $\delta$  Scuti star catalogue (Rodríguez et al., 2000) for stars with at least one frequency pair closer than  $0.05 \text{ c d}^{-1}$  and sufficient frequency resolution (Loumos & Deeming, 1978). The main result of this survey is that at least 50% of the stars with data of sufficient frequency resolution show frequency pairs closer than  $0.05 \text{ c d}^{-1}$ .

### 2. Explanations for double peaks in the power spectrum

- **Observational problems.** Our examination of the data suggests that it is inappropriate to dismiss all reports of close frequencies in  $\delta$  Scuti stars as artifacts of poor frequency resolution, aliasing, incorrect prewhitening during data analyses or observational difficulties.
- **Amplitude variability of a single mode.** Strictly speaking, amplitude variability associated with a single frequency does not lead to a double peak, but to a more complex structure. However, in practice, often only a second peak is noticed in a power spectrum after prewhitening a mode with an incorrectly assumed constant amplitude. We note here that amplitude variability is a common feature in  $\delta$  Scuti pulsators.
- **Two pulsation modes with close frequencies.**

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<sup>1</sup>whole poster: <http://www.astro.univie.ac.at/~schaf/BI-CMi/poster.html>

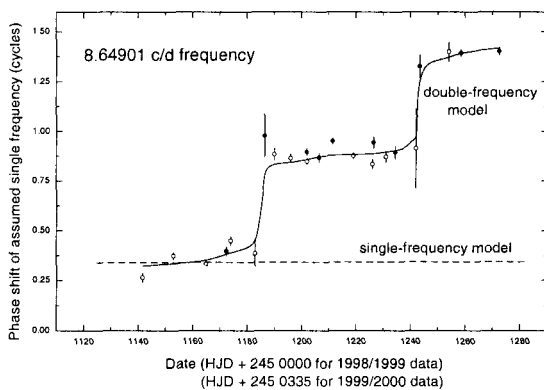


Figure 1. Phase shift diagram for two observing seasons: 1998/1999 (closed circles) and 1999/2000 (open circles). The phase jumps demonstrate the beating phenomenon and the existence of two close frequencies.

### 3. The choice: close frequencies or single frequency solution ?

The major difference between the two hypotheses is not the behavior of the amplitude but the phasing: a pair of close frequencies behave like a single frequency with a nearly constant phase and a sudden phase shift near the minimum amplitude. Therefore, we compare the phase variations during the beat cycle to the amplitude, assuming a single frequency.

We applied this test to the mode(s) near  $8.65 \text{ c d}^{-1}$  in the star BI CMi (Breger et al., 2001) and found regular phase jumps occurring at minimum amplitude. We conclude that the two peaks are caused by two separate pulsation modes, since phase jumps are incompatible with the single-mode/variable amplitude hypothesis.

### 4. Results

At least 50% of the known  $\delta$  Scuti stars with sufficient frequency resolution show frequency pairs closer than  $0.05 \text{ c d}^{-1}$ .

It is possible to confirm the double-mode hypothesis for very close pairs of peaks in the power spectrum of BI CMi by use of the phase-shift method. Consequently, the existence of these close modes needs to be considered in planning the lengths of ground-based as well as space campaigns.

### References

- Breger, M., Garrido, R., Handler, G., et al. 2001, MNRAS, submitted  
 Loumos, G. & Deeming, T. 1978, Ap&SS, 56, 285  
 Rodríguez, E., et al. 2000, in ASP Conf. Ser. Vol. 210: Delta Scuti and related Stars, eds. M. Breger & M. Montgomery, (San Francisco ASP), 499