Characterization of echelle ridges in fast rotating δ Scuti stars: Eigenmodes and rotational splittings

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Abstract

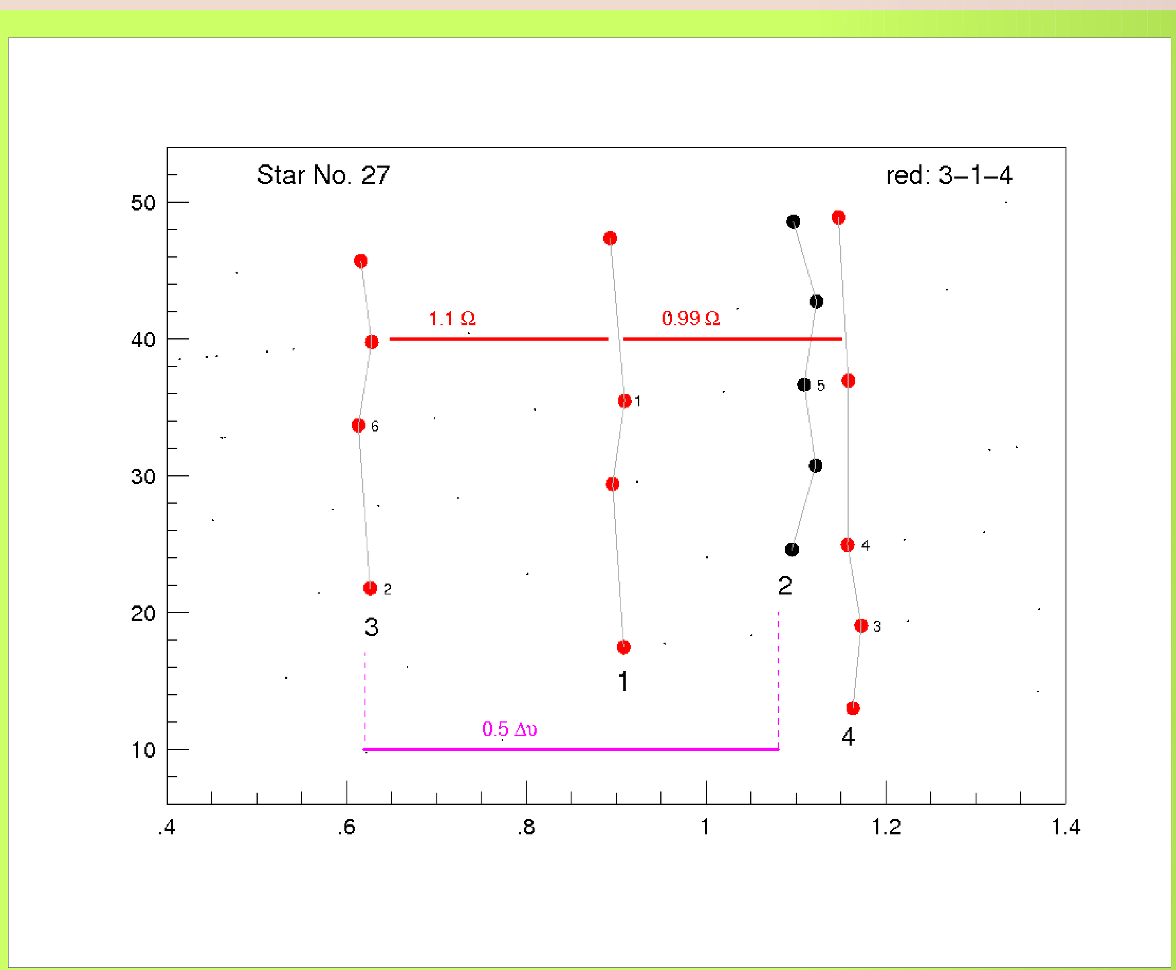
Unexpected regularity of echelle ridges were published for fast rotating δ Scuti stars (Paparó et al, ApJ, 822, 100 and ApJS 224, 41). We present here a subset of stars where the dominant spacing proved to be the large separation according to the relation of Suárez et al (2014). In these stars the eigenmodes and the rotationally split frequencies are located on independent echelle ridges. Eigenmodes and the rotationally split ridges are determined, but only guesses are given for the horizontal quantum number.

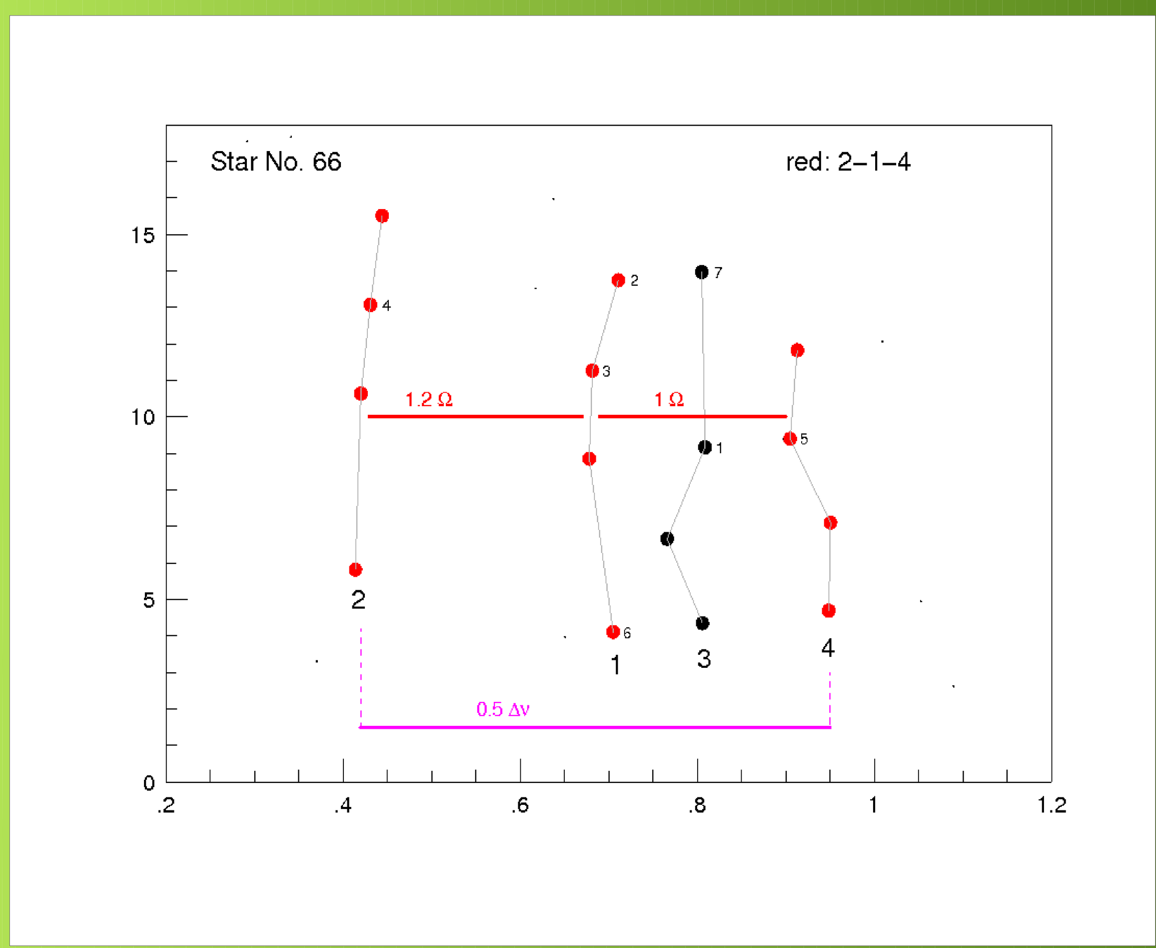
General description of the figures

The triplets with similar rotational splittings (in units of Ω) are marked by the same colour. The value of the splittings are given. The single echelle ridges are marked in black. The shift of the different triplets are marked in black, also in units of Ω. A shift of the echelle ridges by half of the large separation are marked in magenta. In the asymptotic regime, identifications depend on the relative location of the ridges of different types. We assumed that such rules still continue to apply to some extent in the non-asymptotic regime. The rotation rates range from 29% to 31% of the break-up rotation rate, except for Star No. 1 which is at 25%. The frequencies of the highest amplitude modes are marked in order by small black numbers. X-axes: modulo Δν, y-axes: frequency in d^{-1}.

Star No. 27: Δν=5.995 d^{-1}, Ω_{rot}=1.540 d^{-1}, their ratio is 25.7%

The frequencies are near the asymptotic regime and have low amplitudes (0.6 mmag). Two independent echelle ridges exist: ER2 and ER4. Although no radial period ratio is found in ER2, the lack of rotational splittings suggests these are *l*=0 modes. The distance between ER1 and ER2 does not correspond to Δν/2, but these ridges are not close. We suggest ER1, ER3 and ER4 are rotationally split *l*=1 modes.



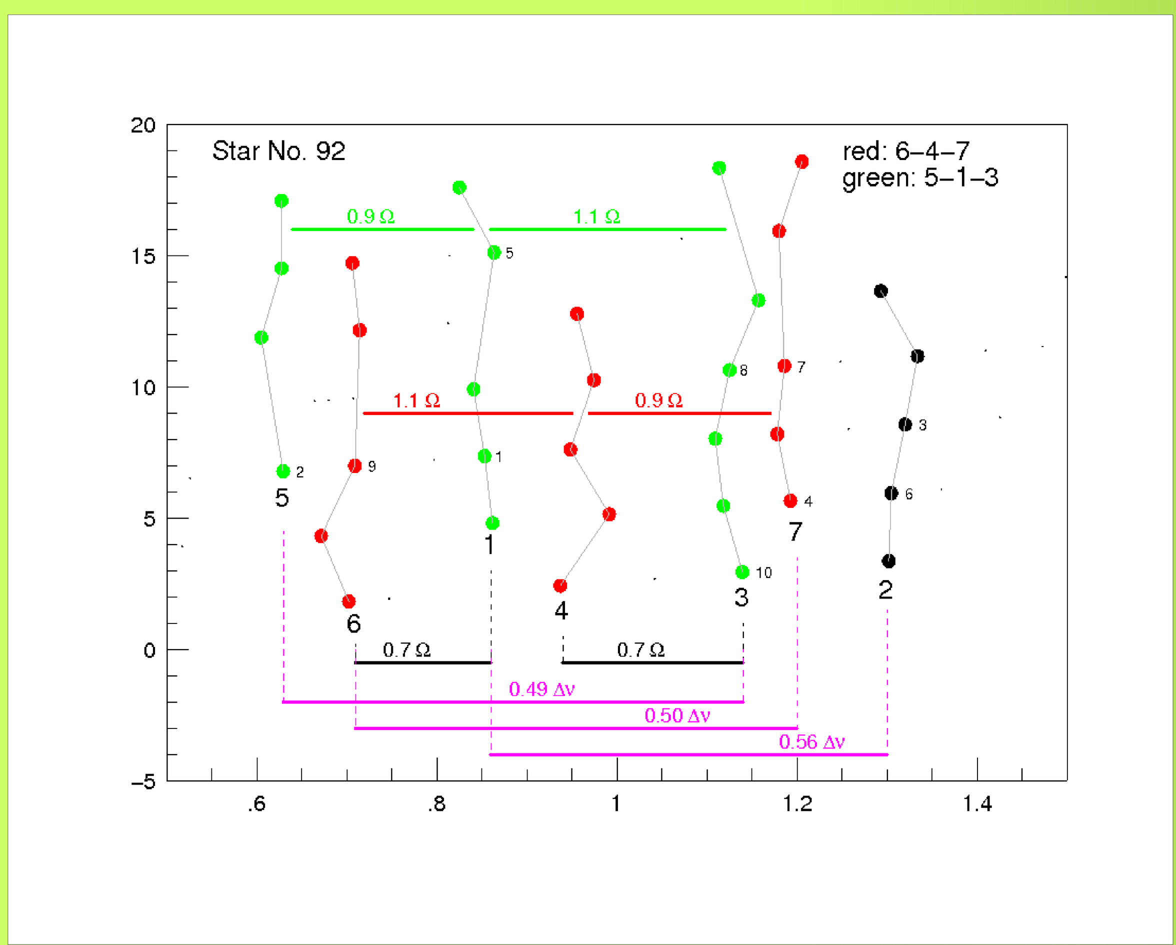


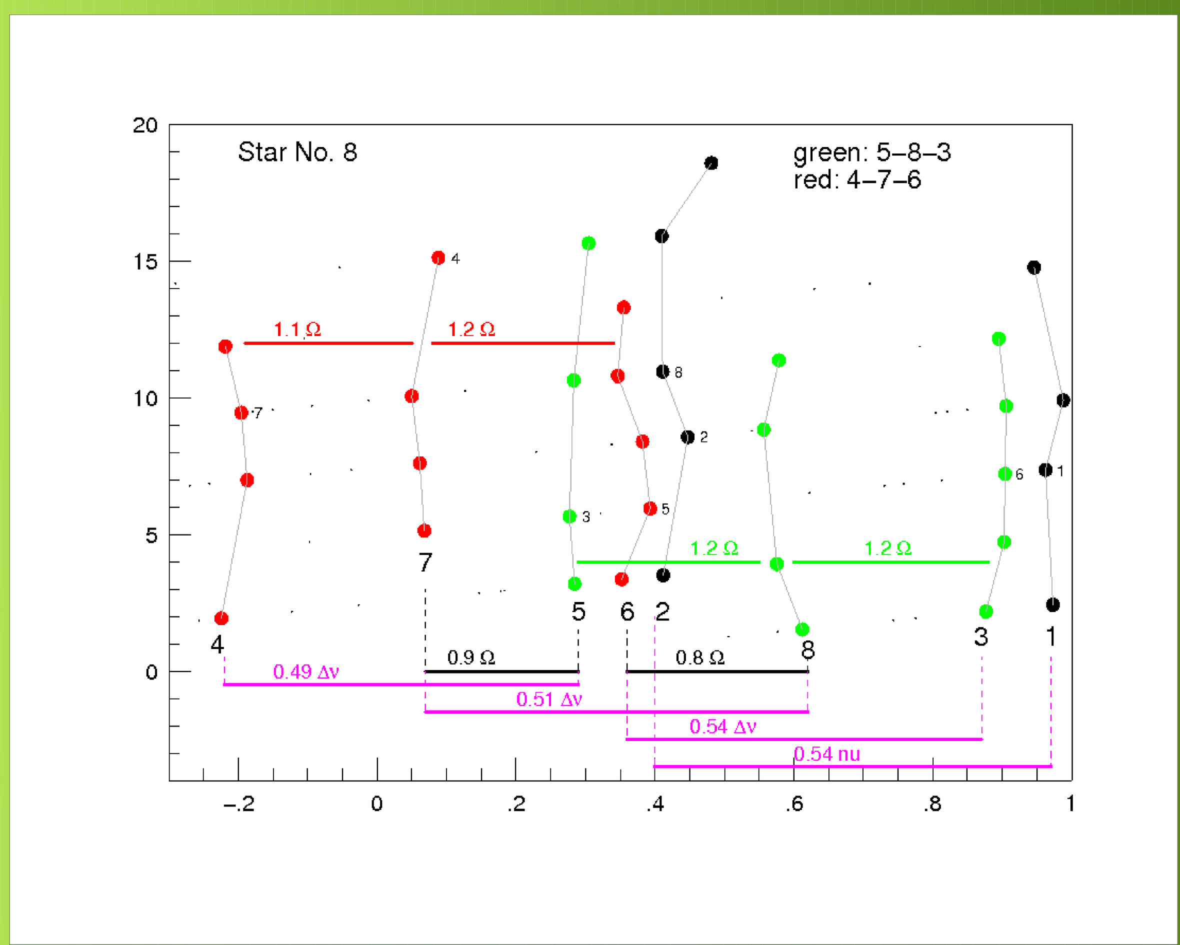
Star No. 66: Δν=2.406 d^{-1}, Ω_{rot}=0.545 d^{-1}, their ratio is 22.7%.

The frequency of the highest amplitude appears in the single echelle ridge, ER3. The period ratio of the lowest frequencies do not precisely agree with either the 0.77 academic value for non-rotating stars, or the 0.744 ratio calculated for the proper rotation rate (0.3). Assuming that ER3 corresponds to *l*=0, the nearby ER1 could have *l*=2 horizontal number.

Star No. 92: Δν=2.576 d^{-1}, Ω_{rot}=0.614 d^{-1}, their ratio is 23. %

Two overlapping triplets exist, shifted by less than the rotational frequency. The single echelle ridge, ER2 is supposed to have *l*=0. The ER1 shifted to mid-way of the large separation, is regarded as *l*=1 and ER4 as *l*=2. The period ratio of the fast rotating stars appears in each echelle ridge in a certain frequency region. This fact does not help us to fiind the radial modes.



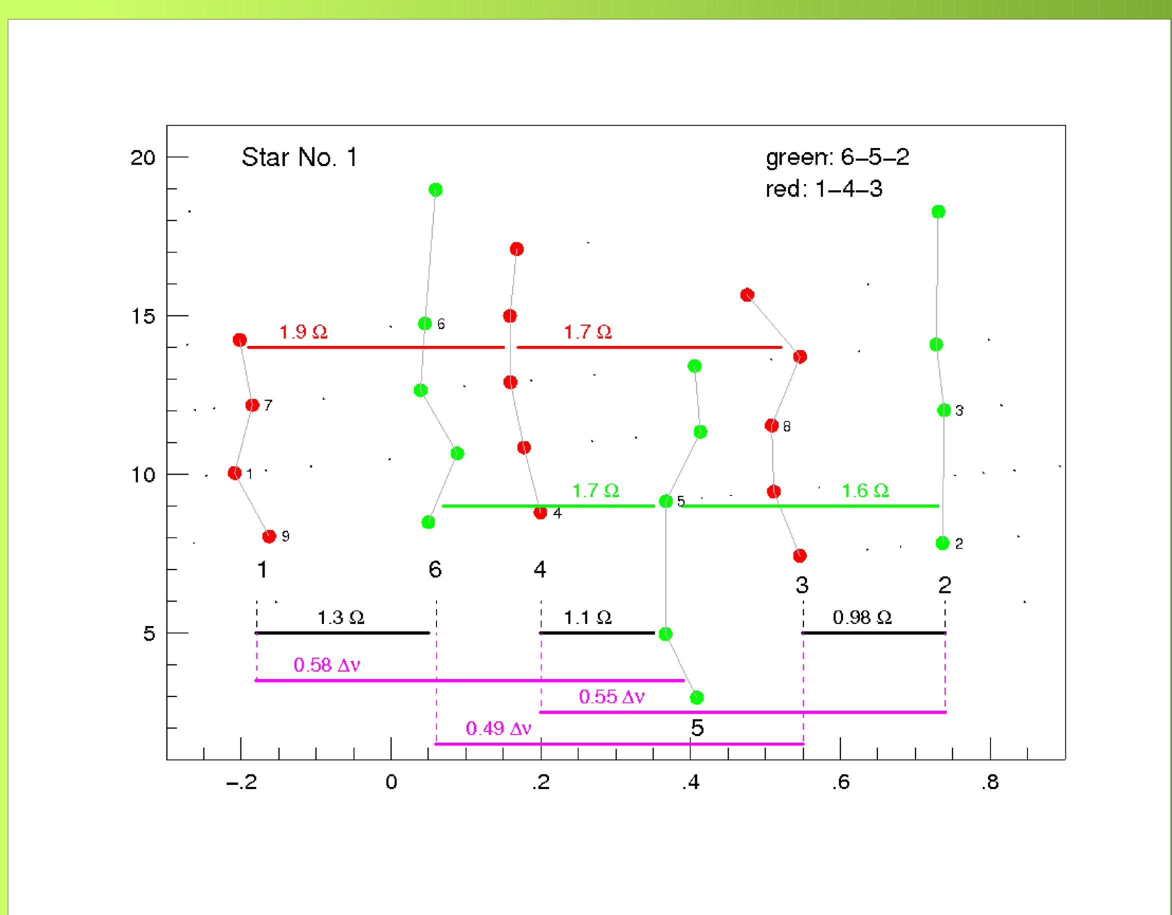


Star No. 8: Δν=2.481 d^{-1}, Ω_{rot}=0.614 d^{-1}, their ratio is 24.7%

The situation is more complicated due to two single echelle ridges, ER2 and ER1, separated by half of the large separation. There is no assumption for this case. If we accept ER2 as a radial ridge (*l*=0), than ER7 can have *l*=1 and the closer one, ER8 can have *l*=2 horizontal number. However, ER2 and ER1 could be another triplet, where the central ridge is missing.

Conclusion

The high level of regularity suggests that the rotation frequency is highly connected to the large separation determined by the structure of the star. Although we can find the eigenmodes and the rotationally split ridges, the unique mode identification is questionable.



Star No. 1: Δν=2.092 d^{-1}, Ω_{rot}=0.404 d^{-1}, their ratio is 19%

The highest regularity appears when the triplets are split by twice the value of the rotational frequency that often appears in the fast rotating models. The triplets are shifted by the rotational frequency. A different identification could be that these are doublets split by the rotational velocity, so instead of two triplets we have three doublets. Many echelle ridges are separated by half of the large separation. There is no single echelle ridge, there is no reference point.

Acknowledgments

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