



Enhancing the signal-to-noise ratio of solar-like targets

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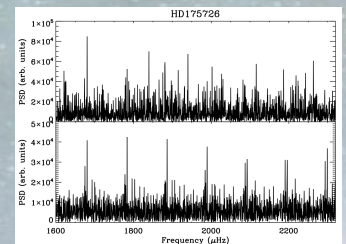
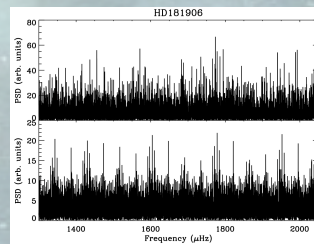
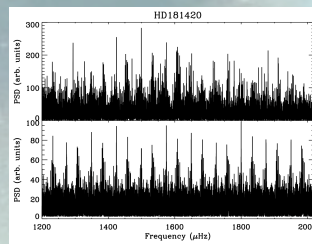
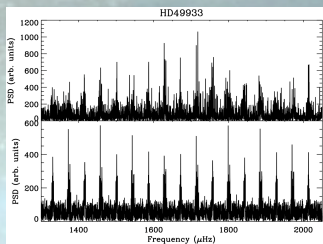
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Abstract

The analysis of the first solar-like targets done by CoRoT has shown that the oscillation amplitudes are about 25% below the theoretical amplitudes while the convective backgrounds are up to three times higher than in the solar case (Michel et al. 2008). In such conditions, the Comb-like structure of the acoustic modes has smaller signal-to-noise ratios than initially expected complicating the characterization of individual modes. In the present work we apply the curvelet filtering to the solar-like targets already observed by CoRoT as well as a partial reconstruction of the signal from the obtained spacing of the comb-like structure of the acoustic modes. It enables us to enhance the signal-to-noise ratio of the ridges in the echelle diagrams. Finally, we study how the analysis of the p modes can be improved.

Partial reconstruction of the signal

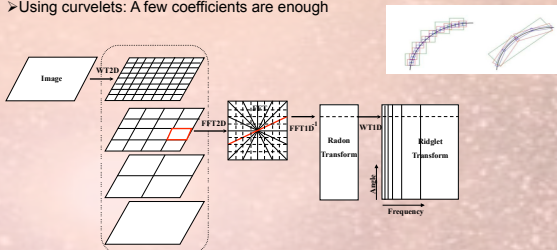
- A possible way of enhancing the signal-to-noise ratio (SNR) of solar-like stars is to take advantage of the asymptotic properties of their p modes.
- In the Fourier spectrum of these stars, the peaks that correspond to the acoustic modes are almost equally spaced in a given frequency range.
- To increase the SNR of the periodic structures (the modes) we perform a selective filtering of the power spectrum of the power spectrum (PSPS) (see Régulo and Roca Cortés, 2002).
- We start by computing the PSPS of a short range in frequency (<1000 μHz) around the maximum power of the p-mode band (the asymptotic part).
- The resultant PSPS is filtered in multiplying it by a window function which is 1 for all the equally spaced bins around multiples of the large separation of the p-modes (that should have been estimated before) starting at zero, while the rest of the bins are settled to zero.
- The inverse Fourier Transform of this filtered PSPS produces a "recovered" power spectrum of the stellar p-modes with a higher SNR.
- This method tends to rigidify the modes towards the borders of the considered region where the modes could be less asymptotic and the large separations could change significantly with frequency.
- The "recovered" amplitudes and linewidths of the modes are modified.



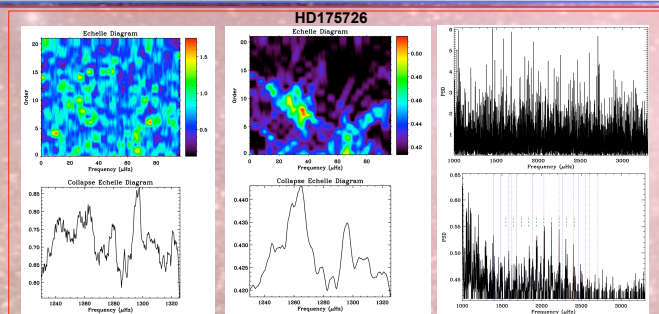
The top figures correspond to the original, full resolution, PSD of each star in the range where the acoustic modes display an excess of energy. The bottom panels shown the "recovered" PSD, where the p-mode pattern is clearly visible.

Curvelet filtering

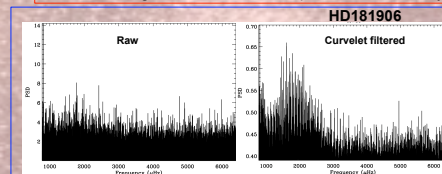
- Echelle Diagrams can help on the mode tagging
 - Used in early stages of helioseismology [Grec et al. 1981]
- To improve the SNR Bedding et al 2004 proposed to use it by smoothing in the vertical direction:
 - Only works well where the ridglets are quasi-vertical:
 - A very good a priori of the large separation ($\Delta\nu$) is needed
 - Only works properly in the asymptotic part
- We propose other denoising technique based on the use of CURVELETS
 - Curvelet transforms are built to deal with curved structures of finite size in the image.
 - A Curvelet transform (Candès & Donoho 1999) is a ridgelet transform (Candès 1998) but used in a localized manner
 - At a small scale any curved line can be approached by a straight line.
 - Using wavelets: Many coefficients are needed
 - Using curvelets: A few coefficients are enough



- It has been successfully tested using Monte-Carlo simulations and real solar data (Lambert et al. 2006).
- The filtering becomes more efficient when the SNR is smaller.
- It needs an estimation of the large separation.



- Raw and resultant curvelet filtered Echelle diagrams (Left and centre panels).
- The collapsed figures are just the sum of each horizontal line of the Echelle diagram.
- In the curvelet filtered diagrams we can clearly identify the presence of two ridges.
- The raw and unfolded curvelet filtered spectrum are plotted in the right hand side plots
 - A Comb-like pattern is clearly visible centred at ~2120 μHz .
 - Dotted lines are the frequencies found by Mosser et al. 2009 (blue = ν_1 ; red = ν_2)
 - Dashed green lines are the frequencies obtained by the partial reconstruction method



- Raw and Resultant curvelet filtered spectrum of HD181906.
- A Comb-like spectrum appears centred at ~1800 μHz
- P-mode like structure extends from 1000 to 2600 μHz

References

- Candès 1998, Ph.D. Thesis, Stanford University
- Candès & Donoho, 1999, in Curves and Surfaces: Saint-Malo 1999, ed. Cohen, Rabut, & Schumaker, (Nashville, TN: Vanderbilt University Press)
- Lambert et al. 2006, A&A, 454, 1021
- Michel et al. 2008, Science, 322, 558
- Mosser et al. 2009, A&A, in preparation
- Régulo and Roca Cortés, 2002, A&A, 396, 745