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On the origin of the 1/f spectrum in the heliosphere

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We present results of numerical simulations in which the low frequency 1/f spectrum is a natural outcome of the turbulent dynamics inside the sub-Alfvenic solar wind. The magnetic field is assumed to be parallel to the radial expanding solar wind, a situation that holds at that short heliospheric distance. We inject fluctuations of short or long periodicity (T=600 or 6000 s) at the base of the chromosphere and study the properties of the resulting (perpendicular and parallel) spectrum that is advected by the solar wind outside the Alfvenic critical point. The formation of the 1/f spectrum is due to the recycling of Alfvenic turbulence between the transition region and the Alfvenic critical point, a mechanism that works thanks to the high Alfven speed in the low corona and the relatively weak nonlinear interactions there.

The perpendicular magnetic spectrum is found to be always a power-law with a slope close to the Kolmogorov value 5/3. The parallel magnetic spectrum shows a double-power-law with slopes depending on the turbulence strength and on the width of the injected spectrum. The latter also determines the frequency of the spectral break. Slopes approximately -1 and -2 at low and high frequencies respectively are found for weak turbulence and wide injected spectrum (T=600 s). A stronger turbulence causes a flattening of the low-frequency slope, a narrower injected spectrum decreases the frequency of the spectral break. This offers the possibility to deduce the form of the chromospheric spectrum from measurements made just outside the Alfvenic critical point.

We suggest that the double-power-law spectrum measured by Helios at 0.3 AU, where the average magnetic field is not aligned with radial direction, results from the combination of the different spectral slopes. At low frequency the parallel spectrum dominates with its characteristic 1/f shape, while at higher frequencies its steep spectral slope (-2) is masked by the more energetic perpendicular spectrum (with a -5/3 slope). Given the location of the frequency break, according to the above mechanism, the 1/f spectrum is a signature of a weak turbulent activity in the corona and a wide seed-spectrum in the chromosphere.