Domain Structure of a Disoriented Chiral Condensate from a Wavelet Perspective *

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Theoretical investigations of nonequilibrium dynamics using the classical linear σ-model have found some evidence for the formation of Disoriented Chiral Condensate (DCC) or the growth of long wavelength pion modes. Although the precise dimension of a typical domain or cluster is still under debate, it seems likely, especially in heavy-ion collisions, that many domains or clusters could be formed in the large interaction volume. If there are many uncorrelated small domains, the integrated probability distribution of the neutral pion fraction f emitted from a disoriented region, predicted to be $P(f) = 1/2\ \sqrt{f}$, would become Gaussian, following the Central Limit Theorem.

Normally DCC domains are localized in coordinate space. If they develop collective motion in the course of their time evolution, they should also appear localized in momentum space. In order to disentangle the DCC domain structure in high energy heavy-ion collisions, we propose a new method which emphasizes not only the behavior of the probability distribution in the full phase space region but also its fluctuation in rapidity η or azimuthal angle ϕ. It is a multiresolution analysis performed by a discrete wavelet transformation (DWT) which has been found effective in systematically detecting structures on various scales in turbulence, astrophysics, and multiparticle production. We demonstrate that the DWT proves to be very useful in identifying and measuring the DCC domain structures *simultaneously* in terms of their size (in scale) and location (in space). Since it is likely that there are other physical scales accompanying the typical DCC domain scale in a physical process, the multiresolution feature of the DWT is essential for identification of the structures of interest. It acts like a mathematical microscope which can zoom in or out to various scales at each location. Due to the completeness and orthogonality of the DWT basis, there will be no information loss.

Shown in Fig. 1 are the wavelet power spectrum in rapidity of different samples. The random noise sample features a flat power spectrum, i.e. the power of fluctuations is the same at any scale. For the DCC sample there should be a flat spectrum when the scale is small and some power build-up should show up when the scale becomes larger than the DCC scale. The crossing point in Fig. 1 is found to be at $j_d = 3.6$ which unambiguously suggests the existence of the DCC clustering with a typical size of $\Delta\eta_d = 2\eta_{\max}/2^{j_d} \simeq 0.8$ units in rapidity. Also plotted is the power spectrum from HIJING Monte Carlo data which is also flat, consistent with the random noise case.

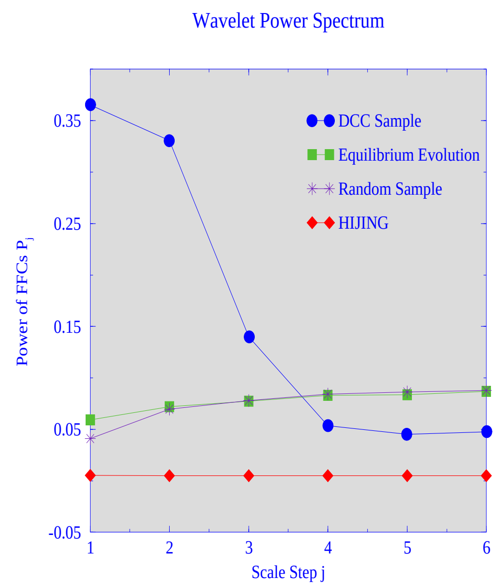

Figure 1: The wavelet power spectra for different dynamical scenarios.

The existence of a plateau structure in the wavelet power spectrum is important in that one may attempt to define an effective "temperature" inside a domain structure where the fluctuations are relatively "stable" against the scale change.

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