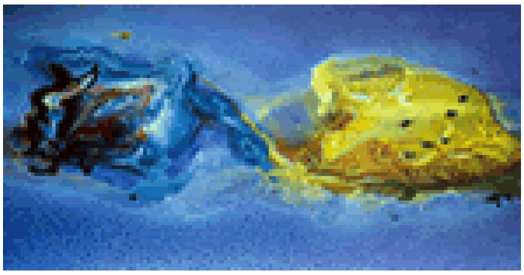

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Fractal structure, power-law distribution and hadron spectrum

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One of the most celebrated features of QCD is the asymptotic freedom that allows calculations of strong interaction with a perturbative method when the momentum transferred is sufficiently large. The non perturbative regime, however, remains veiled to {\it ab initio} calculations, and it is expected that the large amount of data made available by high energy experiments will give some insight to solve the theoretical difficulties on this issue. Meanwhile, phenomenological approaches seems to be one of the best ways to access the non perturbative QCD in those problems where even Lattice QCD struggles to find an answer. An effort is necessary, then, to understand the phenomenological approaches in therms of QCD.

Transverse momentum distribution is one of the most direct experimental observables in high energy collisions, and one of its distinguishing features is the large tail at the high momentum sector, deviating from the exponential distribution expected to be found in a thermodynamically equilibrated system. Chemical production ratios, however, clearly show that such equilibrium is reached in the collisions. One possible solution to this apparent paradox is to attribute the high p_T momentum region to non equilibrium processes, while the bulk of particle production would result from the Boltzmann distributions of a thermal system. Another possibility is to assign the non extensive statistics to the description of the thermodynamics properties of the hadronic system obtained in high energy collisions, which would describe the whole p_T distribution, among other aspects of those collisions. In the present work a system presenting fractal structure in its energy-momentum space is investigated aiming to understand which aspects of QCD could possibly give rise to the fractal structure. Such system, which will be referred to as thermofractals, has been show to follow Tsallis non extensive statistics and also present many aspects also present in hadrons.

Thermofractals were recently introduced in the context of non extensive statistics and features fractal structure in thermodynamics functions as a possible origin of non extensivity [1]. The main aspect of such system is the energy fluctuation that results to be given by
\begin{equation}
P(E)dE=A e_q(-\beta E)\,,
\end{equation}
with $e_q(x)$ being the q-exponential function, given by
\begin{equation}
{e_q(x)=\bigg[1+(1-q)x \bigg]^{\frac{1}{1-q}}}\,,
\end{equation}
and β the inverse of temperature. The presence of the q-exponential makes clear that Tsallis statistics [2] is the proper tool to describe this system thermodynamically.

Fractal features in hadronic multiparticle production were already addressed by Veneziano [3] in association to the complex interaction that arises when one considers high transferred momentum, Q^2 in high order logarithm expansion in the QCD evolution contributions according to Altarelli-Parisi approach [4]. This fractal aspects were in fact observed experimentally through the intermittency analysis, a technique proposed by Bialas and Peschanski [5,6] that allows to measure, from energy, momentum or rapidity distributions, the fractal dimension associated to the particle production process.

There are more direct observations of self-similarity in multiparticle production at high energy collisions. The so-called z-scaling shows that particle energy distributions collapses to a single distribution when described by the z variable, that takes into account fractal dimensions of the particle phase-space. Experimentally, an analysis of transverse momentum dstributions of jets and particles was shown to have the same description in terms of Tsallis distribution. Moreover, when the jet-particles are analyzed with respect to the jet momentum, the transverse momentum distribution with respect to the jet axis direction shows, surprisingly, the same distribution. These are clear manifestations of self-similarity in high energy collisions.

With the introduction of thermofractals it was possible to show that a system like those proposed for fireballs and hadrons should be described by Tsallis statistics instead of Boltzmann one. When Hagedorn's theory [7] is generalized to a non extensive self-consistent thermodynamics, the results present the power-law behavior that describes the outcome of high energy collision by means of two parameters that are likely to be universal for all particle species and all colliding energies. In addition, a new hadron mass spectrum formula is derived, resulting in
\begin{equation}
\rho(m)=A e_q(\beta_o m)\,.
\end{equation}
The hadron mass spectrum for the known hadronic states is described very well by this new mass spectrum formula up to masses as low as the pion mass, performing much better than the Hagedorn's formula for that spectrum.

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\end{thebibliography}

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