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Multi-fractal and Wavelet Analysis for Cosmic Ray Mass Composition Studies using the TACTIC Telescope

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Abstract. We have investigated the efficiency of multifractal and wavelet parameters of the simulated images of atmospheric Cerenkov events, in segregating the events in terms of primary mass. We find that the fractal dimension D_6 and the wavelet dimension β_6 can be employed effectively for studying cosmic ray mass composition at > 20 TeV energy with the TACTIC array.

Keywords : Cosmic -ray mass composition, TACTIC Telescope.

1. Introduction

The increased collection area (~10^9 cm^2) of the TACTIC telescope in the large zenith angle operation mode and the resulting high detection rates for >20 TeV hadron initiated Cerenkov events, enables cosmic-ray composition studies through an appropriate mass-segregation scheme (Bhat et al, 2001). Fractal and wavelet analysis are pattern recognition tools which examine Cerenkov image stuctures on different scale lengths. The fractal and wavelet nature of Cerenkov images quantified in terms of dimensions and moments of various orders, is shown to be useful for mass segregation as described in this communication.

2. Simulation Methodology and Results

We have used the CORSIKA air shower simulation code (version 5.61), with appropriate back-up software to generate Cerenkov images which would be recorded by the 16×16 pixel imaging camera of the TACTIC imaging element in response to the isotropic incidence of primary gamma rays (10-100 TeV; 1500 events), protons (20-200 TeV; 1400 events), Neon (30-300 TeV; 1300

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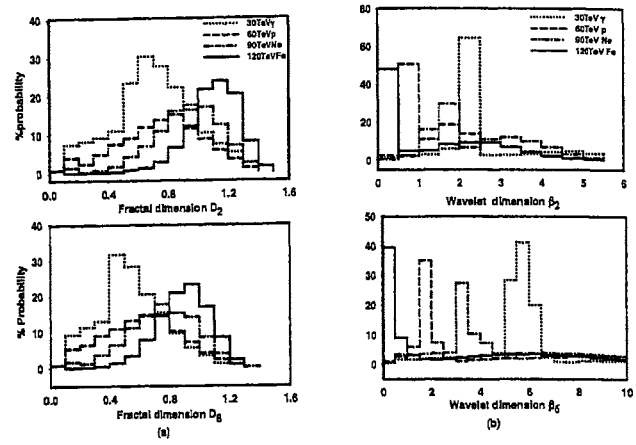

Figure 1. Probability distributions of fractal and wavelet dimension.

events) and Iron nuclei (40-400 TeV; 1300 events) at the top of the atmosphere, within a 4 degree diameter cone centred on the zenith direction of 50 degrees. The sampled images have been parameterized by determining the multifractal moments G_q, fractal dimensions D_q and wavelet moments W_q and wavelet dimensions β_q (Razdan et al, 2002). Figure 1(a) compares the probability distribution of multifractal dimensions D_2 and D_6 for Cerenkov images generated by the four primary species (30 TeVγ, 60 TeV p, 90 TeV Ne and 120 TeV Fe). We find that the peak value of the probability distribution is well separated in case of events initiated by primary gamma-rays and iron nuclei, whileas the distributions for protons and Neon are almost identical. Thus, while the D_6 parameter can efficiently segregate the events in terms of gamma-rays,light nuclei(proton and neon)and heavy nulei(iron),it can not effectively segregate proton initiated events from Ne initiated events. Figure 1(b) shows the probability for the wavelet dimensions β_2 and β_6. Here, we find that the parameter β_6 alone is able to segregate the events efficiently in terms of the primary mass with the peaks in the probability distribution well separated for the four species.It is clear that an algorithm based on D_6 and β_6 parameters can be developed to effectively segregate the recorded Cerenkov events in terms of the primary mass with high confidence.

References

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