

Multivariate Methods of Data Analysis in Cosmic Ray Astrophysics

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Abstract

Each time new type of detectors started to detect Universe they revealed details of a cosmos that don't show up through the eyepiece of an optical telescope. Indeed, every part of the electromagnetic spectrum surprised astronomers in one way or another. And only simultaneous detection of all 25 magnitudes of energy by different kinds of detectors, starting from radio telescopes to giant arrays measuring ultrahigh energy cosmic rays, will allow to understand physics of such exotic objects like black holes, and neutron stars, and such energetic processes like supernova explosions and gamma ray bursts.

Though each experimental device created to detect new type of radiation is a technical breakthrough, we need also intellectual breakthrough to understand and handle abundant multidimensional information available from numerous sensors measuring various types of particles.

One of the most important problems in physical inference from multivariate measurements is development of the reliable statistical procedures dealing with information from modern multipurpose experimental installations.

Nowadays, when multidimensionality of physical phenomena is well recognized and experimental techniques reach excellence to measure simultaneously many parameters with high precision, the necessity of adequate multivariate analysis methods is apparent.

This report will present coherent system of multivariate statistical methods dealing with analysis of data of stochastic nature. All stages of analysis, from preprocessing and indication of outliers to sophisticated physical inference on the theoretical models under consideration, will be presented with numerous examples of application.

The most general framework in which to formulate solutions to physical inference problems in Cosmic Ray Astrophysics experiments is a statistical one, which recognizes the probabilistic nature both of the physical processes of cosmic radiation propagation, and of the form in which the data analysis results should be expressed.

To make the conclusions about investigated physical phenomenon more reliable and significant we have developed a unified framework of statistical inference, based on nonparametric models, in which various nonparametric approaches and Neural Networks are implemented and compared. In this context it is necessary to mention that we consider the Neural information technology not as a "black box", but as an extension of conventional nonparametric technique of statistical inference.

The Analysis and Nonparametric Inference (ANI) program package is the software realization of our concept and appropriate tool for the physical inference in High Energy Cosmic Ray Astrophysics experiments. During last 10 years ANI package was updated and intensively used for comparisons of different nonparametric techniques and for data analysis of world biggest experiments, like PAMIR emulsion chamber collaboration, Wipple air Cherenkov telescope, KASCADE and ANI surface installations for detecting the Extensive Air Showers.