A Magnetic Spectrometer Analysis Method for Ultra High Energy Cosmic Ray Data

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Abstract

Since their discovery at the beginning of the 20^{th} Century, cosmic rays have been the subject of much research. However, fundamental questions, such as the origin of the most energetic of these particles, await an answer. The unambiguous identification of cosmic ray sources is made difficult by the deflections that these charged particles suffer in their propagation through cosmic magnetic fields. This problem is compounded by the extremely low flux of the highest energy cosmic rays at Earth, the arrival directions of which may be expected to retain information about their point of origin.

However, the advent of ultra high energy cosmic ray detectors possessing collecting areas of thousands of square kilometres, such as the Pierre Auger Observatory, means that the number of cosmic rays detected at the highest energies may be sufficient to enable directional cosmic ray astronomy in the near future. The 'magnetic spectrometer analysis', described in this thesis, is designed for the analysis of ultra high energy cosmic ray data sets. The analysis is designed to identify energy ordering in the arrival directions of a cosmic ray data set, and reconstruct the source directions of such events.

A brief history of the discovery of cosmic rays is presented in Chapter 1, along with an introduction to the physics of extensive air showers and methods of detecting them. The current knowledge of the properties of the cosmic ray flux at ultra high energies is reviewed in Chapter 2, and a summary of ultra high energy cosmic ray detectors, both past and present, is presented in Chapter 3.

The propagation of cosmic rays through magnetic fields, and the methods of measuring those fields, is briefly reviewed in Chapter 4. In addition, the Galactic magnetic field models that are used for the production of simulated cosmic ray data sets are described there.

Numerical integration is employed in the generation of the simulated data sets, and the method of doing so, as well as considerations that must be made for such simulations, is described in Chapter 5.

The magnetic spectrometer analysis method is introduced in Chapter 6 in addition to a discussion of related analyses found in the literature. The results of applying the magnetic spectrometer analysis to simulated cosmic ray data sets are presented in Chapter 7.

Finally, the results of an application of the magnetic spectrometer analysis to real data collected by the Pierre Auger Observatory are described in Chapter 8, followed by a discussion of those results and concluding remarks.

Declaration of Originality

I, Benjamin James Whelan, certify that this work contains no material which has been accepted for the award of any other degree or diploma in any university or other tertiary institution and, to the best of my knowledge and belief, contains no material previously published or written by another person, except where due reference has been made in the text.

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