



Ranging of Extensive Airshowers by Spectral Measurements

T. PAUL¹, S. REUCROFT¹, J. SWAIN¹

¹ Dept. of Physics, Northeastern University, Boston, MA 02115, USA

john.swain@cern.ch

Abstract: We point out that the fact that different wavelengths of light are attenuated differently with distance in the atmosphere can in principle provide a way to measure the distance to an extensive airshower via spectral measurements made at one point. This could be an interesting and complementary technique in future experiments.

Introduction

The basic idea of this paper is quite simple, and easily understood by thinking of the physics of the sunset. When the sun is low on the horizon, it appears red due to the preferential scattering (with cross section going as $1/\lambda^4$) of shorter wavelength (redder) light. The light produced by an extensive airshower has a spectral distribution $I(\lambda)$ [1, 2] which will suffer a distortion due to propagation through an atmosphere which attenuates light of different wavelengths differently.

The idea here is very general, but it is perhaps easiest to consider the concrete case of a simple model atmosphere with Rayleigh scattering so that $A(\lambda, R, a_i) = \exp(-aR/\lambda^4)$ for some a . We assume that the initial spectral distribution is known, but not its integral – that is, we don't know how *bright* the original source was. Let us write $I_{\text{initial}}(\lambda) = NI_0(\lambda)$ where I_0 is normalized to unity and N then describes the total (though unknown) intensity.

At a distance R then, one observes

$$I(R) = \exp(-aR/\lambda^4)NI_0(\lambda) \quad (1)$$

We then have

$$\ln \frac{I(\lambda, R)}{I_0(\lambda)} = \ln N - aR/\lambda^4 \quad (2)$$

The left hand side is a function of λ from which aR can now be extracted *independent of the initial*

overall intensity N from a fit. The parameter a is known from basic physics, so this means that we can determine R .

This argument is quite general, and all that is needed is that the attenuation function is non-constant with wavelength. More complex models than Rayleigh scattering can (and probably should!) be used, but the principle is the same.

Note that since the procedure used to extract the distance is via a fit, one automatically will have statistical errors on R (or, indeed, a likelihood distribution for R , which can, if desired, be used to combine the R information here with other data on distance) and one can use goodness of fit as a criterion for how well R was reconstructed (and how well the model used match the observed data).

Summary

We have shown that the nontrivial wavelength dependence of atmospheric attenuation of light from an extensive air shower can, in principle, be used to convert information on the spectrum of light arriving at a single observation point into information about distance to the shower. Further studies and experimental tests will ultimately determine how useful such measurements can be.

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References

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