The Feasibility of Detecting and Characterizing Extensive Air Showers with Passive Radar

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The study of cosmic rays and the extensive air showers (EAS) they produce has been a subject of investigation over the past 100 years. Studying the EAS can give insight into many current problems in particle physics, astrophysics, meteorology and cosmology. Observatories across the world have dedicated vast areas of land to the detection and characterization of EAS, attempting to measure aspects such as energy, composition and trajectory. It is believed that the EAS and the cosmic rays that induce them could have significant effects on global weather, generation of lighting, and astronauts in space flight. Current methods of detection include scintillation counters and methods such as those employed at the Pierre Auger Observatory, which uses large fields of water tanks acting as Cherenkov detectors and fluorescence detectors, to investigate incoming showers. These detection fields can be costly; the Pierre Auger Observatory cost approximately 50 million dollars to construct. Peter Gorham [Astropart. Phys. 15 (2001) 177-202] proposed that pulsed radars can detect ionization columns produced by EAS because they have long enough mean lifetime and large enough density. We will show that it is possible to investigate specific qualities of these showers, such as energy, direction of arrival, and trajectory, using passive radar techniques.

In particular, we investigate the use of a passive, multistatic radar which utilizes commercial FM radio broadcasts as a source of illumination. This system achieves a range resolution of 1.5 km and would detect backscatter from EAS with multiple, spatially distributed receivers. Like all radar systems that use CW illumination, passive FM radar is clutter-limited rather than noise-limited. We identify the implications of this for time resolution and detectable particle energies. Using super-resolution techniques such as interferometry in the spatial and frequency domains, it should be possible to estimate EAS trajectory and origin despite the limited range resolution. We will also discuss how the distributed nature of the passive radar receivers can be used to advantage. Finally, we will comment on techniques for discriminating these showers from other high energy events that create ionized gas columns, such as meteors and lightning strikes. Using passive radar, we can supplement current cosmic ray detection schemes, and possibly provide an alternative, inexpensive method for EAS detection and characterization.