EXTREME SOLAR PARTICLE EVENTS AND THEIR EFFECTS ON METEORITES.

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Introduction: The Sun occasionally emits energetic particles, mainly protons. Those since 1954 have been well studied, first using indirect measurements until good energetic particle detectors began operation in space in the 1960s [1]. Some of these solar particle events (SPEs) are intense enough to make measurable amounts of nuclides in solar-system materials. SPEs were also compared to average solar-proton fluxes inferred using samples returned by the Apollo missions [2]. The solar-proton fluences for SPEs since 1954 are in [3]. Large SPEs that occurred much longer ago have recently been studied.

Modern Solar Particle Events: Between 1956 and 2008, there were 239 SPEs with high event-integrated solar-proton fluences [1]. The trend is for the number of events above a fluence versus fluence to be a line in a log-log plot up to fluences of $3x10^9$ p/cm^2 and to drop steeply for higher fluences, a trend also seen in SEP-produced nitrates between 1561 and 1994 in ice cores [4]. The largest event during this period was in 1859 and is called the Carrington event after the British astronomer who observed an intense flare on the Sun on 1 September 1859 [5]. There was a large SPE on 23 July 2012 that missed the Earth but was observed on the other side of the Sun [6,7]. Most plans to protect things on Earth (such as power lines) and in deep space (e.g., spacecraft) use those data.

Extreme Solar Particle Events: Recently, measurements of ^{14}C in tree rings from individual years have shown that there were some stronger SPEs during the last 3000 years, especially in 775-776 and 993-994 CE [8]. Those SPEs were almost an order of magnitude strong than any SPE seen since 1956, such as the very large August 4, 1972 event and several in 1989.

Solar-Proton-Produced Nuclides in Meteorites. Nuclide production by solar protons is within the top millimeters of the pre-atmospheric surface [9], which is usually removed by ablation. Some near-surface pieces of meteorites survive and show SEP-production, such as Sutter's Mill [10].

It would be good to measure all new meteorite falls to see if any pieces have been recovered with SEP-produced nuclides, such as 2.6-year ^{22}Na. Those pieces will have come from the outmost parts of the meteoroid and would be good candidates for further study. Unfortunately Sutter's Mill fell before the 23 July 2012 SPE. But more recent falls might have recorded that or other very-large SPEs that made many short-lived radionuclides.

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