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Are extreme solar particle events and superflares related? A probabilistic view

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Solar eruptive activity has many forms, the most important and well-studied are solar flares, coronal mass ejections, and solar energetic particle (SEP) events. It is mostly unknown what is the upper limit for the intensity of different eruptive activity events. For now, only traces of extreme solar particle events (ESPEs) were discovered in cosmogenic isotope data in datable natural archives, while extreme solar flares and CMEs were not registered and it is not clear if Sun is capable of producing it. Only several ESPEs were found in cosmogenic isotope data for the Holocene period which makes their frequency roughly 1/1500 years. At the same time, astronomical observation by Kepler satellite recently uncovered superflares on solar-like stars, which are orders of magnitude more intense than ones registered on the Sun. A new reanalysis of Kepler data gives quite a high frequency of these events – up to 1/100 years for flares with bolometric energy more than >1034 erg. The observed occurrence rate of ESPEs produced by Sun and super-flares on solar like stars is biased. In our talk, we are showing that the difference in occurrence rates between extreme eruptive events is natural and caused by the probabilistic nature of eruptive events. For that, we are using the systematic observations made by the GOES satellite series and data from a ground-based network of neutron monitors. Then we are studying in detail the conditional probability of observing SEP events given the registration of solar flare – as a function of both SEP and flare intensity. In the end, we propose an analytical model, that agrees well with direct XRS and SEP observations, as well as predicts the observable rate of ESPEs. Within the model, The occurrence of ESPE does not necessarily require a super-flare as the source, and strong butt not extreme (>X10 class) flares can potentially lead to an ESPE under a very favourable conditions.

Collaboration(s)

Author: KOLDOBSKIY, Sergey (University of Oulu)

Co-author: USOSKIN, Ilya (University of Oulu (FI))

Presenter: KOLDOBSKIY, Sergey (University of Oulu)

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