

Topical Discussion Meeting report

A Topical Discussion Meeting aims at active participation or interaction between the participants. The participants work and discuss on a predefined theme or problem heading towards an outcome or target. A working meeting is a 1h 15min informal afternoon meeting with NO abstract submission form and therefore NO poster contributions.

Name of the meeting:

HIGH-ENERGY SOLAR ENERGETIC PARTICLE EVENTS

Conveners:

Athanasios Papaioannou (National Observatory of Athens), Stepan Poluianov (University of Oulu), Alex Mishev (University of Oulu)

Data – Time – Room: **Thursday 30/11, 17:15 - 18:30, Permeke**

Nr of participants: **35-40**

Objective of the TDM

Recent studies have found a type of Solar Energetic Particle (SEP) events with a high-energy tail, that are either recorded by only polar high-altitude neutron monitors (NMs) or onboard spacecraft. Traditionally, ground-level enhancements (GLEs) comprise the high-energy tail of SEPs and constitute a special class of events in which ions are accelerated to relativistic energies, causing a significant sudden increase of cosmic rays at ground-based detectors, mainly at NMs. The high-energy SEP events are associated with both fast coronal mass ejections (CMEs) and intense solar flares (SFs). Given the new developments, a (possible) sub category, often termed as "sub-GLEs" has emerged in the scientific literature.

Therefore, the objectives of this Topical Discussion was to address the following points:

- Review the current state of knowledge on the acceleration mechanisms from CMEs and from solar flares
- Discuss the definition of a sub-GLE class (in terms of energy or identification) and thus provide the basis for a discussion on terminology of sub-GLEs
- Discuss how high energy SEPs that reach to relativistic energies but are not recorded at Earth, can be included under the category of sub-GLEs (or if these should constitute a new category of events).

Some discussion highlights

The TDM was organized as follows:

- We had short presentations on key points that were addressed by the TDM (see above), in order to put the discussion in actual context and we discussed after and during the presentations.
- The agenda of the TDM (see Annex I) was send in advanced to several mailing lists so that interested colleagues would be informed.
- A web form was established (and distributed) so that colleagues could communicate to the conveners specific points that could be discussed within the TDM.
- Moreover, the ESWW LOC put together a Webex connection and thus other colleagues (unable to be present in ESWW) were able to take part in the TDM.

The presentations were as follows:

1. **Introduction** | A. Papaioannou

The basic points of the TDM, as those are listed here above, were presented. In particular, the current understanding on the origin and acceleration of such high energy SEP events, together with the new observational findings were reviewed and discussed in short.

2. **Modeling of Proton acceleration in application to a GLE** | A. Afanasiev, R. Vainio, A. P. Rouillard, M. Battarbee, A. Aran and P. Zucca

In this presentation, the results of a detailed modeling of proton acceleration with an application to GLE71 were presented. This was based on the Coronal Shock Acceleration (CSA) model. It was shown that the production of relativistic protons is confirmed, that the scattering-center compression ratio is the quantity most decisive in the acceleration process and that the strongest region of the shock, well-connected to the Earth, shows most efficient particle production. However, the timing of proton acceleration was only marginally consistent with the GLE.

3. **Flare, CME and the acceleration of relativistic protons at the Sun** | K.-L. Klein

The two component time profile of GLEs, in connection to their solar drivers and related acceleration processes was presented in this talk. Furthermore, magnetic reconnection in different phases of the flare/CME development, was discussed. Special emphasis was given to the so-called "long duration" flares that were recently measured by FERMI/LAT. The origin of these long-duration events (>2 hr) was further discussed. It was proposed that (at least) two mechanisms are under debate: [a] particle acceleration at the shock, downward streaming to the low solar atmosphere and [b] trapping in extended coronal magnetic structures.

4. **Energetic Particle Events with Protons Above 500 MeV Between 1995 and 2015 Measured with SOHO/EPHIN** | P. Kühl, N. Dresing, B. Heber, and A.B. Klassen

A catalogue of E>500 MeV SEP events that was compiled based on SOHO/EPHIN measurements was presented in this talk. In particular, it was shown that a GEANT 4 simulation was utilized to calculate the response function of the EPHIN instrument. This gave ground to simulation of penetrating protons, alphas and electrons. It was shown that very high energies for proton suffer from contamination from electrons. The catalogue consists of 42 solar energetic particle events. It includes all GLEs within the time period of interest and useful information like the maximum intensity at 500 MeV and the spectral index between 100 and 500 MeV. Finally it was shown that GLE and non GLEs are separated by their intensity.

5. **Sub-GLE and GLE events: in the light of the global NM network** | A. Mishev, I. Usoskin, S. Poluianov

The terminology on sub-GLEs and GLEs, in view of the measurements currently offered by mini-NMs at polar latitudes (e.g. DOM-C) was introduced and proposed in this presentation. Furthermore, the procedure for the analysis of GLEs and sub-GLES was discussed in a comparative manner. In particular, the "typical" analysis of GLE events with a focus on GLE67 (02.11.2003) was presented. In addition, the rigidity spectrum and the pitch-angle distribution (PAD) for the most recent GLE72 (10 September 2017) was shown and discussed. On the other hand, the inherent limitations on the analysis of sub-GLEs were presented, together with the necessary simplifications that makes the analysis of sub-GLEs feasible.

6. **General Discussion**

Main points of the discussion include the

Main conclusion of the meeting

- Multiple high energy (E>500 MeV) SEP events were identified in two recent papers of *Kuel et al., 2017* and *Vainio et al., 2017*. The majority of these events did not make it to the ground, i.e. those were not clearly identified by the network of neutron monitors (NMs). However, several NMs operating in low cut-off rigidity spotted a small increase during these events. This gives rise to a new category of events termed as "sub-GLEs".
- It seems that there are two populations of events, i.e. GLEs and non-GLEs (with a number of these events falling under the definition of sub-GLEs). These categories most probably exhibit differences in the underlying acceleration mechanisms and are separated by their intensity and fluence.
- There is a need to examine in detail all of these cases (non-GLEs / sub-GLEs) and also treat them statistically in order to infer the actual differences between the two populations.

Annexes

Annex I: *Agenda of the TDM*

Annex II: *General presentation on the TDM context (introduction) and front covers from the delivered presentations*