Characteristics of the First Ground Level Enhancement (GLE) of Solar Cycle 25 on 28 October 2021

A. Papaioannou[1], A. Kouloumvakos[2], A. Mishev[3], R. Vainio[4], I. Usoskin[3], K. Herbst[5], A. Rouillard[2], A. Anastasiadis[1] , J. Gieseler[4], R. Wimmer-Schweingruber[5], P. Kuhl[5]

[1]IAASARS, National Observatory of Athens, Penteli, Greece
[2]IRAP, Université Toulouse III—Paul Sabatier, CNRS, CNES, Toulouse, France
[3]Space Physics and Astronomy Research Unit and Sodankylä Geophysical Observatory, University of Oulu, Oulu, Finland
[4]Department of Physics and Astronomy, University of Turku, 20500 Turku, Finland
[5]Institut für Experimentelle und Angewandte Physik, Christian-Albrechts-Universität zu Kiel, 24118 Kiel, Germany

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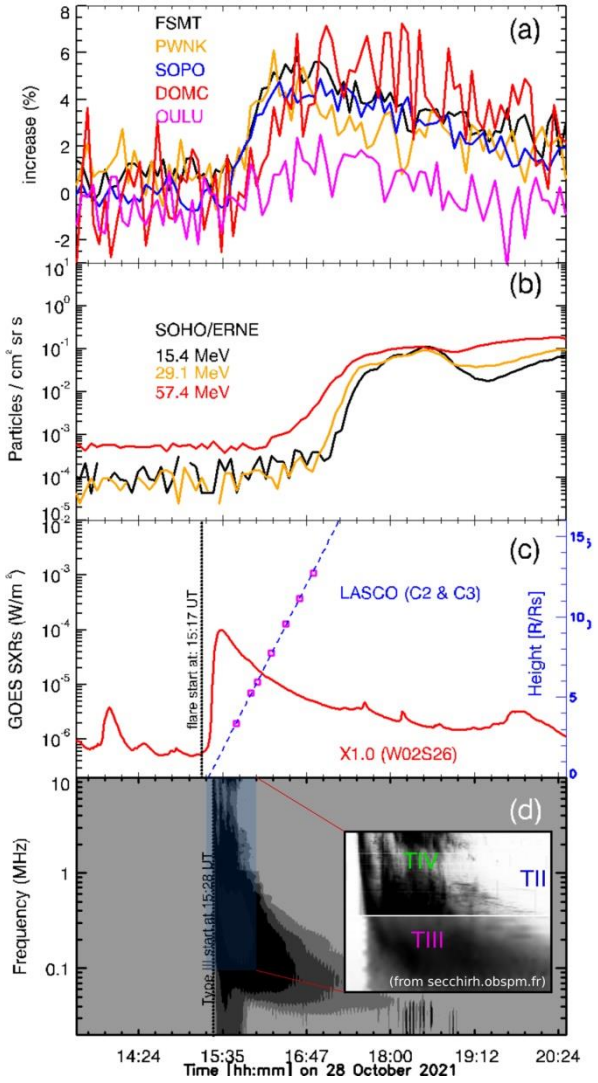
The First Ground Level Enhancement of SC25

Overview



> A Ground Level Enhancement (**GLE**) was marked *on **28 October 2021***

> ***Neutron Monitors*** around the world identified the event (**a**)

> The event was further seen in the ***near-Earth space*** (**b**)

> **GLE73** was associated to an **X1.0 SXR flare** and **a fast CME** (**c**)

> Signatures of **radio bursts** (i.e. type III, type II and type IV) were present (**d**)

[Papaioannou et al., Astron. Astrophys., 2022]

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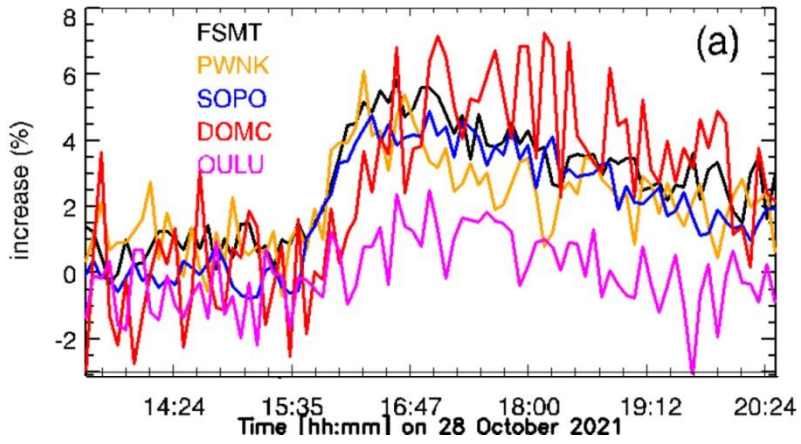
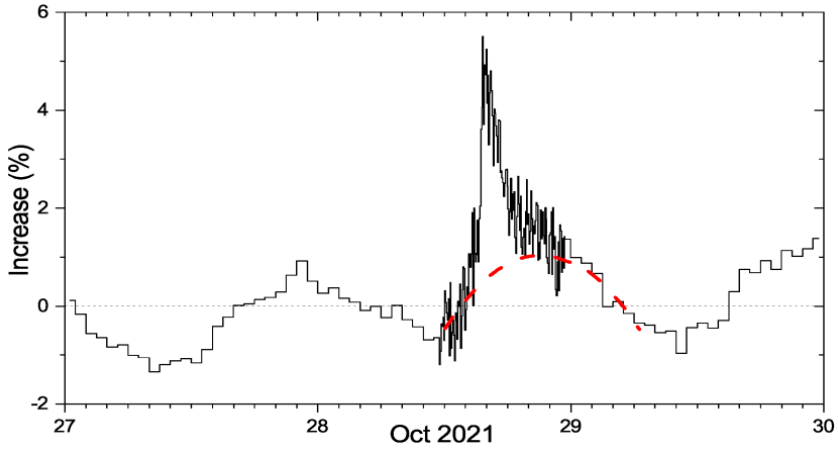
Measurements | Neutron Monitors





> **GLE73** revealed a typical **gradual increase**, and **slight anisotropy** during the onset

> The flux remained above the background level for **~ 4.5 hour**

> The NMs situated at polar stations, i.e. **DOMC recorded the greatest count rate**

> The **rise** as shown by the **FSMT**, **SOPO** and **PWNK** NMs intensity time-profile *indicates that energetic protons had reasonable access to the Sun Earth connecting field lines*.

Presence of diurnal wave |
Using de-trended NM data

[Usoskin et al., Astron. Astrophys., 2022]

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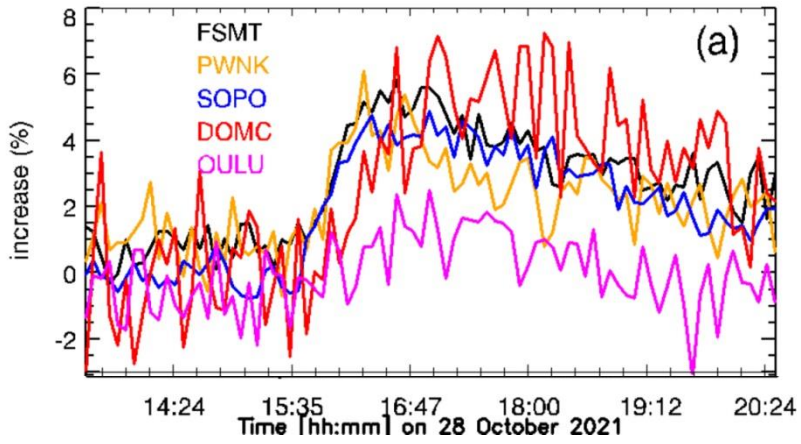
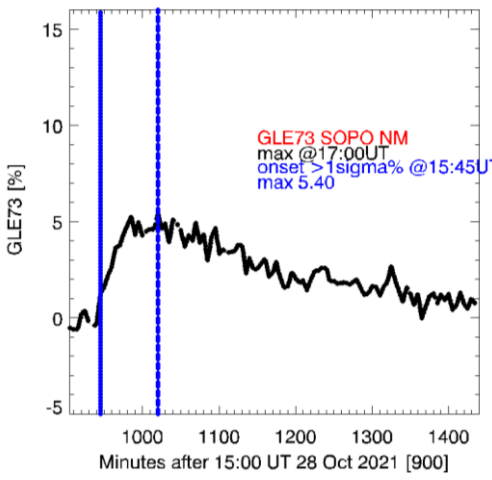
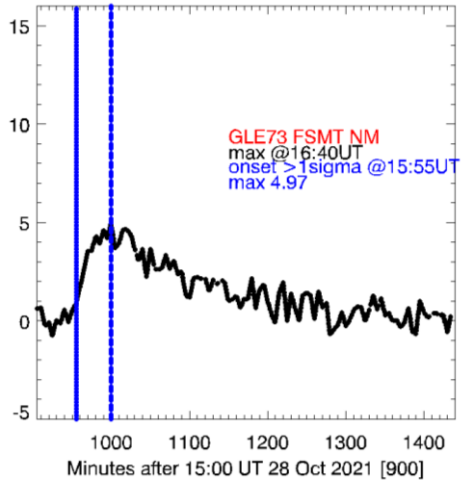
Measurements | Neutron Monitors







Characteristics of GLE73 | recorded by NMs

Neutron Monitor	Onset Time (UT)	Peak Time (UT)	Increase (%)
DOMB	16:00*	18:15	14.0
SOPB	15:50	16:30	6.64
DOMC	16:00*	18:10	7.30
SOPO	15:45	17:00	5.40
PWNK	15:55	16:20	5.10
FSMT	15:50	16:40	4.97
CALG	15:45	16:05	5.01
SNAE	16:15*	17:20	4.86
KERG	16:05	16:50	4.15
INVK	16:05	17:55	3.55
TERA	16:20*	17:50	3.28
OULU	15:55*	17:00	3.24
YKTK	16:05*	16:35	3.10
THUL	16:15*	18:55	2.83

* ambiguous due to data fluctuations

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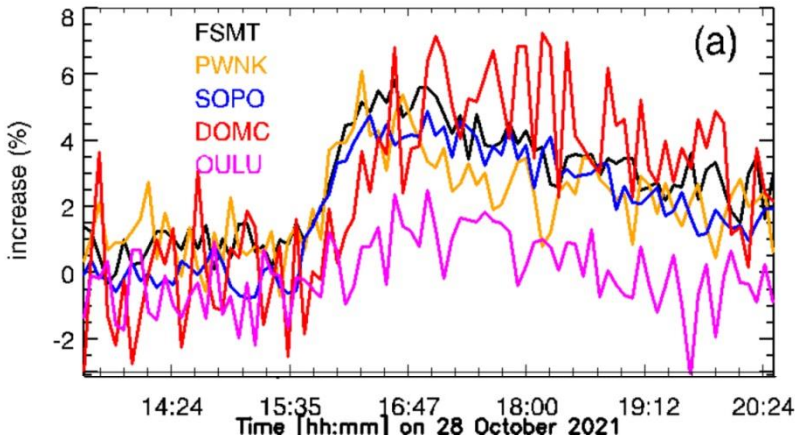
Measurements | Neutron Monitors



> Applied Time-Shifting Analysis (TSA) as follows:

- Calculated the **Parker spiral** based on **Vsw**
- Parameterized the **rigidities** from **1-2.4 GV**
- Calculated **travel times** for each rigidity (energy)
- Subtracted the travel time from **SOPO NM onset**
- **Added 500s (**for comparison with remote sensing measurements at 1 AU**)**

> Results:

- **Vsw**~300 km/s → **L=1.28 AU**
- **Travel time** ranged from **~11min** / **~13 min**

(v=0.93c / 2.4 GV / 1.6 GeV)/(v=0.74c / 1 GV / 500 MeV)

- **Release time** ranges from **15:39 – 15:42 UT**

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Vainio et al., JSWSC, 2013

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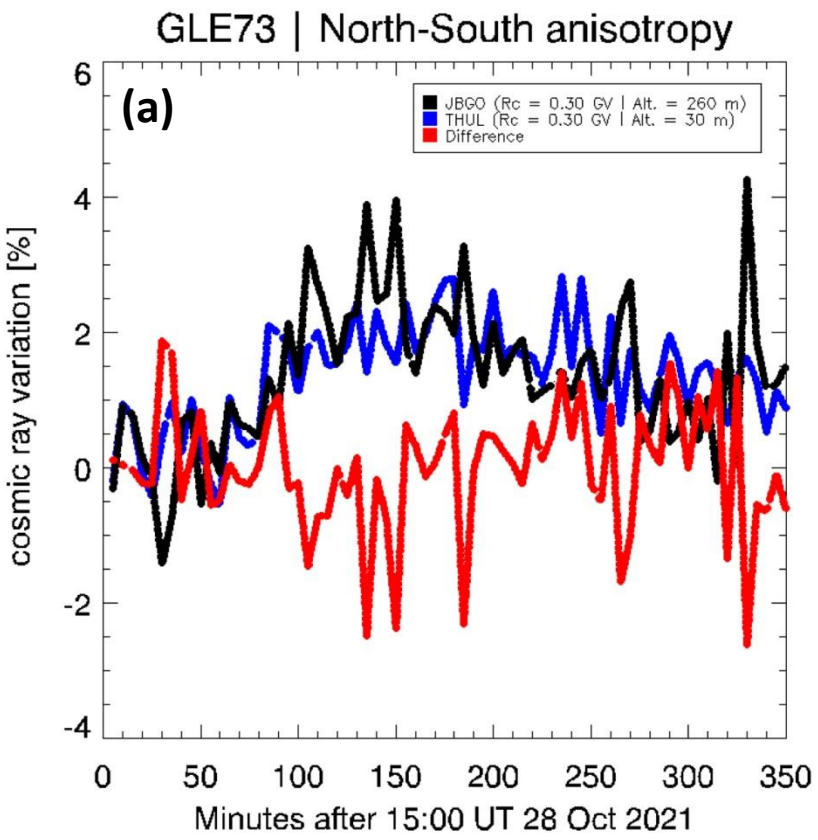
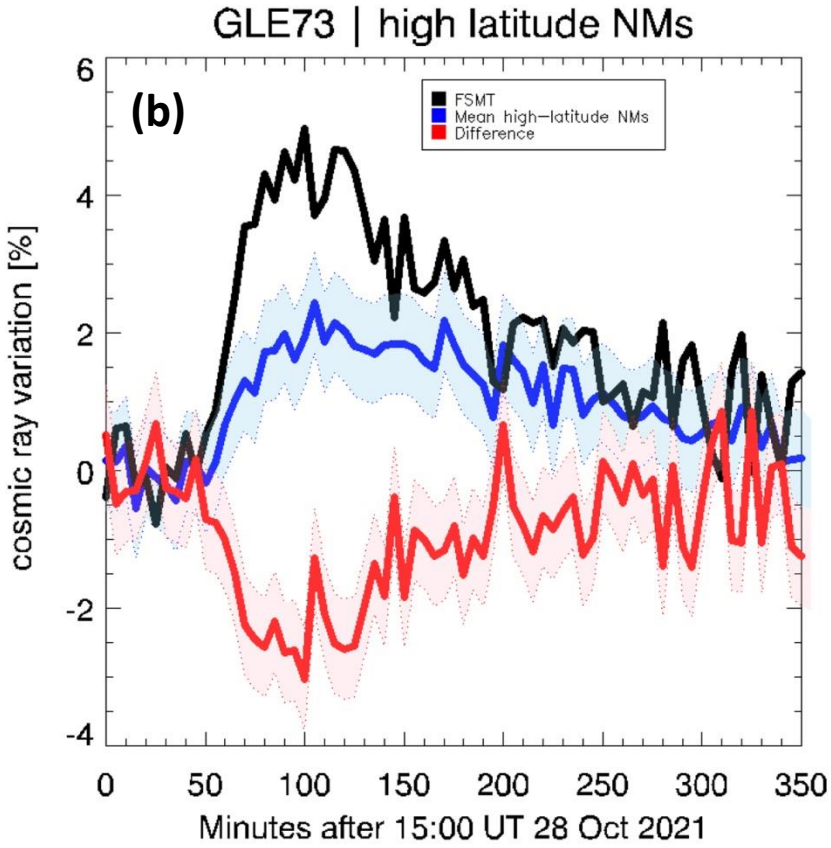
Measurements | Neutron Monitors





> *Slight anisotropy* as seen in the **North-South** component (**a**) and in the comparison of **FSMT** vs **mean of high-latitude NM stations** (**b**)

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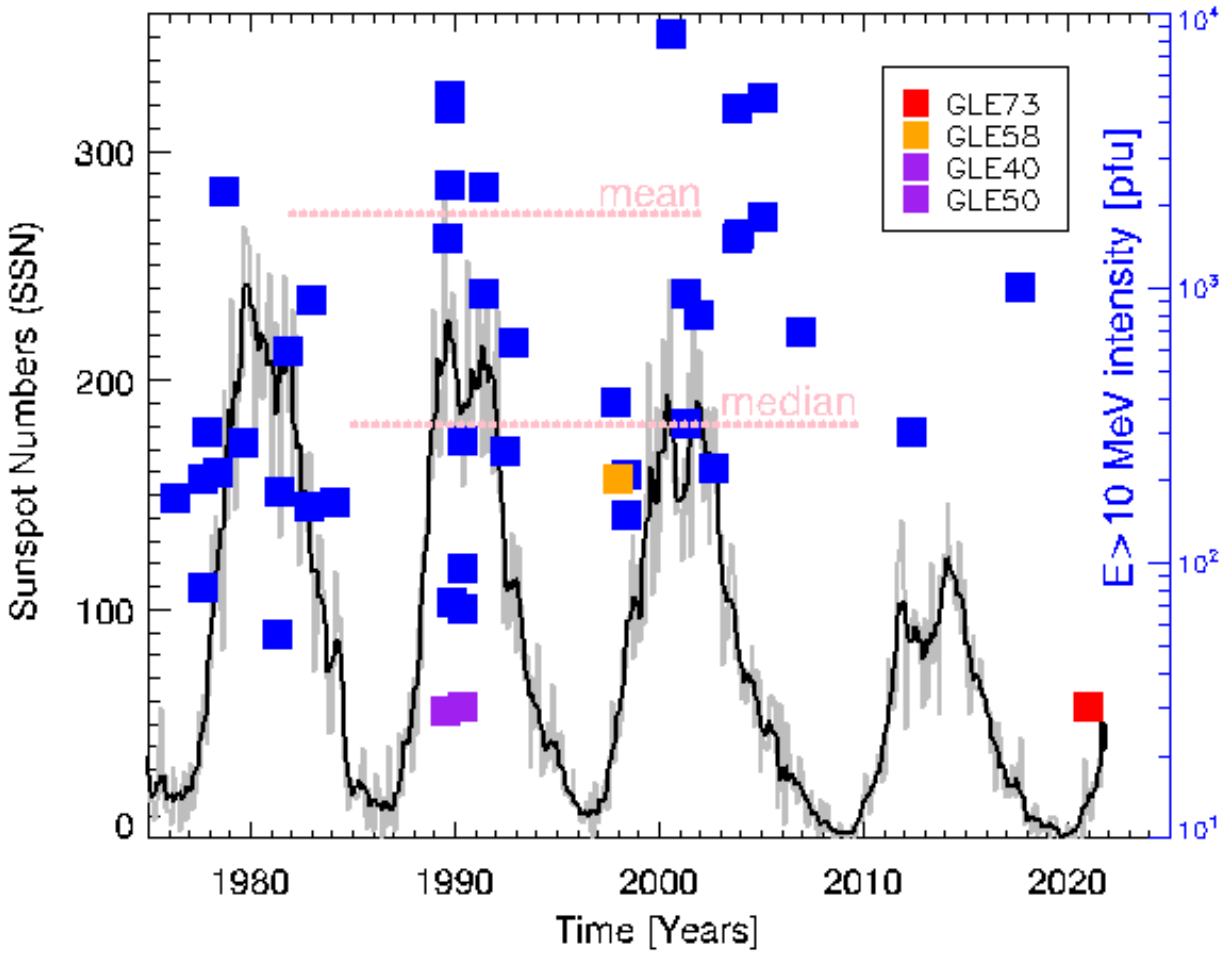
Comparison to other GLEs



> GLEs since 1997 have an **average CME speed of ~1970 km/s**, hence, the CME and the shock speed of GLE73 agree well with this.

> Only **5 GLEs** since **1976** were associated with an **≤X1.0 SXR flare** (i.e. *GLE30, GLE32, GLE58, GLE62 & GLE71*). **GLE58** is associated with a central (E09) X1.0 flare.

> Despite the similar flare flux and position **GLE58** (**orange square**) has an IP at E>10 MeV × 6.7 compared to **GLE73** (**red square**).

> **GLE40** & **GLE50** (**purple squares**) have similar peak proton flux (~30 pfu) but both were limb events (>W85).

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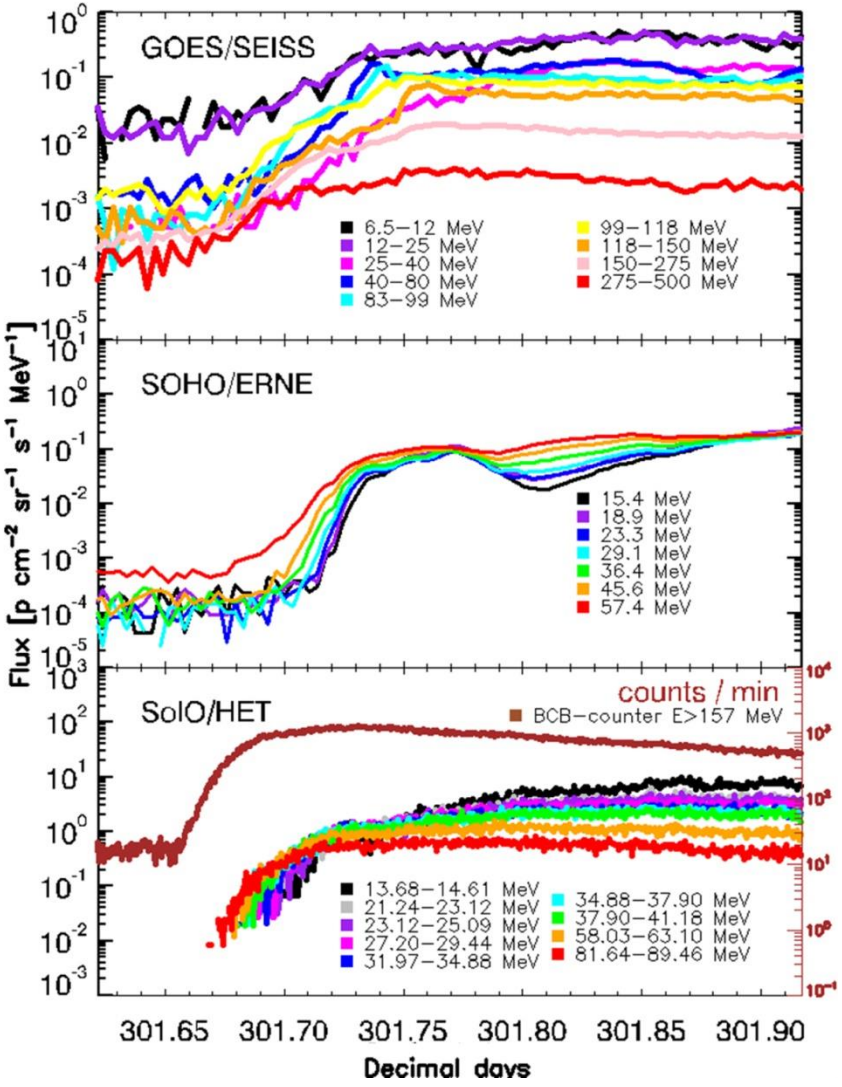
Measurements | Near-Earth Space



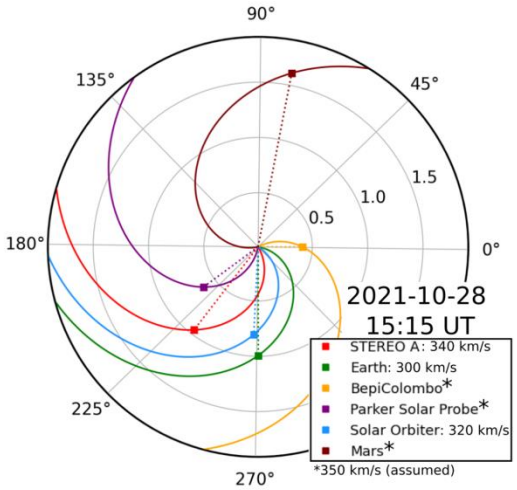
> Time evolution of **GLE73** as this was recorded (from top to bottom) from **GOES/SEISS**, **SOHO/ERNE**, and **SolO/HET**

> The *energy range* covered spans over:

GOES/SEISS | 6.5-500 MeV
SOHO/ERNE | 10-100 MeV [15.4-57.4 MeV]
SolO/HET | 13.68-89.46 MeV

> The *high energy channels* onsets:

GOES/P10 (275-500 MeV) @ 15:55 UT
SOHO/ERNE(57.4 MeV) @ 16:18 UT
STEREO-A/HET(60-100 MeV) @ 15:54 UT



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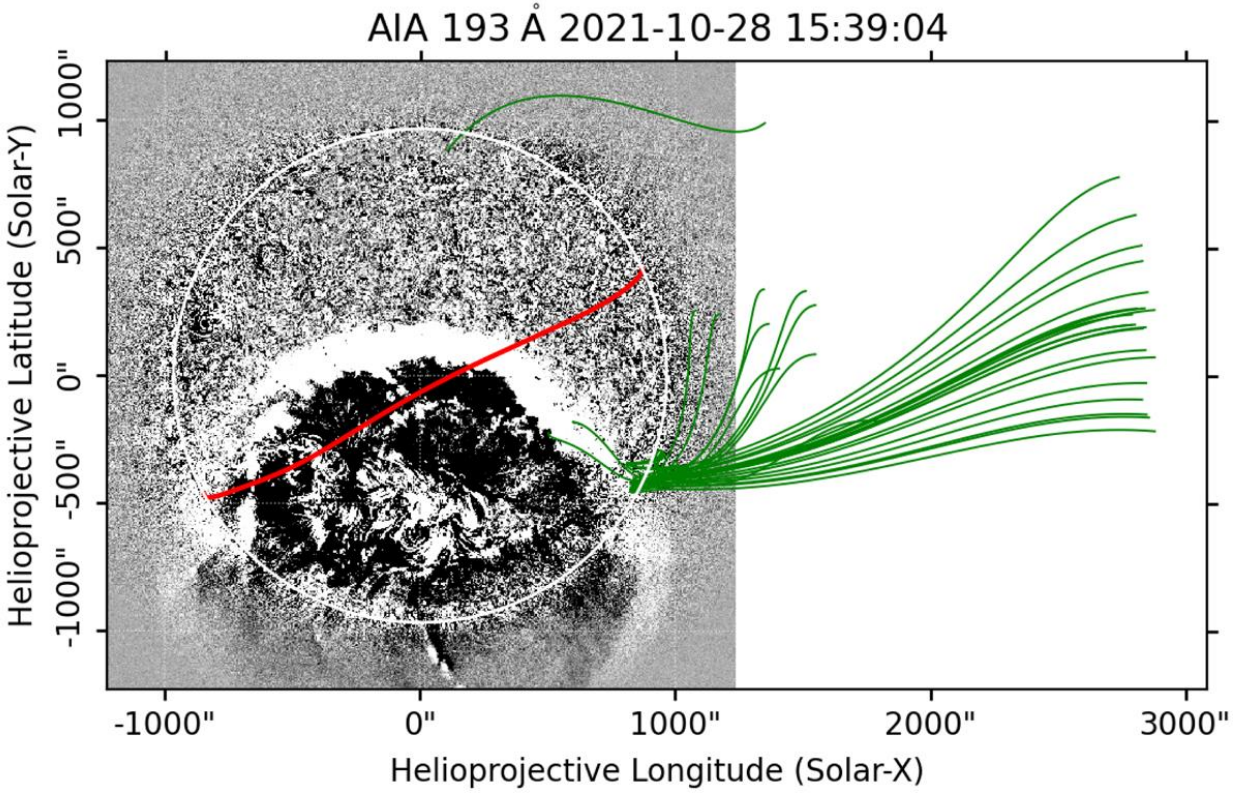
EUV + PFSS



> Evolution of the **EUV wave** and PFSS magnetic field lines for **Earth** (green) presented at **~15:39 UT**. The location of the heliospheric current sheet is shown with the red line

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Conclusions

> One of the characteristic aspects of this GLE is its association with a **central-disk (W02) X1.0 flare** (*fairly untypical for GLEs*). Nonetheless the **CME** itself **was very fast** (*typical for GLE associated CMEs*). The main results of the study are:

- **GLE73** was detected by NMs that **did not exceeded R = 2.4 GV** (E < 1.6 GeV)
- The event had **a weak but long lasting signal in GOES** (E>10 MeV; **peak ~ 30 pfu**)
- **GLE73** is a **multi-spacecraft SEP event** in the inner heliosphere. Particle measurements by **GOES**, **SOHO** and **SolO** were recorded.
- Timing of the **EUV wave evolution** and the inferred **release time** of **high energy protons** seems to be *in good agreement*.

here !