

The first GLE (# 73 – 28-Oct-2021) of solar cycle 25: study using space-borne and NM data

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Outline

- 1. Introduction**
- 2. Model for analysis of strong GLEs using NM data**
- 3. Derived spectra and PAD**
- 4. SOHO/ERNE data**
- 5. Conclusion**

Introduction

GLEs, what, when and where

An important topic of solar physics, space weather, atmospheric physics is

Assessment

Primary SEP parameters:

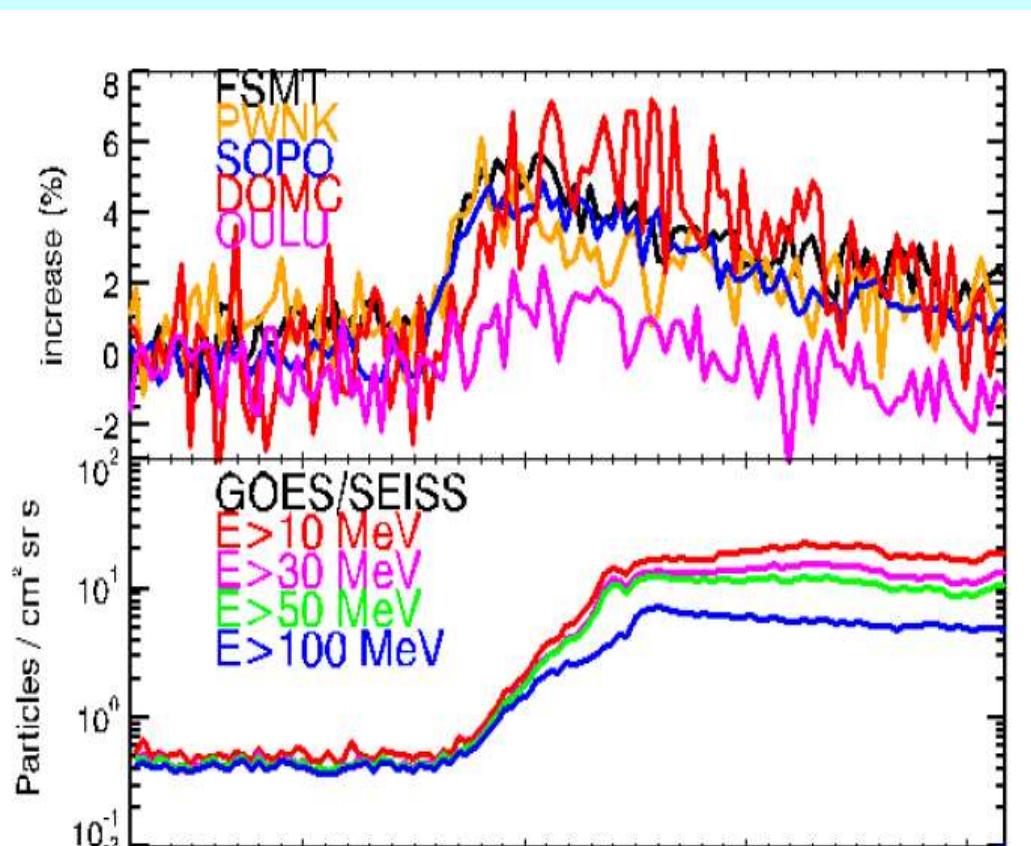
energy spectrum

anisotropy

using the information from NMs

GLE # 73 on 28 October 2021

A Ground Level Enhancement (**GLE**) was observed by the global NM network and space-borne probes *on 28 October 2021*



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

The flux remained above the background level for ~ 4.5 hours

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

The **rapid 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.*

Method for GLE analysis

Modelling the global NM network response

$$N(P_c, h, t) = \sum_i \int_{P_c}^{\infty} S_i(P, h) J_i(P, t) dP$$

$$S_i(P, h) = G(P) \sum_j \int \int A_i(E, \theta) \cdot F_{i,j}(P, h, E, \theta) dE d\Omega$$

$$\frac{\Delta N(P_{cut})}{N} = \frac{\frac{1}{13} \sum_k \int_{P_{cut}}^{P_{max}} J_{sep}(P, t) S_k(P) G(\alpha(P, t)) A(P) dP}{\int_{P_{cut}}^{\infty} J_{GCR}(P, t) Y(P) dP}$$

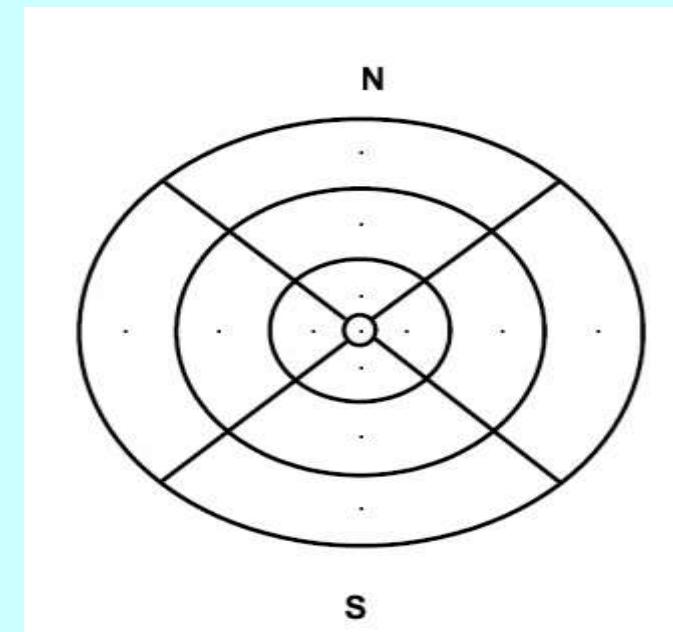
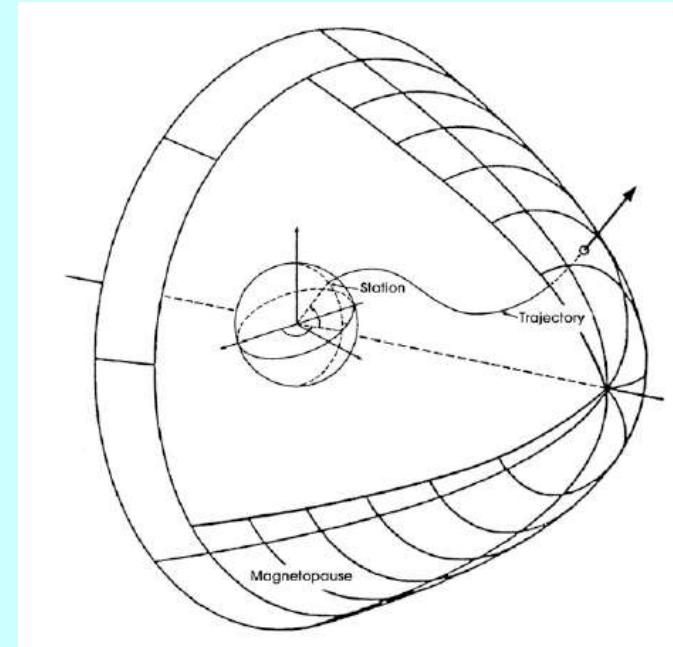
Computation of asymptotic viewing cones and P_c of the NM stations:

Computation of particle trajectory in a model magnetosphere.

Application of a optimization procedure (inverse method)

primary solar proton parameters:

(energy spectrum, anisotropy axis direction, pitch-angle distribution)



Modeling of spectra and PAD of SEPs

Modified power law, exponent or Ellison-Ramaty

$$J_{\parallel}(P) = J_0 P^{-(\gamma + \delta\gamma(P-1))}$$

At $P \leq 1$ GV

$$J_{\parallel}(P) = J_0 \exp(-P/P_0)$$

$$F(R) = J_1 \left(\frac{R}{1 \text{ GV}} \right)^{-\gamma_1} \exp\left(-\frac{R}{R_1}\right) \quad \text{if } R < R_b,$$
$$F(R) = J_2 \left(\frac{R}{1 \text{ GV}} \right)^{-\gamma_2} \exp\left(-\frac{R}{R_2}\right) \quad \text{if } R \geq R_b,$$

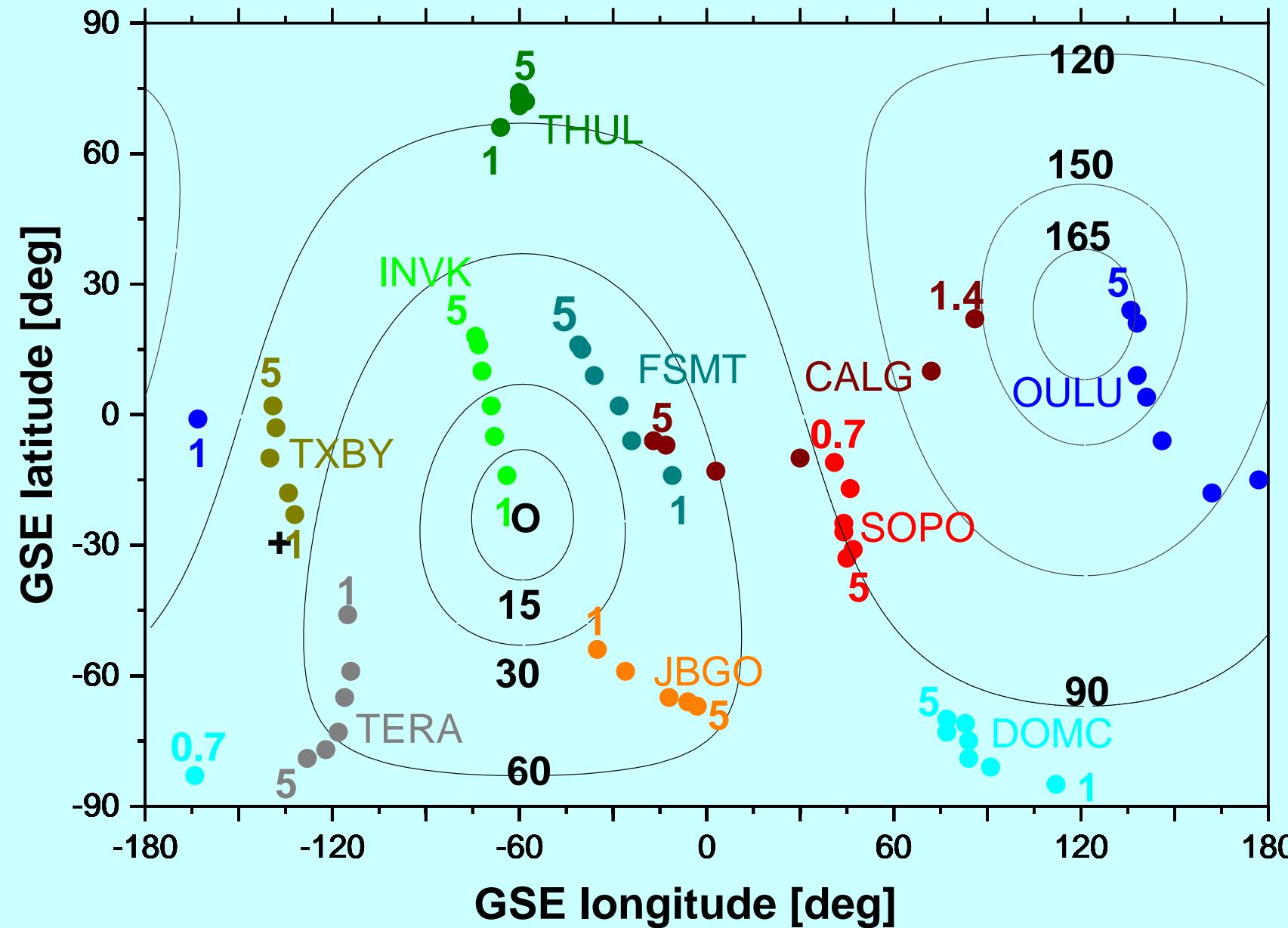
$$J_{\parallel}(P) = J_0 P^{-(\gamma + \delta\gamma \cdot P)}$$

PAD – Gaussian like

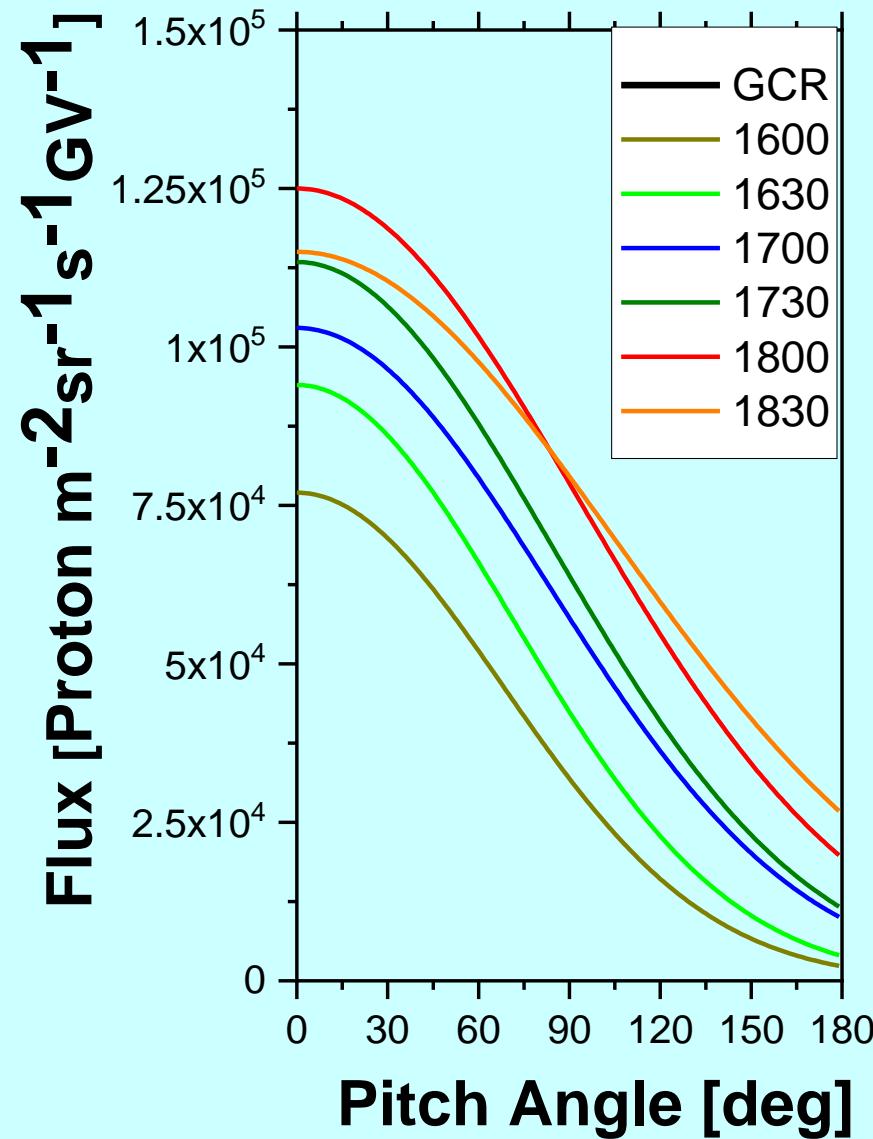
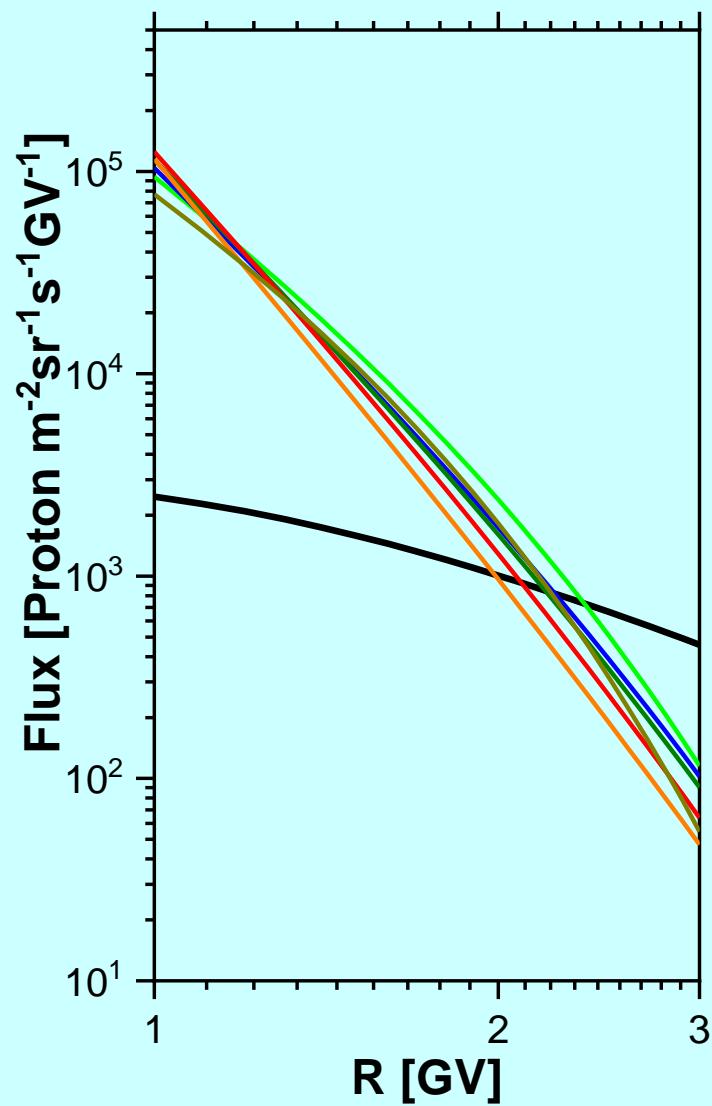
$$G(\alpha) = \infty \sum_i \exp - (\alpha_i - \alpha_i')^2 / \sigma_i^2$$

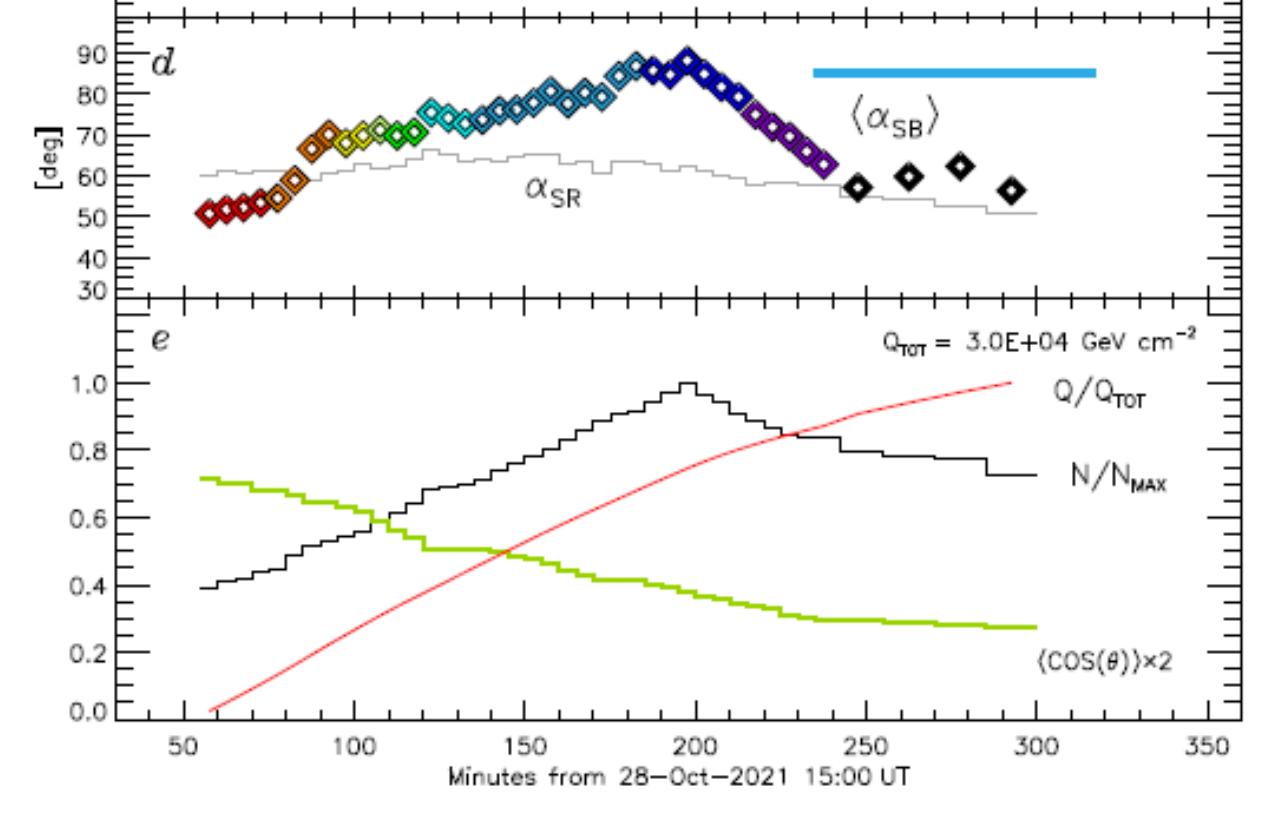
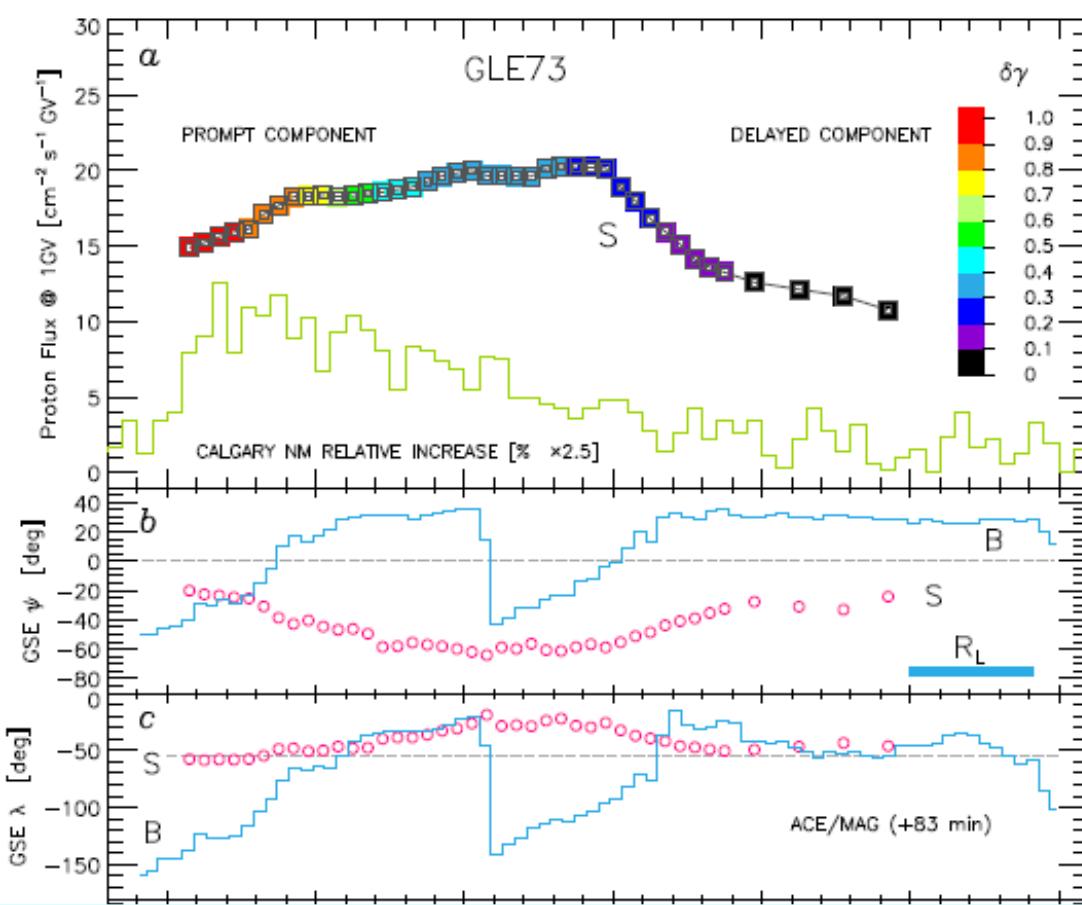
From 5 Up to 14 parameters

Asymptotic directions during GLE # 73 on 28 October 2021



Rigidity spectra and PAD during GLE 73, 28 October 2021

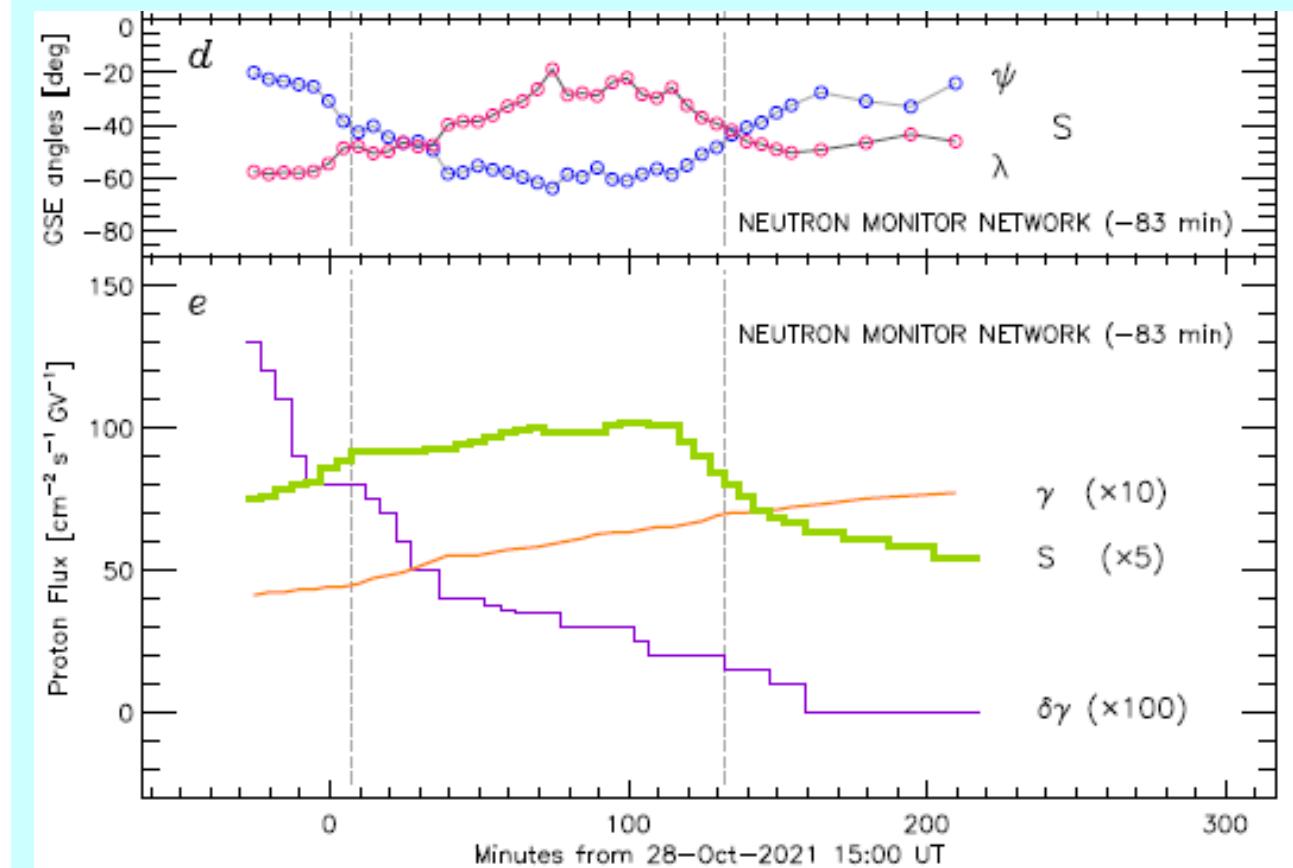
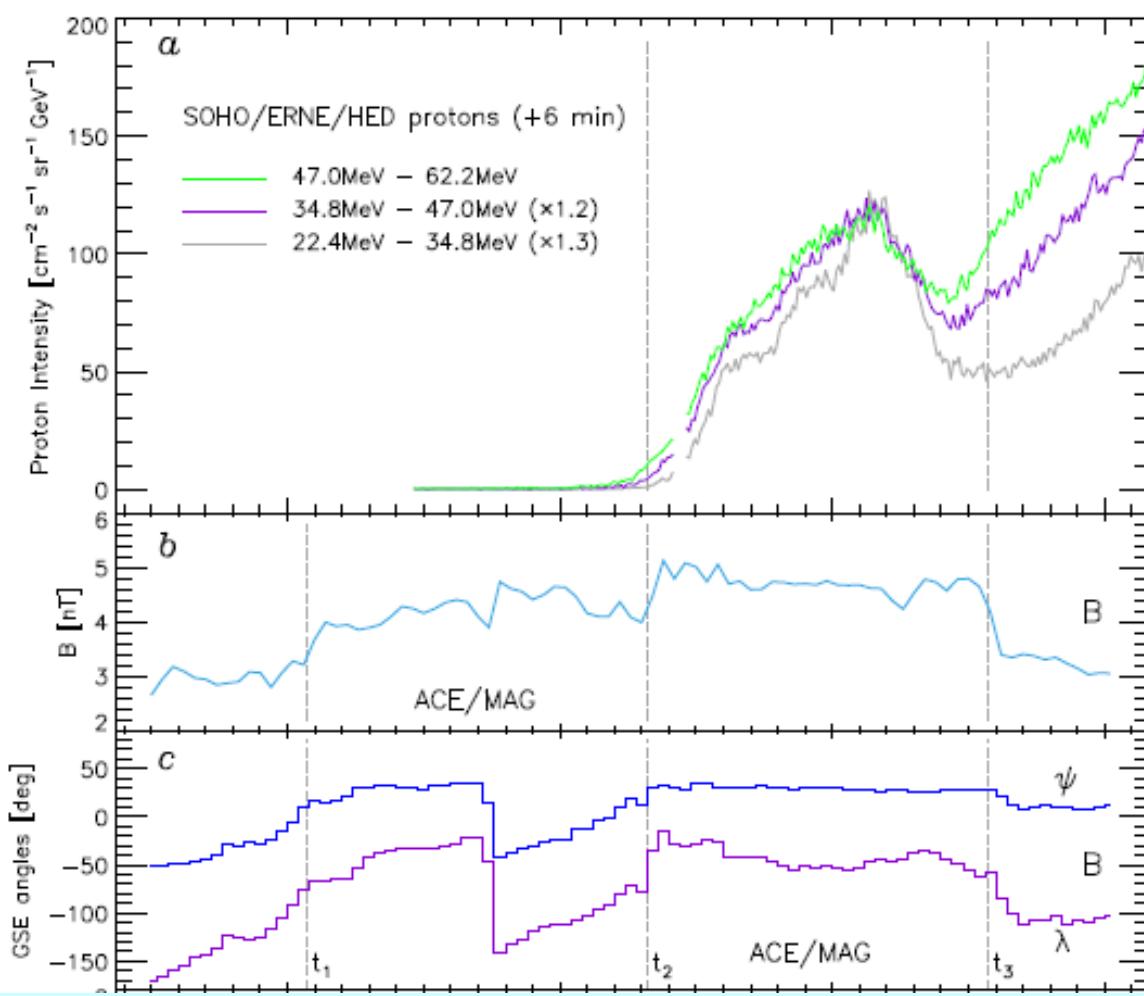




Net flux of the GLE -producing solar protons, S

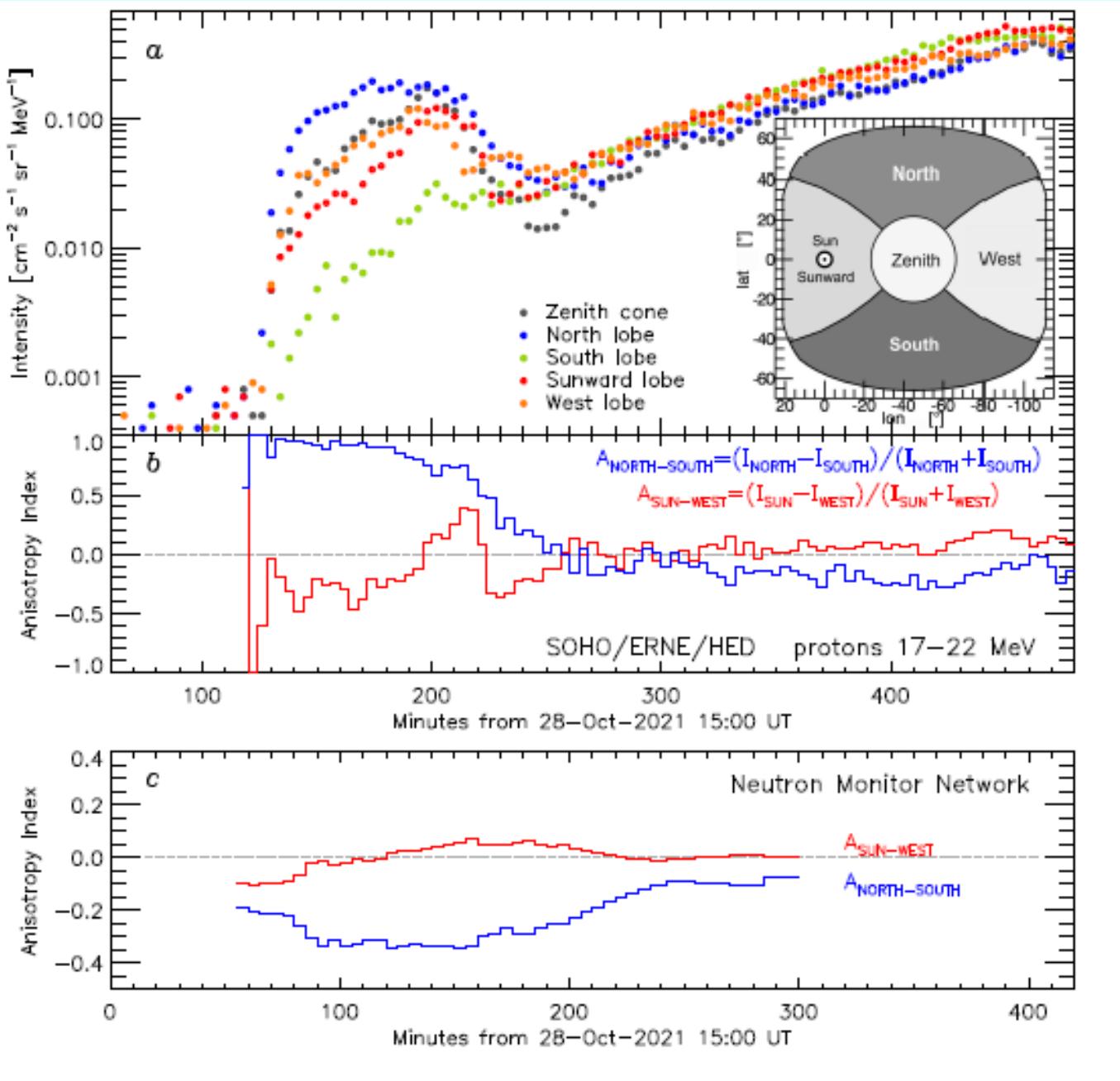
Average angle between the proton flux S and magnetic field B. Additionally shown is the angle between the flux S and the radial, Earth-Sun direction, SR

Average pitch-angle cosine of arriving protons



SEPs in relation with the ACE/MAG-observed structure of the interplanetary magnetic field.

Deka-MeV proton profiles SOHO/ERNE (shifted by the solar wind transit time from the SOHO orbit to the orbit of ACE). Interplanetary magnetic field intensity and direction observed on ACE. Characteristics of the GLE-producing protons deduced from the NM data



Sectoral intensities of the ERNE/HED-observed protons, their anisotropy indices, and anisotropy indices of GeV protons observed by the NM Network.

- The 17–22 MeV proton intensity profiles in five angular sectors of the HED's field of view
- Anisotropy indices of the ERNE-observed protons.
- Anisotropy indices of GLE-producing protons

Conclusion

1. Using verified NM yield function & verified method for GLE analysis based on NM data
2. Spectra and PAD of GLE 73
3. SOHO/ERNE data

THANK YOU

