UMASEP and RELEASE hand on work

B. Heber

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Abstract

Solar energetic particle events may be harmful to modern spacecraft electronics and even an issue for manned space mission. Unfortunately there is no method available in order to predict such events in advance. The two prediction now casting tools UMASEP and RELEASE are able to correlate either remote sensing or in-situ signals to forecast the occurrence of a particle event up to 1 hour. This work aims for understanding physical principles that are behind both tools.

1 Goals of this exercise

1. To understand the difference between model results and measurements. I.e. Model results do not depend
   (a) on the instrument background,
   (b) a finite energy range, and
   (c) a finite pitch angle coverage
2. To get familiar with the onset of electrons and protons utilizing the Velocity dispersion analysis.
3. The same for results provided by interplanetary transport models that solve the focused transport equation.
4. To understand what is the imprint of the restricted pitch angle coverage vs. omni directional intensities.

2 Velocity dispersion analysis and onset times

As explained in the lecture electrons and protons arrive at the observer at different times. In order to estimate these times we calculate in our first exercise the length of the Parker Spiral and the velocity of the particle in charge.

2.1 Length of the Parker Spiral

The length L of the Parker Spiral depends on the distance r, the solar rotation rate $\omega \sim 1.7 \cdot 10^{-4}$ deg/s and the solar wind speed u:

$$L = \int_{r_0}^{r_1} \sqrt{1 + \left(\frac{\omega \cdot r}{u}\right)^2} dr \qquad (1)$$

Table 1: Length of the Parker Spiral

Radial distance (AU)	Solar wind speed (km/s)	Length AU

Task: Utilize the python language to calculate the Length of the Parker Spiral at Venus (0.722 AU), Earth (1 AU), and Mars (1.52 AU) for different solar wind velocities between 250 km/s and 700 km/s in 50 km/s steps. What is 1 AU in km?

2.2 Speed of electrons and protons

The particles of investigation have speeds that need to be calculated in a relativistic manner. Therefore the rest mass of the particle must be known. The rest mass of the electron is $E_0 = 0.511$ MeV and the one of a proton is $E_0 = 938$ MeV. The total energy E is given by If E_k is the kinetic energy of the particle the speed in units of the speed of light can be calculated by:

$$v = \sqrt{1. - (\frac{1}{(\frac{E_k}{E_0} + 1)^2}} \tag{2}$$

Please check the equation.

2.3 Time of arrival

Having these two numbers you can calculate the time the particle needs to get to Earth. The following information for the Wind spacecraft at L1 is included in the SEPServer Greenfunction files:

```
BEGIN METADATA
Data downloaded from the database of Green's functions provided by SEPServer.
If you use these data, please refer to the papers:
   - Agueda et al. 2012, ApJS, 202, 18
```

```
   (http://adsabs.harvard.edu/abs/2012ApJS..202...18A)
   - Agueda et al. 2008, ApJ, 675, 1601
   (http://adsabs.harvard.edu/abs/2008ApJ...675.1601A)
The research leading to this database has received funding from the European
Union's Seventh Framework Programme (FP7/2007-2013) under grant agreement 262773
(SEPServer). If you use data from this database, we would appreciate an
acknowledgment as follows: "The database of Green's functions of interplanetary
transport was generated with funding from the European Union's Seventh Framework
Programme (FP7/2007-2013) under grant agreement 262773 (SEPServer)."
More documentation about the database of Green's functions at the web site:
http://server.sepserver.eu

Simulated Electron Green's function at 1.0 AU recorded in 6 energy channels
E1 (24-30 keV), E2 (30-50 keV), E3 (50-82 keV), E4 (82-135 keV), E5 (135-230 keV), E6 (230-400 keV)
For details about the normalization of the Green's functions, the user should
consult information available in SEPServer.
```

The same for Protons:

```
Simulated Proton Green's function at 1.0 AU recorded in 3 energy channels
E1 (1-3 MeV), E2 (3-6 MeV), E3 (6-11 MeV)
For details about the normalization of the Green's functions, the user should
consult information available in SEPServer.
```

Note, that each files contains sic and three energy channels, respectively.

Tasks:

1. Due to the energy width of each channel that is investigated scientist talk about a channel dispersion. Why?
   In order to understand this calculate the time for each channel the particles with the lowest and highest energy need to reach the spacecraft.

2. Having this in mind plot the velocity dispersion as discussed in the lecture for the six electron and three proton channels for different wind speeds. What is the mean energy?

3 Diffusive particle transport

In Figure 1 the calculated time profile for electrons calculated by the focused transport equation together with the expectation from the velocity dispersion is shown. The directory release/examples contains a set of calculations from SEPServer.

Tasks:

1. Plot the intensity time profiles at different Pitch angles for the mean free path of 0.07 AU, 0.23 AU and 0.7 AU. Compare the onset times with the expected time of arrival. Can you interpret the results?

2. Build synthetic Velocity Dispersion Analysis Diagrams for the Wind spacecraft (electrons and protons).

3. Spacecraft instruments normally do not cover the full pitch angle range. What is the difference between omnidirectional and pitch angle selected VDAs?

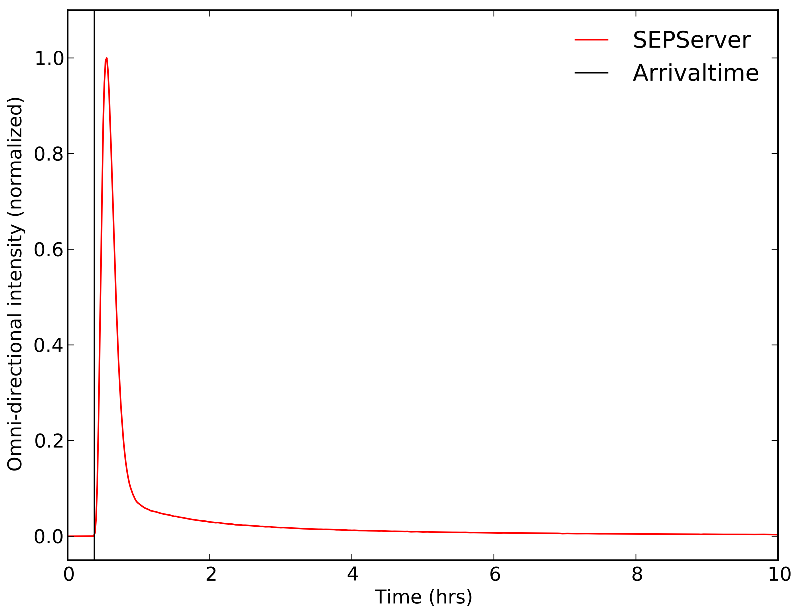

Figure 1: Left time profile of simulated omni directional electrons with two different models. The red line gives the profile from SEPServer. The black vertical line has been calculated as expected onset time for electrons moving along the field lines. Right: Corresponding anisotropies

3.1 Maximum intensities

While we discussed the onset times in the previous section, we now want to investigate the intensity correlation. The e/p ratio is