Solar Physics with LISA

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Abstract:

Primary cosmic rays and Solar Energetic Particles (SEPs) generated by impulsive and gradual solar flares are able to penetrate the LISA test masses. Gradual solar flares are due to Coronal Mass Ejections (CMEs). We propose to use the primary and solar cosmic-ray counters to be installed on board the LISA spacecraft for both test mass charge noise monitoring and solar physics study. Because of the peculiar orbit of the LISA spacecraft around the Sun, this experiment offers a unique chance to monitor an evolving CME contemporary at 2° (among spacecraft) and 20° (between LISA and Earth) intervals in longitude. These observations will result of particular interest for space weather since strong SEP differential flux trends are not predictable above 10 MeV and these events are particularly dangerous to astronauts and also to space equipments.

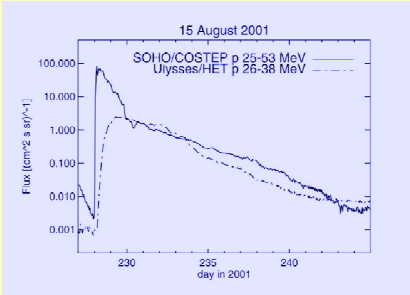


Fig. 1*

Fig. 2*

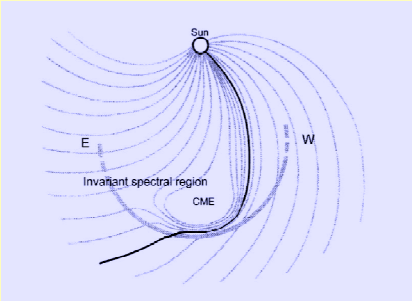


Table 1

Distance from the sun	**149 ÷ 152 • 10⁶ km** *(0.9933 ÷ 1.0133 AU)*
Latitude off the ecliptic	**0.7° ÷ 1.0°**
Longitude difference with respect to Earth	**19° ÷ 21°**

CMEs properties:

The study of the characteristics of propagating CMEs as a function of latitude has been carried out by the Ulysses experiment. As an example, an important latitude effect has been found by Dalla et al., 2003 where a comparison between SEP fluxes (gradual event) measured at Ulysses (latitude 63° N and distance from the Sun of 1.63 AU) and at SOHO (in the ecliptic at 1 AU) has been made. The results are reported in fig.1.

The peak intensity at high latitude is typically smaller than in the ecliptic and it is reached at a later time. The decay phase is characterised by similar decay time constants at the two locations.

A study of the longitude dependence of the spatial and temporal distributions of SEPs has been debated in Reames et al.,1996; Reames et al., 1997. SEP flux measurements ranging between a few and a few hundreds of MeV from three different satellites (Helios 1, Helios 2 and IMP8) separated by large angular distances have been studied for various gradual events.

The lack of longitude dependence of intensities at all energies late in the event, well behind the shock, is in contrast with the dramatic longitude dependence ahead of the shock. We remind that the typical velocity of the shock for strong events is about 1500 km s^{-1}.

The region of the invariant spectra (fig.2) is associated with acceleration on the eastern flank of the shock wave driven out from the Sun by a coronal mass injection.

Due to the topology of the interplanetary magnetic field, events originating in the western hemisphere of the Sun are more likely to produce solar particles able to reach the Earth with respect to those flares in the eastern hemisphere. The properties of SEP profiles are explained in terms of direct magnetic connection between the shock and the detecting spacecraft (fig.3).

Fig. 3*

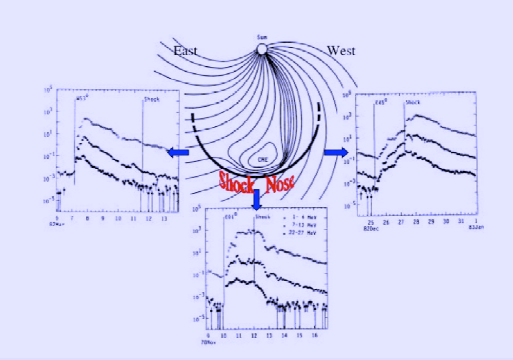
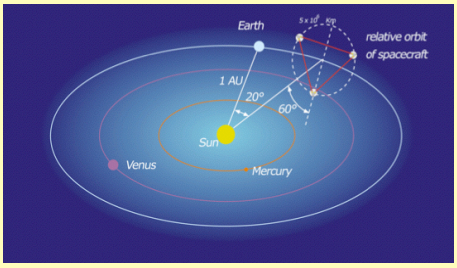


Fig. 4*



CMEs on LISA:

The LISA orbit is reported in fig.4. The spacecraft rotate on an equilateral triangle with a rotation period of one year which results very large with respect to the typical CME transit time of the order of hours among the LISA spacecraft or days between the Earth and LISA.

Spacecraft minimum and maximum radial distances from the Sun, latitudes off the ecliptic plane and longitudes have been reported in Table 1.

Particle counters on board LISA are supposed to guarantee real time info about the rate of the overall incident cosmic-ray flux on the spacecraft in order to monitor the charging process of the test masses (Araùjo et al. 2004, Grimani et al., 2004, Vocca et al., 2004). To this purpose, the material surrounding the particle detectors should be similar to that overlying the test masses (about 13 g/cm^2) and at least one particle detector should be located in each spacecraft. The amount of matter surrounding the masses implies a limit of about 100 MeV on the minimum energy of primary particles able to reach the test masses. Evolving CMEs passage through the LISA spacecraft will be detected by sudden increases of the counting rate in the particle detectors due to highest energy particles.

We suggest to use the cosmic-ray flux monitors on board LISA to study the longitude dependence of evolving CMEs by using the three spacecraft particle counters (max 2° difference in longitude among the three detectors) and Earth detectors (20° difference in longitude).

Solar physics with LISA:

In order to estimate the actual rate of incident particles with energies larger than 100 of MeV on the LISA particle counters, we report the characteristics of the particle fluxes generated by strong CMEs. In fig.5 the solar proton spectra reaching the Earth as a function of time during a strong flare (May 7th 1978 - Grieder, 2001) are compared to the primary cosmic-ray proton spectra at solar minimum and maximum (continuous and dashed lines respectively). The flare generated proton spectra as a function of time have been properly shifted in normalization in order to better show their shape.

It is possible to notice that the particle counters would detect an increase in the counting rate of more than 2 orders of magnitude in terms of one or two hours. Therefore it might be possible to follow the dynamics of a strong CME propagating through LISA. In most cases it might also be possible to correlate the LISA counter observations with GLEs (Ground Level Events - Shea & Smart, 2001) at the Earth and therefore to compare SEP flux measurements at longitudes differing of about 20 degrees.

In general, the transit of the most energetic part of the shock can last a few days, therefore the observations that LISA carries out can be used to estimate the radiation hazard to astronauts and satellite equipments (space weather - Reames, 2001). These data can be compared to the results of other experiments dedicated to similar observations.

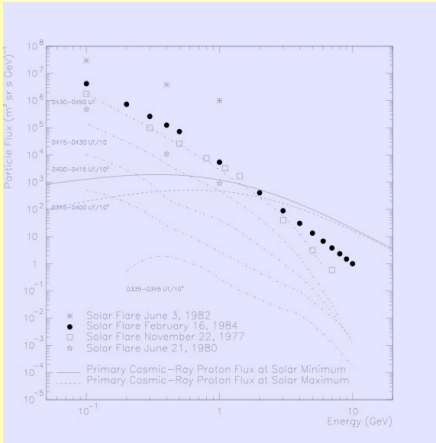


Fig. 5

Conclusions:

The LISA experiment cosmic-ray flux monitors might allow us to map CMEs passage through the three spacecraft. Large events are expected to cover large intervals in longitude. In particular, the strong part of the shock is supposed to extend over up to 60° in longitude. Those events magnetically well connected to the Earth will go through LISA with a known delay of about half a day. Conversely, those events magnetically well connected to LISA will be observed on LISA before reaching the Earth. It will be possible to monitor with great precision the passage of the nose of the shock at different longitudes. These observations are of major interest for both solar physics and space weather study.

* Fig.1 is taken from Dalla et al., 2003
Fig.2 is taken from Reames et al., 1997
Fig.3 is taken from Reames, 2002
Fig.4 is taken from http://lisa.jpl.nasa.gov/gallery.html (modified)

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