Cosmic-ray spectra near the LISA orbit

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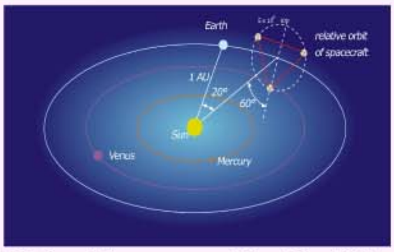
Cosmic-ray particles traverse the LISA apparatus charging the proof masses. This process causes spurious Coulomb forces between the proof masses and the surrounding conducting surfaces mimiking gravitational wave signals.
Approximately 13 g/cm^2 of matter overlie the proof masses. The nucleonic component of cosmic rays (about 99% of the total) below 100 MeV/n stops inside without reaching the masses.



LISA Sun distance range : 149 - 152 x 10^6 Km
LISA Latitudinal Range: 0,7 - 1,0 degree

Fig. 1

It results of major importance to determine the primary and solar cosmic-ray particle fluxes above this energy keeping small the normalization errors.
Cosmic-ray measurements have been mainly carried out with balloon and satellite experiments near the Earth.
The LISA orbit[1] is reported in fig. 1. Maximun and minumum radial distances from the Sun and latitude off the ecliptic plane of the LISA aircrafts have been also indicated.
It is needed to estimate if cosmic-ray observations near the Earth differ significantly from those near the LISA orbit.
Experimental data (Ulysses experiment[2]) shows that for :

COSMIC RAY PROTONS ABOVE 106 MeV/n
Radial distance dependence from the Sun:
3% / AU
Latitudinal dependence from the ecliptic plane
0,33% / deg

Since typical flux normalization errors are about 30 %, we conclude that measurements carried out near Earth can be used to interpolate the cosmic-ray spectra for the LISA simulation.
In fig. 2 we have reported the fit function and the parameter values obtained for the particle flux interpolations.

Primary cosmic ray fluxes

Interpolation function

$$F(E) = A\,(E + B)^{-\alpha}\;E^{\beta}$$

where E is the energy in GeV/n and

Solar minimum

	A	B	α	β
p	18000	1.09	3.66	0.87
He	850	0.99	3.10	0.35
C	23	0.95	3.00	0.29
O	21	0.95	3.00	0.32

Solar maximum

	A	B	α	β
p	18000	1.55	3.90	1.11
He	850	1.25	3.80	0.88
C	23	1.22	3.40	0.69
O	21	1.22	3.40	0.72

Fig. 2

A compilation of primary cosmic-ray experimental data and the results of the fits are reported in figs. 3, 4, 5 and 6.

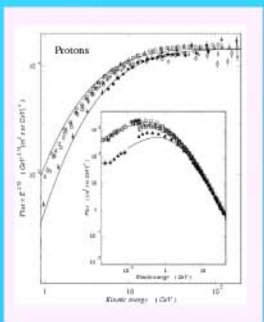


Fig. 3

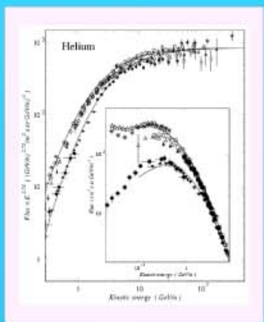


Fig. 4

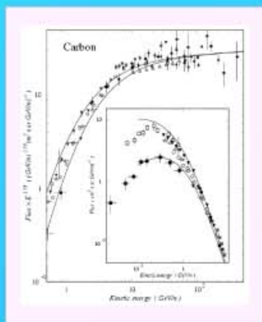


Fig. 5

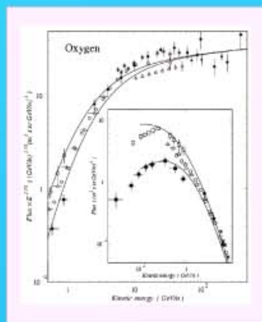


Fig. 6

Particles of solar origin constitute a minor component of the bulk of cosmic rays above 100 MeV/n, moreover solar particles are hardly distinguishable from to other low energy cosmic rays.
However, a very peculiar role is played by solar flares. Tremendous explosions near sunspots, usually along the dividing lines between areas of oppositely directed magnetic lines.
They release major amounts of energy under electromagnetic radiation and energetic particles, mainly electrons and protons.
The flare parameters are the energy, peak flux, duration, and rate of occurrence .
The flare rate per hour during the three solar cycles between 1976 and 2001[3] is reported in fig. 7.
In order to show the effect of a solar flare we compare the proton flux generated by a strong solar flare (February 16th 1984)[4] to the fitted interstellar proton flux at solar minimum (fig. 8).

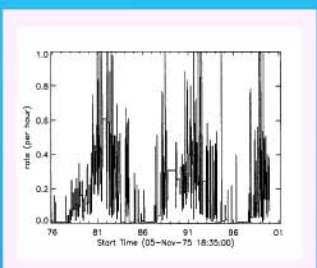


Fig. 7

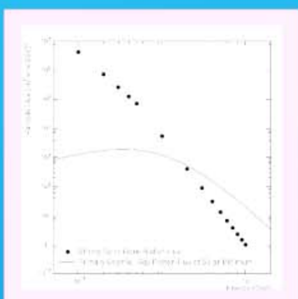


Fig. 8

A simulation of the propagation process of cosmic rays through the LISA proof masses has been carried out with the GEANT toolkit[5].
Other Monte Carlo programs (for example FLUKA[6]) will allow to estimate systematics among different simulation codes.

REFERENCES
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6 Fasso' A. et al., http://www.fluka.org

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