Estimates of the energetic proton environment at L1 point

T. Alberti[1], M. Laurenza[1]

[1]INAF-Istituto di Astrofisica e Planetologia Spaziali, Via del Fosso del Cavaliere 100, 00133, Roma, Italy

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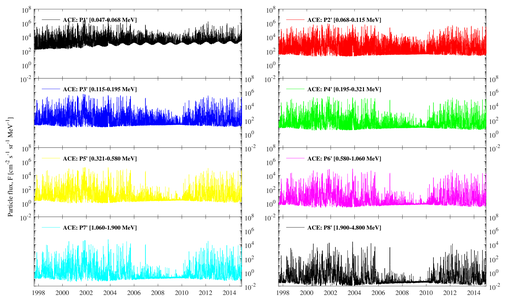
Background

The interplanetary space is permeated by 'thermal' solar wind plasma and by a higher energy particle component, which increases of several orders of magnitude during Solar Energetic Particle (SEP) events. The estimation of this high energy particle background is essential for any mission profile. For instance, protons with energies in the range 50 - 500 keV (the so called soft protons) are of particular interest for the ATHENA mission, as they enter the mirrors, being concentrated towards the focal plane instruments.

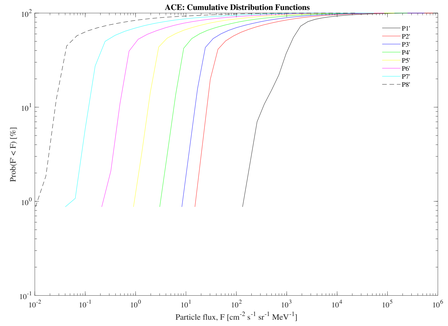
What we did?

- Analysis of proton flux data obtained from both ACE and IMP-8 spacecraft, covering the 1997-2015 interval (solar cycles No. 23 and 24) and the 1973-2001 interval (solar cycles No. 21, 22, and 23), respectively, to estimate the energetic proton environment at L1 point.

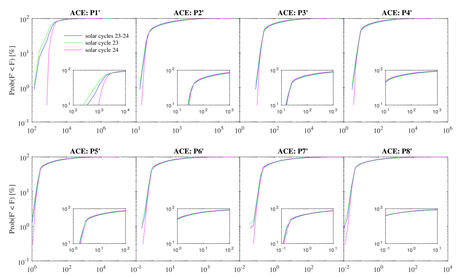
ACE data



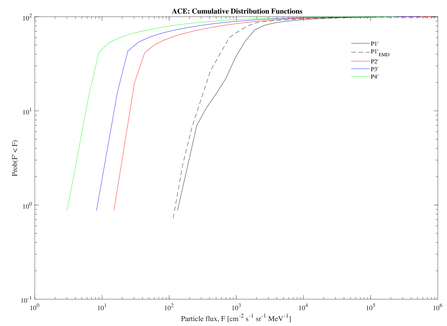
Cumulative distribution functions (CDFs)



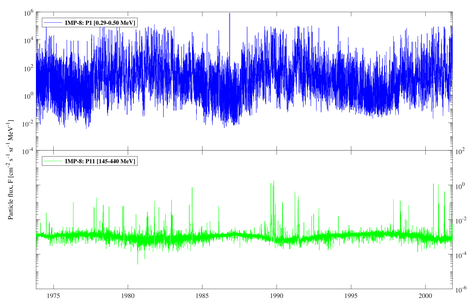
Solar cycles effects



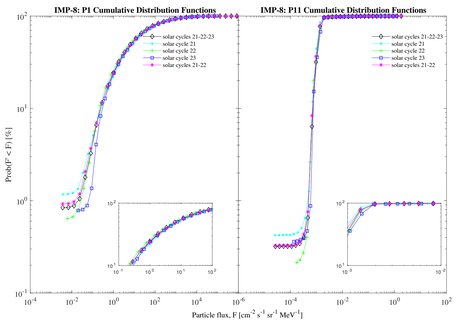
Spurious modulation effects



IMP-8 data



Cumulative distribution functions (CDFs)



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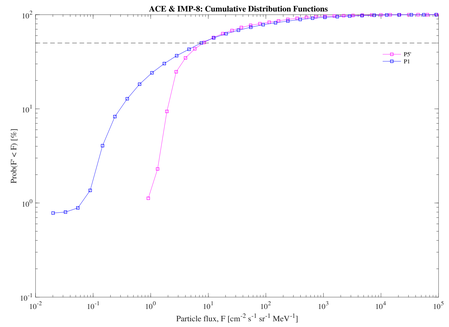
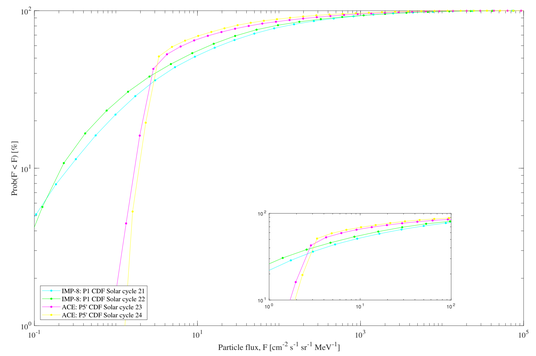
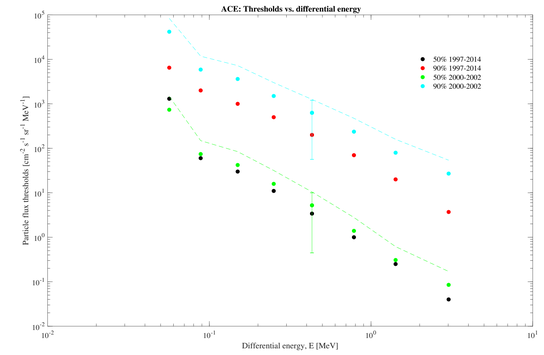
ACE vs. IMP-8 on similar energy-channel



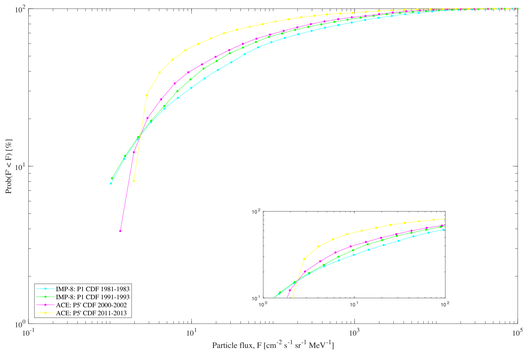
Solar cycles



Particle flux levels



Worst-case scenarios



What we found?

- We produced a corrected (filtered) P1' signal through which correct thresholds can be properly identified, showing that the unphysical modulation tends to increase flux thresholds of a factor 1.2-2, according to the different thresholds considered.
- The flux in the 0.047 - 0.068 MeV (0.068 - 0.115 MeV) channel is higher than 1000 pfu (60 pfu) for 50% of the time, decreasing as energy increases.
- Variations of the CDFs with respect to different solar cycles have also been studied: the P1' CDF, even when filtered, shows some difference for data taken in solar cycle 23 and part of 24, which may be due to the different lengths of the investigated datasets.
- The long term analysis of IMP-8 data in the 0.29-0.50 MeV and 145-440 MeV differential energy channels, covering the period 1973 - 2001 (solar cycles No. 21, No. 22, half cycle 23), shows slightly differences among them due to the activity level of the different solar cycles, more pronounced for the P11 energy channel data.
- Data recorded in the IMP-8 P1 energy channel have been compared with those in its equivalent energy channel ACE P5' over a common acquisition period, from 1997 to 2001. Results show a very good agreement, both having almost equal proton flux thresholds for time percentages greater than 50%.
- Thus, IMP-8 P1 data for solar cycles 21 and 22 have been also used to explore the proton flux variability related with solar activity in different solar cycles.
- The worst case scenario over a wide period (differently from single event cases) has been investigated by computing the CDFs only for the maximum phase of each considered solar cycle. The highest flux thresholds have been obtained for two years (from 1981 to 1983) during the maximum phase of solar cycle 21.
- The proton spectra observed during the 1981 - 1983 (worst case scenario) can be considered to be an upper limit for proton flux variability as a result of the solar activity variability, which tends to increase the proton flux up to about one order of magnitude.

Summary of proton flux levels

	IMP-8: P1					ACE: P5'				
Time percentage [%]	**Solar cycle 21**	**Solar cycle 22**	**1981-1983**	**1991-1993**	**Operational time**	**Solar cycle 23**	**Solar cycle 24**	**2000-2002**	**2011-2013**	**Operational time**
50	$1x10^{1}$	$9x10^{0}$	$3.2x10^{1}$	$2.6x10^{1}$	$7.4x10^{0}$	$4x10^{0}$	$3x10^{0}$	$2x10^{1}$	$6.5x10^{0}$	$3.4x10^{0}$
90	$1.2x10^{3}$	$8.1x10^{2}$	$3x10^{3}$	$1.9x10^{3}$	$6.6x10^{2}$	$3.6x10^{2}$	$1.2x10^{2}$	$1.4x10^{3}$	$3.8x10^{2}$	$2x10^{2}$

- Worst case scenario: 1981-1983
  → maximum phase of solar cycle 21
- ACE measurements during low-intensity solar cycles with respect to IMP-8 ones
  → proton flux background differences of a factor 2-3

E-mail contact: tommaso.alberti@iaps.inaf.it