HUNTING FORBUSH DECREASES IN THE INNER SOLAR SYSTEM

LIP Internship

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LABORATÓRIO DE INSTRUMENTAÇÃO E FÍSICA EXPERIMENTAL DE PARTÍCULAS

BEPICOLOMBO MISSION

- BepiColombo is the first European mission to Mercury (joined mission from ESA and JAXA).
- ► Launched on 20th October 2018 and arrives in the late 2025.
- Comprises two spacecrafts: MPO (Mercury Planetary Orbiter) and Mio (Mercury Magnetospheric Orbiter)





SPACE RADIATION ENVIRONMENT



Van Allen . Radiation Belt

The Van Allen Belt is a zone of energetic charged particles, captured by the planet's magnetosphere.



Galactic Cosmic Radiation (GCR)

Galactic Cosmic Radiation is a constant flux of particles anti-correlated to solar activity.



 Solar Energetic Particles (SEP) are spontaneous events originated in solar flares or shock waves associated with Coronal Mass Ejections (CMEs).

SEP event



BERM MONITOR



► 11 silicon sensors.

 Processes data into 20 channels / counters.



20 Channels:
5 Electrons
8 Protons
5 Heavy Ions
1 "Undetermined"
1 Veto

Max. Ener. deposited on:	Channels																		
	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19
Det #1	X	Х				Х													X
Det #2			Х			Х	Х	X						Х					
Det #3			Х					Х	Х					Х	Х				
Det #4				Х					Х	Х					Х				
Det #5				Х					()	X	Х				Х	Х		()	
Det #6					Х						Х					Х			
Det #7					Х						X	X				Х	Х		
Det #8		Î			Х					1 I I I		Х					Х		<u> </u>
Det #9		1								() (Х	X				Х	X	
Det #10													Х					Х	
Det #11													Х					Х	

OUR AIM – INITIAL OBJECTIVES

1. "Calculate" acceptance for BERM detectors.

$$G = \int_{\Omega} d\omega \int_{S} d\sigma \cdot \hat{r}$$

2. Calculate the expected count rate during quiet periods and compare with the correspondent data.

3. Model data variation in these periods.

Taken from: Sullivan, J.D.; 1971; Geometrical Factor and Directional Response of a Single and Multi-Element Particle Telescope



OUR AIM – FORBUSH DECREASES

4. Compare CME data with the quiet period data and (try to) find FDs and SEPs

Forbush Decreases (FD): observed drops in cosmic ray fluxes associated with the shock and/or eject of an Interplanetary Coronal Mass Ejection (ICME).



Taken from: Cane, Hilary; 2000; Coronal Mass Ejections and Forbush Decreases

ONGOING WORK – Acceptance Calculation

Requires Monte Carlo simulations and statistical analysis with calibration data.

$$C(\mathbf{x}, t_0) = \frac{1}{T} \int_{t_0}^{t_0 + T} dt \int_S d\sigma \cdot \hat{r} \int_\Omega d\omega \int_0^{+\infty} dE \times \sum_\alpha \epsilon_\alpha(E, \sigma, \omega, t) J_\alpha(E, \omega, \mathbf{x}, t)$$



ONGOING WORK – Acceptance Calculation



- > Derived and yet unsolved problems with BERM:
 - Channel Cross talking
 - Unwanted trigger by other particles (protons with electrons and protons with α -particles)
 - Missing simulations with GCR energies.

We simply worked with "factory values" of energy channels.





With the existing Model: ISO 15390 we got the predicted differential flux of particles from Z=1 up to Z=28 from 8/2018 to 7/2019 (for protons channels).



With the several time dependent differential flux data that the Model provided us, we managed to reconstruct particle's flux behaviour.





It was also necessary to transform heavy ions' energies (Z>1) into LET (Linear Energy Transfer) so that we could compare the Model with heavy ions' flux data.

LET tells us the amount of energy that an ionized particles transfers to the material traversed per unit distance

We can compare them with Sunspots detected over the time period that interests us:





We can compare the Model's prediction and the real behaviour of particle flux.

- BepiColombo iscontinuouslytravelling through theinner Solar System.
- The days used to get the fit were too few to have a good statistical behaviour.





... (5 Channels) ...



... (8 Channels) ...







... (5 Channels) ...

For each month proposed to be analysed, we plotted data against the best monthly fits and the Model.



Analysed Periods:

- → 15th May 2019 1 10th June 2019
- → 13th April 2020 to 30th April 2020
- → 20th May 2020 to 10th June 2020
- → 12th October 2020 to
 20th October 2020
- → 1st April 2021 to 30th April 2020

- BERM counts the number of particles for every 30 seconds
- BERM was shut down sometimes and some missing hours appear in random days
- Some channels gave very few statistical information







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Checking for major differences between the best fit and BERM's data.

Some issues encountered in these data variation analysis:

- Only Veto'ed Particles had enough statistical power to allow for a more confident fenomena search.
- The sum of differences to the fit of certain channels only forced error bars to become bigger.
- A linear fit is not enough to have a trustable background environment with which to analyse these data variations.



BepiColombo Mission's Trajectory.

OUR WORK – Discovering Fenomena



OUR WORK – Discovering Fenomena









MAJOR SEP EVENT FOUND!!

Acknowledgements & Final Remarks

