Precision Measurement of the Monthly Proton, Helium, Carbon and Oxygen Fluxes in Cosmic Rays with the Alpha Magnetic Spectrometer on the International Space Station

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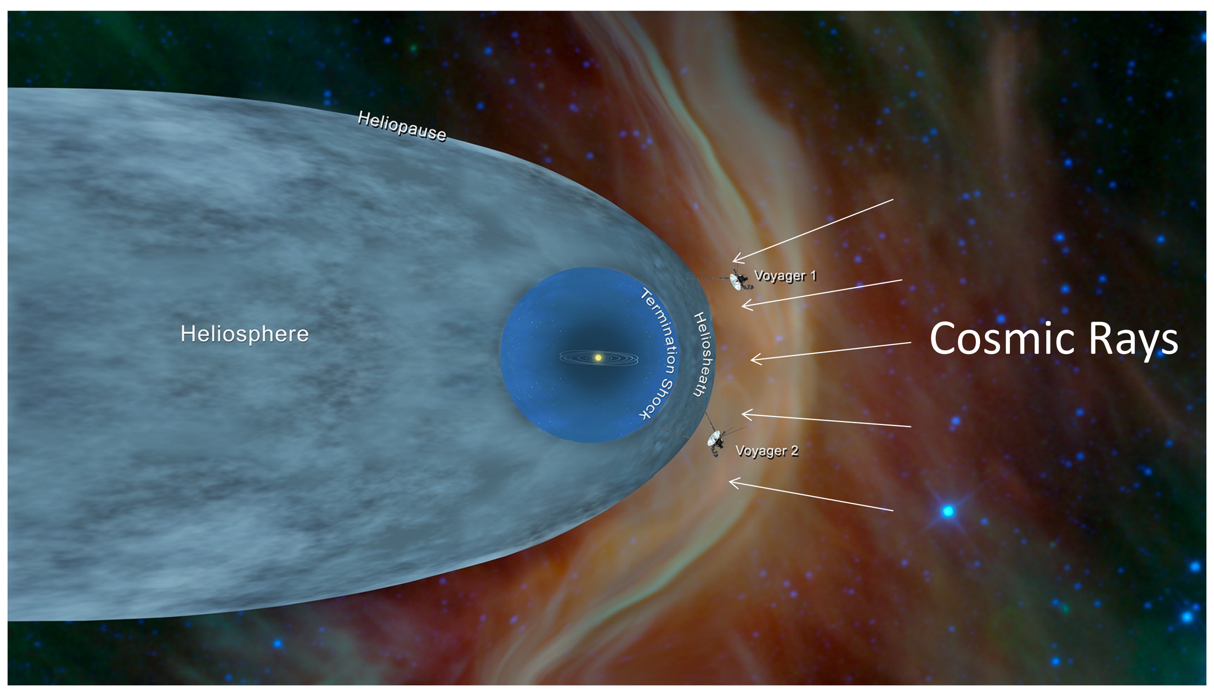
on behalf of the AMS-02 collaboration

Abstract

We present the time evolution of the proton, helium, carbon, and oxygen fluxes from 1 GV to 60 GV. The measurement is based on 5.5×10^9 proton, 7.6×10^8 helium, 2.0×10^7 carbon, and 1.7×10^7 oxygen events collected from May 2011 to November 2019 covering Bartels rotations 2426 to 2540. These AMS measurements provide unique information to understand the contribution of the Local Interstellar Spectrum and the velocity dependence on the cosmic ray propagation inside the heliosphere.

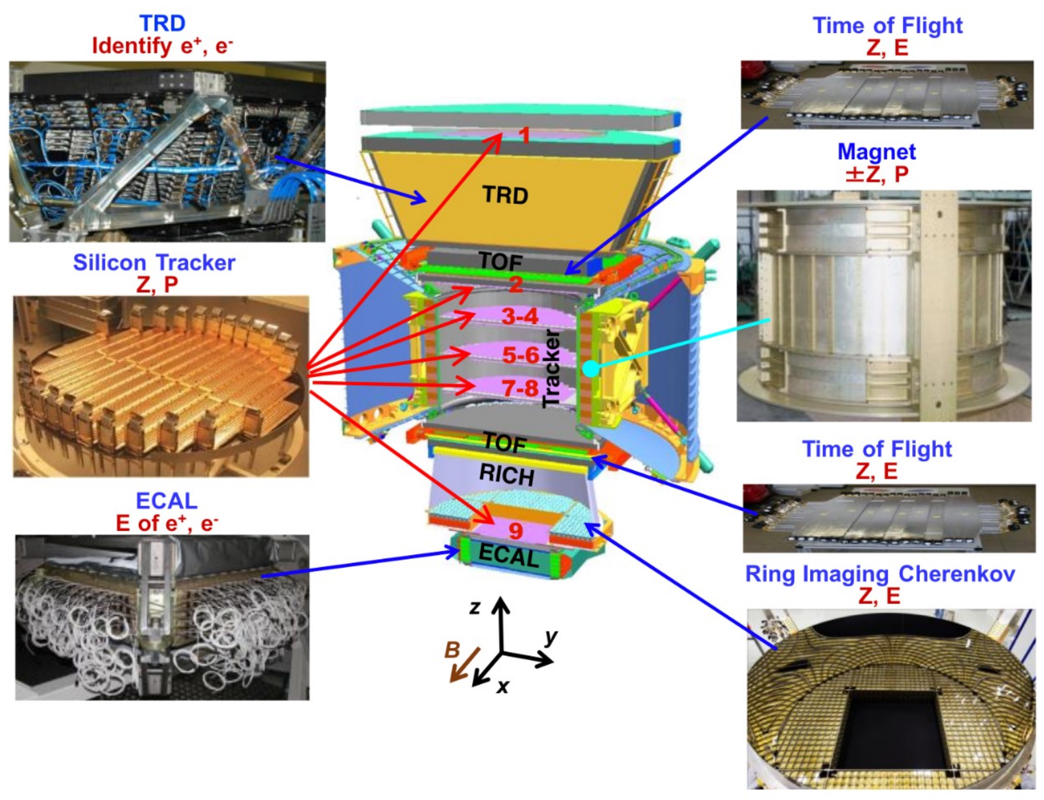
Cosmic Rays inside the Heliosphere



Cosmic rays entering the **heliosphere** are subject to diffusion, convection, adiabatic energy losses, and magnetic drift, as described by the Parker equation. The **temporal evolution** of these processes lead to cosmic ray intensity variations correlated with solar activity, namely known as ***solar modulation***. Cosmic-ray transport in the heliosphere is **rigidity dependent**. Hence the time variation of different particle spectra (p, He, C, O, ...) evaluated at the same rigidity are expected to exhibit a similar behavior. However, according to models based on the Parker equation, the time dependence of distinct nuclei fluxes evaluated at the same rigidity might differ because of (a) differences in the flux rigidity dependence outside the heliosphere (**Local Interstellar Spectrum**), and (b) differences in velocity because of distinct **mass-to-charge ratio**.

Methodology

AMS-02: a multi-TV particle spectrometer



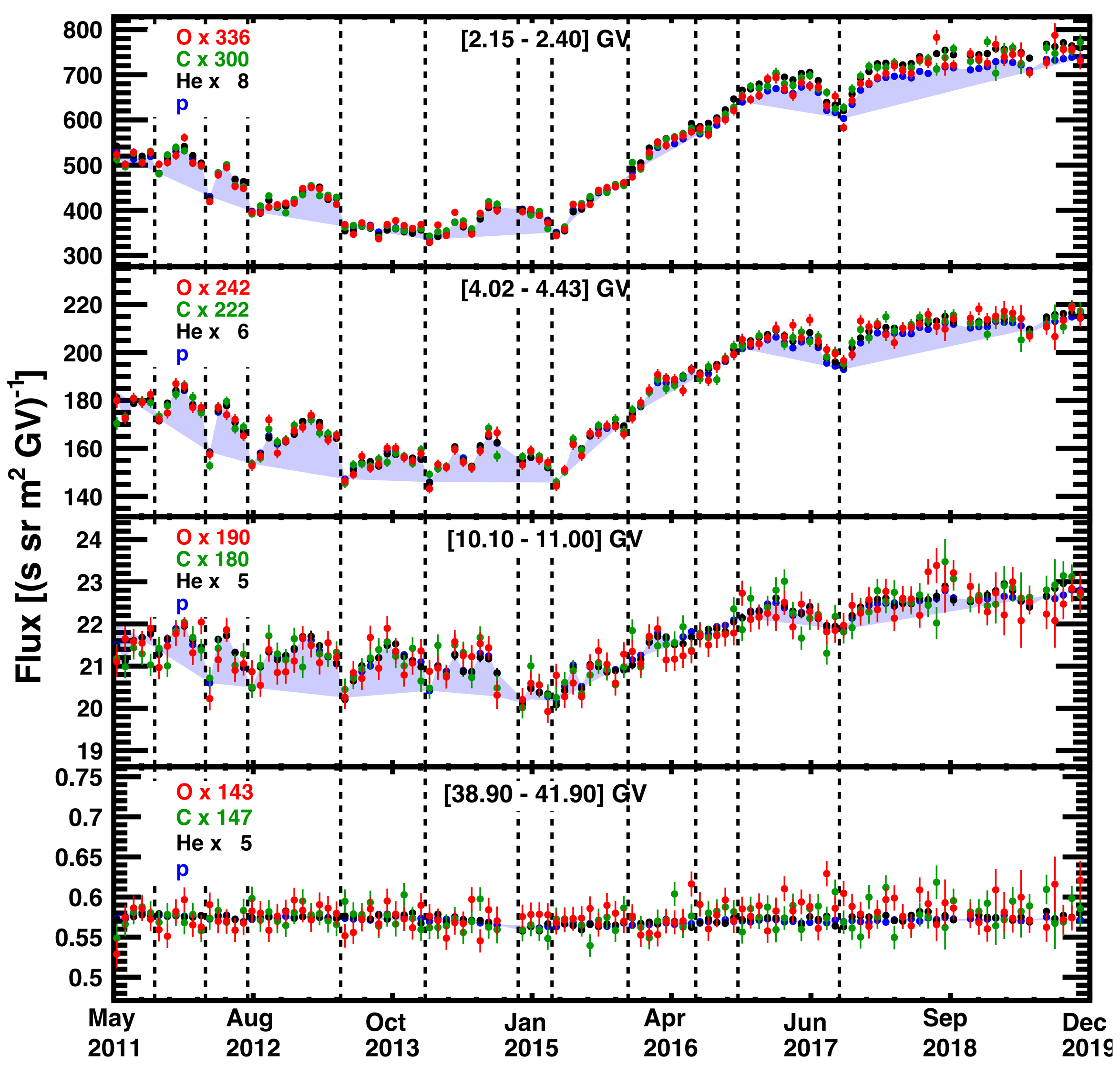
The isotropic flux Φ_i during a Bartels rotation in the i-th rigidity bin (R_i; $R_i + \Delta R_i$) is given by

$$\Phi_i = \frac{N_i}{A_i \epsilon_i T_i \Delta R_i}$$

where, for that Bartels rotation, N_i is the number of events corrected for bin-to-bin migration, A_i is the effective acceptance, ϵ_i is the trigger efficiency, and T_i is the collection time. Fluxes were measured in the rigidity ranges from 1 to 60.3 GV for protons, from 1.71 to 60.3 GV for helium, from 1.92 to 60.3 GV for carbon, and from 2.15 to 60.3 GV for oxygen.

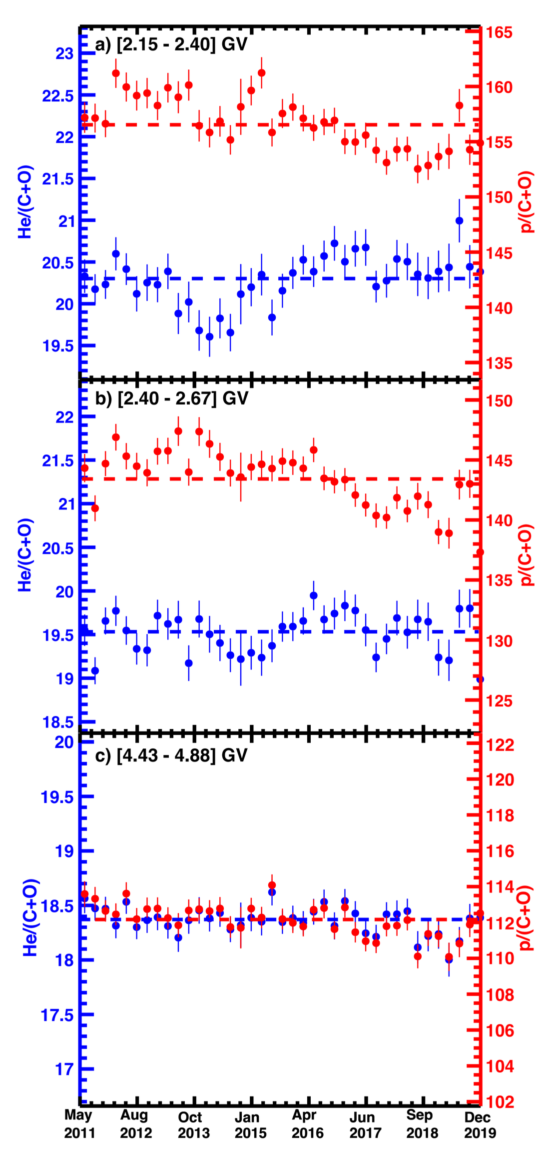
Fluxes vs Time

The proton, helium, carbon, and oxygen fluxes as a function of time for four characteristic rigidity bins. The fluxes exhibit **similar long-term and short-term time dependences**. Both are observed up to 48.5 GV for helium, 25 GV for carbon, 30 GV for oxygen, and over the entire rigidity range for protons.



Ratios vs Time

The **He/(C+O)** ratio is not compatible with a constant value at the 5σ level up to 2.40 GV. We also observe that the ***p/(C+O)*** ratio is not compatible with a constant value at the 5σ level up to 4.43 GV.



Local Interstellar Spectrum

He, C and O have similar **mass-to-charge ratio**, Δ(A/Z) = -0.07 ± 0.03. Therefore the observation that the **He/(C+O)** flux ratio is **not constant in time** implies that the He and (C,O) LISs have **different rigidity dependences** above 2 GV.