DECEMBER 2017
Tomassetti et al. 2017 Res. Notes AAS 1 35

Fresh Insights on Cosmic-Ray Propagation from the new AMS Data

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The Alpha Magnetic Spectrometer (AMS) experiment has released new measurements of primary and secondary nuclei in cosmic rays (CRs) at the TeV energy scale (Aguilar et al. 2016, 2017). Using these data, we present new results based on a global Bayesian analysis of our *two halo* model of CR transport (Feng et al. 2016).

Background — Measurements of energy spectra of *primary* (*i.e.*, accelerated in Galactic sources) and *secondary* (*i.e.*, spallogenic) nuclei are essential to investigate the acceleration and transport properties of CRs in the Galaxy, thereby providing the *astrophysical background* for the search of dark matter via cosmic antimatter. In Feng et al. (2016), we made use of a large compilation of *pre-AMS* data on the B/C ratio to constrain the parameters of a *two halo model* of CR propagation. This model explains the CR spectra in terms of two propagation regions having different energy-dependent diffusion coefficients: $D_i \propto E^{\delta}$ for the inner region near the Galactic disk, where the turbulence is generated by SN explosions, and $D_o \propto E^{\delta+\Delta}$ (with $\Delta \approx 0.55$) for the outer region away from the disk, where the turbulence is driven by CRs (Tomassetti 2015). Our previous results suggested a surprisingly shallow diffusion for CRs in the inner region ($\delta = 0.18 \pm 0.13$ within $l \approx 900\,\mathrm{pc}$) but, owing to uncertainties in the B/C data, these results were still consistent with the conventional Kolmogorov-like expectation $\delta = 1/3$. In this Note, we present fresh results based on an updated Markov-Chain Monte-Carlo sampling of new B/C data from AMS (Aguilar et al. 2016).

New results — The AMS data lead to narrow probability density functions for the CR transport parameters. The resulting uncertainty band for the B/C ratio is shown in Fig. 1b in comparison with the one estimated using pre-AMS data of Fig. 1a. The posterior mean of the near-disk diffusion exponent is $\delta = 0.18 \pm 0.05$. While this agrees with our earlier findings, the value $\delta \equiv 1/3$ is now excluded at 95 % CL. Taken at face value, our results disagree with the observations made by *Voyager-1* in the insterstellar medium, which reported a Kolmogorov-like spectrum of magnetic turbulence (Burlaga et al. 2015). This tension can be relieved by the incorporation of a hard *source component* of Li-Be-B nuclei, generated by nuclear interactions of CRs during acceleration (Blasi & Serpico 2009; Mertsch & Sarkar 2014). The production rate is regulated by the plasma density upstream the CR sources, n_1, which is not well known. Thus, have included interactions in our CR acceleration calculations. We have repeated the fits after fixing $\delta \equiv 1/3$ and leaving n_1 as free parameter. Interestingly, the results are found to be consistent with the average matter density of the Galaxy, $n_1 \sim 1\,\mathrm{cm}^{-3}$ for CR sources of typical age $\tau_{\mathrm{SN}} \sim$ 20-30 kyr, as one expects if the CR flux is provided by a large ensemble of supernova remnants (Tomassetti & Oliva 2017). Similar findings were reported in Aloisio et al. (2015), where a model of nonlinear CR propagation was tested against the preliminary AMS data.

In Fig. 1c, we present the $\bar{p}/p$ astrophysical background calculated with the new B/C-driven constraints. In comparison with the pre-AMS B/C-driven results, we found an increased discrepancy: the flat $\bar{p}/p$ behaviour reported by AMS cannot be recovered by our model. We also note that, as found in our past works, the inclusion of primary antiprotons (from proton-gas interactions inside sources) does not resolve this tension satisfactorily (Tomassetti & Oliva 2017; Tomassetti & Feng 2017). The uncertainties in the $\bar{p}/p$ calculations are now dominated by cross-section data rather than by CR data, and, at low energy, by solar modulation. While these uncertainties could recover the tension, there is yet some room left to squeeze in a potential dark matter component.

Conclusions — The new data released by AMS can be described well by a two-halo model of CR propagation, but they point to a very shallow diffusion, for CRs near the disk, which disagrees with the *Voyager-1* observations of interstellar turbulence. This tension can be relieved if secondary CR production inside sources is included. With the improved constraints, we have also found that a tension between $\bar{p}/p$ data and astrophysical background calculations starts to emerge. Because cross sections are dominating the uncertainties, LHC measurements on antiproton and antineutron production will very precious for clarifying the situation.

N.T. acknowledges the European Commission for support under the H2020-MSCA-IF-2015 action, grant No.707543-MAtISSE. A.O. acknowledges CIEMAT, CDTI and SEIDI MINECO under grants ESP2015-71662-C2-(1-P) and MDM-2015-0509.

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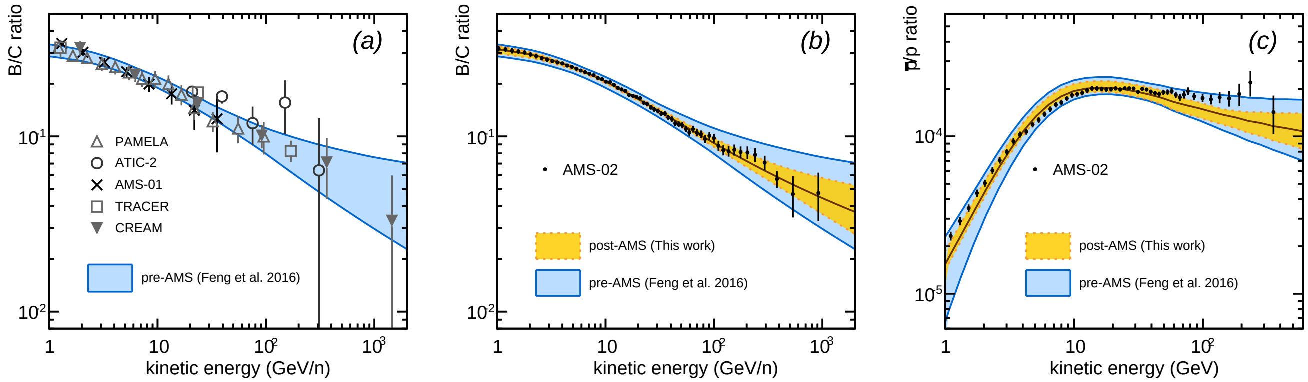

FIG. 1.— Calculations for the B/C (a, b) and $\bar{p}/p$ (c) ratios in comparison with the AMS data. The blue shaded bands are the uncertainties obtained from our pre-AMS data (a) analysis (Feng et al. 2016). The orange band is from this work, *i.e.*, using the AMS data only.