Paradigm Shifts and a Possible Resolution of the PAMELA-Paradox in Astroparticle Physics.

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Abstract

Very recently, PAMELA Collaboration has formally reported two sets of data on positron and antiproton flux measurements done at very high energies and with unprecedented accuracy. The reports reveal a puzzle of great topical interest and importance: it is decisively found that there is a sharp smooth rise of the positron fraction, whereas for antiproton production no such rises occur; rather the fraction either flattens, or shows signs of falling off gradually with increasing energies. The present work is just an attempt to decipher the riddle with the help of a host of radically new ideas about the particle-structure, the multiparticle-production mechanisms and the concept of nucleon break-downs into the constituent partons. The application of these ideas found remarkable successes in the past; exactly similar or more striking are the findings by the present study.

Keywords: Cosmic-ray interactions with the Earth, Positron emission, Cosmic-rays high energy interactions, Dark Matter.

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1 Introduction and Background:

Since the end of October 2008, there has been a tremendous surge of interest and excitement, and then a consequent flurry of activity among the astroparticle and high energy physicists. The two works that shook the world of Astroparticle and Cosmic Ray physics in the last one fortnight are the startling revelations made by Adriani et al in two consecutive reports\cite{1,2}: (i) The PAMELA satellite experiment by Adriani et al\cite{1} observed and convincingly demonstrated a sharply rising ratio of the positron flux measurements up to the studied 10-100GeV range of (secondary) energy; (ii) conversely, the findings on the antiproton-to-proton flux showed no such similar behaviour; rather the ratio-values showed strong tendencies of flattening in the range of 80-100GeV secondary energy\cite{2}. This striking contrast in the nature of antiparticle-to-particle ratios poses a serious puzzle to the theorists and occupies the centre-stage of astroparticle physics domain today, stimulating more than two dozens of works within a very very short span\cite{3-33}. In fact, some previous studies\cite{34,35} had already given very careful but strong hints to the possibilities of such discoveries finally reported only very recently, for which the paradox, once formally reported, instantly caught such a large number of physicists to a feverish pitch compelling them to act.

In the domain of astroparticle physics, particularly with regard to the studies on dark matter (DM) and the weakly interacting massive particles (WIMPs), searches for antimatter cosmic rays comprising positrons and antiprotons constitute a very important corner. Generically, the spectra of both positrons and antiprotons are expected to fall with increasing energy, relative to the corresponding matter particles which are here obviously electrons and protons respectively. Any deviation from such standard expectations might be a strong indication of any new primary cosmic rays\cite{14,17}. In fact, such discoveries might unravel new windows to the physics of dark matter (DM) and/or provide valuable clues to the sources of ultrahigh energy cosmic rays, both of which are still thoroughly unknown. These factors explain the reasons for being drawn to such intense activities by the physicists on the issue in question which really remains an enigma to the adherents of the Standard Models (SMs) in High Energy Physics, Astroparticle Physics and Cosmology, with all their ramifications and interconnectedness.

In the present work here we will concentrate on understanding the nature of the positron flux ratio alone in the light of some non-standard ideas, hypotheses and ansatze about the structure of particles, the mechanism for particle interactions and finally the mode of multiple production.
of hadrons. Very interestingly, the other ratio of $P/P$ turns, in the light of the model(s) applied here, to a non-issue. Because, there is an exclusivity on the production of positrons arising out of the putatively novel concepts about the structure of hadrons. This helps us to obtain with some non-standard additional and asymmetric sources for $e^+\cdot$-production whereas, for the antiprotons no such asymmetric source exists.

Before digressing, at the very outset, we would like to make a few comments. Most surprisingly, the results are no wonder to us; because we had appreciated and emphasised the importance and impact of such similar findings through a published work roughly twenty years ago in a chain of related works; based entirely on the same new paradigms which are outlined in the next section in some detail. The present work is just the resurrection of some of our past works with the latest and newly obtained data from PAMELA collaboration. So neither we build up any new model nor we refurbish the old model. We simply apply an old model built up by one of the authors (SB) to explain the characteristics of the new data produced by PAMELA collaboration on excess production of positrons. By way, PAMELA is the acronym for "Payload for Antimatter-Matter Exploration and Light-nuclei Astrophysics".

2 Paradigm Shifts : Brief Outlines

(i) In the realm of Particle Physics we would introduce the concept integer-charged partonic constituents for hadrons (both mesons and baryons) with an old five-parton model. And the partons, from the viewpoint of these radical works, are identified to be the muonic leptons like positively and negatively charged muons and the muonic neutrinos. So, borrowing the phrase from Baek and Ko, the hadrostructures here are really ‘leptophilic’ or, more precisely, ‘muonophilic’. The details are to be obtained from the works by one of us (SB) and the references therein.

(ii) In the fields of Astroparticle and Cosmic Ray phenomena we introduced the concept of nucleon-breaking mechanism, while the ultra high energy cosmic rays pass through and collide with intergalactic medium consisting of various light nuclei in highly energised states. This concept is entirely different from the ideas of proton- or neutron-decay. In fact, our previous studies on the nature of positron spectrum and estimation of positron flux fractions were based on these two sets of new ideas which mark a radical departure from the Standard Model(SM)-based points of view.

(iii) Our approach to the studies on this particular problem of excess production of positron
fractions pertains in no way to the existence or annihilation of cosmological dark matter (DM)\cite{15} - cold or hot, with spin zero, unity or else. Nor the little Higgs scalars are of any concern to us.

(iv) Besides, none of the Standard Model-related ideas like weakly interacting massive particles (WIMPs), supersymmetric particles (SPs) or supersymmetry, for that matter, and the Kaluza-Klein particles in extra dimensions would be our concern here.

(v) Regarding our choice on the propagation model for the ultra high energy cosmic rays we will avoid the complicated ones and accept the simplest and most commonly used model, called Simple Leaky Box Model (SLBM).

3 The Excess Positron Fraction : The Masterformula and The Results

Based on the above-stated assumptions, ansatzs and arguments, we deduced roughly two decades ago the formula for excess production of positrons in one of our previous works\cite{36}-\cite{38}. So, in order to prevent the repetitive presentations of the same calculational steps, we will simply extract\cite{36} for our present purpose the final working expression therefrom given below.

The standard sources for electrons and positrons are given by

\[ \pi^- \rightarrow \mu^- \rightarrow e^- \]
\[ \pi^+ \rightarrow \mu^+ \rightarrow e^+ \]

where the pions shown here are the secondaries abundantly produced in nature by multiple production of hadrons known as multiparticle phenomena. Similarly, secondary protons and antiprotons are also produced by multiparticle mechanism. In fact, this is the only method for production of the proton-antiprotons.

As stated above, the standard source of cosmic electron production is the normal route of negatively charged pion-decays, where pions of all varieties are produced by multiple production of hadron mechanism. There is no other extraneous source of electron production. But for production of cosmic ray positrons the additional, exotic and non-standard source is the proposed nucleon-breaking mechanism with positive muons residing inside the structure of protons as its constituents. Through the proposed proton-breaking mechanism supposed to be operational only at superhigh energies positive muons are set free, which then could produce positrons through their normal decay channel. These twin (standard and non-standard) sources contribute to the positrons. The model-
based final expression for positron fraction, defined as the ratio of the total flux over total electron plus positron flux, is given by \[36\]

\[
\frac{\phi_{e^+}}{\phi_{e^+} + \phi_{e^-}} = \frac{1}{2 + C' E_{e^+}^{0.5} \sin^2 \theta_{cut}} + \beta E_{e^+}^{0.5}
\] (1)

where \(C'\) is a parameter related to the physics of proton-breaking mechanism, \(\theta_{cut}\) is the cut-off angle of emission or detection of the positrons with the vertical. In the experiments by Adriani et al the cut-off angle is not precisely mentioned for which we have calculated for both small-angle (0 – 10°)(Fig.1) and large-angle (Fig.2) emissions of the positrons. \(\beta\) is a parameter which is to be chosen by the methods of fitting the data. We have maintained the same value \(\beta\) for both small-angle and large-angle scattering. The parameter values are given in Table-1 and Table-2.

Figure 1: Data points are taken from Ref.[1]. The errors are only statistical. The solid curve shows the results based on the present working formula (eqn.1).
Table 1: Chosen numerical values of the fit parameters in the expression for the positron fraction [with small-angle emission].

| $\theta_{\text{cut}}$ | $c'$         | $\beta$          | $\chi^2_{\text{nd}}$ |
|-----------------------|--------------|-------------------|-----------------------|
| 3°                    | $5417.46 \pm 56.45$ | $0.011 \pm 0.0002$ | 4.775/11               |
| 5°                    | $1904.63 \pm 18.13$  | $0.011 \pm 0.0002$ | 4.242/11               |
| 7°                    | $968.567 \pm 9.219$   | $0.011 \pm 0.0002$ | 4.242/11               |
| 10°                   | $472.714 \pm 4.592$    | $0.011 \pm 0.0002$ | 3.271/10               |

Table 2: Chosen numerical values of the fit parameters in the expression for the positron fraction [with large-angle emission].

| $\theta_{\text{cut}}$ | $c'$          | $\beta$           | $\chi^2_{\text{nd}}$ |
|-----------------------|---------------|-------------------|-----------------------|
| 30°                   | $57.248 \pm 0.0556$  | $0.011 \pm 0.0002$ | 3.271/10               |
| 45°                   | $28.632 \pm 0.278$    | $0.011 \pm 0.0002$ | 3.271/10               |
| 60°                   | $19.223 \pm 0.183$    | $0.011 \pm 0.0002$ | 4.242/11               |
| 90°                   | $14.312 \pm 0.139$    | $0.011 \pm 0.0002$ | 3.271/10               |

The results based on the calculations are presented only by graphical plots,[Fig.1 and Fig.2] along with the two adjoining Tables [Table-1 and Table-2] which provide the necessary parameter values. The results are controlled and dominated by the second factor, power-law based term in the final expression. In the data-analysis at ultrahigh energies the first term plays no significant role. And so the results virtually grow independence of the angle of emission.

4 Summary and Conclusions:

The excellent agreement between the measurements and our model-based results are quite evident in all the cases of assumed both small-angle or large-angle emissions of the positrons in the PAMELA experiment. So the anomaly is resolved by virtue of the calculations done on the basis of the conjectures made here which mark a radical departure from the conventional set-patterns of ideas and the fixed standard beliefs. By the same token of argumentative points entailed in the new paradigm we also predict here the detection of the excess of cosmic muon neutrinos and an-
Figure 2: Data points are taken from Ref.[1]. The errors are only statistical. The solid curve shows the results based on the present working formula (eqn.1).

tineutrinos at very very high energies due to the breaking of the nucleons by the cosmic spallation process in the integergalactic space.

The muon charge ratios at very high cosmic ray energies depict normally a very slowly rising nature. Had the muons been not very decay-prone, it would also have met the similar nature arising out of the same nucleon-breaking mechanism. In any case, both the $\mu^+/\mu^-$ and $e^+/e^-$ ratios rise with energy at very high cosmic ray energies. This illustrates and manifests one important aspect of the muon-electron universality property: Our success in interpreting the PAMELA-data reinforces our dependence on models different from the Standard Model(s) in the Particle Physics and the related fields, as the entire edifice of the present work is based on the rejection of the Standard
Model which is artificial and thoroughly questionable from the very start. However, some other comments are in order here for the sake of completeness and totality. (i) The electron-positrons are charged particles. We have, however, neglected here the complications of path-deflections suffered by the charged positrons or electrons arising out of the earth’s magnetic field. It is to be stressed upon that the mechanism suggested here plugs automatically the parallel expectations for the cases of antiprotons, as the nucleon-(or, proton-)breaking mechanism can and does in no way give rise to any excess production of antiprotons. (ii) As it is a ratio, the systematic uncertainties in the data are cancelled; that also allows the cancellation of the solar activity. In reality solar modulations could arise from the phase of the solar cycle and also from the opposite charges of electrons and positrons. But the fact is we do not include these probable disturbing effects in order to escape initially the complications contributing to some very minor effects with no significant numerical values.

However, the model we apply here takes care of the experimental data quite well and successfully solves the anomaly evinced by the adjoining figures, without assuming, however, the role of pulsars, the dark matter annihilations or taking into account some other phenomena evolved from the Standard Model(SM)-based points of view. And the conclusion derived from this work is in perfect accord with what is maintained by Morselli and Moskalenko\cite{49} that the excesses imply a source, conventional or exotic, of additional leptonic component, especially of the positive variety. And this obviously causes a distantiation from the viewpoints expressed by Chen et al\cite{50}.

**NOTE ADDED:**

After the completion of our present work on PAMELA-Paradox, our attention was drawn by a scientific colleague to a very important report\cite{51} and to a few papers\cite{52, 53} with some concrete findings. The report by Butt\cite{51} is an exceptionally brilliant one for its unbiasedness or open-mindedness and near-perfect objectivity. The bump observed by the ATIC collaboration is not to be electron-specific; side by side with the signature-electrons, the positrons are also to be produced in roughly equal measure, as was expressly maintained by Butt\cite{51}, if Kaluza-Klein(KK) WIMPs are their progenitor. But the ATIC measurements\cite{52} were singularly aimed at studying the electrons alone. So, unless the positrons are measured under the same or similar circumstances by these groups\cite{52, 53}, no definitive comment on the status of KK WIMPs is possible. In this context, another comment is yet in order. The measurements by Aharonian et al\cite{53} for detection of cosmic ray electrons at energies beyond 600GeV do not report very clearly, such excesses, as is indicated by
Chang et al [52]. This, therefore, tacitly and indirectly puts a question mark to the measurements of Chang et al until further scrutiny.

Besides, there are a few sharp differences between the two sets of studies [PAMELA, HEAT etc. on the one side, and ATIC, HESS etc., on the other], for which a comparison of the two sets of findings might not be quite significant. Firstly, the studies by PAMELA Collaboration concentrate uniquely on the studies of cosmic antiparticles like positron(s) and antiproton(s), whereas both the ATIC and the HESS Collaborations measure only electron spectrum at much higher energies; they did not report on the measure of corresponding antiparticle production scenario. Secondly, the energy-ranges of the two sets of experiments are grossly different. So the studies on the excess production of cosmic electrons alone at much higher energies do not disturb the pivot of our present work on PAMELA-paradox. Unless ATIC and HESS Collaborations study and report pointedly on the nature of positron and antiproton productions at the same energy-range and under the stringently same experimental conditions we see no tangible reason to redefine our attitude and reconsider our outlook. However, if asymmetric excess electron production alone is repeatedly reported and confirmed, only then we will have to investigate in to some exotic sources or nor-yet-proposed-or-known mechanism for cosmic electron production. So for the present, we are still not in favour of attaching too much importance to the hypothesis of dark matter or the postulates Kaluza-Klein (KK) WIMPs.

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