A new mechanism to account for acceleration of the solar wind

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***Abstract* — An enormous amount of effort has been expended over the past sixty years in attempts to understand the cause of the solar wind, with virtually no progress toward developing an understanding of the precise processes involved in the acceleration process. Here I show how the solar wind can be accounted for simply as a consequence of the acceleration of thermal protons and ions by electrodynamic forces from an electric field which pervades the heliosphere.**

MODULATION OF GALACTIC COSMIC RAYS

Just over a half century ago, despite a widespread belief that no significant electric fields can exist in the highly conductive heliosphere, Ehmert [1] suggested that observations of the modulation of galactic cosmic rays (GCRs) could be largely explained by a solar centered, symmetric, heliospheric electric potential of 1 to 2 GV. This idea did not find acceptance on account of the inability to conceive a mechanism to sustain the potential. Other workers have continued to study this concept, but have been careful to describe the field as a hypothetical "force field" so as to avoid criticism. Work continues to the present on refining the force field model of GCR modulation, using more recent data, which has established that the force field is equivalent to that which would result from a positive electric potential of 800 MV ± 400MV on average [2].

I have recently argued that the force field in the heliosphere is indeed a positive, quasi-static electric field, as Ehmert first suggested, and that it is sustained by the continual penetration of GCR protons and ions deeply into the heliosphere and their deposition there at a rate in excess of the deposition of GCR electrons [3, 4].

EQUILIBRIUM STATE OF THE HELIOSPHERE

If the positive electric field has spherical symmetry as I have assumed, then the field cannot accelerate heliospheric thermal electrons because they are blocked by the presence of other electrons beneath them, with no path to follow. The situation is closely analogous to massive bodies on or beneath Earth's surface, which are prevented from acceleration inward in response to Earth's spherically symmetric gravitational field which acts upon them. For a more detailed discussion see Ref. 4. Clearly, it is not possible for the potential to be diminished by the radial flow of heliospheric electrons. Therefore, the field can only accelerate the thermal protons and ions radially outward in the direction to neutralize the potential, by exiting the heliosphere. This flow has been termed “the solar wind” (SW), and it is comprised of almost as many electrons as protons.

The outflow of thermal ions in the SW is not an efficient way to diminish the potential, because each of the accelerated protons tends to drag a loosely coupled electron along with it. An additional impediment is that the GCR ions travel inward from the termination shock to their place of deposition at a large fraction of the velocity of light, whereas the SW ions travel outward at about three orders of magnitude more slowly.

If it is assumed that the GCR protons responsible for the field are distributed homogeneously throughout the heliosphere, then the field will be zero at the center, increasing linearly to about 120 mV/km at the TS (as shown in Fig. 1 of Ref. [4]). The electric potential is sustained predominantly by GCR protons which arrive near the center of the heliosphere, having lost all but a tiny fraction of their energy to the field. The only GCR protons that can meet these criteria are those with energy in the vicinity of U, where

$$U = eV_{max} ,$$

V_{max} is the maximum potential, and e is the proton charge. For the present day heliosphere $V_{max} \approx 800$ MV so that $U \approx 800$ MeV. These are the GCR protons which can lose almost all of their energy, then scatter diffusively near the center of the heliosphere where the heliospheric magnetic field is most intense and its variations greatest, and the electric field is minimum. These protons spend far more time inside the heliosphere than other GCR protons, before eventually becoming thermalized and ejected by the SW through the TS.

Most GCR protons with less kinetic energy than 800 MeV are turned around by the field and ejected promptly from the heliosphere. Those with less than but near 800 MeV which do not quite reach the central region of the heliosphere are mostly thermalized at a location where there is a significant electric field, so are promptly swept along with the SW and out of the heliosphere. Almost all protons with energy higher than 800 MeV cannot be thermalized by the field unless they are involved in an inelastic collision. These protons also exit the heliosphere promptly, so contribute little to sustaining the potential.

In the range of kinetic energies of interest here, the primary GCR proton spectrum of differential flux versus energy is a power law with spectral index of –2.5. Consequently, if we imagine a hypothetical heliosphere which is smaller than the present one, the GCR flux density of protons which have energy near U enter the heliosphere at an exponentially greater rate. For example, if $U \approx 400$ MeV (factor of 2 less than 800MeV), then the proton flux density will be greater by a factor of $2^{2.5} = 5.7$. Such a large flux density of protons deposited in the smaller heliosphere would rapidly produce a high electric potential, causing the heliosphere to expand due to the greater energy density of the SW, thereby increasing U and decreasing the corresponding proton flux until equilibrium is reached between the flux and potential. Empirically, in this model, we know that equilibrium occurs when the heliosphere radius is 95 AU and the potential is 800 MV (and therefore U = 800 MeV). The equilibrium levels could of course change if the solar system moves into an area of the galaxy where the primary differential GCR proton spectrum is different, as has likely happened in the past.

STATUS OF SOLAR WIND THEORY

The fundamental cause of the SW has been controversial since 1951 when Biermann [5] conceived the idea that comet tails behave the way they do because of a continuous flow of corpuscular radiation from the Sun. Each new attempt to find the cause has led to more new problems than insights. Nicole Meyer-Vernet began her presentation on SW theory at the 2006 International Astronomical Union Symposium [6] with the following introduction:

> "Major properties of the solar atmosphere and wind are not understood. The energy distribution of the solar atmosphere perturbations, over nearly ten orders of magnitude in energy, is close (within one order of magnitude) to a power-law of index -2, even though there is no agreement on the detailed shape. There is no agreed explanation of the origin of the solar wind, either, nor of the fact that the total wind energy flux is independent of speed, latitude, and phase of solar cycle, with an average base flux of 70 W/m^2–a figure that is similar for a number of other cool stellar winds, and is close to the total observed energy flux of solar atmosphere perturbations. A major theoretical difficulty is that both coronal heating and wind production depend fundamentally on the heat flux, and the solar atmosphere is not collisional enough for classical transport theory to hold. Heat transport thus behaves non-classically and the particle velocity distributions may have significant high energy tails, which should dramatically affect coronal heating and solar wind acceleration, in a way that is outside the scope of standard MHD."

On another occasion [7] she observed:

> "Even though there is little doubt that the solar wind stems from the coronal temperature and energy flux—themselves produced by the solar output with the probable mediation of the magnetic field—the basic physics producing the large coronal temperature and the high speed wind acceleration is not known. Are Alfvén waves responsible? Are suprathermal tails responsible? Or both? Or some *Boojum* nobody has yet thought of?

CONCLUSION

I conclude that the mysterious energy flux responsible for the high temperature of the solar corona probably has nothing to do with accelerating the SW, and that the elusive *Boojum* mentioned by Meyer-Vernet [7] is the pervasive electric field that I have described in some detail in References [3] and [4]. The SW is the result of electrodynamic forces acting only on the proton component of the heliospheric plasma, driven by a pervasive, quasi-static, heliospheric electric field, which is sustained by the continual deposition deep inside the heliosphere of GCR protons in excess of GCR electrons.

A very large amount of data was collected during the passage of the two Voyager spacecraft through the TS. If the heliosphere is electrically neutral overall, which seems very likely, then a careful analysis of that data, devoted to the purpose, might reveal the presence of a large negative electric field in or near the TS. See Ref. 4 for a more detailed analysis of this idea.

REFERENCES

[1] A. Ehmert, "On the modulation of primary cosmic ray spectrum by solar activity", *Proc. Moscow Conf. on Cosmic Rays*, vol. 4, pp. 142-148, 1960.
[2] I. G. Usoskin, K. Alanko-Houtari, G. A. Kovaltsov, and K. Mursala, "Heliospheric modulation of cosmic rays: Monthly reconstruction for 1951 – 2004", *J. Geophys. Res*., vol. 110, no. A12, pp. 1 – 10, Dec. 2005.
[3] H. D. May, "A pervasive electric field in the heliosphere", (Part I), *IEEE Trans. Plasma Phys.* vol. 36, no. 5, pp. 2876-2879, Oct. 2008.
[4] H. D. May, "A pervasive electric field in the heliosphere (Part II), *On-line journal viXra*, http://vixra.org/abs/1005.0090 , 2010.
[5] L. Biermann, Solar corpuscular radiation and the interplanetary gas, *Observatory*, vol. 77, pp. 109-110, 1957.
[6] N. Meyer-Vernet, How does the solar wind blow? Some basic aspects, *Proceedings, IAU Symposium No. 233* on "Solar Activity and its Magnetic Origin", V. Bothmer and A.A. Hady, eds., 2006.
[7] N. Meyer-Vernet, "Aspects of solar wind physics", Contribution No. 89, January, 2005 (based on a talk presented at the Institut d'astronomie et de geophysique George Lemaître on October 8, 2004).

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Abstract: see page 1 of document

Content: see pages 1-4 of document

List of references: see page 4 of document