

A new cosmic rays acceleration process related to tachyonic (scalar) fields

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Abstract — The new acceleration scheme that we propose could be valid below 1 MeV and above 10^{20} eV. In between these two limits, the Fermi process is generally admitted as the acceleration mechanism for Cosmic Rays: shocks from supernova remnants are the motors for these mysterious particles spanning from protons to iron. Our scheme assumes only tachyons and their interactions with ordinary matter.

I.INTRODUCTION

In “Darker Side of the Universe ... and the crying need for some bright ideas”! [1] T. Padmanabhan argued that a) the existence of a component with negative pressure (in the universe) constitutes a major challenge in theoretical physics. b) The simplest choice for this component is the cosmological constant (CC); other models based on (faster-than-light i.e. tachyonic) scalar field do not alleviate the difficulties faced by the CC and – in fact – makes them worse. (c) The CC is most likely to be a low energy relic of a quantum gravitational effect ... one needs to get bolder.” A bold idea is that tachyons really exist [2], could be useful in astrophysics [3] and considered as the motor behind the cosmic ray (CR) acceleration process thanks to the tachyoelectric effect (TEE): absorption of a tachyon onto a bradyon, a particle slower than light. Our process could be in complement or in competition with the Fermi one [4].

II.THE CONCEPT OF TACHYON

The concept of tachyon, a faster than light “particle”, has been introduced by Bilaniuk, the late Deshpande and Sudarshan [5] and shown to be compatible with Special Relativity. The name Tachyon came from G. Feinberg [6]. The usefulness of tachyons for CR research was introduced in 1985 [7] and 1994 [8], then by Ehrlich whose model is consistent with five properties of CR Spectrum [9] and proposes a 4.5 ± 2.2 PeV neutron line [10]. A review is: [11] where four hints are suggested : the neutrino is left-handed; the shape of the cosmic ray spectrum has a knee related to the negative mass squared of the neutrino; cosmic ray neutrons would be present; the neutrinoless double beta decay is possible. (Two knees were even proposed [12] with right-handed polarized protons arriving on Earth.) About the existence of tachyons, Ehrlich proposes “(1) they are neutrinos, (2) they interact too weakly with bradyons to be observed, (3) they are created under conditions not yet tried – at higher energies perhaps.”

This overlooks the experiments we performed in the

period 1981-1987 showing the possible existence of the TEE and its astrophysical consequences, summarized in [3]. The timing experiments are very difficult to perform but tachyons could show up when absorbed onto a bradyon recoiling with the kinetic energy

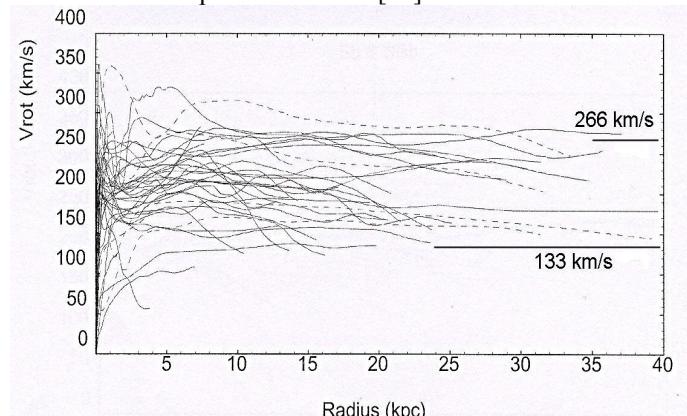
$$T = M^2 / 2m \quad (1)$$

where M is the pseudomass of the tachyon and m the mass of the bradyon (electron, proton, ion). This last one gains energy and momentum very specifically: a bradyon at certain energy-momentum is able to absorb one specific tachyon among the myriad of other tachyons surrounding it. TEE could take place in vacuum contrary to photoelectric effect (PEE) that necessitates the presence of a heavy particle (atom, molecule, and solid) to compensate the mismatch in momentum. The PEE does not take place on free electrons; otherwise stars are invisible and astronomers would not see remote galaxies.

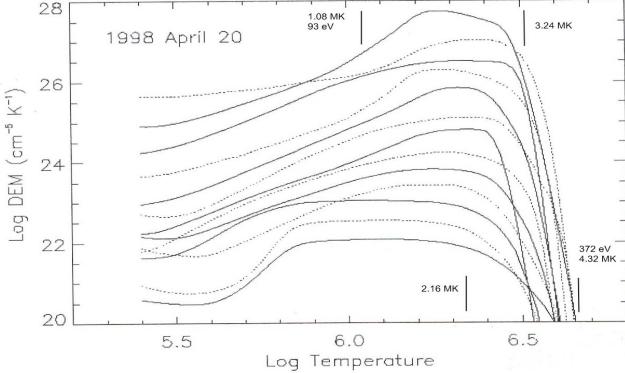
With $c=1$, one writes $E^2 - p^2 = m^2$ (Einstein relation) for bradyons (m is the mass you could put in a scale) and $p^2 - E^2 = M^2$ for tachyons with M a parametric “pseudomass” determined by kinematics. The experiments shown in [3], determined $M = 418$ keV by (1) from electrons recoiling at 170 keV. By the same TEE, protons would recoil at 93 eV, corresponding to a velocity of 133 km/s. If these protons are thermalized, they generate a temperature of 1.08 MK.

III. MULTIPLE TEE

Moreover, successive TEEs are possible on the same proton. If the absorbed momentum is always in the same direction, the velocities are 266, 400, 533 km/s etc... or $n \cdot 133$ km/s after n “fundamental momentum” (fm) or n “quantized” tachyonic absorptions. It is interesting to note that galaxies have a flat rotational curve bracketed between our proposed 133 and 266 km/s, when distance from the center above 15 kpc is considered [13]:

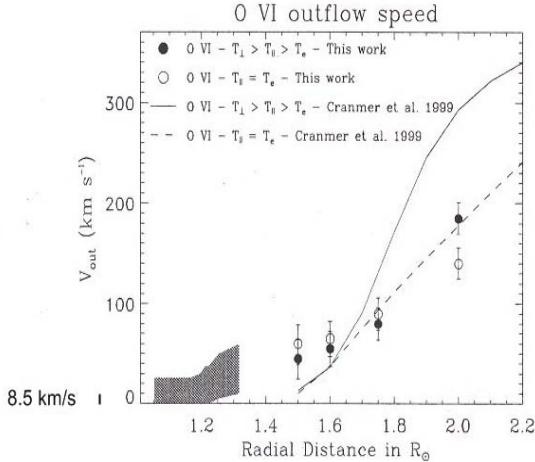


The heating of Solar corona seems to be a big mystery. Common wisdom proposes magnetic reconnection, microflares, and nanoflares as the source of this energy. If $n=1$, a 93 eV proton has a temperature of 1.08 MK, the order of magnitude of Solar corona one. If $n=2$, 372 eV, the temperature is 4.32 MK well above the maxima temperature of the corona. Here we present a loop Differential Emission Measure performed with CDS on SoHO [14]:

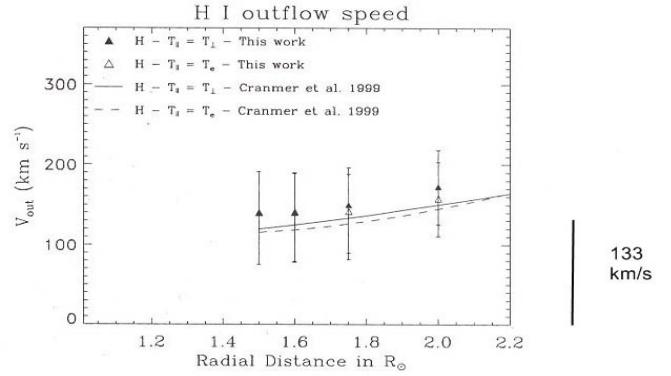


These heating fm would come from the center of the Sun, where gamma rays originating from nuclear reactions would be converted into the conductive core, in analogy with our experiments [3] where gamma rays of *different energy* radioactive sources produced the same bump in the spectra, always at the *same energy*: 170 keV in the NaI(Tl) detector. There was a slight indication in our experiment [2] that fm could behave as light magnetic monopole: metals were repulsive. (Magnetic fields would accelerate fm.)

Solar wind has a velocity of about 400 km/s at the equator and 800 km/s at the pole. This could be related to $n=3$ and $n=6$ multiple fm absorption. The proton velocity would be in proportion to the fm flux. For heavier particles like Oxygen VI, the initial recoil velocity would be less: 133/16 = 8.3 km/s but of the same momentum. This has been observed at the surface of the Sun: about 8.5 km/s [15]:

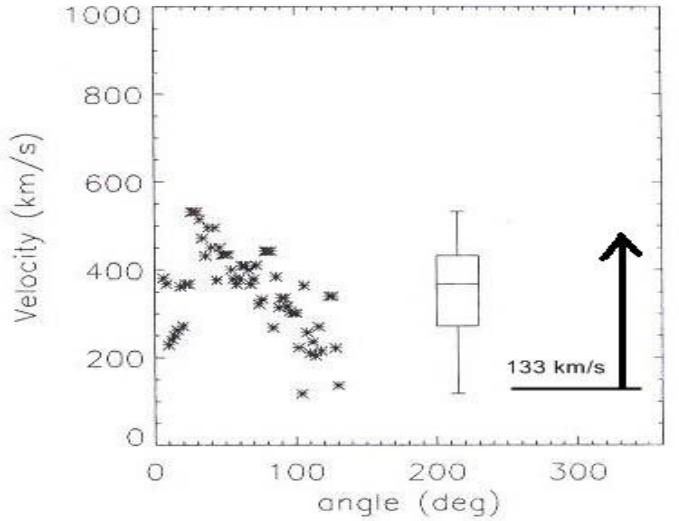


Oxygen progressively increases its velocity up to about 200 km/s, probably via a step-by-step process, immersed in the fm flux. In the mean time Hydrogen stays at about (the initial) 133 km/s, leaving probably the flux more rapidly:



Iron would recoil initially with $133/56 = 2.38$ km/s; to our knowledge, such a measurement has not been performed.

The most spectacular events on the Sun are Coronal Mass Ejection (CME). Velocities have been obtained by the Brussels group. The panel below shows “CME velocity profile as a function of the angle, which runs counterclockwise from the North. A box-plot is drawn: the box itself contains the middle 50% of the measured speeds. The whiskers at both ends indicate respectively the minimal and maximal detected speeds. Note that the whiskers are not error-bars, but indicate the range of the measured speeds” [16]. All the speeds are above our proposed 133 km/s.



IV. INJECTION AND ACCELERATION

Supernovae are still the most probable CR sources in the Galaxy [17]. Diffusive Shock Acceleration is the most likely mechanism for producing cosmic rays but several key elements like *injection* of thermal particles remain poorly understood [18]. (These authors consider a temperature of Diffusive Shock starting from 60 to 170 keV.) Our scheme could start with particle at rest or thermalized. Successive fm absorption is maybe a key process for an efficient *injection*, not related to Alfvén wave heating. With TEE, a suprathermal or non-Maxwellian tail already at the base of the corona is easy to produce. M. Aschwanden [19] pointed out that such an *injection* at 200 to 400 km/s is necessary to

validate the “velocity filtration” model for corona heating, but difficult to test.

The big question is acceleration! By successive fm absorption (sfma), the highest energies could be obtained, provided there is a source of fm of the right energy and momentum. For instance, a proton could reach 2 GeV after about 4058 fma. The next step in the “quantized” acceleration toward 4059 fma requires 1.24 MeV, a type of energy available at the center of the Sun. That value is obtained by iteration using a scheme involving mass m and pseudomass M: $r = (M/2m)^2$ $R = (1 + 1/r)^{1/2}$.

(R and r are working parameters.)

From initial kinetic energy t and total energy $E = t + m$ and momentum $p = (t(t+2m))^{1/2}$ one obtains by conservation of energy and momentum the new kinetic energy

$$T = t + 2r(E + pR) \quad \text{or} \quad T = t - 2r(E + pR).$$

(The minus sign gives a deceleration even when the proton is imbedded in a tachyonic gas; this could be a “cooling flow” as seen in the corona or galactic winds.)

The gain in kinetic energy is $T - t$ and the relative gain is $(T - t)/t$.

The above equations could be implemented easily in any spreadsheet. (Excel, OpenOffice.org Calc...)

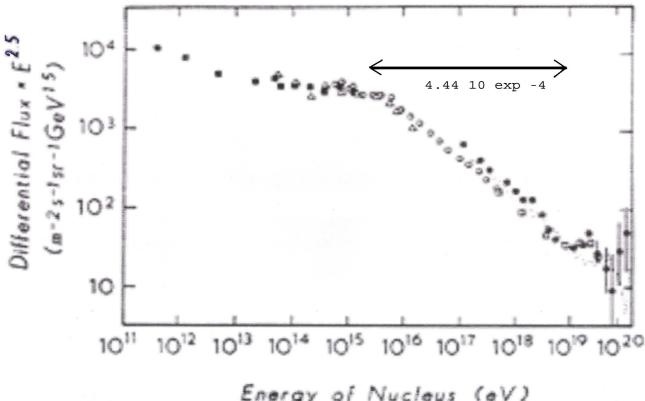
For very high energies $E = t = p$, the relative gain is

$$2r(1 + R)$$

For protons, $r = 4.96 \cdot 10^{-8}$, $R = 4472$ so the relative gain is

$$4.44 \cdot 10^{-4}$$

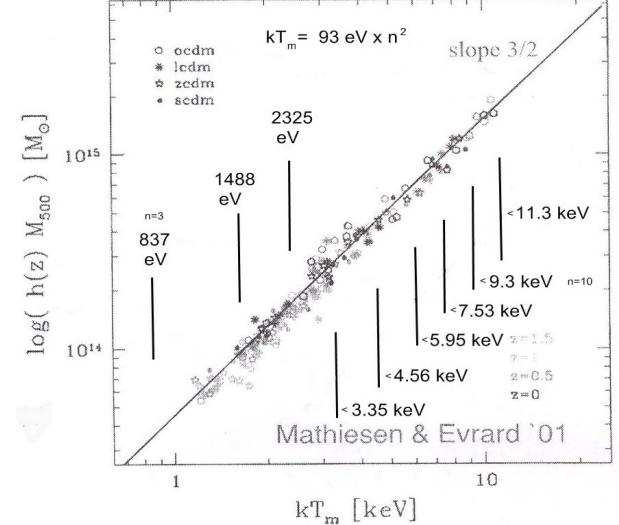
If the knee is at $3 \cdot 10^{15}$ eV and the ankle at $8 \cdot 10^{18}$ eV, the ratio is $3.8 \cdot 10^{-4}$ close to our $4.44 \cdot 10^{-4}$, within 17 %.



This would mean that fm at the knee energy are able to accelerate protons at the ankle energy. But from where are coming these putative fm? From black holes at the centre of galaxies? From big bang? From residues of the inflation? If a fm is absorbed onto a 10^{22} eV proton, it was

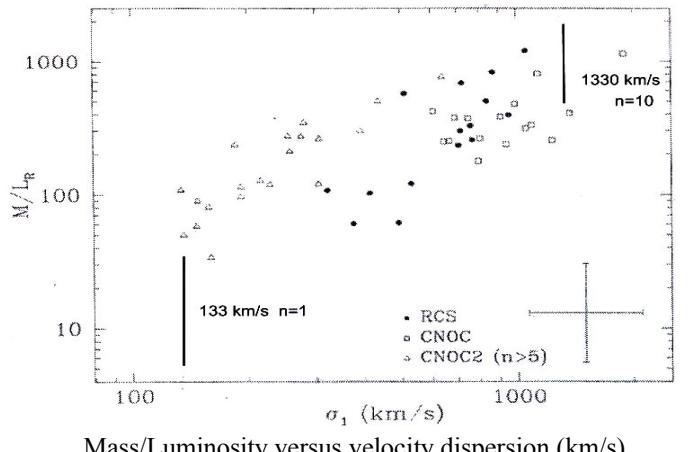
probably present in the universe since the big bang: these fm were just waiting the right partner. (Mgr G. Lemaître [20] was expecting cosmic rays from his “Atome Primitif”. He is maybe right indirectly; only the fm would appear at the instant of the big bang not the ankle proton energies.)

As already pointed out, fm could heat the Solar corona to about 1 MK. By sfma, one could get $kT_m = 837$ eV, $n=3$, to $kT_m = 11.3$ keV, $n=11$ (93 eV $\cdot 3^2$ to 93 eV $\cdot 11^2$) for clusters of galaxies as seen in a diagram [21]



relating log(mass (in solar units)) of various galaxy clusters versus temperature of the gas, a possible consequence of the fm flux, where each star contributes to it.

The study of the dynamical mass of galaxy clusters [22] shows a velocity dispersion σ_1 just above our proposed 133 km/s and maximize at about 1330 km/s corresponding respectively to one and ten fma ($n=1$ and $n=10$), with all the possible values in between :



Mass/Luminosity versus velocity dispersion (km/s)
(the cross indicates the errors)

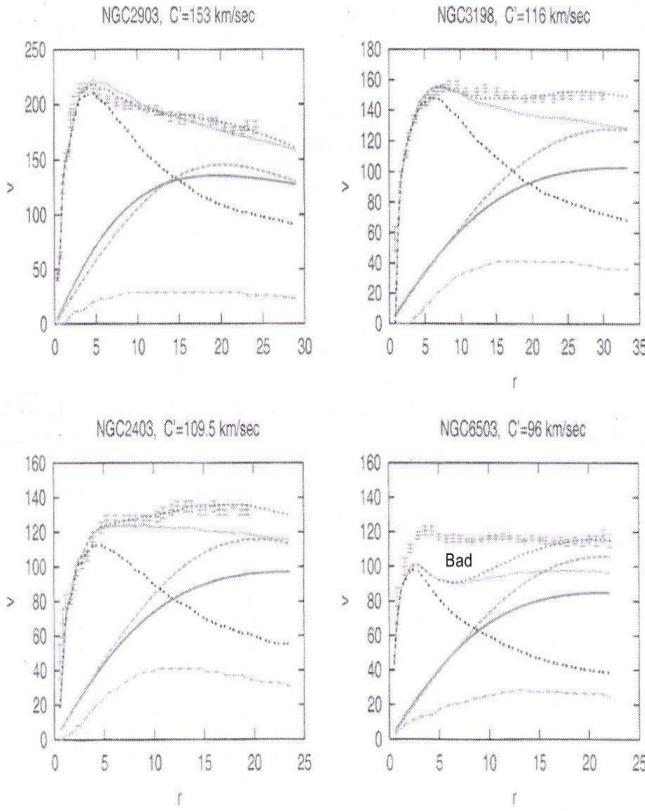
The Bullet Cluster observed by M.Markevitch and collaborators [23], shows temperatures around 69 MK, 6 keV, $n=8$ and around 108 MK, 9.3 keV, $n=10$. This cluster seems to provide the first direct, model independent proof of the Dark Matter (DM) existence thanks to gravitational lensing. The Modified Newtonian mechanics hypothesis

(MOND) is now unnecessary. Like the photon, having energy and momentum (a famous tensor), fm could be trapped by gravitation. It is probably too early yet, to be certain that DM is tachyonic. Nevertheless, what we write above about the heating by “fundamental momentum” in diverse situations is maybe a step in that direction. (There is maybe a new (broken) symmetry between the electron ($m=511$ keV) and the tachyon ($M=418$ keV).)

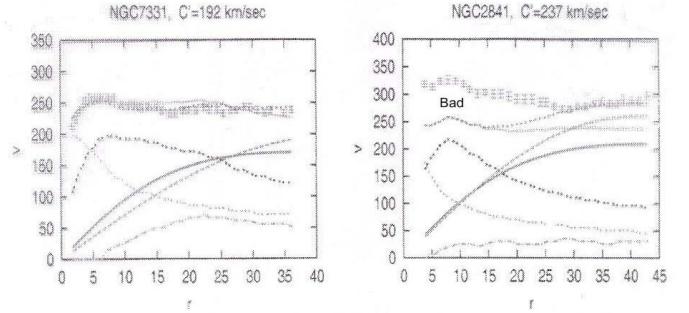
V. SCALAR FIELDS

If DM is tachyonic, what about Dark Energy (DE), that accelerates the expansion of the universe ? It has been proposed that Inflation, DM and DE are unified in a string landscape [24]. A single field would be sufficient. Unification seems more difficult with only DM and DE.

Nevertheless, attempts have been made. DM clusters gravitationally at galactic scales while DE dominating at large scale, does not cluster. M.B. Causse takes into account a scalar field, a rolling tachyon arising from string theory, which seems to be capable of explaining the observations at different scales [25]. She is able to fit the rotation curves of galaxies NGC2903 ($V_{\max}=216$ km/s), NGC3198 ($V_{\max}=157$ km/s) and NGC2403 ($V_{\max}=136$ km/s) with success. For NGC6503 ($V_{\max}=121$ km/s), something is missing between 2 kpc and 15 kpc, maybe a fm flux from the putative central black hole:



For galaxies with bulge: NGC7331 ($V_{\max}=257$ km/s) the fit is good, NGC2841 ($V_{\max}=326$ km/s) the fit is bad between 5 and 25 kpc. (v: velocities in km/s, r: distance in kpc)

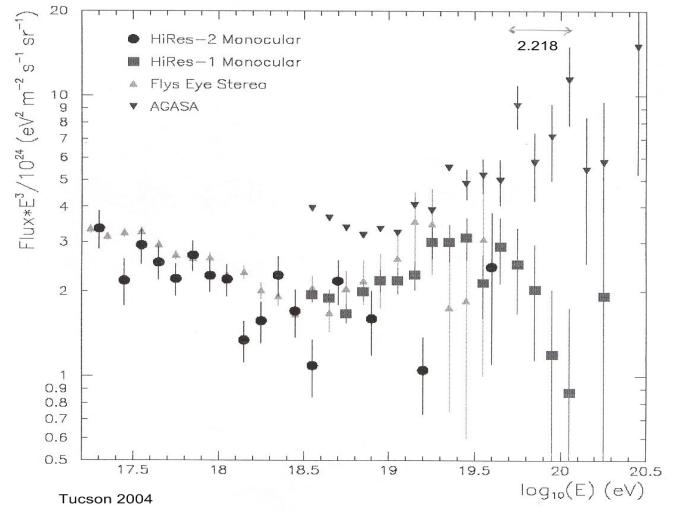


VI. ELECTRONS

The TEE concept could also be applied to electrons. The various recoil energies are 170 keV, 798 keV, 2.3 MeV, 5.7 MeV, etc [3, p 400]. For very high energies, the relative gain in energy is 1.218 and $T=2.218 t$. So, at each acceleration step, the kinetic energy is more than doubled.

The energy of 170 keV is maybe related to SGR 1806-20 (Soft Gamma-ray Repeater) whose flare December 27th, 2004 shows a blackbody temperature with $kT = 175 \pm 25$ keV [26] but there is also a power-law component.

It is not clear if the AGASA experiment shows two peaks, around 10^{20} eV. (The collaboration AUGER does not see such events yet.) The statistics is low but a distance of about 2.218 (log scale) seems to be present [27]:



If true, it would mean that electrons are present at these energies! They are not coming from very far away in the Galaxy [28], but could originate from the Ehrlich chain: $p \rightarrow n \rightarrow p \rightarrow n \rightarrow p \rightarrow n \dots$ where neutrons are important from 10^{19} to 10^{20} eV (proton decay in flight) [9].

VI. CONCLUSION

P.C.W. Davies [29] considered that some DM might be in the form of tachyons. Here we conjectured that DM and DE both are in the form of fm. These fm seem to have a role in

Solar corona heating, solar wind acceleration, inter-clusters of galaxies gas heating and Cosmic Ray acceleration mechanism. The Workshop [30] concluded : "A strong observational confirmation of the existence of cosmological scalar fields will start out a new revolutionary era, not just for physics and cosmology but for science as a whole." Moreover, scalar ($s=0$) or vector ($s=1$) tachyons would be a conceptual evolution as a motor of Solar wind and CR.

ACKNOWLEDGMENT

We want to thank all the organizers of 20th European Cosmic Ray Symposium for bringing us to the level of the latest development, for giving us the opportunity to present a poster n° 48 concerning our ideas, already summarized at the "New Worlds in Astroparticle Physics", Faro, Portugal, 2000 [31]. We thank also Prof. Jules Deutsch, UCL, for pointing us the works of Roman Tomaschitz [32]. Our wife Bethy was very encouraging and helped us a lot mastering the intricacies of Word 2002.

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Historical remark: Formula (1) was proposed by Y.Terletskii (1963, then 1968) and E. Recami (1978), both with no relation to experiments.