Cosmic Luminous Shock Waves
(*and atmospheric events*)

Russell Bagdoo

rbagdoo@gmail.com
Russellbagdoo@outlook.com

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Abstract

We hypothesize the existence of cosmic luminous shock waves which might participate in the formation of clouds and severe weather events, such as tornadoes, hurricanes. These waves would have the peculiarity to be created and modulated by the shock of the galactic cosmic rays with the particles of the solar corona: the energetic particles of cosmic rays collide with atoms of the solar atmosphere, shatter them, with the result that the velocity of the ultra-relativistic electron in the solar plasma might be greater than the speed of light in this medium. What, in particular, would produce a secondary radiation of higher intensity analogous to that of the shock waves radiating in liquids by Cherenkov effect. Their existence may be linked to a visual phenomenon called «experience of bright light flashes» with which all the astronauts are confronted. There would be a Cherenkov radiation in higher atmospheric layers and in the solar plasma, similar to that which exists in liquid medium, suitable for modifying the albedo of the planet and strike the eyes of people in space.

1
Introduction

1 – I. Cosmic rays

Cosmic rays are energetic charged subatomic particles originating from outer space and that seep into our atmosphere. Their genesis derives from many sources including the Sun, the galaxy and other galaxies. They were discovered due to the ionization they produce in our atmosphere. They have an extreme range of energy of incident particles, what allows the physicists to study the aspects of their field which cannot be studied in any other way. The Earth receives an ionizing radiation from the cosmos formed by particles moving at nearly the speed of light. It is composed of two components, one linked to solar activity, the other of galactic origin [1].

Solar origin. The Sun is the root of the sporadic and random component of cosmic radiation. The star ejects particles that are continually added to the galactic radiation with an intensity that varies in a cycle of eleven years. These particles having a lower energy than those of galactic origin, only a small fraction of them reaches the Earth's surface and they are not evenly distributed.

Galactic origin. The permanent component of cosmic radiation draws its genesis in the galaxy. It is formed of particles ejected by the supernova explosions. These particles are atoms private of their electrons because of the high temperatures in these massive agonizing stars. They are of different types, mostly hydrogen nuclei (protons: 85%) and helium (alpha particles: 12.5%), but also heavier nuclei (1%): iron, nickel, cobalt, carbon, oxygen, nitrogen.

It was also discovered a small amount of atomic nuclei of light elements: lithium, beryllium and boron. There are also the electrons (1.5%) [2]. The galactic cosmic radiation is isotropic and continually exposes the entire surface of the Earth.

A part of the galactic radiation is deflected by the magnetic field conveyed by the solar wind. Indeed, the characteristics, especially magnetic, of the flux of particle escaped from the Sun's atmosphere, vary with solar activity and induce a field that keeps away the cosmic radiation of the Earth. It is during periods of large solar activity that the Sun's magnetic field can more effectively deflect Earth cosmic radiation. When solar activity is minimal, the magnetic field loses its ability to deflect cosmic rays. There is a decrease of about 40% of the cosmic ray intensity between the minimum and maximum solar activity. The known solar activity cycle of eleven years permits to foresee on several years the exposure to galactic radiation.

1- II. The radiation in the terrestrial environment

The latitude and altitude, and the stage of the solar cycle, establish the quantity, or intensity, of cosmic radiation. Like all electrically charged particles, ions that constitute the cosmic rays are directed or deflected by magnetic fields like a compass needle. However, the Earth is a large magnet surrounded by a magnetic field whose lines of force enter by the North Pole and go out by the South Pole: it is the magnetosphere. If the cosmic particles possess energy which is greater than a certain threshold, *i.e.* the magnetic cutoff energy, they will cross through the magnetosphere and reach the upper layers of the atmosphere. But if their energy is not sufficient, they will tend to follow the lines of force of the magnetic field and will reach the poles which undergo an irradiation superior to that of the equator.

1- III. Can cosmic rays influence the Earth's climate?

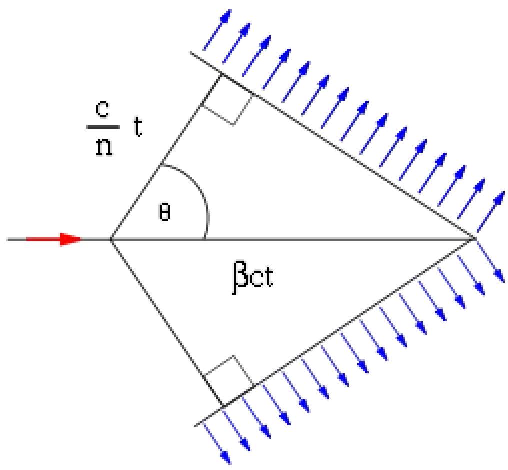
Modulated by the magnetic field of the Sun, has the flow of the galactic space rays an impact on the climate, via the formation of clouds modifying the albedo of our planet? An experiment conducted in Denmark, already shows that a link is actually possible. Another one, Cloud (Cosmics Leaving Outdoor Droplets) at CERN [3], proposes to determine the possible influence of galactic cosmic rays on clouds and climate of the Earth, by studying their microphysical interactions. Indeed, the amount of clouds, their characteristics and their presence at various altitudes have repercussions on the radiative transfer of solar energy. Depending on the case, by reflecting radiation from the Sun or by trapping the one from the Earth, clouds can affect negatively or positively on the evolution of the average temperature of the planet. Yet, we suspect for some time that the intensity of cosmic rays falling on Earth modulates partially the quantity of present clouds in the atmosphere at given heights.

In Part 2, the hypothetical existence of shock waves of light that would be created and modulated by the collision of galactic cosmic ray particles with the particles of the solar corona. In Part 3, discussion on the journey of shock waves of light and their impact on the formation of atmospheric events through the condensation of clouds. Moreover, a look on the Light Flash phenomenon in space.

2
Plausible existence of shock light waves due to a Cherenkov effect in the solar plasma

2 – I. Cherenkov radiation

The theory explaining the appearance of Cherenkov (also known as Vavilov-Cherenkov) radiation was developed by Tamm and Frank in 1937. It proves that Cherenkov had actually discovered a new type of light radiation. The explanation was that an electron moving in a liquid interacts violently with atoms it encounters on its way and the electrons of these atoms also begin to radiate. Therefore, in matter appear light waves from the moving electron which are scattered in all directions. If the speed of the electron is less than that of light, the light waves coming from different regions of its trajectory are mutually damped and we do not see them. But if the electron velocity exceeds the speed of light in a substance, the light waves emitted by the electron as it moves are added the one to the other, giving rise to a light wave which goes away in the form of a cone [2, 4]. It is the conical distribution of the light in the direction of movement of electrons that is called "Cherenkov radiation." Thereafter, Cherenkov demonstrated that positively charged particles – mesons, protons (hydrogen nuclei), nuclei of heavy elements – were also able to emit some light, if their speed was high enough.



The geometry of the Cherenkov radiation (*shown for the ideal case of no dispersion*) [5].

2– II. Hypothesis of a radiation in the solar plasma

The speed of light c_1 in a liquid medium is less than the speed of light c in the empty space. The velocity v of the electron in the liquid is greater than the speed of light in this liquid and less than the speed of light in space.

$$c_1 < v < c. \qquad (1)$$

It is possible that a similar phenomenon could happen in space, in the solar wind. The value determined by the properties of the medium (solar atmosphere, solar wind) is designated $c_1(w)$. The speed limit of the material bodies is the speed of light in vacuum. The speed of light in the solar plasma could be less than the speed of light in empty space, $c_1(w) < c$. The velocity v of a charged particle at high speed could be higher than the speed of light in this plasma. If $v > c_1(w)$, the charge moving in the medium with a constant speed begins to radiate, and if $c_1(w) < c$, this condition is completely filled without violating the requirements of the theory of relativity

$$c_1(w) < v < c. \qquad (2)$$

More these waves are added to each other more they give birth to frontal waves in the form of a narrow cone. So that the radiation generated by the particle would cause luminous shock waves, *i.e.* a Cherenkov radiation. The phenomenon is similar to an airplane which moves faster than the sound in the air and creates a shock wave on which all the sound waves meet.

2- III. Cherenkov effect in the solar plasma by the shock of extragalactic gamma rays

We assume that the electron velocity from the shock with a gamma ray (or γ-ray) will be greater than that of the intact electron coming from the corona and that the light waves will reinforce each other. The interference of each of the waves emitted by each atom disturbed, and also of the waves emitted by the ultrafast electron itself, is then constructive. A coherent wavefront is shown as a cone of light. The frequency of this constructive wave corresponds to the blue or ultraviolet of the Cherenkov effect in water and also to the blue luminosity of the water surrounding the heart of a nuclear reactor.

The sources of gamma radiation in the universe are known since 1948 but have been observed only since the early 1960s. In fact, the gamma photons are almost completely stopped by the Earth's atmosphere. The cosmic gamma radiation source is resulting from the most violent events in the universe: relativistic jets produced by supermassive black holes, gamma ray bursts, etc. The energy of the gamma photons emitted can reach many hundreds of GeV [4]. They are the highest-energy form of light, however, they are invisible to the human eye. There would be more interstellar and intergalactic γ-rays than expected. Incidentally, in November 2010, scientists at the Fermi telescope announced the discovery of two giant gamma ray bubbles emitting gas which appear to come from the center of the Milky Way Galaxy. The origin of these huge structures, which are roughly half of the Milky Way's diameter, and extend 25,000 light-years north and south of the galactic center, is not known, but speculation is considering that they might be "burps" from the massive black hole at the center of the galaxy, or perhaps, they are leftovers from a period of intense star-formation. Sure thing, the center of the galaxy shelters any sorts of wild and woolly high-energy phenomena, including a gigantic black hole and violently spinning pulsars. Cosmological theories suggest that dark matter would be concentrated there and that collisions of dark matter particles could produce showers of γ-rays. These energetic radiations suffer negligible absorption and travel in straight lines from their source toward the solar system. In this regard, γ-rays differ from cosmic rays which, being charged particles, have their motions continually altered by interactions with cosmic magnetic fields [6].

We also know that the solar corona emits many electrons in the direction of the Earth. A coronal mass ejection (CME) is a massive burst of solar wind, other light isotope plasma, and magnetic fields rising above the solar corona or being released into space. CMEs releases huge quantities of matter and electromagnetic radiation into space above the Sun's surface, either near the corona or farther into the planetary system or beyond (interplanetary CME). The ejected material is a plasma consisting primarily of electrons and protons, but may contain small quantities of heavier elements such as helium, oxygen, and even iron [7].

Presumably near the solar corona, when there is an higher flux of γ-rays from the galactic center, or when there is a maximum of solar activity, the particle velocity after the collision with a galactic γ-ray will be greater than that of an intact particle from the corona. The speed of photons in this plasma where the number of occurrence is great will be slightly lower than a photon in a vacuum, but sufficient to produce light waves [8].

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2- IV. Two types of interactions between cosmic gamma radiation (γ-ray) and solar plasma

Laboratory studies of high-energy interactions utilizing proton accelerators have provided much information on the nature of the interactions up to ~30-GeV energies which produce γ-ray. This information has been supplemented by studies of cosmic-ray interactions at higher energies occurring in the atmosphere. The knowledge gained from earthbound studies of high-energy interactions may then be applied to solar and astronomical problems involving cosmic-ray and annihilation phenomena. In passing through matter, gamma radiation ionizes via three main processes: Compton scattering, pair production and the photoelectric effect.

There are two types of interactions of absorption of γ-rays through interactions with matter, solar plasma in this case. The first is the Compton scattering interaction

$$\gamma + e^- \rightarrow \gamma + e^-. \qquad (3)$$

Electrons play the dominant role in the Compton scattering of γ-rays. Compton scattering does not eliminate the γ-ray per se, but will in all probability result in the transfer of some of its energy to the electron. For γ-rays of energy $E\gamma > mc^2$, almost all of the energy of the γ-ray is absorbed, and then we can consider that the γ-ray has "disappeared."

The second type of γ-ray absorption process in matter involves the conversion of a γ-ray into an electron-positron pair in the electrostatic field of a charged particle or nucleus. If we designate such a charge field by the symbol CF, such an interaction may be symbolically written as

$$\gamma + \mathrm{CF} \rightarrow e^+ + e^- + \mathrm{CF}. \qquad (4)$$

The conversion interaction, or pair-production, has a cross section that involves an extra factor of the fine structure constant, $\alpha = e^2/hc$, since it involves an intermediate interaction with an electrostatic field. The threshold energy for pair-production in the field of an atomic nucleus is $2m_ec^2$. In the case of pair-production in the field of atomic electrons, the threshold energy for (4) is $4m_ec^2$. It is an interaction in which γ-rays lose energy to the electron of thermal energy.

In the case of the effects of the solar radiation field on the intensity of cosmic γ-rays, there is a total absorption of γ-rays through interactions with radiation. It is a pair-production in which the energetic cosmic photons disappear

$$\gamma + \gamma_s \rightarrow e^+ + e^-, \qquad (5)$$

where γ represents the cosmic gamma ray and γ_s the low-energy solar photon with which it interacts. This process can only take place if the total energy of the γ-rays of the interaction is greater than or equal to $2m_ec^2$ [9].

2- V. Mechanism of formation of a light wave shock

We assume that the speed of light in the solar plasma tends to be less than the speed of light in vacuum. This can be compared to a transparent material medium with an index of refraction n. The speed of light in that medium is $c_1 = c/n$ (by definition of the refractive index). So the speed of a photon emitted by a solar electron in the solar medium would have a speed slightly less than the speed of light in the vacuum. It is therefore quite possible that very light and energetic charged particles can move in the considered plasma at a speed v greater than $c_1(w)$, (2). On this matter, the gamma rays arriving near the Sun strike the electrons of the Sun, so that they produce electrons moving faster than not struck solar electrons. These charged particles at very high speed, in addition to emit photons interact violently throughout their trajectory with a medium through which they cross. Indeed, they temporarily disrupt the polarization of the electron shells of atoms encountered, causing a radiative emission. So, each atom met by the particle becomes in turn a radiation emitter. This emission is thus provoked at the $v_{e\text{-}g}$ speed of the very high-speed electron. It turns out that the transmitted wave propagates at a speed $v_{e\text{-}s}$ less than $v_{e\text{-}g}$, but greater than $c_1(w)$

$$c_1(w) < v_{e\text{-}s} < v_{e\text{-}g} < c, \qquad (6)$$

what typifies a luminous shock wave.

(The speed $v_{e\text{-}g}$ of the ultrafast electron originating from the shock with gamma rays in the solar plasma is greater than that of the photons emitted by the solar electron at velocity $v_{e\text{-}s}$ and less than the speed of light c in the space.)

3
Discussion: Cosmic luminous shock waves and atmospheric events

3- I. Magnetosphere

The solar wind, a stream of charged particles, primarily electrons and protons, caused by the solar corona, is flowing outward from the Sun, through the solar system at speeds as high as 900 km/s and at a temperature of 1 million degrees Celsius. Our planet is at all times stemming the tide of this persistent plasma. The terrestrial magnetic field takes over when its outer rim cuts the solar wind like the V-shaped crest of the wave of a moving ship.

The region in which the magnetic field governs the large-scale dynamics of the ionosphere is the magnetosphere, starting at height of about 150 km and extending tens of thousands of km into space. In its lower parts, it includes most of the ionosphere, taken to begin at 60-70 km. At very high altitude, the short, energetic wavelengths of the Sun's radiation split a substantial fraction of air molecules and atoms into component parts, and the atmosphere is enriched in free electrical charges: electrons, positively charged atoms, molecules stripped of one or more electrons, ions [10].

The outer regions of the magnetosphere contain the two Van Allen radiation belts – doughnut-shaped concentrations of protons and electrons circling Earth above the magnetic equator, at distances of 10,000 and 20,000 km. The inner belt contains mostly protons. The outer belt, which receives the solar wind, mainly contains electrons. It turns out that a large number of electrons and protons oscillate along the lines of force of the magnetic field without being able to reach the surface of the Earth or to escape into interstellar space. These particles, trapped by the planet's magnetic field geometry, have solar origins, or may have arrived originally from galactic space [2]. We anticipate that under the effect of the shock of the galactic cosmic rays with the particles of the solar corona, the solar atmosphere becomes a source of luminous shock waves that the Earth's magnetic field hampers by no means. As they are deprived of electric charge, they penetrate freely inside the gigantic trap of cosmic particles, consisting of two belts. These waves head straight while the particles, without slowing down, are forced to describe loops around the Earth. The particles whose energy commonly exceed the MeV can remain trapped in the magnetic field for several weeks. Neutral as a neutron, a luminous shock wave would be able to pass through the Van Allen belts and the Earth's ionosphere and its intensity would be strengthened when it reaches the atmosphere, especially during an upsurge of solar activity.

Between the magnetic field and the level of the sea, the atmosphere undergoes an increase of density. At a height of 500 km, the density is a million-millionth of sea levels, at 100 km, it is about one millionth. The intensity of cosmic radiation is about 100 times greater at altitudes where are moving commercial aircraft than on the ground. Arriving in the upper layers of the atmosphere, the ions interact with the atoms they encounter. From these collisions are born cascades of new particles. It is this secondary radiation, composed in particular of charged particles and neutrons, which reaches to the ground, when the primary particle has a sufficient energy. At ground level, cosmic radiation is only 11% of ionizing radiation.

3- II. Troposphere

It is these bottom 20 km or troposphere, that impinges most upon us, for this is where we live. The troposphere contains about 90 percent of the total air mass and much of the atmosphere's dynamical energy. At 20 km above the ground, the air is compressed by a factor of ten. It is within the outlying fringes of the Earth's inner atmosphere that the solar energy breeds the cloud as well as the thunderhead. The solar energy input creates the evaporation-precipitation cycle – prime mover of hurricanes and typhoons – and drives the atmospheric circulation [11].

Weather is of itself an elusive concept. The major source of difficulty lies in the absence of an accurate theory of meteorological processes and of a complete mathematical theory to describe the hydrodynamics of a miscellany of phenomena. The exact prediction of complex flows is impossible; the system is not deterministic [10]. Scientists have hypothesized that cosmic rays can affect the earth by provoking changes in temperature and by causing the formation of clouds in the upper atmosphere, after that their particles have been colliding with the particles in the troposphere and have been disintegrated into pions, muons, etc. Do luminous shock waves stand a chance of participating in this cosmic shower? Could they act on clouds and cause the formation of severe weather events, such as tornadoes, hurricanes? How?

We can suppose a photoelectric effect, in which the photon of a cosmic luminous shock wave interacts with an atomic electron, transfers its energy, thus ejecting this electron from the atom. The kinetic energy of the resulting photoelectron is equal to the energy of the incident photon of the luminous shock wave minus the binding energy of the electron. If the photoelectric effect acts on ice particles of high-altitude clouds or on the water droplet at lower altitudes, and it makes one droplet coming close to another, electrical forces may draw them together and the particles coalesce. This process can gather speed and produce larger, heavier droplets that fall as rain. These luminous shock waves could heat up the low-level air layer, dilate it and form fluffy clouds or thunderheads. Under certain conditions (convection, front, sharp drop in temperature), they could contribute to a very unstable regime and generate severe weather events. Luminous shock waves could even be related to electromagnetic effects and lightning associated with the storm environment when tornadoes occur.

3- III. Light flashes: photons or fermions?

We claim that these supposed shock waves of light could also explain the light flash phenomenon whose cause is not yet known. This refers to abnormal visual sensations reported by astronauts during space flights. The first report of brief flashes of white light dates back to 1969 by astronauts on an Apollo-11 flight to the moon. Subsequently other crews of Apollo, Skylab, Apollo-Soyuz missions, MIR Space Station reported similar experiences. Flashes are perceived in multiple shapes and dimensions: stripes, multiple tracks, stars, explosions, etc. Several theories that have been advanced are the direct interaction of charged particles with the retina by ionisation, the Cherenkov light in the vitreous [12, 1], indirect effect from protons knocked out by neutrons or from alpha-particle. It was also proposed that scintillation in the eye lens could produce the observed flashing lights. Very early, the explanation of the origin of the flashes was the Cherenkov radiation from energetic cosmic rays traversing the eyeball. Although it had been the most widely accepted explanation, dissatisfaction came from indications saying that light from this source is quite faint. On the other hand, the results of ALFMED and MIR tended to assert that all or most of the flashes observed may be provoked by direct interactions of cosmic rays with the retina [13, 14, 15].

However, the exact mechanism remains unexplained. The agreement of the experimental results with the most likely mechanism – creation of a Cherenkov radiation when the particle of cosmic ray passes through the human visual apparatus – suggests that these sudden phenomena could be caused as well by particles, charged or uncharged, than by luminous shock waves associated with the photons of the optical spectrum. Do the bullets at the subatomic scale that cross astronauts, strike their eyes by triggering signals interpreted by the brain as light flashes, are exclusively fermionic? Is the photon the major player? We believe that the mechanism proposed in the above section 2-V produces some much stronger Cherenkov radiations, which corroborate the explanation originally approved. The actual existence of cosmic luminous shock waves should seriously be considered in future tests in order to elucidate the light flash enigma.

Conclusion

We assume a cosmic luminous shock wave satisfying the equations of special relativity that would move to a sub-light speed, that is to say less than the speed of light in vacuum. Although such a type of wave however has no proved physical reality in 2014, the Cherenkov effect – which produces a flash of light when a charged particle traverses a dielectric medium at speeds that are greater than those of light in that medium – can be a formal indication of a form of ionized gaseous medium between the Sun and Earth which can predict this type of wave similar to a shock wave. If their existence was demonstrated, the consequences would be significant as much at the level of climatology than of astronautics. Their flows could have an impact on the formation of atmospheric phenomena by photoelectric microphysical interactions and intensive radiative transfers of solar energy. These waves might also be an effective cause of the strange flashes that have complex neuro-physiologic effects on the astronauts.

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