On the Singularity at Light Velocity

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The Michelson-Morley experiment[1, 2] failed to detect evidence for the wind of luminiferous aether. However, the fact that light propagates without affecting aether wind on the rotating earth means that the medium is also rotating with us. For a compressible medium, effects due to the compressibility are not negligible if the velocity of matter is comparable with light velocity. In this article, we show that matter can form a compressional shock wave in the luminiferous medium, and the singularity at light velocity does not actually exist, by applying the theory of compressible flow. The observations of short-lived particles[3] and light echoes from supernovae[4–7] support this inference.

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> Shock waves are an essential feature of transonic flow, as we know today, and their appearance on a moving body leads to a rapid increase in drag coefficient with increasing Mach number. The new phenomena encountered in this range were, in fact, so baffling to many aerodynamicists used to low-speed, incompressible flow, that the myth of the "sonic barrier" arose. This in spite of the fact that there had already been almost a century of experience with artillery shells, which reach supersonic muzzle speeds and have to decelerate through the speed of sound during their flight.
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> H. W. Liepmann and A. Boshko,
> *Elements of Gasdynamics*[8]

BACKGROUND

The concept of plenism, derived from the discussion on Zeno's paradoxes, has a long history since the time of Aristotle[9]. The theory, which states that nature contains no vacuums, was rejected for gases by Torricelli in the 17th century[10], and apparently rejected for luminiferous aether[11] by Michelson and Morley in the 19th century[1, 2]. To resolve this issue, the theory of Lorentz transformation was formulated[12], although it also introduced the concept that nothing can move faster than light, because of the singularity at light velocity. However, we should note that general relativity predicted that light varies its velocity due to gravitational acceleration[13], which was proved by the Pound-Rebka experiment[14] and gravitational lensing[15], although its mechanism is not yet fully elucidated. This is supported by the equivalence principle[16, 17], or the fact that light appears to propagate uniformly without affecting aether wind on the rotating earth, which means that the medium is also rotating with us like the atmosphere, and that we do not have to assume length contraction.

In his lecture *Ather und Relativitätstheorie* in 1920[17], Einstein stated as follows[18]:

'To deny the ether is ultimately to assume that empty space has no physical qualities whatever. The fundamental facts of mechanics do not harmonize with this view. For the mechanical behaviour of a corporeal system hovering freely in empty space depends not only on relative positions (distances) and relative velocities, but also on its state of rotation, which physically may be taken as a characteristic not appertaining to the system in itself. In order to be able to look upon the rotation of the system, at least formally, as something real, Newton objectivises space. Since he classes his absolute space together with real things, for him rotation relative to an absolute space is also something real. Newton might no less well have called his absolute space "Ether"; what is essential is merely that besides observable objects, another thing, which is not perceptible, must be looked upon as real, to enable acceleration or rotation to be looked upon as something real.'

In this article, we examine the constancy of light velocity, the singularity deduced from the constancy, and the possibility of superluminal motion.

SINGULARITY AT LIGHT VELOCITY

Momentum increase, produced by the relativistic motion of a charged particle[19, 20], is known as a phenomenon that supports the singularity at light velocity.

When the velocity of a fluid in motion becomes comparable with that of its compressional wave, or sound, effects due to the compressibility of the fluid become highly important[21, 22]. According to the perturbation theory of compressible potential flow[8, 22], if we eliminate the density ρ from the equation of continuity

$$\mathrm{div}(\rho \boldsymbol{v}) = \rho \ \mathrm{div}\boldsymbol{v} + \boldsymbol{v} \cdot \mathbf{grad}\rho = 0, \qquad (1)$$

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where $\boldsymbol{v}$ is the velocity of flow, using Euler's equation

$$(\boldsymbol{v} \cdot \mathbf{grad})\boldsymbol{v} = -(1/\rho)\mathbf{grad}p = -(c^2/\rho)\mathbf{grad}\rho, \quad (2)$$

where p is the pressure and c is the velocity of sound at infinity, we obtain

$$c^2 \ \mathrm{div}\boldsymbol{v} - \boldsymbol{v} \cdot (\boldsymbol{v} \cdot \mathbf{grad})\boldsymbol{v} = 0. \quad (3)$$

Introducing the velocity potential by $\boldsymbol{v} = \mathbf{grad}\phi$ and expanding in components, we have

$$(c^2 - \phi_x^2)\phi_{xx} + (c^2 - \phi_y^2)\phi_{yy} + (c^2 - \phi_z^2)\phi_{zz} \\ -2(\phi_x\phi_y\phi_{xy} + \phi_y\phi_z\phi_{yz} + \phi_z\phi_x\phi_{zx}) = 0. \quad (4)$$

Denoting by $\boldsymbol{v}'$ the small difference between the flow velocity $\boldsymbol{v}$ at a given point and that of the main stream $\boldsymbol{v}_1$, the velocity potential is replaced by that of the velocity $\boldsymbol{v}' = \mathbf{grad}\phi'$. Regarding ϕ' as a small quantity and omitting all terms of order higher than the first, we obtain the following linear equation

$$\left(1 - \frac{v_1^2}{c^2}\right)\frac{\partial^2\phi'}{\partial x^2} + \frac{\partial^2\phi'}{\partial y^2} + \frac{\partial^2\phi'}{\partial z^2} = 0 \quad (5)$$

by substituting $\phi = \phi' + xv_1$, where we take the x-axis in the direction of the vector $\boldsymbol{v}_1$. The solution of the equation is reduced to the solution of a problem of incompressible flow

$$\frac{\partial^2\phi'}{\partial x'^2} + \frac{\partial^2\phi'}{\partial y'^2} + \frac{\partial^2\phi'}{\partial z'^2} = 0 \quad (6)$$

by using the variables

$$x' = \frac{x}{\sqrt{1 - v_1^2/c^2}}, \quad y' = y, \quad z' = z, \quad (7)$$

which is known as the Prandtl-Glauert transformation[8, 22, 23], corresponding to the Lorentz transformation for electromagnetic potential in luminiferous aether[19]. Note that this is a linearized approximation when $v_1 \ll c$ holds, and we cannot apply the transformation to a moving object in a flow beyond sound velocity, because the flow resistance approaches infinity near c. In reality, as the number v_1/c gets close to unity, terms of higher order in the x-derivatives of ϕ become nonnegligible, and the object and the fluid around it form a transonic flow expressed in the nonlinear equation

$$\left(1 - \frac{\phi_x^2}{c^2}\right)\phi_{xx} + \phi_{yy} + \phi_{zz} = 0. \quad (8)$$

Beyond sound velocity, it is known that a supersonic shock wave is formed in front of the object[8, 22], which can be regarded as a cylindrical sound wave outgoing from the x-axis in accordance with the equation

$$\left(\frac{v_1^2}{c^2} - 1\right)\frac{\partial^2\phi'}{\partial x^2} + \frac{\partial^2\phi'}{\partial y^2} + \frac{\partial^2\phi'}{\partial z^2} = 0, \quad (9)$$

where the characteristic time is now represented by x/v_1, and the rate of sound propagation by

$$\frac{v_1}{\sqrt{v_1^2/c^2 - 1}}. \quad (10)$$

We show an example of supersonic shock wave in Fig. 1, in which a bullet and the air flowing around it are traveling at 1.5 times the velocity of sound.

We can also examine a similar apparent singularity for a surface wave in incompressible shallow water, known as the hydraulic jump, by moving an object along the surface of water. In this case, the velocity of the wave is given by $\sqrt{gh}$, where g is the gravitational constant and h is the depth of the fluid[22].

The limitation of the Prandtl-Glauert transformation is due to the assumption that the velocity of the wave is constant. In fact, the velocity of the wave depends on the pressure and density of the medium. If we assume the compressibility of luminiferous medium, a similar situation is considered to hold for the momentum increase, which is expressed in the form of the Lorentz transformation

$$p = \frac{mv}{\sqrt{1 - v^2/c^2}}, \quad (11)$$

where p is the momentum, and m is the mass.

We assume here that the displacement of the compressible luminiferous medium propagates in the medium at light velocity, due to a reason we mention later in section Discussion. For a compressible medium, the medium in the direction of motion is compressed, while that in the opposite direction is extended, which forms a compressional wave. The velocity of the light emitted from one of two moving objects approaching each other with velocity v ought to vary continuously from $c + v$ to c, then vary from c to $c - v$ before it arrives at the other. This is consistent with the results of Fizeau's experiment on the relative velocities of light in moving water[24], and Sagnac's experiment on ring interferometry[25, 26], which are employed in ring laser gyroscopes.

By applying the theory of compressible flow, we can predict that the Lorentz transformation becomes invalid as the velocity of a radiating particle reaches light velocity relative to the observer at rest, and the particle appears to form a compressional shock wave associated with γ-ray, which gradually decreases in frequency as the

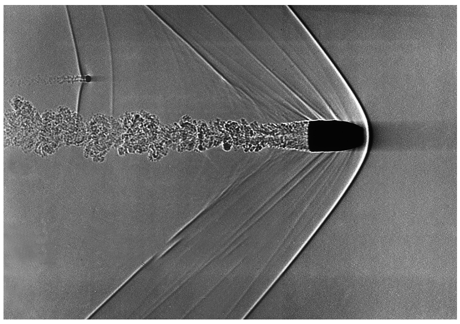

FIG. 1. A bullet and the air flowing around it, which is traveling at 1.5 times the velocity of sound. We can see a series of supersonic compressional waves. Image credit: NASA and Andrew Davidhazy, Rochester Institute of Technology.

shock wave passes over the observer. This will resemble the Cherenkov radiation in a medium with lower light velocity[27], although we assume here that the radiation is emitted by an uncharged luminous particle. The momentum assumes a finite maximum value at the velocity of light and decays in accordance with the equation

$$p = \frac{mv}{\sqrt{v^2/c^2 - 1}}. \tag{12}$$

This is explained by the nonuniformity of the wave velocity, which decreases the reaction from the medium as the velocity of the particle increases beyond the wave velocity at infinity. Note that causality is not broken sufficiently close to the matter, where a wave towards the direction of motion is not passed over by the matter. However, if we observe the motion of the radiating particle from a far distance, causality will not be guaranteed. Introducing the angle θ between the direction of the motion of the particle with velocity v and that of the wave with frequency ω, we find

$$\omega = \frac{\omega_0}{1 - (v/c)\cos\theta}, \tag{13}$$

where ω_0 is the frequency of the oscillation of the source, by the analogy from geometric acoustics[22]. For $v\cos\theta > c$, ω becomes negative, which means that the light reaches in the reverse order. We can see such an example in the femto-photography experiment, where the light that propagates slower in a liquid than in the atmosphere appears to break causality[28]. It may be difficult to assume such a situation in our daily life, but we should remind ourselves that it is a routine event in a particle accelerator[29], in which two moving particles confront each other with superluminal relative velocity. Another example is a short-lived particle created by a cosmic-ray shower at high altitude[3], the lifetime of which is considered to be the evidence of relativistic time dilation based on the singularity at light velocity, although it also causes the twin paradox. Actually, it looks to delate compared with the appearance if the particle and the light emitted from the particle arrive almost simultaneously, but it has nothing to do with the real lifetime of the particle. This means that we have to re-examine the interpretation of the range of short-lived particles.

Owing to the effect of special relativity, the particle appears to increase in velocity, turn blue, and increase in momentum from the direction of motion, whereas from the opposite direction, it appears to decrease in velocity, turn red, and decrease in momentum. However, we should note that it is just an appearance. From the direction of motion, we cannot recognize the particle with light velocity until it passes over. This means that it appears to approach with infinite velocity and infinitely large momentum. We should also note that this holds regardless the kind of wave. It depends only on the relation between c and v. We can see that the statement on the singularity at light velocity is valid only in the case that the Lorentz transformation is valid, that is to say, in the case that the velocity of the particle does not exceed light velocity, by an experiment using a surface wave, for example.

FIELD STUDY

An appropriate subject for the field study of the singularity is the light echo observed in supernovae[4, 6, 30], a concept introduced to explain the superluminal motion of the explosion remnant by the reflection from the interstellar dust behind the star. If we abandon the concept of the singularity, this phenomenon can be interpreted as a high-energy superluminal motion of matter.

If the velocity of matter exceeds that of light at infinity, the spectrum of the electromagnetic wave propagated from the matter will be extremely shifted. Therefore, if we can find a superluminal nova explosion, its structure with transverse velocity should display rainbow-like color variation with blue outer edges and red inner edges owing to the decrease of velocity. In fact, we can see such color variation in Nova Monocerotis 2002[6] (Fig. 2).

This is consistent with the spectral evolution from blue to red observed in luminous red novae like SN 1987A[5] in the Large Magellanic Cloud, Nova Monocerotis 2002[6], and M85 OT2006-1[7]. The structure with radial velocity below c is deformed by relativistic beaming[31] as described in Fig. 3, which is also consistent with the apparent shape of the Nova Monocerotis with no visible structure behind the star that reflects the spectrum. On the contrary, this appears to contradict the light echo mechanism originally proposed for Nova Persei 1901[4], and applied to SN 1987A[5] and Nova Monocerotis 2002[6, 32], because the assumed parabolic structure itself appears to have deformed and expanded with superluminal velocity.

FIG. 2. Explosion of V838 Monocerotis observed by Hubble Space Telescope on September 2, 2002. The structure with transverse velocity displays rainbow-like color variation with blue outer edges and red inner edges. Image credit: NASA, ESA, and H. E. Bond.

Supporting this inference is the fact that the light from the stars behind the supernova is not scattered in the transparent area of the structure (Fig. 4). We can confirm that this is consistent with the visible light observations of Nova Persei (Couderc[4], Figure 2) and SN1987 A (Arnett et al.[5], Figure 11). Considering that the XMM-Newton detected a transient X-ray source in the vicinity of V838 Monocerotis[33], and that the Spitzer detected an extended infrared emission around the star[34], it seems reasonable to assume that the ultra-violet structure is approaching the earth and the ultra-red structure is receding from the earth.

DISCUSSION

In this section, we would like to discuss the quality of the luminiferous medium, following the style of Maxwell and Boltzmann, although it might be somewhat speculative at this stage.

The concept of spacetime is based on the corpuscular theory of light, because a photon should move uniformly. However, the theory does not explain the reason why a photon moves at a constant velocity. If we assume the real existence of the spacetime based on light velocity, we can also assume the spacetime based on sound velocity, which contradicts the former one. We can show this with a crossing alarm and a clock attached to it by observing their motion from a moving train passing them over via sound and light, which will not coincide. We know that such a spacetime does not exist in the case of sound, because sound velocity is not constant. Considering the analogy with a phonon, it is more appropriate to suppose that a photon is not a real particle, but rather a quasiparticle that represents the energy and momentum conserved by the motion of tiny dielectric particles that rotate around the center of gravity. If we assume the existence of a fluid aether, it is natural to consider that a photon finally turns into the translational and rotational motion of a single dielectric aether particle, which will be recognized as a light quantum[35], as a phonon that propagates in a fluid finally turns to the motion of a single fluid molecule. Considering the result of neutrino detection at Kamiokande in 1987[36], the mass of the particle can be estimated to be in the same order of magnitude as that of a neutrino[37], which coincides with the result of the OPERA experiment at CERN in 2011[38]. This is largely equivalent to Planck's compressible aether theory[19], although we assume here that the particle passes through the earth at light velocity. The particle will have a finite mean free path, obeying Maxwell-Boltzmann statistics. As a solar neutrino can be detected by the interaction with an electron

$$\nu + e^- \rightarrow \nu + e^-, \tag{14}$$

we will be able to detect the particle even after it loses its rotational energy, if it interacts with a detectable particle.

Although a gravitational wave is not still directly detected, it seems to be appropriate to identify the compressional wave discussed above with the gravitational wave that propagates the luminiferous medium discussed by Einstein[13, 39–41]. However, we should note that light does not avoid the influence of gravity, as already shown by the experiments[14, 15]. This seems to imply that the information on the gravity propagates faster than light velocity.

CONCLUSION

We note from the above discussion that the velocity of light does not necessarily regulate the motion of matter. By applying the theory of compressible flow, we can predict that matter forms a compressional shock wave as

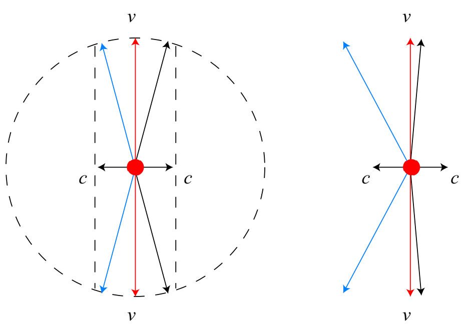

FIG. 3. The structure with radial velocity below c is deformed by relativistic beaming as described, which is consistent with the apparent shape of the Nova Monocerotis with no visible structure behind the star that reflects the spectrum.

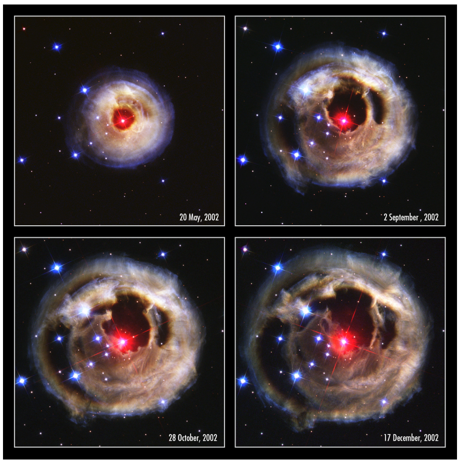

FIG. 4. Series of images of V838 Monocerotis over time. The light from the stars behind V838 Monocerotis is not scattered in the transparent area of the structure. Image credit: NASA.

the velocity of the matter increases beyond light velocity at rest, which is supported by the observation of short-lived particles and light echoes from supernovae. This also seems to imply that we need to re-examine phenomena such as the motion of a spinning electron[42], which has raised discussions about momentum increase. As the kinetic theory of gases finally replaced thermodynamics, we will have a deeper knowledge of space some day in the future.

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