The Cosmological Significance of Superluminality

Hartmut Müller

E-mail: hm@interscalar.com

The paper derives the constancy and the value of the speed of light from stability conditions in chain systems of harmonic quantum oscillators. It is also shown that these stability conditions lead to scale-invariant superluminal velocity quantization. The cosmological significance of superluminality is discussed.

Introduction

I remember well that day in 1997 when my teenage son was asking me: "Why is the speed of light so slow?"

In fact, 299792458 m/s is a very finite velocity, and it is not too high regarding even the solar system. In interstellar and intergalactic scales, it becomes obvious how disappointingly slow it really is.

One year later, reading on the pioneering research of Günter Nimtz [1], my heart started to beat faster. Already in 1992, Enders and Nimtz demonstrated that photonic tunneling proceeds at superluminal signal velocities. The signal velocity is the velocity of the transmitted cause, i.e. of the information. As they reported, no signal reshaping took place during tunneling and all frequency components were equally transmitted. Later superluminal amplitude modulated (AM) and frequency modulated (FM) microwave experiments were carried out using different photonic barriers. Mozart's 40th symphony was FM tunneled at a speed of $4.7c$ without any significant distortion [2].

Superluminal propagation of infrared pulses through periodic fiber Bragg gratings was experimentally demonstrated [3]. Velocities of nearly $3c$ were observed [4] in the propagation of electric pulses along coaxial lines having spatially periodic impedances.

Nevertheless, superluminal tunneling is still under discussion. However, while Nimtz argues with facts (measurements) for superluminal signal transmission, his opponents counter with purely theoretical approaches. One of the main counterarguments is the alleged violation of causality [5, 6].

Causality requires the existence of a maximum speed of physical interaction, but could it be that 299792458 m/s is already high enough? This is very unlikely, if we consider the unity of the universe up to scales of billions light years.

By the way, in astronomic calculations, gravitation is traditionally considered as being instantaneous. First Laplace [7] demonstrated that gravitation does not propagate with the speed of light c. Modern estimations [8] confirm a lower limit of $2 \cdot 10^{10}\,c$. Exceeding 299792458 m/s has nothing to do with time travel, grandfather paradox or any other violation of causality. This would be relevant in the case of an infinitely high velocity, but 299792458 m/s is finite.

Furthermore, the value 299792458 m/s does not follow from any established theory, and consequently, none of those theories had to be changed if the speed of light would be even 55 times higher than 299792458 m/s.

What exactly makes possible to exceed 299792458 m/s? The point is that the tunneling time does not depend on the barrier length. This was theoretically described by Thomas E. Hartman [9] in 1962. Thirty years later, the Hartman effect was demonstrated experimentally with evanescent microwaves by Enders and Nimtz [10]. Numerous studies [11] have shown that the tunneling time equals approximately the reciprocal frequency of the carrier wave, independently of the length and the type of barrier (periodic lattice structures, double prisms, undersized wave guides).

Probably, not only photons and phonons can tunnel, but also electrons [12, 13], protons [14] and atoms [15] can do it.

Is superluminality just a laboratory artefact? It is very unlikely that laboratory experiments can exceed the complexity of astrophysical phenomena. Indeed, there are superluminal processes observed in deep space.

Already in December 1901, Jacobus Kapteyn [16] reported on apparent superluminal motion in the ejecta of the nova GK Persei [17], which was discovered in February 1901 by Thomas Anderson. Superluminal motion is observed in radio galaxies, BL Lac objects, quasars, blazars and recently also in some galactic sources called microquasars [18–21]. Superluminal motion has been observed [22] in the jet of M87. Many of the jets are evidently not close to our line-of-sight. Therefore, their superluminal behavior cannot be dismissed easily as an illusion.

Within the special relativity theory, the speed of light is postulated (not derived) to be constant. Up to now, there have not been sufficiently convincing explanations why the speed of light should be constant and why it should have the value which it has.

As proposed Albrecht and Magueijo [23], the speed of light might vary with the age of the universe and it might not have been constant in early stages. They suggest that a variable speed of light might solve the horizon, flatness and cosmological constant problems. Christoph Köhn [24] proposed a 5D space parametrized with two time coordinates to explain the constancy of the speed of light in the observable universe. For very small length scales of the present universe, or for the very early universe, the model speed of light is not constant, but depends on space-time. This is consistent with current conclusions from loop quantum gravity models [25] and the string theory [26].

In the following we will show that the constancy and the value of the speed of light can be derived from stability conditions in fractal chain systems of harmonic quantum oscillators. Furthermore, we will demonstrate that the same stability conditions lead to scale-invariant superluminal velocity quantization.

Methods

The most stable systems we know are of atomic scale. Proton and electron form stable atoms, the structural elements of matter. The lifespans of the proton and electron surpass everything that is measurable, exceeding 10^{30} years. No scientist ever witnessed the decay of a proton or an electron. Therefore, the proton-to-electron ratio 1836.152674 is considered as fundamental physical constant [27]. Well, but what is the secret of this eternal stability?

Up to now, there have not been sufficiently convincing explanations why the electron and the proton should be stable and why the proton-to-electron ratio should have exactly the value which it has. In standard particle physics, the electron is stable because it is the least massive particle with non-zero electric charge. Its decay would violate charge conservation [28]. Indeed, this answer only readdresses the question. Why then is the elementary electric charge so stable?

In a similar explanation, the proton is stable, because it is the lightest baryon and the baryon number is conserved [29]. Indeed, also this answer only readdresses the question. Why then is the proton the lightest baryon? To answer this question, the standard model introduces quarks which violate the integer quantization of the elementary electric charge that is needed to explain the stability of the electron.

In [30] we introduced fractal chain systems of harmonic quantum oscillators as model of matter and did show that frequency ratios equal to Euler's number $e = 2.718\ldots$, its integer powers and roots inhibit destructive internal resonance interaction and in this way, provide lasting stability [31].

Already Dombrowski [32] did show that irrational numbers inhibit destabilizing resonance interaction, because they cannot be represented as ratios of whole numbers. Though, algebraic irrational numbers like $\sqrt{2}$ do not compellingly prevent resonance, because they can be transformed into rational numbers by multiplication.

Surprisingly, only Euler's number inhibits resonance also regarding all derivatives of the bound periodic processes, because it is the basis of the real exponential function e^x, the only function that is the derivative of itself. Furthermore, Euler's number, its integer powers and roots are always transcendental [33] and therefore, they provide the solution for lasting stability in chain systems of any degree of complexity.

Many physical characteristics of harmonic quantum oscillators are connected with their frequency by the fundamental constants – the speed of light and the Planck constant. Therefore, within our model, Euler's number, its integer powers and roots define also the ratios of wavelengths, velocities, impulses, accelerations and energies which inhibit resonance interaction, and in this way, support lasting stability of the chain system.

This is why we expect that stable quantum systems show ratios of their physical quantities close to integer powers of Euler's number and its roots. Consequently, the natural logarithms of the ratios should be close to integer 0, 1, 2, 3, 4, ... or rational values $\frac{1}{2}, \frac{1}{3}, \frac{1}{4}, \ldots$ In fact, the natural logarithm of the proton-to-electron ratio is close to seven and a half:

$$\ln(1836.152674) = 7.515427\ldots \simeq 6 + \frac{3}{2}.$$

Already in the eighties the scaling exponent 3/2 was found in the distribution of particle masses by Valery Kolombet [34]. Applying hyperscaling [30] by Euler's number (tetration), we get the next approximation of the logarithm of the proton-to-electron ratio:

$$6 + \frac{e^e}{10} = 7.515426\ldots$$

This result supports our assumption that the stability of the proton and electron comes from the transcendence of Euler's number, its integer powers and roots. In this way, the proton mass appears as scaled up by Euler's number and its roots electron mass.

In [35] we have analyzed the mass distribution of hadrons, mesons, leptons, the W/Z and Higgs bosons and proposed fractal scaling by Euler's number and its roots as model of particle mass generation [36]. In this model, the W-boson mass 80385 MeV/c^2 and the Z-boson mass 91188 MeV/c^2 appear as the 12 times scaled up by Euler's number electron rest mass 0.511 MeV/c^2:

$$\ln\left(\frac{80385}{0.511}\right) = 11.97, \qquad \ln\left(\frac{91188}{0.511}\right) = 12.09.$$

Andreas Ries [37] did apply fractal scaling by Euler's number to the analysis of atomic masses and demonstrated that this method allows for the prediction of the most abundant isotopes.

In comparison to dimensionless constants like the proton-to-electron ratio, conversion constants define dimensional ratios. For instance, the Planck constant defines the energy one must invest to generate a harmonic quantum oscillation of a given frequency, and the speed of light defines the propagation space of such an oscillation.

Like one can measure distances in units of time, for example in light years, energy can be measured in units of frequency. Only the dimensions are different.

In this way, we can interpret the speed of light as fundamental space – time converter, the square of the speed of light as fundamental mass – energy converter and the Planck

DIMENSIONS	CONVERSION CONST.	VALUE
space – time	$\lambda / \tau = c$	299792458 m/s
energy – mass	$E / m = c^2$	$8.9875518 \cdot 10^{16}$ m^2/s^2
energy – time	$E \cdot \tau = \hbar$	$1.0545718 \cdot 10^{-34}$ Js
energy – space	$E \cdot s = \hbar \cdot c$	$3.1615267 \cdot 10^{-26}$ Jm
mass – space	$m \cdot s = \hbar / c$	$3.5176729 \cdot 10^{-43}$ kgm
mass – time	$m \cdot \tau = \hbar / c^2$	$1.1733694 \cdot 10^{-51}$ kgs

Table 1: Some fundamental conversion constants (c is the speed of light in a vacuum, $\hbar$ is the Planck constant). Data taken from Particle Data Group [27].

constant as fundamental time – energy converter. Some fundamental conversion constants are shown in table 1.

Table 1 is completely compatible with Planck units. Originally proposed in 1899 by Max Planck, they are also known as natural units, because they origin only from properties of nature and not from any human construct. Natural units are based only on the properties of space-time. Max Planck wrote [38] that these units, "regardless of any particular bodies or substances, retain their importance for all times and for all cultures, including alien and non-human, and can therefore be called natural units of measurement".

In [39] was demonstrated that the natural logarithm of the Planck-to-proton mass ratio equals 44. Consequently, one can define a dimensionless fundamental constant that equals to an integer power of Euler's number and contains the speed of light c, the Planck constant $\hbar$, the gravitational constant G and the proton rest mass m_p:

$$\frac{\hbar \cdot c}{G \cdot m_p^2} = e^{\,88}.$$

For the speed of light, now we can write:

$$c = c_0 \cdot e^{\,88},$$

where $c_0 = G m_p^2 / \hbar \simeq 1.8 \cdot 10^{-30}$ m/s can be interpreted as the velocity of free falling on each other proton masses at Planck length and Planck time. Assumed that the stability of any fundamental constant origins from Euler's number and its roots, we can generalize:

$$c_{n,m} = c \cdot e^{\,n/m},$$

where n, m are integer numbers. In general, the rational exponent is represented by finite continued fractions [30, 40]. The exponents n/m define a fractal set of stable velocities $c_{n,m}$ which are superluminal for $n > 0$.

In the following, we will verify the fractal set $c_{n,m}$ of stable subluminal and superluminal velocities on experimental and astrophysical data.

Results

Let us start with experimental data elaborated by Nimtz [1] in 1998, the barrier traversal time of a microwave packet through a multilayer structure inside a waveguide was measured. The center frequency has been 8.7 GHz. The tunneled signal traversed a 114.2 mm long barrier in 81 ps, whereas the signal spent 380 ps to cross the same air distance. Consequently, the group velocity of the tunneled signal was $c\ (380/81) = 4.7c$ that is close to $c_{3,2} = c \cdot e^{3/2} = 4.5c$.

Already in 1995 a similar experiment was carried out by Aichmann et al. [41]. They modulated Mozart's 40th symphony on a microwave carrier. The modulation of the signal and thus the music traveled at the same superluminal velocity.

In another setup [42], amplitude modulated 9.15 GHz microwaves were generated by a synthesized sweeper, and a parabolic antenna transmitted parallel beams. The propagation time of the signal was measured across the air distance between transmitter and receiver and across the same distance but partially filled with a 28 cm long barrier of quarter wavelength slabs made of acrylic perspex. Each slab was 0.5 cm thick and the distance between two slabs was 0.85 cm. Two such structures were separated by an air distance of 18.9 cm forming a resonant tunneling structure. The signal tunneled the 28 cm long barrier in 125 ps that corresponds to a signal velocity of $7.5c$ that is close to $c_{2,1} = c \cdot e^2 = 7.3c$.

Mojahedi et al. [43] describe an experiment with single microwave pulses centered at 9.68 GHz. The signals tunneled through a one-dimensional photonic crystal with up to $2.5c$ that is close to $c_{1,1} = c \cdot e = 2.7c$. Hache et al. [4] studied the propagation of brief electric 10 MHz pulses along a coaxial line having a spatially periodic impedance. As well, signal velocities approximating $c_{1,1} = 2.7c$ were measured.

Remarkably, the same superluminal velocities were measured also by Hubble telescope observation. Superluminal motion at velocities close to $c_{1,1} = 2.7c$ was found [22] in two small features within the jet knot D about 200 pc from the nucleus of M87, the giant elliptical galaxy near the center of the Virgo Cluster. As well, the jet features DE and DW show velocities close to $c_{1,1} = 2.7c$, while the features DM, DE-W, HST-1α, HST-1γ, HST-1δ, HST-1ϵ and HST-2 show velocities close to $c_{3,2} = 4.5c$.

Other active galactic nuclei (AGN) show the same velocities of superluminal motion. Lister et al. [21] describe the parsec-scale kinematics of 200 different AGN jets based on 15 GHz VLBA data. Various components of the sources 0003+380, 0003-060, 0010+405 show velocities that approximate $c_{1,1} = 2.7c$ or $c_{3,2} = 4.5c$ or $c_{2,1} = 7.3c$.

Jorstad et al. [20] monitored the radio emissions in 42 gamma-ray bright blazars (31 quasars and 11 BL Lac objects) with the Very Long Baseline Array (VLBA) at 43, 22, 15 and 8.4 GHz and found superluminal motions with velocities approximating $c_{1,1} = 2.7c$ or $c_{3,2} = 4.5c$ or $c_{2,1} = 7.3c$ or $c_{5,2} = 12c$ or $c_{3,1} = 20c$ or $c_{7,2} = 33c$ respectively.

Now let us continue with astrophysical data of stable subluminal processes. In [30] we have analyzed the orbital velocities of large bodies in the solar system. For instance, the orbital velocity of Mercury oscillates between two points of Euler stability $c_{-17,2}$ = 61 km/s (perihelion) and $c_{-9,1}$ = 37 km/s (aphelion). The orbital verlocity of Venus is close to $c_{-9,1}$ = 37 km/s. Earth's orbital verlocity is close to $c_{-37,4}$ = 29 km/s. The orbital verlocity of Mars is between 21.97 and 26.50 km/s, approximating $c_{-19,2}$ = 22.4 km/s. Jupiter's orbital velocity is between 12.44 and 13.72 km/s, approximating $c_{-10,1}$ = 13.6 km/s. Saturn's orbital verlocity is between 9.09 and 10.18 km/s, approximating $c_{-31,3}$ = 9.8 km/s. The orbital verlocity of Uranus is between 6.49 and 7.11 km/s, approximating $c_{-32,3}$ = 7 km/s. Neptune's orbital verlocity is close to $c_{-11,1}$ = 5 km/s. Pluto's orbital verlocity oscillates between 6.10 and 3.71 km/s, approximating the same $c_{-11,1}$ = 5 km/s. By the way, the same velocities are typical for underground propagation of seismic P-waves [44].

Within our model, the quantized orbital velocities in the solar system are velocities of free fall, scaled up by Euler's number and its roots from the velocity of free falling on each other proton masses at Planck length and Planck time. The stability [45] of the orbital system origins from the transcendence of Euler's number, its integer powers and roots. In this way, Euler's number, its integer powers and roots define fractal sets of quantized subluminal and superluminal velocities established by stable periodical processes.

Conclusion

The worldwide-reproduced tunneling experiments show convincingly that the conditions required for superluminal signal transmission are not exotic. Therefore, it is possible to imagine that those conditions can emerge also in nature. For the same reason, the probability is quite high that conditions for superluminality can emerge in deep space, and this is already suggested by astrophysical observations.

Our model [30] of matter as fractal chain system of harmonic quantum oscillators suggests that stable processes establish subluminal or superluminal velocities corresponding to the speed of light scaled by integer powers of Euler's number and its roots. This circumstance could affect estimations of intergalactic distances and the meaning of the cosmic light horizon. Superluminal propagation of light and matter suggests the existence of cosmic superluminal horizons with a scale-invariant exponential distribution that follows the sequence of multiples of Euler's number.

In [31] we have discussed the cosmological significance of global scaling [46] and the stabilizing function of Euler's number regarding the apparent distances between the stars and galaxies.

The concept of process stability based on the avoidance of destructive resonance interaction provided by the transcendence of Euler's number and its roots, allowed us to derive the constancy and the value of the speed of light. Deriving the speed of light from the velocity of free falling on each other proton masses at Planck length and Planck time, perhaps we can reach a better understanding of gravitation and its sheer infinite velocity.

Acknowledgements

The author is grateful to Viktor Panchelyuga, Oleg Kalinin, Alexey Petrukhin and Leili Khosravi for valuable discussions.

Submitted on January 11, 2019

References

1. Nimtz G. Superluminal Signal Velocity. arXiv: physics/9812053v1 [physics.class-ph], (1998).
2. Nimtz G. *Prog. Quantum Electron.*, 2003, v. 27, 417.
3. Longhi S. et al. Measurement of superluminal optical tunneling times in double-barrier photonic band gaps. *Phys. Rev. E*, 2002, v. 65(4), 046610 // arXiv:physics/0201013.
4. Hache A., Poirier L. Long-range superluminal pulse propagation in a coaxial photonic crystal. *Applied Physics Letters*, 2002, v. 80(3), 518.
5. Nimtz G., Haibel A. Basics of Superluminal Signals. *Ann. Phys.* (Leipzig), 2002, v. 9(1), 1–5, arXiv: physics/0104063v1 [physics.class-ph] (2001).
6. Nimtz G. Superluminal Signal Velocity and Causality. *Foundations of Physics*, 2004, v. 34(12), 1889–1903.
7. Laplace P. Mechanique Celeste. 1825, pp. 642–645.
8. Van Flandern T. The Speed of Gravity – What the Experiments Say. *Physics Letters A*, 1998, v. 250, 1–11.
9. Hartman T. E. Tunneling of a wave packet. *Journal of Applied Physics*, 1962, v. 33(12), 3427.
10. Enders A., Nimtz G. Evanescent-mode propagation and quantum tunneling. *Physical Review E*, 1993, v. 48(1), 632–634.
11. Nimtz G. Tunneling Violates Special Relativity. arXiv: 1003.3944v1 [quant-ph], (2010).
12. Sekatskii S.K., Letokhov V. S. Electron tunneling time measurement by field-emission microscopy. *Phys. Rev. B*, 2001, v. 64, 233311.
13. Eckle P. et al. Attosecond Ionization and Tunneling Delay Time Measurements in Helium 2008. *Science*, 2008, v. 322, 1525.
14. Tuckerman M. E., Marx D. Heavy-Atom Skeleton Quantization and Proton Tunneling in Intermediate-Barrier Hydrogen Bonds. *Phys. Rev. Lett.*, 2001, v. 86(21), 4946–4949.
15. Lauhon L.J., Ho W. Direct Observation of the Quantum Tunneling of Single Hydrogen Atoms with a Scanning Tunneling Microscope. *Phys. Rev. Lett.*, 2000, v. 85, 4566.
16. Kapteyn J.C. Über die Bewegung der Nebel in der Umgebung von Nova Persei. *Astronomische Nachrichten*, 1901, v. 157(12), 201.
17. Shara M.M. et al. GK Per (Nova Persei 1901): HST Imagery and Spectroscopy of the Ejecta, and First Spectrum of the Jet-Like Feature. arXiv: 1204.3078v1 [astro-ph.SR] (2012).
18. Levinson A., Blandford R. On the Jets associated with galactic superluminal sources. arXiv: astro-ph/9506137v1, (1995).
19. Brunthaler A. et al. III Zw 2, the first superluminal jet in a Seyfert galaxy. arXiv: astro-ph/0004256v1, (2000).
20. Jorstad S.G. et al. Multiepoch Very Long Baseline Array Observations of Egret-Detected Quasars and BL Lacertae Objects: Superluminal Motion of Gamma-Ray Bright Blazars. *The Astrophysical Journal Supplement Series*, 2001, v. 134, 181–240.

21. Lister M.L. et al. MOJAVE X. Parsec-Scale Jet Orientation Variations and Superluminal Motion in AGN. arXiv: 1308.2713v1 [astro-ph.CO], (2013).
22. Biretta J.A., Sparks W.B., Macchetto F. Hubble Space Telescope Obesrvations of Superluminal Motion in the M87 Jet. *The Astrophysical Journal*, 1999, v. 520, 621–626.
23. Albrecht A., Magueijo J. A Time Varying Speed of Light as a Solution to Cosmological Puzzles. *Physical Review D*, 1999, v. 59(4), 043516.
24. Köhn C. The Planck length and the constancy of the speed of light in five dimensional space parametrized with two time coordinates. arXiv: 1612.01832v2 [physics.gen-ph], (2017).
25. Kiritsis E. Supergravity, D-brane Probes and thermal super Yang-Mills: a comparison. *Journal of High Energy Physics*, 1999, v. 9910(10).
26. Alexander S. On the varying speed of light in a brane-induced FRW Universe. *Journal of High Energy Physics*, 2000, v. 0011(17).
27. M. Tanabashi et al. (Particle Data Group), *Phys. Rev. D*, 2018, v. 98, 030001. www.pdg.lbl.gov
28. Steinberg R. I. et al. Experimental test of charge conservation and the stability of the electron. *Physical Review D*, 1999, v. 61(2), 2582–2586.
29. Nishino H. et al. Search for Proton Decay in a Large Water Cherenkov Detector. *Physical Review Letters*, 2009, v. 102(14), 141801, arXiv: 0903.0676.
30. Müller H. Scale-Invariant Models of Natural Oscillations in Chain Systems and their Cosmological Significance. *Progress in Physics*, 2017, v. 13, 187–197.
31. Müller H. On the Cosmological Significance of Euler's Number. *Progress in Physics*, 2019, v. 15, 17–21.
32. Dombrowski K. Rational Numbers Distribution and Resonance. *Progress in Physics*, 2005, v. 1, no. 1, 65–67.
33. Hilbert D. Über die Transcendenz der Zahlen e und π. *Mathematische Annalen*, 1983, v. 43, 216–219.
34. Kolombet V. Macroscopic fluctuations, masses of particles and discrete space-time, *Biofizika*, 1992, v. 36, 492–499.
35. Müller H. Fractal Scaling Models of Natural Oscillations in Chain Systems and the Mass Distribution of Particles. *Progress in Physics*, 2010, v. 6, 61–66.
36. Müller H. Emergence of Particle Masses in Fractal Scaling Models of Matter. *Progress in Physics*, 2012, v. 8, 44–47.
37. Ries A. Qualitative Prediction of Isotope Abundances with the Bipolar Model of Oscillations in a Chain System. *Progress in Physics*, 2015, v. 11, 183–186.
38. Max Planck. Über Irreversible Strahlungsvorgänge. *Sitzungsbericht der Königlich Preußischen Akademie der Wissenschaften*, 1899, vol. 1, 479–480.
39. Müller H. Gravity as Attractor Effect of Stability Nodes in Chain Systems of Harmonic Quantum Oscillators. *Progress in Physics*, 2018, v. 14(1), 19–23.
40. Panchelyuga V.A., Panchelyuga M.S. Resonance and Fractals on the Real Numbers Set. *Progress in Physics*, 2012, v. 8, no. 4, 48–53.
41. Aichmann H., Nimtz G., Spieker H. Verhandlungen der Deutschen Physikalischen Gesellschaft. v. 7, 1258, (1995).
42. Nimtz G. Superluminal Tunneling Devices. arXiv: physics/0204043v1 [physics.gen-ph], (2002).
43. Mojahedi M. et al. Time-domain detection of superluminal group velocity for single microwave pulses. *Phys. Rev. E*, 2000, v. 62(4), 5758–5766 .
44. Müller H. Quantum Gravity Aspects of Global Scaling and the Seismic Profile of the Earth. *Progress in Physics*, 2018, v. 14, 41–45.
45. Müller H. Global Scaling of Planetary Systems. *Progress in Physics*, 2018, v. 14, 99–105.
46. Müller H. Global Scaling. The Fundamentals of Interscalar Cosmology. *New Heritage Publishers*, Brooklyn, New York, USA, (2018).