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The strongest matter: “Einsteinon” could be one billion times stronger than carbon nanotubes

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Abstract

The controversy about the feasibility of space elevator cables is summarized, emphasizing the huge strength-to-density ratio needed for the megacable material, comparable only to that of defect-free carbon nanotubes. In spite of this, the existence of a hypothetical matter, that we have called “Einsteinon”, with strength-to-density ratio one billion times higher than that of carbon nanotubes, is shown to be compatible with Relativity. Einsteinon would be the strongest material, having cracks propagating at the speed of light. A very simple argument is also introduced for a rough unification of the gravitational and nuclear forces, suggesting that such a material would probably be based on sub-nuclear-like interactions.

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1. Introduction: The space elevator

Two recent news@nature articles, *The Space elevator: going down?* [1] or *The Space elevator: going up?* [2], as well as the paper *Space elevator: out of order?* [3] (highlighted by Nature, vol. 450, 22 November 2007) clearly emphasize the controversial viewpoint, and even confusion, still existing on the feasibility of a terrestrial space elevator.

First of all, what is a space elevator? It mainly consists of a cable attached to the planet’s surface for carrying,

with appropriate climbers, payloads into space. If the cable is long enough (around 150,000 km for the Earth), centrifugal forces exceed gravitational forces and the cable work under tension.

But the required material must possess a huge strength-to-density ratio, today displayed only by defect-free carbon nanotubes. Scientists are consequently proposing to develop a megacable with carbon nanotubes, assuming for it their defect-free strength [4]. But a larger cable statistically implies longer cracks, and is clearly therefore weaker [5] (see also the related news@nature [1]). Thus the space elevator is going down if the current “defect-free” design is assumed. On the other hand, a sufficiently strong cable can in principle be built with any material simply considering a uniform tensile stress profile. But technologically, with achievable cable maximum cross-sections, only moderately large defects could be tolerated. Thus the

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space elevator is going up if the “flaw-tolerant” design is assumed [6].

Thus, is the space elevator out of order? At present, yes, since our ability to control defects during the scaling-up procedure is not sufficient to guarantee a moderately large defect in a megacable; but obviously, never say never.

The example of the space elevator clearly emphasizes the fundamental role played in material science by the strength-to-density ratio, raising the question if carbon nanotube can be considered as the ultimate strongest material.

2. The strongest matter

Chemical bonds in carbon nanotubes are probably the strongest, at least among those currently known (see [7] for a periodic table of the nanomechanical properties of the elements). Nevertheless, matters governed by different interactions (e.g. nuclear or sub-nuclear) exist and could perhaps be engineered in a long-term future or could form existing structures in our Universe (e.g. nucleon or quark stars). Also for these hypothetical materials Relativity poses a physical limit to the velocity of the crack propagation v . In fact, information could in principle be transmitted between two persons separated by a solid, by a series of cracks propagating from one side to the other, using for example the Morse code alphabet. Accordingly, the crack velocity must not exceed the speed of light c . The limiting material, corresponding to crack propagations at the speed of light, is here called “Einsteinon” (differently from the “Einsteinium”, element with atomic number 99 and atomic weight 252). In order to estimate the strength-to-density ratio of Einsteinon we assume here the validity of the theory of the limiting speed in dynamic fracture proposed in Ref. [8]. Accordingly, the square root of the strength (σ)-to-density (ρ) ratio is the limiting crack propagation speed, i.e. $v \approx \sqrt{\sigma/\rho}$. Imposing the coincidence between the limiting crack speed and the speed of light, we derived a strength-to-density ratio of $\sim (3 \times 10^8 \text{ m/s})^2 \approx 10^{17} \text{ Pa/kg/m}^3$. For comparison, carbon nanotubes have a theoretical strength-to-density ratio of $\sim 100 \text{ GPa}/1000 \text{ kg/m}^3 = 10^8 \text{ Pa/kg/m}^3$, thus Einsteinon could be one billion times stronger than carbon nanotubes.

3. Unification of the gravitational and nuclear forces

We may also note that according to Dynamic Quantized Fracture Mechanics [9] the strength of a material

is nearly proportional to $a^{-1/2}$, where a is the size of its constituting particles (fracture quantum). Thus, the derived limit on the strength-to-density ratio could also pose limitation to the size of the ultimate fundamental particles.

Limits of the current speculative note, evidently discussing just an hypothetical material, are correlated to the use of continuum approaches. In spite of this, we believe that quasi-continuum corrections are sufficient to derive plausible predictions also in the domain of Quantum Mechanics. To give a simple example we may note that in analogy with Dynamic Quantized Fracture Mechanics [9], not the force but its mean value along a fracture quantum has to be considered (due to the existence of energy quanta). Applying this concept to gravity, the force F exchanged between two masses m placed at a distance r is not Gm^2/r^2 , with G gravitational constant, but

$$F = \frac{1}{a} \int_{r-a}^r \frac{Gm^2}{r^2} dr = \frac{Gm^2}{r^2(1-a/r)}.$$

The singular corrective factor $(1-a/r)^{-1}$ appears. At larger size-scales $r \gg a$ and the classical gravitational force is recovered, whereas at smaller size-scales we expect $r \approx a$ and thus enormously stronger interactions, as observable. Note that a value of $(a/r)_n \approx -2 \times 10^{-38} + 1$ would allow us to unify gravitational and nuclear forces, whereas a value of $(a/r)_e \approx -6 \times 10^{-37} + 1$ would allow us to correlate gravitational and electrical forces, etc. These numbers are derived considering the nuclear, electrical and gravitational force constants to be, respectively, $g^2 \approx 0.3\hbar c$, $e^2/(4\pi\epsilon_0) \approx 0.01\hbar c$ and $Gm^2 \approx 6 \times 10^{-39}\hbar c$ (here g is the nuclear force constant, m is the mass of the proton, e is its electrical charge, ϵ_0 is the vacuum permittivity and \hbar is the Planck’s constant divided by 2π) [10]. This comparison suggests that sub-nuclear-like interactions are probably required in Einsteinon.

4. Conclusions

The controversy about the feasibility of space elevator cables has inspired the question if carbon nanotubes can be considered the ultimate strongest material in the Universe. In this short speculative paper we have shown that the existence of an hypothetical matter, that we have called “Einsteinon”, having cracks propagating at the speed of light and strength-to-density ratio one billion times higher than that of carbon nanotubes, is compatible with Relativity. A very simple argument is also introduced for a rough unification of the gravitational and

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