The vacuum is blowing in the wind

by Harun Šiljak - Thursday, December 17, 2015

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Hero of our today's story is the Dutch physicist Hendrik Casimir. And two plates.

To make the results surprising, let's place the plates in vacuum: not a single atom will be in the space where we put the plates in. We'll put them in parallel, just like we're making a capacitor – just without any electromagnetic field in between. A million boson question: what is the force between these two plates, held at 10 nm apart (it was quite difficult to keep them at this distance, but our imaginary laboratory assistant Igor made it). Sure, gravity, we all know that – but what else?

Now that's difficult: it's vacuum, there are no fields, there's nothing, plates are neutral… do you want to use the "call Casimir" joker? Hendrik Casimir predicted (and experiments confirmed, as soon as we had the technology) that another force exists there, the force we today call Casimir-Polder's and which requires nothing at all. Nothing but the story from the first two antifeuilletons: infinity which is not infinite and zero energy which is not zero (nor infinite). Calculation of this effect is very similar to the one given in short in the previous antifeuilleton, so we won't repeat it. What is much more interesting is just what does this force mean physically.

The missing part of the story are the virtual particles. According to one interpretation, virtual particles are (usually) particle-antiparticle pairs repeatedly forming and annihilating. Why pairs? Well, remember those fermions and bosons we talked about the last time? In case of fermions you can't have just one particle, but a pair (why? Look at the numbers). In case of bosons, it doesn't really have to be a pair.

So, we have a particle-antiparticle pair emerging and quickly annihilating (more energy they have, faster they are to disappear, according to Heisenberg's principle). However, no one said they cannot interact with real particles in the meantime, giving them their energy. Something similar to this phenomenon happens on the edge of a black hole in these "vacuum fluctuations". While fluctuating, one particle can escape to outer space, and that is why the black holes aren't completely black (this is called Hawking's radiation).

Back to our plates, shall we? On a 10 nm distance in our example, the force between the plates can result in a pressure of one atmosphere! Everything is empty, no matter, nothing… and the force is there and it's real. So real that there are already ideas of harnessing it for spacecraft motors.

Few remarks at this point: Casimir's attractive force formula is F=? h c S/(480 l ?), in case you'd like to play around with it. In the formula, h is Planck's constant, c speed of light in vacuum, S the plates' area and l the distance between them.

Next remark is about the nature of Casimir's force. It can be both attractive and repulsive – attractive is caused by virtual bosons such as virtual photons (virtual photons are exactly what the formula above takes into account), while the repulsive force is caused by virtual fermions.

That’s the end of this glass bead game match. The next match, starting with “Mathematician’s flag is deepest space” we’ll leave the realm of physics. Mathematics, vexillology and secrets of Slavic languages await.

[1] *Sure, a little bit of Bob Dylan couldn’t hurt. Originally in Bosnian, this title was a pun from Croatian sitcom “Bitange i princeze” which was quite difficult to translate, so I changed it to this Dylan reference.*

[This is the third of a 10-article series to be published in the coming few weeks at Gonit Sora.]

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