equal amounts of matter and antimatter, which are kept apart by their gravitational repulsion. Virtual particle–antiparticle pairs in the vacuum would be gravitational dipoles. However, because like gravitational charges attract and opposite charges repel, gravitational vacuum polarization would increase gravitational fields that are strong enough to polarize the dipoles, which is different from electric charges where vacuum polarization decreases electric fields. This would lead to dynamics resembling Modified Newtonian Dynamics[9], which fit galactic rotation curves without the need for dark matter[10].

The assumption of repulsive gravity between matter and antimatter simultaneously solves the mysteries of the missing antimatter, dark matter and dark energy — replacing them with the challenge of how to fault all the arguments that have led us to believe that antimatter gravity is attractive[11]. This assumption will soon be tested by the antihydrogen experiments, and if they discover that gravity is repulsive between matter and antimatter, I predict that physicists will quickly find this should have been obvious. Perhaps it already is and we just don't realize it yet. ❐

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QUANTUM TECHNOLOGY

The golden apple

In Greek mythology, the vengeful goddess Eris chose an apple from the garden of the Hesperides (depicted in the painting by J. M. W. Turner, right) and tossed it onto the table at a banquet of the gods. This Golden Apple of Discord was to be given "to the fairest" — and caused a dispute among the goddesses Hera, Athene and Aphrodite that would lead to the judgment of Paris and ultimately the Trojan war. In quantum mechanics, however, the embodiment of discord takes a less dramatic form.

Discord measures the 'quantumness' of correlations. The most famous type of correlation in quantum physics — entanglement — is known to be an important (albeit expensive) resource for quantum technologies. But other, perhaps cheaper, or more resilient types of quantum correlation might also be useful, and might even be better than entanglement for certain tasks. For instance, quantum discord has already been shown to be superior to entanglement for remote state preparation and it can also be used to encode information (B. Dakić *et al. Nature Phys.* **8,** 666–670; 2012 and M. Gu *et al. Nature Phys.* **8,** 671–675; 2012).

More evidence of the usefulness of discord-type quantum correlations is now emerging. Writing in *Physical Review Letters*, Davide Girolami and colleagues demonstrate their value in quantum metrology — more precisely, in quantum phase estimation (*Phys. Rev. Lett.* **112,** 210401; 2014). They show that, in an interferometric setting, correlations between the input states enhance the precision of phase estimation. And these correlations need not be as strong as entanglement: discord-type correlations would be sufficient.


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Quantum discord may also empower 'quantum illumination', a paradoxical technique that exploits entanglement to image objects in an environment so noisy that it should destroy entanglement. Christian Weedbrook and co-workers suggest that discord, rather than entanglement, is behind quantum illumination (preprint at http://arxiv.org/abs/1312.3332; 2013) — which would explain why the technique still works when entanglement breaks down.

So discord seems to be less fussy and survives better in noisy environments, which suggests it might serve well in quantum cryptography. Indeed, when noise is present but is not accessible to all parties (particularly eavesdroppers), some quantum key distribution protocols can still work, even without entanglement. Stefano Pirandola suggests that such noise-assisted quantum cryptography draws its power from quantum discord (preprint at http://arxiv.org/abs/1309.2446; 2013). However, entanglement would still be required for stronger device-independent protocols.

As the role of more general quantum correlations is uncovered in different scenarios, it seems that — unlike the mythological golden apple — quantum discord may be more a blessing than a curse.

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