Internship in ESA's Advanced Concepts Team
On
**Fundamental tests of gravity using a satellite-based quantum network**

European Space Research and Technology Centre
ESA ESTEC

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## Topic description

General relativity has proven to be a highly successful theory, describing accurately the behaviour of massive bodies on large scales whose principal interaction is gravitational. However, its application on cosmological scales, and on microscopic scales, has proven famously problematic; the former due to unresolved questions on the nature of dark matter and dark energy, and the latter in a search for a quantum theory of gravity. As a result, experiments searching for deviations from general relativity and constraining alternative theories of gravitation are of great scientific interest.

Quantum information, in particular metrology, allows for the use of quantum effects to increase the sensitivity of measurement schemes beyond their classical limits. In the context of space, this has been suggested in recent years [1,2,3] as a method for novel, high precision, tests of general relativity, and its interplay with quantum mechanics on systems where both theories could apply.

## Candidate's task

In this internship, a modular framework for satellite-based entanglement distribution in a quantum network, which has been recently developed by the Advanced Concepts Team together with TU Delft, will be utilised to investigate the influence of gravitationally induced corrections to the system.

In particular, the research will involve an analysis of the effects of gravitationally induced decoherence [4,5] and time dilation [6] on the photonic states carrying and transferring quantum information between network nodes; gravitational effects on quantum memories [7] and repeaters that form these nodes might also be studied.

## Joining the ACT

Creativity and out-of-the-box thinking are essential in the ACT. Therefore, the team is constantly striving to be a diverse, inclusive and equitable workplace bringing together people from various backgrounds. We strongly encourage people from under-represented groups to apply to be part of our team as diversity is central to our mission and core values.

In order to make our hiring as fair as possible, we also ask applicants to not include photos in their CVs.

## References


[1] Siddarth Koduru Joshi et al "Space QUEST mission proposal: experimentally testing decoherence due to gravity", New J. Phys. 20 063016 (2018)

[2] Dominic Branford, Christos N. Gagatsos, Jai Grover, Alexander J. Hickey, and Animesh Datta, "Quantum enhanced estimation of diffusion", Phys. Rev. A 100, 022129

[3] Zych, M., Costa, F., Pikovski, I. et al. Bell's theorem for temporal order. Nat Commun 10, 3772 (2019). https://doi.org/10.1038/s41467-019-11579-x

[4] Magdalena Zych, Fabio Costa, Igor Pikovski, Timothy C Ralph and Časlav Brukner, "General relativistic effects in quantum interference of photons", Classical and Quantum Gravity, Volume 29, Number 22 (2012)

[5] Petruzziello, L., Illuminati, F. Quantum gravitational decoherence from fluctuating minimal length and deformation parameter at the Planck scale. Nat Commun 12, 4449 (2021)

[6] Pikovski, I., Zych, M., Costa, F. et al. Universal decoherence due to gravitational time dilation. Nature Phys 11, 668–672 (2015)

[7] Roy Barzel, Mustafa Gündoğan, Markus Krutzik, Dennis Rätzel, Claus Lämmerzahl, "Gravitationally induced entanglement dynamics of photon pairs and quantum memories", arXiv:2209.02099 (2022)