

FUNDAMENTAL PARTICLE INTERACTIONS BEYOND THE STANDARD MODEL

HEP BSM

Anca Tureanu

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HIP SAB Meeting
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Research team

- Project leader: **Anca Tureanu**, Professor
- Senior members (adjoint scientists):
 - **Masud Chaichian**, Professor emeritus
 - **Katri Huitu**, Professor
 - **Esko Keski-Vakkuri**, Senior university lecturer
 - **Timo Kärkkäinen**, PhD, visiting scientist
 - **Oleg Lebedev**, Professor
 - **Markku Oksanen**, University researcher
 - **Jenny Wagner**, PhD, visiting scientist

Research team

- Postdocs
 - Nicola Pranzini
 - Sergi Nadal-Gisbert
 - Hanzhi Jiang
- PhD students
 - Duarte Feiteira
 - Savankumar Hirpara
 - Ron Nyström
 - Santeri Salomaa
 - Sebastian Sassi
 - Nico Stirling
 - Otto Veltheim

Research: Neutrino theory

Tureanu, “On massive neutrinos and coherence in neutrino oscillations”,
Nucl.Phys.B 1018 (2025) 117052, arXiv: 2509.18812 [hep-ph]

- Can flavour neutrino states be coherent superpositions of massive neutrino states of different masses?
- All QFT and QM arguments entail the production of neutrinos as **statistical ensembles of massive neutrino states** :
 - S-matrix definition of flavour neutrino states
 - coherent states compatible with incoherent production and detection
 - uncertainty principle and wave packets
- Conclusion: neutrino oscillations cannot be explained by the superposition of massive neutrino states
- Solution: neutrino flavour waves propagating in quantum vacuum/matter, analogous to circular birefringence

Oksanen, Stirling, Tureanu, Phys.Lett.B 865 (2025) 139461

Oksanen, Stirling, Tureanu, in preparation (2026)

Research: Dark matter production in the Early Universe

Lebedev and Yoon, “Neutrino mixing and gravitational production via inflation”,
arXiv: 2605.11062 [hep-ph]

- Can gravitational fermion production in the Early Universe account for (the) dark matter?
- Framework: gravitational fermion production with a seesaw-like mass matrix in the Early Universe
- Proven that even massless (at present) fermions are efficiently produced by classical gravity as long as they have a time-dependent mixing with other fermions
- Relatively light right-handed neutrinos can be produced simply due to the expansion of space and can potentially constitute all of the dark matter.

Feiteira, Koutroulis, Lebedev and Pokorski, JCAP 03 (2026) 030

Feiteira and Lebedev, JCAP 07 (2025) 003

Research: CPT violation

Chaichian, Oksanen and Tureanu, “Renormalizable and unitary nonlocal quantum field theory with CPT violation and its implication”, arXiv: 2601.04037 [hep-th]

- Key assumption: CPT violation in Lorentz invariant nonlocal QFT with mass splitting between particle and antiparticle
- Can such theories play a role in baryogenesis?
- Renormalizability analysis: UV divergences similar to the local theory
- Unitarity analysis: “tree unitarity” is satisfied
- A path towards establishing a viable CPT violating Lorentz invariant nonlocal QFT, with potential implications on baryogenesis.

Alvarez-Gaume, Chaichian, Oksanen, Tureanu, PLB 850 (2024) 138483

Chaichian, Fujikawa, Tureanu, EPJC 73 (2013) 2349

Research: other topics

- Supersymmetry and extra dimensional models

Ghosh, Huitu and Sahu, JHEP 04 (2025) 063

Ghosh, Huitu and Sahu, PRD 111 (2025) 075011

- Quantum information theory

Keski-Vakkuri in J. de Boer et al., PRA 112 (2025) 032405

Veltheim and Keski-Vakkuri, PRL 134 (2025) 030801

- Gamma-ray bursts delays

Brevik, Chaichian and Tureanu, PLB 861 (2025) 139272

Chaichian, Couto e. Silva and Sánchez-Vega, arXiv:2604.03945 [hep-ph]

- Astronomy: gravitational lensing and dark matter

Wagner, arXiv:2605.12593 [gr-qc]

Wagner and Falco, Astron. & Astrophys. 710 (2026) A129

HEP BSM budget and implementation

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HIP funds cca 115 kEUR (2026)

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- salaries of one university researcher (Oksanen) and (partly) PhD students
- conference travel and visits to research groups abroad
- inviting foreign collaborators for short visits to Helsinki: I. Brevik (Trondheim), J.-H. Yoon (Chungnam University, Korea), M. Shaposhnikov (Lausanne), B. Tekin (Ankara)

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- 1 RCF project (Keski-Vakkuri): salary of 1 PhD student and 1 postdoc
- RCF Quantum Doctoral Pilot program and RCF Finnish Quantum Flagship: 2 PhD students and 1 postdoc
- Finnish private foundations: PhD students and travel grants
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Publications in 2025

- 23 articles in PRL, PLB, EPJC, PRD, PRA, PR Res, JHEP, JCAP, NPB, IJMPA, Astron. Astrophys.