Preprint Series in Particles and Cosmos Physics
nº IPARCOS-UCM-26-040

INSTITUTO DE FÍSICA
DE PARTÍCULAS Y DEL COSMOS

IPARCOS

# Quantum Computers will constrain the Equation of State of Neutron Stars

by A. Castaño-García, et al.
(including F. J. Llanes-Estrada and M. Logrosán Álvarez)

July 2026

Plaza de las Ciencias, 1 28040 Madrid, Spain
www.ucm.es/iparcos/

UNIVERSIDAD COMPLUTENSE MADRID

INSTITUTO DE FÍSICA
DE PARTÍCULAS Y DEL COSMOS

IPARCOS

# Abstract

**The Equation of State (EoS) of Nuclear Matter at high densities, and particularly that of neutron stars, resists ab initio Quantum Chromodynamics (QCD) computations due to the notorious sign problem of Lattice Gauge Theory at finite chemical potential. A quantum computer deploying QCD in canonical quantization should be able to make substantial progress. We set some basic goals for a future quantum computer to predict the EoS, and thus the basic static observables of the star (mass, radius and tidal deformability, for example). We then develop the basic theory to address the canonical Hamiltonian in Weyl (time-axial) gauge expressed in normal modes, together with the squared Gauss operator $G^2$ necessary to execute energy minimization algorithms restricted to the physical Fock subspace. \r\nFinally, we deploy our particle-quantum register encoding of a generic field theory to demonstrate QCD at finite chemical potential for a few (three-four) particles with a modest number of momentum modes, by simulating the quantum computer on a classical cluster. This opens the possibility for effective quantum computers to constrain the microscopic physics of neutron stars simultaneously to the operation of third--generation gravitational wave detectors such as the Einstein Telescope, providing more detailed predictions than has been possible until now.**

UNIVERSIDAD
COMPLUTENSE
MADRID