Using particle accelerators to investigate the quark-gluon plasma of the infant universe

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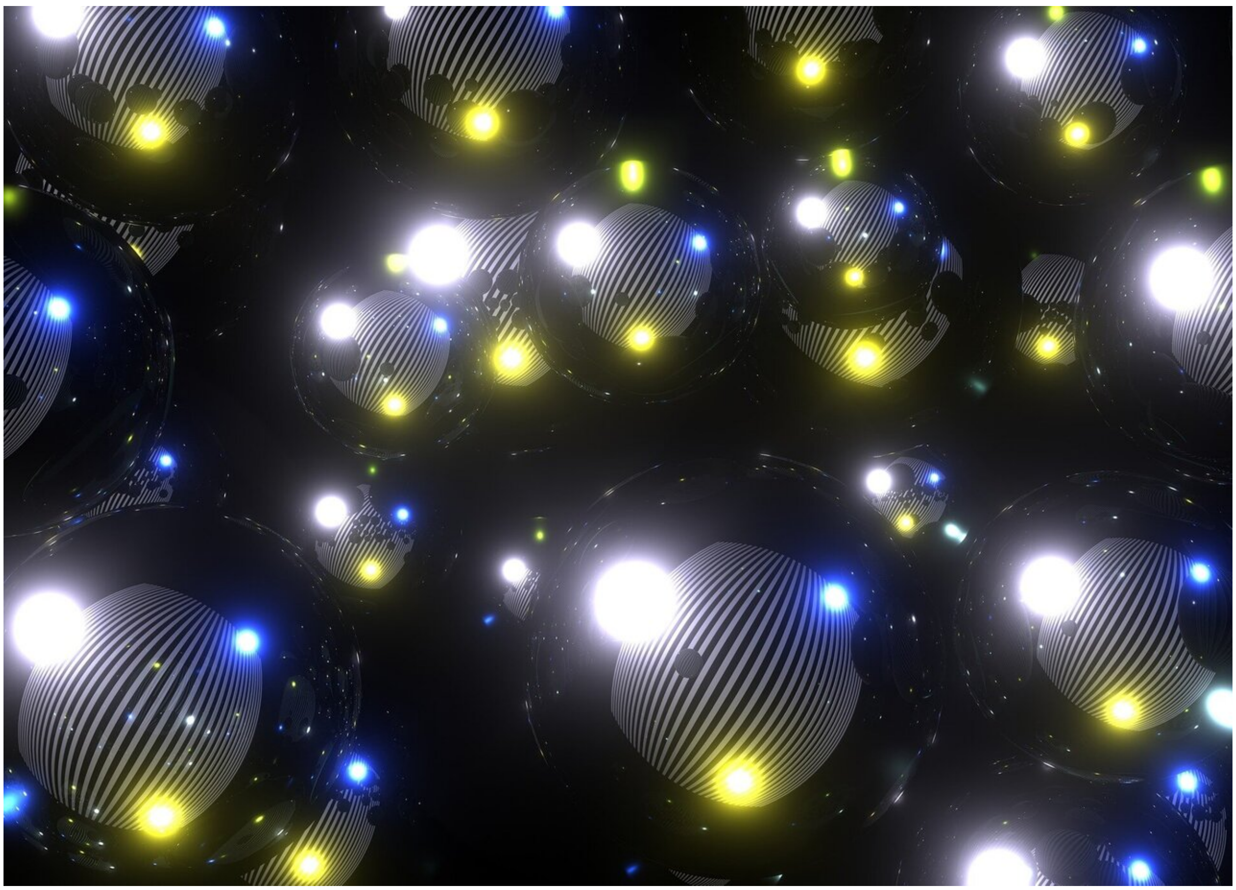

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In the early stages of the Universe, quarks and gluons were quickly confined to protons and neutrons which went on to form atoms. With particle accelerators reaching increasingly higher energy levels the opportunity to study this fleeting primordial state of matter has finally arrived.

Quark-Gluon Plasma (QGP) is a state of matter which existed only for the briefest of times at the very beginning of the Universe with these particles being quickly clumped together to form the protons and neutrons that make up the everyday matter that surrounds us. The challenge of understanding this primordial state of matter falls to physicists operating the world's most powerful particle accelerators. A new special edition of *The European Physical Journal Special Topics* entitled "Quark-Gluon Plasma and Heavy-Ion Phenomenology" edited by Munshi G. Mustafa, Saha Institute of Nuclear Physics, Kolkata, India, brings together seven papers that detail our understanding of QGP and the processes that transformed it into the baryonic matter around us on an everyday basis.

"Quark-Gluon Plasma is the strongly interacting deconfined matter which existed only briefly in the early universe, a few microseconds after the Big Bang," says Mustafa. "The discovery and characterisation of the properties of QGP remain some of the best orchestrated international efforts in modern nuclear physics." Mustafa highlights Heavy Ion Phenomenology as providing a very reliable tool to determine the properties of QGP and in particular, the dynamics of its evolution and cooling.

Improvements at colliders such as the Relativistic Heavy Ion Collider (RHIC) and the Large Hadron Collider (LHC) have radically increased the energy levels that can be attained by heavy nuclei collisions at near-light speeds bringing them in line with those of the infant Universe. In addition to this, future experiments at the Facility for Antiproton and Ion Research (FAIR) and at the Nuclotron-based Ion Collider fAcility (NICA) will generate a wealth of data on QGP and the conditions in the early Universe.

"This collection is so timely as it calls for a better theoretical understanding of particle properties of hot and dense deconfined matter, which reflect both static and dynamical properties of QGP," explains Mustafa. "This improved theoretical understanding of Quark-Gluon Plasma and Heavy Ion Phenomenology is essential for uncovering the properties of the putative QGP which occupied the entire universe, a few microseconds after Big Bang."

Mustafa points out that this improved understanding should also open the doorway to understanding the equation of state of this strongly interacting matter and prepare the platform to explore the theory of quark-hadron transition and the possible thermalisation of the QGP. This could in turn help us understand the steps that led from QGP to the everyday baryonic matter that surrounds us.

"The quarks and gluons which formed the neutrons and protons were confined into them, a few microseconds after the Big Bang," concludes Mustafa. "This is the first time when we have seen them being liberated from their eternal confinement!"

More information: Munshi G. Mustafa, Quark–Gluon plasma and heavy-ion phenomenology, *The European Physical Journal Special Topics* (2021). DOI: 10.1140/epjs/s11734-021-00018-y

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