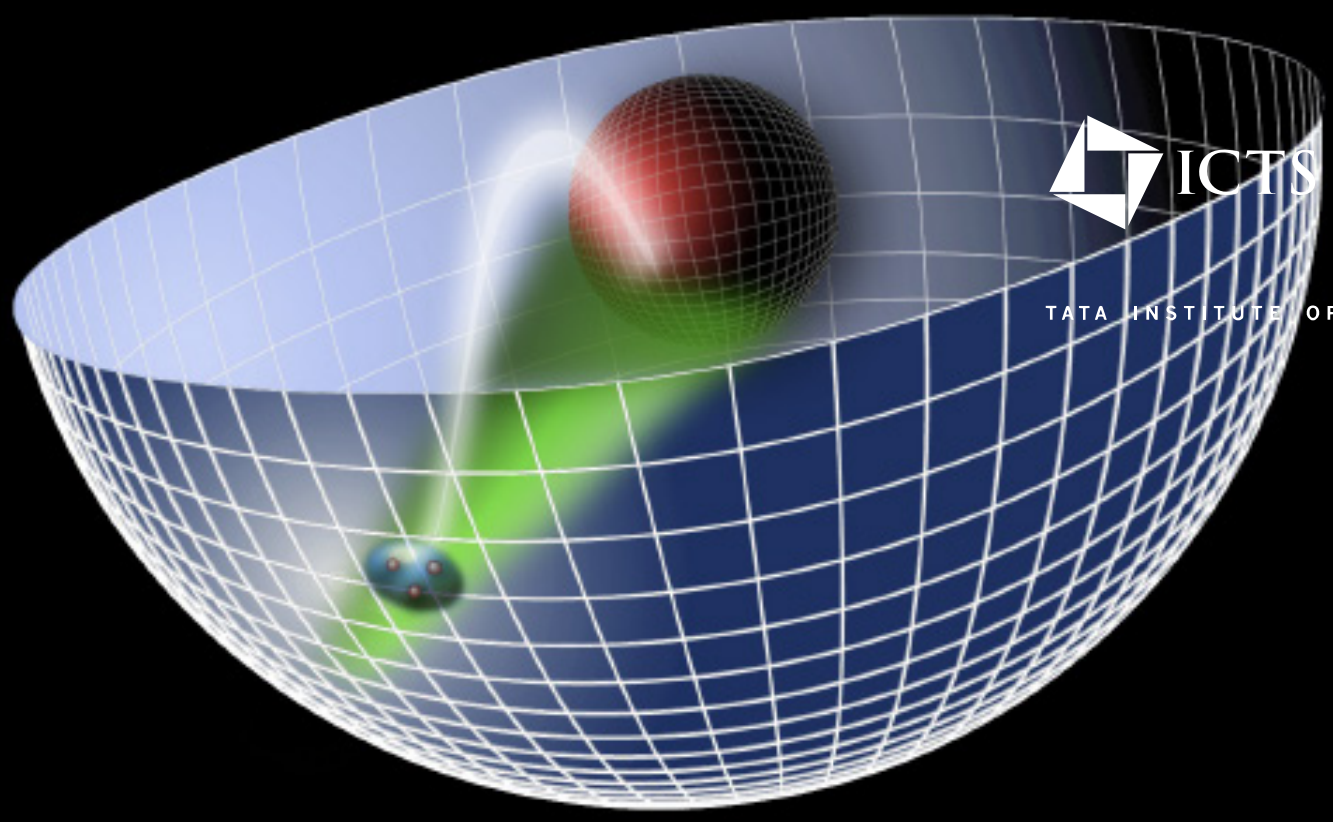

INTERNATIONAL CENTRE for THEORETICAL SCIENCES
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ICTS LECTURE SERIES

# Multi-particle production in QCD and gravity at high energies: from amplitudes to shockwaves

These lectures discuss multi-particle production in QCD and in gravity, remarkable double copy relations, and strong parallels in emergent shockwave dynamics. We motivate the strong relevance of these topics for experimental programs and their role in resolving outstanding open problems.We derive explicitly a BFKL RG equation for multi-gluon production, whose dynamics is captured by a 2-D reggeon EFT. Identical methods apply for multi-graviton production. BFKL RG evolution generates non-perturbative wee parton states of maximal occupancy, whose many-body dynamics can be described as a Color Glass Condensate (CGC). A universal shockwave picture of deeply inelastic scattering and hadron-hadron collisions emerges, wherein the strongly correlated dynamics provides a rich ab initio picture of how quark-gluon plasmas form. Gluon radiation in the CGC EFT has a double copy in gravitational shockwave collisions, which describes multi-particle production in strong fields, self-force and tidal contributions, and classical and quantum noise in the focusing of geodesics. This opens an EFT window into gravitational wave radiation and black hole formation.

## Raju Venugopalan

Distinguished Scientist, Brookhaven National Lab, USA

Raju Venugopalan is a Distinguished Scientist at BNL and the Director of the BNL EIC Theory Institute. He has been an Adjunct Professor at Stony Brook since 2009. Venugopalan's interests are primarily in nonperturbative many-body features of gauge theories. He is known for his seminal work on the Color Glass Condensate effective field theory of high energy QCD, and for his work on thermalization of the quark-gluon plasma. With his BNL colleagues, Venugopalan came up with the idea of introducing a high energy electron beam in the RHIC tunnel, and developed the science case for the Electron-Ion Collider (EIC) now under construction at BNL. A recent research focus of his is on the double copy between QCD and gravitational amplitudes at high energies. Venugopalan is a Fellow of the APS, and has received several awards for his research including the Humboldt Research Award, and most recently, the UK Royal Society Wolfson 2025-2026 Visiting Fellowship.

**20, 22, 27, 29, 30 January 2026**
**03, 05, 06 February 2026**
Emmy Noether Seminar Room
ICTS, Bengaluru

Zoom link: https://shorturl.at/19z5Z
Meeting ID: 981 8980 3732
Passcode: 202030