APR07-2007-000424
Abstract for an Invited Paper
for the APR07 Meeting of
the American Physical Society

Recent Advances in Loop Quantum Cosmology

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Einstein's theory of classical general relativity explains the dynamics of our universe at low energies to an excellent precision. However, it breaks down at the Planck scale before the big bang singularity is reached. Relativity thus fails to tell us about the origin of our cosmos and leaves open various questions which are expected to be answered by a quantum theory of gravity. We will review recent developments in loop quantum cosmology which is a quantization of cosmological spacetimes based on loop quantum gravity – a non-perturbative background independent quantization of gravity. Because, of fundamental discreteness of quantum geometry underlying loop quantum gravity, novel features arise. In particular, for quantum states representing a large classical universe at late times there is an upper bound on the gravitational curvature, of the order of $1/(\text{Planck length})^2$. Thus, non-perturbative quantum gravity effects forbid the cosmological dynamics from entering a regime where curvature or energy density blow up. Evolution in loop quantum cosmology is non-singular. In models studied so far, the backward evolution of our expanding universe does not lead to a big bang but a big bounce to a contracting branch when the gravitational curvature reaches Planck scale. These results which have now been established for various homogeneous spacetimes provide a new paradigm of the genesis of our universe and lead to useful insights on the generic resolution of space-like singularities through quantum gravity effects.