List of referred publications
(the order of authors in the eight recent papers is alphabetical)

1. Bojowald, M., G. Hossain, M. Kagan, and S. Shankaranarayanan, Gauge invariant cosmological perturbation equations with corrections from loop quantum gravity, Phys. Rev. D 79 043505, 2009

   A consistent implementation of quantum gravity is expected to change the familiar notions of space, time and the propagation of matter in drastic ways. This will have consequences on very small scales, but also gives rise to correction terms in evolution equations of modes relevant for observations. In particular, the evolution of inhomogeneities in the very early universe should be affected. In this paper consistent evolution equations for gauge-invariant perturbations in the presence of inverse triad corrections of loop quantum gravity are derived. Some immediate effects are pointed out, for instance concerning conservation of power on large scales and non-adiabaticity. It is also emphasized that several critical corrections can only be seen to arise in a fully consistent treatment where the gauge freedom of canonical gravity is not fixed before implementing quantum corrections. In particular, metric modes must be allowed to be inhomogeneous: it is not consistent to assume only matter inhomogeneities on a quantum corrected homogeneous background geometry. In this way, stringent consistency conditions arise for possible quantization ambiguities which will eventually be further constrained observationally.

2. Bojowald, M., G. M. Hossain, M. Kagan, and S. Shankaranarayanan, Anomaly freedom in perturbative loop quantum gravity, Phys. Rev. D **78**, 063547, 2008

   A fully consistent linear perturbation theory for cosmology is derived in the presence of quantum corrections as they are suggested by properties of inverse volume operators in loop quantum gravity. The underlying constraints present a consistent deformation of the classical system, which shows that the discreteness in loop quantum gravity can be implemented in effective equations without spoiling space-time covariance. Nevertheless, non-trivial quantum corrections do arise in the constraint algebra. Since correction terms must appear in tightly controlled forms to avoid anomalies, detailed insights for the correct implementation of constraint operators can be gained. The procedures of this article thus provide a clear link between fundamental quantum gravity and phenomenology.

3. Bojowald, M., H. H. Hernandez, M. Kagan, and A. Skirzewski**,** Effective constraints of loop quantum gravity, *Phys. Rev. D*, **75**, 64022, 2007.

   Within a perturbative cosmological regime of loop quantum gravity corrections to effective constraints are computed. This takes into account all inhomogeneous degrees of freedom relevant for scalar metric modes around flat space and results in explicit expressions for modified coefficients and of higher order terms. It also illustrates the role of different scales determining the relative magnitude of corrections. Our results demonstrate that loop quantum gravity has the correct classical limit, at least in its sector of

cosmological perturbations around flat space, in the sense of perturbative effective theory.

4. Bojowald, M., H. H. Hernandez, M. Kagan, P. Singh, and A. Skirzewski, Formation and evolution of structure in Loop Cosmology, *Phys. Rev. Lett.* **98**, 031301, 2007.

   Inhomogeneous cosmological perturbation equations are derived in loop quantum gravity, taking into account corrections, in particular, in gravitational parts. This provides a framework for calculating the evolution of modes in structure formation scenarios related to inflationary or bouncing models. Applications here are corrections to the Newton potential and to the evolution of large scale modes which imply non-conservation of curvature perturbations possibly noticeable in a running spectral index. These effects are sensitive to quantization procedures and test the characteristic behavior of correction terms derived from quantum gravity.

5. Bojowald, M., H. H. Hernandez, M. Kagan, P. Singh, and A. Skirzewski, Hamiltonian cosmological perturbation theory with loop quantum gravity corrections, *Phys. Rev. D*, **74**, 123512, 2006..

   Cosmological perturbation equations are derived systematically in a canonical scheme based on Ashtekar variables. A comparison with the covariant derivation and various subtleties in the calculation and choice of gauges are pointed out. Nevertheless, the treatment is more systematic when correction terms of canonical quantum gravity are to be included. This is done throughout the paper for one example of characteristic modifications expected from loop quantum gravity.

6. Bojowald, M. and M.A. Kagan, Loop cosmological implications of a non-minimally coupled scalar field, *Phys. Rev. D*, **74**, 044033, 2006.

   Non-minimal actions with matter represented by a scalar field coupled to gravity are considered in the context of a homogeneous and isotropic universe. The coupling is of the form -(1/2)xi phi^{2}R. The possibility of successful inflation is investigated taking into account features of loop cosmology. For that end a conformal transformation is performed. That brings the theory into the standard minimally coupled form (Einstein frame) with some effective field and its potential. Both analytical and numerical estimates show that a negative coupling constant is preferable for successful inflation. Moreover, provided fixed initial conditions, larger |xi| leads to a greater number of e-folds. The latter is obtained for a reasonable range of initial conditions and the coupling parameter and indicates a possibility for successful inflation.

7. Bojowald, M. and M.A. Kagan, Singularities in Isotropic Non-Minimal Scalar Field Models, *Class.Quant.Grav.*, **23**, 4983, 2006.

   Non-minimally coupling a scalar field to gravity introduces an additional curvature term into the action which can change the general behavior in strong curvature regimes, in particular close to classical singularities. While one can conformally transform any non-minimal model to a minimally

coupled one, that transformation can itself become singular. It is thus not guaranteed that all qualitative properties are shared by minimal and non-minimal models. This paper addresses the classical singularity issue in isotropic models and extends singularity removal in quantum gravity to non-minimal models.

8. Kagan, M.A., Phenomenological implications of an alternative Hamiltonian constraint for quantum cosmology, *Phys. Rev. D*, **72**, 104004-13, 2005.

In this paper we review a model based on loop quantum cosmology that arises from a symmetry reduction of the self-dual Plebanski action. In this formulation the symmetry reduction leads to a very simple Hamiltonian constraint that can be quantized explicitly in the framework of loop quantum cosmology. We investigate the phenomenological implications of this model in the semi-classical regime and compare those with the known results of the standard Loop Quantum Cosmology.

9. Kagan, M.A. and E.A. Khazanov, Thermally induced birefringence in Faraday devices made from terbium gallium garnet-polycrystalline ceramics, *Applied Optics,* **43**(32), 6030-39, 2005.

We have developed a model that describes thermally induced birefringence in polycrystalline ceramics that are exposed to a magnetic field. Conditions under which traditional compensation techniques (for glass and single crystals) can be effective for ceramics have been found. It is shown that a ceramic is almost equivalent to a [111]-oriented crystal if the ratio of the rod length to the grain size is ~300 or more. In particular, residual depolarization (after the compensation techniques are applied) is inversely proportional to this ratio, which is an important consequence of the random nature of thermally induced birefringence in ceramics.

10. Feigin, M.I. and M.A. Kagan, Emergencies as a Manifestation of the Effect of Bifurcation Memory in Controlled Unstable Systems, *International Journal of Bifurcation and Chaos (IJBC),* 14(7), 2439-47, 2004.

Unusual behavior of dynamic systems with a control parameter is analyzed. Bifurcation induced qualitative changes in phase portraits of such systems are quite routine and ensure efficient operation. This class of systems includes ships with high maneuvering capabilities, aircraft and controlled underwater vehicles designed to be unstable in steady-state motion that are interesting in terms of applications. Bifurcations may generate tracks of bifurcation memory that are "indicators" of regions of reduced controllability referred to as phase spots. The transition process in the phase spot is estimated qualitatively as a universal dependence of the index of loss of controllability on the control parameter. The proposed approach has allowed us to predict and investigate emergency manifestations of the bifurcation memory effect occurring during routine maneuvering.

11. Kagan, M.A. and E.A. Khazanov, Compensation of thermally induced birefringence in active medium made of polycrystalline ceramics, in *Collected Papers of*

international conference "Photonics West, Solid State Lasers XII", San Jose, CA, Proc. SPIE 4968**,** 151, 2003.

The essential difference of ceramics from a single crystal is that crystal axes in each grain comprising ceramics are arbitrarily oriented. We apply quaternion formalism (instead of traditional Jones matrix formalism) to describe depolarization of laser beam. This allows us to derive analytical expressions for depolarization ratio for uncompensated case and for all known compensation techniques as well. The analytic results, we have got, are in good agreement with numerical ones. It has been shown, that ceramic is almost equivalent to [111] crystal if the ratio of the rod length to grain length is about 300 or more. In particular, uncompensated depolarization is inversely proportional to this ratio. The latter is an important consequence of the random nature of thermally induced birefringence in ceramics.

12. Kagan, M.A. and E.A. Khazanov, Compensation for thermally induced birefringence in polycrystalline ceramic active elements, *Quantum Electronics,* **33**(10), 876-882, 2003.

Polycrystalline ceramics differ significantly from single crystals in that the crystallographic axes (and hence of the axes of thermally induced birefringence) are oriented randomly in each granule of the ceramic. The quaternion formalism is employed to calculate the depolarisation in the ceramics and the efficiency of its compensation. The obtained analytic expressions are in good agreement with the numerical relations. It is shown that the larger the ratio of the sample length to the granule size, the closer the properties of the ceramics to those of a single crystal with the [111] orientation (in particular, the uncompensated depolarization is inversely proportional to this ratio).

PUBLICATIONS IN PREPARATION **(the order of authors is alphabetical)**

1. **Hossain, G. M., M. Kagan,** On the stress-energy tensor in canonical quantum gravity
2. **Bojowald, M., G. M. Hossain, M. Kagan, and S. Shankaranarayanan,** Phenomenological implications of gauge invariant loop quantum corrected cosmological perturbation equations.