Principle Investigator Prof. Aram Mekjian

Department of Physics and Astronomy, Rutgers University, Piscataway, NJ 08854

e-mail mekjian@physics.rutgers.edu, phone 848-445-8776

Title of Project: "Studies of nuclei under the extreme conditions of density, temperature, isospin asymmetry and the phase diagram of hadronic matter".

The main emphasis of the entire project is on issues having to do with medium energy and ultra-relativistic energy and heavy ion collisions. A major goal of both theory and experiment is to study properties of hot dense nuclear matter under various extreme conditions and to map out the phase diagram in density or chemical potential and temperature. My studies in medium energy nuclear collisions focused on the liquid-gas phase transition and cluster yields from such transitions. Here I developed both the statistical model of nuclear multi-fragmentation and also a mean field theory. Cluster yields also appear in many areas of physics and nuclei offer the possibility of studying two component systems. Nuclei are made of protons and neutrons and a special symmetry known as isospin symmetry plays an important role. The role of the symmetry energy associated with this symmetry was studied, along with the symmetry breaking coming from the Coulomb energy. Both play an important role in the valley of nuclear stability and questions associated with large isospin asymmetric systems fundamental to our understanding of future radioactive beam experiments. A fundamental question is whether the liquid gas phase transition is first or second order. Using a canonical ensemble statistical model developed from our multi-fragmentation cluster yield picture we found the phase transition to be both first order in one and two component systems. A fast recurrence method was introduced to obtain the canonical ensemble for the study of phase transitions. The nuclear compressibility was also studied which is governs nuclear collapse in supernovae explosions. My most recent research involved the questions associated with universal thermodynamics a phenomena associated with scattering lengths that are large compared to inter-particle spacing. Nucleon-nucleon scattering and associated near zero binding energies have this particle feature and are therefore offer an ideal situation for such studies. The role of Feshbach resonances and the unitary limit was analyzed. Also studied are questions associated with perfect fluid behavior governed by the viscosity to entropy density ratio. Ads/CFT made a prediction of a lower limit for this ratio involving Planck's constant and Boltzmann's constant. The low energy nucleon-nucleon case seems to be about five times the lower limit. However near perfect fluid behavior seems to be realized in ultra-relativistic collisions.

The second aspect of my research involves relativistic and ultra-relativistic collisions. Here again I worked on a statistical model to predict particle distributions for both particle-particle collisions and nucleus-nucleus collisions. I was awarded a Fulbright fellowship and went to KFKI and the Hungarian

National Academy in Budapest, Hungary to work on event-by event distributions in particle-particle collisions. A generalized statistical model based on the Gauss hypergeometric distribution was used in the study. An example is the specific case of a Bose-Einstein model of particle multiplicity distribution which was developed with the Budapest group. Previously Bose-Einstein condensation in Laser traps was investigated using a micro canonical description that we solved exactly using partition theorems. I also worked on fluctuations and isospin/strangeness correlations in relativistic heavy ion collisions. Void distributions were also studied and fractal behavior. This work was later extended in a generalized statistical model of voids and hierarchical structure in cosmology.

The third aspect of my work involves exactly soluble models in statistical mechanics. These stem from my studies in cluster yields and multi fragmentation phenomena. Polya theory, partition theory, results from permutation groups, and methods from combinatorial analysis from discreet mathematics, were some of the tools used to generate the partition function of statistical mechanics. The resulting model has a variable called x sub k, which contains the physical variables. For example the physical variables are temperature, volume, Boltzmann factor in binding energy for cluster yields. Besides this factor there are terms relating to critical exponents. Many well-known phenomena, both in physics and even in biology are special cases of the simple generalized model that came out of this work. Some examples discussed in more detail in my last DOE proposal are:

1. Fragmantation and 1st and 2nd order phase transition – the initial motivation for this development

2. Bose-Einstein condensation for atoms in a box and also in a laser trap

3. Pionic event-by-event distributions

4. Percolation on a Bethe lattice

5. Flory-Stockmayer Polymer model

6. Feynman-Wilson gas

7. Connections with disordered systems such as random Ising interaction models and spin glass theory

8. Random permutations

9. Ewen's model in gene diversity and the neutral allele theory

10. Stochastic abundance models in ecology

11. Fibonacci-Lucas descriptions and branching processes.

12. Statistical Mechanics of cosmic strings

13. Power laws and critical exponents.

This last work is being written up as a research textbook "Statistical Models and Stochastic Networks in Physics and Biology".

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1. arXiv:1203.4638 [pdf]
   Title: Viscosity of a nucleonic fluid
   Authors: Aram Z. Mekjian
   Comments: 14 pages, 3 figures. arXiv admin note: text overlap with arXiv:1009.5951
   Subjects: Nuclear Theory (nucl-th); Quantum Physics (quant-ph)

2. arXiv:1202.3412 [pdf]
   Title: Symmetry energy and neutron-proton radii studies with a Wigner-Heisenberg monopole-monopole interaction
   Authors: Aram Mekjian, Larry Zamick
   Comments: 1 table, i figure
   Journal-ref: Phys.Rev. C85 ,057303 (2012)
   Subjects: Nuclear Theory (nucl-th)

3. arXiv:1112.0457 [pdf]
   Title: Nuclear equation of state and incompressibility in a model with correlations from giant monopole vibrations
   Authors: Aram Mekjian. Larry Zamick
   Comments: 10 pages
   Journal-ref: Phys. Rev. C 85,044318 (2012)
   Subjects: Nuclear Theory (nucl-th)

4. arXiv:1108.5790 [pdf, ps, other]
   Title: Neutron Skin size dependence of the nuclear binding energy
   Authors: S. J. Lee, A. Z. Mekjian
   Comments: 18 pages
   Subjects: Nuclear Theory (nucl-th); Nuclear Experiment (nucl-ex)

5. arXiv:1009.5951 [pdf]
   Title: Viscosity, entropy and the viscosity to entropy density ratio; how perfect is a nucleonic fluid?
   Authors: Aram Z. Mekjian
   Comments: 32 pages, 9 figures
   Subjects: Nuclear Theory (nucl-th)

6. arXiv:1003.4864 [pdf, ps, other]
   Title: Symmetry and Surface Symmetry Energies in Finite Nuclei
   Authors: S.J. Lee, A.Z. Mekjian
   Comments: 11 pages, 2 figures, Added a new table
   Journal-ref: Phys.Rev.C82:064319,2010
   Subjects: Nuclear Theory (nucl-th); Nuclear Experiment (nucl-ex)

7. arXiv:1003.1331 [pdf]
   Title: A study of Feshbach resonances and the unitary limit in a model of strongly correlated nucleons
   Authors: Aram Z. Mekjian
   Comments: 39 pages, 15 figures, 2 tables
   Journal-ref: Phys.Rev.C82:014613,2010
   Subjects: Nuclear Theory (nucl-th)

8. arXiv:0910.2471 [pdf]
   Title: Power law behavior associated with a Fibonacci Lucas model and generalized statistical models
   Authors: Aram Z. Mekjian
   Comments: 33 pages, 10 figures,2 tables
   Subjects: Statistical Mechanics (cond-mat.stat-mech); Disordered Systems and Neural Networks (cond-mat.dis-nn); Combinatorics (math.CO); Nuclear Theory (nucl-th)

9. arXiv:0812.3567 [pdf]
   Title: Feshbach Resonances and Limiting Thermodynamics of Strongly Correlated Nucleons
   Authors: A.Z.Mekjian
   Comments: 8 pages, 4 figures
   Journal-ref: Phys.Rev.C80:031601,2009
   Subjects: Nuclear Theory (nucl-th); Quantum Gases (cond-mat.quant-gas)

10. arXiv:0812.2999 [pdf, ps, other]
    Title: Density functional approach to finite temperature nuclear properties and the role of a momentum dependent isovector interaction
    Authors: S. J. Lee, A. Z. Mekjian
    Comments: 14 pages, 6 figures, added more discussion
    Journal-ref: Phys.Rev.C79:044323,2009
    Subjects: Nuclear Theory (nucl-th)

11. arXiv:0712.1778 [pdf]
    Title: Isospin and isospin/strangeness correlations in relativistic heavy ion collisions
    Authors: Aram Mekjian
    Comments: 11 pages
    Journal-ref: Eur.Phys.J.80:22002,2007
    Subjects: Nuclear Theory (nucl-th)

12. arXiv:0712.1217 [pdf]
    Title: Generalized statistical models of voids and hierarchical structure in cosmology
    Authors: Aram Z. Mekjian
    Comments: 25 pages
    Journal-ref: Astrophys.J.655:1-10,2007
    Subjects: Astrophysics (astro-ph); Nuclear Theory (nucl-th)

13. arXiv:0712.1168 [pdf]
    Title: Properties of baryonic, electric and strangeness chemical potentials and some of their consequences in relativistic heavy ion collisions
    Authors: Aram Z. Mekjian
    Journal-ref: Phys.Lett.B651:33-38,2007
    Subjects: Nuclear Theory (nucl-th)

14. arXiv:0711.4397 [pdf]
    Title: Critical Exponents and Particle Multiplicity Distributions in High Energy Collisions
    Authors: A.Z. Mekjian, S.J. Lee, T. Csorgo
    Comments: 10 pages, new table added
    Journal-ref: Nucl.Phys.A809:266-274,2008
    Subjects: Nuclear Theory (nucl-th)

15. arXiv:0709.0228 [pdf, ps, other]
    Title: Nuclear Chemical and Mechanical Instability and the Liquid-Gas Phase Transition in Nuclei
    Authors: S.J. Lee, A.Z. Mekjian
    Comments: 21 pages, 9 figures, Results are changed due to error in program
    Journal-ref: Phys.Rev.C77:054612,2008
    Subjects: Nuclear Theory (nucl-th)
16. arXiv:nucl-th/0612087 [pdf]
    Title: A Bose-Einstein Model of Particle Multiplicity Distributions
    Authors: A. Z. Mekjian, T. Csorgo, S. Hegyi
    Comments: Accepted for publication in Nucl. Phys. A
    Journal-ref: Nucl.Phys.A784:515-535,2007
    Subjects: Nuclear Theory (nucl-th)
17. arXiv:nucl-th/0503009 [pdf]
    Title: Obtaining the Specific Heat of Hadronic Matter from CERN/RHIC Experiments
    Authors: Aram Mekjian
    Comments: 10 pages
    Subjects: Nuclear Theory (nucl-th)
18. arXiv:nucl-th/0502006 [pdf, ps, other]
    Title: Nuclear Incompressibility in Asymmetric Systems at Finite Temperature and Entropy
    Authors: A.Z. Mekjian, S.J. Lee, L. Zamick
    Comments: 11 pages
    Journal-ref: Phys.Rev. C72 (2005) 044305
    Subjects: Nuclear Theory (nucl-th)
19. arXiv:nucl-th/0501069 [pdf, ps, other]
    Title: Expressions for the number of J=0 pairs in even-even Ti isotopes
    Authors: L. Zamick (1), A. Escuderos (1 and 2), S.J. Lee (3), A.Z. Mekjian (1), E. Moya de Guerra (2), A.A.
    Raduta (4), P. Sarriguren (2) ((1) Rutgers University, Piscataway, NJ, USA, (2) C.S.I.C., Madrid, Spain, (3)
    Kyung Hee University, Suwon, KyungGiDo, Korea (4) Bucharest University, Romania)
    Comments: 21 pages, RevTex4
    Journal-ref: Phys.Rev. C71 (2005) 034317
    Subjects: Nuclear Theory (nucl-th)
20. arXiv:nucl-th/0501063 [pdf, ps, other]
    Title: The number of J=0 pairs in {44,46,48}Ti
    Authors: L. Zamick, A. Escuderos, A. Mekjian
    Comments: Abstract Submitted for the APR05 Meeting of The American Physical Society
    Subjects: Nuclear Theory (nucl-th)
21. arXiv:nucl-th/0411063 [pdf]
    Title: Fluctuations in the Statistical Model of Relativistic Heavy Ion Collisions
    Authors: Aram Z. Mekjian
    Comments: 17 pages
    Journal-ref: Nucl.Phys. A761 (2005) 132-148
    Subjects: Nuclear Theory (nucl-th)
22. arXiv:nucl-th/0410108 [pdf, ps, other]
    Title: The Thermodynamic Model for Nuclear Multifragmentation
    Authors: C.B.Das, S.Das Gupta, W.G.Lynch, A.Z.Mekjian, M.B.Tsang
    Comments: 60 pages,24 figures, to be published as Physics Report
    Journal-ref: Phys.Rept. 406 (2005) 1-47
    Subjects: Nuclear Theory (nucl-th); Nuclear Experiment (nucl-ex)
23. arXiv:nucl-th/0408016 [pdf, ps, other]
    Title: Nuclear Incompressibility at Finite Temperature and Entropy
    Authors: A.Z. Mekjian, S.J. Lee, L. Zamick
    Comments: 5 pages
    Journal-ref: Phys.Lett. B621 (2005) 239-245
    Subjects: Nuclear Theory (nucl-th)
24. arXiv:nucl-th/0402089 [pdf, ps, other]

Title: Interrelationship of Isospin and Angular Momentum
Authors: L. Zamick, A.Z. Mekjian, S.J. Lee
Comments: 7 pages
Journal-ref: J.Korean Phys.Soc. 47 (2005) 18-22
Subjects: Nuclear Theory (nucl-th)

25. arXiv:nucl-th/0308031 [pdf, ps, other]
Title: Exploring proton rich systems and Coulomb induced instabilities
Authors: S.J. Lee, A.Z. Mekjian
Comments: 6 pages, 2 figures
Journal-ref: Phys.Lett. B580 (2004) 137-143
Subjects: Nuclear Theory (nucl-th); Condensed Matter (cond-mat); High Energy Physics - Phenomenology (hep-ph)

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1. arXiv:nucl-th/0308031 [pdf, ps, other]
   Title: Exploring proton rich systems and Coulomb induced instabilities
   Authors: S.J. Lee, A.Z. Mekjian
   Comments: 6 pages, 2 figures
   Journal-ref: Phys.Lett. B580 (2004) 137-143
   Subjects: Nuclear Theory (nucl-th); Condensed Matter (cond-mat); High Energy Physics - Phenomenology
   (hep-ph)
2. arXiv:nucl-th/0307019 [pdf, ps, other]
   Title: Specific heat at constant volume in the thermodynamic model
   Authors: C. B. Das (1), S. Das Gupta (1), A. Z. Mekjian (2) ((1) McGill University, Montreal, Canada, (2)
   Rutgers University, Piscataway, New Jersey, USA)
   Comments: Revtex, 7 pages including 4 figures
   Journal-ref: Phys.Rev. C68 (2003) 031601
   Subjects: Nuclear Theory (nucl-th)
3. arXiv:nucl-th/0304057 [pdf, ps, other]
   Title: Development of particle multiplicity distributions using a general form of the grand canonical partition
   function and applications to L3 and H1 Data
   Authors: S.J. Lee, A.Z. Mekjian
   Comments: 7 figures included
   Journal-ref: Nucl.Phys. A730 (2004) 514-547
   Subjects: Nuclear Theory (nucl-th)
4. arXiv:nucl-th/0210037 [pdf, ps, other]
   Title: Liquid-Gas Phase Transition and Instabilities in Asymmetric Two Component Systems
   Authors: S.J. Lee (Kyung Hee Univ.), A.Z. Mekjian (Rutgers Univ.)
   Comments: 5 pagesincluding 2 figures, submitted to PRL
   Journal-ref: Phys.Rev. C68 (2003) 014608
   Subjects: Nuclear Theory (nucl-th); Condensed Matter (cond-mat); High Energy Physics - Phenomenology
   (hep-ph)

5. arXiv:nucl-th/0209010 [pdf, ps, other]
   Title: Model of multifragmentation, Equation of State and phase transition
   Authors: C. B. Das (1), S. Das Gupta (1), A. Z. Mekjian (2) ((1) McGill University, Montreal, Canada, (2) Rutgers University, New Jersey, USA)
   Comments: Revtex, 9 pages including 6 figures: some change in the text and Fig. 1
   Journal-ref: Phys.Rev. C67 (2003) 064607
   Subjects: Nuclear Theory (nucl-th)

6. arXiv:nucl-th/0202065 [pdf, ps, other]
   Title: Comparison of various models of particle multiplicity distributions using a general form of the grand canonical partition function
   Authors: S.J. Lee, A.Z. Mekjian
   Comments: 28 pages including 6 figures. Submitted to PRC
   Subjects: Nuclear Theory (nucl-th); High Energy Physics - Phenomenology (hep-ph)

7. arXiv:nucl-th/0009033 [pdf, ps, other]
   Title: Liquid-gas phase transition in nuclear multifragmentation
   Authors: S. Das Gupta (1), A. Z. Mekjian (2), M. B. Tsang (3) ((1) McGill University, (2) Rutgers University, (3) Michigan State University)
   Comments: 63 pages, 27 figures, submitted to Adv. Nucl. Phys. Some typos corrected, minor text changes
   Subjects: Nuclear Theory (nucl-th); High Energy Physics - Phenomenology (hep-ph); Nuclear Experiment (nucl-ex)

8. arXiv:nucl-th/0006078 [pdf, ps, other]
   Title: The Liquid-Gas Phase Transitions in a Multicomponent Nuclear System with Coulomb and Surface Effects
   Authors: S. J. Lee, A. Z. Mekjian
   Comments: 20 pages including 7 postscript figures
   Journal-ref: Phys.Rev. C63 (2001) 044605
   Subjects: Nuclear Theory (nucl-th)

9. arXiv:nucl-th/0001021 [pdf, ps, other]
   Title: Further Comments On The Effects of Deformation on Isovector Electromagnetic and Weak Transition Strengths
   Authors: Shadow J.Q. Robinson, L. Zamick, A. Mekjian, N. Auerbach
   Comments: 8 pages, Replaced 2/29/00 with version submitted to Phys Rev C
   Subjects: Nuclear Theory (nucl-th)

10. arXiv:nucl-th/9903007 [pdf, ps, other]
    Title: A soluble statistical model for nuclear fragmentation
    Authors: S. Das Gupta, A. Majumder, S. Pratt, A. Mekjian
    Comments: 9 pages, 4 figures
    Subjects: Nuclear Theory (nucl-th)

11. arXiv:nucl-th/9902024 [pdf, ps, other]
    Title: Disoriented Chiral Condensates, Pion Probability Distributions and Parallels with Disordered System
    Authors: A.Z. Mekjian
    Comments: 5 pages, 1 figure included
    Journal-ref: Phys.Rev. C60 (1999) 067902
    Subjects: Nuclear Theory (nucl-th)

12. arXiv:nucl-th/9808018 [pdf, ps, other]
    Title: Various Models for Pion Probability Distributions from Heavy-Ion Collisions
    Authors: A.Z. Mekjian, B.R. Schlei, D. Strottman
    Comments: 12 pages, incl. 3 figures and 4 tables. You can also download a PostScript file of the manuscript from this http URL
    Journal-ref: Phys.Rev.C58:3627-3635,1998
    Subjects: Nuclear Theory (nucl-th)

13. arXiv:nucl-th/9711018 [pdf, ps, other]
    Title: A study of the phase transition in the usual statistical model for nuclear multifragmentation
    Authors: S. Das Gupta, A.Z. Mekjian
    Journal-ref: Phys.Rev.C57:1361-1365,1998

Subjects: Nuclear Theory (nucl-th)
14. arXiv:cond-mat/9708070 [pdf, ps, other]
    Title: Canonical and Microcanonical Ensemble Approaches to Bose-Einstein Condensation: The
    Thermodynamics of Particles in Harmonic Traps
    Authors: K.C. Chase, A.Z. Mekjian, L. Zamick (Rutgers University)
    Comments: 5 pages, 1 figure
    Subjects: Condensed Matter (cond-mat)
15. arXiv:nucl-th/9708022 [pdf, ps, other]
    Title: Randomly Broken Nuclei and Disordered Systems
    Authors: K.C. Chase, P. Bhattacharyya, A.Z. Mekjian (Rutgers University)
    Comments: 10 pages, 4 figures
    Journal-ref: Phys.Rev.C57:822-830,1998
    Subjects: Nuclear Theory (nucl-th)
16. arXiv:nucl-th/9703012 [pdf, ps, other]
    Title: Liquid-Gas Phase Transition in Nuclear Equation of State
    Authors: S.J. Lee, A.Z. Mekjian
    Comments: 12 pages in Revtex including two Postscript figures
    Journal-ref: Phys.Rev.C56:2621-2625,1997
    Subjects: Nuclear Theory (nucl-th); Nuclear Experiment (nucl-ex)
17. arXiv:nucl-th/9609061 [pdf, ps, other]
    Title: Studies in the statistical and thermal properties of hadronic matter under some extreme conditions
    Authors: K.C. Chase, A.Z. Mekjian, P. Meenakshisundaram
    Comments: 22 pages, revtex, includes 6 figures, submitted to Phys. Rev. C
    Journal-ref: Phys.Rev.C55:1410-1419,1997
    Subjects: Nuclear Theory (nucl-th)

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