Pavlos M. Vranas

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Background summary

- World leader in theoretical physics lattice research and numerical simulations.
- Core team architect and designer of the world's fastest supercomputer, BlueGene/L.
- Driving force of the next generation lattice QCD thermodynamic calculations for the RHIC experiments and of lattice SUSY for the physics beyond the standard model.
- Made history by exceeding the 1 TeraFlops sustained speed barrier in QCD simulations.
- Outstanding publications in theoretical physics and supercomputing (64), patents (14), and awards (Gordon Bell, Supercomputing fastest supercomputer, HPC Wire).

Positions

Research Staff Member,
IBM, T.J. Watson Research Laboratory, Yorktown Heights, New York.
Research Scientist,
Physics Department, University of Illinois, Urbana-Champaign, Illinois.
Post Doctoral Research Associate,
Physics Department, Columbia University, New York, New York.

Education

Ph.D. in Theoretical Physics, University of California, Davis.
M.Sc. in Theoretical Physics, University of California, Davis.
B.Sc. in Physics, University of Athens, Greece.

Research experience

Theoretical elementary particle physics

Lattice field theories at zero and finite temperature, with emphasis on QCD.
Supersymmetric field theories.
Numerical simulations of lattice field theories.
Field theories in higher dimensions.
Effective field theories.
Lattice fermion methods.
Topological phenomena.

Supercomputers

Hardware architect and designer of two of the world's fastest supercomputers:
BlueGene/L (360 TeraFlops, 2005, IBM); QCDSP (1 TeraFlops, 1997, Columbia U).
Science applications software for massively parallel supercomputers.

Publications, patents and awards

Over 60 publications in theoretical physics and supercomputing.
Fifteen patents filed with the U.S. patent office under IBM.
Gordon Bell 1998 award for the QCDSP supercomputer.
Supercomputing 2004 award for world's fastest computer.
HPC Wire editor's choice award 2003, most innovative HPC, BlueGene/L supercomputer.

Plenary talks at international conferences

2005 Modern Challenges for Lattice Gauge Theory, UCSB, Santa Barbara, California.
2005 Simulational Physics Workshop, University of Georgia, Athens, Georgia.
2000 International symposium on lattice field theory, Bangalore, India.
2000 Strong and electroweak matter conference, Marseille, France.
1999 Lattice fermions and structure of the vacuum, NATO conference, Dubna, Russia.
1998 High performance Monte Carlo conference, NASA Stennis Space Center, Mississippi.
1994 Aspen conference on elementary particle physics, Aspen, Colorado.

Invited talks

2005 Particle theory seminar, MIT, Boston, Massachusetts.
2004 Particle theory seminar, UCD, Davis, California.
2004 Particle theory seminar, LLNL, Livermore, California.
2004 QCD thermodynamics demo, SuperComputing 2004, Pittsburgh, Pennsylvania.
2004 Talk, High Performance Computing, BNL, Brookhaven, New York.
2004 Talk, International symposium on lattice field theory, Fermilab, Batavia, Illinois.
2002 Talk, International symposium on lattice field theory, MIT, Boston, Massachusetts.
2001 Talk, International symposium on lattice field theory, Berlin, Germany.
1999 Talk, International symposium on lattice field theory, Pisa, Italy.
1999 Particle theory seminar, University of Washington, Seattle, Washington.
1999 Particle theory seminar, UCSD, San Diego, California.
1999 Particle theory seminar, UCLA, Los Angeles, California.
1999 Particle theory seminar, OSU, Columbus, Ohio.
1999 Particle theory seminar, Washington University, St. Louis, Missouri.
1999 Talk, APS, Division of Particles and Fields, UCLA, Los Angeles, California.
1998 Talk, International symposium on lattice field theory, Boulder, Colorado.
1998 Particle theory seminar, University of Illinois, Urbana-Champaign, Illinois.
1997 Talk, International symposium on lattice field theory, Edinburgh, Scotland.
1997 Particle theory seminar, Brookhaven National Laboratory, Brookhaven, New York.
1997 Particle theory seminar, University of Washington, Seattle, Washington.
1997 Particle theory seminar, Stanford Linear Accelerator, Palo Alto, California.
1996 Talk, International symposium on lattice field theory, WU, St. Louis, Missouri.
1996 Particle theory seminar, SCRI, FSU, Tallahassee, Florida.
1995 Talk, International symposium on lattice field theory, Melbourne, Australia.
1995 Particle theory seminar, MIT, Boston, Massachusetts.
1994 Talk, International symposium on lattice field theory, Bielefeld, Germany.
1993 Talk, International symposium on lattice field theory, Dallas, Texas.
1993 Particle theory seminar, UCSD, San Diego, California.
1993 Particle theory seminar, Boston University, Boston, Massachusetts.
1993 Particle theory seminar, Brookhaven National Laboratory, Brookhaven, New York.
1993 Particle theory seminar, Columbia University, New York, New York.
1993 Particle theory seminar, Institute for Advanced Study, Princeton, New Jersey.

Research statement continued

Supercomputer engineering

Massively parallel supercomputers
I am a member of the core team of the IBM BlueGene/L (BG/L) supercomputer and of the Columbia University QCDSP supercomputer. The largest BG/L system is located at the Lawrence Livermore National Laboratory. It has 64,000 nodes and peak speed of 360 Teraflops. It is the world's fastest supercomputer. The QCDSP supercomputer was installed at Columbia University (0.4 Teraflops peak) and at the RIKEN/Brookhaven National Laboratory (0.6 Teraflops peak) in 1997.

Theoretical physics science software
I am the main designer of the C++ Columbia University theoretical physics system software (CPS). The CPS is operational on the QCDSP, BG/L and other platforms. It has now been used by physicists in the US and Europe for the last 7 years.

The main kernel of the physics code for QCD consumes the vast majority of cycles. I hand-coded this kernel in assembly for the QCDSP and BG/L.

In 1998 the QCDSP won the Gordon Bell award for the best sustained performance per dollar. The speed was sustained by the CPS with the hand-coded QCD kernel.

In June 2004, using, the first 2,048 nodes of the BlueGene/L, I ran QCD using the CPS and the hand coded BG/L QCD kernel. For the first time ever, QCD sustained computational speed exceeding 1 Teraflops. This bit of history marks the next generation of lattice gauge theory numerical simulations.

Hardware architecture
I was heavily involved with the BG/L architecture, and, in particular, with the main interconnect network that pulls together this large number of compute nodes to a coherent computing entity that achieves enormous computing speeds.

Hardware design
The main interconnect network of the BG/L is a 3-dimensional torus with dynamical virtual cut-through routing. I am one of the main designers of this unit. This very complex piece of hardware is the backbone of the massively parallel machine.

ASIC engineering design
In the BG/L the data is transmitted between nearest neighbor nodes in the 3-dimensional torus via high speed serial links. I was responsible for the ASIC engineering of the chip designed to test the high speed signaling method.

Verification and bringup software
I wrote critical software for verification and bringup for the BG/L and QCDSP. This software ranges from theoretical physics (QCD) kernel software to complex network traffic tests to full QCD based tests.

System software
I wrote the first node micro-kernel for the QCDSP machine. I was involved with the host software of the QCDSP machine. I was involved with the bringup kernel of the BlueGene/L.

Research statement

Theoretical elementary particle physics

Domain wall fermions
The study of field theories with fermions on the lattice has been difficult because contemporary lattice fermion regularizations break chiral symmetry. Domain wall fermions (DWF) utilize an extra space-time dimension to remove this breaking even at finite lattice spacing. My research has been instrumental in the development and applications of DWF.

QCD thermodynamics with domain wall fermions
I have been a driving force behind the application of DWF in the study of QCD thermodynamics. New points on the QCD phase diagram have been added while current work is pushing towards physical quark masses.

Staggered domain wall fermions
Staggered domain wall fermions (SDWF) were invented to have the DWF chiral properties but also an exact U(1) $\times$ U(1) chiral symmetry.

SUSY on the lattice
The dynamical $\mathcal{N} = 1$, SU(2) Super Yang-Mills theory was studied on the lattice using DWF. The gluino condensate is non-zero even for small volume and mass where zero mode effects due to gauge fields with fractional topological charge appear to play a role.

$U(1)_A$ symmetry above the QCD transition
A study of $U(1)_A$ in the high temperature phase using DWF revealed that $U(1)_A$ remains broken above the transition but the breaking is soft and at the few percent level.

The index theorem on the lattice
Using the overlap formalism ($L_s \to \infty$ limit of DWF) definition of the index it was verified that there is indeed a remnant of the Atiyah-Singer index theorem on the lattice.

Fermion-scalar interaction with DWF
The formulation of DWF in theories with fermion-scalar interactions was developed. This can be used in Yukawa and four-fermion theories as well as in solid-state physics.

Zero temperature QCD
Studies of QCD at zero temperature have produced further insights into the chiral properties of DWF as well as results regarding the hadron spectrum and weak matrix elements.

Finite density
An algorithm for lattice simulations at finite density is being explored.

Resonances and Decays on the Lattice
Work on whether or not the $\lambda\phi^4$ theory can sustain a ρ type resonance has shed light into such phenomena in the Higgs sector.

Low-Energy Effective Theories
Work on pure gauge theories, on the Higgs mass triviality bound, and on the Nambu-Jona-Lasinio model has provided important results and insights.

Quantum information theory
What kind of quantum algorithms could we develop to simulate quantum field theory using quantum computers? And equally important, could quantum field theory provide insights that can be used to construct quantum computers?

Publications in refereed journals

1 **Scientific Applications on the Blue Gene/L Supercomputer.**
P. Vranas and the BG/L scientific applications group,
Lecture Notes in Computer Science, Volume 3648, p. 560, 2005.

2 **Quenched Lattice QCD with DWF and the Chiral Limit.**
RIKEN, BNL, Columbia collaboration, Phys. Rev. D 69 (2004) 074502

3 **Overview of the Blue Gene/L system architecture.**
P. Vranas and the BG/L architecture group,
IBM Journal of research and development, Vol 49, 2/3, 2005.

4 **BlueGene/L torus interconnection network.**
P. Vranas and the BG/L torus network group,
IBM Journal of research and development, Vol 49, 2/3, 2005.

5 **The BlueGene/L advanced diagnostics environment.**
P. Vranas and the BG/L advanced diagnostics group,
IBM Journal of research and development, Vol 49, 2/3, 2005.

6 **Verification Strategy for the BlueGene/L chip.**
P. Vranas and the BG/L verification group,
IBM Journal of research and development, Vol 49, 2/3, 2005.

7 **Kaon Matrix Elements and CP-violation from Quenched Lattice QCD (I).**
RIKEN, BNL, Columbia collaboration, Phys. Rev. D 68 (2003) 114506

8 **The staggered domain wall fermion method.**
G. Fleming and P. Vranas, Phys. Rev. D 66 (2002) 114503

9 **Super Yang-Mills on the lattice with domain wall fermions.**
G. Fleming, J. Kogut and P. Vranas, Phys. Rev. D 64 (2001) 034510.

10 **The finite temperature QCD phase transition with domain wall fermions.**
Columbia collaboration, Phys. Rev. D 64 (2001) 014503.

11 **Non-perturbative Renormalization of DWF: Quark Bilinears.**
RIKEN, BNL, Columbia collaboration, Phys. Rev. D 66 (2002) 014504.

12 **Fermion-scalar interactions with domain wall fermions.**
P. Vranas, Y Tziligakis and J. Kogut, Phys. Rev. D 62 (2000) 054507.

13 **Anomalous chiral symmetry breaking above the QCD phase transition.**
S. Chandrasekharan, D. Chen, N. Christ, W. Lee, R. Mawhinney, and P. Vranas,
Phys. Rev. Lett. 82 (1999) 2463.

14 **Domain wall fermion zero modes on classical topological backgrounds.**
Columbia collaboration, Phys. Rev. D 59 (1999) 054508.

15 **Chiral symmetry in the Schwinger model with domain wall fermions.**
P. Vranas, Phys. Rev. D 57 (1998) 1415.

16 **A numerical test of the continuum index theorem on the lattice.**
R. Narayanan and P. Vranas, Nucl. Phys. B 506 (1997) 373.

17 **A simulation of the Schwinger model in the overlap formalism.**
R. Narayanan, H. Neuberger and P. Vranas, Phys. Lett. B 353 (1995) 507.

18 **A study of the Nambu–Jona-Lasinio model on the lattice.**
K.M. Bitar and P. Vranas, Phys. Rev. D 50 (1994) 3406.

19 **The Nambu–Jona-Lasinio model of QCD on the lattice.**
K.M. Bitar and P. Vranas, Phys. Lett. B 327 (1994) 101.

20 **Adjoint Wilson line in SU(2) lattice gauge theory.**
J. Kiskis and P. Vranas, Phys. Rev. D 49 (1994) 528.

21 **The Hausdorff dimension of random walks and the correlation length** critical exponent in Euclidean field theory.
J. Kiskis, R. Narayanan and P. Vranas, J. Stat. Phys. (1993) .

22 **Numerical analysis of the Higgs mass triviality bound.**
U.M. Heller, M. Klomfass, H. Neuberger, and P. Vranas, Nucl. Phys. B 405 (1993) 555.

23 **Large N analysis of the Higgs mass triviality bound.**
U.M. Heller, H. Neuberger and P. Vranas, Nucl. Phys. B 399 (1993) 271.

In preparation

24 **The QCD phase transition with domain wall fermions on large lattices.**
P. Vranas

25 **Topological dislocation control in lattice QCD with domain wall fermions.**
P. Vranas

26 **Quantum field theories on quantum computers.**
J. Kogut and P. Vranas.

27 **The split lattice algorithm for lattice gauge theory at finite density.**
P. Vranas.

28 **Quark and diquark condensation in four-fermion theories at finite density.**
J. Kogut, C. Strouthos and P. Vranas.

29 $U(1)$ **anomaly above the QCD phase transition with domain wall fermions.**
Columbia collaboration.

30 **Above the quenched QCD phase transition.**
Columbia collaboration.

Conference proceedings

31 **The BlueGene/L supercomputer and QCD.**
G. Bhanot, D. Chen, A. Gara, J. Sexton, and P. Vranas, BNL HPC 2004 proceedings.

32 **QCD on the BlueGene/L supercomputer.**
G. Bhanot, D. Chen, A. Gara, J. Sexton, and P. Vranas, Lattice 2004 proceedings.

33 **Interacting Staggered Domain Wall Fermions.**
G. Fleming and P. Vranas, Nucl. Phys. **119** (Proc.Suppl.) (2003) 819.

34 **The BlueGene/L supercomputer.**
G. Bhanot, D. Chen, A. Gara, P. Vranas, Nucl. Phys. **119** (Proc.Suppl.) (2003) 114.

35 Staggered Domain Wall Fermions.
G. Fleming and P. Vranas, Nucl. Phys. **106** (Proc.Suppl.) (2002) 724.

36 BlueGene/L, a system-on-a-chip.
BlueGene/L IBM group, Keynote Address, 2002 IEEE Cluster Computing (p349).

37 Domain wall fermions and applications.
P. Vranas, Nucl. Phys. **94** (Proc.Suppl.) (2001) 177.

38 Cellular supercomputing with system on a chip.
The IBM T.J. Watson BlueLight group, ISSCC 2001 conference proceedings.

39 QCD thermodynamics with domain wall fermions.
P. Vranas, Strong and electro-weak matter, Marseille, France, June 2000.

40 Domain wall fermions in vector theories.
P. Vranas, NATO workshop, Lattice fermions and structure of the vacuum, 1999, Dubna, Russia, Oct. 1999, hep-lat/0001006.

41 The finite temperature QCD phase transition with domain wall fermions.
P. Vranas, Nucl. Phys. **B83** (Proc. Suppl.) (2000) 414.

42 QCD thermodynamics and the $U(1)_A$ symmetry with domain wall fermions.
P. Vranas, APS DPF99 meeting, Los Angeles, California, Jan 5-9, 1999.

43 Status of the QCDSP project.
The QCDSP collaboration, Nucl. Phys. B (Proc. Suppl.) 73 (1999) 898.

44 Quenched QCD with domain wall fermions.
Columbia collaboration, Nucl. Phys. B (Proc. Suppl.) 73 (1999) 204.

45 The domain wall fermion chiral condensate in quenched QCD.
Columbia collaboration, Nucl. Phys. B (Proc. Suppl.) 73 (1999) 207.

46 The anomaly and topology in quenched QCD above T_c.
Columbia collaboration, Nucl. Phys. B (Proc. Suppl.) 73 (1999) 405.

47 Dynamical QCD thermodynamics with domain wall fermions.
Columbia collaboration, Nucl. Phys. B (Proc. Suppl.) 73 (1999) 456.

48 Lattice QCD on a teraflops parallel supercomputer.
P. Vranas, 1998 high performance Monte Carlo tools, Stennis Space Center, Mississippi.

49 The Chiral Limit of QCD: Quenched and Dynamical Domain Wall Fermions.
Columbia collaboration, Vancouver 1998, High Energy Physics, vol. 2, 1802.

50 QCDSP: A status report.
The QCDSP collaboration, Nucl. Phys. B (Proc. Suppl.) 63 (1998) 997.

51 Domain wall fermions and chiral symmetry restoration rate.
P. Vranas, Nucl. Phys. B (Proc. Suppl.) 63 (1998) 605.

52 QCDSP machines: design, performance and cost.
The QCDSP collaboration, Supercomputing 98.

53 Domain wall fermions and MC simulations of vector theories.
P. Vranas, Lattice 1996, Nucl. Phys. B (Proc. Suppl.) 53 (1997) 278.

54 QCDSP: A Teraflop scale massively parallel supercomputer.
The QCDSP collaboration, Supercomputing 97.

55 Status of the 0.8-Teraflops supercomputer at Columbia.
The QCDSP Collaboration, Nucl. Phys. B (Proc. Suppl.) 47 (1996) 804.

56 Some applications of the overlap formalism.
R. Narayanan, H. Neuberger, P. Vranas, Nucl. Phys. B (Proc. Suppl.) 47 (1996) 596.

57 Architectural choices for the Columbia 0.8-Teraflops machine.
The QCDSP collaboration, Nucl. Phys. B (Proc. Suppl.) 42 (1995) 902.

58 Toward the QCD beta function with dynamical Wilson fermions.
K.M. Bitar, R.G. Edwards, U.M. Heller, A.D. Kennedy, and P. Vranas,
Nucl. Phys. B (Proc. Suppl.) 42 (1995) 796.

59 Flavor parity breaking in the NJL model with Wilson fermions.
K.M. Bitar and P. Vranas, Nucl. Phys. B (Proc. Suppl.) 42 (1995) 746.

60 The Higgs mass triviality bound.
U.M. Heller, H. Neuberger and P. Vranas, Proceedings of the 1994 Aspen Winter Conference, Particle Physics Before the Year 2000.

61 Results from a study of the Nambu–Jona-Lasinio model on the lattice.
K.M. Bitar and P. Vranas, Nucl. Phys. B (Proc. Suppl.) 34 (1994) 661.

62 $SU(2)$ flux at T_c.
J. Kiskis, R. Narayanan and P. Vranas, in *The Fermilab Meeting, DPF92* edited by C. Albright, P. Kasper, R. Raja, and J. Yoh, (World Scientific, Singapore, 1993).

63 The $I = 1$, $J = 1$ channel of the $O(4)$ $\lambda\phi_4^4$ theory.
K.M. Bitar and P. Vranas, Nucl. Phys. B (Proc. Suppl.) 30 (1993) 693.

64 Regularization dependence of the Higgs mass triviality bound.
U.M. Heller, M.Klomfass, H. Neuberger, and P. Vranas,
Nucl. Phys. B (Proc. Suppl.) 30 (1993) 685.

65 The triviality bound on the Higgs mass; its value and what it means.
U.M. Heller, M.Klomfass, H. Neuberger, and P. Vranas,
proceedings of the XXVI International Conference on High Energy Physics,
vol. II, 1360-1367, (American Institute of Physics).