Curriculum Vitae

Pankaj Kumar Mishra
Department of Chemical Physics
Weizmann Institute of Science
Rehovot-76100, Israel

Email: pankajmishr@gmail.com
Phone: +972-543684062
Fax: +972 (8) 934-4123

Personal Details

Gender: Male
Date of birth: 1st January, 1981
Place of birth: Jamshedpur (Jharkhand), India
Present Citizenship: Indian

PhD thesis

Thesis title: Instabilities and Turbulence in Rayleigh-Bénard convection: Numerical and Phenomenological Studies

Thesis Supervisor: Prof. Mahendra K. Verma
Department of Physics,
Indian Institute of Technology Kanpur,
Kanpur (INDIA).

Education

November 2012 - till date: Posdoctoral Researcher
Department of Chemical Physics
Weizmann Institute of Science, Israel.
Supervisor: Prof. Itamar Procaccia.

October 2011 - October 2012: ATER position
Laboratoire de Physique Statistique
Ecole Normale Superieure, Paris, France.
Supervisor: Prof. Stephan Fauve.

May 2011 - September 2011: Project Scientist
High Performance Computing group and Department of Physics
Indian Institute of Technology Kanpur, India.

July 2004 - May 2011: Ph.D.
(Date for PhD defense: 15^{th} of April, 2011)
Department of Physics
Indian Institute of Technology Kanpur, India.

2002 - 2004: M.Sc.
Department of Physics
Indian Institute of Technology Kanpur, India.
grade-6.8/10.

M.Sc. Project: "*Preparation of High-T_c superconductor (YBCO) and its characterization*"
Department of Physics
Indian Institute of Technology Kanpur, India.

1999 - 2002: B.Sc. (Honors) Physics, First Division
Banaras Hindu University, Varanasi, India

Awards/fellowship

November 2012-November 2014: VATAT fellowship for outstanding Post-doctoral researchers from China and India offered by the government of Israel.

Publications

Coauthors with Itamar Procaccia [1]

1. Dynamics of the density of the quantized vortices in superfluid turbulence
   D. Khomenko, L. Kondaurova, V.S. L'vov, P. Mishra, A. Pomyalov, and I. Procaccia, Physical Review B **91**, 180504(R) (2015); DOI:10.1103/PhysRevB.91.180504(Impact Factor-5.1).

2. Dynamics of reversals and condensates in 2D Kolmogorov flows
   P. K. Mishra, J. Herault, S. Fauve, and M. K. Verma, Physical Review E **91**, 053005 (2015); DOI:10.1103/PhysRevE.91.053005 (Impact Factor-2.313).

3. Mechanical properties and plasticity of a model glass loaded under stress control
   V. Dailidonis, V. Ilyin, **P. Mishra**, and I. Procaccia, Physical Review E **90**, 052402 (2014); DOI: 10.1103/PhysRevE.90.052402 (Impact Factor-2.313).

4. Elasticity and Plasticity in Stiff and Flexible Oligomeric Glasses
   O. Gendelman, H. G. E. Hentschel, **P. K. Mishra**, I. Procaccia, and J. Zylberg, Physical Review E **90**, 042315 (2014); DOI: 10.1103/PhysRevE.90.042315 (Impact Factor-2.313).

5. Scaling of heat flux and energy spectrum for very large Prandtl number convection
   A. Pandey, M. K. Verma, and **P. K. Mishra**, Physical Review E **89**, 023006 (2014); DOI: 10.1103/PhysRevE.89.023006 (Impact Factor-2.313).

6. On the Effect of Micro-alloying on the Mechanical Properties of Metallic Glasses
   O. Gendelman, A. Joy, **P. Mishra**, I. Procaccia, and K. Samwer, Acta Materialia **63**, 209 (2014); DOI:10.1016/j.actamat.2013.10.029 (Impact Factor-4.395) citations:2.

7. Energy transfers during dynamo reversals
   P. Mishra, C. Gissinger, E. Dormy, and S. Fauve, Europhys. Lett. **104 (6)**, 69002 (2013); DOI: 10.1209/0295-5075/104/69002 (Impact Factor-2.155).

8. Shear localization in 3-Dimensional Amorphous solids
   R. Dasgupta, O. Gendelman, **P. Mishra**, I. Procaccia, and C. Shor, Physical Review E **88** (3), 032401 (2013); DOI: 10.1103/PhysRevE.88.032401 (Impact Factor-2.313)citations:9.

9. Micro-alloying and the Toughness of Glasses: Modeling with Pinned Particles
   R. Dasgupta, **P. Mishra**, I. Procaccia, and K. Samwer, App. Phys. Lett. **102** (2013); DOI: 10.1063/1.4805033 (Impact Factor-3.794) citations:2.

10. Scalings of heat transport and field correlations in convective turbulence
    M. K. Verma, **P. K. Mishra**, A. Pandey, and S. Paul, Physical Review E **85**, 016310 (2012); DOI: 10.1103/PhysRevE.85.016310 (Impact Factor-2.313) citations:6.

11. Dynamics of reorientations and reversals of large-scale flow in Rayleigh-Bénard Convection
    P. K. Mishra, A. K. De, M. K. Verma, and V. Eswaran, Journal of Fluid Mechanics **668**, pp. 480-499 (2011); DOI:10.1017/S0022112010004830.(Impact Factor-2.183) citations:19.

[1] Alphabetical order according to last name

12. Energy Spectra and Fluxes for Rayleigh-Bénard Convection
P. K. Mishra and M. K. Verma, Physical Review E **81**, 056316 (2010); DOI: 10.1103/PhysRevE.81.056316 (Impact Factor-2.313) citations:18.

13. Patterns and bifurcations for low-P Rayleigh-Bénard convection
P. K. Mishra, P. Wahi, and M. K. Verma, Europhys. Lett. **89**, 44003 (2010); DOI: 10.1209/0295-5075/89/44003(Impact Factor-2.155) citations:10.

14. Bifurcations and Chaos for Zero-P Convection
P. Pal, P. Wahi, S. Paul, M. K. Verma, K. Kumar, and **P. K. Mishra**, Europhys. Lett. **87**, 54003 (2009); DOI: 10.1209/0295-5075/87/54003(Impact Factor-2.155)citations:13.

15. Dynamic Instability of Microtubules: Effect of Catastrophe Suppressing Drugs
P. K. Mishra, A. Kunwar, S. Mukherji, and D. Chowdhury, Physical Review E **72**, 051914 (2005); DOI: 10.1103/PhysRevE.72.051914 (Impact Factor-2.313), citations:12.

    [Selected for the November 15, 2005, issue of the Virtual Journal of Biological Physics Research]

Conference Proceedings

1. Energy Spectra in Rayleigh-Bénard Convection
M. K. Verma, **P. K. Mishra**, M. Chandra, and S. Paul, *Journal of Physics: Conference Series* **318**, 082014 (2011); DOI:10.1088/1742-6596/318/8/082014.

2. Nonlinear dynamics of low Prandtl number Rayleigh-Bénard Convection
P. Wahi, **P. K. Mishra**, S. Paul, and M. Verma, *IUTAM Symposium on Nonlinear Dynamics for Advanced Technologies and Engineering Design* **32**, 123-136 (2013); DOI: 10.1007/978-94-007-5742-$4_1$0.

3. Role of bulk flow in turbulent convection
M. K. Verma, A. Pandey, **P. K. Mishra**, and M. Chandra, *AIP Conf. Proc.* **1582** 224 (2014); DOI:10.1063/1.4865360.

Manuscripts unpublished or under preparation

1. Order and chaos in two-dimensional Rayleigh-Bénard convection
   S. Paul, P. K. Mishra, M. K. Verma and K. Kumar, arXiv:0904.2917 (2009).

2. Velocity profile for wall bounded superfluids turbulent flows
   D. Khomenko, V. S. Lvov, P. Mishra, A. Pomyalov, and I. Procaccia (2014) (In preparation).

3. Dependence of yielding point on temperature for Crystals and glass
   V. Dailidonis, V. Ilyin, P. Mishra, and I. Procaccia (In preparation).

4. Stochastic resonance in poly-disperse glass
   R. Benzi, P. Mishra, I. Procaccia, and J. Zylberg (2014) (In preparation).

Talks and Poster Presentations

1. October 6-October 16, 2014- Delivered a talk on "Dynamics of energy transfers during dynamo reversal", at international conference on Turbulence: In the Sky as on the Earth, International Institute of Physics, Natal, Brazil.

2. July 28-Aug 2, 2014- Delivered a talk on "Atomistic theory and simulation of microscopic structure of shear band in three dimensional amorphous solids", at international conference on Discrete simulation in fluid dynamics (DSFD 14), ENS, Paris, France.

3. November 4-11, 2013- Delivered a talk on "Modeling with Microalloying in the metallic glasses", at workshop on turbulence and amorphous materials, Eilat, Israel.

4. September 1-5, 2013- Poster Presentation on "Energy transfers in dynamo reversal", at European Turbulence Conference (ETC 14), Ecole De Physique, Lyon, France.

5. October 1-4, 2012 - Poster presentation on "Energetic of dynamo reversal", at European GDR dynamo and MHD days, Observatoire de la Cø̂te d'Azur, Nice, France.

6. March 15-16, 2012 - Poster presentation on "Scaling of heat transport and field correlations in convective turbulence", at Rencontre du Non-Linéaire, held at Institut Henri Poincaré, Paris, France.

7. January 17-19, 2011 - Delivered a talk on "Dynamics of Reorientations and Reversals of Large scale flow in Rayleigh-Bénard Convection", at AIM network Indo-European workshop on Hydrodynamic Instabilities, held at Jawaharlal Nehru Center for Advanced Scientific Research, Bangalore, India.

8. December 21-23, 2009 - Delivered a talk on "Dynamics of Reorientations and Reversals of Large scale flow in Rayleigh-Bénard Convection", at International Conference on turbulence, held at Indian Institute of Technology, Kanpur, India.

9. July 07-17, 2009 - Poster Presentation on "Energy Spectra and Fluxes for Rayleigh-Bénard Convection", at International Conference on Turbulence mixing and beyond, held at I.C.T.P., Trieste, Italy.

10. July 17-22, 2008 - Poster Presentation on "Order and Chaos in 2-D Rayleigh-Bénard Convection", at International Conference on Non-linear Dynamic system and Turbulence, held at Indian Institute of Science Bangalore, India.

11. March 15-17, 2007 - Delivered a talk on "Modeling in-vitro motility assay for single headed kinesin motors: effects of load force in bead-assay" at Workshop on Molecular Motors, held at Tata Institute of Fundamental Research, Mumbai, India.

12. March 3-5, 2007 - Delivered a talk on "Effect of load force on single headed Kinesin motors" at Parvartan workshop, held at the Department of Mechanical Engineering, Indian Institute of Technology, Kanpur, India.

13. February 4-6, 2005 - Poster Presentation on "Dynamic Instability of Microtubules: Effect of Catastrophe Suppressing Drugs", at the Condensed Matter Physics Workshop, held at the Indian Institute of Technology, Kanpur, India.

14. July 12-15, 2004 - Poster Presentation on “Dynamic Instability of Microtubules: Effect of Catastrophe Suppressing Drugs”, at Discomb 04 (Satellite Conference of the STATPHYS-22), held at Benaras Hindu University, Varanasi, India.

Conferences, Workshops and Schools attended

1. March 26-30, 2012, International conference on wave turbulence, held at Ecole de Physique, Les Houches, France.
2. March 15-16, 2012, Rencontre du Non-Linéaire, held at Institut Henri Poincaré, Paris, France.
3. January 17-19, 2011, AIM network Indo-European workshop on Hydrodynamic Instabilities, held at Jawaharlal Nehru Center for Advanced Scientific Research, Bangalore, India.
4. January 09-11, 2010, Scientific meeting on Breaking the barriers between Physics and Biology, held at National Centre for Biological Sciences, Bangalore, India.
5. December 21-23, 2009, International Conference on Turbulence, held at Indian Institute of Technology, Kanpur, India.
6. July 07-17, 2009, International conference on Turbulence mixing and beyond, held at International Centre for Theoretical Physics, Trieste, Italy.
7. February 17-20, 2009, Workshop on theoretical tools of Turbulence, held at S. N. Bose Institute, Kolkata, India.
8. July 17-22, 2008, International Conference on Non-linear Dynamical system and Turbulence, held at Indian Institute of Science Bangalore, India.
9. January 17-31, 2008, Workshop on Turbulence, held at Indian Institute of Science, Bangalore, India.
10. February 8-10, 2006, International Workshop on Common trends in traffic systems: Physical and Computational Models in Transportation Engineering and Biological Sciences, Indian Institute of Technology, Kanpur, India.
11. January 2-6, 2006, Discussion meeting on Non-equilibrium phenomena, Vardanhalli, Bangalore, India.
12. July 12-15, 2004, Discomb 04 (Satellite Conference of the STATPHYS-22), held at Benaras Hindu University, Varanasi, India.
13. July 4-10, 2004, STATPHYS-22, held at the Indian Institute of Science, Bangalore, India.

Teaching Experience

October, 2011 to August, 2012 - Teaching assistant for laboratory experiment on Faraday Instability and Acoustic Vibration,
LPS, Ecole Normale Superieure, Paris, France.

July, 2010 to December, 2010 - Tutor in 1st year undergraduate compulsory course Phy-103: Electro-Magnetic Theory,
Indian Institute of Technology Kanpur, India. (Class Strength: 107 Students).

July, 2008 to December, 2008 - Tutor in 1st year undergraduate compulsory course Phy-102: Mechanics,
Indian Institute of Technology Kanpur, India.

January, 2008 to May2008 - Teaching Assistant for the Course SE-316: Order and Chaos in Nature,
Indian Institute of Technology Kanpur, India.

December2006 to May2007 - Teaching Assistant for the M.Sc. Core Course Phy-412: Statistical Physics,
Indian Institute of Technology Kanpur, India.

July2006 to December2006 - Teaching Assistant for the M.Sc. Core Course Phy-543: Condensed Matter Theory,
Indian Institute of Technology Kanpur, India.

July 2004 to December2005 - Teaching assistant for the General Physics Lab for M. Sc. Physics students,
Indian Institute of Technology Kanpur, India.

References

Prof. Mahendra K. Verma

Dept. of Physics	Phone:	+91-512-259 7396,
Indian Institute of Technology Kanpur	Fax:	+91-512-259 0914
Kanpur- 208016, India	Email:	mkv@iitk.ac.in

Prof. Itamar Procaccia

Dept. of Chemical Physics	Phone:	+97289344051
Weizmann Institute of Science,	Fax:	+97289344123
Rehovot-76100, Israel	Email:	itamar.procaccia@gmail.com

Prof. Stephan Fauve

Laboratoire de Physique Statistique	Phone:	+33 1 44 32 35 01
Ecole Normale Superieure		
Paris- 75231, France	Email:	fauve@lps.ens.fr

Prof. Krishna Kumar

Dept. of Physics & Meteorology	Phone:	+91-3222-283828
Indian Institute of Technology Kharagpur		
Kharagpur-721302, India	Email:	kumar@phy.iitkgp.ernet.in

Prof. Vinayak Eswaran
Dept. of Mechanical Engineering Phone: +91-40-2301-6009
Indian Institute of Technology Hyderabad
Hyderabad- 502205, India Email: eswar@iith.ac.in

Prof. Oleg Gendleman
Dept. of Mechanical Engineering Phone: +972-4-8293877
Technion Israel Institute of Technology,
Haifa-32295, Israel Email: ovgend@technion.ac.il

Brief Summary of Doctoral Research

In the following a brief summary of the work done for doctoral Thesis is presented. The main aim of my thesis was to understand the various aspects of dynamics of Rayleigh-Bénard convection that appears near the onset and in a fully developed turbulent regime using direct numerical simulation that solves the Navier-Stokes equations coupled with heat equation and further the development of some phenomenological models based on the information obtained form the numerical simulation. Rayleigh-Bénard convection (RBC), in which a thin layer of the fluid in a box is heated from below and cooled from the top is an active area of research in fluid dynamics. As the fluid is subject to a constant temperature gradient due to heating a unstable configuration of the fluid having top heavy and bottom light configuration is generated. However, there are two stabilizing factor one is the viscous diffusion and another is the thermal diffusion that stops the motion in the fluid. As the destabilizing factor which is generated due to buoyancy of the fluid overcomes the stabilizing factor due to the viscous and thermal viscosities of the fluid the fluid-particles sets into the motion know as convection. The dynamics of RBC is governed by two non-dimensional parameters, Rayleigh number (R), which is the ratio of the buoyancy and the dissipative terms and Prandtl number (P), which is the ratio of the heat diffusion time scale and the viscous diffusion time scale. Generally a particular fluid is characterized by its Prandtl number. The Prandtl number of the fluid in the natural, atmospheric and engineering flow varies in a wide range. As for example the Prandtl number of the fluid in Earth and Sun is very small (of the order of 10^{-8}), the Prandtl number of the atmospheric flow is of the order one, the Prandtl number of Silicon or organic oil ranges from 10-10^4, while the Prandtl number for the Earth's Mantle is of the order of 10^{25}.

The first part of my thesis deals with the dynamics of non-linear interplay of active modes present near the onset of convection. We addressed the nature of energy cascade in the inertial range of isotropic and homogeneous turbulent thermal convection in second part of the thesis. In the final part of my thesis, we corroborated the observations made in some of the state of the art experiments in turbulent convection that is devoted to understand the dynamics of large scale circulation (e.g. reversal, reorientation).

1. **Bifurcation and Chaos in Low Prandtl Number and Zero Prandtl Number Convection**: One of the interesting aspect of RBC is the systematic transition of the flow from the regular circular roll state to the chaotic state as the Rayleigh number is increased for a given Prandtl-number fluid. Near the onset the roll structure becomes unstable due to time dependence wavy instability. This wavy instabilities further results the appearance of the 3-D periodic structure of the flow as the control parameter Rayleigh number is increased. This periodic structure make the transition to the aperiodic or chaotic state on further increase of the parameter.

In the experiment it is observed that the range of the Rayleigh number in which the flow exhibits roll structure shrinks as the Prandtl number is decreased. The question arises what is the instability mechanism of the flow as the Prandtl number is decreased to a very low value of the Prandtl number or even for zero-Prnadtl number convection.

In order to have a clear picture of the detailed dynamics near onset for zero and low-P, we performed direct numerical simulations (DNS) of convective flows for $P = 0, 0.02, 0.005, 0.002$, and 0.0002 for R ranging from 657.5 to 800 on 64^3 rectangular grid. We used a pseudo-spectral procedure with fourth-order Runge-Kutta as the time-stepping scheme. The aspect ratio of our simulations was $\Gamma_x = 2\sqrt{2}, \Gamma_y = 2\sqrt{2}$. Using DNS as our guide to choose the active modes, we constructed a low-dimensional model to study the detailed bifurcation scenario and route to chaos for low-Prandtl number and zero-Prandtl number. Using the Galerkin projection technique, we developed a 13-mode model for zero-P and 30-mode model for low-P and perform a detailed bifurcation analysis for both the models near the onset. We obtained that the results for the low-dimensional models were in very good agreement with those obtained from DNS. Interestingly, we observed that the system attains chaos just at the onset of convection for zero-P. Furthermore, we demonstrated that the bifurcation diagram for low-P convection was very similar to the zero-P convection, except near the onset of convection where 2D stationary rolls, stationary asymmetric squares, and oscillatory asymmetric squares are observed for nonzero Prandtl numbers. We this study we established that the zero-P convection may be treated as a limiting case of very low-P convection. The range of Rayleigh numbers for which 2D rolls are observed appeared to shrink rapidly ($\sim P^2$) as P was decreased, which was very much consistent with earlier reported results.

The detailed results for zero-P and low-P convection are published in *Europhys. Lett.*(2009,2010).

2. **Energy Spectra and Fluxes of Convection**: Another interesting problem in Rayleigh-Bénard convection is the behaviour of energy cascade in the inertial range of turbulence regime. It has been observed both theoretically and numerically that above the Bolgiano length, the buoyancy term dominates over the inertial term and the energy cascade is carried by the thermal flux. In this range energy cascade follows Bolgiano-Obukhov(BO) scaling. Below the Bolgiano length scale, energy cascade is carried independently by kinetic and thermal flux and hence the cascade of both temperature and energy follow the Kolmogorov-Obukhov(KO) scaling. It is observed that the Bolgiano length becomes of the order of container's size for low-P, hence only KO scaling is expected for low-P, however, both KO and BO scalings are expected for high-P.

   In order to further explore earlier phenomenological theories and experimental observations, we numerically computed the spectra and fluxes of the velocity and temperature fields of convective turbulence using a pseudo-spectral method in 3-D box on 512^3 grid sizes. The numerical simulations were performed for a large range of Prandtl numbers—zero-P, low-P, and large-P. In order to void the extra effect of the velocity boundary layer on the energy cascade we considered the Free-slip boundary condition for the velocity. However, we retained the thermal boundary condition and considered the isothermal boundary conditions for the temperature. We observed for zero-P and low-P convection the energy cascade was mainly governed by the inertial term and hence the observed scaling was Kolmogorov-Obukhov scaling. However, large-P convection, the numerical results could not be able to give convincing result, yet the BO scaling appeared to be most convincing for the energy cascade than the KO scaling. This result was indeed helped to ascertain some of the laboratory experiments performed by the researchers mainly in Europe and United states.

The detailed study related to this work is reported in manuscript " Energy spectra and fluxes for Rayleigh-Bénard convection".

3. **Dynamics of Large scale Circulation in Convection**: Large Scale Circulation (LSC), also known as 'mean wind', appears at large length scales in turbulent Rayleigh-Bénard convection. It is a coherent structure of the flow in which fluid particle ascends from one side of the wall and descends down the azimuthally opposite side. It has been observed in laboratory experiments that the vertical plane containing LSC undergoes a diffusive motion in the azimuthal direction of the cylindrical container. Sometimes, in the course of its motion, the plane of the LSC changes by a significant angle. This phenomena, called the reorientation of the LSC, leads to flow reversal exhibiting a rich dynamical behaviour.

   In order to study the dynamics of the reorientation of the LSC for air (Prandtl number =0.7) we used the numerical model in which the dynamical equations were solved in a cylindrical container of aspect ratio one having similar boundary conditions as taken in the laboratory experiments. We used a range of Rayleigh numbers ranging from $R = 6 \times 10^5$ to $R = 3 \times 10^7$ and concentrated our study in the bulk region of the container. First in numerical simulation we established the presence of Large scale circulation in the turbulent region using the statistical Physics tools like cross-correlation. We put forward a noble conjecture that the dynamics of LSC in the azimuthal direction can be captured by the Fourier mode with the small wavenumber. We asserted that the amplitude and phase of the lowest Fourier mode would provide a very good estimate of the strength and orientations of LSC. Using this model we obtained both rotation-led and cessation-led partial as well as full azimuthal reorientation of the flow as observed in earlier laboratory experiments. We showed that the ratio of the amplitude of the second Fourier mode and the first Fourier mode rises sharply during the cessation-led reorientations which indicated a very comprehensive morphology of the flow during the flow reversal. We obtained that the flow structure remained to be quadrupolar flow during the cessation-led reorientations. This behaviour was highlighted first time in our numerical simulation. Finally, we presented a test of our conjecture regarding the importance of the small wavenumber Fourier mode in dictating the dynamics of the LSC. We obtained that the flow reorientation was vanished completely as the phase change of the first Fourier mode during reorientation was subtracted from the other higher modes. This observation indeed suggested the importance of the first Fourier mode in dictating the dynamics of LSC even the flow was in the turbulent regime.

   The detailed observations of this work are discussed in our manuscript " Dynamics of reorientations and reversal of large scale flow in Rayleigh-Bénard Convection".

Aside from my work on convection, I have studied the effect of catastrophe suppressing drugs on the dynamics of Micro-tubules as a part of my Masters Degree, (Paper published in Phys. Rev. E (2005)). I have also worked on the dynamics of cyto-skeleton and cyto-skeleton based molecular motors. Using tools of non-equilibrium Statistical Mechanics, we improved upon an earlier Brownian-Ratchet transport model for single-headed molecular motors (Kif1A, which plays important role of carrying a cargo in the neuron cells) by including their internal chemical states.