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Research Experience

I have been fortunate to have worked in different fields linked to computational physics and numerical simulation. My research encompassed computer modeling of a variety of physical phenomena, extending from the interaction of solid state matter with high intensity laser beams, fusion, space and astrophysical plasma to application within the field of medical physics. I have equally extensive experience in simulation codes and algorithm development, conducting parallel and large scale simulations, as well as statistical data analysis using variety of state of the art numerical/statistical techniques. Most of my research activity led to publications and talks (see CV) in prestigious journals, such as: ***Nature, Astrophysical Journal, Brain Topography, Computer Physics Communication, Physical Review E****, etc.* Below is a summary of some of my previous research activity and some of the research projects I worked on:

1. Computational Laser-Matter/Plasma interaction and Fusion research:

Location: National Institute of Scientific Research (INRS-EMT), University of Quebec, Canada; ***Date:*** 06/2000-09/2004

Mentor: Prof. Jean-Pierre Matte

The main focus of my Ph.D. thesis was the numerical study of electron/ion transport during laser-plasma interaction, effect of non-Maxwellian distribution functions, instabilities, and atomic physics. This study was done for plasmas under thermonuclear fusion conditions (inertial, i.e. Laser beams). The nature of the interaction and the laser pulse varied from, a relatively long (picosecond) low intensity (10^{14}-10^{15} W/cm^2) beam interacting with an expanding plasma up to the critical density, and a short (femtosecond) high intensity (~10^{18} W/cm^2) laser beam interacting with solid density plasma. Most of this study was conducted through kinetic simulations, by solving the Fokker-Planck equation for particles coupled with the wave equation for the laser beam. I developed some of the codes used and contributed to others (see CV), examples include: Fokker-Planck codes “FPI”, “FPI+”, “FPTRANS” (Alouani Bibi *et al.* (2004)) and hydrodynamic code “HYDRO+”. Comparative tests where made with the LASNEX code (Developed at Lawrence Livermore National Laboratory) under joint collaboration to quantify non-local effects in laser-created plasma and other scenarios relevant to the ICF (inertial confinement fusion). Among the results of my thesis were: 1 - Development of a new model for thermal conduction in the presence of strong non-local electron transport and/or non-

Maxwellian plasma (Alouani Bibi *et al.* (2002)) where the classical Spitzer theory is not applicable because of the increasingly large free path of those electron carrying the bulk of the heath flux (maximizing $4\pi v^2 v^3 f(v)dv$) relative to the temperature gradient; correction to the electron-ion energy exchange rate (Alouani Bibi *et al.* (2003)); 2 - Study of supra-thermal electron transport in solid density plasmas (relevant for fast ignition fusion); 3 - Implementation of semi-anisotropic Rosenbluth potentials in electron-electron collisions and showing their impact on the relaxation of a bi-Maxwellian electron velocity distribution function; 4 - Quantify the effect of non-Maxwellian distribution function on the growth rate of "Filamentation" of laser beam in under-dense plasma and the changes in the rate of different atomic processes. 5 – Development of Kinetic and Hydrodynamic codes.

2. Computational non-Linear Dynamics with application to Neuro/Cognitive science:

Location: University of California Irvine, CA, USA; ***Date:*** 09/2004-06/2006

Mentor: Prof. Ramesh Srinivasan

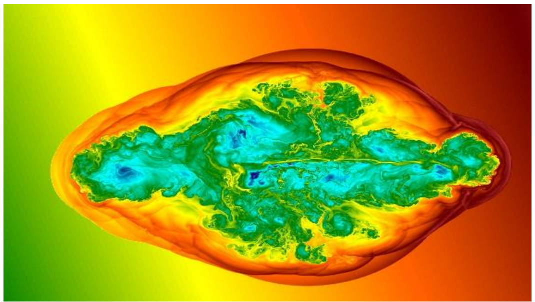
I worked on the collection of large, EEG and MEG, data sets from humans subjects exposed to different types of visual stimuli with controlled frequency. The subjects were in some cases expected to interact with the stimulus by giving feedback or an answer, and in other cases the subjects are passive during the experiment. The goal was to model human brain activity as a wave propagation phenomenon. This was done by using a variety of signal processing technics and self-developed computational tools mostly in matlab to explore the power spectral density in wave vector space. Then correlate frequencies at which the power spectral density is at its maximum based on the EEG/MEG data and the frequency or harmonics of the stimuli frequency. Results of this study were published in (Srinivasan et al. 2006) in which I was a co-author.

3. Computational Plasma Astrophysics I:

Location: University of Oxford, St Johns College, UK; ***Date:*** 06/2006-11/2008

Mentor: Prof. Katherine Blundell

I have computationally investigated the interaction of the relativistic jets of the galactic micro-quasar (SS433) and the surrounding W50 nebula. W50 is assumed to be the remnant of a supernova explosion; SS433 is an X-ray binary (black hole or neuron star) with a companion, having an orbital period of 13 days. I studied the SS433/W50 system using 2D/3D AMR



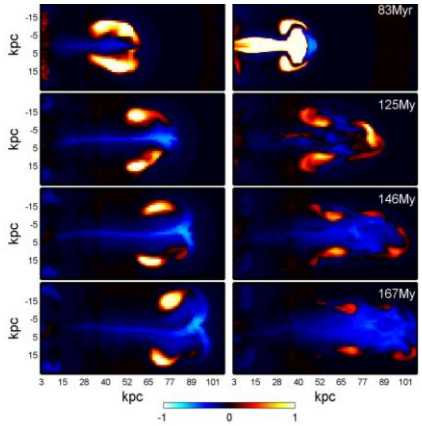
Result of a conducted 2D AMR-parallel, Hydrodynamic simulation (density map) of SS433/W50 interaction.

Hydrodynamic/Magneto-Hydrodynamic simulations, starting with the supernova evolution, from the free-expansion through the Sedov then the final snow-plow phase. After the expanding SNR reaches the observed radius of W50, a twine relativistic jets, v~0.26c, emitted from the central object, black hole/neutron star, are introduced in the simulations. Some of these results and a detailed description of the numerical model are published in (Goodall *et al.* 2011) in which I am a co-author.

4. Computational Plasma Astrophysics II:

Location: University of Oxford, St Johns College, UK; ***Date:*** 06/2006-11/2008

Mentor: Prof. James Binney



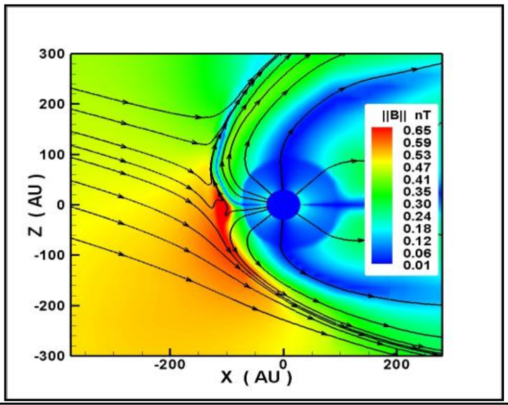
Maps of entropy index as function of time for one and two cycle's jets.

Cooling flow (CF) clusters are galaxy clusters of medium to low redshifts. They have a strongly peaked central density profile. X-ray luminosity of the order of ($L_X = 10^{41}$ - 10^{46} erg/s) and inferred cooling time ($t_c = 10^8 – 10^9$ yr), which is shorter than the life span of such objects, assumed to be the Hubble time 1.3-1.5 10^{10} yr. Therefore, for these systems not to undergo a cooling catastrophe caused by a loss of thermal pressure due to a continuous radiative cooling followed by an eventual gravitational collapse of the intra-cluster gas toward the central object, heating and/or reversing of the inflow of gas into the cluster core must be taking place. This has been a central question for almost four decades. I worked in creating a numerical time dependent model to simulate to evolution of these objects and the AGN jet feedback into the intra-cluster plasma. Some of the results are published in (Benney et al. 2007, Alouani-Bibi & Binney 2008), I was co-author in both papers. Our results showed that the energy input from the AGN jets to the create synchrotron/radio bubbles (or X-ray cavities) was largely over estimated in the past and that in fact only about 10% of jet's energy is within these bubbles. This has a direct impact on the required duty cycle of the AGN jets needed to offset cooling flow.

5. Computational Space plasma I:

Location: George Mason University, VA, USA; ***Date:*** 12/2008-12/2010

Mentor: Prof. Merav Opher



Heliosphere: magnetic field module (color-map), the plasma flow pattern (streamlines).

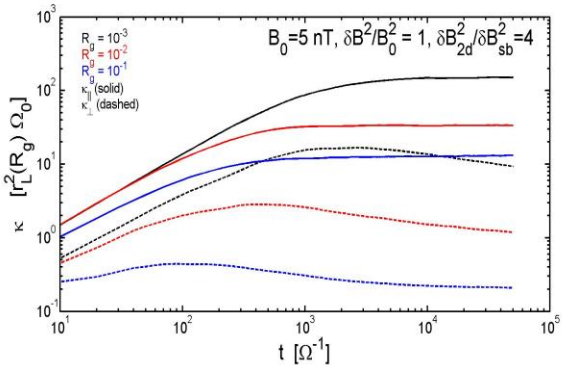
The interaction of solar wind plasma with local interstellar medium and the formation of the heliosphere is one of the most fascinating subjects in space plasma. For one, this is the environment in which our solar system is embedded, i.e the heliosphere. The two NASA missions Voyager 1 (V1) and Voyager 2 (V2) recently crossed (December 2004 and August 2007 respectively) one of the first heliospheric boundaries, namely the termination shock (TS). These NASA missions, i.e. V1 and V2, provided highly valuable data regarding: the nature of the heliosheath flows, the peculiar morphology of heliospheric boundary (TS), allowing for more accurate predictions of the properties of the solar wind with the local interstellar medium. One of the important findings from the data transmitted by V1 and V2 was a ~7 AU difference in the distance from the sun to the TS at the locations where these two satellites have crossed. I was actively involved in modeling the expansion of solar wind and formation of the heliosphere, using large scale parallel magnetohydrodynamic simulations. Large data sets were being analyzed some of these results are published in (Opher et al. 2009, Alouani-Bibi et al. 2011).

6. Computational Space plasma II:

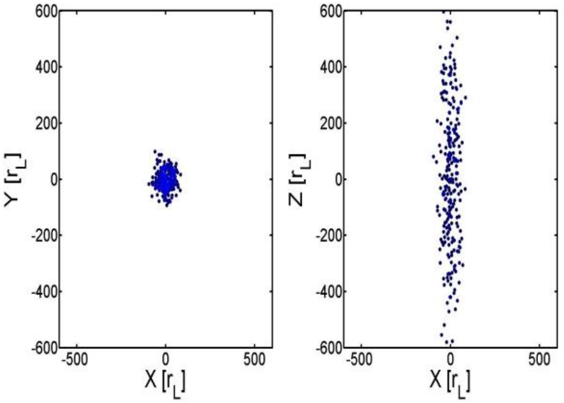
Location: University of Alabama in Huntsville, AL, USA; ***Date:*** 01/2011-06/2013

Mentor: Prof. Jakobus le Roux

I presently work on the kinetic aspect of high energy particles/cosmic rays transport and interaction with the turbulent interplanetary magnetic field, accounting for the presence of a strong multi-fractal intermittency with a non-Gaussian PDF. We consider different models for the turbulence, such as: 3D-isotropic, 1D Alfvenic (slab) and quasi-3D composite: i.e. combination of a 1D Alfvenic (slab) and a 2D structured component. The scattering and the diffusion coefficients both parallel and perpendicular to the background field are derived from test-particle simulations. To this end, I developed a fully parallel (MPI) relativistic Monte-Carlo code to track particles along their trajectories. Our simulations showed that for uniform turbulence, absence of intermittency, initial motion of the particle is super-diffusive, while at the later time, the parallel motion becomes diffusive while the cross-field motion is sub-diffusion for the slab model and diffusive for



Diffusion coefficients: parallel (solid) and perpendicular (dashed) to the background field.



The distribution of particles end-of-trajectories in the parallel and perpendicular plane to the background field.

high rigidity particle for the composite model (Alouani-Bibi & leRoux, 2012, 2013a,b). The presence of intermittency, strongly affects the transport of particles, leading to enhanced cross-field diffusion due to an increased field-line random walk.

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