PLAN of STUDY/RESEARCH for the academic year 2016-2017

Name: Davide **Surname:** Cavaliere

CYCLE: XXXII

C	
R	
S	
Visto	

- Curriculum

  - [x] Mathematics for Engineering
  - [ ] Electromagnetics
  - [ ] Science of Materials

C: Courses

- *Nonlinear Ordinary Differential Equations: perturbation methods and applications* (3 CFU). Prof. Sandra Carillo. Sbai Department, University of Rome La Sapienza.
- *Onde Non Lineari e Solitoni* (6 CFU). Prof. Paolo M. Santini. Department of Physics, University of Rome La Sapienza.
- *Fisica dell'Ambiente* (6 CFU). Prof. Wolfango Plastino. Department of Mathematics and Physics, University of Roma Tre.
- *Fisica Terrestre* (6 CFU). Prof. Elena Pettinelli. Department of Mathematics and Physics, University of Roma Tre.

Alternatively, one of the previous courses could be substituted with:

Meccanica dei Mezzi Continui in Fisica Terrestre e dell'Ambiente (6 CFU). Teacher: to be defined. Department of Mathematics and Physics, University of Roma Tre.

R: Research perspectives

My Master's Thesis, entitled "Characteristic times in diffusive processes in finite geometries", is a numerical study of transport and diffusion of a passive scalar in a bounded domain by means of the so-called "standard map". Given an initial distribution of "tracers", our aim was to separate, in the overall homogeneization process, the contributions of the relaxation times (to the uniform distribution) associated to the effective and the molecular diffusion processes. We didn't observe the expected two-time scale advection-diffusion process. However, we obtained a good agreement between the numerical data for the characteristic times and the theoretical results derived from the diffusion equation and from a Markovian model of diffusion.
Problems investigated in this thesis are related to dynamical systems, standard transport and diffusion, stochastic processes and fluid dynamics. In line with my thesis, there are other relevant topics that could be studied:

- FSLE. Working in bounded domains, it is possible to analyze diffusion processes by means of the Finite Size Lyapunov Exponent (FSLE). This tool allows to define the Finite Size Diffusion Coefficient and to study systems with no separation of scale between the linear dimension of the domain and the characteristic length of the velocity field (this frequently happens in geophysical problems).
- Transport and diffusion problems with gradually more complicated conditions, for example in presence of turbulence.

These concepts could be applied in the field of oceanography or environmental hydraulics [1, 2, 3], to describe the evolution of the concentration of pollutants in bounded regions of seas or lakes in presence of advection and diffusion processes.

Beside techniques coming from the so-called "chaos theory" and from statistical theories, there are interesting concepts and tools developed in the last decades in the framework of integrable systems (e.g.: solitons and IST), which have several applications in fluid dynamics, wave propagation and other research fields [4]. One of my objectives is to deepen and master these techniques, improving also my knowledge of PDEs of relevant importance in mathematical physics, in both analitical and numerical/computational aspects.

My intent is to apply all of these techniques to geophysical problems, with a special focus on the construction of mathematical models for the prediction of natural disasters (water contamination, tsunamis, floods, earthquakes) or climate changes, and their impact on civil infrastructures.
For example, recent studies tried to put in relation complex dynamics and bifurcation theory with early-warning signals near critical transitions [5].

S: Supervisor

To be defined.

References

[1] V. Artale, G. Boffetta, A. Celani, M. Cencini, and A. Vulpiani. Dispersion of passive tracers in closed basins: Beyond the diffusion coefficient. *Phys. Fluids*, 9:3162, 1997.

[2] J.H. Lacasce and C. Ohlmann. Relative dispersion at the surface of the Gulf of Mexico. *Journal of Marine Research*, 61:285–312, 2003.

[3] I. Koszalka, J.H. Lacasce, and K.A. Orvik. Relative dispersion in the Nordic Seas. *Journal of Marine Research*, 67:411–433, 2009.

[4] G. B. Whitham. *Linear and Nonlinear Waves*. Wiley, 1974.

[5] M. Scheffer, J. Bascompte, W.A. Brock, V. Brovkin, S.R. Carpenter, V. Dakos, H. Held, E. van Nes, M. Rietkerk, and G. Sugihara. Early-warning signals for critical transitions. *Nature*, 461:53–59, 2009.