Editorial

The study of dynamical systems has been at the origin of the modern science since the work of Newton, and lies at the very heart of astronomy and physics. During the nineteenth century very important theoretical developments are due to the work of Lagrange, Laplace and Poincaré. In the twentieth century, one of the most important puzzling problem remaining since the Poincaré studies, i.e. the problem of integrability of slightly perturbed systems, has been solved theoretically by Kolmogorov, Arnold and Moser in the now celebrated KAM theorem. The key point is the introduction of the sophisticated number theory, which allowed to solve the old problem of series convergence due to the small denominators in the series coefficients. The state of the art didn't remain in the mathematical framework of beautiful theorems, thanks to the development, at the same epoch, of computers allowing to start numerical experiences on physical systems. Numerical experiments allowed a renewal of the study of the dynamics of celestial bodies, going from the small bodies of the Solar System to planets, up to galactic dynamics. The new theoretical framework of the KAM, but also of the Nekhoroshev theorem, has given a new picture of the dynamics in which chaos and order coexist and provide a peculiar resonant structure to the phase space. Numerical tools for the global analysis of the phase space have then been developed, one of them coupling simplicity of computation with sensitivity of detection, the so called Fast Lyapunov Indicator. Moreover, computer assisted techniques allowed to provide proof of the KAM theorem for values of the perturbation close to the Jupiter mass, i.e. to the realistic physical parameters for the Solar System. Another remarkable development is the use of modern computer for signal processing in the aim of pattern recognition useful for the study of asteroids families as well as for galaxies groups.

This topical issue covers a large part of these modern developments, and its main purpose is to present the state of the art about the chaos which is operating in different kinds of dynamical systems, and to strengthen links between teams who, although working on gravitational systems, are often confined to the classes of celestial objects they study (minor Solar System bodies, solar and extrasolar planets, galaxies, and so on). The first contribution reviews recent numerical studies of hyperbolic manifolds, the skeleton of chaotic motions, and the relation between the topology of hyperbolic manifolds and diffusion. The problematic of dissipative systems is at the center of the second contribution. An overview of the dynamics of minor bodies (asteroids, comets, meteors) and of the evolutionary history of the Solar system is the subject of contribution three. Contribution four provides a review of recent results in galactic dynamics with a special emphasis on the methods of analysis common with celestial mechanics. The last contribution is devoted to fundamental notions of stochastic modelling with applications to pattern detection in spatial astronomical data.

This topical issue is an outcome of the 2009 Aussois Summer School “Dynamics of gravitational systems – challenges and prospects” for PhD students, young researchers and, more generally, researchers in any field related to gravitational dynamics.

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References

1. D. Benest, C. Froeschlé (eds.), *Les méthodes modernes de la Mécanique Céleste [Modern Methods of Celestial Mechanics]* (Éditions Frontières (C36), 1990)
2. D. Benest, C. Froeschlé (eds.), *Interrelations Between Physics and Dynamics for Minor Bodies in the Solar System* (Éditions Frontières (C49), 1992)
3. D. Benest, C. Froeschlé (eds.), *An Introduction to Methods of Complex Analysis and Geometry for Classical Mechanics and Non-Linear Waves* (Éditions Frontières, 1994)
4. D. Benest, C. Froeschlé (eds.), *Chaos and Diffusion in Hamiltonian Systems* (Éditions Frontières, 1995)
5. D. Benest, C. Froeschlé (eds.), *Impacts on Earth*, Lecture Notes in Physics, Vol. 505 (Springer, 1998)
6. D. Benest, C. Froeschlé (eds.), *Analysis and Modelling of Discrete Dynamical Systems – with Applications to Dynamical Astronomy*, Advances in Discrete Mathematics and Applications, Vol. 1 (Gordon and Breach, 1998)
7. D. Benest, C. Froeschlé (eds.), *At the frontiers of chaotic dynamics of gravitational systems*, Special Issue of Celest. Mech. Dyn. Astron. **72**, 1 (1999)
8. D. Benest, C. Froeschlé (eds.), *Singularities in gravitational systems – Applications to chaotic transport in the Solar System*, Lecture Notes in Physics, Vol. 590 (Springer, 2002)
9. D. Benest, C. Froeschlé, E. Lega (eds.), *Hamiltonian Systems and Fourier analysis – New prospects for Gravitational Dynamics*, Adv. Astron. Astrophys., Vol. 9 (Cambridge Scientific Publishers, 2005)
10. D. Benest, C. Froeschlé, E. Lega (eds.), *Topics in Gravitational Dynamics – Solar, Extra-Solar and Galactic Systems*, Lecture Notes in Physics, Vol. 729 (Springer, 2007)