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Some comments about computational astrophysics in Italy

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Abstract. Modern science is becoming more and more dependent on the use of computers. Actually, there is a new paradigm other than the classical two of experimental and theoretical science: computational science, that is the one which makes use of powerful computer facilities to perform simulations of those complex systems that cannot be fully theoretically modeled neither fully experimentally checked. We are all aware of the great success of high performance computational science in the understanding of the human genoma, for instance. In the field of astronomoy and astrophysics, high performance computing has already met applications of overwhelming importance. It is one of the field of major development, in an international context. In this brief introduction to the Meeting I express some opinions on the state of the art of computational astrophysics in our national scientific community.

1. Few words of introduction

In order to receive reliable answers, the most debated open problems in astrophysics and cosmology require an accurate modelling.
Actually, semi-analytical simplifications are still used, and useful, to give an insight to some very complicated astronomical topics, like those involving physical processes mutually interacting and acting on a variety of time and space scales. A typical example is the study of structure formation, from a gaseous phase to stars, binaries, stellar clusters, galaxies, etc.. Micro-physics is linked to macro-physics, and cooling and heating processes are relevant to the overall (i.e. on large scales) dynamics, which, in its turn, has an important feedback on the small scales. This means that the evolution is strongly non-linear and, consequently, hard to follow in detail with a reasonable computational time. Consequently, the study of phase transition from gas to stars, like many other astronomical phenomena, cannot be deeply approached with normal computational tools but need, contemporarily, sophisticated algorithms and massively parallel computational platforms. A prototype of problem that requires high precision in heavy computations is the dynamics of a globular cluster, composed by up to a million stars interacting among themselves and with the external galactic gravitational field. It is known, indeed, that the global evolution of a dense cluster is determined by encounters among stars on the whole available range of impact parameters

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(from tenth to few tens parsecs), thing that makes necessary an evaluation of the gravitational force as precise as possible, being its approximation often unsuitable.

In this context, it seems even superfluous reminding the fundamental role played by supercomputing in the study of the large scale structure of the universe. But in this highly debated field, I think, there is a trick. Indeed, it seems that people performing heavy simulations are more aiming at increasing resolution, i.e. number of particles in the cosmological simulation box, than caring of the physical interpretation of results. As a matter of fact, the question about the role of gravity in inducing clustering and about the precise modes of clustering itself and, consequently, the interpretation of the distribution of space scales in the observed universe is, in my opinion, still far from being convincingly answered. It is likely that solutions to these fundamental problems reside in a careful coupling of heavy computations with a solid theoretical physical interpretation of the involved processes that extend from micro- to macro-physics; in addition, simulations should cover a reliable (sufficiently long) time scale. I am also convinced that a deep analysis of the possible observables will constitute a substantial help in driving the numerical simulations.

To resume, it may be sometime dangerous to have overwhelming computing capabilities because it may make people thinking that a brutal attack to the problem is sufficient to solve it, while this is not (always) true.

I guess that everyone who has been seriously involved in supercomputing knows that one of the most serious problems to face is the skepticism that, sometime, emerges in the audience. A typical question is: OK, but what are all these computations for?. A way to overcome this question is to use heavy computations just if and when they are needed and couple them with deep physical undestanding, as said, but this in not enough if precise and simple conclusions, i.e. answers to the astrophysical questions, are not eventually given.

It is, in some sense, a relevant epistemological problem that logically arises when trying to find a consistent interpretation to observational data (it is, by the way, a privilege of theorists to deal with this problem and they should not complain about it).

Skepticism about numerical simulations is in our local scientific community probably more evident than in others where the development of science making use of high performance simulations has reached a more advanced stage, both technical and methodological. I think this skepticism may be easily overcome by showing and illustrating the relevance of the results obtained by the national scientific community. This is one of the scopes of this national meeting. This meeting in Bologna has been, indeed, organized to collect the various groups working, often at a level of absolute international excellence, in Italy in the field of astrophysical supercomputing, both in numerical simulations and in the development of related tools and facilities.

I sincerely hope that we will conclude this meeting having, at least partially, focused the present and future role of astrophysical numerical simulations in our country; personally, I am convinced that numerical simulations are crucial to obtain solution to fundamental astrophysical problems. The large number of young people present at this meeting shows that this is not just my individual opinion.

Another proof of this is that the same opinion is shared by the most developed international scientific communities. Actually, it is undoubtely fundamental to invest resources into the construction of new telescopes and other observational facilities, but, please, do not forget that the scientifical output of the exceedingly large amount of observing material necessarily requires an adequate theory and, thus, numerical checks of theory. As a consequence, some resources must be specifically allocated to the development of numerical modelling and related (hardware and software) tools. Otherwise we will have enormous data bases without a proportional quantity of scientifical knowledge. This point seems well accepted in the most developed scientific countries, but not yet in ours. In Italy we need making choices coherent with those made in those countries: helping the development of an organized computational community with adequate technical and, mainly, human resources.

This is our fundamental challenge; if we do not succeed we risk to lose a very important possibility to be competitive with other countries at the highest level of astronomy and cosmology.