STRUCTURE FORMATION IN ASTROPHYSICS

Understanding the formation of objects at all scales in the universe, from galaxies to stars and planets, is a major issue in modern astrophysics, and one of the most exciting challenges of twenty-first century astronomy. Even though they are characterized by different scales, the formation of planets, stars and galaxies share many common physical processes and are rooted in the same underlying domains of physics.

This unique reference for graduate students and researchers in astrophysics is the first to cover structure formation on various scales in one volume. This book gathers together extensive reviews written by world experts in physics and astrophysics working in planet, star and galaxy formation, and related subjects. It addresses current issues in these fields and describes the recent observational status and state-of-the-art theoretical and numerical methods aimed at understanding these problems.

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Preface

Understanding the formation of gravitationally bound structures at all scales in the universe is one of the most fascinating challenges of modern astronomy. It is now realized that the initial building blocks of galaxies were small collapsing dark matter halos, produced by the primordial fluctuations. These blocks then merged and were assembled into progressively larger galaxies, a scheme generally described as the hierarchical model of galaxy formation. The modern understanding of star formation involves large-scale turbulent motions producing local overdensities which eventually collapse and form prestellar cores under the action of gravity. The most likely scenario for planet formation is the collapse of a vast gaseous envelope onto a central dense core formed from the aggregation of millimetre-size grains in the original protoplanetary nebula, although disk fragmentation could remain an alternative scenario in some situations. The detailed processes responsible for the formation of these structures, however, remain poorly understood. Many important issues remain unsettled, so the robustness of these general paradigms is still ill determined. All these scenarios for the formation of galaxies, stars and planets, although involving vastly different scales, share many underlying physical mechanisms. They all involved hydrodynamical processes, generally leading to turbulent motions, but the very nature of these motions and their real role in structure formation remains unclear. The role of magnetic fields, in the collapse itself and in the generation of winds and jets, remains one of the major unknowns in the formation of structures. As a structure starts to collapse, its ability to cool determines the final bound objects and thus radiation, or more precisely radiation hydrodynamics is a key process in galaxy, star and planet formation. How the ubiquitous presence of gravity modifies the impact of all these processes remains a major issue. Only a comprehensive description of these complex physical mechanisms, and of their interplay, will enable us to fully assess the validity of the aforementioned scenarios for the formation of gravitationally bound structures in the universe.

It was indeed the aim of this conference, organized at the foot of Mont Blanc, in Chamonix, to bring together world experts in galaxy, star and planet formation, in order to address these issues and to share their expertise and problems over the course of a week. Since 'the star is always right', all the sessions started with an observational review, presenting our current understanding of the problem and the main questions to be answered. The theoretical talks addressed in detail the various physical problems encountered in the astrophysical situations of interest, as well as the numerical methods and challenges in the description of these complex processes. The talks were followed by lively discussions between the participants during the daily poster sessions, the lunches taken together on the site and the long morning and afternoon breaks, promoting interactions between the various communities.

I am deeply indebted to the different speakers for their outstanding reviews and for the remarkable review chapters they have written, which are included in the present volume. Bringing together various authors to write a common, genuine review was a challenge and I am really thankful to all the contributors for having accepted this task. I believe this has generated a volume which will be useful to young and less young researchers interested in or working in the exciting field of structure formation in astrophysics. My profound gratitude to all the members of the Scientific Organizing Committee (SOC),[1] whose input was essential in choosing the various topics and speakers, and in shaping up the scientific backbone of the conference. I am also deeply indebted to Cathy Meot and to the whole team at the Hotel Majestic for their kindness, their efficiency and their remarkable professionalism. Their role was essential in making this conference a success. Special thanks also to Jimmy Paillet, our talented artistic graduate student, who designed the logo of the conference, and to the city and the mayor of Chamonix, for hosting the conference in this unique site. Finally, it is important to mention that this conference could not have been organized without the essential financial support of various sponsors, namely the Ecole Normale Supérieure de Lyon, the Centre National de la Recherche Scientifique, the Ministère de la Recherche et de la Technologie, the Institut National des Sciences et de l'Univers, the Centre de Recherche Astrophysique de Lyon, the Région Rhône-Alpes and the Conseil Général de Haute-Savoie. My last thoughts will be for the IAU and the 'experts' of the various Divisions/Commissions, that the proposal had been submitted to, for deciding *not* to support the conference, for the general reason that it was unlikely that people coming from different scientific communities would be persuaded to listen to each other. This certainly strengthened my wish to take up the challenge!

[1] The SOC of the conference was composed of: Ph. André (Paris), I. Baraffe (Lyon), P. Bodenheimer (UCSB), V. Bromm (Austin), C. Cesarsky (ESO), G. Kauffmann (Garching), R. Klessen (Heidelberg), R. Larson (Yale), M. Mayor (Geneva), C. McKee (Berkeley), Ph. Myers (Harvard), J. Papaloizou (Cambridge), E. Salpeter (Cornell), F. Shu (UCSD) and J. Silk (Oxford).