Preface

The determination of stellar ages is a key, yet thorny, issue in astrophysics. Precise and accurate stellar ages are indeed required in many fields, including exoplanetology, stellar physics, the dynamical and chemical evolution of galaxies, and in cosmology. For instance, we need to know the ages of stars embedded into HII regions to be able to study how they can induce star formation in their environment. The identification and characterization of stellar populations in our Galaxy (and in other galaxies) rely on the knowledge of the age of the stars they host. Furthermore, the ages of the oldest stars of the Milky Way, located in the halo (including globular clusters) is an important independent constraint for cosmology. These ages are related to the onset of stellar formation in our Galaxy and they have to be consistent with the cosmological age inferred independently from the measurements of the expansion rate of the Universe (Hubble constant). Another example comes from the properties of exoplanets, which change with time. For instance giant planets contract and cool down as they become older. Therefore to be able to decipher the internal structure of exoplanets, it is crucial to estimate precisely the age of their host stars.

Stellar ages cannot be measured directly, except in the solar case. They have to be inferred either from theoretical models or empirical laws. As reviewed by Soderblom (2010) several age-dating methods can be used depending on the kind of stars considered: single stars, stars in clusters, young stars, evolved stars. Fundamental and semi-fundamental dating methods such as nucleocosmochronometry or the study of the kinematics of the Galaxy rely on observations and well-known physical processes. Empirical methods are based on relations linking age and observational parameters: rotation period (gyrochronology), activity, surface lithium depletion, etc.. Statistical methods consider broad galactic trends: age-metallicity relations and/or dynamical processes. The most bona fide method relies on stellar evolution models, which allow one to infer stellar ages with the least number of assumptions. The model isochrone placement method has been used in many contexts over the past decades and is very powerful to age-date large samples of stars, while asteroseismology has recently proved to be able to provide independent and very powerful tools to probe stellar interiors and infer their evolutionary state and age. Likewise, the theoretical cooling sequences of white dwarfs, when compared with their observational counterparts in stellar clusters allow one to estimate the cluster age. Much progress has been made in this field, although the inferred ages do not always agreed with the one inferred from the stars on the Main Sequence. Considerable progress in stellar age-dating has been recently made possible in the context of the massive acquisition of very precise observational data. For instance,

the remarkable very high-precision photometric data delivered by the CoRoT and *Kepler* satellites not only led to the discovery of new exoplanetary systems but also provided asteroseismic diagnostics of the internal structure and evolutionary state of stars. In parallel, very large telescopes equipped with modern instruments (for instance UVES, HARPS, and AMBER at ESO) or large spectroscopic surveys such as RAVE lead to a very high accuracy in the determination of the classical parameters of stars and their planets (magnitude, temperature, abundances of chemical elements in the atmosphere, mass, radius, etc.). At the same time, new theoretical techniques (mostly Bayesian) have been undertaken to refine the standard age-dating methods and design new ones with better performances. Their goal is to take full benefit of the observational constraints to improve both the precision and accuracy on age determination using as prior information the results of stellar evolutionary tracks. For instance, the ages of old stars can be estimated through nucleocosmochronometry when very high resolution spectra can be obtained revealing long-living elements such as thorium and uranium. Also, new observations have improved the empirical relations between stellar chromospheric activity, rotation, and age. Furthermore, the asteroseismic analysis has made a great leap forward since the launch of CoRoT and *Kepler*. Theoretical studies have shown that the signature of the gradient of chemical composition inside a star is seen in the stellar oscillation frequencies. From the observed frequencies, it is therefore possible to determine the size of the nuclear burning core, which can be related to the age of the star through internal structure models. In this respect, the interpretation of CoRoT and *Kepler* data has already provided reliable results. However even if progress on stellar age-dating has been remarkable, a lot of errors remain, both random and systematic. The methods have to be much improved in order to ensure the optimal exploitation of the Gaia-ESA astrometric and photometric mission. Gaia performs astrometric, photometric and spectroscopic observations which will provide stellar global parameters for large samples of stars located everywhere in our Galaxy (discs, bulge, and halo) with an unprecedented accuracy. Furthermore the recently selected PLATO-ESA mission, scheduled for a launch in 2024, will pursue and extend the work of CoRoT and *Kepler*. It is therefore crucial to go on making progress on the identification of the error sources of the age-dating methods and to estimate their consequences in other fields (*i.e.* the evolution of the Galaxy, characterization of exoplanetary systems, etc.). This volume offers lectures given by world experts in the field during the Evry Schatzman School on Stellar Physics (EES 2013) held in Roscoff, France. The multiple facets of stellar age-dating are reviewed and the status of the capabilities of age-dating methods is given. These reviews of the present strengths and weaknesses of stellar age-dating are intended to facilitate the interpretation of forthcoming observational data such as those that will be provided by the Gaia and PLATO ESA space-missions. Therefore this book will be a valuable reference for researchers and students in the coming years.

The school was sponsored by the Centre National de la Recherche Scientifique (CNRS, Formation Permanente), the Programme National de Physique Stellaire (PNPS) of CNRS/INSU, the Programme National Cosmologie et Galaxies

(PNCG) of CNRS/INSU, the Action Spécifique Gaia, the Centre National d'Etudes Spatiales (CNES), the Great Research for European Astronomy Training (GREAT), European Research Foundation, and the Observatoire de Paris.

We warmly thank the Scientific Organizing Committee. We are greatly indebted to our colleagues from the GEPI at Meudon Observatory for their hard work on the practical organization of the school: Sabine Kimmel and Stéphane Thomas who managed the administrative aspects, and Sylvestre Taburet who designed the web site of the school. We are grateful to everyone from the staff of the Station Biologique de Roscoff for their cordial welcome and help during the school.

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The Organisers of EES 2013.