# XXI Century Challenges for Stellar Evolution

*Cefalú (Sicily - Italy), 29 August - 2 September, 2007*

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# FOREWORD

The theory of stellar evolution and theoretical stellar models are nowadays a fundamental tool to investigate the formation and evolution of Galactic and extragalactic stellar populations, and to constrain several cosmological parameters. To this purpose, stellar evolution modelling has to be able to predict accurately lifetimes, surface chemical abundances, photometric and spectral properties of stars of different masses and initial chemical compositions. The reliability of these theoretical predictions rests entirely on the accuracy of the physical assumptions employed in the model computations.

The latest generation of imagers and spectrographs available at the ground-based 8m class telescopes together with space-based instruments (HST, Spitzer, Galex) are providing us with a huge flow of data, that cover also less explored wavelength regions, crucial for understanding the physics of both stars and galaxies. This large amount of observations is opening a unique opportunity to use stellar evolution to investigate the universe at progressively higher redshifts. At the same time, they are also providing a wealth of constraints to test the accuracy of the current generation of stellar models. A large body of observations pose several challenges to the 'standard' stellar evolution prescriptions that are routinely used in the model computations. To give just a few examples, empirical data indicates that the observed surface abundances of Li in globular cluster and Halo field stars might be explained only if, together with the 'standard' convection and gravitational settling mechanisms, some additional element transport processes are included in stellar models; spectroscopy of Planetary nebulae has revealed neutron-capture element abundances difficult to reproduce with current AGB-model nucleosynthesis; the new determination of the solar metal mixture challenges the agreement between 'standard' solar models and helioseismology; the mass-radius relation for low-mass stars based on eclipsing binary systems cannot be reproduced by current standard stellar models; recent results concerning the luminosity function of red giant branch and white dwarf stars highlight discrepancies with the theoretical predictions; some empirical determinations of the Cepheid P-L relationship dependence on metallicity are at odds with theoretical predictions.

From August 29 until September 2, 2007, the Municipal Palace of Cefalu' (Sicily, Italy) has hosted an international workshop devoted to discuss the many existing challenges to stellar evolution. The aim was to bring together both theoreticians and observers in the field of stellar studies, to discuss the main open problems, and to move towards their theoretical understanding. The meeting has been organized by the Astrophysics Research Institute of the Liverpool John Moores University (UK) together with the INAF - Osservatorio Astronomico di Teramo (Italy), and with the additional support of the Istituto Nazionale di Astrofisica, INAF - Osservatorio Astronomico di Roma, INAF - Osservatorio Astronomico di Palermo, Fondazione Mandralisca, Comune di Cefalu', Parco delle Madonie, Associazione Cefalu' and Astronomy.

The first announcement early in 2007 received an enthusiastic feedback, and about 120 participants from 16 countries have attended the meeting, structured in 11 sessions devoted to 'Setting the stage: comparing theory with observations', 'Simple and composite stellar populations', 'Horizontal Branch stars', The bright, cool side of the CMD', 'Variable stars', 'Chemical abundances, constraints on stellar models', 'The faint end of the CMD', 'Non-standard physical processes', 'Exotic objects', 'Asteroseismology as diagnostic of stellar interiors, and calibration of stellar models', 'Beyond 1D theoretical models'. Overall, the meeting featured 60 talks and 50 posters (plus two well-received public lectures). The following pages contain the papers based on these presentations.

We would like to thank all colleagues sharing with us the duties of the Scientific Organizing Committee, for their advice and help organizing the scientific programme: Giuseppe Bono, Roberto Buonanno, Cesare Chiosi, Flavio Fusi-Pecci, Alvio Renzini, Oscar Straniero, Allen V. Sweigart, Amedeo Tornambe', Don A. Vandenberg, Achim Weiss. Also our collaborators in the Local Organizing Commitee are warmly thanked for their time and help: Giuseppe Bono, Luciano Burderi, Marco Castellani, Tiziana Di Salvo, Lucio Pacinelli, Adriano Pietrinferni. A special thank goes to Giorgia Busso, Daniel Brown, Nino Gugliuzza, William Priestley and Massimo Quintini, for their continuous involvement during the meeting.

The workshop has been dedicated to the memory of Vittorio Castellani, who sadly passed away in May 2006. We thought that this could be the perfect occasion for a small commemoration of Vittorio, whose contribution to stellar evolution and stellar population studies has been wide-ranging. To this purpose, an afternoon has been devoted to a small tribute – 'Vittorio's legacy' – with some personal memory of Vittorio from colleagues who knew him well and/or collaborated with him, and a series of short talks given by colleagues who both studied and collaborated with him, and are continuing nowadays to work on projects started together with Vittorio. All 11 speakers for Vittorio's legacy are gratefully acknowledged: Alessandro Chieffi, Giuseppe Bono, Marcella Marconi, Scilla degl'Innocenti, Oscar Straniero, Enzo Brocato, Elio Antonello, Amedeo Tornambe', Alistair Walker, Cesare Chiosi, Robert Rood. In recognition of his outstanding scientific activity, the SOC members have decided to dedicate this volume to Vittorio, and to include a small contribution outlining his legacy.

Finally, we wish to thank all participants to the meeting for their enthusiasm and for sharing with us their insights and their most recent results.

Santi Cassisi and Maurizio Salaris

# VITTORIO'S LEGACY

On 2006 May 19, we lost one of the leading astronomers of the second half of the 20th century, Vittorio Castellani. He passed away in Rome after a one-year fight with a cruel disease.

During his long and productive career, Vittorio has made many fundamental contributions to theoretical astrophysics, working on a wide range of problems, including the internal structure and evolution from the very low- to the intermediate-mass stars, the properties of stellar populations, the pulsational properties of the various types of variable stars, and so on.

Inspired by Livio Gratton, in the middle of 60' he founded together with some colleagues "The roman school of Stellar Evolution" in Frascati (Rome). All together, they provided in that period many pivotal contributions to our understanding of stellar astrophysics. Just to quote a few illustrative examples, they clearly outlined the physical processes at the basis of the semiconvection during the core He-burning stage of low-mass stars, and were among the first to compute accurate stellar models for horizontal branch (HB) stars. This allowed them and their collaborators to obtain more reliable predictions about the HB evolutionary lifetimes that, once compared with star counts in galactic globular clusters, lead to estimates of the primordial helium content lower than commonly assumed at that time, and more in line with cosmological nucleosynthesis results.

Vittorio Castellani's group were also among the first to devote a significant effort in computing reliable models for both extremely metal-poor and metal-rich stars; a scientific interest that he never abandoned during his career.

In the early 80s, Vittorio and his colleagues started working on many scientific topics, that they will further develop in the following years together with their students.In this context we can quote the analysis of stellar variability, and the impact of non scaled-solar heavy element distributions on the evolutionary and structural properties of low-mass stars.

In more recent years, owing to the possibility to obtain more accurate insights on both stellar evolution and the properties of the various stellar populations, stellar pulsation theory largely attracted the interest of Vittorio. In this field, he provided relevant contributions to the study of both RR Lyrae and Cepheid variables. In this context, his personal contribution to long-standing problems as the Oosterhoff dicothomy, and the RR Lyrae and Cepheid distance scales cannot be overlooked.

One of the most intriguing aspects of Vittorio's personality as a scientist, was his own way of approaching the problems: he always made a big effort of reducing a scientific problem to its fundamental features, by pruning all the non-relevant, distracting, points. A clear evidence of this kind of approach is the one provided by his work on the "solar neutrinos problem", where he was able to show that an astrophysical solution of the discrepancy between the observed and predicted neutrinos flux cannot exist.

His ability to use stellar astrophysics for tackling problems related to fundamental physics, such as neutrino physics and the efficiency of diffusive processes, highlights one of the most important features of Vittorio's legacy: the stars *have to* be used also as an ideal laboratory for fundamental physics.

Vittorio has authored of more that 200 papers in international scientific journals, and a huge number of papers on non-specialized journals; he has been also author of a book - written in italian language - on stellar astrophysics that has been "The bible" for many generations of italian students and significantly contributed to the fact that many of them fell in love with stellar astrophysics.

However, Vittorio has not been "only" an astronomer. He was, during his whole life, very interested in archeology and speleology. In the context of such disciplines he published an impressive number of papers showing the results of several archaeological surveys in Italy and abroad. A lot of interesting information about this aspect of Vittorio's activity can be found at the WEB site of the "Centro di Ricerche Sotterranee Egeria". One of the main interests of Vittorio in this field was to understand the whole aspects of the tunnels excavated by men in the past.

Vittorio was also very interested in Archeo-astronomy, a research field based on the analysis of the astronomical issues related to monuments and archaeological findings. This research field offers new material for the archaeological, anthropological and ethnological investigations, since usually archaeologists are not very familiar of topics related with astronomy. During the years, Vittorio contributed significantly to some basic topics concerning the foundations of this field.

Vittorio's death is a great loss for the italian scientific community and for astronomy as a whole. It is a great loss for the many students who he inspired, fascinated and guided along the right track in their research. All of us who were fortunate to know him for many years, miss him deeply.