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Ian W. Roxburgh Jean-Louis Masnou (Eds.)

Physical Processes in Astrophysics

Proceedings of a Meeting
in Honour of Evry Schatzman
Held in Paris, France
22-24 September 1993

Springer

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Evry Schatzman

Preface

This volume is based on the papers presented at the Jubilee meeting in honour of Evry Schatzman, which was held in the Ministère de l'Enseignement Supérieur et de la Recherche, Paris in September 1993. The meeting was highly successful, both as a scientific meeting in its own right, and as a fitting occasion to honour Evry for his lifetime's contribution to physics and astronomy, and to the education and inspiration of generations of students, many of whom were able to participate in the meeting.

When planning the scientific programme for the meeting, we wished to cover in depth some of those areas of physics and astronomy to which Evry has made a special contribution. This gave us a wide choice. But we finally chose to concentrate on stellar physics, covering stellar evolution, solar neutrinos, stellar rotation and spin down, convection and mixing, neutron stars, white dwarfs, and novae.

One of the features of Evry's approach to science is the combination of the study of the physical processes of importance in astrophysics combined with the application of those areas of physics to explaining the observed properties of astrophysical objects. It was this approach that we sought to replicate in both the scientific meeting and in this volume, which contains the papers presented there.

It was the aim of the organisers, and the express wish of Evry, that the volume based on the meeting should be of value to a wide scientific community, especially to students starting research in the field. This led us to allocate all the time to major in-depth reviews so that the speakers had time both to develop the basics of their subject and to cover the most-recent work. This was a successful format and this volume reflects the structure of the meeting. All the review speakers and authors are acknowledged experts in their own areas, most were strongly influenced or inspired by Evry at some stage in their career and all were eager to contribute to the Jubilee meeting in his honour. The resulting text therefore has an authority that will make it a valuable resource for some years to come, valuable for new research students and old astronomers alike.

The meeting was devoted to three main areas: solar and stellar evolution, very dense stars, and transport processes. This volume follows the same pattern. The first three review talks are on solar and stellar evolution. André Maeder's article on *Physical Processes in Stellar Evolution* gives an in-depth account of the current status of stellar evolution theory with particular emphasis on areas where there is considerable uncertainty, namely mass loss and mixing. John Bahcall then reviews the present position on *Solar Neutrinos*. There has been a long-standing solar neutrino problem in that the flux of solar neutrinos measured in the Homestake mine $^{37}C\ell$ experiment is about one third of the value predicted by models of the Sun. This problem was compounded by the results of the Kamiokande and Gallium experiments, rendering it almost impossible to construct a solar model that is compatible with these observations. John's conclusion is that the actual explanation lies in particle physics not in astrophysics, and the MSW effect – or some similar consequence of a non-zero neutrino mass –

is the actual explanation; which is an example of how astrophysics contributes to the development of physics. Leon Mestel covers the problems of *Angular Momentum Loss Rates and Stellar Spin-Down*, the rotation of a star evolving through mass and angular momentum loss in the form of a stellar wind that is magnetically coupled to the star. This general concept was considered by Evry himself many years ago and Leon gives a masterly presentation of how the subject has developed. Understanding mass and angular momentum loss is important not only for explaining the observed rotation of stars, but also for understanding mixing and mass loss in stellar evolution, problems covered by André Maeder and by Jean-Paul Zahn.

The next three chapters are on matter at very high densities and the stars that are in this state, namely white dwarfs, neutron stars, and novae. Evry was one of the pioneers of the study of white dwarfs and his book *White Dwarfs* is still a valuable source of information and inspiration after nearly 40 years. The chapter by Pawel Haensel provides an in-depth review of the properties of matter at very high densities and of neutron stars; I learned a lot both from his talk and from the chapter in this volume, and I commend this as a valuable reference source for those wishing to learn about the subject. The next chapter by Steve Kawaler on *White Dwarfs: Useful Stars* covers both the results of very recent work using the new and valuable tool of stellar oscillations – or asteroseismology – and the interior structure and evolution of white dwarfs. The following chapter, by Sumner Starrfield, is on novae. As the title of his chapter suggests, this too is an area to which Evry has made major contributions, and Sumner provides the reader with an in-depth analysis both of the historical development of research in this field and of our present understanding of the cause of the nova outbursts.

The final three chapters are devoted to convection and mixing processes in stars. Convection in stars is turbulent and turbulence remains one of the major unsolved problems of classical physics. Ed Speigel gives us an exciting personal perspective on the problems in this field and of the progress that has been and may be made in the future. The following chapter by Jean-Paul Zahn is devoted to problems of transport processes in stars, again an area to which Evry has made significant contributions. Understanding the transport of matter and of angular momentum, whether it be due to rotationally driven circulation, mild turbulence, or by waves, is a major area of uncertainty in stellar physics. It effects the mixing of chemical elements in stellar interiors and hence both the evolution of stars and the chemical evolution of the galaxy. Jean-Paul gives us a review of a variety of possible mechanisms and a pool of ideas that remain to be explored.

The last chapter is by Evry himself and Montalbán, on transport process in the Sun and the solar neutrino problem. I first heard Evry talk about his ideas on mild diffusion, and how it may affect solar and stellar evolution, at the IAU General Assembly in Grenoble in 1976. Since then these ideas have been developed by Evry himself and by others, amongst them André Maeder, Jean-Paul Zahn, and myself. Evry's conclusion is that such diffusion could take place, driven by gravity waves originating in the solar convective zone and it might be

strong enough to affect the chemical evolution of the sun, and possibly lower the solar neutrino production. Whether or not the explanation of the solar neutrino problem is one of astrophysics or whether, as John Bahcall argues, the problem is one of particle physics, Evry's pioneering work on diffusive mixing is important for all of stellar evolution theory; as André Maeder emphasises, mixing in stars has to be understood and incorporated into stellar evolution theory before we can hope to successfully model and explain the wide range of observed systems.

Whilst we deliberately only had major review talks during the meeting, many of the participants contributed poster papers on problems falling within one of the three subject areas. These papers add to the reviews by focusing on specific problems within each area and they are included in the last section of the book.

Many people contributed to the success of the meeting. My colleagues on the Scientific Organising Committee, the speakers and authors, the Comité de Parrainage that helped us to raise the financial support, the Ministère that provided the facilities for the meeting, the many organisations that contributed financially to the cost of the meeting, my colleagues on the Local Organising Committee, in particular Madame Adam and Jean-Louis Masnou, and the group of colleagues, friends and students of Evry that first proposed this meeting in his honour.

But above all the meeting was a success because of Evry Schatzman. Without him there would have been no meeting, there would be a huge gap in our understanding of the physical processes in astrophysics, and a huge gap in our lives. The meeting was to honour Evry for the contributions he has made to physics and astronomy and this volume is a permanent record of that occasion. But it is not simply a conference proceedings; it is an authoritative record of the state of understanding of several inter-related areas of stellar astrophysics that will be a valuable reference source both for students starting out in research and for established scientists.

Finally I wish to record my personal thanks to Evry for the inspiration he has provided over the 33 years since we first met. I was deeply honoured to have been invited to chair the scientific organising committee of this meeting and I hope that the meeting itself, and this volume, goes some small way to thanking Evry for that inspiration. I know I present the views of all those who participated in the meeting, and the many others who could not, when I say to Evry, thank you, as a scientist and as a friend.

London
July 1995

Ian W Roxburgh

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The poster was by Jean-Claude Pecker and edited by Isabelle Souriau (CORE)

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