

Preface

The theory of neutron stars, which along with white dwarfs and black holes form the family of astrophysical compact objects, involves an intimate interplay between diverse branches of theoretical physics. It covers a range from the theory of microscopic nuclear forces to general relativistic gravity, from the particle physics of the radiation of light and neutrinos to the low-temperature physics of superfluids, from the solid-state physics of highly compressed matter to the atomic physics in ultra-high magnetic fields. Hardly in any other physical context do all the forces of nature – the electroweak, strong, and gravitational – emerge as equally important ingredients in the physical picture. It is this diversity of fields and the uniqueness of their interplay that makes the study of neutron stars both exciting and challenging.

The idea of neutron stars has its roots in the 1930s when it was realized that self-gravitating matter can support itself against gravitational contraction by the degeneracy pressure of fermions obeying the Pauli principle. Thus, unlike ordinary stars, which are stabilized by their thermal pressure, neutron stars owe their very existence to the quantum nature of matter. When this idea was combined with the newly developed theory of general relativity neutron stars were born – in theory. It was not until 1967, when the remarkable discovery of pulsars by J. Bell and A. Hewish gave a second birth to neutron stars, that their observational studies became a reality.

The past four decades have seen a dramatic increase in the theoretical activity in this field. Many factors have contributed to the progress. On the observational front the discoveries of neutron stars in X-ray binaries, millisecond pulsars, binary pulsars, and highly magnetized neutron stars (magnetars) have opened new channels of information on these objects. Then, too, the exploration of the nature of interactions among the strongly and weakly interacting constituents of matter at terrestrial accelerators impacted on our conception of superdense matter, its strangeness content, the quark degrees of freedom, phase transitions and reactions involving neutrinos. Another factor is the increase in computational capabilities.

This book is a collection of lectures given at the ECT* (European Centre for Theoretical Studies in Nuclear Physics and Related Areas) in June and July 2000 and covers the theory of neutron star interiors at the forefront of active research. It includes reviews of the traditional material (e.g. the equation of state of superdense matter, the thermal evolution) and, as well, it contains lectures

on new issues, for example the recent developments in QCD at finite density, and the possible astrophysical manifestations of the QCD deconfinement phase transition. The choice of topics included in this book was selective. Clearly it is not possible to cover all the current problems of neutron star theory in a single volume; we have provided a list of monographs on the subject for further reference. Naturally enough, the level of presentation throughout the book is uneven; nevertheless, these pedagogical lectures are intermediate between what can be found in the standard texts on the subject and the current research literature; they should be a useful guide to those who wish to enter the field and to those who are actively working in the field.

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