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 it 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.

Acknowledgements The editors of this volume express their appreciation for the support and facilities of the ECT* at Trento, Italy, and to its former Director, Rudi Malfliet, for his hearty encouragement of the workshop in the summer of 2000 from which this volume was conceived.

Rostock, Berkeley, Paris
January 2001

David Blaschke
Norman K. Glendenning
Armen Sedrakian

List of Contributors

Mark Alford
Department of Physics and Astronomy
University of Glasgow
G12 8QQ, United Kingdom
m.alford@physics.gla.ac.uk

Marcello Baldo
INFN, Sezione di Catania
Corso Italia 57
95129 Catania, Italy
marcello.baldo@ct.infn.it

David Blaschke
Fachbereich Physik,
Universität Rostock
Universitätsplatz 3
18051 Rostock, Germany
david.blaschke@physik.uni-rostock.de

Ignazio Bombaci
Universita' di Pisa
Dipartimento di Fisica and
INFN Sezione di Pisa
Via Buonarroti 2
56127 Pisa, Italy
bombaci@pi.infn.it

Jeffrey A. Bowers
Massachusetts Institute of Technology
77 Massachusetts Ave.
Cambridge, MA 02139, USA
jbowers@mit.edu

Fiorella Burgio
INFN Sezione di Catania
57 Corso Italia
95129 Catania, Italy
fiorella.burgio@ct.infn.it

Brandon Carter
CNRS
Observatoire de Paris - Meudon
92195 Meudon, France
Brandon.Carter@obspm.fr

Monica Colpi
Universita' di Milano
Department of Physics G. Occhialini
Via Celoria 16
20133 Milano, Italy
colpi@mi.infn.it

Norman K. Glendenning
Nuclear Science Division and
Institute for Nuclear and Particle
Astrophysics
Lawrence Berkeley Natl. Laboratory
University of California
Berkeley, CA 94720, USA
NKGlendenning@lbl.gov

Hovik Grigorian
Yerevan State University
Alex Manoogyan 1
375025, Yerevan, Armenia
hovik@darss.mpg.uni-rostock.de

Pawel Haensel
Copernicus Astronomical Center
Bartycka 18
00-716 Warszawa, Poland
haensel@camk.edu.pl

M.B. Hecht
Physics Division
Argonne National Laboratory
Argonne, IL 60439-4843, USA
hecht@theory.phy.anl.gov

Hans-Thomas Janka
MPI für Astrophysik
Karl-Schwarzschild-Str. 1
85740 Garching, Germany
thj@mpa-garching.mpg.de

Konstantinos Kifonidis
MPI für Astrophysik
Karl-Schwarzschild-Str. 1
D-85740 Garching, Germany
kkifonidis@mpa-garching.mpg.de

Dong Lai
Cornell University
Space Sciences Building
Ithaca, NY 14853 USA
dong@spacenet.tn.cornell.edu

James Lattimer
Department of Physics and Astronomy
State University of New York
Stony Brook, NY 11794-3800, USA
lattimer@astro.sunysb.edu

Umberto Lombardo
Dipartimento di Fisica
Universita di Catania and
INFN-LNS
57 Corso Italia
95129 Catania, Italy
umberto.lombardo@ct.infn.it

Fabio Pizzolato
Universita' degli Studi di Milano
Dipartimento di Astrofisica
Via Celoria 16
20133, Milano, Italy
fabio@pccolpi.uni.mi.astro.it

Gevorg S. Poghosyan
Yerevan State University
Alex Manoogian 1
375025 Yerevan, Armenia
gevorg@ysu.am

Jose A. Pons
Department of Physics and Astronomy
State University of New York
Stony Brook, NY 11794-3800, USA
jpons@quark.ess.sunysb.edu

Sergei B. Popov
Moscow State University
Universitetskii pr. 13
119899 Moscow, Russia
polar@sai.msu.ru

Andrea Possenti
Osservatorio Astronomico di Bologna
Via Ranzani 1
40127, Bologna, Italy
l_possenti@astbo3.bo.astro.it

Madappa Prakash
Department of Physics and Astronomy
State University of New York
Stony Brook, NY 11794-3800, USA
prakash@nuclear.physics.sunysb.edu

Krishna Rajagopal
Massachusetts Institute of Technology
77 Massachusetts Ave.
Cambridge, MA 02139 USA
krishna@ctp.mit.edu

Angels Ramos
University of Barcelona
Departament E.C.M.
Facultat de Fisica
Av. Diagonal 647
08028-Barcelona, Spain
ramos@ecm.ub.es

Markus Rampp
MPI für Astrophysik
Karl-Schwarzschild-Str. 1
D-85740 Garching, Germany
mrampp@mpa-garching.mpg.de

Sanjay Reddy
Institue for Nuclear Theory
University of Washington
Physics-Astronomy Bldg.
Box 351550
Seattle, WA 98195-1550, USA
reddy@phys.washington.edu

Craig Roberts
Physics Division
Argonne National Laboratory
Argonne, IL 60439-4843, USA
cdroberts@anl.gov

Thomas Schäfer
Department of Physics
State University of New York
Stony Brook, NY 11794 , USA
schaefer@nuclear.physics.sunysb.edu

Jürgen Schaffner-Bielich
Physics Department
RIKEN BNL Research Center
Upton, NY 11973 USA
JSchaffner@bnl.gov

Hans-Josef Schulze
E.C.M. Facultat de Fisica
Universitat de Barcelona
Av. Diagonal 647
08028 Barcelona, Spain
schulze@ecm.ub.es

Sebastian M. Schmidt
Physics Division
Argonne National Laboratory
Argonne, IL 60439-4843, USA
basti@darss.mpg.uni-rostock.de

Armen Sedrakian
Groupe de Physique Theorique
Institut de Physique Nucleaire
91406 Orsay Cedex, France
sedrakia@ipno.in2p3.fr

Edward Shuryak
Department of Physics and Astronomy
State University of New York
Stony Brook, NY 11794-3800, USA
shuryak@dau.physics.sunysb.edu

Andrew W. Steiner
Department of Physics and Astronomy
State University of New York
Stony Brook, NY 11794-3800, USA
steiner@nuclear.physics.sunysb.edu

Dmitry Voskresensky
Moscow Institute for Physics and Engineering
Kashirskoe Shosse 31
115409 Moscow, Russia
d.voskresensky@gsi.de

Jochen Wambach
Institut für Kernphysik
TU Darmstadt
Schlossgartenstr. 9
64289 Darmstadt, Germany
wambach@physik.tu-darmstadt.de

Ira Wasserman
Cornell University
Department of Astronomy
626 Space Sciences Bldg.
Ithaca, NY 14853, USA
ira@spacenet.tn.cornell.edu

Fridolin Weber
University of Notre Dame
Department of Physics
226 Nieuwland Science Hall
Notre Dame, IN 46556-5670, USA
fweber@darwin.helios.nd.edu