

IAU COLLOQUIUM 147

**The Equation of State in
Astrophysics**

**EDITED BY GILLES CHABRIER
and EVRY SCHATZMAN**

What do we understand of the properties of the dense ionised matter found in the interiors of low-mass stars and giant planets? The 147th IAU Colloquium gathered together international experts to address this question, and their answers are provided in this opportune proceedings.

In this volume, reviews by world experts in plasma and dense matter physics and in stellar astrophysics cover everything from the cooling theory of white dwarfs and their accretion-induced collapse through to the internal structure of low-mass stars and giant planets. They cover a wide range of topics related to the equation of state in dense matter, from the fundamental basis of the N -body problem to astrophysical applications.

Together these articles provide an essential review of the most recent achievements in the field and give direction for future research, for graduate students and researchers

The Equation of State in Astrophysics

IAU Astronomical Union
Union Astronomique Internationale

The following Colloquia of the International Astronomical Union are published for the Union by Cambridge University Press.

82. Cepheids. *Edited by Barry F. Madore.* 0 521 30091 6. 1985
91. History of Oriental Astronomy. *Edited by G. Swarup, A. K. Bag and K. S. Shukla.*
0 521 34659 2. 1987
92. Physics of Be Stars. *Edited by A. Slettebak and T. P. Snow.* 0 521 33078 5. 1987
101. Supernova Remnants and the Interstellar Medium. *Edited by R. S. Roger and T. L. Landecker.* 0 521 35062 X. 1988
105. The Teaching of Astronomy. *Edited by Jay M. Pasachoff and John R. Percy.*
0 521 35331 9. 1990
106. Evolution of Peculiar Red Giant Stars. *Edited by Hollis Johnson and Ben Zuckerman.*
0 521 36617 8. 1989
111. The Use of Pulsating Stars in Fundamental Problems of Astronomy. *Edited by Edward G. Schmidt.* 0 521 37023 X. 1989
136. Stellar Photometry – Current Techniques and Future Developments. *Edited by C. J. Butler and I. Elliott.* 0 521 41866 6. 1993
139. Stellar Pulsation and Pulsating Variable Stars. *Edited by James M. Nemeč and Jaymie M. Matthews.* 0 521 44382 2. 1993
143. The Sun as a Variable Star. *Edited by J. M. Pap, C. Fröhlich, H. S. Hudson and S. K. Solanki.* 0 521 42006 7. 1994
145. Supernovae and Supernova Remnants. *Edited by Richard McCray.*
0 521 46080 8. 1994
147. The Equation of State in Astrophysics. *Edited by Gilles Chabrier and Evry Schatzman.*
0 521 47260 1. 1994

The Equation of State in Astrophysics

Proceedings of IAU Colloquium No. 147
Saint-Malo, France
14–18 June 1993

Edited by

Gilles Chabrier
Ecole Normale Supérieure de Lyon

and

Evry Schatzman
Observatoire de Meudon



Published by the Press Syndicate of the University of Cambridge
The Pitt Building, Trumpington Street, Cambridge CB2 1RP
40 West 20th Street, New York, NY 10011-4211, USA
10 Stamford Road, Oakleigh, Melbourne 3166, Australia

© Cambridge University Press 1994

First published 1994

Printed in Great Britain at the University Press, Cambridge

A catalogue record for this book is available from the British Library

Library of Congress cataloguing in publication data available

ISBN 0 521 47260 1 hardback

Contents

<i>Group photograph</i>	x
<i>List of participants</i>	xi
<i>Preface</i>	xvi
Reviews	
1 Equations of state in stellar structure and evolution <i>H.M. Van Horn</i>	<i>page 1</i>
2 Equation of state of stellar plasmas <i>F.J. Rogers</i>	<i>page 16</i>
3 Statistical mechanics of quantum plasmas. Path integral formalism <i>A. Alastuey</i>	<i>page 43</i>
4 Onsager-molecule approach to screening potentials in strongly coupled plasmas <i>Y. Rosenfeld</i>	<i>page 78</i>
5 Astrophysical consequences of the screening of nuclear reactions <i>J. Isern and M. Hernanz</i>	<i>page 106</i>
6 Crystallization of dense binary ionic mixtures. Application to white dwarf cooling theory <i>R. Mochkovitch and L. Segretain</i>	<i>page 126</i>
7 Non crystallized regions of White dwarfs. Thermodynamics. Opacity. Turbulent convection <i>I. Mazzitelli</i>	<i>page 144</i>
8 White dwarf crystallization <i>E. García-Berro and M. Hernanz</i>	<i>page 161</i>
9 Gravitational collapse versus thermonuclear explosion of degenerate stellar cores <i>J. Isern and R. Canal</i>	<i>page 186</i>
10 Neutron star crusts with magnetic fields <i>D.G. Yakovlev and A.D. Kaminker</i>	<i>page 214</i>
11 High pressure experiments for astrophysics <i>P. Loubeyre</i>	<i>page 239</i>
12 Equation of state of dense hydrogen and the plasma phase transition; A microscopic calculational model for complex fluids <i>F. Perrot and C. Dharma-wardana</i>	<i>page 272</i>
13 The equation of state of fluid hydrogen at high density <i>G. Chabrier</i>	<i>page 287</i>
14 A comparative study of hydrogen equations of state <i>D. Saumon</i>	<i>page 306</i>
15 Strongly coupled ionic mixtures and the H/He equation of state <i>H.M. DeWitt</i>	<i>page 330</i>
16 White dwarf seismology: Influence of the constitutive physics on the period spectra <i>G. Fontaine and P. Brassard</i>	<i>page 347</i>
17 Helioseismology: the Sun as a strongly-constrained, weakly-coupled plasma <i>W. Däppen</i>	<i>page 368</i>
18 Transport processes in dense stellar plasmas <i>N. Itoh</i>	<i>page 394</i>

19 Cataclysmic variables: structure and evolution <i>J.-M. Hameury</i>	page 420
20 Giant planet, brown dwarf, and low-mass star interiors <i>W.B. Hubbard</i>	page 443
21 Searches for brown dwarfs <i>J. Liebert</i>	page 463
22 Jovian seismology <i>B. Mosser</i>	page 481
 Observational projects	
23 EVRIS: first space experiment devoted to stellar seismology <i>A. Baglin</i>	page 512
24 The HIPPARCOS mission and tests for the equation of state <i>A. Baglin and Joao Fernandes</i>	page 517
25 Ground based helioseismology: IRIS and GONG <i>F.-X. Schmider</i>	page 525
26 The spatial GOLF project <i>S. Turck-Chièze</i>	page 532
27 The DENIS survey <i>T. Forveille</i>	page 537
28 PRISMA: A mission to study interior and surface of stars <i>P. Lemaire</i>	page 540
 Posters	
29 Towards a helioseismic calibration of the equation of state in the solar convective envelope <i>S. V. Vorontsov, V. A. Baturin, D. O. Gough, W. Däppen</i>	page 545
30 Thermal cyclotron and annihilation radiation in strong magnetic fields <i>V.G. Bezchastnov and A.D. Kaminker</i>	page 550
31 Modified adiabatic approximation for a hydrogen atom moving in a magnetic field <i>V.G. Bezchastnov and A.Y. Potekhin</i>	page 555
32 Computations of static white dwarf models: A must for asteroseismological studies <i>P. Brassard and G. Fontaine</i>	page 560
33 The Chandrasekhar mass of a gravitating electron crystal <i>D.Engelhardt and I. Bues</i>	page 565
34 Coulomb corrections in the nuclear statistical equilibrium regime <i>D. García and E. Bravo</i>	page 571
35 Molecular Opacities: Application to the Giant Planets <i>T. Guillot, D. Gautier and G. Chabrier</i>	page 576
36 On Radiative Transfer Near the Plasma Frequency at Strong Coupling <i>Yu. K. Kurilenkov and H.M. Van Horn</i>	page 581
37 Effects of Superfluidity on Spheroidal Oscillations of Neutron Stars <i>Umin Lee, T.J.B. Collins, R.I. Epstein and H.M. Van Horn</i>	page 586
38 Magnetic Field Decay in the Non-superfluid Regions of Neutron Star Cores <i>A. G. Muslimov and H. M. Van Horn</i>	page 591

39 On the equation of state in Jovian seismology J. Provost, B. Mosser and G. Chabrier	<i>page</i> 596
40 Analysis of the screening formalisms in solar and stellar conditions H. Dzitko, S. Turck-Chièze, P. Delbourgo-Salvador and Ch. Lagrange	<i>page</i> 601
41 Theoretical Description of the Coulomb Interaction by Padé-Jacobi Approximants W. Stolzmann and T. Blöcker	<i>page</i> 606
42 New Model Sequences from the White Dwarf Evolution Code M. Wood	<i>page</i> 612
43 Low temperature opacities C. Neuforge	<i>page</i> 618