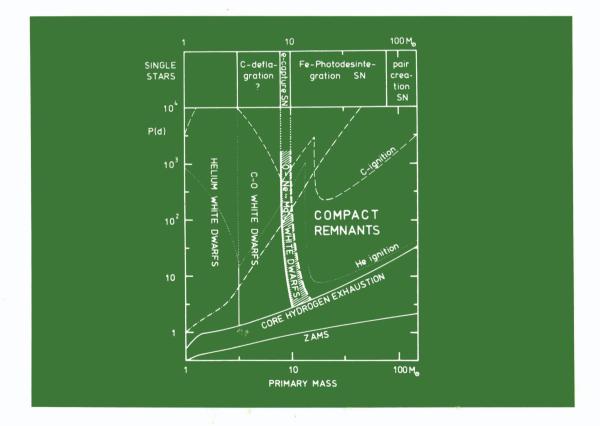
INTERNATIONAL ASTRONOMICAL UNION

SYMPOSIUM No. 93

# FUNDAMENTAL PROBLEMS IN THE THEORY OF STELLAR EVOLUTION

# Edited by D. SUGIMOTO, D. Q. LAMB, and D. N. SCHRAMM





INTERNATIONAL ASTRONOMICAL UNION D. REIDEL PUBLISHING COMPANY / DORDRECHT : HOLLAND BOSTON : U.S.A. / LONDON : ENGLAND



# FUNDAMENTAL PROBLEMS IN THE THEORY OF STELLAR EVOLUTION

### SYMPOSIUM No. 93

'In order for models to be called *Theory*, they should enable us to understand not only their individual nature but also the general characteristics of such systems.' With this introductory remark Daiichiro Sugimoto points to one of the central problems when theorising about stellar evolution. The essays in this collection are grouped around problems which are truly fundamental while developments in detailed mondeling with the 'Computer Age' have been critically assessed.

Apart from the many invited and contributed papers, this volume records in edited form discussions at the 93rd IAU Symposium concerning bold assessments of known facts, interrelations between them and strategy to surmount a barrier standing in front of the coming phase in the stellar evolution theory.

#### Audience

All astronomers will find this overview of stellar evolutionary theory of great interest.

### D. REIDEL PUBLISHING COMPANY DORDRECHT : HOLLAND / BOSTON : U.S.A. LONDON : ENGLAND

# FUNDAMENTAL PROBLEMS IN THE THEORY OF STELLAR EVOLUTION

# INTERNATIONAL ASTRONOMICAL UNION UNION ASTRONOMIQUE INTERNATIONALE

# SYMPOSIUM No. 93

HELD AT KYOTO UNIVERSITY, KYOTO, JAPAN, JULY 22-25, 1980

# FUNDAMENTAL PROBLEMS IN THE THEORY OF STELLAR EVOLUTION

EDITED BY

DAIICHIRO SUGIMOTO

Department of Earth Science and Astronomy, College of General Education, University of Tokyo, Tokyo, Japan

DONALD Q. LAMB

Harvard Smithsonian Center for Astrophysics, Cambridge, Massachusetts, U.S.A.

and

DAVID N. SCHRAMM

Astronomy and Astrophysics Center, The University of Chicago, Chicago, Illinois, U.S.A.



# D. REIDEL PUBLISHING COMPANY

DORDRECHT : HOLLAND / BOSTON : U.S.A. / LONDON : ENGLAND



Library of Congress Cataloging in Publication Data

CIP

Main entry under title:

Fundamental problems in the theory of stellar evolution.

At head of title: International astronomical union. Sponsored by IAU commission 35 on stellar constitution and by commission 42 on close binary stars. Includes index. 1. Stars-Evolution-Congresses. I. Sugimoto, Daiichiro, 1937-. II. Lamb, Donald Q. III. Schramm, David N. IV. International astronomical union. V. International astronomical union. Commission 35. VI. International astronomical union. Commission 42. **OB806.F86** 521'.58 81-4057 ISBN 90-277-1273-5 AACR2 ISBN 90-277-1274-3 (pbk.)

Published on behalf of the International Astronomical Union by D. Reidel Publishing Company, P.O. Box 17, 3300 AA Dordrecht, Holland

All Rights Reserved Copyright © 1981 by the International Astronomical Union

Sold and distributed in the U.S.A. and Canada by Kluwer Boston Inc., 190 Old Derby Street, Hingham, MA 02043, U.S.A.

In all other countries, sold and distributed by Kluwer Academic Publishers Group, P.O. Box 322, 3300 AH Dordrecht, Holland

D. Reidel Publishing Company is a member of the Kluwer Group.

No part of the material protected by this copyright notice may be reproduced or utilized in any form or by any means, electronic or mechanical, including photocopying, recording or by any informational storage and retrieval system, without written permission from the publisher

Printed in The Netherlands

Preface	xi
The Organizing Committees	xii
List of Participants	xiii
Introductory remarks	
D. SUGIMOTO: Symposium on Fundamental Problems in the Theory of Stellar Evolution	1
Session 1: STAR FORMATION IN ROTATING AND MAGNETIC GAS CLOUDS Chairman; W.M. TSCHARNUTER	
Review papers	
P. BODENHEIMER: The Effects of Rotation during Star Formation	5
T.Ch. MOUSCHOVIAS: The Role of Magnetic Fields in the Forma- tion of Stars	27
Contributed papers	
T. NAKANO: Quasistatic Contraction of Magnetic Protostars due to Magnetic Flux Leakage	63
T. UMEBAYASHI and T. NAKANO: Role of Grains in the Drift of Plasma and Magnetic Field in Dense Interstellar Clouds	65
M. KONDO: On the Correspondence of OH/H <sub>2</sub> O Maser Sources to the Stage of Proto-Star Formation	66
Y. YOSHII and Y. SABANO: On the Star Formation in Early Stage of Galactic Evolution	68
H. KIMURA and C.P. LIU: On the Structure and Evolution of Massive Interstellar Clouds	70
Y. SABANO and Y. SOFUE: Chain-Reacting Thermal Instability and its Implication on Star-Formation in Interstellar CO Clouds	72

TABLE	OF	CONTENTS
IABLE	Or	CONTENTS

113

S. IKEUCHI: Global Structure of Interstellar Medium and Star Formation Rate	73
Session 2: PRE-MAIN-SEQUENCE EVOLUTION AND FORMATION OF BINARY STARS Chairman; S-A. SØRENSEN	
Review papers	
L.B. LUCY: The Formation of Binary Stars	75
G.S. BISNOVATYI-KOGAN: Pre-Main-Sequence Stellar Evolution (read by A.G. MASSEVITCH)	85
Contributed papers	
S. ISOBE and G. SASAKI: Age Spread of the Orion Nebular Stars	99
N. UKITA: Monitor Observations of the Orion SiO Maser	100
V.A. AMBARTSUMIAN and L.V. MIRZOYAN: An Observational Approach to the Early Stages of Stellar Evolution	101
S-A. SØRENSEN, S. NARITA and D. McNALLY: Fragmentation of Col- lapsing Gas Clouds	103
W.M. TSCHARNUTER: Accumulation of a Rapidly Rotating Proto- star and the Formation of an Associated Nebula as a Result of Angular Momentum Transport by Turbulent Friction	105
R.A. GINGOLD and J.J. MONAGHAN: Fragmentation of Isothermal Gas Clouds	107
R.H. DURISEN and J.E. TOHLINE: Numerical Studies of the Fission Hypothesis for Rotating Polytropes	109
K-Y. CHEN: Pre-Main-Sequence Evolution of Close Binaries with Mass Transfer	111
G.S. BISNOVATYI-KOGAN and S.A. LAMZIN: Chromospherical and Coronal Phenomena in Young Contracting Stars (read by A.V. TUTUKOV)	*
Session 3: ORIGIN OF THE SOLAR SYSTEM Chairman; E. SCHATZMAN	
Review paper	

C. HAYASHI: Formation of the Planets

vi

### Contributed papers

T.V. RUZMAIKINA: On the Angular Momentum of Presolar Nebula (read by A.V. TUTUKOV)	*
L. MESTEL: Magnetic Braking, the Solar Nebula and the Comet- ary Cloud	129
Y. NAKAGAWA, K. NAKAZAWA and C. HAYASHI: Growth and Sedimen- tation of Dust Grains in the Primordial Solar Nebula	131
H. MIZUNO: Formation of the Giant Planets	133
M. SEKIYA, K. NAKAZAWA and C. HAYASHI: Dissipation of the Pri- mordial Terrestrial Atmosphere due to Irradiation of Solar EUV	135
Session 4: MASS EXCHANGE ON CLOSE BINARY STARS AND THE EFFECT ON STELLAR EVOLUTION Chairman; C. de LOORE	
Review papers	
A.V. TUTUKOV: Evolution of Close Binaries	137
E.P.J. van den HEUVEL: The Formation of Compact Objects in Binary Systems	155
Contributed papers	
B.W. BOPP and S.M. RUCIŃSKI: The Rapidly Rotating Giants of the FK Comae-type	177
D. Ya. MARTYNOV: RX Cassiopeiae A Binary System with Rapid Evolution (read by A.G. MASSEVITCH)	*
Y. KONDO and G.E. McCLUSKEY: Patterns of Mass Flow in Close Binaries Based on Ultraviolet Observations (read by K. NOMOTO)	*
W. PACKET: Rotation and the Evolution of the Mass-Accreting Component in Close Binary Systems	179
O. VILHU and T. RAHUNEN: Contact Binary Evolution and Angular Momentum Loss	181
D. VANBEVEREN: Non-conservative Evolution of Massive O-Type Close Binaries with Galactic and with Magellanic Cloud Chemical Abundances	183

J.P. de CUYPER: Asymmetric Supernova Explosions: The Missing Link between Wolf-Rayet Binaries, Run-Away OB Stars and Pulsars	184
A.G. MASSEVITCH, A.V. TUTUKOV and L.R. YUNGELSON: Evolution of Low Mass Binaries under the Influence of Gravitational Radiation	185
J.C. WHEELER, H. SAIO and M. BREGER: Blue Stragglers as Long- Lived Stars	187
<u>Session 5</u> : MASS-ACCRETION ONTO COMPACT STARS AND RESULTANT EXPLOSIVE PHENOMENA AND NUCLEOSYNTHESIS Chairman; A.G. MASSEVITCH	
Review papers	
D. SUGIMOTO and S. MIYAJI: Generalized Theory of Shell Flash and Accreting White Dwarfs	191
P.C. JOSS: Thermonuclear Processes on Accreting Neutron Stars	207
Contributed papers	
S. MIYAJI, M.Y. FUJIMOTO and T. HANAWA: Shell-Flashes on Ac- creting Neutron Stars and Mode Profiles of Type-I X-Ray Bursts	229
E.V. ERGMA and A.D. KUDRYASHOV: On Hydrogen Burning in High Temperature and Density Evolution (R-P Process) (read by A.V. TUTUKOV)	*
G.S. BISNOVATYI-KOGAN and V.M. CHECHETKIN: Formation of Heavy Elements at the Outbursts from the Neutron Stars	*
S. TSURUTA, T. MURAI, K. NOMOTO and N. ITOH: The Current Sta- tus of Neutron Star Cooling Theories	231
E.E. SALPETER: Cyclotron Line Emission from Accretion onto a Magnetized Neutron Star	233
G.J. WEAST, R.H. DURISEN, J.N. IMAMURA, N.D. KYLAFIS and D.Q. LAMB: Effects of Nuclear Burning on X-Ray and UV Emission from Accreting Degenerate Dwarfs	234
F. TAKAHARA: Comptonized X-Ray Emission from the Accretion Disk around a Massive Black Hole	235

Session	6:	EFFECT	OF	ROTAT	LON	AND	MAGNETIC	FIELD
		IN STEE	LAF	R EVOLU	JTION	1		
		Chairma	in;	Е.Е.	SALF	PETER		

### Review papers

R.	KIPPENHAHN and HC. T	THOMAS: Rota	ation and	Stellar	
	Evolution			237	7

L. MESTEL: Magnetic Fields and Stellar Evolution 257

### Contributed papers

M.P. SAVEDOFF: Progress towards a Quasistatic Two Dimensional Rotation Code (read by K. NOMOTO)	*
T. FUKUSHIMA, Y. ERIGUCHI, D. SUGIMOTO and G.S. BISNOVATYI-KOGAN: Concave Hamburger Equilibrium of Rotating Bodies	273
Y. ERIGUCHI: Rapidly Rotating and Fully General Relativistic Polytropes	274
V. CASTELLANI: The Influence of Rotation on Horizontal Branch Stars and on RR Lyrae Pulsational Properties	275
K. NARIAI: Can Stellar Atmospheres be in Quasi-Static Equili- brium in the Presence of Magnetic Fields ?	276
Y. OSAKI and G. GONCZI: Influence of Convection on the Pulsa- tional Stability of Stars	278
D.R. XIONG: A Statistical Theory of Non-local Convection in Chemical Inhomogeneous Star (read by H. KIMURA)	*
W. UNNO, T. NAKANO and M. KONDO: Viscosity, Thermal and Elec- trical Conductivities in Turbulent Convection	280
E. SCHATZMAN: On the Presence of Turbulent Diffusion in Stars and its Effect on Stellar Evolution	281
N. ARIMOTO and M. SIMODA: On the Number Ratio of Horizontal Branch Stars to Red Giant Stars in Globular Clusters	284
Session 7: SUPERNOVA EXPLOSIONS LEADING TO THE FORMATION OF NEUTRON STARS AND BLACK HOLES	

Chairman; O. VILHU

### Review papers

J.C. WHE	ELER: Super	novae: Progenit	or Stars	and Me	echanisms	285
----------	-------------	-----------------	----------	--------	-----------	-----

ix

<ul> <li>K. NOMOTO: Supernova Explosions in Degenerate Stars</li> <li> Detonation, Deflagration and Electron Capture</li> </ul>	295
Contributed papers	
H.J. HAUBOLD and R.W. JOHN: A New Approach to the Analytic Evaluation of Thermonuclear Reaction Rates	317
N. ITOH, H. TOTSUJI, S. ICHIMARU and H.E. DeWITT: Enhancement of Thermonuclear Reaction Rate due to Strong Screening	318
V.M. CHECHETKIN: The Neutronization of the Matter and Hydro- dynamic Instability at Final Stages of Stellar Evolution	320
R. MOCHKOVITCH: Non-Explosive Collapse of White Dwarfs (read by E. SCHATZMAN)	*
T.J. MAZUREK: Stellar Collapse and Nascent Neutron Stars	322
T. NAKAMURA, K. MAEDA, S. MIYAMA and M. SASAKI: General Rela- tivistic Collapse of an Axially Symmetric Star Leading to the Formation of Neutron Stars and Black Holes	326
K. ARAI and K. KAMINISHI: Stability against Radial Perturba- tions of Slowly Rotating Neutron Stars	327
Session 8: GENERAL DISCUSSIONS Chairman; S. HAYAKAWA	
Rapporteur talks	
R.J. TAYLER: Concluding Remarks	329
E.E. SALPETER: Comments and Impressions	335
General discussions	
C. HAYASHI: (included in general discussions)	339
AUTHOR INDEX	343
SUBJECT INDEX	345