

OBSERVATIONAL TESTS OF THE STELLAR EVOLUTION THEORY

INTERNATIONAL ASTRONOMICAL UNION
UNION ASTRONOMIQUE INTERNATIONALE

SYMPOSIUM No. 105

HELD IN GENEVA, SWITZERLAND, SEPTEMBER, 12-16, 1983

OBSERVATIONAL TESTS OF THE STELLAR EVOLUTION THEORY

EDITED BY

ANDRÉ MAEDER

Geneva Observatory, Sauverny, Switzerland

and

ALVIO RENZINI

Astronomy Department, University of Bologna, Bologna, Italy

D. REIDEL PUBLISHING COMPANY

A MEMBER OF THE KLUWER



ACADEMIC PUBLISHERS GROUP

DORDRECHT / BOSTON / LANCASTER



Library of Congress Cataloging in Publication Data

Main entry under title:

CIP

Observational tests of the stellar evolution theory.

At head of title: International Astronomical Union, Union astronomique internationale.

Includes bibliographies and index.

1. Stars—Evolution—Congresses. I. Maeder, André, 1942-
II. Renzini, Alvio. III. International Astronomical Union.
QB806.O27 1984 523.8 84-6978
ISBN 90-277-1774-5
ISBN 90-277-1775-3 (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
© 1984 by the International Astronomical Union*

*Sold and distributed in the U.S.A. and Canada
by Kluwer Academic Publishers,
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*

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 information storage and retrieval system, without written permission from the publisher

Printed in The Netherlands

TABLE OF CONTENTS

PREFACE	xv
ORGANIZING COMMITTEES, CHAIRMEN	xvii
LIST OF PARTICIPANTS	ixx
OPENING OF THE SYMPOSIUM	xxiii
I. EVOLUTION OF LOW AND INTERMEDIATE MASS STARS: OBSERVATIONS AND MODELS	
I. IBEN, Jr. (<i>Invited lecture</i>) Fundamental problems and basic tests of stellar evolution theory - The case of carbon stars	3
A. RENZINI (<i>Invited lecture</i>) Selected topics on the evolution of low and intermediate mass stars	21
A.N. COX, R.B. KIDMAN Some investigations about the Carson opacities	41
SOLAR CONSTRAINTS	
J. PROVOST (<i>Invited lecture</i>) Solar constraints	47
D.B. GUENTHER, P. DEMARQUE Resonant three-wave interactions and an application to solar g mode oscillations	67
R. VAN DER BORGHT, P. FOX Convective motions as an indicator of solar structure	71
A.A. PAMYATNYKH, I.K. SAPSAJ Two nonstandard solar models: with mixed interiors and with enhanced heavy element opacity	75

OPEN AND POPULOUS CLUSTERS, RED GIANTS

P.J. FLOWER Intermediate mass stellar models: ages of Magellanic Cloud star clusters	79
S.A. BECKER, G.J. MATHEWS, W.M. BRUNISH Comparisons between observational color-magnitude diagrams and synthetic cluster diagrams for young star clusters in the Magellanic Clouds	83
W.M. BRUNISH, A.N. COX, S.A. BECKER, K.H. DESPAIN The role of the radiation pressure gradient in giant and supergiant star evolution	89
D.L. CRAWFORD Stellar evolution as evidenced by members of open clusters near the turn-off from the main sequence	93
P.E. NISSEN Strömgren photometry of F-type stars in M67 and NGC 3680	95
G. BARBARO, L. PIGATTO Statistical analysis of the red giant distributions of old open clusters	97
G. MICELA, S. SCIORTINO, S. SERIO, G.S. VAIANA, L. GOLUB, F.R. HARNDEN, R. ROSNER X-ray survey of the Pleiades: dependence of X-ray luminosity on stellar age	101
M. GRENON, J.C. MERMILLIOD The $\log L/\log T_e$ diagram for intermediate mass pop I red giants	105
J. LATTANZIO Grain sedimentation and main sequence evolution	109
B.N.G. GUTHRIE Rotation of B-type stars as an indicator of star formation mechanisms	113
L.O. LODÉN A composite color-magnitude diagram for a number of very poor clusterings in the Milky Way	117
A. OSMAN, A. KHALIL, A. AIAD, M. MARIE UBV photometry of NGC 581	119

M. KONTIZAS, E. KONTIZAS, N. STEWART The luminosity function of the SMC clusters NGC 152 and K3	121
----------------------------------------------------------------------------------------------------	-----

Globular Clusters and Horizontal Branch Stars

R.D. CANNON (<i>Invited lecture</i>) Observations of low mass stars in clusters: some constraints and puzzles for stellar evolution theory	123
----------------------------------------------------------------------------------------------------------------------------------------------------	-----

J.E. HESSER, G.L.H. HARRIS, R.A. BELL, R.D. CANNON Spectroscopy of main-sequence and subgiant stars in globular star clusters	139
-------------------------------------------------------------------------------------------------------------------------------------	-----

D.A. VANDENBERG Theoretical red-giant branches for globular clusters	143
-------------------------------------------------------------------------	-----

H.B. RICHER, G.G. FAHLMAN Faint CCD photometry in globular clusters. II. Comparison of theoretical isochrones with the globular clusters M4 and M15	147
--------------------------------------------------------------------------------------------------------------------------------------------------------------	-----

G. ALCAINO, W. LILLER Systematic main sequence photometry of globular cluster stars for age determination	153
-----------------------------------------------------------------------------------------------------------------	-----

A.J. PENNY The main-sequences of NGCs 288, 3201, 4590, and 6809	157
--------------------------------------------------------------------	-----

D.A. CROCKER, R.T. ROOD Monte Carlo simulations of globular cluster red giant branches	159
----------------------------------------------------------------------------------------------	-----

M. GRENON, A. BLECHA The NGC 6752 HR-diagram	163
-------------------------------------------------	-----

R.T. ROOD A non-explanation of the Sandage effect: $[CNO/Fe] \neq 0$	167
-------------------------------------------------------------------------	-----

A.G.D. PHILIP, D.S. HAYES, K.D. PHILIP Remarks concerning the masses of horizontal-branch A stars	171
------------------------------------------------------------------------------------------------------	-----

Asymptotic Giant Branch Evolution

J.A. FROGEL, V.M. BLANCO Luminosity functions for asymptotic giant branch stars	175
------------------------------------------------------------------------------------	-----

P.R. WOOD, D.J. FAULKNER On the termination of asymptotic giant branch evolution	179
L.A. WILLSON, G.H. BOWEN Constraints on terminal AGB evolution from properties of Miras and OH-IR sources	183
R.D. McCLURE Radial velocity observations of Barium, CH and R stars	187
E. BÖHM-VITENSE On the origin of the Barium stars	191
K.H. DESPAIN Some observable indicators of s -process environments?	195
K. ERIKSSON, B. GUSTAFSSON, U.G. JØRGENSEN, Å. NORDLUND HCN and C ₂ H ₂ in carbon stars	199
T. LLOYD EVANS Evolution of S stars in the Magellanic Clouds	203
 PLANETARY NUCLEI AND OB SUBDWARFS	
R.P. KUDRITZKI, R.H. MÉNDEZ, K.P. SIMON Non-LTE analysis of central stars	205
D. SCHÖNBERNER The H.R.-diagram of central stars of planetary nebulae	209
A. ACKER Spectroscopic observations of nuclei of planetary nebulae	213
U. HEBER, K. HUNGER, R.P. KUDRITZKI, K.P. SIMON NLTE analysis of SDO stars	215
J.S. DRILLING, D. SCHÖNBERNER The H-R diagram of O-type subdwarfs	219
U. HEBER, K. HUNGER, G. JONAS, R.P. KUDRITZKI The atmosphere of subluminoous B stars	223
W.-R. HAMANN Mass loss from highly evolved stars	225
V. WEIDEMANN Constraints on stellar evolution by observation of white dwarfs	229

II. EVOLUTION OF MASSIVE STARS: EVOLUTION AND MODELS

P.S. CONTI (<i>Invited lecture</i>) Basic observational constraints on the evolution of massive stars	233
N.R. WALBORN, R.J. PANEK Ultraviolet spectral morphology of ON and OC stars	255
K. DAVIDSON, R.J. DUFOUR, N.R. WALBORN, T.R. GULL CNO-cycled material ejected by Eta Carinae	261
K.P. SIMON, R.P. KUDRITZKI Non-LTE analysis of massive O-stars	265
W. SCHMUTZ On the hydrogen abundance in Wolf-Rayet stars	269
K.A. VAN DER HUHT, P.M. WILLIAMS, P.S. THE Circumstellar dust shells around WN10-11 and WC8-10 stars: an evolutionary sequence?	273
R.M. HUMPHREYS (<i>Invited lecture</i>) Massive star evolution in nearby galaxies	279
A. MAEDER (<i>Invited lecture</i>) Evolution of massive stars, supergiants and Wolf-Rayet stars	299
J.V. FEITZINGER, Th. SCHMIDT-KALER The interaction of the supermassive object R136a with the interstellar environment	321
Th. SCHMIDT-KALER, J.V. FEITZINGER Further candidates of supermassive stars in other galaxies	325
L. GREGGIO Evolution of massive stars with mass loss: surface abundances	329
G. BERTELLI, A. BRESSAN, C. CHIOSI Observational tests for overshoot and opacity enhancement based on massive stars	333
H.J.G.L.M. LAMERS, M. DE GROOT, A. CASSATELLA P Cygni stars as an intermediate stage between red supergiants and Wolf-Rayet stars	337

C. DOOM, J.P. DE GREVE, C. DE LOORE The "age" of OB associations	341
A.M. JAKOBSEN Ages, age differences, masses of stars in young open clusters	345
J.-C. MERMILLIOD, A. MAEDER Evidence for a main sequence widening for massive stars	349
M. TAPIA, M. ROTH, R. COSTERO, S. NAVARRO Infrared and visual observations of η and χ Persei	353
N. ITOH, Y. KOHYAMA Neutrino-pair Bremsstrahlung in dense stars	355
III. BINARITY, PULSATION, ROTATION AND MIXING	
BINARY EVOLUTION	
C. DE LOORE (<i>Invited lecture</i>) Binary evolution and observational constraints	359
J.-P. ZAHN (<i>Invited lecture</i>) Tidal effects in close binary stars	379
J. ANDERSEN, J.V. CLAUSEN, H.E. JØRGENSEN, B. NORDSTRÖM Constraints on stellar evolution theory from precise eclipsing binary data	391
C.J. CORBALLY, S.J. A test of stellar evolution theory by visual binaries	395
J. ANDERSEN, J.V. CLAUSEN, B. NORDSTRÖM, M. MAYOR A new test case for normal giant evolution: TZ Fornacis	397
G.M.H.J. HABETS The evolutionary history of Be/X-ray binaries	399
G. BURKI, M. MAYOR Observational study of the evolution of massive binary stars	403
J.P. DE GREVE, W. PACKET Observational constraints from models of close binary evolution	407

M. MAYOR, J.-C. MERMILLIOD Orbit circularization time in binary stellar systems	411
C.S. JEFFERY Apsidal motion in main-sequence binary stars	415
A. GIMÉNEZ Apsidal motion in evolved binary systems	419
 EVOLUTION AND PULSATION	
A.N. COX (<i>Invited lecture</i>) Constraints on stellar evolution from pulsations	421
J.D. FERNIE Cepheid period changes and stellar evolution	441
L. SZABADOS Observations of evolutionary changes in the pulsation period of cepheids	445
E. BÖHM-VITENSE, S. BORUTZKI, H. HARRIS Cepheid companions and the masses of cepheids	449
G. BURKI HR 7308 (V473 Lyr): the strangest cepheid	453
K. BARLAI RR Lyrae variables and stellar evolution in M15	457
R.F. STELLINGWERF Convective effects and the RR Lyrae instability strip	461
J.M. NEMEC Double-mode RR Lyrae stars in the Draco dwarf galaxy and in other stellar systems	465
E.A. BINGHAM, C. CACCIARI, R.J. DICKENS, F. FUSI PECCI BV photometry of RR Lyrae variables in M15	467
Yu.A. FADEYEV FG Sagittae, a test of the theory of evolution of double shell source stars	471

ROTATION AND MIXING

J.-L. TASSOUL (<i>Invited lecture</i>) The role of rotation in stellar evolution	475
E. SCHATZMAN (<i>Invited lecture</i>) Physical mechanisms of mixing in stellar interiors	491
L. MESTEL Some remarks on the theory of rotating stars	513
I.W. ROXBURGH On the Tassoul approximation scheme for determining the structure of rotating stars	517
I.W. ROXBURGH On turbulent mixing	519
W.-Y. LAW, E. KNOBLOCH, H.C. SPRUIT Evolution of the sun with mixing by hydrodynamic instabilities	523
O. BIENAYMÉ, A. MAEDER, E. SCHATZMAN Stellar evolution with turbulent diffusion mixing in low mass stars and $^{12}\text{C}/^{13}\text{C}$ ratio in giants of the first ascending branch	525
A. BAGLIN, P.J. MOREL Lithium abundances in late main-sequence stars. The case of the Hyades	529
R. CAYREL A random walk approach to the problem of turbulent diffusion and lithium destruction in main-sequence stars	533
R. CAYREL, G. CAYREL, B. CAMPBELL, W. DÄPPEN An observational test on stellar interior mixing: The lithium depletion in twelve Hyades dwarfs	537
IV. RELATION WITH CHEMICAL EVOLUTION OF GALAXIES AND COSMOLOGY	
J. AUDOUZE (<i>Invited lecture</i>) Relations between the galactic evolution and the stellar evolution	541
R.J. TAYLER (<i>Invited lecture</i>) The relation between stellar evolution and cosmology	549

M. TOSI, A.I. DIAZ Theoretical predictions for the radial distribution of oxygen in spiral galaxies	563
R.T. ROOD, T.M. BANIA, T.L. WILSON $^3\text{He}^+$ in galactic H II regions: possible evidence for non- convective mixing in low mass stars	567
J.A. FROGEL, V.M. BLANCO, A.E. WHITFORD M giants at two latitudes in the nuclear bulge of the galaxy	571
F. MATTEUCCI, A. TORNAMBÉ Primeval oxygen overabundance and type I-1/2 supernovae	577
D. ERYURT-EZER Evolutionary track of an intermediate mass first-generation star	579
CONCLUDING REMARKS: LOOKING AHEAD	583
INDEX OF NAMES	587