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# PHYSICAL PROCESSES IN RED GIANTS

Edited by Icko Iben Jr. and Alvio Renzini

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VOLUME 88

PROCEEDINGS



D. REIDEL PUBLISHING COMPANY

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

# PHYSICAL PROCESSES IN RED GIANTS

PROCEEDINGS OF THE SECOND WORKSHOP, HELD AT THE  
ETTORE MAJORANA CENTRE FOR SCIENTIFIC CULTURE,  
ADVANCED SCHOOL OF ASTRONOMY,  
IN ERICE, SICILY, ITALY, SEPTEMBER 3-13, 1980

Edited by

ICKO IBEN, Jr.

*Department of Astronomy, University of Illinois at Urbana-Champaign, U.S.A.*

and

ALVIO RENZINI

*Osservatorio Astronomico, Università di Bologna, Italy*



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

Library of Congress Cataloging in Publication Data  
Main entry under title:

**CIP**

*Physical processes in red giants.*

(Astrophysics and space science library. Proceedings ; v. 88)

Organized by the Advanced School of Astronomy.

Includes indexes.

1. Red giants—Congresses. I. Iben, Icko, 1931–  
II. Renzini, Alvio. III. Ettore Majorana International Centre for  
Scientific Culture. Advanced School of Astronomy. IV. Series.  
QB843.R42P49 523.8'2 81-5882  
ISBN 90-277-1284-0 AACR2

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Published by D. Reidel Publishing Company,  
P.O. Box 17, 3300 AA Dordrecht, Holland.

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

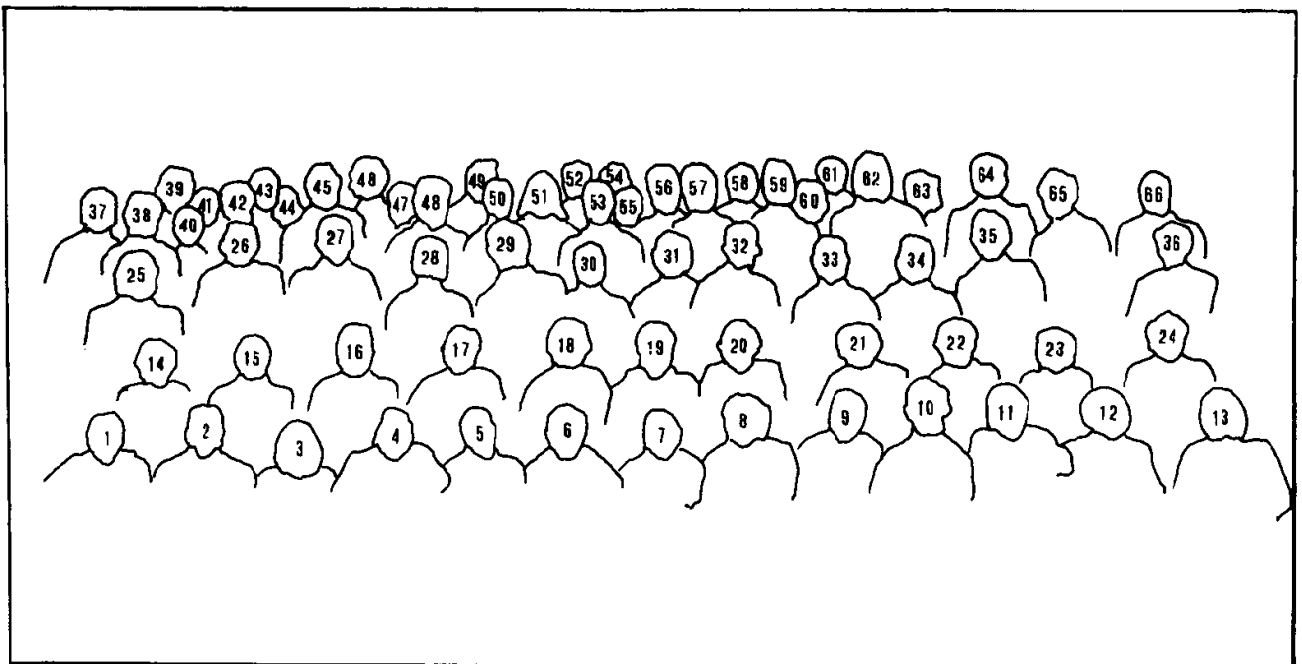
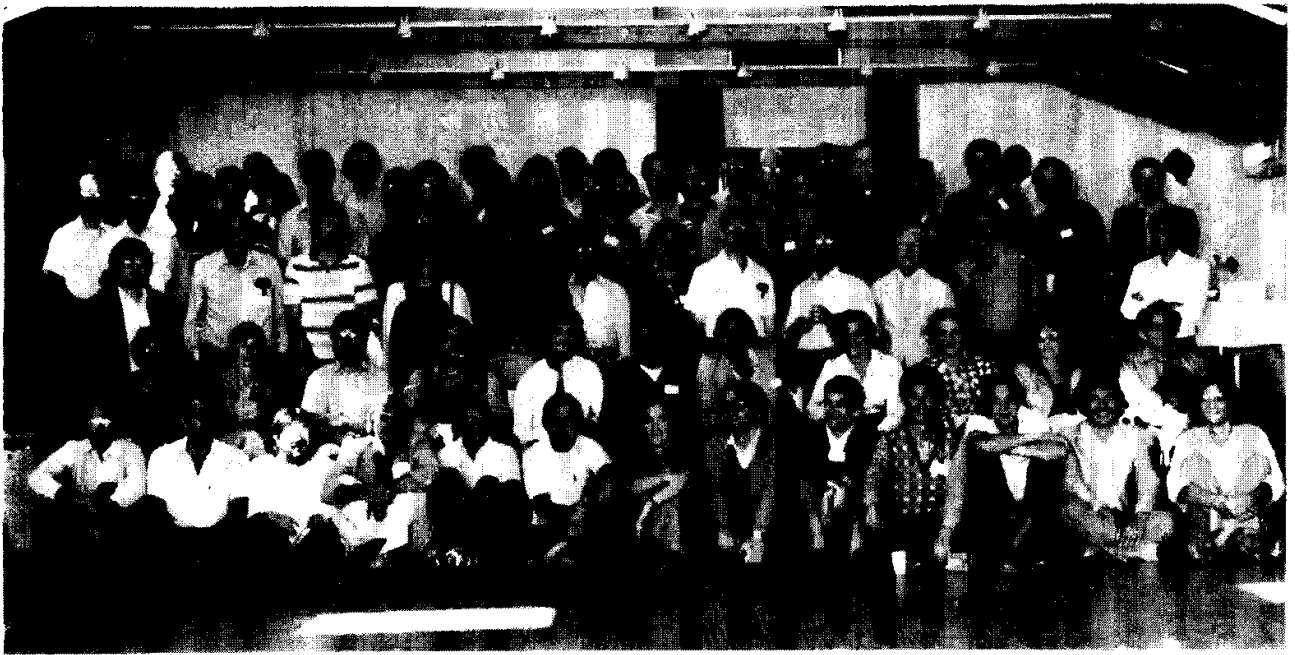
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P.O. Box 322, 3300 AH Dordrecht, Holland.

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Printed in The Netherlands



1. Clegg, 2. Wing, 3. Serrano, 4. Littleton, 5. Preite-Martinez, 6. Iben, 7. Schönberner, 8. Peimbert, 9. Voli, 10. Iijima, 11. Olnon, 12. Renzini, 13. Bienaymé, 14. Natta, 15. Woodrow, 16. Despain, 17. Richer, 18. Cacciari, 19. Altamore, 20. de la Reza, 21. Malagnini, 22. Magalhães, 23. Bianco, B. M., 24. Blanco, V. M., 25. Fujimoto, 26. Becker, 27. Rood, 28. Caloi, 29. Tornambè, 30. Marilli, 31. Chieffi, 32. Linsky, 33. Pottasch, 34. Weidemann, 35. McCabe, 36. Capuzzo-Dolcetta, 37. Castor, 38. Kwok, 39. Draine, 40. Rieu, 41. Wood, 42. Rocca-Volmerange, 43. Olofsson, 44. Willson, 45. Elitzur, 46. Toelle, 47. Erikson, 48. Unidentified, 49. Feast, 50. Morossi, 51. Engels, 52. Ridgway, 53. Strazzulla, 54. Gallino, 55. Castellani, 56. Lub, 57. Herman, 58. Goldberg, 59. Kinman, 60. Unidentified, 61. Frogel, 62. McCarthy, 63. Unidentified, 64. Reimers, 65. Gustafsson, 66. Eggleton.

## P R E F A C E

In recent years, it has become clear that the red-giant phase is one of the most dramatic periods in a star's life, when all of its parts become involved in ways that have both direct and indirect observational consequences. This is most particularly true of low- and intermediate-mass stars during the second ascent of the giant branch. Such stars bring to their surfaces products of nucleosynthesis currently taking place in their deep interiors, they pulsate as Mira variables, develop extended outward-flowing atmospheres that may exhibit maser properties, and shed great quantities of matter, sometimes highly processed, into the interstellar medium.

The manner in which processed matter is brought to the surface is far from being completely explained, and the precise mechanism or mechanisms whereby matter is ejected from the stellar surface (whether by deposition of Alfvén waves, radiation pressure on grains, or as a consequence of some large scale envelope instability) has yet to be elucidated to everyone's satisfaction.

The purpose of the second workshop in Astrophysics, organized by the "Advanced School of Astronomy", was to bring together experts on all the physical processes occurring in red giants in an effort to emphasize the interrelatedness of these individual processes, and to encourage a dialogue among experts that might serve to initiate a synthesis, or at least sharpen our understanding of the most important problems to address in the future.

The workshop was held in Erice, Sicily, at the "Ettore Majorana Centre for Scientific Culture", during the period September 3 through 13, 1980, and was organized about a sequence of review lectures, each followed by contributed talks related to the preceding review. Discussion during and after talks was spirited, and all participants were urged to incorporate, in the written versions of their contributions, insights they may have gained as a consequence of their participation.

It is hoped that this volume will reflect some of the excitement in learning new things that many of us experienced during the workshop, and that many of the articles, though written ostensibly by one person, exhibit those positive characteristics of multiple authorship that the organizers hoped to promote. This volume also includes the review lecture

that Dr. J.M. Scalo would have given if he had not been impeded from coming at the last minute to attend the meeting.

Icko Iben Jr.  
Editor,  
Director of the Workshop

Alvio Renzini  
Editor,  
Director of the  
"Advanced School of Astronomy"

P A R T I C I P A N T S

|                      |                        |
|----------------------|------------------------|
| Altamore, A.         | Roma, Italy            |
| Andriesse, C.D.      | Groningen, Netherlands |
| Becker, S.A.         | Pasadena, CA, U.S.A.   |
| Bedijn, P.J.         | München, W. Germany    |
| Bienaymé, O.         | Nice, France           |
| Blanco, B.M.         | La Serena, Chile       |
| Blanco, V.M.         | La Serena, Chile       |
| Cacciari, C.         | Villafranca, Spain     |
| Caloi, V.            | Frascati, Italy        |
| Castellani, V.       | Frascati, Italy        |
| Castor, J.I.         | Boulder, CO, U.S.A.    |
| Capuzzo-Dolcetta, R. | Roma, Italy            |
| Catalano, S.         | Catania, Italy         |
| Chieffi, A.          | Frascati, Italy        |
| Chiosi, C.           | Padova, Italy          |
| Clegg, R.E.S.        | Leiden, Netherlands    |
| D'Antona, F.         | Roma, Italy            |
| de la Reza, R.       | Rio de Janeiro, Brazil |
| Despain, K.H.        | Haverford, PA, U.S.A.  |
| Draine, B.T.         | Princeton, NJ, U.S.A.  |
| Eggleton, P.P.       | Cambridge, England     |
| Elitzur, M.          | Lexington, KY, U.S.A.  |
| Engels, D.           | Bonn, W. Germany       |
| Erikson, K.          | Uppsala, Sweden        |
| Feast, M.W.          | Cape, South Africa     |
| Frogel, J.A.         | La Serena, Chile       |
| Fujimoto, M.Y.       | Urbana, IL, U.S.A.     |
| Gallino, R.          | Torino, Italy          |
| Goldberg, L.         | Tucson, AZ, U.S.A.     |
| Greggio, L.          | Padova, Italy          |
| Gustafsson, B.       | Uppsala, Sweden        |
| Herman, J.           | Leiden, Netherlands    |
| Iben, I.Jr.          | Urbana, IL, U.S.A.     |
| Iijima, T.           | Asiago, Italy          |
| Kafatos, M.          | Fairfax, VA, U.S.A.    |

|                      |                             |
|----------------------|-----------------------------|
| Kinman, T.           | Tucson, AZ, U.S.A.          |
| Kwok, S.             | Ottawa, Canada              |
| Lambert, D.L.        | Austin, TX, U.S.A.          |
| Linsky, J.L.         | Boulder, CO, U.S.A.         |
| Littleton, J.E.      | Morgantown, WV, U.S.A.      |
| Lub, J.              | La Silla, Chile             |
| Magalhaes, A.M.      | Sao Paulo, Brazil           |
| Malagnini, M.L.      | Trieste, Italy              |
| Marilli, E.          | Catania, Italy              |
| Matteucci, F.        | Padova, Italy               |
| Mazzitelli, I.       | Frascati, Italy             |
| McCabe, E.M.         | Brighton, England           |
| McCarthy, M.F.       | Castelgandolfo, Italy       |
| Morossi, C.          | Trieste, Italy              |
| Mullan, D.J.         | Newark, DE, U.S.A.          |
| Natta, A.            | Frascati, Italy             |
| Olson, F.M.          | Leiden, Netherlands         |
| Olofsson, H.         | Onsala, Sweden              |
| Paternò, L.          | Catania, Italy              |
| Peimbert, M.         | Mexico, Mexico              |
| Pottasch, S.R.       | Groningen, Netherlands      |
| Preite-Martinez, A.  | Frascati, Italy             |
| Reimers, D.          | Hamburg, W. Germany         |
| Renzini, A.          | Bologna, Italy              |
| Richer, H.B.         | Vancouver, BC, Canada       |
| Ridgway, S.T.        | Tucson, AZ, U.S.A.          |
| Rieu, N.-Q.          | Paris, France               |
| Rocca-Volmerange, B. | Paris, France               |
| Rodonò, M.           | Catania, Italy              |
| Rood, R.T.           | Charlottesville, VA, U.S.A. |
| Rumpl, W.M.          | Greenbelt, MA, U.S.A.       |
| Schmid-Burgk, J.     | Bonn, W. Germany            |
| Schönberner, D.      | Kiel, W. Germany            |
| Serrano, P.A.        | Mexico, Mexico              |
| Strazzulla, G.       | Catania, Italy              |



LIST OF PARTICIPANTS

xv

|               |                        |
|---------------|------------------------|
| Toelle, F.    | Heidelberg, W. Germany |
| Tornambè, A.  | Frascati, Italy        |
| Voli, M.      | Bologna, Italy         |
| Weidemann, V. | Kiel, W. Germany       |
| Willson, L.A. | Ames, IA, U.S.A.       |
| Wing, R.F.    | Columbus, OH, U.S.A.   |
| Wood, P.R.    | Canberra, Australia    |
| Woodrow, J.   | Vancouver, BC, Canada  |

TABLE OF CONTENTS

|                       |      |
|-----------------------|------|
| CONFERENCE PHOTOGRAPH | x    |
| PREFACE               | xi   |
| LIST OF PARTICIPANTS  | xiii |

*EVOLUTION AND COMPOSITION PECULIARITIES OF RED GIANTS*

|  |    |
|--|----|
| Icko Iben Jr.<br>ON THE INTERIOR PROPERTIES OF RED GIANTS  | 3  |
| Bengt Gustafsson<br>THE PHOTOSPHERES OF RED-GIANT STARS  | 25 |
| Robert F. Wing<br>COLOR TEMPERATURES OF RED GIANTS AND THEIR RELATION TO THE<br>EFFECTIVE TEMPERATURE  | 41 |
| S.T. Ridgway, G.H. Jacoby, R.R. Joyce, D.C. Wells<br>CARBON STAR EFFECTIVE TEMPERATURES  | 47 |
| Robert T. Rood<br>THE EFFECT OF [CNO/FE] ON EVOLUTION OF EXTREMELY<br>METAL POOR RED GIANTS  | 51 |
| Jay A. Frogel, S.E. Persson, Judith G. Cohen<br>GLOBULAR CLUSTER GIANT BRANCHES AND THE HELIUM FLASH:<br>A COMPARISON BETWEEN OBSERVATION AND THEORY               | 55 |
| Jay A. Frogel<br>M GIANTS IN THE NUCLEAR BULGE OF THE GALAXY   | 63 |
| T.D. Kinman, Robert P. Kraft, Nicholas B. Suntzeff<br>ON THE METAL ABUNDANCE OF GIANTS IN THE DRACO DWARF GALAXY-<br>PRELIMINARY RESULTS OF A SPECTROSCOPIC SURVEY | 71 |
| John M. Scalo<br>OBSERVATIONS AND THEORIES OF MIXING IN RED GIANTS   | 77 |

|  |     |
|--|-----|
| David L. Lambert   |     |
| THE CHEMICAL COMPOSITION OF RED GIANTS - THE FIRST<br>DREDGE-UP PHASE                                      | 115 |
| Peter R. Wood  |     |
| THE CONDITIONS FOR DREDGE-UP OF CARBON DURING THE HELIUM<br>SHELL FLASH AND THE PRODUCTION OF CARBON STARS | 135 |
| Stephen A. Becker  |     |
| MORE DETAILS ON THERMAL PULSES AND THE THIRD DREDGE-UP<br>PROCESS IN INTERMEDIATE-MASS STARS               | 141 |
| Victor M. Blanco, Martin F. McCarthy   |     |
| LOW DISPERSION SURVEYS FOR CARBON STARS  | 147 |
| Harvey B. Richer   |     |
| THE LUMINOSITY FUNCTION OF CARBON STARS IN THE<br>LARGE MAGELLANIC CLOUD                                   | 153 |
| Jay A. Frogel, Judith G. Cohen, S.E. Persson, Jonathan H. Elias  |     |
| OBSERVED BOLOMETRIC LUMINOSITIES OF CARBON STARS   | 159 |
| Alvio Renzini  |     |
| CARBON STARS IN THE MAGELLANIC CLOUDS: THEORY VS. OBSERVATIONS   | 165 |
| Keith H. Despain   |     |
| ON THE STABILITY OF NUCLEAR-BURNING REGIONS IN RED GIANTS  | 173 |
| Peter P. Eggleton, John Faulkner   |     |
| WHY DO STARS BECOME RED GIANTS?  | 179 |
| Cesare Chiosi  |     |
| MASS LOSS FROM MASSIVE STARS THROUGHOUT THE HR DIAGRAM   | 183 |
| <br><i>RED-GIANT VARIABILITY AND ENVELOPE DYNAMICS</i>   |     |
| Michael W. Feast   |     |
| RED VARIABLES OF SPECTRAL CLASS M  | 193 |
| Peter R. Wood  |     |
| THEORETICAL ASPECTS OF PULSATION AND ENVELOPE EJECTION<br>IN RED GIANTS                                    | 205 |

|   |     |
|---|-----|
| Lee Anne Willson  |     |
| THEORETICAL RELATIONSHIPS BETWEEN OBSERVABLE QUANTITIES<br>FOR MIRA VARIABLES | 225 |
| Antônio M. Magalhães  |     |
| LINEAR POLARIZATION CHANGES ACROSS TiO BANDS IN COOL<br>VARIABLES: V CVn      | 231 |
| Friso M. Olnon  |     |
| THE EXPANSION VELOCITIES IN MIRA ENVELOPES                                    | 237 |
| John E. Littleton   |     |
| RADIATION PRESSURE ON MOLECULES IN MIRA VARIABLE ATMOSPHERES                  | 241 |
| <br><i>WINDS: CHROMOSPHERES, GRAINS, OR WHAT?</i>                             |     |
| Jeffrey L. Linsky   |     |
| OUTER ATMOSPHERES OF LATE-TYPE STARS  | 247 |
| Minas Kafatos, A.G. Michalitsianos, W.A. Feibelman, R.W. Hobbs                |     |
| ULTRAVIOLET OBSERVATIONS OF $\tau^4$ SERPENTIS (M5 IIb-IIIa)                  | 263 |
| Dieter Reimers  |     |
| WINDS IN RED GIANTS   | 269 |
| John I. Castor  |     |
| ORIGIN OF WINDS IN COOL GIANTS AND SUPERGIANTS                                | 285 |
| Leo Goldberg  |     |
| ACCELERATION OF MASS FLOW IN THE CHROMOSPHERE OF $\alpha$ ORIONIS             | 301 |
| Stephen T. Ridgway  |     |
| TIMESCALE OF POSSIBLE EPISODIC BEHAVIOR IN MASS LOSS FROM<br>COOL STARS       | 305 |
| Carla Cacciari, Kenneth C. Freeman  |     |
| MASS LOSS IN POPULATION II RED GIANTS   | 311 |
| Bruce T. Draine   |     |
| DUST FORMATION PROCESSES AROUND RED GIANTS AND SUPERGIANTS                    | 317 |

|   |     |
|---|-----|
| Robin E.S. Clegg<br>SPECTROSCOPY AND CHEMICAL KINETIC STUDIES OF THE CIRCUMSTELLAR<br>SHELL IRC + 10216 | 335 |
| V. Pirronello, G. Strazzulla, G. Foti<br>EROSION OF N <sub>2</sub> FROZEN GAS BY MeV HELIUM IONS        | 337 |
| Johannes Schmid-Burgk, Michael Scholz<br>WHY NOT MAKE DUST IN PHOTOSPHERES OF M STARS?                  | 341 |
| Janice E.J. Woodrow<br>TIME-DEPENDENT MODELS OF GRAIN-FORMING ATMOSPHERES                               | 347 |
| C.D. Andriesse<br>A STATISTICAL THEORY OF STELLAR WINDS   | 351 |
| Dermott J. Mullan<br>MASS LOSS FROM WARM GIANTS: MAGNETIC EFFECTS                                       | 355 |

#### *RED-GIANT MASERS*

|  |     |
|--|-----|
| Moshe Elitzur<br>RED GIANT MASERS  | 363 |
| J. Herman, H.J. Habing<br>TIME VARIATIONS OF OH MASERS IN LATE-TYPE STARS          | 383 |
| Hans Olofsson, O.E.H. Rydbeck<br>DETECTION OF A NEW SiO MASER LINE                 | 391 |
| Nguyen-Quang-Rieu<br>OH AND IR EMISSION FROM RED GIANTS                            | 395 |
| Dieter Engels, G.V. Schultz, W.A. Sherwood<br>INFRARED OBSERVATIONS OF OH/IR STARS | 401 |

#### *RED-GIANT REMNANTS: PLANETARY NEBULAE*

|  |     |
|--|-----|
| Manuel Peimbert<br>PLANETARY NEBULAE AND STELLAR EVOLUTION | 409 |
|--|-----|

|  |     |
|--|-----|
| Sun Kwok   |     |
| FROM RED GIANTS TO PLANETARY NEBULAE   | 421 |
| Antonella Natta, Nino Panagia  |     |
| THE PROPERTIES OF DUST IN PLANETARY NEBULAE  | 427 |
| Alvio Renzini  |     |
| RED GIANTS AS PRECURSORS OF PLANETARY NEBULAE  | 431 |
| Stuart R. Pottasch   |     |
| THE POSITION OF THE CENTRAL STARS OF PLANETARY NEBULAE IN THE<br>HERTZSPRUNG-RUSSELL DIAGRAM | 447 |
| Detlef Schönberner, Volker Weidemann   |     |
| MASSES AND EVOLUTION OF CENTRAL STARS OF PLANETARY NEBULAE                                   | 463 |
| NAME INDEX   | 469 |
| OBJECT INDEX   | 485 |

*EVOLUTION AND COMPOSITION PECULIARITIES OF RED GIANTS*





# ON THE INTERIOR PROPERTIES OF RED GIANTS<sup>1</sup>

Icko Iben, Jr.

University of Illinois at Champaign-Urbana

## I. INTRODUCTION

If one focuses solely on the excursions which they make in the Hertzsprung-Russell diagram on an evolutionary, nuclear-burning, time scale, red giants are perhaps among the least interesting objects in the sky. They do practically nothing! Low luminosity red giants simply grow uneventfully brighter at nearly constant surface temperature (when viewed in a diagram that contains main-sequence stars and white dwarfs) for a period of perhaps  $10^8$  yr. They then transform into brighter red giants, which also grow steadily brighter at nearly constant surface temperature over a period of perhaps  $10^6$  yr.

If, however, one examines their behavior on ever shorter time scales and takes a careful look at phenomena occurring in their interiors and at their surfaces, one finds that red giants are incredibly complex and fascinating objects. They pulsate acoustically, on occasion they blow up in their central cores, and some of them are veritable factories for the synthesis of dozens of new elements that are subsequently convected to the surface, where they enrich the spectral distributions which we view through our telescopes. In the "surface" regions of the red giant which we can "see," matter is being expelled permanently from the star, perhaps as a consequence of shock heating, the action of Alfvén waves, the pressure of radiation on grains forming in the cool atmosphere, or perhaps by some combination of all of these processes.

All stars whose initial mass on the main sequence  $M_{\text{MS}}$  is less than  $M_{\text{C5}} \cong 8 - 10 M_{\odot}$  effectively end their lives as consumers of nuclear fuel while on the red giant branch. In a last burst of rapid mass loss on the red giant branch, a low mass star in this range expels most of its hydrogen-rich envelope. The expelled envelope becomes a planetary nebula and the remnant core evolves rapidly to the white dwarf stage. A more massive star in this range may explode totally as a supernova, provided that the mass in its hydrogen- and helium-exhausted core reaches a value of about  $1.4 M_{\odot}$  before its outer