

THE PHYSICS OF STARS

THE PHYSICS OF STARS THE PHYSICS OF STAR FORMATION AND EARLY STELLAR EVOLUTION PRINCIPLES OF STAR FORMATION THE PHYSICS OF STARS NUCLEAR PHYSICS OF STARS PHYSICS, FORMATION AND EVOLUTION OF ROTATING STARS PHYSICS OF STARS PHYSICS OF BINARY STAR EVOLUTION PHYSICS OF STAR FORMATION IN GALAXIES THE FORMATION OF STARS THE LIFE OF STARS THE PHYSICS OF STARS NUCLEAR PHYSICS STARLIGHT THE PHYSICS AND ASTROPHYSICS OF NEUTRON STARS COMPACT STARS NEUTRON STARS 1 EVOLUTION OF STARS AND STELLAR POPULATIONS THE PHYSICS OF STARS AN INTRODUCTION TO THE EVOLUTION OF SINGLE AND BINARY STARS A. C. PHILLIPS CHARLES J. LADA PETER BODENHEIMER ANTHONY C. PHILLIPS CHRISTIAN ILIADIS ANDRE MAEDER A. C. PHILLIPS THOMAS M. TAURIS F. PALLA STEVEN W. STAHLER GIORA SHAVIV MATHIAS SCHOLZ NATIONAL RESEARCH COUNCIL KEITH ROBINSON LUCIANO REZZOLLA NORMAN K. GLENDENNING P. HAENSEL MAURIZIO SALARIS SAMUIL ARONOVICH KAPLAN MATTHEW BENACQUISTA

THE PHYSICS OF STARS THE PHYSICS OF STAR FORMATION AND EARLY STELLAR EVOLUTION PRINCIPLES OF STAR FORMATION THE PHYSICS OF STARS NUCLEAR PHYSICS OF STARS PHYSICS, FORMATION AND EVOLUTION OF ROTATING STARS PHYSICS OF STARS PHYSICS OF BINARY STAR EVOLUTION PHYSICS OF STAR FORMATION IN GALAXIES THE FORMATION OF STARS THE LIFE OF STARS THE PHYSICS OF STARS NUCLEAR PHYSICS STARLIGHT THE PHYSICS AND ASTROPHYSICS OF NEUTRON STARS COMPACT STARS NEUTRON STARS 1 EVOLUTION OF STARS AND STELLAR POPULATIONS THE PHYSICS OF STARS AN INTRODUCTION TO THE EVOLUTION OF SINGLE AND BINARY STARS A. C. PHILLIPS CHARLES J. LADA PETER BODENHEIMER ANTHONY C. PHILLIPS CHRISTIAN ILIADIS ANDRE MAEDER A. C. PHILLIPS THOMAS M. TAURIS F. PALLA STEVEN W. STAHLER GIORA SHAVIV MATHIAS SCHOLZ NATIONAL RESEARCH COUNCIL KEITH ROBINSON LUCIANO REZZOLLA NORMAN K. GLENDENNING P. HAENSEL MAURIZIO SALARIS SAMUIL ARONOVICH KAPLAN MATTHEW BENACQUISTA

THE PHYSICS OF STARS SECOND EDITION IS A CONCISE INTRODUCTION TO THE PROPERTIES OF STELLAR INTERIORS AND CONSEQUENTLY THE STRUCTURE AND EVOLUTION OF STARS STRONGLY EMPHASISING THE BASIC PHYSICS SIMPLE AND UNCOMPLICATED THEORETICAL MODELS ARE USED TO ILLUSTRATE CLEARLY THE CONNECTIONS BETWEEN FUNDAMENTAL PHYSICS AND STELLAR PROPERTIES THIS TEXT DOES NOT INTEND TO BE ENCYCLOPAEDIC RATHER IT TENDS TO FOCUS ON THE MOST INTERESTING AND IMPORTANT ASPECTS OF STELLAR STRUCTURE EVOLUTION AND NUCLEOSYNTHESIS IN THE SECOND EDITION A NEW CHAPTER ON HELIOSEISMOLOGY HAS BEEN ADDED ALONG WITH A LIST OF PHYSICAL CONSTANTS AND EXTRA STUDENT PROBLEMS THERE IS ALSO NEW MATERIAL ON THE HERTZSPRUNG RUSSELL DIAGRAM AS WELL AS A GENERAL UPDATING OF THE ENTIRE TEXT IT INCLUDES NUMEROUS PROBLEMS AT THE END OF EACH CHAPTER AIMED AT BOTH TESTING AND EXTENDING STUDENT S KNOWLEDGE

THE ORIGIN OF STARS IS ONE OF THE PRINCIPLE MYSTERIES OF NATURE DURING THE LAST TWO DECADES ADVANCES IN TECHNOLOGY HAVE ENABLED MORE PROGRESS TO BE MADE IN THE QUEST TO UNDERSTAND STELLAR ORIGINS THAN AT ANY OTHER TIME IN HISTORY THE STUDY OF STAR FORMATION HAS

DEVELOPED INTO ONE OF THE MOST IMPORTANT BRANCHES OF MODERN ASTROPHYSICAL RESEARCH A LARGE BODY OF OBSERVATIONAL DATA AND A CONSIDERABLE LITERATURE NOW EXIST CONCERNING THIS TOPIC AND A LARGE COMMUNITY OF INTERNATIONAL ASTRONOMERS AND PHYSICISTS DEVOTE THEIR EFFORTS ATTEMPTING TO DECIPHER THE SECRETS OF STELLAR BIRTH YET THE YOUNG ASTRONOMER/PHYSICIST OR MORE ADVANCED RESEARCHER DESIRING TO OBTAIN A BASIC BACKGROUND IN THIS AREA OF RESEARCH MUST SIFT THROUGH A VERY DIVERSE AND SOMETIMES BEWILDERING LITERATURE A LITERATURE WHICH INCLUDES RESEARCH IN MANY DISCIPLINES AND SUB DISCIPLINES OF CLASSICAL ASTROPHYSICS FROM STELLAR STRUCTURE TO THE INTERSTELLAR MEDIUM AND ENCOMPASSES THE ENTIRE RANGE OF THE ELECTROMAGNETIC SPECTRUM FROM RADIO TO GAMMA RAYS OFTEN THE REWARD OF A SUCCESSFUL FORAY THROUGH THE CURRENT LITERATURE IS THE REALIZATION THAT THE RESULTS CAN BE OBSOLETE AND OUTDATED AS SOON AS THE INK IS DRY IN THE JOURNAL OR THE CONFERENCE PROCEEDING IN WHICH THEY ARE PUBLISHED

UNDERSTANDING STAR FORMATION IS ONE OF THE KEY FIELDS IN PRESENT DAY ASTROPHYSICS THIS BOOK TREATS A WIDE VARIETY OF THE PHYSICAL PROCESSES INVOLVED AS WELL AS THE MAIN OBSERVATIONAL DISCOVERIES WITH KEY POINTS BEING DISCUSSED IN DETAIL THE CURRENT STAR FORMATION IN OUR GALAXY IS EMPHASIZED BECAUSE THE MOST DETAILED OBSERVATIONS ARE AVAILABLE FOR THIS CASE THE BOOK PRESENTS A COMPARISON OF THE VARIOUS SCENARIOS FOR STAR FORMATION DISCUSSES THE BASIC PHYSICS UNDERLYING EACH ONE AND FOLLOWS IN DETAIL THE HISTORY OF A STAR FROM ITS INITIAL STATE IN THE INTERSTELLAR GAS TO ITS BECOMING A CONDENSED OBJECT IN EQUILIBRIUM BOTH THEORETICAL AND OBSERVATIONAL EVIDENCE TO SUPPORT THE VALIDITY OF THE GENERAL EVOLUTIONARY PATH ARE PRESENTED AND METHODS FOR COMPARING THE TWO ARE EMPHASIZED THE AUTHOR IS A RECOGNIZED EXPERT IN CALCULATIONS OF THE EVOLUTION OF PROTOSTARS THE STRUCTURE AND EVOLUTION OF DISKS AND STELLAR EVOLUTION IN GENERAL THIS BOOK WILL BE OF VALUE TO GRADUATE STUDENTS IN ASTRONOMY AND ASTROPHYSICS AS WELL AS TO ACTIVE RESEARCHERS IN THE FIELD

THERMONUCLEAR REACTIONS IN STARS IS A MAJOR TOPIC IN THE FIELD OF NUCLEAR ASTROPHYSICS AND DEALS WITH THE TOPICS OF HOW PRECISELY STARS GENERATE THEIR ENERGY THROUGH NUCLEAR REACTIONS AND HOW THESE NUCLEAR REACTIONS CREATE THE ELEMENTS THE STARS PLANETS AND ULTIMATELY WE HUMANS CONSIST OF THE PRESENT BOOK TREATS THESE TOPICS IN DETAIL IT ALSO PRESENTS THE NUCLEAR REACTION AND STRUCTURE THEORY THERMONUCLEAR REACTION RATE FORMALISM AND STELLAR NUCLEOSYNTHESIS THE TOPICS ARE DISCUSSED IN A COHERENT WAY ENABLING THE READER TO GRASP THEIR INTERCONNECTIONS INTUITIVELY THE BOOK SERVES BOTH AS A TEXTBOOK WITH MANY EXAMPLES AND END OF CHAPTER EXERCISES BUT ALSO AS A REFERENCE BOOK FOR USE BY RESEARCHERS WORKING IN THE FIELD OF NUCLEAR ASTROPHYSICS

ROTATION IS UBIQUITOUS AT EACH STEP OF STELLAR EVOLUTION FROM STAR FORMATION TO THE FINAL STAGES AND IT AFFECTS THE COURSE OF EVOLUTION THE TIMESCALES AND NUCLEOSYNTHESIS STELLAR ROTATION IS ALSO AN ESSENTIAL PREREQUISITE FOR THE OCCURRENCE OF GAMMA RAY BURSTS IN THIS BOOK THE AUTHOR THOROUGHLY EXAMINES THE BASIC MECHANICAL AND THERMAL EFFECTS OF ROTATION THEIR INFLUENCE ON MASS LOSS BY STELLAR WINDS THE EFFECTS OF DIFFERENTIAL ROTATION AND ITS ASSOCIATED INSTABILITIES THE RELATION WITH MAGNETIC FIELDS AND THE EVOLUTION OF THE INTERNAL AND SURFACE ROTATION FURTHER HE DISCUSSES THE NUMEROUS OBSERVATIONAL SIGNATURES OF ROTATIONAL EFFECTS OBTAINED FROM SPECTROSCOPY AND INTERFEROMETRIC OBSERVATIONS AS WELL AS FROM CHEMICAL ABUNDANCE DETERMINATIONS HELIOSEISMOLOGY AND ASTEROSEISMOLOGY ETC ON AN INTRODUCTORY LEVEL THIS BOOK PRESENTS IN A DIDACTICAL WAY THE BASIC CONCEPTS OF STELLAR STRUCTURE AND EVOLUTION IN TRACK 1 CHAPTERS THE OTHER MORE SPECIALIZED CHAPTERS FORM AN ADVANCED COURSE ON THE GRADUATE LEVEL AND WILL FURTHER SERVE AS A VALUABLE REFERENCE WORK FOR PROFESSIONAL ASTROPHYSICISTS

A GRADUATE LEVEL TEXTBOOK ON THE ASTROPHYSICS OF BINARY STAR SYSTEMS AND THEIR EVOLUTION PHYSICS OF BINARY STAR EVOLUTION IS AN UP TO DATE TEXTBOOK ON THE ASTROPHYSICS AND EVOLUTION OF BINARY STAR SYSTEMS THEORETICAL ASTROPHYSICISTS THOMAS TAURIS AND EDWARD VAN DEN HEUVEL COVER A WIDE RANGE OF PHENOMENA AND PROCESSES INCLUDING MASS TRANSFER AND EJECTION COMMON ENVELOPES NOVAE AND SUPERNOVAE X RAY BINARIES MILLISECOND RADIO PULSARS AND GRAVITATIONAL WAVE GW SOURCES AND THEIR LINKS TO STELLAR EVOLUTION THE AUTHORS WALK THROUGH THE OBSERVED PROPERTIES AND EVOLUTION OF DIFFERENT TYPES OF BINARIES WITH SPECIAL EMPHASIS ON THOSE CONTAINING COMPACT OBJECTS NEUTRON STARS BLACK HOLES AND WHITE DWARFS ATTENTION IS GIVEN TO THE FORMATION MECHANISMS OF GW SOURCES MERGING DOUBLE NEUTRON STARS AND BLACK HOLES AS WELL AS ULTRA COMPACT GW BINARIES HOSTING WHITE DWARFS AND TO THE PROGENITORS OF THESE SOURCES AND HOW THEY ARE OBSERVED WITH RADIO TELESCOPES X RAY SATELLITES AND GW DETECTORS LIGO VIRGO KAGRA EINSTEIN TELESCOPE COSMIC EXPLORER AND LISA SUPPORTED BY ILLUSTRATIONS EQUATIONS AND EXERCISES PHYSICS OF BINARY STAR EVOLUTION COMBINES THEORY AND OBSERVATIONS TO GUIDE READERS THROUGH THE WONDERS OF A FIELD THAT WILL PLAY A CENTRAL ROLE IN MODERN ASTROPHYSICS FOR DECADES TO COME 465 EQUATIONS 47 TABLES AND 350 FIGURES MORE THAN 80 EXERCISES ANALYTICAL NUMERICAL AND COMPUTATIONAL OVER 2 500 EXTENSIVE UP TO DATE REFERENCES

THE BOOK BEGINS WITH A HISTORICAL INTRODUCTION STAR FORMATION THE EARLY HISTORY THAT PRESENTS NEW MATERIAL OF INTEREST FOR STUDENTS AND HISTORIANS OF SCIENCE THIS IS FOLLOWED BY TWO LONG ARTICLES ON PRE MAIN SEQUENCE EVOLUTION OF STARS AND YOUNG CLUSTERS AND OBSERVATIONS OF YOUNG STELLAR OBJECTS THESE ARTICLES ON THE FASCINATING PROBLEM OF STAR FORMATION FROM INTERSTELLAR MATTER GIVE A THOROUGH OVERVIEW OF PRESENT DAY THEORIES AND OBSERVATIONS THE ARTICLES CONTAIN MATERIAL SO FAR UNPUBLISHED IN THE ASTRONOMICAL LITERATURE THE BOOK ADDRESSES GRADUATE STUDENTS AND CAN BE USED AS A TEXTBOOK FOR ADVANCED COURSES IN STELLAR ASTROPHYSICS

THIS BOOK IS A COMPREHENSIVE TREATMENT OF STAR FORMATION ONE OF THE MOST ACTIVE FIELDS OF MODERN ASTRONOMY THE READER IS GUIDED THROUGH THE SUBJECT IN A LOGICALLY COMPELLING MANNER STARTING FROM A GENERAL DESCRIPTION OF STARS AND INTERSTELLAR CLOUDS THE AUTHORS DELINEATE THE EARLIEST PHASES OF STELLAR EVOLUTION THEY DISCUSS FORMATION ACTIVITY NOT ONLY IN THE MILKY WAY BUT ALSO IN OTHER GALAXIES BOTH NOW AND IN THE REMOTE PAST THEORY AND OBSERVATION ARE THOROUGHLY INTEGRATED WITH THE AID OF NUMEROUS FIGURES AND IMAGES IN SUMMARY THIS VOLUME IS AN INVALUABLE RESOURCE BOTH AS A TEXT FOR PHYSICS AND ASTRONOMY GRADUATE STUDENTS AND AS A REFERENCE FOR PROFESSIONAL SCIENTISTS

IT IS THE STARS THE STARS ABOVE US GOVERN OUR CONDITIONS WILLIAM SHAKESPEARE KING LEAR A FEW WORDS ABOUT WHAT WHY AND HOW THE STRUCTURE OF THE STARS IN GENERAL AND THE SUN IN PARTICULAR HAS BEEN THE SUBJECT OF EXTENSIVE SCIENTIFIC RESEARCH AND DEBATE FOR OVER A CENTURY THE DISCOVERY OF QUANTUM THEORY DURING THE LAST HALF OF THE NINETEENTH CENTURY PROVIDED MUCH OF THE THEORETICAL BACKGROUND NEEDED TO UNDERSTAND THE MAKING OF THE STARS AND HOW THEY LIVE OFF THEIR ENERGY SOURCE PROGRESS IN THE THEORY OF STELLAR STRUCTURE WAS MADE THROUGH EXTENSIVE DISCUSSIONS AND CONTROVERSIES BETWEEN THE GIANTS OF THE ELDS AS WELL AS BRILLIANT DISCOVERIES BY ASTRONOMERS IN THIS BOOK WE SHALL CAREFULLY EXPOSE THE BUILDING OF THE THEORY OF STELLAR STRUCTURE AND EVOLUTION AND EXPLAIN HOW OUR UNDERSTANDING OF THE STARS HAS EMERGED FROM THIS BACKGROUND OF INCESSANT DEBATE ABOUT HUNDRED YEARS WERE REQUIRED FOR ASTROPHYSICS TO ANSWER THE CRUCIAL QUESTIONS WHAT IS THE ENERGY SOURCE OF THE STARS HOW ARE THE STARS MADE HOW DO THEY EVOLVE AND EVENTUALLY DIE THE ANSWERS TO THESE QUESTIONS HAVE PROFOUND IMPLICATIONS FOR ASTROPHYSICS PHYSICS AND BIOLOGY AND THE QUESTION OF HOW WE OURSELVES COME TO BE HERE WHILE WE ALREADY

POSSESS MANY OF THE ANSWERS THE THEORY OF STELLAR STRUCTURE IS FAR FROM BEING COMPLETE AND THERE ARE MANY OPEN QUESTIONS FOR EXAMPLE CONCERNING THE MECHANISMS WHICH TRIGGER GIANT SUPERNOVA EXPLOSIONS MANY INTERNAL HYDRODYNAMIC PROCESSES REMAIN A MYSTERY YET SOME GLOBAL PICTURES CAN INDEED BE OUTLINED AND THIS IS WHAT WE SHALL ATTEMPT TO DO HERE

INTERESTED STUDENTS IN THE NATURAL AND ENGINEERING SCIENCES AS WELL AS HIGH SCHOOL GRADUATES INSTRUCTORS TEACHERS AND AMATEUR ASTRONOMERS WILL FIND A VALUABLE OVERVIEW OF THE PHYSICS OF STARS IN THIS BOOK THE ONLY PREREQUISITE IS A BASIC MATHEMATICAL AND PHYSICAL BACKGROUND WHICH DOES NOT GO BEYOND THE KNOWLEDGE OF INTEGRAL AND DIFFERENTIAL CALCULUS IN THIS REGARD THIS BOOK AIMS TO BRIDGE THE GAP WITH THE SPECIALIZED LITERATURE AVAILABLE ON THE INTERNET ALLOWING READERS TO BENEFIT FROM IT THE FIRST PART TRACES THE HISTORICAL DEVELOPMENT THAT LED TO A DETAILED UNDERSTANDING OF THE NATURE OF STARS AND THEIR LIFE CYCLES THE GOAL OF THE FOLLOWING CHAPTERS IS TO PROVIDE A PRAGMATIC INTRODUCTION TO THE PHYSICAL PROCESSES THAT DETERMINE THE STRUCTURE AND EVOLUTION OF STARS BASED ON THEIR FUNDAMENTAL PARAMETERS SUCH AS MASS AND CHEMICAL COMPOSITION IT WILL SHOW WHAT CAN BE LEARNED FROM THE ANALYSIS OF STARLIGHT ABOUT STELLAR ATMOSPHERES THE FUNDAMENTAL ROLE OF THE VIRIAL THEOREM IN THE LIVES OF STARS AND THE NUCLEAR PROCESSES DEEP INSIDE STARS THAT PROVIDE THE ENERGY THAT MAKES THEM SHINE FINALLY THERE WILL BE AN IN DEPTH PHENOMENOLOGICAL LOOK AT THE FINAL STAGES OF STELLAR EVOLUTION THIS SECTION WILL DISCUSS STATES OF MATTER THAT ARE FAR FROM EXPERIMENTAL REALIZATION BUT WHOSE PROPERTIES CAN BE AT LEAST IN PRINCIPLE INFERRED FROM THE OBSERVATION OF CONCRETE OBJECTS SUCH AS WHITE DWARFS OR NEUTRON STARS EXCITING DEVELOPMENTS ARE STILL EXPECTED IN THIS AREA IN THE FUTURE

MATHIAS SCHOLZ IS HOBBY ASTRONOMER HE STUDIED PHYSICS AT THE UNIVERSITY OF ROSTOCK FROM 1981 TO 1986 INTERESTED STUDENTS IN THE NATURAL AND ENGINEERING SCIENCES AS WELL AS HIGH SCHOOL GRADUATES INSTRUCTORS TEACHERS AND AMATEUR ASTRONOMERS WILL FIND A VALUABLE OVERVIEW OF THE PHYSICS OF STARS IN THIS BOOK THE ONLY PREREQUISITE IS A BASIC MATHEMATICAL AND PHYSICAL BACKGROUND WHICH DOES NOT GO BEYOND THE KNOWLEDGE OF INTEGRAL AND DIFFERENTIAL CALCULUS IN THIS REGARD THIS BOOK AIMS TO BRIDGE THE GAP WITH THE SPECIALIZED LITERATURE AVAILABLE ON THE INTERNET ALLOWING READERS TO BENEFIT FROM IT THE FIRST PART TRACES THE HISTORICAL DEVELOPMENT THAT LED TO A DETAILED UNDERSTANDING OF THE NATURE OF STARS AND THEIR LIFE CYCLES THE GOAL OF THE FOLLOWING CHAPTERS IS TO PROVIDE A PRAGMATIC INTRODUCTION TO THE PHYSICAL PROCESSES THAT DETERMINE THE STRUCTURE AND EVOLUTION OF STARS BASED ON THEIR FUNDAMENTAL PARAMETERS SUCH AS MASS AND CHEMICAL COMPOSITION IT WILL SHOW WHAT CAN BE LEARNED FROM THE ANALYSIS OF STARLIGHT ABOUT STELLAR ATMOSPHERES THE FUNDAMENTAL ROLE OF THE VIRIAL THEOREM IN THE LIVES OF STARS AND THE NUCLEAR PROCESSES DEEP INSIDE STARS THAT PROVIDE THE ENERGY THAT MAKES THEM SHINE FINALLY THERE WILL BE AN IN DEPTH PHENOMENOLOGICAL LOOK AT THE FINAL STAGES OF STELLAR EVOLUTION THIS SECTION WILL DISCUSS STATES OF MATTER THAT ARE FAR FROM EXPERIMENTAL REALIZATION BUT WHOSE PROPERTIES CAN BE AT LEAST IN PRINCIPLE INFERRED FROM THE OBSERVATION OF CONCRETE OBJECTS SUCH AS WHITE DWARFS OR NEUTRON STARS EXCITING DEVELOPMENTS ARE STILL EXPECTED IN THIS AREA IN THE FUTURE

DRAMATIC PROGRESS HAS BEEN MADE IN ALL BRANCHES OF PHYSICS SINCE THE NATIONAL RESEARCH COUNCIL'S 1986 DECADAL SURVEY OF THE FIELD THE PHYSICS IN A NEW ERA SERIES EXPLORES THESE ADVANCES AND LOOKS AHEAD TO FUTURE GOALS THE SERIES INCLUDES ASSESSMENTS OF THE MAJOR SUBFIELDS AND REPORTS ON SEVERAL SMALLER SUBFIELDS AND PREPARATION HAS BEGUN ON AN OVERVIEW VOLUME ON THE UNITY OF PHYSICS ITS RELATIONSHIPS TO OTHER FIELDS AND ITS CONTRIBUTIONS TO NATIONAL NEEDS NUCLEAR PHYSICS IS THE LATEST VOLUME OF THE SERIES THE BOOK DESCRIBES CURRENT ACTIVITY IN UNDERSTANDING NUCLEAR STRUCTURE AND SYMMETRIES THE BEHAVIOR OF MATTER AT EXTREME DENSITIES THE ROLE OF NUCLEAR PHYSICS IN ASTROPHYSICS

AND COSMOLOGY AND THE INSTRUMENTATION AND FACILITIES USED BY THE FIELD IT MAKES RECOMMENDATIONS ON THE RESOURCES NEEDED FOR EXPERIMENTAL AND THEORETICAL ADVANCES IN THE COMING DECADE

THIS IS A BOOK ABOUT THE PHYSICS OF STARS AND STARLIGHT THE STORY OF STARLIGHT IS TRULY FASCINATING ASTRONOMERS ANALYZE AND INTERPRET THE LIGHT FROM STARS USING PHOTOMETRY AND SPECTROSCOPY THEN INSPIRATIONAL DETECTIVE WORK COMBINES WITH THE LAWS OF PHYSICS TO REVEAL THE TEMPERATURES MASSES LUMINOSITIES AND OUTER STRUCTURE OF THESE FAR AWAY POINTS OF LIGHT THE LAWS OF PHYSICS THEMSELVES ENABLE US TO JOURNEY TO THE VERY CENTER OF A STAR AND TO UNDERSTAND ITS INNER STRUCTURE AND SOURCE OF ENERGY STARLIGHT PROVIDES AN IN DEPTH STUDY OF STELLAR ASTROPHYSICS THAT REQUIRES ONLY BASIC HIGH SCHOOL MATHEMATICS AND PHYSICS MAKING IT ACCESSIBLE TO ALL AMATEUR ASTRONOMERS STARLIGHT TEACHES AMATEUR ASTRONOMERS ABOUT THE PHYSICS OF STARS AND STARLIGHT IN A FRIENDLY EASY TO READ WAY THE READER WILL TAKE AWAY A PROFOUNDLY DEEPER UNDERSTANDING OF THIS TRULY FASCINATING SUBJECT AND FIND HIS PRACTICAL OBSERVATIONS MORE REWARDING AND FULFILLING AS A RESULT

THIS BOOK SUMMARIZES THE RECENT PROGRESS IN THE PHYSICS AND ASTROPHYSICS OF NEUTRON STARS AND MOST IMPORTANTLY IT IDENTIFIES AND DEVELOPS EFFECTIVE STRATEGIES TO EXPLORE BOTH THEORETICALLY AND OBSERVATIONALLY THE MANY REMAINING OPEN QUESTIONS IN THE FIELD BECAUSE OF ITS SIGNIFICANCE IN THE SOLUTION OF MANY FUNDAMENTAL QUESTIONS IN NUCLEAR PHYSICS ASTROPHYSICS AND GRAVITATIONAL PHYSICS THE STUDY OF NEUTRON STARS HAS SEEN ENORMOUS PROGRESS OVER THE LAST YEARS AND HAS BEEN VERY SUCCESSFUL IN IMPROVING OUR UNDERSTANDING IN THESE FASCINATING COMPACT OBJECTS THE BOOK ADDRESSES A WIDE SPECTRUM OF READERS FROM STUDENTS TO SENIOR RESEARCHERS THIRTEEN CHAPTERS WRITTEN BY INTERNATIONALLY RENOWNED EXPERTS OFFER A THOROUGH OVERVIEW OF THE VARIOUS FACETS OF THIS INTERDISCIPLINARY SCIENCE FROM NEUTRON STAR FORMATION IN SUPERNOVAE PULSARS EQUATIONS OF STATE SUPER DENSE MATTER GRAVITATIONAL WAVE EMISSION TO ALTERNATIVE THEORIES OF GRAVITY THE BOOK WAS INITIATED BY THE EUROPEAN COOPERATION IN SCIENCE AND TECHNOLOGY COST ACTION MP1304 EXPLORING FUNDAMENTAL PHYSICS WITH COMPACT STARS NEWCOMPSTAR

NEUTRON STARS ARE THE SMALLEST DENSEST STARS KNOWN WITH DENSITIES SOME 10^{14} TIMES THAT OF THE EARTH THEY ROTATE WITH PERIODS OF FRACTIONS OF A SECOND AND THEIR MAGNETIC FIELDS DRIVE INTENSE INTERSTELLAR DYNAMOS LIGHTING UP ENTIRE NEBULAE THIS TEXT DISCUSSES THE PHYSICS OF THESE EXTREME OBJECTS IT INCLUDES THE NEEDED BACKGROUND IN CLASSICAL GENERAL RELATIVITY IN NUCLEAR AND PARTICLE PHYSICS

THE BOOK GIVES AN EXTENDED REVIEW OF THEORETICAL AND OBSERVATIONAL ASPECTS OF NEUTRON STAR PHYSICS WITH MASSES COMPARABLE TO THAT OF THE SUN AND RADII OF ABOUT TEN KILOMETRES NEUTRON STARS ARE THE DENSEST STARS IN THE UNIVERSE THIS BOOK DESCRIBES ALL LAYERS OF NEUTRON STARS FROM THE SURFACE TO THE CORE WITH THE EMPHASIS ON THEIR STRUCTURE AND EQUATION OF STATE THEORIES OF DENSE MATTER ARE REVIEWED AND USED TO CONSTRUCT NEUTRON STAR MODELS HYPOTHETICAL STRANGE QUARK STARS AND POSSIBLE EXOTIC PHASES IN NEUTRON STAR CORES ARE ALSO DISCUSSED ALSO COVERED ARE THE EFFECTS OF STRONG MAGNETIC FIELDS IN NEUTRON STAR ENVELOPES

EVOLUTION OF STARS AND STELLAR POPULATIONS IS A COMPREHENSIVE PRESENTATION OF THE THEORY OF STELLAR EVOLUTION AND ITS APPLICATION TO THE STUDY OF STELLAR POPULATIONS IN GALAXIES TAKING A UNIQUE APPROACH TO THE SUBJECT THIS SELF CONTAINED TEXT INTRODUCES FIRST THE THEORY OF

STELLAR EVOLUTION IN A CLEAR AND ACCESSIBLE MANNER WITH PARTICULAR EMPHASIS PLACED ON EXPLAINING THE EVOLUTION WITH TIME OF OBSERVABLE STELLAR PROPERTIES SUCH AS LUMINOSITIES AND SURFACE CHEMICAL ABUNDANCES THIS IS FOLLOWED BY A DETAILED PRESENTATION AND DISCUSSION OF A BROAD RANGE OF RELATED TECHNIQUES THAT ARE WIDELY APPLIED BY RESEARCHERS IN THE FIELD TO INVESTIGATE THE FORMATION AND EVOLUTION OF GALAXIES THIS BOOK WILL BE INVALUABLE FOR UNDERGRADUATES AND GRADUATE STUDENTS IN ASTRONOMY AND ASTROPHYSICS AND WILL ALSO BE OF INTEREST TO RESEARCHERS WORKING IN THE FIELD OF GALACTIC EXTRAGALACTIC ASTRONOMY AND COSMOLOGY COMPREHENSIVE PRESENTATION OF STELLAR EVOLUTION THEORY INTRODUCES THE CONCEPT OF STELLAR POPULATION AND DESCRIBES STELLAR POPULATION SYNTHESIS METHODS TO STUDY AGES AND STAR FORMATION HISTORIES OF STAR CLUSTERS AND GALAXIES PRESENTS STELLAR EVOLUTION AS A TOOL FOR INVESTIGATING THE EVOLUTION OF GALAXIES AND OF THE UNIVERSE IN GENERAL

AN INTRODUCTION TO THE EVOLUTION OF SINGLE AND BINARY STARS PROVIDES PHYSICISTS WITH AN UNDERSTANDING OF BINARY AND SINGLE STAR EVOLUTION BEGINNING WITH A BACKGROUND AND INTRODUCTION OF BASIC ASTRONOMICAL CONCEPTS ALTHOUGH A GENERAL TREATMENT OF STELLAR STRUCTURE AND EVOLUTION IS INCLUDED THE TEXT STRESSES THE PHYSICAL PROCESSES THAT LEAD TO STELLAR MASS COMPACT OBJECT BINARIES THAT MAY BE SOURCES OF OBSERVABLE GRAVITATIONAL RADIATION BASIC CONCEPTS OF ASTRONOMY STELLAR STRUCTURE AND ATMOSPHERES SINGLE STAR EVOLUTION BINARY SYSTEMS AND MASS TRANSFER COMPACT OBJECTS AND DYNAMICAL SYSTEMS ARE COVERED IN THE TEXT READERS WILL UNDERSTAND THE ASTROPHYSICS BEHIND THE POPULATIONS OF COMPACT OBJECT BINARY SYSTEMS AND HAVE SUFFICIENT BACKGROUND TO DELVE DEEPER INTO SPECIFIC AREAS OF INTEREST IN ADDITION DERIVATIONS OF IMPORTANT CONCEPTS AND WORKED EXAMPLES ARE INCLUDED NO PREVIOUS KNOWLEDGE OF ASTRONOMY IS ASSUMED ALTHOUGH A FAMILIARITY WITH UNDERGRADUATE QUANTUM MECHANICS CLASSICAL MECHANICS AND THERMODYNAMICS IS BENEFICIAL

AS RECOGNIZED, ADVENTURE AS WELL AS EXPERIENCE VIRTUALLY LESSON, AMUSEMENT, AS SKILLFULLY AS HARMONY CAN BE GOTTEN BY JUST CHECKING OUT A BOOK **THE PHYSICS OF STARS** WITH IT IS NOT DIRECTLY DONE, YOU COULD SAY YOU WILL EVEN MORE IN THE REGION OF THIS LIFE, SOMETHING LIKE THE WORLD. WE PROVIDE YOU THIS PROPER AS COMPETENTLY AS SIMPLE PRETENSION TO GET THOSE ALL. WE MEET THE EXPENSE OF THE PHYSICS OF STARS AND NUMEROUS BOOKS COLLECTIONS FROM FICTIONS TO SCIENTIFIC RESEARCH IN ANY WAY. AMONG THEM IS THIS THE PHYSICS OF STARS THAT CAN BE YOUR PARTNER.

1. WHERE CAN I PURCHASE THE PHYSICS OF STARS BOOKS? BOOKSTORES: PHYSICAL BOOKSTORES LIKE BARNES & NOBLE, WATERSTONES, AND INDEPENDENT LOCAL STORES. ONLINE RETAILERS: AMAZON, BOOK DEPOSITORY, AND VARIOUS ONLINE BOOKSTORES OFFER A WIDE SELECTION OF BOOKS IN PRINTED AND DIGITAL FORMATS.
2. WHAT ARE THE VARIED BOOK FORMATS AVAILABLE? WHICH KINDS OF BOOK FORMATS ARE CURRENTLY AVAILABLE? ARE THERE DIFFERENT BOOK FORMATS TO CHOOSE FROM? HARDCOVER: STURDY AND RESILIENT, USUALLY PRICIER. PAPERBACK: MORE AFFORDABLE, LIGHTER, AND MORE PORTABLE THAN HARDCOVERS. E-BOOKS: ELECTRONIC BOOKS ACCESSIBLE FOR E-READERS LIKE KINDLE OR THROUGH PLATFORMS SUCH AS APPLE BOOKS, KINDLE, AND GOOGLE PLAY BOOKS.
3. WHAT'S THE BEST METHOD FOR CHOOSING A THE PHYSICS OF STARS BOOK TO READ? GENRES: TAKE INTO ACCOUNT THE GENRE YOU PREFER (FICTION, NONFICTION, MYSTERY, SCI-FI, ETC.). RECOMMENDATIONS: ASK FOR ADVICE FROM FRIENDS, PARTICIPATE IN BOOK CLUBS, OR EXPLORE ONLINE REVIEWS AND SUGGESTIONS. AUTHOR: IF YOU LIKE A SPECIFIC AUTHOR, YOU MAY ENJOY MORE OF THEIR WORK.
4. WHAT'S THE BEST WAY TO MAINTAIN THE PHYSICS OF STARS BOOKS? STORAGE: STORE THEM AWAY FROM DIRECT SUNLIGHT AND IN A DRY SETTING. HANDLING: PREVENT FOLDING PAGES, UTILIZE BOOKMARKS, AND HANDLE THEM WITH CLEAN HANDS. CLEANING: OCCASIONALLY DUST THE COVERS AND PAGES GENTLY.

5. CAN I BORROW BOOKS WITHOUT BUYING THEM? COMMUNITY LIBRARIES: LOCAL LIBRARIES OFFER A WIDE RANGE OF BOOKS FOR BORROWING. BOOK SWAPS: BOOK EXCHANGE EVENTS OR WEB PLATFORMS WHERE PEOPLE SWAP BOOKS.
6. HOW CAN I TRACK MY READING PROGRESS OR MANAGE MY BOOK COLLECTION? BOOK TRACKING APPS: LIBRARYTHING ARE POPULAR APPS FOR TRACKING YOUR READING PROGRESS AND MANAGING BOOK COLLECTIONS. SPREADSHEETS: YOU CAN CREATE YOUR OWN SPREADSHEET TO TRACK BOOKS READ, RATINGS, AND OTHER DETAILS.
7. WHAT ARE THE PHYSICS OF STARS AUDIOBOOKS, AND WHERE CAN I FIND THEM? AUDIOBOOKS: AUDIO RECORDINGS OF BOOKS, PERFECT FOR LISTENING WHILE COMMUTING OR MULTITASKING. PLATFORMS: LIBRIVOX OFFER A WIDE SELECTION OF AUDIOBOOKS.
8. HOW DO I SUPPORT AUTHORS OR THE BOOK INDUSTRY? BUY BOOKS: PURCHASE BOOKS FROM AUTHORS OR INDEPENDENT BOOKSTORES. REVIEWS: LEAVE REVIEWS ON PLATFORMS LIKE GOODREADS. PROMOTION: SHARE YOUR FAVORITE BOOKS ON SOCIAL MEDIA OR RECOMMEND THEM TO FRIENDS.
9. ARE THERE BOOK CLUBS OR READING COMMUNITIES I CAN JOIN? LOCAL CLUBS: CHECK FOR LOCAL BOOK CLUBS IN LIBRARIES OR COMMUNITY CENTERS. ONLINE COMMUNITIES: PLATFORMS LIKE GOODREADS HAVE VIRTUAL BOOK CLUBS AND DISCUSSION GROUPS.
10. CAN I READ THE PHYSICS OF STARS BOOKS FOR FREE? PUBLIC DOMAIN BOOKS: MANY CLASSIC BOOKS ARE AVAILABLE FOR FREE AS THEY'RE IN THE PUBLIC DOMAIN.

FREE E-BOOKS: SOME WEBSITES OFFER FREE E-BOOKS LEGALLY, LIKE PROJECT GUTENBERG OR OPEN LIBRARY. FIND THE PHYSICS OF STARS

INTRODUCTION

THE DIGITAL AGE HAS REVOLUTIONIZED THE WAY WE READ, MAKING BOOKS MORE ACCESSIBLE THAN EVER. WITH THE RISE OF EBOOKS, READERS CAN NOW CARRY ENTIRE LIBRARIES IN THEIR POCKETS. AMONG THE VARIOUS SOURCES FOR EBOOKS, FREE EBOOK SITES HAVE EMERGED AS A POPULAR CHOICE. THESE SITES OFFER A TREASURE TROVE OF KNOWLEDGE AND ENTERTAINMENT WITHOUT THE COST. BUT WHAT MAKES THESE SITES SO VALUABLE, AND WHERE CAN YOU FIND THE BEST ONES? LET'S DIVE INTO THE WORLD OF FREE EBOOK SITES.

BENEFITS OF FREE EBOOK SITES

WHEN IT COMES TO READING, FREE EBOOK SITES OFFER NUMEROUS ADVANTAGES.

COST SAVINGS

FIRST AND FOREMOST, THEY SAVE YOU MONEY. BUYING BOOKS CAN BE EXPENSIVE, ESPECIALLY IF YOU'RE AN AVID READER. FREE EBOOK SITES ALLOW YOU TO ACCESS A VAST ARRAY OF BOOKS WITHOUT SPENDING A DIME.

ACCESSIBILITY

THESE SITES ALSO ENHANCE ACCESSIBILITY. WHETHER YOU'RE AT HOME, ON THE GO, OR HALFWAY AROUND THE WORLD, YOU CAN ACCESS YOUR FAVORITE

TITLES ANYTIME, ANYWHERE, PROVIDED YOU HAVE AN INTERNET CONNECTION.

VARIETY OF CHOICES

MOREOVER, THE VARIETY OF CHOICES AVAILABLE IS ASTOUNDING. FROM CLASSIC LITERATURE TO CONTEMPORARY NOVELS, ACADEMIC TEXTS TO CHILDREN'S BOOKS, FREE EBOOK SITES COVER ALL GENRES AND INTERESTS.

TOP FREE EBOOK SITES

THERE ARE COUNTLESS FREE EBOOK SITES, BUT A FEW STAND OUT FOR THEIR QUALITY AND RANGE OF OFFERINGS.

PROJECT GUTENBERG

PROJECT GUTENBERG IS A PIONEER IN OFFERING FREE EBOOKS. WITH OVER 60,000 TITLES, THIS SITE PROVIDES A WEALTH OF CLASSIC LITERATURE IN THE PUBLIC DOMAIN.

OPEN LIBRARY

OPEN LIBRARY AIMS TO HAVE A WEBPAGE FOR EVERY BOOK EVER PUBLISHED. IT OFFERS MILLIONS OF FREE EBOOKS, MAKING IT A FANTASTIC RESOURCE FOR READERS.

GOOGLE BOOKS

GOOGLE BOOKS ALLOWS USERS TO SEARCH AND PREVIEW MILLIONS OF BOOKS FROM LIBRARIES AND PUBLISHERS WORLDWIDE. WHILE NOT ALL BOOKS ARE AVAILABLE FOR FREE, MANY ARE.

MANYBOOKS

MANYBOOKS OFFERS A LARGE SELECTION OF FREE EBOOKS IN VARIOUS GENRES. THE SITE IS USER-FRIENDLY AND OFFERS BOOKS IN MULTIPLE FORMATS.

BookBoon

BookBoon specializes in free textbooks and business books, making it an excellent resource for students and professionals.

How to Download Ebooks Safely

Downloading ebooks safely is crucial to avoid pirated content and protect your devices.

Avoiding Pirated Content

Stick to reputable sites to ensure you're not downloading pirated content. Pirated ebooks not only harm authors and publishers but can also pose security risks.

Ensuring Device Safety

Always use antivirus software and keep your devices updated to protect against malware that can be hidden in downloaded files.

Legal Considerations

Be aware of the legal considerations when downloading ebooks. Ensure the site has the right to distribute the book and that you're not violating copyright laws.

Using Free Ebook Sites for Education

Free ebook sites are invaluable for educational purposes.

Academic Resources

Sites like Project Gutenberg and Open Library offer numerous academic resources, including textbooks and scholarly articles.

LEARNING NEW SKILLS

YOU CAN ALSO FIND BOOKS ON VARIOUS SKILLS, FROM COOKING TO PROGRAMMING, MAKING THESE SITES GREAT FOR PERSONAL DEVELOPMENT.

SUPPORTING HOMESCHOOLING

FOR HOMESCHOOLING PARENTS, FREE EBOOK SITES PROVIDE A WEALTH OF EDUCATIONAL MATERIALS FOR DIFFERENT GRADE LEVELS AND SUBJECTS.

GENRES AVAILABLE ON FREE EBOOK SITES

THE DIVERSITY OF GENRES AVAILABLE ON FREE EBOOK SITES ENSURES THERE'S SOMETHING FOR EVERYONE.

FICTION

FROM TIMELESS CLASSICS TO CONTEMPORARY BESTSELLERS, THE FICTION SECTION IS BRIMMING WITH OPTIONS.

NON-FICTION

NON-FICTION ENTHUSIASTS CAN FIND BIOGRAPHIES, SELF-HELP BOOKS, HISTORICAL TEXTS, AND MORE.

TEXTBOOKS

STUDENTS CAN ACCESS TEXTBOOKS ON A WIDE RANGE OF SUBJECTS, HELPING REDUCE THE FINANCIAL BURDEN OF EDUCATION.

CHILDREN'S BOOKS

PARENTS AND TEACHERS CAN FIND A PLETHORA OF CHILDREN'S BOOKS, FROM PICTURE BOOKS TO YOUNG ADULT NOVELS.

ACCESSIBILITY FEATURES OF EBOOK SITES

EBOOK SITES OFTEN COME WITH FEATURES THAT ENHANCE ACCESSIBILITY.

AUDIOBOOK OPTIONS

MANY SITES OFFER AUDIOBOOKS, WHICH ARE GREAT FOR THOSE WHO PREFER LISTENING TO READING.

ADJUSTABLE FONT SIZES

YOU CAN ADJUST THE FONT SIZE TO SUIT YOUR READING COMFORT, MAKING IT EASIER FOR THOSE WITH VISUAL IMPAIRMENTS.

TEXT-TO-SPEECH CAPABILITIES

TEXT-TO-SPEECH FEATURES CAN CONVERT WRITTEN TEXT INTO AUDIO, PROVIDING AN ALTERNATIVE WAY TO ENJOY BOOKS.

TIPS FOR MAXIMIZING YOUR EBOOK EXPERIENCE

TO MAKE THE MOST OUT OF YOUR EBOOK READING EXPERIENCE, CONSIDER THESE TIPS.

CHOOSING THE RIGHT DEVICE

WHETHER IT'S A TABLET, AN E-READER, OR A SMARTPHONE, CHOOSE A DEVICE THAT OFFERS A COMFORTABLE READING EXPERIENCE FOR YOU.

ORGANIZING YOUR EBOOK LIBRARY

USE TOOLS AND APPS TO ORGANIZE YOUR EBOOK COLLECTION, MAKING IT EASY TO FIND AND ACCESS YOUR FAVORITE TITLES.

SYNCING ACROSS DEVICES

MANY EBOOK PLATFORMS ALLOW YOU TO SYNC YOUR LIBRARY ACROSS MULTIPLE DEVICES, SO YOU CAN PICK UP RIGHT WHERE YOU LEFT OFF, NO MATTER WHICH DEVICE YOU'RE USING.

CHALLENGES AND LIMITATIONS

DESPITE THE BENEFITS, FREE EBOOK SITES COME WITH CHALLENGES AND LIMITATIONS.

QUALITY AND AVAILABILITY OF TITLES

NOT ALL BOOKS ARE AVAILABLE FOR FREE, AND SOMETIMES THE QUALITY OF THE DIGITAL COPY CAN BE POOR.

DIGITAL RIGHTS MANAGEMENT (DRM)

DRM CAN RESTRICT HOW YOU USE THE EBOOKS YOU DOWNLOAD, LIMITING SHARING AND TRANSFERRING BETWEEN DEVICES.

INTERNET DEPENDENCY

ACCESSING AND DOWNLOADING EBOOKS REQUIRES AN INTERNET CONNECTION, WHICH CAN BE A LIMITATION IN AREAS WITH POOR CONNECTIVITY.

FUTURE OF FREE EBOOK SITES

THE FUTURE LOOKS PROMISING FOR FREE EBOOK SITES AS TECHNOLOGY CONTINUES TO ADVANCE.

TECHNOLOGICAL ADVANCES

IMPROVEMENTS IN TECHNOLOGY WILL LIKELY MAKE ACCESSING AND READING EBOOKS EVEN MORE SEAMLESS AND ENJOYABLE.

EXPANDING ACCESS

EFFORTS TO EXPAND INTERNET ACCESS GLOBALLY WILL HELP MORE PEOPLE BENEFIT FROM FREE EBOOK SITES.

ROLE IN EDUCATION

AS EDUCATIONAL RESOURCES BECOME MORE DIGITIZED, FREE EBOOK SITES WILL PLAY AN INCREASINGLY VITAL ROLE IN LEARNING.

CONCLUSION

IN SUMMARY, FREE EBOOK SITES OFFER AN INCREDIBLE OPPORTUNITY TO ACCESS A WIDE RANGE OF BOOKS WITHOUT THE FINANCIAL BURDEN. THEY ARE INVALUABLE RESOURCES FOR READERS OF ALL AGES AND INTERESTS, PROVIDING EDUCATIONAL MATERIALS, ENTERTAINMENT, AND ACCESSIBILITY FEATURES. SO

WHY NOT EXPLORE THESE SITES AND DISCOVER THE WEALTH OF KNOWLEDGE THEY OFFER?

FAQs

ARE FREE EBOOK SITES LEGAL? YES, MOST FREE EBOOK SITES ARE LEGAL. THEY TYPICALLY OFFER BOOKS THAT ARE IN THE PUBLIC DOMAIN OR HAVE THE RIGHTS TO DISTRIBUTE THEM. HOW DO I KNOW IF AN EBOOK SITE IS SAFE? STICK TO WELL-KNOWN AND REPUTABLE SITES LIKE PROJECT GUTENBERG, OPEN LIBRARY, AND GOOGLE BOOKS. CHECK REVIEWS AND ENSURE THE SITE HAS PROPER SECURITY MEASURES. CAN I DOWNLOAD EBOOKS TO ANY DEVICE? MOST FREE EBOOK SITES OFFER DOWNLOADS IN MULTIPLE FORMATS, MAKING THEM COMPATIBLE WITH VARIOUS DEVICES LIKE E-READERS, TABLETS, AND SMARTPHONES. DO FREE EBOOK SITES OFFER AUDIOBOOKS? MANY FREE EBOOK SITES OFFER AUDIOBOOKS, WHICH ARE PERFECT FOR THOSE WHO PREFER LISTENING TO THEIR BOOKS. HOW CAN I SUPPORT AUTHORS IF I USE FREE EBOOK SITES? YOU CAN SUPPORT AUTHORS BY PURCHASING THEIR BOOKS WHEN POSSIBLE, LEAVING REVIEWS, AND SHARING THEIR WORK WITH OTHERS.

