Sirius

Brightest Diamond in the Night Sky

Jay B. Holberg

Sirius

Brightest Diamond in the Night Sky

Springer

Published in association with
Praxis Publishing
Chichester, UK

PRAXIS

Dr Jay B. Holberg
Senior Research Scientist
Lunar and Planetary Laboratory
University of Arizona
Tucson
Arizona
U.S.A.

SPRINGER–PRAXIS BOOKS IN POPULAR ASTRONOMY
SUBJECT *ADVISORY EDITOR*: John Mason B.Sc., M.Sc., Ph.D.

ISBN 10: 0-387-48941-X Springer Berlin Heidelberg New York
ISBN 13: 978-0-387-48941-4 Springer Berlin Heidelberg New York

Springer is part of Springer-Science + Business Media (springer.com)

Library of Congress Control Number: 2006938990

Printed in Germany

Cover design: Jim Wilkie
Project management: Originator Publishing Services, Gt Yarmouth, Norfolk, UK

Printed on acid-free paper

Contents

Acknowledgments

The idea for a book on the star Sirius occurred to me in April 2001 while I was organizing some old 19th century observations of the orbit of the star's companion. At the time I had only a few vague notions of just how rich and varied this subject would become. As coincidence would have it, I was not alone in my interests in Sirius. Dr. Hugh Van Horn (National Science Foundation, retired), an expert on the stellar interiors and someone who has trained numerous graduate students in the study of white dwarfs, was also making similar plans. We became aware of each other's efforts at a White Dwarf Workshop in Naples, Italy in the summer of 2002. I remain most grateful to Hugh for generously allowing me to proceed, for his encouragement of my efforts, and for his careful reading of an early draft of this book. I am also very indebted to Professor François Wesemael of the University of Montreal, for his interest and encouragement in this project, for his comments on early drafts of this work, and for his help with French translations, including the Chacornac logbook from the Observatoire de Paris.

Many others have provided valuable help with various aspects of this book. Professor Volker Weidemann, Kiel University, was instrumental in helping to locate several sources of material from the early days of white dwarf research. Dr. Lotfi Ben Joffel of the Institut d'Astrophysique de Paris-CNRS (IAP) assisted with Arabic and Koranic material on Sirius, as did Bassel Reyahi, who provided a copy of an English summary of his book *Sirius: A Scientific and Qur'anic Perspective*. Dr. Alain Lecavelier of the Institut d'Astrophysique de Paris-CNRS (IAP) provided a very enjoyable tour of the Observatoire de Paris. Dr. Ben Joffel also helped with arrangements for my visit to the Observatoire de Paris library.

Much of the effort in writing this book involved my immersion into several subject areas in which I have had no professional training; this is particularly true of the Dogon material. I have profited enormously from discussions with John

McKinney, of Bamako, Mali. His intimate knowledge of the Dogon and the history of missionary work in Mali in the early 20th century was of great value. Dr. Geneviève Calame-Griaule, the daughter of Marcel Griaule, contributed her valuable insights into her father's work among the Dogon. Dr. Walter van Beek of the African Studies Centre, in Leiden, also shared his views and comments on the Dogon controversy. Silvio Bedinni and Erich Martel were very helpful with material and background on Benjamin Bannekar. Dr. Richard Wilkinson of the Classics Department of the University of Arizona provided his expert advice on the world of the Egyptians, through a careful reading of Chapter 1. Dr. Michael R. Molnar (Rutgers University, retired) provided his unique insights on the coinage of the ancient world, as well as superb images of ancient coins from his collection. Ms. Kate Magargal helped with some of the research for this book, and also provided material from her independent study project at the University of Arizona on the stellar lore and navigation techniques of the Polynesians. Dr. Jean-François Mayer, of the Freiberg University in Switzerland, supplied insight and suggestions on the subject of the Solar Temple.

A great deal of the material in this book comes from hard-to-find publications and 19th century archives. In this regard I wish to thank Brenda Corbin and Gregory Shelton at the U.S. Naval Observatory in Washington, D.C., for helping me locate many very difficult references as well as Ms. Mary Guierri at the National Optical Astronomy Observatories Library in Tucson for her patience and assistance. Some of the material on the discovery of the companion of Sirius, involving G. P. Bond and Alvan Clark, comes from the Harvard College Observatory Archives and I wish to thank Ms. Alison Doane, for her assistance with Harvard Plate files and the observatory logs. I am also most grateful to Josette Alexandre of the Library at the Observatoire de Paris for locating and providing copies of records from Jean Chacornac's 1862 observing logs and for facilitation of my visit to the Library. Thanks are also due Dr. Dan Lewis of the Huntington Library in San Marino, California, for providing copies of the correspondence between Walter Adams, Arthur Eddington, and Ejnar Hertzsprung. Additional thanks is due to Dr. Alan Batten of the Herzberg Institute of Astrophysics in Victoria, BC, for locating the image of Otto Struve and to Richard Dreiser of Yerkes Observatory and Alison Doane for providing other historical images.

A number of people were of great help in reading, correcting, and commenting on early drafts of this book. I particularly wish to thank my wife, Dr. Catharine J. Holberg, for her constant encouragement and patient reading of all of my drafts. Her questions and alternative suggestions of my explanations of various topics helped me enormously in shifting from my habit of writing for other astronomers, to that of the general public. I also wish to thank fellow physicist Dr. Bradford Barber, of the Nuclear Medicine Department of the University of Arizona, whose insightful comments and encouragement were of immense help. Professor James Liebert of Steward Observatory, the University of Arizona, also contributed many insightful comments on my final chapter. Dr. Bradley Schaefer of the Louisiana State University suggested a number of corrections and changes to Chapter 2. I wish to express my gratitude to Dr. Simon Mitton of St. Johns College, Cambridge, for his encouragement and wise council in helping to get this book published. Finally, much gratitude is due Clive Horwood of Praxis Publishing for the expeditious and professional manner in which this book was brought to press.

Introduction

This book was written to tell two stories. The first and most obvious is why the star known as Sirius has been regarded as an important fixture of the night sky by many civilizations and cultures, since the beginnings of history. A second, but related, narrative is the prominent part that Sirius has played in how we came to achieve our current scientific understanding of the nature and fate of the stars. These two topics have a long intertwined history, and the telling of one story eventually leads back to the other. Presently, new observations from space are revealing, in precise terms, how stars like Sirius and the sun have evolved and what they will ultimately become, while at the same time answering some of the age-old questions about Sirius.

The introduction to this book is a particularly good place to establish some of the well-known facts regarding Sirius. Of all the fixed stars in the night sky, Sirius is by far the brightest—almost twice as bright as its nearest rival, the star Canopus, which resides too far south to be viewed over much of the northern hemisphere. Only the sun, the moon, and at times the planets Venus, Jupiter, and on rare occasions Mars, appear brighter. Sirius, with its flashing brilliance, is a striking feature of the northern winter sky and has understandably drawn the attention of observers of the heavens for thousands of years. Sirius can be easily seen over most of the surface of the earth, except for a zone north of the Arctic Circle, where it never rises. Every year Sirius emerges from the glare of the sun in late July, and by year's end it hangs on the meridian at midnight. In late May it disappears from view, rejoining the sun for a period of slightly over two months. It was around this annual coming and going that certain ancient cultures and civilizations organized their religious year, and synchronized their calendars with the agricultural cycles. It was also surrounding Sirius that a host of elaborate legends and beliefs came into being.

Sirius has many names, astronomers recognize over fifty designations for the star, but the most prominent is Alpha Canis Majoris, the brightest star in the constellation Canis Major, Latin for the great dog. Over the centuries many beliefs have come to be associated with Sirius. Some of these beliefs still echo in such phrases as "the dog days of summer", which the ancient Romans understood well. Other old beliefs long ago fell from public consciousness—only to be revived and to grow into modern popular and scientific controversies. Still other notions regarding Sirius abound in various forms in the occult and new-age sections of bookstores—and in even greater profusion on the Internet. Although these beliefs may seem quite recent, many have their origins in the ancient lore surrounding Sirius: humans seem naturally drawn to its brilliance, and a surprising number of modern cults have nucleated around beliefs in which Sirius plays a prominent role.

Today we know Sirius as a rather typical star, with a surface temperature nearly twice that of the sun. The average temperature of the visible outer layers of its atmosphere is approximately 9400 K (16,900 F): this explains its striking blue–white appearance. Its apparent brightness is due to its relative proximity to the earth of about 8.6 light years. There are relatively few stars as hot as Sirius in the solar neighborhood. The most similar nearby star, Vega, lies at a distance of 26 light years from the sun, and consequently appears 3.76 times fainter than Sirius. Sirius has 2.03 times the mass and 1.80 times the radius of the sun, but it produces energy at a rate nearly 50 times greater. Regardless of its size and brightness, Sirius, for historical reasons, is astronomically classified as a dwarf star. We now know a great deal about Sirius and can calculate its history and its destiny with considerable confidence.

In spite of its celestial prominence, Sirius managed to conceal an important family secret, until some 160 years ago, when it was discovered to possess a strange faint companion. It is the nature of this tiny companion that has commanded most of the subsequent scientific interest in Sirius and which helped to revolutionize our understanding of how stars evolve and finally die. This small star has also provided a natural laboratory that first demonstrated some of the more striking discoveries of 20th century physics. It is the story of this remarkable companion that dominates the latter half of this book.

This book naturally divides itself into five parts. The first section concerns the ancient lore that surrounds Sirius: the ideas and legends of the ancient Egyptians, Greeks, and Romans, as well as those of other cultures such as the Islamic, and the Chinese. The second section begins the long journey towards a scientific understanding of the stars and Sirius, starting with the concepts of the ancient Greeks. This section also includes the critical period, beginning a little less than five hundred years ago, when Copernicus, Kepler, and Galileo helped to overthrow the old Greek ideas of the cosmos. Later in this period key figures, such as Isaac Newton, Edmond Halley, and others, played a prominent role in changing our ideas about the stars, their distances, and their motions. During this time two key developments occurred: the realization of just how far away the stars really are and the discovery of double stars. Both of these developments made possible the appreciation of such stellar properties as their true luminosities and masses. The second section of the book concludes with the fascinating story of how the mysterious companion of Sirius was first theoretically deduced in 1844, and then finally discovered in 1862. The third section of the book follows 19th and early 20th century astronomers as they began using new instruments and techniques to make some the first physical measurements of the stars: including temperatures and radii, and the determination of the chemical composition of the atmospheres of the stars. This section concludes with the highly successful applications of these developments, and traces the new ideas of quantum physics as they were used to determine how the stars produce their energy and how they evolve and die. The fourth section of this book takes an in-depth look at some of the modern mythologies that surround Sirius. These include: the idea that Sirius appeared as a prominently red star some two thousand years ago; that the Sirius system may conceal a third member; the fascinating way that Sirius figures in the cosmogony of the Dogon tribe of west central Africa; and the story of a modern cult that made Sirius a central aspect of their beliefs, with disastrous consequences. The fifth and final section of the book takes an up-to-date scientific look at what new observations of Sirius from space have revealed. It concludes with the stellar evolution of Sirius and its companion, how they appeared in the past, how they will appear in the future, and how this evolution contrasts with that of our sun.

I was drawn to Sirius more than twenty years ago, when I first observed the star with the ultraviolet spectrometer on board the *Voyager 2* spacecraft, while it was traveling between Saturn and Uranus. I was hooked, and have continued making observations of Sirius using other spacecraft ever since. During most of this period, my interest was primarily astronomical and centered on obtaining better estimates of the mass and radius of the white dwarf companion to Sirius. Five years ago, however, I became involved in a project to observe this white dwarf with the *Hubble Space Telescope* in an effort to improve the determination of its orbit. Part of this study involved a recomputation of the orbit, from all of the old visual observations going back over 160 years. This ultimately required collecting thousands of observations scattered through scores of old journals. It proved necessary to visit libraries across the country to locate some of the more obscure older references. Through this process I became aware of the scope of the history of Sirius and began to appreciate how influential the star and its companion have been in the development of modern stellar astrophysics. It seemed to me that the only adequate way to tell this story was to go all the way back to the beginning, to ancient Egypt, and conclude with an up-to-date account of what we are still learning today about this remarkable star. I hope that this book accomplishes these objectives.

Jay Holberg

NOTES ON TERMINOLOGY, UNITS AND DATING CONVENTIONS

Astronomy, with its huge distances, enormous masses, and unfathomable time spans, faces a problem in conveying its discoveries to the general public. For the distances to the stars, I use variously, the light year (the distance that light travels in one year), and the parsec (the distance at which the diameter of the earth's orbit would appear to subtend an angle of one arc second). (One parsec = 0.306 light years = 3.09×10^{18} centimeters = 1.92×10^{13} miles, where in scientific notation, the superscripts following the ten indicate the number of trailing significant zeros in the quantity.) In discussing the stars I have tried, wherever possible, to use relative units, such as the mass, radius, and luminosity of the sun. Elsewhere, when discussing other aspects of the stars I follow the astronomical practice of using the centimeter–gram–second version of the metric system. In these units the solar mass is 1.99×10^{33} grams, the solar radius is 6.96×10^{10} cm, and the solar luminosity (its total power output) is 3.85×10^{33} ergs/second $= 3.85 \times 10^{26}$ Watts. In addition to the parsec and light year astronomers have other unique units of measurement, which are ingrained in the field. Some of these are the Angstrom unit for measuring the wavelengths of light ($1\,\text{Å} = 10^{-9}$ m $= 3.94 \times 10^{-10}$ inches); for example, the wavelength of the red line of hydrogen is 6656 Å. In the solar system the convenient unit of distance is the mean distance of the earth from the sun, the Astronomical Unit ($1\,\text{AU} = 1.50 \times 10^{8}$ km = 93 million miles). Stellar magnitudes are another area of potential confusion. Magnitudes are basically negative logarithmic measures of stellar brightness, so that the brightest stars have the lowest magnitudes and the faintest the highest. The basis of this system is Vega, defined to be magnitude 0. The step size of 1 magnitude is a factor of 2.51 in brightness. Thus, Sirius with a magnitude of -1.44 is 3.77 times *brighter* than Vega, while the faint companion of Sirius, at magnitude 8.48, is 2470 times *fainter* than Vega. For other potentially unfamiliar, or technical, terms there is also a Glossary (see Appendix A, p. 225).

Mathematics is the native language of the physical sciences, but it creates barriers for some readers. For this reason I have endeavored to make limited use of a few simple equations, such as proportions and inverse relations that are needed to express important concepts. Wherever practical, this usage is accompanied by written statements of the relations being expressed. For more complex relations, I have tried to use graphs and figures. I also presume the reader is familiar with the shorthand of exponents, and logarithms for dealing with large numbers.

For familiar historical reasons, I have tended to use English units when discussing instrumentation, prior to the 20th century; for example, in referring to telescope apertures and focal lengths, such as the Clark's $18\frac{1}{2}$-inch 1862 refractor. Dates and spelling are another issue. I use the traditional Latin eras, BC and AD, to designate historical dates, and use Julian calendar dates prior to the introduction of the Gregorian Calendar in 1582, unless otherwise noted. For Egyptian dates and spellings I have adopted the conventions of the *Oxford Encyclopedia of Ancient Egypt*.

Figures

Abbreviations and Acronyms

ANS	Astronomical Netherlands Satellite
AU	Astronomical Unit
CCD	Charged Coupled Device
DA	A white dwarf having a pure hydrogen atmosphere
EUV	Extreme UltraViolet
EUVE	*Extreme UltraViolet Explorer*
FUSE	*Far Ultraviolet Spectroscopic Explorer*
HST	*Hubble Space Telescope*
LHS	Luyten Half arc-Second stars
LTT	Luyten Two Tenths
NICMOS	*Near Infrared Camera and Multi-Object Spectrometer*
ROSAT	*The Roentgen Satellite*
STIS	*Space Telescope Imaging Spectrograph*