Patrick Moore's Practical Astronomy Series

Other Titles in this Series

Navigating the Night Sky
How to Identify the Stars and Constellations
Guilherme de Almeida

Observing and Measuring Visual Double Stars
Bob Argyle (Ed.)

Observing Meteors, Comets, Supernovae and other transient Phenomena
Neil Bone

Human Vision and The Night Sky
How to Improve Your Observing Skills
Michael P. Borgia

How to Photograph the Moon and Planets with Your Digital Camera
Tony Buick

Practical Astrophotography
Jeffrey R. Charles

Pattern Asterisms
A New Way to Chart the Stars
John Chiravalle

Deep Sky Observing
The Astronomical Tourist
Steve R. Coe

Visual Astronomy in the Suburbs
A Guide to Spectacular Viewing
Antony Cooke

Visual Astronomy Under Dark Skies
A New Approach to Observing Deep Space
Antony Cooke

Real Astronomy with Small Telescopes
Step-by-Step Activities for Discovery
Michael K. Gainer

The Practical Astronomer's Deep-sky Companion
Jess K. Gilmour

Observing Variable Stars
Gerry A. Good

Observer's Guide to Stellar Evolution
The Birth, Life and Death of Stars
Mike Inglis

Field Guide to the Deep Sky Objects
Mike Inglis

Astronomy of the Milky Way
The Observer's Guide to the Southern/Northern Sky Parts 1 and 2 hardcover set
Mike Inglis

Astronomy of the Milky Way
Part 1: Observer's Guide to the Northern Sky
Mike Inglis

Astronomy of the Milky Way
Part 2: Observer's Guide to the Southern Sky
Mike Inglis

Observing Comets
Nick James and Gerald North

Telescopes and Techniques
An Introduction to Practical Astronomy
Chris Kitchin

Seeing Stars
The Night Sky Through Small Telescopes
Chris Kitchin and Robert W. Forrest

Photo-guide to the Constellations
A Self-Teaching Guide to Finding Your Way Around the Heavens
Chris Kitchin

Solar Observing Techniques
Chris Kitchin

How to Observe the Sun Safely
Lee Macdonald

The Sun in Eclipse
Sir Patrick Moore and Michael Maunder

Transit
When Planets Cross the Sun
Sir Patrick Moore and Michael Maunder

Light Pollution
Responses and Remedies
Bob Mizon

Astronomical Equipment for Amateurs
Martin Mobberley

The New Amateur Astronomer
Martin Mobberley

Lunar and Planetary Webcam User's Guide
Martin Mobberley

(Continued after Index)

Astrophysics is Easy! An Introduction for the Amateur Astronomer

Mike Inglis

Springer

Dr Mike Inglis FRAS
SUNY
inglism@sunysuffolk.edu

Library of Congress Control Number: 2007925262

Patrick Moore's Practical Astronomy Series ISSN 1617-7185
ISBN-13: 978-1-85233-890-9 e-ISBN-13: 978-1-84628-736-7
Springer Science+Business Media
Springeronline.com

For Dad and Alan, who are already amongst the stars

Contents

Preface and Thanks

Once again, I took paper to pen, and began a journey to explain the mysterious and beautiful complexities of stars, galaxies, and the material that lies between them. It was a journey that took many roads with many side-turnings as I often spent many long, lonely hours worrying whether I was being too obtuse, or at times patronizing. It is a fact that many amateur astronomers are very knowledgeable of the subject that they pursue with a passion. However, the book eventually came into sight, and this, for me a mammoth task, was completed. You now hold it in your hands!

Throughout the entire process of writing the book, I was lucky enough to have the support of my publisher, Harry Blom, who, as a professional astronomer himself, knows only too well that astronomy authors are a breed apart and need to be pampered and dealt with extreme patience. Thanks, Harry—I owe you a pint. I must also thank my great friend John Watson, also associated with Springer, who gave the initial thumbs-up when I first outlined the idea for the book. John is an amateur astronomer himself, so he knows exactly what should go into a book, and perhaps even more importantly, what should be left out! I also owe you a pint.

I am fortunate to have been taught astronomy by some of the world's leading experts, and it was, and still is, a privilege to know them. In my humble opinion, not only are they superb astronomers, whether theoretical or observational, but also wonderful educators. They are Chris Kitchin, Alan McCall, Iain Nicolson, Robert Forrest, and the late Lou Marsh. They were the best teachers I ever had.

During the time spent writing this book, usually alone, usually at night, usually tired, I had the company of some wonderful musicians whose music is truly sublime. They are Steve Roach, David Sylvian, John Martyn, and the Blue Nile.

Many friends have helped raise my spirits during those times when not all was going right according to the Inglis Master Plan. They listened to me complain, laughed at my jokes, and helped me remain sane—for the most part. So I want to say thank you to my British friends—Pete, Bill, Andy and Stuart—and my new friends here in the USA—Sean and Matt. It is nice to know that beer is the universal lubricant of friendship, whether it is McMullens or Blue Point.

Astronomy is a very important part of my life, but not as important as my family; my brother, Bob, is a great friend and a strong source of support, especially during my formative years as an astronomer. My mother, Myra, is amazing, full of energy, spirit, and laughter, and has been supportive of my dream to be an astronomer since I was knee-high to a tripod. She is truly an example to us all. And of course Karen, my partner. I am not exaggerating when I say this book would not have seen the light of day without her help. *"Diolch Cariad."*

For making my life so much fun, cheers!

Dr. Mike Inglis
Long Island, USA, 2006

Acknowledgements

I would like to thank the following people and organisations for their help and permission to quote their work and for the use of the data they provided:

The European Space Organization, for permission to use the *Hipparcos* and *Tycho* catalogues.

My colleagues at *Suffolk County Community College*, USA, for their support and encouragement.

The astronomers at *Princeton University*, USA, for many helpful discussions on the whole process of star formation.

The astronomers at the *University of Hertfordshire*, UK, for inspirational lectures and discussions.

Gary Walker, of the *American Association of Variable Star Observers*, for information on the many types of variable stars.

Cheryl Gundy, of the *Space Telescope Science Institute*, USA, for supplying astrophysical data on many of the objects discussed.

Dr. Stuart Young, of the *University of Hertfordshire*, UK, for discussions and information relating to star formation and the Hertzsprung-Russell diagram, and impromptu tutorials on many aspects of astronomy.

Dr. Chris Packham, of the *University of Florida*, USA, for his help on pointing out several mistakes I have made over the years and for his input regarding AGNs.

Karen Milstein, for the superb and professional work that she did reading through the initial proofs of the book, when there seemed to be more errors than facts!

The *Smithsonian Astrophysical Observatory*, USA, for providing data on many stars and star clusters.

Robert Forrest, of the *University of Hertfordshire Observatory*, UK, for use of his observing notes.

Michael Hurrell and Donald Tinkler of the *South Bayfordbury Astronomical Society*, UK, for use of their observing notes.

In developing a book of this type, which presents a considerable amount of detail, it is nearly impossible to avoid error. If any arise, I apologize for the oversight, and I would be more than happy to hear from you. Also, if you feel that I have omitted a star or galaxy that you think would better describe a certain aspect of astrophysics, please feel free to contact me at: inglism@sunysuffolk.edu. I can't promise to reply to all e-mails, but I will certainly read them.

Overview

To most normal people, astrophysics—the science of stars, galaxies, and the universe we live in—would seem to be a topic suited to a university-level textbook, and so the idea of a guide to astrophysics for the amateur astronomer may not, on first appearance, make any sense. However, let me assure you that anyone can understand how a star is born, lives its life, and dies, how galaxies are thought to evolve and what their shape can tell us about their origins and age, and even how the universe began and how it may end. In fact, very little mathematics is needed, and when it is used, it is only a matter of multiplication, division, subtraction, and addition![1]

What is more, there are many wonderful objects that can be observed in the night sky that will illustrate even the most obtuse astrophysics concepts. All one needs is a willingness to learn and a dark night sky.

Learning about, say, the processes that give rise to star formation, or what happens to a very large star as it dies, or even why some galaxies are spiral in shape whereas others are elliptical can add another level of enjoyment and wonder to an observing session. For instance, many amateur astronomers are familiar with the star *Rigel*, in the constellation *Orion*, but how many of you know that it is a giant star, with a mass more than 40 times that of the Sun, and it is nearly half a million times more luminous than the Sun? How many know that the closest large galaxy, *M31* in Andromeda, has a supermassive black hole lurking at its center with a mass more than 50 million times that of the Sun? Or that the *Orion Nebula,* regarded by many as the premier nebula in the sky, is in fact an enormous stellar nursery where stars are actually being born as you read this book? Knowing details such as these can add another level of enjoyment to your observing sessions.

Each section of this book addresses a specific aspect of astrophysics. The first part focuses on the concepts needed for a complete understanding of the remainder of the book, and as such will be divided into specific topics, such as the brightness, mass, and distance of stars, and so on. Then we will look at the tools of an astronomer, namely spectroscopy. It is true to say that nearly all of what we know about stars and galaxies was and is determined by this important technique. We shall spend a fair amount of time looking at something called the Hertzsprung-Russell diagram; if ever a single concept or diagram could epitomize a star's life (and even a star cluster's life), the *H-R* diagram, as it is known, is the one to do it. It is perhaps the most important and useful concept in all of stellar evolution, and it is fair to say that once you understand the *H-R* diagram, you understand how a star evolves.

Moving on to the objects themselves, we start with the formation of stars from dust and gas clouds, and conclude with the final aspect of a star's life, which can end in a spectacular event known as a supernova, resulting in the formation of a neutron star and perhaps a black hole!

On a grander scale, we delve into galaxies, their shapes (or morphology, as it is called), distribution in space, and origins.

The topics covered are chosen specifically so that examples of objects under discussion can be observed; thus, at every point in our journey, an observing section will describe the objects that best demonstrate the topics discussed. Many of the objects, whether they be stars, nebulae, or galaxies, will be visible with modest optical instruments, and many with the naked eye. In a few exceptional cases, a medium-aperture telescope may be needed. Of course, not all observable objects will be presented, but just a representative few (usually the brightest examples). These examples will allow you to learn about stars, nebulae, and galaxies at your own pace, and they will provide a detailed panorama of the amazing objects that most of us observe on a clear night.

For those of you who have a mathematical mind, some mathematics will be provided in the specially labelled areas. But, take heart and fear not—you do not have to understand any mathematics to be able to read and understand the book; it is only to highlight and further describe the mechanisms and principles of astrophysics. However, if you are comfortable with maths, then I recommend that you read these sections, as they will further your understanding of the various concepts and equip you to determine such parameters as a star's age and lifetime, distance, mass, and brightness. All of the maths presented will be simple, of a level comparable to that of a 4th-year school student, or an 8th-grader. In fact, to make the mathematics simpler, we will use rough (but perfectly acceptable) approximations and perform back-of-the-envelope calculations, which, surprisingly, produce rather accurate answers!

An astute reader will notice immediately that there are no star maps in the book. The reason for this is simple: in previous books that I have written, star maps were included, but their size generated some criticism. Some readers believed the maps were too small, and I tend to agree. To be able to offer large and detailed star maps of every object mentioned in this book would entail a doubling of its size, and probably a tripling of cost. With the plethora of star-map software that is available these days, it is far easier for readers to make their own maps than to present any here.

A final point I wish to emphasize here is that the book can be read in several ways. Certainly, you can start at the beginning and read through to the end. But if you are particularly interested in, say, supernovae and the final stages of a star's life, or in galaxy clusters, there is no reason that you should not go straight to that section. Some of the nomenclature might be unfamiliar, but I have attempted to write the book with enough description that this should not be a problem. Also, many of you will undoubtedly go straight to the observing lists. Read the book in the way that is most enjoyable to you.

Without further ado, let us begin a voyage of discovery…

Note

1. Well, o.k.—we do use powers of ten occasionally, and numbers multiplied by themselves from time to time. But nothing else…honest!

CHAPTER ONE

Tools of the Trade

1.1 Distance

To determine many of the basic parameters of any object in the sky, it is first necessary to determine its proximity to us. We shall see later how this is vitally important because a star's bright appearance in the night sky could signify that it is close to us or that it is an inherently bright star. Conversely, some stars may appear faint because they are at immense distance from us or because they are very faint stars in their own right. We need to be able to determine which is the correct explanation.

Determining distance in astronomy has always been, and continues to be, fraught with difficulty and error. There is still no consensus as to which is the best method, at least for distances to other galaxies and to the farthest edges of our own galaxy—the Milky Way. The oldest method, still used today, is probably the most accurate, especially for determining the distances to stars.

This simple technique is called *Stellar Parallax.* It is basically the angular measurement when the star is observed from two different locations on the Earth's orbit. These two positions are generally six months apart, and so the star will appear to shift its position with respect to the more distant background stars. The parallax (p) of the star observed is equal to half the angle through which its apparent position appears to shift. The larger the parallax (p), the smaller the distance (d) to the star. Figure 1.1 illustrates this concept.

If a star has a measured parallax of 1 arcsecond (1/3600th of a degree) and the baseline is 1 astronomical unit (AU), which is the average distance

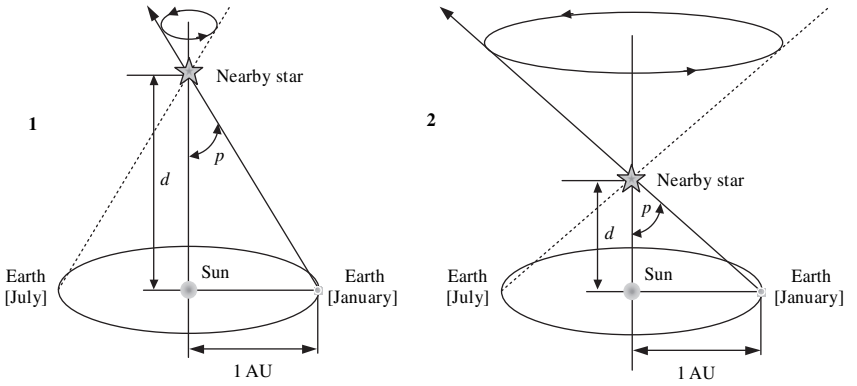

Figure 1.1. Stellar Parallax. (1) The Earth orbits the Sun, and a nearby star shifts its position with respect to the background stars. The parallax (p) of the star is the angular measurement of the Earth's orbit as seen from the star. (2) The closer the star, the greater the parallax angle (PA).

from the Earth to the Sun, then the star's distance is 1 parsec (pc)—"the distance of an object that has a **par**allax of one **sec**ond of arc." This is the origin of the term parsec, which is the unit of distance used most frequently in astronomy.[1]

The distance (d) of a star in parsecs is given by the reciprocal of its parallax (p), and is usually expressed as thus:

$$d = \frac{1}{p}$$

Thus, using the above equation, a star with a measured parallax of 0.1 arcseconds is at a distance of 10 pc, and another with a parallax of 0.05 arcseconds is 20 pc distant.

Box 1.1: Relationship between Parallax and Distance

$$d = \frac{1}{p}$$

d = the distance to a star measured in pc
p = the parallax angle of the measured star in arcseconds

This simple relationship is a significant reason that most astronomical distances are expressed in parsecs, rather than light years (l.y.). The brightest star in the night sky is

Sirius (α *Canis Majoris*), which has a parallax of 0.379 arcseconds. Thus, its distance from the Earth is:

$$d = \frac{1}{p} = \frac{1}{0.379} = 2.63\,\text{pc}$$

Note that 1 pc is equivalent to 3.26 l.y. This distance can also be expressed as:

$$d = 2.63 \times \frac{3.26\,\text{l.y.}}{1\,\text{pc}} = 8.6\,\text{l.y.}$$

Surprisingly, all known stars have a parallax angle smaller than 1 arcsecond, and angles smaller than 0.01 arcseconds are very difficult to measure from Earth due to the effects of the atmosphere; this limits the distance measured to about 100 pc (1/0.01). However, the satellite Hipparcos, launched in 1989, was able to measure parallax angles to an accuracy of 0.001 arcseconds, which allowed distances to be determined to about 1000 pc.[2]

But, this great advance in distance determination is useful only for relatively close stars. Most of the stars in the Galaxy are too far for parallax measurements to be taken. Another method must be resorted to.

Many stars actually alter their brightness (these are the variable stars). Several of them play an important role in distance determination. Although we shall discuss their properties in far greater detail later, it is instructive to mention them here.

Two types of variable stars are particularly useful in determining distances. These are the *Cepheid* variable stars and *RR Lyrae* variable stars.[3] Both are classified as *pulsating variables*, which are stars that actually change their diameter over a period of time. The importance of these stars lies in the fact that their average brightnesses, or luminosities,[4] and their periods of variability are linked. The longer the time taken for the star to vary its brightness (the period), the greater the luminosity. This is the justifiably famous *Period–Luminosity* relationship.[5] The period of a star is relatively easy to measure, and this is something that many amateur astronomers still do. Once the period has been measured, you can determine the star's luminosity. By comparing the luminosity, which is a measure of the intrinsic brightness of the star, with the brightness it appears to have in the sky, its distance can be calculated.[6] Using Cepheid as a reference, distances of up to around 60 million l.y. have been determined.

A similar approach is taken with the RR Lyrae stars, which are less luminous than Cepheids and have periods of less than a day. These stars allow distances to about 2 million l.y. to be determined.

Another method of distance determination is that of spectroscopic parallax, whereby determining a star's spectral classification can lead to a measure of its intrinsic luminosity, which can then be compared with its apparent brightness to determine its distance.

There are other distance determination methods used for the objects farthest from us—galaxies. These methods include the Tully Fisher method and the very famous Hubble Law.

All of these methods—Cepheid variable, Tully Fisher, and the Hubble Law—will be addressed in greater detail later in the book.

A final note on distance determination is in order. Do not be fooled into thinking that these methods produce exact measurements. They do not. A small amount of error is inevitable. This error is usually about 10 or 25%, and even an error of 50% is not unheard of. Remember that a 25% error for a star estimated to be at a distance of 4000 l.y. means it could be anywhere from 3000 to 5000 l.y. away. Table 1.1 lists the 20 nearest stars.

Let us now discuss some of the nearest stars in the night sky from an observational point of view. The list (Table 1.1) is by no means complete but includes those stars that are easily seen. Many of the nearest stars are very faint, and thus present an observing challenge; they are not included here.

Throughout the book, I have used the following nomenclature with regard to stars: the first item will be its common name, followed by its scientific designation. The next item will be its position in right ascension and declination. The final item will identify the months when the star is best positioned for observation (the month in bold type is the most favorable time of observation).

The next line will present standard data and information pertinent to the star under discussion: its apparent magnitude, followed by its absolute magnitude, other specific data relating to the star, and, finally, the constellation in which the star resides.

Table 1.1. The 20 nearest stars in the sky

	Star	Distance, l.y.	Constellation
1	Sun	----	----
2	Proxima Centauri	4.22	Centaurus
3	Alpha Centauri A[7]	4.39	Centaurus
4	Barnard's Star	5.94	Ophiuchus
5	Wolf 359	7.8	Leo
6	Lalande 21185	8.31	Ursa Major
7	Sirius A[7]	8.60	Canis Major
8	UV Ceti A[7]	8.7	Cetus
9	Ross 154	9.69	Sagittarius
10	Ross 248	10.3	Andromeda
11	Epsilon Eridani	10.49	Eradinus
12	HD 217987	10.73	Piscis Austrinus
13	Ross 128	10.89	Virgo
14	L 789–6 A[7]	11.2	Aquarius
15	61 Cygni A	11.35	Cygnus
16	Procyon A[7]	11.42	Canis Minoris
17	61 Cygni B	11.43	Cygnus
18	HD173740	11.47	Draco
19	HD 173739	11.64	Draco
20	GX Andromadae[7]	11.64	Andromeda

1.1.1 The Nearest Stars to Us[9]

Proxima Centauri	**V645 Cen**	**$14^h29.7^m$**	**−62°41′**	Mar-**Apr**-May
$11.01_v m$[8]	**15.45M**	**4.22 l.y.**	**0.772″**	**Centaurus**

This is the second-closest star to the Earth and the closest star to the Solar System, and thus it is included albeit faint. It is a red dwarf star and also a flare star with frequent bursts, having maximum amplitude of around one magnitude. Recent data indicate that it is not, as previously thought, physically associated with *α Centauri*, but is, in fact, on a hyperbolic orbit around the star and just passing through the system.

Sirius A[α Canis Majoris]	**$06^h45.1^m$**	**−16°43′**	Dec-**Jan**-Feb
−1.44 m	**1.45M**	**8.6 l.y. 0.379″**	**Canis Major**

Sirius, also known as the Dog Star, is a lovely star to observe. It is the sixth-closest and brightest star in the sky. It is famous among amateur astronomers for the exotic range of colors it exhibits due to the effects of the atmosphere. It also has a dwarf star companion—the first to be discovered. A dazzling sight in any optical device.

Procyon	**α Canis Minoris**	**$07^h39.3^m$**	**+56°13′**	Dec-**Jan**-Feb
0.40 m	**2.68M**	**11.41 l.y.**	**0.283″**	**Canis Minor**

Procyon is the fifteenth-nearest star and the eighth brightest. Like its neighbor *Sirius*, Procyon has a white dwarf companion star, but it is not visible through amateur telescopes.

Barnard′s Star[HD21185]	**$17^h57.8^m$**	**+4°38′**		Apr-**May**-Jun
9.54 m	**13.24M**	**5.94 l.y.**	**0.549″**	**Ophiuchus**

The third-closest star is a red dwarf. What makes this star so famous is that it has the largest proper motion of any star[10]—0.4 arcseconds per year. *Barnard's Star*, also known as *Barnard's Runaway Star*, has a velocity of 140 km per second; at this rate, it would take 150 years for the star to move the distance equivalent to the Moon's diameter across the sky. It has also been thought that the star belonged to the Galaxy's *Halo Population*.

61 Cygni A	**V1803 Cyg**	**$21^h06.9^m$**	**+38°45′**	Jul-**Aug**-Sep
5.20_v m	**7.49M**	**11.35 l.y.**	**0.287″**	**Cygnus**

This is a very nice double star with separation 30.3 arcseconds and a PA of 150° (see section 3.7). Both stars are dwarfs and have a nice orange color. It is famous for being the first star to have its distance measured successfully, by F. W. Bessel in 1838, using stellar parallax.

GX And	**Grb34**	**$00^h18.2^m$**	**+44°01′**	Aug-**Sep**-Oct
8.09_v m	**10.33M**	**11.65 l.y.**	**0.280″**	**Andromeda**

This is one of a noted red dwarf binary system with the primary star itself a spectroscopic double star. Also known as *Groombridge 34 A*, *GX And* is located about 1/4° north of 26 Andromedae.

Lacille	**HD 217987**[11]	**$23^h05.5^m$**	**−35°52′**	Aug-**Sep**-Oct
7.35m	**9.76M**	**10.73 l.y.**	**0.304″**	**Pisces Austrinus**

This is a red dwarf star with the fourth-fastest proper motion of any known star, traversing a distance of nearly 7 arcseconds a year and thus would take about 1000 years to cover the angular distance of the full Moon, which is 1/2°. *Lacille* is in the extreme southeast of the constellation, about 1° SSE of *π Pisces Austrinus*.

UV Ceti	**L726 − 8A**	**$01^h38.8^m$**	**−17°57′**	Sep-**Oct**-Nov
12.56_vm	**15.42M**	**8.56 l.y.**	**0.381″**	**Cetus**

The seventh-closest star is a red dwarf system, which is rather difficult, but not impossible, to observe. The prefix UV indicates that the two components are flare stars; the fainter star is referred to in older texts as "*Luytens Flare Star*" after its discoverer, W. J. Luyten, who first observed it in 1949.

Epsilon Eridani	**HD 22049**	**$03^h32.9^m$**	**−09°77′**	Oct-**Nov**-Dec
3.72m	**6.18M**	**10.49 l.y.**	**0.311″**	**Eridanus**

The tenth-closest star is a naked-eye object. Recent observations indicate that there may be an unseen companion star with a very small mass, approximately 0.048 that of the Sun.

1.2 Brightness and Luminosity

There is an immense number of stars and galaxies in the sky, and for the most part they are powered by the same process that fuels the Sun. This does not mean that they are all alike. Stars differ in many respects, such as mass, size, and so on. One of the most important characteristics is their *luminosity*, *L*. Luminosity is usually measured in *watts* (W), or as a multiple of the Sun's luminosity,[12] $L_\odot$. This is the amount of energy that the star emits each second. However, we cannot measure a star's luminosity directly because its brightness as seen from Earth depends on its distance as well as its true luminosity. For instance, *α Centauri A* and the Sun have similar luminosities, but, in the night sky, *α Centauri A* is a dim point of light because it is about 280,000 times farther from the Earth than the Sun.

To determine the true luminosity of a star, we need to know its *apparent brightness*, which we define as the amount of light reaching the Earth per unit

area.[13] As light moves away from the star, it will spread out over increasingly larger regions of space, obeying what is termed an *inverse square law*. If the sun were to be viewed at a distance twice that of the Earth, then it would appear fainter by a factor of $2^2 = 4$. If we view it from a distance 10 times that of the Earth, it would appear 10^2 times fainter. If we were to observe the Sun from the same location as α *Centauri A*, it would be dimmed by $270,000^2$, which is 70 billion times!

The inverse square law describes the amount of energy that enters, say, your eye or a detector. Imagine an enormous sphere of radius d, centered on a star. The amount of light that will pass through a square meter of the sphere's surface is the total luminosity (L) divided by the total surface area of the sphere. Now, as the surface area of a sphere is given by the formula $4\pi d^2$, you will understand that, as the sphere increases, d increases, and so does the amount of luminosity. You may understand now why the amount of luminosity that arrives at the Earth from a star is determined by the star's distance.

This quantity, the amount of energy that arrives at our eye, is the apparent brightness mentioned earlier (sometimes just called the brightness of a star). It is measured in watts per square meter (W/m^2).

Box 1.2: The Luminosity Distance Formula

The relationship between distance, brightness, and luminosity is given as:

$$b = \frac{L}{4\pi d^2}$$

where b is the brightness of the star in W/m^2
L is the star's luminosity in W
d is the distance to the star in m

Example:
Let us apply this formula to *Sirius*, which is at a distance of 8.6 l.y.
[Note: 1 l.y. is 9.46×10^{15} m; thus 8.6 l.y. is $8.6 \times 9.46 \times 10^{15} = 8.14 \times 10^{16}$ m]

$$b = \frac{3.86 \times 10^{26}\,\mathrm{W}}{4\pi\,(8.14 \times 10^{16}\,\mathrm{m})^2}$$

$$b = 1 \times 10^{-7}\,\mathrm{W/m^2}$$

This means that, say, a detector of area $1\,m^2$ (possibly a reflecting telescope) will receive approximately one-ten millionth of a watt!

Astronomers measure a star's brightness with light-sensitive detectors, and this procedure is called *photometry*.