50 THINGS TO SEE ON THE MOON

A FIRST-TIME STARGAZER'S GUIDE

John A. Read

With foreword by David M. F. Chapman

"ONE SMALL STEP FOR A MAN, ONE GIANT LEAP FOR MANKIND."

— Neil Armstrong, first man on the Moon

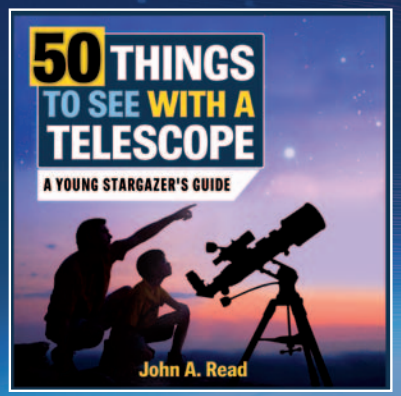
Have you always wanted to explore the Moon like Neil Armstrong or the eleven other astronauts who have walked on its surface? You can tour the Moon from your own backyard with a small telescope or binoculars. This book will point you to the Sea of Tranquility (the landing spot for Apollo 11) and many other fascinating features you can spot on the Moon's surface.

Beginning with the New Moon, as each day passes, an additional slice of the Moon becomes visible. With each new slice comes new craters, lunar seas and jagged mountain ranges. This easy-to-use, illustrated reference book enables everyone, young and old, to better appreciate our nearest neighbour in space.

JOHN A. READ has taught people of all ages how to observe the Moon and other celestial objects with a backyard telescope. He is now a telescope operator at Halifax's Burke-Gaffney Observatory, sits on the board of directors at the Halifax Centre of the Royal Astronomical Society of Canada and is studying astrophysics at Saint Mary's University. He lives in Halifax, Nova Scotia.

Astronaut Gene Cernan in the lunar rover.
(Image credit: NASA)

ALSO BY JOHN A. READ



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FOREWORD:
Why Observe the Moon?

As a boy growing up in Winnipeg, Manitoba, I caught the astronomy bug. My father took me outside one cold winter's night and pointed out the star patterns of the Big Dipper and Orion. I was hooked! I devoured all the astronomy books in the public library and drooled over the ads for fancy telescopes in *Sky & Telescope*, the only astronomy magazine available at the time. On my tenth birthday, my parents gave me a little 60-mm telescope on a wooden tripod, and an astronomy book by Patrick Moore.

That very night I started keeping a record of things I saw in my telescope (I still have the logbook — but not the telescope — more than half a century later). The first observation I wrote down was a list of craters, seas, and mountains I could find on the Moon with my little telescope. Later, I started making crude drawings of what the Moon looked like through the eyepiece. I also observed lunar eclipses, occultations of stars by the Moon, earthshine — in short, all the things described in the book you are holding in your hands now. I wish I'd had this book way back then!

Of course, I moved on from the Moon to observe stars, planets, galaxies, nebulae, and all sorts of things. I also worked my way up to using bigger telescopes. When other amateur astronomers stayed indoors "because the Moon is out ruining the sky," I was that guy sitting outside at the telescope, spending time with an old friend.

I have a unique relationship with the Moon: in the wee hours of my sixteenth birthday, astronaut Neil Armstrong stepped down from the *Eagle* lunar lander onto the surface of the Moon, the first human to do so. I watched it live on fuzzy black and white TV, then went outside and gazed at the Moon. "Holy cow," I said to myself, "there are people up there!" I will never forget that.

There are many reasons to explore the Moon (with a telescope from Earth, that is). It is our nearest neighbour in space, it's easy to find, it's bright, it has a variety of visual details to enjoy, you don't have to go anywhere special to view it (your urban yard is fine), and you don't need a fancy telescope. It's just that easy. But the best reason to observe the Moon as a beginning amateur astronomer is that you will learn how to operate your telescope and to interpret what you see. Then you will be much better prepared to go hunting for planets, double stars, galaxies, and other, more challenging objects. I assure you this is the truth!

With this book, John Read has wiped the slate clean and started from scratch. He has years of experience helping ordinary folk appreciate the night sky, and he has developed an excellent sense of what excites them. He's picked out 50 interesting lunar features that he has observed, photographed, and researched himself. I've watched him do it and can attest that he has put his heart and soul into the project. Whether you are embarking on a new lifelong hobby, or just having fun, this book is for you!

David M. F. Chapman, Emeritus Editor
RASC Observer's Handbook (2012–2016)

This book is dedicated to the members of the Royal Astronomical Society of Canada for fostering advancement in astronomy for over 150 years.

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TABLE OF CONTENTS

Introduction to the Moon

About 4.5 billion years ago, in a planetary system riddled with deadly asteroids, a rocky planet orbited the young Sun. An asteroid, 7,000 km across, collided with the planet, shredding it apart and spewing debris into outer space. Under gravity's influence, the debris eventually coalesced, forming two unique worlds. The larger world we call Earth, and the smaller we call the Moon.

The Moon, Earth's neighbour, has always been a fixture in the lives of humans. The Moon stabilizes Earth's spin, causes **tides**, and lights up the night. Early humans used the Moon to determine when to plant crops, and when to harvest; they developed calendars based on the lunar cycles. In fact, we get the word "month" from the Moon.

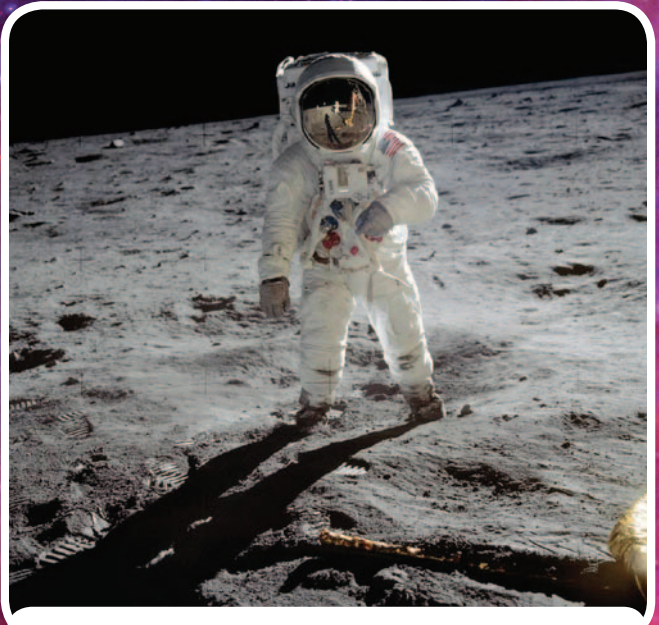
Over time, humans invented new calendars, built skyscrapers, and discovered electricity to light up the night. For many, the Moon became nothing more than an uninteresting rock. Then, in the midst of the Cold War with the Soviet Union, a US president demanded superiority over communist domination in outer space.

"We choose to go to the Moon!"
— President John F. Kennedy, 1962

The Soviets sent many robotic spacecraft to the Moon. They were the first to successfully send a robotic probe (Luna 2), which crashed on the Moon's surface. They were the first to **orbit** the Moon and to take pictures of the Moon's **far side** (Luna 3). They were the first to safely land a probe on the Moon (Luna 9). And, by the late 1960s, they were getting close to sending humans to the Moon.

But in 1968, three astronauts — Frank Borman, William Anders, and Jim Lovell — left Earth and coasted toward the Moon. This was the historic Apollo 8 mission, the first time humans left Earth's orbit. However, their spacecraft did not include a lunar lander. Upon reaching the Moon, they spent 20 hours in lunar orbit before heading home.

Then, in 1969, an American named Neil Armstrong descended from the lunar lander and set foot on the Moon. America's Cold War enemy was watching every move. With that one small step, America had won the Space Race.



Buzz Aldrin on the Moon (Neil had the camera).

As Neil Armstrong and Buzz Aldrin climbed back into the lunar module to prepare for their trip home, an uncrewed Soviet spacecraft, named Luna 15, orbited overhead. The Soviet probe changed its trajectory, possibly to get a closer look at the American astronauts, but also to prepare for landing. But adding to the Soviets' defeat, the robotic probe then crashed into a lunar mountain, just a few hundred kilometres from Neil and Buzz.

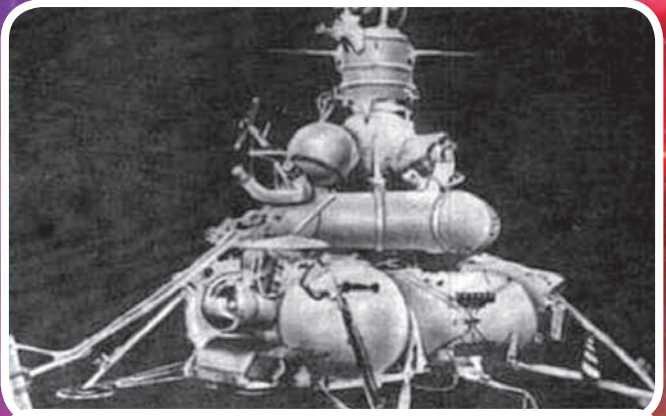


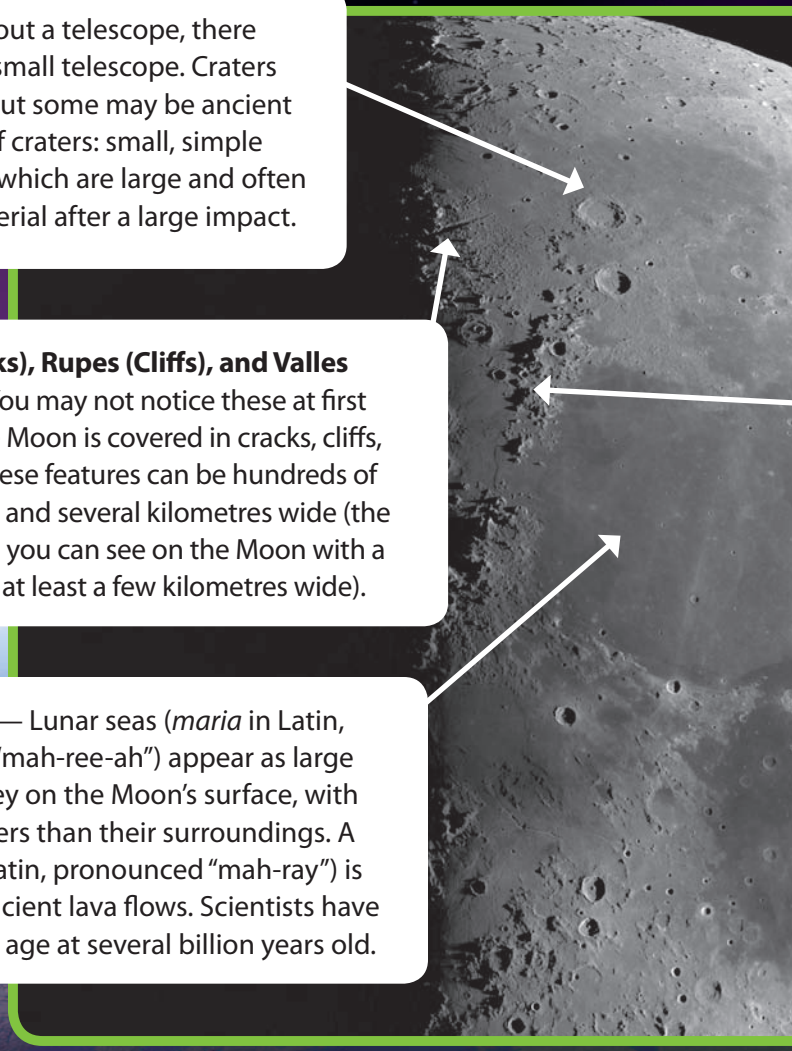
Image of Luna, uncrewed Soviet moon lander.

The Soviets' crewed lunar program suffered several failures in the shadow of Apollo's success. Most noticeably, the failure to successfully launch the giant rocket that would boost cosmonauts into space. With Americans on the Moon, the Soviets' crewed lunar program lost political support, and was subsequently cancelled.

The Moon at a Glance

You don't need any maps to appreciate the Moon — you really don't even need a telescope or binoculars (though these definitely help). Just admiring the Moon is a joy in itself. But once you view it through a telescope, you'll notice several things straight away.

Craters — Though only one or two are visible without a telescope, there are thousands of craters on the Moon visible with a small telescope. Craters are mainly formed by asteroid or meteoroid impact, but some may be ancient collapsed volcanoes. There are two general types of craters: small, simple craters, shaped like cereal bowls; and complex craters, which are large and often have a central peak formed by the rebounding of material after a large impact.



Rilles (Cracks), Rupes (Cliffs), and Valles (Valleys) — You may not notice these at first glance, but the Moon is covered in cracks, cliffs, and valleys. These features can be hundreds of kilometres long and several kilometres wide (the smallest details you can see on the Moon with a telescope are at least a few kilometres wide).

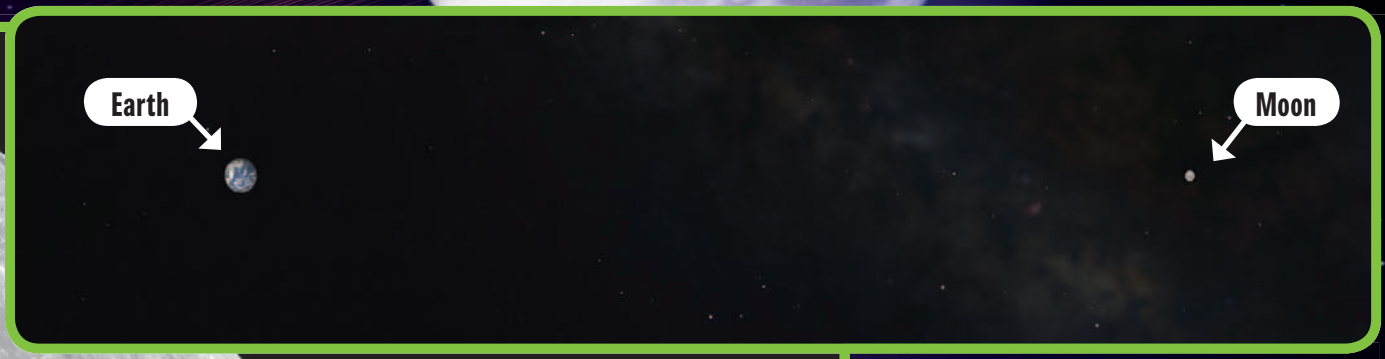
Lunar Seas — Lunar seas (*maria* in Latin, pronounced "mah-ree-ah") appear as large patches of grey on the Moon's surface, with far fewer craters than their surroundings. A sea (*mare* in Latin, pronounced "mah-ray") is formed from ancient lava flows. Scientists have measured their age at several billion years old.

Stellar Fact!

It was a Jesuit astronomer named Giovanni Riccioli (1598–1671) who decided to name the craters after scientists and philosophers. He started the naming process by listing the most ancient names in the north and most recent in the south. Riccioli also named the *maria*, or seas, giving them Latin names meaning tranquility, rainbows, rains, cold, vapours, and several others.

How Far is the Moon?

When you look at the Moon through a telescope, it almost seems as if you can reach out and touch it. However, the Moon is an average of 384,000 km away. That's over 35 times the distance from New York City to Tokyo, Japan! If you were to drive that distance non-stop, going 90 km/h, it would take almost six months!



Lunar Mountain Ranges — Just like Earth, the Moon has mountains! Most of the Moon's mountains were formed when rock was pushed up by giant asteroid impacts, which means they were formed in a matter of minutes! The most prominent (and some say spectacular) mountain range is *Montes Apenninus*, which ranges almost 600 km long, with peaks over 5 km high.

Rays — Formed when rock and dust (called ejecta) is dislodged after a meteor impact, lunar rays appear as bright streaks emanating away from the impact zone. Some rays, like those emanating from the crater Tycho, are thousands of kilometres long! They last for millions of years.

Moon scale — The Moon is 3,475 km across, about as wide as the US. The smallest detail viewed without a telescope — a lunar sea, for example — is still about the size of Texas. Through binoculars it is possible to explore craters that are as small as 100 km in diameter, or about the size of Los Angeles county. Only when you view the Moon through a telescope do you see details as small as a few kilometres, or about the size of Manhattan Island in New York.

How to Use This Book

Lunar days — This book will follow the **phases** of the Moon from New Moon to Full Moon. This transition represents about 14 days of unique views of the Moon in the evening sky. As each day passes, an additional slice of the Moon becomes visible, with the most prominent features appearing along the **terminator**, which is the ragged north–south line along which the Sun is either rising or setting on the Moon.

Moonrise and Moonset
Although the Moon rises in the east and sets in the west every day, just like the Sun, it rises about 50 minutes later each day. If you observe the Moon at the same time every day, it would appear to move from west to east.

The Moon viewed just after sunset each evening.

This image shows the Moon in the evening sky when it is "waxing," which means the illuminated area is expanding. For the next 14 days, the Moon is "waning," which means the illuminated area is decreasing. However, the waning phases are only visible later at night and into the morning.

*As viewed from the northern hemisphere

You can replicate the phases of the Moon by holding a ball at arm's length at sunset and spinning in a circle. In this image, Marni Berendsen, education project coordinator at the Astronomical Society of the Pacific (ASP), does just that.

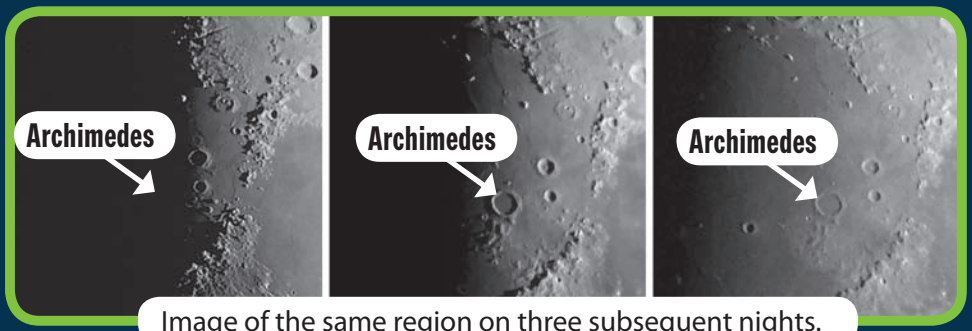


Image of the same region on three subsequent nights.

The terminator is the line between the Moon's night and day, and is the best place to concentrate your observing efforts. At first, the tall mountains and crater rims come into view. As the craters fill with light, walls and nearby mountains cast long shadows. Finally, once bathed in overhead light, the shadows recede and the finer details fade into hues of grey and white.

The Moon will appear differently depending on the type of telescope or binoculars you are using. These additional views will help you orient your telescope to find the more challenging targets.

Upright / Binoculars

Inverted / Newtonian

Mirror-Reversed View / Refractor

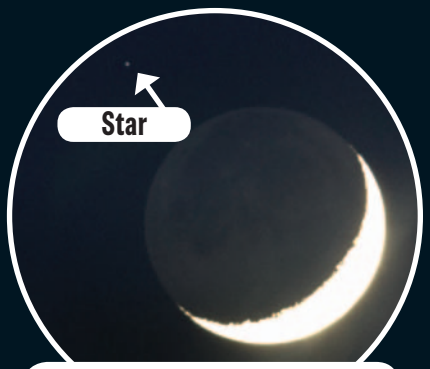
Each page contains three separate images of the Moon. The larger image is how the Moon looks visually or with binoculars. The other zoomed-in images are from either a Newtonian or refractor telescope. Use the image that matches your type of scope.

Lunar Events and How to See Them

Conjunctions — When the Moon and a star, planet, or some combination of objects appear close to each other in the sky, the event is called a "conjunction." The celestial objects are not physically close to one another, they just appear in the same general direction from Earth. Technically, a conjunction occurs when objects share the same **Right Ascension (RA)**, a term to indicate location east and west in the night sky.

Venus, Mars, and the Moon, near conjunction on January 31, 2017.

Occultations — Lunar occultations occur when the Moon passes in front of a planet or a star (although only occultations of bright stars and planets are easy to observe). A list of upcoming occultations can be found online (link provided on page 80). It's often fun to observe the Moon during an occultation — you'll see the star or planet disappear at the advancing, western **limb** of the Moon (east in the sky), and reappear on the eastern limb (west in the sky) within 60 minutes.



The Moon prior to occulting a bright star on March 20, 2018.

Lunar Eclipses — When the Moon crosses into the Earth's shadow, we call this a lunar eclipse. Such an eclipse can be partial or total and can be observed over a large part of the Earth (the part that is experiencing nighttime). During an eclipse, especially during **totality** (when the Moon is fully eclipsed), the Moon appears slightly red from sunlight passing through Earth's atmosphere. Check the schedule in Appendix 1 for the dates of upcoming lunar eclipses.

Lunar Eclipse, December 21, 2010.

Solar Eclipses — When the Earth crosses under the Moon's shadow, we call this a solar eclipse. Because the width of the Moon's shadow (about 100 km) is so much smaller than the diameter of the Earth (12,800 km), a total solar eclipse is only visible from the few places located under the shadow, which quickly moves across the surface of the Earth. The narrow shadow occurs because the Moon and Sun have approximately the same angular size in the sky. Check the eclipse schedule in Appendix 2 to see when the next solar eclipse occurs near you.

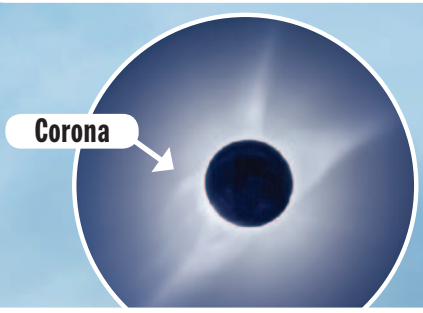
Just because you're not under the Moon's shadow doesn't mean you can't see a partial eclipse. Be sure to use commercial eclipse glasses when viewing this event.

Stellar Fact!

Not all solar eclipses are total solar eclipses. If an eclipse occurs when the Moon is farther from Earth in its orbit, it doesn't quite cover the Sun. We call this an **annular eclipse**, and you still have to be under the narrow eclipse path to see it. When the Moon covers only part of the Sun we call this a partial solar eclipse, but these are observable over a much wider area.

During an annular eclipse, when the Moon still doesn't fully cover the Sun's disk, we call this the "Ring of Fire." Be sure to use commercial eclipse glasses when viewing this event.

Full Moon — The lunar cycle has long functioned as a calendar of sorts and it is still used in traditional Indigenous, Asian, and Muslim calendars. You may hear names like Harvest Moon, Hunter's Moon, or **Supermoon** in the news, but from a scientific standpoint there is nothing particularly out of the ordinary about these Moons. For those who enjoy space, a Full Moon is a good time to identify all the major lunar *maria* and observe the lunar rays.



If you're under the Moon's shadow during a total solar eclipse, you experience totality. During this time you can see the Sun's corona, and even bright stars and planets.

Note: Solar and lunar eclipse schedules are included in the Appendices.

How the Moon Appears through a Telescope or Binoculars

You may have looked at the Moon through your telescope and wondered why it appears backwards, upside down, or both! Telescopes use lenses and/or mirrors to bring light from space to your eye, but lenses turn images inside out and mirrors reverse the view! How the Moon appears in your telescope will depend on the details of its optics.

Explore Scientific AR102 Refractor

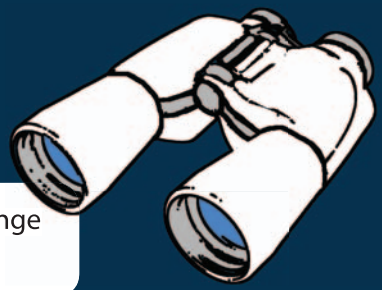
Explore Firstlight 114mm Reflector Telescope

A reflecting (Newtonian) telescope has a large concave mirror that collects the light. The light is then reflected by a diagonal mirror inside the body of the telescope, 90 degrees sideways into the eyepiece. The combination of the two reflections creates an image of the Moon that is upside down AND mirror reversed — that is, an inverted image, the same as a 180-degree rotation.

A refracting (lens-based) telescope has a large lens that collects the light. The basic refracting astronomical telescope inverts the view — that is, it reflects the image through a central point, which is the same as a 180-degree rotation. More commonly, a refractor employs a diagonal mirror or prism to reflect the image 90 degrees upwards into the eyepiece; this image of the Moon will be right side up, but will be mirror-reversed. (Some telescopes come with something called an erecting eyepiece. With this attached, the image will no longer be reversed. Spotting 'scopes, intended for nature and sports, are equipped in this way, and provide good low-power Moon views.)

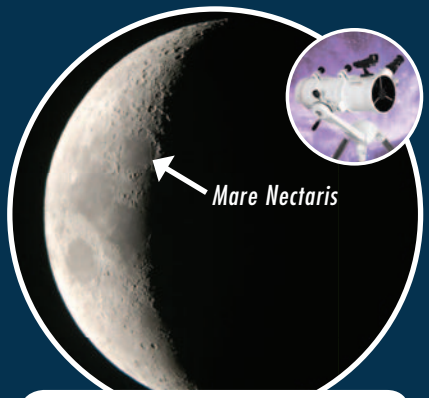
This Explore Firstlight 127mm Mak-Cassegrain telescope produces a right-side-up, mirror-reversed image, just like a refractor with a 90-degree diagonal.

Many telescope designs use two mirrors and a star diagonal (which contains another mirror). In this case, the combination of three reflections creates a right-side-up, mirror-reversed image.



Binoculars use lenses and prisms (solid glass wedges) to arrange the image to match the orientation of the unaided eye.

Binocular (or naked eye) view



Newtonian or Dobsonian view (inverted image)

Refractor and Schmidt-Cassegrain view with 90-degree diagonal (mirror-reversed image)

Viewing *Mare Nectaris* with binoculars, a Newtonian telescope, and a refractor telescope.

Directions on the Moon

When looking at the Moon "naturally" (as you would with unaided eyes or in binoculars, right side up and not mirror-reversed), in general terms, north is up, south is down, east is right and west is left (reversed in the southern hemisphere), as is the custom with all planetary bodies, Earth included. Note that east–west on the Moon is opposite east–west in the sky. This can be confusing! For example, as you watch the Moon in the sky during the night, it rapidly moves from east to west as the Sun and stars do. At a slower rate, the Moon moves west to east in the sky relative to the stars. When the Moon covers (or occults) a star, the star disappears behind the western limb of the Moon and reappears up to an hour later from behind it.