
## Introduction

Selene, Luna, Mistress of the Dark - the moon has many names. Forged in fire and catastrophe, been Earth's faithful companion for billions of years. the only world on which we can see topography and the only world mankind has visited in person. But its commonplace appearance in our skies belies its fascinating history and its observational pleasures.

Observe the moon over a few nights and you'll soon notice a couple things about it. It doesn't rise and set at roughly the same time of day (as does the Sun) and the bright portion of its disk changes slightly from night to night, sometimes the bright fraction decreases and sometimes it increases. Other observations you might make are that the moon looks bigger on the horizon than when overhead; you can see large dark and bright areas on its surface and smaller features as well; you can sometimes see it during the day and occasionally, it turns a coppery brown colour. So what's going on?

## The Moon's Face

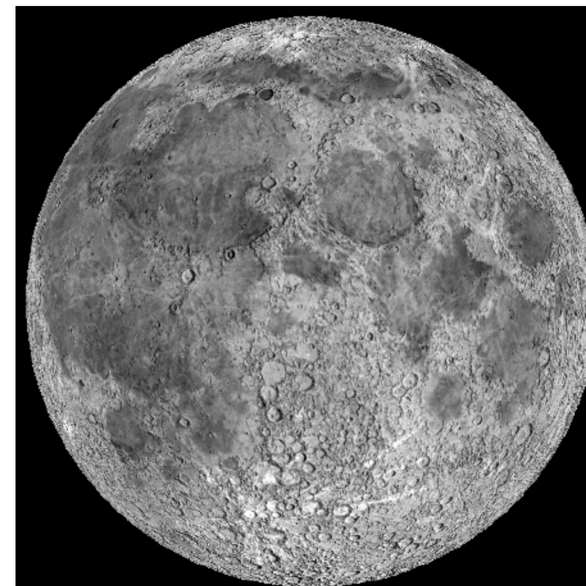
Do you remember when you were a kid, your dad (most likely – but not being sexist here) pointed out the man in the moon to you? Well, if you don't, or he didn't, too bad. I always though the man in the moon had been in one fight too many by the looks of him - a somewhat sinister disfigured visage.

How and ever, the man in the moon's facial features are composed of a variety of actual physical lunar landscapes. Contrary to a once-popular cultural myth, the moon is made of rock and not green cheese (surprisingly – or perhaps not! – 12% of Americans believe at least part of the Moon is made of cheese!). The surface of the moon contains a multitude of craters, splash marks, lava outflows, walls and mountains ranging in colour from dark grey to white. These features are changeless as the moon has no atmosphere to cause the erosion that Earth's atmosphere does down here. The features you see on the moon every night have essentially been that way for a billion years. Occasionally, though, a meteor will strike the moon, creating a new crater and altering the local landscape with a splash of lunar dust and pulverised rock. Such events, though, are exceedingly rare.

## Why the Moon Always Looks the Same

Further observation of the moon will show that it always keeps the same face to us. No matter what night you go out to look at the moon, it always looks the same apart from its phase. Why is this?

It all comes down to what are called "tidal forces". Everyone knows that the moon causes the tides in our oceans, but what is less-well known but equally real is that there is a tidal distortion of our entire planet. The continents and everything underneath (such as magma, the molten material on which the continents float) are deformed on a daily basis by the tidal forces of the sun and moon. Surprisingly, tides are raised in the continents as well as the oceans, although not to the same extent (and you never noticed!). The closer a moon or satellite to its planet, the greater the tidal force on both bodies. But I haven't really explained what a tidal force is. It all has to do with gravity. Gravity is an inherent property of matter. Everything from the smallest atom



*Full Moon - where mythological features can be seen!*

to entire galaxies posses it. The more mass a body has (i.e. the more stuff that's in it), the greater its gravity. That's why leaping with abandon on an asteroid is not such a good idea - their gravity is too low to stop you sailing away into space.  not such a good idea down here either as you'll come crashing to the ground and look like a complete pratt. The moon, being smaller than the Earth, has less gravity and you too could be superman (or woman) on such a world, leaping tall(ish) buildings in a single bound.

**A digression on the Nature of Tides**

But gravity is a funny thing. It obeys what's called the inverse square law. All that means is that the closer you are to a large body (like a planet), the stronger you feel its "pull". That's why you accelerate when you fall - on Earth, air resistance eventually stops your acceleration once you reach a certain velocity but on the moon and other airless bodies, you would continue to accelerate until you finally hit the ground. (As they say, not the fall that kills you but the sudden stop at he end!)

Now, here's the weird bit: Another consequence is that gravity doesn't act on a body as a whole, but differentially on each atom in it. So the near side of the moon is attracted more strongly by the Earth than the far side. Likewise, the side of Earth facing the moon is attracted by the moon more strongly than the Earth's opposite side. The net effect is that the bodies are stretched slightly. You can think of it this way: think of a beach ball and imagine that you glue it to the ground (using a super glue that actually works). You then attach a really powerful suction cup (with associated handle) to the ball at the point where it's exactly on the opposite side of the ball to the point where the ball is glued to the ground. You then impersonate the moon by pulling on the suction cup handle. Assuming the glue holds and you haven't thrown the Earth (the ball) out of the solar system, the ball should contort slightly so that  now shaped more like a rugby ball than a soccer ball. Congratulations, despite the arrival of the men in white coats (whom your neighbours so obligingly called), you've demonstrated a simple example of tidal forces.

## Has Anyone Ever Seen a Meteor Strike the Moon? - Part I

Well, possibly, is the answer. About an hour after sunset on June 18, 1178 A.D., a group of five eyewitnesses watched as the upper horn of the bright, new crescent Moon "suddenly split in two. From the midpoint of this division a flaming torch sprang up, spewing out...fire, hot coals and sparks... The body of the moon, which was below writhed...throbbed like a wounded snake." The phenomenon recurred another dozen times or more, the witnesses reported.

The dramatic passage in question appears in the medieval chronicles of Gervase of Canterbury.

What was it they saw? A geologist suggested in 1976 that this account is consistent with the location and age of the 22-kilometre (14-mile) lunar crater Giordano Bruno, the youngest crater of its size or larger on the Moon. But this idea doesn't hold up under scientific scrutiny.

Such an impact would have triggered a blizzard-like, week-long meteor storm on Earth - yet there are no accounts of such a storm in any known historical record, including the European, Chinese, Arabic, Japanese and Korean astronomical archives.

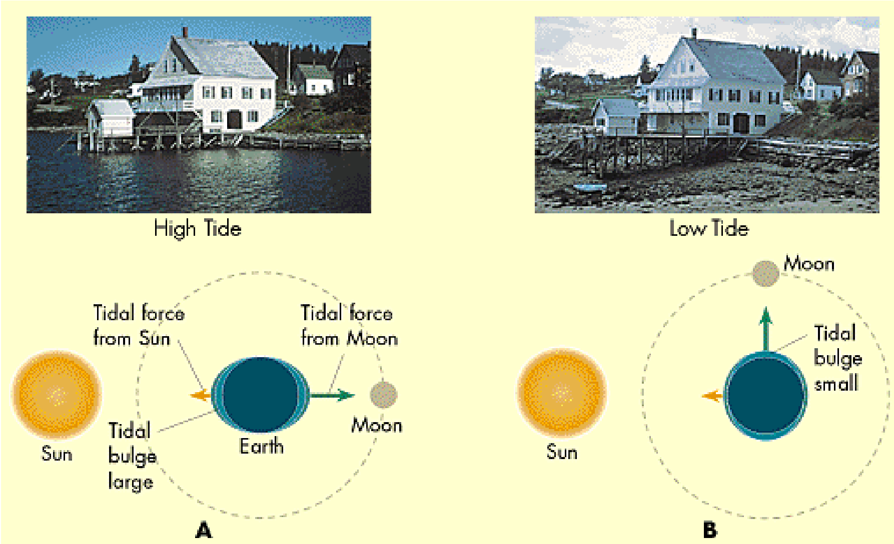
Based on the size of the crater, it must have been a one-to-three kilometre wide (a half-mile to almost 2-mile wide) asteroid that blasted Giordano Bruno into the Moon's northeast limb. Such an impact on the Earth would be "civilization threatening".

The impact would have launched 10 million tons of ejecta into the Earth's atmosphere in the following week, previous studies have shown. This would have caused a week-long meteor storm comparable to the peak of the 1966 Leonids. Ten million tons of rock showering the entire Earth as pieces of ejecta about a centimetre across (inch-sized fragments) for a week is equivalent to 50,000 meteors each hour. They would also have been very bright, and very easy to see at magnitude 1 or magnitude 2.

Yet no vigilant 12th century sky watcher reported such a storm. So what did the witnesses see that the Canterbury monk recorded?

What’s likely to have happened is that they were in the right place at the right time to look up in the sky and see a meteor that was directly in front of the moon, coming straight towards them. This idea was strongly suggested by scientists in a 1977 scientific paper.

And it was a pretty spectacular meteor that burst into flames in the Earth's atmosphere - fizzling, bubbling, and spluttering. If you were in the right 1-2 km patch on Earth's surface, you would get the perfect geometry to see the event. That would explain why only five people are recorded to have seen it.




*How the moon affects the tides*

While this example isn't strictly correct, it serves to illustrate what gravity is doing. The key thing with tides on a spherical body such as the moon or Earth, is to think of a rugby ball shape rather than a soccer ball shape. So, on Earth, there are always two tides - the one facing the moon and the one on the diametrically opposite side of Earth. The same goes for the moon and every other planet and satellite in the Universe (and stars for that matter). The effects, though, are at their most significant when bodies are close together.

To complicate matters further, the tidal bulges do not line up exactly with the centres of the Earth and the Moon. The Earth's rotation sweeps the near side bulge slightly ahead of the centre line and the far side bulge therefore lags slightly behind it. Both bulges have mass which, in turn, exerts a slight gravitational pull on the moon. Since the tidal bulge is ahead of the moon, it pulls the Moon **forward** in its orbit by a slight amount. This gives the Moon more orbital energy. Now, an orbit with higher energy has a larger radius, and so as the bulge pulls the Moon forward, the Moon moves farther away from the Earth. Surprised, huh? The rate at which the moon is moving away from the Earth has been measured as being a few centimetres a year. Not a lot, you might think, but it adds up to a substantial amount over 4 billion years - over 100,000km! Indeed, early in its history, the Moon was 15 times bigger in the sky than it is today. Wouldn't that have been a sight to see?!

Gravity, of course, is not a one-way force - the Moon also pulls on the leading bulge as well. Since the Moon is "behind" the bulge (relative to the rotation of the Earth), it is pulling the bulge backward and slowing it down. Because of friction with the rest of the Earth, this slowing of the bulge actually slows the rotation of the Earth, making the day longer. The effect is small, but measurable.

Eventually, the Earth will become tidally locked to the Moon. The Earth's rotation will be slowed down so much that the tidal bulge will line up exactly with the centres of the Earth and the Moon. When this happens, the Moon will no longer be pulling the bulge back, and the Earth's spin will remain constant. When this happens, the time it takes for the Earth to rotate once will be exactly the same time it takes for the Moon to go around the Earth once! If you were to stand on the Moon and look at the Earth, you would always see the same face of the Earth. As a result, there would be places on the Earth where the moon will never be visible. What a vision the moon would be to travellers from the Earth's far side.

**Back to the Point**

Okay, that's tides explained but that doesn't explain why the moon keeps the same face towards Earth, I hear you cry! Hang on, I'm getting there. A consequence of tidal forces is that bodies of different sizes experience different accelerations which, in turn, alters the rotation rates of the bodies involved until a state of equilibrium is reached. This state of equilibrium occurs when the rotation rate of a body is the same as the amount of time it takes to orbit another body. What does all that gobbledygook mean in plain English?

Well, in this case, a body such as the moon, is in equilibrium when its day is as long as its year. Its tidal bulges are then pointed towards the centre of the body it orbits ( not rotating fast enough to throw its tidal bulges forward of the planet-moon centre line). For the moon, its tidal bulges point towards the centre of the Earth. You can demonstrate this by swinging a bucket around your head. Uh oh, the men in white coats are back! Before you're dragged away again, your experiment shows that the bucket's open end always faces you - the bucket is tidally locked to your body!

This is what has happened to our Moon, it has become tidally locked and hence always shows its same face to us. Other moons around other planets in the solar system have undergone the same process and are tidally locked to their planets. Double star systems can become tidally locked as well.

Here's another example to better illustrate tidal locking: Place a chair in the centre of the room - this represents the Earth. Next, walk around the chair so that you face it all the time. You'll notice that when you have walked around the chair once, you would have also turned through 360°, i.e., turned once about your axis. If someone is sitting on the chair, they will always see the same side of you - just as an observer sees the moon from the Earth.

**Earth Moon Distance**

Have you ever wondered how far away the moon actually is? Would you be surprised to learn that the distance changes over time (I'm not talking about the moon receding from the Earth here)? Almost all planets and satellites have elliptical rather than circular orbits. A circle is, essentially, a special kind of ellipse. An ellipse has two, what are called, foci. Their distance apart determines how flattened the ellipse is. In a circle, the two foci are at exactly the same position.  relatively simple to draw an ellipse. Stick two pins in a board some small distance apart. Wrap a piece of string around the pins and have a pencil take up the slack. Then, keeping the pencil tight against the string, drag the pencil around the pins. What you end up with is an ellipse. How squashed the ellipse is depends on how far apart the pins were and the size of the ellipse is set by the amount of slack that was in the string. For satellites, the planet they orbit is at one of the foci (Earth is at one of the foci for the moon's orbit). For planets, the star they orbit is at one of the foci for their orbital paths (in Earth's case, the Sun sits at one of the foci).

## Has Anyone Ever Seen a Meteor Strike the Moon? - Part II

In the early morning hours of Nov. 15, 1953, an amateur astronomer in Oklahoma photographed what he believed to be a massive, white-hot fireball of vaporized rock rising from the centre of the Moon's face. If his theory was right, Dr. Leon Stuart would be the first and only human in history to witness and document the impact of an asteroid-sized body impacting the Moon's scarred exterior.

Almost a half-century, numerous space probes and six manned lunar landings later, what had become known in astronomy circles as "Stuart's Event" was still an unproven, controversial theory. Skeptics dismissed Stuart's data as inconclusive and claimed the flash was a result of a meteorite entering Earth's atmosphere. That is, until Dr. Bonnie J. Buratti, a scientist at NASA's Jet Propulsion Laboratory, Pasadena, Calif., and Lane Johnson of Pomona College, Claremont, Calif., took a fresh look at the 50-year-old lunar mystery.

Buratti and Johnson's reconnaissance of the 35-kilometre (21.75-mile) wide region where the impact likely occurred led them to observations made by spacecraft orbiting the Moon. First, they dusted off photographs taken from the Lunar Orbiter spacecraft back in 1967, but none of the craters appeared a likely candidate. Then they consulted the more detailed imagery taken from the Clementine spacecraft in 1994.

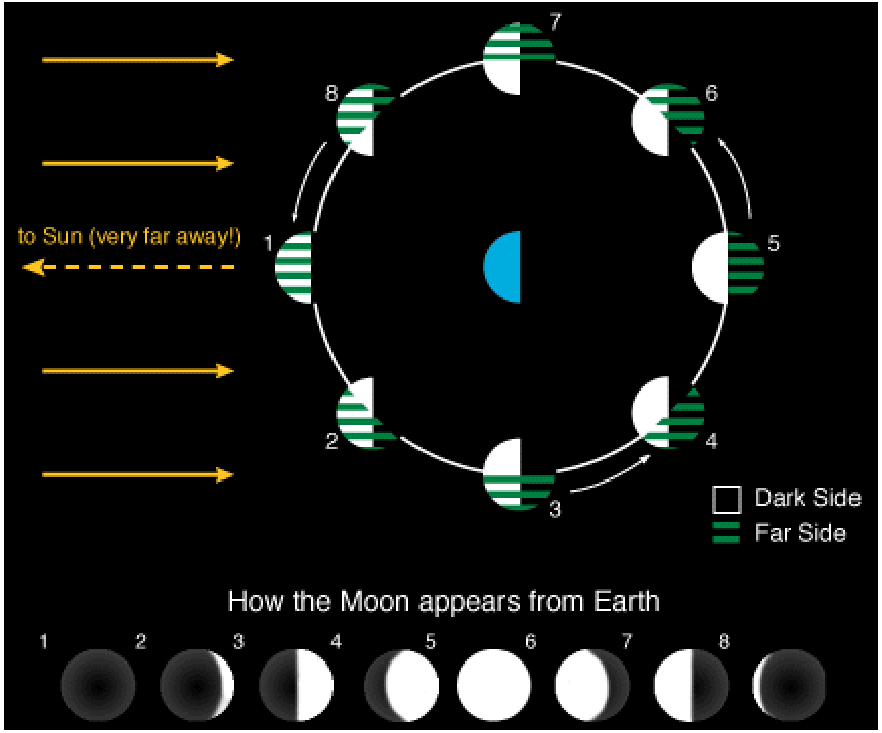
Using Stuart's photograph of the lunar flash, they estimated that the object that hit the Moon was approximately 20 meters (65.6 feet) across, and the resulting crater would be in the range of one to two kilometres (.62 to 1.24 miles) across. They were looking for fresh craters with a non-eroded appearance.

Part of what makes a Moon crater look "fresh" is the appearance of a bluish tinge to the surface. This bluish tinge indicates lunar soil that is relatively untouched by a process called "space weathering," which reddens the soil. Another indicator of a fresh crater is that it reflects distinctly more light than the surrounding area.

Buratti and Johnson's search of images from the Clementine mission revealed a 1.5-kilometre (0.93 mile) wide crater. It had a bright blue, fresh-appearing layer of material surrounding the impact site, and it was located in the middle of Stuart's photograph of the 1953 flash. The crater's size is consistent with the energy produced by the observed flash; it has the right colour and reflectance, and it is the right shape.

Having the vital statistics of Stuart's crater, Buratti and Johnson calculated the energy released at impact was about 0.5 megatons (35 times more powerful than the Hiroshima atomic bomb). They estimate such events occur on the lunar surface once every half-century.

While Dr. Stuart passed on in 1969, his son Jerry Stuart offered some thoughts about Buratti and Lane's findings. "Astronomy is all about investigation and discovery. It was my father's passion, and I know he would be quite pleased," he said.




*Top-down view of sun-earth-moon: It might be a bit difficult to visualise why we see different phases of the Moon. Take a look at the diagram to see how we come to see them. It's important to note that the Sun always illuminates half the moon and that we are seeing the moon from a different vantage point than the sun. As the moon goes through its orbit, the Sun illuminates a different section of the moon. It's exactly the same process as that which gives us day and night here here on Earth. (Astronauts on the moon were able to see the Earth changing phase when they looked back at our planet!)*

If you look at a diagram of the Earth-Moon system, you'll see that at some points in its orbit, the moon is closer to the Earth on average, and at other points farther away. There are terms to describe the point of nearest distance (Perigee) and farthest distance (Apogee).

The average distance is about a quarter of a million miles. Now the moon looks pretty big in the sky when full and the Earth looked even bigger in the lunar sky when the astronauts were looking back. But what is the scale of the earth moon system overall?

Well, if the Earth was an orange, the moon would be a cherry over 12 feet away! We tend not to appreciate what a quarter of a million miles really equates to. And think of the accuracy in getting something smaller than a speck of dust from our orange to our cherry 12 feet away, especially when the orange is rotating under its own steam and the cherry is orbiting the orange. It certainly makes one appreciate, all the more, the engineering feats achieved in getting 30 men from Earth orbit into lunar orbit given all the variables involved!

**Phases of the Moon**

As mentioned earlier, watching the moon over successive nights will show how the illuminated portion of face changes from night to night. This changing fraction is known as the moon's **phase**.

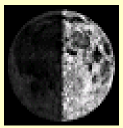
The moon, like the Earth, is a sphere and so, from anywhere on Earth, the Moon appears to be a circular disk which, at different times, is to a greater or lesser degree illuminated by direct sunlight.

Like the Earth, the Moon is always half illuminated by the Sun, but as the Moon orbits the Earth we get to see sometimes more, sometimes less, of the illuminated half. During each lunar orbit, the Moon's appearance changes from not being visible at all, to being partially illuminated, fully illuminated, then back through partially illuminated to not illuminated again. Although this cycle is a continuous process, there are four distinct, traditionally recognized stages, called major phases (New, First Quarter, Full and Last Quarter) and four other recognised phases. The two crescent and two gibbous phases are intermediate phases, each of which lasts for about a week between the major phases, during which time the exact fraction of the Moon's disk that is illuminated gradually changes. These phases describe two attributes: how much of the Moon is illuminated and the geometric appearance of the illuminated part. They and their sequence of occurrence (starting from New Moon), are listed in Table 1.

Did you know that a Full moon occurs at an instant in time - down to the second? So why does the moon appear to be full for several days in a row? because the percentage of the Moon's disk that is illuminated changes very slowly around the time of Full Moon (also around New Moon, but the Moon is not visible at all then). The Moon will appear to be fully illuminated only on the night closest to the time of the exact Full Moon. On the night before and the night after, it will be 97-

**New Moon** - The Moon's unilluminated side is facing the Earth. The Moon is not visible (except during a solar eclipse).

**Waxing Crescent** - The Moon appears to be partly but less than one-half illuminated by direct sunlight. The fraction of the Moon's disk that is illuminated is increasing.

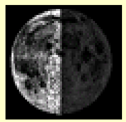


**First Quarter** - One-half of the Moon appears to be illuminated by direct sunlight. The fraction of the Moon's disk that is illuminated is increasing.

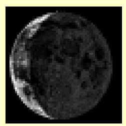
**Waxing Gibbous** - The Moon appears to be more than one-half but not fully illuminated by direct sunlight. The fraction of the Moon's disk that is illuminated is increasing.

**Full Moon** - The Moon's illuminated side is facing the Earth. The Moon appears to be completely illuminated by direct sunlight.

**Waning Gibbous** - The Moon appears to be more than one-half but not fully illuminated by direct sunlight. The fraction of the Moon's disk that is illuminated is decreasing.



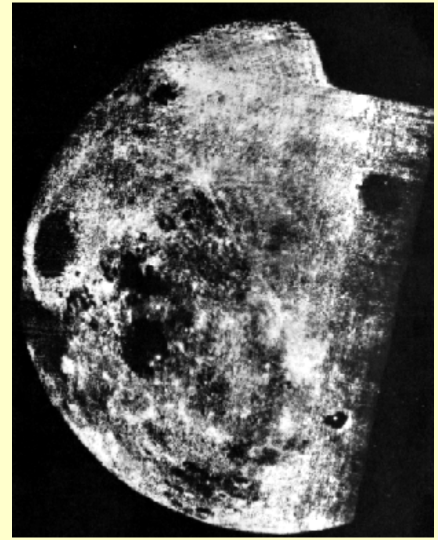
**Last Quarter** - One-half of the Moon appears to be illuminated by direct sunlight. The fraction of the Moon's disk that is illuminated is decreasing.



**Waning Crescent** - The Moon appears to be partly but less than one-half illuminated by direct sunlight. The fraction of the Moon's disk that is illuminated.

***Table 1: The eight "recognised" phases of the moon***

## Factino



The only people to have ever seen the far side side of the moon with their own eyes are the Apollo astronauts. They, and spacecraft, have taken images of the far side so that the rest of us can get in on the act.  The first time human eyes ever viewed images of the far side of the moon was in 1959. The images were taken by the Soviet Luna 3 probe and radioed back to Earth. Lacking the digital image technology familiar now, Luna 3 took the pictures on 35 mm film which was automatically developed on board the spacecraft. The pictures were then scanned and the signal transmitted to Earth days later in what was perhaps also the first interplanetary fax. In all, seventeen pictures were received providing enough coverage and resolution to construct a far side map and identify a few major features [above picture].

Luna 3 followed closely on the heels of another Soviet probe, Luna 2, which become the first spacecraft to impact the Moon on September 13th of that same year.

99% illuminated although most people won't notice the difference. Even two days from Full Moon the Moon's disk is 93-97% illuminated and a casual observer will be hard pressed to notice that the moon is not full.

### Lunar Month

A complete phase cycle takes an average of 29.5 days. The "age" of the moon is the time in days counted from the last New Moon. That's why some some people describe the moon as being 3 days old, for instance. Each complete cycle of phases is called a "lunation" - a lunar month, during which time the Moon completely circles the Earth in its orbit.

### Observing Projects

Some religions, whose calendars are based on a lunar cycle rather than a solar one, place great emphasis on the first visibility of the crescent moon after a New Moon as this determines when a new month in their calendar begins. However, seeing a thin silvery crescent low in the western sky after sunset has its own observational delights. We'd like to hear from you if you try to spot these crescents and are successful, especially for the very thin crescents. If you're adventurous enough to take photos, send them in to us. We'll put them up on the magazine webpage and include the best we receive in the **Night Sky Observer** magazine.

Other projects to try are to draw or photograph the moon from night to night to see how the phase changes. (Again, send us your results) and to observe where on the horizon the moon rises from night to night. Try correlating these with how high the moon rises into the sky each night.

## Astronomy Ignorance

**Strange Astronomy Questions:**

1) Is the Moon larger than the Earth?
2) Do the phases of Venus match the phases of the Moon? (strange thought?)
3) Is the Moon larger than the Sun?
4) You can't see the Moon during the day, can you?
5) Is the Earth bigger than the Sun?
6) Which is closer to us: Jupiter or that star next to it?

During an annular solar eclipse in El Paso a few years ago an amateur showed one 55-year-old woman the lunar shadow obscuring the sun's disk through mylar, filtered binoculars, and a filtered telescope many times over a 45-minute period. Towards the end of the eclipse, she turned to him and asked: "...now which one is the sun?"

At one public star night in an unnamed US society, someone asked what constellation the Big Bang happened in. This was right after one of their members had given a short talk about cosmology and what the "Big Bang" meant. Maybe the questioner had been daydreaming about donuts during the talk...

A amateur was showing some members of the public some of the brighter objects in the sky through his telescope. After looking at Jupiter and its moons, he was asked: "So how many moons does the earth have ?!"

## Does the Moon's phase affect the crime rate?

We've all heard stories about how loonies roam the streets during a full moon, causing mayhem and murder. Indeed, many police officers and emergency room personnel have noted that they become much busier and receive more calls around this time. Scientists have looked for a correlation between the phase of the Moon and activities such as murders, violent crime and births. Studies have, however, shown **no** such correlation, contrary to the beliefs of those involved. In other words, the Moon's phase doesn't appear to have any effect on the number of crimes committed or babies born.

So why do people apparently notice an increase in these events around the time of the full Moon? Social scientists speculate that it's because people are more likely to notice, and remember, a full Moon, rather than the Moon when it's in a different phase. So, if some strange murder is committed when the Moon is a crescent, folks dealing with the crime or its consequences may not remember the phase of the Moon that night. If, however, the Moon is full, a police officer might be more likely to remember it since the full Moon is bright and very obvious. So, while crimes, births, and strange occurrences happen all month long, only those that occur on nights with a full Moon are remembered when people talk about them.

## Some Names for Full Moons

| | |
|---|---|
| **January:** | Wolf |
| **February:** | Snow |
| **March:** | Worm |
| **April:** | Pink |
| **May:** | Flower |
| **June:** | Strawberry |
| **July:** | Buck |
| **August:** | Sturgeon |
| **September:** | Harvest |
| **October:** | Hunter's |
| **November:** | Beaver |
| **December:** | Cold |

## Is the moon's far side ever illuminated by the Sun?

The answer is: yes, it is. We never get to see the far side of the moon from Earth because the moon always keeps the same face towards our planet. But, because the moon is orbiting the Earth, it shows a different face to the Sun each day.

# That Earthrise Photograph

The Apollo moon program resulted in a legacy of thousands of images - all of them of immense value as both scientific and documentary records.

Yet 30-odd years after the event, most of them speak only as images from history. However, one particular Apollo photograph transcends all others, an image so powerful and eloquent that even today it ranks as one of the most important photographs ever taken.

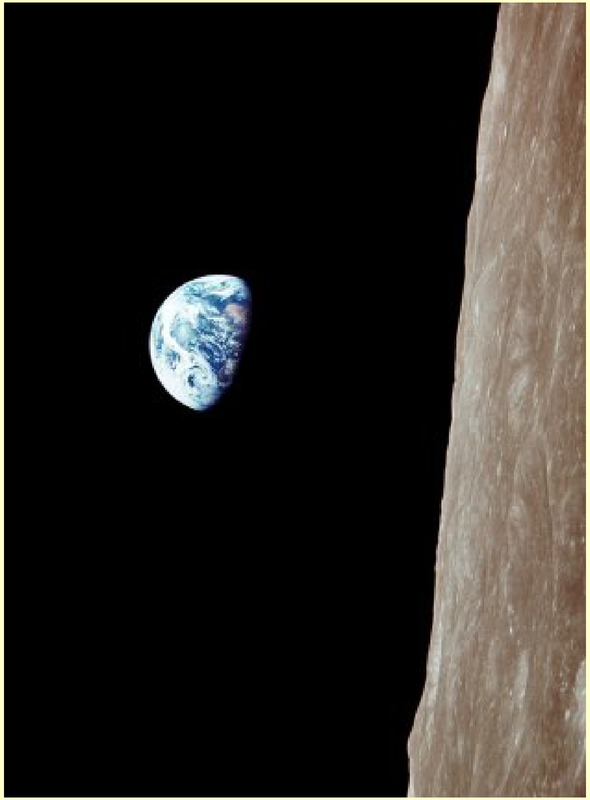
The colour photograph is "**Earthrise**" - taken by Apollo 8 astronaut, William A. Anders on December 24, 1968, seven months before the first lunar landing. Although the photograph is usually mounted with the moon below the earth, this is how Anders saw it.

Apollo 8 was the mission which put humans into lunar orbit for the first time. Until then, no human eyes had seen the far side of the Moon - (all previous images of the far side of the moon had come from robot spacecraft).

Virtually all of the photographs scheduled for the Apollo 8 mission were to do with capturing high resolution images of the lunar surface - both of the far side and of potential landing sites on the near side.

The 'Earthrise' photograph was not on the mission schedule and was taken in a moment of pure serendipity.

In order to take photographs of the far side of the moon the Apollo spacecraft had been rolled so that its windows pointed towards the lunar surface. During this time, the Moon was between the spacecraft and Earth, effectively cutting-off all radio communication with mission control. As Apollo 8 emerged from the far side on its fourth orbit, crew commander Frank Borman rolled the spacecraft so as to position its antennas for radio contact with mission control. Looking to the lunar horizon for reference he exclaimed - "Oh my God, look at that picture over there! Here's the Earth coming up!"



The famous photograph that was taken in the next two minutes is usually credited to crewman William Anders, although commander Frank Borman has always claimed that he took it.

It turns out that in fact three photographs were taken, one in black and white and two in colour. The black and white shot was taken first - by Borman, and the two colour shots were taken moments later by William Anders.

The curious thing about the images is the difference in the way the two men perceived what they were seeing. Frank Borman related the 'Earthrise' to a moonrise on Earth, with the lunar surface horizontal and the Earth rising above it. But William Anders framed his photographs from the perspective of being in orbit about the lunar equator. So his horizon was the plane in which he was travelling. This meant he framed it so the edge of the Moon was vertical, with planet Earth a little to the left but with its North and South poles aligned the same way as the North and South poles of the Moon.

(It is interesting to note that the colour photographs taken by William Anders are almost always re-published with the image on its side - i.e. from the perspective that Borman adopted for his B&W photograph).

But regardless of which way the photograph was taken, the image shows our entire world as a small and blue and very finite globe, with our nearest celestial neighbour a desolate presence in the foreground.

US Nature photographer Galen Rowell has described this image as "the most influential environmental photograph ever taken". It is an image which still speaks to us today.

## Lunation

A lunation is commonly defined as the mean time between successive new moons. However, as a result of the influence of the Sun on the moon's orbital motions, the actual time interval between consecutive new moons varies considerably but averages 29 days, 12 hours, 44 minutes.

## Apogee and Perigee

As is the case with all orbits, the moon's is elliptical rather than circular with the Earth sitting at one of the focus points of this ellipse. This means that during the course of its monthly orbit of our planet, the moon is sometimes closer to Earth and sometimes farther away.

The terms **Apogee** and **Perigee** are used to describe these two maximum and minimum distances from Earth. They refer to when the moon is in specific positions in its orbit - Apogee is when it's at its farthest from Earth during its orbit and Perigee is when it's at its closest.

*The difference in the size of the Moon at perigee (closest to Earth [left]) and at apogee (farthest from Earth [right])*

### Why were the lunation counts started in 1922?

Lunation 1 on January 16, 1923 was the first lunar synodic month for which Prof. Ernest Brown at Yale University had detailed lunar occultation data for developing his mathematical models of lunar motion. The 'Brown Theory' of lunar motion forms the basis for modern predictions of lunar motion, eclipses and occultation events. A synodic month, or lunation, begins at the New Moon and runs until the next New Moon 29.5 days later.

Due to a combination of factors (primarily from the Earth and the Sun), the moon's orbit precesses about the Earth and results in the times and distances of the apogee and perigee points changing from month to month. On occasion, the moon can make comparatively close approaches to the Earth during Perigee. One such close approach occurred in December 2002 when the moon came as close as 367,903 km, appearing slightly larger in the sky than usual. It was estimated to have been about 14% brighter than normal at full moon as a result.

## Libration

The moon's elliptical orbit has another consequence for the observer. Over time, the moon appears to 'nod' left and right and up and down slightly. This effect is known as Libration.

To see a demonstration of this effect, take a look at thso mpeg movie:

http://www.nightskyobserver.com/LunarPhaseCD/LibrationMovie1.mpg

As on Earth, the position of features on the Moon are measured in latitude and longitude (called Selenographic Latitude and Longitude). The lunar equator lies at 0 degrees latitude and the prime meridian (at 0 degrees longitude), runs from the north to south poles along the (vertical) running down the centre of the moon's disk.

As explained in the last article, the moon always presents the same face to observers since it takes as long to turn once on its axis as it does to complete one orbit of the Earth.

Since the Moon's orbit is elliptical rather than circular, the moon speeds up near perigee and slows down near apogee in accordance with Kepler's laws. The Moon's axial rotation speed remains essentially constant from month to month as a consequence of the conservation of angular momentum.

The Moon's orbit is also tilted to the ecliptic plane and to the Earth's equator by about 5 degrees. All these factors combine to make the Moon appear to nod from side to side and up and down during a lunar month, and it is possible to observe about 59% of the Moon's surface over a period of time, although we can only see 50% at any one instant.

There are, in fact, three types of libration involved in the moon's motions. Libration in latitude (up/down movement) is due to the Moon's axis being slightly inclined relative to the Earth's. Each of the lunar poles will appear to be alternately tipped slightly toward and away from the terrestrial observer over a roughly four week cycle.

Diurnal libration is due to the observer being up to four thousand miles to one side of the Earth-Moon axis on the surface of the Earth - a significant proportion of the centre-to-centre distance. The difference in perspective between the rising and setting of the Moon appears as a slight turning of the Moon first to the west and then to the east.

Libration of longitude is an effect of the Moon's varying rate of travel along its slightly elliptical orbit. Its rotation on its own axis is more regular, the difference appearing again as a slight east-west oscillation.

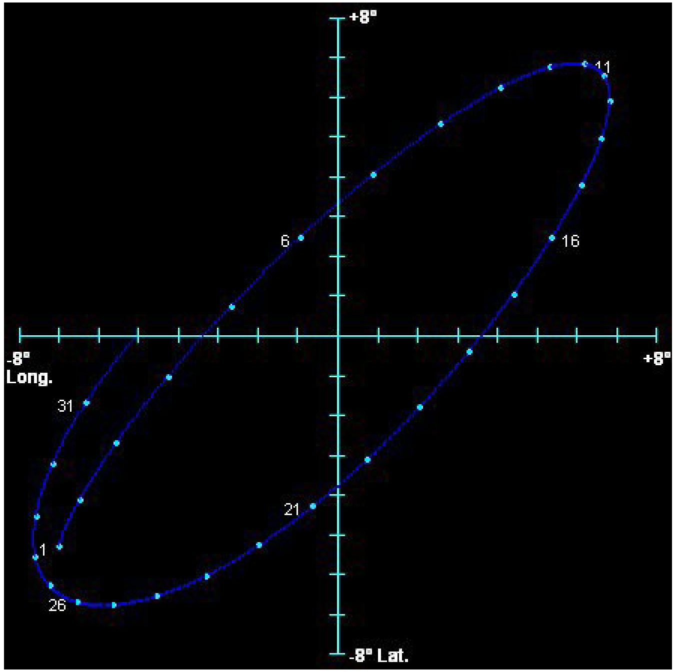


*Fig.1: Geocentric Libration Diagram for May 2004.*

At very favourable librations, the moon can rotate by as much as 8 degrees in latitude or longitude, bringing features that are normally on the limb into better view (as was the case with Mare Orientale on November 17th, 2003.

Fig.1 shows the libration diagram for May 2004. The dots represent each day in the month, with every 5th date being marked. The lines between the dates show the orientation of the moon in the intervening periods. The way to read this diagram is to pick the date you're interested in and measure left/right to the vertical axis to see how many degrees the moon has rotated North/South (a positive value (e.g. +4° for May 7th) shows that the Lunar North Pole is better placed for observing. A negative value indicates the South Pole is better placed. The higher the number of degrees, the more the tilt towards the observer and the better your chance of seeing extreme northern or southern features.

Likewise, for East/West librations, drop a line from the date you're interested in to the horizontal axis. A negative value indicates the Western limb is better placed for observing and a positive value indicates the Eastern limb. The higher the number of degrees, the better your chance of seeing extreme eastern or western features.

Fig.1 shows geocentric lunar libration - that is, libration as it would be seen from the centre of the Earth. Such diagrams are "generic" and can be used by anyone on the planet and will give a reasonable approximation of libration as seen from where you live. However, if you want the most accurate representation of libration, you

## The Moon Below the Equator

Those of you who have traveled in far-southern climes will be aware that the moon as seen from Southern latitudes does not look the same as when seen from Northern latitudes - it looks upside-down!

As we know, all bodies, including the moon, rise in the East and set in the West. In the Northern hemisphere, the bodies travel from left to right across the southern sky. In the Southern hemisphere, it's the opposite - the moon (and everything else) travel from right to left across the northern sky.

However, the above is merely a generalisation. From just south of the equator (say, Mombasa, 4° S), the moon can often appear in the **south**, and appear to travel from left to right across the sky, just as it does to northern hemisphere observers. That's because the ecliptic extends to 23.5° S and with the moon's inclined orbit, it can appear a further 5+° south than that.

In such circumstances, it would appear to move from left to right, getting highest up in the south - much as the summer sun appears to do from, say, the Canaries.

Of course, the converse can apply to locations just north of the equator, where the moon can someties appear in the **north**! That's something to look out for if the moon is near its northern limits the next time you're in the South Carribean, Gambia, Sri Lanka, Southern India, Bankok, etc. So you could be facing north, looking at Polaris above the north horizon and see the moon pass to the North of you, moving from right to left.

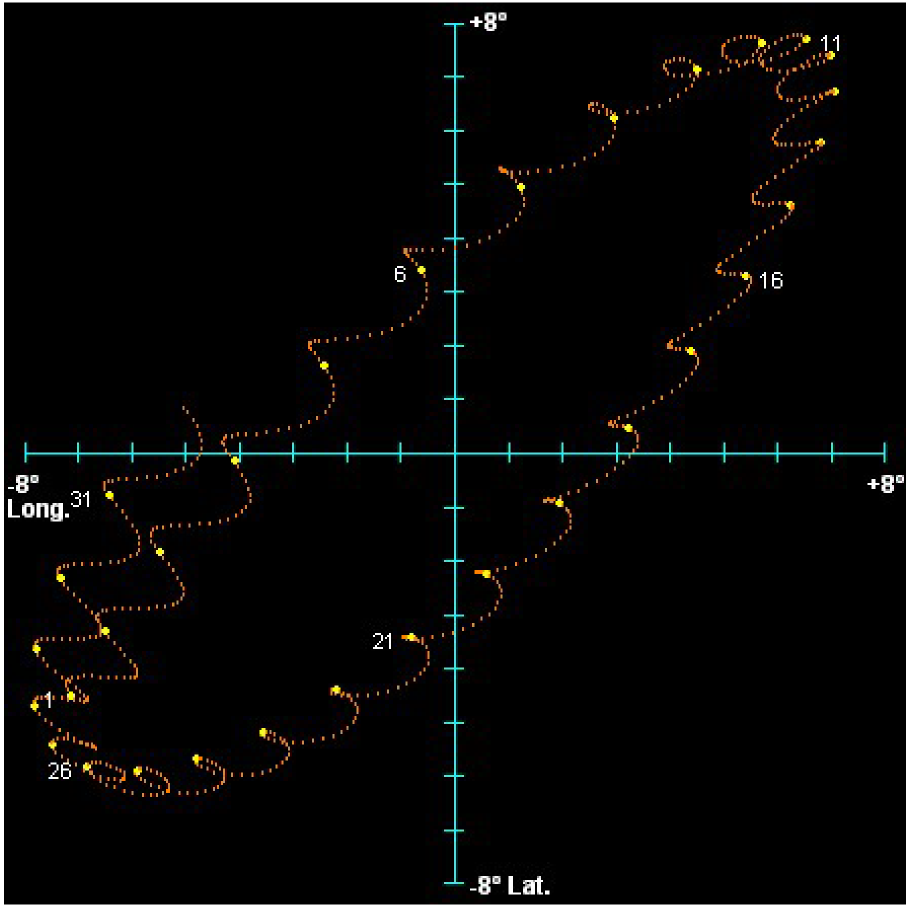



*Fig.2: Topocentric Libration Diagram for May 2004 (Dublin, Ireland)*

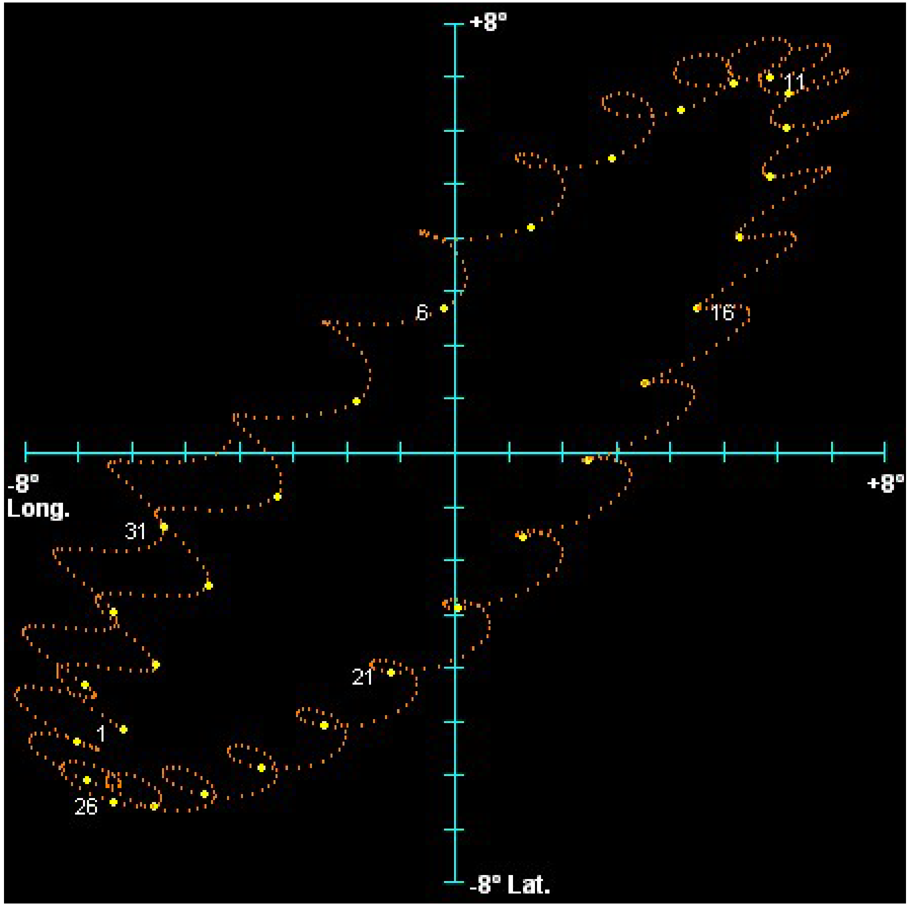



*Fig.3: Topocentric Libration Diagram for May 2004 (Los Angeles, USA)*

need to look at a Topocentric Libration diagram. These take account of the fact that we live on the surface of the planet and not at its core! They include the diurnal effects detailed earlier.

The Topocentric diagram for May 2004 (figs.2 and 3) show the oscillations that the moon goes through on a daily basis - in this case, fig.2 is for Dublin, Ireland. Fig. 3 shows the diagram for Los Angeles. If you examine the two diagrams, you'll see subtle differences between them, showing that libration is different from different parts of the planet.

If all this sounds too technical, just remember that libration and these diagrams give you, the observer, a

*The Rabbit in the Moon*

*The Lady in the Moon*

*Fig.4: Other moon features*

clue as to when to point your binoculars or telescope at the moon to see limb features that are normally very difficult to see due to the foreshortening of seeing them edge-on.

### Moon Illusions

As children, we all heard about how certain lunar features conspired to create the illusion of the Man in the Moon. There are, however, quite a few other illusory figures that can be seen when looking at a full moon with the naked eye. What image you (potentially) see depends on the season, your location and the time of night. Fig. 4 shows two of the figures.

### The Moon Illusion

Have you ever had the impression that the moon looks larger on the horizon when rising than it does when high in the sky? This, in fact, is an optical illusion. If you hold your thumb and index finger a pencil width apart and hold it at arm's length, you will always be able to fit the moon between them no matter where it is. It's simply a matter of perspective - the moon looks bigger next to a tree than when it is overhead and surrounded by black.

That, at least, is the simplistic explanation. If you wonder why this famous moon illusion occurs, you should read the article at the web address below, for, as illusion researchers know, a new explanation is needed, because the explanations currently offered by textbooks and the popular media (including most of the sites on the internet) simply do not explain the moon illusion.

The article reviews and applies a new theory of "size" illusions previously presented (since 1983) only in a few technical articles in specialized psychology publications. It is catching on among illusion researchers. This article is long because, first of all, it describes the moon illusion more completely than do conventional discussions, and in a very different and more logical way. Secondly, it reviews the currently best-known theories, and shows why vision scientists (psychologists) don't accept them. Thirdly, it reviews the new theory which proposes that the moon illusion is merely an example of the less familiar, but ubiquitous, "size" illusion known as oculomotor micropsia/ macropsia. Finally, in order to complete the theory, it reviews an explanation for oculomotor micropsia.

In other words, the new theory for the moon illusion is not simple: But it currently is the most satisfactory explanation.

You'll find it at: **The Moon Illusion Explained**

### Photographing the Moon

This topic alone deserves a dedicated article (any takers?) but I'll give some basic information on taking photographs of the moon.

One of the big mistakes that beginners make when trying to photograph it is in using a camera that has a lens with too short a focal length. Although the moon may seem quite large to the naked eye with a goodly amount of detail being visible, when photographed the resulting image is (unexpectedly) small and appears as a small dot on the print or slide, with little detail recorded.

In order to demonstrate how large (or small) the moon appears on a 35mm film frame, take a look at fig.5 which shows a number of photographs of the Moon through different lenses ranging from a wide angle lens of 24mm focal length right up to a 1600mm focal length telephoto (an 800mm lens with a 2x telecon-


*Fig.5: The size of the moon on a 35mm film frame as produced by lenses of different focal lengths*

verter) - these last two would also be in the focal length range of popular 4-5” refractors and 8-10” reflectors.

As you can see, you really need a focal length of 800mm or over for results that show significant lunar detail. 1600mm - 1800mm focal lengths allow the moon to fit in the frame easily.

A simple calculation will let you determine the image size of the Moon on 35mm film:

**Focal Length of Lens (mm) / 110**
**= Size of image**

So, for a 800mm focal length lens, the size of the image would be (800/110) or 7.27mm, roughly one-third of the height of a film frame.

**Using Teleconverters**

It is often said that teleconverters degrade an image and should be avoided, and that they also lose a lot of light, typically 2 stops for a 2x converter.

However, an image produced with a teleconverter is *far superior* to an image taken with the same lens without the converter where the image is enlarged to the same scale.

Why is this? Well it's down to the resolving power of the film. If you enlarge a negative or transparency you enlarge the grain, and the amount that the teleconverter degrades the image is less than you lose by enlarging the film. You also have the added advantage of having a larger image on your film frame in the first place.

You need not stop at one teleconverter; two 2x converters can be used together and the results are quite acceptable, far better than enlarging the image afterwards.

As to the light loss, well, we’re talking about photographing the 2nd brightest object in the sky, so you can afford to sacrifice a little in order to get better images.

There’s no doubt that a 1000mm lens will produce better images than a 500mm with a 2x converter but large lenses are very expensive whereas 2x converters are not. You’ll likely find them in the “used” section of camera shops for a few tens of euro or dollars. Just make sure that you get one that’s designed for your camera.

**What Camera to Use?**

The best type to use is a Single-Lens-Reflex (SLR) camera as this allows you to manually adjust the parameters for making an exposure (shutter speed, aperture, focus, etc.) SLRs also allow you to interchange lenses of different focal lengths.

Automatic cameras are not suitable as under exposure can occur if the light sensor of the camera is in the centre of the image, where the bright moon will cause the camera to either stop down the lens or reduce the exposure time.

The opposite may occur if the sensors pick up more of the background. Also, automatic cameras tend not to work so well in sub-zero temperatures (Winter astrophotography). It’s better to use an SLR camera or, if you must an automatic, use one that has a manual over-ride.

Always try to mount your camera on a tripod or rest it on some stable platform to cut down on image shake.

### What Film to Use?

As the Moon is a bright object, slow fine grain films can be used rather than the courser grained fast films. The best results are achieved with the slowest films such as Kodak Technical Pan 2415 (ISO 25) for black and white photographs and Kodak Kodachrome 25 for colour slides. Any film with an ISO rating of 50 or less will give good detail on any photos you take.

The faster the ISO rating of the film, the larger the film grain and the more degraded your picture will become. Using fine-grained films is more important if you're using low-power telephoto lenses as you need to record as much detail as possible in the small area of the film frame occupied by the moon.

### Calculating Exposures

The moon is lit by sunlight, so it should be treated as any daytime object would be on Earth, even at night! Always bracket your exposures - take one at a slower speed setting and one at a higher setting. This makes it more likely that you'll capture a good image. As a reference, Table 1 lists exposures for typical camera lens f-ratios and lunar phases. It should only be used as a starting guide though!

### Digital Cameras

While these cameras are not well suited to taking direct images of the moon, they come into their own when used at the eyepiece end of the telescope. Placing the camera over the eyepiece (in place of your eye) and taking a photo using this eyepiece-projection method can yield some pretty impressive pictures. It should be possible to achieve good results using the cameras with binoculars as well, but you will need to

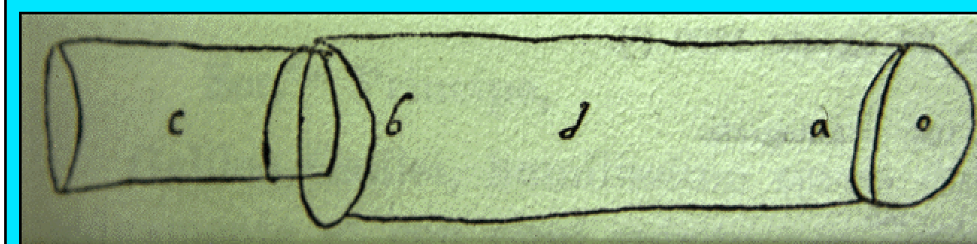
## Was Galileo the first to Turn a Telescope Towards the Moon?

The telescope, when invented, was a very humble and simple device. It is possible that in the 1570s Leonard and Thomas Digges in England actually made an instrument consisting of a convex lens and a mirror, but if this proves to be the case, it was an experimental setup that was never translated into a mass-produced device.

The telescope was unveiled in the Netherlands. In October 1608, the States General (the national government) in The Hague discussed the patent applications first of Hans Lipperhey of Middelburg, and then of Jacob Metius of Alkmaar, on a device for "seeing faraway things as though nearby." It consisted of a convex and concave lens in a tube, and the combination magnified three or four times. The gentlemen found the device too easy to copy to award the patent, but it voted a small award to Metius and employed Lipperhey to make several binocular versions, for which he was paid handsomely. It appears that another citizen of Middelburg, Sacharias Janssen had a telescope at about the same time but was at the Frankfurt Fair where he tried to sell it.

The news of this new invention spread rapidly through Europe, and the device itself quickly followed. By April 1609 3X spyglasses could be bought in spectacle-maker's shops on the Pont Neuf in Paris, and four months later there were several in Italy. Thomas Harriot observed the Moon with a 6X instrument early in August 1609. Harriot's observation of sunspots of December 1610 is also the first on record. But although Harriot shared his observations with a group of correspondents in England, he did not publish them.

It was Galileo who made the instrument famous. He constructed his first 3X spyglass in June or July 1609, presented an 8X instrument to the Venetian Senate in August, and turned a 20X instrument to the heavens in October or November. With this instrument he observed the Moon, discovered four satellites of Jupiter, and resolved nebular patches into stars. He published *Sidereus Nuncius* in March 1610.



***The earliest known illustration of a telescope. Giovanpattista della Porta included this sketch in a letter written in August 1609***

have your binoculars sturdily mounted.

### Some Final Tips

- Don't be afraid of taking many photographs in one session. Shoot a whole roll of film if you can afford to do so, just in order to get one or two good photos.
- Avoid camera shake by using a good tripod or solid platform .
- If its windy, find a sheltered spot - it will cut down on vibration.
- Check the sky conditions - poor seeing (turbulence in the atmosphere) will affect your results
- Try taking some photos of the moon in a daylight sky

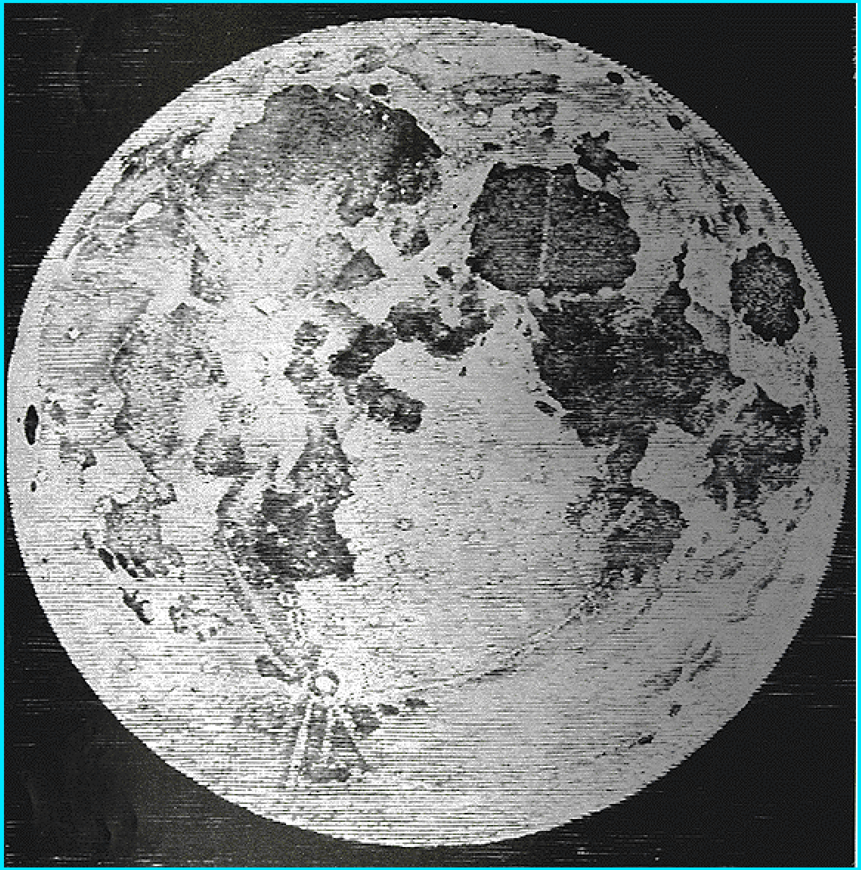
Lunar Libration diagrams produced with **LunarPhase Pro**

**Table 1: Lunar Phases (Exposure Times in Seconds)**

| f | Thin Cres. | Wide Cres. | Quarter | Gibbous | Full |
|---|---|---|---|---|---|
| 1.4 | 1/125 | 1/250 | 1/500 | 1/1000 | - |
| 2 | 1/60 | 1/125 | 1/250 | 1/500 | 1/2000 |
| 2.8 | 1/30 | 1/60 | 1/125 | 1/250 | 1/1000 |
| 4 | 1/15 | 1/30 | 1/60 | 1/125 | 1/500 |
| 5.6 | 1/8 | 1/15 | 1/30 | 1/60 | 1/250 |
| 8 | 1/4 | 1/8 | 1/15 | 1/30 | 1/125 |
| 11 | 1/2 | 1/4 | 1/8 | 1/15 | 1/60 |
| 16 | 1 | 1/2 | 1/4 | 1/8 | 1/30 |
| 22 | 2 | 1 | 1/2 | 1/4 | 1/15 |
| 32 | 5 | 2 | 1 | 1/2 | 1/8 |
| 45 | 15 | 5 | 2 | 1 | 1/4 |
| 64 | 45 | 15 | 5 | 2 | 1/2 |
| 90 | - | 45 | 15 | 5 | 1 |
| 128 | - | - | 45 | 15 | 2 |
| 250 | - | - | - | 45 | 5 |

## Early Moon Map

The French artist, Claude Mellan, was the first person to produce a detailed map of the moon in the late 1630s. Commissioned by Pierre Gassendi (canon of Digny in Provence, France) and his colleague Nicolas Claude Fabri de Peiresc, Mellan used a telescope of Galilean design which afforded a very narrow field of view, taking in less than a quarter of the moon's diameter.



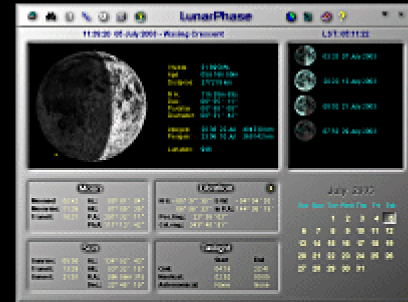
# LunarPhase Pro

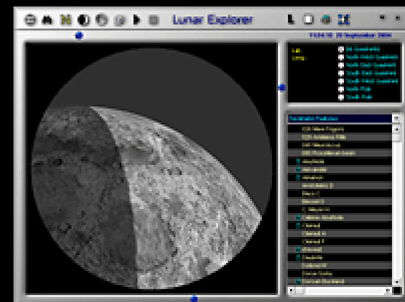
***** New V2.16 Release *****

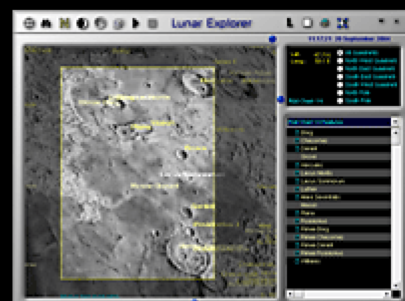
**CD: $39.95   Download: $34.95**

### New Version 2 Features

- Find future times and dates for when lunar features are under the same illumination
- Now over 9,200 lunar features are included in the inbuilt database, including the Lunar 100 list
- Rukl Chart outlines can be overlaid on moon map
- Lists of features for each Rukl Chart can be viewed
- Emulate the view of the moon as seen through your own eyepieces
- Record your own observation notes - many features come with preinstalled notes
- Link multiple images to specific lunar features
- Different map textures can now be selected - 3 mineral, one gravity and a Clementine Near infra-red map.
- Record the positions of any properties on the Moon you've bought, see their position on the map and link to satellite photos of their regions




### Main Features

- Moon's Phase and information displayed in realtime
- Displays daily moon, sun rise/set and twilight times
- Monthly ephemeris of moon and sun rise/set times
- Maps corrected for libration. Monthly libration animation
- Identify features on maps of from dropdown lists with a simple mouse-click, by clicking on the maps directly or from user-configurable labels that can be displayed on the maps
- Lunar Explorer screen lets you identify over 9,200 features
- Optional multi-coloured map labels for easy identification
- Zoom and pan over 3D and 2D moon maps. Print out maps.
- List of terminator features updated in real time
- Monthly Libration diagrams for determining the best limb-features to view
- Calculates times of sunrise/set for over 9,200 lunar features
- Calculates times and circumstances of lunar eclipses
- First Crescent Visibility predictions
- Store multiple observing locations
- Maps, charts and data can be printed out
- Many more features

**http://www.nightskyobserver.com/LunarPhaseCD**   gnugent@utvinternet.com

## LunarPhase Pro

If you would like to continue your explorations of the Moon, LunarPhase Pro provides everything you need, whether you're a novice, intermediate or advanced where Earth's nearest neighbor is concerned, from basic information on phase and rise/set times to an interactive Moon Atlas that lets you identify over 9,200 near and far side features with a simple mouse-click. Or see what libration really looks like when speeded up. Click the ad opposite for more information on the software, including sample screenshots.

If you'd like to read independent reviews of the software, you can do that at:
http://www.nightskyobserver.com/LunarPhaseCD/Reviews2.html

Or you can read what users have had to say here:
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If you don't need the advanced features of [LunarPhase Pro]() then this simple application may suit your needs.

It contains a Daily View diagram that shows where the Moon and Sun will be during the day, overlaid on a blue band that shows morning and evening twilight and the hours of daylight. Azimuth and altitude of the two bodies are also listed.

**Available only as a Digital Download [2Mb] for $9.95.**

http://www.nightskyobserver.com/LunarPhaseLite

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http://www.nightskyobserver.com/mooncal2005.htm

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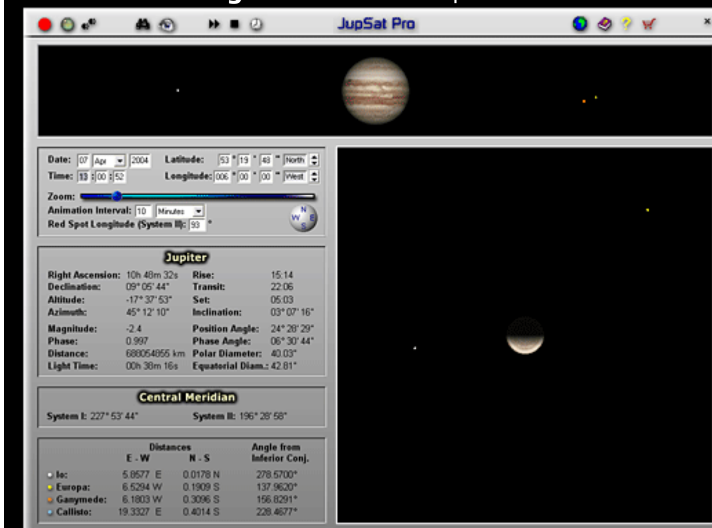


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