Hi this is Steve Nerlich from Cheap Astronomy www.cheapastro.com and this is *Moonlight.*

As you are probably aware, the Moon is gravitationally locked onto the Earth, meaning it doesn't spin on its axis and we on Earth only ever see one side of it. But since the Moon doesn't orbit the equator and since we are viewing it from the surface of a spherical planet rather than a single point in space, it's actually possible to see 59% of the Moon's surface from Earth.

The apparent swaying motion of the Moon in its orbit, allowing us to see this extra surface, is called libration and there's a nice video mock-up of it on Wikipedia.

The majority of moons in the solar system do orbit their planet's equator so the Moon's different orbit is kind of interesting. In fact the Moon is following what's called a *Laplace plane* which is a geometric representation of the local warping of space-time generated by the Earth versus the overarching warping generated by the Sun – which sits at the centre of the solar system and holds 98.6% of the solar system's mass. While the Moon is well and truly captured in orbit around the Earth, the Earth's gravity well is just a little dent in the side of the Sun's gravity well.

It seems likely that early on in its history, when the Moon orbited much closer to the Earth, it probably did orbit around the Earth's equator. But as it's moved further out, its orbital plane has begun to trend towards the ecliptic – which is the apparent path of the Sun through our sky – and in reality the orbital plane of the planets around the Sun to which the Earth's axis is tilted by 23.5 degrees.

At this point in its history, the Moon's orbital plane is now titled only 5 degrees from the ecliptic – and will presumably get even closer over the next billion years or so.

Until then, the difference in the Moon's orbital plane and the ecliptic is why solar and lunar eclipses are relatively rare events. Remember that the ecliptic also represents Earth's orbital plane around the Sun – even though the Earth's axis is tilted. So, a total solar eclipse is only going to be possible around the time of a new Moon and only when the orbital plane of the Moon crosses the Earth's – all of which happens about twice a year.

At these times the umbral shadow of the Moon follows a track of about 16,000 kilometres long and only 160 km wide and if you're standing inside this track you *should* enjoy a total eclipse. I say should because sometimes there are eclipses where the Moon isn't actually big enough to fully cover the Sun's disk – called annular eclipses. This is because the Moon has an elliptical orbit. When it's at its closest point to Earth, the perigee of the ellipse, it's about 360,000 km away and about 13% bigger, than when it's at apogee and about 407,000 km away.

So if you want to see a totally total eclipse you really want the Moon close to perigee. And just to keep it interesting, be aware that its orbit also precesses quite fast – meaning the whole ellipse with its perigee and apogee progressively shifts about the Earth – doing a complete cycle once every 8.8 years.

As early as 300BC, the Babylonians are known to have identified the Saros Cycle, which means that starting with one solar eclipse in one location, be it total, annular hybrid or partial, you can accurately predict that another geometrically identical eclipse will occur at a location to the west, one third of the way around the Earth, eighteen years, 11 days and 8 hours later. So, if you wait three Saros Cycles, or 54 years and 33 days, a geometrically identical eclipse will return to the first location you started with.

This brings me to the significance of the Moon in timekeeping. Although the Moon takes only 27.3 days to orbit the Earth, there will be about 30 days between one full Moon and the next. This is because the Earth has progressed about one twelfth of its way around the Sun in the intervening period, so the Moon has to progress about one twelfth further in its orbit before it once again rises just as the Sun sets – giving you a full Moon.

Although there is a close approximation between months in our calendar – and the lunar cycle, it is an approximation. There's 12.3 full Moons per year and – something which is of interest to traditional farmers – there's about three full Moons in each season. And, just occasionally, you can get four full Moons in the one season – and that second one is what farmers called a blue Moon. So, next time you hear that something happens once in a blue Moon – that's actually once every 2.7 years.

The Moon orbits the Earth from the west to the east – which is the same direction that the Earth is spinning. If you looked down on the Earth from above the North Pole, the Moon would be orbiting in an anti-clockwise direction and the Earth would be spinning an anti-clockwise direction, but over 27 times faster. Of course it's the Earth's west to east spin which makes everything in the sky seem to move relatively quickly from east to west. This is why you should check the Moon's position at about the same time each night if you want to see that it is actually orbiting from west to east.

For the two weeks prior to a full Moon if you look for it just after sunset, it will progress night by night from a new Moon, to a waxing crescent to first quarter in about one week, then become waxing gibbous until you get a full Moon another week later. Then for two weeks after the full Moon, it will rise later in the night as waning gibbous, then third quarter which will be rising around midnight a week after the full Moon, then a waning crescent shrinking back to a new Moon, nearly 30 days after the last one.

Moonlight is of course just reflected sunlight – and sometimes the Moon will seem brighter because it's in the perigee of its orbit and hence appears 13% bigger. The amount of light per unit area being reflected at Earth also varies depending on the angle it is being lit from the Sun. For example, during the first and third quarters, although we still see around 50% of the Moon's face lit, the Moon is only 8% as bright as it will be on a full Moon. This is because, at first and third quarters, we are seeing it lit from the side and more of the surface has shadows than during a full Moon.

Overall though, the Moon isn't particularly good at reflecting sunlight. Reflectivity of sunlight, also known as albedo, ranges from about 99% for Saturn's ice covered moon Enceladus, 65% for cloud covered Venus and down to 5% for some of the asteroids. The albedo of the Moon's surface is only around 7% – which is about as good as it gets with most regolith covered celestial objects with no atmosphere.

It's been estimated that the sight of a full Earth from the Moon's surface would be 100 times brighter than the full Moon seen from Earth. This is partly because the Earth would be bigger in the sky, but also because it has a much higher albedo, averaging at 37%, though varying a lot depending on cloud cover and what part of the surface is in view.

No-one has ever seen a full Earth from the Moon, since you can only see one during a mid lunar night and NASA didn't want its astronauts stumbling around in the dark, even with some Earthshine to work under. There are pictures of Earth in crescent phase from the Apollo missions – which show that from the Moon's surface, the crescent always appears horizontally lit. Michael Collins, the command module pilot of Apollo 11, admits he got it wrong when designing their mission patch which shows an imagined crescent Earth that is lit from the side.

Thanks for listening. This is Steve Nerlich from Cheap Astronomy, www.cheapastro.com. Cheap Astronomy offers an educational website where your capacity for saving is infinite. No ads, no profit, just good science. Bye.