

Phases of Charon

Middle/high school grades

Lesson Summary

Students explore the interaction of lunar orbital period, planetary rotation period, and rotational axis to map the phases of Pluto's moon, Charon.

Prior Knowledge & Skills

- Latitude and longitude
- Planetary and lunar orbits

AAAS Science Benchmarks

The Physical Setting

The Universe

NSES Science Standards

- **Earth and Space Science:** Earth in the Solar System

NCTM National Mathematics Standards

- **Geometry:** Use visualization, spatial reasoning and geometric modeling to solve problems

Teaching Time: 30 minutes

Materials

Each student needs:

- A copy of "Phases of Charon"

Advanced Planning

Preparation Time: 20 minutes

1. Review the handout

Why Do We Care?

This brainteaser pushes students' understanding of latitude, longitude, obliquity, and moon phases. It allows students to test their powers of mental visualization on a system somewhat different from the Earth-moon system.

Pluto and Charon are thought to have unusually similar masses (Pluto is about 10 times more massive than Charon, which in this context is "roughly comparable"). Some scientists therefore describe Pluto and Charon as a "double planet" rather than planet and moon.

Source: *Marc W. Buie, Lowell Observatory*

Phases of Charon as seen from Pluto

The following *Challenge Question* was posted to the Live from Hubble Space Telescope project.

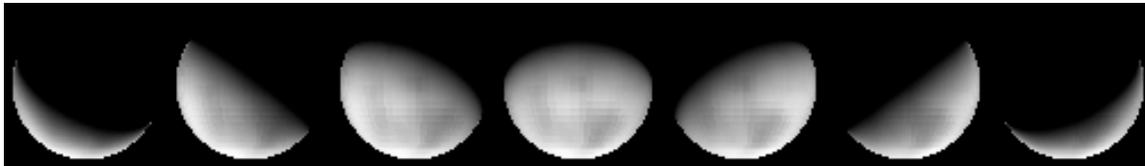
Pick two spots on Pluto (other than the poles) that are on opposite hemispheres. From these two vantage points, describe the phases of the moon, Charon, that you would see. (Hint: there are two periods of time to worry about, one long and one short.)

First, some essential background about Charon and Pluto. Pluto's obliquity (that's the tilt of the pole with respect to its orbit plane) is quite high, near 124 degrees. Just like Uranus, Pluto's rotational axis lies nearly in the plane of its orbit. Now, where is Charon relative to all this? Charon orbits around Pluto in Pluto's equatorial plane. So, like Pluto, the axis of its orbit and its rotation pole are tipped and nearly lie in the plane of Pluto's orbit around the Sun. There are three parts to this answer.

1. Let's pick two spots on Pluto. To make life easy, both locations are on the equator, one at 0 degrees longitude (Pluto's equivalent of Greenwich, England), and one at 180 degrees longitude (Pluto's equivalent of the international date line). The trick here is knowing that the length of Pluto's day is *exactly* the same as Charon's orbital period. That means Pluto always presents the same face toward Charon and Charon always presents the same face toward Pluto. This is just what our own Moon does. What is different, is that standing on Pluto, Charon does not appear to move relative to the horizon. That's because Charon orbits over Pluto's equator. Charon has the same type of orbit we use here near the Earth for communication satellites. This geometry means you never see a moonrise from Pluto's surface. This also means that over half the planet, you can never see Charon. The longitude system is defined such that 0 degrees longitude is in the center of the hemisphere that can see Charon. So, from 180 degrees you wouldn't see *any* phases at all. The rest of the answer will deal just with the side of Pluto where you can see Charon.
2. The quickest change in the phase of Charon happens during one orbit of Charon around Pluto. This orbit takes about 6.4 days. Let's consider the time when the Sun is directly over the equator. This time of "year" coincides with the start of spring. At "new" moon, Charon would be directly in front of the Sun and we'd see an eclipse. Then as Charon moves in it's orbit it would progress through the same phases that our own moon exhibits every month, taking only 6.4 days to complete the cycle.

- Another longer term cycle also affects the phases and that is Pluto's orbit around the sun. Since Pluto's rotation axis is tipped on its side, it has very pronounced seasons. Unlike our Moon, Charon also undergoes the same exact seasons. The only time you'd see a completely full moon would be at the start of spring or fall. At the start of summer or winter, just over half the surface would be illuminated at its fullest, either the north or south polar regions depending on the season.

I've created some pictures to help demonstrate these changes visually. When Pluto was discovered in 1930, it was just prior to the start of winter in the northern hemisphere. At that time, the Sun would pass overhead if you were at 53 degrees South latitude (that's similar to Tierra Del Fuego, South America on Earth). Here's what a full cycle would look like:



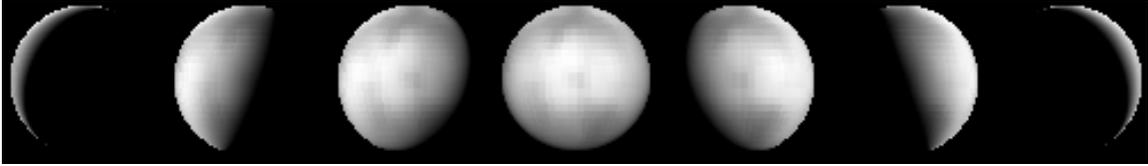
When Charon was discovered in 1978, it was late winter in the northern hemisphere. At that time, the Sun would pass overhead at 22 degrees South latitude (similar to Rio de Janeiro on Earth). Notice that full moon is getting more full.



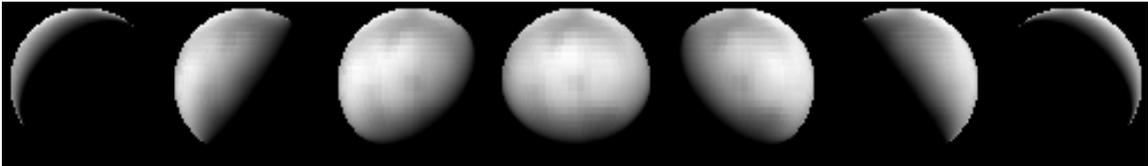
The Sun crossed the equator in 1988 during the middle of a 6 year season of eclipses that would have been very spectacular to watch. This marked the start of spring in the northern hemisphere and full moon was really full.



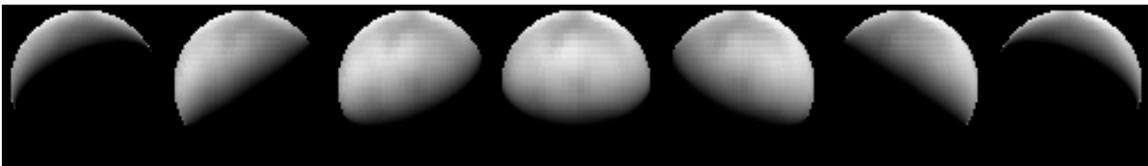
We've just begun to monitor Pluto for changes with HST in the Live from Hubble Space Telescope project. Here in 1996, the Sun passes overhead at 19 degrees North latitude (similar to Hawaii on Earth). Full moon isn't quite so full anymore but now the lit area is shifting to the north.



What does the future hold? Well, if we're lucky, by the year 2010 we might have just flown by Pluto with a spacecraft for our first up close look. At that time, the Sun will pass overhead at 35 degrees North latitude (similar to Baltimore, Maryland).



To round out the collection of phases, the next extreme will be in 2030 at the start of summer in the Northern hemisphere when the Sun passes over 56 degrees North latitude (That would be near Scotland on Earth).



This completes the tour of the phases of Charon. The cycle turns back from here and returns to an equatorial view sometime around the year 2110. Talk about long seasons!

Marc W. Buie, Lowell Observatory