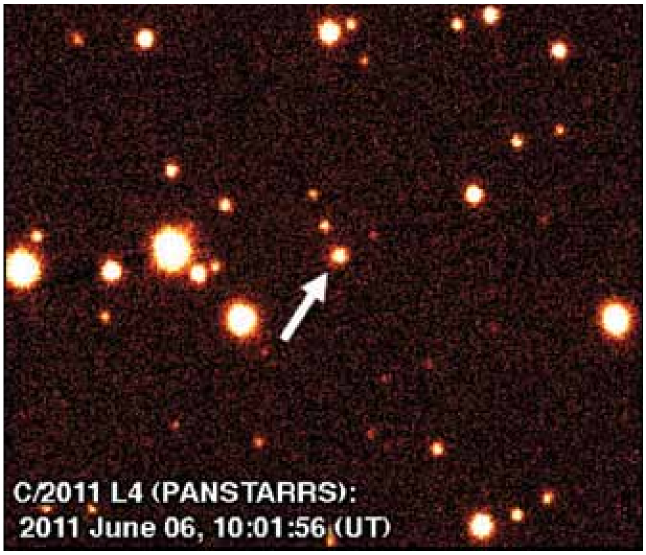
# Which way is north?

*by Bob Riddle*

In the January column, I described the small village of Cambridge Bay located in northern Canada above the Arctic Circle at around 69˚ north latitude. For those who live in Cambridge Bay, as well as at other locations, GPS and Google Maps can provide travel directions. However, when these are not available, the North Star is always reliable for determining the direction north. From the North Star, the other compass directions, as well as the latitude, may be determined. The latter, latitude, is easily determined by measuring the angle (or altitude) of the North Star (Polaris) above the northern horizon.

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Discovery image of the newfound comet C/2011 L4 (PANSTARRS), taken by Hawaii's Pan-STARRS 1 telescope.

## Three poles

As a rotating object, the Earth has a spin axis, around which it rotates. As a result, at opposite ends of the axis is a point called the *pole*, one of which is the North Pole; the opposite one is the South Pole. Midway between the two poles is the Earth's equator. We know that each pole is at 90˚ latitude, or 90˚ from the Earth's equator. In astronomy, we have extended our grid system of latitude and longitude into space and superimposed the grid onto what we call the celestial sphere—the apparent shape of space around the Earth. On the celestial sphere, there are also two poles, and each pole is also 90˚ from the equator (the celestial equator). However, astronomers use the term *degrees of declination* rather than *degrees of latitude* to describe locations north or south of the celestial equator. One additional pole, the ecliptic pole, is not based on the equator but on the ecliptic (the Earth's orbital path around the Sun), or as we view it, the Sun's apparent path during the year. The plane of the ecliptic is tilted from the plane of the equator by approximately 23.5˚, the axial tilt of the Earth. The ecliptic poles are each located 90˚ from the ecliptic.

The altitude of the North Star is equal to your local latitude. This happens as a result of the position of the North Star being nearly directly in line or above the Earth's north pole. (*Polaris* comes from the Latin for *polestar*.) Using latitude, we know that the Earth's north pole is at 90˚ north, and similarly, using the celestial sphere, we find that the North Star, the north celestial pole, is at 90˚ north declination. As you move south from either the celestial or surface pole position toward the celestial equator or the Earth's equator, the degrees of latitude and degrees of declination decrease from 90˚ at the pole to 0˚ at the equator. Likewise, as latitude decreases, the altitude of the polestar above the horizon also decreases, moving from straight up at the pole to on the horizon at the equator. The latitude you observe from that number of degrees of latitude will also equal the altitude of the North Star (latitude = altitude).

With this in mind, what would it be like on other planets in the solar system? Would each planet have its own polestar, or would our Polaris also serve as the "Polaris" for other planets? Consider that the planets in our solar system have axial tilts that range from close to 0 for Mercury, to the upside-down planet Venus with an axial tilt of 177˚. Also, each planet is inclined from the plane of the ecliptic by varying amounts (see Figure 1). The north pole of each planet presumably points toward a unique star that would serve as that planet's north star. Or does it?

To answer this requires an understanding of the layout of the planets in our solar system and the use of an

**FIGURE 1** Planet data table

| Name | North celestial pole declination | Axial tilt | Orbital inclination | Constellation and star closest to zenith |
|---|---|---|---|---|
| Sun | 89˚50′ | 7.5˚ | — | Draco and Altais |
| Mercury | 59˚24′ | ~0˚ | 7˚ | Draco and Omicron Draconis |
| Venus | -67˚41′ | 177.36˚ | 3.4˚ | Volans and Delta Volantis |
| Earth | 89˚19′ | 23.4˚ | 0˚ | Ursa Minor and Polaris |
| Mars | 67˚41′ | 25.19˚ | 5.1˚ | Cygnus and Deneb |
| Jupiter | 65˚41′ | 3.13˚ | 1.9˚ | Draco and Zeta Draconis |
| Saturn | 89˚19′ | 26.73˚ | 1.3˚ | Ursa Minor and Polaris |
| Uranus | -15˚ 44’ | 97.77˚ | 2.5˚ | Ophiuchus and Sabik |
| Neptune | 45˚9′ | 28.32˚ | 1.8˚ | Cygnus and Delta Cygni |
| Pluto | 11˚18′ | 122.53˚ | 17.2˚ | Delphinus and Epsilon Delphini |

astronomy program that could simulate the view of the sky from the surface of other planets in the solar system. In my classes and for this column, I use Starry Night, one of the many commercial planetarium programs available for simulating the daylight and nighttime skies from user-determined locations and times. One of the features of the astronomy program I use is the ability to set the viewing location to the surface of other objects in the solar system, not just other planets. For each planet, I set the viewing location to 90˚ north. For any planet, as with Earth, it is assumed that from the position of a planet's north pole, the north star is directly above the north pole, at or near the zenith. From that position on each planet, the north ecliptic pole and the zenith (the point directly overhead) are determined, and then marked on the star chart (see Resources).

The north ecliptic pole is the point in space that is 90˚ "above" the plane of the ecliptic—just like the north celestial pole is 90˚ "above" the celestial equator. The plane of the ecliptic is described as the Sun's apparent orbit throughout the year set against stars making up the background, when in reality the plane of the ecliptic is the Earth's orbital path around the Sun. The plane of the ecliptic is the common reference point used for determining each planet's orbital inclination and axial tilt. However, the other planets do not necessarily orbit the Sun on the same plane as the Earth, but are inclined from the Earth's orbital plane by varying amounts. The difference from the Earth's orbit is called *orbital inclination* and is measured in degrees (see Figure 1).

The location of a planet's north pole and zenith is based on the spin axis of the planet. Therefore, the poles for a planet are located where the spin axis exits from that planet's surface. Also assumed is that north is "up" for the solar system, based on the Earth's North Pole. With this in mind, the planet Uranus and dwarf planet Pluto rotate around their respective spin axes on their side, while Venus rotates upside down, with north "down" and south "up." As a result, Venus also rotates in the opposite direction, as do the other planets (see Figure 2).

For each planet, the north ecliptic pole is located where a line perpendicular to the ecliptic plane intersects the celestial sphere, whereas the north celestial pole for each planet is the point where a line perpendicular to a planet's equator meets the celestial sphere (see Figure 3). For the record, there are also south ecliptic and celestial poles, both of which are directly opposite and, as with their northern counterparts, are also separated from the plane of the ecliptic and celestial equator, respectively, by 90˚.

Interestingly, for each planet, the difference between the declination of the north ecliptic pole and the declination of the planet's north celestial pole is the same as the planet's axial tilt. Earth, for example has its north ecliptic

**FIGURE 2** The north pole of Venus points south

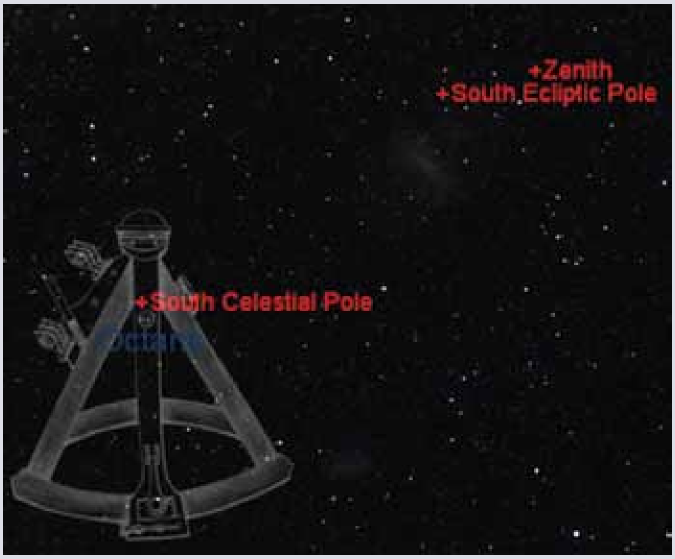
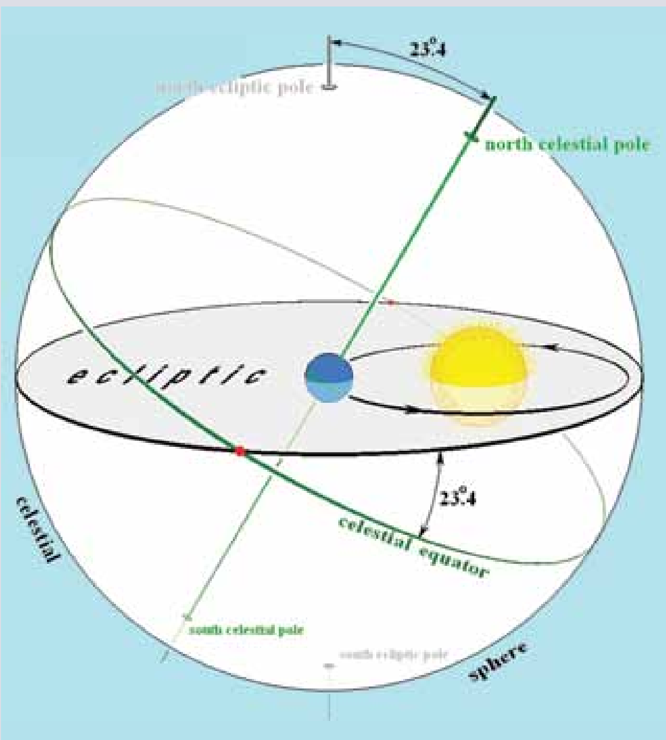



**FIGURE 3** The celestial sphere and poles




pole at 66°34′ north declination, while the celestial north pole is at approximately 89°, a difference of about 23.5°, or the Earth's axial tilt.

The Sun is also tilted on its spin axis from the plane of the ecliptic by about 7.5°. During the year, the Sun's poles, like the Earth's, go through a regular cycle of tilting. During March, when the Earth's axial tilt places the Sun over the equator, the Sun's south pole is tilted toward the Earth. Half a year later, during September, the Sun's north pole is tilted earthward. June and December are the intermediate periods when the Sun's poles are not tilted toward us.

## Visible comet?

Comet predictions are reasonably accurate, with the exception of predicting how bright a comet will become. We do know that comets brighten as they come closer to the Sun, with maximum brightness at perihelion, or a comet's closest distance to the Sun. However, the comet may break apart or simply not produce a coma and tail as expected and not become as bright as predicted. If the comet perihelion happens when the comet is relatively close to the Earth, then it may reach naked-eye brightness. Such is the case for inbound comet 2011 L4 Pan-STAARS, which was discovered with the Panoramic Survey Telescope and Rapid Response System in Hawaii. (See the February 2013 column for more information about the telescope.) Current calculations show the comet reaching perihelion on March 10 and then being closest to the Earth on March 13. During the week around this time period, the comet may reach a magnitude brighter than the stars of the Big Dipper. During March, the comet will be visible after sunset over the western horizon. See Figure 4.

## Visible planets

**Mercury** will move into the evening skies this month.
**Venus** will be too close to the Sun to be visible this month.
**Mars** will be too close to the Sun to be visible this month.
**Jupiter** will be high above the southern horizon and will be visible all night.
**Saturn** will rise before midnight and be visible the rest of the night.

**FIGURE 4** March 13 at 8 p.m. (EDT)

## March

| | |
|---|---|
| 2 | Waning gibbous Moon near Saturn |
| 4 | Mercury at inferior conjunction |
| | Last quarter Moon |
| 5 | Moon at perigee (369,954 km; 229,879 mi.) |
| 6 | Moon very close to Pluto |
| 10 | Spring forward: Set clocks one hour ahead |
| | Comet 2011 L4 Pan-STAARS closet to Sun |
| 11 | New Moon |
| 13 | Comet 2011 L4 Pan-STAARS closet to Earth |
| 17 | Waxing crescent Moon near Jupiter |
| | Jupiter near Aldebaran |
| 18 | Moon at apogee: (404,262 km; 251,196 mi.) |
| 19 | First quarter Moon |
| 20 | March equinox (6:02 a.m. [EST]) |
| 27 | Full Moon |
| 28 | Venus at superior conjunction |
| | Uranus at solar conjunction |
| 29 | Waning gibbous Moon near Saturn |
| 30 | Moon at perigee (367,494 km; 228,350 mi.) |
| 31 | Mercury at western elongation |

## Questions for students

1. If you were standing at the Earth's north pole, in which direction would your first step take you? How about at the Earth's south pole? (*From the North Pole, your first step would be toward the south, while at the South Pole, the first step would be northward.*)
2. It is said that the Earth "leans" or is "tilted" toward the Sun in Northern Hemisphere summer and leans or is tilted away from the Sun during winter. Does the Earth actually lean toward and away from the Sun? (*No, it does not actually tilt back and forth. The Earth's axis is tilted at the same angle. The North Pole, for example, always points toward the same spot in space during the year as the Earth revolves around the Sun.*)
3. How do comets get their name? (*Comets, in general, are named after their discoverer and follow guidelines established by the International Astronomical Union (see Resources). Comet 2011 L4* Pan-STAARS *is named for the automated telescope that imaged the comet.*)
4. Can you balance an egg only on an equinox day? You don't have to go to the equator to test this idea. (*One of the most enduring examples of bad science revolves around the idea that an egg will balance on the equinox day. Have students investigate this idea—but not just on the equinox day. See Riddle 2006.*)

### Reference

Riddle, B. 2006. Scope on the Skies: The equinox. *Science Scope* 29 (6): 78–79.

### Resources

Cambridge Bay—*www.cambridgebay.ca*

C/2011 L4 (PANSTARRS)—*http://cometography.com/lcomets/2011l4.html*

C/2011 Pan-STAARS orbit diagram (requires Java)—*http://ssd.jpl.nasa.gov/sbdb.cgi?orb=1;sstr=2011+L4*

Comet Pan-STAARS—*http://bobs-spaces.net/comets/comet-pan-staars-c2011-l4*

Guidelines for cometary names—*www.ss.astro.umd.edu/IAU/csbn/cnames.shtml*

Pan-STAARS—*http://pan-starrs.ifa.hawaii.edu*

Planetary fact sheet—*http://nssdc.gsfc.nasa.gov/planetary/factsheet/planet_table_british.html*

Riddle, B. 2011. Scope on the Skies: Changing of the seasons. *Science Scope* 34 (7): 88–91.

SFA star charts (PDF)—*http://observe.phy.sfasu.edu/SFAStarCharts/SFAStarChartsAll.pdf*

Starry Night software—*astronomy.starrynight.com*

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