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Reflector

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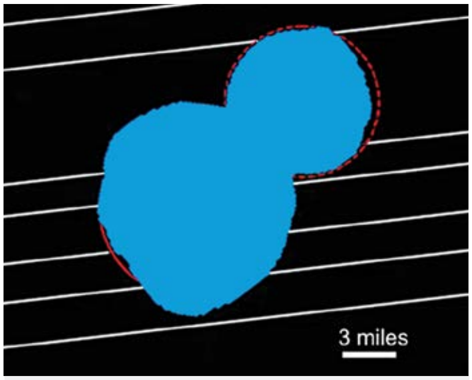
lobe to lobe through the neck, but is more likely perpendicular to the lobe-to-lobe line. The rotational period for Halley is 52.8 hours.

The European Space Agency's Giotto spacecraft captured this close-up image of Comet Halley's nucleus as it traversed the inner Solar System. The comet has a very dark surface, with jets of gas and dust spewing out of the comet's sunward side. The nucleus is peanut-shaped, the first example of a bilobed comet to be imaged. This image is a composite taken on March 14, 1986, from a distance of 1,242 miles. Image Credit: European Space Agency

The New Horizons spacecraft flew past the Kuiper Belt asteroid (486958) Arrokoth (2014 MU_{69}) on January 1, 2019. This asteroid is also bilobed, showing that both comets and asteroids can have this shape. Arrokoth is a contact binary; the two lobes are thought to be two similar, but separate, asteroids that have been pulled together by their mutual gravity. The spin axis runs through the larger lobe, just above the neck and perpendicular to the lobe-to-lobe line. It spins once every 15.94 hours.

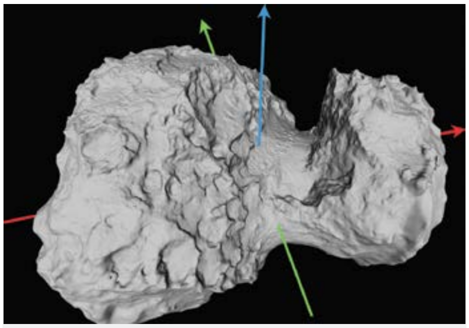


While the New Horizons team was planning for the flyby of (486958) Arrokoth, they discovered that it would occult an unnamed star in Sagittarius for observers in South America on July 17, 2017. Twenty-four telescopes were set up to observe the event and five of them saw the star blink out. This occultation defined the size and shape of Arrokoth in preparation for the flyby. The blue outline of Arrokoth as observed by New Horizons is overlayed on this plot. Image Credit: NASA/JHUAPL/SwRI

Other examples of bilobed minor bodies imaged by spacecraft include (25143) Itokawa, (243) Ida, (951) Gaspra, (5535) Annefrank, and (9969) Braille. Of the seven comets that have been imaged close-up, five are bilobed, suggesting that bilobed comets may be fairly common. Other asteroids have been scanned by radar, but these must come near the Earth to produce a strong enough radar reflection.

Comet 67P/Churyumov-Gerasimenko received a guest on August 6, 2014, when the European Space Agency's Rosetta spacecraft reached the comet. It found that 67P was also bilobed, again with its spin axis perpendicular to the lobe-to-lobe line. It rotates once in 12.4043 hours. 67P has also been identified as a contact binary because the striations on the two lobes are in different orientations.

A team led by Purdue University's Masatoshi Hirabayashi and the University of Colorado at Boulder's Daniel Scheeres have studied 67P intensively and found two cracks in the comet's



Comet 67P/Churyumov-Gerasimenko is another bilobed object that has been studied in detail. The rotational axis, analogous to the north-south polar axis on the Earth, is marked by the blue line. The red (x-axis) and green (y-axis) lines are perpendicular to the rotational axis. This image was generated from data taken by the European Space Agency's Rosetta spacecraft. Rosetta landed on the surface in September 2016 as it ended its mission to this comet. Image Credit: ESA/Rosetta/MPS for OSIRIS Team MPS/UPD/LAM/IAA/SSO/INTA/UPM/DASP/IDA

neck that are each longer than a football field. They modelled the structure of the comet and used the model to simulate an increase in the rotation rate, reducing the period from the current twelve hours to seven to nine hours. This caused similar cracks to appear on the neck in the model, just where they had been observed on the real comet.

While 67P is unlikely to pull itself apart at its current rotational speed, when the comet flies past the Sun or Jupiter, their gravity could speed up the rotational rate. Gas jets from the comet can also increase or decrease its rotational speed. If the comet spins fast enough, the two lobes will separate. They will not fly apart, but will begin orbiting each other. After a period as short as hours, but probably longer, the two lobes will come together again in a new configuration.

The researchers used their model to create one thousand clones of 67P, each with slightly different initial conditions. They were run through a five-thousand-year period that showed that the comet's rotation sped up and slowed down in a chaotic manner. It is very likely that bilobed comets separate and recombine as a part of their normal lifespans. A separation when the comet is near the Sun would cause more surface area to be exposed to sunlight. This would cause more dust and gas to be released, enhancing the tail. Perhaps this is what creates a great comet.

—Berton Stevens

Deep-Sky Objects

THE TRIANGULUM GALAXY

The Triangulum Galaxy (M33) is the third largest galaxy in the Local Group, the galaxy group that includes our Milky Way. The largest galaxy in the group is the Andromeda Galaxy, M31, followed by the Milky Way. Both the Milky Way and M31 are approximately 20 times more massive than M33. At 2.7 million light-years away, the Triangulum Galaxy is slightly more distant than the Andromeda Galaxy, which is 2.5 million light years away. M33 has an integrated magnitude of 5.7, therefore, in extremely dark skies, some with exceptional night vision can spy this galaxy naked-eye, making it the most distant object visible without optical aid.

M33 lies about four degrees west and one degree north of the magnitude 3.4 star Metallah (Alpha Trianguli). It is also seven degrees southeast of 2nd-magnitude Mirach (Beta Andromedae). These two stars frame the galaxy nicely, making it easy to find.

M33 spans 1.0 by 0.6 degrees in the sky. At its measured distance, the long axis of the galaxy stretches 60,000 light-years, compared to 100,000 light-years for the Milky Way. This nearly face-on galaxy has an Sc Hubble galaxy classification. Sc galaxies are spiral galaxies with small cores compared to their disk diameters. The Milky Way and M31 have much larger cores and galactic bulges for their size.

The first astronomer to catalog the Triangulum Galaxy was an Italian comet hunter named Giovanni Battista Hodierna some time before the year 1654. Charles Messier, also a comet hunter, rediscovered M33 in 1764. Messier, a Frenchman, was probably not familiar with Hodierna and his publications.

The accompanying image of M33 captures most of the galaxy's extent. It was captured with a 132 mm f/7 apochromatic refractor using a

0.8× focal reducer/field flattener to yield f/5.6. The exposure was 180 minutes using an SBIG ST-2000XCM CCD camera. North is up and east is to the left. The bright orange star on the right edge is magnitude 8. Likewise, the bright orange star on the upper left side of the image is also magnitude 8. The image does not resolve individual stars in M33, so most of what appear to be stars in the galaxy are foreground Milky Way stars. However, some of the faintest star-like dots on the image are massive star associations or globular star clusters in M33 that are not resolved.

The Triangulum Galaxy is a great object to view in binoculars and small telescopes. These devices allow the entire disk of the galaxy to be seen in the same field of view. Larger telescopes are able to zoom in on regions of the galaxy, revealing more detail in the eyepiece.

One of the best regions to view in M33 is the bright red emission nebula NGC 604. Located on the northeast side of the galaxy, NGC 604 is one of the largest H II (ionized atomic hydrogen) regions known and extends 1,500 light-years. In comparison, the Orion Nebula is only 24 light-years in extent. NGC 604 contains more than 200 stars 15 to 60 times the mass of the Sun. There are three other emission nebulae in M33 found in the New General Catalog: NGC 588, NGC 592, and NGC 595. Entries 131 to 143 in the Index Catalog (IC) also belong to nebulae or star clusters in M33. All are 13th to 14th magnitude or fainter. All of these NGC and IC object are visible in dark skies using 16-inch or larger telescopes.

As can be seen in the accompanying image, M33 has two main spiral arms with several dimmer arms branching from the main arms. Dark nebulae are found throughout the galaxy. NGC 604 is the bright pinkish-red patch on the upper left side of the galaxy in the image. This light comes from the neutral hydrogen-alpha transition at 656.3 nanometers. NGC 604 is approximately 1.9 arcminutes in size. It's cataloged at magnitude 12 and is visible in an 8- to 10-inch telescope in really dark skies.

The other pinkish-red nebula located to the upper right of the galactic core on the accompanying image is NGC 595. NGC 595 is 30 arcminutes in size and is magnitude 13.5. It should be visible in 12- to 14-inch telescopes. Down and to the right of NGC 595 is NGC 592, an association of up to 12 massive O and B stars embedded in a star-forming nebula. The combined magnitude of this association is 13.0 and it is about 42 arcseconds in size.

The Triangulum Galaxy is located a mere 750,000 light-years from the Andromeda Galaxy and may be gravitationally bound to it. Regardless, an unobstructed view of M33 from a planet in M31, and vice versa, must be quite impressive. The separation of the two galaxies is decreasing, and both galaxies are approaching the Milky Way. The views will only get better!

In the late autumn and early winter evening hours, M33 is well positioned for northern hemisphere astronomers. On clear nights, the cold, steady winter skies should be ideal for exploring the Triangulum Galaxy!

—Dr. James Dire