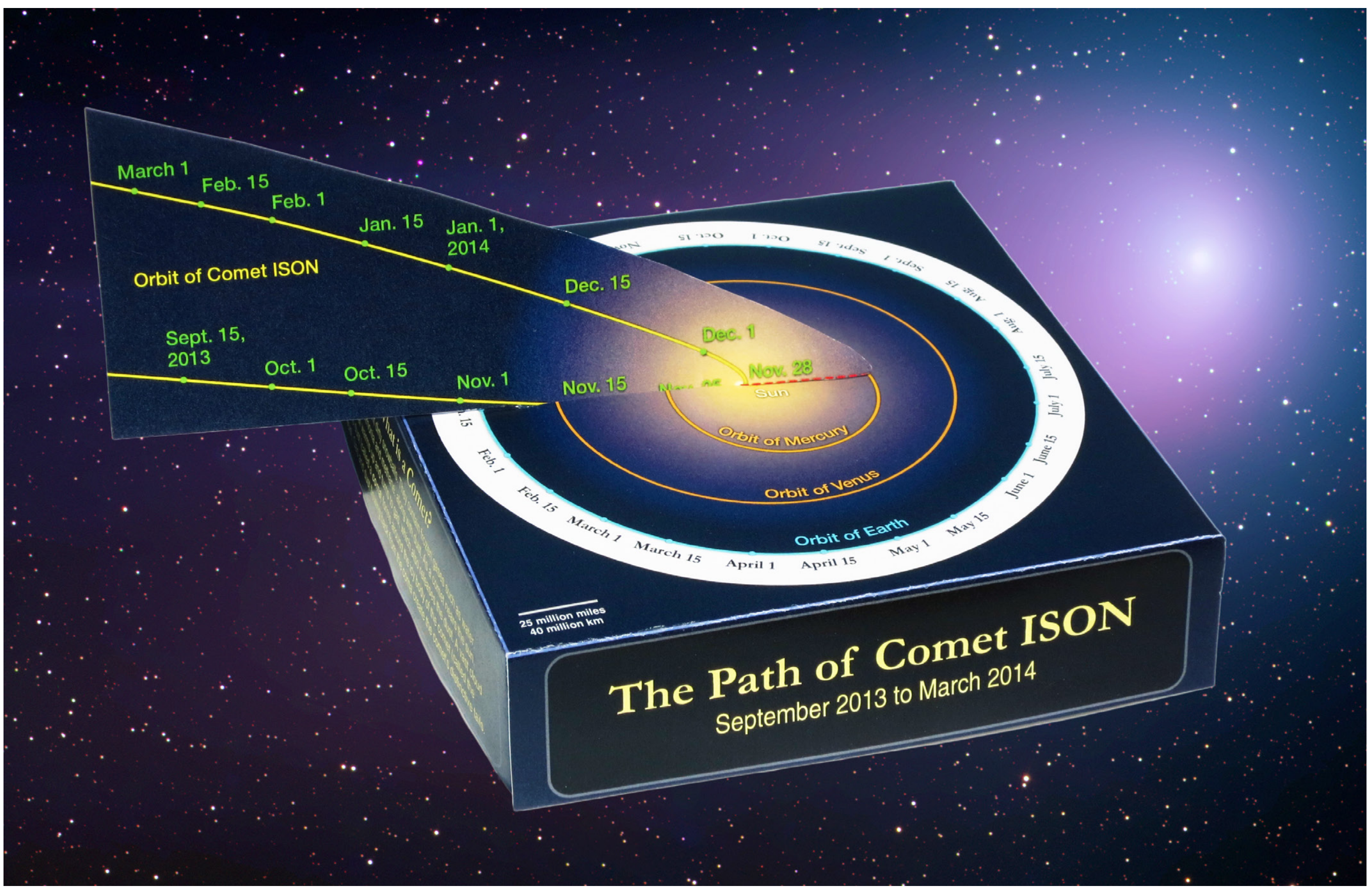
Paper Model of Comet ISON's Orbit

Comet ISON, officially known as C/2012 S1, is an icy visitor from the edge of the solar system. Its unusual orbit carries it extremely close to the sun on Nov. 28, 2013. Around this time, comet ISON may become bright enough to glimpse in the daytime just by blocking the sun's glare.

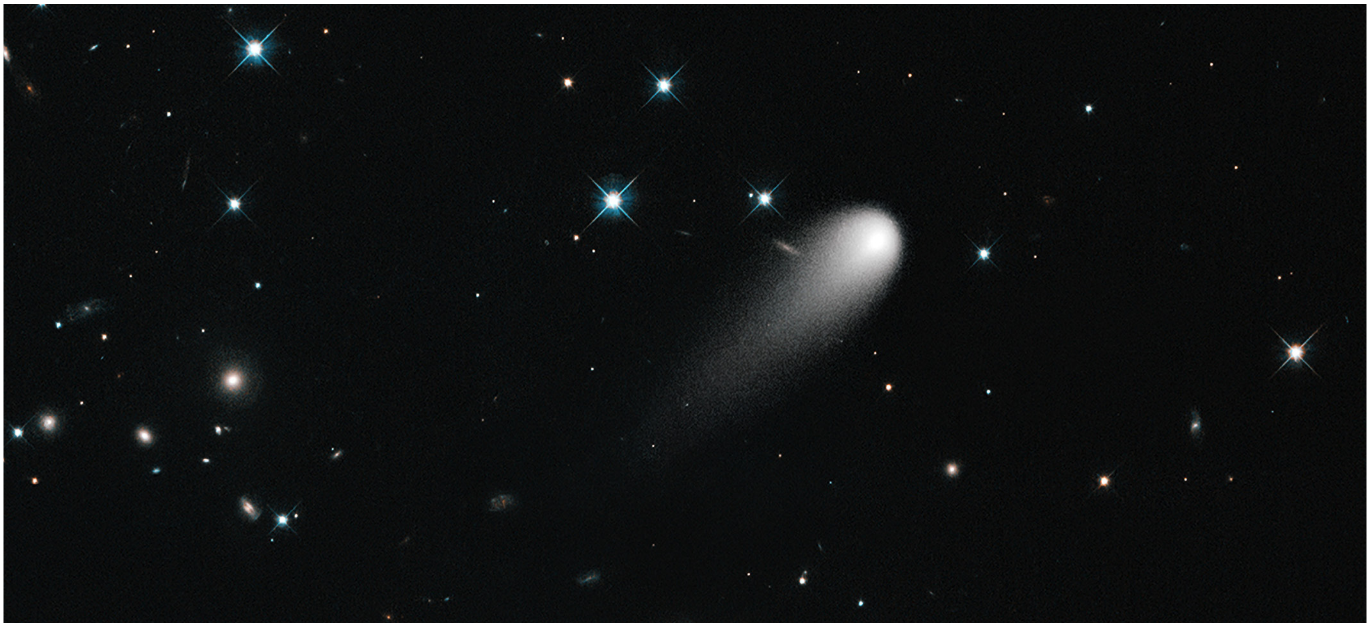
Comet ISON follows such an eccentric and steeply angled orbit that it can be difficult to picture how it relates to the orbits of the inner planets. This paper model illustrates the comet's path during its six-month trek in the vicinity of Earth, Venus and Mercury. Track how the relationship between Earth and the comet constantly changes by referring to the dates along both orbits.

The top of the model's Display Base represents the plane of Earth's orbit around the sun. The comet spends less than a month south of (below) this plane as it whips around the sun.

Long ago, perhaps due to the gravitational influence of a passing star, comet ISON was nudged out of the Oort cloud, a storage zone at the fringes of the solar system that may hold a trillion comets. ISON fell toward the sun along an elongated path



Comet ISON is making its way through the inner solar system. Visualize its unusual orbit and track its journey around the sun with this paper model. The background image shows comet NEAT (C/2001 Q4) during its 2004 appearance. Background: T. A. Rector (Univ. of Alaska Anchorage), Z. Levay and L. Frattare (STScI) and WIYN/NOAO/AURA/NSF



Comet ISON floats against a backdrop of stars and galaxies in this composite image, acquired April 10, 2013, by the Wide Field Camera 3 instrument aboard the Hubble Space Telescope. At the time of this observation, the comet was 394 million miles from Earth. NASA, ESA, and the Hubble Heritage Team (STScI/AURA)

that is quite unlike the nearly circular orbits of the inner planets. The planets travel in orbits only slightly tilted out of Earth's orbital plane, but ISON's track is steeply inclined to it. Based on the details of its orbit, astronomers think this is ISON's first passage through the inner solar system and near the sun.

Comet ISON will pass about 6.7 million miles (10.8 million km) from Mars on Oct. 1. That's about six times closer than it will ever come to Earth, so scientists are planning to make intriguing observations using spacecraft now working at Mars, such as NASA's Mars Reconnaissance Orbiter. Although the orbit of Mars is not shown on the model, its location can be estimated. Using the scale on the Display Base, just measure down from the comet's position on the date of its closest approach.

On Nov. 28, comet ISON makes its sweltering swing around the sun, passing about 728,000 miles (less than 1.2 million km) above its visible surface. This incredibly close encounter is what classifies ISON as a "sungrazing" comet.

Satellites designed to study the sun, such as NASA's Solar Dynamics Observatory, will be monitoring how ISON responds to the fierce solar heat. Scientists plan to use the comet's tail as a solar probe to trace how hot gases move throughout the sun's atmosphere, a region called the corona.

Using data acquired by several space observatories, including NASA's Swift and the Hubble Space Telescope, astronomers have estimated the size of the comet's icy body to be about 3 miles (5 km) across. Scientists think this may be large enough for ISON to survive its fiery solar passage, but they cannot discount the possibility that the comet may break up into numerous small fragments that quickly evaporate. In fact, this is the typical fate of sungrazing comets.

If ISON survives, it may be visible to the unaided eye in morning twilight during the first week of December. As it pulls away from the sun, the comet will quickly fade in brightness even as it comes closer to Earth. ISON makes its closest approach to Earth on Dec. 26, when it passes 39.9 million miles (64.2 million km) away or about 167 times farther than the moon. About three weeks later, on Jan. 15, 2014, Earth passes through the plane of the comet's orbit.

This project was developed by Francis Reddy at Syneren Technologies Corp. and NASA's Goddard Space Flight Center, with assistance from Barbara Mattson (USRA/CRESST) and Pat Tyler (Syneren), also at Goddard. We thank Dennis Bodewits and Michael Kelley (University of Maryland, College Park) and Matthew Knight (Lowell Observatory, Flagstaff, Arizona) for their scientific review.

Build the model!

You will need a printed version of the parts, scissors or a hobby knife, and tape.

1. Carefully cut out the three parts along the printed area. Also cut along the dashed lines around any tabs. Carefully cut a slot along the dashed line on the Comet Orbit that extends

to the center of the circular sun symbol. Cut slots along the two dashed lines on the top of the Display Base. Make sure the longer cut extends to the center of the sun symbol.

2. Fold back the tabs in the Display Base, then fold back the four large flaps that will form the sides of the box.

3. Tape each tab on the Display Base to a neighboring flap so that the base becomes a box. Insert the bottom of the Comet Orbit into the large slot on the Display Base. Slide the slot on the Comet Orbit into the top of the Base, then adjust the Orbit to line up the sun symbols on both pieces.

4. Fold back the tab and the triangular flaps of the Orbit Support. Insert the tab into the short slot on the Display Base. Adjust the flaps and the Comet Orbit so that the two make contact. If needed, use a piece of tape to secure the Comet Orbit to the support.

Classroom activity

How fast does a comet move? Using string, have students measure how far the comet moves between each date. Students may then use the scale bar on the Display Base to convert their measurements to a distance in kilometers. Lastly, have them calculate the comet's speed using Rate = Distance / Time. Caution them that the time increment between dates changes as the comet gets closer to the sun.

For example, from Feb. 15 to March 1, 2014, the comet moves 1.3 cm on the model. The scale bar indicates that 1.4 cm equals 40 million km. **(Measurements may differ from this example based on variations in the model's printed size.)** Between these dates, the comet will move 37.1 million kilometers. To determine its average speed, divide this distance by the number of days between measurements (14, in this case). For this period, the comet is moving 2.7 million km per day, on average.

Have students complete the following data table for dates along the comet's orbit.

Orbit segment (dates)	Number of days	Measured distance (cm)	Actual distance (millions of km)	Orbital speed

Ask students about the orbital speeds they have calculated. Is there a pattern? Are the speeds constant? If not, how do they change? Using the same procedure, have students calculate several orbital speeds for Earth. Do they notice changes in Earth's orbital speed similar to those of the comet? How does the comet's speed compare with Earth's?

These calculations may serve as a lead-in for discussion of Kepler's Laws of planetary motion, which apply to all orbiting bodies. To learn more, please visit:

Understanding Solar System Dynamics: Orbits and Kepler's Laws
http://go.nasa.gov/15OUG8Q

Further classroom resources

NASA's Comet ISON Toolkit
http://go.nasa.gov/1dWapVY

Comet Mystery Boxes
http://go.nasa.gov/13YjCJu

Comparing Comets
http://ter.ps/comets

Comet on a Stick
http://ter.ps/cometmodels

Additional resources

Comet ISON Observing Campaign
http://www.isoncampaign.org/

NASA's Swift Sizes Up Comet ISON
http://go.nasa.gov/13E3yfZ

Hubble Captures Comet ISON
http://go.nasa.gov/11KS6IA

Live Images of the Sun
http://go.nasa.gov/13Sq1WD

Eyes on the Solar System
http://eyes.nasa.gov/

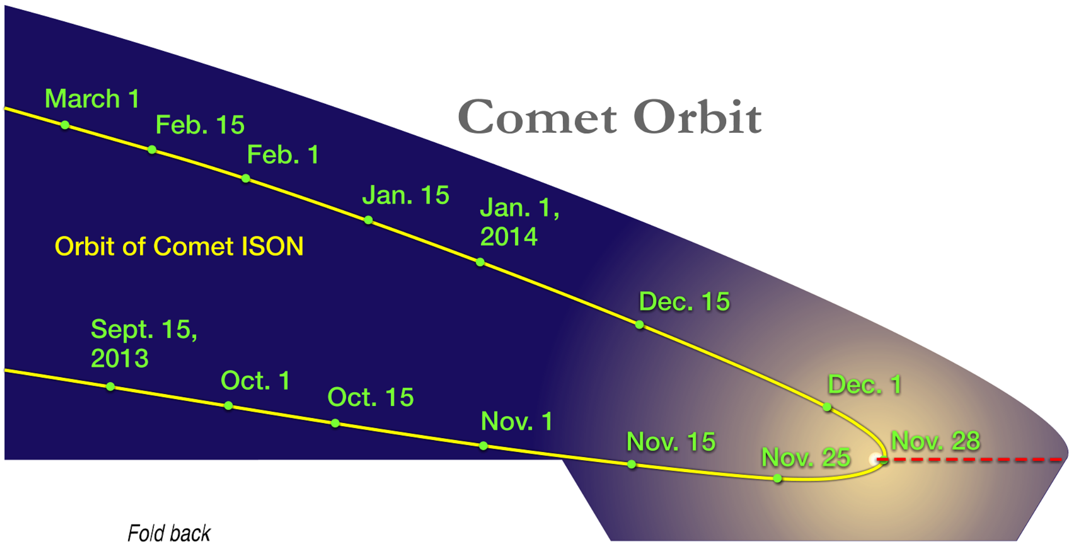
Comet Interactive
http://go.nasa.gov/Q2KNHy

Orbit Diagrams: NASA's Near Earth Object Program
http://neo.jpl.nasa.gov/orbits/

Explore! Comets
http://bit.ly/10kuxbD

Sungrazing Comets
http://sungrazer.nrl.navy.mil/

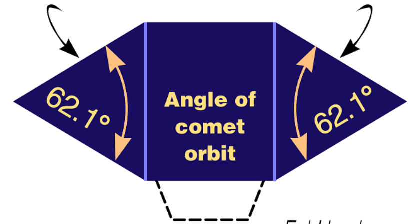
Comet Orbit



Orbit Support

Fold back

Fold back



Fold back

Display Base

Fold back flaps

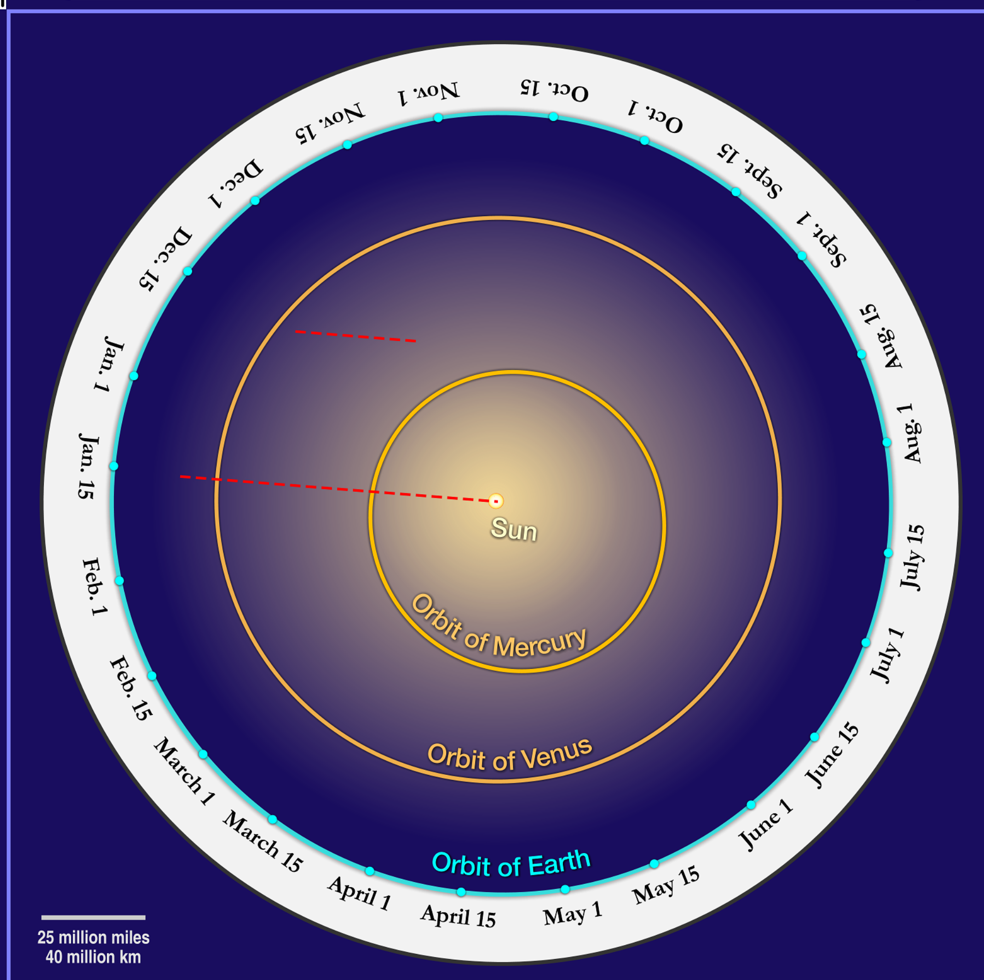
Fold back tabs, tape to flaps

Where Do Comets Come From?

Comets formed among the planets but were scattered by strong gravitational interactions. They were either thrown out of the solar system or tossed into one of two deep-freeze zones: the Kuiper Belt, beyond Neptune's orbit, or the Oort comet cloud, which may extend a third of the way to the star nearest the sun. Possibly dislodged by the gravity of a passing star, comet ISON began its long fall from the Oort cloud, likely making its first-ever passage near the sun.

What is a Comet?

Think of comets as giant dirty snowballs. They contain frozen gases such as water, carbon dioxide, ammonia and methane, along with dust. As a comet nears the sun, this icy material warms up and turns to gas, which also releases the dust. A vast cloud of gas and dust (called a ***coma***) forms around the icy body of the comet (called the ***nucleus***). Gas and dust flowing back from the coma create the comet's distinctive tails.



Facts about Comet ISON

Official name: C/2012 S1
Discovered Sept. 21, 2012, by the International Scientific Optical Network (ISON)
The comet passes 6.7 million miles (10.8 million km) from Mars on Oct. 1, 2013.
ISON is just 728,000 miles (1.2 million km) from the sun's visible surface on Nov. 28.
The comet passes 39.9 million miles (64.2 million km) from Earth on Dec. 26.

The Path of Comet ISON

September 2013 to March 2014