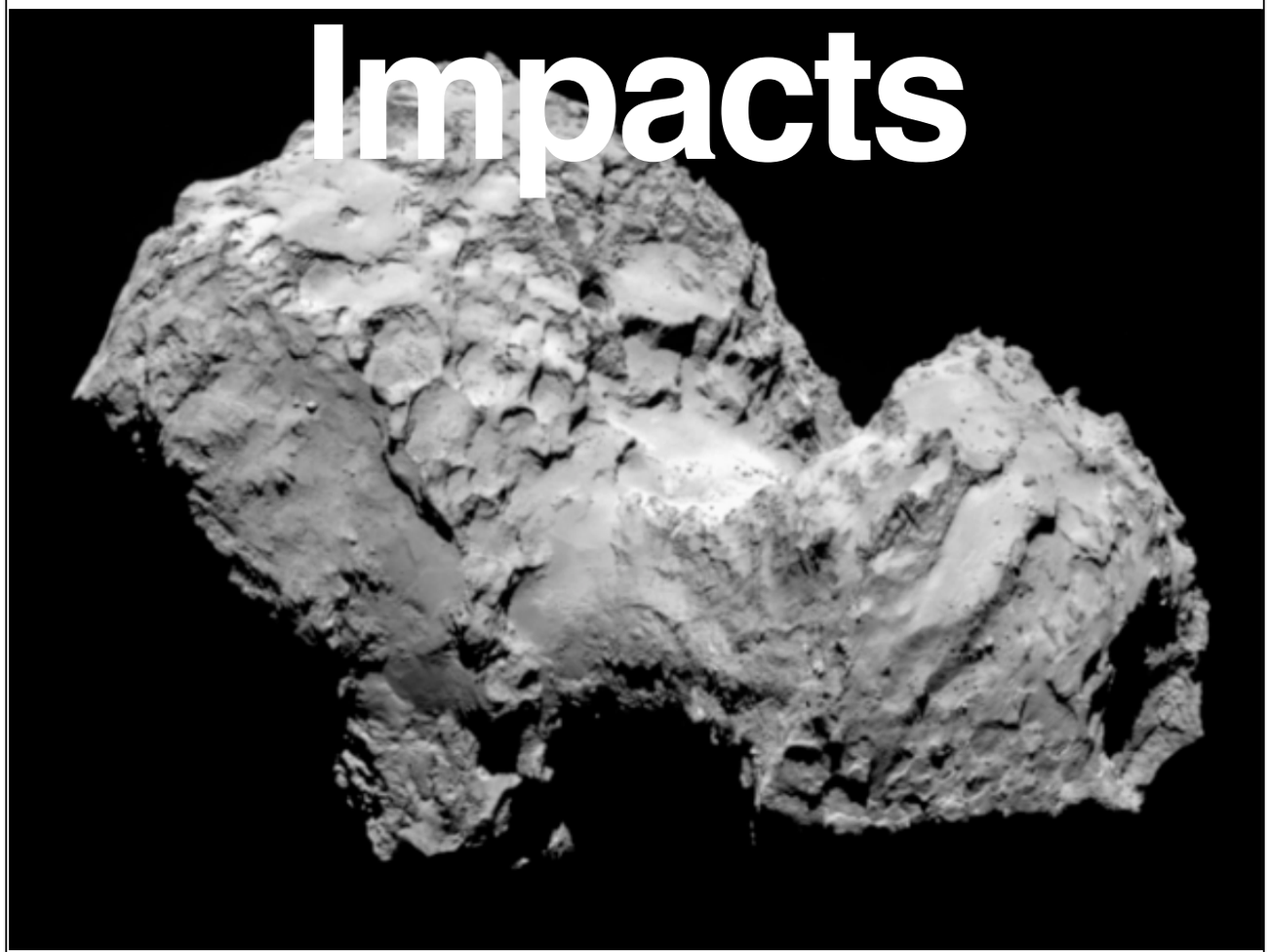
UNIT 9

Comets, Asteroids, Meteors and Impacts



Kortenkamp

UNIT 9

Space Debris and Impacts

What are comets?

Comets are small, icy worlds that originate primarily from two regions of the Solar System. Short period comets (those with an **orbital period*** of less than 200 years) originate from the Kuiper Belt, a disc-like collection of frozen remnants from the formation of the Solar System just beyond the orbit of Neptune. Long period comets (those with orbital periods of up to tens of thousands of years) are thought to originate from a spherical halo of icy material towards the edge of our Solar System known as the Oort Cloud. Reaching out to a distance of many thousands of **astronomical units (AU)***, the Oort Cloud is too far away to be imaged directly. Instead we must track a long period comet orbit back in time to determine its origin.

Comets

Figure 1.1 Comet Hale-Bopp

Comet Hale-Bopp: The great comet of 1997.

Key Terms

1. ***Astronomical unit (AU)**: 1 AU is the average distance between the Earth and the Sun, or the Earth's orbital radius, which is approximately 93 million miles.
2. ***Gravitational perturbations**: changes to the orbit of a celestial body (e.g. planet, comet) due to interactions with the gravitational fields of other celestial bodies (e.g. giant planets, other stars).
3. ***Orbital period**: time taken to complete one orbit.
4. ***Solar wind**: a stream of high-energy particles (plasma) being emitted by the upper atmosphere of the Sun in all directions. It contains mostly electrons and protons.
5. ***Sublimate (sublimation)**: when heating causes a substance to change directly from the solid phase to the gas phase, bypassing the liquid state. When the gas is re-cooled, it typically forms a solid deposit.

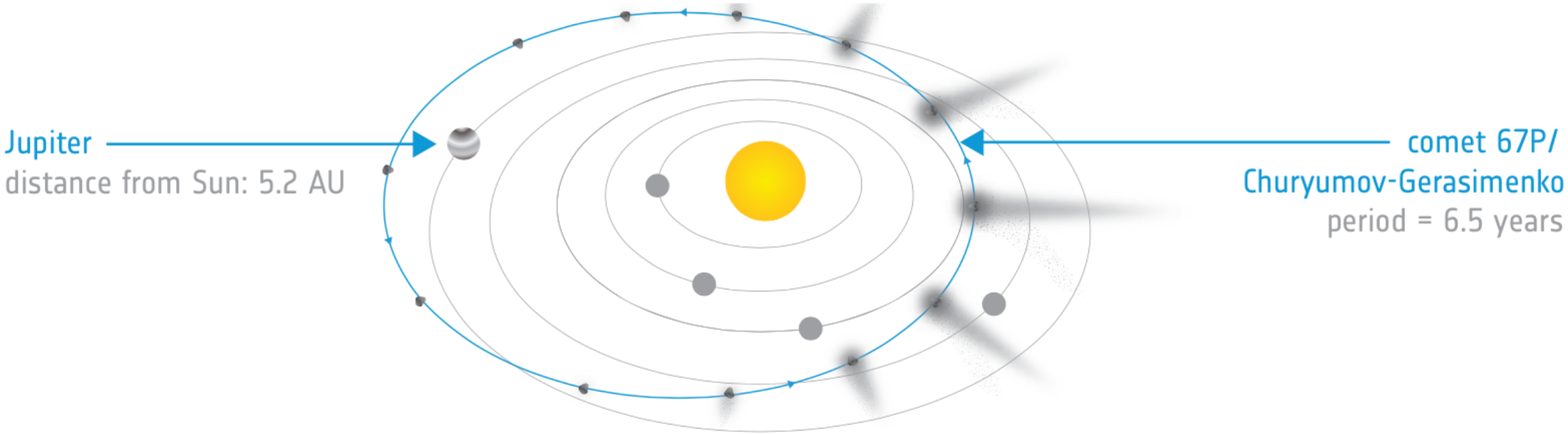
Comets will, for the most part, orbit the Sun in stable orbits. However, Kuiper Belt objects can be influenced by the gravitational fields of the giant planets (Jupiter, Saturn, Uranus and Neptune), and Oort Cloud objects by **gravitational perturbations*** caused by the motions of other stars. These perturbations can occasionally change the orbits of these small, cold worlds, sending them racing towards the inner Solar System.

As these objects approach the Sun they begin to heat up and the ice within them **sublimates***.

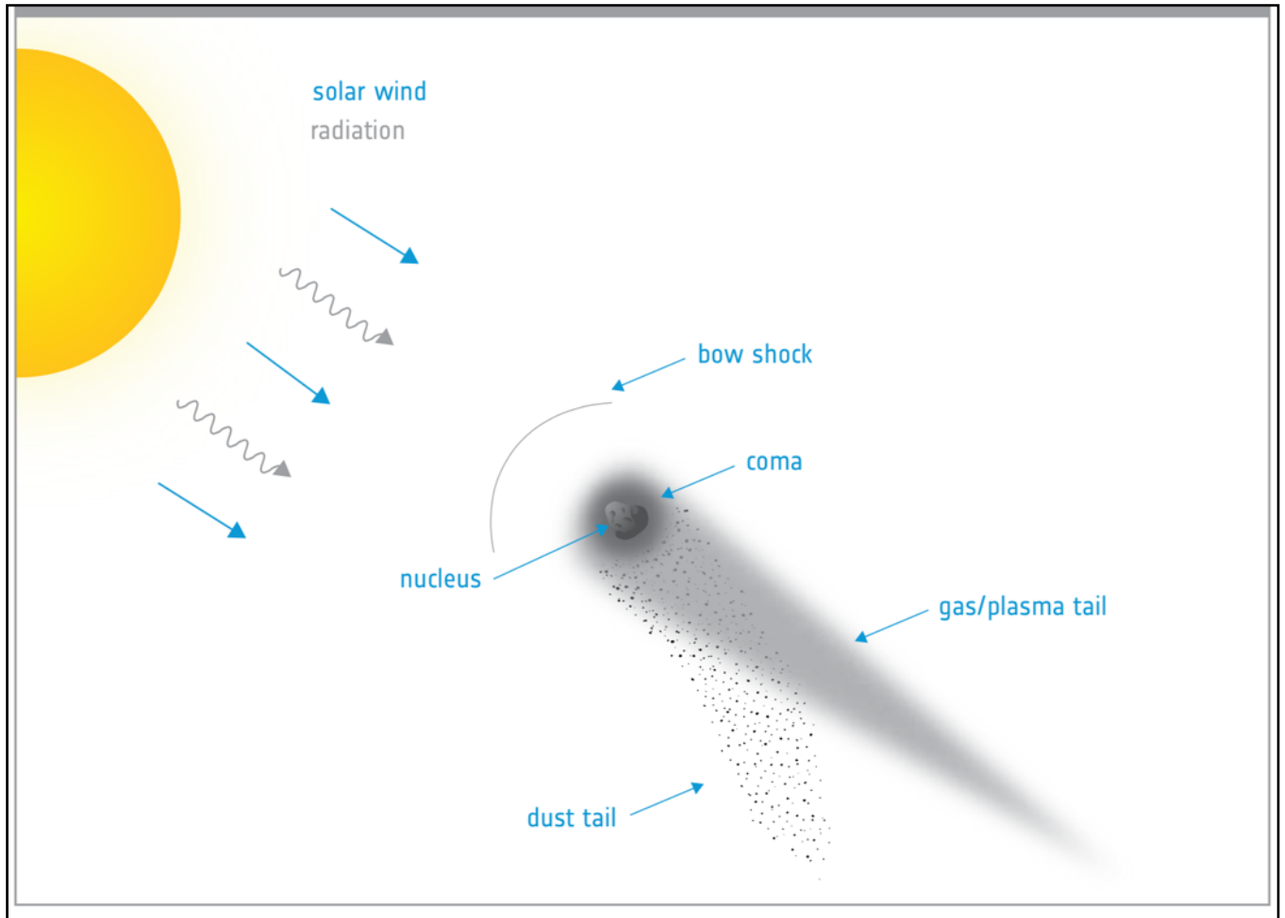
The original structure is now referred to as a 'nucleus'. As the nucleus heats up, it gives off gas and dust forming a thin, but vast, 'atmosphere' known as the coma (Figure 3).

As the comet gets even closer to the Sun, the interaction of the coma with increasing levels of solar radiation and the **solar wind*** produce the spectacular 'tails' with which comets are most often associated. Very occasionally the tails are bright enough to be seen by an observer on Earth in daylight.

Gallery 1.1 Some well known comets and their periods.



There is overwhelming evidence that planets are regularly (on geological timescales), hit by comets and asteroids. Impact processes formed most of the craters observed on the surfaces of moons and planets throughout the Solar System. The highest frequency of impacts occurred early in the history of the Solar System (Late Heavy Bombardment period), but impacts do still occur at the present time.

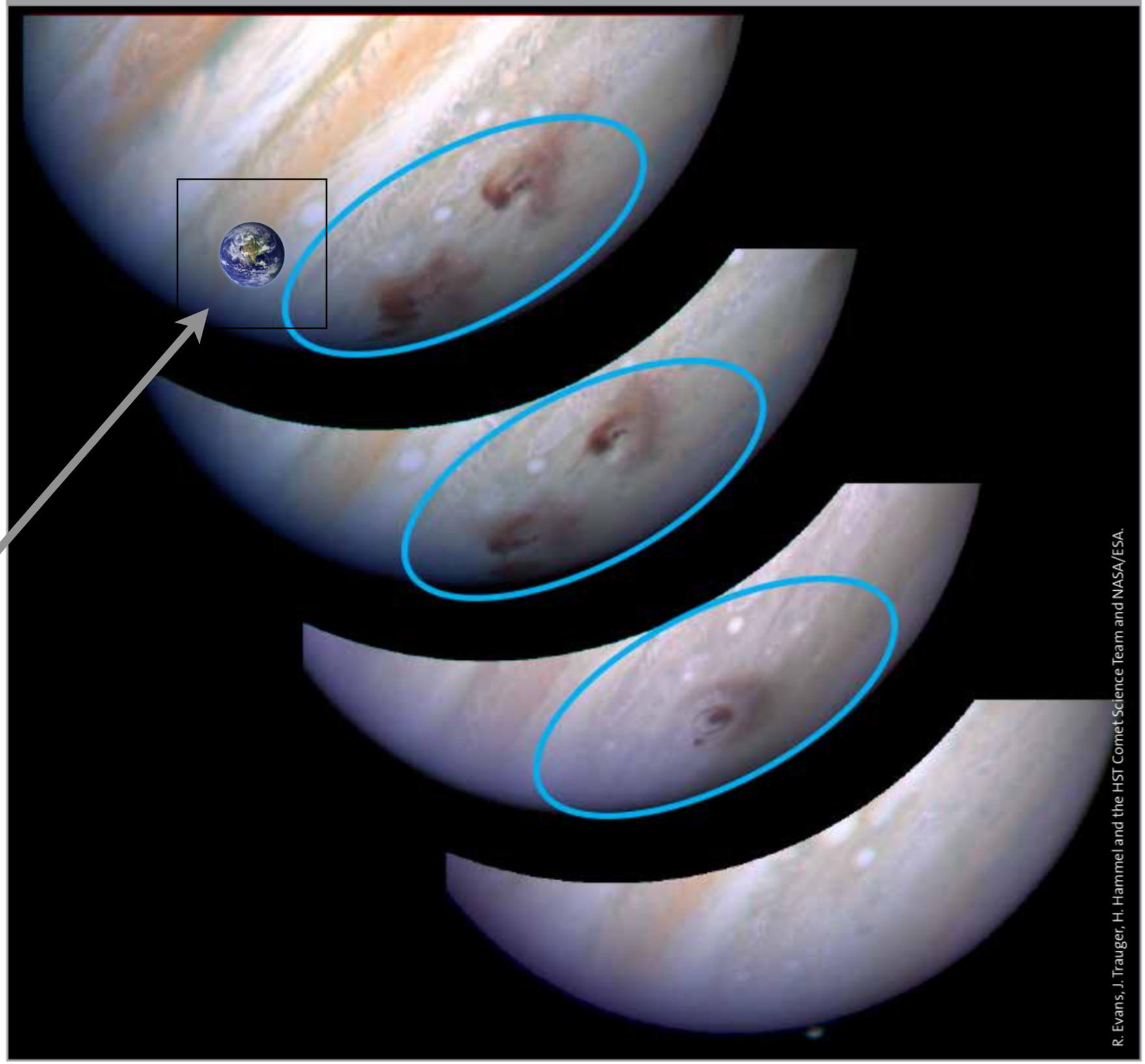


↑ The anatomy of a comet.

In 1994, numerous fragments of comet Shoemaker-Levy 9 (D/1993 F2) impacted the surface of Jupiter. The largest impact scar observed was thousands of kilometers in diameter. This was caused by the G fragment of the comet, which

Earth is shown to scale here to give an idea of the size of the impact.

Figure 5



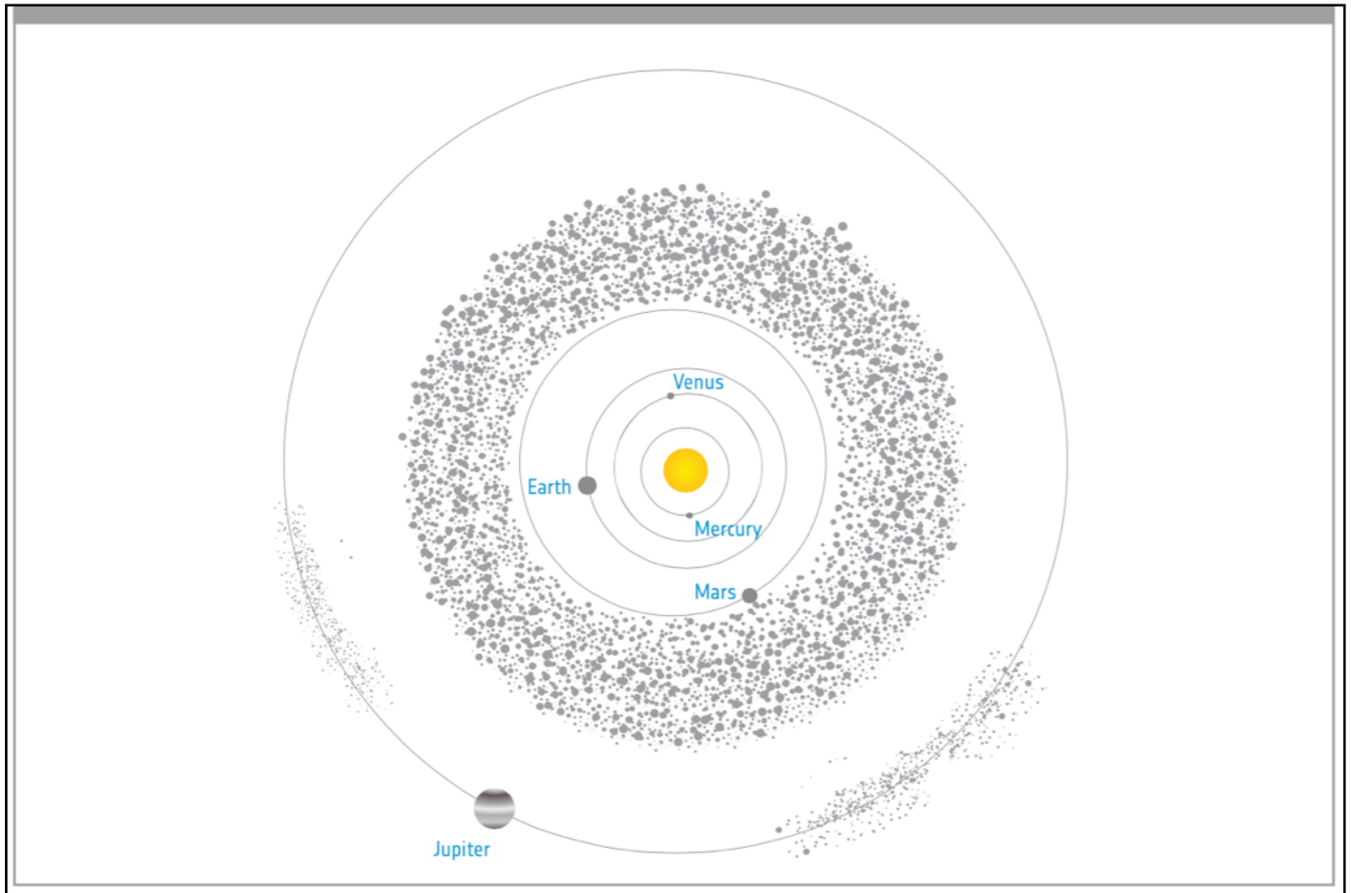
R. Evans, J. Trauger, H. Hammel and the HST Comet Science Team and NASA/ESA.

↑ This mosaic of images shows the evolution of the G impact site on Jupiter (highlighted by the blue ellipse).

Asteroids

Key Terms

1. ***Lagrangian points**: in any orbital configuration there are five points at which an object only affected by gravity can orbit stably.



↑ A diagram of asteroid distribution in the Solar System. The majority of asteroids reside in the main belt between the orbits of Mars and Jupiter. Other large groups of asteroids are the Jupiter Trojans which occupy the stable **Lagrangian points***, L4 and L5, on the orbit of Jupiter.

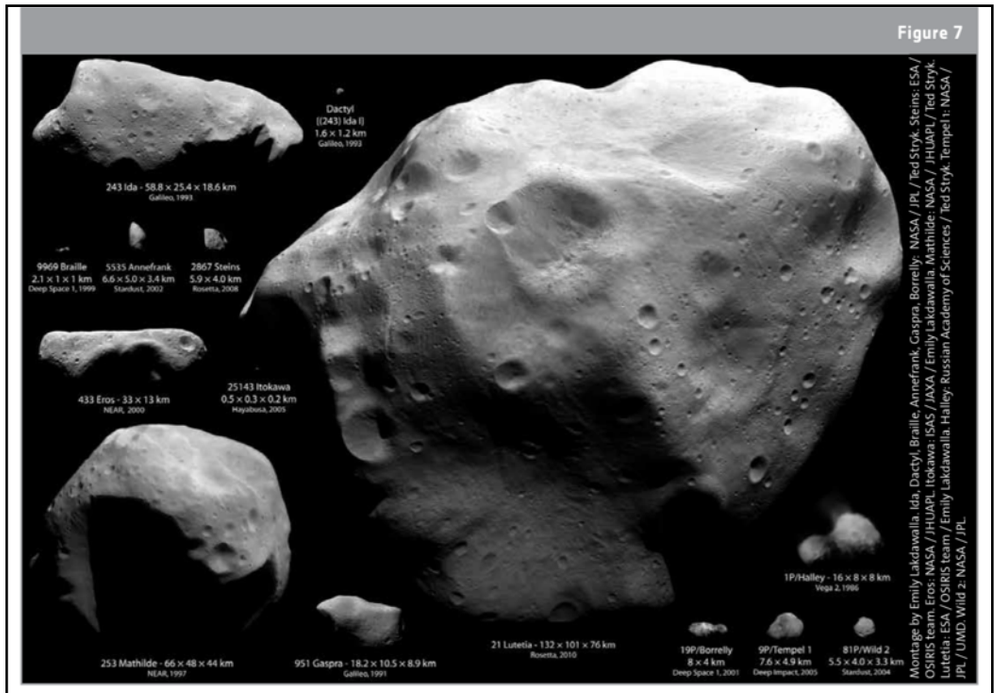
Comets are not the only objects that hit the Earth and other Solar System bodies. Asteroids, which originate largely in the Asteroid Belt between Mars and Jupiter (see image above), are large rocky or metallic objects. On the whole asteroids formed much closer to the Sun and therefore contain fewer light elements than comets. Metals, metal oxides, minerals and silicates dominate the composition of asteroids. In comets, the larger quantities of light elements, such as, carbon, hydrogen, oxygen, nitrogen, phosphorus and sulphur, allow for the formation of certain compounds, for example, water, methane and carbon dioxide.

The largest known asteroid, Ceres, is 950 km in diameter and is often regarded as a dwarf planet. Figure 7 shows a size comparison of some asteroids and comets. The irregular asteroids shown in Figure 7 are much smaller than Ceres, but many are considerably larger than the comet nuclei that have been imaged.

Impacts on Earth

On Earth, active tectonic and weathering processes at the surface mean that craters generally last for a few million years before disappearing from visible sight. However, geological analysis of subsurface rocks, and other features, can be used to infer the past formation of a crater. In the early 1990s this led to the confirmation that

Figure 7



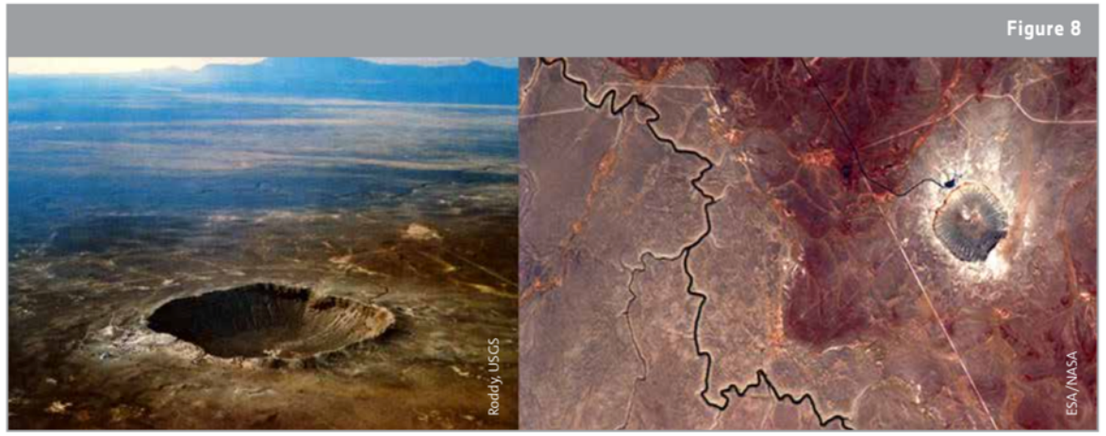
↑ Size comparison of asteroids and comets.

around 65 million years ago a comet or asteroid, with a diameter of around 10 km, impacted the Earth in the area now known as Yucatán, Mexico. This impact formed a crater over 150 km in diameter. The subsequent global climatic change that occurred was a major contributor to one of the largest extinction events in Earth's geological history – the Cretaceous – Paleogene extinction – which ultimately led to the extinction of the dinosaurs.

On much more recent time scales, smaller craters have formed that are still visible, such as Meteor Crater (also known as the Barringer Crater) in Arizona, USA, shown in Figure 8.

Meteor Crater was formed approximately 50 000 years ago by a nickel-iron asteroid that smashed into the plains of Arizona, USA. This impact formed a crater nearly 200 m deep and 1.5 km in diameter. Fragments of the original impactor are scattered across the surrounding landscape.

Figure 8



↑ Left image: Meteor Crater, Arizona, USA. Right image: Meteor Crater photographed from the International Space Station.

In 1908 an asteroid or comet, thought to be over 50 m in diameter, exploded at an altitude of 5 - 10 km over a remote forest area near the Tunguska River in what is now Krasnoyarsk, Russia. Whilst the asteroid or comet is not thought to have impacted the Earth's surface, the force of the explosion flattened an area of forest more than 2000 km2 (Figure 9).

Figure 9

↑ Trees knocked over in the Tunguska blast.

SECTION 3

Level 2 - Impact Simulation

-The 2 answers to the questions and the 4 screen shots will be entered into THIS FORM for credit on this level.

-Looking back at what you learned in the "Impacts on Earth" section, we will run a couple simulations to investigate two impacts mentioned.

- First we'll examine the Dinosaur extinction. We saw that the predicted size of the impactor was 10km and the crater diameter is around 150km. Let's assume that the velocity of the object was 60km/s, it was a direct (90 deg.) hit, and it struck Sedimentary Rock. ***What could the impactor have been made up of?***

- Navigate to the following Impact Simulation Website

- Once you have the outcome in the simulator that you think is correct take a screenshot of the "Impact Values" screen, then click "Go Back" and take a screen shot of the "Impact Parameters" screen. Finally record your answer to the question above and upload your screen shots into the form at left.

-Now we'll examine the Meteor Crater impact. Based off what you've read about it and assuming it had a 200 m diameter and hit sedimentary rock, ***how fast would it have been traveling?***

-Take your two screen shots like you did above and complete the form at left answering the question.

-Submit your form