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Asteroids - Friend or Foe? An Examination of the Past, Present, and Future of Some of Our Solar System's Most Elusive Celestial Objects

by Camille Diebold

(Honors Astronomy 1122)

Human beings have long turned their eyes to the heavens for prediction, examination, study, discovery, prayer, and simply to marvel at its wondrously vast expanse and beauty. The great celestial bodies within our solar system and beyond have been awe-inspiring to many who dream of what could lie beyond the confines of our tiny world. Our own sun and moon, the planets, and even the distant stars have been observed since people first gazed skyward. However, there too lies a group of celestial bodies which remained unnoticed for most of human's history. These elusive but numerous objects are asteroids. Only in recent years have these objects been known to exist, and an even shorter period of time has passed since they were truly studied or remotely understood.

Asteroids, sometimes called "minor planets" or "planetoids," are relatively small, rocky objects in space. Although their name means "starlike bodies," like the Earth and all other planets in our solar system, asteroids travel in orbits around the sun. Too small to be classified as actual planets, asteroids can vary greatly in size. Their size ranges from pebbles or lumps of ice, to rocky or icy worlds nearly one thousand kilometers in length. It is believed that asteroids may have been the "building blocks" of the inner planets. Additionally, some scientists believe that asteroids may also have played a role in the delivery of carbon and water (life's building blocks) to Earth.

To understand the history of asteroids we must look to the first known human discovery of an asteroid. Because of asteroids' small sizes, no astronomer discovered an asteroid with the naked eye prior to the invention of the telescope. Even though a few asteroids can be visible occasionally by the naked eye, if unknowingly watched, they would appear merely as faint stars in the nighttime sky. However, even after the advent of telescopes, most astronomers were mainly interested in observing the moon, planets, and stars. The largest known asteroid, Ceres, was discovered through a fortunate accident by astronomer Giuseppe Piazzi in 1801. Subsequently, within the next few years, the asteroids Pallas, Juno, and Vesta were also discovered. In the early nineteenth century astronomers also began to actively seek what they believed to be a "missing planet" between the outermost terrestrial planet, Mars, and the innermost Jovian planet, Jupiter. As will be discussed later, this "planet" was in actuality a belt of copious smaller bodies – asteroids.

The sizes and shapes of asteroids are both interesting and unique properties of these diverse bodies. The shapes of asteroids are amazingly varied and range from the rather spherical larger asteroids, to the "potato" shaped asteroid Eros, to the "dog bone" shaped asteroid Kleopatra. In his book *Target Earth*, Duncan Steel comments on the amazing diversity and peculiarities of asteroids: "We've seen some pretty peculiar sights in the solar system: a volcano higher than Mount Everest on Mars, sulfur volcanoes on Io, and ice eruptions on Triton. But nothing compares with the shapes of asteroids revealed by radar observations" (Steel, p.120). Another interesting phenomenon of asteroid shapes is what is called "binary asteroids." These dual asteroids are thought to have been formed by the destruction of a larger asteroid. We have evidence on both Earth and on other planets in our solar system of binary asteroid impacts. One striking example is the Clearwater Lakes in Canada which constitute a pair of enormous side-by-side craters formed by a binary asteroid. It is believed that binary asteroids separate shortly before impact which create these double craters. Duncan Steel comments on impact cratering while speaking of binary asteroids: "As such a binary asteroid

approaches on a collision course with Earth, it would be expected that tidal forces would rip the two bodies apart, causing them to impact at close but distinct points” (Steel, p.55).

Asteroids, compared to other bodies in our solar system and beyond, are considered very small in size. In fact, astronomers must rely on indirect methods to determine the sizes, shapes, and compositions of asteroids because they are too small to be resolved using Earth-based telescopes. Put together, all known asteroids actually amount to considerably less than the Moon’s mass (Chaisson and McMillan, p.356). Asteroids are so tiny that it is generally impossible to measure their sizes directly. Instead, other measuring methods, such as timing how long a star disappears from view (occultation) as an asteroid whizzes “in front” of it, must be considered. So why do these bodies that do not contribute significantly to the total mass of the solar system now receive such a disproportionate amount of attention in the astronomical community? To answer this question, we must first examine these fascinating yet mysterious objects more closely.

Asteroids are literally leftover debris from the formation of the solar system. It is believed that the composition of many asteroids, especially smaller ones, are accumulations of loosely bound rock which are held together by gravity – in essence, mobile rubble piles. However, the discovery of several rapidly rotating asteroids has led to the belief that at least some asteroids are single rocks. This is considered factual because of the great strength of self-gravity that would be necessary to hold together a “rubble pile” that is spinning rapidly. However, the only tangible pieces of asteroids that are currently in human hands are pieces of asteroids that fell as meteorites to Earth, and their mineral composition has been examined and identified in laboratories. However, meteorites available for scientific study are a limited resource. Another method currently used to determine the actual composition of asteroids studies the spectrum of sunlight reflected from asteroids. This identification is possible because the minerals on the surface of an asteroid reflect and absorb light and heat in different ways. Referring to the studies of the spectrum of sunlight reflected off asteroids, in his book *Rain of Iron and Ice*, John S. Lewis discusses the classifications of asteroids based on this information: “About two dozen distinct types of asteroids have been found by this technique, of which some can be confidently linked to particular classes of meteorites” (Lewis, p. 75).

Most known asteroids move in quite eccentric orbits around the sun in well defined regions far removed from Earth. The main asteroid belt is an interesting phenomenon located between Mars and Jupiter and lies 300 million kilometers from earth at its closest point. According to John K. Davies in *Cosmic Impact*, “The orbital studies also showed that the asteroid belt was not just a collection of randomly orbiting objects – there was a very definite structure in the way their orbits were laid out” (Davies, p.50). All the dynamics of the asteroid belt are not known, but astronomers and other scientists theorize that the asteroid belt is in existence because for some reason, a planet failed to form in that region of the solar system. Due to the powerful gravitational pull of Jupiter, this region contains hundreds of thousands of known asteroids, and perhaps even millions of asteroids. The main asteroid belt is also home to the largest known asteroid, Ceres, which has a diameter of nearly 1000 kilometers. The asteroid belt is broadly zoned into bands of different types of asteroids that are typically classified by composition, or the properties of their reflected light.

- *C-type* asteroids dominate the outer half of the belt and are carbon-rich asteroids. Apparently composed of very dark material, this most common type of asteroids is believed to contain water within clay minerals.
- *P and D-type* asteroids appear to be composed of the same material as the C-types. However, the proportions of these components are believed to be different. These asteroids are mainly found in the outermost belt.

- *S-type asteroids*, located in the inner portions of the asteroid belt, are more reflective than the C-type and are the second most common type of asteroid. They are believed to contain significant amounts of iron metal, silicate, and rocky material.
- *M-type* asteroids contain large amounts of nickel and iron and are located in the inner regions of the asteroid belt.

American Daniel Kirkwood made an important discovery regarding the main asteroid belt when he showed that there were no asteroids with orbital periods equaling that of a simple fraction of the orbital period of Jupiter. In honor of Daniel Kirkwood's discovery, these gaps, or zones of avoidance, in the asteroid belt are now known as *Kirkwood gaps*. Although these gaps still contain some asteroids, they are nevertheless prominently underpopulated regions in the distribution. The gravitational pull of the gas giant Jupiter, combined with collisions between other asteroids or comets, serves to slowly alter the orbits of these relatively tiny, but numerous bodies. Asteroids at particular resonances receive a periodic "tug" from Jupiter. The "cumulative effect of all the tugs is to deflect the asteroid into an elongated orbit – one that crosses the orbit of Mars or Earth" (Chaisson and McMillan, p.362).

Trojan asteroids, or Jupiter asteroids, are a unique group of asteroids that follow the same orbit as Jupiter. They are divided into two sub-groups, one group orbits sixty degrees ahead of Jupiter and one group orbits sixty degrees behind Jupiter, named the *Achilles Group* and the *Patroclus Group* respectively. Locked in a 1:1 resonance with Jupiter with the same orbital period, these asteroids are located on what is called the Lagrange points 4 and 5.

Collisions between asteroids are thought to be quite a common occurrence in the solar system, especially in the asteroid belt. In fact, there are meteorites found on Earth that are believed to have been pieces of the asteroid Vesta as a result of collisions incurred with other asteroids (Chaisson and McMillan, p.356). So, it is not surprising that "asteroids may be both the attackers and the attacked" (Steel, p.48). Like most other celestial bodies in our solar system, asteroids are heavily marked by impact craters, but with their own kind to blame.

Near-Earth asteroids are asteroids whose orbits bring them relatively close to the Earth every few years. Hundreds of near-Earth objects have been discovered. However, exact numbers of these bodies are unknown and there may very well be closer to one thousand. Because of the variety of asteroid orbits they have been categorized into several main types.

- *Apollo* asteroids are asteroids whose semi-major axes are greater than 1 astronomical unit (A.U.). They have perihelion points inside the Earth's orbit and are considered the most likely to collide with Earth.
- *Aten* asteroids encompass all other Earth crossing asteroids. *Aten* asteroids typically spend most of their time inside of Earth's orbit.
- *Amor* asteroids have orbits that cross the orbit of Mars and approach the Earth's orbit but are not Earth-crossing asteroids. *Amor* asteroids have the potential to eventually move toward Earth. However, this would most likely occur far in the future.

Of these categories, the groups of most concern to astronomers are *Apollo asteroids* and *Aten asteroids*. Collectively called *Earth-crossing asteroids*, these asteroids are a sub-group of near-Earth asteroids, and have the greatest potential for colliding with Earth. These asteroids have highly elliptical orbits taking them inside Earth's orbit. Near-Earth asteroids and Earth-crossing asteroids are of great interest to astronomers because at some point in the future, most of these asteroids will come very close to our planet, or perhaps even collide with it. Although most Earth-crossing asteroids are relatively small (about 1 kilometer in diameter), even the impact of one of these "small"

asteroids has enough energy to devastate an area 100 kilometers in diameter. This sort of collision is the equivalent to a million 1-megaton nuclear bombs and would be catastrophic to the Earth.

The Apollo asteroid Icarus occasionally comes close to Earth and its orbit is well within Earth's orbit. Thus, Icarus is one of the most thoroughly examined asteroids in our solar system. However, there are many other asteroids which pose a great threat to life on Earth. In March of 1989, the 200 – 500 meter wide 1989 FC asteroid came within 691,870 kilometers of Earth. Amazingly, Earth was in that exact spot where a collision would have occurred a mere six hours earlier (Barnes–Svarney, p.217). This asteroid was a true “wake-up call.” If luck had not been in Earth's favor, the asteroid's explosive impact would have been the equivalent to more than one million tons of TNT: in other words – globally catastrophic. This example is just one of many “close calls,” some of which may, especially in the past, have even gone unnoticed to humans on Earth. With increasingly higher telescopic quality, astronomers have been able to locate numerous other near-Earth asteroids, and still the hunt continues.

It is common awareness in the astronomical community that it is not a question of *if* an asteroid will collide with the Earth, but rather *when*. What would happen if an asteroid were to truly pose a serious threat to our Earth? Would we have enough knowledge about its properties and orbit to determine if it would indeed strike us? Even if we possessed that knowledge, would we have enough time to figure out how to minimize and cope with the problem? These are questions that astronomers and other scientists face. Unnoticed by many of Earth's inhabitants (myself included until just a few short weeks ago), there are organizations currently working to answer these questions, and solve potential problems in advance, so that Earth will not have to again face the catastrophic collisions that are believed to have shaped and reshaped Earth many years past.

One such watch-dog organization is NASA's *Near Earth Asteroid Tracking* (NEAT) program which searches for asteroids and comets that come close to the Earth. NEAT works in a cooperative effort with NASA/Jet Propulsion Lab and the U.S. Air Force in an effort to prevent catastrophic impacts on Earth. A camera and computer system on a 1-meter GEODSS telescope is used to search the sky for near-Earth objects. However, as Duncan Steel soberly points out in his book *Rogue Asteroids and Doomsday Comets*, there are even more logistical problems that these astronomers face: “The total number of people engaged in this sort of work worldwide is less than the staff of an average McDonald's restaurant. As a consequence, we can cover only a small fraction of the sky...” (Steel, p.187).

As previously mentioned, some astronomers maintain an “asteroid watch,” which is an effort to watch and predict asteroid collisions with Earth in order to prepare us for a possible impending catastrophe. Determining the orbits of asteroids is possible through orbital mechanics and allows us to “keep an eye” on asteroids that may make their way toward Earth. Even though determining the orbits of asteroids is an important tool in preventing their possible collision with Earth, the first step is locating all these threatening asteroids.

However, there still is the question of what measures we could take to prevent an asteroid from colliding with Earth. NASA's asteroid workshop addressed just such a question, and based on current technology, the consensus was reached that in the event of an impending collision, “nuclear would be the best way to nudge or eliminate an asteroid” (Barnes-Svarney, p.257). However, a solution is not actually clear cut. It has also been suggested that the best procedure may be to blow up the asteroid rather than nudging it off its course. However, even blowing up an impending asteroid may have serious consequences, such as nuclear safety, damaging fragments of the asteroid raining down on Earth, and fires caused by superheated fragments. These potential consequences have the possibility of being more devastating than the collision of the asteroid itself. There are many other possible theories, but not everyone is in agreement on even the planned course of action that ought to be taken *now* while we still have the luxury of time – time that may very well be shorter lived than we ever expected.

In its very essence, space is still a new frontier. Studying and exploring space is a way for humans to advance our knowledge, technology, and seems to offer limitless opportunities for discovery. Conceivably, the study of space has been a constant fascination for those who wish to know more about the universe, or life itself, for as long as man has inhabited the Earth. Some scientists believe that asteroids may in fact provide us with key resources to aid us in our exploration of the solar system and beyond. It is believed that asteroids may reveal the beginnings of our solar system and provide us more valuable information than all the cumulative data that could be gathered by remote satellites or ground-based telescopes.

Ralph Waldo Emerson's words in *Trying Times* perhaps most accurately depict our ever-changing universe: "There are no fixtures in nature. The universe is fluid and volatile. Permanence is but a word of degrees" (Barnes-Svarney, p.25). This quote eloquently illustrates the precariously balanced nature of our world, and is an apt example of why we must strive to be vigilant of our neighbors (known and unknown) in the universe – even seemingly small and harmless bodies such as asteroids. So, to answer the question: "Why are humans worried about such small objects?" Because it only takes one significant asteroid to ruin our day. I am grateful to those behind the scenes who attempt to hold our fragile world together by protecting it from collisions that could reshape the face of our planet forever. There is much to be tracked and predicted if our own Earth is to be protected. There are also various theories as to the best line of defense to protect this planet we call "home." However, until a decision as the best course of action can be made, we must continue to watch and study these remarkable, evasive asteroids and prepare as best we can – hoping and praying that we will find them before they find us.

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