ESSAI

Volume 5 Article 17

1-1-2007

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Recommended Citation

Diebold, Kennerly (2007) "Magnificent Meteoroids, Meteors, and Meteorites," ESSAI: Vol. 5, Article 17. Available at: http://dc.cod.edu/essai/vol5/iss1/17

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Magnificent Meteoroids, Meteors, and Meteorites

by Kennerly Diebold

(Honors Astronomy 1122)

"Can there be anyone on Earth who has not been struck by the phosphorescent lights that glide through the somber night, leaving a brilliant silver or golden track – the luminous, ephemeral trail of a meteor?... sometimes... a shining speck is seem to detach itself... from the starry vault, shooting lightly through the constellations to lose itself in the infinitude of space... Those bewitching sparks attract our eyes and chain our senses. Fascinating celestial fireflies, their dainty flames dart in every direction through space, sowing the fine dust of their gilded wings upon the fields of heaven. They are born to die; their life is only a breath; yet the impression which they make upon the imagination of mortals is sometimes very profound."

- Camille Flammarion

It is of no doubt that meteors and meteorites have captured the imaginations and hearts of man throughout the history of the Earth. Historically, there have been numerous religious and superstitious associations ascribed to meteorites. In many cases throughout time, and even to the present, humans have reacted to these visitations by enshrining the celestial objects as consecrated or even ominous visitors. For instance, it has been reported from India that it was necessary for officers of the Geological Survey to immediately descend upon the impact location when a report of a fall was received, because otherwise the mass would either have been enshrined, or broken into small pieces to release the evil spirits it contained. In either outcome, the meteorite would effectively be lost to science. Enshrinement of these sacred meteorites is also reported from Africa, and in Australia it is also believed by some aborigines that a carrier of tektites (a type of glassy meteorite) will possess magical powers. On our own soil, an American Indian practice involved transporting meteorites long distances to similarly remove the presence of evil spirits from their community.

For the most part, the scientific study of meteors did not exist until late in the eighteenth century. True, our nighttime sky-watching ancestors of ancient Babylonian times (and undoubtedly earlier) could hardly have failed to notice these occasional meteors, or more commonly, "shooting stars," during their nightly vigils. However, it is not until around 2000 BC that we find the first indications of meteors being recorded as astronomical phenomena. These early records come from China and Korea. (Bone, p. 47) Still, before the eighteenth century, few had made a significant effort to attempt to understand this phenomenon. Although, interestingly, in just the fourth century BC, the Greek philosopher Aristotle, in his work, *Meteorologica*, correctly treated meteors, along with clouds and auroras, as atmospheric phenomena. Additionally, the philosopher believed meteors to be the result of "hot exudates" that were being driven off the Earth by the sun, and subsequently becoming ignited by friction upon rising to the lowest of the "celestial spheres." (Bone, p.49) Partially due to religious grounds, Aristotle's theory, along with many others, remained largely unopposed for some time. Yet another popular theory concerning meteors, from ancient times, was that they were residual rays of sunlight appearing after dark. Even late into the eighteenth century, few people believed that meteors could possibly have their origins beyond Earth's atmosphere. Today, we now know differently. It was not until the eighteenth century that two German students, Henrich William Brendes (1777-1834) and Johann Friedrich Benzenberg (1777-1846) laid the foundations for subsequent studies concerning the questions of what meteors really are and where they originate and

concluded through observations and experiments that meteors occur at altitudes in excess of 35 kilometers (40 miles).

The word "meteor" comes from the Greek word *meteora* or *meteorus*, which roughly translated means "objects lifted high into the air" (Barnes-Svarney, p.75). This term was once used to describe any atmospheric occurrence, such as auroras, lightning, rainbows, etc. Today, the terms meteoroid, meteor, and meteorite are often misused and confused with one another. *Meteoroid* refers to material in space not associated with a comet prior to entering Earth's atmosphere. Meteoroids can be made up of various types of materials, often material left over from the formation of the solar system. *Meteors* are the momentary streaks of light in the sky which mark the demise of small particles of interplanetary debris as they careen through the tenuous upper fringes of the Earth's atmosphere. Common, and somewhat romantic, terms for meteors include "shooting stars" or "falling stars," but in reality, they have nothing to do with stars. Finally, a *Meteorite* is "any piece of interplanetary debris that survives its fiery passage through our atmosphere and finds its way to the ground." (Chaisson, p.374)

Most large meteoroids, typically those over a few centimeters in diameter, are generally associated with asteroids. In fact, the only difference between the two types of bodies is size. Their composition is similar, if not the same, and meteoroids are generally thought to be "small bodies that have strayed from the asteroid belt, possibly as the result of collisions with or between asteroids" (Chaisson, p.377). Not surprisingly, these objects have largely been the source of craters on the surfaces of the Moon, Mercury, Venus, Mars, and some of the Jovian worlds. However, not all meteoroids originate from the asteroid belt; in addition, some are known to have originated from Mars and also from the Moon.

It is speculated that on any given night at a clear, dark site, an individual with average eyesight should see about ten "shooting stars" per hour. The bright flash of a meteor is caused by its contact with millions of air molecules, heating up and vaporizing the meteoroid as it enters Earth's atmosphere. The resulting gases from its vaporization form the object's "tail." From our vantage point on Earth, the meteor appears as a bright trail of light due to the incandescence of the atmosphere surrounding the object and the burning of the mass itself. Most of these "falling stars" disappear so quickly because the majority of the meteoroids that enter the Earth's atmosphere are so small that they vaporize after just a few moments of intense heating. These meteors appear in random locations in the sky and travel in various directions. Astronomers call them "sporadic meteors."

However, meteors do not always occur as the isolated events of a piece of interplanetary debris passing through Earth's turbulent atmosphere. Some meteors are not random at all, but instead move in complexes of common origin. When Earth's orbit happens to intersect the orbit of a comet, a spectacular "meteor shower" can result. This is because when a comet passes near the Sun, pieces of its body are broken off and begin to travel around the comet in what is known as a "meteoroid swarm." At first, the swarm travels in a very close grouping, but after some time, the cluster begins to disperse, and eventually these "micrometeoroids" spread out all the way around the orbit of their parent comet. Interestingly, meteor shower activity can be traced back into ages past. For example, there are records which reveal that Perseids, a current favorite meteor shower of many astronomical enthusiasts, was active at least as long ago as 36 AD: "More than one hundred meteors flew thither in the morning" (Bone, p.47). Another example includes the Lyrids in 687 BC: "Stars fell like a shower" (Bone, p.47). It appears as if our ancestral observers were just as fascinated by this spectacular phenomenon as we are today!

On occasion, an observer of the nighttime sky will be treated to a very bright and uncharacteristically slow meteor known as a "fireball." These phenomena are loosely classified as fireballs if they are brighter than the planet Venus. Fireballs can last up to several seconds as make their fiery descent through the atmosphere and may at times be bright enough to cast shadows,

amazingly, even rivaling the full moon! Fireballs that appear to break up and/or produce sound are called *bolides*, from the Greek word for missile or, *bolis*. Peter Grego further elaborates on bolides in his book *Collision Earth: the Threat from Outer Space*, "some fireballs, traveling faster than the speed of sound as they penetrate through the lower levels of the atmosphere, can produce sonic booms audible to those on the ground." Grego also provides an account of a fireball, complete with sonic effect and a persistent train, given by a first hand observer and officer of the USS Alaska:

"All at once a loud rushing noise was heard, like that of a rocket descending from the heavens with intense force and velocity. It proved to be a meteor, and when within ten degrees of the horizon, it exploded with much noise and flame, the fragments streaming down into the ocean like great sparks and sprays of fire..." (Grego, p.126)

Another unusual, though not generally so spectacular, type of meteor is called a "Point Meteor." This is a meteor that is heading straight toward you and so instead of viewing a flash across the sky, you would see a quickly brightening point of light. Just hope that the Point Meteor you may be fortunate to observe does not become *too* bright!

There have been many legends and stories in the past concerning injuries and damage caused by meteorites. Although it is estimated that just over five tons of meteoritic material plunges into the Earth's atmosphere every day, seventy percent of the Earth is covered in water and the vast majority of meteorites that even fall upon land, instead of being lost in water, are not witnessed by human eyes. However, there have been numerous cases where meteorites have struck buildings, animals, and people causing damage, injuries, and in many cases, great excitement. Surprisingly, even though meteorites have hit a few people, no one has been killed, although it has been rumored throughout history that there have been some that have met an untimely cosmic end. Probably the most famous recent strike to a human by a meteorite was incurred by an Alabama woman, Mrs. E. Hewlett Hodge. In November of 1954, Mrs. Hodges was comfortably relaxing at home on her couch when a 3.9 kilogram meteorite crashed through her roof, ricocheted off a radio, and struck her leg. Besides a large bruise, Mrs. Hodges was fine, although to her dismay, she was not even allowed to keep the meteorite because she was renting the house, and it was deemed the property of the owner. Another, and one of the most unusual known falls, occurred in Nakhla, Egypt, in 1911, when about 40 meteorites fell, one reportedly killing a dog. The Nakhla meteorites are particularly valuable because they are believed to be of Martian origin, and thus are classified as "Mars rock"!

Interestingly, a historic meteoritic fall occurred in our own backyard, in the suburb of Park Forest! In 2003, a meteoroid careened through the atmosphere at an estimated 44,000 miles per hour and scattered thousands of pieces of meteoritic debris over a six-mile-wide field that centered on Park Forest. In a Tribune special that covered the event, the article quoted Menakshi Wadhwa, a curator of the Field Museum, as saying, "It was definitely unique in that it was the most populous area ever struck by a fall of this size." It was indeed a once in a life-time event, not only for the people of Park Forest, but also for the meteorite and astronomical community at large. Although the largest chunk found to date was an "11-pounder," the most famous of all the pieces is known as "the Ganza Stone." It was named after the family whose house it crashed though, plunging though the ceiling and landing near their 14 year-old son. It is estimated by some meteorite dealers that the stone probably sold for just under fifty-thousand dollars! In fact, just about everything that "the Ganza Stone" touched was snatched up by meteorite collectors and dealers, including a set of blinds that the meteorite struck, which sold for two-hundred dollars. Although the fragments from the meteoroid were not petrographically rare, they were of high value because they both hit objects, and were from a witnessed fall, two significant value criteria for meteorite collectors.

On the basis of their composition, meteorites are divided into three basic categories: irons, stones, and stony-irons. As their name suggests, *iron meteorites*, consist almost entirely of metal;

principally a nickel-iron alloy. At the opposite extreme, are the *stony meteorites* that consist chiefly of silicates and contain fewer metallic materials than *iron meteorites*. *Stony meteorites* are further subdivided on the basis of their texture as chondrites, which contain small, near spherical chondrules, and achondrites, which are strikingly similar to rocks found on Earth. According to the book *Meteorites*, "Almost 90 percent of the meteorites seen to fall are chondrites, as are most of those found in Antarctica" (Hutchison, p.21). A third category, *stony-iron meteorites*, includes the meteorites that contain similar amounts of metals (nickel-iron) and silicates. To further subdivide meteorite classification we must be more specific about the minerals that make up a meteorite: *which* silicates are present, and *what kind* of metals are components? To answer these more specific questions, a greater amount of detail must be seen than is visible to the unaided human eye.

In recent years, a growing number of enthusiasts have been embracing the rewarding past-time of meteorite hunting. The beauty of this potential recreational activity is that one must simply have the time, inclination, a few key facts, and readily available tools to become a meteorite hunter. According to an article by Mark Bostick, on the website MeteoriteArticles.com, the basic tools of a meteorite hunter are a metal detector, GPS unit, a 10x Magnifier glass or a jeweler's loupe, and a map and compass.

Meteorites are collected by two means, and may be described as either "falls" or "finds." Most of the meteorites in collections are "finds" – objects that have been identified as extraterrestrial in origin, but whose arrival on Earth was not witnessed. Of course, a fair degree of chance is involved in such meteorite discoveries. "Finds" may include "stones" which have been removed from fields by farmers, or even meteorites which have lain undisturbed in remote desert areas since their fall, to be discovered much later. A "fall" discovery usually results from a fireball event which has been well observed and that leads to an accurate determination of the likely drop-zone for any remaining debris.

Interestingly, even though the majority of meteorites stumbled across by chance belong to the iron group, the total number of *stony meteorites* in museum collections is far greater than the amount to *iron meteorites* and *stony-iron meteorites* combined. This interesting imbalance is due to priority placed on discovery of *stony meteorites*, which can be attributed to a simple matter of identification. *Stony meteorites* tend to blend into most environments well because of the fact that they weather quickly, and soon camouflage themselves to appear as just another mundane-looking grey or black rock. So, these more illusive objects are especially sought after by some meteorite hunters. On the other hand, *iron meteorites* erode more slowly than their stony comrades and many times appear noticeably different in comparison to the surrounding terrain. This relatively simple identification as an alien material is many times obvious even to the eyes of non-geologists and amateur meteorite hunters.

Additionally, there are many visual clues that a meteorite hunter can look for when searching for these hidden "gems." The book *Falling Stars: A Guide to Meteors and Meteorites*, describes four main visual clues for recognizing a meteorite:

- 1. It attracts a magnet (contains metallic iron).
- 2. It has a usually dark, thin, melted surface layer (called a fusion crust, due to the melting of the minerals on the meteorite's surface during the plunge through the Earth's atmosphere).
- 3. It has an aerodynamic shape (acquired during the high speed flight).
- 4. It has thumbprint-shaped indentations (called regmaglypts, made during the entry through the atmosphere).

Meteorites can be found from the tropics to the poles and the location of their fall to Earth is largely random. However, there is a higher concentration of meteorite impacts near the equator than

at the poles. In fact, for every three meteorites that land near the poles, four land near the equator! This difference is due to gravitational focusing, which favors the equatorial region (Hutchison, p.6). Additionally, meteors can enter the atmosphere, and meteorites can fall at any time of the day. However, there is a large amount occurring in the afternoon and evening because as the Earth rotates, the hemisphere between noon and midnight (local time) encounters debris in orbit around the Sun that are closing in on Earth. When this occurs, an object's capture by Earth's gravity is more likely than at other times. Additionally, the slower an object is traveling, the higher its chance of survival through the atmosphere. For this reason, the few meteors that are orbiting in the opposite direction of Earth are usually destroyed at their first contact with the atmosphere.

I must admit that although I would not consider myself to be a superstitious person in any sense, I cannot resist succumbing to the romantic and long-held "magic" notion involving meteors. Although I know that these streaks of light gliding across the night sky are really nothing more than some interplanetary debris vaporizing upon entering Earth's atmosphere, there is something intriguing and mystical about these phenomena that have been watched and speculated about by humans on Earth since the beginning of time. Just last week, while star-gazing in a large grassy field behind my house, I saw a momentary streak of light cross the southern sky and gleefully wished upon that "shooting star." Even if my wish should not come true – at least I can hold on to the possibility that someday a meteorite might smash into my house and I could sell it for \$50,000. Oh, the possibilities!

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