Meteoroids, Meteors, Meteorites, and Tektites

A M.A.R.S. Resource Document

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for the

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Astronomical Measurements

It is a good idea to review certain measurements that are used throughout this document. A **mile** (abbreviated: mi) is a unit of length that is well known in the United States. It is also known as a statute mile, and is equivalent to 5280 feet or 1760 yards. This **kilometer** is not as well understood. Those currently studying the metric system in school or having recently completed their schooling can probably understand its use. A kilometer (abbreviated: km) is equivalent to 0.621 mile, or 3280.8 feet. To convert a distance from miles to kilometers, multiply the number by 1.609. For quick, rough conversions from kilometers to miles, a distance stated in kilometers is approximately 2/3 of the number in miles (example: 100 km is *roughly* 66 mi and *exactly* 62.1 mi). The large distances within our Solar System are often given in **AU** or **astronomical units**. This is equal to the mean distance between the Earth and the Sun (92,900,836.17 mi or 149,598,770 km). Most people might be familiar with the rough approximation of 93 million miles. This number is good for making rough conversions as long as you are not using the figure for something important, like a school paper or a space flight E.T.A.! For longer distances, astronomers use such units as a **light-year** (abbreviated: lt-yr or l-y). This is the distance which light travels in one mean solar year, and approximately equivalent to 5,880,000,000,000 mi (5,800 billion miles) or 9,460,000,000,000 km (9,460 billion kilometers) or 63,240 AU. This unit of measure relies upon the **constant velocity of light** (commonly referred to as the "speed of light"), which is equivalent to 299,792.5 kilometers per second, or about 186,282.3976 statute miles per second.

A **kilogram** (abbreviated kg is a metric measure of weight. One kilogram is equal to 2.205 pounds.

Celsius (abbreviated C) is a metric measure of temperature. The scale is based on the boiling and freezing points of water at se level. Water freezes at 0°C and boils at 100°C. To convert Fahrenheit to Celsius subtract 32 degrees and multiply by 5, then divide the number by 9. To convert Celsius to Fahrenheit, multiply by 9, divide by 5 and then add 32. Kelvin (abbreviated K) is another measure of temperature. One degree of Kelvin is equal to one degree of Celsius. The main difference is that the **Kelvin** scale begins at absolute zero, which is the lowest theoretically attainable temperature. Absolute zero is the point at which the motion of atoms and molecules stops. Absolute zero is 0°K, which is equal to –273.15°C. Water freezes at 273.15°K and boils at 373.15°K.

Meteors

On clear nights, if the sky is dark enough, you may see needle-like streaks of light cutting across the sky. Anywhere from one to a dozen or more may be seen in an hour. They have been called *shooting stars* and *falling stars*, but the objects that make up these trails are actually bits of ice, stone and iron from outer space. When one of these bits falls into our atmosphere the effect it produces is called a meteor.

What's in a Name?

The terms meteor, meteorite and meteoroid are confusing to many, and with good reason. They all refer to the same object, but under different circumstances. Let us first examine the origin of these terms. The word meteor comes from the Greek word *meteoron*, meaning astronomical phenomenon, or something in the heaven above. This meaning can be understood when considering that meteorology is the science dealing with the atmosphere and its phenomenon. In its most literal sense, anything that occurs in the sky could be called a meteor, whether it be a thunder cloud, a supernova or a UFO. For the purpose of sanity, we shall confine its usage to small bodies which drift through space, fall into Earth's atmosphere, and sometimes reach the ground.

A *meteoroid* is a small object, smaller than an asteroid or minor planet, drifting through space in orbit around the Sun (bits smaller than grains of sand are sometimes called micrometeoroids). A *meteor* is the effect produced as the meteoroid falls into our atmosphere and streaks across the sky. A glowing trail, sometimes called a train, is created to mark the path of the meteoroid as it falls. When a meteoroid, or a fragment of it, reaches the ground, it is called a *meteorite*. These may be found, dug up, held, and examined (The only way to hold a meteoroid is either to float in space or fall through the sky with it!).

Look, a meteor!

Before the 19th century meteors were considered an atmospheric phenomenon, like auroras and clouds. Then on April 26, 1803 about 2,000 meteorites fell at L'Aigle in France. The citizens picked them up and even reported that some of the fragments were still warm. The event was reported by French physicist Jean Baptiste Biot (1774-1862). It was not until Biot's published report that scientists finally accepted the fact that solid bodies were falling to Earth from outer space.

Many meteoroids are the size of salt or surger grains and most are no bigger than grains of rice, though some can be the size of giant boulders weighing several tons. As the meteoroids enter Earth's atmosphere, at speeds ranging from 11 to 72 kilometers (7 to 45 miles) per second, their surfaces collide with the atoms and molecules of the atmosphere. These collisions break loose material from their surface and also break up the atoms and molecules of both the meteoric material and the atmosphere into charged particles. The ionized atoms are excited and begin to glow 50 to 75 miles up. These glowing tubes that the meteoroids create as they pass are called trails or trains. Some meteor trails are short, and some are long -- spanning 20° or more across the sky. Most trails are white, blue, or yellow, but some can be red or even green. These ionized trails also show as reflections on radar. Astronomers have used radar since 1945 to record the rate of meteors that fall. Radar observations allow astronomers to track meteor showers that occur during the daytime as well.

The slow, bright meteors are called *fireballs*. Frequently their trails remain visible for some time after they pass. Fireballs are produced by large meteoroids ranging in size from that of a basketball to that of small cars. Sometimes their path is crooked or broken, and several explosions may mark their course. Fireballs that explode are called *bolides*.

Most meteoroids turn into vapor and dust long before they reach the ground. The larger ones break up during their fiery trip through our atmosphere and fragments of these hit the Earth. Once every few hundred years a really big one hits, such as the meteoroid that made Barringer Meteor Crater near Winslow, Arizona, which is estimated to have fallen between 25,000 to 40,000 years ago. The crater is nearly 4,000 feet (1.2 kilometers) in diameter, surrounded by a rim 140 feet above the surface, with a distance of over 500 feet from the bottom of the crater to the rim.

There are approximately 100 known meteor craters on the Earth and over a dozen are larger than Barringer Meteor Crater. For example, the Chubb crater in Ungana, Canada is about 5 kilometers (3 miles) across. The Manicougan crater in Quebec, Canada is about 35 miles (56 kilometers) across. The Popiagi crater in the former Soviet Union is about 65 miles (105 kilometers) across. In addition to the known craters, there are many more geological formations that may have been created by the impacts of meteorites.

Meteor Showers

On any night, an observer may see one meteor every 10 minutes. These are called *sporadic meteors*. In certain parts of the sky, over periods of days or weeks, *showers* of meteors can be seen. Up to 150 meteors per hour may be observed. Showers occur whenever Earth, in its journey around the Sun, encounters a vast swarm of meteors--often the remains of a comet.

As a comet orbits the Sun and the Sun slowly boils away some of the comet's material, the comet leaves a trail of tiny particles dispersed along its path. If Earth's orbit and the comet's path intersect, and there is a sufficiently large amount of cometary material, there will be a meteor shower. Some showers return annually, others at greater intervals, irregularly, or not at all depending on the relative positions of the shower orbits and Earth's orbit.

When the meteoroid orbital path has a concentration, it is known as a *swarm*. Swarms are responsible for meteor storms, with thousands of meteors visible per hour. When meteoroids are distributed evenly throughout the path of their orbit, as they are with older showers, the path is known as a *stream*. Streams produce consistent, regular meteor showers with reliable hourly rates of a few hundred per hour or less. The length of a meteor shower varies with the width of a shower's orbital stream and the number of days required for Earth to pass through it. When Earth reaches the point where the meteoroid stream is the most dense, the meteor shower reaches its peak, or *maximum*. Some showers have more than one maximum, possibly because of several strands or "ropes" of concentration within the stream.

A meteor shower appears to radiate from one point in the sky, called the *radiant*, and the shower is likely to recur from that point about the same time each year. Showers are usually named after the constellation from which they seem to radiate.

Meteor showers vary in strength, but usually the three best meteor showers of the year are the Perseids around August 12, the Orionids around October 21, and the Geminids around December 13. These showers feature meteors at the rate of about 60 per hour.

A serious study of meteor showers was not begun until the 19th century. On April 26, 1803 about 2,000 meteorites fell at L'Aigle in France. The citizens who picked them up reported that some of the fragments were still warm. The event was reported by French physicist Jean Baptiste Biot (1774-1862). This event was notable because it was not until Biot's published report that scientists finally accepted the fact that solid bodies were falling to Earth from outer space.

The great meteor storm of November 12-13, 1833 is regarded as the date of the birth of meteor astronomy. Following that meteor storm, Professors Olmsted and Twining of then Yale College pointed out that the meteors appeared to radiate from a point in the constellation Leo, the Lion. The fact that the meteors radiated from a single point indicated that they were all part of a swarm of meteoroids moving in the same orbital path. Later, Professor Hubert Anson Newton (1830-1896) an astronomer and mathematician who was also of Yale College, calculated that the orbit had a period of 33 years and used records to trace appearances of the shower as far back as AD 902. He also observed that the time of the Leonid shower moved along the calendar at the rate of about a month in a hundred years. Newton then successfully predicted the appearance of the 1866 Leonid storm. A few weeks after the 1866 storm astronomers found that the orbit of the meteoroid stream was identical with Temple's Comet, seen a year earlier. About this same time Italian astronomer Giovanni Schiaparelli (1835-1910) showed that the Perseid meteors came from a stream that moved in an orbit identical to the bright comet of 1862. These were the first observations to connect comets with the fall meteor showers.

The dates of meteor showers are not always the same from year to year. Some meteoroid orbital paths, because of their angle and orbital period, are affected by the gravity of other planets in the solar system, particularly the planet Jupiter. This orbital change affects the location where the meteoroids intersect or come close to the Earth's orbit, thereby affecting the time of year when the shower is seen. For example, the time of the Andromedid shower moved gradually over time from December to November, and finally to October. The gravity of other planets can also shift the orbit of meteoroid paths to the point where Earth no longer passes close enough to experience a shower. This may have occurred to the Andromedid shower, which was last observed in the 1940s and is now though to be defunct.

Since about 1945, radar observations have revealed meteor showers regularly occurring in the daylight sky, where they are optically invisible.

Table of Meteor Showers

(listed chronologically by maximum date)

Shower Name	Max	Duration	Entry Velocity (km/sec)	Avg Hourly Rate	Radiant RA hrs	Radiant RA min	Radiant Dec °	Parent
Quadrantid	Jan 3/4	Jan 1-6	41	40-110	15	28	+50	unknown
Cyrillid (defunct)	Feb 9	-	?	?	-	-	-	unknown
Arid (Corona Australid)	Mar 16	Mar 14-18	?	5	16	20	-48	unknown
Virginid	Mar 20	Mar 5 - Apr 2	?	5	12	40	00	unknown
(April) Lyrid	Apr 21/22	Apr 19-25	48	12-15, irregular	18	16	+34	1861 I (Thatcher)
Pi Puppid (daytime)	Apr 24/25	Apr 21-26	?	40, irregular	01	00	-55	unknown

Eta Aquarid	May 3/4	May 2-6	66	20	22	24	00	P/Halley
Arietid (daytime)	?	May 29 - Jun 17	?	?	?	?	?	unknown
Xi Perseid (daytime)	?	Jun 1 - Jun 15	?	?	?	?	?	unknown
Ophiuchid	Jun 20	Jun 17-26	?	20	17	20	-20	unknown
Boötid	Jun 27/28	Jun 20 - Jul 5	?	30-100, irregular	?	?	?	P/Pons -Winnecke
Beta Taurid (daytime)	Jun 29/30	Jun 23 - Jul 5	?	20	03	40	+15	P/Encke
Northern Delta Aquarid	Jul 29	Jul 15 - Aug 18	?	10	22	36	00	unknown
Southern Delta Aquarid	Jul 28/29	Jul 21 - Aug 15	41	20-35	22	36	-17	unknown
Pisces Australid	Jul 30	Jul 15 - Aug 20	?	20	22	40	-30	unknown
Capricornid	Jul 25	Jul 10 - Aug 5	23	20	21	00	-15	unknown
Alpha Capricornid	Aug 2/3	Jul 15 - Aug 25	?	8	20	36	-10	Honda-Mrkos -Pajdusakova

Perseid	Aug 11/12	Jul 25 - Aug 21	59	50-68	03	04	+58	1862 III P/Swift-Tuttle
Kappa Cygnid	Aug 20	Aug 18-22	20	50	19	20	+55	unknown
(October) Draconid (Giacobinid)	Oct 8/9	Oct 7-10	20	irregular	17	23	+57	Giacobini -Zinner
Orionid	Oct 22	Oct 1 - Nov 7	66	25-30	06	20	+15	P/Halley
Andromedid (thought defunct)	Nov 1	11 days	21	(weak)	?	?	?	P/Biela (now gone)
Northern Taurid	Nov 1	Oct 15 - Dec 1	?	5	03	44	+22	P/Encke
Southern Taurid	Nov 3	Sep 15 - Dec 15	?	5-15	03	44	+14	P/Encke
Leonid	Nov 17	Nov 16-17	71	10-15, irregular	10	08	+22	55P/Temple -Tuttle
Phoenicid	Dec 5	Dec 3-7	?	50	01	00	-55	unknown
Geminid	Dec 13/14	Dec 7-16	34	58	07	32	+32	asteroid

								3200 Phaeton?
Ursid	Dec 21/22	Dec 17-25	?	15	14	28	+76	P/Tuttle

Meteors Listed Alphabetically by Name

Alpha Capricornid Meteor Shower

This shower is caused by Periodic Comet Honda-Mrkos-Pajdusakova. Meteors from this shower may be visible from July 15 through Aug. 25 with the peak on Aug. 2/3. The meteor hourly rate may be about 8. The meteors will appear to originate from a point in the constellation of Capricornus (RA 20hrs 36min, Dec -10°).

Andromedid Meteor Shower

The meteors were also known as Bielids because they were caused by Comet Biela, also known as Biela's Comet. Meteors from this shower fell for an eleven day period at the end of October and beginning of November. The meteors fell at a fairly slow rate of 21 kilometers per second. Though this shower was known for occasional storms, the average hourly rate was weak, perhaps 5 to 10 per hour. Andromedid meteors had a reddish color. This shower was first recorded in 1741. Because of drifting of the path of the debris over time, the peak of the shower had moved from December to November and then into October. This shower is now believed to be defunct.

History

December 7, 1798 - A strong shower of Andromedid meteors was seen. The actual hourly meteor rate is not known.

December 7, 1838 - A strong shower of Andromedid meteors was seen. The actual hourly meteor rate is not known.

November 27, 1872 - A storm of Andromedid meteors fell over western Europe. It was recorded that the meteors fell at the rate of several thousand per hour. The peak of the shower had actually been calculated by Weiss, D'Arrest and Galle for November 28.

November 27, 1885 - An Andromedid meteor storm fell over Europe. The meteors appeared to fall at the rate of 75,000 per hour, though counting was virtually impossible.

November 27, 1886 - A shower of Andromedid meteors fell. On this same day an iron meteorite fell near Mazapil in northern Mexico. It was suggested that the meteorite was a fragment from the Andromedid shower, and therefore a fragment of Periodic Comet Biela, the parent comet of the shower.

November 23, 1892 - A fairly strong Andromedid meteor shower was observed.

November 24, 1899 - An Andromedid meteor shower was observed with meteors falling at a rate of 200 per hour.

November 15, 1940 - An Andromedid meteor shower was observed with meteors falling at the rate of about 30 per hour. This was one of the last years in which Andromedid meteors were observed in any strength.

Arid Meteor Shower

This is a southern-hemisphere shower. Its meteors may be visible from March 14 through 18 with the peak on March 16. The meteors have a modest rate of 5 per hour. They appear to originate from a point in the constellation of Ara, the Altar (RA 16hrs 20min, Dec -48°). The Arid shower was formerly known as the Corona Australid shower.

Arietid Meteor Shower

This is a daytime shower which is observable by radar. Meteors from this shower fall from May 29 through June 17. On radar, they appear to originate from a point in the constellation Aries, the Ram. The parent comet of this shower is not known.

Beta Taurid Meteor Shower

This is a daytime shower observable by radar. Meteors from this shower fall from June 23 to July 5 with the peak on June 29/30. The meteors have an average rate of 20 per hour. On radar, they appear to originate from a point near the star Beta Taurid in the constellation of Taurus, the Bull (RA 03hrs 40min, Dec +15°). This is one of the showers associated with Comet Encke, the other being the Northern and Southern Taurids of the fall and winder.

Boötid Meteor Shower

The meteors from this shower are also called the June Draconids or the Pons-Winneckids. This shower is caused by dust from Comet Pons-Winnecke. Meteors from the Boötid shower may be visible from approximately June 20 to July 5. The shower peaks on June 27/28. The rate of the shower is extremely variable and the peak lasts only a few hours. Good displays of this shower are not predictable because they appear to follow a path used by the comet earlier in the 20th century. Jupiter has perturbed its orbit since that time, and so the the comet's return, which happens about every 6 years, cannot guarantee a good display. The meteors will appear to originate from a point in the sky near the constellations Boötes the Herdsman and Draco the Dragon. The shower appears to have several radiant points spread over an area of a few degrees. Bootid meteors move much slower than other meteors of this time of year and so also may be identified by their relative speed.

History

June 12, 1819 - A comet was discovered from Marseilles, France by comet hunter Jean-Louis Pons. He was sweeping the constellation Leo with his 100-millimeter (4-1/2-inch) refractor and noticed a small 8th-magnitude comet without a tail. Though it brightened some, observers lost sight of it at the end of July.

Spring 1858 - A comet was discovered by Friedrich Winnecke in Bonn, Germany. It was quickly determined that the comet was actually Pons' comet of 1819, and was renamed Pons-Winnecke. The body attracted special interest because it made a close approach to Jupiter every other time it circled the Sun.

June 30, 1860 - A shower of Boötid meteors was seen, though it was not known by that name at the time. At its peak, the zenithal hourly rate was estimated to be 30 to 40 meteors. A Mr. Lowe, observing that night, reported seeing "many meteors."

June 30, 1861 - A shower of Boötid meteors was seen, though it was not known by that name at the time. At its peak, the zenithal hourly rate was estimated to be 30 to 40 meteors. As in the previous year, a Mr. Lowe, observing that night, reported seeing "many meteors."

June 28, 1916 - A shower of Boötid meteors was seen, though it was not known by that name at the time. At its peak, the zenithal hourly rate was

100 meteors. English amateur W. F. Denning counted 55 Boötid meteors over one hour and 45 minutes. The observer meteor path suggested a radiant between Boötes and Draco. In the U.S. William R. Brooks and Edward Emerson Barnard also noticed the shower. Denning and U.S. expert Charles P. Oliver independently connected the meteors with comet Pons-Winnecke. They noted that the Earth had passed through the plane of the comet's orbit during the last few days of June every year. The shower occurred 10 months after the comet passed through the inner Solar System. It was also noted that the observed meteor path

June 28-29, 1921 - The Boötid meteor shower was barely detected. At its peak, the zenithal hourly rate was approximately 10 meteors. English astronomer W. F. Denning counted only 3 Boötid meteors over a 105-minute period. Similar observations were made in Europe. This event was particularly disappointing to observers since the parent comet reached perihelion only two weeks earlier.

July 3 and 5, 1921 - There were questionable reports of Boötid meteor activity over Japan. The reporters claimed rates exceeding 100 per hour, but the observations were made several days after the expected maximum.

June 1927 - A Boötid meteor shower was observed and reported by U.S. observers as well as a group in Tashkent, U.S.S.R. At its peak, the zenithal hourly rate was 30 meteors.

June 24, 1995 - A Boötid fireball of magnitude -5 was seen over Japan. It was photographed by three stations of the Japanese Fireball Network. The fireball followed a path similar to that of the parent comet from much earlier in the 20th century.

June 27, 1998 - A significant Boötid meteor shower was seen. At its peak, the zenithal hourly rate was 80 meteors. The shower followed a path similar to that of the parent comet from earlier in the 20th century. Its path had been perturbed by Jupiter since that time.

Capricornid Meteor Shower

This shower is visible from July 10 through August 5 with the peak on July 25. The meteor rate averages 20 per hour. This shower appears to originate from a point in the constellation Capricornus (RA 21hrs 00min, Dec -15°).

Cyrillid Meteor Shower in History

This shower was an apparent one-time event which occurred February 9, 1913. The meteors did not radiate from a single point in the sky, suggesting that they were not in a predictable orbital path around the Sun. The shower is named after St. Cyril of Alexandria, on whose feast day the shower occurred.

History

February 9, 1913 - A meteor shower occurred which had no radiant (it did not appear to radiate from a single point in the sky). The meteors seemed to enter the atmosphere from a circular orbit around the Earth. It was named the Cyrillid shower because it was observed on the feast day of St. Cyril of Alexandria.

Draconid Meteor Shower

The meteors from this shower are also called the October Draconids or the Giacobinids. This shower is caused by dust from Comet Giacobini-Zinner. Meteors from the Draconid shower may be visible from October 7 to 10. The shower peaks on October 8/9. The rate of the shower is variable and the peak lasts only a few hours. This shower gives a good display only when the parent comet returns to perihelion, which is every 6.5 years. The meteors will appear to originate from a point in the sky near the head of the constellation Draco, the Dragon (RA 17hrs 23min, +57°).

History

October 9, 1926 - A Draconid shower was seen with a rate of 17 per hour.

October 9, 1933 - On this Monday night a great, brief, and unexpected Draconid meteor storm was seen over Europe, Asia, Africa and America. The overall rate for the fall was estimated at 5,000 per hour. Observers in Malta recorded a meteor rate of 480 per minute. In Ireland it was reported that the meteors fell as thickly as flakes of snow in a snow storm. Several Russian observers reported more than 100 meteors per minute and in Syria 168 meteors were counted in a 30-minute period. About five hours after the shower had reached its maximum in Europe some of the meteors struck different parts of the United States, but U.S. observers reported lower fall rates up to 10 per minute. The parent comet, Giacobini-Zinner had passed this point in Earth's orbit in July, just three months earlier.

October 10, 1946 - A great Draconid meteor storm was seen over Europe and the United States with an estimated rate of 5,000 per hour.

October 9, 1952 - A Draconid meteor shower was seen with an estimated rate of 180 per hour.

October 8, 1985 - A Draconid meteor shower was seen with an estimated rate of 400 per hour. The size of the shower came as a surprise to astronomers.

October 8, 1998 - A Draconid meteor shower was seen over Japan and China, with Europe witnessing the tail end of the activity. The shower peaked between 13:00 and 14:00 UT with an estimated rate greater than 500 per hour.

Eta Aquarid Meteor Shower

Meteors from the Eta Aquarid shower may be visible from April 18 through May 28 with the peak on the evening of May 4 and morning of May 5. The meteor hourly rate fluctuates over the period of the shower, but may reach 35 or more at its peak. The meteors will appear to originate from a point in the constellation of Aquarius, the Water Bearer, near the 4th-magnitude star Eta Aquarii (RA 22hrs 20min, Dec -01°). This shower is one of two caused by Periodic Comet Halley, the second being the Orionid shower in October. The Eta Aquarid meteoroids come into our atmosphere at a speed of 66 kilometers per second. This speed creates the bright fireballs and long paths for which the Eta Aquarids are well known.

This shower was first recorded in 74 BC. The shower actually has several radiants, all of which are centered around the main radiant coordinates. Meteors from this shower can be observed at a moderate rate from April 24 until May 20. There are actually 4 or 5 peaks during the shower's extended maximum, which occurs between May 4 to 8.

Geminid Meteor Shower

This is a reliable shower, giving consistent rates each year. Geminids have been observed since 1838. It has not been confirmed what causes this shower, although the planet-crossing asteroid 3200 Phaethon does move in the same orbit as the dust stream. It may be possible that Phaethon is an extinct cometary core. Meteors from the Geminid shower may be visible from December 7 through 16 with the peak occurring December 13/14. Meteors from the Geminid shower are yellowish in color and average a magnitude of 2.5. The meteor hourly rates may range from 58 to possibly 100 or more at the shower's peak. The Geminid hourly rates tend to increase steadily for several days before maximum, then drop off quickly in the days following. The meteors will appear to originate from a point in the sky near the star Castor in the constellation Gemini (RA 7hrs 28min, Dec +32°).

Kappa Cygnid Meteor Shower

Meteors from this shower may be visible from Aug. 18 through Aug. 22 with the peak on Aug. 20. The meteors have a rate of about 50 per hour. Meteor speeds average 20 kilometers per second, one of the slowest moving streams. The meteors will appear to originate from a point west of the star Kappa Cygni in the constellation of Cygnus, the Swan (RA 19hrs 20min, Dec +55°).

Leonid Meteor Shower

Meteors from this shower may be visible from Nov. 15 through Nov. 20 with the peak on Nov. 17. Leonid meteors have a bluish-green tint. This shower is caused by Periodic Comet Tempel-Tuttle. This comet returns to the inner solar system every 32.9 years. This shower is sometimes a veritable storm of meteors in the years surrounding the comet's return. This last occurred in 1966, when up to 40 meteors per second were seen for about an hour! Comet Tempel-Tuttle's return in 1999 has observers hopeful for another storm.The best chances to see a storm are in the early morning hours during the days surrounding the peak (Nov. 16, 17, 18). The meteors will appear to originate from a point in the constellation of Leo (RA 10hrs 08min, Dec +22°).

History

October 13, 902 - A storm of Leonid meteors was observed. One observer described it as a "small starlike fire." The storm occurred 597 days after the passing of parent comet P/Temple-Tuttle.

October 14, 1002 - A storm of Leonid meteors was observed. One observer reported that the "stars flew early in the morning." The storm occurred 634 days after the passing of parent comet P/Temple-Tuttle.

October 18, 1202 - A storm of Leonid meteors was observed. One observer reported that "stars rushed across the heaven." The storm occurred 613 days after the passing of parent comet P/Temple-Tuttle.

October 18, 1238 - A storm of Leonid meteors was observed. One observer reported "countless large and small meteors." The storm occurred 1,456 days after the passing of parent comet P/Temple-Tuttle.

October 25, 1533 - A storm of Leonid meteors was observed. One observer reported that there were "countless meteors till dawn." The storm occurred 230 days after the passing of parent comet P/Temple-Tuttle.

November 5, 1601 - A storm of Leonid meteors was observed. One observer reported that the "stars became like rain." The storm occurred 465 days after the passing of parent comet P/Temple-Tuttle.

November 12, 1799 - A strong Leonid meteor storm was seen across the western hemisphere. German scientist Friedrich Heinrich Alexander von Humboldt (1769-1859) and his companion Bonpland were in Venezuela at the time at made note of the event. The actual hourly meteor rate of the shower is not known.

November 12-13, 1833 - North America witnessed a great Leonid meteor storm, though it was not yet known by that name. One observer from the U.S. reported that the "stars descended like snow." Witnesses later recalled 1833 to their families as "the year the stars fell." The meteors fell at an approximate rate of 100,000 per hour. This event initiated the first serious study of meteor showers. Immediately after the shower, Professors Olmsted and Twining of then Yale College called attention to the fact that the meteors all radiated from the same point in the sky, indicating that they were all part of a swarm moving in the same orbital path. Later, Professor Hubert Anson Newton (1830-1896), also of Yale College, calculated that the orbit had a period of 33 years and used records to trace appearances of the shower as far back as AD 902. He then successfully predicted the appearance of the 1866 Leonid shower. (The 1833 Leonid storm occurred 308 days after the passing of parent comet P/Temple-Tuttle.)

There is historical evidence that Abraham Lincoln (1809-1865) witnessed the Leonid meteor storm of 1833 as a young man of 24. According to cross-referenced records and personal journals, Lincoln was apparently in New Salem, Illinois staying at the Rutledge Tavern, a log cabin then owned by Henry Onstot, a cooper by trade (bucket and barrel maker) and member of the Cumberland Presbyterian Church. Lincoln recounted the story in the presence of American writer Walt Whitman (1819-1892) who was a frequent guest of the Lincoln White House. Whitman later published the story in his book *Specimen Days & Collect*, published 1882. When asked by another White House guest whether the Union would survive the ongoing Civil War, Whitman noted that Lincoln, ever the story-teller, replied with this story. *"When I was a young man in Illinois," said he, "I boarded for a time with a Deacon of the Presbyterian church. One night I was roused from my sleep by a rap at the door, & I heard the Deacon's voice exclaiming 'Arise, Abraham, the day of judgement has come!' I* *sprang from my bed & rushed to the window, and saw the stars falling in great showers! But looking back of them in the heavens I saw all the grand old constellations with which I was so well acquainted, fixed and true in their places. Gentlemen, the world did not come to an end then, nor will the Union now."*

November 17, 1865 - A Leonid meteor shower was seen with many colorful fireballs. This shower was the prelude to the great meteor storm the following year.

November 14, 1866 - A storm of Leonid meteors was observed. The maximum took place over Europe around 1:10 UT. Meteors fell at an approximate rate of 5,000 per hour. The storm was notable in that H. A. Newton of then Yale College predicted that the Leonid storm would occur this year based upon orbital calculations and occurrences of storms in previous years.(The 1866 Leonid storm occurred 299 days after the passing of parent comet P/Temple-Tuttle.)

November 13, 1867 - A storm of Leonid meteors was observed. The maximum took place over North America with a bright Moon in the sky. Meteors fell at an approximate rate of 3,600 per hour. The storm occurred 664 days after the passing of parent comet P/Temple-Tuttle.
November 13, 1868 - A storm of Leonid meteors was observed. Meteors fell at an approximate rate of 1,500 per hour. The storm occurred 1,030 days after the passing of parent comet P/Temple-Tuttle.

November 17, 1966 - The peak of the annual Leonid meteor shower became a meteor storm that was best observed by the western U.S. and eastern Siberia. It was estimated that over 150,000 meteors were observed per hour, averaging approximately 41 meteors per second. During one 40-minute period, over 1,000 meteors per minute were observed. The average magnitude of the trails was 1.5 or 2. Some of the brighter meteor trails lasted for more than a minute. The storm occurred 561 days after the passing of parent comet P/Temple-Tuttle.

November 17-18, 1997 - A Leonid meteor storm was observed. The meteor rate was estimated over 100 per hour. The storm occurred 108 days after the passing of parent comet P/Temple-Tuttle.

November 17, 1998 - A Leonid meteor shower was observed with many colorful fireballs, peaking at a rate of over 450 fireballs per hour around 5:00 UT. The observed colors included violet, red, blue, and green. The "regular" meteors peaked, later, around 17:00 UT, at a rate of 150 per hour. The shower began over Europe and finished over North America. It was suggested that this Leonid shower, like the one in 1865, was prelude to a Leonid storm in 1999. The storm occurred 257 days after the passing of parent comet P/Temple-Tuttle.

November 17-18, 1999 - A spectacular Leonid meteor shower was seen that was comparable to the Draconid storms of 1933 and 1946. At its peak, the zenithal hourly rate was estimated to be 3,700 meteors. Many observers reported about one Leonid per second during the shower's maximum, which lasted roughly 15 minutes around 2:00 Universal Time (UT) November 18. Europe and Asia saw the highest rates with U.S. observing lesser rates a few hours later. Following the maximum, the rate fell as low as 80 by 5:00 UT, remained around 60 for several hours and rose to nearly 200 for a time. Some shower predictors are forecasting a modest shower in 2000 with a much stronger storm and multiple peaks on the morning of November 18, 2000.

Lyrid Meteor Shower

Also called the April Lyrids, meteors from this shower may be visible from April 19 through 25 with the peak on April 21/22. The meteors have an irregular rate, but average 12 to 15 per hour. They appear to originate from a point in the constellation of Lyra (RA 18hrs 16min, Dec +34°). Appearances of this shower have been traced back over 2,500 years. The parent of this shower is Comet Thatcher, 1861 I. The earliest record of the Lyrid shower was in 687 BC.

History

March 27, 15 BC - A spectacular Lyrid meteor storm was observed. One observer recorded that the "stars fell like rain."

April 20, 1803 - A brilliant Lyrid meteor shower was seen, though an hourly rate of the meteors was not recorded.

April 21, 1922 - A fair display of the Lyrid meteor shower was seen, though an actual hourly rate of meteors is not known.

Northern Delta Aquarid Meteor Shower

Meteors from this shower may be visible from July 15 to August 18 with the peak on July 29. The meteors have a rate of 10 per hour. They appear to originate from a point near Delta Aquarii (Scheat) in the constellation of Aquarius, the Water Bearer (RA 22hrs 36min, Dec 00°). The parent comet of this shower is not known. This shower and the Southern Delta Aquarid meteor shower probably originated from the same parent comet or comets.

Northern Taurid Meteor Shower

This is one of two showers visible in the fall and winter that originate from the constellation Taurus. Both of these showers appear to be caused by

Periodic Comet Encke. The other shower is called the Southern Taurid shower. The Northern Taurid meteors are visible from October 15 through December 1 with the peak on November 1. The shower has a moderate rate of 5 per hour. The coordinate for the radiant of the Northern Taurid shower is RA 03hrs 44min, +22°.

Ophiuchid Meteor Shower

Meteors from this shower may be visible from June 17 through 26 with the peak on June 20. The meteors have a rate of about 20 per hour. Meteor speeds average 20 kilometers per second. The meteors will appear to originate from a point in the constellation of Ophiuchus, the Serpent Bearer (RA 17hrs 20min, Dec -20°). The parent comet of this shower is not known.

Orionid Meteor Shower

This shower is caused by dust from Halley's Comet, which is also responsible for the Eta Aquarid Shower in the spring. Meteors from the Orionid shower may be visible throughout the month of October and through the first week of November. The maximum lasts from about the 19th through the 23rd, with the peak around the 22nd. This is a reliable shower, giving consistent rates each year. At its height the shower produces about 15 to 20 meteors per hour. The meteors will appear to originate from a point in the sky between the constellations Gemini and Orion (RA 06hrs 20min, Dec +15°).

Perseid Meteor Shower

Meteors from this shower may be visible from July 25 through Aug. 21 with the peak on Aug.11/12. This is a reliable shower, giving consistent rates each year. The meteor hourly rate may be about 75. Perseid meteors are yellow in color. This shower is caused by Periodic Comet Swift-Tuttle, also called Comet 1862 III, discovered on July 16, 1862 by Lewis Swift and then independently discovered three days later by Horace Tuttle. The meteors will appear to originate from a point in the constellation of Perseus (RA 03hrs 04min, Dec +58°).

Phoenicid Meteor Shower

This is minor southern hemisphere shower, visible from December 3 to 7 with the peak on December 5. The shower has an average rate of 50 per hour. They appear to originate from a point near the star Zeta Phoenicis in the constellation Phoenix (RA 01hrs 00min, Dec -55°). The parent comet of this shower is not known.

Pi Puppid Meteor Shower

This is a daytime shower occurring in the southern hemisphere and observable by radar. Meteors from this shower fall from April 21 to 26 with the peak on April 24/25. The meteors have an irregular rate, but average 40 per hour. On radar, they appear to originate from a point near the star Pi Puppis in the constellation of Puppis, the Stern (deck) (RA 01hr 00min, Dec -55°). The parent comet of this shower is not known.

Pisces Australid Meteor Shower

This is a southern-hemisphere shower. The meteors may be visible from July 15 to August 20 with the peak on July 30. The meteors have a rate of 20 per hour and appear to originate from a point in the constellation of Piscis Austrinius, the Southern Fish (RA 22hrs 40min, Dec -30°). The parent comet of this shower is not known.

Quadrantid Meteor Shower

Meteors from the Quadrantid shower may be visible from January 1 through 6 with the peak on January 4. The meteor hourly rates may range from 40 to possibly 110 at the shower's peak. The meteors will appear to originate from a point in the sky near the constellation of Boötes the Herdsman (RA 15hrs 28min, Dec +50°) high in the eastern sky. This is not a prime time shower. Ambitious observers will either have to get up very early or stay up very late. And you will only have a few hours to observe. The radiant point of the shower will begin rising about 1:00 a.m. but it will not reach its zenith before sunrise.

The Quadrantid shower has no known parent comet. It was first noticed about 1835. Most meteor showers are named after the constellation which contains the radiant. The Quadrantids are the exception to this rule. These meteors come from an area of the now-rejected constellation Quadrans Muralis (the Mural Quantrant), which is now the northern part of the constellation Boötes. A mural quadrant was an early instrument used for measuring declination. It is a large graduated circle with a sighting arm and telescope. The word "mural" indicated that the instrument was attached to a wall.

Southern Delta Aquarid Meteor Shower

Meteors from this shower may be visible from July 25 to August 2 with the peak on July 28/29. The meteors have a rate of 20-35 per hour. They appear to originate from a point near Delta Aquarii (Scheat) in the constellation of Aquarius, the Water Bearer (RA 22hrs 36min, Dec -17°).

This shower and the Northern Delta Aquarid meteor shower probably originated from the same parent comet or comets.

Southern Taurid Meteor Shower

This is one of two showers visible in the fall and winter that originate from the constellation Taurus. Both of these showers appear to be caused by Periodic Comet Encke. The other shower is called the Northern Taurid shower. The Southern Taurid meteors are visible from September 15 through December 15 with the peak on November 3. The average rate ranges from 5 to 15 per hour. The coordinate for the radiant of the Southern Taurid shower is RA 03hrs 44min, +14°.

Ursid Meteor Shower

This shower is caused by dust from Comet P/Tuttle, also known as 1790 II. The comet was originally found by French astronomer Pierre Méchain in 1790, and rediscovered by Horace Tuttle of the Harvard Observatory in

1858. This comet has a period of 13.7 years. Meteors from the Ursid shower may be visible from December 17 through 25 with the peak occurring December 21/22. The Ursid meteor rate is not spectacular, averaging only 5 per hour. The meteors will appear to originate from a point near the star Beta Ursae in the middle of the constellation Ursa Major (RA 14hrs 28min, Dec +76°) in the northern sky.

History

December 22, 1945 - A strong Ursid meteor shower was seen with the peak rate of around 100 per hour. It was later determined that the strong display was due to a swarm, or concentration of dust, on the opposite side of the orbit of the parent comet P/Tuttle.

Virginid Meteor Shower

Meteors from this shower may be visible from March 5 through April 2 with the peak on March 20. The meteors have a modest rate of 5 per hour.

They appear to originate from a point in the constellation of Virgo (RA 12hrs 40min, Dec 00°). The parent comet of this shower is not known.

Xi Perseid Meteor Shower

This is a daytime shower which is observable by radar. Meteors from this shower fall from June 1 through 15. On radar, they appear to originate from a point near the star Xi Persei in the constellation Perseus. The parent comet of this shower is not known.

Observing Meteors

Usually more meteors are seen near midnight and in early mornings, because during that time our part of Earth is facing in the direction of our orbital path, and we are heading into the meteor swarms. Best observing conditions occur with the absence of moonlight, usually when the Moon's phase is between waning crescent and waxing first quarter.

Observers preparing for an evening of observing should bring along a few things: a sleeping bag or blankets for warmth, a recliner or lawn chair, and a hot beverage to help cut the chill. Binoculars are not necessary but they help. Wide-field ones are the best.

In group observing for meteors, each person has his or her own section of the sky to patrol. Wide-field binoculars can help an observer confine his or her attention to their own piece of sky.

Meteor trails make interesting photographs. Also, amateurs with a short-wave radio receiver can "listen" to meteors. This is done by tuning the receiver to a very weak distant station, preferably above 15 megacycles. The volume is kept very low. When a meteor in the upper atmosphere ionizes a patch of air, creating momentary "reflector" for signals, the volume of the station's signal rises sharply. Doppler changes in pitch may occur. On a good morning, several hundred meteors may be heard.

Meteor Activities

- Observe showers, alone or with groups.
- Count the number of meteors seen in an hour. If observing a shower, count the number per minute.
- On a star chart, plot the beginning and ending points of meteor trails.
- If a meteor falls in your vicinity, try to find it. Watch your local newspaper for a report. Find persons who saw the meteor fall and attempt to trace it. Cooperate with a nearby observatory or museum, if any.

Meteorites

The Chinese have records of meteoric falls as early as 687 BC. The amount of meteoric material that enters Earth's atmosphere daily may total several tons. The number of meteors that actually reach the ground may be in the billions, but these are so small that their total weight is estimated at only one ton. Meteorites often fall in an elliptical pattern, reflecting the fact that they were fragments of a larger body that broke up as it fell.

Meteorites are particularly important to astronomers because, aside from the samples returned to Earth from lunar missions, meteorites are the only extraterrestrial material that may be studied on Earth in a laboratory. In fact, meteorites may give us our best look back to the events surrounding the formation of the solar system. Their texture and internal structure provide clues to that early time. Many meteorites are believed to be fragments of asteroids, which formed about the same time as Earth, some 4.5 billion years ago. It is also believed that some meteorites are fragments from comets, which are considered by many to be remnants of the dust and gas that formed the solar system.

Most meteorites are composed of rocky material, chiefly silicate. These are often called *stony meteorites*. They usually resemble terrestrial stones, although they are normally more dense, or heavy. Stony meteorites are rich in silicates but poor in metal and sulfides. The principle subclass of the stony meteorites are the achondrites. Some carbonaceous meteorites, another subclass of stony meteorites, might actually be fragments of comets.

Some meteorites are composed primarily of nickel-iron alloy. These are called *iron meteorites*. They are made of iron and 5 to 15 percent nickel usually combined in a mixture, or alloy. There is often a small amount of cobalt or even smaller amounts of other elements. Iron meteorites usually have a pitted, brownish appearance when they are found because of rust from exposure.

A third type has nickel-iron alloy intermixed with silicate material. These are called *stony-iron meteorites*.

Some meteorites are so large that they have become monuments in various countries around the world. The largest meteorite ever moved weighs 31,000 kilograms (34 tons). This is the Ahnighito meteorite, which was found in 1892 and brought back from the Arctic by Robert Peary and Matthew Henson, who claimed to be the first people to reach the North Pole. The meteorite is now on display at the American Museum of Natural History in New York City.

Meteorites look fused, or melted, on the outside. For this reason they are easily confused with bits of slag. Meteorites usually have peculiar shapes and are heavy for their size. The easiest meteorites to find are those that do not resemble the surrounding terrain. It is thought that many stony meteorites are never found because they so closely resemble Earth stones. The largest number of meteorites have been found in recent years in Antarctica, where they have accumulated undisturbed over long periods of time. Observers who want to be able to identify meteorites should study specimens on display in planetariums and museums.

Micrometeorites, which are smaller than grains of sand, are difficult but not impossible to collect. They have been gathered on filters attached to aircraft flying in the stratosphere. Micrometeorites also accumulate on the bottom of the deep ocean. The larger ones can be identified and separated from cores drilled from the muddy deposits on the seafloor. Scientists have also found micrometeorites mixed with snow drifts in the barren regions near Earth's northern and southern poles.

Meteorite History

November 16, 1492 - A meteorite weighing about 260 pounds fell at Ensisheim in Alsace about noon. It buried itself to a depth of 5 feet. The impact was witnessed by a child.

December 13, 1795 - A meteorite weighing 56 pounds fell in Wold Cottage, Yorkshire, England.

April 26, 1803 - About 2,000 meteorites fell at L'Aigle in France. The citizens who picked them up reported that some of the fragments were still warm. The event was reported by French physicist Jean Baptiste Biot (1774-1862). This event was notable because it was not until Biot's published report that scientists finally accepted the fact that solid bodies were falling to Earth from outer space.

April 5, 1804 - A meteorite weighing 10 pounds fell in High Possil, Glasgow, Scotland.

August 1810 - A meteorite weighing 7-3/4 pounds fell in Mooresfort, Tipperary, Ireland.

September 10, 1813 - A small shower of meteors fell on Limerick (Adare), Ireland. The largest meteorite weighed 65 pounds.

February 15, 1830 - A meteorite weighing 2-1/2 pounds fell in Launton, Oxfordshire, England.

May 17, 1830 - A meteorite measuring 7-1/2" in diameter fell in Perth, Scotland. Most of the fragments have since been lost.

August 4, 1835 - A meteorite weighing 1-1/2 pounds fell in Aldsworth, Glos., England.

October 13, 1838 - A small shower of meteorites fell at Cold Bokkeveld, South Africa. The fragments were remarkable in that they contained small amounts of solid hydrocarbons, which could be extracted from them by alcohol and ether.

April 29, 1844 - A small shower of meteors fell on Killeter, Tyrone, Ireland. A few of the fragments were preserved.

July 14, 1847 - An iron meteorite fell through the roof of a house in Braunau, Bohemia. The impact was even more remarkable in that it only showered debris on a bed in which three children were sleeping.

August 12, 1865 - A meteorite weighing 5 pounds fell in Dundrum, Tipperary, Ireland.

June 9, 1866 - About 1,000 meteorites fell near Knyahinya in Czechoslovakia. The largest one weighed 645 pounds and was reported to have made a hole in the ground 11 feet deep. The meteorite is on display at the National History Museum in Vienna.

January 30, 1868 - About 180,000 meteorites fell near Pultusk, Poland. Those collected were estimated to have a total weight of 2 tons. It is thought that they were fragments of a large body that broke apart in the atmosphere.

January 1, 1869 - 500 meteorites fell in Hessle, Sweden. They fell at such a low rate that those which landed on ice only a few inches thick actually bounced on impact.

February 12, 1875 - 100 meteorites fell near Homestead, Iowa.

April 20, 1876 - A meteorite weighing 7-3/4 pounds fell in Rawton, Shropshire, England.

March 14, 1881 - A meteorite weighing 3-1/2 pounds fell in Middlesboro, Yorkshire, England.

February 3, 1882 - About 3,000 meteorites fell in Mocs, Transylvania.

1886 - An iron meteorite weighing 107 pounds fell near Cabin Creek, Arkansas. Soon after the event, the inhabitants changed the name of their village to Lamor.

November 27, 1886 - An iron meteorite fell near Mazapil in northern Mexico. Because the meteorite fell on the maximum date of the Andromedid meteor shower, it was suggested that the meteor was a fragment from Periodic Comet Biela, the parent comet of the Andromedid shower.

1887 - A meteorite fell in Russia that was composed mostly of carbon.

June 25, 1890, 1 p.m. local time - A brilliant fireball was seen over the mid-west of the United States. The resulting meteorite landed in Farmington, Kansas. It was found to be chondrite, a form of stony meteorite.

September 13, 1902 - A meteorite weighing 9 pounds fell in Crumlin, Antrim, Ireland.

June 30, 1908, 7:30 a.m. local time - A meteorite fell on the Tunguska River Valley, a region in the desolate swamps of northern Siberia. Eyewitnesses spoke of a brilliant object moving overhead from the southeast, dropping sparks and leaving behind a trail of smoke. The explosion was seen from four hundred fifty miles away and was heard from seven hundred miles away. The site was first located in 1927, nineteen years later, by a scientific expedition led by L. A. Kulik. The area of destruction was over 25 miles (40 kilometers) across, larger than New York City and its suburbs combined. The forest was obliterated in many areas. The remaining trees were charred and knocked down in a pattern that radiated outward from the center point of the blast. Only trees within the 9 miles of the central point remained standing, though they were stripped of their branches. No impact crater was found. It has since been accepted by most scientists that the destruction was cause by a comet or asteroid that was superheated from its passage through the atmosphere, and exploded above the ground from the rapid expansion of internal gases. Since the event occurred on the maximum of the annual daytime Beta Taurid shower, many suggest that the meteor was a large Beta Taurid meteor, and therefore a fragment of Periodic Comet Encke, which is the parent of the Beta Taurid shower.

July 19, 1912 - 14,000 meteorites fell near Holbrook, Arizona. Thousands of the fragments recovered were only slightly larger than grape seeds.

October 13, 1914 - A meteorite weighing 33 pounds fell in Appley, Bridge, Lancashire, England.

December 3, 1917 - Four meteorites, weighing 22-1/4, 2-1/2, 2-3/8, and 2-1/4 pounds, fell in Strathmore, Perthshire, Scotland. One of the four crashed through the roof of a house.

March 9, 1923 - A meteorite weighing 2-3/4 pounds fell a few yards from a laborer in Ashdon, Essex, England. A visible trail was not seen, but the whizzing of its flight was heard before impact.

February 7, 1930 - A meteorite weighing 820 pounds fell early in the morning near Paragould, Arkansas. The sound made by the impact awoke sleeping people in Arkansas, Tennessee and Missouri. Several police departments were alerted. The meteorite was found about five weeks later, measuring 26 x 36 inches. The rock was moved to the Field Museum at Chicago.

March 24, 1933 - A fireball exploded in the early morning over northern New Mexico. The flash of light and the sound of the explosion awoke people in New Mexico, Oklahoma, Kansas, Texas, Arizona and Colorado.

A cloud of meteoric dust remained in the atmosphere and was visible until long after sunrise. A collection of meteorite material weighing 4 kilograms was later recovered from an area 45 kilometers (28 miles) long.

April 20, 1933 - A brilliant fireball with a greenish tint was seen from all parts of Oregon and Washington state. It was first observed over southern Oregon and traveled north-northeast, passing over Yakina, Washington. It was seen to burst into fragments and disappeared about thirty miles beyond Yakina.

February 12, 1947, 10:35 a.m. local time - A large meteorite weighing about 70 tons fell in the Sikhote-Alin northern range, a few hundred miles north of Vladivostok. The forest was laid waste over an area two miles long and one mile wide. The first scientific expedition to reach the site was led by Dr. E. L, Krinov.

November 30, 1953 - A meteorite crashed through the living room ceiling of Mrs. Hewlett Hodges of Sylocuga, Alabama. Mrs. Hodges received a grazing blow on the hip, but was not seriously injured. A revealing photograph of the bruise was circulated in the newspapers.

December 24, 1965 - Meteorites fell over a wide area in the village of Barwell in Leicestershire, England. A total of 50 kilograms of material was recovered. Because the meteorites landed in an elliptical pattern, it was suggested that the meteorites were fragments of a larger body which broke up as it fell.

September 10, 1967, 8:50 p.m. local time - A large fireball was observed over northern Ohio moving from east to west and broke up into smaller pieces near Oberlin. No trail was observed, but the meteor did produce a hissing sound as it passed. An eyewitness in Akron reported that the fireball appeared several times larger than the Moon. "It had every color and a boiling surface moving slow enough to see molten colors moving on the surface." the entire event lasted about 5 seconds. The break up of the fireball produced a rumbling sound that lasted for several seconds afterward.

April 25, 1969 - A fireball was seen traveling north-east over England, Wales and Ireland, visible over a distance of 310 miles (500 kilometers). The meteor fragmented toward the end of its path, creating sonic booms. Two meteorite fragments were recovered some 37 miles (60 kilometers) apart, the larger at Bovedy, Northern Ireland, which gave its name to the fall.

October 9, 1992 - A meteorite weighing 27 pounds slammed into the trunk portion of a red 1980 Chevy Malibu then owned by Michelle Knapp in Peekskill, New York. The meteorite was probably related to a spectacular meteor that was seen traveling north-northeast over neighboring states. Following the event, the car was purchased by a rock collector and became an attraction at national rock and meteorite conventions.

Tektites

Tektites are silicate-based material associated with meteorite impacts. Their origin is not completely certain. At first glance they resemble volcanic rock. However, a closer inspection shows that they have the appearance of small distorted globules of liquid rock which solidified during flight.

The name tektite is derived from the Greek *tektos* meaning "molten." Tektites have a range of shapes including tear drops, rods, disks, flanged buttons, and even dumb-bells. All of these shapes appear to be the result of solidifying in flight. Their colors range through black, brown, a kind of bottle-green, and they range in size from a walnut (or smaller) to an apple.

The origin of tektites could be explained by two basic processes. (a) They were terrestrial in origin and may be a result of volcanic activity. (b) They are a product of meteorite impact--either in the form of modified cosmic material or earthly material transformed by heat.

Current opinion favors the meteorite origin. Tektites smaller than 1 mm diameter, called *microtektites*, have been discovered in marine sediments of the South Pacific which date at approximately 700,000 years. These resemble the nearby Australian mainland tektites, lending support to the opinion of meteorite origin.

The areas where tektites are found are called *strewnfields*, referring to the way the objects appear to be scattered or strewn about. There are four main strewnfields around the world. They are:

1) **Australasia**: Tasmania (Tasmania Darwin Glass), across Australia (Australites) to Sumatra (Javanites) and the Philippines (Philippinites) and south-east Asian mainland (Indochinites). Australites are 830,000 years old, compared with the remainder for this strewnfield, which are 690,000 years old. This may indicate they resulted from two different

impacts. Australasia tektites are opaque, unless very thin. The largest tektites come from south-east Asia, weighing up to 31 pounds (15 kilograms).

2) **Ivory Coast**: These tektites (Lilyan Desert Glass) are 1.3 million years old, and apparently related to the Lake Bosumptwi, Ghana, impact crater which is of similar age. Like Australasia tektites, Ivory Coast tektites are opaque, unless very thin.

3) **Moldavites**: These tektites (Czechoslovakia Moldavites) are in the area of former Czechoslovakia (Czech Republic and Slovakia). They are 14.7 million years old, linking them with the Ries impact structure in southern Germany. Moldavites are the only tektites with the bottle-green color and are highly prized by collectors and jewelry makers.

4) **North America**: These are the tektites in Texas, Georgia, and Martha's Vineyard, Massachusetts. They are brown in color and 34 million years old.

The tektites of Australasia and North America are not linked to any known impacts. Microtektites resembling Australasia, Ivory Coast and North American tektites have been found in marine sediments.

Useful Resources

Organizations and Societies

American Association of Variable Star Observers (AAVSO) – An organization for professionals and amateurs. Address 25 Birch Street, Cambridge, MA 02138. Telephone: (617) 354-0484; URL: www.aavso.org

American Association for the Advancement of Science (AAAS) – established 1848. Membership (1996): 140,000. Address: 1200 New York Avenue NW, Washington, DC. Telephone: (202) 326-6400; URL: www.aaas.org

American Astronomical Society (AAS) – The major professional organization in North America for astronomers and other scientists and individuals interested in astronomy, established 1899. Membership (1996): 6,500. Address: 2000 Florida Avenue NW, Suite 400, Washington, DC 20009. Telephone: (202) 328-2010; URL: www.aas.org

American Meteor Society, Ltd. – An organization for amateurs and professionals, founded in 1911. URL: www.amsmeteors.org

Association of Lunar and Planetary Observers (ALPO) – Address: 8930 Raven Drive, Waco, TX 76712. URL: www.lpl.arizona.edu/alpo

Astronomical Society of the Pacific – A non-profit, educational organization. Address: 390 Ashton Avenue, San Francisco, CA 94112. Telephone: (415) 337-1100; URL: www.aspsky.org

Barringer Meteor Crater – URL: www.barringercrater.com

International Astronomical Union (IAU) – An international organization which promotes and safeguards the science of astronomy in all its aspects through international cooperation. IAU is the sole internationally recognized authority for assigning designations to celestial bodies and surface features on such bodies. URL: www.iau.org

Museum Astronomical Resource Society (MARS Astronomy Club)
URL: http://www.marsastro.org

Planetary Society – established 1980. Membership (1996): 100,000. Address: 65 North Carolina Avenue, Pasadena, CA 91106. URL: www.planetary.org

Periodicals

Astronomy – Monthly magazine for amateur astronomers. To subscribe write to address: Kalmbach Publishing Company, 21027 Crossroads Circle, P.O. Box 1612 Waukesha, WI 53187-1612. Telephone (800) 533-6644. URL: www.astronomy.com

Sky & Telescope – Monthly magazine for amateur astronomers. Address: P.O. Box 9111, Belmont, MA 02178-9111. URL: www.skypub.com

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