ICE & STONE 2020

WEEK 47: NOVEMBER 15-21

Presented by The Earthrise Institute

#47

Authored by Alan Hale

THIS WEEK IN HISTORY

NOVEMBER 15 | 16 | 17 | 18 | 19 | 20 | 21

NOVEMBER 15, 1927: Arnold Schwassmann and Arno Wachmann at Hamburg Observatory in Bergedorf, Germany, discover a very unusual comet, 29P/Schwassmann-Wachmann 1, that travels entirely between the orbits of Jupiter and Saturn and that undergoes repeated outbursts at irregular intervals. It is this week's "Comet of the Week."

NOVEMBER 15, 2016: Polish astronomers Filip Berski and Piotr Dybczynski announce their findings that the star Gliese 710, currently located 64 light-years away, will pass just 13,400 AU from the sun 1.35 million years from now. The significance of this event, including its effects on the Oort Cloud, is discussed in a previous "Special Topics" presentation.

15 | NOVEMBER 16 | 17 | 18 | 19 | 20 | 21

NOVEMBER 16, 1835: Comet 1P/Halley passes through perihelion at a heliocentric distance of 0.587 AU. The story of Comet Halley, including important observations made during this return, is the subject of a previous "Special Topics" presentation.

15 16 NOVEMBER 17 18 19 20 21

NOVEMBER 17, 1966: An extremely strong display of the Leonid meteor shower is visible across the western U.S. – a display that I personally witnessed. The Leonid meteors are associated with Comet 55P/Tempel-Tuttle, and the relationship between comets and meteor showers is the subject of this week's "Special Topics" presentation.

NOVEMBER 17, 1998: A strong display of the Leonid meteor shower, involving many bright fireballs, is widely observed from many places around the world. Studies of this shower were instrumental in defining the relationship between comets and meteor showers, as discussed in this week's "Special Topics" presentation.

NOVEMBER 17, 2020: The Leonid meteor shower is expected to be at its peak. This will likely be a pretty weak display, with no more than perhaps 10 meteors per hour, although since the moon will be just past its "new moon" phase the viewing conditions are good this year.

Meteor during the 2009 Leonid Meteor Shower. Courtesy Ed Sweeney.

15 16 17 NOVEMBER 18 19 20 21

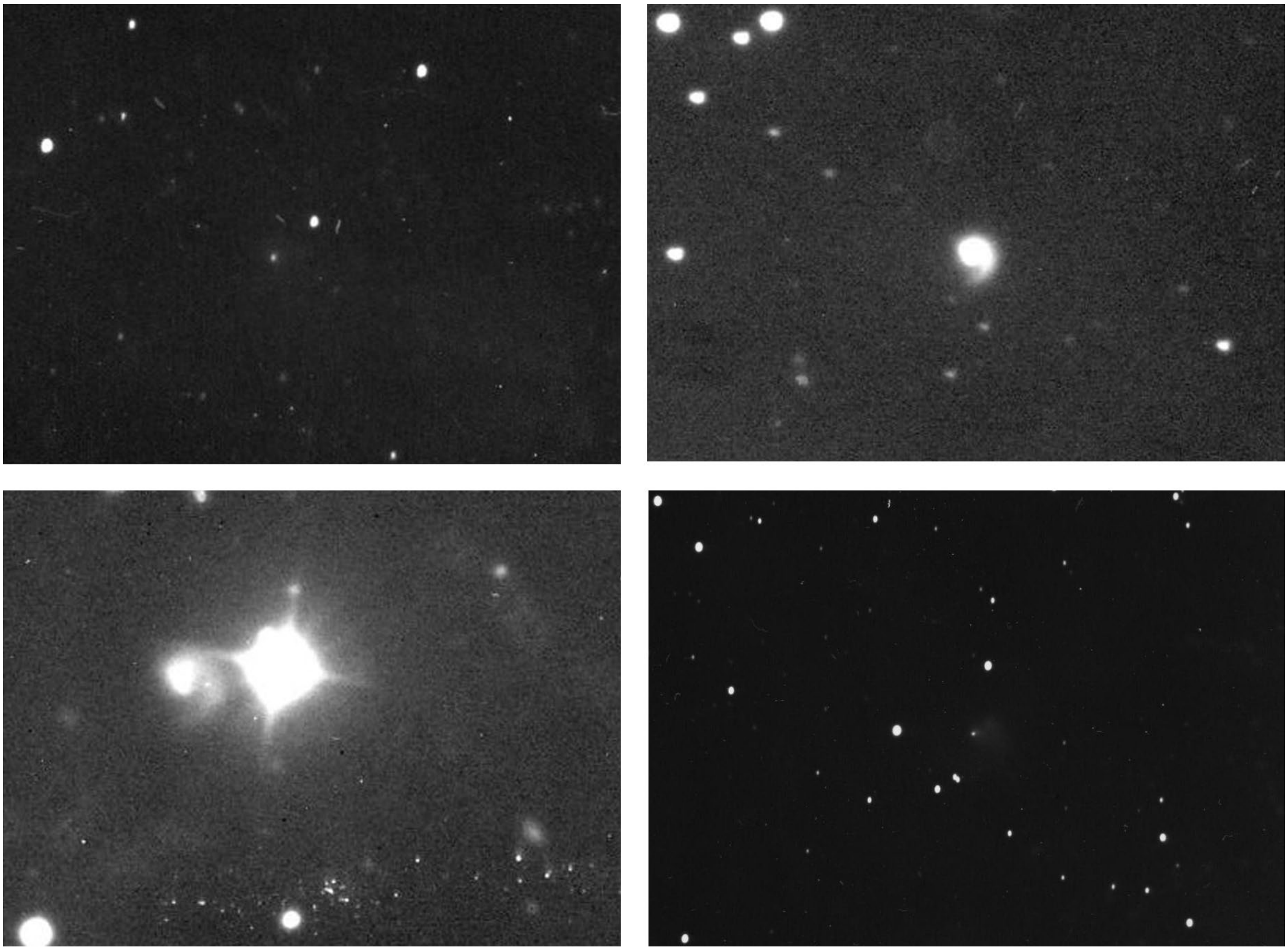
NOVEMBER 18, 1999: A strong display of the Leonid meteor shower is visible from parts of Europe and the Middle East. Observers reported five brief flashes on the moon's unlit side that were apparently due to Leonid meteors striking the lunar surface.

15 16 17 18 NOVEMBER 19 20 21

NOVEMBER 19, 2005: JAXA's Hayabusa mission briefly touches down on the surface of the Apollo-type asteroid (25143) Itokawa, although this was not realized until later. Hayabusa would briefly touch down on the asteroid again six days later and collect a small amount of surface materials that it eventually returned to Earth. The Hayabusa mission is discussed in more detail in a previous "Special Topics" presentation.

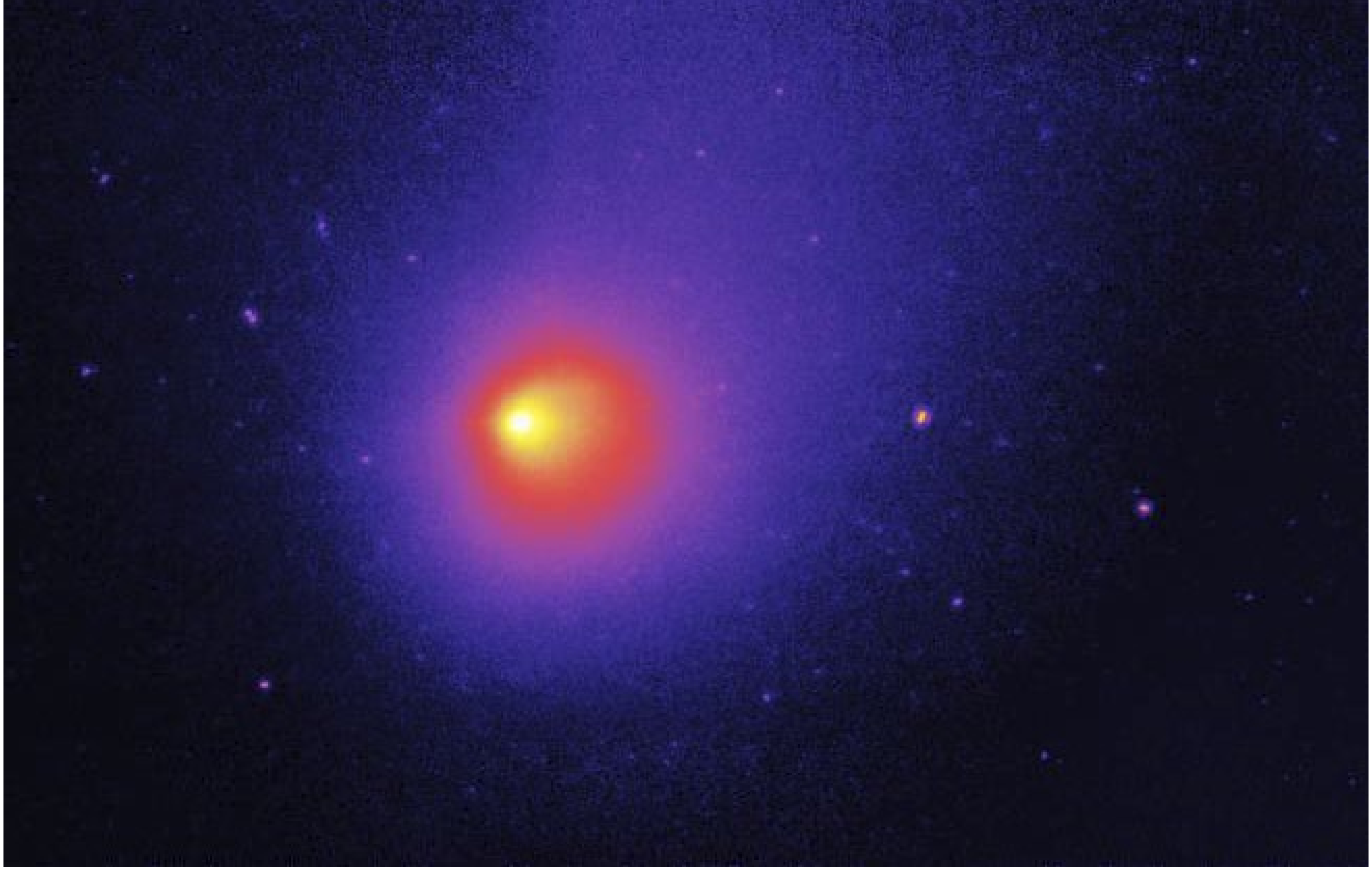
COMET OF THE WEEK: 29P/SCHWASSMANN-WACHMANN 1 1927J

Perihelion: 1925 May 7.84, q = 5.475 AU



Evolution of a typical outburst of Comet 29P/Schwassmann-Wachmann 1, which took place in February 1981. Left to Right: February 1; February 10; February 13; February 28. The photographs were taken by Jerome Shao and Gunther Schwartz at Harvard College Observatory, provided courtesy Harvard College.

One of the most unusual and remarkable comets that we know about was discovered just a little less than a century ago, when on November 15, 1927 the duo of Arnold Schwassmann and Arno Wachmann at Hamburg Observatory in Bergedorf, Germany, found it on photographs as it was near opposition and traveling slowly through the constellation Pisces. It was about 13th magnitude at the time, but faded pretty quickly, to about 16th magnitude in December and to 17th magnitude when it disappeared into evening twilight the following February. The comet's unusual nature began to become clear once orbital calculations revealed that it had passed through perihelion over 2½ years earlier at a heliocentric distance of 5.5 AU – a record perihelion distance at the time – and moreover was traveling in a near-circular orbit (eccentricity 0.15) entirely between the orbits of Jupiter and Saturn with an orbital period of 16.4 years. What has really made this comet so remarkable is that it was soon found to be undergoing outbursts, sometimes of several magnitudes, at irregular and unpredictable intervals, and several such events were recorded over the next few years, including around the time the comet was at aphelion in 1933.



Infrared image of Comet 29P taken with the Spitzer Space Telescope on November 24, 2003, during an outburst. Courtesy NASA/JPL/CalTech/Ames Research Center/University of Arizona.

In 1931 Karl Reinmuth at Heidelberg Observatory in Germany found images of a 12th-magnitude comet on photographs taken on two nights in March 1902, which was soon identified as being Comet 29P during another outburst. Meanwhile, the comet has been under almost continuous observation ever since its discovery, except for the times when it is near conjunction with the sun and thus is unobservable. An extended encounter with Jupiter during the late 1970s acted to further circularize its orbit by increasing the perihelion distance to its present value of 5.8 AU, decreasing the eccentricity to 0.04, and shortening the orbital period to slightly under 15 years. The comet was most recently at perihelion on March 7, 2019, and will be at aphelion in September 2026. It was at opposition earlier this month and last underwent one its outbursts in late July, when it became slightly brighter than 13th magnitude.

When it is quiescent Comet 29P is usually around 16th or 17th magnitude and exhibiting a small, faint coma. The outbursts occur on the average of perhaps two or three times a year, but this can vary; sometimes several outbursts may occur over a period of a few months, and on rare occasions the comet has gone two or three years without one. During an outburst the comet will normally reach 12th or 13th magnitude, but on a few occasions has become brighter, to 11th or even 10th magnitude, and once – in early 1946 – it almost reached 9th magnitude. Many astronomers monitor the comet on a regular basis to watch for outbursts; I began doing this myself in early 1981, saw my first outburst three months later, and as of now I have seen several dozen of them.

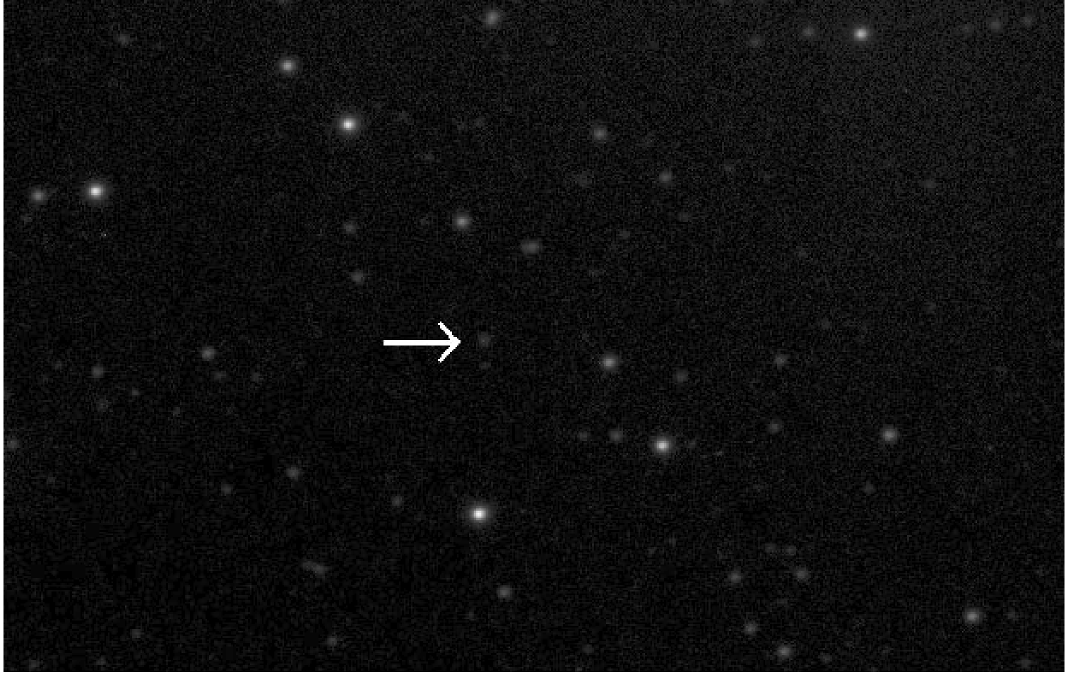
Although the specific sequence of events may vary somewhat from one outburst to another, these typically begin with the appearance of a bright, near-stellar condensation near the center of its regular small coma. Over the course of a few hours this condensation expands and make take on the appearance of a bright disk, which over the next few days will expand outwards and start to become more diffuse; at times this may take on a spiral-shaped structure. After a couple of weeks this resulting outer coma will be quite spread out and diffuse, and before much longer it disperses into space, leaving the comet once again in a quiet state. Every once in a while a new outburst may begin before the original one has subsided, keeping the comet at a fairly bright level for two or three months or more.

Images of Comet 29P I have taken with the Las Cumbres Observatory facility at Cerro Tololo Inter-American Observatory in Chile: Left: October 10, 2018, about three weeks after the onset of a large outburst. Right: November 28, 2018. A fresh outburst has just started, as evidenced by the bright central coma; the dispersing coma from the previous outburst is faintly visible extending to the east (left).

The specific cause of these outbursts has remained a mystery ever since the comet was discovered, as there has been no real correlation between their occurrences and phenomena like solar activity, or with the comet's location in his orbit. In 1990 American astronomer David Jewitt proposed that the outbursts may be due to phase changes in "amorphous ice" in the nucleus that is occasionally exposed to sunlight, with the comet's remaining at just the right heliocentric distance for this to occur. More recently, British astronomer Richard Miles has provided evidence that the nucleus – which is apparently quite large, perhaps as large as 60 to 70 km in diameter – rotates very slowly (with a rotation period of 58 days), and that the comet's coma is produced via sudden and brief eruptions on its surface. A continuous monitoring campaign that he has organized has been detecting about 20 such "mini-outbursts" (of approximately half a magnitude) per year, with much of this material falling back onto the nucleus creating a crust that in turn allows pressure to build up underneath and form "cryomagma." The larger and more conventional outbursts then arise from eruptions of "cryovolcanoes" on the surface.

In the late 2030s Comet 29P will again undergo an extended encounter with Jupiter, which will increase its perihelion distance further to 5.9 AU, its eccentricity to 0.07, and its orbital period to 15.9 years. Over longer timescales, its orbit is chaotic (in a mathematical

Artist's conception of Comet 29P in a few millennia if it should get perturbed into a short-period Jupiter-family comet's orbit. Courtesy Heather Roper.



The recently-discovered object 2020 MK4, as imaged on July 16, 2020 by the Las Cumbres Observatory facility at the South African Astronomical Observatory.

sense), and at some point in the future – perhaps a few thousand years from now – Jupiter will either perturb it into a smaller, shorter-period orbit in the inner solar system, or else place it into a hyperbolic orbit and eject it from the solar system altogether. Indeed, from a dynamical perspective, Comet 29P's orbital evolution is similar to that of centaurs – discussed in a previous "Special Topics" presentation – and by some definitions it can actually be considered as such an object. A recent study by a team of astronomers led by Gal Sarid at the Florida Space Institute concludes that Comet 29P presently occupies what could be considered a "gateway" between the Kuiper Belt object-to-centaur progression and short-period Jupiter-family periodic comets. If, in a few thousand years' time, Comet 29P were to become such a periodic comet, it would likely be an amazingly spectacular object, that moreover returns every few years to brighten up the nighttime sky. It is thus possible that our descendants in a few millennia may be in for quite a show.

Curiously, just this past June the Pan-STARRS program in Hawaii discovered a faint object, designated 2020 MK4, that is traveling in a near-circular orbit strikingly similar to that of Comet 29P. Its physical nature is still somewhat unknown, but the fact that it has not been detected on images taken before this year, and some data that appears to show some weak activity, suggests that it could be a comet similar to, albeit quite a bit smaller than, Comet 29P, that possibly has recently become active and that conceivably could also be in a "gateway" status. Meanwhile, two spacecraft missions, dubbed Centaurus and Chimera, have been proposed for missions to Comet 29P, although neither of these have been selected for further development at this time.

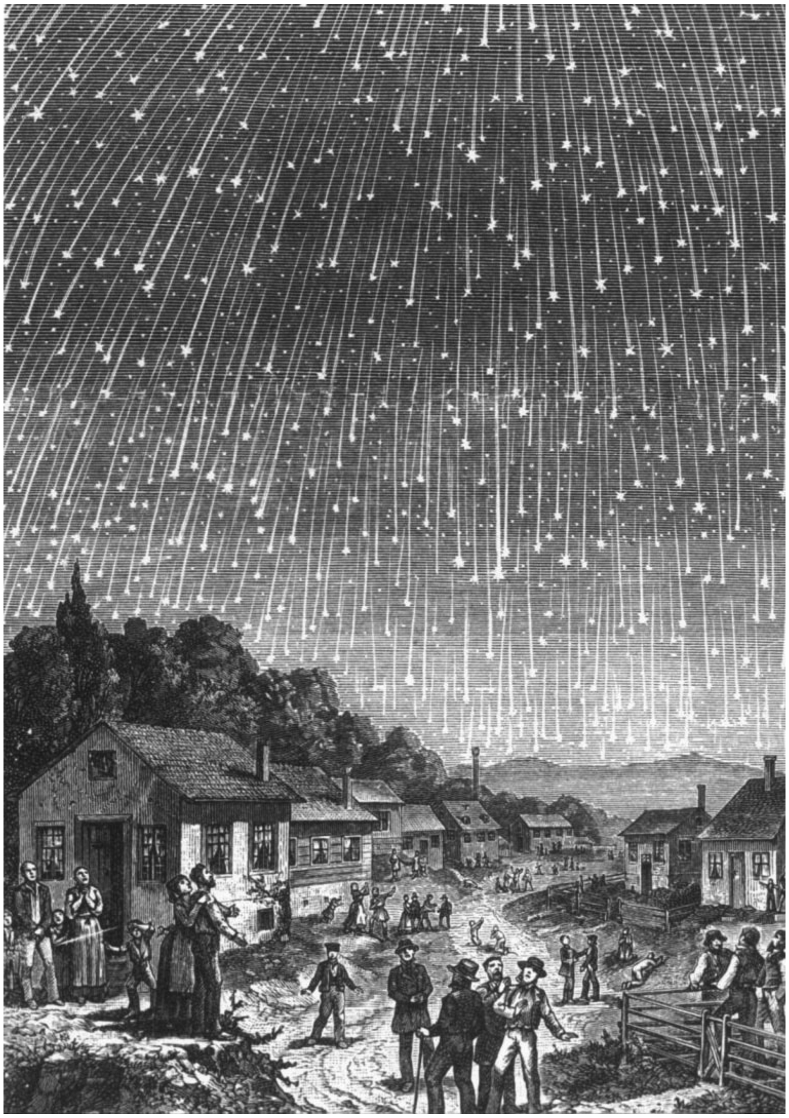
SPECIAL ADDENDUM

It is most appropriate that this comet should undergo a new outburst during the very week that it is the "Ice and Stone 2020" "Comet of the Week." The new outburst took place on November 19 and was first independently detected by amateur astronomers Jean-Francois Soulier in France and Nick James in England, both of whom are collaborating with Richard Miles in the observing campaign mentioned above. After reading of their reports, I successfully observed the comet visually about 16 hours later, and it appeared as a small condensed object near magnitude 13½. British amateur astronomer Martin Mobberley has posted an image of the comet he took about three hours before my observation that illustrates this basic appearance.

If this outburst follows the pattern that most outbursts follow, this small and condensed inner coma will expand out and grow progressively more diffuse over the next two to three weeks. The comet should remain visually detectable near the same brightness for about that same length of time before fading out – unless, of course, new outbursts occur, which are always possible.

SPECIAL TOPIC: COMETS & METEOR SHOWERS

I first began to show an interest in astronomy when I was 6 years old, although my interests shifted between astronomy and various other scientific fields over the next few years. My father was an early riser, and one morning when I was 8 he was engaged in his normal morning routine when he noticed that an intense meteor shower was going on outside, and he came and aroused his astronomically-inclined son out of bed. Through our living room window we watched the meteors appearing so quickly it almost looked like it was snowing outside.



The night "stars fell on Alabama," the Leonid meteor storm on November 13, 1833, from the eastern U.S. This engraving was made by Adolf Vollmy based on a painting by Swiss artist Karl Jauslin, which in turn is based upon eyewitness descriptions.

The date was November 17, 1966. What my father and I had witnessed was the Great Leonid Storm of 1966, one of the strongest meteor showers in all of recorded history. New Mexico, where we lived, and in fact the entire western part of the U.S., was in the right location to witness this event, and the peak rate, which lasted for perhaps twenty minutes, was somewhere between 100,000 and 150,000 meteors per hour.

While the Leonid meteor shower is normally a pretty weak affair, producing no more than about ten meteors per hour, it has on occasion, like in 1966, produced significantly stronger displays. One such "storm" took place on October 13, 902, when observers in Europe, Egypt, and elsewhere reported that stars were falling "as thickly as snowflakes." (The difference in calendar dates is due largely in part to the switch from the Julian Calendar to the Gregorian Calendar in 1582.) An intense Leonid "storm" was visible from parts of Europe and South America on November 12, 1799, and another very strong "storm" – apparently every bit as strong as the one I witnessed – took place on November 13, 1833, as seen from the eastern U.S.; this was the famous night when "stars fell on Alabama." A somewhat weaker, but still very strong shower with a peak rate of approximately 5000 meteors per hour, was seen from Europe on November 14, 1866. Shortly thereafter the French mathematician Urbain Le Verrier, who had correctly predicted the location of Neptune prior to its discovery two decades earlier, determined that the orbital period of the Leonid meteors was 33 years, which matched the approximate periodicity of the intense showers.

It so happened that in mid-December 1865 the French astronomer Wilhelm Tempel had discovered a 6th-magnitude comet near the "bowl" of the Little Dipper, which in turn was independently discovered by the American astronomer Horace Tuttle in early January 1866 when it was near its peak brightness of magnitude 5.5. The following year the Austrian astronomer Theodor von Oppolzer calculated that that comet – now known as Comet 55P/Tempel-Tuttle – has an orbital period close to 33 years. It was obvious that the correspondence in orbital periods was not a coincidence, and the Italian astronomer Giovanni Schiaparelli soon conclusively demonstrated the relationship between that comet and the Leonid meteors.

Schiaparelli had also just recently demonstrated

Twelve-minute exposure of the 1966 Leonid meteor storm, November 17, 1966, taken by Scott Murrell at New Mexico State University. I observed with Scott a few times while I was a graduate student. He passed away in 2004.

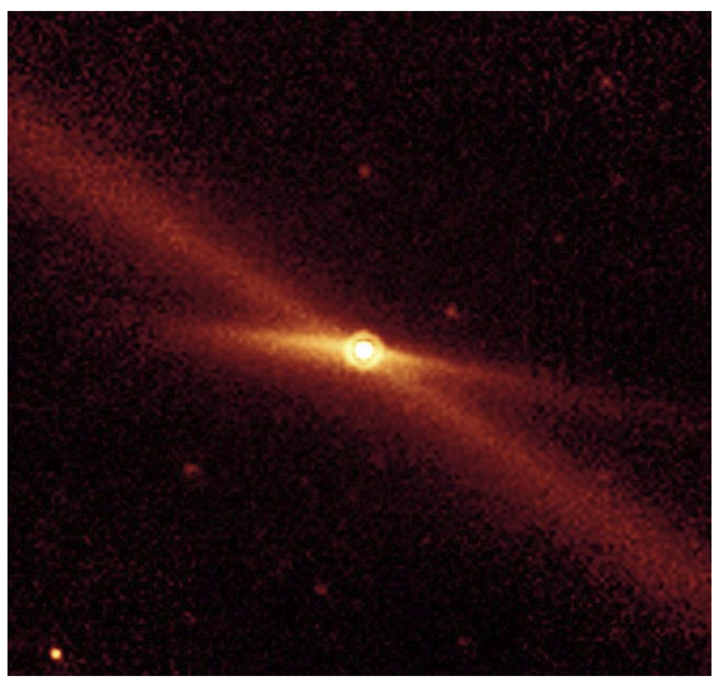
the relationship between another comet and a meteor shower: the comet now known as Comet 109P/Swift-Tuttle, which had been seen in 1862 (and which returned in 1992, and is a future "Comet of the Week"), and the Perseid meteor shower, which is one of the strongest of the "annual" meteor showers and which peaks during the second week of August each year. Over the years and decades which have elapsed since then, numerous other meteor showers have been found to be associated with various comets.

As a comet approaches perihelion and becomes active, the dust grains that are ejected from the nucleus for the most part do not return to it, but instead keep traveling around the sun in the same basic orbit as the comet's. Over time these dust grains spread out into a "stream" that essentially marks the comet's orbit through the inner solar system. (These dust streams have been detected by infrared-sensitive spacecraft missions.) If these dust streams happen to come close to Earth's orbit, then every year at the time what that close passage occurs the dust grains will enter the atmosphere at speeds of up to several km per second, and vaporize, and we see this as a "shower" of meteors. The meteors will all appear to come from the same basic location in the sky, which is an effect of perspective similar to the parallel lines of a road appearing to converge in the distance; this location is called the shower's "radiant." Most meteor showers are named for the constellation in which the radiant appears, or if there is more than one meteor shower associated with a given constellation, for the star which the radiant might lie near.

The strengths of the various meteor showers vary widely, and can be affected by factors such as the activity level of the parent comet and the closest distance between the earth's orbit and the comet's dust stream. These factors can also influence the duration of a given shower; some showers extend over several days, while others exhibit a very sharp peak in strength which might last no more than a few hours at most. Furthermore, since cometary dust streams are affected by gravitational influences just like comets themselves are, the orbits can shift over time and become stronger or weaker over a period of decades.

For some comets, 55P/Tempel-Tuttle being among them, the dust has not had enough time to spread out all along their respective orbits, and thus much of the dust travels in "clumps" close to the comet itself. The result of this is what we see with the Leonid shower: normally quite weak, but extremely intense around times that the comet returns to perihelion. Even here, the gravitational effects on the dust stream can affect the displays we see: while the Leonid shower associated with the comet's return in 1866 was a strong one, the ones associated with the return in 1899 were much weaker, and only a slight enhancement of meteor activity was exhibited during the comet's 1932 return. (For what it's worth, the comet itself was missed during those returns). The situation was reversed for the 1965 return – when the comet was seen again, although it remained distant and faint – and the result was the extremely intense "storm" I witnessed the following year.

There was much anticipation among astronomers as Comet Tempel-Tuttle returned to perihelion again



Spitzer Space Telescope image of Comet 2P/Encke taken on June 23, 2004. The diagonal glow is the comet's dust stream within its orbit. Courtesy NASA/JPL-CalTech/University of Minnesota/Michael Kelley.

in 1998. It was duly recovered, and the viewing geometry was relatively favorable, with its reaching a peak brightness close to 8th magnitude early that year. Predictions seemed to suggest a strong Leonid display that year – and there indeed was one, although not as strong as originally expected, and in a departure from previous Leonid displays, this one lasted for the better part of a day and was widely viewed from around the world. (It also featured a large number of bright fireballs, and I personally consider it to be the second-best meteor shower I have ever seen, second only to the 1966 "storm.")

Astronomers began to realize that, in order to make accurate predictions of a meteor shower's display, it was necessary to take into account the dust streams released during individual returns of the parent comet. Two individuals who took this up were Rob McNaught in Australia and David Asher in Ireland, and together they predicted that a strong but brief display of the Leonids would be visible in 1999 from Europe and the Middle East. They turned out to be correct – with peak rates of between 3000 and 5000 meteors per hour being seen – and one interesting feature of this shower is that some observers recorded at least five bright flashes on the moon's unlit portion that were apparently due to Leonid meteors striking the lunar surface. Meanwhile, and somewhat surprisingly, Asher and McNaught predicted that the strongest Leonid showers would take place in 2001 and 2002 – and, again, they were correct, although the 2002 shower coincided with full moon and from an observational perspective was not as impressive as it otherwise might have been.

The strongest of the "annual" showers are the Quadrantids in early January, the Perseids in August,

A composite of 30 images of the Geminid meteor shower over the European Southern Observatory in Chile. Photo copyright Stephane Guisard (Instagram), used with permission.

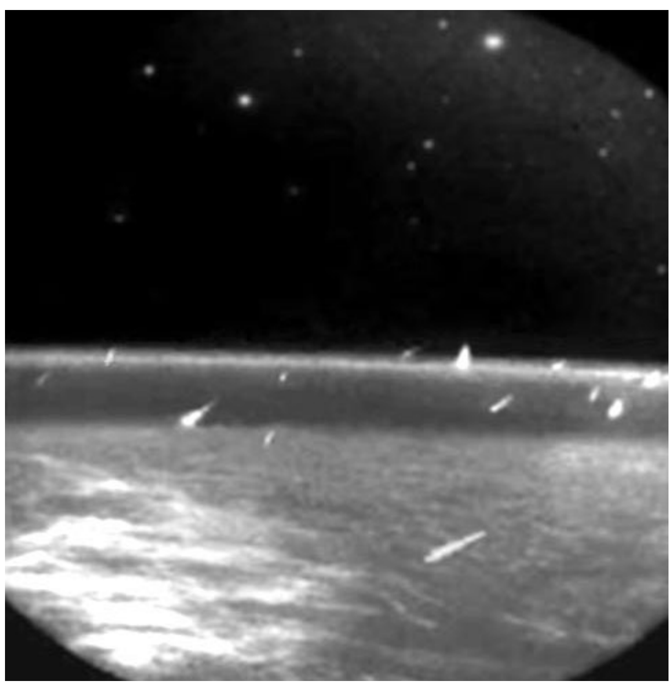
and the Geminids in December, all of which can exhibit peak rates in excess of 100 meteors per hour (although the peak of the Quadrantid shower is very brief). While what one might consider a "strong" shower is perhaps somewhat subjective, the below table lists some of the stronger and more notable meteor showers that appear during the course of a typical year (keeping in mind that at least a few will be affected by strong moonlight). The table also gives the parent comet and the "zenithal hourly rate," or ZHR, which is the peak rate that an observer would see with a perfectly clear and unobstructed sky from a dark rural site; the true observed rate will almost always be somewhat less than this.

The Draconids and Andromedids are "clumpy" showers like the Leonids that have produced intense displays in the past, and are discussed more thoroughly in the "Comet of the Week" presentations for their respective parent comets. While at face value it may not appear to be one of the stronger meteor showers, the Lyrids have on rare occasions produced strong displays (700 per hour in 1803 and 90 per hour in 1922 and 1982); the parent comet, incidentally, has an approximate orbital period of 415 years. The Ursids have also occasionally produced some strong displays, sometimes when the parent comet is near aphelion. The Arietids are the strongest of the daytime meteor showers, observable via radar techniques (described in a previous "Special Topics" presentation), although a few meteors may be visible during dawn. The likely parents are the Marsden "family" of near-sun comets discussed in the upcoming "Special Topics" presentation on comet and asteroid "families."

An Orionid meteor, October 2017. Courtesy Con Stoitsis in Victoria.

Shower	Maximum Display (2020)	Parent Comet	ZHR
Quadrantids	January 4	(196256) 2003 EH1	120
Lyrids	April 22	Thatcher 1861 I	18
Eta Aquarids	May 5	1P/Halley	50
Arietids	June 7	SOHO P/1999 J6?	30
Delta Aquarids	July 30	96P/Machholz 1?	16
Perseids	August 12	109P/Swift-Tuttle	110
Draconids	October 8	21P/Giacobini-Zinner	10
Orionids	October 21	1P/Halley	20
Taurids	November 12	Encke	5
Leonids	November 17	55P/Tempel-Tuttle	10
Andromedids	December 2	Biela	3
Geminids	December 14	(3200) Phaethon	150
Ursids	December 22	8P/Tuttle	10

It will be noticed, of course, that the parent "comets" of two of the strongest meteor showers are apparent asteroids, and this hearkens back somewhat to the active-comet-to-inert-asteroid discussion in an earlier "Special Topics" presentation. (3200) Phaethon was discovered by the InfraRed Astronomical Satellite (IRAS) spacecraft in 1983 and has an orbital period as small as 1.4 years and a very small perihelion distance of 0.14 AU; it has been observed to exhibit "cometary" activity of sorts when near perihelion and is discussed more thoroughly in an upcoming "Special Topics" presentation on "Active Asteroids." (196256) 2003 EH1, which was discovered in 2003 by the LONEOS program in Arizona, has an orbital period of 5.5 years and a perihelion distance of 1.19 AU; it has never been seen to exhibit any kind of cometary activity, but on the other hand it has never been observed close to Earth and thus far hasn't been amenable to any detailed investigations. (Indeed, its next "close" approach to Earth doesn't take place until 2052, and that is still a somewhat distant 0.33 AU.)



The 1997 Leonid meteor shower from space. This is a composite image taken (over a span of 48 minutes) by the Midcourse Space Experiment (MSX) satellite on November 17, 1997. Courtesy Peter Jenniskens and colleagues, Applied Physics Laboratory, UVISI, MSX, and BMDO.

There are many, many more meteor showers that have been cataloged, in fact, almost 800 showers have been identified (with more being added all the time), although only a little over a hundred of these are considered "established" at this time. Most of these are very minor affairs with ZHRs no higher than 1 or 2. The parent bodies for many of these showers have not been identified, and indeed it is quite possible that at least some of these no longer exist. On the other hand, some of the showers appear to be associated with near-Earth asteroids, which suggests that these objects are either possible extinct comets, or that the showers are the result of impact events on the parent bodies.

On any given night, even if it is not around the time of one of the "major" showers, at least a few of the minor showers are active, and almost all meteors that appear – even the "sporadic" ones – are members of some shower or other. Just about any meteor we might see, then, has come to us from the nucleus of some comet at some point in time in the past.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