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C O L L E G E

COSMIC DUST

A Lecture by

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Cosmic Dust

For a few hours during the night of Nov. 12th – 13th 1833, the newly emergent American nation on the eastern seaboard of the USA must have thought the end of the world was upon them. Between the hours of 2 a.m. and dawn, tens, no- hundreds of thousands of meteors rained down on them out of the sky. Nor were these just the simple average flash of light, they left smoke trains which lasted for fifteen to twenty minutes by which time, movements of the upper atmosphere twisted and turned them into grotesque serpents writhing in agony. When daylight and relief came many remembered their bible, the text of Revelations:

> "And the stars of heaven fell unto the Earth....For the great day of wrath is come"

No doubt those people who had sinned recently resolved to be better people. (Historians have speculated just how many US religous movements were born that night). Other less penitent observers thought they had been subject to a freak electrical storm caused by warm moist sea air colliding with the cold air over the land. Those with the most enquiring minds decided to find out just what had been the cause of a phenomenon which could not have been unprecedented even though America had just witnessed the most spectacular meteor storm in recorded history.

In the meteor calendar, given a clear moonless night, there are a number of opportunities to see more than just the occasional misnamed "shooting star". Meteors are not stars at all but little pieces of extraterrestrial material heated to incandescence as their kilometres/second velocity is reduced to zero by friction. The most common meteors are probably only sugar sized grains but a really good one might be sugar lump dimensions. The dates when the chances to observe are high are well known (see below).

METEOR SHOWERS VISIBLE TO THE NAKED EYE, LATE TWENTIETH CENTURY

Shower	*Shower Maximum Date*	*Single Observer Hourly Rate*	*Speed of Encounter with Earth in kilometres/sec.*	*Normal Duration to 1/4 Strength of Max., in days*	*Associated Comet*
Quadrantids	Jan. 3	40	41	1.1	?
Lyrids	Apr. 22	15	48	2	1861 I
Eta Aquarids	May 4	20	65	3	Halley
S. Delta Aquarids	July 28	20	41	7	?
Perseids	Aug. 12	50	60	4.6	1862 III
Orionids	Oct. 21	25	66	2	Halley
S. Taurids	Nov. 3	15	28	—	Encke
Leonids	Nov. 17	15	71	—	1866 I
Geminids	Dec. 14	50	35	2.6	(1983 TB)?
Ursids	Dec. 22	15	34	2	Tuttle

Data based on table by P. M. Millman in *Observer's Handbook* of the Royal Astronomical Society of Canada (1985).

The frequency of events which an undistracted observer can encounter during the known showers are also well documented. Those who wait to see the Perseids in August, the Geminids in December or the Quadrantids in January will be pleased if they are rewarded with fifty to a hundred flashes of light; the more patient go to bed happy if they have had twenty chances to wish upon a falling star in a single evening. Normally, the Leonids of November come into this category, 15 meteors an hour is good in an average year, but if your hearts desire is to win the lottery then Nov. 17th 1998 or 1999 may be your chance see enough shooting stars to last a lifetime. The trouble is everyone else similarly inclined will be doing the same because if the increases seen in Leonid abundances over the past few years are to be believed, a repeat of the 1833 storm is being heralded.

What then causes meteor showers? The simple answer is passage of the Earth through the orbital path of a comet. As comets shed their dusty tails the debris spreads out around their track through the solar system. Some comets have orbits which transect that of the Earth, so when our planet passes through these areas of cometary debris there is an increased opportunity for meteors to be observed. During normal times just sporadic particles of no known source make their dramatic appearance.

Many of the well known meteor streams can be matched to known comets, for example the Orionids in October are the residue of Halley passing repeatedly round the sun. This association between meteor showers and their parents has of course been derived by matching their orbits. Extrapolating this information only a very short way explains why meteor storms occur. They happen when the Earth meets high concentrations of cometary material. The most obvious occasion being when the orbital coincidence takes place immediately after the comet has passed on its way. Meteor storms are evidence of another near miss in the game of Russian roulette Nature keeps asking Earth to play.

Just as Edmond Halley searched through the ancient records for periodic appearances of the comet which was to bear his name, men who wanted to understand what had happened in the USA in 1833 looked for precedents in the past. It was Denison Olsmsted, for example who examined all the reports he could find of the highly publicised meteor storm and found that wherever they were viewed from they seemed to originate in the constellation of Leo, hence the name Leonids being given. Interviewing sea captains arriving in New England after their transatlantic crossing was particularly useful in this respect; one such enquiry of Captain Hammond of the good ship Restitution that provided the information that a similar but not so formidable event had occurred the same day of the previous year when he was at Mocha in Yemen. And was it coincidence that the celebrated German scientist Alexander von

Humboldt had written an account of shooting stars that he had seen in the Caribbean on Nov. 12th 1799!

Although a number of contemporary newspapers commented on the above circumstancial facts, it was left to Yale Professor, Hubert A. Newton, to scour European and ancient Chinese/Arab records for even earlier accounts. He painstakingly pieced together thirteen times when somewhere in the world a meteor storm had been encountered in or around early November. From the reports he studied between 902 and 1833 Newton worked out a period of 33.25 years and confidently predicted another calamity in 1866. He was a brave man and perhaps to be admired at least as much as Halley because the chance of being at the eye of the Leonid storm is not great; just one night of bad weather and all hope of seeing it has gone. At least comets remain visible for weeks on end. Indeed Newton was not celebrating in 1866 but a year later reports emanating from Europe confirmed his theory – the Leonids of 1867 errupted to exhibit 5000/hour. This time astronomers were ready and the orbital information aquired for the Leonids matched the newly discovered comet 1866 I, called Temple-Tuttle.

The idea that a close encounter with a comet caused meteor storms became so accepted that the next year 1868, a Viennese astronomer Edmund Weiss predicted a manifestation of the Bielids for Nov 27th 1872. An impressive display duly appeared this time over Greenwich with 10,000 meteors being seen between 5.30 p.m. and 11.30 in the evening. Hearing the news, German astronomer Wilhelm Klinkerfues of Gottingen calculated where comet Biela ought to be. This comet had last been seen in 1852, after it split in two in 1846. Intent on rediscovering Biela, Klinkerfues telegraphed a friend in India, Norman Pogson, the coordinates of where to look. Pogson turned his telescope to the sky and sure enough there was a comet. Fame for both perhaps, but no, it was later to transpire that Pogson's comet is not the lost Biela but a new one, so Pogson has one of posterity's greatest accolades entirely because of Klinkerfues faux-pas.

The mistake proved only a minor set back in new science of meteor-comet association. As the knowledge of orbits and periods were refined everyone began confidently predicting the reappearance of massive numbers of Leonids for Nov. 15th 1899. On November 10th 1899, one astronomer G. J. Stoney got cold feet and in a presentation to the Royal Astronomical Society he announced that the particle stream would only be encountered if it was wider than 0.014 Astronomical Units. He had looked at close encounters of the Leonids and Temple-Tuttle with Jupiter and Saturn and decided a slight deviation in the orbit was to be expected. The public took no notice of this Cassandra in their midst and were predictably upset and angry with astronomers when the long awaited Leonid storm steadfastly refused to materialise.

No one was much worried then when the 1933 Leonids did not show up so it came as a surprise when in 1966 it was discovered they were back with a vengence. We now believe that it takes two or three passages around the sun to build up a substantial dust trail. Even so no one is massively confident yet about saying whether 1998 or 1999 is the right time to look for the next Leonid storm. When Earth crosses the Leonid stream in 1998, we will be just 257 days after Temple-Tuttle has passed by. In 1965 the time elapse between the comet and our planet was 195 days but the meteor maximum frequency was only 120. For 1966 the gap was 561 days, when the meteor count was the most since 1833. Thus 1999 might be a better time for Leonid spotters because then we will pass 622 days behind the comet. In all this speculation we have to remember last year, 1997, >100 meteors were seen and Earth was actually in front of the comet then!

Not withstanding the astronomer's perennial nightmare, the weather, the disappointing thing about the Leonids is the extremely narrow width of the dust trail, estimated at only 35,000 km. This means that Earth will pass through very quickly and will only be in the appropriate place for a few hours.The chances of seeing a meteor if it is not dark are very slim unless it is a very big one.

The guessing game about where to be on Earth when it finds itself in the appropriate part of Temple-Tuttle's orbit is already well underway. The best choice for 1998 seems to be central to south east Asia. Europe is less well favoured and the USA is believed to have little chance. In 1999 however Europe will be the ideal place, so if this year turns out to be a disaster then there's always next year. If the Leonids do not live up to expectation in 1998/9 then the future is bleak, since in 2029 another interaction with Jupiter could cause a diversion as happened just prior to 1899. Leonid displays after 1999 are likely to be uninspiring for a hundred years or more. All night Leonid parties for 1998/9 are a must and as already said even a moderate apparition of over 100 trails/hour is would be enough to satisfy the average casual observer.

Whilst the general public might be viewing the prospect of Leonids with great anticipation, the commercial satellite operators are dreading their version of the millenium bug. The damage inflicted on a satellite by a sugar grain travelling at 71 km/sec is colossal. Temple-Tuttle like Halley is a retrograde comet so the velocity of its dust and that of the Earth are additive - a head on collision no less. This is the reason why Leonid meteors, when they are seen, glow so brightly and so persistently. An impact involving a slightly larger particle would be catastrophic. This is the first time a meteor storm has been predicted in the satellite driven age. Satellite operators who can are taking cover. Wherever possible expensive space hardware will be manoeuvred so that the less important sides are backed into the teeth of any onslaught. Anyone working with satellites will remember the Giotto spacecraft flying 500,000 km from comet Halley and just about living to tell the tale. John Glenn and any other astronauts can expect to be safely back by Nov. 17th. The Hubble Space Telescope will not be monitoring the event, and many of the other 500 or so satellites in orbit will rotate their sensitive solar panels edge on. A direct hit on a communications satellite will give a foretaste of the millennium bug paralysis. A recent non impact induced problem with the Galaxy IV telecom satellite stranded doctors and others relying on bleepers for communication, all over America. Think of the chaos, not peace, if everyones' mobile phone is suddenly switched off.

Although some will suffer, others will undoubtedly gain a wealth of information, for example people who study the nature of cosmic fluxes from the impact pits left as battle scars. The Leonids could very well provide the first data on the composition of a specific comet to those skilled enough to interpret the clues left as impact residues.

We actually already have material on Earth which is believed to be cosmic dust of cometary origin, though of course we have no way of knowing which comet was involved. Surprisingly the first micrometeorites, as they are called, were dredged up as parts of the Challenger expeditions of the 1870's which explored the Pacific. Here, because far from land ocean floor sediments accumulate so slowly, the infall from space can readily be discovered and collected. Modern day techniques have employed magnetic rakes to obtain preferentially bits of ablated meteorite or perhaps even remnants of individual meteors. These grains are horribly melted and, whilst interesting, much of their information content has been obliterated.

More valuable are tinier grains brought back from the stratosphere on fly-paper like collectors flown by former US Cold War spy planes. The delicate structure, almost snowflake like, of these particles, called Brownlee particles after Don Brownlee who predicted their existence, almost have to be cometary. Their own structure certainly seems to have been left by the evaporation of ices etc. Some of the grains are very rich in carbon.

Flying planes at great altitude, even redundant ones, is very costly and alternative routes to finding Brownlee particles on the ground have been sought. The obvious one being to melt ice on both Antarctica and Greenland. Remote parts of the Antarctic plateau far from terrestrial volcanic erruption are an important target. Large quantities of ice have been steam melted, filtered and picked over by Michel Maurette, a French scientist nicknamed by the his national media "the star hunter". Maurette has almost single handedly kept the cosmic dust analytical community supplied in recent years. Going out in the field with steam generators to process even slowly accumulating ice is a strain on resources so one of Maurette's success stories was devising ways to filter glacial melt water by natural means. He also recognised that lakes (cryoconite holes) appeared in Greenland during the summer months and these, he predicted, would be traps for cometary or micrometeoroid debris released by ice melting. In a good season he has returned home with perhaps two grams of dust gathered from such sources to study.

Two grams might not sound like much but bearing in mind of the size of the cosmic dust particles two grams represents millions upon millions of individual meteorites. And just think if the Leonids reach 1000 strikes/hour that might only be about the same mass, but still a minute proportion of all the meteoritic material which falls to Earth annually. It is estimated that 40,000 tons, mostly as cosmic dust, is deposited on us each year, most of it undetected despite the countless observers who will turn their eyes skywards on Nov. 17th.

Further Reading

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For information on Leonid Watch call 0345 600 444