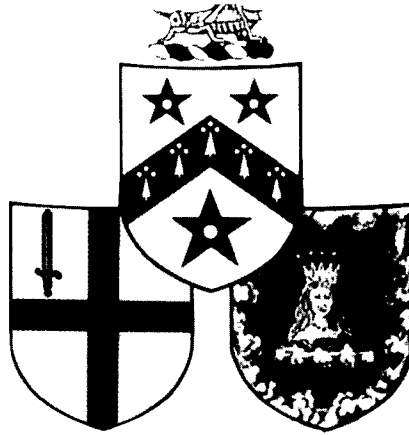


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THE SOLAR SYSTEM:  
OUR LOCAL NEIGHBOURHOOD IN SPACE

Lecture 5

THE TALE OF HALLEY'S COMET

by

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18 February 1994

## THE TALE OF HALLEY'S COMET

Lecture given by Professor Heather Couper at Gresham College  
on February 18 1994

Of all the comets in the sky  
There's none like Comet Halley  
We see it with the naked eye  
And periodically.

Of all the comets in the sky  
There's none like Comet Hawley  
We see it with the naked eye  
But this time rather poorly.

Remember Halley's Comet? Did you see it when it brushed past us on its last visit in 1985-86? Probably not. But you will almost certainly remember all the hype associated with its coming - not least the vexed question of how you pronounced the comet's name. Was it Halley, rhyming with 'alley'? Or Hawley, as in the second verse above? The first was written in 1910 - the comet's last visit - by Sir Harold Spencer Jones, who would later become Astronomer Royal (perhaps it is as well he was not made Poet Laureate). The second, celebrating the comet's more recent coming, was penned by John Mason of the British Astronomical Association. It very much summed up how things were when it came to seeing the comet back in 1985-86!

Comets have always provoked strong reactions - and not just ones of amusement. If you have ever seen a really big comet, hanging in the twilight with its tail fanning out amongst the stars, I'm sure you'll agree with me that it is one of the most awesome sights in nature. Before people knew what comets were, they provoked fear and terror; what were these silent, looming daggers? There is a famous cartoon that shows a grinning comet tearing the Earth in two. And comets have always been associated with death and bad luck. As Shakespeare himself wrote in *Julius Caesar*: "When beggars die, there are no comets seen; the heavens themselves blaze forth the death of princes".

What is a comet? In the words of Patrick Moore: "The nearest thing to nothing that something can be". It is a piece of cosmic debris: a bit of rubble left over from the building of the Solar System. But while some cosmic rubble is rocky (like the asteroids), comets are basically icy. They are frozen fragments of the giant gas and dust cloud that formed the Sun and planets nearly 5 billion years ago.

In their natural state - frozen balls maybe 10, 20 miles across - comets live in two giant swarms in the outer parts of the Solar System. Some live in the inner, disc-shaped Kuiper Belt. But the vast majority - reckoned to run into millions - are in the spherical Oort Cloud, which may stretch halfway to the nearest star. Most comets will spend their entire existence in these swarms.

But occasionally, the weak pull of a passing star jostles the comets. Like penguins teetering on the edge of the pack ice, a few will fall

in - in this case, towards the Sun. As a comet approaches the inner Solar System, it will start to accelerate under the influence of the Sun's powerful gravity. Faster and faster it moves, plunging down towards the Sun. Some comets collide with the Sun. The majority of "first time" comets manage to get back whence they came. But a few are trapped close to the Sun when their orbits are pulled out of shape by the gravity of a nearby planet. Their fate is to tramp around amongst the planets until they wear out.

Most of these comets' orbits are not like the near-circular paths of the planets - sometimes, they are not even in the same plane. They travel in elongated paths coming from above and below the main plane of the Solar System, reflecting the fact that they originated much further out and from a different distribution of material. A comet behaves very differently depending whether it is close to the Sun, or a long way away. When it is at the furthest point in its orbit, it creeps around very slowly, and is totally frozen. As it moves closer to the Sun, it starts to pick up speed. It also starts to feel the Sun's warmth. The ices on its surface 'sublime' - they evaporate without first melting in the vacuum of space - and form a glowing head of gas (the 'coma') around the body of the comet (the 'nucleus'). The closer it gets to the Sun, the more gas boils off the nucleus, and the larger the coma grows.

Close in to the Sun, the comet starts to feel the force of the solar wind - a "gale" of electrically-charged particles escaping from the Sun. It blows the comet's gas straight back behind it, forming the comet's trademark - its tail. (A comet actually has two tails - one of gas, the other of tiny dust particles also boiling off the nucleus. The dust tail is often curved, but the gas tail interacts with the charged particles in the solar wind, and is always straight.)

When the comet rounds the Sun, it is travelling very quickly to avoid being pulled in. Its tail may be millions of kilometres long, and, if the Earth is in a position to get a good view, the comet is a magnificent sight. Then it's downhill all the way. The comet heads back to the far point of its orbit, becoming less and less active as it draws away from the Sun. But because of the ubiquitous solar wind, its tail goes before it. The comet travels "tail-first" in the manner of an over-deferent courtier backing away from the royal presence. As it goes, the comet starts to freeze up again. It spends most of its time in this frozen state, producing fireworks only when it is close to the Sun. Yet the fireworks take their toll; and on every visit to the inner Solar System, there is a little bit less of the comet. Once trapped amongst the planets, a comet will wear out in about 250,000 years.

So much for comets. Who was Halley himself? The answer is that he was such a remarkable man, he needs a whole lecture series solely dedicated to him and his achievements. Although today he is remembered almost exclusively for his comet, comets in fact occupied just 3% of his time. His work spread across an astonishing number of categories: maths, physics, upper atmosphere phenomena, comets, stars, eclipses and transits, longitude and latitude, the Moon's motion, editorial

work and the classics. It is a little-known fact that he was also a pioneer of deep-sea diving and patented an improved diving bell!

He was born to a rich London merchant in 1656, and went to Oxford to study. In his third year, bored with student life, he decided to sail off to the southern hemisphere and chart the stars visible from down there. He was able to pull strings in immensely high places to get funding - like Charles II, the Secretary of State, and the Astronomer Royal. On his return, he told the King he had created a constellation especially for him: 'Robor Carolinum', or 'Charles' Oak - an allusion to the oak tree in which the King hid after the Battle of Worcester. In gratitude, the King granted Halley his MA degree without having to sit any exams!

Halley's charm, fine brain and diplomatic skills held him in good stead during all his long life (he lived to be 85, and allegedly died with a glass of red wine in his hand). He held a succession of posts, ranging from sea captain to Savilian Professor of geometry at Oxford, and these culminated in his appointment as Astronomer Royal when he was 65. By then, he had already seen "his" comet - it was visible in 1682 - and he noticed that its orbit was very similar to comets that had appeared in 1607 and 1531. He suggested that the three comets were one and the same - and made the bold scientific prediction that it would return in 1758. Sure enough, it did - and it was immediately named in honour of the great man.

Once astronomers realised that Halley's Comet returns to the inner Solar System every 76 years, they started looking through the historical record to check on its appearances in the past. This approach isn't as straightforward as it sounds, because Halley's orbital period is only roughly 76 years. If it has a close encounter with Jupiter when it is on its way in or out, it can disrupt the regular cycle. Nonetheless, astronomers have now managed to find records of every return of the comet back to 240BC.

Among these, there have certainly been some memorable encounters! In the 240BC apparition, it was logged by Chinese astronomers as a 'broom star'. By AD 65-66, it was being seen as a portent of disaster, "a broadsword-shaped star hanging over the city of Jerusalem". Flavius Josephus, the Jewish historian and military commander who wrote those words, saw it as an omen of the city's destruction - and Jerusalem was ransacked by the Romans in AD 70.

The encounter I would have wanted to be around for was that of AD 837. On that occasion, Halley passed closer to us than any time in history - just 15 times further away than the Moon. It was visible in broad daylight, and its tail stretched halfway across the sky. At its closest approach, it moved across one-third of the sky in the space of a day. It must have been an incredible sight - but imagine the terror it must have caused!

One of the encounters familiar to almost all of us is that of 1066, for the comet is worked into the Bayeux Tapestry. In this year, Halley was as bright as the planet Venus, and the Saxons regarded it

is an unfavourable omen - especially in the context of their war with the French. The tapestry shows a worried King Harold on his throne, surrounded by horrified advisors looking at the comet. The caption reads "Isti Mirant Stella" - "They wonder at the star". Although the comet had disappeared by the time Harold was killed by the Normans at the Battle of Hastings on 14 October 1066, its gory reputation had been enhanced.

The 1301 return was so spectacular that it inspired a Florentine artist to leap for his easel. In his Nativity, painted two years later, Giotto di Bondone's Star of Bethlehem has a long tail - Giotto had used the comet as his reference. I wonder how Giotto would have felt had he known that, nearly 700 years later, a European spacecraft scheduled to intercept the comet would be named after him?

My final encounter from far-off history took place in 1456. Again, the comet was a spectacular sight over Europe, and came to the attention of the Pope, Callixtus III. He condemned the unfortunate apparition as "an agent of the Devil", and there is even an apocryphal story that he excommunicated it from the Catholic Church!

The last return that is still remembered by some people alive today is that of 1910. Although many people did see the comet in the late spring, others swear they saw it earlier. In fact, Halley was upstaged by a much brighter comet - the Great Daylight Comet - that graced the skies in January and February. Although Halley was quite a bit fainter, it nevertheless caused quite a stir. On May 20, Earth actually passed through the comet's tail. Hearing that astronomers had discovered minute amounts of cyanide in the comet's gases, several gullible people barricaded themselves in their homes that day for fear of being poisoned!

1910 saw the first true "Halleyphernalia" - commercial ephemera that sold on the strength of the comet's name. Halley the man would no doubt have been amused at seeing his comet selling everything from custard to champagne. The comet was also celebrated in song and verse; in fact, I have a French song about the comet which features an astronomer ("with his long telescope") and a lady ("who would rather be friendly than pally"). The lyrics are absolutely unprintable.

Following this first brush with sordid commercialism, Halley's Comet retreated to the furthest point of its orbit beyond the planet Neptune. Then, in 1948, it started back on its return journey - this time to face a flotilla of spaceprobes from planet Earth. But more of that anon. On this, its most recent return, the comet was first spotted on an image taken by the 5-metre Hale Telescope on Palomar Mountain, on October 16, 1982. It was then still beyond the orbit of Saturn, and 20 million times too faint to be seen with the unaided eye.

As time went by, the comet began to accelerate towards the Sun. Its ices started to sublime, and before long it had developed a coma and a short tail. But it would still be three years before it came within the grasp of amateur-sized telescopes. In Britain, the late Alan Young

and Ron Arbour - both of whom had been searching for months - managed to photograph the comet on the same night, July 15 1985. Alan was first by just 15 minutes!

Now the comet was growing brighter every day. I got my first glimpse of it in September 1985, using a large amateur telescope near Houston, Texas. It was still 1500 times fainter than the naked-eye limit. But it was a very emotional experience to see the cosmic visitor for myself, after all I had heard and read about it. All at once, I felt strong bonds linking me with both the past and the future.

Two months later, and the comet had increased dramatically in brightness. Even so, it was barely visible to the unaided eye as it shifted imperceptibly slowly across the sky beneath the stars of the Pleiades cluster. If you knew where to look, you could see it; most people couldn't.

But professional astronomers, with large telescopes at the ready, had a field day. Using new, fast electronic techniques unimagined at the time of Halley's last visit, they were able to dissect, probe, analyse and examine every aspect of the comet. At one stage, a major chunk of its gas tail dropped away; but with gas boiling vigorously off the comet, it was soon replaced.

One thing that didn't change from 1910 was the Halleyphernalia. In fact, there was even more of it this time. Cartoons, comet champagne, a Comet Gala, comet kits, the Halleymites (8ft tall cosmic Wombles) - most of it was fairly dire. And our technological advances since 1910 presented fresh commercial opportunities - like flights that escaped our light-polluted cities to give a good view of the comet.

The ultimate 'comet flight' had to be the inaugural Concorde trip from London to Auckland, New Zealand. I was invited to be "tame astronomer" on this trip, and couldn't believe my luck. I began to think a little differently when we were 12 miles above the Indian Ocean and I could scarcely see a star, let alone a faint comet, out of Concorde's thick windows. When I finally *did* get to spot Halley, it was right against the Milky Way - a fuzzy blob against a fuzzy blur. Fortunately, after a few days in New Zealand, the comet climbed out of the Milky Way and stood on its own in the skies. Because it had by now passed its closest point to the Sun, it was reasonably bright as well. We got quite nonchalant about seeing it hanging in the sky.

The rapid brightening we saw when the comet approaches the Sun is mirrored - in reverse - when the comet recedes. Just a month after I was in New Zealand, in May 1986, I went on holiday to Rhodes. I could just glimpse Halley through my binoculars. And that will probably be the last time I'll ever see it.

But our tale of Halley's Comet isn't over. For before it plunged back towards the frozen wastes of the Solar System, Halley had an encounter of its own - with an international flotilla of five spaceprobes from Earth. There were two Japanese craft, Suisei and Sakigake; two Russian, Vegas 1 and 2; and the European Giotto probe. All the

encounters took place in March 1986, when the comet had just rounded the Sun and was therefore at its most active.

The two Japanese probes passed the comet at relatively great distances: Sakigake at 7 million km and Suisei at 200,000 km. It was Russia's turn next. On March 6 and March 9, the Vega probes (which had already dropped balloons into Venus' atmosphere en route), flew within 10,000 km of the comet. These bulky craft, powered by huge wing-like solar panels, took a real battering from the onslaught of dust and gas emerging from the comet's head. But the Vegas did two important things. First, they were able to act as 'pathfinders' for Giotto, pinpointing exactly where the comet's nucleus was under its enormous head of steam. Second, they got close-up images of Halley's nucleus. These strange colour-coded images suggested that the comet in its naked state was double - or, at least, peanut-shaped.

On March 13-14, Giotto headed in. Travelling at a speed of 250,000 kph straight towards Halley's nucleus, many scientists working on the Giotto team believed it would be a kamikaze mission. Privately, they were sad: over the past 8 months, they had grown very fond of the brave, cuddly, spaceprobe that was not much bigger than a Robin Reliant.

That night, the scientists watching at the European Space Agency's (ESA) Mission Control in Darmstadt, Germany, were joined by millions of TV viewers as Giotto raced towards its doom. Closing in, Giotto's specially-designed bumper-shield began to register thousands of impacts as the plucky probe was literally sandblasted by dust. Other instruments sampled the boiling gases, the charged particles, and the shape of the comet's coma. Giotto's colour TV camera began to show a perplexing fan of colour that got bigger and bigger as the probe got closer. Even taking into account that these were 'false-colour' images, it was very hard to see what was going on.

Then, just as Giotto was virtually at the nucleus, TV screens in Mission Control shuddered - and then went blank. Had Giotto hit the comet? No - but there would be no more pictures. A "big" particle (about the size of a pea!) had hit the probe, knocking it off course. By the time Giotto recovered from the impact - half an hour later - the comet had been left well behind. But at least Giotto had survived. It had passed within 1000km of Halley's nucleus, and six years later, it would pass even closer to Comet Grigg-Skjellerup. But this time there were no pictures: the encounter with Halley had destroyed the TV camera.

It wasn't until the day after the Halley encounter that scientists realised what the pictures were telling them. The 'fan' was not the comet, but gas boiling off the nucleus. At the apex of the fan was a tiny, dark, comma-shaped object. After some preliminary image-processing, everything became clear: the comma was the comet. You could see very clearly a dark, potato-shaped object emitting brilliant jets of gas. If you had the eye of faith, you could make out miniature mountains and craters. We were seeing a naked comet for the first time: an object that, through the centuries, had excited awe, terror,

superstition and dread - and yet it measured just 16km x 8 km x 5 km across.

The Giotto images compared well with the Vega pictures, which had simply made the comet look peanut-shaped because of their lower resolution. And with further massaging of the Giotto images by computer, more details began to emerge. The most surprising thing of all, however, was the darkness of the comet's surface. Halley's Comet is coated with some of the darkest material in the Solar System - rather like a cosmic choc-ice! Giotto also revealed that the dark material is rich in carbon - the element that joins with itself in long chains to form the backbone of life. Although few astronomers would go as far as Fred Hoyle and suggest that comets brought life to our planet, it is possible that they could have contributed to its building blocks.

But how typical a comet is Halley? We don't know. That is why Giotto was later sent on to encounter Grigg-Skjellerup, which turned out to be a far less dusty comet. And there are more plans to visit further comets on the drawing-board. ESA scientists are hoping to get funding for a probe called Rosetta, which will fly early next century. Rosetta will actually fly with a comet through space, and will drill into its icy surface to get sample of its material.

Halley is now on its way back to the depths of the Solar System, but not without a final flourish. A few years ago, it suddenly brightened unexpectedly, leading to speculation that it could have suffered a collision. But no-one is sure what happened - a sign that, despite Halley's last visit, our understanding of comets is far from complete.

Who knows what Halley's Comet has in store for it when it visits us again in 2061? One thing's for sure: it will be an even worse encounter than the last one, with the Earth and the comet situated far apart. AD 2136 will be better... But Halley will carry on. For the next hundred thousand years or so, until it wears out completely - or is permanently flung off course by Jupiter - Halley will return. And I'm sure humans won't just see it as a celestial visitor, but as we do now - a link between the past, present and future.

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