Halley's Comet

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The computer programs in this book have been tested and if properly keyed in to an appropriate computer will perform the tasks for which they are intended. The Publishers regret that they cannot enter into any correspondence concerning any aspect of the programs with any user.

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I

Introduction

1 What is so special about Comet Halley?

Halley's comet was successfully found again on the morning of 16 October 1982, after an absence of about 72 years. Attempts to detect it were being made as long ago as 1977 with the 200-inch (5.1 metre) optical telescope at Mount Palomar, USA. The search was largely being conducted by professional astronomers because they have access to large telescopes with great light-gathering characteristics. Recently modern sensing devices, such as the charge-coupled detector (CCD) and associated equipment (see section 31), have made these telescopes even more efficient at recording the images of extremely faint objects. The search for new comets, and the rediscovery of comets which have been seen before, are very much occupations of amateur astronomers because large telescopes with an observer at the eyepiece are not suitable for sweeping the sky in search of new comets; although where there is a reliable forecast of the position of a returning comet a large telescope can be used to photograph that part of the sky. It is true that some new comets are discovered on photographic plates taken by the professionals for other purposes, and a few professional astronomers do spend some time in recovering old comets. Professor Elizabeth

Roemer, formerly of the United States Naval Observatory at Flagstaff, Arizona, and now at the Lunar and Planetary Laboratory University of Arizona, Tucson, USA, has a special reputation for this activity. The large telescopes are generally being used on more fundamental problems such as trying to solve the problem of the origin of our universe and expanding our knowledge of its evolution. Some studies in the infra-red part of the spectrum are undertaken, though these and studies in other parts of the spectrum (see section 23) are far better based in artificial satellites and with radio telescopes. Research on pulsars, quasars and black holes also takes up time on the large expensive telescopes. It therefore normally falls to the amateur astronomer with more modest equipment such as small telescopes and binoculars to spend many hours of the night and early morning searching the skies for new comets. These dedicated amateurs have an almost unbelievable knowledge of the positions of a very large number of stars in the sky, so they can more readily identify a newcomer, such as a comet.

No other comet has received such priority of attention from professional astronomers, so why is Comet Halley so special?

First, Halley's comet belongs to the family of comets known as *periodic*. This means that each travels in an elongated orbit round the sun forming a closed loop. So, with some exceptions, after being observed once from the Earth in that part of the orbit which takes them near to the Sun, and completing the remaining part of their orbit, they return to be visible on future occasions. Halley's comet is exceptional in that it has returned close to the Earth on no less than 29 previous occasions, having been observed at all but one of these appearances – that of 164 BC – since 239 BC. There is some evidence, however, that this comet has been seen on several more returns since 1140 BC, over a remarkable span of over 3000 years.

Second, whereas typically many periodic comets have orbits going out only as far as the orbit of the planet Jupiter and back in a period of about seven years, Halley's comet travels beyond the orbit of the farthermost planet of the solar system, Pluto, before returning. The former group of comets, approaching 100 in number, are ones which have passed sufficiently close to Jupiter on their way into, or out of, the solar system for their motion to have been materially disturbed by the gravitational effects of this massive planet. Their original orbits have consequently been changed to much smaller ones – see section 32.

Third, because of its very elongated orbit (see figure 5), the period of Halley's comet is about 76 years, though it has been as low as 74 and as high as 79. This is especially interesting because three score years and ten is still a reasonable average for the lifespan of man. Many people therefore will have the opportunity to observe this unusual comet twice in a lifetime, and no doubt have tales to tell about the last appearance, in 1910. As luck will have it, there was another bright comet early in 1910, the 'Daylight Comet', much brighter than Halley's, and it is likely that some of the tales will quite innocently be about the wrong comet.

Fourth, although reputable astronomers A. C. D. Crommelin and Professor Raymond Lyttleton consider that there must be tens of thousands of comets in the solar system which are theoretically observable, most of them are fainter than the faintest star visible with the naked eye (about magnitude 6; see section 8). Only a few are observed by dedicated astronomers, professional and amateur. Halley's comet has been seen at times which coincide with events of special historical significance, sometimes of a tragic nature. In AD 66 its appearance was taken as a warning to the Jews of the coming (AD 70) siege and capture of Jerusalem by the Romans under their emperor Vespasian. A little nearer our time, possibly the most notable appearance of Halley's comet was that which coincided with the Battle of Hastings in AD 1066. Its clear visibility at that time made it of sufficient importance to be represented pictorially in the Bayeux Tapestry which records the Norman conquest. Its appearance in the tapestry seems to be connected with disaster for the English, but its appearance in the sky could have been happily significant for Harold, Earl of Wessex, who had earlier been released from captivity by William the Bastard after a campaign in Brittany.

Last, we live in an age of technological and scientific achievement, which makes this return of Halley's comet one of intense interest to scientists. The instruments available today for scientific detection and measurement are as never before. In particular our ability to launch space probes with extreme accuracy over large distances has set afoot several projects to rendezvous with or fly by Comet Halley so that our understanding of the nature of comets in general, at present far from complete, can be greatly enhanced.

As Halley's comet approaches, to possibly within binocular range by 1985, interest in it will increase rapidly. A similar situation arose in 1973 when Comet Kohoutek took the imagination of the press. Because it was discovered by Dr Lubos Kohoutek at a distance of over 400 million miles from Earth, which is exceptional, it was assumed that this comet must be very large. Its calculated orbit would place it very favourably for observation, and a predicted magnitude (see section 22) of −12 (section 21) would make it very bright indeed, nearly as bright as the Moon. Daylight naked-eye visibility seemed certain. The reality was that Kohoutek's actual brightness fell far short of that predicted, well below naked-eye visibility, although Patrick Moore saw it from an aeroplane at magnitude about 3 and with a very short tail indeed. Such are the hazards of comet prediction (see section 22).

Nevertheless, as Halley's comet comes closer to the Earth and Sun, similar and more searching questions will naturally be posed by the layman, students in colleges and schools, and others. This book anticipates many of these questions and sets out to answer them in a straightforward way. Other relevant material, including some scientific background, is included to make the subject more intelligible and more interesting to those who wish to go deeper. These sections can be skipped without any loss by the general reader. Adequate cross-referencing and a small amount of repetition allow the reader to dip into the book at any place after reading this Introduction. A feature of the book which may be of particular interest to some readers is the inclusion of microcomputer programs.

2 Why is it called Halley's comet?

When an astronomer considers that he has seen a new comet, or has found on a photograph of a part of the sky an image which he thinks is a new comet, he uses the standard procedure for sending a report of his discovery to the International Astronomical Union's Central Bureau for Astronomical Telegrams (see appendix C). Steps are taken to confirm the original observations using other independent observers. If the object observed is confirmed, the new comet is then labelled with the year of discovery followed by the letter of the alphabet which indicates how many comets have previously been discovered in that year. If the observer is shown to be the first person to have discovered the new comet, it will be given his or her name. Thus, Comet Halley 1909c was the third comet to be discovered in 1909. The position of this comet had been predicted from observations made at its previous appearance in 1835, and so it did not carry the name of the person who first rediscovered it, on a photographic plate, in 1909 – thought to be Professor Max Wolf at Heidelberg.

After a period of about two years the comet will be given a more permanent label which indicates the year of its *perihelion* passage (when it is closest to the Sun) together with Roman numerals indicating the chronological order of that perihelion passage compared with other comets with perihelion passages in that year. Thus, Comet Halley was labelled 1910 II. If the comet is known to be periodic it will be given the name of the discoverer preceded by the letter P. So we have P/Halley 1910 II.

No such system existed in the time of Edmond Halley (1656–1742), nor did Halley actually discover the comet which bears his name. This will be clear from the number of appearances which the comet had already made before Halley was born. Nor did Halley rediscover it on its reappearance in September 1682, but what he did was truly remarkable.

Halley lived at the time of the publication of Isaac Newton's *Principia* (*Philosophiae Naturalis Principia Mathematica*). (Indeed, he not only encouraged Newton to publish this great work; he provided the funds to pay the printer and edited the work himself. He had some unusual rewards in addition to the profits from the first edition: free copies of a book on fishes published by the Royal Society.) Newton had put forward in *Principia* his theory of universal gravitation and had extended this to show that comets must travel in orbits of specific shapes (ellipses, parabolas or hyperbolas) (see section 4 and figure 1) round the Sun.

Halley took the observations of the comet of 1682 and, applying tedious computations (still tedious today unless one has a computer), deduced that its path must be elliptical. Newton himself had favoured parabolas for all comets. Certainly many comets when they are near the Sun move in elliptical paths which differ very little from parabolic paths (see figure 1). If indeed the path of the 1682 comet was elliptical, the comet must move round the closed

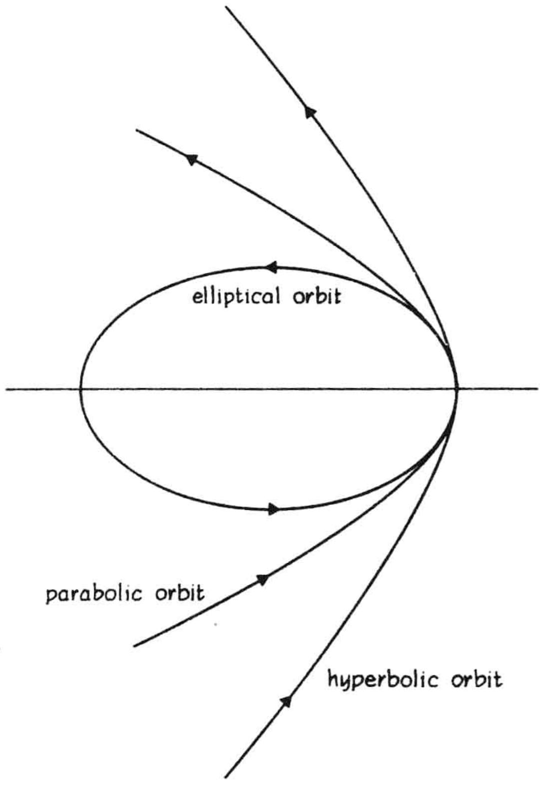

FIGURE 1 *The shapes of the orbits of a comet moving under the gravitational influence of the Sun.*

loop of the ellipse and Halley predicted that it would reappear near the Sun in about 75 years. For the first time it was realized that not all comets are new; that some are reappearances of old ones. Halley's calculations would be put to the test in 1758. The comet was observed in December 1758, some say on Christmas Day, but Halley died in 1742 and never saw the reappearance of the comet which so clearly proved his calculations.

This comet is therefore called Halley's comet whatever number is assigned to it on each appearance. The comet was found again on 16 October 1982 and designated 1982i, being the ninth comet of 1982.

3 Who *was* Halley?

Edmond Halley (plate 1) lived from 8 November 1656, or 26 October 'by his own account', until 14 January 1742. This sort of slight discrepancy on dates runs through the literature on Halley, but they generally vary by less than a year. Halley and Newton were friends and each helped the other in his own way. Their characters and temperaments could scarcely have been more unlike.

Halley was born in Shoreditch, London. He attended St Paul's School before going up to Queen's College, Oxford, in 1673. It was here that he met John Flamsteed who was to become the first Astronomer Royal. One important problem of their time, which presents no difficulty at all in our day of artificial satellites, was the determination of one's position at sea, particularly longitude, and the post of Astronomer Royal was created in 1675 by King Charles II specifically to study this problem. John Flamsteed was a person whose later attitude and behaviour to both Halley and Newton were often antagonistic. The second Astronomer Royal was Edmond Halley himself, who held the post from 1721 until his death at the age of 85.

His visits to the Royal Greenwich Observatory, while he was a student at Oxford, stimulated his interest in astronomy. He left the university to go to St Helena where he spent a year cataloguing stars in the southern hemisphere. Flamsteed was carrying out a similar exercise for stars in the northern hemisphere, but the equipment was better at St Helena, and, at a latitude of 16° south of the equator, the island was the most southerly territory under British rule in

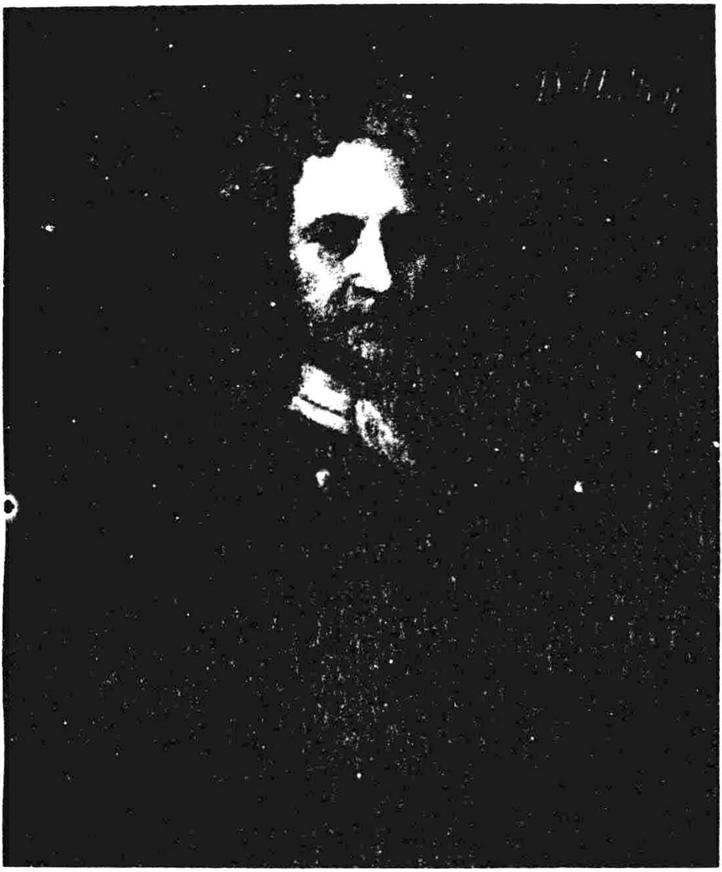

PLATE 1 *Edmond Halley, second Astronomer Royal.*

the south Atlantic. Halley's catalogue, published late in 1678, gave the coordinates of 341 stars in the southern hemisphere.

On his return to England in 1678 Halley was awarded his MA at Oxford, with some assistance from the King. In the same year he was elected a Fellow of the Royal Society of London, of which he became successively Clerk in 1686