COMET HALLEY AND HISTORY

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This meeting is being held at a most auspicious time, for we are just about to celebrate the four-hundredth anniversary of the birth of the scientific study of comets. Almost exactly four centuries ago, in November 1577, the Great Comet of that year burst over the skies of Europe (Fig. 1). Chief among those making observations of this comet was Tycho Brahe, at his observatory on the island of Hven. From a comparison of his own observations with those of other astronomers, notably Michael Maestlin in Würtemberg, Cornelius Gemma in Louvain and Thaddeus Hagecius in Prague, Tycho was able to demonstrate quite unequivocally that the comet was located at least four times farther away than the moon. As shown in Fig. 2, Tycho considered the comet to travel about the sun in a circular (or possibly slightly oval) path outside the orbits of Mercury and Venus, while the moon and the sun themselves orbited around the earth. Tycho's "System of the World" was a compromise between the Ptolemaic and the Copernican views, and while he was wrong about the details of the revolutions, particularly in the case of that of the comet, there is no doubt that he completely revolutionized thought on comets, which until then had held that comets were simply fiery exhalations in the earth's atmosphere. Terrestrial observations of countless comets since Tycho's time have considerably advanced our knowledge of these objects, of course, but on the occasion of this quatercentennial it seems appropriate that we should think in terms of another cometary revolution and make a definite commitment to launch a space mission to a comet.

More than a century was to pass after Tycho's revolution until the next significant contribution was made to cometary astronomy. Johannes Kepler made his brilliant discovery of the laws of planetary motion, but

Fig. 1. The Great Comet of 1577. The original shows a vivid yellow comet, moon and stars in a light blue sky (courtesy Istanbul University per O. Gingerich).

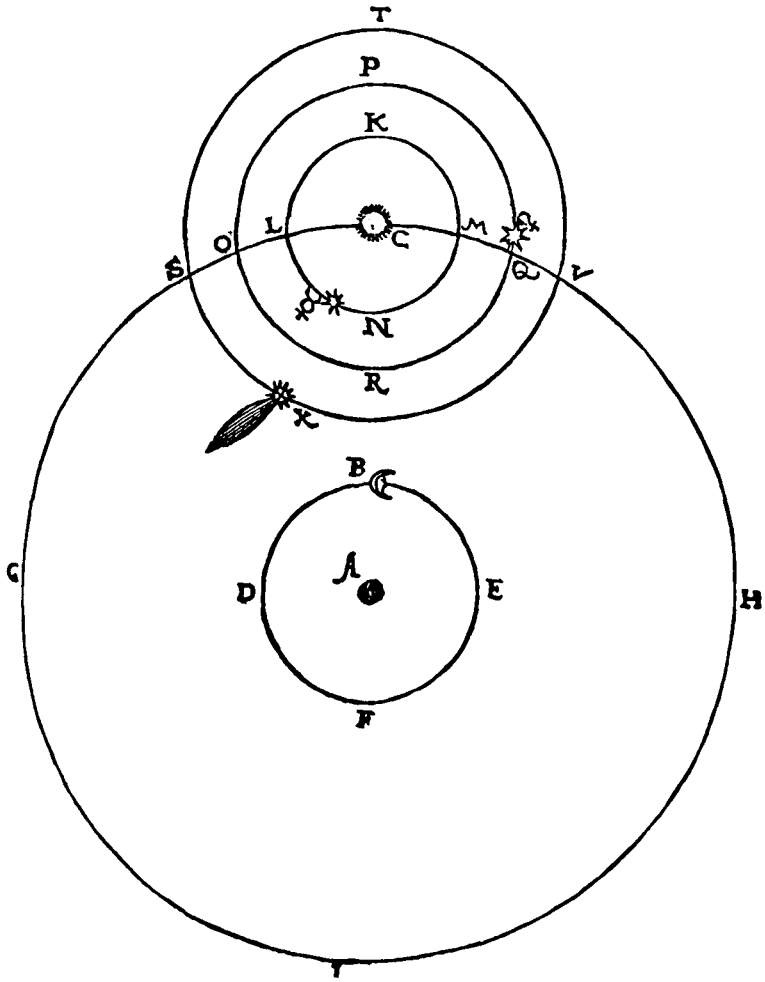


Fig. 2. Tycho's System of the World. The comet of 1577 is shown orbiting the sun outside the orbits of Mercury and Venus, while the moon and the sun are orbiting the earth.

it never seems to have occurred to him that comets might be subject to such laws. He steadfastly held to the neo-platonist view that the planets, being eternal, have circular (or nearly circular) paths, whereas the temporal comets must travel in straight lines. Other seventeenth-century astronomers, notably Johannes Hevelius, began to suspect that comets moved in elliptical or parabolic orbits, although Hevelius' adoption of the latter was based on the idea that comets were projectiles thrown out by Jupiter and Saturn, and the foci of the parabolas he calculated were not situated at the sun. It was Georg Dörffel who was the first to realize, in the case of the great comet of 1680, that the sun was at the focus of the parabolic orbit, and soon afterwards Isaac Newton confirmed this by showing that the motions of both planets and comets conform to the law of gravitation.

As is well known, Edmond Halley then applied Newton's methods and determined the orbits of 24 comets that had appeared between 1337 and 1698. In the course of his work, published in 1705, he made his famous pronouncement concerning the identity of the comets of 1531, 1607 and 1682, suggesting that, with its period of 75½ years, the comet should return around the year 1758. It is perhaps not so well known that Halley felt that the comets of 1532 and 1661 were also identical, and that the great comet of 1680 was a return of one seen in the year 1106. Fig. 3 depicts the presumed orbits of the three comets, but we now know that only the orbit with the 75½-year period is correct.

Halley's 1758 prediction was refined by Alexis Clairaut, who, with the assistance of Joseph Lalande and Madame Hortense Lepaute, worked out step-by-step the effects of the gravitational attractions of Jupiter and Saturn on the comet. It was a race against time, and they worked

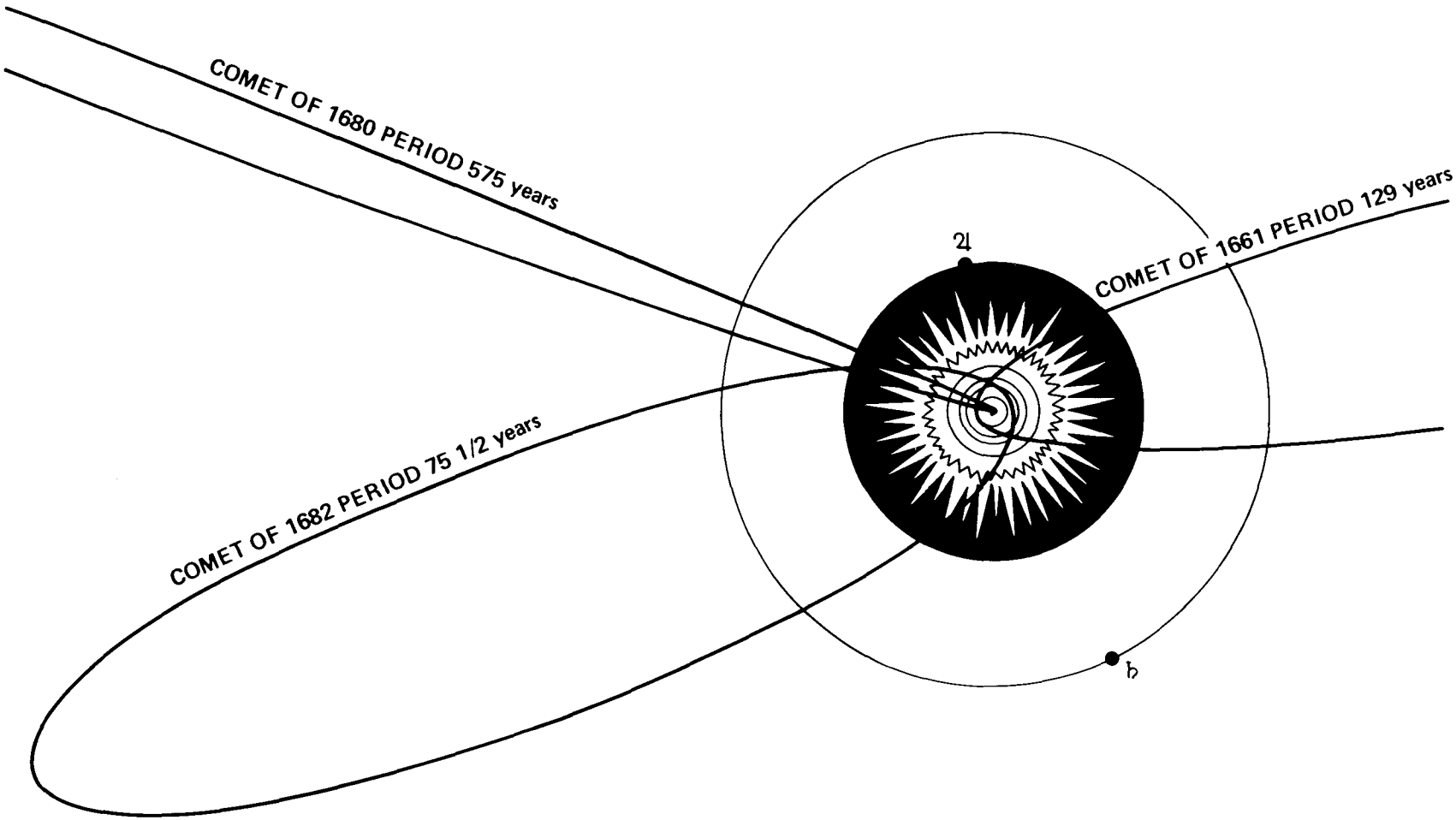


Fig. 3. Three of the comets supposed by Halley to be periodic. Only the period of the comet of 1682 is correct.

from morning till night for six months. Clairaut was finally able to announce the result in November 1758. Fortunately, as Halley himself had indicated, the effect of the planets would be to delay the comet's return somewhat, and their predicted date for perihelion passage was 15 April 1759. The comet was recovered on 25 December 1758 by the farmer Johann Palitzsch near Dresden, almost a month before it was picked up by any of the professional astronomers who were making searches. Still ignorant of Palitzsch's prior claim, the first professional to find the comet was Charles Messier in Paris, but his announcement was also delayed owing to the pettiness of the observatory director Delisle. The observations indicated that the comet had returned just one month earlier than predicted, a remarkable achievement at that time.

Predictions for the comet's return in 1835 were due to Charles Damoiseau and Gustave de Pontécoulant in France and to Jacob Lehmann and Otto Rosenberger in Germany. The comet was recovered by Étienne Dumouchel in Rome, the observations indicating that Rosenberger's prediction was only four days too early. For the 1910 return, early predictions by de Pontecoulant and by Anders Ångström were refined by the British astronomers P. H. Cowell and A. C. D. Crommelin, and the recovery, first announced by Max Wolf in Heidelberg, again indicated that the best prediction was about three days too early.

Several astronomers, in particular J. R. Hind and P. A. E. Laugier in the mid-nineteenth century and Cowell and Crommelin early in the twentieth, attempted to trace the orbit of Halley's Comet back into the past, and the two last-named investigators succeeded in identifying observational records of the comet at every perihelion passage bar one back to 240 B.C. On re-examining their calculations in 1967 with a

high-speed computer H. F. Michielsen discovered that the computations systematically required correction by about four days at each perihelion passage, suggesting that the comet was being influenced by forces of a regular, but nongravitational nature, such as those expected in the case of Fred Whipple's cometary model. Michielsen was thus the first to suggest that Halley's Comet will next be at perihelion on 9 February 1986, a result later confirmed by J. L. Brady and E. Carpenter by means of the addition of a nongravitational term into the comet's equations of motion. More recently, T. Kiang has refined the comet's perihelion dates in the past with the help of ancient oriental observational records, and using a more complete modeling of the nongravitational forces D. K. Yeomans has made a definitive study of the comet's orbit since 837, before which time the computations are rendered problematic because the comet evidently passed only 4 million miles from the earth in that year. Confirming the next perihelion date of 9 February 1986, Yeomans suggests that there must still be an uncertainty of ± 0.25 day, and he gives 29 July 2061 as the date of the following perihelion passage.

Since time immemorial, comets have been regarded as portents of disasters, and the discoveries of Tycho Brahe and Halley, not to mention all the more recent research on the nature of comets, have done relatively little to change this attitude. The past 2000 years have produced many comets that are brighter than Halley's, but Halley's Comet seems to have been responsible for more than its fair share of tragedies. In 12 B.C. its appearance over Rome presaged the death of Agrippa, and its swordlike appearance at its next return in A.D. 66 was regarded as a sign that Jerusalem was shortly to be destroyed. It appeared in Europe in 451 at the time of the battle of Châlons, when Attila the Hun was defeated by

the Roman general Aetius -- a nice example of one man's meat being another's poison. The same was true in 1066 when, as the Bayeux tapestry depicts (Figure 4), the English were fearing for the safety of King Harold; on the other hand, the spectacular phenomenon appearing in the sky hardly bode ill for the invading Normans, and a contemporary Norman chronicle mentioned that the mysterious three-tailed star appeared simply because England wanted a new king, thereby giving William the Conqueror carte blanche. A French king got his come-uppance in 1223, however, and the appearance of Halley's Comet in that year was widely held as responsible. Perhaps the most famous ancient appearance of Halley's Comet is that of 1456, when the Turks were besieging Belgrade; Pope Calixtus III ordered prayers for deliverance from both the comet and the Turks, although the suggestion that he actually excommunicated the comet is certainly apocryphal. As the program for this meeting indicates, Halley's Comet inspired much public dread at its most recent return in 1910 (Fig. 5). Of course, there was on this occasion the unfortunate circumstance that the earth was actually to pass through the comet's tail, so one can perhaps understand why the ladies of Chicago stopped up their doors to keep out the deadly cyanogen gas. The entrepreneurs had a heyday selling "comet pills," and The New York Times shrugged off the episode in a delightfully poetic sub-headline: "Scarfed in a filmy bit of it, we'll whirl on in our dance through space, unharmed, and, most of us, unheeding."

The comet of 1680, such a source of inspiration to Isaac Newton, also played a role in the meandering thoughts of his not so illustrious successor to the Lucasian chair of mathematics at Cambridge, William Whiston. By indiscriminate application of the 575-year period suggested by Halley, Whiston attributed the Deluge to the comet -- though whether in 2344 B.C.

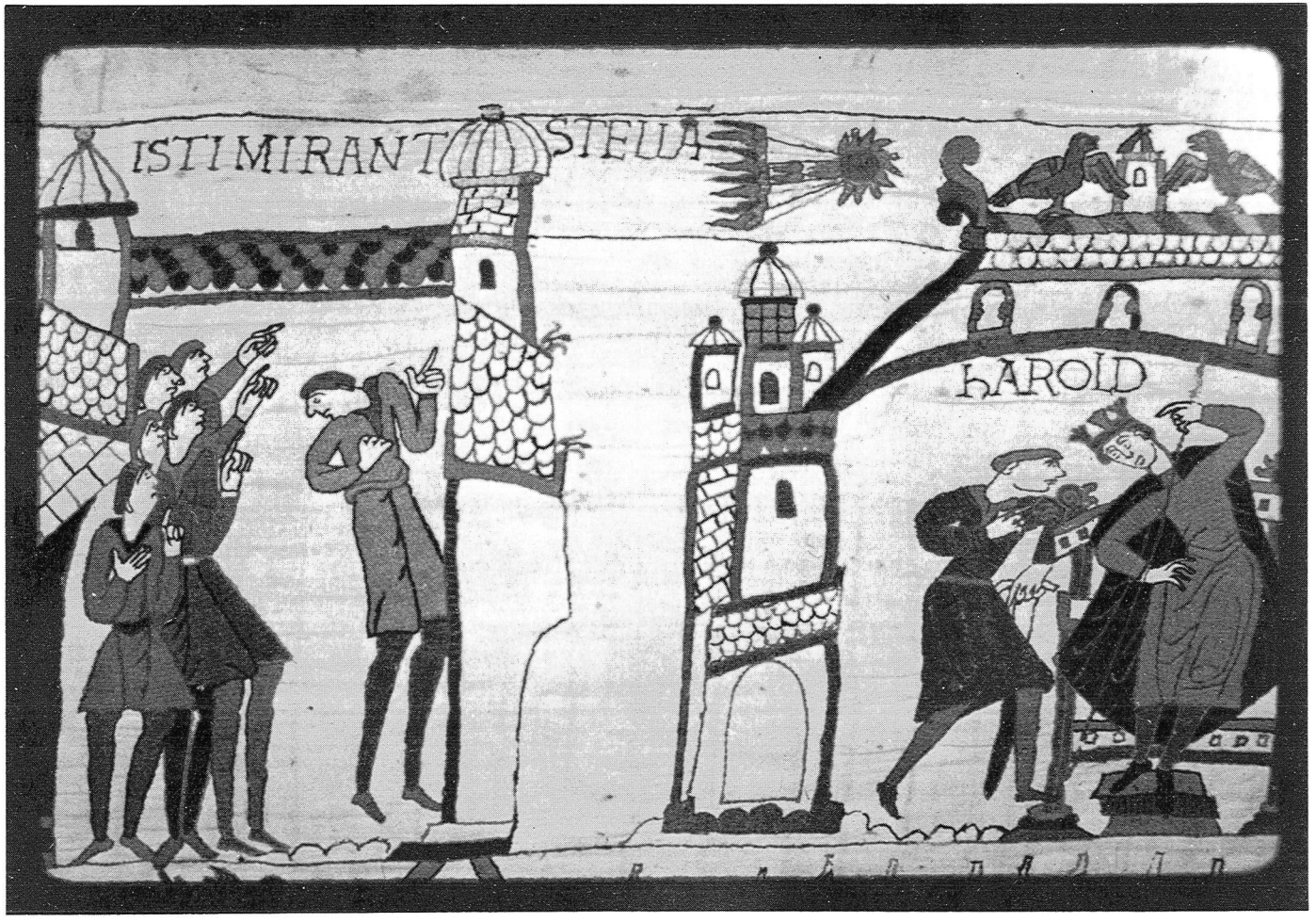
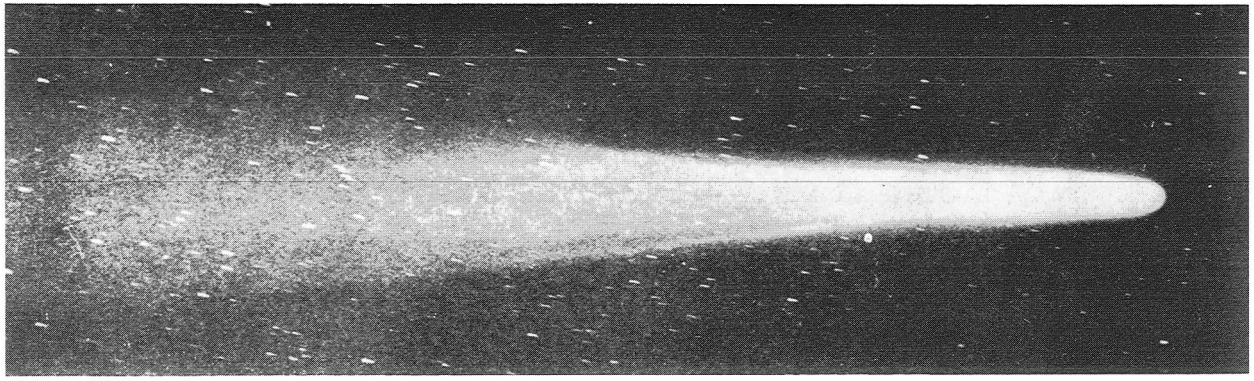
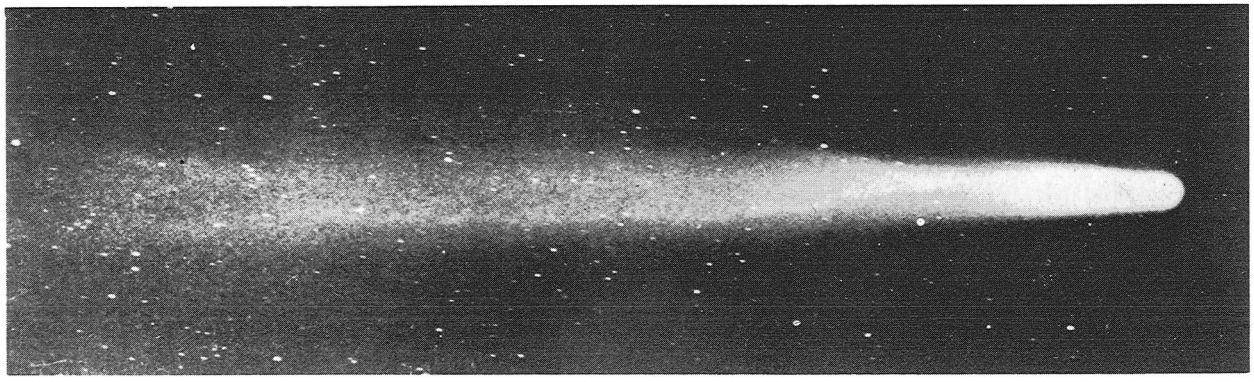


Fig. 4. Halley's Comet as recorded in 1066 on the Bayeux Tapestry.



Comet Halley May 6.9, 1910



Comet Halley May 7.9, 1910

Fig. 5. Halley's Comet as observed on 6 and 7 May 1910 at the Mt. Wilson Observatory.

or in 2919 B.C. is not completely clear; and he suggested that the comet's next return in A.D. 2255 will signify the end of the world! In 1680, the feeble of mind were terrified by the report that a hen laid a "wonder egg" marked with a comet. The Paris Academy later corrected the story by noting that the hen had never in fact laid an egg before, that the event caused the hen to cackle extraordinarily loudly, that the egg was uncommonly large, and that it was marked, not with a comet, but with several stars (Fig. 6).

In contrast to most of its brethren, the comet of 1811 seems generally to have been regarded in a beneficial manner. It was presumed responsible for the excellent port and claret vintages of that year, and Napoleon considered it a good omen for his march to Moscow. Napoleon always felt that comets were beneficial to him, for one had been present at his birth in 1769. As it turned out, the comet of 1811 did not do him much good. Donati's Comet of 1858 (Fig. 7) also apparently yielded an excellent claret, but Lord Malmesbury wrote in his diary: "Everyone now believes in war."

The possibility that the earth would collide with a comet always excites the public imagination. As expected, the earth suffered no ill effects when it passed through the tail of Halley's Comet in 1910, but what about a collision with a comet's head? A paper announced by Lalande in 1773 set Paris into a terrible panic. Although concluding that the possibility was extremely remote, the paper discussed how planetary perturbations could deflect a comet enough to make a collision occur. As it happened, the paper was not given at its appointed time, and -- to Lalande's extreme embarrassment -- a vivid public imagination soon convinced the populace that the earth was in imminent danger of

Wunder-Ey.

Welches den 1/12. Decembris dieſes mit 8. Att zu Endlauffenden 1680.
Heil. Jahrs zu Rom / von einer Henne mit groſſen Geſchrey iſt geleget / und von
hoher glaubwürdiger Hand ſolcher Geſtalt in den Entwurff und Abriß
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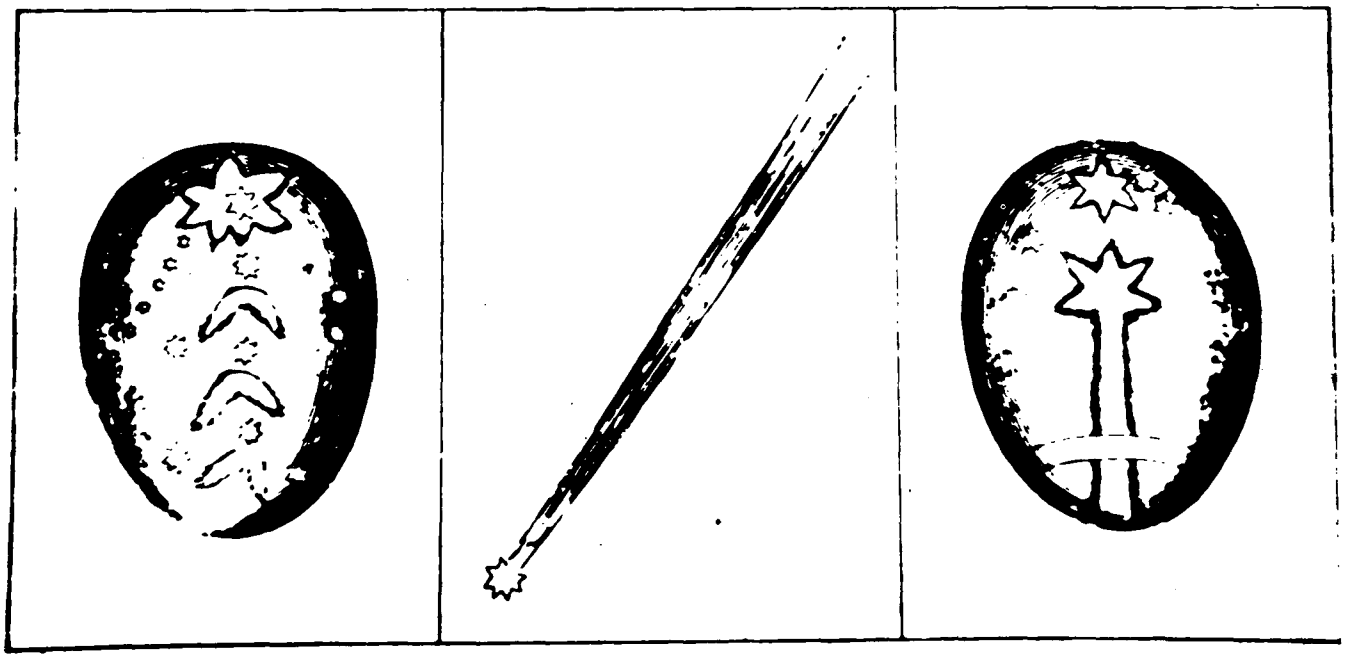

Fig. 6. The "wonder egg," allegedly laid with the comet of 1680 marked on it.

Fig. 7. Evidently Donati's Comet in October 1858.

destruction. Biela's Comet has often been a source of distress: when Wilhelm Olbers pointed out that in 1832 the comet would pass within 20,000 miles of the earth's orbit, his qualifying remark that the earth would not reach that part of its orbit for another month went virtually unnoticed; and the unusually warm weather in Atlanta, Georgia, in November 1872 led a later generation to believe that the comet was bringing about the end of the world. Perhaps the most famous panic of this type was occasioned in 1857 (Fig. 8) by a pamphlet entitled "Will the Great Comet Now Rapidly Approaching Strike the Earth?" The event under consideration was the presumed return of the comet of 1264 and 1556 -- although as it turned out no comet came at all, and the identity of the 1264 and 1556 comets is highly questionable.

But the present age is certainly no more enlightened in this respect, and the sensationalist press produced headlines like "Comet May Kill Millions" when the notorious Comet Kohoutek was approaching its perihelion passage at the end of 1973. The article goes on: "If the enormous comet should land in any of the world's oceans, tidal waves as high as 100 feet would sweep over coastal cities as far as 2000 miles away." It admits that the "dreaded comet ... may not come close enough -- but it may" and quotes a Dr. Bernard Hostetter of the Smithsonian Astrophysical Observatory as saying "we have absolutely no way to know." There is not and never was a Dr. Bernard Hostetter at the Smithsonian Astrophysical Observatory, and if the newspaper had chosen to check its facts with any responsible person on the staff it could easily have learned that Comet Kohoutek would miss us by a clear 75 million miles.

While much of the other press coverage of Comet Kohoutek was decidedly unsatisfactory, most of it was more responsible than the above. After the

Fig. 8. Cartoon inspired by the expected collision of a comet with the earth in 1857.

initial build-up, the press somehow felt obliged to follow through. One can, I suppose, excuse such headlines as "The Star-Spangled Ripoff" and "Kohoutek's Dim Display Makes it Astronomy's Edsel, but Scientists Enjoyed Ride," as well as some of the cartoons that appeared (Fig. 9). Even if Comet Kohoutek had been as bright as some of the early predictions suggested, those hoping to see it streaking across a light-polluted sky would have been disappointed. The well-publicized Comet Ikeya-Seki of 1965 was also a dud as far as the public in the northern part of the U.S. was concerned, yet the two most spectacular comets observable from north temperate latitudes in recent years, Bennett in 1970 and West in 1976, at their best in the morning sky, were virtually ignored by the press.

Unfortunately, in 1985-6, Halley's Comet is expected to be even fainter than its 1974 predecessor, Comet Kohoutek. If one wants to have a good view of Halley's Comet, he should plan a trip to the southern hemisphere in March or April 1986, when it should be a moderately impressive object in the early morning hours. It is as well that we do not raise too high the hopes of those who want to see this celestial visitor about which they have heard so much. On the other hand, it is still possible that the public can receive vicarious pleasure in that a space probe will be out there adding to our understanding of this mysterious body at an opportunity that presents itself once a lifetime. To the man in the street, the solar system consists of Mars, the rings of Saturn and Halley's Comet. Viking missions have taught us a lot about Mars, and probes are on their way to the vicinity of Saturn. If we omit Halley's Comet from all consideration for space exploration, it seems to me that the public is going to want to know why.

Fig. 9. Cartoon inspired by the disappointing display of Comet Kohoutek in 1974 (reprinted by permission of the Chicago Tribune--New York News Syndicate, Inc.).