Comfort for next century but one

Rumours of an impending calamitous collision of a comet with the Earth have been discounted by the use of ancient Chinese records to refine the orbit of the prograde comet Swift–Tuttle.

FEARS that the world will end on or about 14 August 2126 can now be put aside, at least for the time being. That is the immediate outcome of a recalculation of the orbit of Comet Swift–Tuttle, the comet whose debris is recognizable as the Perseid meteor shower, which was most recently observed in the weeks preceding its most recent perihelion passage in December 1992.

As comets go, Swift–Tuttle is a prime candidate for terrestrial collision because its perihelion distance is smaller than, but differs by less than five per cent from, the radius of the Earth's orbit. That means that, for some weeks on either side of perihelion, the comet moves in a trajectory never further than a few million kilometres from the orbit, roughly parallel with it and in the same direction as the Earth, but at greater speed. The chance of a collision obviously depends rather critically on the exact times at which the comet crosses the Earth's orbit. A few days either way can make a critical difference.

Whatever happens, those in a position to observe the night sky in the weeks preceding the next perihelion passage on 12 July 2126 are almost guaranteed the sight of a bright comet with an illuminated tail. The hope, for their sake, must be that the uncertainties in the recalculation due to Kevin Yau, Donald Yeomans and Paul Weissman of the Jet Propulsion Laboratory in Pasadena, California (*Mon. Not. R. astr. Soc.* **266**, 305–316; 1994) are not so great that there is a collision after all.

For those of us who will not be there to see the sights, the recalculation has the great interest of illustrating how to make bricks without straw — the exiled Israelites' daunting task. Until its apparition in 1992, Swift–Tuttle had been observed properly only in 1862, from Western Europe before perihelion and from the Cape of Good Hope in South Africa afterwards.

The best estimate of the orbit of the comet from those observations was made retrospectively in 1973 by B. G. Marsden. His calculation gave equal weight to the observations in the Northern and Southern Hemispheres, and raised the possibility of a collision with the Earth in 2126. Yau, Yeomans and Weissman, by contrast, are able convincingly to discard the Cape observations as likely to have been systematically in error by dredging more informative data from ancient records, notably from the Chinese.

By good luck, as it now appears, the Jesuit missionary Ignatius Koegler, who ran Chinese astronomy for a quarter of a century until his death in 1746, recorded in 1737 the appearance of a guest-star in the sky between 7 and 16 July. That now seems to have been the last apparition but two of Swift–Tuttle. But even the Chinese records are innocent of earlier sightings of the comet for a millennium and a half, when a surviving record from the Han Dynasty describes a guest-star that appeared on 28 July 188, moved southwest over the sky on successive nights and then disappeared. And there is an even earlier record of a guest-star behaving in much the same way that appeared between 20 and 27 August in 69 BC.

The value of these early records for the determination of the orbit of Swift–Tuttle is comparable with that of a distant landmark when taking a compass-bearing: the more distant in time the putative apparition, the more accurately the free parameters in the orbital equation can be determined. But the decision to accept the Chinese records as authentic observations of the comet, and to discard the authentic observations of 1862 from the Cape of Good Hope on the grounds that they must have contained a systematic error, raises an interesting question in the psychology of the analysis of data.

The Chinese records may refer to quite unrelated phenomena, but Yau and his colleagues are impelled to regard them as genuine observations of the comet by the compulsion of coincidence. When they project their best trial orbit for the comet backwards two thousand years, they postdict apparitions in 69 BC and 188, just as the Chinese said. But there is other circumstantial evidence to make the argument convincing.

What, for example, happened to Swift–Tuttle between 188 and 1737? With a recurrence period of 130 years or so, it should have reappeared a dozen times in that long interval. Why was it not seen and recorded somehow? The explanation, based on the best orbit of Yau and his colleagues, seems to be that on each occasion it would have been too faint to be seen with the naked eye (and, of course, there were no telescopes before the seventeenth century).

The argument is that the comet is visible from the Earth only when within a distance of 0.6 astronomical units (one astronomical unit is the radius of the Earth's solar orbit). That means that it should have been just at the limits of visibility during perihelion passages in the years 59, 698 and 1079. Will other historians now take up the challenge to find other records of guest-stars appearing in the sky in the northern summer months of these years? For their part, the authors wring their hands with regret that evidence of a visible apparition of 447 BC is likely to have been destroyed by the sacking of Hsien-Yang in 216 BC, if not by an earlier act of imperial vandalism.

Meanwhile, it is important that the orbit of Swift–Tuttle now provided is not a mathematically defined ellipse with large eccentricity, but a series of ellipses obtained by the numerical integration of the motion of the comet that allows for its gravitational interaction not just with the Sun but also with all the planets outside the Earth's orbit except Pluto (which is too small to matter).

In this simulation of the comet's motion, the gravitational forces are updated every notional three months. Inevitably, that technique reproduces many of the features of a chaotic system; the interval between successive approaches to perihelion jumps about, ranging from 127 years to more than 135 for example, while the authors acknowledge that there is little purpose in calculating the ephemeris of the comet beyond the next few orbits (or centuries).

No doubt that is also a prudent acknowledgement that, by the next apparition of Swift–Tuttle, there will be a still better description of the movement of the planets even than those now available, most spectacularly (on magnetic tape) at the Jet Propulsion Laboratory. Even so, the calculation of the past motion of Swift–Tuttle rests on a planetary ephemeris of 1970s vintage corrected to match later versions. Without a shadow of hesitation in their prose, the authors flatly say that there will not be a collision with the Earth at the next two apparitions, on 12 July 2126 and 11 August 2261.

That may be just as well, for the success with which the orbit of Swift–Tuttle accords with the ancient Chinese observations suggests that the comet is dynamically much less disturbed by the emission of gases under the influence of the Sun than is, for example, Halley's Comet (where the dynamical effect of outgassing adds several days to the period of the comet at each return). Swift–Tuttle is intrinsically as bright as Halley, suggesting that outgassing on the same scale has much less dynamical effect, most simply explained if the comet is much more massive than Halley.

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