Fig. 2.1 Two meteorites. Peter Jenniskens arrives to collect meteorites that fell from the asteroid 2008 HJ on to the Nubian Desert (NASA)

Chapter 2
When the Stars Fell Down

2008 TC3: THE ASTEROID THAT FELL TO EARTH

It is hard to determine from afar what minor planets are made of. But there has been one case in which a minor planet has been tracked in space, and was witnessed as a fireball as it hit Earth. Later, bits of meteorites have been recovered from its impact area and analyzed. That was the asteroid known as 2008 TC3 that fell to Earth on October 6–7, 2008.

2008 TC3 was discovered at 06:39 GMT on October 6, 2008, by Richard Kowalski, (7392) Kowalski, who was that night carrying out work for the Catalina Sky Survey with its 1.5-m (60-in.) telescope at Mount Lemmon, near Tucson, Arizona. Although targeted at larger asteroids, the Catalina Sky Survey also identifies smaller asteroids that approach near to Earth. To react quickly enough to nearby asteroids, astronomers have formed themselves into a loose organization of internet-based networks and mailing lists known as Spaceguard, to make observations so that the object's orbit can be calculated. In the 19 h following the discovery of 2008 TC3, 27 amateur and professional astronomers made over 1000 observations of it. Its orbit was quickly calculated by the University of Pisa and the Jet Propulsion Laboratory's Sentry system, which was created exactly for the purpose of tracking asteroids that might well collide with Earth. Within an hour of receiving the data, JPL predicted that the asteroid would enter Earth's atmosphere above northern Sudan around 02:46 GMT on October 7.

One key observation was made 16 h after its discovery and just 3 h before it entered Earth's shadow, disappeared from view and was destroyed. By chance astronomer Alan Fitzsimmons, (4985) Fitzsimmons, and his colleagues of Queen's University in Belfast, specialists in the study of asteroids, had been scheduled to use the 4.2-m William Herschel Telescope on La Palma in the Canary Islands—but one night too late. He telephoned Gavin Ramsay, who had been scheduled to use the telescope for the crucial period but to study binary stars. Exploiting the community spirit that exists among astronomers, Fitzsimmons explained the importance of an immediate observation of 2008 TC3. Ramsay was willing to give up that night and use the following night instead. Stuck in Belfast because of his teaching commitments, Fitzsimmons had sent his more junior team, Ph.D. student Sam Duddy and postdoctoral fellow Henry Hsieh, (17857) Hsieh, to La Palma. Fitzsimmons had to follow the work sitting on the sofa at home, marking exam papers while monitoring his laptop computer link to the telescope.

The astronomers moved the telescope to the right place, the position predicted for the asteroid for a few minutes' ahead of the time, expecting that after any necessary fine adjustments the telescope would be in the predicted place at the moment the asteroid arrived there. To their consternation they could not see the asteroid at all. The telescope's TV camera showed the star field where the telescope was pointing, but there were no new "stars"—no asteroid.

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Worried thoughts chased through their mind. Had they positioned the telescope incorrectly? Had something gone wrong with the orbital calculations? Had something gone astray as the positional data was transmitted to La Palma? Just as they were about to panic, their attention was caught by something moving onto the edge of the TV picture. The asteroid was venturing into the field of view of the telescope. It was the first time they had ever seen an asteroid moving so fast that they could see the motion just by looking. Usually the asteroids that they observe are millions of kilometers away; this one was thousands. Being so much closer, the asteroid was whizzing across the sky, just as, to someone lying on his or her back in the grass, a bee would fly quickly across their field of view while a jet aircraft, high up and a long way away, would seem to dawdle.

The observing team obtained a spectrum of 2008 TC3 that showed the asteroid was a type known as an F-type. The meaning of this classification was later established for the first time by ground study, when fragments of the asteroid were recovered from the Nubian Desert in the Sudan.

JENNISKENS: FINDING THE ALMAHATA SITTA METEORITES

The impact point of 2008 TC3 on Earth was established by the calculations of its orbit and refined through the testimony of eyewitnesses who saw the asteroid fall as a bolide or fireball. The pilot and co-pilot of KLM flight 592 flying over Chad saw a sudden yellow and red brightening of the sky about 1500 km (1000 miles) to the northeast over the Sudan. Bystanders in the city of Wadi Halfa described a rocket-like fireball that ended abruptly. Sensors aboard secret US government satellites monitoring for rocket launches and other possibly hostile activity first detected the fireball at 02:45 GMT as the asteroid entered the atmosphere at 65 km altitude (210,000 ft). (The US military had been warned about the imminent impact, in case they had misinterpreted the explosion.)

The fireball pulsed twice in brightness as it broke into pieces at 37 km (121,000 ft) and then faded away. Abdel Moniem Magzoub, the attendant at a railway station on the north-south railway line between Wadi Halfa and Khartoum, near where the asteroid fell, was awoken by the bright light of the first explosion, sat up, witnessed the fireball continue and saw the second, weaker, final explosion. A short time afterwards, he heard the explosions, the delay being the time for the sound to travel to the railway station. A European meteorological satellite, Meteosat, monitoring cloud- and dust-cover and temperature over Africa, saw the explosions and the cloud of hot meteorite dust that resulted from the break-up. As dawn broke over Wadi Halfa later that morning, a lingering wind-blown dust trail was visible in the sky, lit from below the horizon by the rising Sun.

An asteroid became a meteor. Did the meteor become meteorites? The only way to answer that was to find out if there were any meteorites strewn in the field below the bolide's trail. The search area was defined by combining the eyewitness accounts with orbit calculations from the Jet Propulsion Laboratory, and adding new calculations of the possible trajectory of the meteor as it curved and tumbled through the air. The search area was 28 sq. km (11 sq. miles) in extent, a long box aligned along the asteroid's roughly east-west trajectory. That is a large area to search for pieces of rock, but the search was facilitated by the fact that the Nubian Desert consists of rocky plains, interspersed with hills, rocky outcrops and sandy river valleys, relatively easy to traverse. The ground is light colored, with little vegetation in which the darker meteorites could hide.

The man who set out to find the meteorites was Peter Jenniskens, (42981) Jenniskens, a meteor astronomer with the SETI Institute in Mountain View, California. In December, 2008, Jenniskens joined the Sudanese environmentalist Muawia Shaddad of the University of Khartoum to carry out the search. Jenniskens traveled to the search area for 18 h in a bus from Khartoum with 45 students and staff from the university. The group lined up, 20 m (20 yards) between each person, in a row a kilometer (three quarters of a mile) long, and systematically swept the terrain. The participants walked 18 km (11 miles) each day for the 3-day search. The first meteorite was found by a student, Mohammed Alameen, 2 h into the search on December 6, 2008. It was a small, black stone which stood out on the light sand. It was found simply resting on the surface, with no crater, not even a depression. What happens to a small meteorite is that in the atmosphere it slows down, impeded by the air, eventually falling vertically at a moderate speed, with little drama.

Few people have actually seen a meteorite fall. One of the best documented early falls occurred near the village of Wold Newton near Scarborough in England. A pillar marks the spot where in 1795 a 17-year old ploughman, John Shipley, saw and heard a 25-kg (55-lb) meteorite impact on the ground 8 m (26 ft) away and was showered by earth from the 50-cm (1.6-ft) deep crater that it made. Shipley escaped without injury from this unexpected event but suddenly died in 1829. The headstone at his grave in the cemetery of the village church near to the fall draws a moral from the parallels between the sudden end to his life and his earlier narrow escape:

Erected
TO THE MEMORY OF JOHN SHIPLEY
WHO DEPARTED THIS LIFE
MAY 17TH 1829
AGED 51 YEARS

All you that do behold my stone
O: think how quickly I was gone:
death does not always warning give
therefore be careful how you live.

A much smaller meteorite fell in Glatton, Cambridgeshire in the United Kingdom on May 5, 1991, about 20 m (60 ft) from Mr. Arthur Pettifor, who was working in his back garden. He heard a whining noise and looked up to see the branches of conifers in a hedge disturbed by something falling through them. Beneath the conifers he found a single crusted stone weighing about 0.75 kg (1.5 lb). The stone had made a shallow depression, only about 2 cm (1 in.) deep. The stone was warm but not hot when first picked up.

The asteroid 2008 TC3 was about 4 m (13 ft) in size and had a mass of, probably, 80 m. tons. Evidently friction with the air on its passage through the atmosphere had dispersed much of it as dust, and the final fireball explosions had shattered what remained into small pieces, which fell gently.

The fragment found by Mohammed Alameen was logged, then wrapped in aluminum foil to prevent contamination from handling and secured. Further fragments were found in the next days, increasing in size along the track from small pebbles to egg-size pieces (the larger pieces of an exploding meteorite travel further). Jenniskens himself found some of the pieces and described the experience: "For a moment you realize that you are the first person to lay eyes on these rocks from space, laying there in the sand much the same as the day they fell on the ground," he said. Every find brought back that euphoric sense of discovery (Fig. 2.1).

The team found 250 fragments over those 3 days, strewn along 29 km (18 miles) of the meteor track, and the number doubled in further searches, adding to a total of 10 kg (22 lb). The meteorites are known collectively as the Almahata Sitta meteorite fall. Meteorites are named from the nearest place, and the name is Arabic for "Station Six," the train station, on the approach to which the largest fragments fell.

Asteroids are the leftovers from the formation of the terrestrial planets—Mercury, Venus, Earth and Mars. Some are, as it were, the off-cuts from the raw material that built up larger planets, and some are fragments and chips from collisions between planets. Most of the asteroids that we know have been jumbled together in the Main Belt, having been formed in different zones of the Solar System, condensing from material that had been partially separated into different compositions. From that varied start, the asteroids experienced different histories, interacting one with another, moving and separating into different orbits. The larger asteroids "differentiated": that is to say, as they were warmed by heat liberated in their interior by radioactivity, the minerals of which they were made plasticized, flowed, and separated into different zones in the body of the asteroid. If such an asteroid is shattered by a collision, its fragments vary in composition.

As a result of all this, asteroids are incredibly diverse. We can only view most asteroids from afar, visit rather few asteroids with robot spacecraft, retrieve small samples from an even smaller number (just one so far) and examine some bits of asteroids of unknown provenance that fell to Earth as meteorites. It is hard to make sense of it all. 2008 TC3 and the

Almahata Sitta meteorites are important because they are firmly linked, but we do not yet really know what to make of them. The meteorites are of a rare type known as ureilites, and 2008 TC3 was an F-class asteroid, which comprise only 1 % of the asteroid population. Astronomers are struggling to understand how these facts fit into the jigsaw-puzzle picture that will knit together asteroids and meteorites, mineral compositions and colors, orbits and distributions, shapes and sizes, and ultimately show how all the different kinds of minor planets originated.

There is one certainty in the conclusions that we might draw from the incident when 2008 TC3 fell. The asteroid revealed whether we could cope with a somewhat larger, death-dealing asteroid on an approach path. It showed that most of us would only be passive, impotent bystanders, listening to reports of what had already happened. Some of us would be more or less knowledgeable about what was about to happen—some astronomers, a few mathematicians, some whose jobs include surveillance of the world for peaceful and for military purposes, and, in the final seconds, some spectators who were simply in the right (or wrong) place at the right (or wrong) time. Most of us would be going about our everyday business, not knowing what is happening. At the present time, none of us could do anything effective about the situation; perhaps ignorance would be best. It is likely that we would have to react to problems rather than anticipate them, because disaster-planning for an asteroid strike is in a rudimentary state.

I know this because, when I worked at the British National Space Centre, I commissioned a report on the hazards associated with asteroid impact and witnessed the government response. The report's authors, responsible public figures, produced a careful, reasoned assessment of the risks. I had thought that the Home Office, the government department in the UK responsible for public safety, would respond by using the report as the basis for the production of a plan of what it would do, nuanced, realistic and proportionate. It could have analyzed the potential hazards according to the size of the asteroid. Few defensive measures are currently available to divert a very large asteroid on a collision course with Earth, although we might get warning far in advance. Mitigation after impact would have to be very wide-ranging and long-lasting, so specific measures may be inappropriate. In any case, the risk that a very large asteroid will impact Earth during the lifetime of people alive today is now known to be small, since most large asteroids have been found by recent surveys, and their orbits are well-enough determined to say that none of the big ones are likely to collide with Earth soon. At the other extreme of the size range, small asteroids such as 2008 TC3, can be seen only when close and arrive quickly, but these are generally harmless. Between the two sizes, however, the risk is real; there are numerous asteroids known to constitute a hazard. The damage they might cause will vary according to the height of the fall, and whether the asteroid falls onto ground or into the sea. Notice of the potential impact will vary too, from hours to years, depending on how far away the asteroid can be detected and from which direction it approaches. These factors indicate what could be done as mitigation in each combination of circumstances. For example, is a tsunami likely? On which coasts? Is it practical to evacuate the vulnerable coasts, or would this cause more casualties than the tsunami? If the parameters of the impact were analyzed, a disaster response plan could be drawn up, and filed, to be taken out and used as and when necessary.

In fact, the Home Office washed its hands of the report, and said only that it would rely on the local emergency services to act appropriately. It decided to do nothing at all. The plan, such as it was, was not much more sophisticated than a decision that, if an asteroid plunged onto British soil, the Home Office would send a bobby around on a bicycle.

55P/TEMPEL–TUTTLE: SOURCE OF THE LEONIDS

The impact of an asteroid with Earth is potentially momentous but, in miniature, beautiful. I have stood under a night sky, awestruck, gazing up at showers of meteors zipping through the air some tens of kilo meters (many thousands of feet) above me, miniscule versions of a death-dealing asteroid impact. Likewise, I have stood on an island on the edge of Victoria Falls, dizzy from the noise and motion, watching the Zambezi River thundering over the sheer drop meters from my feet, falling 100 m down into rapids hidden by the spray. And I have stood in the radiant heat, close to a creaking stream of red-hot lava flowing from the volcano, Kilauea, down into the steaming sea near Kalapana on the Big Island of Hawaii. All these streams were beautiful and awe-inspiring natural sights, the more exciting because of the proximity of danger, even death.

On a normal night there might be half a dozen sporadic meteors per hour. They streak through the sky in random directions. But at certain times of the year there are showers of meteors, anything up to tens of thousands of meteors per hour, that all appear to come from the same point in the sky. The meteors of a shower have a common origin, a single meteoroid stream through the Solar System—small grains of dust, up to pebble-sized stones, moving together on the same orbit. There are lots of these streams crisscrossing the Solar System, and meteor showers arise from those streams that happen to intersect Earth's orbit. Earth passes through the river of tiny asteroids. The intersection of the orbit of Earth and the orbit of the meteoroid, each passing at high speed, causes the dust and stones to streak into Earth's atmosphere. The meteoroid compresses the air, which heats up, just as air squashed in a bicycle pump gets hot. The meteoroid itself heats. Atoms of air (nitrogen, oxygen and the like) and atoms from the solid material of the meteoroid (sodium, in particular) are damaged, some of their electrons splitting off. As the electrons recombine into their parent atoms they emit light, which shows as a meteor trail.

Since the meteoroids travel in parallel tracks along their orbit, the meteors appear to radiate from the same point, just as, through the phenomenon of perspective, parallel railway tracks radiate from a point on the horizon. The point in the sky from which the meteors of a shower seem to originate is called the radiant. It lies in some constellation or other and that constellation gives the shower its name, such as the Leonids, which radiate from the constellation Leo, and the Geminids, which radiate from Gemini.

Each meteor stream remains more or less stationary in the Solar System. This means that, if Earth's orbit intersects one, it passes through the stream, taking a few hours or days to pass through at the same time each year, on the same date.

The Leonids can be the most dramatic meteor shower. They recur reliably, every year, between November 15 and 20, but the shower is more dramatic some years than others, because, while the Leonid meteoroids litter the entirety of their orbital track, there is a dense clump of meteoroids orbiting in a cloud, and, most years, Earth misses the cloud. The cloud is in the vicinity of Earth once per orbital period of 33 years. The Leonid meteor shower of November 1833 was quite spectacular, peaking at 1000 meteors per minute. It was best seen from North America and was recorded by Native Americans. The Sioux tribes keep a calendar by naming each year after a notable event, and 1833/34 was called "stars all falling down year," adding: "They feared the Great Spirit had lost control over his creation."

The same shower was witnessed by President Abraham Lincoln, (3153) Lincoln. According to the American essayist Walt Whitman, Lincoln was asked by a White House guest whether the Union would survive the ongoing Civil War. He replied:

> *When I was a young man in Illinois, I boarded for a time with a Deacon of the Presbyterian church. One night [in 1833] I was roused from my sleep by a rap at the door, & I heard the Deacon's voice exclaiming "Arise, Abraham, the day of judgment has come!" I sprang from my bed & rushed to the window, and saw the stars falling in great showers! But looking back of them in the heavens I saw all the grand old constellations with which I was so well acquainted, fixed and true in their places. Gentlemen, the world did not come to an end then, nor will the Union now.*

The same meteor shower inspired the 1934 jazz standard "Stars Fell on Alabama."

Analyzing this shower, two Yale University scientists, Denison Olmsted and Alexander Catlin Twining identified the radiant and explained it as the orbital path of the meteoroid stream. Later, Hubert Newton listed historical records of the shower back to AD 902 and calculated the orbital period of the meteoroids at 33 years.

The connection between the Leonids and a comet came a generation later with the discovery of Comet 55P/Tempel-Tuttle. This comet is the 55th that was found to be periodic (hence the "55P" in its designation) and was co-discovered by two astronomers, after whose names it is called. Wilhelm Tempel, (3808) Tempel, was an amateur astronomer who devoted his time and his earnings as a lithographer to his study of astronomy, during the course of which, as I will tell later, he discovered a number of asteroids and other celestial novelties. He discovered the comet late in 1865.

Within a month the comet was independently discovered by Horace Parnell Tuttle, (5036) Tuttle. Tuttle was an assistant astronomer at Harvard College Observatory, with a colorful career. He started work, unpaid, at Harvard in 1857. In his first year there, aged 20, he found four comets, an achievement for which he was awarded the Lalande Prize by the French Academy of Sciences. When the American Civil War started in 1861, Tuttle joined the Union Army, then within a year transferred to the Navy as a paymaster. He served on *USS Catskill* and was engaged in the capture of the British blockade runner *Deer* as it carried Confederate supplies into Charleston harbor, but he continued to hunt for and observe comets, sweeping the sky with his telescope when he could, from the decks of his ships.

After the war, Tuttle returned to Harvard and discovered Comet 55P/Tempel-Tuttle. His career crashed ten years later, in 1875. In the relative calm after the Civil War, after the military urgency, there was time for the Navy to audit its account book, and Tuttle's were found to be wanting. In particular, he had illegally cashed a large Navy check, falsely claiming that most of the money had been stolen by others. He was court martialed and convicted of embezzlement and "scandalous conduct tending to the destruction of good morals." He was dishonorably discharged from the Navy. Despite this, he was taken back into government service with the US Geographical and Geological Survey, helping to establish the boundary between Wyoming and Dakota, and then into the US Naval Observatory, from where he found one last comet in 1888. Altogether he discovered eight comets and two asteroids, (66) Maja and (73) Klytia. Penniless, he died in 1893.

Comet 55P/Tempel-Tuttle was seen briefly in 1865-66, long enough for the general features of its orbit to be measured but not long enough for an accurate orbit to be calculated. Hence the comet was lost and missed on two returns in 1899 and 1932. It was recovered in 1965, with help given by the discovery that the comet had been previously seen in close approaches to Earth in 1366 and 1699. This enabled Joachim Schubart (b. 1928; (1911) Schubart), of the Astronomisches Rechen-Institut in Heidelberg, to predict its return in 1965.

In 1867, the Italian astronomer Giovanni Schiaparelli, (4062) Schiaparelli, realized that the orbit of Comet 55P/Tempel-Tuttle, computed after the comet's apparition of 1865, matched the orbits of the Leonid meteors. The icy body of the comet followed the same path as the tiny bits of dust that made the meteors. The comet was the parent body of the Leonids.

Comets are essentially "dirty snowballs." They are made of bits of dust held together by ice. In the heat of the Sun, the ice vaporizes. The comet releases the dust in a tail, which litters the path of the comet with small meteoroids, which continue in orbits parallel to the orbit of the comet. The dust particles become meteors when, on falling to Earth, they become incandescent by friction with the air, as outlined above.

PHAETHON: DEAD SOURCE OF THE GEMINIDS

The Geminids are another meteor shower, usually visible around December 13–14, with about 150 meteors per hour. The shower suddenly appeared in 1862, and its origin was unknown until 1983. In that year an asteroid, provisionally designated 1983 TB, was discovered by British astronomers Simon Green, (9831) Simongreen, and John Davies, (9064) Johndavies, who were searching data from the infrared sensitive telescope on the Infra-Red Astronomy Satellite, IRAS.

Green was a Ph.D. student and Davies was a post-doctoral fellow, both of them working with the data stream that came from IRAS to the scientists through the Rutherford-Appleton Laboratory ground station. In each 100-min orbit, IRAS scanned the sky in a strip, using detectors that followed one another in succession in the same scan, seconds apart. Large enough signals were automatically extracted from the data as possible stars and galaxies. There was always the possibility that some glitch in the electronics or software had created spurious signals, so only signals seen twice in succession at the same place seconds apart were regarded as possibly real celestial sources. Indeed, the scans made during consecutive orbits of the satellite were made to overlap by 50 %, and only if there were signals at the same place, both seconds apart and orbits apart, was the celestial source regarded as confirmed to be real.

At each stage of processing, the signals that were detected but rejected were listed, and Green's and Davies's job was to search the rejected signals for sources that were actually real but moving in a consistent trajectory, displaced by seconds and then by 100 min. Sources moving too fast were space junk (bits of broken spacecraft and rockets orbiting Earth), but sources moving at the right rate could be asteroids or comets, warmed by the Sun so they give out infrared radiation. The job to find them had to be done as soon as the data came in, so that they could be followed up in other investigations.

Almost every day, one of Green and Davies sat in a temporary cabin at the ground station, sifting through long lists of computer printout. The pair of astronomers were under strong pressure to ensure that an object was real by getting someone on a list of pre-arranged collaborators who all had access to ground-based telescopes to confirm it before communicating about it to the world at large. The pressure was particularly strong about the first object they found, because no one could be sure about the processes that they had built up for the analysis. It turned out to be Comet IRAS-Araki-Alcock, a real comet, so the techniques had worked, and everyone was relieved.

Phaethon was the first rapidly moving asteroid that they found and confirmed. They were themselves convinced there were many more before this in data that were not convincing enough for other people to believe. As it happened, Phaethon was moving in the same direction that IRAS advanced its scan strip, so the asteroid got hit on a number of consecutive orbits, so it was a pretty good detection, even without the ground-based confirmation. When Green first saw Phaethon, he was determined not to lose it, so he immediately telephoned the first observatory westwards that was under nighttime skies. It was the Palomar Schmidt Telescope, and Charles Kowal was observing. He took down the coordinates and went straight to the right spot to find it.

When the discovery was published, Harvard astronomer Fred Whipple, (1940) Whipple, noticed that the orbit of the asteroid was virtually the same as the orbits of Geminid meteors. Their parent body had been discovered—not a comet but an asteroid that has never shown any strong signs of being a comet. For example, it has never had a tail, not even a small one. Some of Phaethon's properties are more consistent with it being a rocky body, but in 2009 it increased in brightness as it passed the point in its orbit near to the Sun. Maybe it is an asteroid with more ice than usual, or a comet with more rock than usual, perhaps a transitional object mid-way between the two kinds of objects. Or maybe it is a comet that has been past the Sun so often that nearly all the ice has vaporized. Or maybe it is an asteroid that is responding to its extreme orbit: perhaps it experiences such intense heat at its nearest approach to the Sun that its surface cracks, releasing rock and dust particles, similar to but much more extreme than, the freeze-thaw action on rocks on Earth, which, as I write in a cold winter, is cracking and flaking scallops of brick off the wall in my garden.

The beauty of a meteor shower distracts us from the implicit danger. The shower reveals that Earth passes through a path of meteoroids littered along an orbit. The litter of meteoroids has been dropped by a minor planet or comet, which orbits somewhere within the meteoroids and which, like the meteoroids, passes close to Earth. Just as wrappers dropped by cars make a path of litter that is wider than the road, the meteoroids form a thick cloud, within which the minor planet or comet tracks, a small lump within a thick tube of dust. Phaethon passes close to Earth, in the middle of a tube of Geminids, but major impact is not inevitable. The minor planet is certainly potentially hazardous. It would certainly constitute a danger if, at 5 km (3 miles) in diameter, Phaethon were to strike Earth. The same is true for Comet 55P/Tempel-Tuttle.

Phaethon not only passes close to Earth, it also passes very close to the Sun, within 0.140 times the distance of Earth from the Sun. One of Green's colleagues at Leicester University, Nick Eaton, came up with the name for the asteroid, based on the facts about its orbit. In Greek mythology, Phaethon's father, Helios (the Greek equivalent of the Roman sun god Apollo), offered to give his son anything he should ask. Phaethon asked to drive the chariot on which Helios carried the Sun in its course across the sky from day to day. Helios was reluctant to let Phaethon do this, because of the danger—the chariot was hot and its horses exhaled flames—but he had to keep his promise. Phaethon was unable to control the horses, and the chariot careened out of control, moving too high so that Earth grew cold, then too close to Earth so that it burned, creating deserts, drying lakes and rivers, charring Africans black. The mythological trajectory of the chariot seemed to fit the extraordinary orbit of the asteroid and to make the name apt.

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