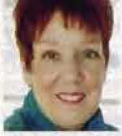


 BY MARCIA BARTUSIAK

Comet Tale

How Edmund Halley validated Isaac Newton

Some repeatedly come and go with the precision of a clock. Others arrive unexpectedly at our cosmic doorstep, providing a few days or weeks of nighttime entertainment, only to disappear into deep space and never return. And a few, like our visitor last November, fizzle out altogether.

For centuries, people both feared and revered comets. For many they were harbingers of disaster, their long tails sweeping across the sky like a fiery sword, symbol of death and destruction. But to others they were messengers of good news. Shortly after Julius Caesar's assassination in 44 BC, a comet appeared in the sky that was so luminous it could be seen in broad daylight, a rare feat for a comet (it has only happened nine times in the last three centuries). Caesar's successor, Augustus, wrote that this brilliant star signified "that the Soul of Caesar was received among the Divine powers of the immortal Gods."

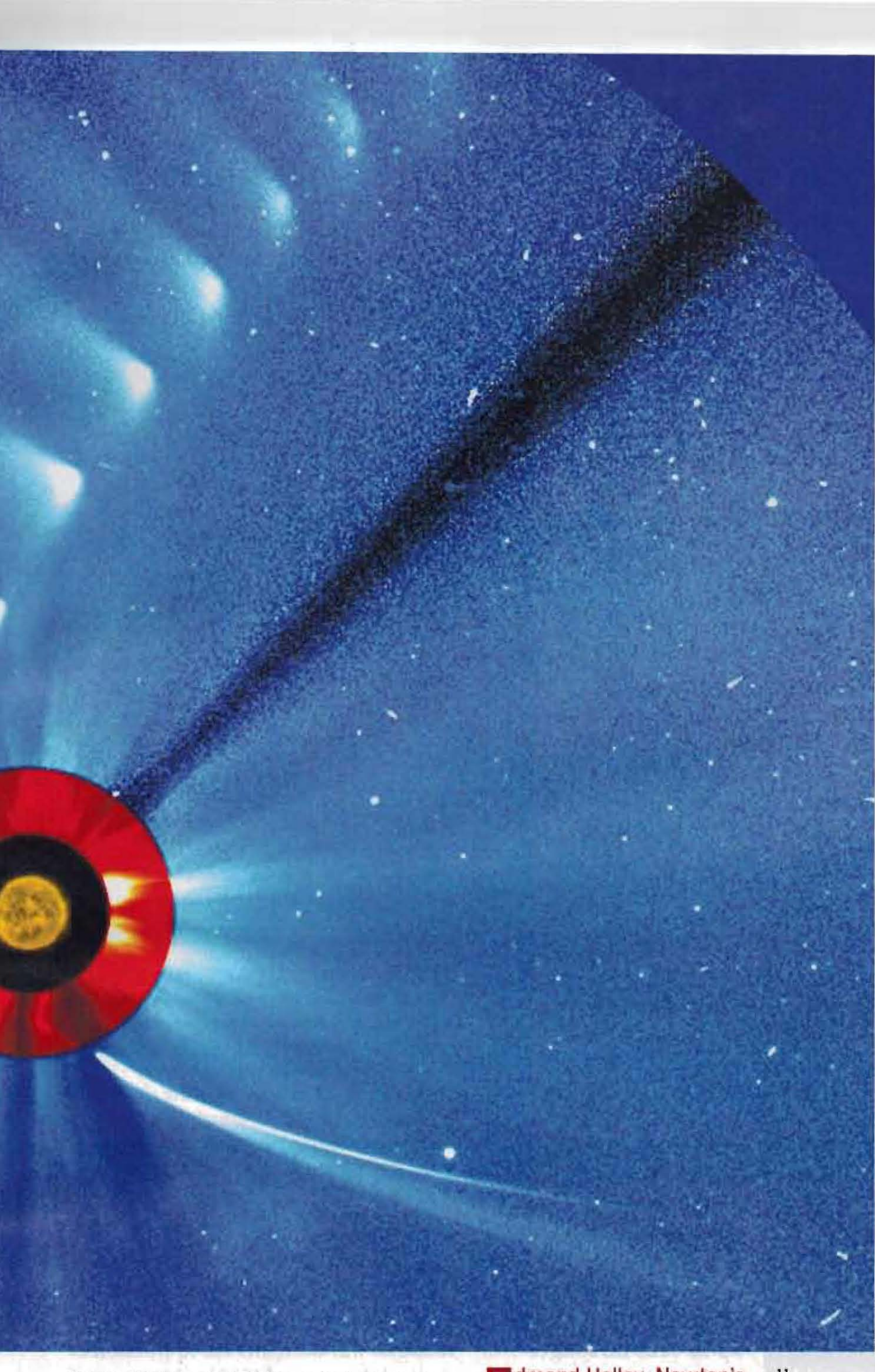
Humanity had to await the Age of Enlightenment for a more reasoned explanation of a comet's nature. It appeared in the grand finale of the *Principia,* Isaac Newton's masterful treatise on gravitation published in 1687. There, in his closing chapter, Newton laid out his mathematical theory of the motion of comets, an effort, he told a colleague, that was "the most difficult of the whole book."

Newton had been inspired by the appearance of a spectacular comet in 1680, the first comet to be discovered with a telescope. In the *Principia* Newton traces the path of this comet across the constellations during the months it was visible. A diagram he included in his book was the first figure in astronomical history to show a comet completely swinging around the Sun, owing to gravity. Before that, observers were not sure that a comet approaching the Sun was actually the same object seen later to fly away from it. Newton had accurately determined that "comets are a kind of planet and revolve in their orbits with a continual motion." Their paths could be in the form of a very elongated ellipse, similar to a planet's, or an open hyperbola. In that case, the comet would forever depart from the solar system.

Newton also concluded that the comet was "solid, compact, fixed, and durable," just like the bodies of planets. "For if comets were nothing other than vapors or exhalations of the earth, the sun, and the planets," he wrote, "this one ought to have dissipated at once during its passage through the vicinity of the sun." And the tail? Hardly more mysterious than an "extremely thin vapor that the head or nucleus of the comet emits" when heated by the Sun. Comets were not omens of doom, Newton was saying, but simply small planetoids. Nothing to be afraid of.

More problematic to his fellow scientists was Newton's law of gravity itself. His mathematics implied that imperceptible ribbons of attraction somehow radiated over distances, both long and short, to keep moon to planet and boulder to Earth. For many, this feat appeared more resonant with the occult than science. Johannes Kepler in the early 1600s had suggested that threads of magnetic force emanating from the Sun were responsible for pushing the planets around. A little later the French philosopher René Descartes visualized the planets carried around like leaves trapped within a swirling whirlpool by vortices of *aether*, the tenuous substance then thought to permeate the heavens.

Newton's critics demanded a physical mechanism. What was replacing either magnetism or vortices? This led to Newton's famous statement in the *Principia*: "I have not as yet been able to deduce from phenomena the reason for these properties of gravity, and I do not feign hypotheses." Newton did not want to stoop to speculating or conjuring up some kind of hidden cosmic machinery. It was



ESA/NASA

Comet ISON moves in from the bottom right, around the sun (yellow center), and out toward the upper right, in a time-lapse image from NASA's Solar and Heliospheric Observatory.

enough for him that his laws allowed successful calculations to be made.

Total acceptance took a while, but as the years passed, the rest of the physics community did eventually come over to Newton's side. And it was a comet, of all things, that provided the incentive.

Edmond Halley, Newton's colleague at the Royal Society of London, had used his friend's mathematical laws to make the first prediction of a comet's return. After poring over historic records, Halley compiled a list of twenty-four comets observed from 1337 to 1698 and computed their motions. Looking over this record he came to recognize that a comet sighted in 1682 had much in common with comets previously observed in 1531 and 1607. For one, they shared the same orbital characteristics (all went around the Sun in the opposite direction to the planets). This made him suspect it was the same comet returning every 75 to 76 years. "The space between the Sun and the fixed stars is so immense," he wrote, "that there is room enough for a comet to revolve, though the period of its revolution be vastly long."

Based on his calculations, which took into account the additional tugs by Jupiter in the comet's journey through the solar system, Halley made a prediction. "I dare venture to foretell," he announced in his 1705 paper, "that it will return again in the year 1758."

The comet appeared on schedule, just as Halley foretold. On Christmas Day in 1758, thirty-one years after Newton's death and sixteen years after Halley's, an amateur astronomer and gentleman farmer in Saxony named Johann Georg Palitzsch was the first to catch sight of the comet as a nebulous star in the nighttime sky. French observer Charles Messier, already on the lookout for the comet, saw the same fuzzy object four weeks later from Paris. It was soon confirmed to be Halley's returnee, and by March the comet was rounding the Sun.

The public was bedazzled, and the critics of Newton's controversial law of gravity were instantly silenced. Despite its lack of a mechanism, that law was at last triumphant among both scientists and the public. Who could argue with a theory that allowed for a spot-on prediction about the solar system's behavior nearly a century in advance?

The universe came to be viewed as intrinsically knowable, ticking away like a well-oiled timepiece. And Halley's name became forever linked to a periodic celestial visitor.

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