**On Prediction in Science**

In order to bring into proper focus the significance of correct prediction in science, I offer at the start a short survey of the most celebrated cases, and it is not by chance that almost all of them come from the domain of astronomy. These cases are spectacular and, with one or two exceptions, are well known.

The story of scientific “clairvoyance” in modern astronomy starts with Johannes Kepler, a strange case and little known. When Galileo, using the telescope he had built after the model of an instrument invented by a Danish craftsman, discovered the satellites circling Jupiter, Kepler became very eager to see the satellites himself and begged in letters to have an instrument sent to Prague; Galileo did not even answer him. Next, Galileo made two more discoveries, but before publishing them in a book, he assured himself of priority by composing cryptograms, not an uncommon procedure in those days: statements written in Latin were deliberately reduced to the letters of which the sentences were composed, or, if the author of the cryptogram so wished, the letters were re-assembled to make a different sentence. The second way was chosen by Galileo when he thought he had discovered that Saturn is “a triple” planet, having observed appendices on both sides of Saturn, but not having discerned that they were but a ring around the planet, a discovery reserved for Christian Huygens in 1659, half a century later. Kepler tried to read the cryptogram of letters recombined into a non-revealing sentence, but did not succeed. He offered as his solution: “Salute, fiery twin, offspring of Mars” (“Salve, umbistineum geminatum Martia proles” ). Of this, Arthur Koestler in *The Sleepwalkers* (1959) wrote (p. 377): “He [Kepler] accordingly believed that Galileo had discovered two moons around Mars.” But Galileo did not discover them and they remained undiscovered for more than two hundred fifty years. Strangely, Koestler passes over the incident without expressing wonder at Kepler’s seeming prescience.

As I have shown in *Worlds in Collision* (“The Steeds of Mars” ) the poets Homer and Virgil knew of the trabants of Mars, visualized as his steeds, named Deimos (Terror) and Phobos (Rout). Kepler referred to the satellites of Mars as being “burning” or “flaming” , the same way the ancients had referred to the steeds of Mars.

Ancient lore preserved traditions from the time when Mars, Ares of the Greeks, was followed and preceded by swiftly circling satellites with their blazing manes. “When Mars was very close to the earth, its two trabants were visible. They rushed in front of and around Mars; in the disturbances that took place, they probably snatched some of Mars’ atmosphere, dispersed as it was, and appeared with gleaming manes” *(Worlds in Collision,* p. 230).

Next, Galileo made the discovery that Venus shows phases, as the Moon does. This time he secured his secret by locking it in a cryptogram of a mere collection of letters—so many A’s, so many B’s, and so on. Kepler again tried to read the cryptogram and came up with the sentence: “Macula rufa in Jove est gyratur mathem etc.” which in translation reads: “There is a red spot in Jupiter which rotates mathematically.”

The wondrous thing is: how could Kepler have known of the red spot in Jupiter, then not yet discovered? It was discovered by J. D. Cassini in the 1660’s, after the time of Kepler and Galileo. Kepler’s assumption that Galileo had discovered a red spot in Jupiter amazes and defies every statistical chance of being a mere guess. But the possibility is not excluded that Kepler found the information in some Arab author or some other source, possibly of Babylonian or Chinese origin. Kepler did not disclose what the basis of his reference to the red spot of Jupiter was — he could not have arrived at it either by logic and deduction or by sheer guesswork. A scientific prediction must follow from a theory as a logical consequence. Kepler had no theory on that. It is asserted that the Chinese observed solar spots many centuries before Galileo did with his telescope. Observing solar spots, the ancients could have conceivably observed the Jovian red spot, too. Jesuit scholars traveled in the early 17th century to China to study Chinese achievements in astronomy.

Kepler was well versed in ancient writings, also knowledgeable in medieval Arab authors; for instance, he quoted Arzachel to support the view that in ancient times Babylon must have been situated two and a half degrees more to the north, and this on the basis of the data on the duration of the longest and shortest days in the year as registered in ancient Babylon.[1](http://www.varchive.org/ce/predict.htm%22%20%5Cl%20%221)

Jonathan Swift, in his *Gulliver’s Travels* (1726) tells of the astronomers of the imaginary land of the Laputans who asserted they had discovered that the planet Mars has “two lesser stars, or satellites, which revolve about Mars, whereof the innermost is distant from the center of the primary planet exactly three of [its] diameters, and the outermost Five; the former revolves in the space of ten hours, and the latter in twenty-one-and-a-half; so that the squares of their periodical times are very near in the same proportion with the cubes of their distance from the center of Mars, which evidently shows them to be governed by the same law of gravitation that influences the other heavenly bodies.”

About this passage a literature of no mean number of authors grew in the years after 1877, when Asaph Hall, a New England carpenter turned astronomer, discovered the two trabants of Mars. They are between five and ten miles in diameter. They revolve on orbits close to their primary and in very short times: actually the inner one, Phobos, makes more than three revolutions in the time it takes Mars to complete one rotation on its axis; and were there intelligent beings on Mars they would need to count two different months according to the number of satellites (this is no special case — Jupiter has twelve moons and Saturn ten\*), and also observe one moon ending its month three times in one Martian day. It is a singular case in the solar system among the natural satellites that a moon completes one revolution before its primary finishes one rotation.

 Swift ascribed to the Laputans some amazing knowledge—actually he himself displayed, it is claimed, an unusual gift of foreknowledge. The chorus of wonderment can be heard in the evaluation of C. P. Olivier in his article “Mars” written for the *Encyclopedia Americana* (1943):

“When it is noted how very close Swift came to the truth, not only in merely predicting two small moons but also the salient features of their orbits, there seems little doubt that this is the most astounding ’prophecy’ of the past thousand years as to whose full authenticity there is not a shadow of doubt.”

The passage in Kepler is little known—Olivier, like other writers on the subject of Swift’s divination, was unaware of it, and the case of Swift’s prophecy appears astounding: the number of satellites, their close distances to the body of the planet, and their swift revolutions are stated in a book printed one hundred and fifty years to the year before the discovery of Asaph Hall.

Let us examine the case. Swift, being an ecclesiastical dignitary and a scholar, not just a satirist, could have learned of Kepler’s passage about two satellites of Mars; he could also have learned of them in Homer and Virgil where they are described in poetic language (actually, Asaph Hall named the discovered satellites by the very names the flaming trabants of Mars were known by from Homer and Virgil); and it is also not inconceivable that Swift learned of them in some old manuscript dating from the Middle Ages and relating some ancient knowledge from Arabian, or Persian, or Hindu, or Chinese sources. To this day an enormous number of medieval manuscripts have not seen publication and in the days of Newton (Swift published *Gulliver’s Travels* in the year Newton was to die), as we know from Newton’s own studies in ancient lore, for every published tome there was a multiplicity of unpublished classical, medieval, and Renaissance texts.

That Swift knew Kepler’s laws, he himself gave testimony, and this in the very passage that concerns us: “. . . so that the squares of their periodical times are very near in the same proportion with the cubes of their distance from the center of Mars” is the Third Law of Kepler.

But even if we assume that Swift knew nothing apart from the laws of Kepler to make his guess, how rare would be such a guess of the existence of two Martian satellites and of their short orbits and periods? As to their number, in 1726 there were known to exist: five satellites of Saturn, four of Jupiter, one of Earth, and none of Venus. Guessing, one could reasonably say: none, one, two, three, four, or five. The chance of hitting on the right Figure was one in six, or the chance of any one side of a die’s coming up in a throw. The smallness of the guessed satellites would necessarily follow from their not having been discovered in the age of Newton. Their proximity to the parent planet and their short periods of revolution were but one guess, not two, by anybody who knew of the work of Newton and Kepler. The nearness of the satellites to the primary could have been assumed on the basis of what was known about the satellites of Jupiter and Saturn, lo, one of the Galilean (or Medicean) satellites of Jupiter, revolves around the giant planet in I day 18.5 hours (the satellite closest to Jupiter was discovered in 1892 by Barnard and is known as the “fifth satellite” in order of discovery; it revolves around Jupiter, a planet ten thousand times the size of Mars, in 1 1.9 hours). The three satellites of Saturn discovered by Cassini before the days of Swift - Tethys, Dione and Rhea - revolve respectively in I day 21.3 hours, 2 days 17 hours, and 4 days 12.4 hours. (Mimas and Enceladus, discovered by Herschelin 1789, revolve in 22. 6 hours and I day 8.9 hours.) The far removed satellites of Jupiter were not yet discovered in the days of Newton and Swift.

It remains to compare the figures of Swift with those of Hall: there was no true agreement between what the former wrote in his novel and what the latter found through his telescope. For Deimos, Swift’s figure, expressed in miles from the surface of Mars, is 18,900 miles; actually it is 12,500 miles; Swift gave its revolution time as 21.5 hours—actually it is 30.3 hours. For Phobos, Swift’s figures are 10,500 miles from the surface and 10 hours revolution period, whereas the true Figures are 3,700 miles and 7.65 hours. Remarkable remains the fact that for the inner satellite Swift assumed a period of revolution, though not what it is, but shorter than the Martian period of rotation, which is true. However, Swift did not know the rotational period of Mars and therefore he was not aware of the uniqueness of his figure. If he were to calculate as an astronomer should, he would either have decreased the distance separating the inner satellite from Mars - a distance for which he gave thrice its true value - or increased its revolution period to comply with the Keplerian laws by assuming the specific weight of Mars as comparable with that of Earth. But Swift had no ambitions toward scientific inquiry in his satirical novel.

 **References**

1. The reference is found in the collected works of Kepler *(Astronomica opera omnia,* ed. C. Frisch, vol. VI, p. 557) published in 1866.