Satellites of Asteroids Coming into Vogue

Astronomers agree now that such satellites can exist, but skeptics argue that the evidence is still only suggestive, not conclusive

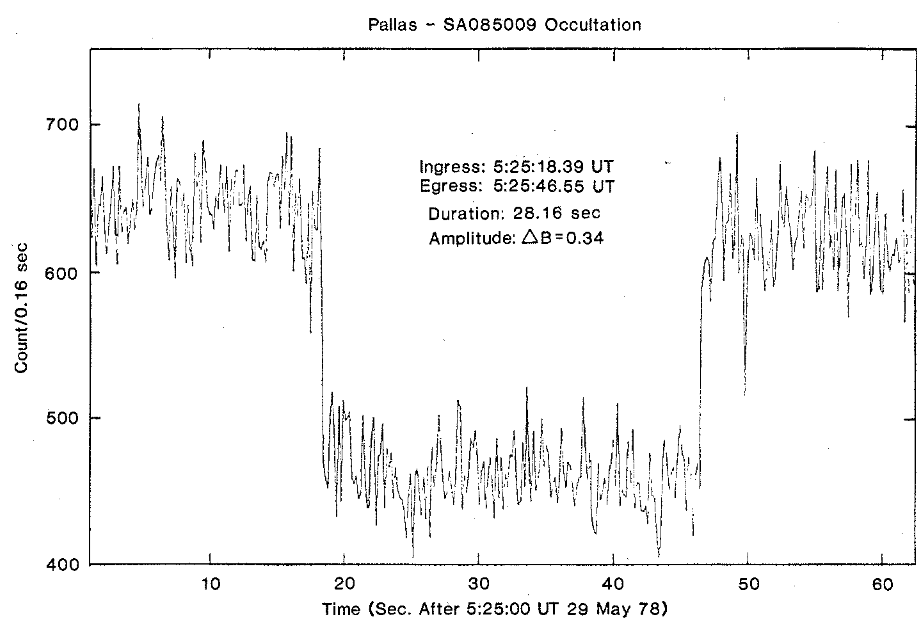
Until a few years ago, astronomers believed that asteroids travel alone about the solar system, unaccompanied by satellite companions. No one had seen anything to convince them otherwise, and, besides, everyone knew that such tiny systems would be inherently unstable. Then observers studying the sizes and shapes of asteroids began reporting some curious observations. They said that, while watching asteroids pass briefly in front of stars, something besides the known asteroid would at times block out the star as well. Was that something a satellite of the asteroid?

The astronomical community has not made up its mind. Observers now agree, after consultation with theorists, that asteroidal satellites would be dynamically stable. But the observational evidence for their existence remains contentious. A few researchers consider the evidence conclusive, some others think it highly suggestive, but many question whether any meaningful data supporting their existence have been collected yet. At a minimum, these skeptics say, many of the observations of star occultations by supposed asteroidal satellites must be in error. While occultation observers are seeking more definitive data, a technique new to the study of asteroids, called speckle interferometry, may help resolve the question for them.

The possibility that asteroidal satellites may exist has been discussed for at least 50 years, but the few suggestive observations, being of poor quality, did not impress researchers. In addition, notes Harold Reitsema of the University of Arizona, there "was a common belief among astronomers that asteroid-satellite systems would not be stable enough" to persist. Apparently, he says, nobody asked theoreticians for their opinion. Since the time of Newton, Alan Harris of the Jet Propulsion Laboratory points out, theoreticians have known that even miniscule bodies in the solar system can have satellites, as long as all is on the proper scale. If the density of the body remains constant, the scaling depends only on its radius. Harris cites the example of a bowling ball. If it were orbiting about the sun in the asteroid belt, a bowling ball could have a pebble orbiting it as far away as a few hundred radii, or about 50 meters. If the pebble were any farther out, the sun's gravity would grab the pebble away from the bowling ball.

Determining how satellites of asteroids might originate has not been so straightforward, but astronomers do not now consider that a problem. Harris believes that multiple asteroid systems could have survived tidal disruption, as well as possible collisions, since the formation of the solar system 4.5 billion years ago. Clark Chapman of the Planetary Science Institute in Tucson, Arizona, suggests that, rather than forming along with the satellite systems of the planets, asteroidal satellites might have formed later from collisions between asteroids. A number of uncertainties are involved in any calculation, he says, but if an asteroid 100 kilometers wide, for example, were already spinning and then were hit off-center by an asteroid of similar size at a speed of 5 kilometers per second, some of the debris from the collision could go into orbit around the asteroid. Perhaps 1 to 10 percent of today's asteroids could be at this stage, he says, as they evolve toward complete destruction.

None of this theoretical support would have been developed had it not been for the surge of interest that followed the serendipitous observation of a suspected satellite of the asteroid Herculina in 1978 (*Science*, 11 August 1978, p. 516); this was the first such report taken at all seriously by researchers. The seminal observation came as Edward Bowell of Lowell Observatory in Flagstaff and Michael A'Hearn of the University of Maryland waited at Lowell for the predicted occultation of a star by Herculina. Instead of recording a single disappearance of the star, their photoelectric detector recorded two distinct drops in brightness. One was the predicted occul-



Occultation by an asteroid—and by a satellite?

A photoelectric record (brightness versus time) of a stellar occultation by the asteroid Pallas, obtained by Richard Radick at the University of Illinois's Prairie Observatory. The primary event, when Pallas obscured the star, appears from 18 to 47 seconds. The secondary event, a possible occultation by an unknown satellite of Pallas, appears 3 seconds later (at about 50 seconds). This record presents only averaged data, but in the highest resolution record the pointed spike of the secondary event actually has several points at the same brightness level as the true occultation. [*Source:* *Richard Radick*]

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tation. The other, lasting about 5 seconds, preceded the predicted event by about 2 minutes. Bowell and A'Hearn took particular interest in this secondary drop when James McMahon, an amateur observer, reported a similar experience. While waiting near Boron, California, to make visual observations through a small, portable telescope of the same occultation, McMahon also saw a secondary event of about the same duration and at the right time to coincide with the Lowell secondary event.

"Taken at face value," Bowell says, the observations "pretty strongly indicate the presence of a secondary body at Herculina." An unseen satellite, to be responsible for the secondary event, would have to be at least 45 kilometers in diameter, a quarter of the size of Herculina, and at an apparent distance of 990 kilometers from the asteroid at the time.

Once the Herculina event caught the attention of observers, apparent secondary occultations became a bit more respectable—and more commonly reported. New reports of both visual and photoelectric observations came from amateurs and professionals alike. A positive report, made on the basis of photographs, has arrived from as far away as the Purple Mountain Observatory in the People's Republic of China. Researchers there have submitted a paper to the American astronomical journal *Icarus* claiming that they have discovered a bulge on the photographic image of the asteroid Metis, which they take to be a 60-kilometer satellite at a distance of 1100 kilometers from Metis. By identifying the bulge seven times over a few months, they found that it circles Metis every 4.6 days. According to David Dunham, an astronomer at Computer Sciences Corporation in Silver Spring, Maryland, and president of the International Occultation Timing Association, the Chinese calculations "seem to match up pretty well" with a visual secondary occultation reported by amateurs observing Metis in Venezuela in late 1979.

As interest burgeoned, less direct evidence supporting the existence of asteroidal satellites surfaced. Edward Tedesco of the University of Arizona suggested that the variable brightness of the asteroids Ophelia and Pales can be best explained if each is a pair of asteroids, circling each other as double stars do. When one member of a pair passes in front of the other, the observed brightness would drop, he notes. Another bit of evidence, says Peter Noerdlinger of Michigan State University is the existence of neighboring, large craters on Earth that were formed at the same time. The Clearwater Lakes craters in Canada, a pair of craters 32 and 24 kilometers in diameter, are 31 kilometers apart and apparently formed simultaneously. But his calculations and those of others suggest that a single asteroid could not have split in two as it approached Earth and still moved far enough apart to produce such widely separated craters. The best explanation, he says, is that a binary asteroid system fell to Earth.

This accumulated evidence, and in particular the apparent secondary occultations, has given some researchers considerable confidence in the existence of asteroidal satellites. "I would be very surprised at this point," says Dunham, "if we don't [have asteroidal satellites]. I admit that we don't have 100 percent confidence yet. But it seemed very solid for Herculina at the time." Thomas Van Flandern of the U.S. Naval Observatory in Washington, D.C., terms the Herculina satellite "confirmed," 12 others as probable, and another 10 as suggested. He concludes that asteroidal satellites are "numerous and commonplace."

A number of other researchers cannot

Extending the Known Universe

Four giant elliptical galaxies—10 billion light-years from Earth and the most distant celestial bodies ever studied—have been identified by astronomers from the University of California, Berkeley, and the Kitt Peak National Observatory, Arizona. The remotest galaxies known previously were reported 6 years ago and are at a distance of 8 billion light-years. Detection of the new objects thus increases the size of the observable universe by 25 percent; it also means that astronomers have now seen galaxies more than halfway back in time to the Big Bang, some 18 billion years ago.

"These galaxies were already pretty old looking," says Berkeley astronomer Hyron Spinrad, who coauthored the report on the findings in the 2 March *Astrophysical Journal*, along with doctoral candidate John Stauffer and Kitt Peak astronomer Harvey Butcher. The spectroscopic properties of the galaxies are most consistent with an age of 6 billion years, he explains; adding on the 10 billion years it took their light to reach Earth gives a total age of 16 billion years.

"This tells you that, at least for the large ellipticals, the burst of galaxy formation happened very quickly after the Big Bang," says Spinrad. The universe was only 2 billion years old when these objects formed. "And it was over quickly, within about 1 billion years," he adds. "Otherwise we'd be seeing a lot more light from young, blue stars than we do."

Such arguments are prey to the uncertainties in galactic and stellar evolution models, he admits, but such models are thought to be fairly well understood.

The problem with doing spectroscopy on such distant and faint objects is that the light of the galaxy is swamped by the background light of the night sky, says Spinrad. He, Stauffer, and Butcher made their observations at California's Lick Observatory, which suffers from, among other things, the street lights of nearby San Jose. "The signal from the galaxies being studied was less than 2 percent of the total signal," says Spinrad. "You can still get the spectra, but it takes a long time."

Their technique was to use a Wampler scanner, a digital image tube that allowed them to subtract out the background. To collect enough light they had to repoint the telescope to the same galaxies again and again, building up a total of 40 hours of exposure on 23 separate nights over 3 years.

It has taken 20 years for astronomers to double the size of the observed universe from 5 billion to 10 billion light-years, says Spinrad. But new detectors based on CCD's (charge-coupled devices), which have good quantum efficiency at the longer wavelengths, should soon enable astronomers to push 20 to 30 percent farther yet. "Newly forming galaxies, if they could be seen from distances up to 16 billion light-years, should be spectacularly luminous," he says.—M. MITCHELL WALDROP

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accept that conclusion yet. The evidence is only suggestive, they say. They contend that most of the reported secondary events cannot be actual occultations—the reports are simply too numerous to be believable. According to Harris's calculations, if every asteroid had as many satellites as can be fitted around it without an undue number of collisions, a single observer would have one chance in a hundred of seeing a secondary occultation. If asteroidal satellite systems resembled those of the planets, an observer would have one chance in a thousand of seeing a satellite pass in front of a given star. "All of the observations cannot be valid," he says. "We're looking at the wrong order of magnitude of events. A lot of them must be spurious."

Believing that there is some obvious chaff to be winnowed out of the record, skeptics are demanding that the same stringent standards be applied to the interpretation of secondary events as are required for other occultation data. As Robert Millis of the Lowell Observatory explains it, a convincing case could be made if even one photoelectric record had been made of a well-behaved secondary event. By "well behaved" he means that the combined brightness of the asteroid plus the star must drop sharply as the star winks out and must rise sharply as it reappears from behind the obstructing object; but the brightness must drop to that of the asteroid alone, no higher and no lower. The idea is to rule out the possibility that a passing plane or a glitch in the instruments might masquerade as an occulting body.

By those standards, even the Herculina event, which is often cited as the best evidence available so far, does not measure up, according to the man who made the observations. "I think it's real," Bowell says, "but have no way of proving it from these observations." The brightness during the secondary event fell and rose much more slowly than during the primary Herculina event. And Bowell cannot say for sure whether the brightness dropped to that of the asteroid alone or to that of the empty sky. Viewing the event in dawn twilight near the horizon meant that the light of Herculina could not be distinguished from that of the sky. In addition, the coincidence of the visual and photoelectric observations could have been a matter of chance, others point out, in view of the fact that McMahon recorded five other secondary events within 2 minutes of the main occultation. The situation remains imponderable, Bowell says.

Other photoelectric observations during the $2\frac{1}{2}$ years since the Herculina event have either shown no secondary events or were flawed in some way, skeptics say. Millis cites five photoelectric observations as a star passed near Sophrosyne and three of an occultation by Kleopatra, all with no secondary events reported. The largest effort mounted recently was for an occultation by Juno. Observers at 26 sites, most using photoelectric detectors, watched the primary event as the star passed behind Juno near its equator. They reported no secondary events. "It's apparent," Millis says, "that, even though intensely observed, only a small fraction of the possible area [that might contain satellites] was covered. We didn't prove that there was nothing there. But, if there are swarms of satellites around Juno, it's peculiar that we didn't see anything."

One photoelectric observation of the last few years may meet the most stringent criteria, but it has not been formally published and thus it has received only limited attention. In 1978, Richard Radick, now of the Sacramento Peak Observatory in Sun Spot, New Mexico, was observing, through the University of Illinois' 1-meter telescope, a stellar occultation by Pallas. Three seconds after the star emerged from behind Pallas, the photoelectric detector recorded a sharp downward spike in the brightness level. At the urging of Van Flandern, Radick inspected the details of the spike on a high-speed magnetic tape recording of the data, which contained a brightness level at every 10 milliseconds. Although the event appeared to be a spike in the less detailed record, in the expanded record it resembled a brief but otherwise normal occultation, Radick says. The brightness fell and rose much as it did during the primary occultation and it bottomed out for about 50 milliseconds at the level of the primary occultation. According to Van Flandern's calculations, a body 1 kilometer wide near Pallas would be required.

"If there were no other reports of secondary events," Radick says, "I probably wouldn't have reported it. But there's nothing in the data that convinces me it couldn't be a satellite." He has only one reservation. Because there was a light haze that night, some unspecified atmospheric effect could conceivably be responsible, he says. Reitsema and others who have heard preliminary descriptions of this secondary event believe that it looks good enough to merit more intensive evaluation.

One other reported secondary event, although not observed with a photoelectric detector, may possibly sway those now casting doubt on the quality of the occultation data. On the night of 10 October 1980, when Kleopatra was due to occult a star, Gerry Ratley and William Cooke, two amateurs from San Jose, set up two visual observing stations 0.6 kilometer apart on a line parallel to the path of the shadow to be cast by the star and asteroid. In that way, only if an event were reported by both observers simultaneously could it be considered an occultation. Although in the wrong position to see the predicted occultation by Kleopatra, both observers reported secondary events lasting 0.9 second and coinciding within about 0.7 second. Both observers also reported a change from the bluish color of the asteroid to the reddish tinge of the star during the event. That suggests, says Dunham, that it was a satellite of the asteroid, not a plane, a cloud, or a bird that blocked the light momentarily. This report, too, deserves closer scrutiny, occultation specialists say.

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While one group of astronomers is sorting out occultation observations, another is applying a technique to the problem that could soon make it possible to unequivocally decide whether asteroids have relatively large satellites. The first results to be reported from the use of speckle interferometry, a technique most often applied to the study of double stars, have tended to support the existence of double asteroids. Speckle interferometry can be used to resolve distant, closely spaced objects because it retrieves information from a telescopic image that is normally lost. With the use of very short exposures, the individual "speckles" of light created by atmospheric turbulence are recorded and then the information that they contain is extracted by mathematical manipulation. Keith Hege and his colleagues at Steward Observatory in Arizona have reported that their speckle observations are "highly suggestive" of a satellite companion 175 ± 20 kilometers wide for Pallas (which is 550 ± 50 kilometers wide) and another one for Victoria. The initial reception for these observations has been generally positive. Two other groups of speckle observers have looked at a few asteroids, Victoria and Pallas included, but their preliminary analyses have not yet revealed any possible companions.

Speckle observers, not being at the mercy of celestial motions, have an edge in the effort to confirm the existence of such large asteroidal satellites; it will fall to occultation observers, catching as catch can, to demonstrate the existence of smaller companions, or to pile up negative evidence until once again asteroidal satellites appear unlikely.

—RICHARD A. KERR

Tumor Viruses and the Kinase Connection

Protein kinases, made under the direction of certain RNA tumor viruses, may produce the malignant changes evoked by those viruses

Over the past 2 to 3 years, researchers have finally begun to get a handle on how one group of tumor viruses converts normal cells to malignant ones. For each of these viruses, malignant transformation has been linked to the production in cells of a single protein, made under the direction of the viral genetic material, which is RNA.

That a single protein can bring about the numerous changes seen in transformed cells might seem surprising at first glance. As Tony Hunter of the Salk Institute puts it, "Transformation causes a major disruption of cell activities and cell shape." But the recent work suggests that the transforming proteins are enzymes of the kind called protein kinases, which transfer phosphate groups from adenosine triphosphate (ATP) to protein acceptors. Most protein kinases can phosphorylate more than one acceptor, and can thus affect more than one cell activity. Moreover, they regulate such a wide variety of cellular events that no one would be especially surprised if they also helped to regulate cell division.

In fact, epidermal growth factor (EGF), a naturally occurring stimulator of cell division, may produce its effects by first activating a protein kinase with properties similar to those of the transforming proteins. Ora Rosen of Albert Einstein College of Medicine says, "I think we are now seeing the coming together of two very different fields not previously thought to impinge on one another; they are growth factor activity and cell transformation by these RNA viruses." The kinase connection implies that the viruses might produce the abnormally rapid cell division characteristic of malignancy by subverting normal growth control machinery.

Other major—and hitherto mysterious—transformation changes may also be explained by the discovery of the transforming virus kinases. These include the disruption of the microscopic filaments that compose the cell skeleton and the Warburg effect, the increased rate of glycolysis seen in tumor cells. (Glycolysis is a relatively inefficient anaerobic pathway for obtaining energy from the sugar glucose.)

The best evidence suggesting that a viral kinase might bring about transformation comes from studies of Rous sarcoma virus (RSV), the grandfather of all the tumor viruses, which was discovered in 1911 by Francis Peyton Rous. Almost 70 years would elapse before investigators began to find out how the virus produced tumors, but by the mid-1970's work from several laboratories had made it clear that just one of the four genes in the RSV genome carried all the information needed for transformation (*Science*, 13 January 1978, p. 161). Shortly thereafter, Ray Erikson of the University of Colorado School of Medicine in Denver identified a protein with a molecular weight of 60,000 as the product of the *src* (for sarcoma) gene, as the transforming gene is called. Erikson and other investigators, including J. Michael Bishop and Harold Varmus of the University of California at San Francisco, went on to produce evidence suggesting that the protein is a kinase (*Science*, 25 August 1978, p. 702).

Since then the pace of the research has accelerated dramatically. Guided by the RSV work, investigators began looking at other RNA tumor viruses to see if they, too, direct the synthesis of protein kinases. And it seems that several of them do, although kinase production is not a universal ability of the RNA tumor viruses. Most of those that have the ability are either sarcoma viruses or leukemia viruses. The former include two sarcoma viruses of cats and Fujinami sarcoma virus, which, like RSV, infects chickens. Among the latter is the Abelson mouse leukemia virus.

The case for kinase production by the viruses is not airtight, however. Peter Duesberg of the University of California at Berkeley remarks, "The use of the word 'associated' in the papers is conspicuously high." Duesberg was referring to a problem that is the bête noire of transforming protein research. It is simply very hard to tell by the methods currently available whether an enzymatic activity is inherent in the various viral gene products as they are prepared from transformed cells or whether the activity belongs to a minor protein contaminant that is merely associated with the gene products. G. Steven Martin, also at Berkeley, says, "It is clear with RSV that the kinase activity must be very tightly associated [with the *src* gene product] or it is intrinsic. . . . But there are a lot of kinases in cells, especially in membranes."

Despite this caveat about the potential for contaminating viral proteins with cellular enzymes, the evidence for at least some of the viral kinases is beginning to approach the firmness of that for the RSV protein. One way the evidence has been strengthened is through studies of variant and mutant viral strains. For example, David Baltimore of the Massachusetts Institute of Technology and

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