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Uranus rings

continued from page 17

by beta, and from S. K. Gupta and H. S. Mahra at the Uttar Pradesh Observatory (Naini Tal). All the rings but epsilon might better be called ribbons, for the ring system of Uranus appears to consist mainly of gaps. Calculations by Brian G. Marsden (Smithsonian Astrophysical Observatory) yield radii of approximately 45 000 km for alpha and 52 000 km for epsilon, measured from the center of Uranus;[3] yet in this nearly 7000-km-wide belt, epsilon—the broadest of all detected rings—is estimated to have a width of only 50–100 km, and the others are much narrower.

In 1973 Gordon Taylor (Royal Greenwich Observatory) first predicted the occultation of SAO 158687, a ninth-magnitude red giant, by Uranus on 10 March 1977. It was hoped that light curves obtained as Uranus moved between the star and Earth would reveal information concerning the temperature, pressure and composition of the planet's atmosphere and provide a means to determine the diameter and oblateness precisely. The Cornell and Lowell groups, which had earlier cooperated on the observation of an occultation of the star Epsilon Geminorum by Mars,[4] began coordinating their efforts in 1976 to observe the Uranus event.

A flight into dawn. On the night of the occultation Elliot and his associates flew above 75% of Earth's atmosphere, on a course that would take them far south over the Indian Ocean, in a modified C-141 aircraft—the Kuiper Airborne Observatory—made available by NASA's Ames Research Center. With them the Cornell team carried a three-channel occultation photometer attached to the 91-cm KAO telescope. Three observation wavelengths—6190 Å, 7280 Å and 8520 Å—were selected to maximize the brightness of the star with respect to Uranus. About 40 minutes before the occultation by Uranus was expected, a sharp decrease in light intensity was observed for seven seconds, followed by four lesser (≈ 1 sec) dips. After the 25-minute occultation by the planet, the pattern was repeated in reverse. The morning sky's brightness ended observations.

Meanwhile, at Perth, Millis and his collaborators, due to their geographic position, actually detected the first unexpected drop in signal level—lasting about eight seconds—some 70 seconds ahead of the Cornell team. Using a single-channel photometer in conjunction with Perth's 61-cm telescope, Millis had begun observing in the 8500-Å region almost an hour before the anticipated time for the occultation. The failure of a beamsplitter in Millis's photometer caused the team to miss both the delta and alpha rings, but they still recorded five events, counting the two between alpha and Uranus, before dawn; the shadow of Uranus itself passed south of Perth. Millis's record shows considerable detailed structure in his first-detected event (later to be known as the epsilon ring).

At Kavalur, despite predictions that the shadow of Uranus would miss India (it did), Bhattacharyya observed and recorded the Uranian events for 90 minutes using the observatory's 102-cm telescope. About 40 minutes before the occultation by Uranus he noted a dip of 53% in the star's brightness for about nine seconds; several more sharp spikes were recorded before the Indians lost sight of the planet. Bhattacharyya told us the major event seen at Kavalur was the epsilon occultation; it has since been reported that the weaker fluctuations he detected match with the alpha, beta, gamma and delta events recorded elsewhere.

When the first anomalous occultation was observed aboard the Kuiper aircraft, Elliot, still on the plane, contacted Marsden, who heads an international information clearinghouse for discoveries of transient astronomical phenomena. (Marsden put out a statement that same day that a previously unknown satellite of Uranus had been detected.) When the Kuiper plane landed in Australia around 9:30 in the morning Millis was there to meet it; Elliot's first words to his fellow observer as he stepped off the plane were "How many satellites did you see?". It was not until he was back at Cornell that Elliot unrolled his chart record and found the correlations between pre-immersion and post-emersion occultations that spelled rings.

The rings take shape. The very brief duration of occultations by the ribbons indicates that they have widths of only a few kilometers; Uranus's shadow crossed Earth's surface at about 12 km sec^{-1}, so Elliot estimates the narrow rings are only 12 km wide. On the same basis, he has determined a width of approximately 85 km for the immersion section of epsilon and 35 km for its emersion section. Epsilon must therefore either be elliptical or inclined to the plane of the other rings and satellites; it is also possible that portions of two incomplete rings were observed, rather than different chords of a single object. Marsden cites the Sun, Neptune and Uranus's satellites as possible sources of perturbations that would result in "imperfect" rings.

None of the rings were seen to obscure the star completely; Elliot saw an occultation of about 90% in the case of epsilon, while the light intensity was cut off by approximately 50% for alpha, beta, gamma and delta and by only 20% in the case of two events that correspond to Millis's inner objects. The implication is that the rings are composed of many small objects with diameters of less than four-to-six km, the projected diameter of SAO 158687 at Uranus. The maximum obscuration observed by Millis, in the epsilon ring, corresponds to an optical thickness of 2.3, about twice that of Saturn's B ring.

Many questions remain. The old science-fiction art that showed multitudes of ringed planets floating in space no longer looks quite so unrealistic in the light of the Uranus discovery. But if ringed systems are common in the universe, it is at least clear that they are not all alike. We asked Marsden why the rings of Uranus, in contrast with Saturn's, are so very narrow, with such wide gaps between them. He told us that resonances account for the gaps in the Saturnian rings; the famous Cassini's division, for instance, occurs because particles orbiting at that distance from Saturn would have exactly half the period of Mimas, the innermost confirmed moon—every two revolutions such particles would find themselves in the same orientation with respect to Mimas and would tend to be pulled out of place. Such resonances can sometimes produce *enhancements* of particle density as well—thus, perhaps, are thin rings formed.

Uranus's ring system, according to Marsden, may be a relatively new object in comparison to the age of the solar system, and it may—especially in the case of epsilon—be unstable in the long term. However, "things happen slowly out there," in Marsden's words, and the rings should certainly last long enough to check on them another time. A search has already begun with the object of locating other, fainter stars whose paths may be crossed in the future by Uranus, its ring system . . . or Neptune. An observed occultation by Neptune nine years ago revealed no rings. —FCB

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in brief

The Massachusetts Institute of Technology is building the Alcator C tokamak at a total cost of $6.4 million. The device will have a capability of reaching 140-kG magnetic fields. □