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# DISCOVERING OF NEW SATELLITES OF SATURN

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**The latest news of the possible discovery of new satellites of Saturn during the Earth's crossing through Saturn's ring-plane is reported.**

KEY WORDS Saturn's satellites

Every 15 years the Earth crosses the plane of Saturn's equator. At this time the rings of the planet are tilted edge-on to the observer and their brightness becomes minimum. Historically this has enabled astronomers to discover new satellites which are usually lost in the glare of the system of bright rings of Saturn.

The previous passages of the Earth through a plane of rings occurred 1965, 1980 and 1995. Until 1965 only nine classical satellites of Saturn were known of: Mimas, Enceladus, Tethys, Dione, Rhea, Titan, Hyperion, Iapetus and Phoebe. In 1980 ground-based observations revealed the satellite 1980 S1 (Janus) which was identified with the satellite observed by Dollfus (1967) in 1966. Satellite 1980 S3 Epimetheus discovered during the flight of Pioneer-11 in 1979 is thought be the satellite already observed by Fountain and Larson (1978). It has almost the same orbit as Janus, and they are coorbital satellites.

The satellites S XII (Helene), S XIII (Telesto) and S XIV (Calypso) also were discovered by ground-based observations in 1980. Satellite Helene appears to be located at a Lagrange point of Saturn's large satellite Dione, and Telesto and Calypso are Tethis's lagrangians. Other small moons of Saturn were discovered by Voyager-1 in 1980. Satellite S XV Atlas orbits just outside the A-ring of Saturn and seems to establish the outer boundary of the A-ring. Prometheus (S XVI) and Pandora (S XVII) are the outer and inner shepherding satellites that stabilize Saturn's F-ring.

Careful inspection of many images taken by the Voyager spacecraft reveals the presence within the Encke gap of Saturn's eighteenth satellite. The Pan ephemeris was determined by Showalter (1991).

Thus all known small Saturn's satellites are between the A-ring and the orbit of Dione. These satellites have irregular shapes and are characterized by average radii

of 10 to 110 km. These orbits can be divided into three types: coorbital satellites, lagrangians and shepherding satellites of rings.

The past year was not exceptional. Circular IAU 6192 reported that observers of the Lowell Observatory, A. Bosh and A. Rivkin have discovered four new possible small satellites of Saturn. The new satellites were found using the Wide Field Planetary Camera of the Hubble Space Telescope as it crossed the plane of rings on May 22, 1995. These moons also have small sizes, their radii vary from 15 to 28 km, and magnitude at opposition from 16 to 18.3 mag. The new satellites have received the serial numbers S/1995 from S1 to S4. For each satellite 11 to 15 observations were obtained. The determination of orbits took into account gravitational perturbations from the non-spherical field of Saturn.

The orbits, determined with high accuracy, are circular and lie in the plane of Saturn's rings. The maximum errors for all orbits do not exceed 0.5 arcsec, and for satellites S2 and S3 they are less than 0.15 arcsec.

For each satellite Table 1 presents the following data: the orbital radius; angular distance from Saturn on a moment of passage through the plane of rings at May 22.48584 UT (negative values indicate that the satellite is west of Saturn); the longitude at the same epoch (measured from the subearth point); the approximate V magnitude at opposition; the number of images in which the satellite was observed.

**Table 1.** Some parameters of Saturn's new satellites at May 22.48584, 1995 UT

| *Satellite* | *The orbital radius R (km)* | *Angular distance from Saturn (arcsec)* | *The longitude (deg)* | *Magnitude at oppos. V (mag)* | *Number of images N* |
|---|---|---|---|---|---|
| S/1995 S1 | 137450 ± 200 | −16.4 | +120 | 17.2 | 15 |
| S/1995 S2 | 139700 ± 300 | −18.0 | +69 | 16.3 | 12 |
| S/1995 S3 | 141050 ± 100 | −10.5 | +33 | 17.5 | 14 |
| S/1995 S4 | 146450 ± 450 | +14.2 | −44 | 18.3 | 11 |

Satellites S1, S2 and S3 were identified in each case, in which they were not close to Saturn or to a bright satellite. S/1995 S4 was not identified in seven cases, in which it should have been seen, but the bright background noise was higher.

The authors indicate that there is some probability that satellite S1 is Atlas, and S2 is Prometheus, but their positions differ by 26 and 21 degrees, respectively, from the predicted positions of these satellites at a specified time.

Similar doubts about whether these satellites are new unknown objects have been stated by R. A. Jacobson (IAU Circ. No. 6196). He calculated angular distances from Saturn of known small satellites at the moment of ring-plane crossing on May 22, 1995. For Pandora he obtained 15.3 arcsec, for Atlas 18.9 arcsec, for Prometheus 19.3 arcsec. Thus, he came to the conclusion that S1 may be Pandora, and S2, Atlas or Prometheus.

As has been shown by Arlot and Thuillot (1993), the Earth has crossed the plane of Saturn's rings three times over the period 1995–1996. The first time this occurred

was on May 22, 1995. It also took place on August 10, 1995 and on February 11, 1996. At these times the saturnocentric declination of the Earth is equal to zero and the rings should disappear for a terrestrial observer.

The observers were already prepared for this event and conducted 12 hr period of observation during the crossing of the Saturnian ring-plane on August 10, 1995 using the HST Wide Field Planetary Camera (IAU Circular No. 6243). The authors indicate, that in addition to Janus, Epimetheus and Pandora they observed at least of four other objects, rotated in the vicinity of the F-ring. They confirm, that S/1995 S2 lags behind the predicted position of Prometheus by 19° in comparison with 21° during the passage on May 22, therefore S2 can probably be assumed to be Prometheus, though it seems weaker at 0.5 mag.

For each of three new objects in Table 2 the following data are given: the orbital radius, longitude at epoch 1995 August 10.5 UT (at Saturn), measured from the ascending node of Saturn's equator on the J2000.0 Earth equator, equivalent radius, approximate $V$ magnitude at opposition and number of observations.

**Table 2.** Some parameters of Saturn's new satellites at August 10.5 1995 UT

| *Satellite* | *The orbital radius R (km)* | *Longitude at epoch Aug. 10.5 (deg)* | *Radius (km)* | *Magnitude at oppos. V (mag)* | *Number of images N* |
|---|---|---|---|---|---|
| S/1995 S5 | 140060 ± 400 | 130.0 ± 0.5 | 26 | 17.1 | 15 |
| S/1995 S6 | 139910 ± 200 | 246.0 ± 0.1 | 19 | 17.8 | 9 |
| S/1995 S7 | 139440 ± 250 | 324.7 ± 0.3 | 18 | 17.9 | 10 |

The orbits of these satellites, calculated from observations with the account $J_2$ and $J_4$ from Saturn's field are circular. Maximum deviations are of 0.16 arcsec which corresponds to 1000 km or less. The orbits of S/1995 S5 and S6 coincide with the orbit of the F-ring ($R$ = 140 200 km), and the authors state the assumption that these objects are clumps or arcs within this ring rather than undiscovered satellites. The object S/1995 S5 shows appreciable changes of brightness depending on phase, which also suggests an arc-like structure of the object. The orbit of S/1995 S7, does not differ greatly from the orbit of Prometheus, which is identified with S2, and trails Prometheus by 15°.

The existence of a new object, the ephemerides of which coincide with the object S/1995 S6, has been confirmed by observers at the Paris Observatory and ESO (IAU Circular No. 6269). Using the 3.6-m ESO telescope during the crossing of the ring-plane on August 10, they observed Janus, Epimetheus and Pandora in their expected places, as well as an unknown object detected on two occasions – in the western and eastern elongations, respectively.

The object was visible on August 9.4388 and 9.4493 UT, located 21.6 and 21.7 arcsec east from Saturn's centre, respectively. On August 10.3462 and 10.3710 UT it was observed 21.9 arcsec westward of the planetary centre on seven images. Thus, these observations may represent the prediscovery of satellite S/1995 S6.

**Table 3.** Some parameters of new satellites of Saturn at August 10.5, 1995 UT

| *Satellite* | *Number of images N* | *Radius of orbit R (km)* | *Longitude at Aug. 10.5 (degree)* |
|---|---|---|---|
| S/1995 S8 | 16 | 141400 ± 1000 | 323 ± 1 |
| S/1995 S9 | 16 | 141400 ± 2000 | 315 ± 1.8 |
| S/1995 S10 | 8 | 140050 ± 100 | 131.4 ± 1.1 |

Sicardy and Poulet (Paris Observatory), Beusit and Prado (European Southern Observatory) informed (IAU Circ. No. 6395) that following to IAU Circ. No. 6269, four images taken on 1995 August, 9 reveal the presence of an unresolved object. They identified this object as S/1995 S5, detected by the HST more than a day later (IAU Circ. No. 6243).

IAU Circ. No. 6407 reported about several hundred exposures obtained at the 3.6-m Canada – France – Hawaii telescope during the four nights of the 1995 August ring-plane crossing. Janus, Epimetheus, Helene, Telesto, Calypso, Pandora and Prometheus were identified, positions are in fair agreement with the new ephemerides deduced from HST observations. Three additional objects – S/1995 S8, S9 and S10 – have been discovered (Table 3).

According to the received data the region between the A-ring and Mimas orbit is as described in Table 4.

**Table 4.** The summary table of some formations of Saturn from the A-ring to orbit of Mimas

| *Satellite or ring* | *Orbital radius R (km)* | *Mean daily motion (deg/d)* | *Magnitude at oppos. V (mag)* | *Mean radius (km)* | *Number of images N* |
|---|---|---|---|---|---|
| The ring A | 122170 (int) | | | | |
| Pan | 133528.8 ± 0.8 | 626.044 ± 0.006 | | 10 | 23 |
| The ring A | 136780 (ext) | | | | |
| S/1995 S1 | 137450 ± 200 | | 17.2 | < 28 | 15 |
| Atlas | 137670 | 598.08 ± 0.05 | 18 | 15 | |
| Prometheus | 139350 | 587.28 ± 0.02 | 16 | 110 | |
| S/1995 S7 | 139440 ± 250 | 586.9 ± 1.6 | 17.9 | 18 | 10 |
| S/1995 S2 | 139700 ± 300 | | 16.3 | < 28 | 12 |
| S/1995 S6 | 139910 ± 200 | 584.0 ± 1.2 | 17.8 | 19 | 9 |
| S/1995 S10 | 140050 ± 100 | | | | 8 |
| S/1995 S5 | 140060 ± 400 | 583.0 ± 2.5 | 17.1 | 26 | 15 |
| The ring F | 140200 ± 30 | 582.3 | | | |
| S/1995 S3 | 141050 ± 100 | | 17.5 | 12 | 14 |
| S/1995 S8 | 141400 ± 1000 | | | | 16 |
| S/1995 S9 | 141400 ± 2000 | | | | 16 |
| Pandora | 141700 | 572.77 ± 0.02 | 16 | 100 | |
| S/1995 S4 | 146450 ± 450 | | 18.4 | < 28 | 11 |
| Epimetheus | 151422 | 518.49 ± 0.01 | 15 | 70 | |
| Janus | 151472 | 518.24 ± 0.01 | 14 | 110 | |

For the A and F rings radii of internal and external boundaries of the ring are indicated; for satellites average orbital radii, average daily motion, magnitude at opposition V and average radii of satellites are given.

As was already known, the satellite Atlas is shepherding the A-ring and is located at a external boundary of the A-ring. The satellite S/1995 S1 has a close orbital radius and, if it is not Atlas, it is also shepherding the A-ring.

Although the radius of satellite S2 differs from that of Prometheus, observers have concluded that these satellites are the same. Satellite S3 is also shepherding an external boundary of the F-ring as well as Pandora. The orbits of objects S5 and S6 are consistent with that of the F-ring and are clumps or arcs of the thin structure of the F-ring, unless they are not confirmed as satellite.

Object S7 moves on the orbit of Prometheus with a lag of 15°, i.e. they are also a pair of coorbital satellites similar to Janus and Epimetheus.

The S/1995 S8 may be identified with S7 observed by HST. The S/1995 S9 azimuthal extent of 5° suggests an arc structure, which may be embedded in the F-ring; it cannot be linked with any other objects discovered by HST at the same epoch.

The S/1995 S10 is coorbital to the F-ring and is most probably the candidate satellite S/1995 S5, which was observed by the HST on August 10, 1995.

Thus our understanding of the structure of vicinity of the rings of Saturn essentially change with time.

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