

FIRST RESULTS OF THE PHESAT95 CAMPAIGN OF OBSERVATION OF THE PHENOMENA OF THE SATELLITES OF SATURN

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1. Introduction

From 1992 to 1999, the satellites of Saturn are involved in several phenomena: eclipses or occultations by the planet, transits in front of Saturn, or transits of their umbra. These phenomena occur thanks to the geometrical circumstances in 1995 when the Earth and the Sun went through the plane of the Saturnian ring and consequently through the orbital planes of the main satellites. These circumstances are also favorable to the observation of mutual phenomena occurring when the satellites eclipse or occult each other. These mutual phenomena and the eclipses by Saturn are rare as they occur only every 15 years. But, they are very useful to get highly accurate astrometric observations and they allowed us to estimate some physical parameters. We have organized the PHESAT95 campaign to observe these phenomena and a special effort was made to observe as many events as possible. At the present time, the observations are still being collected from different teams and different countries; this paper shows the first results which have been obtained in several sites, and the first comparison with the theory of the motions.

2. The Phenomena

Every 15 years, the Earth and the Sun cross the equatorial plane of Saturn. Fortunately, the 1995 opposition of Saturn was close to the crossing plane event: the 1995 period of phenomena was a favorable one. During about three years, from 1994 to 1996 several eclipses by the planet and mutual events were observable. Predictions of these phenomena have been made (Arlot and Thuillot, 1993; Aksnes and Dourneau, 1994), and have shown

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TABLE 1. Main sites of the PHESAT95 network with the number of mutual events (Mut.) and eclipses by Saturn (Ecl.) observed; (*): not yet available.

Location	Country	Mut.	Ecl.	Location	Country	Mut.	Ecl.
Assy Obs.	Kazakhstan	2		Itajuba Obs.	Brazil	(*)	
Bangalore Obs.	India	(*)		Lumezzane	Italy	3	
Bordeaux Obs.	France	12(*)		Meudon Obs.	France	7	
Bucarest Obs.	Romania	1		OHP (St Michel)	France	16	2
Catania Obs.	Italy	10		Pic du Midi	France	10	16
Charlottesville	USA	4		Saint V é ran	France	3	
Chelmsford	U.K.	2		Sternberg lab.	Krymea	3	
ESO	Chile	20	2	Stuttgart	Germany	1	

that 159 eclipses and 182 mutual events at more than 5 arcsec from the edge of Saturn were observable (Thuillot and Arlot, 1995).

These geometric circumstances are in fact favorable to observe several phenomena by Saturn: eclipses, occultations, transits and transits of umbra. Among them, eclipses are the most convenient to observe with photometric detectors, but the proximity of Saturn and its rings is a real difficulty which assigns these observations mainly to CCD detectors installed in good sites. On the other hand, mutual events may occur much farther from the planet. Furthermore, the mutual eclipses and occultations do not involve any atmosphere (except when Titan is implied) and thus, their astrometric analysis can lead to a better accuracy.

3. The PHESAT95 Campaign of Observation

At the Bureau des longitudes, we have organized an international campaign to observe the phenomena of the Saturnian satellites. The goal of this campaign was to get high accuracy astrometric measurements of these satellites thanks to photometric observations with CCD cameras or photometers. These observations will be used to improve the dynamical models of their motions.

In order to collect the maximum of observations, sites with various longitudes were included in the PHESAT95 network. Table 1 gives the names and countries of the main sites of this network. CCD cameras have generally been used; only a few observers used photometers which are more difficult to use because of the brightness of the planet.

4. Preliminary Analysis of the Observations

Observational data are still being collected. We can have a general status of the results obtained: mainly mutual events have been observed. At the

TABLE 2. Number of eclipses disappearances (ECD) and reappearances (ECR) by satellites.

Sat.	1	2	3	4	5	6	7
ECD	—	—	1	1	2	1	—
ECR	2	3	5	2	3	—	—

TABLE 3. Number of mutual events (A eclipses/occults B) by satellites for the 57 eclipses and 27 occultations collected.

Sat. B		1	2	3	4	5	6	7
Sat. A	1	—	—	—	—	—	—	—
	2	1/3	—	2/1	—/2	—	—	—
	3	15/—	5/5	—	—/2	5/—	1/—	1/—
	4	—	3/3	3/4	—	7/1	—/2	—
	5	2/—	2/—	1/—	3/4	—	2/—	—
	6	2/—	2/—	—	—	—	—	—
	7	—	—	—	—	—	—	—

present time, as shown in Table 1, we get 94 mutual events observations and 20 eclipses by Saturn; all these observations are raw data and they must now be analyzed. Models of lightcurves, similar to those we used for the mutual events of the Galilean satellites (Descamps *et al.*, 1992; Descamps, 1994), have to be applied in order to deduce the best accurate astrometric data and some physical parameters related to the surface parameters.

The available observations, regarding the involved satellites, are in Table 2 for the eclipses by Saturn, and in Table 3 for the mutual eclipses and mutual occultations. Contrarily to positional observations, the observations of events do not give uniform sets of data: events implying fast satellites (but not too close to the planet) are more numerous and more often observed than events involving distant and slow moving satellites. In these tables Hyperion is involved in only one phenomenon. But, this type of observation allows us to get more accurate measurements. Table 4 shows the preliminary residuals obtained for some observations made at the Pic du Midi, Meudon and Haute-Provence observatories. Residuals are computed thanks to Dourneau's theory of the motions (Dourneau, 1993). All of these observations have been done with THX7863 CCD cameras.

5. Conclusion

For the observations of the Saturnian satellites, mutual events and eclipses are a rare opportunity to get accurate astrometric measurements. We

TABLE 4. Preliminary residuals obtained for observations made at the Pic du Midi (PDM), Meudon observatory (MEU) and Observatoire de Haute-Provence (OHP) in France.

Date 1995	Event	C-O [s]	Prec. [s]	Observatory
June 17	2E3	3	± 15	OHP
July 22	3E2	15	± 10	OHP
Aug. 25	3O2	14	± 3	OHP
Sept. 21	4O3	21	± 21	PDM
Sept. 24	3E5	17	± 17	OHP
Nov. 9	6E2	-68	± 6	PDM
Nov. 14	4E2	7	± 2	OHP
Nov. 14	5E2	24	± 18	OHP
Nov. 18	5E6	16	± 55	MEU
Nov. 18	5E4	-13	± 4	MEU
Nov. 27	5E2	0	± 49	MEU

are now at the end of the PHESAT95 campaign that we organized in order to catch the maximum of these rare events. The first results, we obtained, show the good quality of the observations made. We have now to collect the whole set of observations, to apply homogeneous methods of analysis and reduction, and then to apply this material to the improvement of the dynamical model of the motions. Global results will lead the observers to publish a catalogue as it has been done during the previous campaign involving the Jovian satellites (PHEMU91 observers, 1996). On the other hand, we have also prepared the new campaign of observations of the mutual events of the Galilean satellites (Arlot, 1996; Arlot *et al.*, 1996) which will occur during the next year. Further information on these campaigns are available on the WEB server of the Bureau des longitudes (<http://www.bdl.fr>).

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