J. Astrophys. Astr. 1989, **10**, 85–88

Occultations by Possible Material in Saturn's Outer Magnetosphere—2

R. Vasundhara *Indian Institute of Astrophysics, Bangalore* 560034

Received 1988 December 28; accepted 1989 February 28

Abstract. Results of a search for occultations of stars in the SAO catalogue by Saturn's outer magnetosphere during 1989–1990 are presented. A total of nine events are predicted to occur during this period. The most favourable event will be the occultation of 28 Sgr (SAO 187255) during July 2–3, 1989. Occultations of SAO 187036, SAO 188348 and SAO 188120 occur near opposition and therefore can be observed over a wide longitude range.

Key words: occultations—Saturn, rings—Saturn, magnetosphere

Following the suggestion by Lazarus, Hasegawa & Bagenal (1983) of a possible existence of particulate or gaseous material in Saturn's outer magnetosphere, investigations were carried out using direct imaging (Baron & Elliot 1983), occultation technique, based on predictions by Mink (1983) (Vasundhara *et al.* 1984; Vasundhara, Battacharyya & Rozario 1986; Mahra *et al.* 1985), and reviewing of Voyager LECP data (Cheng, Lanzerotti & Maclennan 1985). To enable further studies of this part of the magnetosphere, a programme was undertaken to search the SAO catalogue for occultations of stars by the planet (Vasundhara 1988, hereafter paper 1). The present paper contains the results of the search for the years 1989–1990.

The method of the search programme has been briefly explained in paper 1. The position angle (P) of the projection of the north pole of the planet on the sky plane and the angle of inclination of the line of sight to the ring plane (B), were not readily available, and therefore were calculated using the relations

$$\begin{aligned} \sin B &= -[\sin\delta_p \sin\delta_s + \cos\delta_p \cos\delta_s \cos(\alpha_s - \alpha_p)], \\ \cos B \sin P &= -\cos\delta_p \sin(\alpha_s - \alpha_p), \\ \cos B \cos P &= -\cos\delta_p \sin\delta_s \cos(\alpha_s - \alpha_p) + \sin\delta_p \cos\delta_s, \end{aligned} \tag{1}$$

where (α_p, δ_p), the co-ordinates of the north pole of the planet with respect to the mean equator and equinox at the time of the event were obtained from 1950.0 positions (α_0, δ_0)

$$\alpha_0 = 38.50 - .034\ T, \qquad \delta_0 = 83.31 - .004\ T.$$

Where T is the interval in Julian ephemeris centuries from the standard epoch of JED 2433282.5 (Davies *et al.* 1983). The planetary positions (α_s, δ_s) used in Equations (1) refer to the DE 200 ephemeris, with the nutation terms removed (Explanatory Supplement to the Ephemeris p. 362, 1977). As the origin of the DE 200 reference frame is the mean

1989JApA...10...85V

Table 1.

No	Date	Vis. Mag.	SAO no.	Sp. type	Position (1950.0) R.A. / DEC	Geocentric impact Parameter (arcsec) / Sky plane velocity km s^{-1}	Event*		UT	Position angle $N-E$ deg.	Distance from Saturn (arcsec)	Region of visibility
1	1989 March 03	9.1	187383	G5	18 49 10.639 / −22 15 50.14	44 / +24.03	19*R*	Imm	03:54	54	86	Libya
							12.5*R*	Imm	11:29	339	46	Texas, Mexico
							12.5*R*	Em	15:01	305	69	Hawaii
							19*R*	Em	22:39	283	147	India, Sri Lanka
2	1989 July 02–03	5.8	187255	K2	18 43 19.765 / −22 26 46.86	02 / −20.17	19*R*	Imm	17:21	264	159	S & E Africa, Asia, Australia
							12.5*R*	Imm	22:18	263	104	E South America, Europe, Africa, India
							A Ring	Imm	06:07	259	18	Americas
							Sat.	Imm	06:53	254		Hawaii, Americas
							Sat.	Em	08:31	95		Hawaii, North America, W South America
							A ring	Em	09:31	89	20	East Australia, New Zealand, Hawaii, W North America
							12.5*R*	Em	17:20	85	107	S & E Africa, Asia, Australia
							19*R*	Em	22:17	85	162	Europe, Africa, Middle East, India
3	1989 Aug 06–07	9.6	187036	B9	18 33 24.882 / −22 40 09.51	38 / −14.38	19*R*	Imm	10:38	245	118	Australia, Japan, Hawaii
							12.5*R*	Imm	19:08	224	59	Africa, India, Sumatra
							12.5*R*	Em	13:56	105	108	Malaysia, S China, Japan, Australia
							19*R*	Em	22:38	97	172	E South America, Europe, Africa
4	1989 Nov. 08	8.1	187196	F5	18 40 41.540 / −22 43 16.25	63 / +27.24	19*R*	Imm	11:48	12	65	Malaysia, Indonesia, W Australia
							19*R*	Emm	20:31	300	114	(Atlantic Ocean)

5	1989		187347		18	47	55.717	08	19*R*	Imm	22:59	89	141	West Indies
	Nov.	9.1		G0	−22	38	30.26	+33.24	12.5*R*	Imm	02:05	91	94	
	25–26								*A* ring	Imm	07:36	125	12	
									A ring	Em+	08:09	167	08	(Parts of Pacific Ocean)
									Sat	(graze)	08:14	176	7.8	
									12.5*R*	Em	13:40	261	84	S India, Sri Lanka
									19*R*	Em	16:45	262	131	N E Africa
6	1990		188468		19	39	17.283	55	19*R*	Imm	10:34	103	147	Mexico, Guatemala
	March	9.2		G5	−21	16	46.52	+22.56	19*R*	Em	01:01	190	59	S & E Africa, Middle East
	18–19													
7	1990		188580		19	45	03.180	75	19*R*	Imm	16:29	286	158	Malaysia, S China, Australia, Japan, New Zealand
	May	6.7		G0	−21	04	55.98	−09.42	19*R*	Em	14:49	327	80	Indonesia, Australia, Japan, New Zealand, Hawaii
	25–26													
8	1990		188348		19	33	59.801	17	19*R*	Imm	00:02	252	125	South America, Europe, Africa, Middle East
	July	9.2		K0	−21	36	21.26	−20.05	12.5*R*	Em	04:38	247	75	Central & E North America, South America, SW Africa
	10–11													
									12.5*R*	Em	21:01	88	109	S Europe, Africa, India, Indonesia
									19*R*	Em	01:37	86	160	West Indies, South America, Europe, Africa
9	1990		188120		19	23	20.197	35	19*R*	Imm	16:17	240	103	Asia, Australia
	Aug.	8.7		K0	−22	02	29.41	−15.26	12.5*R*	Imm	23:17	217	52	South America, Europe, Africa
	15–17								12.5*R*	Em	16:54	98	113	E Africa, Asia, Australia
									19*R*	Em	00:01	92	170	South America, Africa

*19*R* = 1146270 km, 12.5 *R* = 754125 km

+ very close to planet

equator and dynamical equinox of J2000.0, the pole position as well as the apparent star positions were corrected for the zero point shift (Fricke 1982).

Table 1 gives the geocentric circumstances of the events and is presented in the same format as in paper 1. The regions of observability are land regions in increasing east longitude where Saturn is more than 15° above the horizon and Sun is more than 15° below the horizon. The most favourable event is the occultation of the brightest star SAO 187255 (also predicted previously by Taylor 1983 and Killian & Dalton 1985), which occurs when the planet is near opposition. On 1989 November 26, track of SAO 187347 would be grazing past the top of the planet's atmosphere at a radial distance of 60800 km, 5 minutes after the emersion behind the A ring as seen from centre of earth. Observers in northern latitudes would be able to record the grazing occultation by the atmosphere at deeper levels. Use of a filter in the methane band would greatly help in getting a favourable signal/noise ratio. Unfortunately the event occurs at a time when the planet is nearing conjunction with the Sun, and also the observable longitude strip passes over the Pacific ocean. Occultation of SAO 188580 behind the 19*R* region of the planet occurs at a slow speed, the star being fairly bright and reasonably far away from the planet. Fast spectral scans of the star as it is occulted would help in investigating the nature of material in this region (Mahra *et al.* 1985; Vasundhara, Bhattacharyya & Rozario 1986). The prediction programme was run on the Mightyframe II computer at the Institute.

The author wishes to thank Prof. J. C. Bhattacharyya for his guidance and encouragement and Dr. A. K. Bhatnagar, Positional Astronomy Centre, India, for providing the planet's ephemerides. It is a pleasure to thank Prof. D. J. Mink for useful comments.

References

Baron, R. L., Elliot, J. L. 1983, *Astr. J.*, **88,** 562.
Cheng, A. F., Lanzerotti, L. J., Maclennan, C. G. 1985, *Nature*, **317,** 508.
Davies, M. E., Abalakin, V. K., Lieske, J. H., Seidelmann, P. K., Sinclair, A. T., Sinzi, A. M., Smith, B. A., Tjuflin, Y. S. 1983, *Celestial Mechanics*, **29,** 309.
Fricke, W. 1982, *Astr. Astrophys.*, **107,** L13.
Killian, A. M., Dalton, A. S. 1985, *Astr. J.*, **90,** 2372.
Lazarus, A. J., Hasegawa, T., Bagenal, F. 1983, *Nature*, **302,** 230.
Mahra, H. S., Pande, A. K., Vijay Mohan, Sanwal, B. B. 1985, *Nature*, **313,** 38.
Mink, D. J. 1983, *Astr. J.*, **88,** 559.
Taylor, G. 1983, in IAU Comm. 20 working group on Prediction of Occultations by Satellites and Minor Planets, *Bulletin*, 30.
Vasundhara, R. 1988, *J. Astrophys. Astr.*, **9,** 63.
Vasundhara, R., Bhattacharyya, J. C., Rozario, M. 1986, *Bull. astr. Soc.*, **14,** 232.
Vasundhara, R., Bhattacharyya, J. C., Santhanam, P., Pande, A. K., Vijay Mohan, Mahra, H. S. 1984, *Nature*, **317,** 621.