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Structures in Saturn's Magnetosphere

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1. Introduction

During the Pioneer XI and Voyager passes by Saturn, it was noticed that at specific distances from the planet, the ion probe results displayed prominent dips (Lazarus *et al.* 1982). These dips were noticed in all the three passes, and at approximate locations where the dipole model magnetic field of the planet intersects its equatorial plane at 14 and 19 radii. One possible explanation offered was that there are distributed particulate matter at those locations which affect the ion recombination co-efficient and cause these dips. Such clouds, if present, could be detected during events when the planet Saturn with its complete environment of rings, satellites and plasma, occults a reasonably bright star.

Possibilities of such events were computed from planetary ephemerides (Mink 1983). One of the events was ideally suitable for investigation from the longitudes of India when both the eastern and western regions at 14 L occultated an 8.5 magnitude star on two successive nights of 24 and 25 March 1984 with the object conveniently located for observations. A continuous watch with a high speed photometer was maintained on both nights which indicated possible presence of such clouds, probably in the form of a set of rings or tori.

2. Observations

2.1 *The 14 L region*

The telescope used was the 1 metre telescope at Kavalur Observatory ($15^h\,15^m\,19^s.6$E, $+12^0\,34^1.58$) (now named as Vainu Bappu Observatory), with a photometer and a pulse counting arrangement with 1 second integration. The observations were taken on the nights of 24th and 25th March 1984. Both the nights enjoyed photometric skies during the 3 hour observation period each. To maximise signal to noise ratio, no filter was employed on 24th night, but a Johnson B filter was used on 25th night, with a slight reduction in the S/N ratio.

The same event was also observed from Nainital Observatory ($5^h\,17^m\,49^s.71$ E, $+29^0\,21^1.65$) with a slightly different recording arrangement. They, however, had mixed luck about the observing conditions; while being able to record a substantial part of 24th event, clouds frustrated their efforts on 25th. All the records show dips due to increased extinction at instants which could be connected to the passage of star beams through the circumplanetary clouds (Vasundhara *et al.* 1984). Five major dips were noticed in both the Kavalur records, and three in the Nainital record of 24th. The position is shown in Fig. 1.

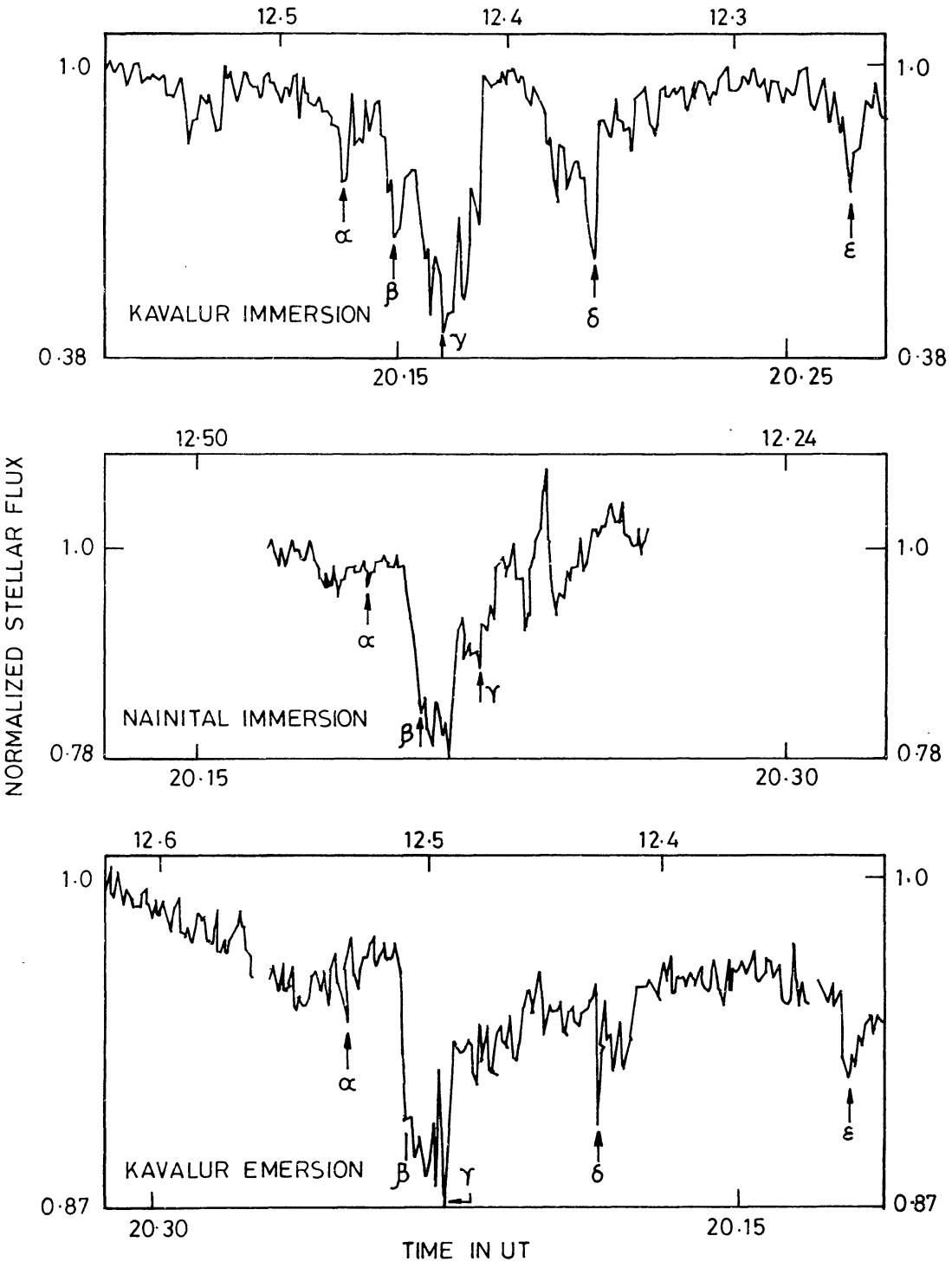

Figure 1. Occultation of an 8.5 magnitude star by Saturn.

For estimation of the distances of these clouds from the planet's centre, a simplified model has been assumed. In the model the extinction clouds have been assumed to be contained in a thin equatorial ring, as in the case of the visible rings of the planet. The physical orientation and the ephemerides of the planet being known the time scale

cloud be directly related to the planetocentric distances; according to these schemes all the dips in the three records were found to have occurred when the starbeam crossed regions between 12.2 to 12.8 Saturn-radii. Relative depths of minima as displayed in the three records were found to be consistent, thereby suggesting the presence of well marked clouds in those regions.

Since these clouds have been found on both the east and west sides of the planet, at almost the same distances, we can assume that this is in the form of a set of complete rings. Some variations in the depths, widths and locations have been noticed, but the data being meagre, detailed calculations to ascertain the shape and stability will be fruitless.

An attempt was made to confirm the existence of such a structure through another occultation event. The event was not observable in India, so the help of a foreign observatory was sought. The record was not a clean one, but again after scaling the data, comparing with our old records, some features could be seen to be repeated at almost the same planetocentric distances.

Another attempt to reinvestigate the region of magnetosphere at 12.5 Saturn radius was made by enlisting the help of a large number of observatories in the eastern hemisphere on 2–3 July 1989 when the Saturn system occulted 28 Sgr. Poor sky conditions at most places precluded a systematic comparison of the records. Two of the observers reported negative results at the predicted times.

2.2 *The 19 L region*

In May 1984, another event was observable from India, when the 19 L feature was predicted to be occulted. This time, bad weather was encountered at Kavalur, but at Nainital they could obtain a record from which certain features of this outer system could be found (Mahra *et al.* 1985). The data from Kavalur, was noisy, but still some features could be seen in this record. But the locations as calculated from the adopted equatorial shell model and the timings of dip-events did not match Nainital findings, so that the findings remain unconfirmed till date.

3. Attempts for direct detection

As the occultations are few and far between and subject to vagaries of weather, some attempts were made to do area photometry of the concerned regions. The first attempt was made by Baron & Elliot (1983), who employed a CCD camera for detecting any abnormality in these regions. The experiment was marred by a very strong gradient of scattered illumination from the planet, and no definite conclusions could be drawn. An attempt was made at VBO, by employing the 'Diffuse Masking' technique developed by Dave Malin (1977) but the results were vitiated by unforeseen artifacts of the technique. Fresh attempts, however, are being planned.

4. Discussions

The results of the occultation experiments have been, however, criticised by Cheng *et al.* (1985) on grounds of negative results of space probes and disagreement between

different occultation records. The latter comment can be traced to rather uncritical examination of observational results, while the former is not free from controversies (Schardt *et al.* 1984).

The results of the occultation experiments on 24 and 25 March 1984 have been critically examined as regards the possibility of their spurious origin, but nothing could be found which may cast a doubt about their reality. The only weak point about the analysis is perhaps the assumption of their containment in a thin ring in the equatorial plane; for if these are composed of fine dust mixed with plasma in Saturn's magnetosphere, the electromagnetic forces are bound to play an important role in their dynamics. In all probabilities, they cannot be contained in a thin equatorial ring, but will have considerable spread along the magnetic lines. Some of the observed characteristics of the dip minima suggests such lateral spreads of the clouds (Bhattacharyya & Vasundhara 1985). The negative results of occultation of 28 Sgr on 3rd July at the predicted time would possibly be attributed to an error in prediction which was based on an equatorial model.

It is now necessary to tackle the question from two different angles: More observations and predictions of occultation events should be continued, and attempts to do the faint photometry by suitable methods should be renewed; and the dynamics of charged dust particles in the circumplanetary magnetic field must be better understood.

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