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INTERCOMPARISON OF VARIOUS MEASUREMENTS OF THERMAL PLASMA DENSITIES AT AND NEAR THE PLASMAPAUSE

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ABSTRACT

Four methods of investigating the thermal plasma density near the plasmapause have been intercompared for the period 1 to 15 July 1972. These methods are whistlers, the double floating probe on Explorer 45, three IMP I plasma wave signatures and observations made aboard both Prognoz 1 and Prognoz 2. Explorer 45 data have provided new information on the plasmapause bulge which, during this period, occurs at 16 L.T. This displacement from the accepted time of 18 L.T. or even later is substantiated by the Russian satellites. All methods give the result that the plasmapause is found at an electron number density somewhere between 20 and 120 cm^{-3} or, alternatively, at 60 cm^{-3}, to within a factor of 2.

With the increasing number of satellite measurements of the thermal magnetospheric plasma density, it is timely to make a comparative study between several in situ methods and whistler measurements. For this purpose, a two week period from 1 to 15 July 1972 is chosen; particular attention is paid to plasma densities at and near the plasmapause. The methods considered are whistlers, recorded at Halley, Antarctica, and observations made by the double floating probe experiment aboard Explorer 45 (S^3-A), the plasma wave experiment aboard IMP I, and the thermal ion probes on Prognoz 1 and 2. S^3-A is in an equatorial orbit, going out to L = 5.4, with an orbital period of 7.82 hours, whereas IMP I, Prognoz 1 and Prognoz 2 are in highly eccentric orbits, each with a period of about 4 days.

Fig. 1 shows the L-value at which the Explorer 45 double floating probe instrument [1] saturated on all plasmapause crossings in the two week interval, plotted against magnetic local time. Where the observations were taken at very nearly the same local time, i.e. when the satellite crossed the plasmapause more than once, bars have been introduced to represent the range of positions. Each day has its own particular symbol; this conveys information about the response of the plasmapause to a change in magnetic activity. A bulge at approximately 16 L.T. is clearly defined. This effect is not due to magnetic activity being high on the day when 18 L.T. is sampled, because days following enhanced activity also exhibit the bulge at 16 L.T. This feature does not agree fully with the whistler-derived position of the bulge, which is usually at post-dusk local time, at approximately 18 to 21 L.T. [2].

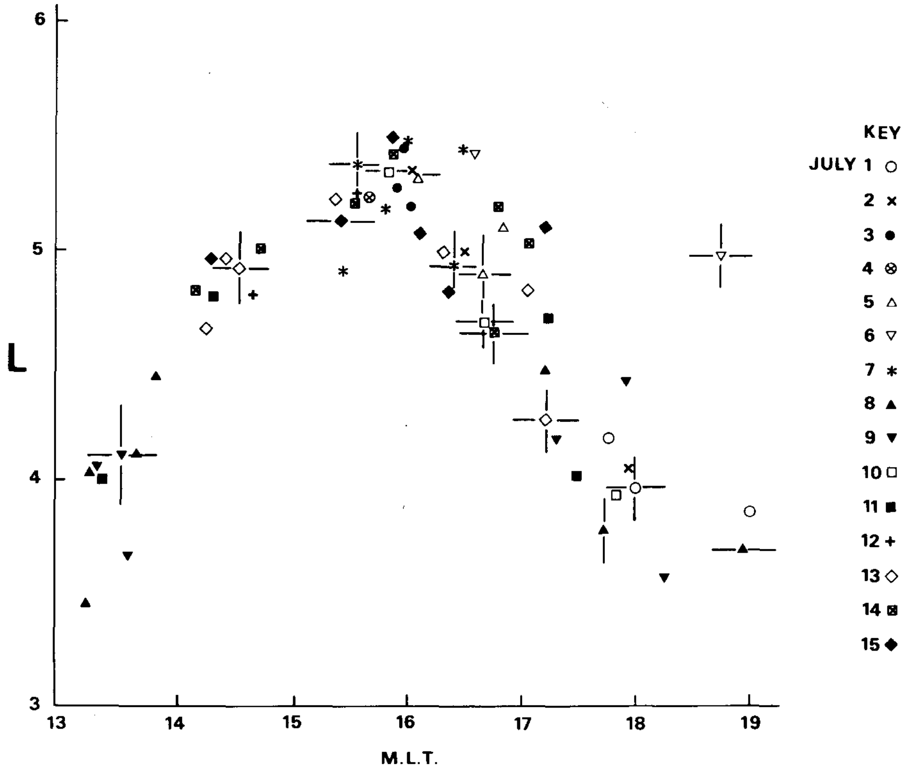

Fig. 1. L-value of plasmapause, on different days in July 1972, derived from Explorer 45 (S^3-A) data and plotted against magnetic local time.

IMP I plasma wave data (passband filters) provide three methods for recognizing the plasmapause boundary [3, 4]. Identifications, as the sudden increase of solar array interference generated, beyond the plasmapause, as shadows are cast on the solar panel array, and of the termination of electromagnetic plasmaspheric hiss (~ few kHz) are not always clear. Identifications based upon the rapid decrease, on an outbound orbit, of the frequency of electron plasma/upper hybrid frequency noise are most useful. By these means, within the 15 day period, there are at most 4 days on which the plasmapause position can be determined.

Plasma density profiles have been derived from the maxima of the passbands, assuming noise generation at the electron plasma frequency. All except one (July 2) exhibit the sharp plasma density gradients characteristic of the plasmapause. The plasmapause positions derived from the plasmaspheric hiss (spectrum analyzer data) all fall within an electron density range of 20 to 90 cm^{-3}. They thus agree with the estimates of electron density at the plasmapause published by Morgan and Maynard [5].

Near equatorial plane hydrogen ion density profiles for the same period obtained from Prognoz 1 (at 10 L.T.) and Prognoz 2 (at 16 L.T.) have been studied. These exhibit considerable fine structure, on a spatial scale of ~ 0.1 to 0.2 R_E, particularly in the vicinity of the plasmapause. The plasma density at the midpoint of the plasmapause (when the profile is plotted on a logarithmic density scale) lies within a factor of two of 60 cm^{-3}.

Whistlers recorded at Halley, Antarctica (75°S, 27°W) between 8 and 12 July 1972 have been analyzed both at Sheffield University and at Dartmouth College by conventional methods to derive not only plasmapause positions but also electron density profiles in the magnetospheric equatorial plane. Since S^3-A data were available for these five days, at definite times (U.T.) the positions of the plasmapause thus determined were compared with those found from the whistler data. It was noted that, in general, the plasmapause L values found using S^3-A were lower than those obtained using whistlers. However, by adding 0.2 R_E to these S^3-A recorded L values, much closer agreement with the whistler results was obtained; these corrected values are shown in Fig. 2. This fact could imply that S^3-A identifies the inner plasmapause (i.e. nearer the top of the knee in the electron density profile). Thus the plasma density at the whistler definition of the plasmapause is probably $\leq$ 60 cm^{-3}.

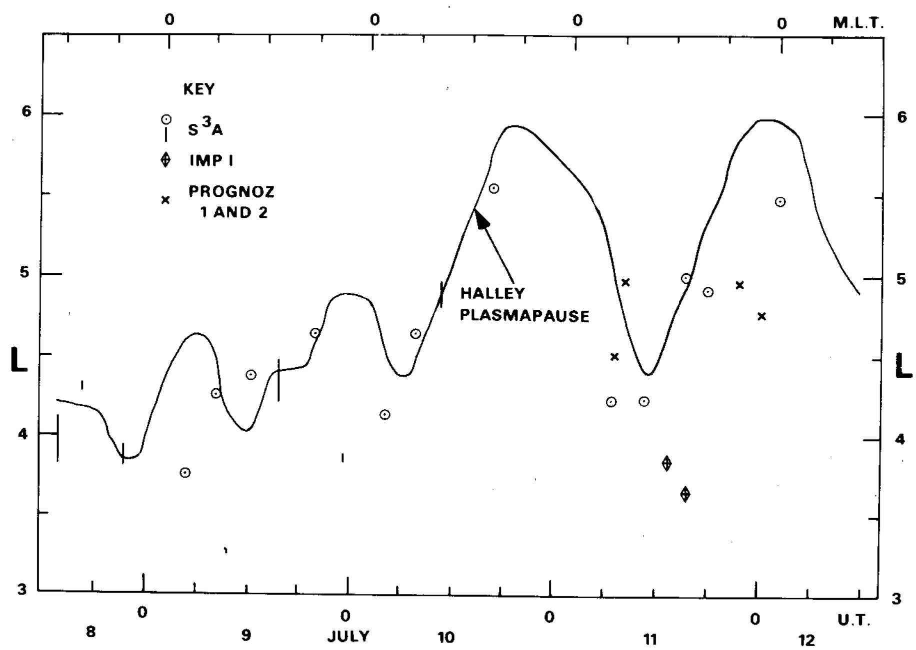

Fig. 2. Variation of L-value of plasmapause, from 12 U.T. on 8 July to 15 U.T. on 12 July 1972, derived from whistlers recorded at Halley, Antarctica (solid curve), from S^3-A (circled points and bars), from IMP I (diamonds) and from Prognoz 1 and 2 (crosses).

For the IMP I satellite, the only data covered in this period were taken on July 11. They show poor agreement with the whistler plasmapause determination (see Fig. 2), with a discrepancy of up to 1 R_E. Even allowing for a difference between the local times at which the respective data were taken, the plasmapause L values derived from the IMP are low.

The data from Prognoz 1 and 2, also included in Fig. 2, show reasonable agreement with the results derived from whistlers. This is not altogether unexpected, since both whistlers and Prognoz employ the same method of identifying the plasmapause as the midpoint of the knee in the near equatorial plane plasma density profile.

In conclusion, this investigation has used instruments on several satellites and also whistlers to study the plasmapause, an important boundary between the regime of plasma corotating with the earth, and the regime of plasma that is controlled by the solar wind. At the plasmapause, the thermal plasma density falls off very rapidly, providing a means of its identification, and in fact the methods discussed all employ this physical property either directly or indirectly.

Comparison with Halley whistler data shows that the plasmapause L value derived from Explorer 45 (S^3-A) data was 0.2 R_E lower; this could be due, on an outbound orbit, to the ready saturation of the double probe, d.c. electric field detector. These S^3-A data place the plasmapause bulge at 16 L.T., significantly earlier than the more usually accepted time of 18 to 21 L.T. This earlier bulge feature is also evidenced in the data from Prognoz 1 and 2; the IMP results appear to disagree, which could be due to the limited IMP I data sample available. The midpoint of the plasmapause (on a logarithmic plot) occurs at 60 cm^{-3} to within a factor of two. The statement is broadly consistent with all the data examined here.

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