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INVESTIGATION OF LOW ENERGY SPACE PLASMA

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by

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and

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ANALYSIS TECHNIQUES AND SOFTWARE DEVELOPMENT

An important modification has been made in the method for computing ion densities from DE1/RIMS observations, based on the observed relationship between total plasma density and spacecraft potential. An iterative technique has been developed to require that this relationship be preserved in all individual observations, not just in the average sense observed. Results of employing this technique have been examined closely and are found to generally improve the final densities in terms of agreement with densities obtained from PWI upper hybrid frequency observations. It also has the effect of reducing scatter in the density vs. L profiles. By insuring that a common spacecraft potential is used in determining all ion densities, an improved accuracy and consistency in composition determinations also results. Since this technique has been developed as a separate stage in the processing, all previous results can be treated without reanalysis. A paper describing this technique is in preparation (Ref. 1).

Techniques developed for automated analysis of data in the period after the RIMS radial head RPA malfunction have been incorporated into an interactive analysis program. This program is now functioning and is being used assess the accuracy of the automated procedure. It will also be used for case studies involving relatively small amounts of data in which accuracy is of paramount importance. Some optimization to reduce run time remains to be done.

Accuracy of the end-head temperature analysis also remains to be examined.

Improvements are continuing to be made in the temperature part of the automated analysis. The present algorithm for selecting points from the end head RPA curve was designed for the -Z head and works fairly well for that head. The +Z head has significantly different characteristics in the region of negative spacecraft potentials such that the algorithm does not operate well for that head under those conditions. The empirical model team is working to develop a single algorithm that will successfully select appropriate points from either head under all circumstances.

Parameterization of a three-dimensional electric potential model, which includes parallel potential drops, has been largely completed, and the initial studies of ion motion in these fields begun. We have started quantitative modeling of the ion motions through the polar cap and then longitudinally into the nightside auroral arcs in order to investigate the possible origin of nightside auroral ion beams.

A program has been developed to extract spin curve data from RIMS MAF1 files and integrate them with temperature, density and potential data from the analysis program for detailed statistical studies of the ion distribution in the DE-1 wake. Development of a second program to bin these results by appropriate dimensionless parameters for statistical analysis has been initiated.

A semi-kinetic model of the polar wind, originally written by Tom Moore, is being modified to correct discontinuities in the code results at the lower boundary. With a working code, we plan to study the effect of higher ion temperatures on the polar wind, particularly on the oxygen ion escape flux.

DATA ANALYSIS AND MODELING

A considerable volume of data has been processed during this period. Some of it has already been used in current studies, and some is for use in future statistical analyses. Temperature, density and potential files available for use have been extended to more than 125 plasmasphere transits. For all of these files, the densities have been further processed by the technique noted above, which will be the standard henceforth. In addition, more than 75 of these data sets have been processed with the corresponding MAF1 files to provide inputs for a DE-1 wake analysis study, which is under way with Uri Samir.

A preliminary study of ion composition was carried out to gain some idea of how it varied spatially and with geomagnetic activity. It was found that H+ constitutes from 70% to 85% of the plasma beyond L ~ 2, the smaller fraction tending to occur on the evening side. The He+ percentage of the total decreases with L, reaching a minimum and leveling off between L ~ 2 to 3 at around 12% on the morning side and 18% on the evening side. The heavy ion 'torus' is evident in the statistics for O+ and O++. Effects of geomagnetic activity were only weakly evident in this data set except in O+, which shows an enhancement at lower L shells for the highest levels of activity. These preliminary results were presented to the IAGA Symposium on Variability of Ion Composition in the Earth's Magnetosphere at the IUGG Meeting in Vancouver, Canada (Ref. 2).

Some additional work has been done in the study comparing theoretical models of ion distributions in spacecraft wakes, in a tangential response to referee comments on the manuscript. The SHEATH program was used to examine the effect of aperture acceptance angle on the ratio of wake flux to ram flux. It is found that this ratio decreases with aperture acceptance angle due to the fact that flux variations with spin angle are greater in the wake than in the forward hemisphere (ram direction). This paper has now been accepted for publication (Ref. 3).

Based on a subset of data from the earlier observational study of ion fluxes in the DE-1 wake (Ref. 4), we have carried out a preliminary theory/ observation comparison with the 1-dimensional plasma expansion model of Singh. Over the range of ion Mach numbers typical of H+ in the plasmasphere, the agreement was reasonable, within factors of 3 to 5. However, a number of approximations had to be used in order to match the conditions of the calculation with those of the observations, with sufficient uncertainties involving both larger and smaller results that an adequate assessment of the plasma expansion mechanism could not be made. A more appropriate boundary geometry in a 2- or 3-dimensional model should provide a much improved comparison. A draft of the preliminary results has been prepared for subsequent submittal (Ref. 5). Work on the improved model is continuing.

Work is continuing on the study of polar O+ beams. These beams, which have energies of ~ 10-20 eV, are being examined with observations from a number of DE-1 and DE-2 instruments, including RIMS, PWI, HAPI, EICS, SAI, and LAPI.

RIMS data has been provided for use in a paper studying plasmapause signatures in F-region electron temperatures (Ref. 6).

A review of our efforts to date on kinetic modeling of ionospheric ion transport into the magnetosphere will be presented to an IEEE simulation meeting in October, 1987 (Ref. 7).

LABORATORY PLASMA FLOW STUDIES

The capability to perform plasma-body interactions in a supersonic, collisionless, binary ion plasma stream has been successfully added to the space plasma physics research laboratory at SSL. The motivation for the new source was to develop a plasma beam where ions with unequal masses would flow at a common velocity, thereby simulating, for example, the motion of natural and/or artificial satellites through planetary ionospheres. The plasma beam characteristics are not optimal as yet, but sufficient to allow performance of an experiment where the flow about the edge of a large plate was examined. The nominal conditions of the plasma for the experiment were as follows:

ion constituents -- neon (Ne+) and krypton (Kr+)

mass ratio -- M(Kr+)/M(Ne+) = 4.1

drift energy -- Ed(Ne+) = 20-25 eV and Ed(Kr+) = 85-95 eV

ambient density -- n = 0.1-1.1E5 cm(-3) at ~ 70 cm from source

ion component ratio -- n(Ne+)/n(Kr+) = variable

electron temperature -- Te = 3000-4000 K

plasma space potential -- 2-3 volts

ion temperature -- Ti < Te.

Three cases of ion density ratios were treated in the experiment: n(Ne+)/n(Kr+) = 2.0, 0.5, 0.2. In the wake of the plate for each case, relative motion between the light mass (Ne+) and the heavy mass (Kr+) is observed to increase somewhat as the density of Ne+ decreases. The normal component of the Ne+ velocity, relative to the flow direction incident at the plate, attains values greater than the ion acoustic speed in the ambient plasma due to the electric field generated from space charge effects in the plasma-plate edge boundary region. The normal velocity component for Kr+ barely reaches supersonic speeds at the farthest measurement locations.

The filling of the wake region is analogous to the processes involved in the 'plasma expansion into a vacuum'. For the single ion plasma case this has been recently demonstrated by Wright et al. (Ref. 7,8). Results of the binary plasma experiment are consistent with some of the theoretical predictions of binary ion expansion, however, the present beam conditions allow only a limited comparison. Data are still being analyzed, and the experiment and results are being documented (Ref. 9).

PERSONNEL

Dr. Gordon R. Wilson has joined our group as a Research Associate. He recently received his Ph. D. (Ref. 10) from Brigham Young University. He will augment our capabilities in both numerical modeling and data analysis.

MEETINGS

Dr. Comfort participated in the NSF Workshop on Solar Terrestrial Physics, August 6-8, 1987 in Seattle, WA. He also attended the IAGA/IUGG Meeting in Vancouver, Canada, August 9-22, 1987, where he presented a paper on ion composition (Ref. 2) and an invited paper (Ref. 11) on plasmasphere-ionosphere coupling for Dr. Horwitz, who was unable to attend. Drs. Comfort and Horwitz attended the Workshop on Experiments with Magnets in Low Earth Orbit Using Space Plasma Laboratory Diagnostics, September 15-16, 1987, Huntsville, AL. Dr. Horwitz was a co-author on a paper on dynamics of reconnected flux tubes, presented to the Spring AGU Meeting (Ref. 12).

PUBLICATIONS

In addition to the papers noted above, the following papers are at the indicated stage of the publication cycle:

* Papers published during this period are those on: the geomagnetic spectrometer in the magnetotail lobes (Ref. 13), O++ in the plasmasphere (Ref. 14), invited IUGG report on core plasma in the magnetosphere (Ref. 15), plasmasphere and plasmapause characteristics (Ref. 16), models of plasmaspheric plasma distributions (Ref. 17), plasmasphere thermal structure (Ref. 18), electron temperature enhancements in satellite wakes (Ref. 19), ring current effects on SAR arc formation (Ref. 20), conical ion distributions near 1 RE (Ref. 21), solar wind control of the geomagnetic mass spectrometer (Ref. 22), ATS-6 record charging events (Ref. 23), and SCATHA potential modulations (Ref. 24).

* Papers accepted for publication and in press are those on: heavy ion enhancements in the outer plasmasphere (Ref. 25), tail lobe ion spectrometer (Ref. 26), MHD wave speeds in the inner magnetosphere (Ref. 27), perpendicular ion heating effects on refilling (Ref. 28) magnetic mirror force (Ref. 29), kinetic approach in global plasma transport modeling (Ref. 30), particle and field signatures associated with SAR arc field lines (Ref. 31), electron beam experiments at high altitudes (Ref. 32), modeling with an outer plasmasphere heat source (Ref. 33), statistical models of equatorial trapped plasma (Ref. 34), dynamical evolution of low energy ions in Earth's magnetosphere (Ref. 35), statistical survey of plasmaspheric

ion properties (Ref. 36), high altitude electron beam experiments (Ref. 37), and broadband electrostatic noise near the shuttle orbiter (Ref. 38).

* Papers submitted for publication and in review are those on: centrifugal ion acceleration in the polar ionosphere (Ref. 39), and plasmapause signatures in F-region electron temperature signatures (Ref. 6).

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REFERENCES

1. Comfort, R. H., P. D. Craven, D. L. Gallagher, R. L. West, C. R. Chappell, Spacecraft potential dependence on plasma density and its application to DE-1/RIMS density analysis, to be submitted to J. Geophys. Res., 1987.

2. Comfort, R. H., I. T. Newberry, C. R. Chappell, Variations of thermal ion composition in the plasmasphere with geomagnetic activity, submitted for presentation to the 19th IUGG General Assembly, August 9-22, 1987, Vancouver, Canada.

3. Samir, U., R. H. Comfort, N. H. Stone, and K. H. Wright, Jr., A comparison between plasma wake models for plasmaspheric and ionospheric conditions, Planet. Space Res., in press, 1987.

4. Samir, U., R. H. Comfort, C. R. Chappell, N. H. Stone, Observations of low-energy ions in the wake of a magnetospheric satellite, J. Geophys. Res., 91, 5725, 1986.

5. Samir, U., R. H. Comfort, N. Singh, K. S. Hwang, and N. H. Stone, Expansion of a space plasma into the wake of a plasmaspheric satellite: theory/experiment comparison, to be submitted to Phys. Rev. Lett., 1987.

6. Brace, L. H., C. R. Chappell, R. H. Comfort, M. O. Chandler, and J. L. Horwitz, F-region electron temperature signatures of the plasmapause based on Dynamics Explorer 1 and 2 measurements, submitted to J. Geophys. Res., 1987.

7. Wright, Jr., K. H., N. H. Stone, and U. Samir, A study of plasma expansion phenomena in laboratory generated plasma wakes: preliminary results, J. Plasma Physics, 33, 71, 1985.

8. Wright, Jr., K. H., D. E. Parks, I. Katz, N. H. Stone, and U. Samir, More on the expansion of a collisionless plasma into the wake of a body, J. Plasma Physics, 35, 119, 1986.

9. Wright, Jr., K. H., A study of single and binary ion plasma expansion into laboratory generated plasma wakes, Ph. D. Dissertation, University of Alabama in Huntsville, in preparation, 1987.

10. Wilson, G. R., Simulation of the plasma interaction with thin dust clouds, Ph. D. Dissertation, Brigham Young University, 1987.

11. Horwitz, J. L., R. H. Comfort, L. H. Brace, M. O. Chandler, C. R. Chappell, W. B. Hanson, J. U. Kozyra, Dynamics Explorer measurements of plasmasphere-ionosphere coupling near trough flux tubes, presented to the 19th IUGG General Assembly, August 9-22, 1987, Vancouver, Canada.

12. Saflekos, N., J. L. Burch, M. Sugiura, D. A. Gurnett, and J. L. Horwitz, Observations of reconnected flux tubes within the midaltitude cusp, EOS Transactions of the American Geophysical Union, 68, 383, 1987.

13. Horwitz, J. L., Geomagnetic spectrometer in the magnetotail lobes, Chapman monograph on Magnetotail Physics, ed. A. T. Y. Liu, Johns Hopkins Press, p. 291, 1987.

14. Chandler, M. O., J. J. Ponthieu, T. E. Cravens, A. F. Nagy, and P. G. Richards, Model calculations of minor ion populations in the plasmasphere, J. Geophys. Res., 92, 5885, 1987.

15. Horwitz, J. L., Core plasma in the magnetosphere, Rev. Geophys., 25, 579, 1987.

16. Horwitz, J. L., R. H. Comfort, and C. R. Chappell, Plasmasphere and plasmapause region characteristics as measured by DE-1, Adv. Space Res., 6, 21, 1987.

17. Torr, D. G., P. G. Richards, J. L. Horwitz, and M. R. Torr, Models of the plasmaspheric thermal plasma distribution, Adv. Space Res., 6, 151, 1987.

18. Comfort, R. H., Plasmasphere thermal structure as measured by ISEE-1 and DE-1, Adv. Space Res., 6, 31, 1987.

19. Singh, N., U. Samir, K. H. Wright, Jr. and N. H. Stone, A possible explanation of the electron temperature enhancement in the wake of a satellite, J. Geophys. Res., 92, 6100, 1987.

20. Kozyra, J. U., E. G. Shelley, R. H. Comfort, L. H. Brace, T. E. Cravens and A. F. Nagy, The role of ring current O+ in the formation of Stable Auroral Red arcs, J. Geophys. Res., 92, 7487, 1987.

21. Olsen, R. C., and C. R. Chappell, Conical ion distributions near one earth radius, Adv. Space Res., 6, 117, 1986.

22. Waite, Jr., J. H., M. Lockwood, T. E. Moore, M. O. Chandler, J. L. Horwitz, and C. R. Chappell, Solar wind control of the geomagnetic mass spectrometer, Solar Wind-Magnetosphere Coupling, Terra Scientific Publishing Co., p. 707, 1986.

23. Olsen, R. C., The record charging events from ATS-6, J. Spacecraft Rockets, 24, 362, 1987.

24. Craven, P. D., R. C. Olsen, J. Fennell, D. Croley, and T. Aggson, Potential modulations on the SCATHA spacecraft, J. Spacecraft Rockets, 24, 150, 1987.

25. Roberts, W. T., Jr., J. L. Horwitz, R. H. Comfort, J. H. Waite, Jr., J. L. Green, and C. R. Chappell, Heavy ion enhancements in the outer plasmasphere, J. Geophys. Res., in press, 1987.

26. Candidi, M., S. Orsini, and J. L. Horwitz, The tail lobe ion spectrometer: theory and observations, J. Geophys. Res., in press, 1987.

27. Moore, T. E., D. L. Gallagher, J. L. Horwitz, and R. H. Comfort, MHD wave breaking in the outer plasmasphere, Geophys. Res. Lett., in press, 1987.

28. Singh, N., and K. S. Hwang, Perpendicular ion heating effects on the refilling of the outer plasmasphere, J. Geophys. Res., in press, 1987.

29. Comfort, R. H., The magnetic mirror force in plasma fluid models, Monograph on Huntsville Workshop on Magnetosphere Ionosphere Plasma Models, in press, 1987.

30. Horwitz, J. L. The kinetic approach in global plasma transport modeling: advantages and difficulties, Monograph on Huntsville Workshop on Magnetosphere Ionosphere Plasma Models, in press, 1987.

31. Kozyra, J. U., T. E. Cravens, A. F. Nagy, D. A. Gurnett, R. L. Huff, R. H. Comfort, J. H. Waite, Jr., L. H. Brace, R. A. Hoffman, J. D. Winningham, J. L. Burch, and W. K. Peterson, Observations by the Dynamics Explorer satellites of new signatures in particle and field measurements associated with SAR arc field lines at magnetospheric heights, Adv. Space Res., in press, 1987.

32. Olsen, R. C., Electron beam experiments at high altitudes, J. Electrostatics, in press, 1987.

33. Chandler, M. O., J. U. Kozyra, J. L. Horwitz, R. H. Comfort, W. K. Peterson and L. H. Brace, Modeling of the thermal plasma in the outer plasmasphere: a magnetospheric heat source, Monograph on Huntsville Workshop on Magnetosphere Ionosphere Plasma Models, in press, 1987.

34. Olsen, R. C., and C. R. Chappell, Statistical models of equatorial trapped plasma, Monograph on Huntsville Workshop on Magnetosphere Ionosphere Plasma Models, in press, 1987.

35. Giles, B. L., C. R. Chappell, J. H. Waite, Jr., T. E. Moore, J. L. Horwitz, Dynamic evolution of low energy ions in the terrestrial magnetosphere, Monograph on Huntsville Workshop on Magnetosphere Ionosphere Plasma Models, in press, 1987.

36. Comfort, R. H., I. T. Newberry and C. R. Chappell, Preliminary statistical survey of plasmaspheric ion properties from observations by DE-1/RIMS, Monograph on Huntsville Workshop on Magnetosphere Ionosphere Plasma Models, in press, 1987.

37. Olsen, R. C., and H. A. Cohen, Electron beam experiments at high altitudes, Adv. Space Res., in press, 1987.

38. Hwang, K. S., N. H. Stone, K. H. Wright, Jr., and U. Samir, the emissions of broadband electrostatic noise in the near vicinity of the shuttle orbiter, Planet. Space Sci., in press, 1987.

39. Swinney, K., J. L. Horwitz, and D. Delcourt, Centrifugal acceleration of ionospheric ions in the polar magnetosphere, submitted to J. Geophys. Res., 1987.