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MAGNETIZED ION FLUX TO ARBITRARY-SHAPED OBJECTS

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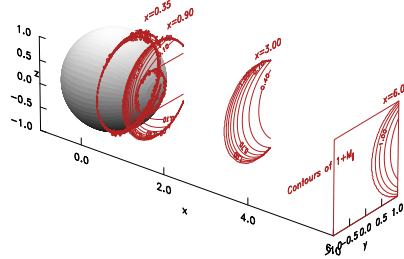
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A full analytic solution has been obtained[1], in the drift-approximation, of the interaction of magnetized plasma ions with a collecting object, such as a Langmuir probe, of arbitrary shape. This solution provides the theoretical basis for interpreting “perpendicular” or “oblique” Mach probes that seek to determine the parallel and perpendicular background plasma flow by measuring the ion flux as a function of the orientation of the collector surface.

It is also relevant, for example, to the charging of large space-craft in low earth orbit, and to the interaction of the moons of Jupiter with its magnetosphere.

The theory avoids any dependence upon heuristic diffusion and instead calculates the solution, using the method of characteristics, accounting for parallel velocity, all cross-field drifts, and self-consistent boundary conditions. This model is a properly justified description of the typical situation where a probe is smaller than the surrounding turbulent eddies and localized diffusion is absent.

When the external perpendicular velocity arises purely from $E \times B$ drifts, the plasma solution in the entire region surrounding the object is obtained explicitly, as illustrated here.



When external diamagnetic drifts are present, considerable complications arise, but the flux density to the surface per unit perpendicular area, is shown for practical purposes to be given by a relatively simple formula:

$$\ln \left\{ \frac{\Gamma_{\parallel p}}{n_{\infty} c_s} \right\} = -1 - M_{\parallel \infty} + \cot \theta [M_E + (1 + M_{\parallel \infty}) M_{Te} + M_{Di} - \left(\frac{1 - \sin \alpha}{1 + \sin \alpha} \right) M_D],$$

where α is the angle between the probe surface and the magnetic field (in 3-dimensions), and θ is the angle within the plane containing field and external drift. All drift velocities here refer to the external, unperturbed plasma.

The first line (incorporating only the $E \times B$ drift Mach number, M_E) agrees within 10% with prior formulas. The second line arises from various diamagnetic drifts: of the ions (M_{Di}) the electrons due to temperature gradients (M_{Te}) and the difference ($M_D = M_{Di} - M_{De}$). These terms were previously unknown, but may contribute importantly to Mach-probe interpretation.

REFERENCES

- [1] I.H.Hutchinson, *Physics of Plasmas*, **15**, 123503 (2008)