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About the definition of a "local" temperature around a spacecraft in the ionosphere

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During the 1970's a hot controversy emerged between in-situ measurements of the electron temperature in the ionosphere and ground measurements by incoherent backscatter radars. We suggest a possible explanation to this controversy. We define the "local" temperature of ionized species by the variance of the square root of the energy, and here by:
$3 \frac{}{2n_\infty kT(\mathbf{r}) = \int_{(-2q\phi(\mathbf{r})/m)^{1/2}}^{+\infty} \left(q\phi(\mathbf{r}) + \frac{1}{2}mv^2\right)\left(\frac{m}{2\pi kT}\right)^{3/2} e^{-\left[q\phi(\mathbf{r}) + \frac{1}{2}mv^2\right]/kT(\mathbf{r})} \, \mathrm{d}^3\mathbf{v}.} Here n_\infty$ is the ambient density of the ionized gas, k the Boltzmann constant, T the temperature, q the charge, ϕ the electric potential at a point $\mathbf{r}$ and m is the mass. For repelled species, this equation has an analytical solution, and we obtain: $3 \frac{}{2kT(\mathbf{r}) = e^{-q\phi(\mathbf{r})/kT(\mathbf{r})}\left[q\phi(\mathbf{r}) + \frac{3}{2}kT(\mathbf{r})\right],} withtheconditions: \lim_{\mathbf{r}\to+\infty} \phi(\mathbf{r}) = 0; \ \lim_{\mathbf{r}\to+\infty} T(\mathbf{r}) = T_\infty; \ \lim_{\mathbf{r}\to+\infty} n(\mathbf{r}) = n_\infty. If the electric potential vanishes, the local temperatures of ionized species go towards their ambient temperatures. Thetheor$

Like Laframboise and Parker (1973), we shall consider an ionized gas without collisions and the ideal case of a potential well with a spherical symmetry, but there is no physical body. We define the number density as: n = $\int f \, \mathrm{d}^3\mathbf{v} = n_\infty \left(\frac{m}{2\pi kT(r)}\right)^{3/2} \exp\left(\frac{-q\phi(r)}{kT(r)}\right) \int_{(-2q\phi(r)/m)^{1/2}}^{+\infty} e^{-mv^2/2kT(r)} \, 4\pi v^2 \, \mathrm{d}v. For repelled species; we generalize Boltzmann's fo$ $n_\infty \exp\left[\frac{-q\phi(r)}{kT(\phi(r), r)}\right]$.

We now calculate particles fluxes for attracted and repelled species. This will be a generalisation of Laframboise and Parker's (1973) formulas: J = $\int f v_r \, \mathrm{d}^3\mathbf{v} = J_0 \left(1 - \frac{q\phi(a)}{kT(\phi(a), a)}\right), where$ J_0 is the thermal flux and a the radius of a spherical probe. For the repelled species, we have: J = $J_0 \exp\left[\frac{-q\phi(a)}{kT(\phi(a), a)}\right]$.

In other words, the current due to repelled species is no longer an exponential! Our results also imply a modification of the PIC simulation methods. Because the temperature is no longer considered as a parameter but as a variable.

Reference:

Laframboise, J.G. and Parker L.W. (1973), {\it The Physics of Fluids}, p. 629.

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