Ann. Geophys. Discuss., https://doi.org/10.5194/angeo-2018-64-RC6, 2018

Annales Geophysicae Discussions
Open Access

Interactive comment on "Dynamics Geomagnetic Storm on 7–10 September 2015 as Observed by TWINS and Simulated by CIMI" *by* Joseph D. Perez et al.

Anonymous Referee #1

Received and published: 17 August 2018

My comment is simple: How did the authors calculate the plasma pressure?

The following is the procedure that I am currently understanding. First of all, please make sure if my understanding is correct.

1. For the TWINS results, the authors obtained the differential flux F from ENA images. For CIMI, the authors calculated the differential flux F. F has units of the number of ions/(unit energy · unit time · unit area · unit solid angle).

Yes that is correct.

2. The authors calculated the pressure terms by integrating F with respect to energy and pitch angle.

$$P_\perp = \int d\cos\alpha \sin^2\alpha \int dE \sqrt{\frac{2E}{m}} F, \qquad (1)$$

$$(2) \quad P_{||} = 2\int d\cos\alpha \cos^2\alpha \int dE \sqrt{\frac{2E}{m}} F.$$

We can only apologize to the Referee. There was a typing error in the equations we sent in our previous reply. The factor in the integral should be $\sqrt{2mE}$. There also is a factor of 2π from the integral over the gyrotropic angle. The paragraph in the proposal is now

The pressure anisotropy shown in Figure 3 is defined as

$$A = \frac{P_\perp - P_{||}}{P_\perp + P_{||}}$$

with

$$\begin{Bmatrix} P_{\perp} \\ P_{\parallel} \end{Bmatrix} = 2\pi \int_{-1}^{+1} d\cos\alpha \begin{Bmatrix} \sin^2\alpha \\ 2\cos^2\alpha \end{Bmatrix} \left(\int_0^{\infty} dE\, \sqrt{2mE}\; F(E, n, \cos\alpha) \right)$$

where *α* is the ion pitch angle, *E* is the ion energy, *n* is the ion density, *m* is the ion mass and *F(E,n,cos α)* is the number flux per unit area, energy, time, steradian. This definition is derived from Braginskii (1965) and is consistent with previous formulations, e.g., Lui et al. (1987).

The units are now $steradians * E\sqrt{m^2v^2}\,\frac{1}{El^2t * steradians} = E\frac{mv}{mv^2t} = \frac{E}{l^3}$, i.e., energy/vol as it should be.

comment

Now, I realized that the confusion comes from the definition of F.

That is exactly correct.

Eqs. (1) and (2) will be understandable if F is the velocity distribution function, NOT differential flux!

I am not sure what you mean by "differential flux". It is my understanding that one can have energy flux, number flux, charge flux, etc either per velocity, per energy, etc.

It is true that f is often the used for the velocity distribution function. That is not what F is the equation above and in the paper.

The velocity distribution function, which is the number of particles in 6-dimensional space, is defined by

$$F \equiv \frac{dN}{d^3\mathbf{x}d^3\mathbf{v}},$$

where N is the number of particles, and v is velocity.

Yes.

The relationship between the velocity distribution function F and the differential flux j is given by

$$F = \frac{m^2}{2E} j.$$

Using this relationship, Eqs. (1) and (2) yield

$$P_{\perp} = \int d\cos\alpha \sin^2\alpha \int dE \sqrt{2Em} j, \quad (3)$$

$$P_{||} = 2 \int d\cos\alpha \cos^2\alpha \int dE \sqrt{2Em} j. \quad (4)$$

Printer-friendly version

Eqs. (3) and (4) are consistent with Eqs. (7) and (8) of De Michelis et al. (1997) who use the symbol *J* to represent the differential flux.

Yes, the corrected equations above are exactly as you say. If all that is needed to make it clear is to change *F* to *j*, we have no problem with that.

Hereinafter, I would like to define the terms F and *j* to be the velocity distribution function and the

differential flux, respectively, to avoid confusion. I would appreciate if the authors make sure which equations, (1)-(2), or (3)-(4), the authors used to calculate the pressure.

Discussion paper

We want the function in the integral to per unit energy. That is not what we would call a "velocity distribution".

In the second reply, the authors stated that the plasma pressure was calculated by

$$P_\perp = \int p_{eq} d\cos\alpha \sin^2\alpha, \tag{5}$$

$$P_{||} = 2\int p_{eq} d\cos\alpha \cos^2\alpha, \tag{6}$$

$$p_{eq} = \frac{2\pi}{m}\int EjdE. \tag{7}$$

Although Eqs. (5)-(7) are different from Eqs. (1)-(2) and Eqs. (3)-(4), the authors state that the change of the equations does not affect the results. Why? Does it mean that the authors did not use these equations to calculate the pressure? Does Eqs. (5)-(7) include typographical error?

Honestly, we do not remember an equation of mine with a *j* in it. We would not say that Eqs. (5-6) contain typographical errors. We would say they were ill-defined and unclear. We appreciate your efforts to make them clear. At this point, we think that they are at least well-defined and describe appropriately the equations we used to calculate the anisotropy measurements and simulations we report in the paper.

I may misunderstand something, but I would appreciate very much if the authors answer these questions.

Given the unclear definitions we presented originally and the mistakes made in the equation we sent in our earlier reply, it is reasonable that you have not understood. To the best of our knowledge, the equations are now correct and well-defined.

To summarize, we want to use #ions per unit energy*area*time*steradians in the integral definition of the parallel and perpendicular pressure.

We have tried and will gladly continue to try to answer your questions until you are satisfied.

Interactive comment on Ann. Geophys. Discuss., https://doi.org/10.5194/angeo-2018-64, 2018.