Observations on Temperature Anisotropy in RISR-N Heating Events

Aidan Thayer [1], Lindsay V Goodwin [1], William J Longley [1], Jean-Pierre St-Maurice [2, 3]

1- Center for Solar-Terrestrial Research, Department of Physics, New Jersey Institute of Technology, Newark, NJ, USA
2- Department of Physics and Engineering Physics, University of Saskatchewan, Saskatoon, SK, Canada
3- Department of Physics and Astronomy, University of Western Ontario, London, ON, Canada

Introduction

- One of the longstanding problems in ionospheric science is that we assume the F-region ion temperature to be isotropic
- This means the ion temperature is the same in all directions with respect to the magnetic field and is the result of resonant charge exchange between O+ and O.
- However, works from and Raman et al (1981)[1] and St.-Maurice et al (1976)[2], show in times of heating due to strong electric fields (> 50 mV/m), the O+ velocity distribution distorts, and the ion temperature becomes anisotropic.
- **Here, data from advanced modular incoherent scatter radars (AMISRs) is used to characterize ion temperature anisotropy during strong heating events.**

Figure 1. Photo of Resolute Bay Incoherent Scatter Radar- North (RISR-N) (Photo Credit Craig Heinselman)

Methodology

- Heating events were identified in RISR-N scans with overlapping beams, as seen in Figure 2
  - In the F-region, plasma along the same magnetic field line will be subjected to the same plasma dynamics and E x B drift
  - Looking along the magnetic field line provides a calibration beam to check relative electron temperature and plasma density
  - Events that had heating above 1500 K for periods longer than 1 hour were chosen
- Events with strong electron heating (> 3000 K electron temperature), and low altitude/latitude overlap were removed.
  - 20 heating events from RISR-N data have been identified so far.

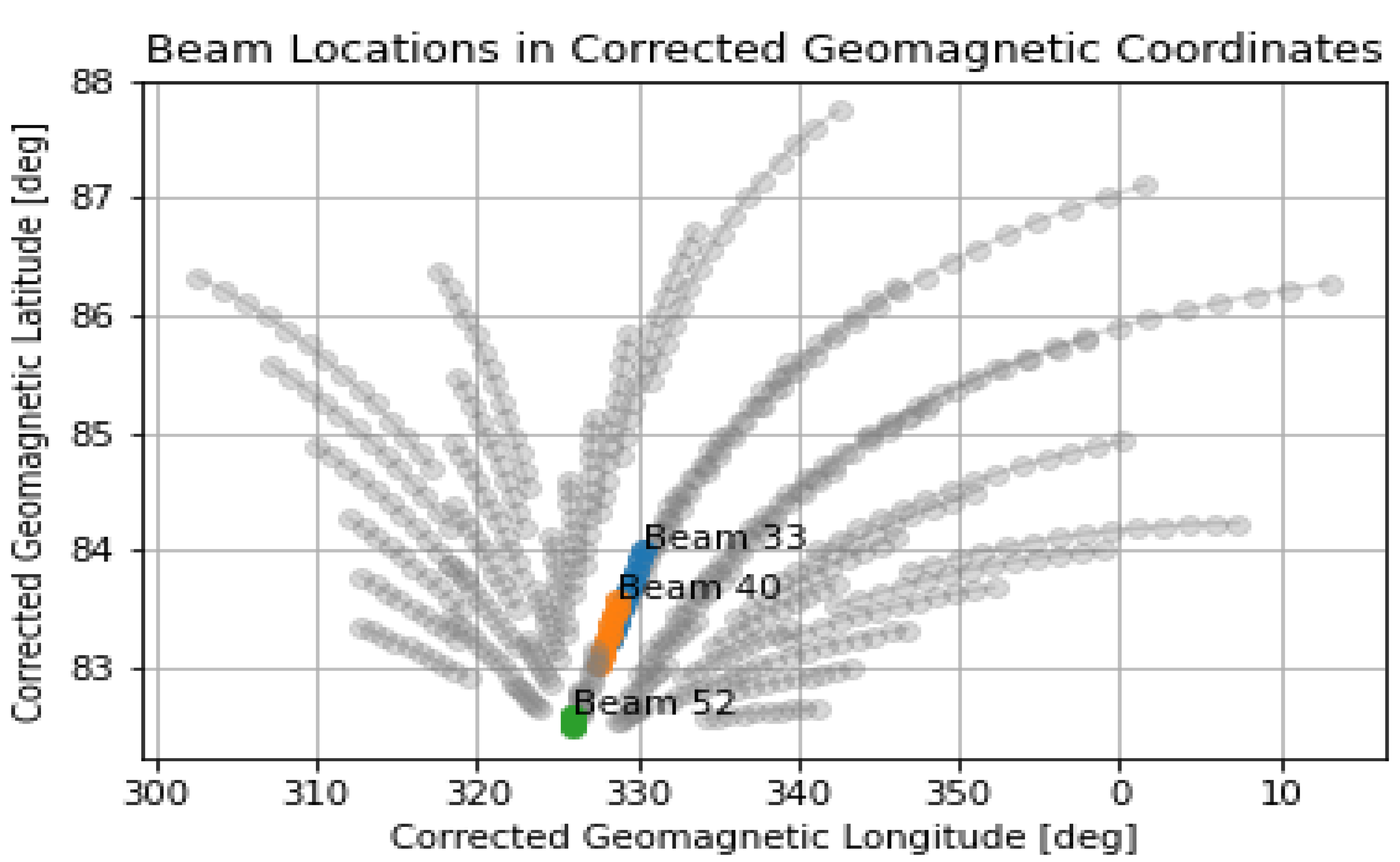


Figure 2. Beam Map of ImagingLP Beams. Note Beams 33 and 40 Overlap

Results

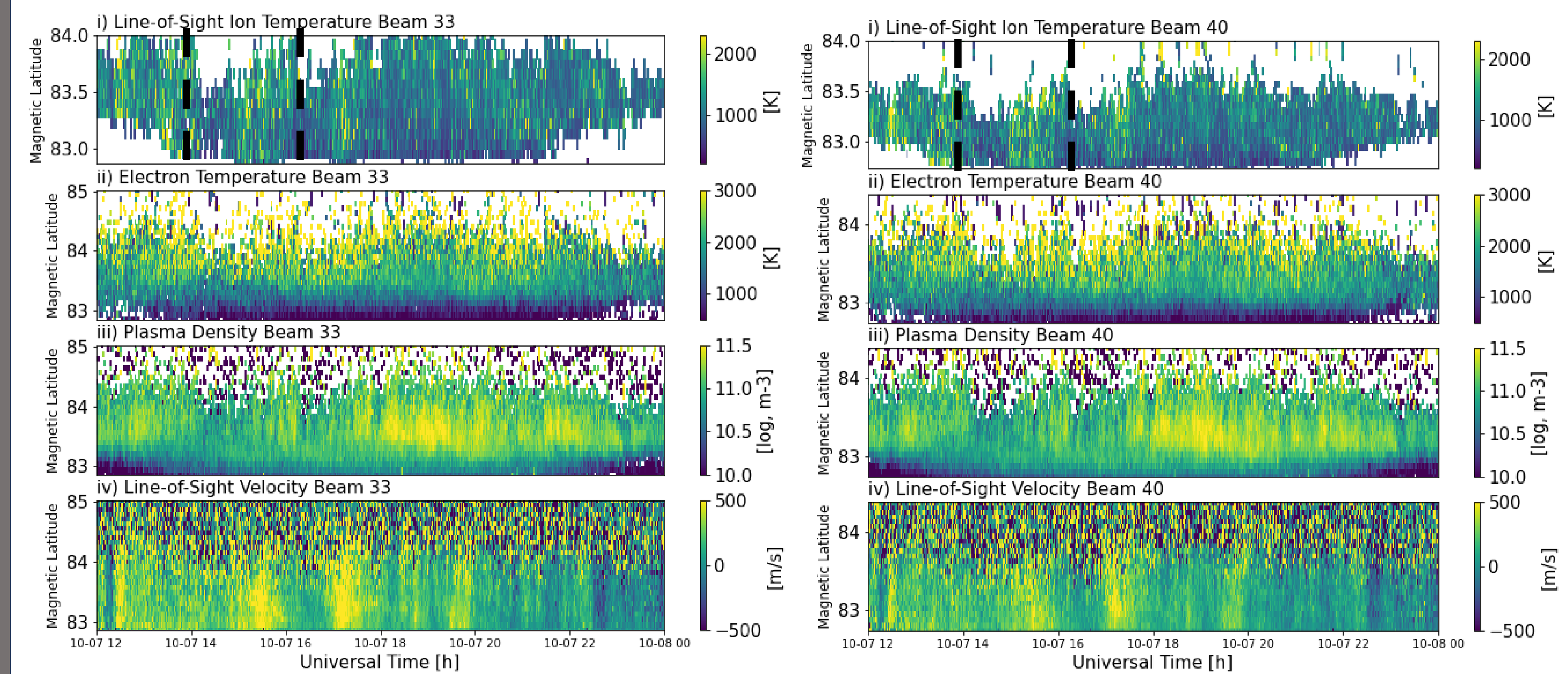


Figure 3-5. Range Time Intensity Plots of RISR-N Data from ImagingLP 10/7/2018. Beams 33, 40, and 52, Respectively. Azimuth Angle of 26 degrees, Elevation Angle 62, 69, and 87 degrees respectfully.

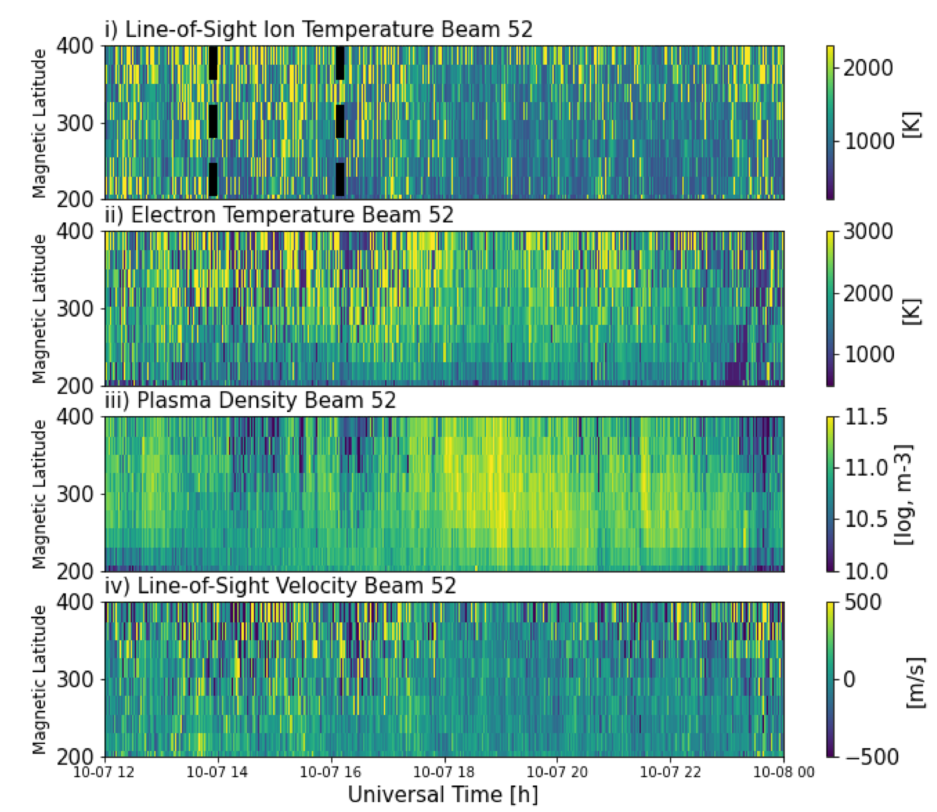
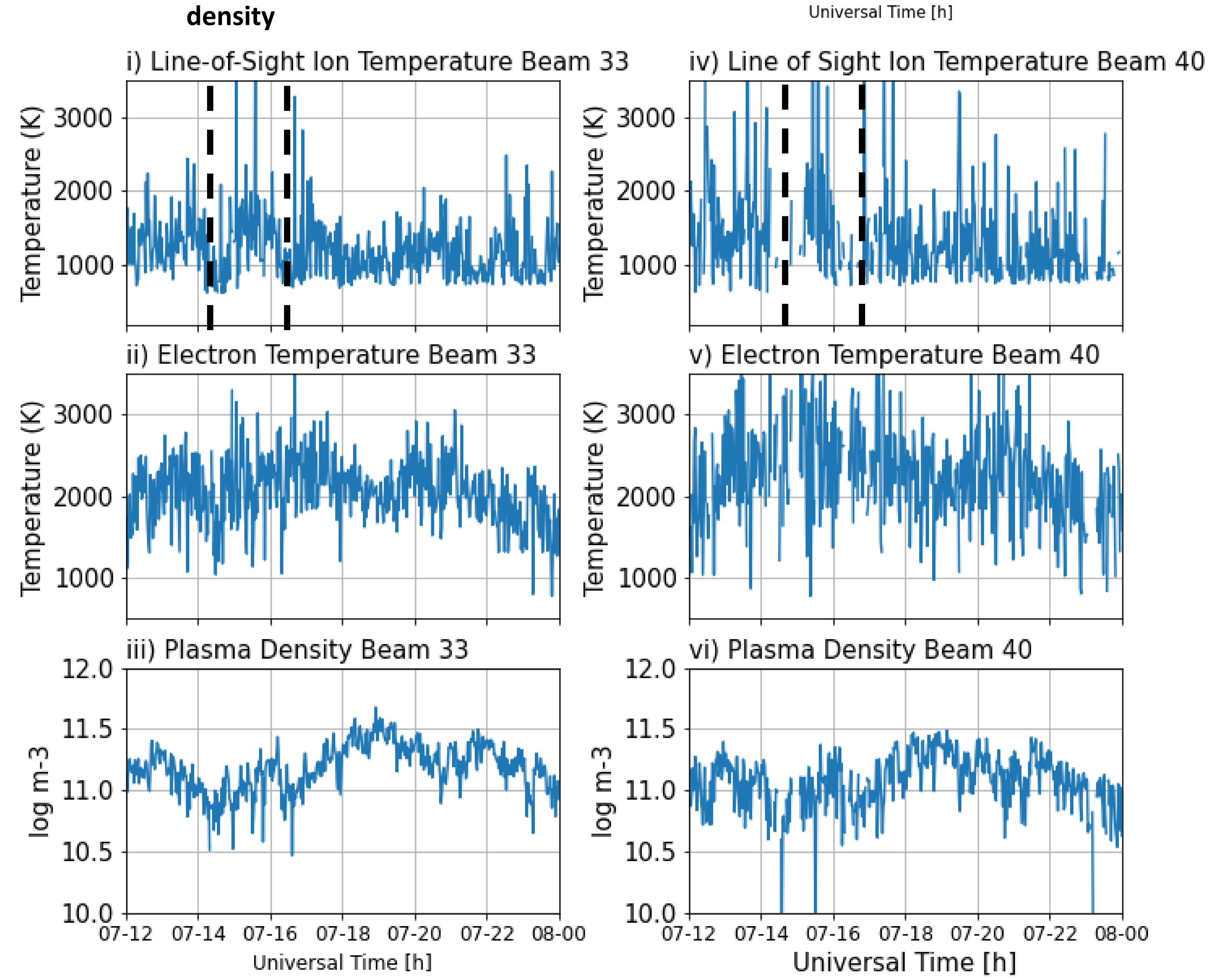


Figure 6: A Latitude Cut at 83 +- 0.009 degrees of Beam 33 and Beam 40 (at 290 and 371 km).. The figure shows line of sight ion temperature, electron temperature, and plasma density



Results (cont.)

$$T_{\parallel} = \frac{T_{\phi_1} - T_{\perp}\sin^2(\phi_1)}{\cos^2(\phi_1)}$$

$$T_{\perp} = \frac{T_{\phi_2} - \frac{T_{\phi_1}\cos^2(\phi_2)}{\cos^2(\phi_1)}}{\sin^2(\phi_2) - \tan^2(\phi_1)\cos^2(\phi_2)}$$

- T_{ϕ_1} Temperature of Beam 33
- T_{ϕ_2} Temperature of Beam 40
- ϕ_1 Aspect angle of Beam 33 w.r.t. magnetic field
- ϕ_2 Same for beam 40

To better characterize anisotropy independent of beam pair, the ion temperature perpendicular and parallel to the magnetic field was calculated using the overlapping beams, using the method proposed by Raman et al (1981) [1].

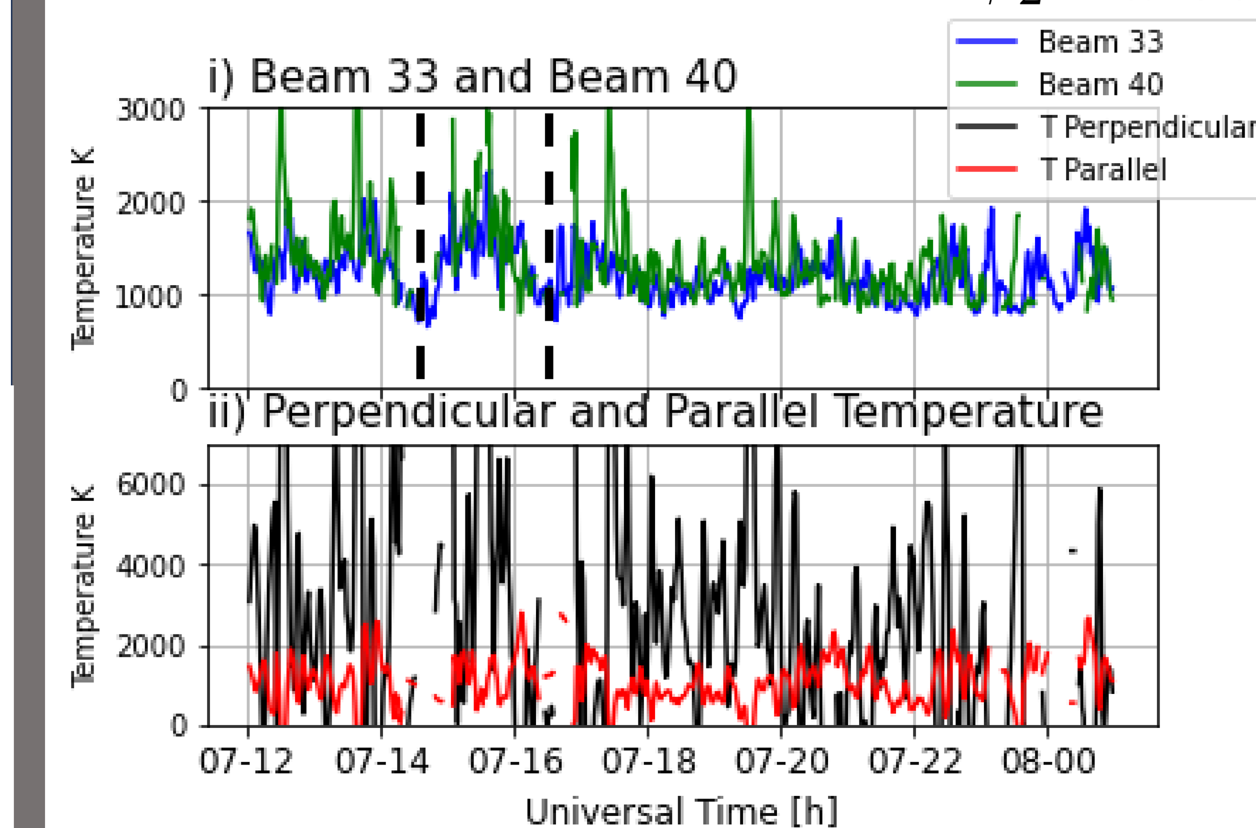


Figure 7: A comparison with a 3-point rolling average of i) Beam 33 and Beam 40 Ion Temperature at 290 and 371 km, respectively and ii) Calculated Parallel and Perpendicular Ion Temperatures. Heating event marked by dashed lines

Discussion and Future Work

This event shows very strong temperature anisotropy, but has some unfortunate non-physical temperature characteristics, especially outside of the heating event of interest. The perpendicular ion temperature is above the parallel ion temperature nearly always as the theory suggests, but the perpendicular ion temperature sometimes dips to near zero values. This could possibly be due to the existing electron heating or poor fits from high error bars in fitting of the ion line.

The limiting factor here is many heating events are disqualified, due to their high electron temperature. The effect of electron precipitation could therefore be studied and isolated.

This work can be continued for:

- More events
- Potentially expanding to other altitudes as well (through other beam pairs).

Works Cited

1- Raman, R. S. V., St-Maurice, J. P., & Ong, R. S. B. (1981). Incoherent scattering of radar waves in the auroral ionosphere. *Journal of Geophysical Research*, *86*(A6), 4751–4762. https://doi.org/10.1029/ja086ia06p04751

2- St-Maurice, J.-., Hanson, W. B., & Walker, J. C. G. (1976). Retarding potential analyzer measurement of the effect of ion-neutral collisions on the ion velocity distribution in the auroral ionosphere. *Journal of Geophysical Research*, *81*(31), 5438–5446. https://doi.org/10.1029/ja081i031p05438

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