How the solar wind dynamo affects the two polar regions differently

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1. Introduction

Aurora as observed by all-sky cameras on the ground and global imagers from space are mainly caused by electrons precipitating along the terrestrial magnetic field lines. Auroral brightness as observed with global imagers therefore indicate the presence of currents coupling the magnetosphere to the ionosphere. Bright aurora (precipitating electrons) is hence associated with a FAC out of the ionosphere.

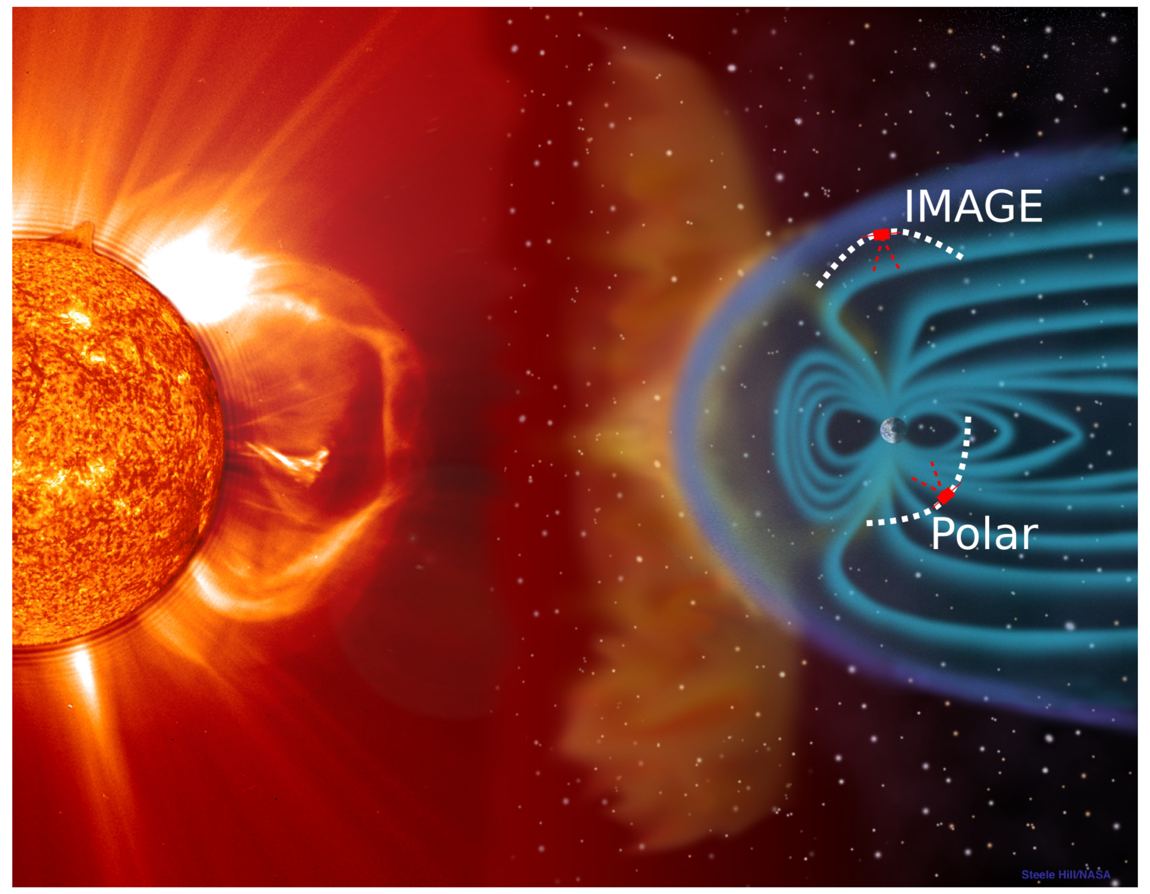

Figure 1: Credit: Steele Hill/NASA

Studies using simultaneous auroral imaging from space (IMAGE and Polar satellites, see Figure 1) suggest that large-scale asymmetries of the aurora in the two hemispheres can be explained by three generator mechanisms [2]:

1. Hemispheric differences in solar wind dynamo strength
2. Penetration of IMF B_y into the closed magnetosphere
3. Conductivity differences in conjugate regions

After a careful analysis of 19 hours conjugate imaging (see Figure 3), mechanism 1 seems to be most prominent in producing large-scale asymmetric aurora on the nightside.

Here we explain the basic principle of this mechanism; the solar wind dynamo current generator, which is believed to affect the two hemispheres differently. In Figures 6 and 5 we also show preliminary results of ongoing research that investigates the ionospheric response of these phenomena.

2. Solar Wind Dynamo

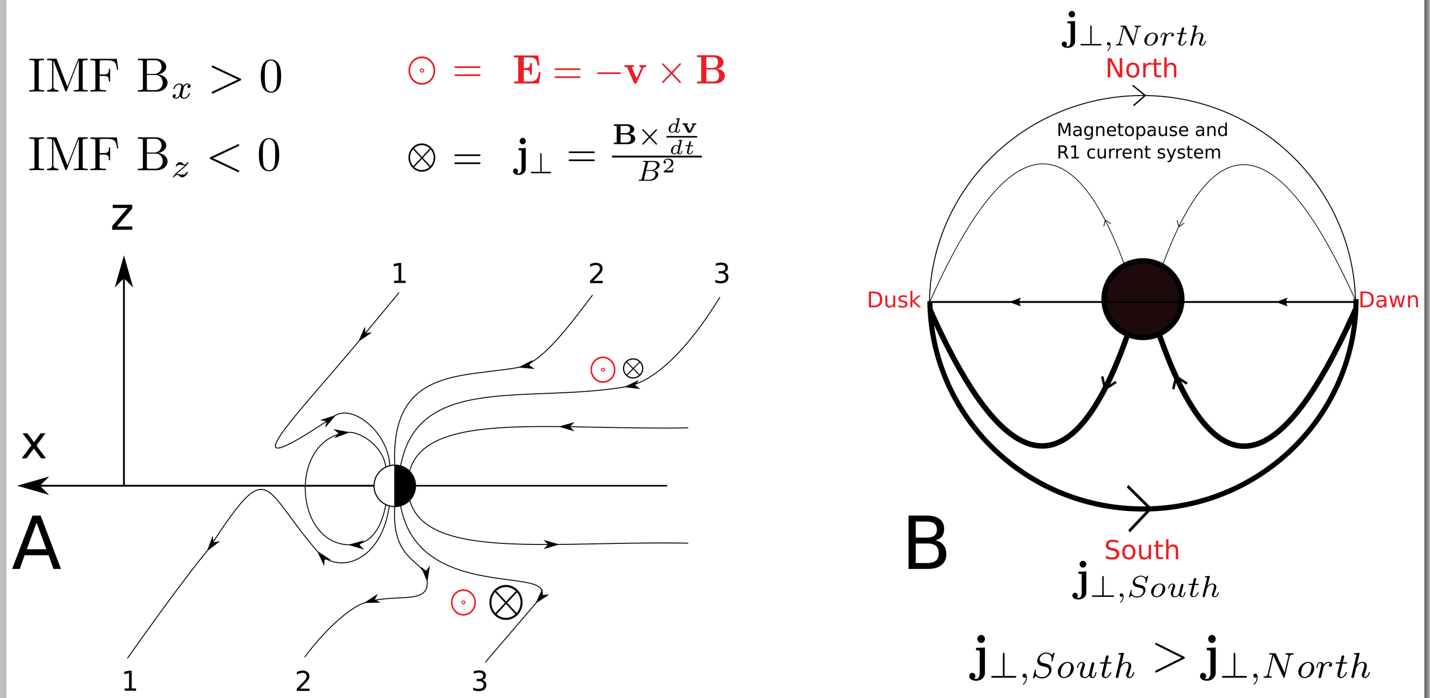

Figure 2: A) Magnetospheric response to a positive IMF B_x. The greater curl of B in the Southern Hemisphere drives stronger magnetopause currents in this hemisphere (large black arrow into the plane). The figure is a redrawing of Figure 2 in [1]. B) Cross-section of the magnetotail viewed towards the Earth's nightside. Magnetopause currents couple to their respective ionosphere via field-aligned currents.

3. An Example

Here we see an example of brighter aurora in the Northern Hemisphere pre-midnight sector observed by IMAGE compared to the aurora observed simultaneously in the opposite hemisphere by Polar. The solar wind is dominated by a large negative B_x and B_z leading to a more efficient solar wind dynamo in the Northern Hemisphere.

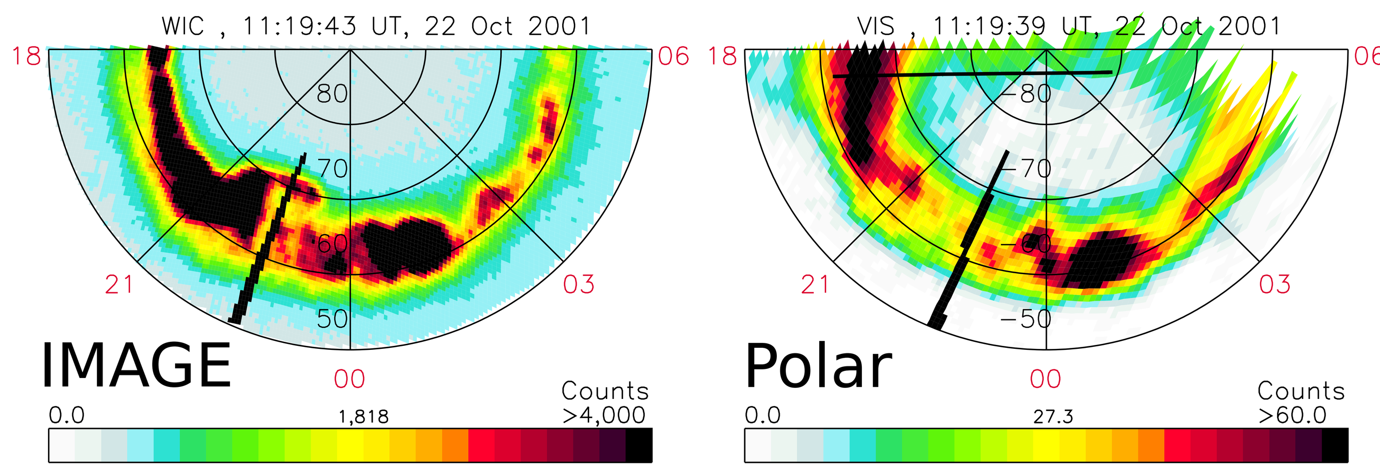

Figure 3: An example of asymmetric aurora caused by larger solar wind dynamo currents in the Northern Hemisphere. IMF $[x, y, z] = [-12, 2, -6]$ nT, λ_{tilt} = -10°, AE = 900 nT.

4. Search for statistical evidence - Method

By searching for global auroral images from the Northern Hemisphere only for conditions not favorable to mechanism 2 and 3 we, compare two extreme cases: Cases where the dynamo effect is believed to be strong in the Northern Hemisphere (coded black in Figures 6 and 5), and cases where the dynamo effect is believed to be strong in the opposite hemisphere (coded red in Figures 6 and 5).

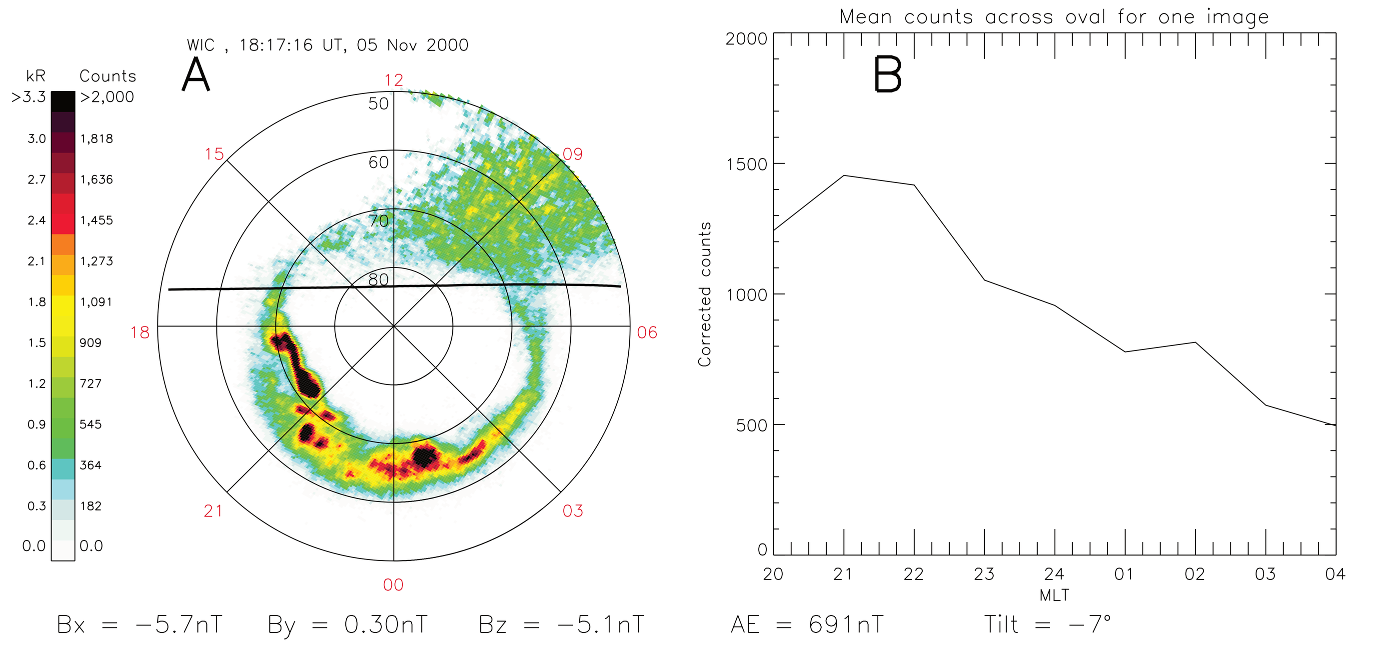

Figure 4: A) Example of an image satisfying the search criteria for the B_x negative case (black). B) Average counts along auroral oval from image in A).

5. Data survey

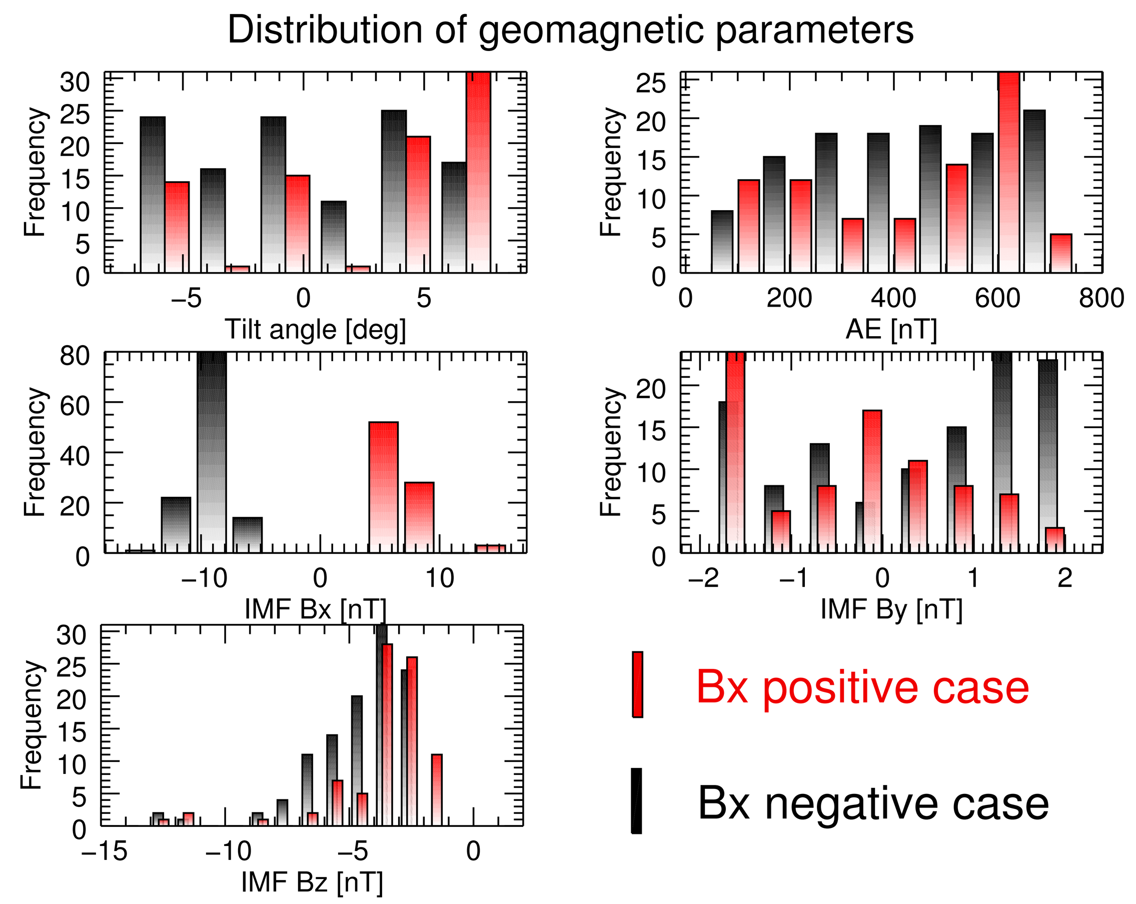

Figure 5: Distribution of geomagnetic parameters used in statistics in Figure 6.

6. Results - averaging search

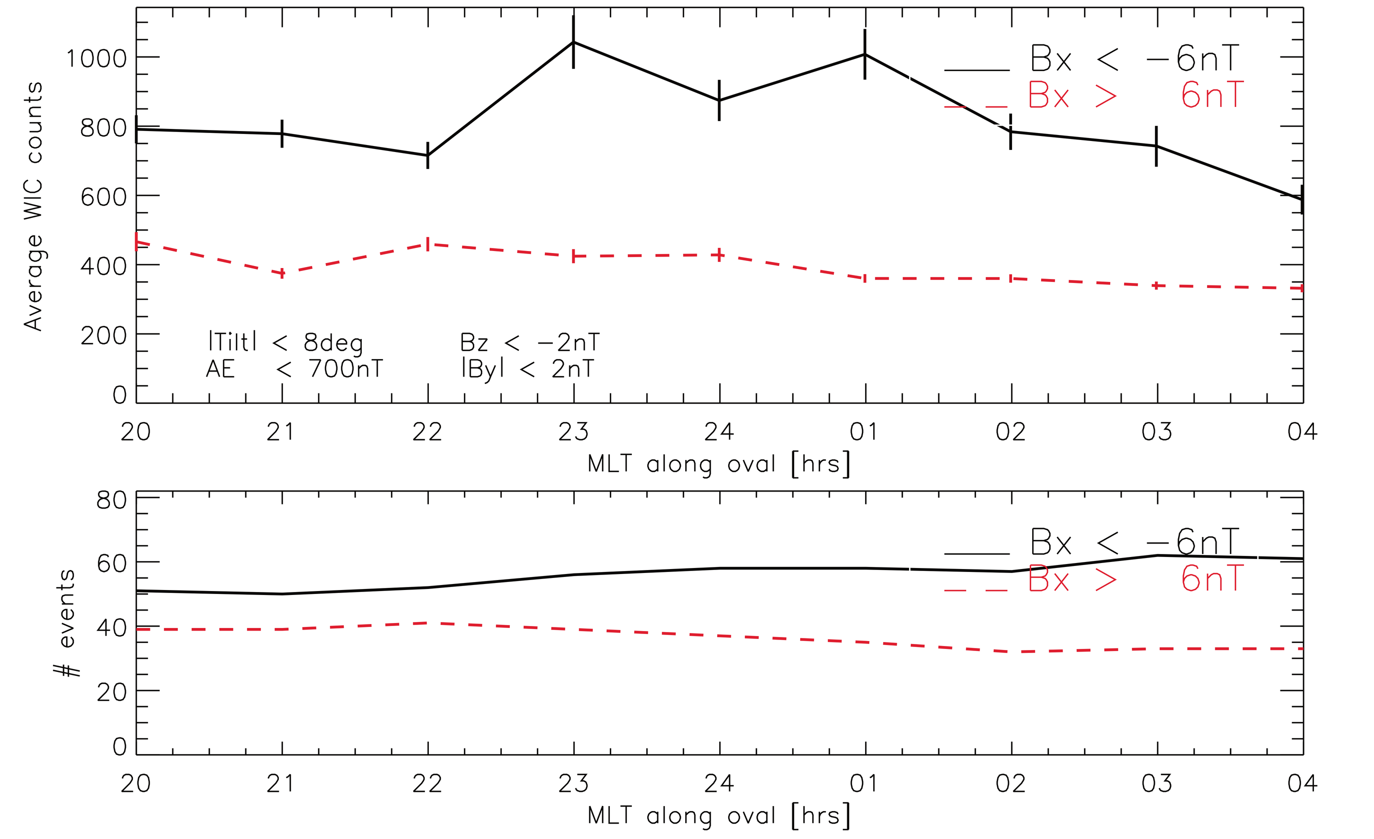

Figure 6: Upper panel: Result from averaging of search. Bottom panel: Number of events in the above statistics.

7. Conclusions/applications for space weather

- The two hemispheres respond differently to solar wind input when IMF has a significant B_x component during B_z negative
- The differences are consistent with the theory of hemispheric differences in solar wind dynamo efficiency [1] and earlier observational results [3]
- Improved knowledge of north/south impact preference from the solar wind
- Solar wind dynamo induced currents are most likely to affect Northern Hemisphere during IMF B_x negative conditions

8. References

[1] Cowley, S. W. H. Asymmetry effects associated with the x-component of the IMF in a magnetically open magnetosphere. *Planetary and Space Science 29*, 8 (Aug. 1981), 809–818.

[2] Østgaard, N., and Laundal, K. M. Auroral asymmetries in the conjugate hemispheres and interhemispheric currents. *Geophysical Monograph* (2012).

[3] Shue, J.-H., Newell, P. T., Liou, K., Meng, C., and Cowley, S. W. H. Interplanetary magnetic field Bx asymmetry effect on auroral brightness. *Journal of Geophysical Research 107* (2002), 1–10.