Journal of Special Topics

A1_3 Could the Northern Lights be seen in Leicester?

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October 19, 2009

Abstract

The Earth's auroras are caused by the interaction between the Earth's magnetosphere and the solar wind. This report discusses this mechanism and investigates the conditions that would allow the aurora to be seen at the latitude of the University of Leicester.

Introduction

The Earth's magnetosphere is primarily dipolar and is squashed on the dayside and stretched out into a tail on the night side by the solar wind. Energy into the Earth's magnetosphere comes from the solar wind, through a process called reconnection where solar field lines connect with geomagnetic field lines. The conditions are favourable for reconnection when the solar magnetic field (dragged out by the solar wind to form the interplanetary magnetic field (IMF)) is directed southwards.

Dayside reconnection occurs more frequently than reconnection in the tail of the magnetosphere. In the tail, the open flux created by dayside reconnection is stored for a time, before being released all at once in a process called a substorm where the open field lines reconnect in the tail.

When reconnection occurs, the plasma particles along the field lines are accelerated, and can travel down the field lines to the Earth and interact with the Earth's upper atmosphere. This interaction is what causes the aurora.

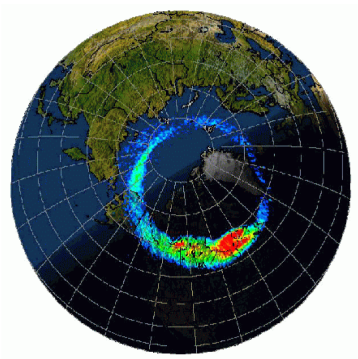

Fig.1 [1]

Viewed from space, the aurora appears as an oval, as shown in Fig.1. The oval represents the boundary between open and closed magnetic flux. When more open flux is being created, the oval expands towards the equator. Therefore, if enough open flux is created, the aurora could be seen as far south as Leicester.

However, the process of dayside reconnection that creates open flux is balanced by night side reconnection that close the flux again. This cycle of opening and closing magnetic flux is called the Dungey cycle. When open flux is created, the auroral oval expands, but it contracts again when night side reconnection closes the flux.

The auroral oval can be roughly modelled as a circle of radius λ, with the centre offset slightly from the pole.

It has been suggested [2] that large expansions of the oval could be possible through the suppression of night side reconnection by the Earth's ring current. This is a current caused by the drift of charged particles, which lies in the equatorial plane. It creates a magnetic field that opposes the Earth's intrinsic field.

Analysis

The ring current intensity is measured by the Sym-H index, H_{SYM}. Sharp decreases to values of -100nT or more are indicative of geomagnetic storms (disturbances in the geomagnetic field caused by changes in the solar wind). The relation between the oval radius, λ, dayside reconnection rate Φ_D and H_{SYM} was estimated to be given by equation 1 [2].

$$\lambda = 18.2 - 0.038H_{SYM} + 0.042\Phi_D \tag{1}$$

where λ is in degrees latitude, Φ_D is in kV and H_{SYM} is in nT.

The values for Sym-H lie approximately between –500nT and +100nT [3]. The greatest lambda will occur at the smallest value of H_{SYM} so we will assume a value of –500nT in the following calculation. This does mean that we are assuming that a large geomagnetic storm is occurring.

In order to see the aurora at Leicester, the oval would need to expand to 30 degrees latitude, which corresponds to an oval radius of 60 degrees.

The dayside reconnection rate needed is therefore given by

$$\Phi_D = \frac{\lambda - 18.2 + 0.038H_{SYM}}{0.042} \tag{2}$$

$$= \frac{60 - 18.2 + (0.038x(-500))}{0.042}$$

$$= 542.9kV$$

This value is large, but not impossible. Typical dayside reconnection rates are between 90kVand 150kVfor periods of southwards IMF [4], though values as high as 300kV have been observed in the past [5] and that was not during the most active period of the Sun. However, in order to get high levels of dayside reconnection the IMF must be directed southwards for large amounts of time, which mostly happens when the Sun is particularly active. Currently, the Sun is at a minimum in its activity cycle and so it seems very unlikely that we will see the northern lights here for quite a while yet.

Conclusion

Though it is theoretically possible for the auroral oval to expand far enough to be seen in Leicester, the high reconnection rate and intense ring current required mean that it is very unlikely considering that it is a solar minimum at the current time.

At solar maximum, the conditions would be more favourable for large expansions of the auroral oval, with larger ring currents and solar activity possible. In the past there have been recorded instances of the oval expanding to very low latitudes. In 1989 on March 13^{th} the northern lights were seen as far south as Florida [6], which is at 15 degrees latitude, significantly further south than Leicester. So, while unlikely, the Northern Lights may possibly be seen in Leicester when the Sun reaches another maximum.

References

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