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The formation of Earth's transpolar arcs by magnetotail reconnection

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Abstract

Transpolar arcs (or theta aurora) are auroral features which extend into the Earth's polar cap [1]. They occur predominantly when the interplanetary magnetic field (IMF) is northward [2]. A multitude of mechanisms (reviewed elsewhere [3]) has been proposed to explain their formation, but we have recently reported two statistical studies [3, 4] which demonstrate that transpolar arcs are consistent with the predictions of one specific mechanism in which they are formed by the closure of lobe magnetic flux by magnetotail reconnection in a twisted magnetotail [5]. In this mechanism, the twist results in a configuration where newly closed flux in the midnight sector has northern and southern hemisphere footprints that straddle the midnight meridian; this prevents the closed flux from returning to the day side in a simple manner. As tail reconnection continues, the footprints of closed field lines protrude into the polar cap, and the auroral emissions on these footprints form the transpolar arc.

The statistical evidence for the reconnection mechanism is twofold. First, whilst several studies have found a link between the location at which transpolar arcs form and the IMF B_Y component, the correlation is strongest if B_Y is evaluated approximately 4 hours before the arc forms [3], consistent with the timescale for newly-opened flux to be transported from the day side to the inner lobe [6]. Second, characteristic ionospheric flows predicted by the mechanism are observed shortly before the arcs form [4].

One untested prediction of the reconnection mechanism is that it implies that when transpolar arcs occur, the magnetotail should contain closed magnetic field lines that are embedded within the open lobes and which can be observed at high latitudes. We present in situ observations of this phenomenon, taken by the Cluster spacecraft on 15th September 2005. Cluster was located at high latitudes in the southern hemisphere lobe (far from the typical location of the plasma sheet), and a transpolar arc was observed by the FUV

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Figure 1: An example transpolar arc taken from the statistical study by Fear & Milan [3]. The image is projected onto a magnetic latitude/magnetic local time grid, with noon at the top of the image. Day glow is visible at the top, the main auroral oval is at about 65°N magnetic latitude, and the arc has formed at 2 MLT and extended into the polar cap (the dim region poleward of the main oval).

cameras on the IMAGE satellite. Cluster periodically observed plasma similar to a typical plasma sheet distribution, but at much higher latitudes - indicative of closed flux embedded within the high latitude lobe. Each time that this plasma distribution was observed, the footprint of the spacecraft mapped to the transpolar arc (significantly poleward of the main auroral oval). These observations are consistent with closed flux being trapped in the magnetotail and embedded within the lobe, and provide further evidence for transpolar arcs being formed by magnetotail reconnection.

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