3D Topology of the Magnetic Field in the Solar Corona

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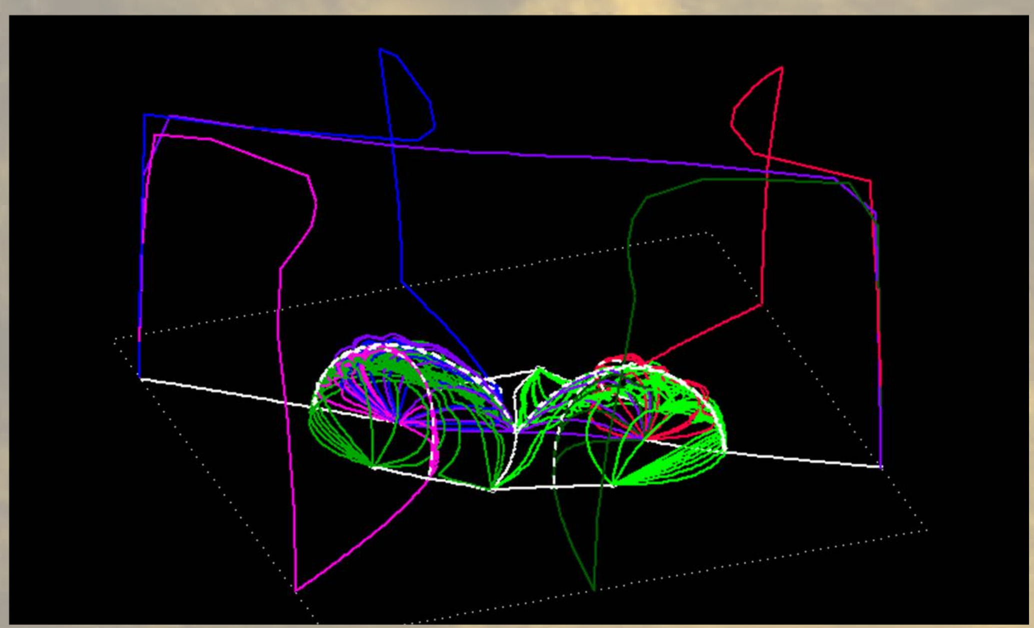
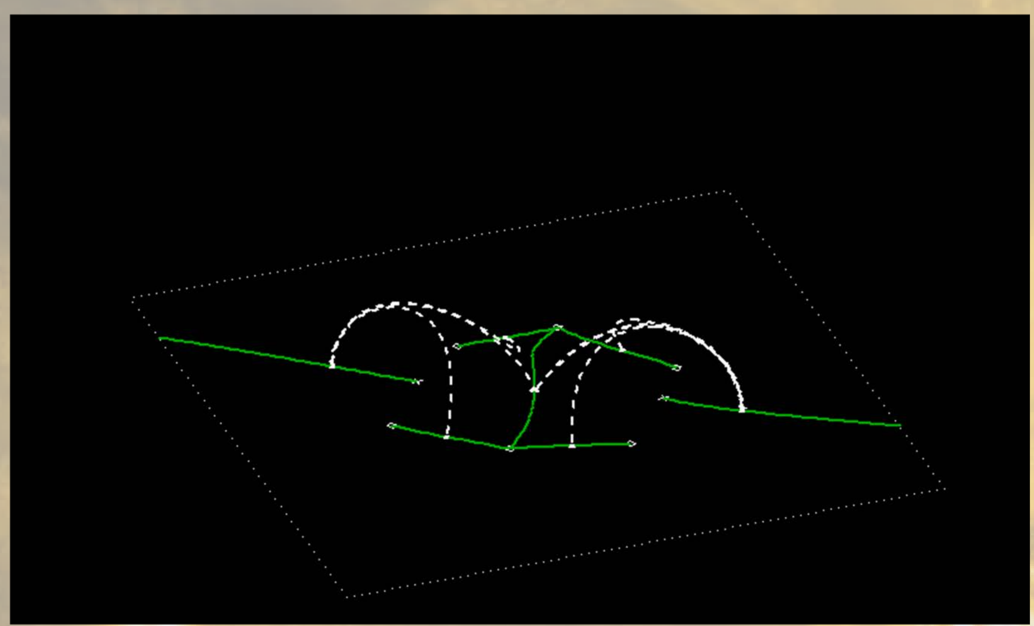
Introduction

The solar atmosphere is dominated by the Sun's magnetic field which is generated in the solar interior and protrudes into the atmosphere across the Sun's surface at sunspots, pores and plage. Scattering positive and negative magnetic sources across the solar surface allows a variety of topological states to be modelled. Each topology is defined by the configuration of its magnetic flux sources, null points and separatrix surfaces. Often, the null points of the structure are confined to the solar surface, but it is possible for them to rise up into the corona and remain there (a coronal null point).

It is proposed that null points may act as sites where reconnection can occur. Thus, in order to study reconnection in the solar corona, we must first understand how coronal null points behave and interact with one another, particularly in the corona. The following simulation presents a topology which undergoes a series of bifurcations, in which three coronal null points are found.

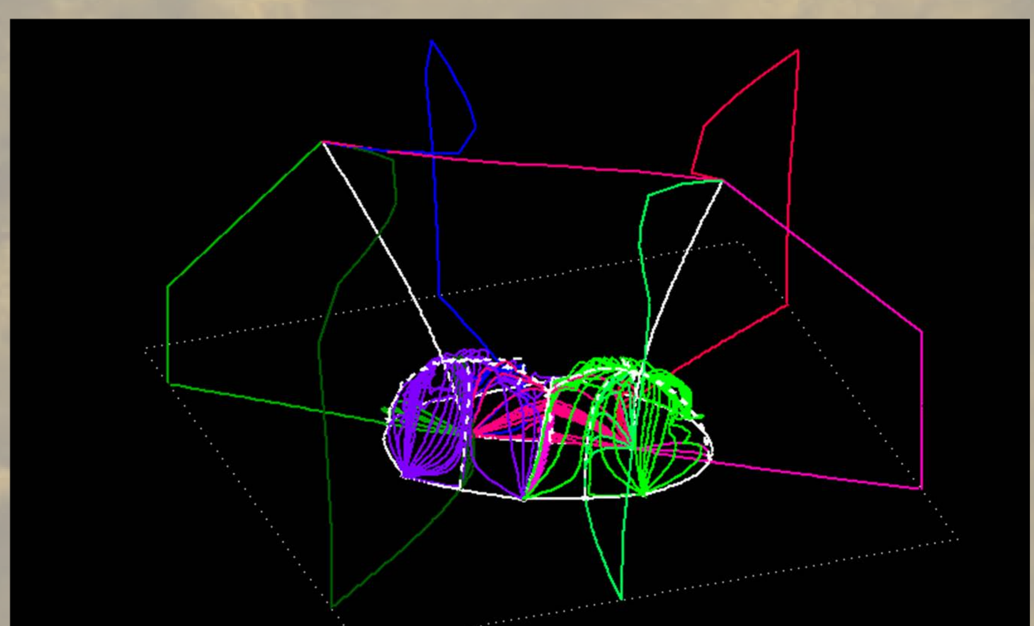
Starting Configuration

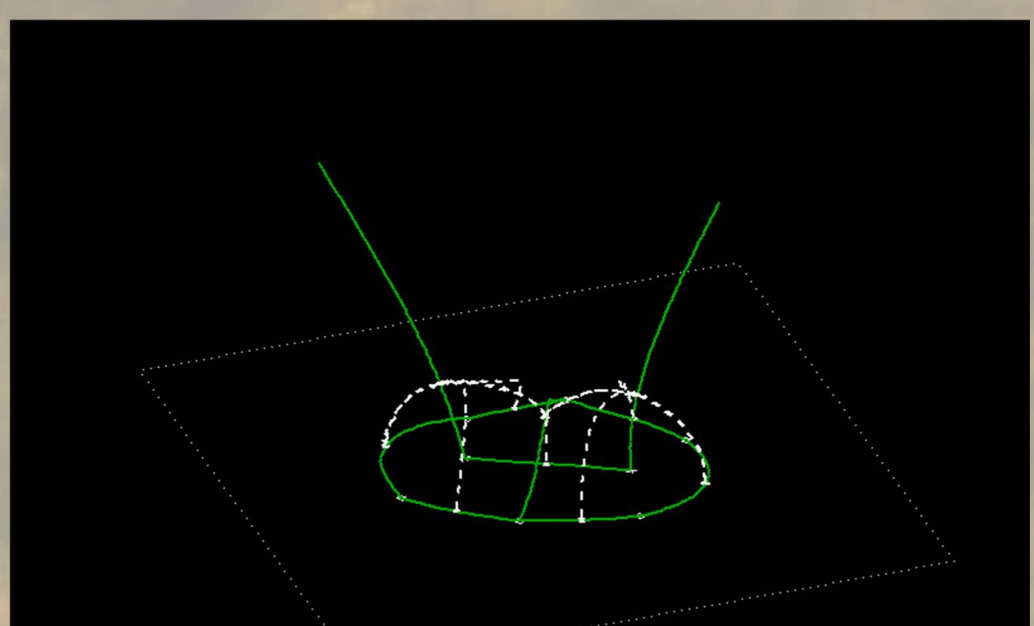




Consider a configuration set up as follows: two positive central sources are surrounded by a network of six negative sources. A ninth balancing source is placed at a great distance away. This locally unbalanced configuration has seven photospheric null points. There are two separatrix domes and five separatrix walls present. Each dome is intersected by three walls, with the central wall intersecting each of the domes. There are six separators, each of them connecting a positive photospheric null to a negative null, formed by the intersection of the walls with the domes. In total there are fourteen regions of connectivity which are preserved throughout the simulation.

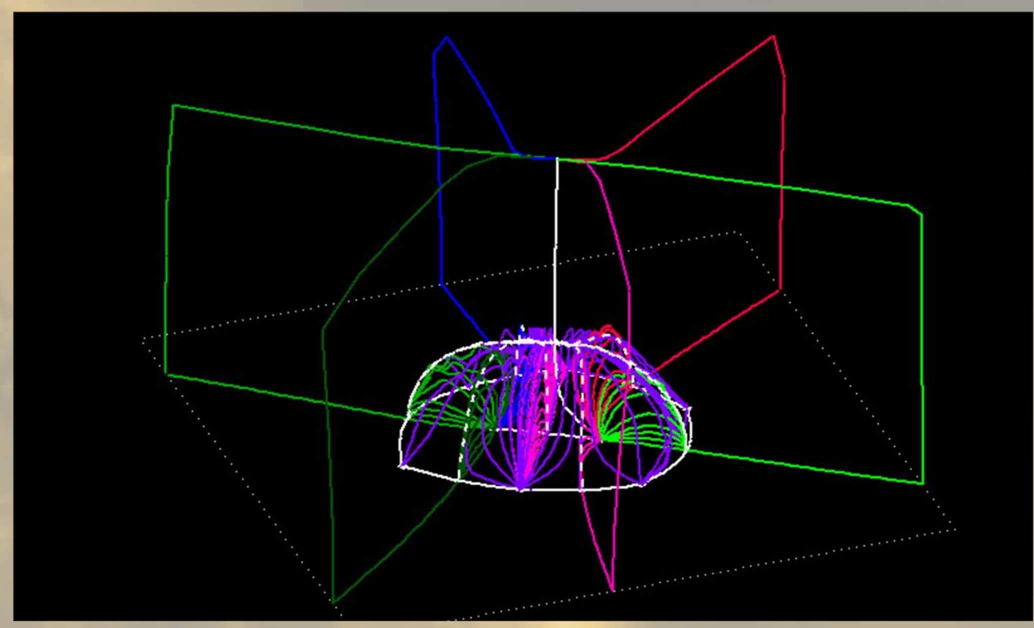
Pitchfork Bifurcations

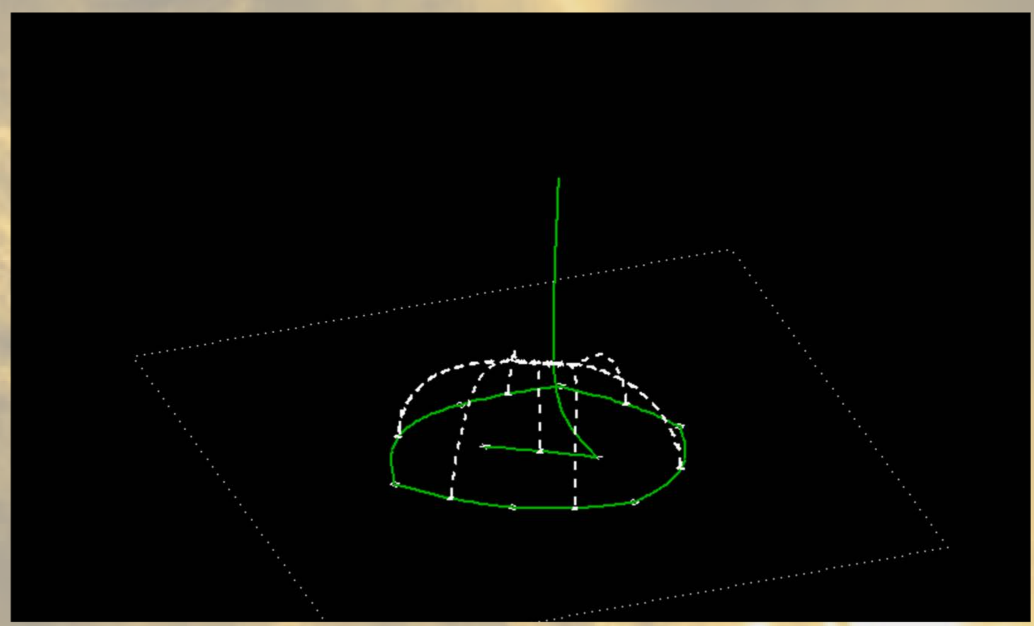




The configuration has been allowed to evolve, and the two positive sources have been guided towards the centre of the configuration. At some critical parameter values, three of the photospheric nulls undergo a pitchfork bifurcation, each one producing a coronal null point (along with a mirror null point in the negative volume. The two domes are now produced by the fans of the two positive coronal null points and each is intersected by four walls. The fan of the negative coronal null is bounded by the spines of the positive coronal nulls. The wall of the central null is now bounded by the spine of the central coronal null and is similar to the wall formed in the three source touching state (Brown & Priest 1999). Each time a pitchfork bifurcation occurs, a new separator is also formed, which connects the coronal null point to it's 'parent' null in the photosphere. All other separators which previously connected the photospheric null to another null point, now connect at the coronal null point.

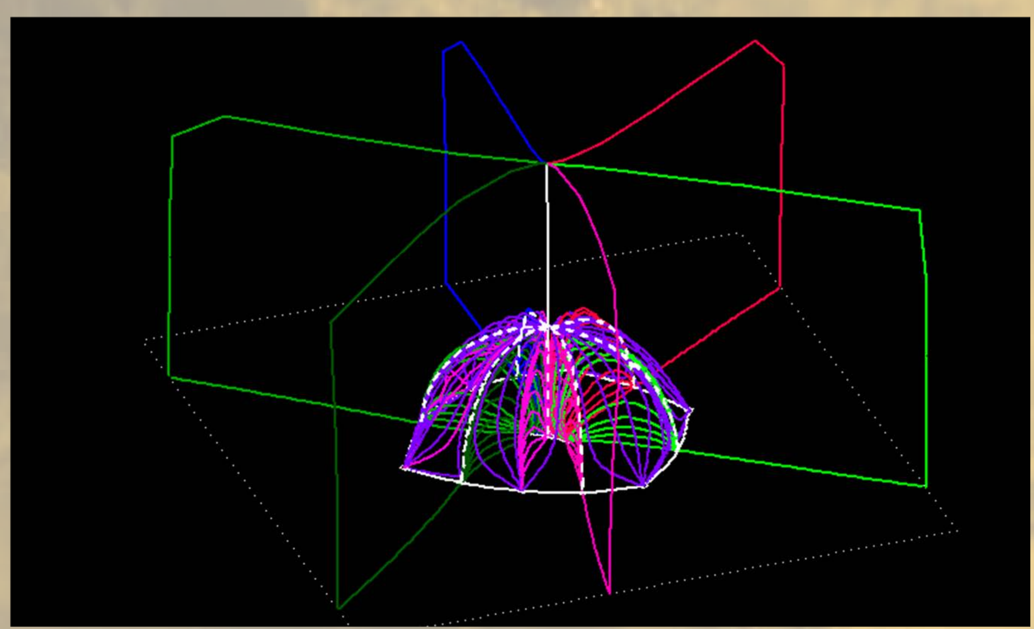
Turning Point Bifurcation

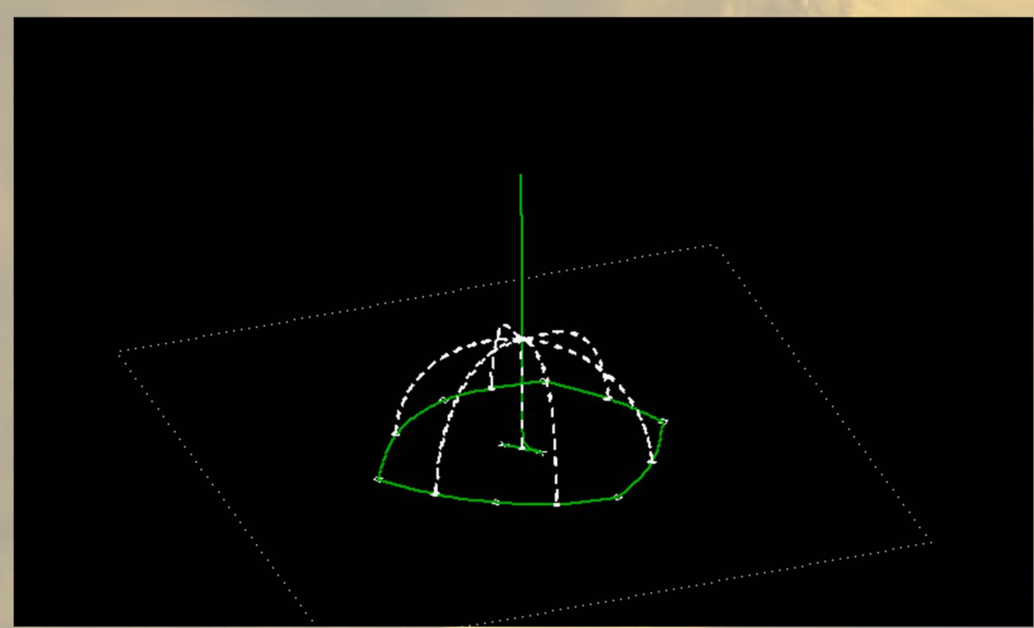




Once the configuration has evolved further, a turning point bifurcation results in the cancellation of two of the coronal nulls. As the nulls get close together, they coalesce, forming a second order null point which then vanishes. As a consequence of this, two separators are also destroyed, leaving seven remaining.
It is possible for a turning point bifurcation in the corona to result in the creation of two coronal null points. This can occur when four distinct separators become pinched and approach one another. (Beveridge, 2003) Hence, this turning point bifurcation is the reverse of this process, with a number of separators becoming more distant from one another and thus becoming "un-pinched".
Topologically, the system now consists of a single coronal dome which connects to all of the sources. This dome is intersected by the six separatrix walls, and bounds the wall of the central null point.

Final State





During the final stages of the simulation, no further bifurcations take place. The two positive sources and the coronal null point continue to move towards the centre of the configuration. The topology consists of seven separatrix walls, one contained within the coronal dome, the remaining six intersect the coronal dome. In total there are seven separators, each one connecting a photospheric null to the coronal null point. This topological state is analogous to the 4-source coronal null state discussed by Brown & Priest (2001).

Conclusion

Understanding how coronal null points behave and interact with one another is crucial to developing our understanding of coronal reconnection events. The work here has illustrated how such an interaction, where two coronal null points annihilate each other, may occur. It has also illustrated how such occurrences can affect a network of separators, which are also potential locations for reconnection, by causing them to pinch together with one another. Future work will use continuous source models in order to improve our recreation of what may occur in the solar corona.

Acknowledgements

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References

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2. **Brown, D. S., Priest, E. R., 1999,** Topological Bifurcations in Three-Dimensional Magnetic Fields, *Proc.R.Soc.London, Ser. A, Vol.455, No.1991, p.3931-3951*
3. **Brown, D. S., Priest, E. R., 2001,** The Topological Behaviour of 3D null points in the Sun's Corona, *A&A, v.367, p.339-346*