

Survey of Coronal Null Points with SDO/AIA & WSO



Michael Freed, Dana Longcope and David McKenzie
Montana State University

Abstract

Magnetic fields in the corona can be approximated by using PFSS (Potential Field Source Surface) model in conjunction with magnetogram measurements of the photosphere. This approach is incorporated here to find locations of magnetic null points in the solar corona. Observations from WSO (Wilcox Solar Observatory) provide the necessary harmonic coefficients for a PFSS model. We located all magnetic null points in the PFSS model going back to Carrington Rotation 2098. The time and location where they cross the West limb is compared to high resolution observations made by SDO/AIA. Variations in predicted and observed null point locations will be examined. This work will provide a catalog of potential coronal nulls observed by SDO that can be examined further for interesting dynamical behavior or variations in neighboring plasma.

PFSS Model

A typical approach used for finding the global \mathbf{B} of the corona is the Potential Field Source Surface (PFSS). This model uses two boundary conditions for determining the potential of the corona. The lower boundary comes from magnetogram data taken at the photosphere ($r=R_\odot$) and the upper boundary is formed at the location where the solar wind's \mathbf{B} becomes completely radial ($B_\theta=B_\phi=0$). The radius of the upper boundary is referred to as the source radius R_s and is assigned the value $2.5R_\odot$ for this extrapolation.

The field can be written as a magnetic scalar potential χ if it's assumed no current source exist between the boundaries. This leads to the following general solution to Laplace's equation with Dirichlet boundary conditions:

$$\chi(r, \theta, \phi) = \sum_{l=1}^{\infty} \sum_{m=0}^l \left[\left(\frac{R_s}{r} \right)^{l+1} - \left(\frac{r}{R_s} \right)^l \right] P_l^m(\cos \theta) [g_l^m \cos(m\phi) + h_l^m \sin(m\phi)]$$

P_l^m is the associated Legendre polynomial and harmonic coefficients g_l^m & h_l^m can be determined from magnetograms taken over a complete solar rotation. The coefficients were obtained up to $l=29$ from WSO [2] and this places a limit on the PFSS model's spatial resolution of approximately 100 Mm.

Geometry of Field Around a Null

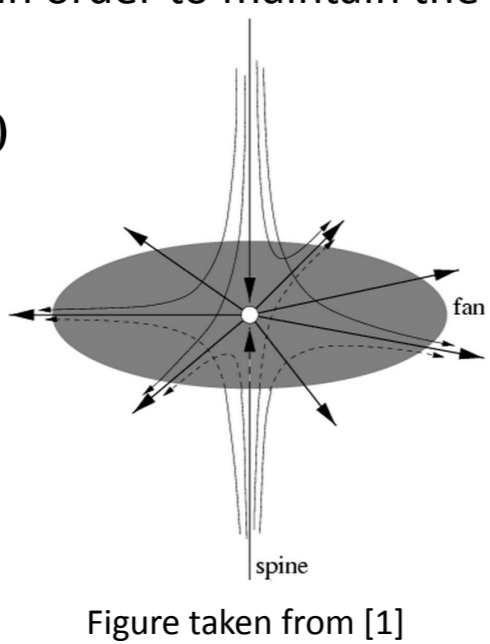
Null points can be determined from \mathbf{B} by the following:

$$B_i(x) = \sum_{j=1}^3 (x_j - x_{o,j}) M_{ij} + \dots \quad \text{where } M_{ij} \equiv \left. \frac{\partial B_i}{\partial x_j} \right|_{x_o}$$

M_{ij} represents the field's Jacobian Matrix and x_o is the location of an isolated null point. The field's behavior around a null can be described by the eigenvectors and eigenvalues associated with the Jacobian Matrix. All the eigenvalues must sum to zero in order to maintain the following condition:

$$\nabla \cdot \mathbf{B} = \sum_i M_{ii} = 0$$

The figure on the right is an example of a positive null point. An eigenvector from λ_1 establishes the orientation of the spine field line and $\lambda_2 = \lambda_3$ form a fan surface. This configuration is called a positive null due to the field lines in the fan resembling \mathbf{E} from a positive charge.



Locating the Catalog

You can find the potential Coronal Null Point Catalog by visiting the website below or scanning the QR code to the right.

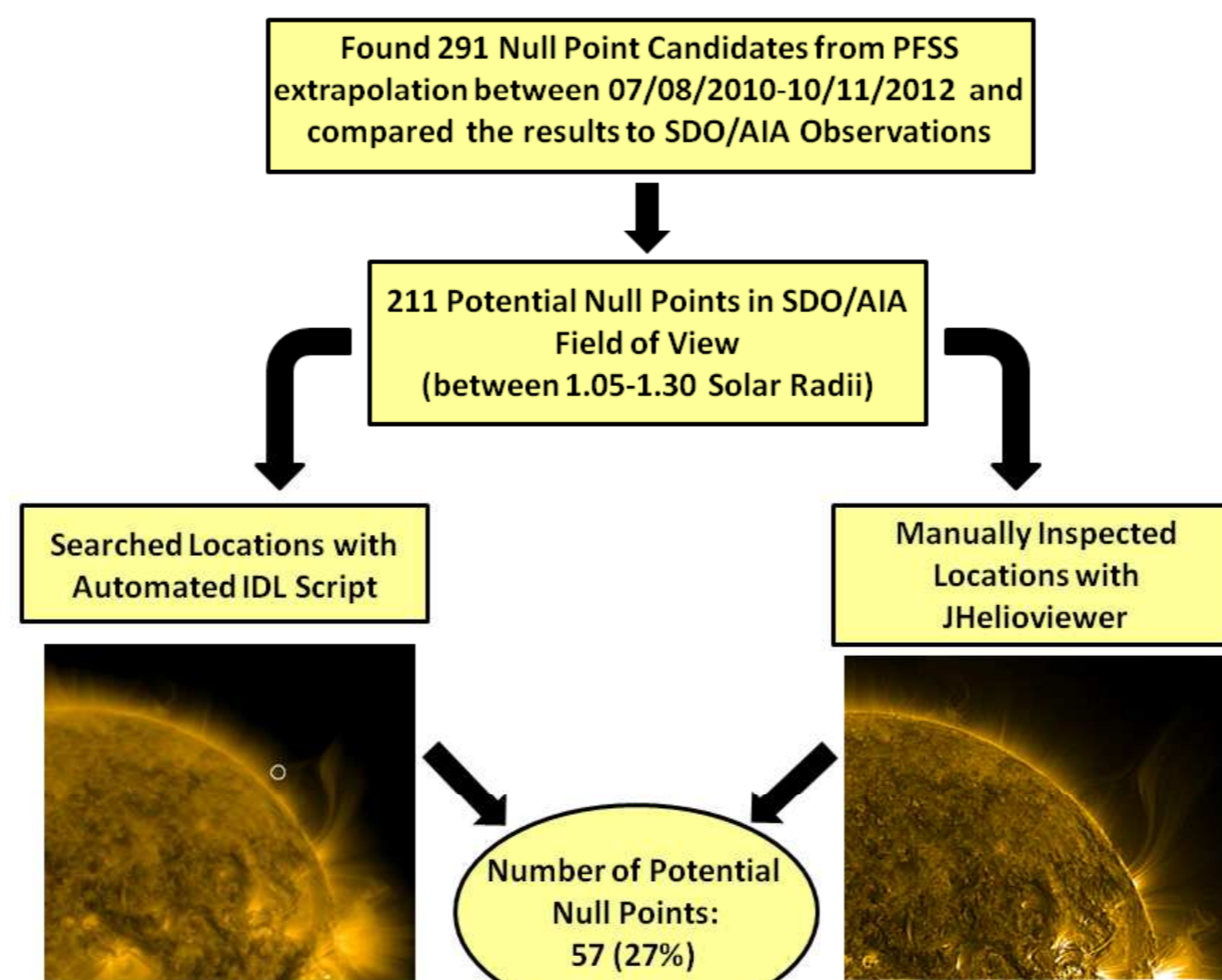
<http://solar.physics.montana.edu/mfreed/Research.html>



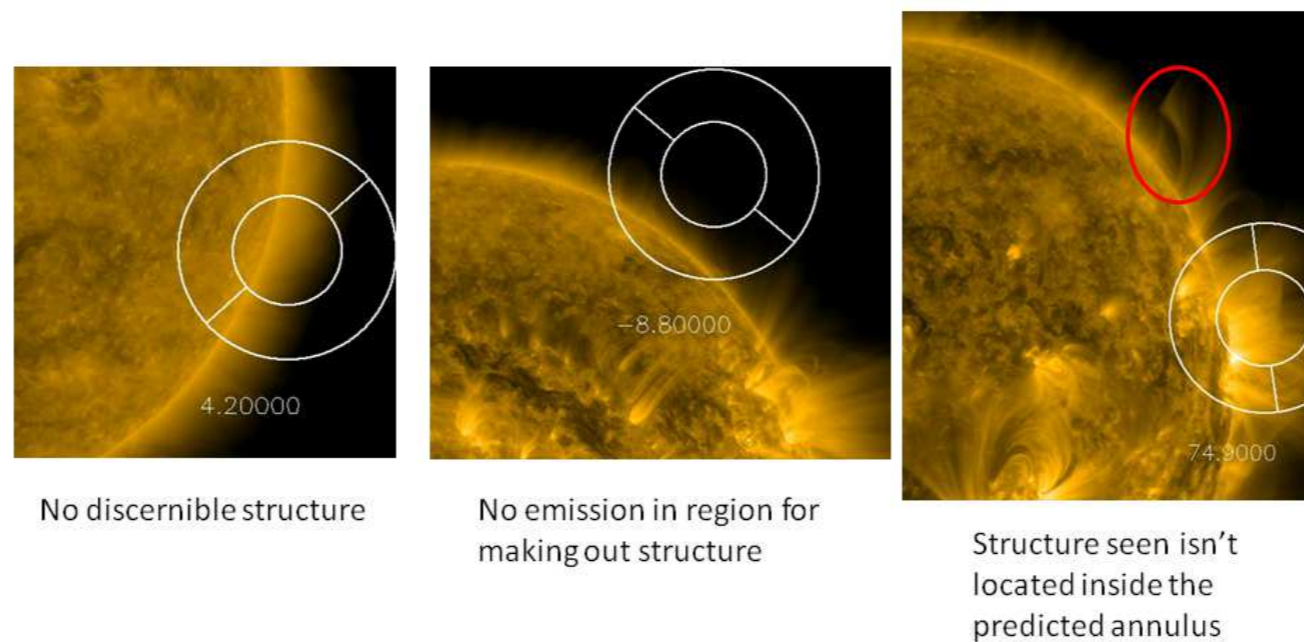
Null Point Catalog

Catalog of Potential Coronal Null Points

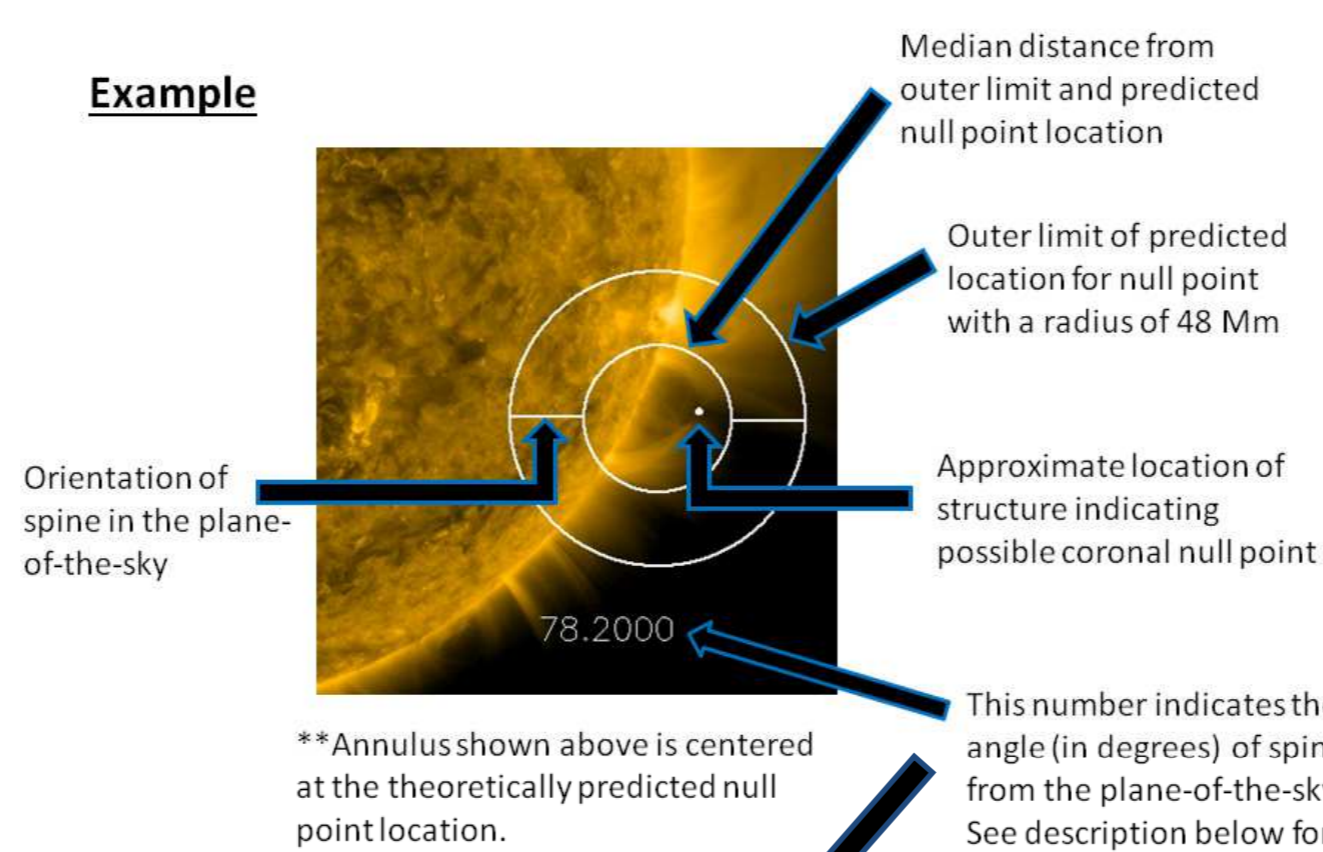
Breakdown of Observations Made at 171 Å



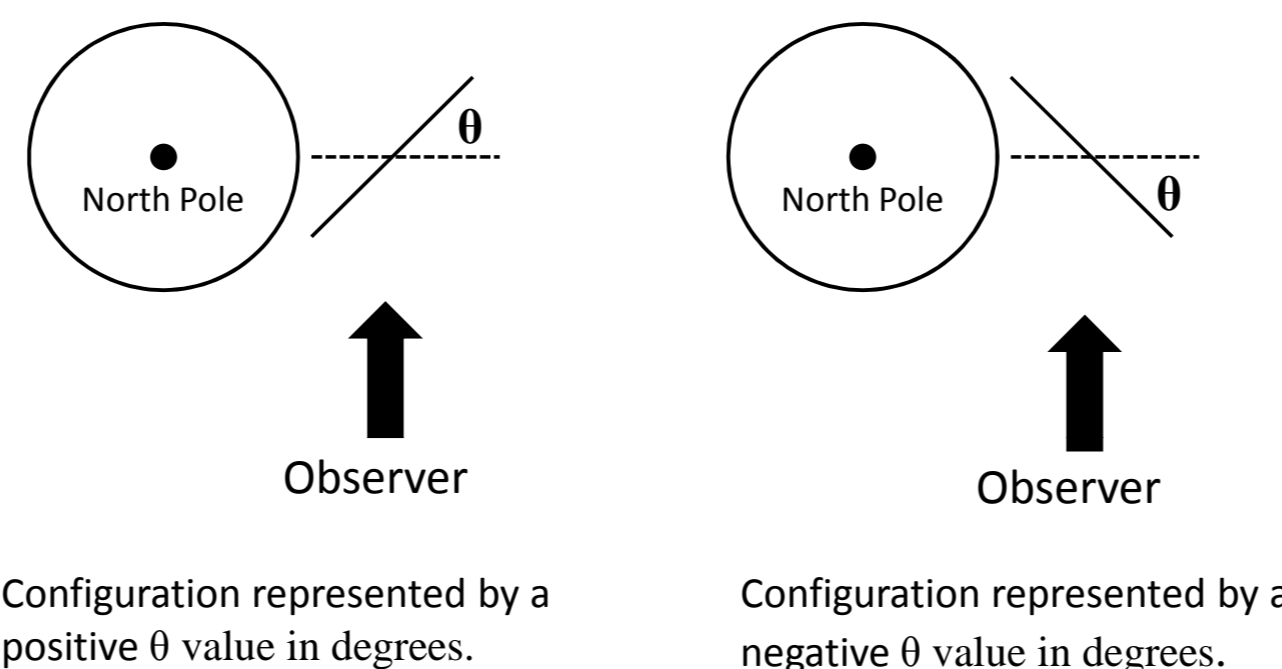
Examples of Negative Null Point Classification



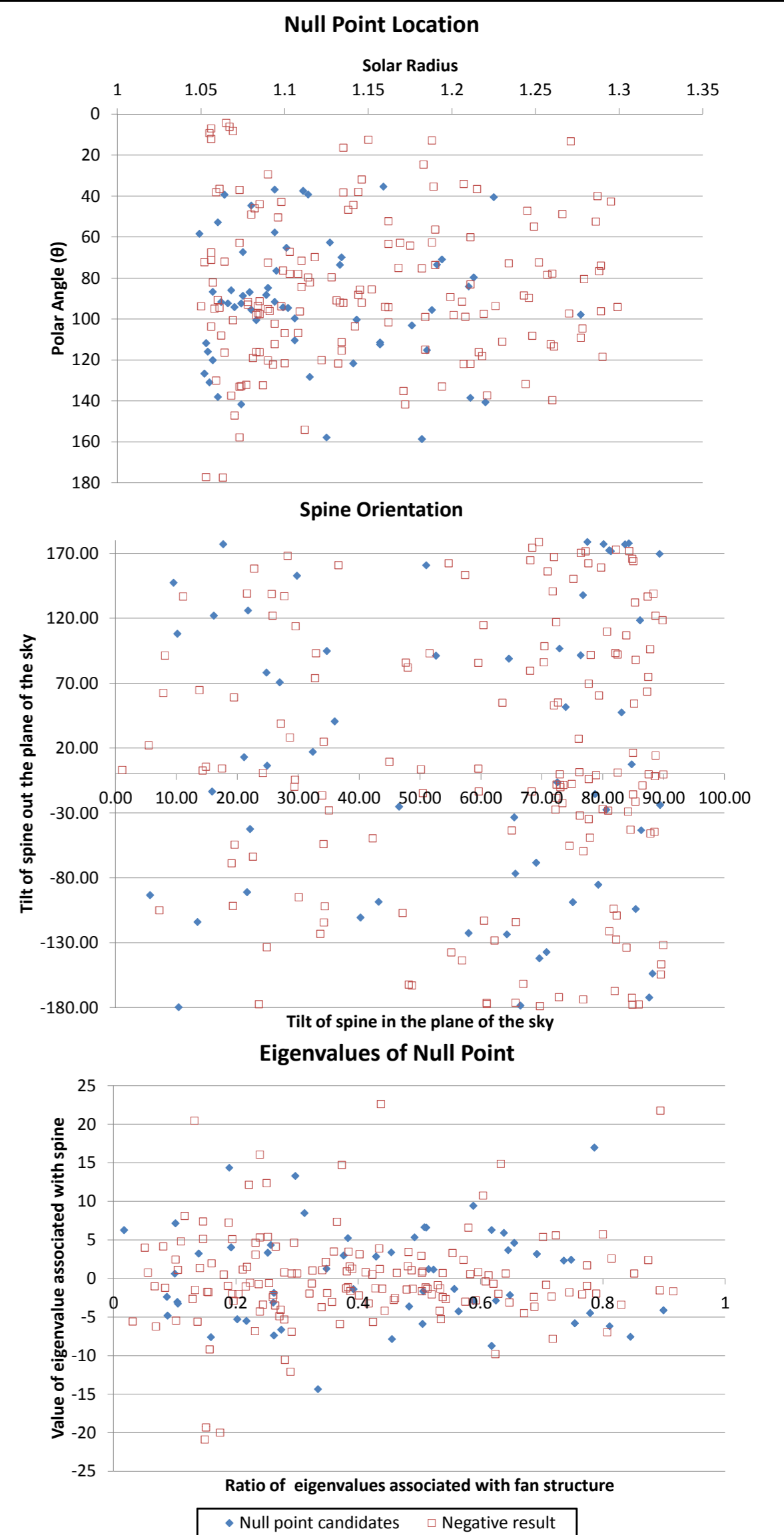
Information Presented with Error Templates



Explanation of Numerical Value (θ) given for Spine Orientation Relative to the Plane of the Sky



Analysis of Catalog Data



Discussion

Results:

- Cataloged observations of 57 potential coronal null points with PFSS model (28 positive and 29 negative nulls)
- 13 locations displayed dynamic behavior when compared against SOHO LASCO CME Catalog data
- Most of the predicted null points were located near the active equator
- Location, spine orientation, and values of eigenvalues associated with null have no noticeable effect on its observability

Future work:

- Ascertain if there is any visible null structure before reaching the west limb
- Quantify the temperature and density distribution around the nulls
- Compare observed features against theoretical 3D configurations

References

- [1] Dana Longcope, "Topological Methods for the Analysis of Solar Magnetic Fields", *Living Rev. Solar Phys.* 2, (2005), 1. URL (accessed 7/1/13) <http://www.livingreviews.org/lrsp-2005-7>
- [2] Wilcox Solar Observatory data used in this study was obtained via the web site <http://wso.stanford.edu> at 2013:07:04_12:51:29 PDT courtesy of J.T. Hoeksema.