WHY ONLY THE ELLIPTICAL CONE MODEL CAN BE USED TO ACCURATELY INFER THE 3-D CHARACTERISTICS OF HALO CMES

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The Circular Cone Model (1/2)

- Widely used to invert 3D characteristics of halo CMEs
  - Relatively simple
  - Unique solution
- Results are trusted but not necessarily valid in most situations
  - ~10% of observed halo CMEs
The Circular Cone Model (2/2)

- Assumptions
  - Radial propagation direction, as a rule
    - Exceptions [Plunkett Et al. 1997; St. Cyr et al. 2000]
  - Constant angular width ($\omega_y$, $\omega_z$)
    - [Webb et al. 1997; Webb and Jackson 1990]
5 Halo Parameters: Geometry
Types of Observed Halo CME

<table>
<thead>
<tr>
<th>Type A</th>
<th>Type B</th>
<th>Type C</th>
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<tbody>
<tr>
<td>• $</td>
<td>\psi</td>
<td>&lt; 10^\circ$</td>
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<tr>
<td>• $SA_{xh} &lt; Sa_{yh}$</td>
<td>• $SA_{xh} \geq Sa_{yh}$</td>
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</table>

- From 30 event table [Cremades 2005, Tbl. 3]
  - 3 Type A
  - 7 Type B
  - 20 Type C

- Circular Cone Model only works for Type A

**ONLY ~10% OF ALL OBSERVED EVENTS!**
Examples of 3 Types
The CC Model: Limitations (1/2)

CC MODEL MINOR AXES MUST PASS THROUGH SOLAR DISK CENTER

ONLY ~10% OF ALL OBSERVED EVENTS!
The CC Model Limitations (2/2)

3 different sets of model parameters (left column)

Identical halo parameters for given $\beta$ (right column)

CC Model solutions not necessarily unique
Importance of Generalizing the Cone Model

- MHD codes for Solar Wind use Cone Model as an input/boundary parameter
- Better science
  - Johannes Kepler had to give up circles too
The Zhao Elliptic Cone (ZEC) Model (1/2)
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The Zhao Elliptic Cone (ZEC) Model (1/2)
The Zhao Elliptic Cone (ZEC) Model (1/2)
The ZEC Model (2/2)

Assumptions & Ambiguities

- Same assumptions as CCM (Radial Propagation + constant angular width)
- Need a method to determine propagation direction (\(\beta\)-angle between \(X_c\) and \(X'_c\)) in order to uniquely solve inversion equations
  - 1 point: Associated flare location
  - 2 point: Two simultaneous images from different points in the ecliptic (STEREO)
Determination of Propagation Direction (1-point Approach)

- Specified $\alpha$ narrows possible $(\lambda, \phi)$ from entire plane to a line
- Point represents spatial location of associated flare
- Optimal $\beta =$ minimum distance between point and curve (after correcting $B_0$)
Validation of 1-point Approach

- Overlay calculated cone projection onto observed CME image
- Generally good agreement
All figures from Zhao 2008, Journal of Geophysical Research, Vol. 113