Magnetic Topology of Quiescent Prominence Bubbles

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Outline

I. **Motivation: Bubbles and Plumes in Prominences**
   - **Observations:** Quiescent Prominences from SOT and AIA
   - **Models:** Rayleigh-Taylor instability in dipped geometry

II. **LFFF Models of Prominence Magnetic Field**
   - 2.5D topologies: OX/OF topology

III. **The Polar Crown Prominence of April 20th, 2011**
   - **Observations:** Hα, SDO/AIA 304Å, 193Å
   - Connection to magnetic field and emerging flux
   - Toy models of quiescent prominences
   - Magnetic topology: Bubbles, bright arches and separators

IV. **The Polar Crown Prominence of June 22nd, 2010**
   - **Observations:** SDO/AIA 304Å, 193Å
   - Symmetric and Asymmetric models
   - “Large” and “Small” bubbles: Within body and within feet
Many “vertical” threads

- plane-of-sky velocities, i.e., “vertical motions” up to 2 – 15 km s$^{-1}$ (time-slice technique)

- Hα Doppler-shifts:
  - counter-streaming
  - velocities up to 15 km s$^{-1}$

$\Rightarrow$ Threads are NOT vertical, but highly inclined to LOS

Schmieder et al. (2010), A&A 514, A68
Berger et al. (2011), Nature 472, 197
Hillier et al. (2011), Astrophys. J. 736, L1;  
Hillier et al. (2012), Astrophys. J. 746, 120
II. Prominences: LFFF Models

Force-free fields:

\[ \nabla \times B = \alpha B , \]
\[ \nabla \cdot B = 0 , \]

\[ B_x = \frac{\tilde{B}_{(n_x,n_y)}}{k_x^2 + k_y^2} \left( - \frac{\alpha k_y \sin(k_x x) \sin(k_y y)}{k_x^2 + k_y^2} - \frac{l k_x \cos(k_x x) \cos(k_y y)}{k_x^2 + k_y^2} e^{-l_z} \right) , \tag{4} \]

\[ B_y = \frac{\tilde{B}_{(n_x,n_y)}}{k_x^2 + k_y^2} \left( \frac{\alpha k_x \sin(k_x x) \sin(k_y y)}{k_x^2 + k_y^2} - \frac{l k_y \cos(k_x x) \cos(k_y y)}{k_x^2 + k_y^2} e^{-l_z} \right) , \tag{5} \]

\[ B_z = \tilde{B}_{(n_x,n_y)} \sin(k_x x) \cos(k_y y) e^{-l_z} . \tag{6} \]

with \( \tilde{B}_{(n_x,n_y)} \) is the amplitude of the harmonic \((n_x; n_y)\), and
\[ k_x = n_x \cdot 2\pi / L_x , \tag{7} \]
\[ k_y = n_y \cdot 2\pi / L_y , \tag{8} \]
\[ l = \sqrt{k_x^2 + k_y^2 - \alpha^2} . \tag{9} \]

Prominences: 2.5D Topologies

Topography for $\alpha = 0.99$

- OF
- OBP
- FX
- Arcade

Graphs showing:

- OF, $B_2 = -0.83$, $B_3 = 0$
- OX, $B_2 = -0.83$, $B_3 = 0.71$

Graphs (a) and (b) illustrate contour lines in the $x(Mm) - z(Mm)$ plane.

Graphs (c) and (d) show $B_2$ versus $x(Mm)$ and $B_2$ versus $x(Mm)$ respectively.
Prominences: 3D OX Flux Ropes

Aulanier et al. (1999), Astron. Astrophys. 335, 309
III. Prominence of April 22\textsuperscript{nd}, 2011
Prominence of April 22\textsuperscript{nd}, 2011

Emerging flux

\textit{Dudík et al. (2012), Astrophys. J., 761, 9}
08:30 UT 193Å

08:30 UT

pixel along the cut [0.3 arcsec]

08:43 UT
18 Minutes Later – a Plume
How to Create a Bubble...

Synthetic magnetogram
- creates the OX flux rope
- strong parasitic bipole
- no magnetic shear
Sheared Bipole: Cusp-Shape

Magnetic Dips
Bipole Arcade
Negative null-point spine/fan
Positive null-point spine/fan
Separator
Tree-shaped Prominences

Magnetic Dips
Bipole Arcade

Negative null-point spine/fan
Positive null-point spine/fan
Separator
Emerging bipole: The Bubble
Emerging bipole: The Bubble

Dudík et al. (2012), Astrophys. J., 761, 9
IV. Prominence of June 22\textsuperscript{nd}, 2010

Berger et al. (2011), Nature 472, 197

The Unsheared Model: Off-Limb
Symmetric and Asymmetric
Bubbles and plumes are not brighter than the surrounding corona

Bubbles are topologically complex structures
- magnetic arcades, not dips
- null points and separators
- plumes due to reconnection at the separator?

The magnetic field of the quiescent prominences can be modeled with minimum of physics
- OX topology and 1 – 2 sheared bipoles

The configurations approximate well the observed prominences
Thank you for your attention