An Application of the Random-Walk Model to Proper Motions of Coronal Bright Points from SDO Data

Ivica Skokić
ivica.skokic@asu.cas.cz
The Team

R. Brajša, D. Sudar
Hvar Observatory, Faculty of Geodesy, Kačićeva 26, 10000 Zagreb, Croatia

S. H. Saar
Harvard-Smithsonian Center for Astrophysics, 60 Garden Street, Cambridge, MA 02138, USA

I. Poljančić-Beljan
Department of Physics, University of Rijeka, Radmile Matejčić 2, 51000 Rijeka, Croatia

I. Skokić
European ALMA Regional Center, Czech Node, Astronomical Institute of the Czech Academy of Sciences, Fričova 298, 251 65 Ondrejov, Czech Republic
Outline

- Coronal Bright Points
- Dataset, SDO/AIA, method
- Solar velocity field
- CBP proper motions and random walk model
- Diffusion of magnetic elements
- Comparison with other measurements
- Conclusion
Coronal Bright Points (CBPs)?

- small bright structures in lower corona
- visible in EUV and X-ray images
- associated with small magnetic bipolar regions in the photosphere
- lifetime from few minutes to several days
- several hundred CBPs present on the Sun every instant
Data – Solar Dynamics Observatory

- SDO/AIA, 19.3 nm channel
- Segmentation algorithm, modification of the McIntosh and Gurman (2005) (Martens et al. 2012)
- $t \sim 5$ months
- Cadence 10 min
- Processing, height correction, outlier removal, etc.
Data – CBP distribution

(a)

(b)
Data – velocity field
CBP derived differential rotation profile

Sudar et al. (2016)

\[ A = 14.406 \pm 0.005 \]
\[ B = -1.66 \pm 0.05 \]
\[ C = -2.74 \pm 0.08 \]

n 80 966
t \sim 5 \text{ months}
Residual rotational and meridional velocities

$\Delta v_{\text{rot}}$ – signs of torsional oscillation pattern

$v_{\text{mer}}$ – predominantly polar flow in agreement with Doppler measurements

Sudar et al. (2016)
Motion of the individual CBP

![Graphs showing motion of individual CBP](image)
Random walk model

- CBPs as "atoms" – tracers of small magnetic elements (Leighton, 1964)

- displacement proportional to the square of elapsed time

- lifetime $\tau$, velocity $v$

- Mean free path $l = \tau \cdot v$

- Diffusion coefficient $D = \frac{\langle l^2 \rangle}{4\tau}$
Velocity distributions
Absolute velocity

\[ v_{abs} = \sqrt{v_{mer}^2 + \Delta v_{rot}^2} \]
Data – Solar Dynamics Observatory, AIA
Results

- Complete dataset
  \[ n = 80966, \ l \sim 3000 \text{ km}, \ D \sim 250 \text{ km}^2/\text{s} \]

<table>
<thead>
<tr>
<th>Source</th>
<th>( l ) [km]</th>
<th>( \tau ) [h]</th>
<th>( D ) [km(^2) s(^{-1})]</th>
</tr>
</thead>
<tbody>
<tr>
<td>Brajša et al. (2008)</td>
<td>5200</td>
<td>12</td>
<td>160</td>
</tr>
<tr>
<td>Brajša et al. (2008)</td>
<td>8600</td>
<td>30</td>
<td>170</td>
</tr>
<tr>
<td>Brajša et al. (2008)</td>
<td>15100</td>
<td>60</td>
<td>260</td>
</tr>
<tr>
<td>Hagenaar et al. (1999)</td>
<td>&lt; 3</td>
<td></td>
<td>70-90</td>
</tr>
<tr>
<td>Hagenaar et al. (1999)</td>
<td>&gt; 8</td>
<td></td>
<td>200-250</td>
</tr>
<tr>
<td>Iida (2014)</td>
<td>6</td>
<td></td>
<td>200</td>
</tr>
<tr>
<td>DeVore et al. (1985)</td>
<td></td>
<td></td>
<td>200-400</td>
</tr>
<tr>
<td>Wang (2004)</td>
<td></td>
<td></td>
<td>500-600</td>
</tr>
</tbody>
</table>
Results

- Over different lifetimes:
  - 0..6h: \( n = 69603, l \sim 2800 \text{ km}, D \sim 250 \text{ km}^2/\text{s} \)
  - 6..12h: \( n = 9475, l \sim 4000 \text{ km}, D \sim 170 \text{ km}^2/\text{s} \)
  - 12..18h: \( n = 1551, l \sim 5100 \text{ km}, D \sim 150 \text{ km}^2/\text{s} \)
  - 18..24h: \( n = 337, l \sim 6100 \text{ km}, D \sim 140 \text{ km}^2/\text{s} \)

- Similar trend observed in two-day SDO data (Brajša et al. 2015)
Comparison with other measurements (Iida, 2014)

\[ K(\tau) = \frac{1}{4} \frac{\partial L(\tau)}{\partial \tau} \]
Conclusions

- A preliminary analysis
- CBPs good tracers of the solar velocity field (spatial and temporal coverage)
- Studies of short-term variations of differential rotation and meridional motions
- Better understand CBP formation, structure and evolution
- Random walk model applied to SDO CBP data results in diffusion coefficient \( D = 150-250 \text{ km}^2/\text{s} \),
- \( D \) varies over different scales
- In general agreement with other measurements but not with simulations