

Figure 1 PROBA2/SWAP image with a fan structure on the East limb.

Abstract

Coronal fans (see Figure 1) are bright observational structures that extend to large distances above the solar surface and can easily be seen in EUV (174 Å) above the limb. They have a very long lifetime and can live up to several Carrington rotations (CR), remaining relatively stationary for many months. Note that they are not the off-limb manifestation of similarly-named active region fans.

The solar conditions required to create coronal fans are not well understood. The goal of this research was to find as many associations as possible of coronal fans with other solar features and to gain a better understanding of these structures. Therefore, we analysed many fans and created an overview of their properties. We present the results of this statistical analysis and also a case study on the longest living fan.

Method of analysis

Data used	Method	Features of interest
<ul style="list-style-type: none"> PROBA2/SWAP movies and images (174 Å) SDO/HMI magnetograms GONG/Hα images SDO/AIA images: 171 Å, 193 Å, 211 Å 	<ul style="list-style-type: none"> track the footpoints from limb onto disk center (SWAP movies) obtain Carrington coordinates of the footpoints from SWAP image (IDL code) apply differential rotation time corrections overplot the footpoint locations onto Hα, HMI, and AIA images (see Figure 2) generate PFSS extrapolation in footpoints area 	<ul style="list-style-type: none"> correlation of fans with filaments, active regions, coronal holes magnetic connectivity magnetic field structure (separatrix surfaces; presence of sharp bend or "knee" in EUV brightness)

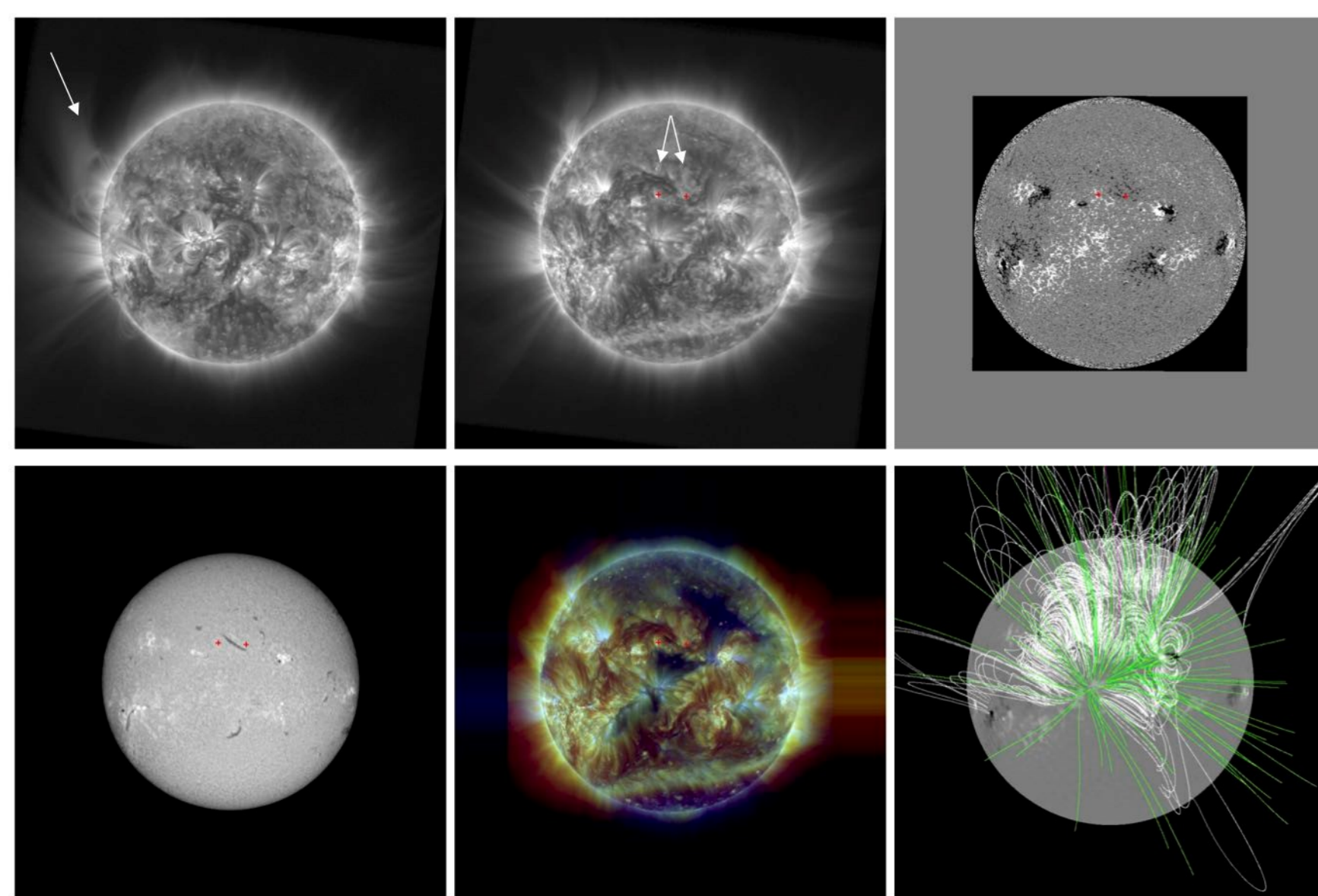


Figure 2 Data used for the analysis (from top left to bottom right): PROBA2/SWAP image with the fan on the East limb, SWAP image with the fan on the center of the disk, SDO/HMI magnetogram, GONG/H α image, composite SDO/AIA image, PFSS extrapolation. The red crosses indicate the location of the coronal fan footpoints.

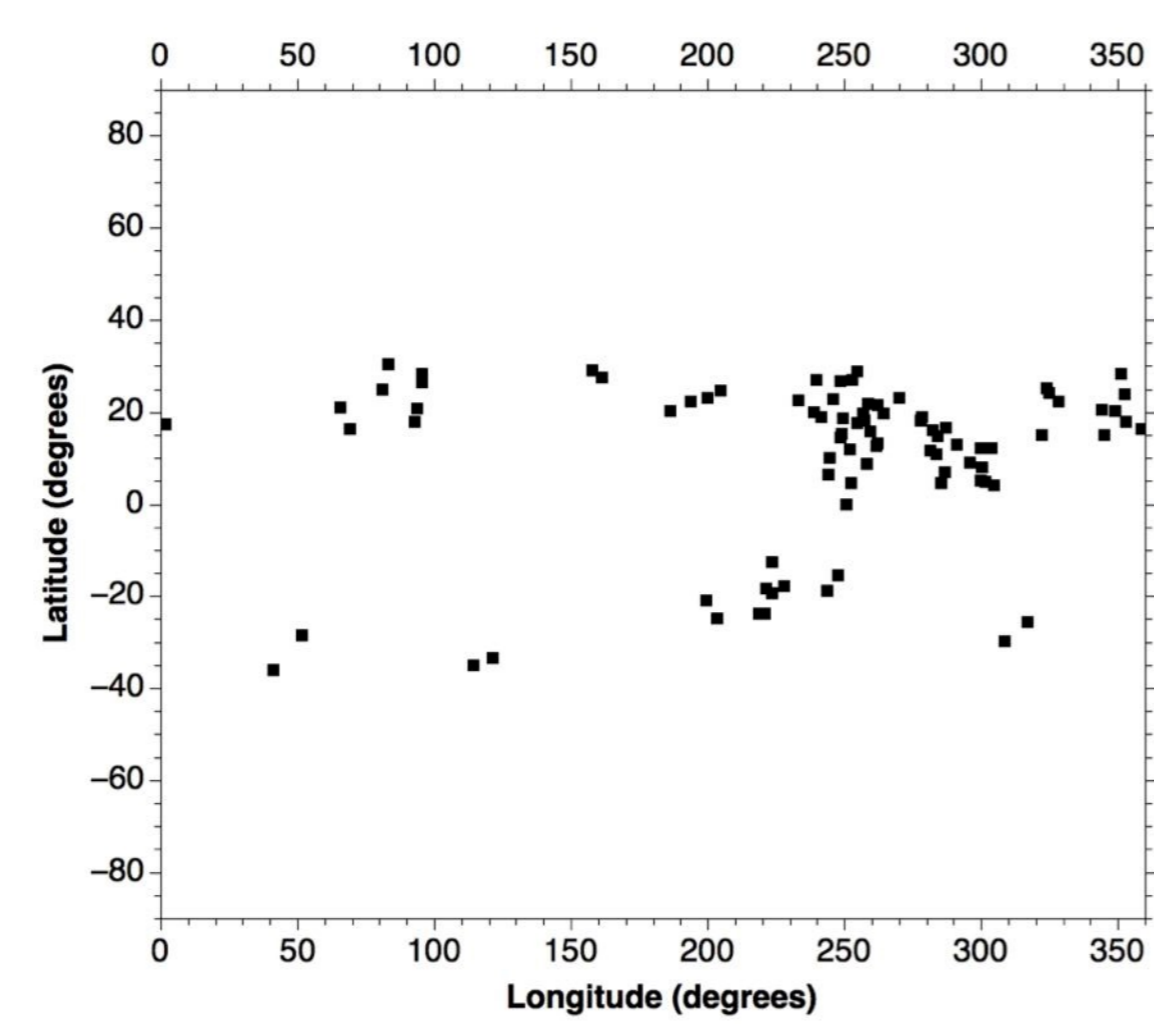


Figure 3 Distribution of the fan footpoints in Carrington coordinates; notice the latitude delimitation between [-40°, 40°].

Statistical results

- Analysed periods of time: March - July 2010, July 2012 - October 2014
- Total of 15 fans with lifetimes of 1 - 7 CR; measurements were made for each CR and for each fan
- PFSS extrapolations:
 - open field lines near footpoints; separatrix surface (in agreement with Seaton et al., 2013)
 - 1/2 of cases – fans' open field had the same polarity as the corresponding pole (the rest: no open field/different polarity)
- Presence of "knee" varies -> streamers and pseudostreamers
- 1/3 of cases – filaments present near the footpoints
- 1/2 of cases – large active regions in the vicinity of the footpoints
- 1/2 of cases – footpoints were near coronal holes
- NO footpoints inside coronal holes
- All footpoints: within latitude interval [-40, 40] degrees (see Figure 3)

Case study

- Analysed fan: 20140408NE (7 CR lifetime)
- Footpoints:
 - same magnetic domain
 - parallel to the polarity inversion line; also seen in Figure 4 - left: inversion of the inclination between CR 2149-2150
 - split along with the positive patch of magnetic field (also seen in Figure 4 - right)
- Fan shape:
 - size increases until CR 2154; CR2155: active region nearby => strength decreases
 - "knee" presence: varies
 - occasionally connects to the pole (polarity shift?)

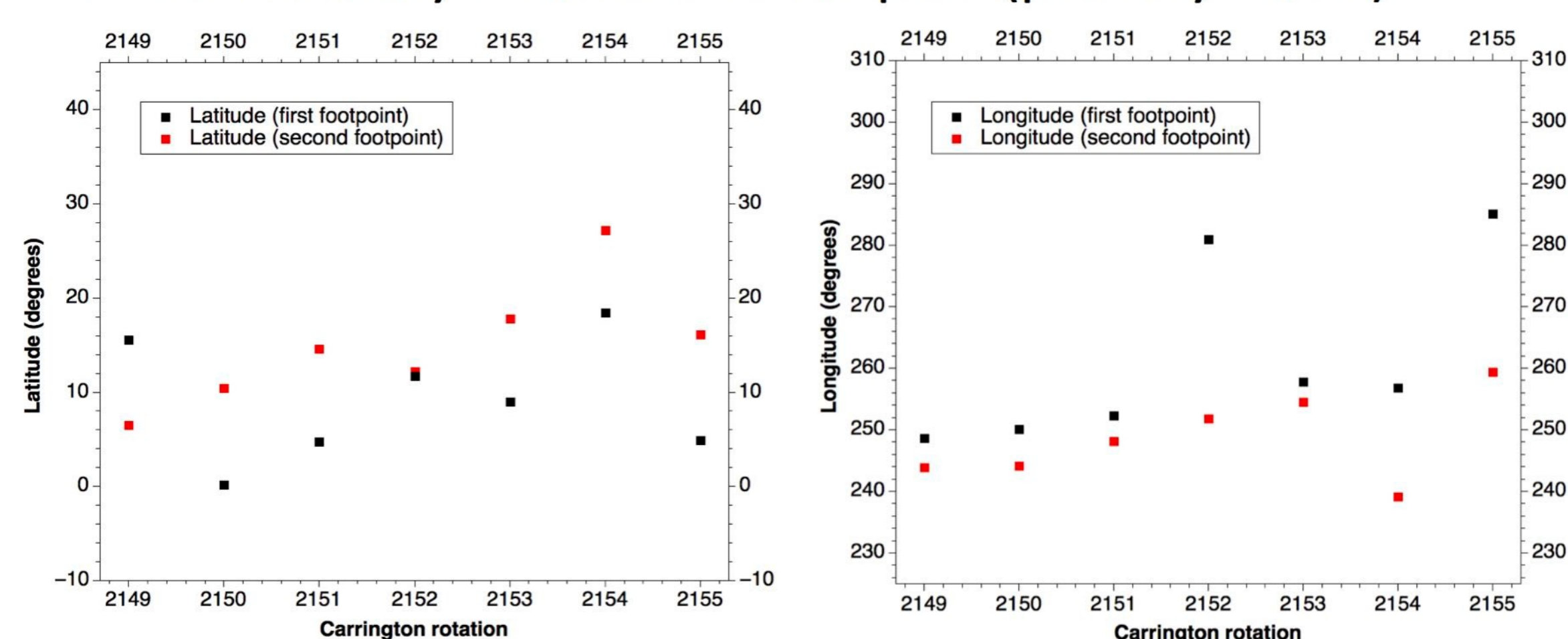


Figure 4 The dependence of footpoints coordinates (latitude – left and longitude – right) on Carrington rotation.

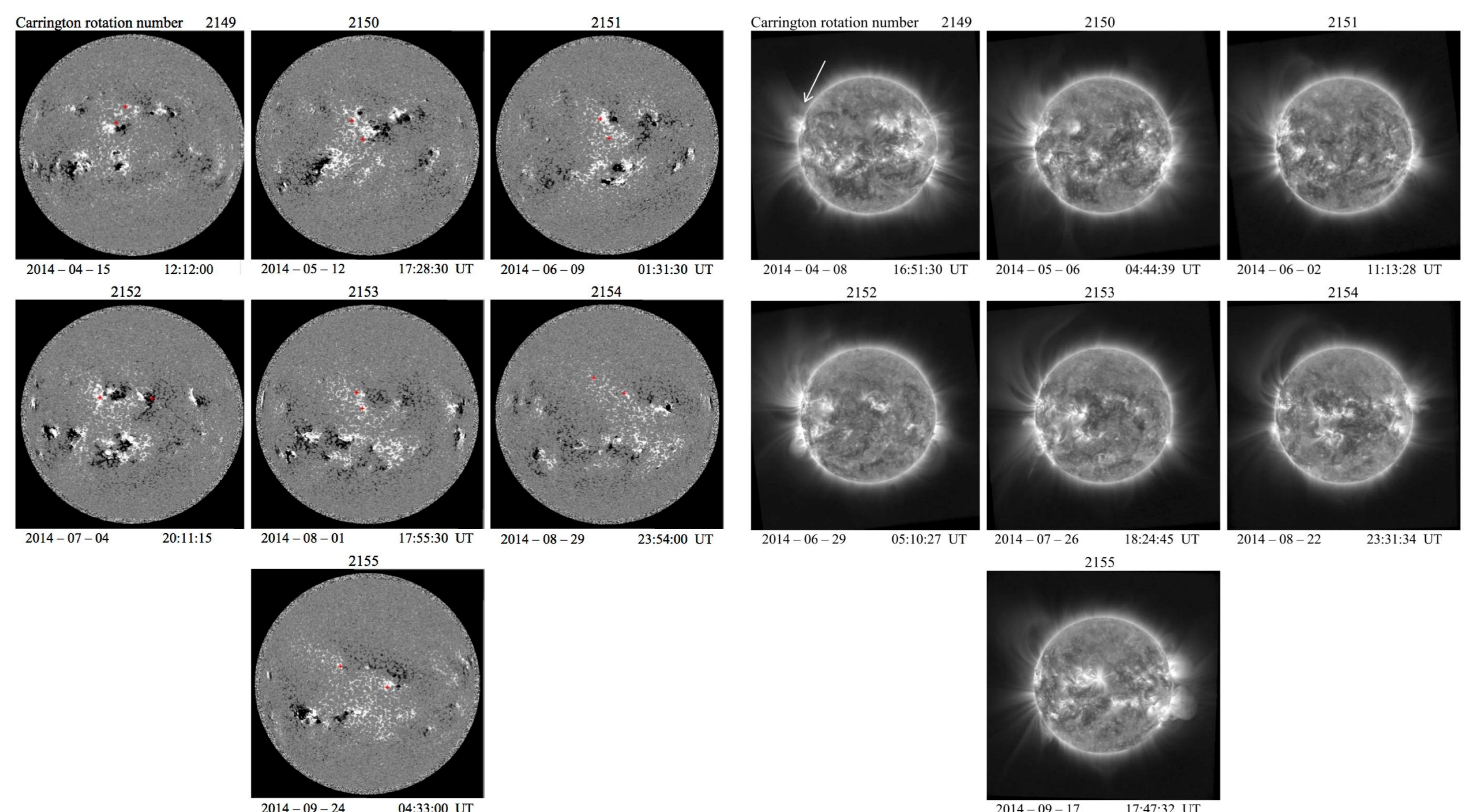


Figure 5 The evolution of the 20140408NE fan footpoints during 7 Carrington rotations (from 2149 to 2155) plotted on the HMI magnetograms (red crosses). Courtesy of NASA/SDO and the AIA, EVE and HMI science teams.

Figure 6 The evolution of the 20140408NE fan shape during 7 Carrington rotations (from 2149 to 2155), present on the eastern limb of the Sun. The arrow in the first image indicates the initial knee. Credit: ESA/SWAP PROBA2 science centre.

Conclusions

- A total of 15 fans were analysed, with a lifetime varying from one to seven Carrington rotations.
- In almost all of the cases:
 - PFSS extrapolations contain open field originating from the area of the footpoints
 - sharp edges of the fans lie along a separatrix surface
 - the two footpoints remain in the same magnetic domain and don't cross a polarity inversion line.
- The presence of the knee varies greatly, indicating that fans can be associated with both streamers and pseudostreamers.
- If a patch of different magnetic polarity occurs between the two footpoints, the fan breaks into two and it may even disappear. This can also occur if an active region appears nearby, or if the one that already is in the vicinity of the footpoints erupts.
- All** footpoints remain in the latitude interval [-40, +40] degrees, showing a strong correlation to the active region bands.
- No** footpoints were present inside coronal holes.
- Open question: physical reason for which this seemingly open field is bright compared to coronal hole plasma