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Solar Polar Rays Are Not Polar

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Abstract. We discuss the nature of polar rays, based on limb synoptic images constructed from Yohkoh/SXT and SOHO/EIT data. In the literature, polar rays and polar plumes are often mentioned interchangably. We find that polar rays are projection effects caused by hot plasma from equatorial active areas and are not physically associated with the coronal polar holes. Instead, the rise in number and strength of polar rays toward solar activity maximum may be responsible for hiding the polar holes and polar plumes.

1. Introduction

Polar rays are bright ray-like or arch-like features seen above or near the poles of the sun in single images. They were first seen in white light during total solar eclipses and have been described in the literature for at least a century (e.g., Maunder 1901). As suggested by their name, they are often considered as features of the solar polar coronal holes (e.g., Guhathakurta et al 1996). The ground-based white light images in Figure 1 show the coronal appearance from solar minimum (1996) to solar maximum (1999). Unfortunately, from these single images, it is not clear how (or whether) the polar rays are related to polar holes. Our new time series observations based on coronal emission limb synoptic maps have revealed that polar rays are indeed NOT physically related to the polar coronal holes. They are high altitude, hot gas structures from active regions that project to the plane of the sky above the solar poles.

2. Time Series Observations

Figures 2a and 2b are limb synoptic maps showing the signals extracted around the limb on the y-axis and plotted as functions of time (along the x-axis). The two figures were made from Yohkoh/SXT X-ray and SOHO/EIT 195 Å UV images. Some of the most obvious features of these maps are bright, quasi-sinusoidal structures above both northern and southern polar holes. They are clearly associated with more equatorial active regions. The number and strength of the polar sinusoids both increase from 1996 to 1999, as the sun moves from minimum towards maximum activity. These bright features are identified as

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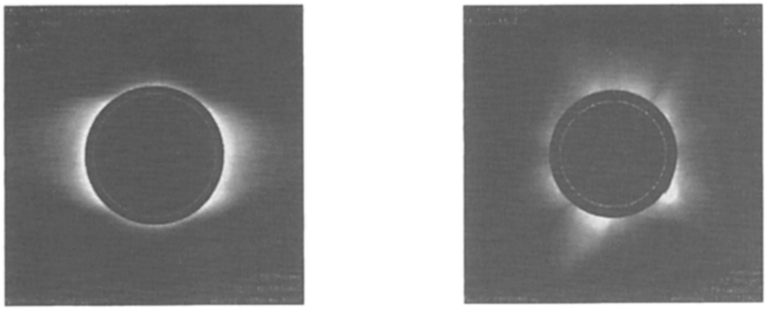

Figure 1. Mauna Loa white light coronagraph images taken on January 2, 1996 a) and August 7, 1999 (b). Image (a) shows the solar corona during solar minimum, and image (b) shows the corona near solar maximum.

polar rays in individual images. They are also sometimes called high latitude streamers (Smith et al 2000). The simultaneous appearance of polar sinusoids at both North and South poles shows that the hot gas responsible is of global extent along the solar meridian. We have successfully modelled the polar sinusoids with emitting structures that extend over both hemispheres of the sun and which have vertical extents high enough to be seen in projection above the solar polar coronal regions (Li et al 2000). The model neatly explains periodic reversals in the sense of asymmetry of the brightness of the polar rays: these reversals are also projection effects caused by the varying heliographic latitude of the sun.

It is well known that the polar coronal holes vary in brightness and shape through the solar cycle. It is usually assumed that these variations are intrinsic. We are interested to know if these variations might be, at least in part, caused by projection effects from high altitude plasma. It is certainly evident from the maps in Figures 2a and 2b that the density of polar rays is high enough near solar maximum to confuse the underlying morphology of the polar holes. Limb synoptic maps will help us to unravel the answer from the large amount of imaging data now available.

3. Conclusion

A number of conclusions are listed from our work:

1. Polar Rays originate from active regions. They are hot high-altitude plasma projected above the poles in the plane of the sky and carried round by solar rotation.

2. Unlike polar plumes, which are clearly rooted in the polar holes, the polar rays are not physically associated with the holes.

3. Annually reversing asymmetries in the polar ray brightness on limb synoptic maps are caused by projection effects due to the varying heliographic latitude.

4. Individual polar rays can be long lived (more than 5 rotations in this study) and increase in number as the solar activity cycle approaches maximum.

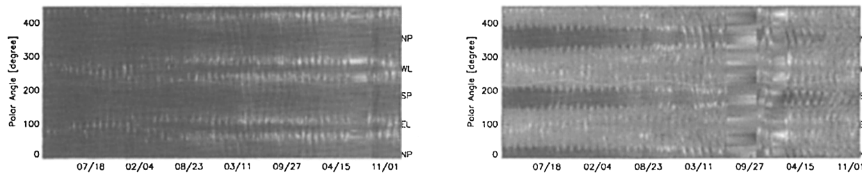

Figure 2. The off limb synoptic map is made with SXT/Yohkoh AlMg filter (a) and EIT/SOHO 195 Å (b). The off limb altitude is from 1.0 to 1.03 solar radia. The map covers time period of 1996 to 1999. The tick marks on x-axis represent 07/18/1996, 02/04/1997, 08/23/1997, 03/11/1998, 09/27/1998, 04/15/1999, and 11/01/1999. The northern pole is at 0°polar angle, and the east limb is at 90°polar angle along y-axis. The heliographic latitude (B_0) is overplotted on the graph as function of time.

5. Variations in the visibility of the coronal polar holes may be largely controlled by the projection of hot gas from more equatorial regions. Polar plumes are features best seen at solar minimum. Polar rays are most prominent near solar maximum.

6. The correlated appearance of polar rays above both north and south holes shows that these features are caused by equatorial plasma structures with a latitudinal extent comparable to the solar diameter.

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References

Guhathakurta, M., Fisher, R., and Strong, K., 1996, ApJ, 471, L69

Li, J., Jewitt, D., LaBonte, B., and Acton, L., 2000, ApJ Letter, 539, L67; see also http://www.ifa.hawaii.edu/users/jing/papers.html

Maunder, E.W., 1901, The Total Solar Eclipse of May 1900 (London: Witherby and Co.)

Smith, P.L., Miralles, M.P., Panasyuk, A., Strachan, L., Gardner, L.D., Suleiman, R., Cranmer, S.R., Romoli, M., and Kohl, J.L., 2000, IAUS. 203E.168S

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