Solar Sector Structure: Fact or Fiction?

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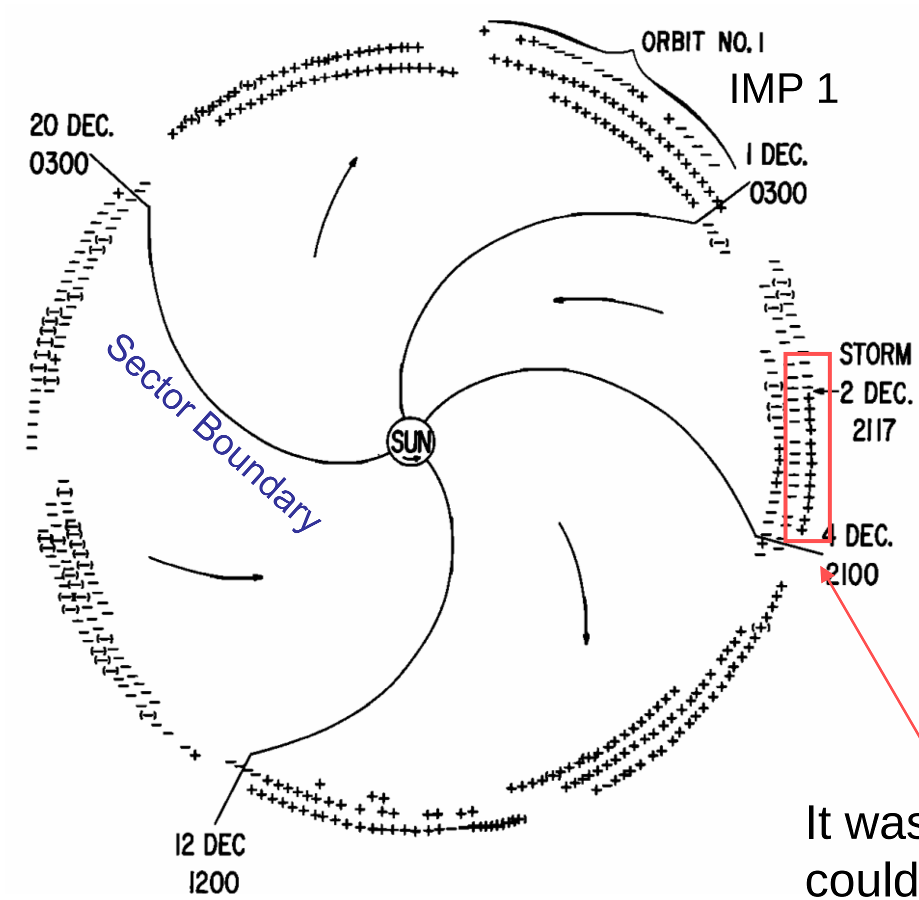
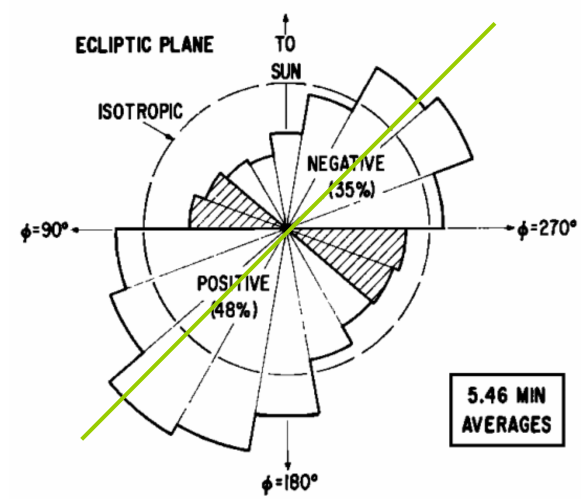
Discovery of Sector Structure

Quasi-Stationary Corotating Structure in the Interplanetary Medium
John M. Wilcox & Norman F. Ness (1965), JGR, 70, 5793.



The large-scale structuring of the IMF was a surprise at the time



It was also noted that solar storms could briefly disrupt the structure

The Structure Organizes Solar Wind Properties and Responses to those

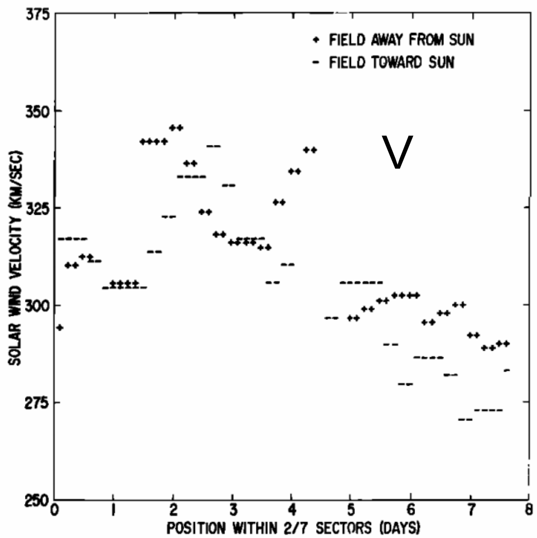


Fig. 8. Superposed epoch analysis of the solar wind velocity as a function of position within the 2/7 sectors.

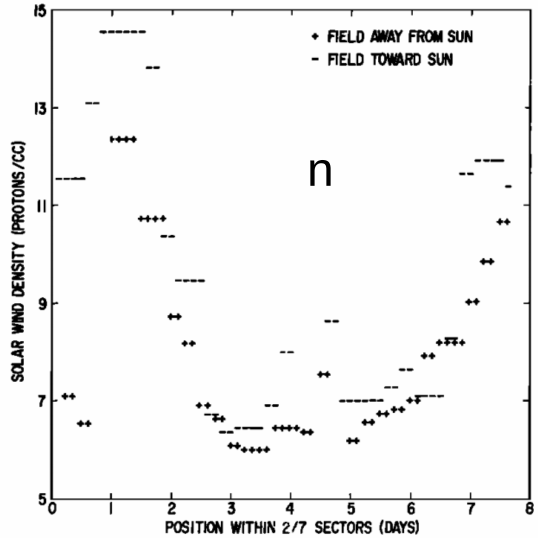


Fig. 9. Superposed epoch analysis of the solar wind density as a function of position within the 2/7 sectors.

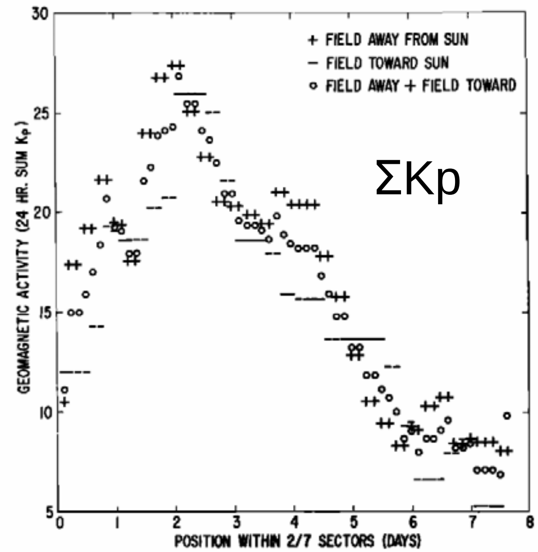


Fig. 11. Superposed epoch analysis of the geomagnetic activity index 24-hour sum K_p as a function of position within the 2/7 sectors.

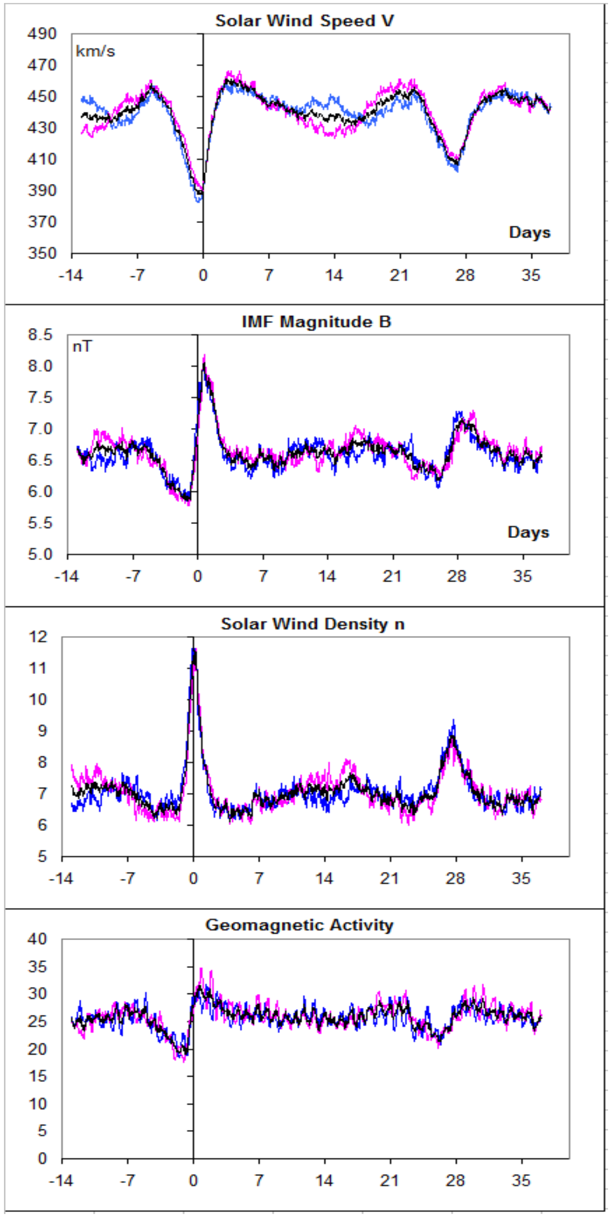
Solar Wind High-speed Stream

Density Spike

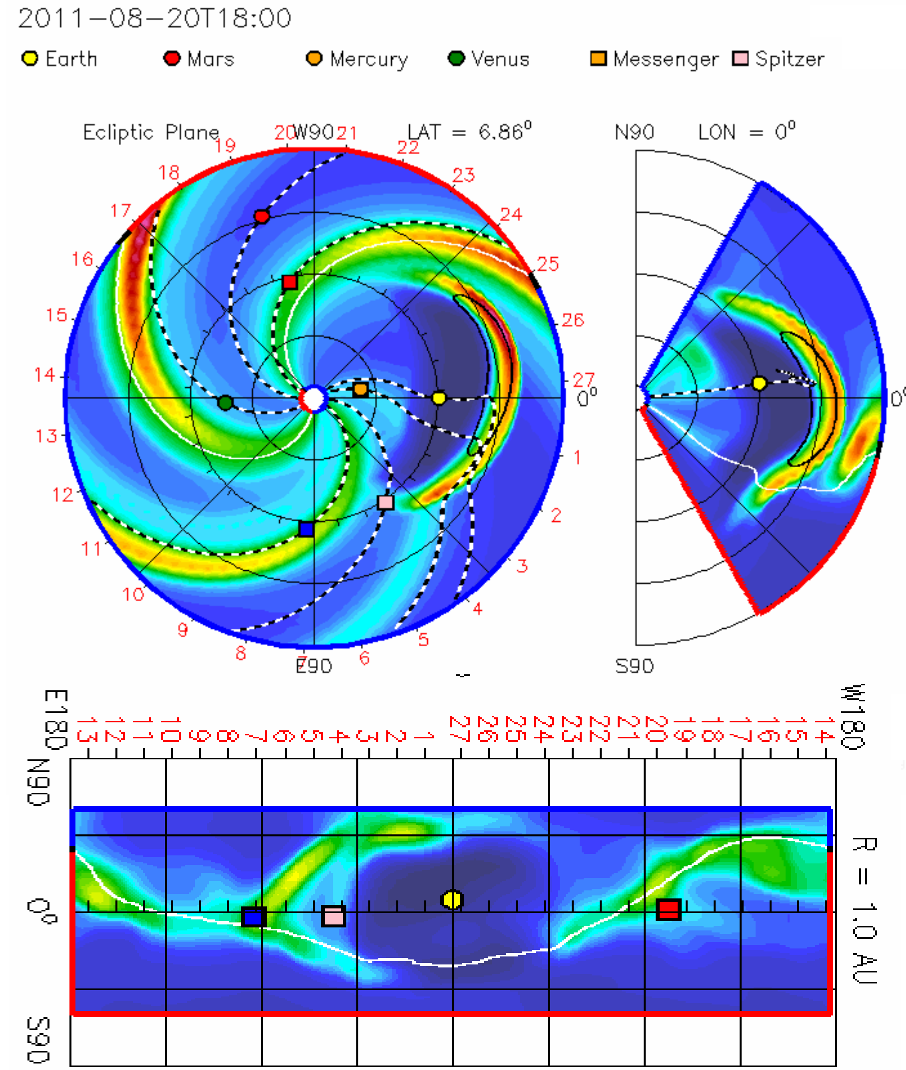
Geomagnetic Activity

Also: Cosmic Ray Intensity, IMF Strength, Flares, UV Flux, Green Corona, etc. Almost anything was later claimed by people to be organized by the structure: Weather, Agitation of Inmates in Mental Institutions, etc. Like Global Warming today causes everything…

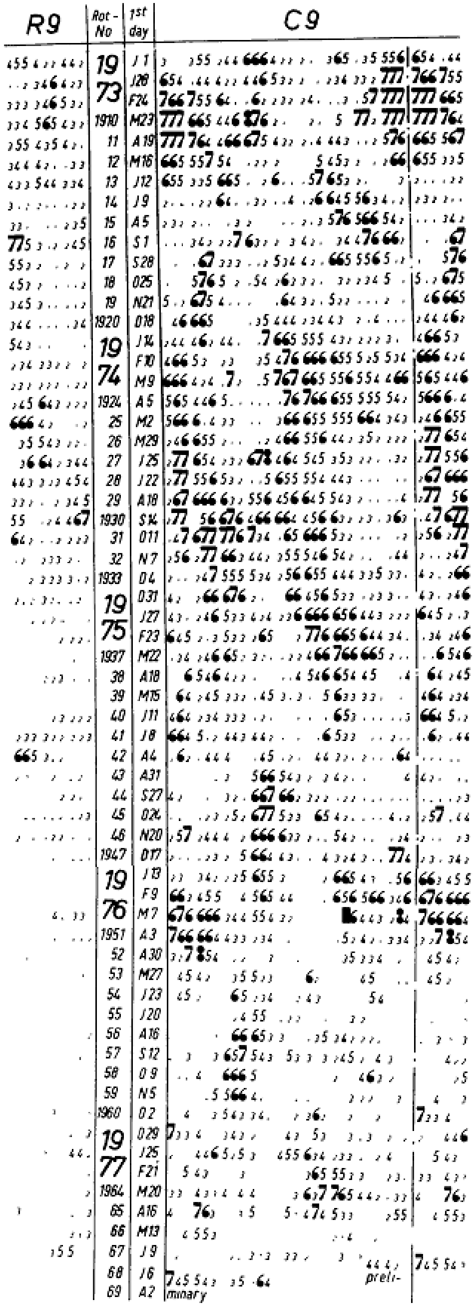
Organization is Robust (Co-rotating Interaction Regions)

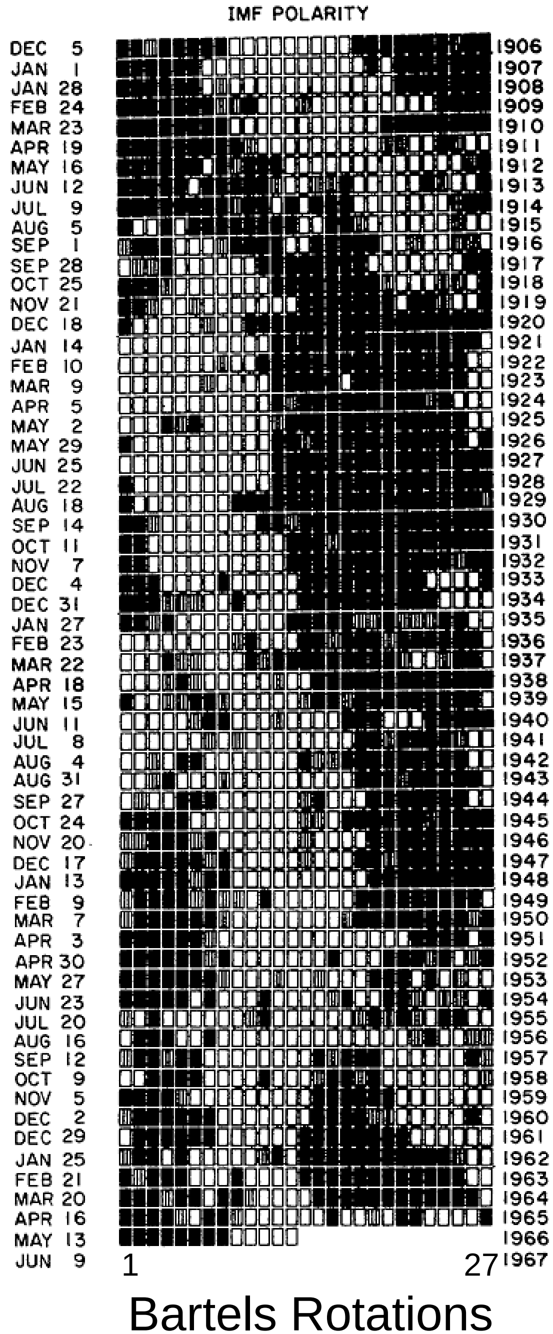


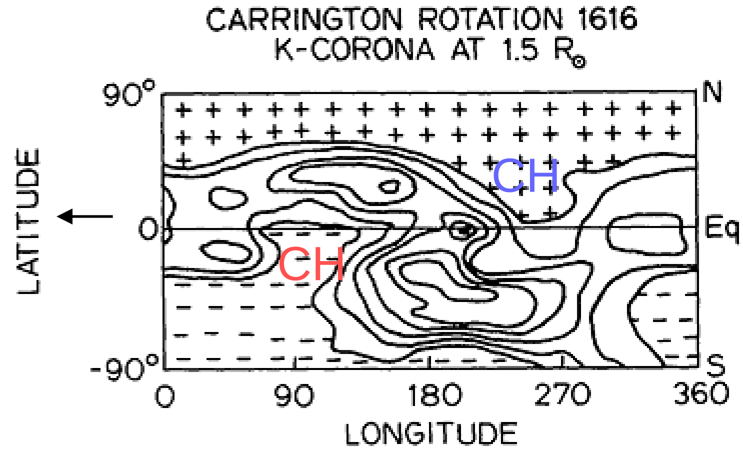
Superposed Epoch ~1000 Boundaries

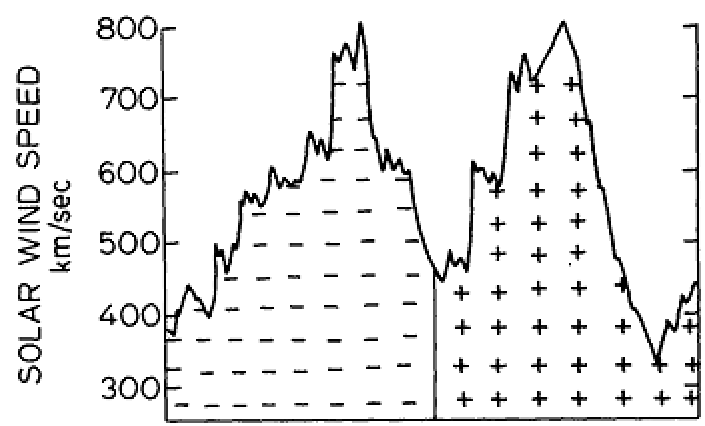


Rotation Plots of the Sector Polarity



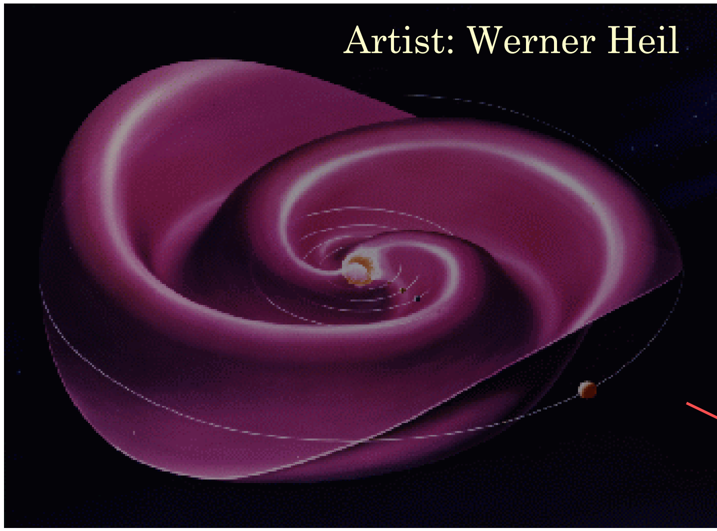


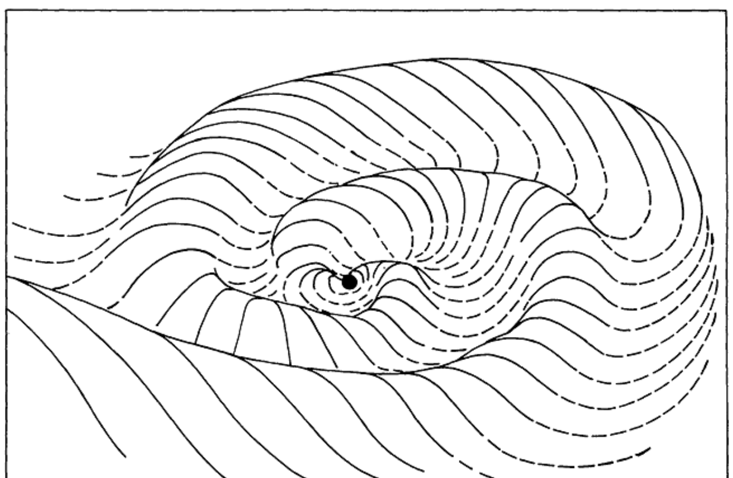




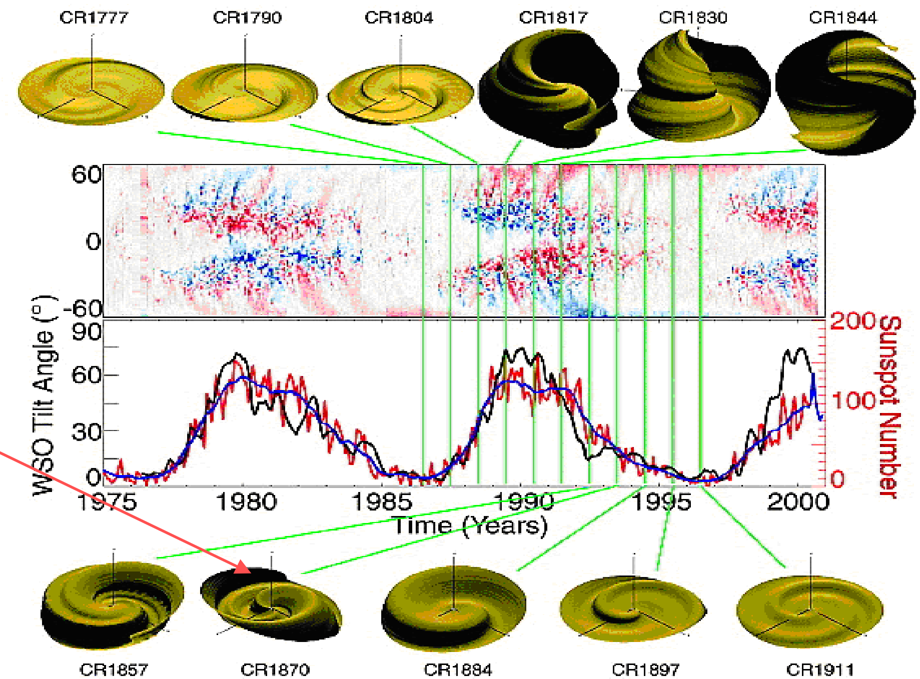
Skylab Workshop, 1976

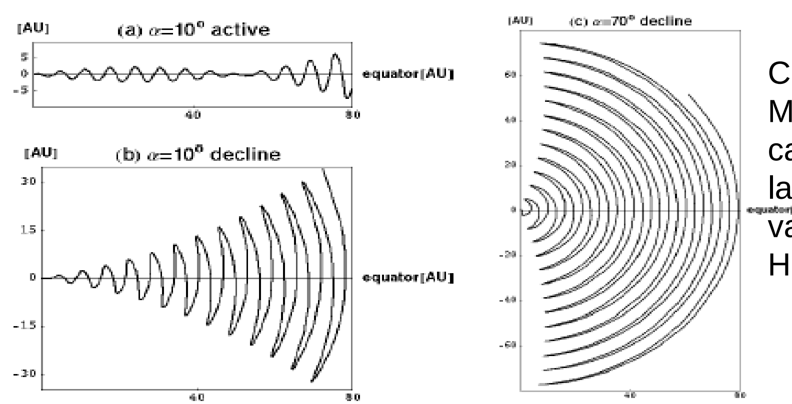
The Heliospheric Current Sheet





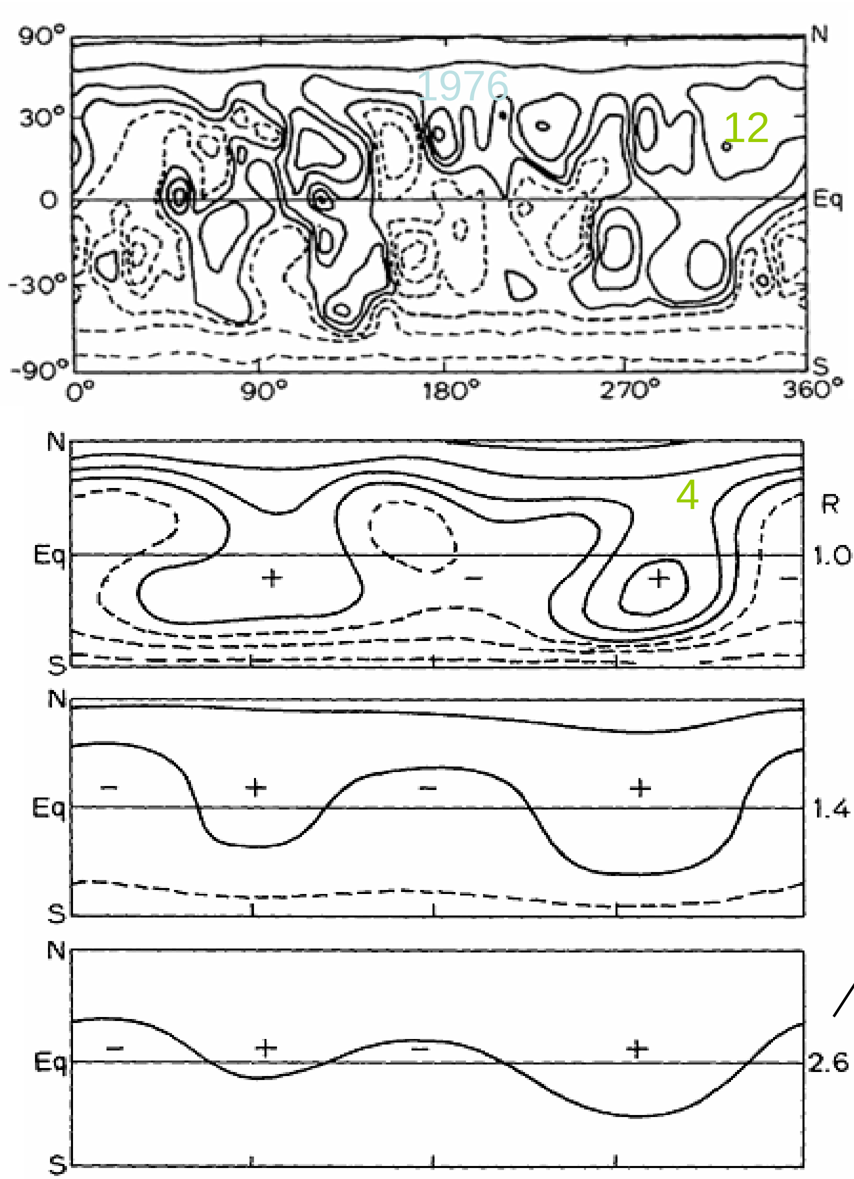
Svalgaard & Wilcox, *Nature*, 1976



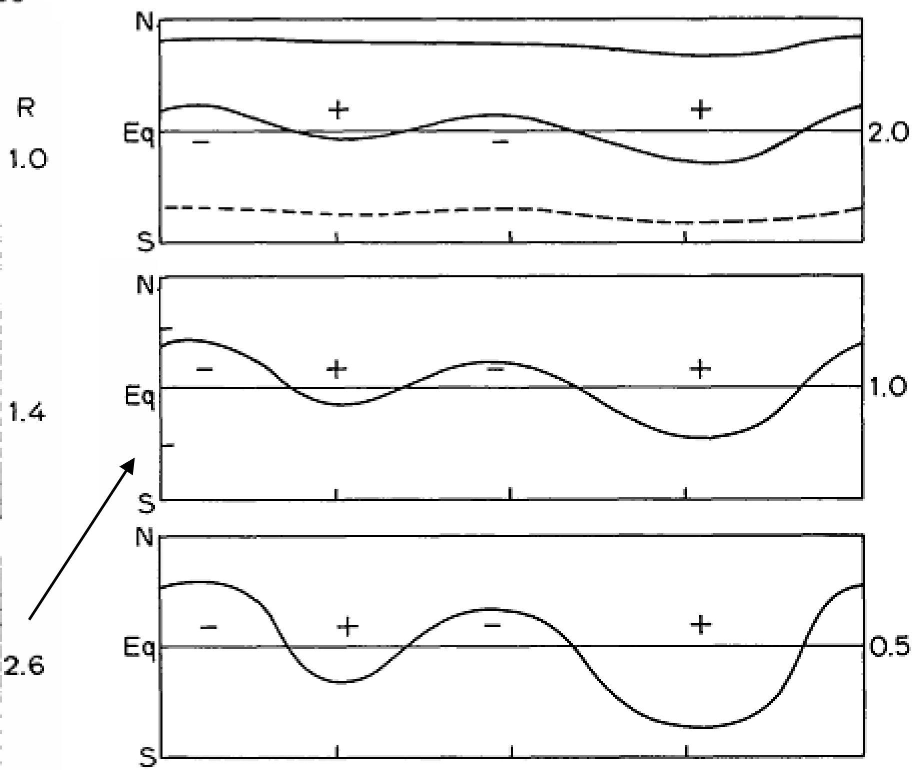


Cosmic Ray Modulation caused by latitudinal variation of HCS and CIRs

The Potential Field Source Surface Model Illustrates Many First-Order Effects

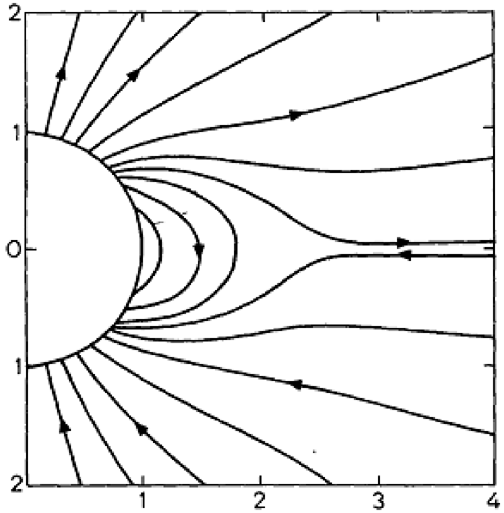


Simplification and Flattening with Height
“Domes of closed field lines”



Flattening with Polar Fields

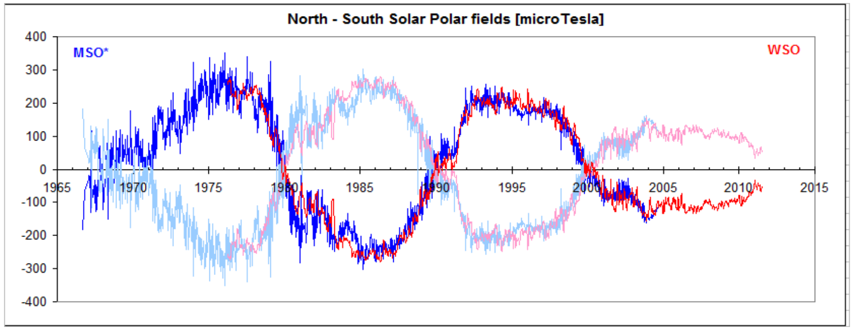
The Importance of the Polar Fields

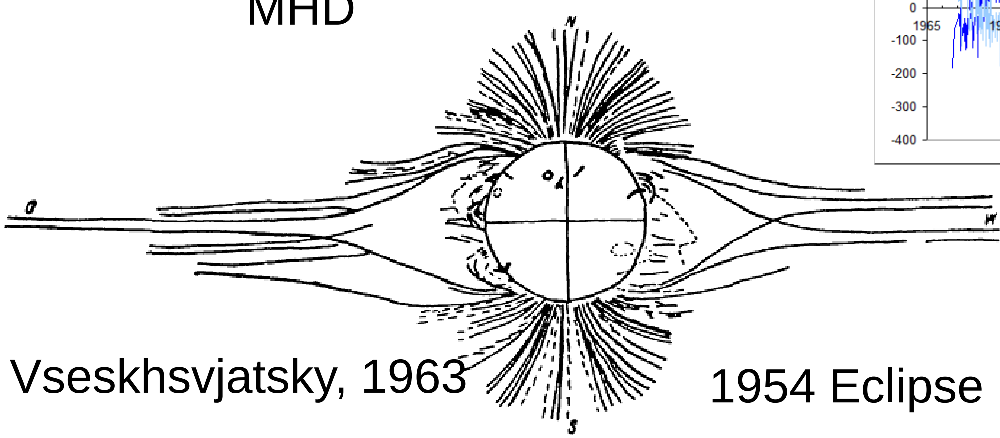


Pneuman & Kopp, 1971
MHD

Even with all the sophistication of current models of the Corona and HMF they are hostage to the correct value of the solar polar fields, which may be different at the two poles and even have longitudinal structure within the polar caps.

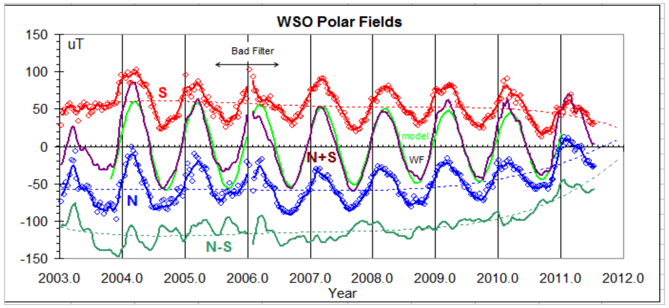
This is particularly important at solar minimum when the HCS is largely flat.





Vseskhsvjatsky, 1963

1954 Eclipse

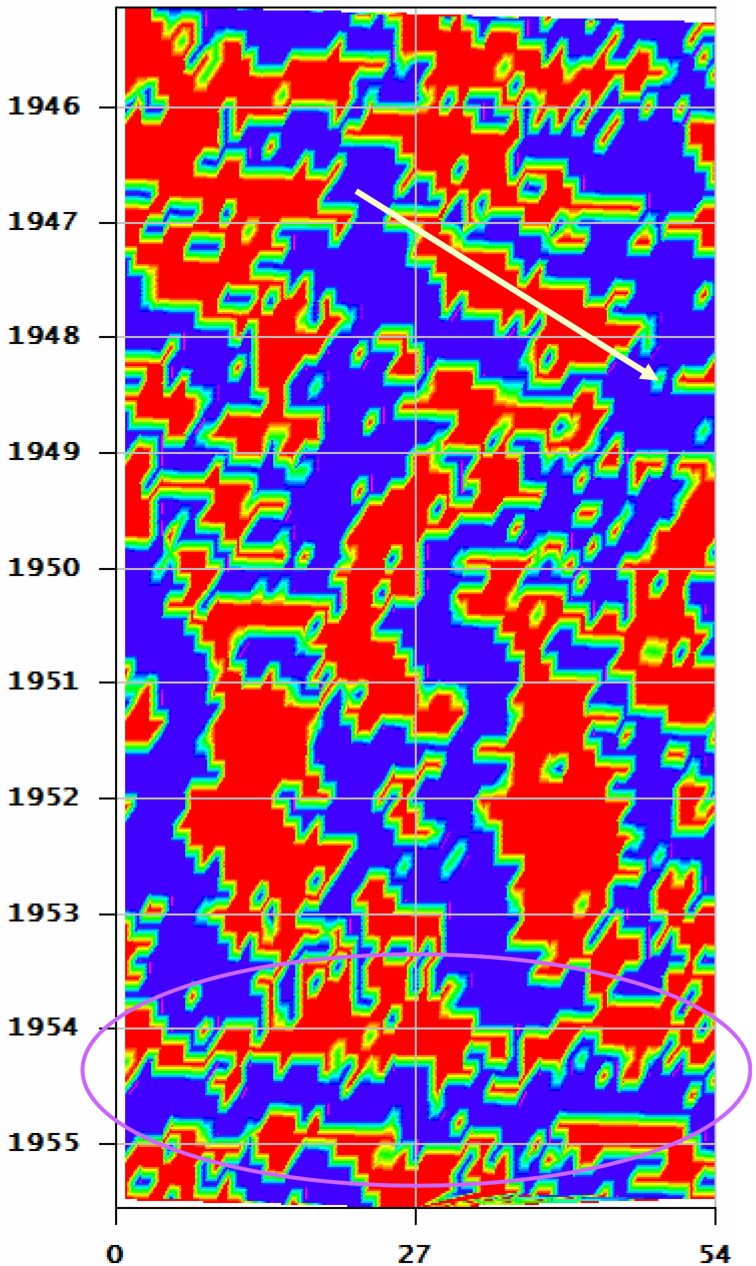


Rotation Plots of Polarity

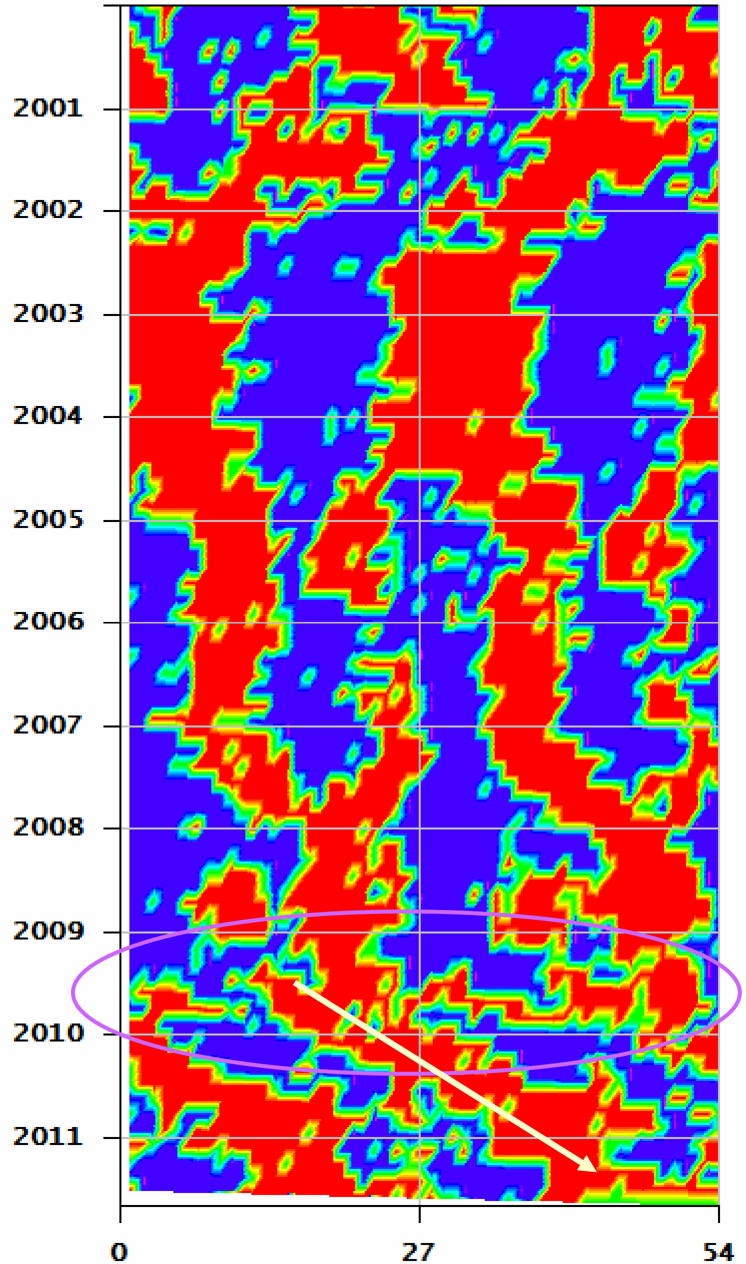
Recurrent for years

Towards, -

Away, +

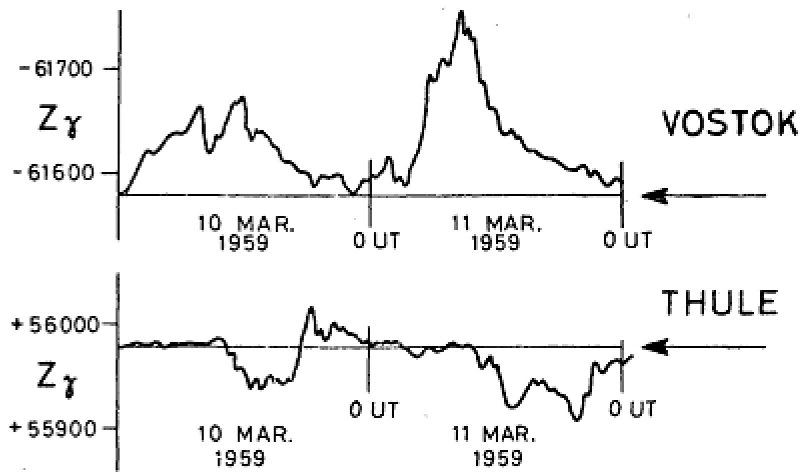


In 1954 the HCS was so flat that the Earth was above the sheet for six months at a time



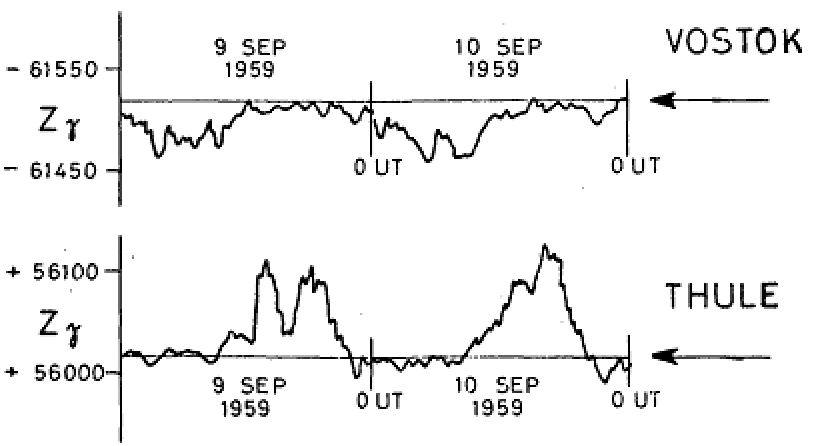
Rosenberg-Coleman Effect

How do we know the Sector Polarity Before the Space age?

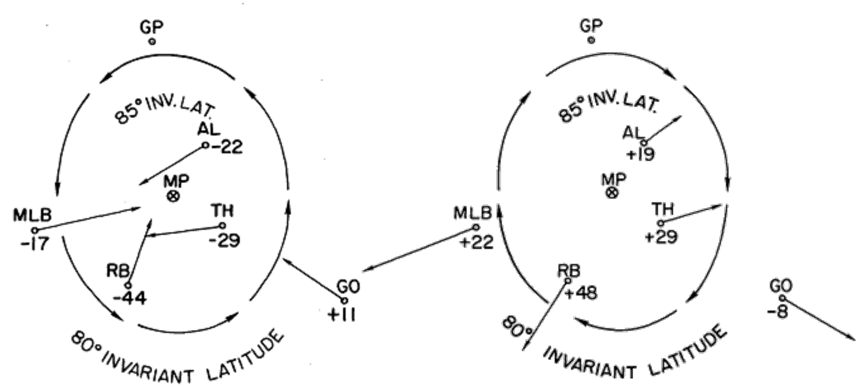


Sample magnetograms from away sector

The HMF reconnects with the Earth's magnetic field and deforms it depending on the sign of the HMF. This creates an electric current vortex, whose magnetic effects we can measure on the ground:



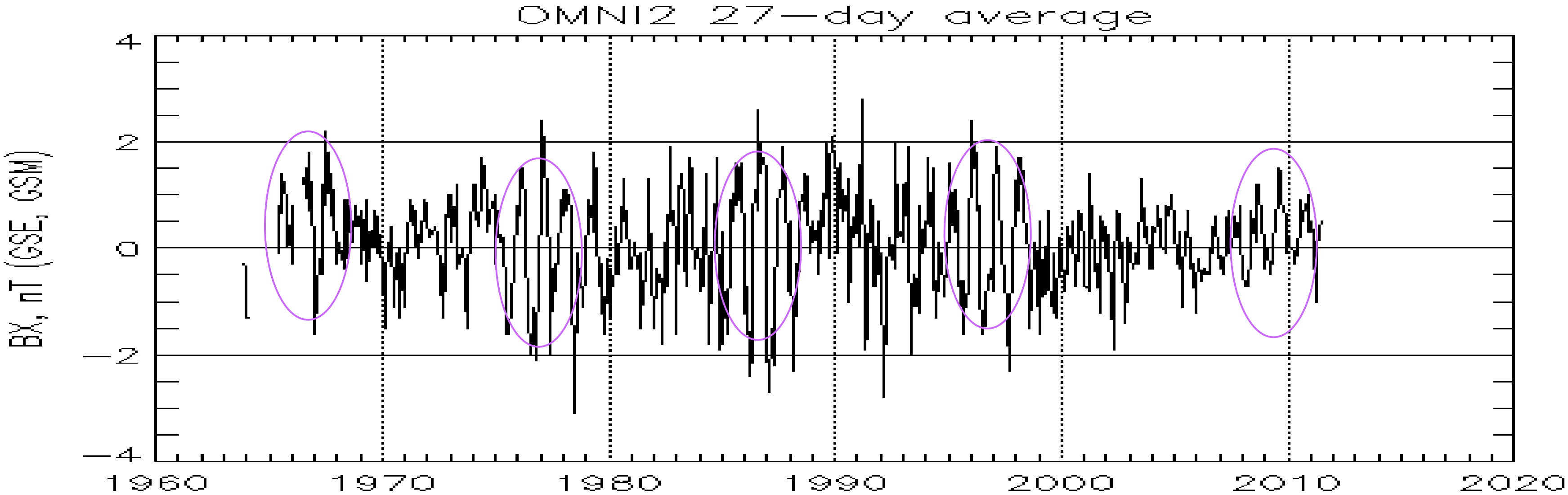
Sample magnetograms from toward sector

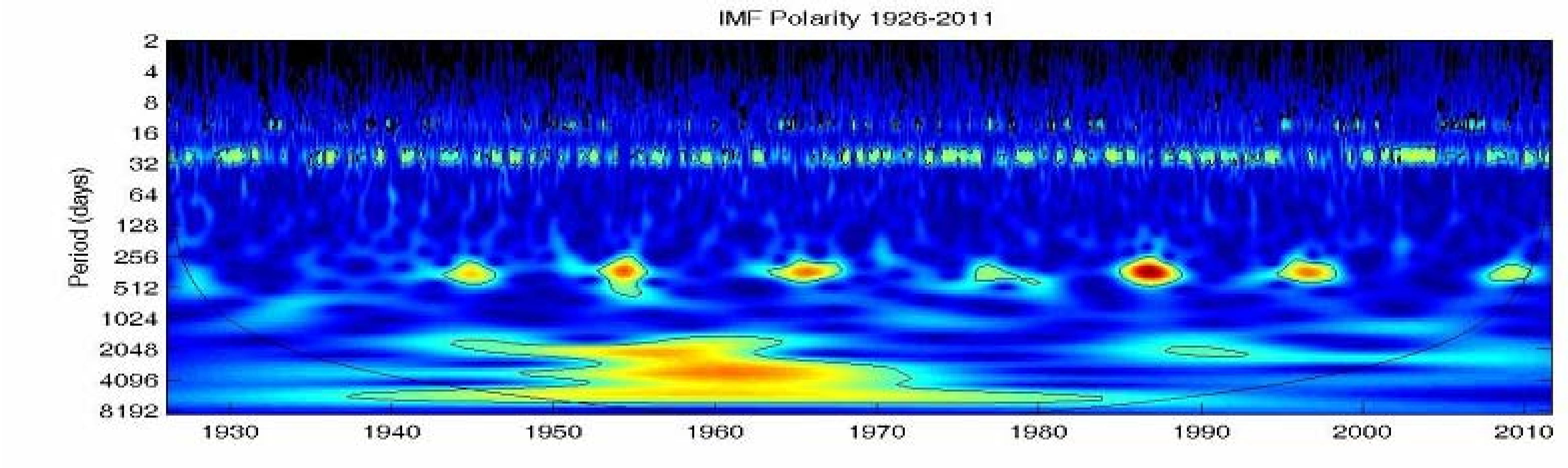


Away   Toward

Data goes back to 1926

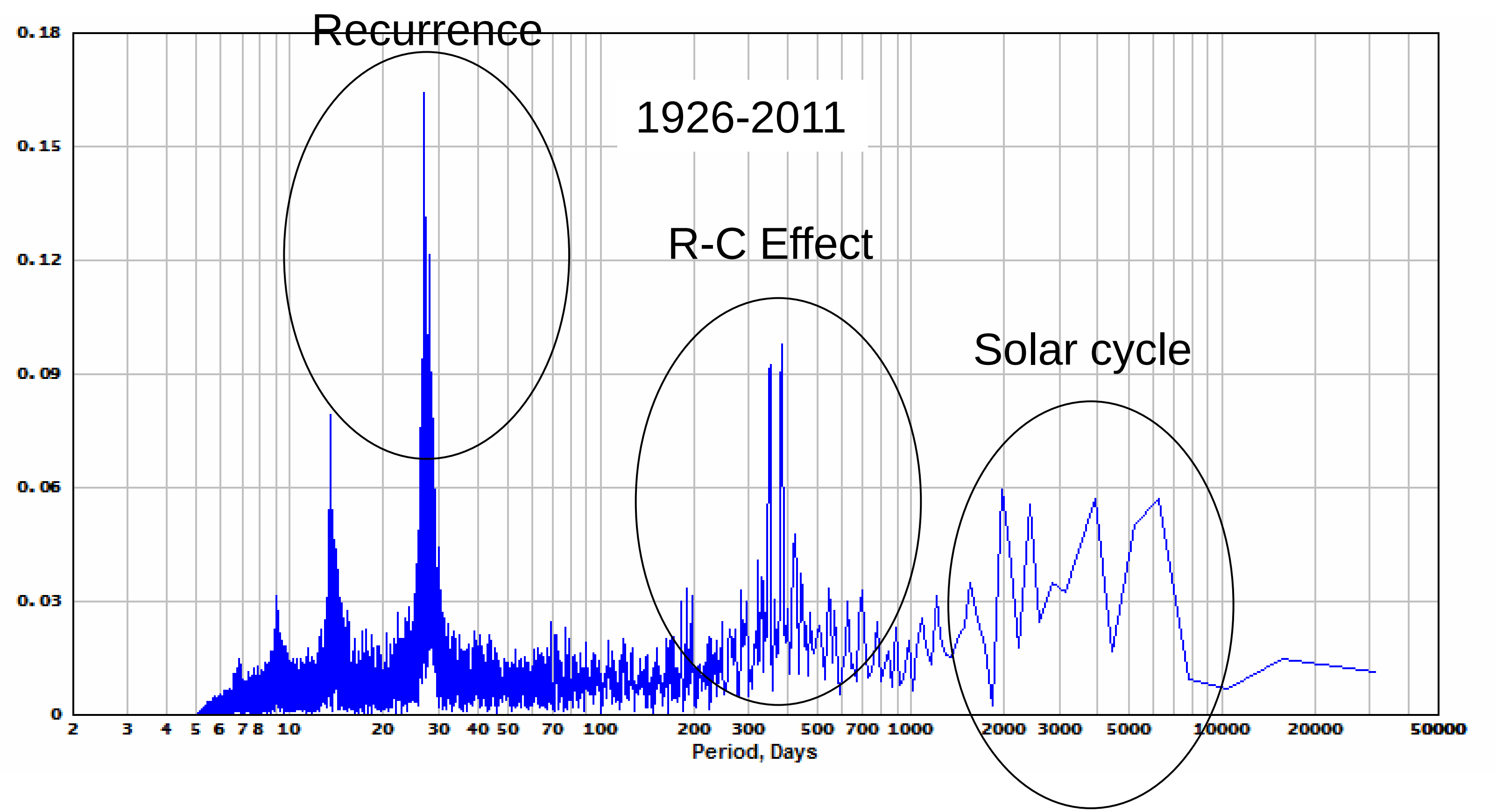
Dominant Polarity: Rosenberg-Coleman Effect





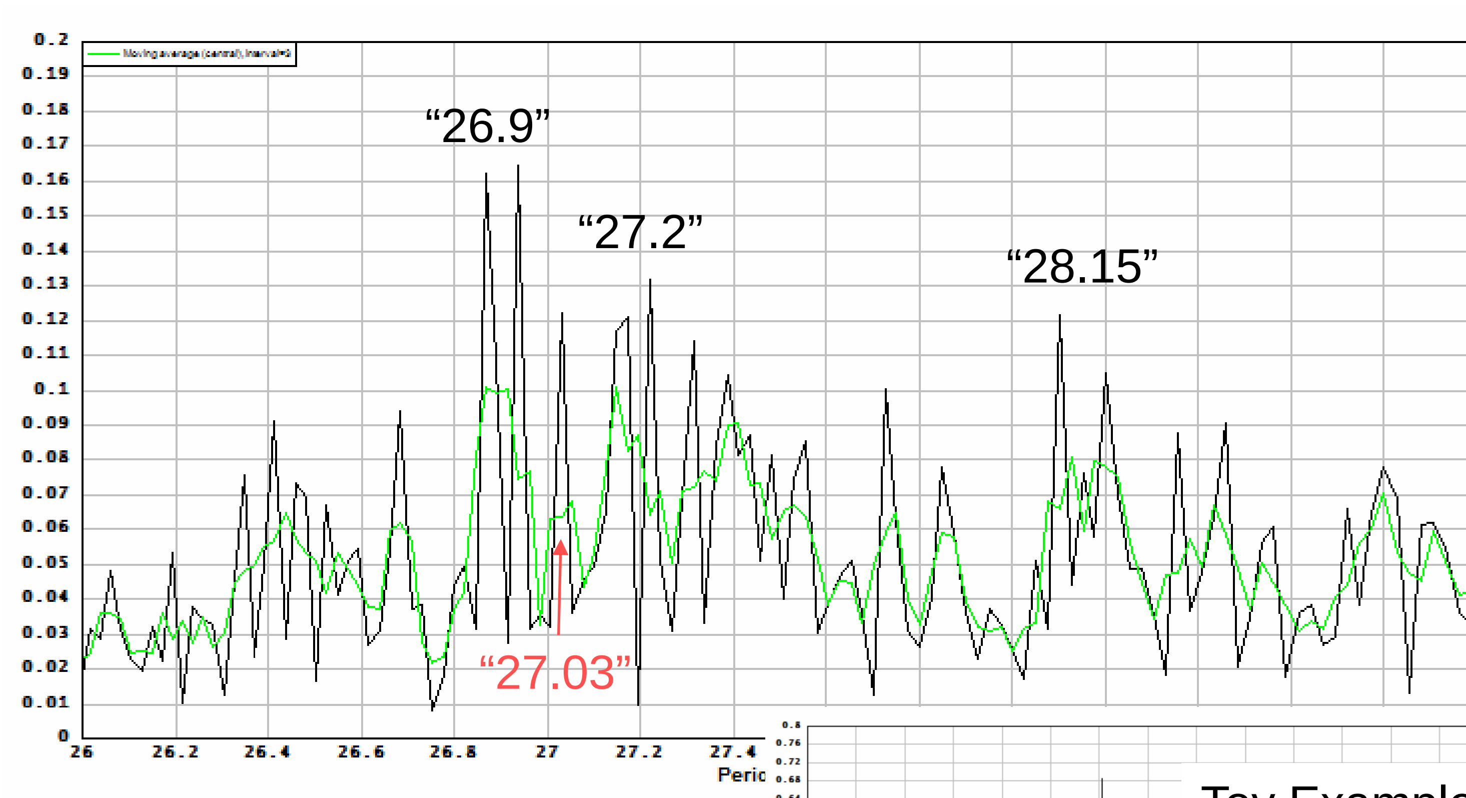
Proves Polar Field Reversals in the Past

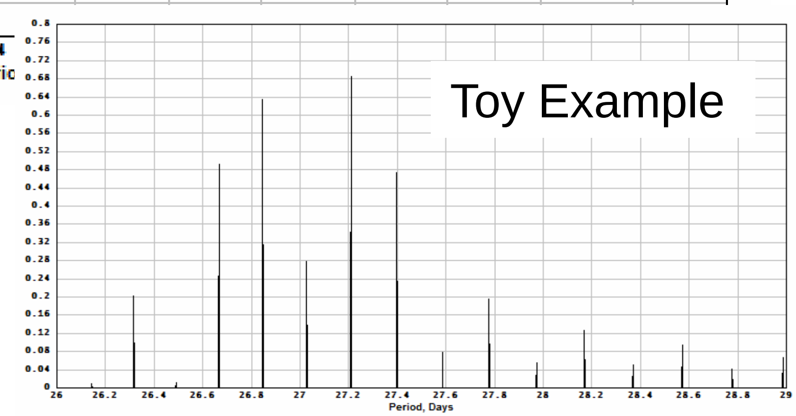
FFT Power Spectrum of Polarity



The Recurrence Line is split into several lines

Recurrence Peak: Fine Structure





The 27.03 line is an artifact having contributions from the 26.9 and 27.2 lines

Average Recurrence Period in Solar Wind Data

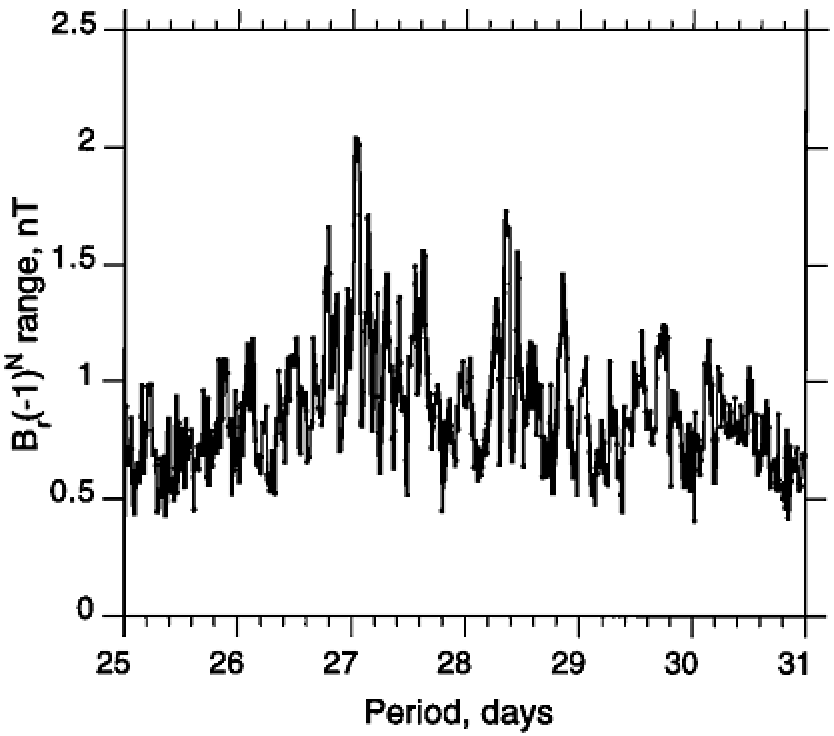
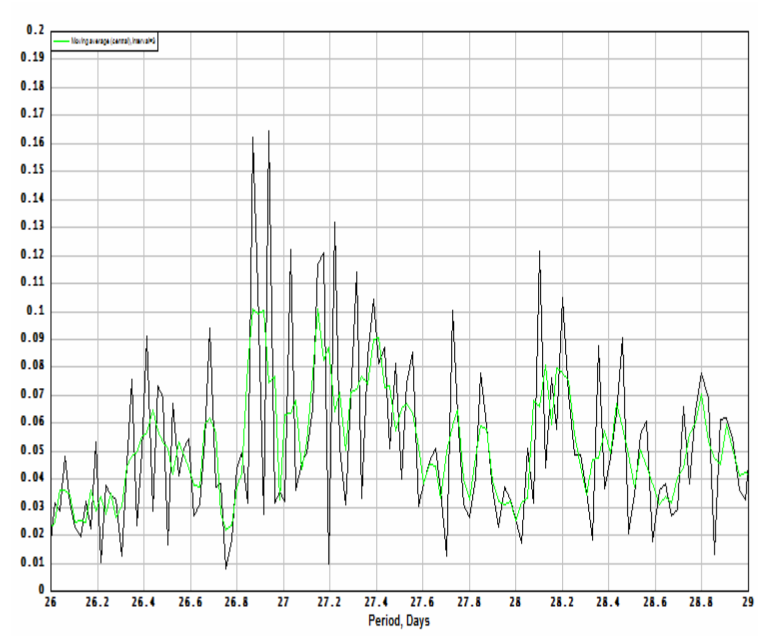
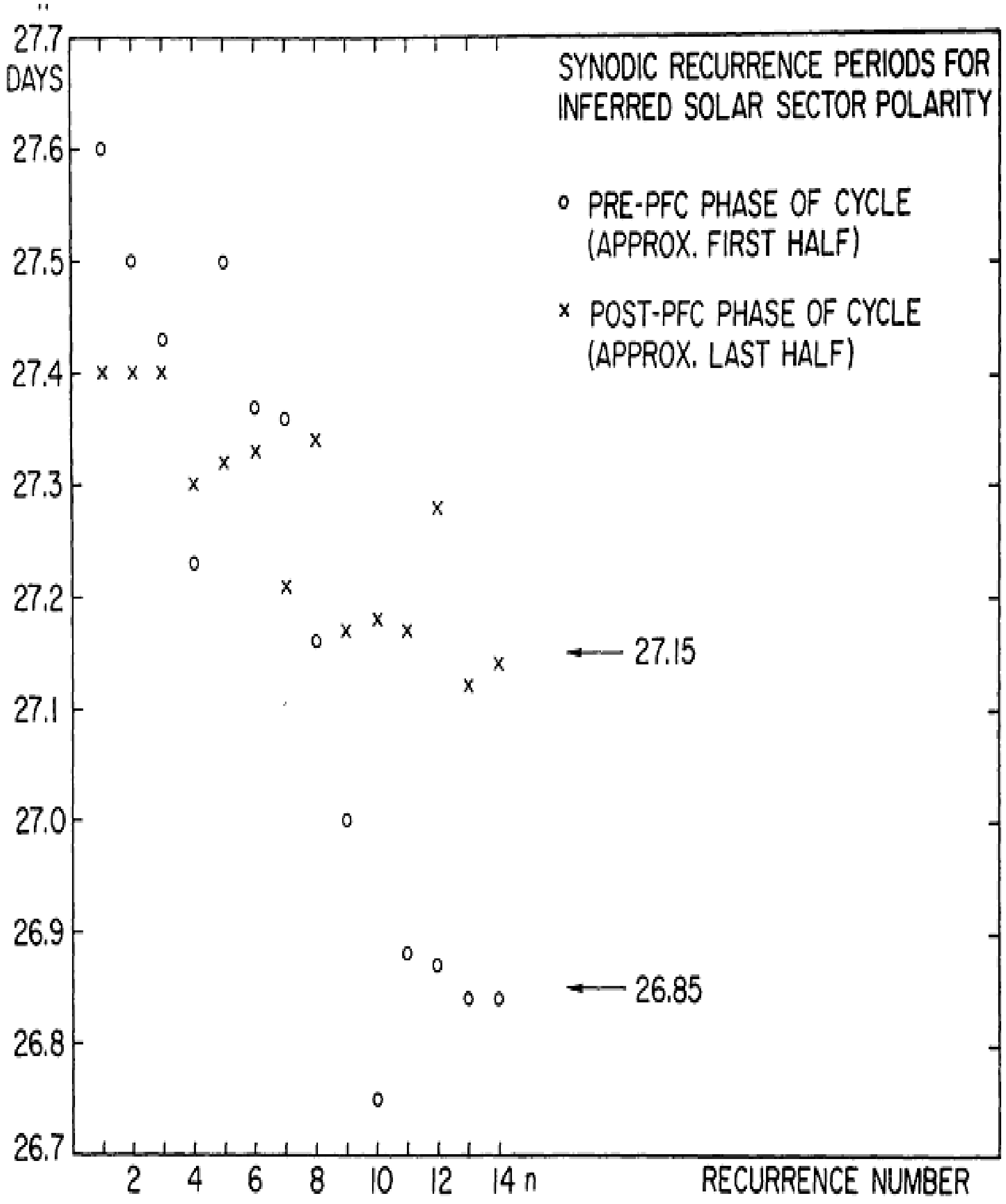


Figure 5. The difference between the highest and the lowest values of $B_r(-1)^N$ for the time-averaged $B_r(-1)^N$ versus longitude curves as a function of solar rotation period from 25 to 31 days.

Neugebauer et al., 2000



"On average, solar magnetic field lines in the ecliptic plane point outward on one side of the Sun and inward on the other, reversing direction approximately every 11 years while maintaining the same phase. The data are consistent with a model in which the solar magnetic dipole returns to the same longitude after each reversal."



Svalgaard & Wilcox, 1975

Recurrence Period depends on Solar Cycle Phase

26.85 d before polar field reversal

27.15 d after polar field reversal

Autocorrelation at different lags shows peaks at *n* * *P*(*n*)

Active Longitudes [an Example]

The Physics of Chromospheric Plasmas

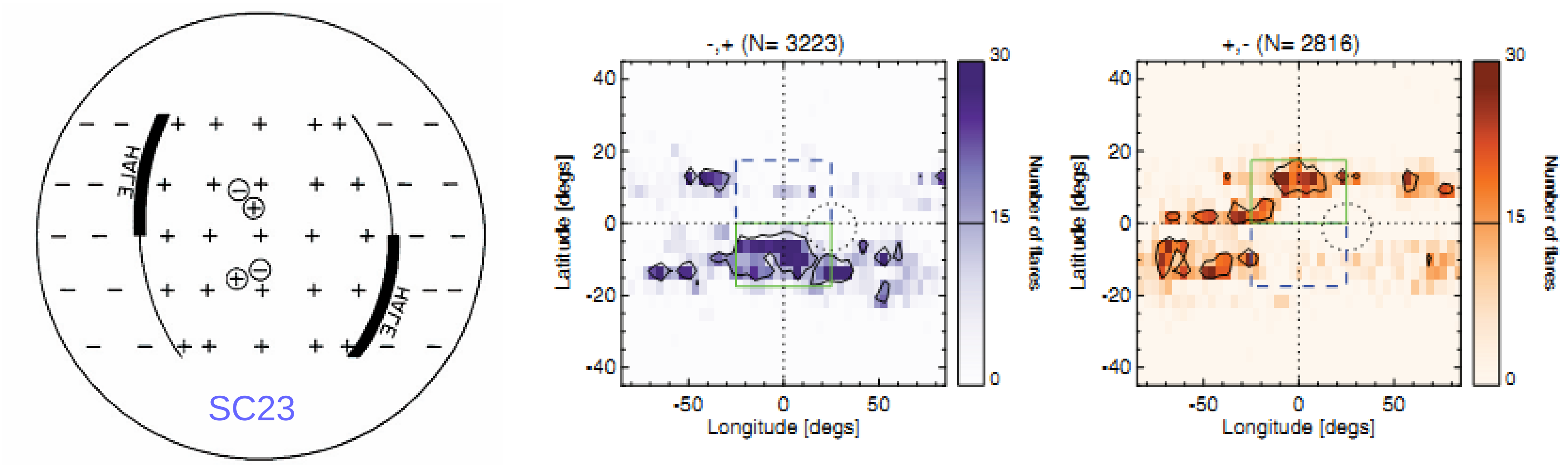
ASP Conference Series, Vol. 368, 2007

Regularities in the Distribution of Solar Magnetic Fields

V. Bumba, M. Klvǎna and A. Garcia

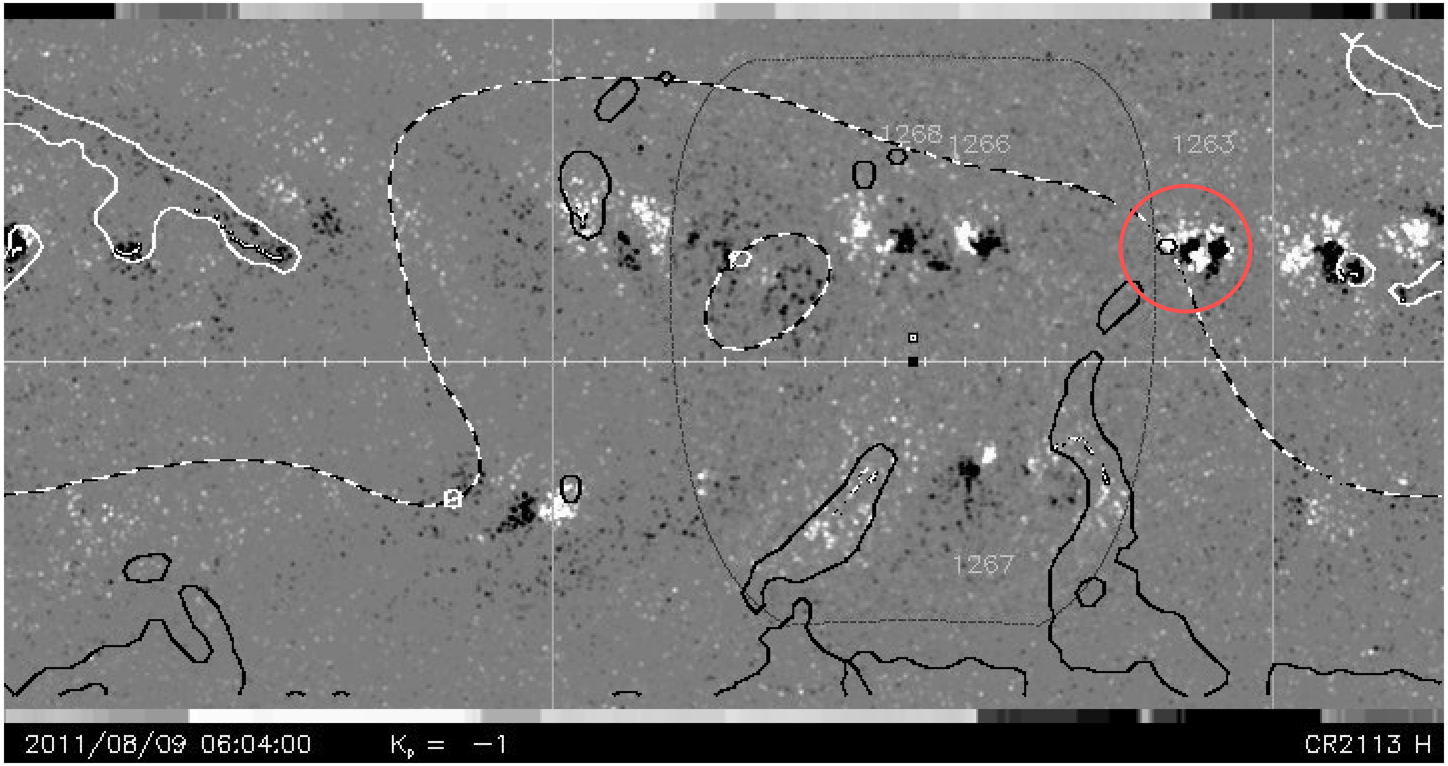
Abstract. We examined the distribution and concentration of the solar magnetic fields from the Wilcox observatory synoptic charts for the whole period of their existence (May 1976 – February 2006). We divided them into four latitudinal zones, studying the changes of their various structures, density, etc. These sets of maps demonstrate striking regularities in the photospheric magnetic field distribution with time, continuous existence of characteristic longitudes of magnetic field concentration and their longitudinal shift with three main rotational periods of 26.8, 28.2, and 27.14 days. They show formation of specific structures of background weaker fields, connected with the development of activity complexes, polarity alternation, etc…

Hale Boundaries and Flares



Distribution of RHESSI flares within ±24 hr of 223 sector boundaries mapped back to central meridian (dashed vertical line) for part of solar cycle 23, 2002 March to 2008 March. The left and right panels show the (−, +) and (+,−) boundaries, respectively. The green boxes show where flares are expected, based on association with strong magnetic fields, i.e., at the Hale boundary. The dashed purple boxes show that hardly any flares occur near a non-Hale boundary. The number of flares in each distribution is shown above each plot. Only flares within ±85° of CM are counted. The small dashed line circles show the center of the bias area for the RHESSI imaging axis.

Recent X7 Flare on Hale Boundary



Is the magnetic field already ‘stressed’ when emerging if on a Hale Boundary? McClymont & Fisher (1989) make this case generally: the emerging flux adds stressed magnetic fields directly to the lower solar atmosphere, storing the non-potential energy needed for flaring.

The Issue

- Is the solar sector structure the result of surface flux transport of essentially randomly distributed flux?
- Or is the sector structure the result of deep-seated solar processes, resulting in longitudinal organization of the field?
- Helioseismology might discover longitudinal structures and flows (if we look for them)