Long-lived Low Latitude Coronal Holes

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Using the McIntosh Archive to track coronal hole lifetimes.

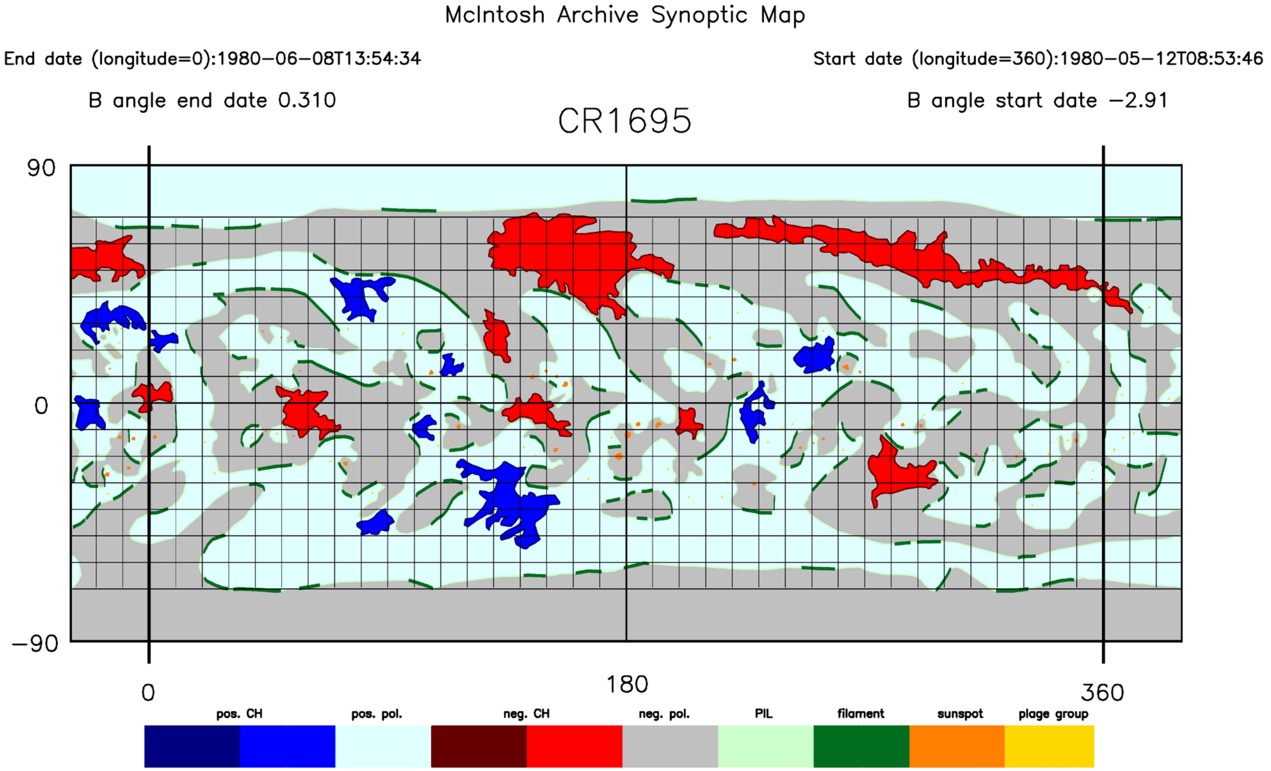


Fig 1 - The McIntosh Archive (McA) of synoptic maps are a global representation of the evolving solar magnetic field. This is an example of a processed McA synoptic solar map. Magnetic features are identified by a distinct number or color, as described in the legend. We used about 32 years of these synoptic maps to follow low latitude coronal holes from rotation to rotation.

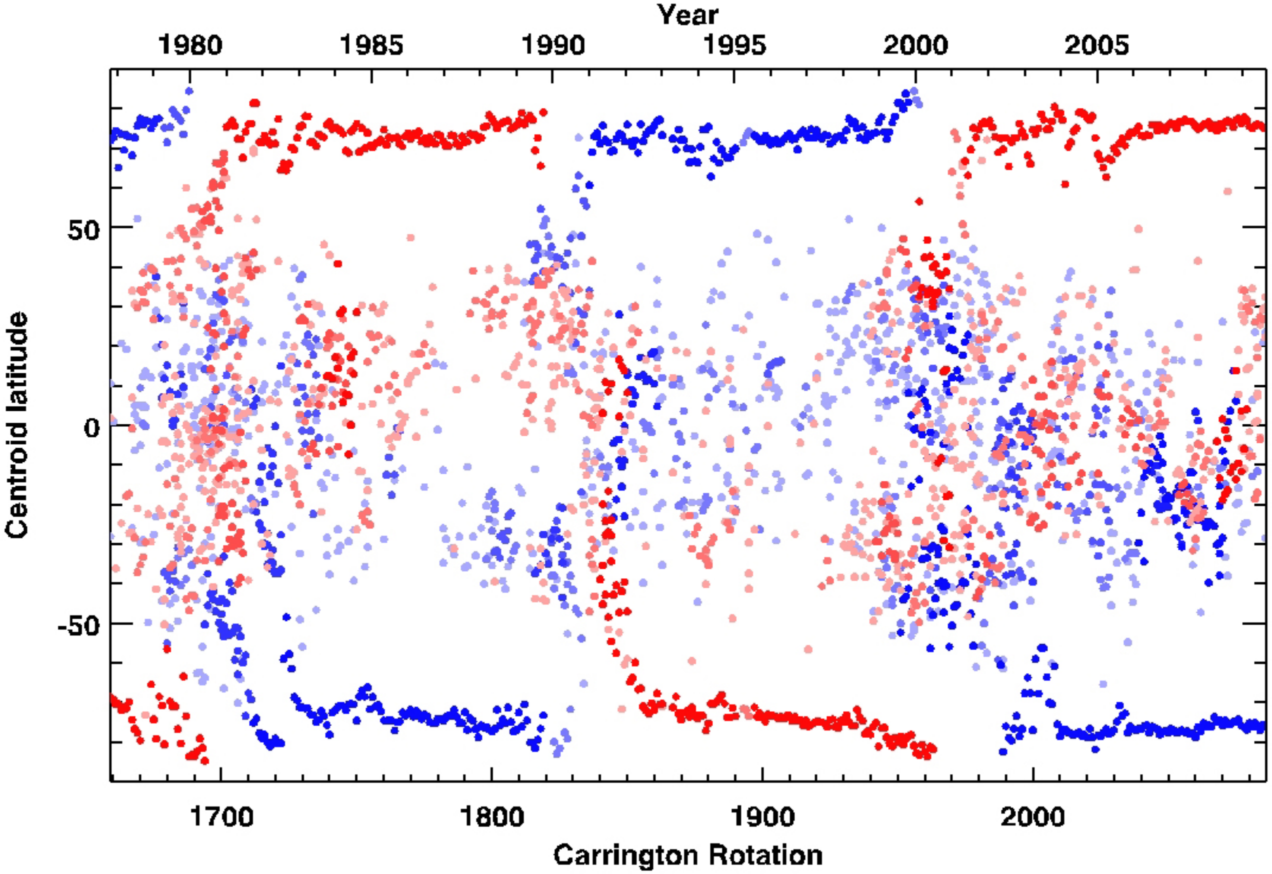
Introduction

- McIntosh Archive Solar Synoptic maps are based on Hα images from 1964 (SC20) to 2009 or ~45 years, ~600 Carrington Rotations (CRs), or over four complete solar cycles of synoptic maps.
- Maps show Large-scale organization of the solar magnetic field (McIntosh, 1979, NOAA, UAG-70), where magnetic polarity inversion lines (PILs) connect widely separated filaments, fibril patterns and plage corridors.
- Coronal hole boundaries are from ground-based HeI 10830Å images. Although McIntosh didn't begin using HeI 10830Å images consistently until 1981-2 we are in the process of adding all HeI 10830Å data available from NSO which began in April 1974 (early SC21). We also added Skylab data for about 8 CR's in 1973 and 1974.
- Currently completing, digitizing and archiving missing or incomplete maps. The 42 missing and incomplete maps in the beginning of SC21 will be included in a paper.
- This study covers most of SC21, and all of SC22, SC23 and the beginning of SC24 for about 425 CR's.

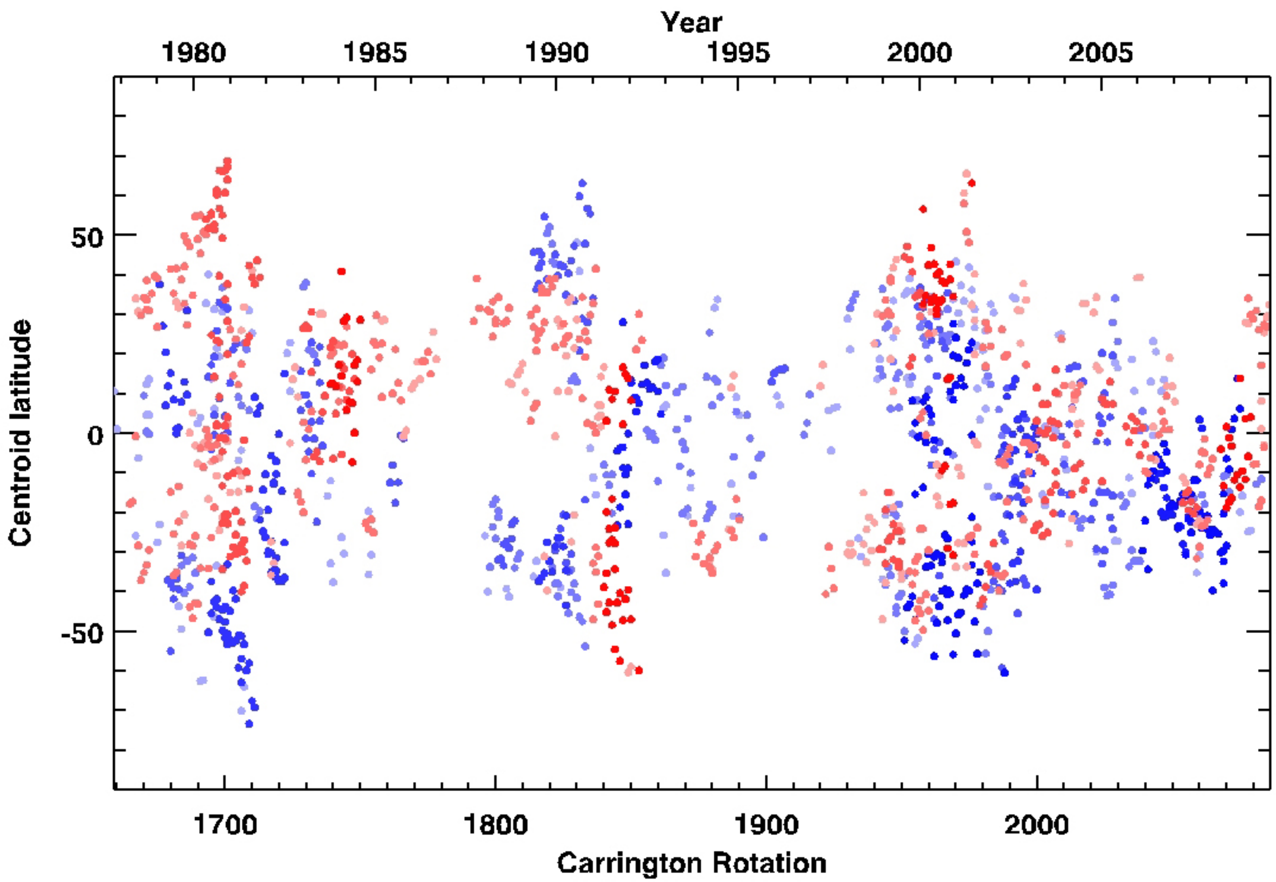
Focus of Study

- We are looking at coronal hole positions and lifetimes.
- Our interest lies in the similarities and interconnections between the magnetic and activity cycles.
- We subdivide coronal holes into three primary varieties. First, we separate those with a polar component (which we define as any coronal hole that has a maximum latitude of above 89°), from non-polar (any coronal hole that has a maximum latitude of less than 89°). Then we further subdivide the non-polar holes into short-lived (they only appear in one Carrington Rotation) and long-lived (they appear in approximately the same location on more than one consecutive Carrington Rotation).

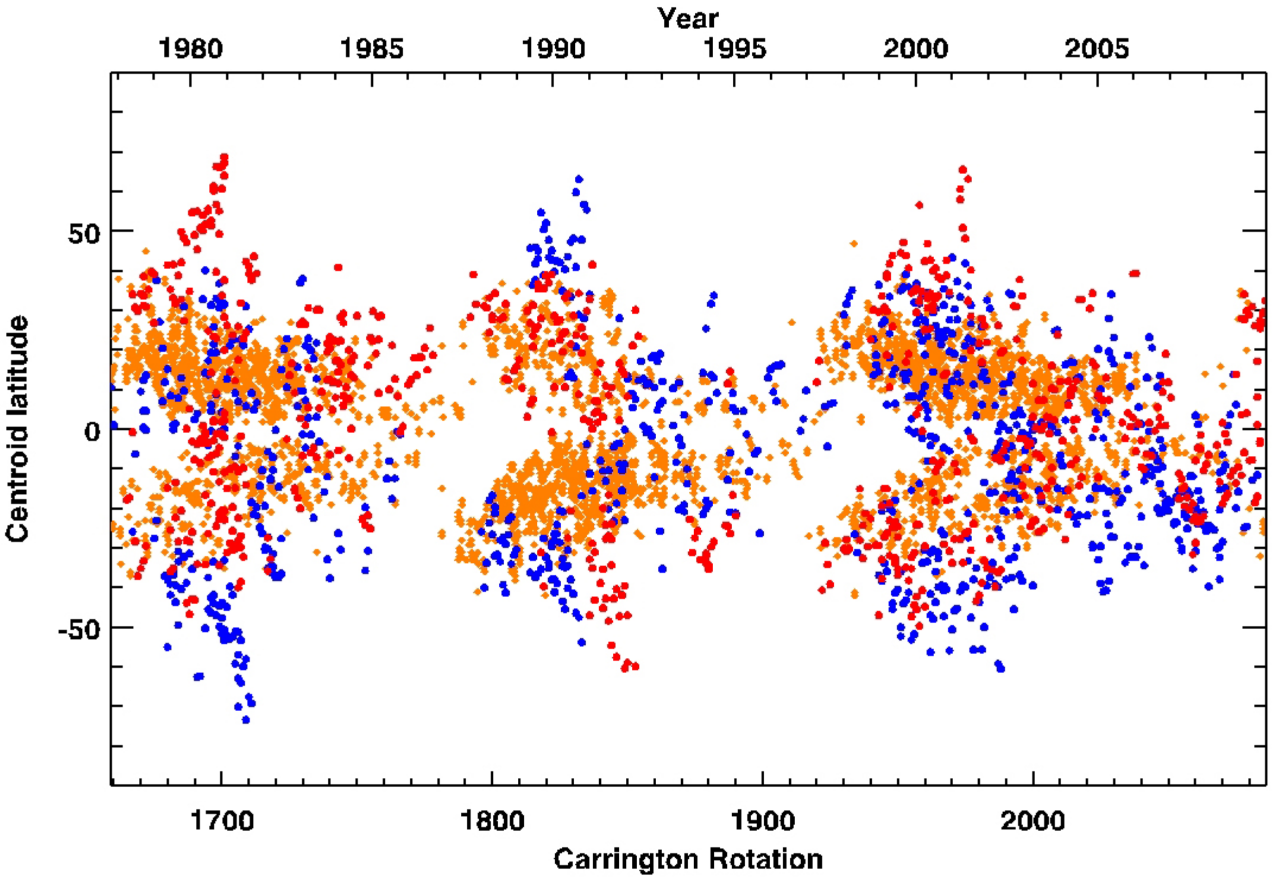
Results - All coronal hole centroids are shown here, plotted by Carrington Rotation, year and latitude. Red represents negative polarity and blue represents positive, with the darker shades representing longer lifetimes. We define lifetimes by the number of rotations a given coronal hole recurs. The 11-year magnetic polarity flip as observed by Lowder (Lowder, et al., Sol Phys (2017) 292: 18) is shown here as well as the slight hemispherical asymmetry of the appearance and evolution of coronal holes at each pole (Webb et al., Sol. Phys (1984) 92, 109).



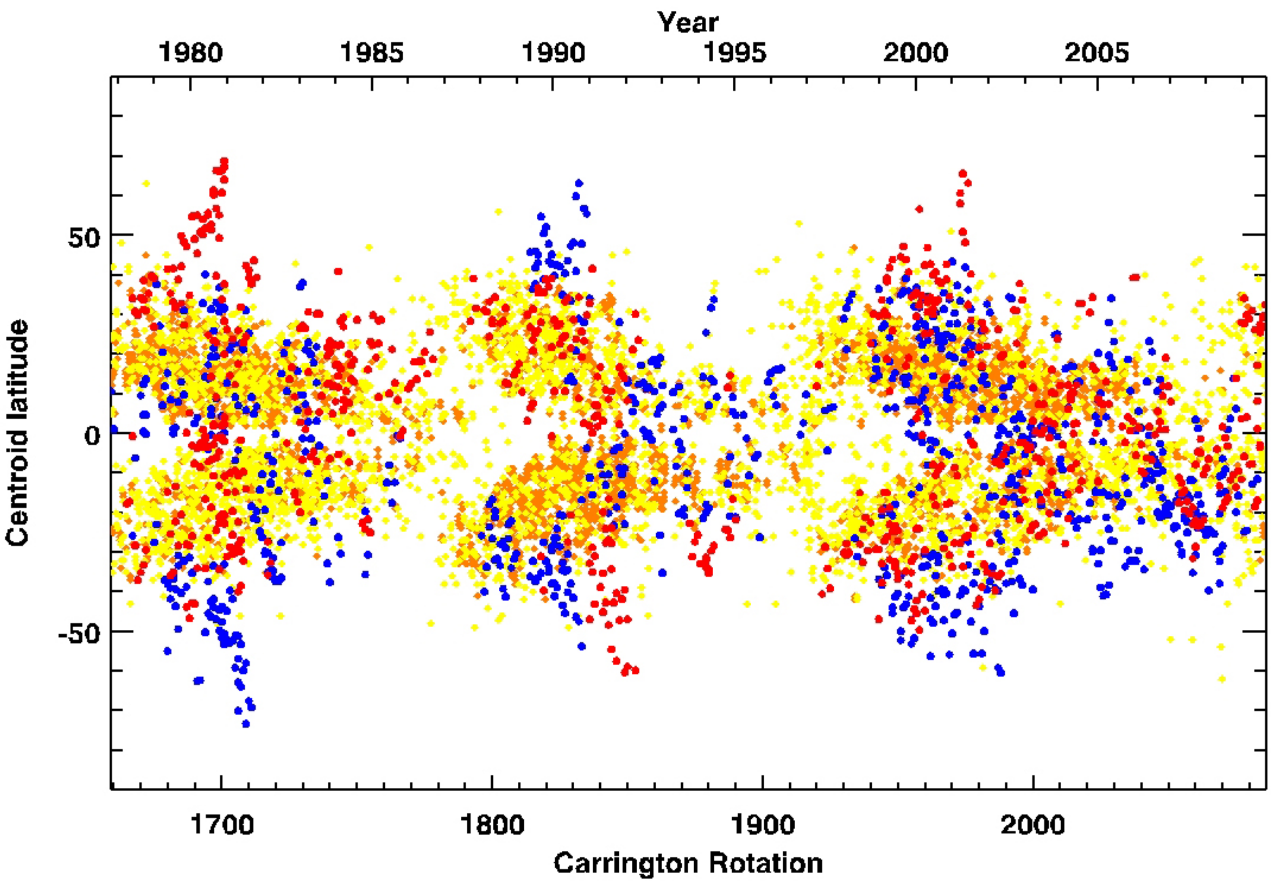
This plot is a subset of Figure2 and shows the centroids of all coronal holes that do not have a polar component and do have a lifetime of more than one rotation plotted by centroid over time. These longer-lived low latitude coronal holes have a pattern reminiscent of the sunspot butterfly diagram.



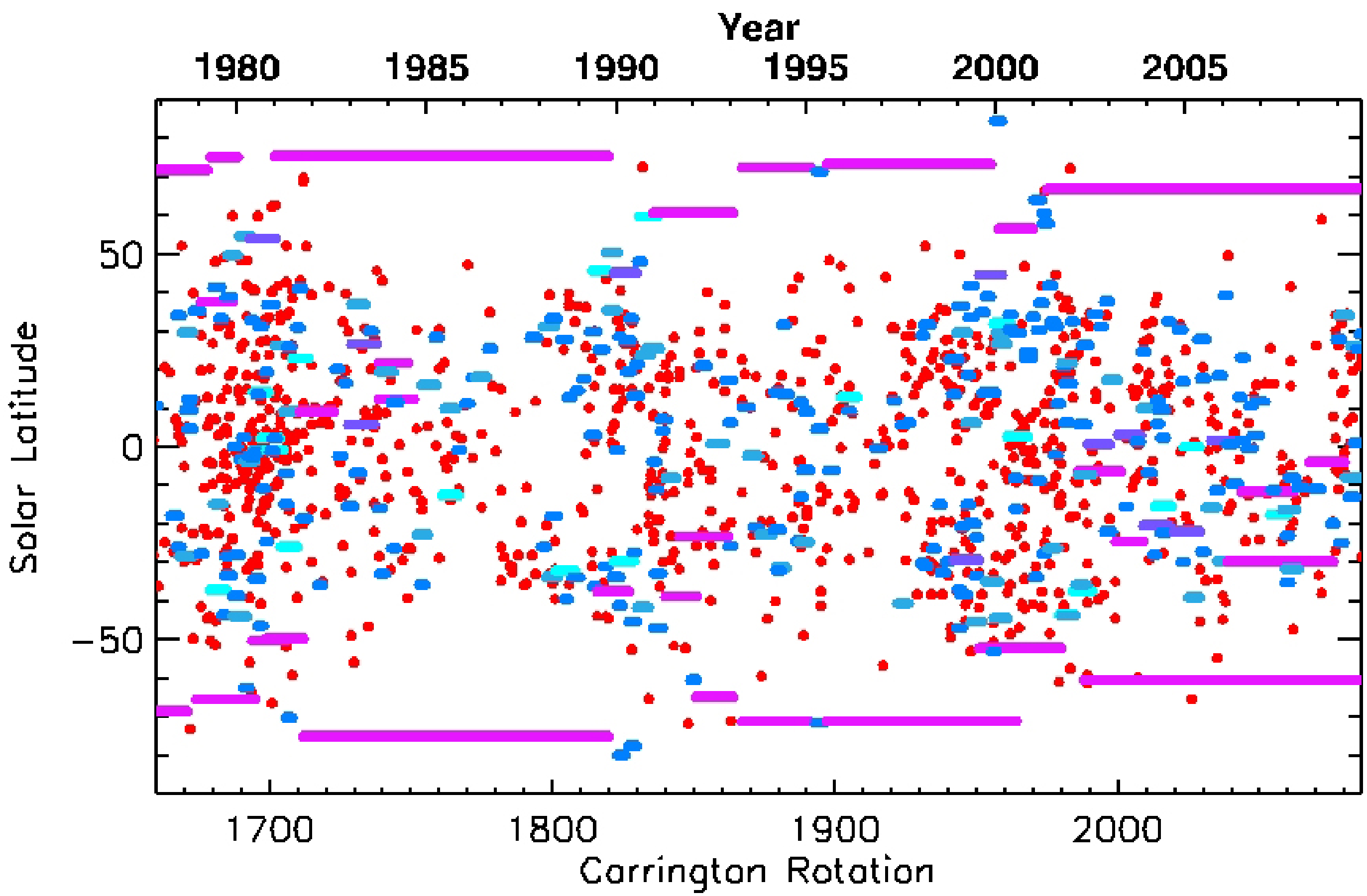
This plot adds to the previous plot. Note the similarity in the butterfly pattern. S. McIntosh et al. (2015, Nature Comm., 6, 6491) have reported a “butterfly structure in temporal evolution of the latitude distribution of coronal hole centroids”, which is apparent below.



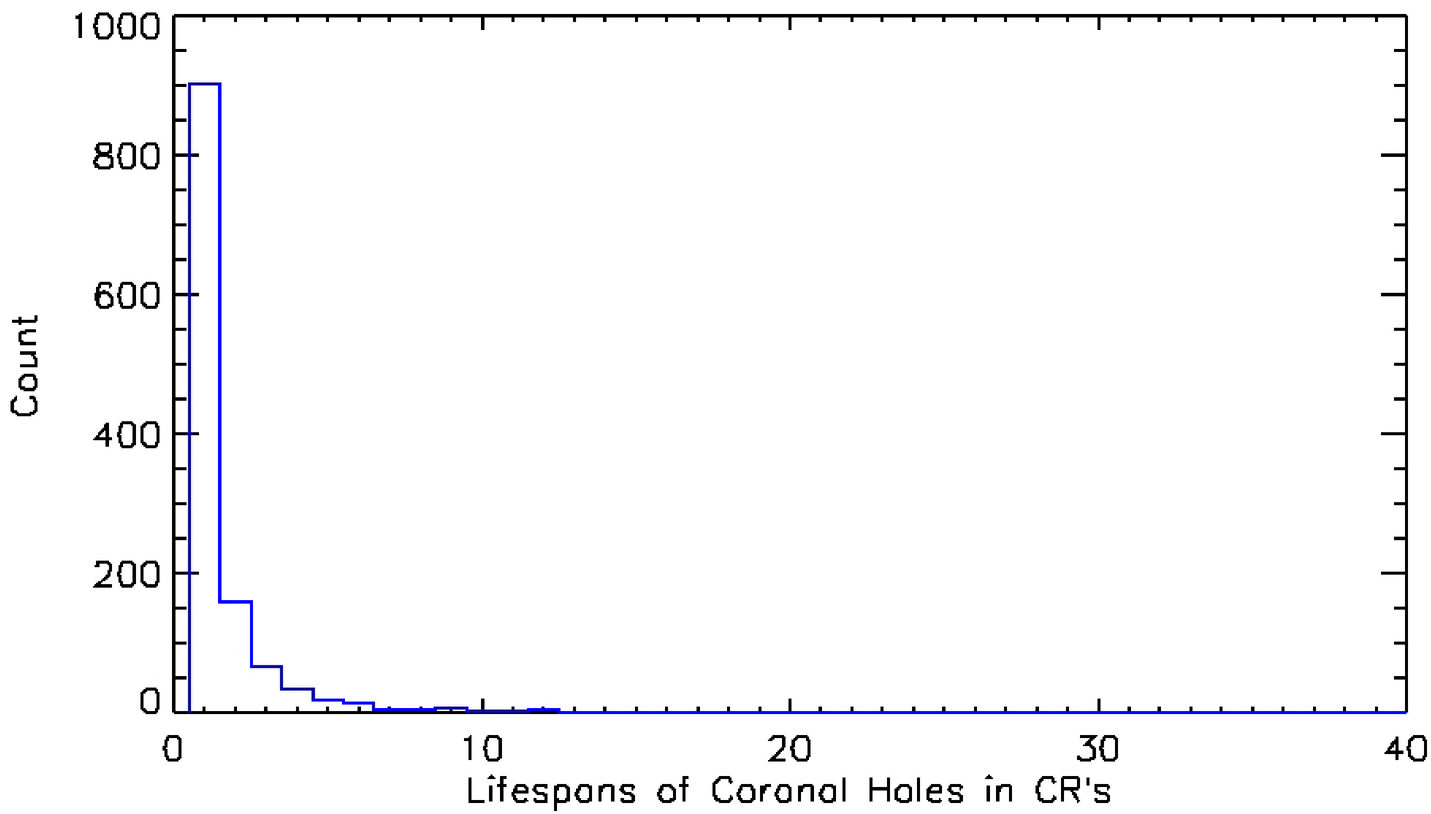
This plot is the same as the previous with the addition of plage centroids. Note that the centroids of the plage regions extend the butterfly to higher latitudes in a somewhat similar manner to the coronal hole centroids.



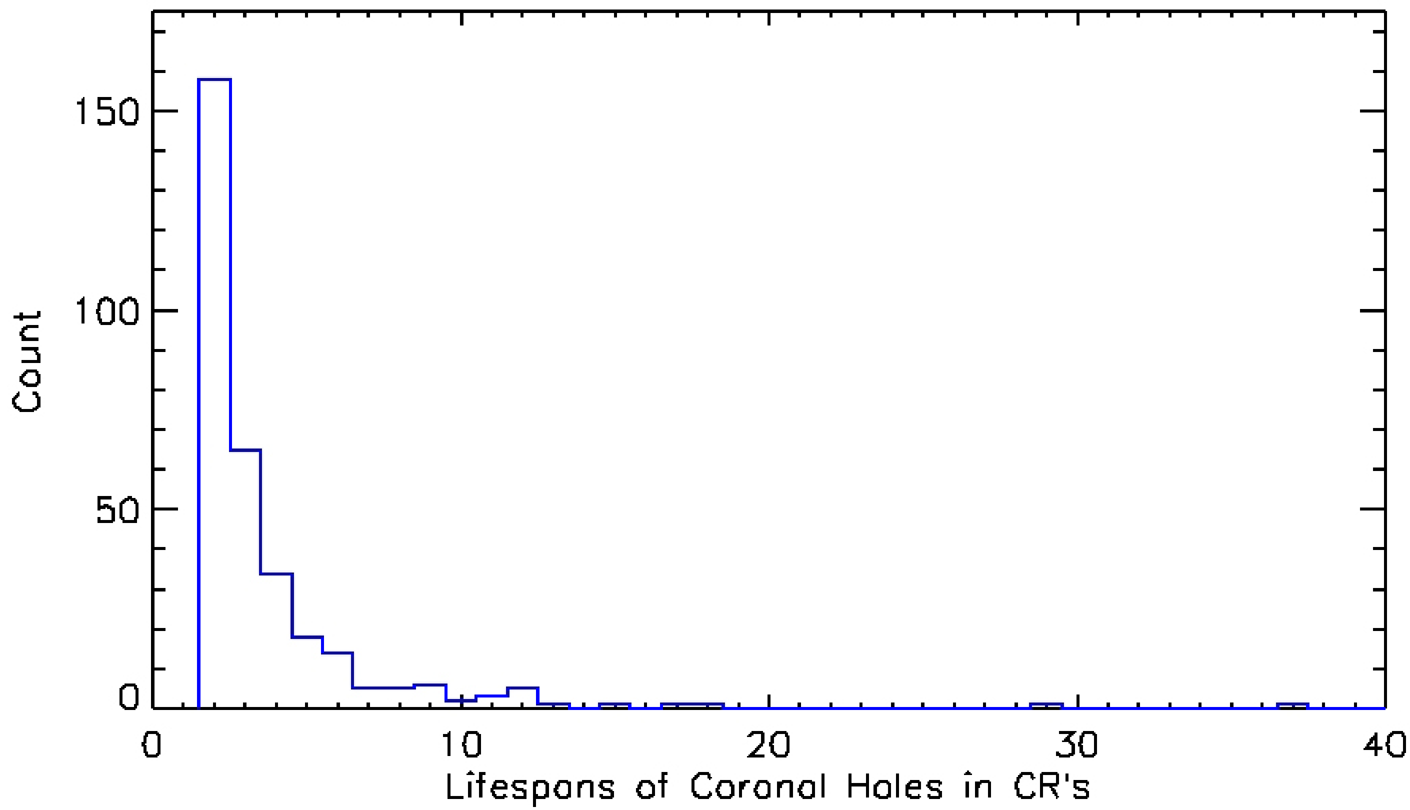
This plot is another way to look at the positions of all coronal holes by heliographic latitude and lifetime. Red represents 1 rotational lifetime, Blue 2 – 3 lifetimes, medium blue 4-5, light blue 6-7, cyan 8-9, purple 10-11, magenta 12+. A similar plot for SC24 was created by Krista et al. (2018, Astron. J., 155, 153, Figure 5b).



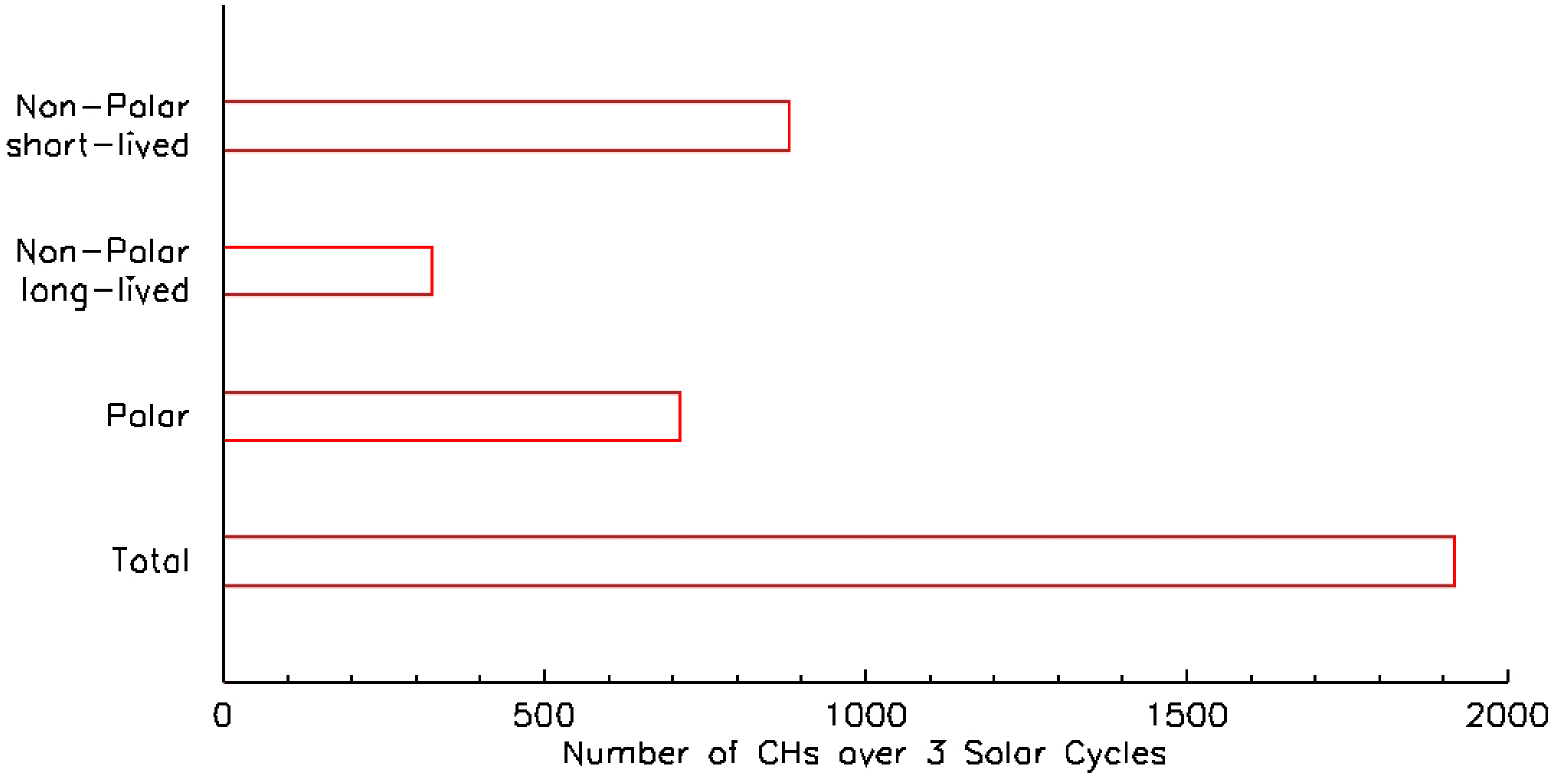
This plot breaks down the number of low-latitude coronal holes that fall into each lifespan category. Not surprisingly, we find that many coronal holes live for a short period while fewer long lifetimes.



This plot is the same as the previous one except that single rotation lifespans are removed. This is done to allow one to see the longer lifespans more clearly. Note that some lasted a very long time while evolving, dividing, reconnecting and moving with the features on the photosphere.



Here, the proportions of the different types of coronal holes are plotted as compared to the total number of all coronal holes for almost 3 solar cycles. Total numbers of low latitude coronal holes that last only one lifetime are plotted against low latitude coronal holes that live longer than one rotation. The polar coronal holes, which tend to last many rotations, are also plotted.



Conclusions

- When we look at all coronal hole centroids plotted over nearly three solar cycles, we see a repetition of two similar eleven-year patterns with alternating polarity that parallel the timing of the sunspot cycle that actually create a 22-year cycle.
- We find that the vast majority of low latitude coronal holes (LLCH) are very short lived lasting less than 28 days. However, some evolve, change and survive for periods of up to two to three years moving along with features below them in the photosphere.
- When we plot only the LLCH's that survive 2 or more Carrington Rotations or more we see a butterfly pattern that is similar to that created by both sunspots and plage regions.
- We intend to conduct a super posed epoch analysis and correlation analysis of sunspot centroids to long lived low latitude coronal holes for a future paper.
- Data available a: https://www2.hao.ucar.edu/mcintosh-archive/four-cycles-solar-synoptic-maps
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