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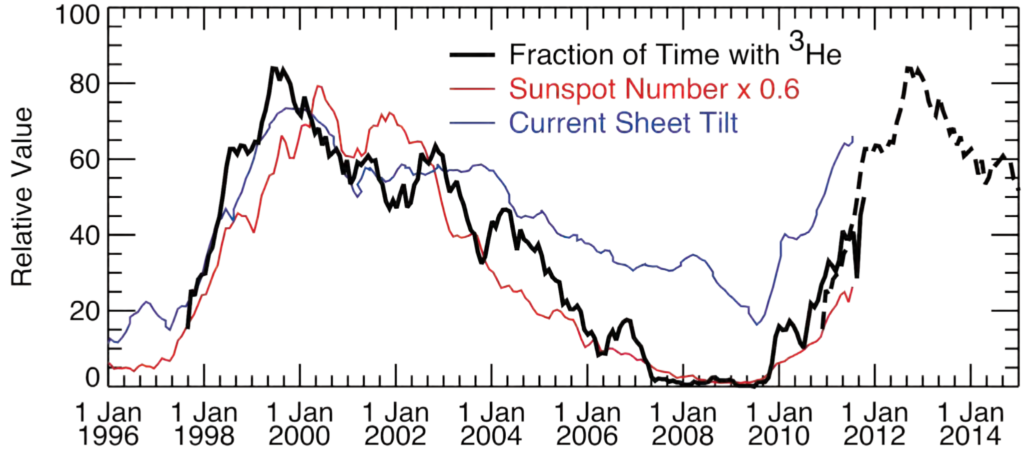
The Return of Energetic ^{3}He in the Inner Heliosphere



Time dependence of the frequency of occurrence of ^{3}He (black), of sunspot number (red), and of heliospheric current sheet tilt (blue, in degrees) over the period 1998—2011. Each curve is smoothed over ~7 solar rotations. The dashed curve shows how the ^{3}He may vary during the next several years if the variation during solar cycle 24 is a copy of that which occurred during cycle 23 but shifted by 13.25 yr.

During the maximum of solar cycle 23 it was found that suprathermal ions in the interplanetary medium provide seed material that can be efficiently accelerated by shocks driven by coronal mass ejections. The contribution of small impulsive solar energetic particle (SEP) events to the suprathermal particle population can be studied using compositional signatures of impulsive SEP events, the most dramatic of which is the large enhancement of the rare helium isotope, ^{3}He, which is sometimes enhanced relative to ^{4}He by as much as 3 or 4 orders of magnitude over the solar wind value of ~$5x10^{-4}$.

Using the ULEIS and SIS instruments on ACE we have been monitoring the fraction of time that ^{3}He from impulsive SEP events is detectable near Earth over the past 14 years. The solid black curve in the figure shows how the occurrence of energetic ^{3}He has varied over this time period. Early in cycle 23 the frequency of occurrence rapidly increased to more 60% and remained at high values until 2003, after which it gradually decreased to values of no more than a few percent during the cycle 23/24 minimum. Since early 2010 ^{3}He has again shown a rapid increase during the onset of solar activity, suggesting that the asymmetric shape of the curve observed during 1998—2008 may be a characteristic feature of the ^{3}He time dependence. Since energetic ^{3}He is produced in association with reconnection activity in active regions, it is reasonable to ask whether the ^{3}He time dependence is simply tracking the sunspot number (SSN), which should also be approximately proportional to the rate of solar flares. The red curve shows the SSN time dependence over the duration of our study. Although the SSN rose faster than it declined during cycle 23, the asymmetry was less dramatic than observed for the ^{3}He. The asymmetry of the ^{3}He time dependence may provide a clue to the origin of the ^{3}He observed in the ecliptic plane near 1 AU. Other solar parameters that are known to change rapidly early in a solar maximum and then return more slowly to their solar-minimum values include the tilt of the heliospheric current sheet (blue curve) and the heliographic latitudes at which large active regions appear, as seen in solar "butterfly diagrams" (e.g., solarscience.msfc.nasa.gov/SunspotCycle.shtml). Although the current sheet tilt and the ^{3}He closely tracked one another from 1998 through 2002, the current sheet remained above ~20° for much of solar minimum and started increasing almost a year before the reappearance of the ^{3}He. Thus the close correlation early in cycle 23 is probably not indicating a causal connection between the two quantities.

Based on the similar time dependences of the ^{3}He occurrence frequency during the early parts of cycles 23 and 24, the dashed curve shows how one would expect the ^{3}He to vary over the next several years assuming that the ^{3}He during the current cycle simply tracks that observed in the pervious cycle with a shift of 13.25 years.

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