The Livingston & Penn Observations and Speculations

Leif Svalgaard
Stanford University
ISSI 233, May 2012
What is Livingston Measuring?

Since 2000 Livingston and Penn have measured field strength and brightness at the darkest position in umbrae of 2943 spots using the Zeeman splitting of the Fe 1564.8 nm line. Most observations are made in the morning [7h MST] when seeing is best. Livingston measures the absolute, true, field strength averaged over his [small: 2.5"x2.5"] spectrograph aperture, and not the Line-of-Sight [LOS] flux density.
Bill Livingston at Work
(Simultaneous) Drawings of Sunspot Group at Different Observatories

Livingston makes a ‘finding chart’ of the spots he observes directly from the projected image.
Using the Finding Chart we can identify the spots on HMI (and other) magnetograms.
In spite of large scatter the magnetic field has decreased 500 G since 2001.

Livingston also measures the intensity of the umbra compared to the continuum and finds that [in the infrared] that for all spots he can see [i.e. intensity < 1] the field is greater than ~1450 G. Another 500 G to go...

Hence his statement that if [when?] the decline of the field continues, spots will effectively 'disappear' or at least be much less visible.
Magnetic Field in Umbrae over Time

![Graph showing Umbral Magnetic Field over time with Gauss scale on the y-axis and Year on the x-axis. The graph includes various data points and a legend indicating "B Gauss".](image)
Umbral Magnetic Field

B
Gauss

Year

Umbral Magnetic Field

B Gauss

Year
Umbral Magnetic Field

$B$ (Gauss)

Year
The Distribution of Field Strengths has Shifted with Time

Is this just a sunspot cycle dependence?
Using automatic detection of sunspots

But still some teething problems

Their STARA algorithm does not seem to perform very well for small spots so the data in 1996-1997 and 2008-2010 is suspect.

So, unfortunately, it is hard to draw any firm conclusion one way or the other. The next year or two will be crucial.
Extrapolating the behavior from the past 13 years into the next 13 years suggests the Sun may enter a new Grand Minimum.

If true, we shall learn a lot about ‘The Forgotten Sun’ that nobody alive today has ever seen, with obvious implications for the climate debate and environmental issues generally.

Are there other indications that this might happen?
Other indications of fewer spots

Since ~1996 there have been fewer visible sunspots for a given F10.7 flux.
Since the Sunspot Number is dominated by the number of small spots, the loss of visibility of small spots might be a natural explanation.

Was the Maunder Minimum just an example of an extreme L&P effect?

Is this happening again?
Similar effect seen in SSN compared to sunspot areas
Our ‘Understanding’ of the Extended Solar Cycle ??

Diagram notes:

- handle to the problem
- luminosity variations
- magnetic braking
- Which is the seat of the dynamo?
- \( \alpha \omega \) dynamo
- polar vortex
- (\( \# \)) weak link of the theory
- differential rotation
- down drafts
- thermal shadow
- active nest
- \( \alpha^2 \) dynamo
- topological

[Diagram with various labeled parts and questions related to solar cycle understanding.]
And We Have to Leave it at That, because there are More Questions than Answers (what a Wonderful Time)