Sunspots and the Scientific Method: Models

"It's black, and it looks like a hole.
I'd say it's a black hole."

Hypothesis Driven Science

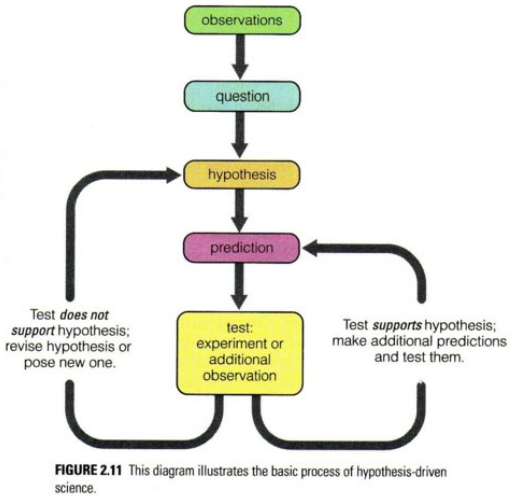


FIGURE 2.11 This diagram illustrates the basic process of hypothesis-driven science.

Hypothesis:

An educated speculation about how a particular phenomenon behaves- very narrow in scope.

Model:

A broad bush visualization attempting to make sense of a limited range of phenomena.

Theory:

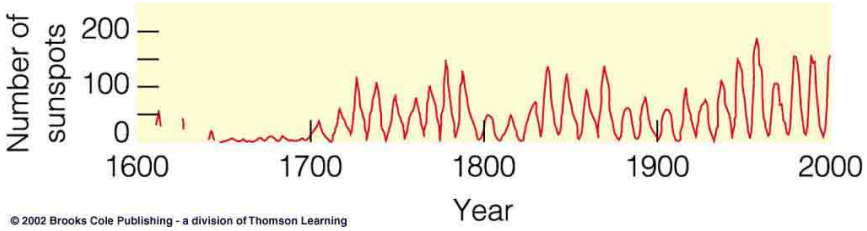
The construction of a cohesive set of mathematically based principles describing how a wide range of phenomenon behave.

Laws:

The mathematical formulae of a theory that have never been found to be wrong- they have survived testing trial after trial.

The Sunspot Cycle

The number of sunspots at any given time varies and has a repeatable time period of 11 years from peak to peak.



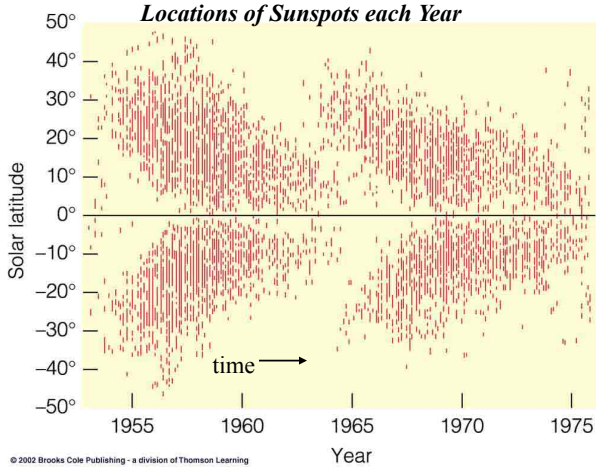
At Sunspot Maximum there are roughly 100 sunspots.

At Sunspot Minimum there are a few at any given time.

We are right smack in the middle of a Sunspot Maximum!

Maunder Butterfly Diagram

Sunspots cycles begin at middle latitudes (~40 degrees)
at Sunspot Maximum are at lower latitudes (between 10-40 degrees)
at Sunspot Minimum are at lowest latitudes (~5 degrees)

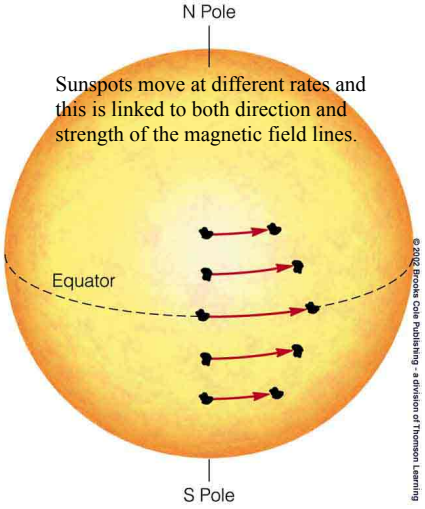


How this chart is made:

As sunspots appear and disappear throughout a given year, measure their latitudes. Then plot each sunspots latitude on the chart.

Next year do the same, and so on for decades.

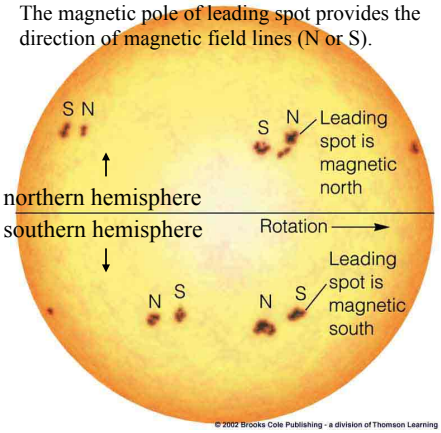
Differential Rotation



Rotation is faster at the equator (25 days) and slower at mid-latitudes (28 days).

Polarity and Hemisphere

Sunspot pairs align parallel to rotation direction. The magnetic pole of leading spot provides the direction of magnetic field lines (N or S).



Note that the direction is opposite in northern and southern hemispheres

The polarity of the sunspot pairs reverses every cycle (11 years)!

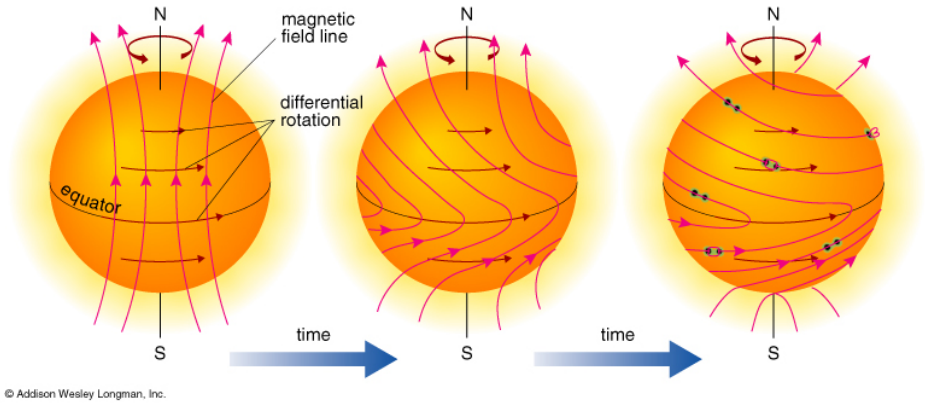
Making a Model of the Sunspot Cycle

A scientific model must (1) begin with observational facts, (2) obey known laws of physics, (3) explain the observational facts, (4) make predictions (happens naturally).

Let's review the observational facts of sunspots:

1. Sunspots are regions of strong magnetic fields (Zeeman splitting).
2. The number of sunspots come in 11 year cycles.
3. Sunspots first occur at higher latitudes and later times at the solar equator (Maunder Butterfly).
4. The sun rotates differentially (faster at solar equator).
5. The polarity of the sunspot pairs is parallel to the direction of rotation. This polarity is opposite about the solar equator.
6. This polarity reverses every cycle.

The Babcock Model



a) Consider the start of a cycle. The magnetic field lines are in an unperturbed configuration.

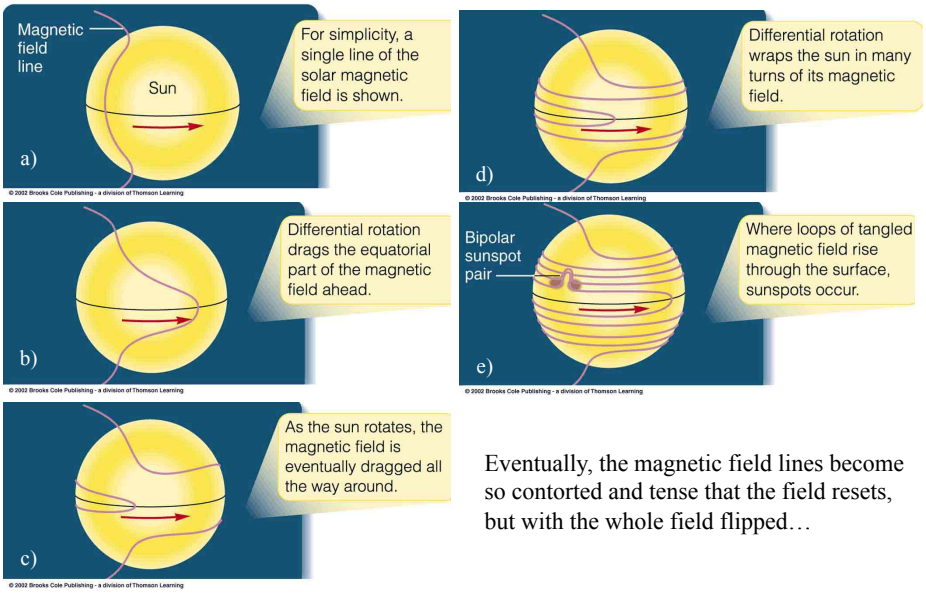
b) The polarity is north pole to the North (N) and south pole to the South (S).

c) As time marches on, the differential rotation begins to wind the magnetic field lines. This is because the ionized gas and the field lines are locked together.

d) Sunspot activity begins and increases because winding of fields creates a localized "tensions" that results in small loops. In these loops material is "locked in" and cools.

The Babcock Model

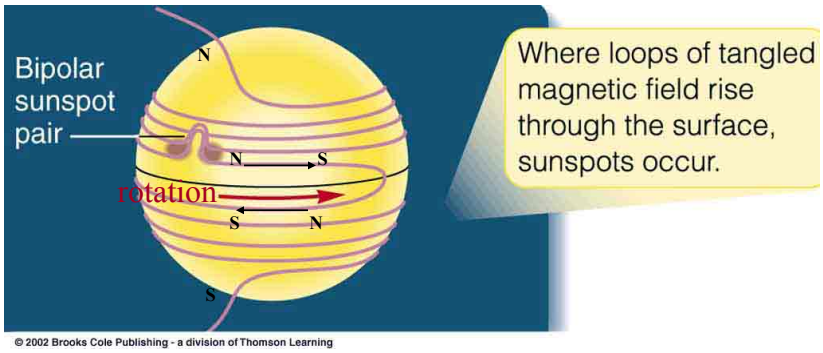
The Solar Magnetic Cycle



Eventually, the magnetic field lines become so contorted and tense that the field resets, but with the whole field flipped…

Explains Sunspot Pair Polarity being Opposite Above and Below the Solar Equator

Because the field line is bent about the solar equator its direction appears to reverse, as shown with the black arrows below.



This model accounts for all of the observational facts, but can not explain why it takes 11 years for the cycle.