

Space Climate

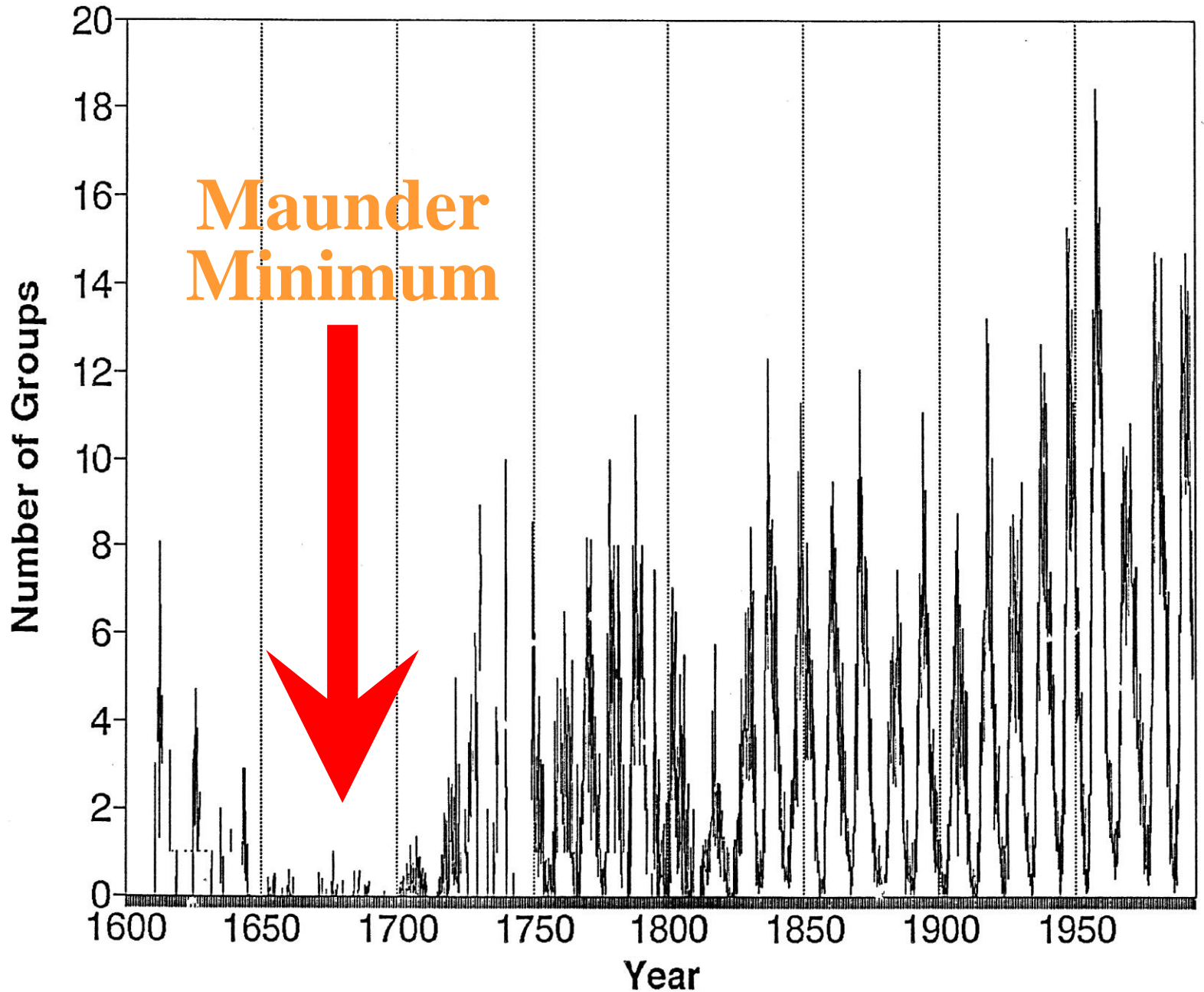
Direct and Indirect Observations of Long-Term Solar Activity
20-23 June 2004, Oulu, Finland

Maunder Minimum in Context of Solar Dynamo Theory

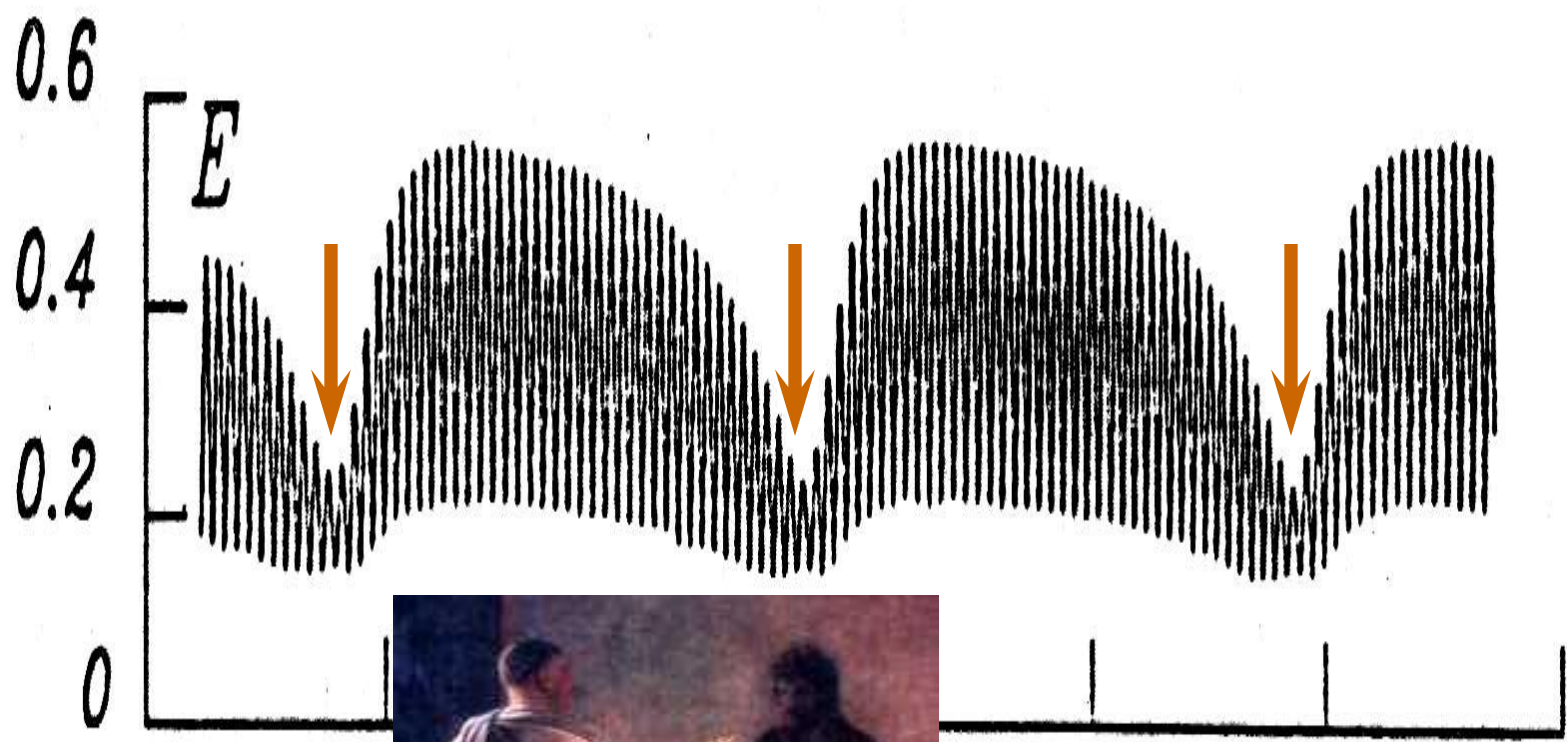


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Moscow State University
Moscow, Russia

Monthly Mean Number of Sunspot Groups



Great Minima in numerical simulations



Arrows = Great Minima
↓

What is truth?

Axel Brandenburg

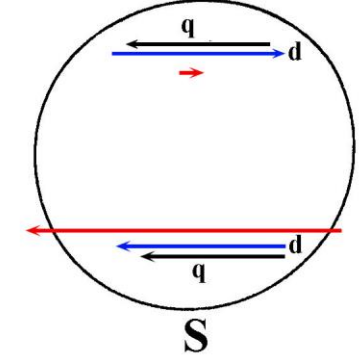
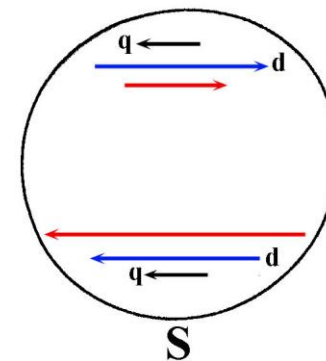
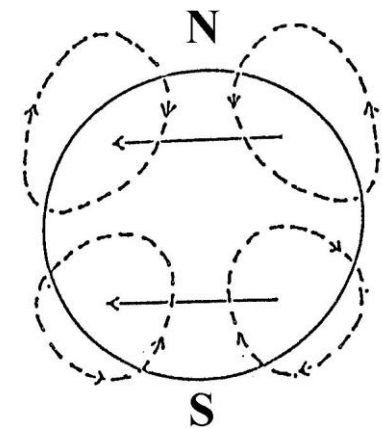
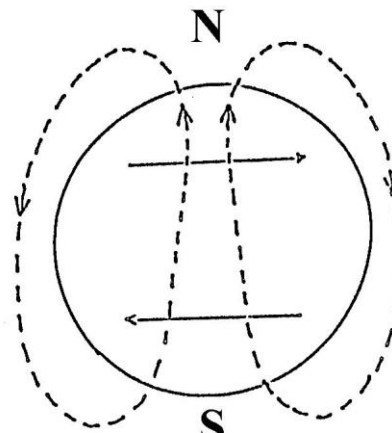
PARKER DYNAMO

$$\mathbf{B}_P \xrightarrow{\Omega} \mathbf{B}_T$$

Differential rotation

$$\mathbf{B}_T \xrightarrow{\alpha} \mathbf{B}_P$$

Helicity



WKB APPROACH

$$\begin{pmatrix} B_P \\ B_T \end{pmatrix} = \begin{pmatrix} \mu \\ \nu \end{pmatrix} e^{D^{2/3}\gamma t + iD^{1/3}S}$$

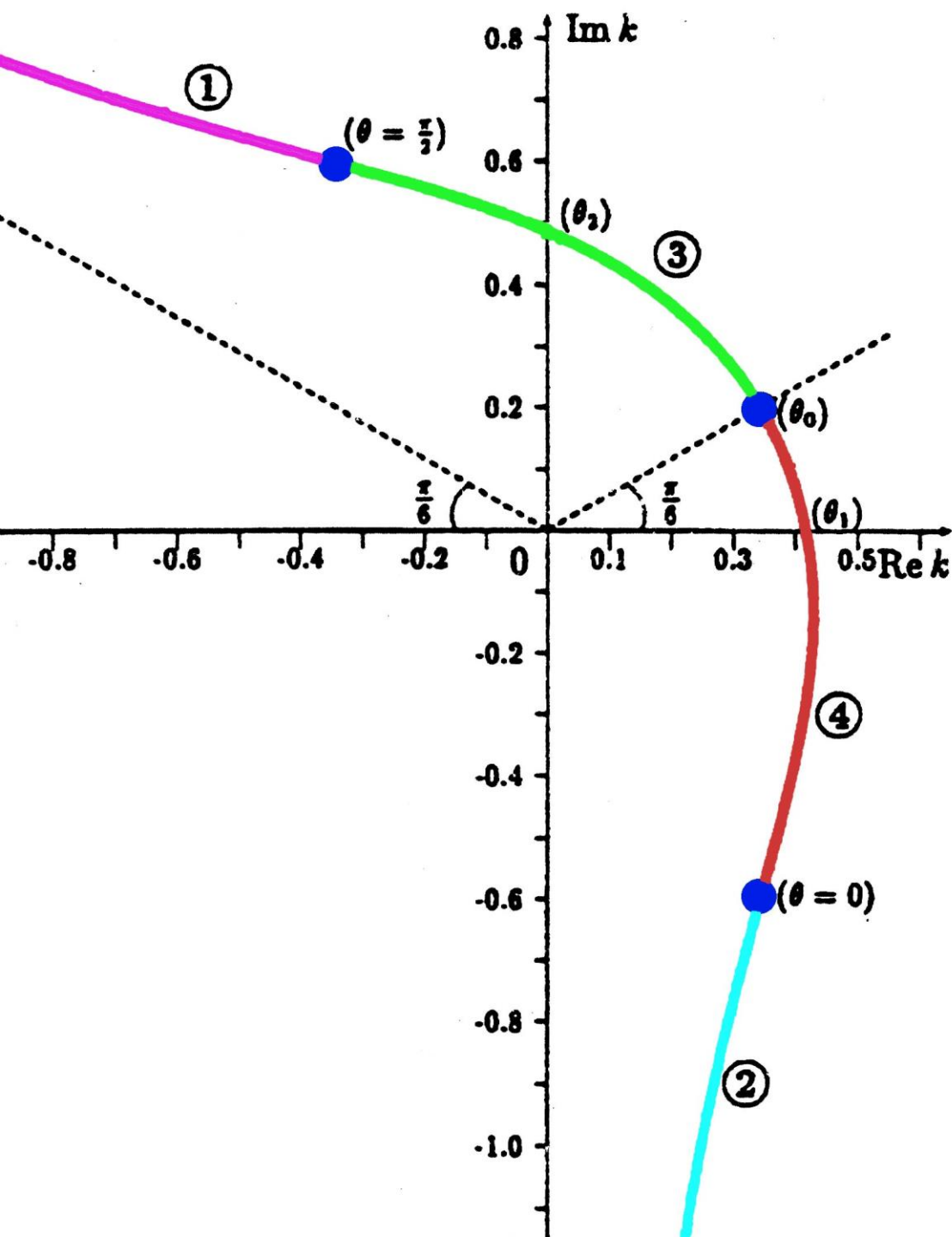
$$|D| \gg 1; k = \nabla S$$

D - Dynamo number

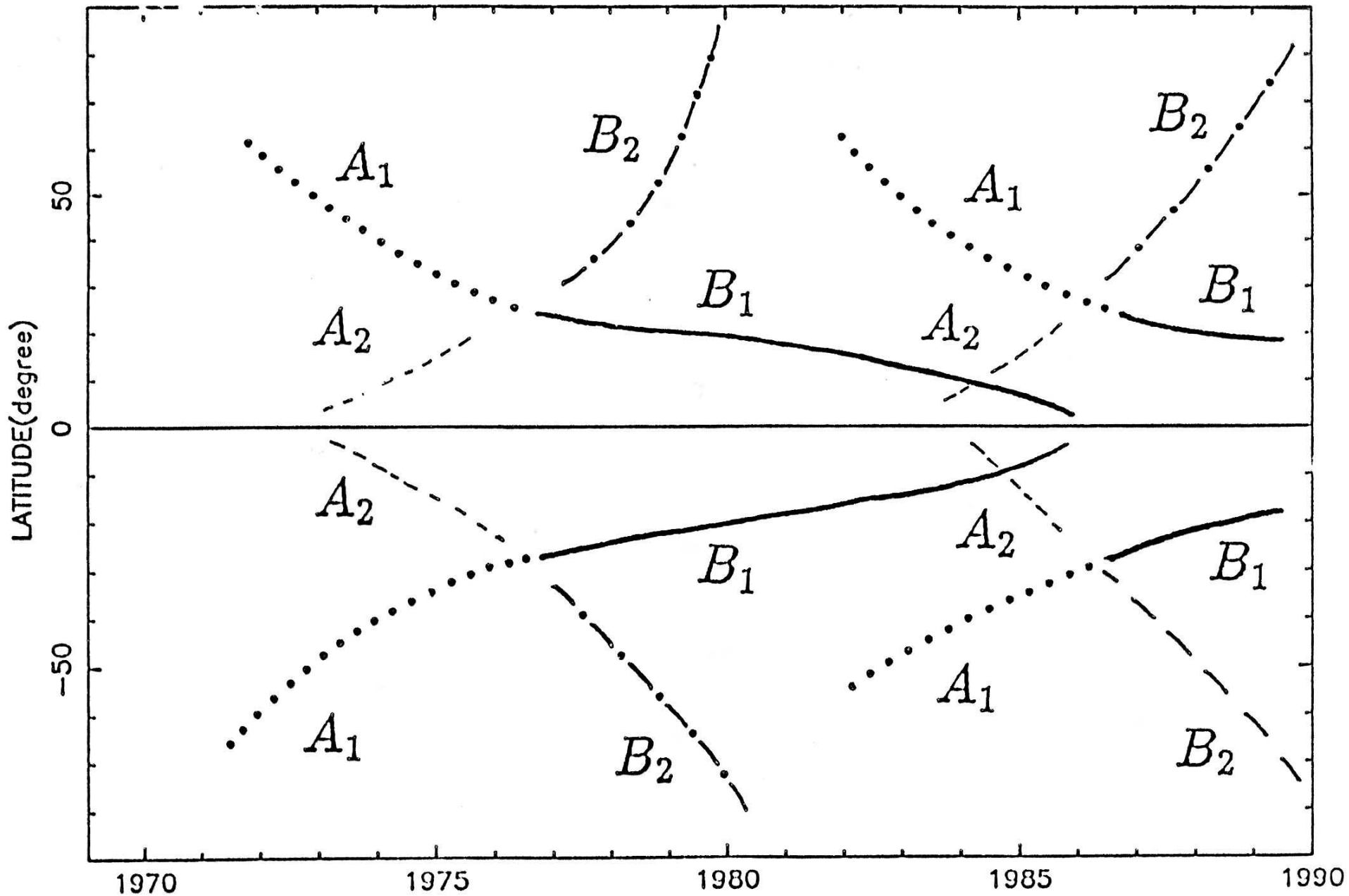
$$\mathbf{P}_4(\mathbf{k}) = 0$$

**Hamilton-Jacobi
equation**

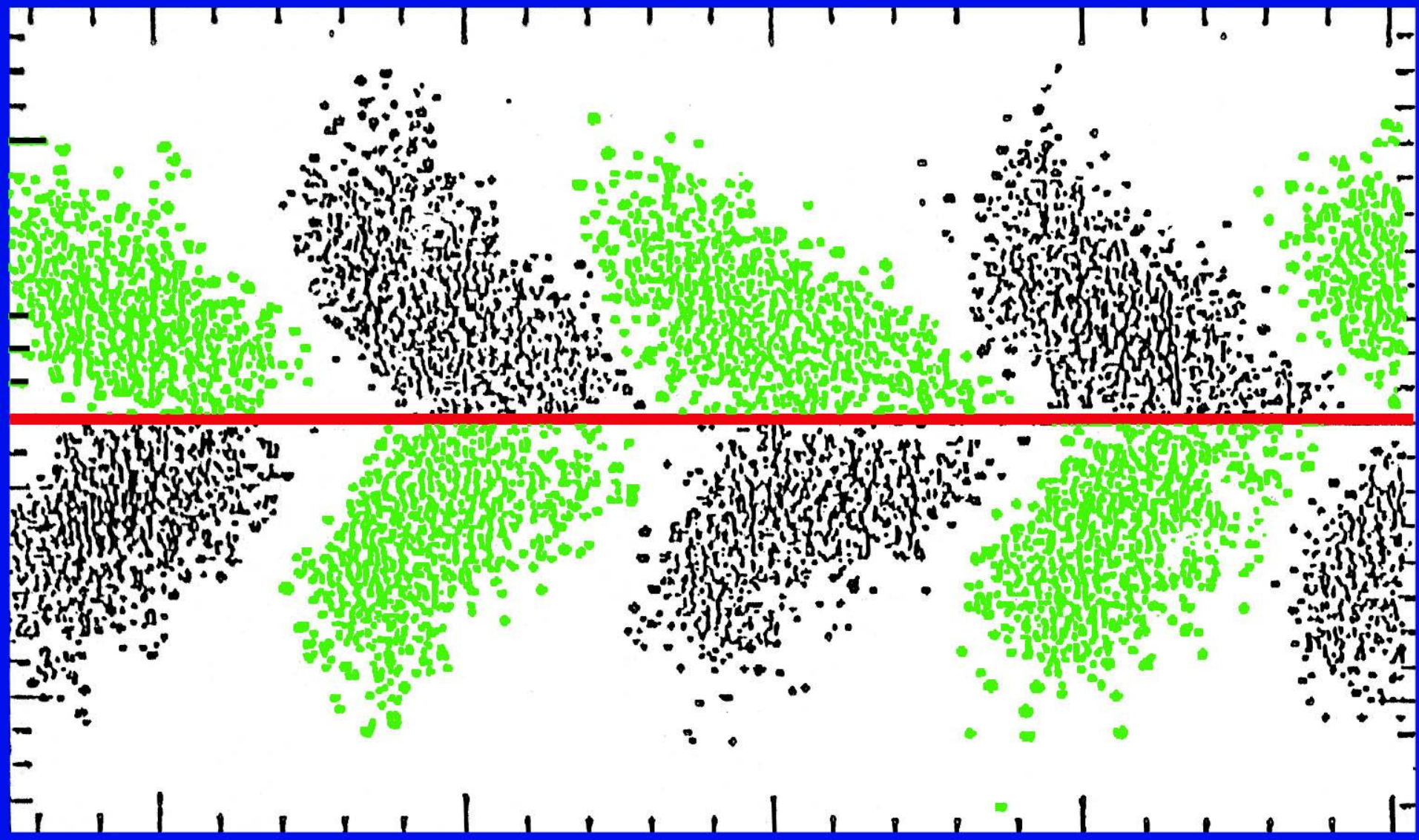
Solution of the Hamilton-Jacobi equation



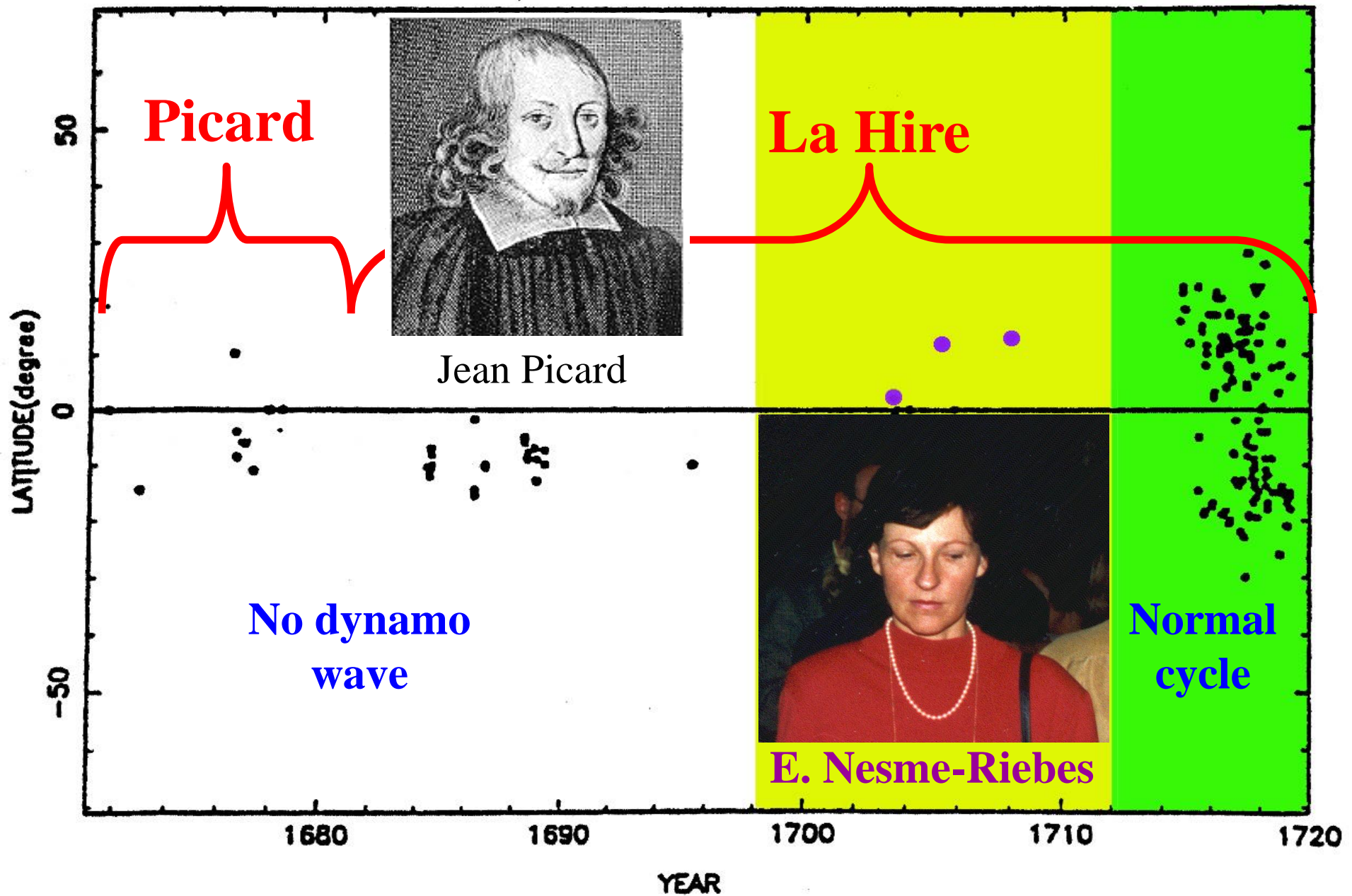
Butterfly diagrams of dynamo waves



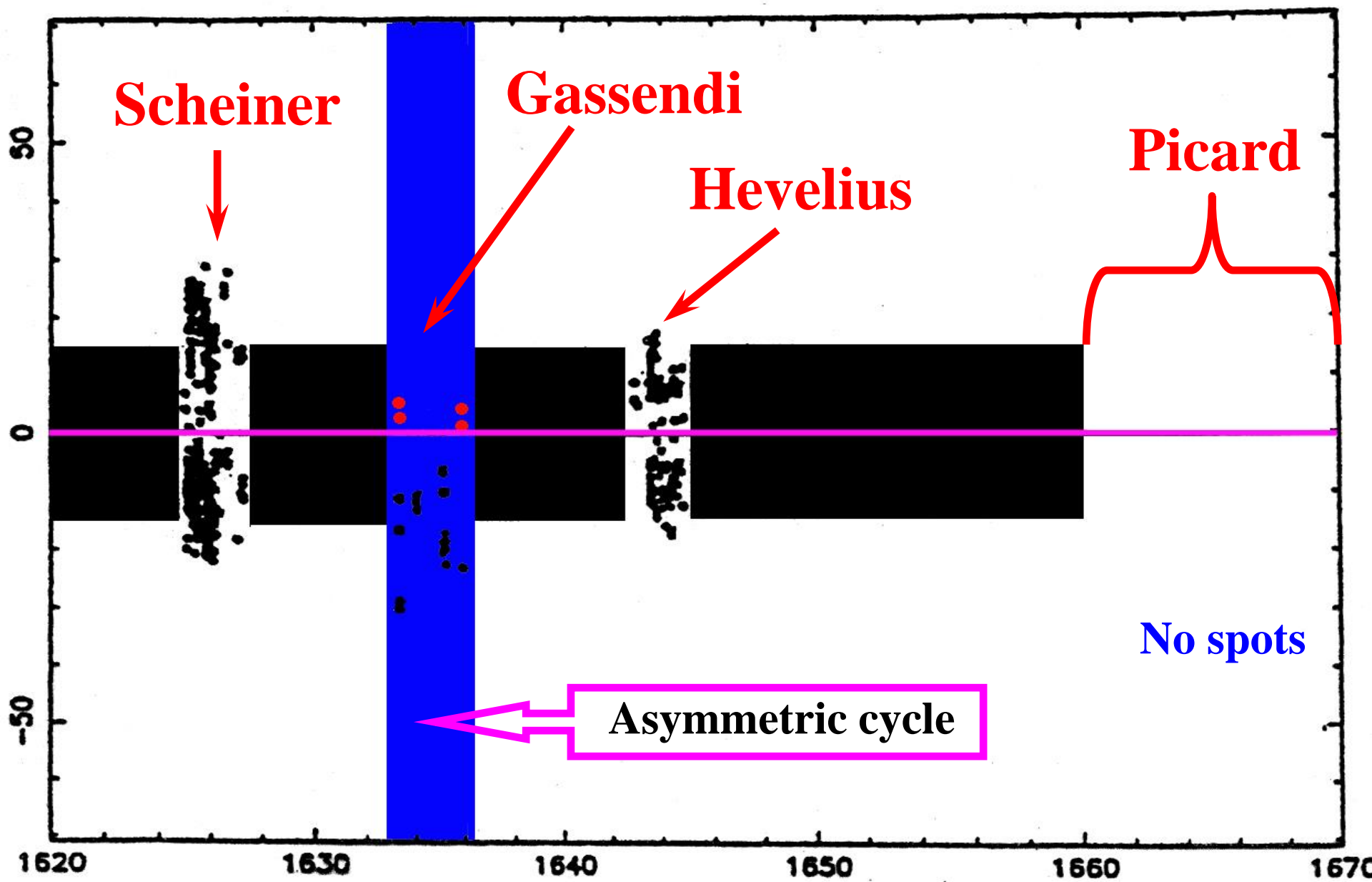
Butterfly diagram for normal cycle

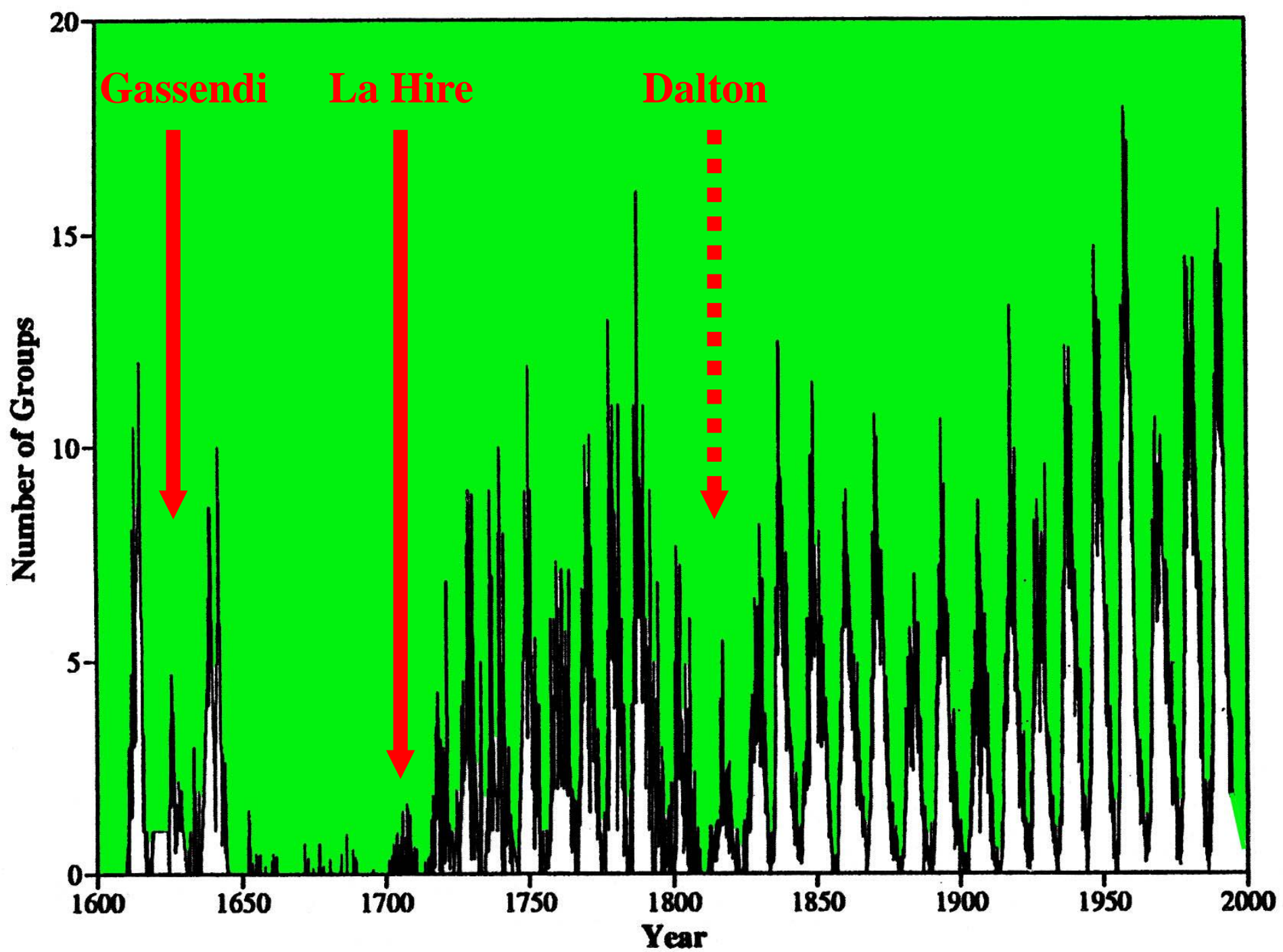


Butterfly diagram at the end of the Maunder minimum

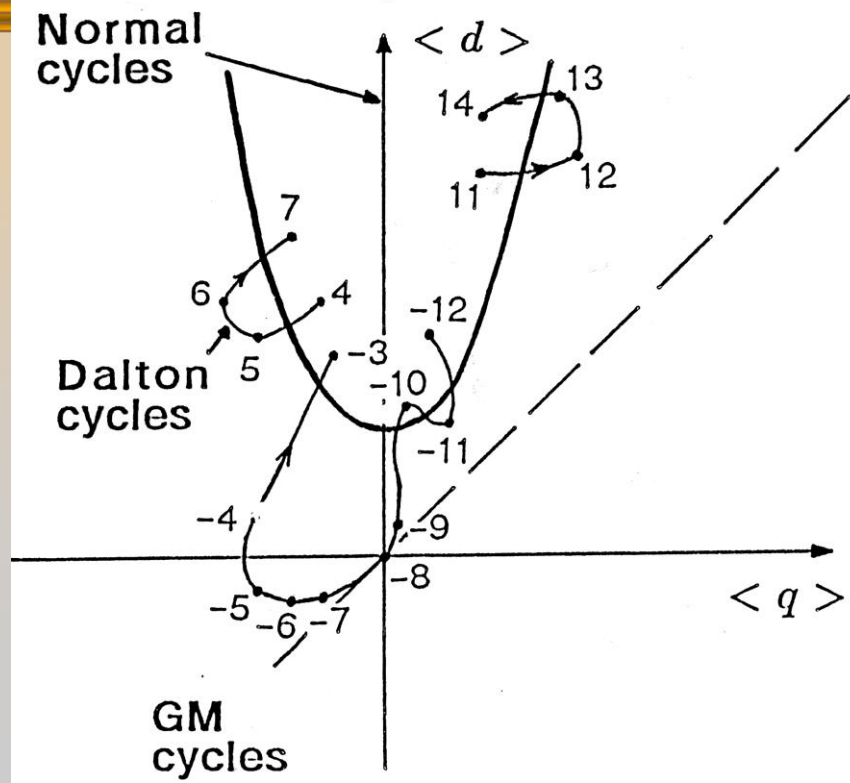
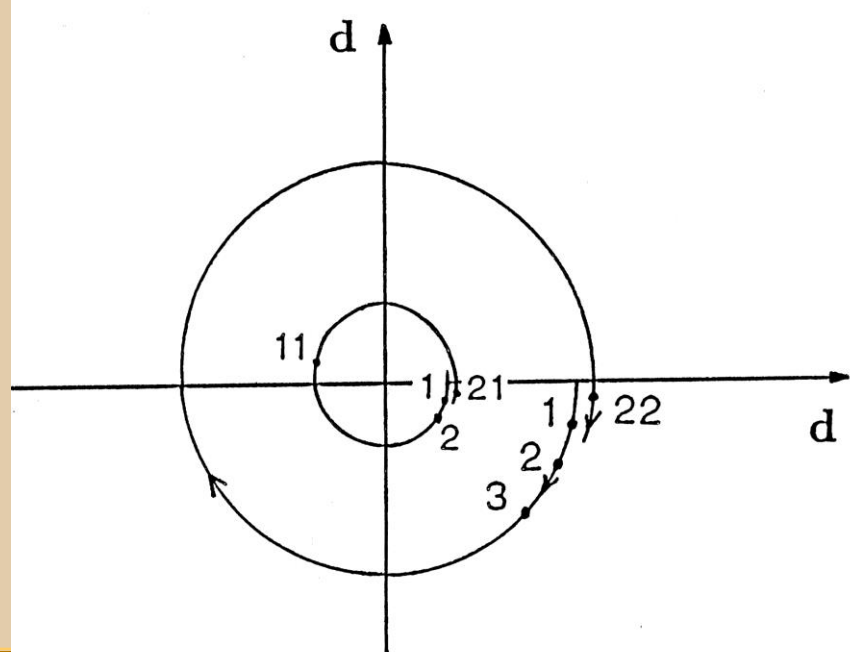


Beginning of the Maunder minimum

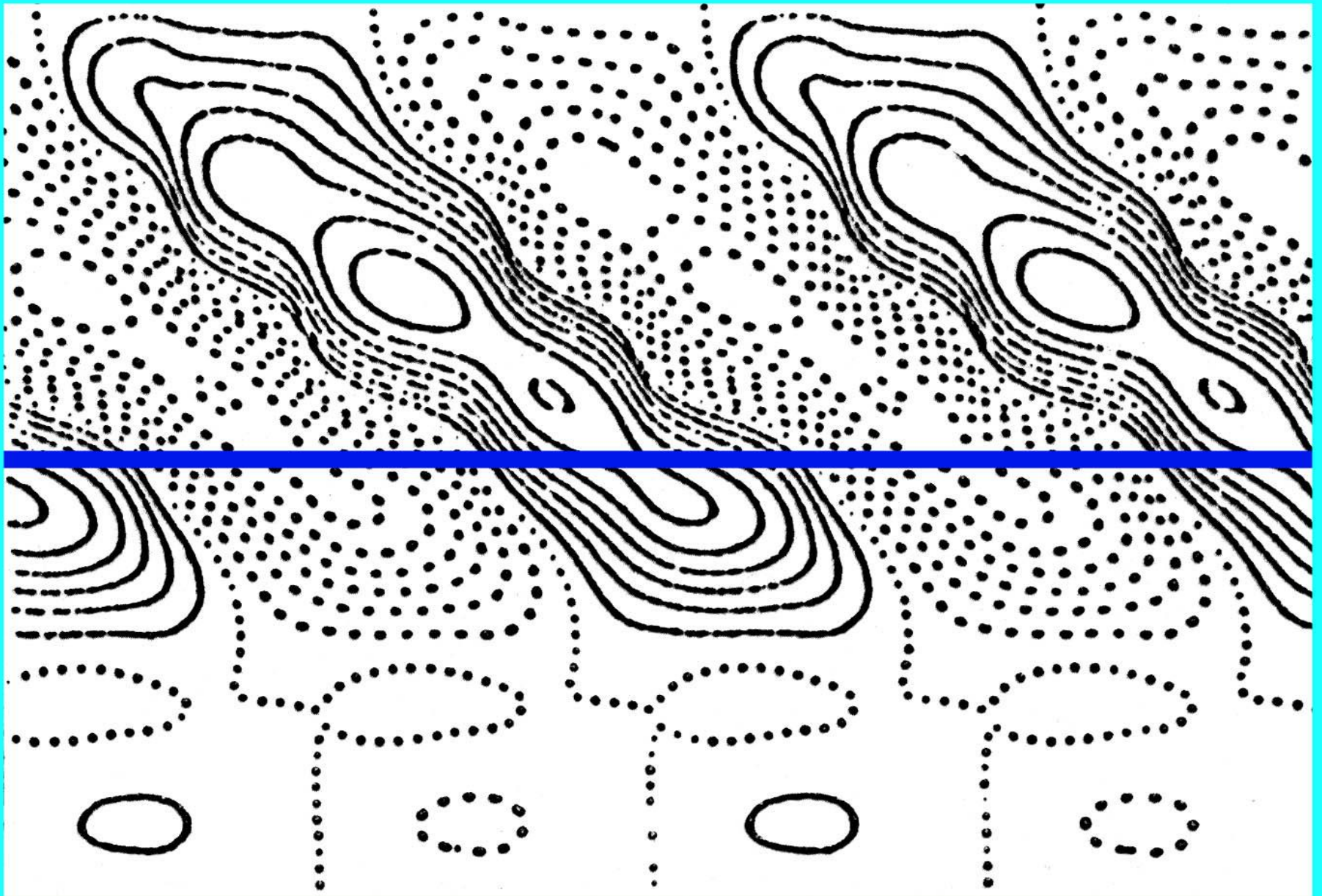




Symmetry of Great minima



R. Jennings & N. Weiss. Asymmetric cycles



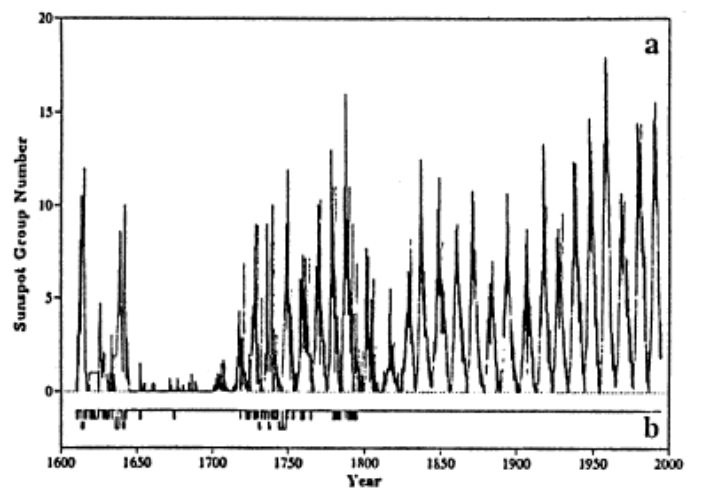
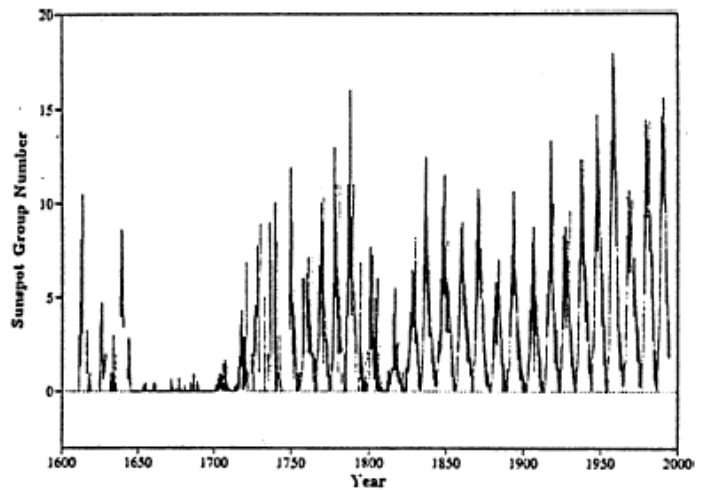


Fig. 2. Monthly mean number of sunspot groups (1610 - 1994).



Wavelet transform for solar activity 1610-1994.

Morlet wavelet: Module

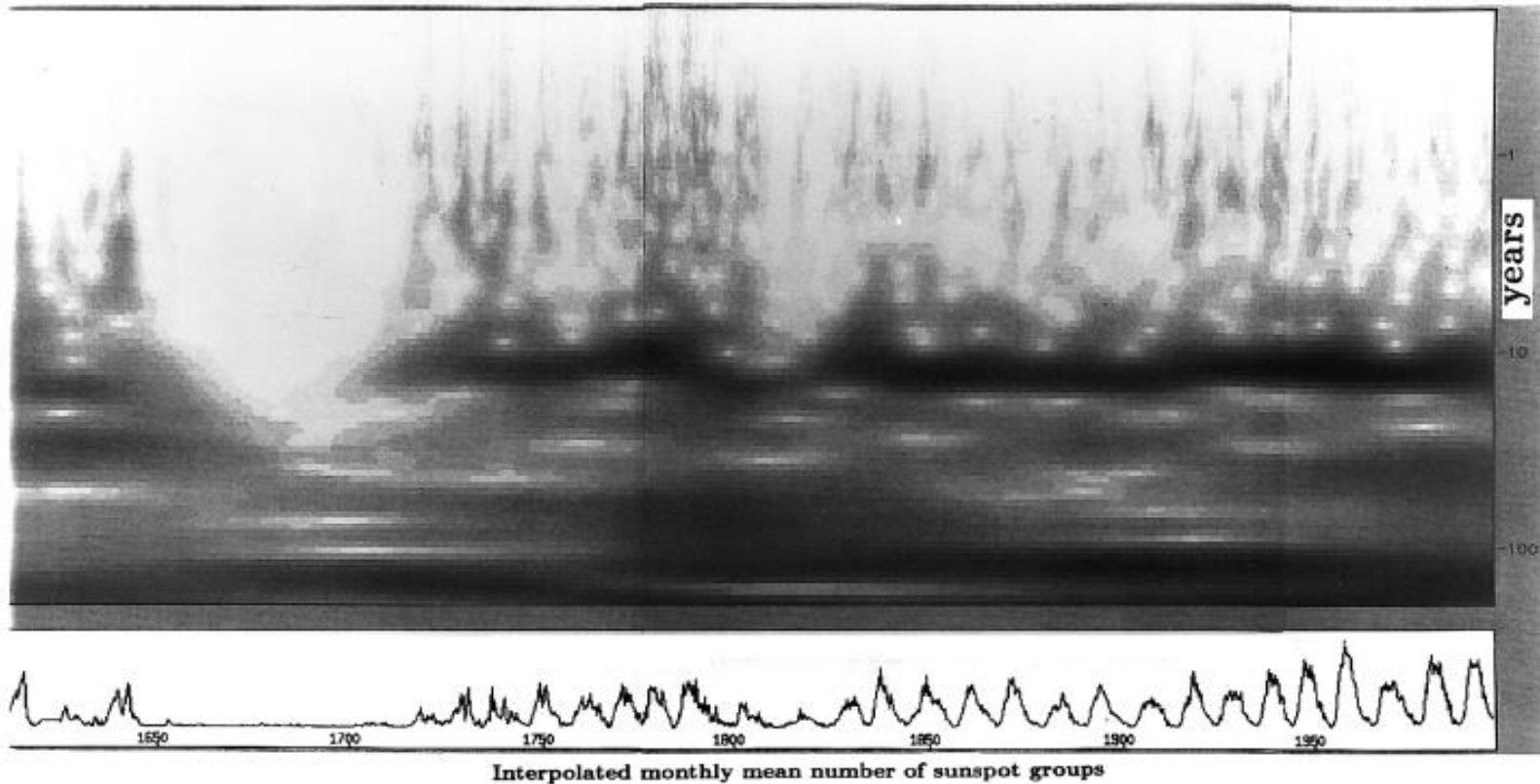
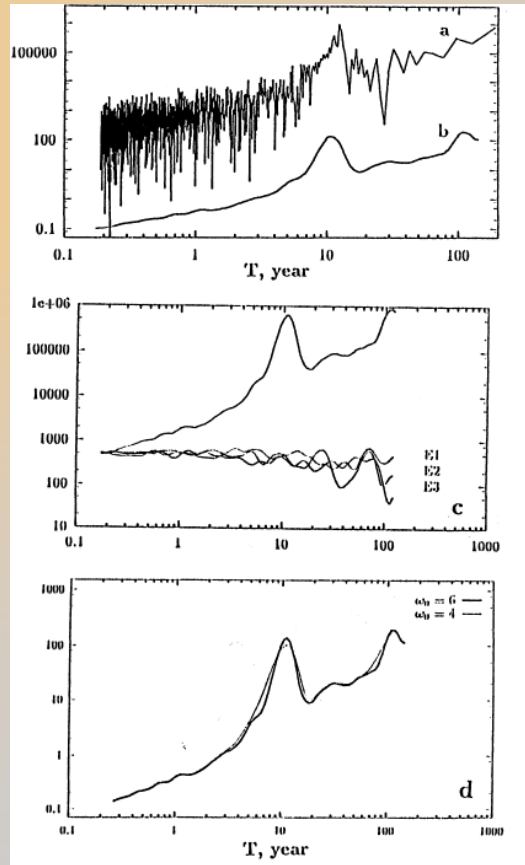
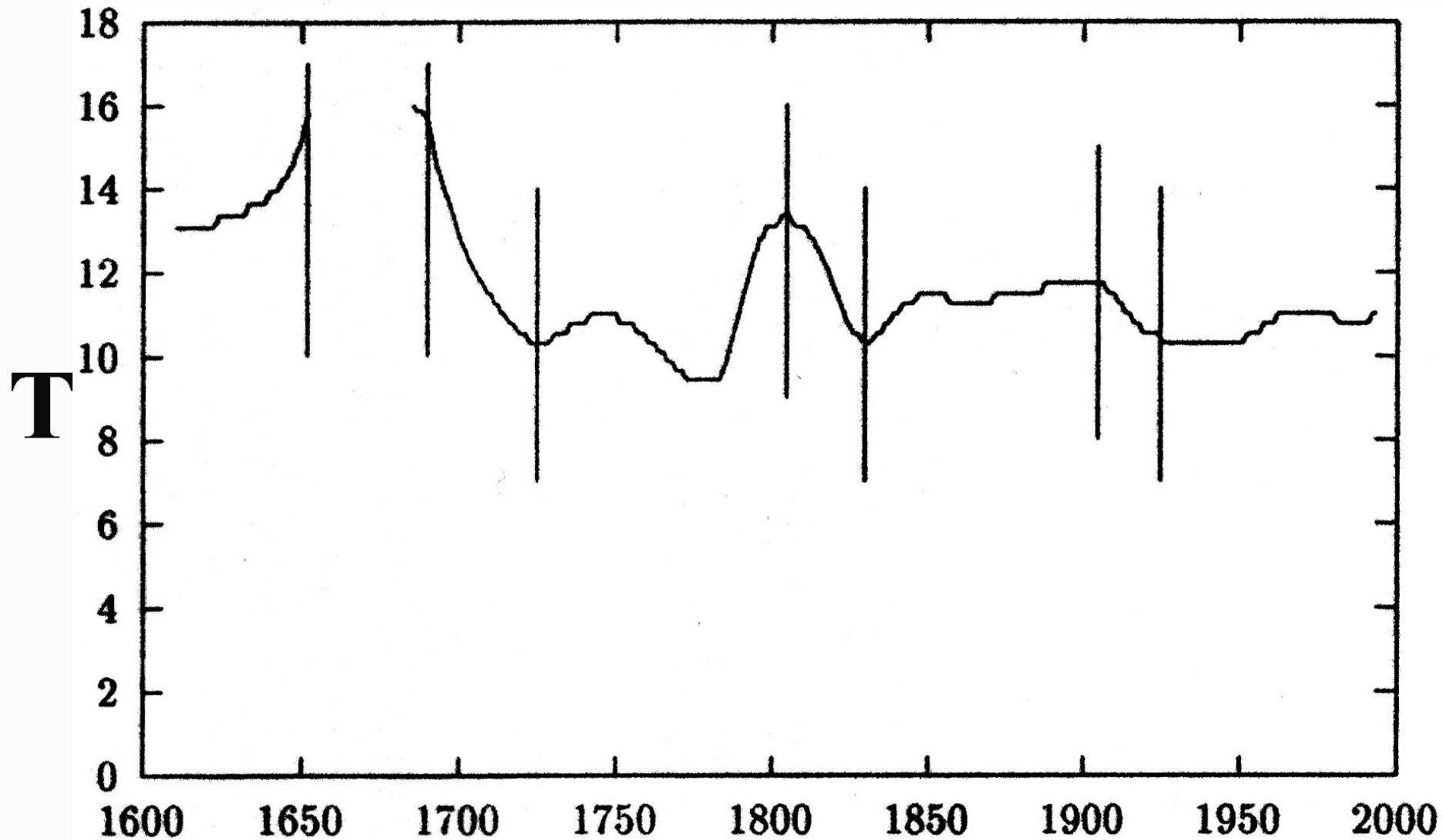


Fig. 4. Wavelet transform for solar activity 1610 – 1994; Morlet wavelet modulus.

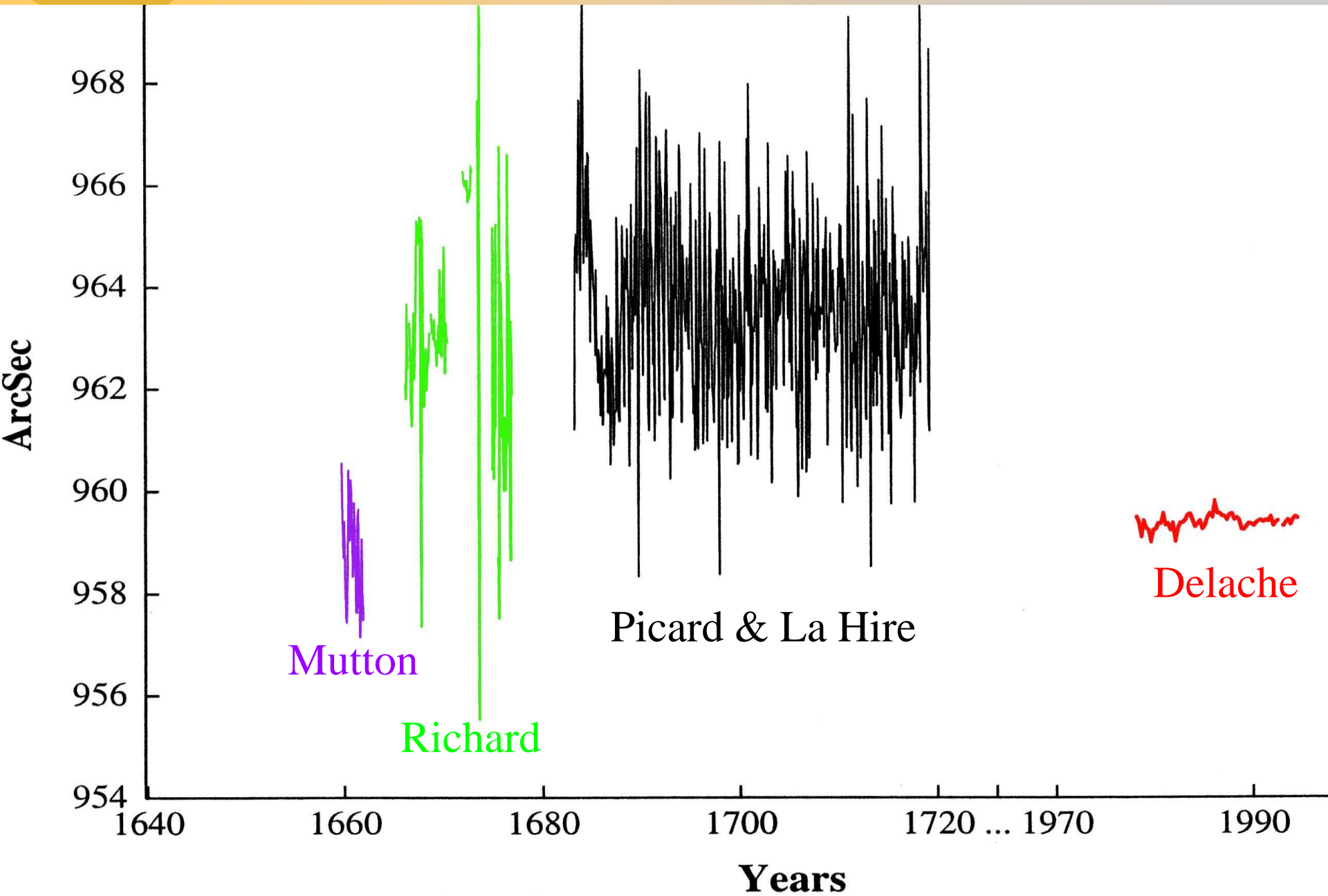




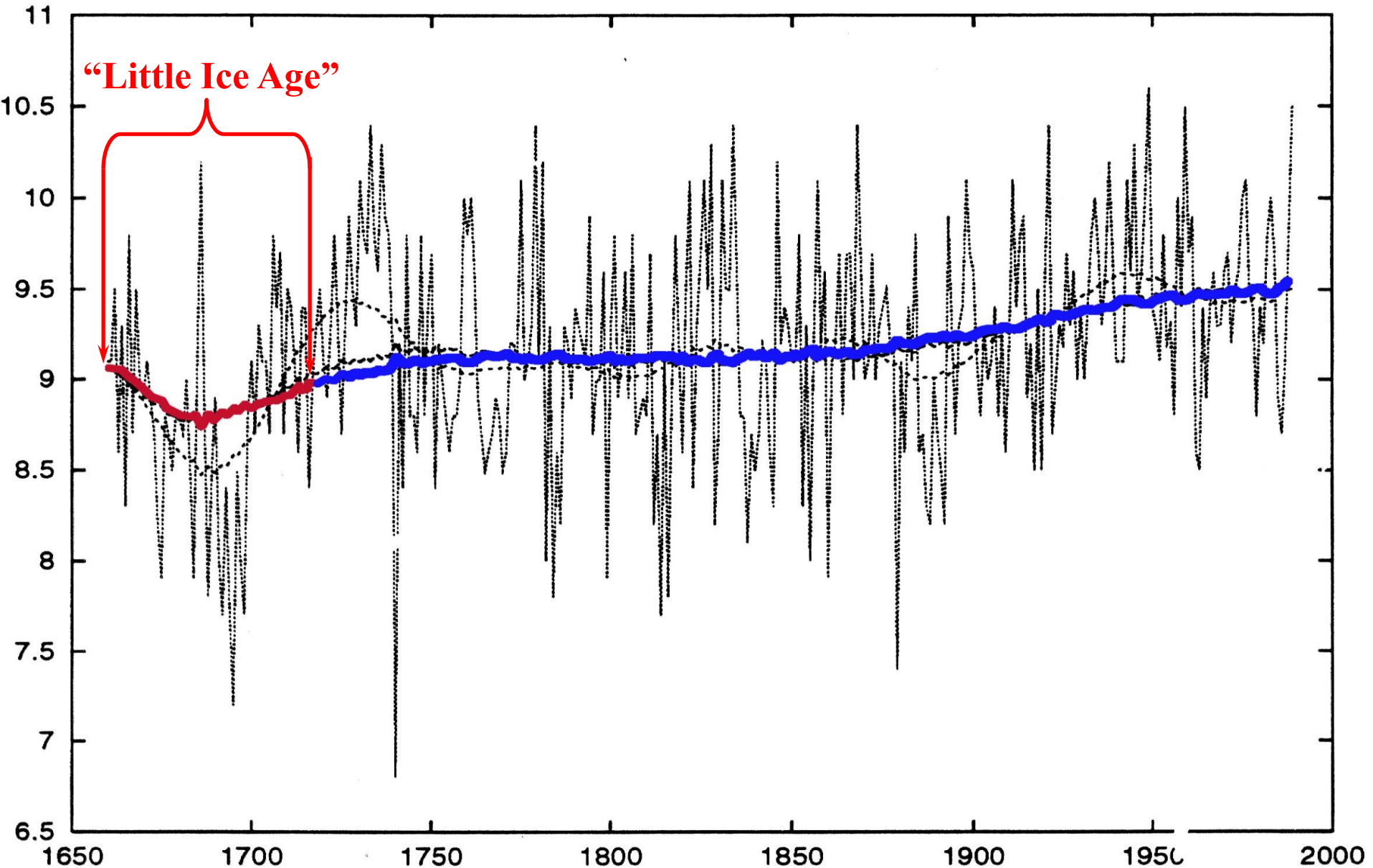
Solar dynamo: perfect nonlinear oscillator

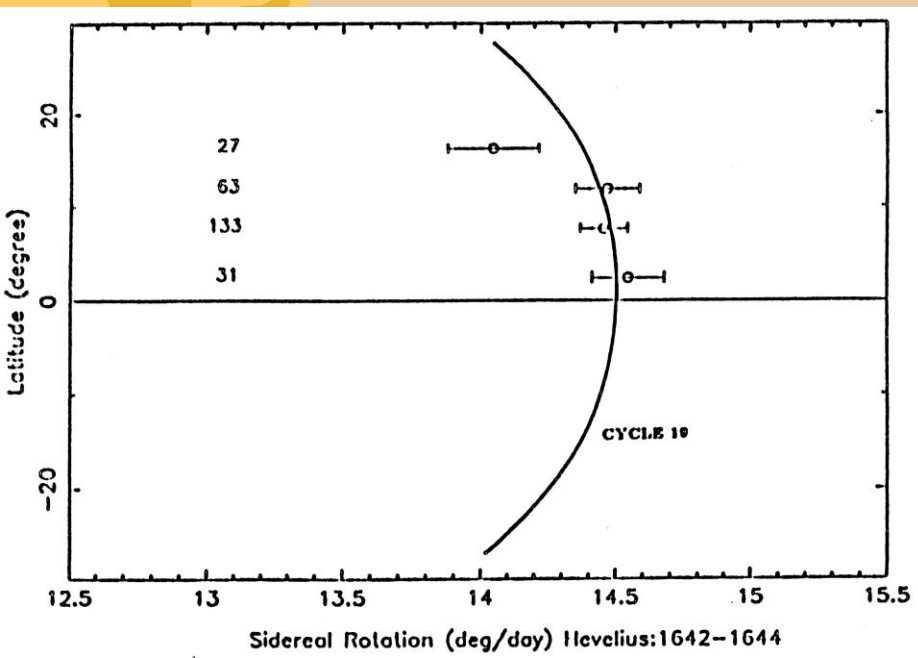
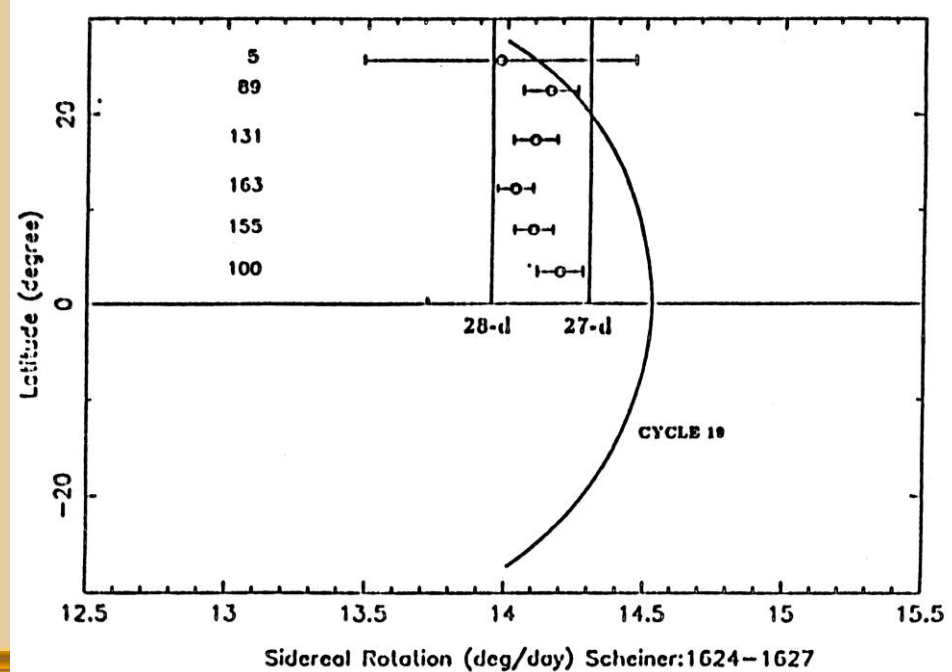
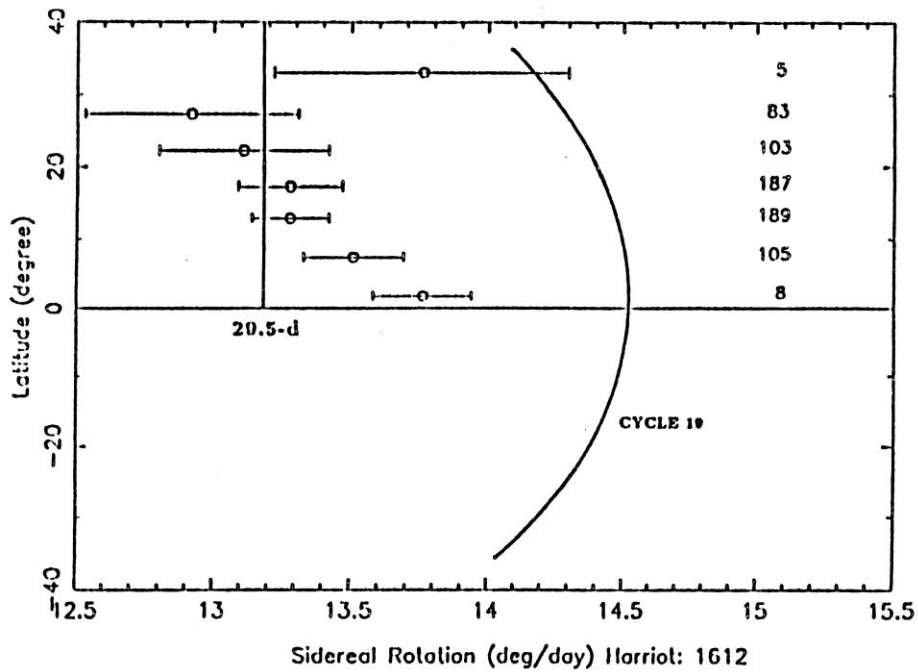


Apparent solar diameter variations

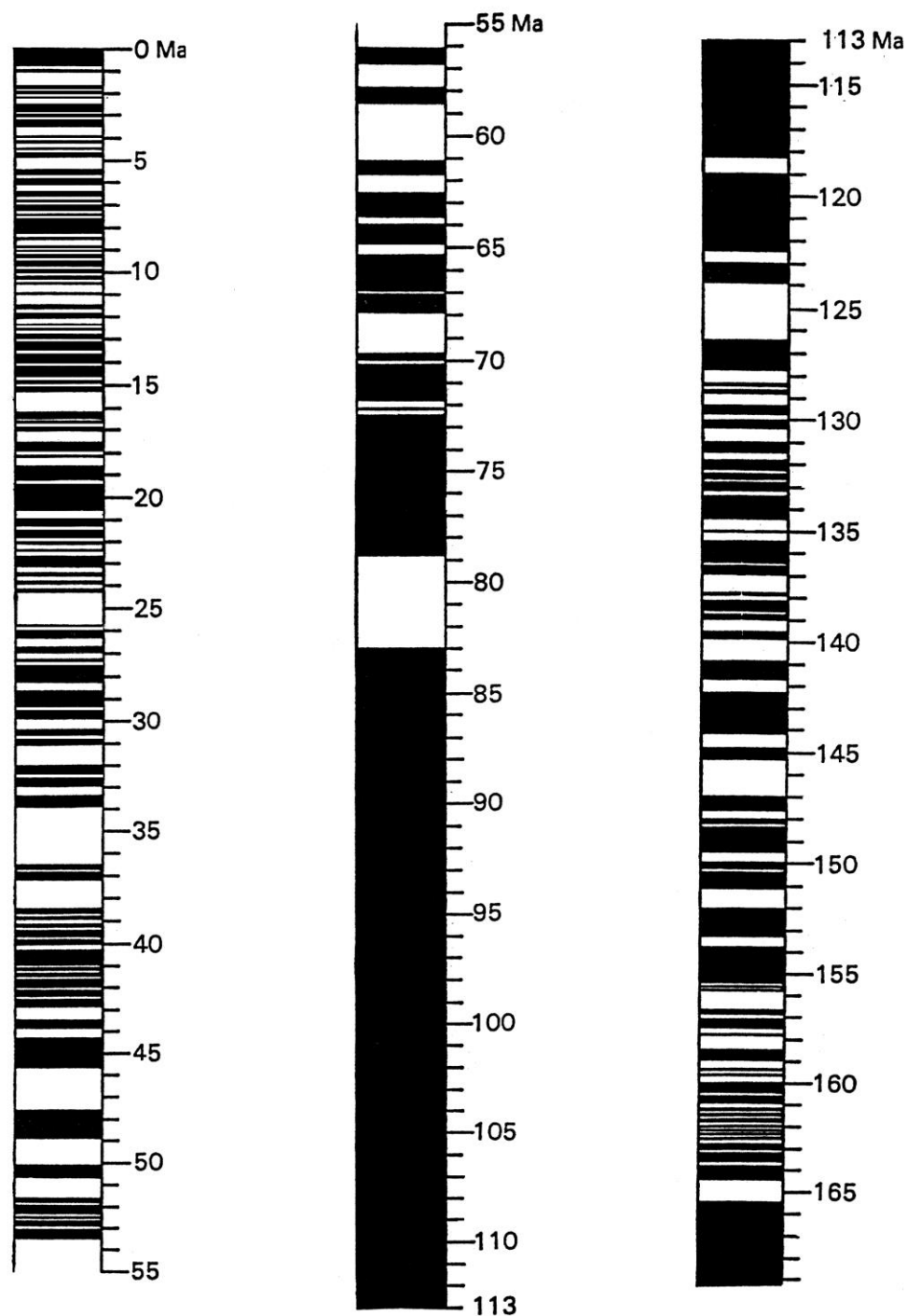


“Little Ice Age” during the Maunder minimum after Central England temperature data





Variations of Solar rotation curve at the beginning of Maunder minimum



Analogy to the Earth magnetic field history

**Hausdorff
dimension = 0.9**

