GINZBURG CONFERENCE OF PHYSICS

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Stellar Activity Waves: New Ideas

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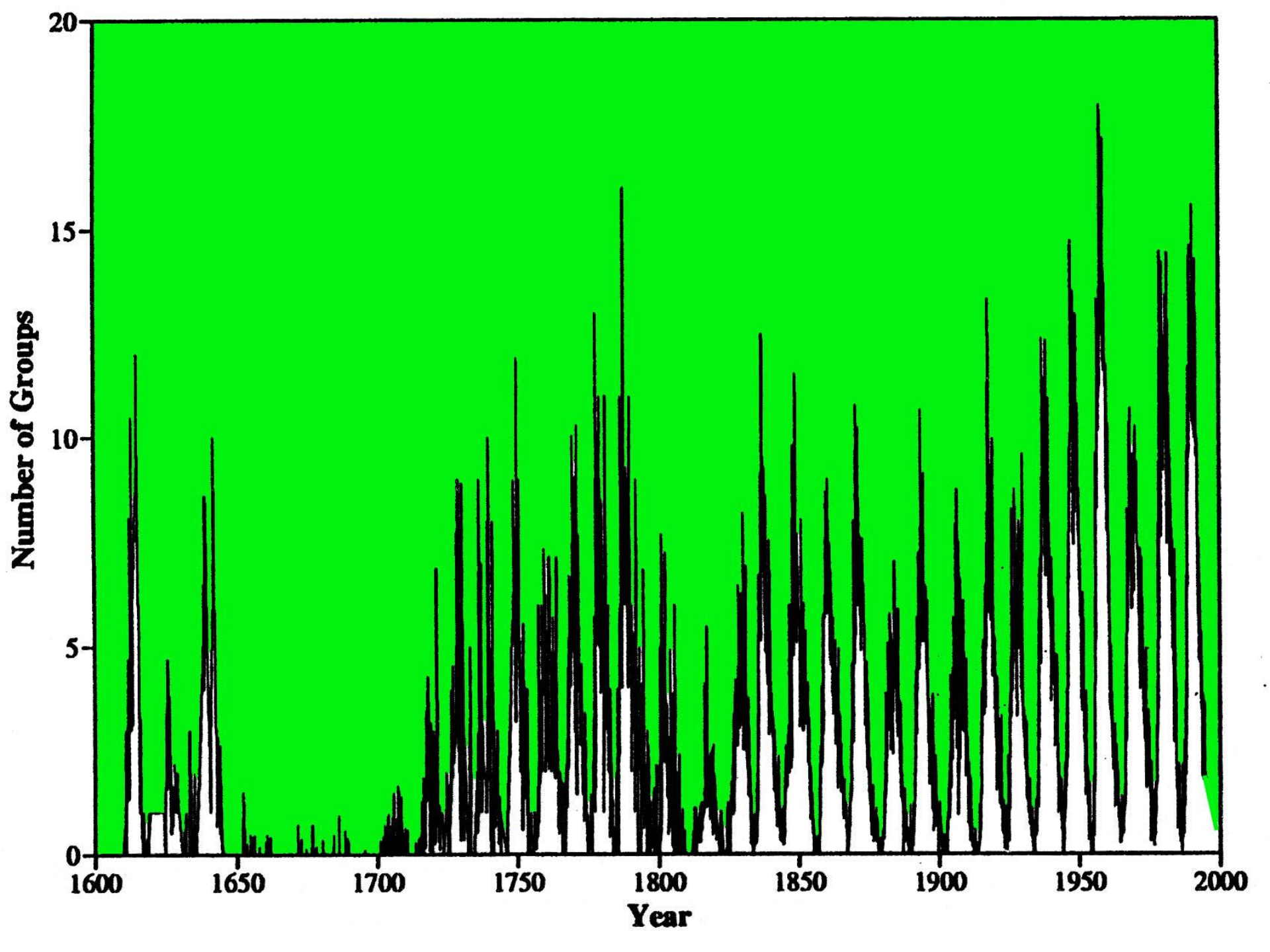
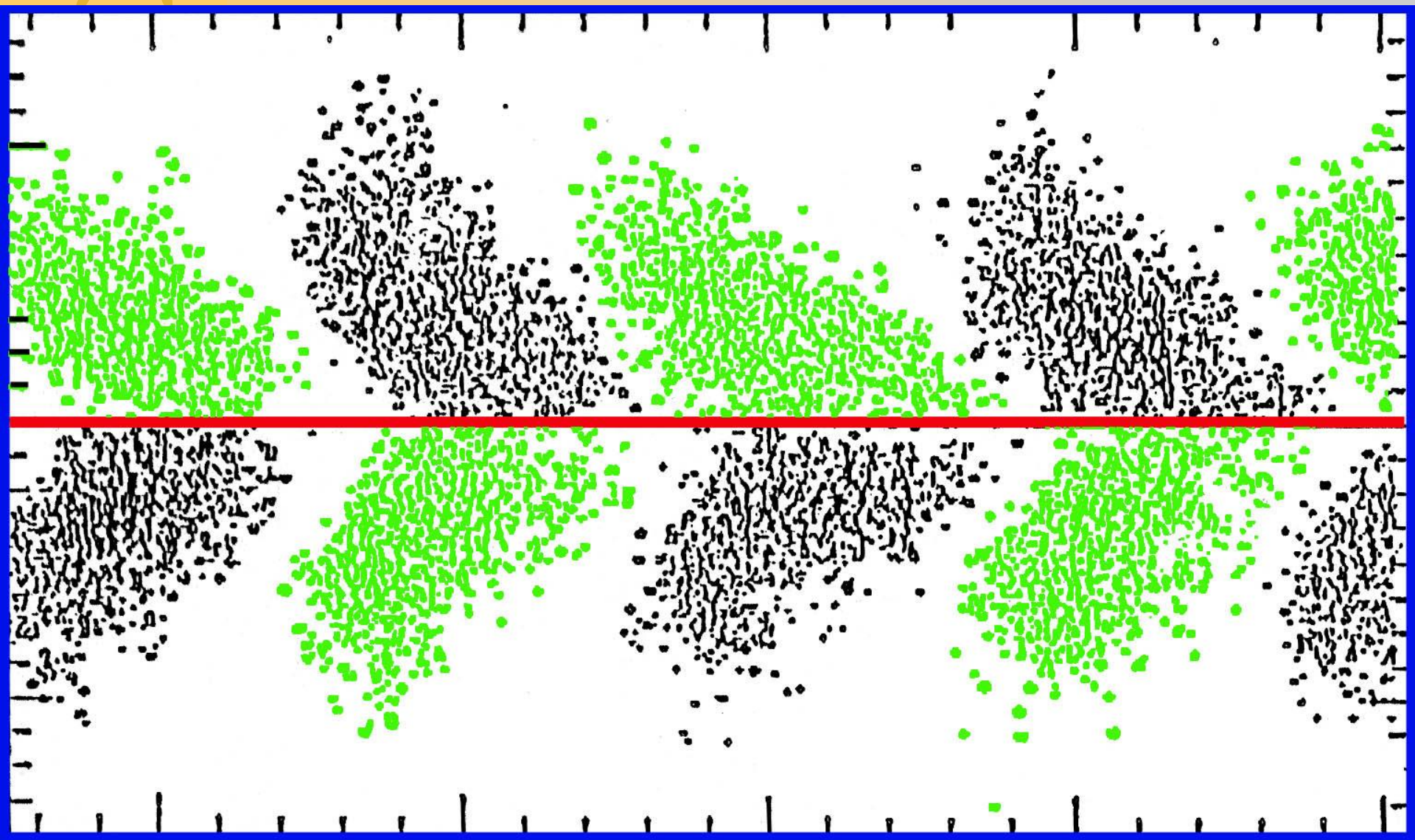
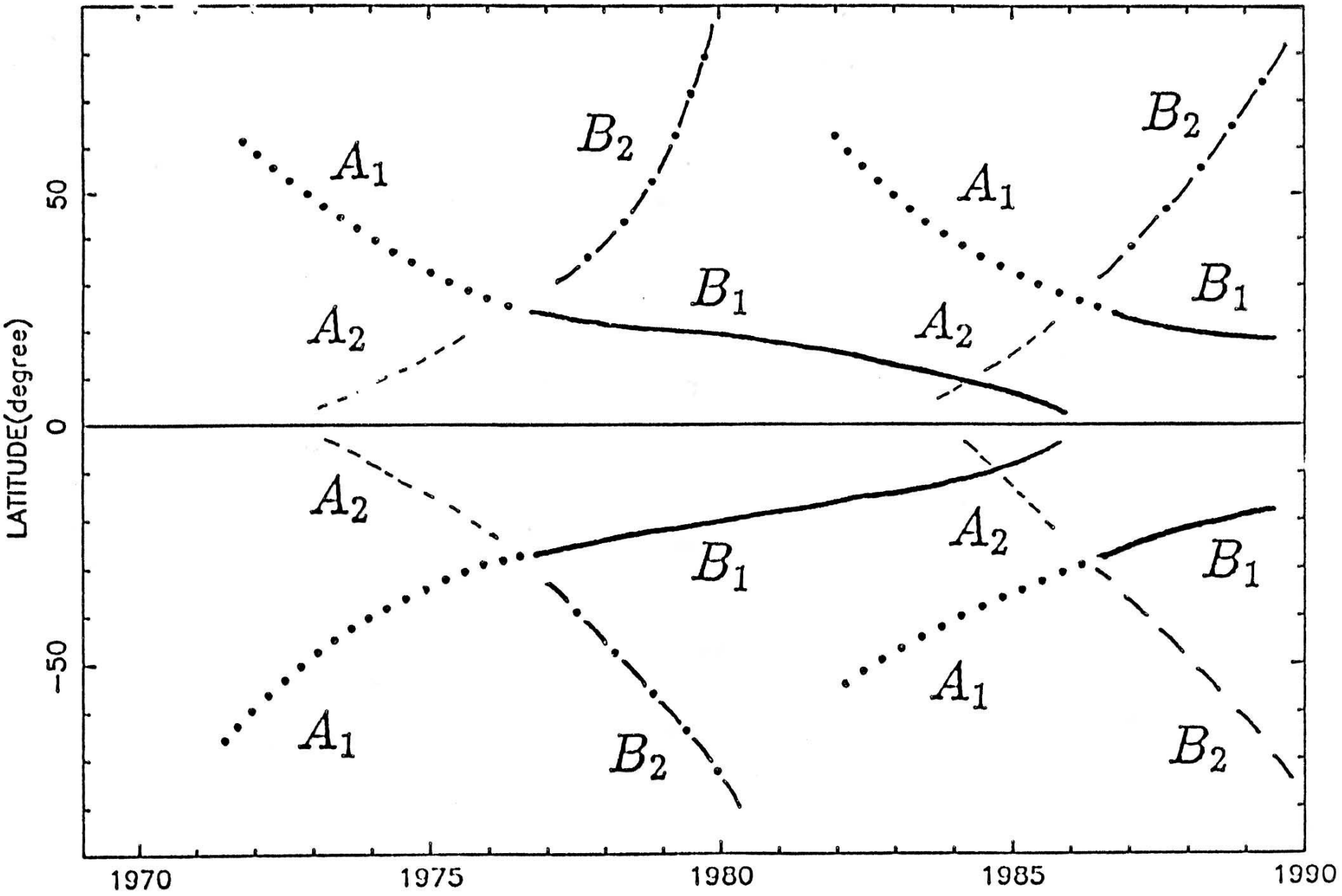

20
15
10
5
0
Number of Groups
1600
1650
1700
1750
1800
1850
1900
1950
2000
Year

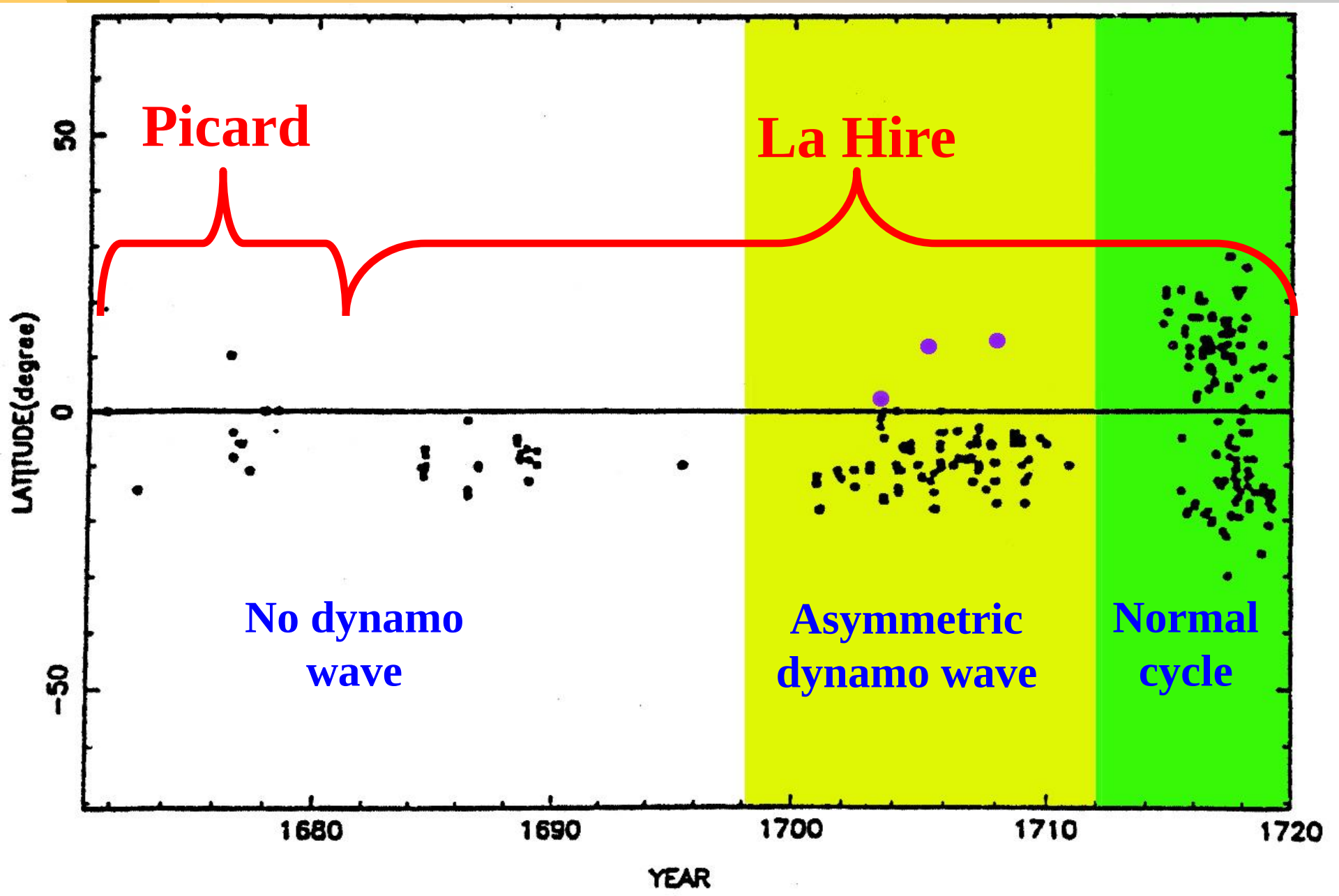
Butterfly diagram for a typical solar cycle: Propagating waves



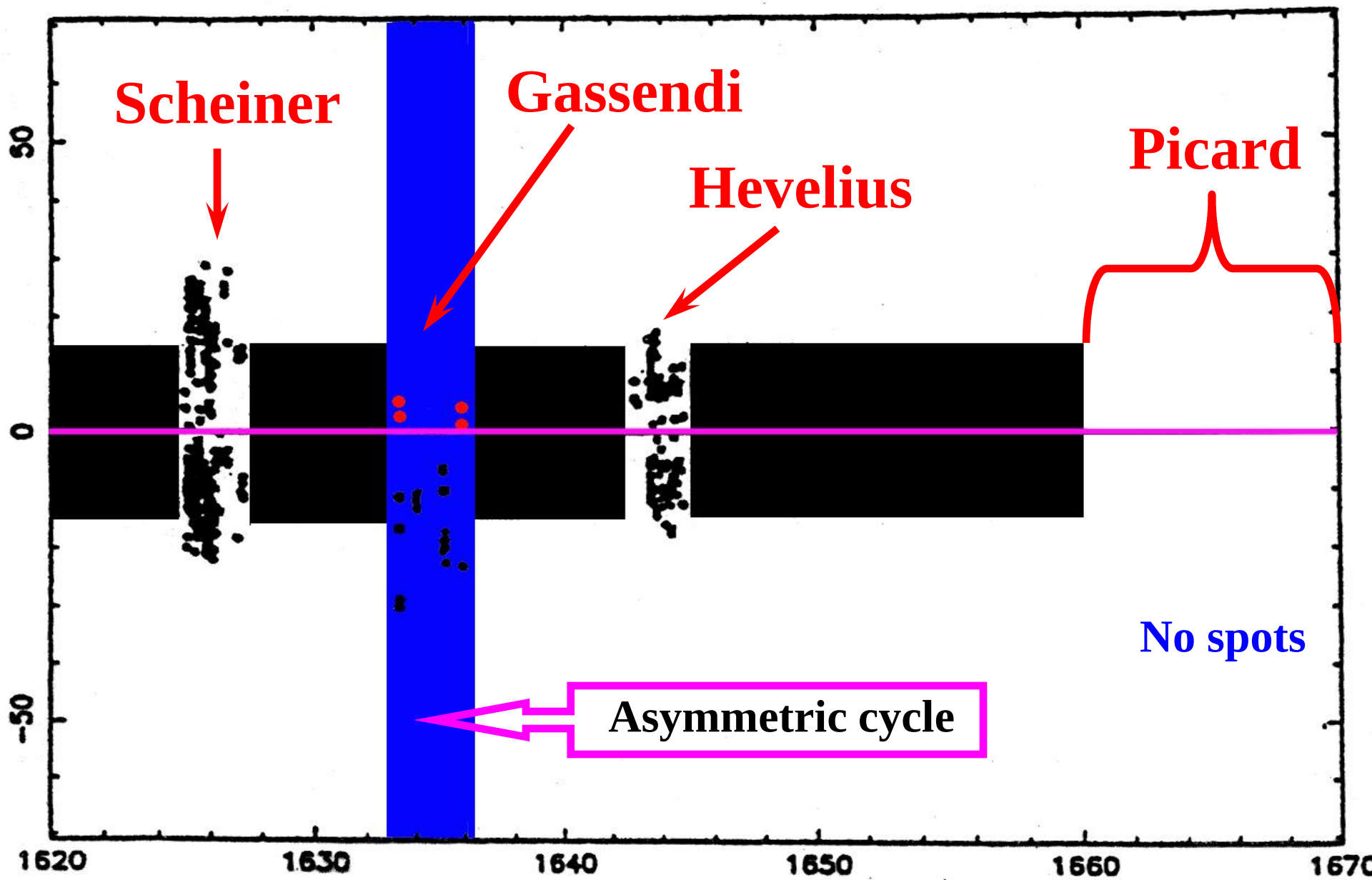
Dynamo waves propagation



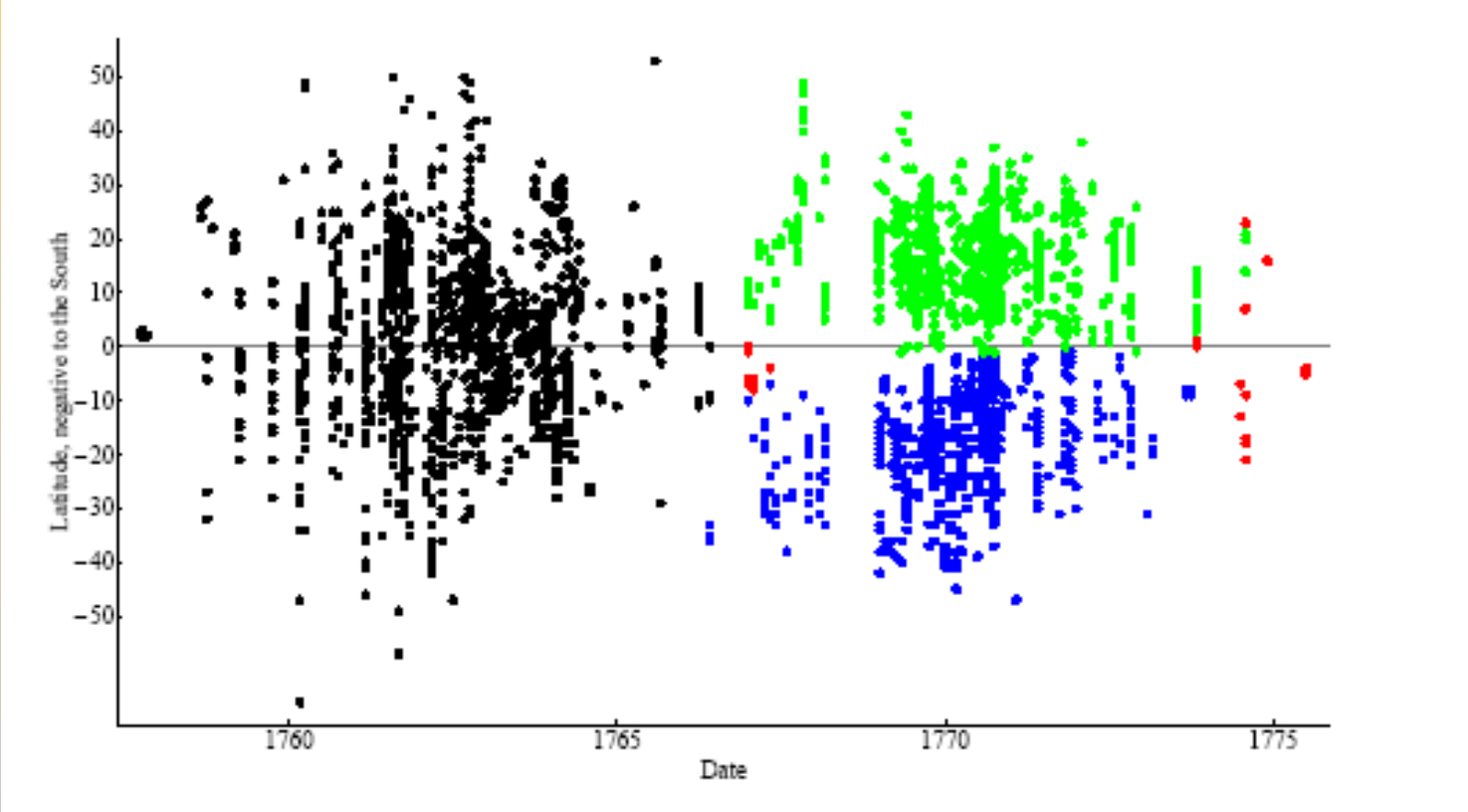
End of the Maunder minimum: asymmetric waves



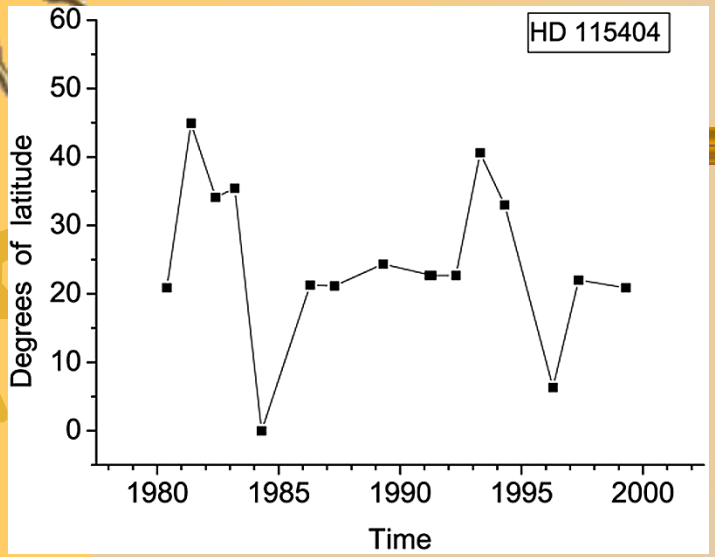
Beginning of the Maunder minimum

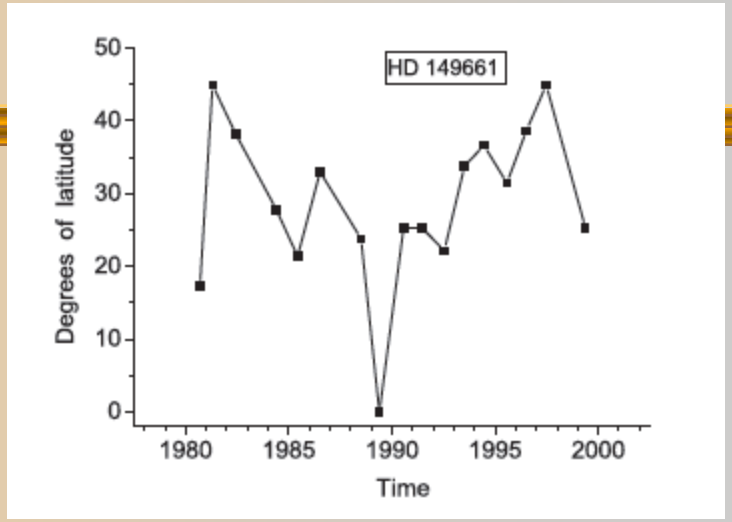


Hint to a quadrupole symmetry



Stellar activity cycles



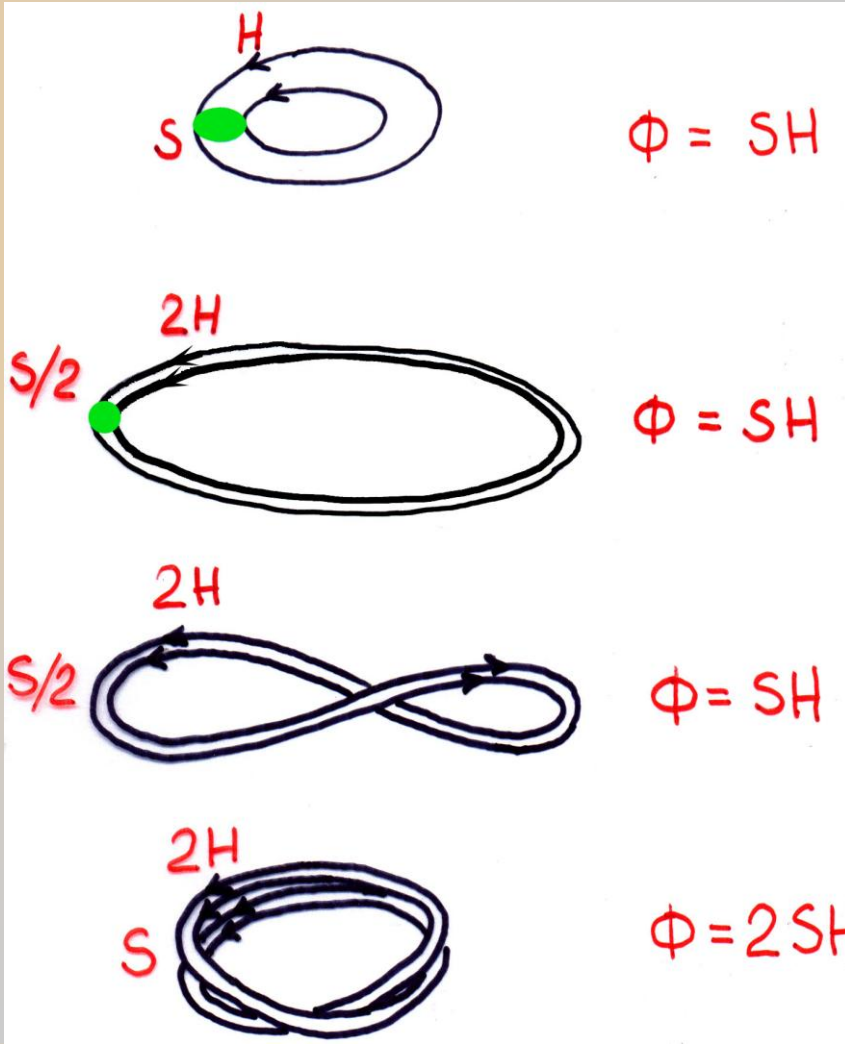


First examples of stellar butterfly diagrams (Kazova et al., 2010 - above).

Berdyugina and Henry HR 1099 – two activity waves Propagating in the same latitudinal belt in opposite directions

Dynamo action: stretch, twist, fold

Frozen-in magnetic field



Zeldovich
Krakow, 1972

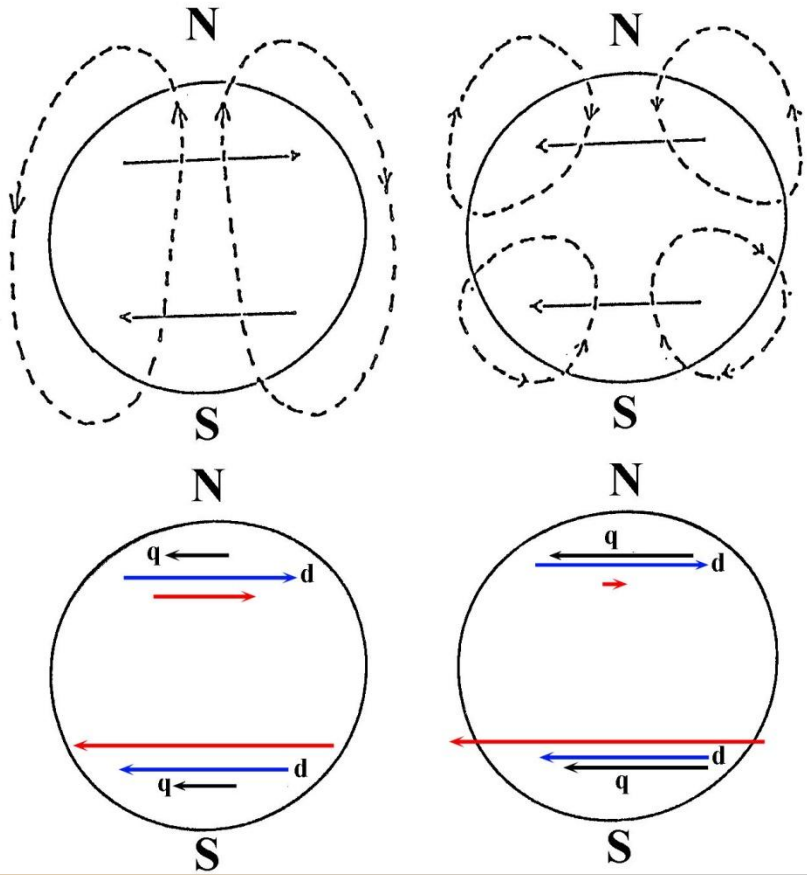
PARKER DYNAMO

$$B_P \xrightarrow{\Omega} B_T$$

Differential rotation

$$B_T \xrightarrow{\alpha} B_P$$

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

$$P_4(k) = 0$$

Hamilton-Jacobi equation

α-effect

$$\alpha = \frac{\tau < \mathbf{v} \; \mathbf{rot} \; \mathbf{v} >}{3}$$

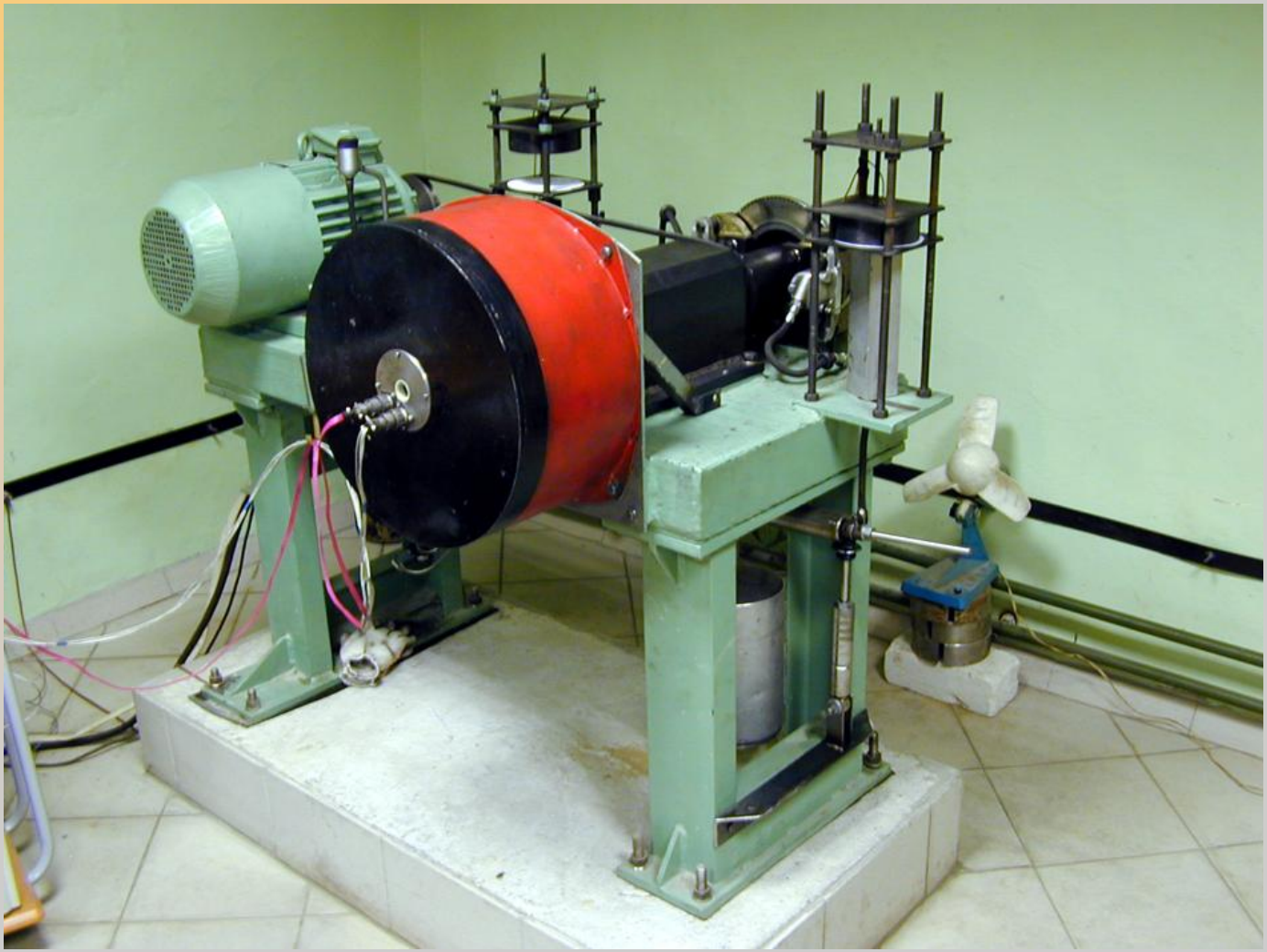
$$J = \alpha B$$

$$\frac{\partial \mathbf{H}}{\partial t} = \nabla \times \mathbf{v} \times \mathbf{H} + \nu_m \Delta \mathbf{H}$$

$$\varepsilon = <\mathbf{u} \times \mathbf{b}> = \beta \nabla \times \mathbf{B} - \alpha \mathbf{B}$$

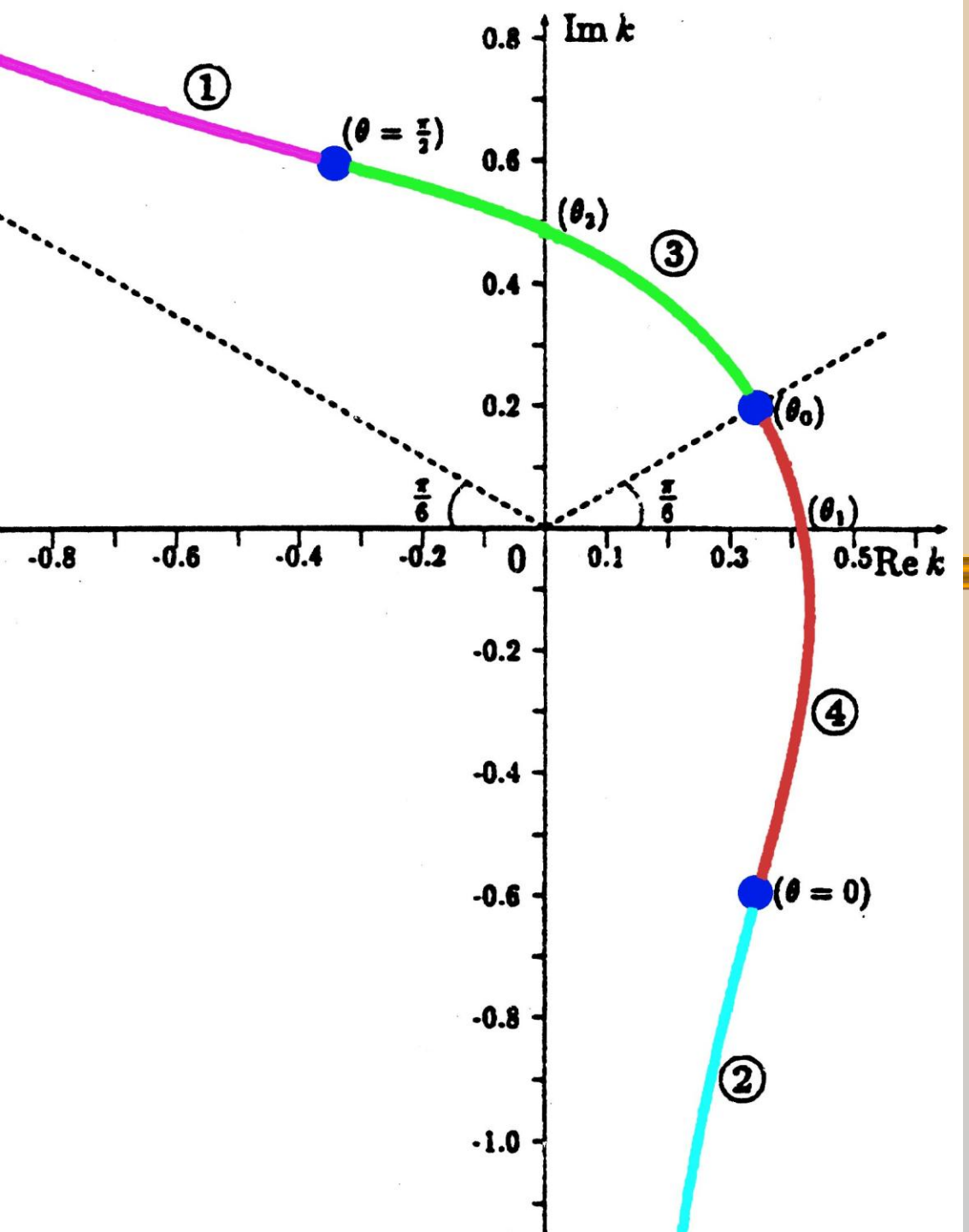
$$\partial_t \mathbf{B} = \nabla \times \alpha \mathbf{B} + \beta \nabla^2 \mathbf{B}$$

Laboratory verification is now under development



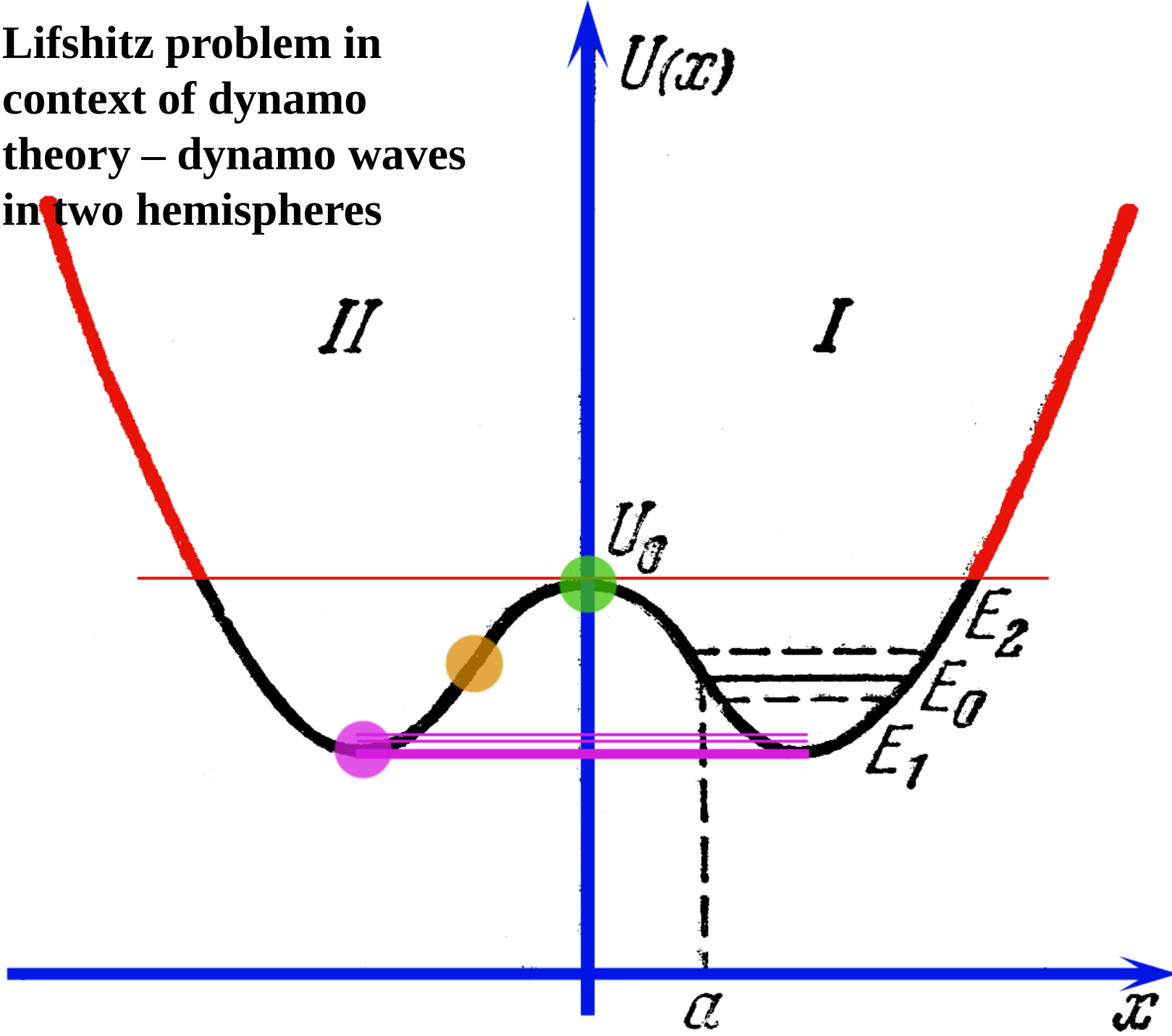
Dynamo (activity) wave as a physical (and mathematical) phenomenon: specific features

1. Parabolic (rather hyperbolic) equations.
2. Propagation is obligatory combined with excitation.
3. Preferable direction of propagation.
4. Moderate variations of the propagation governing parameters substantially affect the wave amplitude.
5. Resonant effect are much lower then these amplitude variations



WKB for dynamo waves: impulse is an essentially complex quantity

Lifshitz problem in context of dynamo theory – dynamo waves in two hemispheres



Dynamo models

Quadrupole solutions +

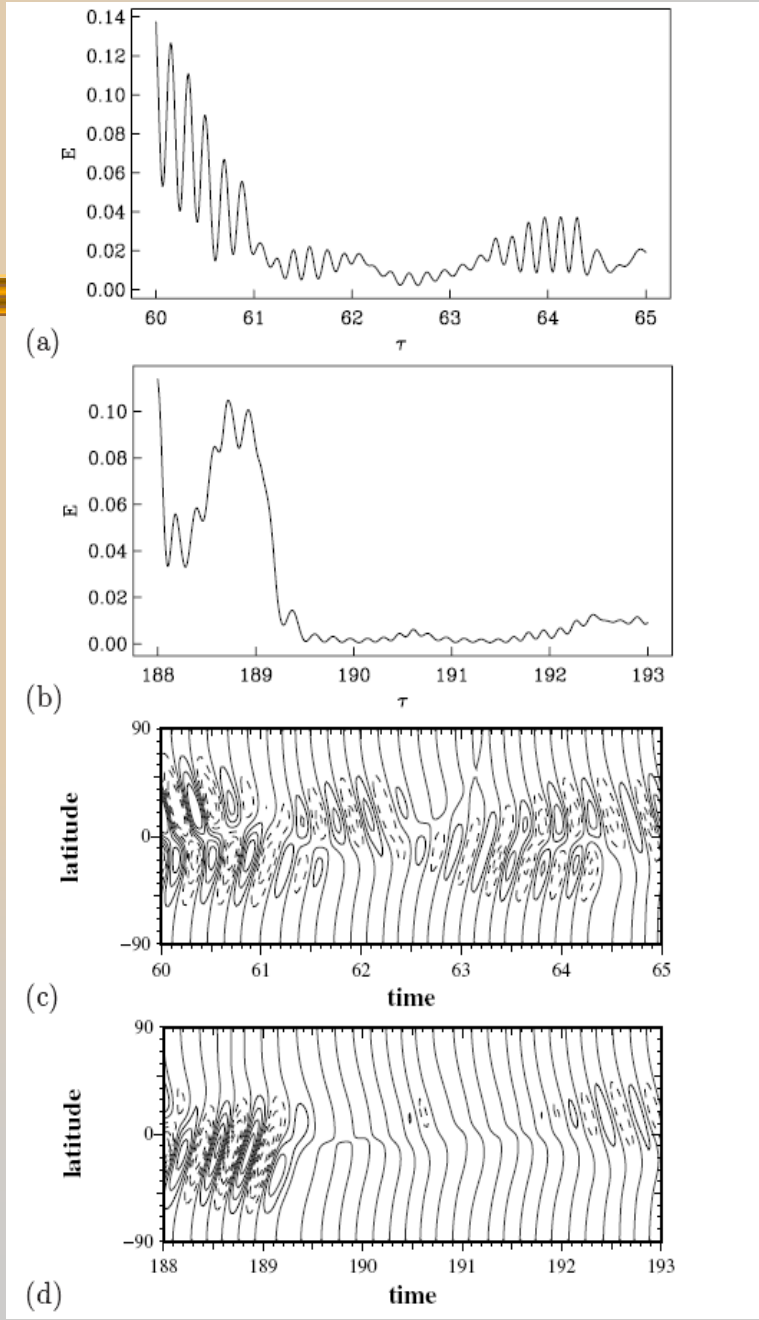
Independent propagation of two waves in two separate layers +

For comparison: a coexistence of dipole waves and steady solutions (galactic disc and halo) is impossible. Enslaved modes.

Fluctuations of the governing parameters

- $N=10^4 \quad N^{-1/2}=0.01$
- Alpha is weak 0.1v
- Alpha fluctuations of about 10%
- Turbulent diffusivity fluctuations1%

Grand Minima



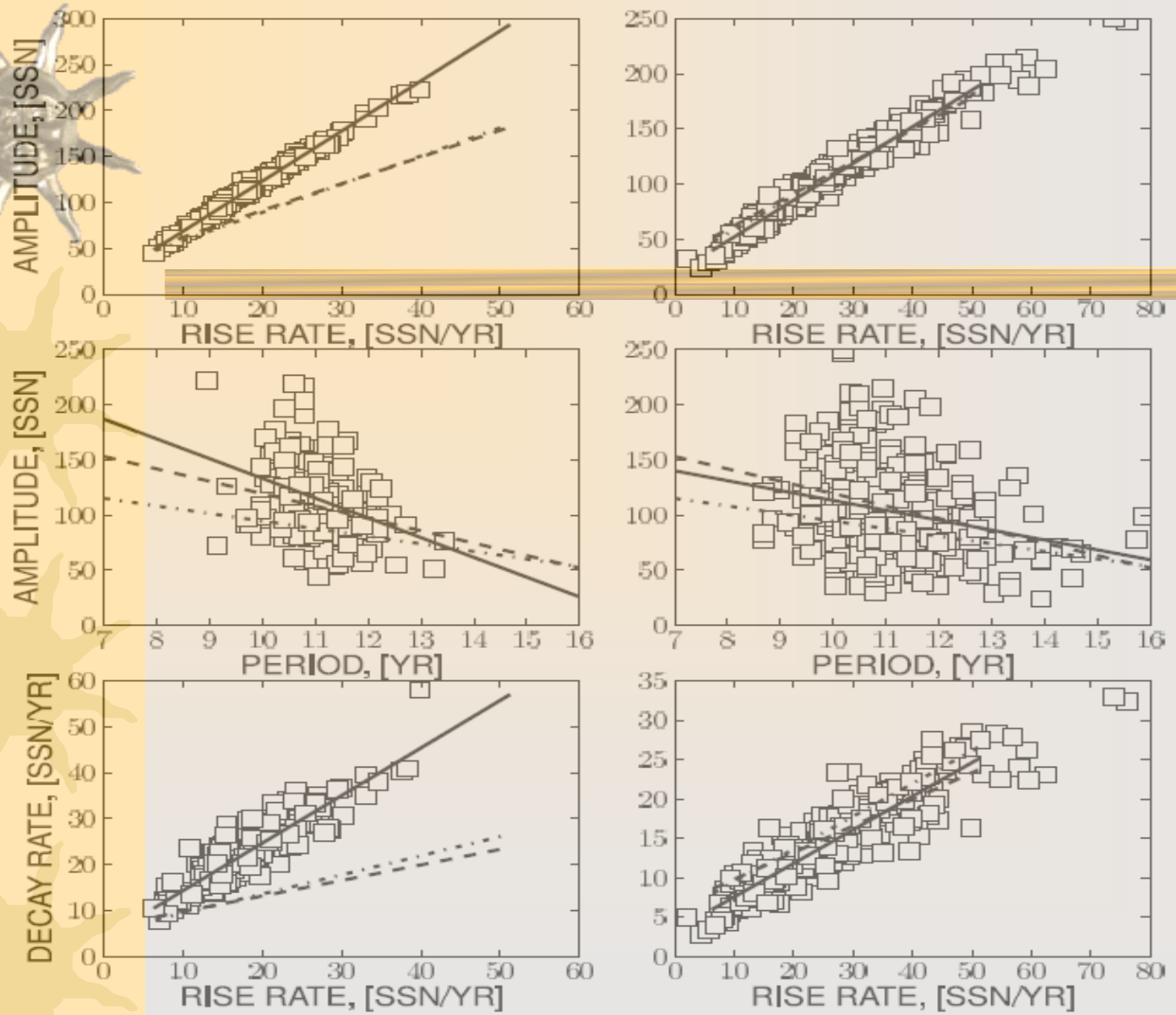
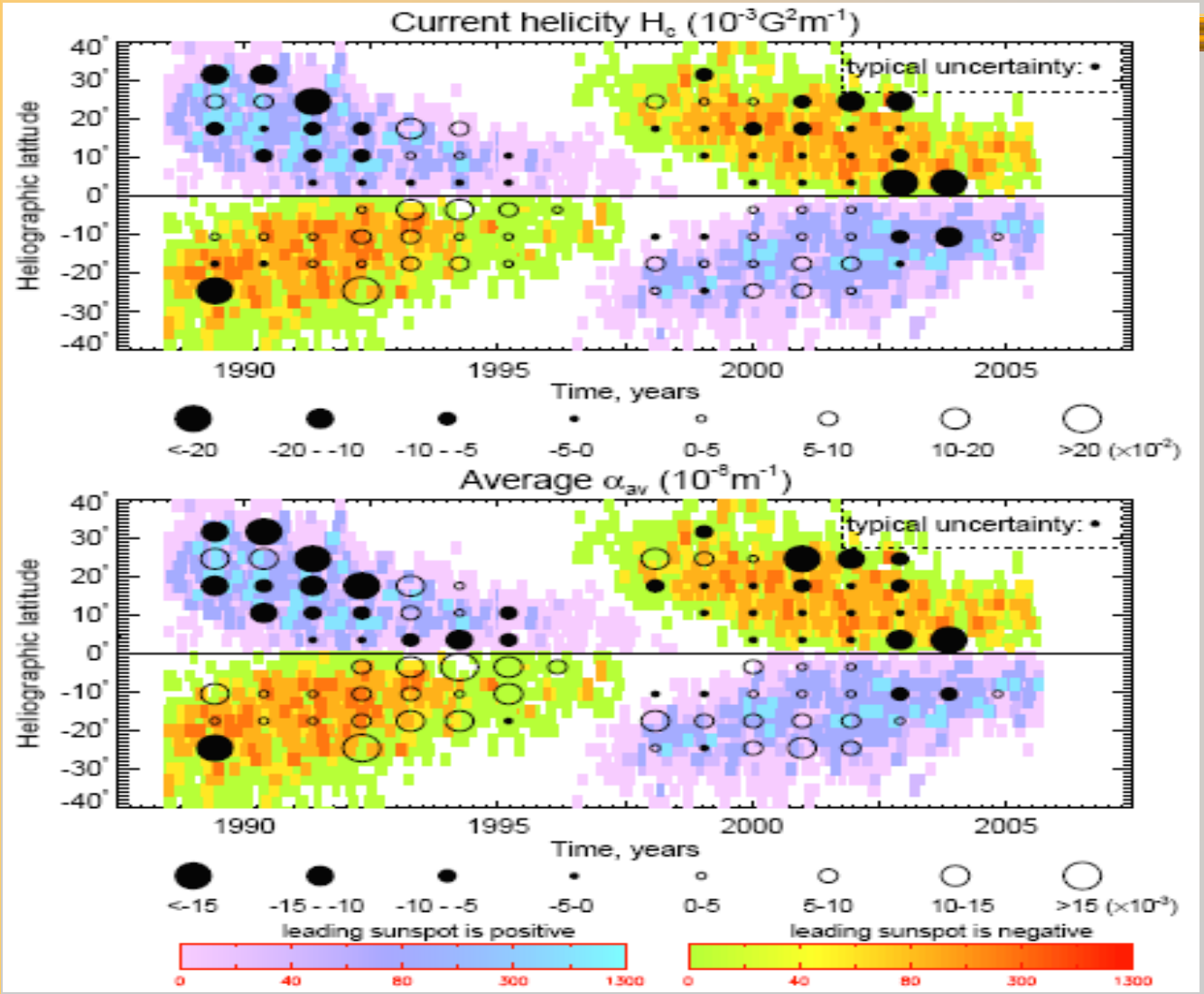
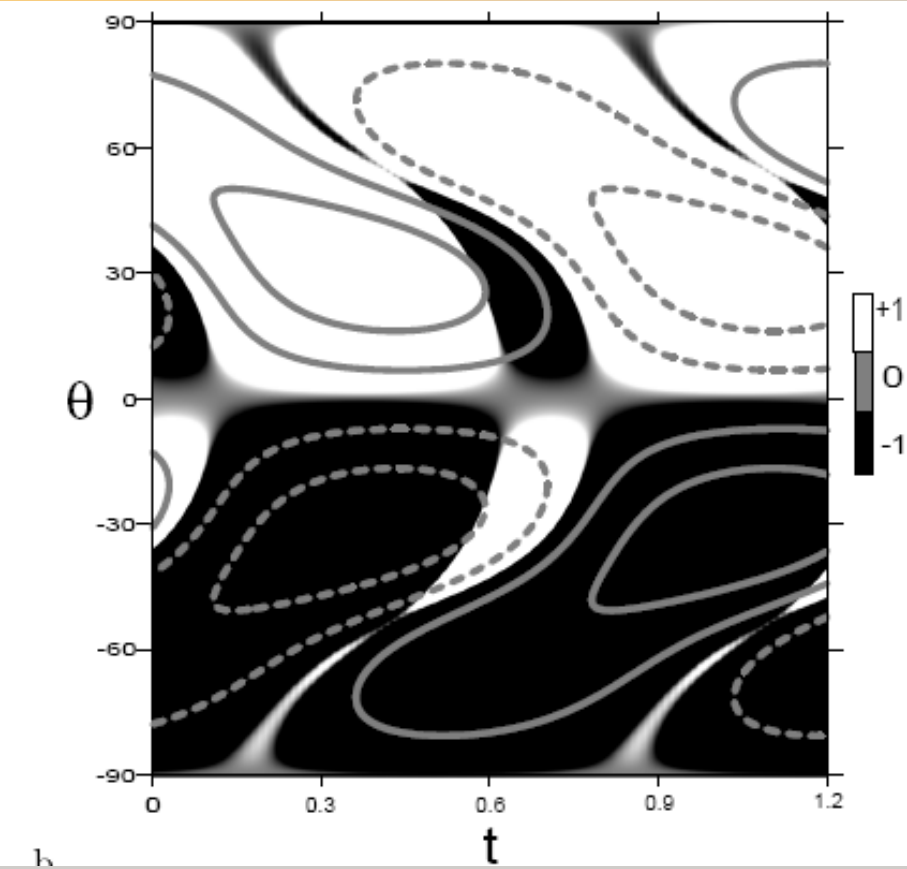


Figure 7. The Waldmeier relations for 1D1 (left) and 2D1 (right) models. The linear fits are shown the solid lines, the dashed lines shows the fits for the SIDC data and the dash-dot line - for the NIMV data.

Helicity butterfly diagram (observations)



Dynamo saturation and magnetic helicity conservation