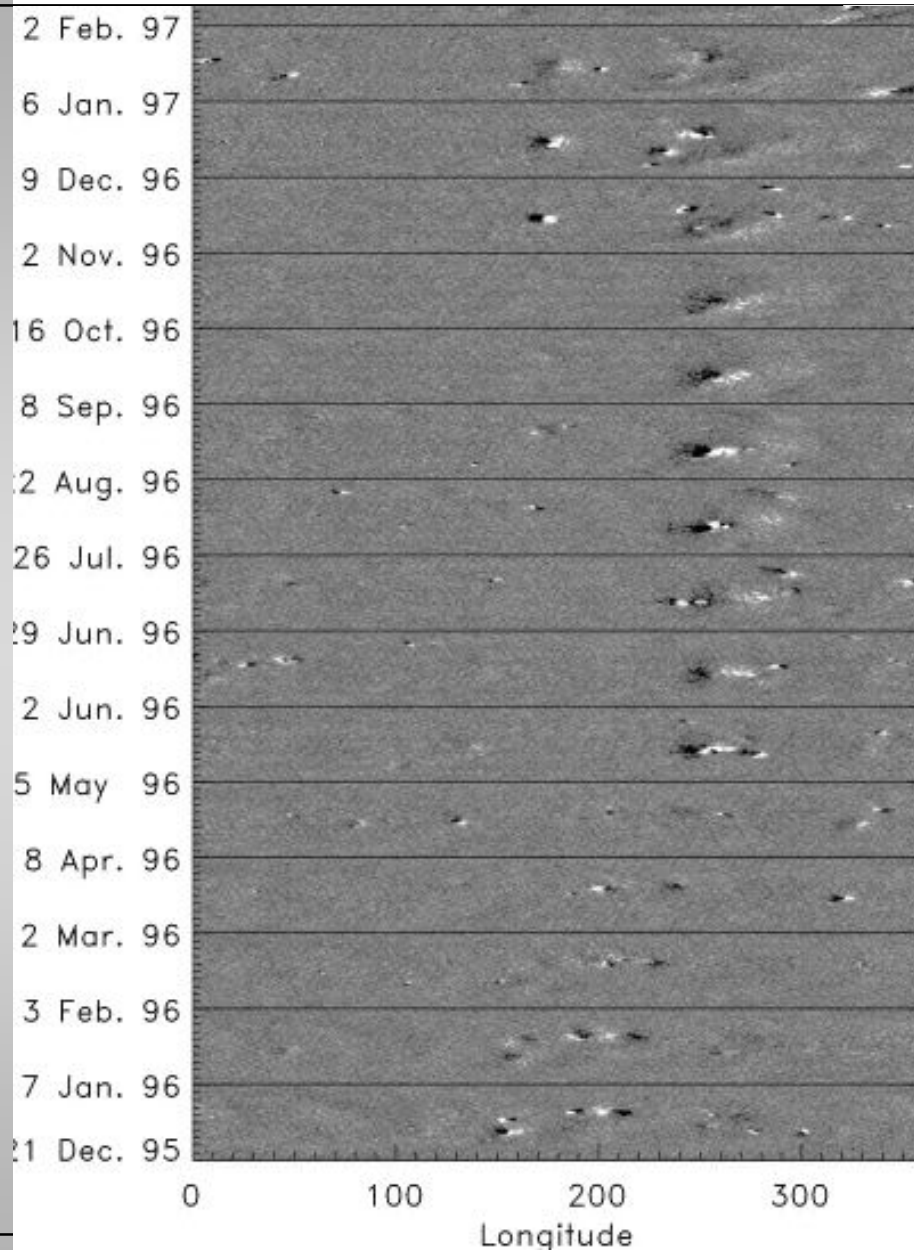

*The Non-Axisymmetric
Solar Magnetic Fields*

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and

alberto Bigazzi

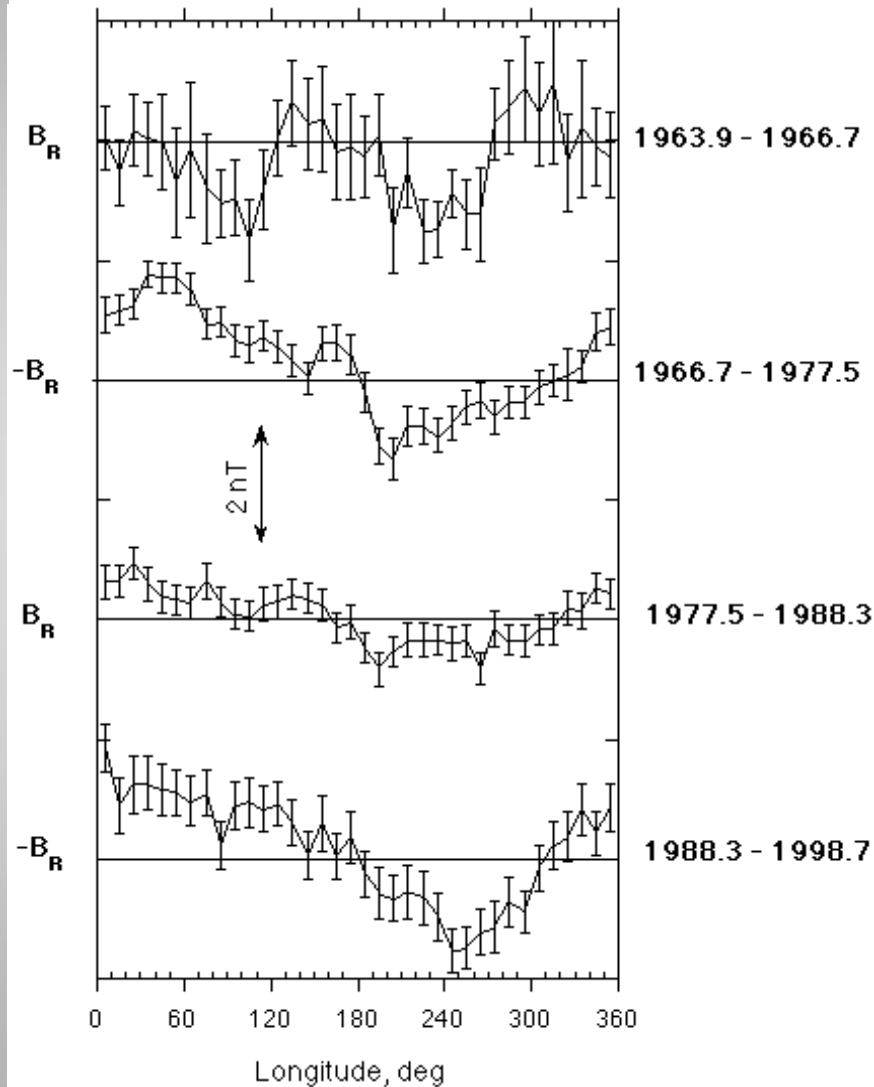
Solar PL



Solar magnetic activity clustering (a stack of magnetograms $\pm 45^\circ$)

-de Toma et al, 2000

PL in the interplanetary field



Cycle averaged B_r

Period 27.03 days

Phase of longitudinal pattern remained steady over 38 years.

-Neugebauer et al, 2000

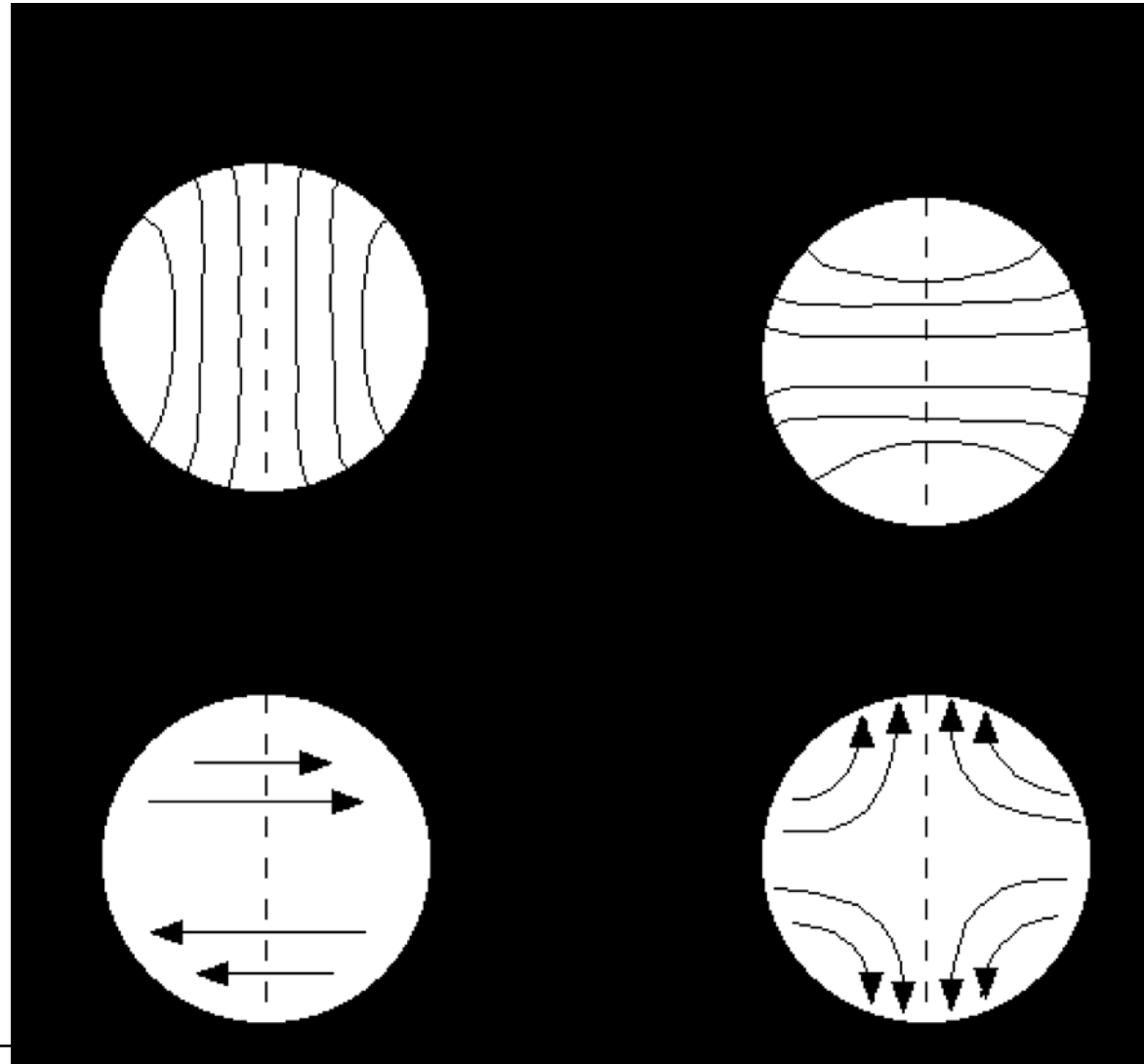
m-modes

$$\mathbf{B} = \sum \mathbf{B}_m(r, \theta, t) e^{im\varphi}$$

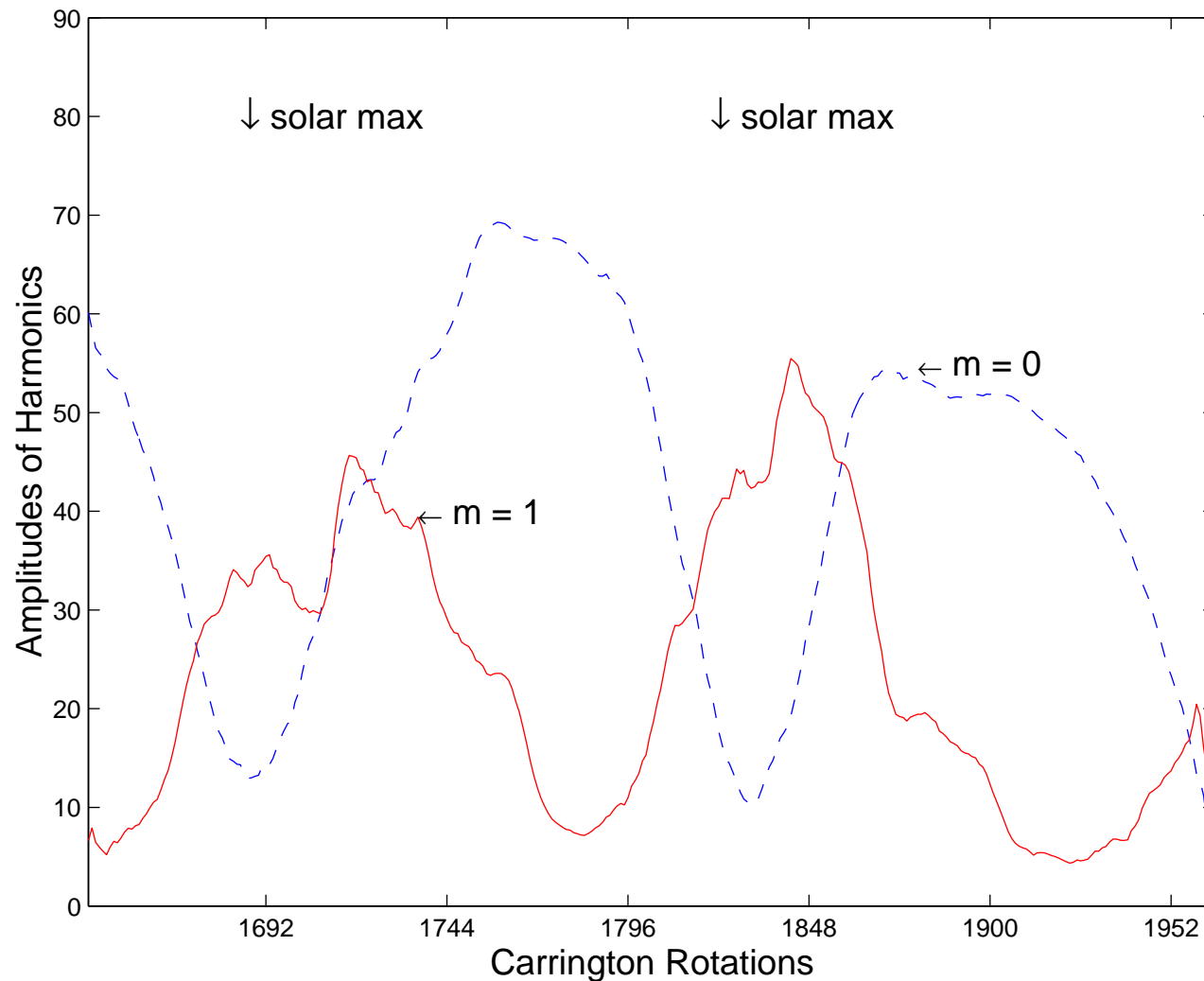
- ◆ $m = 0$ axisymmetric dipole, no PL
- ◆ $m = 1, 2, \dots$ PL, westward and eastward drifts
- ◆ pole of $m = 1$ dipole from ts of magnetograms:
$$B_r(t, \varphi, \theta) = (g(t)\cos\varphi + h(t)\sin\varphi) \sin\theta$$
$$\varphi_{\max}(t) = \text{atan}(h/g)$$

is used to find its rotation rate

m-modes: field lines



$m = 0, 1$ modes on the Sun



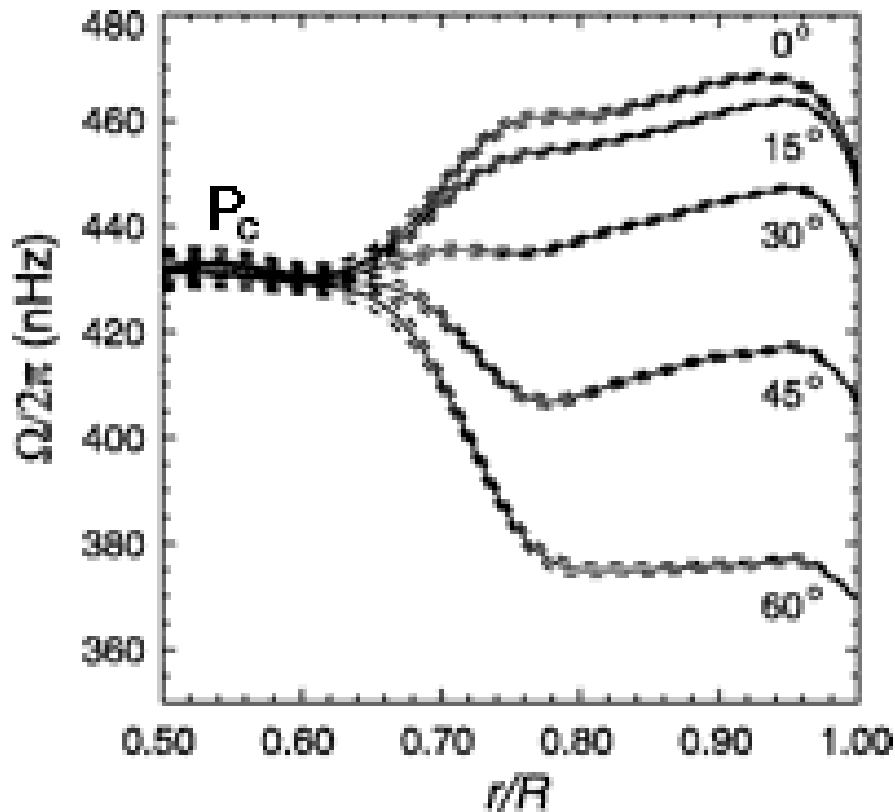
WSO data

Mean-Field Dynamo

$$\partial_t \mathbf{B}_m = \text{rot}(\boldsymbol{\Omega} \times \mathbf{r} \times + \mathbf{u}_M \times + \boldsymbol{\alpha} - \eta \text{rot}) \mathbf{B}_m$$

- ◆ excites m-modes
- ◆ eqs are decoupled for axisymmetric $\boldsymbol{\alpha}, \eta$

Solar Rotation



Interior Rotation

$$P_{\text{core}} = 28.7\text{d}$$

(synodic)

$$P(30^\circ)_{\text{surface}} \approx P_{\text{core}}$$

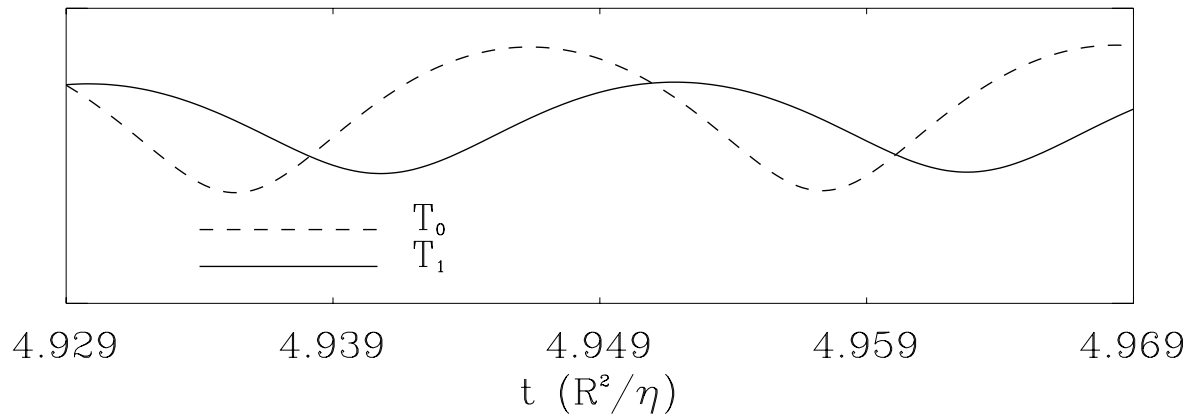
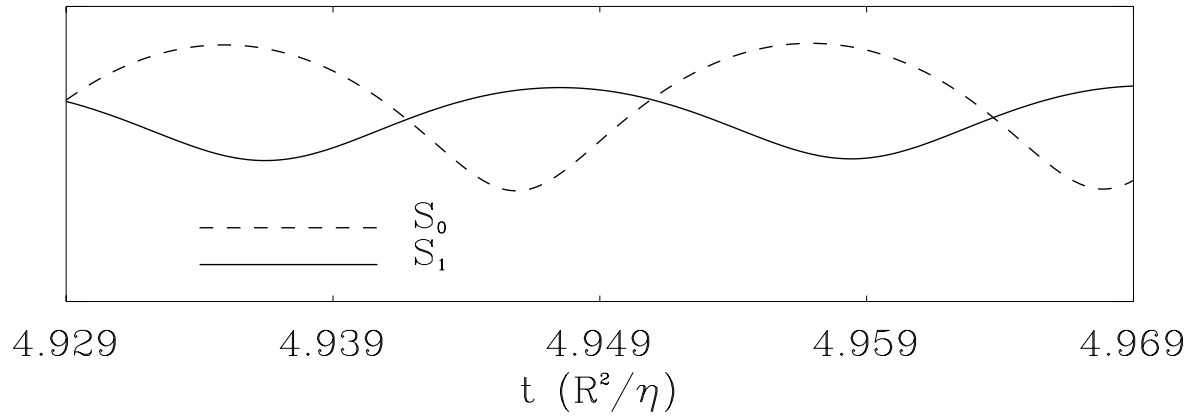
-Howe et al., 2000

Coupling of m-modes

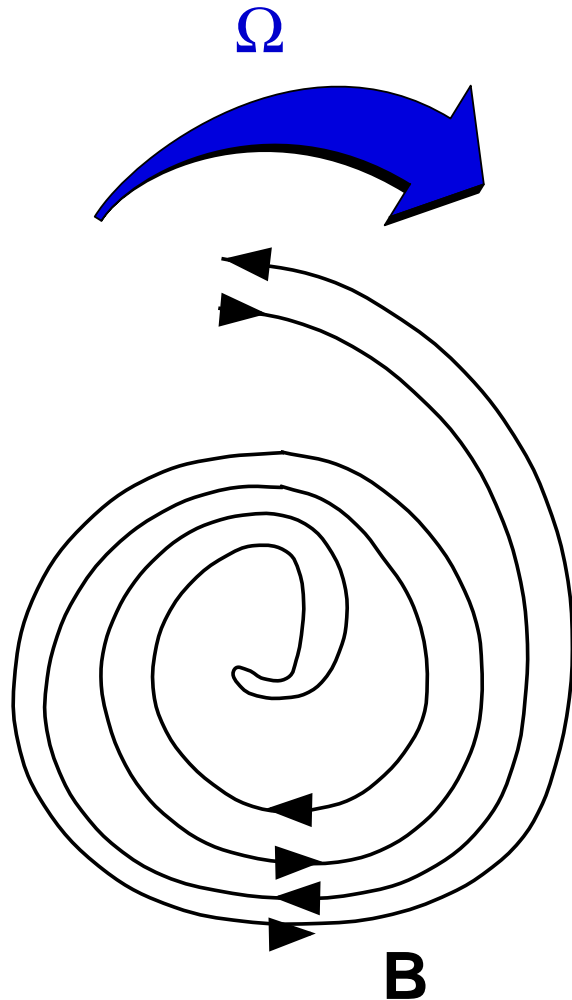
$$\alpha = \alpha_0(r, \theta) + \alpha_1(r, \theta, \varphi)$$

$$\begin{aligned} \partial_t \mathbf{B}_m = & \text{rot}(\boldsymbol{\Omega} \times \mathbf{r} \times + \mathbf{u}_M \times + \alpha_0 - \eta \text{rot}) \mathbf{B}_m + \\ & + \text{rot}(\alpha_1 \mathbf{B}_m,) \end{aligned}$$

m1 coupled to m0

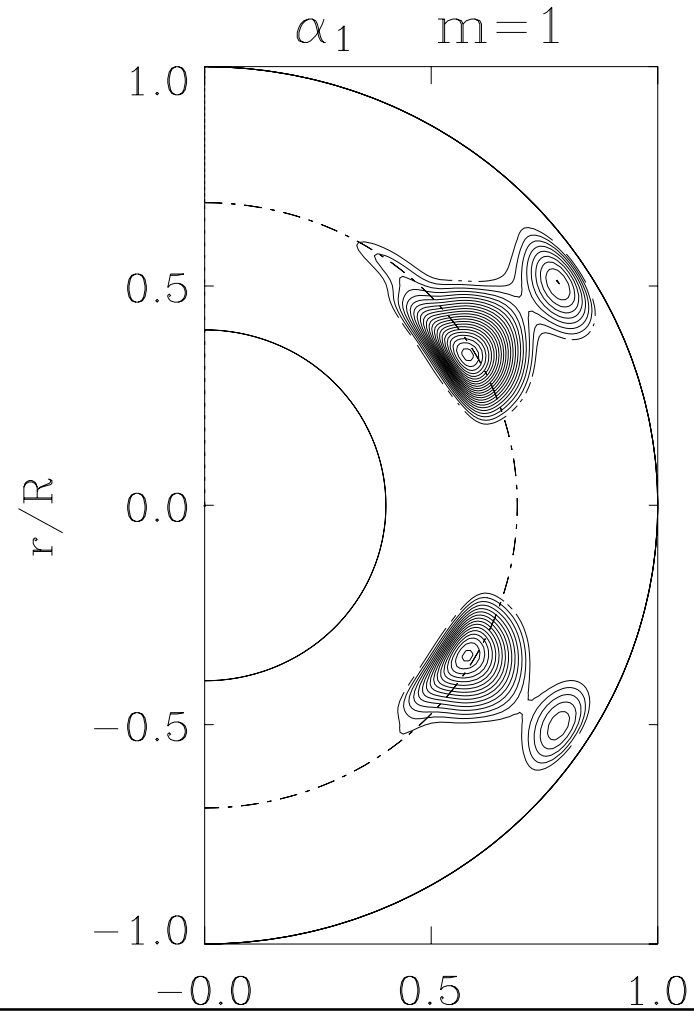
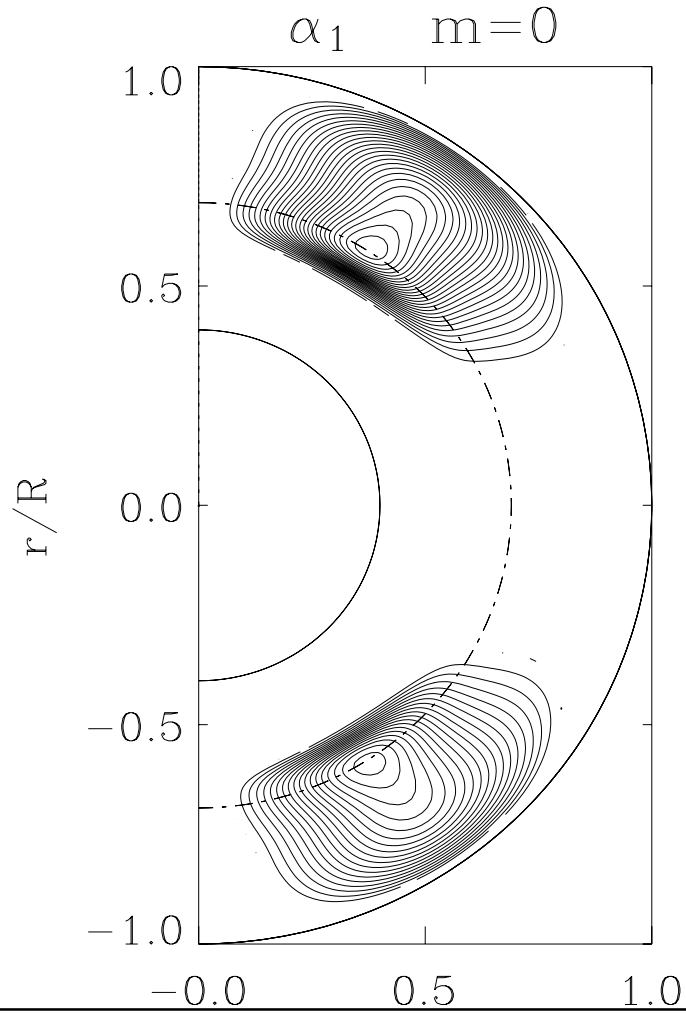


Localization of m modes



$m \neq 0$ modes are excluded from dif-rotating regions

Localization of m modes



Conclusions

- ◆ m-modes of solar magnetic field give PL
- ◆ m1 mode performs the solar cycle due to coupling to m0 mode
- ◆ it is localized near tachocline and around the starting latitude of AR formation (30°)