The Non-Axisymmetric Solar Magnetic Fields

alexander ruzmaikin

and

alberto Bigazzi
Solar PL

Solar magnetic activity clustering (a stack of magnetograms ±45º)

-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

\[ B = \sum B_m(r, \theta, t) e^{im\phi} \]

- \( m = 0 \) axisymmetric dipole, no PL
- \( m = 1, 2, \ldots \) PL, westward and eastward drifts
- pole of \( m = 1 \) dipole from ts of magnetograms:
  \[ B_r(t, \phi, \theta) = (g(t)\cos\phi + h(t)\cos\phi) \sin\theta \]
  \[ \phi_{\text{max}}(t) = \tan(h/g) \]
  is used to find its rotation rate
m-modes: field lines
$m = 0, 1$ modes on the Sun

![Graph showing Carrington Rotations and Amplitudes of Harmonics with peaks at solar max.]
Mean-Field Dynamo

\[ \partial_t B_m = \text{rot}(\Omega \times r x + u_M x + \alpha - \eta \text{rot}) B_m \]

- excites m-modes
- eqs are decoupled for axisymmetric \( \alpha, \eta \)
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

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

\[ \partial_t B_m = \text{rot}(\Omega \times \mathbf{r} \times + \mathbf{u}_M \times + \alpha_0 - \eta \text{rot})B_m + \]

\[ + \text{rot}(\alpha_1 B_m',) \]
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
- $m_1$ mode performs the solar cycle due to coupling to $m_0$ mode
- It is localized near tachocline and around the starting latitude of AR formation (30°)