

Physics 681: Solar Physics and Instrumentation – Lecture 12

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Oscillations

- Observations
 - Five-Minute Oscillation
 - The Spectrum of Solar Oscillations
 - Low-Degree p Modes
 - Line Width and Asymmetry
- Linear Adiabatic Oscillations of a Non-Rotating Sun
 - Basic Equations
 - Spherical Harmonic Representation
 - The Cowling Approximation
 - Local Treatment
 - Boundary Conditions
 - Asymptotic Results
- Helioseismology
- Excitation and Damping

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Five-Minute Oscillation

- Acoustic waves
- Pressure gradient is the restoring force "p modes"
- Probe the interior of the Sun
- Gravity can also provide a restoring force
- However, g modes have not yet been confirmed
- Leighton et al. discovered the five-minute oscillations in 1960 in dopplergrams
- Spectroscopy \Rightarrow vertical velocities from 0.5 to 1.0 km/s
- Periodic variations of the intensity (few percent)
- Largest amplitudes (2-5 mHz or 3-8 min)
- Areas of 30,000 km oscillate in phase
- Evanescent waves

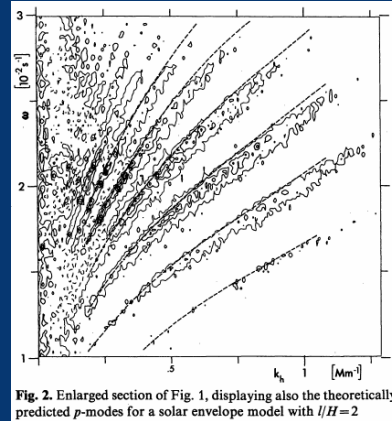


Fig. 2. Enlarged section of Fig. 1, displaying also the theoretically predicted p-modes for a solar envelope model with $l/H = 2$

Deubner, Ulrich, & Rhodes (1979)



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Spectrum of Solar Oscillations

- Temporal and spatial frequencies

$$\Delta\omega = 2\pi / T \leq \omega < \pi / \Delta t$$

$$\Delta k_x = 2\pi / L_x \leq \omega < \pi / \Delta x$$

- Fourier transform of a vertical velocity signal

$$v(x, y, t) = \int f(k_x, k_y, \omega) \exp[i(k_x x + k_y y + \omega t)] dk_x dk_y d\omega$$

- Power spectrum

$$P(k_x, k_y, \omega) = ff^*$$

- Radial symmetric power spectrum

$$P(k_h, \omega) = \frac{1}{2\pi} \int_0^{2\pi} P(k_h \cos \phi, k_h \sin \phi, \omega) d\phi$$

$$k_h = (k_x^2 + k_y^2)^{1/2}$$



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Spherical Harmonics

- Spherical surface harmonics (polar coordinates (r, θ, ϕ))

$$v(\theta, \phi, t) = \sum_{l=0}^{\infty} \sum_{m=-l}^l a_{lm}(t) Y_l^m(\theta, \phi)$$

- Legendre polynomials

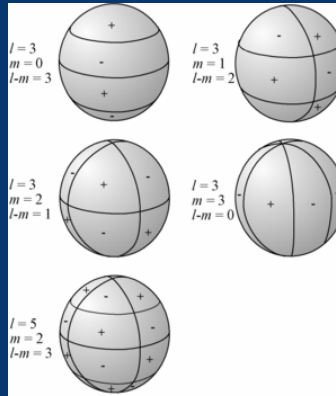
$$Y_l^m(\theta, \phi) = P_l^{|m|}(\cos\theta) e^{im\phi}$$

- Power in the l, ν -diagram

$$P(l, \nu) = \hat{a}_l(\nu) \hat{a}_l^*(\nu)$$

- Zonal harmonics $m = 0$ (longitudinal averages)

$$k_h r_{\odot} = [l(l+1)]^{1/2}$$



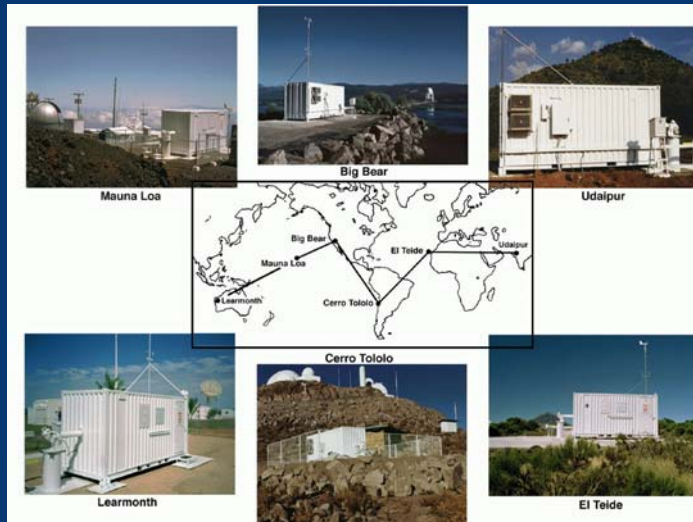
http://commons.wikimedia.org/wiki/Spherical_harmonic

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Global Oscillation Network Group (GONG)

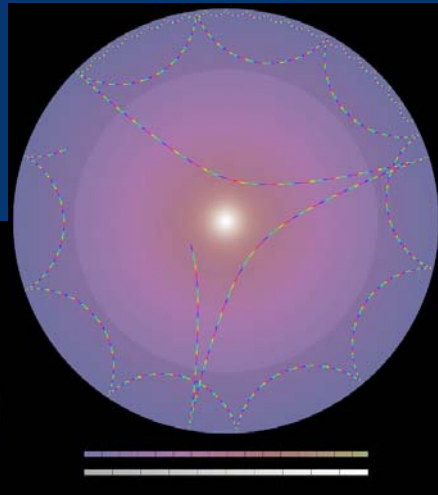
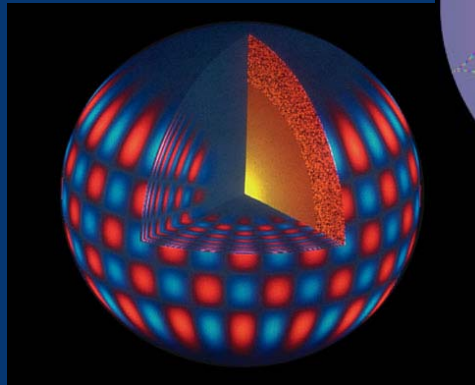


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Pressure Waves



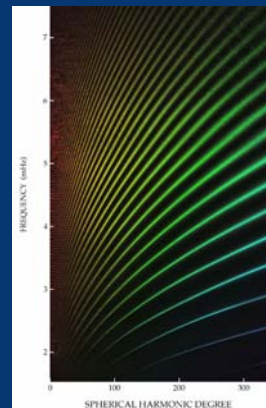
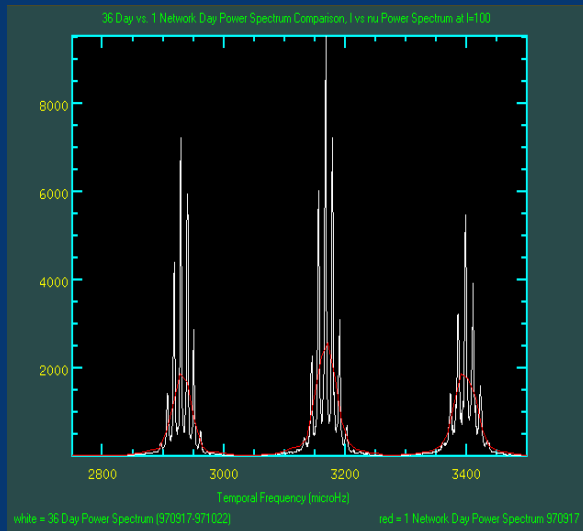
The images on these pages were taken from <http://gong.nso.edu/>.



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Power Spectrum and l, ν -Diagram

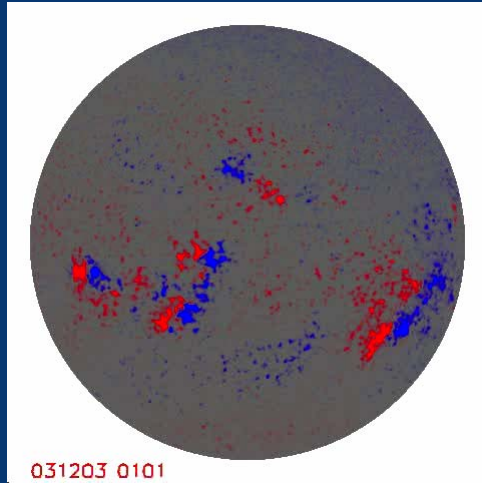


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GONG Magnetogram Movie

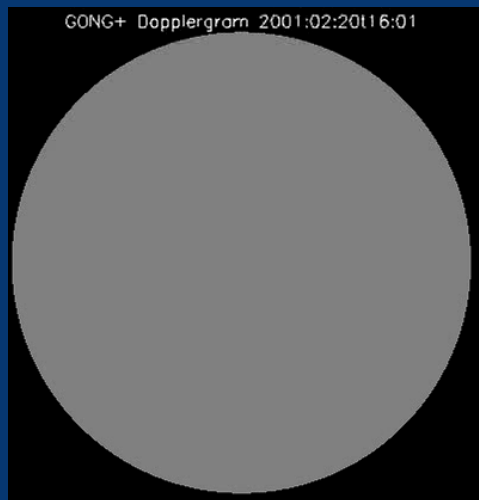


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GONG Dopplergram Movie



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