COUPLED GROUPS OF g-MODES IN A SUN WITH MIXED CORE

by

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ABSTRACT

Groups of linear g-modes can sum to create long-lived nonlinear oscillations in small "hot volumes" very deep in the Sun that help drive the modes. In these volumes (dimensions ~10 Mm), the time average rate of ^{3}He burning doubles as temperature fluctuations exceed 10% and rises by an order of magnitude for fluctuations of 25%. To be consistent with locally large motions, we impose a mixed shell on an otherwise standard solar model before computing g-mode solutions. Mixing in the assumed shell r = $(0.10 \pm 0.03) R_{sun}$ is rapid ($<<10^6$ yr) with slower mixing somewhat beyond. If l is the principal spherical harmonic index, a set of g-modes for any single $l \le 5$ with five consecutive radial harmonics can be excited with nearly linear thermal amplitudes, $A_T \le 0.053$, throughout the star and a fractional temperature fluctuation in its hot volume of $\Delta T/T \le 0.18$. These thresholds for excitation will become smaller when sets for several values of l are computed simultaneously. There is some evidence for the rotation of g-mode sets in the long solar activity record and g-mode upward wave flux has been suggested to explain the 1.3 yr reversing flows tentatively detected below the Sun's convective envelope (CE). The large local amplitudes needed for excitation implies that g-modes may transport a non-negligible fraction of the solar luminosity, yet their near linear amplitudes outside the hot volume suggests amplitudes over most of the solar surface that would be barely detectible for $l > 3$. A formalism is presented for summing the g-modes and estimating growth rates under the approximation that modes are strictly linear except in a hot volume which holds only a few percent of mode kinetic energy. Finally over the range $2 \le l \le 30$, we summed all zonal harmonics, m, for a given l and computed the relative angular orientations that would release the most nuclear energy. This should be close to the physically preferred angular state of such a family and a few examples were displayed.

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POPULAR SUMMARY

The Sun has a large family of oscillations (g-modes) whose energy is concentrated in the central regions where the nuclear fires burn. This gives them great importance since they can modulate the luminous output of the Sun's core. A g-mode has extreme rotational predictability and long lifetime since it engages most of the Sun's mass in an organized motion. But theoreticians could not explain how to excite the many modes that have been detected by their rotation rates. This is because they were computing each mode as though none of the others were there. Wolff and O'Donovan show that, by combining whole families of modes with similar rotation rates, a small but highly nonlinear "hot volume" is created in the Sun's core that releases enough extra nuclear energy to excite the entire family. The large amplitudes in the hot volumes also mix the center of the Sun and will force new computations of solar evolution.