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Using a Microgravity Environment to Probe Wave Turbulence

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The experimental key to observing stochasticity or turbulence in a distribution of interacting propagating waves is (a) the achievement of high amplitude and (b) the use of a medium with a large coefficient of nonlinearity. Our research indicates that capillary waves are the best means of observing this phenomenon, however gravitational modifications of the capillary wave dispersion law greatly reduce (b). Thus we intend to search for wave turbulence in a large drop of fluid that is positioned in a microgravity environment. Capillary waves that run around the surface of the drop will be excited and their power spectrum and higher order correlations will be analyzed for wave turbulence. Our theoretical calculations indicate that modulations of the power spectrum should propagate as second sound waves. These issues have consequences for signal processing and plasma confinement.

Turbulence

- reversible nonlinear processes beat out linear transport.
- Density of states >> nonlinear rollover time

Vortex: $\vec{\nabla} \times \vec{v} \neq 0, \vec{\nabla} \cdot \vec{v} = 0$

- Stirred liquids; Kolmogorov

Wave: Dispersion law

$\vec{v} = \vec{v}' \exp(ik \cdot r - i\omega t)$

- Sound waves
- Surface g waves
- Alfven waves
- Capillary waves
- SAW = Love/Rayleigh waves
- Flexing waves (e.g. gongs)

Wave Turbulence: A. Larraza, P.H. Roberts. Possible experiments being considered by S. Garrett, Gary Williams, M. Barmatz

Note: No controlled lab experiments on either fully developed, wave or vortex turbulence.

POWER SPECTRUM OF SURFACE WAVES IN THE OCEAN DRIVEN BY A STORM

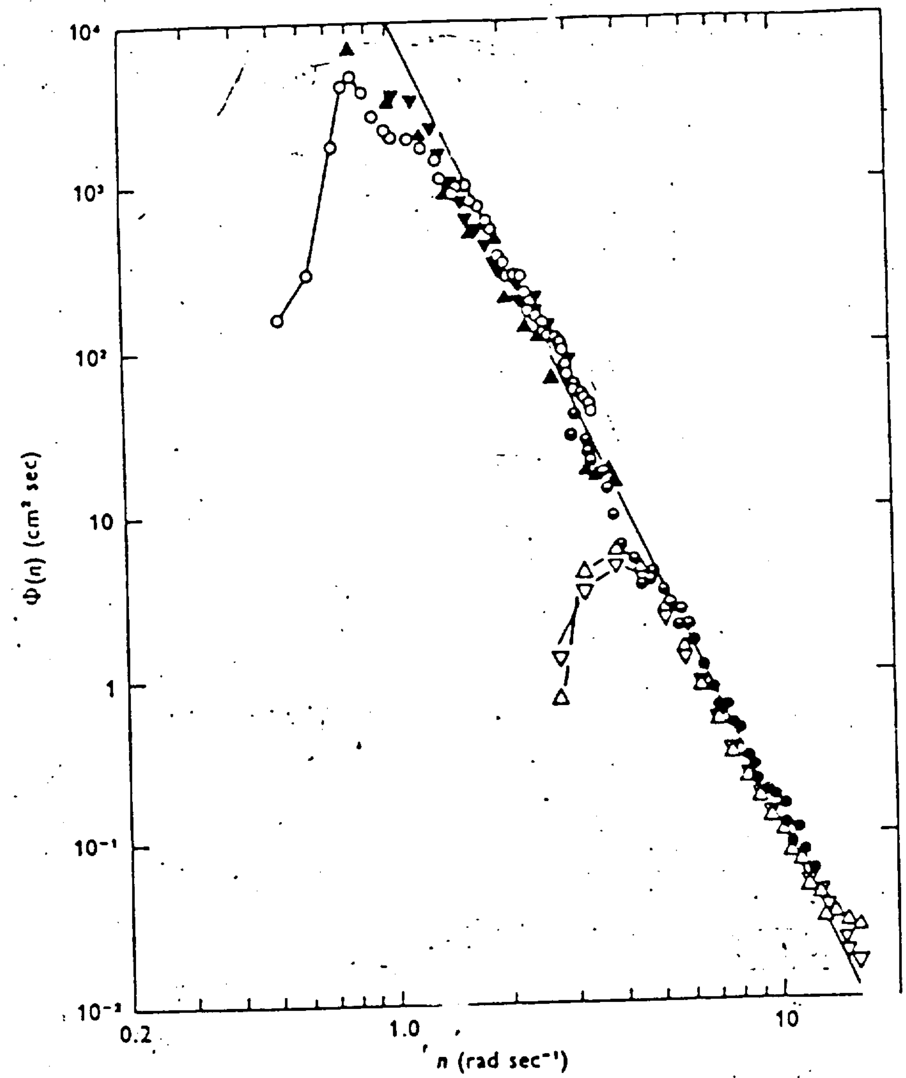


Fig. 4.8. The equilibrium range of the frequency spectrum of wind-generated waves. The logarithmic vertical scale covers six decades. The shape of the spectral peak is included in only three cases; otherwise only the saturated part of each spectrum is shown. Measurements by:

○	Stereo-Wave Observation Project (Pierson, 1962)	Floating wave spar	1 spectrum
▲	Longuet-Higgins *et al.* (1963)	Accelerometer	1 spectrum
▼	DeLeonibus (1963)	Inverted fathometer	Mean of 6 spectra
△	Kinsman (1960) November series	Capacitance probe	Mean of 16
▽	Kinsman (1960), July series	Capacitance probe	Mean of 16
●	Burling (1959)	Capacitance probe	Mean of 11
⊖	Walden (1963)	Probe and cinematograph	1 spectrum

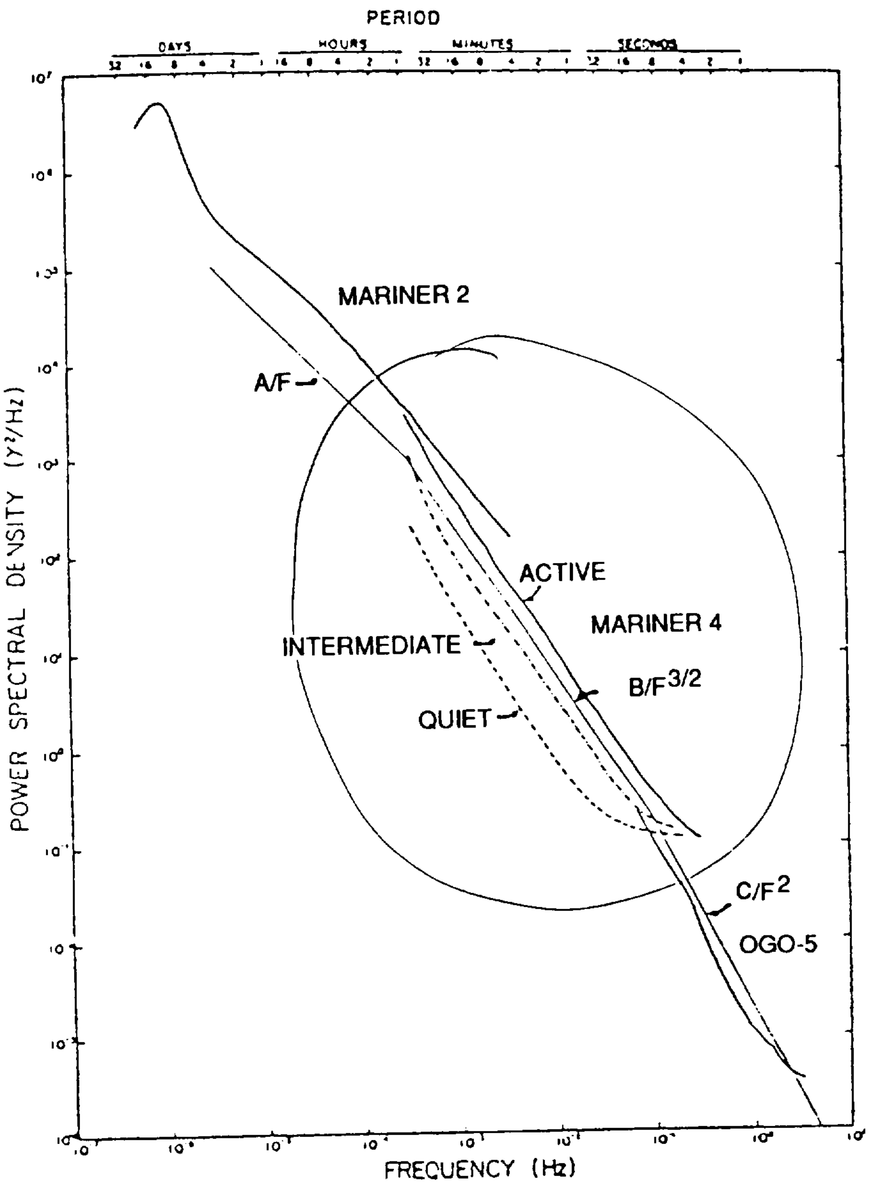


Figure 8. A composite spectrum of the radial component of the interplanetary magnetic field as observed on Mariner 2 [Coleman, 1968], on Mariner 4 [Siscoe et al., 1968], and on OSO - 5. Three spectra illustrating the range of variability of the interplanetary spectrum are shown for Mariner 4. Since the Mariner 2 data are consistently higher than the Mariner 4 data in the overlapping range of frequencies, it is assumed that the Mariner 2 data were obtained during an usually disturbed period of time and the typical spectrum has lower power. Three straight line segments have been drawn with slopes of - 1, - 1.5, - 2 to roughly represent the expected average spectrum near 1 AU.

Capillary Waves

$$\left[\frac{\partial e(\omega)}{\partial y}\right]_+ \approx \frac{G^2\omega^2}{\sigma}[e\omega]^2 + \nu k^2 e(\omega)$$

= rate at which erg/cm^2 leave ω due to nonlinearity and damping

- σ = surface tension
- ν = kinematic viscosity

When nonlinearities dominate

$$e(\omega) \cong \left[\frac{q}{G^2}\right]^{1/2} \frac{1}{\omega^{3/2}}$$

Dispersion Law

$$\omega^2 = gk + \frac{\sigma}{\rho} k^3$$

Quality Factor

$$Q_\omega = \frac{1}{2\nu}\left[\frac{\sigma\lambda}{2\pi\rho}\right]^{1/2}$$

Mach # = ζ/λ ; ζ = displacement amplitude

Turbulence $\Leftrightarrow$

$$M_\omega^2 \gg \frac{1}{Q_\omega G^2}$$

If ν irrelevant then classical system far off equilibrium has 2nd sound

Why low g?

- Spherical drop
- Large drop

  1.mm vs 4. cm.

- Large wavelengths $\Leftrightarrow$

  low damping

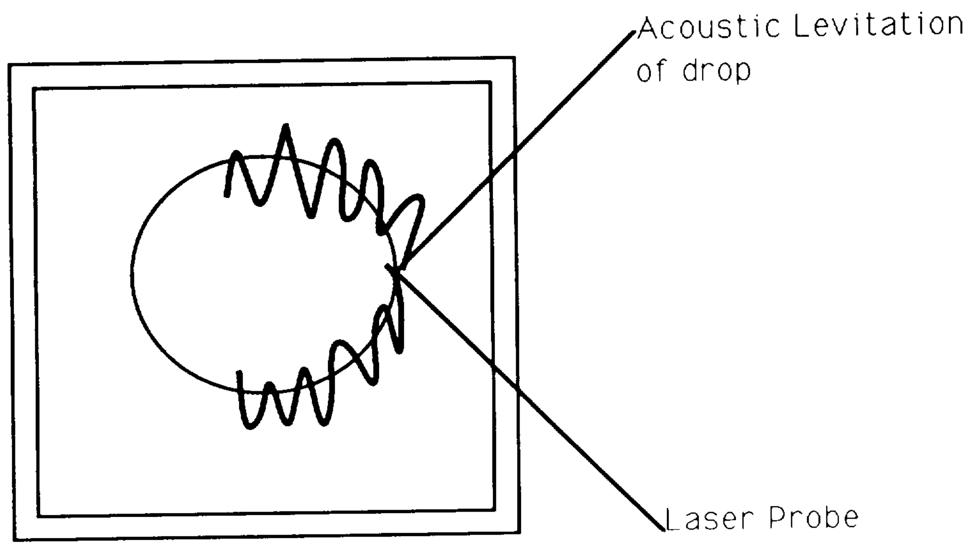
Key requirement $$gk < \frac{\sigma}{\rho} k^3$$

σ	=	surface tension
ρ	=	density
$2\pi / k$	=	wavelength

WHY USE CAPILLARY WAVES TO STUDY TURBULENCE?

USE A DROP:

CLOSED SPHERICAL RESONATOR
LARGE MACH NUMBERS ARE POSSBILE COEFF. OF NONLINIARITY IS HUGE



Why do experiments on wave turbulence?

1	Universal power spectra
2	Higher order correlations
3	Some reasonable theory exists
1+ 2 +3	Signal Processing
4	Transition from weak to strong nonlinear effects
5	Second Sound-elasticity of turbulence - controlled fusion

$$\mathrm{He}^4 \quad \chi \equiv \frac{K}{e} \sim 10^{-4}\,\frac{\mathrm{cm}^2}{\mathrm{sec}} \qquad \text{Normal}$$

$$\chi \equiv \frac{K}{e}\,\frac{d^2c^2}{\nu} \sim 10^{12}\,\frac{\mathrm{cm}^2}{\mathrm{sec}} \qquad \text{2nd Sound}$$

v	=	kinematic viscosity
c	=	geometry
x	=	thermal diffusivity