

Rather, the issue is: Are human beings free or are they the property of the government (or society)? Not just scientists or Jews but every single "citizen" of the Soviet Union. The oppression of a particular group is just a manifestation of the general Soviet policy of the suppression of all individual rights. It is on the basis of this fundamental requirement of freedom that the fight must be waged.

Let us progress beyond the relatively easy task of supporting individual cases and concentrate on the source of the problem, which is the nature of the Soviet system. Here I am not limiting the problem just to the practical aspects of their present system but also include the professed ideals behind that system; the present actuality is the only possible result of those ideals. Sadly, there are many individuals who can serve as example but, as long as the root evil remains, examples will be never ending. The proper response of intellectuals is to undertake the task of persuading the civilized population of the world to apply moral and economic sanctions against the Soviet system until it frees all its "citizens."

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Gravity waves

I should like to add a few comments to Jonathan Logan's well written and informative article, "Gravitational Waves—A Progress Report," (March, page 44). Unfortunately, gravitational-wave receiving antennas, like their electromagnetic counterparts, obviously suffer gross inefficiency when they are small compared to a wavelength of the radiation. In addition to this, the mechanical antennas presently in use seem to be unusually insensitive when we consider that Joseph Weber reported¹ a flux density of about 10^2 ergs/cm² sec or 0.1 watts/m²⁸, only 10^{-4} orders of magnitude less than the solar constant at one AU. This flux density is equivalent to the intensity of ten moons in intensity, a sight that would prove difficult to miss with our large (as compared to a wavelength) eyes. The difficulty with detectors using shear waves is evidently traceable to the gross impedance mismatch, a fact that seems to follow from Freeman Dyson's calculation for the coupling constant.² This mismatch is in sharp contrast to antennas used for the detection of electromagnetic waves.

The level of gravitational-wave power density required to produce even the small, nearly insignificant, space warp of 10^{-16} cm over a distance of 10 meters at a frequency of 1.6 KHz, is a truly amazing 0.1 watts/m². Even more so is the fact that the universe

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may provide us with a source of useful energy in the form of gravitational waves if only some way could be found for their efficient conversion. This energy might prove useful as a source of power for travel in deep space, since the waves may originate in our galactic center. For example, a space ship with $\lambda/4$ gravitational antenna of efficiency equal to that of its electromagnetic counterpart, could extract as much as one megawatt of power from a gravitational-wave train of flux density 10^{-2} watts/ m^2 , which is an order of magnitude less than that reported by Weber.¹ "Captain to engineroom, accelerate the Starship to Warp Six," may not be science fiction forever.³

References

1. J. Weber, Phys. Rev. Lett. 25, 180 (1970).
2. F. J. Dyson, Astrophys. J. 156, 529 (1969).
3. Quote from the television science-fiction series, *Star Trek*.

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THE AUTHOR COMMENTS: Cosmological data (observed rate of expansion of the universe) set an upper limit on the average mass-density of gravitational radiation at all wavelengths of about 10^{-28} g/ cm^3 , or a flux of 10^3 erg/ cm^2sec .

Effective gravitational radiation antennas must be made of very stiff material, so that the driving field will perform maximum work; a sound or shear-wave velocity near c is required. To achieve coupling comparable to the electromagnetic case fabulous densities are required to compensate for the intrinsic weakness of gravitational interaction. (There are some complications in the calculations when the wavelength is comparable to absorber size and when resonant absorption of monochromatic radiation with negligible damping is considered, and there are factors of order unity for antenna geometry, but these are not relevant here.) The material limits dominate the factors due to antenna design.

According to the handbook values, single cubic-crystal diamond is the best available material (around 100 times better than aluminum). Taking the frequency of the radiation (arbitrarily) to be 1 Hz, a million-ton spaceship made of this material could absorb no more than about 10^{-9} ergs/sec or 10^{-16} watts. This would evidently be insufficient to drive the phasors of the starship *Enterprise*.

JONOTHAN LOGAN
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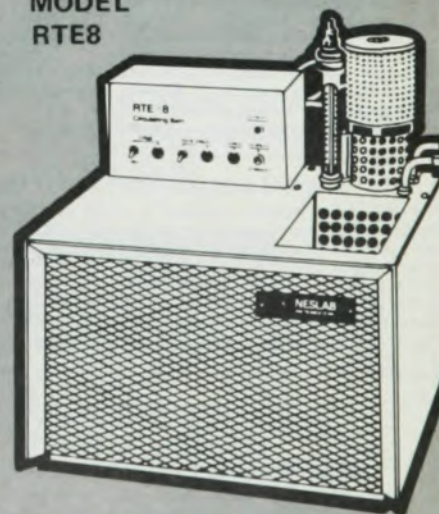
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