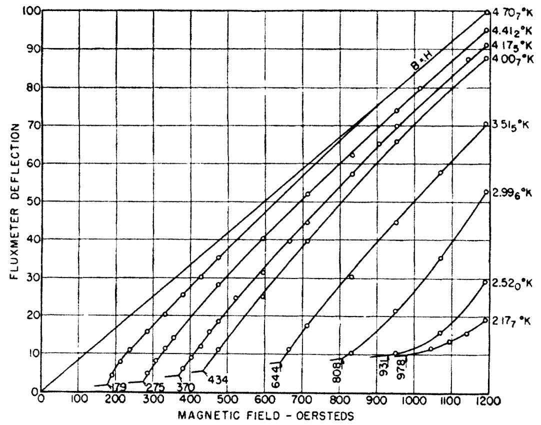

FIG. 1. Magnetic induction of superconductive vanadium.

It appeared to us that for the clarification of the nature of the properties of the hard superconductors the study of the superconductivity of vanadium would be most fruitful. In the first place, the temperature range in which this metal exhibits superconductivity is very convenient from an experimental viewpoint. Secondly, vanadium has a relatively low melting point, a factor which facilitates metallurgical treatment of the metal.

The superconductivity of vanadium, as determined by resistance measurements, was first reported by Meissner and Westerhoff.[4] The recent data of Webber *et al.*[5] gave an initial slope of 4100 oersteds per degree for a particular sample of vanadium.

Through the kindness of Dr. B. W. Gonser of the Battelle Memorial Institute a sample of pure vanadium was made available to us. The magnetic properties of the superconductive material were determined by a method which, in principle, was the same as that used by Keeley and Mendelssohn.[6] A coil of No. 40 copper wire was wrapped around the specimen which was a cylinder 0.070 in. in diameter and 1 in. long. The residual resistivity relative to the ice-point resistivity of a strip rolled from this cylinder was 0.051.

Isothermal measurements were made at each of eight temperatures. These consisted in the determination of a quantity proportional to the integral of the voltage induced in the coil when the field was reduced from a given value to zero. The data are indicated in Fig. 1. For each temperature, the fluxmeter deflection is a linear function of the field until a critical value is reached. These critical values have been assumed to represent the threshold fields at the various temperatures, and have been plotted in Fig. 2. The initial slope of this curve is 400 oersteds per degree; in general the curve is quite similar to that for tantalum on the basis of which Daunt and Mendelssohn have made thermodynamic calculations. From Fig. 1 it is seen that the "Meissner effect" is most pronounced near the critical temperature and that the reversibility becomes much poorer at lower temperatures.

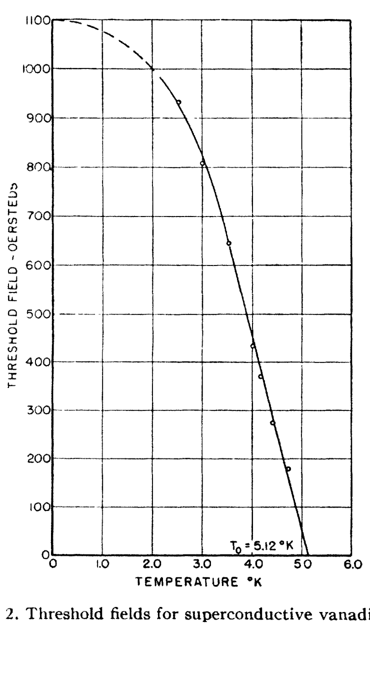

FIG. 2. Threshold fields for superconductive vanadium.

Work is in progress on the factors responsible for the irreversibility associated with the transition and hence the data herein reported are given provisionally.

A detailed account of the experimental methods used and of the effect of metallurgical factors upon the electrical and magnetic properties of superconductive vanadium will be reported in the near future.

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Cosmic Rays as the Source of General Galactic Radio Emission

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THE galactic radio emission is not a thermal free-free radiation of interstellar gas, as was first believed. The electronic temperature would have to be of the order of 100,000° in contradiction to all spectroscopic evidence which gives values around 10,000°. Stars could be considered as sources only under very artificial assumptions. The observed intensities, which must come from the outermost layers of stellar atmospheres, could not be blackbody radiation[1] and might be understood only in terms of coherent plasma oscillations of extended regions. The formation and maintenance of these oscillations is hardly possible in stellar atmospheres.[2]

It will now be shown that the general cosmic radiation of our star system is a high frequency source of sufficient power. In interstellar space, at least inside the interstellar clouds which occupy about 5 percent of space, the mean density of kinetic energy ought to be of the same order as the magnetic-field energy; therefore, fields of around 10^{-6} gauss are to be expected. An energetic electron with energy $W \gg m_0c^2$, which is circulating in this field, is radiating electromagnetic energy into a very narrow cone whose angular aperture is m_0c^2/W in the direction of motion. Therefore, an observer at rest receives very short pulses corresponding to a frequency which is very much higher than the classical Larmor frequency, ν_0. The mean spectral intensity distribution of this radiation will then be[3]

$$P(\nu) \approx (e^2/\pi R)(\nu/\nu_0)^{\frac{1}{3}}$$

for $\nu_0 \ll \nu < \nu_c$, where R is the radius of the electron's circular orbit and $\nu_c = \frac{2}{3}\nu_0(W/m_0c^2)^3$. If n_e is the number of electrons per cm^3 with energy W, the emissivity of high frequency radiation will be

$$\epsilon_\nu \Delta\nu = n_e P(\nu)\Delta\nu = (e^3H/\pi W)n_e(\nu/\nu_0)^{\frac{1}{3}}\Delta\nu \text{ ergs/cm}^3\text{/sec.}$$

This increases steadily with frequency until $\nu = \nu_c$ and then decreases rapidly. The observed distribution[1,4] within the frequency range of 10 to 3000 Mc seems rather to be $\propto \nu^{-0.3}$. We therefore expect to be already in a region with $\nu \geq \nu_c$. Also the involved interstellar magnetic field strengths might vary through space and so influence sensibly the spectral intensity distribution. If the thickness of the emitting layer is D, the intensity of the radiation becomes $I=\epsilon_\nu \Delta\nu D$. Let us suppose that there is one electron per 100 cosmic-ray particles,[5] that is, $n_e \approx 3\times 10^{-11}$ cm^{-3}. If we tentatively put $W=10^8$ ev and $D=1000$ light years (1/100 of the diameter of the galaxy), assuming $\nu=100$ Mc, and $\Delta\nu=10$ Mc, we get a radiation intensity of $I\approx 10^{-11}$ erg/cm^2/sec. This agrees in order of magnitude with the observations of Hey, Parsons, and Philips.[4]

The total radiation loss of an electron moving in a homogeneous magnetic field, H, is

$$-dW/dt=(4\pi/3)\nu_0(e^2/R)(W/m_0c^2)^4 \sim W^3H^2.$$

Since this radiation loss increases so rapidly with energy, electrons with energies greater than about 10^9 ev are not expected. It seems also possible that electrons are eliminated from cosmic rays in the vicinity of stars by collisions with thermal photons.[6] The composition of cosmic rays we observe at the outer boundary of the earth's atmosphere (being close to the sun) is therefore not an average sample of interstellar space.

The general radio emission shows some relation to the visible structure of the galaxy,[4] but does not seem to be directly correlated with stars or other galactic objects. It follows, therefore, that the sources of radio emission are more closely related to the general shape of the galaxy than to its visible components. This conclusion favors Fermi's hypothesis that the distribution of cosmic rays and of galactic matter is more or less the same, cosmic rays being created in interstellar space and not by the stars.

A relation between radio emission and cosmic rays has previously been suggested by Alfvén[7] for the special case of so-called radio stars (discrete centers of strong radio emission). This interesting suggestion, which has stimulated the above analysis, appears to the writer to be in need of re-examination.

I wish to thank Mr. Grote Reber for helpful discussions.

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[5] There must be a certain number of electrons in cosmic rays as a direct consequence of their ionization losses in interstellar space and of electron pair production by encounters of protons and thermal starlight photons. Also there is some indication of the existence of electrons in the primary radiation given by direct measurements (B. Rossi, Rev. Mod. Phys. **21**, 104 (1949)) and by the east-west asymmetry (L. Jánossy, *Cosmic Rays* (Oxford University Press, London, 1948)).
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Ferromagnetic Block

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THE theory of ferromagnetic domains has recently been ably discussed,[1] and it is now commonly accepted that a region in which the electron magnetic moments responsible for ferromagnetism are collectively constrained to be nearly parallel is not, in general, homogeneous in all other respects.

Depending upon conditions during crystallization and upon mechanical, thermal, and magnetic treatments thereafter, a single domain in a technically unsaturated specimen may contain many crystals, may be part of one crystal, or may be a temporary coalition of whole crystals and parts of crystals. A single domain boundary may therefore be a crystal boundary in part and may elsewhere be determined by defects in homogeneity within what is ordinarily called a crystal.

The tendency of real crystals[2] to be inhomogeneous, and to constitute so-called mosaics,[3] or lineages[4] of more nearly homogeneous structure, is now very well known, and explains how a domain boundary, in its progress through a crystal after a change in applied field or stress, may be temporarily stopped before a whole crystal has been added to the expanding domain.

The stepwise motion of a domain boundary, the Barkhausen phenomenon, can thus proceed by steps that are individually less than the linear dimensions of whole domains, and this is easier the larger the domains. In a stretched or bent polycrystalline wire, for example, the stable domains may be large fractions of the whole volume, and still the analysis of a jump in their average magnetization will disclose the transfer of very small regions from one domain to another.

These facts have led to some confusion in describing the processes occurring along technical magnetization curves. Thus, authors have estimated "domain" size from data on changes in domain size rather than by more direct means, such as powder patterns, which locate domain boundaries at rest positions. Such confusion would be less likely if a separate term could be used for a region which can be transferred continuously, quickly, and spontaneously, from one domain to another, when the potential barrier to the initiation of the transfer has been surmounted or penetrated. As already suggested, such a region may not, in many cases, be capable of existence as a stable isolated domain, so that it should not be so labeled.

The name suggested for this structural unit of the ferromagnetic domain is "ferromagnetic block." The boundaries of a ferromagnetic block are the surfaces at which local inhomogeneities can stop the migration of a domain boundary under appropriate conditions. This confines a block to a single crystal and usually to a part of a single crystal, whereas a domain is not so limited. It is also clear that domain boundaries are predominantly also block boundaries, but that the converse statement is not valid. In actual changes in magnetization, the transfer of a block is sudden only for particular directions of motion of domain boundaries across it, those directions in which the block has its stable directions of magnetization. In microcrystalline powders, of course, there are still blocks, even when no volume large enough to form a domain can be found.

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Debye Modes and Superconductivity

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RANDOMNESS is an essential characteristic of thermal motion that is omitted from conventional discussions of the modes of vibration of a crystalline solid. Randomness can be taken care of if we include a proper statement concerning the phases of the Debye modes. A complete analysis of the state of motion of the lattice is possible only in terms of boundary conditions at the surface of the crystal. Under thermal bath conditions the boundary of the crystal is subject to random changes due to thermal fluctuations in the bath. An ideal single crystal of finite size is not subject to definable stationary boundary conditions and therefore the phases of the normal modes are not determinable, being necessarily subject to random changes in the course of time.

If we resolve any stationary mode into two progressive waves, there will exist an effective free path during which no phase change will occur. This free path defines a domain magnitude within which the modes are coherent in phase, while between neighboring domains their phases are incoherent. A positive sur-