

RESEARCH FACILITIES AND PROGRAMS

The black-body universe—spectrum extended

Studies of the absorption spectrum of interstellar CN molecules and of radio waves at 20.7-cm wavelength seem to add more evidence that the universe is full of 3°K black-body radiation left over from a primeval fireball. The first two points that fit the 3° spectrum were measured directly from radio emanations by Arno A. Penzias and Robert W. Wilson, who looked at 7.5-cm wavelength, and P. G. Roll and D. T. Wilkinson, who recorded at 3.2 cm (see *PHYSICS TODAY*, April 1966, page 60). The CN work was done by George B. Field working with John L. Hitchcock [*Phys. Rev. Letters* 16, 817 (1966)] and by Patrick Thaddeus working with John F. Clauser [*Phys. Rev. Letters* 16, 819 (1966)]. It yields a point of the spectrum at about 2.6 mm. The 20.7-cm radio observations were done by T. F. Howell and J. R. Shakeshaft [*Nature* 210, 1318 (1966)].

CN work. Whereas the measurements at centimeter wavelengths record the black-body radiation directly, the CN observations are indirect. Deductions from optical spectra lead to the conclusion that the interstellar CN has a rotational temperature of about 3°K . This excitation could be produced by a flux of radiation at 2.6 mm, and after rejecting other heating mechanisms (with a cautionary note regarding one of them), the four authors conclude that such radiation is most likely to be responsible.

The measurements were done on spectra of the stars ζ Ophiuchi and ζ Persei (the latter by Field and Hitchcock only), in which appear CN absorption lines at 387.46 nanometers and at 387.40 nm. These lines represent electronic transitions in the CN molecules, and if the lines are unsaturated, the rotational temperature of the CN can be found directly from the ratio of their intensities. The temperature comes out to be $3.75 \pm 0.50^\circ\text{K}$ (ζ Oph, Thaddeus and Clauser), $3.22 \pm 0.15^\circ\text{K}$ (ζ Oph, Field

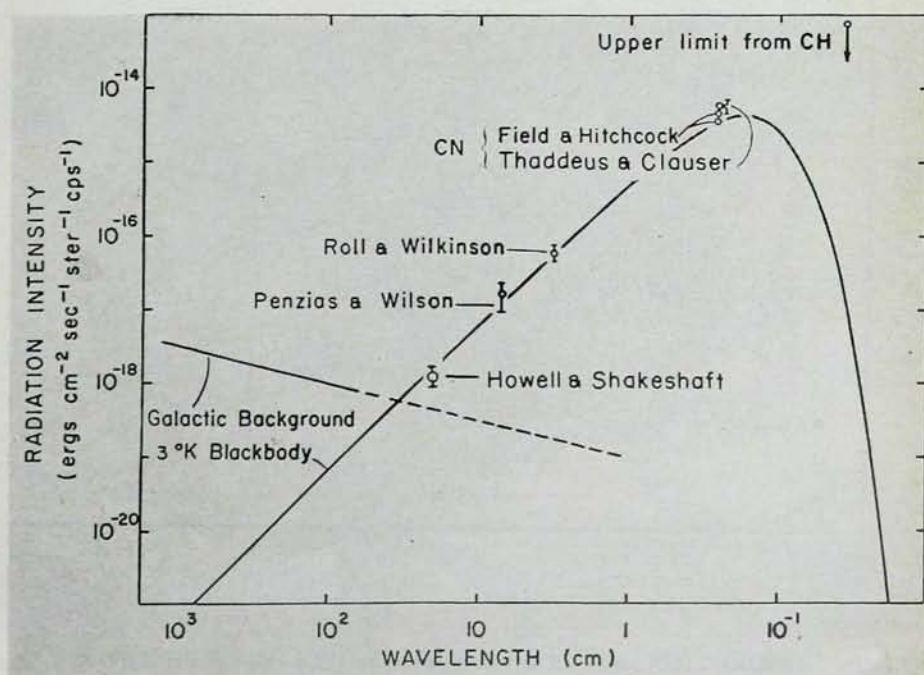
and Hitchcock) or $3.0 \pm 0.6^\circ\text{K}$ (ζ Pers, Field and Hitchcock).

Both pairs of authors consider other possible means of heating the CN, such as fluorescence, electron collisions and proton collisions. Only the proton collisions seem to be a serious alternate to absorption of 2.6-mm radiation since all the other means would be too weak. (Radiation from sources other than a cosmic black-body background is rejected for the same reason.) Thaddeus and Clauser give a strong warning that proton collisions may be the cause of excitation although their presence in sufficient numbers would require the CN to be in an anomalous region of space (filled with ionized hydrogen). Field and Hitchcock acknowledge the possibility of proton excitation, but consider the anomaly much less likely since equal density in the hypothetical ionized clouds would be required in ζ Oph and ζ Pers. Their final sentence runs: "The present measurements therefore

verify the black-body nature of the spectrum over a 28:1 wavelength interval, extending close to the black-body maximum at 1-mm wavelength."

20.7-cm. Howell and Shakeshaft's measurement (at a wavelength nearly one hundred times that of the CN observations) falls at the opposite end of the black-body spectrum, very nearly at the point where galactic radiation becomes stronger than the putative black body. Their procedure (similar to that at the shorter centimeter wavelengths) was to use a Dicke type radiometer to view the sky at the zenith between right ascensions 0930 and 1200 hours where galactic radio emission is a minimum. The experiment was done at night to avoid solar interference.

The effective antenna temperature came out to $6.8 \pm 0.3^\circ\text{K}$, a figure that includes galactic radiation, atmospheric emission, ground radiation, and losses in the horn, waveguide and coaxial transition along with cosmic background, if any. Of the subtractions necessary to find the cosmic



COSMIC BLACK-BODY SPECTRUM. Solid curve represents a 3°K blackbody. The six experimentally determined points

between 20.7 cm (at left) and 2.6 mm (at right) can be seen to fit the black-body spectrum very closely.

background, only the atmospheric absorption and emission represented a theoretical uncertainty. One could use either a theory by J. H. Van Vleck and Victor F. Weisskopf or a theory put forward by K. S. Stankevich of the USSR. The Stankevich theory gives a figure for absorption that would almost eliminate the effect of the cosmic black body. There is experimental evidence at short wavelengths to support the Van Vleck-Weisskopf theory, but at the same time certain evidence at long wavelengths seems to support Stankevich. Howell and Shakeshaft reject the Stankevich the-

ory on grounds both of other long-wave evidence (which supports Van Vleck and Weisskopf) and of arguments that the mechanism proposed by Stankevich could not be significant at the relevant pressures.

When all the subtractions are made, the temperature of the cosmic background contribution comes to $2.8 \pm 0.6^\circ\text{K}$. Taking into account all previous determinations, Howell and Shakeshaft conclude that there is excellent agreement over a range of 80:1, "thus providing very strong evidence that the radiation has a black-body spectrum."—DET

Photons from synchrotrons for solid-state and atomic physics

Electron synchrotron radiation is being explored as a continuum-radiation source of high intensity and polarization in the far-infrared, far-ultraviolet and soft x-ray regions. With existing accelerators, one can obtain kilowatts of total radiation. Already, at the National Bureau of Standards, synchrotron far-ultraviolet radiation is disclosing hundreds of new resonances in rare-gas spectra. And

synchrotron radiation sources may prove valuable for solid-state spectroscopy as well.

A committee on synchrotron radiation sources for solid-state spectroscopy evaluated their potentialities in a report written last spring. The committee (Frederick C. Brown, chairman, P. L. Hartman, P. Gerald Kruger, Benjamin Lax, R. A. Smith and George H. Vineyard) was convened

by the solid-state physics panel of the National Academy of Sciences—National Research Council.

Electrons traveling in a circular orbit through a magnetic field radiate energy at a continuum of frequencies. One can control the peak wavelength by varying energy or using a synchrotron with a different orbital diameter. The radiation is highly polarized and confined to a narrow cone.

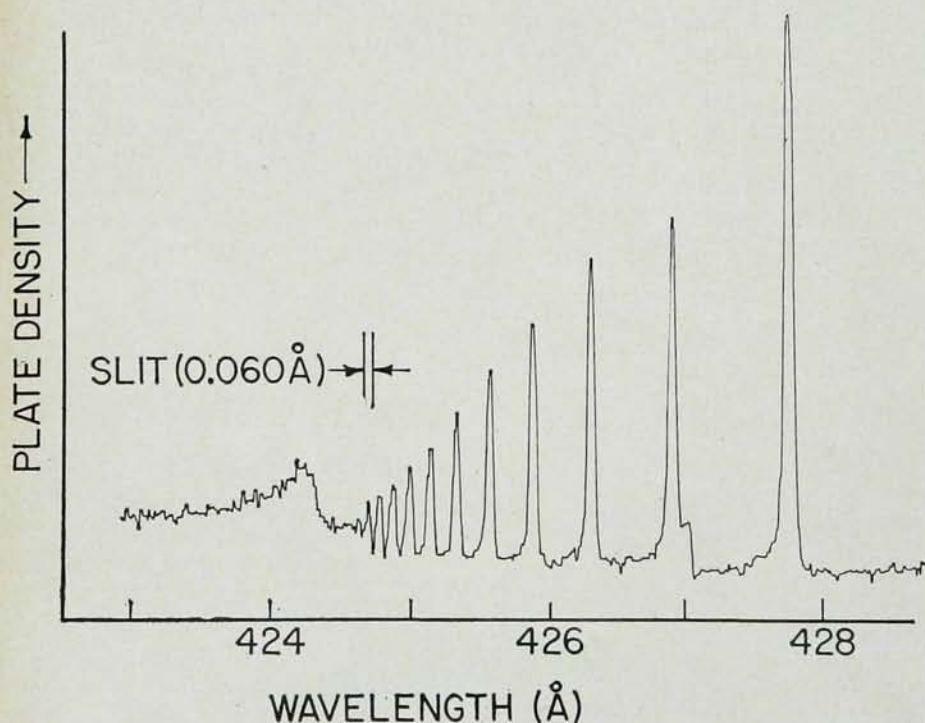
In high magnetic fields, of 100 kG or so, 100-MeV electrons are extremely efficient radiators in the far ultraviolet and are also a good source of infrared radiation, the report notes. By using a high-current storage-ring system, the total radiated power in the far ultraviolet would surpass existing sources by several orders of magnitude; this would make ultraviolet-spectroscopic resolution as good as that available in the visible region.

Far-infrared synchrotron-radiation sources would also be useful, the report comments, but their power output does not justify construction of an expensive machine expressly for the purpose (especially since gas lasers and parametric-amplifier devices are rapidly being developed as excellent infrared sources).

Storage rings. The least expensive way to get intense synchrotron radiation, according to the report, is to inject electrons into a storage ring from a relatively simple source, use these electrons for their lifetime (possibly many minutes) and then refill the ring. The more or less constant synchrotron radiation losses can be made up by an rf cavity in the storage ring.

Midwest Universities Research Association, at Stoughton, Wisconsin, hopes this fall to start operating a storage ring with one to possibly ten amperes of 250-MeV electrons, thus producing the highest currently available storage-ring current.

If the MURA ring works as expected, it could become a good tool for solid-state experiments, the report says. Using a light-exit port already available, along with a grazing incidence spectrometer designed for ultrahigh vacuum, one could make a monochromator system able to isolate a band of wavelengths at 10 nanometers or any other usable wavelengths.



ARGON ABSORPTION SPECTRUM. Densitometer trace of photographic plate obtained with 3-m spectrograph of 0.006-nm resolution. Note direction of increasing plate density. This series of res-

onances in the photoionization continuum of Ar has appearance of a series of emission lines. It is, in fact, a series of window-type resonances showing discrete lacks of absorption.