possible by visual observations. Conventional optical measurements are limited in accuracy, by variations in refraction by the atmosphere, to a resolution of about 0.4 sec of arc. 18-cm microwave radiation is not affected so much by atmospheric refraction, and we have seen that 0.02 sec of arc resolution is possible. The OH emitters like W3, and some of the quasars are of sufficiently small size to be good fiducial marks for measurements of the length of the day. The improvement in accuracy should be from 5 msec to less than 0.25 msec. The earth's rotational period varies with regular annual, semiannual, monthly, fortnightly, daily and semidaily components, plus irregular variations. The increased accuracy of radio interferometers would lead to better measurements of short-term fluctuations that in turn would give information on the tidal motion of the earth's solid mantle and on fluid motion within the atmosphere, oceans and core.

Maser? Many of the puzzling features of the hydroxyl emission and absorption have been tentatively explained as arising from a natural maser action in interstellar space. The high-intensity, narrow-bandwidth lines could arise from maser amplification, and the apparent small size of the OH sources could be due to coherent, parallel emission from a region that is very much larger. The problem is to devise a mechanism by which the excited states are "pumped" to produce the population inversion that is necessary before stimulated emission can occur. Radiation pumping by the ultraviolet continuum from hot HII regions has been suggested, but Philip Solomon of Columbia University believes that if his guess for the hydroxyl internuclear potential-energy curves is right this radiation would dissociate the molecule. Solomon's alternative theory is based on a form of chemical pumping arising from formation of the molecule by pre-association, or in more familiar language, inverse pre-dissociation: $O + H \rightarrow OH^*$. The kinetic energy of the atoms all goes into excitation of the molecule. Solomon says that when the electronically excited state decays to the ground state, a population inversion of the Λ-doublet results that would give maser action. The hydroxyl radical is destroyed by collisions with atomic hydrogen: $OH + H \rightarrow H_2 + O$. Solomon has calculated the equilibrium concentration of OH from these two processes, and his value of 10^{-7} for the OH/H abundance ratio is in good agreement with the absorption measurements.

Another explanation of the OH emission anomalies that has been advanced—perhaps with tongue firmly located in cheek—is that someone "out there" is trying to speak to us. The properties desired in an interstellar communication network are all here; the signals are of good intensity, narrow bandwidth, they fluctuate in an apparently random manner and originate from a small region in space. Perhaps the intensity anomalies in the four OH lines have been deliberately introduced to draw attention to them!

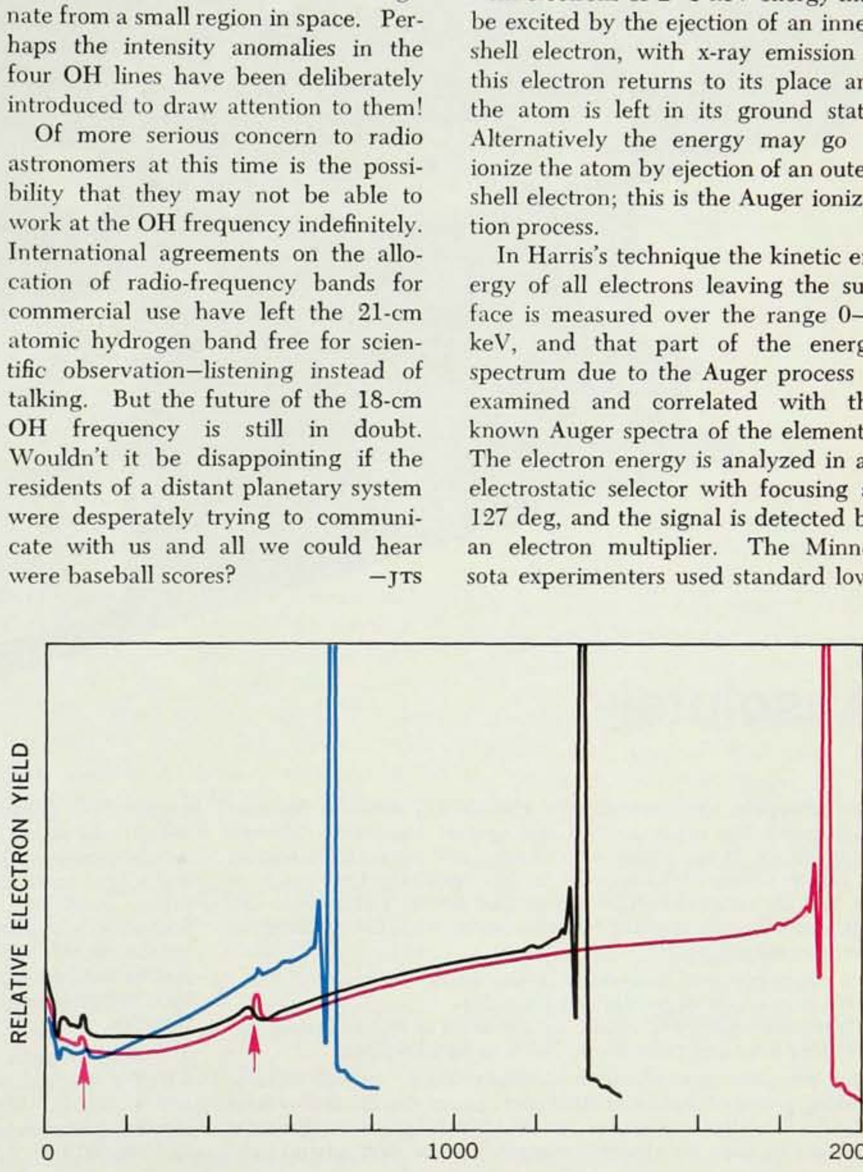
Of more serious concern to radio astronomers at this time is the possibility that they may not be able to work at the OH frequency indefinitely. International agreements on the allocation of radio-frequency bands for commercial use have left the 21-cm atomic hydrogen band free for scientific observation—listening instead of talking. But the future of the 18-cm OH frequency is still in doubt. Wouldn't it be disappointing if the residents of a distant planetary system were desperately trying to communicate with us and all we could hear were baseball scores? —JTS

Auger Electron Emission Can Identify Surface Impurities

Auger electron emission can be used to detect and identify contaminants on solid surfaces, with some advantages over the customary x-ray method. Lawrence Harris, of the G. E. Research Center at Schenectady, developed the technique, and at the University of Minnesota Roland Weber and William Peria demonstrated that 1% of a monolayer of cesium can be detected on substrates of either germanium or silicon.

The atoms of a specimen bombarded with electrons of 2–3 keV energy may be excited by the ejection of an inner-shell electron, with x-ray emission if this electron returns to its place and the atom is left in its ground state. Alternatively the energy may go to ionize the atom by ejection of an outer-shell electron; this is the Auger ionization process.

In Harris's technique the kinetic energy of all electrons leaving the surface is measured over the range 0–2 keV, and that part of the energy spectrum due to the Auger process is examined and correlated with the known Auger spectra of the elements. The electron energy is analyzed in an electrostatic selector with focusing at 127 deg, and the signal is detected by an electron multiplier. The Minnesota experimenters used standard low-



ENERGY DISTRIBUTION OF AUGER ELECTRONS emitted from pure beryllium bombarded with 695-eV (blue), 1310-eV (black) and 1910-eV (red) electrons. The two vertical arrows show Auger levels.

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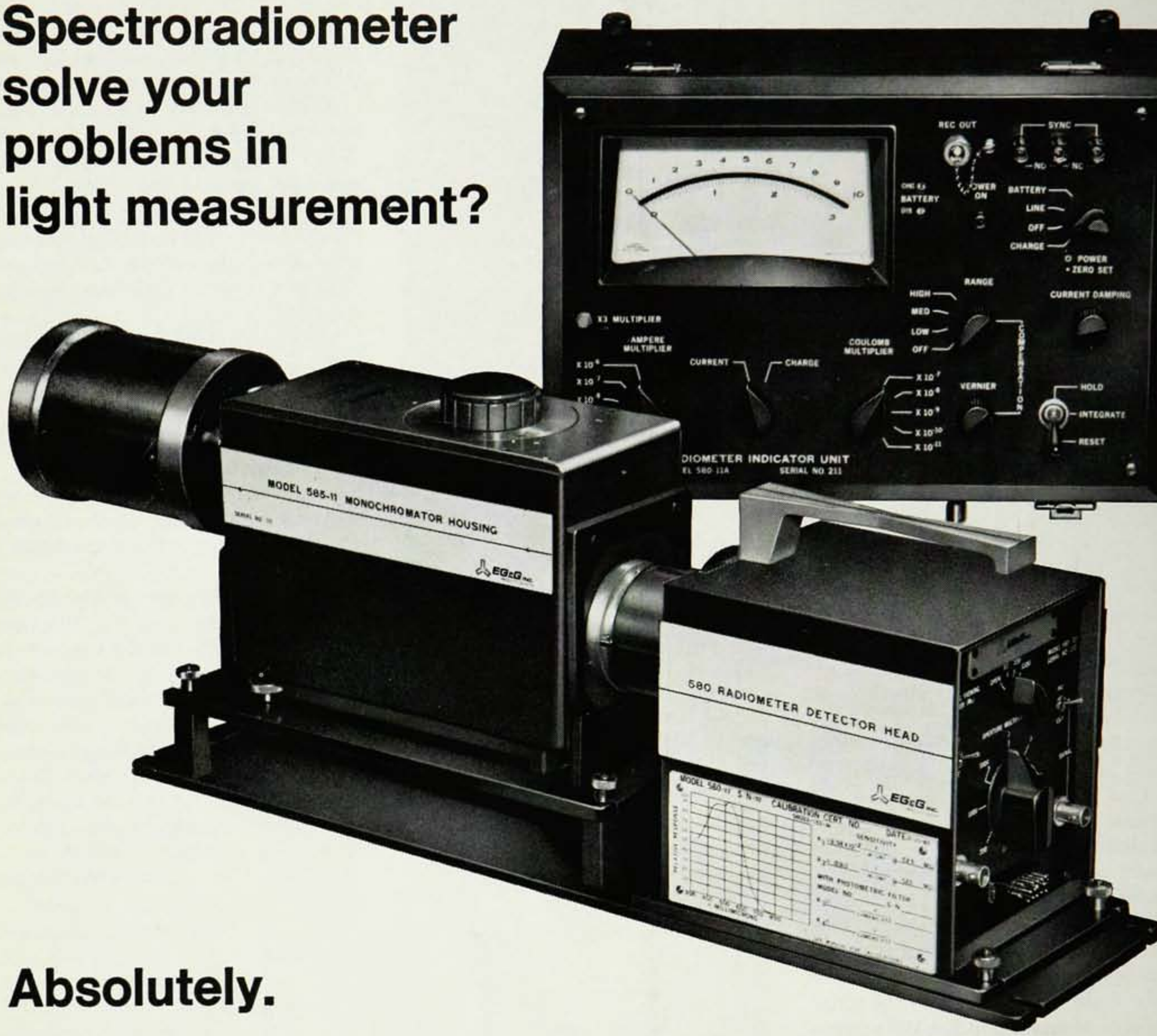

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- Integrated energy of pulsed light sources as fast as 1 nsec
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The complete system, with detector head, monochromator grating, and input optics, is calibrated against standards traceable to NBS. The detector head is also calibrated as a basic radiometer and can be used for absolute measurement of narrowband light sources. The system operates on a 110v line for laboratory applications and on an internal, rechargeable battery for field use. A unique compensation system negates the effects of ambient light and allows most measurements to be made under normal laboratory conditions. In addition, a new wavelength transducer accessory is available to complement the new Y-axis recorder output of the indicator unit. This new accessory provides an X-axis recorder output allowing a complete X-Y plot of amplitude vs. wavelength to be plotted directly on a standard X-Y recorder.

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energy electron diffraction (LEED) apparatus.

Auger emission is not the only process producing secondary electrons at the surface, as can be seen in the figure, which shows curves for 1910-, 1310- and 695-eV electrons incident on pure beryllium. The major process, elastic scattering with little or no loss of energy, yields the very big peaks, which are useful in defining the energy scale of the spectrum. Reflection with energy loss caused by plasma oscillations of valence electrons in the crystalline solid gives rise to peaks that appear at characteristic energies below each large peak. Auger emission can be easily identified as the peaks show up at energies that depend only on the material being studied and not on the bombarding energy.

In this way the presence of surface contaminants introduced on silicon and germanium has been confirmed, and sulfur has been detected on the surface of nickel samples at a bulk concentration of less than 10 ppm. Conventional x-ray analysis becomes more difficult with light elements because there is a decrease in x-ray fluorescence compared with heavier ones. This decrease is due to a parallel increase in Auger emission, and Harris's method is superior to x-ray analysis for these lighter elements, from lithium to oxygen. The apparatus is claimed to be both simpler and cheaper than the equivalent x-ray spectrometer.

New CP-Violation Experiments Reported: Theory Still in Doubt

Since the discovery three years ago (by James Christenson, James Cronin, Val Fitch and Rene Turlay) that the product of the charge conjugation operator (C) and the parity operator (P) is not conserved in the weak interaction, particle physicists have been trying to find out how and why this occurs. The latest experiments on the decay of the K_2^0 meson, reported in *Phys. Rev. Letters,* 23 Oct., seem to show a charge asymmetry in the leptonic decay of K_2^0.

In an experiment at the Brookhaven AGS Jack Steinberger and his collaborators (Sheldon Bennett, David Nygren, Harry Saal and John Sunderland of Columbia University) found the decay rate of $K_2^0 \rightarrow \pi^- + e^+ + \nu$ was a trifle larger than that of $K_2^0 \rightarrow \pi^+ + e^- + \nu$. The difference between the two rates divided by the sum of the two rates was $(2.24 \pm 0.36) \times 10^{-3}$.

In an experiment at the Stanford Linear Accelerator Melvin Schwartz and his collaborators (D. Dorfan, J. Enstrom, D. Raymond and S. Wojcicki of Stanford University and D. H. Miller and M. Paciotti of the University of California, Berkeley) the decay rate of $K_2^0 \rightarrow \pi^- + \mu^+ + \nu$ was somewhat larger than $K_2^0 \rightarrow \pi^+ + \mu^- + \nu$. The same ratio in this case was $(4.05 \pm 1.3) \times 10^{-3}$.

The Steinberger and Schwartz experiments are the last in a series of experiments to complete the phenomenological description of CP violation in K-meson decay. As a noted theorist told PHYSICS TODAY, "In a certain sense the experimental physicist has now delivered the theorist the finished product, and the theorist must formulate a behind-the-scenes theory to explain it."

After CP violation was uncovered in K_2^0 decay, people started looking for violations in other weak decays, such as that of the lambda or sigma. None have been found so far. Many theories have been advanced, but they were necessarily speculative since details of the K_2^0 decay were largely unknown.

One such theory, proposed by Jeremy Bernstein, Gerald Feinberg and T. D. Lee, says that the electromagnetic interaction strongly violates both C and T (time reversal) invariance, and this shows up as a small CP violation in K_2^0 decay. The theory suggests that the neutron has an electric dipole moment. Both Norman Ramsey and Clifford Shull recently reported their attempts to find such an electric dipole moment, but within experimental error the value was zero (PHYSICS TODAY, Sept., page 64). The theory, however, may still be viable.

Neutral K mesons exist in two states: K^0 with positive strangeness and $\bar{K}^0$ with negative strangeness. In decays, however, one sees K_1^0 (short lived) and K_2^0 (long lived). Until the Christenson experiment it was believed that K_2^0 was a 1:1 mixture of K^0 and $\bar{K}^0$. The experiment found that a decay forbidden by CP invariance, namely $K_2^0 \rightarrow \pi^+ + \pi^-$, did in fact occur, but only weakly. This meant that K_2^0 was actually some more complicated mixture of K^0 and $\bar{K}^0$, but the deviation from 1:1 was not known.

Phenomenology. Shortly afterward C. N. Yang and T. T. Wu developed a phenomenological framework for describing the CP-violating decay. A parameter ϵ describes the composition of K_1^0 and K_2^0 in terms of K^0 and $\bar{K}^0$; ϵ measures the extent to which K_2^0 is not an eigenstate of CP. Two other parameters η_{+-} and η_{00} measure relative decay rates. $|\eta_{+-}|^2$ is the ratio of the probability for $K_2^0 \rightarrow \pi^+ + \pi^-$ to the probability for $K_1^0 \rightarrow \pi^+ + \pi^-$. $|\eta_{00}|^2$ is the same ratio, except that it is for decays into two neutral pions. If CP violation were due only to the composition of K_2^0 then $\eta_{+-} = \eta_{00}$.

The Christenson experiment determined $|\eta_{+-}|$ but not its phase. Then the phase of η_{+-} was determined in experiments by Val Fitch and his collaborators at the Princeton-Pennsylvania Accelerator, by Carlo Rubbia, Steinberger and others at CERN, and by M. Bott-Bodenhausen and collaborators at CERN.

Late last year Jean-Marc Gaillard, E. Manning and collaborators at CERN and James Cronin and collaborators at PPA (PHYSICS TODAY, March 1967, page 83) determined $|\eta_{00}|$.

The Schwartz and Steinberger experiments determine the phase of η_{00} and $|\epsilon|$. The phase of ϵ was previously known quite accurately from theory; so now all the Yang-Wu parameters are available for ambitious theorists.

The experiments of Cronin and Gaillard also showed that $|\eta_{00}| \neq |\eta_{+-}|$; that is, the structure of K_2^0 is not the sole cause of CP violation.

It has been known for almost ten years that in strangeness-changing weak interactions the $\Delta I = 1/2$ rule works pretty well; that is, the change in isotopic spin I during a reaction is at most $1/2$. But even then particle physicists knew that although $\Delta I = 1/2$ decay is dominant, there is some $\Delta I \neq 1/2$ behavior.

Two effects. Thus it now appears that the CP violation in the weak decay of K_2^0 occurs from two effects: (1) K_2^0 and K_1^0 are made up of a peculiar combination of K^0 and $\bar{K}^0$. (2) There is a $\Delta I > 1/2$ weak interaction in the decay of K_2^0 into two