LETTERS TO THE EDITOR

ASTROPHYSICS

Strength of Cosmic Radio Sources

THE discovery of quasi-stellar objects has brought with it the realization that bremsstrahlung radiation in the radio wave region as generated in a plasma has not been properly understood. The present communication represents an effort to account for the unusually high levels of radio emission from quasars and to explain, in particular, the spectral output from the sub-structures A and B of $3C$-273.

It was suggested earlier[1] that the intense radio-wave emission from quasi-stellar bodies might be explained in terms of radiation from tenuous plasmas. Subsequent calculations[2] based on a stimulated bremsstrahlung mechanism in optically thin plasmas revealed that for $3C$-273 B a self-consistent model confirming the Hubble law deduced location of the source (in the megaparsecs range) could be obtained. Indeed, the flat spectral power output in the neighbourhood of 10^3 Mc/s was reproduced.

The problem remained, however, to account for the power spectrum of $3C$-273 A, the spectral index of which $(-0 \cdot 9)$ had prompted speculation[3] that a synchrotron mechanism was indicated, although it was rather doubtful that sufficiently adequate magnetic fields were present; in point of fact, there was no evidence of strongly polarized radio waves from this portion of $3C$-273.

The following rational explanation is offered as a unified theory not only for parts A and B of $3C$-273 and quasars generally, but possibly for radio galaxies as well. Suppose the number of ions and electrons in a fixed volume be augmented. The power will at first grow as more and more free transition occurs; but soon the inverse bremsstrahlung will tend to cut down the radiative transfer to the surface of the plasma as the black-body limit is approached. In other words, a maximum output of bremsstrahlung radiation prevails at some intermediate plasma density. Presumably part B of $3C$-273 at $n = 10/\text{cm}^3$ lies close to this point with a small optical depth in effect, whereas part A at $n = 10^7/\text{cm}^3$ manifests a larger optical depth, so that self-absorption gives rise to a fall-off of radio power at higher frequencies.

Galaxies at still higher densities are further from the optimum region and are then characterized by varying degrees of power drop-off at high frequencies. Combining this aspect with the fact that quasi-stellar sources have lower temperatures (10^4 °K compared with 10^5 °K or greater), the enhancement factor m_0c^2/kT for the latter provides added cause for quasars to emit proportionately larger amounts of radio waves. In essence, then, the combination of stimulated emission and low opacity for a plasma can give rise to unexpectedly large quantities of emitted electromagnetic radiation, particularly in the longer wave-length region of the spectrum.

It is not surprising that very dense, hot plasmas are notoriously poor sources of steady radio emission. The Sun, for example, exhibits low levels of steady thermal radiation.

The effect of optimal density plasmas should be looked for in the laboratory and more systematically investigated. Theoretical effort is being directed toward characterizing the build-up of radiated power from a plasma as the carrier density runs the gamut from the low- to the high-density region.

This work was supported in part by a grant from the National Aeronautics and Space Administration and is based on a Sigma Xi address delivered at Fordham University on December 15, 1965.

LOUIS GOLD

Department of Physics,
Stevens Institute of Technology,
Hoboken, New Jersey.

[1] Gold, L., and Moffat, J. W., *Phys. Letters*, **9**, 138 (1964).
[2] Gold, L., and Moffat, J. W., unpublished report presented at American Physical Society, Washington, D.C., April, 1964.
[3] Greenstein, J. L., and Schmidt, M., *Astrophys. J.*, **140**, 1 (1964).

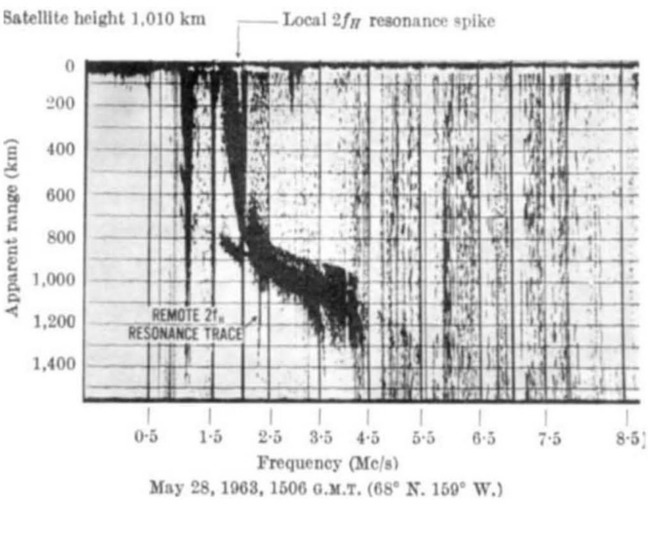
GEOPHYSICS

Remote Cyclotron Resonance Phenomenon observed by the *Alouette* Satellite

A NOVEL cyclotron resonance phenomenon associated with the second harmonic of the electron gyrofrequency $2f_H$ is sometimes observed on *Alouette* topside ionograms. The phenomenon occurs remote from the satellite and will consequently be called the 'remote resonance'. The cyclotron resonances which occur in the vicinity of the satellite, and which are responsible for the cyclotron spikes, have been discussed by previous authors[1,2].

A topside ionogram showing the trace produced by the remote resonance ('resonance trace') is presented in Fig. 1. The presence of substantial range-spreading of the echoes, commonly known as 'spread F', tends to obscure some of the features on this ionogram; for clarity, a somewhat idealized schematic diagram of this same ionogram is presented in Fig. 2. In Fig. 1 the lowest observed frequency of the resonance trace occurs at a delay time corresponding to an apparent range of about 1,450 km. At slightly higher frequencies it appears at rapidly decreasing range and subsequently joins the extraordinary wave trace. The frequency at which the resonance trace meets the extraordinary reflexion trace is defined as the 'cut-off frequency' f_c (see Fig. 2). The second harmonic cyclotron spike ($2f_H$ spike) caused by a local resonance at the satellite is also indicated on the ionogram.

Fig. 3 shows the real height of reflexion of the extraordinary wave (obtained from the ionogram of Fig. 1) plotted as a function of frequency. Also shown is the variation with height of $2f_H$ calculated from the Jensen



May 28, 1963, 1506 G.M.T. (68° N. 159° W.)