LETTERS TO THE EDITOR

ASTROPHYSICS

Ionosphere, and X-ray Images of the Sun

Russell[1,2] has obtained X-ray photographs of the Sun at an epoch close to the recent minimum in solar activity which occurred late in 1964 and which preceded the present rising phase of the new solar cycle. The photographs were taken from a high-altitude rocket, and the quality and resolution are sufficiently good to allow limb brightening to be clearly distinguished from several small active regions that were present on the disk. The photographs seem to suggest that, in contrast to the brightening at the limbs, there was also some darkening at the north and south poles.

These directly made photographs provide at least qualitative confirmation of the solar brightness distribution derived by me[3] from ionospheric observations made during the previous solar minimum in 1954. This distribution was based on measurements of the changes in electron density, in the ionosphere, that were caused by the total solar eclipse of June 30, 1954. On the day of the eclipse, the Sun was exceptionally quiet and no active area of any importance was visible on the disk. Analysis of the ionospheric data led to the conclusion that, on this occasion, 82 per cent of the radiation could be attributed to an extended source which covered the entire disk and which was uniformly bright except for some darkening near the north and south poles. The remaining radiation (18 per cent) was attributed to limb brightening, although the slight asymmetry which was observed suggests that there may have been a very small active area near the west limb.

When ionospheric data are used to determine the brightness of the limbs relative to the uniform background, the degree of brightness which results depends on the value assumed for the effective recombination coefficient, α', in the expression:

$$J(t) = \left[\frac{1}{\alpha'}\frac{dNe}{dt} + Ne^2\right]\sec\chi$$

where $J(t)$ is proportional to the intensity of the incident radiation, Ne is the electron density at the peak of the E or $F1$ layer, and χ is the zenith angle of the Sun[4]. The accuracy of the calculated brightness distribution is limited mainly by the uncertainty in the value of α'.

It seems likely that the new X-ray photographs will give good quantitative information about the actual degree of limb brightening near the 1964 minimum, and it is probably reasonable to assume that the brightening during the 1954 minimum cannot have been very different. If this assumption is correct, it would be possible to use the 1954 ionospheric data, in conjunction with the 1964 value for limb brightening, in a new determination of α'. The result would be of considerable interest because the numerical value and the precise significance of α' have long been subjects for controversy.

Russell also refers to the presence of sources of X-radiation which extend outwards beyond the visible limb of the Sun, as predicted theoretically by Elwert[5]. A knowledge of the rapidity with which the intensity decreases with distance from the limb would allow estimates to be made of the amount of residual X-radiation which is present during the total phase of a solar eclipse. This information also could be used in the determination of α' from ionospheric data obtained during total eclipses, and its use for this purpose has been discussed on previous occasions[6,7].

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Radiation Balance of Jupiter and Saturn

It is frequently stated[1,2] that the radiation balance of Jupiter presents a significant problem in that the temperature derived for the cloud tops ($\sim 165°$ K) is considerably higher than the value which would be achieved by a rapidly rotating body having Jupiter's characteristics in simple equilibrium with solar radiation ($\sim 125°$ K). This discrepancy has been cited as possible evidence for thermal radiation from the interior of the planet; that is, it has been suggested that Jupiter might still be cooling down from an early, high-temperature phase[2]. The role of the atmosphere in maintaining the thermal balance has generally been disregarded since it has been assumed that the known constituents were all transparent in the wavelength region of importance (20–40μ). The situation for Saturn is very similar; the temperatures are simply somewhat lower. A number of recent findings when considered together appear to require a revision of these ideas.

Trafton[3] has pointed out that the pressure-induced dipole absorption of H_2 may produce significant absorption in the case of Jupiter. He finds that temperatures of the order of 147° K are not difficult to maintain by an atmospheric greenhouse effect depending only on this absorber. Owen[4] has reviewed a number of measurements of the temperature of Jupiter and has analysed one of the methane bands in the planet's spectrum to obtain a value of $200° \pm 25°$ K. The conclusion of this investigation was that there appeared to be strong evidence for temperatures in the range 175°–200° K in and above the cloud layer which is envisaged as considerably more complex than a simple flat surface. It thus seems necessary to invoke another absorber if the atmosphere is to provide the necessary opacity.

The way out of this dilemma appears to be provided by some recent laboratory studies of ammonia. Walsh[5] has obtained spectra of ammonia in the region 20–35μ at a number of path-lengths, with the gas subjected to various degrees of pressure broadening by N_2. A series of his tracings for an equivalent path-length of about 12 m atm. of ammonia at three different pressures of N_2 is reproduced in Fig. 1. It is evident that, even with no broadening by N_2, the transparency in this region is very low. In Jupiter's atmosphere, of course, the temperature will be lower than the laboratory value, so the population in the higher rotational levels (which are responsible for the absorption shown in Fig. 1) will be diminished. On the other hand, the atmospheric pressure within the region of the clouds is almost certainly in excess of 76 cm mercury and, while the broadening gases will be H_2 and He instead of N_2, the susceptibility of ammonia to pressure broadening is so great that at the expected pressures the absorption