LETTERS TO THE EDITOR

COSMOLOGY

Creation Rate of Matter and the Heisenberg Uncertainty Principle

ACCORDING to the steady-state theory of the universe, new matter is continuously being created out of nothing[1,2]. The Heisenberg uncertainty principle, however, precludes the possibility of proving 'nothing', that is, absence of energy, unless the time of observation is infinite. Now, whatever the explanation of the famous red-shift phenomenon in astronomy, the result is always a finite volume for the observable universe; any observer, irrespective of his position, finds himself in the centre of an analogous observable universe. On the Sandage scale[3], and assuming a Euclidean space for simplicity, extrapolation of Hubble's law yields a value of about $1{\cdot}3 \times 10^{10}$ light years for the radius (R) of the theoretically observable universe.

The lowest energy quantum possible in a finite observable universe is limited by the largest possible wave-length, $\lambda = 2R\pi$; thus, the theoretically lowest energy quantum in our universe has a mass $m = \dfrac{h}{2R\pi c}$ (about 3×10^{-66} g) and its period of vibration is $\dfrac{2R\pi}{c}$ (about $2{\cdot}5 \times 10^{18}$ sec). This length of time—about 8×10^{10} years—is considerable even on a cosmological scale, yet it is not infinite. Making use of the uncertainty relation $h\Delta\nu \times \Delta t = h$, one finds that in our universe the theoretically minimal quantum mechanical energy fluctuation of vacuum around zero is equal to $\pm \dfrac{h}{2R\pi c}$ every $2{\cdot}5 \times 10^{18}$ sec. It should be noted that this process does not violate the energy conservation law. Obviously, to make use of this value, one must know how many times the process occurs in our universe. One can assume that this number equals the number of centres of analogous observable universes contained in our universe and that the shortest distance between such neighbouring centres cannot be less than the quantum mechanical 'minimum length', λ_0 ($1{\cdot}32 \times 10^{-13}$ cm); this space quantization yields about 3×10^{123} such centres in our universe. Since the subsequent calculations refer to positive energy, the positive half of fluctuations will be taken into account.

On the foregoing assumptions the amount of matter created in the observable universe in each vibration period $\left(\dfrac{2R\pi}{c}\right)$ is:

$$\frac{h\ R^2}{3c\lambda_0{}^3} \qquad (1)$$

where h is the Planck constant, R the Hubble radius of the observable universe, c the velocity of light *in vacuo*, and λ_0 the quantum mechanical minimal length. The resulting value for the creation rate of matter is $2{\cdot}5 \times 10^{-46}$ g cm^3 sec^1. It seems of some relevance that Bondi[4], using a different approach, found practically the same value for the rate of creation of matter.

In a system with continuous creation of matter and disappearance of matter over the horizon, according to Hubble's law the two processes automatically tend towards a state of equilibrium at which the mean density of matter in the universe (ρ) is constant; using (1), ρ has the value:

$$\rho = \frac{\text{creation rate} \times R}{3c} = \frac{h}{24\pi^2 R\ c\lambda_0{}^3} = 3{\cdot}3 \times 10^{-29}\ \text{g/cm}^3;$$

thus, more exact determination of ρ might represent an observational test of (1).

To sum up, according to the present suggestion all energy, including matter, in our universe is continually being created as virtual energy on loan to be repaid after some 8×10^{10} years; the continuous creation of matter *ex nihilo*, and its disappearance into the void again, is interpreted by the Heisenberg uncertainty principle applied to a finite observable universe.

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GEOPHYSICS

Infra-sonic Waves from Aurorae

DURING times of high geomagnetic activity, long-period acoustic waves have been observed at the ground[1,2]. The source of these atmospheric waves can be ascribed to auroral activity, particularly to the periodic heating around the E-layer in the polar upper atmosphere corresponding to pulsating types of aurorae[3,4]. Auroral pulsations, which are sometimes called auroral coruscations, have periods that are quite similar to those of geomagnetic pulsations recorded simultaneously at the ground[5,6]. However, periods of auroral sonic waves are significantly longer than some of the auroral and geomagnetic pulsations recorded within the same period of geomagnetic activity.

The main purpose of this communication is first to point out the characteristics of auroral infra-sonics, and secondly to give some interpretation of the wave-form and periodicity of these atmospheric travelling auroral pressure waves which are observed at the ground.

Many kinds of atmospheric travelling pressure waves have been observed at the ground, particularly those produced by volcanic eruptions, large-scale explosions, earthquakes and meteorological disturbances such as tornadoes. These sounds from distant tropospheric sources are generally characterized by horizontal phase velocities near the local speed of sound, and by signal velocities (determined from the travel time from the source) of about the average sound speed of the atmosphere. These waves show irregular dispersion[7]. By contrast, sounds from aurorae have been shown to exhibit horizontal phase velocities usually greater[1] than 400 m/sec. They appear to radiate from the night side of the auroral zones[1,3].

Examples of auroral pressure waves recorded at Fort Yukon, Alaska, and at the National Bureau of Standards in Washington, D.C., are shown in Figs. 1 and 2. Each line in the figures corresponds to a record from a microphone. The separate microphones for each figure were spaced 2–7 km from each other in a space array at ground-level. Fig. 1 shows clearly the apparent acoustic mode dispersion typical of auroral zone measurements[2] with short periods arriving first and the longer periods arriving later in time.

It is well known that there are two types of pressure waves in the atmosphere, which are called acoustic (sonic) and thermobaric (internal gravity) modes, respectively[8,9]. Periods of thermobaric waves are longer than τ_B, which is called Brunt's period or Väisälä's period, while those of acoustic waves extend to short periods below τ_A, which has been called the atmospheric acoustic resonance period[10] or modified acoustic stability period[11].