The Social Sciences Section consisted of six papers, most of them having to do with the business methods of governments.

The Geology Section listened to numerous papers. Chas. N. Gould, of the National Park Service, spoke on the geology of the national parks. The discussion relative to the geomorphology of the Gulf Coast was completed.

The high point of the meeting was the annual dinner of the academy, with over two hundred and fifty present. After a most enjoyable dinner, a musical program given by the students of the Incarnate Word College, San Antonio, ushered in the regular program of the evening. Secretary Frederick A. Burt gave a review of the year's work of the academy together with the plans for the coming year and the problems that should be brought to the attention of the members. An honorary life membership was conferred upon Clyde T. Reed, the first president of the present academy. The annual address of the president, entitled "Problems of the Texas Pleistocene Ice Age," illustrated by slides, was a scholarly production. An illustrated lecture on "The Next Hundred Years" by Walter P. Taylor, senior biologist of the U. S. Biological Survey, dealt with what has happened in the last hundred years and what might be done to bring back desirable conditions that once existed.

The Saturday program found Sections on Physics, Chemistry, Mathematics and Biology in session. Chemistry predominated and centered around certain interesting organic compounds rather well known in all sciences. The Biology Section had a very full program, centered around the general topic of a marine biological laboratory to be located on the Gulf Coast. Walter P. Taylor reviewed the Texas Cooperative Wildlife Service, and connected this with what might be accomplished between the Wildlife Service and the marine laboratory. Gordon Hunter, Albert Collier and O. Sanders, all of whom have collected very largely on the Gulf, gave their reactions as to what might be done.

A business session was held during the noon hour. The officers for the following year are: Don O. Baird, Sam Houston State Teachers College, Huntsville, *president;* E. B. Isely, Trinity University, Waxahachie, *executive vice-president;* Frederick A. Burt, Texas A. and M. College, College Station, *secretary;* A. J. Kirn, Somerset, *treasurer;* Mrs. Helen Jeanne Plummer, Austin, *editor;* representative to the American Association for the Advancement of Science, S. W. Bilsing, Texas A. and M. College, College Station. A committee was appointed to select from the numerous offers made a place for the next annual meeting.

H. B. PARKS,
Secretary Emeritus

SAN ANTONIO, TEXAS

SPECIAL ARTICLES

THE SIZE OF THE UNIVERSE AND THE FUNDAMENTAL CONSTANTS OF PHYSICS[1]

THE problem of the size of the universe is usually treated in connection with the ideas of a curvature of space and an expansion of the universe. It seems, however, that results concerning the size of the universe may also be gained without any reference to these ideas. If we consider a homogeneous sphere, it follows from the theory of potentials that the amount of the gravitational energy is $3\,f\,M^2/(5\,R)$, where M and R are the total mass and the radius of the sphere and f the gravitational constant. On the other hand, the proper energy of this sphere is $M\,c^2$, where c denotes the velocity of light.

We may now make the rather obvious assumption that the amount of the gravitational energy of the sphere can not be smaller than its proper energy. This means

$$\frac{3\,f\,M^2}{5\,R} \leq M\,c^2. \tag{1}$$

On the other hand, the mass is equal to the density (ρ) multiplied by the volume of the sphere, or

$$M = \frac{4}{3}\pi\,R^3\rho. \tag{2}$$

The combination of the two formulas yields the relation

$$M \leq \frac{5^{3/2}\,c^3}{6\,\sqrt{\pi\rho}\,f^{3/2}} \tag{3}$$

or, if we insert the well-known values of c and f

$$M \leq \frac{10^{42}}{\sqrt{\rho}} \tag{4}$$

Astronomical research gave for the average mass density in the observable part of the universe the empirical value of 10^{-28} gms per ccm. According to formula (4) we find as an upper limit for the mass of a sphere of this density a value of 10^{56} gms. On the other hand, we find also an upper limit for the density of a sphere of given mass. If, *e.g.,* we assume this mass to be equal only to the sum of the masses of all actually observable astronomical objects, that is, equal

[1] A paper delivered at the Tercentenary Conference of Arts and Sciences at Harvard University, September, 1936.

to 10^{50} gms, we find as an upper limit for the density 10^{-16} gms per ccm.

It might be mentioned incidentally that we arrive at the same value for the mass of the universe as does Sir Arthur Eddington if we simply start from the following two hypotheses:

(1) That the sum of the proper energies of all particles contained in the universe equals the amount of the gravitational energy of the universe (either exactly or at least in the order of magnitude);

(2) That the sum of the spheres of action of all the electrons contained in the universe is as great as the surface of a sphere which would include a volume equal to the total volume of the universe.[2]

It might also be mentioned that Sir Arthur Eddington's wave-mechanical considerations make it probable that a purely arithmetical relation connects the masses of the hydrogen-atom and the electron, that is

$$\frac{m_H}{m} = 4\pi \times 137 \times \sqrt{\frac{17}{15}} \qquad (5)$$

The ratio 17/15 is the same as 136/120, whereas the whole number 137 is, according to Sir Arthur Eddington, the reciprocal of the Sommerfeld constant of fine structure of the hydrogen-spectrum. The arithmetical relation (5) yields the value 1,833, whereas the empirical value is 1,835.[3]

The elementary quantum of action may be represented, as is well known, either as a product of energy and time or as a product of length and momentum. If we, therefore, divide the elementary quantum of action by cosmic constants of the dimensions of time, energy, length and momentum, respectively, we obtain four "subatomic" constants (about 10^{-43} ergs, 10^{-103} sec, 10^{-93} cm, and 10^{-54} gm cm sec^{-1}). The subatomic energy constant, which might be called the primordial energy-element, seems to find a simple interpretation. As is well known, the red-shift in the line-spectra of extra-galactic nebulae can be described by the formula

$$\frac{\Delta\nu}{\nu} = \frac{s}{c\,t^*} \qquad (6)$$

Here $\Delta\nu$ means the diminution in frequency of a photon emitted by an object in the distance s, and $c\,t^*$ is a distance of 1,700 million light years, and therefore

$$1/t^* = 1.8 \times 10^{-17}\ \text{sec}^{-1}. \qquad (7)$$

The primordial energy-element (w) is given by the relation

$$w = \frac{h}{t^*} = 1.2 \times 10^{-43}\ \text{ergs}, \qquad (8)$$

h denoting the elementary quantum of action.

[2] *Cf.* A. Haas, *Phys. Rev.*, 49: 411, 1936.

[3] *Cf.* A. Haas, *Phys. Rev.*, 49: 636, 1936.

If we denote the energy of the photon by ε (where $\varepsilon = h\nu$), we may write equation (6) in the following form

$$\Delta\varepsilon = h\,\nu\,t/t^*$$

where t denotes the time during which the photon has been traveling, or

$$\Delta\varepsilon = w \times \nu \times t \qquad (9)$$

We now recognize at once the significance of the constant w if we put t equal to a period of a single oscillation, that is, equal to the reciprocal of ν. In this special case the loss in energy becomes equal to w. This means that every photon, irrespective of its wave-length, gives off a primordial energy-element during each vibration or in traveling one wave-length.

The number of primordial energy elements which are given off in a definite time depends on the frequency, but the relative diminution in energy in this time is independent of the frequency. A violet photon, *e.g.*, loses twice as many primordial energy elements per second as a red photon, but, on the other hand, the violet photon contains twice as much energy as the red photon.

We have in the universe, on the average, a quantity of radiant energy of about 3×10^{15} ergs, referred to one gram of matter.[4] The loss in radiant energy which is the consequence of the continual "reddening" would, therefore be, according to equation (6)

$$3 \times 10^{15} \times 1.8 \times 10^{-17}$$

or about 0.1 ergs per gram and second.

On the other hand, the energy production by the stars and star-systems amounts to about one tenth of an erg per gram and second.[5] The energy which is given off in the form of primordial energy elements might, therefore, be compensated by the energy production of the stars. Perhaps we might consider the energy which is liberated in the form of primordial energy elements, as the source of the radiation of the star-systems.

ARTHUR HAAS

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TYPE SPECIFIC ANTIPNEUMOCOCCUS RABBIT SERUM

BOTH horses and rabbits may be immunized against pneumococci of the various types, and the sera of these animals not only react specifically *in vitro* with the homologous micro-organisms and their products, but also afford protection against infection in laboratory animals. The sera from these two species of animals,

[4] *Cf.* A. Haas, "Kosmologische Probleme der Physik," Leipzig, 1934, Chapter IV.

[5] *Cf.* A. Haas, *Anzeiger Akad. Wiss. Vienna*, 70: 265, 1933.