ASTROPHYSICAL PHENOMENA AND RADIOCARBON

PHYSICS

1965

SovietRxiv

Abstract

Full Text

UDC 537.591.5

PHYSICS

Academician B. P. KONSTANTINOV, G. E. KOCHAROV

ASTROPHYSICAL PHENOMENA AND RADIOCARBON

The carbon isotope C^{14}, with a half-life of 5570 years, has in recent decades been widely used in archaeological studies to determine the age of wooden objects, and also for dating recent organic deposits (1, 2).

It is generally accepted that C^{14} is formed in the Earth' s atmosphere under the action of cosmic rays. Neutrons of the secondary component of cosmic rays produce radiocarbon by the reaction $N^{14}(n, p)C^{14}$. The average content of C^{14} in the atmosphere is determined by the balance between the rate of its formation and the rate of transfer into the biosphere and into the bound state in ocean waters (mainly in the form of carbonates). During the last half-century, a substantial role has also been played by the entry into the atmosphere of ancient carbon, containing no C^{14}, as a result of the burning of billions of tons of fossil organic fuel (oil, gas, coal). In the last two decades the content of C^{14} in the atmosphere and in plants has increased considerably because of nuclear-weapons tests. Analysis of changes in the content of C^{14} in the atmosphere and in plants over the last 10–15 years has made it possible to estimate the rate of exchange (the removal of C^{14} from the atmosphere), as well as the amount of carbon in the "exchange" reservoir of the oceans and the land surface (3). Further processing of the analytical data will apparently make it possible to determine accurately the characteristic times of mixing and exchange and to write the equation of the carbon balance.

Analysis of annual tree-ring layers, carried out on tree samples precisely dated for the last 1300 years, reveals substantial fluctuations in the content of C^{14} (4). These fluctuations reflect real changes in the content of C^{14} in atmospheric carbon dioxide. One of the most probable causes of these changes may be variations in the cosmic radiation incident upon the Earth' s atmosphere. Variations in cosmic radiation occur as a result of cyclic changes in solar activity and, possibly, accompany such comparatively rare phenomena as supernova explosions, etc.

In this connection we would like to draw attention to the importance of comparing the content of C^{14} in annual rings of trees, both living and archaeologically dated, with historically known astronomical phenomena or with data from modern observations that allow us to determine the date of some catastrophic event in the past.

In a recently published article by Cowan, Atluri, and Libby (^5), an attempt was made to compare the widely known fall of the Tunguska meteorite with an increase in the content of C^14 in annual tree layers near 1908. In two tree trunks, one of which had been felled in Arizona and the other in California (at a distance of not less than 800 km from each other), the content was determined in five-year intervals from 1870 to 1936. The rings for 1908, 1909, and 1910 were analyzed separately. The determination was carried out with great care (the number of counter pulses reached 90,000 for each sample), with a correction introduced for the change in the $C^{13/C}12$ ratio and for dilution by ancient carbon (the Suess effect).

Despite the remoteness of the places where the trees grew, the two curves presented in paper (5) practically coincide, and on them an increase in the activity of C^14 for 1909 by 1% in comparison with 1908 and 1910 is clearly visible. The authors attempt, on the basis of the data they obtained, to substantiate the hypothesis of the antimatter nature of the Tunguska cosmic body. We shall not discuss here these suppositions of the authors. We would like to draw special attention to the practical identity of the spectra of C^14 activity in annual layers for both trunks and to the presence of a number of maxima and minima exceeding in magnitude the peak of 1909. Thus, the five-year period centered on 1893 gives an activity 2% lower than the two neighboring five-year periods. A detailed analysis of carbon activity by annual layers, with the accuracy achieved by the authors (5), will make it possible to date archaeological wood to an accuracy of 1 yr not by its mean activity, but precisely from the graph of annual variations.

Determining the causes of variations in the C^14 content in annual layers is a complex problem, and the answer is unlikely always to be unambiguous. However, as indicated above, comparison of the carbon activity of annual layers with known astronomical phenomena may prove to be a very promising method of investigation.

As an example, let us point to the increase in C^14 content in epochs around 1700 and around 1050 (4, 6–8). Around 1700, as is known, there occurred an outburst of the supernova Cassiopeia A (9), and in 1054, of the supernova in the Crab Nebula.

If the electromagnetic radiation accompanying a supernova outburst contains also γ-quanta with energies of tens of megaelectronvolts, then atoms of C^14 can be formed in the Earth' s atmosphere through the reactions O^16(γ, n)O^15, N^14(n, p)C^14; N^14(γ, n)N^13, N^14(n, p)C^14; O^16(γ, 2p)C^14. An estimate carried out shows that when a γ-quantum with an energy of several tens of megaelectronvolts enters the atmosphere, the isotope C^14 is formed with a probability of 1%.

Let us make an estimate for the amount of energy emitted in a supernova outburst in the form of hard γ-radiation, assuming that it is possible to measure a change in C^14 activity of 1%. For the supernova Cassiopeia A (around 1700) we obtain a value of 10^51 erg, for the Crab Nebula and Kepler' s supernova (1604) 10^50 erg, and for Tycho Brahe' s supernova (1572) 10^49 erg. The obtained energy values do not contradict existing estimates of the energetics of supernovae (9).

Physical-Technical Institute named after A. F. Ioffe
Academy of Sciences of the USSR

Received
30 VII 1965

CITED LITERATURE

1. W. F. Libby, *Radiocarbon Dating*, Chicago, 1955.
2. I. E. Starik, *Nuclear Geochronology*, Moscow, 1961.
3. W. S. Broecker, E. W. Olson, *Science*, **131**, 712 (1960).
4. E. H. Willis, H. Tauber, K. O. Münnich, *Am. J. Sci.*, Radiocarbon Suppl., **2**, 1 (1960).
5. C. Cowan, C. R. Atluri, W. F. Libby, *Nature*, **206**, 861 (1965).
6. H. De Vries, *Koninkl. Nederl. Akad. Wetensch. Proc.*, Ser. B, **61**, 94 (1958).
7. E. K. Ralph, R. Stuckenrath, *Nature*, **188**, 185 (1960).
8. W. S. Broecker, E. A. Olson, J. Bird, *Nature*, **183**, 1582 (1959).
9. V. L. Ginzburg, S. I. Syrovat-skii, *The Origin of Cosmic Rays*, Moscow, 1963.

Note: Figure translations are in progress. See original paper for figures.

Source: Math-Net.Ru and CyberLeninka. Machine translation. Verify with the original.