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COSMIC RAYS FROM NEARBY SUPERNOVAE

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Comment on the Biological Effects of  
Cosmic Rays from Nearby Supernovae\*

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Terry and Tucker<sup>1</sup> have just speculated that cosmic radiation from exploding supernovae could have caused the extinction of many animals on Earth in geologic times. They give an estimate that over a period of  $6 \times 10^8$  years animals on the Earth would have been exposed to a dose of 25,000 roentgens (arriving in a few days or less) at least once, 1,000 roentgens at least 4 times, etc. Such bursts of radiation could cause the extinction of many exposed animals without simultaneously extinguishing plant life.

The above calculations depend sensitively on a major assumption. "Since diffusion effects can be neglected for relativistic particles traveling over comparatively short interstellar distances, such as are of interest here, the relevant time interval is that for the release of the energy in the form of cosmic rays ... . Therefore, it is safe to say that the dose D is received over a period of, at most, a few days."

This assumption conflicts seriously with most current theories of cosmic ray propagation within the galaxy. These theories describe cosmic ray particles as either diffusing through the interstellar medium or as moving along galactic magnetic field lines so twisted as to produce the remarkable degree of isotropy experimentalists observe. In either case, the typical distance for straight line propagation of cosmic ray particles from their source is taken to be approximately 3 light years. As a result, cosmic rays reaching the earth even from the relatively nearby supernovae Terry

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and Tucker refer to would travel tortuous paths en route. Instead of arriving in one sudden burst concentrated in a few days or less, their radiation would be spread over years. The biological effect described therefore would be appreciably smaller, and probably negligible.

To illustrate this we can consider the one supernova explosion in  $6 \times 10^8$  years Terry and Tucker describe which produces the largest dose, 25,000 roentgens. If this is due to a supernova which releases  $10^{50}$  ergs in the form of cosmic rays, as they assume, it is approximately 10 light years away. Cosmic rays diffusing to the earth would pass through better than 3 mean free paths en route. Standard diffusion model calculations<sup>2</sup> show that they would take approximately 40 years on the average to arrive. The peak radiation would be spread over a period of several years rather than several days.

Similarly, Terry and Tucker describe more distant supernovae which might occur once every  $1.5 \times 10^8$  years and produce doses of 1,000 roentgens. These supernovae would average 50 light years distance, their cosmic rays would arrive at the earth 1,000 years afterwards, with the peak radiation spread over hundreds of years. More distant supernovae would spread their doses over appreciably longer intervals, thereby reducing further their biological effect.

The above numbers are based on a diffusion model for cosmic ray propagation with mean free paths of about 3 light years. Other models would differ in detail but would share the characteristic of lengthening appreciably the period during which the total radiation described would impinge on animals.

Even if supernovae are assumed to release the far larger amount of cosmic ray energy,  $10^{51}$  ergs, which Terry and Tucker refer to, the biological effects would be appreciably reduced for all but the very closest

(and rarest) supernovae. Thus doses of 10,000 roentgens might occur once every 150 million years, but each such dose would be spread over hundreds of years and therefore produce much less damage to animal life than is assumed.

Physicists long have observed that non-solar cosmic rays arrive at the earth steadily from all directions. This spatial and time isotropy probably is due to the tortuous paths cosmic rays follow in traversing the interstellar medium. The same characteristics of galactic space which produce this non-linear motion would serve to spread appreciably in time the radiation dose produced by a nearby supernova. Only an explosion within several light years of the earth would result in the catastrophic effects suggested by Terry and Tucker. Since very few stars of any kind are that close to us, nearby supernovae such as they require would be very rare indeed.

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References:

1. Terry and Tucker, Science, 159 #3813, 421-23, Jan. 26, 1968.
2.  $t = \frac{R}{\lambda v}$  In this case  $R=10$  light years,  $\lambda=3$  light years, and  $v$  is the speed of light. For a general discussion, see, for example, P. Morrison in Handbuch der Physik, Vol. 46, or Ginzburg and Syrovatskii's The Origin of Cosmic Rays, Pergamon Press, 1964.