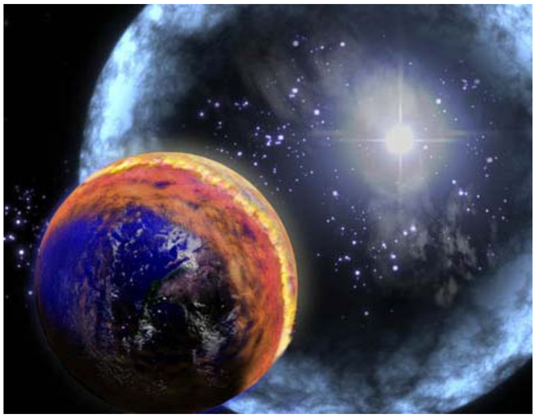
Ionizing Radiation Episodes and the Evolution of Complex Life. A.L. Melott, Department of Physics and Astronomy, University of Kansas, Lawrence, KS 66045 (melott@ku.edu)



Introduction: Episodic large ionizing radiation events are expected from astrophysical sources. Some are expected to sporadically induce mass extinctions on terrestrial planets with oxygenated atmospheres. The primary mechanism is depletion of the ozone layer which normally provides protection from external ultraviolet-B radiation. I describe the nature and expected interval for known threats, and one associated with a newly emerging probable threat from the Sun.

Important sources of ionizing radiation bursts:

Supernovae. Supernovae are a known threat to life on Earth. The threshold distance for mass extinction is about 10 pc (~31 light years). A burst of UV/X-ray photons can ionize the atmosphere, followed by an extended irradiation as cosmic rays diffuse from the source [1]. Such an event is likely at intervals of a few hundred Myr. Evidence is building that a supernova near enough to provide moderately elevated radation and possible climate change occurred at the beginning of the Pleistocene (~2.5 Myr ago) [2,3].

Gamma-ray bursts. Gamma-ray bursts appear to originate in supernova-like events involving collapse to a black hole and the emission of strongly beamed radiation. They are powerful enough to induce extinction-level events from as much as 2 kpc away, if pointed toward an inhabited planet [4]. Estimates of rates suggest that the mean "dangerous event" interval in the Earth's galactic environment is again of order a few hundred Myr [1,5].

It has been argued [5] that gamma-ray bursts will extensively modify the galactic and temporal habitable zones in such a way as to bias the appearance of complex life on terrestrial planets away from cosmologically earlier times and away from the centers of galaxies.

The Sun. Recently, there have been two lines of accumulating evidence that the Sun may be capable of energetic bursts much more powerful that anything seen in modern history. First, geoisotope records from trees on three continents and Antarctic ice cores show evidence for ionizing radiation effects in the atmosphere in 775 and 993 A.D [6], consistent with major energetic events from the Sun [7,8]. Studies with the Kepler satlellite have revealed extremely large flares on G-stars apparently similar to the Sun, suggesting that even larger events are plausible [9,10]. This is an emerging and controversial area of research.

Effects on life. Planets like Mars, with thin atmosphere, would leave any indigenous surface life exposed directly to radiation—but any such life would have to be somewhat radiation resistant. Life under very thick atmospheres or icy crusts would be nearly impervious to radiation effects, because even secondary air showers would fail to penetrate. Earthlike planets are normally protected from ultraviolet radiation of their host stars by a layer of ozone, but radiation bursts render their atmospheres partially UVB transparent, with the potential to kill off some organisms [4]. Evaluating damage to the biota is a complicated matter, as even phototrophic bacteria vary greatly in their resistance to UVB [11]. However, UVB damage is a generic threat to life as DNA and proteins strongly absorb in that band, with resultant damage [12]. In addition, in supernovae, many muons as secondaries will reach the ground and will provide an additional stress on organisms there and as deep as 1 km in the ocean [13].

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