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ORIGINAL ARTICLE

Nuclear criticality as a contributor to gamma ray burst events

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Abstract Most gamma ray bursts are able to be explained using supernovae related phenomenon. Some measured results still lack compelling explanations and a contributory cause from nuclear criticality is proposed. This is shown to have general properties consistent with various known gamma ray burst properties. The galactic origin of fast rise exponential decay gamma ray bursts is considered a strong candidate for these types of events.

Keywords Gamma ray bursts · Nuclear criticality · Energy spectrum

1 Background

The Oklo uranium mine in South Africa is a place where the natural abundance of U235 was found to be consistently less than the 0.72 % found everywhere else on the planet (with the remainder of the uranium being almost entirely U238). It was not until the excess isotopic distribution from the stable fission product decay nuclides was found that it was realized this was an ancient natural nuclear reactor (Cowan 1976). Because the half life of U235 is almost an order of magnitude smaller than that of U238, the ratio of U235 to U238 increases in reverse time. By going back far enough in time, the abundance of the two nuclides would become comparable. With sufficiently enriched uranium in the soil, addition of moisture from rain would then provide the necessary moderation for the earth to sustain a natural nuclear chain reaction until the heat would drive away the water and return the system to a subcritical state. This process is believed to have occurred over a billion years ago in central Africa (Fujii et al. 2000).

If the Oklo reactor occurred naturally as a result of uranium created in supernovae (SN) events, it is not incredible to think that it could occur prior to accumulation into planetary form from other SN events. In other words, just after the SN creation of the uranium and transuranic isotopes, most of the already radioactive elements created will quickly decay into stable atoms leaving these fissile and fissionable isotopes close to their original abundance. Even if a large fraction of the Pu239 (which is fissile with a moderately long half life of just over 24 ka) were to decay away, there would still be almost the initial amount of U233 (which is fissile with a moderately long half life of just under 0.2 ma) with only a negligible fraction of the U235 having decayed away. If a gravitational accumulation of the SN excreta were to occur within some few years, a longer list of potential fissile isotopes could be present in the material including Pu241, Am243, Cm243, Cm245, Cm247, etc. while the majority of the radioactive elements would still have decayed into stable isotopes. This presents a dynamic reactivity dependency in terms of the fissile nuclides generated which would be strongly dependent on the initial isotopic distribution source term.

The model presented here has the potential to explain some of the highly varied nature of a portion of measured gamma ray bursts (GRBs). These include the random nature of the events in terms of their parametric values and ranges. Specifically many measured values of energy and time distributions, pulsing, and afterglows appear to fit those attainable with the proposed criticality model.

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