therefore, to explain the radio emission using the gravitational lens mechanism.

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L. N. K. de Silva

Astronomy Centre,
University of Sussex.

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Extensive Air Shower Arrays as Detectors of Prompt Gamma Rays from Supernovae Explosions

Supernovae explosions with total energies of 10^{49} to 10^{52} ergs constitute the most energetic single events in our galaxy[1,2]. Pulsars, which now appear to be rotating neutron stars formed in supernovae, contain similar amounts of energy[3,4], and it is believed that a large portion of this energy goes into accelerating relativistic particles, producing cosmic rays[3–5]. The acceleration mechanism models fall into two general classes: the gradual transfer of rotational energy through electromagnetic channels to particles[4,6], and the shock wave hypothesis where most of the cosmic rays are accelerated during the initial explosion as the outer layers of the star are blown out at relativistic speeds[5,7]. As a consequence of the shock wave acceleration mechanism Colgate has shown that a burst of photons of total energy 5×10^{47} ergs per decade should accompany the explosion. The time width of this pulse is a fraction of a microsecond at the maximum photon energy of few GeV and proportionally longer at lower energies[8]. An experiment designed to detect this type of pulse using the atmospheric fluorescence method has already achieved the sensitivity and operation time necessary to observe such pulses, with negative results as yet[9].

A recent revision by Colgate[10] to include the electron–positron pair production opacity results in an increase of maximum photon energies to the 10^{13}–10^{14} eV range and a decrease of the total energy in this decade to 10^{46} ergs. This pulse of high energy photons should produce measurable effects on present day high altitude extensive air shower arrays.

High energy photons produced in the explosion would travel coherently through space and strike the top of the atmosphere simultaneously. They will produce small air showers in which the electromagnetic component will reach a maximum and be absorbed before reaching sea level. The muonic component, produced by the decaying mesons which in turn are created in photonuclear interactions, will propagate through the atmosphere. To an extensive air shower array such an event will appear as an air shower with very flat lateral distribution function, triggering most of the detectors in the array. Arrays with effective areas of 1 km² or more will be able to detect such events unambiguously, unlike small arrays which may show flat responses to large air showers with distant cores.

The total number of charged particles N produced by a primary of energy E is $2 \times 10^{-10}\ E(\text{eV})$[11]. If we use an average maximum energy of 3×10^{13} eV for the incident photons, at the maximum atmospheric depth of 420 g cm^{-2} they should produce around 6,000 particles. An air shower array such as the one of BASJE group at Mt Chacaltaya, Bolivia, where the altitude is 5,300 metres (an atmospheric depth of 530 g cm^{-2}), should be able to observe these showers close to its limit of detection. Assuming that the average triggering sensitivity of the detectors n is about 2 particles m^{-2}, such pulses of photons are detected up to a distance $R_{\max}$ given by:

$$R_{\max} \simeq \left(\frac{\alpha W}{4\pi n}\right)^{1/2} = 2\cdot2 \times 10^{25}\ \text{cm (7 Mpc)}$$

where $W = 10^{46}$ ergs is the energy released by the supernovae in high energy photons, and $\alpha = 125$ particles erg^{-1} is a constant relating the total number of particles N produced per unit energy by a photon of average energy 3×10^{13} eV.

Within this distance $R_{\max}$ a number of galaxies should yield supernovae. The rate r at which these pulses should be detected is given by:

$$r = \frac{2}{3}\pi R_{\max}^3 \rho f \simeq 1 \text{ per year}$$

where we have assumed that the density of galaxies $\rho = 5 \times 10^{-75}$ galaxies cm^{-3}, the supernovae rate per galaxy f is one in 100 years and the solid angle of the array is 2π.

In the case of sea level arrays only the muonic component will reach the detectors. Since the number of muons of a photon initiated shower is a factor of about 100 less than the electromagnetic component at energies of 3×10^{13} eV, α will be ~ 100 times less[12]. Even though the minimum threshold detection level n of some sea level arrays could be as low as 5×10^{-5} cm^{-2}, the maximum detection radius $R_{\max}$ is decreased to $4\cdot4 \times 10^{24}$ cm and the rate r to only one event per 125 years.

The operation time of the BASJE array has been sufficient to see several such events. It is conceivable that in a large sample of proper air showers such events have been overlooked or rejected during automated analysis procedures.

I conclude that high altitude extensive air shower arrays are capable of investigating the very early phases of cosmic ray acceleration by supernovae. Even in the pulsar acceleration models of cosmic rays it is possible that the initial pulses could be extremely short and contain energies over 10^{46} ergs in high energy photons. Since there is considerable uncertainty in the rates calculated (due to the inexactness of several of the parameters involved), it seems worthwhile to examine past and future data of all extensive air shower arrays for this type of event

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H. Ögelman

Middle East Technical University,
Ankara, Turkey.

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