LA-UR -83-1049

(1)

Conf-830830--1

Los Alamos National Laboratory is operated by the University of California for the United States Department of Energy under contract W-7405-ENG-36.

LA-UR--83-1049

DE83 011319

TITLE: THE ISOTROPY OF ULTRA-HIGH-ENERGY COSMIC RAYS AND MULTIPLE SUPERNOVA I GALACTIC SOURCE

AUTHOR(S): Stirling A. Colgate, T-6

SUBMITTED TO: For presentation and the proceedings of the 18th International Cosmic Ray Conference, Bangalore, India, August 22 to September 3, 1983.

MASTER

April 7, 1983

Los Alamos Los Alamos National Laboratory
Los Alamos, New Mexico 87545

FORM NO. 836 R4
ST. NO. 2629 6/81

THE ISOTROPY OF ULTRA HIGH ENERGY COSMIC RAYS AND MULTIPLE SUPERNOVA I GALACTIC SOURCE

Stirling A. Colgate
Los Alamos National Laboratory, Los Alamos, New Mexico 87545 USA

ABSTRACT

Ultra-high-energy cosmic rays are usually associated with an extragalactic origin. Active galactic nuclei are an unlikely source because of photon drag. Here the possibility of supernova events are considered. The time spread of arrival of 10^{20} eV protons is 100 to 400 years at 10 to 20 kpc and the angular spread is ± 15 to ± 30° depending upon the Galactic field configuration. The time spread is sufficient to include several to a dozen type I SN. This is enough events and angular spread to include the observed data. The concentration of the observed events at the galactic poles is contradictory. The flux is reasonable if the observed flux and slope at 10^{12} to 10^{15} eV is characteristic of the source(s) and confined at this energy for roughly 100 traversals of the Galaxy, or 3×10^6 years.

INTRODUCTION

Ultra high energy cosmic rays $E > 10^{19}$ eV are usually assumed to originate external to the Galaxy. However, the anisotropy grows with energy (Cunningham et al[1]), and so this would indicate the likely presence of some galactic structure. The extreme difficulty of assuming acceleration in observed extragalactic energetic objects, active galactic nuclei, is discussed in a separate paper (Colgate OG6-1). This is because of photon damping during acceleration by the photons originating within the object.

ANISOTROPY OF GALACTIC SN SOURCES

Here the possibility of a galactic origin from type I supernova is examined in terms of possible anisotropy and flux.

A supernova, a distance D from the earth emitting particles of larmor radius R_L, have an increased path length, ΔD, due to a deflection angle θ such that

$$D = 2R_L(\sin \theta/2) \tag{1}$$

or for small θ, $\theta = D/R_L$ then

$$\Delta D \cong D(\theta^2/24). \tag{2}$$

For a galactic field of 3×10^{-6} gauss, R_L = 11 kpc, a field that extends above the galactic plane by $D(\theta^2/2)$ or 100 pc for D = 11 kpc and θ = 0.3 radians at $E = 10^{20}$ eV is then sufficient to delay such particles arriving at the earth by 120 years relative the direct path. We have chosen the highest energy CR events of 10^{20} eV because the relative delay by Eq. 2 becomes rapidly small. The time spread of 120 years is enough to presume several type I SN occurring within the galaxy in this period at a mean distance of 10 kpc. The angular spread of arrival directions will be $\theta \cong \pm 0.3$ radians. This number of sources and angular spread of events is compared to the latest data in Fig. 1 as analyzed by Lloyd-Evans and Watson.[2]

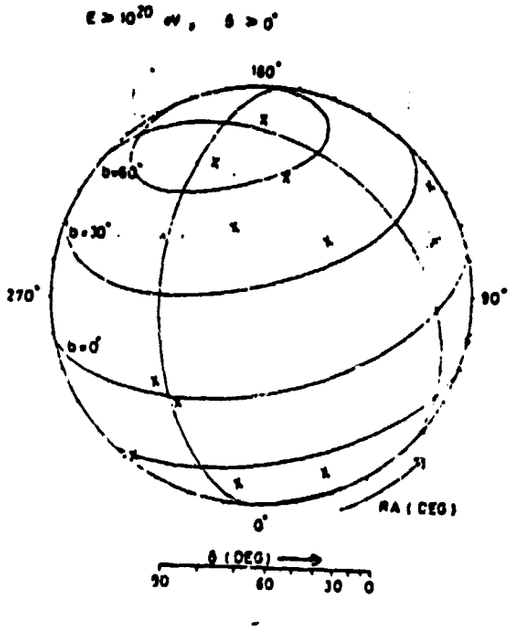

Fig. 1. From Lloyd-Evans and Watson.[2] An equal exposure plot of 11 events with estimated energies above 10^{20} eV.

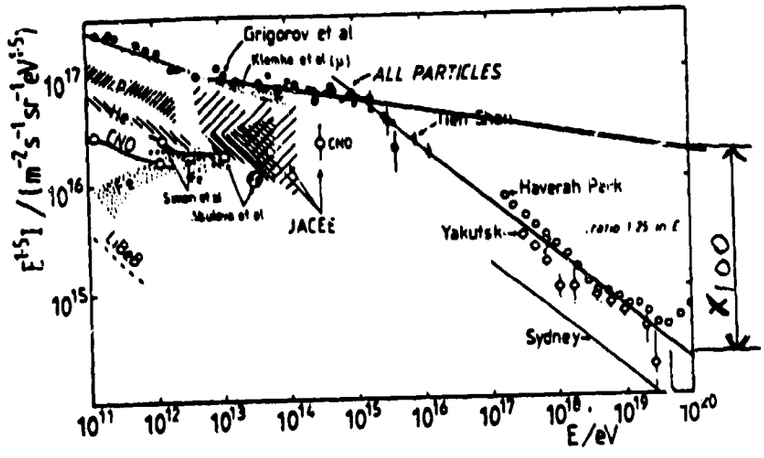

Fig. 2. From Hillas.[3] Assembled results of all the reported energy spectra. (Data extending below 2.10^{12} eV are earlier observations at the top of the atmosphere, for comparison.)

The concentration of events at high Galactic latitudes is contrary to this supposition , but an extended galactic dipole field and one high galactic latitutde event at D = 20 kpc would be adequate.

REQUIRED FLUX

Let us suppose that the entire CR spectrum is made in the same events. Then the extrapolated spectrum above 10^{12} eV steepens by 0.5 power above 10^{15} eV to 10^{19} eV (Hillas[3]). This is presumed to be leakage from the Galaxy. Then the CR source would have to correspond to a flux of CR's observed above 10^{19} eV with no galactic confinement, and the flux at 10^{15} eV would correspond to the source enhanced by a factor = $(10^{19}/10^{15})^{0.5} = 100$ because of greater confinement, Fig. 2. This would correspond to an age of 100×10 kpc/c = 3×10^6 years for cosmic rays of 10^{12} to 10^{15} eV and only 3×10^4 years for the direct leakage of 10^{20} eV particles. This is not an unreasonable lifetime.

CONCLUSION

The flux and anisotropy of CR events up to 10^{20} eV is not inconsistent with a Galactic origin in SN events provided one high galactic latitude event at a distance of 20 kpc occurred in the last several hundred years.

ACKNOWLEDGEMENT

I am indebted to Albert Petschek for discussions. This work was supported by DoE and the Astronomy Section of NSF.

REFERENCES

1. Cunningham, G., Lloyd-Evans, J., Pollock, A.M.T., Reid, R.J.O., and Watson, A. A. 1980, Ap. J. 236, L71.
2. Lloyd-Evans, J. and Watson, A. A., "Anisotropy Measurements above 10^{15} eV," preprint University of Leeds, Leeds LS2 9JT, UK, and presented at the 8th European CR Symposium, September 8, 1982, Rome, Italy.
3. Hillas, A. M., 17th International CR Conference, Paris 1981, Rapporter Papers, p. 9.