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Geminga as a cosmic ray source

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Abstract. The complete 150 kyr record of ^{10}Be concentration in the Vostok ice core in Antarctica displays several steep and relatively brief increases. Out of these, the increase at ~ 33 Kyr is unique, as this is not accompanied by signatures of climatological and other factors responsible for short term variations of cosmic ray intensity, associated with solar terrestrial-relationships. Earlier attempts to relate this variation to possible supernova explosion in the solar neighbourhood have met with some success. A suggestion is made here that the newly discovered gamma ray pulsar Geminga is the supernova responsible for this brief increase in cosmic ray intensity. Thus for the first time we are able to see a direct correlation between the increase in cosmic ray intensity and a supernova explosion.

Key words : cosmic ray source—gamma ray pulsar

1. Introduction

Over the past three decades detailed direct measurement of cosmic ray intensity, energy spectrum and composition have been made. These have yielded important information about the short term variations in cosmic ray intensity mediated by conditions in the interplanetary space, governed principally by the solar wind. However when averaged over several solar cycles the changes turn out to be very small. It is well-known that several sources should be contributing to the cosmic rays which we observe at the Earth. The only source of high energy particles which has been directly responsible for the increase at the Earth is our Sun, that too only at the low energy end of the spectrum, much less than a GeV. Hence it will be exciting to detect a direct increase in cosmic ray intensity and relate it to a known source of these high energy particles like a supernova explosion. Since these events have taken place in the past, it is only through geophysical effects of cosmic rays, these effects can be monitored. These studies have been summarized by Lal (1987) and Kocharov (1990).

The increase in cosmic ray intensity is recorded by the increase in abundance of cosmic ray produced isotopes like ^{10}Be etc. So by studying the variation of ^{10}Be intensity over the years, it is possible to detect any increase in cosmic ray intensity in the past. The Antarctic ice sediments suggest themselves as a proper monitoring source, as it is free from major pollution from the earthly causes. This has been done by the variation of ^{10}Be intensity as a function of the depth of the Vostok ice sediments (Raisbeck *et al.* 1987). However it should be borne in mind that the increase in the ^{10}Be intensity may be due to several causes. The climatological causes can increase the sedimentation rate, the troposphere-stratosphere exchange also affects the intensity. Thus it is necessary to make a correlated study with several cosmic ray produced isotopes sensitive to several of these causes. Such studies have been undertaken by Beer *et al.* (1983) and Raiseback *et al.* (1987). From such a study over the past 150 thousand years (Kyr) two distinct increases corresponding to roughly 33 (Kyr) and 60 (Kyr) have been isolated. Out of these the increase corresponding to 60 (Kyr) displays the oxygen isotope effects too and hence can be accounted for by appealing to troposphere-stratosphere exchange. Thus the increase corresponding to the 33 (Kyr) stands out. This increase has been interpreted as possibly due to a nearby source (Kocharov 1992; Konstantinov *et al.* 1990). However no definite source identification was done and only suggestion was the possibility of a nearby source at a distance of about 100 pc or less. Ramadurai (1993) has followed the suggestion and predicted one of the gamma ray burst sources, named Geminga, as the candidate source, urging that proper motion of this source should be observable. This has been done.

2. Geminga

The gamma ray burst sources can be interpreted in terms of accreting neutron stars (see Vahia's review in this meeting for this and other alternative scenarios). One of the strongest gamma ray burst in the sky has been detected several years ago by the SAS-2 satellite and a rough location was given (Fichtel *et al.* 1975). Later on the Einstein observatory also could see this source named Geminga (Bignami *et al.* 1993). The real breakthrough came with the X-ray and the recent EGRET observations which could detect the period derivative of this source (Bertsch *et al.* 1992; Bignami & Craveo 1992; Halpern & Holt 1992). With that it was clear that the source is about 125000 years old and nearby. With the possible identification of optical counterpart of Geminga by Halpern & Tytler (1988), as soon as the possibility of nearness was suggested by the recent EGRET and X-ray observations, it was only a matter of time before proper motion of the optical counterpart was detected. This has been done now (Bignami *et al.* 1992) and from this distance has been inferred to be about 100 pc.

It is seen that the increase in intensity is nearly a factor of two over the average intensity. It is known that the average energy density is given by the products of the energy from a typical source, the number of sources over the galaxy and the lifetime of a particular source divided by the confinement volume. The increase due to a single source is given by the energy from the source multiplied by the propagation function, which takes into account the time of the event, the diffusion coefficient, the distance of the source etc. (See Berezinsky *et al.* 1992 for further details). Substituting the observed values for Geminga (Bertsch *et al.* 1992) as well as the average cosmic ray energy density of 1 ev.cm^{-3} one obtains a value of 1.8 for the increase in CR intensity from Geminga. Thus it is seen that Geminga is the source responsible for the increase seen in the Vostok ice sediment. Further confirmation that Geminga is a possible cosmic ray source comes from the recent suggestion from a search of the archival data on Geminga obtained at Ooty indicating possible TeV gamma ray signals from this source during 1984-1985 (Vishwanath *et al.* 1993) as well as during October 1986 (Gupta *et al.* 1993).

3. Conclusions

It is shown that Geminga is a possible candidate for the increase in cosmic ray emission recorded by ^{10}Be increase of ~ 33 Kyr ago. Other consequences like radio emission etc. are being worked out at present.

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