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NON-ASSOCIATION OF A CELESTIAL γ-RAY SOURCE WITH THE NEW MILKY WAY SATELLITE GALAXY

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Non-Association of A Celestial γ-Ray Source with the New Milky Way Satellite Galaxy

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Non-Association of a Celestial γ-Ray Source with the new Milky Way Satellite Galaxy

The announcement[1] of a new satellite galaxy located in the galactic anti-center region (core position $\ell = 197.3 \pm 0.6°$, $b = +2.1 \pm 0.5°$) has stimulated us to re-examine carefully the nearby γ-ray source previously reported by this group[2,3]. Our purpose was to see if there were good evidence either for or against an association of the γ-ray source with the new galaxy.

The γ-ray source has an intensity approximately equal to the intensity of the source associated with the Crab Nebula and its pulsar of $\sim 3 \pm 1 \times 10^{-6}$ (photons > 100 MeV)/cm^2s. The error on this intensity includes possible systematic uncertainties as well as statistical errors. The confidence level that there is indeed a localized source is greater than 7σ. Of the localized sources seen by the Small Astronomy Satellite (SAS-2), only that associated with the Vela pulsar is stronger. Yet the source has not been identified with any previously catalogued celestial object[3].

In this note the considerations which have led us to conclude that the γ-ray excess is not associated with the galaxy will be discussed. The main points are associated with the exact location and the intensity.

Figure 1a shows the region of the sky near the galactic anti-center observed by the SAS-2 detector. Each point on the map represents the arrival direction for a detected γ-ray whose measured energy was in excess of 50 MeV. The arrival direction reflects a recently incorporated small improvement in direction determination. The detection efficiency varies slowly over the area shown. Within the region bounded by the large dashed curve the relative detection efficiency is greater than 50%. The small circle and ellipse will be discussed later. Two strong sources are clearly evident in the figure. One of them, near $\ell = 185°$, $b = -5°$, is identified with the Crab Nebula and its central pulsar PSR 0531 +21. An analysis of approximately one-half of the events has been published previously[4]. Most of the excess γ-radiation is pulsed at the PSR 0531 + 21 frequency, and therefore the identification of this source with the Crab is firmly established.

The other source is located near $\ell = 193°$, $b = +3°$ and may be identified as γ (193 + 3).

Figure 1b shows the variation in γ-ray intensity along a line between the two sources. The dashed curves indicate the expected response to two equal intensity point sources superimposed on a constant background.

We have analyzed both regions in detail in order to extablish the precise location of each enhancement. We find that the Crab source is within 1.4 ± 0.7° of its known position. The other source is 4.3 ± 0.7° away from the quoted position of the galaxy. Thus there is an obvious incompatibility in position between the new galaxy and the γ-ray source. One may take an alternative point-of-view that the slight offset of the Crab is indicative of a systematic error of 1.4 ± 0.7° that should be applied as a correction to the events in the surrounding region. If this offset is treated as a correction the second source would be 4.4 ± 0.9° from the position of the new galaxy. We believe that the error quoted properly accounts for all sources of possible error, both statistical and systematic. In either view this difference in position would appear to be decisivly against any association of the two objects. This conclusion is illustrated in figure 1a. A circle of 5° radius which should contain 63% of all events from a point source is drawn centered at the known position of the Crab (ℓ = 184.6, b = -5.8). The circle contains much of the region of enhanced intensity and is reasonably well centered.

The core of the satellite galaxy is reported to be elongated with an angular extent of 7° x 2° with an orientation of 40 ± 20° with respect to the galactic equator[1]. If we assume a Gaussian distribution of matter in the core with dimensions (FWHM) as given by Simonson, an angular resolution ellipse of semi-major axis 6° and semi-minor axes 5° would be appropriate for the source. Such an ellipse is drawn on the figure 1a. There is a clear misalignment by approximately 4°.

Another argument against the association is based on a comparison of the observed intensity with an estimate of the expected γ-ray emission from the galaxy. There is a discrepancy of approximately two orders of magnitude, as will be discussed below. The observed flux from the γ-ray source is about 3×10^{-6} (photons > 100 MeV)/cm^2s. Simonson[1] has estimated the mass of hydrogen in the core to be in the range of $(0.4$ to $1.6) \times 10^7 M_\odot$ and the distance from the sun to be 17 ± 4 Kpc. Assuming the cosmic ray density to be as great as it is locally, a γ-ray flux of about $5^{+6}_{-3} \times 10^{-8}$ (photons > 100 MeV)/cm^2s would be expected from the interaction of cosmic rays with the matter assuming the source function as given by Stecker[5]. This calculated flux is about (1/60) of the flux actually observed in the nearby region.

Further, it is more reasonable to assume the cosmic ray density is lower than it is locally. Unless the cosmic ray flux is universal, which currently seems to be the less likely possibility, the cosmic ray density would be expected to be less in this smaller, less dense galaxy than in the local spiral arm of our galaxy because, as explained by Parker[6] and discussed further by Bignami et al.[7], the cosmic rays are held by the matter to which they are tied by the magnetic fields. For equilibrium to exist the total pressure due to the cosmic rays, magnetic fields, and kinetic motion cannot exceed that which can be contained by gravity. Estimating the volume of the new galaxy to be in the range (0.5 to 1) x 10^{65}cm^3, the hydrogen gas density would be (1/4) to (1/8) that locally, and, hence, the cosmic ray density would be expected to be lower. The best estimate of the γ-ray flux may, therefore, very well be on the order of 10^{-8} (photons > 100 MeV)/(cm^{2}sec) rather than 5 x 10^{-8} (photons > 100 MeV/cm^{2}sec).

It could perhaps be speculated that there are a very large number of cosmic ray sources and that, even though the lifetime for escape is short, the density could be high, or it might be suggested that there are large numbers of high intensity γ-ray sources in this small galaxy. However, both these possibilities seem unlikely because the conditions for forming objects that are likely to be emitters of cosmic rays or high energy γ-rays are very likely less favorable in this small galaxy than in our own.

REFERENCES

1. Simonson, S.C. III, Astrophys. J. Lett., 201, L103 (1975)
2. Fichtel, C.E., Hartman, R.C., Kniffen, D.A., Thompson, D.J., Bignami, G.F., Ögelman, H., Özel, M.D., and Tümer, T., Astrophys. J. 198, 163 (1975)
3. Kniffen, D.A., Bignami, G.F., Fichtel, C.E., Hartman, R.C., Ögelman, H.B., Thompson, D.J., Özel, M.E., and Tümer, T., 14th International Cosmic Ray Conference Munich, 1, 100 (1975)
4. Kniffen,D.A., Hartman, R.C., Thompson, D.J., Bignami, G.F., Fichtel, C.E., Ögelman, H., Tümer, T., Nature, 251, 397 (1974)
5. Stecker, F.W., Astrophys. J., 185, 499, (1973)
6. Parker, E.N., Astrophys. J. , 145, 811, (1966)
7. Bignami, G.F., Fichtel, C.E., Kniffen, D.A., Thompson,D.J., Astrophys. J. 199, 54, (1975)

Figure Caption

Fig. 1a. Map of arrival directions associated with detected γ-rays of energy > 50 MeV. The detection efficiency varies slowly and within the region bounded by the large dashed curve the relative detection efficiency is greater than 50%. The circle and ellipse are centered on the known positions of the Crab Nebula and the new galaxy respectively.

Fig. 1b. Variation in γ-ray intensity along the line between the two sources. Each point represents the intensity associated with a 1° x 8° rectangle. The dashed curves indicate the expected response to two point sources superimposed on a constant background. The intensity is in arbitrary units.

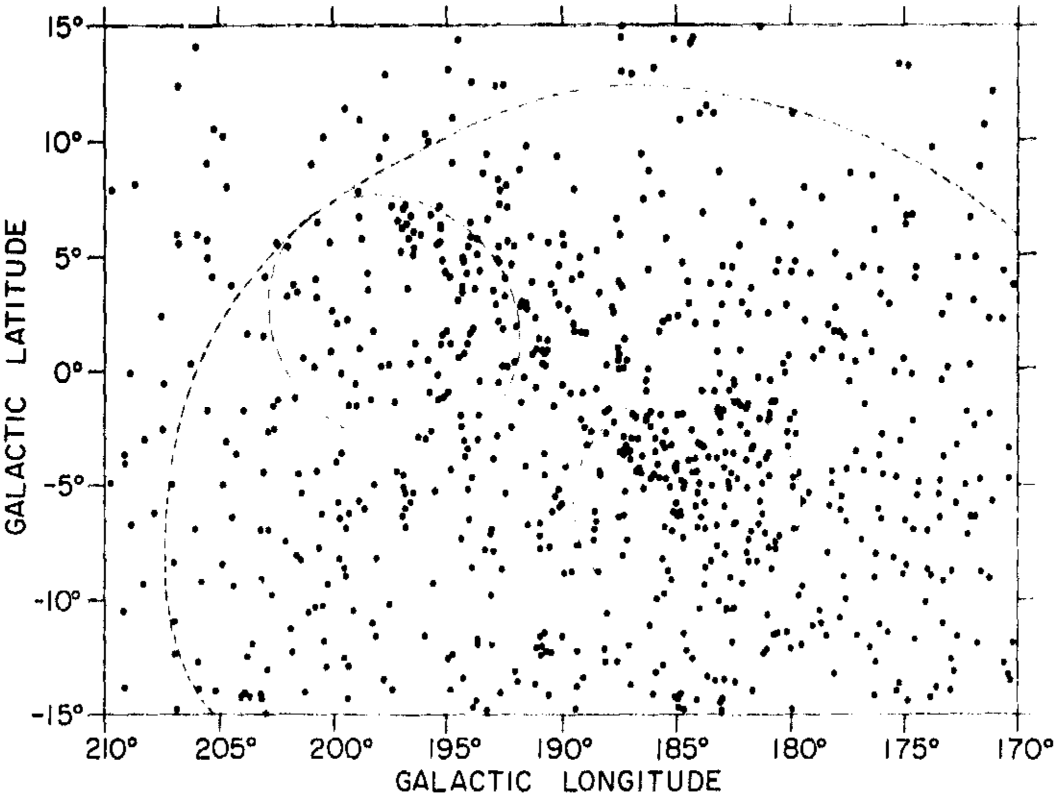
15°
10°
5°
0°
-5°
-10°
-15°
GALACTIC LATITUDE
210°
205°
200°
195°
190°
185°
180°
175°
170°
GALACTIC LONGITUDE

Fig. 1a

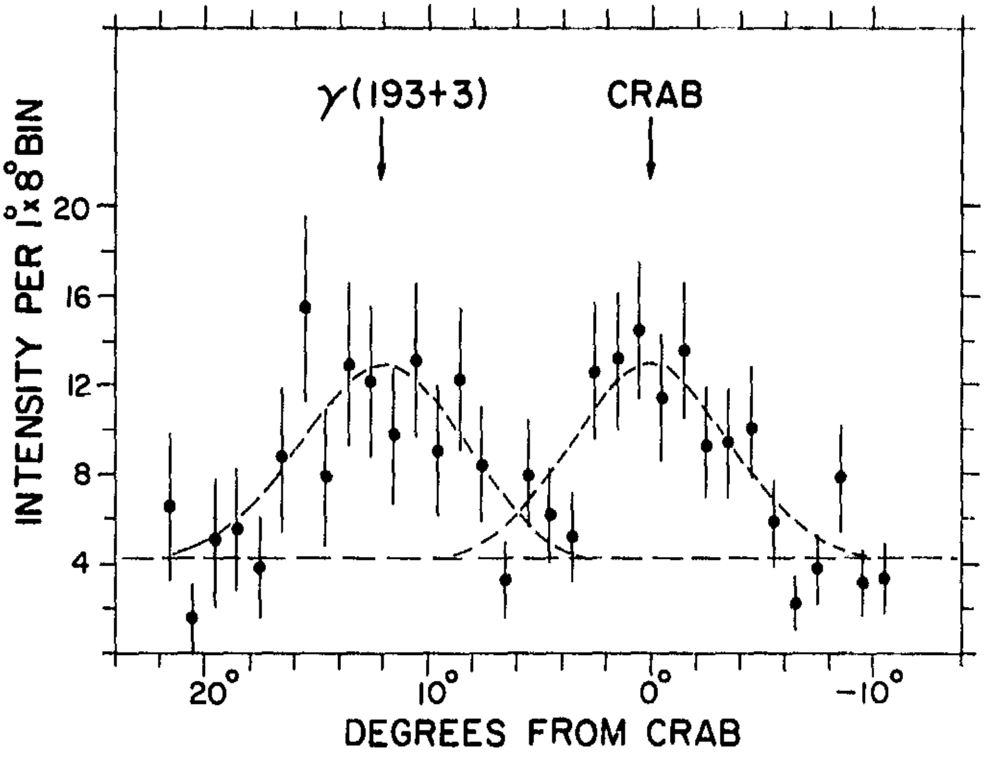
γ(193+3)
CRAB
INTENSITY PER 1°x8° BIN
20
16
12
8
4
20°
10°
0°
-10°
DEGREES FROM CRAB

Fig. 1b