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GALACTIC DISTRIBUTION OF INTERSTELLAR ^{26}Al

W. A. Mahoney, J. C. Higdon, J. C. Ling,
W. A. Wheaton, and A. S. Jacobson
Jet Propulsion Laboratory 169-327
4800 Oak Grove Drive
Pasadena, CA 91109, USA

1. Introduction. The observation of ^{26}Al in the present interstellar medium (ISM) was an exciting milestone for nuclear gamma-ray spectroscopy. It provided direct experimental proof that intermediate-mass nuclei are continuously being synthesized in the Galaxy. This discovery was made with the high-resolution gamma-ray spectrometer on HEAO 3 (1) and was subsequently confirmed by the SMM gamma-ray experiment (2). A narrow cosmic gamma-ray line at 1809 keV was discovered (1) which we interpreted as resulting from the decay of ~3 $M_\odot$ of ^{26}Al residing in the galactic disk. While its intrinsic width was unresolved by the HEAO 3 spectrometer, a (1σ) limit of 3 keV FWHM was obtained; this corresponds to bulk motions of $|v| \lesssim 250$ km/s, which is consistent with material at rest in the ISM.

Even prior to the discovery of the cosmic gamma-ray line at 1809 keV, there had been considerable discussion in the literature on the nucleosynthesis of ^{26}Al. Sites which have been suggested include type II supernovae (3) and massive stars (4) which are members of the extreme population I, as well as novae (5) and red giants (6) which are associated with an older disk population. We have attempted to use the HEAO 3 data to distinguish between these two stellar populations.

2. Analysis. HEAO 3 was a scanning mission with a spin period of 20 minutes. Conventional analysis techniques involve the accumulation of counts from many scans followed by a source-background fitting. Because the HEAO 3 shield has non-zero transmission at 1809 keV even at large angles from the viewing direction, this technique does not work for an extended source, and the source intensity must be determined by a global fit to the data. Thus we have developed a new technique which returns the amplitude of the source function computed for each ten minute stretch of data. The calculated fluxes from hundreds of such scans are averaged together to give the final result. Since ten minutes is short compared to the spacecraft orbital period, systematic effects which arise because of the intense, time-variable, background count rate are nearly eliminated. While this method results in a significant reduction in both the systematic and statistical errors, it is not yet possible to measure the spatial distribution of a source flux. Rather a source distribution must first be assumed and then convolved with the instrument transmission as a function of scan angle. Initially supernovae were believed to be the prime candidates for the source of ^{26}Al. Since the million-year mean life of ^{26}Al is much longer than the average time between galactic supernovae (~100 years), the diffuse 1809 keV line emission would reflect the accumulation from thousands of production sites. Thus we assumed the ^{26}Al formed an extended source in the galactic equatorial plane with an

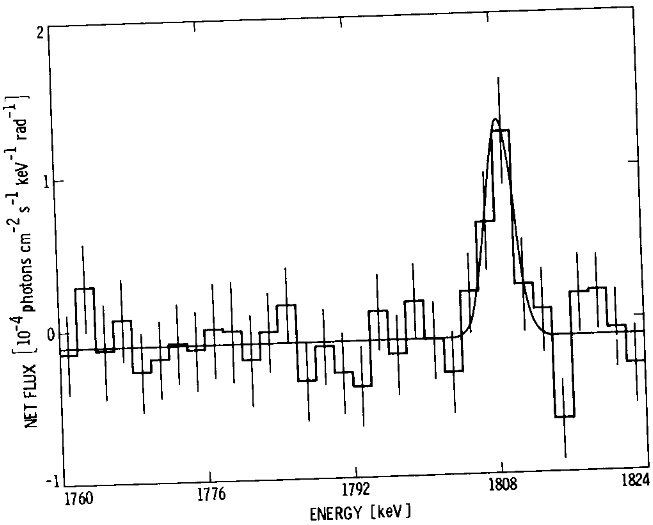

Figure 1. Net diffuse galactic gamma-ray emission near 1809 keV.

extreme population I distribution (1). The results of an analysis using this source function are shown in Figure 1 where a narrow line at 1809 keV is evident above an otherwise featureless continuum.

Since establishing the existence of a cosmic feature at 1809 keV, we have analyzed the HEAO 3 data with the aim of distinguishing between various models for its origin. From the initial analysis (1), it was clear that the emission from the galactic center was more intense than from the anticenter. Thus we first determined the centroid of the distribution by using the extreme population I source model and shifting

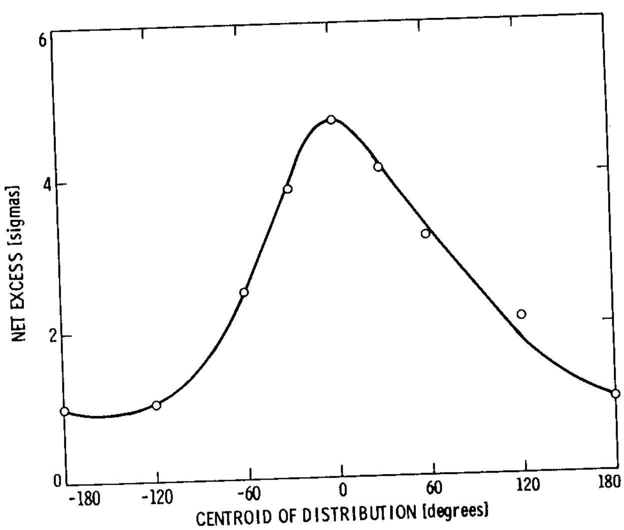

Figure 2. Significance of the 1809 keV observation as a function of galactic longitude.

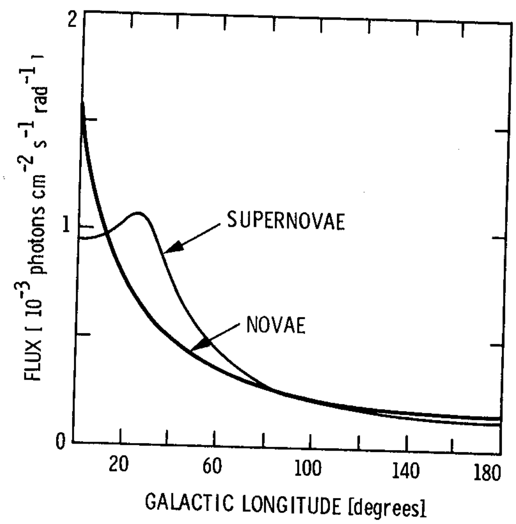

Figure 3. Galactic longitude distributions corresponding to extreme population I (supernovae) and an older disk population (novae). Both have been normalized to a total galactic luminosity of 10^{43} photons/s.

the model's centroid to various galactic locations. For each location, the significance of the net cosmic line was computed. The results in Figure 2 clearly show that, as a function of galactic longitude, the emission is peaked in the direction of the galactic center. Adding the results of a similar shift in galactic latitude shows that the emission is centered at $\ell = -6° \pm 22°$ and $b = -4° \pm 20°$.

We next studied two galactic distributions which we believe are representative of stellar populations suggested as the source of the ^{26}Al (Figure 3). The measured galactic CO distribution (7) was assumed to model type II supernovae and massive main sequence stars. For the older disk population containing novae and red giants, we chose the total visual distribution in the Galaxy (8). Analysis of recent CCD observations of M31 has shown that novae follow precisely the visual luminosity as a function of galactic radius (9). A previous work (10) has employed a nova distribution that is more peaked toward the galactic center, but we believe the visual luminosity is more representative.

TABLE 1

Assumed Distribution	Flux ($\ell = 0°$) [photons/cm^2-s-rad]	^{26}Al Mass [$M_\odot$]	Significance [sigmas]
Extreme Population I	$(4.3 \pm 0.8) \times 10^{-4}$	3.1	5.2
Visual	$(7.3 \pm 1.5) \times 10^{-4}$	2.3	4.8

The results of the analysis of the first two months of HEAO 3 data are shown in Table 1. Note that while the quoted intensity from the galactic center is higher for the visual distribution than for the population I model, the implied mass is lower. This results because the visual distribution is much more peaked toward the galactic center (Figure 3). The analysis thus far does not distinguish between these two populations.

3. Discussion. While the HEAO 3 data are consistent with both the supernova and nova distributions, theoretical models of these two types of events tend to favor novae (11) as the main source of ^{26}Al. Supernova calculations (3) indicate that the ^{26}Al/^{27}Al isotopic production ratio is $\sim 10^{-3}$ whereas a production ratio of nearly 0.1 is required to explain the observations. Nova calculations (5), on the other hand, give a ^{26}Al/^{27}Al production ratio near 1 and indicate that they can account for about 1 $M_\odot$ of ^{26}Al in the present ISM. Furthermore, the nova models used outdated values for the rates of the ^{25}Mg(p, γ)^{26}Al reaction, the main production mode of ^{26}Al. Recent measurements of the cross sections (12) revealed a new resonance which translates into a vastly increased reaction rate at temperatures typical of novae. Thus it appears novae are capable of producing nearly all the observed ^{26}Al. The contribution from massive stars (4) and red giants (5) as well as supernovae appears small compared to the nova production.

We will continue analyzing the HEAO 3 data in an attempt to measure the latitude extent of the emission and to try to differentiate between the suggested stellar populations responsible for the ^{26}Al production.

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