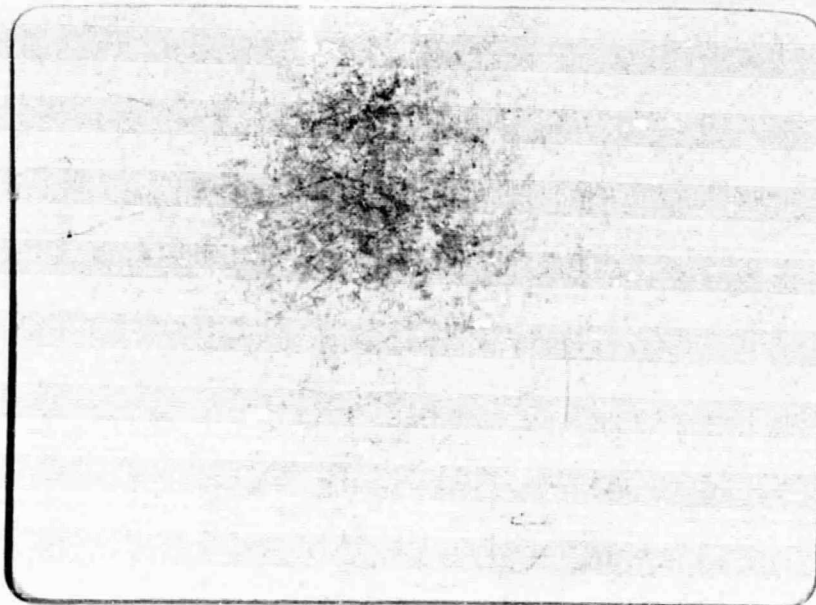# N O T I C E

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SECRETARIA DE PLANEJAMENTO DA PRESIDÊNCIA DA REPÚBLICA
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INSTITUTO DE PESQUISAS ESPACIAIS

16.Summary/Notes   The detection of the 0.511 MeV electron-positron annihilation line coming from the Galactic Center can provide the means to estimate the rate of positron production and to test some theoretical sources of positrons. In this work we present the result of the measurements of the 0.511 MeV line flux made with a gamma-ray experiment on board a stratospheric balloon. The detector field of view looked at the galactic longitude range $-31°<\ell^{II}<+41°$. The observed flux is $(6.70\pm0.50)x10^{-3}$ photons cm^{-2}s^{-1}, which is in very good agreement with the expected flux when assuming that the Galactic Center is a line source emitting uniformly.

MEASUREMENT OF THE 0.511 MeV γ-RAY LINE FROM THE GALACTIC CENTER

J.O.D. JARDIM, J.L. BENSON*, M.V.A. JARDIM AND I.M. MARTIN

Instituto de Pesquisas Espaciais - INPE
Conselho Nacional de Desenvolvimento Científico e Tecnológico - CNPq
São José dos Campos, S.P., Brasil

RESUMO

A detecção do fluxo da linha de aniquilação eletron-positron em 0.511 MeV proveniente da direção do Centro Galático fornece condições de estimar a taxa de produção de positrons e de testar algumas fontes de positrons teóricas. Neste trabalho apresentamos o resultado de medidas da linha 0.511 MeV, obtidas com um experimento para medir raios gama à bordo de um balão estratosférico. O ângulo de visada do detetor observou o disco galático no intervalo de longitude $-31^\circ < \ell^{II} < +41^\circ$. O fluxo observado é $(6.70\pm0.50) \times 10^{-3}$ fótons $cm^{-2} s^{-1}$, o qual concorda muito bem com o valor de fluxo calculado supondo-se que o Centro Galático é uma fonte linear emitindo uniformemente.

ABSTRACT

The detection of the 0.511 MeV electron-positron annihilation line coming from the Galactic Center can provide the means to estimate the rate of positron production and to test some theoretical sources of positrons. In this work we present the result of the measurements of the 0.511 MeV line flux made with a gamma-ray experiment on board a stratospheric balloon. The detector field of view looked at the galactic longitude range $-31^\circ < \ell^{II} < +41^\circ$. The observed flux is $(6.70\pm0.50) \times 10^{-3}$ photons $cm^{-2} s^{-1}$, which is in very good agreement with the expected flux when assuming that the Galactic Center is a line source emitting uniformly.

Key words: GAMMA-RAY LINES-GALACTIC CENTER-ELECTRON-POSITRON ANNIHILATION.

* Present Address: Max-Planck Institut für Aeronomie, Lindau, FRG.

I. INTRODUCTION

The search for the 0.511 MeV electron-positron annihilation line flux emitted from the Galactic Center (GC) region has been a difficult task to achieve by the few groups working in gamma ray spectroscopy since the observation made by Haymes et al. (1975). They used a telescope with about 13° full width at half-maximum (FWHM) angular resolution and reported a flux coming from $-4^\circ < \ell^{II} < +6^\circ$ galactic longitude interval as $(8.0 \pm 2.3) \times 10^{-4}$ photons $cm^{-2} s^{-1}$ for the 0.511 MeV line.

Later, Leventhal et al. (1978) flew a telescope from Alice Springs (Australia) with $\approx 15^\circ$ FWHM angular resolution and using a large high-purity (HP) Ge detector of 130 cm^3. They reported a 0.511 MeV line flux of $(1.22 \pm 0.22) \times 10^{-3}$ photons $cm^{-2} s^{-1}$ coming from the GC.

Due to a Brazilian-French collaborative program, a telescope using a large Ge(Li) crystal of 140 cm^3 has flown from Guaratinguetá (Brazil), in 1977, on board a stratospheric balloon (Albernhe et al., 1977). Da Costa (1980), analyzing the data obtained from two flights, calculated an intensity of $(4.19 \pm 1.56) \times 10^{-3}$ photons $cm^{-2} s^{-1}$ for the 0.511 MeV line flux from the Galactic Center.

In this paper we report the measurement of the electron-positron annihilation line emitted from the GC disk in the $-31^\circ < \ell^{II} < +41^\circ$ longitude interval using the upper NaI(Tl) detector of a balloon borne telescope.

The payload was launched from Cachoeira Paulista ($22^\circ 40'$S, 45°W), Brazil, in March 29, 1980.

We measured an intensity of $(6.70 \pm 0.50) \times 10^{-3}$ photons $cm^{-2} s^{-1}$ for the 0.511 MeV line coming from the GC direction.

II. THE EXPERIMENT AND THE FLIGHT

The telescope is made up of two 10.16cm x 10.16cm cylindrical NaI(Tl) crystals separated vertically by 90cm and a 20cm diameter cylindrical lead (Pb) shield, 5cm thick, is placed in

between the detectors. Each detector is surrounded by an aluminum powder shield and has a 1.5cm thick NE102A plastic scintillator in front of the crystal in order to reduce some of the charged particle background.

The array defines an aperture angle of 30° FWHM at about 1.2 MeV when we make the differences in counting rate between the upper and lower detector as a function of angle.

Each detector is connected to a RCA 8054 photomultiplier and to a 128 channels SEIN encoder in order to provide the spectra in the 0.3 to 3.0 MeV energy interval.

A complete description of the telescope will be given by Benson et al. (1981).

The payload was carried aloft by a stratospheric balloon $(74,000m^3)$ which was launched at 02:07UT in March 29, 1980.

The balloon reached the ceiling of about 4 millibars at 04:04UT and the flight duration was 15 hours, as it was discontinued by a pyromechanical device for purposes of recovering.

The pressure data was obtained using a Rosemount pressure sensor.

The encoded signals, pressure and temperature data as well as azimuthal directions obtained from two crossed fluxgate magnetometers were telemetered to the ground via FM-FM telemetry.

We observed the transit of the GC through the field of view of the telescope.

To calculates the flux at the 0.511 MeV line due to the GC we used only the upper detector assembly (FWHM$\approx72^{\circ}$) for which the setting was about 25 keV/channel. If we had used the telescope in its present electronic configuration for this purpose it would have been difficult to locate the peak position with confidence.

The measured energy resolution is 14% at 0.511 MeV for the 4"x4" NaI(Tl) crystal.

III. RESULTS AND CONCLUSIONS

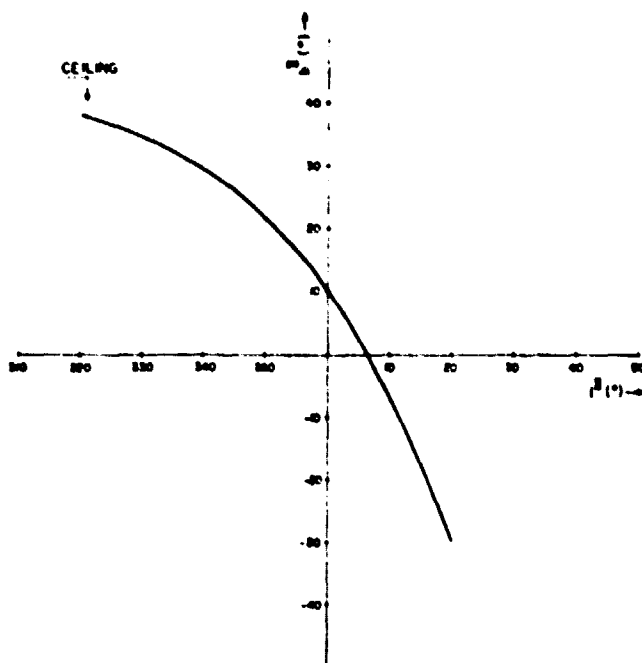In Figure 1 is shown the path of the balloon in galactic coordinates after the payload reached the ceiling.

FIG. 1. Path of the balloon in galactic coordinates after reaching the ceiling.

We show in Figure 2 the average fluxes for the background (BKC) and for the region where the axis of the telescope was looking toward the galactic coordinates $l^{II} = 5.54°$ and $b^{II} = + 1.92°$, i.e., when the region in galactic latitude ranging from $-31°$ up to $+41°$ was within the FWIIM of the upper detector.

From the measurements and after taking into account the atmospheric absorption (Fig. 2) we calculated the flux coming from the GC direction as being $(6.70 \pm 0.50) \times 10^{-3}$ photons $cm^{-2} s^{-i}$.

If we assume that the galactic disk is a line source emitting uniformly the 0.511 MeV line radiation we can use the results

estimated from the observations.

On the other hand, the highest estimated value from theoretical models for the intensity of the 0.511 MeV line due to electron-positron annihilation is given by Stecker (1971) as 2×10^{-3} photons $cm^{-2}s^{-1}sr^{-1}$.

If we use our result and the detector solid angle to transform the flux into the same units used by Stecker (1971) we get 5.58×10^{-3} photons $cm^{-2}s^{-1}sr^{-1}$, which is about 3 times higher than the theoretical estimate. It suggests that other sources of positrons are needed to explain the observations.

It is worth to note that the GC line emission profile appears to be more alike a flat extended source than to be a point source with a few degrees wide.

Finally, the fact that Mandrou et al. (1980) give only an upper limit flux for that line seems to suggest that the extent of the 0.511 MeV emitting region is less than 90° FWHM in longitude.

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Mandrou, P.; Bui-Van, N.A.; Vedrenne, G. and Niel, M. 1980, *Ap.J.*, 237, 424.

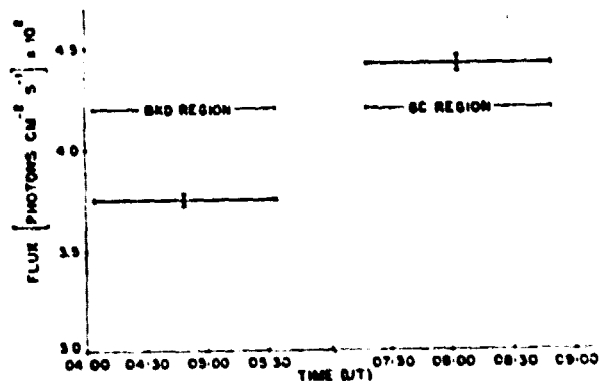Stecker, F.W. 1971, in *Cosmic Gamma Rays*, NASA SP-249, p. 167.

FIG. 2. Average fluxes for background and for the region where the GC was within the field of view.

from Haymes et al. (1975), Leventhal et al. (1978) and Da Costa (1980) and take into account their angular field of view to estimate the flux that our detector would observe.

Using this procedure we calculated an expected line flux of $(6.67\pm0.94)\times10^{-3}$ photons $cm^{-2}s^{-1}$, in very good agreement with our measurement.

Mandrou et al. (1980) observed the region $-45^{\circ}<\ell^{II}<+45^{\circ}$ using a telescope with 90° FWHM which was launched in 1977 from Guaratinguetá, Brazil. They give an 1σ upper limit for the 0.511 MeV line flux as 9.7×10^{-3} photons $cm^{-2}s^{-1}$.

Using our measurement and the fluxes observed by Haymes et al. (1975), Leventhal et al. (1978) and Da Costa (1980) and the line source assumption to estimate the flux they would have observed we get $(9.22\pm0.60)\times10^{-3}$ photons $cm^{-2}s^{-1}$. Therefore, their reported upper limit flux is compatible with the value