The GeV-band source population in the Galactic-Center region as seen by Fermi Large Area Telescope

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on behalf of the Fermi LAT collaboration

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***Abstract*. The Galactic Center is among the richest and most complex regions in the Galaxy, due to the number of possible sources and the difficulty to correctly model the diffuse emission due to cosmic ray interaction with the local molecular clouds complex. Despite detection in the GeV (EGRET) and TeV range (H.E.S.S.), an accurate description of the high-energy emission in that region still eludes us. The Fermi Gamma-ray Space telescope has been successfully launched on June 11 2008, and is currently performing a one-year all sky survey. We report here on the observation of the Galactic Center region with Fermi Large Area Telescope (LAT), a pair conversion detector designed to study the gamma-ray sky in the energy range 20 MeV to more than 300 GeV, with unprecedented sensitivity and resolution. In this talk we describe Fermi measurements of individual sources of GeV-band gamma-ray emission in the Galactic Center region.**

***Keywords*: Galactic Center Sources; Fermi Large Area Telescope; High Energy Gamma rays;**

I. INTRODUCTION

The Galactic Center region contains a large number of hard X-ray sources [21] that are potential sources of high-energy γ-ray emission [26]. A point source of GeV-scale γ-ray emission, 3EG J1746-2851, has been detected with EGRET [25][16], but no firm identification with sources known in other frequency bands has been made to date. The exact localization of 3EG J1746-2851 is difficult to establish on account of large uncertainties in the intensity distribution of diffuse galactic γ-ray emission from that region, but careful studies indicate that 3EG J1746-2851 is displaced from the exact Galactic Center towards positive Galactic longitudes, and Sgr A* seems to be excluded as possible counterparts at the $> 95\%$ level [17][29].

Very high-energy γ-rays have also been detected from the Galactic Center region with the Whipple 10m telescope [20], the CANGAROO telescope [33], and the HESS array [2]. The HESS data indicate a power-law spectrum with photon index $\alpha = 2.21 \pm 0.09$, the extrapolation of which does not fit the GeV-scale flux measured with EGRET. The source of TeV-scale γ-ray emission is coincident with Sgr A* to within about 0.002°, and it is also consistent with the location of a hard X-ray source [7]. The HESS collaboration also reports the detection of a diffuse TeV-band emission from the inner 200 pc [4], that appears spatially correlated with the dense cores of molecular clouds as traced by molecular CS line emission [32].

Many models have been published to explain 3EG J1746-2851, e.g. invoking an advection-dominated accretion flow onto the supermassive black hole known as Sgr A* [24], [27], the decay of neutralinos [8], the acceleration of quasi-monoenergetic electrons in the radio arc [28]. For the TeV-band emission, the lack of a cut-off in the γ-ray spectrum seems to disfavor models involving the annihilation of dark-matter particles [9], [12], [15], [18], for a very high mass $m_x \gtrsim 12$ TeV of the hypothetical neutralino would be required. More conventional models for the high-energy emission from the Galactic Center region have also been proposed. Electron acceleration by plasma turbulence near the supermassive black hole [30] may be a very efficient process [23], [22]. [6] argue that the combination of ADAF-type accretion with a subrelativistic MHD outflow can explain the TeV-scale emission as well as that at X-rays and lower frequencies, but 3EG J1746-2851 would be a separate source. [13] discuss Sgr A East, a nonthermal radio source with a supernova-like morphology located near the Galactic Center, as a possible counterpart of 3EG J1746-2851 , and [11] attempt to relate 3EG J1746-2851 , the TeV-scale γ-ray source, and anisotropies in the UHE cosmic-ray intensity to Sgr A East. Detailed correlation studies between X-ray and TeV-band γ-ray emission can be used to potentially verify the association of very-high-energy sources with individual sources in the Galactic-center region [5].

One of the fundamental questions is whether or not the sources seen in the GeV and TeV bands are identical.

II. FERMI LAT DATA ANALYSIS

The Fermi Gamma-ray Space telescope (hereafter $Fermi$) was launched on June 11th 2009, and has been operating in nominal sky survey mode since the beginning of August. With its unprecedented field of view (∼2.4 sr at 1GeV), effective area (∼8000 cm^2 at

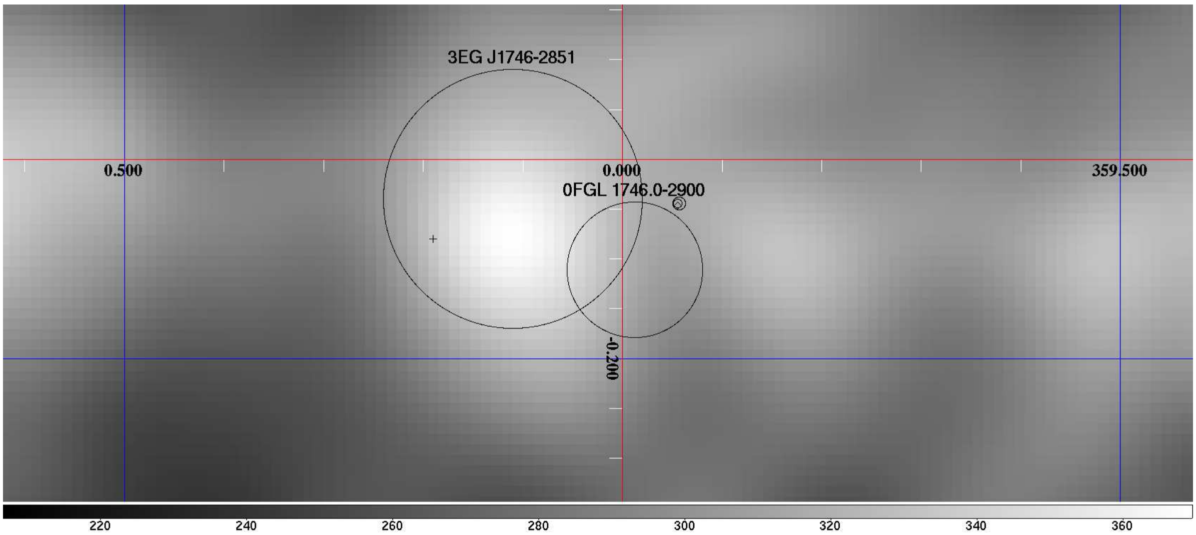

Fig. 1. Source positions of EGRET and H.E.S.S observations, compared with the preliminary localization of the Fermi LAT source 0FGL J1746.0−2900. The background map is a close-up of the H.E.S.S. Galactic Center region residual map. The diamond denotes the compact radio source SgrA*, and the two small circle nearby are the H.E.S.S. 2004 dataset result, and the improved analysis from [34]. The cross marks the best fit result of the EGRET reanalysis in [17].

1 GeV), angular resolution ($\sim$0.8° for the 68% containment radius at 1 GeV), and energy resolution (better than 15% above 100 MeV), the Large Area Telescope (LAT) on Fermi already produced a deeper and better-resolved map of the γ-ray sky (in the energy range from 20 MeV to more than 300 GeV) than any previous space mission.

The LAT collaboration recently released initial results for energies above 100 MeV for the 205 most significant (statistical significance greater than $\sim 10\,\sigma$) γ-ray sources in the first three months of data [1]. This bright source list (hereafter BSL) includes positional information with a conservative 95% C.L. error radius including systematics (hereafter noted θ_{95}), and the integrated fluxes obtained by a likelihood fit to a powerlaw in two energy bands, from 100 MeV to 1 GeV and from 1 GeV to 100 GeV.

In this proceeding, we report mainly on the LAT observation of the Galactic Center based on this released material, deferring to the conference talk updated analyses and detection of further sources. The BSL includes two sources in this neighborhood, that we discuss hereafter (the actual skymap will be presented at the conference as well).

III. 0FGL J1746.0−2900

As expected from EGRET observations, the presence of a LAT source very close to the Galactic Center region could already be distinguished in the LAT "first light" skymap, released to the press early August 2008 and corresponding to the first ~ 4 days of observations in nominal sky survey mode. In the BSL, this source, 0FGL J1746.0−2900, is indeed confirmed with a significance of 36 σ. We discuss its main features below.

A. Source position

In the third EGRET catalog [16], the closest source from the Galactic Center is 3EG J1746-2851, localized at l=$0°6'36''$, b=$-0°2'24''$ with a 95% C.L. error radius of about $8'$ (selecting only photons above 1 GeV). Two subsequent analyses [17], [29], making use of an improved likelihood analysis and of a better understanding of systematics, excluded the position of Sgr A* to better than 99% C.L., in contradiction to the conclusion reached in [25].

The H.E.S.S. collaboration also reported a strong detection of a source at the Galactic Center, localized at l=$359°56'33.3'' \pm 9.7''$, b=$-0°2'40.6'' \pm 10''$ [3]. A more recent analysis ([34], still pending further verifications) improved the systematics and obtained as best fit positions l=$359°56'41.1'' \pm 6.4''$(stat), b=$-0°2'39.2'' \pm 5.9''$(stat).

As a result, one of the fundamental questions that the LAT needs to address is whether the GeV and TeV sources are indeed positionally inconsistent. The BSL best fit position for 0FGL J1746.0−2900 is l=$359°59'16.1''$, b=$-0°6'40.7''$ with a 95% C.L. error radius of $4'$, and is plotted on figure 1.

B. Variability

Variability, if observed, strongly constrains source models, e.g. eliminating Dark Matter explanations. In order to detect variability, the data between 200 MeV and 300 GeV are subdivided into 12 time intervals of a little more than one week, and the flux in each interval is fitted using a simple power law and fixing the photon index to its overall fitted value. A simple χ^2 criterion is then used to detect variability. Though the BSL catalogue reported a marginal variability for 0FGL J1746.0-2900, the 6-month dataset does not confirm

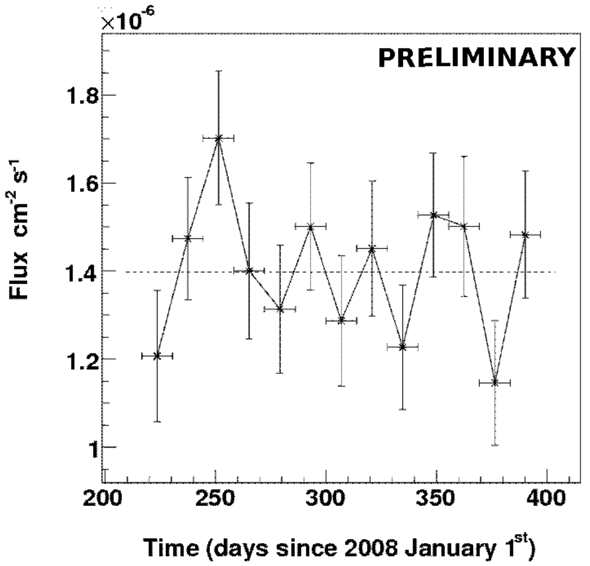

Fig. 2. Updated 6 month light curve for 0FGL J1746.0−2900. Early mild indication of variability, as mentioned in [1], is not confirmed, pending further investigations.

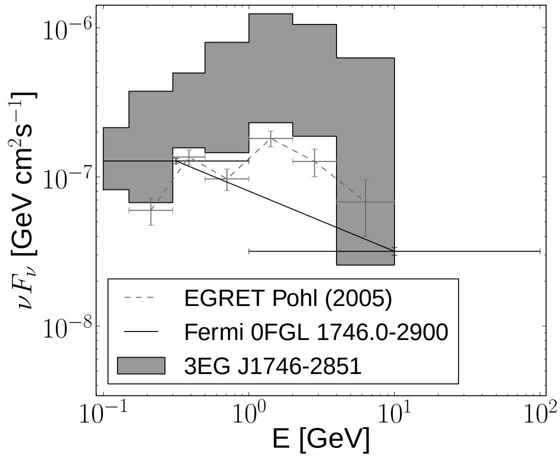

Fig. 3. Spectra of the Galactic Center source, as obtained in [25] with EGRET (in blue, with error bars from [19]), EGRET reanalysis from [29], and the two-band integrated flux from Fermi, as published in [1]

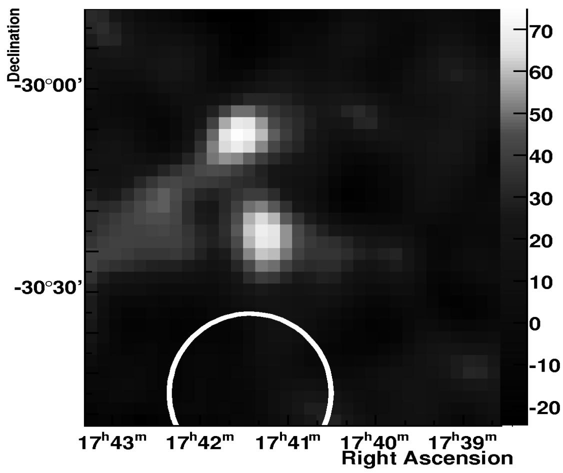

Fig. 4. Preliminary H.E.S.S. skymap in the region around HESS J1741-302, from [31]. The thick white circle shows the approximate 95% C.L. error radius around 0FGL J1741.4-3046.

this result, as can be seen on figure 2. The variability index obtained with this updated dataset indeed results in a $\chi^2 = 13.686$ for 11 degrees of freedom, which corresponds to a 25% probability to get such a χ^2 value or higher, even for a non variable source. Further studies are ongoing to analyze data on smaller intervals and assess the possibility of some residual variability in the region of interest, early in the mission life.

C. Spectral modeling

Spectral modeling is especially difficult in this crowded region where several emitters could potentially emit in the GeV band. Besides, the Galactic diffuse model as obtained with GALPROP is probably inaccurate in the Galactic ridge, where the matter distribution is poorly known and thus the gamma emissivity resulting from cosmic ray interactions with the local gas is not well determined at small scale. Figure 3 compares the spectra obtained with EGRET and Fermi. Though the LAT two-band integrated spectra seem to better agree with the EGRET re-analysis found in [29], analysis is ongoing and LAT results with an updated dataset will be presented and discussed at the conference.

IV. 0FGL J1741.4−3046

This non-variable faint source is listed in the BSL with a significance 11.5 σ, and a best-fit point-source localization at (l=$357°57'32.4''$, b=$-0°11'20.4''$), with a 95% C.L. error radius of 0.197°. The 2-band fluxes are $(24.7 \pm 5.4) \times 10^{-8}$ and $(2.00 \pm 0.31) \times 10^{-8}$ cm^{-2}s^{-1}, respectively. Recently [31], the H.E.S.S. collaboration reported preliminary results on HESS J1741−302, a very faint (∼1% of the Crab) extended source in the Galactic Center region. Figure 4 shows that this H.E.S.S. excess is not quite positionally consistent with 0FGL J1741.4−3046, although a larger LAT dataset is warranted to draw any firm conclusion. A few other galactic sources show a displacement of the peak intensity in the GeV and TeV bands (e.g. [35]), and thus a positional inconsistency does not necessarily imply the presence of two separate sources. Spectral analyses and improvements in localization, made difficult by the faintness of the source and the complexity of the region, are ongoing in both collaborations, and updated results will be presented at the conference.

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