Gamma-ray properties of globular clusters and the "fundamental planes"

Pak-Hin Thomas Tam[1], C. Y. Hui[2], Albert K. H. Kong[1], and K. S. Cheng[3]

[1] Institute of Astronomy and Department of Physics, National Tsing Hua University, Hsinchu, Taiwan, phtam@phys.nthu.edu.tw
[2] Department of Astronomy and Space Science, Chungnam National University, Daejeon, Republic of Korea
[3] Department of Physics, University of Hong Kong, Pokfulam Road, Hong Kong

Introduction

Radio and X-ray observations have revealed about 140 millisecond pulsars (MSPs) in 26 globular clusters (GCs) [1]. However, the presence of much stronger X-ray emitters can contaminate the X-ray observations of MSPs. Because MSPs are the only known steady γ-ray sources in GCs [2], γ-ray observations of GCs serve as an alternative channel in studying the underlying MSP populations in GCs.

Using the Large Area Telescope (LAT), γ-rays from 8 GCs [3] have been discovered, including 47 Tucanae [4] and Terzan 5 [5].

Models of γ-rays from globular clusters

The radiation mechanism of γ-rays is unclear. In the pulsar magnetosphere model, e.g. [6], γ-rays up to a few GeV come from the MSPs through curvature radiation. On the other hand, inverse Compton (IC) processes resulted from energetic particles up-scattering low-energy photons, such as starlight and infrared light, may give rise to γ-rays of MeV to TeV energies, e.g. [7]. In either model, it is expected that the γ-ray luminosity of a GC is proportional to the stellar encounter rate, a measure of the number of MSPs in a GC.
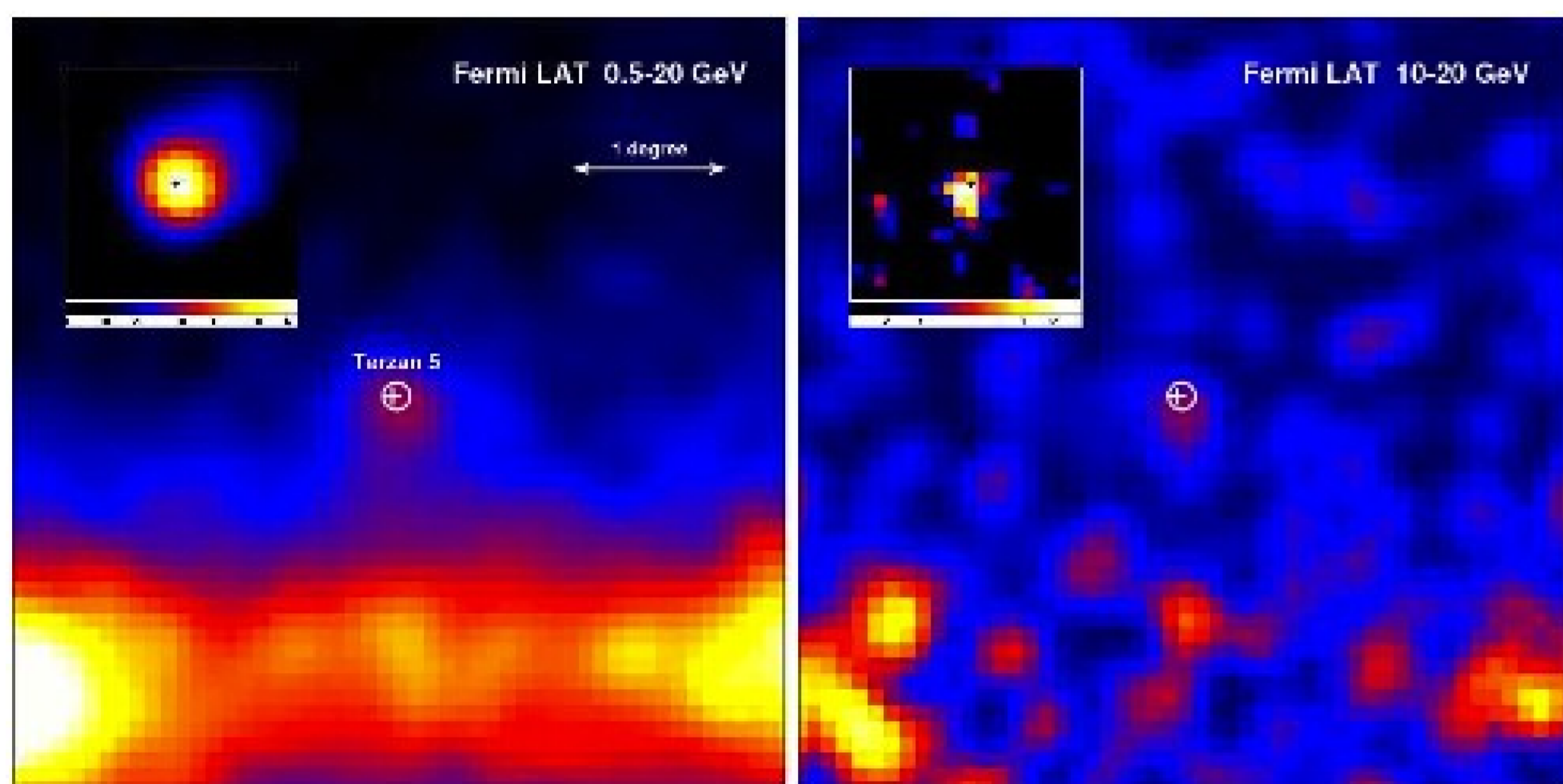

Figure 1
The count maps of the 5° x 5° region centered on Terzan 5. The insets show the test-statistic maps.

New γ-ray GCs uncovered

Terzan 5 contains the largest number of known MSPs among all GCs. It was discovered as the second known GC after 47 Tucanae [5] (see Fig 1). Like 47 Tucanae, its γ-ray spectrum also shows a cutoff at ~3 GeV.

After the discovery of other six γ-ray emitting GCs [3], we also identified a group of GCs with high encounter rate. Using more than 2 years of data taken from LAT, we found γ-ray emission from the directions of Liller 1, NGC 6624, and NGC 6752. The test-statistic maps of the regions around these 3 GCs are shown in Figure 2 (below). For M80, NGC 6139, and NGC 6541, the detection is marginal (4-5σ) when it was first reported [8].

For the cases where the γ-ray emission is offset from the core (i.e. Liller 1 and NGC 6624), the spectra are presented in Figure 3 (right column).
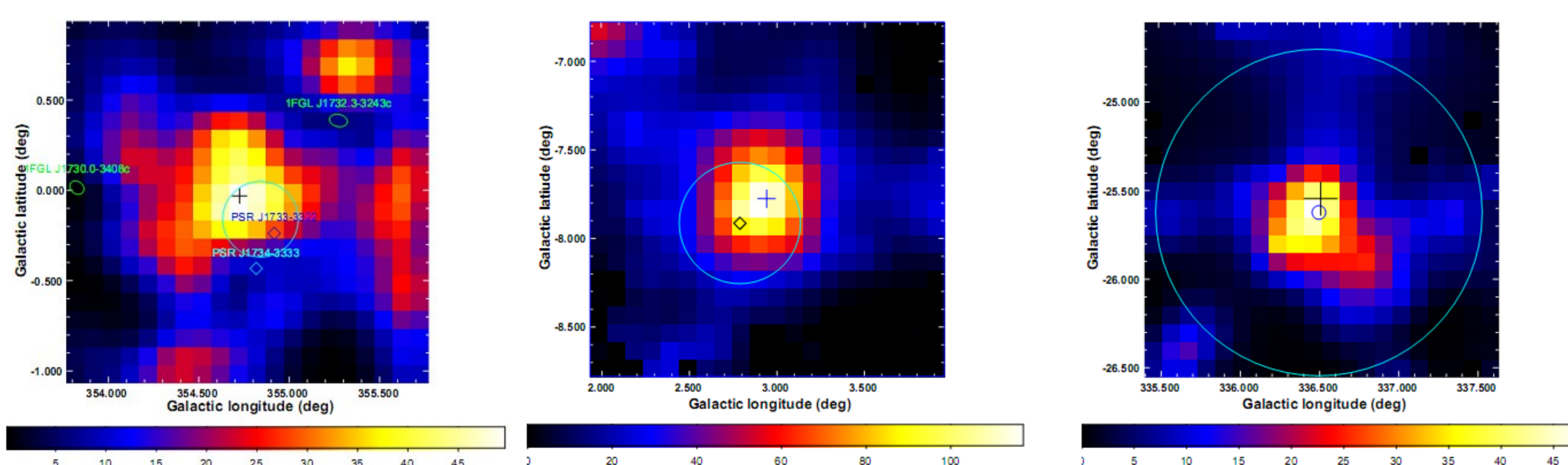

Figure 2
The test-statistics maps of Liller 1 (left), NGC 6624 (middle), and NGC 6752 (right)
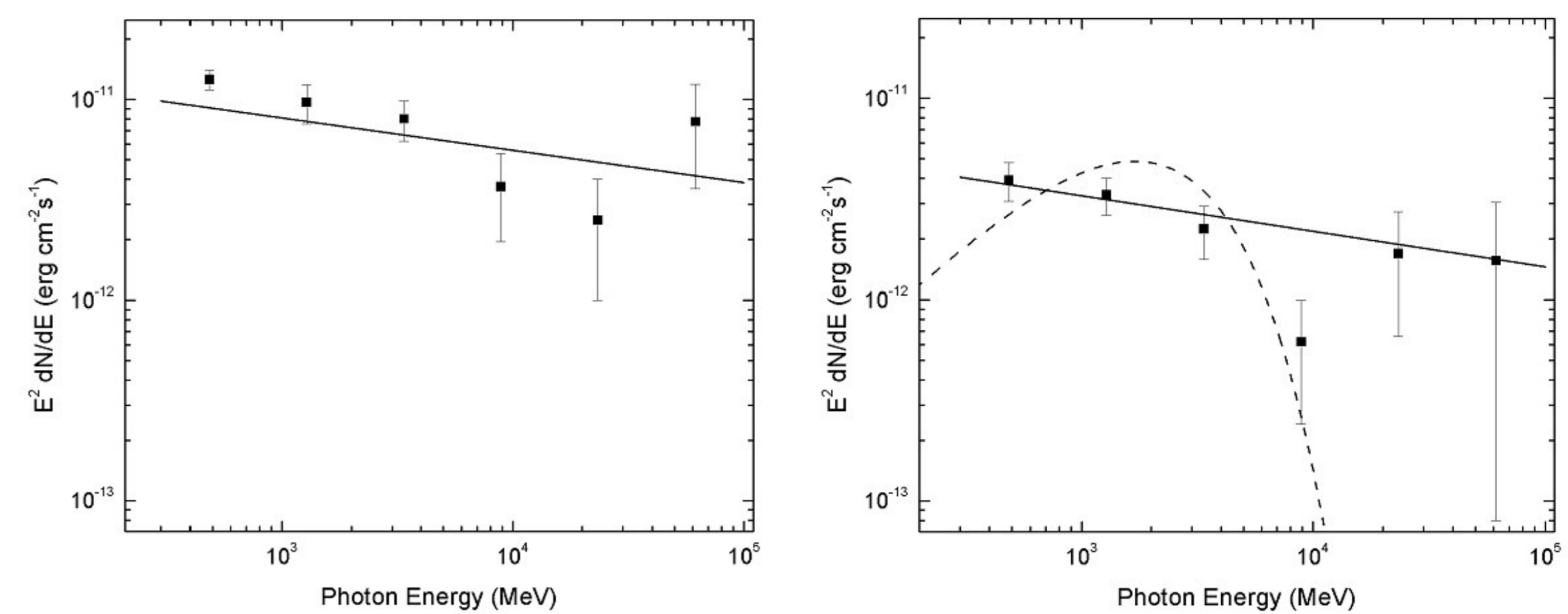

Figure 3
Spectra of Liller 1 (left) and NGC 6624 (right).

The solid and dashed lines represent the best-fit power law and power law with exponential cutoff, respectively.

The Fundamental Planes of γ-ray Globular Clusters

We have investigated the properties of the γ-ray emitting globular clusters [9]. By correlating the observed γ-ray luminosities with various cluster properties, we probe the origin of the high energy photons from these GCs. We found that the γ-ray luminosity is positively correlated with the encounter rate and the metalicity [Fe/H] which places an intimate link between the γ-ray emission and the MSP population. We also found that the γ-ray luminosity increases with the energy densities of the soft photons at the cluster location. When combining two parameters at the same time, the correlation is even stronger. The edge-on fundamental plane relations of γ-ray GCs are depicted in Figure 4 (below).

This finding strongly suggests that models that incorporate optical or infrared photons should be taken into considerations in explaining the γ-ray emission from GCs, e.g. the IC models [7].
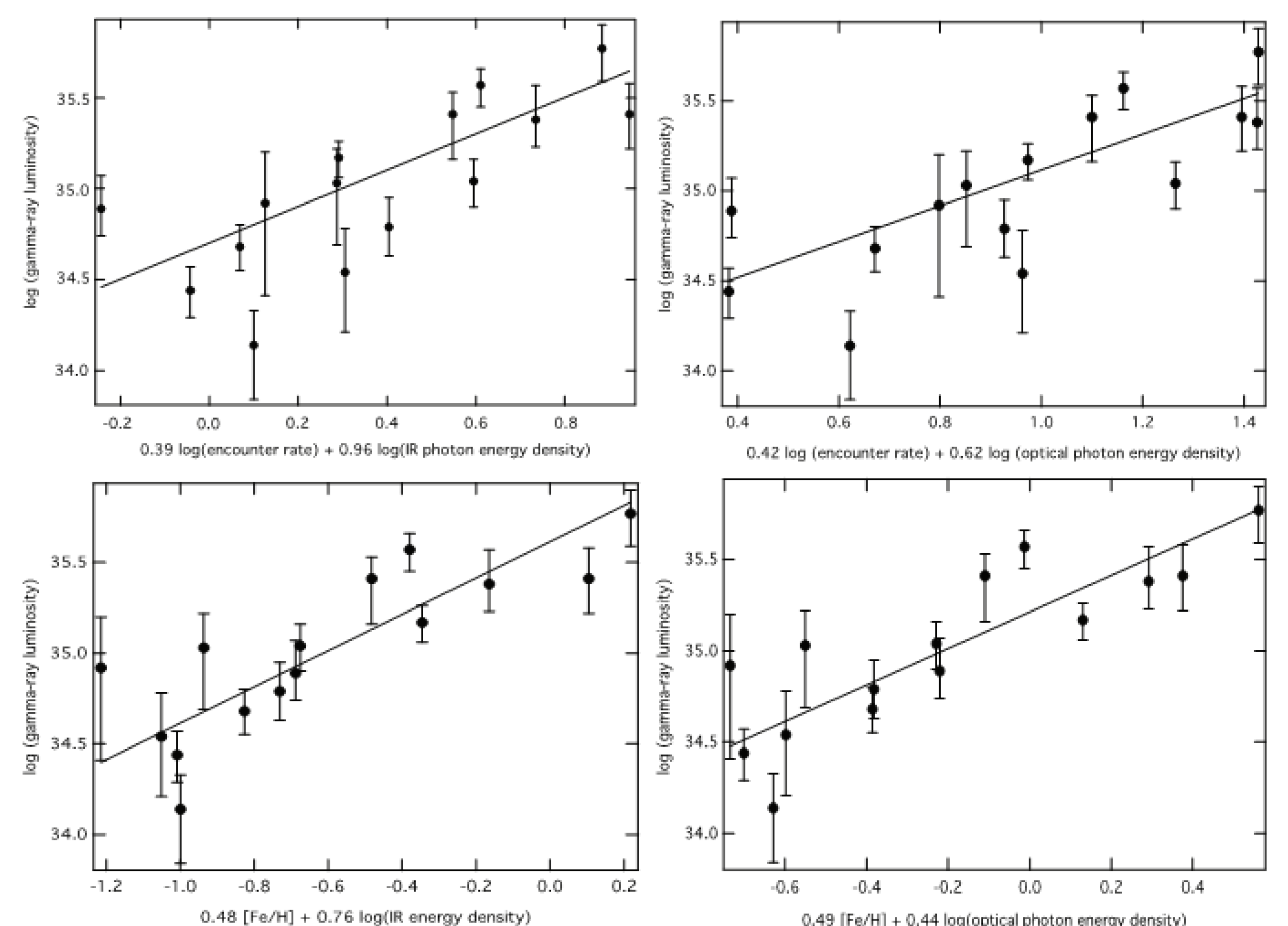

Figure 4
The edge-on views of the fundamental plane relations of γ−ray GCs. The straight lines in the plots represent the projected best-fits.

References

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A Fermi science workshop will be held at National Tsing Hua University in Hsinchu, Taiwan on August 1-5, 2011. Details can be found under *http://crab0.astr.nthu.edu.tw/FAN2*.

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