Lunar gamma ray emission as seen by FERMI

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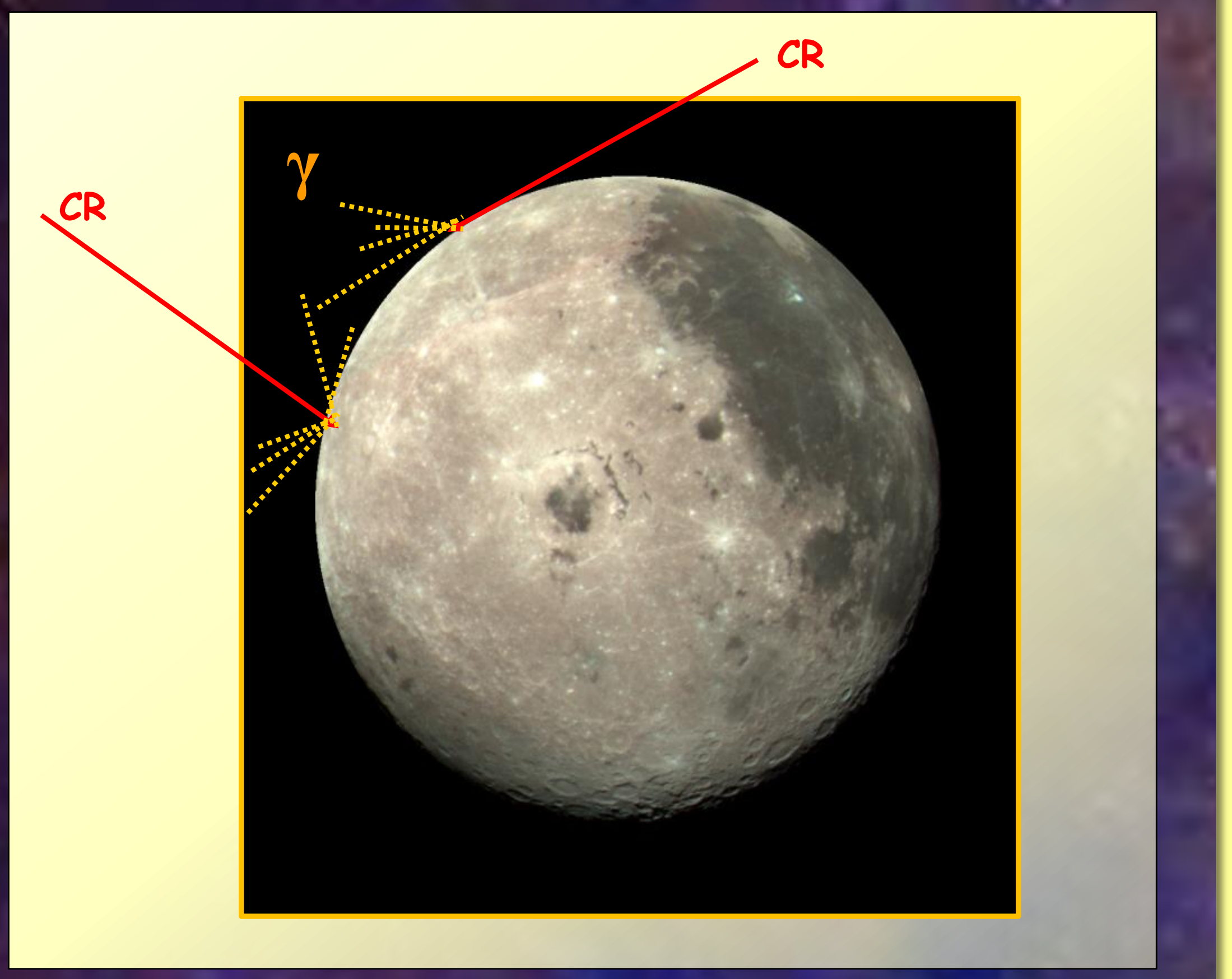
Abstract

We report the Fermi-LAT observations of the lunar emission during the extended period of low solar activity. During this period the CR-induced emission was the brightest. While the Moon was detected by the EGRET instrument on the CGRO with low statistics, Fermi is the only gamma-ray mission capable of detecting the Moon and monitoring it over the full 24th solar cycle. We present the gamma-ray images of the Moon, its spectrum, and flux measurements in comparison with models and previous EGRET results.



The Spectrum

The gamma-ray emission produced by solid solar system bodies is due to the interactions of Galactic cosmic ray nuclei (mainly protons) with their surface layers.The main processes involved are the production and decay of neutral pions and kaons by ions, bremsstrahlung by electrons and Compton scattering of the secondary photons.

The spectrum of gamma-rays from the Moon is steep with an effective cutoff around 3–4 GeV (600 MeV for the inner part of the lunar disk). Due to the kinematics of the collision, the secondary particle cascade from cosmic ray particles hitting the lunar surface at small zenith angles develops deep into the rock making it difficult for gamma-rays to get out. Therefore the lunar gamma-ray emission is produced by a small fraction of splash albedo particles in the surface layer of the Moon rock. High energy gamma-rays can be produced by cosmic ray particles hitting the Moon surface with a more tangential trajectory; thus only a very thin limb contributes to the high energy emission.

Previous Observations

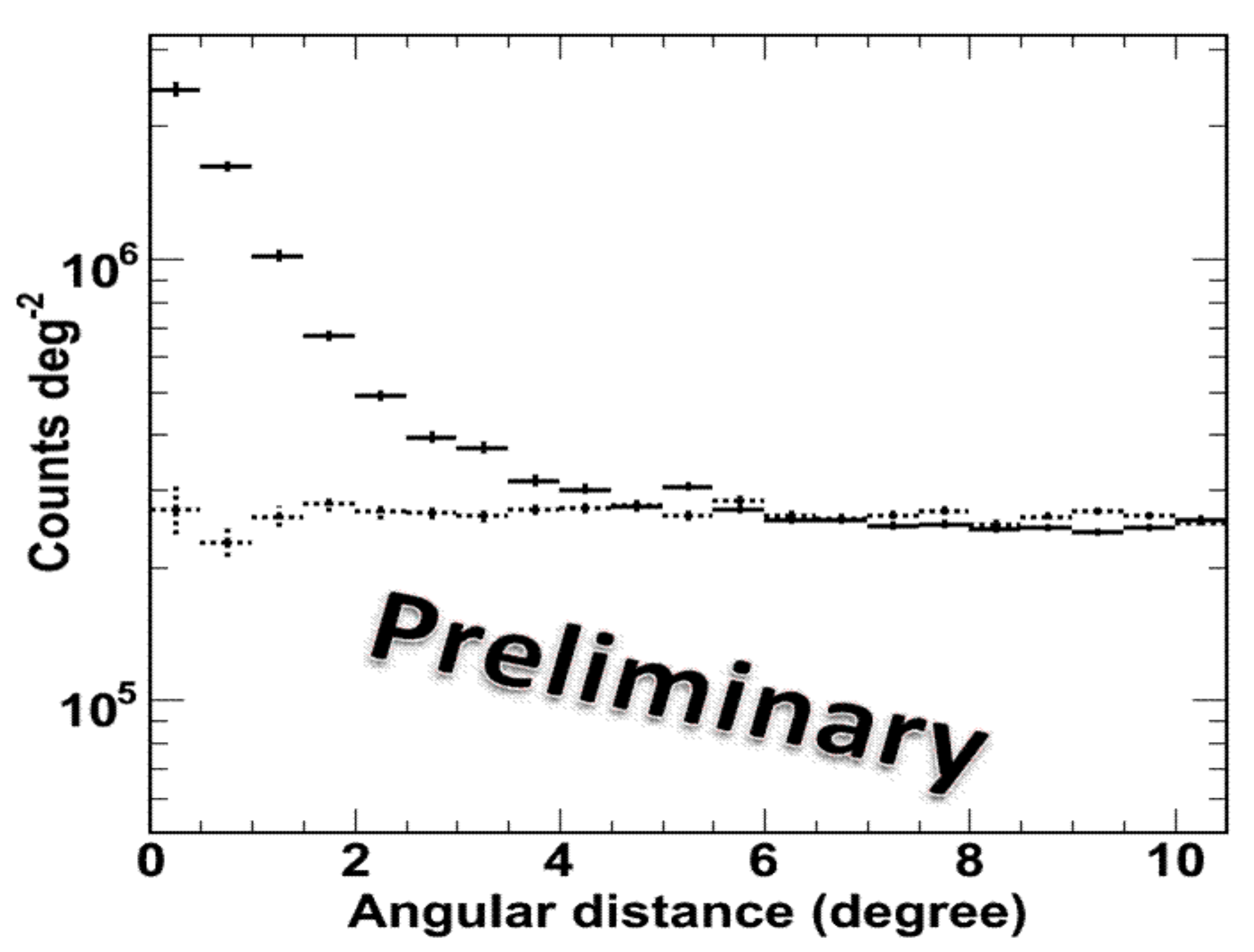
The Gamma-ray telescope EGRET on the Compton Gamma-Ray Observatory detected the gamma-ray emission from the Earth [1], the Moon [2, 3], and the Sun [2]. The Moon is so far the only observed gamma-ray emitting body with the solid surface. For the Sun the gamma-ray emission from the disk, due to the interactions of cosmic ray nuclei with the solar atmosphere [2, 5], is accompanied by extended and brighter gamma-ray emission due to the inverse Compton scattering of Galactic cosmic ray electrons of solar photons [2, 6, 7].

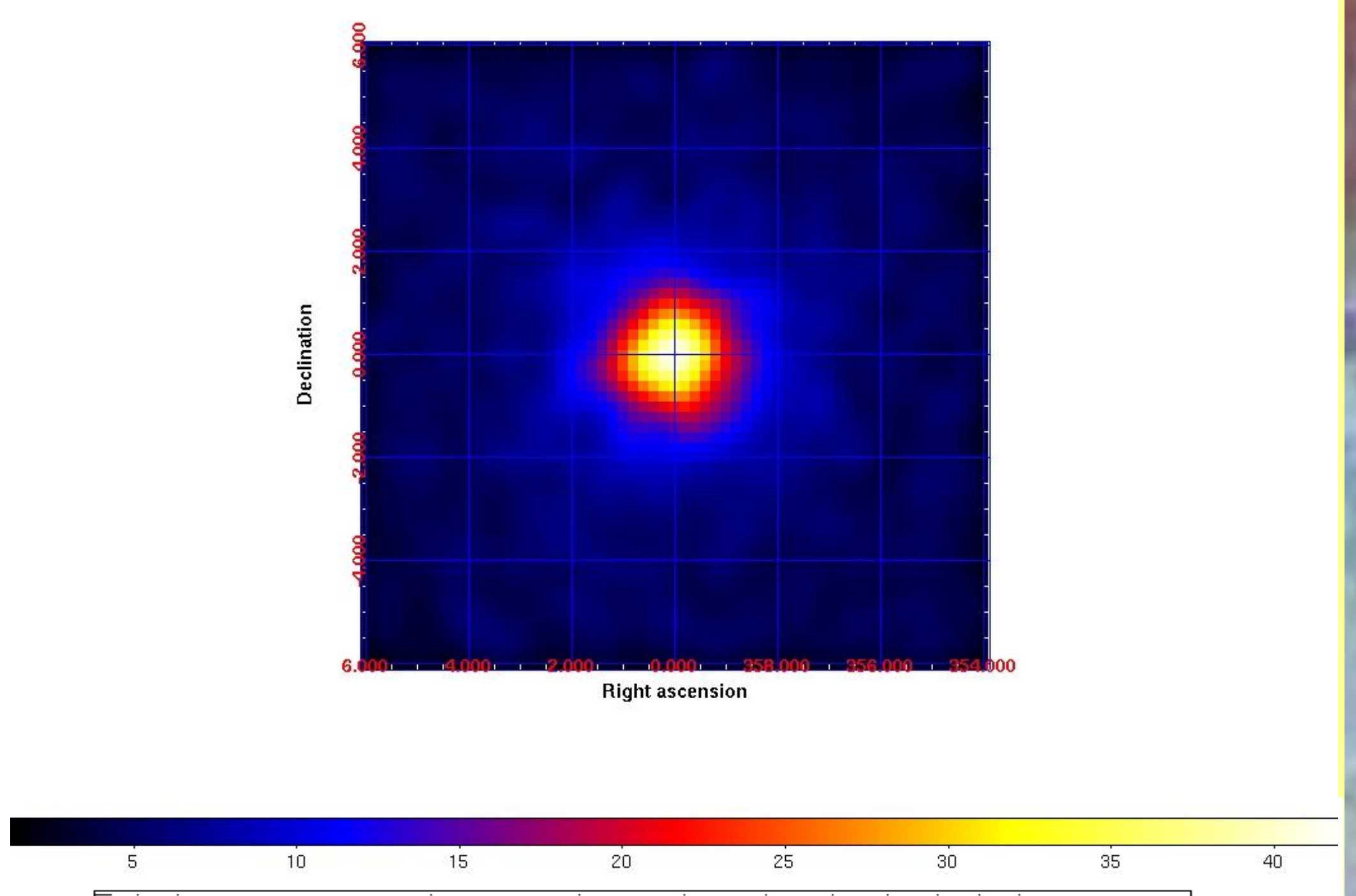
Recent reanalysis of EGRET observation of the Moon confirmed the detection and yielded a flux **$F(E > 100\ \mathrm{MeV}) = (5.55 \pm 0.65) \times 10^{-7}\ \mathrm{cm}^{-2}\ \mathrm{s}^{-1}$** averaged over the entire mission duration [2].

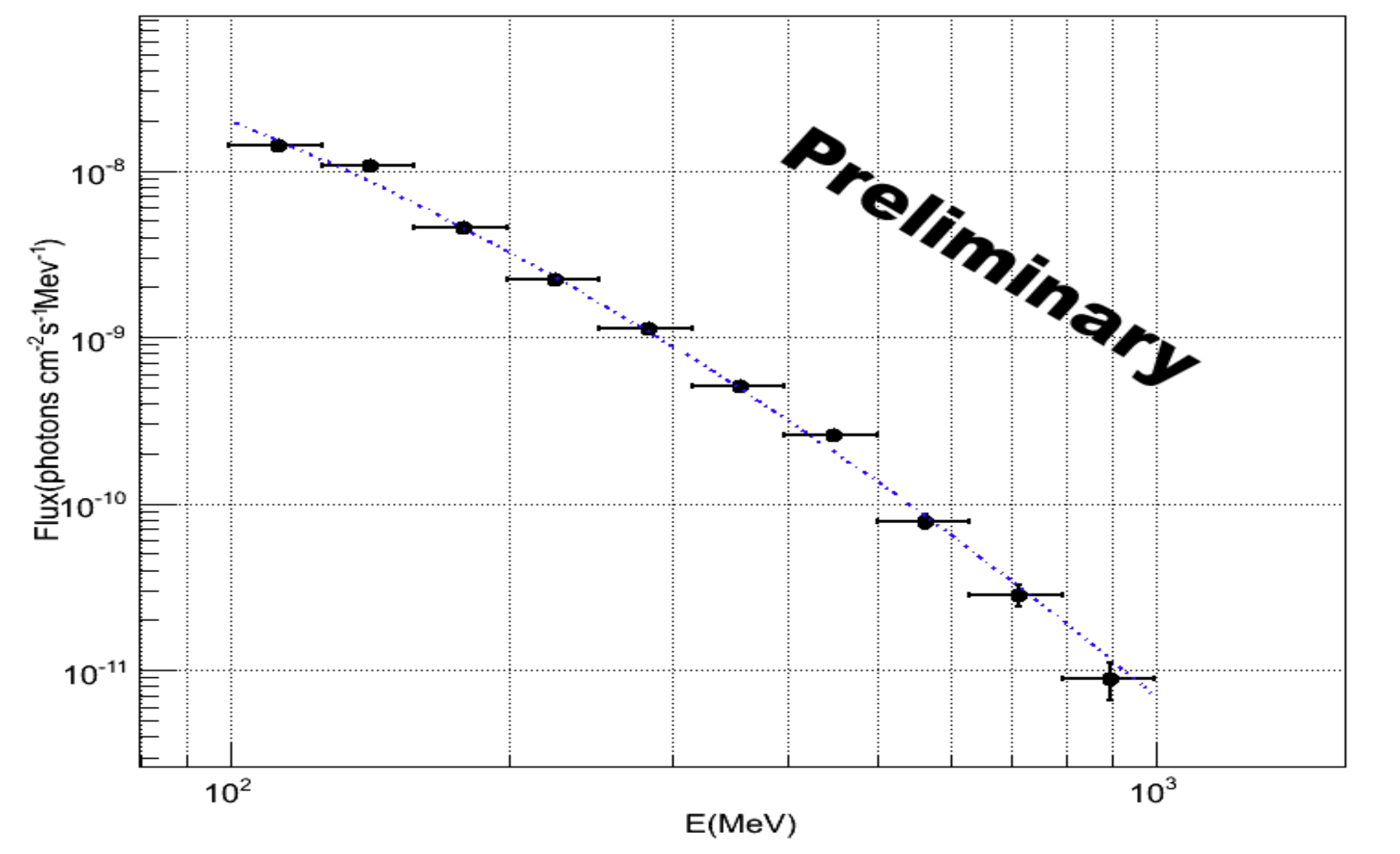
Data Selection

The LAT data used in this analysis of the Moon and quiescent solar emission was collected from August 4, 2008 until February 4, 2010. During the period covered by this analysis the Sun is at the beginning of the 24th Solar cycle, hence in a period of minimum activity. Then, the quiescent solar gamma-ray flux during this period is expected to be at its maximum.

Since the Moon is quickly moving across the sky, the data are selected in a moving frame centered on the instantaneous source position, computed using an interface to JPL libraries, taking into account parallax corrections [10]. To evaluate the background for sources in a relative coordinate frame, we use the so called “fake source” method [11]: we consider source path in the Sky and we use as stating fake position the first position in the source path, at least 30^o displaced from the real one.







Results

The average integral flux mesured with the LAT from the beginning of the mission to February 2010 for E>100MeV is: **$F = (1.21 \pm 0.02 \pm 0.2) \times 10^{-6}\ \mathrm{cm}^{-2}\mathrm{s}^{-1}$**, taken during the period of the prolonged solar minimum.

Results show that the Moon spectrum is weel understood: the continuum intensity depends on the phase of the solar cycle. Its lower energy part is expected to exhibit a narrow pion-decay line at 67.5 MeV, perhaps unique in astrophysics and never before observed. Than, the monitoring of the lunar spectrum allows one to study the ambient spectrum of CR particles, in correlation with the solar activity [9].

Paper in preparation.

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