MAX-PLANCK-GESELLSCHAFT

MAX-PLANCK-INSTITUT FÜR EXTRATERRESTRISCHE PHYSIK

The extended solar emission

- an analysis with EGRET data -

Elena Orlando, Dirk Petry, Andrew W. Strong

P17.16

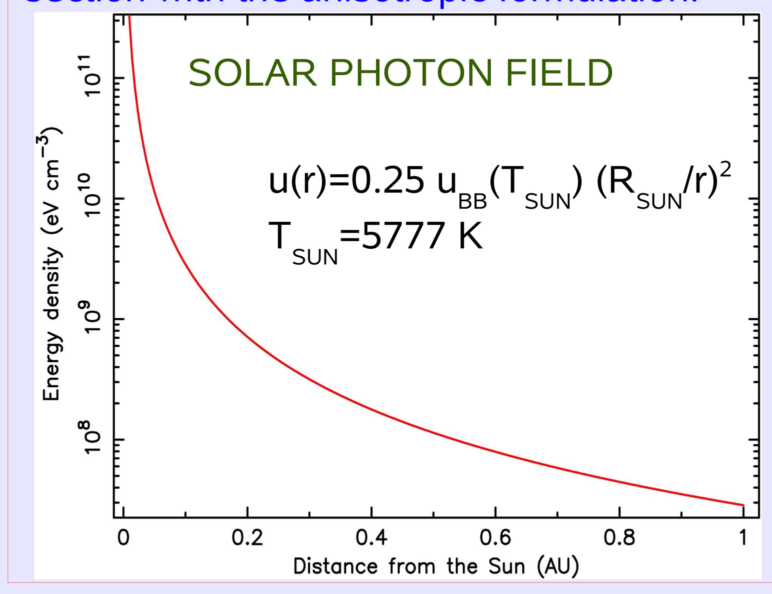
ABSTRACT

In previous work (Orlando & Strong 2006) we studied the Sun as a potentially bright extended source of gamma-ray emission, produced by inverse-Compton scattering of cosmic-ray electrons with the solar radiation. We predicted the emission to contribute to the diffuse extragalactic background even at large angular distances from the Sun. While this emission is expected to be readily detectable in future by GLAST, the situation for available EGRET data is more challenging. We present a detailed study of the EGRET database (Petry et al. 2007), using a time-dependent analysis, accounting for the effects of the emission from 3C279 and the moon which interfere with the solar signal. The technique is tested on the moon signal, with results consistent with previous work (Thompson et al. 1997). We find clear evidence for emission from the sun and its vicinity. The observations are compared with models for solar gamma-ray production.

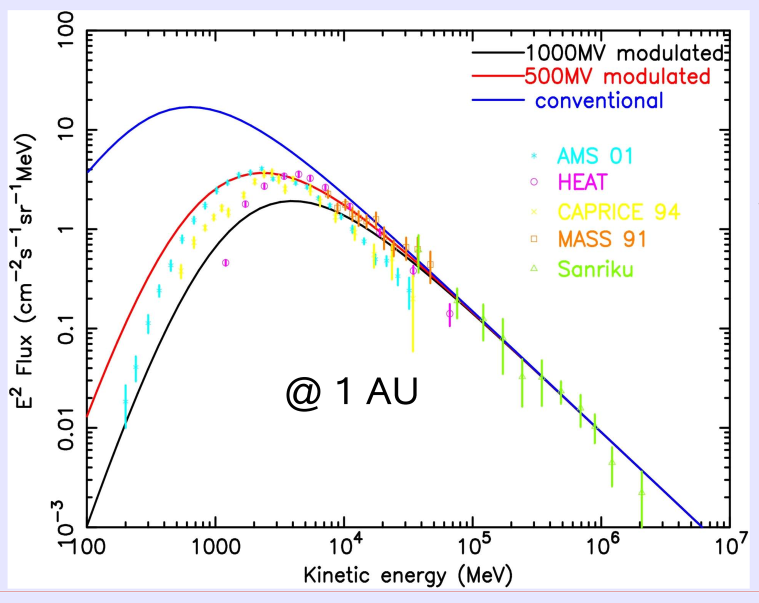
THE MODEL OF EXTENDED SOLAR EMISSION

With respect to Orlando & Strong 2006, the model* has been improved using the modulated electron spectrum instead of the measured local electron spectrum, and using the anisotropic formulation. However these improvements do not affect the previous conclusions.

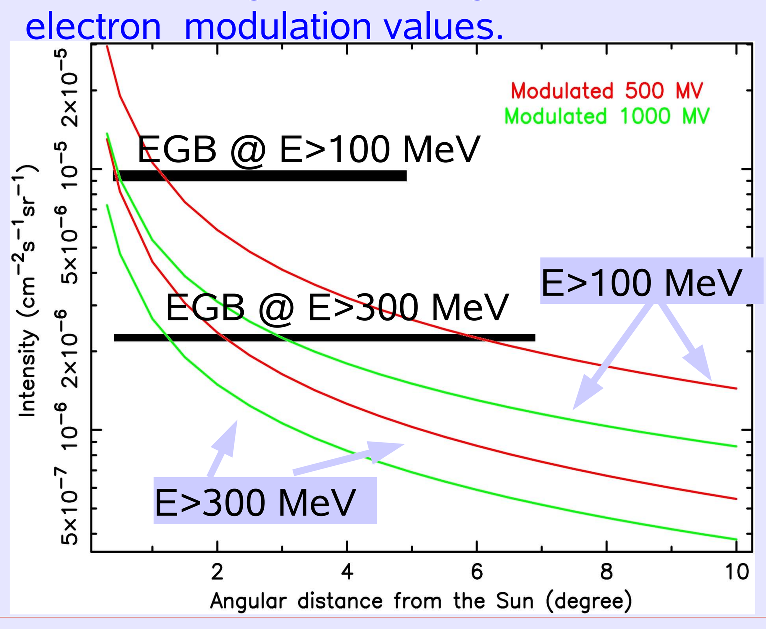
The IC has been computed using the cosmic-ray electron spectrum, the solar photon field and the Klein-Nishina cross section with the anisotropic formulation.



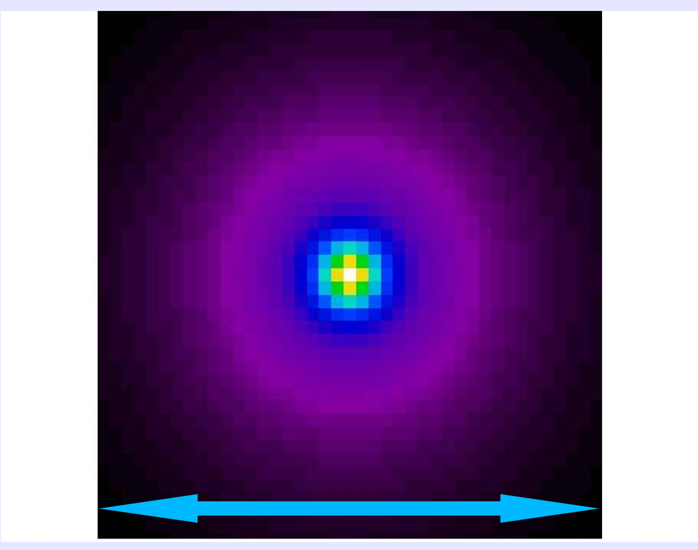
We have used the modulated electron spectrum for solar maximum and minimum (Moskalenko et al 2006)



We calculated the IC intensity as a function of angular distance from the Sun and compared with the extragalactic background for different electron modulation values.



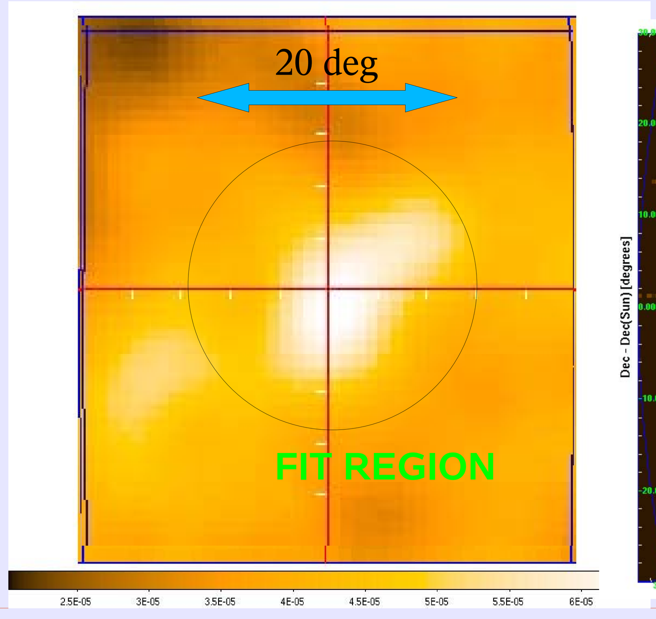
Example of the shape of the intensity resulting from the model

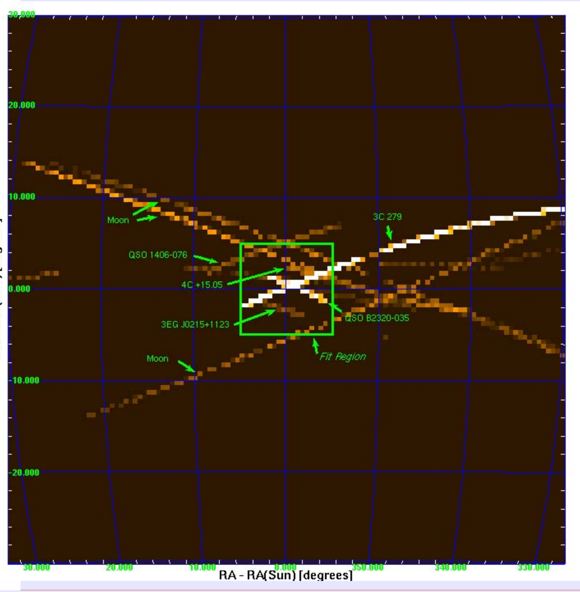


20 deg

DATA

➔Used data analysis code developed for the moving target "Earth" and added necessary features (solar + lunar ephemerides, occultation, close encounter detection, source trace...).
➔Reduced diffuse background by excluding |b|<15 deg (this also eliminates the detected solar flare of 11 June 1991).
➔Included point sources into the overall background model (3C279, Moon, several quasars)
➔Tested for the moon with results agreeing with Thompson et al. 1997

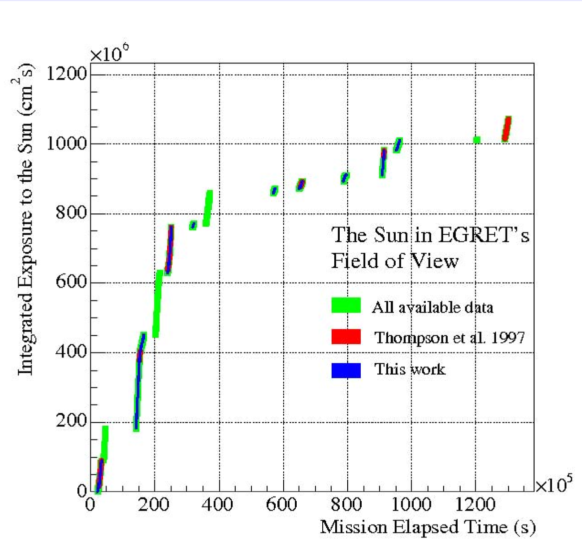




Differences with analysis of Thompson et al. 1997

(who did not detect solar emission)

1. Instead of excluding data near the sources 3C279 and the moon,they are included in the model. This leads to more exposure using contributions from all observing periods.
2. Special dedicated analysis software
3. Anticentre data (affected by Crab, Geminga) excluded
4. Inclusion of the extended emission from the sun producing a more realistic prediction of the total data



ANALYSIS METHOD

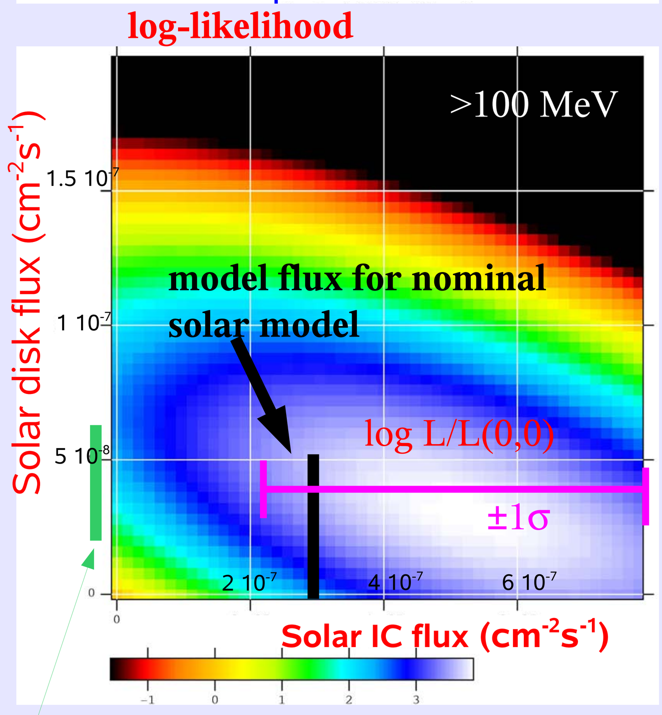
The data in the sun-centred system are fitted using a multi-parameter likelihood fitting technique with 6 components and 4 free parameters

1. solar disk flux f_D
2. solar extended inverse-Compton flux f_{IC}
3. 3C279 flux multiplied by the trace of 3C279
4. moon flux multiplied by the trace of moon
5. traces of 3EG sources
6. uniform background (Galactic + isotropic)

where all of these are convolved with the energy-dependent EGRET PSF.
The predicted counts are the sum of the above components. The region used for fitting is a circle of radius 10° centered on the Sun. Since the moon flux is expected to be almost constant its flux was determined from moon-centred fits. The 3EG source fluxes were fixed at their catalogue values.
Since the interesting parameters are solar disk source and extended emission the likelihood is maximized over the other components for a grid of solar fluxes.

RESULTS

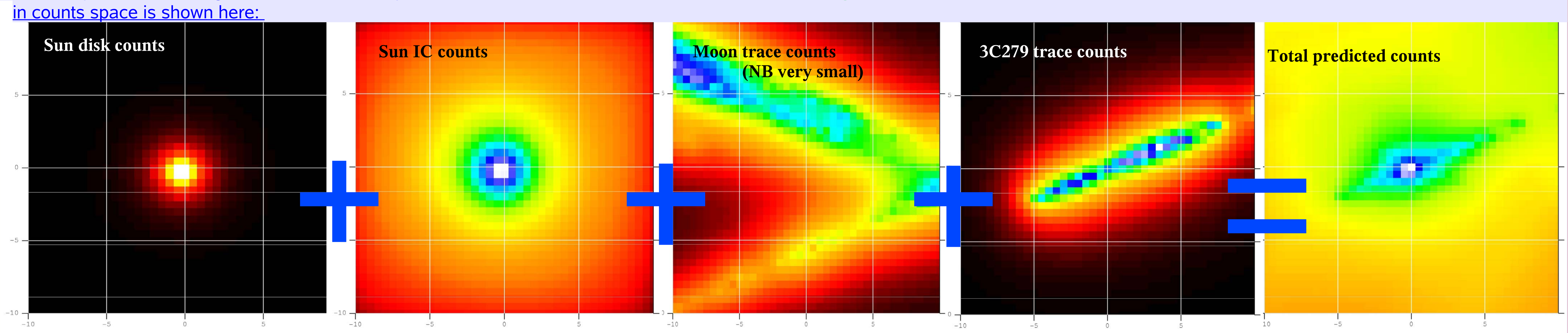
The log-likelihood (log L) is displayed as a function of (f_D,f_{IC}) *relative to the case* f_D=f_{IC}=0.
According to the usual theory -2 (log L/L_{max}) is distributed as χ_2^2.
The level of the predicted IC model flux is shown for E>100 MeV and for modulation level Φ=500 MV.



Solar disk model range Seckel et al.

The solar emission is detected at a level of about 5.3σ
The fluxes >100 MeV are consistent with expectation from a disk source and IC. There is evidence for the extension of the emission but at a level of only 2.7*σ*; the maximum logL indicates a positive **extended component with a flux compatible with the IC model**. The total flux from the Sun is more than expected for the disk source (Seckel et al. 1991), so this is clear evidence for the IC emission even without the proof of extension. The best-fit IC flux is a factor ~2 higher than the basic model but the allowed range is fully consistent with a unit factor and is anyway within the uncertainty of the model.
Future work: Models with different solar modulation levels of the electron spectrum will be tested. A full spectral analysis will be made.

The composition of the signal into the main components in counts space is shown here:



***See also poster P17.10: "GLAST detectability of gamma-ray emission from photon fields of luminous stars", Orlando, E. & Strong A.W.**

REFERENCES:
Orlando, E. & Strong, A.W. (http://arxiv.org/abs/astroph/0607563)(2006) , Ap&SS in press.; D. J. Thompson et al. Journal of Geophys. Res. 102 (A7), 14735 (1997);
Petry et al. (2007) in preparation; Moskalenko, I. V., et. al., ApJL 652 (2006) L65-L68; Seckel, D. et al., ApJ, 382, 652 (1991).

For more information, please contact: elena.orlando@mpe.mpg.de; petry@mpe.mpg.de; aws@mpe.mpg.de