

A photograph of a sunset over the ocean. The sun is a bright orange-red disk just above the horizon line, which is very low. The sky is filled with horizontal bands of clouds, some of which are illuminated from below by the sun, creating a dramatic orange and yellow glow. The water in the foreground is dark blue with white-capped waves breaking. The overall scene is serene and atmospheric.

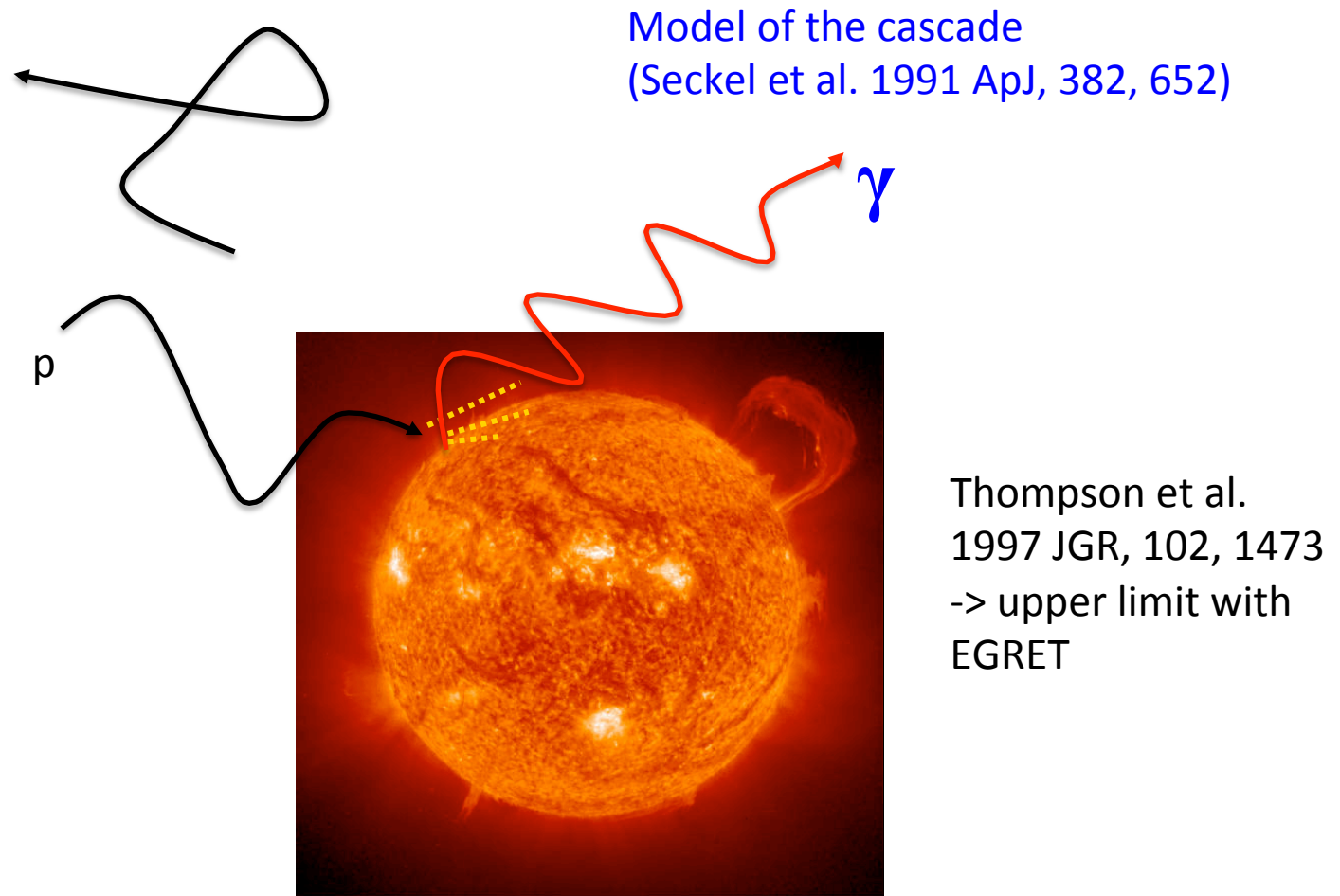
The quiet Sun: a recently-known gamma-ray source

The only way to study Cosmic Rays close to the Sun !

Elena Orlando
(Stanford University)

1) Emission from the disc

Hadronic interactions of cosmic rays with solar atmosphere



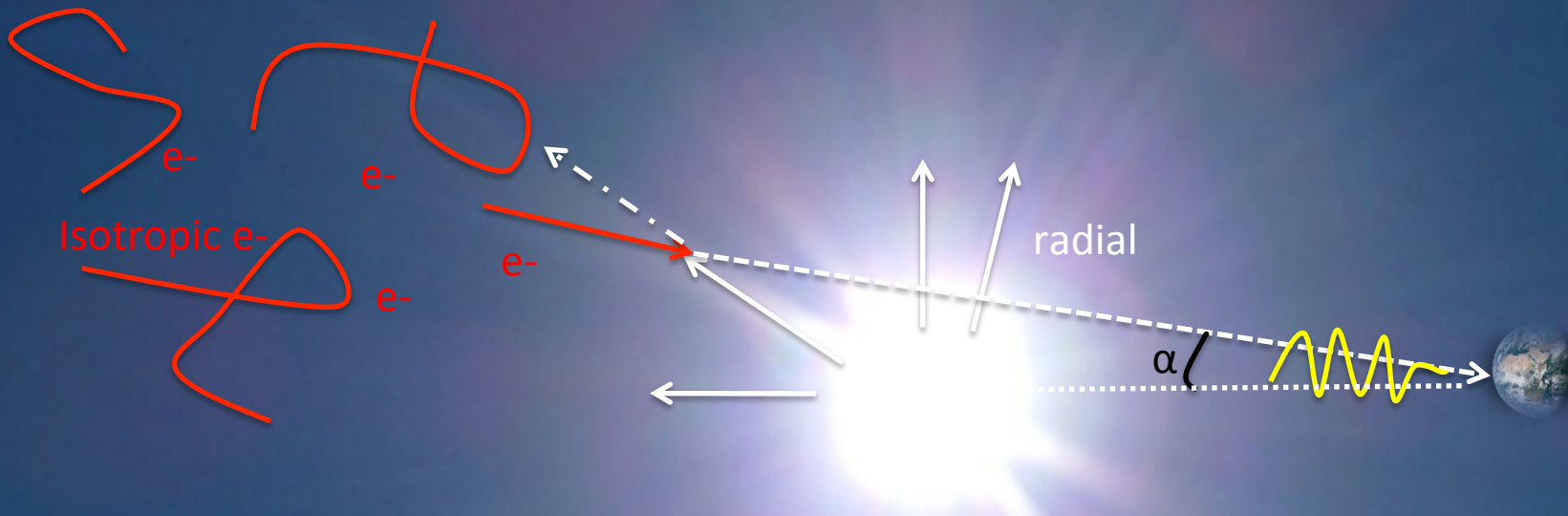
2) Extended Inverse Compton (IC) emission

GeV electrons (CR) + eV photon (solar photons) \rightarrow gamma rays

First theory:

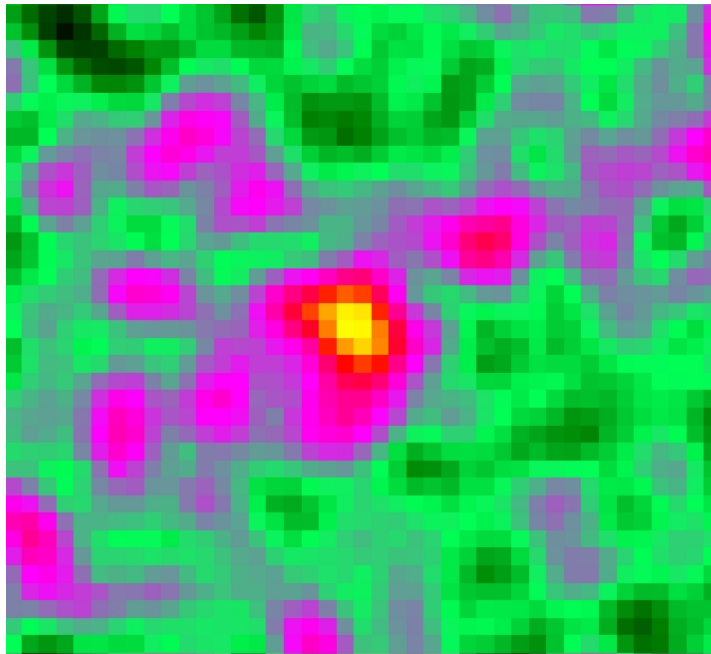
Orlando & Strong, 2006 arXiv:astro-ph/0607563; 2007 Ap&SS, 309, 59;

Moskalenko, Porter & Digel, 2006 ApJ 652, L65



Detection of the quiet sun in gamma rays and of its extended inverse Compton (IC) emission

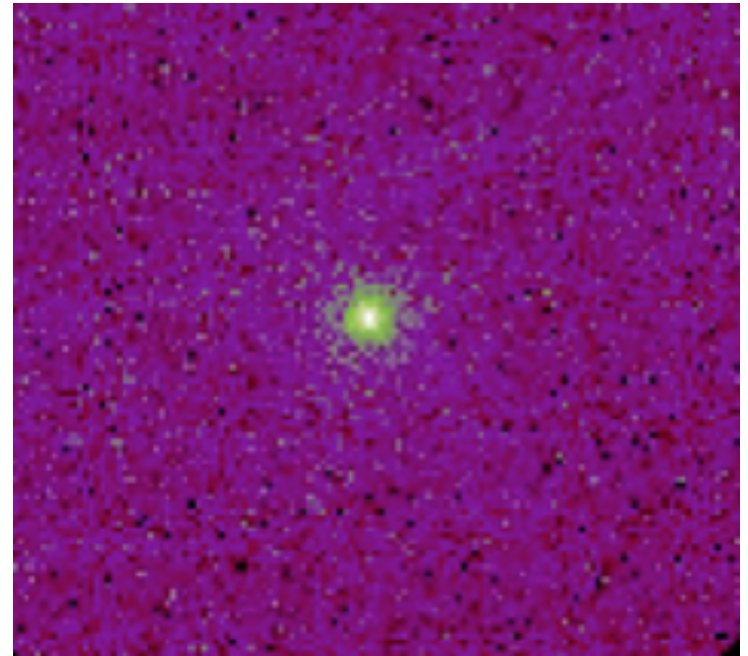
Orlando & Strong (2008) A&A, 480, 847,
with **EGRET: FIRST DETECTION !**



Entire mission of EGRET including
both solar minimum and maximum
activity

Count maps
>100 MeV
in sun-centred
system

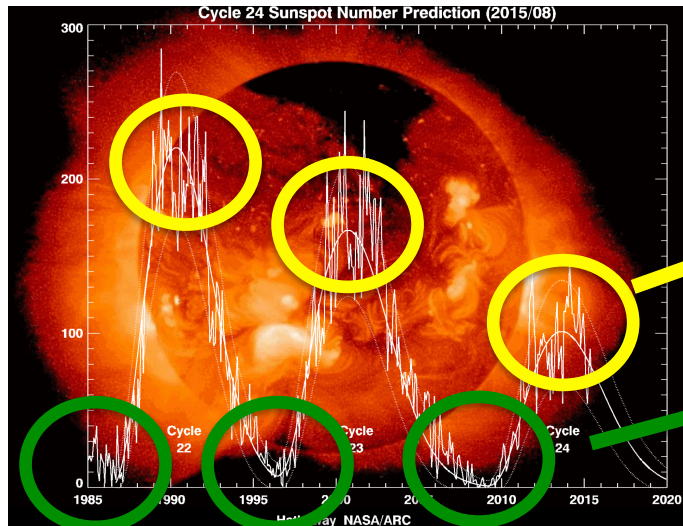
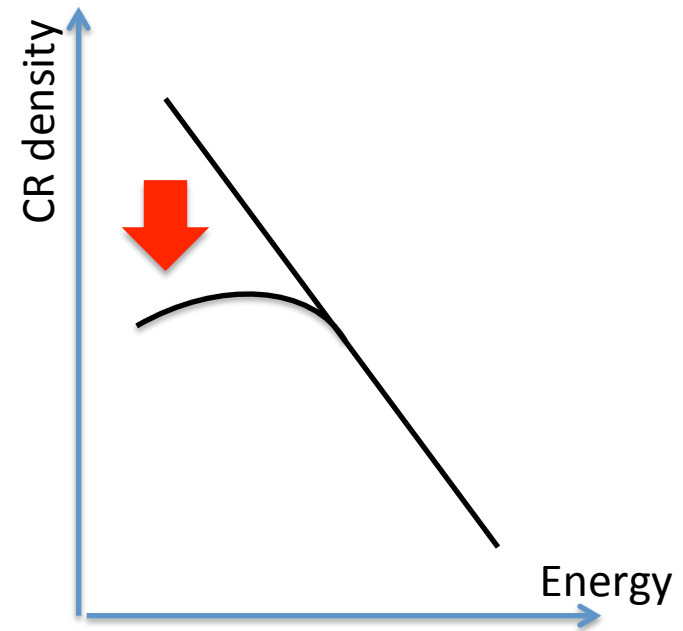
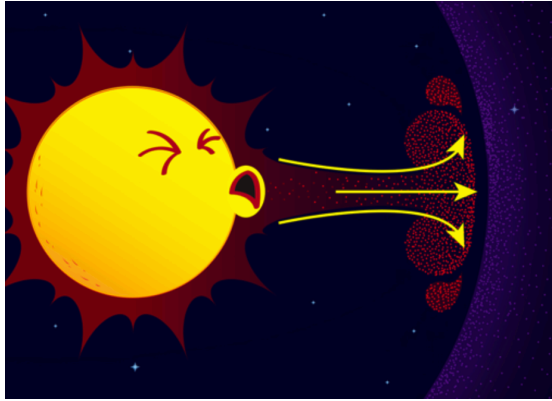
Abdo et al. ApJ. (2011) 734, 116,
with **FERMI LAT**



First 18 months of the LAT mission
during solar minimum activity

Observations are in general agreement with predictions, but some discrepancies still remain

Solar modulation of CRs in the heliosphere



Lower CR flux

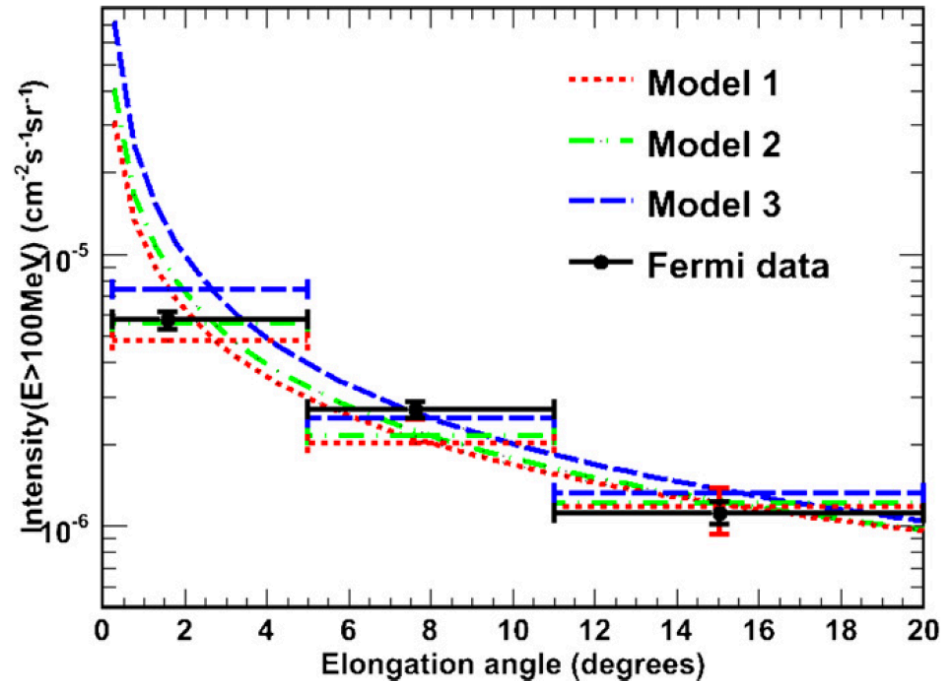
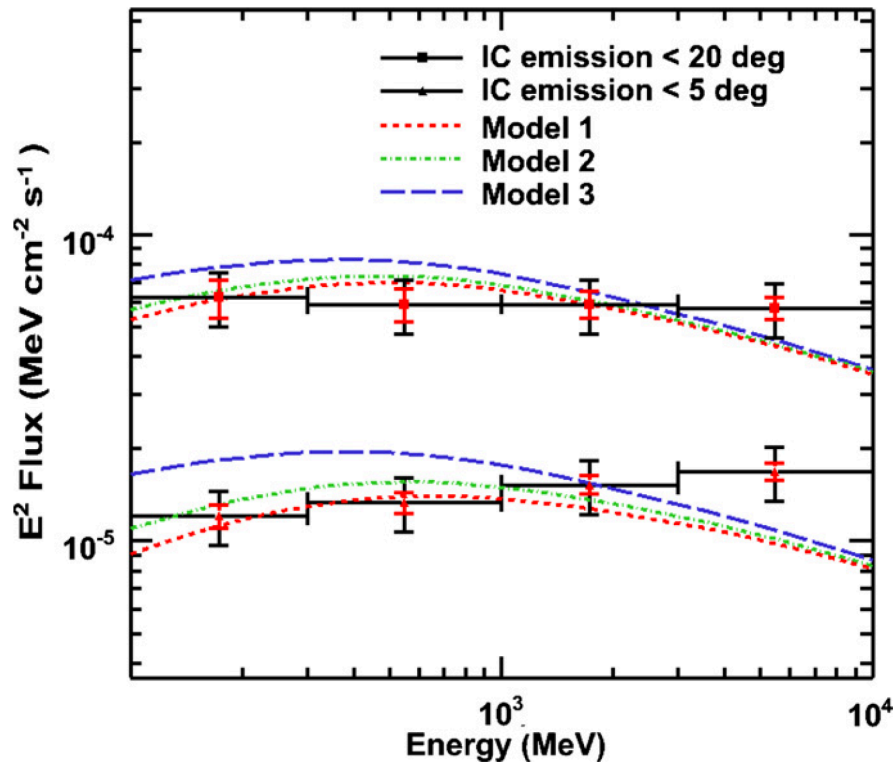
Higher CR flux

Lower
gamma-ray flux

Higher
gamma-ray flux

Observations of the IC emission with Fermi

Abdo et al. (2011) Apj 734, 116



No best model found.

Predictions at MeV – fundamental effect of solar modulation

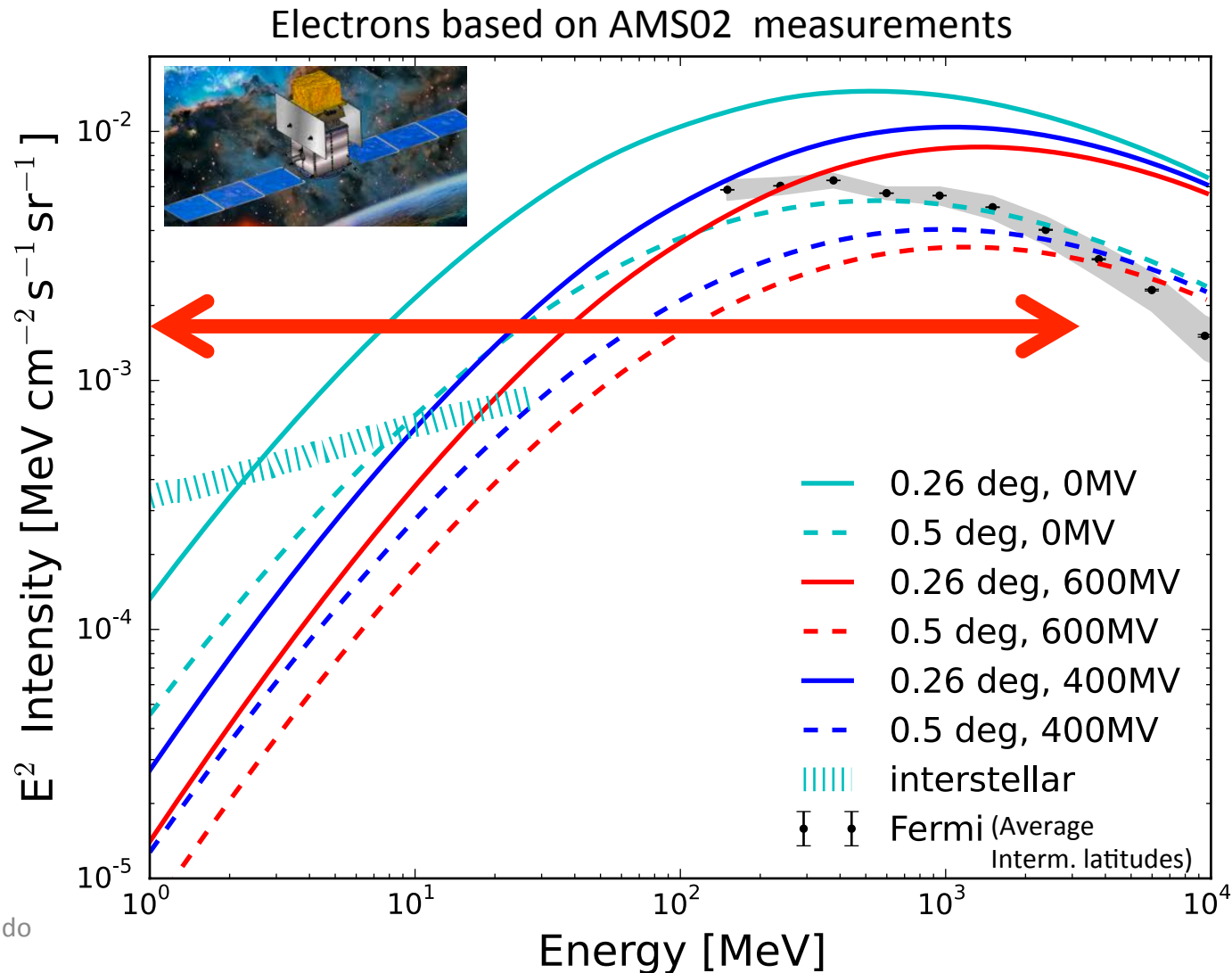
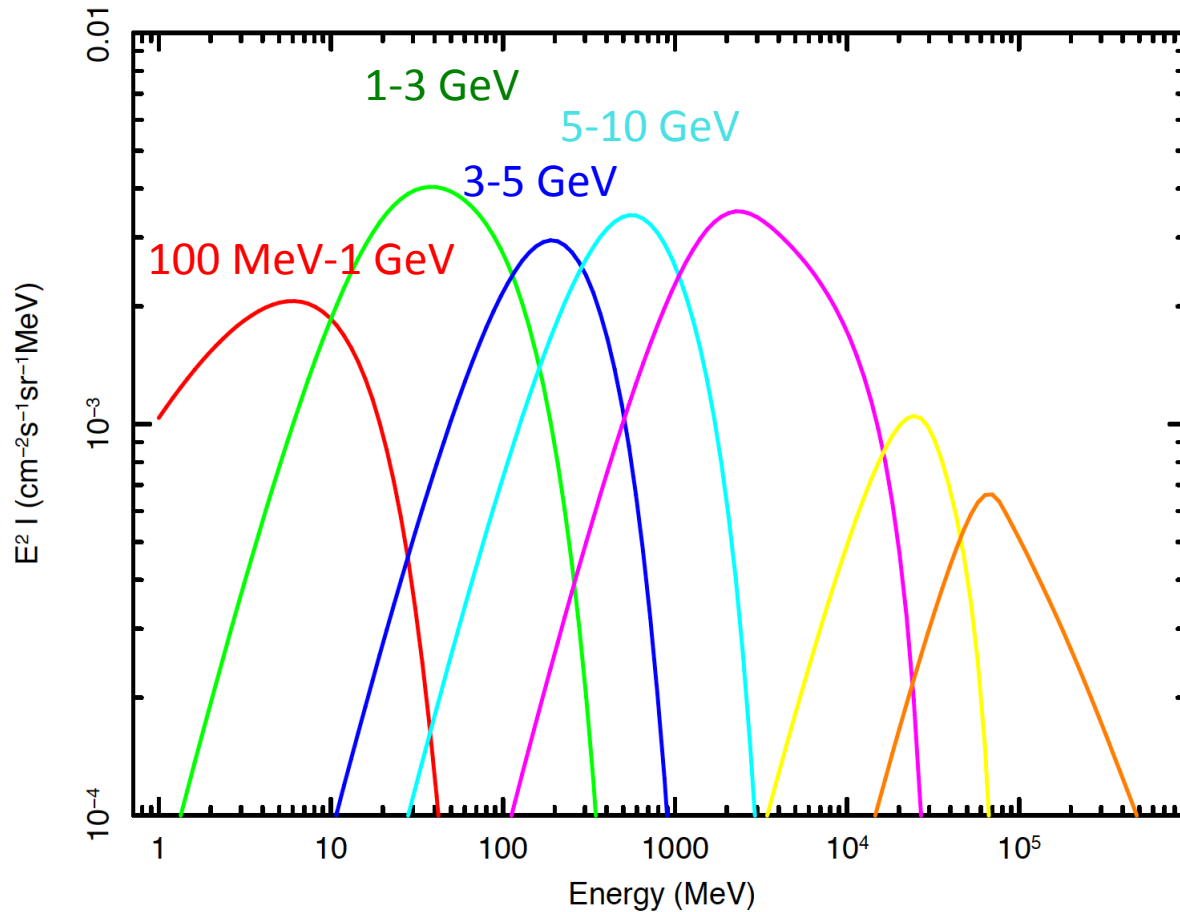


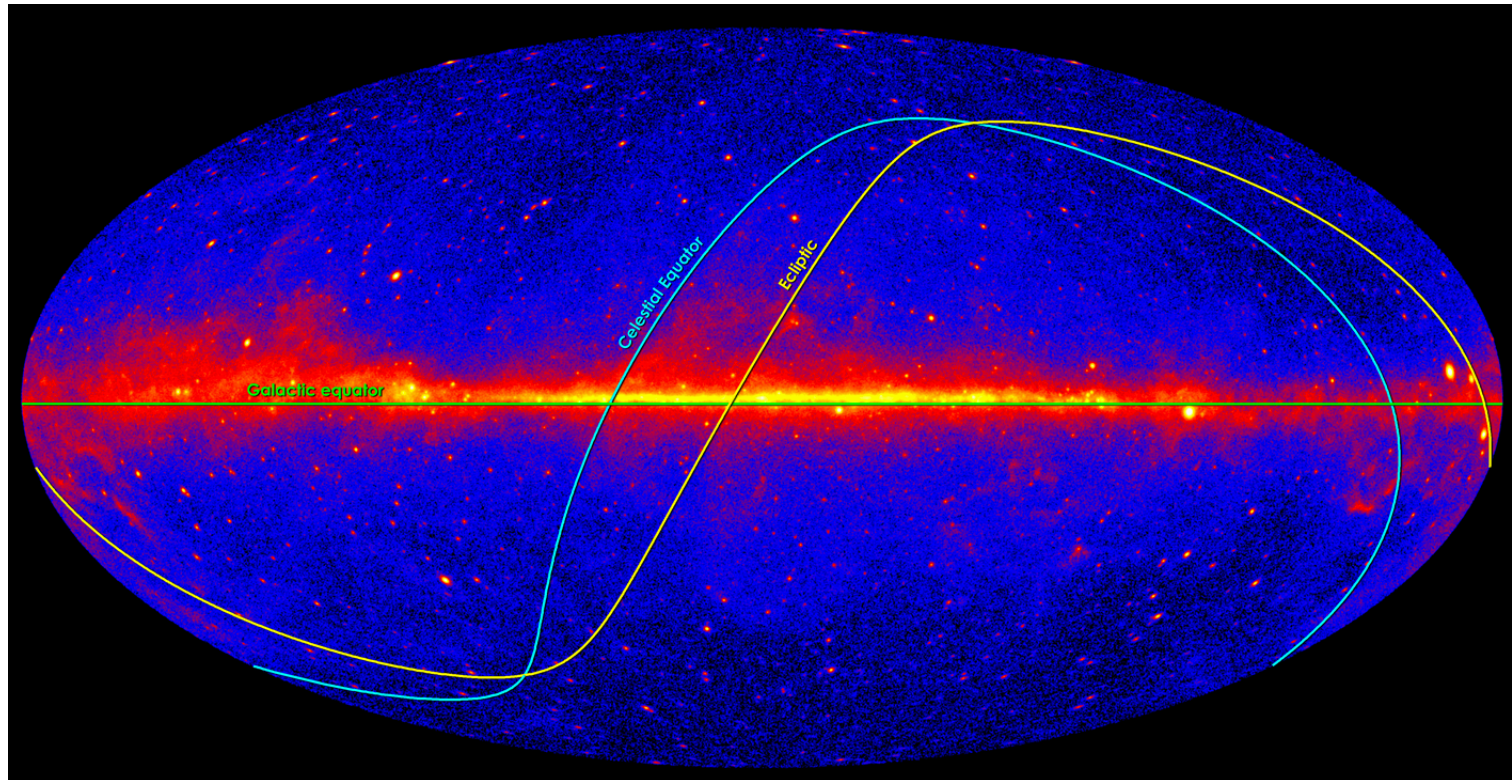
Figure in the contribution

Solar IC emission and electrons



Orlando & Strong (2008) A&A, 480, 847

Solar emission as confusing background for other studies



In Fermi LAT we need to account for it for both short and long exposure !
And we will need at MeV energies as well !

Accounting for the quiet sun in Fermi LAT analyses

NASA
National Aeronautics and Space Administration
Goddard Space Flight Center

Fermi • FSSC • HEASARC
Sciences and Exploration

Fermi Science Support Center

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Data

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 - + [Cicerone](#)

Generating solar and lunar templates

Fermi-LAT data analysis is performed in a coordinate system fixed with respect to distant stars. This poses problems for the inclusion of emission from the Sun and the Moon that are moving with respect to this coordinate system. This tutorial shows how to use the Solar System Tools to create a template of the Solar and Lunar emission for likelihood analysis.

Before going through this tutorial, you should go through the [binned likelihood tutorial](#) as some of the initial steps are very similar. A description of the Solar System Tools can be found in [Johannesson & Orlando 2013](#). These tools are designed solely to account for constant emission from the moon and the quiescent sun. The templates produced will not account for emission due to solar flares.

1) Dedicated Fermi Science Tools to generate the template

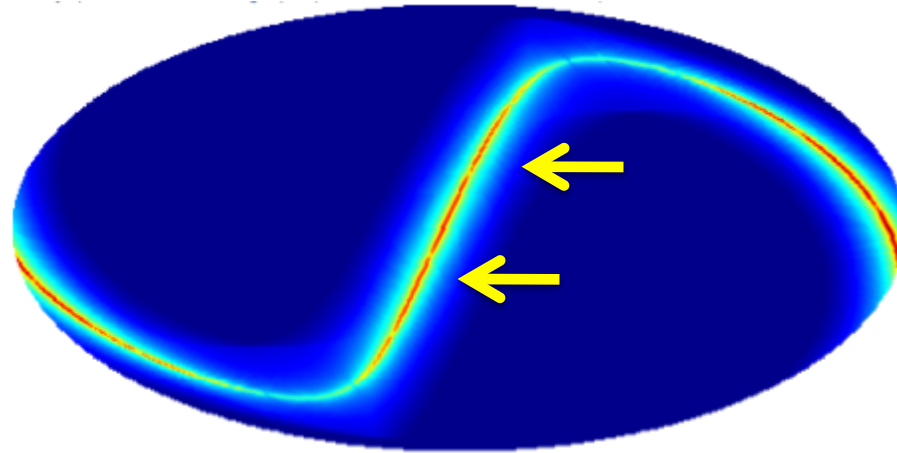
(Johannesson & Orlando 2013, Proc. 33rd International Cosmic Ray Conference, p.0957, arXiv:1307.0197)

2) Input IC models for the Science Tools from the StellarICs code

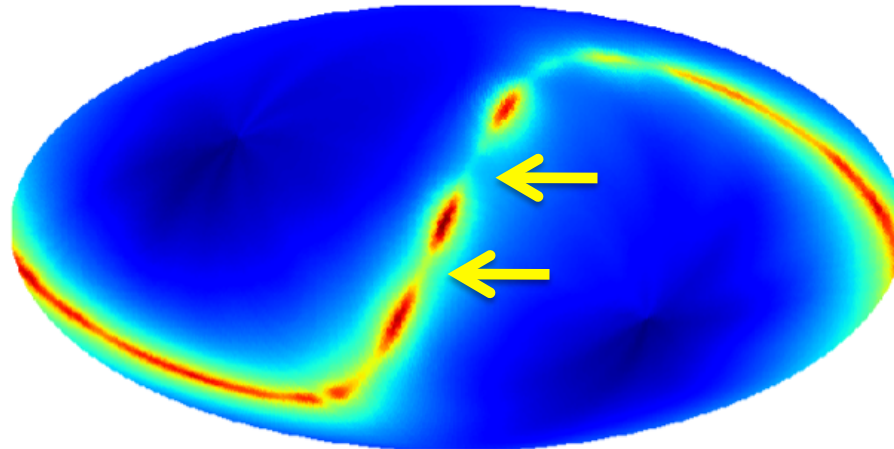
(Orlando, E., & Strong, A. 2013, Nuclear Physics B Proceedings Supplements, 239, 266)

Example of solar template for long exposure

With an average exposure



Appropriate, accounting for instantaneous temporal variation of the exposure



Summary

The quiet Sun is among the **Fermi LAT science cases** (the only way to study CRs in the inner Heliosphere)

Predictions at MeV suggests that this energy range will be very important **to study CRs close to the Sun and their heliospheric propagation for different solar activity !**

The Sun acts as a **confusing background source for other studies**, need to account for it for missions at MeV energies