Diffuse gamma-ray emission with PICARD

Felix Niederwanger

Institute for Astro- and particle physics
University of Innsbruck, Austria

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Today's topics

1. High energy sky
2. Simulation framework
3. Conclusion

Gamma-rays: A new window to the universe

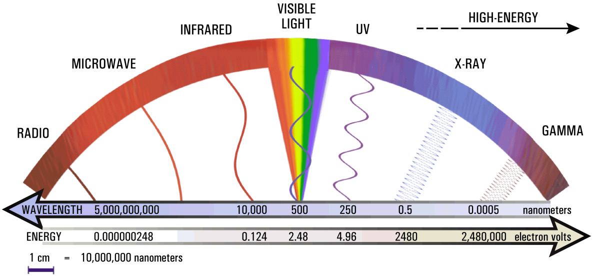

Figure: Illustration of the spectrum of light (NASA/CXC/SAO/MPE)

Convenient definition

The gamma energy regime starts at 511 keV - Rest mass of a e^+ or e^-. There are also other definitions.

Gamma-ray sources

Point or point-like sources

- Supernova remnants (SNR)
- Pulsars
- Active galactic nuclei (AGN)
- Gamma-ray binaries

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Diffuse radiation

- Diffuse background emission
- Molecular clouds

Gamma-ray sources

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- Active galactic nuclei (AGN)
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Diffuse radiation

- Diffuse background emission
- Molecular clouds

Other

- Gamma-ray bursts

FERMI view of the high energy sky

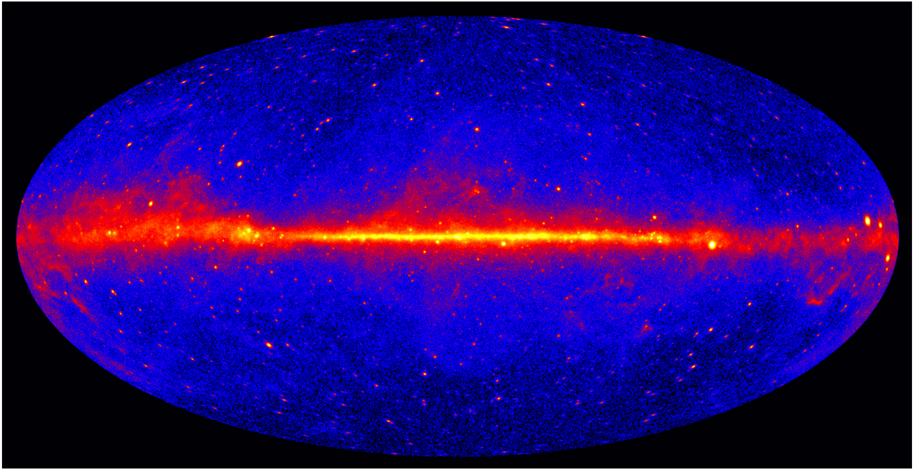

Figure: Fermi-LAT 5 years of observation. Source: Fermi web presence

H.E.S.S. - High Energetic Spectroscopic System

Imaging atmospheric cherenkov telescope (IACT) located in Namibia.
Imaging the shower-development of γ-rays

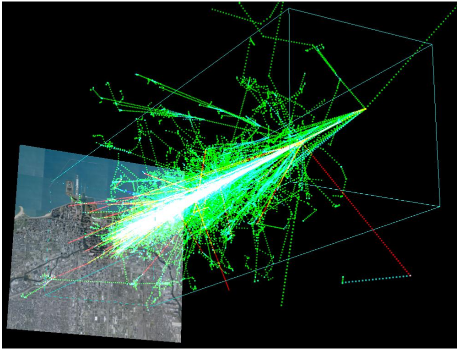

Figure: Visualisation of a proton shower. Source: Cosmus

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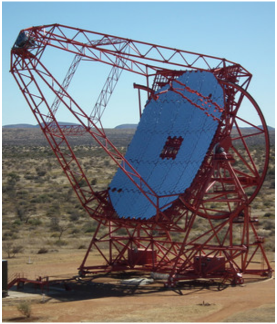

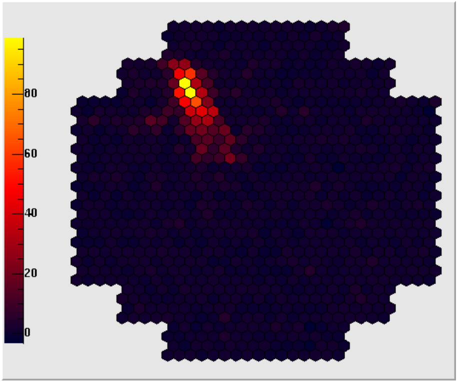

Figure: H.E.S.S. telescope and camera picture

H.E.S.S. galactic plane survey

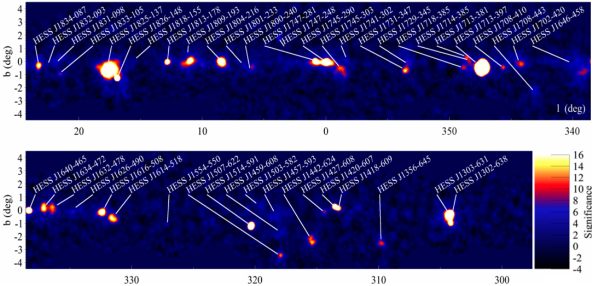

Figure: Inner part of the H.E.S.S. galactic plane survey (Carrigan et al. [2013])

H.E.S.S. galactic plane survey

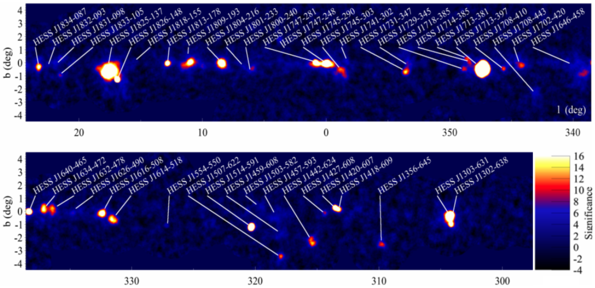

Figure: Inner part of the H.E.S.S. galactic plane survey (Carrigan et al. [2013])

H.E.S.S. galactic plane survey

The H.E.S.S. galactic plane survey (Carrigan et al. [2013]) shows, that we have to deal with the diffuse background on the milky-way.

PICARD

PICARD Code (Kissmann [2014])

- Solver for the cosmic-ray transport equation

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Cosmic ray transport equation

$$\frac{\delta N(E,r,t)}{\delta t} + \nabla \left[uN(E,r,t) - \kappa_d \nabla N(E,r,t) \right] + \frac{\delta}{\delta E}(\dot{E} N(E,r,t)) = Q(E,r,t)$$

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PICARD

PICARD Code (Kissmann [2014])

- Solver for the cosmic-ray transport equation
- MPI-parallelised, cluster-ready
- Compatible input files (GALDEF) with Galprop v54

Cosmic ray transport equation

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PICARD - Key concepts

Cosmic ray transport equation

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Features of PICARD

- Steady state solution (i.e. $\frac{\delta N(E,r,t)}{\delta t} = 0$)

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Features of PICARD

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- Native 3D

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Cosmic ray transport equation

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Features of PICARD

- Steady state solution (i.e. $\frac{\delta N(E,r,t)}{\delta t} = 0$)
- Native 3D
- Propagation datacube and gamma-ray maps at ♁

Propagation data

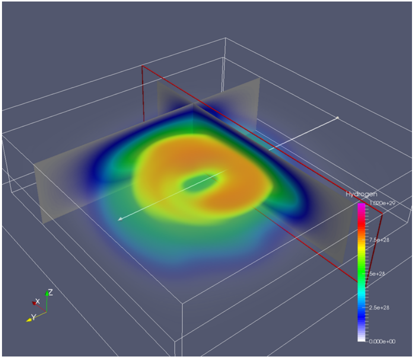

Figure: NE2001-Model (Cordes and Lazio [2002])

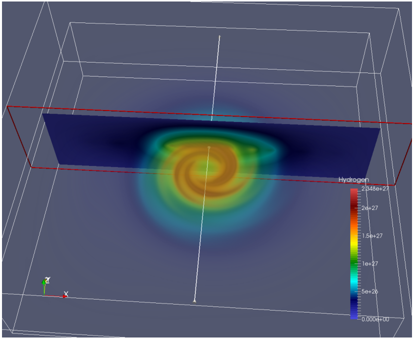

Figure: Spiral arm galaxy model (Kissmann et al. [2015])

PICARD - Preliminary results

Gamma-ray intensity

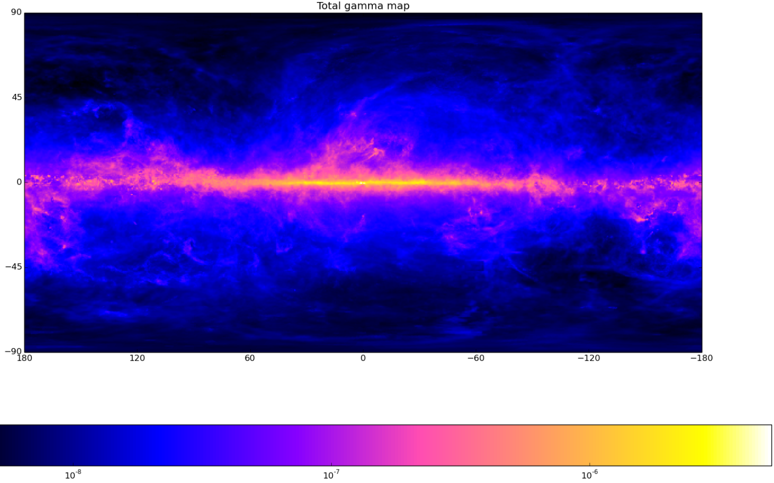

Figure: Gamma map at ♁, produced by PICARD

Summary

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- PICARD - solver for the cosmic ray transport equation
- Compatible to the input format of Galprop v54 (GALDEF)
- High resolution 3D simulation of the galaxy, including structures
- Real steady-state solution
- Propagation datacubes and gamma-ray maps

Goal of my thesis

Simulation of cosmic ray propagation and creation of realistic maps of the diffuse gamma-ray background emission for advanced analysis in H.E.S.S.

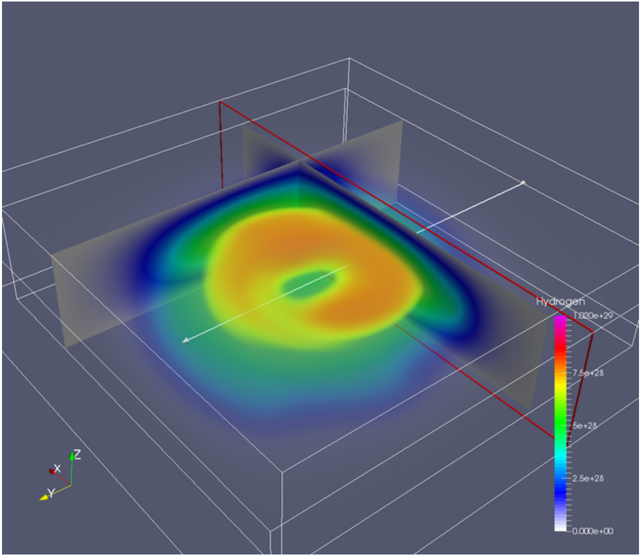
S. Carrigan, F. Brun, R. C. G. Chaves, C. Deil, A. Donath, H. Gast, V. Marandon, M. Renaud, and for the H. E. S. S. collaboration. The H.E.S.S. Galactic Plane Survey - maps, source catalog and source population. ArXiv e-prints, July 2013.

J. M. Cordes and T. J. W. Lazio. NE2001.I. A New Model for the Galactic Distribution of Free Electrons and its Fluctuations. ArXiv Astrophysics e-prints, July 2002.

R. Kissmann. PICARD: A novel code for the Galactic Cosmic Ray propagation problem. Astroparticle Physics, 55:37–50, Mar. 2014. doi: 10.1016/j.astropartphys.2014.02.002.

R. Kissmann, M. Werner, O. Reimer, and A. W. Strong. Propagation in 3D spiral-arm cosmic-ray source distribution models and secondary particle production using PICARD. Astroparticle Physics, 70:39–53, Oct. 2015. doi: 10.1016/j.astropartphys.2015.04.003.

Propagation datacubes / Higher resolution



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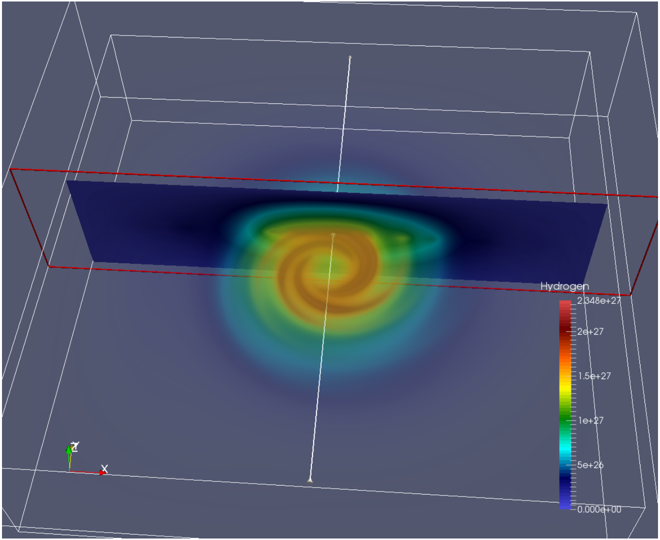

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