

# The search for the origin of high-energy cosmic-ray electrons

Martin Brunner, Karl Mannheim

Lehrstuhl für Astronomie  
Universität Würzburg

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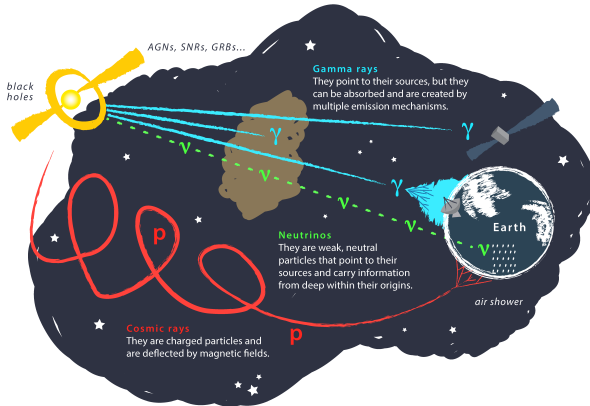
IBWS Karlovy Vary 2019



1. cosmic rays
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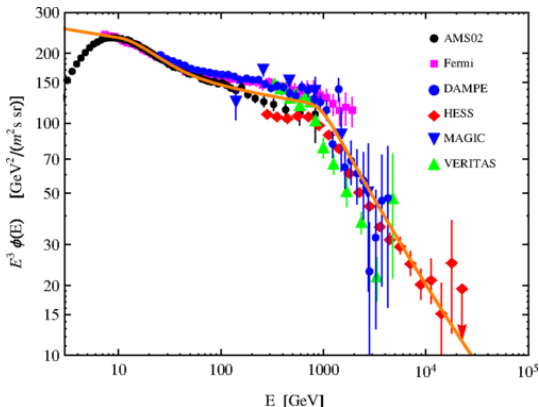
# Cosmic rays



Credit: Juan Antonio Aguilar and Jamie Yang. IceCube/WIPAC

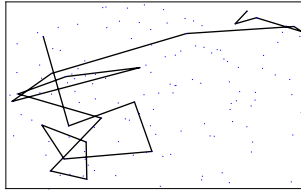


# Motivation



Flux of electrons and positrons measured at Earth.  
P. Lipari, S. Vernetto (2018)





- random walk
- interactions of cosmic rays with matter, radiation fields, and irregular magnetic fields



energy losses to

- inverse-Compton scattering  $\propto E^2$
- synchrotron radiation  $\propto E^2$
- Bremsstrahlung  $\propto E \log E$
- ionisation and Coulomb interaction  $\propto \log E$



change in position

$$\begin{pmatrix} \Delta x \\ \Delta y \\ \Delta z \end{pmatrix} = \begin{pmatrix} B_{11} & B_{12} & B_{13} \\ B_{21} & B_{22} & B_{23} \\ B_{31} & B_{32} & B_{33} \end{pmatrix} \begin{pmatrix} \Delta W_x \\ \Delta W_y \\ \Delta W_z \end{pmatrix}$$

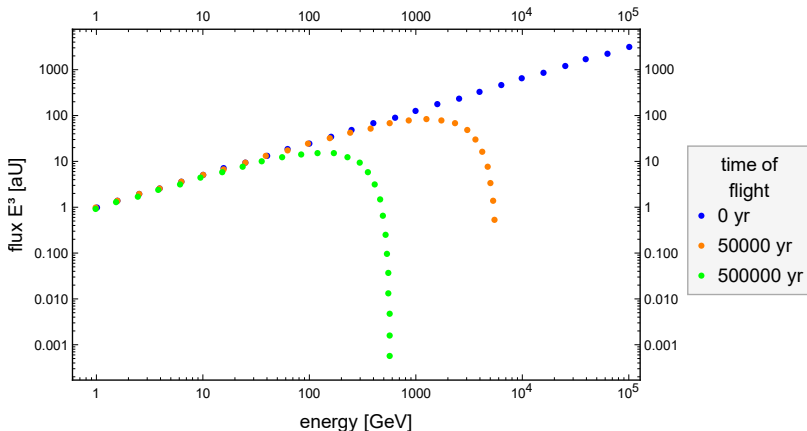
$$\Delta W_i = \sqrt{\Delta t} N_i$$

$$B^\dagger B = 1/2\kappa$$

$N$  is a normal distributed random number



# Numeric model results

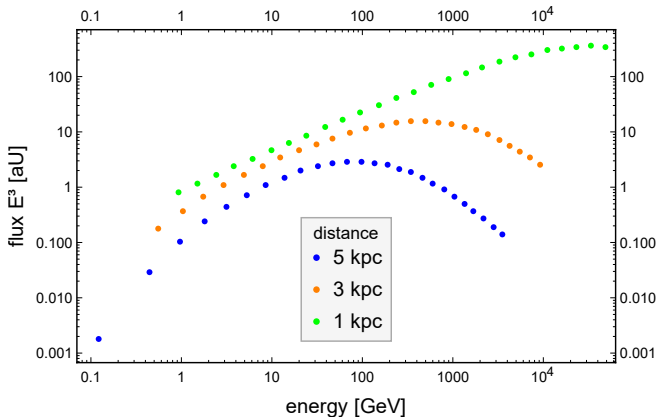


Electron flux after different time of flight with a starting flux  $\propto E^{-2.3}$





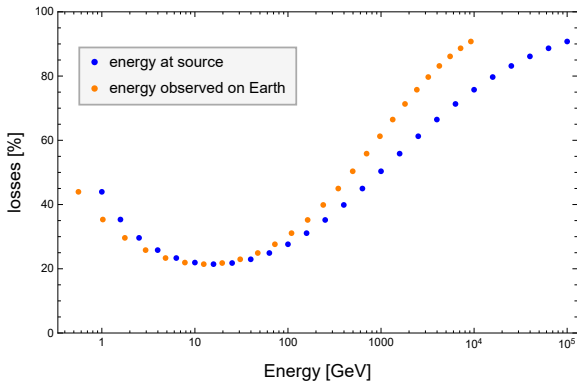
# Numeric model results



Electron flux for different distances of the source with a starting flux  $\propto E^{-2.3}$



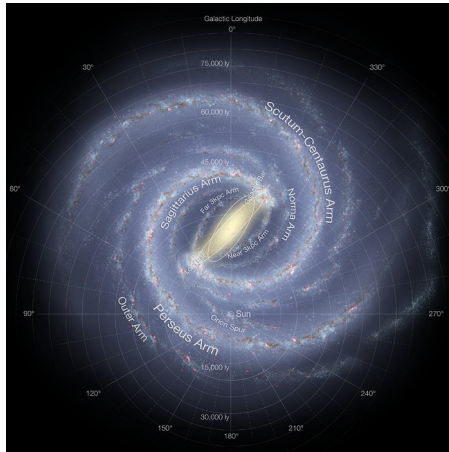
# Numeric model results



Losses of the cosmic ray electrons from a source at a distance of 3 kpc depending on the starting energy.



# Galaxy modeling



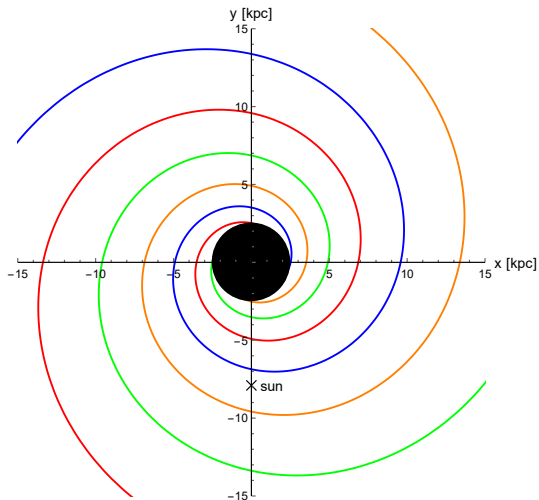
Credit: NASA/JPL-Caltech/ESO/R. Hurt

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Origin of cosmic-ray electrons



# Galaxy modeling

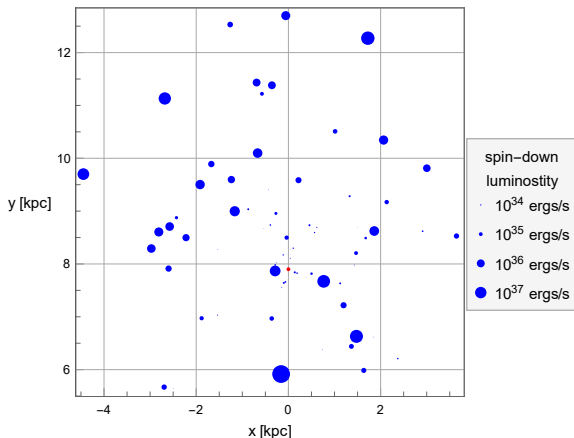


model parameters:

- dust density
- magnetic field
- radiation background
- source distribution



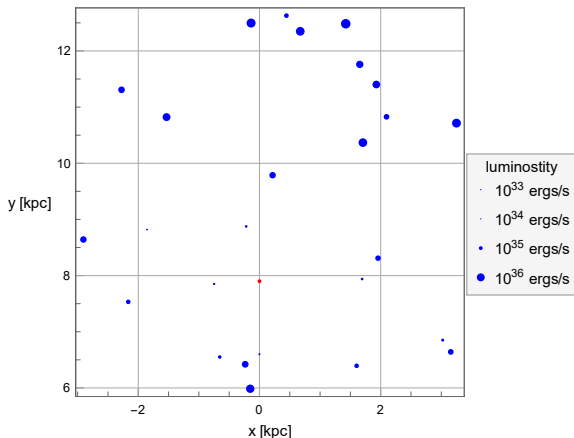
# Pulsar as potential sources



Source distribution of pulsars. Point size represent log of luminosity.  
*Fermi*-LAT collaboration (2013)



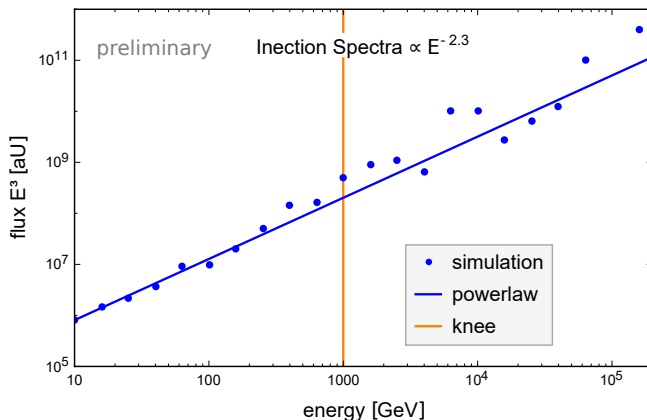
# Supernova remnant as potential sources



Source distribution of supernova remnant. Point size represent log of luminosity. *Fermi*-LAT collaboration (2016)



# Vela pulsar

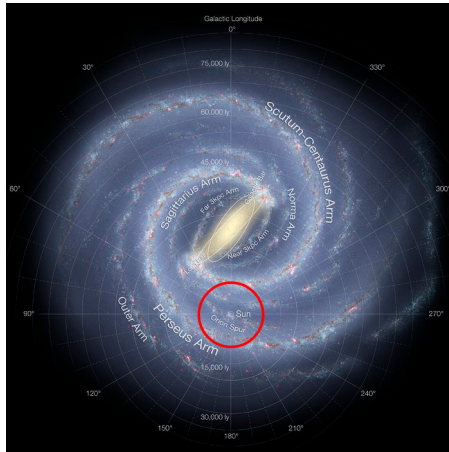


Numeric simulation of the electron spectra from the Vela pulsar with a injection spectra  $\propto E^{-2.3}$





# Source location



Credit: NASA/JPL-Caltech/ESO/R. Hurt

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Origin of cosmic-ray electrons



# Conclusion

- knee in electron spectra
- knee depends on time of flight
- diffusion model leads to a relation between position of peak and distance of source
- flux near knee dominated by a few sources
- electron spectra consistent with
  - a) supernova remnant
  - b) maybe a anisotropic 3D diffusion model, caused by magnetic field

