Non-thermal Diffuse Emission in NGC 253 from Hard X-rays to TeV Gamma Rays*

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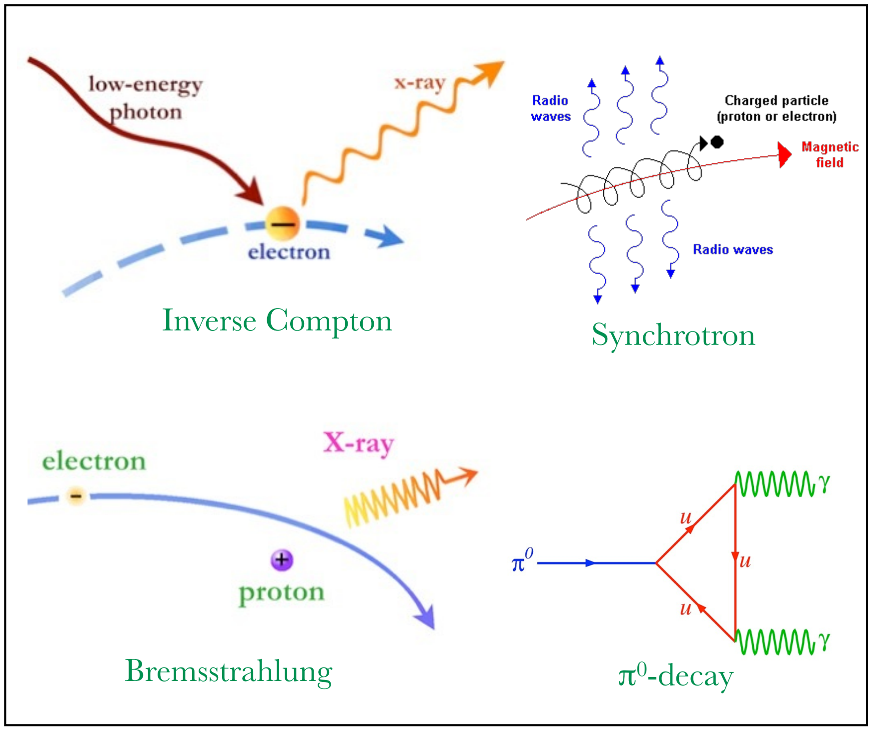
*in collaboration with D. Wik, B. Lehmer, A. Hornschemeier, M. Yukita, A. Ptak, A. Zezas, V. Antoniou, M. K. Argo, K. Bechtol, S. Boggs, F. Christensen, W. Craig, W. Hailey, F. Harrison, R. Krivonos, T. J. Maccarone, D. Stern, & W. Zhang
(Wik et al. 2014, ApJ accepted)

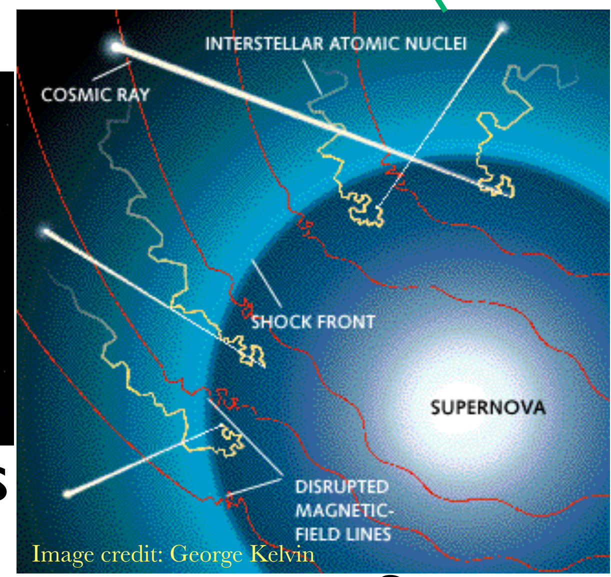
The Life of a Cosmic Ray

$$\frac{\partial N(E)}{\partial t} = D\nabla^2 N(E) + \frac{\partial}{\partial E}\left[b(E)N(E)\right] - \frac{N(E)}{\tau(E)} + Q(E)$$



Cooling Losses

Escape Losses



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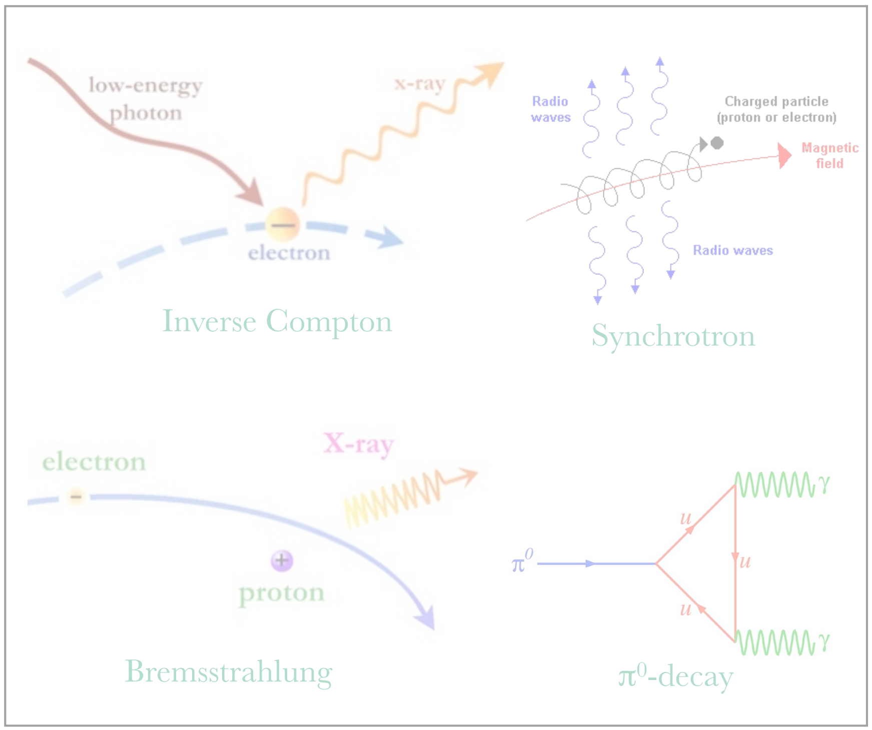

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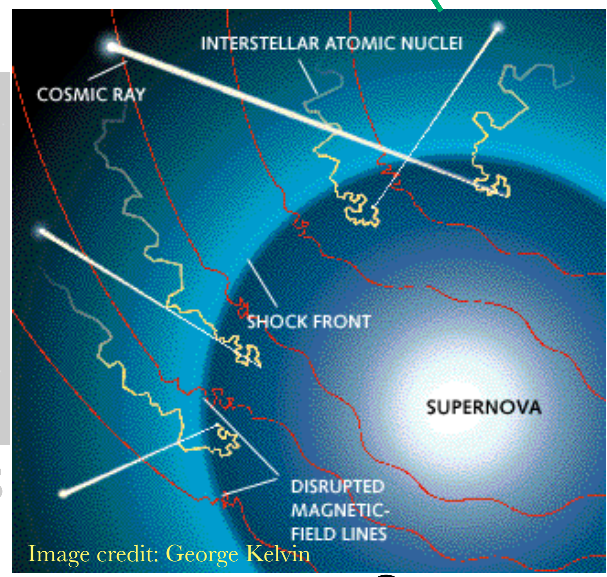

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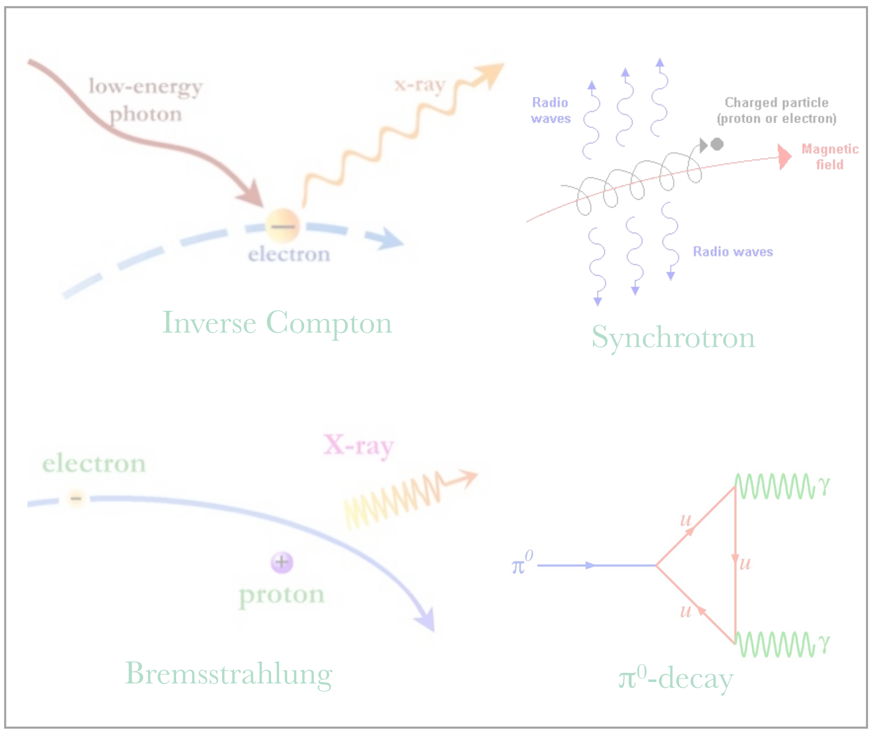

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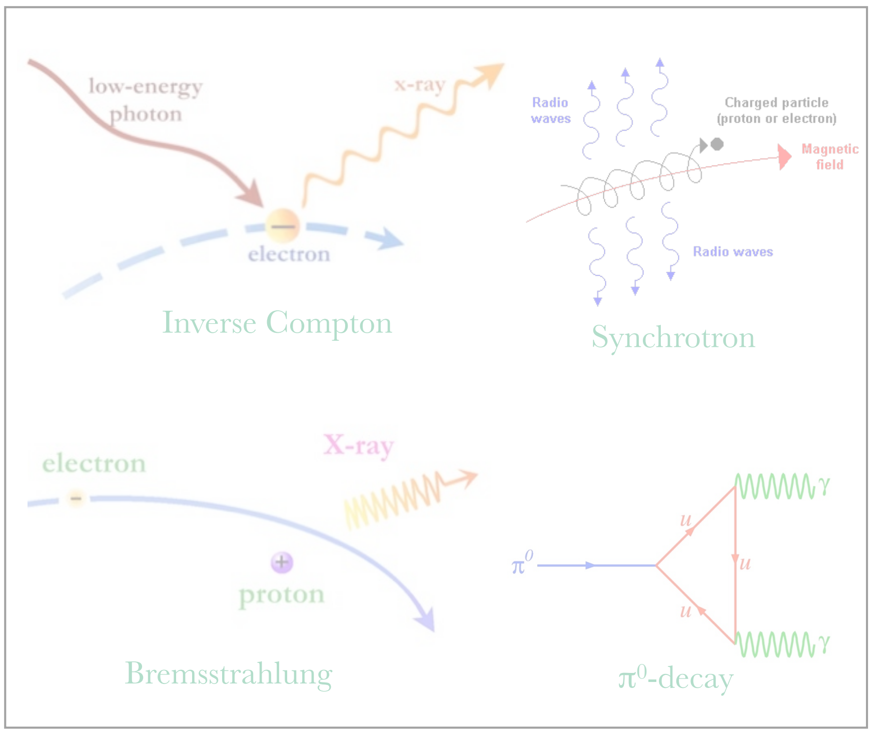

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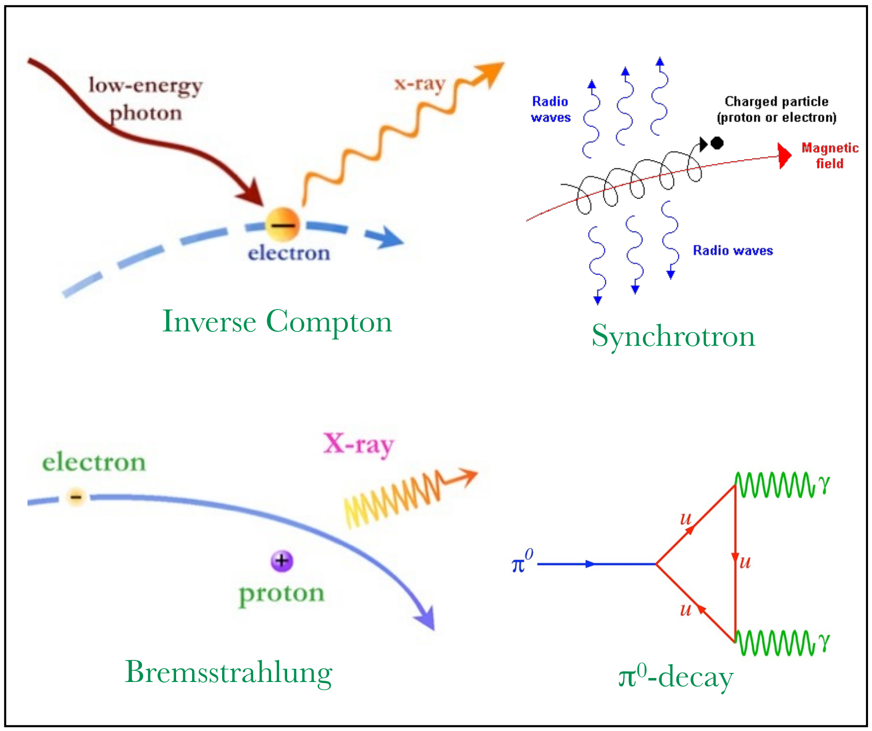

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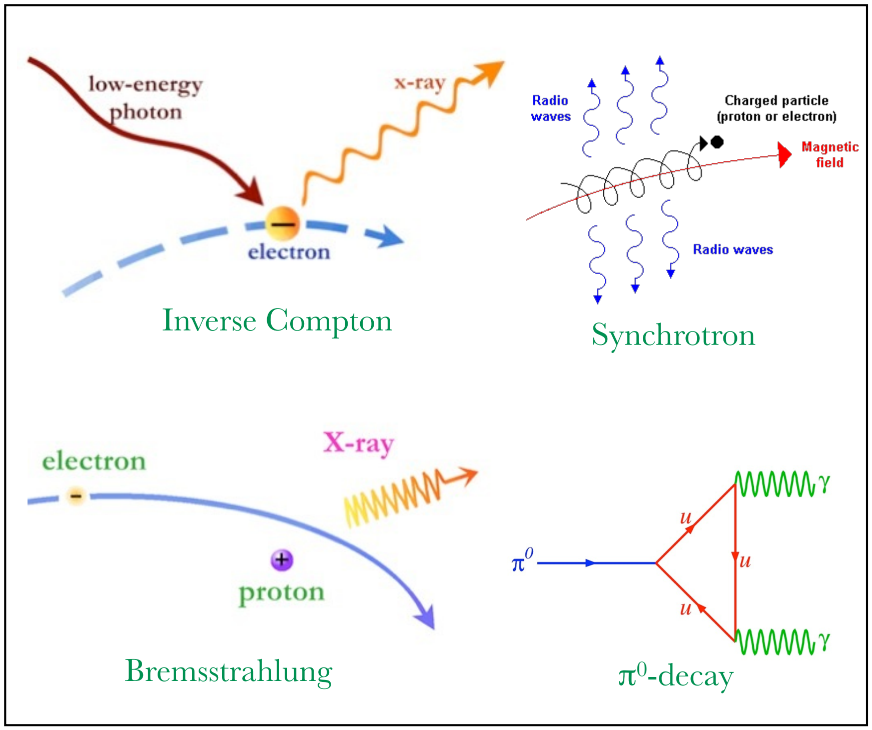

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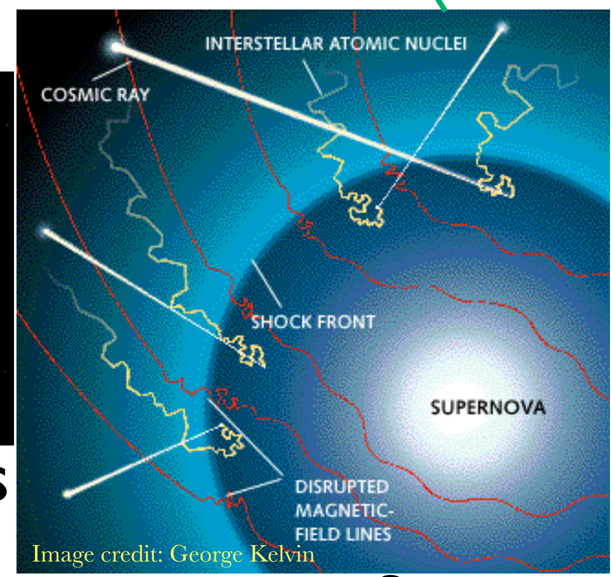

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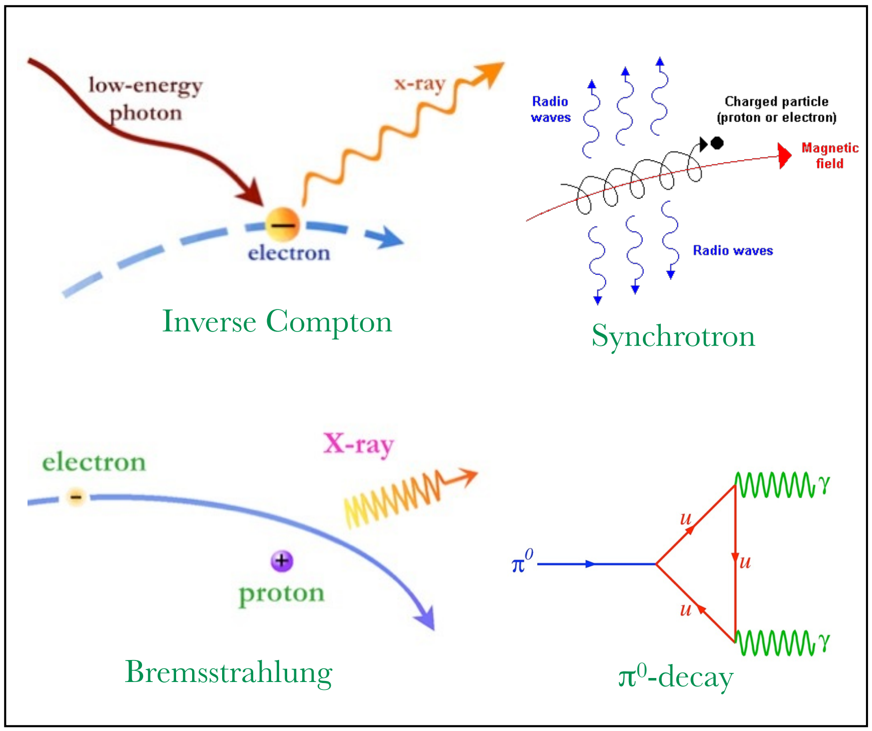
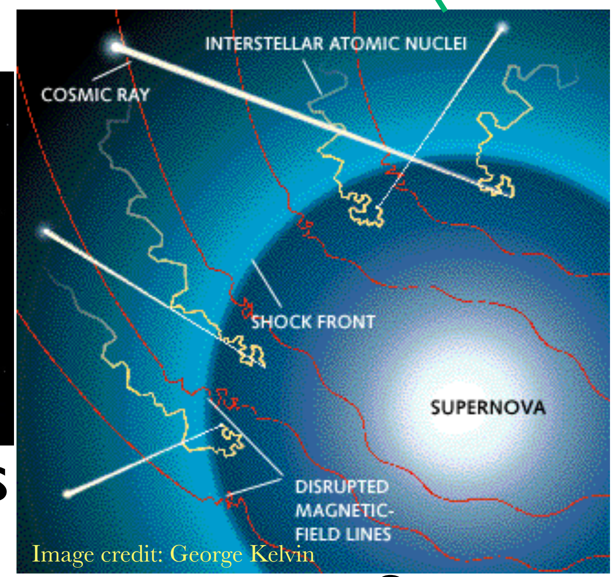


Cooling Losses

- Interstellar Medium
- Interstellar Radiation Field
- Magnetic Field

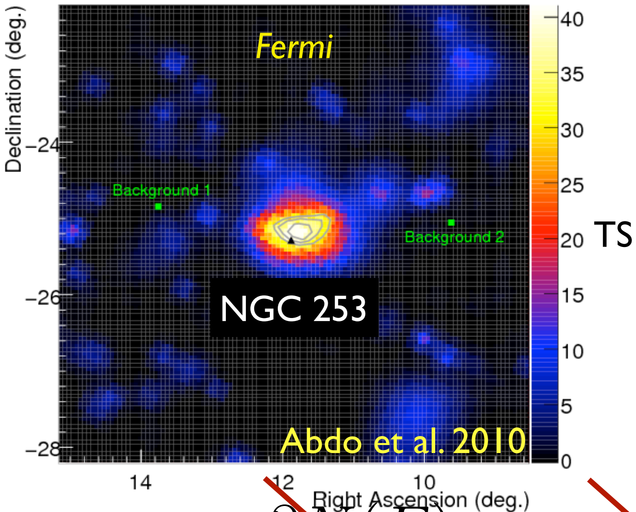
Escape Losses

- Diffusion
- Starburst Wind (Advection)
- Annihilation (positrons)



Sources

- Supernova Rate
- Acceleration Efficiency
- Primary Spectrum



Cosmic Rays in Starburst Galaxies

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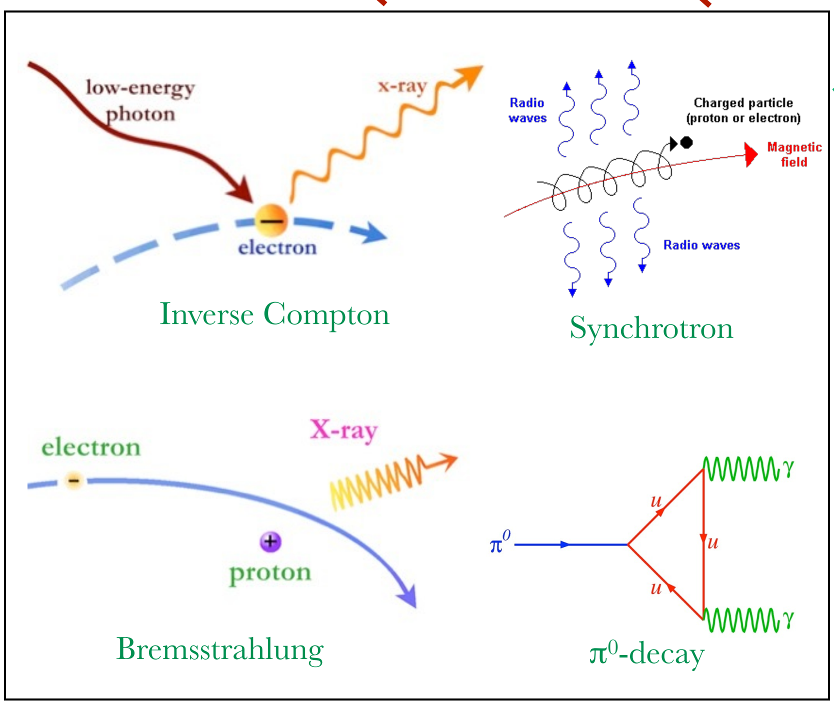

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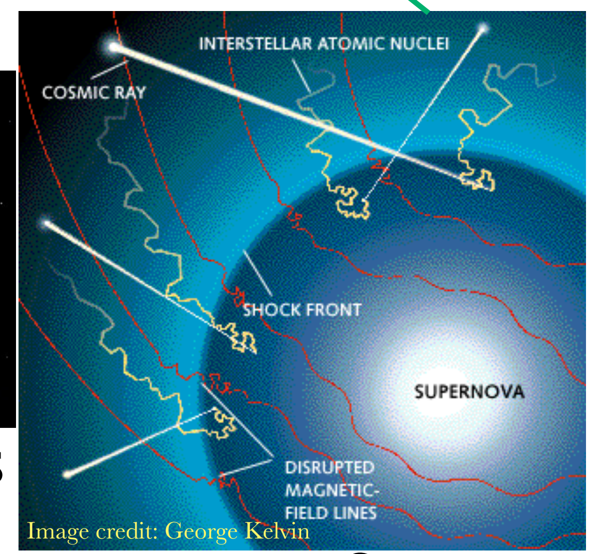

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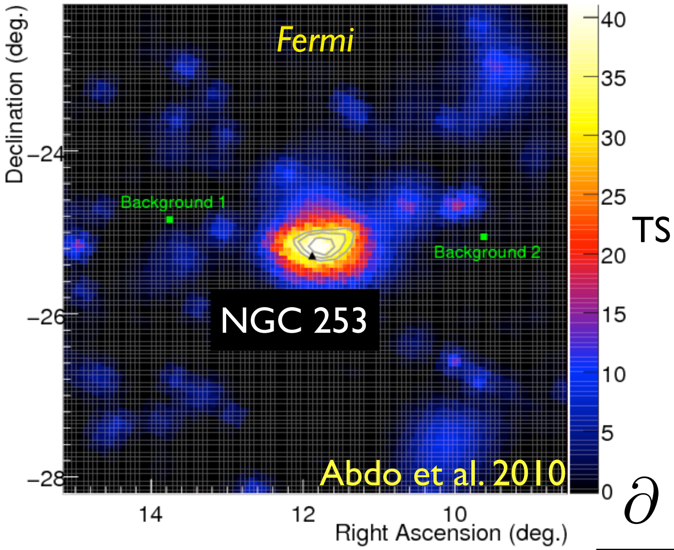

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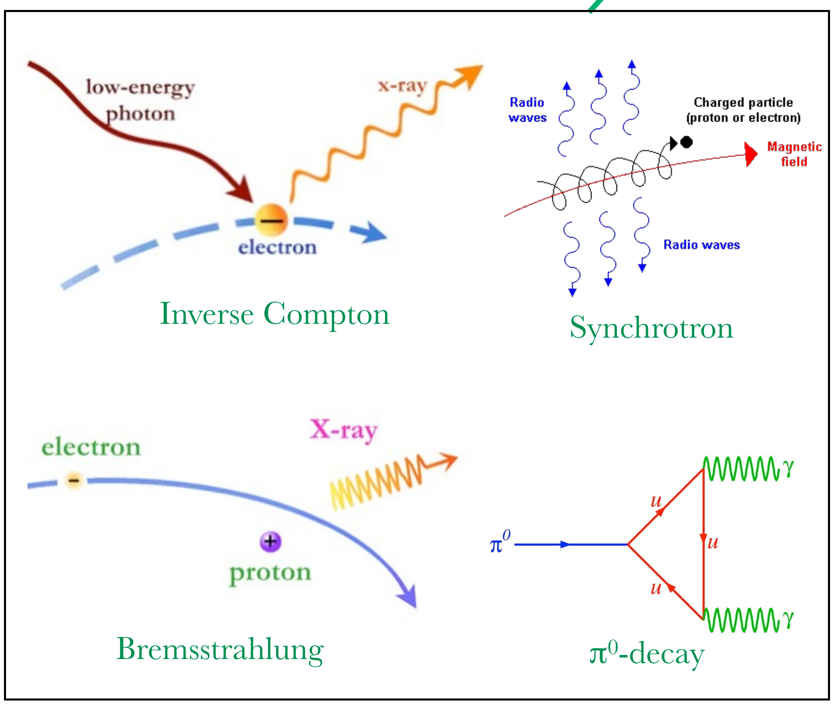
$$\frac{\partial}{\partial E}[b(E)N(E)] = \frac{N(E)}{\tau(E)} - Q(E)$$



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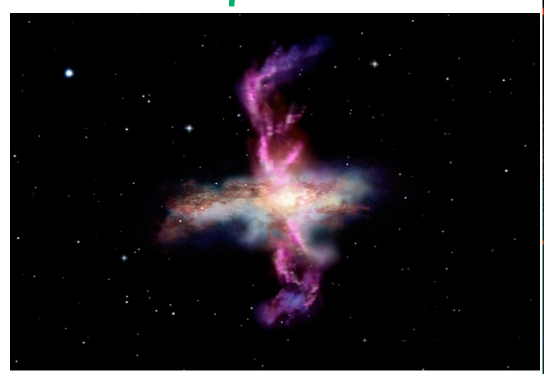

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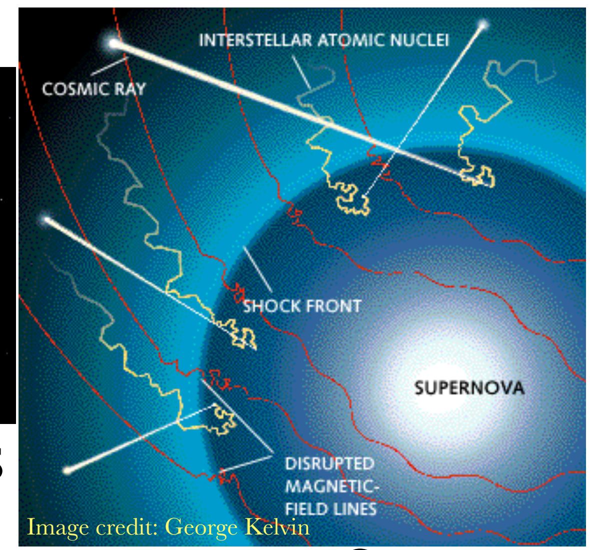

Image credit: George Kelvin

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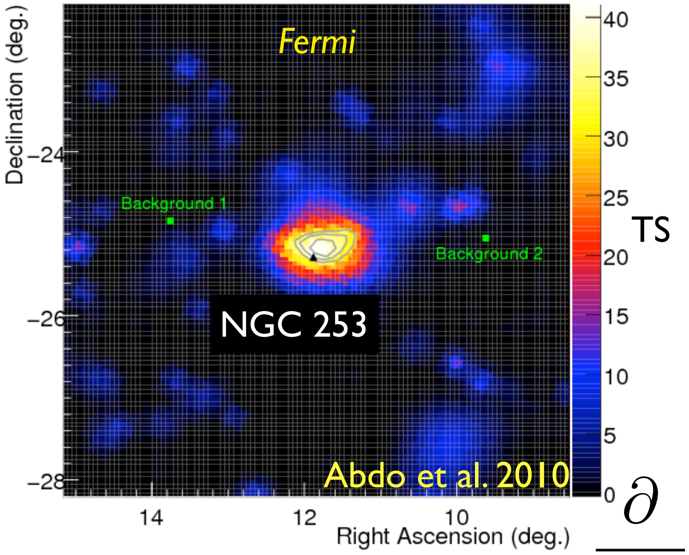

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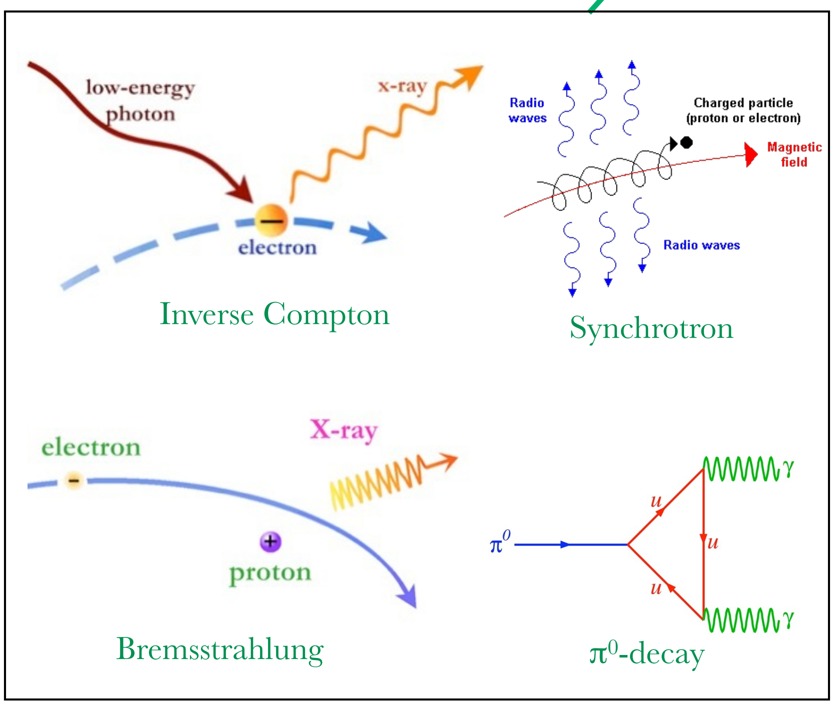

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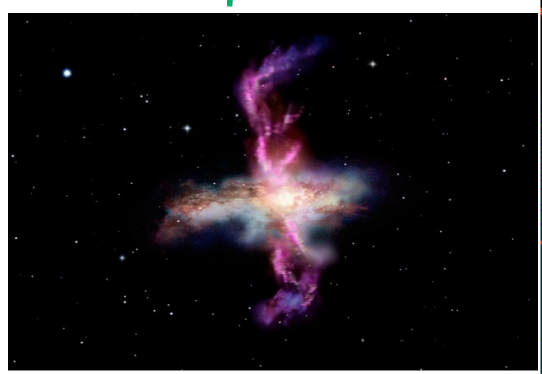

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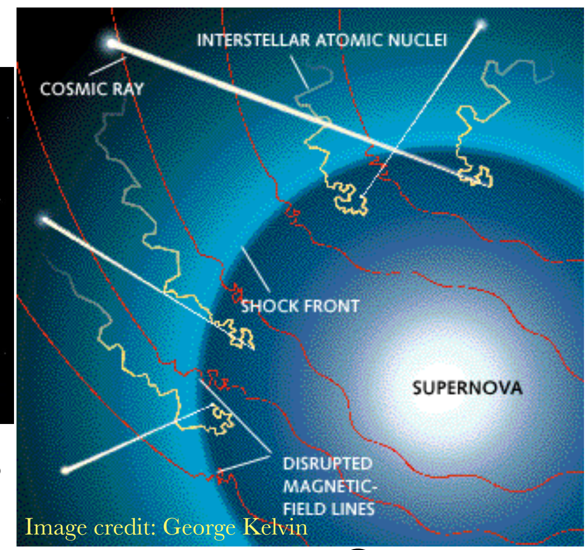

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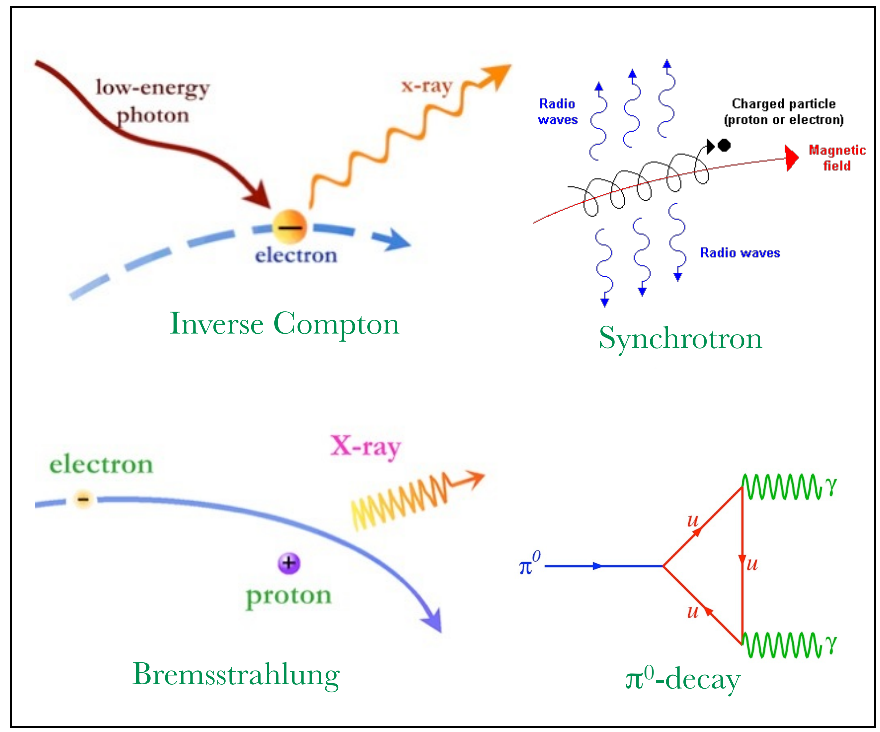
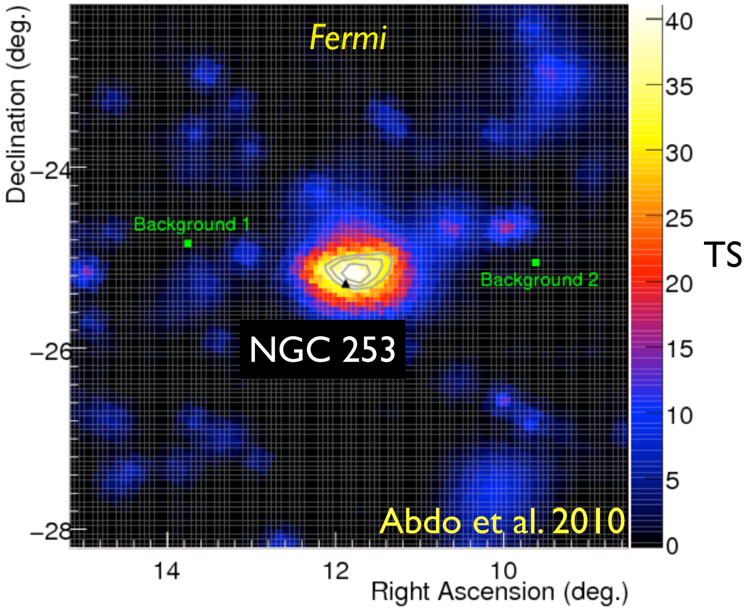
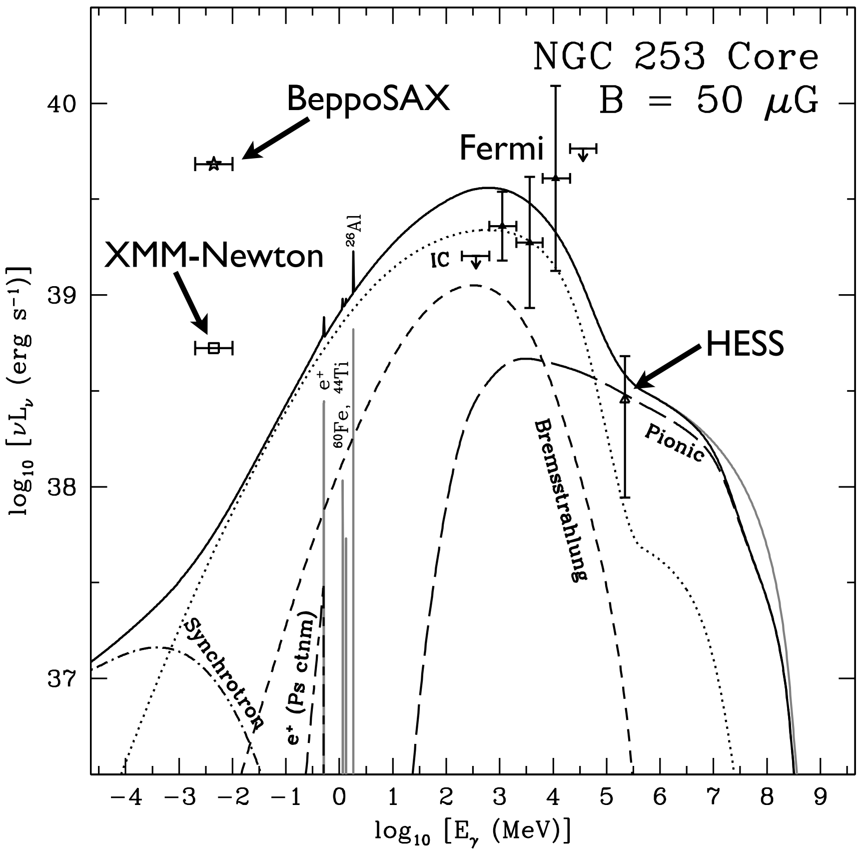
Non-thermal Diffuse Emission in Starburst Galaxies

$$N(E) \otimes \begin{matrix} n_{\mathrm{phot}}(E) \\ n_{\mathrm{ISM}}(E) \\ B^2 \end{matrix} \otimes$$

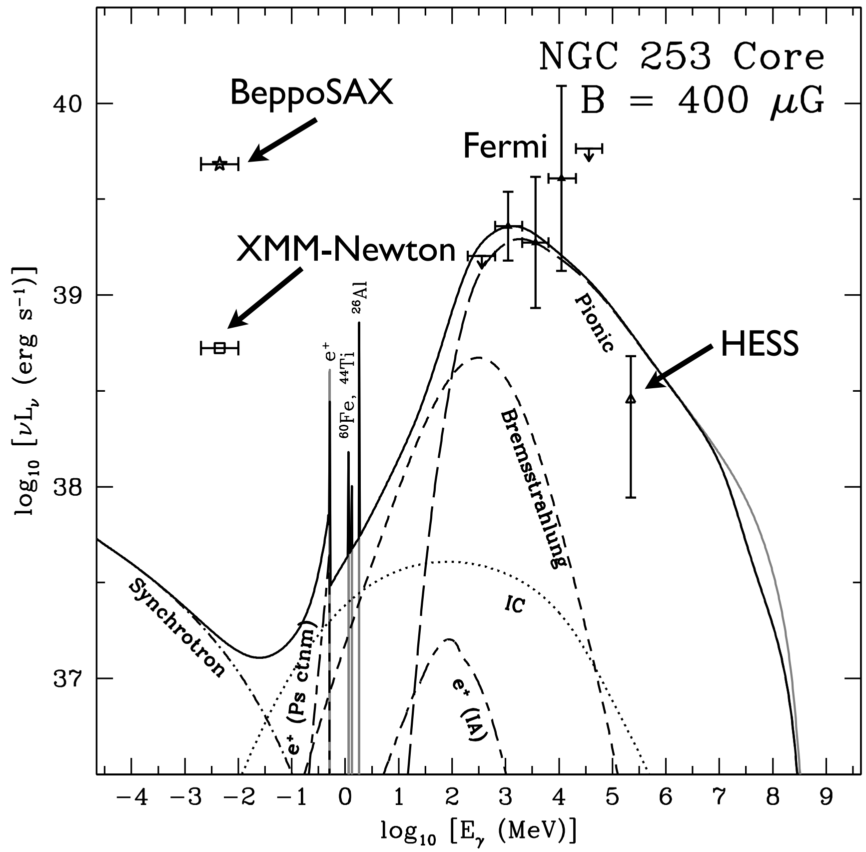




Broadband Spectra



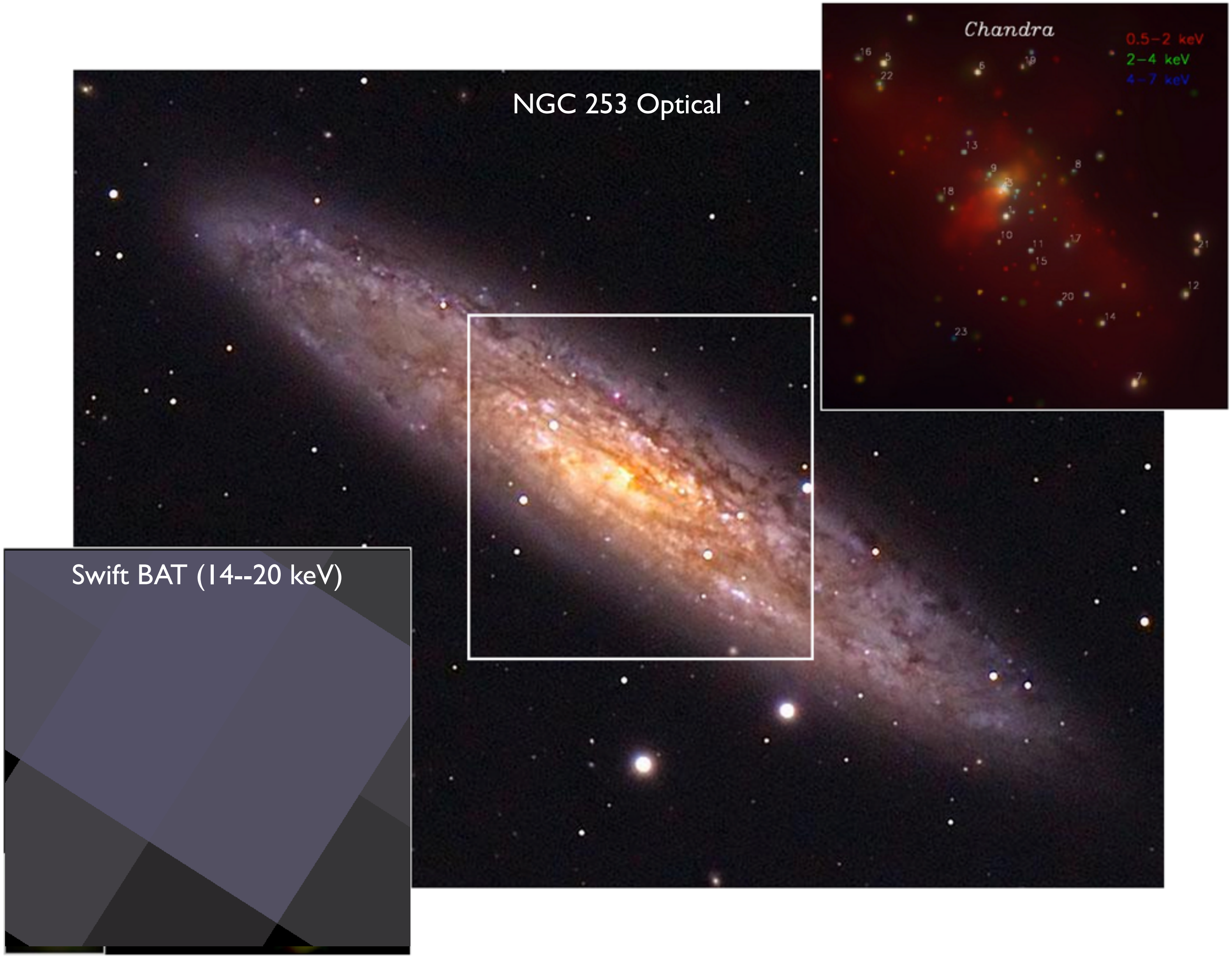
Leptonic Model



Hadronic Model

Lacki et al. 2012

Imaging Capability in Hard X-rays



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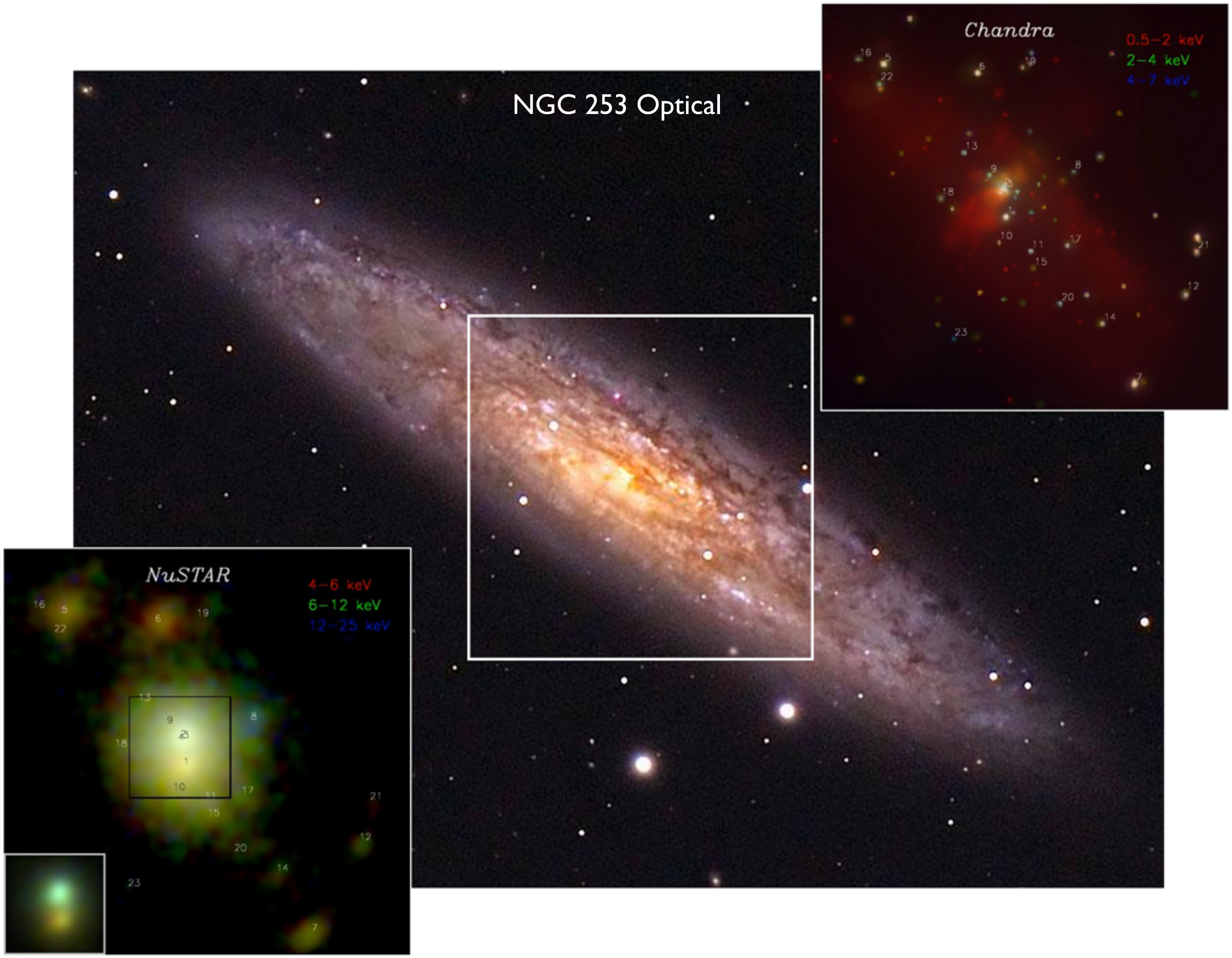
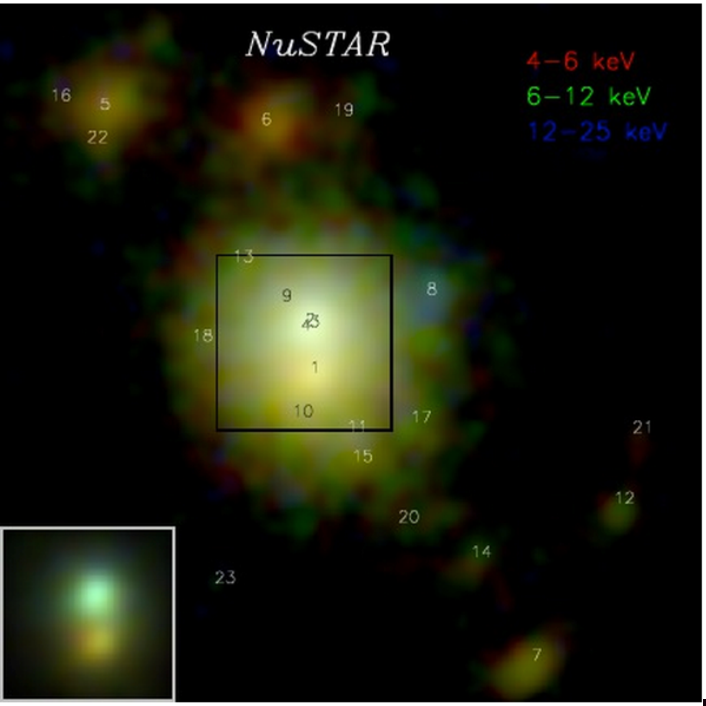
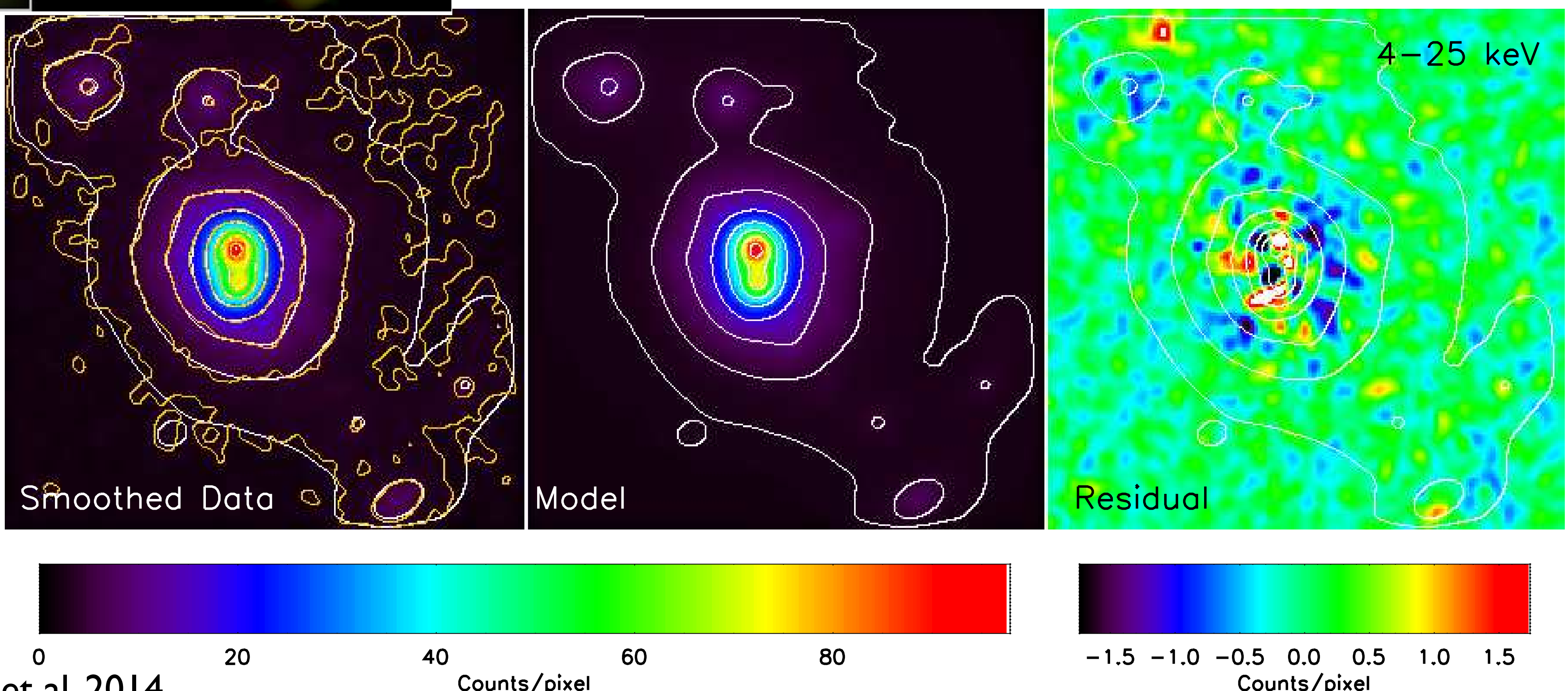


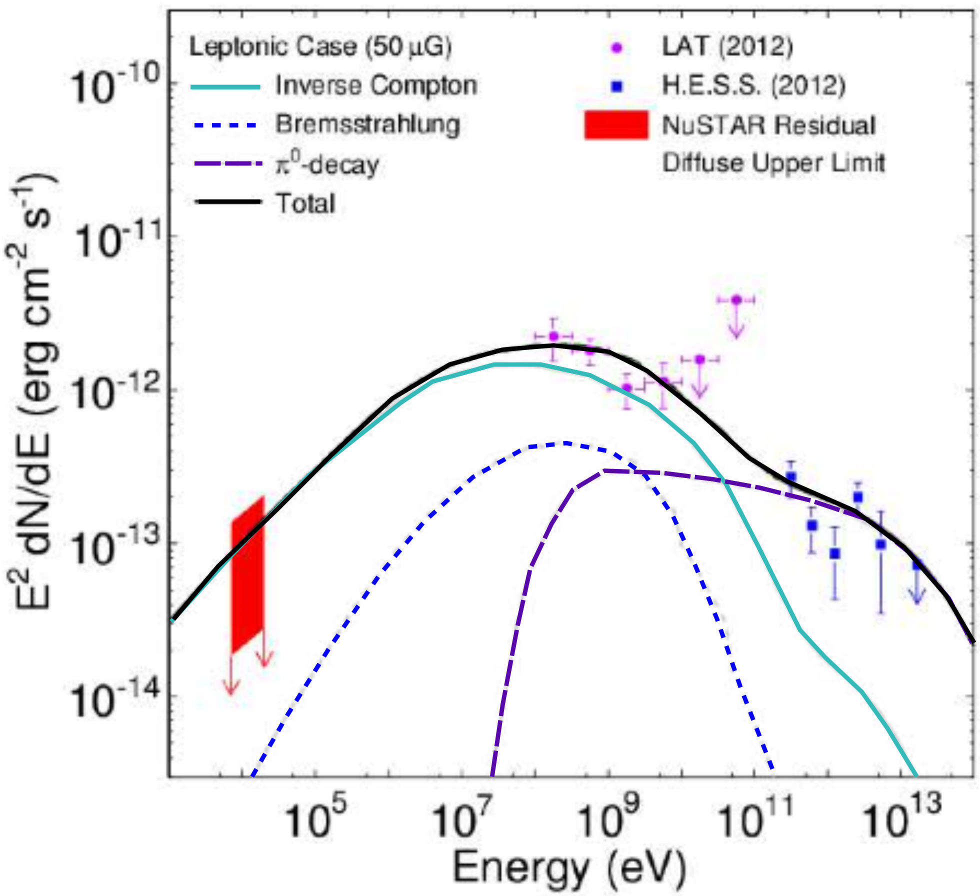
NuSTAR's Look at NGC 253





Wik et al. 2014

NuSTAR Constraints on Inverse Compton



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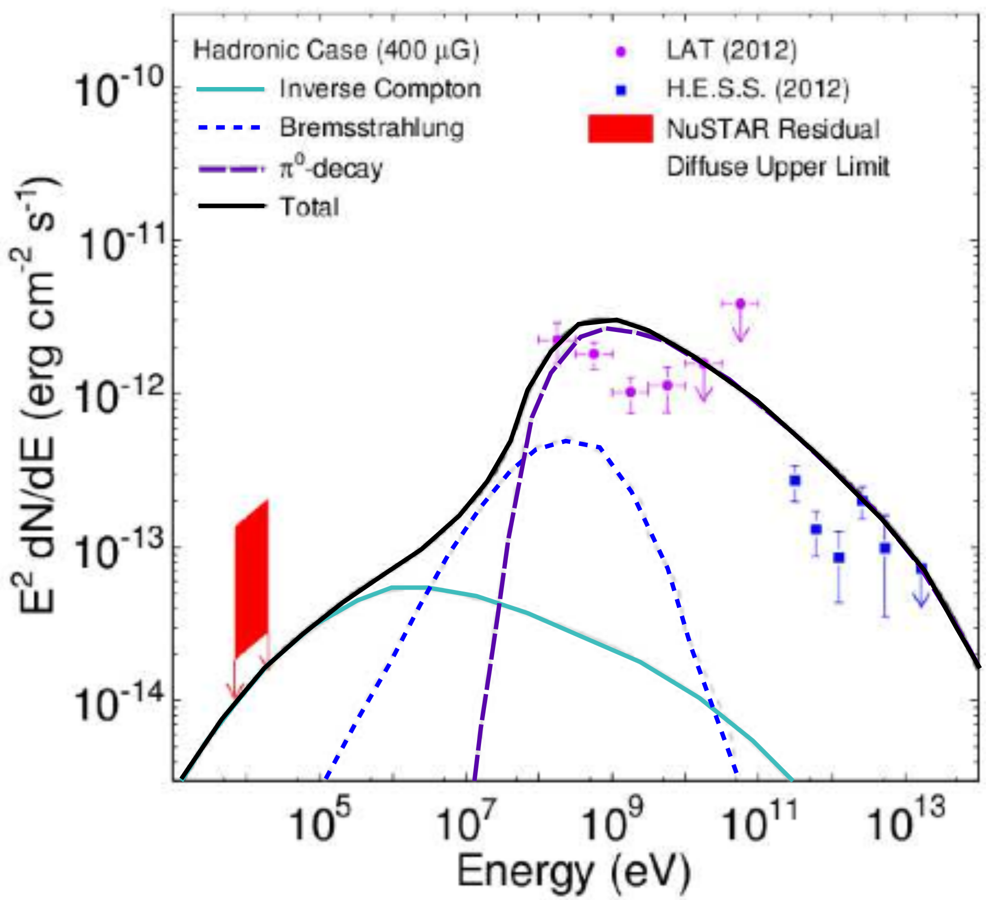

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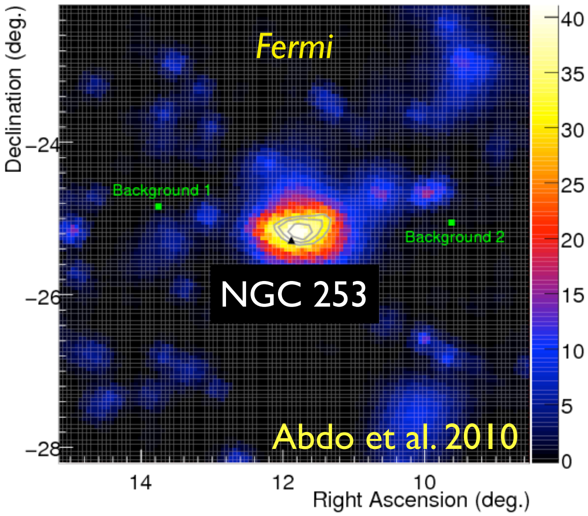
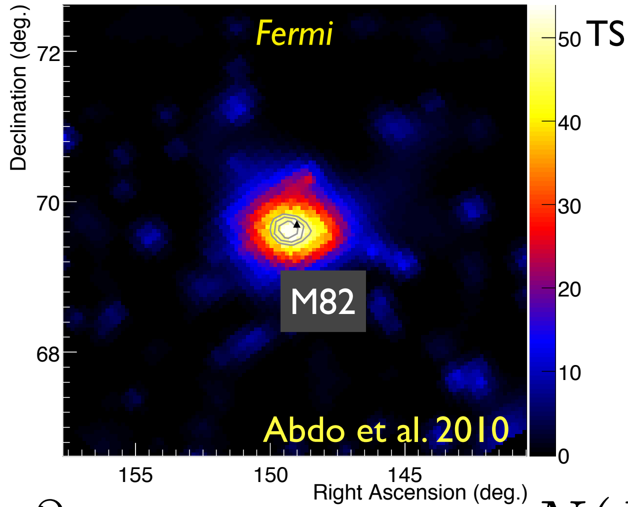
Wik et al. 2014





Future Work

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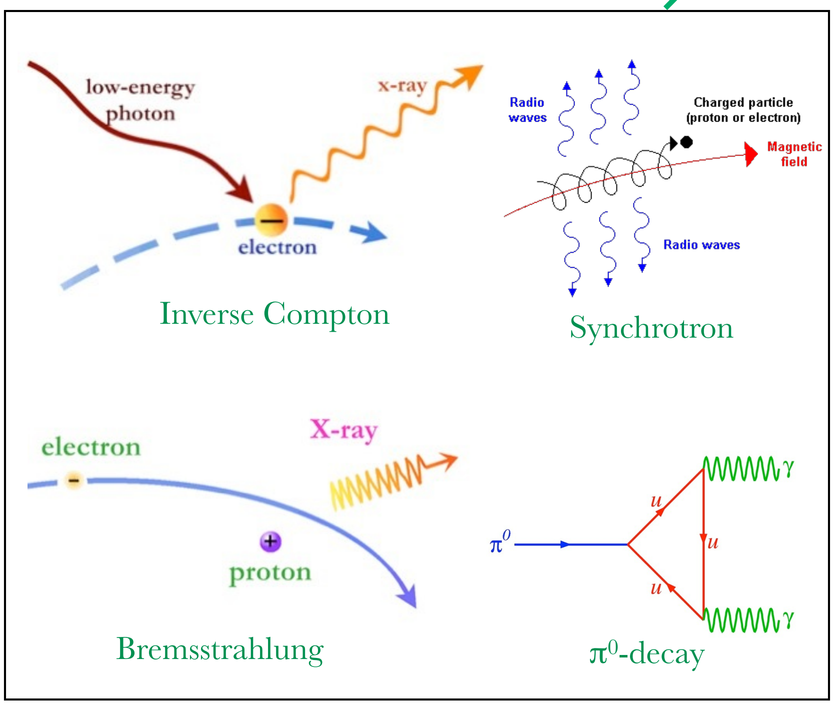

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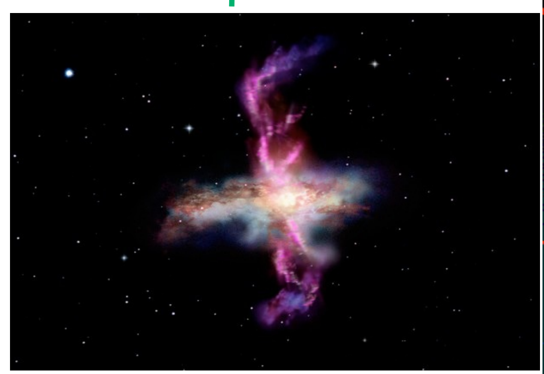

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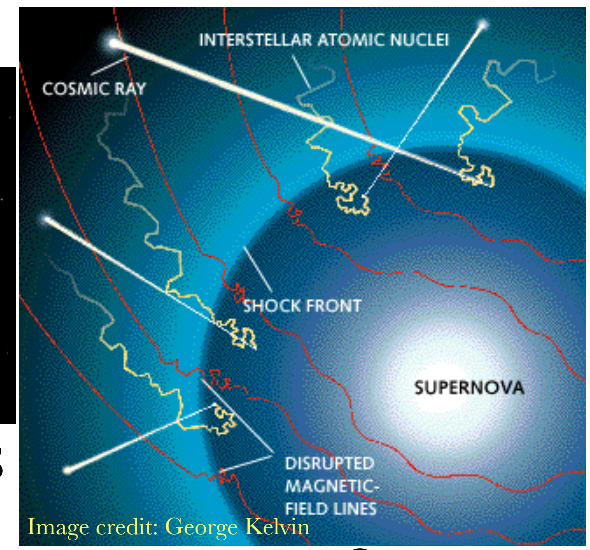

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Summary

- With its enhanced imaging capability in hard X-rays, NuSTAR has placed the deepest constraint to date on the Inverse Compton emission in NGC 253.
- Further modeling in light of the NuSTAR constraint and updated observations from Fermi and HESS will allow us to constrain the physical parameters of NGC 253 (e.g., cosmic ray energy density, magnetic field, etc.).
- Similar analyses and modeling will performed using existing and upcoming observations for M82.