

The Galactic center: a model for cosmic ray interactions in starburst galaxies?

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Abstract. The Galactic center contains strong magnetic fields, high radiation fields, and dense molecular gas, as is also the case in starburst galaxies. The close proximity of the Galactic center allows for more and better observations of the interstellar medium than for extragalactic sources making it an ideal place for testing models for cosmic ray interactions. We compare our semi-analytic model for cosmic ray interactions to published data for both the Galactic center and the starburst galaxy NGC 253. We present the predicted radio and γ -ray spectra and compare the results with published measurements. In this way we provide a quantitative basis for assessing the degree to which the Galactic center resembles a starburst system.

Keywords. cosmic rays, Galaxy: center — galaxies: individual (NGC253) — galaxies: starburst — gamma rays: galaxies — radio continuum: galaxies

1. Introduction

Previously, we developed a single-zone model for cosmic ray interactions in starburst nuclei (Yoast-Hull *et al.* 2013a). Due to the observed similarities between the Galactic center and starburst nuclei, we now compare the model to observations of the Galactic center and of the starburst galaxy NGC 253.

In the model, we assume that cosmic rays sample the mean density of a three-phase interstellar medium (ISM) (Boettcher *et al.* 2013). Due to the extremely high densities in starburst nuclei, energy losses dominate and so we neglect cosmic ray diffusion and only consider energy and advective losses, applying the model to the central molecular zone (CMZ). Additionally, we assume a constant particle acceleration efficiency from supernovae with a power-law injection spectrum. From a primary cosmic ray population, we calculate a secondary population of cosmic ray electrons and positrons. Both the primary and secondary populations of electrons/positrons are included in our models for the radio spectrum.

2. Results

We use a χ^2 test to compare our model to both γ -ray and radio data. For the γ -ray spectrum, the model includes neutral pion decay, bremsstrahlung, and inverse Compton emission. The radio spectrum is fit with both non-thermal synchrotron emission in the hot, diffuse medium and free-free absorption and emission from warm, ionized gas clouds. The goodness of the fit depends on molecular gas mass, ionized gas density, magnetic field strength, advection speed, and absorption fraction. We find that blindly applying

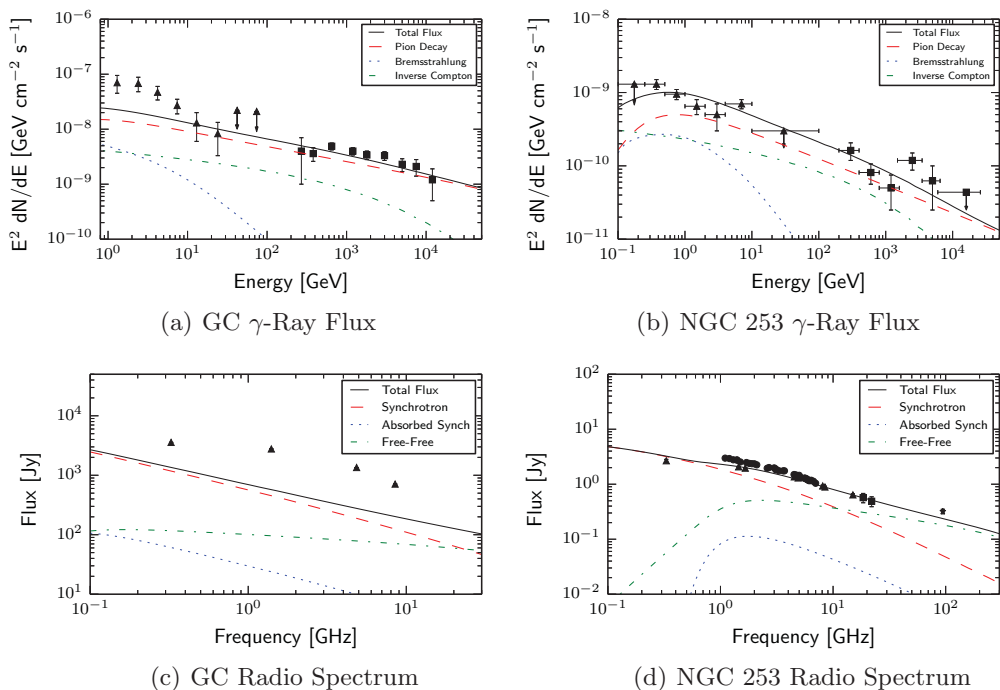


Figure 1. Data from Yusef-Zadeh *et al.* (2013), Abramowski *et al.* (2012), Carilli (1996), Paglione & Abrahams (2012), Peng *et al.* (1996), Ricci *et al.* (2006), Williams & Bower (2010). [A COLOR VERSION IS AVAILABLE ONLINE.]

the model to the Galactic center results in a γ -ray spectrum which does not fit the observed *Fermi* data.

3. Conclusions

Although the model works well for NGC 253 (Yoast-Hull *et al.* 2014), from the excess of hadronic emission at TeV energies and lack of leptonic emission at GeV energies, it is clear that the starburst model fails for the Galactic center. The underestimated γ -ray and radio spectra suggest that the electron to proton ratio is too low by a factor of ~ 8 . An excess of free-free emission in the radio spectrum is another difficulty for this model.

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