Very High Energy γ-rays from Supernova Remnants and Constraints on the Galactic Interstellar Radiation Field

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ABSTRACT

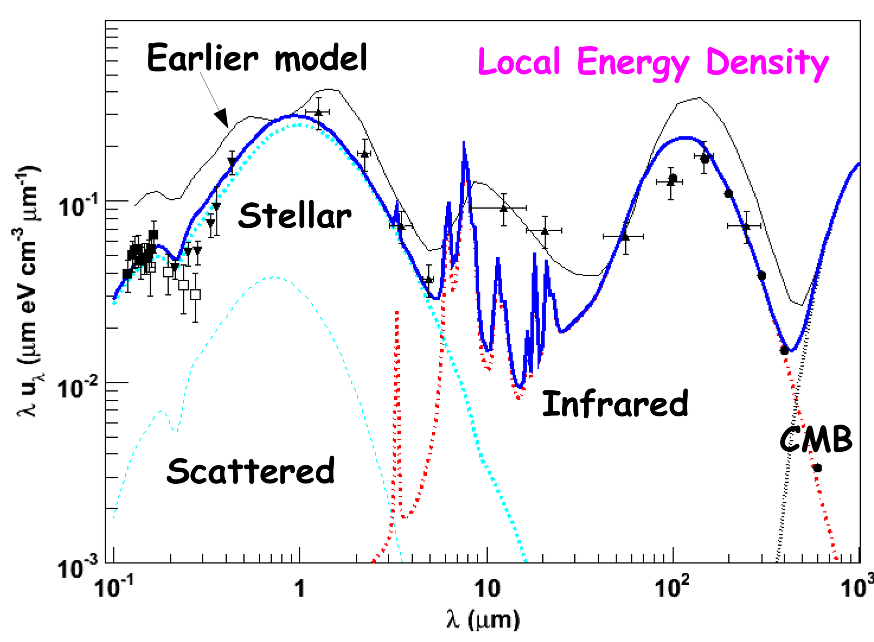
The combination of the Galactic interstellar radiation field (ISRF) and cosmic-ray electron distribution give the inverse Compton contribution to the diffuse Galactic γ-ray emission. Several models of the ISRF exist. The most recent one, which has been calculated by us, predicts a significantly higher contribution by stellar emission and dust re-processing of starlight than the well-used model of Mathis, Mezger, and Panagia (A&A 128,212 [1983]). This is due to several reasons: the improved treatment of stellar populations; the treatment of dust scattering, absorption and re-emission of the starlight. However, comparison with data is limited to local observations. In this contribution, we discuss how GLAST, with current and future VHE instruments, may be able to provide upper bounds on the large-scale Galactic ISRF.

INTERSTELLAR RADIATION FIELD

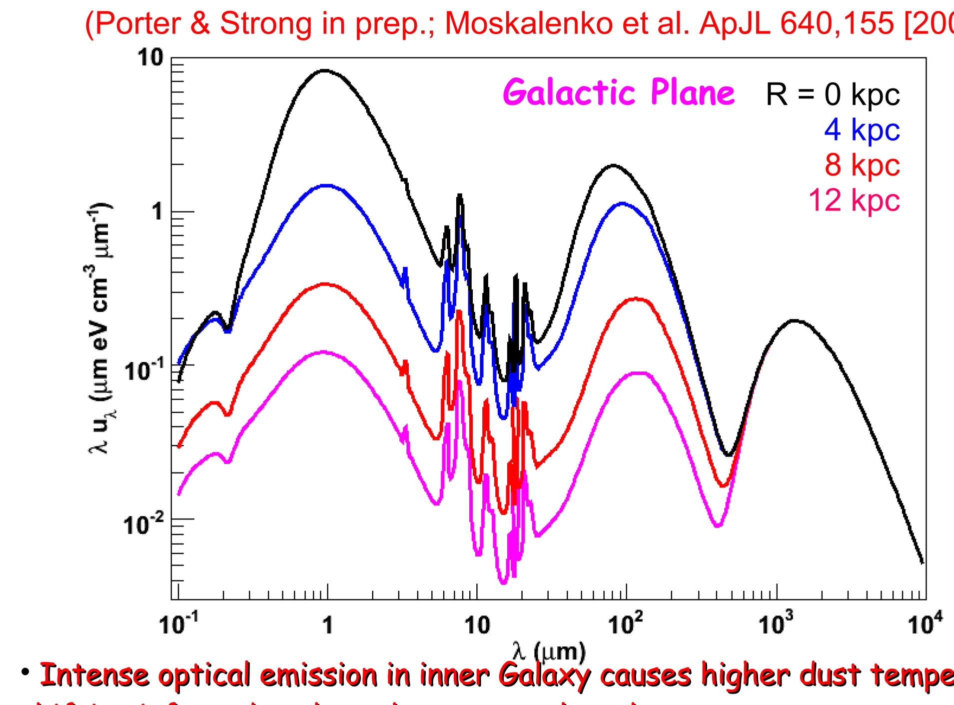
- Stellar emission model incorporating thin and thick disc, bulge/bar, and halo/spheroid
- Stellar populations adjusted to reproduce observed V- and K-band luminosity functions for thin disc and bulge
- Dust model included for absorption and scattering of starlight
- Absorption and re-emission of starlight gives infrared, scattering gives diffuse galactic light
- Dust includes PAHs, graphite, and silicate with size distribution ranging from ~ 5 Å to ~ 3 μm
- Dust follows Galactic metallicity gradient and hydrogen distribution
- Intensities and energy density calculated for cylindrically symmetric Galactocentric geometry (R, z) for wavelengths from ~ 912 Å to 10000 μm

INTERSTELLAR RADIATION FIELD IN VARIOUS LOCATIONS IN THE GALAXY

(Porter & Strong in prep.; Moskalenko et al. ApJL 640,155 [2006])

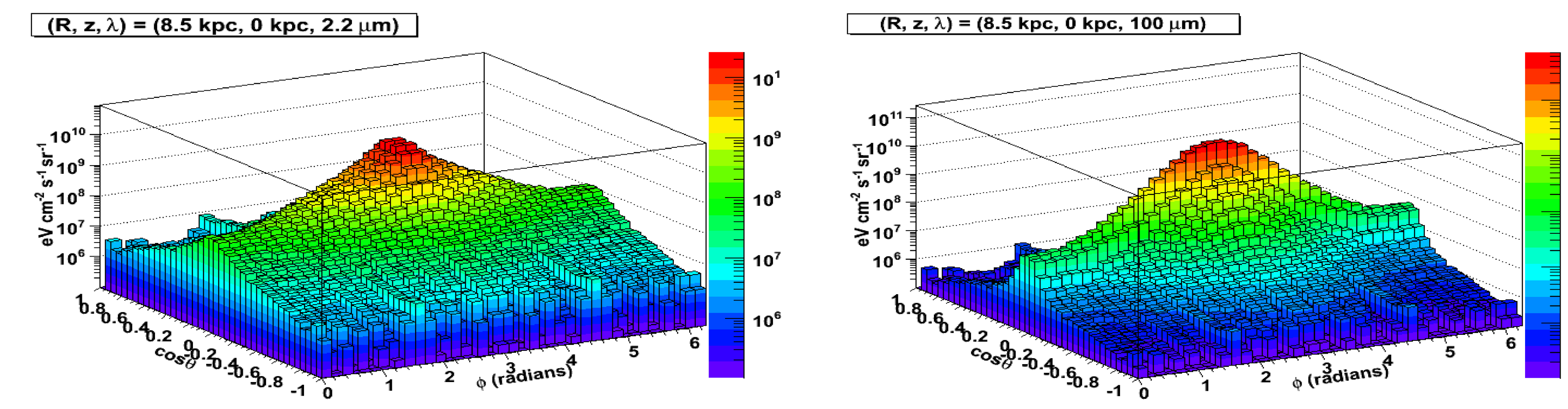


Data: filled squares, Apollo (Henry et al. 1980); open squares S2/68 (Gondhalekar et al. 1980); inverted triangles, OAO-2 (Witt & Johnson 1973); triangles, DIRBE (Arendt et al. 1998); circles, FIRAS (Finkbeiner et al. 1999).



- Intense optical emission in inner Galaxy causes higher dust temperatures, shifting infrared peak to shorter wavelengths
- Infrared emission scales mostly with dust abundance

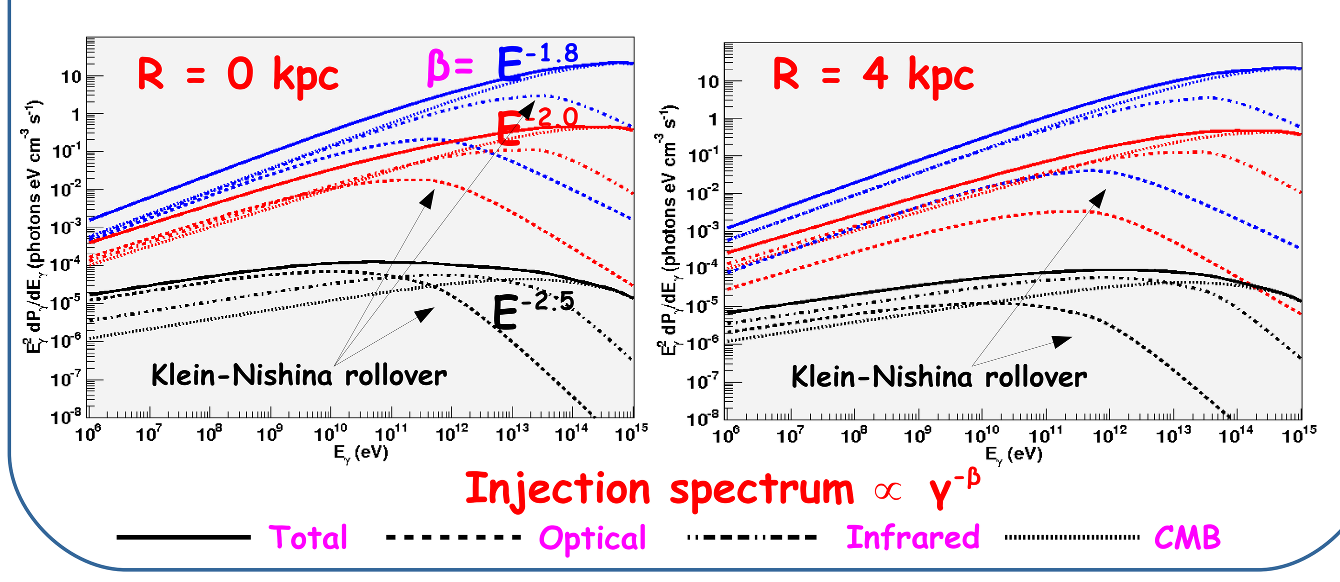
ANGULAR DISTRIBUTION OF THE LOCAL INTERSTELLAR RADIATION FIELD



φ=Galactic Longitude + 180°

Θ=90° – Galactic Latitude

INVERSE COMPTON EMISSIVITY IN GALACTIC PLANE



OPTICAL DEPTH CALCULATIONS

The optical depth for VHE γ-rays is given by the general formula

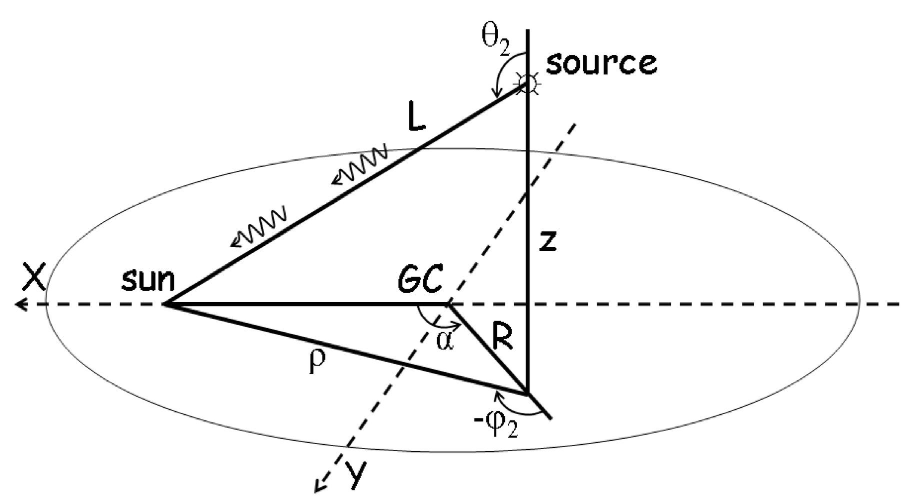
$$\tau_{\gamma\gamma}(E) = \int_L dx \int d\epsilon \int d\Omega_1 \frac{dN(\epsilon, \Omega_1, \boldsymbol{x})}{d\epsilon\, d\Omega_1} \sigma_{\gamma\gamma}(\epsilon_c)(1 - \cos\theta),$$

$$\epsilon_c = [\tfrac{1}{2}\epsilon E(1 - \cos\theta)]^{1/2}$$

For the calculation of the optical depth in the CMB field, we use the formula

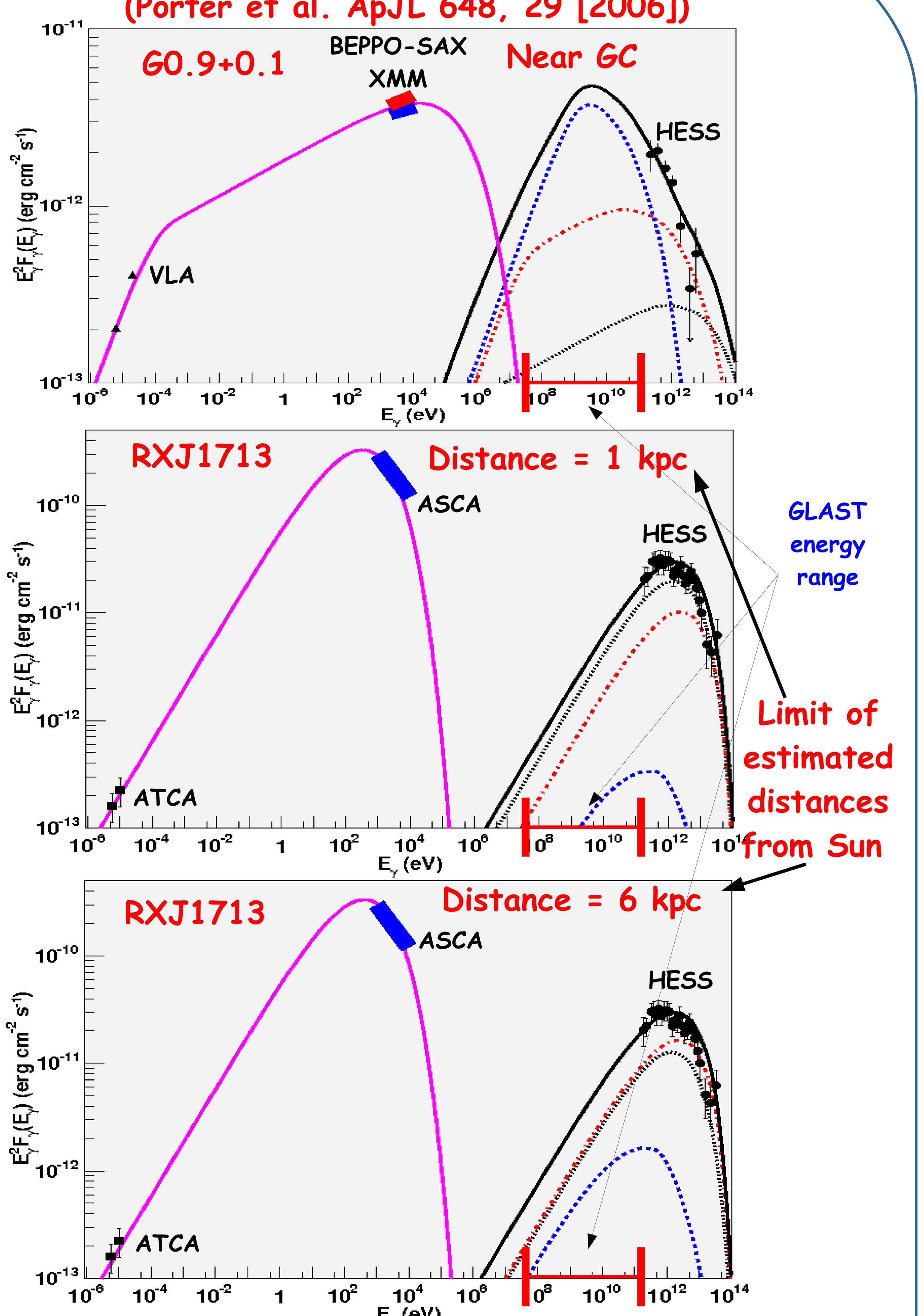
$$\tau_{\gamma\gamma}^{\rm CMB}(E) = -\frac{4kT}{(\hbar c)^3 \pi^2 E^2} \times \int_L dx \int_{m_e c^2}^{\infty} d\epsilon_c\, \epsilon_c^3 \sigma_{\gamma\gamma}(\epsilon_c) \log(1 - e^{-\epsilon_c^2/EkT}),$$

where kT is the CMB temperature and $m_e c^2$ is the electron rest mass.



EMISSION FROM SNRs

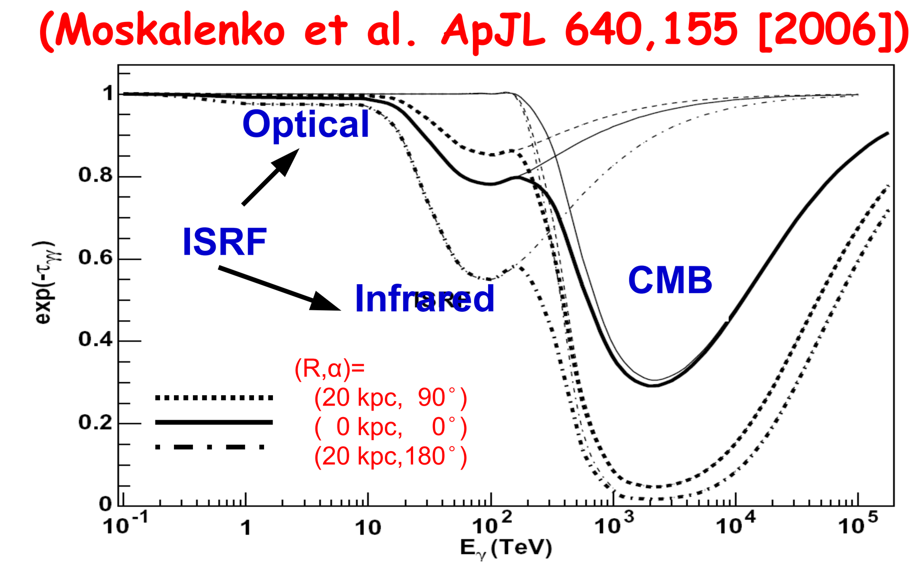
(Porter et al. ApJL 648, 29 [2006])



- Fit SNR flux spectrum with simple one-zone leptonic model using calculated large-scale Galactic ISRF
  - Adjust electron spectrum and magnetic field to reproduce VHE, X-ray, and radio
- Between GC and solar circle, optical and infrared dominate; GLAST range is optical dominated @ GC
- Outside solar circle, CMB dominates IC emission
- IC from ISRF is minimum; additional local RF from SNR possible, ∴ attributing all emission to ISRF ⇒ upper limit on ISRF

TRANSMITTANCE FOR VARIOUS POSITIONS IN THE GALACTIC PLANE

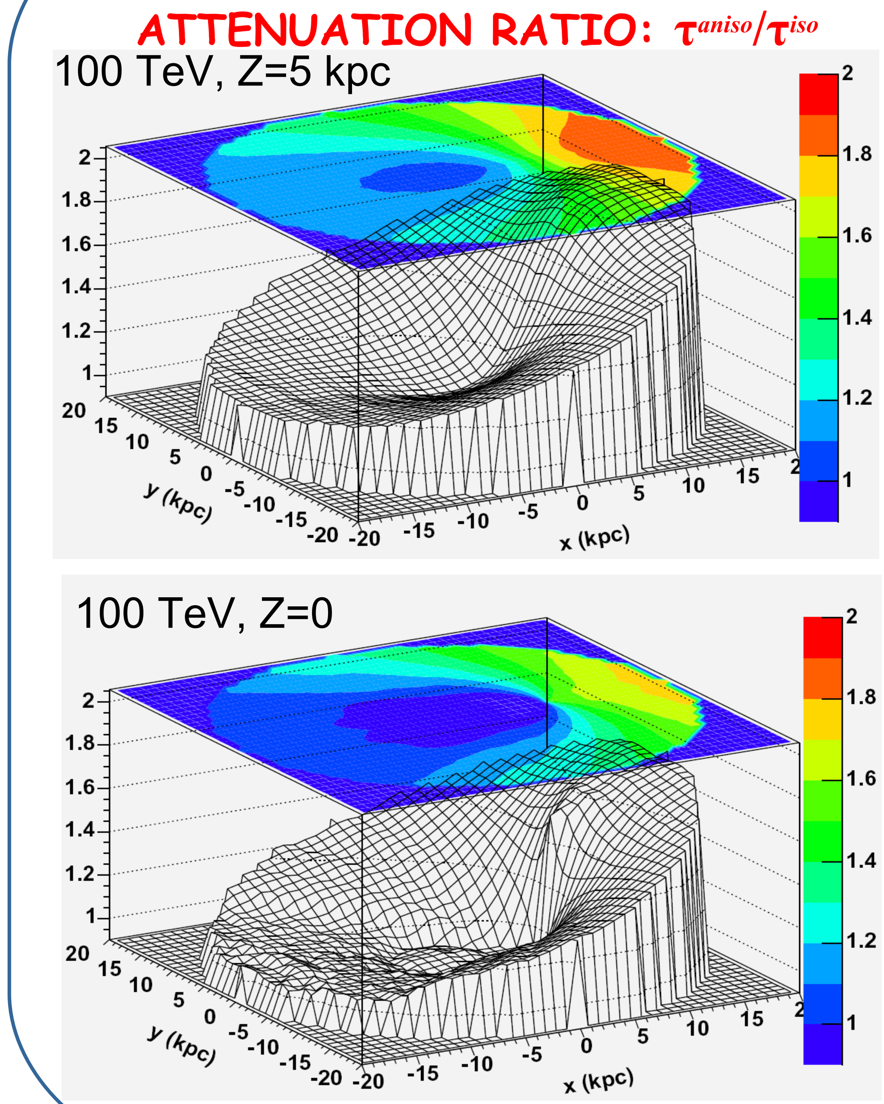
(Moskalenko et al. ApJL 640,155 [2006])



Optical Depth $\tau_{\gamma\gamma}$ at 30 and 100 TeV

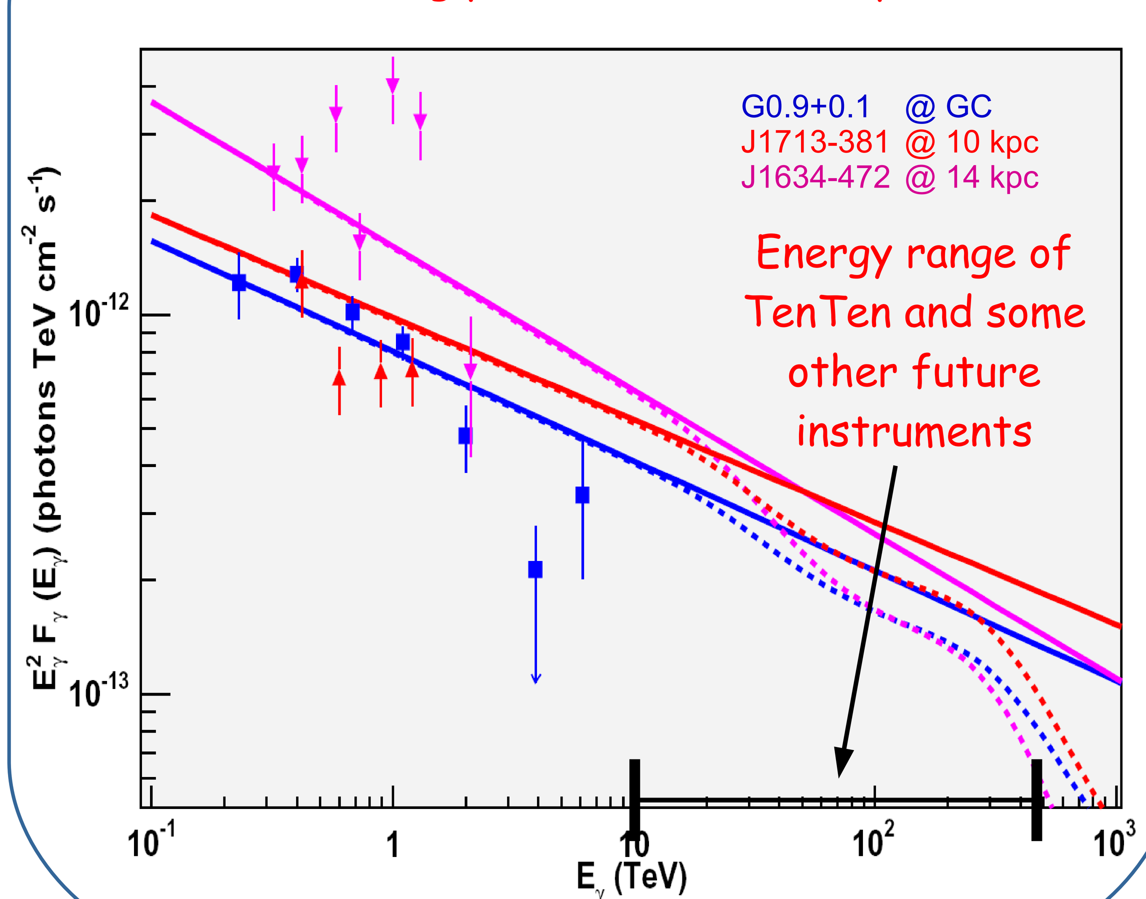
R (kpc)	30 TeV α = 0°	30 TeV α = 90°	30 TeV α = 180°	100 TeV α = 0°	100 TeV α = 90°	100 TeV α = 180°
z = 0 kpc:						
0	0.12	...	...	0.25	...	...
5	0.01	0.15	0.22	0.05	0.32	0.41
10	0.01	0.08	0.28	0.02	0.21	0.54
15	0.02	0.07	0.31	0.05	0.18	0.58
20	0.03	0.07	0.32	0.06	0.16	0.60
z = 5 kpc:						
0	0.03	...	...	0.09	...	...
5	0.01	0.04	0.06	0.05	0.10	0.15
10	0.02	0.05	0.09	0.04	0.12	0.21
15	0.03	0.05	0.12	0.05	0.13	0.26
20	0.03	0.06	0.14	0.06	0.13	0.29

ANISOTROPIC/ISOTROPIC ATTENUATION RATIO: τ^{aniso}/τ^{iso}



EFFECT ON HESS SOURCES,

assuming power-law intrinsic spectra



CONCLUSIONS

- The IC emission of individual SNRs can include significant contributions by the large-scale ISRF, particularly in the inner Galaxy
- Observations of classes of SNRs in the outer Galaxy (e.g., PWN), where IC of CMB photons dominates, could help determine source class intrinsic properties (if any), which could be applied to similar objects in the inner Galaxy
- The GLAST energy range is particularly suited to constraining the IC emission on the optical and near-infrared
- Future experiments may be able to see features in VHE spectra due to absorption on the ISRF (mainly the infrared component)
- Non-observation of absorption implies an upper bound on the number of infrared photons between the source and observer, thus constraining the dust emission