Cosmic MeV-GeV Background Radiation: Astrophysical Sources vs. DM Annihilaiton

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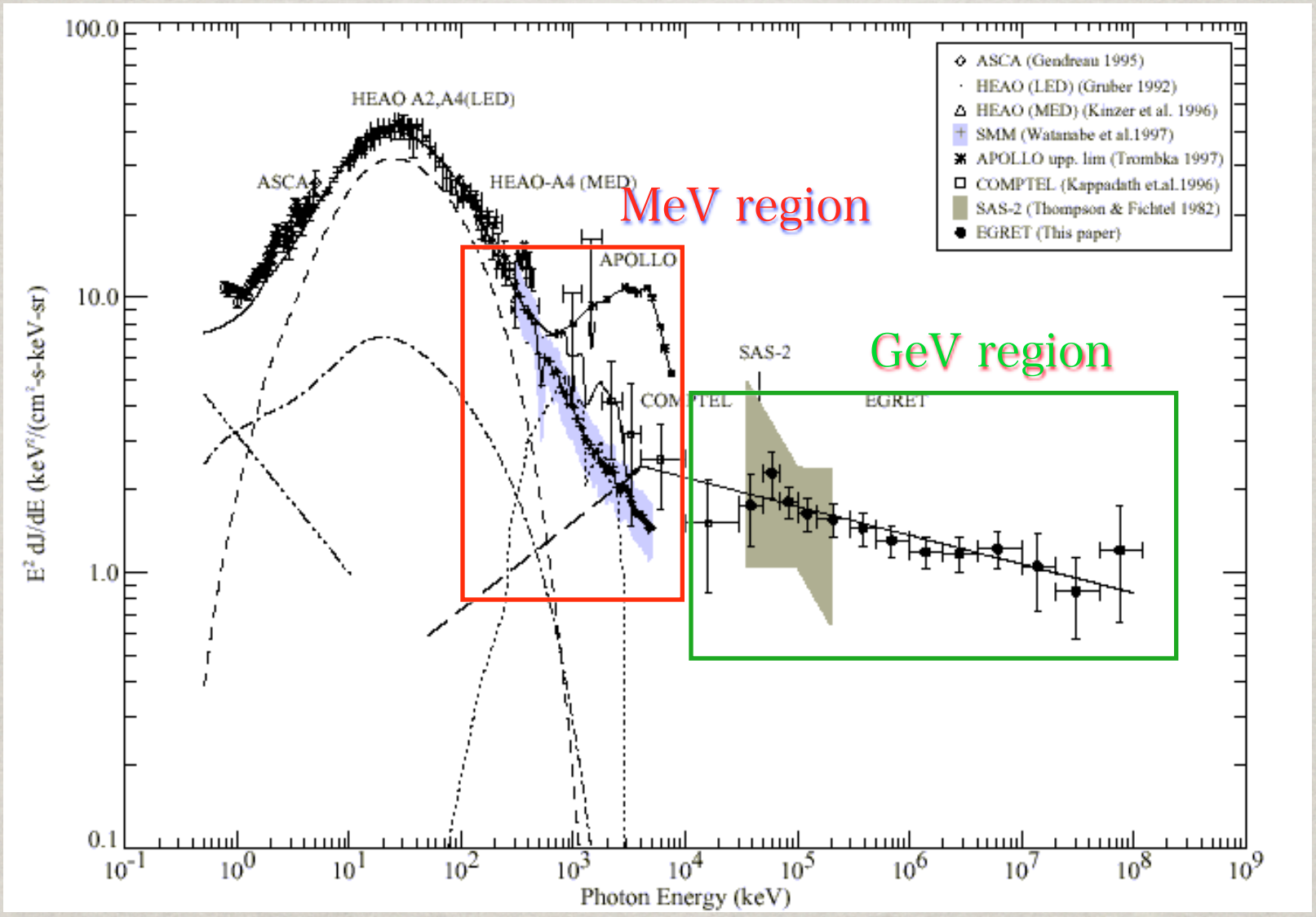
Cosmic X-ray & gamma-ray background (CXB, CGB)



Sreekumar et al. 1998

Understanding of CXB, CGB

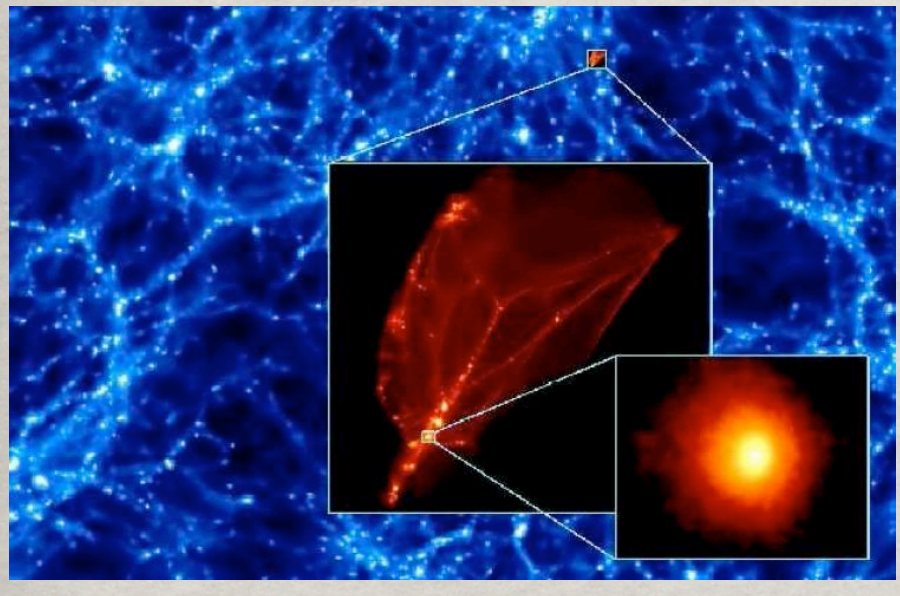
- Cosmic X-ray background (CXB)
  - can be explained by integration of normal X-ray AGNs
  - has mostly been resolved into discrete sources

- MeV background
  - SN Ia? (rate not sufficient)
  - AGN? (past AGN models for CXB cannot explain)
  - MeV-mass dark matter annihilation!?

- GeV background
  - blazars? (only <~30% of CGB can be explained: Chiang & Mukherjee '98; Mucke & Pohl '00; Narumoto & Totani '06)
  - galaxy clusters? (probably negligible under standard assumptions)
  - WIMP annihilation!?

DM annihilation contribution to gamma-ray background?

- In the case of WIMPs contributing GeV background, a large boost factor is necessary from the standard prediction
  - DM substructure down to earth mass scale may have such an effect (Oda, Totani & Nagashima '05)



Diemand+ '05

Oda+ '05

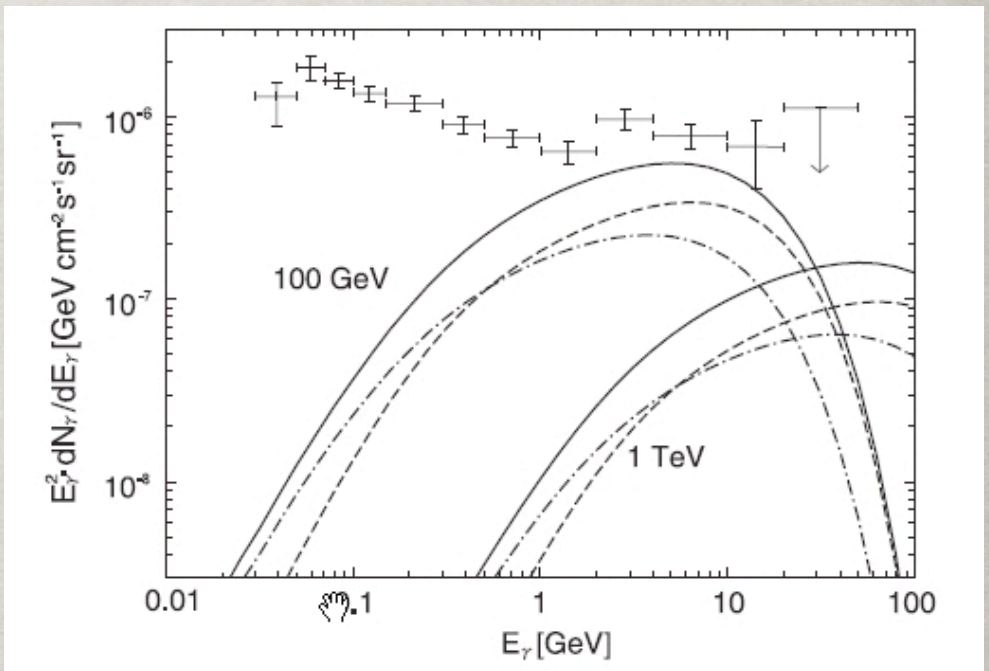
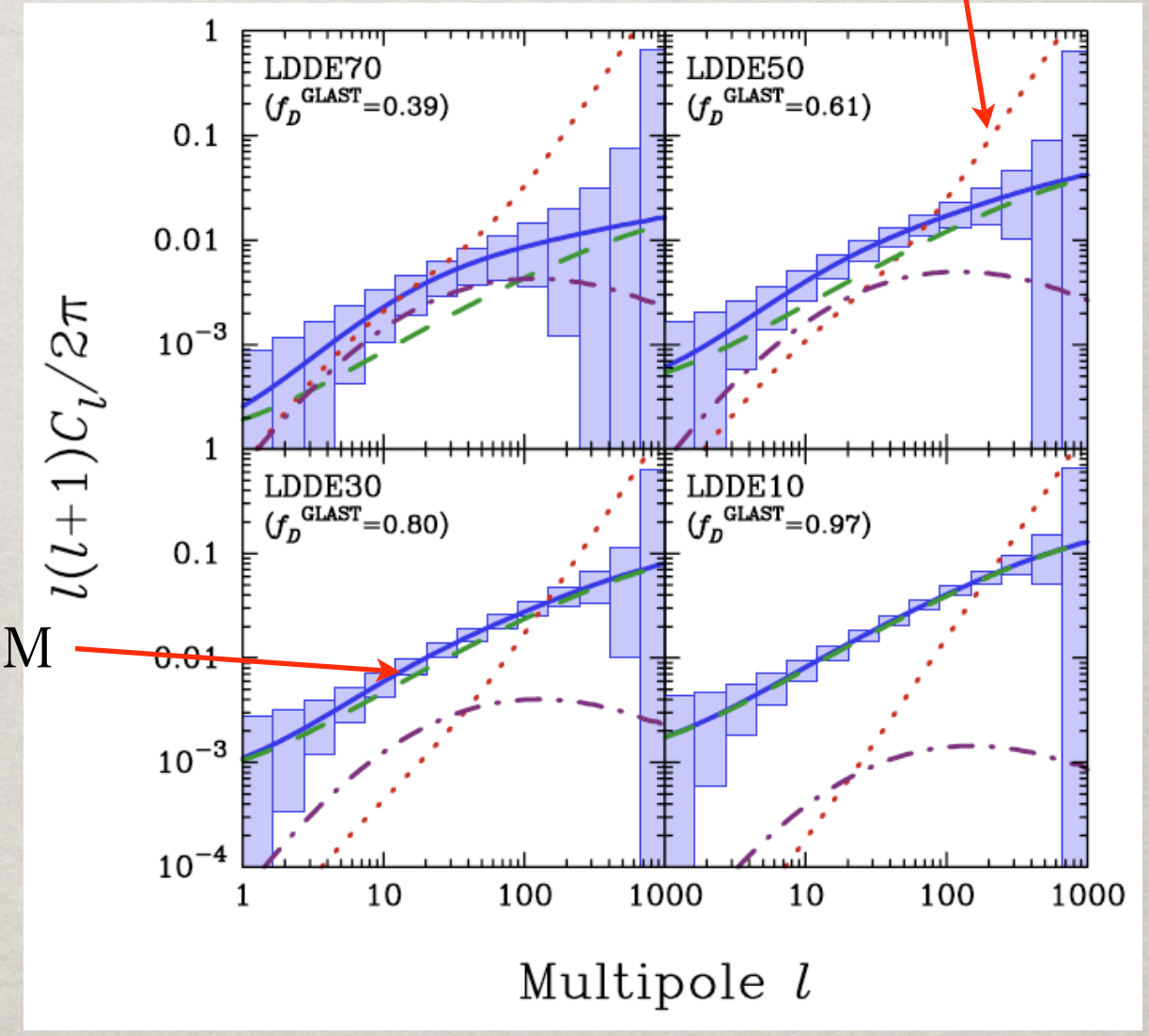


FIG. 1: The background gamma-ray flux from neutralino an-

Anisotropy background signal from DM annihilation?

- angular correlation power-spectrum predicted by Ando+'07
- see also Cuocco+'08, Miniati+'07, Hooper+'07

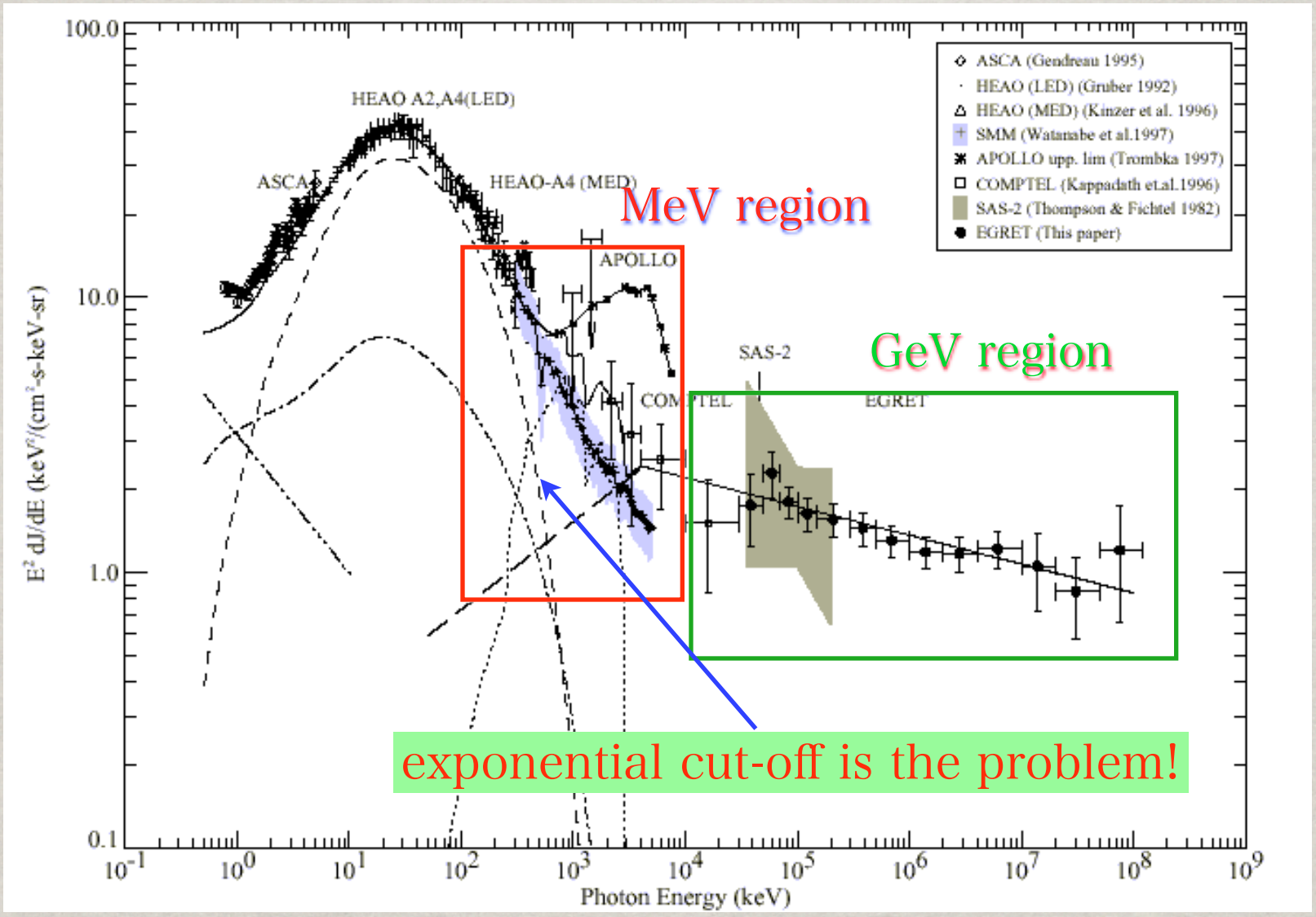


The focus of this talk

- Do we really have to resort to DM annihilation to explain MeV or GeV background radiation?

I. MeV Background

Cosmic X-ray & gamma-ray background (CXB, CGB)

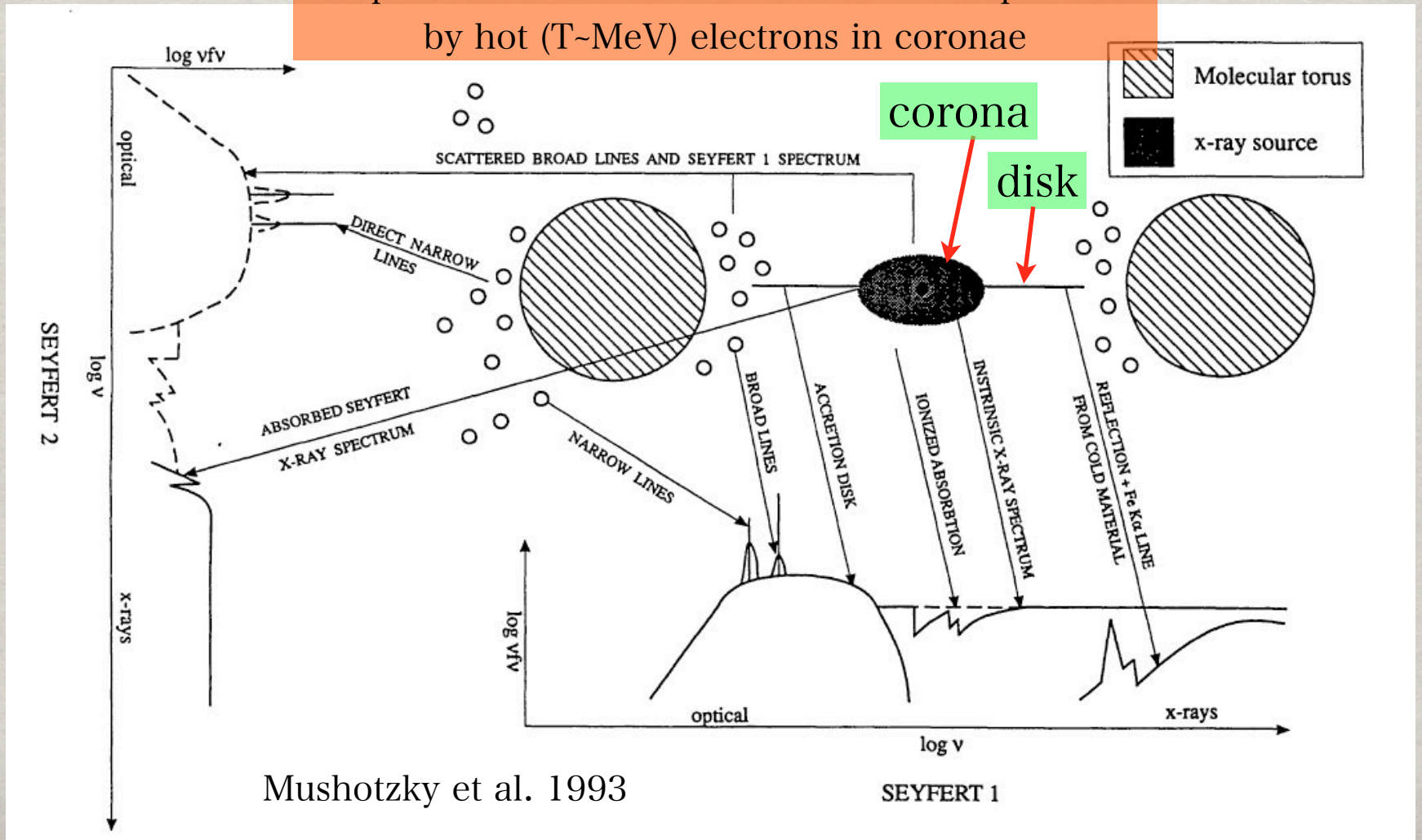


Sreekumar et al. 1998

AGN X-ray Spectra

- picture of normal X-ray AGNs (e.g., Seyferts)

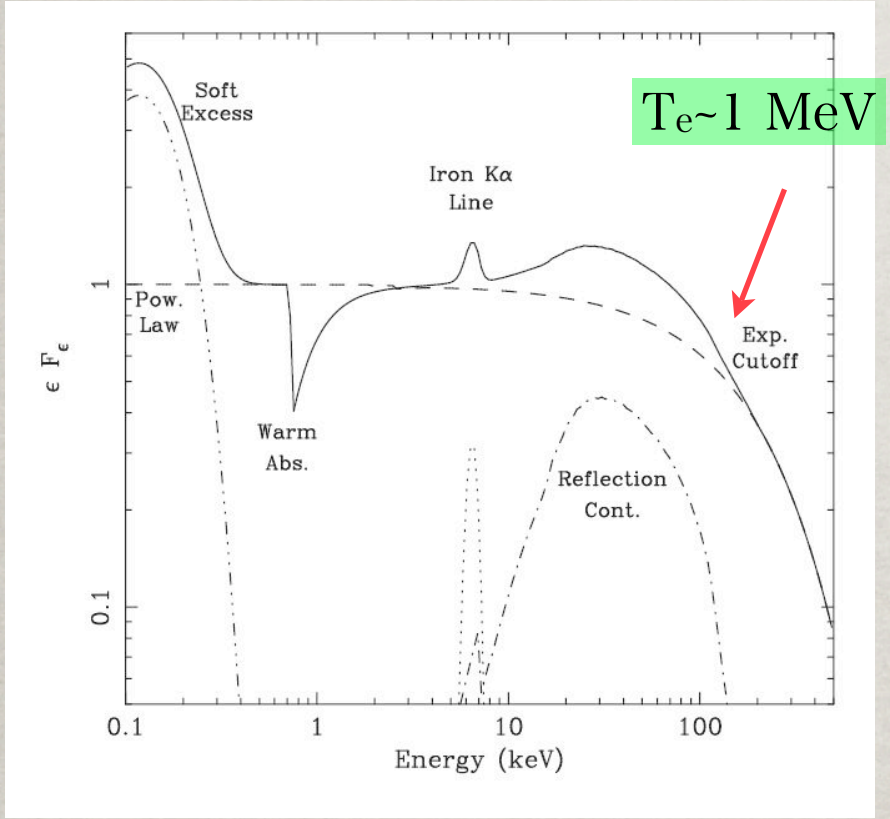
UV photons from accretion disks are Comptonized by hot (T~MeV) electrons in coronae



Mushotzky et al. 1993

AGN X-ray Spectrum vs. CXB

schematic AGN spectrum



Fabian 1998

CXB spectrum

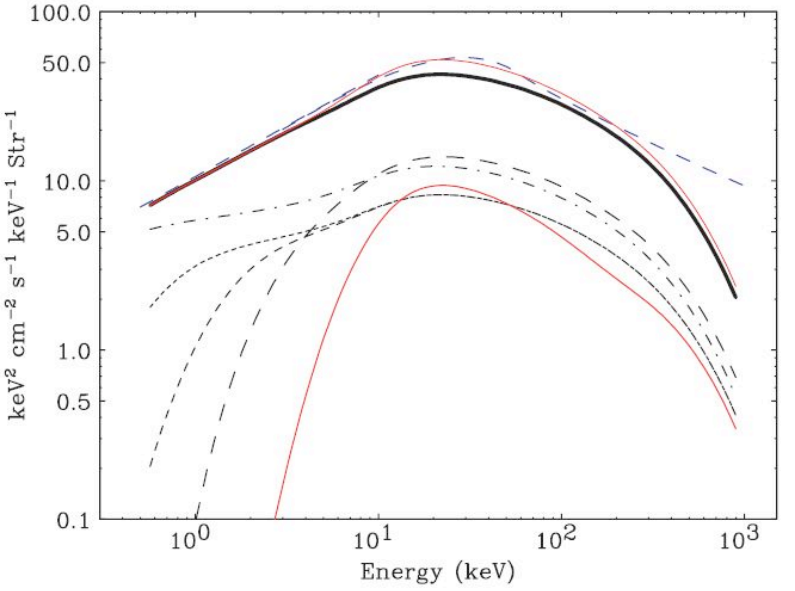


FIG. 19.—Contribution to the CXB from AGNs with different N_H ranges. *Uppermost blue dashed curves*: CXB spectrum, same as Fig. 18. *Thick black solid curve*: Integrated spectrum of Compton-thin AGNs. *Upper thin red solid curve*: Integrated spectrum when the same number of Compton-thick AGNs with $\log N_H = 24$–25 as those with $\log N_H = 23$–24 is included. Lower curves show a separate contribution to the CXB from AGNs with $\log N_H < 21$ (*black dot-dashed curve*), $\log N_H = 21$–22 (*short-dashed curve*), 22–23 (*medium-dashed curve*), 23–24 (*long-dashed curve*), and 24–25 (*red solid curve*).

Ueda+ '03

MeV background by AGNs with nonthermal coronal electrons

- Inoue, TT, & Ueda 2008, ApJ, 672, L5
- Energy fraction 3.5%, $dN_e/dE_e \propto E_e^{-3.8}$ will explain MeV background
- consistent with MeV observations of nearby AGNs

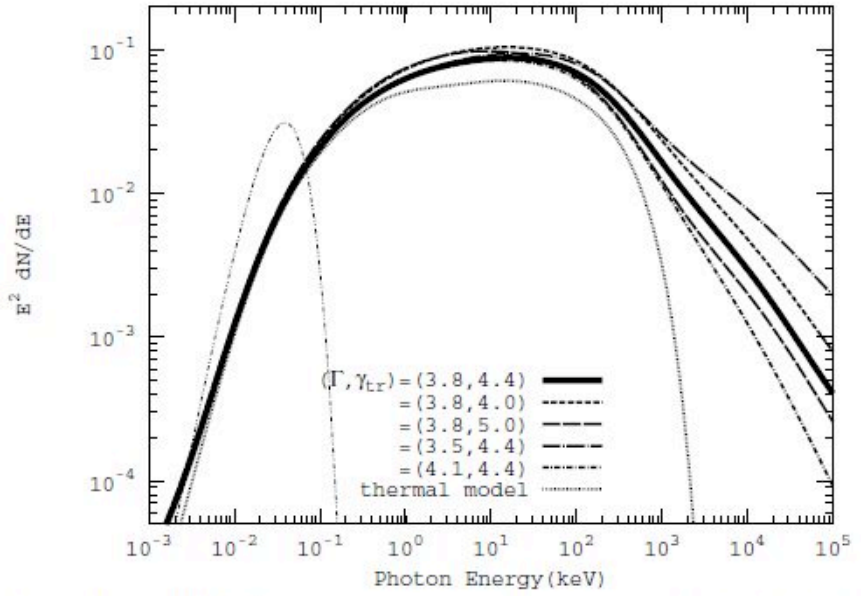


FIG. 1.— The AGN spectra in X-ray and gamma-ray bands calculated by our model. The flux is shown in an arbitrary unit of E^2dN/dE, where dN/dE is a differential photon spectrum. They are Comptonization of UV seed photons without taking into account the reflection component and the absorption effect. The thick solid curve is our standard spectrum with $\Gamma = 3.8$ and $\gamma_{tr} = 4.4$. The other thick curves are for the cases of different model parameters as indicated in the figure. The thick dotted curve is the spectrum only with the thermal component ($kT_e = 256$ keV). The thin dotted curve is the input UV spectrum (a black body with $T_d = 10$ eV).

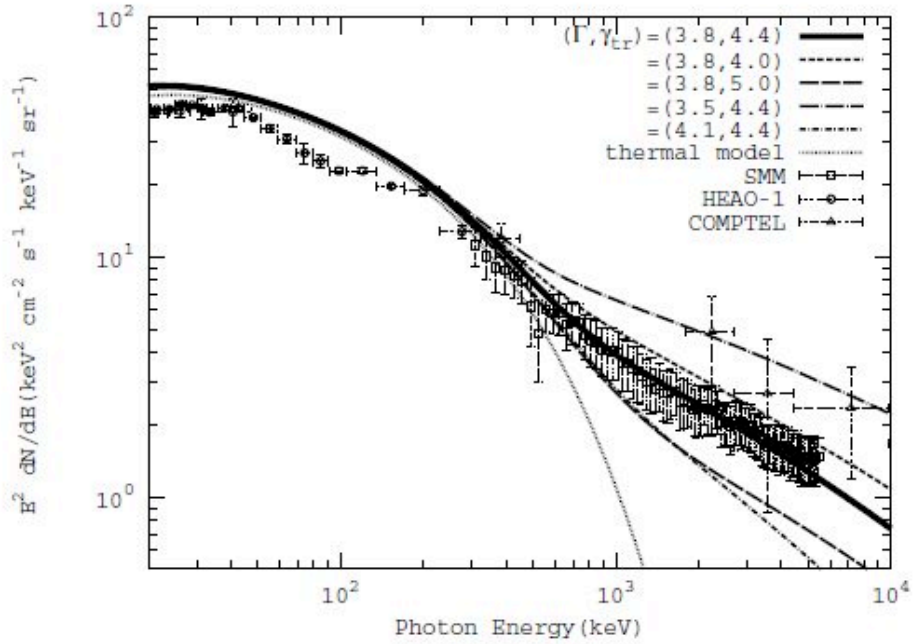
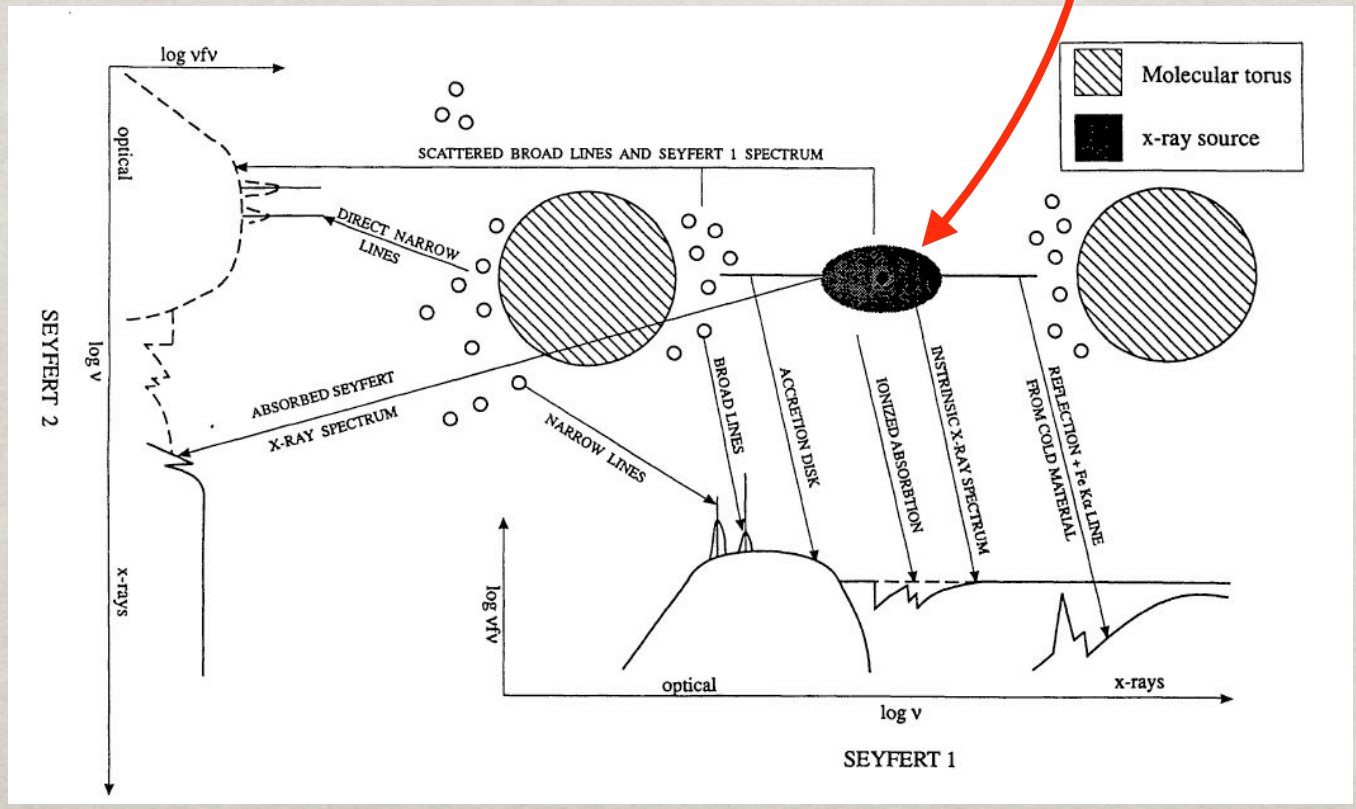


FIG. 2.— The spectrum of the cosmic background radiation in X-ray and gamma-ray bands, predicted by our model of AGN spectra shown in Fig. 1. For each line-marking, the corresponding AGN spectrum in Fig. 1 is used for the calculation. The data points of HEAO-1 (Gruber et al. 1999) SMM (Watanabe et al. 1999), and COMPTEL (Kappadath et al. 1996) experiments are also shown.

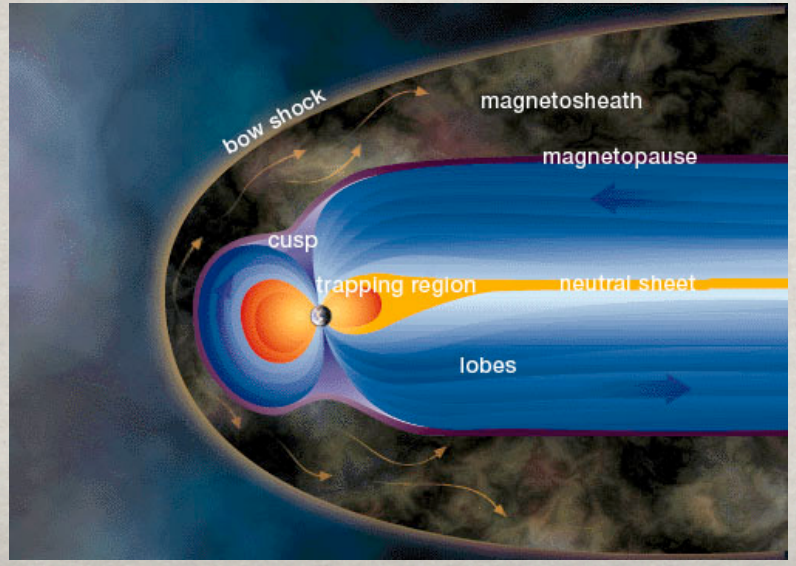
On the Origin of Non-thermal Electrons in Hot Coronae in AGNs

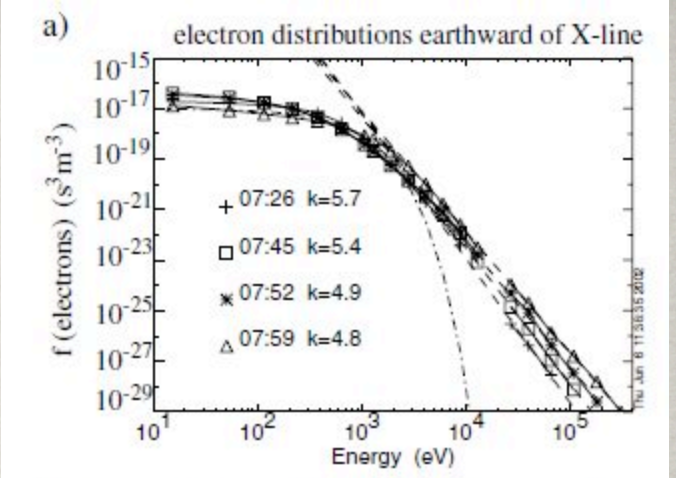
- The heat source of corona is unknown
  - A plausible scenario: magnetic reconnections
  - non-thermal particles are accelerated in reconnections!

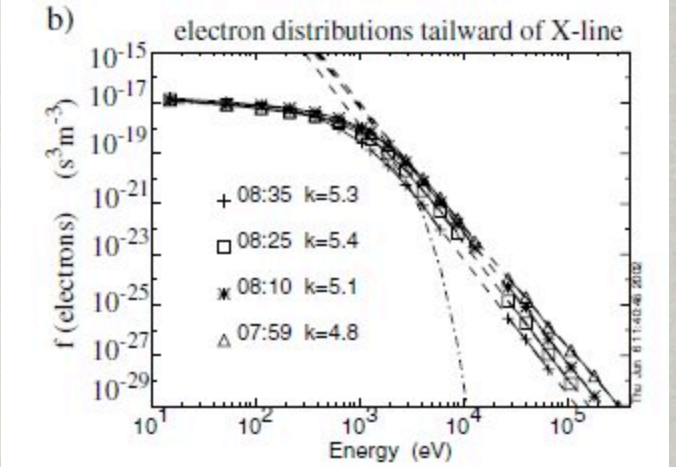


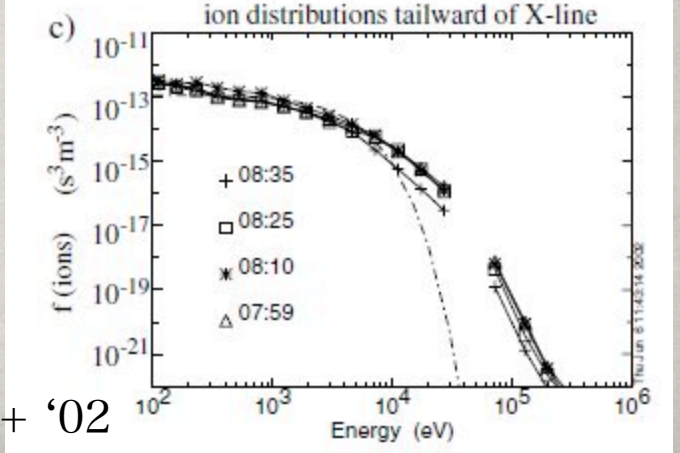
Particle accelerations in reconnections

- soft power-law spectrum (index ~ -4) is typically found in solar flares or Earth magnetosphere
- Interestingly very similar to X-ray-MeV background spectrum!
  - A reasonable explanation, supporting the reconnection hypothesis for AGN coronae



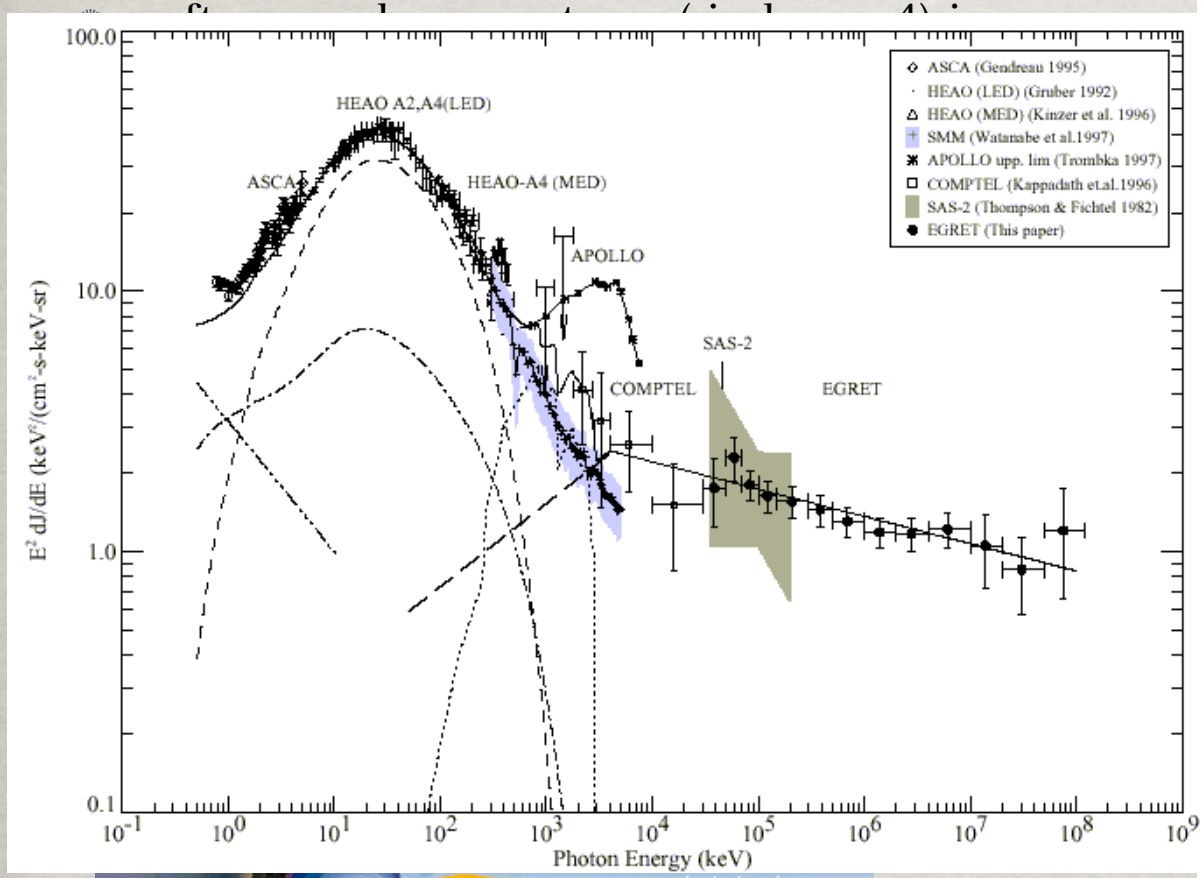


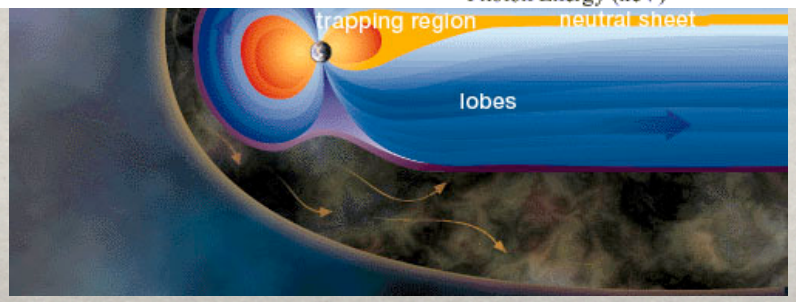


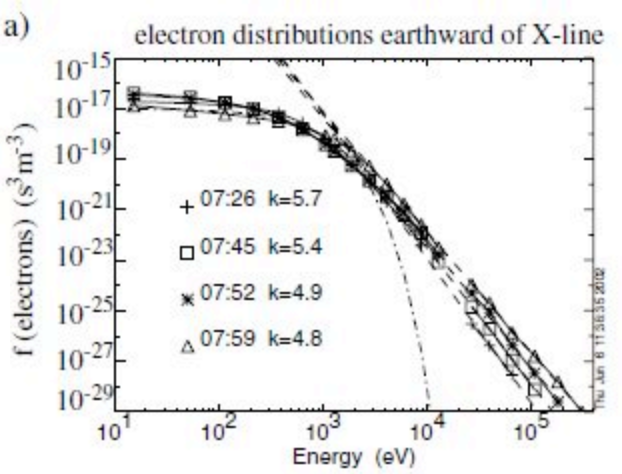


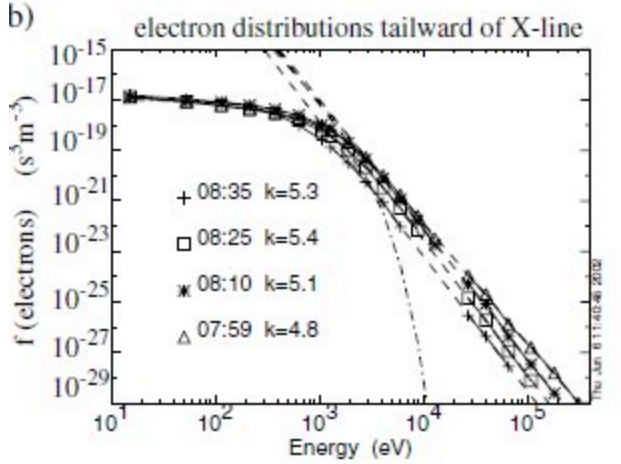
Oieroset+ '02

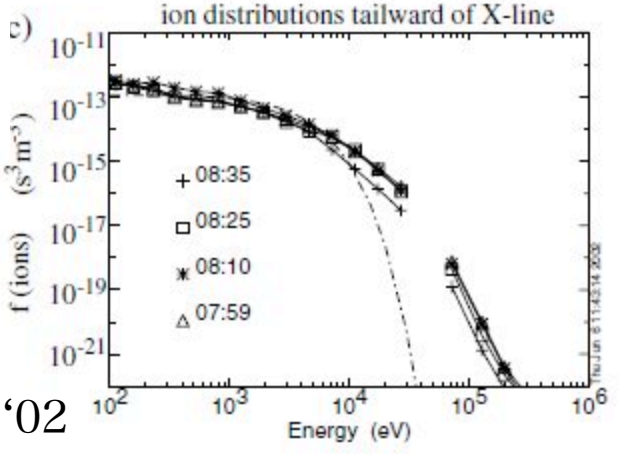
Particle accelerations in reconnections











Oieroset+ '02

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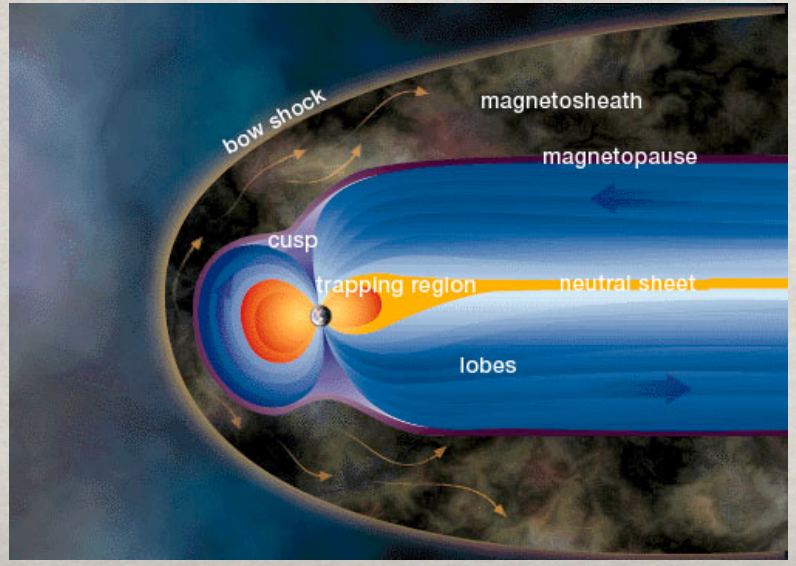
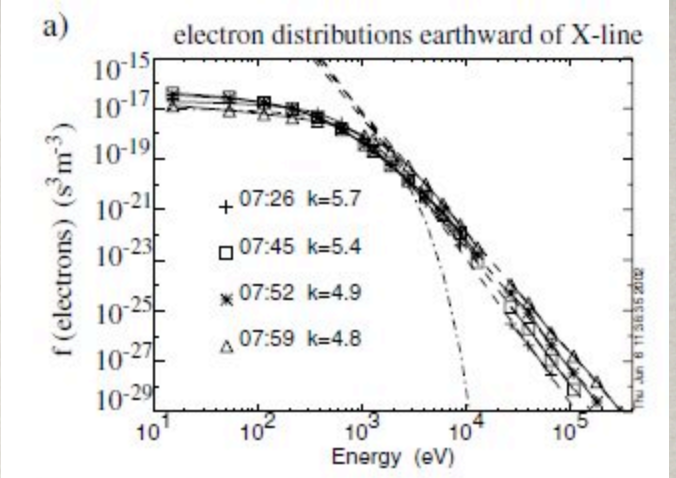
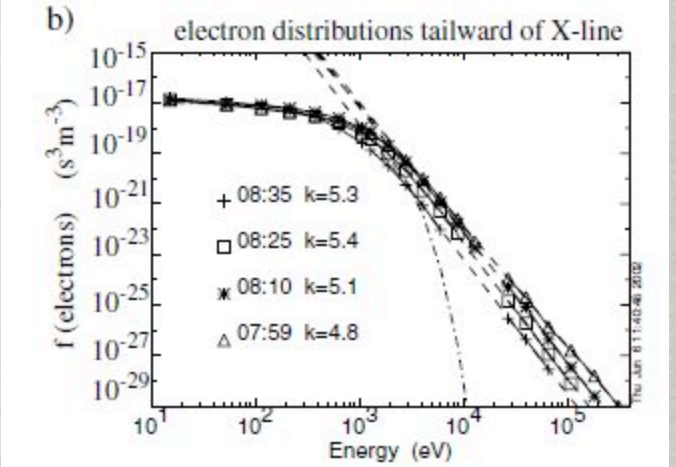
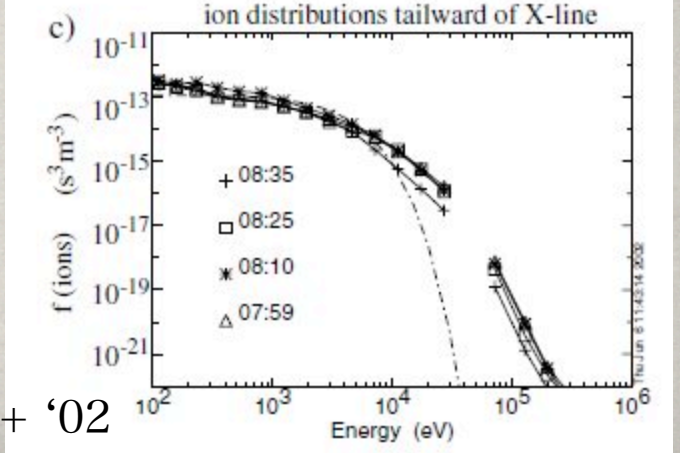








Oieroset+ '02

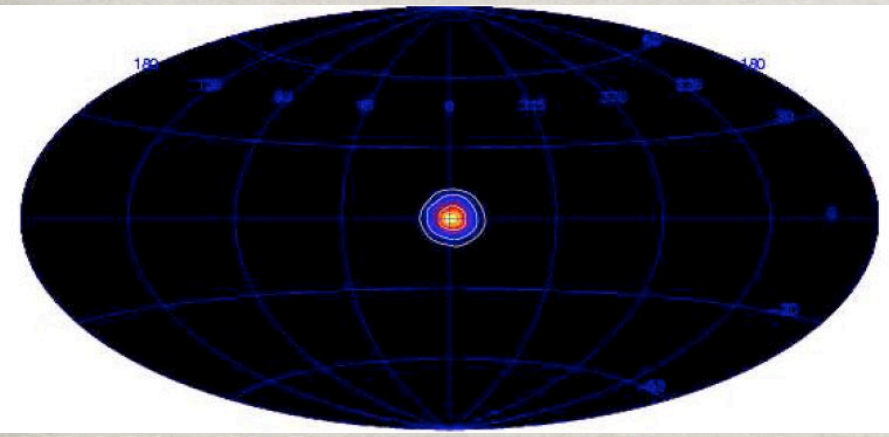
On the MeV DM Possibility

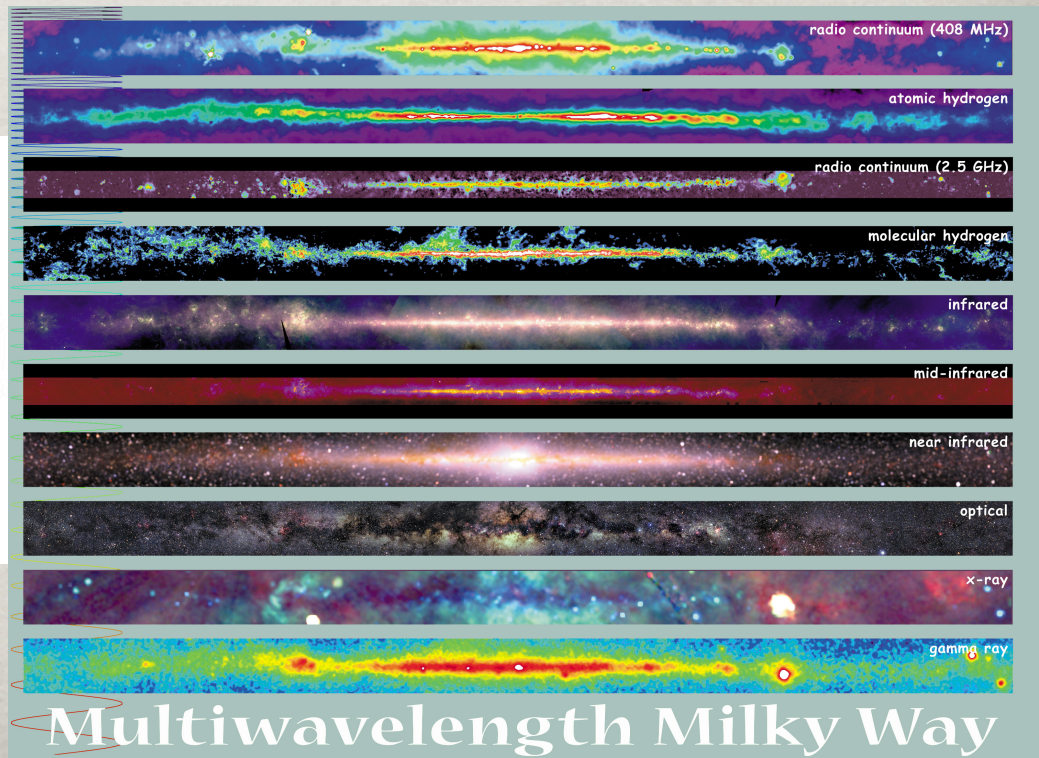
- cosmic MeV background can be explained by a physically reasonable extension of AGN spectrum for CXB

- Another motivation for MeV DM: 511 keV emission from the Galactic Center or bulge region?

The 511 keV Annihilation Line Emission from GC

- extended spherical bulge with ~8 deg FWHM (~1.1 kpc)
- bulge / disk flux ratio = 3-9 (c.f. mass ratio 0.3-1.0)
- positron production rate ~1.5×10^{43} s^{-1}





The Origin of the 511 keV Emission!?

- narrow line width (~5.4 keV FWHM)
  - injection positron energy <~ 3 MeV (Beacom+'05)
  - cooled in interstellar matter
  - travelling time scale before annihilation ~ 10^7 yr
- large bulge-to-disk ratio
  - excluding massive stars, supernovae, pulsars, GRBs, etc.
  - low-mass X-ray binary: still low B/D (Weidenspointner+'07)
  - SN Ia: rate not sufficient
- MeV mass scale dark matter?
  - no natural particle physics candidate...

511 keV emission from supermassive black hole Sgr A* ?

- positron production rate from accretion flow onto Sgr A* can be calculated from the currently standard RIAF (radiatively inefficient accretion flow) model (Totani 2006)
  - too low e^+ production rate for the current accretion rate
  - ~10^3 times higher accretion rate in the past 10^7 yrs can explain the 511 keV emission

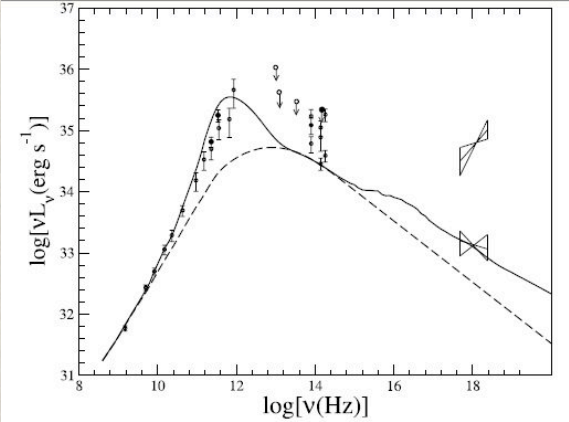


FIG. 1.—RIAF model for the quiescent state of Sgr A*. The IR data with error bars are from Ghez et al. (2004) and Genzel et al. (2003), the radio data with error bars from Falcke et al. (1998, *open circles*) and Zhao et al. (2003, *filled circles*), the IR data with upper limits from Serabyn et al. (1997, *open circles*) and Hornstein et al. (2002, *filled circles*), and the two "bow ties" in the X-ray for the quiescent (*lower*) and flaring (*higher*) states from Baganoff et al. (2003, 2001). The dashed line shows the synchrotron emission by power-law electrons with $p = 3$. The solid line shows the total quiescent emission, including that from thermal electrons. The slight difference in the value of p compared with that in YQN03 ($p = 3.5$) is to fit the quiescent IR data better.

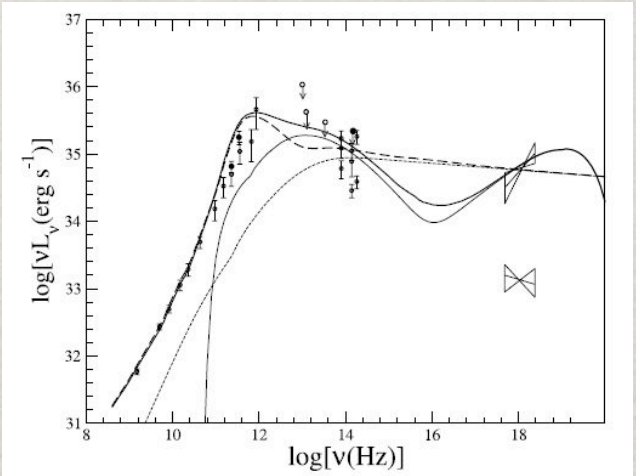
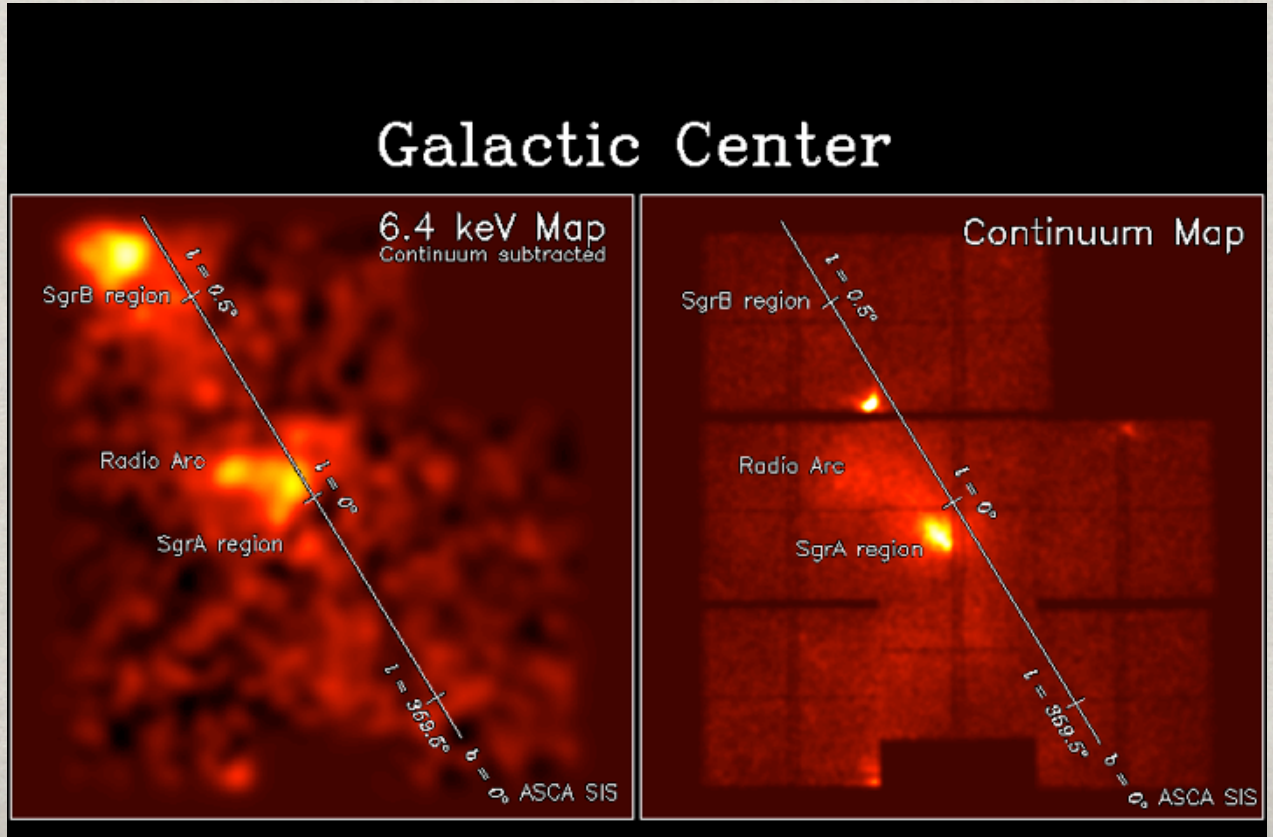


FIG. 3.—Pure synchrotron models for the IR and X-ray flares in Sgr A*. The two dashed lines are models in which the electrons are assumed to have $p = 2.1$. The solid lines are for the broken power-law model (eq. [1]), with $p_1 = 3, p_2 = 1, \eta = 7\%, \gamma_{max} \sim 10^6$, and $\eta_{IRX} = 1$. In each case, the thin lines correspond to the emission from only the power-law electrons, and the thick lines to the total emission, including the thermal electrons.

Yuan+ '04

Evidence for the past higher activity of Sgr A*

- X-ray reflection nebulae around GC indicate that Sgr A* was much more luminous ($\times 10^{5\text{-}6}$) than now until 300 yrs ago (Koyama+'96; Murakami+'00, Koyama+'08)
- this factor consistent with $\times 10^{3}$ higher accretion rate in RIAF



Why Sgr A* currently so dim?

- The Key: supernova remnant Sgr A East
  - Sgr A* appears to be inside the Sgr A East bubble
  - current accretion rate must be quite different from ordinary rate
  - $\times 10^3$ higher accretion rate is typical for nuclei of nearby Milky-Way-like galaxies

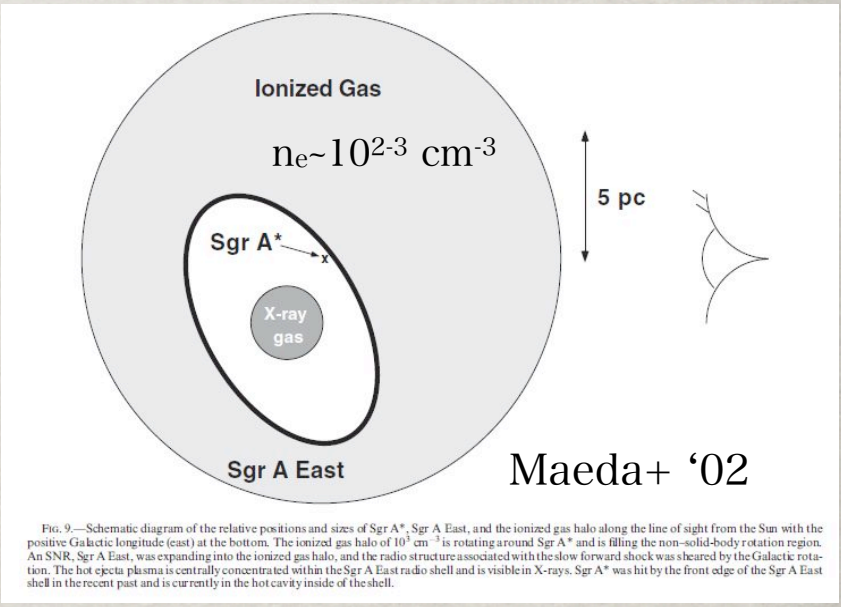
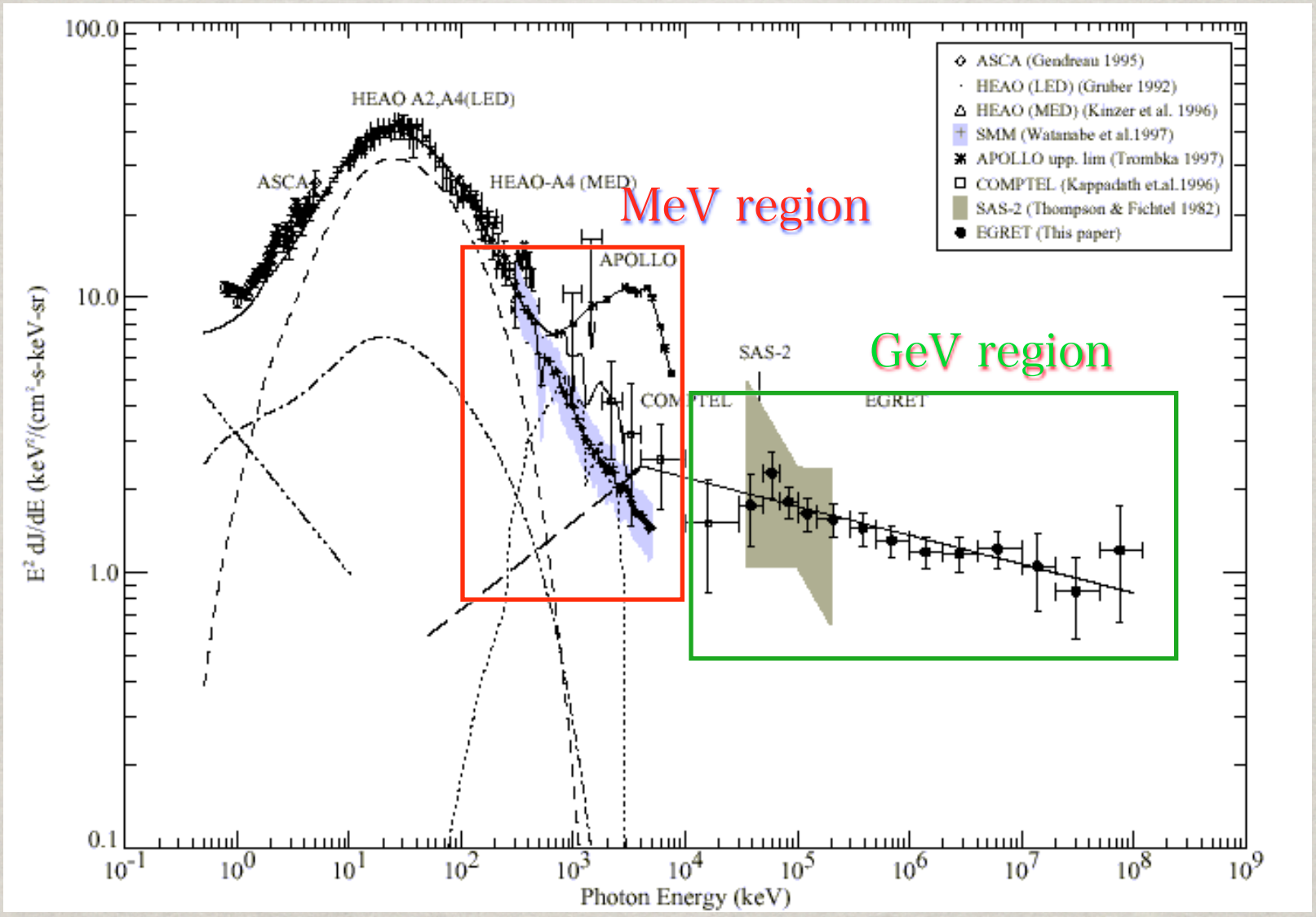


FIG. 9.—Schematic diagram of the relative positions and sizes of Sgr A*, Sgr A East, and the ionized gas halo along the line of sight from the Sun with the positive Galactic longitude (east) at the bottom. The ionized gas halo of 10^3 cm^{-3} is rotating around Sgr A* and is filling the non–solid-body rotation region. An SNR, Sgr A East, was expanding into the ionized gas halo, and the radio structure associated with the slow forward shock was sheared by the Galactic rotation. The hot ejecta plasma is centrally concentrated within the Sgr A East radio shell and is visible in X-rays. Sgr A* was hit by the front edge of the Sgr A East shell in the recent past and is currently in the hot cavity inside of the shell.

- Sgr A* gives a reasonable explanation for the large B/D ratio of the 511 keV emission
  - astrophysical explanation well possible
  - no strong pressure to consider MeV dark matter

GeV background

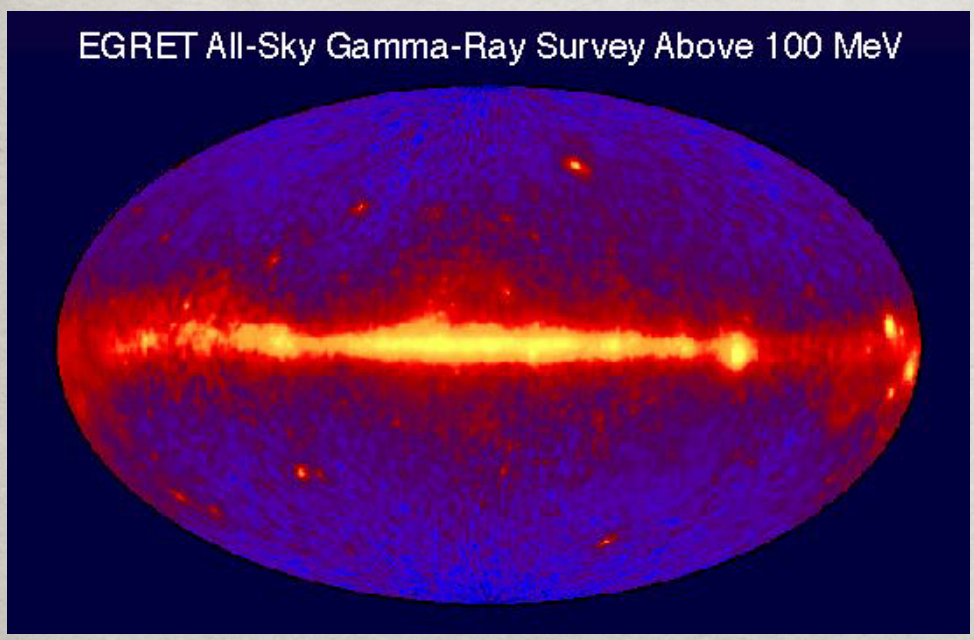
Cosmic X-ray & gamma-ray background (CXB, CGB)

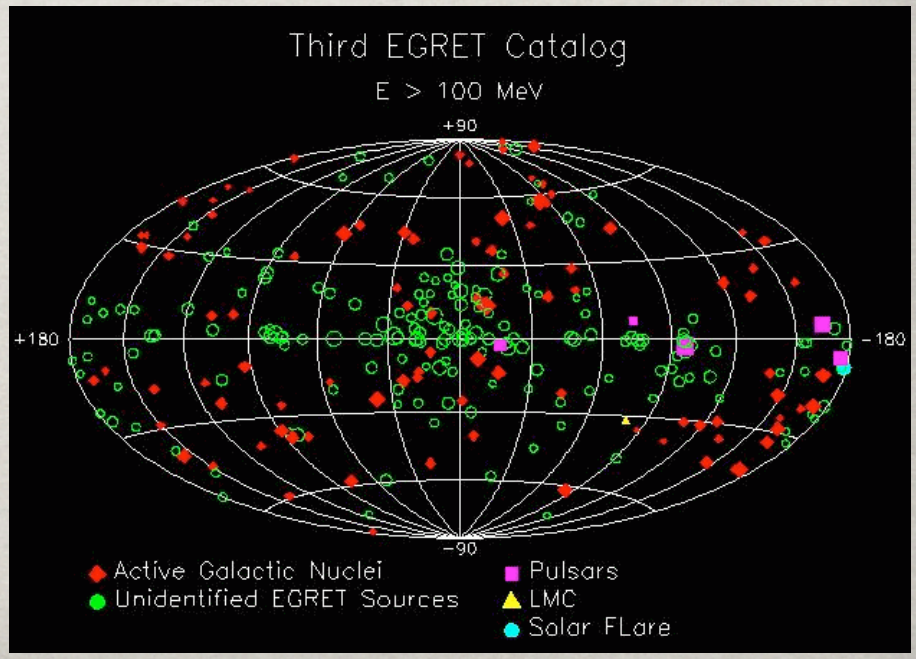


Sreekumar et al. 1998

blazars are the primary candidate for GeV background

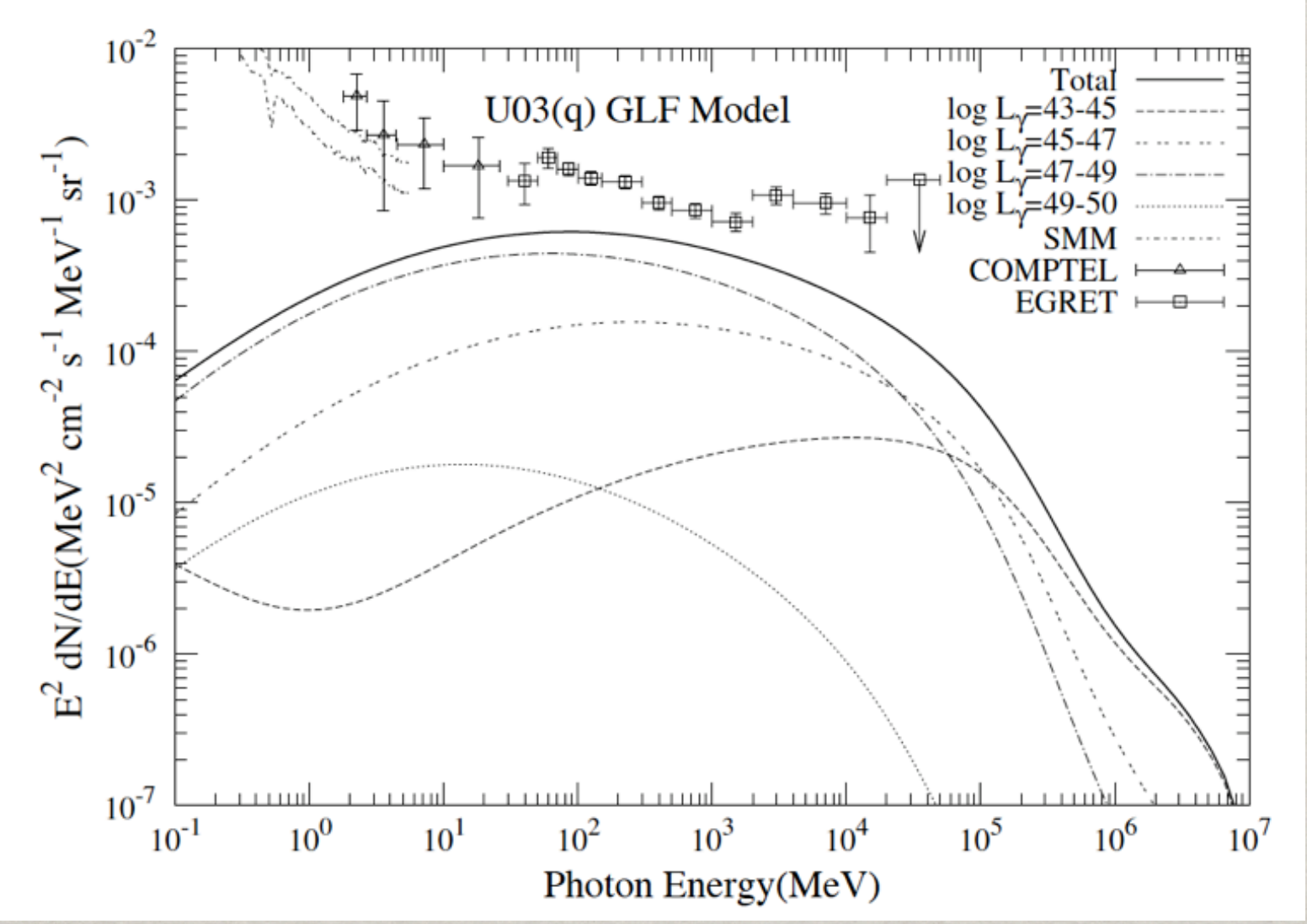
- almost all extragalactic EGRET sources are blazars
- But...
  - blazar luminosity function evolution model can explain at most ~30% of the gamma-ray background, when EGRET blazar data are taken into account
  - what's wrong? new sources? DM?





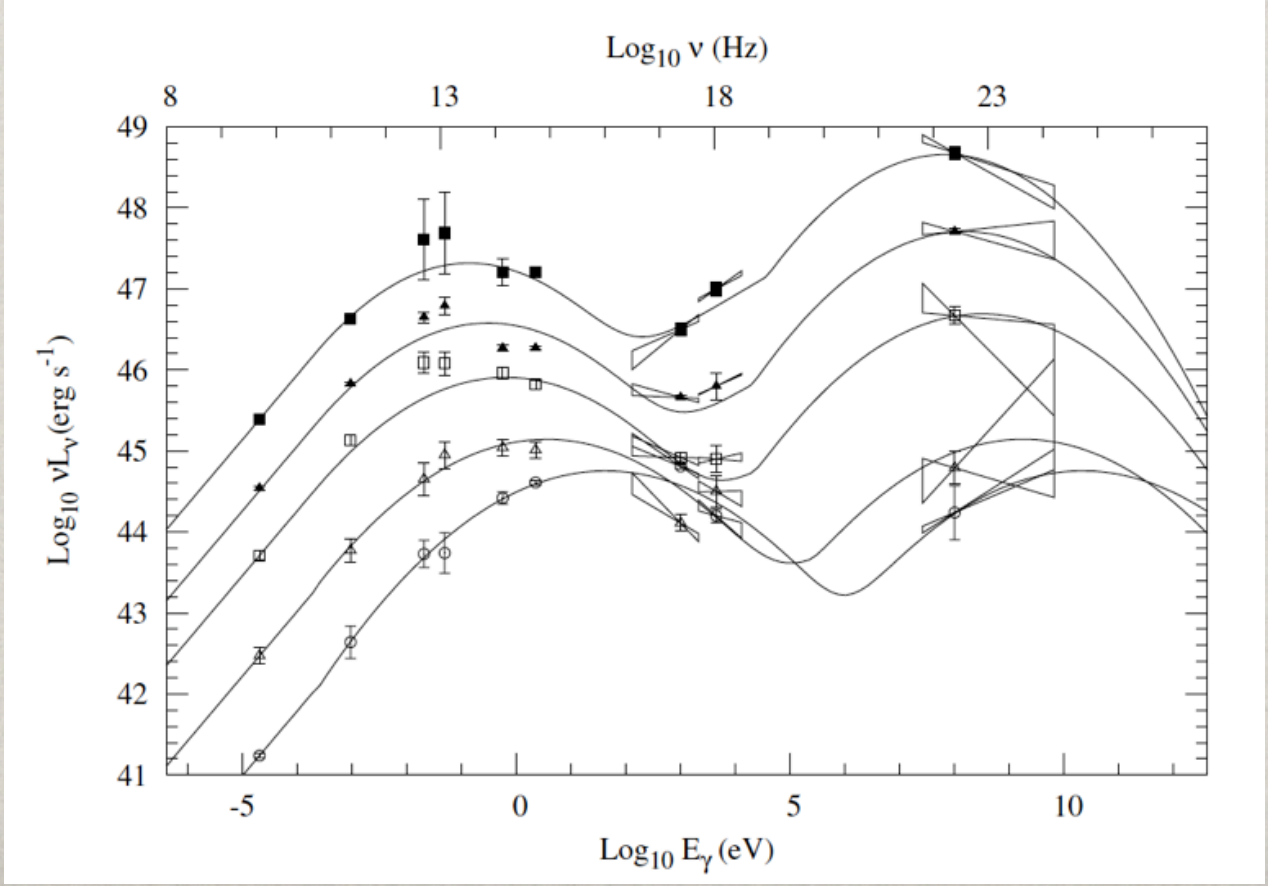
Latest model of GeV background from blazars

Inoue+Totani '08 in prep.

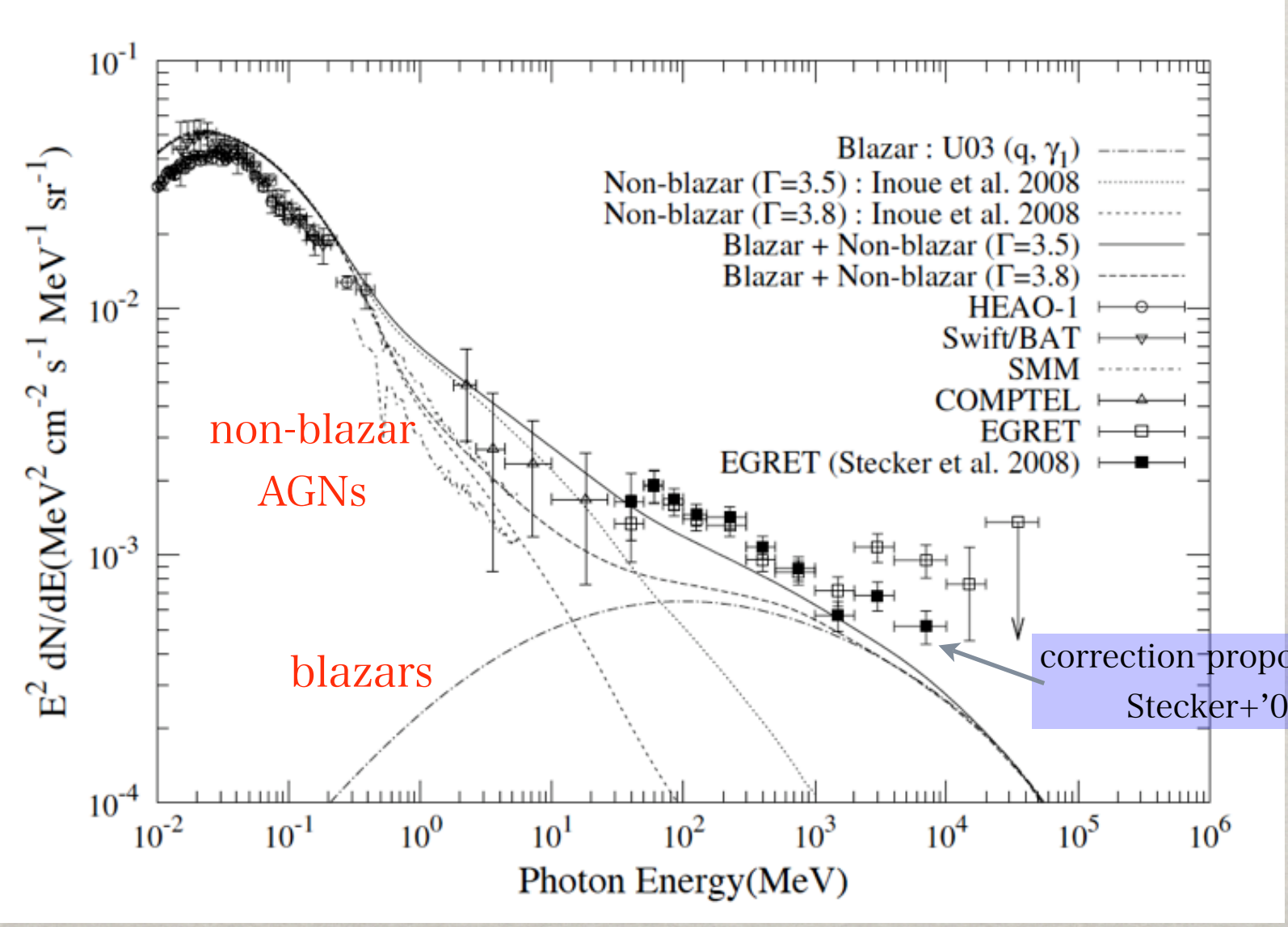


The Blazar background model

- jet power luminosity function from X-ray AGNs ($L_{jet} \propto L_X$)
- The blazar SED (spectral energy distribution) sequence
- nicely consistent with the EGRET blazar distributions



Total gamma-ray background from normal+blazar AGNs



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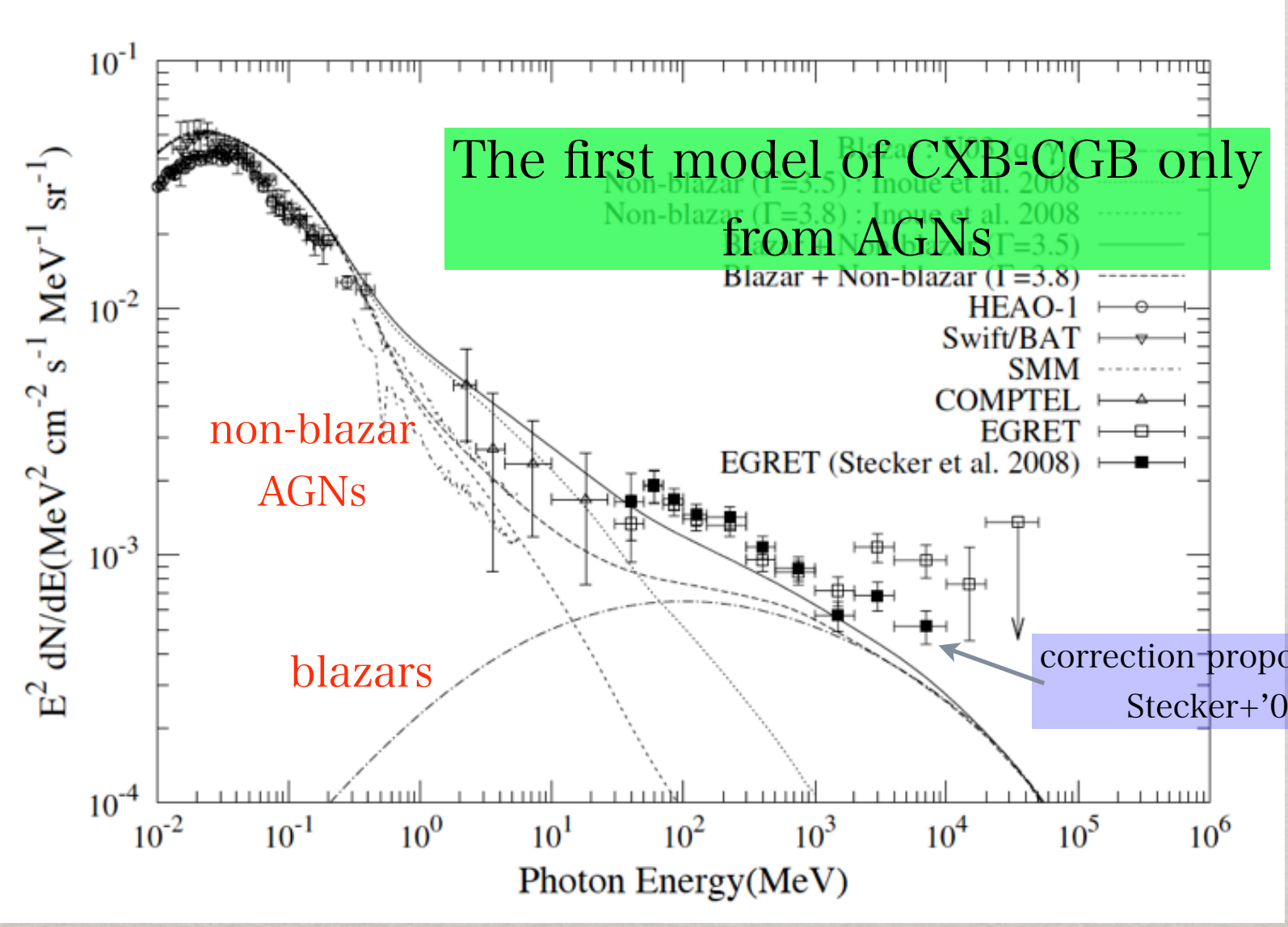

Conclusions

- MeV:
  - MeV background can naturally be explained by non-thermal electrons in AGN coronae
  - The Galactic 511 keV emission can be explained by the past higher activity of Sgr A*
  - no strong motivation to consider about MeV DM particle
- GeV:
  - a latest model succeeds to explain all MeV-GeV cosmic background only by AGNs including blazars
  - no evidence for DM contribution to GeV background, although WIMPs (neutralinos) are theoretically well-motivated DM candidate
  - waiting for the new Fermi data!