Cosmic Gamma-ray Background Radiation

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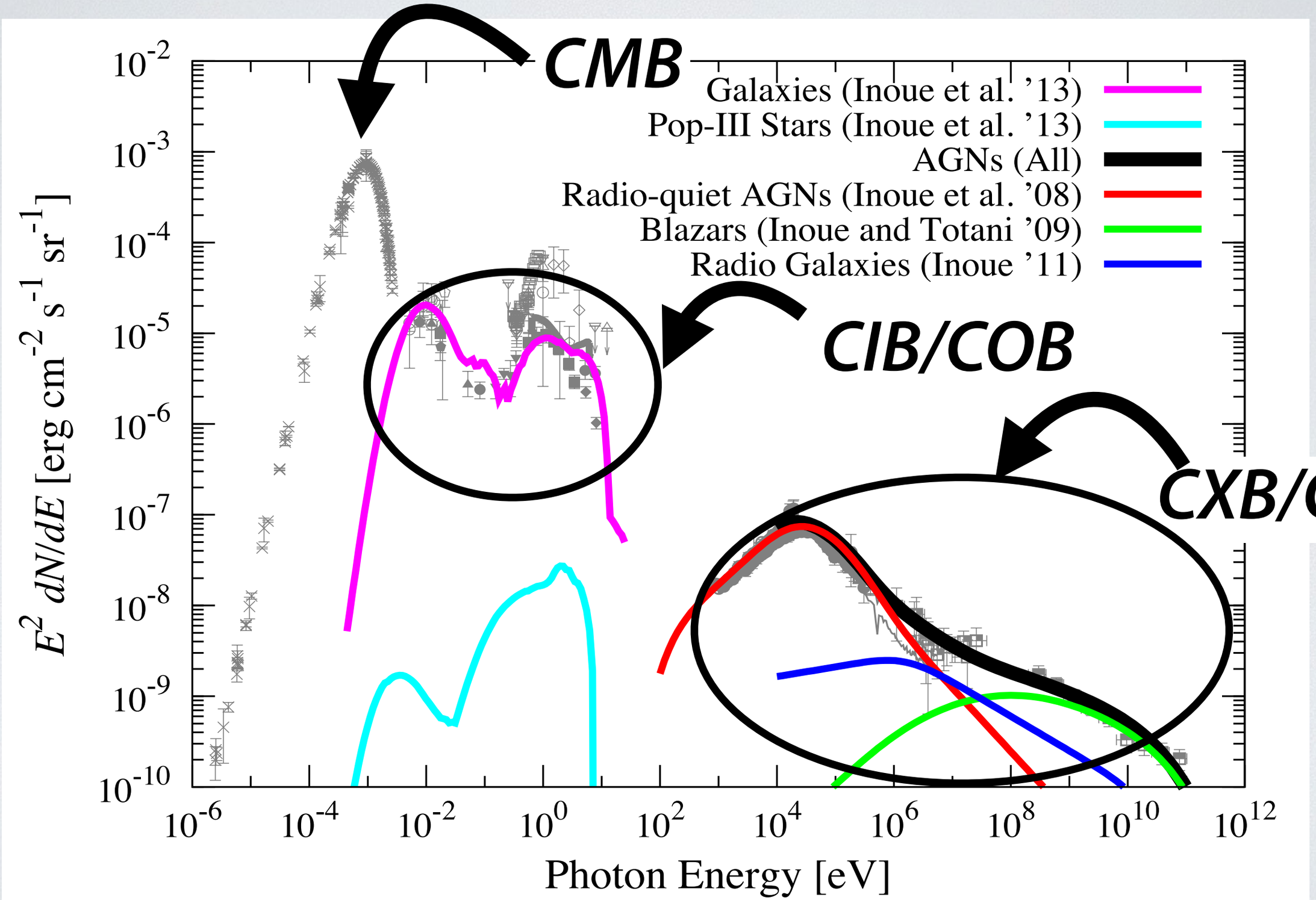
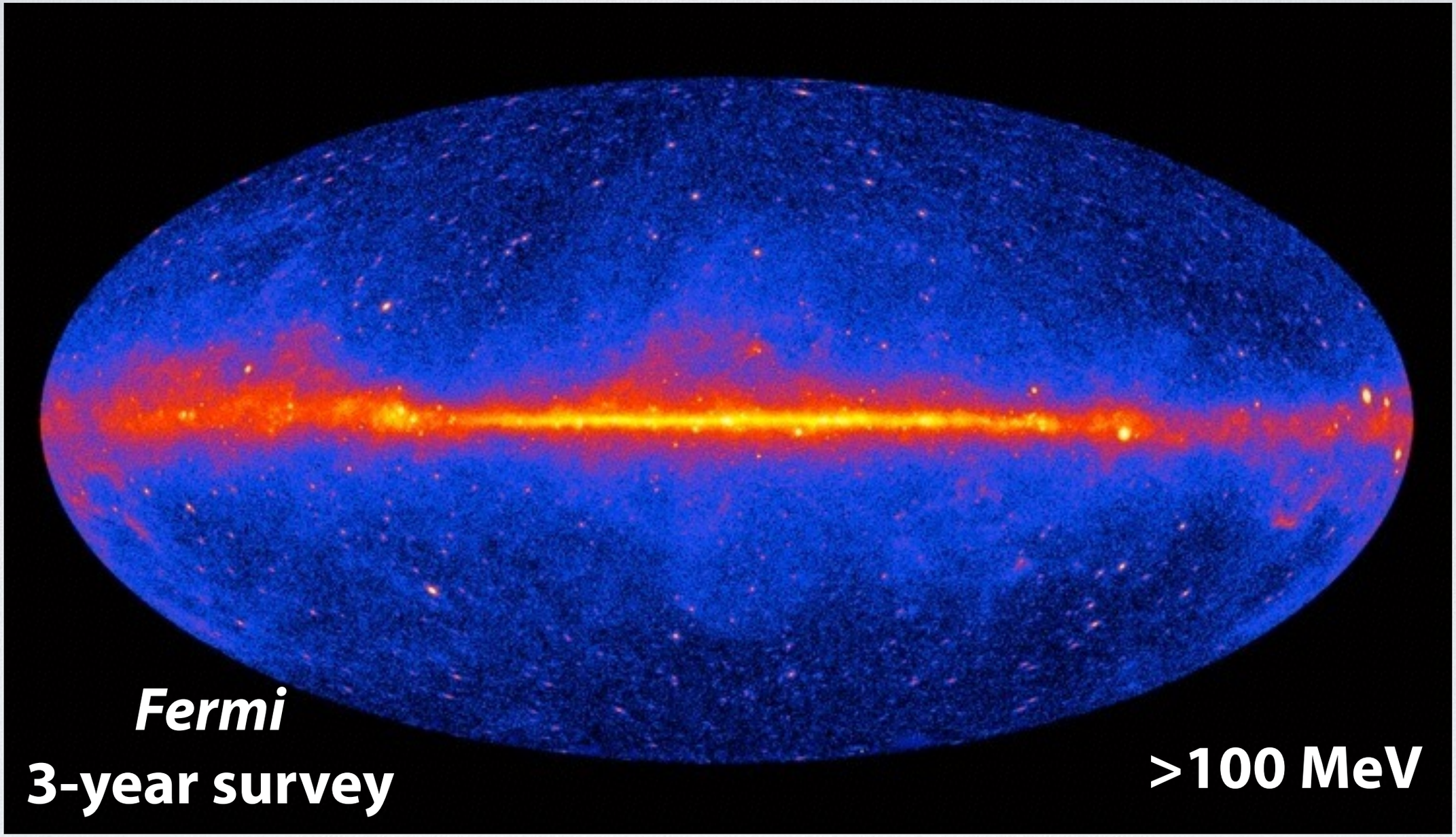
Cosmic Background Radiation Spectrum

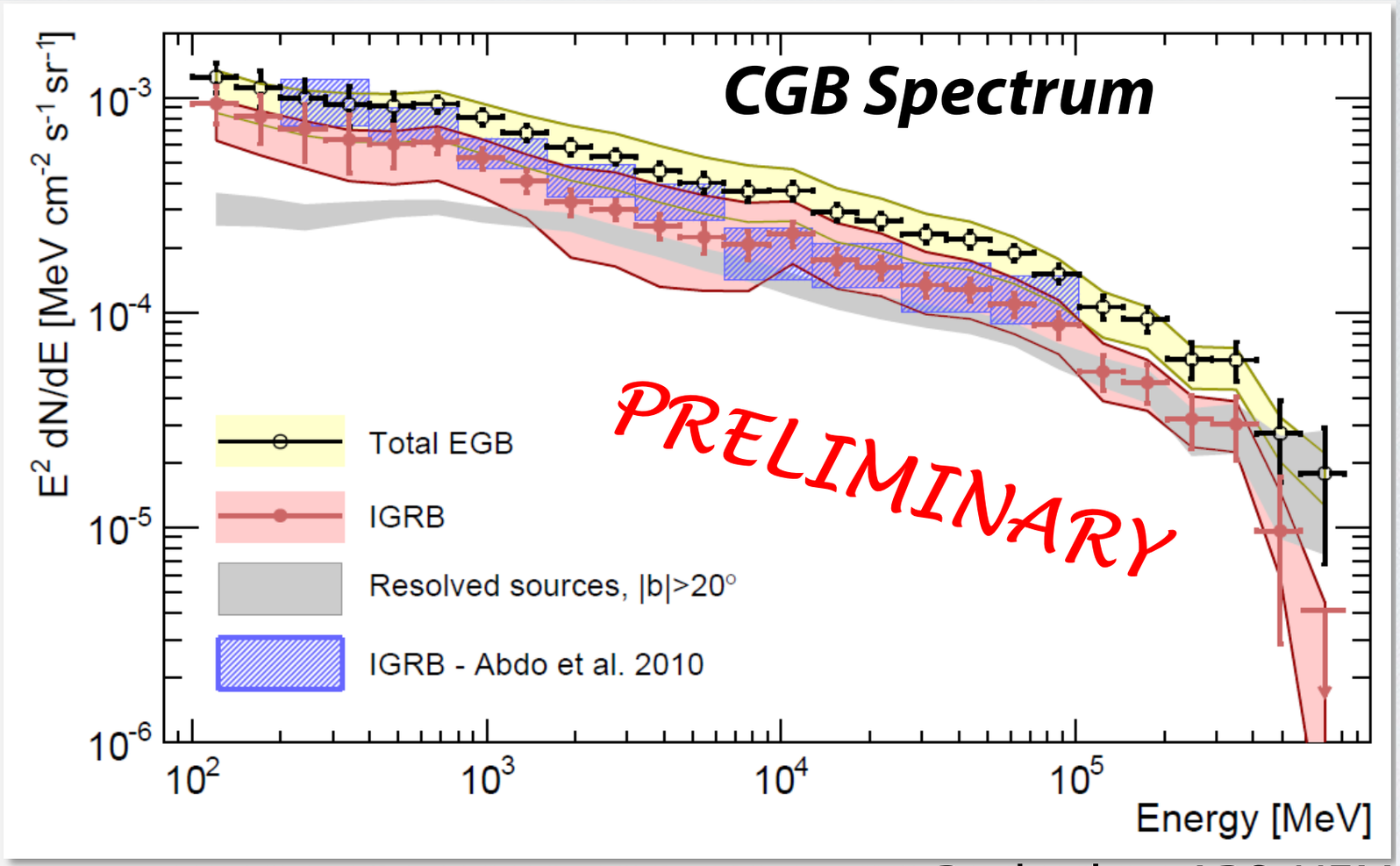


Cosmic Gamma-ray Background



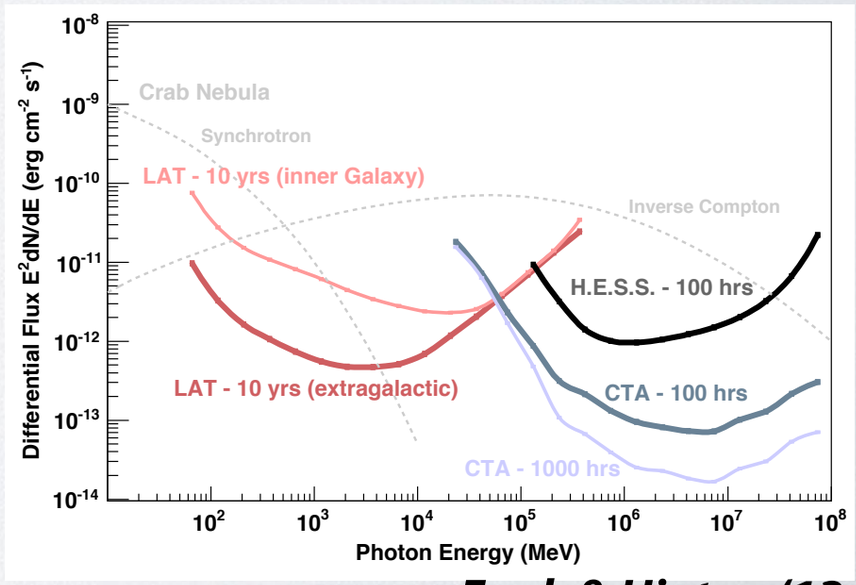
- Numerous sources are buried in the cosmic gamma-ray background (CGB).

Cosmic Gamma-ray Background Spectrum at >0.1 GeV



Bechtol+@ APS, HEM14

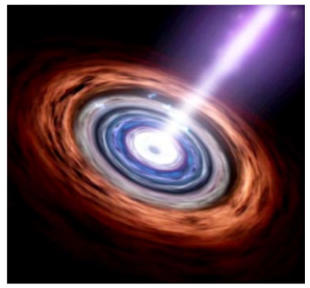
- Softening around ~250 GeV.
- Fermi resolves CGB more at higher energies.
- See Ackermann's talk



Funk & Hinton '13

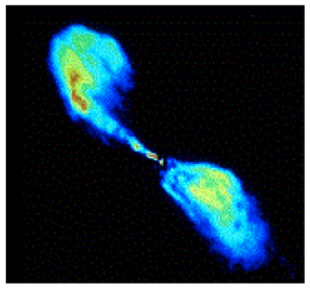
Possible Origins of CGB at GeV

Unresolved sources



Blazars

Dominant class of LAT extra-galactic sources. Many estimates in literature. EGB contribution ranging from 20% - 100%

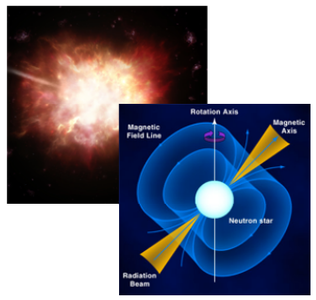


Non-blazar active galaxies

27 sources resolved in 2FGL
~ 25% contribution of radio galaxies to EGB expected.
(Inoue 2011)

Star-forming galaxies

Several galaxies outside the local group resolved by LAT. Significant contribution to EGB expected. (e.g. Pavlidou & Fields, 2002)



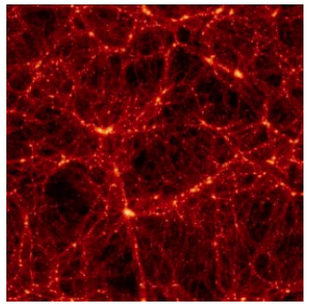
GRBs
High-latitude pulsars

small contributions expected.
(e.g. Dermer 2007, Siegal-Gaskins et al. 2010)

Diffuse processes

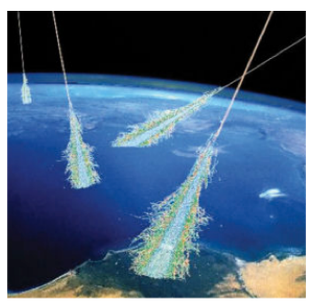
Intergalactic shocks

widely varying predictions of EGB contribution ranging from 1% to 100% (e.g. Loeb & Waxman 2000, Gabici & Blasi 2003)



Dark matter annihilation

Potential signal dependent on nature of DM, cross-section and structure of DM distribution
(e.g. Ullio et al. 2002)



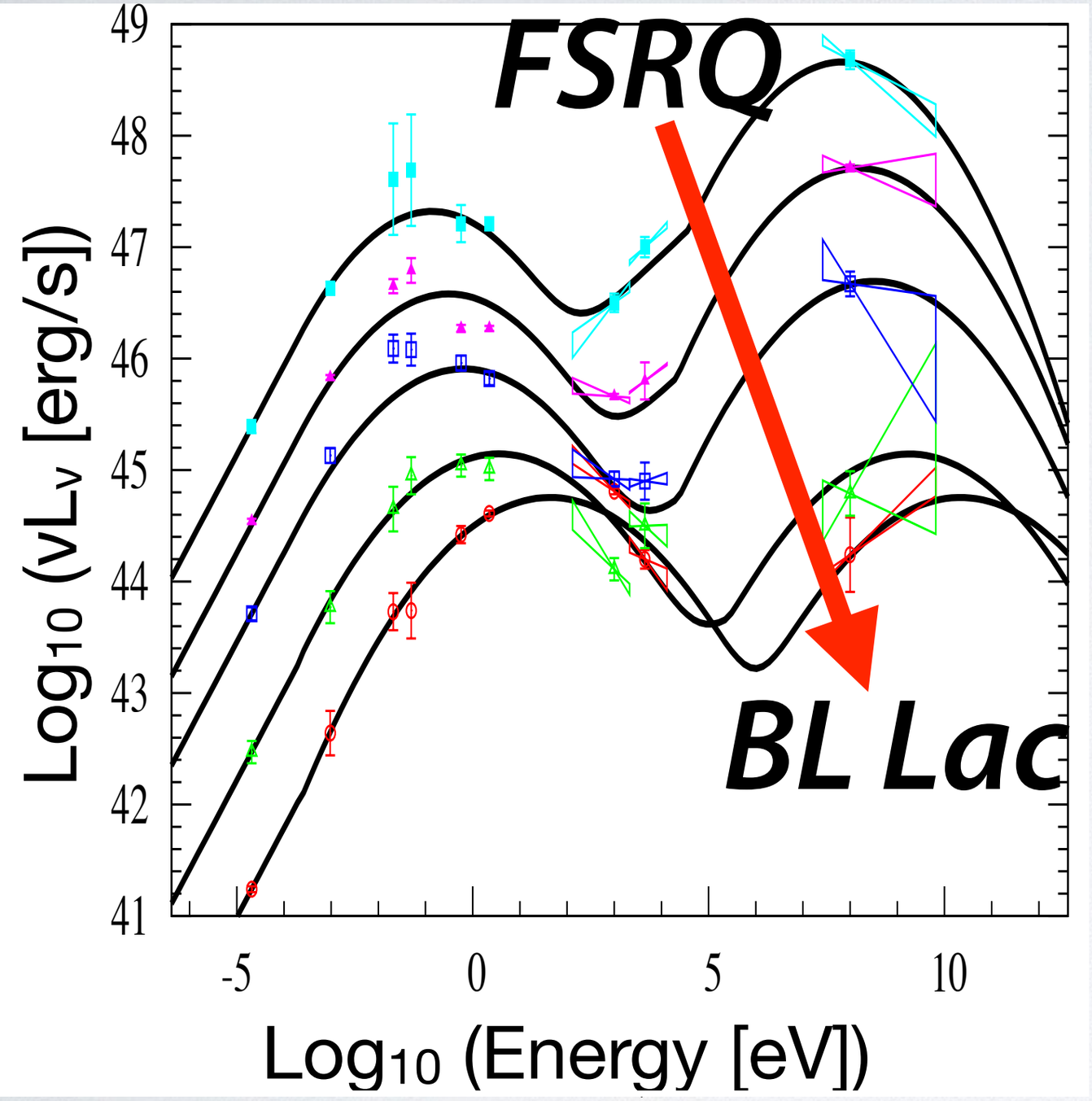
Interactions of UHE cosmic rays with the EBL

dependent on evolution of CR sources, predictions varying from 1% to 100 % (e.g. Kalashev et al. 2009)

Extremely large galactic electron halo (Keshet et al. 2004)

CR interaction in small solar system bodys (Moskalenko & Porter 2009)

Typical Spectra of Blazars

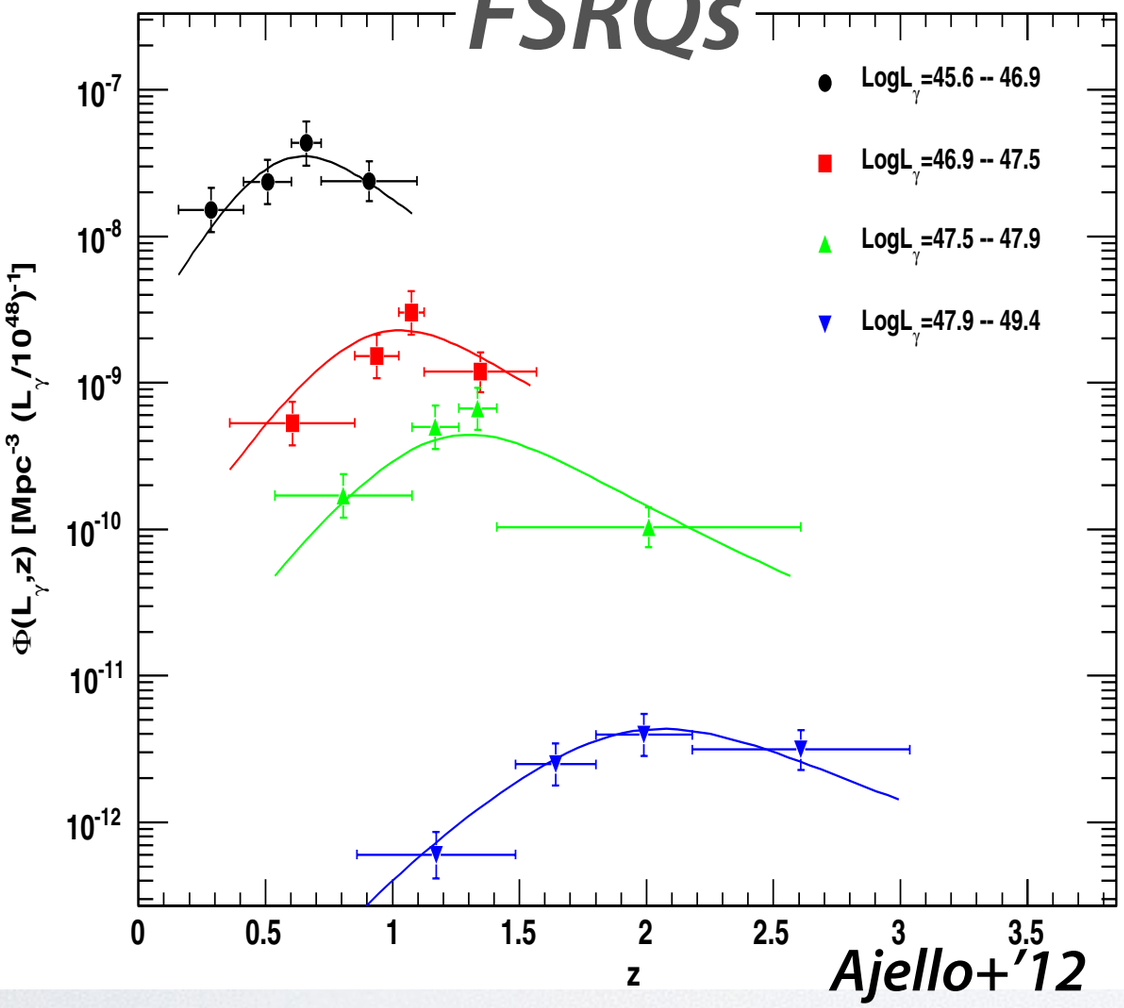


Fossati+'98, Kubo+'98,
YI & Totani '09

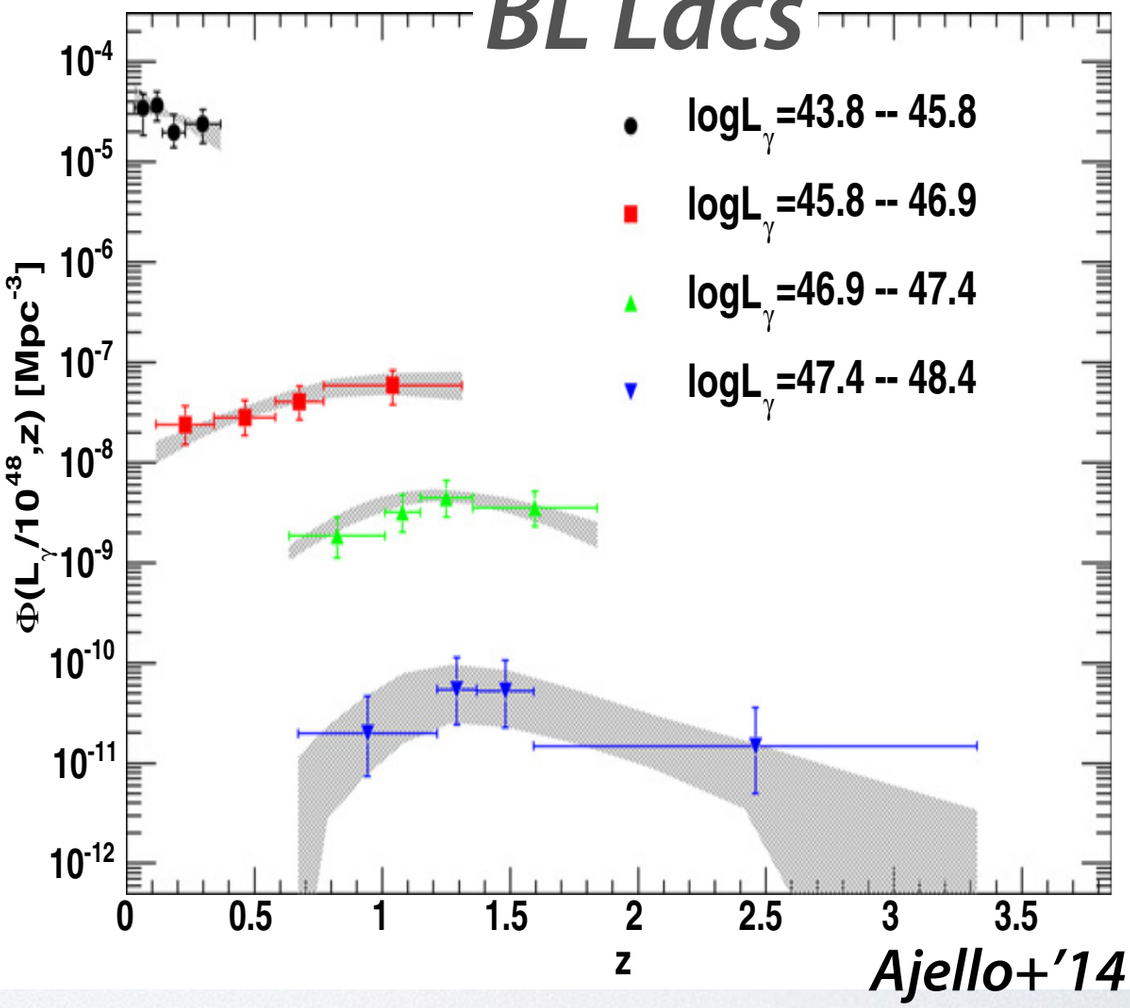
- Non-thermal emission from radio to gamma-ray
- Two peaks
  - Synchrotron
  - Inverse Compton
- Luminous blazars (Flat Spectrum Radio Quasars: FSRQs) tend to have lower peak energies (Fossati+'98, Kubo +'98)

Cosmological Evolution of Blazars

FSRQs

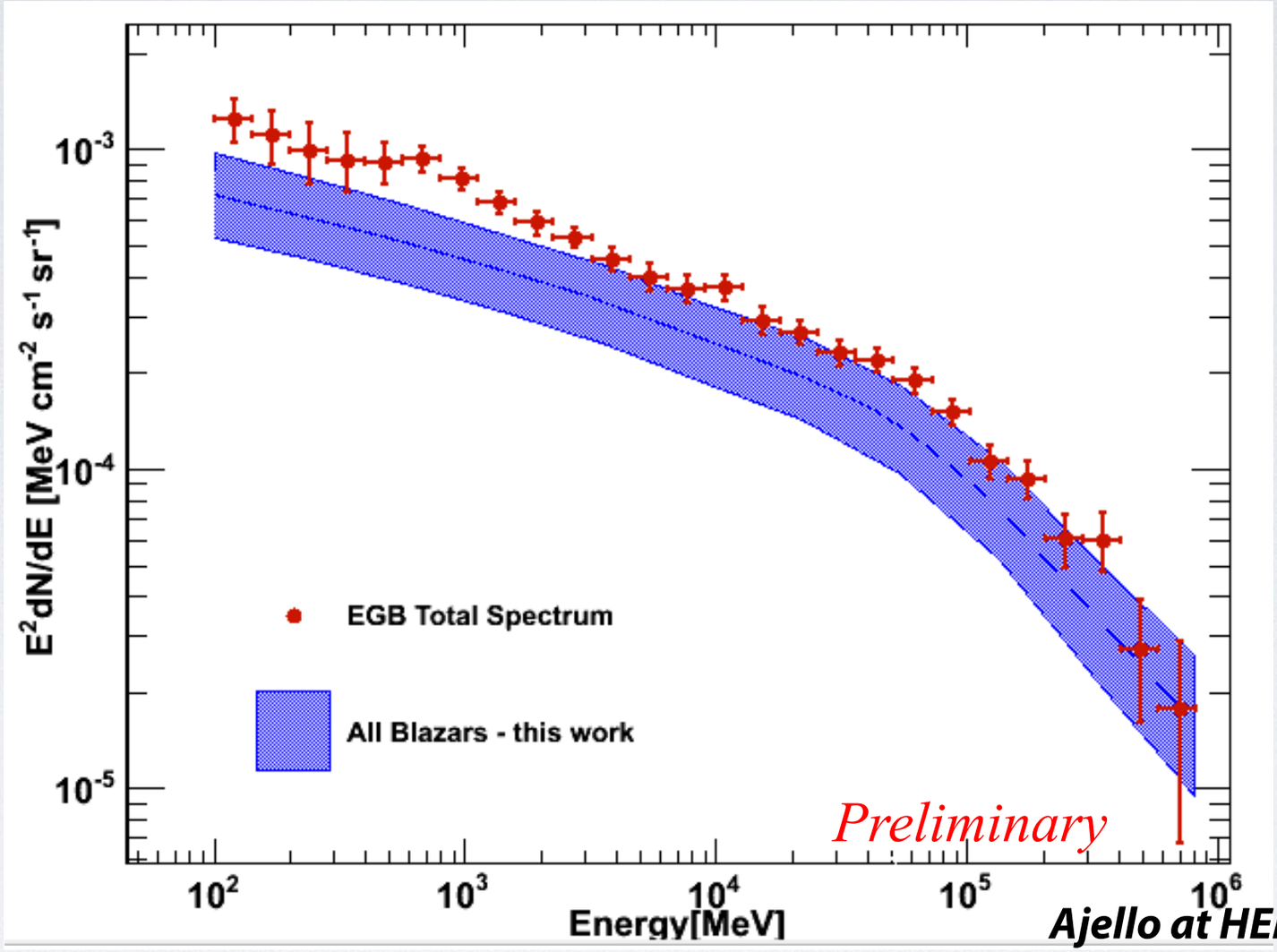


BL Lacs



- FSRQs, LBLs, & IBLs show positive evolution.
- HBLs show negative evolution unlike other AGNs.

Blazar contribution to CGB

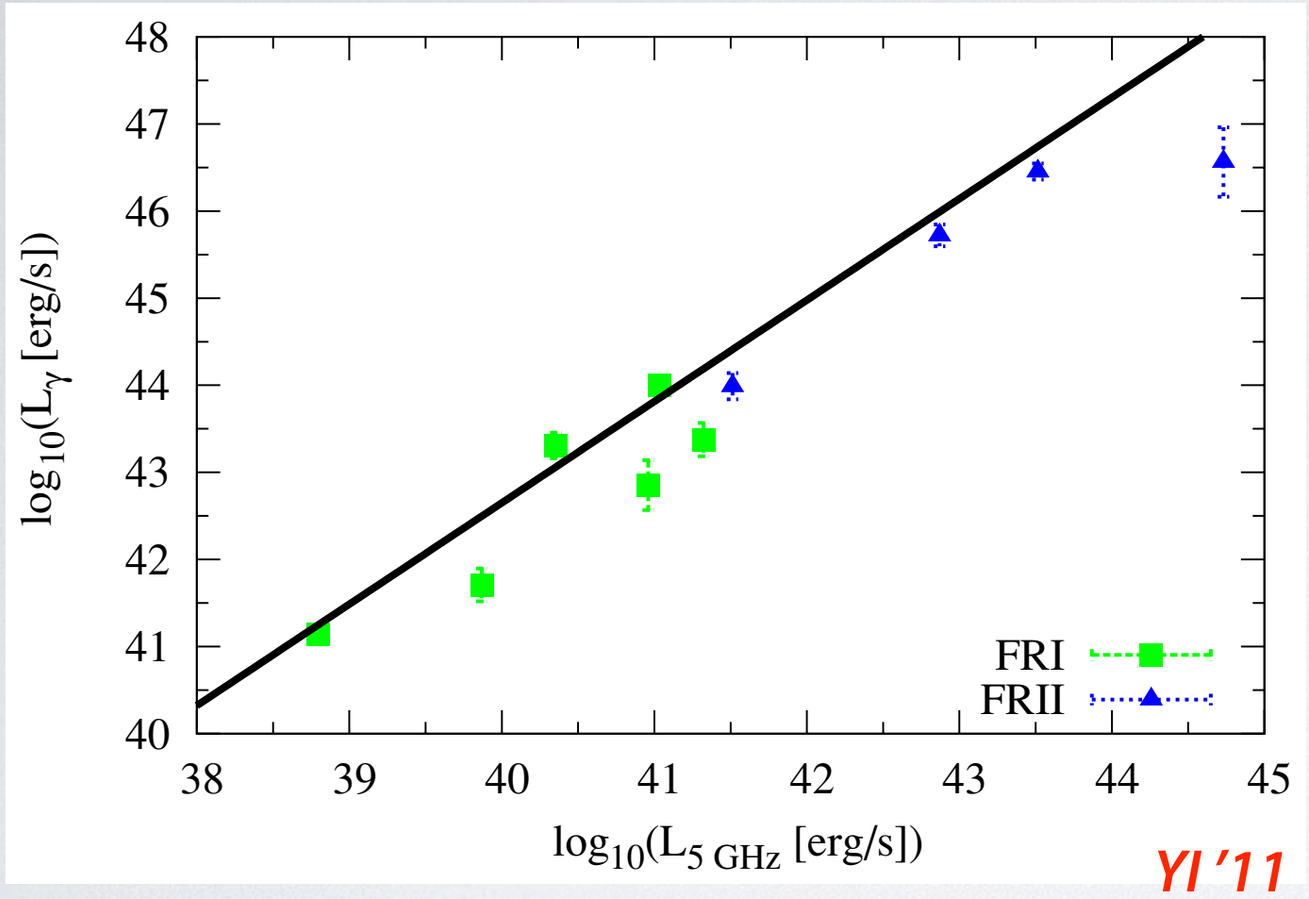


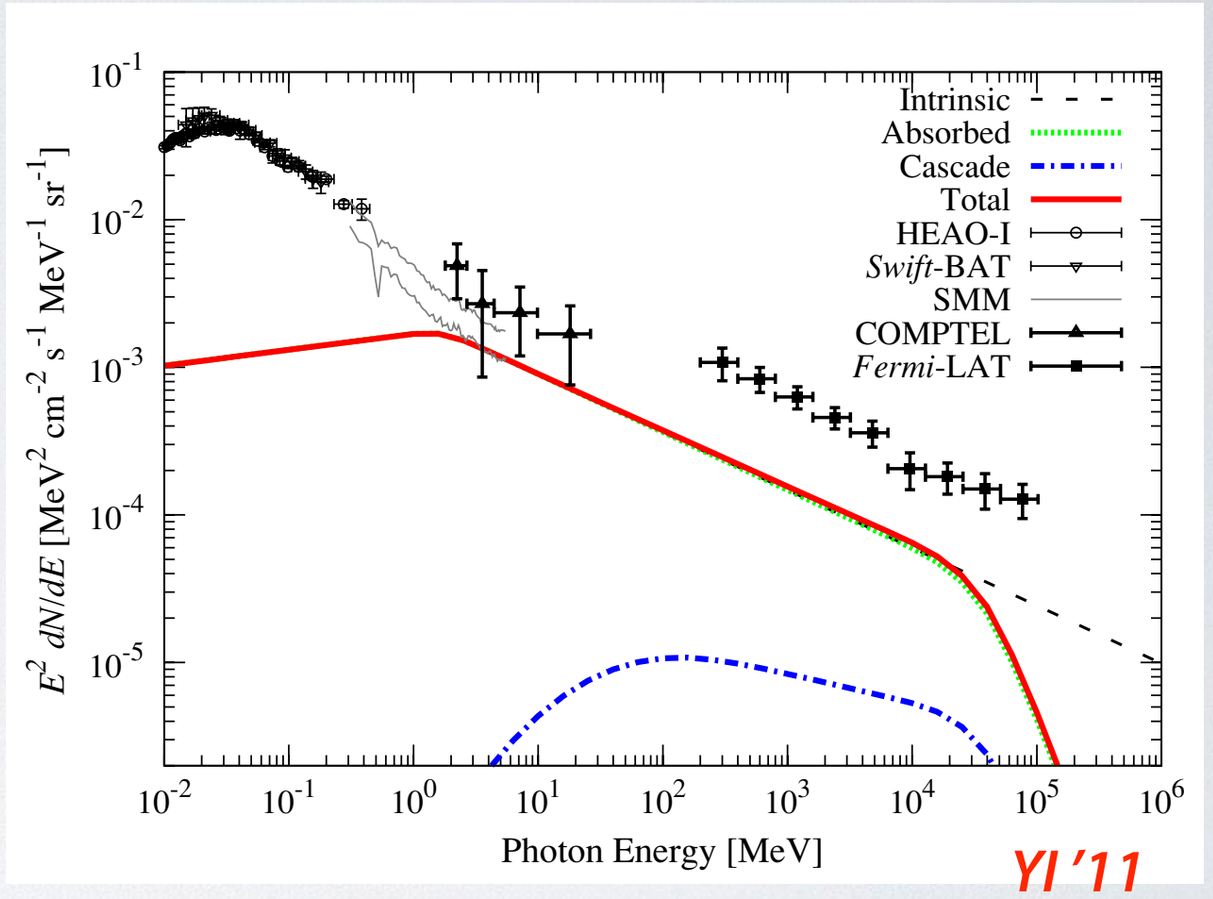
Ajello at HEM14

- Padovani+'93; Stecker+'93; Salamon & Stecker '94; Chiang + '95; Stecker & Salamon '96; Chiang & Mukherjee '98; Mukherjee & Chiang '99; Muecke & Pohl '00; Narumoto & Totani '06; Giommi +'06; Dermer '07; Pavlidou & Venters '08; Kneiske & Mannheim '08; Bhattacharya +'09; ***YI & Totani '09***; Abdo+'10; Stecker & Venters '10; Cavadini+'11, Abazajian+'11, Zeng+'12, Ajello+'12, Broderick+'12, Singal+'12, Harding & Abazajian '12, Di Mauro+'14, Ajello+'14,Singal+'14

- Blazars explain ~50% of CGB at 0.1-100 GeV.

Radio Galaxies

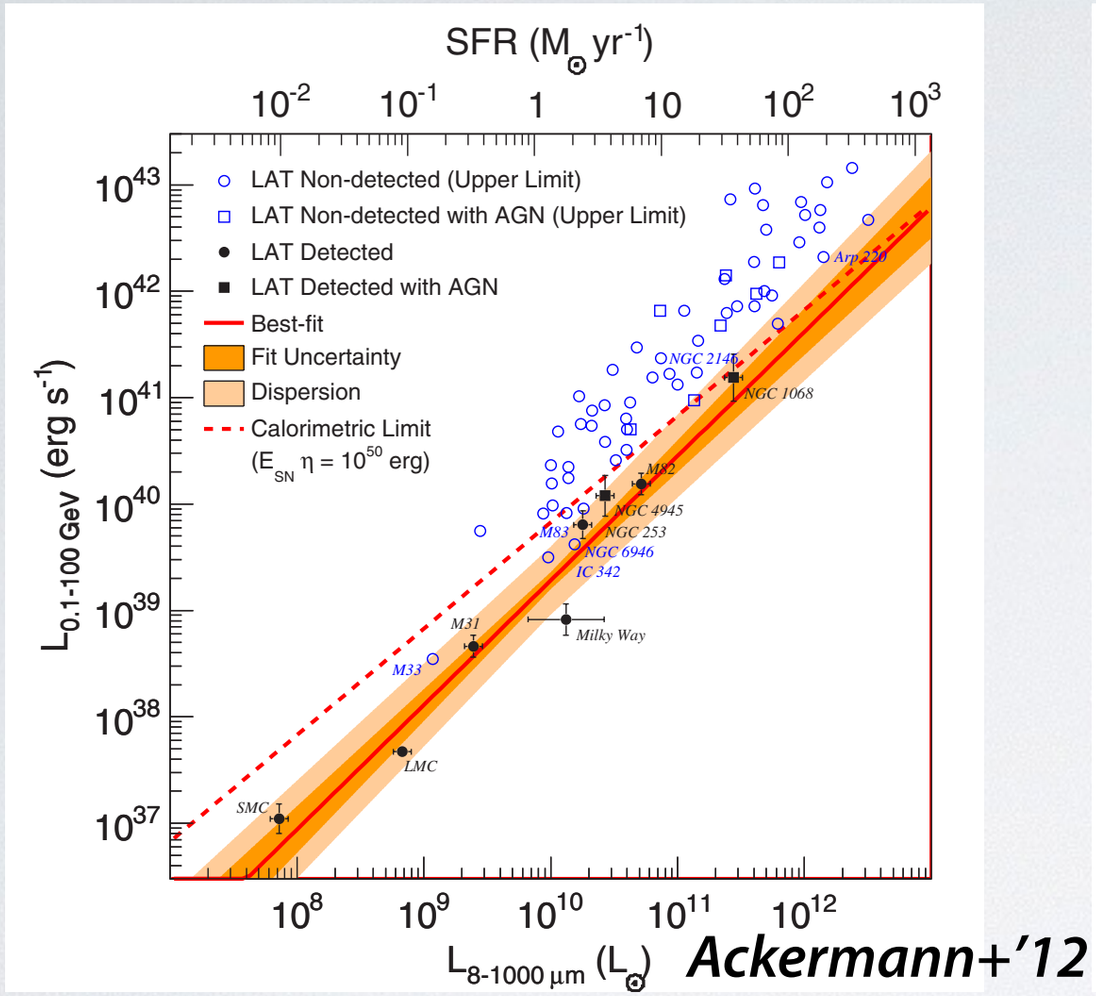


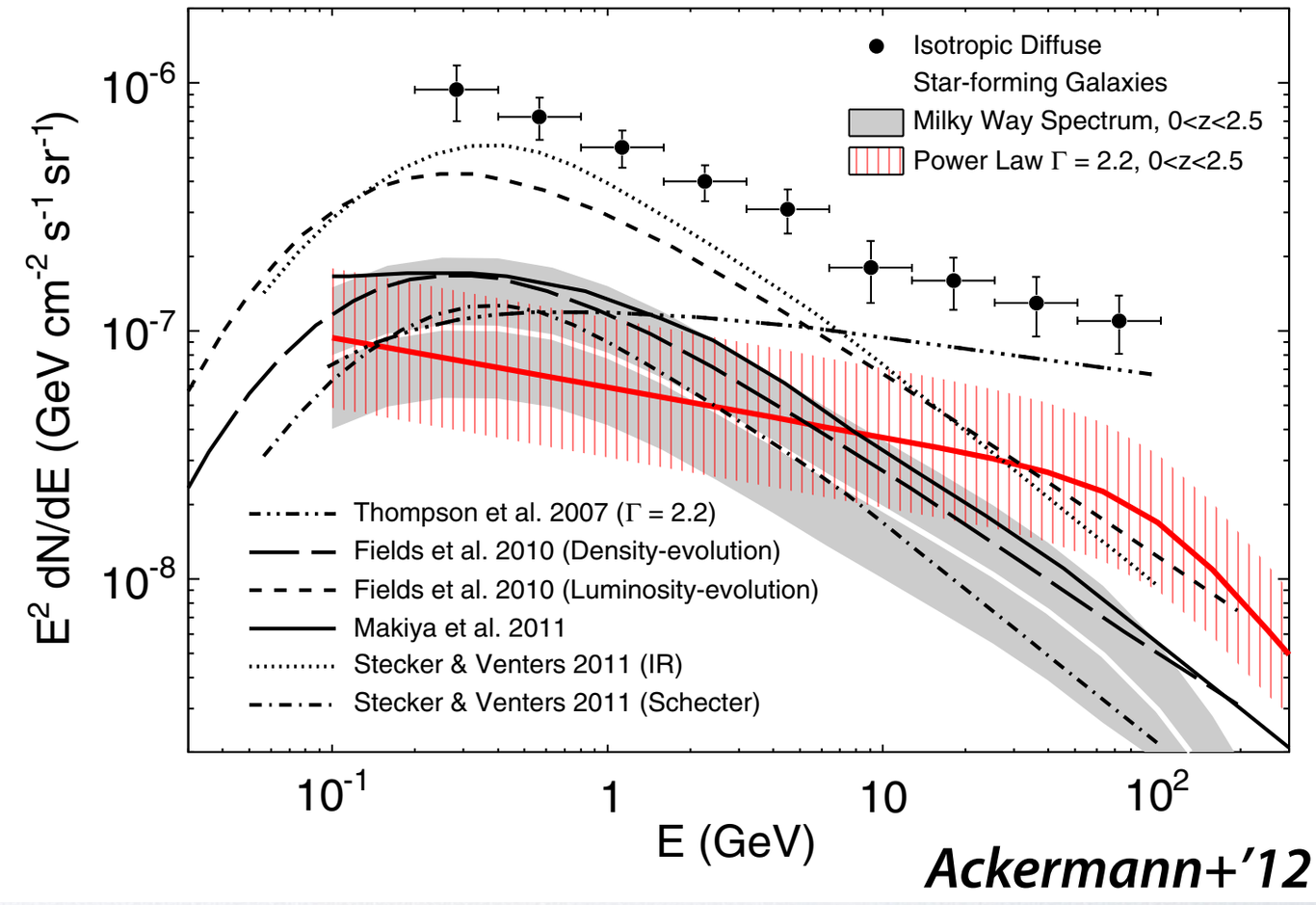


- Strong+'75, Padovani+'93; ***YI '11***; Di Mauro+'13; Zhou & Wang '13

- Use gamma-ray and radio-luminosity correlation.
- ~20% of CGB at 0.1-100 GeV.
- But, only ~10 sources are detected by Fermi.

Star-forming Galaxies





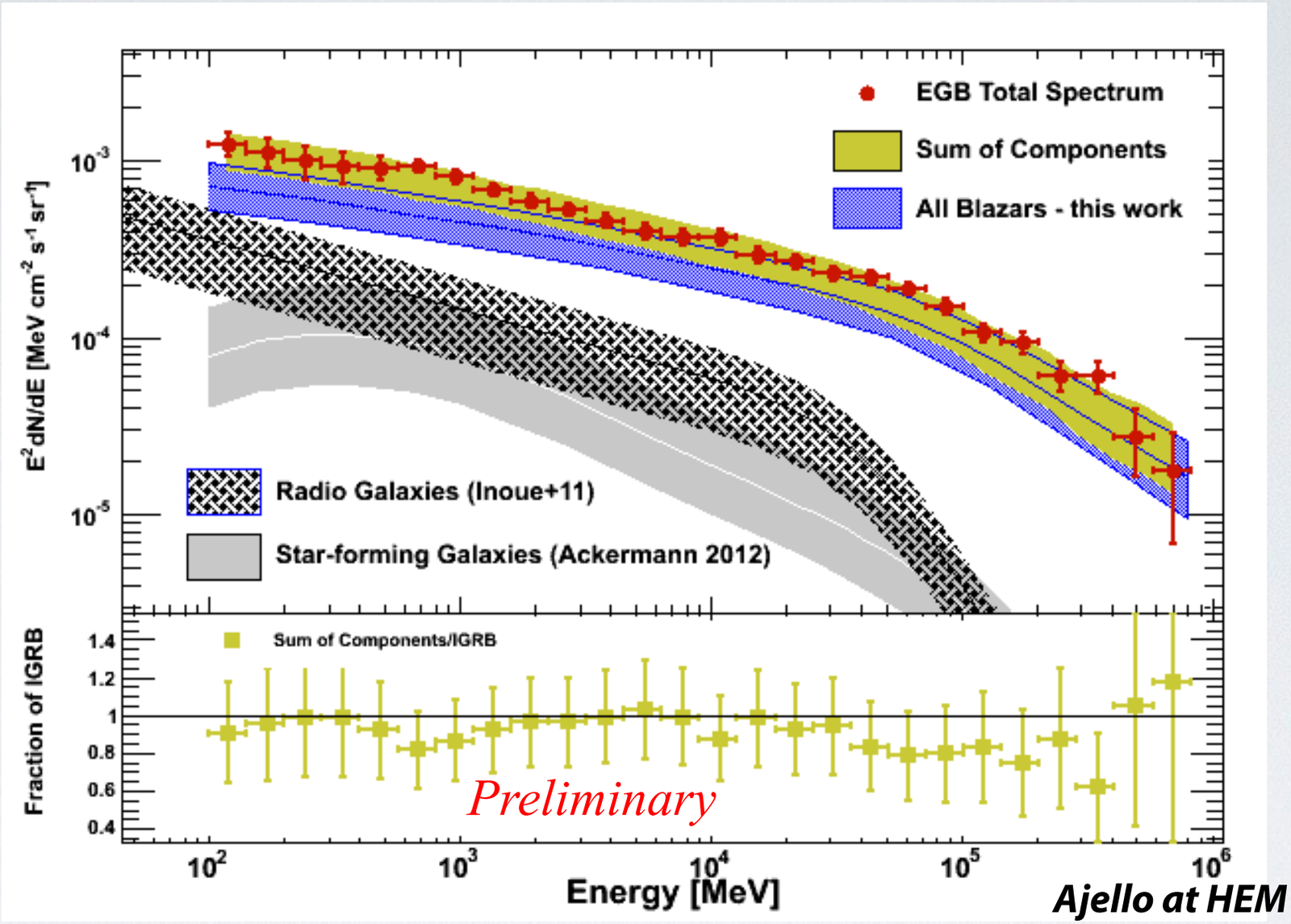
- Soltan '99; Pavlidou & Fields '02; Thompson +'07; Bhattacharya & Sreekumar 2009; Fields et al. 2010; Makiya et al. 2011; Stecker & Venters 2011; Lien+'12, Ackermann+'12; Lacki+'12; Chakraborty & Fields '13; Tamborra+'14

- Use gamma-ray and infrared luminosity correlation

- ~10-30% of CGB at 0.1-100 GeV.

- But, only ~10 sources are detected by Fermi.

Components of Cosmic Gamma-ray Background



Ajello at HEM14

- FSRQs (Ajello+'12), BL Lacs (Ajello+'14), Radio gals. (YI'11), & Star-forming gals. (Ackermann +'12) makes almost 100% of CGB from 0.1-1000 GeV.

- However, we need to assume SEDs at higher energies.

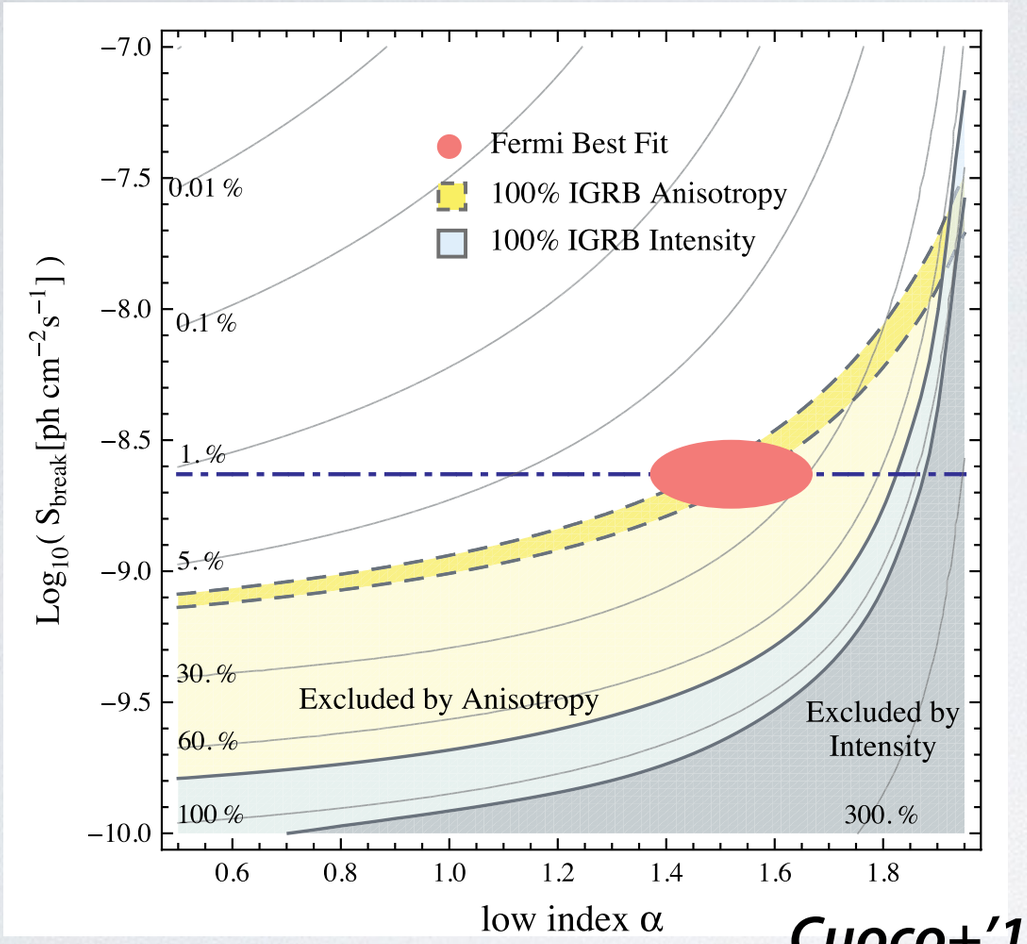
- **See Di Mauro's talk**

Future CGB studies

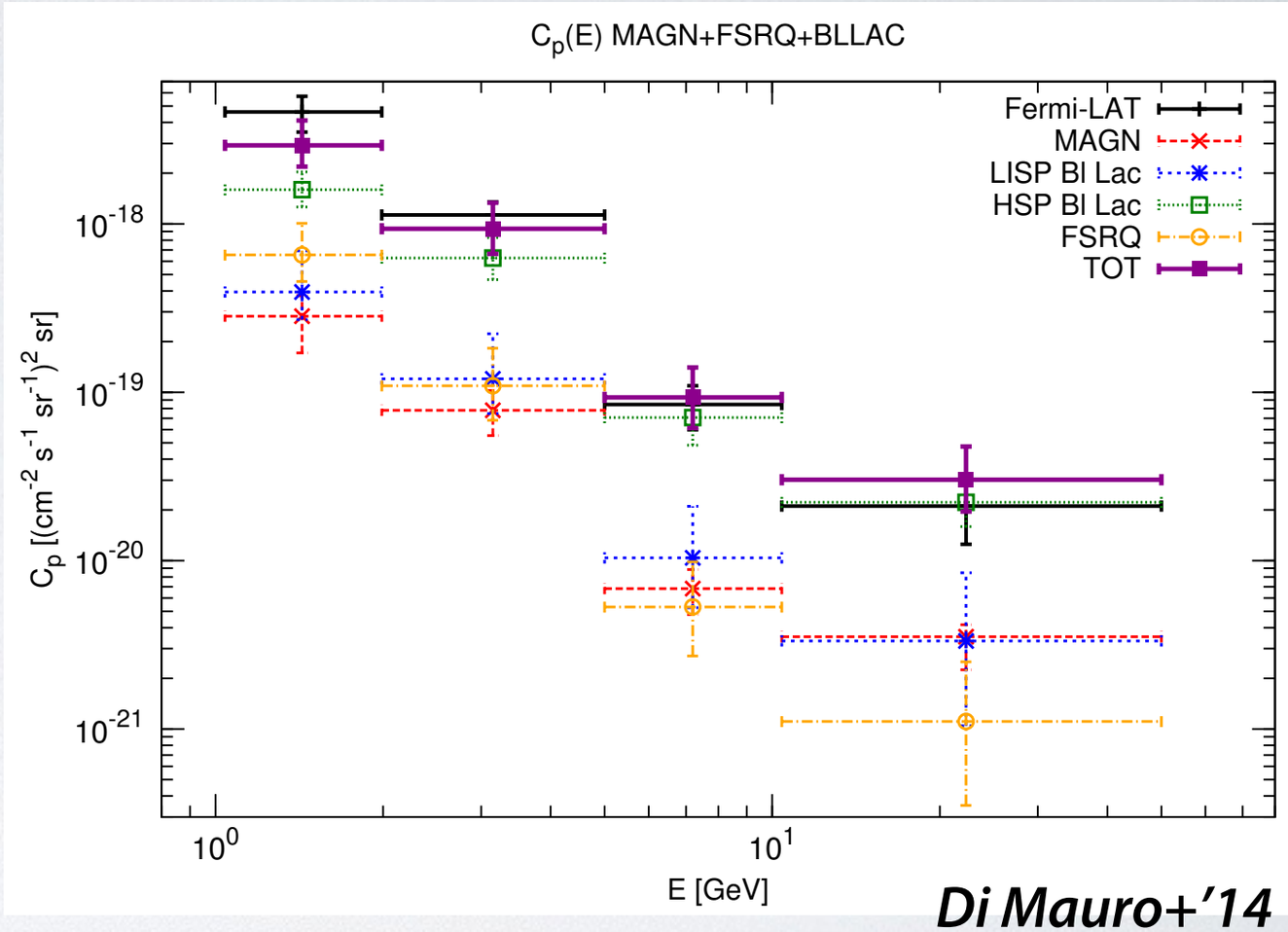
- ***Anisotropy*** of Cosmic GeV Gamma-ray Background
  - Searching Dark Matter signature
- Cosmic ***MeV*** Gamma-ray Background
  - Origins are still unknown.
- Cosmic ***TeV*** Gamma-ray Background
  - Connection to the IceCube TeV-PeV neutrinos

Anisotropy of Cosmic Gamma-ray Background

Anisotropy of Cosmic Gamma-ray Background



Cuoco+'12

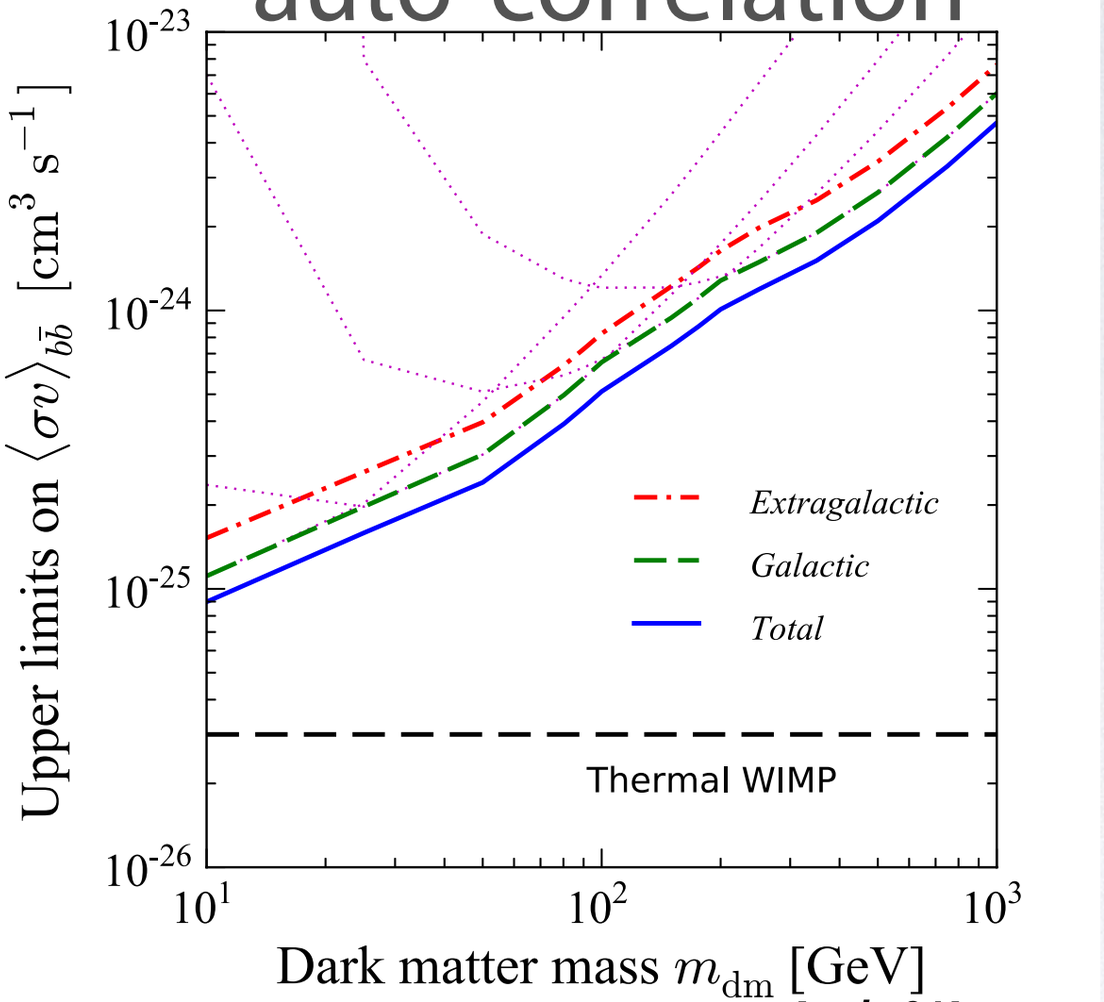


Di Mauro+'14

- Anisotropy puts strong constraints on the evolutionary models of blazars (Cuoco+'12, Harding & Abazajian '13).
- CGB anisotropy is well explained by known radio-loud AGN populations (Di Mauro+'14) -> **See Donato's talk**.

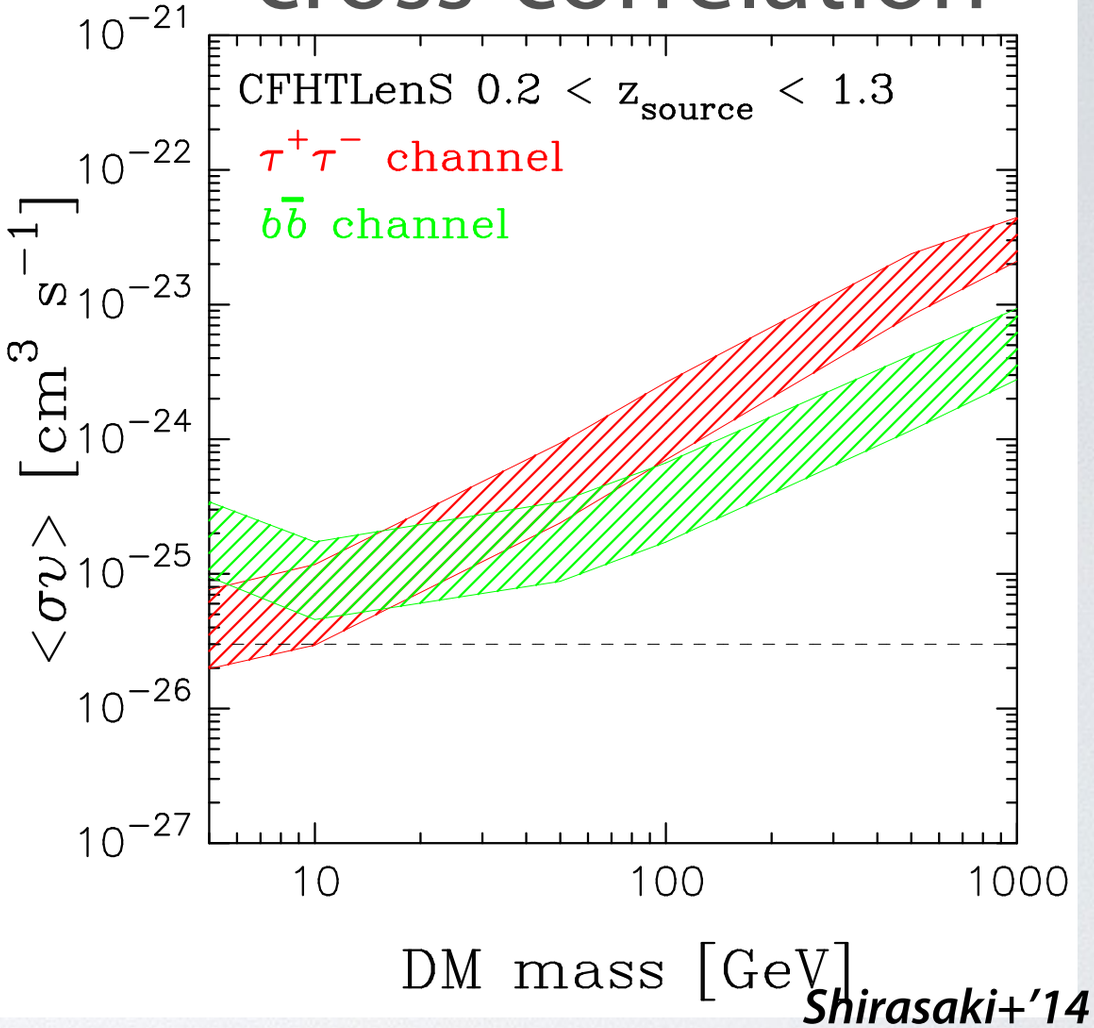
Anisotropy & Dark Matter

auto-correlation



Ando&Komatsu '13

cross-correlation



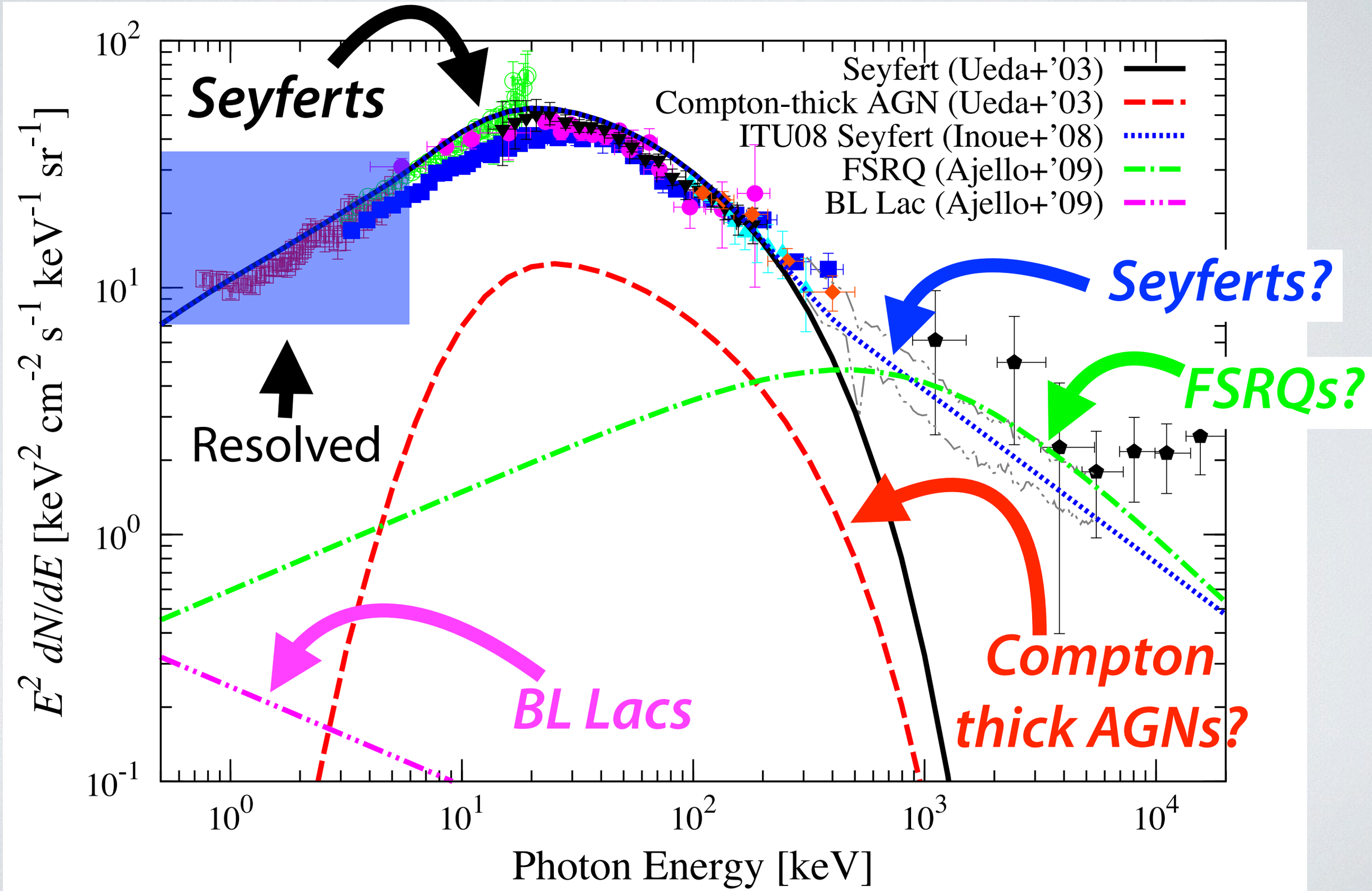
Shirasaki+'14

- Angular power spectra of CGB is a powerful tool to constrain the DM properties (e.g. Ando & Komatsu '06, '13).

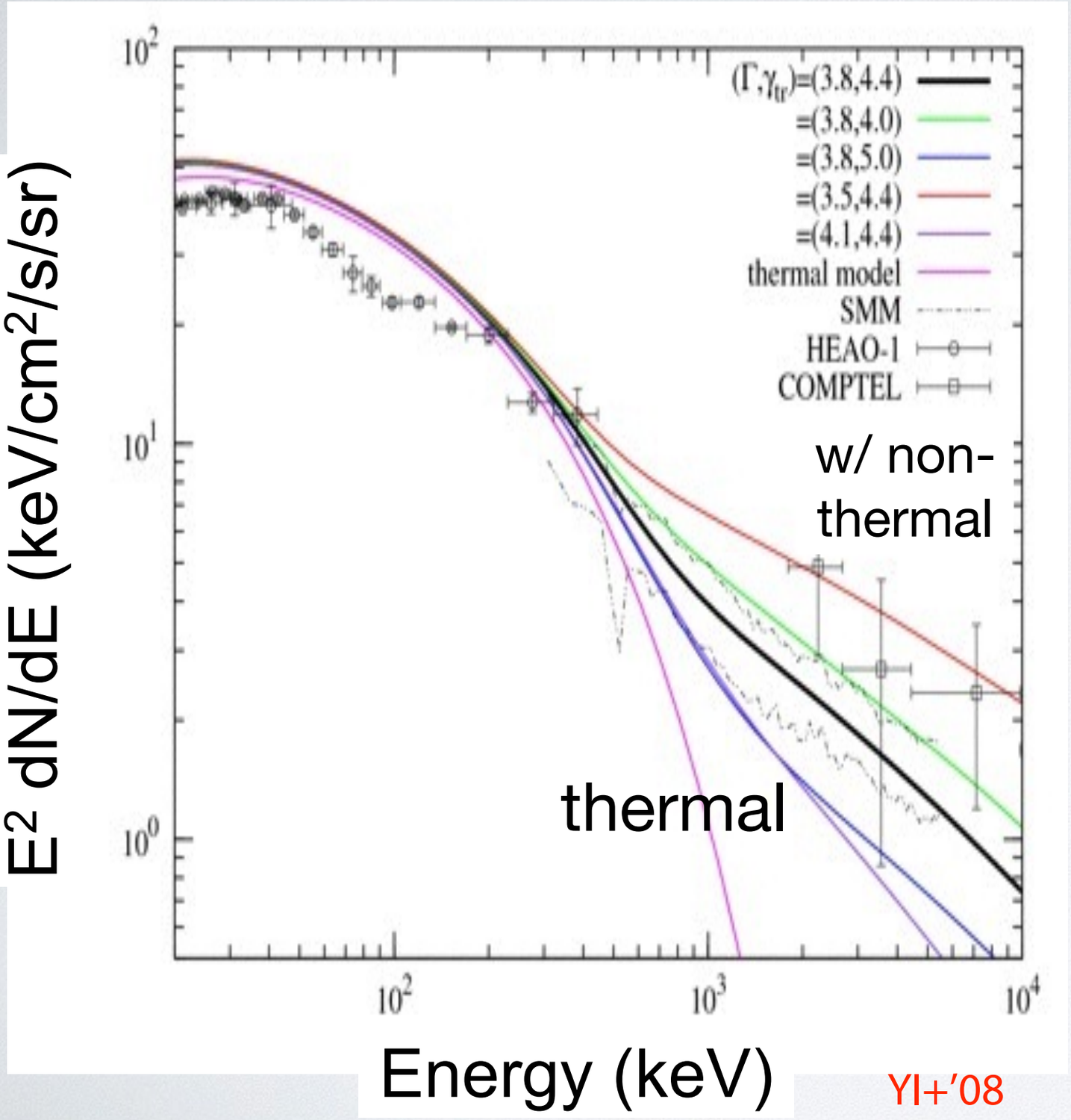
- Cross-correlation between cosmic shear and CGB will be a new powerful tool (e.g. Shirasaki+'14) -> **See Shirasaki's talk**.

Cosmic MeV Gamma-ray Background

Cosmic X-ray/MeV Gamma-ray Background



Seyferts and Cosmic MeV Gamma-ray Background



YI+'08

- Required non-thermal electron distribution is similar to that in solar flares and Earth's magnetotail

  ➡Magnetic reconnection-heated corona?

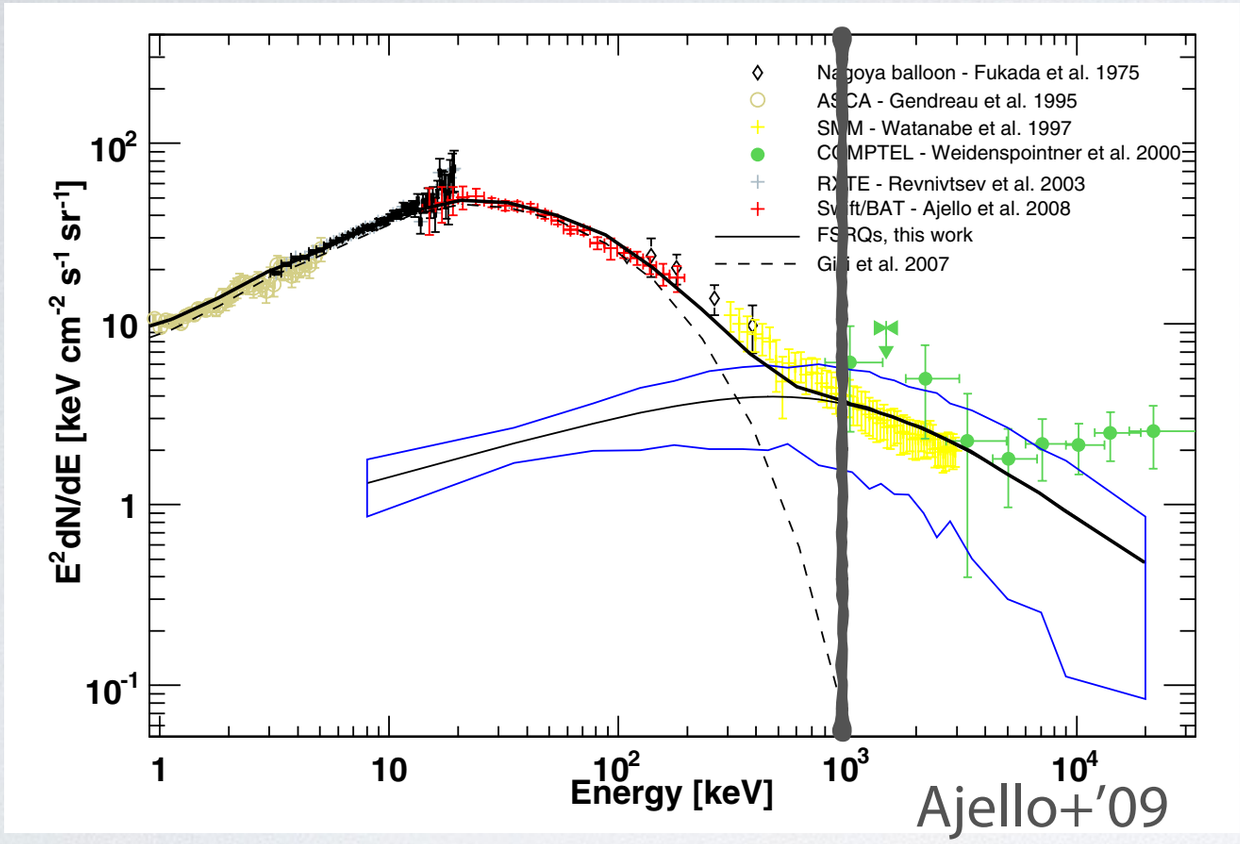
  (Liu, Mineshige, & Shibata '02)

- ALMA may probe the corona heating scenario

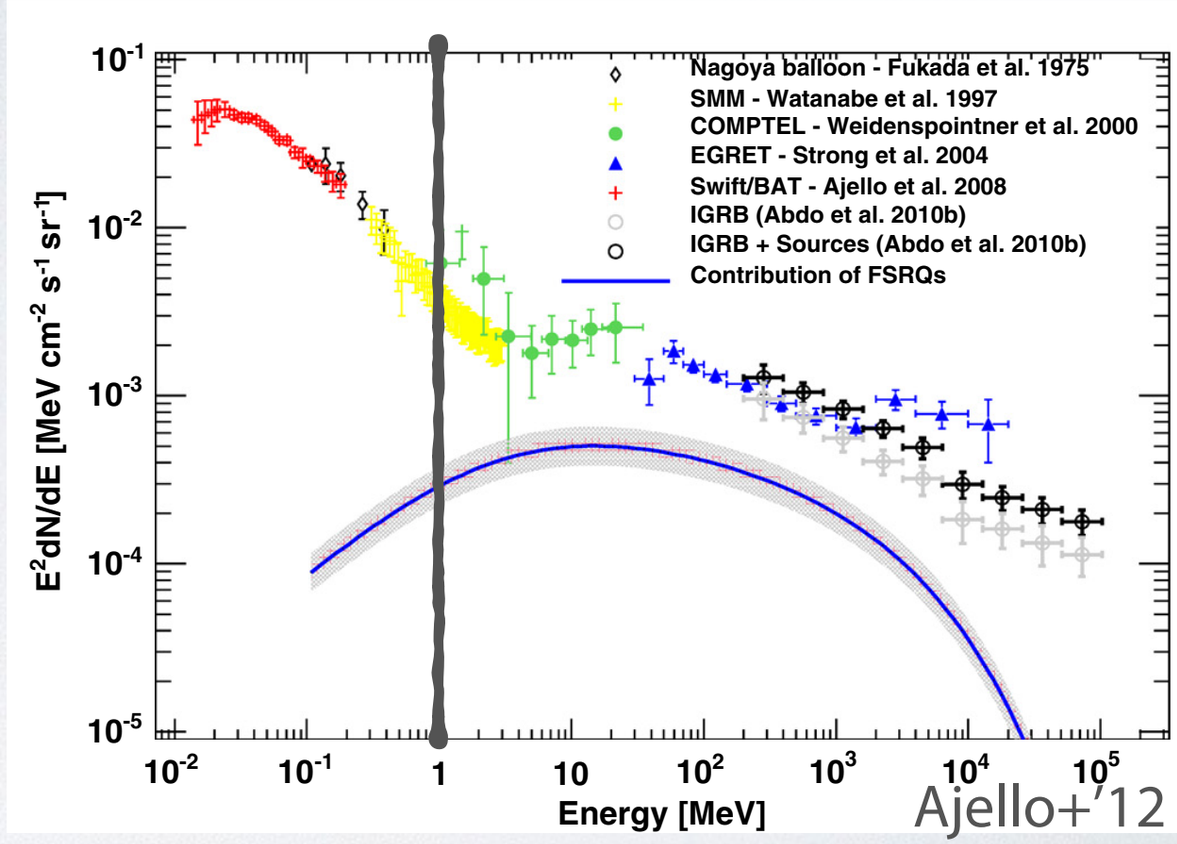
  (YI & Doi '14, YI & Doi in prep.).

Blazars and Cosmic MeV Gamma-ray Background

Based on Swift-BAT



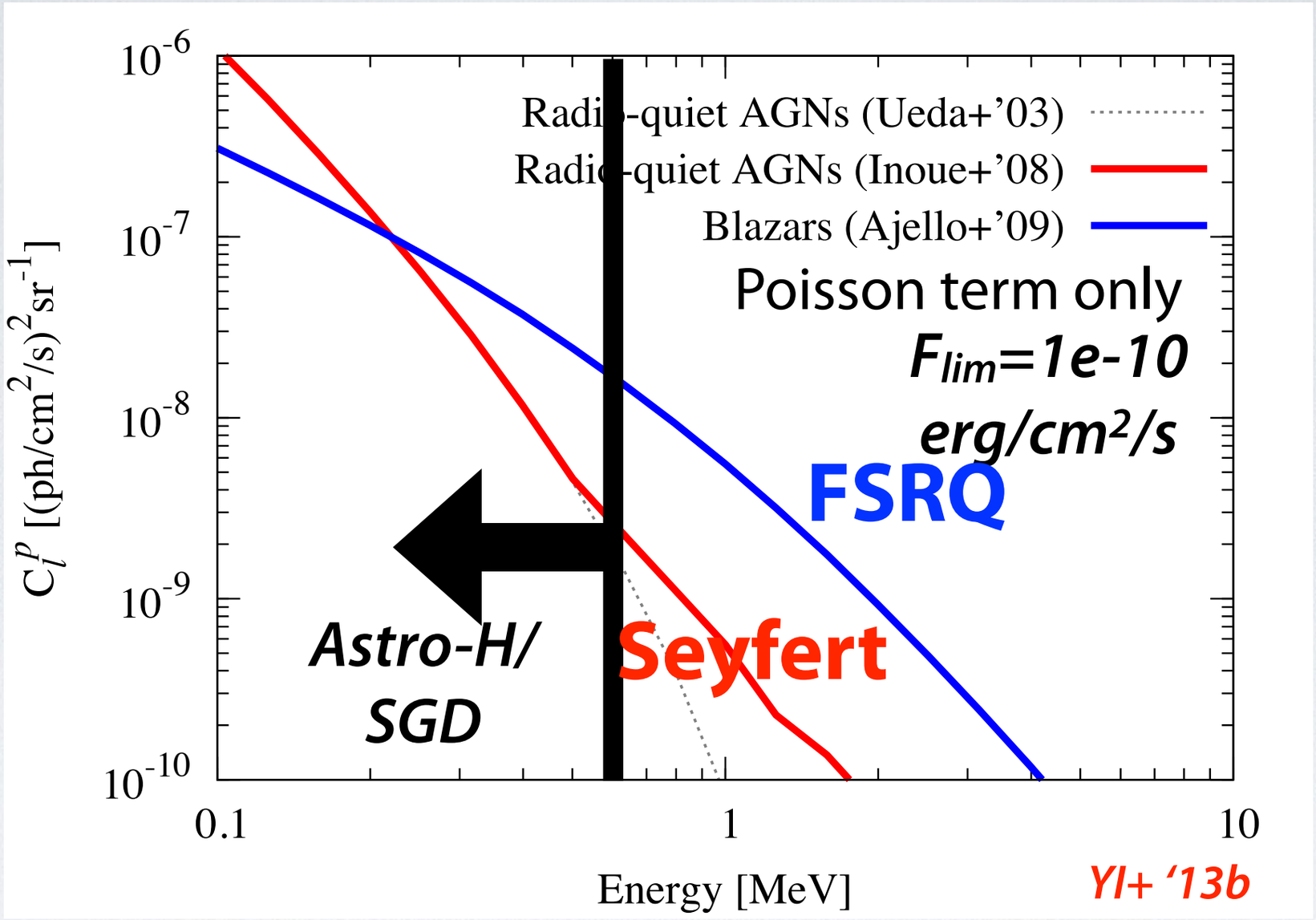
Based on Fermi-LAT



- FSRQs contribute to the GeV gamma-ray background with a peak at ~100 MeV (e.g. YI & Totani '09, Ajello +'12)

  ➡Two components in gamma-ray spectra or two FSRQ populations?

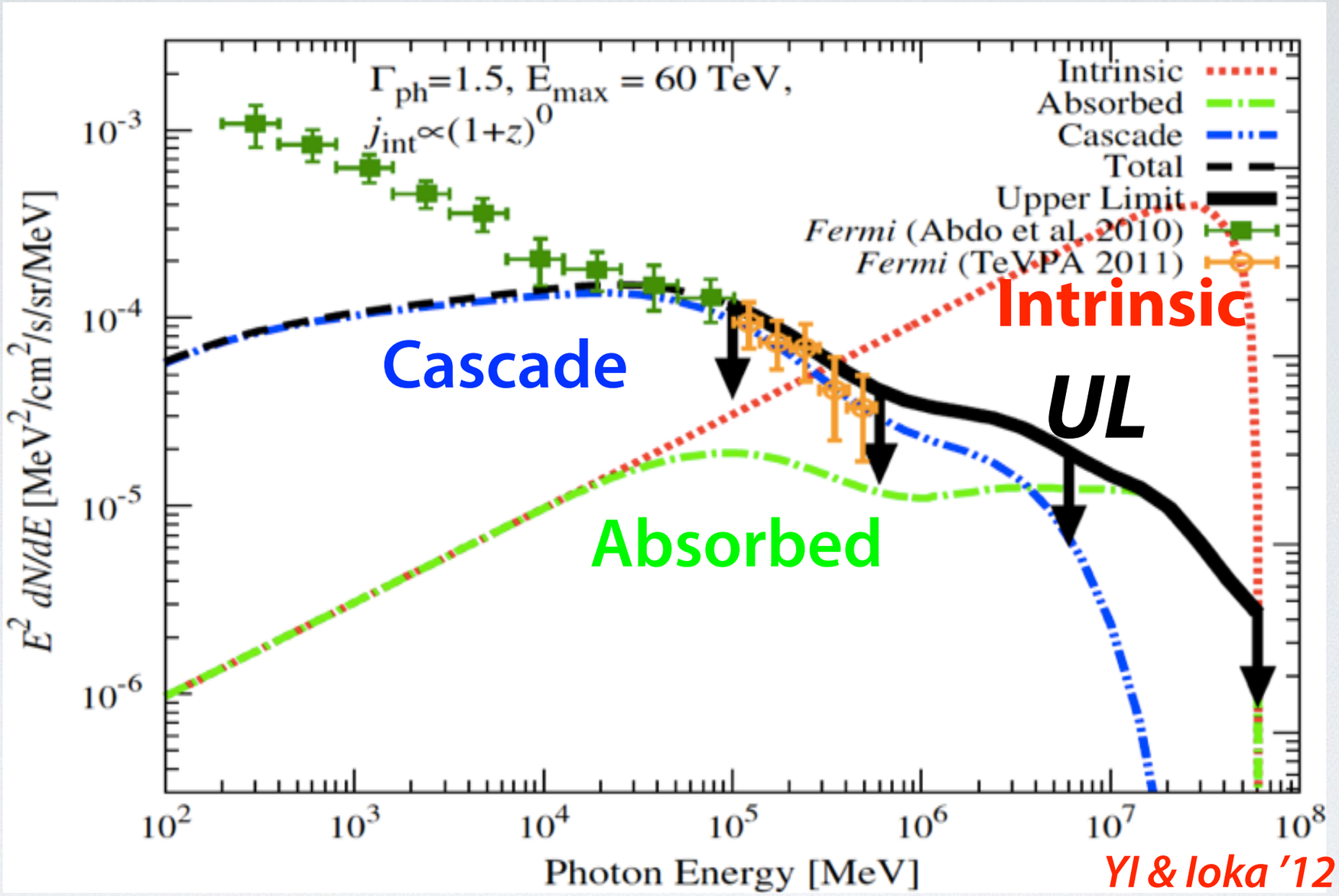
Cosmic MeV Gamma-ray Background "Anisotropy"



- Astro-H (SGD) / future MeV satellites will distinguish Seyfert & blazar scenarios through anisotropy in the sky.

Cosmic TeV Gamma-ray Background

Upper Limit on Cosmic Gamma-ray Background



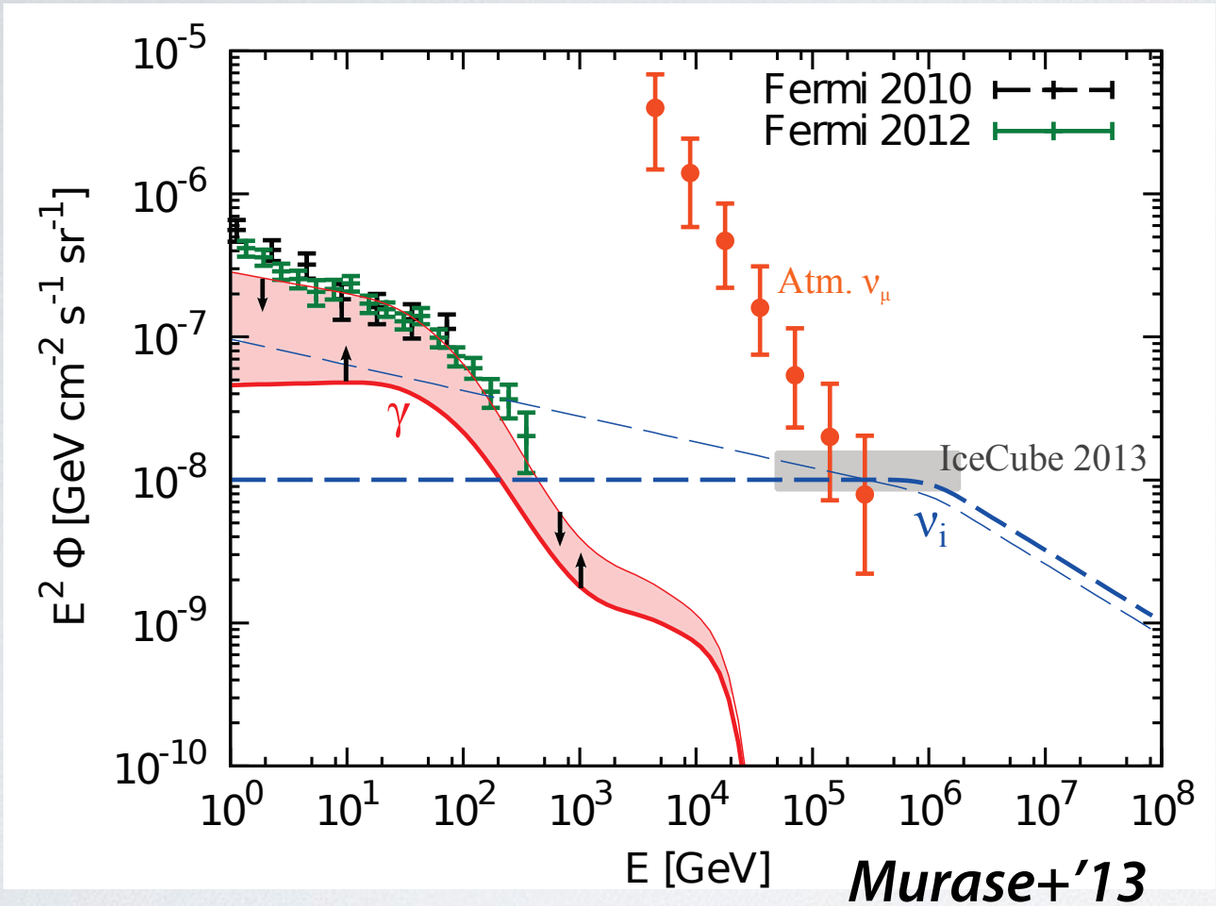
YI & Ioka '12

- Cascade component from VHE CGB can not exceed the Fermi data

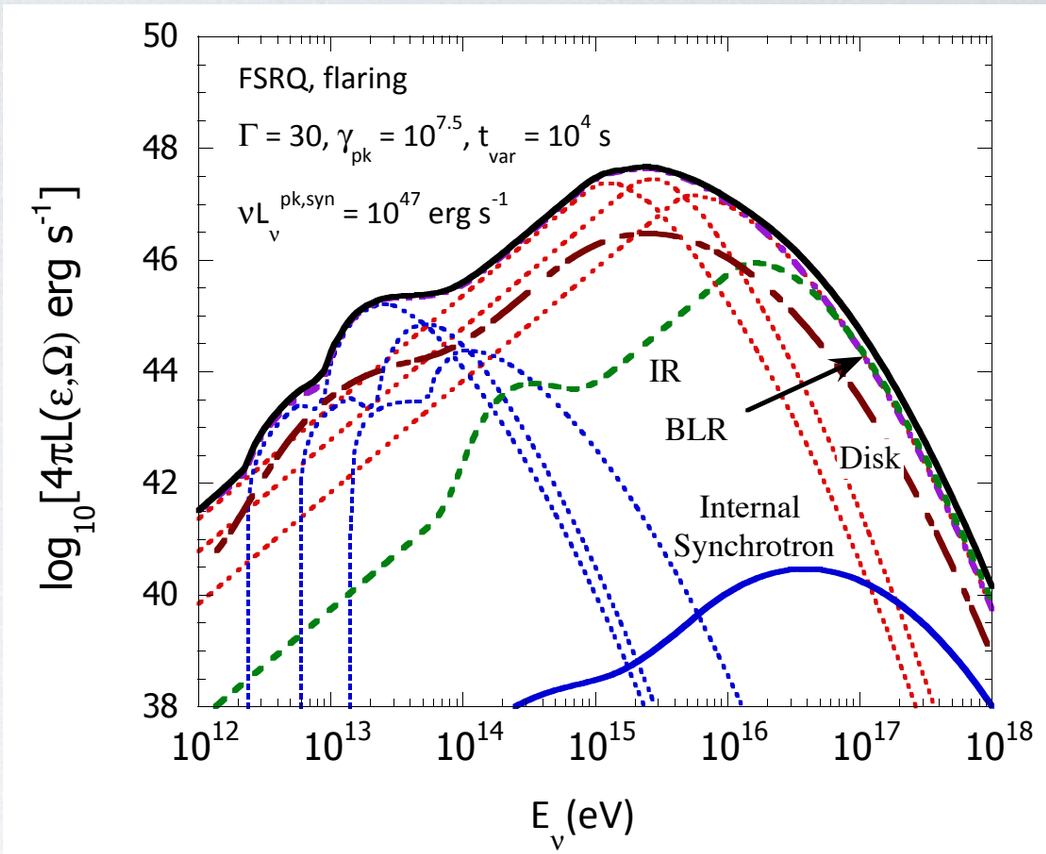
  (Coppi & Aharonian '97, YI & Ioka '12, Murase+'12, Ackermann+'14).

  - No or negative evolution is required -> HBLs show negative evolution (Ajello+'14).

IceCube Neutrinos and Cosmic Gamma-ray Background



Murase+'13

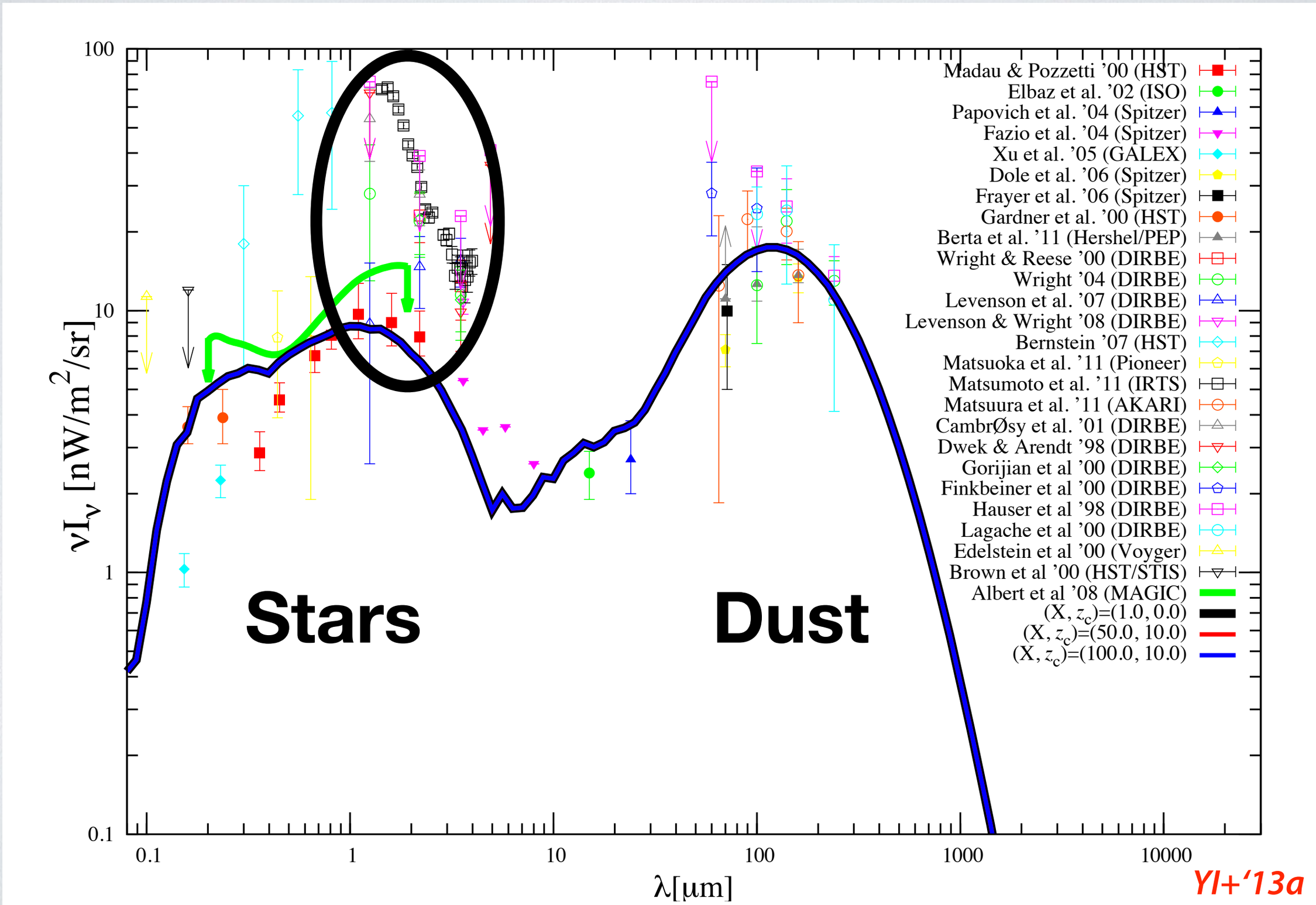


Dermer, Murase, & YI '13

- Extragalactic ***pp*** scenario (galaxies or clusters) for IceCube events will provide 30-100 % of CGB (Murase+'13).
- Extragalactic ***pγ*** scenario (e.g. FSRQs) depends on the target photon spectra (e.g. Murase, YI, & Dermer '14, Dermer, Murase, & YI '14).
- -> **See Ahlers' talk & Reimer's talk**.

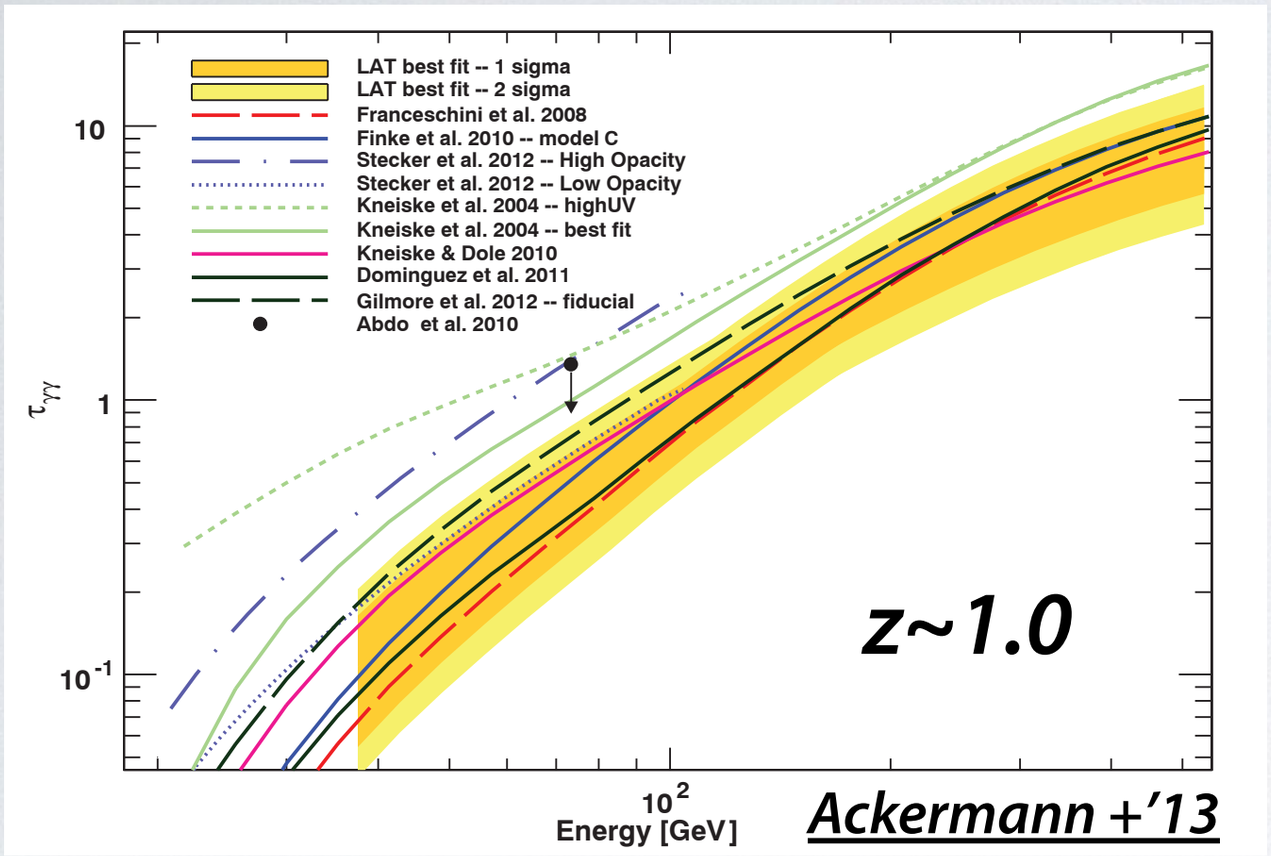
Cosmic UV/optical/infrared Background Radiation

Cosmic Optical & Infrared Background (COB & CIB)

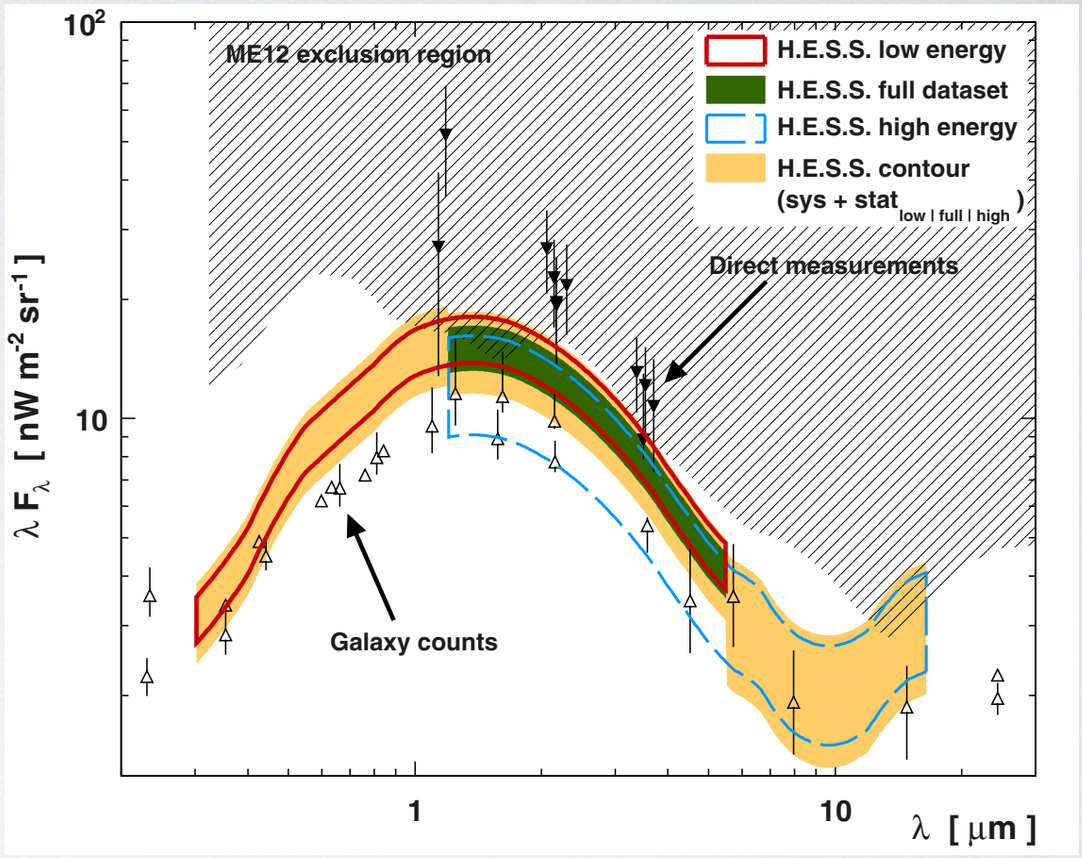


YI+'13a

Constraints from Gamma rays



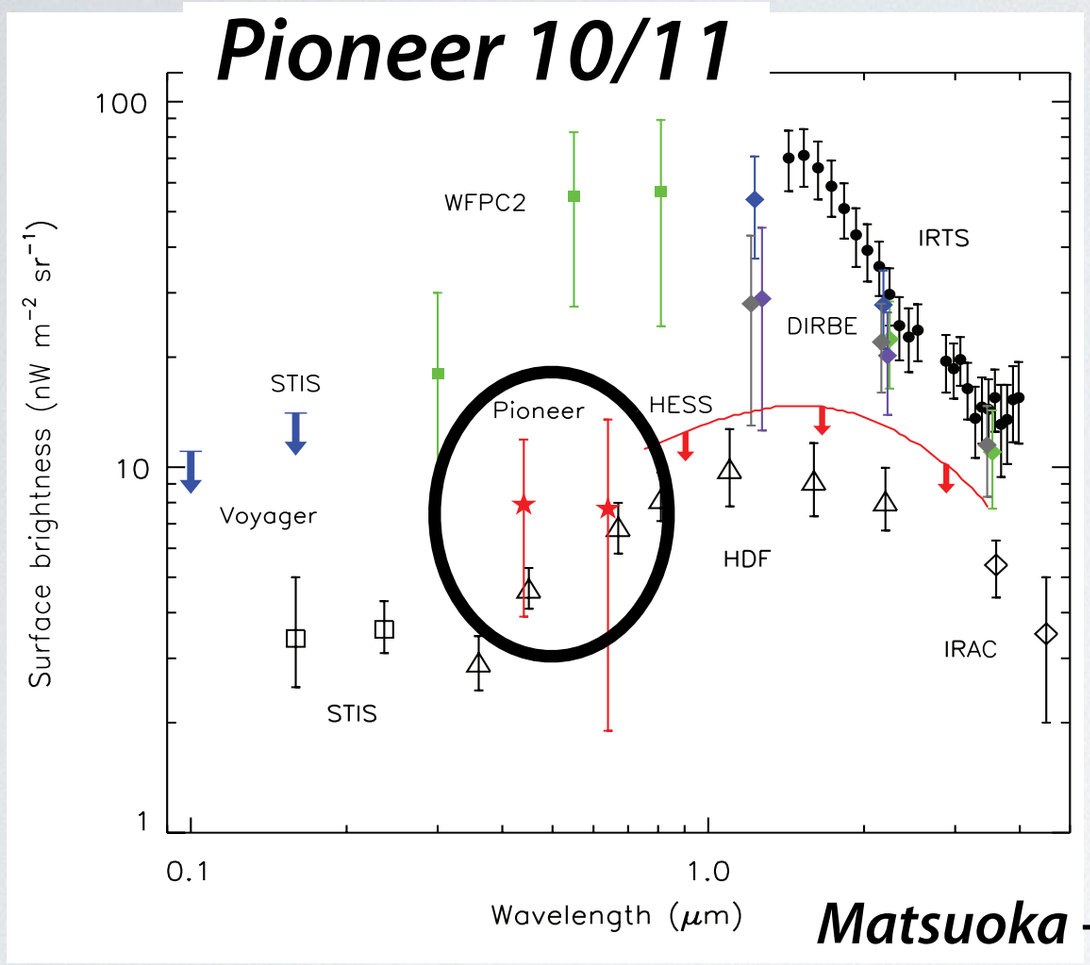
Ackermann +'13



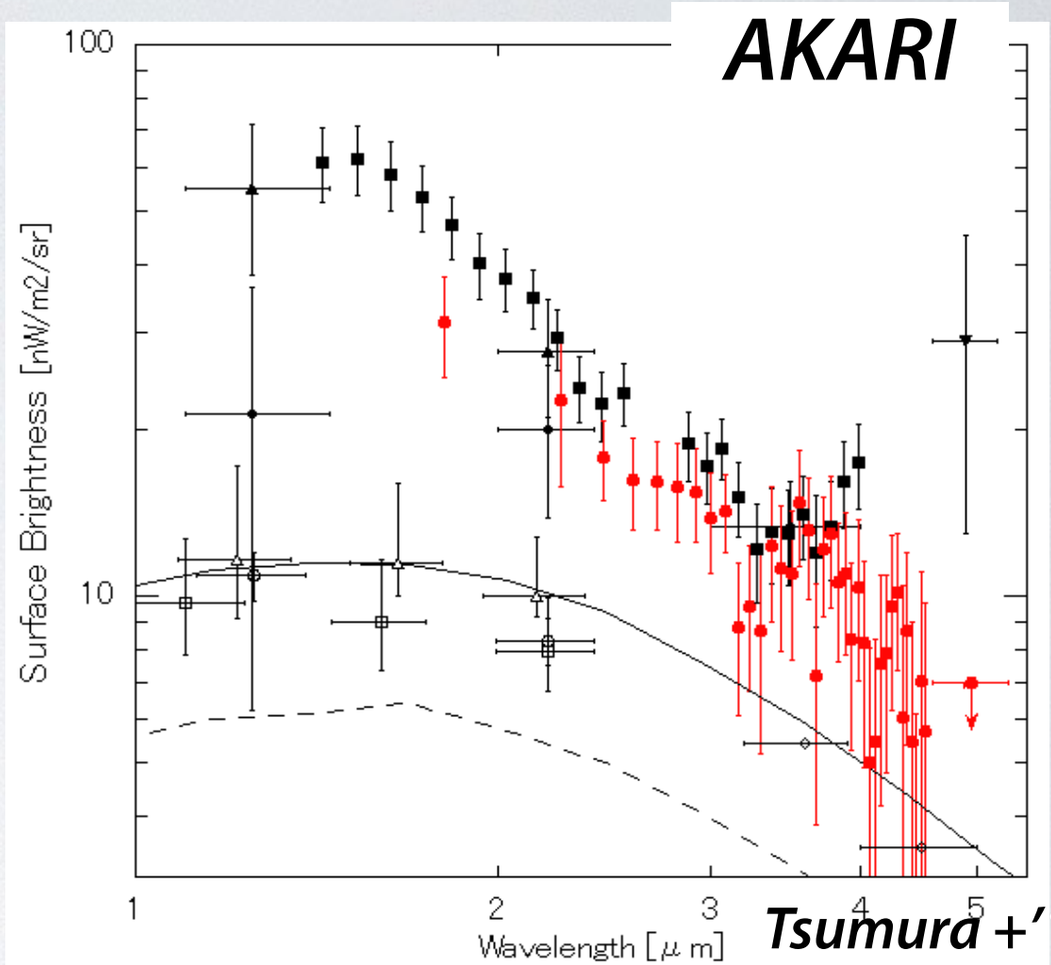
Abramowski +'13

- Fermi derived the COB opacity using the combined spectra of blazars (see also Gong & Cooray '13, Dominguez +'13).
- H.E.S.S. derived the COB intensity using the combined spectra of blazars.

Direct Measurements of COB & CIB



Matsuoka +'11

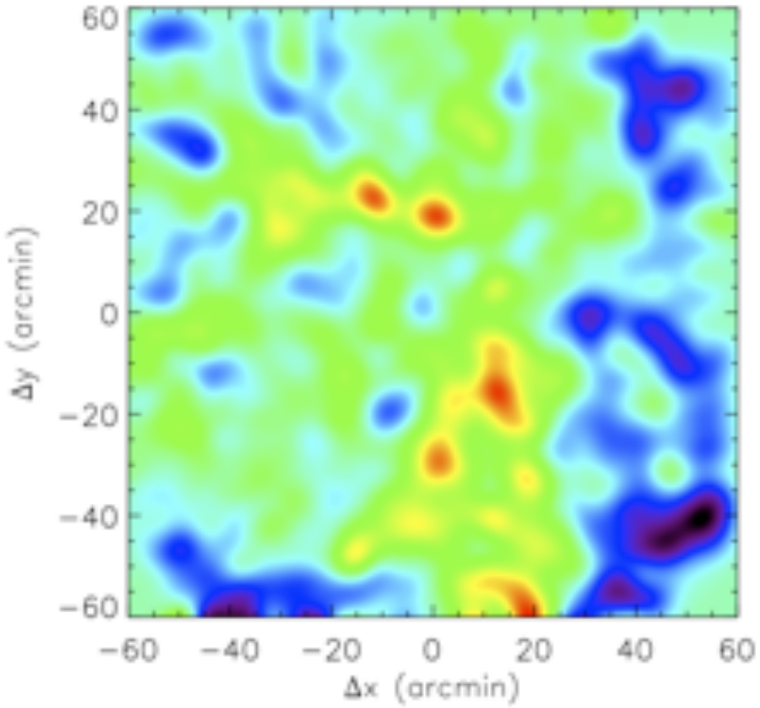


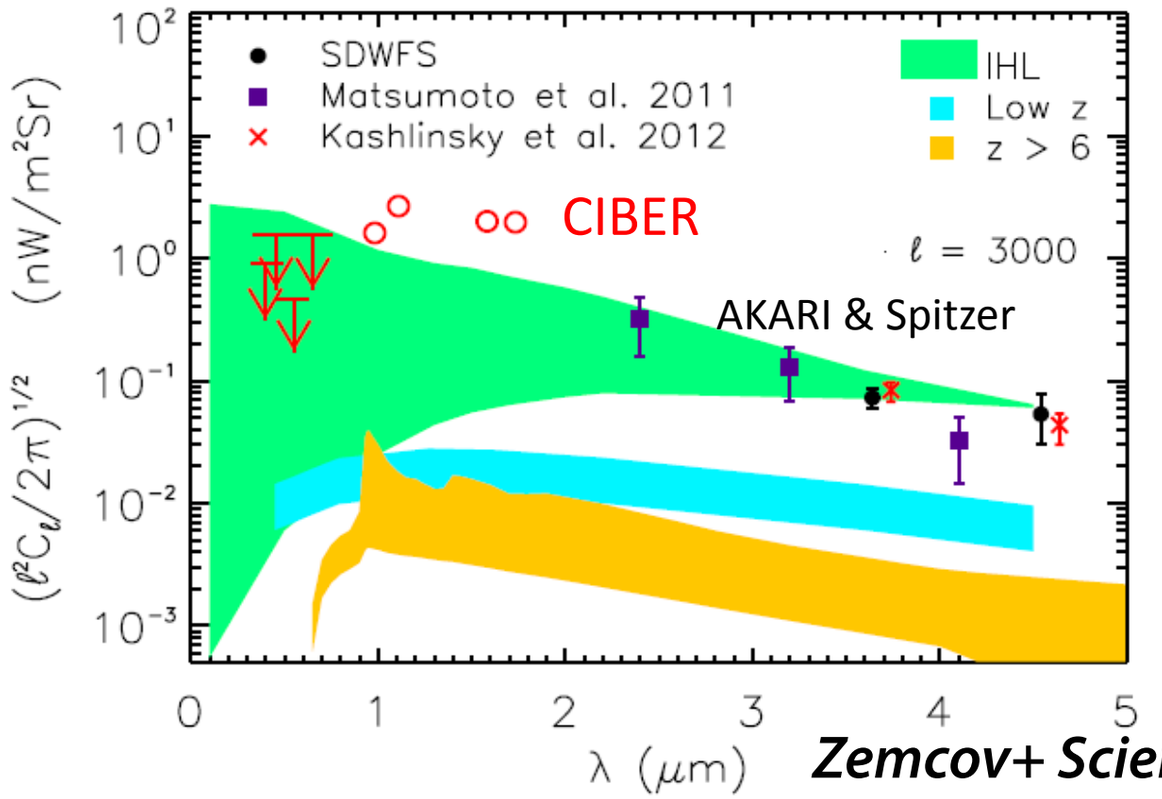
Tsumura +'13

- Pioneer 10/11 measurements are consistent with the galaxy count lower limit.
- But, recent AKARI measurement is consistent with IRTS.
  - Peak at near infrared?

CIBER Experiment at NIR region

CIB fluctuations image at l = 3000





Zemcov+ Science in press.

- CIBER confirmed a large scale fluctuation reported by Spitzer & AKARI, which can not be explained galaxies (Zecmov+'14 Science).
  - A population other than galaxies may significantly contribute to CIB.
- They will report the CIB absolute intensity measurement soon.

Summary

- CGB at GeV band is composed of blazars, radio galaxies, and star-forming galaxies.
- CGB at MeV band may be come from blazars or Seyferts.
  - Anisotropy measurement will distinguish these two scenarios.
- CGB at TeV band is constrained by CGB at GeV band through cascade emission.
  - Need to check consistency with IceCube neutrino measurements.