Discovery of the millimeter excess in a nearby Seyfert nucleus: Toward unveiling the magnetic field in the vicinity of a supermassive black hole

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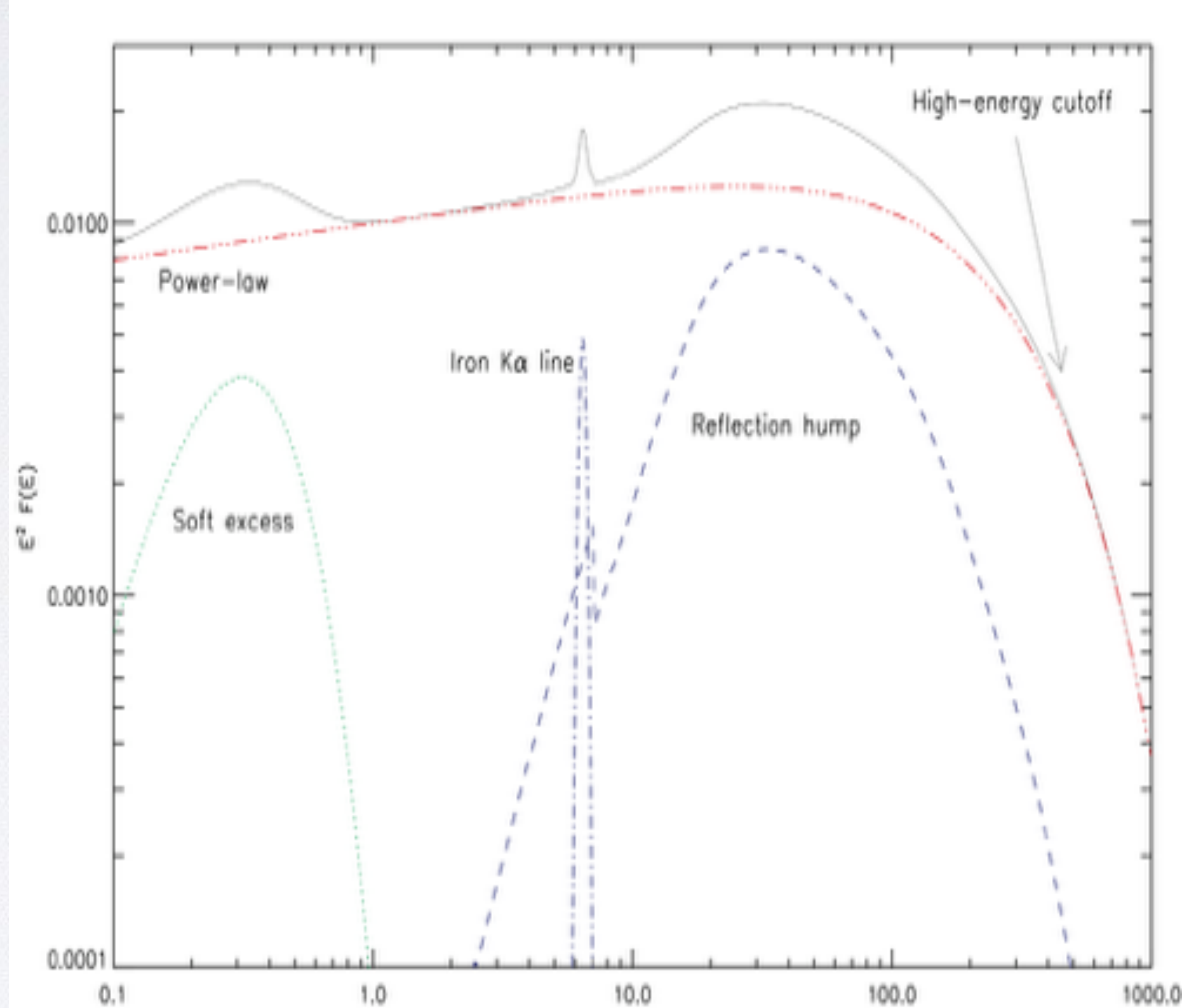
What makes Seyfert X-ray continuum?

- Continuum is generated by Comptonization in the disk corona.

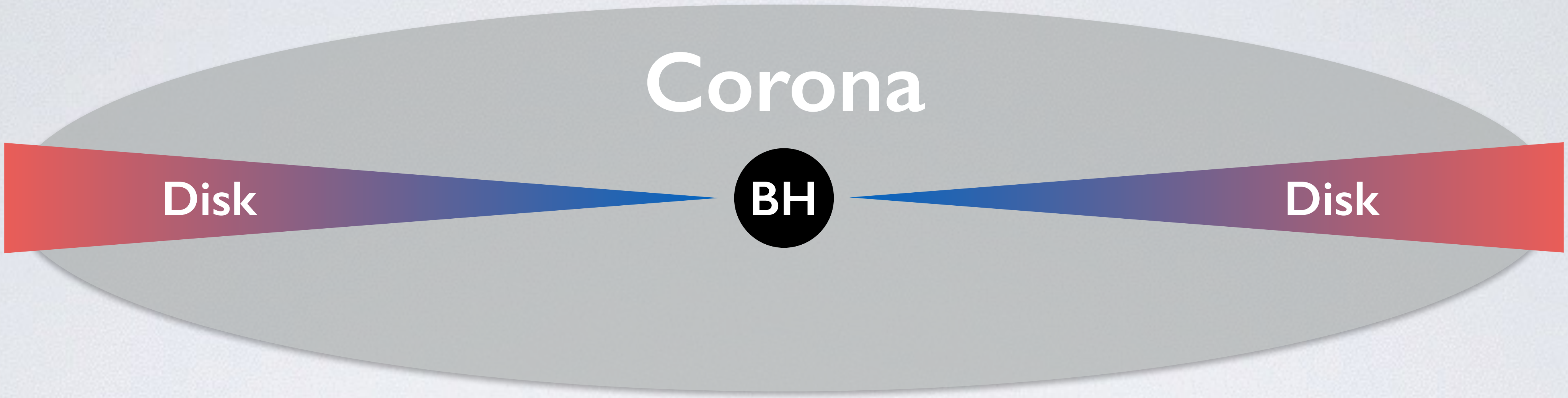
- “Corona” is important.

    - How are they generated?



Ricci ’11

Observed properties of disk coronae



- High energy cutoff

➡ $T_e \sim 10^9$ K $(k_B T_e \sim 10^2$ keV$)$

- Power-law spectrum
  - Compton-y parameter $(y = 4k_B T_e/\tau_e m_e c^2 \sim 1)$
  - $n_e \sim 10^9 \left(\frac{k_B T_e}{100\ \mathrm{keV}}\right)\left(\frac{M_{\mathrm{BH}}}{10^8 M_\odot}\right)^{-1}\ \mathrm{cm}^{-3}$
  - Assuming the size of a corona as $l = 10R_s$

Magnetic Reconnection-Heated Corona Model

Liu, Mineshige, Shibata '02

1. Reconnection heating = Compton Cooling in corona

$$\frac{B^2}{4\pi}V_A \approx \frac{4k_BT_e}{m_ec^2}n_e\sigma_T cU_{\rm seed}l \sim ycU_{\rm seed}$$

2. Conduction heating = evaporation cooling in disk chromosphere

$$\frac{k_0T^{7/2}}{l} \approx \frac{\gamma}{\gamma-1}n_ek_BT_e\left(\frac{k_BT_e}{m_H}\right)^{1/2}$$

$$T_e \sim 10^9\left(\frac{B}{10^3\ \rm G}\right)^{3/4}\left(\frac{l}{10^{14}\ \rm cm}\right)^{1/8}\left(\frac{U_{\rm seed}}{10^5\ \rm erg/cm^3}\right)^{-1/4}\ \rm K$$

$$n_e \sim 10^9\left(\frac{B}{10^3\ \rm G}\right)^{3/2}\left(\frac{l}{10^{14}\ \rm cm}\right)^{-3/4}\left(\frac{U_{\rm seed}}{10^5\ \rm erg/cm^3}\right)^{-1/2}\ \rm cm^{-3}$$

- Assuming equipartition of magnetic energy with gas energy in the disk.

Synchrotron radiation from a corona

- If ... on
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- BU
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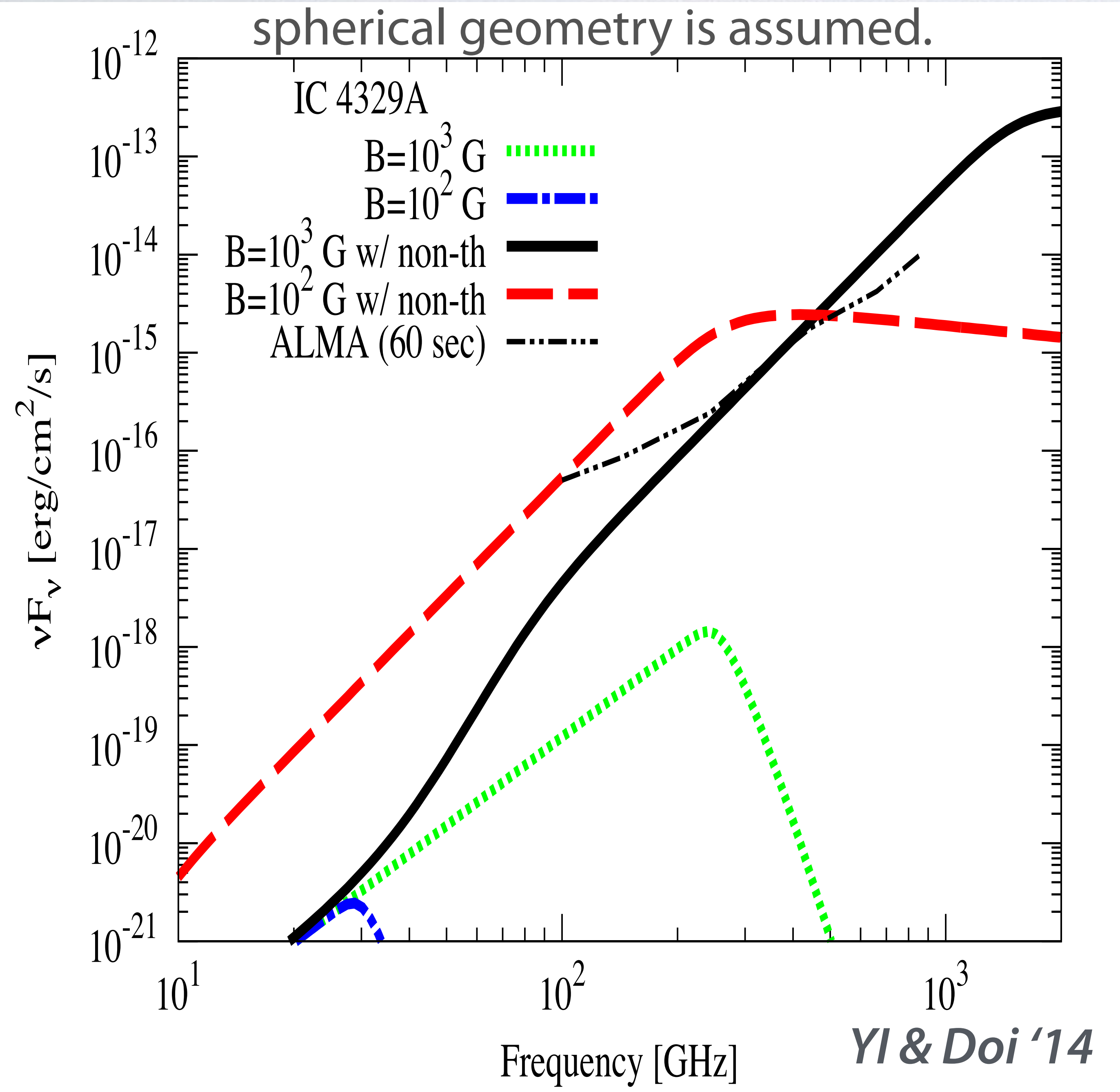
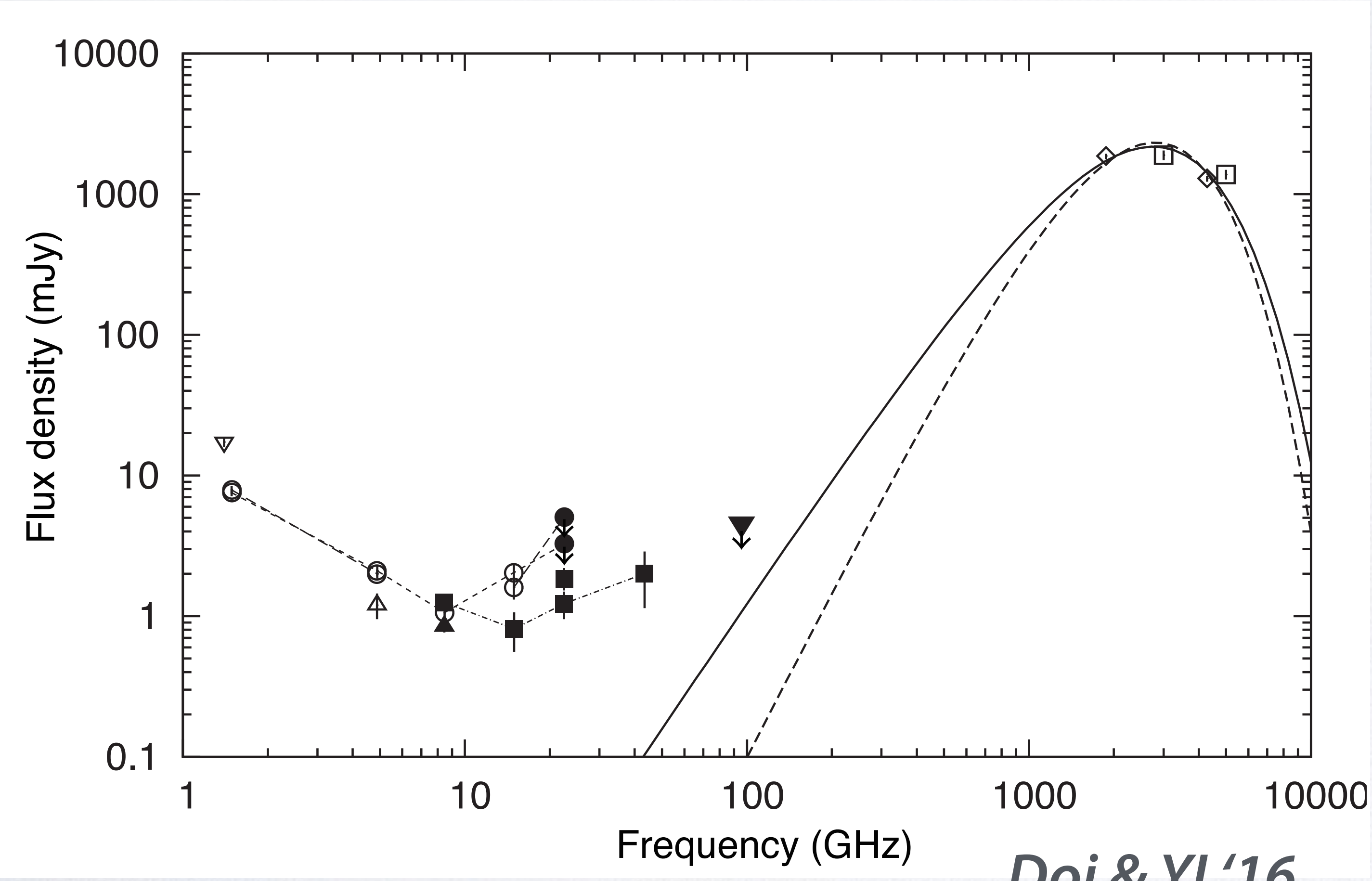
http://alma.mtk.nao.ac.jp

A Case for a Nearby AGN IC 4329A



- Coronal properties are determined by ***Suzaku/NuSTAR*** joint observation (Brenneman+'14).
  - T_e = 50 keV, τ_e=2.34
- hard to see the emission from a pure thermal corona.
  - Synchrotron-self absorption is effective below sub-mm.
- If non-thermal electrons exist in the corona, ALMA will see the coronal synchrotron radiation.

Millimeter Excess? NGC 985



Doi & YI '16

- Free-free emission from BLR clouds?
  - but, 10^{11} clouds required
- self-absorbed Synchrotron jets?
  - but, the scale is ~500 r_s (~0.01 pc). >100 times smaller than GHz-Peaked Spectrum sources.
  - The life time will be less than 1 year due to cooling.
- Coronal Synchrotron Emission?

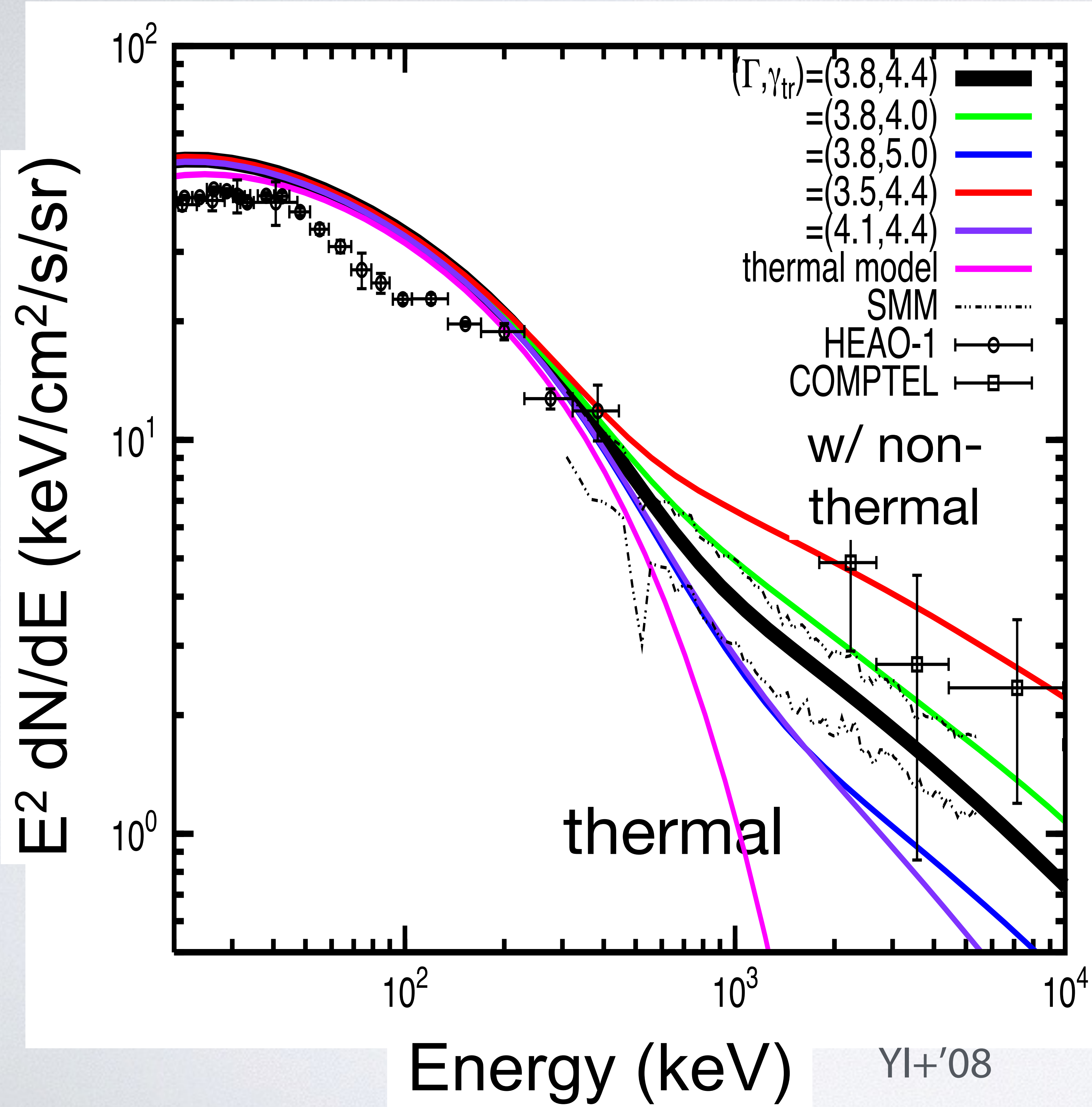
➡***~100 GHz data is required.***

ALMA Observation toward NGC 985

- ALMA Cycle-3 Observation on this March.
- The excess is confirmed.
  - with the size of <0.02 arcsec (<16pc).
  - first discovery of the millimeter excess in Seyferts.
- Coronal Synchrotron emission is the most likely.
  - But, currently not clear whether it is thermal or hybrid.

- Our ALMA Cycle-4 proposal is recently accepted for higher frequency observations.

Seyferts and Cosmic MeV Gamma-ray Background

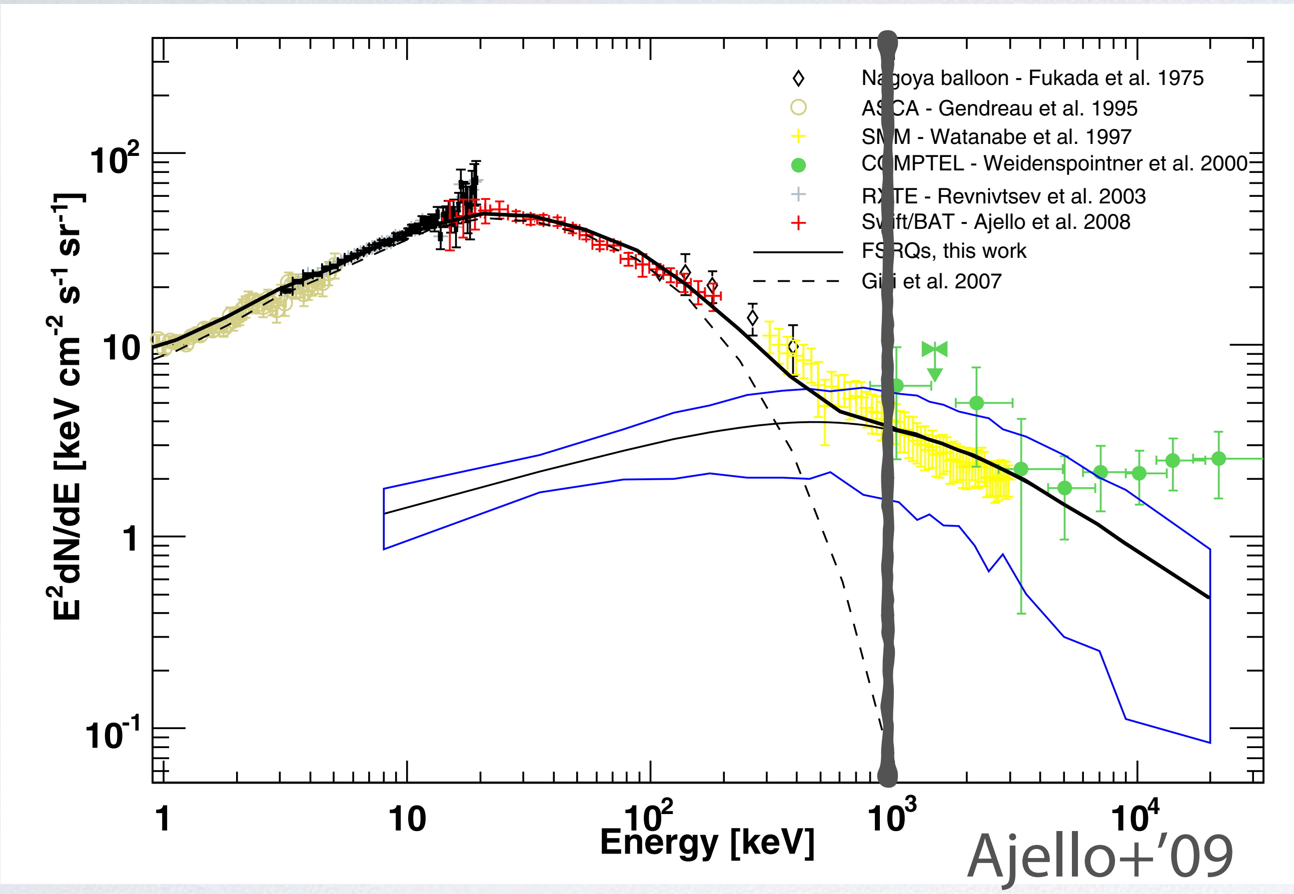


YI+'08

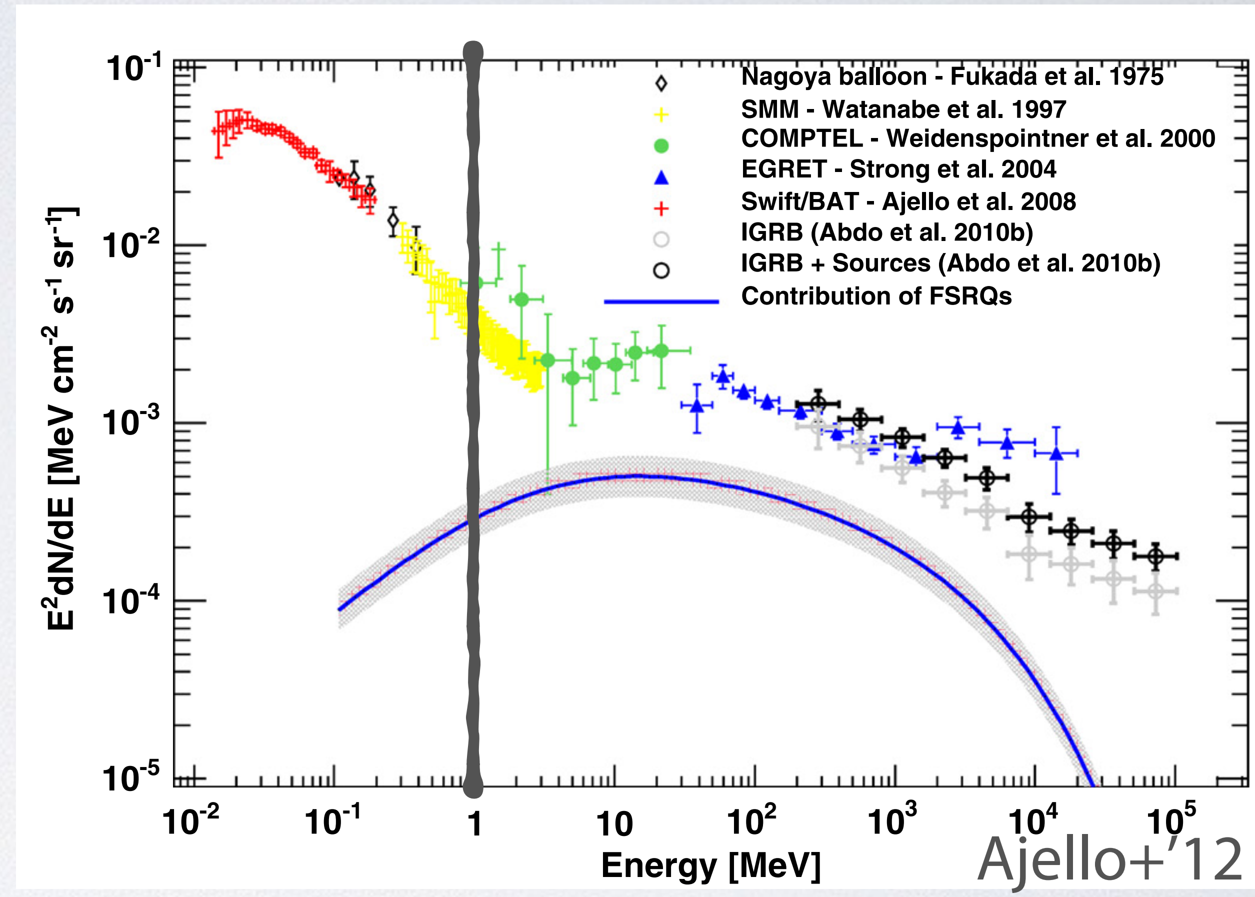
- Existence of non-thermal e^- in coronae extends the IC emission to MeV.
  - The MeV gamma-ray background can be explained by this tail.
  - The same non-thermal population is assumed.

Blazars and Cosmic MeV Gamma-ray Background

Based on Swift-BAT



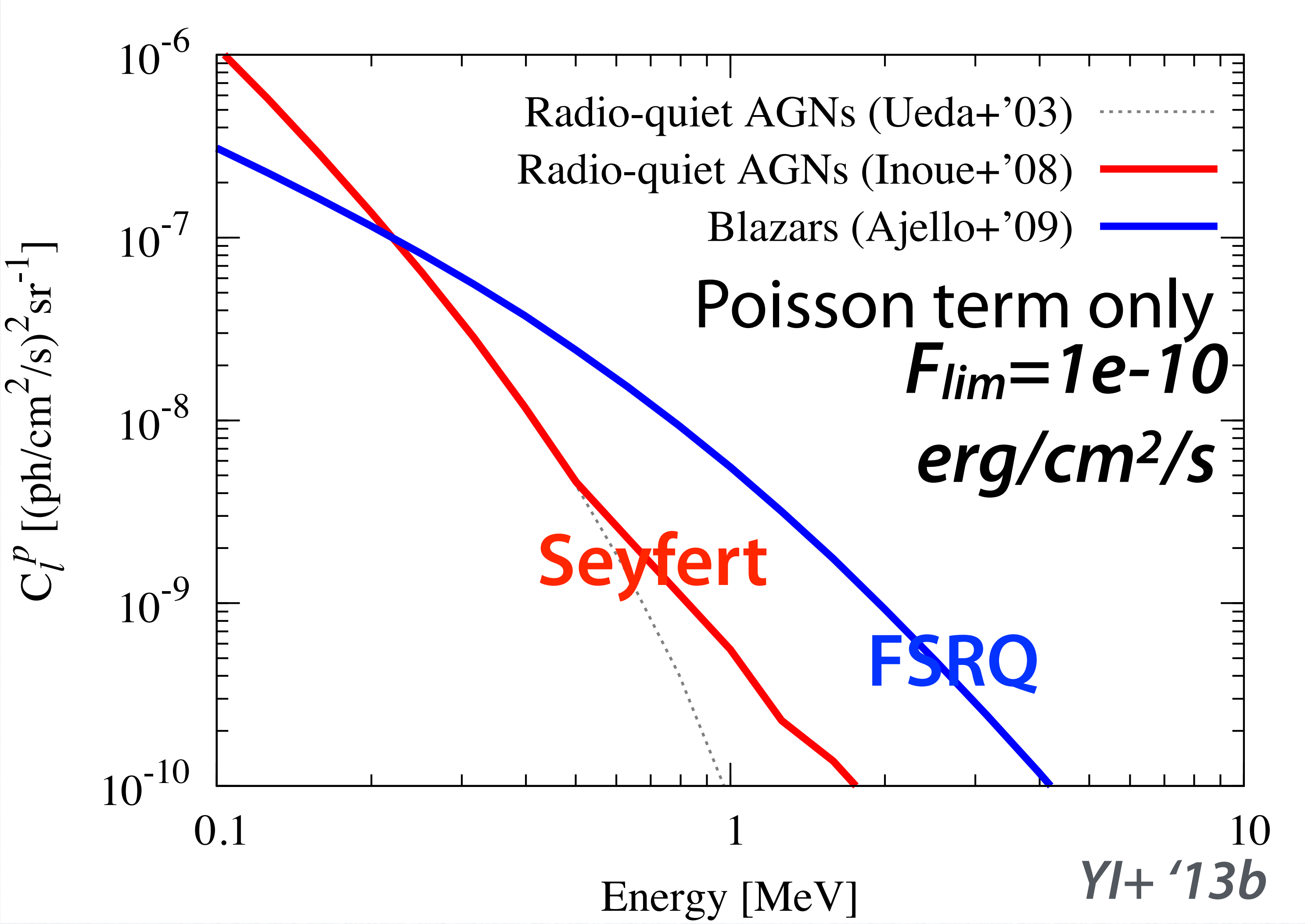
Based on Fermi-LAT



- 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?

Angular Power Spectra of the MeV background



- Even achieving the sensitivity of 10^{-11} erg/cm^2/s, it is hard to resolve the MeV sky (***YI+'15***).
- Answers are in "***Anisotropy***".
  - Cosmic background radiation is not isotropic.
- future MeV satellites will distinguish Seyfert & blazar scenarios through anisotropy in the sky.

Summary

- ALMA will be able to measure the B-field in the vicinity of SMBH through coronal radio emission.
  - a key for understanding the corona heating and the jet launching mechanism
  - We have already seen the coronal radio component in the latest ALMA observation.
- If non-thermal component exists in corona, it will be also able to explain the MeV background by Seyferts.
- ALMA, X-ray, and future MeV gamma-ray observations will unveil the nature of AGN coronae.