Coronal Magnetic Activity in nearby Active Supermassive Black Holes

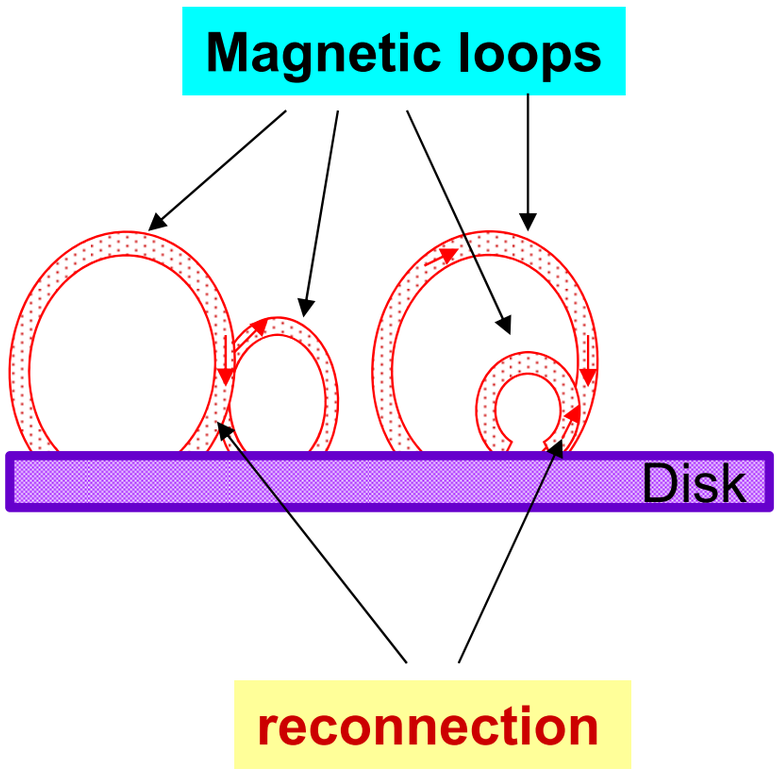
Yoshiyuki Inoue
Akihiro Doi, Dmitry Khangulyan

ASJ Meeting @ Tsukuba, 2020-03-16

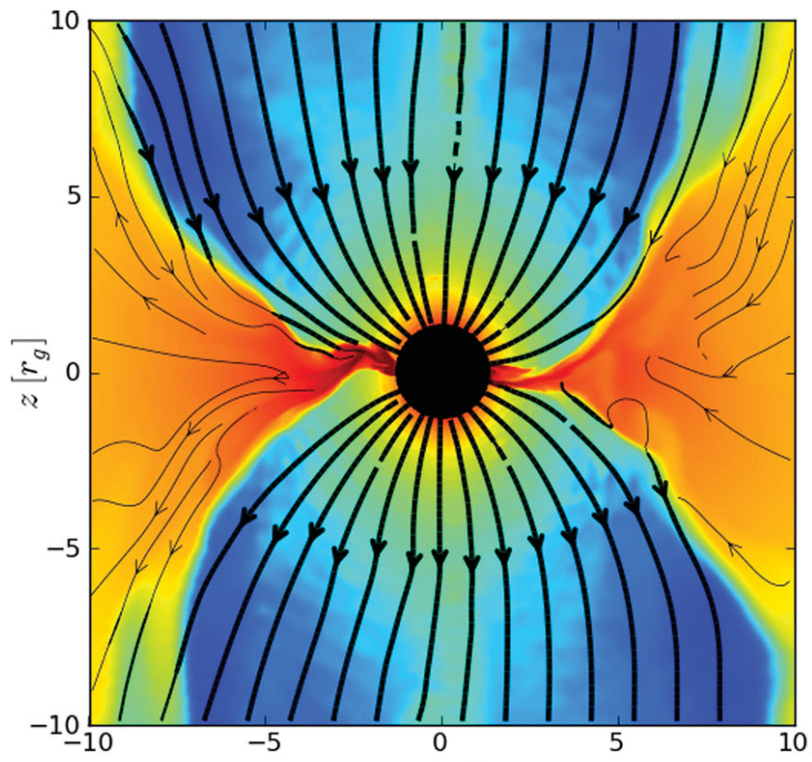
RIKEN iTHEMS KAVLI IPMU INSTITUTE FOR THE PHYSICS AND MATHEMATICS OF THE UNIVERSE

Magnetic Fields around SMBHs

- Never measured. But important for
  - Corona heating
    (e.g., Haardt & Maraschi ’91; Liu, Mineshige, & Shibata ’02)
  - Jet launching
    (e.g., Blandford & Znajek ’77; Tchekhovskoy+’10, ’11)



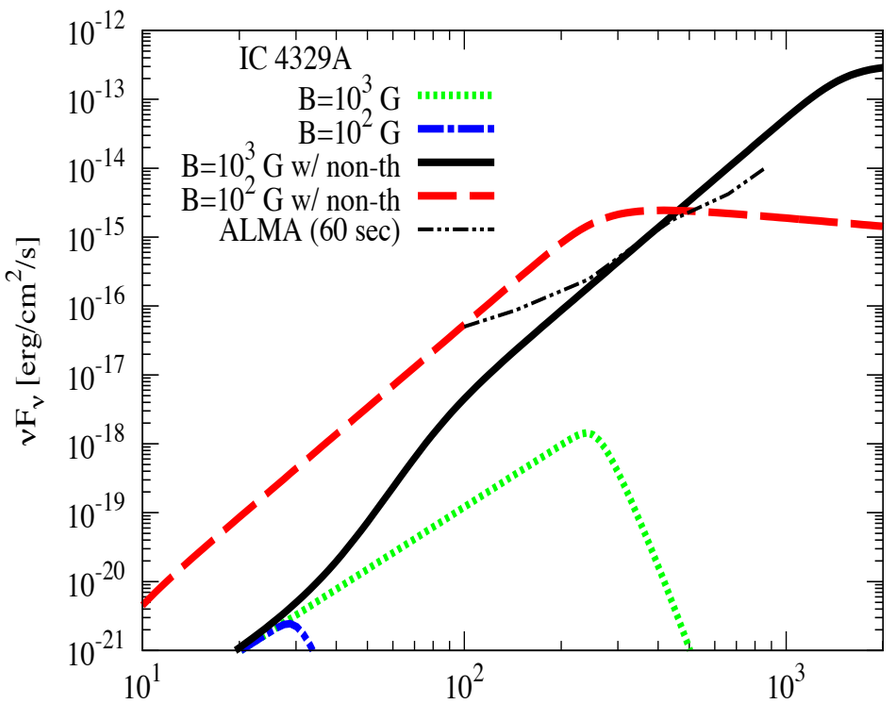
(c) B. Liu



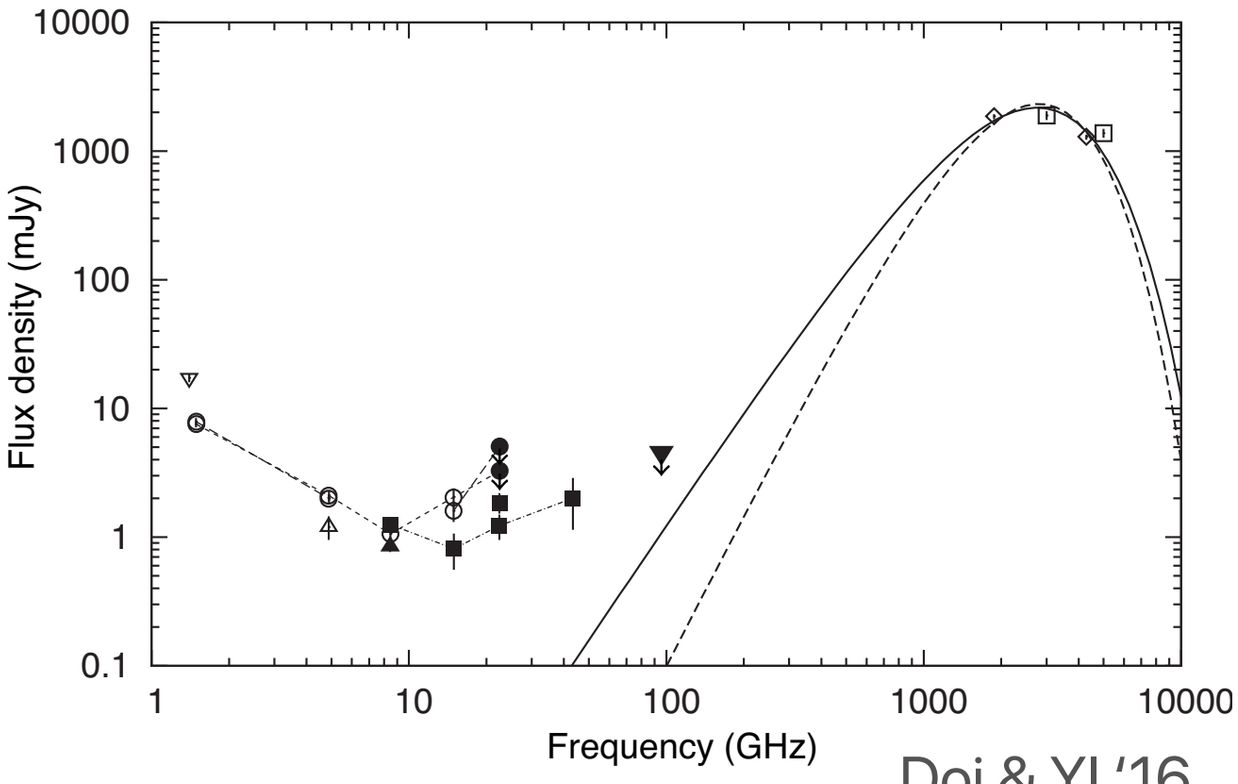
McKinney et al. ’12

Millimeter Excess?

- If the AGN corona is magnetized, synchrotron radiation is expected
  (Di Matteo+'97; YI & Doi '14, Raginski & Laor '16)



YI & Doi '14



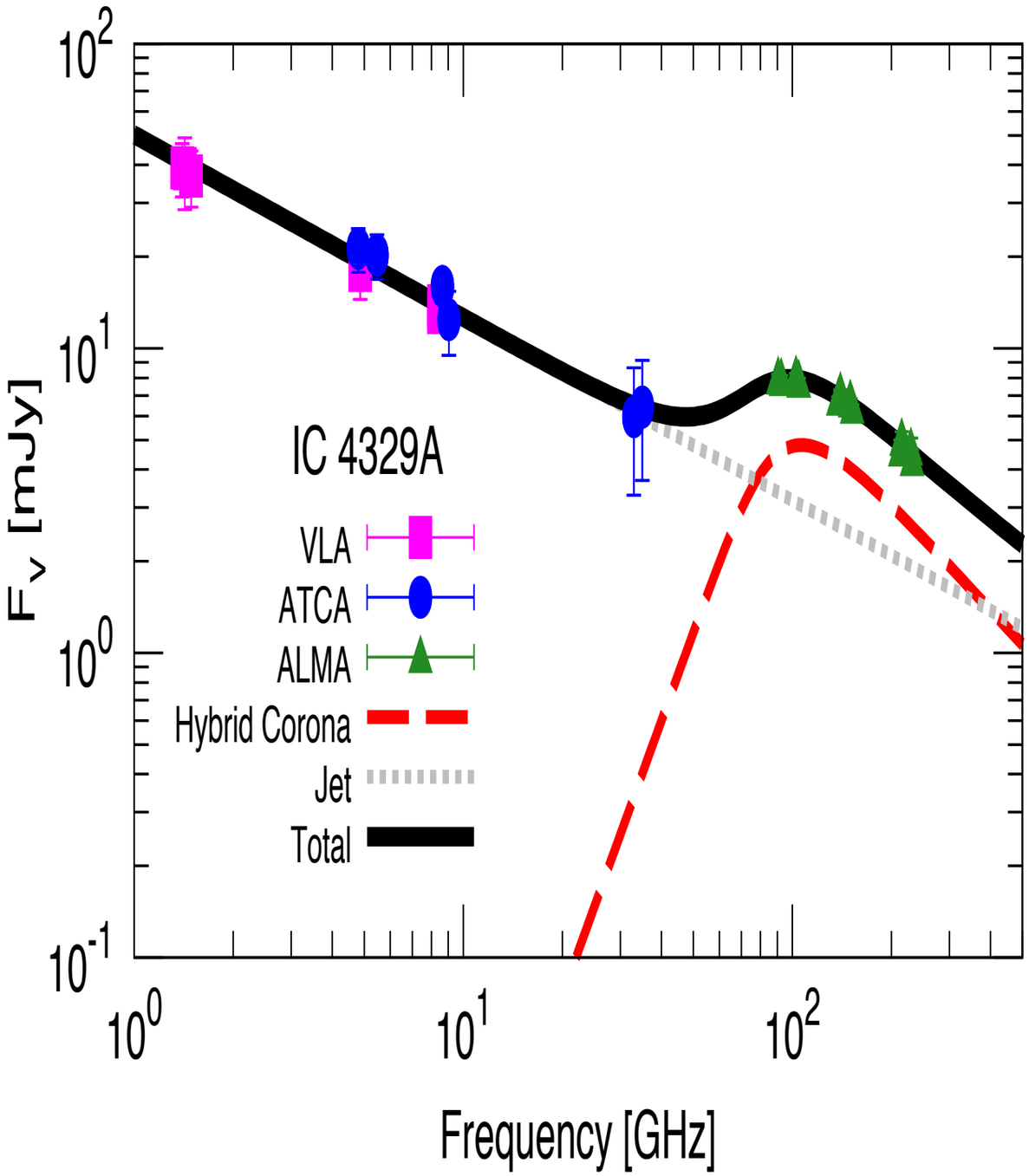
Doi & YI '16

- Possible mm excess
  (e.g., Antonucci & Barvainis'88; Barvainis+'96; Doi & Inoue '16; Behar+'18)
- Contamination of extended components
- Lack of multi-frequency observations.

ALMA Observation toward IC 4329A

- IC 4329A
  - One of the brightest Seyfert galaxies in the Southern sky
  - Type: Seyfert 1.2
  - Distance: ~70 Mpc (~2e26 cm)
  - $M_{BH} \sim 1.2 \times 10^8\ M_\odot$
  - Corona parameter from X-ray by Suzaku/NuSTAR
    - T_e = 50 keV, τ_e=2.34 (Brenneman+'14)

cm-mm spectrum of IC 4329A Core



- Hybrid corona model (YI & Doi '14)
- Non-thermal electron fraction : $\eta = 0.03$ (fixed)
- Non-thermal spectral index $p = 2.9$
- Size: 40 r_s
- B-field strength : 10 G

YI & Doi 2018

Reconnection Corona

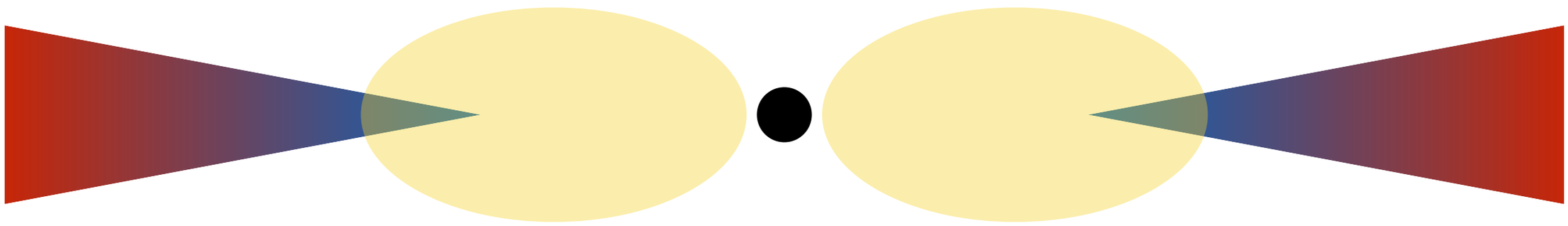
$$\frac{B^2}{4\pi} V_{\rm A} \approx \frac{4kT}{m_e c^2} n\sigma_T c U_{\rm rad} l, \quad \textbf{?}$$

- Magnetic Heating Rate
  - $Q_{B,\,heat} \sim 10^{10}$ erg/cm^2/s
- Compton Cooling Rate
  - $Q_{IC,\,cool} \sim 10^{13}$ erg/cm^2/s (w/ L = 0.1 L_{Edd})
- Magnetic field energy is **NOT** sufficient to keep coronae hot.

A possible interpretation: Truncated disk

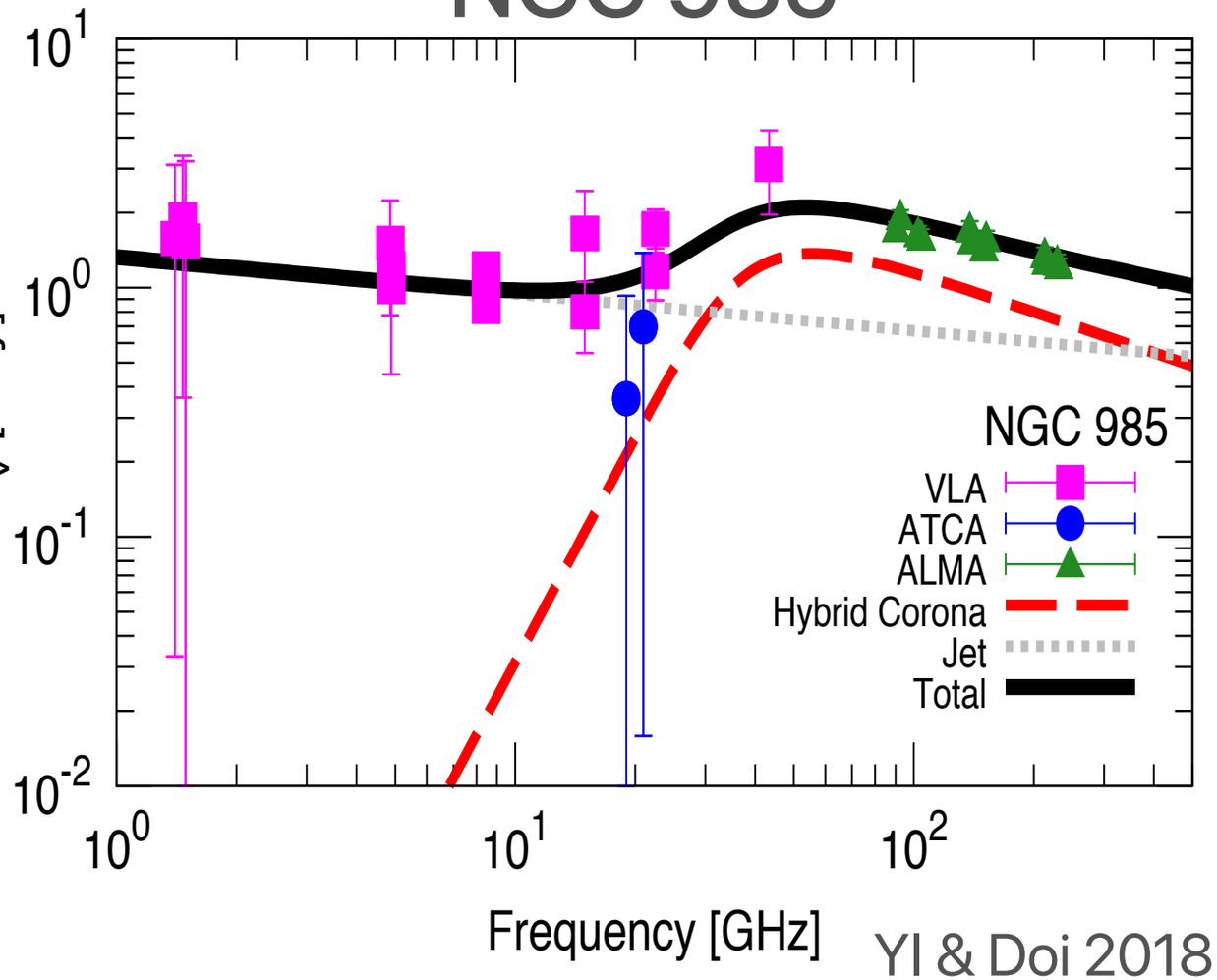
- Standard disk is truncated at some radii (e.g. ~40 r_s)
  - The inner part becomes hot accretion flow (Ichimaru '77, Narayan & Yi '94, '95).
    - Heated by advection.
- Suggested for Galactic X-ray binaries.

  (e.g. Poutanen+'97; Kawabata+'10; Yamada+'13).



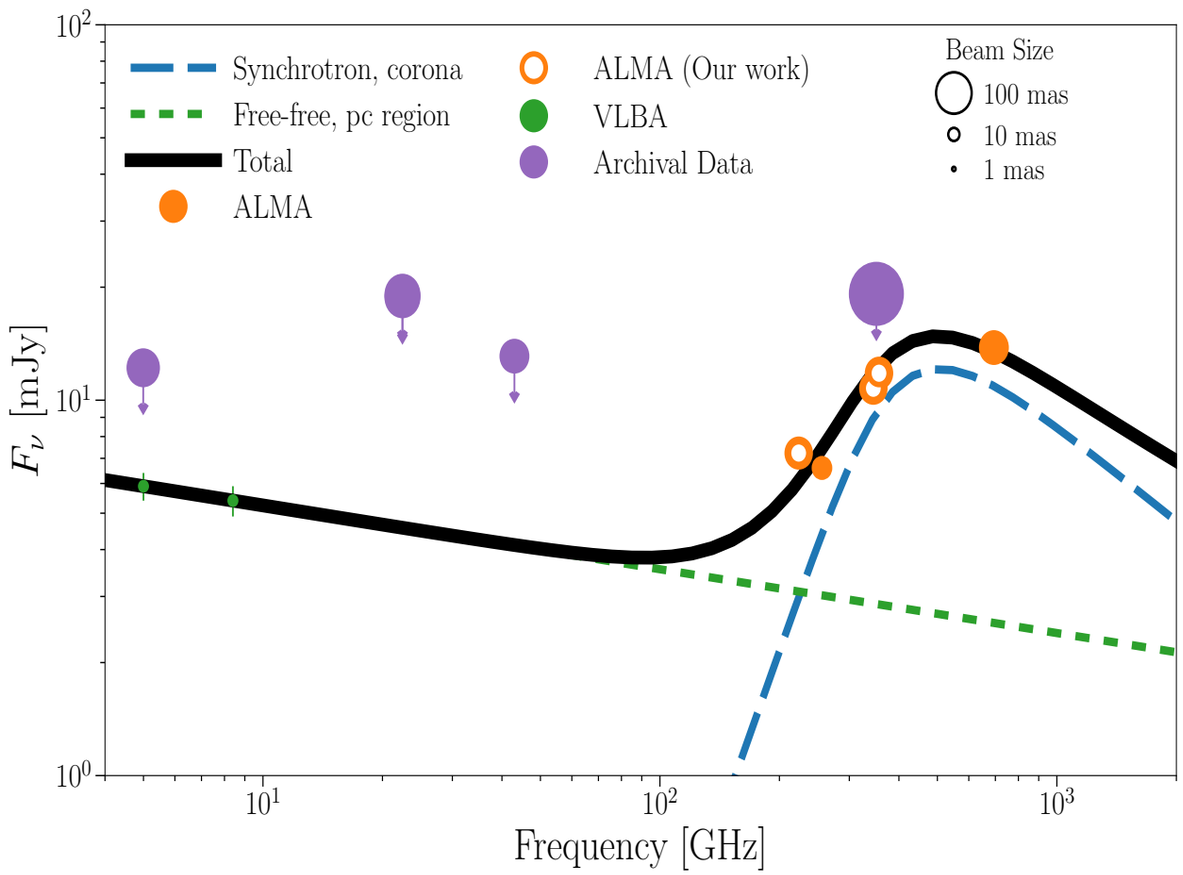
mm-Excess in Other RQ AGNs

NGC 985



YI & Doi 2018

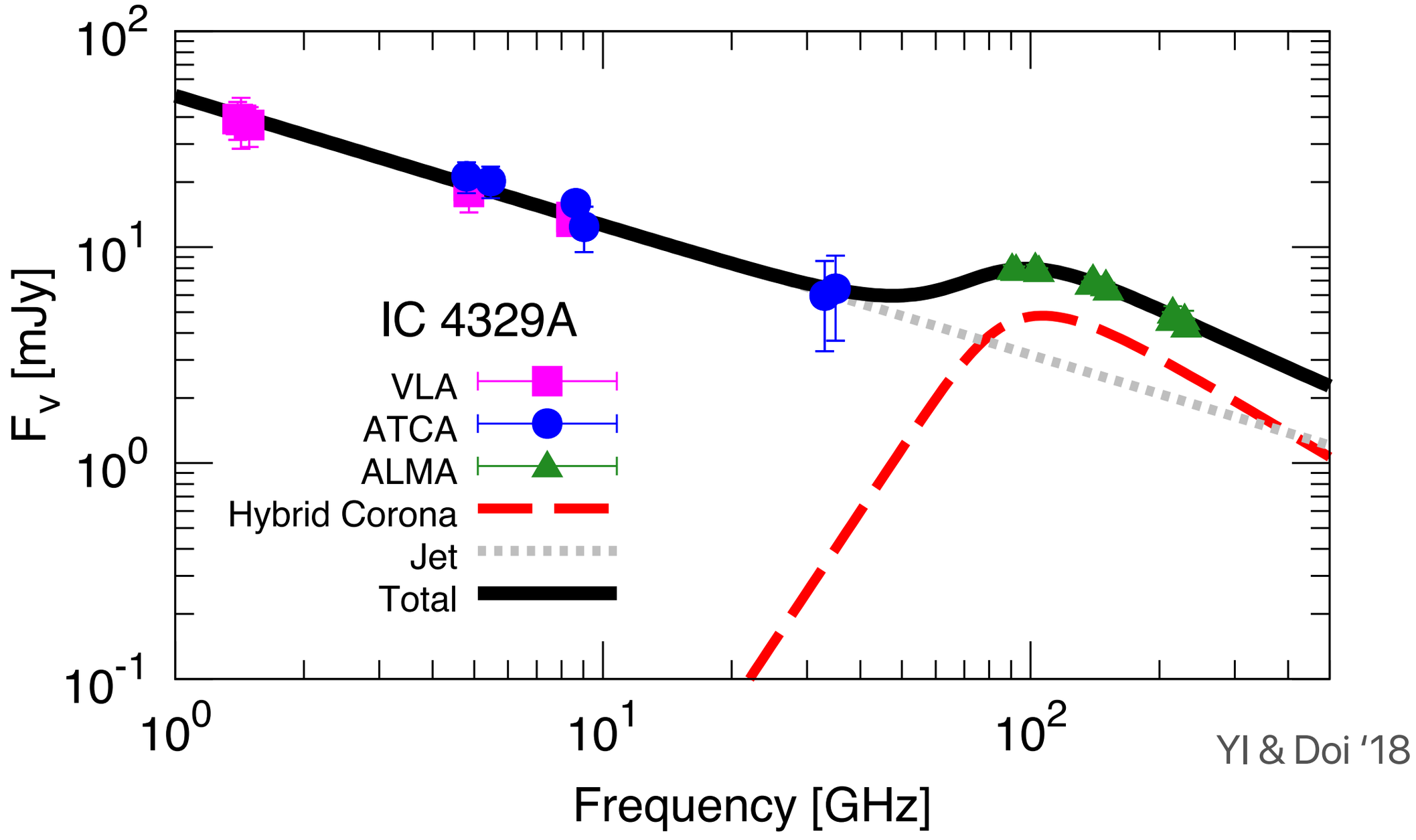
NGC 1068



YI, Khangulyan, & Doi, '20

- NGC 985 is detected. NGC1068 is also marginally detected.
- 9 more RQ AGNs are observed in the ALMA cycle-6.

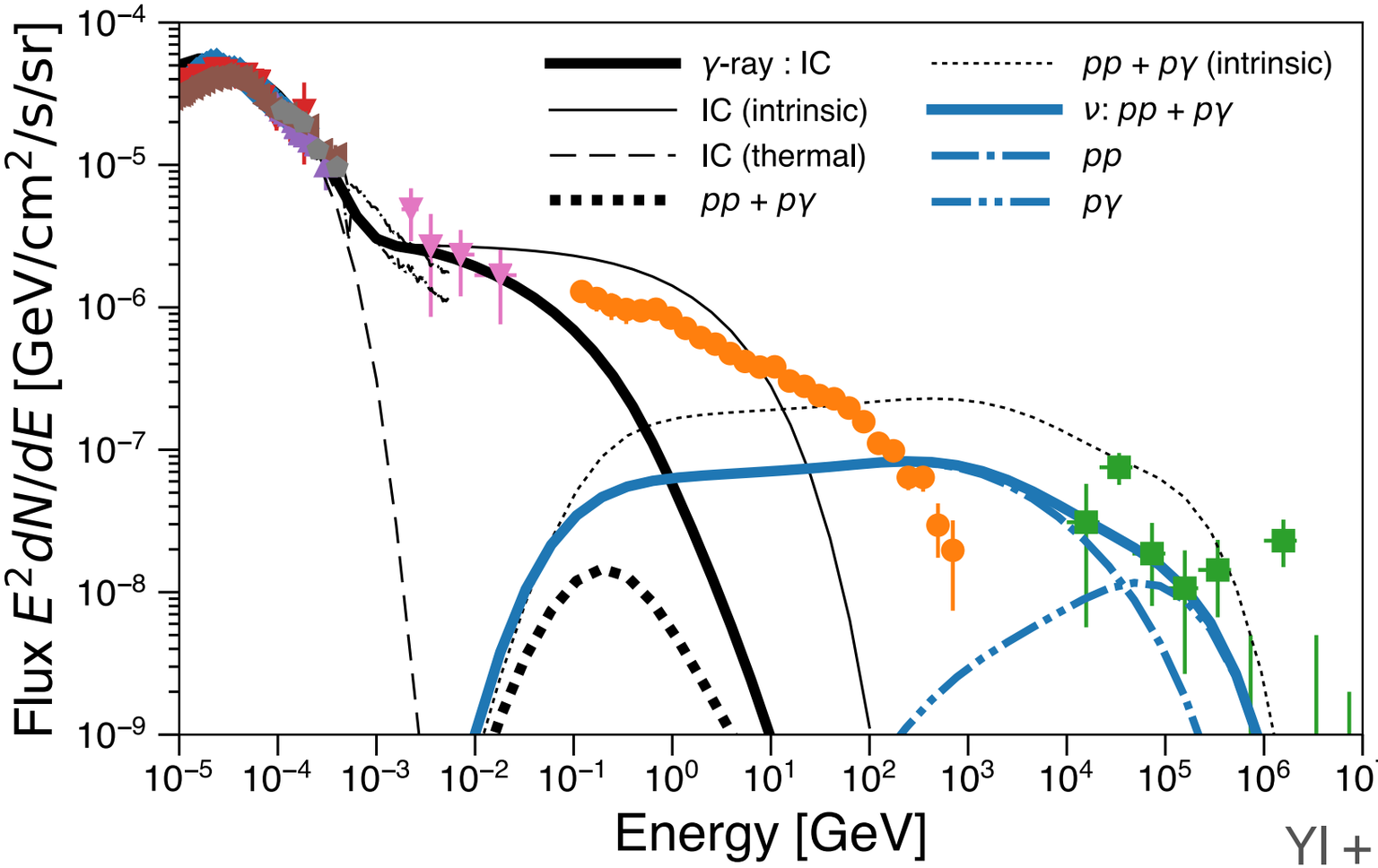
cm-mm spectrum of IC 4329A Core



YI & Doi ‘18

- Non-thermal electrons should exist in the coronae

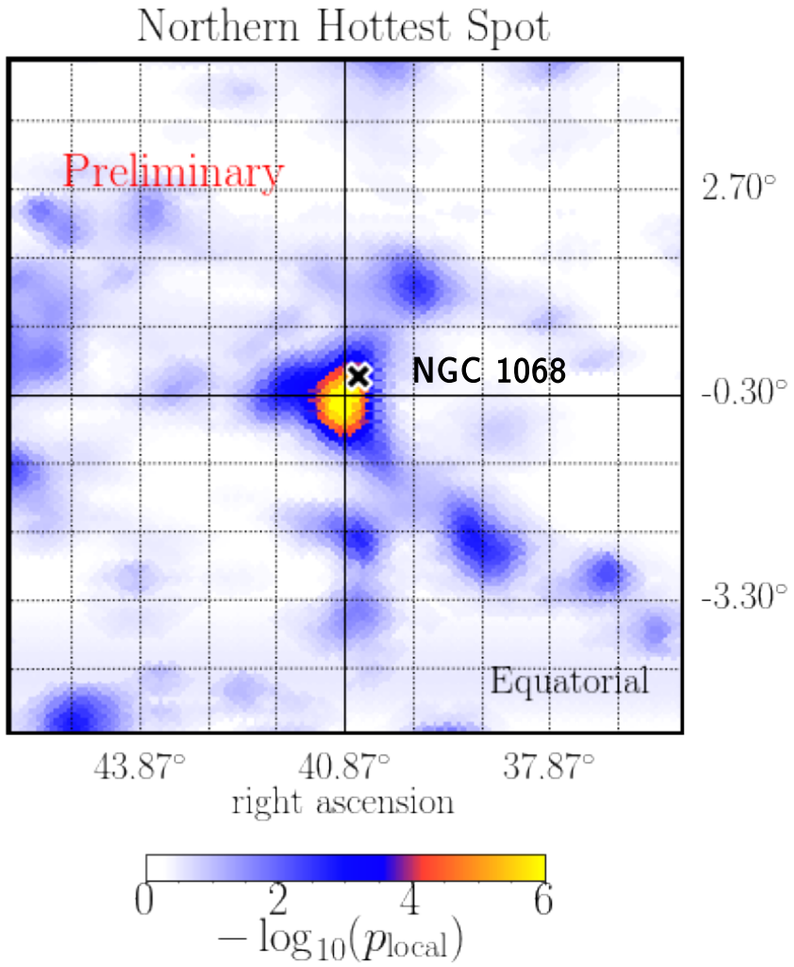
High energy emission from AGN coronae : Cosmic High Energy Background



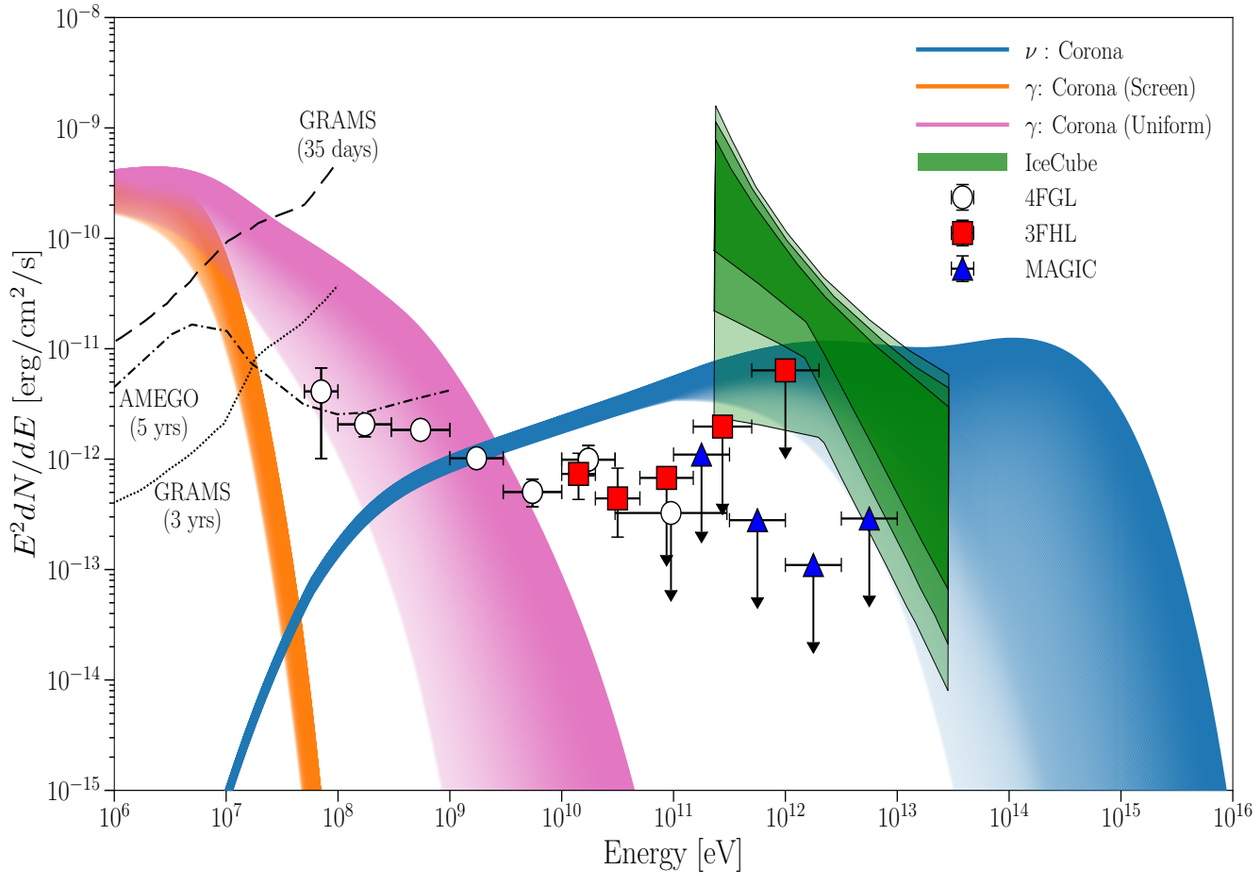
YI + '19

- No GeV emission due to gamma-gamma attenuation
- High energy neutrinos (see also Begelman+'90; Stecker+'92; Kalashev+'15; Murase+'19)
- RQ AGNs can explain X-ray, MeV gamma-ray, & TeV neutrino background.

IceCube Hottest Spot



IceCube 2019 (ICRC)



YI, Khangulyan, & Doi, '20

- Type-2 Seyfert NGC 1068 is reported at 2.9-σ.
- If the signal is real, corona is the neutrino production site.

Summary

- Coronal synchrotron emission from Seyferts are detected.

- Seyferts may be responsible for the cosmic X-ray, MeV gamma-ray, and TeV neutrino background fluxes.

- NGC 1068, type-2 Seyfert, is the hottest spot in the IceCube data.

    - due to the constraints from the gamma-ray band, the coronal activity provides the most feasible explanation.