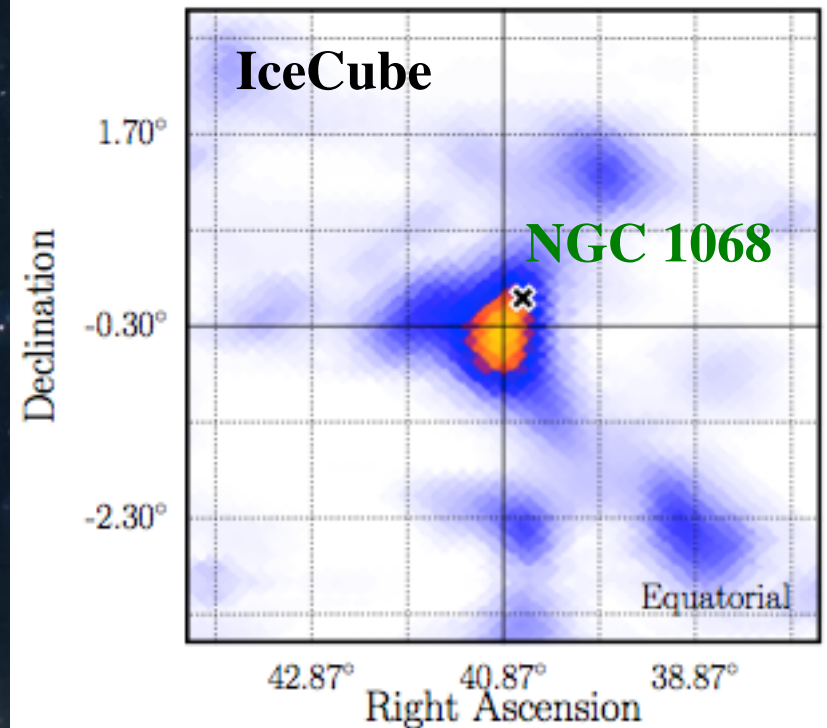
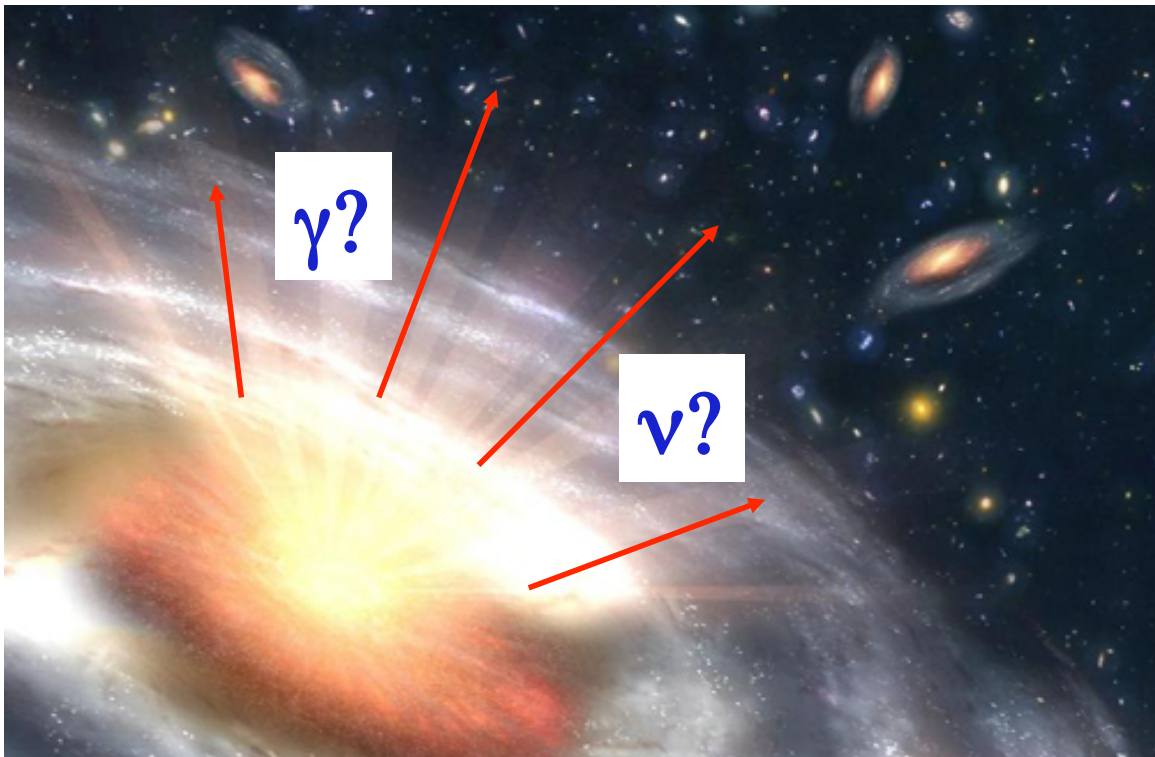


High-Energy Neutrino and γ -Ray Emission from AGN-Driven Winds (NGC 1068)

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Ruo-Yu Liu (Nanjing U), Kohta Murase (PSU/YITP)



*Any way the wind blows
does really matter to me...*



importance of AGN winds

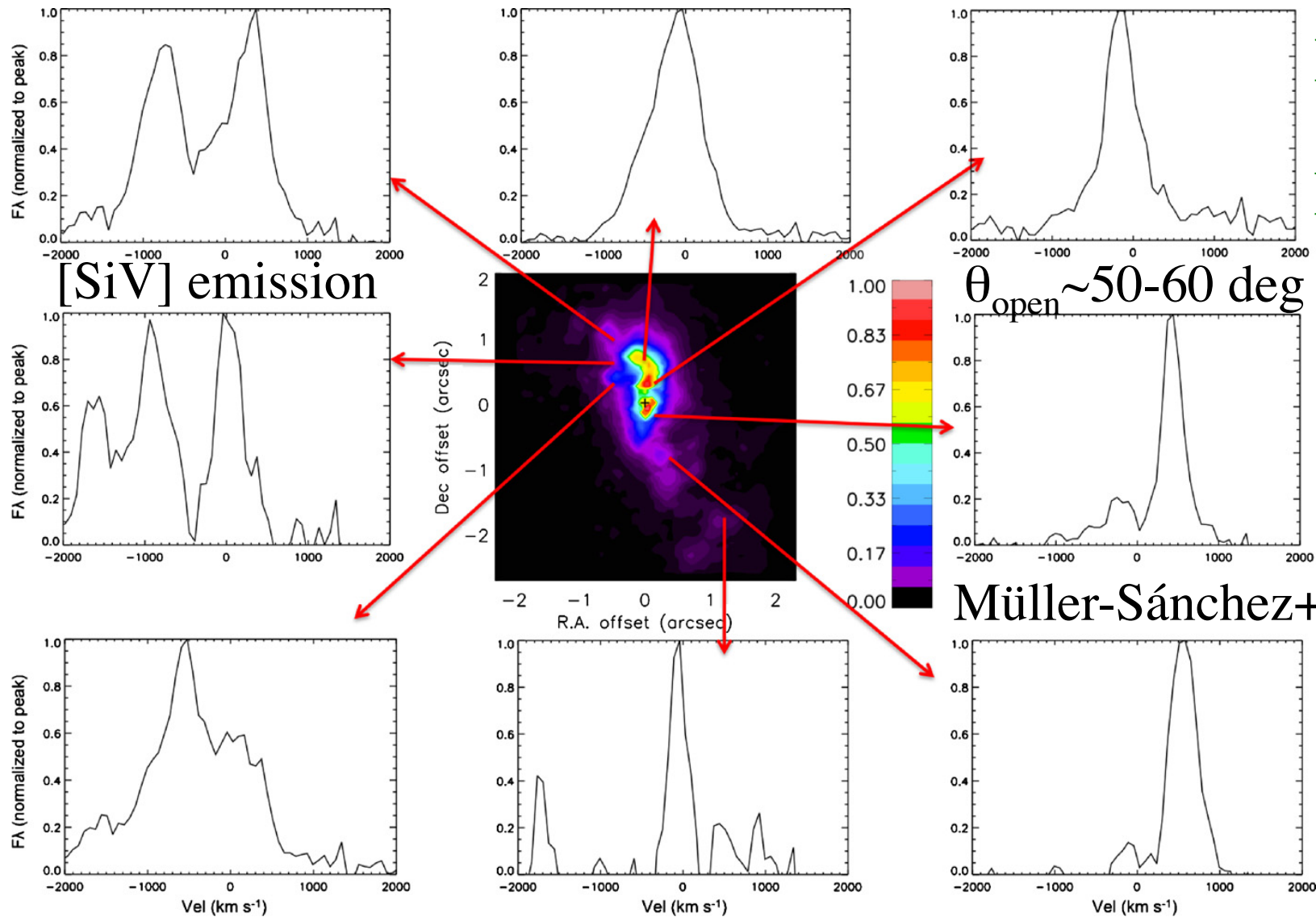
thermal, baryonic plasma; weakly collimated <-> rel. jets

1. Observed to exist, widespread (radio-quiet + radio-loud)
2. Plausibly expected from accretion disks via various mechanisms (unlike jets): thermal, radiative, magnetic...
3. May be important for collimating jets in radio-loud objects
4. May provide mechanical/thermal feedback onto host gas
-> observed BH scaling relations, star formation quenching
5. **May be particle accelerators + nonthermal emitters**
weakly beamed, quasi-isotropic <-> rel. jets
 - kpc-scale external shocks (wind + host galaxy gas)
 - subpc-scale “internal” shocks

evidence for AGN winds

subkpc - fast, highly ionized winds

NGC 1068
Sy 2
D~14 Mpc



evidence for AGN winds

subpc:

ultra-fast outflows (UFOs)

- blue-shifted X-ray absorption lines
- $v \sim 0.05-0.3c$
- $L_{\text{kin}} \sim 0.01-0.1 L_{\text{edd}}$
- $> \sim 40\%$ of all AGNs \leftrightarrow jets

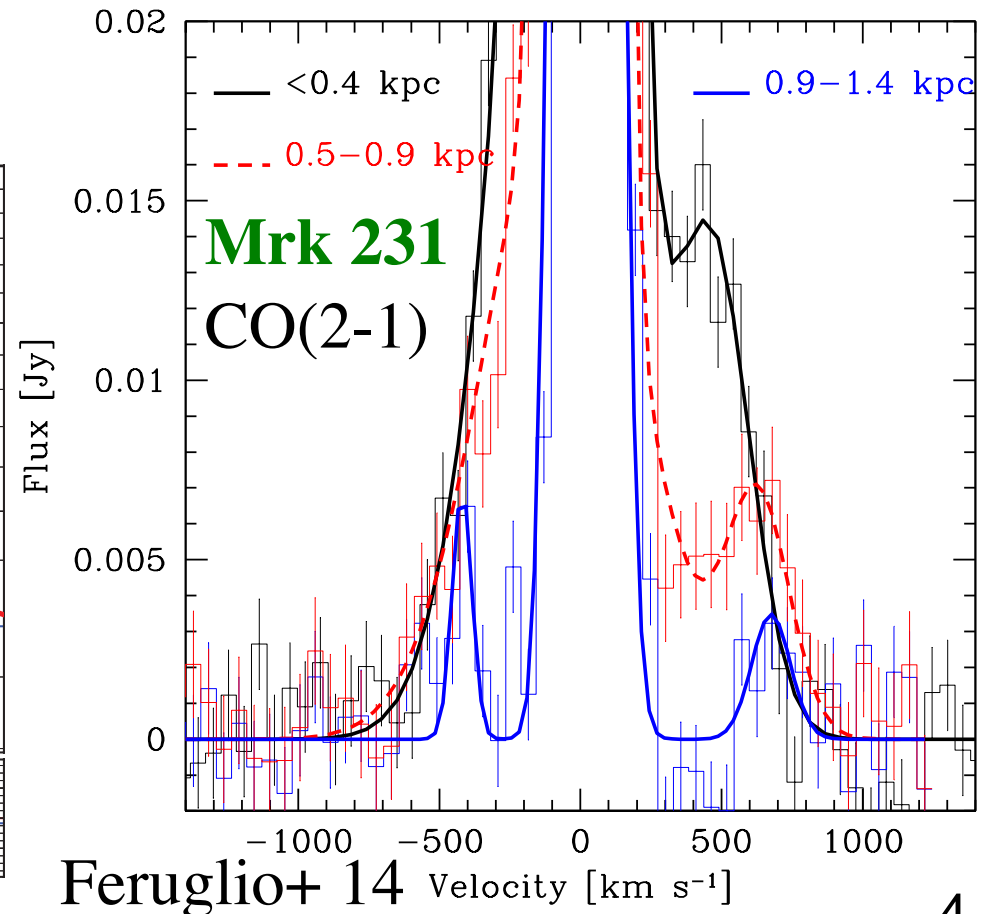
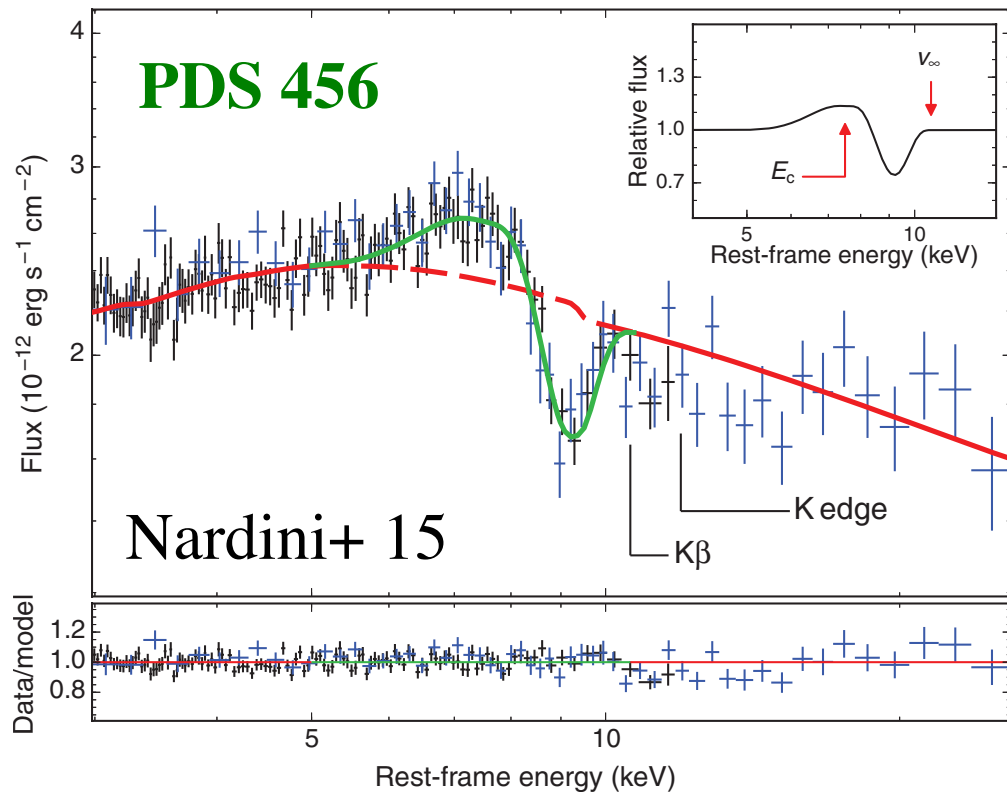
$> \sim \text{kpc}$:

massive molecular outflows

CO, OH etc. emission

$\rightarrow v \sim 100-1000 \text{ km/s}$,

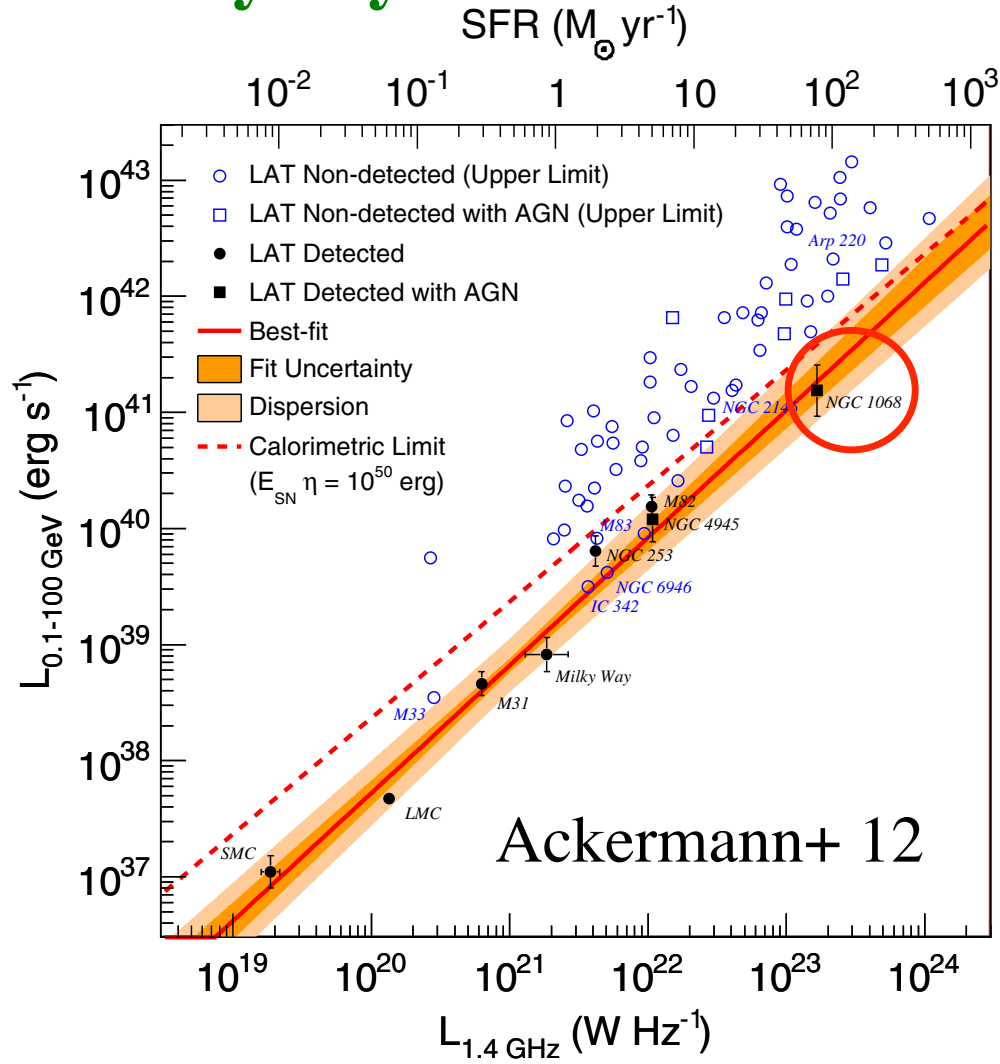
$\dot{M} \sim \text{few } 10-100 M_{\odot}/\text{yr}$, $L_{\text{kin}} \sim < L_{\text{bol}}$



GeV gamma rays from NGC 1068: starburst?

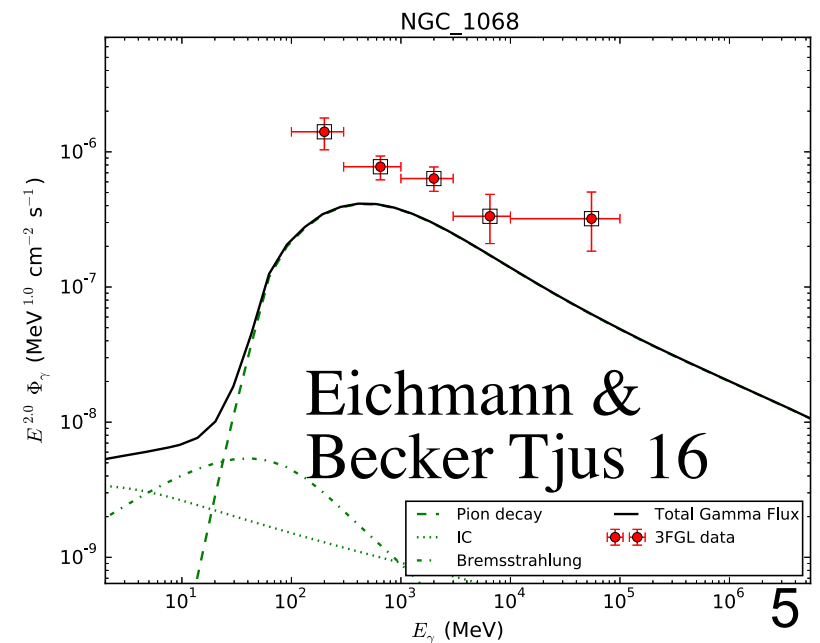
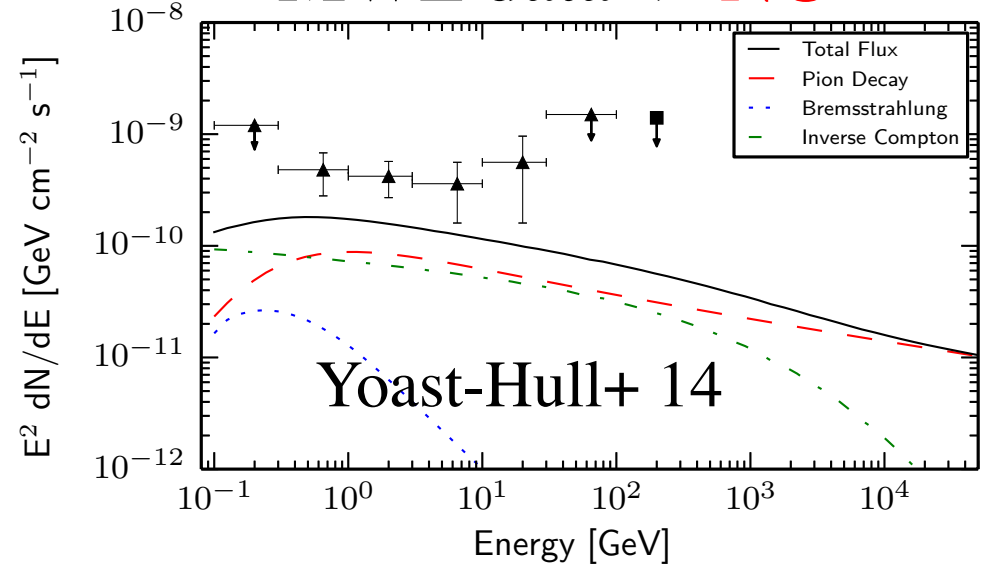
consistency with L_γ -SFR relation

-> **maybe yes**



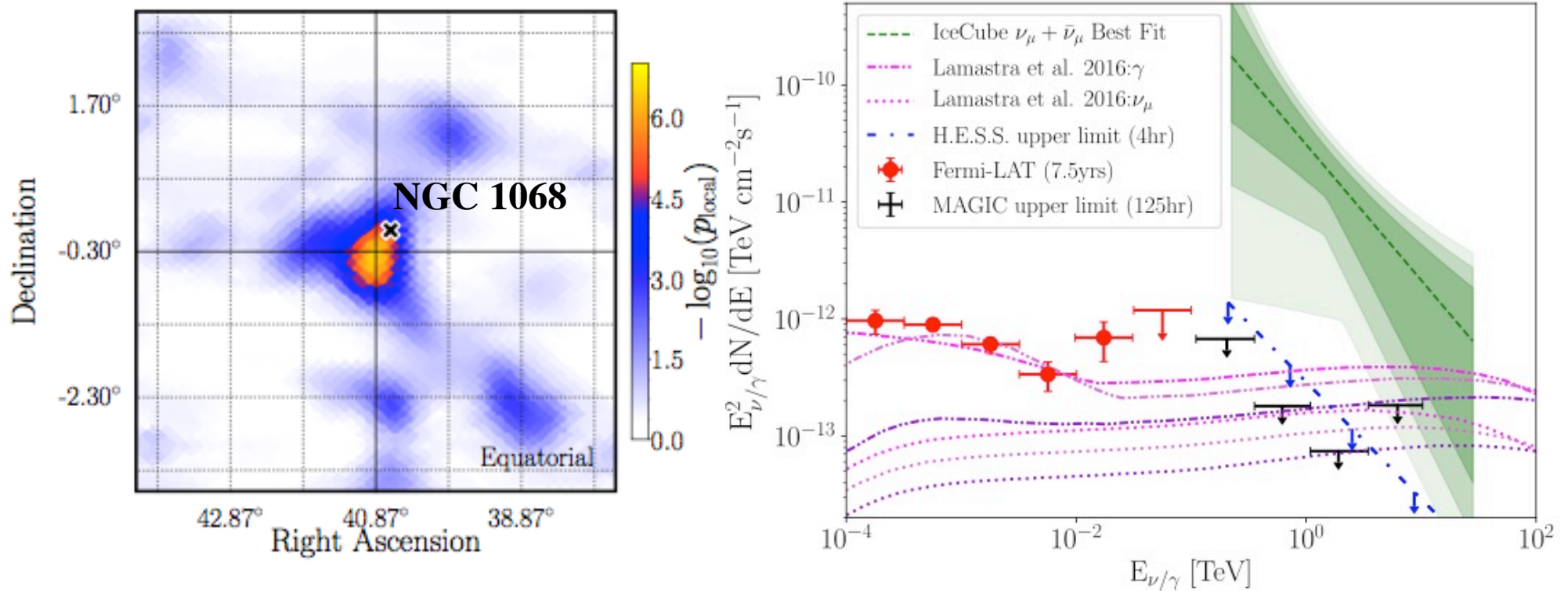
Fermi-LAT sample of
“starburst”+normal galaxies

modeling of detailed
MWL data -> **NO**



high-energy neutrinos from NGC 1068?

IceCube 10-yr time-integrated source search 1910.08488



- most significant point in North from full-sky scan coincident with NGC 1068
- 2.9σ excess at position of NGC 1068 in source catalog search

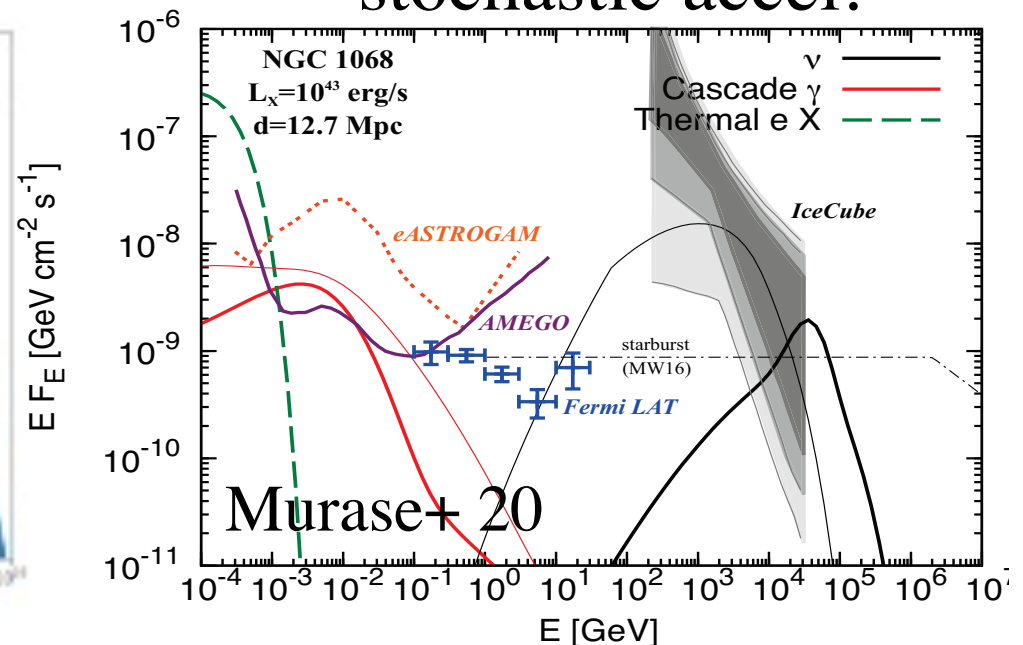
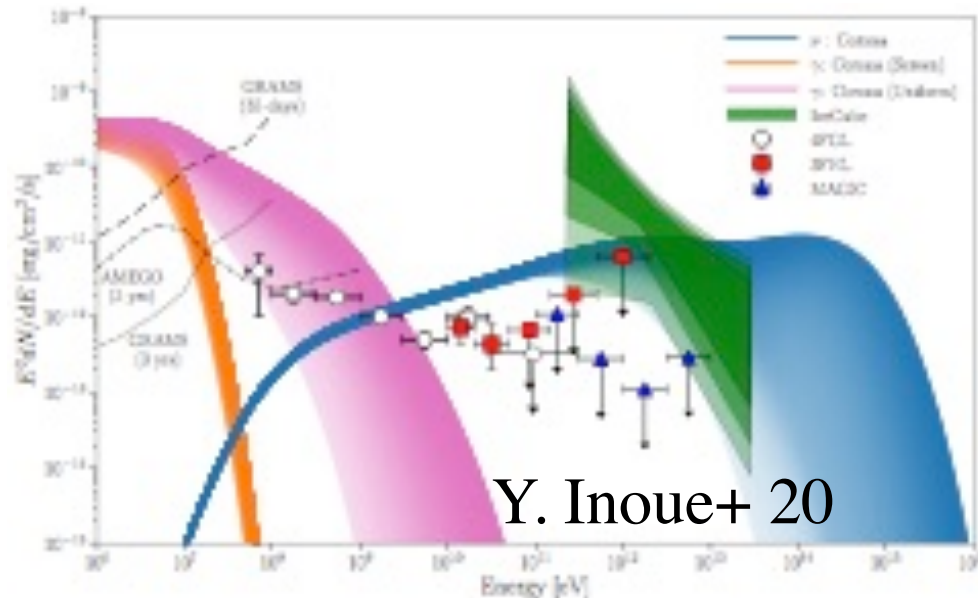
neutrino + gamma from NGC 1068: AGN origin?

AGN wind external shock models e.g. Lamastra+ 16
 (generally pp models optically thin to $\gamma\gamma$)
 strongly constrained by MAGIC TeV upper limits



pp(+p γ) in compact regions optically thick to $\gamma\gamma$,
 e.g. accretion disk coronae?
 shock accel.

stochastic accel.



GeV γ rays? robustness of particle acceleration?

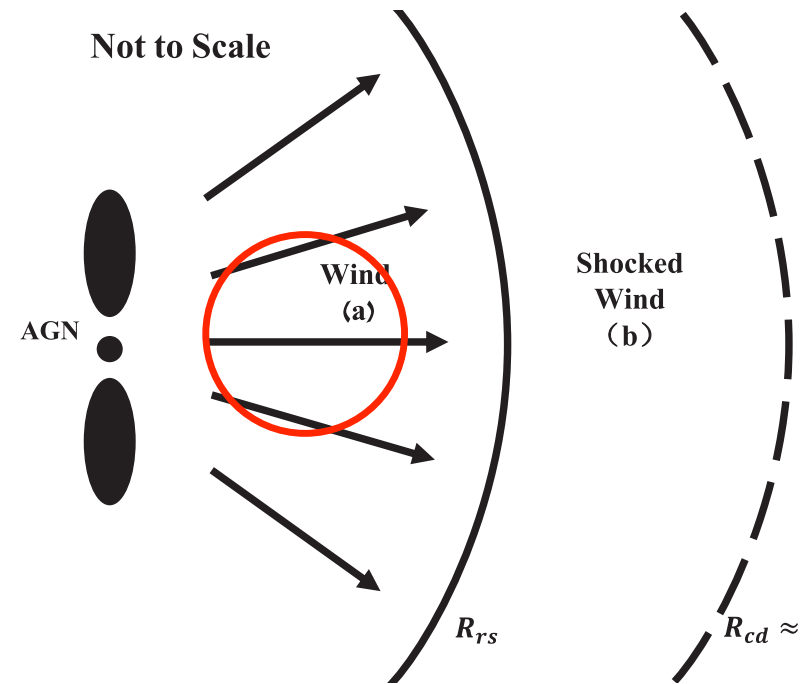
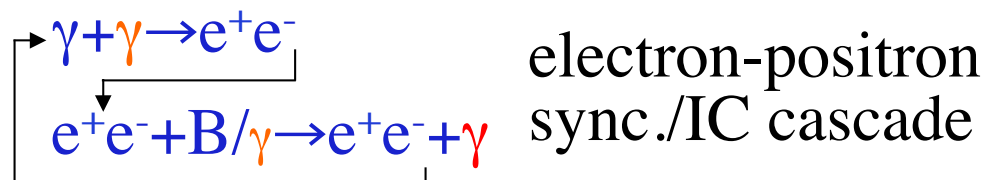
$p\gamma$ ν (+ γ) from inner regions of AGN winds

potential particle acceleration via:

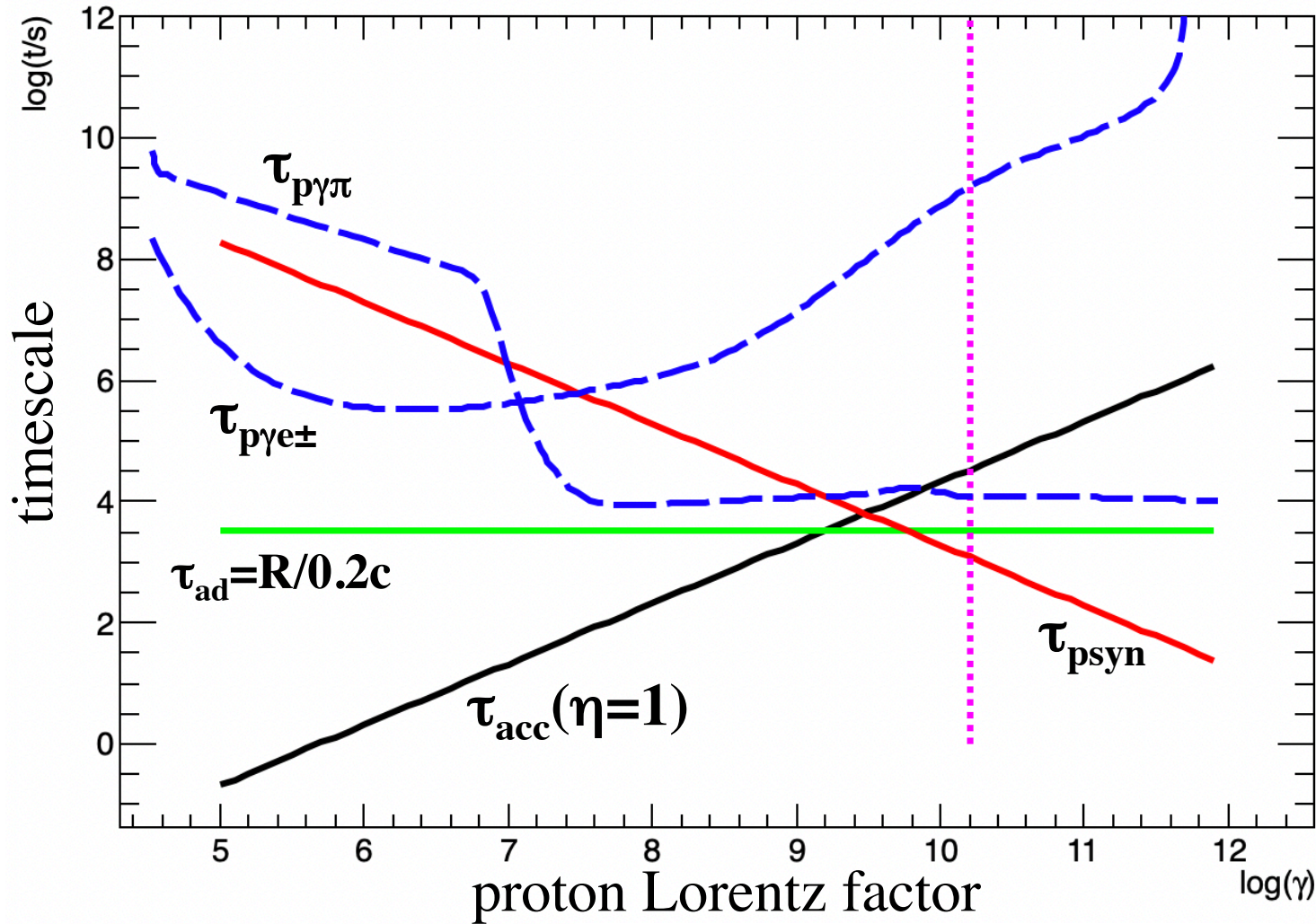
- internal shocks caused by highly variable wind ejection (observational evidence + theoretical support)
- “interaction” shocks with external or internal clouds/stars

$p\gamma$ interactions with nuclear radiation

- neutrinos $\sim < 10$ PeV
- cascade $\sim < \text{MeV-GeV}$

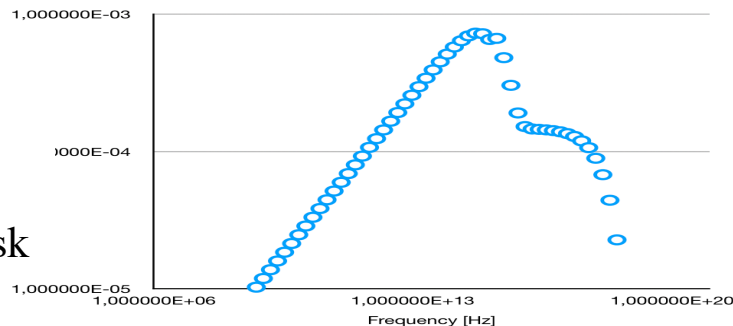


py in inner regions of AGN winds: timescales

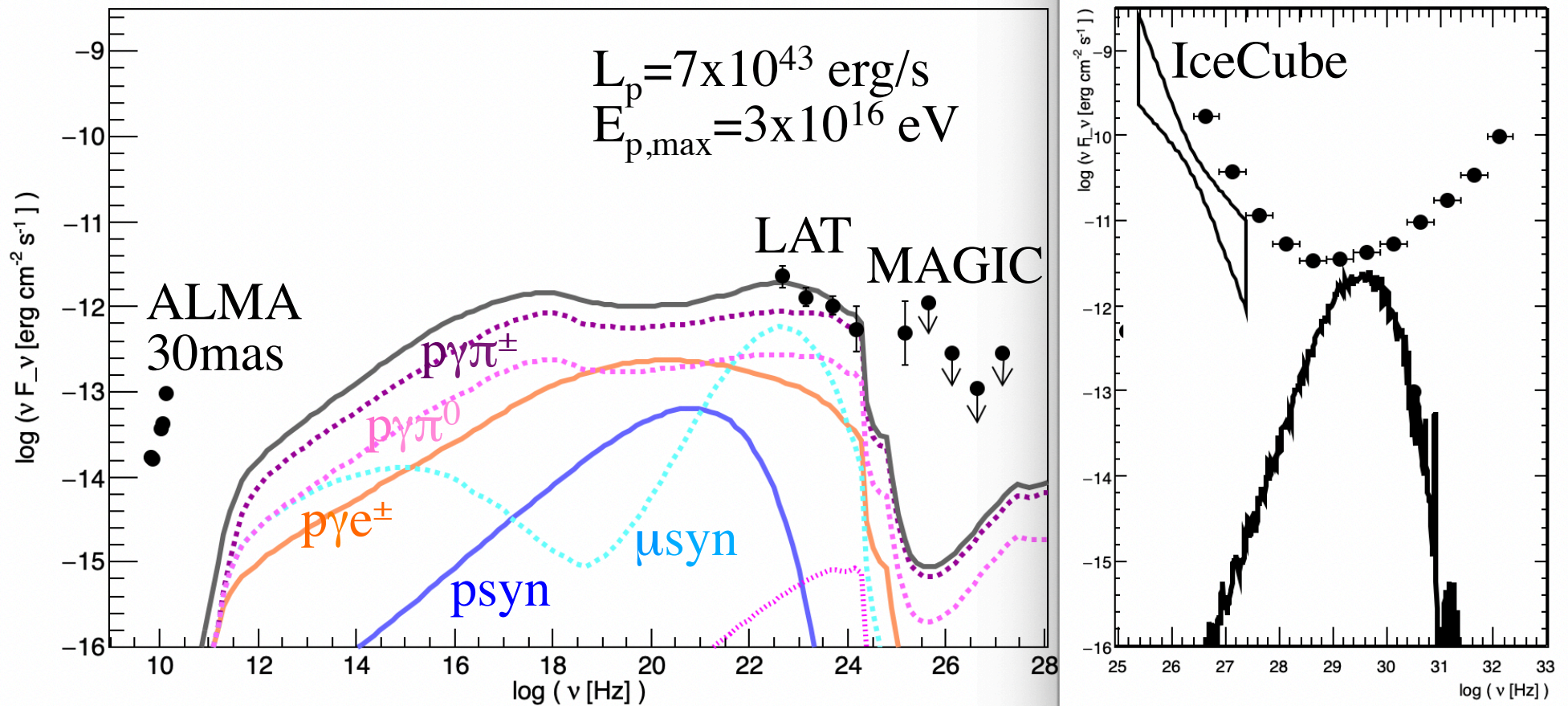


$R=10^{14}$ cm ($3R_s$)
 $z=10^{15}$ cm ($30R_s$)
 $B=500$ G
 (c.f. $\epsilon_B \sim 0.08$ for
 $L_{kin}=5 \times 10^{44}$ erg/s)

$M_{BH}=10^8 M_\odot$
 $L_{disk}=10^{44}$ erg/s
 $L_{cor}=0.01-0.1 L_{disk}$



wind internal model for NGC 1068: example



- promising in comparison with observed GeV-TeV γ, ν
- > parameter search in progress, please stay tuned
- clear break due to $\gamma\gamma$ on disk field
- cascade spectrum: $f_\nu \propto \nu^{-1}$ @keV-GeV, $\propto \nu^{-0.5}$ <keV
below observed radio/submm

summary High-energy $\nu+\gamma$ emission from AGN winds

fact: AGN winds - fast, powerful, widespread

potential consequences: (besides feedback onto host galaxy gas, etc)

- particle acceleration+nonthermal $\nu+\gamma$ emission
- possible origin of GeV $\gamma+\nu$ from NGC 1068
- > modeling in progress, please stay tuned

outlook

- nearby Seyferts by IceCube-Gen2, CTA, etc
- contribution to diffuse n
- unique info on AGN winds (B field, etc)