Galaxy/Cluster Mergers: Diffuse γ, ν Backgrounds

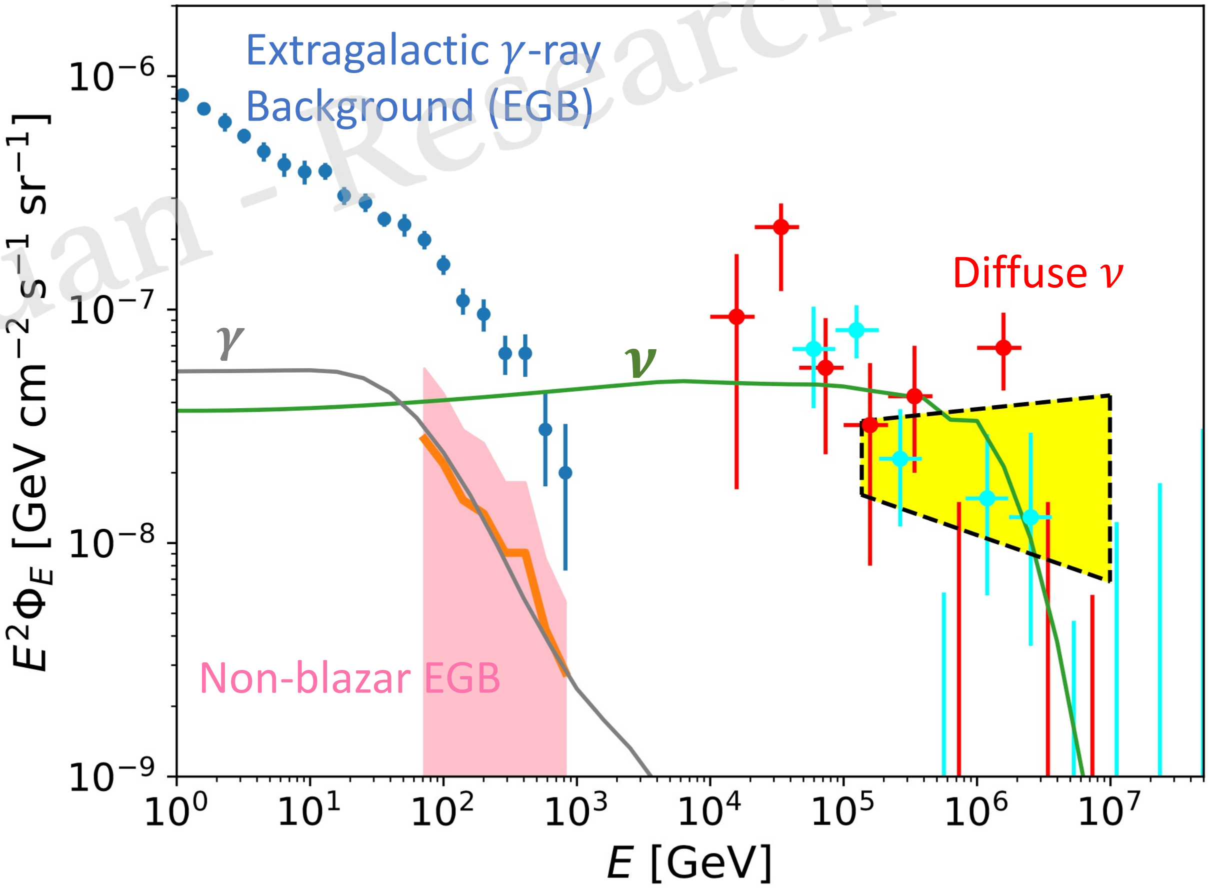
Blazars account for 86^{+16}_{-14} % of the total EGB flux. (Ackermann+ 2016)
but are not the dominant source of IceCube diffuse ν background. (Aartsen+17 …)

γ-ray hidden neutrino emitters -> Diffuse ν

Galaxy/cluster mergers: ✓
- **Strong shocks**
  CR acceleration + *pp* interaction -> HE ν
- **Strong redshift evolution**
  cosmic $\gamma\gamma$ attenuation with EBL/CMB suppresses γ-ray flux

We model:
halo mass function + redshift evolution of gas fraction, galactic/intergalactic magnetic field, shock velocities, … + CR transport/interactions

Yuan+ 18 ApJ 857:50



Stacking and Multiplet Constraints

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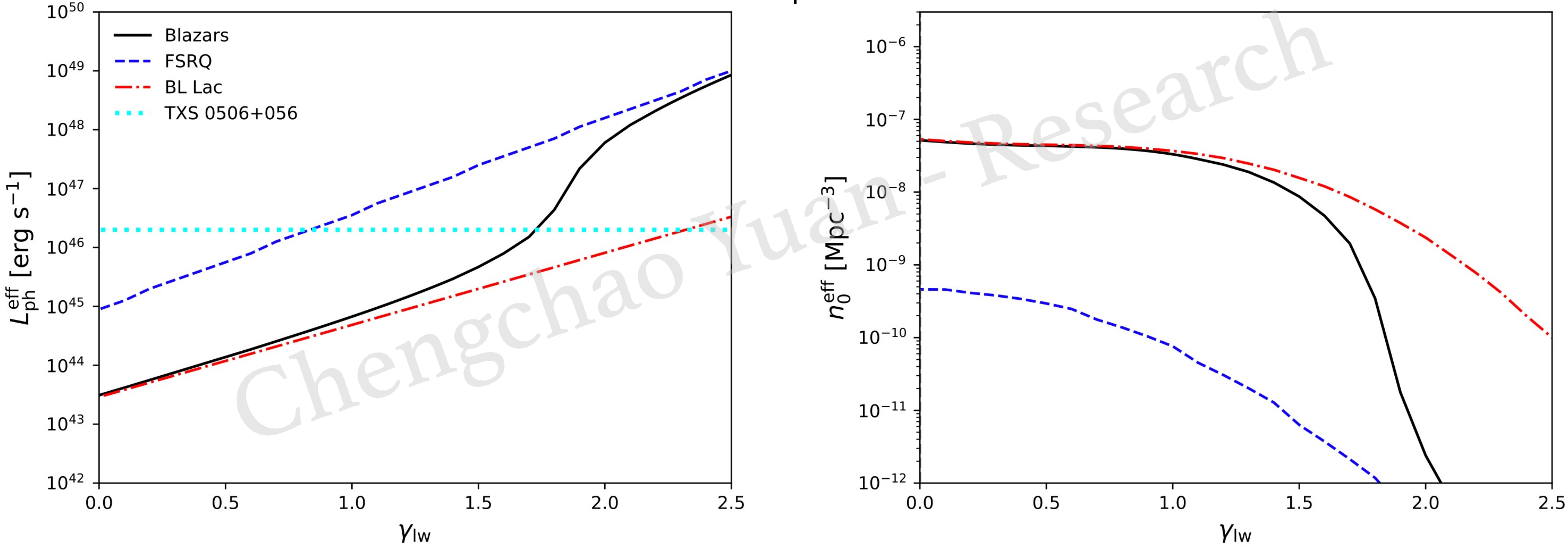


Figure 4. Left panel: the effective gamma-ray luminosity for FSRQs (blue dashed line), BL Lacs (red dashed–dotted line), and all blazars (black line). The dotted horizontal line indicates the luminosity of TXS 0506+056, one blazar that features an intermediate luminosity ($L_{TXS} \simeq 10^{46.3}$erg s^{-1}; Murase et al. 2018). Right panel: the effective local number densities for different source classes. The line styles in this panel have the same meaning as the left panel.

Constraints on Blazar Neutrinos

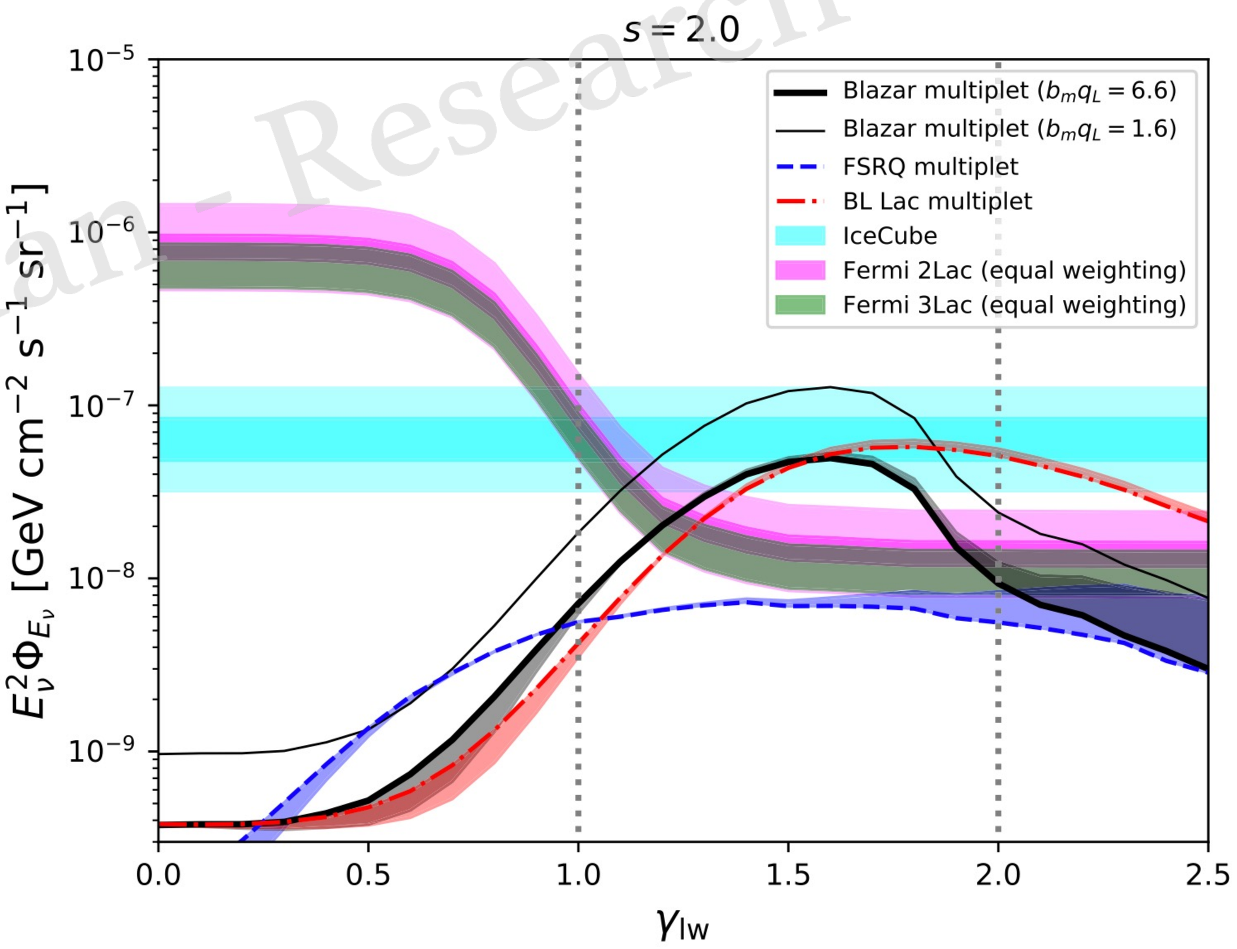
Stacking and cross-correlation analyses with *Fermi* 2LAC/3LAC/4LAC:
no more than 15-27% IC diff. ν
(e.g., Aartsen+17, Hooper+19, Smith+21…)

Multiplet constraint: absence of clustering in HE **ν**s
-> tightly limits the number density and effective luminosity of sources

For a general weighting $L_\nu \propto (L_{\rm ph})^\gamma$, **they are complementary**.

Blazars are disfavored as the dominant sources of the 100 TeV **ν** background.

But, can AGNs be the main source?



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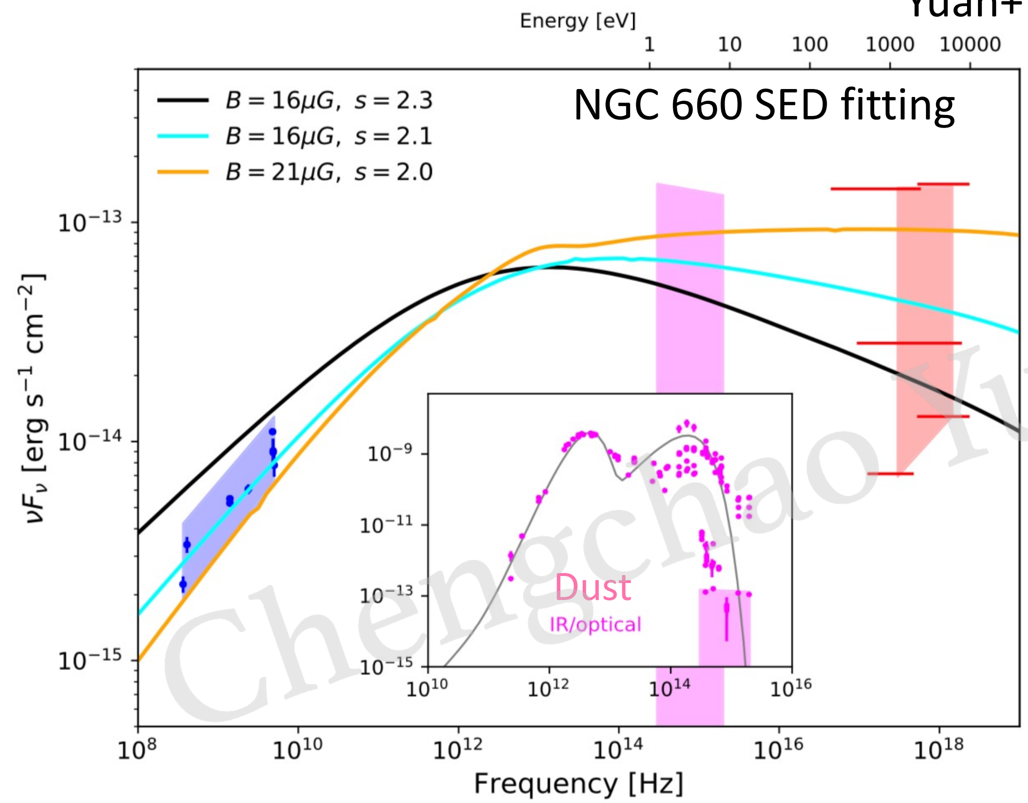
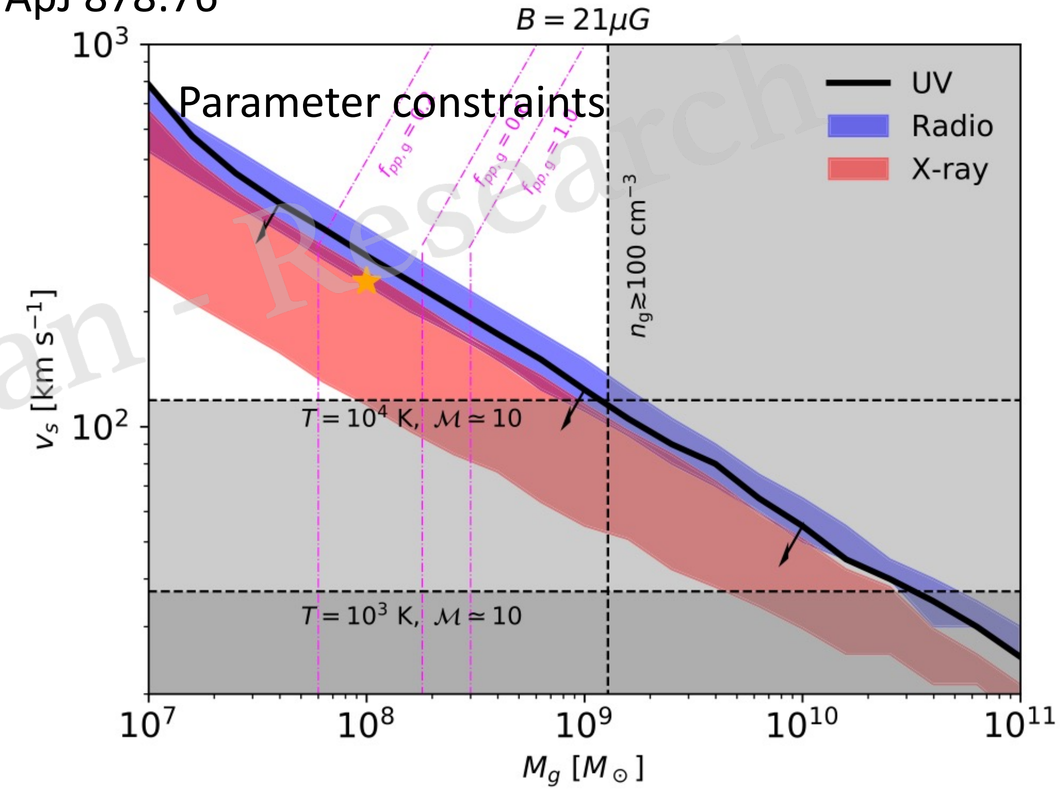
Galaxy/Cluster Mergers: Secondary EM Emission

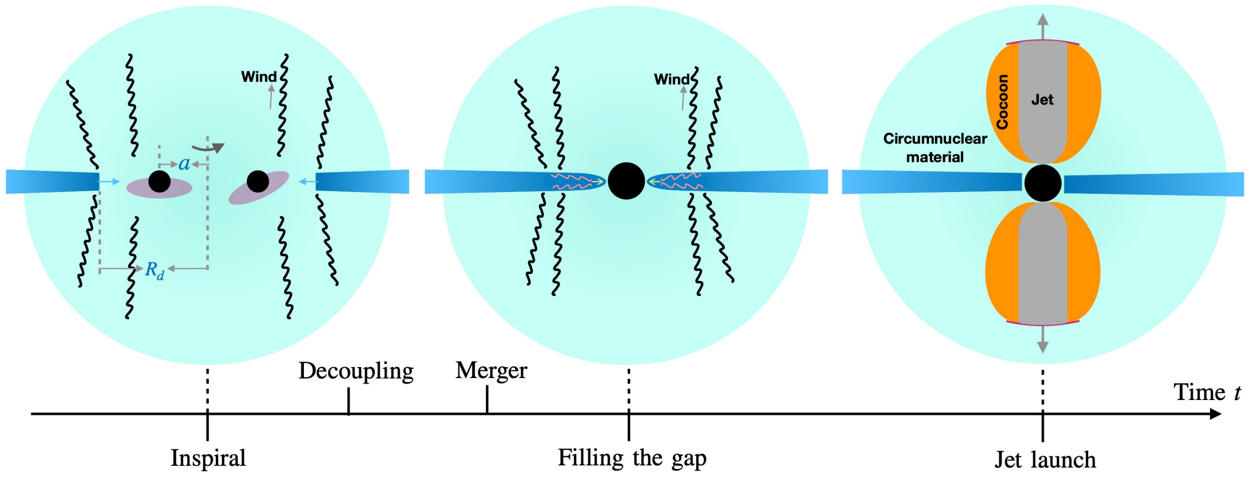
Yuan+ 19 ApJ 878:76





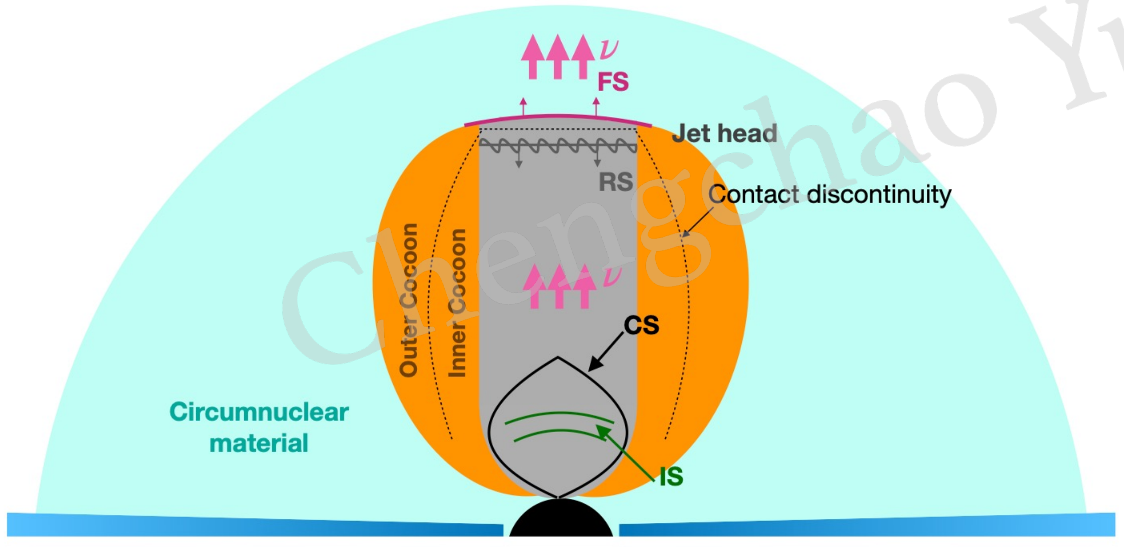
- *pp* collision -> secondary e^-/e^+ (+galactic mag. field) -> observable radio/X-ray emission (via **synchrotron + synchrotron self-Compton**)
- This scenario can explain the radio and X-ray fluxes of merging galaxies such as **NGC 660**.
- **Stringent constraints** on gas mass, shock velocity, mag. field, and the CR spectral index.

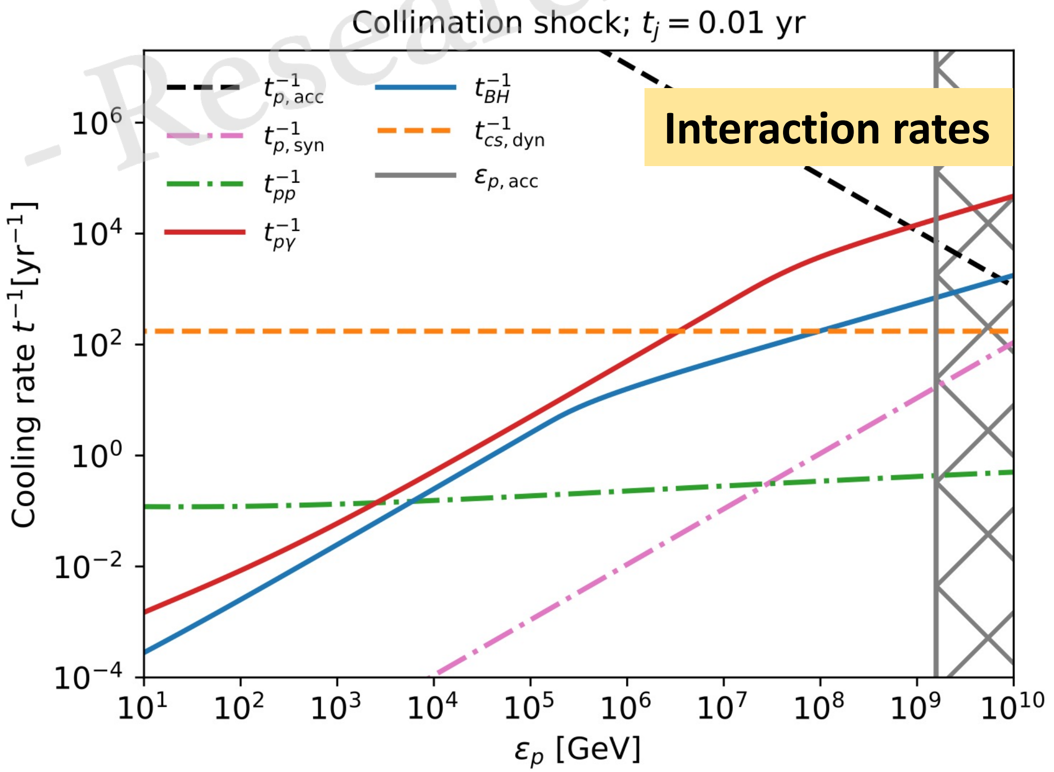
νs from SMBH Mergers: Physical Picture



Merger -> circumnuclear gas bubble (wind) + jet (BZ mechanism) -> internal, collimation, forward and reverse shocks -> **VHE CRs, PeV neutrinos ($p\gamma$)**

Time lag between GW burst and jet launch: **10^{-3}-10^{-2} yr**





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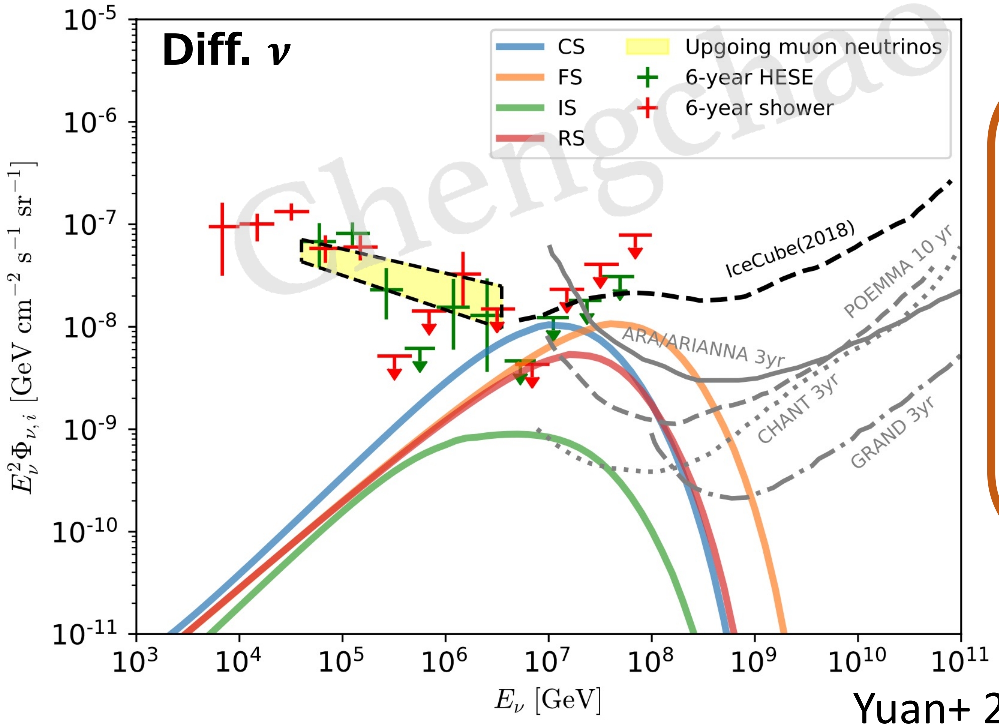
νs from SMBH Mergers: Detectability, Diff. ν

Neutrino detection rate $\dot{N}_{\nu,i}$ for SMBH mergers within the LISA detection range $z \lesssim 6$ [yr^{-1}]

	Optimistic parameters $\dot{m}=10,\ L_{k,j}\simeq 3.4\times10^{46}$ erg s^{-1}, $\epsilon_p=0.5,\ h=0.3$			Conservative parameters $\dot{m}=0.1,\ L_{k,j}\simeq 3.4\times10^{44}$ erg s^{-1}, $\epsilon_p=0.5,\ h=0.01$		
Scenario	IC (up+hor)	IC (down)	IC-Gen2 (up+hor)	IC (up+hor)	IC (down)	IC-Gen2 (up+hor)
CS	0.019	0.014	0.16	8.2×10^{-5}	4.3×10^{-5}	3.7×10^{-4}
IS	9.1×10^{-4}	7.8×10^{-4}	4.2×10^{-3}	1.7×10^{-6}	1.3×10^{-6}	9.5×10^{-6}
FS	2.6×10^{-3}	1.8×10^{-3}	0.013	9.6×10^{-5}	7.2×10^{-5}	4.1×10^{-4}
RS	0.011	8.4×10^{-3}	0.044	3.5×10^{-4}	1.9×10^{-4}	2.1×10^{-3}

Super-Eddington **Sub-Eddington**



Optimistic case (super-Edd.): **IceCube Gen2 + LISA coincident detection rate ~1-2 per decade**; Challenging for sub-Edd. cases.

Optimistic cases can explain a significant potion of diffuse ν in the 1-100 PeV energy range. Can be tested by next-gen ν detectors.

Uncertainties: luminosity and redshift distributions of SMBH mergers

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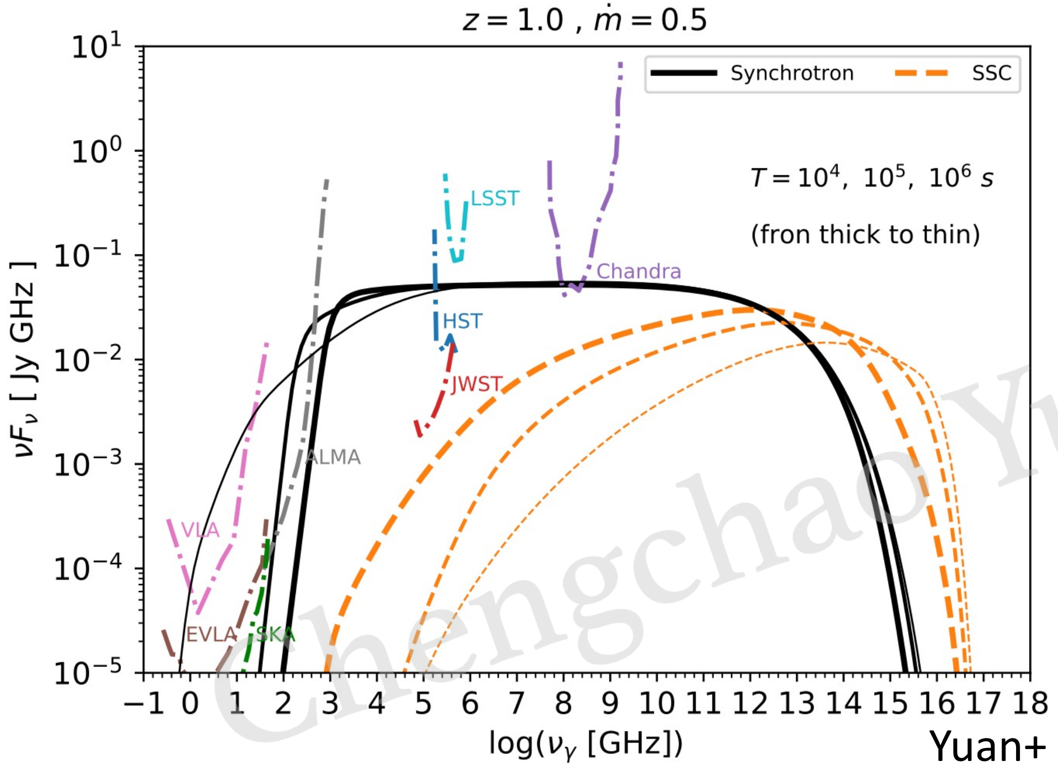
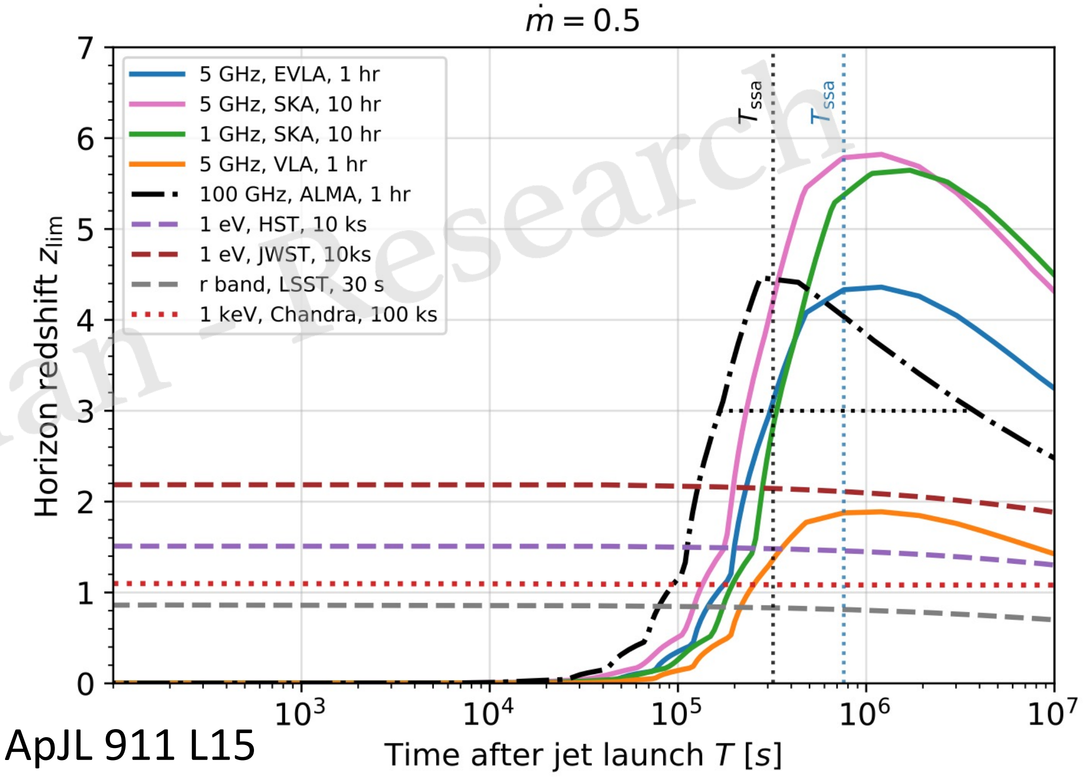
SMBH Mergers: EM Counterpart





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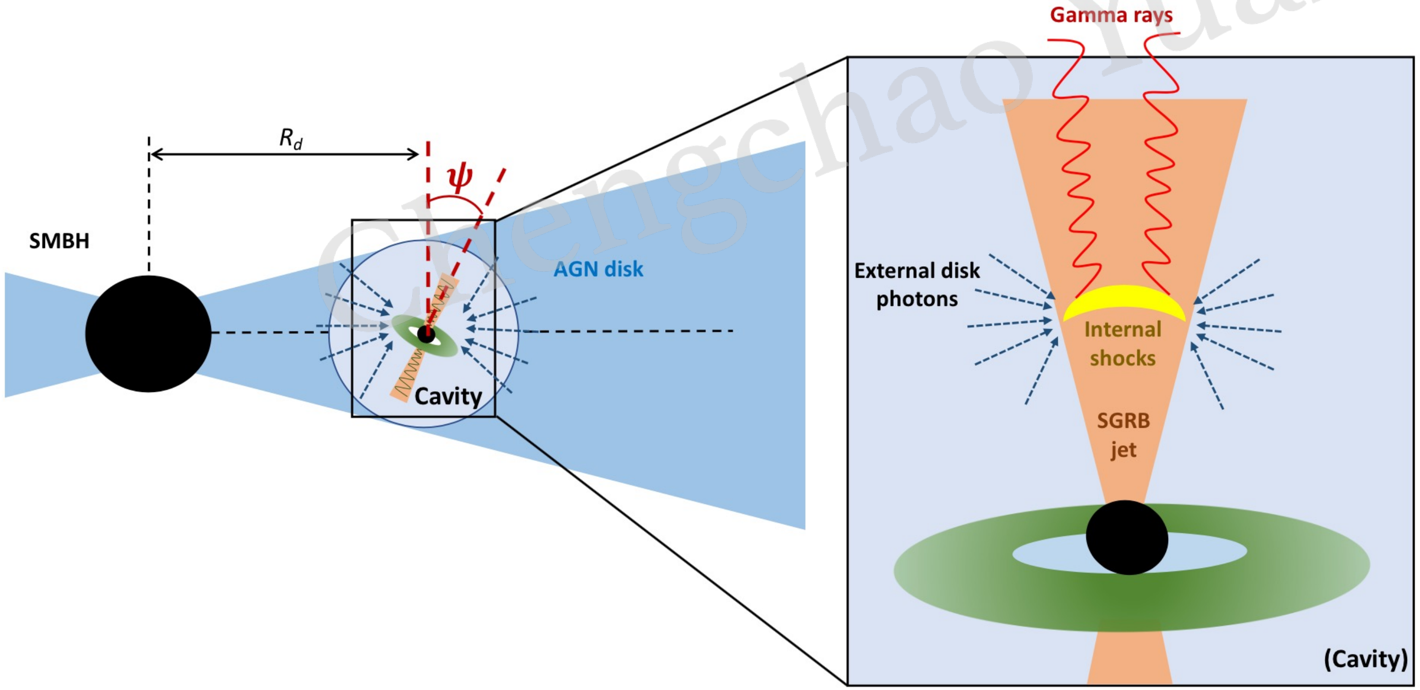
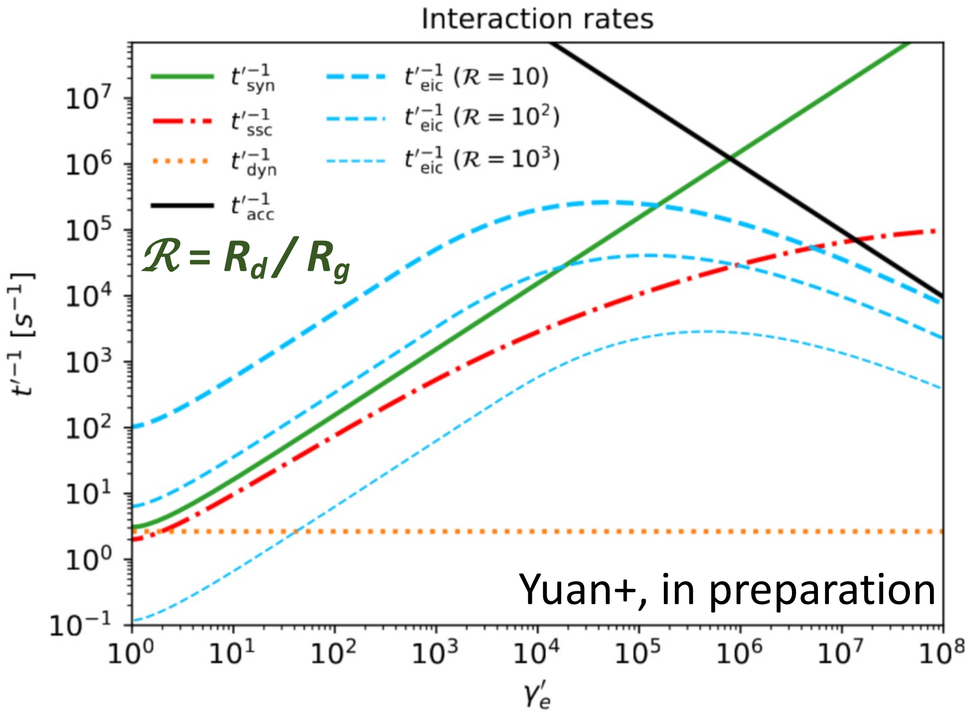
- Inside the pre-merger wind bubble (disk-driven winds), the jet is mild relativistic $\boldsymbol{\Gamma \sim 2.0}$
- Early radio emission is suppressed by **synchrotron self-absorption (SSA)**
- Non-thermal **EM (syn.+SSC)** signals are detectable up to the detection horizon of LISA, **(1-10)f_b per year**
- **Initial observation with** large FOV telescopes (SKA, LSST) can guide narrow FOV detectors.

Short GRBs in AGN Disks: Physical Condition

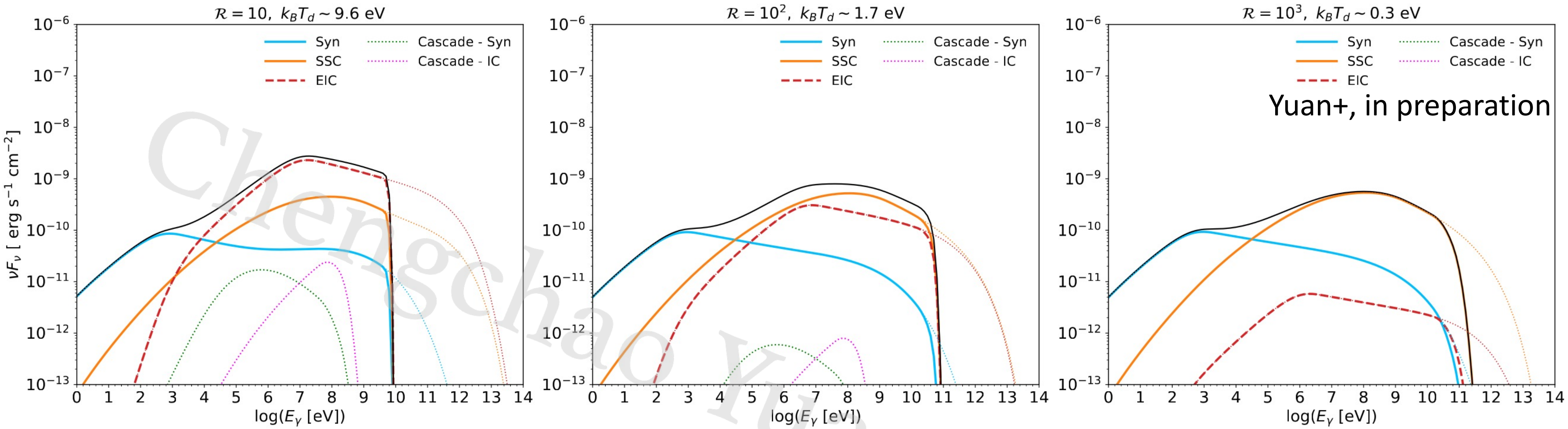
- A subpopulation of short GRBs occurs in the AGN accretion disks **near a migration trap**.
- Winds from BNS (highly super-Eddington) -> **low-density cavity** -> **successful GRB jets**
- Non-thermal electrons -> **syn. + SSC + external inverse Compton (EIC, with thermal disk photons)**
- EIC component depends on the distance to the SMBH, $\boldsymbol{R_d}$ **(**$\mathcal{R} = R_d / R_g$**,** $\boldsymbol{R_g}$**:** Schwarzschild radius**)**





Short GRBs in AGN Disks: Gamma Rays

Gamma-ray spectra



- Extended emission: $L_{k,iso}$ **~10^48.5 erg/s, duration 10²-10³ s,** Γ **~50**
- **HE cutoff:** $\gamma\gamma$ attenuation with disk photons; **Cascade – subdominant**
- Close to SMBH (low R_d): more EIC flux, stronger HE cutoff
- 25 GeV - 100 GeV: **detectable for CTA upto z = 1.0**
- **Gamma-ray (CTA) + GW (LIGO) joint detection rate**

$$\dot{R}^{(L)}_{\rm SGRB-AGN} = f_{\rm EE} f_b f_{\rm L,BCO/BBH} \dot{R}_{\rm L,BBH} \sim (2.5 \times 10^{-3} - 0.35)\theta^2_{j,-1}\ {\rm yr}^{-1}.$$

- Next step: implications to neutrino detections