Big and young SMBHs in the early Universe

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Blazars as SMBHs tracers

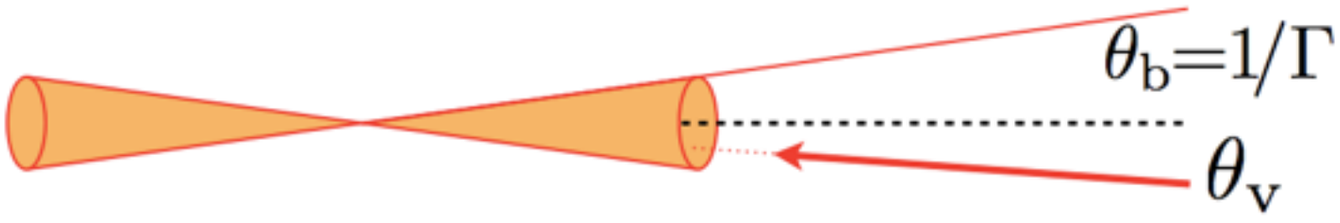
finding extremely massive SMBHs at high redshift

$$M_{\rm BH} > 10^9 M_\odot$$
$$z > 4$$

→ constraints on SMBH formation **models!**

viewing angle:

$$\theta_{\rm v} < 1/\Gamma$$



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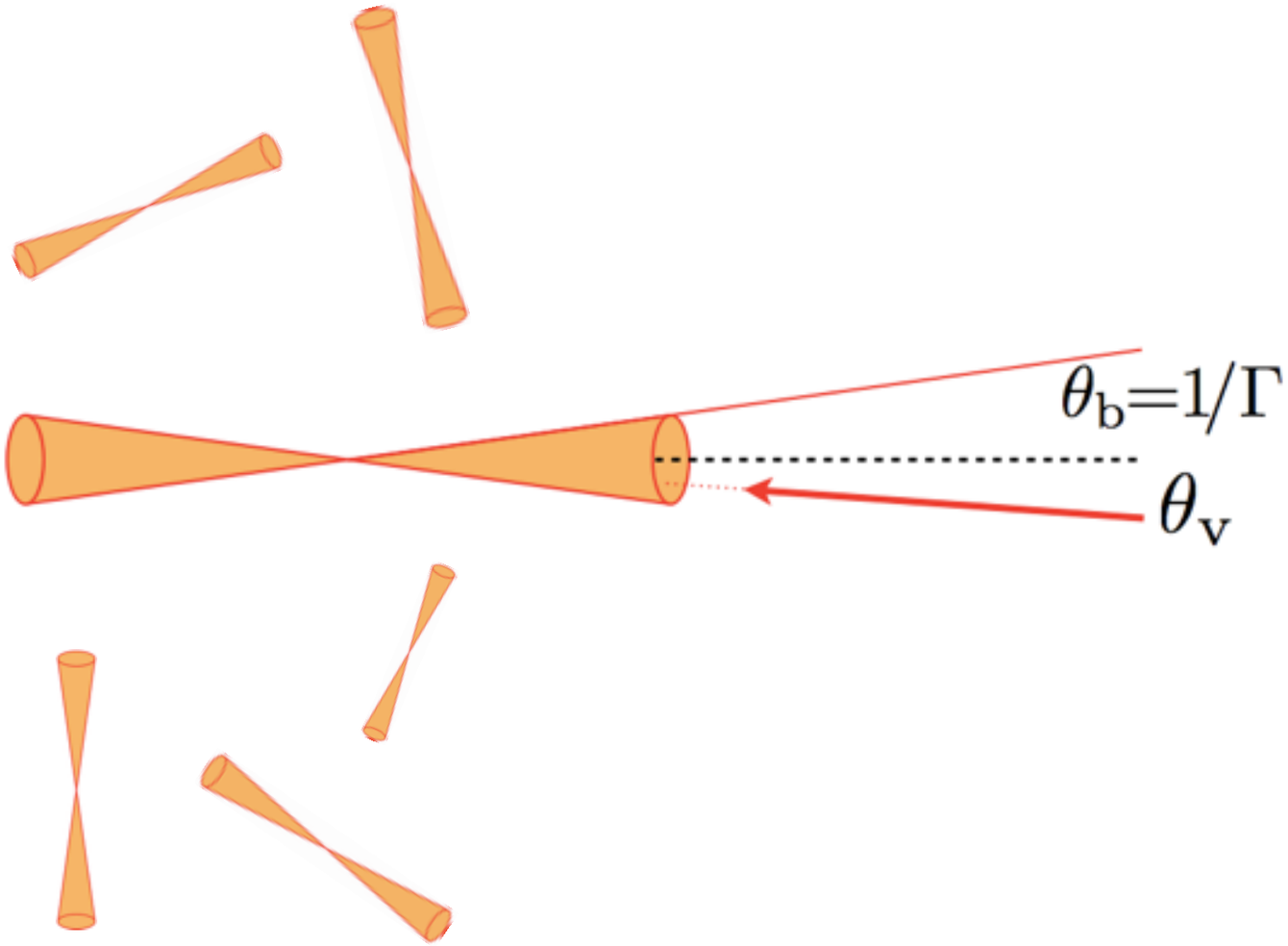

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$$\theta_{\rm v} < 1/\Gamma$$

analogous jetted AGN, randomly oriented:

$$2\Gamma^2 \sim 450$$

Why only serendipitous?

high redshift → **most powerful** → most massive SMBH

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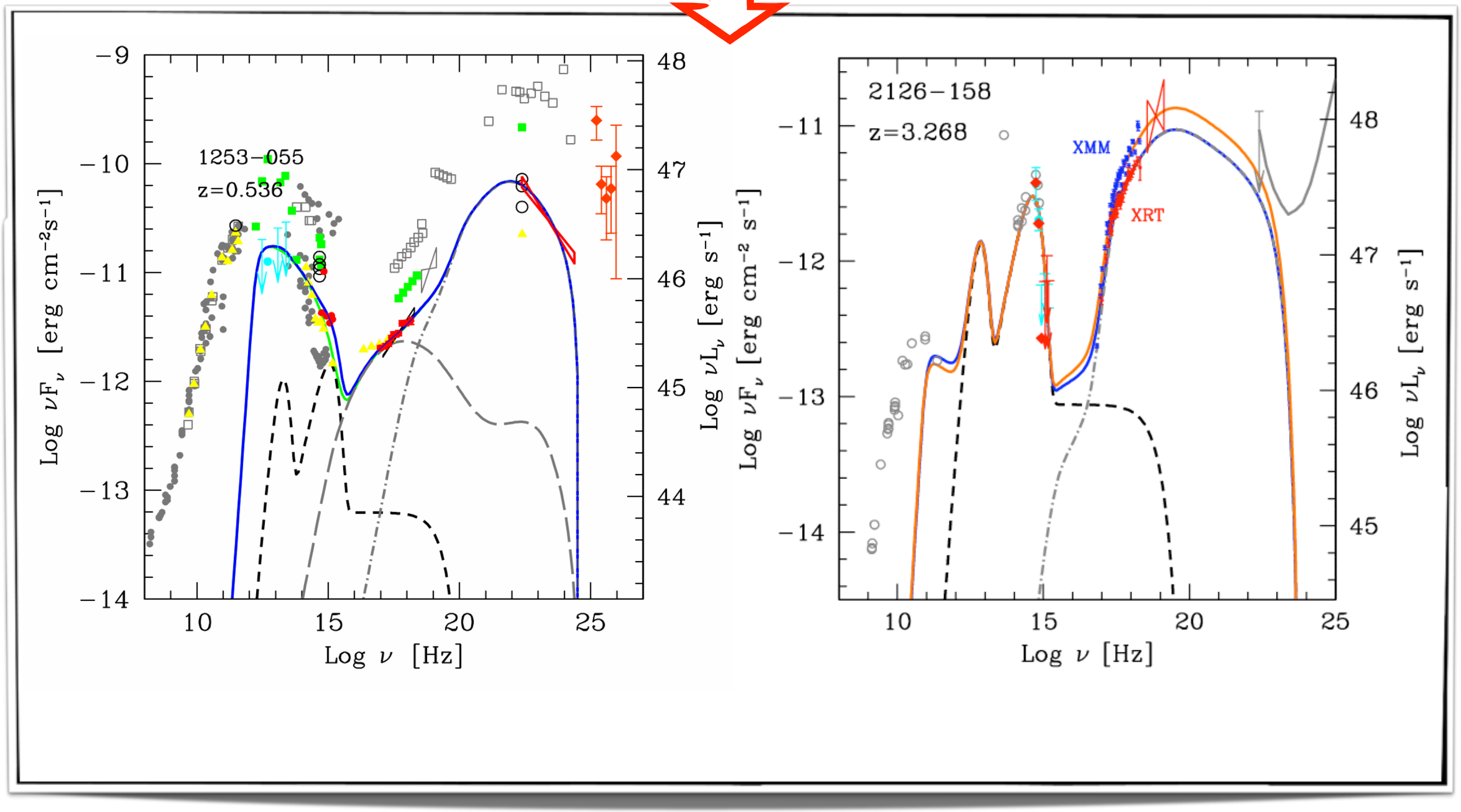

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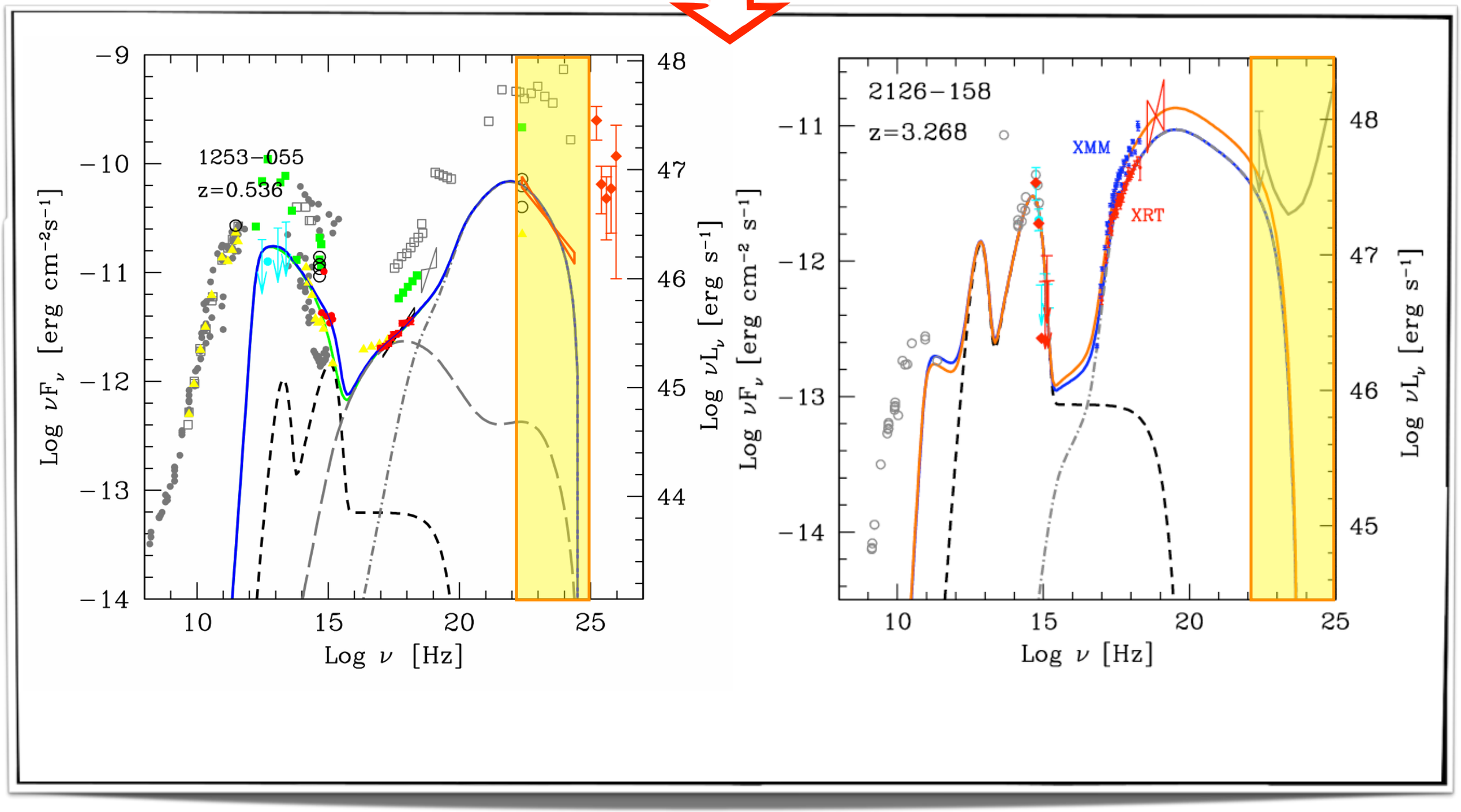

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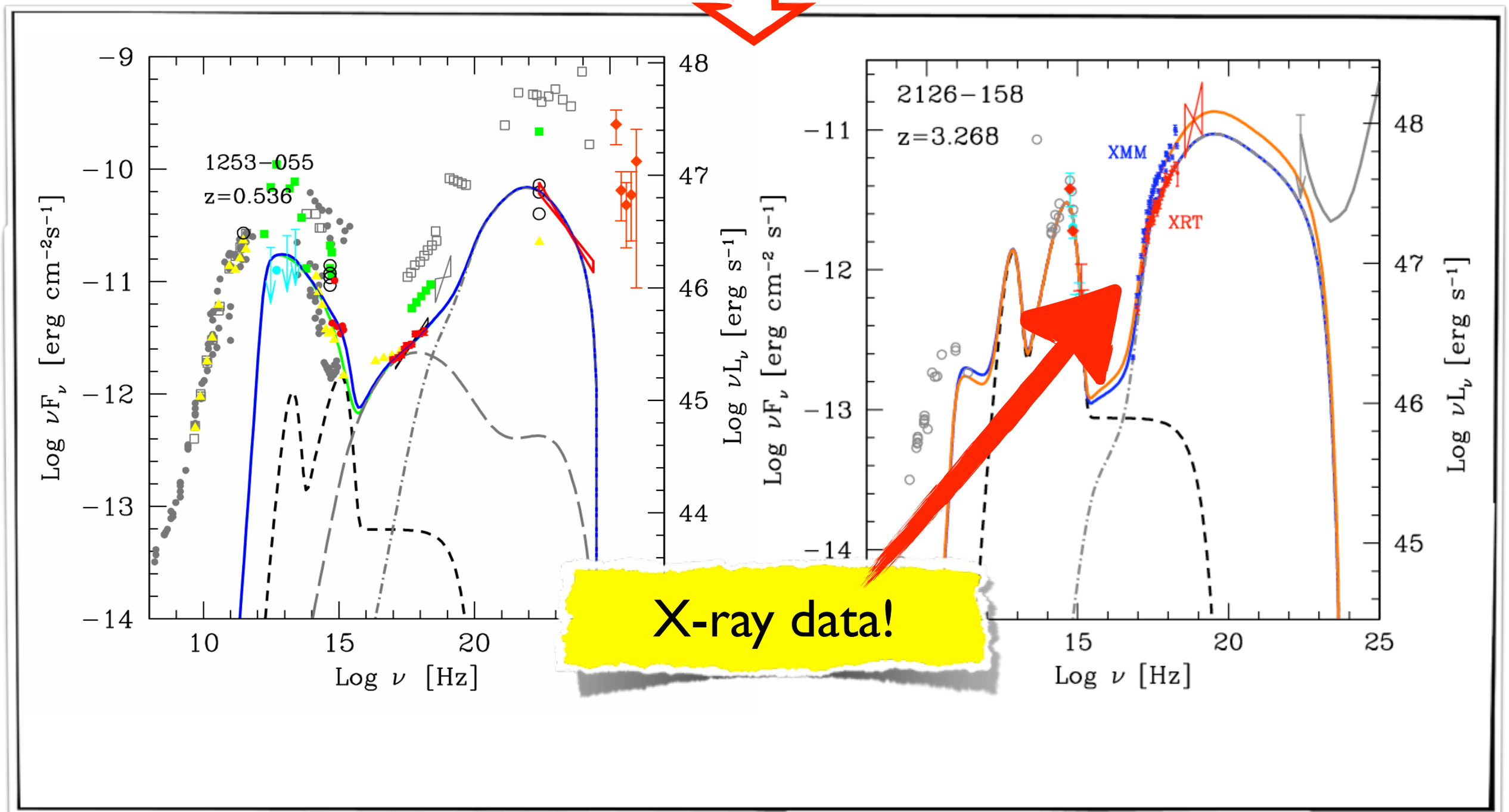

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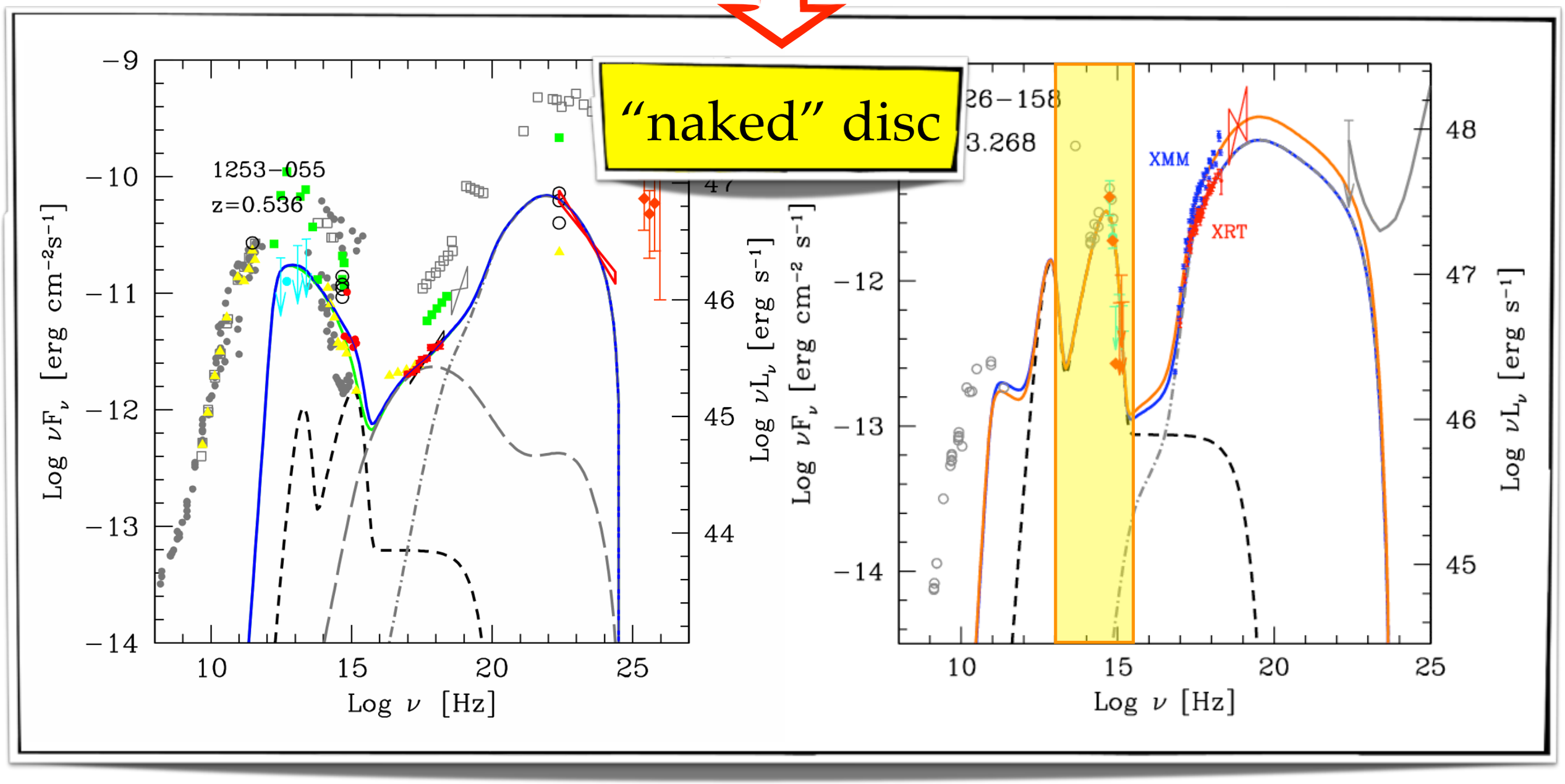

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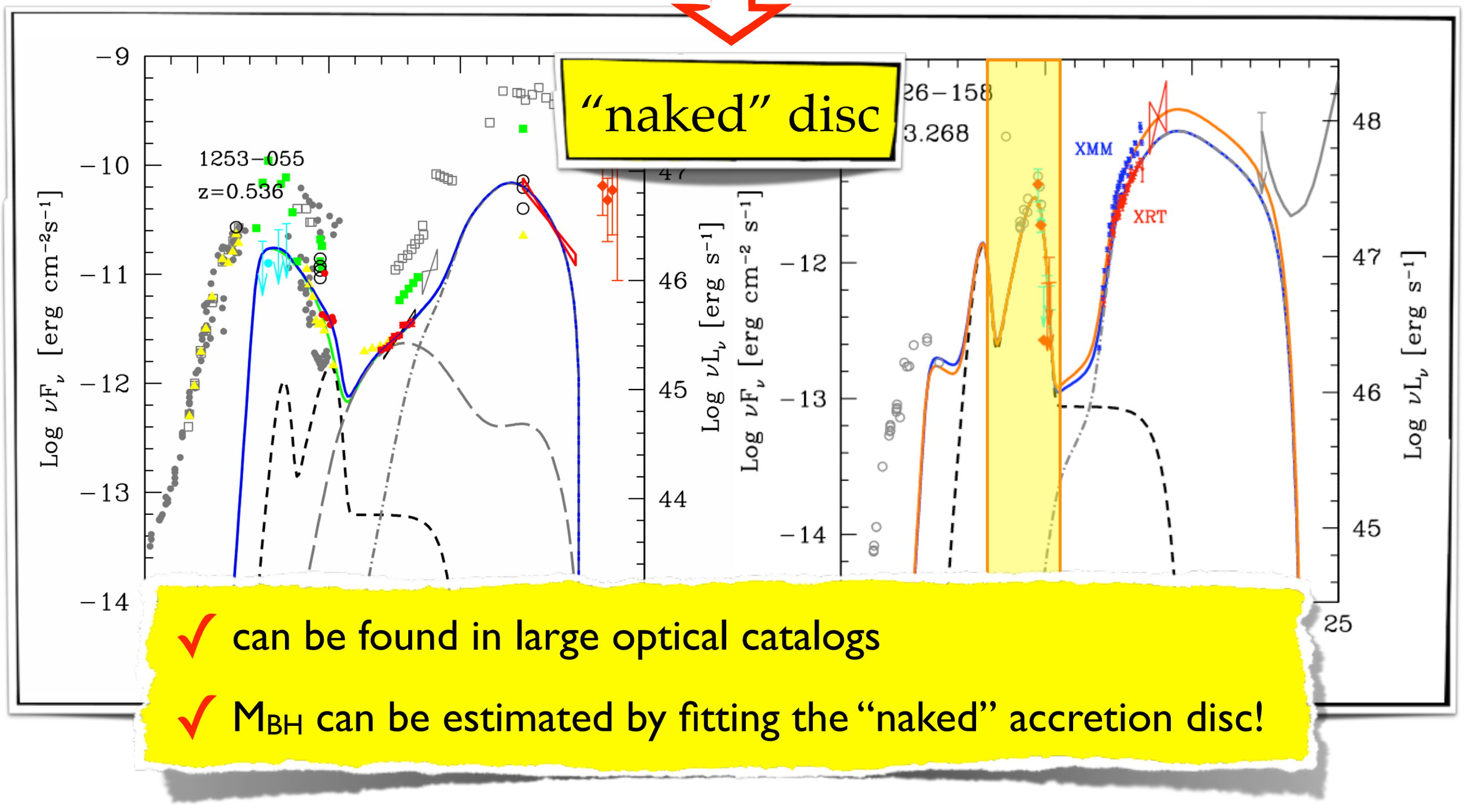
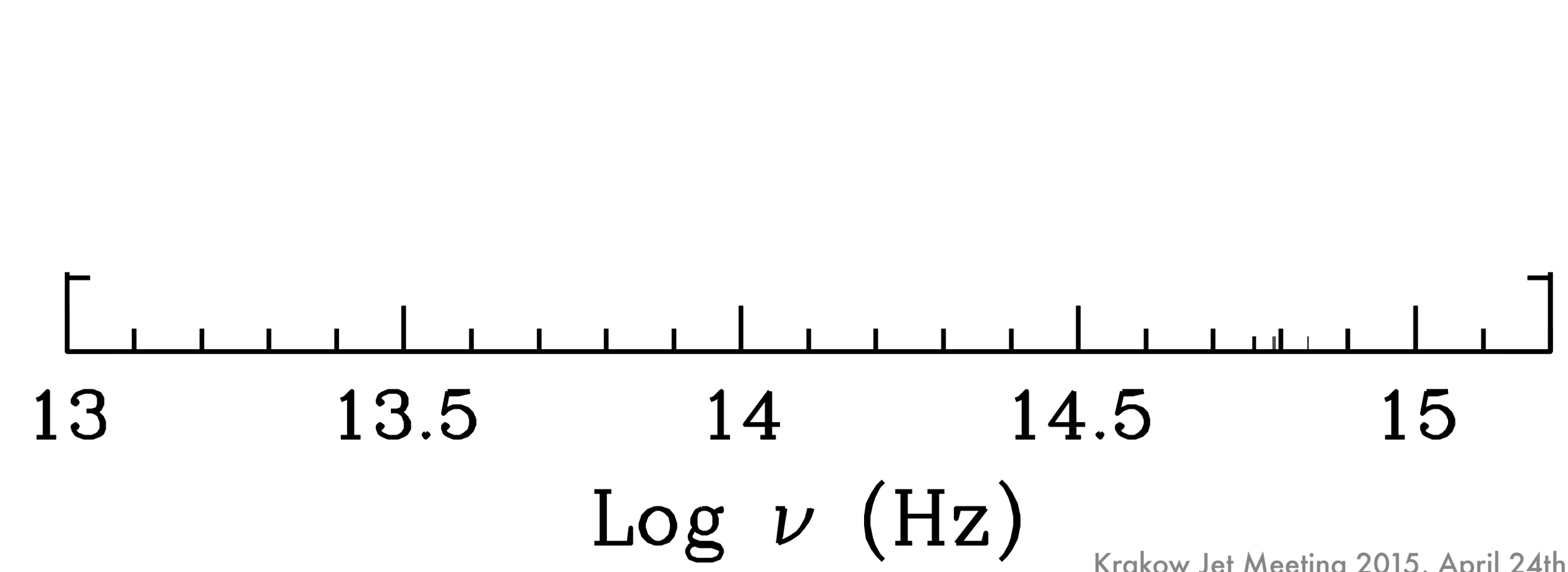


- ✓ can be found in large optical catalogs
- ✓ M_{BH} can be estimated by fitting the "naked" accretion disc!

Systematic approach

Sbarrato et al. 2013a



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SDSS DR7	- z>4	1248
+ FIRST	- radio-detected *>1mJy*	53
	- R>100 $R=F_{5GHz}/F_B$	31
GROND	- visible from La Silla	19

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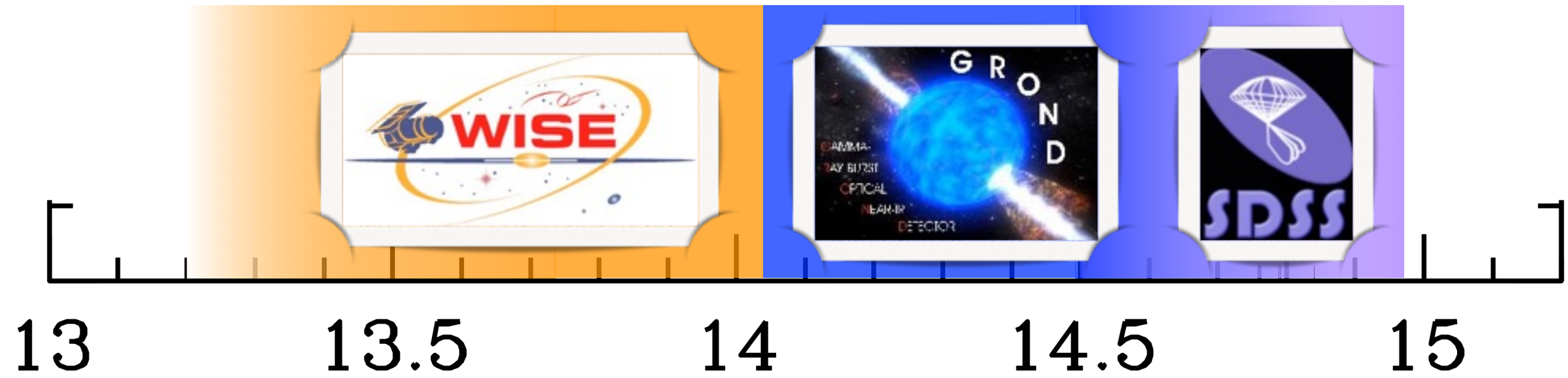
19 high-z, extremely radio-loud blazar candidates

$$\left\langle \log \frac{M_{\rm BH}}{M_\odot} \right\rangle = 9.31 \pm 0.21$$

$$\langle L_{\rm d} \rangle \sim 25\% L_{\rm Edd};\ L_{\rm d} > 10\% L_{\rm Edd}$$



B2 1023+25

Sbarrato et al. 2012b; Sbarrato et al. 2013b

Best blazar candidate:

$z = 5.3$

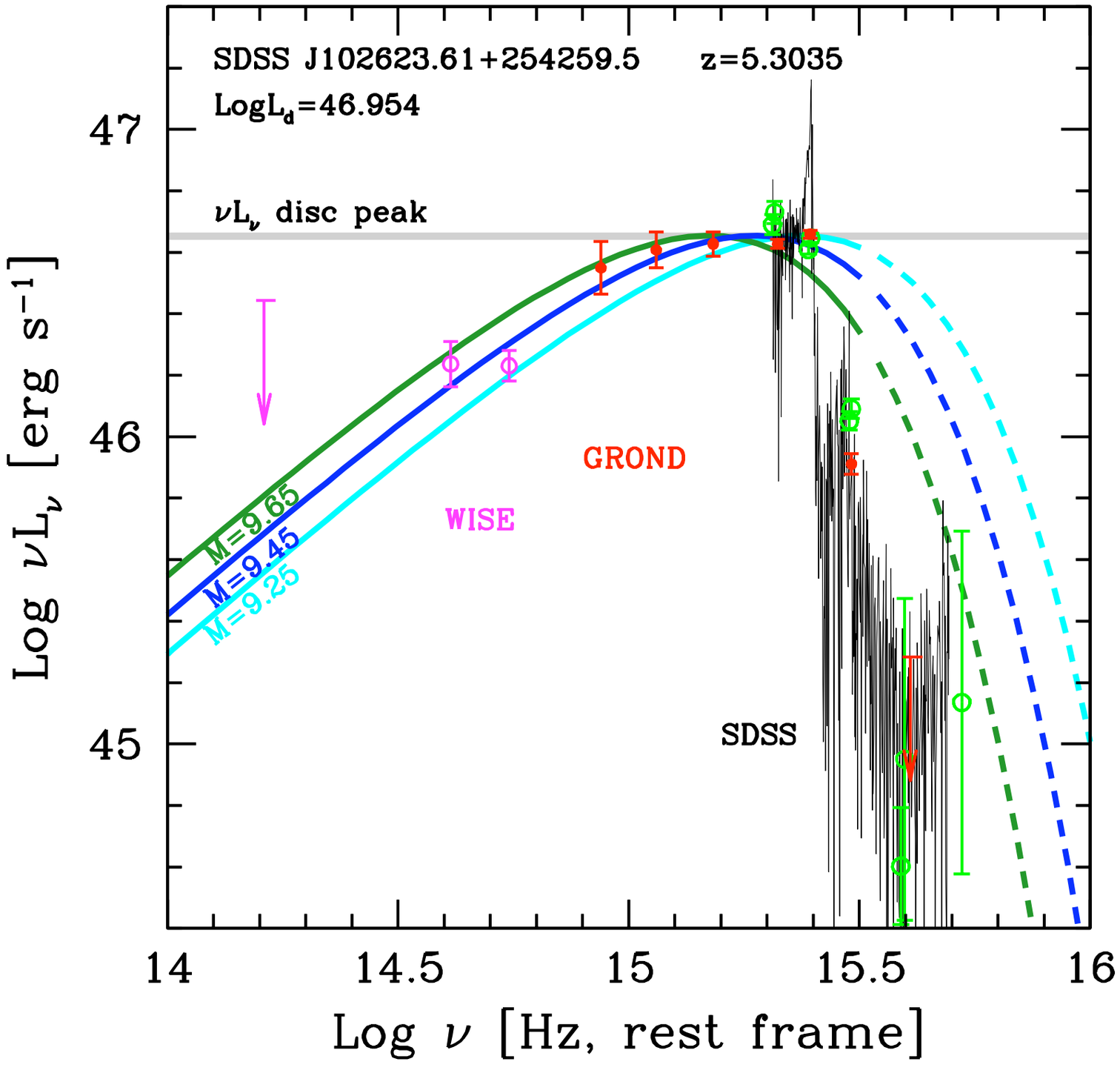
$R \sim 5200$

$F_{1.4\mathrm{GHz}} = 260\mathrm{mJy}$

Accretion disc fitting:

$\log L_\mathrm{d} = 46.95$

$\log \frac{M_\mathrm{BH}}{M_\odot} = 9.45$



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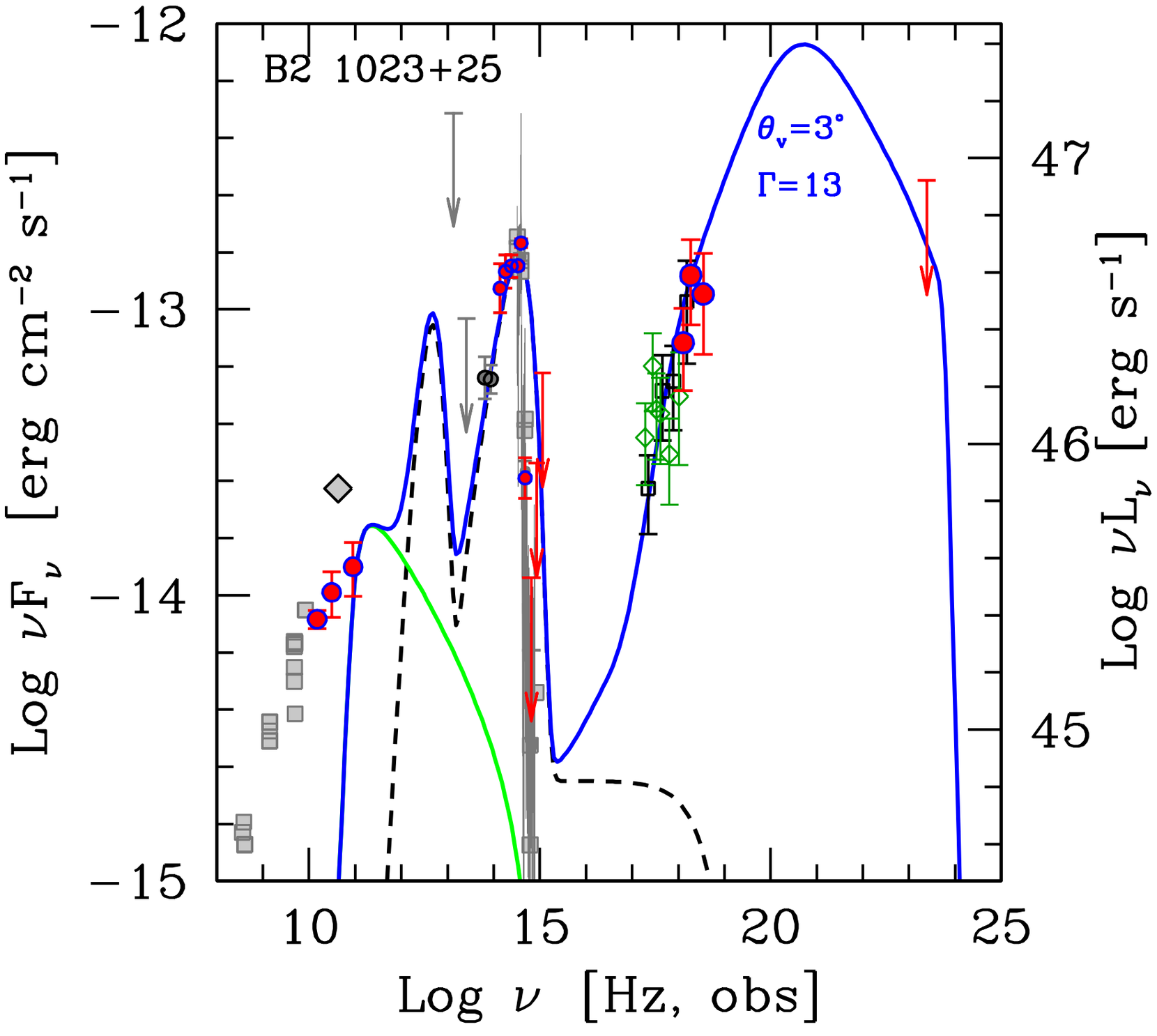
NuSTAR and *Swift*/XRT:
strong and hard X-ray flux

$$F_{\mathrm{X}}[5-10\mathrm{keV}] = 5.5 \times 10^{-14}\mathrm{erg\,cm^{-2}s^{-1}}$$

$$\Gamma_{\mathrm{X}} = 1.60^{+0.27}_{-0.26}$$



How many SMBHs does it trace?

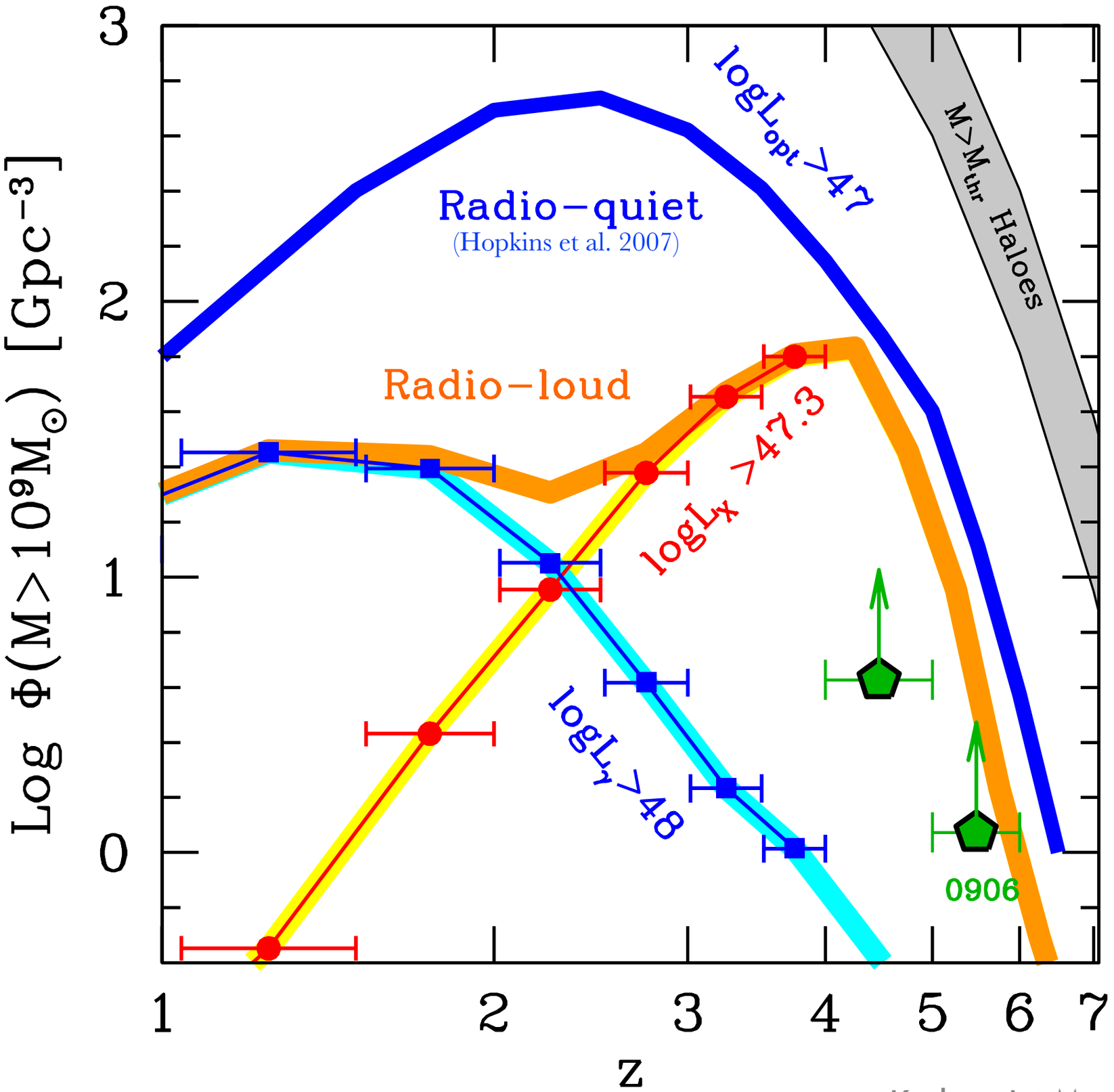
- B2 1023+25 is seen with viewing angle smaller than the jet beaming angle

$$\left.\begin{array}{r}\Gamma = 13 \\ \theta_{\rm v} = 3^\circ\end{array}\right\} \quad \theta_{\rm v} < 1/\Gamma \longrightarrow 2\Gamma^2 \simeq 338$$

- SDSS+FIRST cover ~8770 square degrees, i.e. 1/4 of the whole sky

B2 1023+25 traces at least ~1540 analogous misaligned quasars

High masses at high redshift!



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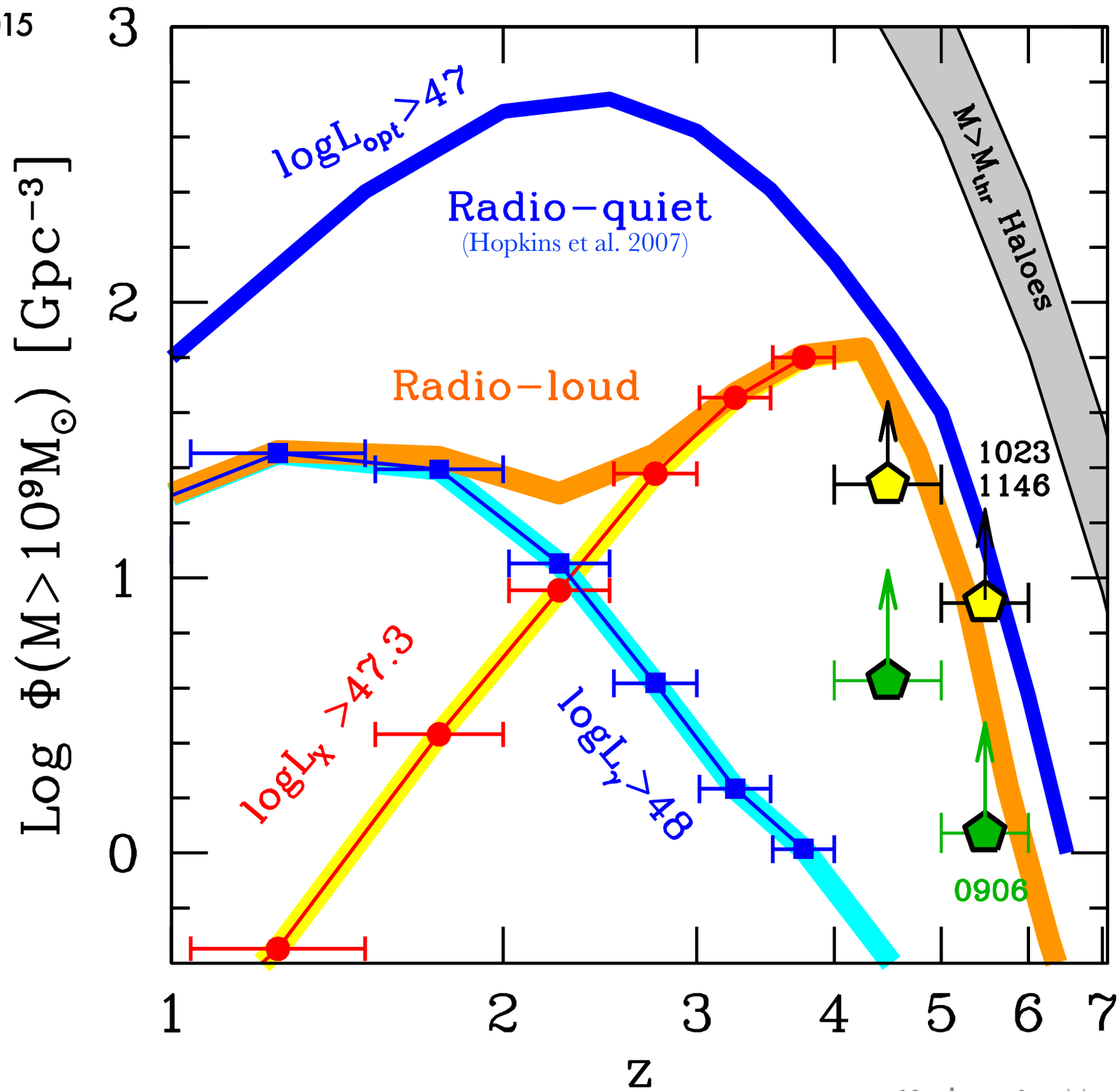

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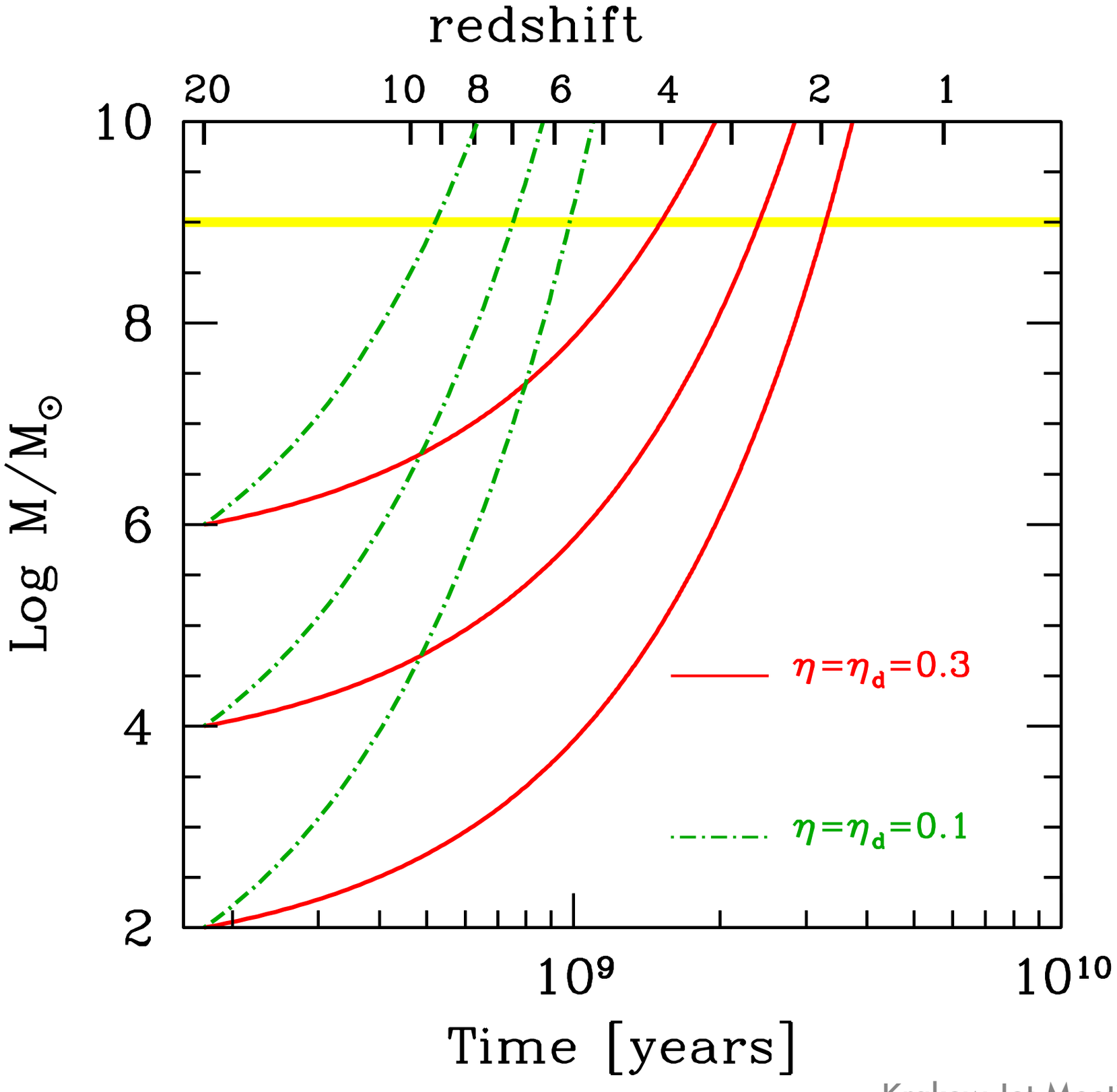

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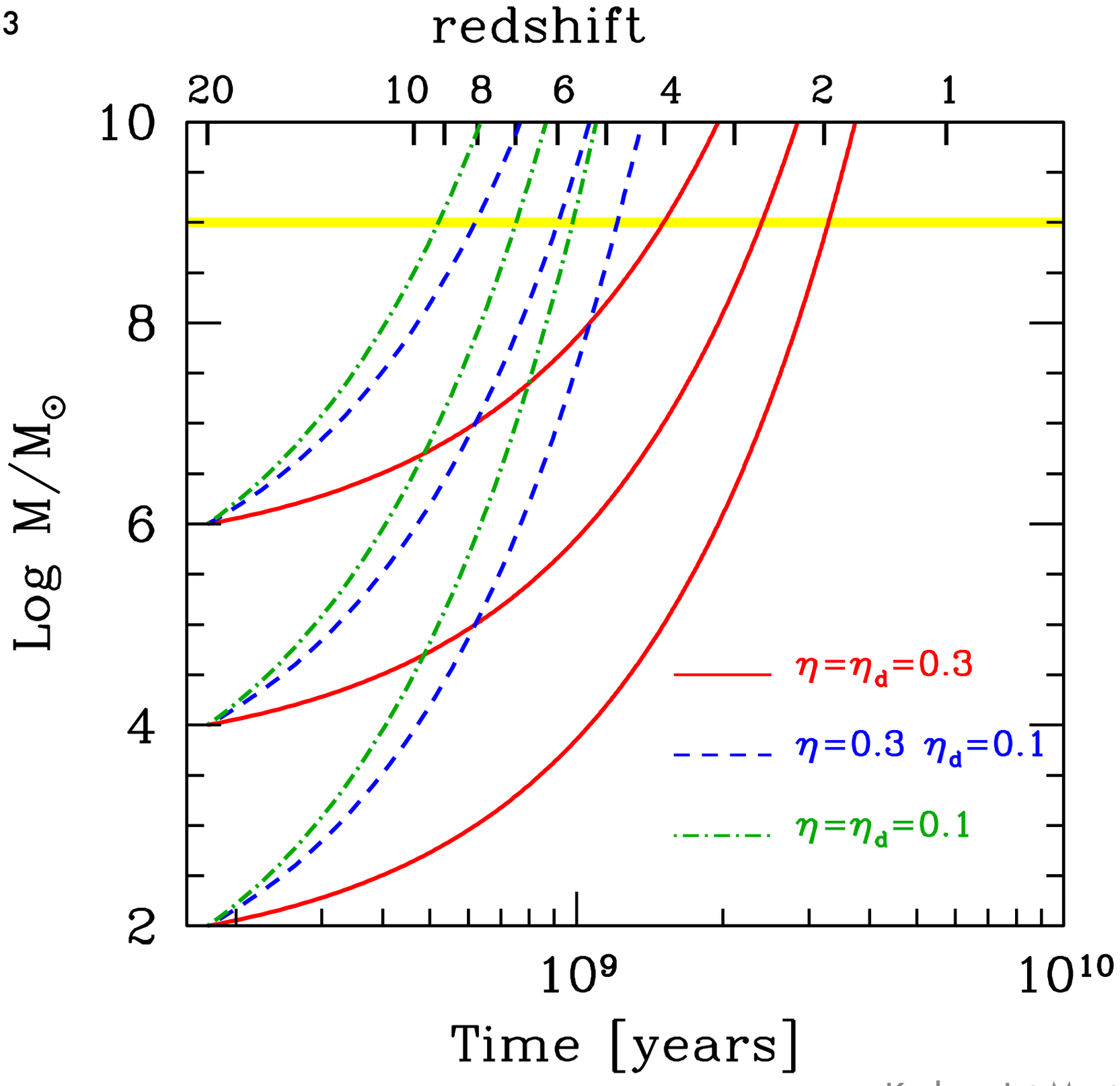
Ghisellini et al. 2013



Conclusions

- blazars are good to look for extremely massive BHs at high z
  *they **trace** their **parent population***
- to confirm "blazarness": **X-ray data**

- two different formation epochs for highly massive SMBHs:
  jetted systems preferentially form at **z~4**
  non-jetted systems *at z~2-2.5*
- it's hard to form such massive BHs in the early Universe
  ➡ the presence of **jets** might help