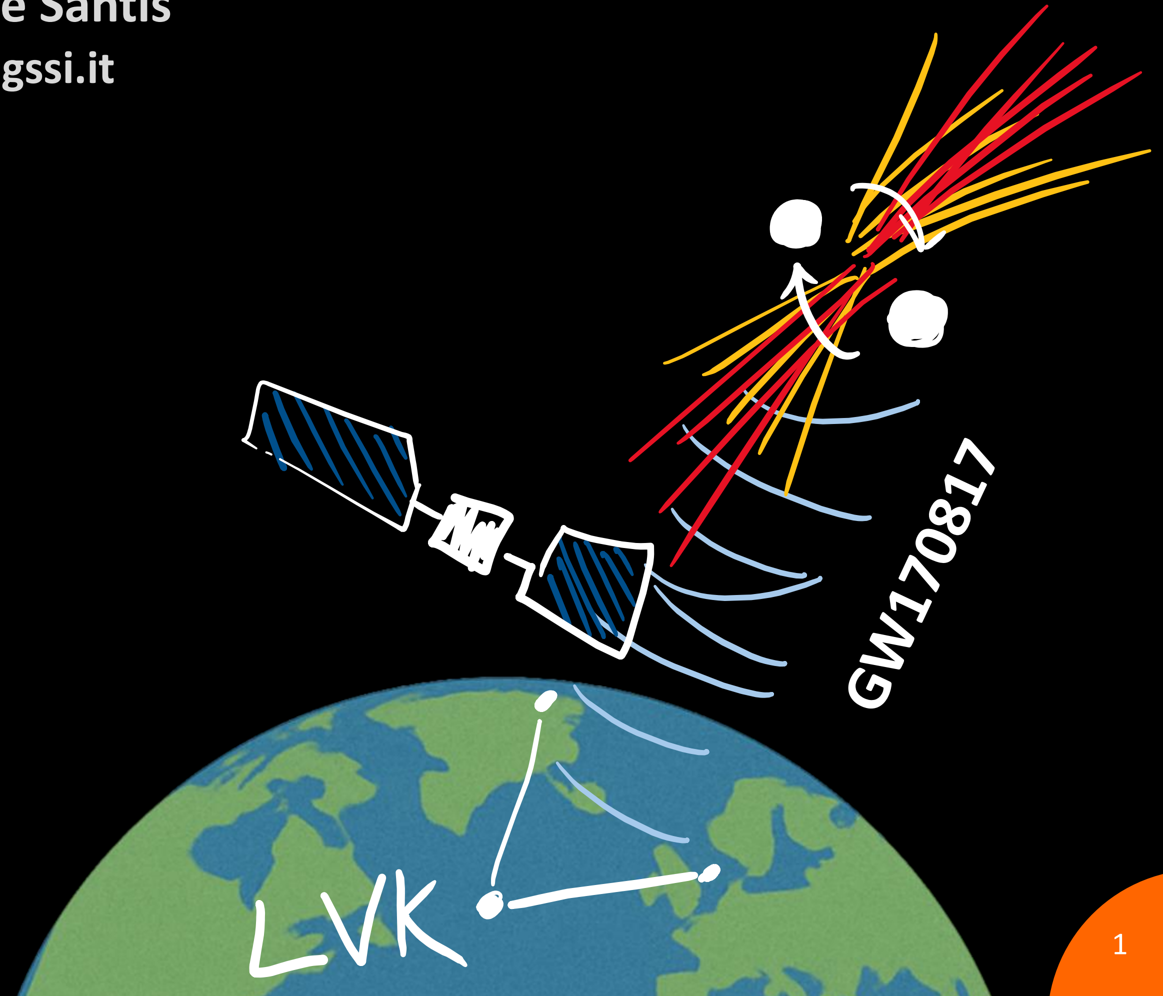
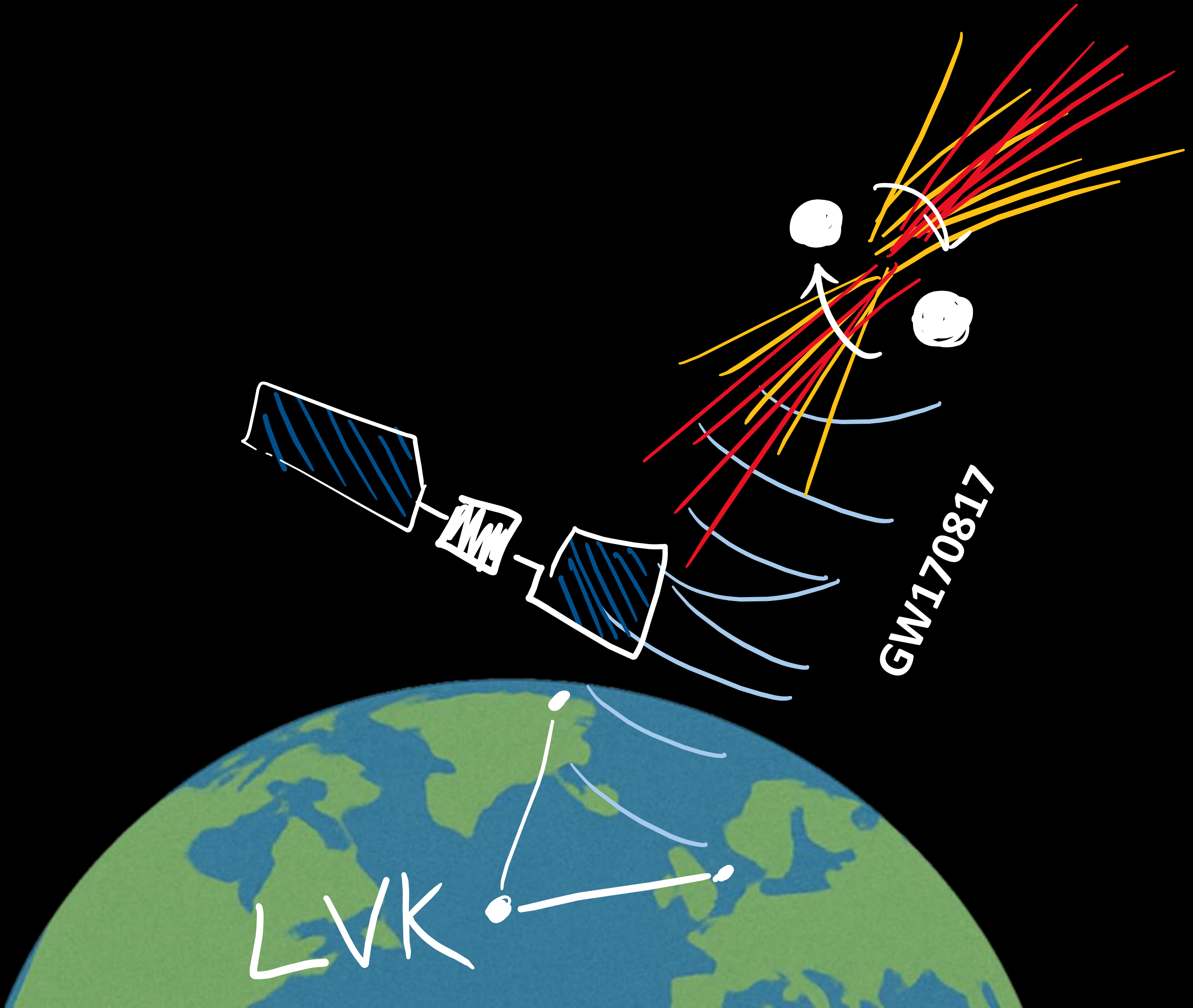
Emerging tension between BNS rates and short GRB observations

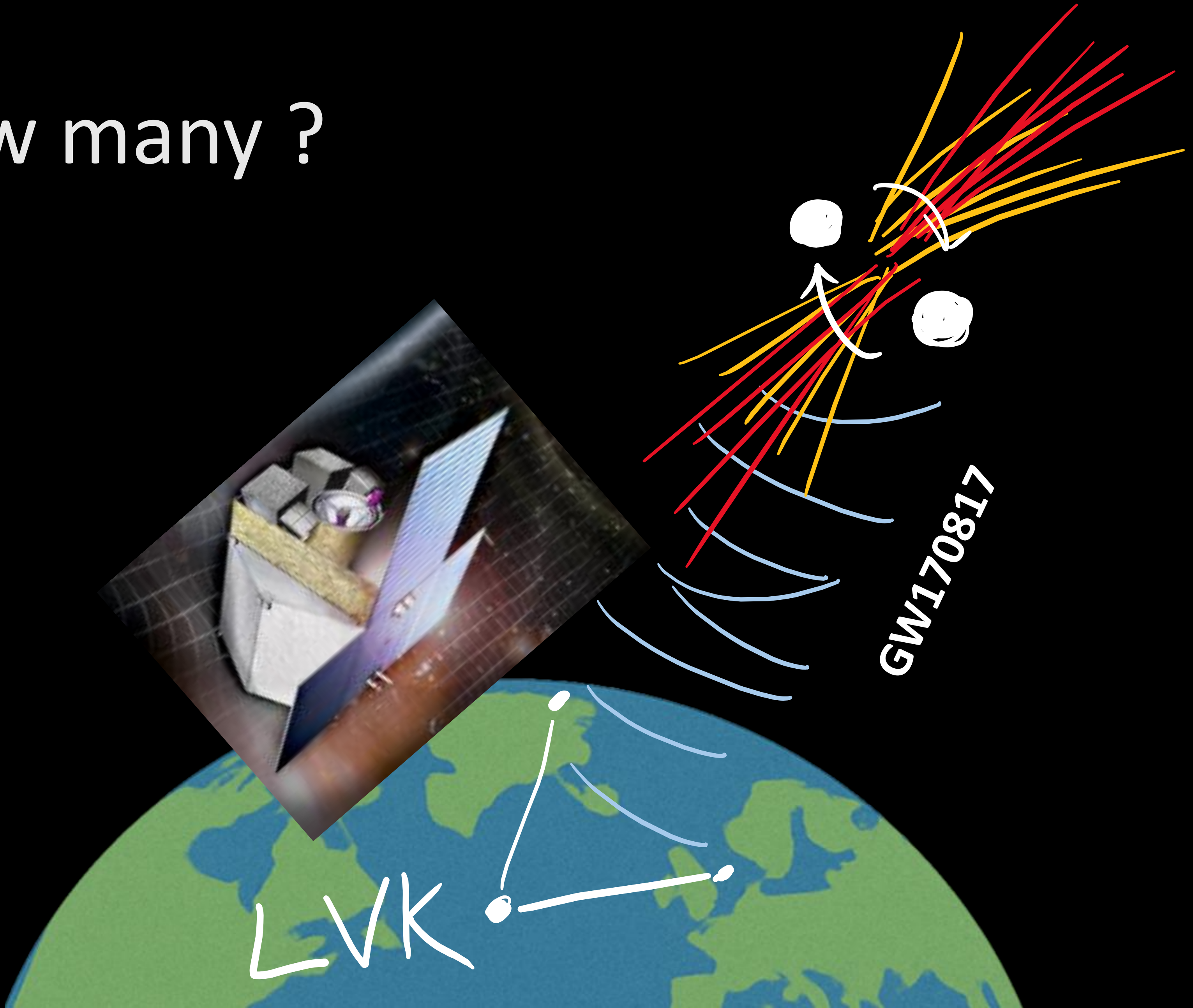
Alessio Ludovico De Santis
alessio.desantis@gssi.it

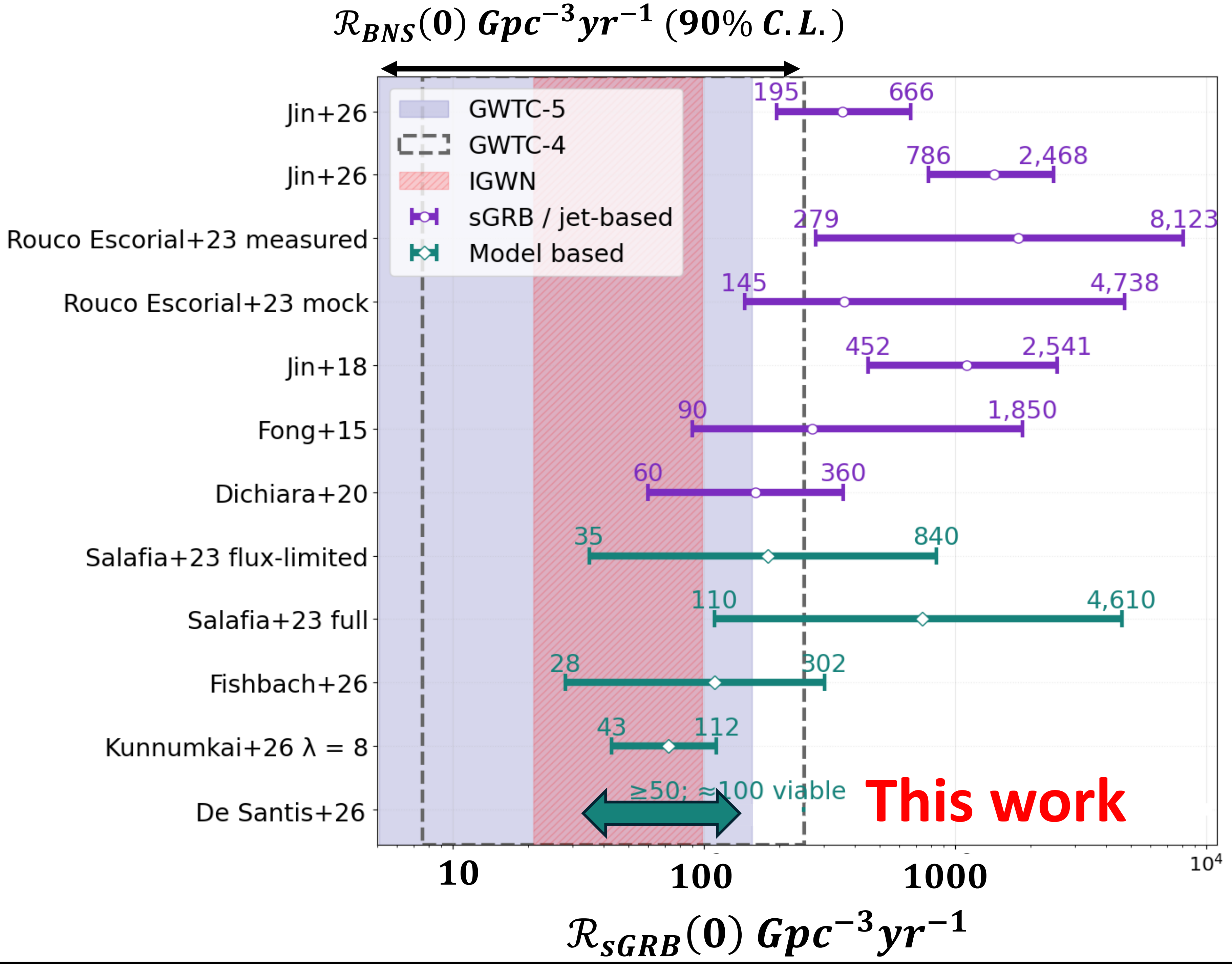


Advisors :
Filippo Santoliquido,
Samuele Ronchini,
and **Marica Branchesi**


GW170817
LVK

How many ?




$\mathcal{R}_{BNS}(0)\ Gpc^{-3}yr^{-1}$ (90% C.L.)
GWTC-5
GWTC-4
IGWN
sGRB / jet-based
Model based
Jin+26
195
666
Jin+26
786
2,468
Rouco Escorial+23 measured
279
8,123
Rouco Escorial+23 mock
145
4,738
Jin+18
452
2,541
Fong+15
90
1,850
Dichiara+20
60
360
Salafia+23 flux-limited
35
840
Salafia+23 full
110
4,610
Fishbach+26
28
302
Kunnumkai+26 λ = 8
43
112
De Santis+26
≥50; ≈100 viable
This work
10
100
1000
10^4
$\mathcal{R}_{sGRB}(0)\ Gpc^{-3}yr^{-1}$

Our approach

MULTI-MESSENGER ASTRONOMY

MAGGPY

WITH GW AND GRBS

De Santis et al. 2026

GitHub

GRB Rates

$$\boxed{R^{\mathrm{pred}}_{\mathrm{sGRB}}} = \epsilon_{\mathrm{GBM}} \cdot f_j \cdot \underbrace{\int_0^{\theta_c} \sin\theta_v \, d\theta_v}_{\langle f_b \rangle} \cdot \int \Phi(\boldsymbol{\theta}_p, z) \frac{R_{\mathrm{BNS}}(z)}{1+z} \frac{dV}{dz} \, d\boldsymbol{\theta}_p dz$$

De Santis+26 Ronchini+22

Want to match *GBM* rate
~ 40/yr

GRB Rates

$$R_{\mathrm{sGRB}}^{\mathrm{pred}} = \boxed{\epsilon_{\mathrm{GBM}}} \cdot f_j \cdot \underbrace{\int_0^{\theta_c} \sin\theta_v \, d\theta_v}_{\langle f_b \rangle} \cdot \int \Phi(\boldsymbol{\theta}_p, z) \frac{R_{\mathrm{BNS}}(z)}{1+z} \frac{dV}{dz} \, d\boldsymbol{\theta}_p dz$$

GBM **FOV + Duty Cycle**
$\sim \mathbf{60\%}$

Burns et al, 2016

GRB Rates

$$R^{\mathrm{pred}}_{\mathrm{sGRB}} = \epsilon_{\mathrm{GBM}} \cdot f_j \cdot \underbrace{\int_0^{\theta_c} \sin\theta_v \, d\theta_v}_{\langle f_b \rangle} \cdot \int \Phi(\boldsymbol{\theta}_p, z) \boxed{\frac{R_{\mathrm{BNS}}(z)}{1+z} \frac{dV}{dz}} d\boldsymbol{\theta}_p dz$$

64 BNS population synthesis tested

GRB Rates

$$R^{\mathrm{pred}}_{\mathrm{sGRB}} = \epsilon_{\mathrm{GBM}} \cdot f_j \cdot \underbrace{\int_0^{\theta_c} \sin\theta_v \, d\theta_v}_{\langle f_b \rangle} \cdot \boxed{\int \Phi(\boldsymbol{\theta}_p, z)} \frac{R_{\mathrm{BNS}}(z)}{1+z} \frac{dV}{dz} \, d\boldsymbol{\theta}_p dz$$

Constrained by *GBM* observables + MCMC

example: E_p, E_{iso}

GRB Rates

$$R_{\mathrm{sGRB}}^{\mathrm{pred}} = \epsilon_{\mathrm{GBM}} \cdot f_j \cdot \boxed{\underbrace{\int_0^{\theta_c} \sin\theta_v \, d\theta_v}_{\langle f_b \rangle}} \cdot \int \Phi(\boldsymbol{\theta}_p, z) \underbrace{\frac{R_{\mathrm{BNS}}(z)}{1+z}}_{\text{Sampled by MCMC}} \frac{dV}{dz} \, d\boldsymbol{\theta}_p dz$$

Beaming fraction

Ex: universal jets have

$\langle f_b \rangle = 1 - \cos(\theta_c)$

GRB Rates

$$R_{\rm sGRB}^{\rm pred} = \epsilon_{\rm GBM} \boxed{\cdot\, f_j \,\cdot} \underbrace{\int_0^{\theta_c} \sin\theta_v \, d\theta_v}_{\langle f_b \rangle} \cdot \int \Phi(\boldsymbol{\theta}_p, z) \frac{R_{\rm BNS}(z)}{1+z} \frac{dV}{dz} \, d\boldsymbol{\theta}_p dz$$

***Inferred** Jet fraction*

$$f_j = \frac{\mathcal{R}_{\boldsymbol{sGRB}}}{\mathcal{R}_{\boldsymbol{BNS}}}$$

Ensures Predictions are **consistent** with **observations**

The bridge : GRB jet properties

Jet core energy distribution:

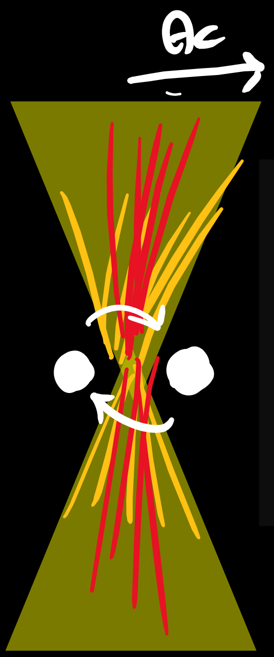
$$P(E_t \mid k, E^*) = \frac{k}{\Gamma(1-k^{-1})\, E^*} \left(\frac{E_t}{E^*}\right)^{-k} \exp\left[-\left(\frac{E_t}{E^*}\right)^{-k}\right]$$

Spectrum:

$$f(E, E_p) = C_n \left[\left(\epsilon \frac{E}{E_p}\right)^{-\alpha n} + \left(\epsilon \frac{E}{E_p}\right)^{-\beta_s n}\right]^{-1/n}$$

Peak energy distribution:

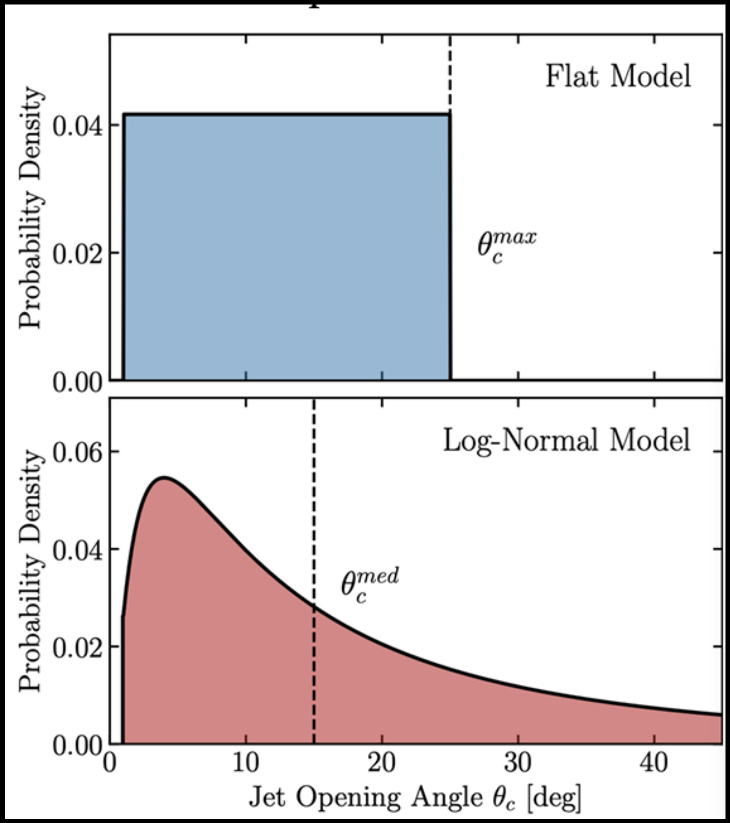
$$\mathcal{N}(\log_{10}(\mu_E),\, \sigma_E)$$



Top – Hat

Structured

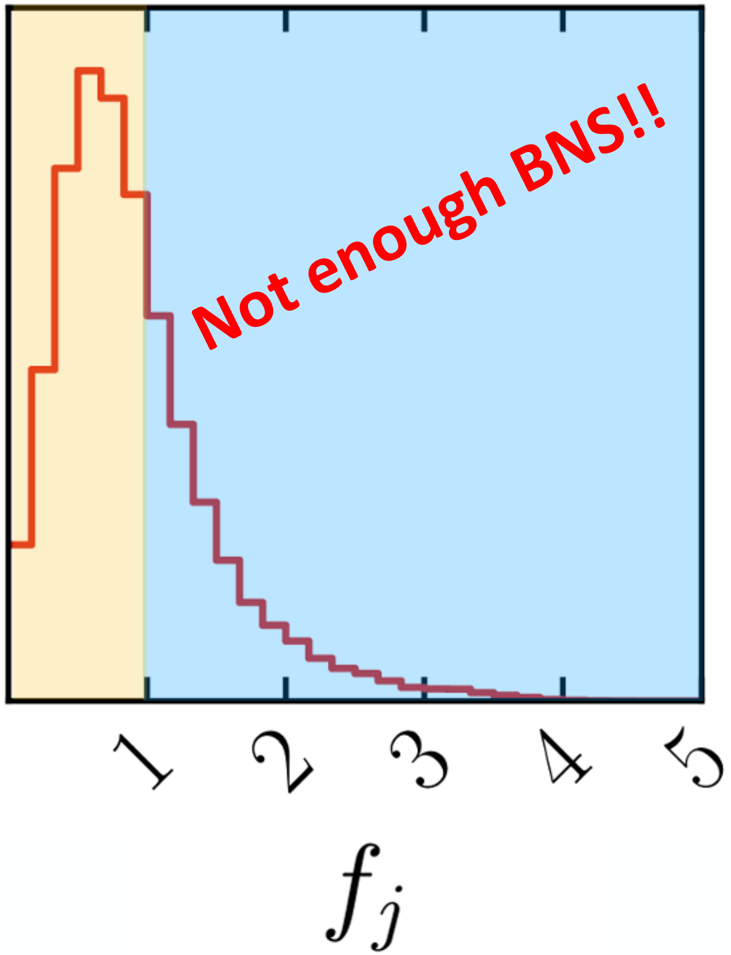
Jet core aperture distribution:

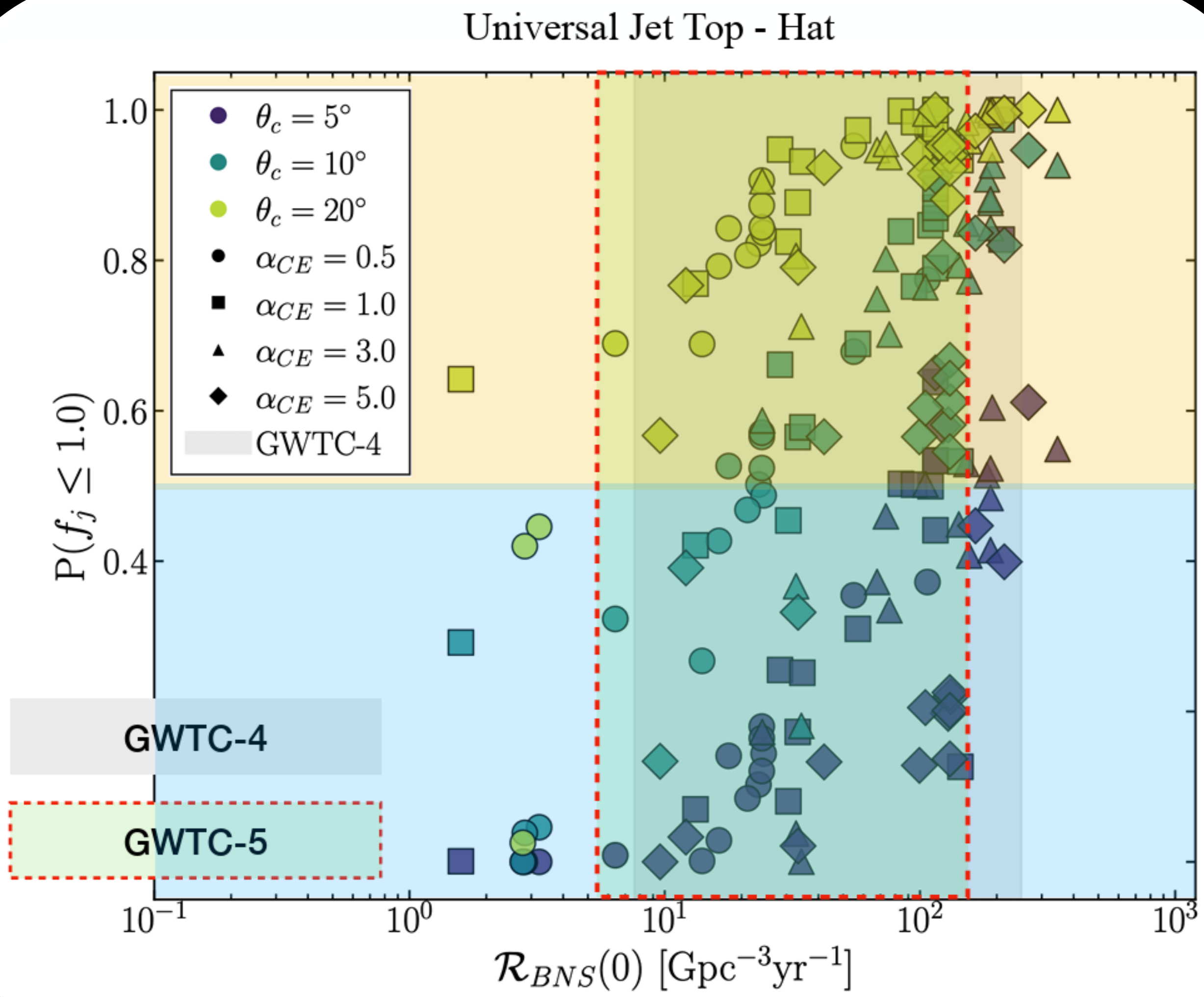


+ Universal Top-Hat

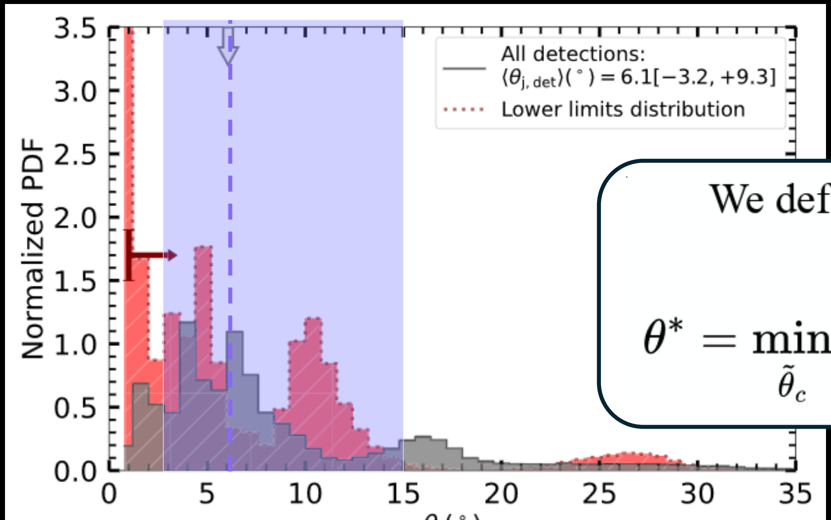
+ Universal GW170817-like

How to assess compatibility





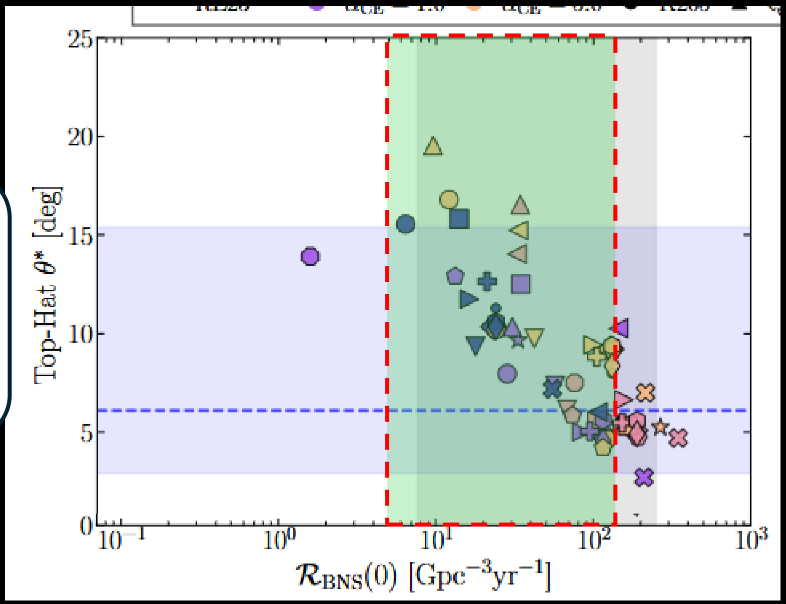
Characteristic opening angle (θ^*)



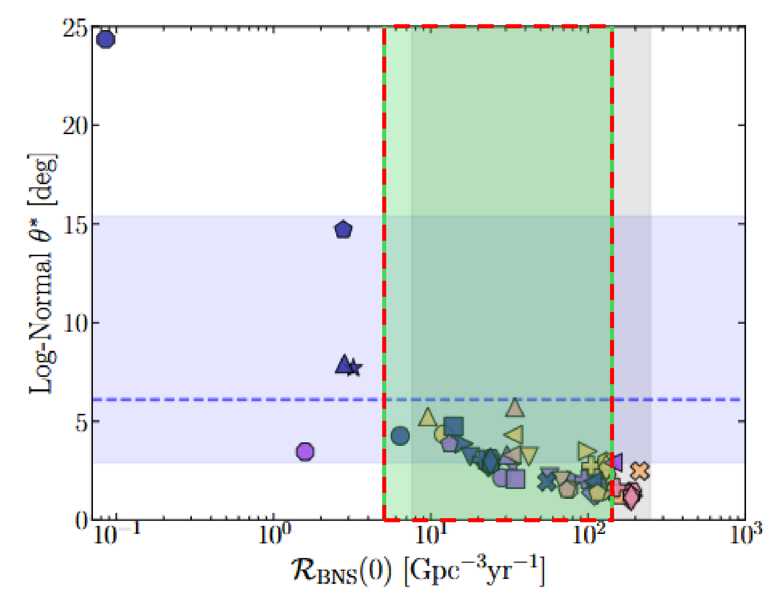
Rouco Escorial+23

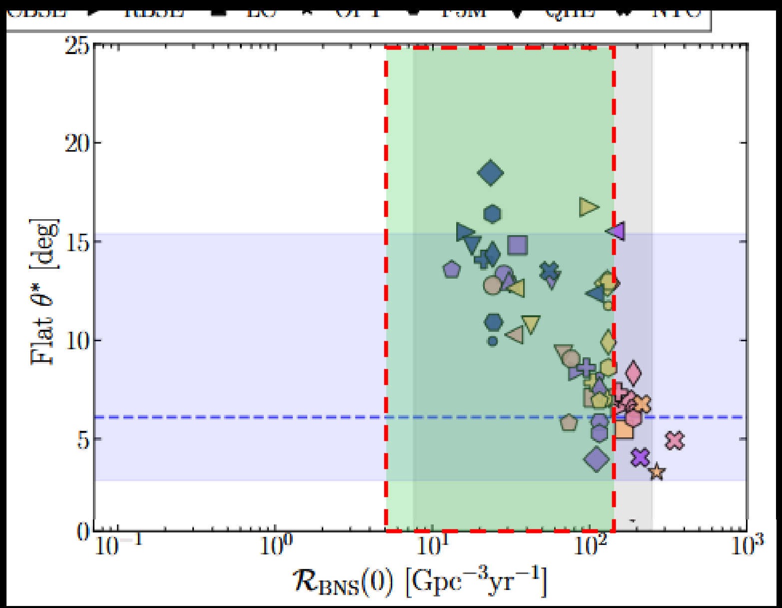
We define the min characteristic opening angle

$$\theta^* = \min_{\tilde{\theta}_c} \left\{ \tilde{\theta}_c \mid P\left(f_j \leq 1\right) \geq 0.5 \right\}$$



GWTC-5





Guess who ?

α_{CE}	Universal top-hat 0.5	1.0	3.0	5.0	Non-univ. flat 0.5	1.0	3.0	5.0	Non-univ. log-normal 0.5	1.0	3.0	5.0	Universal structured 0.5	1.0	3.0	5.0
F	×[a]	✓	✓	×	×	✓	✓	×	✓	✓	✓	✓	×	✓	✓	×
K265	×[a]	×	×	×[a]	×	×	×	×	✓[b]	✓	✓	✓[b]	×	×	×	×
K150	×	×	✓	×	×	×	×	×	✓	✓	✓	✓	×	×	×	×
QCBSE	×[a,c]	×	×[a]	×[a]	×	×	×	×	×[b]	✓	✓[b]	✓[b]	×	×	×	×
QCBB	✓	×	×	×	✓	✓[a]	×	×	✓	✓	✓	✓[b]	×	×	×	×
RBSE	×	×[a]	✓	×	×[a]	✓	✓	×[a]	✓[b]	✓	✓	✓[b]	×	✓	✓	×
LK	×[a,c]	×[c]	×	✓	×	×	✓	✓	×[b]	✓[b]	✓	✓	×	×	×	✓
LC	×[a]	×	✓	✓	×	×	✓	✓	✓[b]	✓	✓	✓	×	×	✓	✓
LX	×[a,c]	×	✓	✓	×	×	✓	✓	×[b]	✓[b]	✓	✓	×	×	✓	✓
OPT	×[a,c]	×	✓	×[c]	×	×	✓	✓	×[b]	✓	✓	✓	×	×	✓	✓
F19	×[a]	✓	✓	×	×[a]	✓	✓	×	✓	✓	✓	✓	×	✓	✓	×
F5M	×[a]	✓	✓	×[a]	×	✓	✓	×	✓	✓	✓	✓	×	✓	✓	×
SND	×	×[c]	✓	×	×[a]	✓	✓	×	✓	✓	✓	✓	×	✓	✓	×
QHE	×	✓	✓	×	×	✓	✓	×	✓	✓	✓	✓	×	✓	✓	×
NT	×	×[c]	×[c]	×	×	✓	✓	×	✓	✓	✓	✓	×	✓	✓	×
NTC	×	✓	✓	✓	×	✓	✓	✓	✓	✓	✓	✓	×	✓	✓	×

✓ median $f_j \le 1$

× median $f_j > 1$

a,b,c : require opening angles > observed ones

Guess who ?

α_{CE}	Universal top-hat				Non-univ. flat				Non-univ. log-normal				Universal structured			
	0.5	1.0	3.0	5.0	0.5	1.0	3.0	5.0	0.5	1.0	3.0	5.0	0.5	1.0	3.0	5.0
F	$\times^{a}$	$\checkmark$	$\checkmark$	$\times$	$\times$	$\checkmark$	$\checkmark$	$\times$	$\checkmark$	$\checkmark$	$\checkmark$	$\checkmark$	$\times$	$\checkmark$	$\checkmark$	$\times$
K265	$\times^{a}$	$\times$	$\times$	$\times^{a}$	$\times$	$\times$	$\times$	$\times$	$\checkmark^{b}$	$\checkmark$	$\checkmark$	$\checkmark^{b}$	$\times$	$\times$	$\times$	$\times$
K150	$\times$	$\times$	$\checkmark$	$\times$	$\times$	$\times$	$\times$	$\times$	$\checkmark$	$\checkmark$	$\checkmark$	$\checkmark$	$\times$	$\times$	$\times$	$\times$
QCBSE	$\times^{a,c}$	$\times$	$\times^{a}$	$\times^{a}$	$\times$	$\times$	$\times$	$\times$	$\times^{b}$	$\checkmark$	$\checkmark^{b}$	$\checkmark^{b}$	$\times$	$\times$	$\times$	$\times$
QCBB	$\checkmark$	$\times$	$\times$	$\times$	$\checkmark$	$\checkmark^{a}$	$\times$	$\times$	$\checkmark$	$\checkmark$	$\checkmark$	$\checkmark^{b}$	$\times$	$\times$	$\times$	$\times$
RBSE	$\times$	$\times^{a}$	$\checkmark$	$\times$	$\times^{a}$	$\checkmark$	$\checkmark$	$\times^{a}$	$\checkmark^{b}$	$\checkmark$	$\checkmark$	$\checkmark^{b}$	$\times$	$\checkmark$	$\checkmark$	$\times$
LK	$\times^{a,c}$	$\times^{c}$	$\times$	$\checkmark$	$\times$	$\times$	$\checkmark$	$\checkmark$	$\times^{b}$	$\checkmark^{b}$	$\checkmark$	$\checkmark$	$\times$	$\times$	$\times$	$\checkmark$
LC	$\times^{a}$	$\times$	$\checkmark$	$\checkmark$	$\times$	$\times$	$\checkmark$	$\checkmark$	$\checkmark^{b}$	$\checkmark$	$\checkmark$	$\checkmark$	$\times$	$\times$	$\checkmark$	$\checkmark$
LX	$\times^{a,c}$	$\times$	$\checkmark$	$\checkmark$	$\times$	$\times$	$\checkmark$	$\checkmark$	$\times^{b}$	$\checkmark^{b}$	$\checkmark$	$\checkmark$	$\times$	$\times$	$\checkmark$	$\checkmark$
OPT	$\times^{a,c}$	$\times$	$\checkmark$	$\times^{c}$	$\times$	$\times$	$\checkmark$	$\checkmark$	$\times^{b}$	$\checkmark$	$\checkmark$	$\checkmark$	$\times$	$\times$	$\checkmark$	$\checkmark$
F19	$\times^{a}$	$\checkmark$	$\checkmark$	$\times$	$\times^{a}$	$\checkmark$	$\checkmark$	$\times$	$\checkmark$	$\checkmark$	$\checkmark$	$\checkmark$	$\times$	$\checkmark$	$\checkmark$	$\times$
F5M	$\times^{a}$	$\checkmark$	$\checkmark$	$\times^{a}$	$\times$	$\checkmark$	$\checkmark$	$\times$	$\checkmark$	$\checkmark$	$\checkmark$	$\checkmark$	$\times$	$\checkmark$	$\checkmark$	$\times$
SND	$\times$	$\times^{c}$	$\checkmark$	$\times$	$\times^{a}$	$\checkmark$	$\checkmark$	$\times$	$\checkmark$	$\checkmark$	$\checkmark$	$\checkmark$	$\times$	$\checkmark$	$\checkmark$	$\times$
QHE	$\times$	$\checkmark$	$\checkmark$	$\times$	$\times$	$\checkmark$	$\checkmark$	$\times$	$\checkmark$	$\checkmark$	$\checkmark$	$\checkmark$	$\times$	$\checkmark$	$\checkmark$	$\times$
NT	$\times$	$\times^{c}$	$\times^{c}$	$\times$	$\times$	$\checkmark$	$\checkmark$	$\times$	$\checkmark$	$\checkmark$	$\checkmark$	$\checkmark$	$\times$	$\checkmark$	$\checkmark$	$\times$
NTC	$\times$	$\checkmark$	$\checkmark$	$\checkmark$	$\times$	$\checkmark$	$\checkmark$	$\checkmark$	$\checkmark$	$\checkmark$	$\checkmark$	$\checkmark$	$\times$	$\checkmark$	$\checkmark$	$\times$

Both BNS and NSBH local rates compatible with GWTC-5 90% CI

BNS and/or NSBH local rates not compatible with GWTC-5 90% CI

Guess who ?

	Universal top-hat				Non-univ. flat				Non-univ. log-normal				Universal structured			
α_{CE}	0.5	1.0	3.0	5.0	0.5	1.0	3.0	5.0	0.5	1.0	3.0	5.0	0.5	1.0	3.0	5.0
F	×[a]	✓	✓	×	×	✓	✓	×	✓	✓	✓	✓	×	✓	✓	×
K265	×[a]	×	×	×[a]	×	×	×	×	✓[b]	✓	✓	✓[b]	×	×	×	×
K150	×	×	✓	×	×	×	×	×	✓	✓	✓	✓	×	×	×	×
QCBSE	×[a,c]	×	×[a]	×[a]	×	×	×	×	×[b]	✓	✓[b]	✓[b]	×	×	×	×
QCBB	✓	×	×	×	✓	✓[a]	×	×	✓	✓	✓	✓[b]	×	×	×	×
RBSE	×	×[a]	✓	×	×[a]	✓	✓	×[a]	✓[b]	✓	✓	✓[b]	×	✓	✓	×
LK	×[a,c]	×[c]	×	✓	×	×	✓	✓	×[b]	✓[b]	✓	✓	×	×	×	✓
LC	×[a]	×	✓	✓	×	×	✓	✓	✓[b]	✓	✓	✓	×	×	✓	✓
LX	×[a,c]	×	✓	✓	×	×	✓	✓	×[b]	✓[b]	✓	✓	×	×	✓	✓
OPT	×[a,c]	×	✓	×[c]	×	×	✓	✓	×[b]	✓	✓	✓	×	×	✓	✓
F19	×[a]	✓	✓	×	×[a]	✓	✓	×	✓	✓	✓	✓	×	✓	✓	×
F5M	×[a]	✓	✓	×[a]	×	✓	✓	×	✓	✓	✓	✓	×	✓	✓	×
SND	×	×[c]	✓	×	×[a]	✓	✓	×	✓	✓	✓	✓	×	✓	✓	×
QHE	×	✓	✓	×	×	✓	✓	×	✓	✓	✓	✓	×	✓	✓	×
NT	×	×[c]	×[c]	×	×	✓	✓	×	✓	✓	✓	✓	×	✓	✓	×
NTC	×	✓	✓	✓	×	✓	✓	✓	✓	✓	✓	✓	×	✓	✓	×

Some populations remain **compatible with GWTC-5**, but **inconsistent** with observed **aperture angles**

Can someone help the BNS ?

EM-bright NSBH

De Santis+ in prep.

$$R_{\rm sGRB}^{\rm pred} = \epsilon_{\rm GBM} \left\{ \left[f_j \underbrace{\int_0^{\theta_c} \sin\theta_v \, d\theta_v}_{\langle f_b \rangle} \int \Phi(\theta_p, z) \frac{R_{\rm BNS}(z)}{1+z} \frac{dV}{dz} \, d\theta_p \, dz \right]_{\rm BNS} \right.$$

$$\left. \boxed{+ \, [{\rm same}]_{\rm NSBH}} \right\}.$$

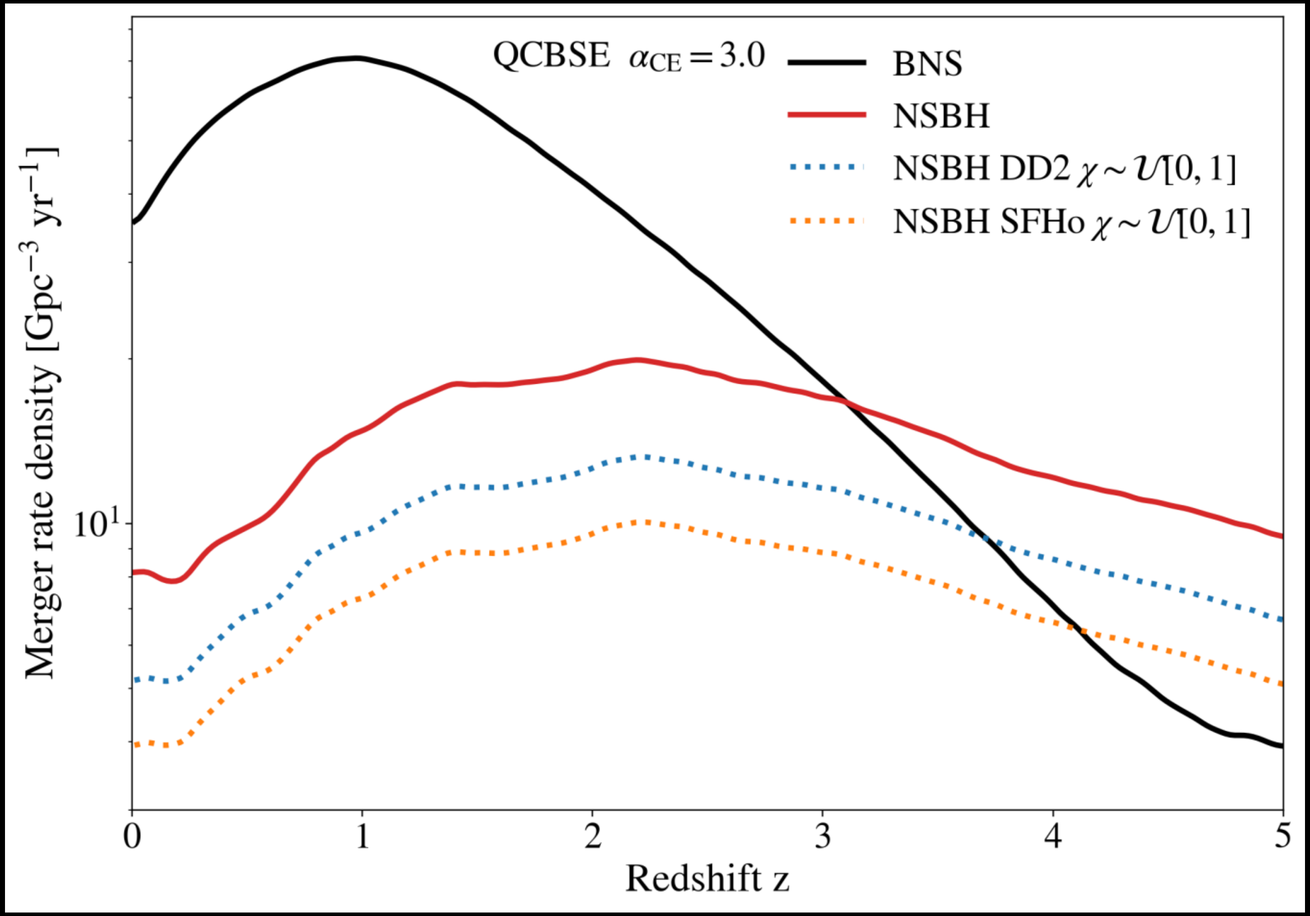
Goal: show that not even adding NSBH is sufficient to alleviate tension → Assume the best case (**absurd**) scenario where $f_j = 1$ for NSBH:

EM-bright NSBH : How many?

$$M_{\rm out}\left(M_{\rm NS}, M_{\rm BH}, \chi_{\rm BH}, {\rm EOS}\right) > 0$$

Foucart + 18

Stiff DD2 EOS : more EM bright



Soft SFHo EOS : less EM bright

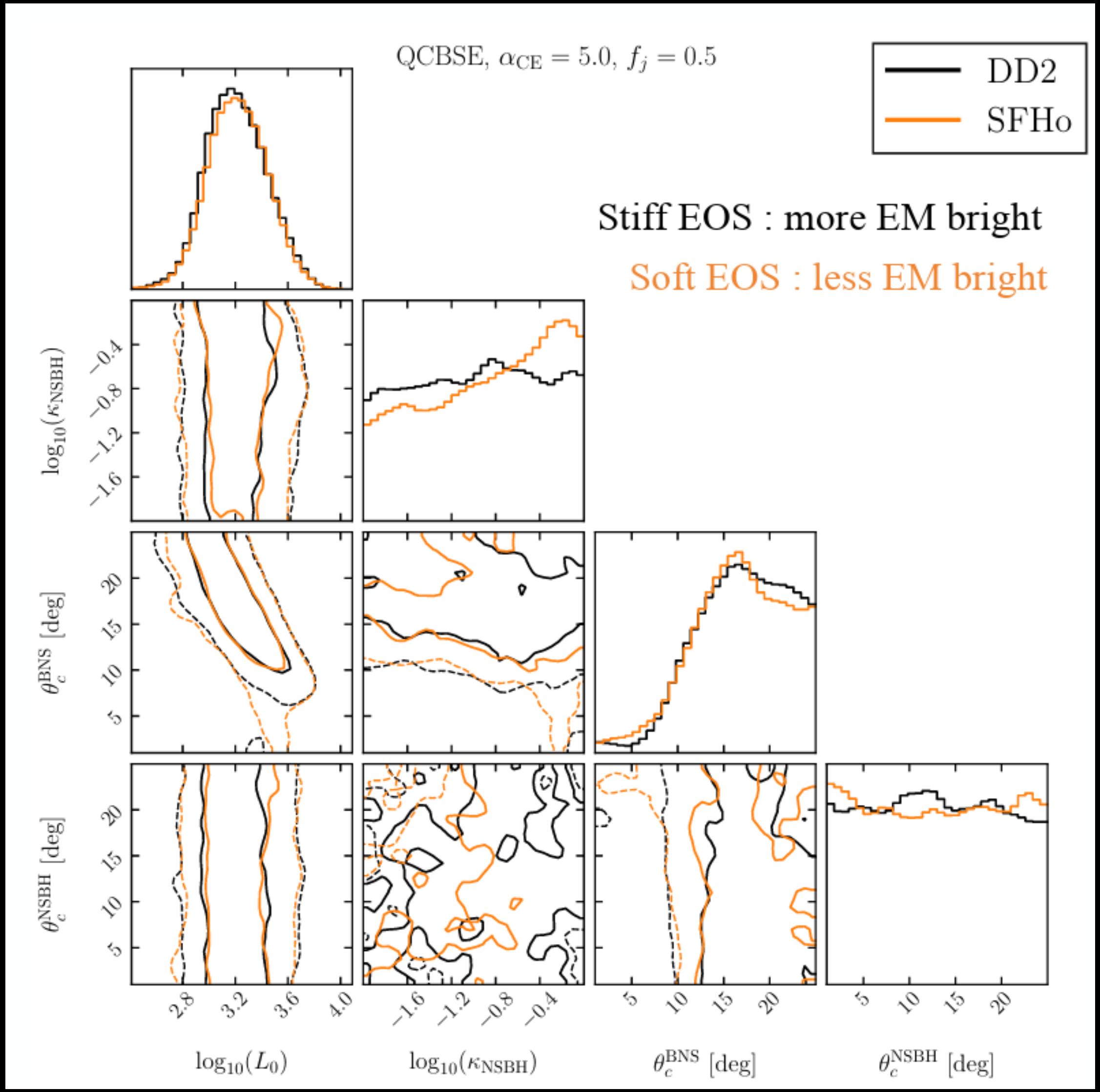
EM-bright NSBH : How are you?

$$L_0^{\mathrm{NSBH}} = \kappa_{\mathrm{NSBH}} L_0^{\mathrm{BNS}},$$

$$\theta_{\mathrm{BNS}} \neq \theta_{\mathrm{NSBH}}.$$

Introduce **two** new parameters

EM-bright NSBH : How are you?

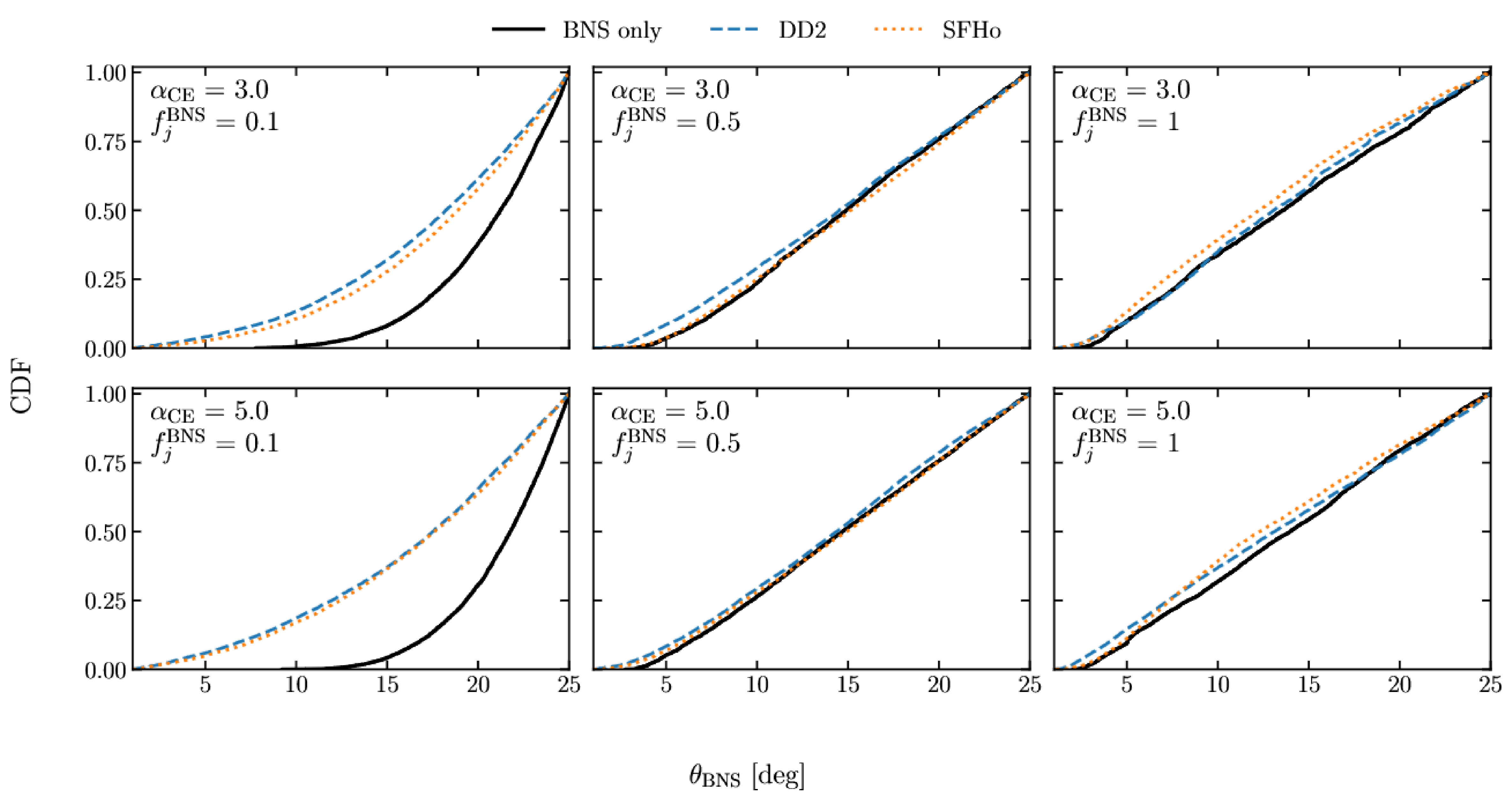


$$L_0^{NSBH} = \kappa_{NSBH} L_0^{BNS},$$

$$\theta_{BNS} \neq \theta_{NSBH}.$$

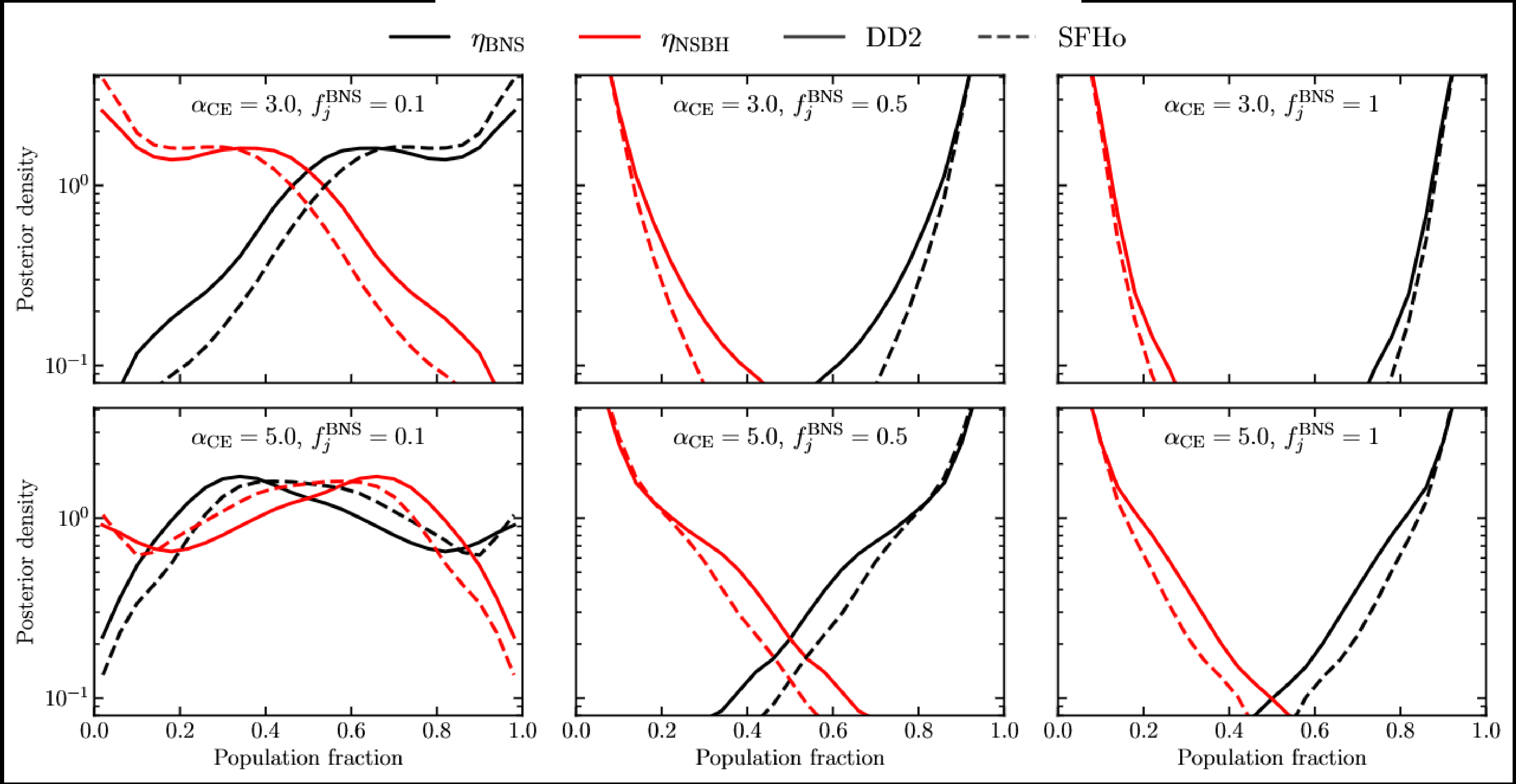
Including NSBH marginally alleviates the tension

Only slight improvement for GRB aperture angle



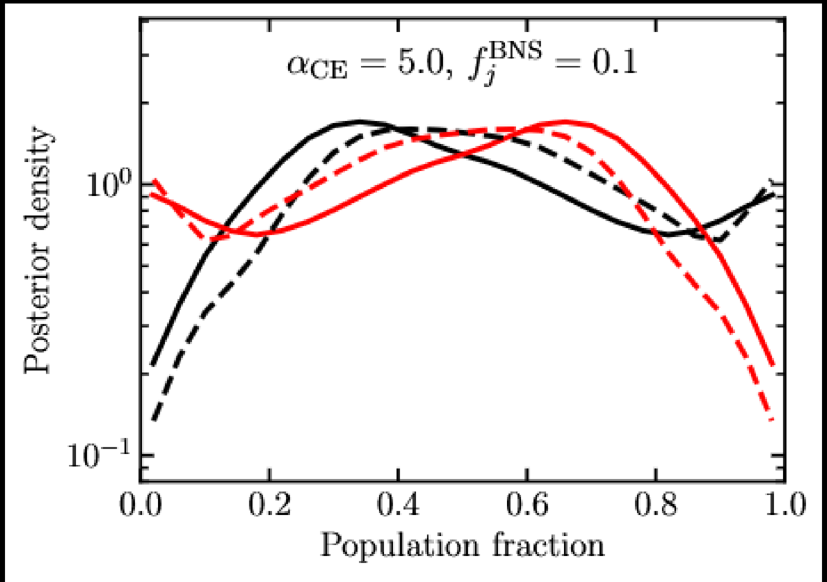
Relative contribution of BNS and NSBH to observed sGRBs

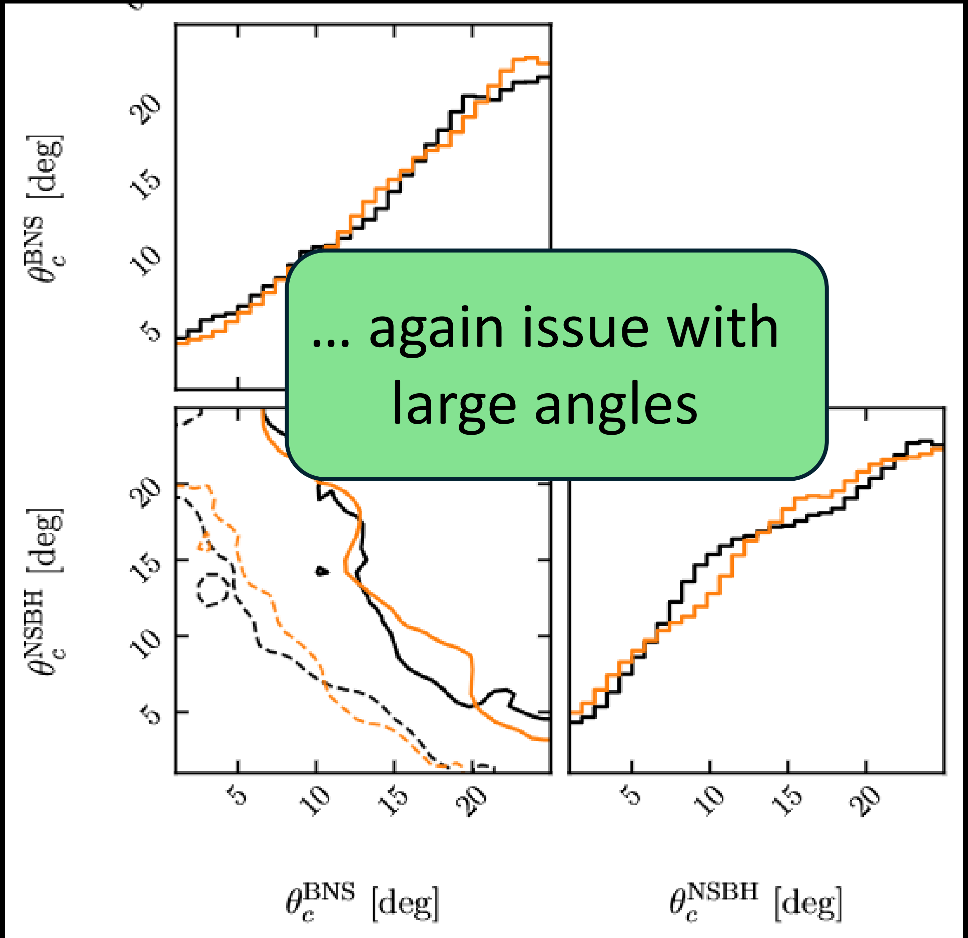
$$\eta_X = \frac{R_{\mathrm{sGRB\ from\ }X}}{R_{\mathrm{sGRB}}}, \qquad X = \mathrm{BNS,\ NSBH}.$$



Relative contribution of BNS and NSBH to sGRBs

If BNS highly inefficient for jet launch, NSBH can dominate, **BUT…**





… again issue with large angles

Conclusion

BNS local rates keeps decreasing, now $\mathcal{R}_{BNS} = 5.1 - 154.7\ Gpc^{-3}yr^{-1}\ (90\%\ C.L.)$

Is $\mathcal{R}_{BNS}$ compatible with $\mathcal{R}_{sGRB}$?

We find two scenarios

- $\mathcal{R}_{BNS}(0) \sim 50 - 100\ Gpc^{-3}yr^{-1} \leftrightarrow$ **compatible with jet-break constrains, but rates keep getting lower**
- $\mathcal{R}_{BNS}(0) \leq 50\ Gpc^{-3}yr^{-1} \leftrightarrow$ **aperture angles of sGRB require a distribution with >10% of jets larger than 15^o**

Can NSBH alleviate?

- **Marginally!** Under an **optimistic** scenario $f_j^{NSBH} = 1$
- They can play a non-negligible role **only if BNS are highly inefficient in launching a jet** (prob. < 10%)

Thank you

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NITRATES

MAGGPY

BAT-GLIMPSE

RAVEN

Multi-messenger Alert System

GWFish Tutorials

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