

GRBs and electromagnetic counterparts of gravitational wave events

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with G. Ghirlanda, G. Ghisellini, M. Colpi, M. Branchesi, E. Chassande-Mottin



Gamma-ray bursts: observational appearance

Gamma-ray detector (spectral range: few keV to several MeV) on spacecraft

Swift/BAT



Fermi/GBM



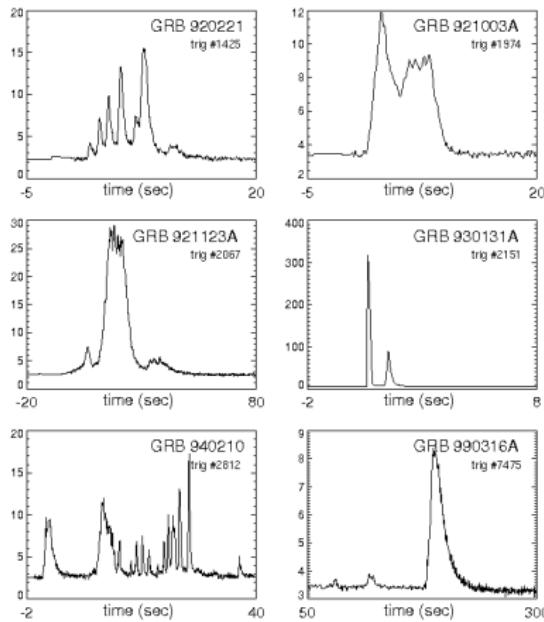
CGRO/BATSE



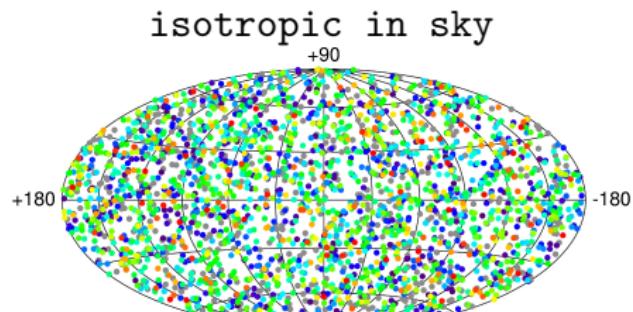
Gamma-ray bursts: observational appearance

Once every few days detector gets triggered by burst

diverse lightcurves



[D. Perley using CGRO/BATSE data]

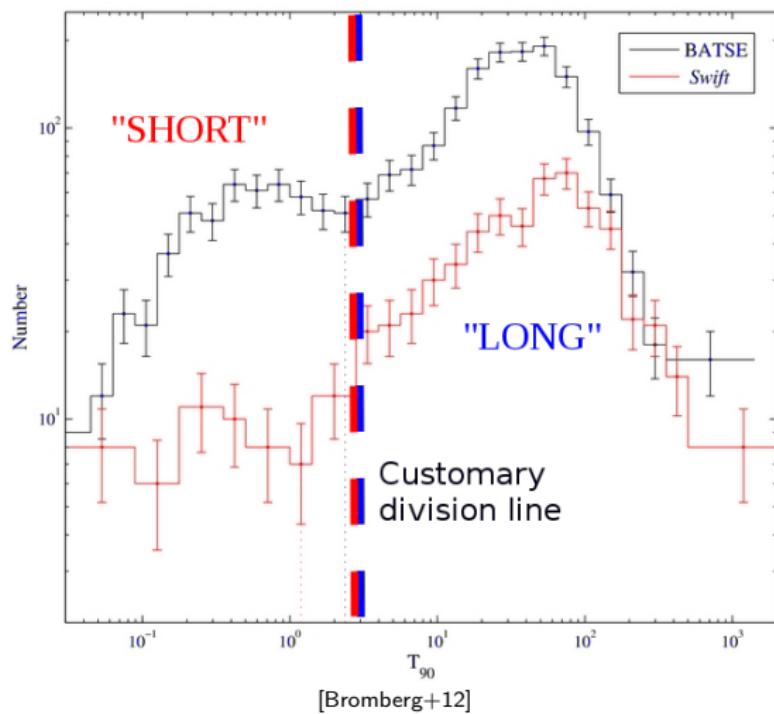


2704 BATSE Gamma-Ray Bursts

[NASA/BATSE team]

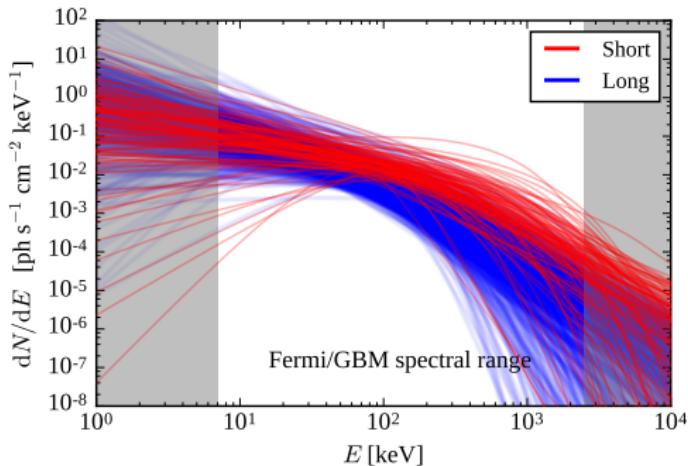
Gamma-ray bursts: observational appearance

Bimodal duration distribution



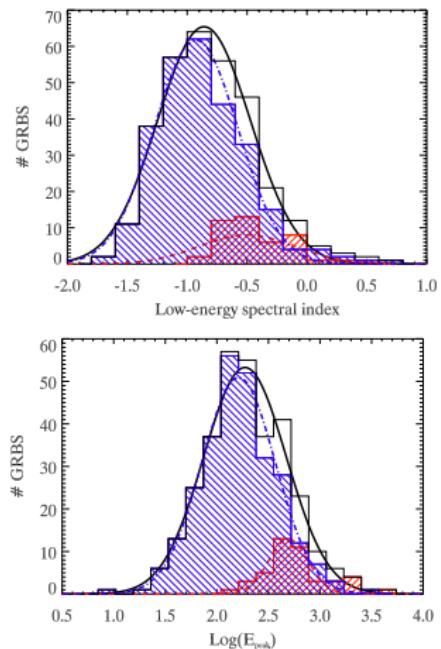
Gamma-ray bursts: observational appearance

non-thermal spectra



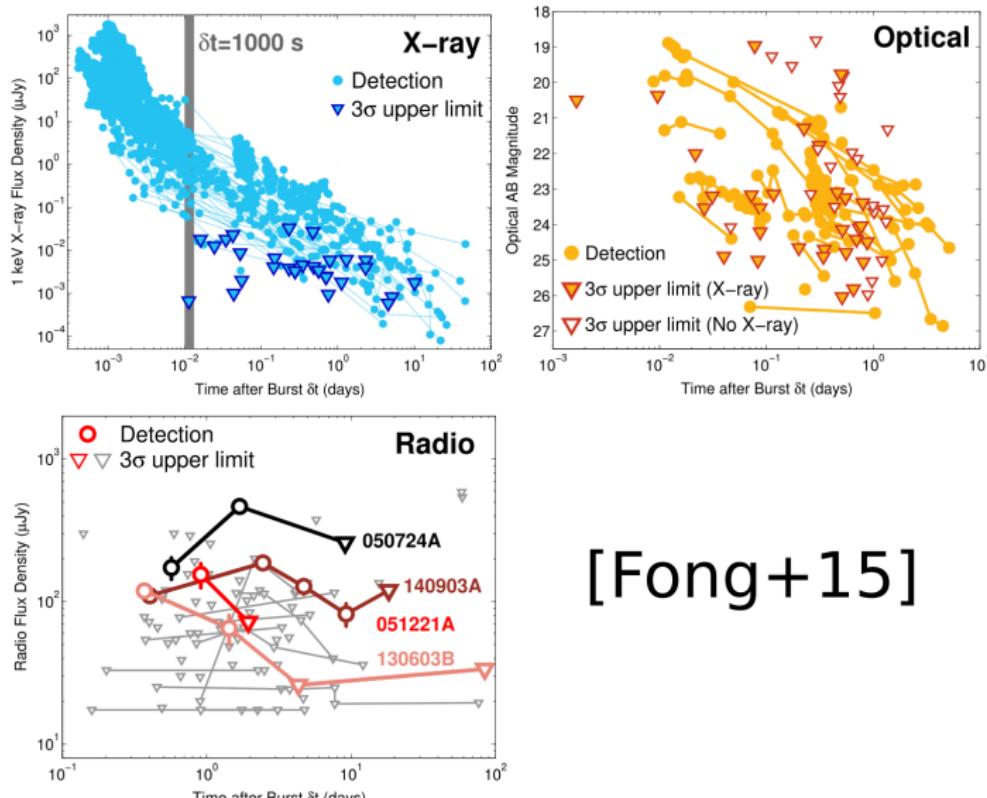
[Spectral fits to Fermi/GBM data]

SGRBs harder on average



[Nava+12]

GRB afterglow: observational appearance



Gamma-ray bursts: progenitors

Long GRBs

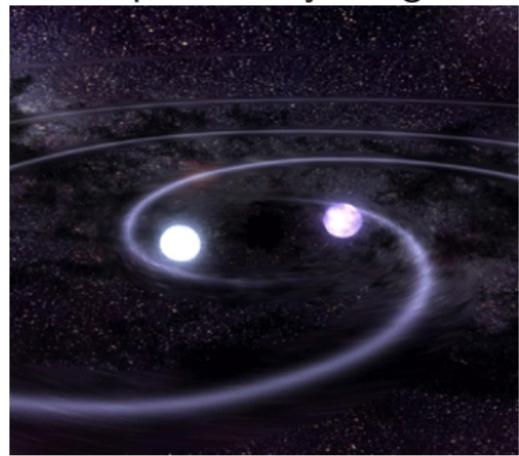
Massive star collapse



(supernova association)

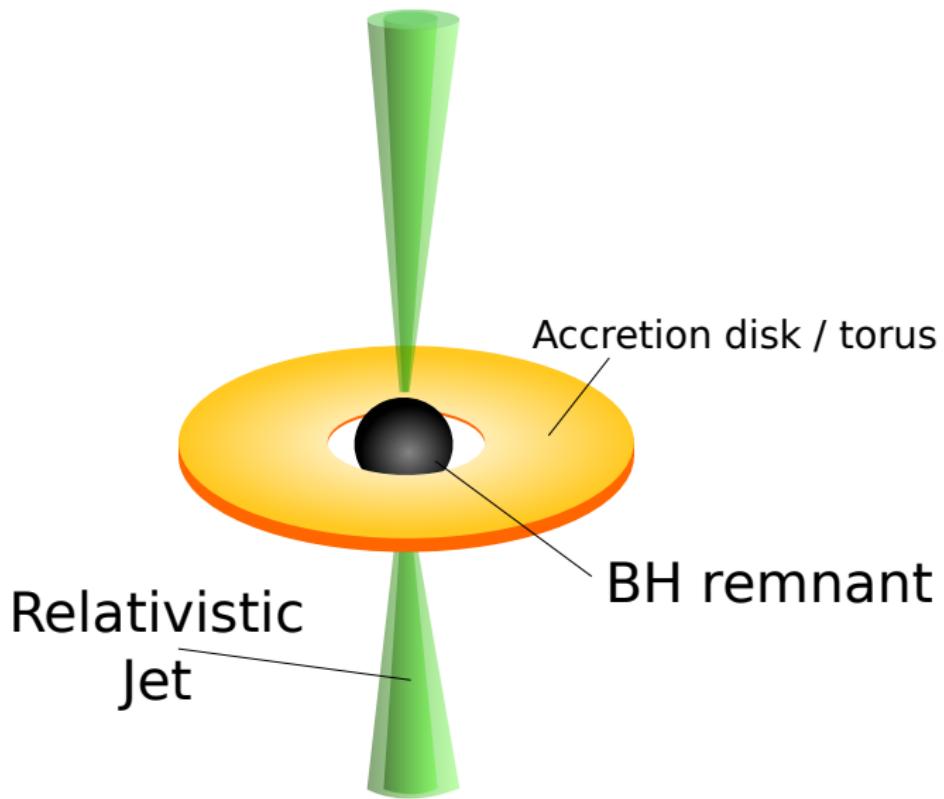
Short GRBs

Compact binary merger?

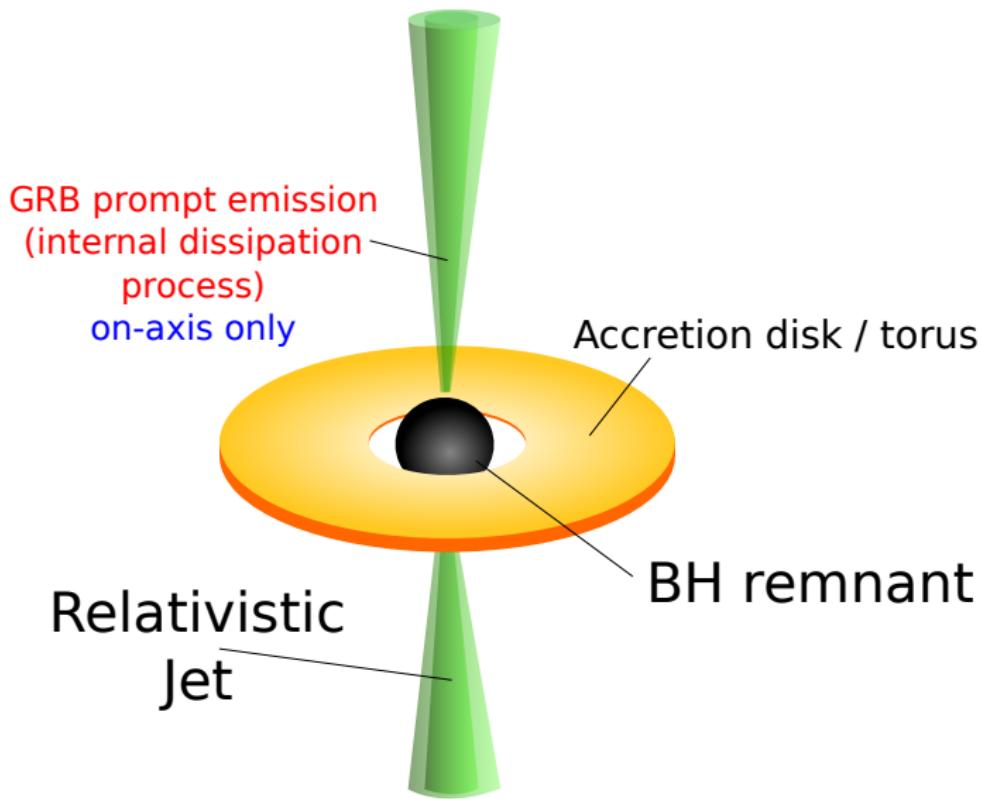


(possible macronova association)

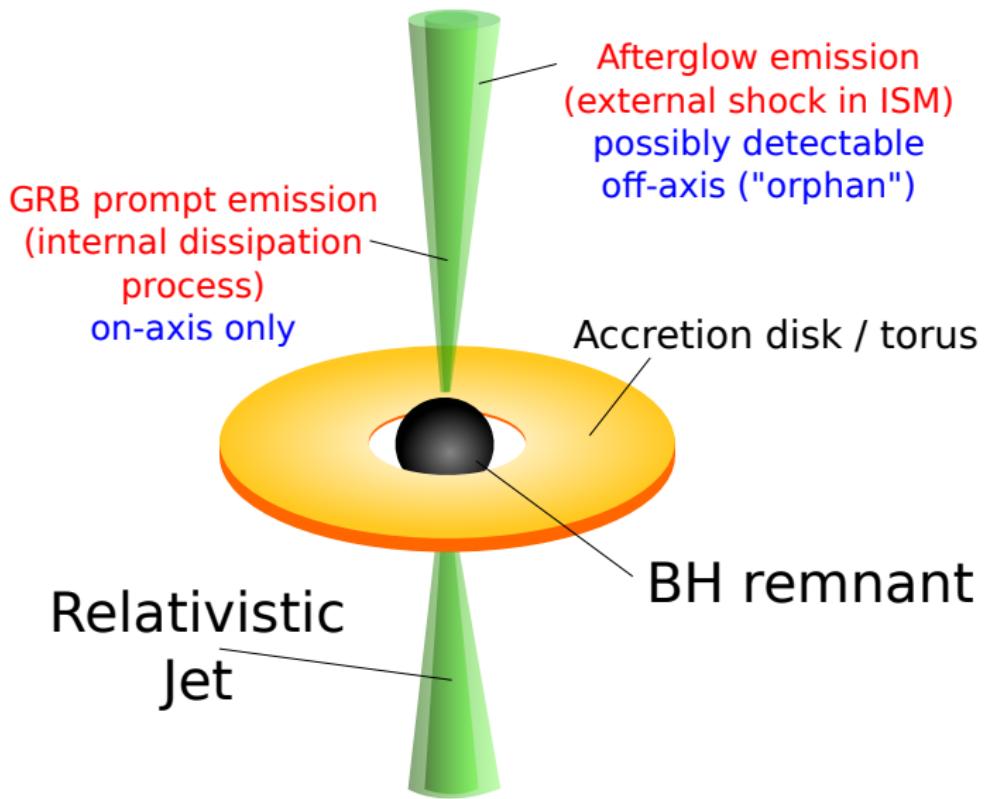
The central engine



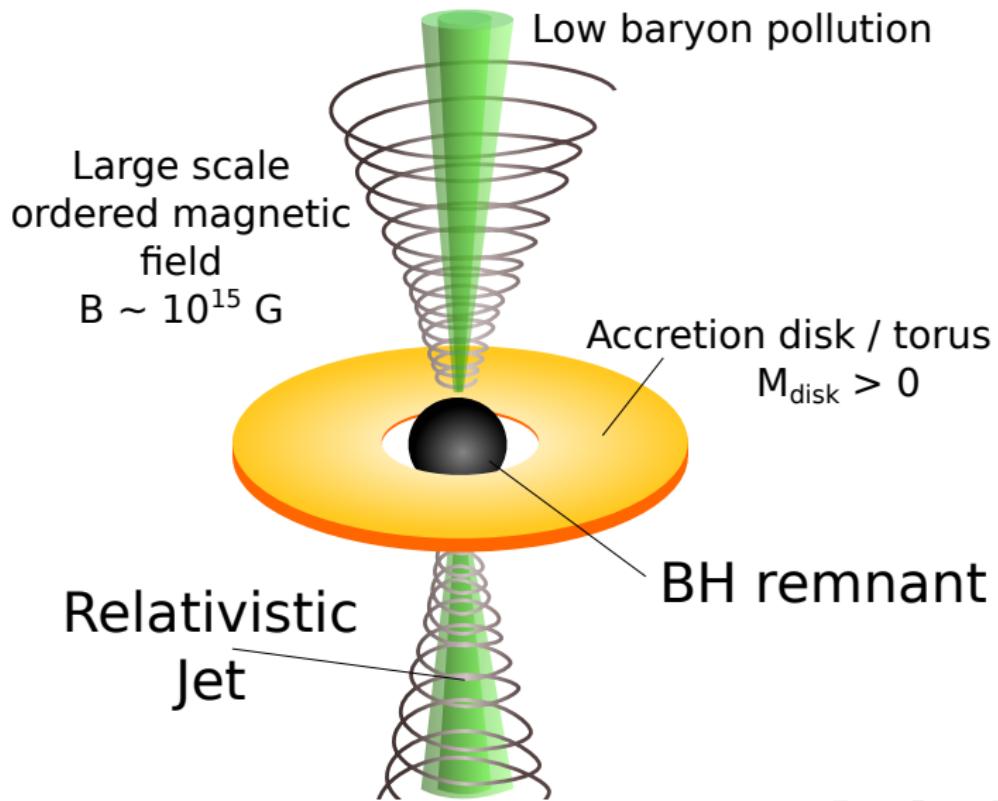
The central engine



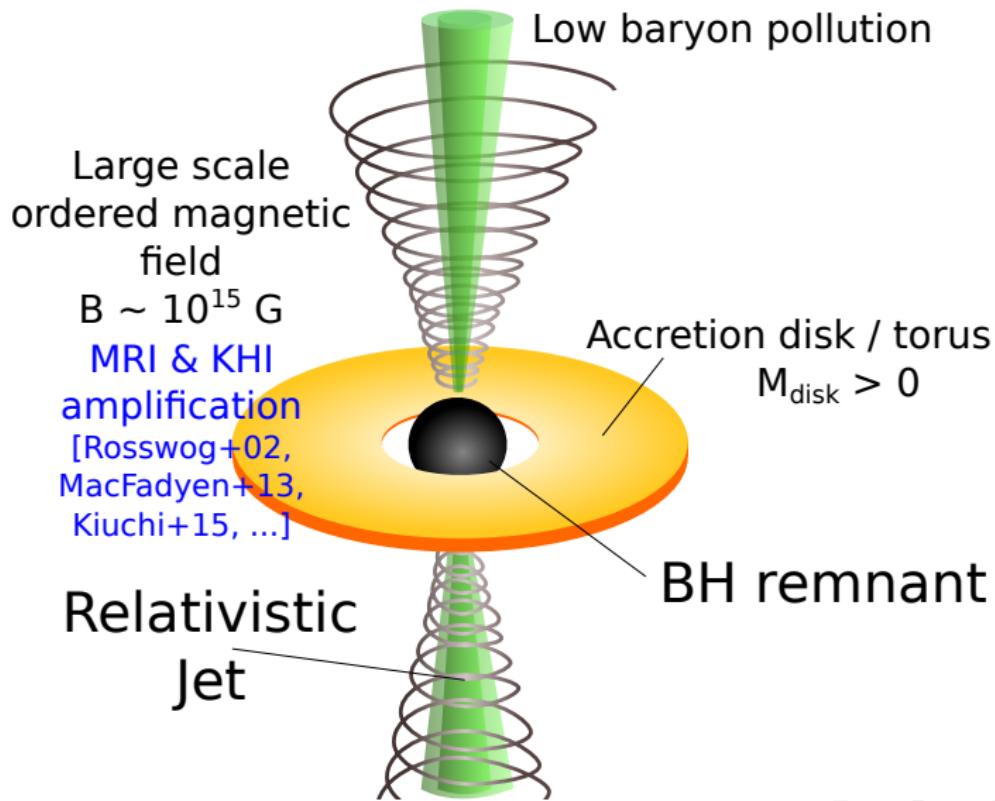
The central engine



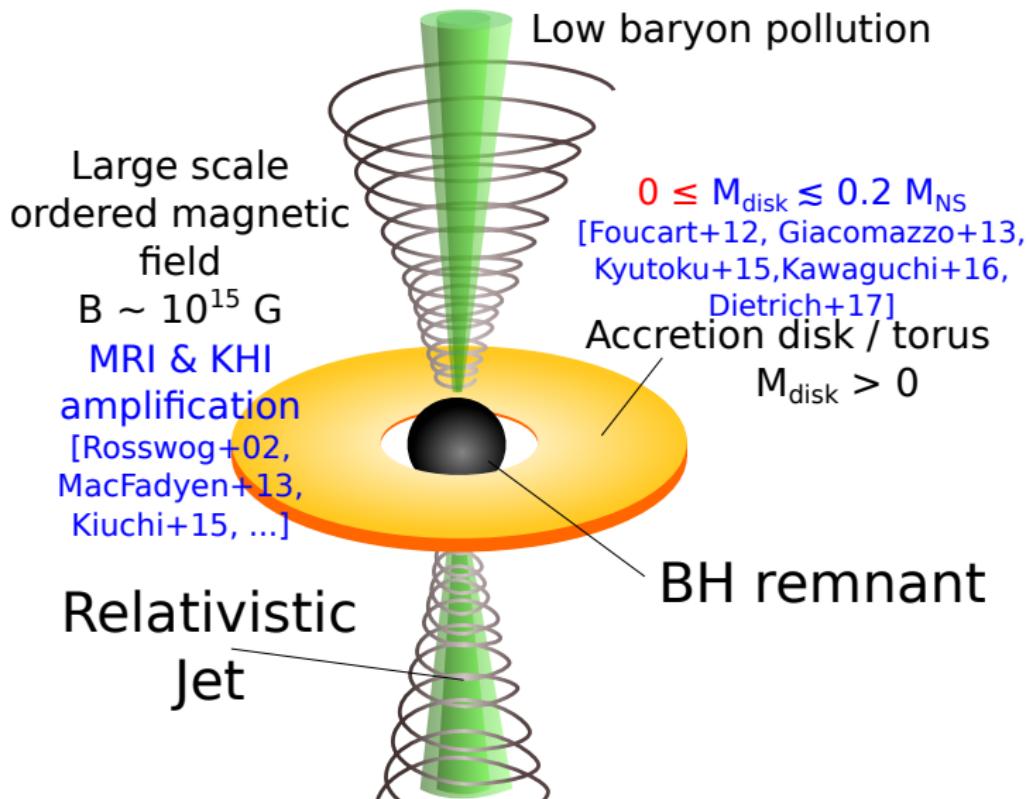
Conditions for jet launching: satisfied in post-merger?



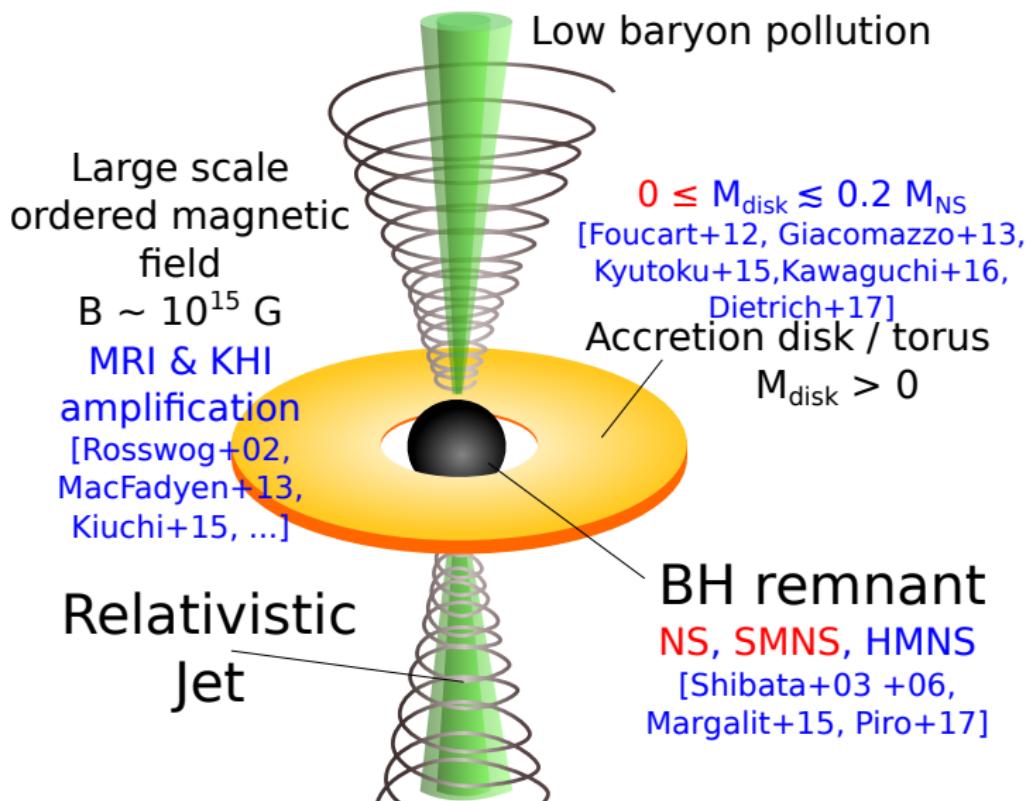
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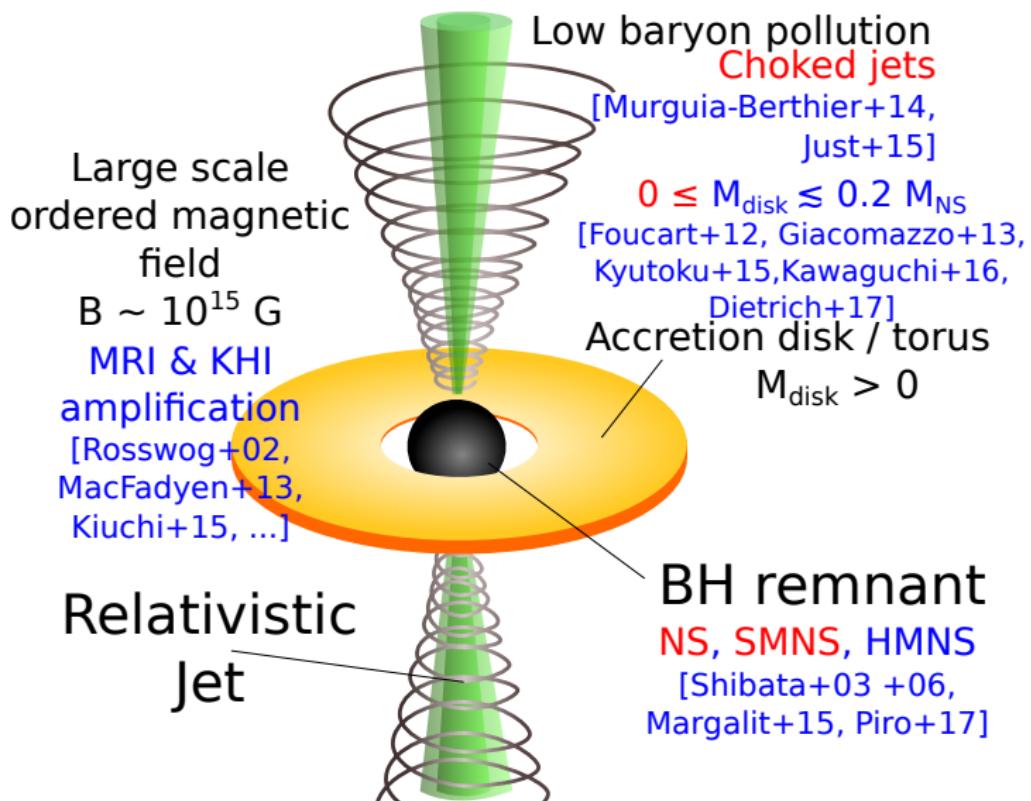
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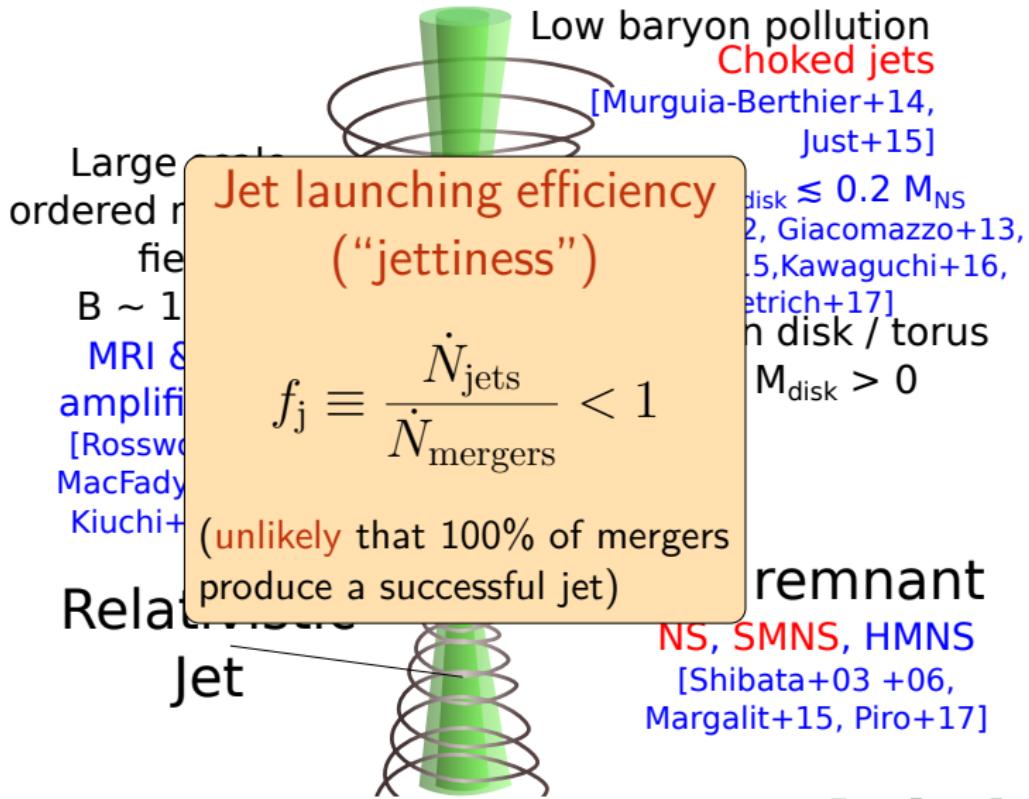
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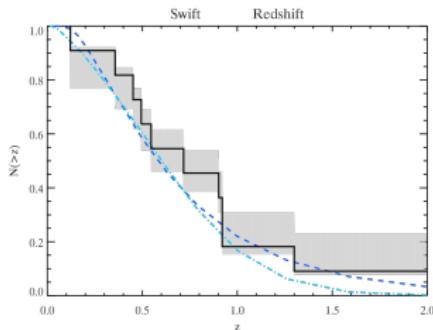
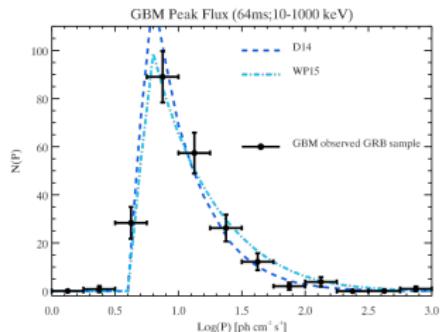


Conditions for jet launching: satisfied in post-merger?



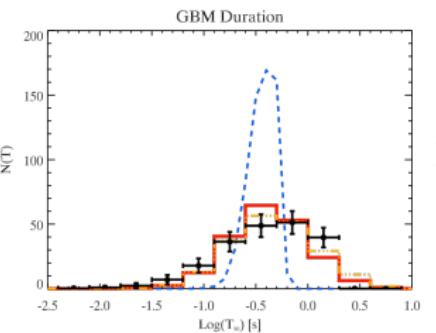
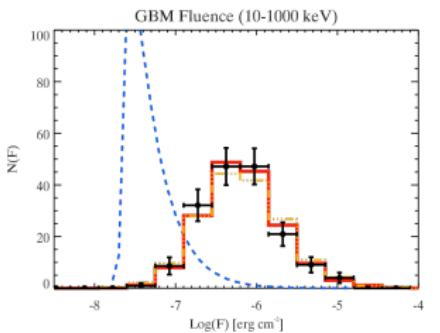
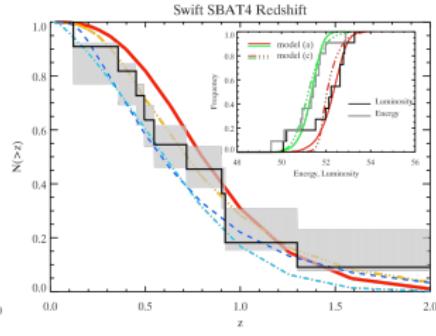
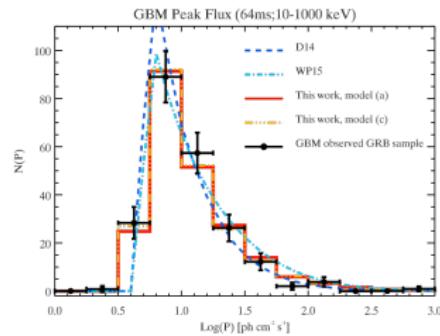
SGRB population \iff NS-NS population

SGRB population properties: fitting all observables

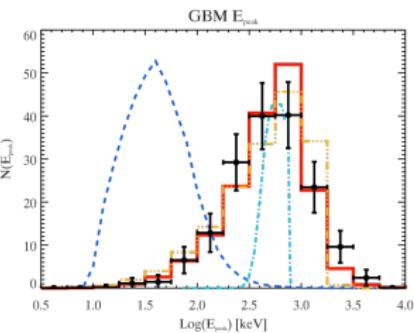


[Guetta+05,06]
 [D'Avanzo+14]
 [Wanderman+15]
 Peak flux + Redshift

SGRB population properties: fitting all observables

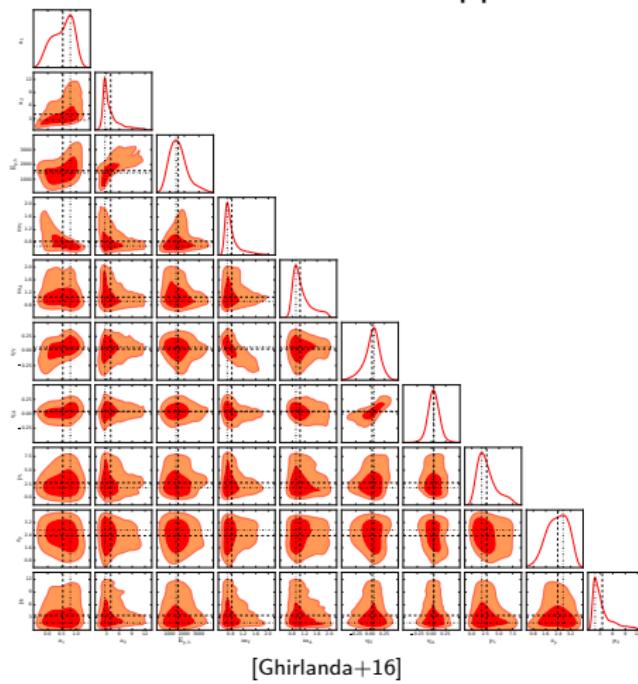


[Guetta+05,06]
 [D'Avanzo+14]
 [Wanderman+15]
Peak flux + Redshift
 [Ghirlanda+16]
All constraints

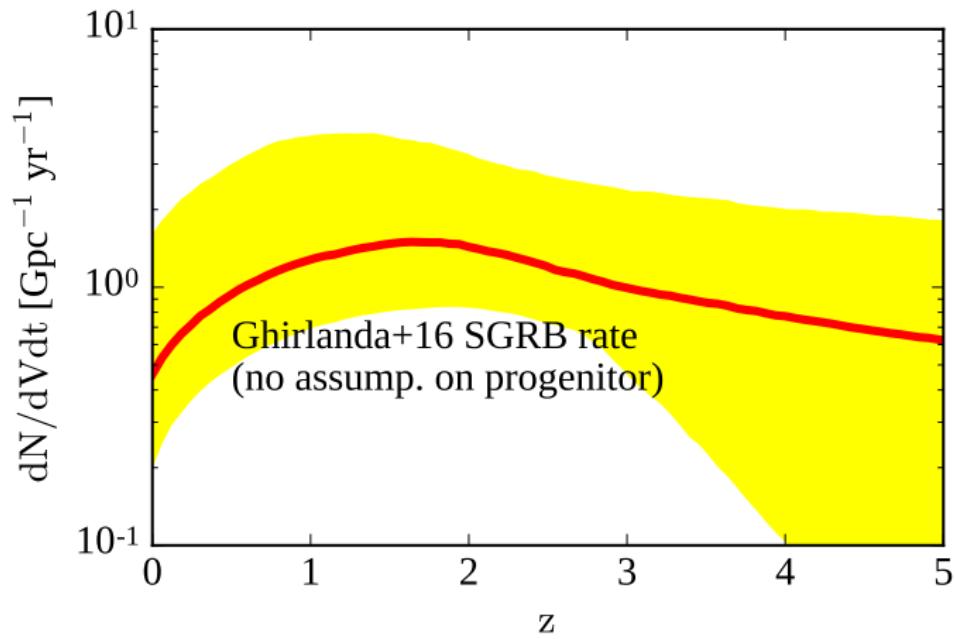


SGRB population properties: fitting all observables

Find most likely intrinsic parameters that reproduce the observed distributions: MCMC approach

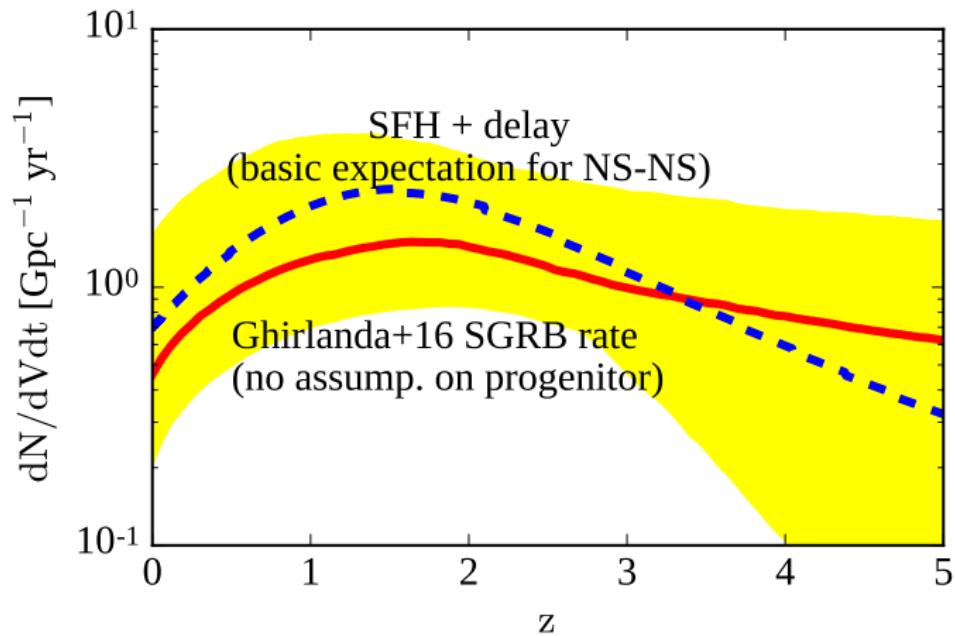


SGRB redshift distribution



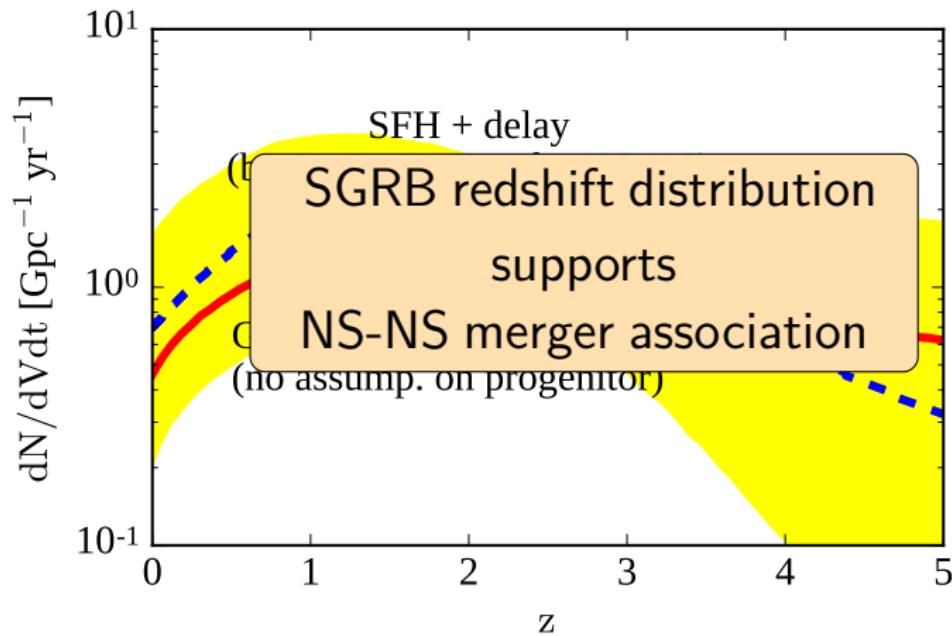
[data from Ghirlanda+16]

SGRB redshift distribution



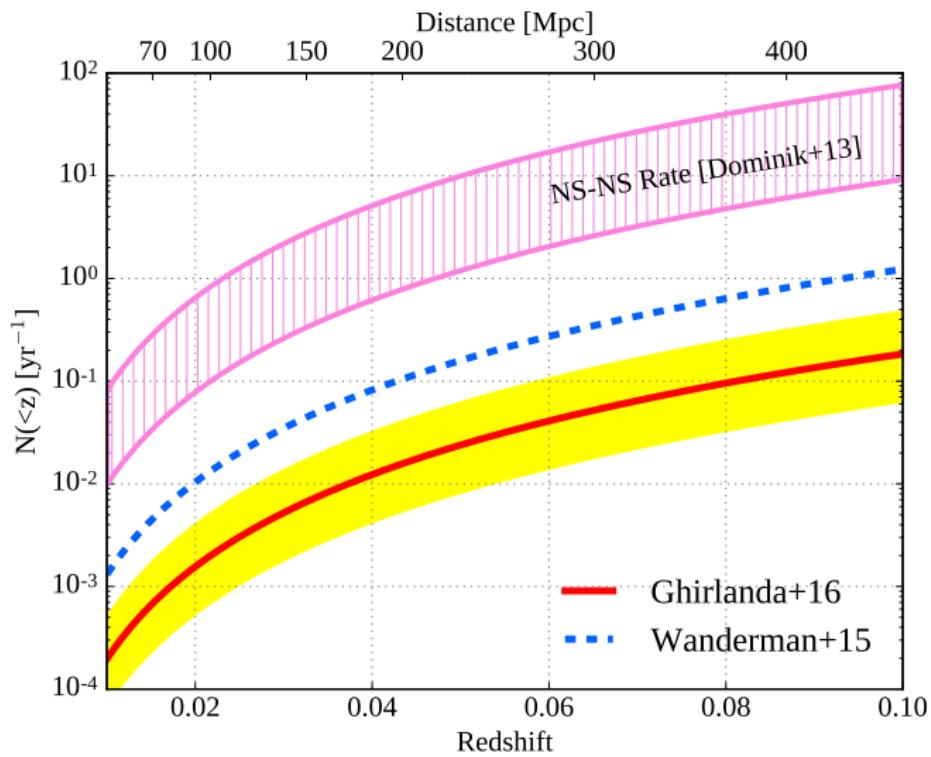
[data from Ghirlanda+16]

SGRB redshift distribution

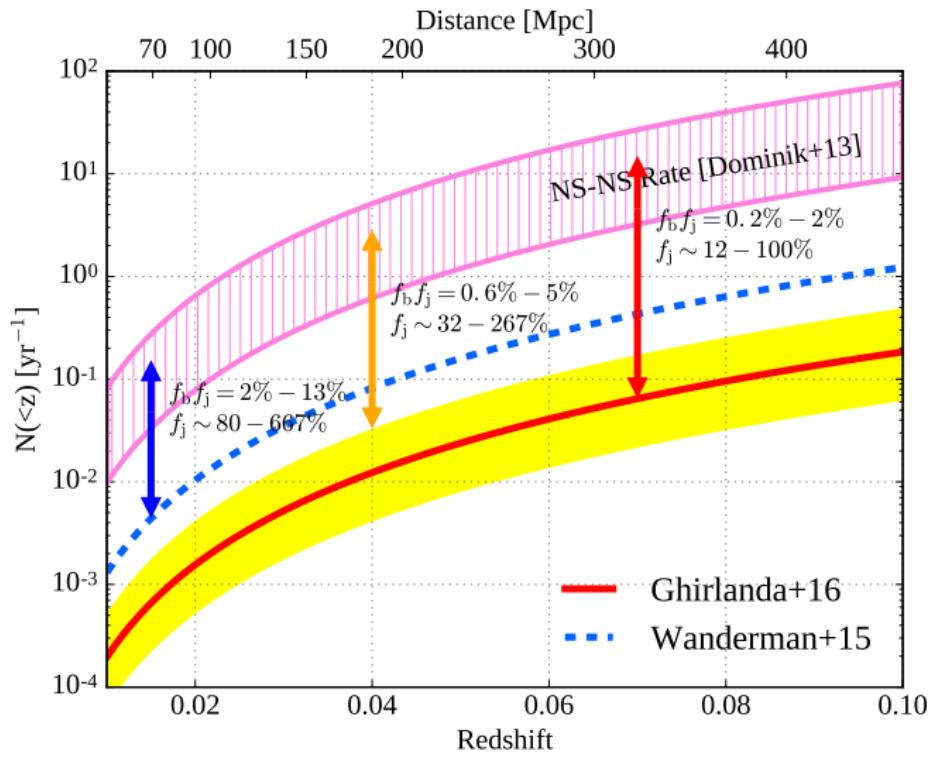


[data from Ghirlanda+16]

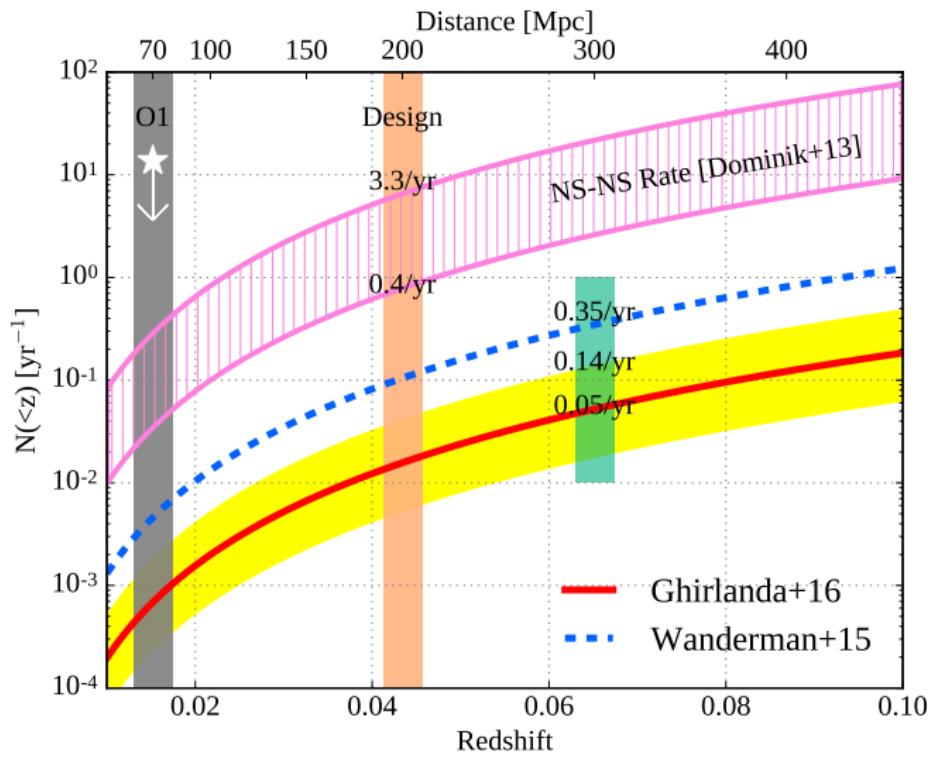
SGRB local event rate



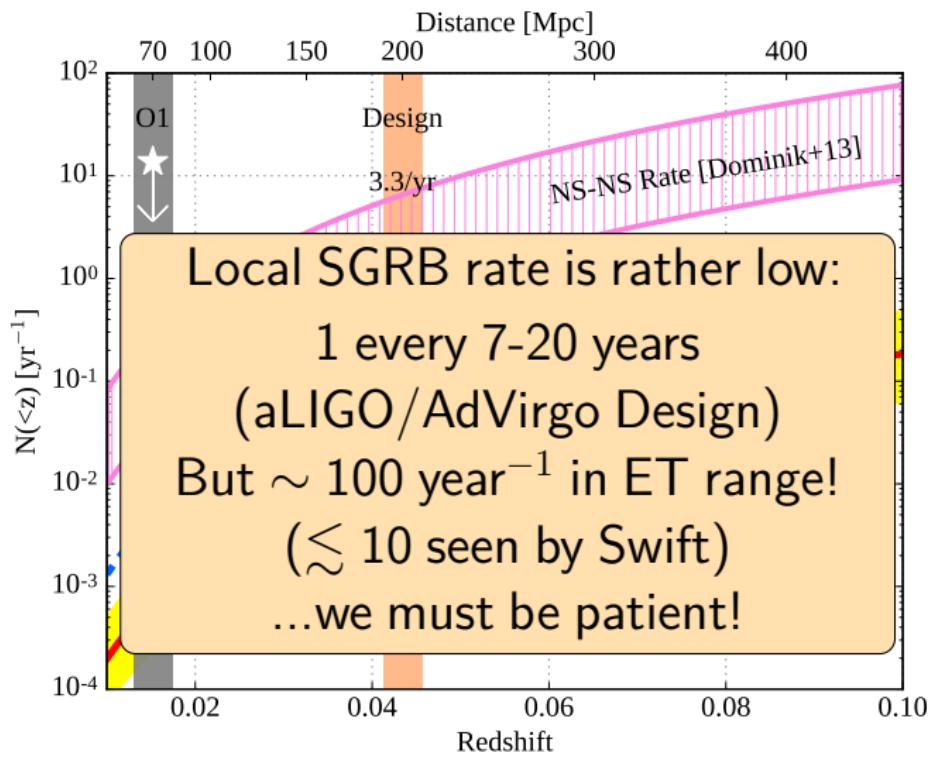
SGRB local event rate



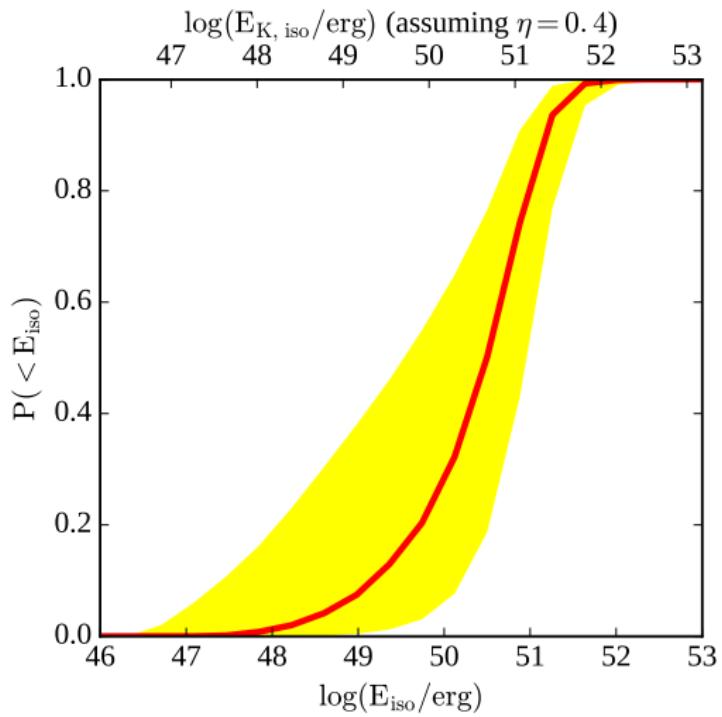
SGRB local event rate



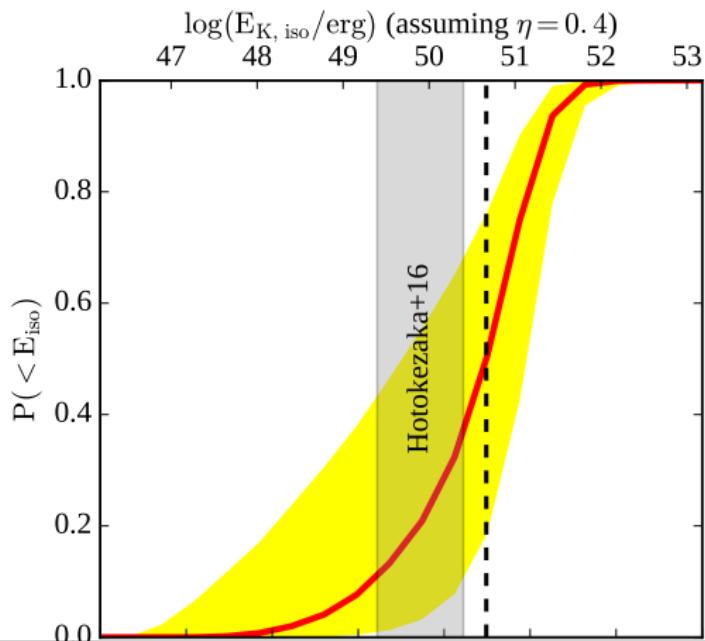
SGRB local event rate



SGRB energy distribution

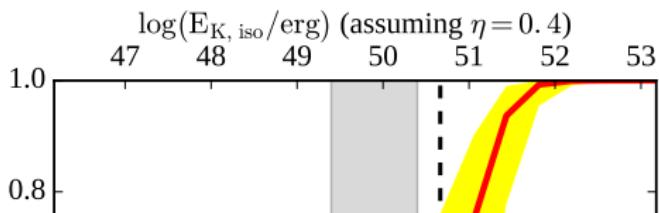


SGRB energy distribution



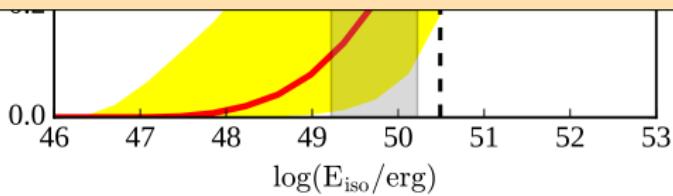
Hotokezaka+16: predictions about Radio orphan afterglows detectability (as EM counterparts of NS-NS mergers)

SGRB energy distribution

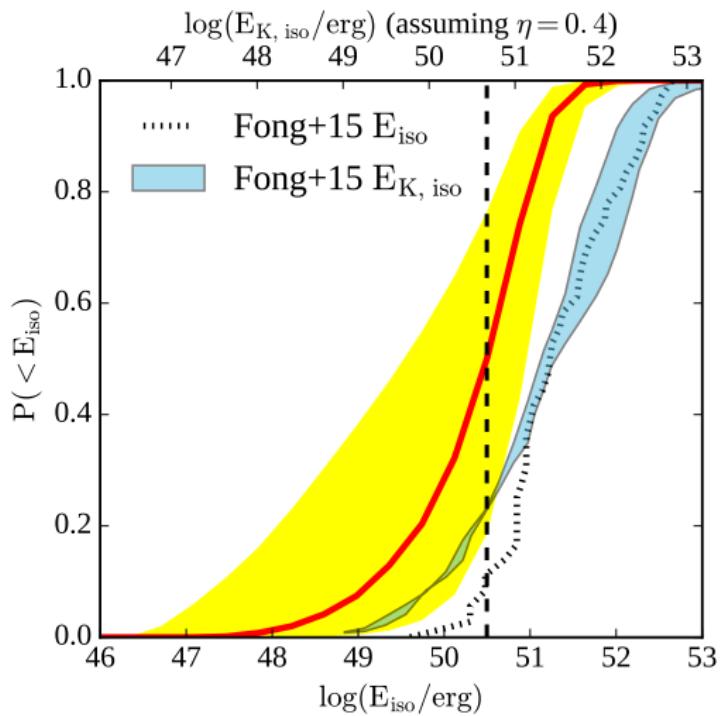


Better prospects for (orphan)
afterglows!

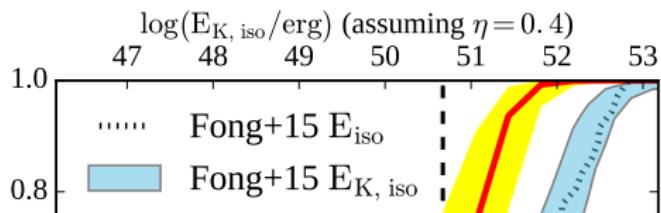
(we're working out the expected rate
for various surveys)



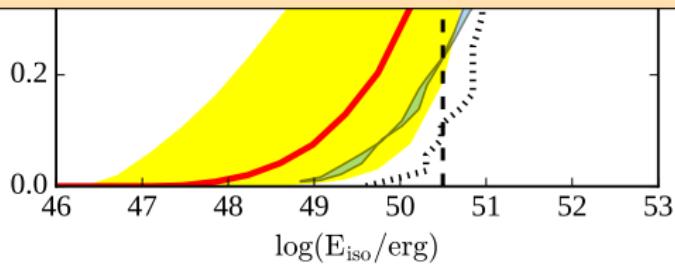
SGRB energy distribution



SGRB energy distribution



Still
afterglows are intrinsically dimmer than
observed on average



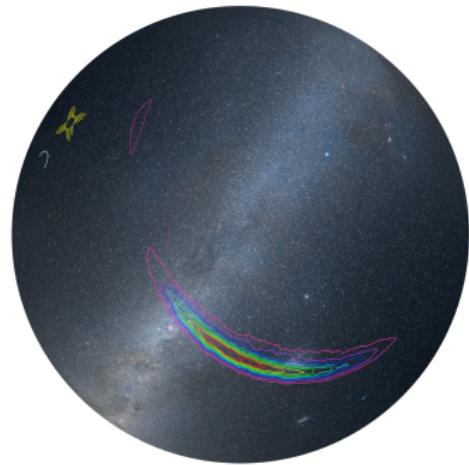
The follow-up problem

EM counterparts are dim

→ need to go **deep**

BUT

Localization areas are **large**



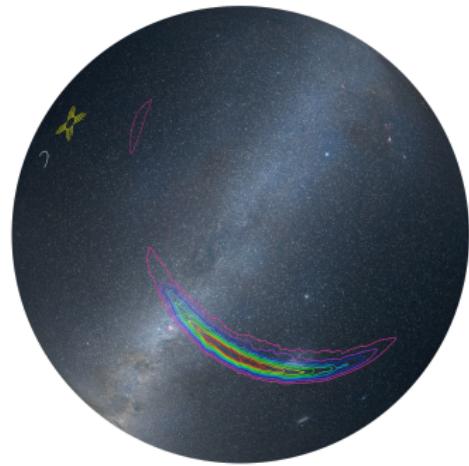
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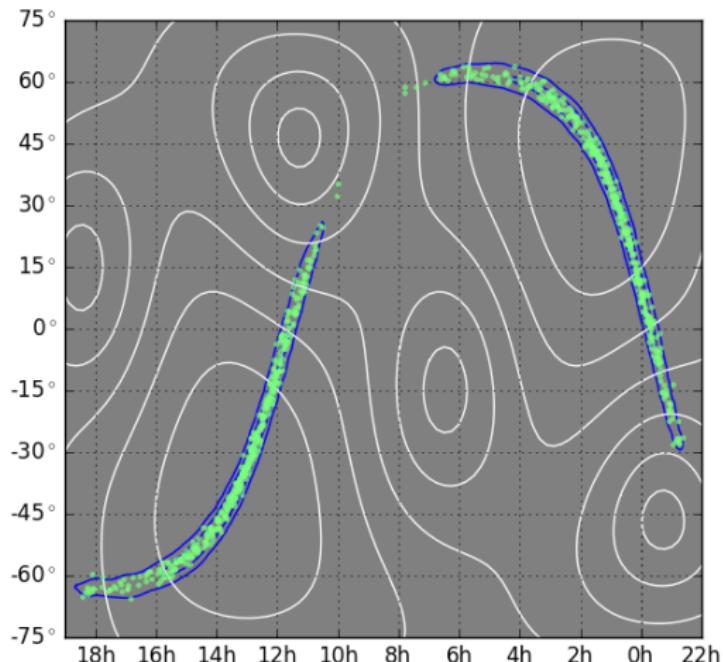
BUT

Localization areas are **large**



Need for **optimized follow-up strategies**
(advertisement time!)

From CBC parameters to SGRB afterglow lightcurve



[Salafia+17]

Posterior samples → lightcurves

[Salafia+17]

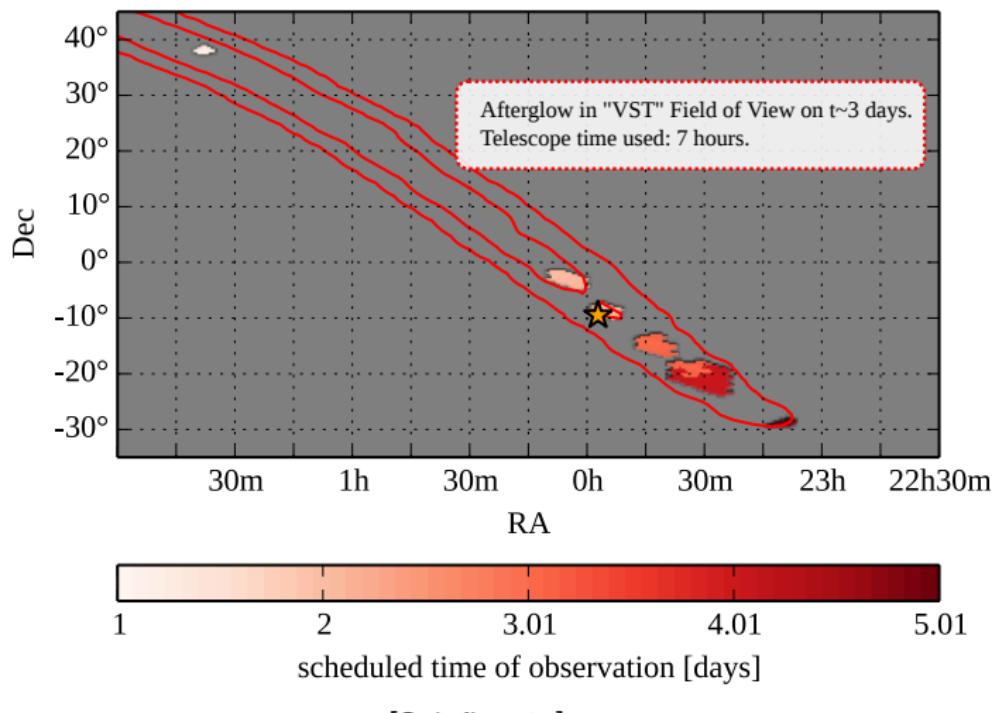
Fraction of lightcurves above threshold

[Salafia+17]

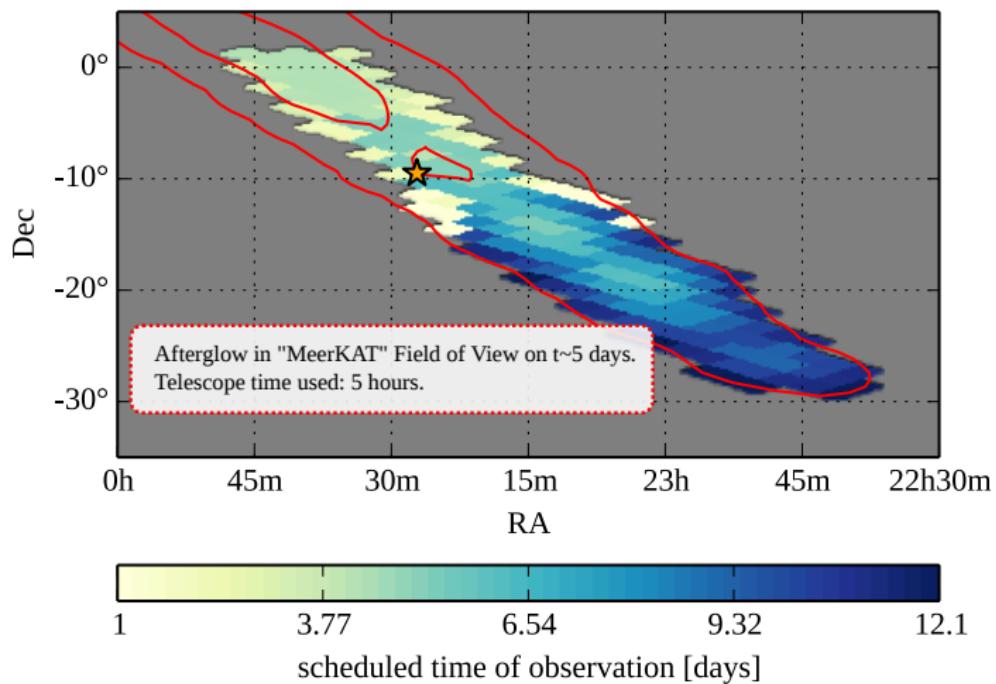
Where and when

Can be used to optimize follow-up
(see the “where and when” paper [Salafia+17])

Test example: Optical search

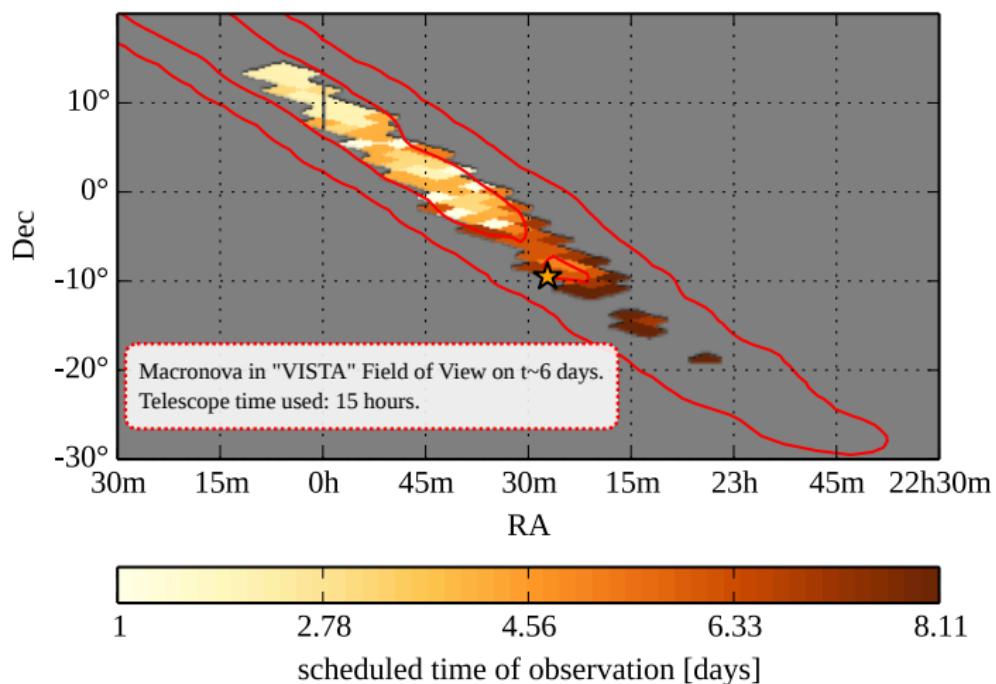


Test example: Radio search



[Salafia+17]

Test example: IR search (Macronova)



[Salafia+17]

Post-detection: association confidence assessment

Even if not used for follow-up optimization:
increase/decrease confidence in GW-EM association
(details in future work)

Concluding remarks

- A CBC involving at least one NS is a viable SGRB progenitor, but unlikely 100% of mergers produce a jet
- The intrinsic redshift distribution of SGRBs is compatible with the expected shape of CBC redshift distribution
- The intrinsic rate of SGRBs is 50÷500 times lower than Dominik+13 NS-NS rate (this accounts for beaming factor & jettiness). Not very encouraging for SGRB–GW association
- Intrinsic energy distribution of SGRBs: better (larger average energy) than previously expected, but still most jets are weaker than the observed population: need deep EM follow-up for (orphan) afterglow detection
- follow-up can be optimized using info from GW signal (see [Salafia+17]). Works for other candidate EM counterparts as well!

THANK YOU!