The puzzling long GRB 191019A Evidence for Kilonova Light

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on behalf of
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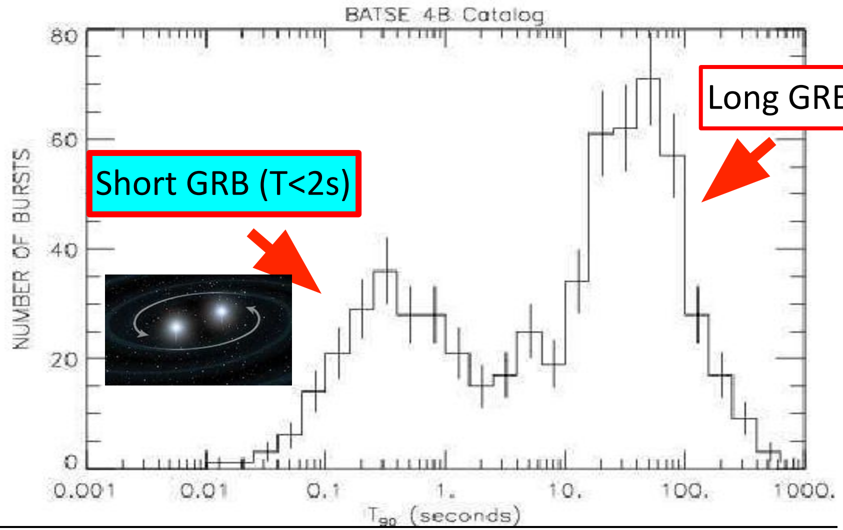
BOLOGNA

Gamma ray bursts and mergers

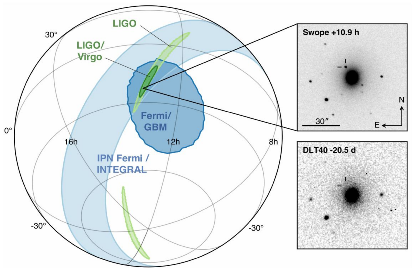
The burst duration shows a bimodal distribution interpreted to be (indirect) evidence of two classes of progenitors



BATSE data *Kouveliotu et al. 1993*

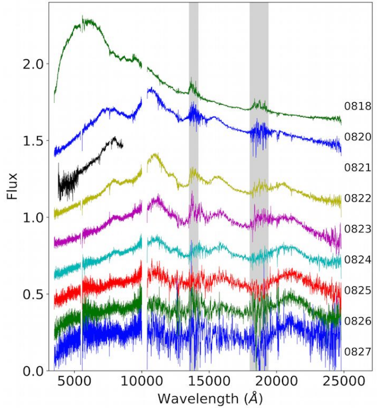
The duration is a possible(!) indicator of the origin of a GRB

GRB 170817A, GW170817



Abbot+17

Coulter+17

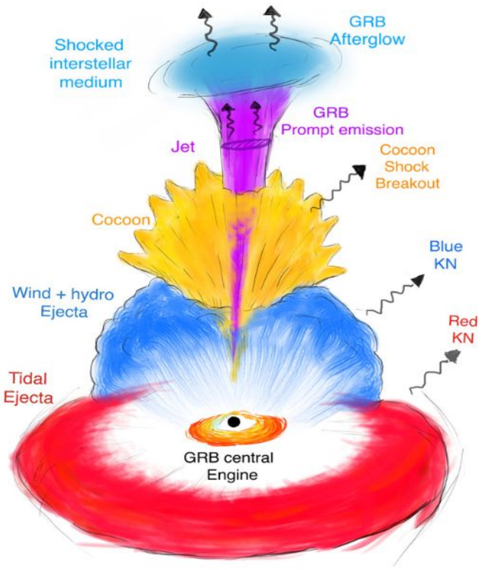


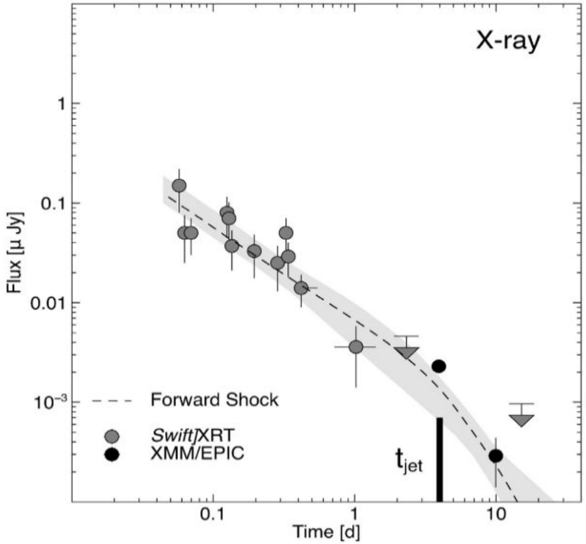
Pian et al., 2017

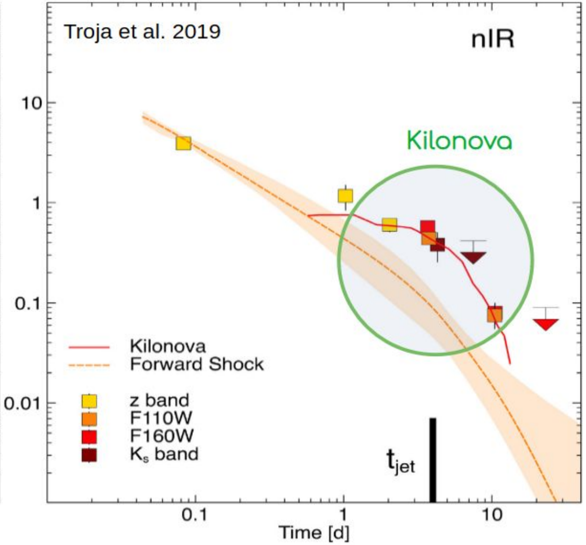
Kilonovae in GRB mergers

Modelling of electromagnetic counterparts in the X-ray and UV/Optical/NIR bands

e.g., short GRB 160821B





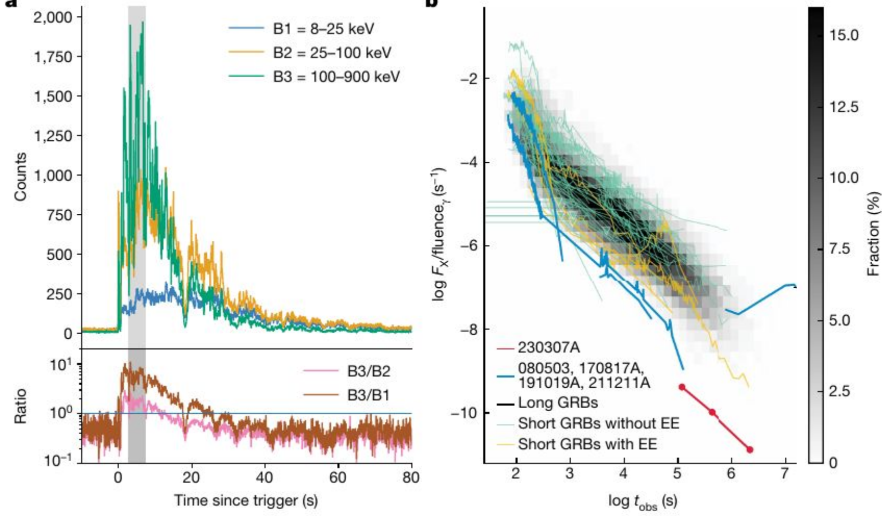


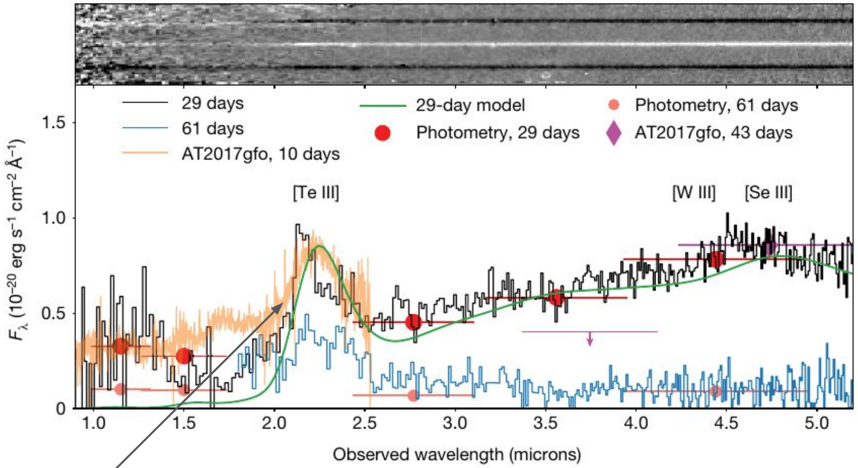
Ascenzi+21

“*Long*” GRBs followed by a KN: e.g. GRB 230307A

GRB 230307A
Fermi-GBM

Swift-XRT





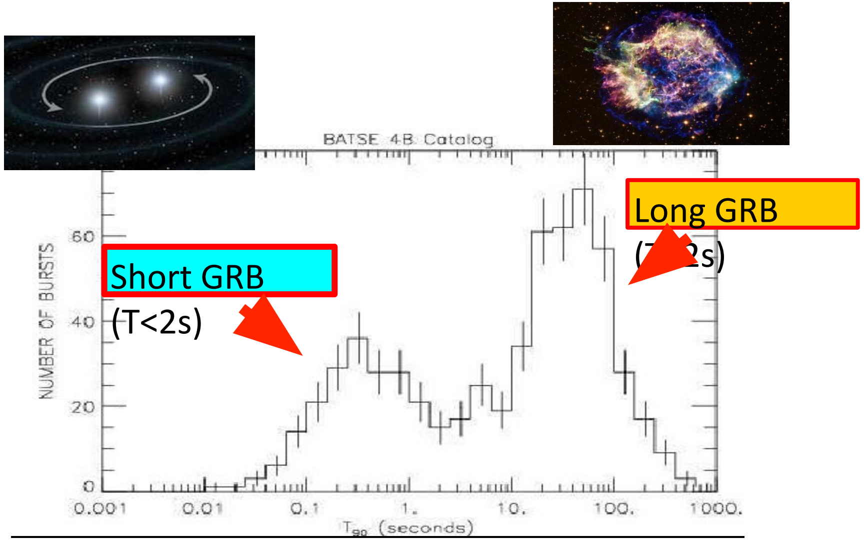
Clear emission at both 29 and 61 days, consistent with the expected location of [Te III] (Hotekezaka+18).

Note: ~40kpc (in projection) offset from its host

Levan et al., 2024, *Nature* **626**, 737

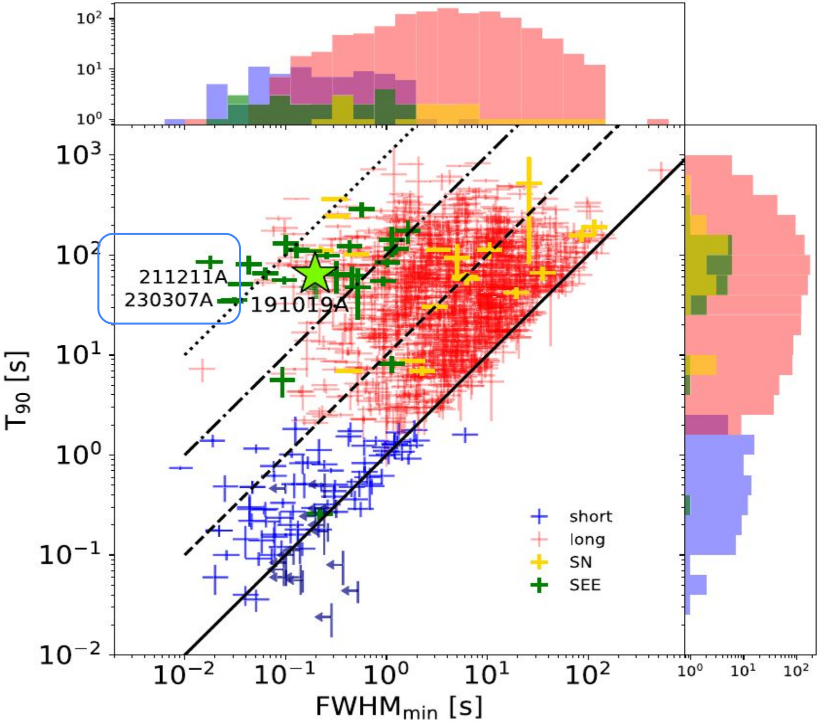
see also e.g., Gillanders+23, Yang+23

The case of GRB 191019A



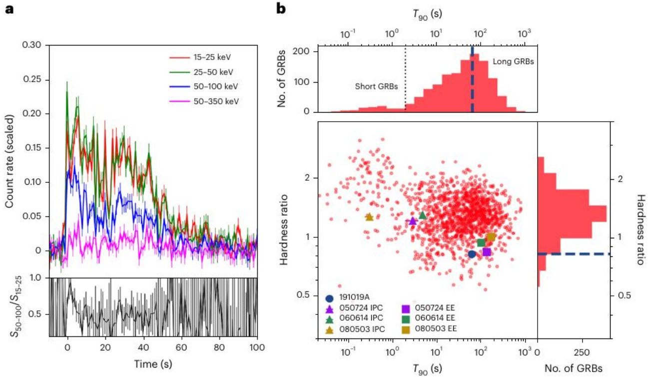
BATSE data *Kouveliotu et al. 1993*

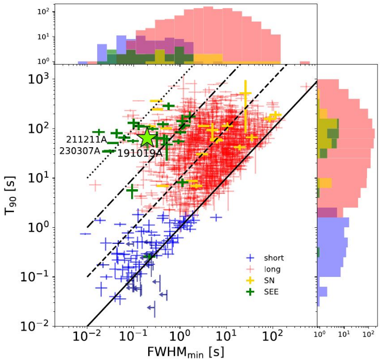
Other prompt properties:
e.g. minimum variability timescale

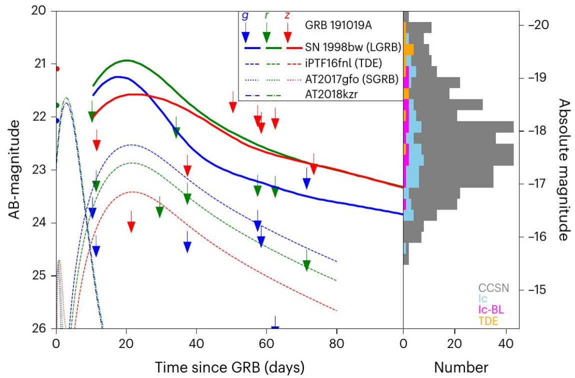


Camisasca, A. E., et al.: A&A 671, A112 (2023)
Stratta et al. 2025, ApJ 979, 159

GRB 191019A: a long GRB without SN in a passive host-galaxy

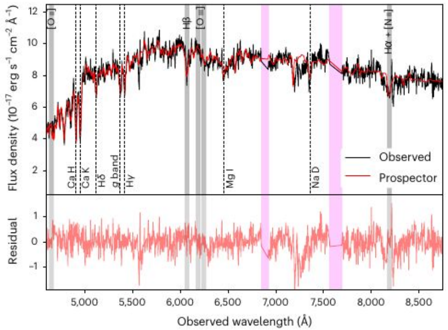


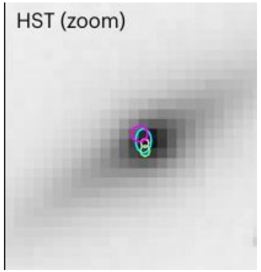




GRB 191019A, prompt, AG, host properties

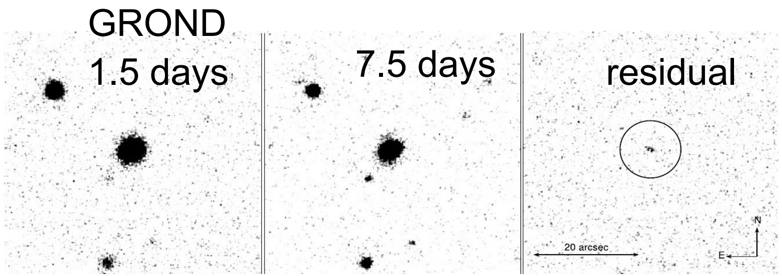
- Long duration (64.4 s), soft like collapsar events
  <u>*However:*</u>
- T90/MVT typical of SGRB with extended emission
- **No supernova** down to deep limits
- Passive host galaxy <u>but small offset</u> at z = 0.248





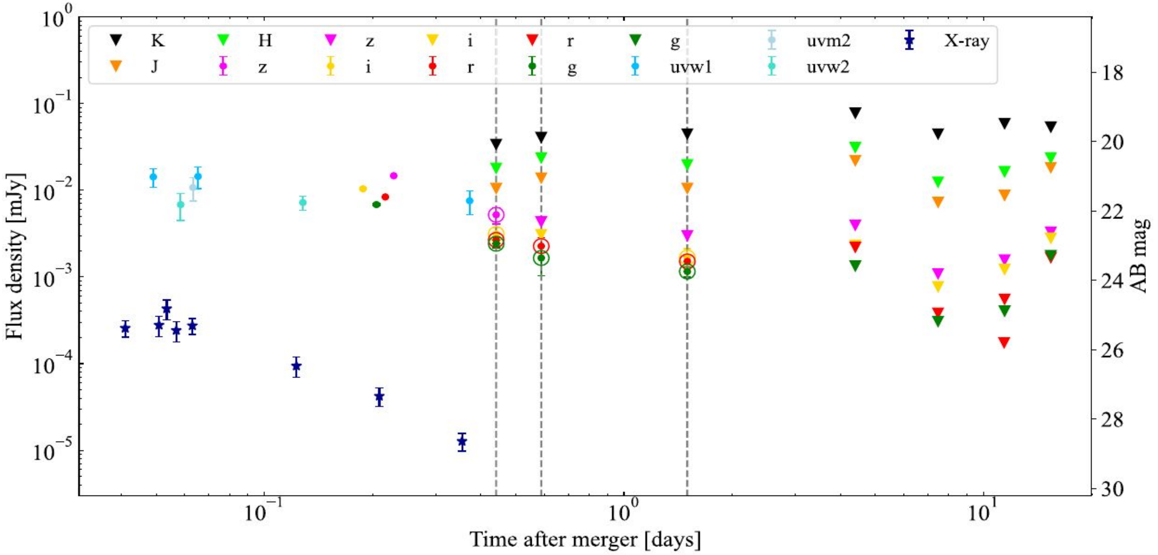
Levan et al. 2023, Nature Astronomy 7, 976
see also Lazzati et al. 2023, ApJ 950, L20

GRB 191019A: a long GRB with a late re-brightening



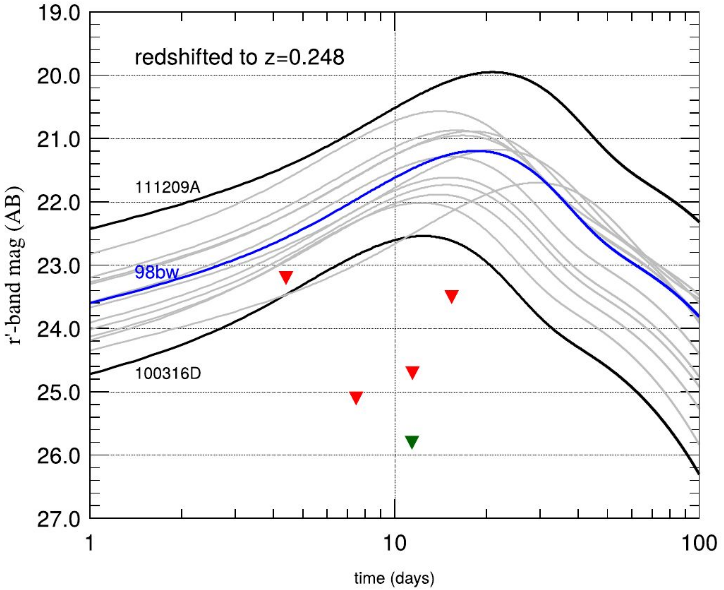
New unpublished data:

- 0.4- 2 days GROND grizJHK
  - (+upper limits up to 16 days)
- image subtraction reveals a transient
- Confirmed against 4 yr late time griz LBT data

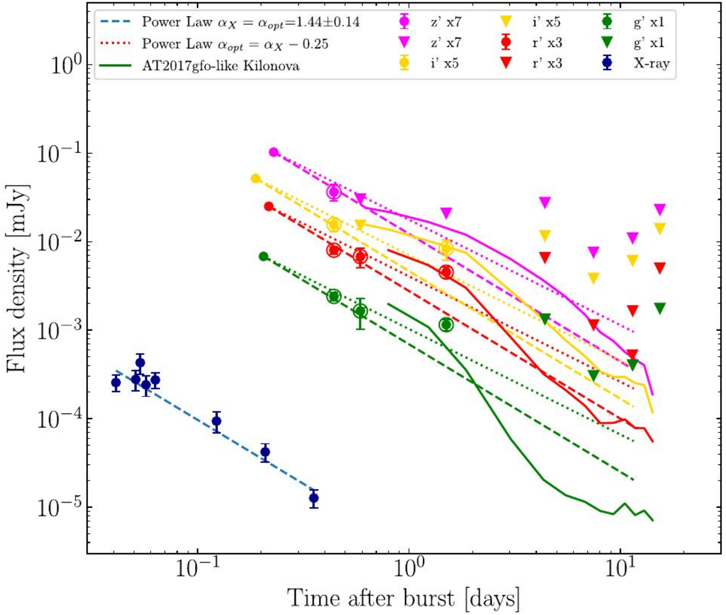


Stratta et al. 2025, ApJ 979, 159

GRB 191019A: a long GRB without SN



No supernova

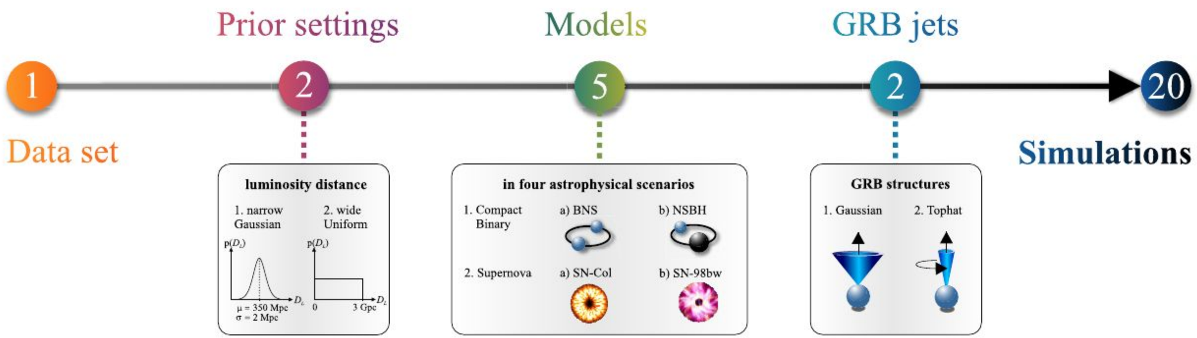


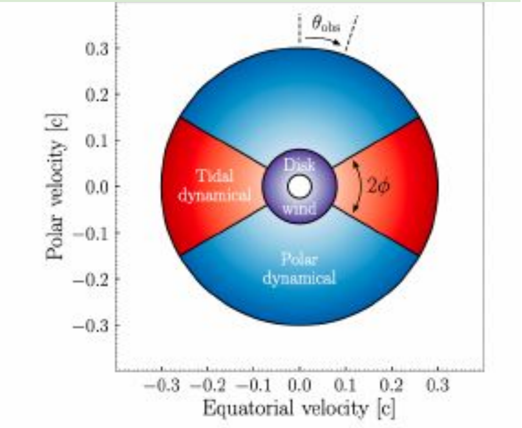
Flattening at 1 day

Stratta et al. 2025, ApJ 979, 159

GRB 191019A: Joint Inference with NMMA

The Nuclear Multimessenger Astronomy (NMMA) framework*





NMMA
joint Bayesian inference of multi-messenger events
(e.g., Pang+23, Kann+23, Ragosta+24, Kunert+24, Hussenot-Desenonges +24)

We modelled with
- an afterglow (AG) model
- AG+ Kilonova model from BNS, similar to AT2017gfo associated with the BNS merger GW 170817: *only event with direct evidence*

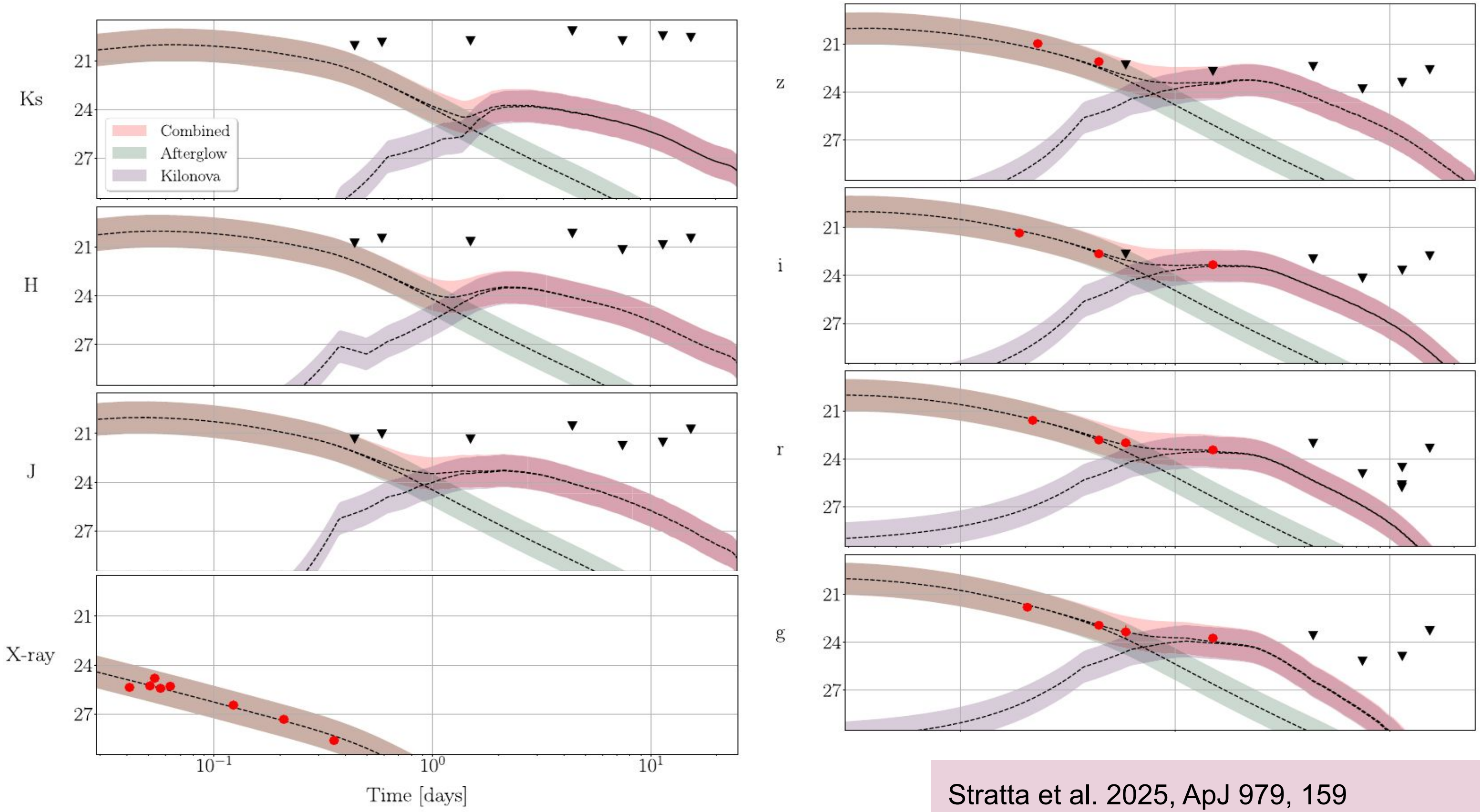
POSSIS kilonova models
3D Monte Carlo radiative transfer code.
- POSSIS parameters:
  M_{dyn}, M_{wind} and composition angle Phi

(Bulla 2019, modified as in Dietrich + 20)

Afterglow: we use afterglowpy (Ryan+20)
viewing angle, θ = 0°.

*https://nuclear-multimessenger-astronomy.github.io/nmma/ Dietrich +2020

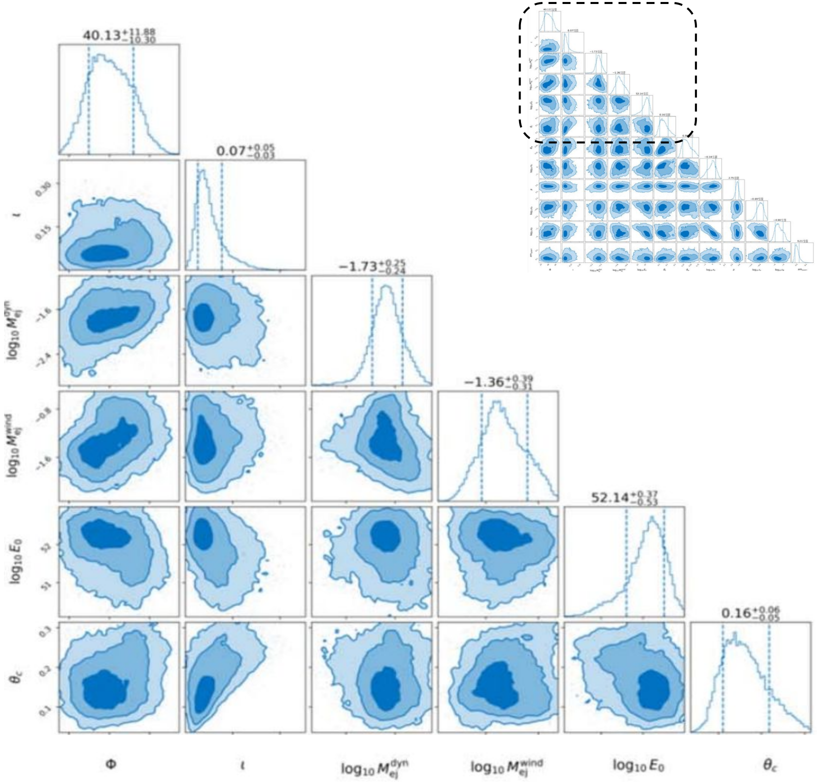
GRB 191019A: modelling



Stratta et al. 2025, ApJ 979, 159

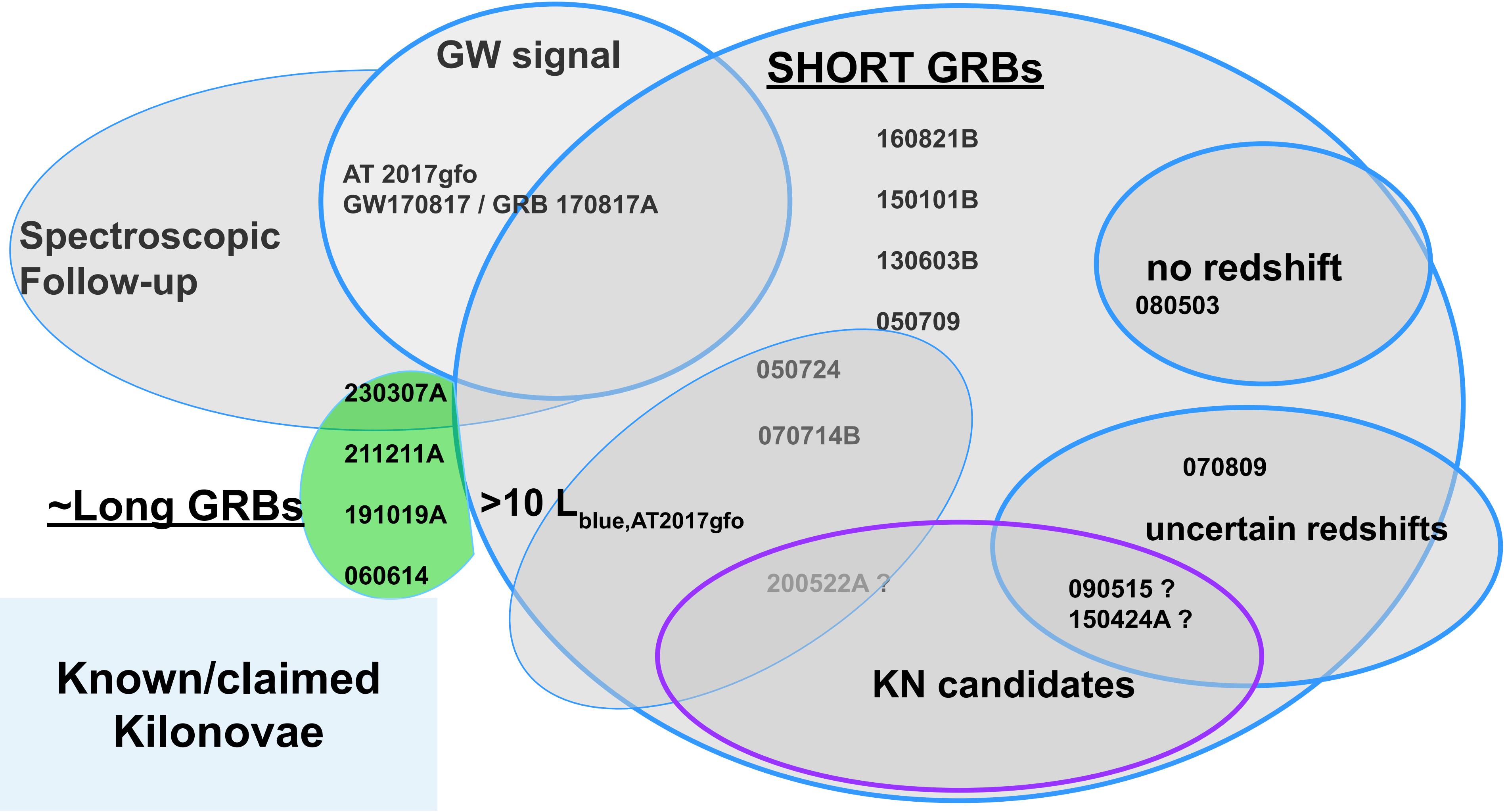
GRB 191019A: modelling

		Bu19-BNS-Jet	Afterglow	Prior
$\log(E_0)$	(erg)	$50.55^{+0.30}_{-0.21}$	$50.44^{+0.15}_{-0.14}$	U (49, 53)
$\log(n_0)$	(cm^{-3})	$-2.14^{+0.70}_{-0.86}$	$-0.27^{+0.21}_{-0.32}$	U (−3, 7)
θ_c	(rad)	$0.21^{+0.05}_{-0.10}$	$0.23^{+0.04}_{-0.04}$	U (0.01, $\pi/10$)
θ_w	(rad)	$0.39^{+0.20}_{-0.18}$	$0.57^{+0.15}_{-0.25}$	U (0.01, $\pi/4$)
ι	(rad)	$0.05^{+0.13}_{-0.03}$	$0.26^{+0.05}_{-0.05}$	Sine(0.0, $\pi/8$)
p		$2.72^{+0.06}_{-0.06}$	$2.23^{+0.16}_{-0.18}$	U (2.01, 3.0)
$\log(M_{\rm ej}^{\rm dyn})$	($M_\odot$)	$-1.74^{+0.30}_{-0.33}$	…	U (−3, −1)
$\log(M_{\rm ej}^{\rm wind})$	($M_\odot$)	$-1.28^{+0.46}_{-0.47}$	…	U (−3, −0.5)
Φ	(deg)	$44.56^{+11.19}_{-13.04}$	…	U (15, 75)
$\log(\epsilon_e)$		−0.3	−0.3	fixed
$\log(\epsilon_B)$		−2.0	−2.0	fixed
Bayes Evidence		−13.5	−19.2	…



RESULTS
- Best match with an afterglow + kilonova
- kilonova properties resemble AT2017gfo
- a total ejected mass of ~0.06 Msun.

Stratta et al. 2025, ApJ 979, 159



GW signal
SHORT GRBs
AT 2017gfo
GW170817 / GRB 170817A
Spectroscopic
Follow-up
160821B
150101B
130603B
050709
no redshift
080503
050724
070714B
230307A
211211A
191019A
060614
~Long GRBs
>10 L blue,AT2017gfo
070809
uncertain redshifts
200522A ?
090515 ?
150424A ?
KN candidates
Known/claimed
Kilonovae

Summary

- **Study of the multi-frequency follow-up of GRB 191019A**
  - No SN signature
  - We constrained KN and GRB geometry and ejecta properties
  - This is another KN from a long GRB

Stratta et al. 2025, ApJ 979, 159

- **New scenarios: (missed) population of merger-long GRBs**
  - The simple duration is NOT an indicator of the origin of a GRB
  - keep an eye on missing SN, passive and/or massive host-galaxy, offset from the host, prompt GRB properties

- **Open questions: GRB rates?**
  - merger-GRBs could be more frequent
  - collapsar-GRBs could be less frequent

THANK YOU

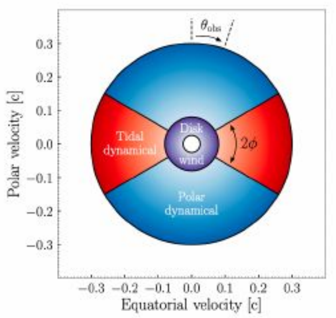

THANK YOU

BACKUP SLIDES

		Bu19-BNS-Jet	Bu19-NSBH-Jet	Kasen17-Jet	Metzger17-Jet	Afterglow	Prior
$\log(E_0)$	(erg)	$50.55^{+0.30}_{-0.21}$	$50.58^{+0.25}_{-0.22}$	$50.37^{+0.32}_{-0.13}$	$50.91^{+0.35}_{-0.64}$	$50.44^{+0.15}_{-0.14}$	U (49, 53)
$\log(n_0)$	(cm^{-3})	$-2.14^{+0.70}_{-0.86}$	$-1.99^{+0.86}_{-0.89}$	$-1.49^{+0.39}_{-1.04}$	$-3.01^{+1.74}_{-1.05}$	$-0.27^{+0.21}_{-0.32}$	U (−3, 7)
θ_c	(rad)	$0.21^{+0.05}_{-0.10}$	$0.22^{+0.05}_{-0.10}$	$0.25^{+0.04}_{-0.05}$	$0.21^{+0.05}_{-0.04}$	$0.23^{+0.04}_{-0.04}$	U (0.01, $\pi/10$)
θ_w	(rad)	$0.39^{+0.20}_{-0.18}$	$0.50^{+0.12}_{-0.26}$	$0.53^{+0.14}_{-0.16}$	$0.51^{+0.20}_{-0.18}$	$0.57^{+0.15}_{-0.25}$	U (0.01, $\pi/4$)
ι	(rad)	$0.05^{+0.13}_{-0.03}$	$0.17^{+0.08}_{-0.14}$	$0.12^{+0.06}_{-0.06}$	$0.10^{+0.09}_{-0.05}$	$0.26^{+0.05}_{-0.05}$	Sine(0.0, $\pi/8$)
p		$2.72^{+0.06}_{-0.06}$	$2.73^{+0.06}_{-0.11}$	$2.71^{+0.06}_{-0.09}$	$2.70^{+0.06}_{-0.07}$	$2.23^{+0.16}_{-0.18}$	U (2.01, 3.0)
$\log(M_{ej}^{dyn})$	($M_\odot$)	$-1.74^{+0.30}_{-0.33}$	$-1.60^{+0.25}_{-0.22}$	⋯	⋯	⋯	U (−3, −1)
$\log(M_{ej}^{wind})$	($M_\odot$)	$-1.28^{+0.46}_{-0.47}$	$-1.03^{+0.27}_{-0.39}$	⋯	⋯	⋯	U (−3, −0.5)
$\log(M_{ej})$	($M_\odot$)	⋯	⋯	$-1.67^{+0.29}_{-0.35}$	$-0.88^{+0.21}_{-0.61}$	⋯	U (−3, −0.5)
$\log(v_{ej})$	(c)	⋯	⋯	$-1.06^{+0.18}_{-0.21}$	$-1.00^{+0.18}_{-0.30}$	⋯	U (−2, −0.5)
Φ	(deg)	$44.56^{+11.19}_{-13.04}$	⋯	⋯	⋯	⋯	U (15, 75)
$\log(\epsilon_e)$		−0.3	−0.3	−0.3	−0.3	−0.3	fixed
$\log(\epsilon_B)$		−2.0	−2.0	−2.0	−2.0	−2.0	fixed
$\log(\chi_{lan})$		⋯	⋯	$-5.86^{+0.72}_{-1.25}$	⋯	⋯	U (−9, −1)
$\log(\kappa_r)$		⋯	⋯	⋯	$-0.60^{+0.43}_{-0.22}$	⋯	U (−1, 2)
β					$3.98^{+0.65}_{-1.53}$		U (1, 5)
ln(Z)		−13.5	−12.4	−12.9	−18.7	−19.2	⋯

GRB 191019A: Joint Inference with NMMA

The Nuclear Multimessenger Astronomy (NMMA) framework*



NMMA:

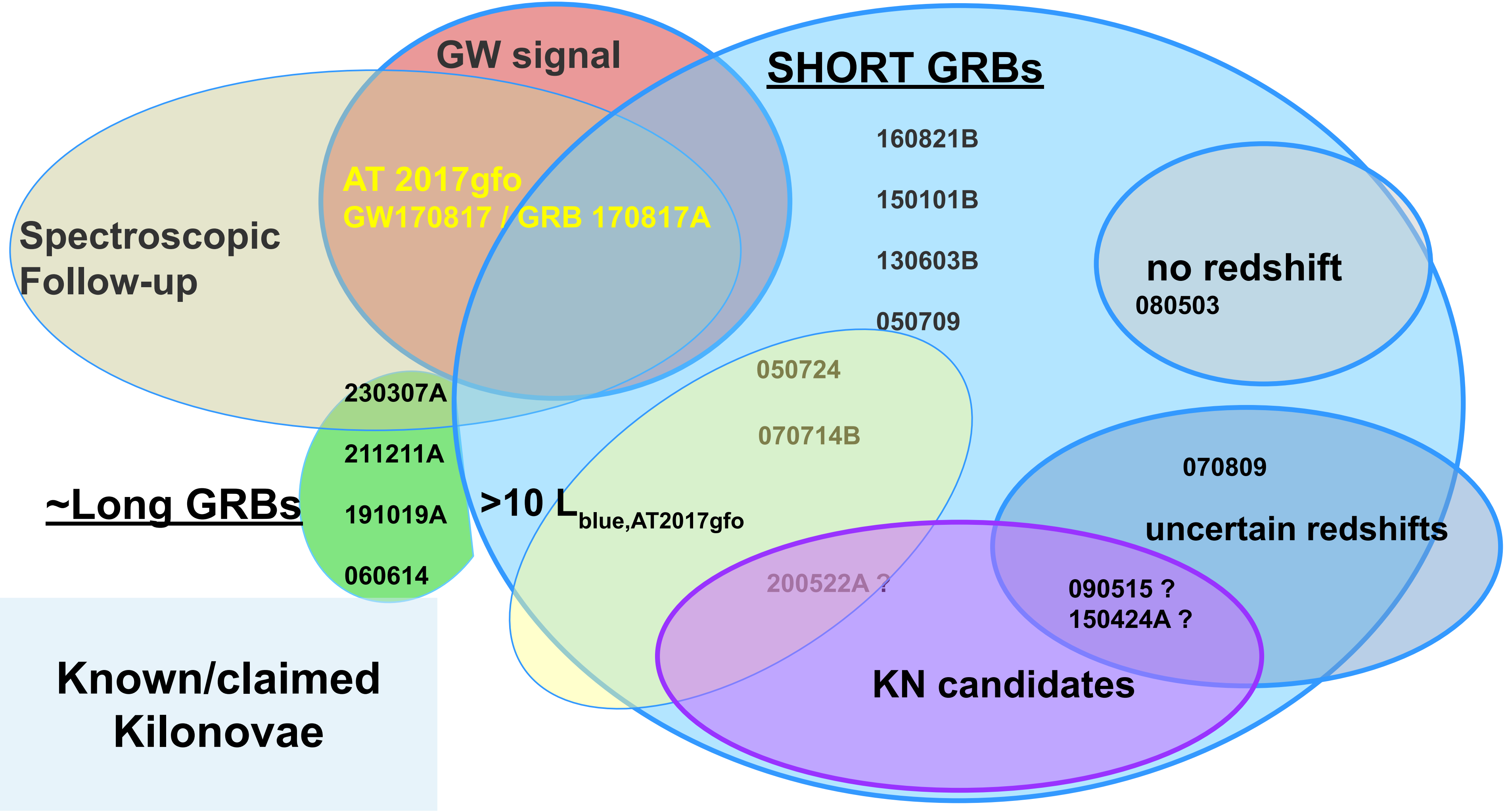
- Is a publicly available code
- allows GW+EM data analysis (BNS, NSBH)
- GR+GW is unique
- NMMA performs a full parameter estimation combining both likelihood:
  $L(\theta) = L_{GW}(\theta_{GW}) \times L_{EM}(\theta_{EM})$ where $\theta = \theta_{GW}, \theta_{EM}$

KN models:
e.g. POSSIS (Bulla, 2019) (Bulla, 2023 coming), Kasen+18, Wollaeger+21, Metzger +17, Barnes & Metzger +22

*https://nuclear-multimessenger-astronomy.github.io/nmma/
Dietrich +2020, Pang+2023

POSSIS

- Simulated spectra using the multi-dimensional Monte Carlo radiative transfer code POSSIS (Bulla 2019).
- Dynamical ejecta: • $0.08<v/c<0.3$
- lanthanide rich composition at angle +/-Phi
- Main source of opacity in kilonova ejecta is given by bound-bound line transitions.
- bound-bound opacities κbb assumed for the dynamical ejecta are wavelength- and time-dependent, (Bulla+2019)
- Wind ejecta (post-merger ejecta): • $0.025<v/c<0.08$, spherical component (ejecta released from the merger remnant and debris disk)
- Bound-bound opacities are intermediate to the above (~0.1 cm2 g−1 at 1μm and 1.5 d)
- SEDs and corresponding light curves are then controlled by four parameters: Mdyn , Mwind , Φ, and the observer viewing angle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AT 2017gfo
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Follow-up
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no redshift
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KN candidates
Known/claimed
Kilonovae