Low−Γ Jets from Compact Stellar Mergers: Candidate Electromagnetic Counterparts to Gravitational Wave Sources

Gavin P Lamb & Shiho Kobayashi

IAU Symposium 324
12 September 2016
Cankarjev dom
Ljubljana
http://adsabs.harvard.edu/abs/2016arXiv160502769L

@lamb_gl

Summary

- EM counterparts: Radio flares; Kilonova; SGRB; Off/On-axis (orphan) afterglow
- GW triggered search can reveal hidden population of low Lorentz factor merger jets
- Strong candidate for EM follow-up searches
- Determine Lorentz factor distribution of jets

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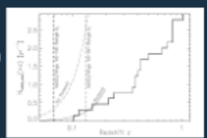
Event Rates

- Swift detects ~10 SGRB per year
- Redshift for ~1/4
- Metzger & Berger (2012) <0.03 SGRB per year within aLIGO range by Swift
- By considering the all sky rate:

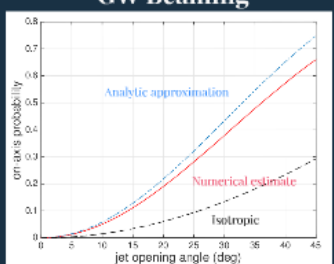


Metzger & Berger 2012

~2.6 on-axis orphan afterglow per year within 300 Mpc (NSNS)

This assumes the jet-opening angle is constant 20 degrees

GW Beaming

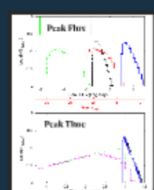


GPL & Kobayashi 2016

- **GW strongest on-axis (Kochanek & Piran 1993):**
- **With GW detection, on-axis probability higher than isotropic**
- **We assumed all jets have opening angle 20 degrees**
- **Lorentz factor - opening angle relation? Jet could be wider!?**

Monte Carlo - compact merger jets

Using a=1.75 for Lorentz factor distribution, and Wanderman & Piran (2015) luminosity and redshift distributions:



Peak on-axis orphan afterglow time after GW signal

Green: X-ray (10^{18} Hz)
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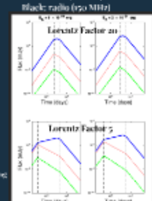
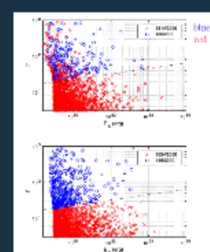


Sample light-curves including peak time and jet break assuming jet opening angle ~20 degrees

GPL & Kobayashi 2016



blue 15-150 keV bright
red 15-150 keV dark

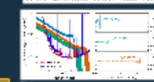
0<z<3
91% *Swift* undetected

0<z<0.07
78% *Swift* undetected
(<300 Mpc)

GPL & Kobayashi 2016

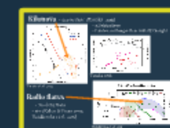
Compact Stellar Mergers

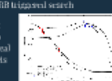
Gravitational Wave Sources



The next GW breakthrough!?
NS-BH or NS-NS mergers

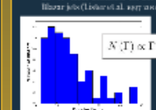
Electromagnetic Counterparts

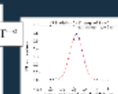




Low−Γ Jets

Lorentz-factor Distribution for Astrophysical Jets





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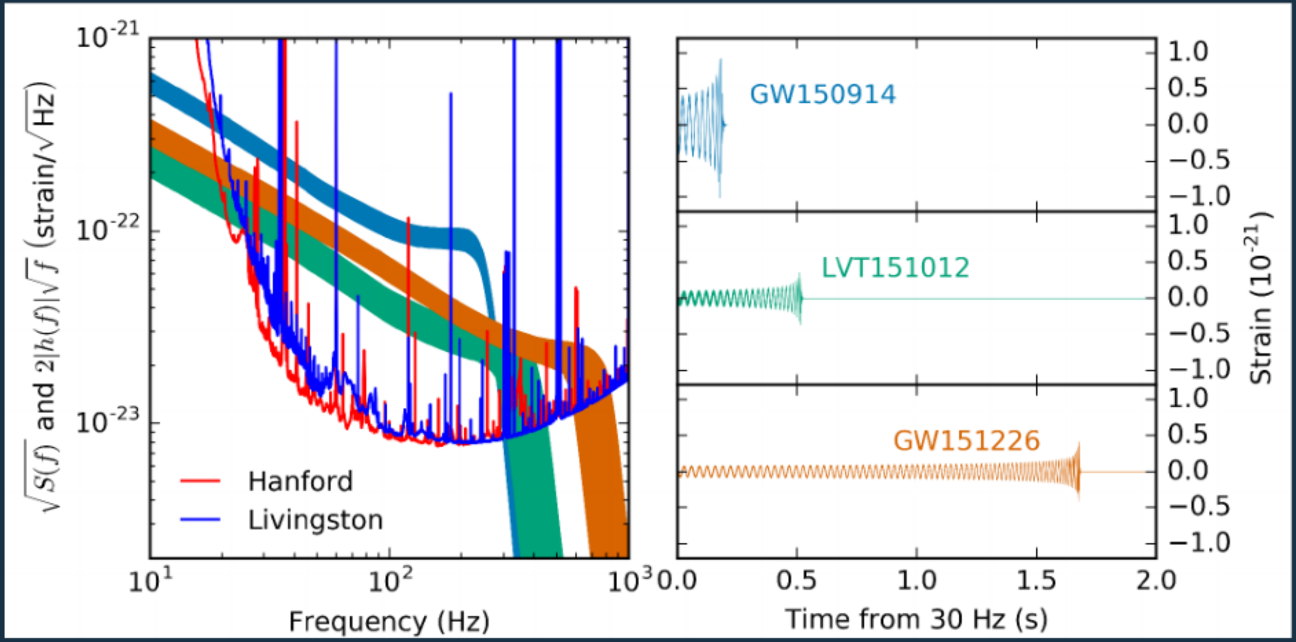
Compact Stellar Mergers:

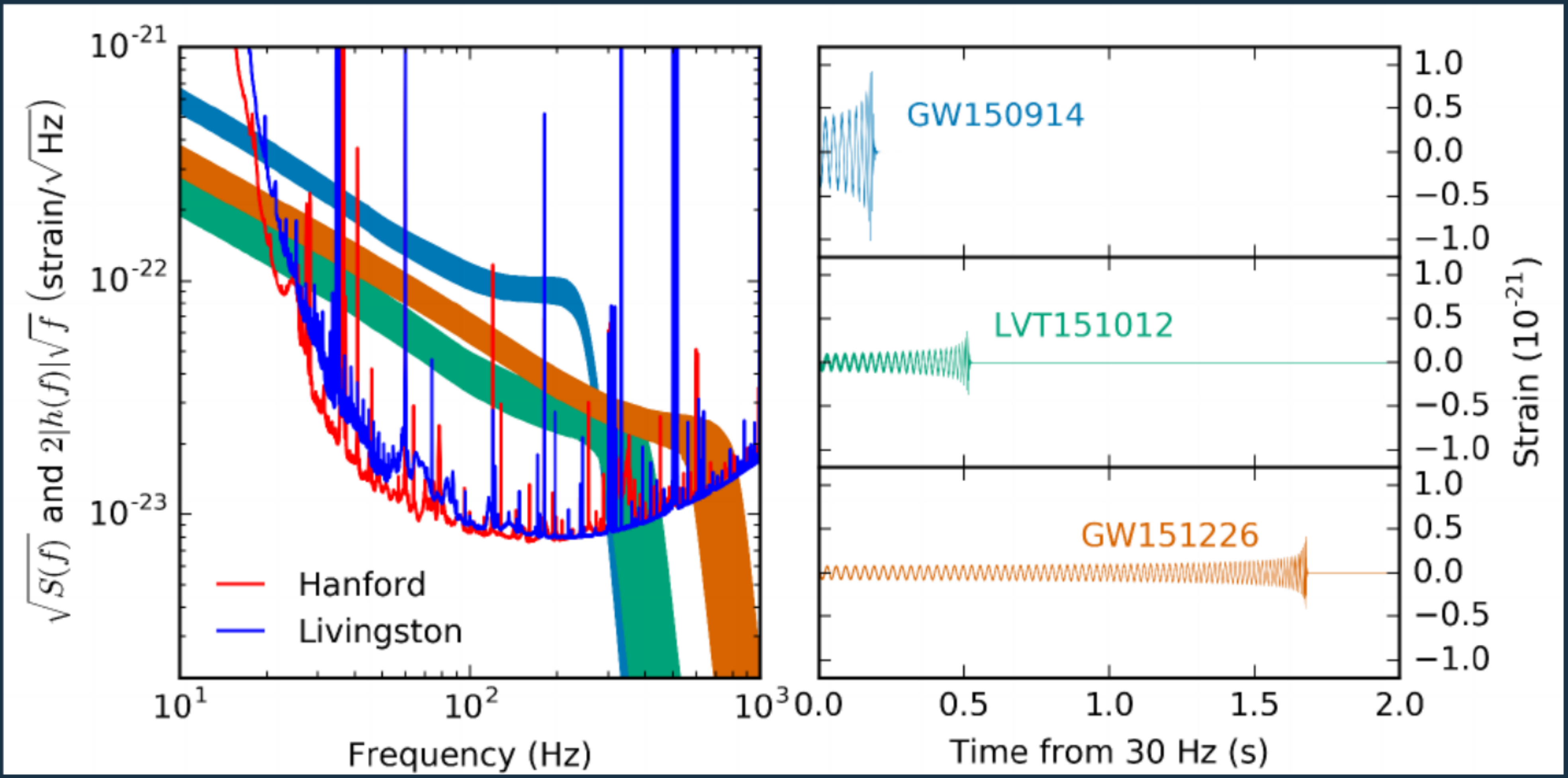
- Merger of a binary system due to gravitational wave (GW) emission
- Binary components - neutron stars (NS) or black holes (BH)

Gravitational Wave Sources



LVC 2016

Gravitational Wave Sources



LVC 2016

2(3) detections of BH-BH mergers in 2015

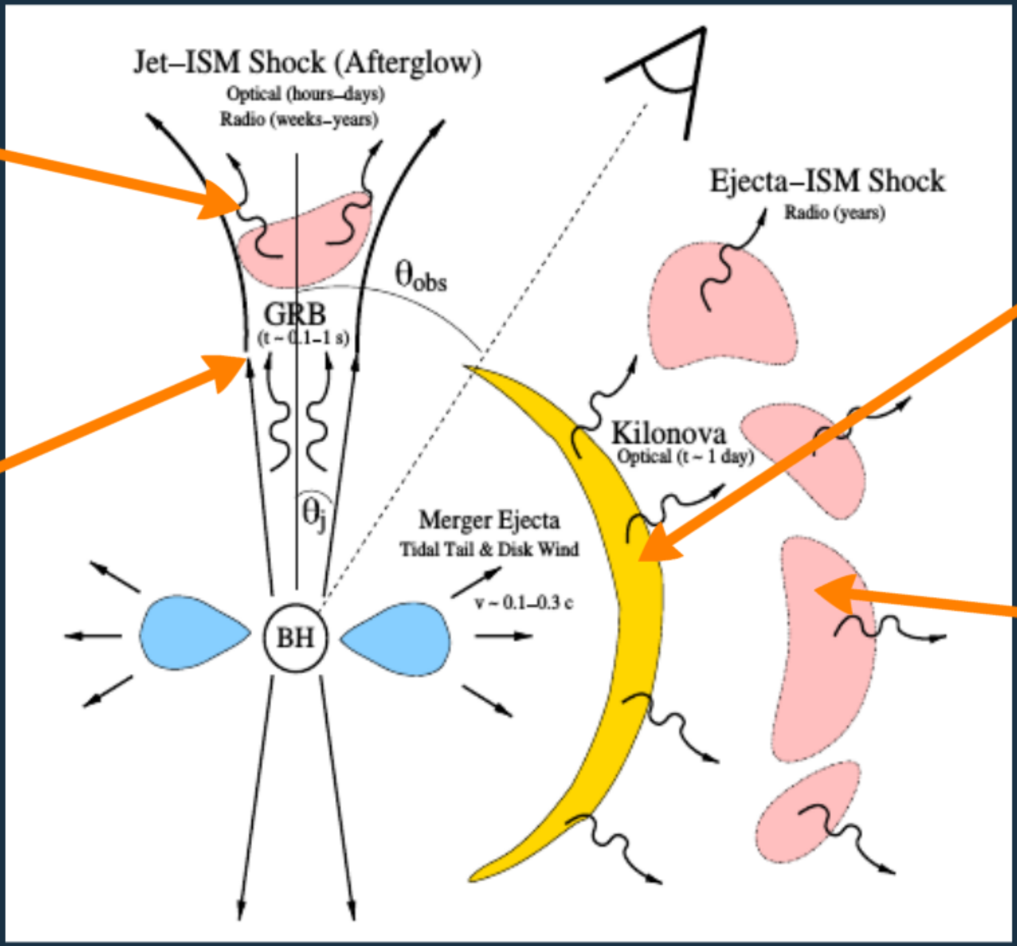
BH-BH mergers - no expected electromagnetic counterparts(!?)

The next GW breakthrough!?
NS-BH or NS-NS mergers

Electromagnetic Counterparts

Afterglow
-hours/days

Short GRB
-seconds

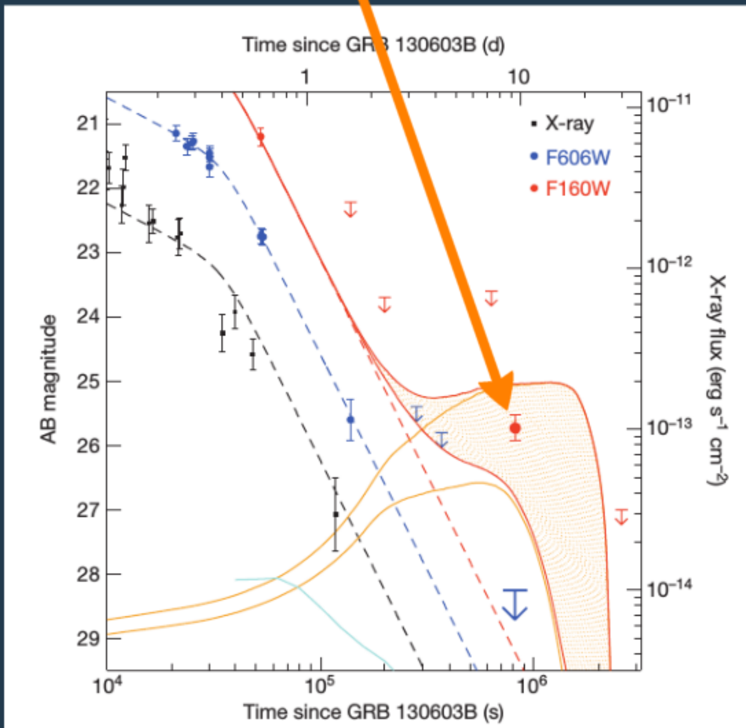


Metzger & Berger 2012

Kilo/Macronova
-days/weeks

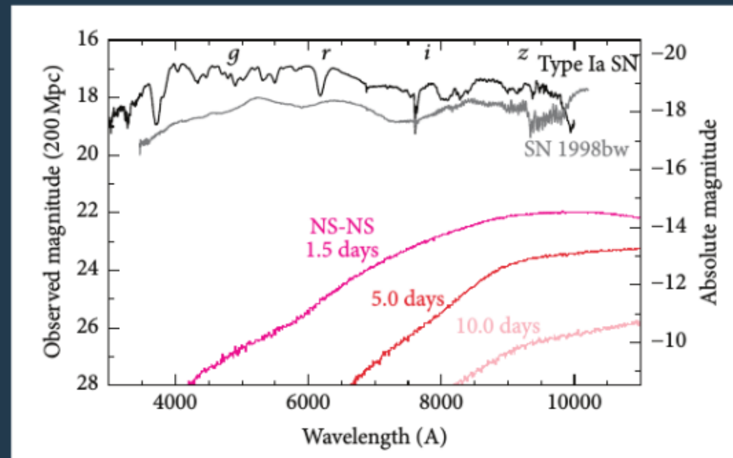
Radio flare
-months

Kilonova – see review (Tanaka 2016)



Tanvir et al. 2013

- 1(2) detections
- Fainter and longer than initially thought

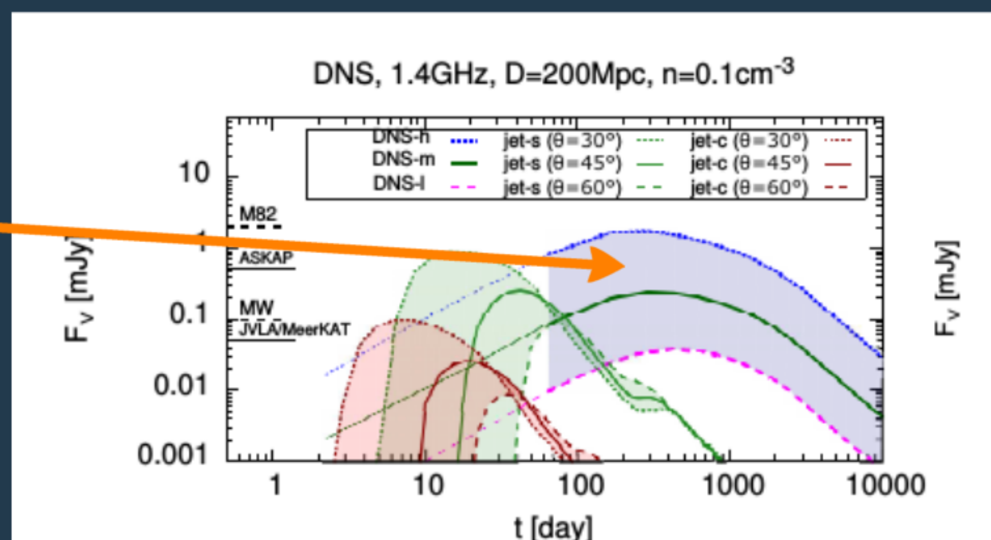


Tanaka 2016

Radio flares

- No detections

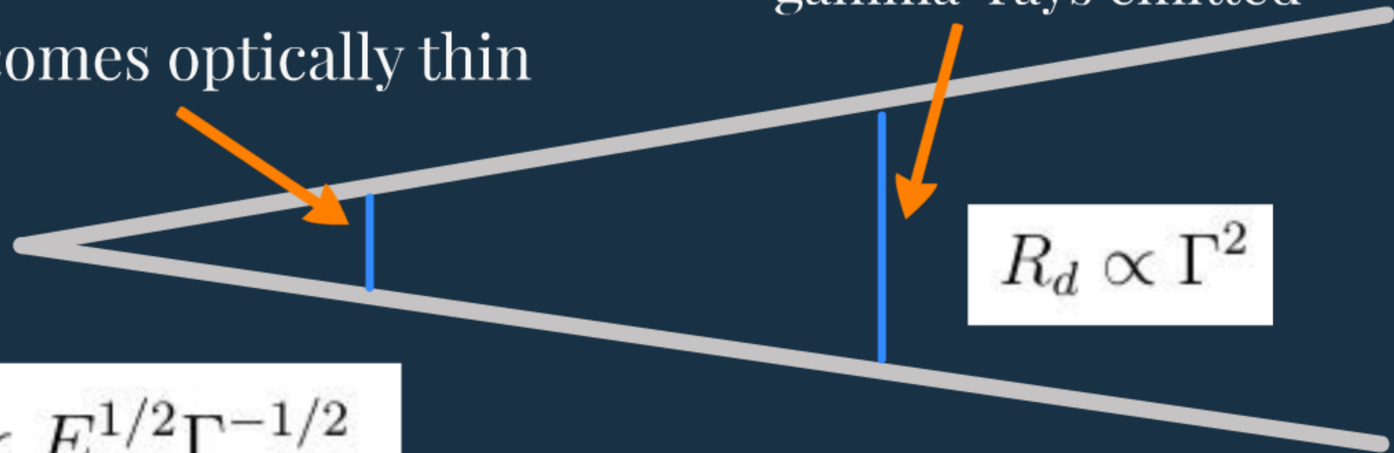
– see (Nakar & Piran 2011; Hotokezaka et al. 2016)



Hotokezaka et al. 2016

Photospheric radius
- becomes optically thin

Dissipation radius
- gamma-rays emitted



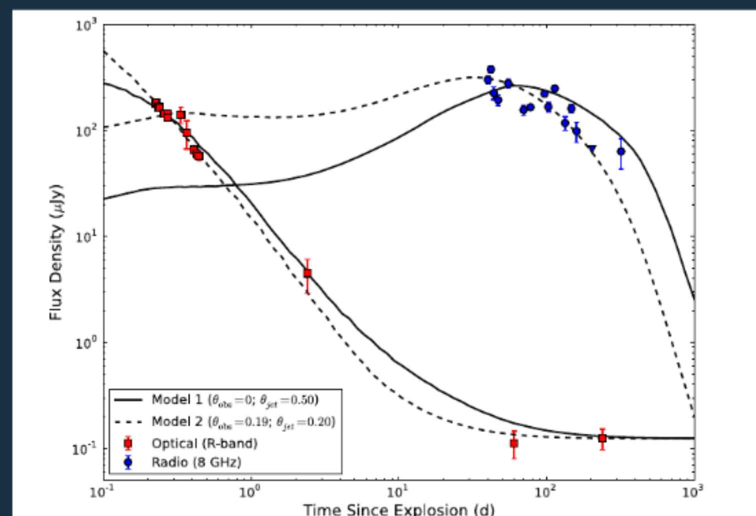
$$R_d \propto \Gamma^2$$

$$R_\star \propto E^{1/2}\Gamma^{-1/2}$$

Requires Lorentz factor >100

Except 2 cases* (Cenko et al. 2013; 2015) -
afterglows are discovered by GRB triggered search

- Requires ultra-relativistic jet
- Selection bias - Gamma ~100
- GW triggered search may reveal low-Lorentz factor merger jets
- On-axis orphan afterglow



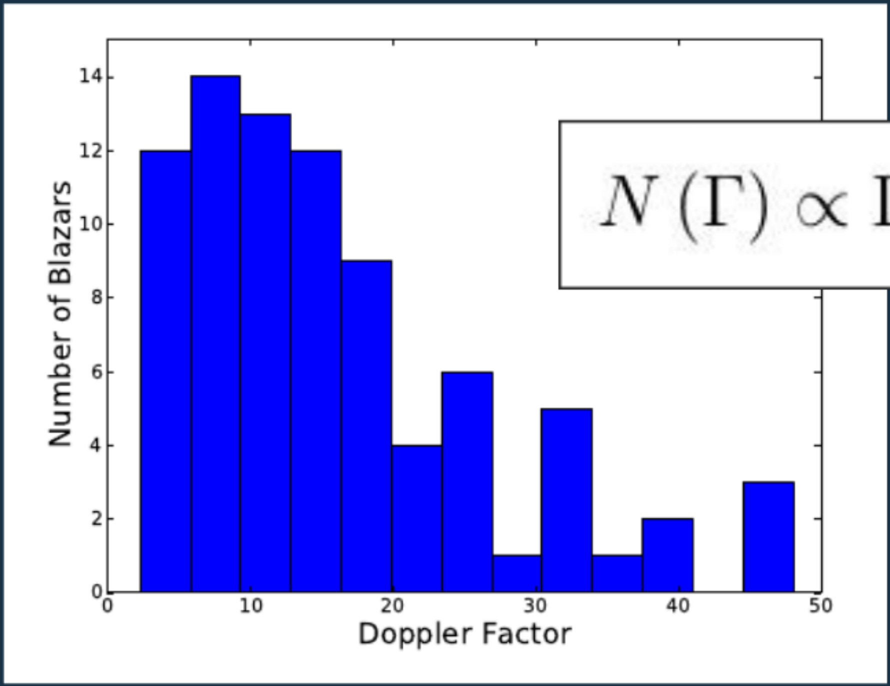
*1 case is an on-axis orphan afterglow! Not thought to be NS-NS   Cenko et al. 2013

Low−Γ Jets

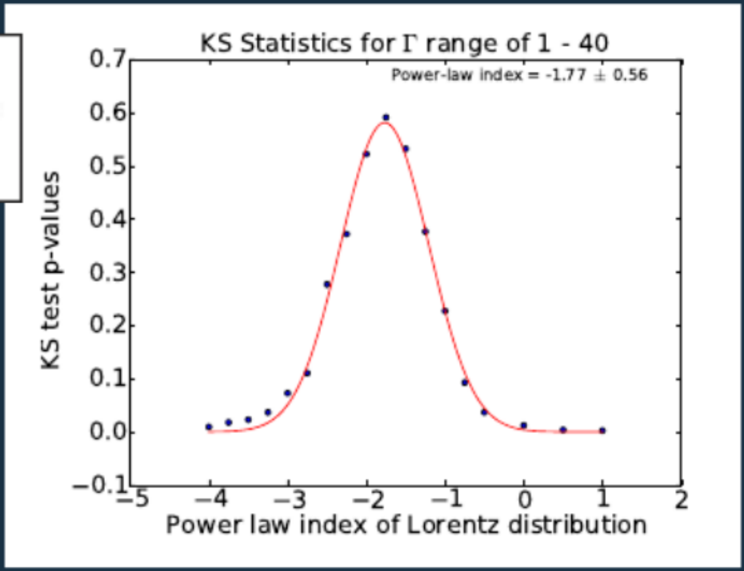
- Dissipation radius below photosphere
- Gamma-rays suppressed
- On-axis orphan afterglow

Lorentz-factor Distribution for Astrophysical Jets

- Lower values dominate the Lorentz-factor distribution in AGN/ Blazar jets (Lister et al. 1997 2009; Saikia et al. 2016)



$$N(\Gamma) \propto \Gamma^{-a}$$



Saikia et al. 2016

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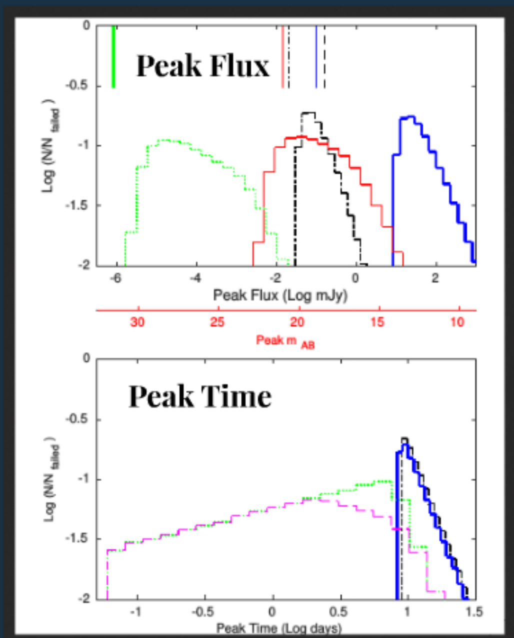

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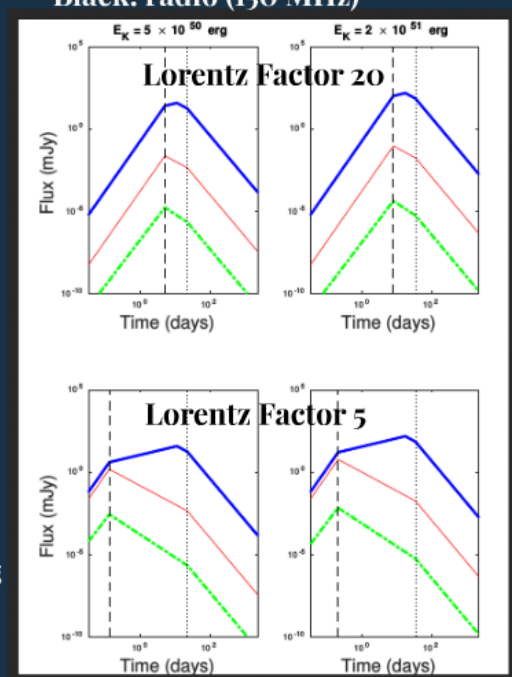

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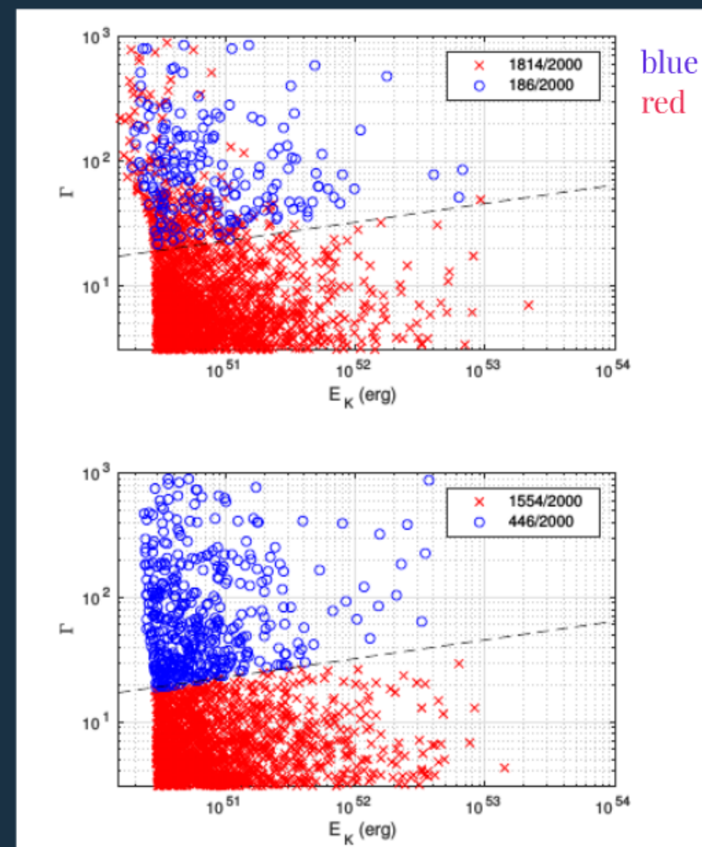

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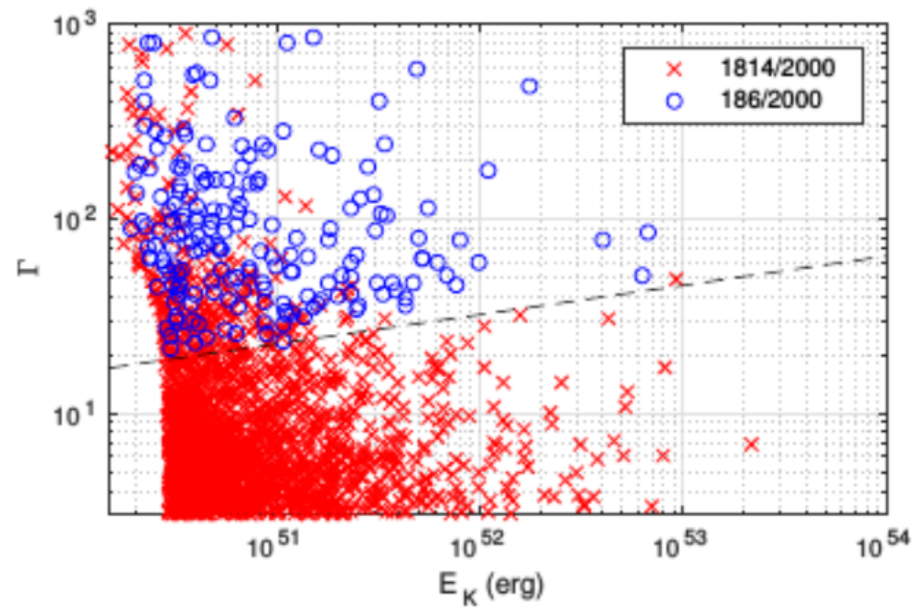

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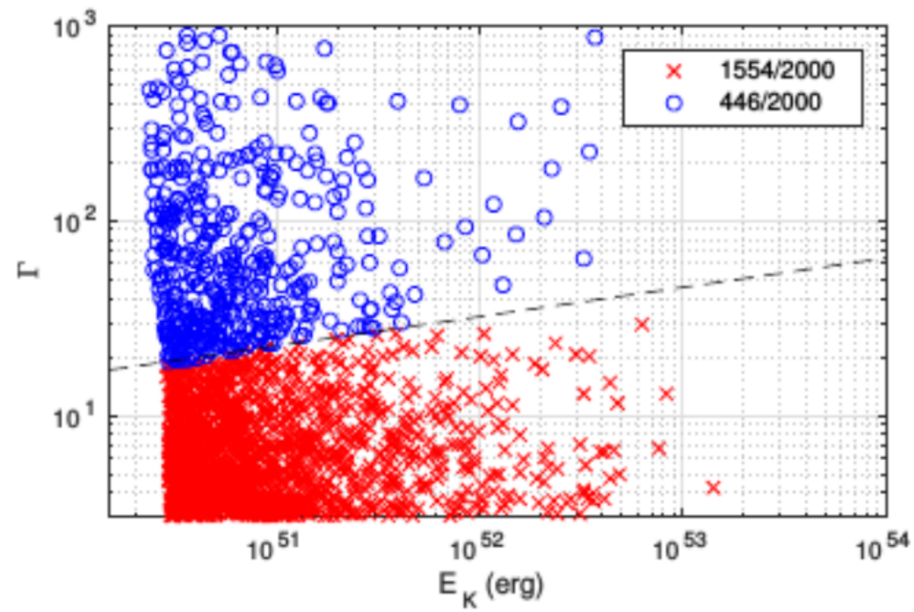

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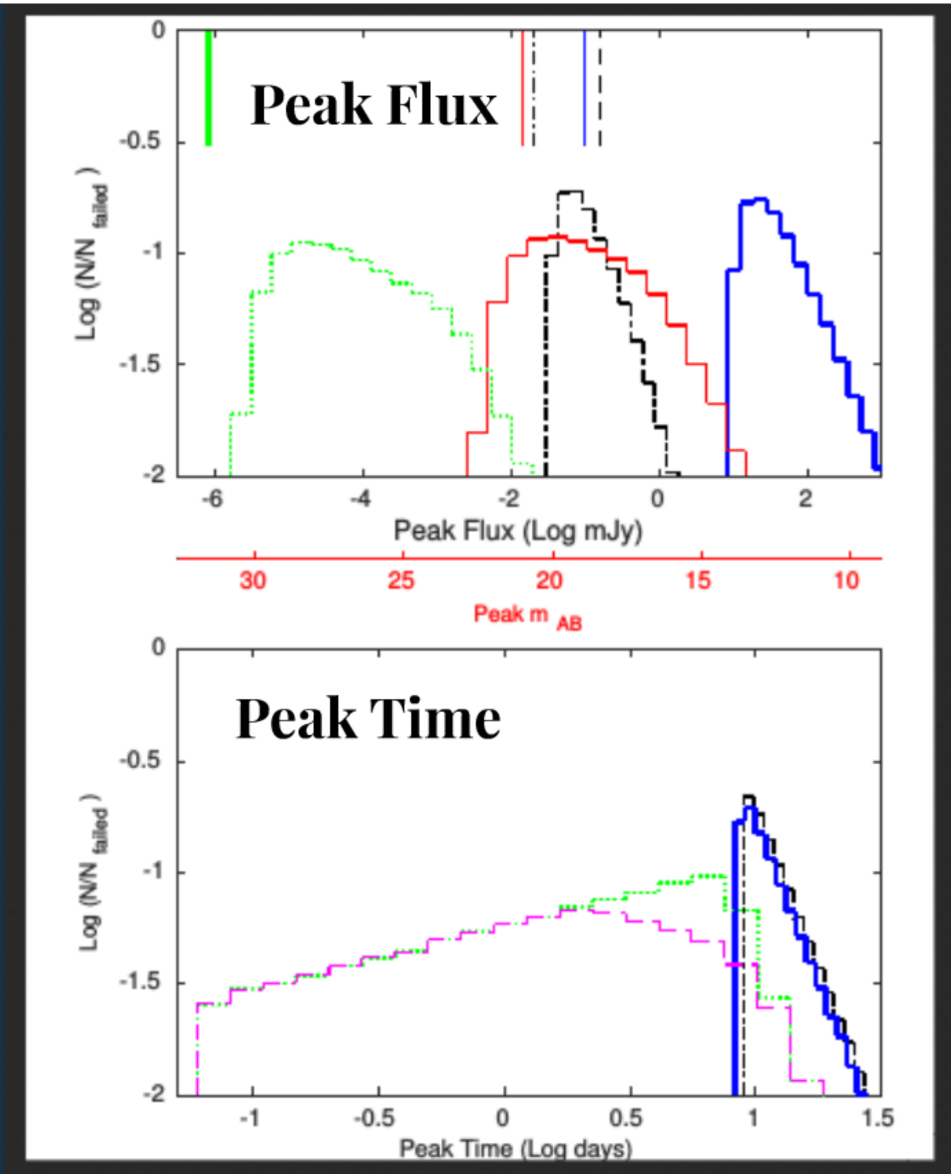

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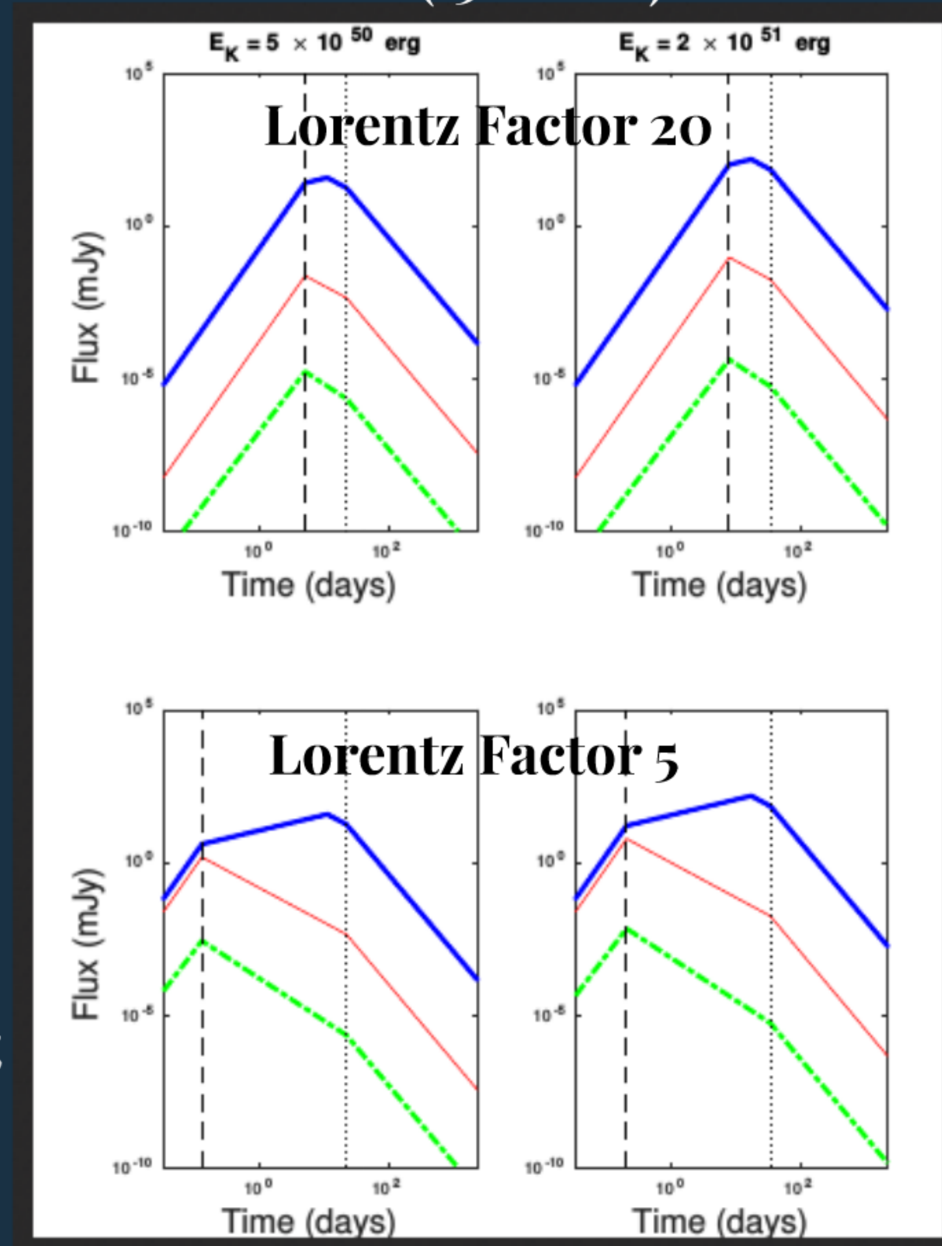

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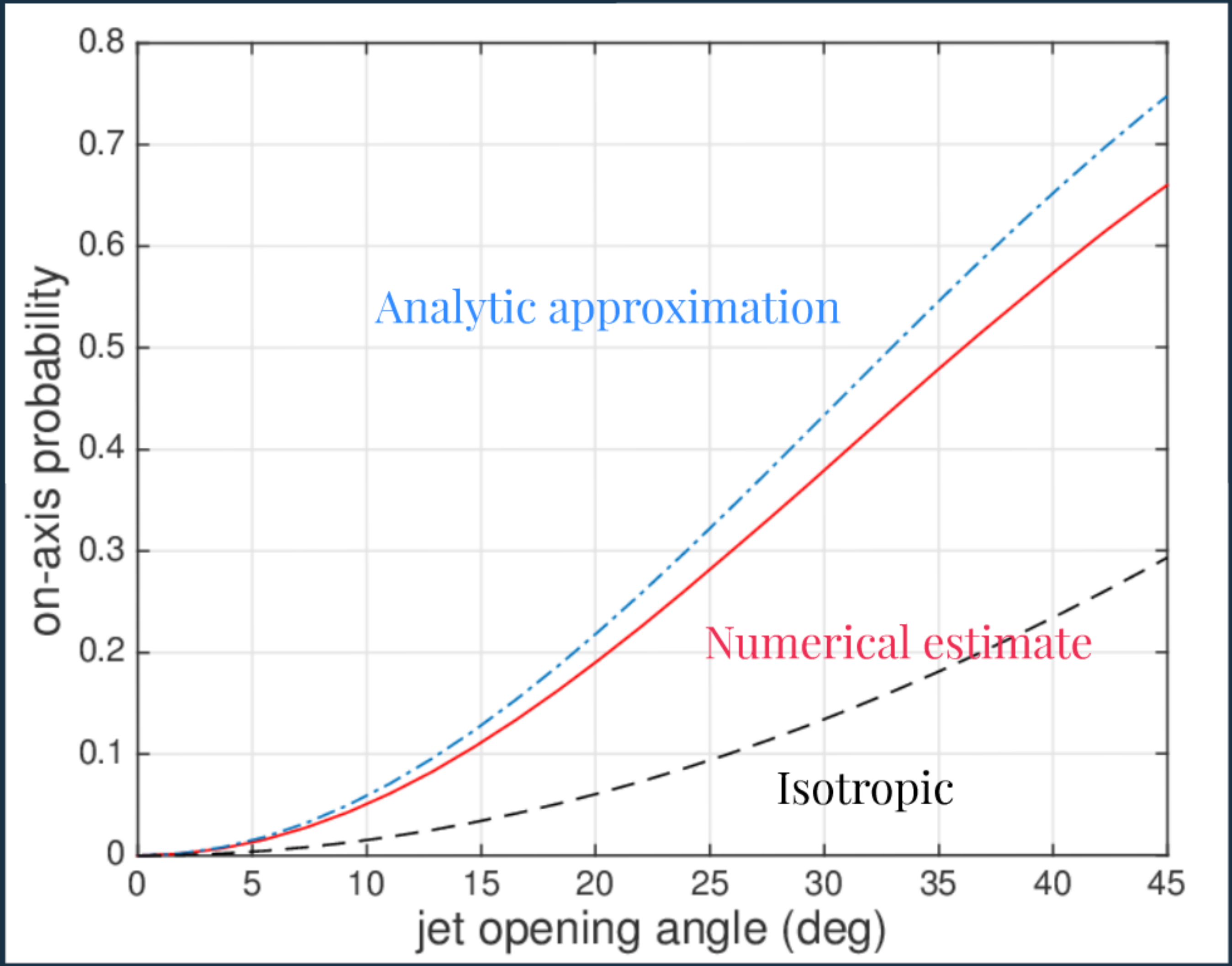

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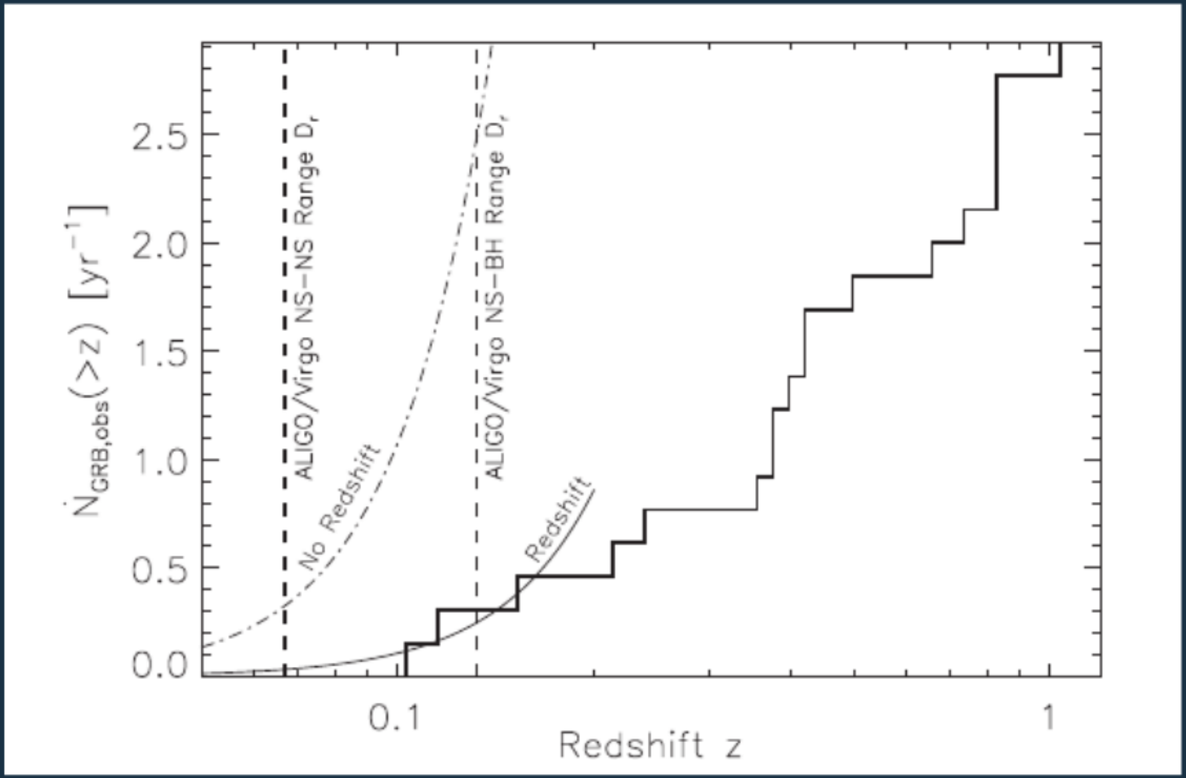

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