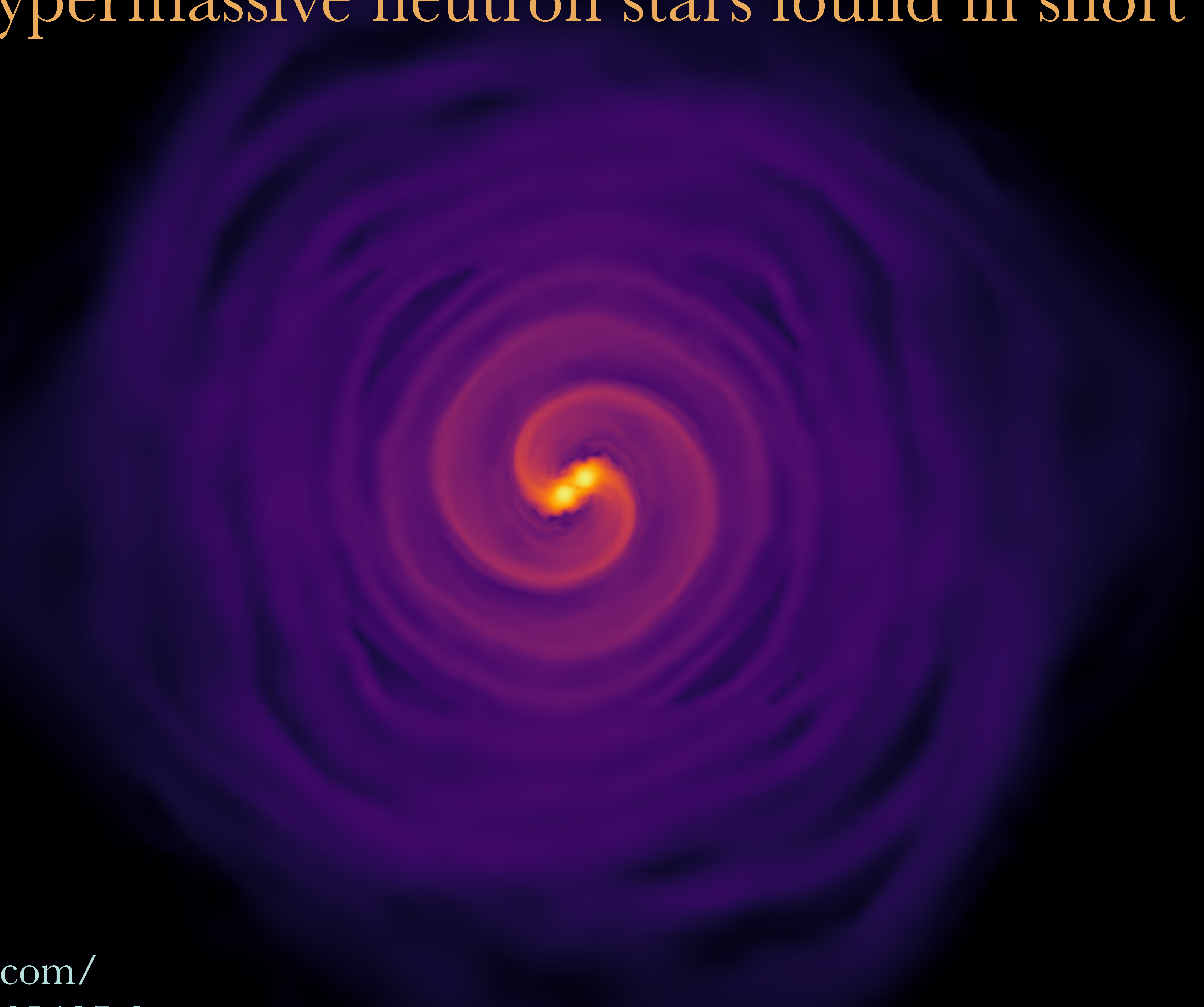
Hypermassive neutron stars found in short gamma-ray bursts



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https://www.nature.com/articles/s41586-022-05497-0

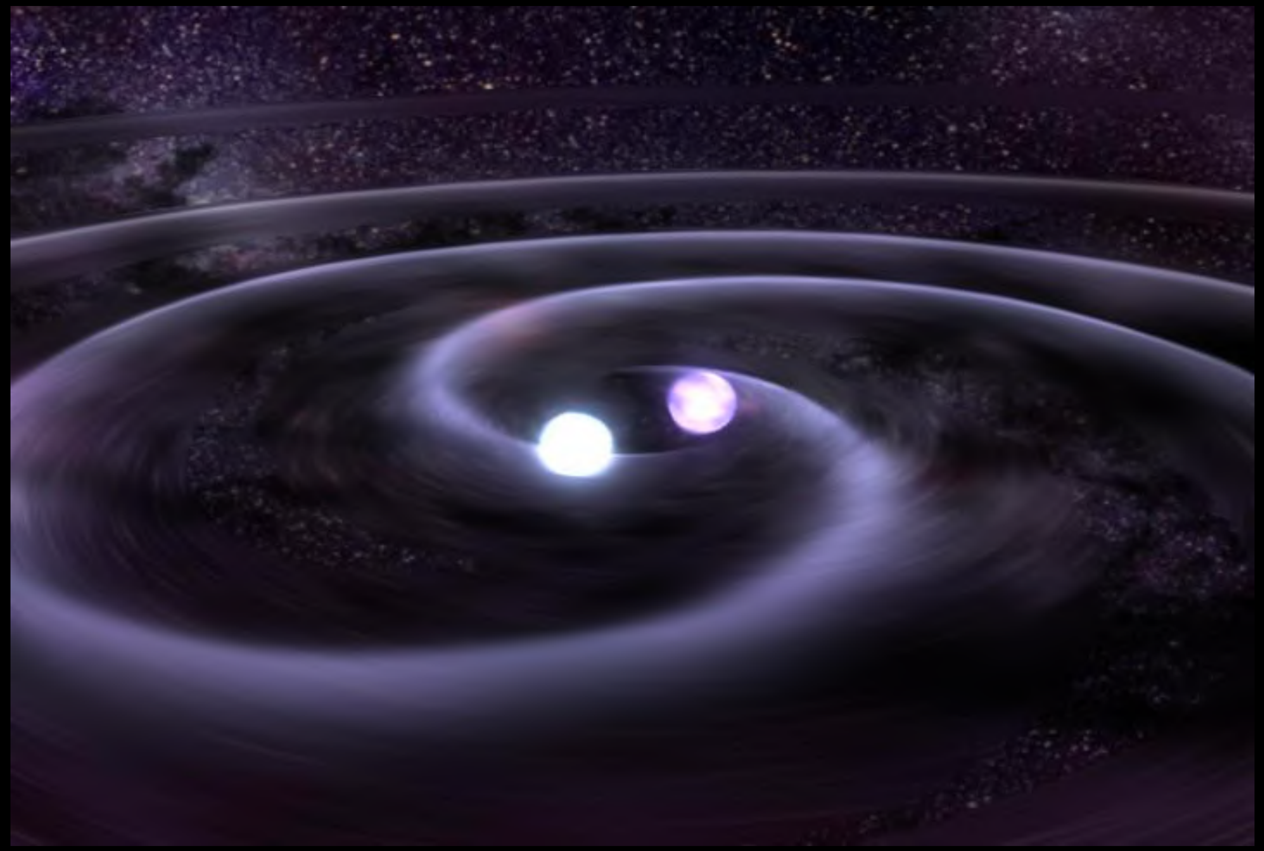
AAS241 Winter Meeting - Press briefing - January 2023

The players

Neutron stars (NSs)

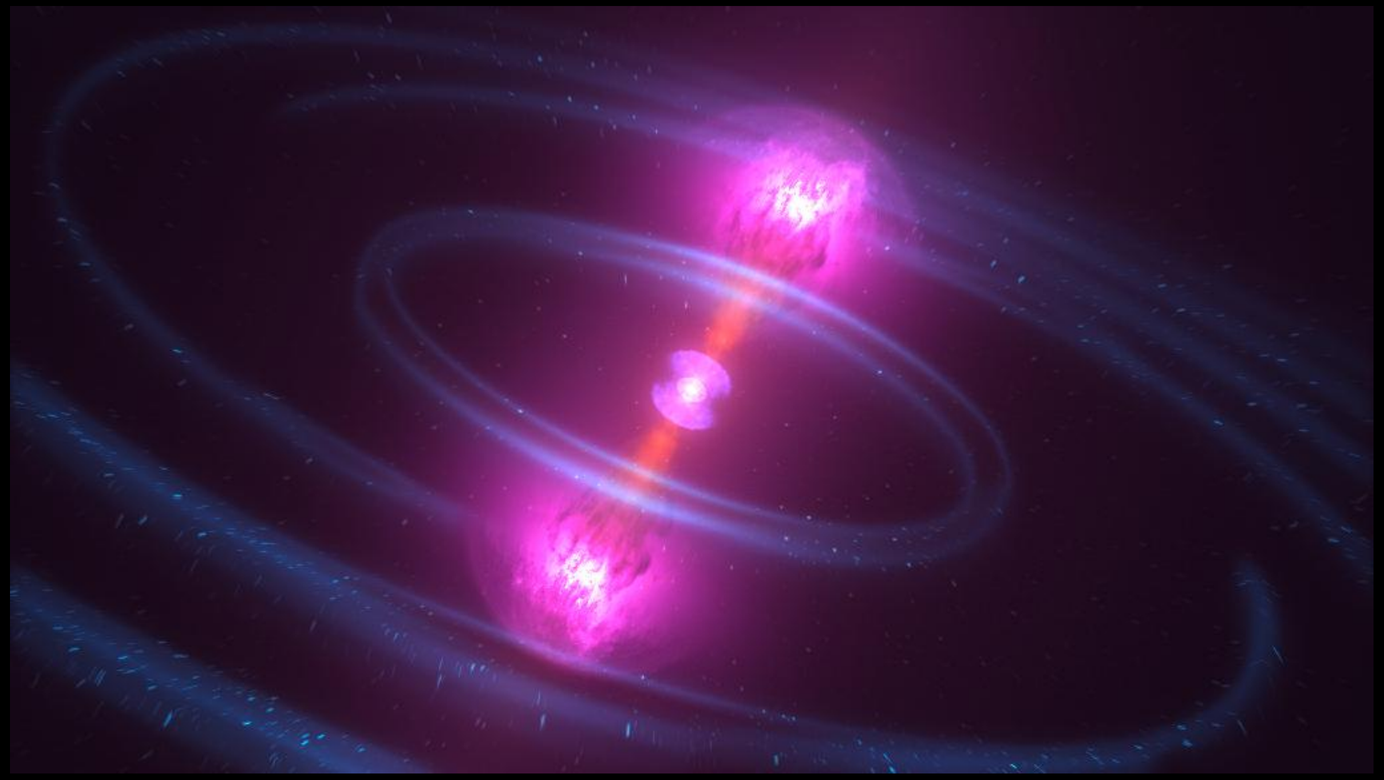
First observed as pulsars in 1967

Predicted by Einstein
Emitted by accelerating masses



Gravitational Waves (GWs)

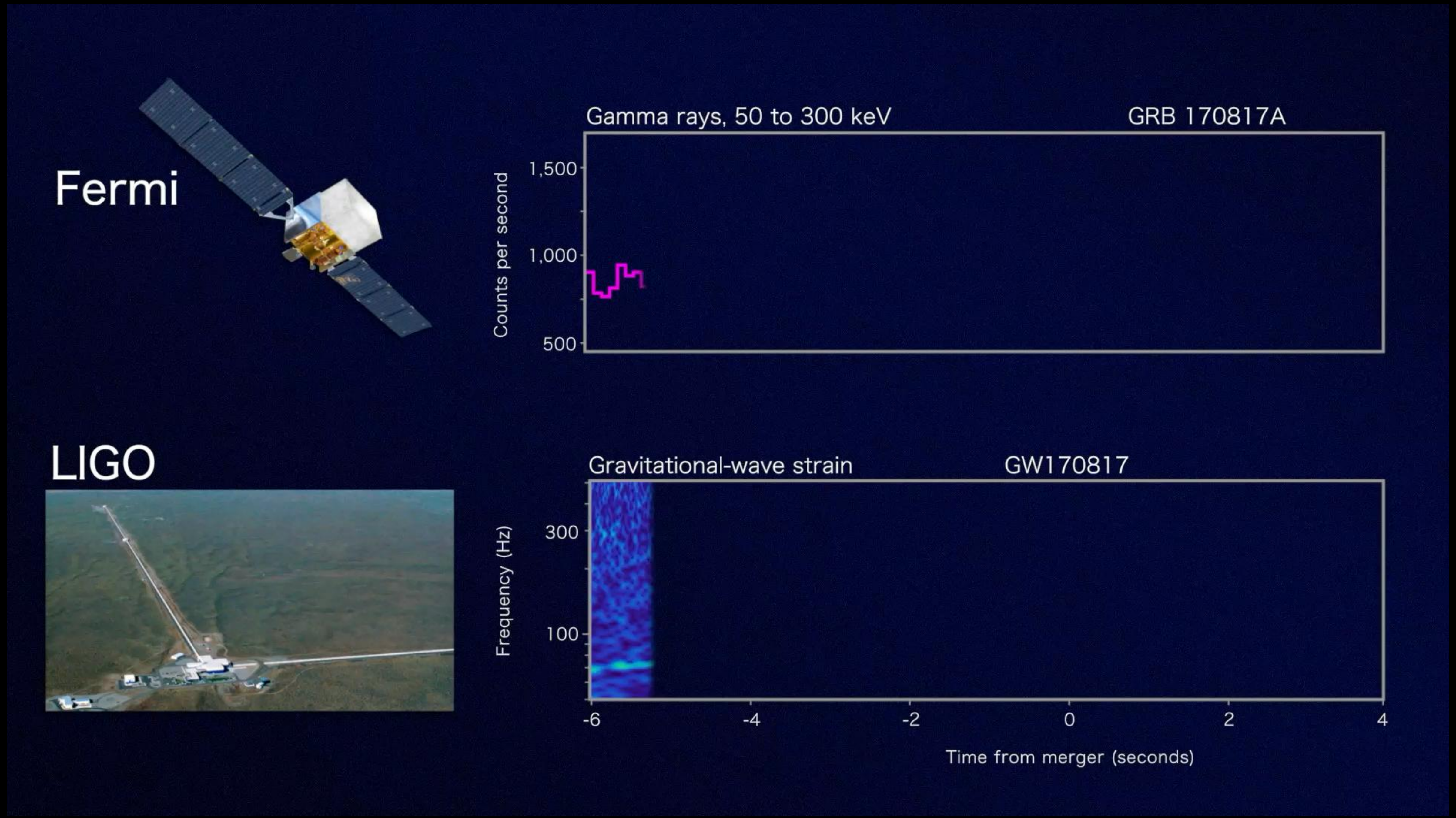
Gamma-ray bursts (GRBs)



Highest-energy form of light
Merging neutron stars → short GRBs

Between the "*whoop*" and the "*ding*"…

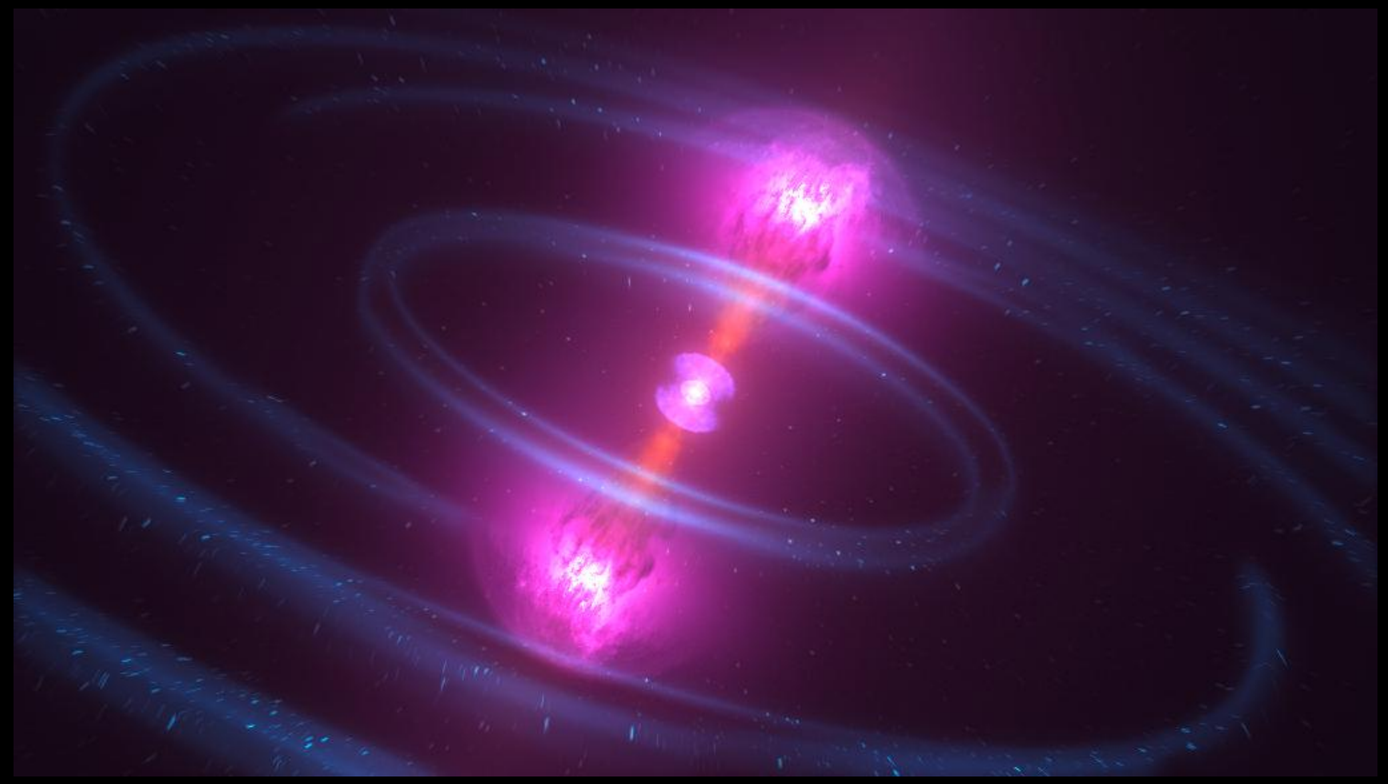
Binary neutron star merger



→ **GRB**
ding!

→ **GWs**
whoop!

When is the GRB launched?

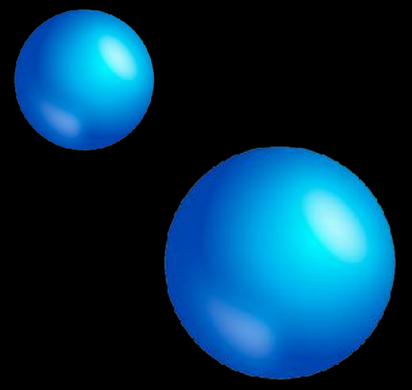


… a hypermassive neutron star?

HMNS lives for < 1s, spins fast, jiggles and emits kHz GWs
too high for current GW detectors!

From simulations:

heavier 20% more mass
than the heaviest known
pulsar: J0740+6620



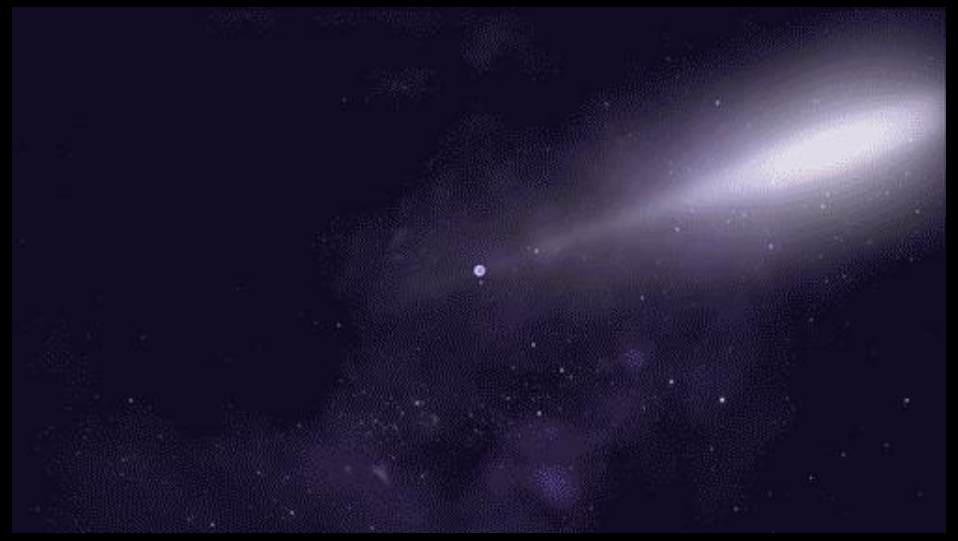
bigger 2 times the size
of a typical NS

An HMNS can be heavier than a normal NS **because** of its fast spin!

Periodic signal

single frequency

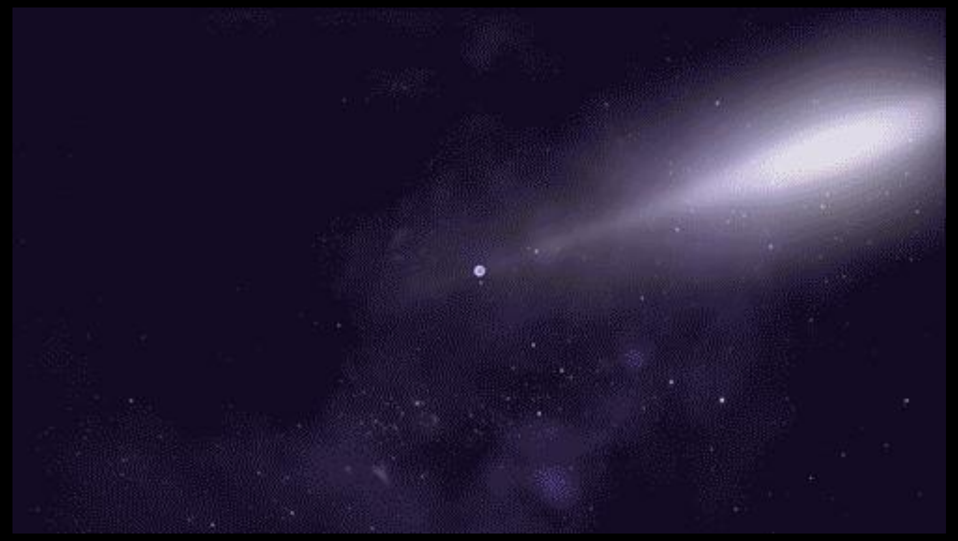
astrophysical example: pulsars



Periodic signal

single frequency

astrophysical example: pulsars



Quasi-periodic signal

not a single frequency

causes of quasi-periodicity:

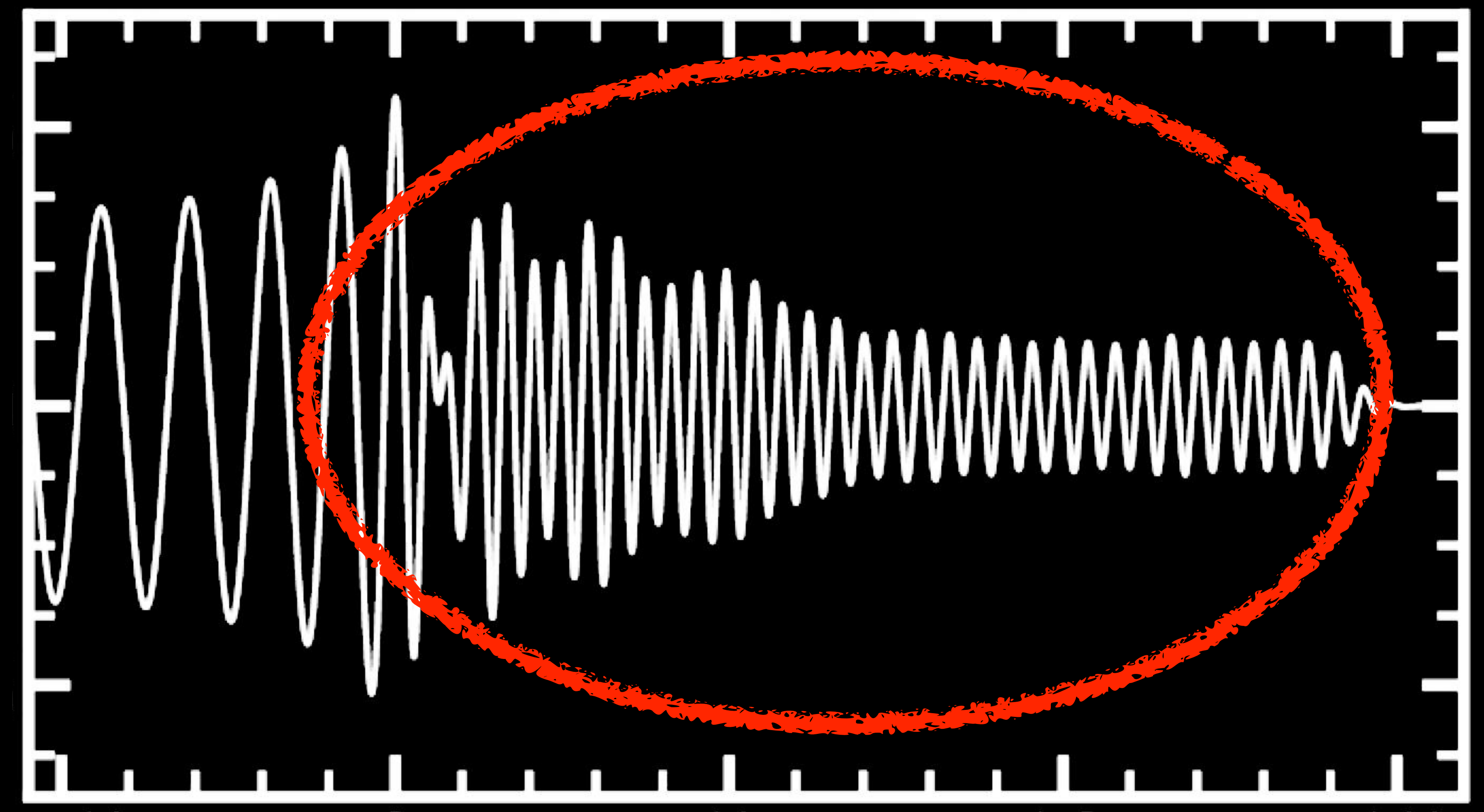
many close frequencies,
dissipation or time variation

Quasi-periodic oscillations

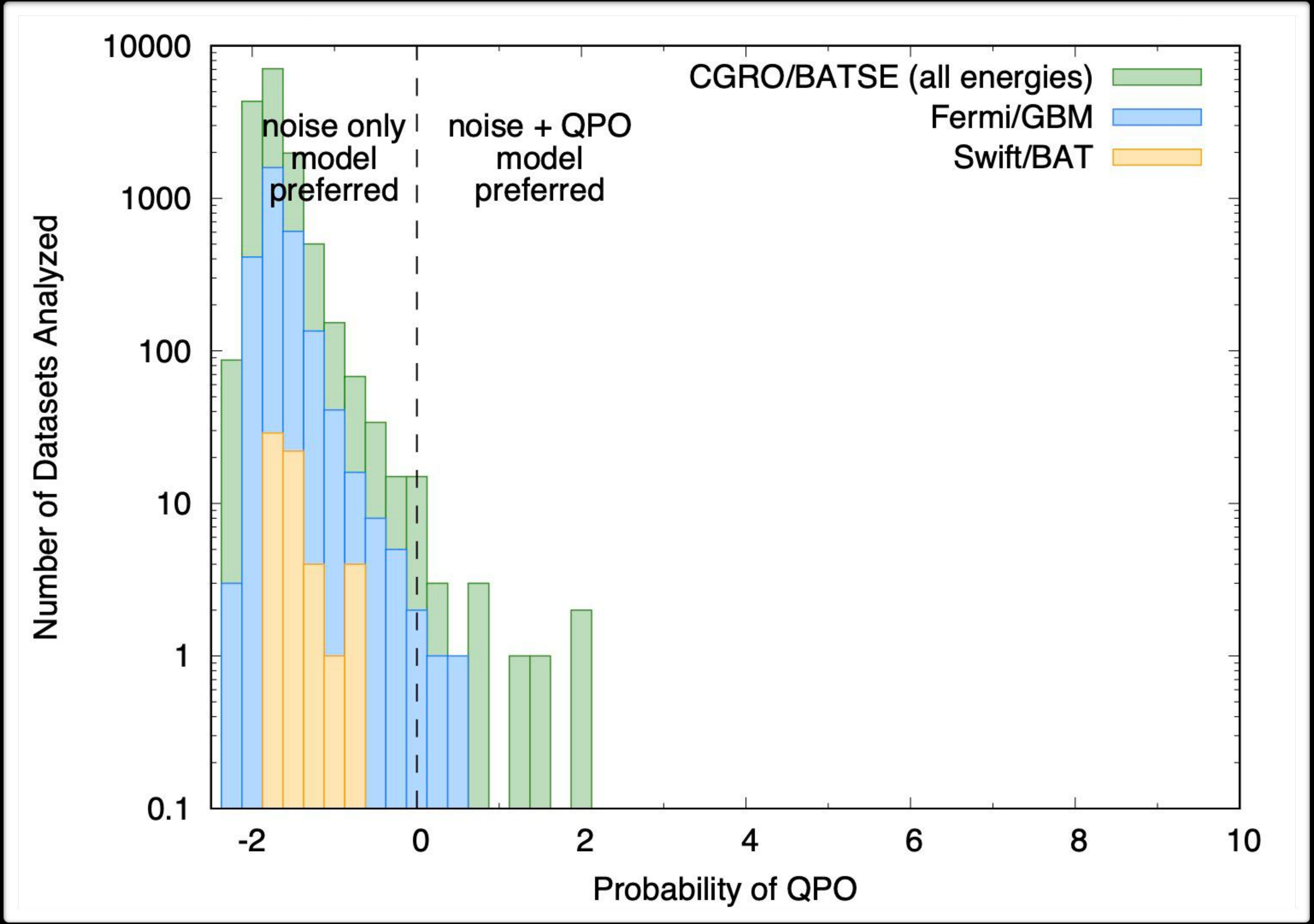
HMNS signal:	short-lived time-evolving dissipative	$\Rightarrow$	quasi-periodic oscillations (QPOs)

what does it look like?

in this case (sort of) like a messy damped mass-spring system



Opening the treasure trove



More than 700 short GRBs analyzed

Each GRB split in smaller segments for analysis

Nothing pops up in Fermi or Swift data

Something in the BATSE data?
Let's look more closely.

CGRO transforms GRB science

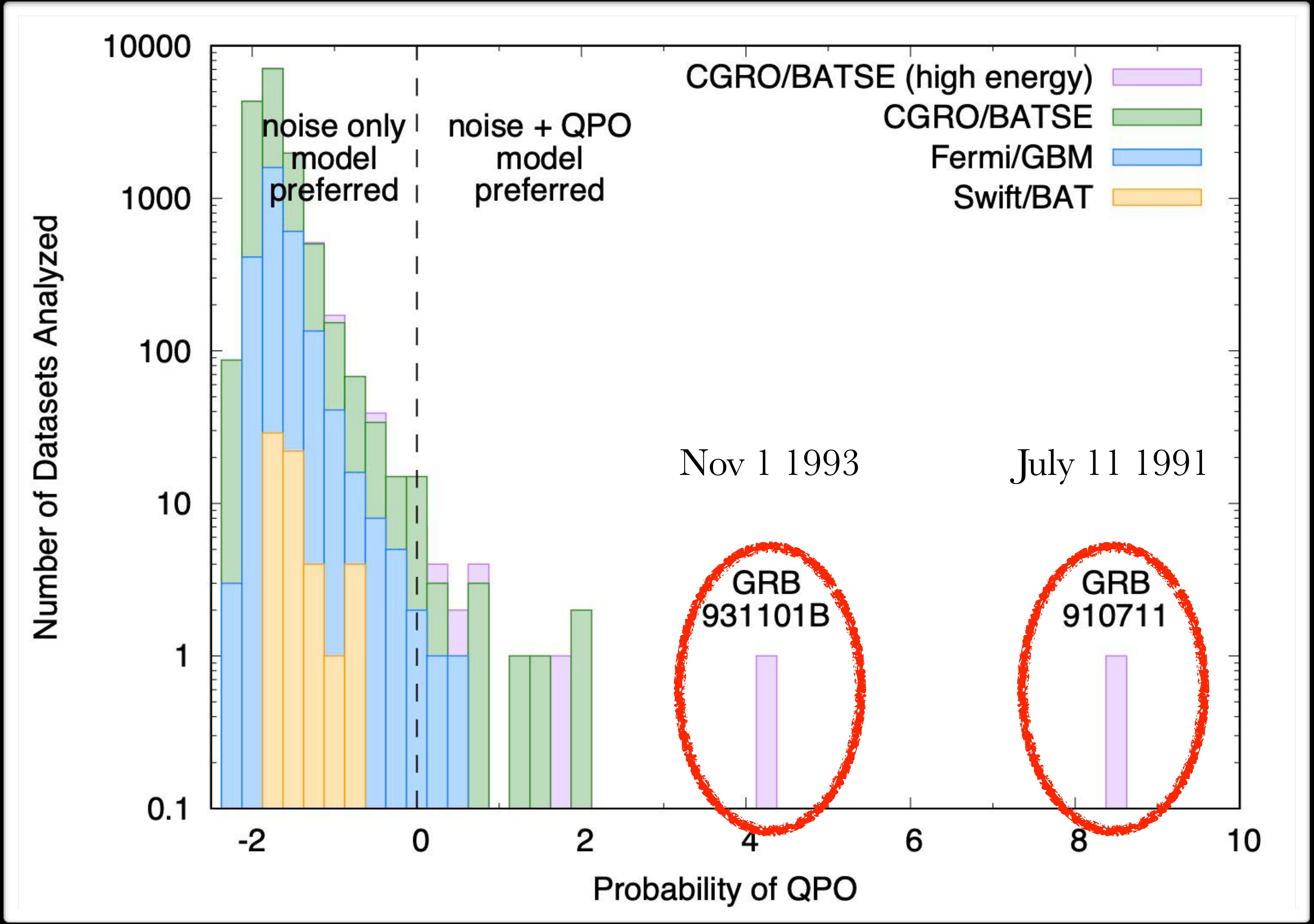
Launched in 1991
De-orbited in 2000

Over 2,700 GRBs detected

Compton Gamma-Ray Observatory was one of NASA's Great Observatories

Astronaut Jerry Ross had to whack the antenna in space to release it.

Opening the treasure trove



… and **bang**! Two signals. The combined false positive rate is 1 in 3.3 million!

Both signals have:
2 QPOs each
with similar frequencies
and good agreement with simulations

Simulated Gravitational Waves
Brightness
Milliseconds
GRB 910711 Data
Milliseconds
Simulation: STAG Research Center/Peter Hammond

A record-breaking neutron star

These signals are consistent with an HMNS:

QPO 1 High frequency!
~ 1kHz
lower amplitude

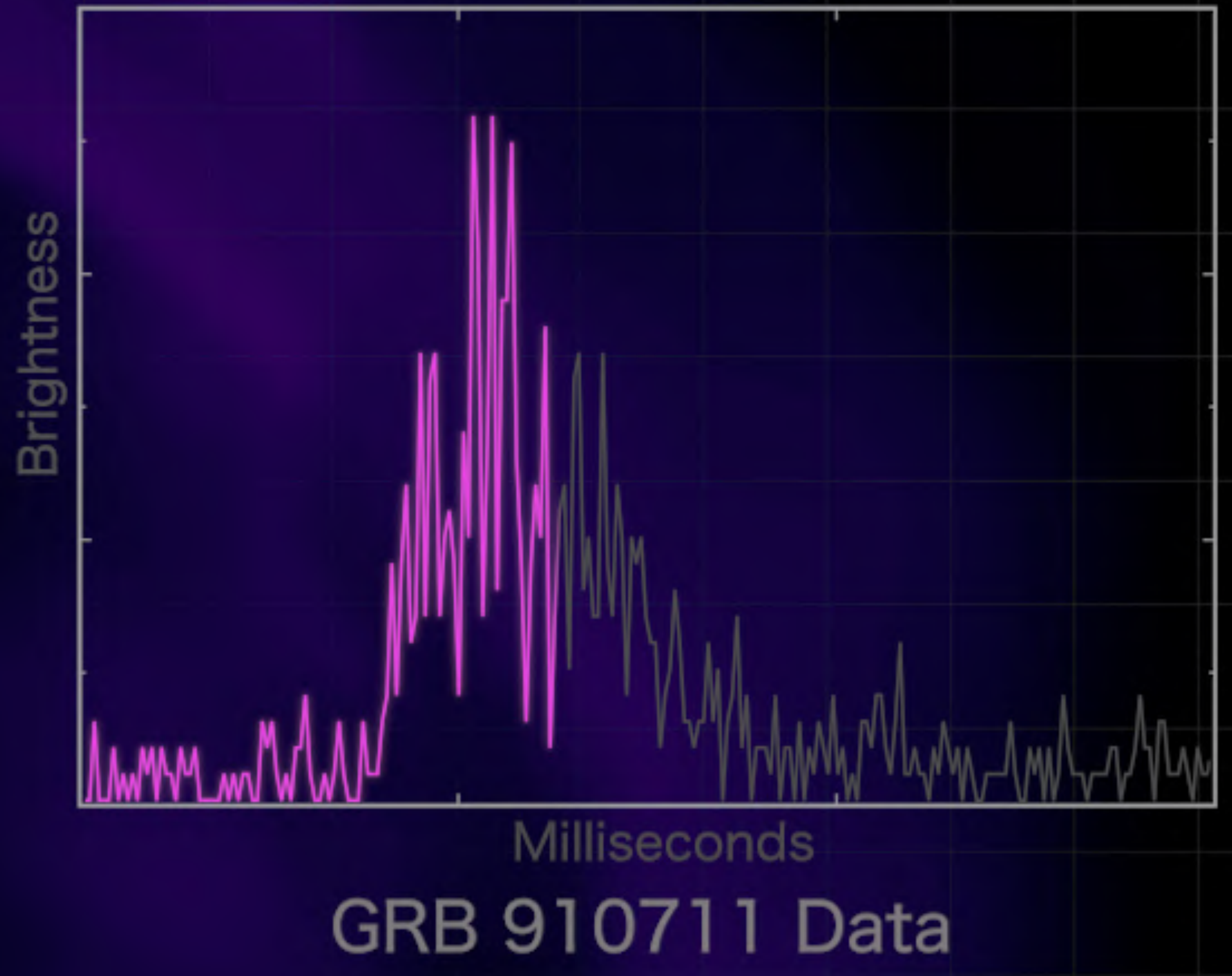
QPO 2 *Higher* frequency!
~ 2.7 kHz, higher amplitude
info on NS composition

Compared with other NSs, the HMNS is:

faster 78,000 rpm, almost 2 times the spin of the fastest known pulsar: J1748−2446ad

forms a black hole 10 times faster than the blink of an eye: signals last for only 10 millisecs

Between the *whoop* and the *ding* of a binary NS merger, an HMNS can be formed. We looked for them and found two: GRB 910711 and GRB 931101B.



Future gravitational wave detectors (2030s) will be sensitive to these kHz frequencies too! In the meantime, we'll be looking for them with gamma rays.

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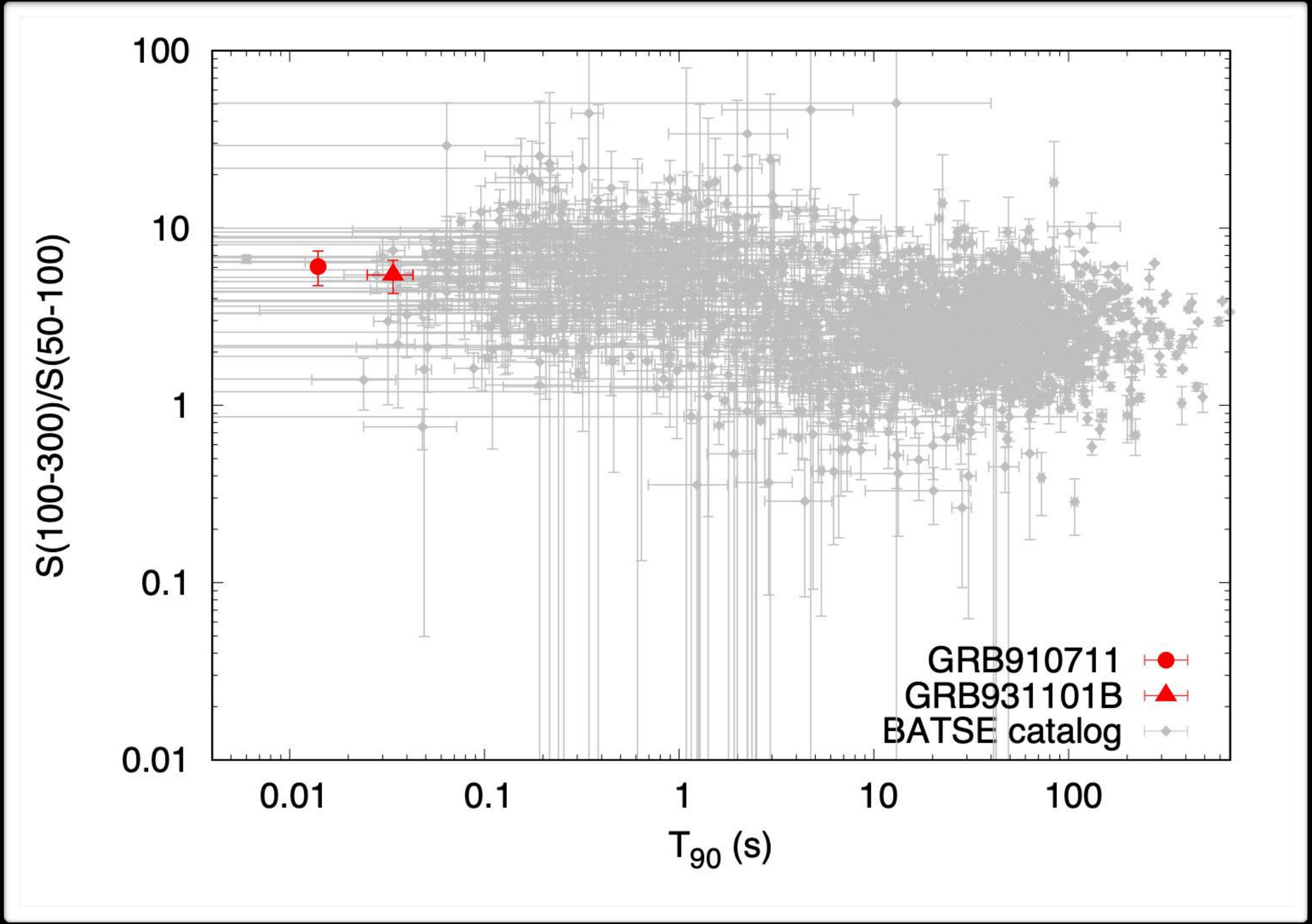
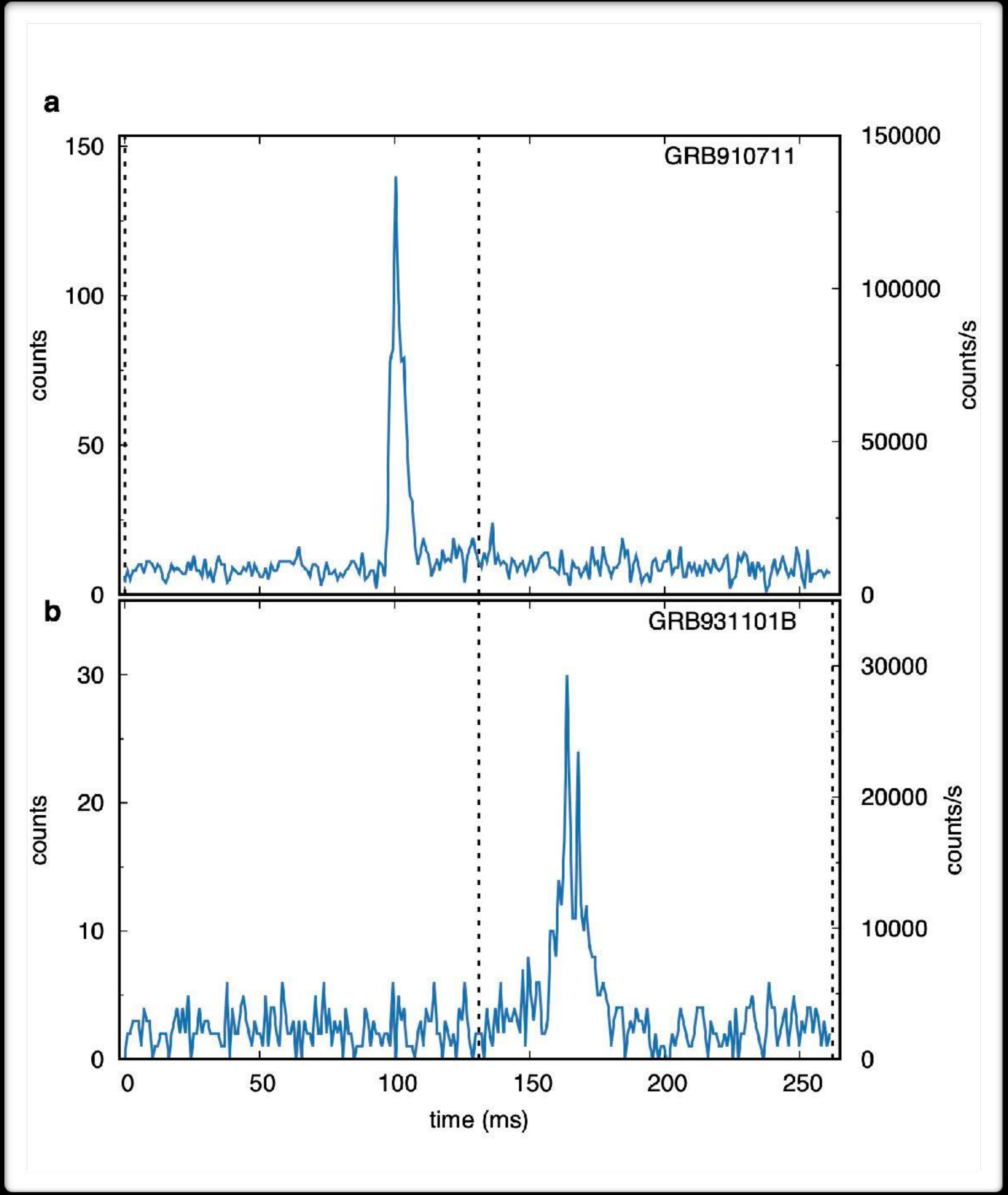
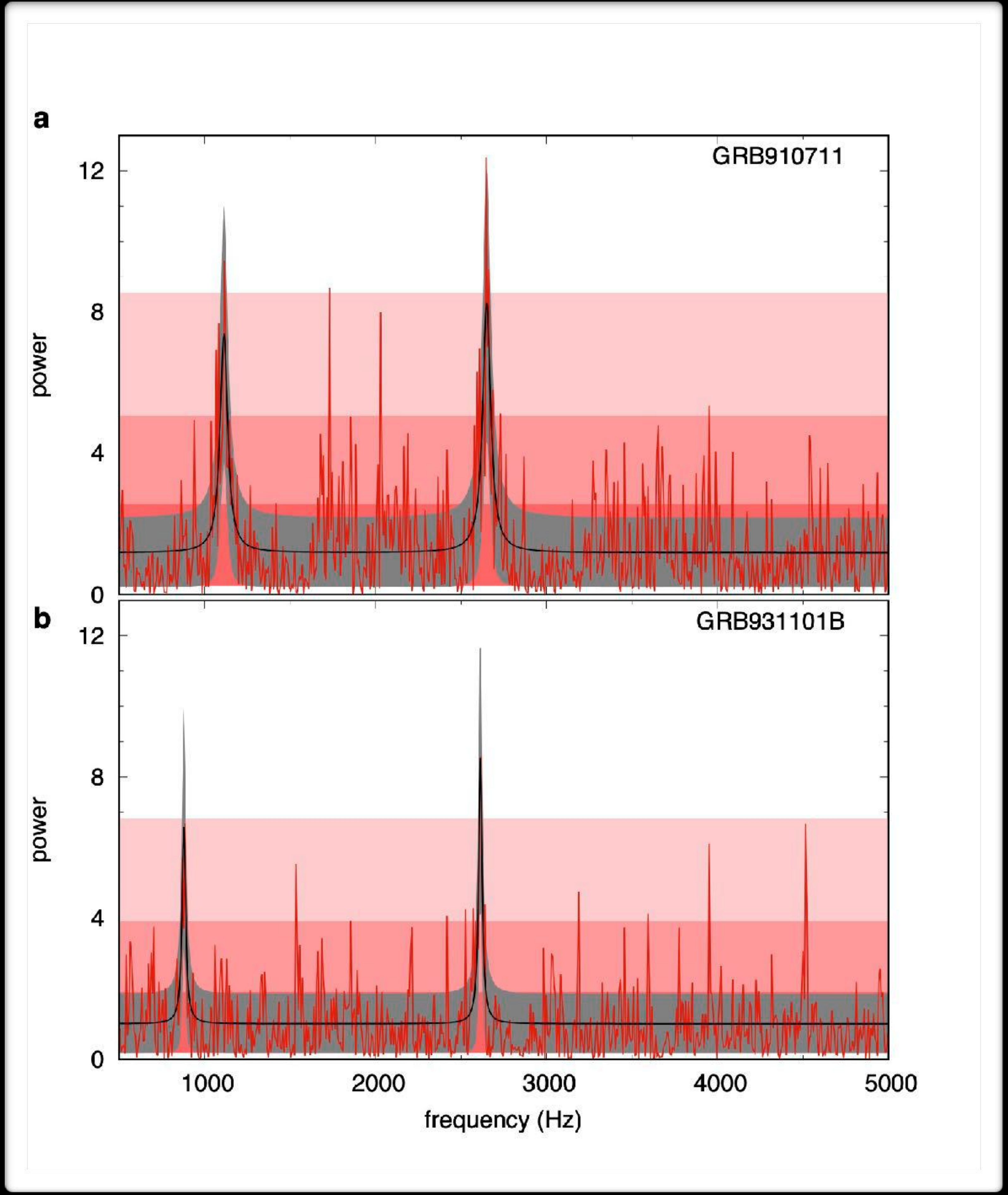
Backup slides

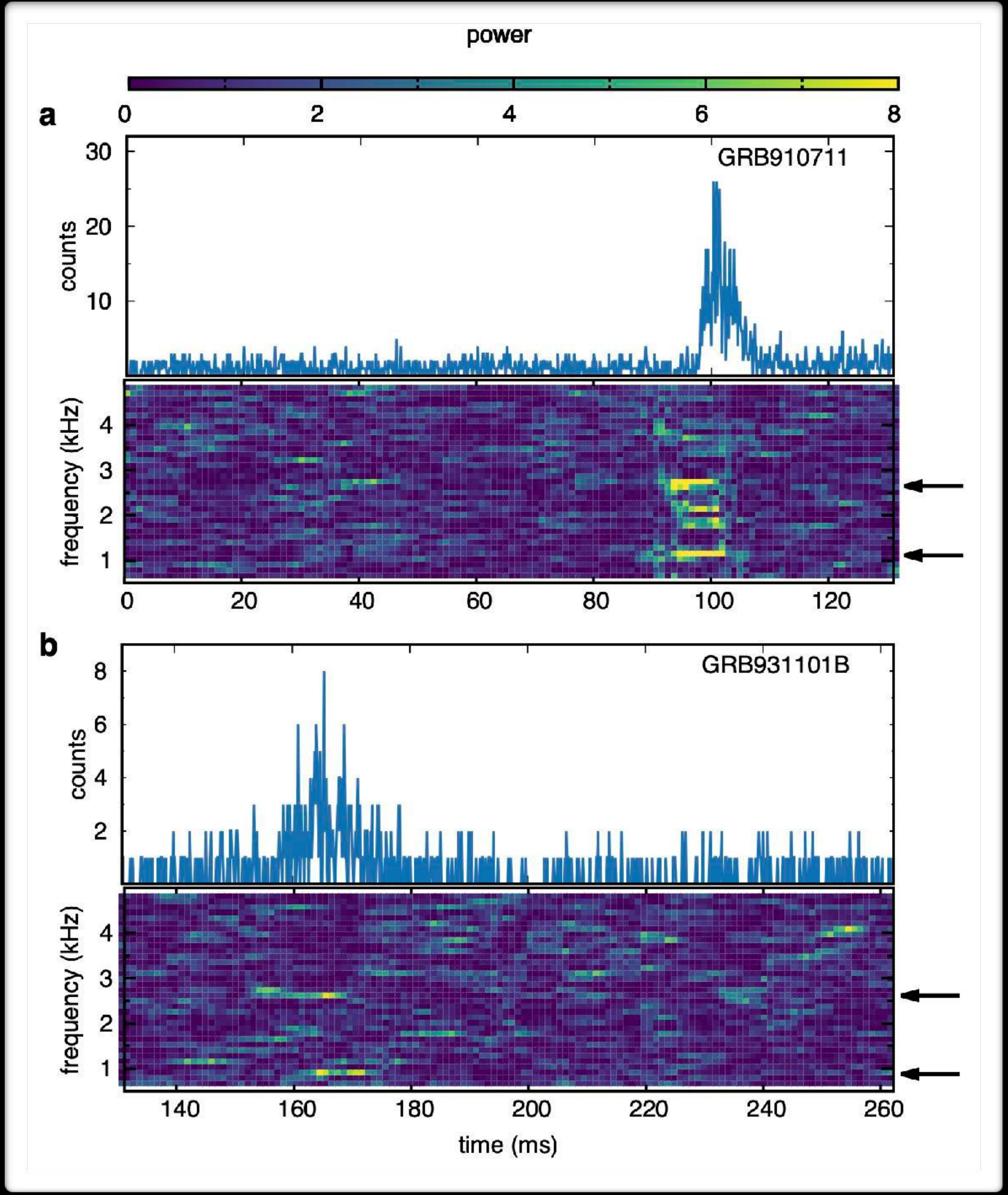
BATSE GRB distribution



Light curves and power spectra







False positive estimate