The properties of ultra-long GRBs

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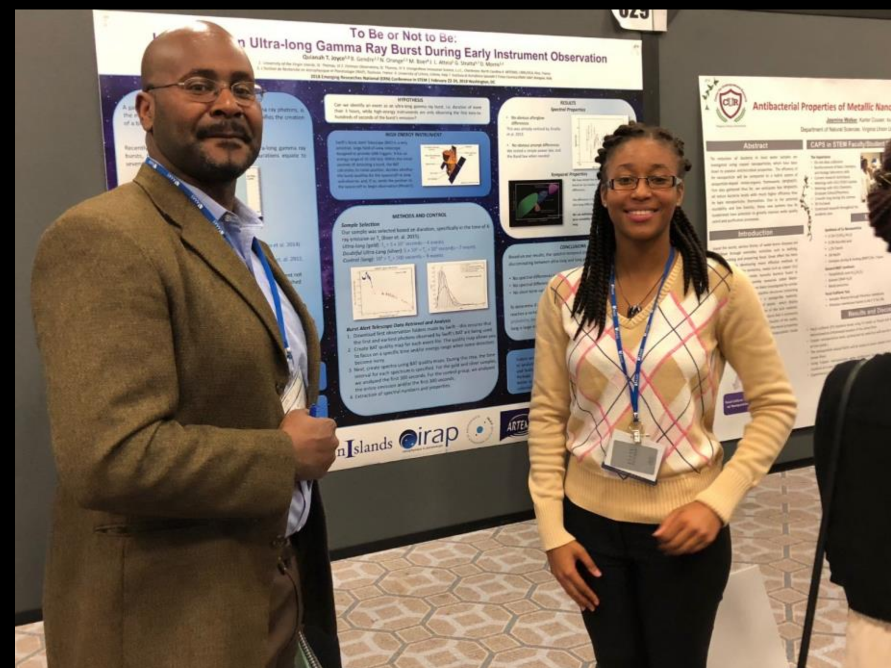
With some help from…

The captains of the field, G. Stratta, and M. Boër

Our boatswain,
Brice « Graybeard » Orange



And introducing our new cabin boy, Q. Joyce

Who won a US national prize for her work

Ultra-long GRBs?

The initial fact:

- ★ Several burst have a continuous emission for more than 10^3 s

- ★ The first hint came with BATSE, and Konus-Wind detected the early ones (see next talk by D. Svinkin)

Most of them were detected by Swift

Their exact number is difficult to state, due to the way we classify them

The concept of duration

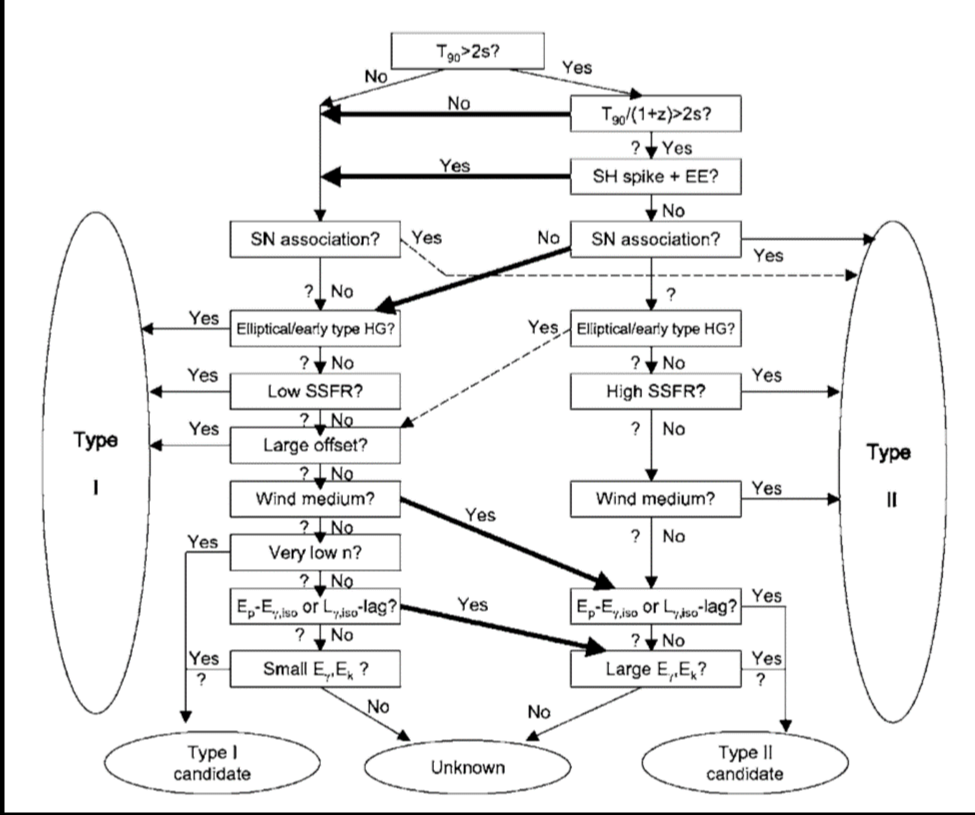
The duration is highly dependent of the instrument

- ★ Observation band
- ★ Sensitivity
- ★ Duty Cycle

Some have proposed a method to remove these biases (see e.g. Zhang et al. 2009)

There is only one little problem…

ZHANG ET AL. 2009



The concept of duration

It is complicated and not very practical

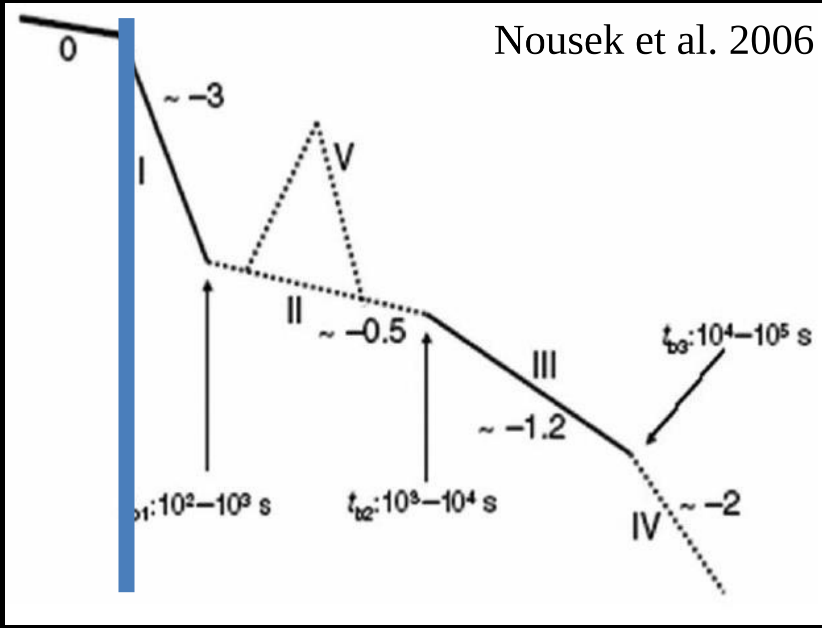
How long the central engine is active?

How about going to a band where there is no instrumental bias?

- ★ X-ray band

The canonical Swift light curve is described by segments (Nousek et al. 2006)

- ★ Segments 0-1 are explained by the prompt emission (Willingale et al. 2007)
- ★ Transition point is when the central engine stops
- ★ the end of the prompt phase



This is the best estimate of the duration of the physical event

We defined it as Tx

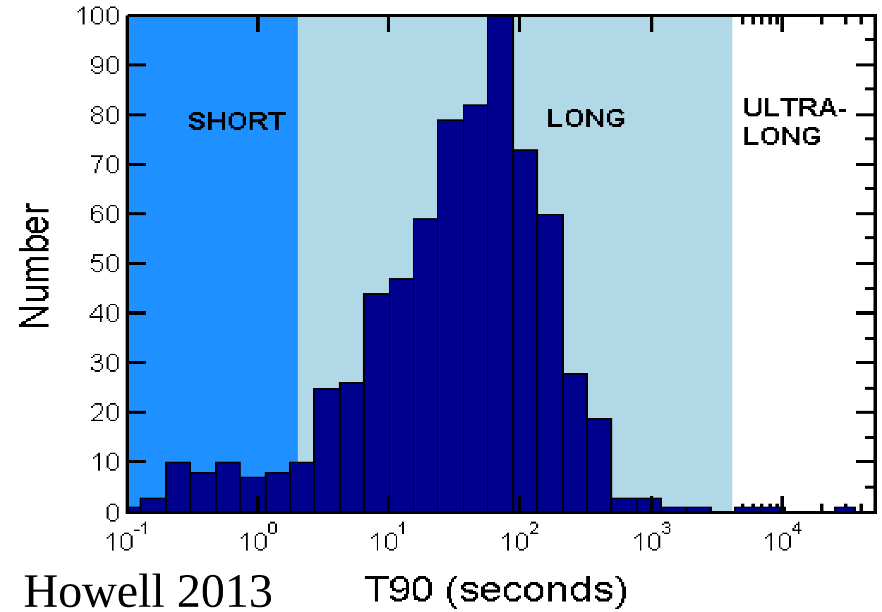
Two classes or not two classes?

Several classes of GRBs

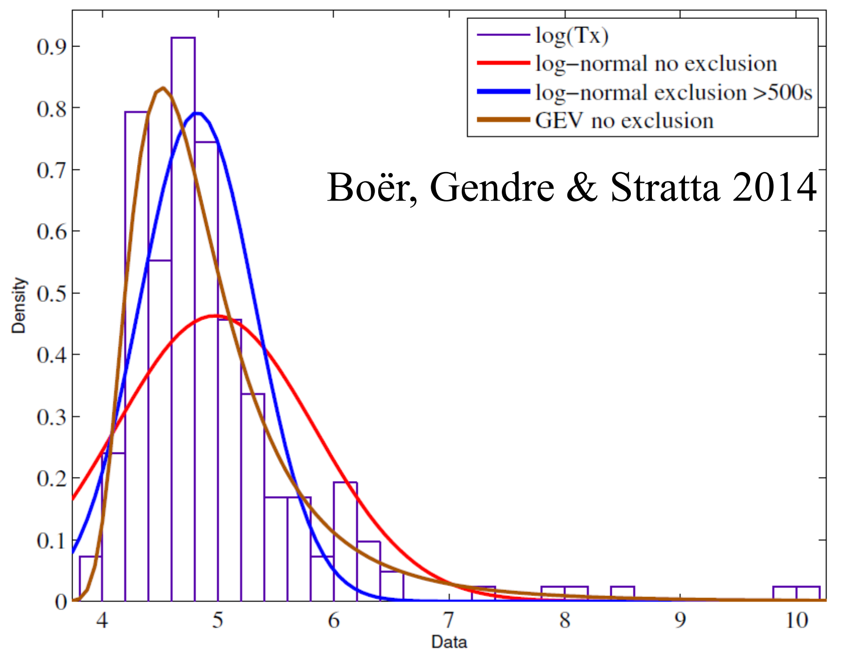
- ★ Long-soft
- ★ Short-hard (Kouveliotou et al. 1993)
- ★ Ultra long-energetic (Gendre et al. 2013)

Some initial discussion about the ultra-long events class

- ★ The tail of the distribution of long events? (Virgili et al. 2013, Zhang et al. 2014)
- ★ Not compatible with the distribution of duration of normal long GRBs (Boër et al. 2014)



Howell 2013



Boër, Gendre & Stratta 2014

The sample of ulGRBs

It is possible to define a sample of Swift ulGRBs

- ★ Marginal statistical significance
- ★ Separated between gold and silver events

Gold events (5)

- ★ Are lasting > 5 000 seconds
- ★ Are not compatible with the tail distribution of long ones at more than 3σ

Silver events (7)

- ★ Are not gold events
- ★ Are lasting > 1000 seconds
- ★ Are not compatible with the tail distribution of long ones at more than 2σ

Table 1. The gold sample of ulGRBs with $T_X > 5 \times 10^3$ s. We list selected properties.

Name	Duration (T_{90}, s)	Duration (T_X, s)	Redshift
GRB 101225A	>7000	5296	0.847
GRB 111209A	25 000	25 400	0.677
GRB 121027A	>6000	8000	1.77
GRB 130925A	4500	10 000	0.35
GRB 170714A	420	16 600	0.793

Table 2. The silver sample of possible ulGRBs, selected with 5×10^3 s > $T_X > 10^3$ s. We list selected properties.

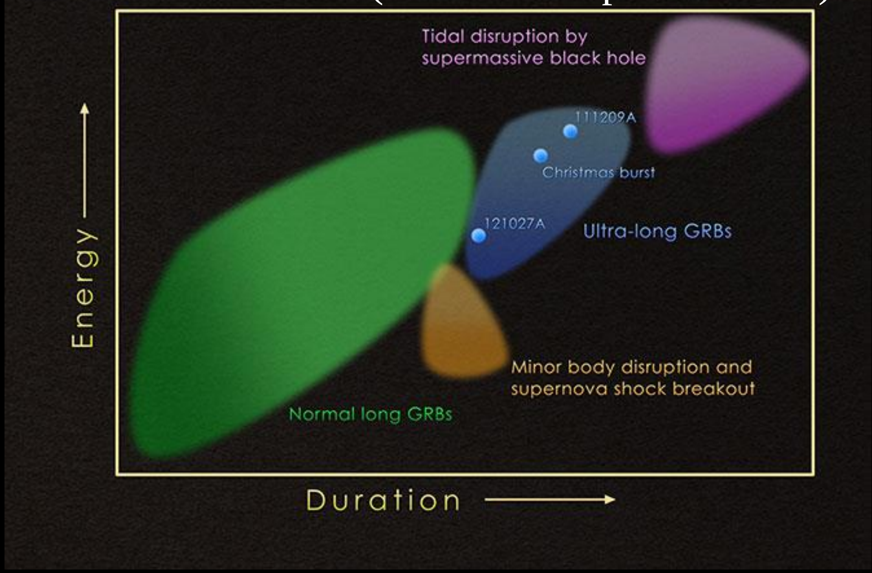
Name	Duration (T_{90}, s)	Duration (T_X, s)	Redshift
GRB 060111A	13.2	3243	5.5
GRB 060218A	2100	2917	0.03
GRB 121211A	182	1415	1.023
GRB 141031A	920	1100	–
GRB 141121A	1410	<5000[a]	1.47
GRB 140413A	140	3899	–
GRB 161129A	35.5	2000	0.645

Note. [a]The start of the fast X-ray decay is missing in the XRT data due to a gap in the observation. We can set only an upper limit.

From Gendre et al. 2019

Why studying ulGRBs?

Gendre et al. 2013 (from NASA press release)



The main question is about the progenitor of these event

- ★ How to provide enough energy
- ★ In the time scale of the event
- ★ And still be a compact source?

Possible classes of progenitors:

- ★ Ultra-massive stellar progenitor with low metallicity (Suwa & Ioka 2011)
- ★ Tidal disruption of dwarf star (McLeod et al. 2014)
- ★ Magnetar formation (Greiner et al. 2015)

The afterglow properties

- ★ Similar flux and spectral shape than normal long GRB
- ★ GRB 111209A (Stratta et al. 2014)

The stellar wind

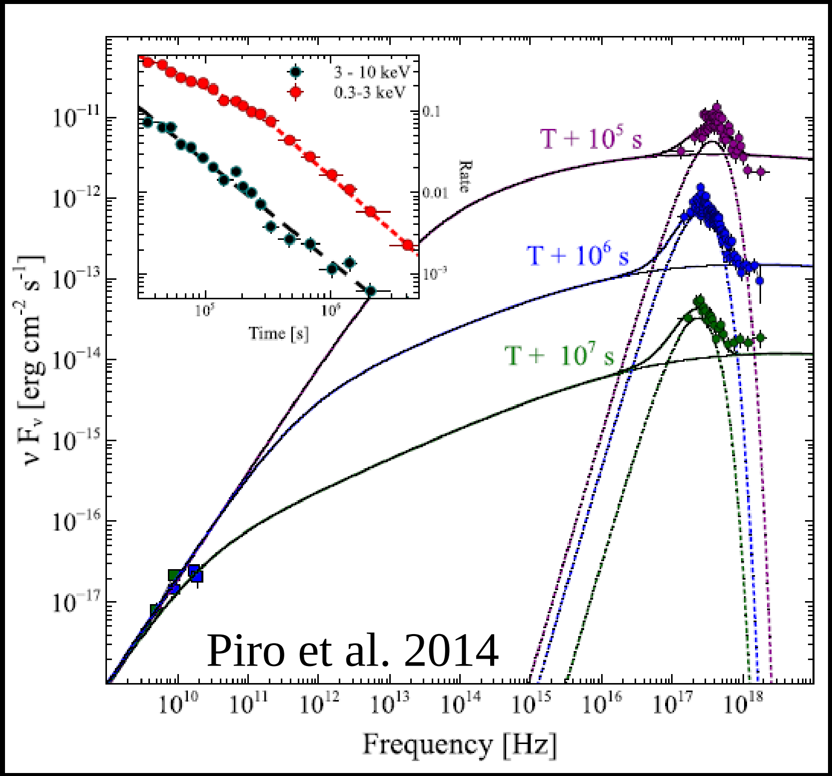
- ★ Preferred by the spectral models
- ★ GRB 130925A (Piro et al. 2014)

The supernova

- ★ Best evidence that we observed a star
- ★ GRB 111209A (Greiner et al. 2015)

A thermal component

- ★ Interaction of the jet with stellar layers
- ★ GRB 130925A (Piro et al. 2014)



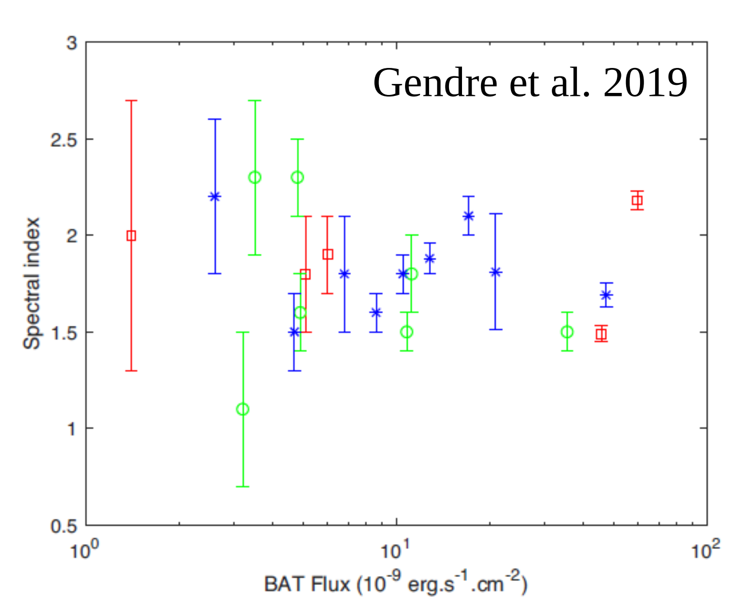
Prompt properties

What is known:

- ★ They last longer
- ★ They are releasing more energy in total

What we can test:

- ★ Their instantaneous properties
- ★ Their properties integrated on a short time scale



Gold sample
Silver sample
Control long GRBs

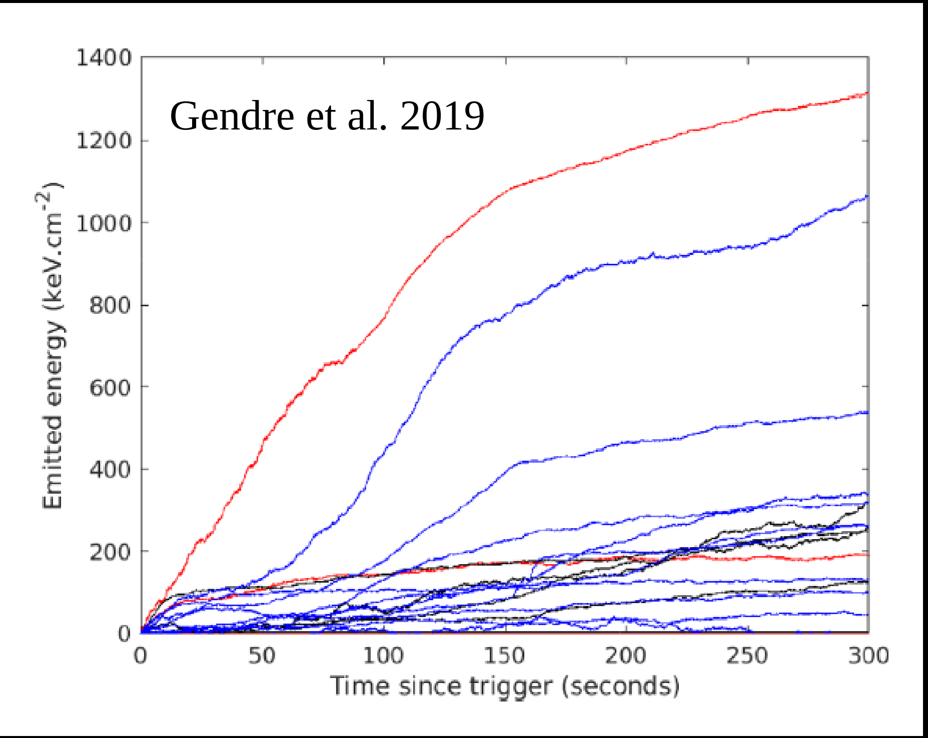
Instantaneous properties (BAT data)

- ★ Similar spectral shape
- ★ Similar distribution of mean flux
- ★ No difference between long and ulGRBs

Prompt properties

Comparing integrated properties

- ★ Full integration → energetic
- ★ Windowed integration → rate of emission



Window of 300 seconds used

- ★ Good compromise between short scale activity (flares) and duration limits

Gold sample

Silver sample

Control long GRBs

Start at trigger time

- ★ Possibility to predict the duration if some discrepancies are found

No discrepancies found

Consequence on the progenitor of ulGRBs

We have the same emission rate and level for both long and ul GRBs

The only difference is the duration

We have the same afterglow emission

- ★ Linked to the environment
- ★ Thus we should have the same environment for both long and ul GRBs

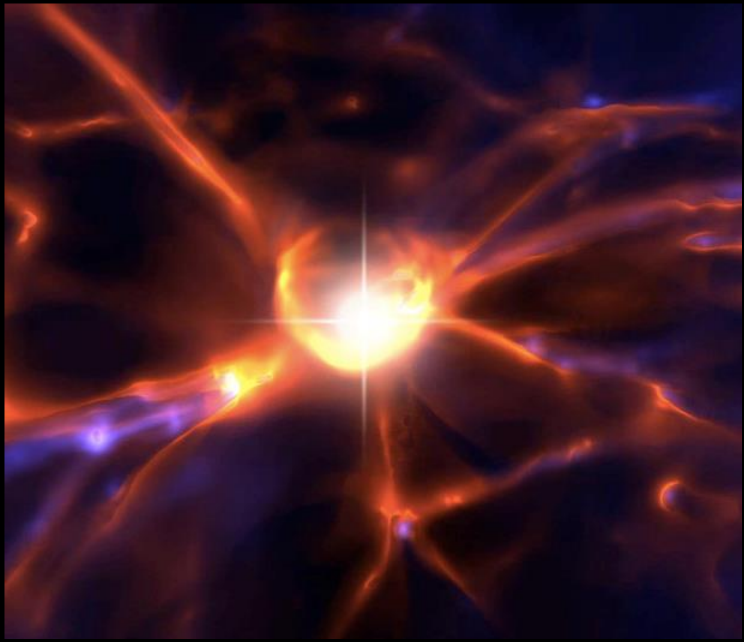
This would privilege a similar progenitor for both long and ul GRBs

- ★ Tidal disruption is not OK (different class of progenitor)
- ★ Magnetar…

Can the magnetar be an alternative?

Back to the blackboard

- ★ Extraction/emission of rotation energy by magnetic brakes
- ★ Duration is linked to the initial rotation speed
- ★ For ulGRBs, the initial rotation speed would destroy the cohesion of the neutron star



Back to the model

- ★ Explain the short bursts (Usov 1992)
- ★ Proposed for the plateau phase (Troja et al. 2007)
- ★ Now proposed to explain ulGRBs
- ★ Seems to me this model can do everything if you ask it to do it, like someone else…

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- ★ Tidal disruption is not OK (different class of progenitor)
- ★ Magnetar… how can you store rotation energy beyond the dynamical breaking point of a neutron star?
- ★ Collapsar is OK (duration is linked to the size of the star)