The Short GRB 130603B: the first evidence of a r-process Supernova

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Nasa Postdoctoral Program Fellow (NASA/Goddard/ORAU)

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Cucchiara et al. 2013

Tanvir et al. 2013
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Cabo de Gata - Sept. 26 2013

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Outline

- Little history of Short-GRBs
- Recent advancements
- SGRBs in the context of Gravity Waves progenitors
- GRB 130603B: phenomenology
- GRB 130603B as r-process Supernova

Little bit of context...
...long time ago...

Short GRB in a ``nutshell”

Thanks mainly to the BATSE, HETE II, KONUS-WIND satellites first and, in the last ~9 year,s to Swift we now can describe SGRB based on some key observables:

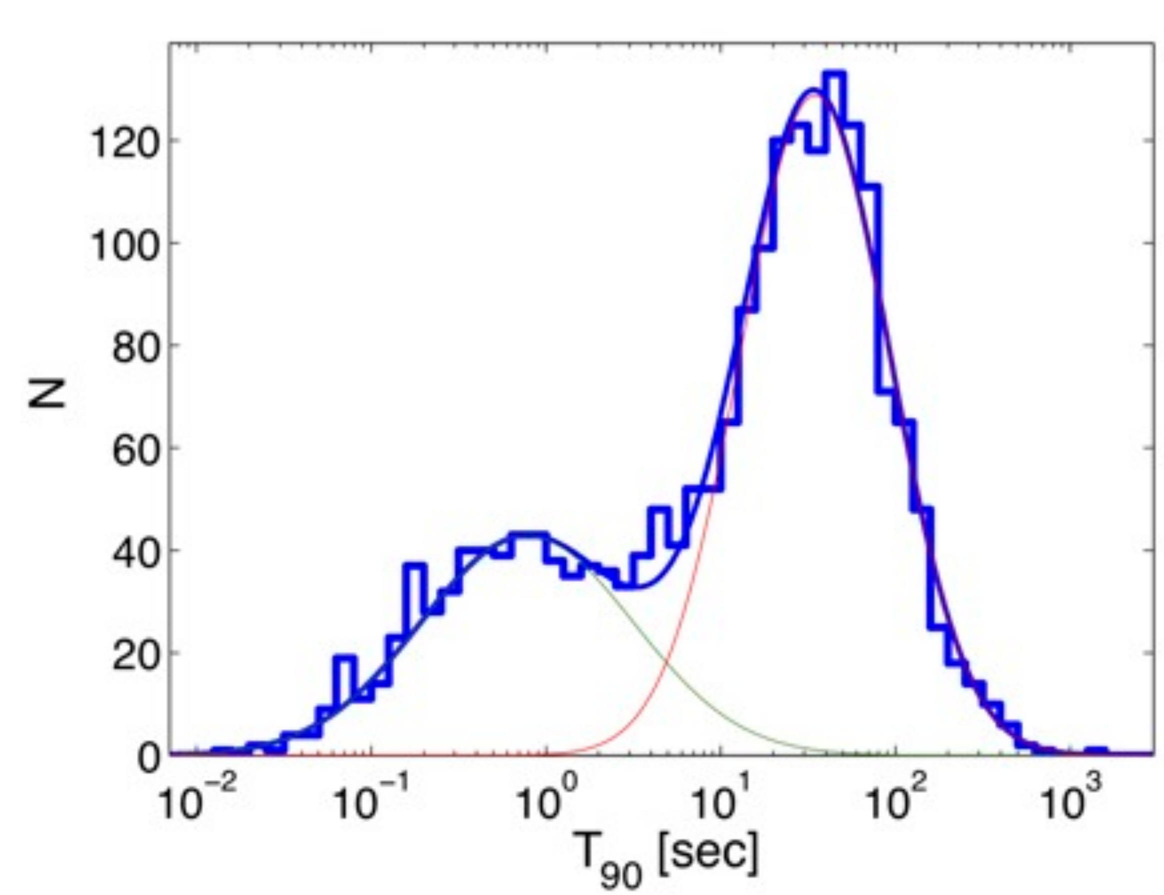
★ Short GRBs have $T_{90} \leq 2s$

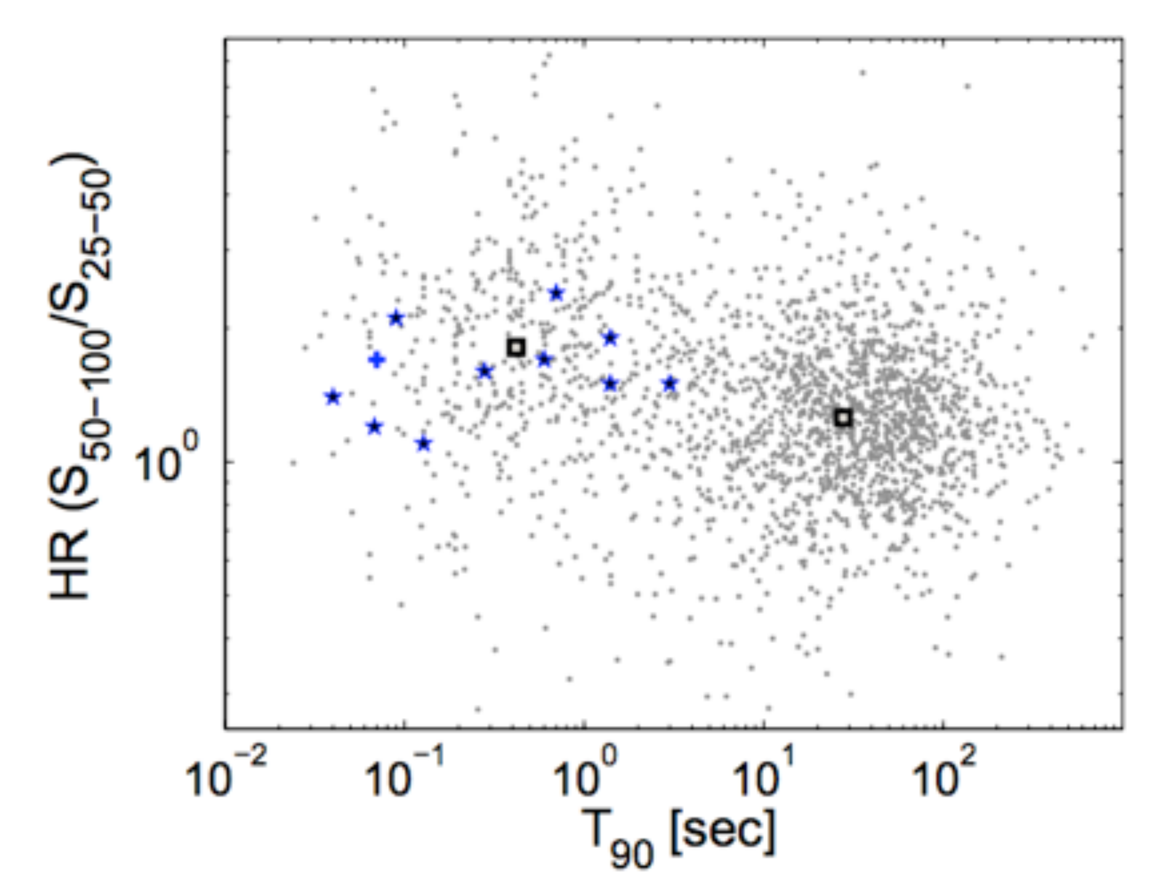
★ Their spectrum is harder than LGRBs

★ Spectral lag analysis (lag between soft and hard component ~ 0)

★ They are intrinsically fainter

★ Their afterglows decays faster than LGRBs





Kouveliotou et al. 1993,
Ghirlanda et al. 2004,
Mazets et al. 2004,
Lazzati 2005 et al. ,
Lee and Ramirez-Ruiz 2007
Nakar et al. 2007 (review)

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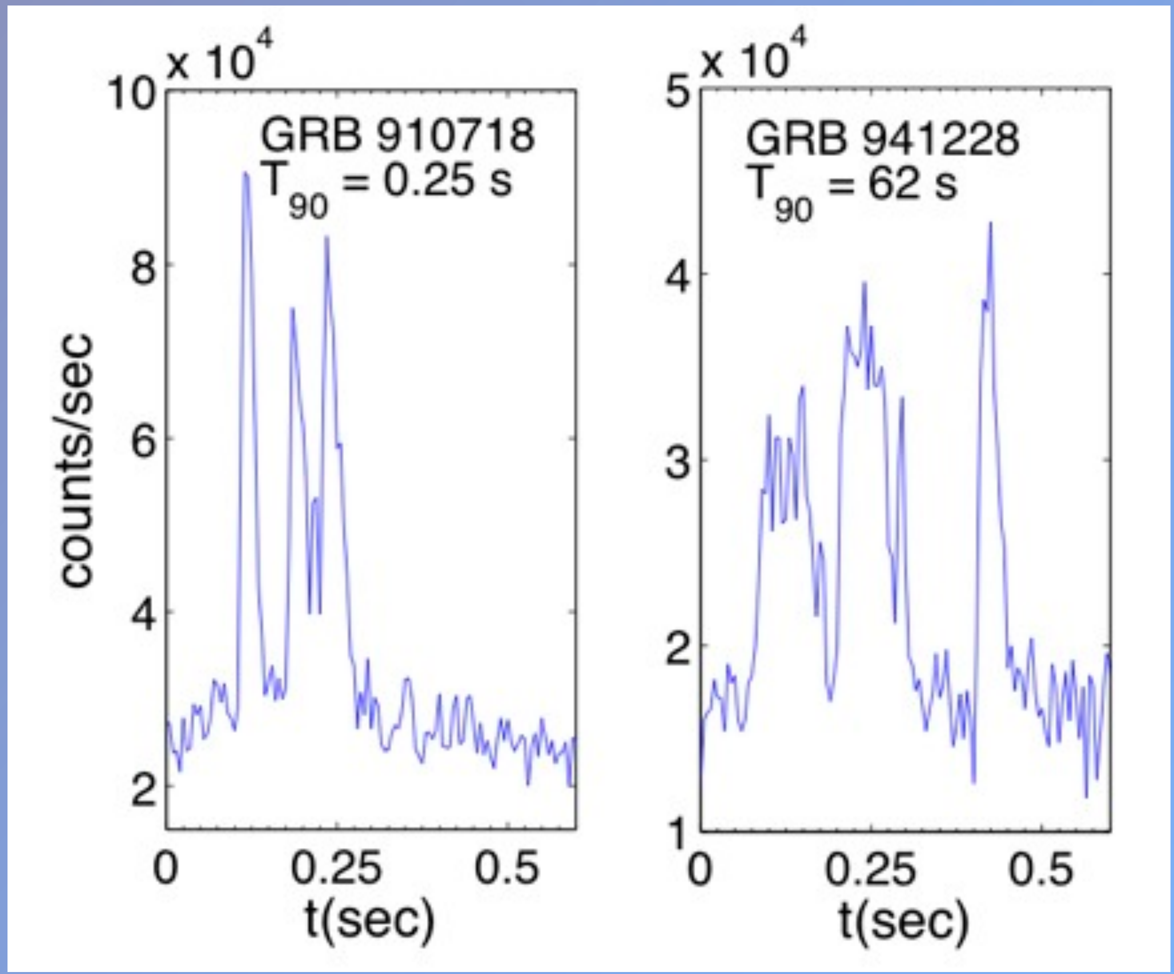
Short GRB in a ``nutshell''

These are two examples of long and short prompt emission from BATSE.



Nakar et al. 2007

★ Short GRBs have $T_{90} \leq 2$s

★ Their spectrum is harder than LGRBs

★ Spectral lag analysis (lag ~ 0)

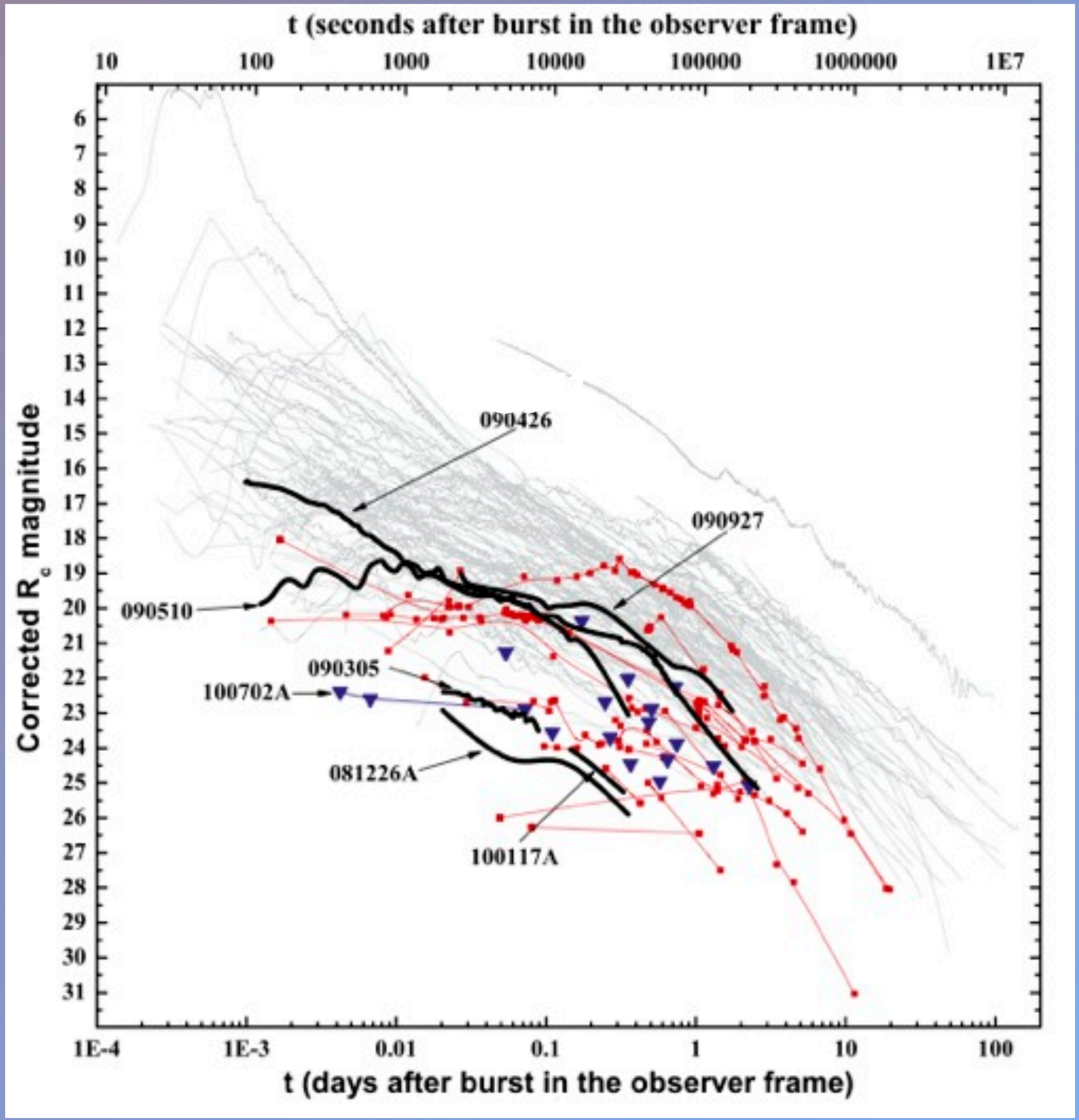
★Spectrum is often not fitted by the usual Band function

★ They are intrinsically fainter

...in the recent years...

Afterglows

From the extensive work of Kann et al. 2011 (Nicueasa Guelzebu et al. 2012)we can see that the afterglow is fainter then the usual long population.



Nicuesa Guelbenzu et al. 2012

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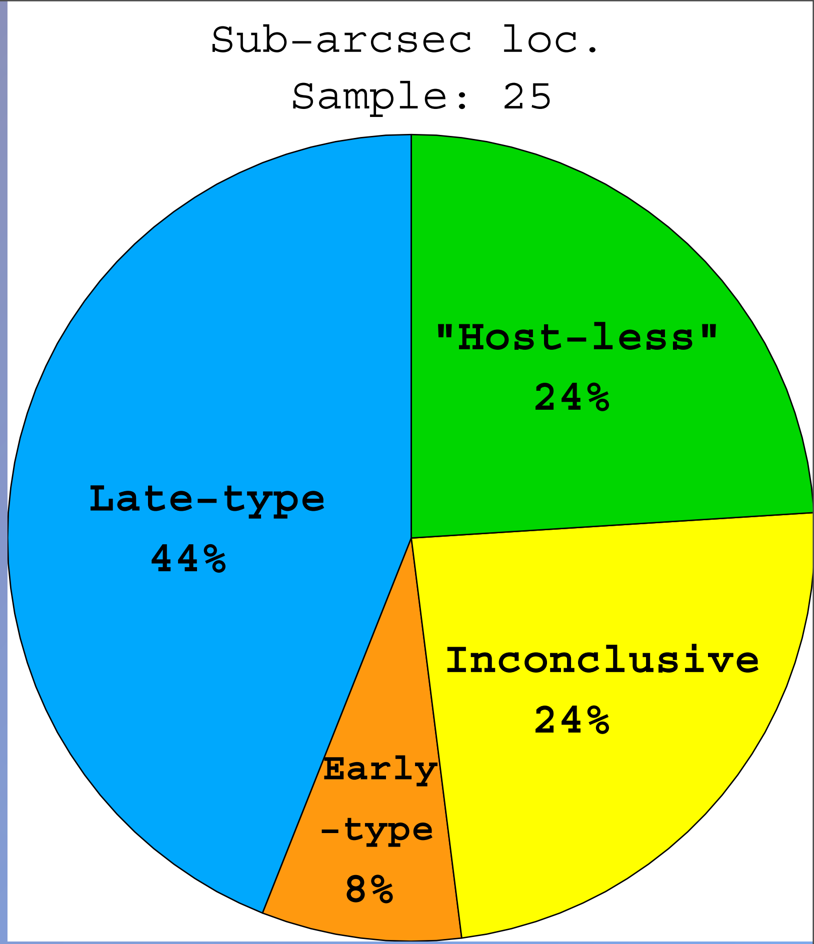
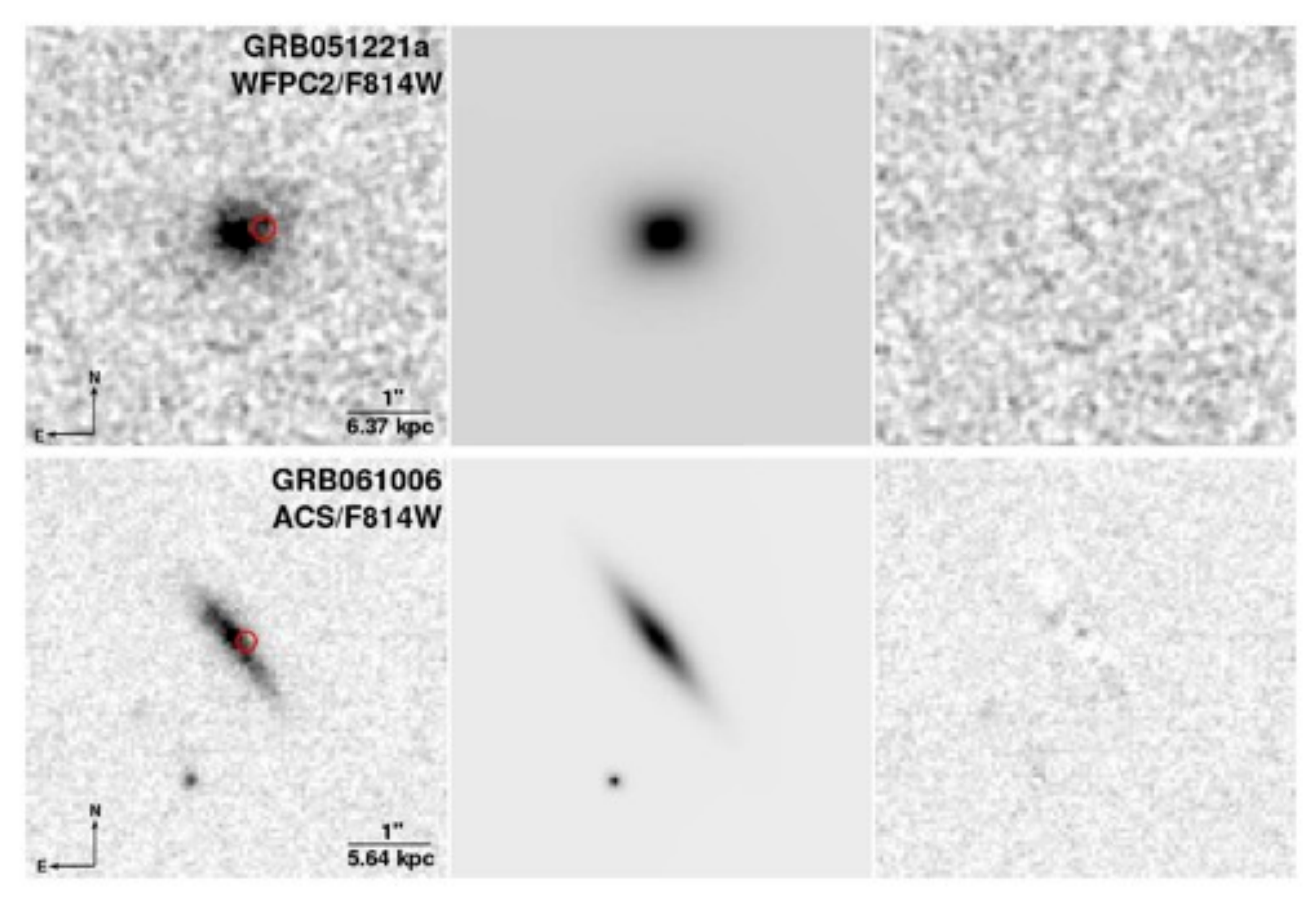
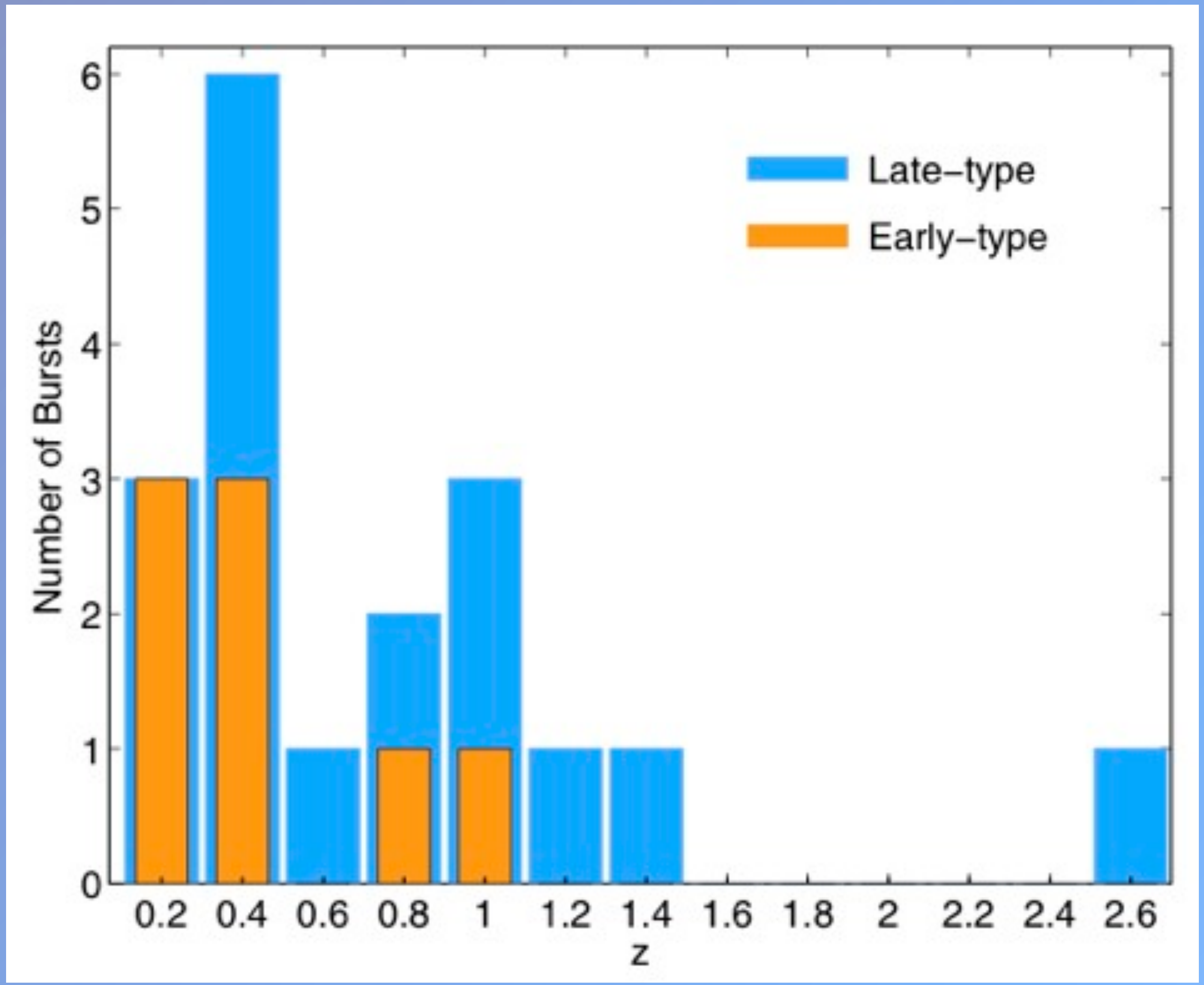


Host Galaxies

a lot of work has been done to associate the host to the short GRB. It has not been easy since the GRB position is known only from the X-ray afterglow position (~2-3 arcsecs).

Overall Fong et al. 2013 has determine that 44% of the secure identified host are late-type galaxies





See also Bloom 2002, Berger et al. 2009, 2011

What are SGRB progenitors?

*

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Goodman (1986)
Goodman, Dar & Nussinov (1987)
Eichler et al. (1989)
Narayan, Paczynski & Piran (1992)
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Are there any reasonable observables that come out from these models?

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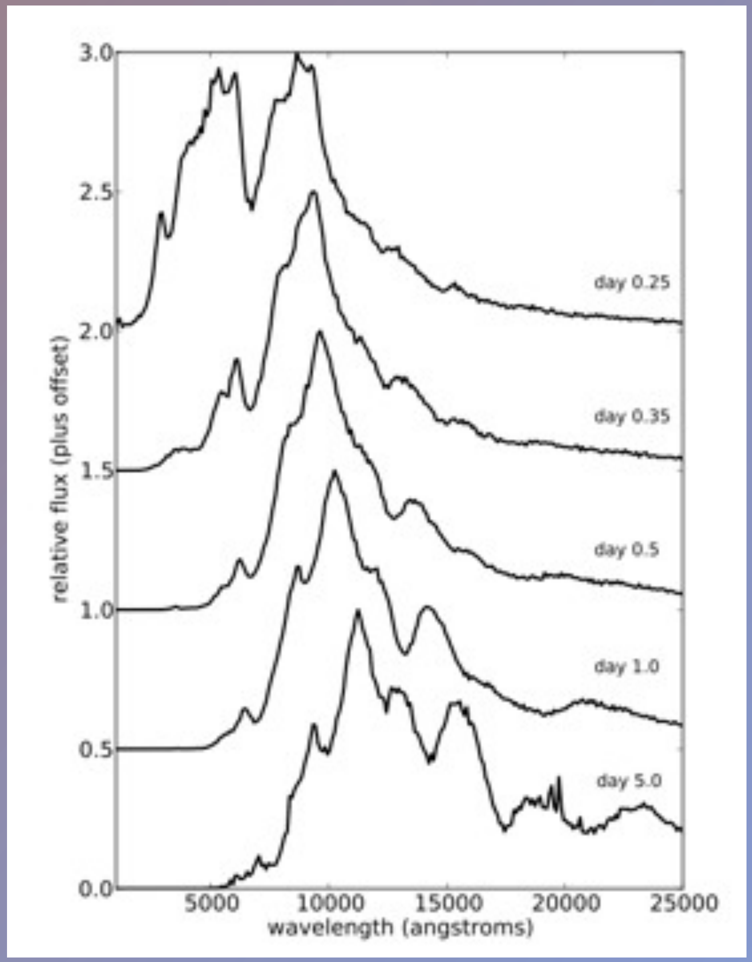
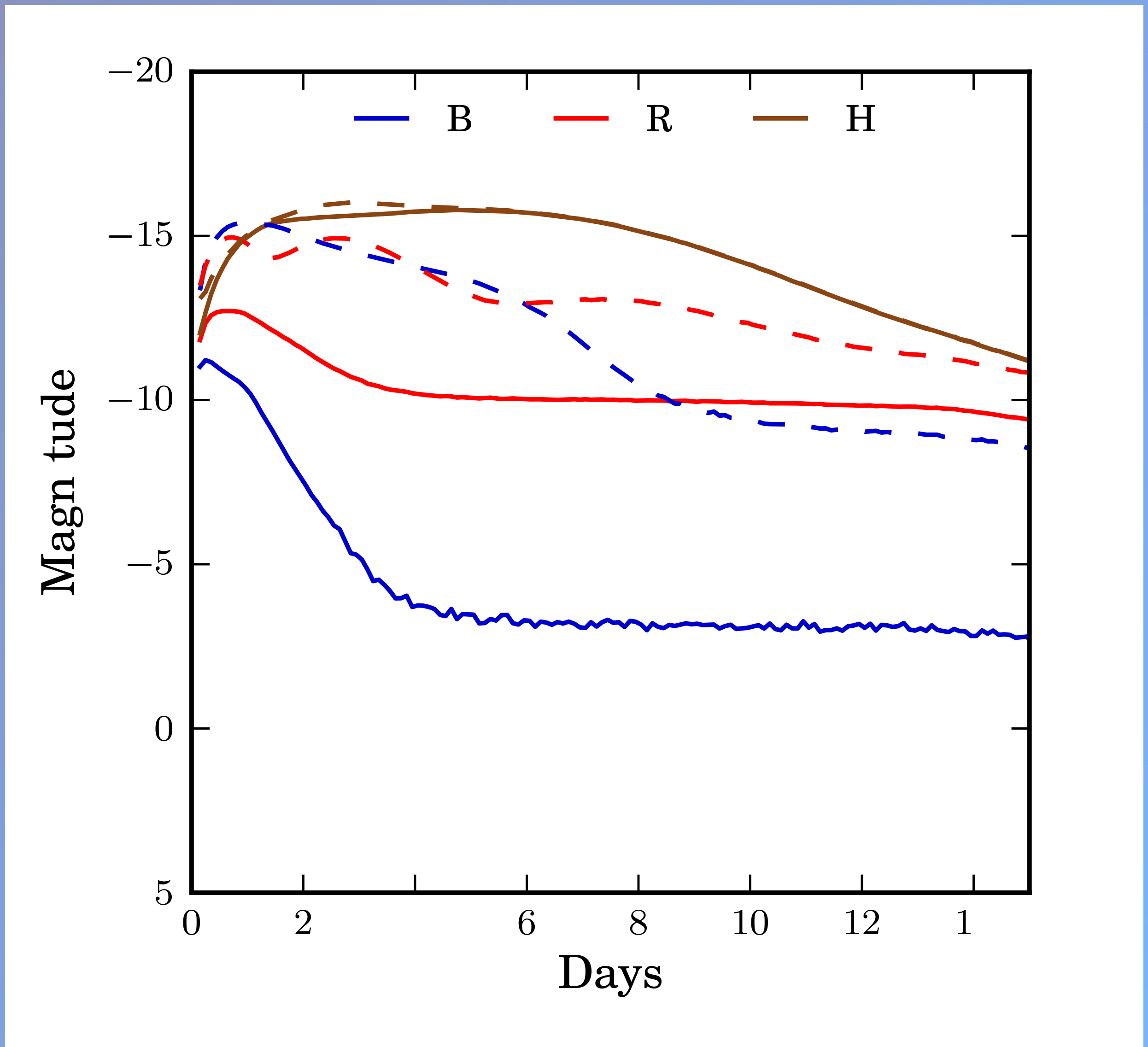
Observables anyone?

Barnes 2013, Kasen 2013 and Tanaka 2013, have investigated the outcome of NS-BH/NS-NS events in terms of afterglow properties: there is the possibility that after the afterglow radiation (synchrotron) radioactive, neutron reach elements are ejected.
The opacity produced by these elements will suppresses the optical/UV emission letting a very long-living (red) near-infrared counterpart (called "kilonova", `"macro-nova", or "r-process SN" .

Spectrum from Kasen 2013



Lightcurve from Barnes 2013



This is observable signature is now at reach of our capability!!!

GRB 130603B - the night of the discovery

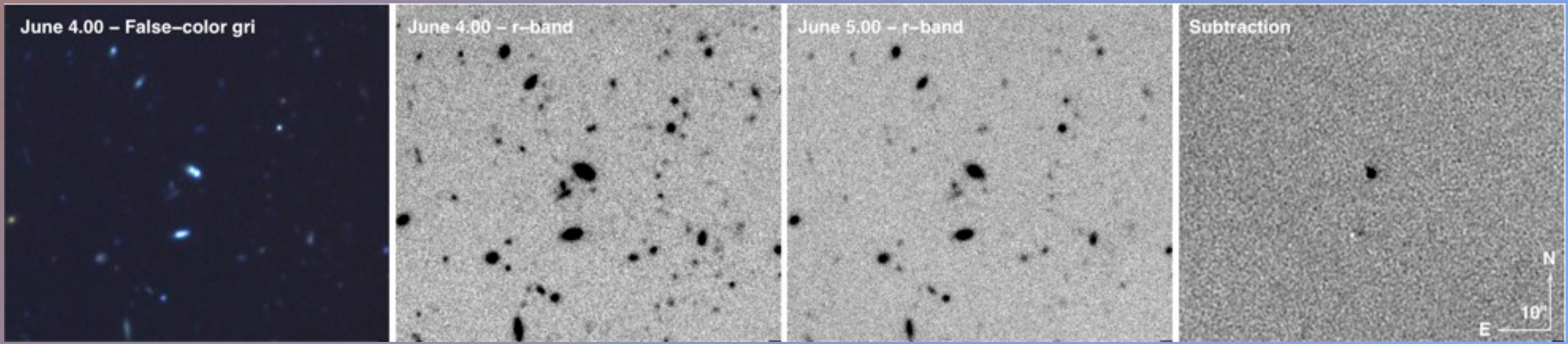
In strict chronological order:

1. GRB Swift discovery - GCN14735, Melandri et al.
2. XRT enhanced position - GCN 14739, Evans et al .
3. BAT refined analysis - GCN 14741, Barthelmy et al
4. **WHT afterglow detection - GCN 14742 Levan et al.**
5. NOT afterglow detection - GCN 14743 de Ugarte et al.
6. **GTC spectrum/redshift (I) - GCN 14744 Thoene et al.**
7. Magellan spectrum/redshift - GCN 14745 Foley et al.
8. GTC spectrum/redshift (I) - GCN 14746 Sanchez-Ramirez et al.
9. **Gemini spectrum/redshift - GCN 14748 Cucchiara et al.**
10. **VLT spectrum/redshift - GCN 14757 Xu et al.**

- Tanvir et al. GCN 14893 - SN limits
- Berger et al. GCN 14895 - Emerging Kilonova?

Properties of the host (Cucchiara et al. 2013)

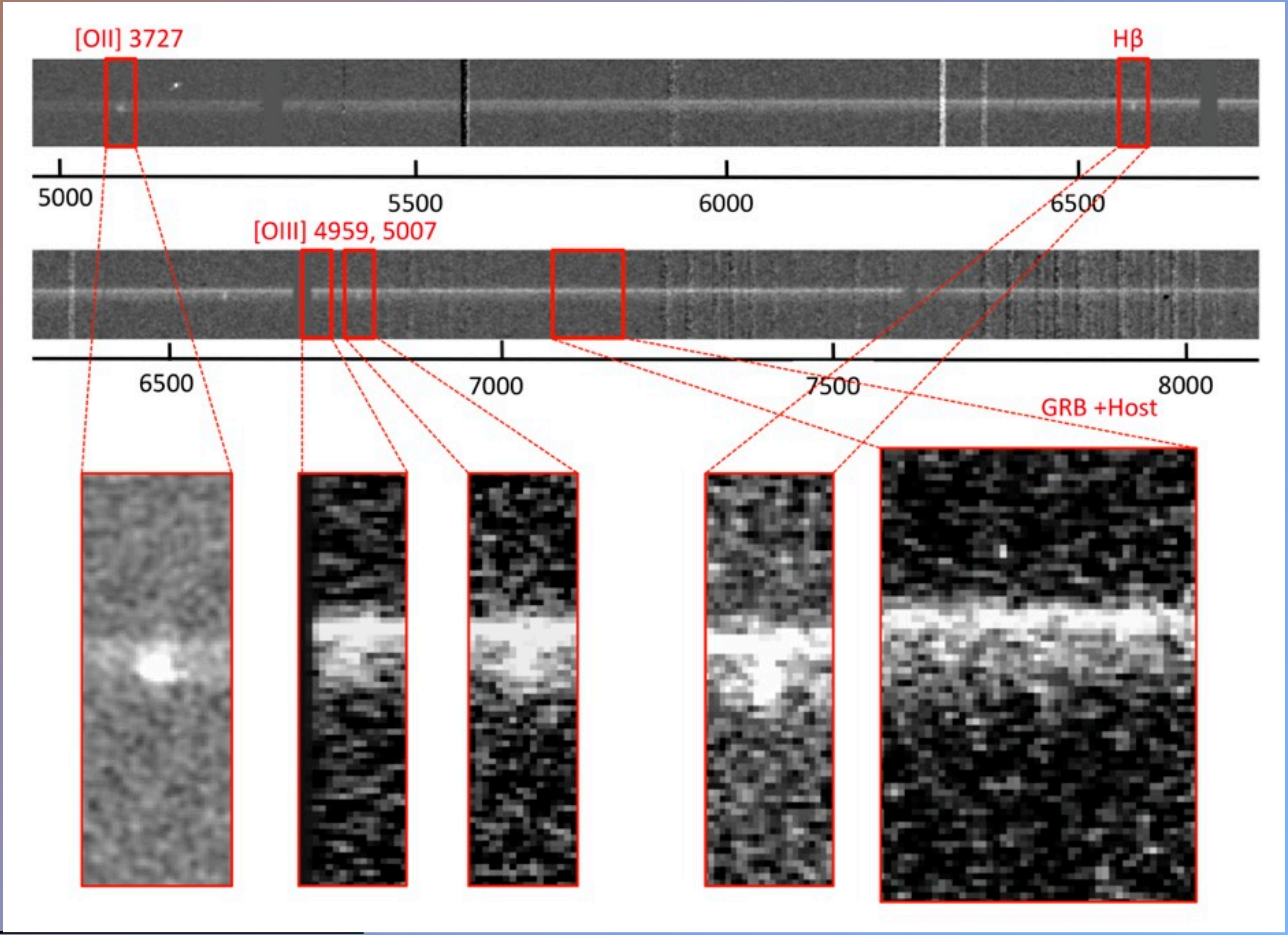
Despite the short nature of GRB13063B the afterglow was detectable several hours after the explosion, allowing follow-up by many different facilities.



We trigger our program on the Gemini South telescope using the GMOS imaging/spectrograph (R~1200 @ 6000 A).

We obtained two spectra nodding along the slit including both the host galaxy and the afterglow. We reduce them separately with the IRAF tools and calibrated the extracted 1D spectra using the standard star Feige110.

Gemini results



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Cucchiara et al. 2013

Gemini results

- We were able to obtain a spectrum of the short GRB (z=0.3568)
- The GRB continuum appears pretty flat, with some exception
- The Host continuum is fainter than the afterglow one and emission lines are identified
- The emission lines are broad BUT do not extend at the GRB location

Host Properties

SFR ~ 1.84 $M_\odot$/yr

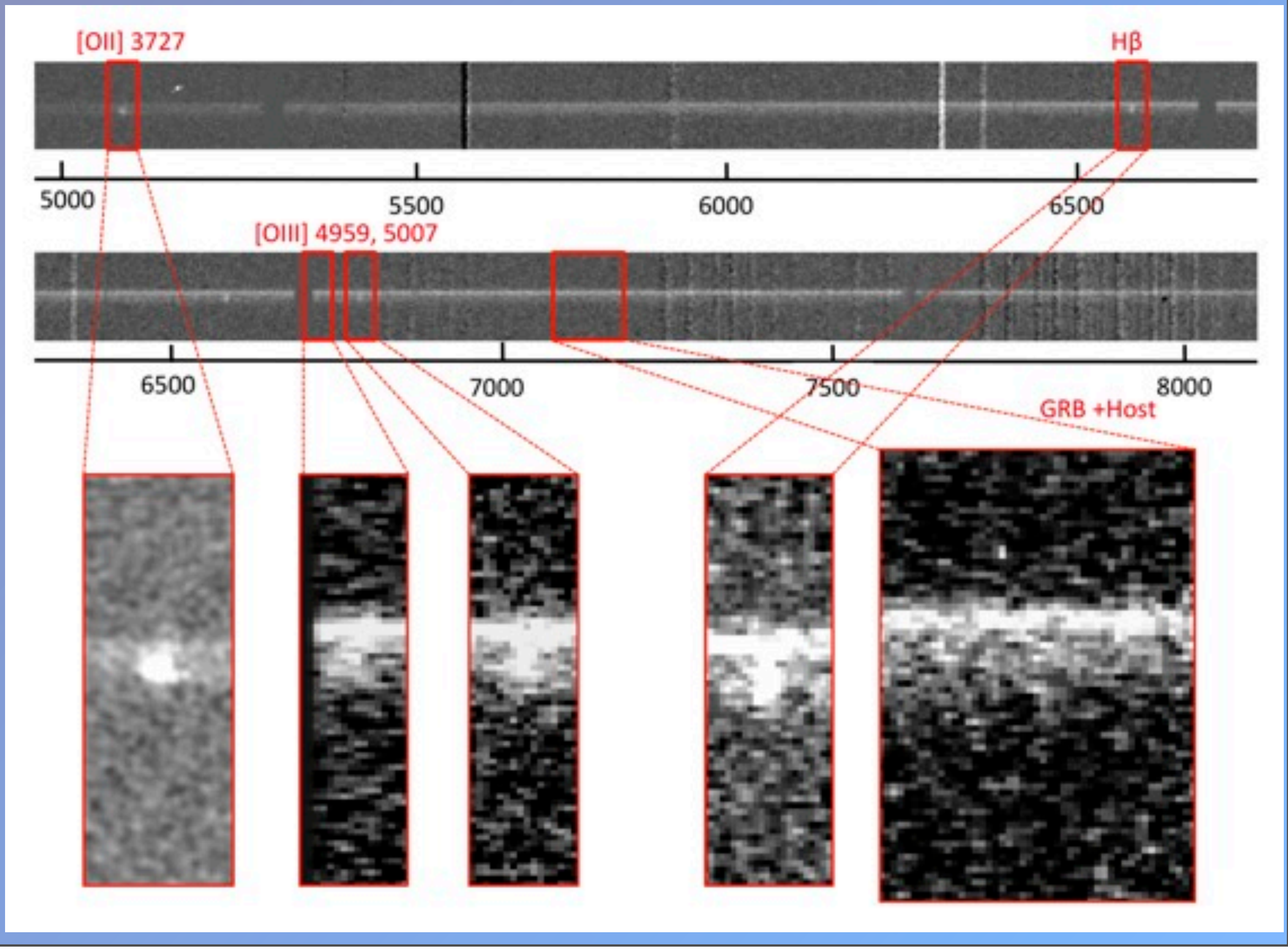
12+log(O/H) ~ 8.4

Mass = $5\times10^9\ M_\odot$

M_B= -20.96 (~L^*)

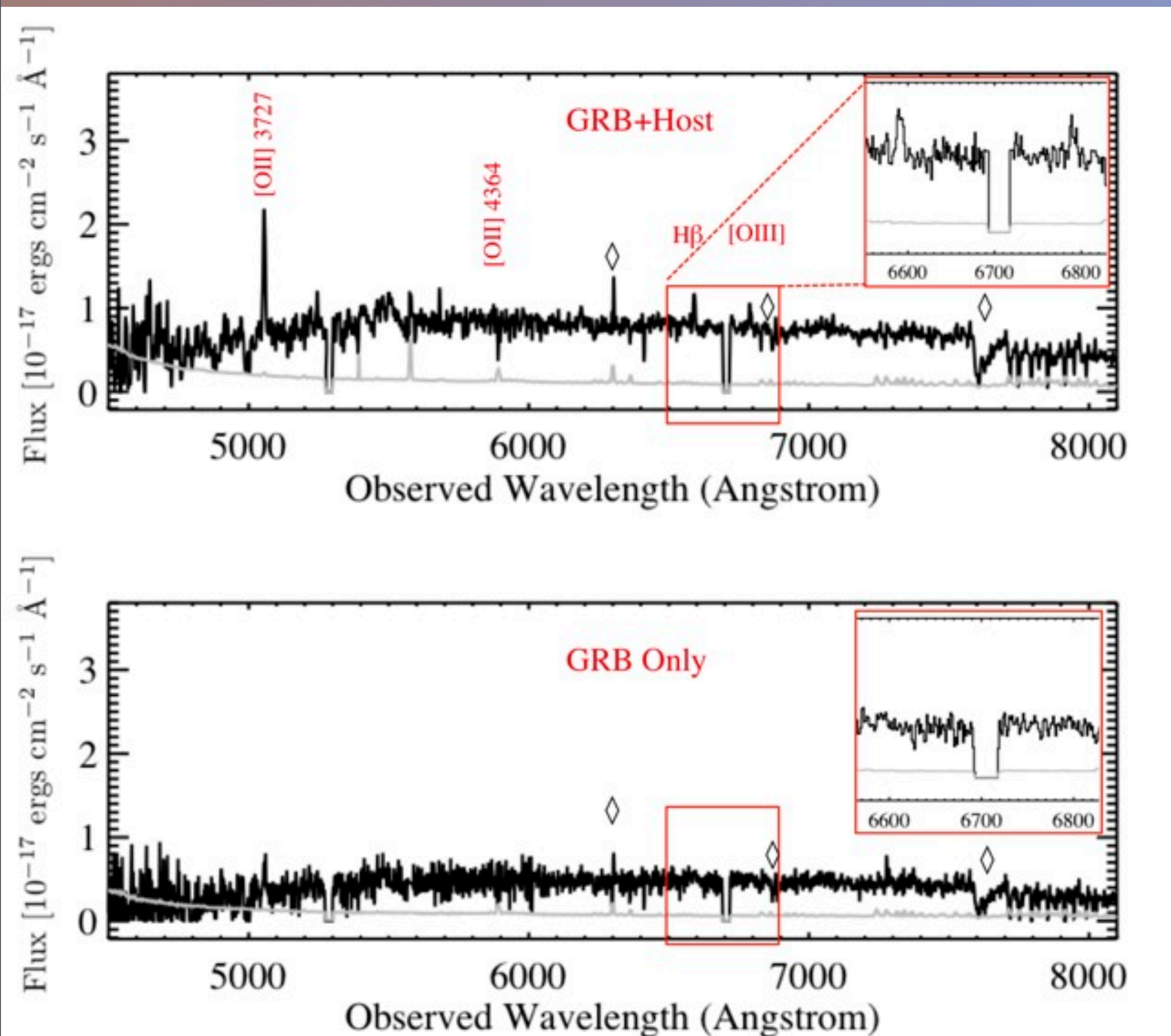
GRB location Properties

SFR < 0.4 $M_\odot$/yr



Results

Emission/Absorption line analysis: we were able to extract the spectrum of the host and the afterglow. This allowed to secure the redshift and determine the properties of the host and the GRB explosion location. We also obtained a spectrum with Keck/Deimos of the host galaxy only at later time.



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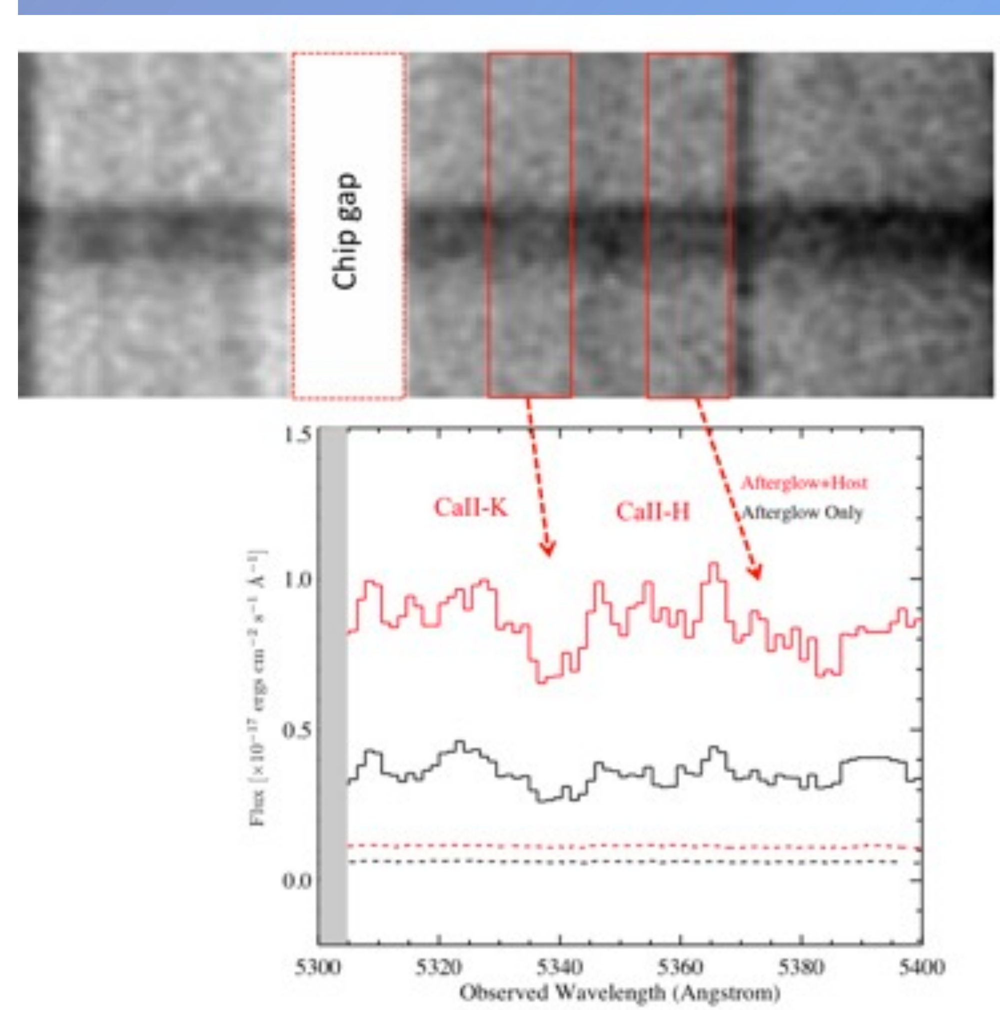


Properties of the host (de Ugarte-Postigo et al. 2013)

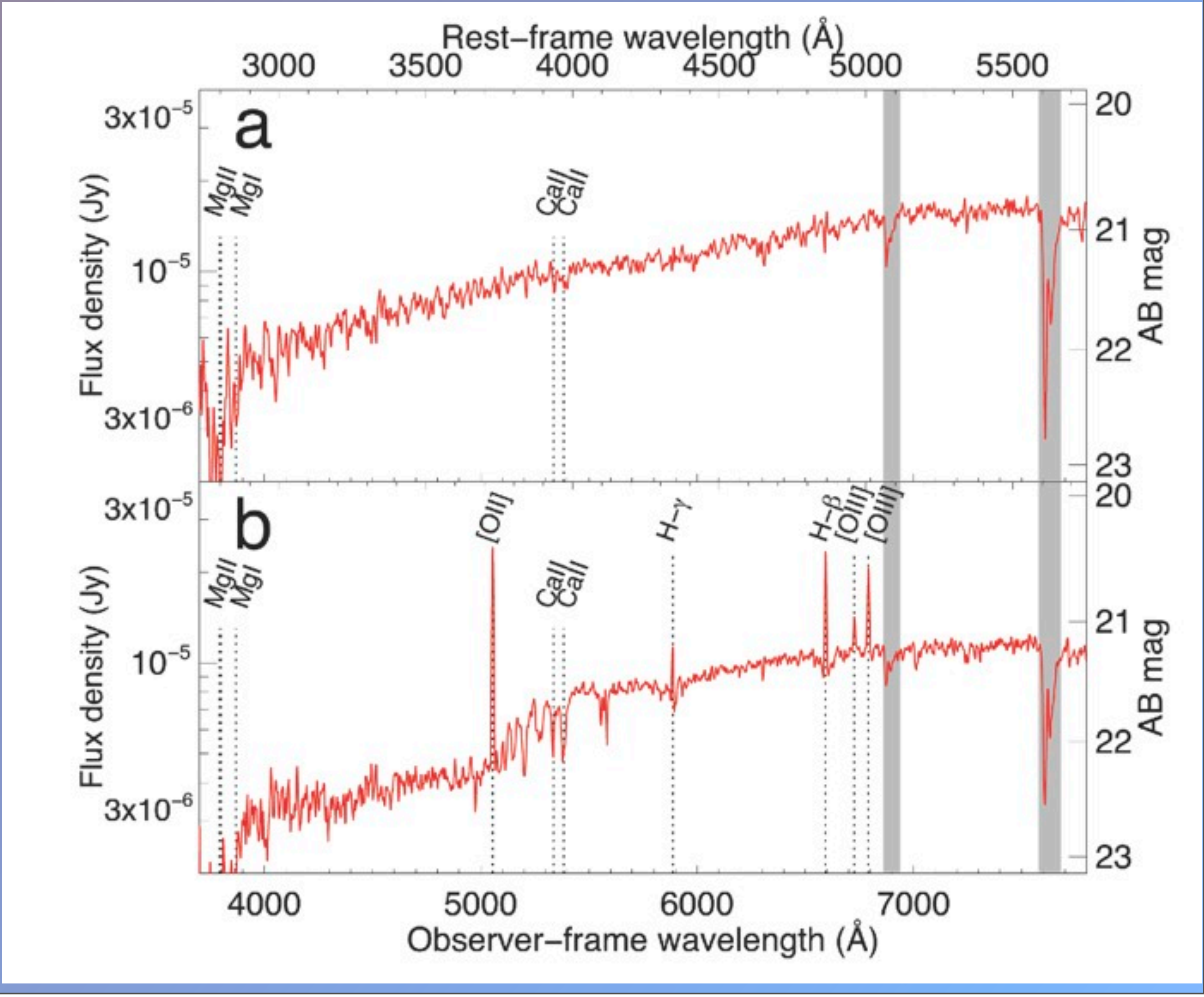
GTC/NOT/X-Shooter/FORS
and more

Host Properties

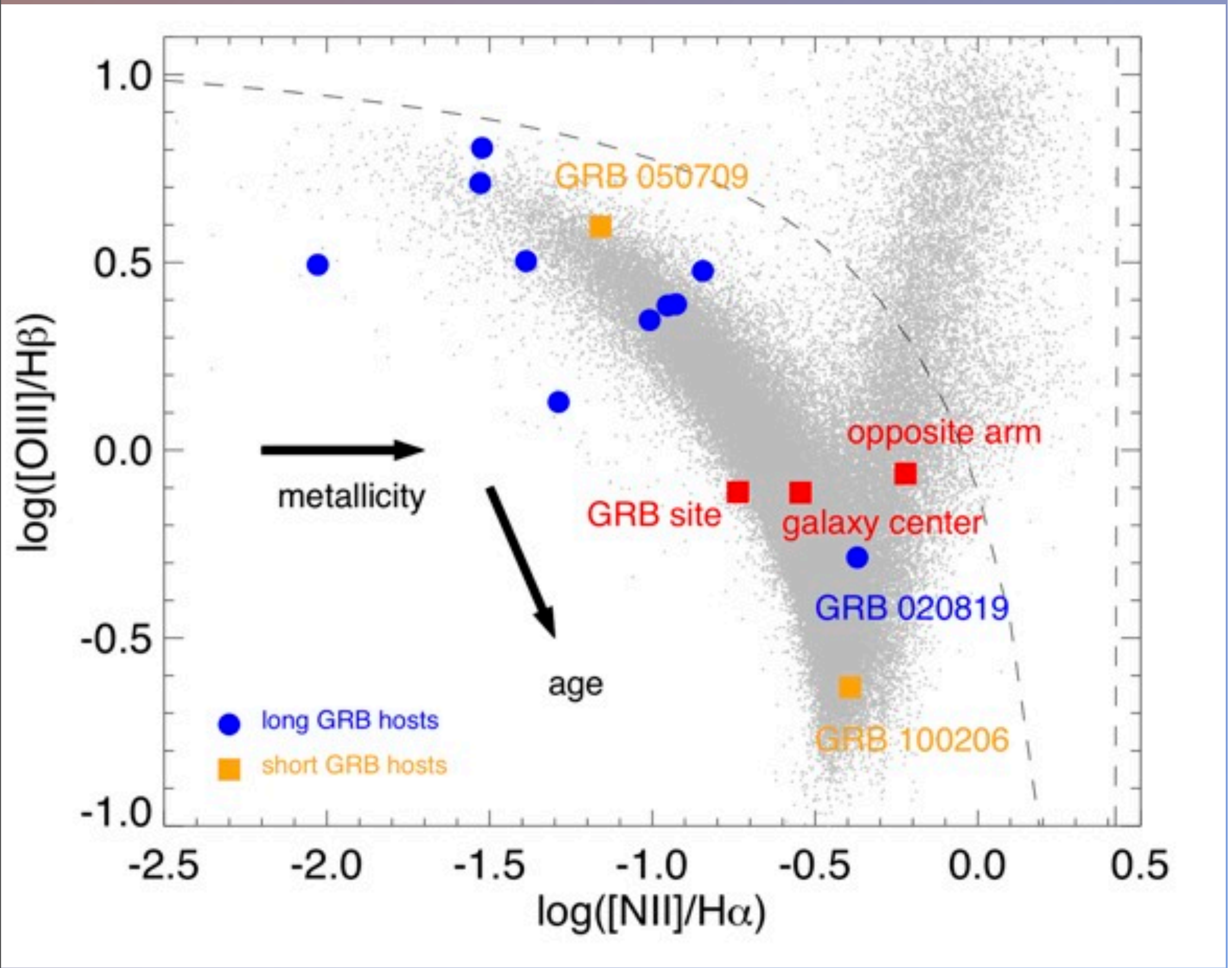
SFR ~ 4.84 M⊙/yr

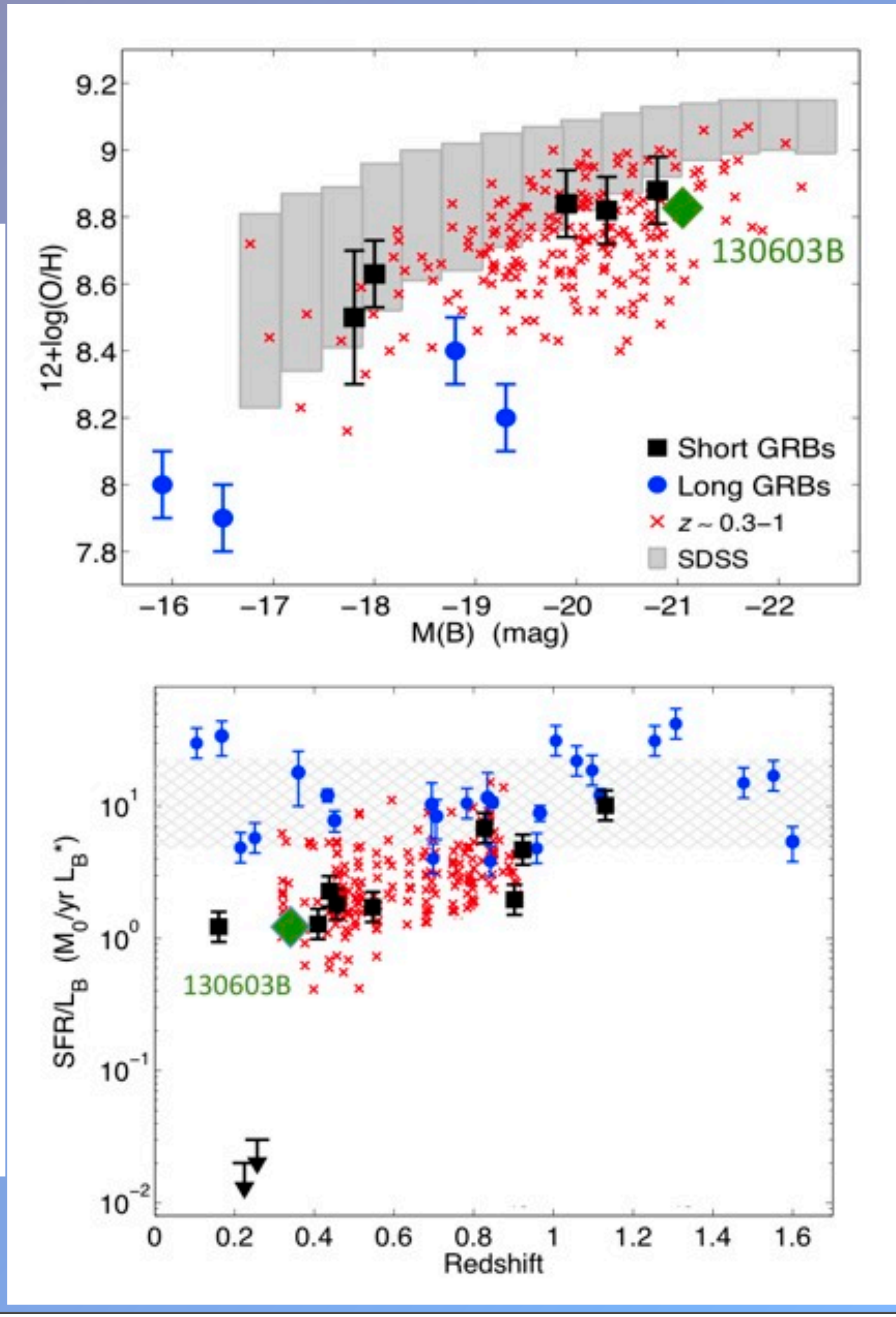
12+log(O/H) ~ 8.6

Mass = 1.7x10^9 M⊙



Properties of host (Cucchiara et al. and de Ugarte-Postigo et al.)





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We have to be careful when we associate SFR to SGRB hosts. What we can say for sure is that the hosthas similar properties than other SGRBs.

Properties of the afterglow (Tanvir et al. 2013)

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I hope to have convinced you that the host
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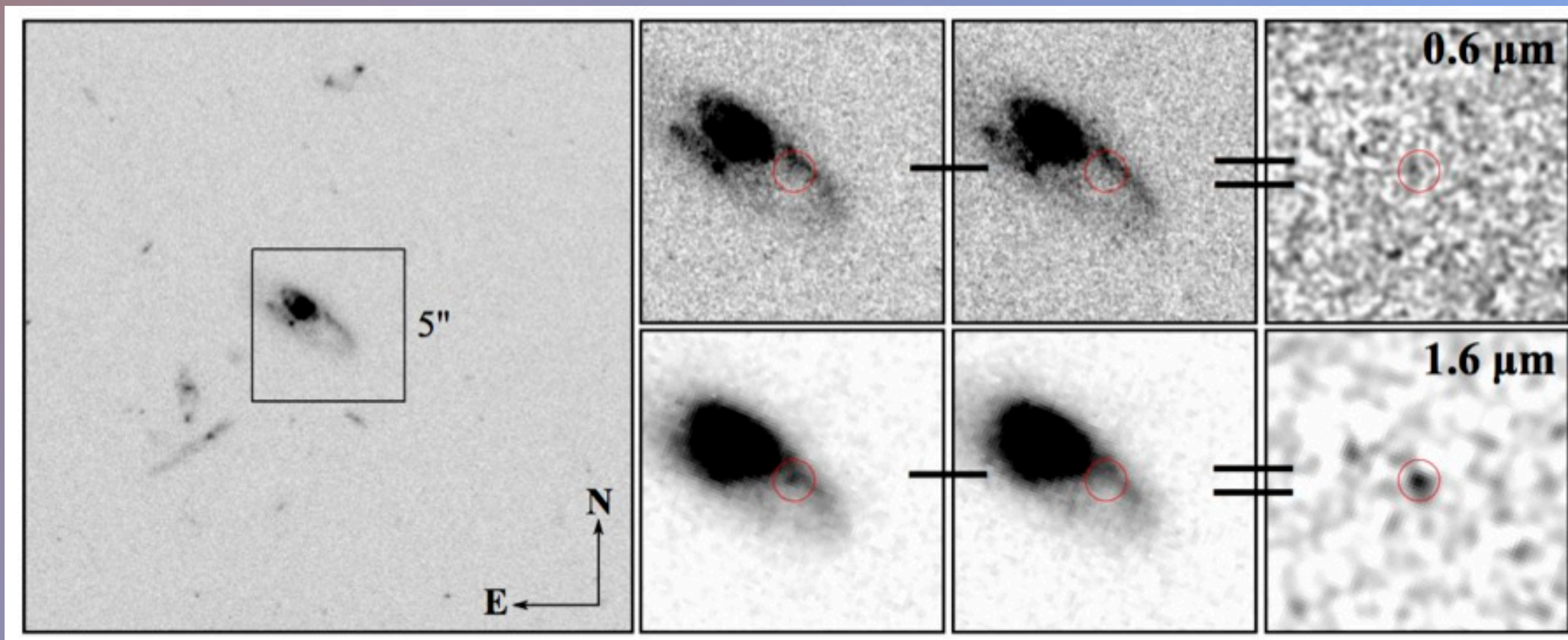
Let's look at more careful at the lightcurve

Several groups (including us) observed the GRB130603B in several bands for few epochs (it was short overall). Tanvir et al. had a HST program to follow up short GRB in search for signature of their progenitors.



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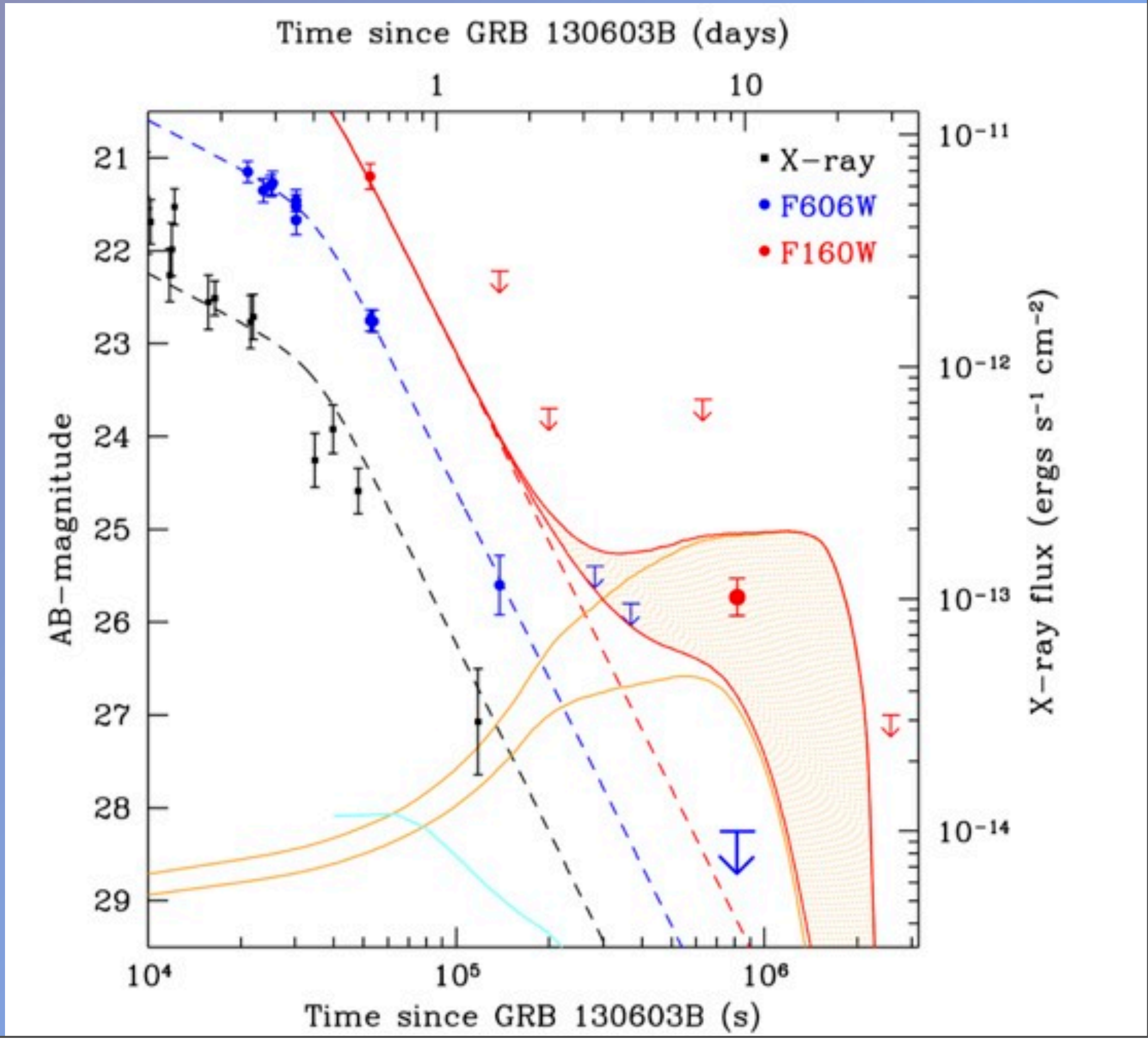
Combining all the available data (propriety and not) Tanvir was able to construct the lightcurve of the afterglow in optical and infrared.

SED is very red
(R-H=2.5)
and not synchrotron



Is GRB 130603B a r-process SN?

If GRB 130603B is indeed produced by the coalescence of a NS-BH binary the opacity in the explosion envelope will suppress the optical emission (very red colors).
This emission will rise on the time scale of ~1 week (as expected).

The models are still in development, work needs to be done to be sure that the opacity is estimated properly.

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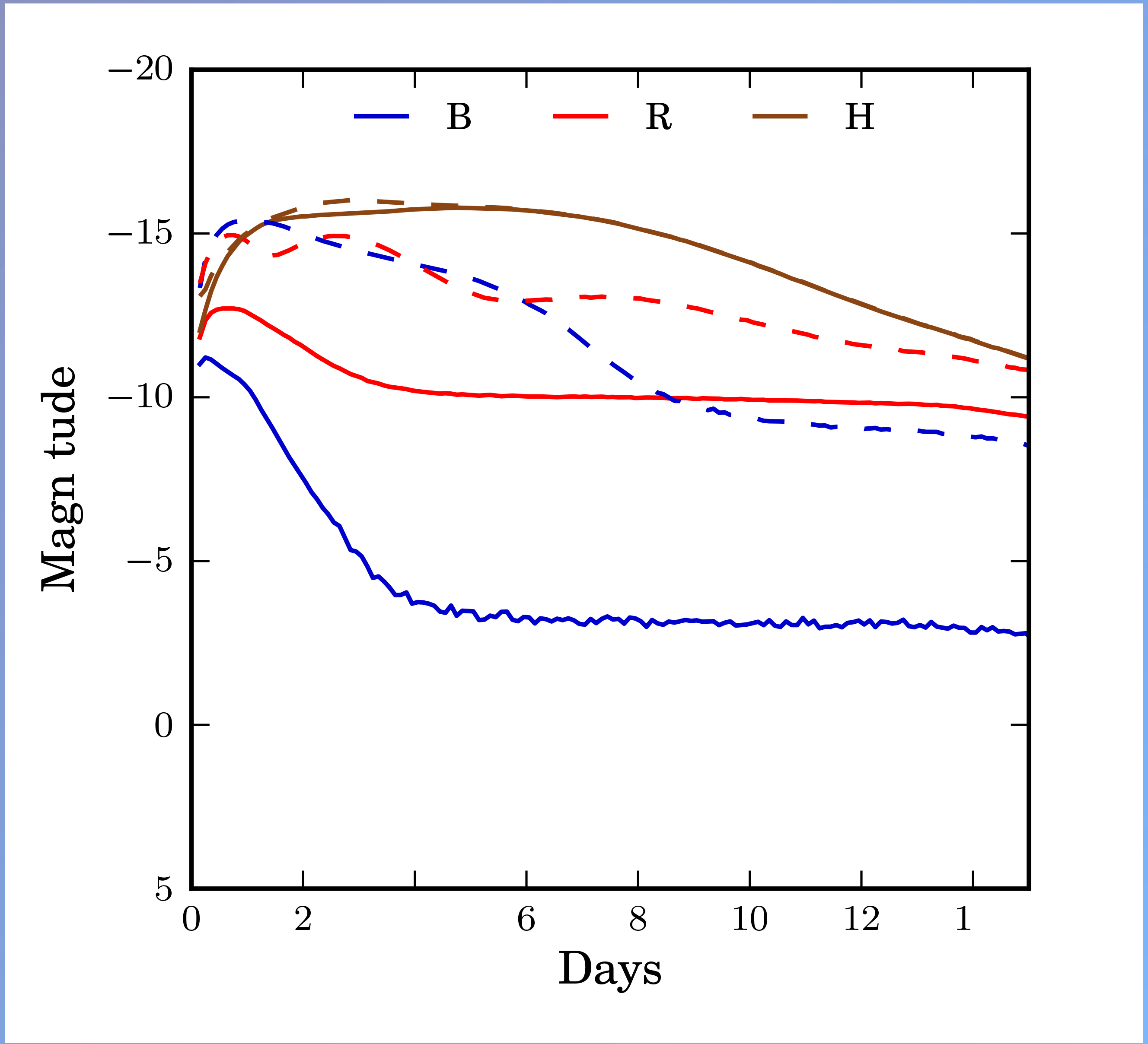
The ejected masses are within 0.01 and 0.1 $M_\odot$



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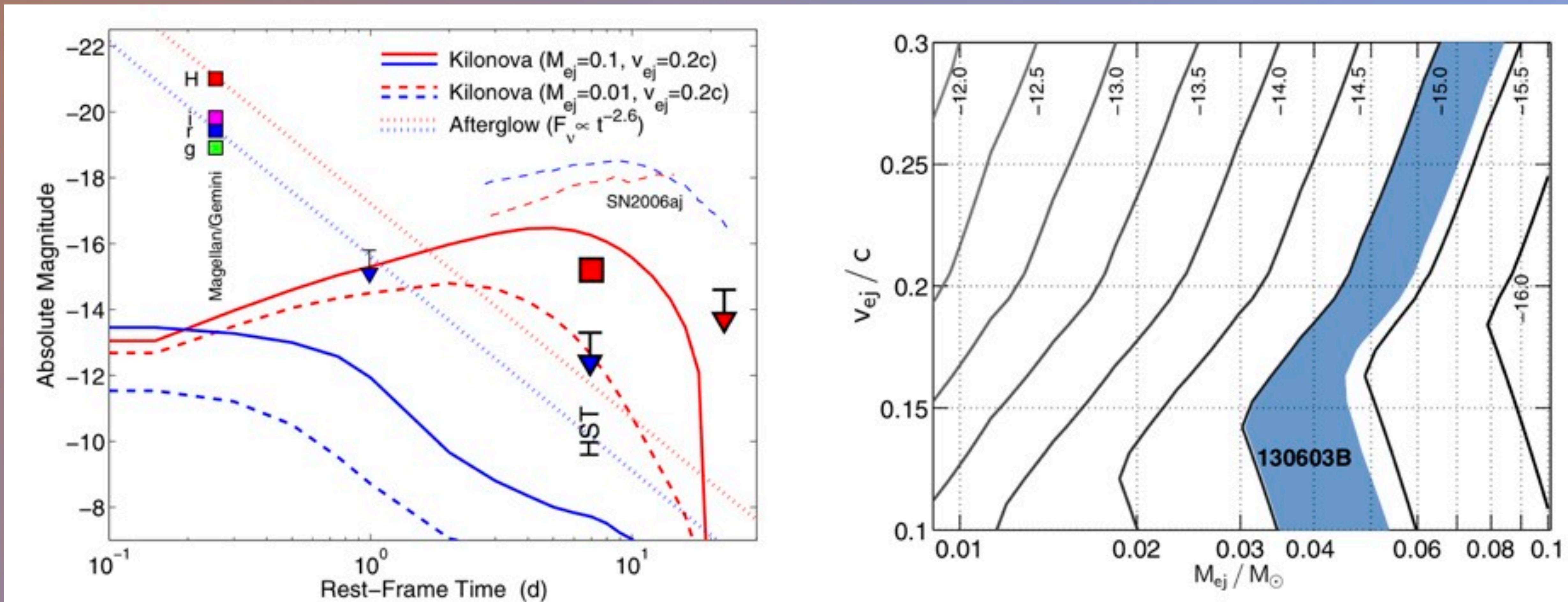

Berger et al. 2013

Summary and Conclusions

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- Short-GRBs are still important (probably more than before)
- We were able for the first time to obain a spectrum of a SGRB afterglow
- GRB 130603B occurred in a region of negligible star-formation
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Future SGRB follow-up campaigns and GW detectors will bring new light to this still not fully understood phenomena

Smoking Gun or Smoldering Embers? A Possible r-process Kilonova Associated with the Short-Hard GRB 130603B

E. Berger, W. Fong, R. Chornock (Harvard)

(Submitted on 17 Jun 2013 (this version), latest version 3 Aug 2013 (v2))

Hubble Space Telescope

GO/DD 13497

Wed Sep 25 11:30:50 EDT 2013

Principal Investigator: Nial Tanvir
PI Institution: University of Leicester
Investigators (xml)

Title: A smoking gun for a neutron star merger in a short GRB?
Cycle: 20

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Why are short GRBs important?

In order to produce such short living emission, the energy observed and the afterglow behavior the collapsar model does not work. The merging of two compact objects (NS, WD and BH) has been proposed since the mid-80s*.

The idea is that during the coalescence an accretion disk is formed and its dissipation onto the newly formed blackhole produces a jet (see Pozanenko's talk).
Simulation has been carried out and produced some predictions about the timescale of the merger, the energy released and the ejection velocity of the blastwave (Rosswog 2005, Metzger 2010).

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