



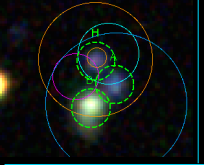
Keck Observations of 150 GRB Host Galaxies

Daniel Perley

Caltech / UC Berkeley

**+Joshua Bloom,
Brad Cenko,
Jason Prochaska,
Shri Kulkarni,
and many others...**

Legend:
● Optical position
● Ultraviolet position
● X-ray position
● Labeled object
N
E
unless indicated

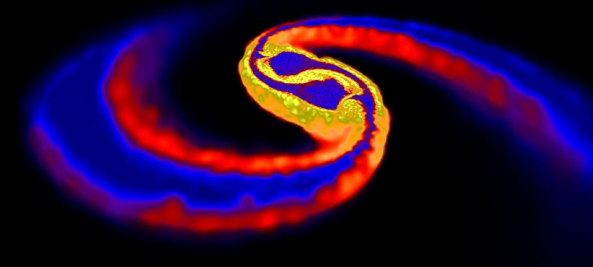
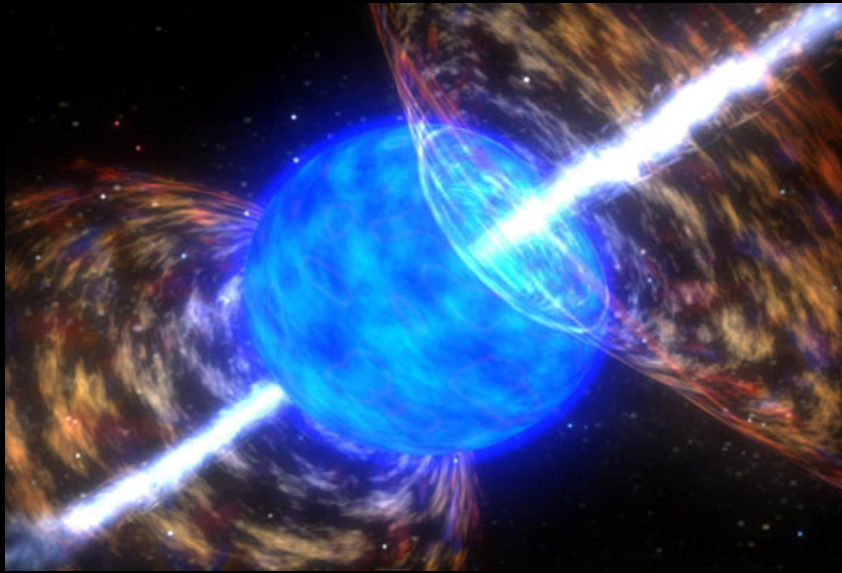
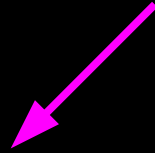


Motivation

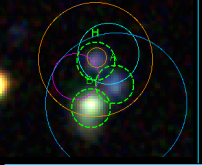
Why care about GRB host galaxies?

Motivation

Why care about **GRB** host galaxies?

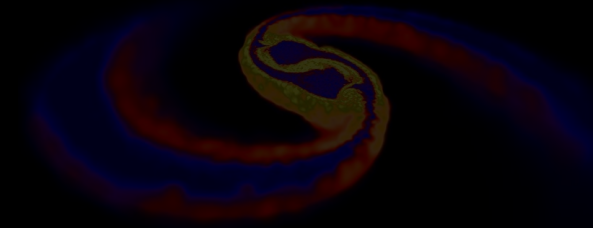
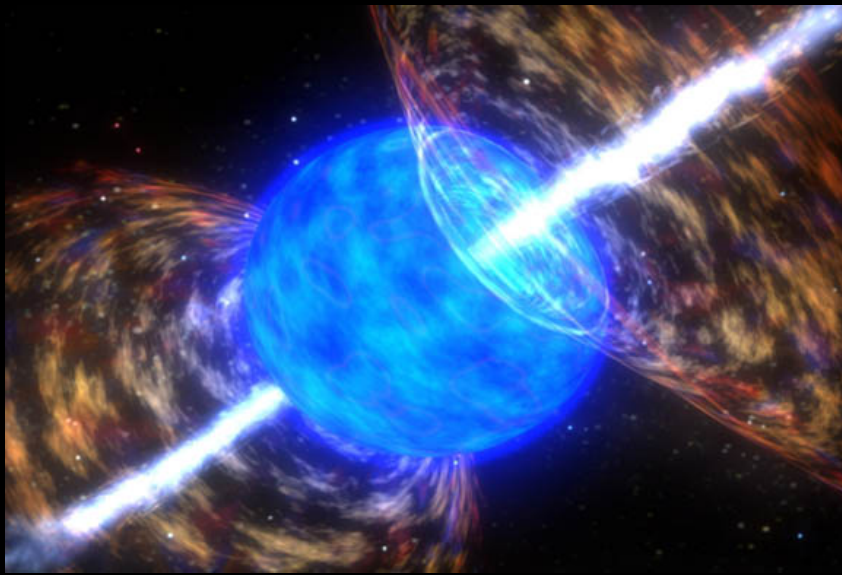
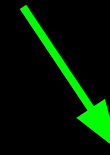
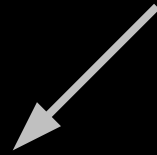


+ ???



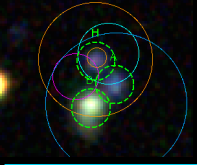
Motivation

Why care about GRB host **galaxies**?



+ ???





Motivation

Why 150 GRB host galaxies?

Useful statistics on “normal” hosts

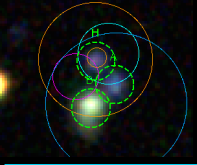
- Redshift distribution

Many GRB subclasses:

- Short GRBs
- Soft GRBs (XRFs)
- Dark GRBs
- GRB/SN connection

not in this talk:

- DLAs
- Intervening absorbers
- Fermi-LAT / high-Eiso GRBs
- Misc. GRBs of community interest



Sample Properties

147 unique targets

135 with optical imaging

(LRIS, g + R or I)

80 host detections

26 w/ known redshift

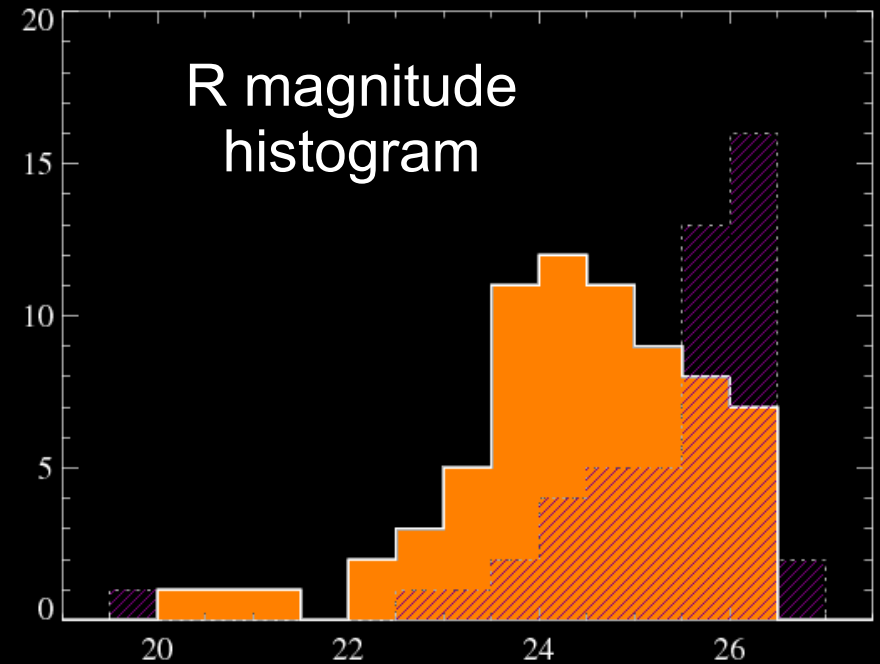
46 with spectroscopy

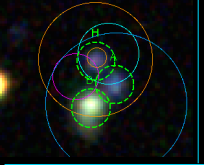
(LRIS, 3500 to 9000 or 10000 Å)

21 successful/probable host redshifts

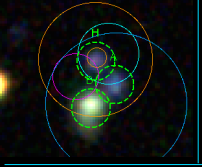
(no lines apparent for other 25)

14 redshifts discovered by these observations





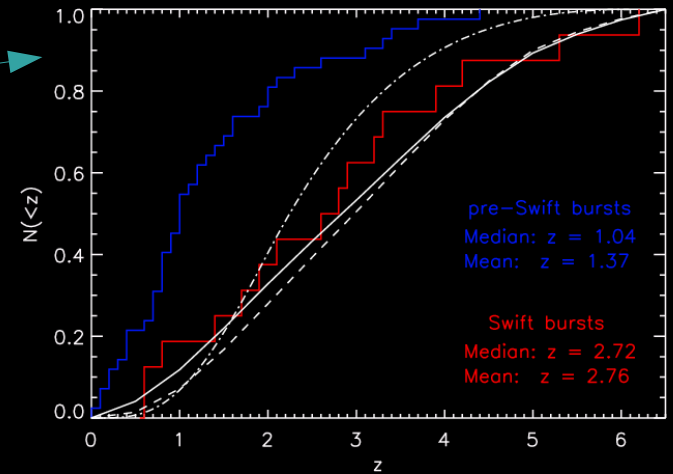
The Swift Redshift Distribution



Swift-era Redshifts

< 20% of Swift GRBs have afterglow redshifts
(< 5% have host redshifts)

Observed distribution (e.g. [Jakobsson+ 2005](#)) is based on optically bright bursts, subject to follow-up biases – is this representative?



P60: unbiased afterglow sample



Various: afterglow redshifts



Keck: host redshifts

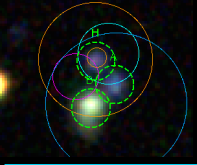


+

+

=

...

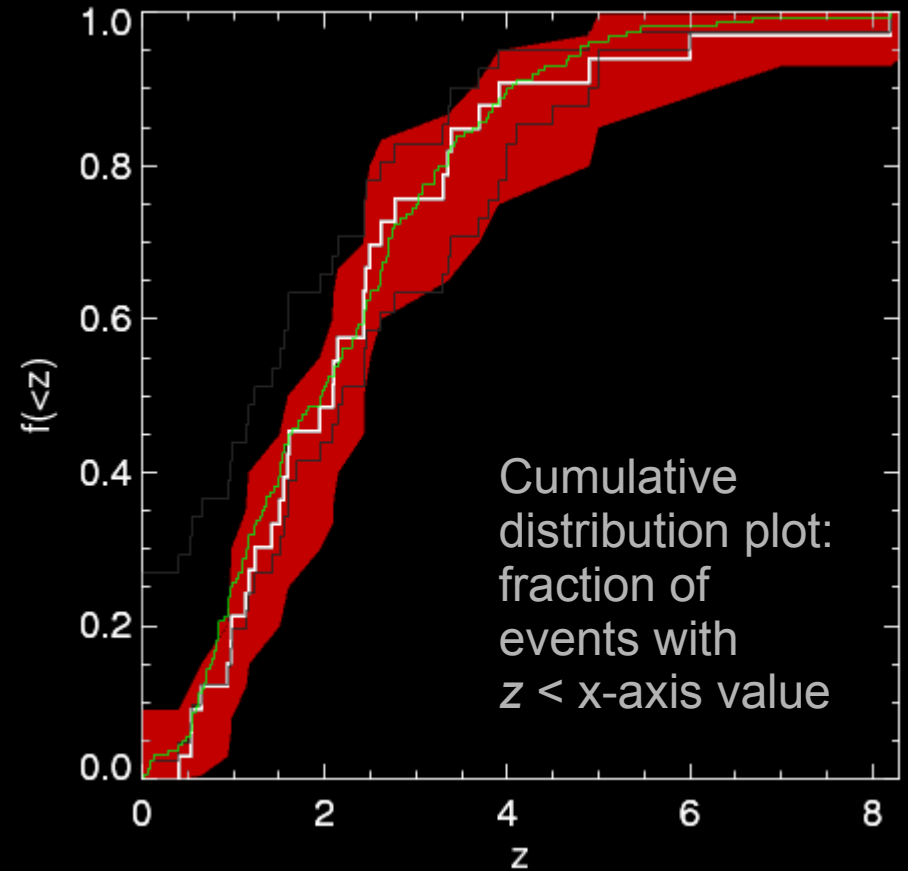


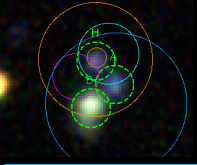
Swift Redshift Distribution

050412	<4.5
050416A	0.65
050607	<4
050820A	2.61
050908	3.35
050915A	0.44
060210	3.91
060502A	1.51
060510B	4.9
060805A	<4
060906	3.69
060908	2.43
060923A	<4
061222A	2.09
070208	1.17
070419A	0.97
070521	1.35
071003	1.60
071010A	0.98
071020	2.15
071122	1.14

080310	2.43
080319A	<3
080319B	0.94
080319C	1.95
080320	~5
080604	1.42
080607	3.30
080707	1.23
081007	0.53
081222	2.77
081228	<3.5
090102	1.55
090313	3.38
090418A	1.61
090423	8.2
090530	<1.7
090618	0.54
090709A	<4
090812	2.45
090813	<5

>80% redshift complete
(100% complete with upper limits)



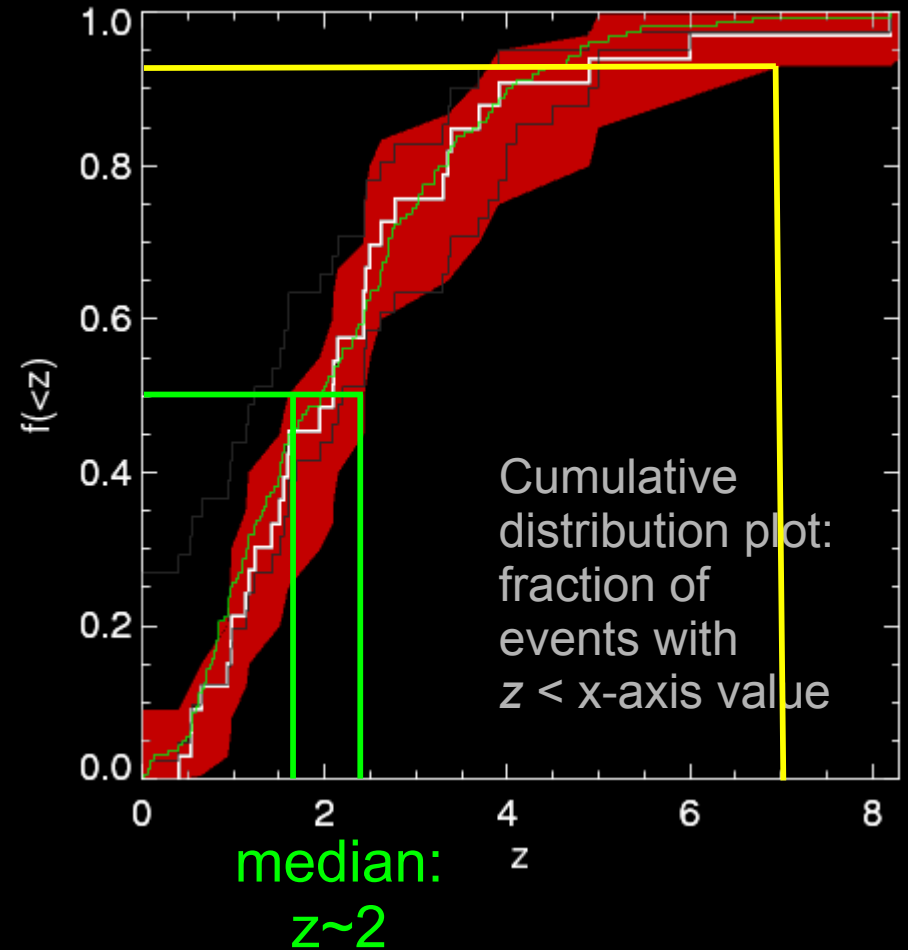


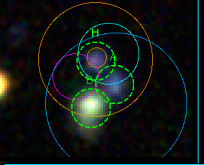
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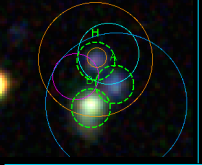
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high-z rate:
0.2–7%

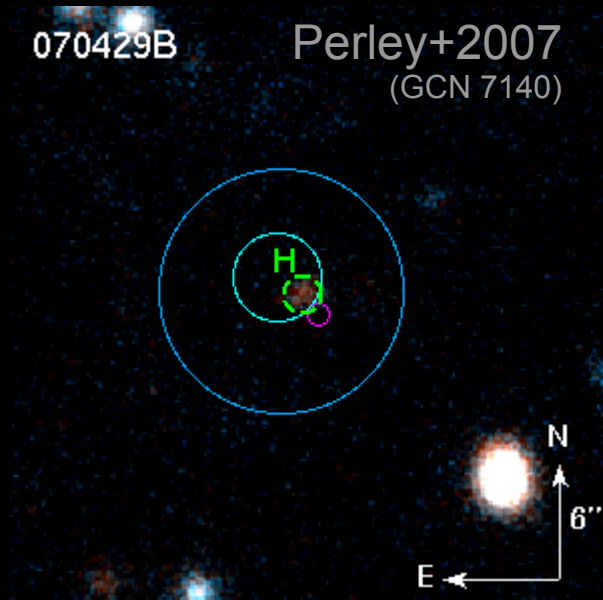
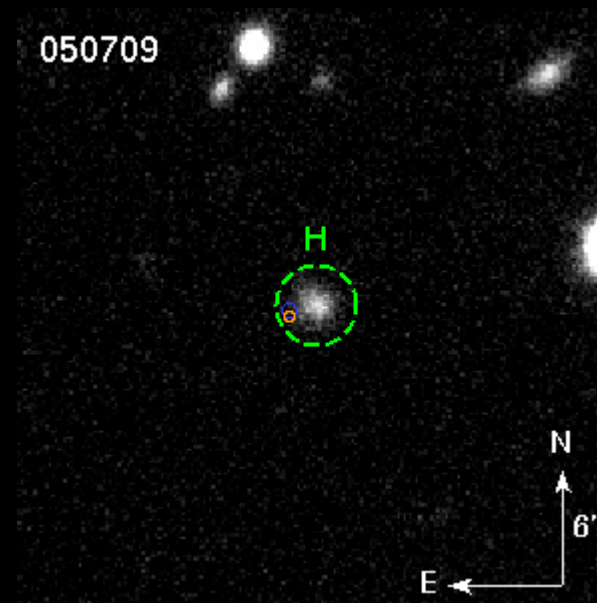
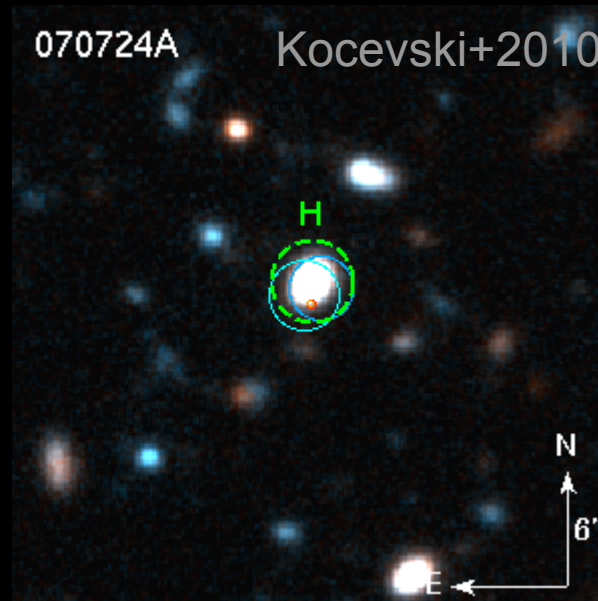
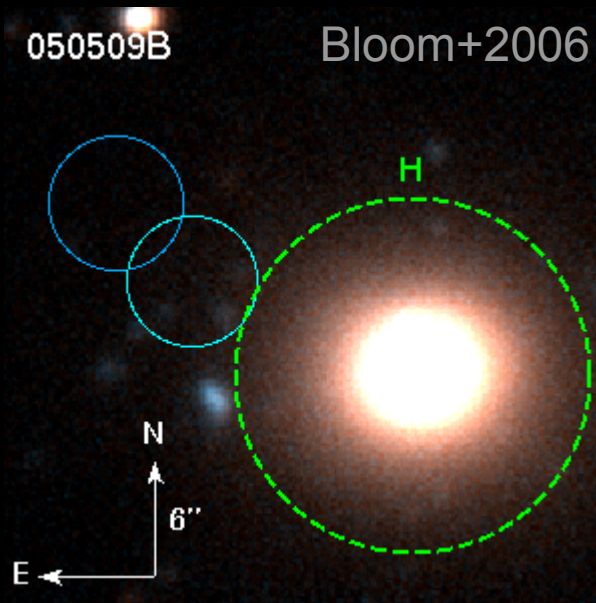




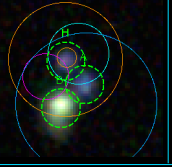
Short GRBs



Short GRBs

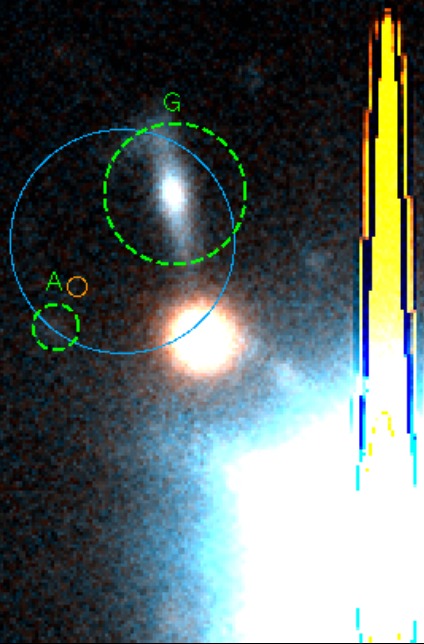


Very few hosts (**two**, both in 2005) actually look like this!

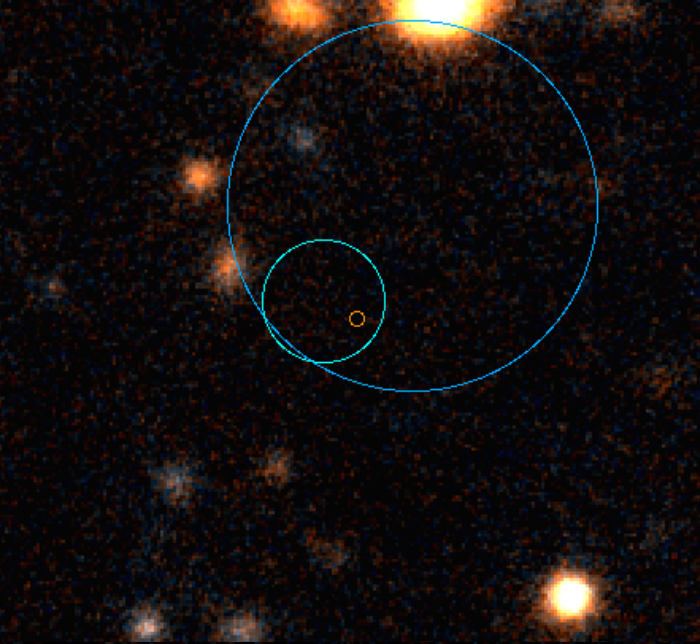


Hostless Systems?

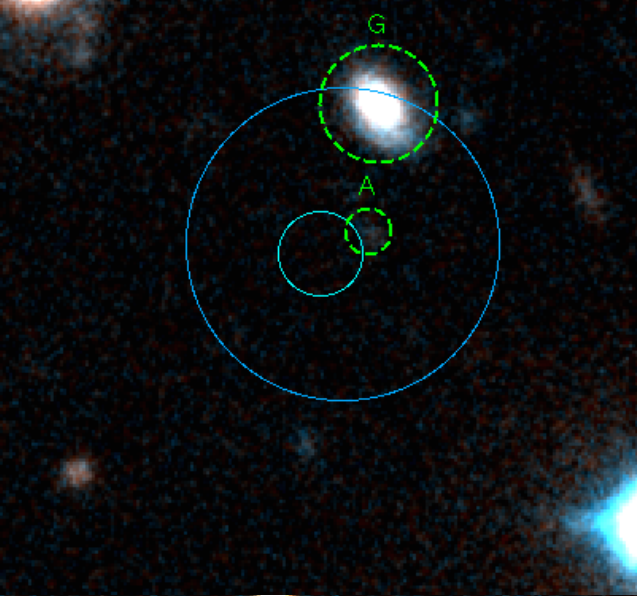
070809 Fruchter in prep.



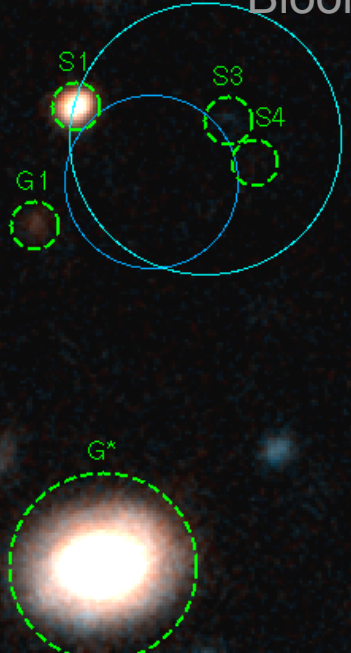
090515



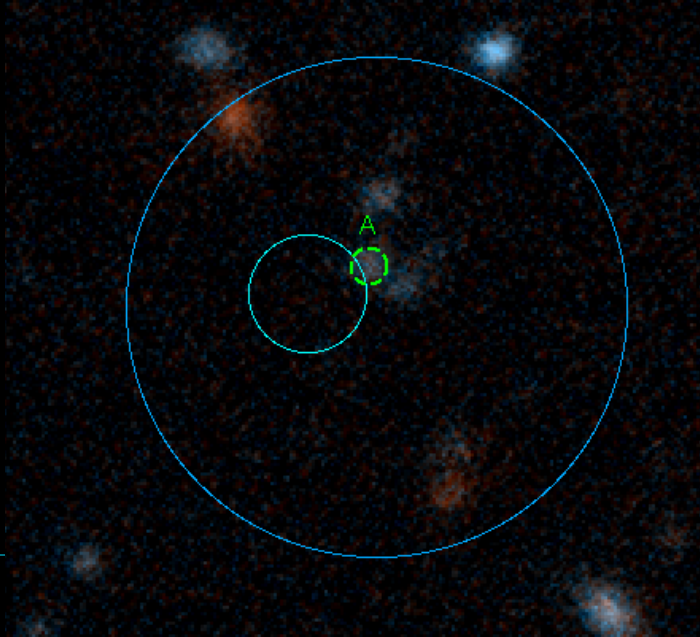
081211B Perley+2007 (GCN 8914)



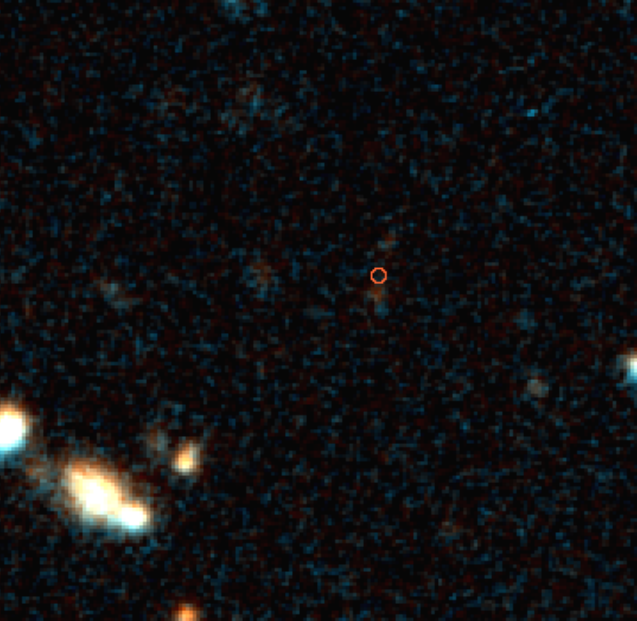
060502B Bloom+2007

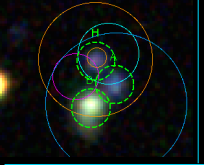


070729

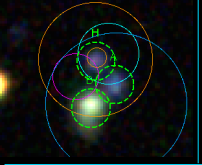


080503 Perley+2009



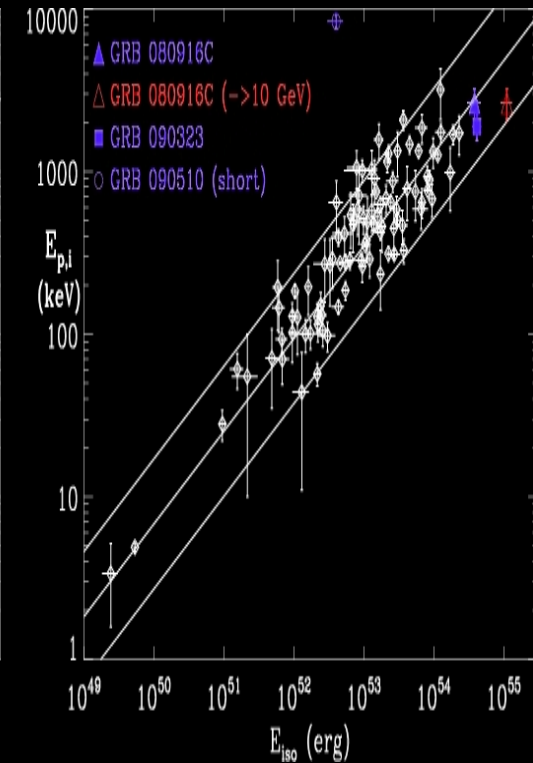
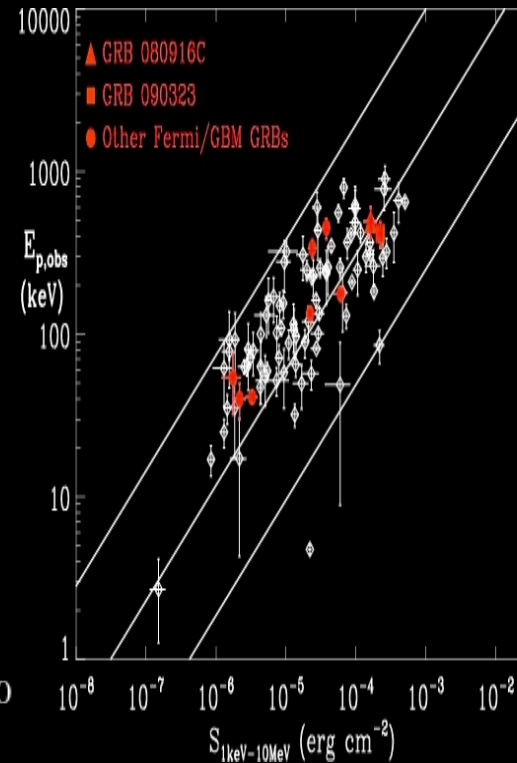
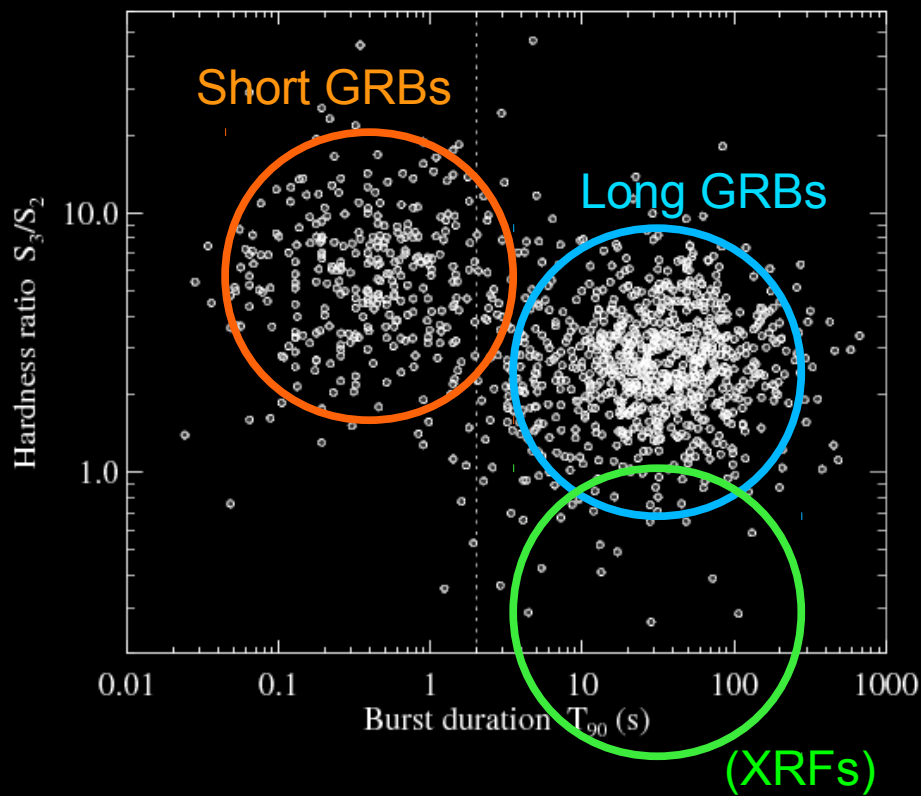


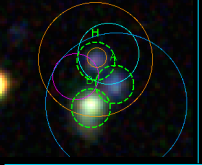
XRFs



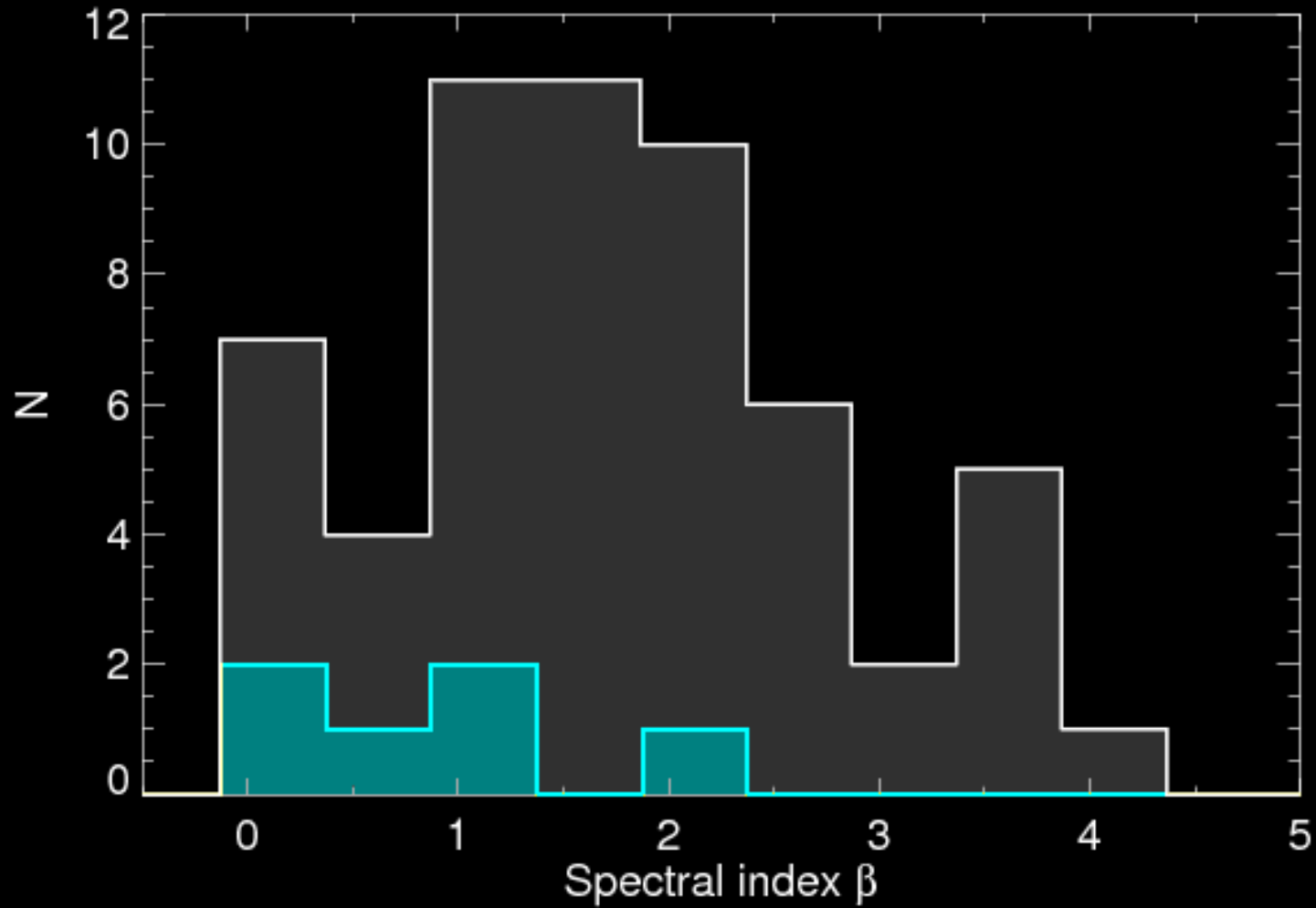
X-Ray Flashes

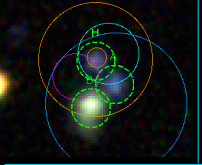
Soft long-duration GRBs: $E_{\text{peak}} < 30 \text{ keV}$





XRF Colors



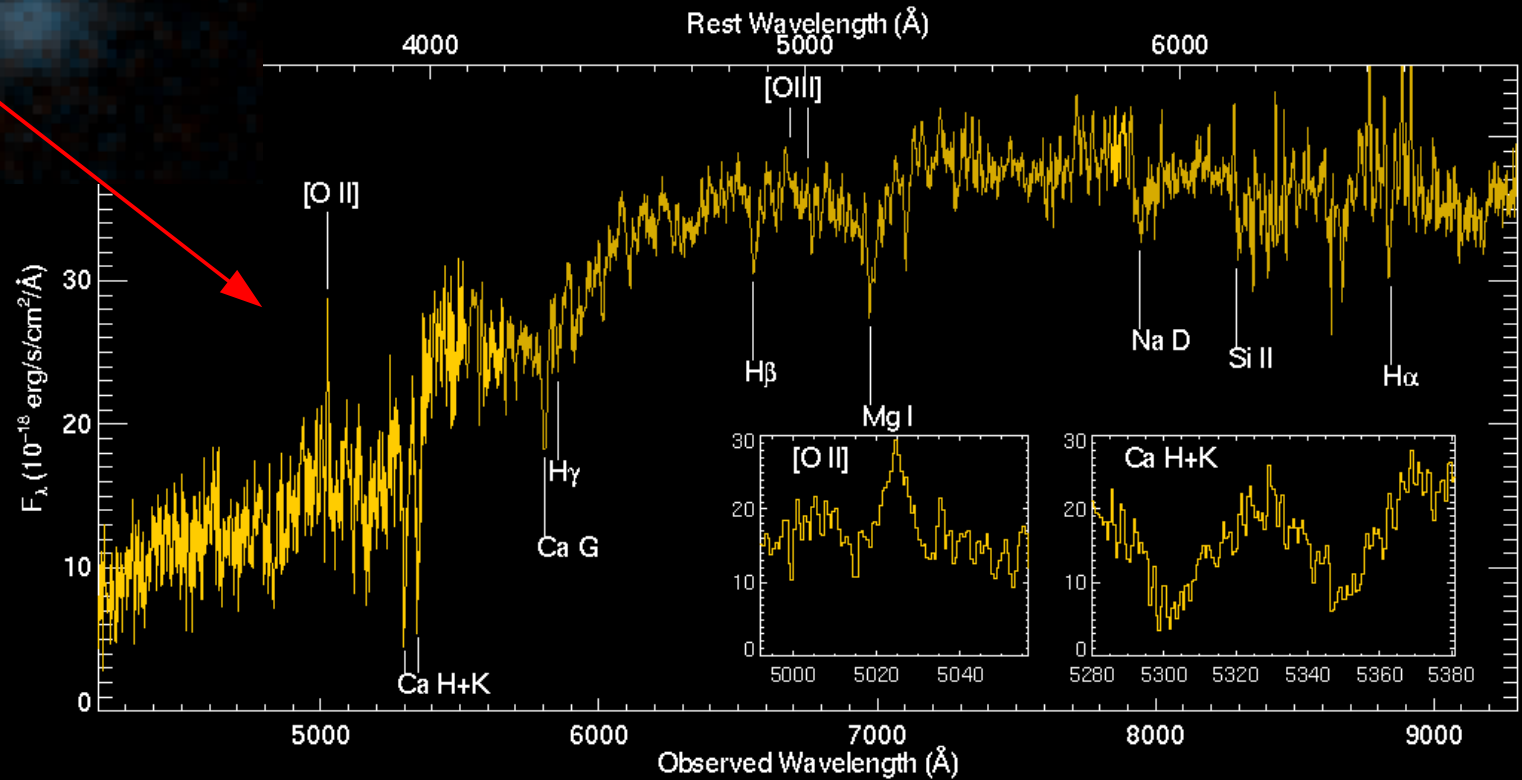
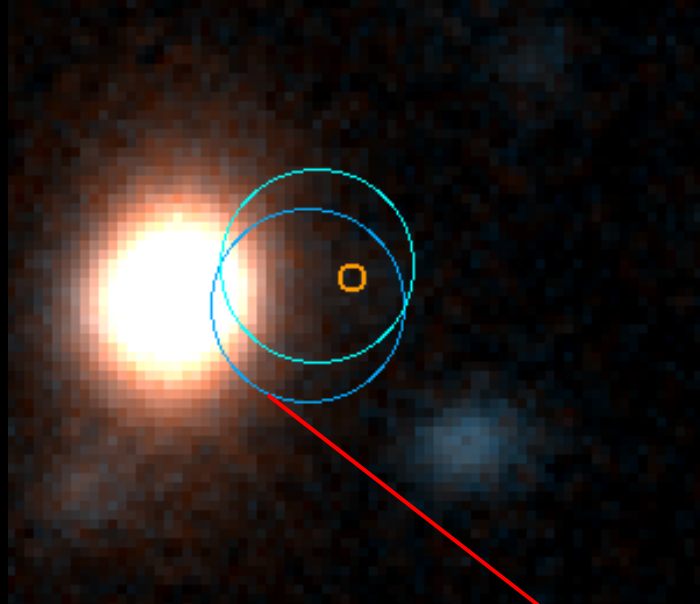


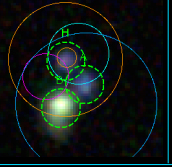
XRF 060428B

Perley+2007

060428B

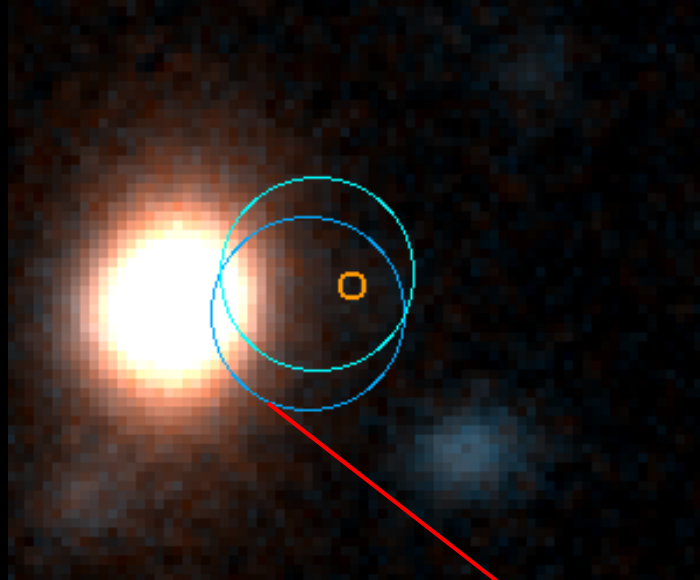
Outskirts of an early-type host with minimal star formation?





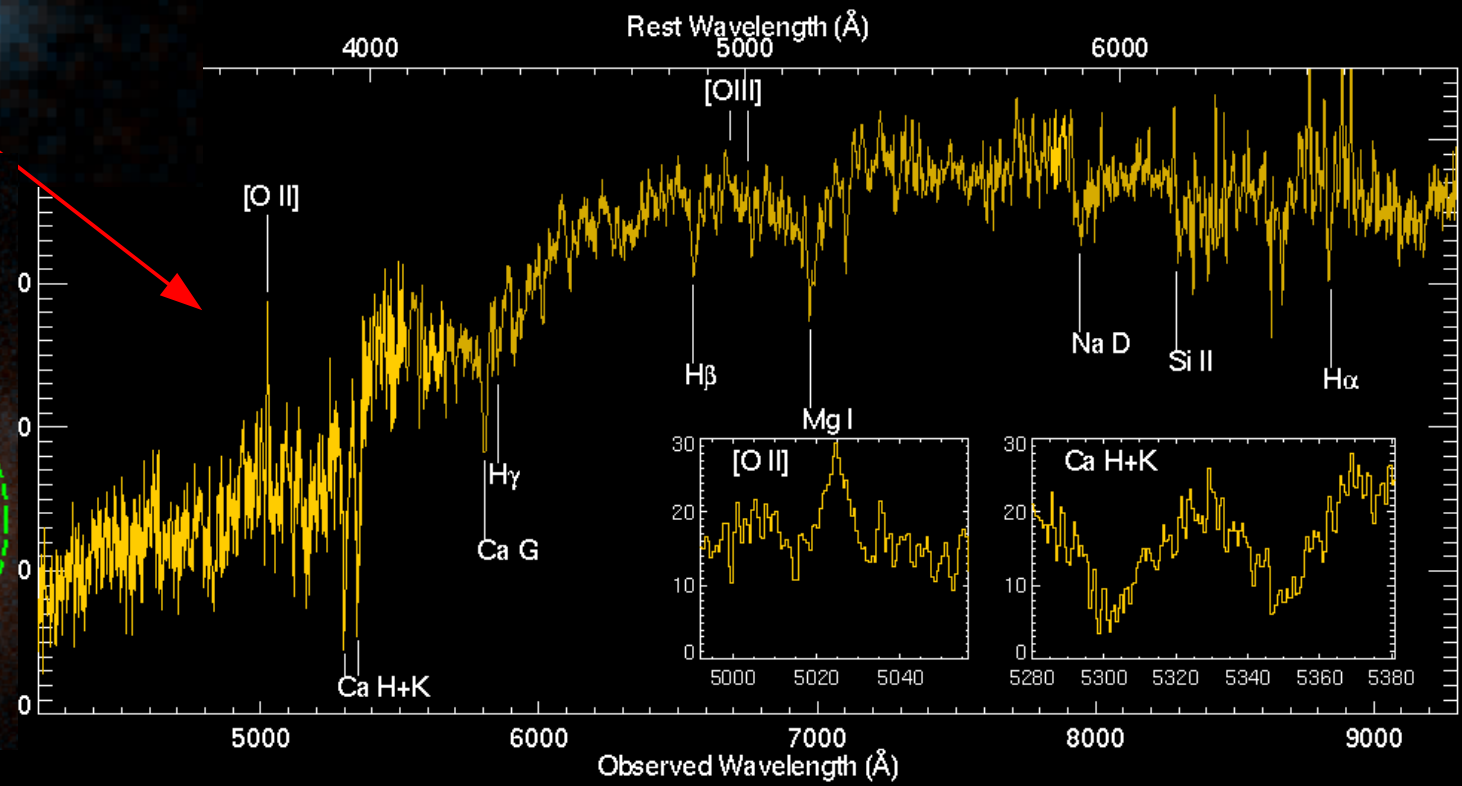
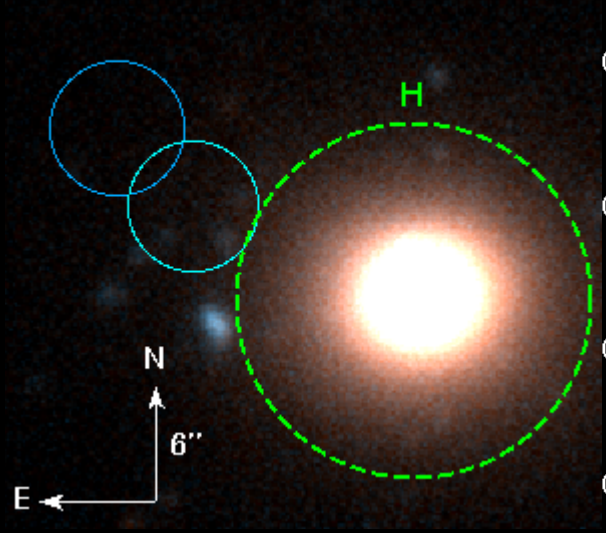
XRF 060428B

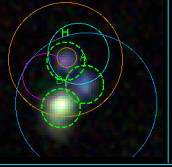
060428B



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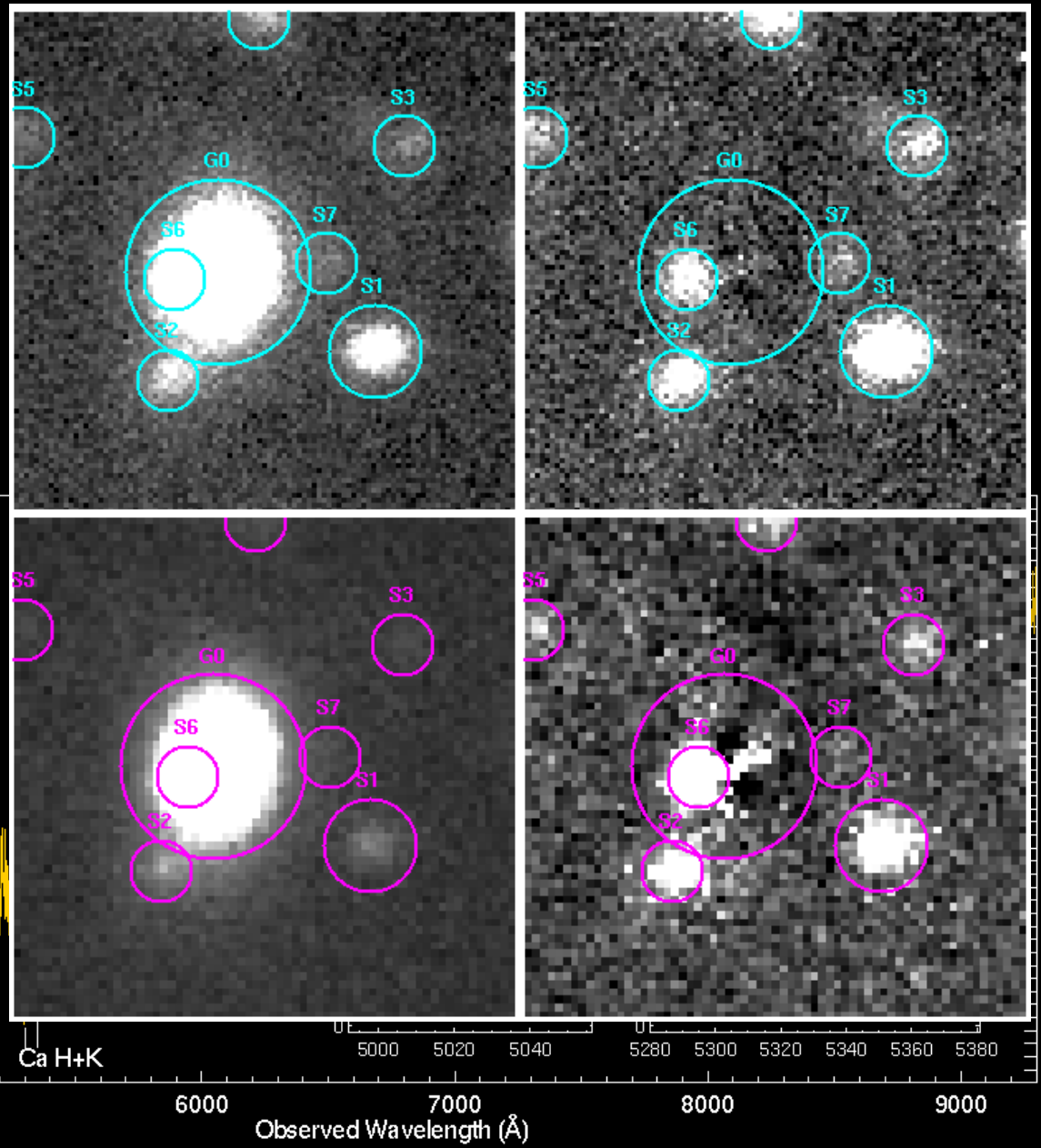
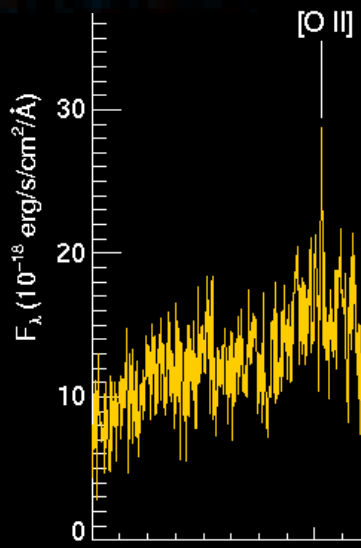
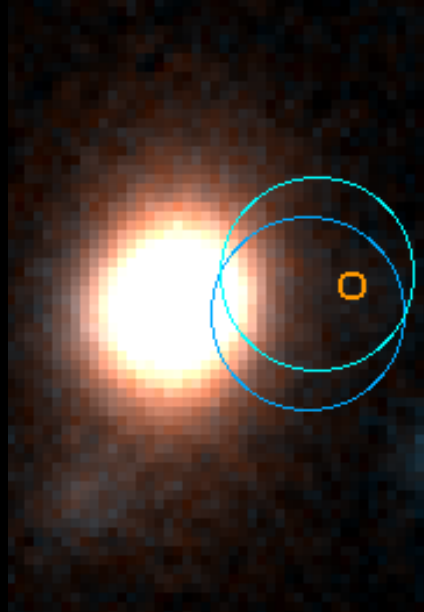
050509B

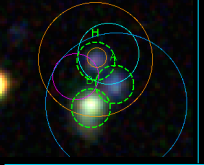




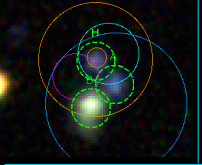
XRF 060428B

060428B

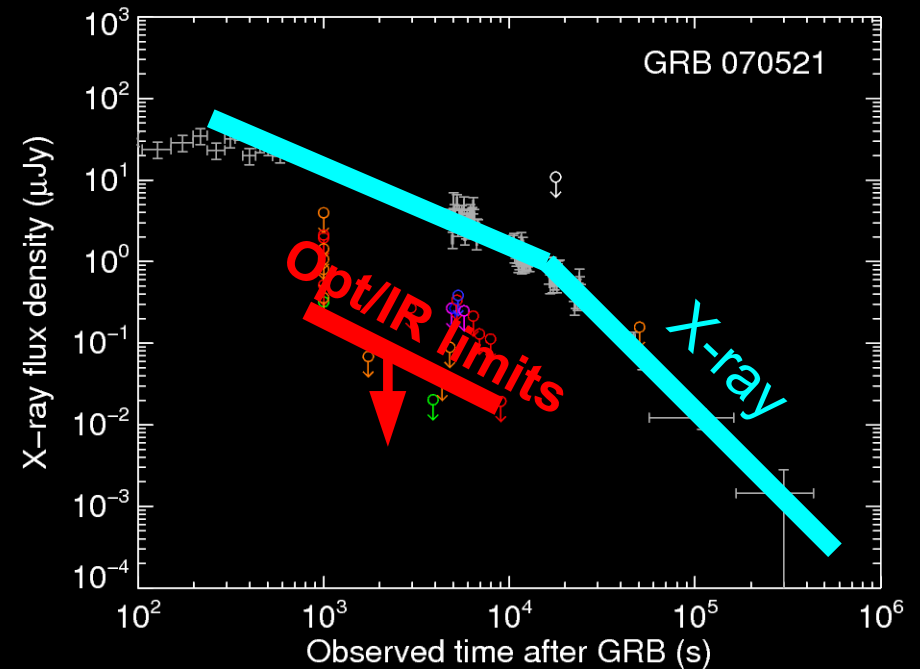
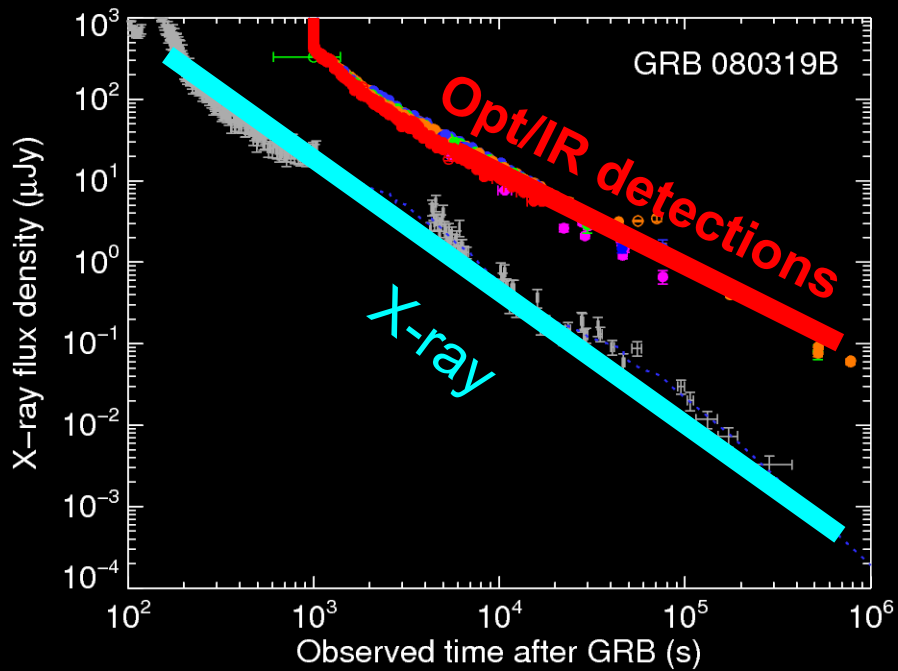
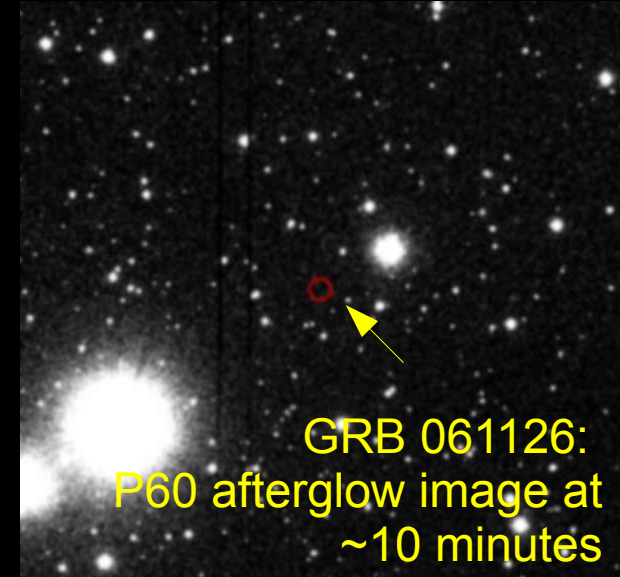




Dark GRBs

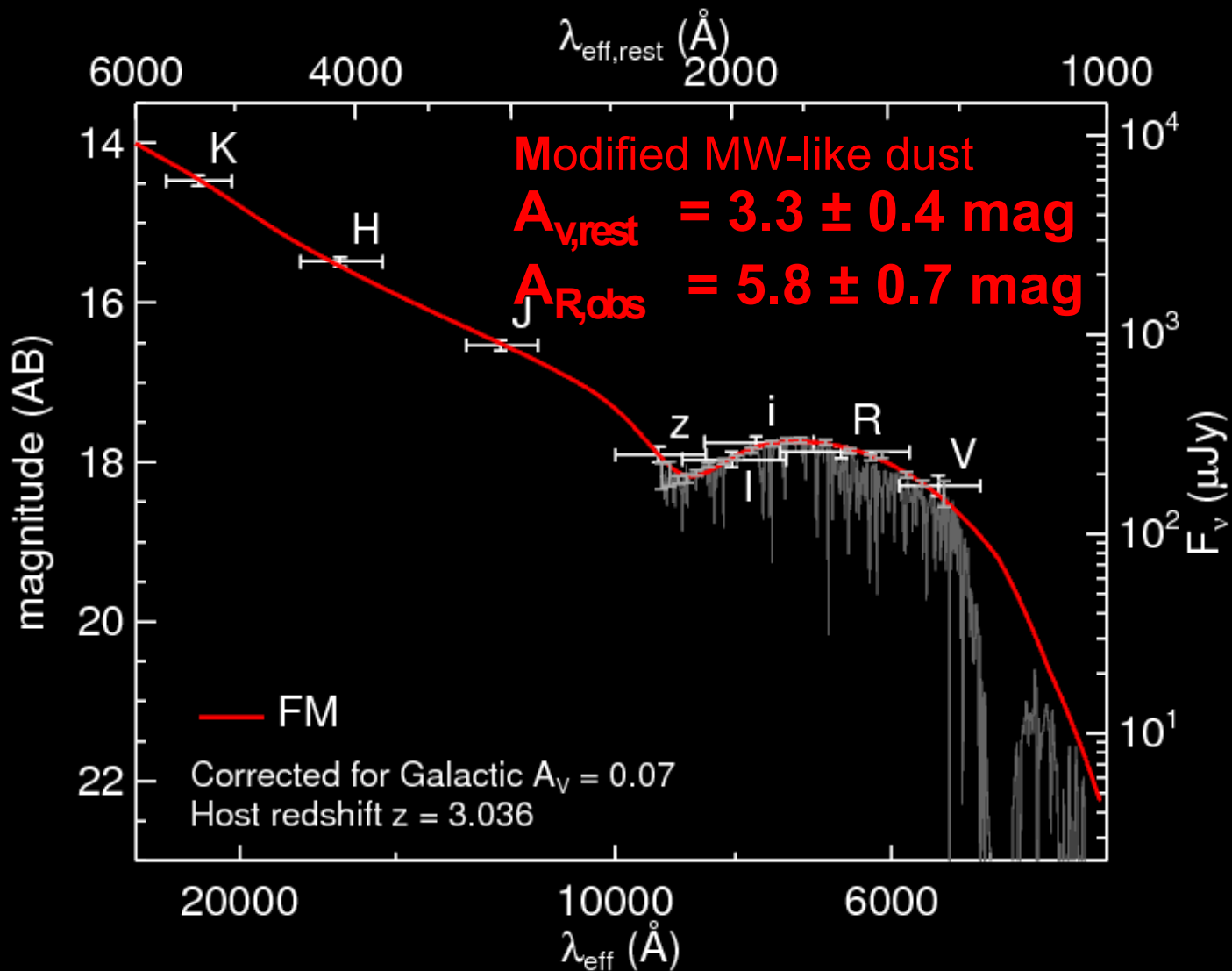


Dark Bursts

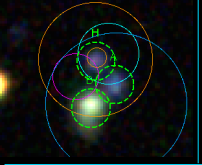


Ultraluminous “Dark” GRB 080607

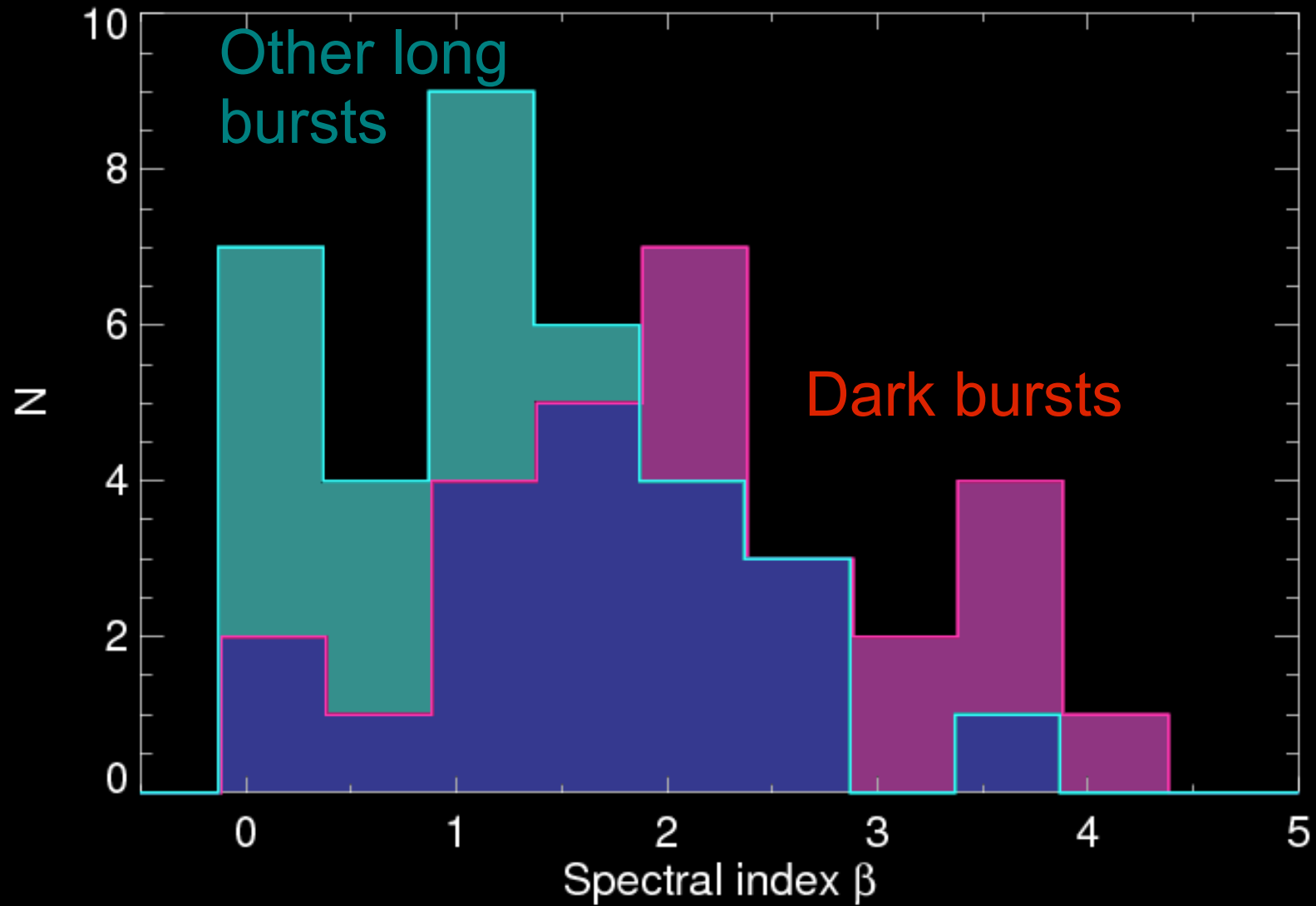
High-S/N LRIS afterglow spectrum thorough ~6 mags of host extinction!

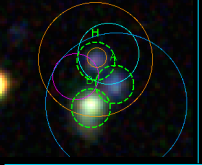


Prochaska+2009
Perley+2011

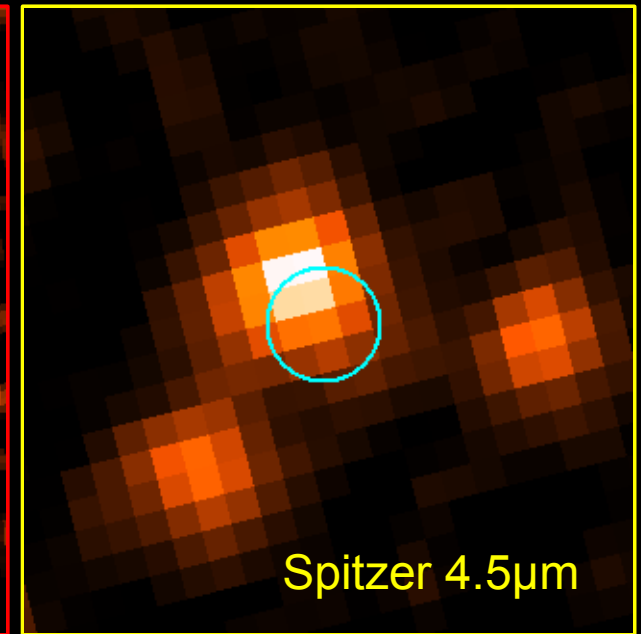
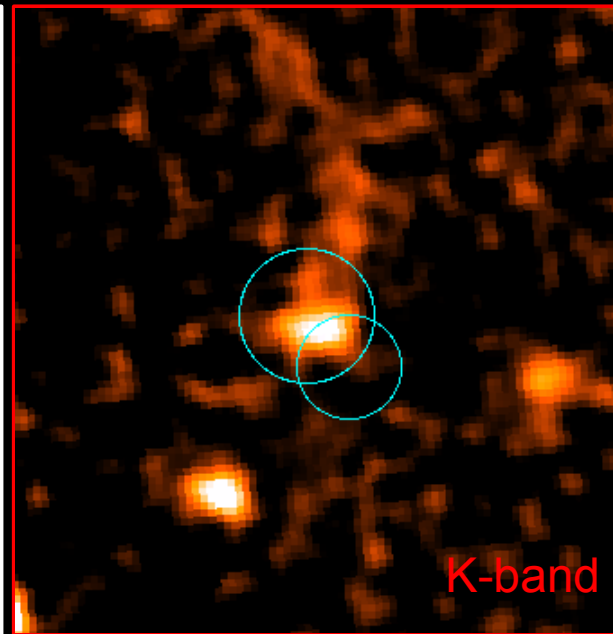
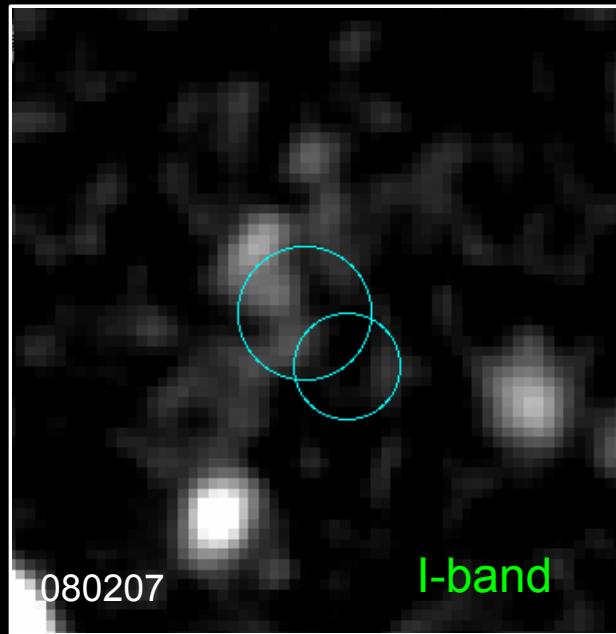


Dark Burst Host Colors





Dark GRB 080207



Fairly dark burst with...

Extremely red host:

I-K ~ 5.5 mag

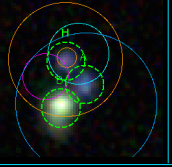
In top ~5% of brightest hosts observed by Spitzer,
also detected at 24μm with MIPS

Optically faint, z unknown

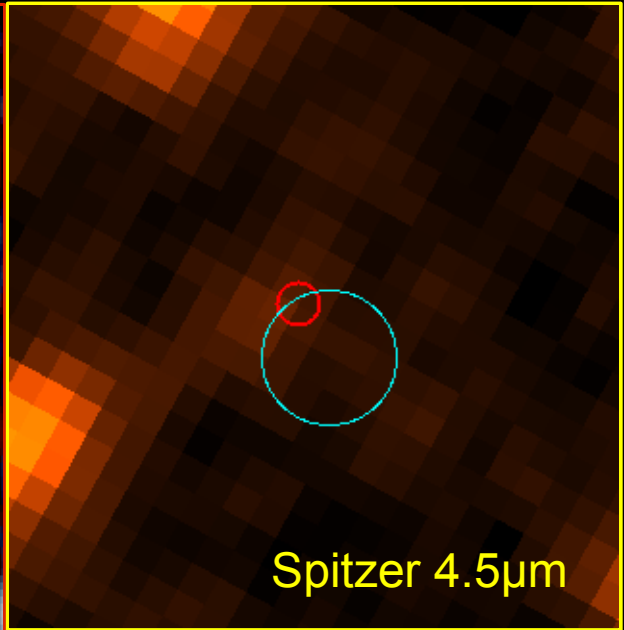
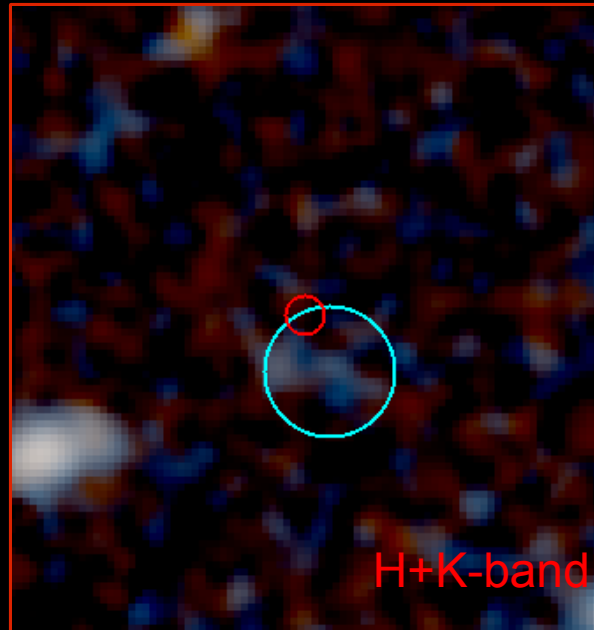
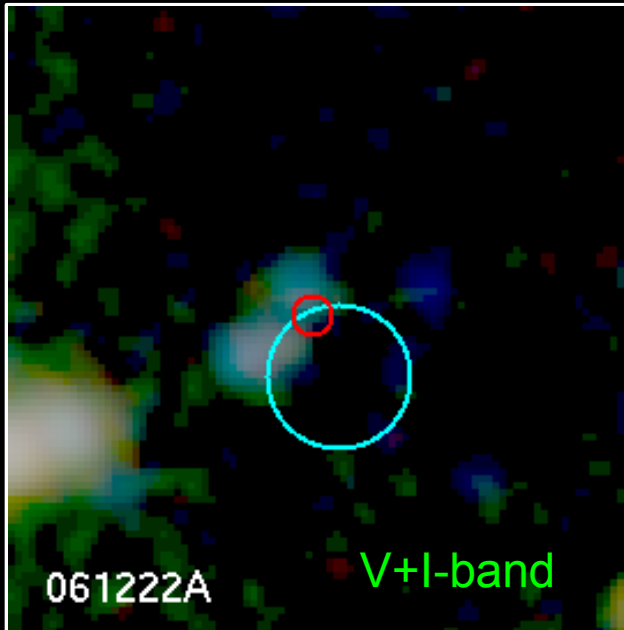
(photo-z~2)

Svensson+2011

Hunt+2011

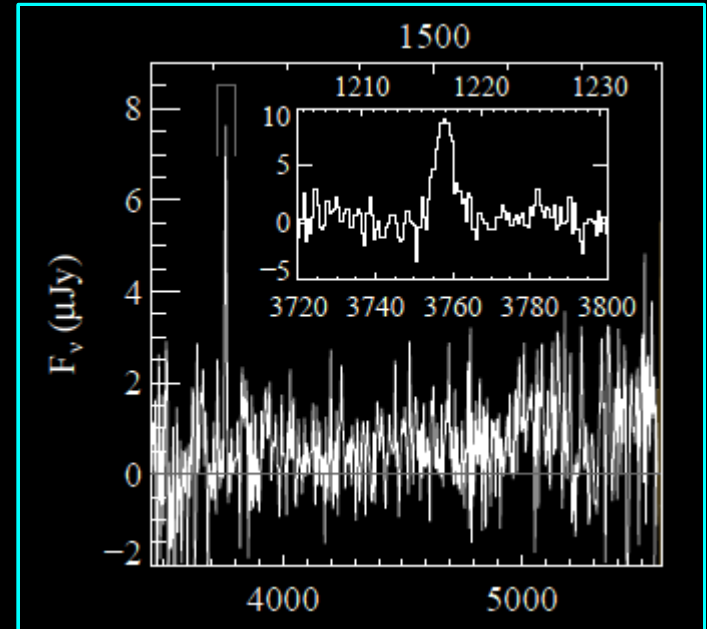


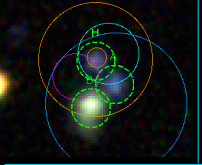
Dark GRB 061222A



Ultra-dark burst ($A_v > 5$ mag), but
Extremely blue host:
I-K ~ 2 mag
marginal or no Spitzer detection
Ly- α emitter at $z=2.1$

Perley+2009b

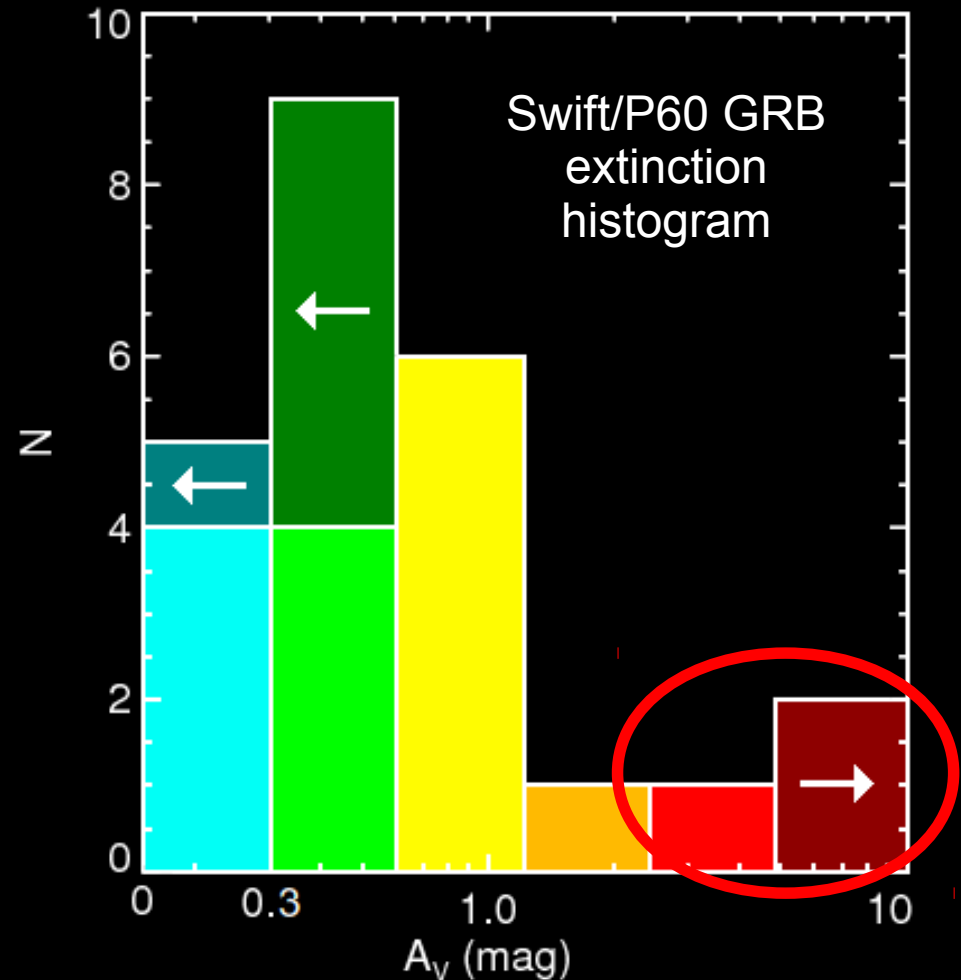


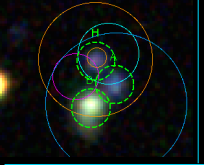


Swift Extinction Distribution

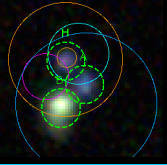
GRBs as pure star formation tracers
after all?

very dark GRBs are only **~15%** of
all GRBs.

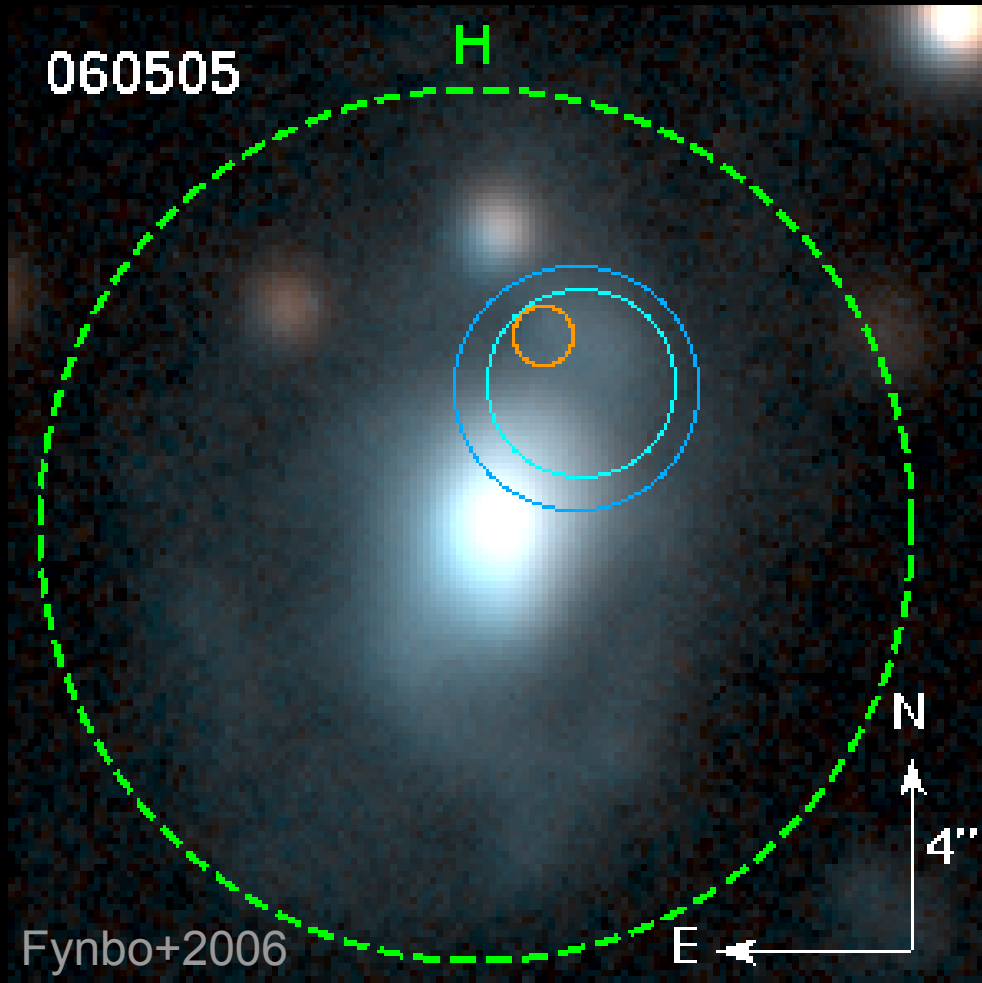




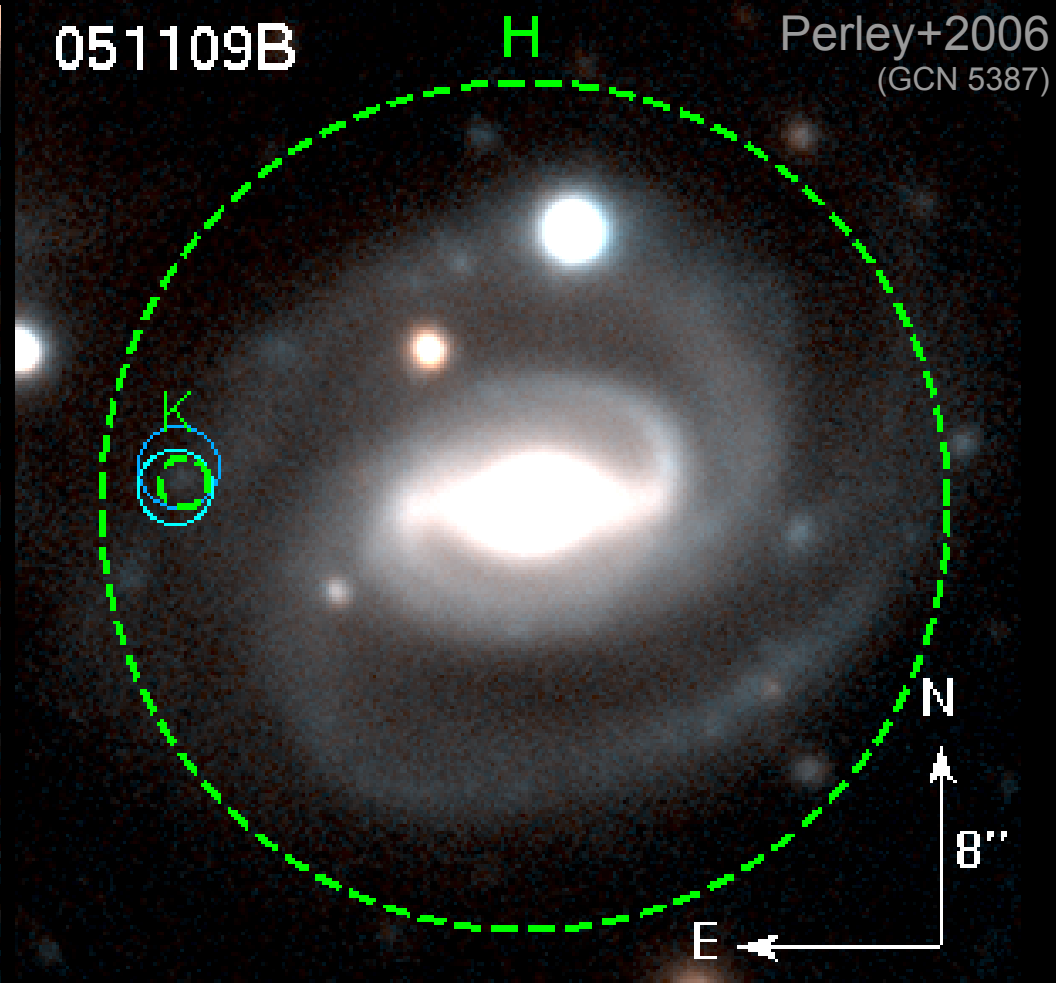
SN-less long GRBs?



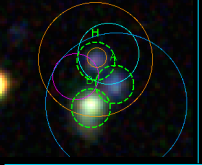
GRBs without SNe



$z=0.09$ spiral
21 days after GRB
>5 mags fainter than 1998bw



$z=0.08$ spiral
8 months after GRB
>2 mags fainter than 1998bw



Conclusions

Long GRBs

Star forming hosts; $\langle z \rangle \sim 2$, 93-99% are at $z < 7$

Short GRBs

No ellipticals since '05; many are “hostless” to Keck limits

XRFs

Not distinct from ordinary long GRBs

Dark GRBs

Dust-obscured

Most (but not all!) hosts are also red and dusty

Low-z GRB SNe

2/3 of $z < 0.1$ GRBs in spiral hosts produced no SN?

All optical imaging data will be made available starting January 2012.