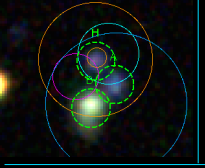
Keck Observations of 150 GRB Host Galaxies

Daniel Perley

+Joshua Bloom, Bradley Cenko, and many others

UC Berkeley



Motivation

Before Swift:

- ~66 GRBs with <3” afterglow localizations
  - nearly all from *optical* afterglow – biased sample?
- ~90% have reported hosts (or deep limits)
- ~40 known host galaxies
- ~50% of redshifts from emission

Since Swift:

- ~450 GRBs with <3” afterglow localizations
  - almost all bursts have *X-ray* afterglow from XRT
- ~20% have reported hosts (or deep limits)
- ~80 known host galaxies
- ~10% of redshifts from emission

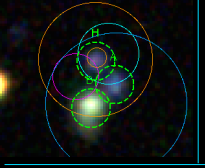
Observing Program

Six years of GRB host observations at Keck

- 2005-present
- 25 dedicated nights
- + addl. data from other groups at Caltech, UCSC, TOOs, etc.

Emphases:

- Host discovery & basic characterization
- Redshift measurement



Observing Goals

Combination of many related projects:

- Redshifts for bursts of local interest
- Overall *Swift* redshift distribution
- GRB diversity (short bursts? XRFs?)
- Understanding pre-Swift biases (dark bursts)
- The unexpected

Also:

- DLAs
- Mg II absorbers
- Searching for SN emission
- Hosts of LAT-detected bursts

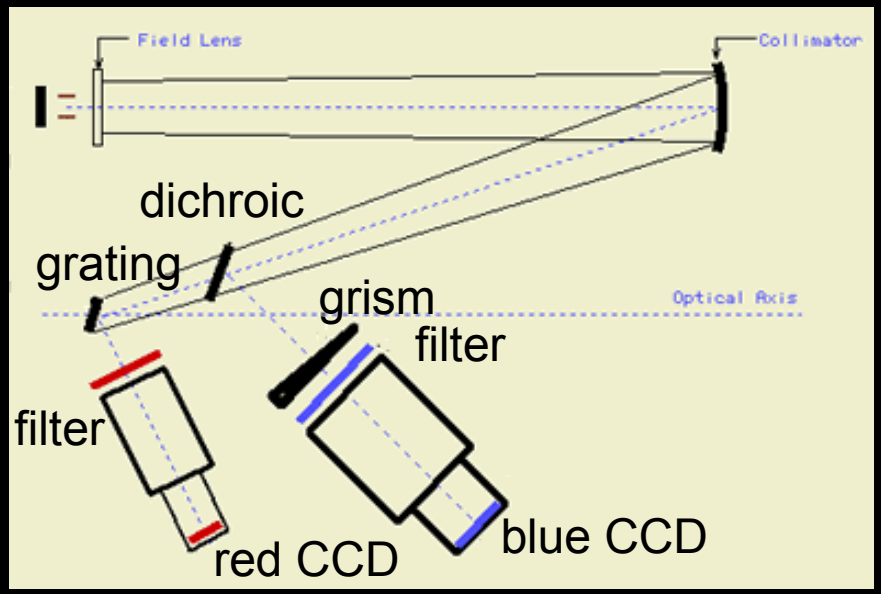
Avoid repeating existing observations
(so relatively few low-z, etc.)

Not a single program -
Nonuniform sample selection!

Observations

LRIS imaging

- 2 optical filters w/dichroic
  - usually g+R or V+I
  - usually 15-30 minutes / target
    - depth of g~27, R~26 (3σ)

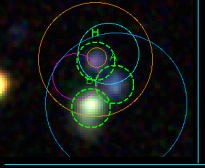


LRIS spectroscopy

- full coverage, 3400-9000 Å; low resolution (4-7 Å)
  - (10000Å after summer 2009 upgrade)

Sometimes: NIR imaging (dark bursts)

Accompanying Lick 1m field calibration program



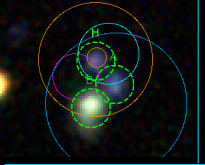
Sample Properties

147 unique targets

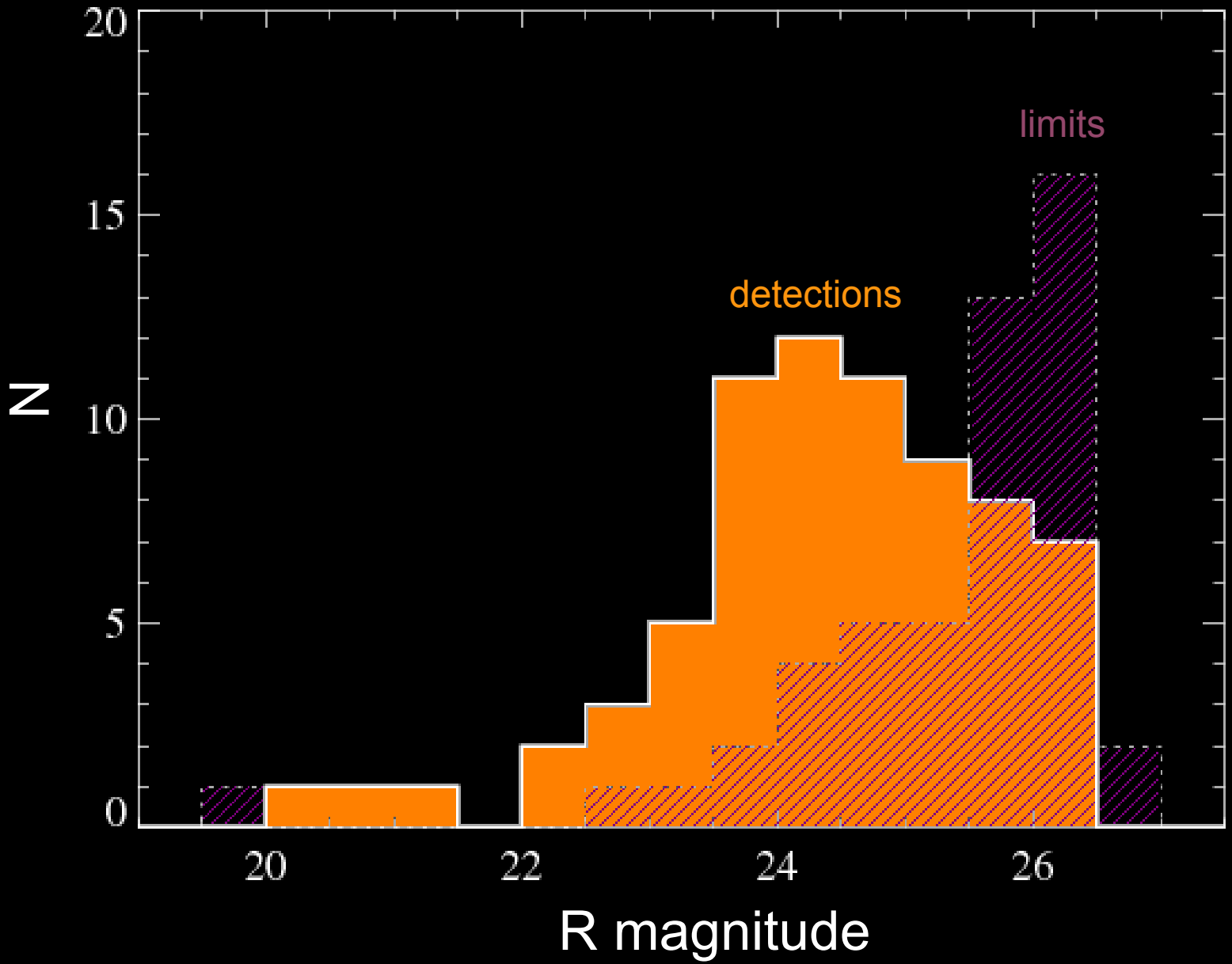
135 with Keck optical imaging
- 103.1 filter-hours
- 334 filter-fields
- **80** host detections (55 non-detections)
  - 26 w/ known redshift

46 with LRIS spectroscopy
- ~30 hours integration
- **21** successful/probable host redshifts
  - (no lines apparent for other 25)
- **14** discovered by our observations

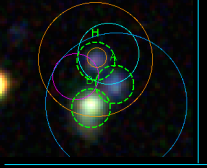
General Sample Results

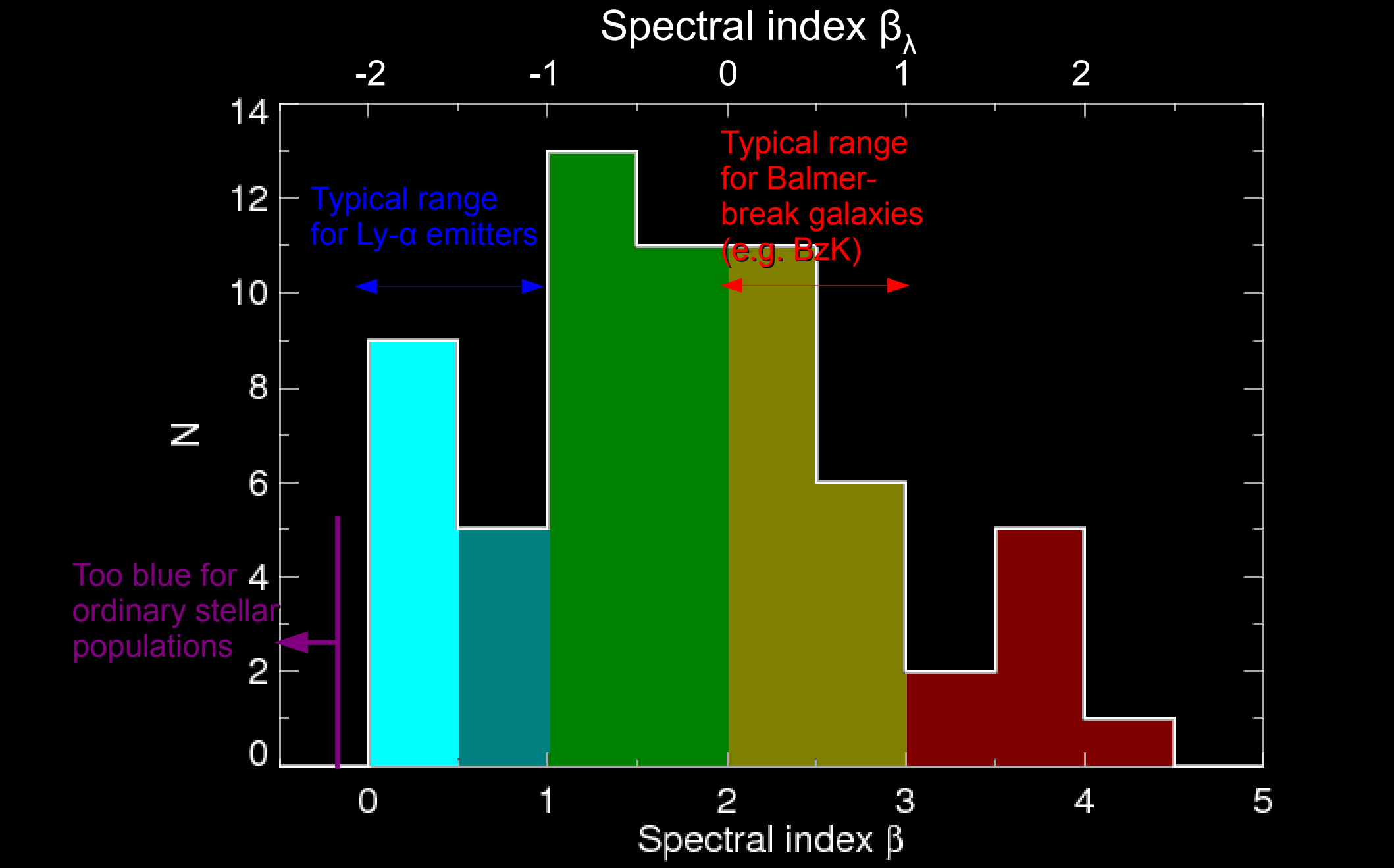


Host magnitude distribution

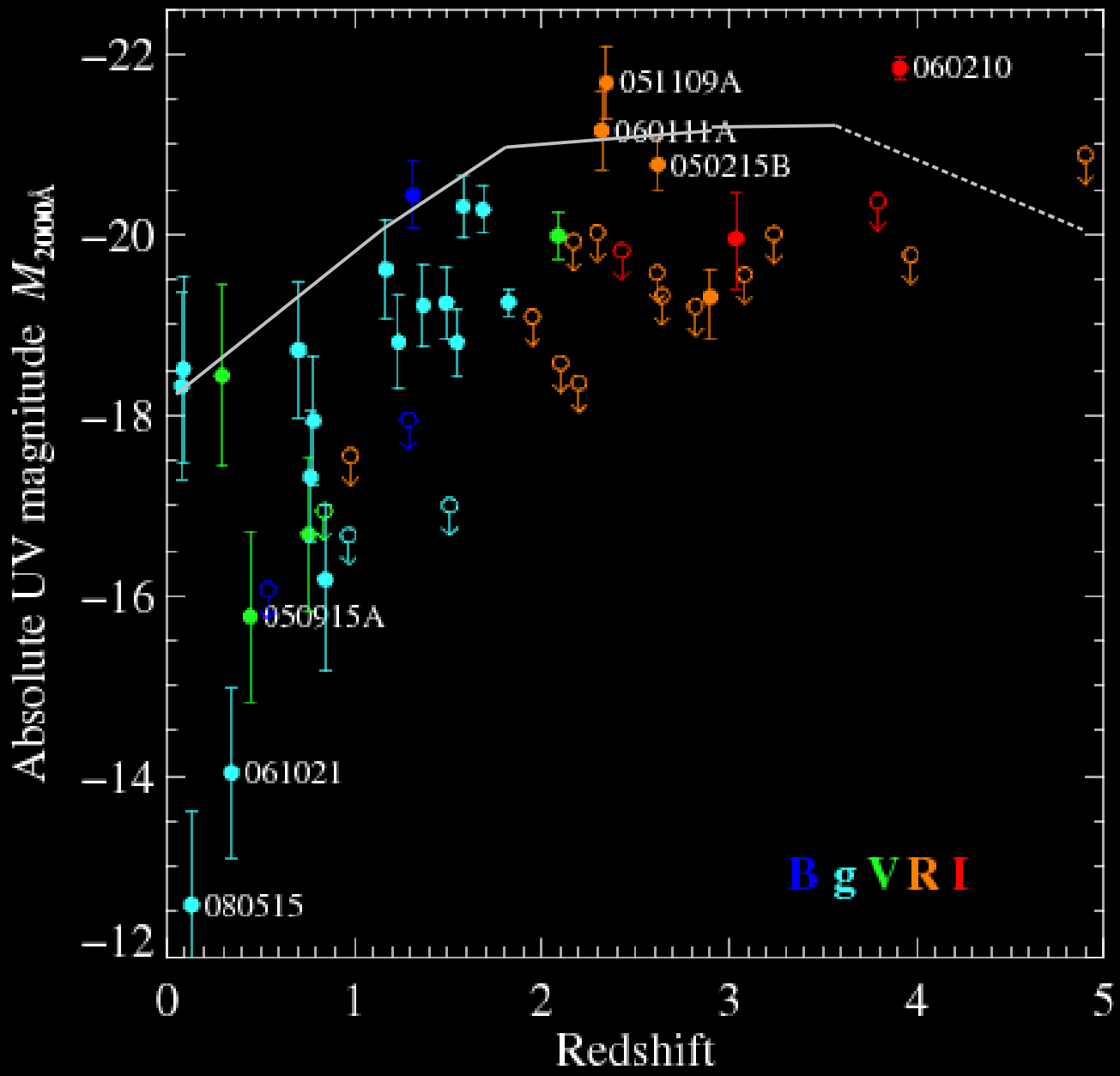


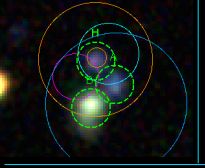
Host Color Distribution





Host Luminosity Distribution





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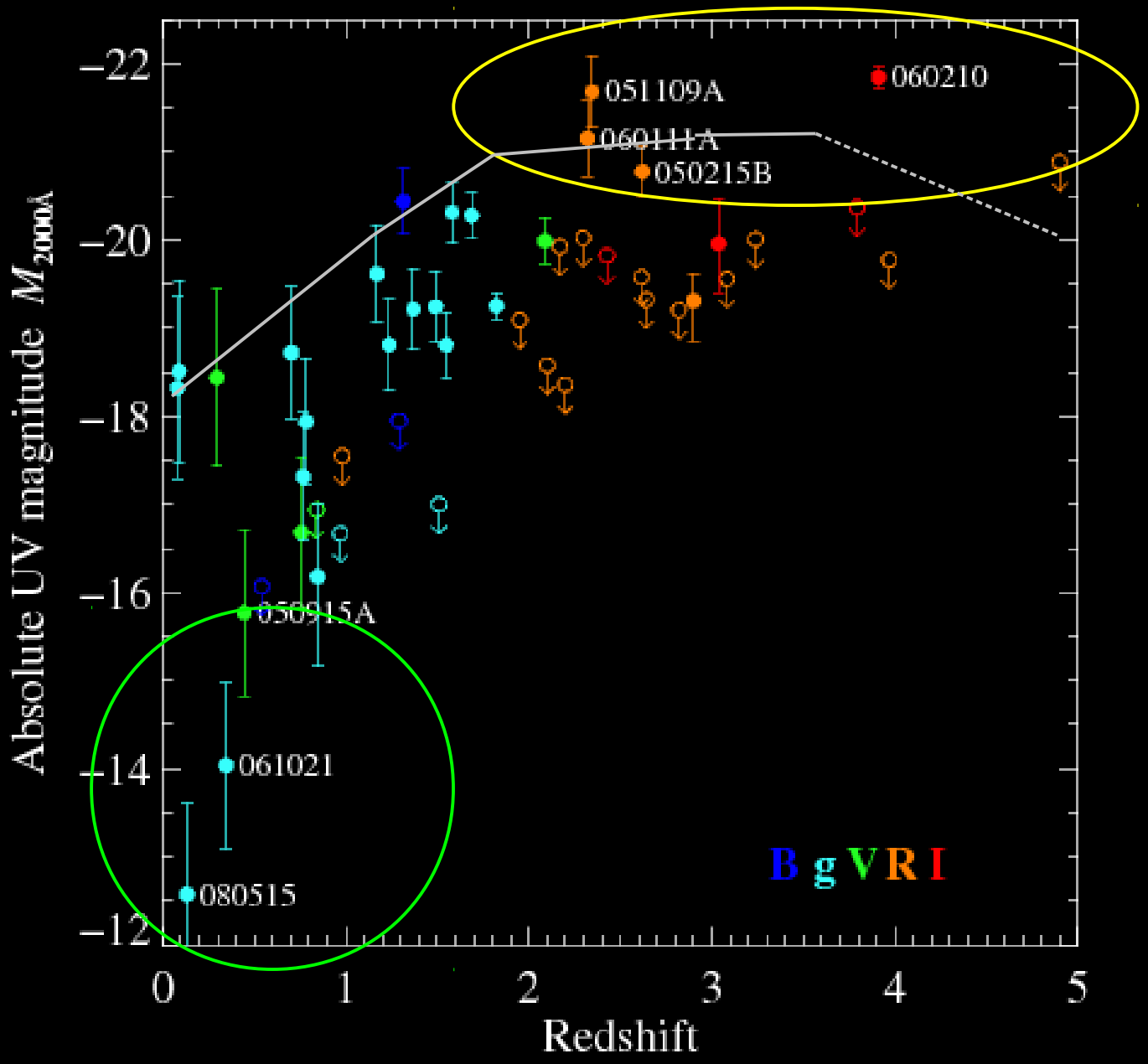
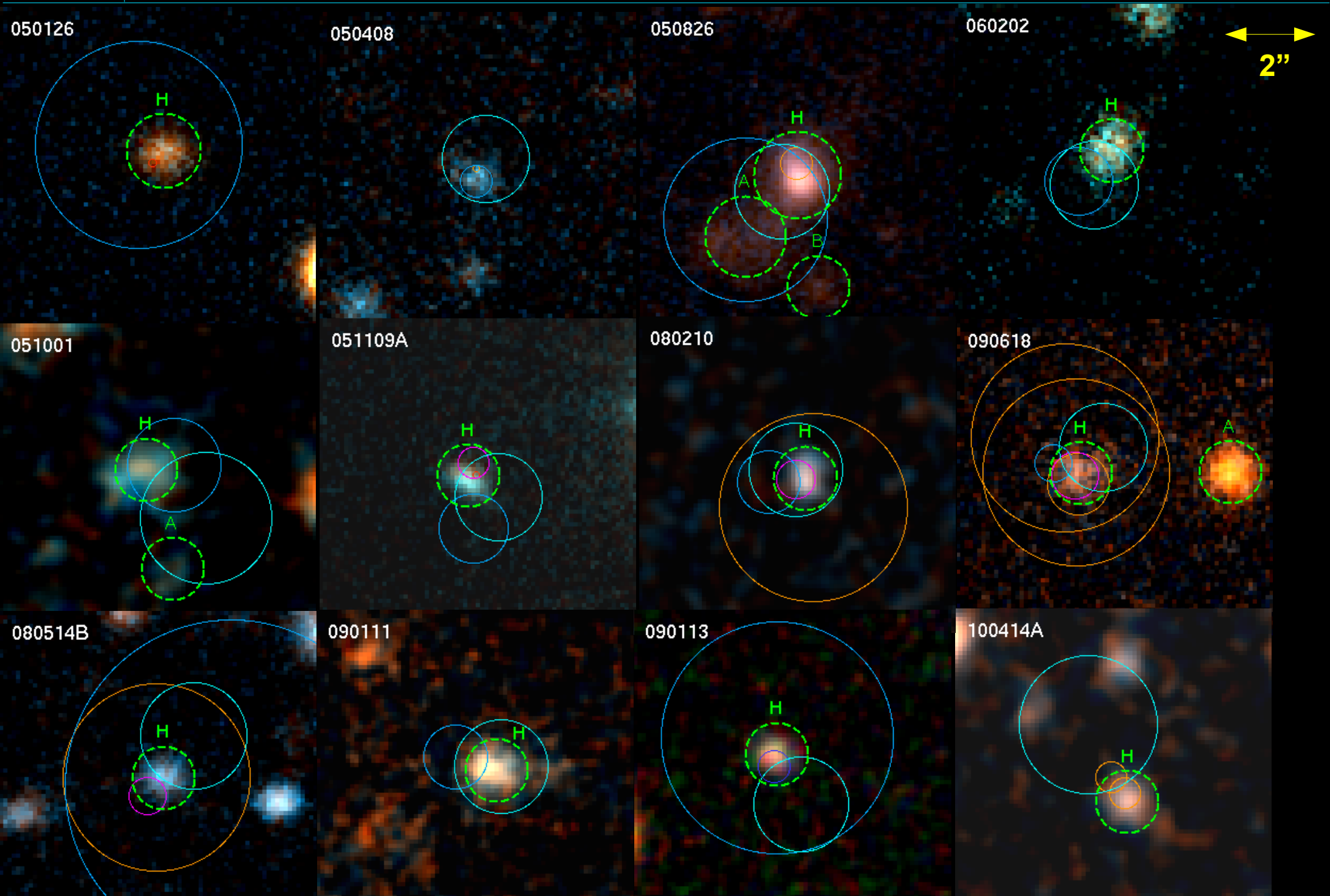
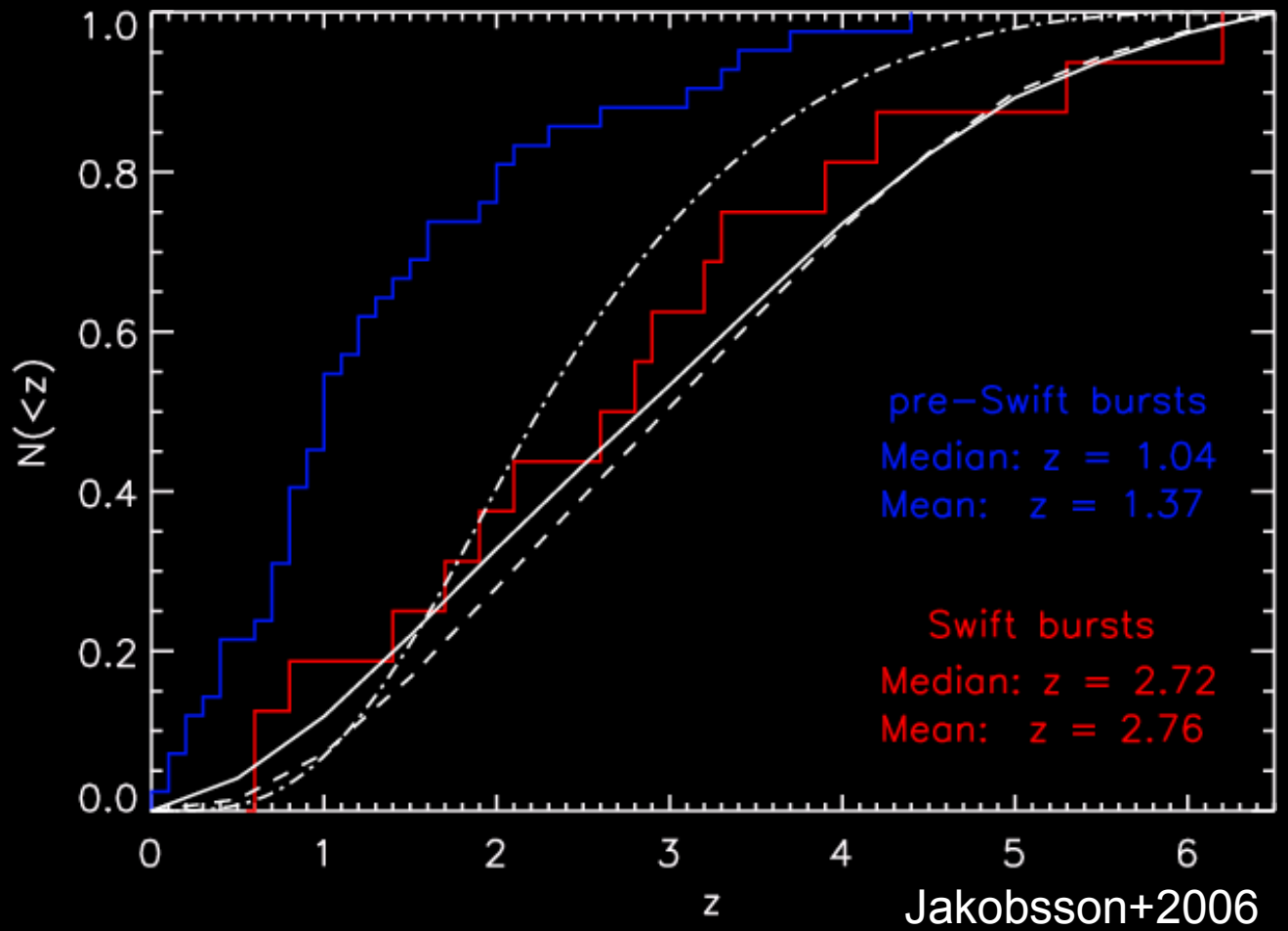


“Morphology”


050126
H
050408
050826
H
A
B
060202
H
2”
051001
H
A
051109A
H
080210
H
090618
H
A
080514B
H
090111
H
090113
H
100414A
H

The Swift Redshift Distribution

Less than 20% of Swift GRBs have afterglow redshifts...

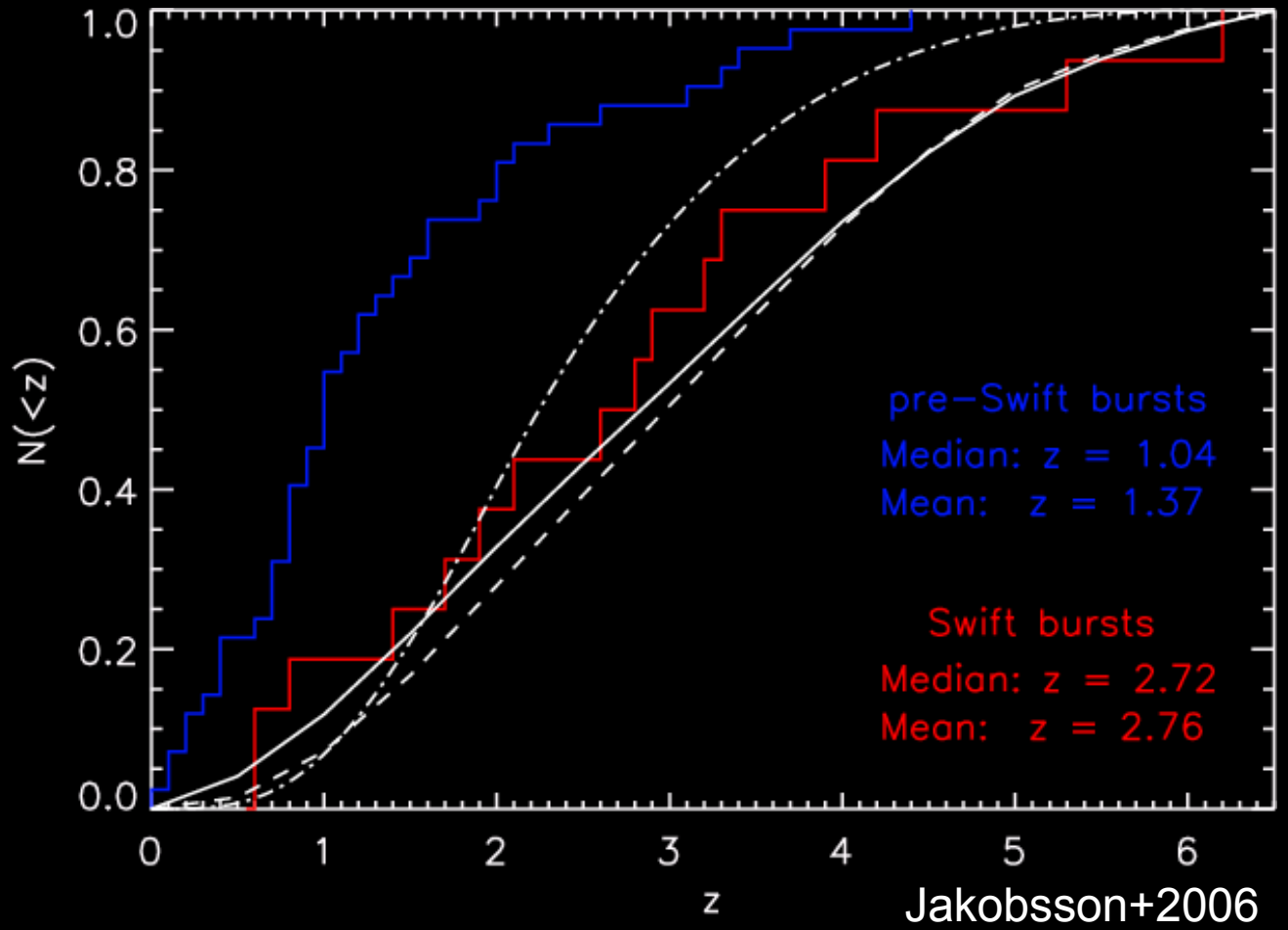


Jakobsson+2006

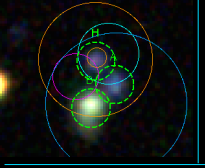
The Challenge of Swift Host Spectra

Pre-Swift <z> ~ 1
- L* galaxy has R~23
- [OII] at 7500 Å

Swift <z> ~ 2
- L* galaxy has R~25
- [OII] at 11000 Å

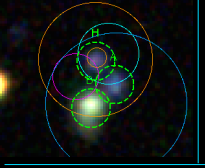


Jakobsson+2006



P60

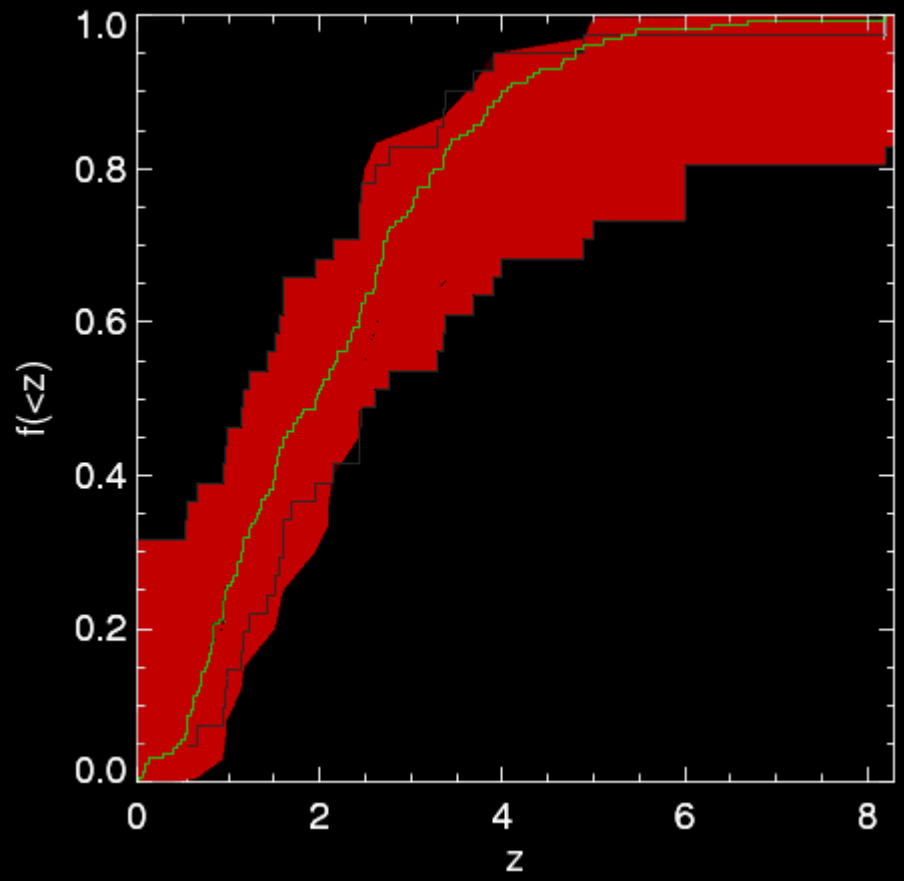
1.5m robotic telescope 2 hours east of Hawaii



P60/Swift Redshift Distribution

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

080310	2.43
080319A	<5
080319B	0.94
080319C	1.95
080320	
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	
090812	2.45
090813	<5



P60/Swift/Keck 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
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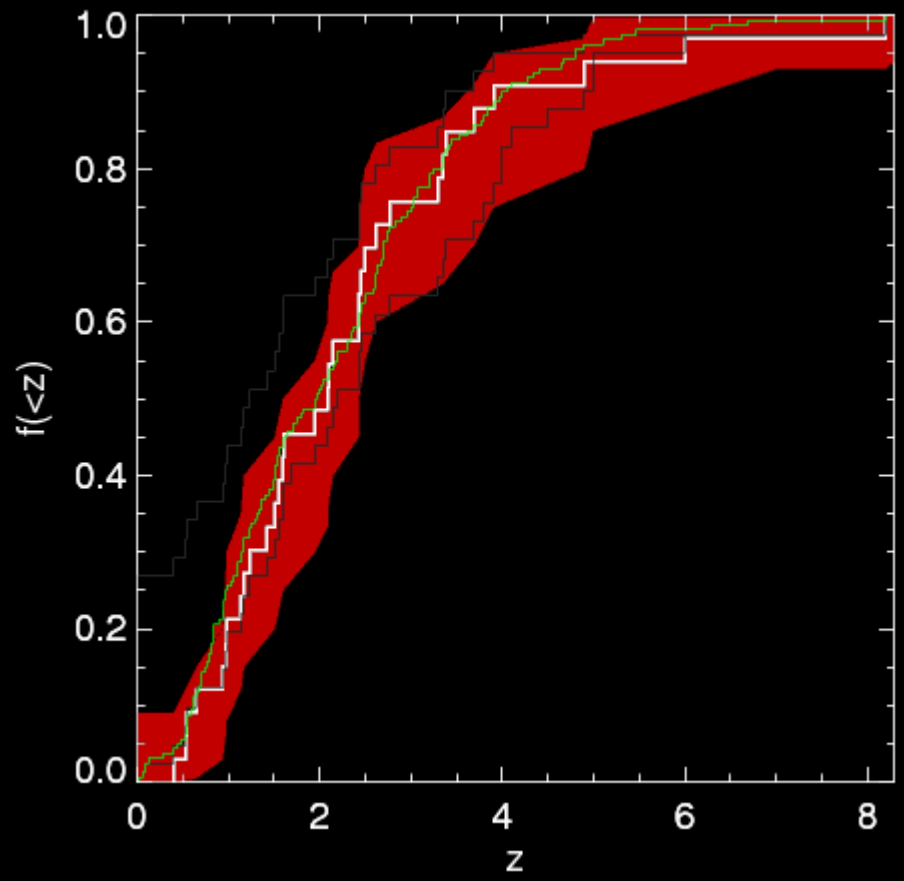

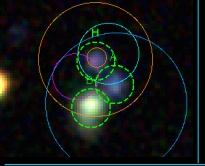

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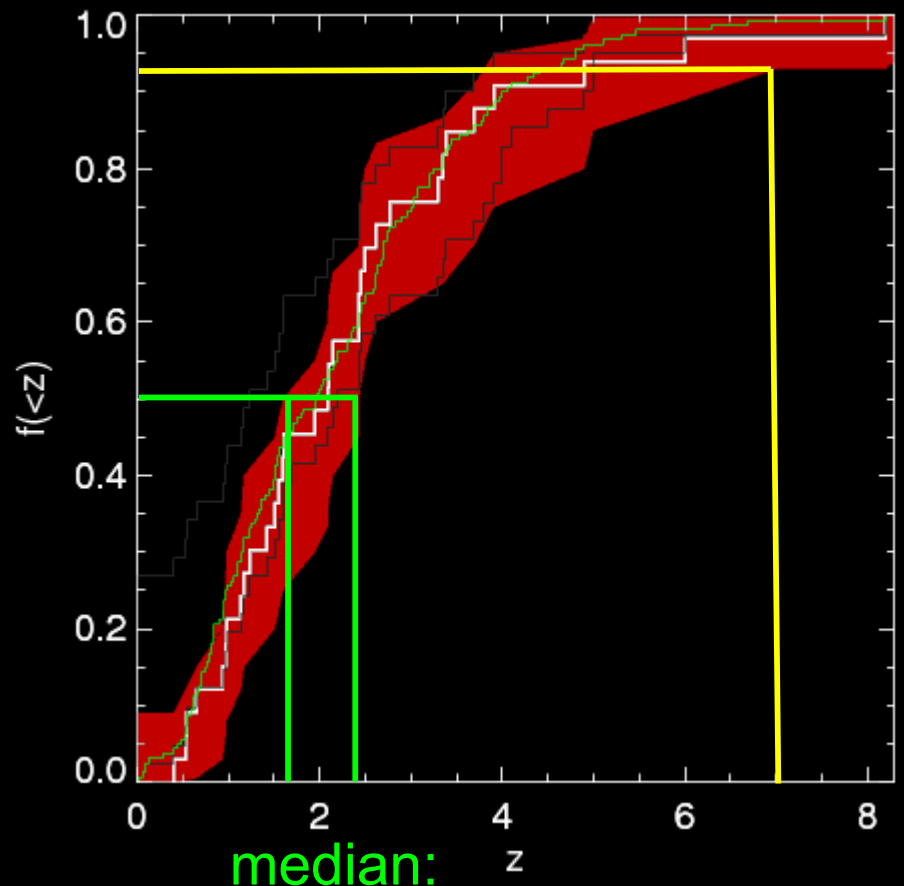
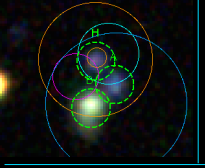
090423	8.2
090530	<1.7
090618	0.54
090709A	<4
090812	2.45
090813	<5

high-z rate:
0.2–7%

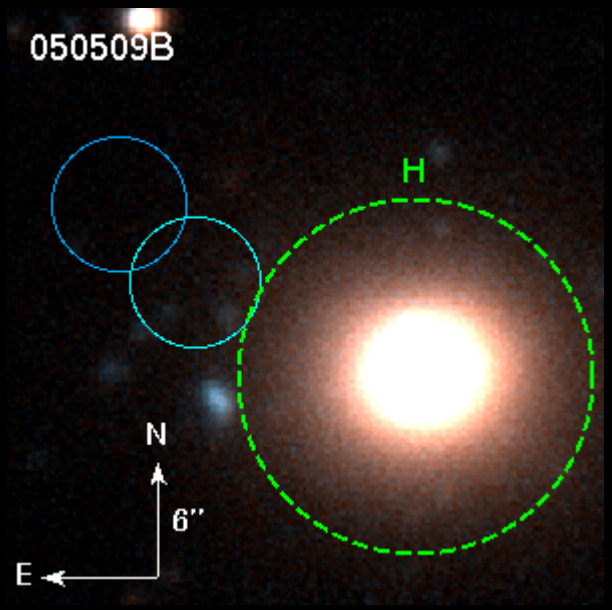


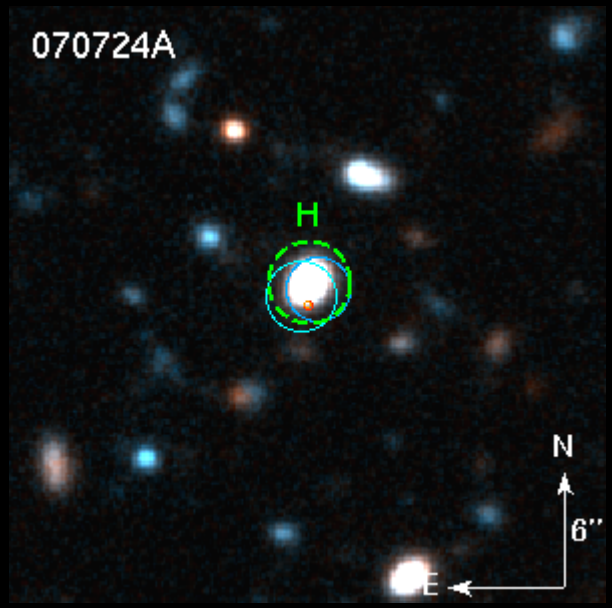
median:
z~2

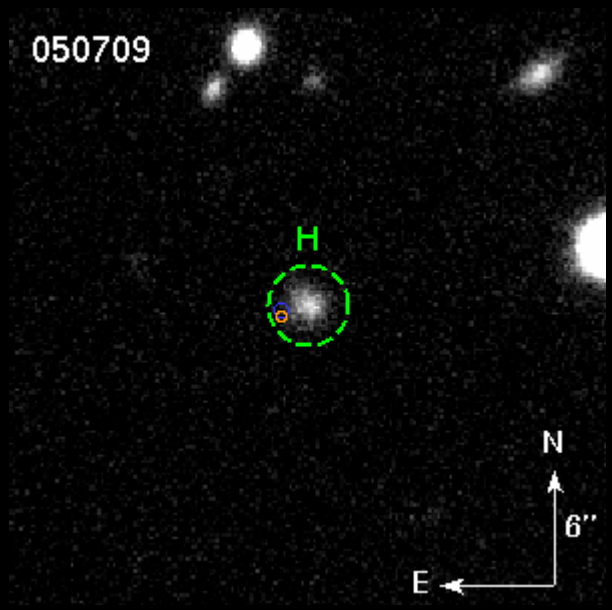
Short GRBs

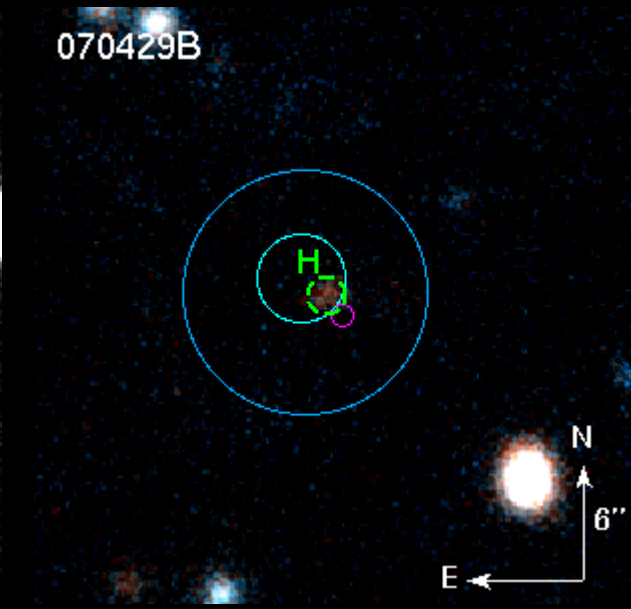


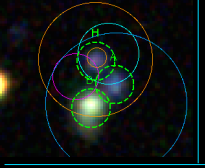
Short GRBs



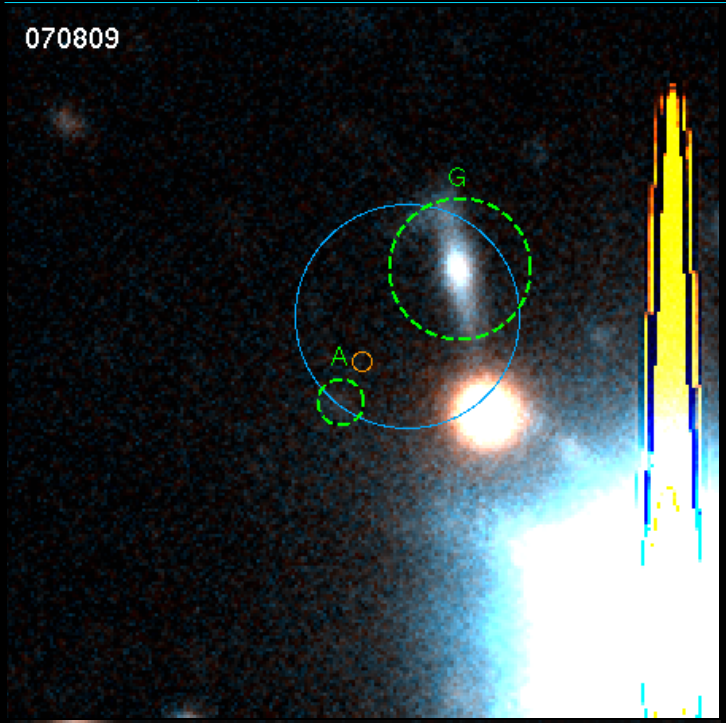


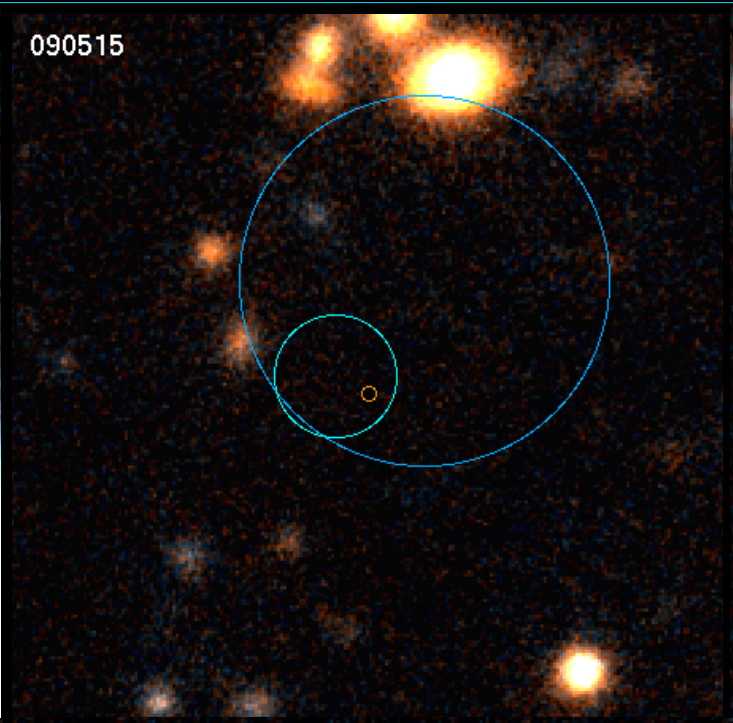


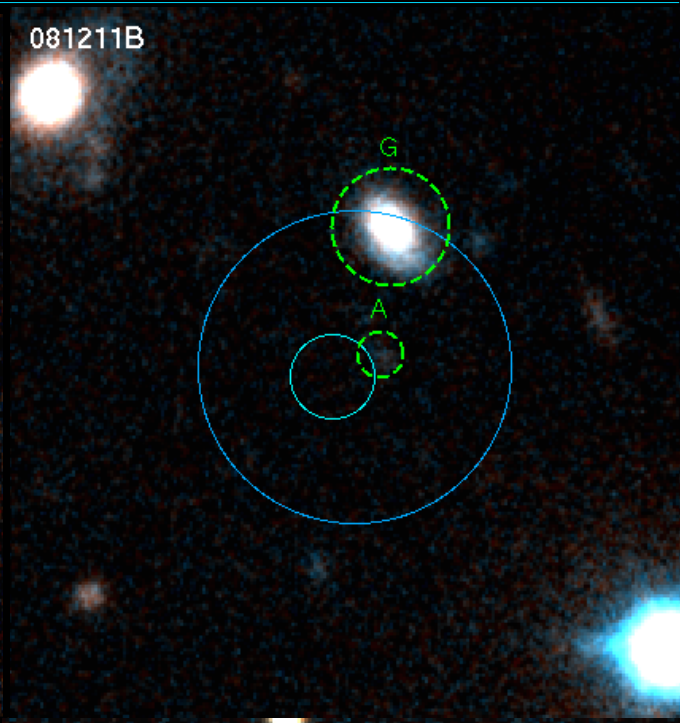


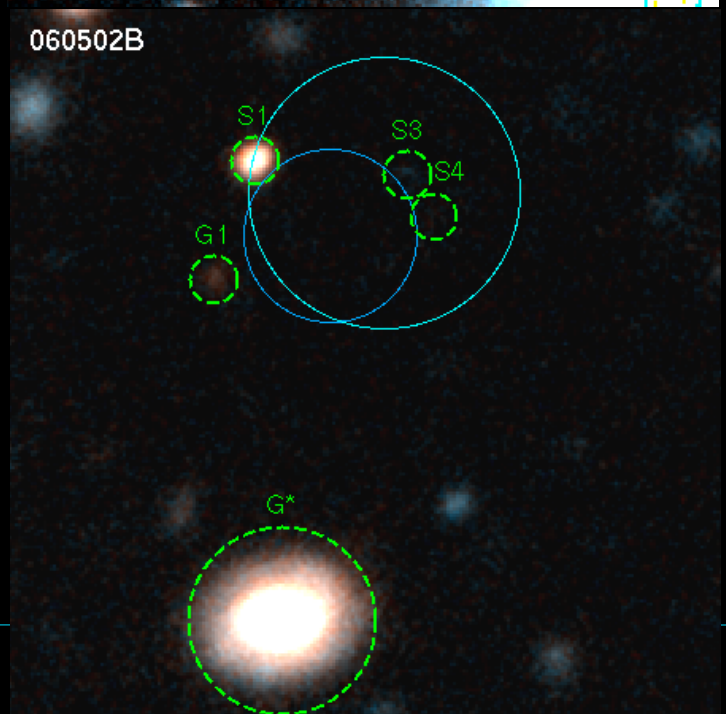


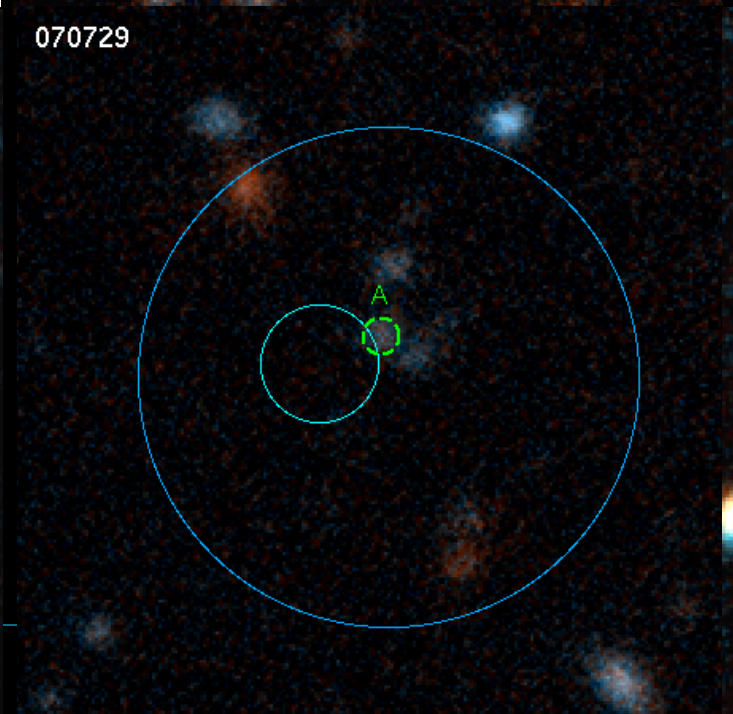
Hostless Systems?

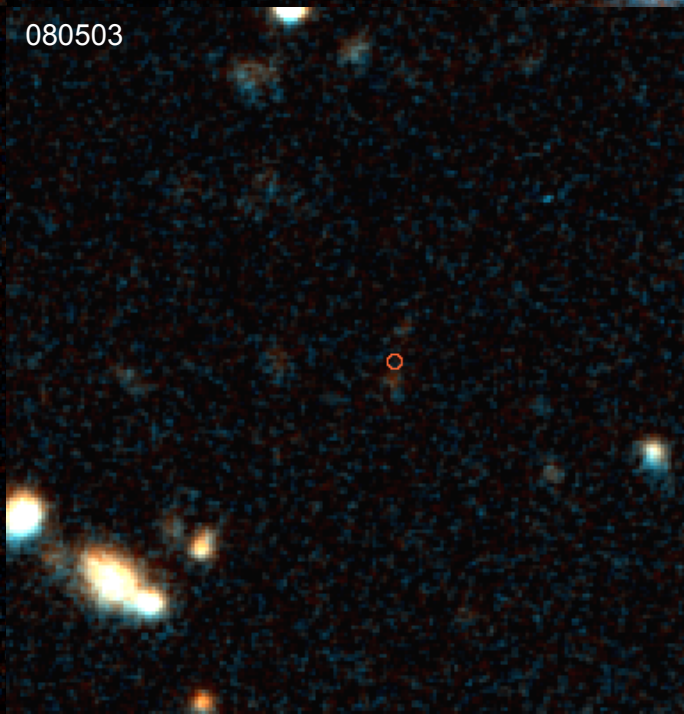






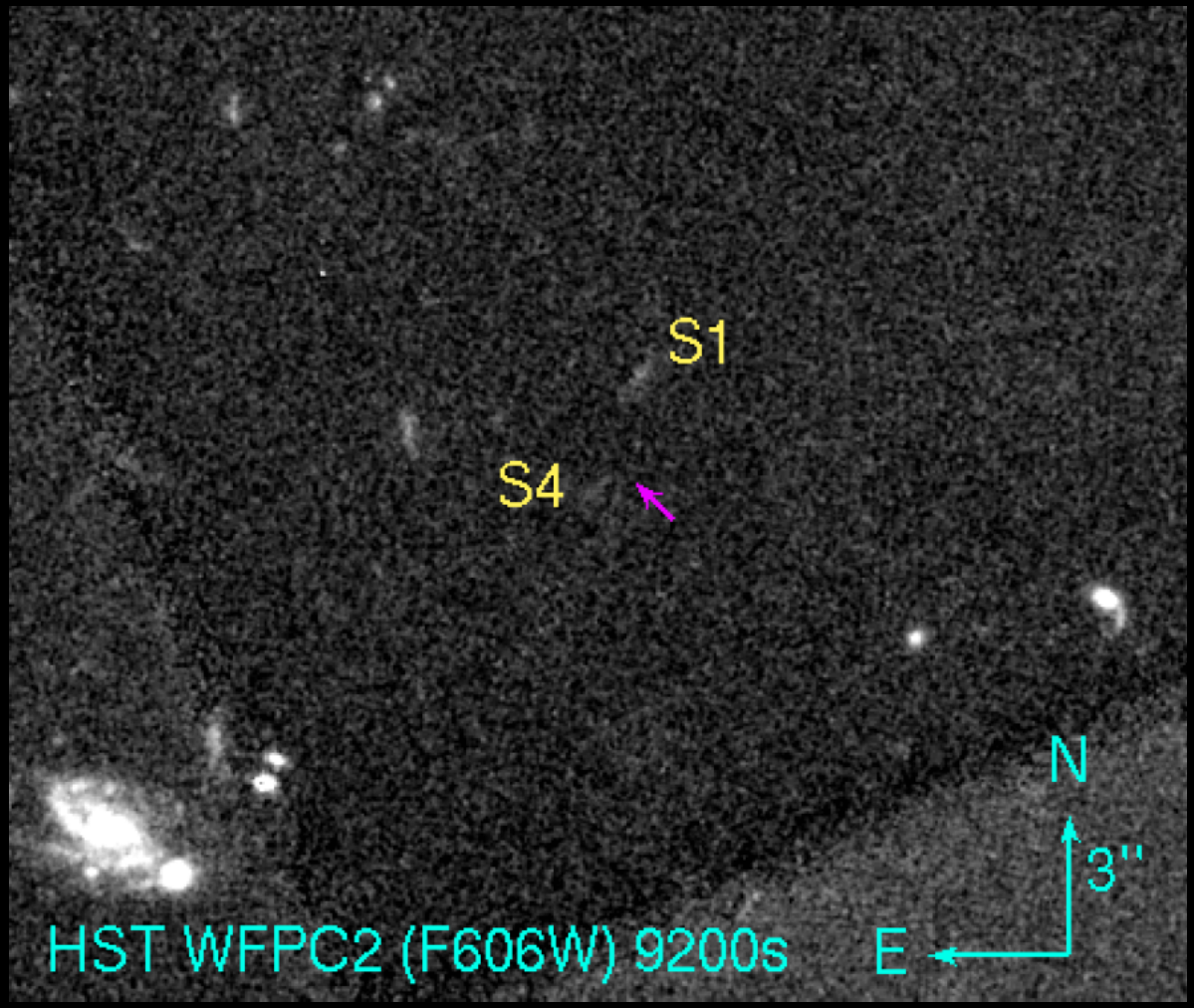




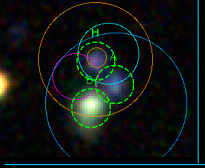


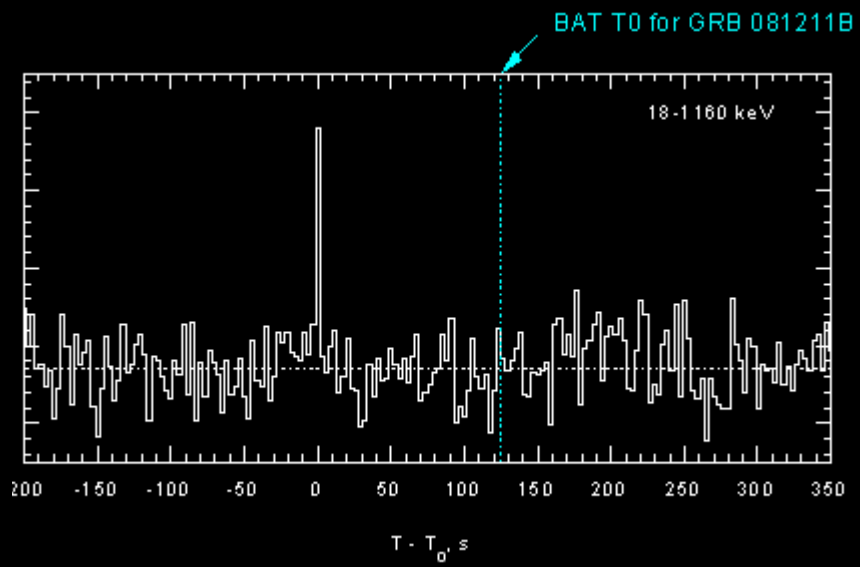
Hostless GRB 080503

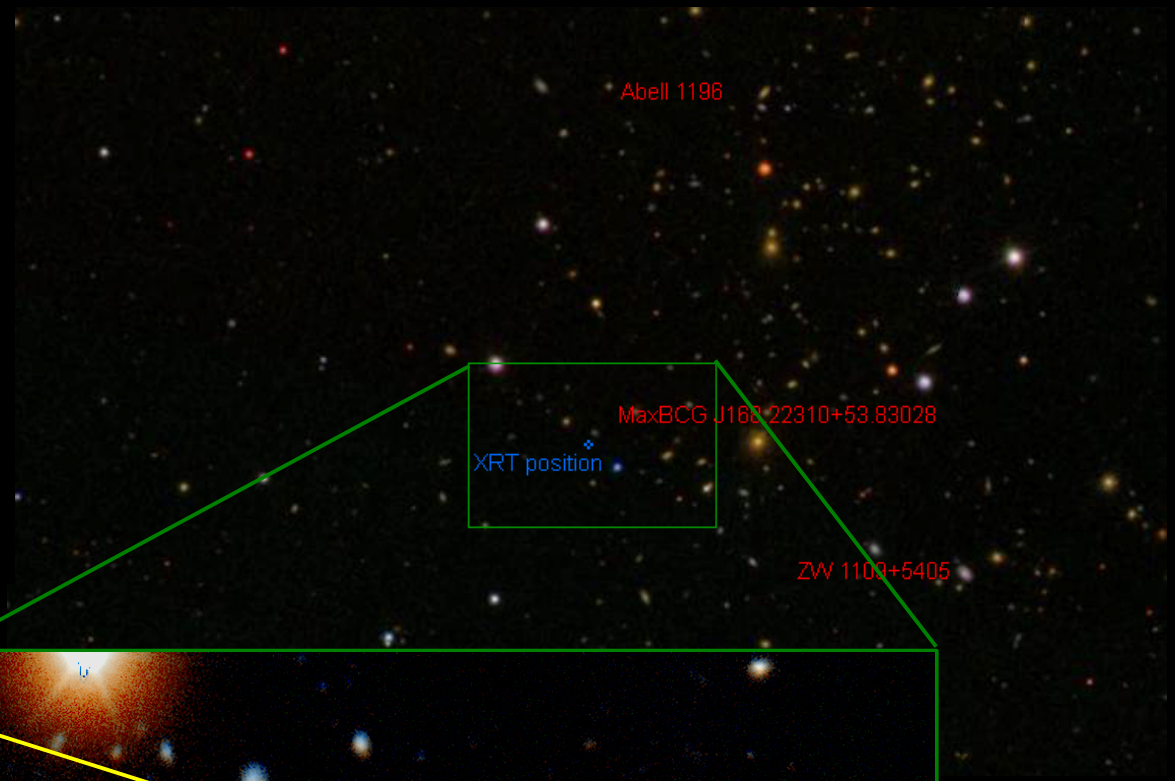
Extremely faint afterglow,
No host galaxy to >28 mag

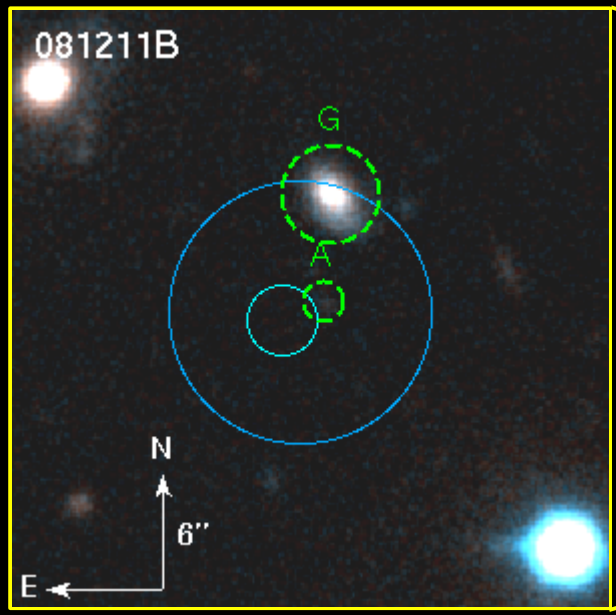


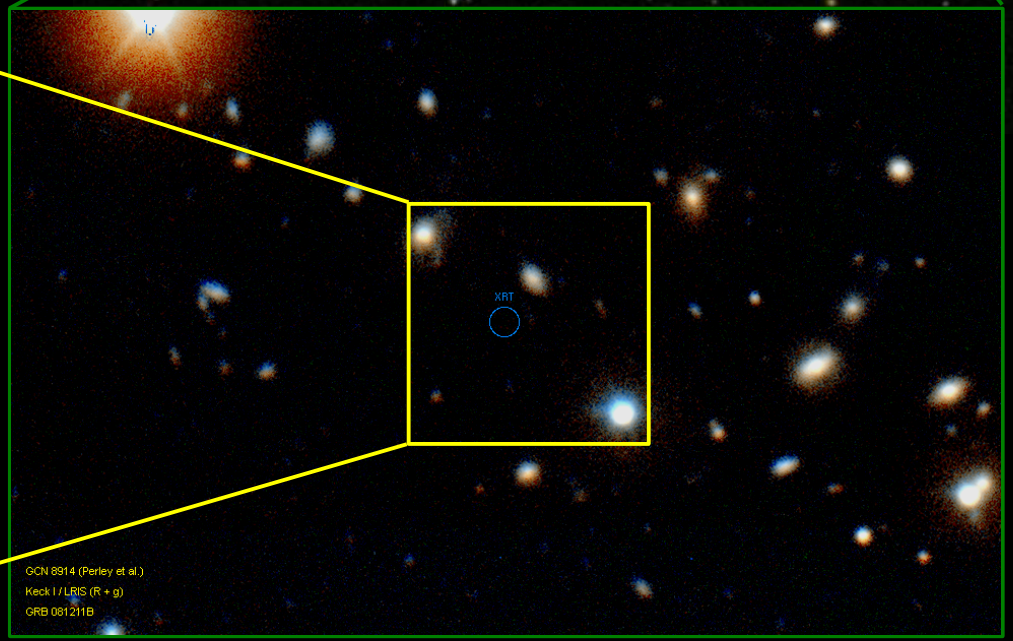
Intracluster GRB 081221







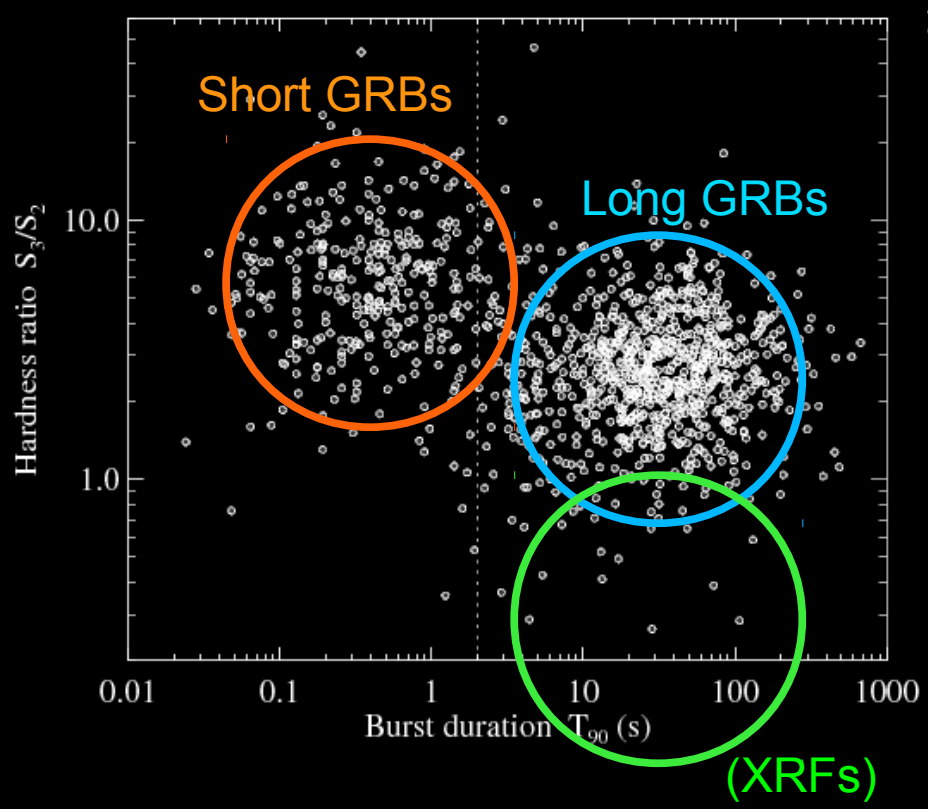


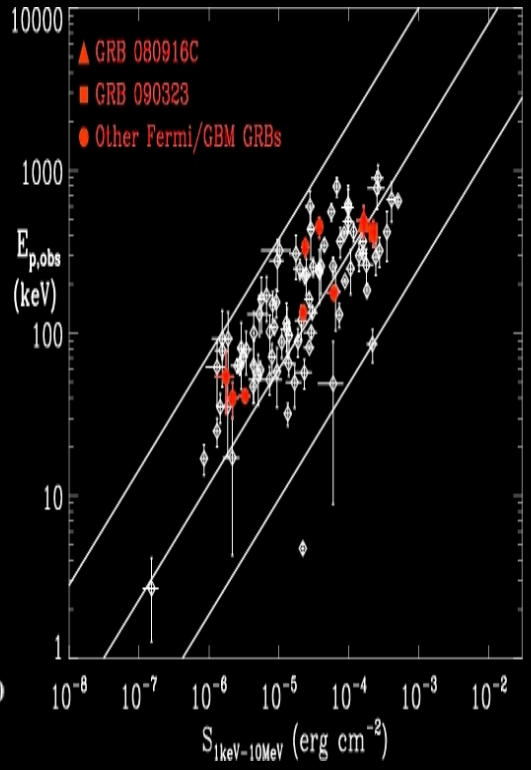


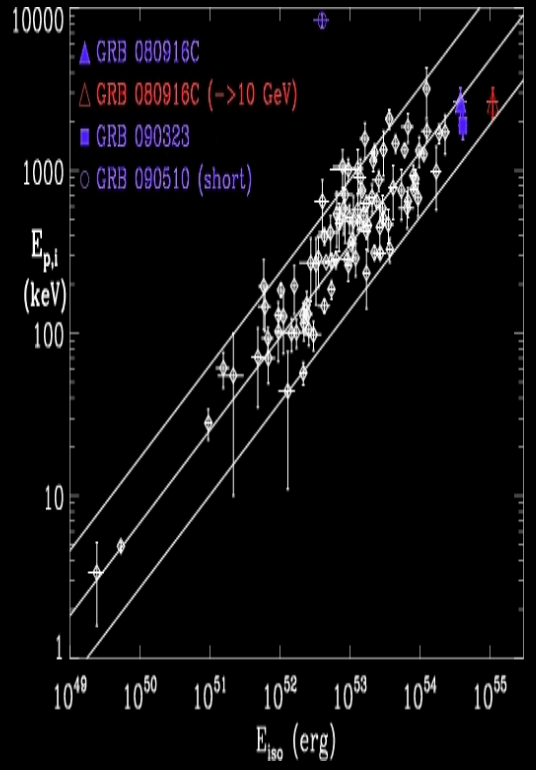
XRFs

X-Ray Flashes

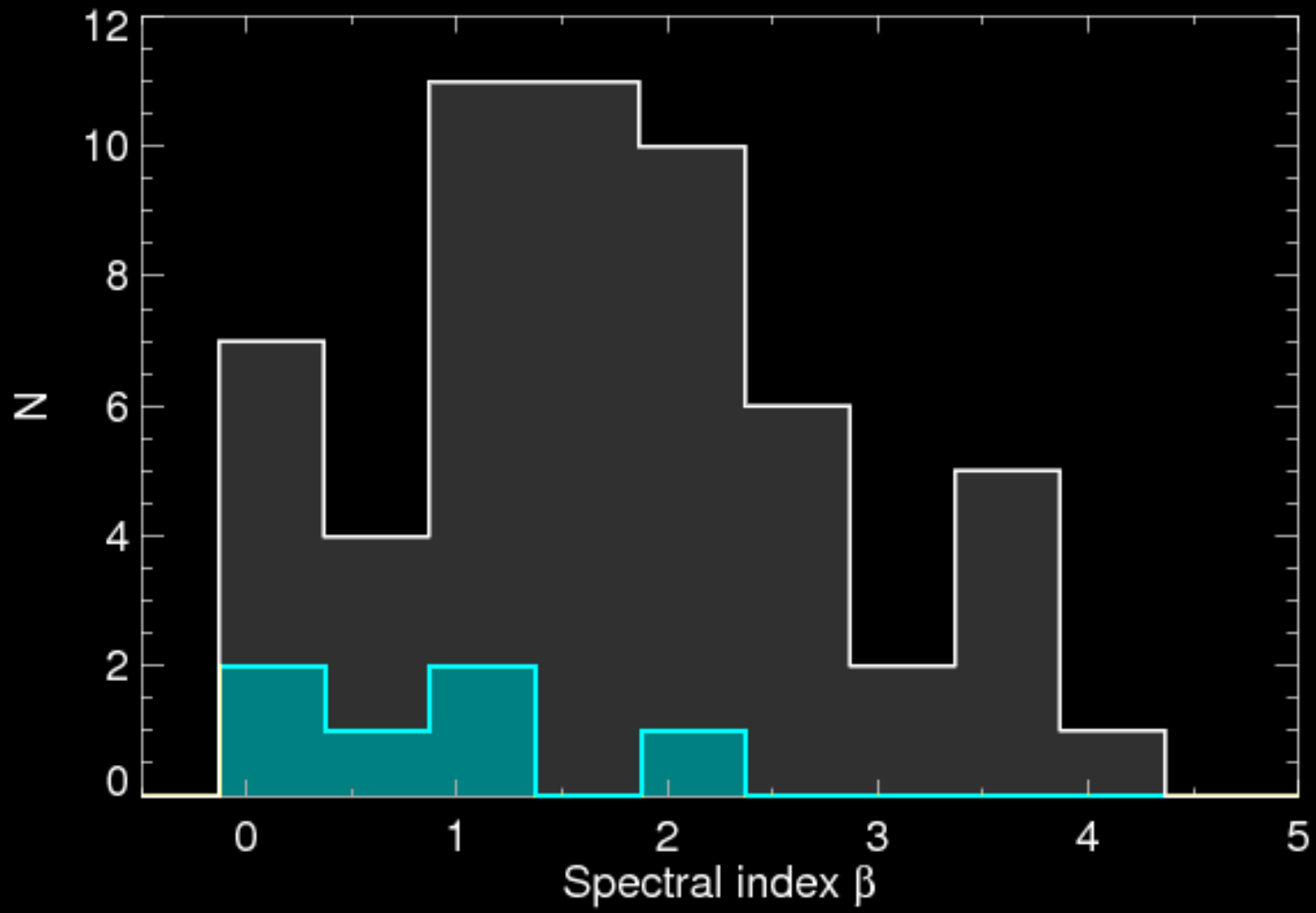
Soft long-duration GRBs: E_{peak} < 30 keV

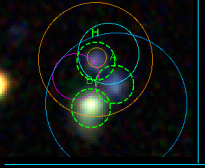




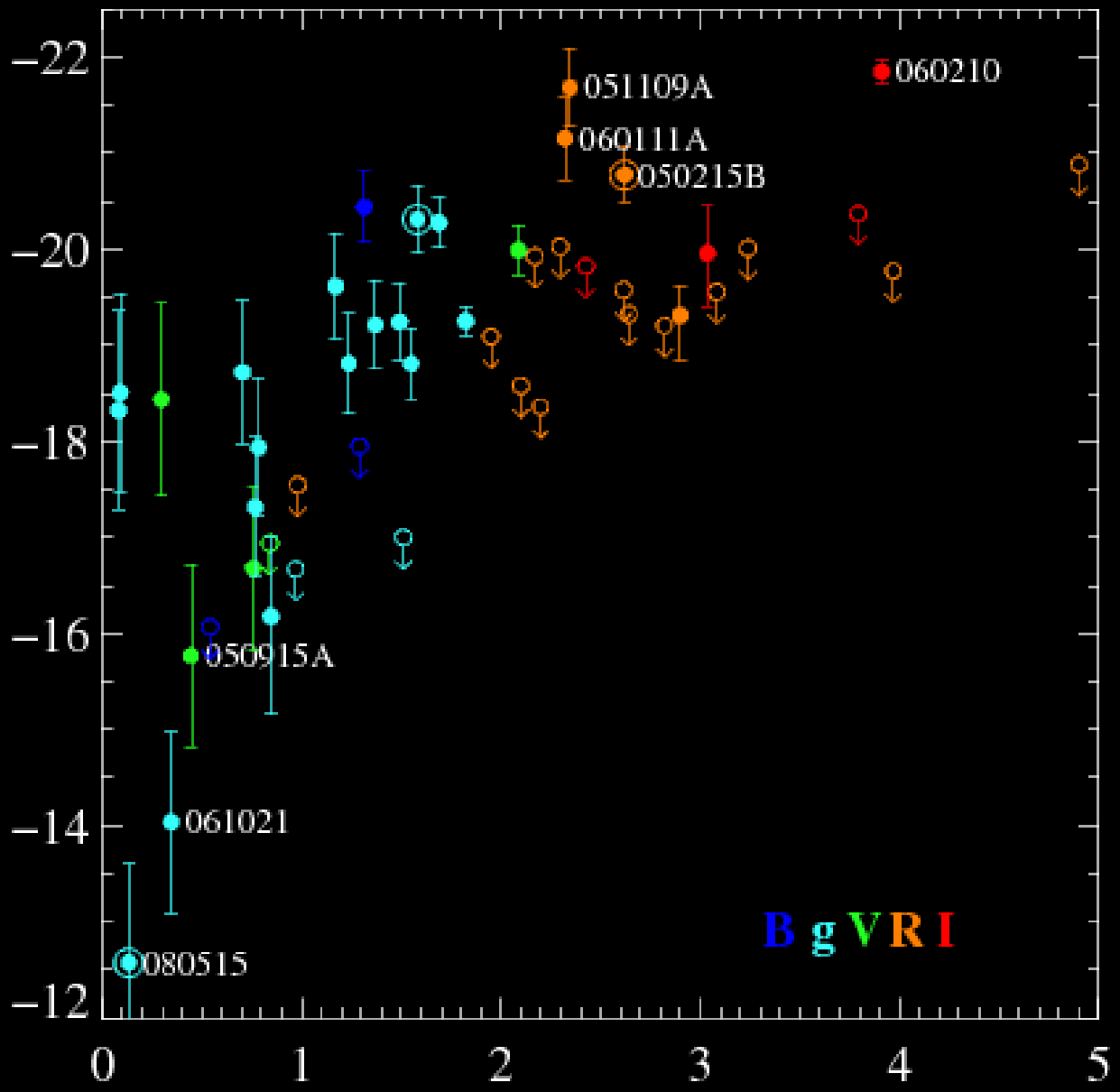


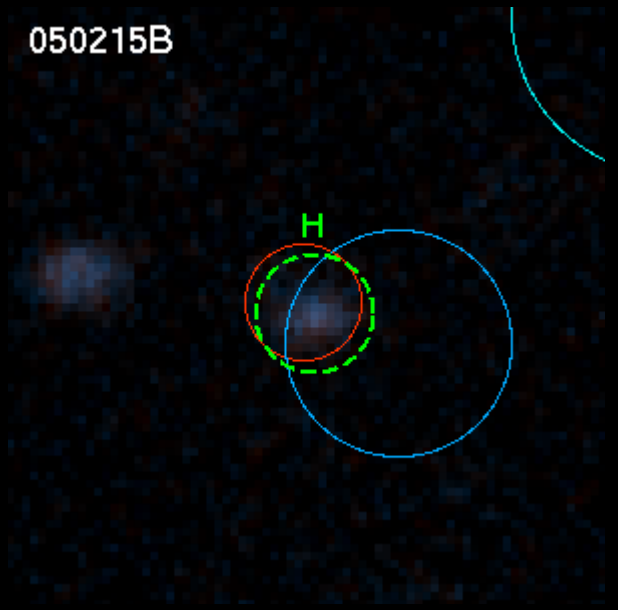
XRF Colors

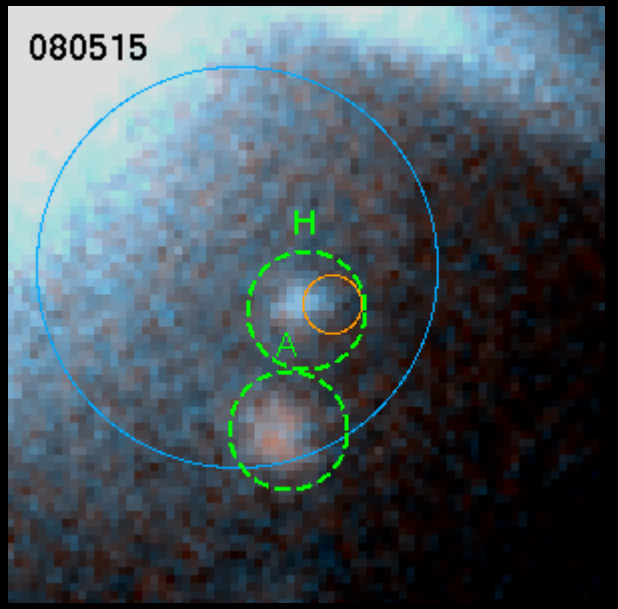




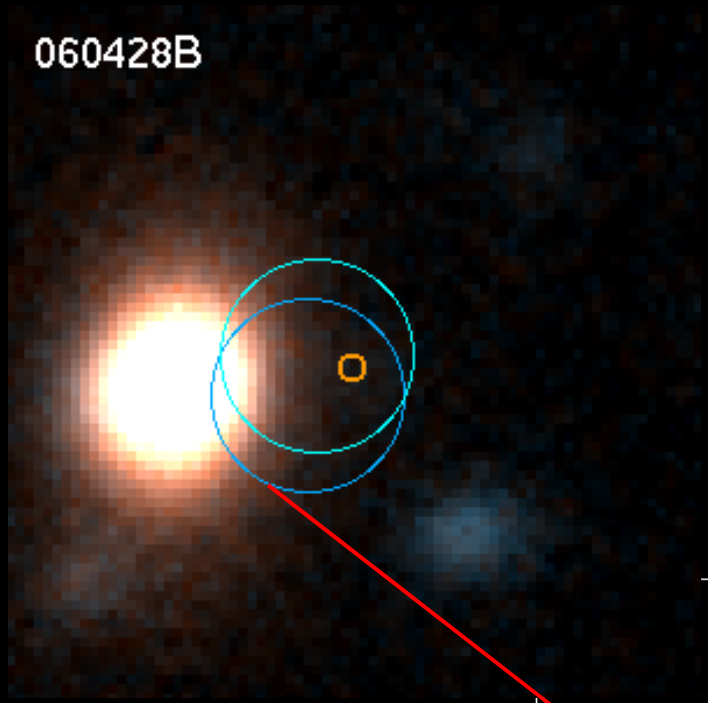
XRF Luminosities



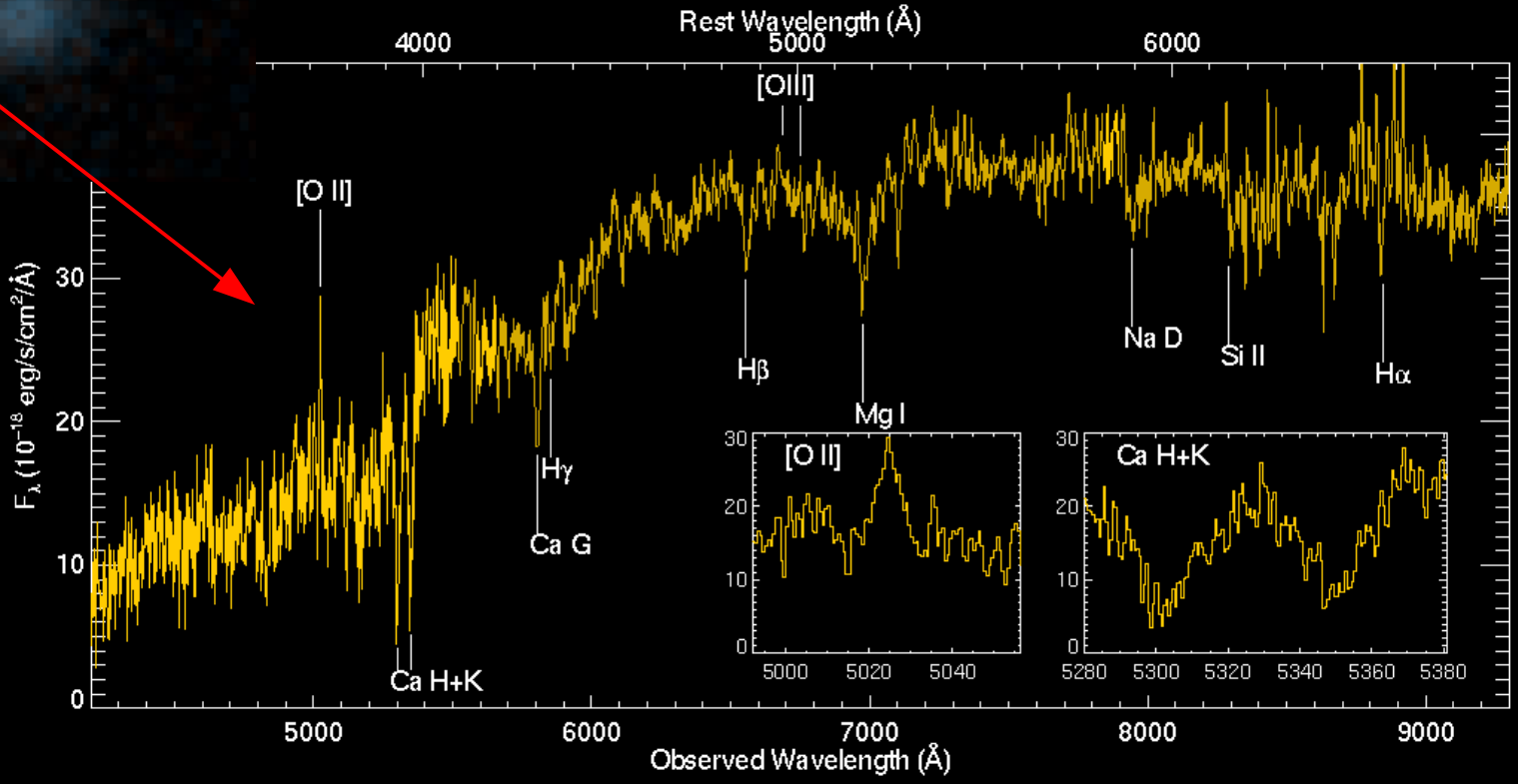




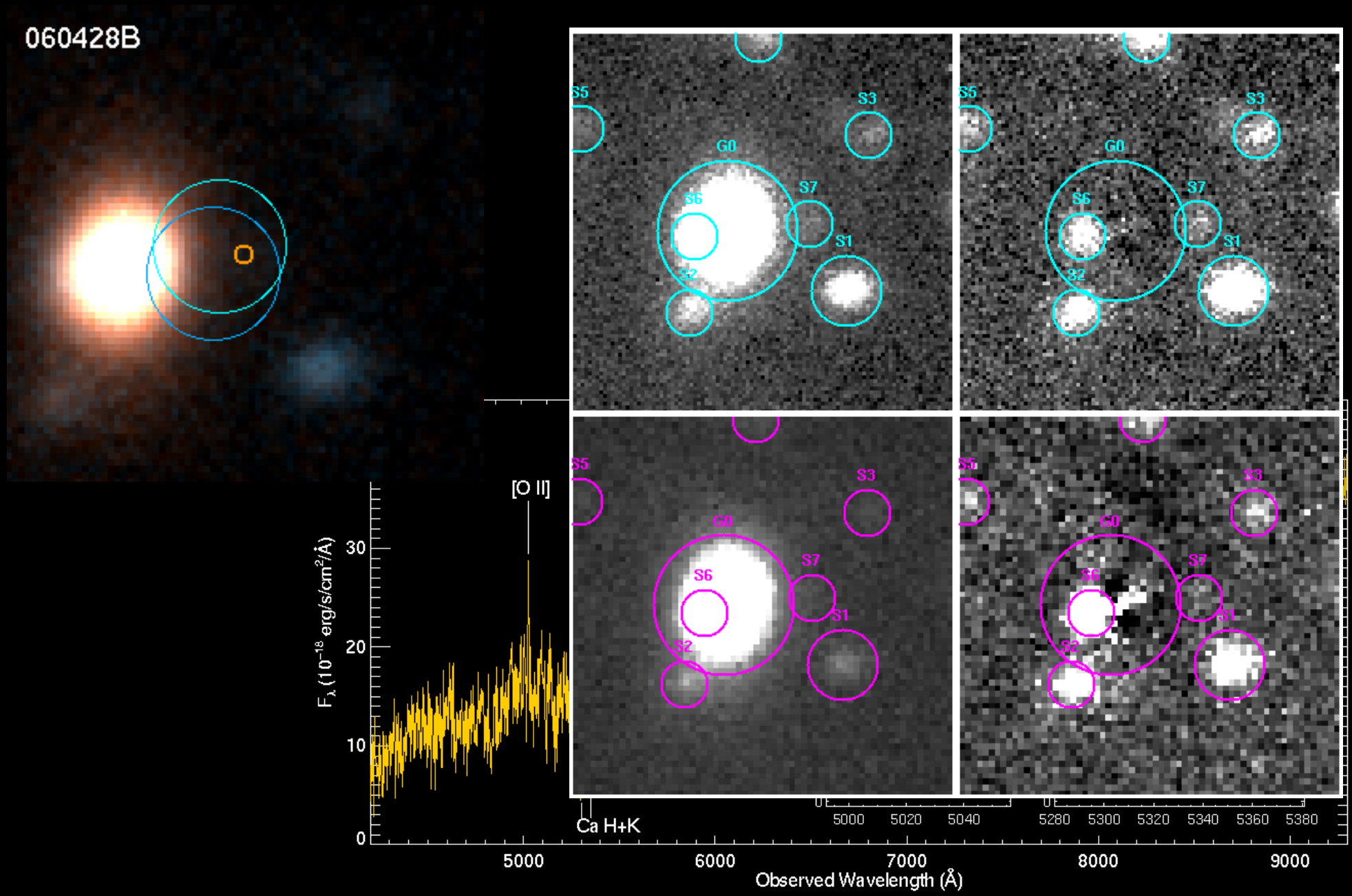
XRF 060428B



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



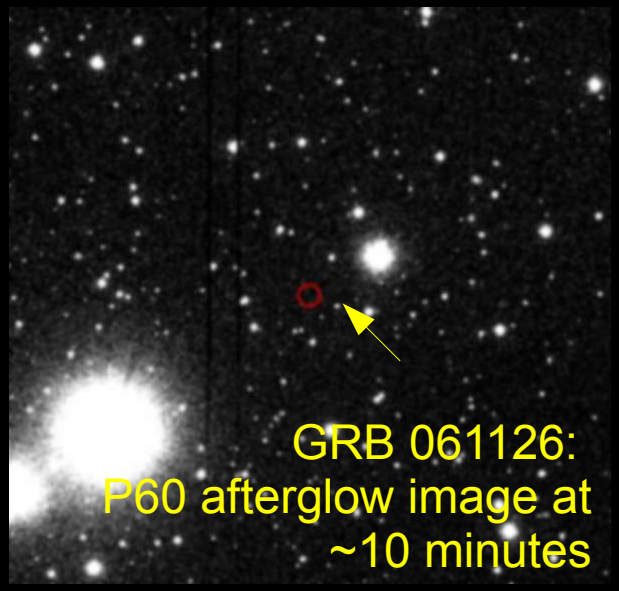
XRF 060428B


060428B
S5
S3
G0
S7
S6
S1
S2
[O II]
Ca H+K
F_λ (10^{-18} erg/s/cm^2/Å)
Observed Wavelength (Å)

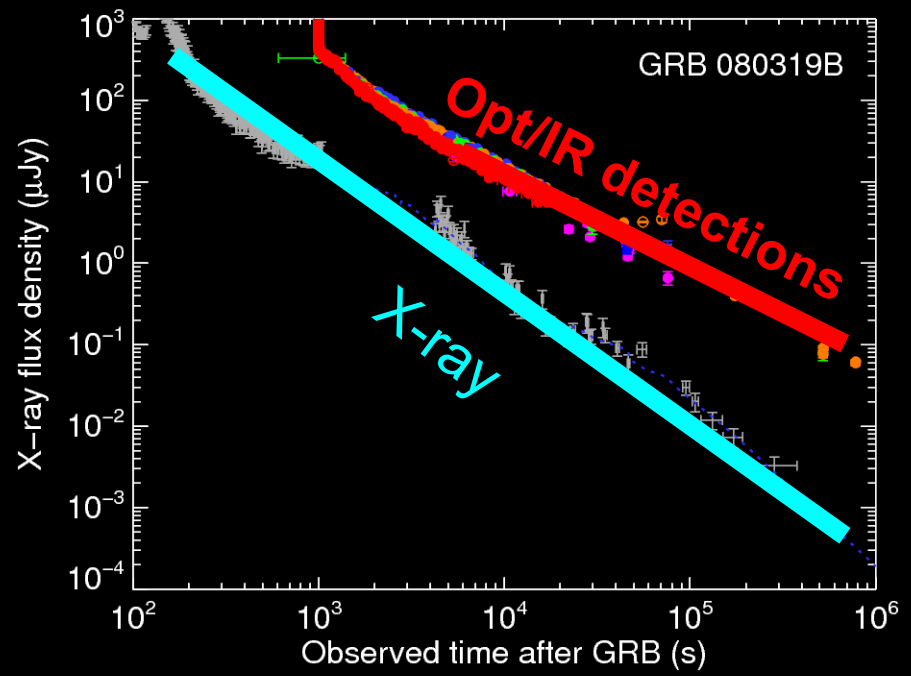
Dark GRBs

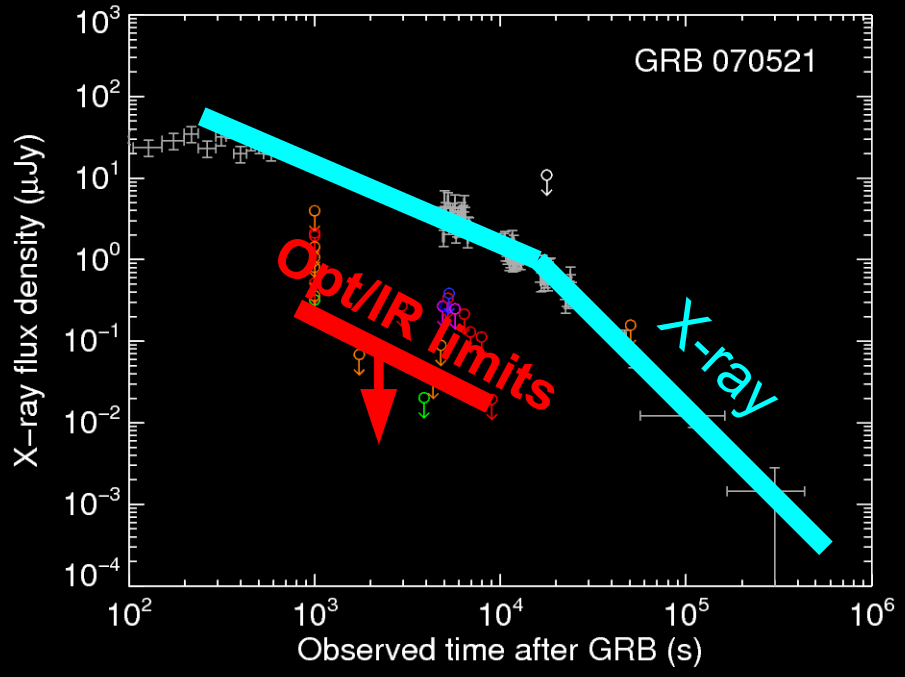
Dark Bursts

GRB 080319B:
P60 afterglow image at
~10 minutes

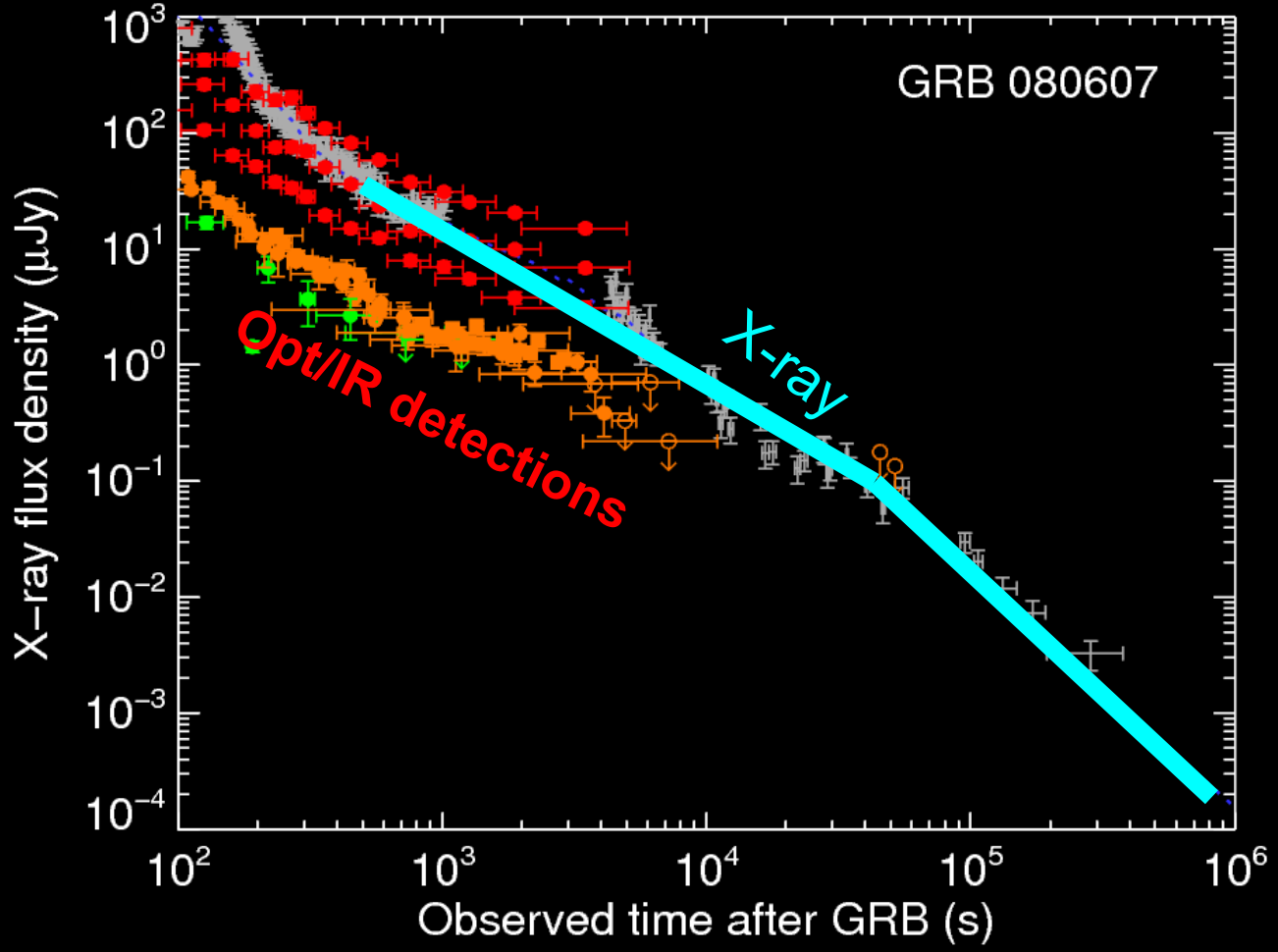


GRB 061126:
P60 afterglow image at
~10 minutes

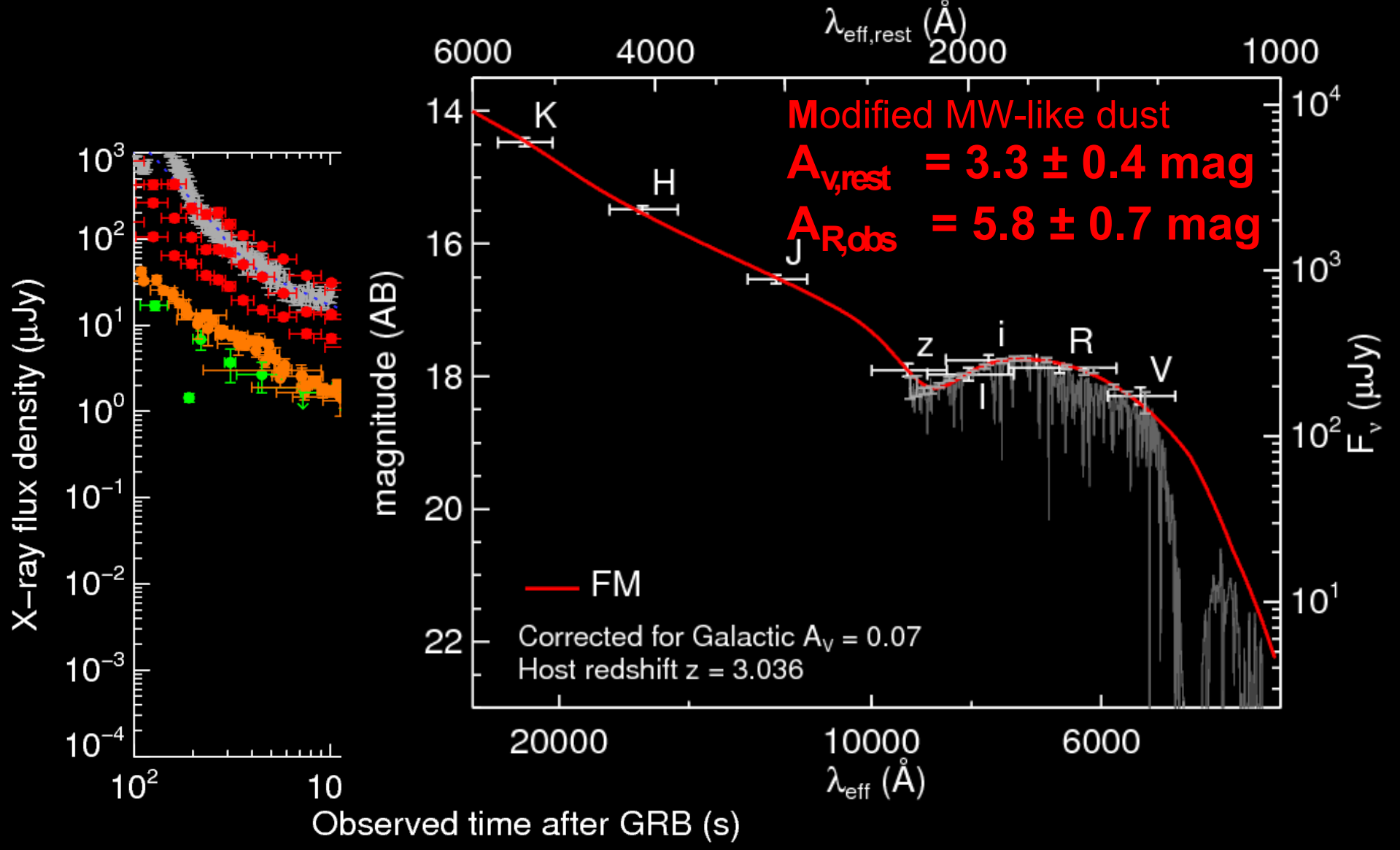




Dark Bursts


GRB 080607
X-ray
Opt/IR detections
X−ray flux density (μJy)
Observed time after GRB (s)
10^3
10^2
10^1
10^0
10^{-1}
10^{-2}
10^{-3}
10^{-4}
10^2
10^3
10^4
10^5
10^6

Dark Bursts


Modified MW-like dust
$A_{V,rest}$ = 3.3 ± 0.4 mag
$A_{R,obs}$ = 5.8 ± 0.7 mag
FM
Corrected for Galactic A_V = 0.07
Host redshift z = 3.036
K
H
J
z
i
R
V
I
$\lambda_{eff,rest}$ (Å)
λ_{eff} (Å)
magnitude (AB)
F_ν (μJy)
X−ray flux density (μJy)
Observed time after GRB (s)

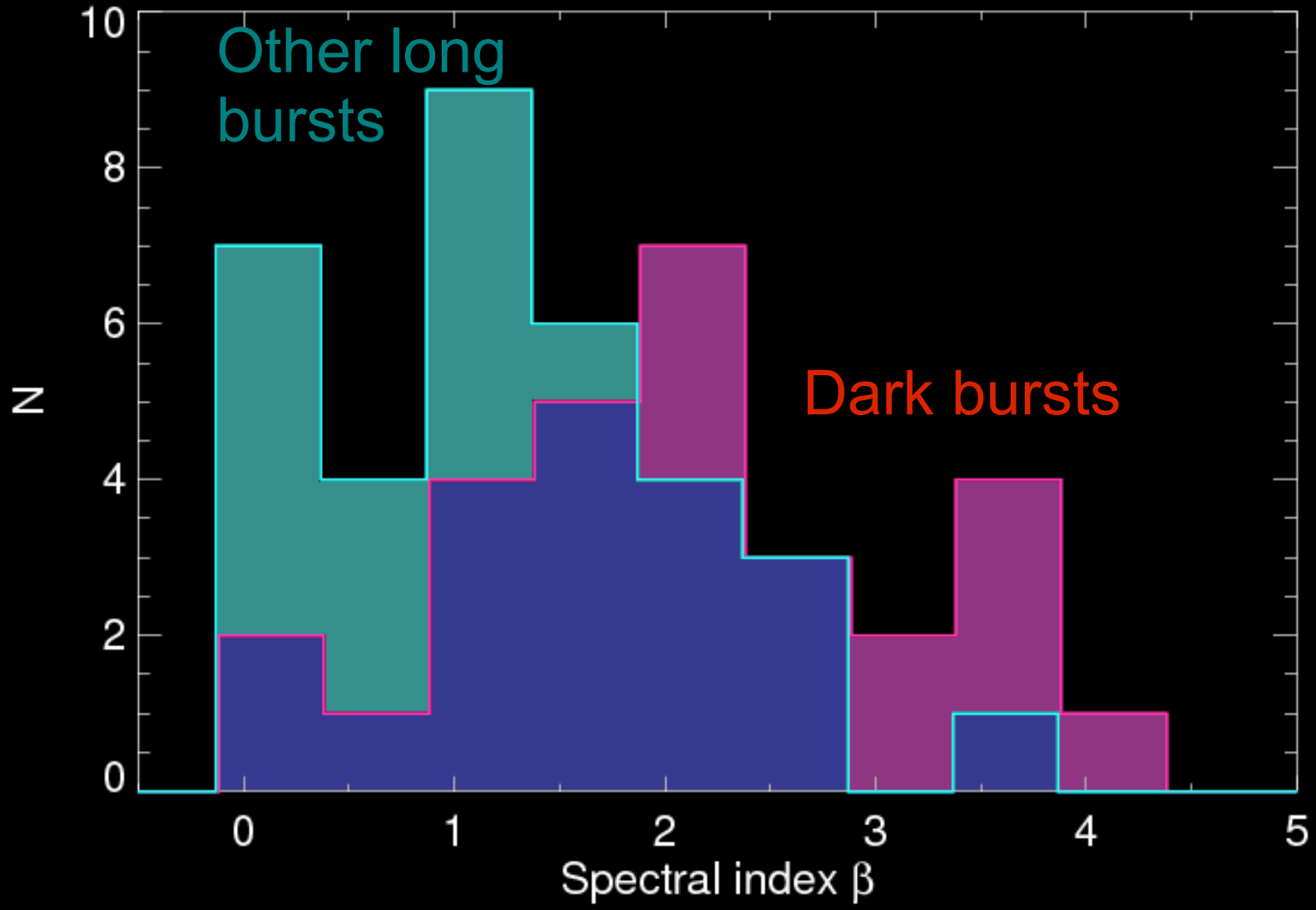
Dark Bursts

No optical afterglow or faint optical afterglow
(despite bright X-rays)
e.g., Jakobsson et al. 2004

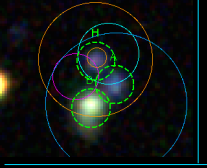
Largest component of the project
41 targets (28 detections)

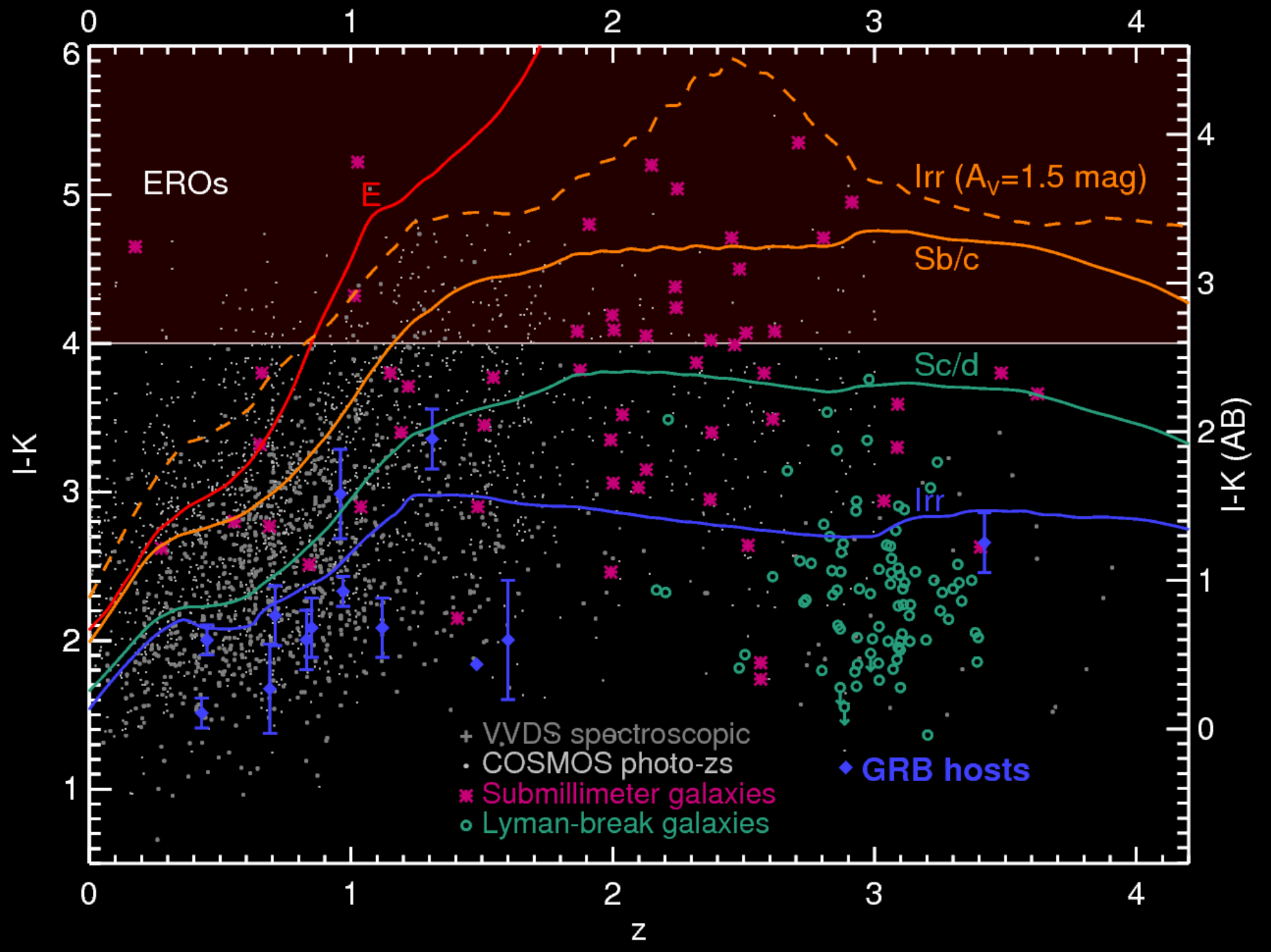
Very few pre-Swift dark GRB hosts
No other way to measure redshifts!

Dark Burst Colors

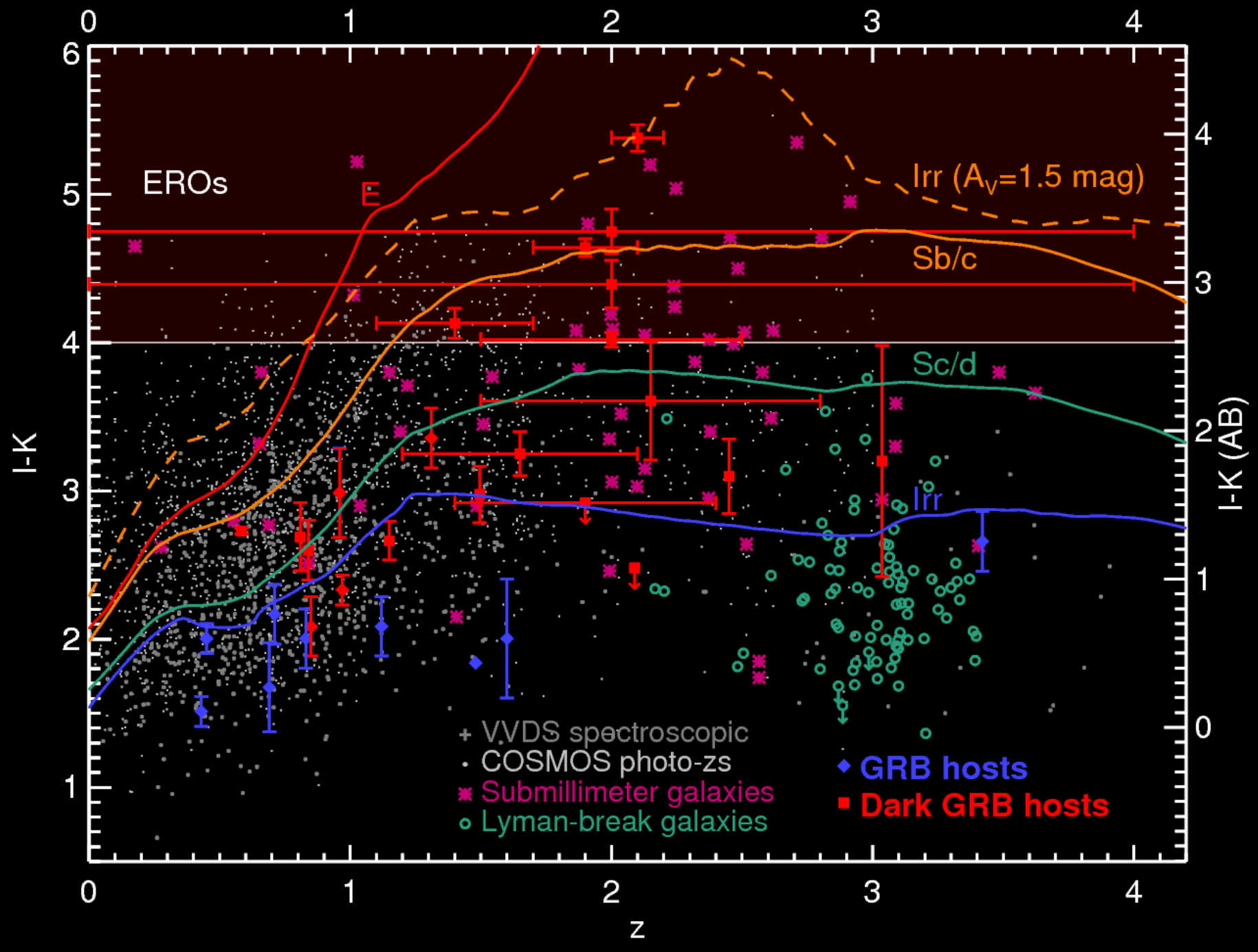


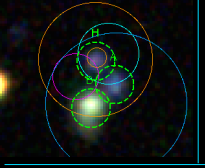
Dark Burst Opt-NIR Colors





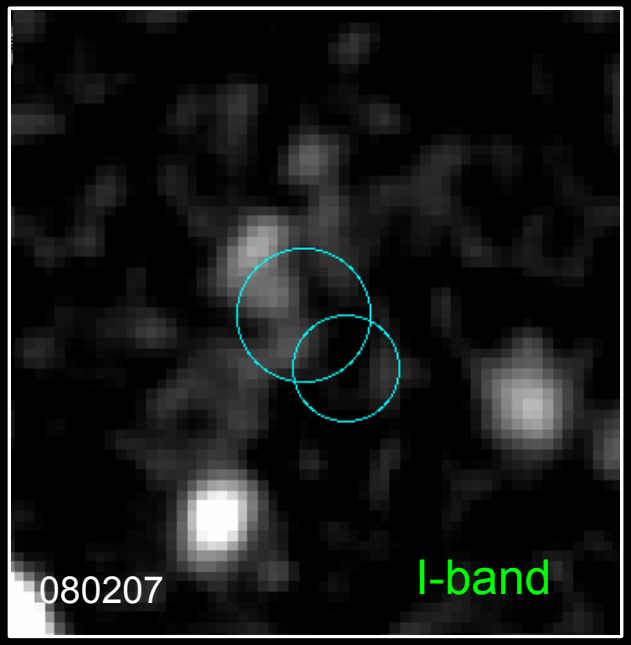
Dark Burst Opt-NIR Colors

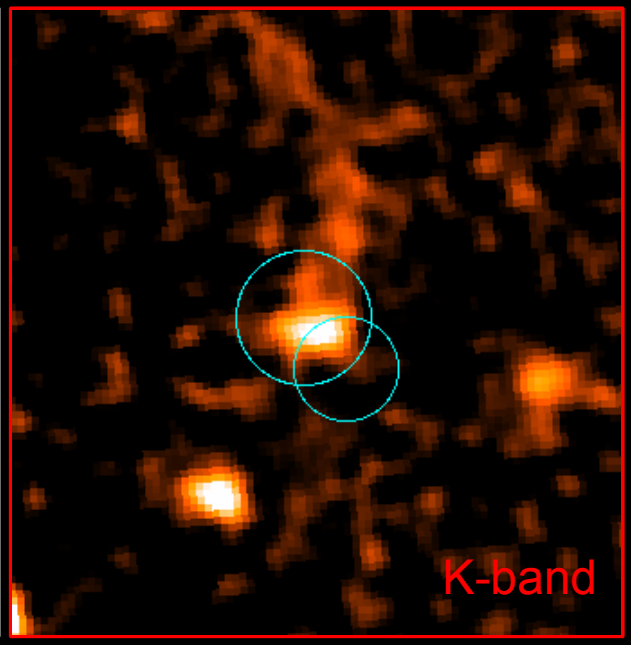


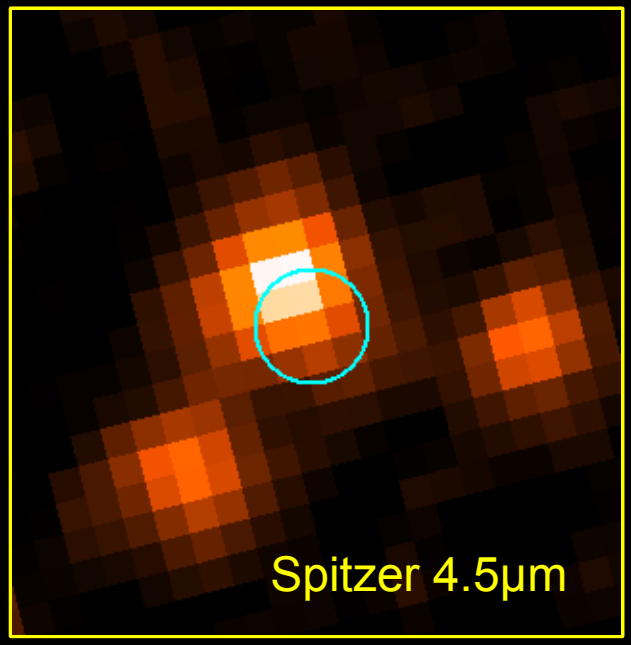


Spitzer Detections

Dark GRB 080207







Fairly dark burst with...

Extremely **red** host:

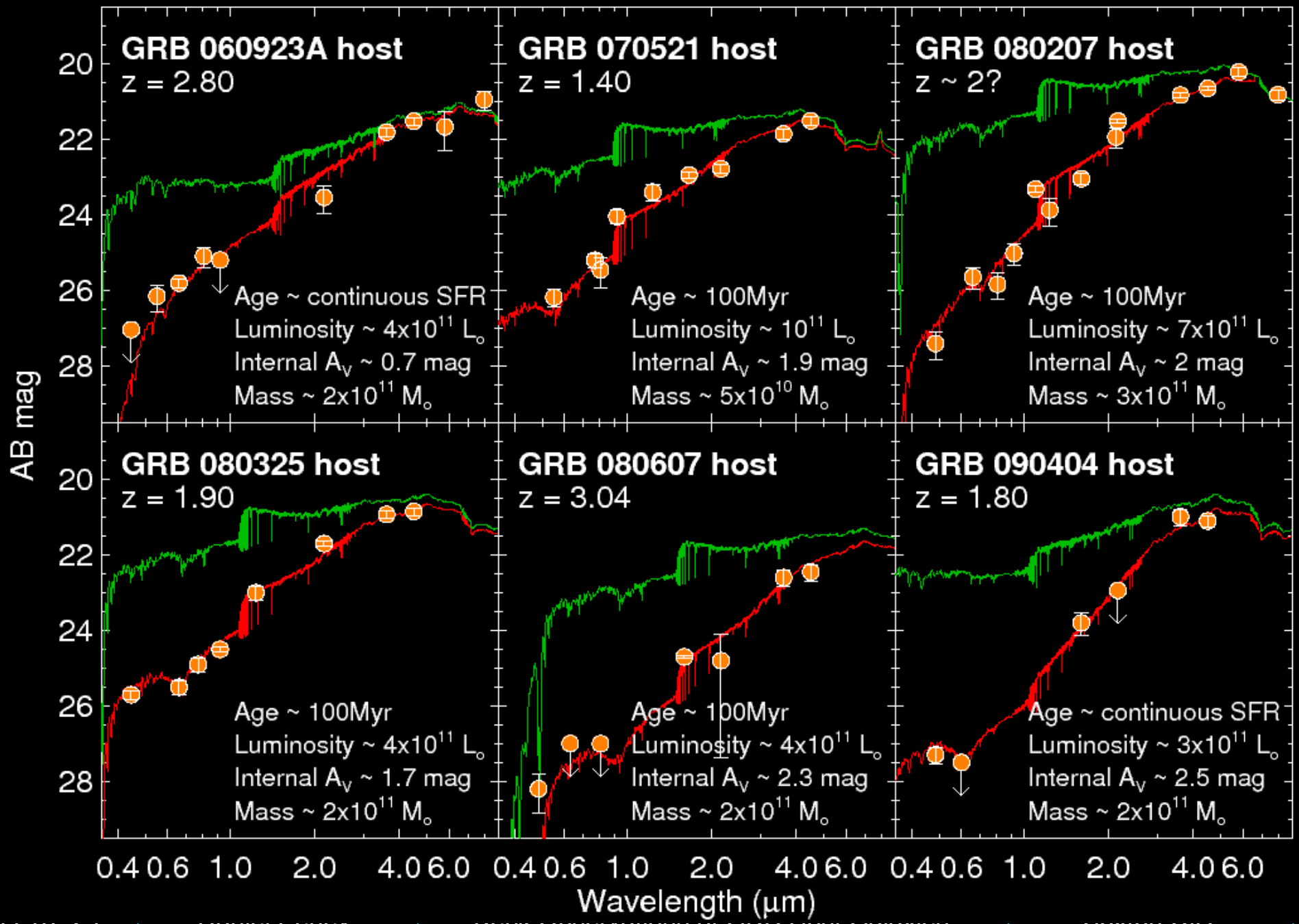
I-K ~ 5.5 mag

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

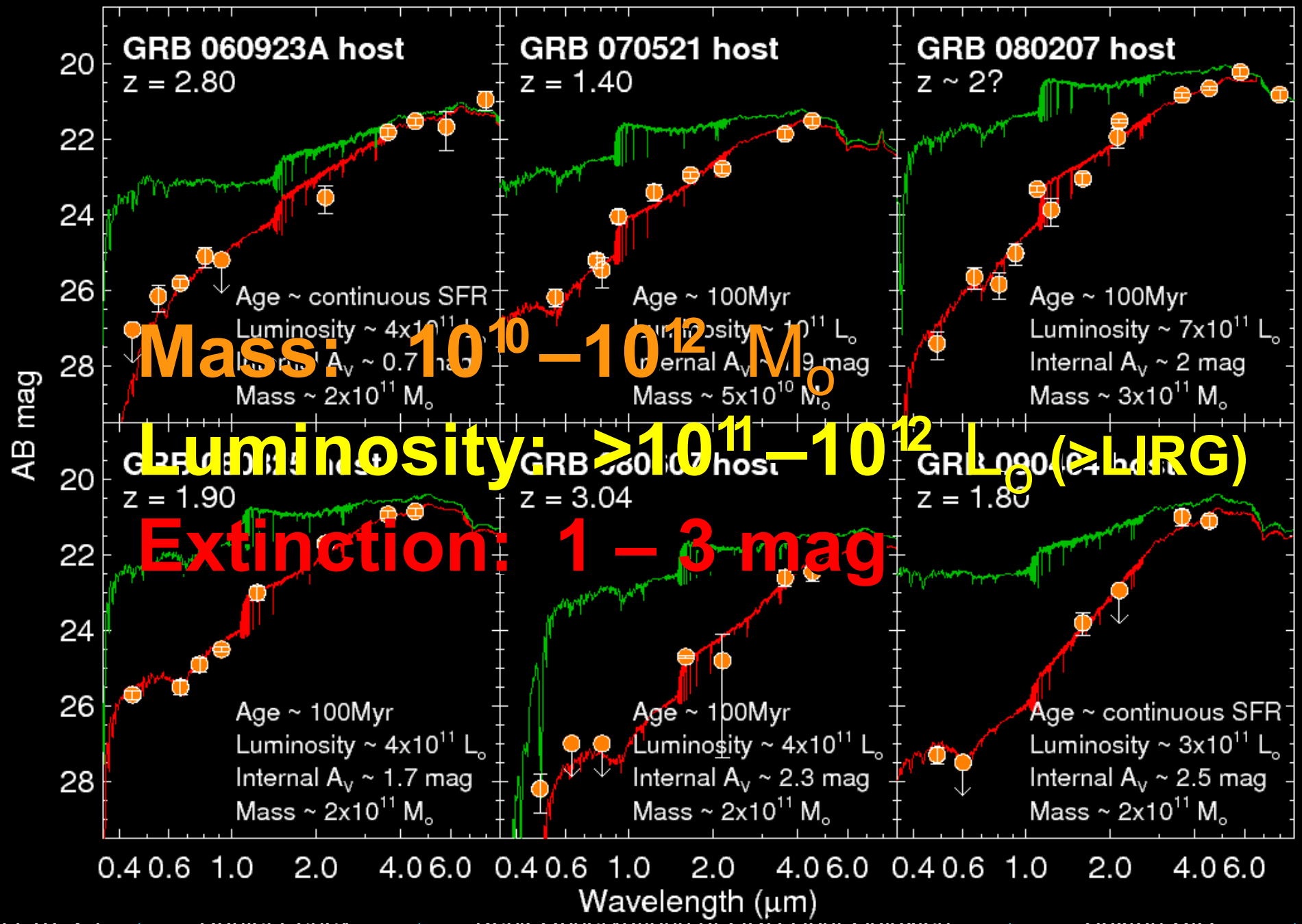
Optically faint, *z* unknown

(photo-z~2.1 from Svensson et al. in prep)

Other Red Dark Burst Hosts



Other Red Dark Burst Hosts

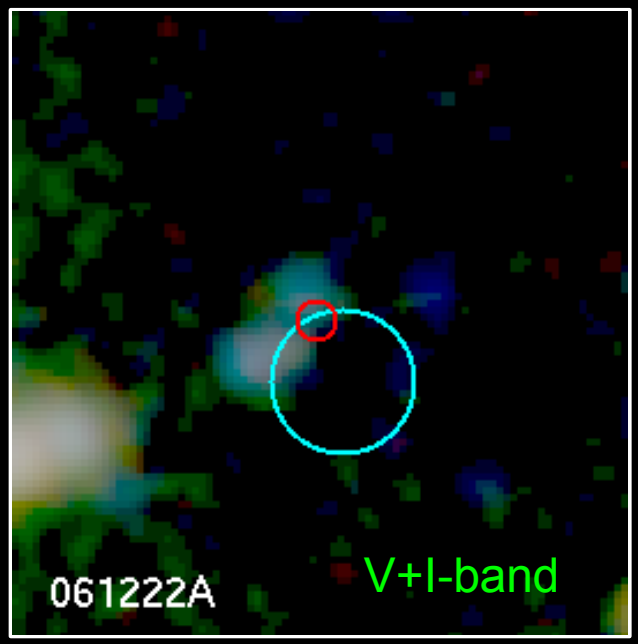


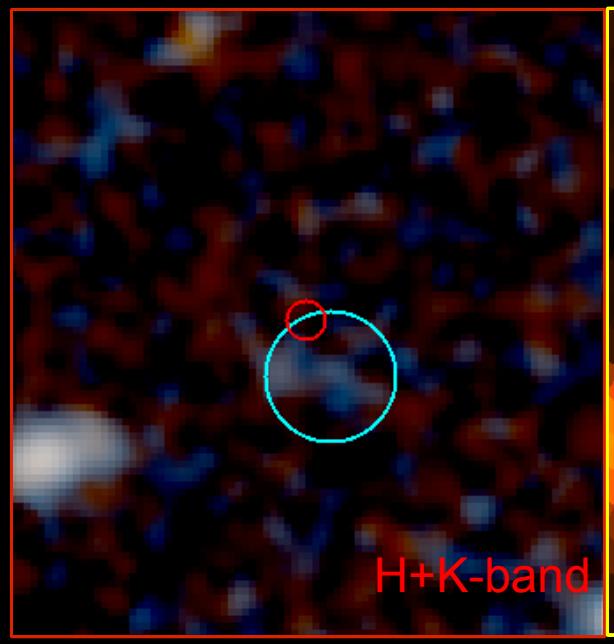
Mass: 10^{10} – 10^{12} $M_\odot$

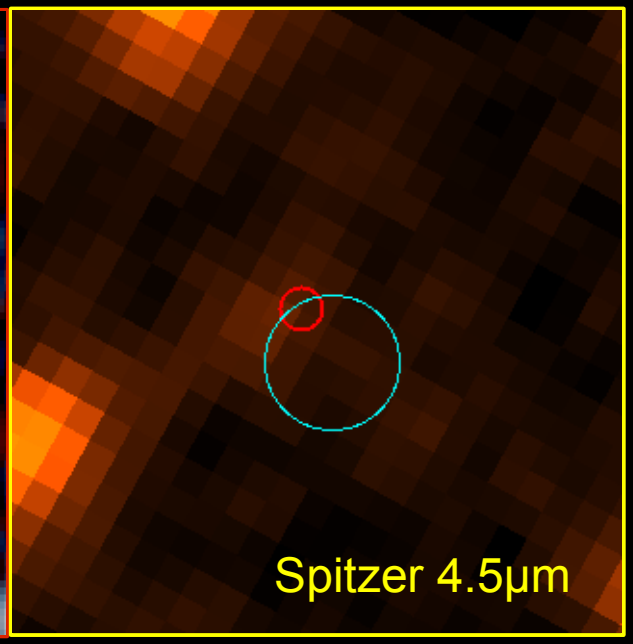
Luminosity: $\geq 10^{11}$ – 10^{12} $L_\odot$ (>LIRG)

Extinction: 1 – 3 mag

Dark GRB 061222A







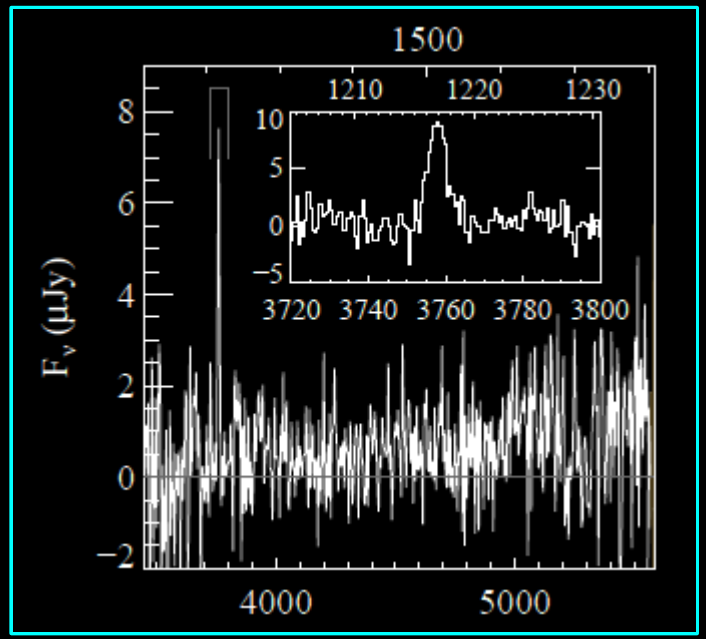
Ultra-dark burst (Av > 5 mag), but

Extremely blue host:

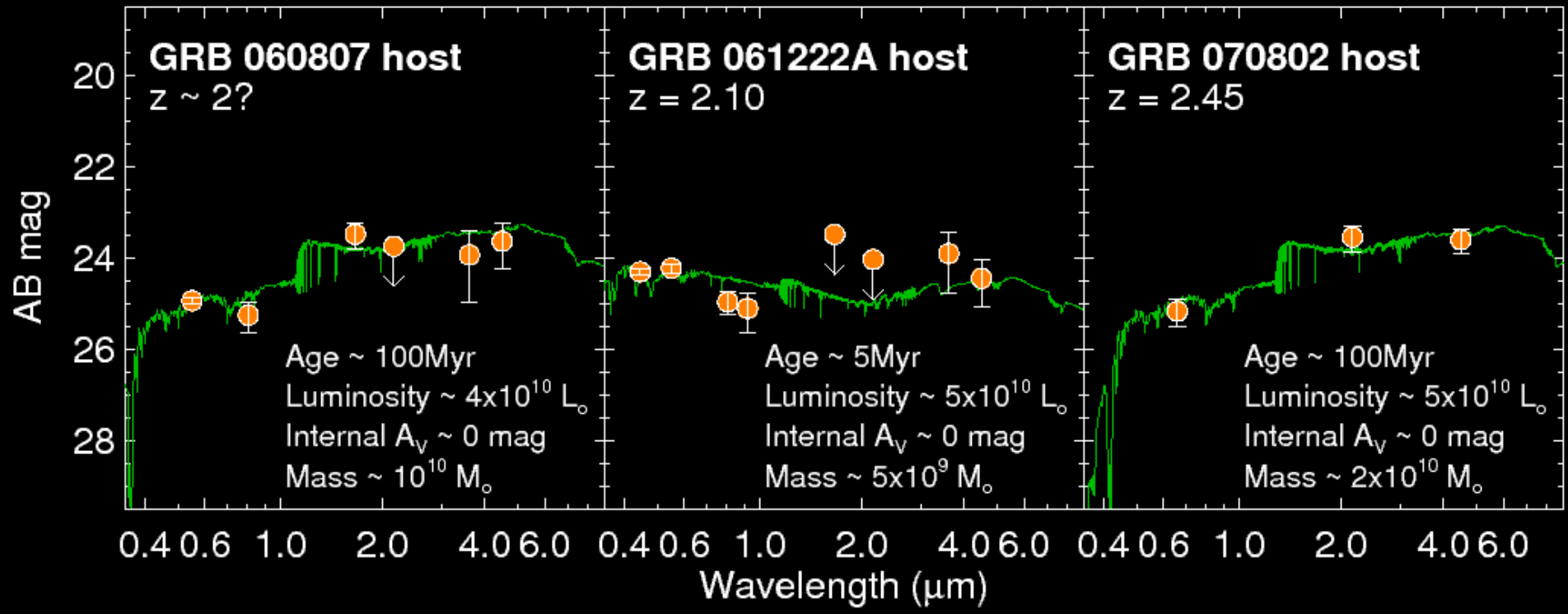
I-K ~ 2 mag

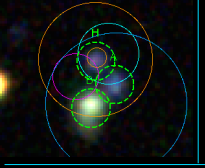
marginal or no Spitzer detection

Ly-α emitter at z=2.1

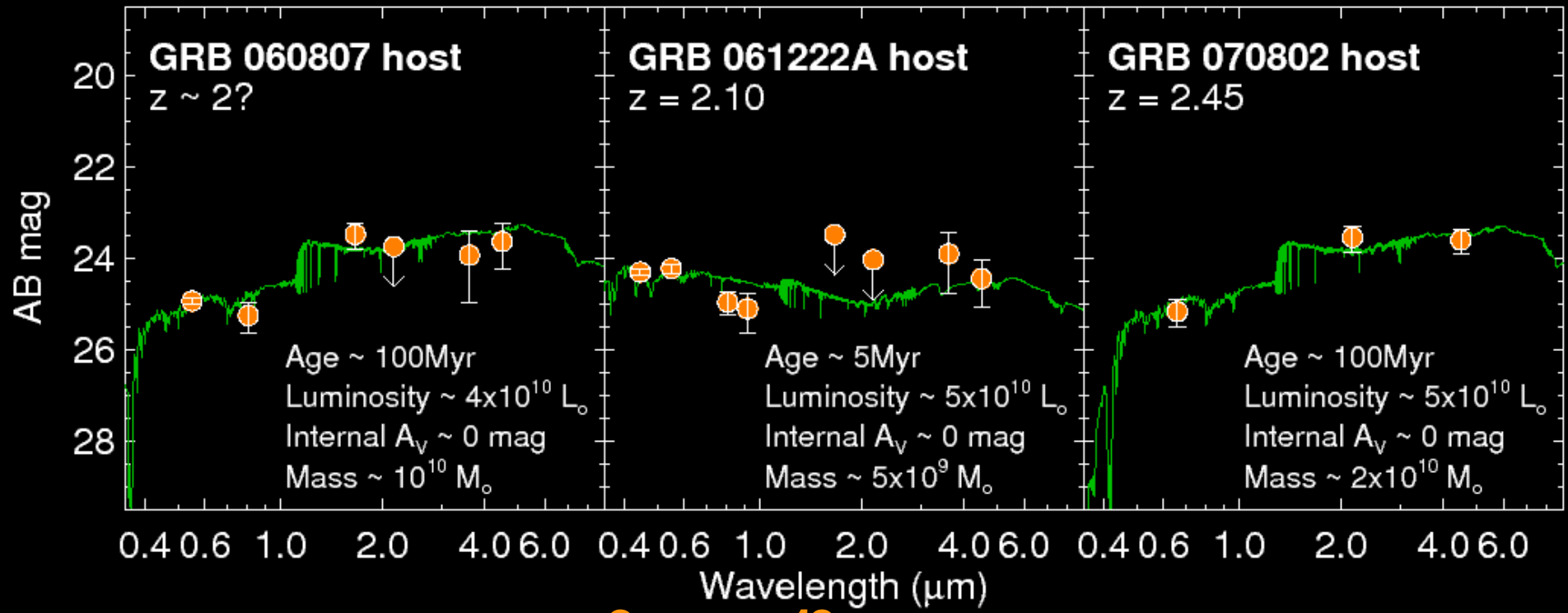


Other Blue Dark GRB Hosts





Other Blue Dark GRB Hosts

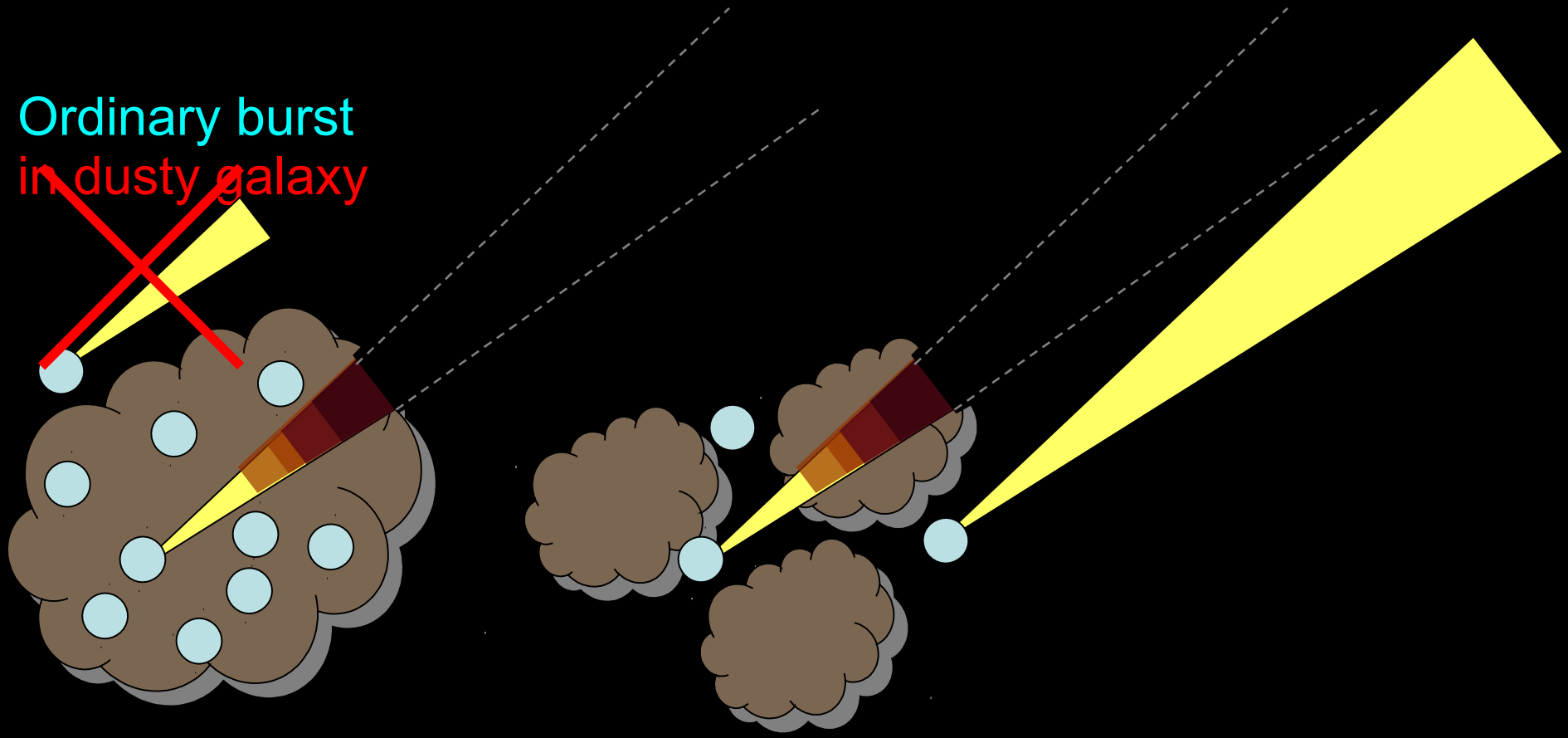


Mass: 10^9–10^{10} M_o

Luminosity: 10^{10}–10^{11} L_o

Extinction: negligible

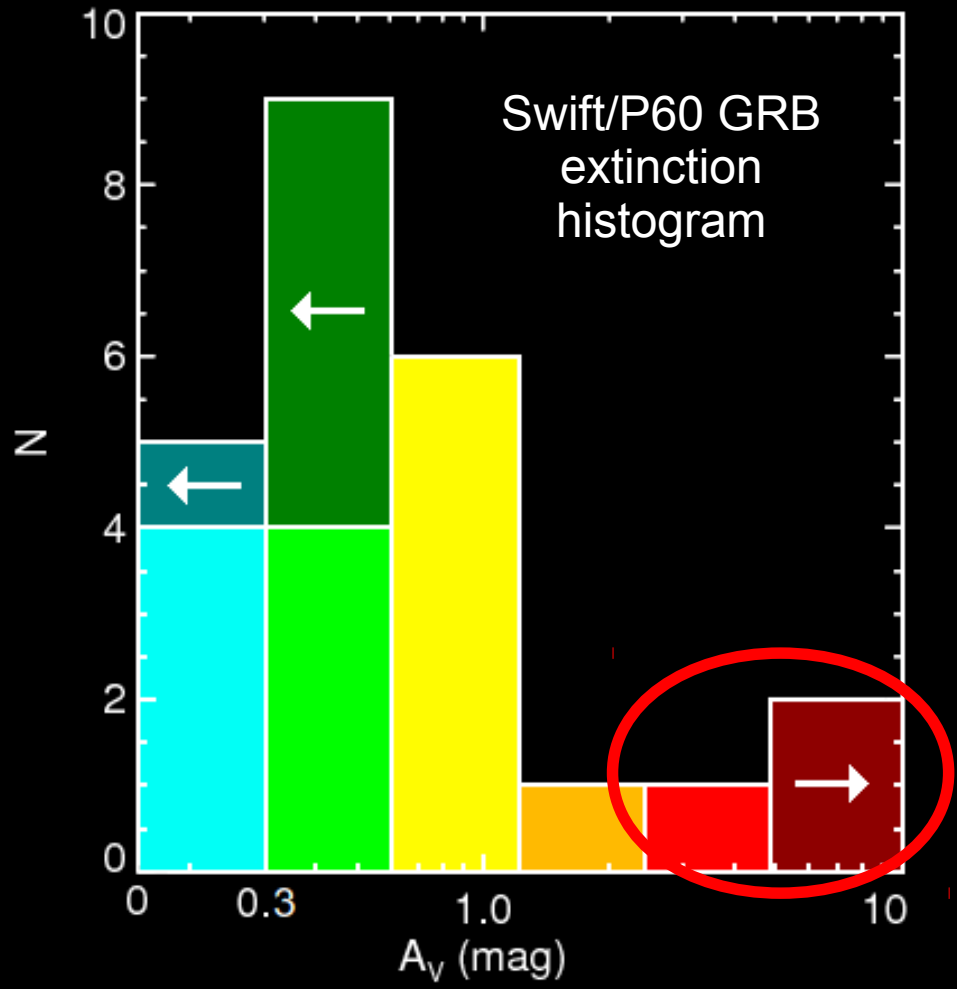
Dust in GRB Hosts

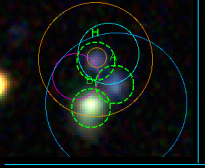


Swift Extinction Distribution

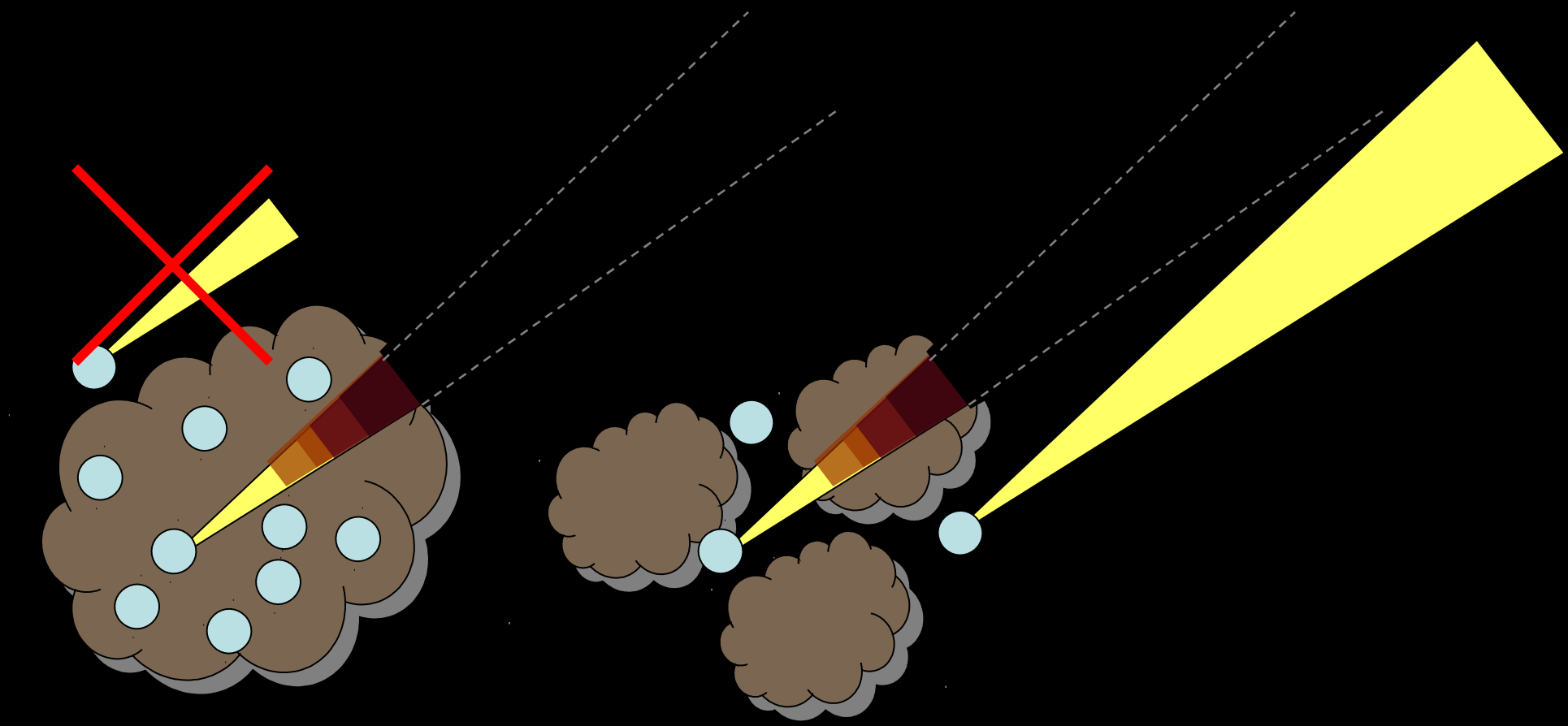
GRBs as pure star formation tracers after all?

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





Dust in GRB Hosts



Dark burst in dusty galaxy

~8%

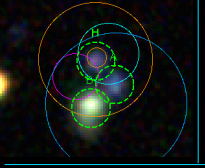
Dark burst in ordinary galaxy

~7%

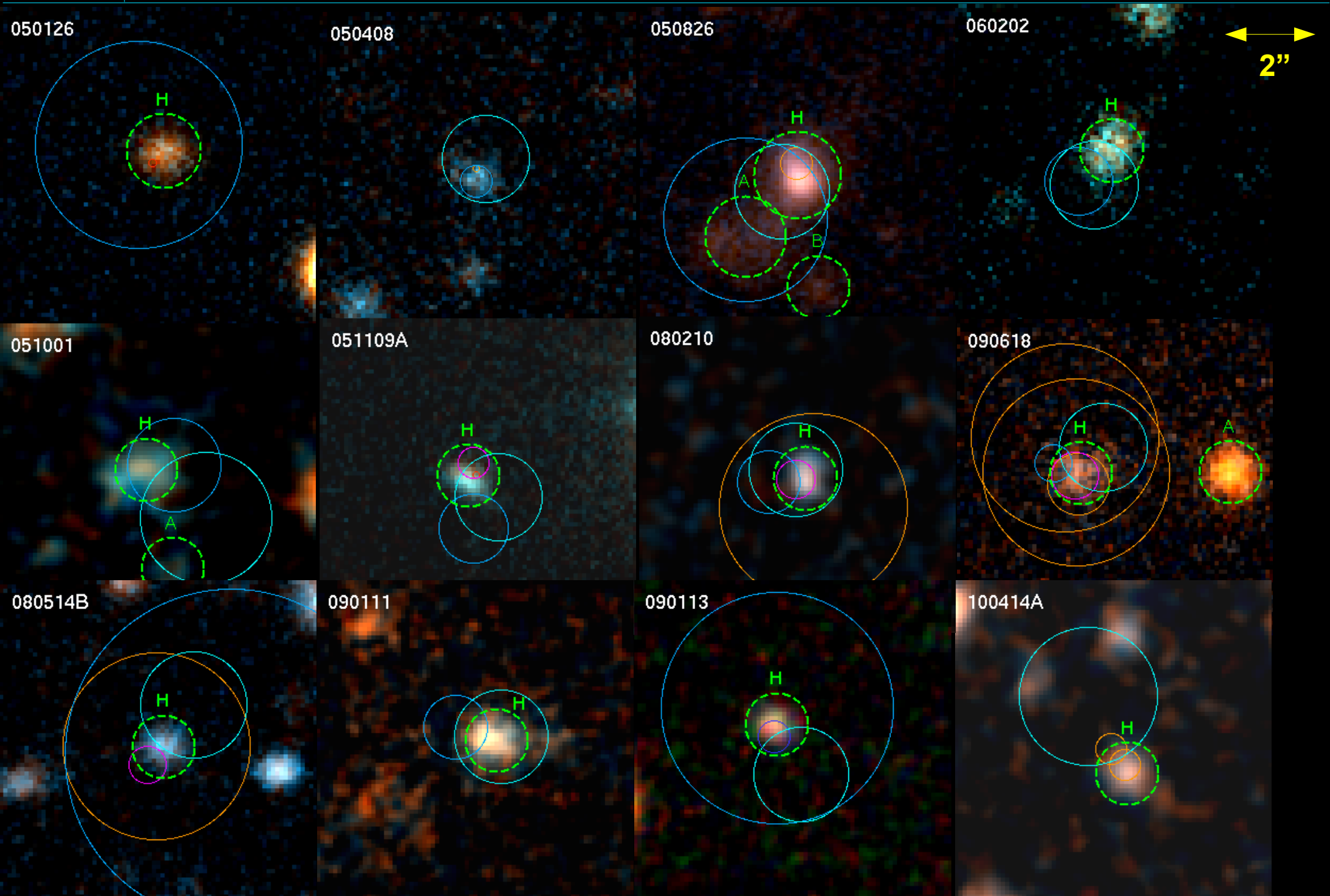
Ordinary burst in ordinary galaxy

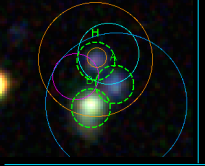
~85%

Other Highlights



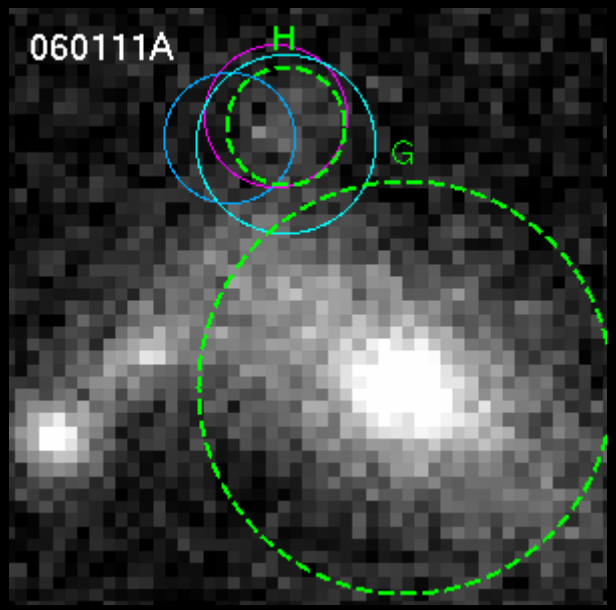
“Morphology”

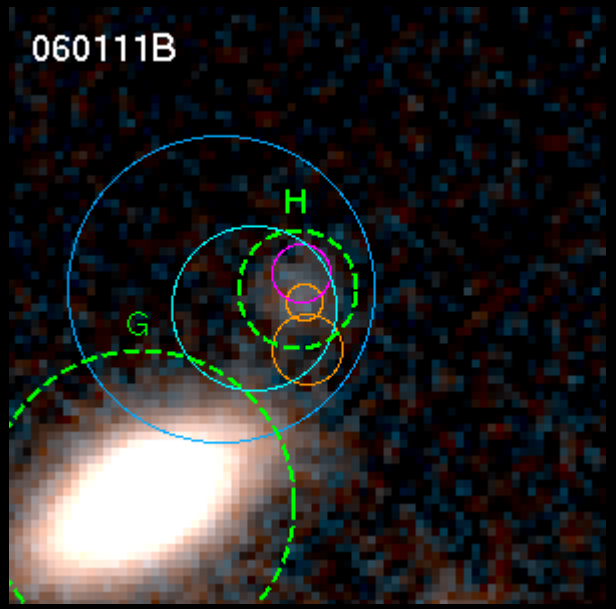

050126
H
050408
050826
H
A
B
060202
H
2”
051001
H
A
051109A
H
080210
H
090618
H
A
080514B
H
090111
H
090113
H
100414A
H

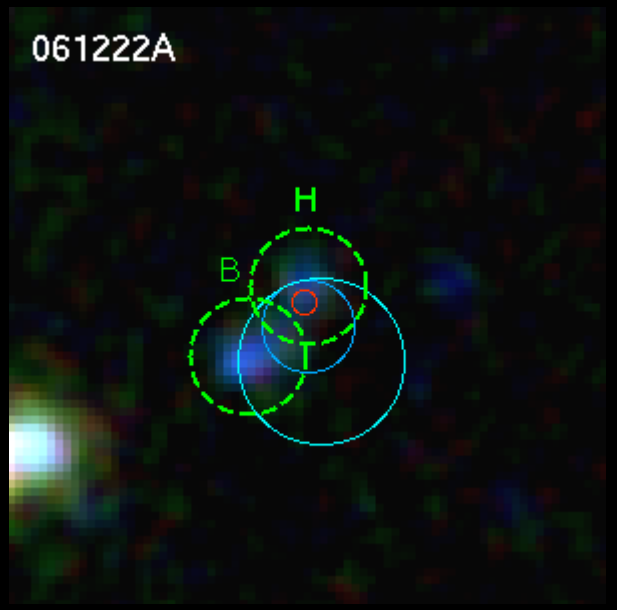


Interactions? Satellites?

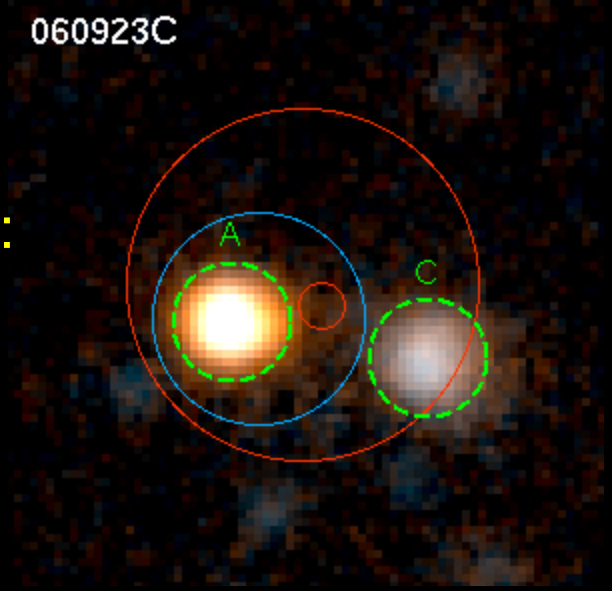
no:

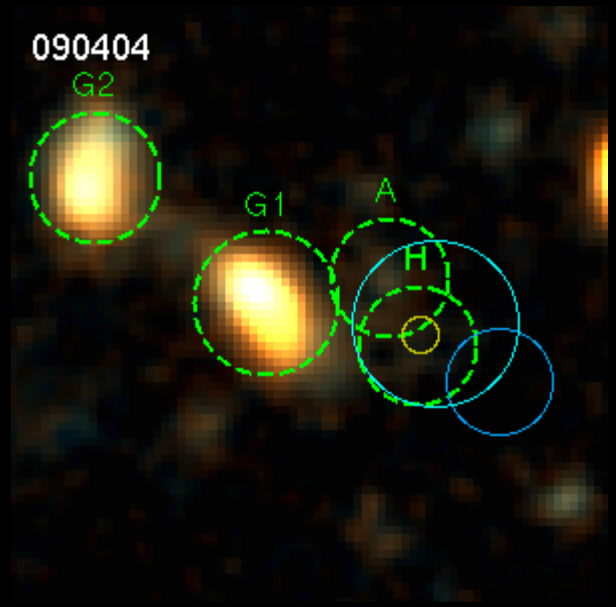


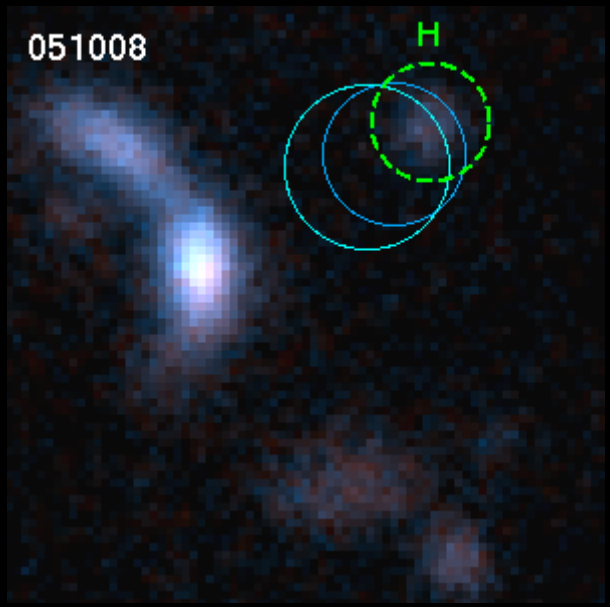




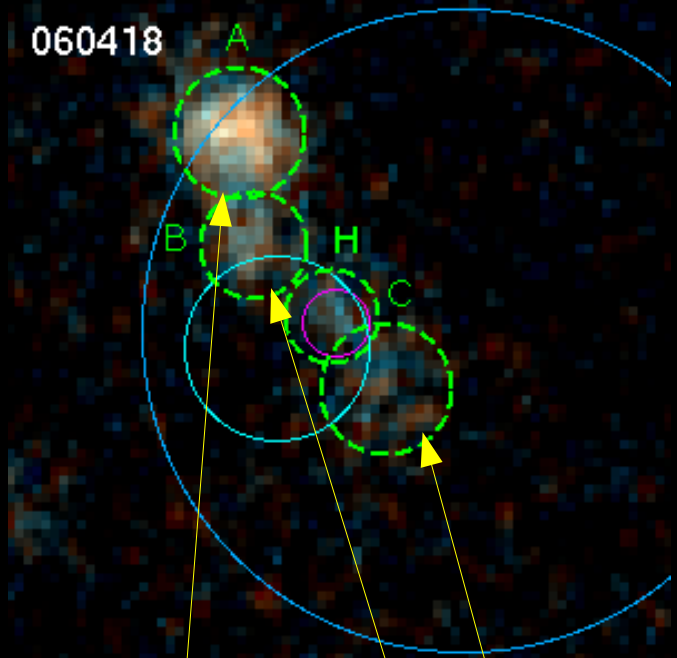
maybe:

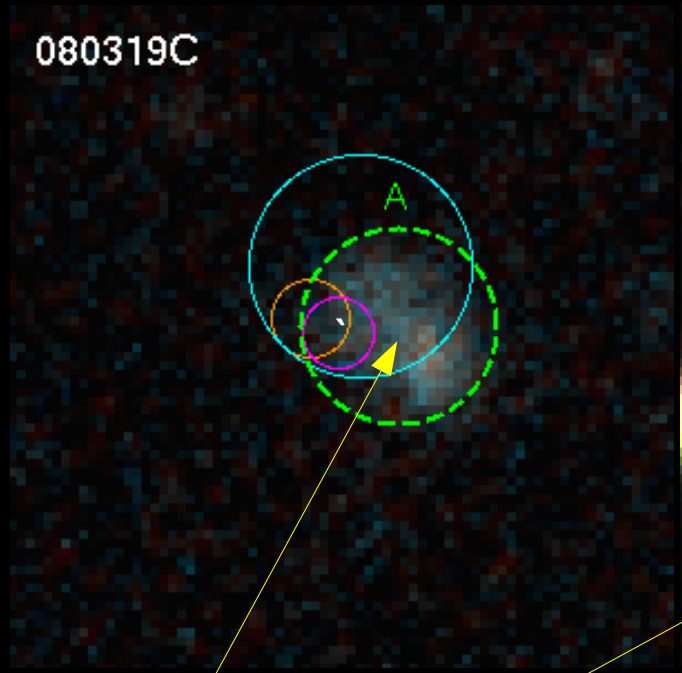


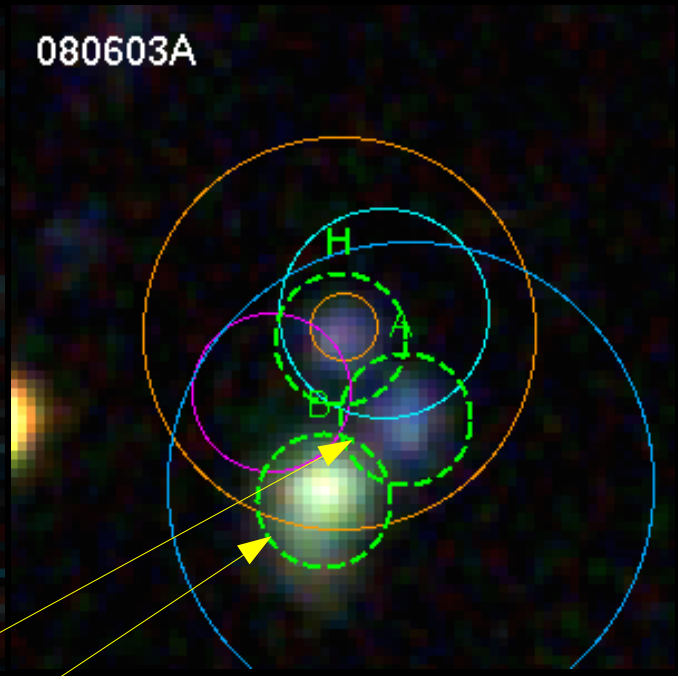


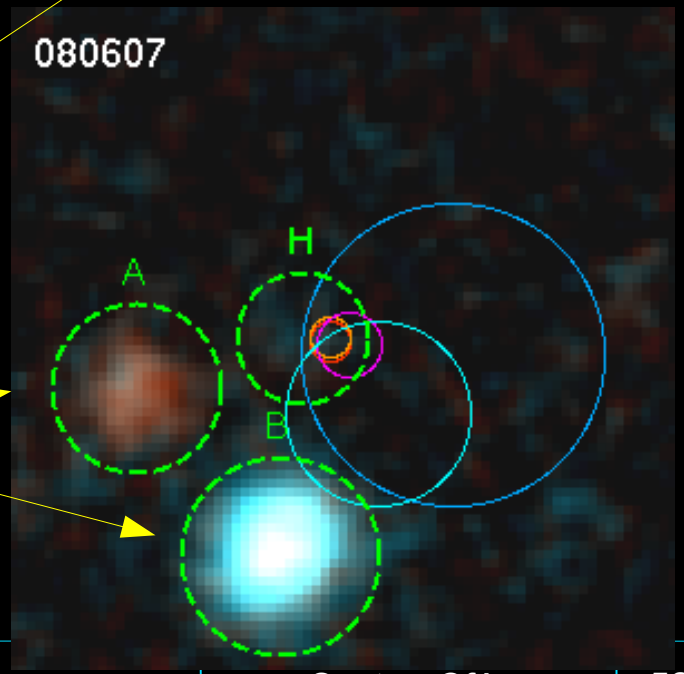


MgII Absorbers









z=0.656 absorber

z=1.107 absorber??

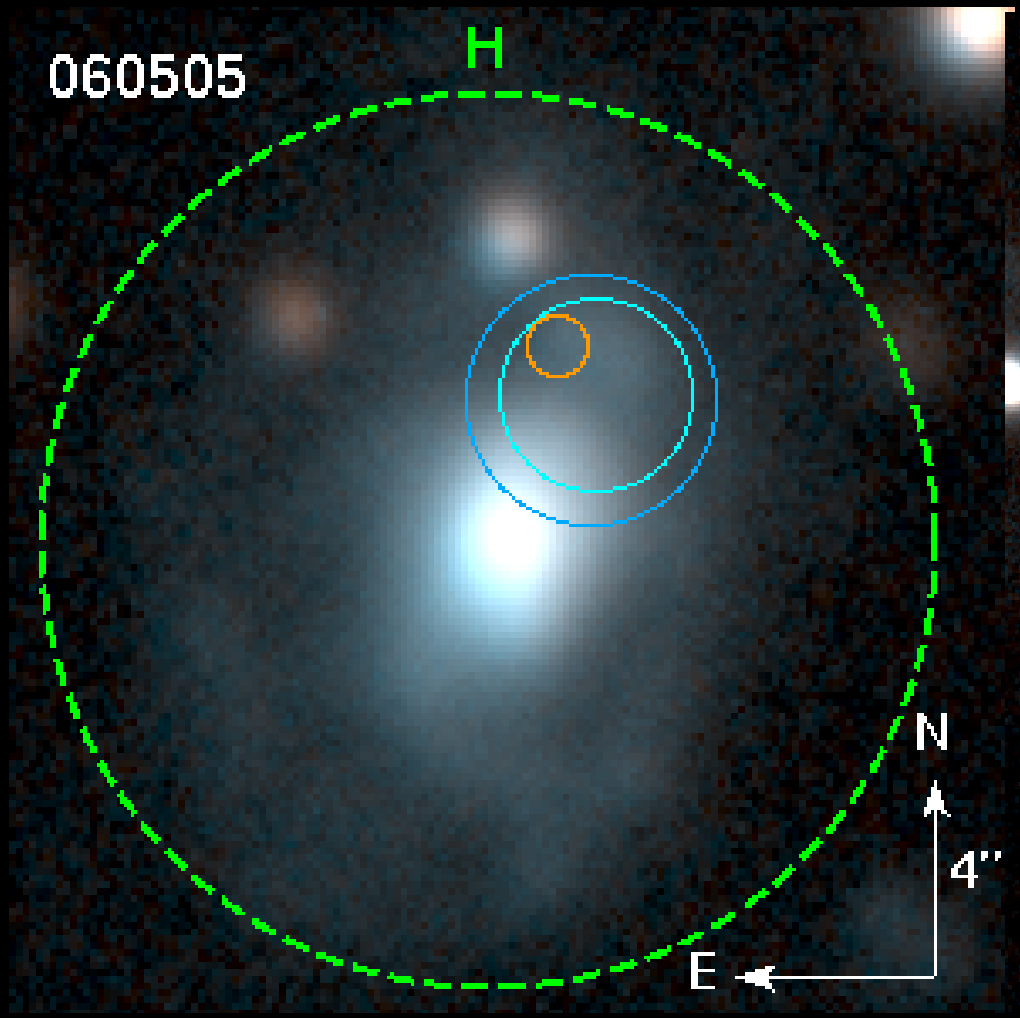
z=0.603 absorber?

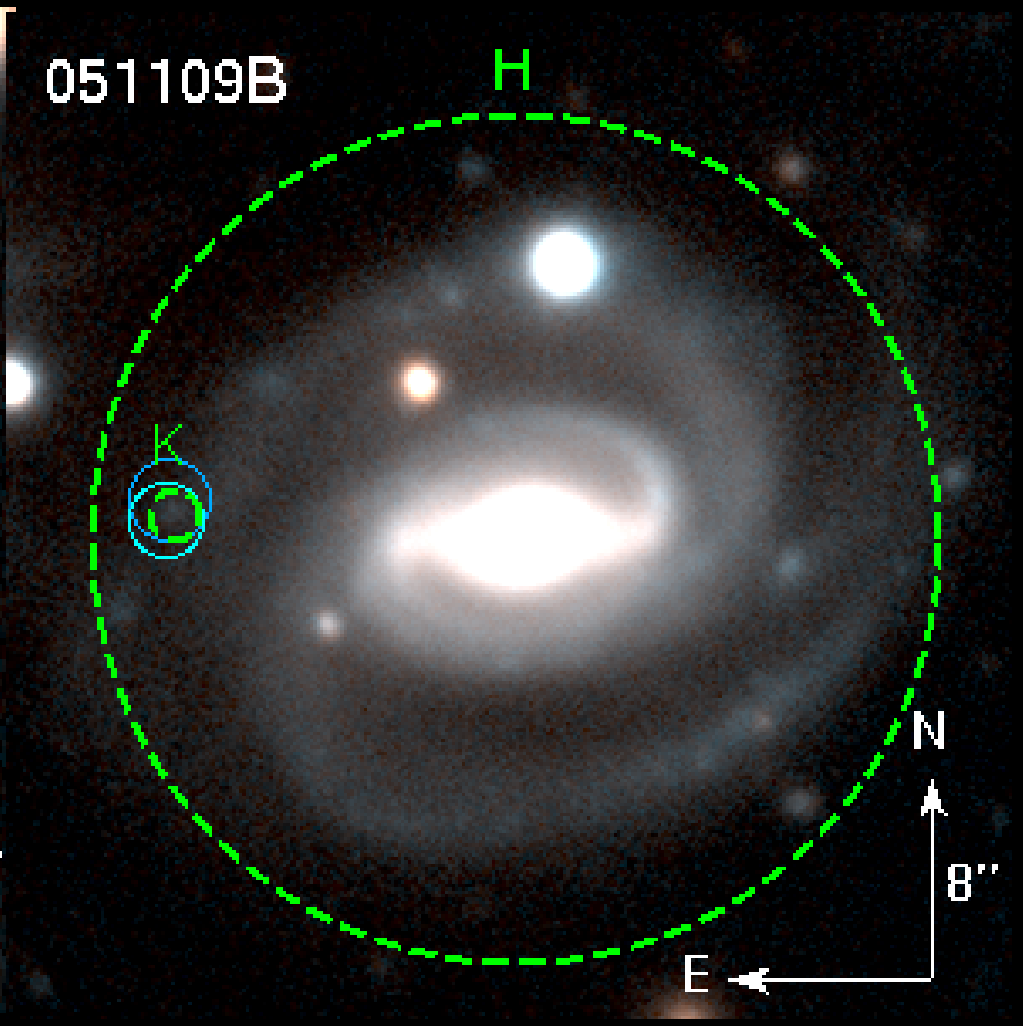
z=0.810 absorber

z=1.27, z=1.56 absorbers?

z=1.34, z=1.46 absorbers?

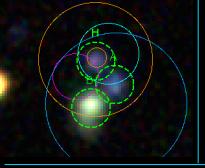
GRBs without SNe





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 galaxies, more diverse than Ly-α emitters

Short GRBs

Many are “hostless” to Keck limits

XRFs

Not distinct from ordinary long GRBs

Dark GRBs

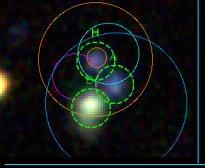
Afterglow extinction correlates with host redness
Many dark GRBs have very dusty hosts

Mg II Absorbers

Foreground galaxies, typically a few arcsec in projection

Low-z GRB SNe

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



Data Availability

Now – by request

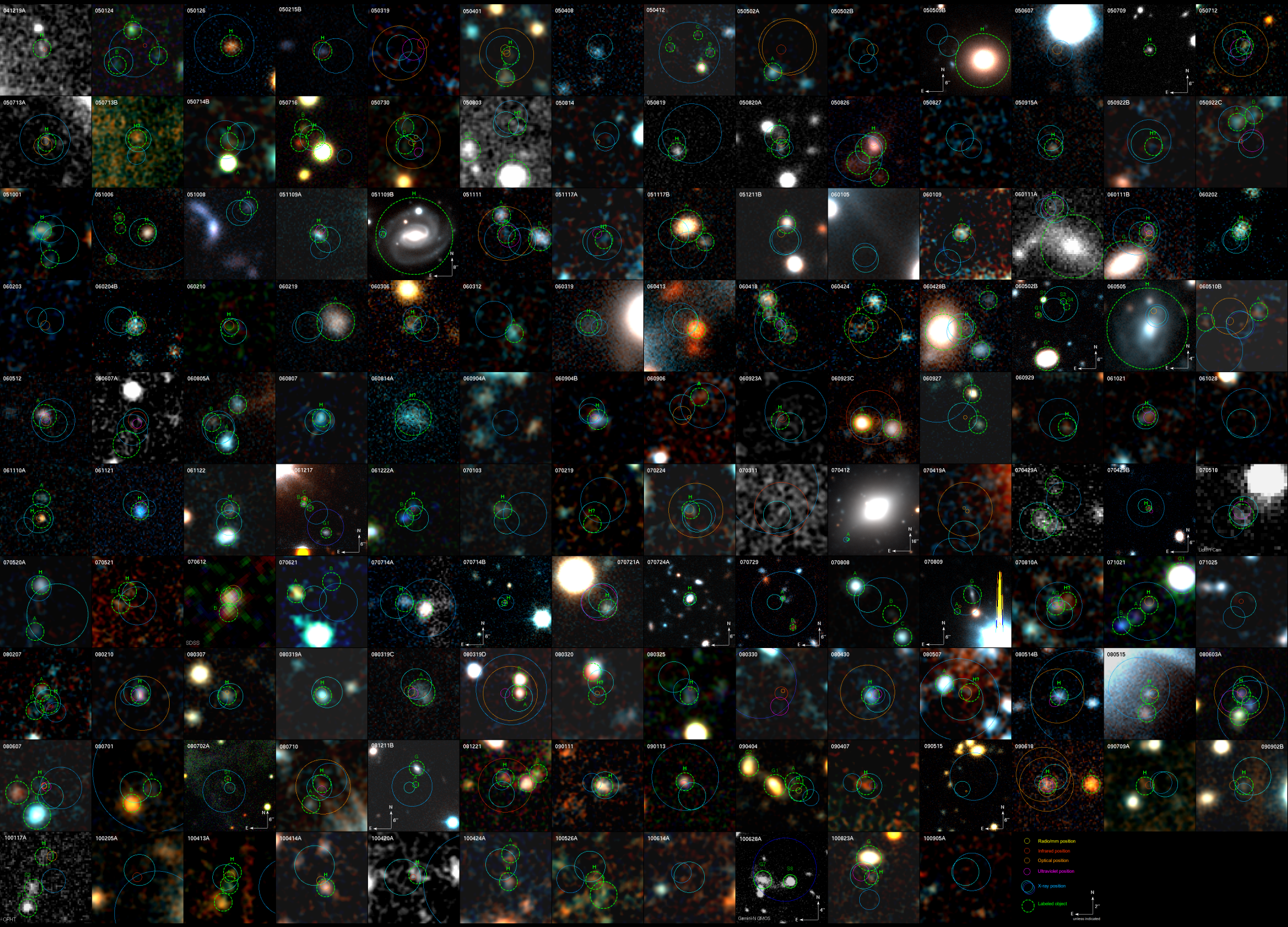
Target list:

041219A	041223	050124	050126	050215B	050319	050401	050408	050412
050416B	050502A	050502B	050509B	050603	050607	050709	050712	050713A
050713B	050714B	050716	050730	050803	050814	050819	050820A	050824
050826	050827	050915A	050922B	050922C	051001	051006	051008	051022
051105	051109A	051109B	051111	051117A	051117B	051211B	060105	060109
060111A	060111B	060123	060124	060202	060203	060204B	060210	060219
060306	060312	060319	060413	060418	060424	060428B	060502B	060505
060510B	060512	060607A	060805A	060807	060814A	060904A	060904B	060906
060923A	060923C	060927	060929	061021	061028	061110A	061121	061122
061217	061222A	070103	070219	070224	070311	070412	070419A	070429A
070429B	070518	070612	070520A	070521	070621	070714A	070714B	070721A
070724A	070729	070808	070809	070810A	070810B	071021	071025	080207
080210	080229A	080307	080310	080319A	080319C	080319D	080320	080325
080330	080430	080507	080514B	080515	080603A	080607	080701	080702A
080710	081211B	081221	090111	090113	090404	090407	090515	090618
090709A	090902B	100117A	100205A	100206A	100413A	100414A	100420A	100424A
100526A	100614A	100628A	100823A	100905A				

http://astro.berkeley.edu/~dperley/keckgrbhosts/

End of 2011 – public

Catalogs, raw data, reduced data online


041219A
050124
050126
050215B
050319
050401
050408
050412
050502A
050502B
050509B
050607
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050713A
050713B
050714B
050716
050730
050803
050814
050819
050820A
050826
050827
050915A
050922B
050922C
051001
051006
051008
051109A
051109B
051111
051117A
051117B
051211B
060105
060109
060111A
060111B
060202
060203
060204B
060210
060219
060306
060312
060319
060413
060418
060424
060428B
060502B
060505
060510B
060512
060607A
060805A
060807
060814A
060904A
060904B
060906
060923A
060923C
060927
060929
061021
061028
061110A
061121
061122
061217
061222A
070103
070219
070224
070311
070412
070419A
070429A
070429B
070518
070520A
070521
070612
070621
070714A
070714B
070721A
070724A
070729
070808
070809
070810A
071021
071025
080207
080210
080307
080319A
080319C
080319D
080320
080325
080330
080430
080507
080514B
080515
080603A
080607
080701
080702A
080710
081211B
081221
090111
090113
090404
090407
090515
090618
090709A
090902B
100117A
100205A
100413A
100414A
100420A
100424A
100526A
100614A
100628A
100823A
100905A
Radio/mm position
Infrared position
Optical position
Ultraviolet position
X-ray position
Labeled object
unless indicated
CFHT
Gemini-N GMOS
Lick/PFCam
SDSS