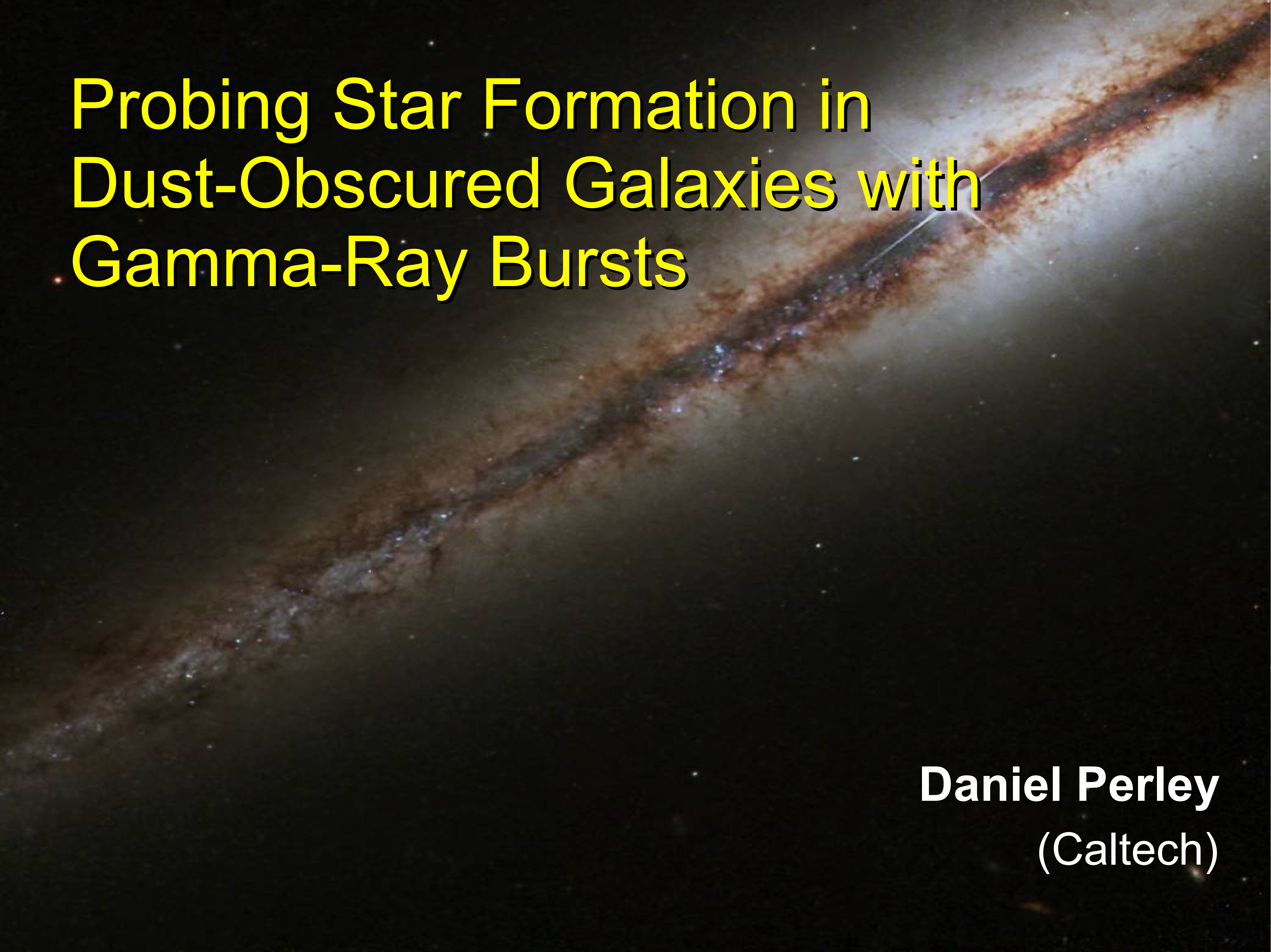
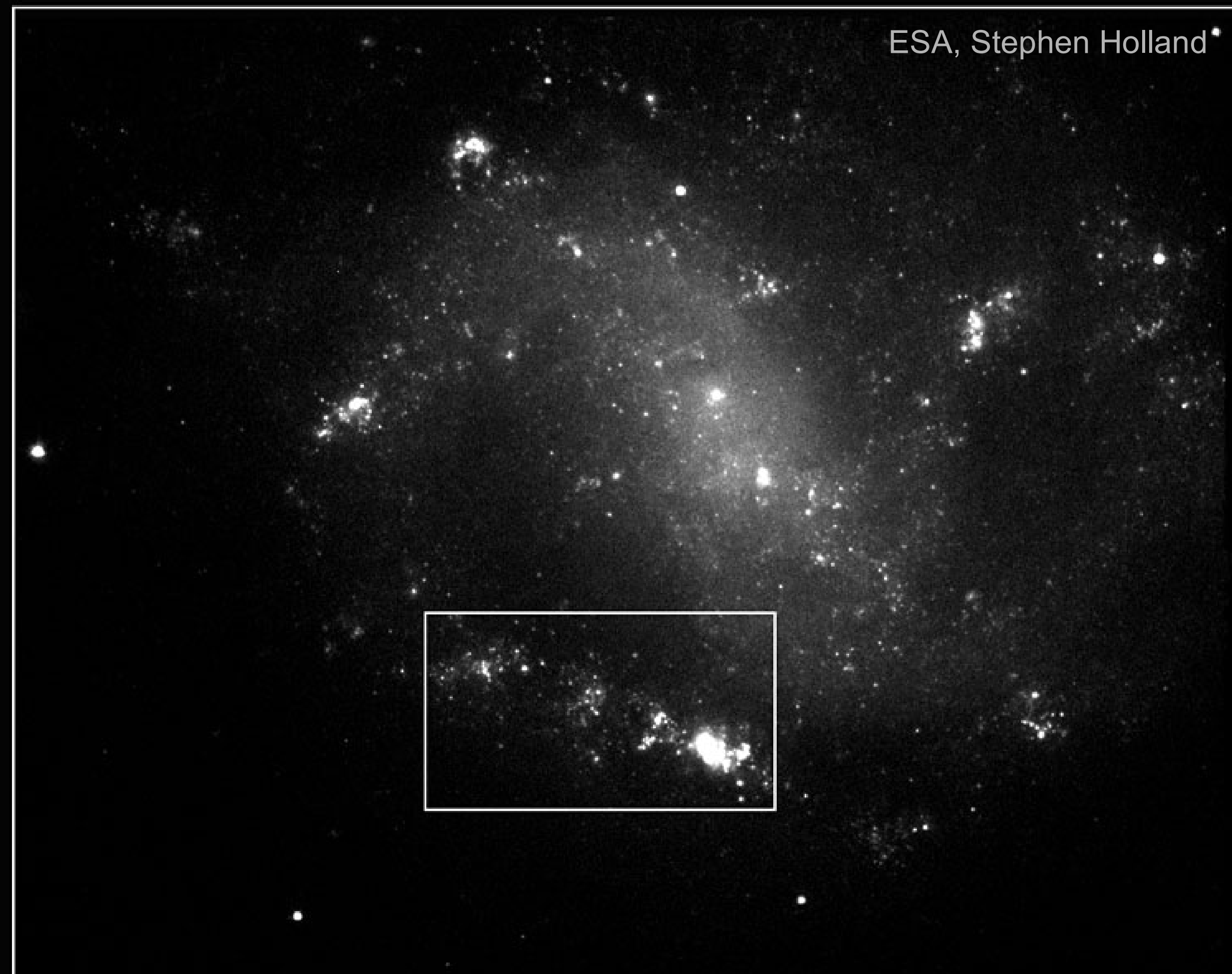


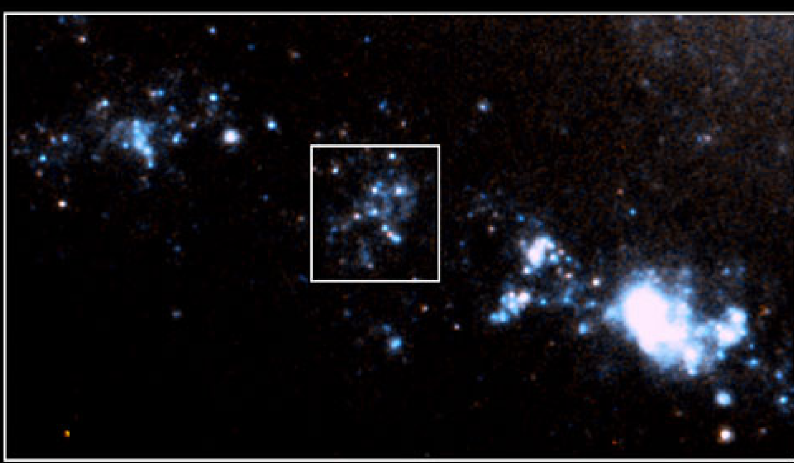
Probing Star Formation in Dust-Obscured Galaxies with Gamma-Ray Bursts

Daniel Perley
(Caltech)

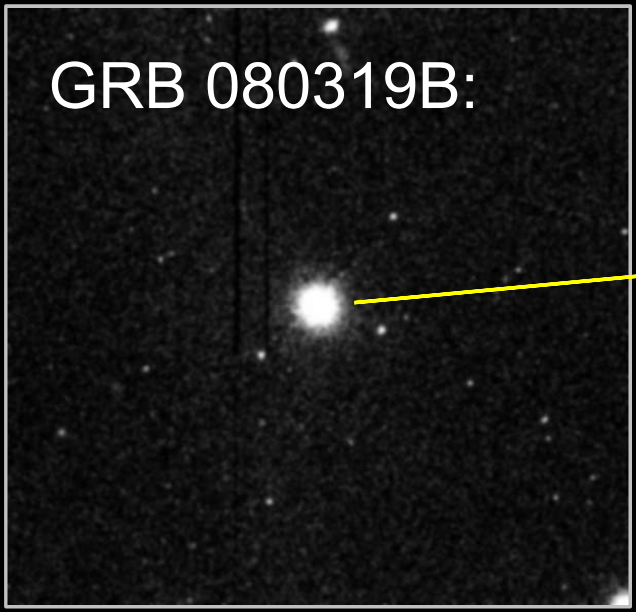
(Long) GRBs: Massive Stellar Core-Collapse

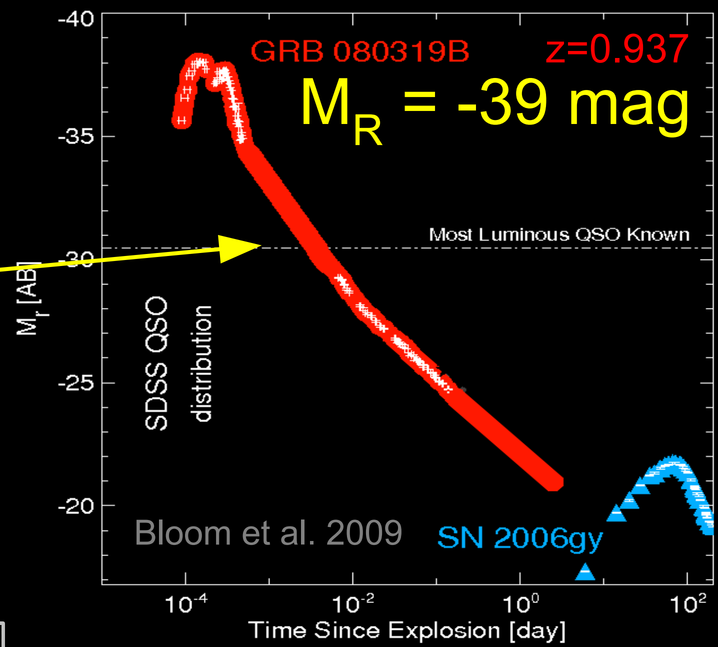
GRB 980425 / SN 1998bw at z=0.008

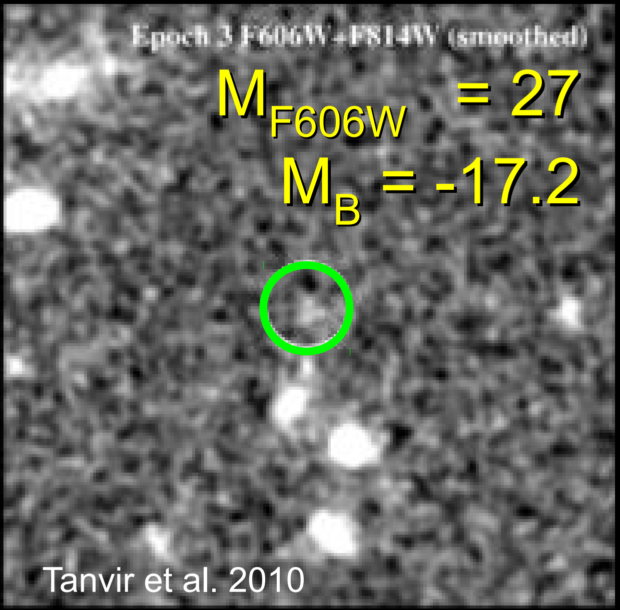


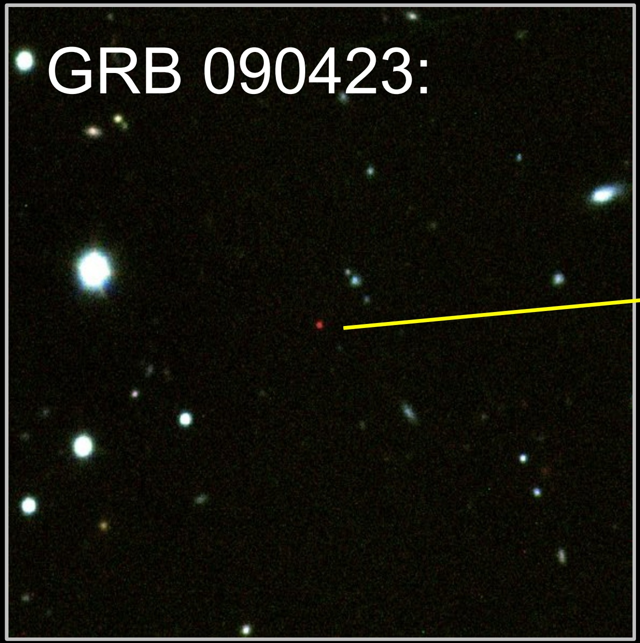


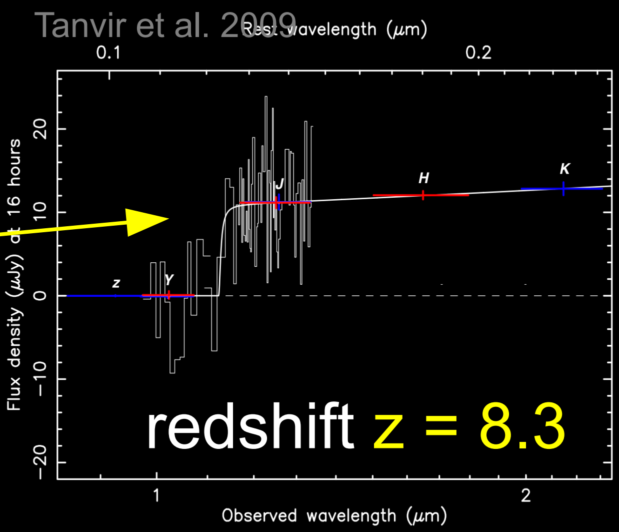
Lighthouses for the High-z Universe

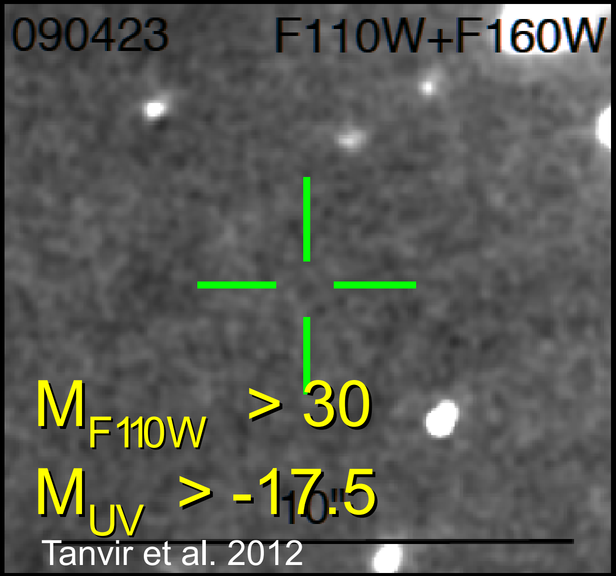




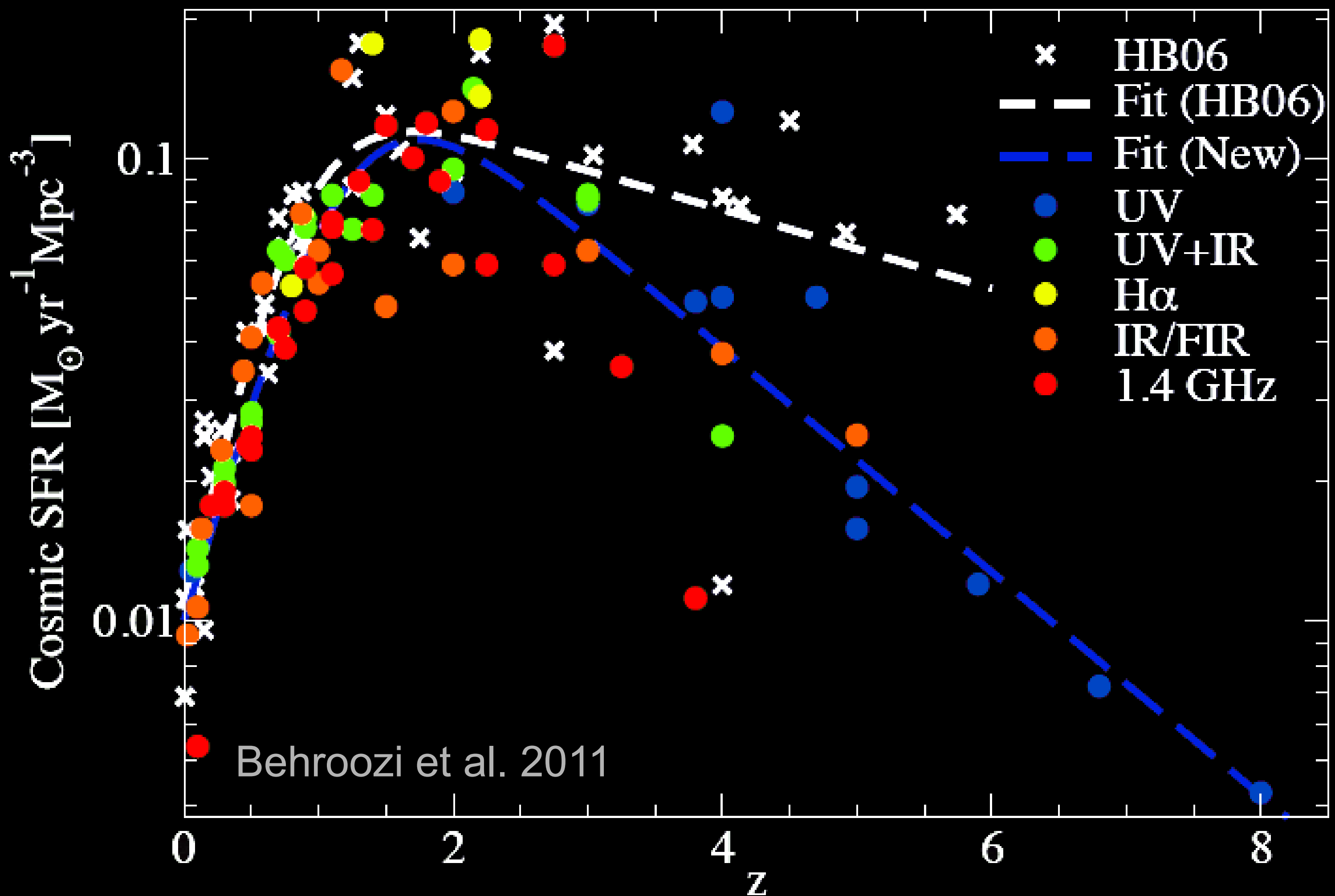








Tracers of Star-Formation?



$$R_{GRB} = \mathrm{const} \times R_{SFR}$$

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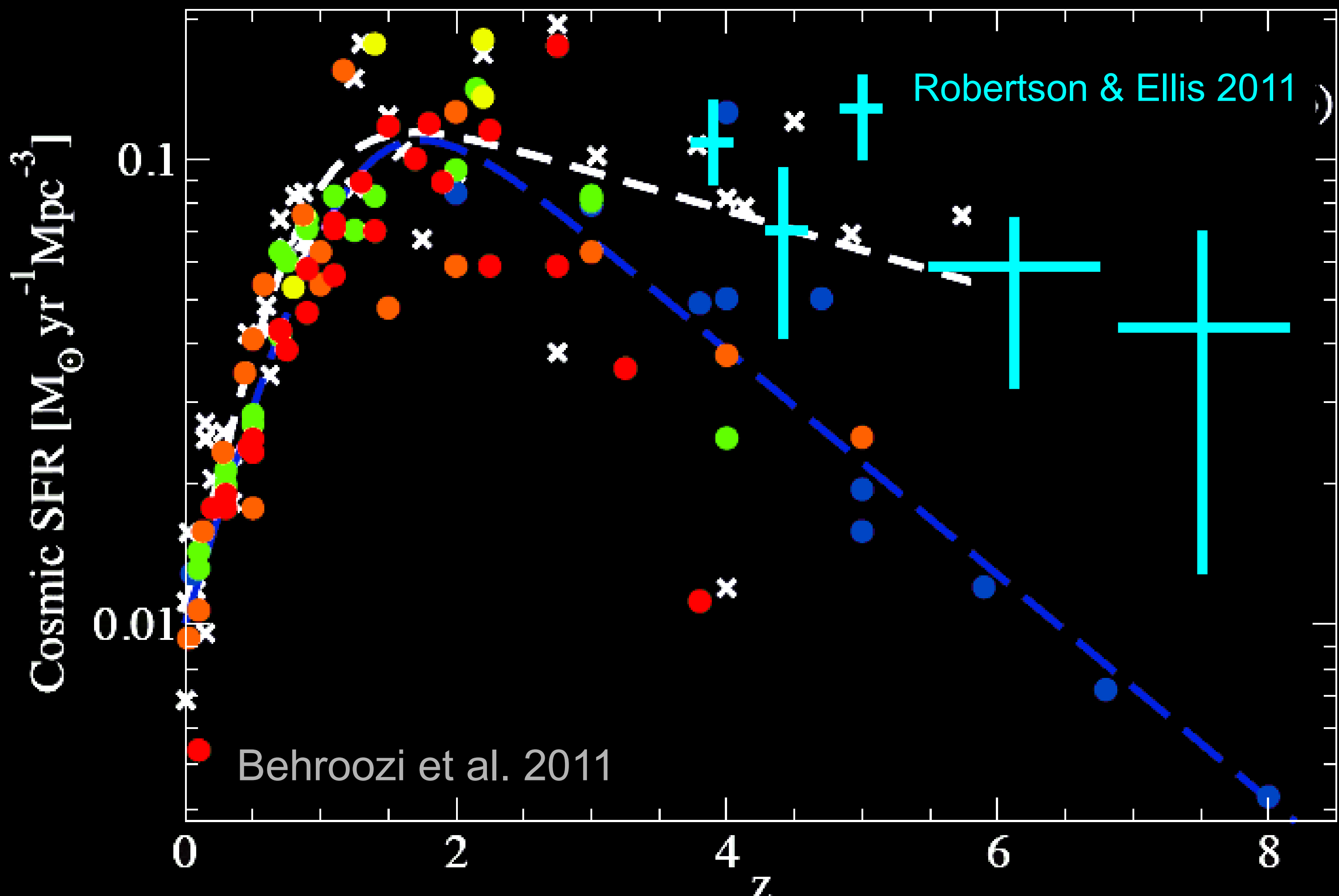

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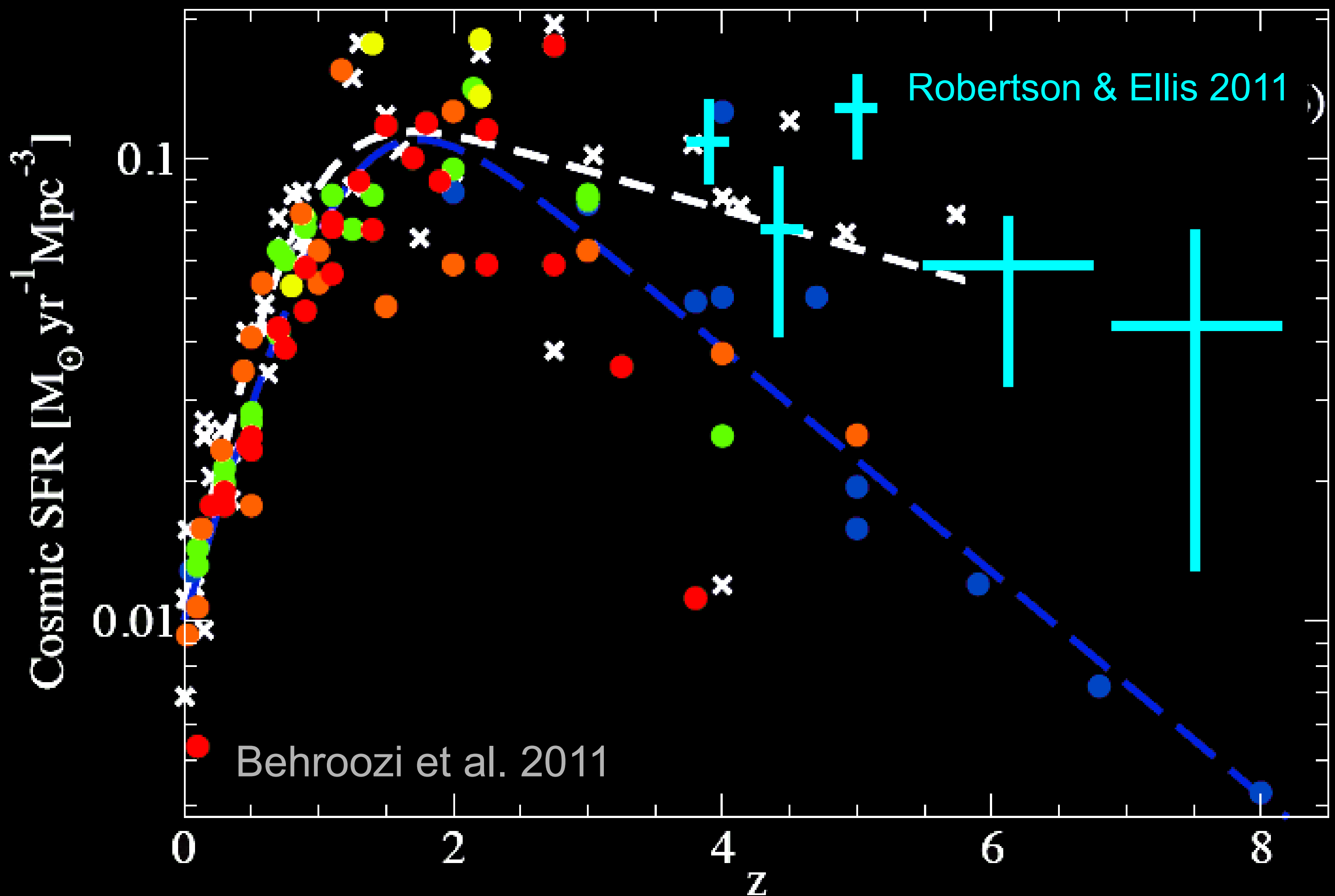
Tracers of Star-Formation?

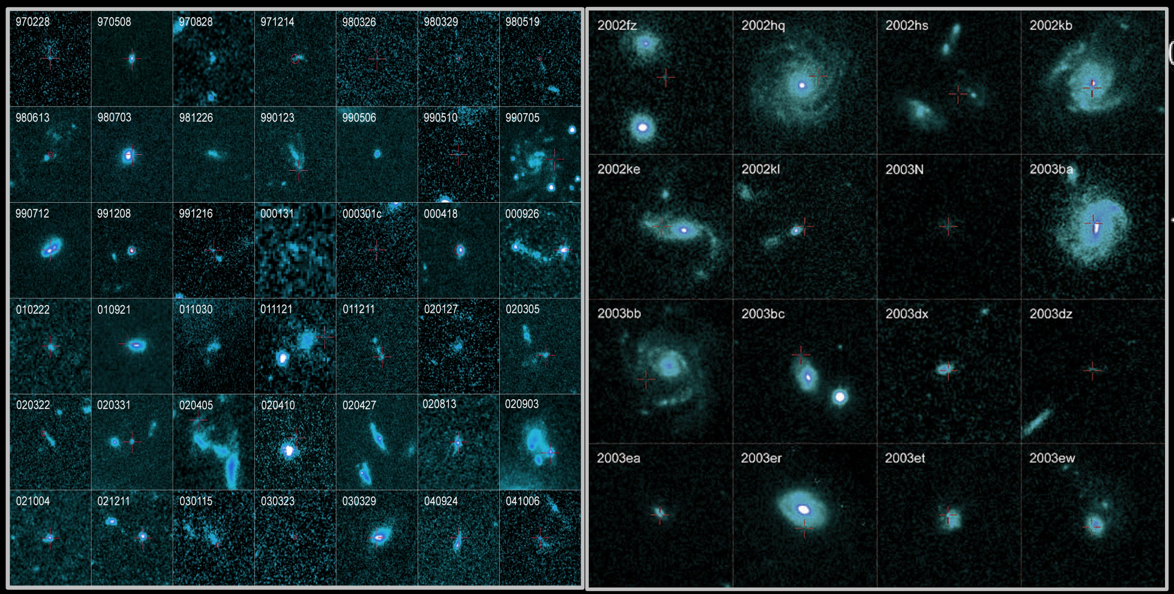


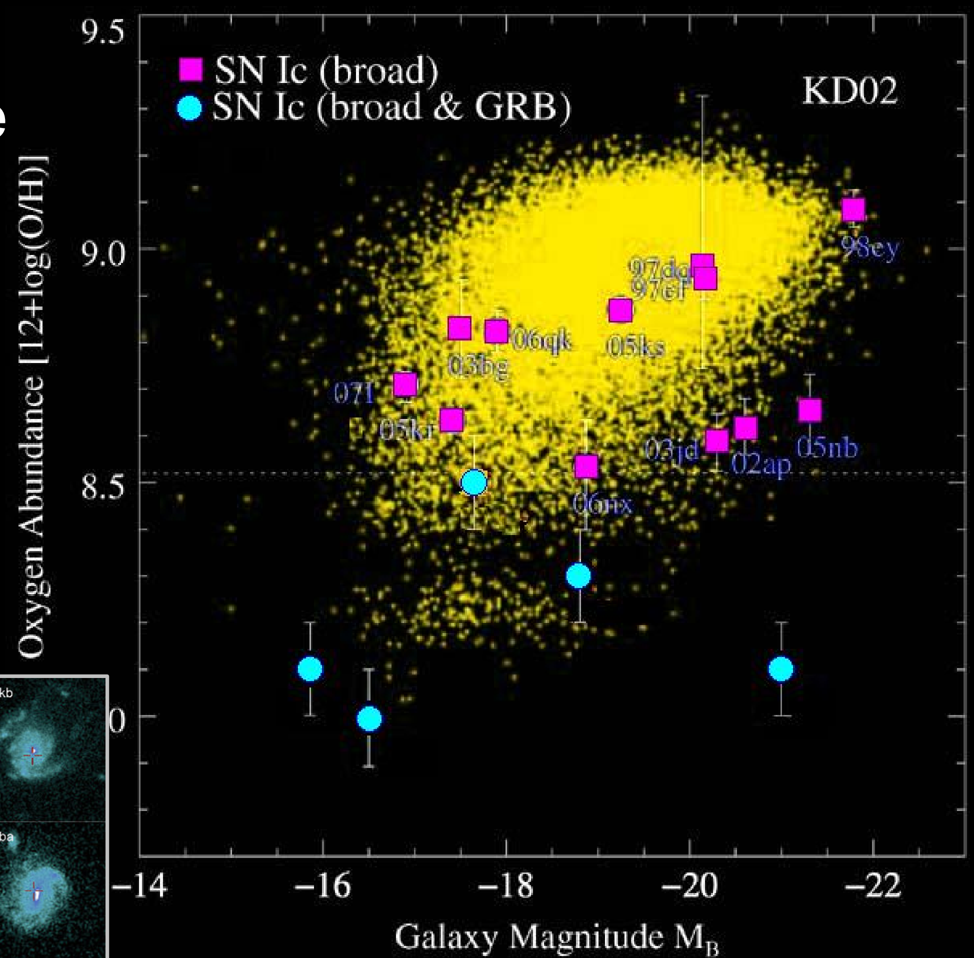
$$R_{GRB} = \text{const} \times R_{SFR} \times f(???)$$

Key Differences

Low-z GRB hosts have lower metallicitities than Ic supernovae
Modjaz et al. 2008

Low-z GRB hosts are more irregular than Ib supernova hosts
Fruchter et al. 2006





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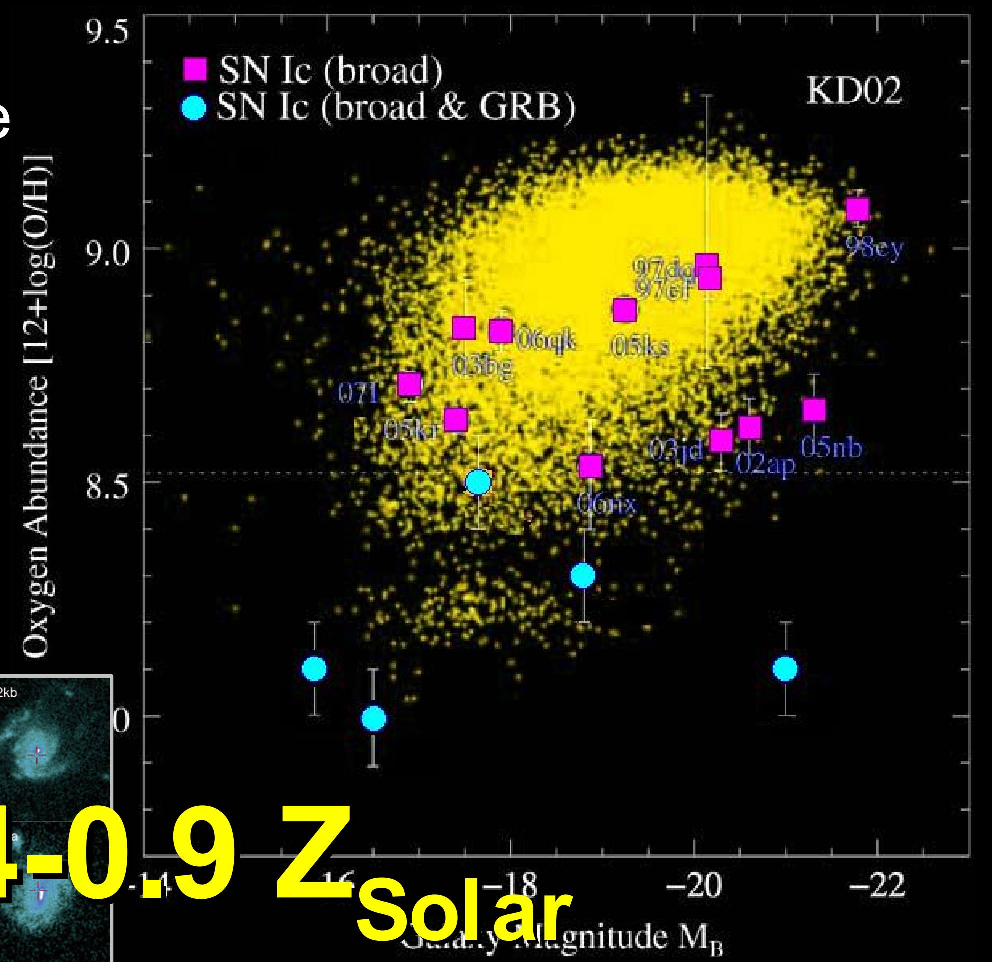

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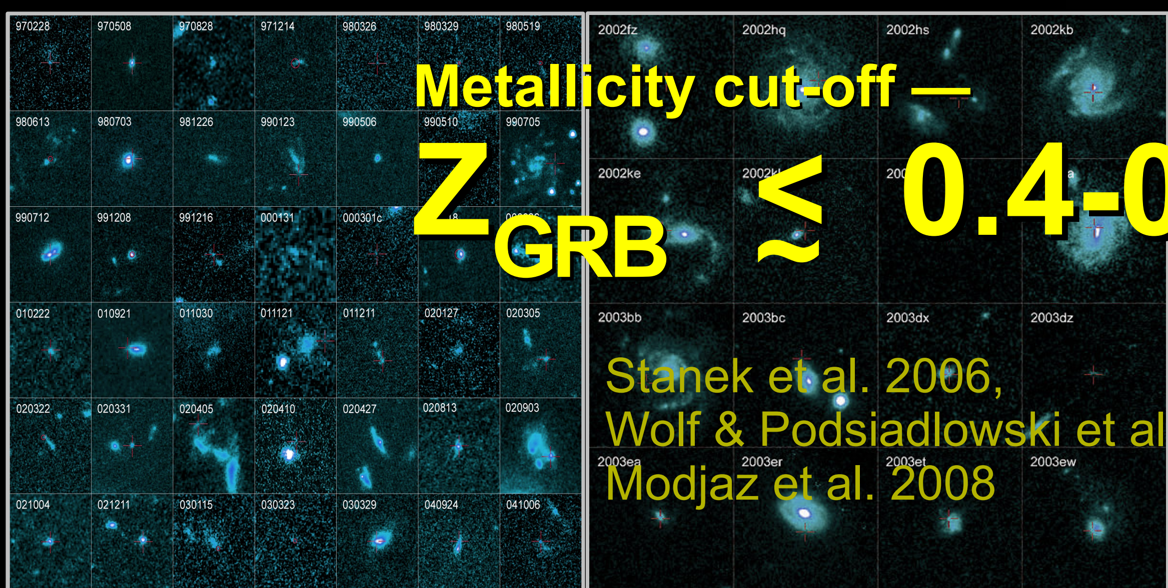

Metallicity cut-off —

$$Z_{GRB} \lesssim 0.4\text{-}0.9\ Z_{Solar}$$

Stanek et al. 2006,
Wolf & Podsiadlowski et al. 2007,
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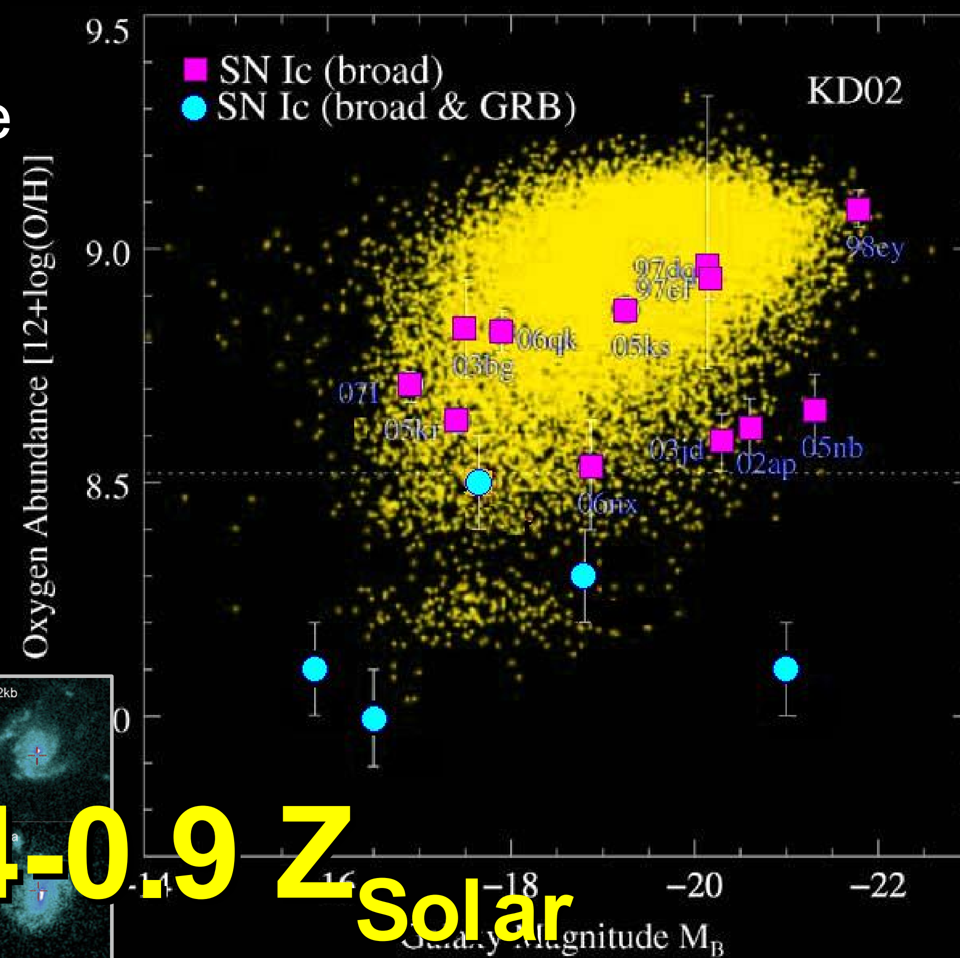

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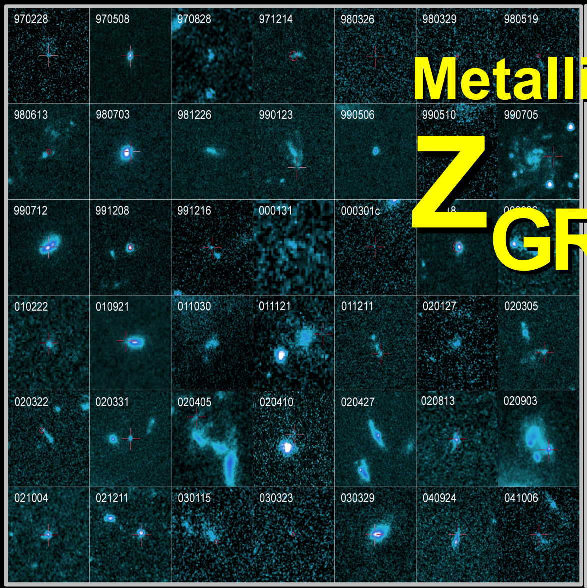

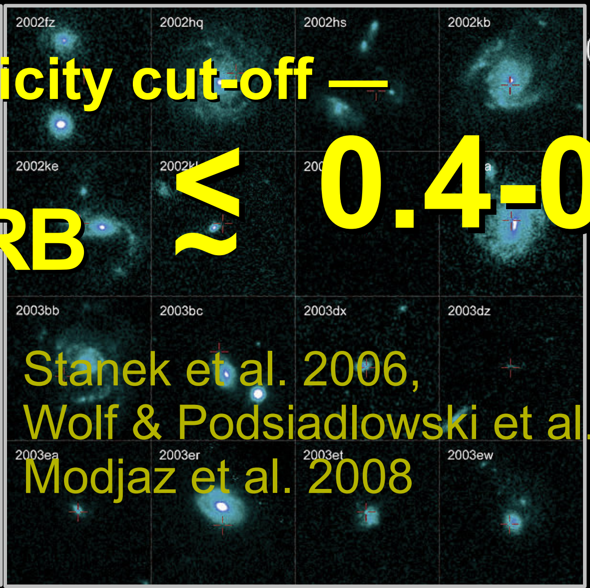

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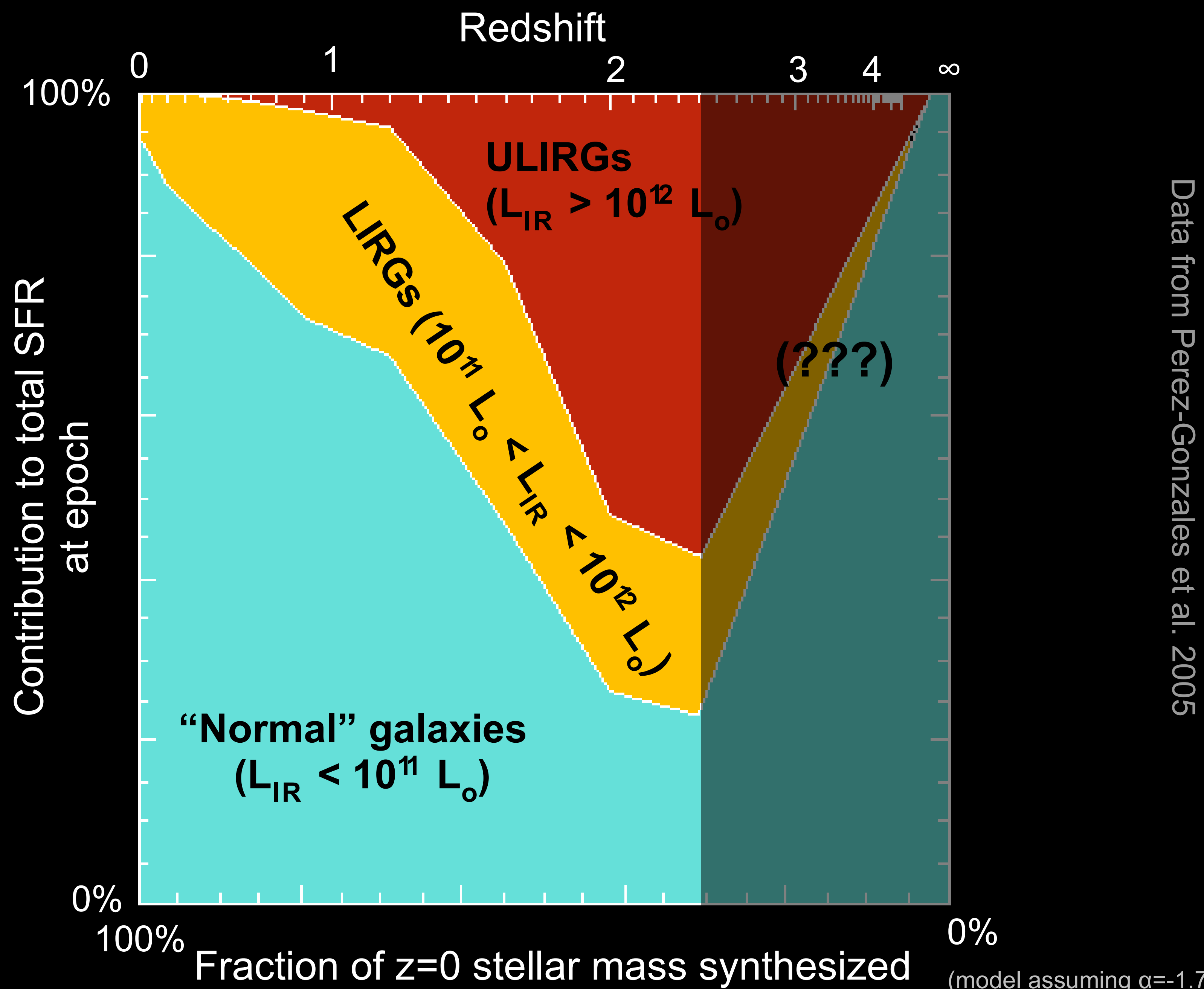
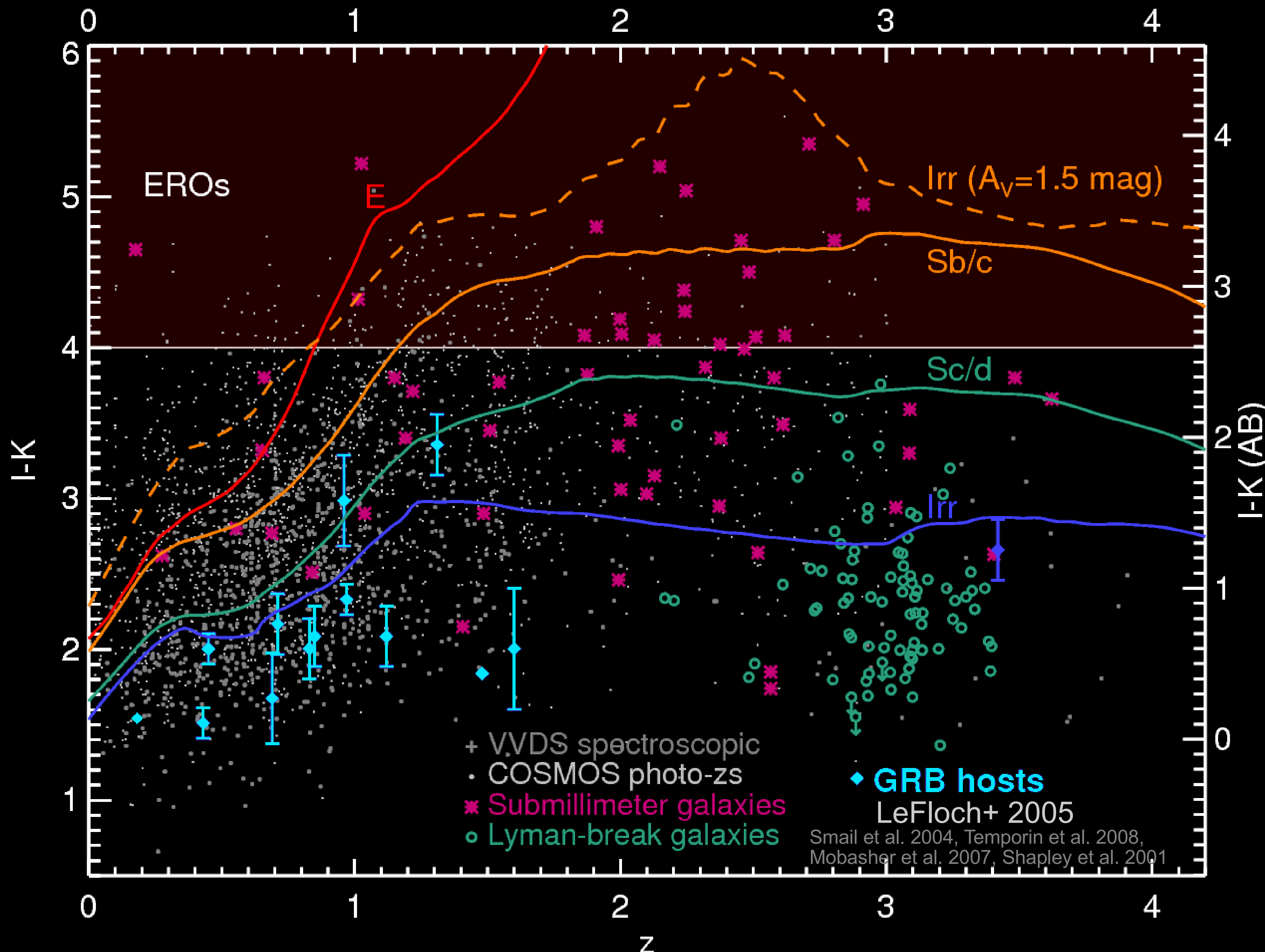
Stanek et al. 2006,
Wolf & Podsiadlowski et al. 2007,
Modjaz et al. 2008

Both methods struggle at z>1, when most GRBs actually occured!

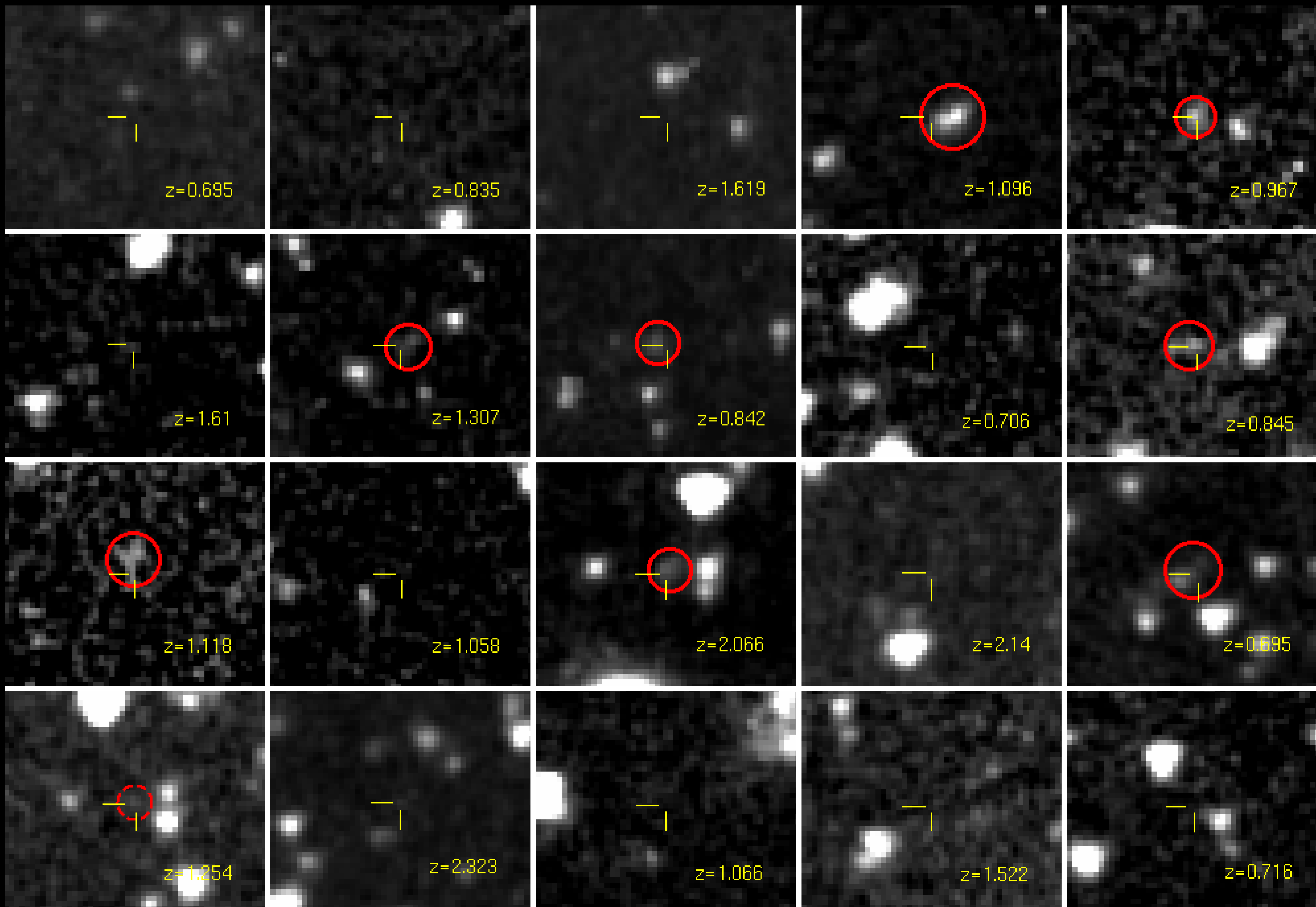
SFH from IR-Luminous Galaxies



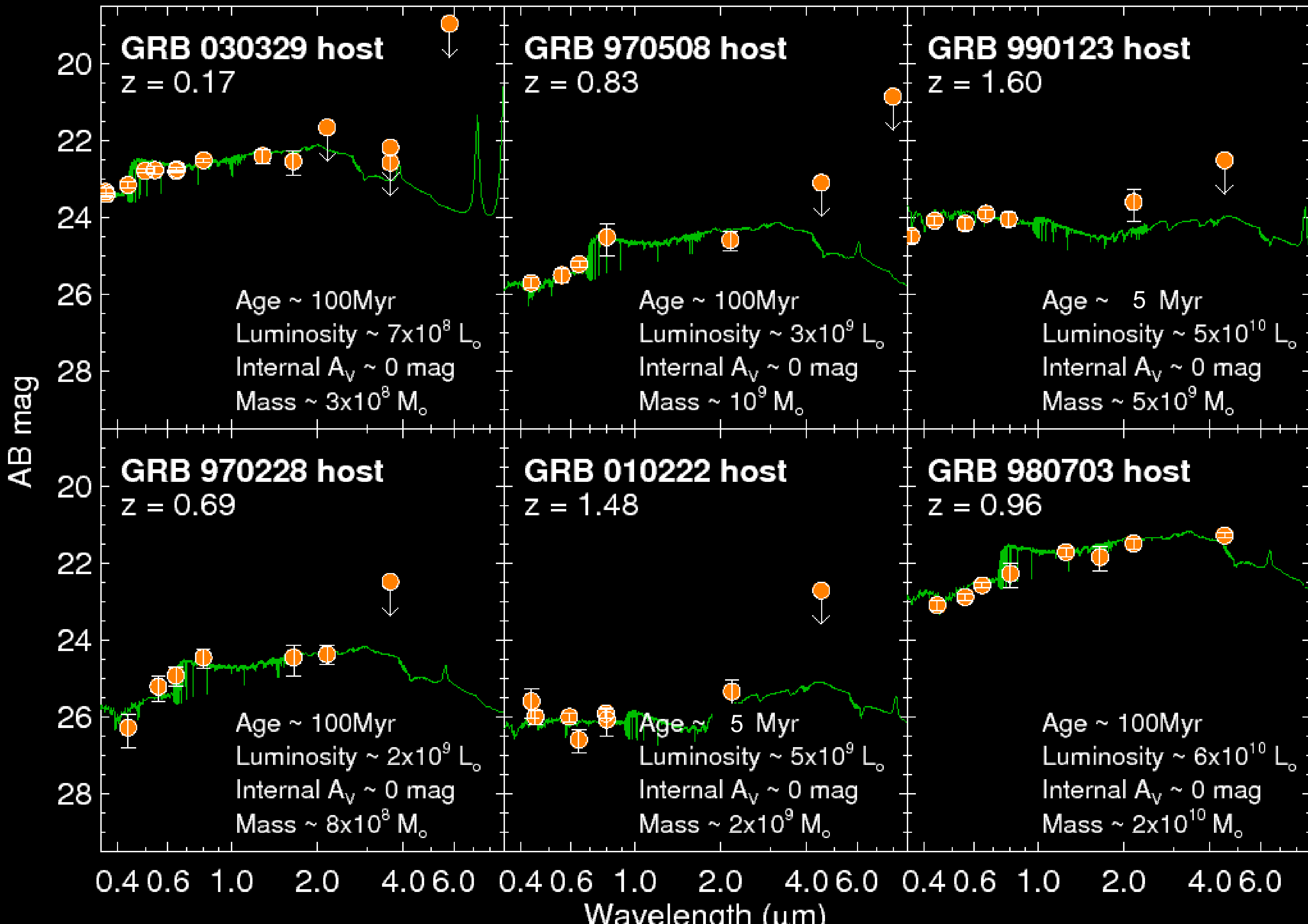
GRB Hosts: Universally Blue?



Few IRAC Detections

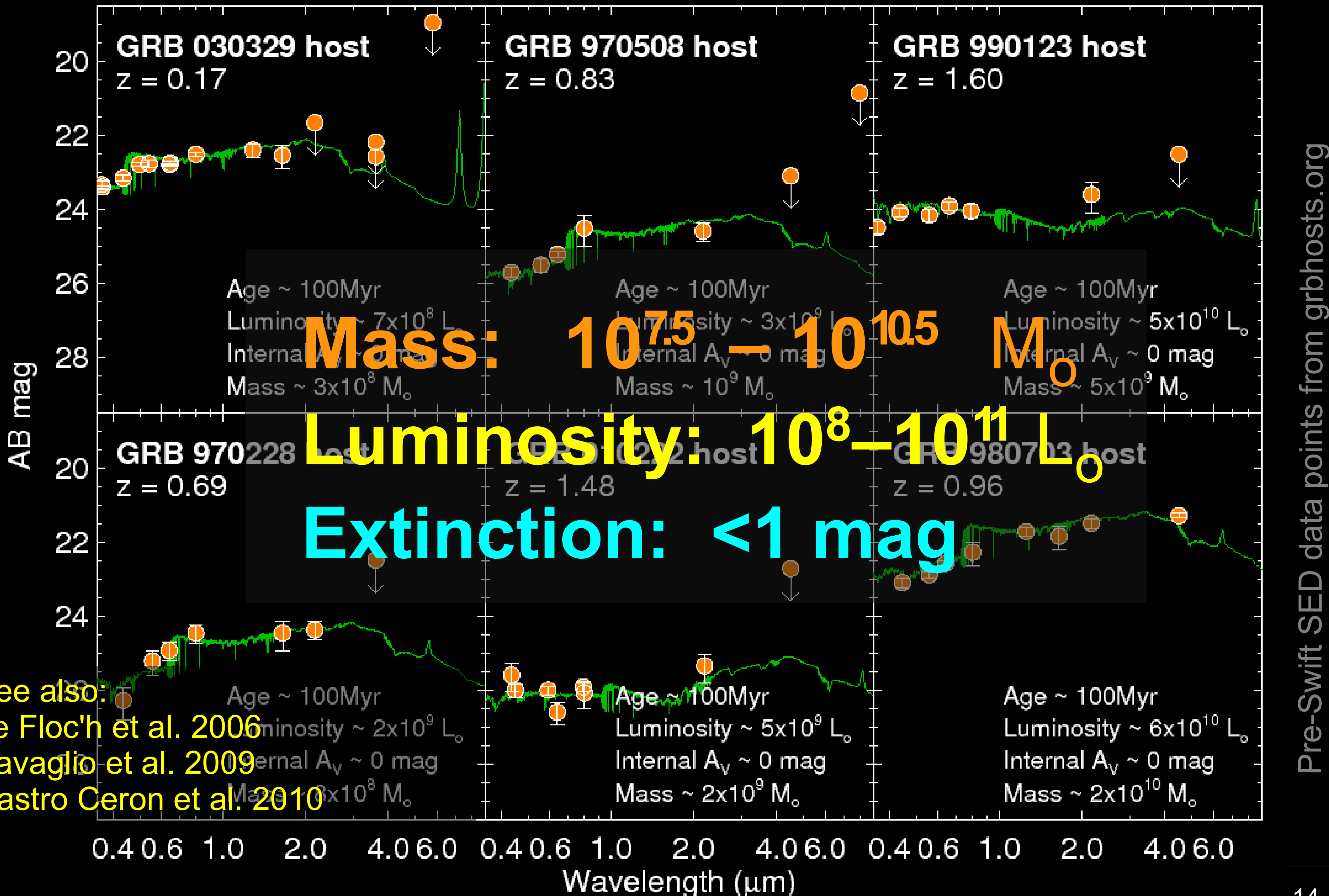


Low-Mass, Low-Luminosity, Low-Dust



Pre-Swift SED data points from grbhosts.org

Low-Mass, Low-Luminosity, Low-Dust



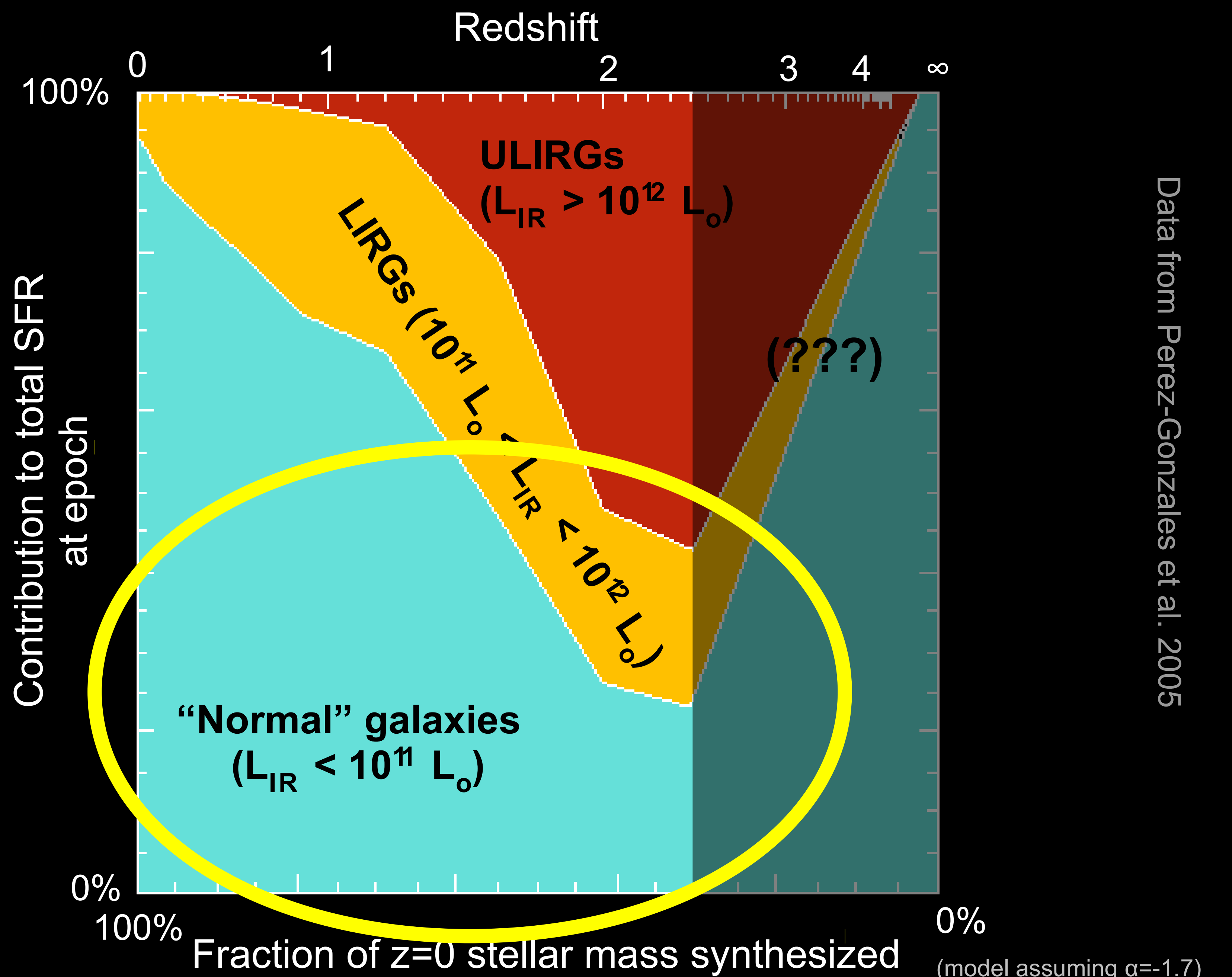
Mass: $10^{7.5} – 10^{10.5}$ M_O

Luminosity: $10^{8}–10^{11}$ L_O

Extinction: <1 mag

See also:
Le Floc'h et al. 2006
Savaglio et al. 2009
Castro Ceron et al. 2010

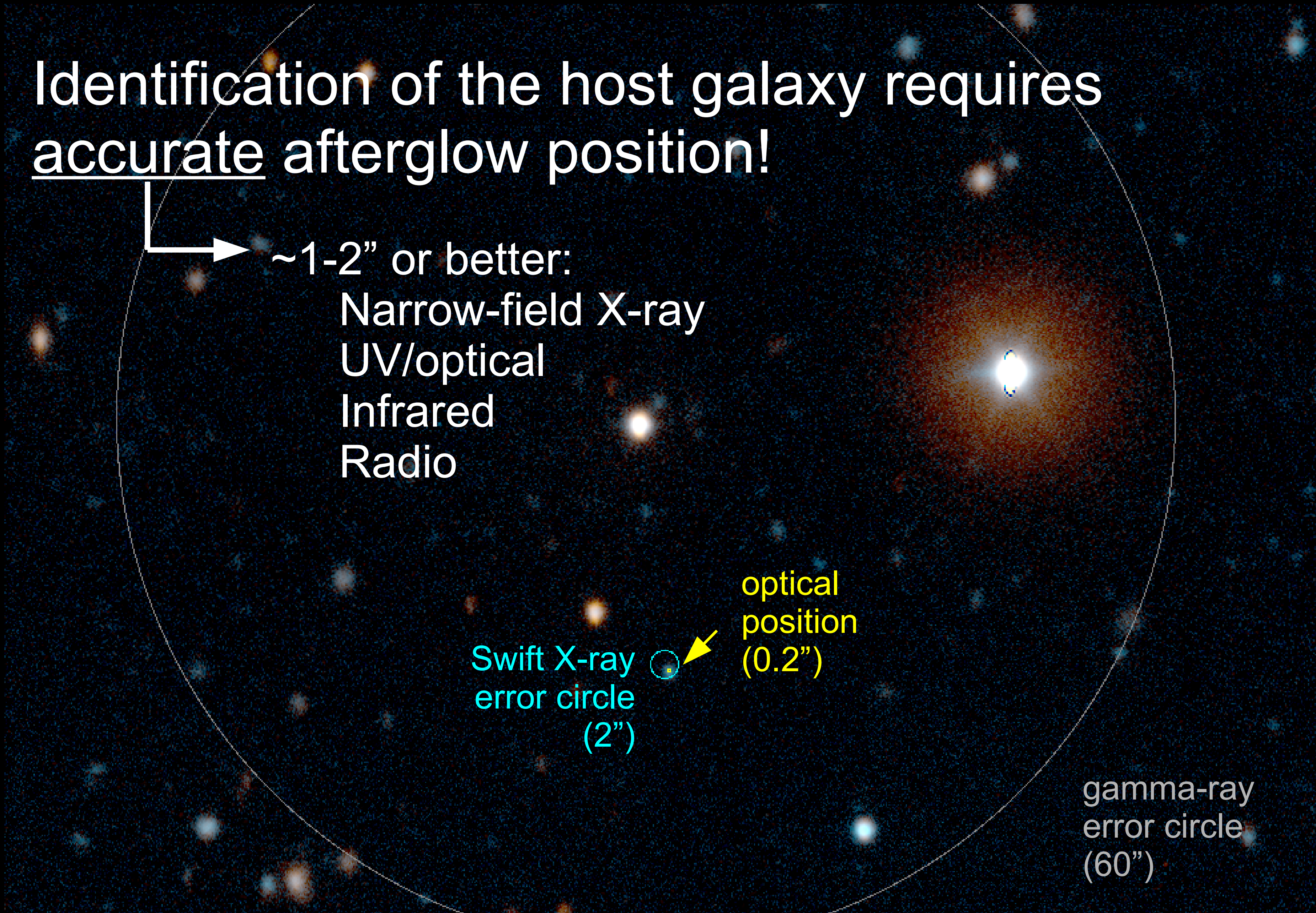
SFH from IR-Luminous Galaxies



Host Selection Biases

Identification of the host galaxy requires accurate afterglow position!

~1-2” or better:
- Narrow-field X-ray
- UV/optical
- Infrared
- Radio



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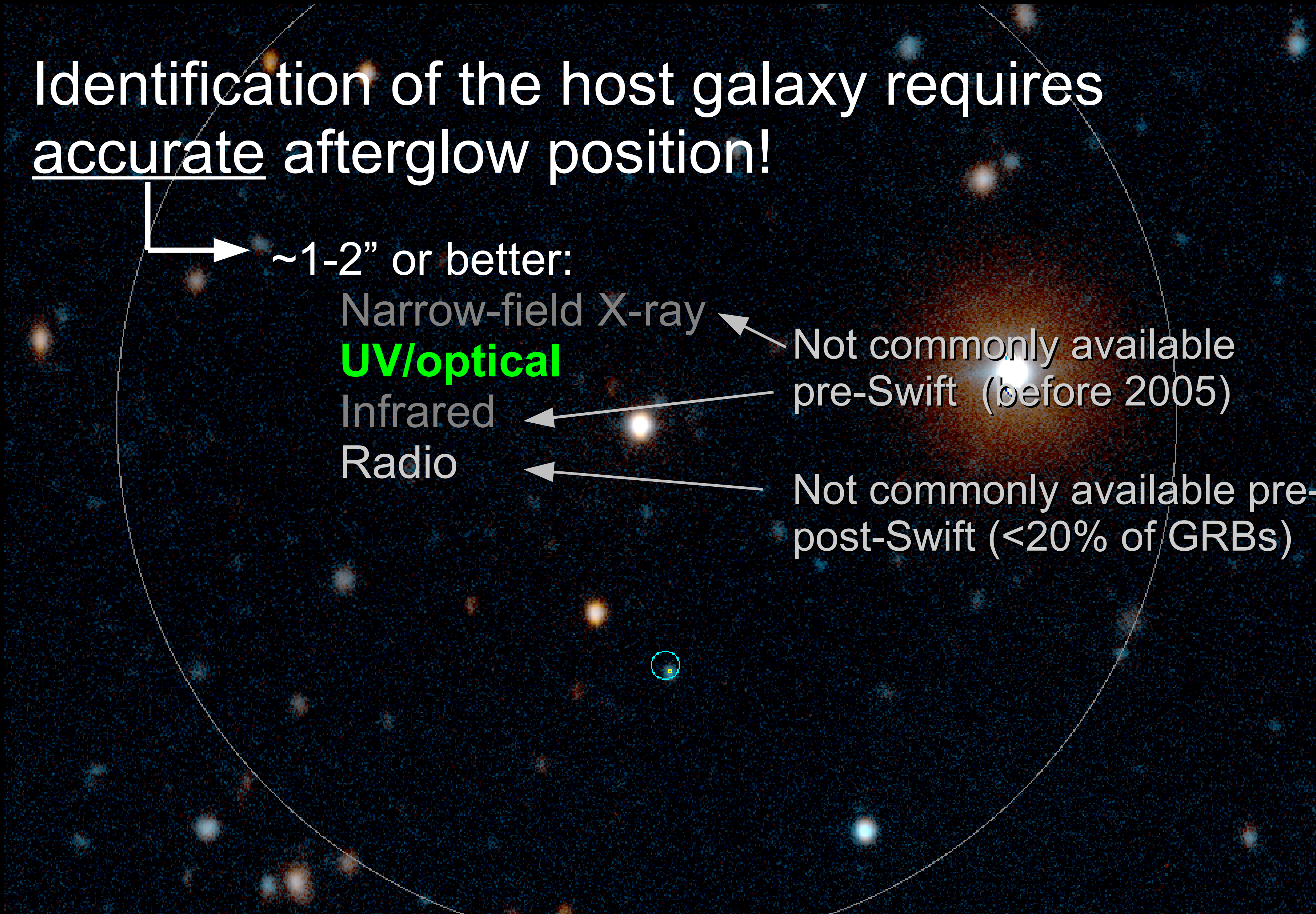


Identification of the host galaxy requires accurate afterglow position!

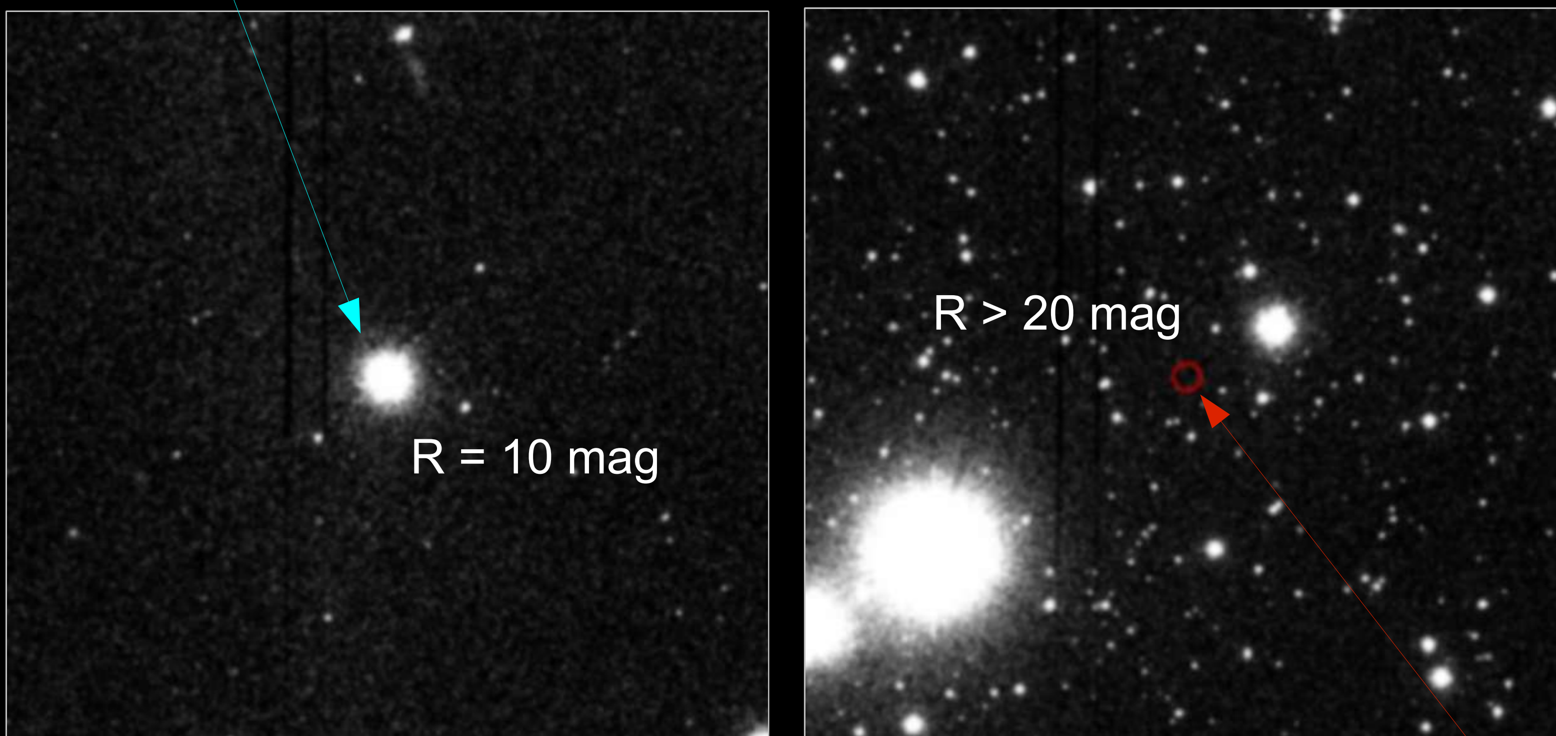
→ ~1-2" or better:

- Narrow-field X-ray
- **UV/optical**
- Infrared
- Radio

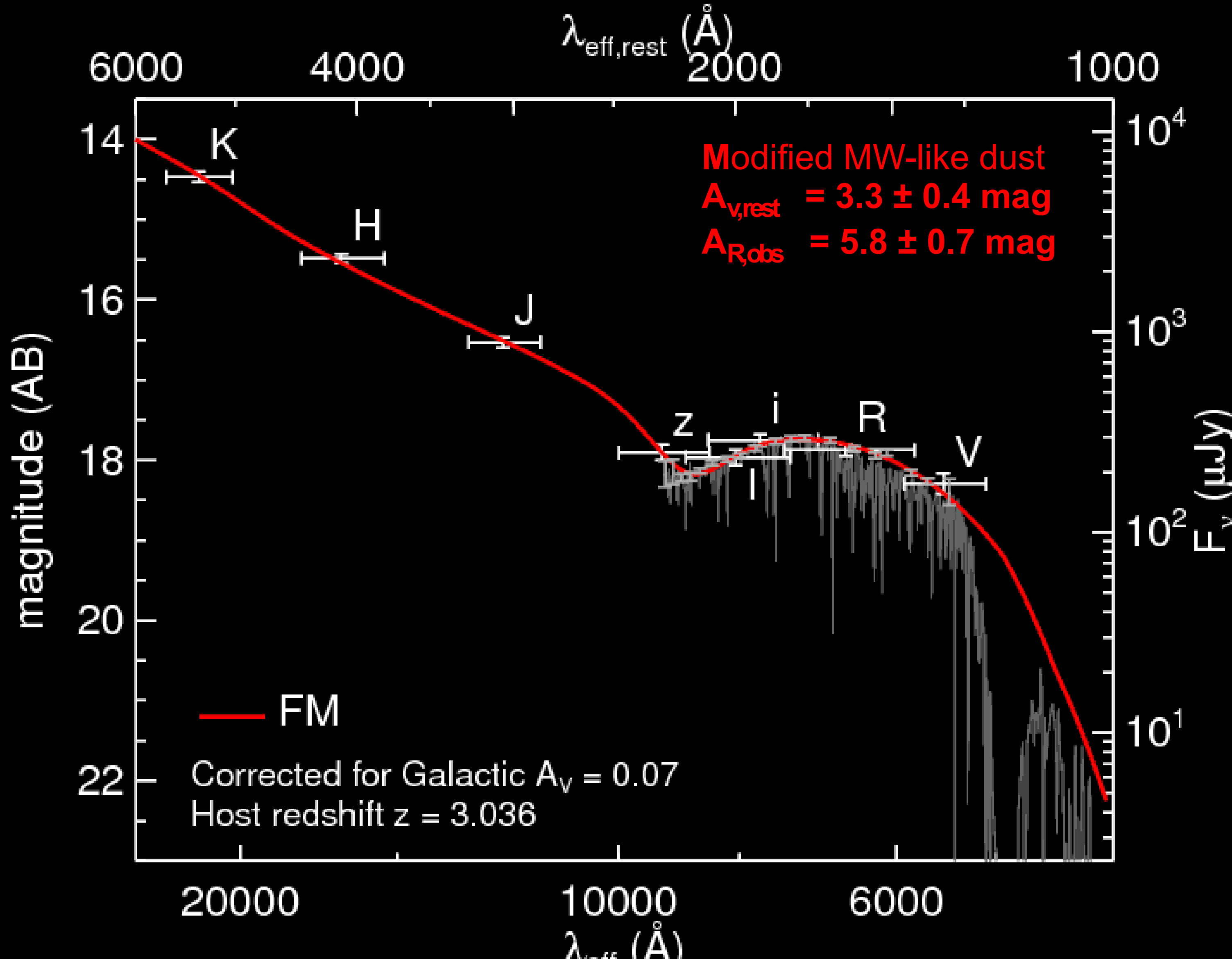
Narrow-field X-ray, Infrared ← Not commonly available pre-Swift (before 2005)

Radio ← Not commonly available pre- or post-Swift (<20% of GRBs)

Some GRBs have exceedingly faint optical afterglows.



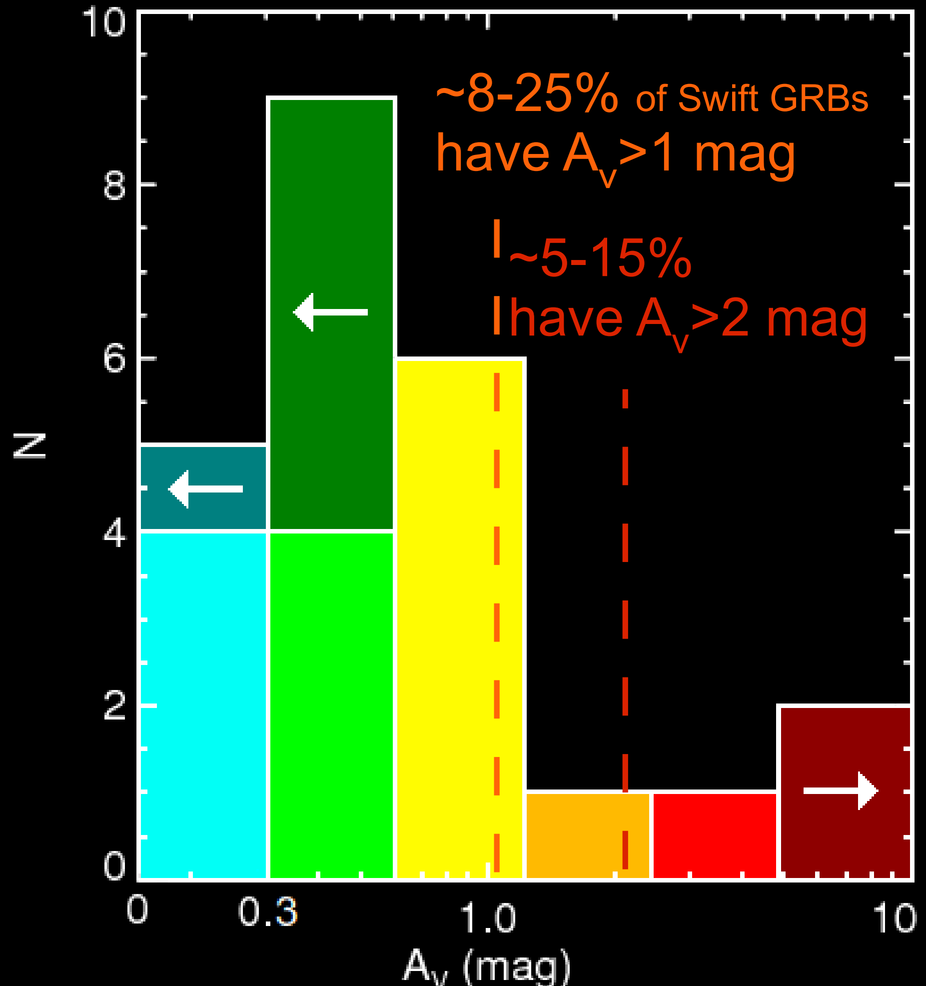
Direct Evidence for Extinction



Perley et al. 2010b

Extinction Distribution

Many (but not most: ~20%) GRBs are highly extinguished.

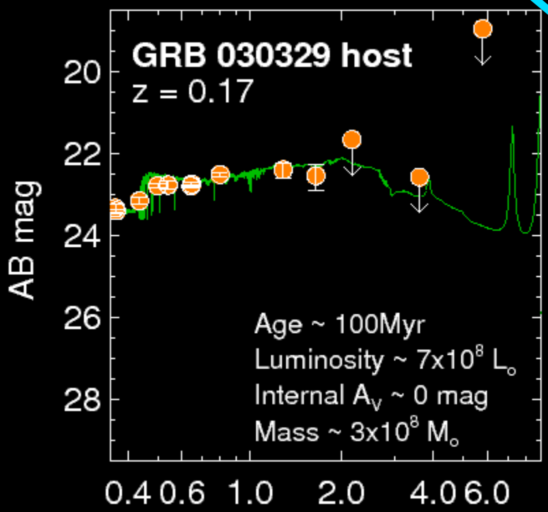


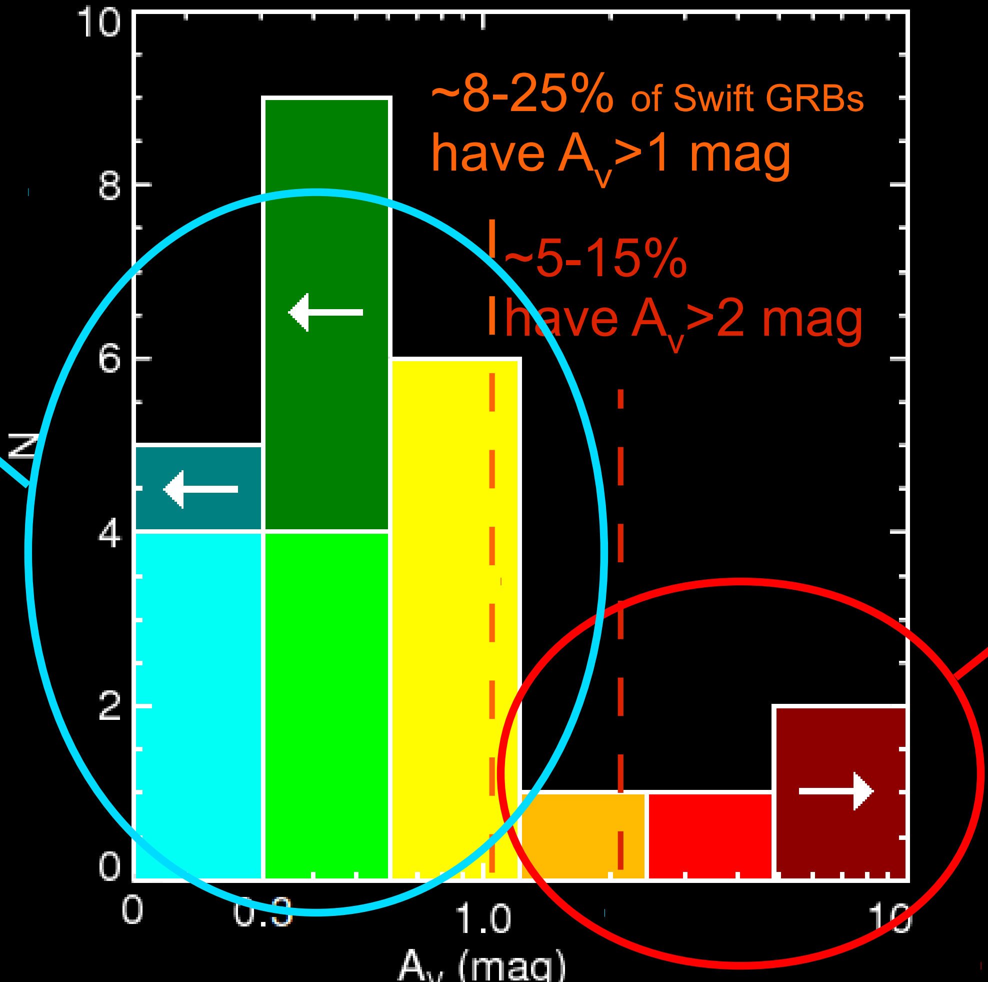
Perley et al. 2009
+ Kruehler et al. 2011

Extinction Distribution

80%

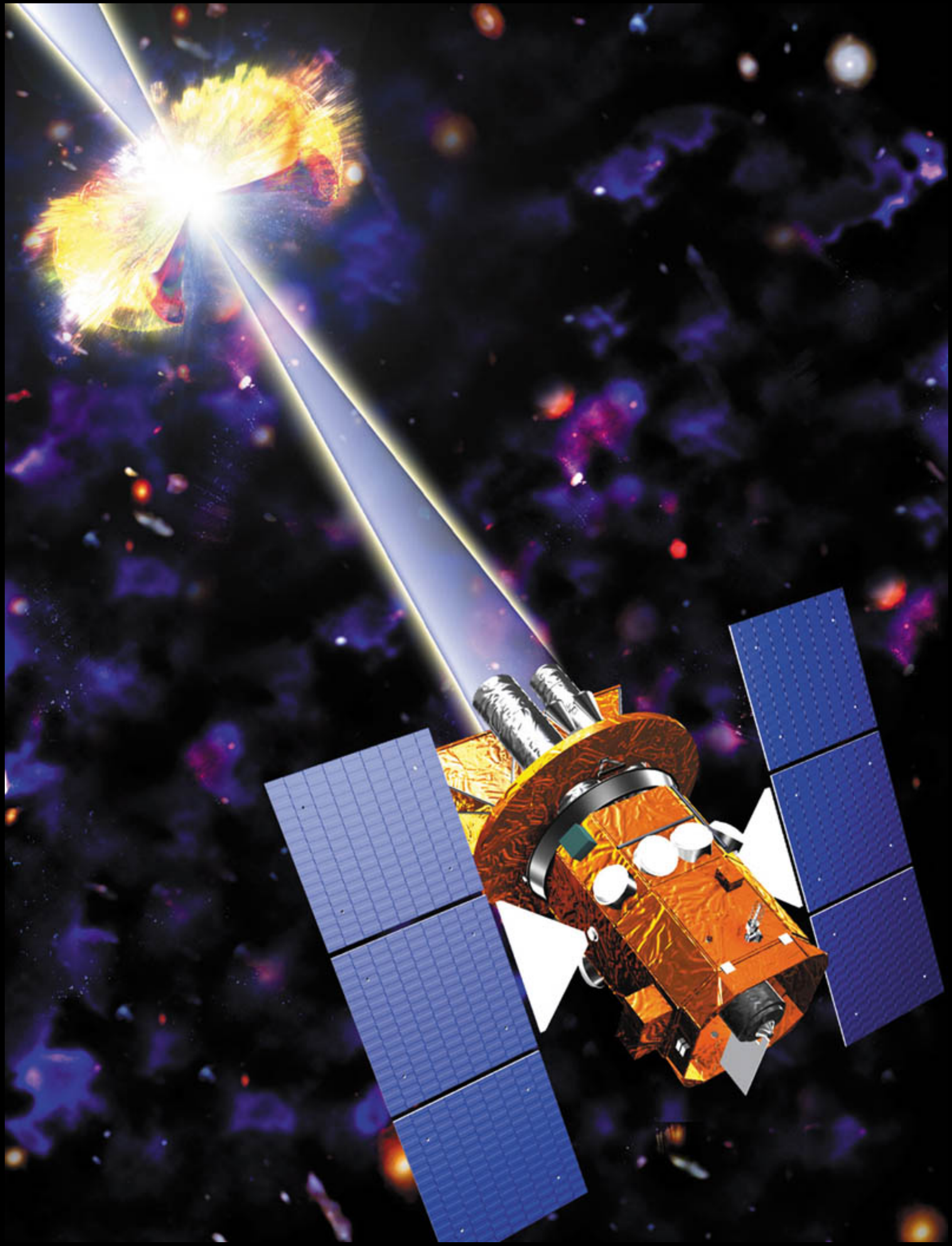
20%



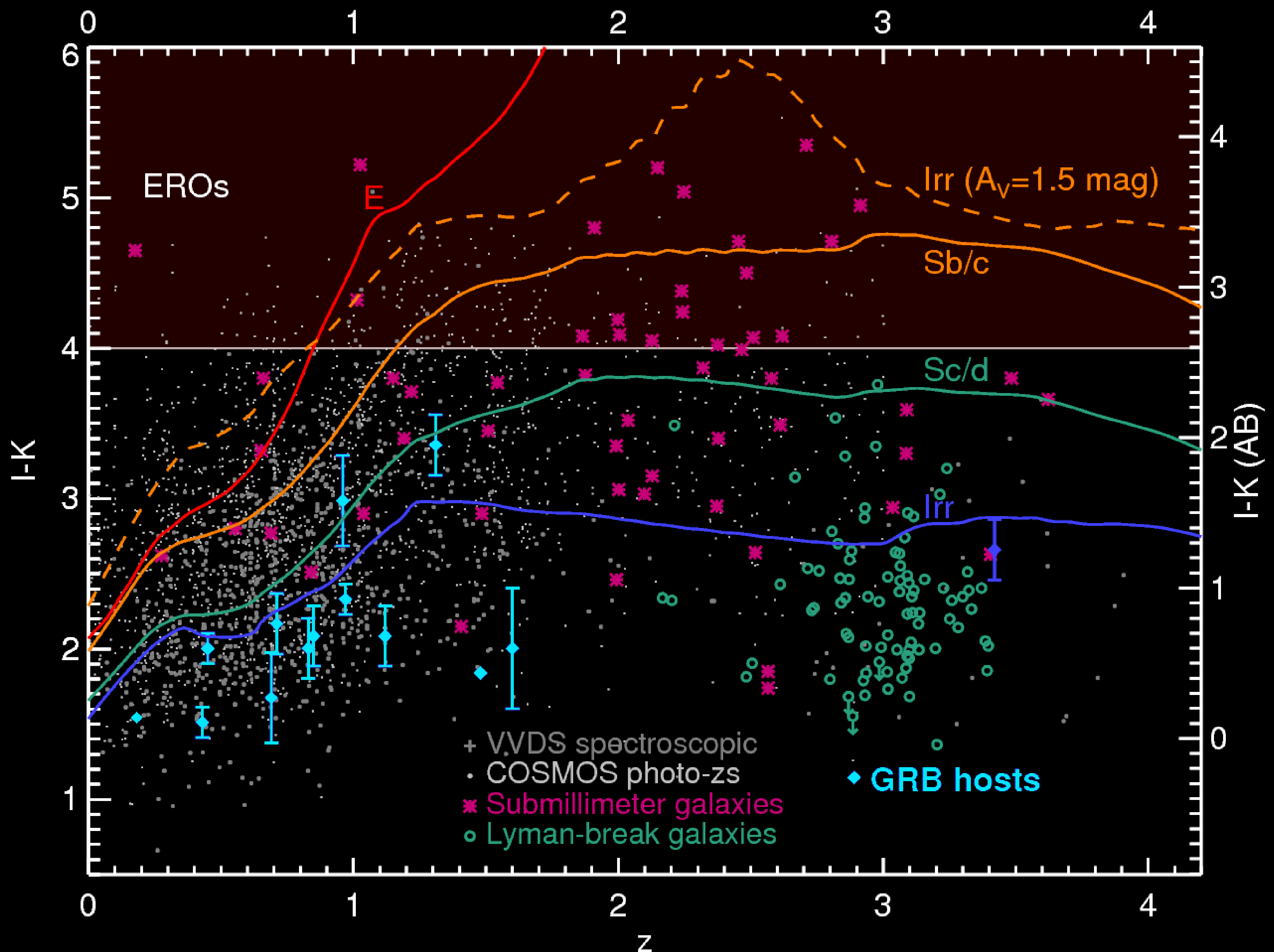


?

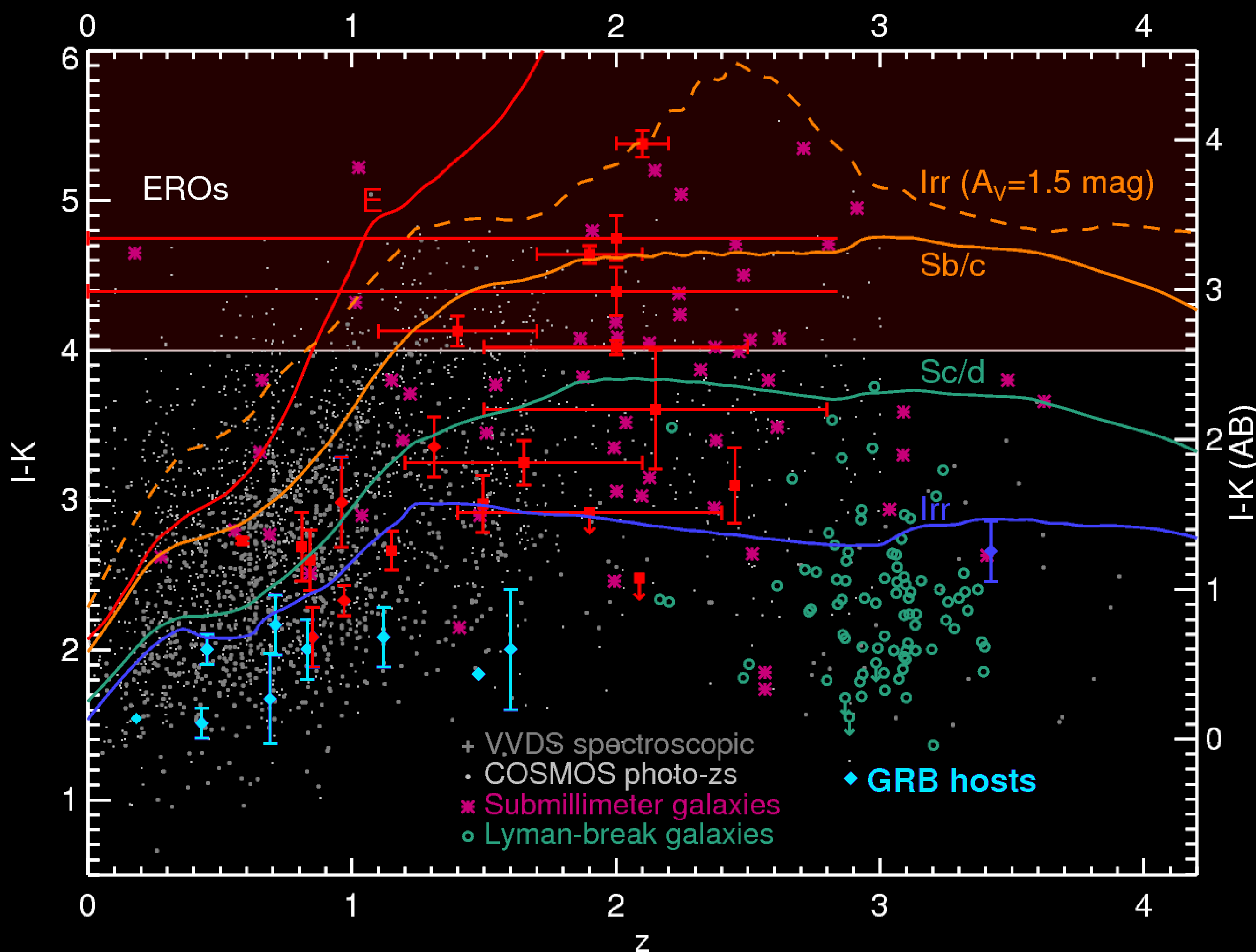
Swift: X-ray Afterglow Guaranteed



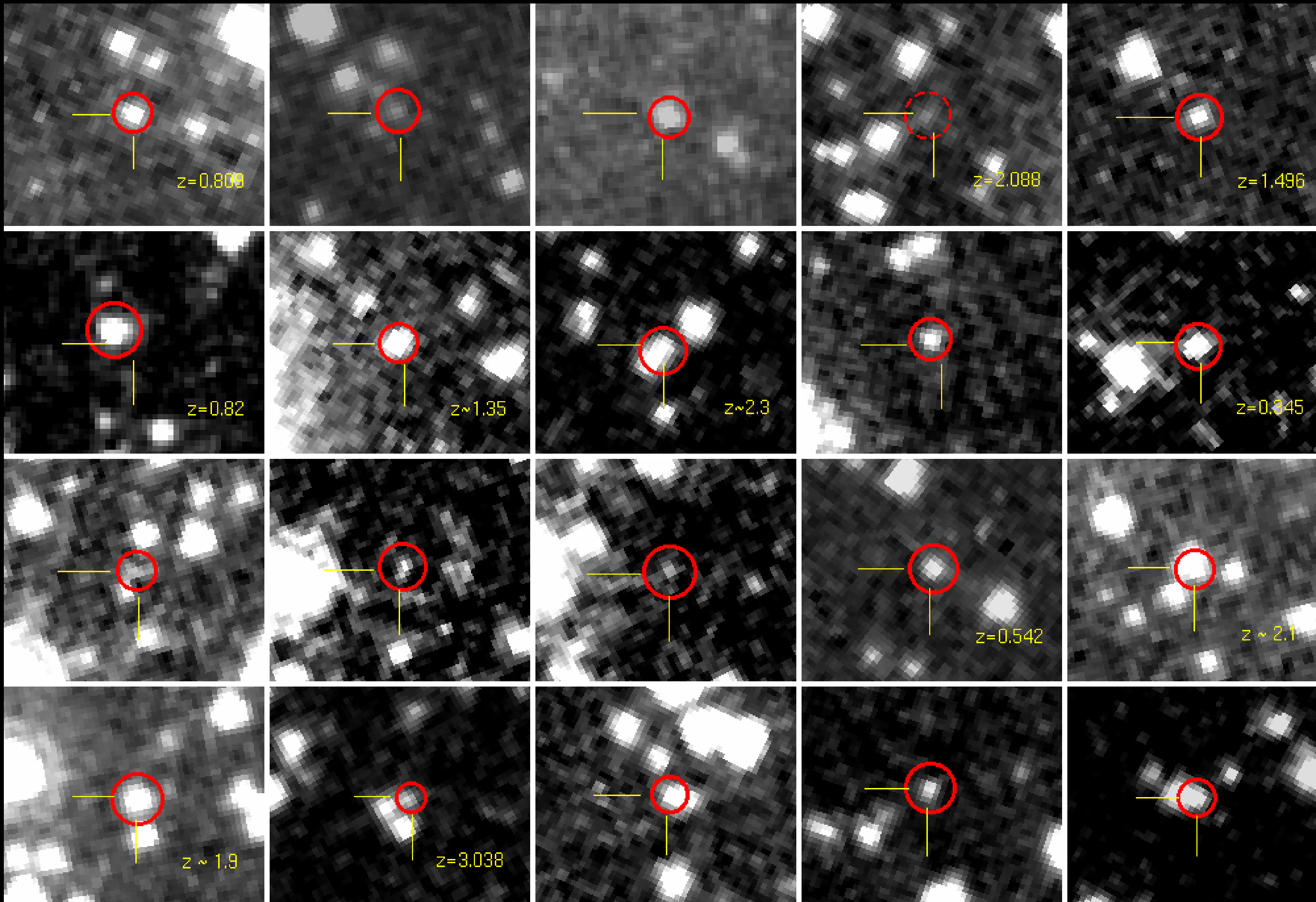
Bright GRB Hosts: Universally Blue?



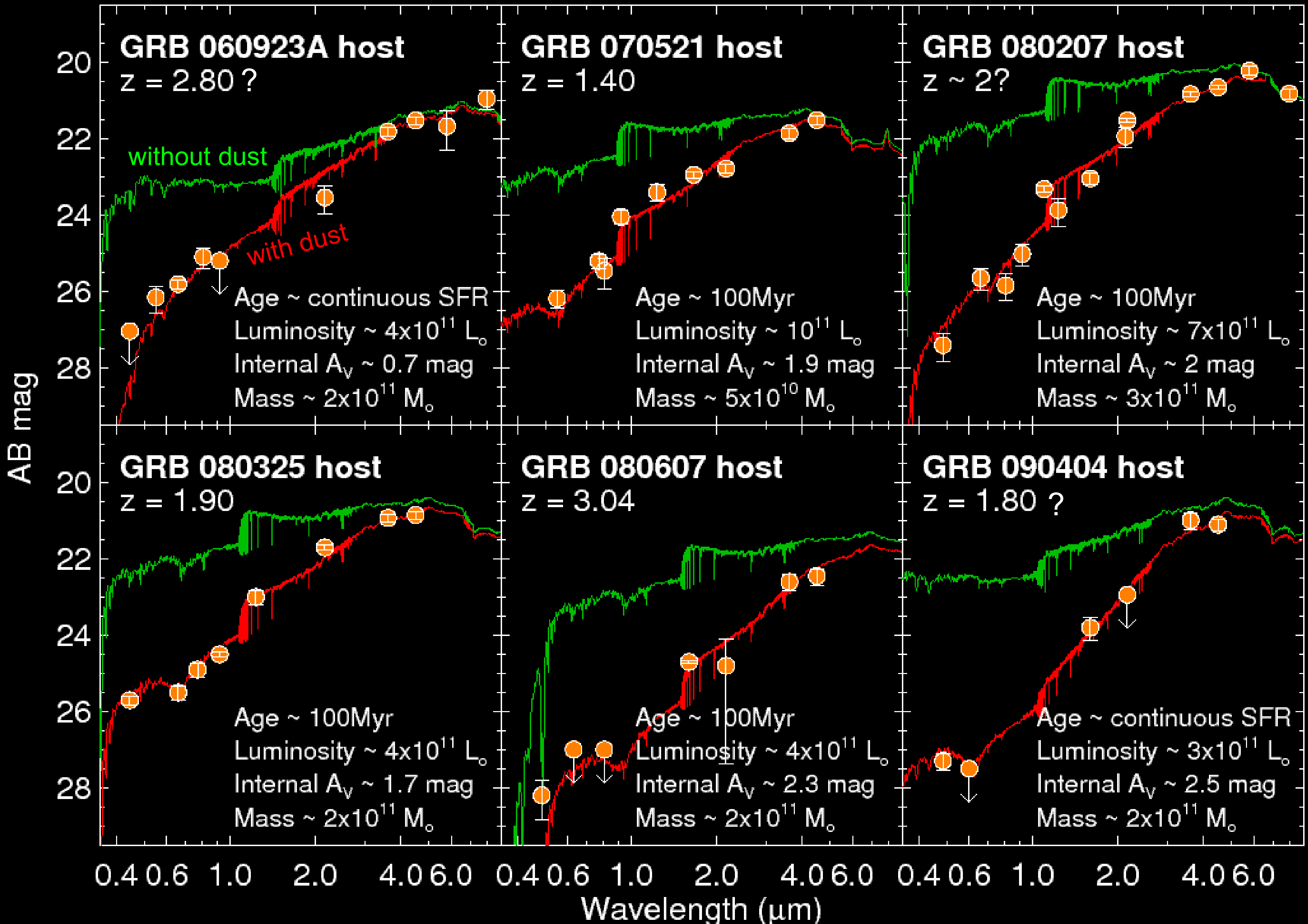
Dark GRB Hosts: Often Very Red



Dark Hosts Always Detected at 4.5μm



Dusty, Massive, Luminous Systems

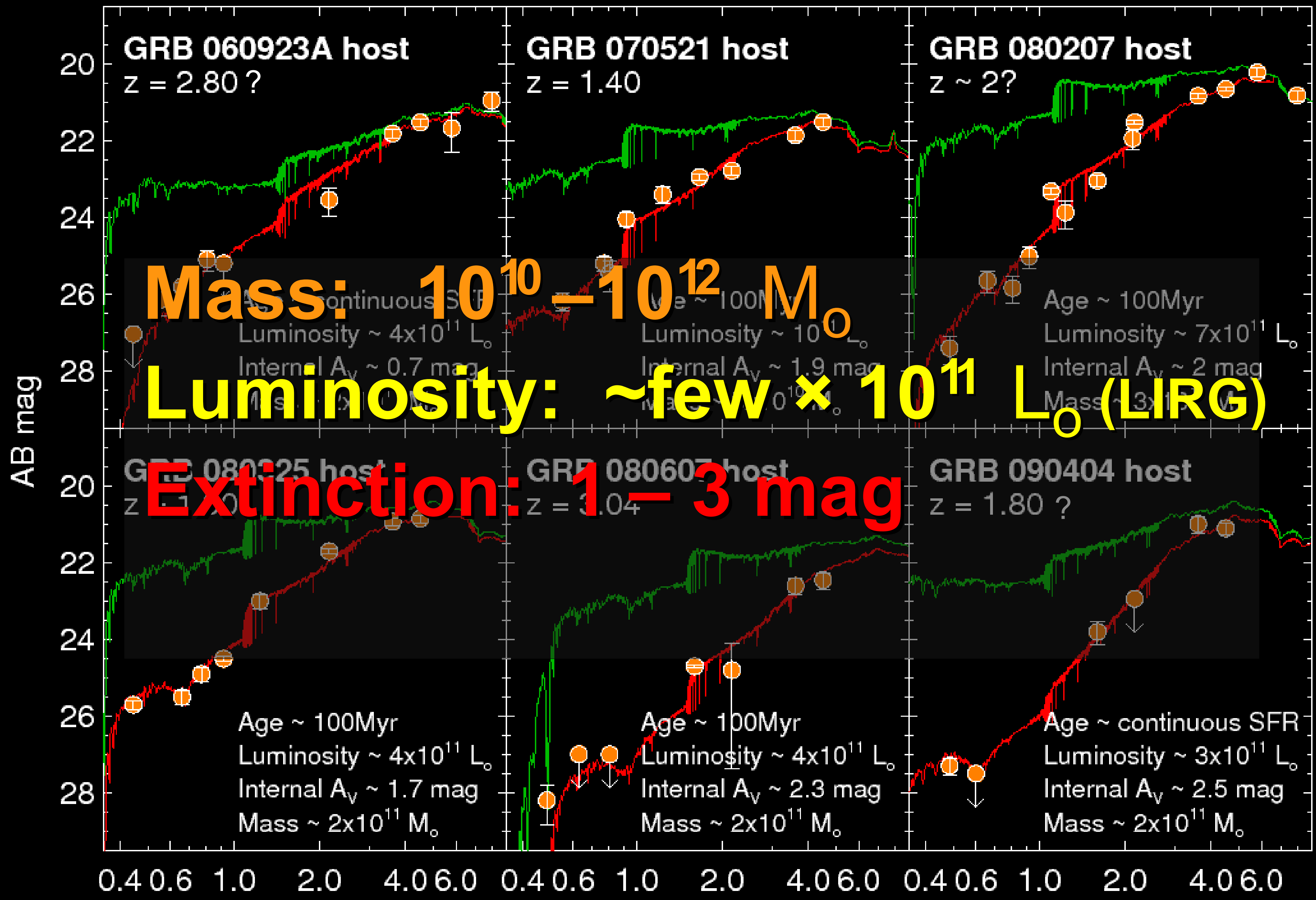


Dusty, Massive, Luminous

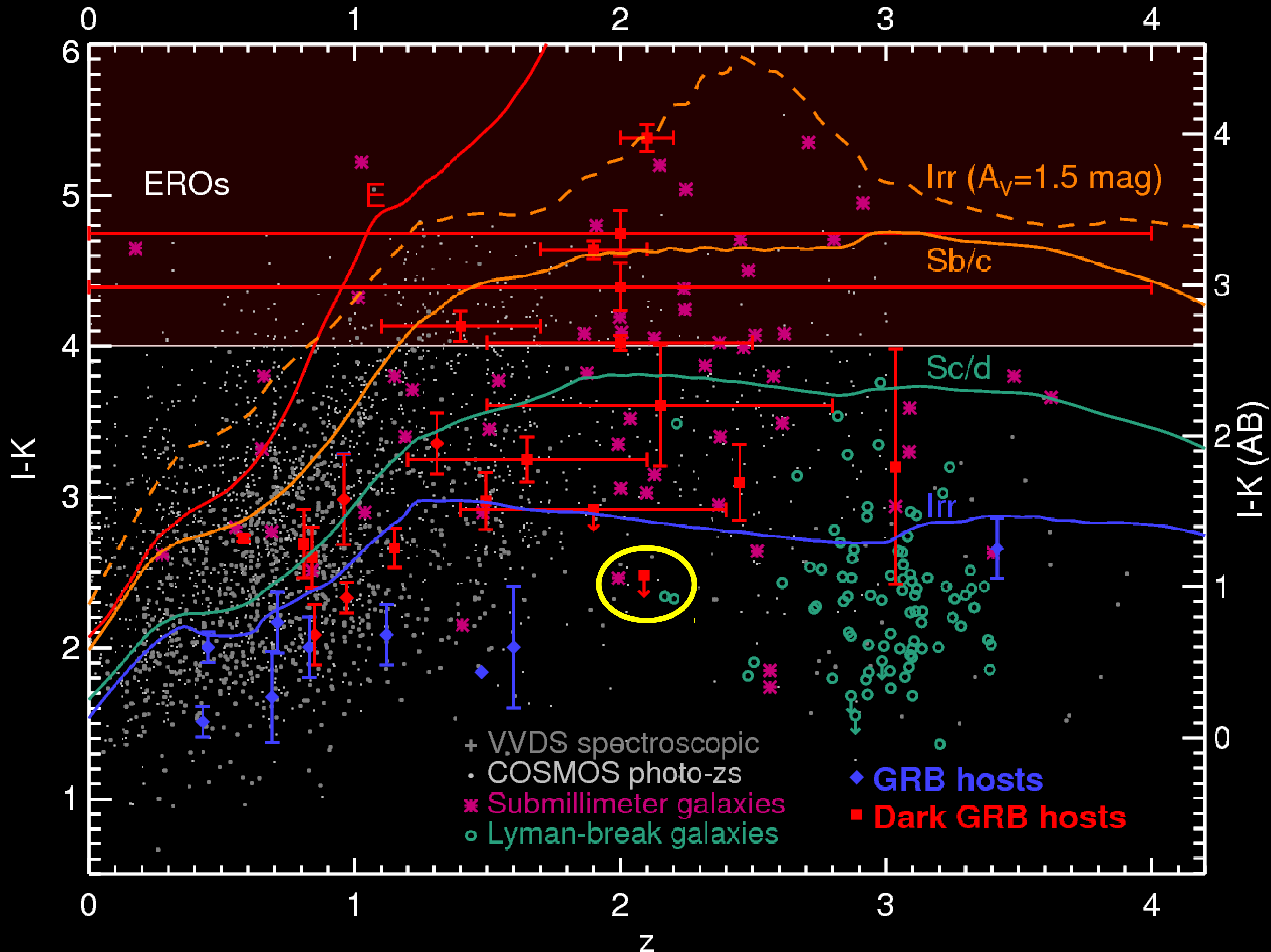
Mass: 10^{10}–10^{12} $M_{\odot}$

Luminosity: ~few × 10^{11} $L_{\odot}$ (LIRG)

Extinction: 1 – 3 mag



(But Not Always!)



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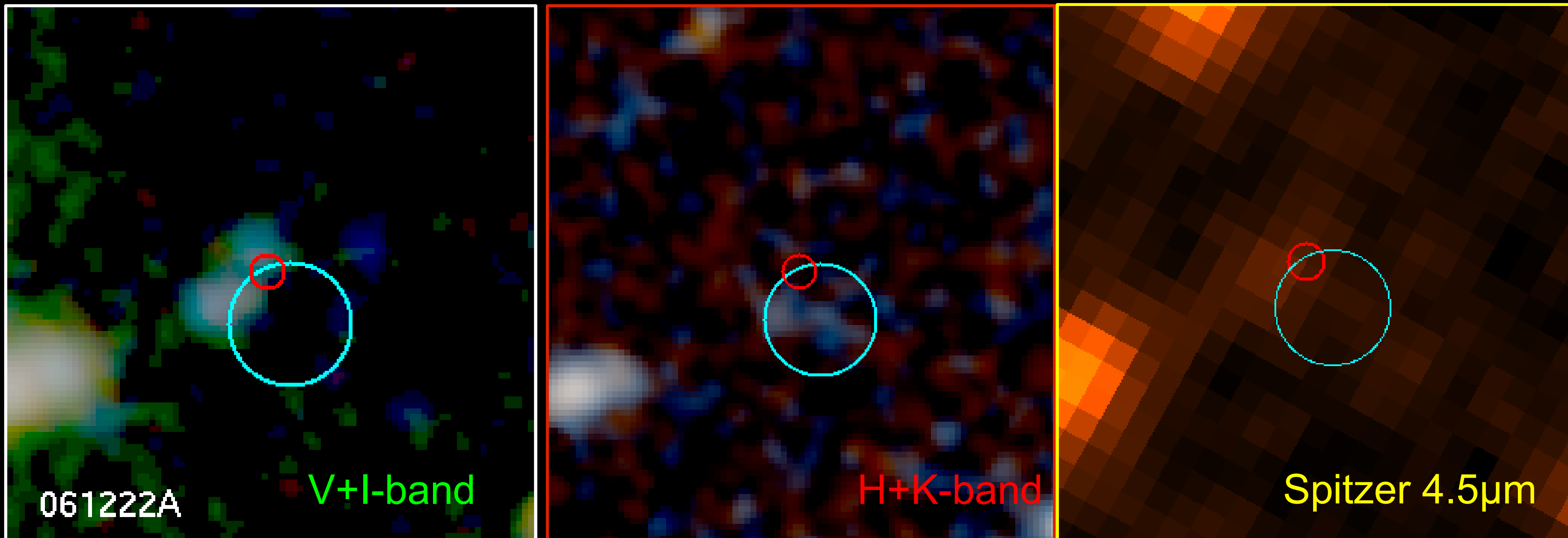


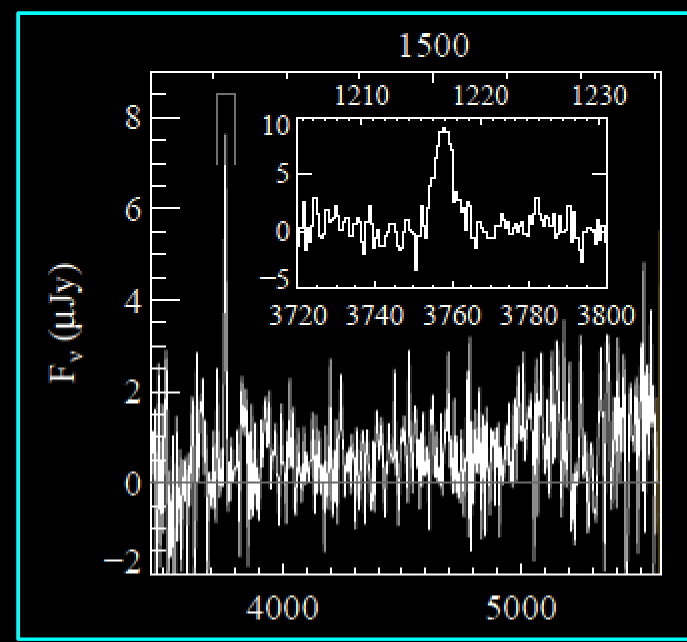
Ultra-dark burst (Av > 5 mag), but

Extremely **blue** host:

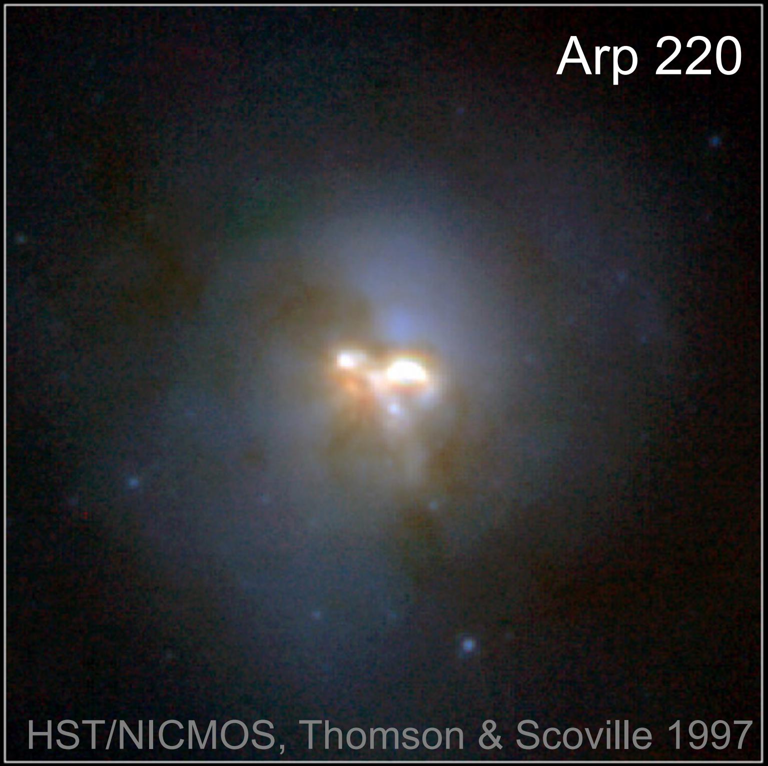
I-K ~ 2 mag

marginal or no Spitzer detection

Ly-α emitter at z=2.1

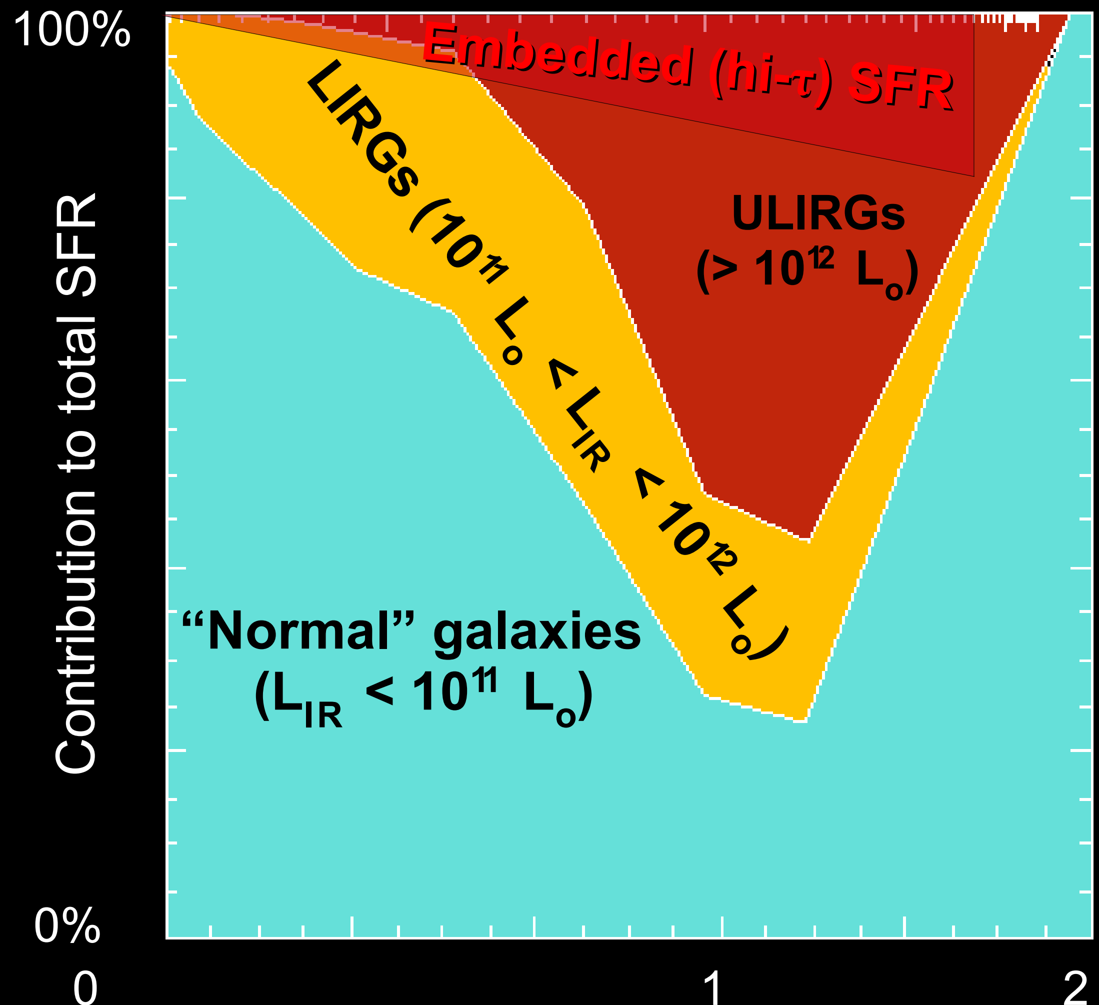


Highly-Embedded Star Formation?



SFR >> dust-corrected optical SFR

Low-z: ULIRGs High-z: SMGs

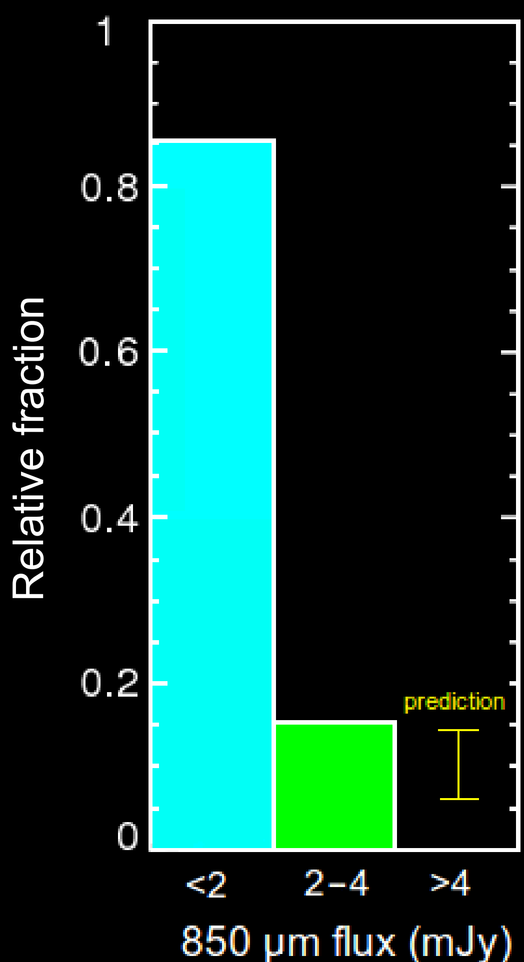


~20% of cosmic SFR at z~2

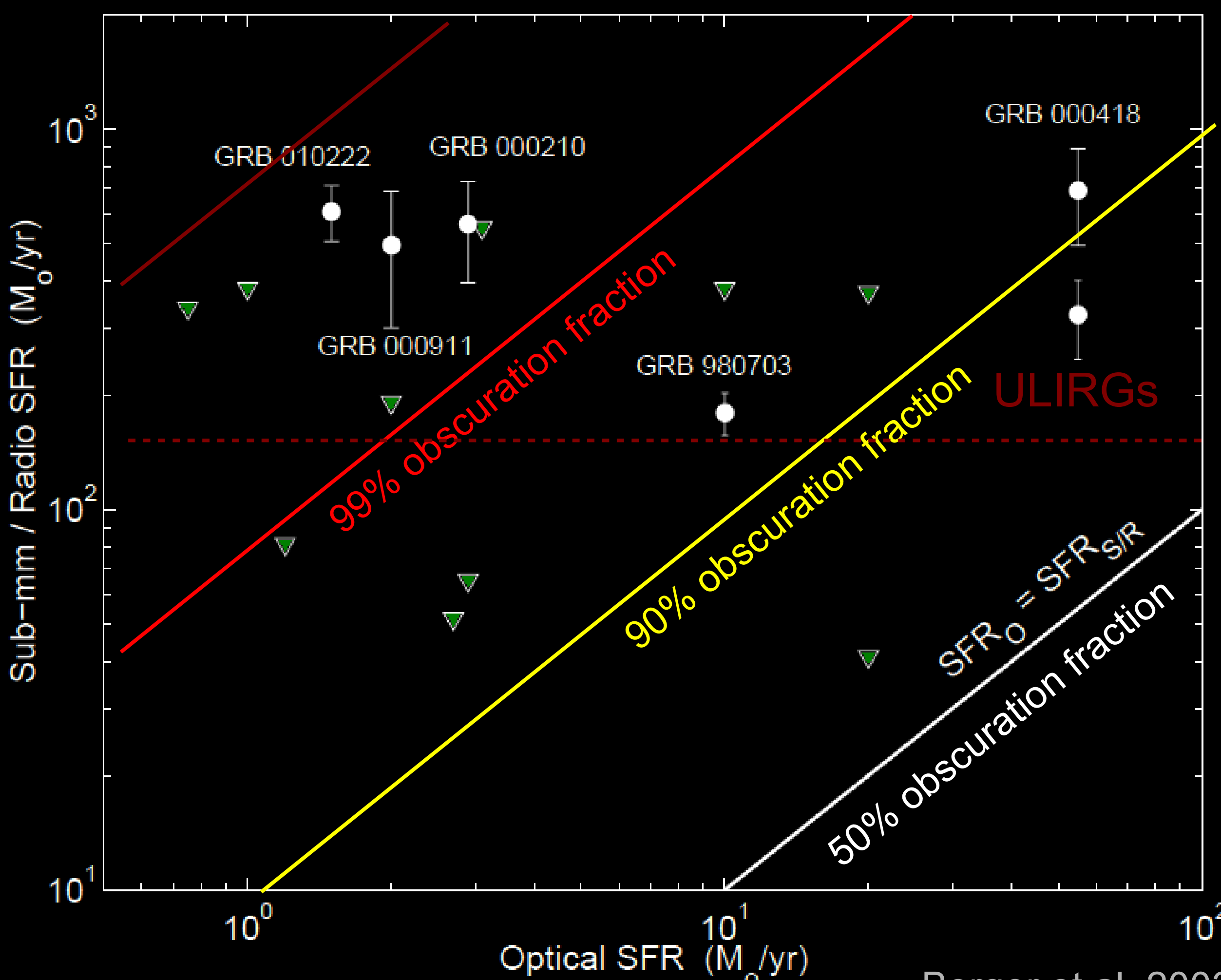
Michalowski et al. 2010, also Chapman et al. 2004

Pre-Swift Submillimeter Observations

Only a few pre-Swift detections (blue galaxies!)



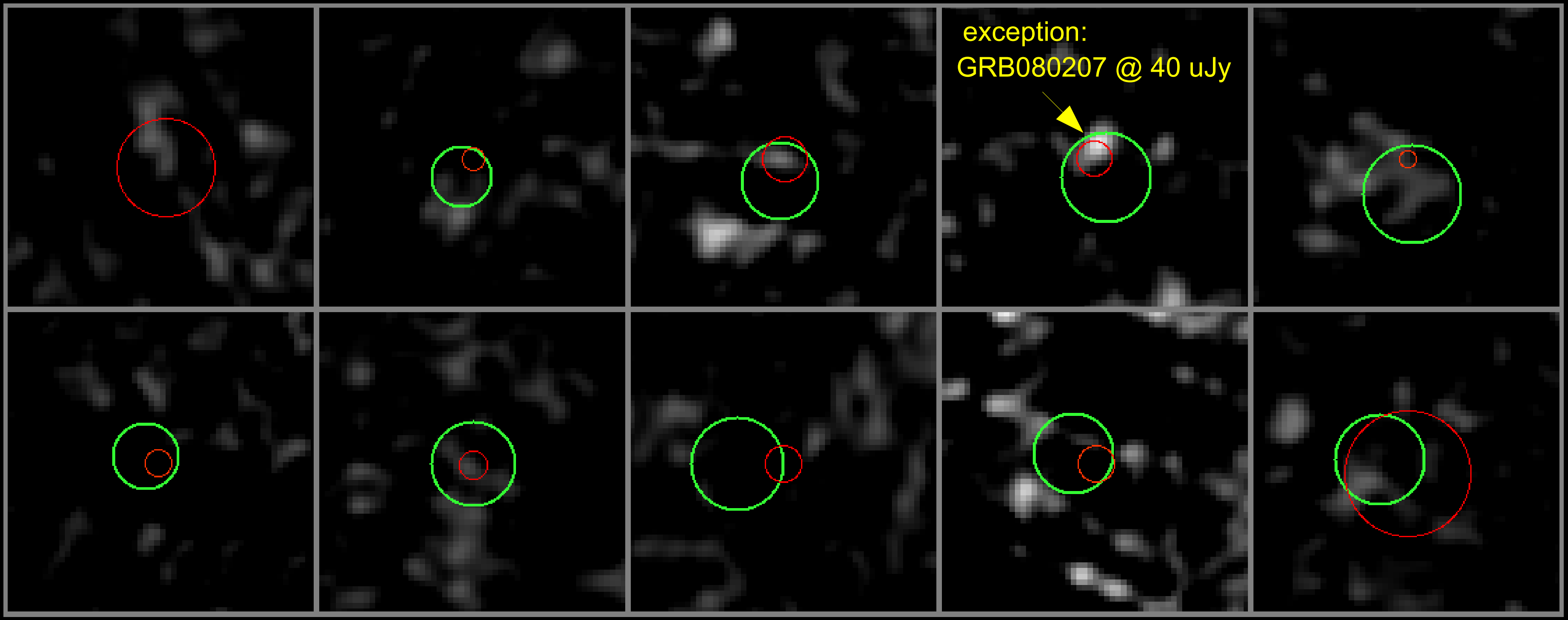
Tanvir et al. 2004



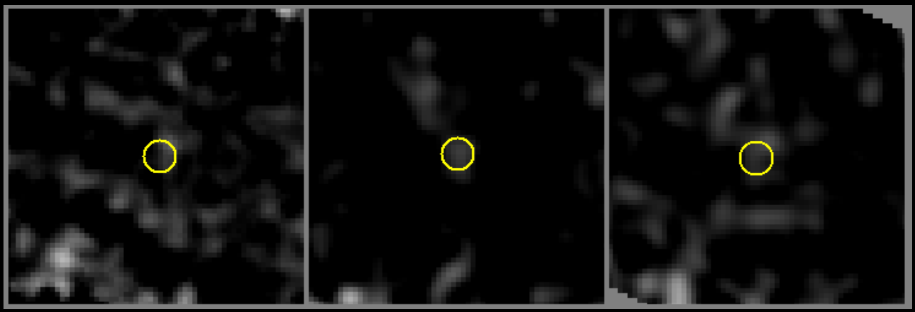
Berger et al. 2003

Radio/submm observations

No EVLA detection (to ~15 μJy @ 5 GHz)
for 9 out of 10 Spitzer-brightest hosts



No CSO detection (to ~10 mJy)
for 3 Spitzer-bright hosts



5-15 hr integration/target

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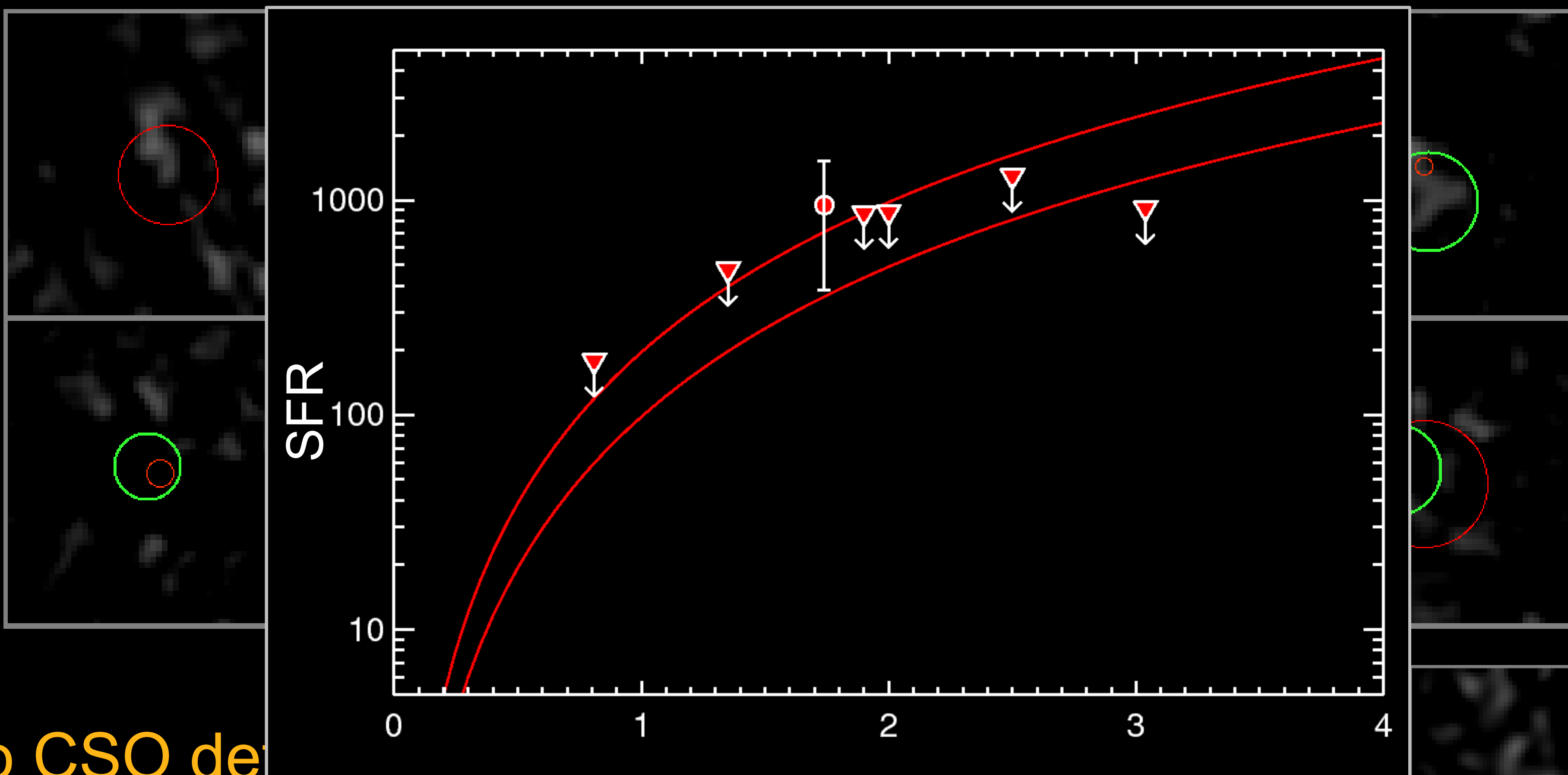

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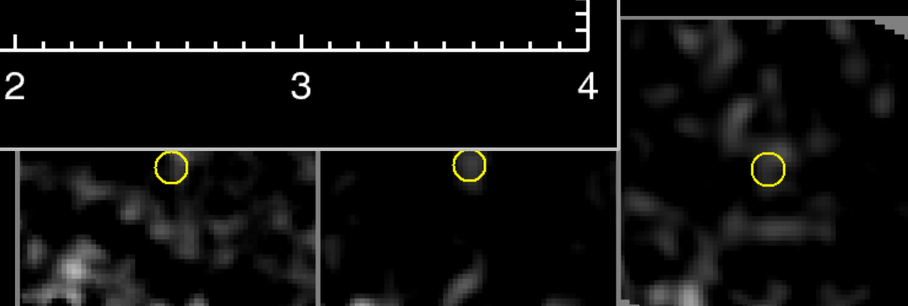
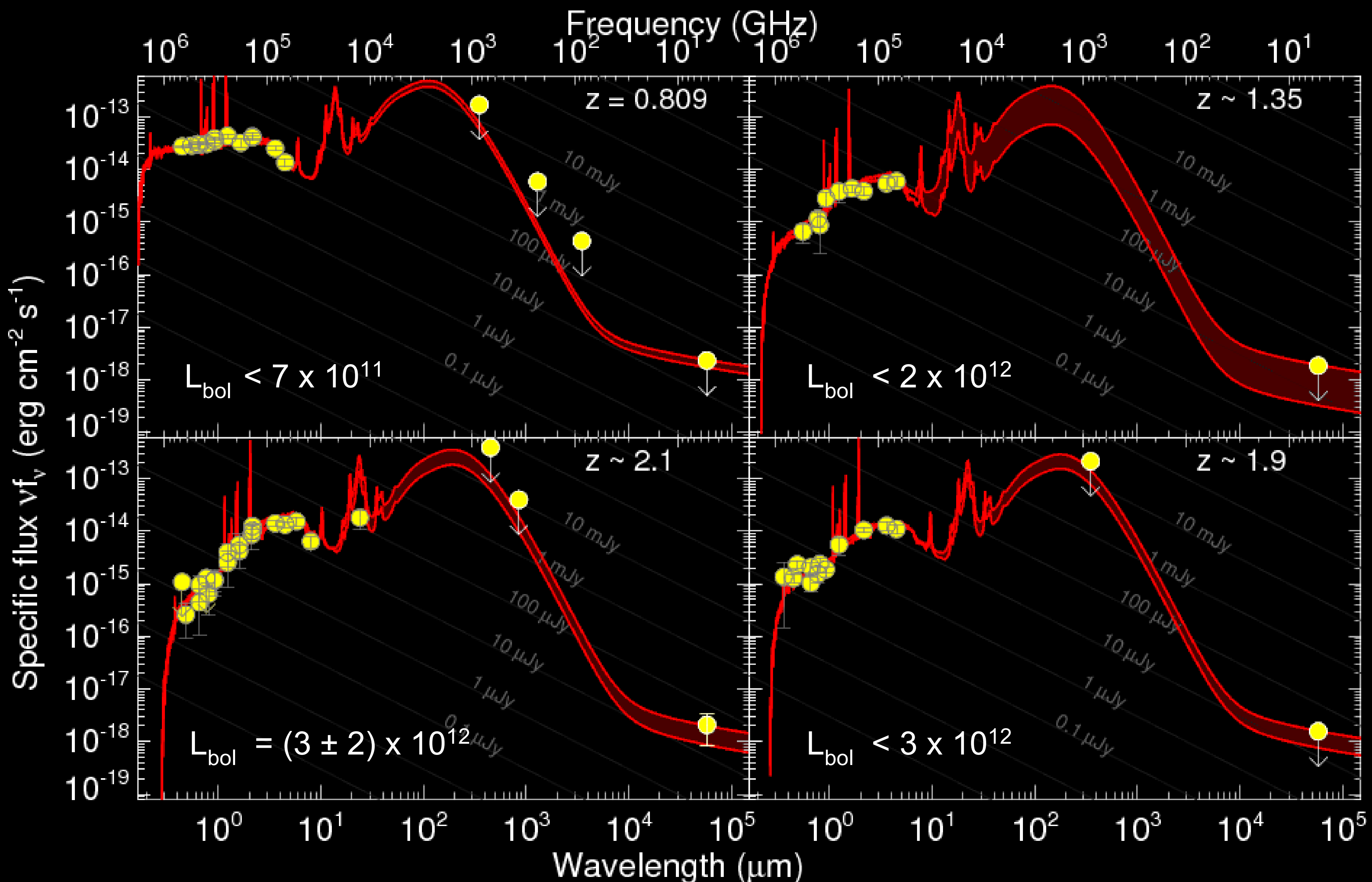


5-15 hr integration/target

LIRGs, not ULIRGs



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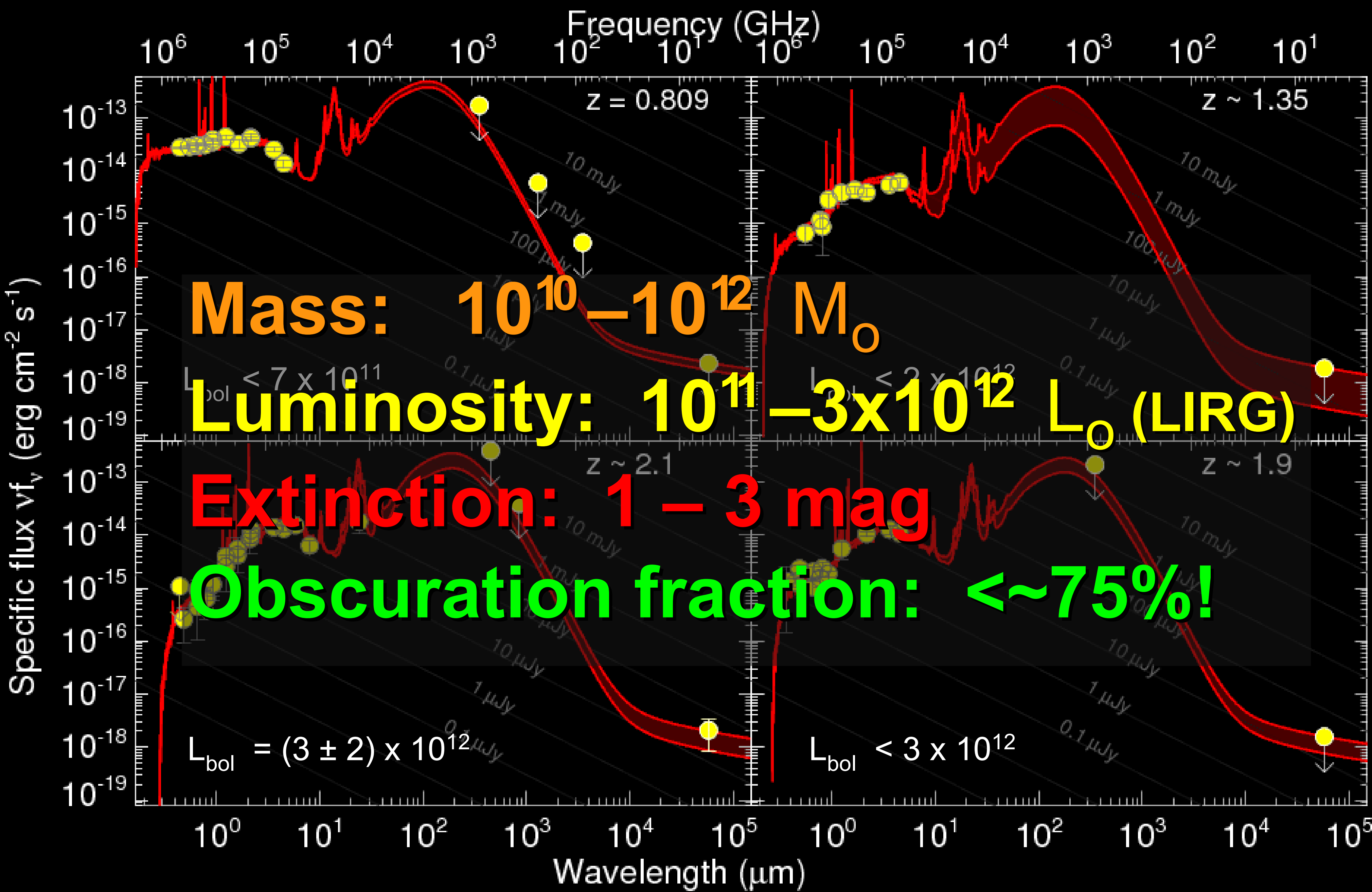


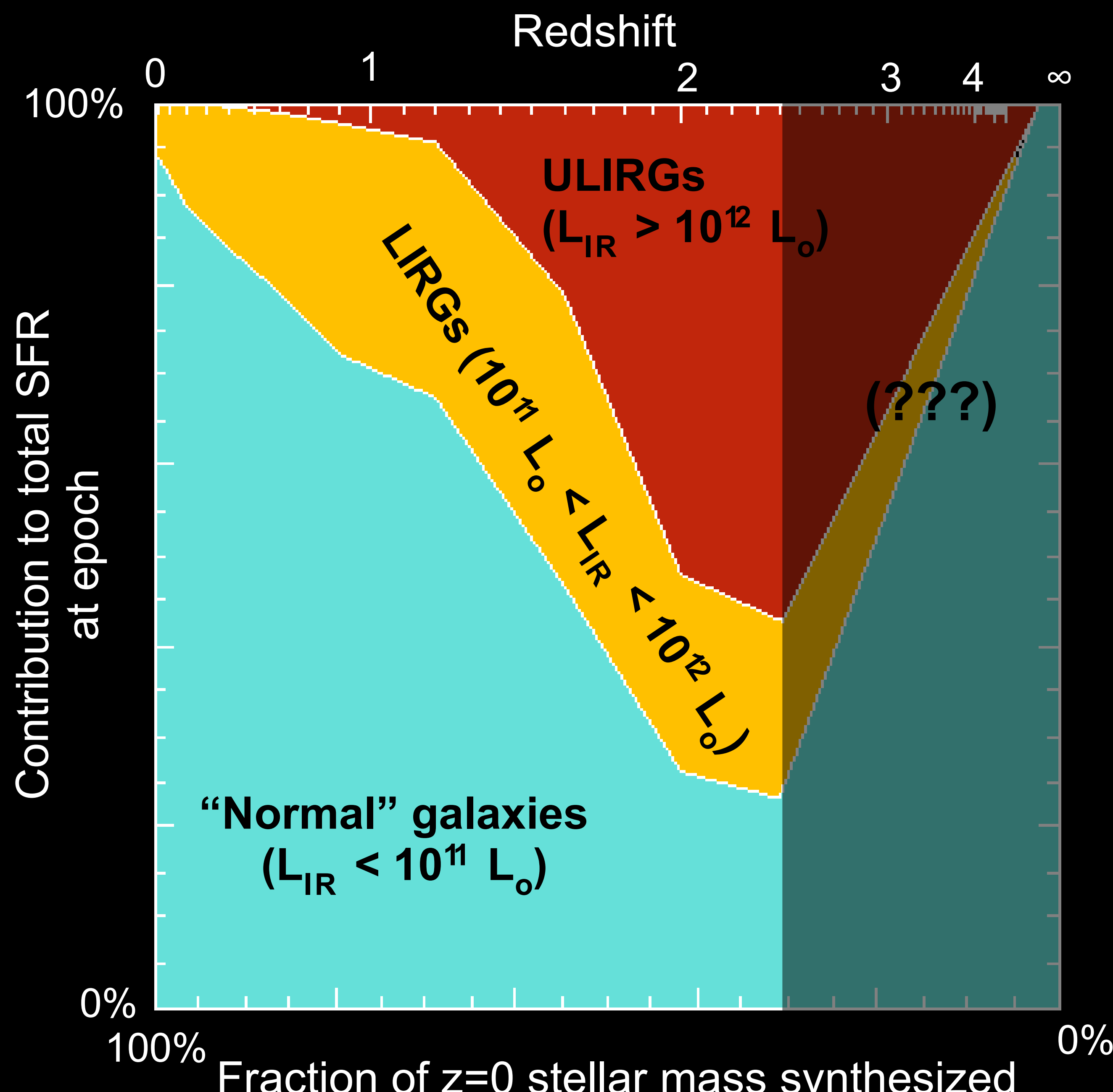
Mass: 10^{10}–10^{12} M_O

Luminosity: 10^{11}–3x10^{12} L_O (LIRG)

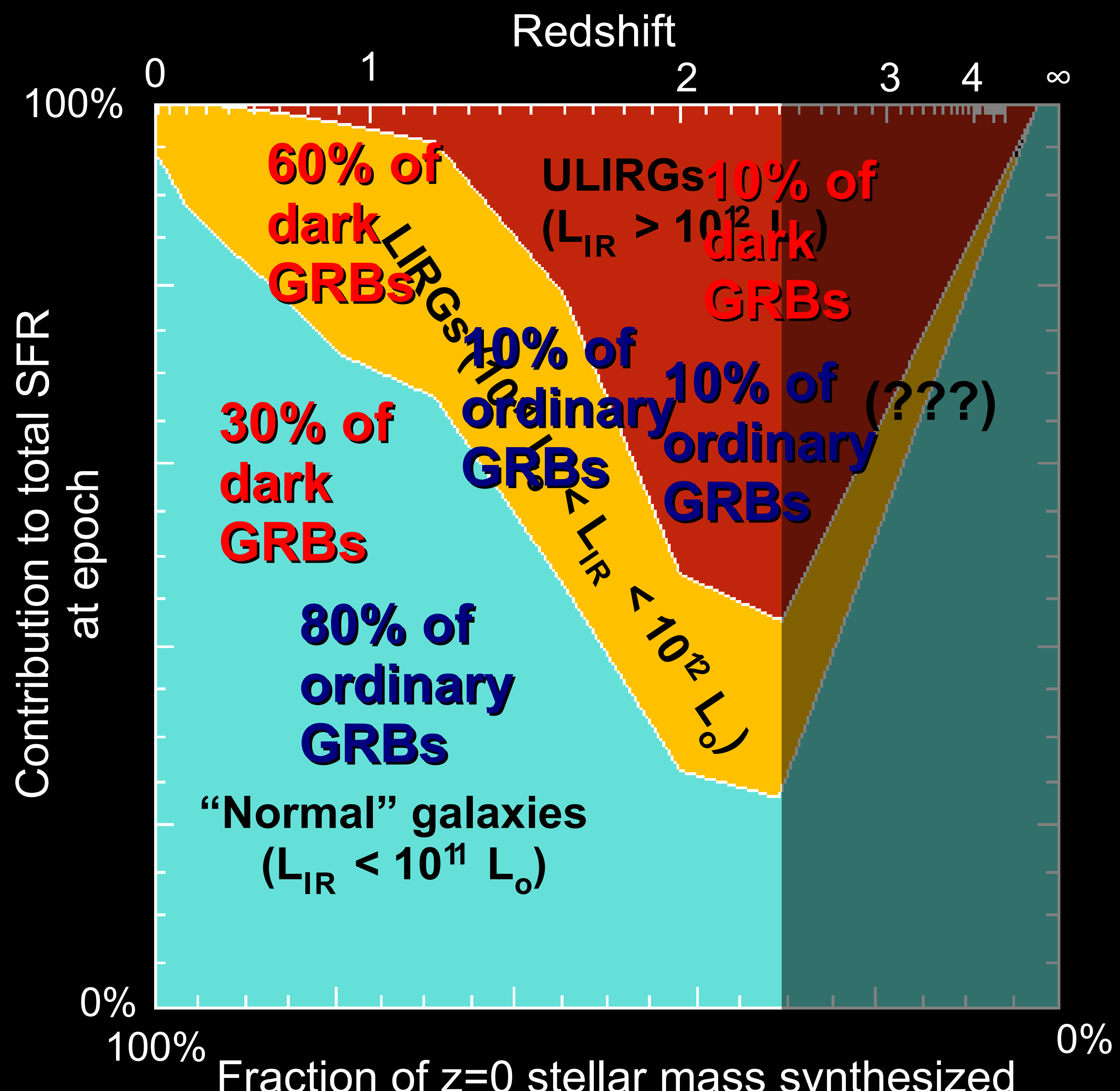
Extinction: 1 – 3 mag

Obscuration fraction: <~75%!

Implications for GRBs vs. SFR



Implications for GRBs vs. SFR



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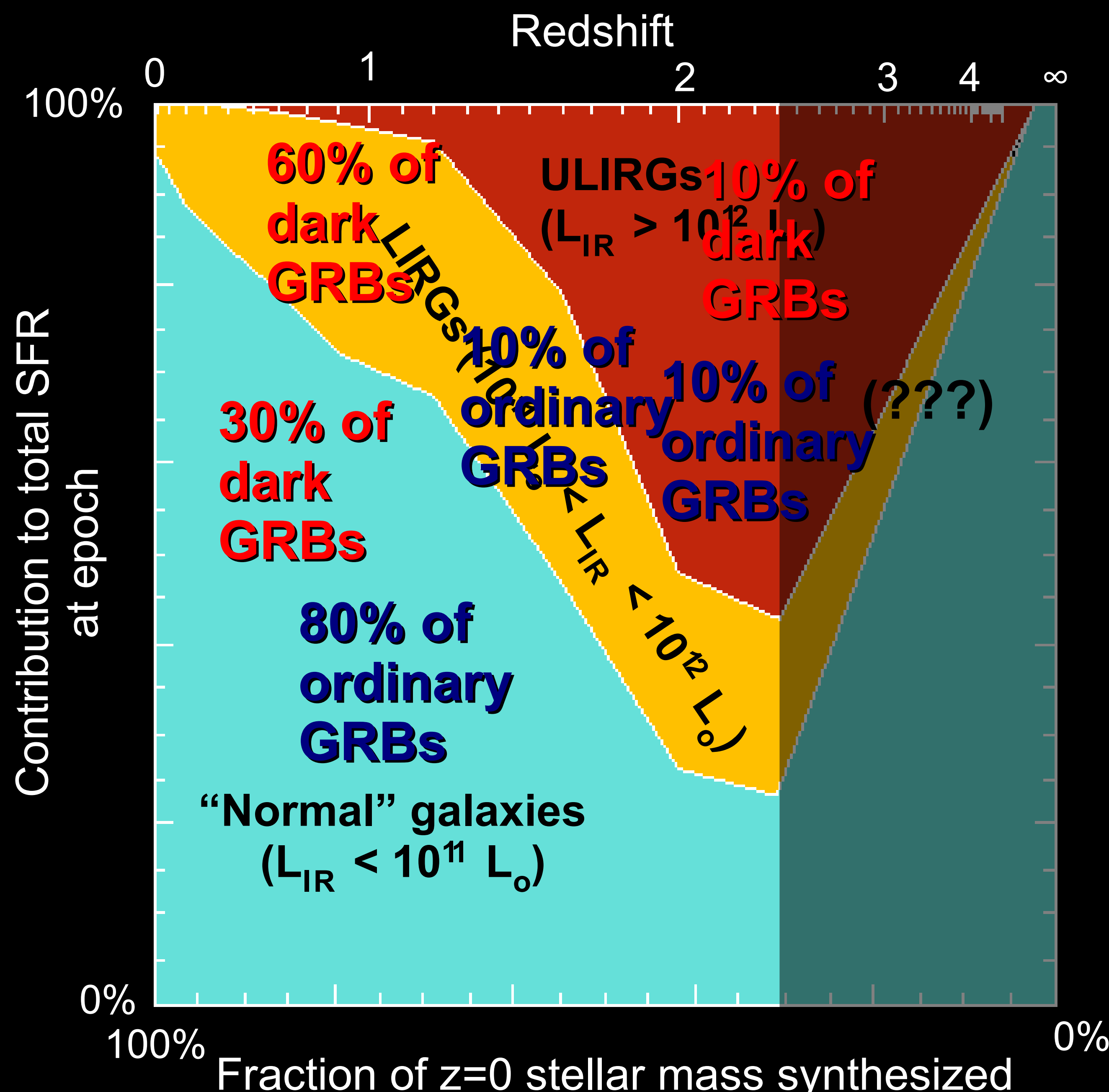
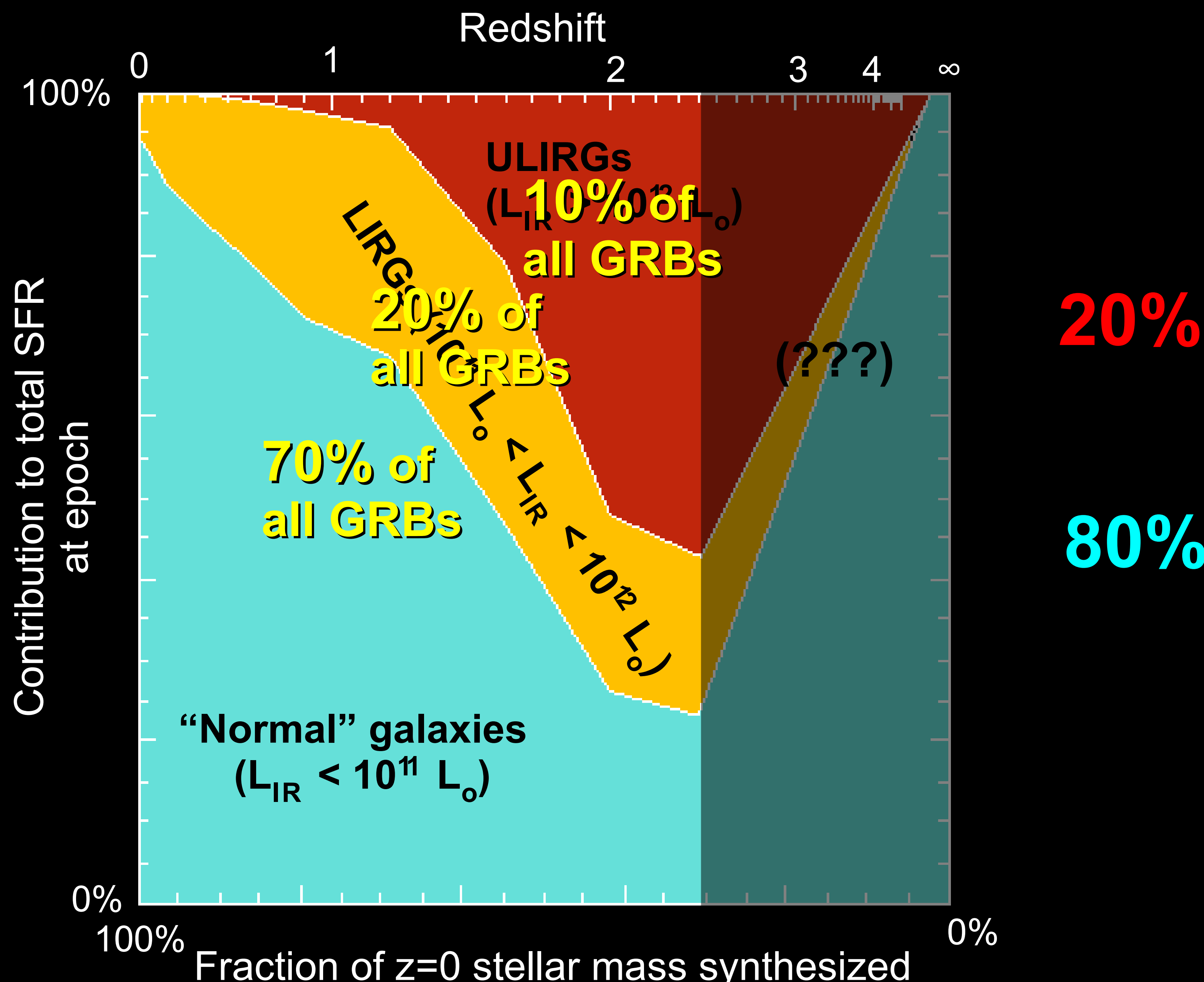


20%

80%

Implications for GRBs vs. SFR



Implications for GRBs vs. SFR

Still not enough GRBs from the dustiest galaxies(?)
(more data/analysis coming soon!)

GRBs aren't perfect (linear) SFR tracers –
but they *can* happen anywhere.

e.g.
Kistler et al. 2008
Butler et al. 2009
Robertson et al. 2011

What makes them underabundant?

Metallicity?

Complex, non-cutoff rate(Z) relation?

Are cores of dusty galaxies particularly metal rich?

Variable IMF?

If GRBs are from >20 Mo stars, rate should be ultra-sensitive to variations. Some evidence that high-z high-sSFR systems are top-light.