The Swift GRB Host Galaxy Legacy Survey

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Ruben Ramirez (PUC)
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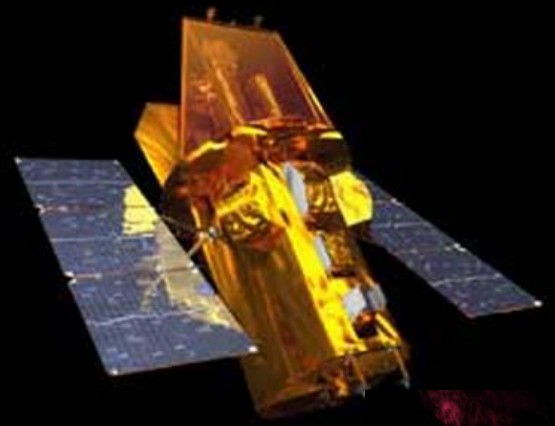
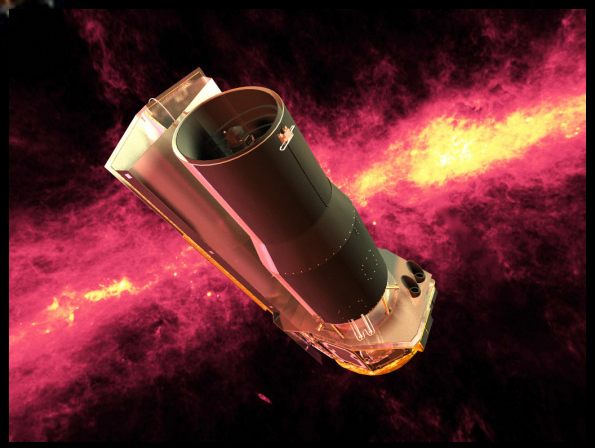
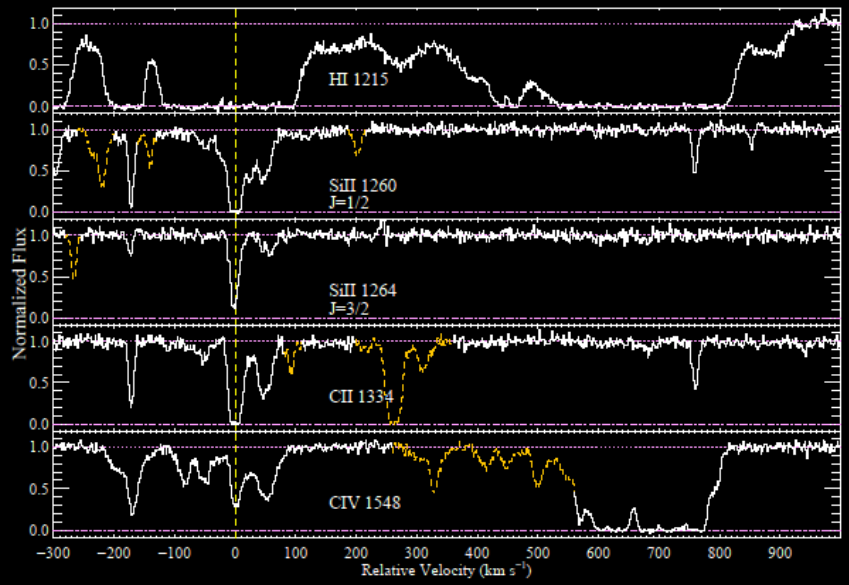


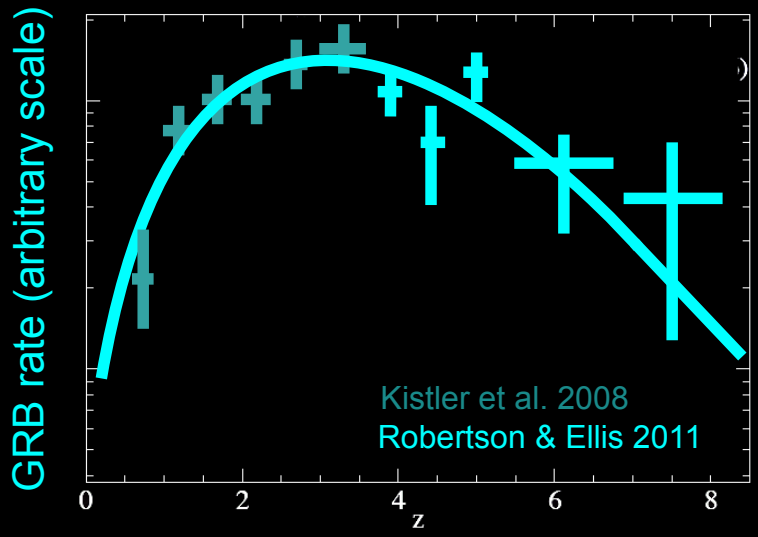


GRBs, Galaxies, and Cosmic History

What is the **GRB progenitor**?
(Binary, single, ...?)

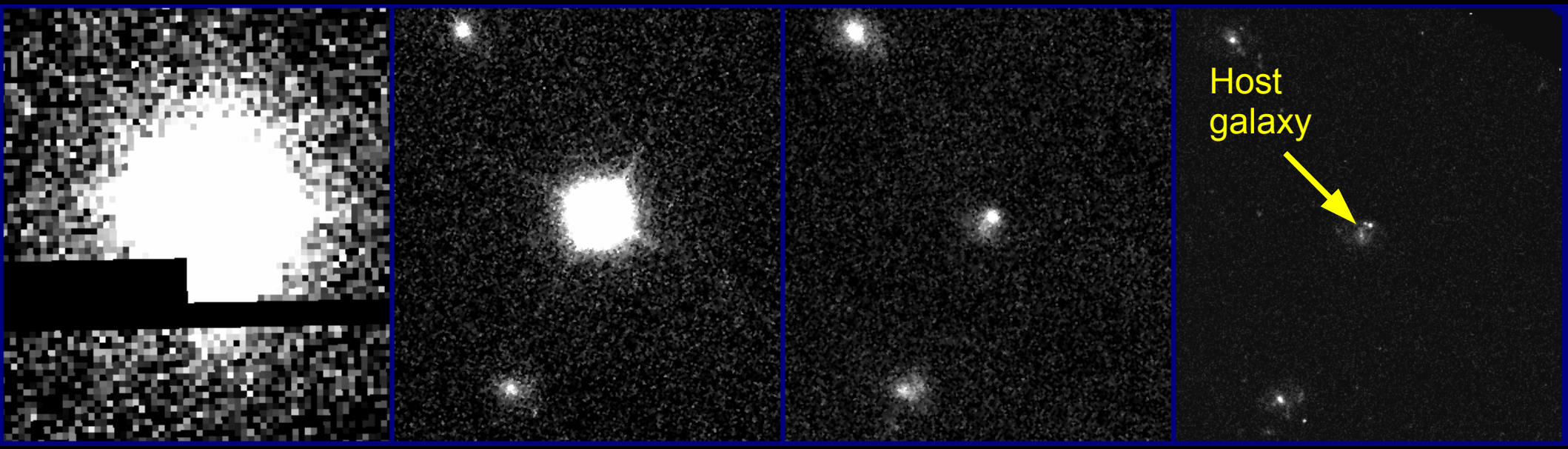
What is the nature of the **high-z galaxies** whose **ISM** we observe in afterglow spectra?





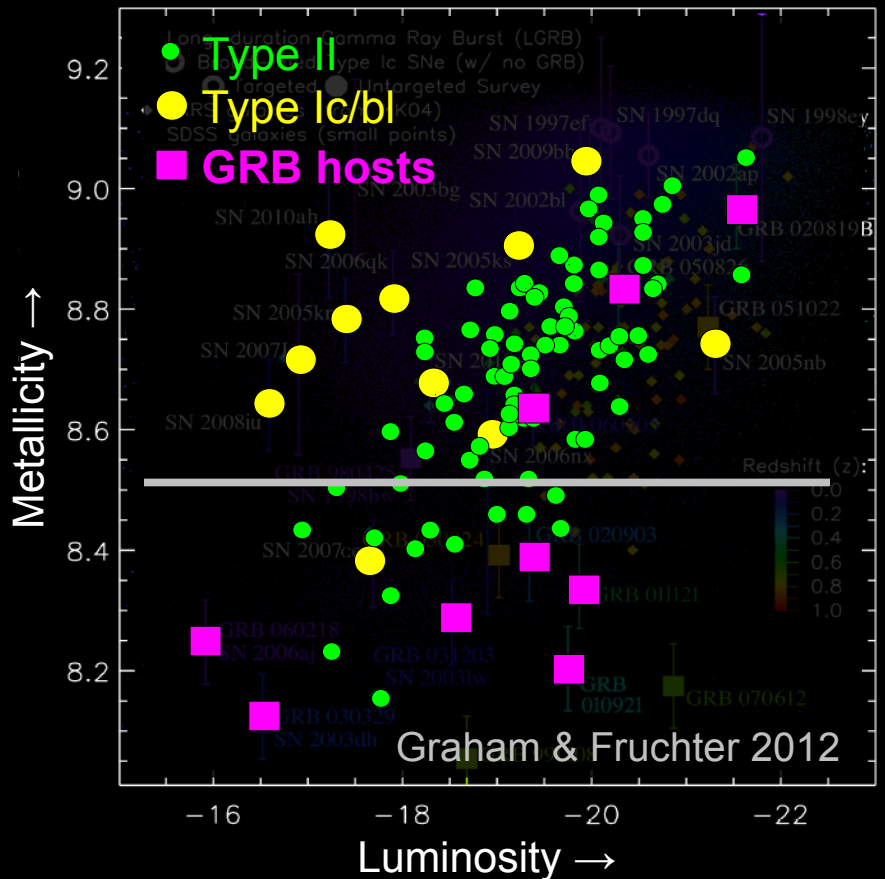
Can we use GRBs to study **cosmic star-formation** (including dusty, distant, and ultra-faint galaxies?)

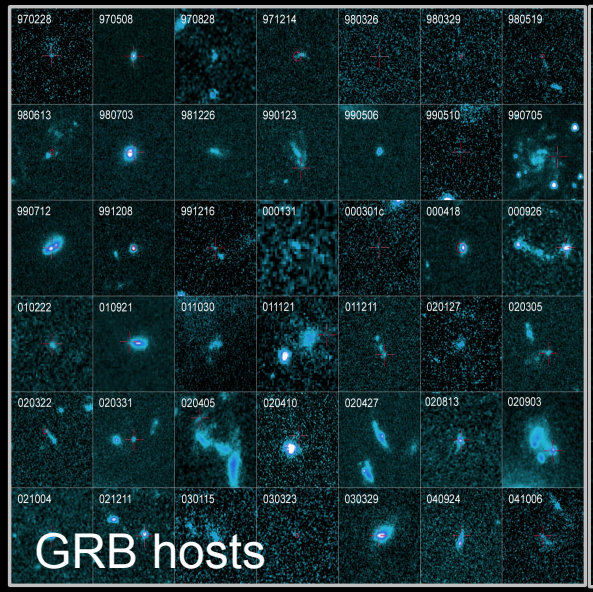
GRB Host Studies

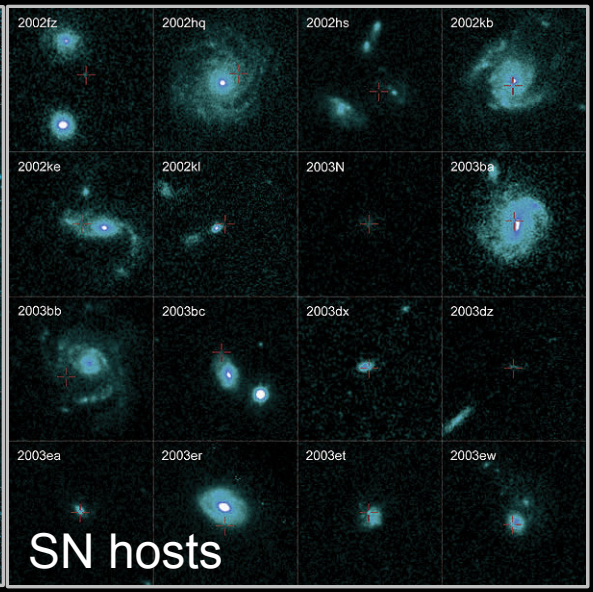


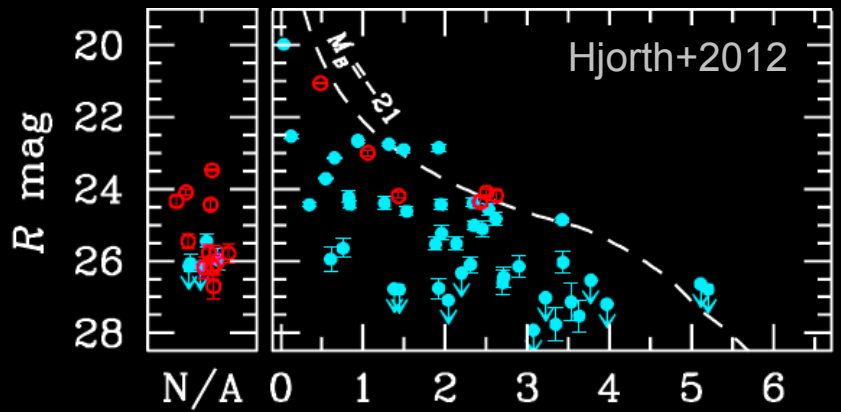
Δt ~ 6 minutes ~ 1 hour ~ 20 days ~ 75 days

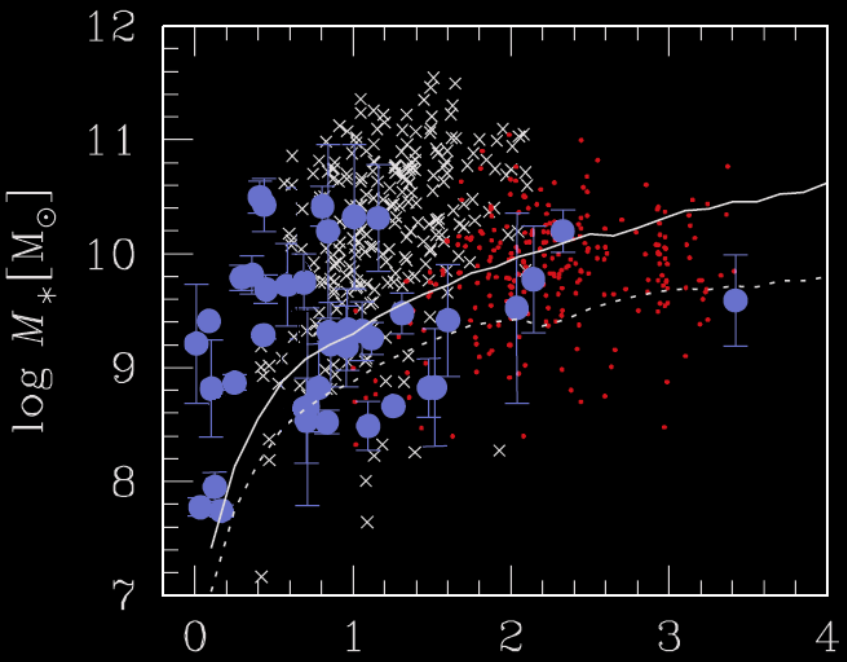
GRB Host Studies











Unanswered Questions

But even after 10 years of *Swift*, no clear consensus:

Why do GRBs favor faint, low-mass galaxies at z~0?

Metallicity upper limit? Metallicity dependence?

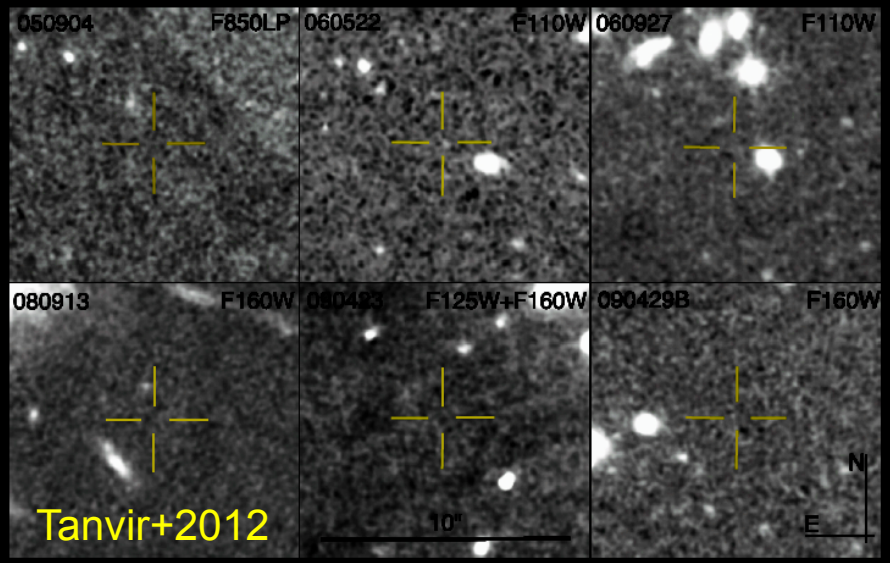
Something else? Multiple factors?

e.g., Wolf+2007, Modjaz+2009, Levesque+2010, Mannucci+2011, Kocevski+2011, Graham+2013, van den Heuvel+2013, Trenti+2014, Perley+2013a,2014b, Kelly+2014, Hashimoto+2014

How/why do GRB host properties evolve with redshift?

How will the "bias" at low-z affect studies at high-z?

(Ultra-deep HST observations → at z>6 detect few or no hosts; how do we interpret this?)



The Need for an Ambitious New Survey

Other GRB host surveys to date have been **small**, **non-uniform**, or had **limited wavelength coverage**.

small: too few events in any specific redshift range to determine distribution of properties.

non-uniform: dark bursts (even mildly dark bursts) sample a very different host population!

e.g., Kruehler+2011, Rossi+2012, Hjorth+2012, Perley+2013, Hunt+2014

limited wavelength coverage: optical samples rest-frame UV; hard to distinguish low-luminosity vs. dusty galaxies. Ground-based NIR cannot go deep enough beyond z>1 to detect most galaxies.

The Swift Host Galaxy Legacy Survey

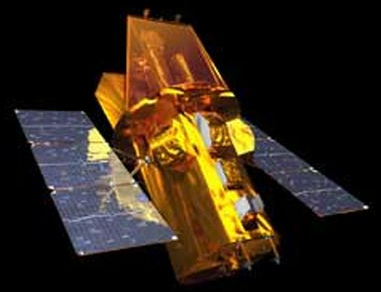
"**SHOALS**": A **large**, **uniform**, **multiwavelength** survey of Swift GRB host galaxies at all redshifts.

large: collect enough events to provide reliable parameter distributions *even after* subdivision into redshift bins ($\Delta z \sim 0.5$): 20 per bin, so >100 overall.

uniform: Use unbiased selection criteria to select well-observed bursts (usually have known redshifts) *without* imposing a bias against dark bursts.
(similar strategy as TOUGH & BAT6 samples)

multiwavelength: Acquire *deep* imaging in multiple optical filters *and* in mid-infrared to measure full stellar SED: young stars, old stars, impact of dust.

SHOALS Selection Criteria

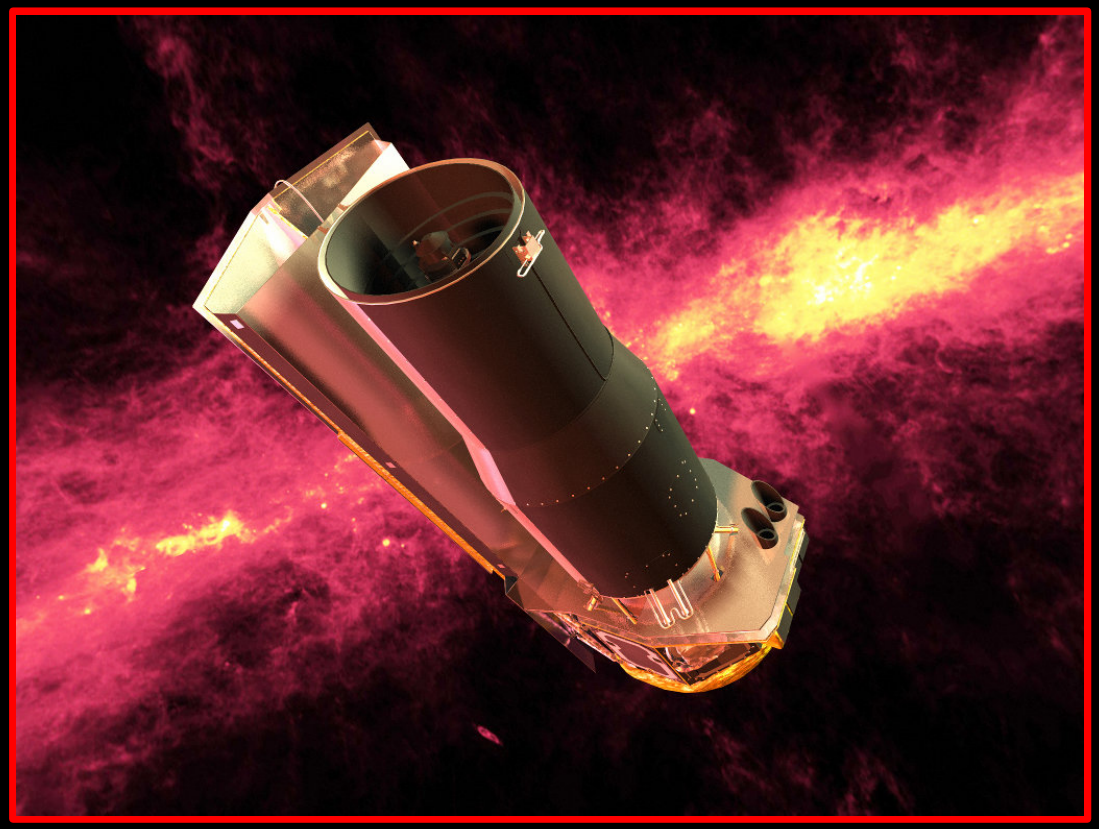


- *Swift* detected; gamma-ray fluence > 10^{-6} erg/cm^2
- *Swift* slewed immediately to the position
- Well-observed or at least well-observable:
  - (a) Autonomously triggered a 2m-class telescope, *or*
  - (b) >5 hours from Sun and between 2005-2009*, *or*
  - (c) Satisfied TOUGH positional criteria
- Low Milky Way foreground extinction
- No nearby bright foreground stars/galaxies
- Localized within 2”

		total	w/redshift	redshift completeness before survey	redshift completeness current
	SHOALS	**119**	**110**	**73%**	**92%**
(Hjorth+2012)	TOUGH	69	58	55%	89%
(Salvaterra+2012)	BAT6	58	53	86%	90%
	All Swift bursts	855	303	35%	
	Jakobsson+2006	248	132	53%	

* slightly more restrictive than initial sample of 2005-2010

SHOALS Observations



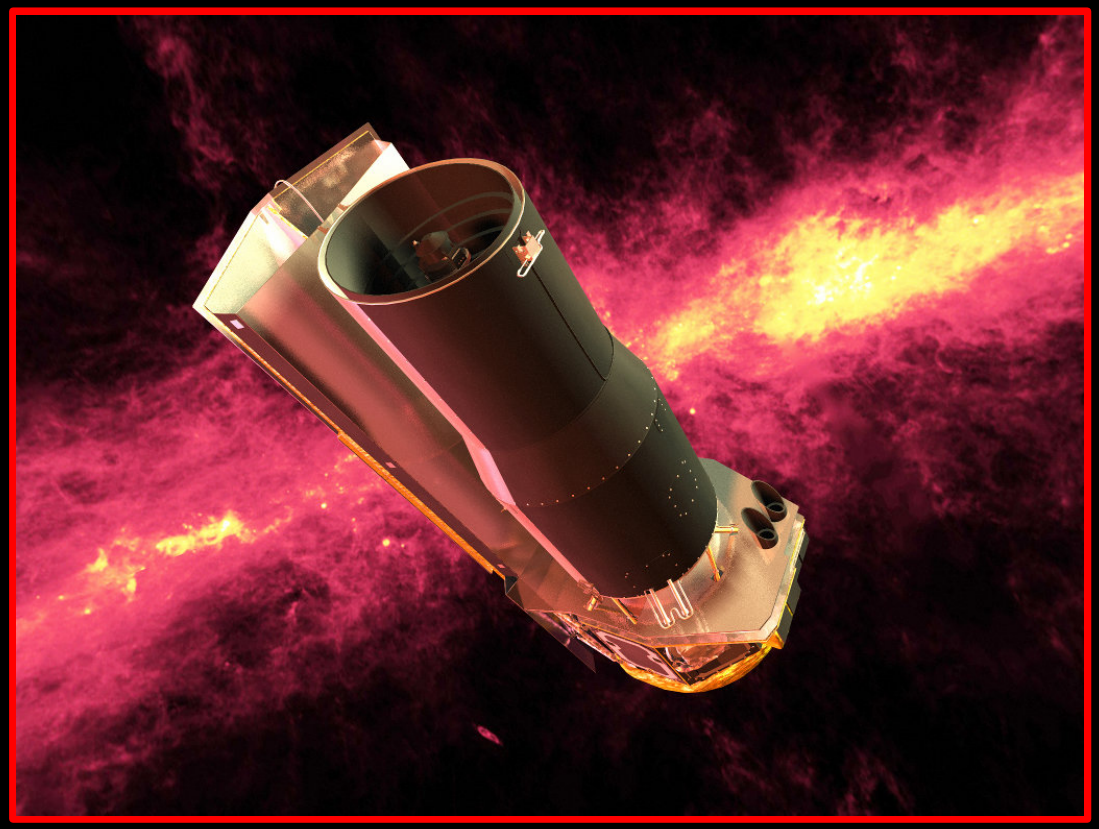
Spitzer (3.6 μm imaging):

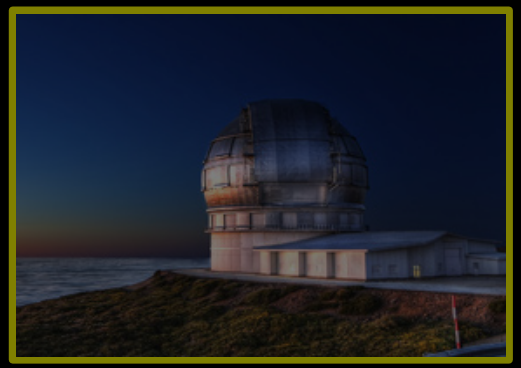
- Good **stellar mass** proxy (even with no color information);
- Sensitive to 10^{10} $M_{\odot}$ galaxies to z~5
- 230-hour large program to observe **all SHOALS targets** (+ some others of interest)
  - Two archival fields turned out to be afterglow-contaminated

Keck, Gemini, VLT, GTC

- Spectroscopy to complete redshift distribution, measure metallicities of some galaxies
- Multicolor optical/NIR imaging for full SED modeling (age, extinction, improved stellar masses) for **all (sufficiently bright) galaxies**
- Ongoing, worldwide campaign

SHOALS Observations





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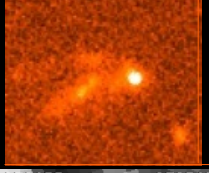
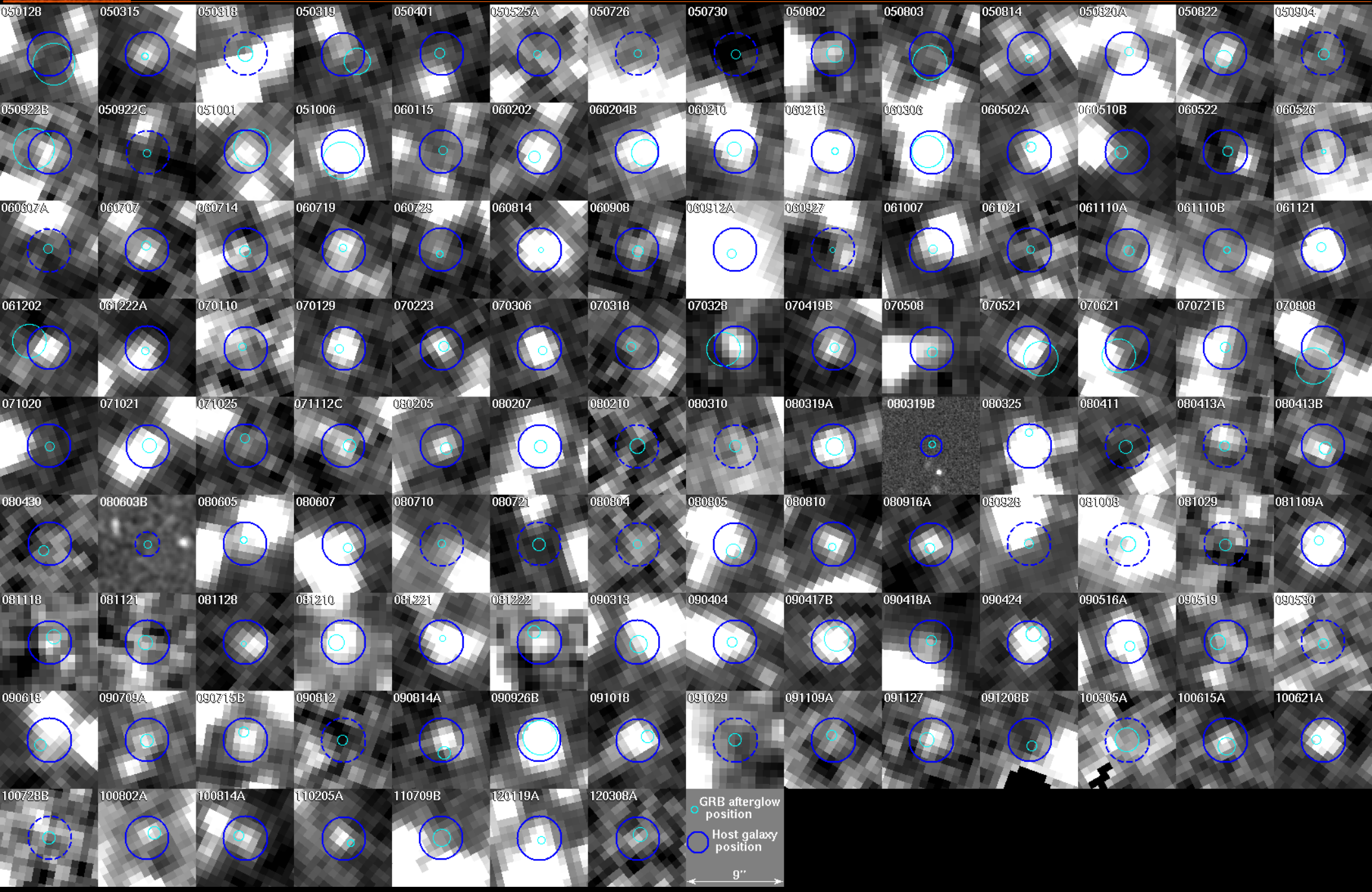
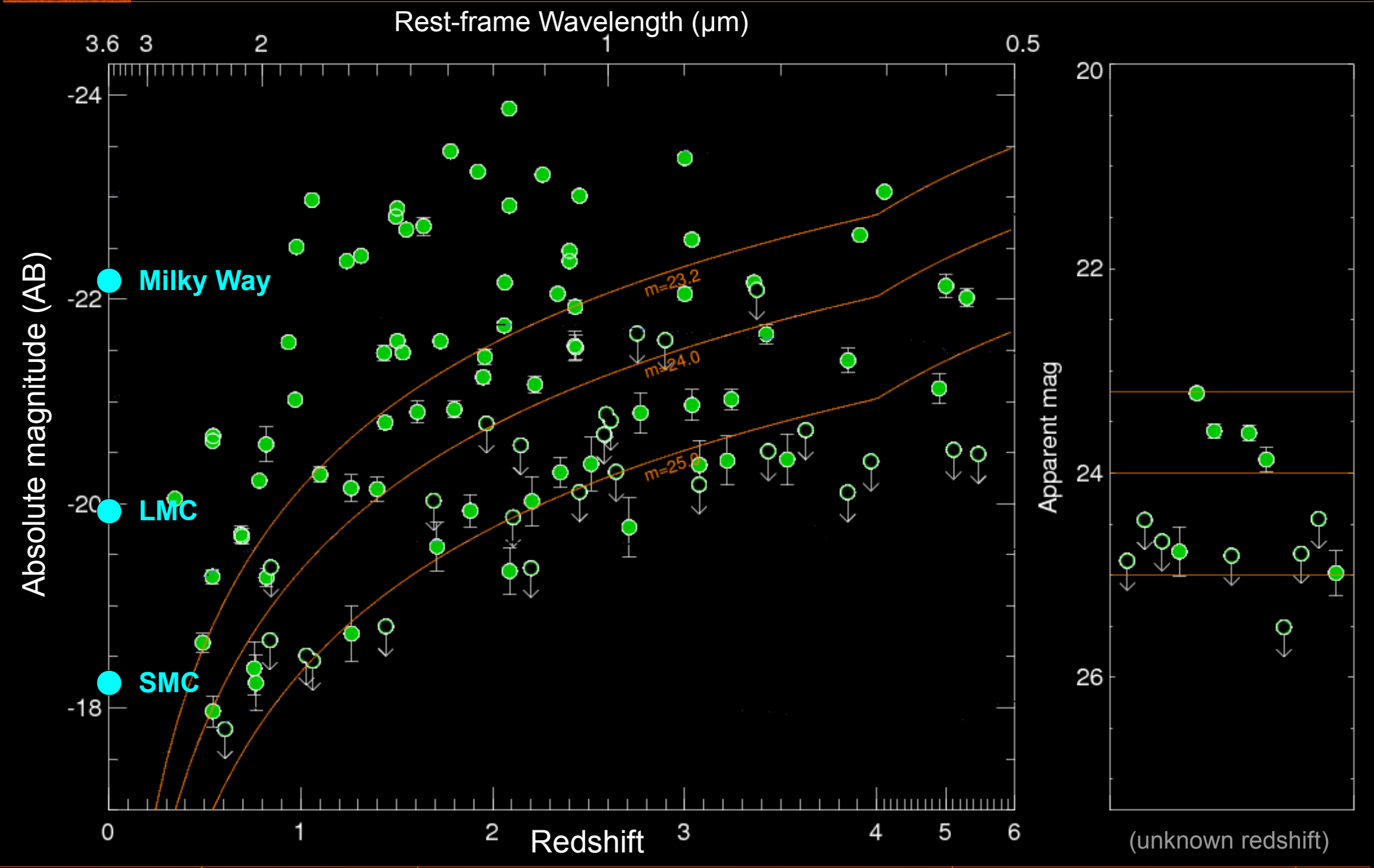


117 GRB Host Galaxies from Spitzer

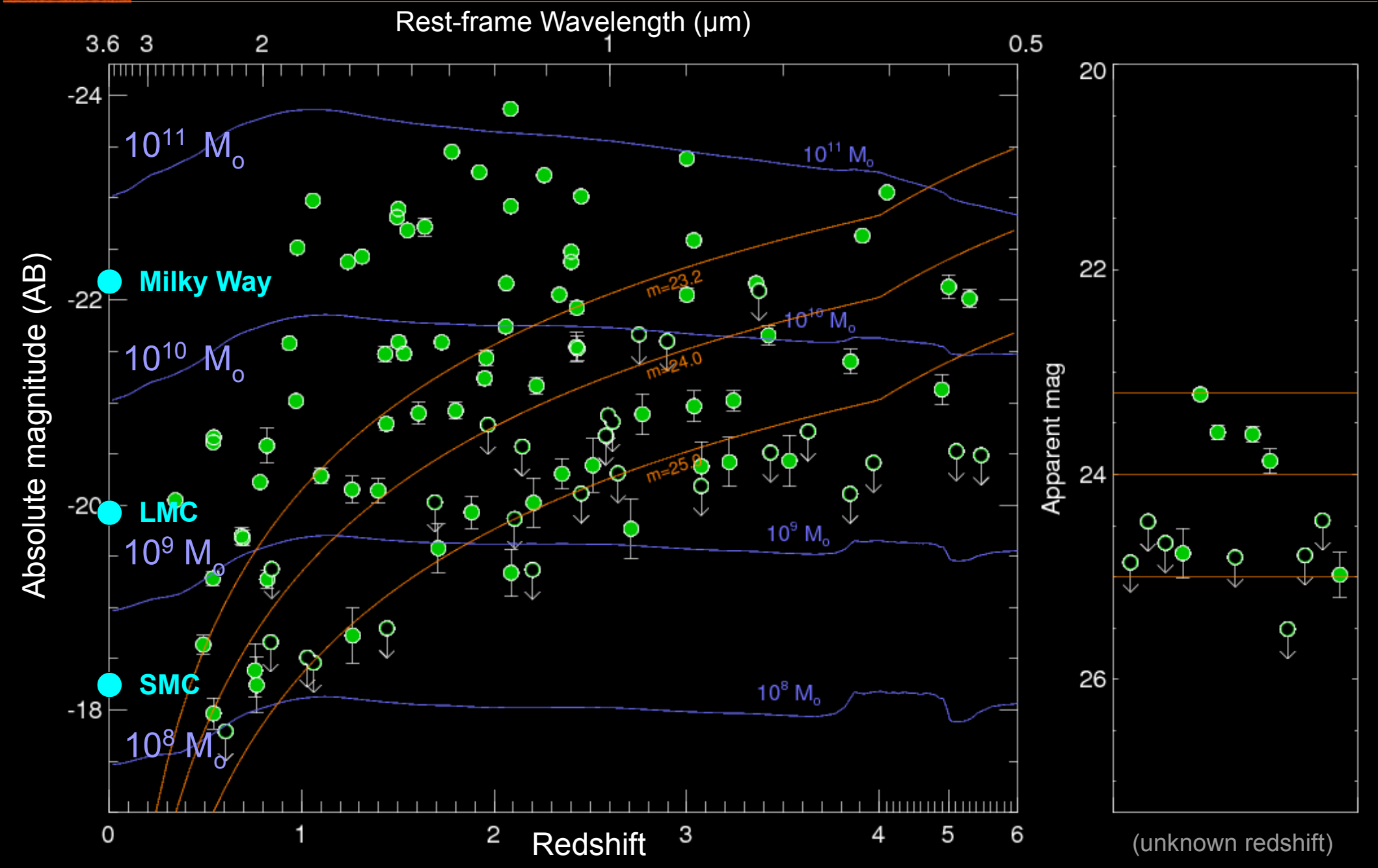



117 GRB Host Galaxies from Spitzer
050128
050315
050318
050319
050401
050525A
050726
050730
050802
050803
050814
050820A
050822
050904
050922B
050922C
051001
051006
060115
060202
060204B
060210
060218
060306
060502A
060510B
060522
060526
060607A
060707
060714
060719
060729
060814
060908
060912A
060927
061007
061021
061110A
061110B
061121
061202
061222A
070110
070129
070223
070306
070318
070328
070419B
070508
070521
070621
070721B
070808
071020
071021
071025
071112C
080205
080207
080210
080310
080319A
080319B
080325
080411
080413A
080413B
080430
080603B
080605
080607
080710
080721
080804
080805
080810
080916A
080928
081008
081029
081109A
081118
081121
081128
081210
081221
081222
090313
090404
090417B
090418A
090424
090516A
090519
090530
090618
090709A
090715B
090812
090814A
090926B
091018
091029
091109A
091127
091208B
100305A
100615A
100621A
100728B
100802A
100814A
110205A
110709B
120119A
120308A
GRB afterglow position
Host galaxy position
9"

GRB host luminosities to z~6



GRB host stellar masses to z~6



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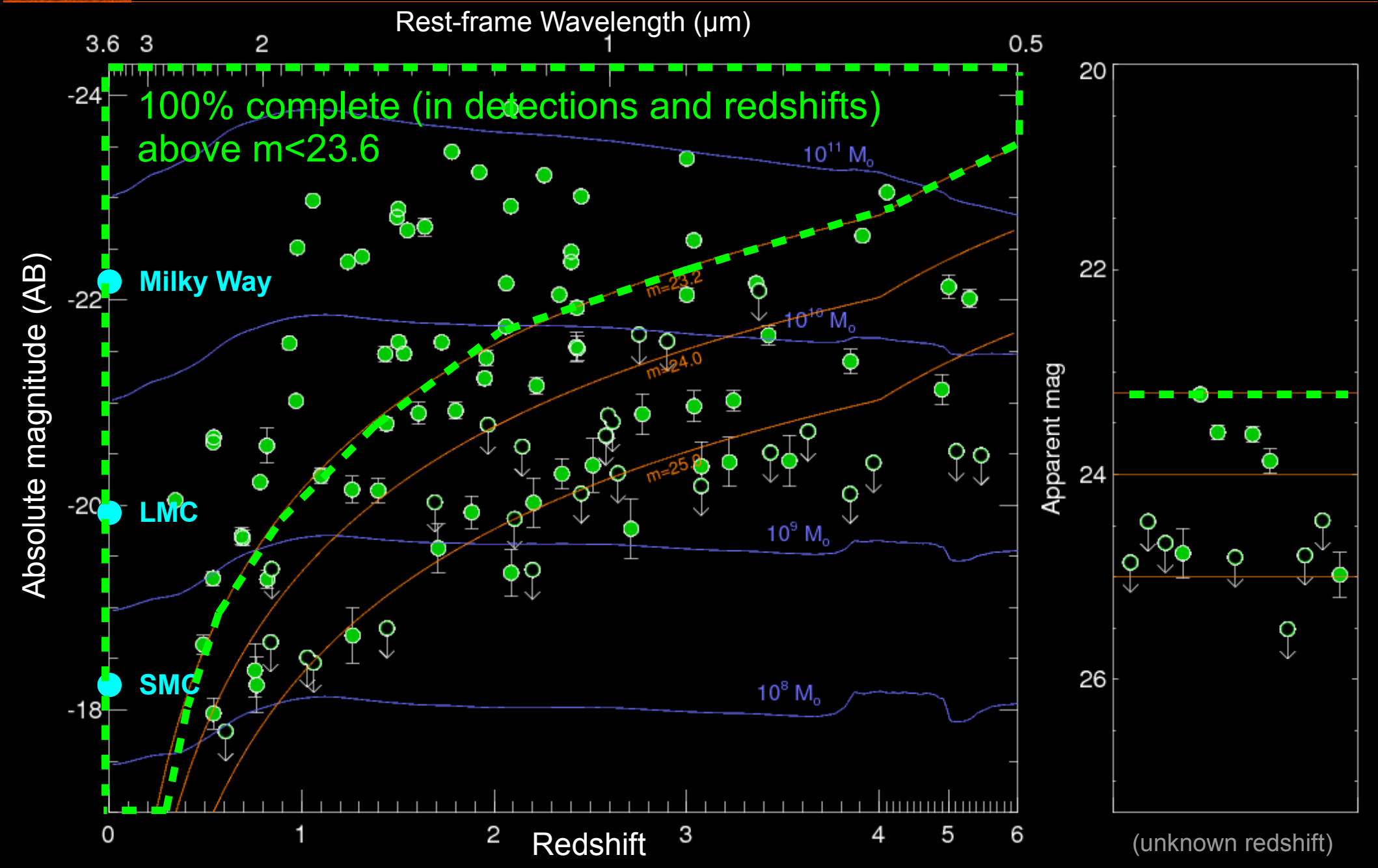
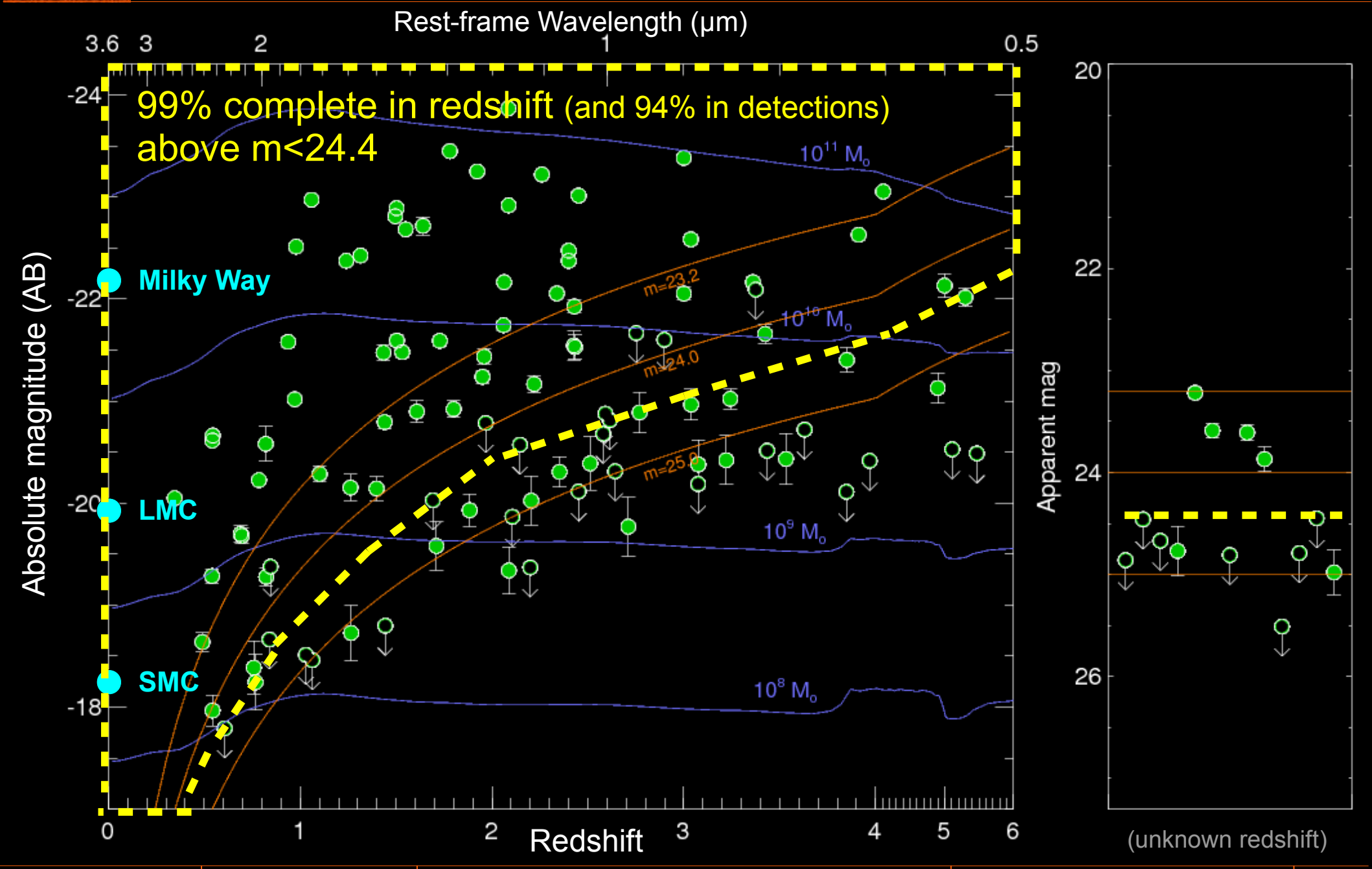


GRB host stellar masses to z~6



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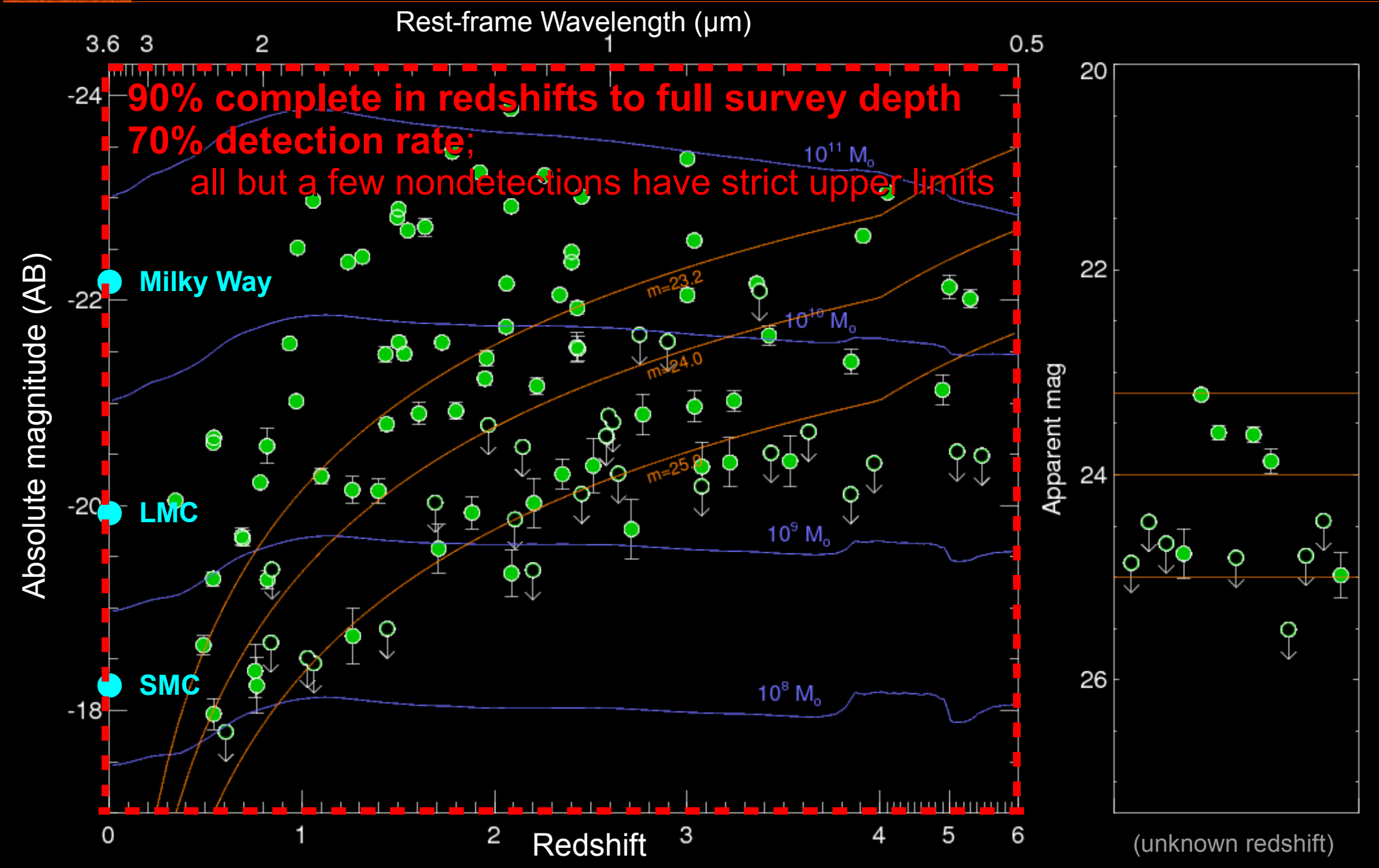
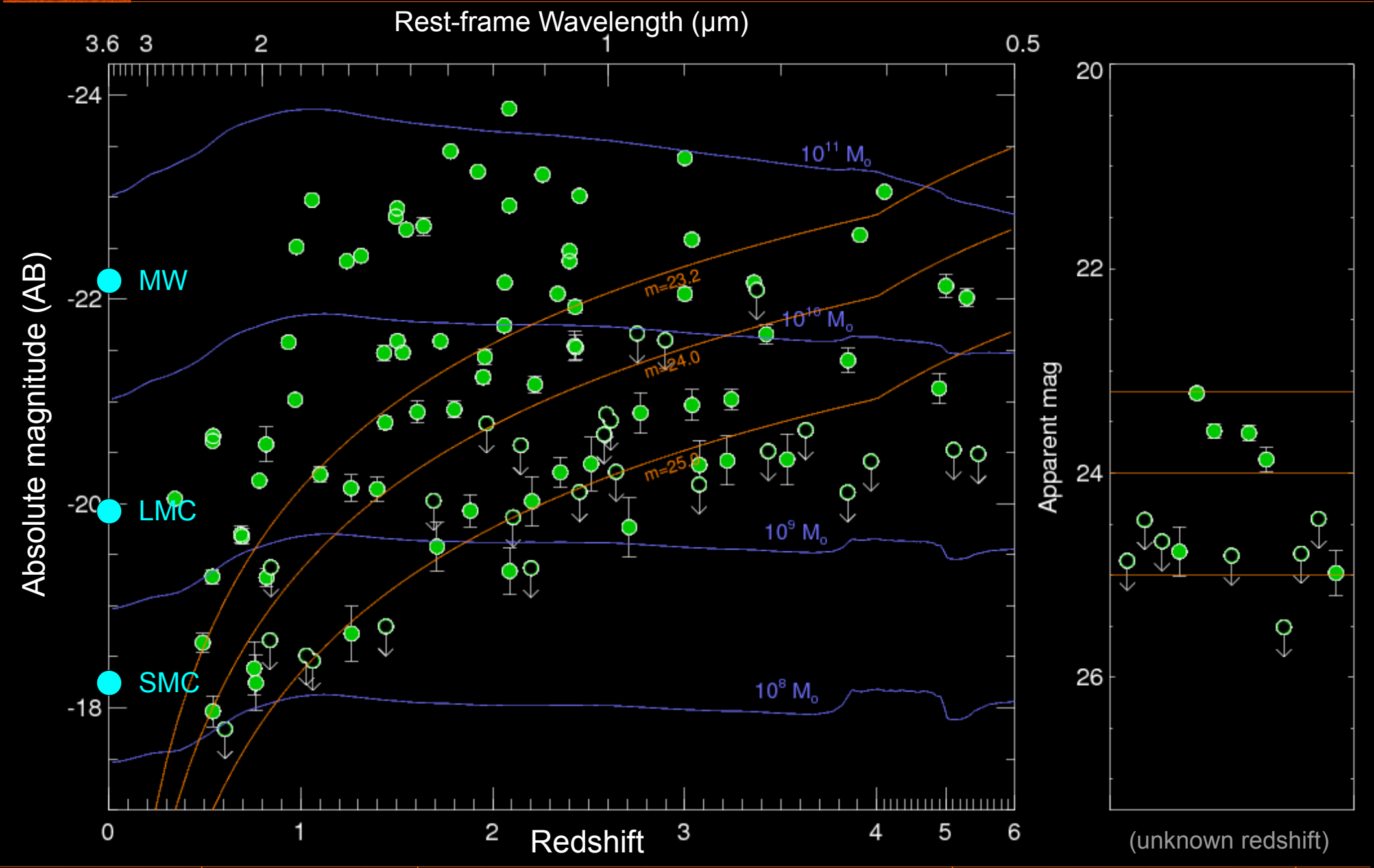


Stellar mass and dust obscuration



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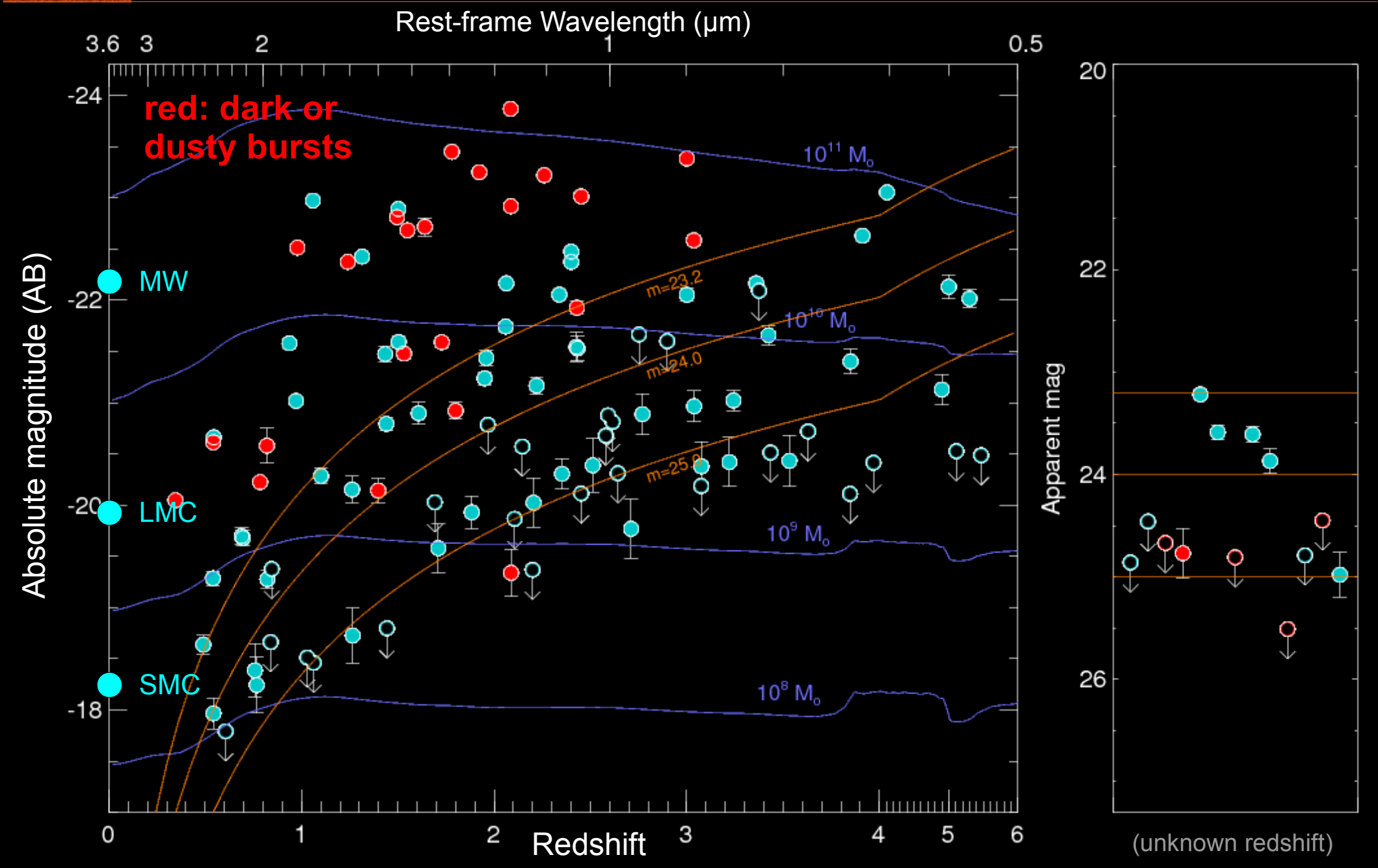

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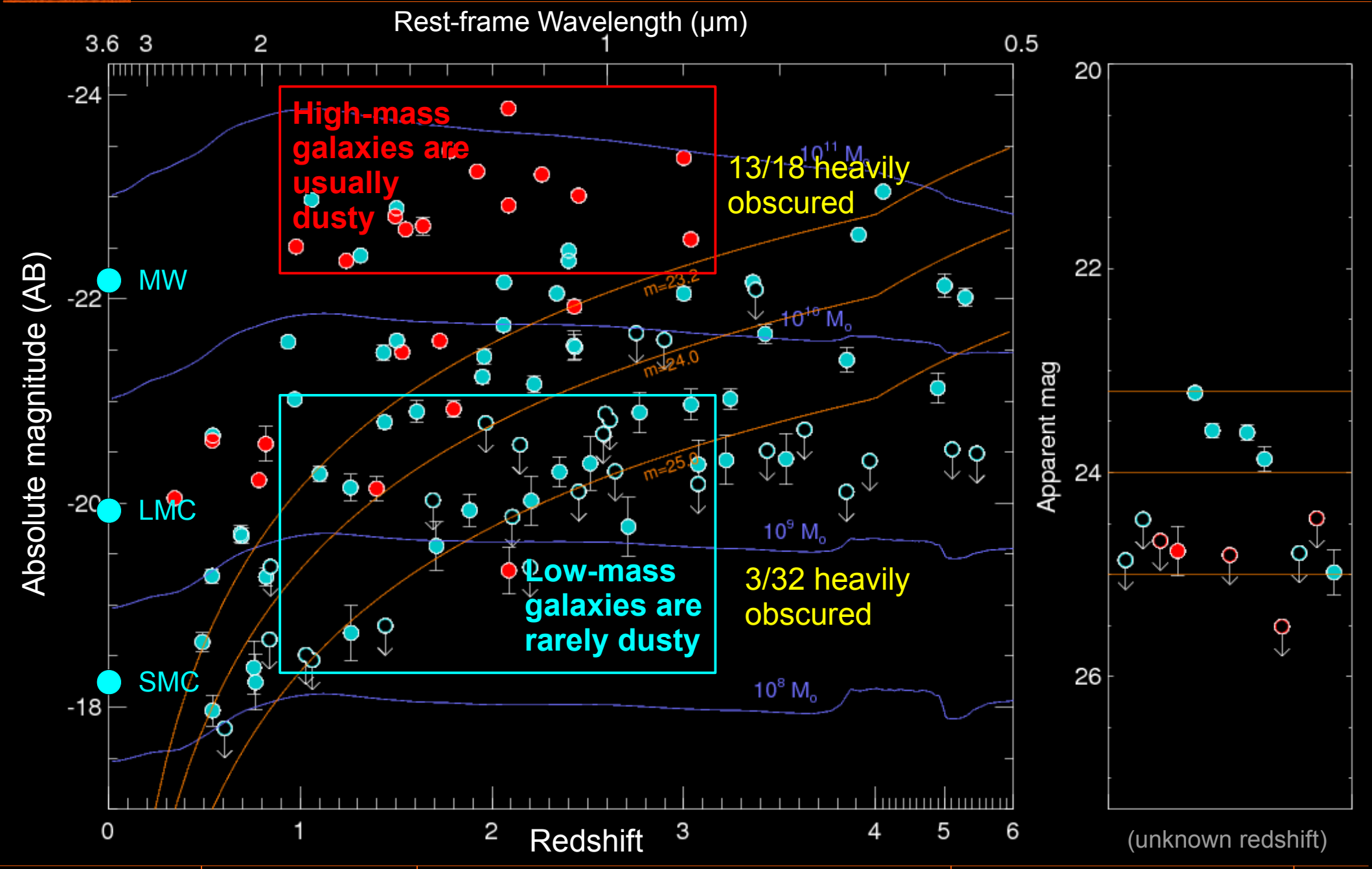

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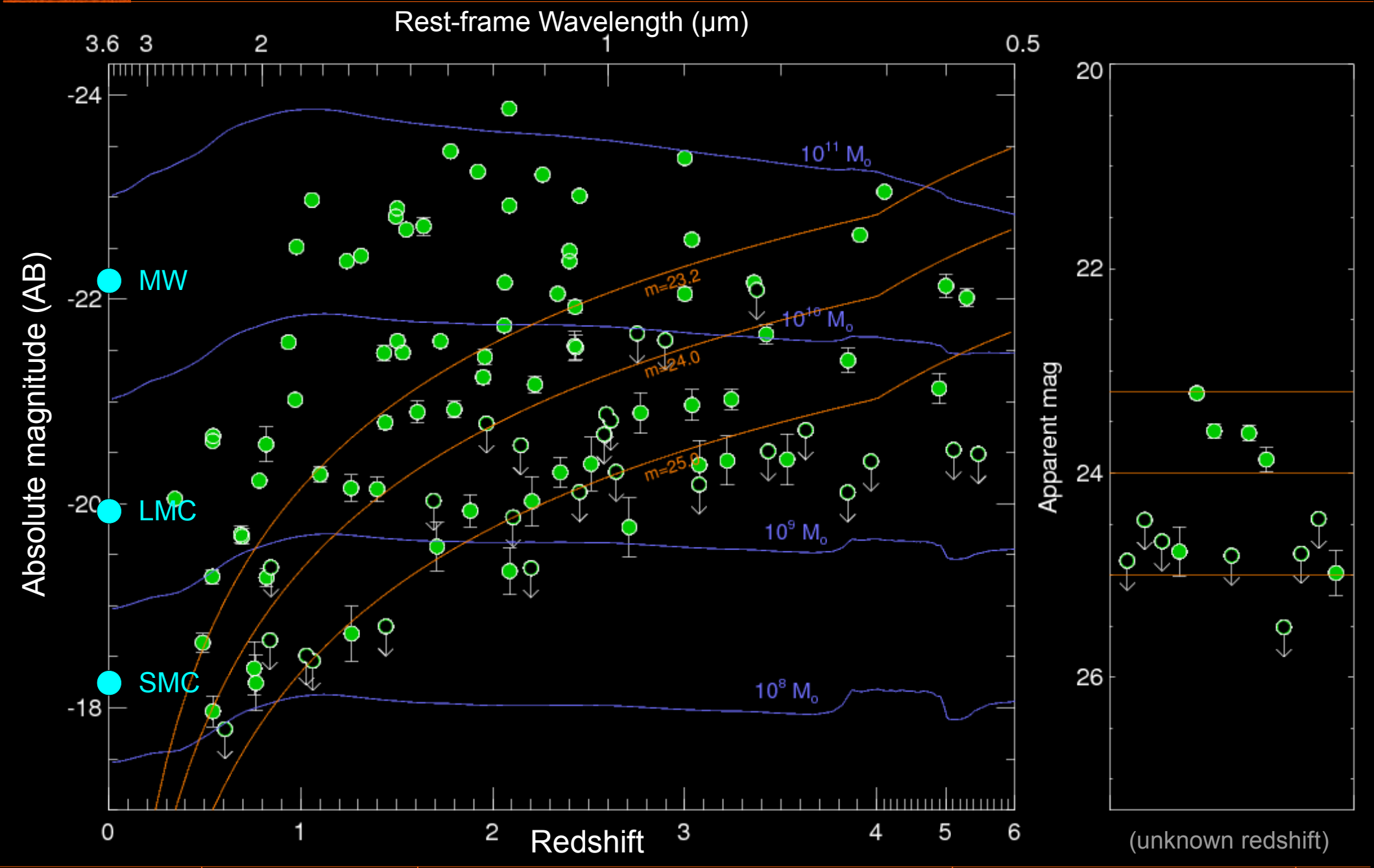
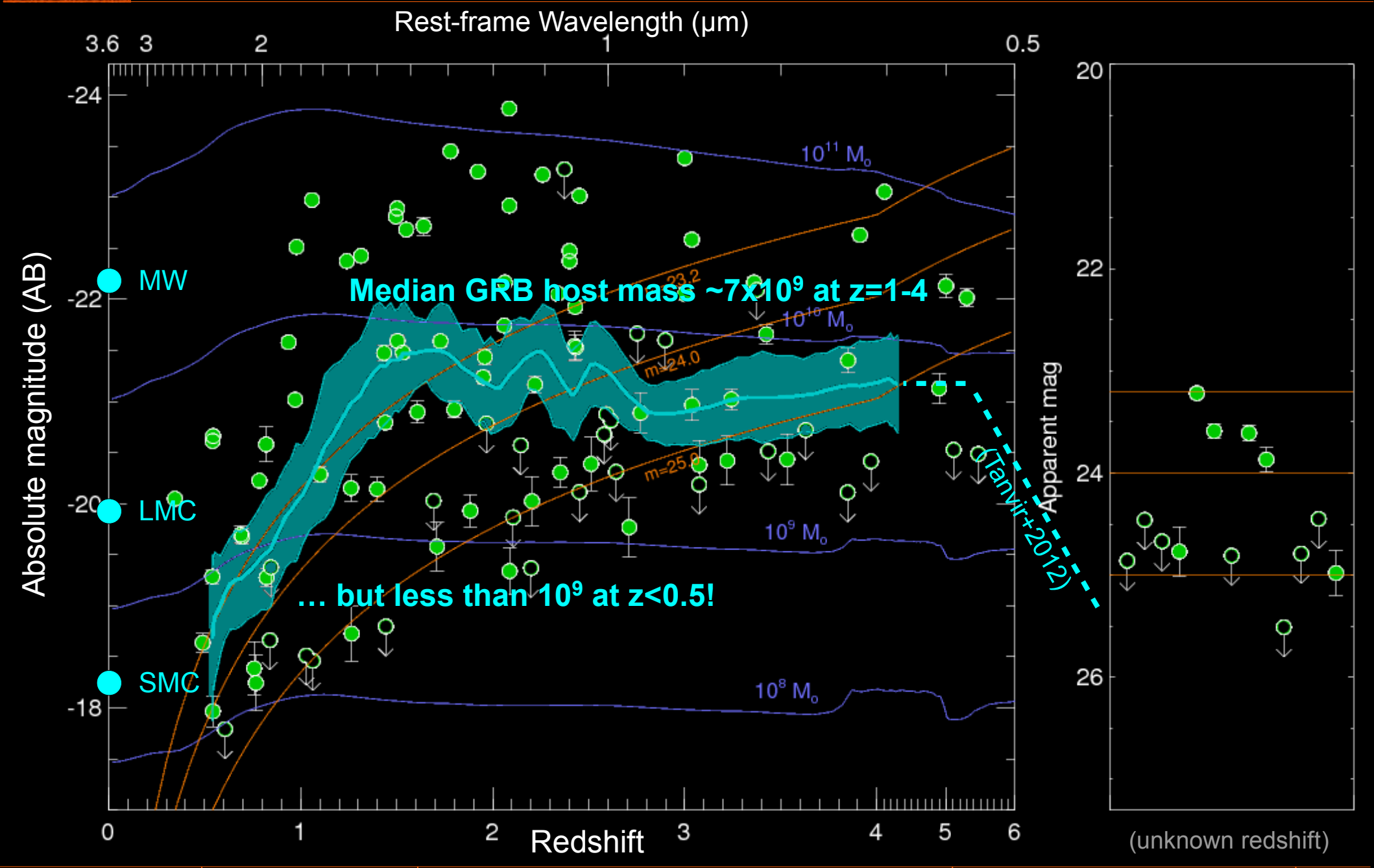


GRB host redshift evolution



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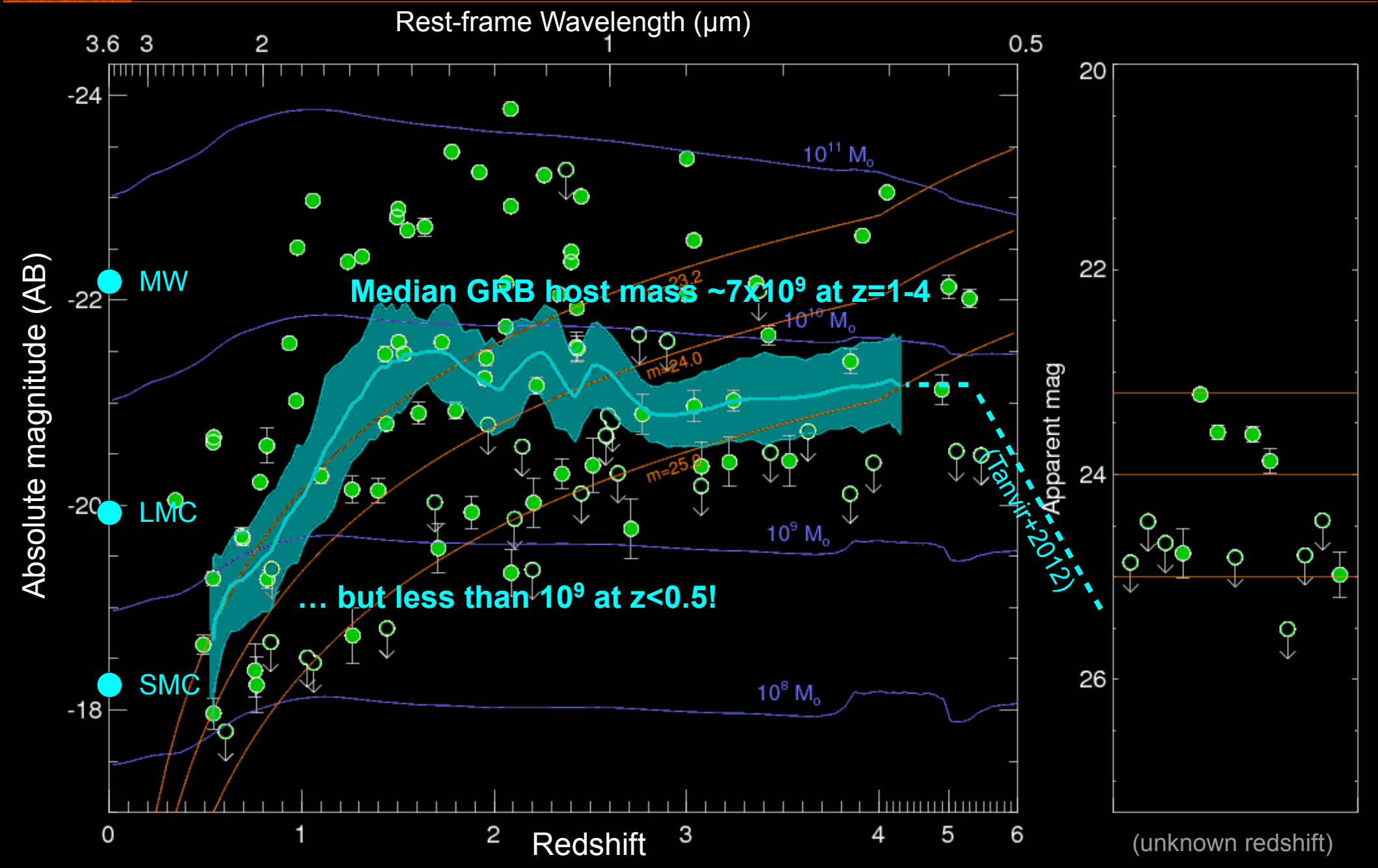

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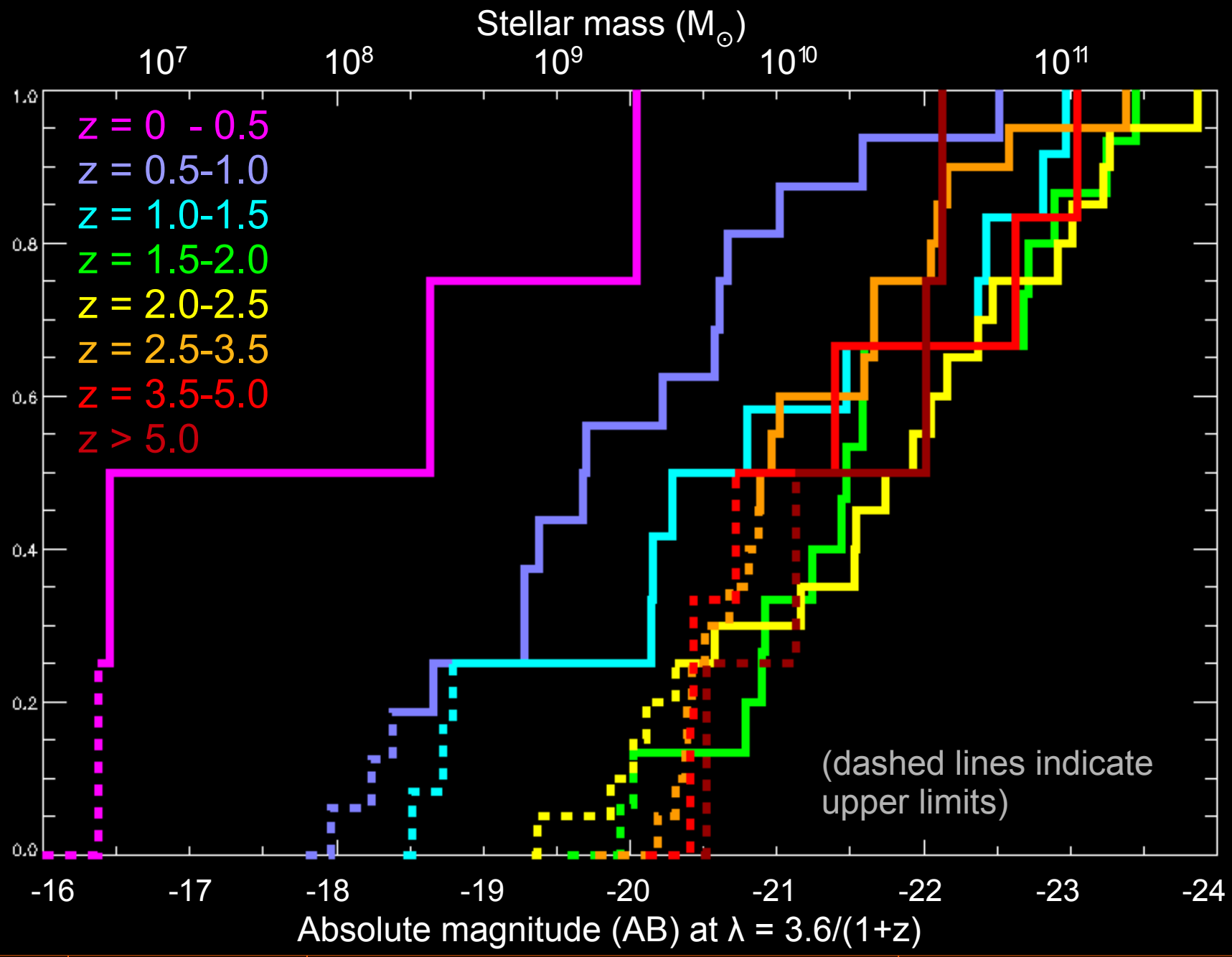

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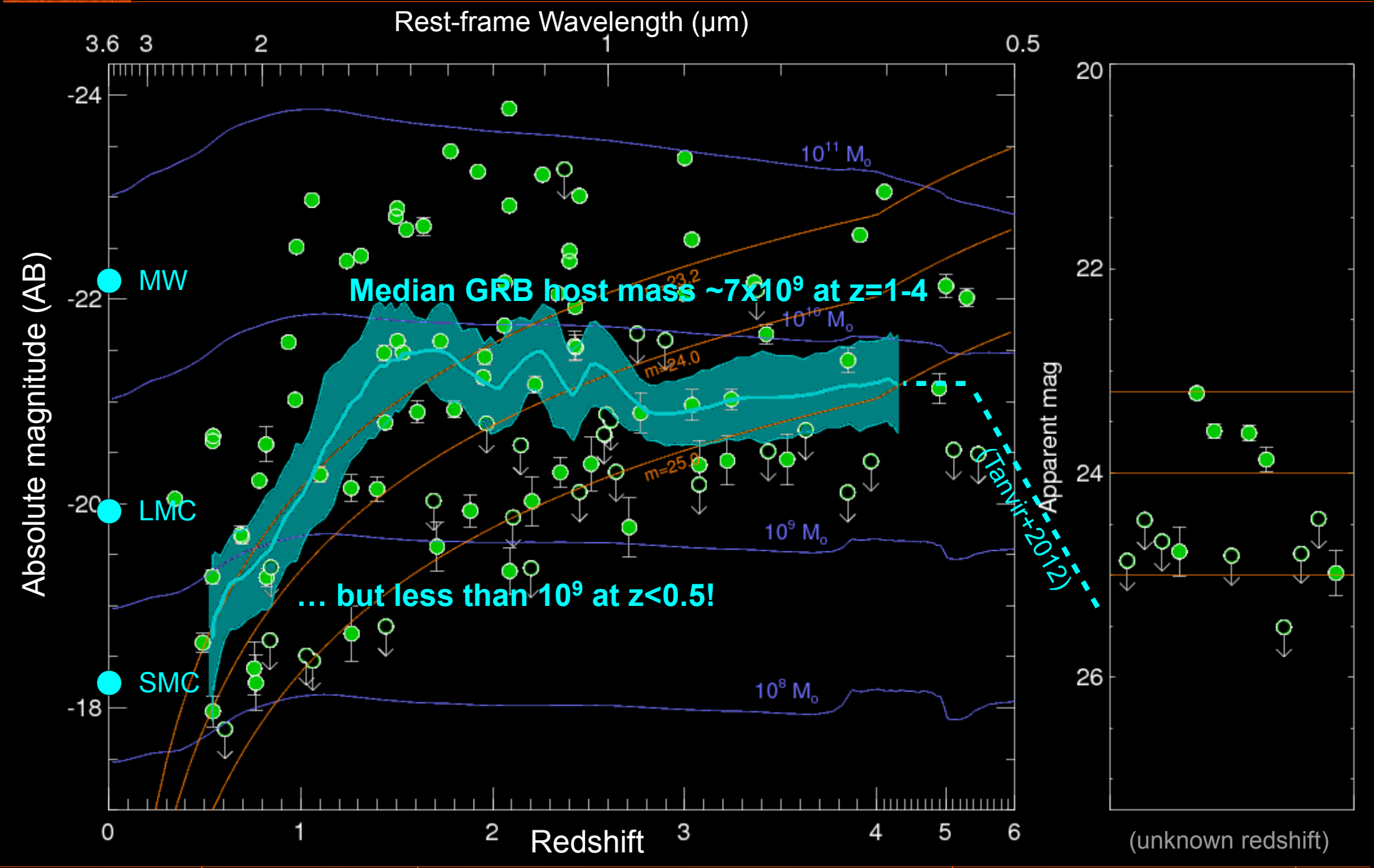
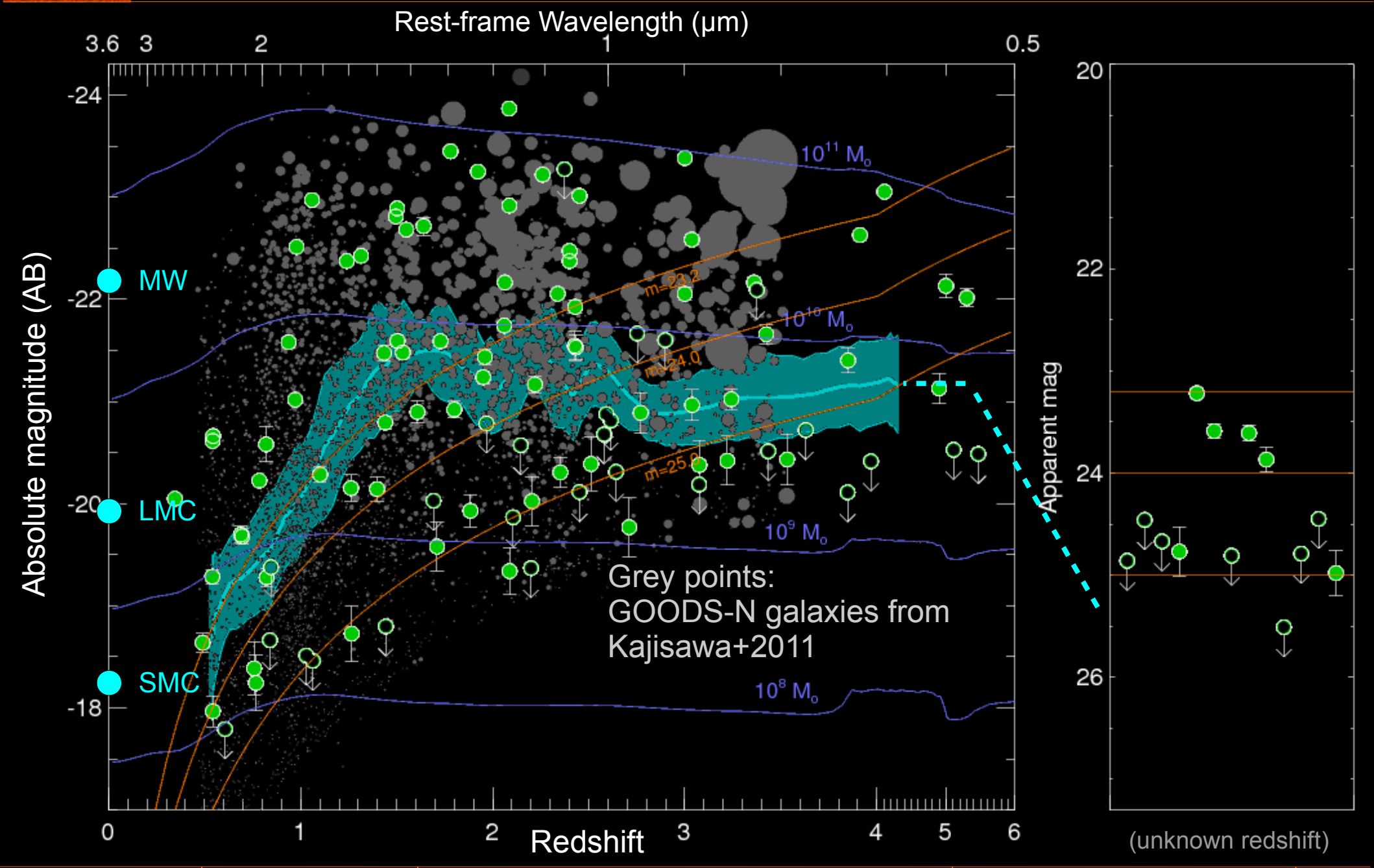


GRB hosts vs. SFR-selected galaxies



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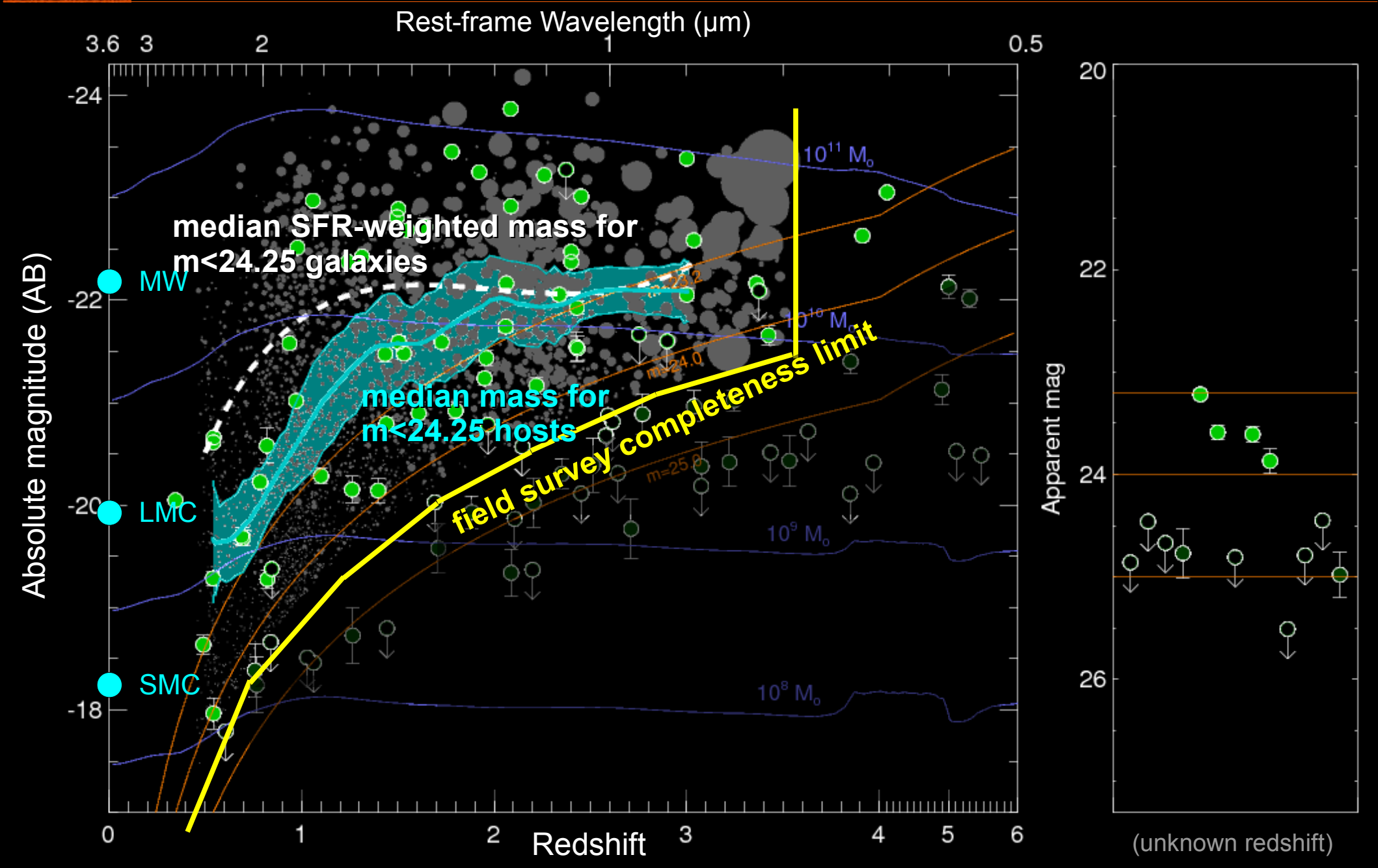

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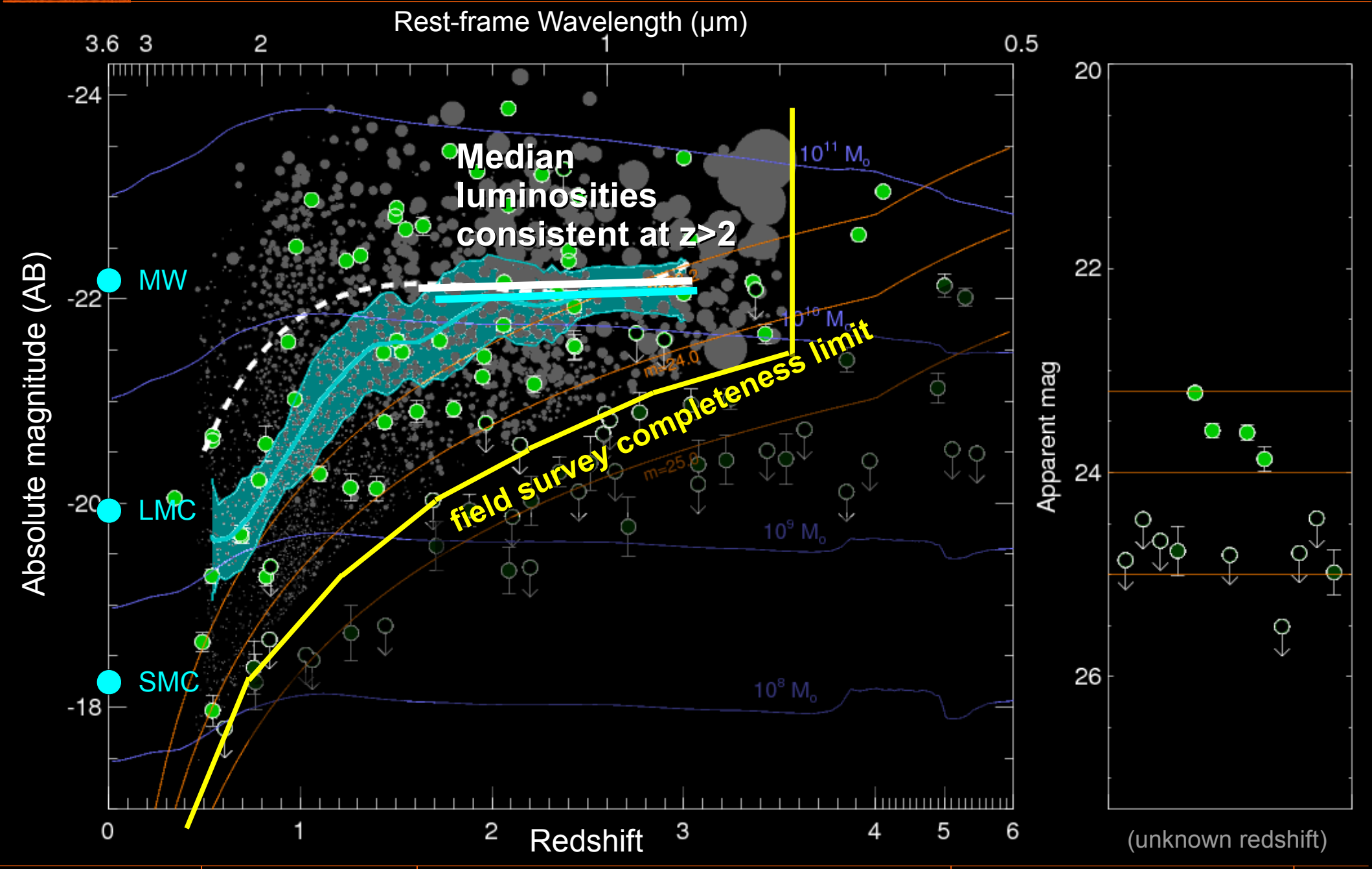

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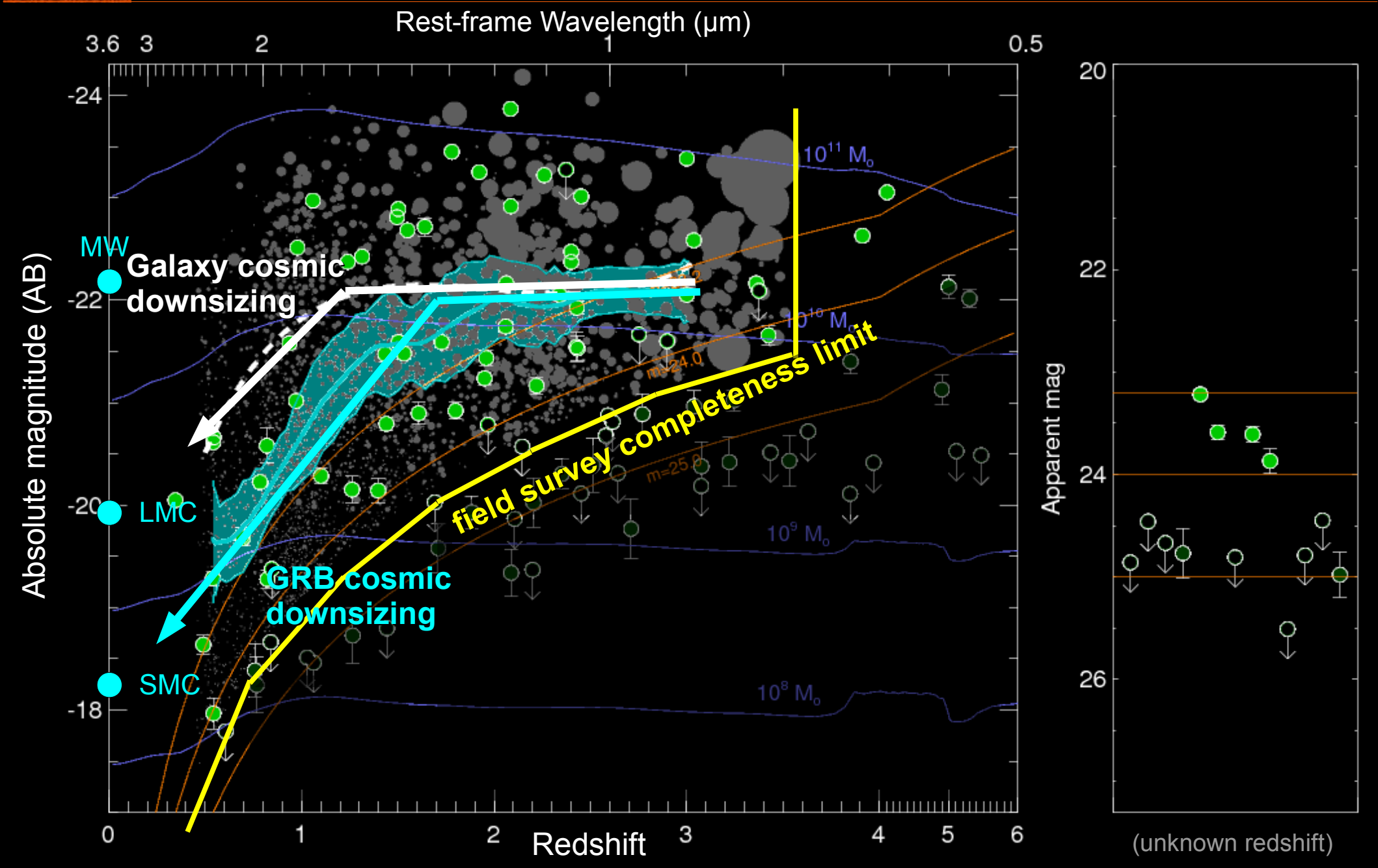
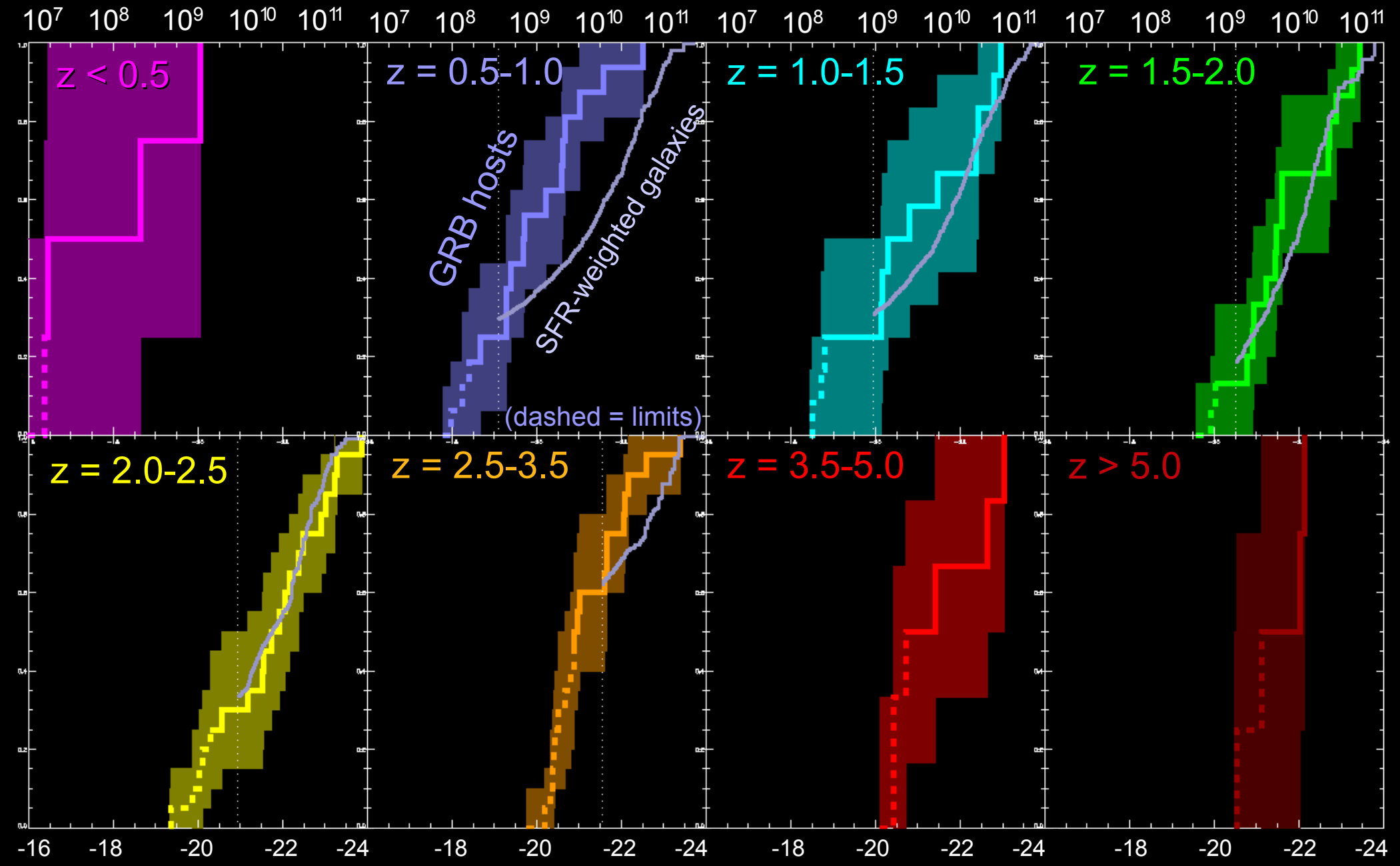


Luminosity Distribution vs. Galaxies



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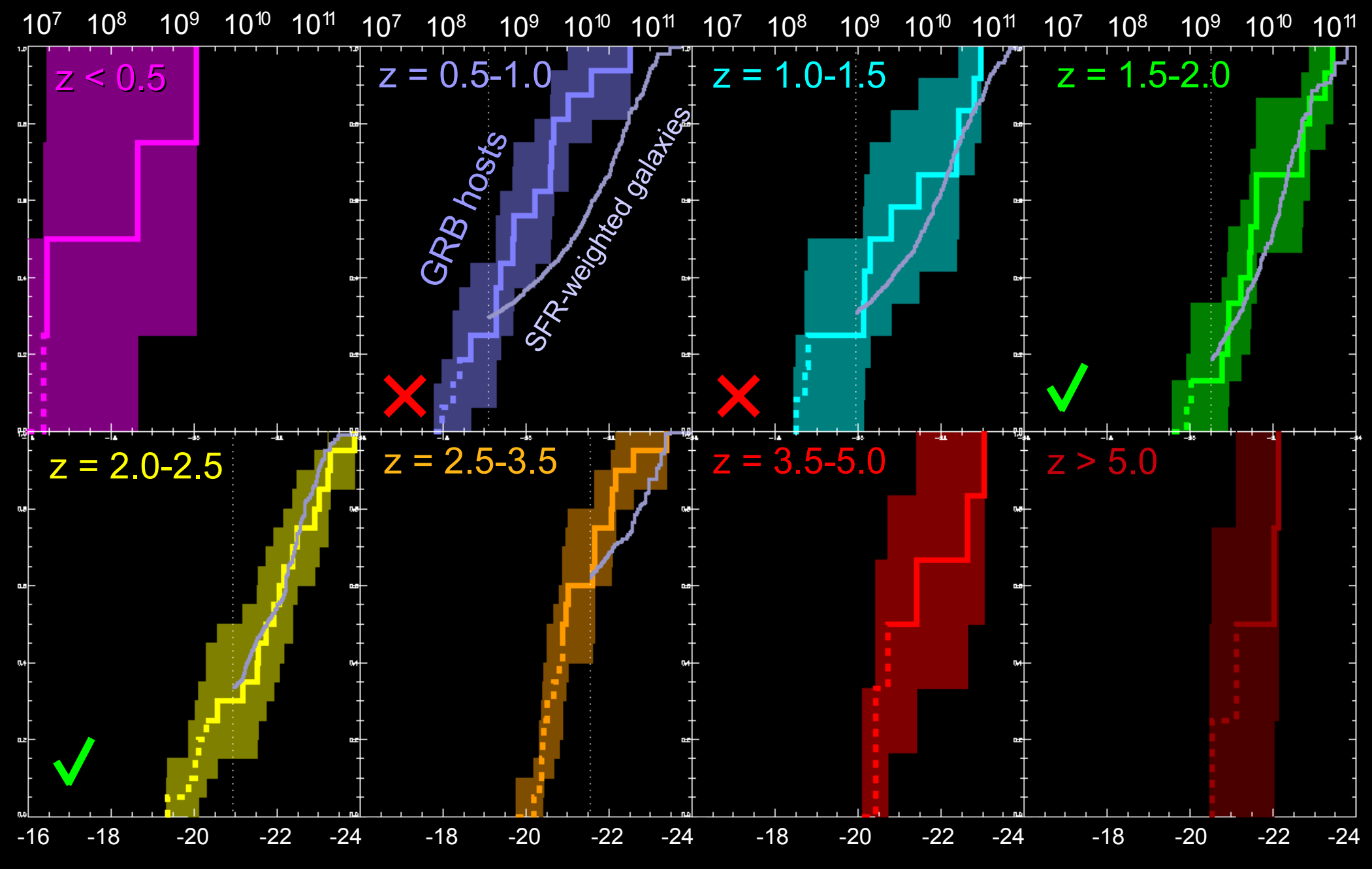

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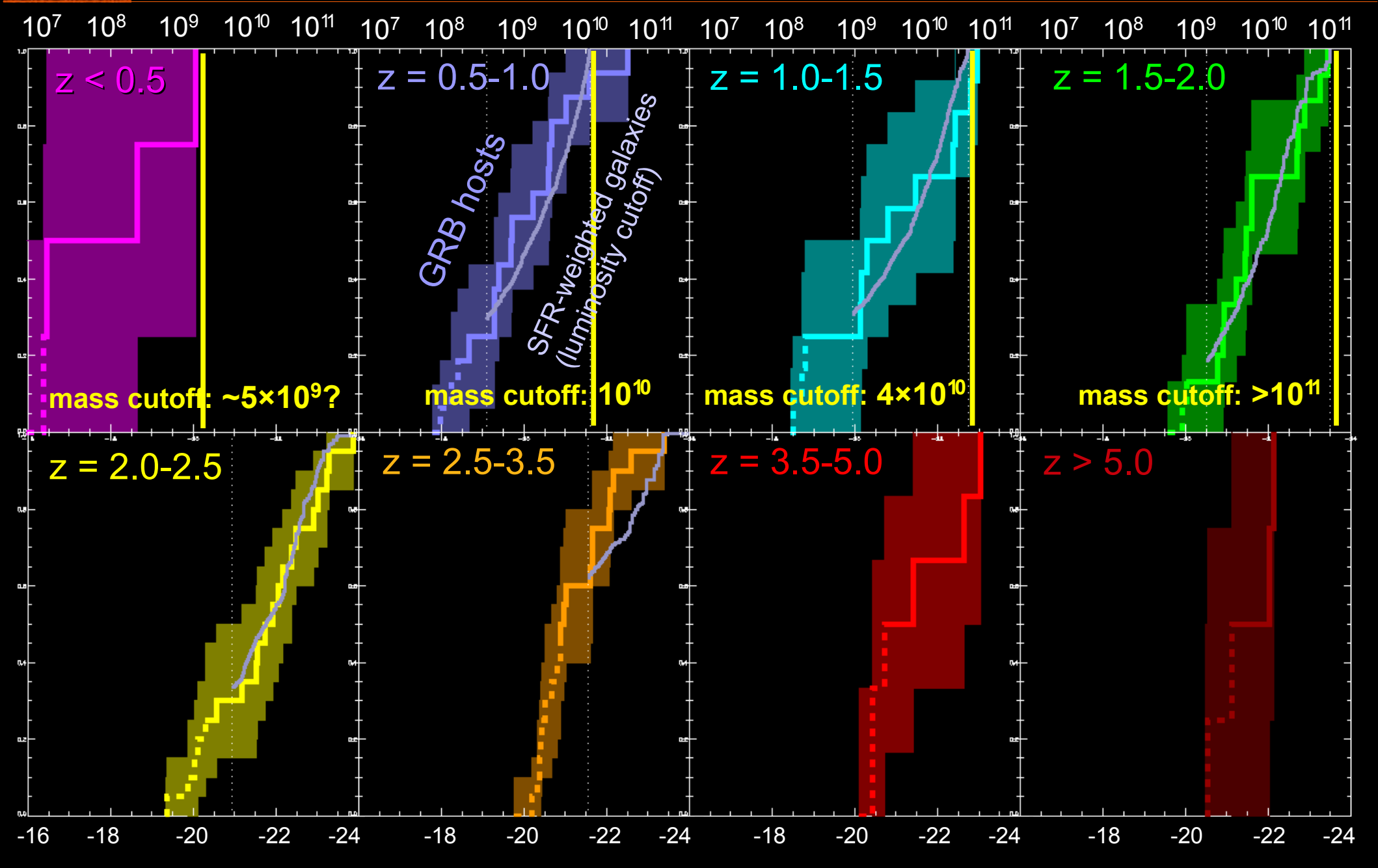
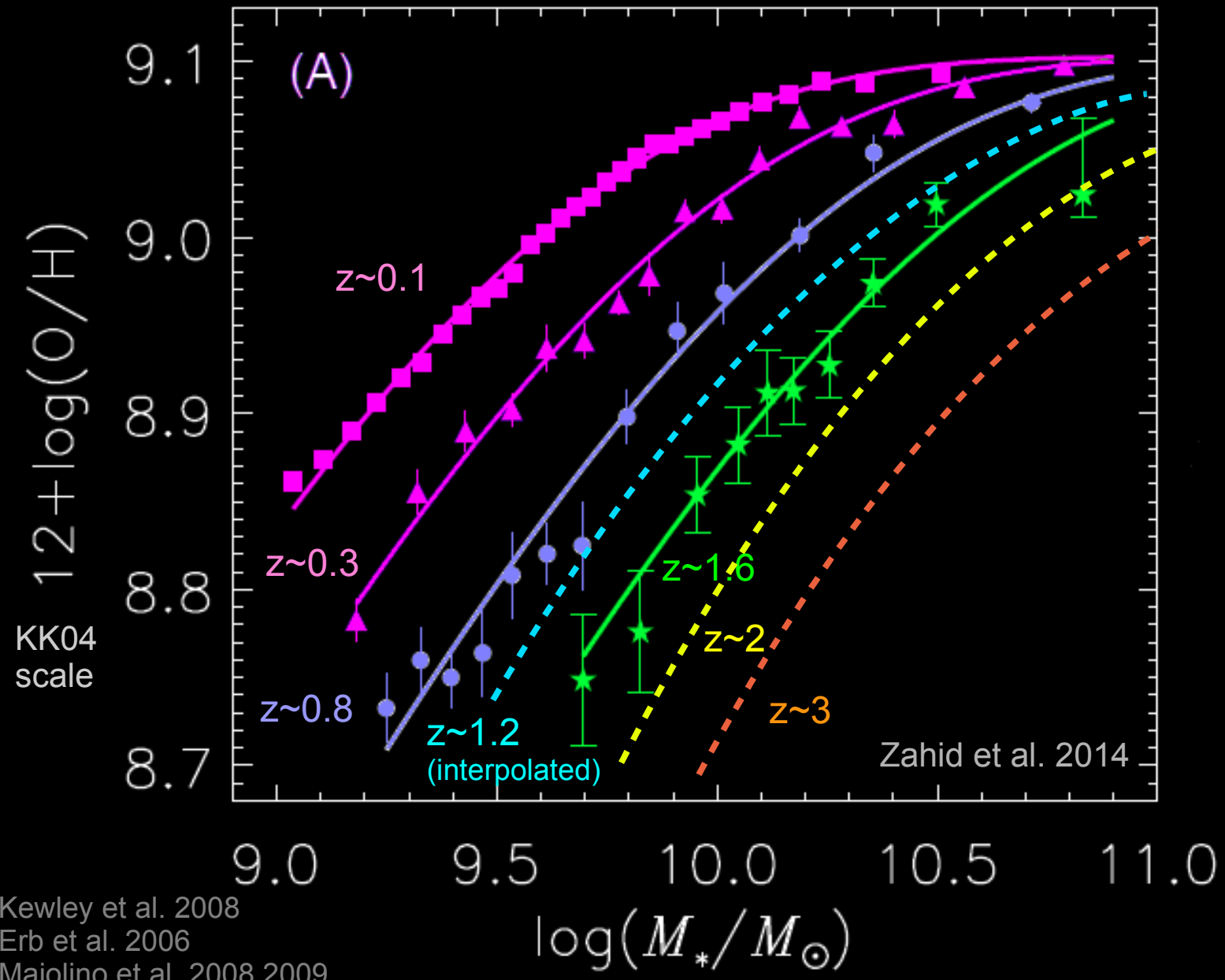


Sharp Metallicity Cutoff?



Kewley et al. 2008
Erb et al. 2006
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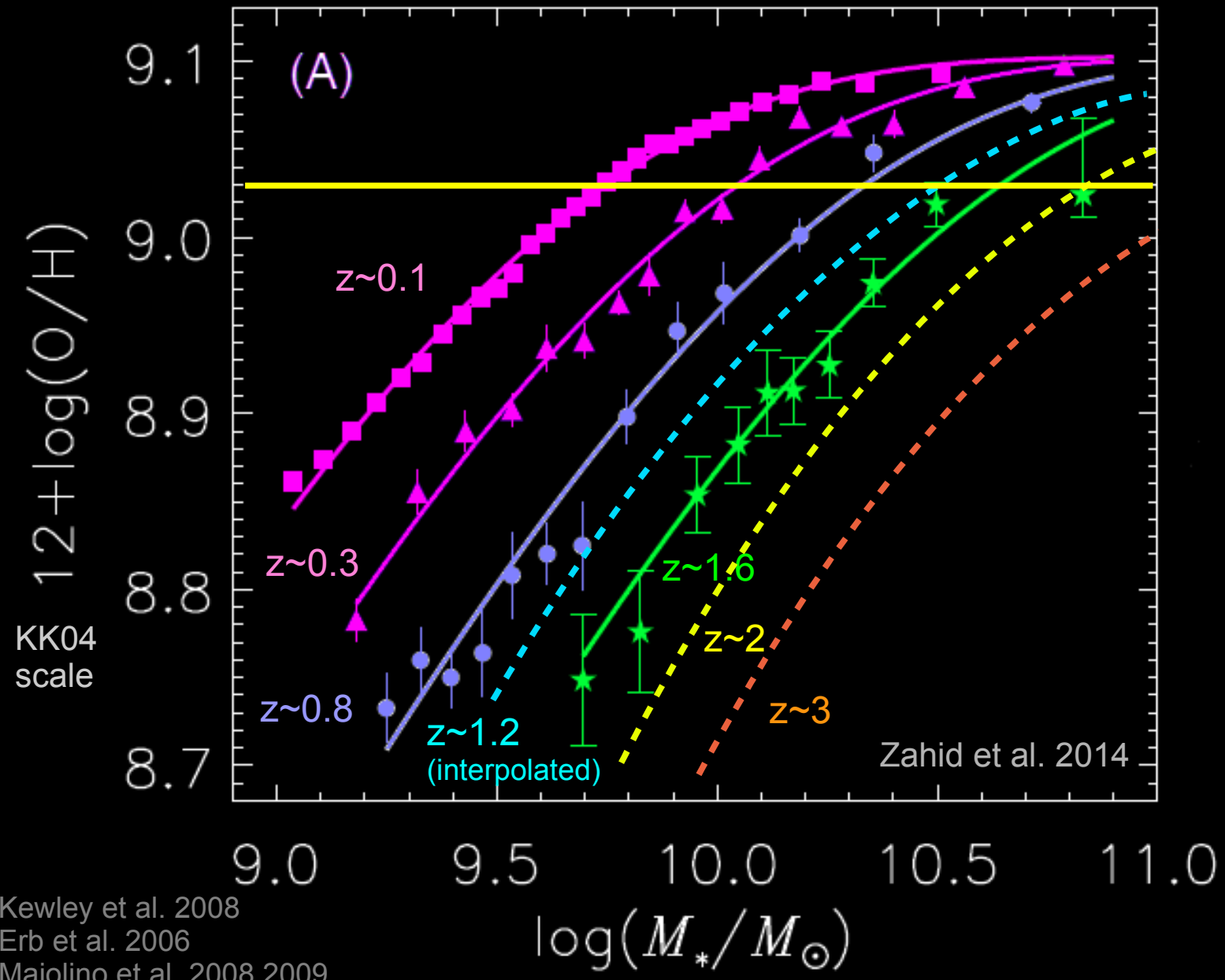

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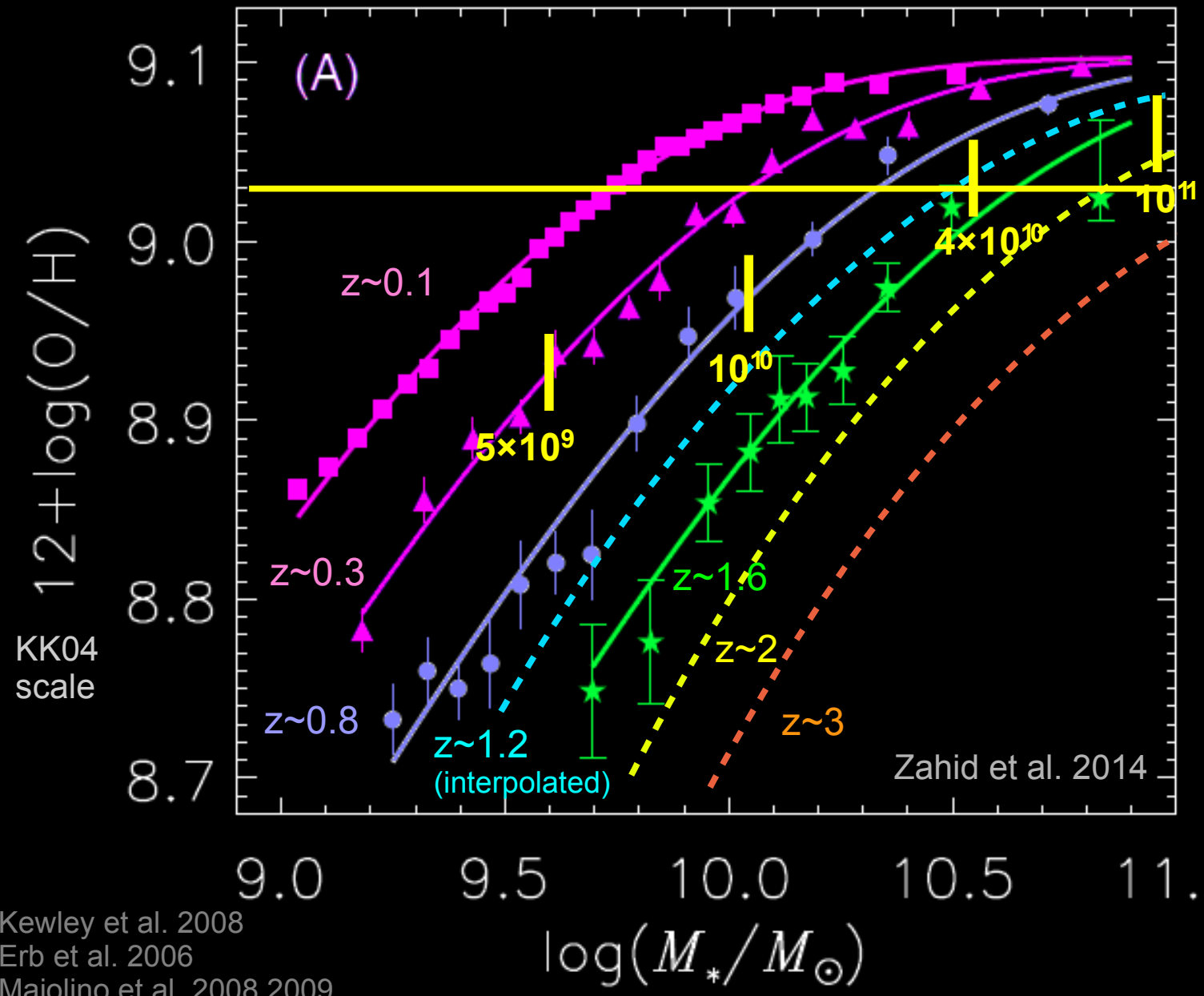


Kewley et al. 2008
Erb et al. 2006
Maiolino et al. 2008,2009

Conclusions

GRBs probe typical star-forming galaxies at high redshift (z>1.5)

- Median host mass is ~6×10^9 $M_\odot$, intermediate between LMC and MW.
- Host mass distribution agrees with SFR-weighted galaxy population;
  - weak dependence on environment *at these redshifts*.
- Very little evolution in host mass distribution between $1.5 < z < 5$.
  - No large, unseen population of low-mass galaxies.
  - Deep mass-selected surveys see most cosmic SFR out to z~6.
- **Very encouraging for using GRBs to trace SFR at high-z!**

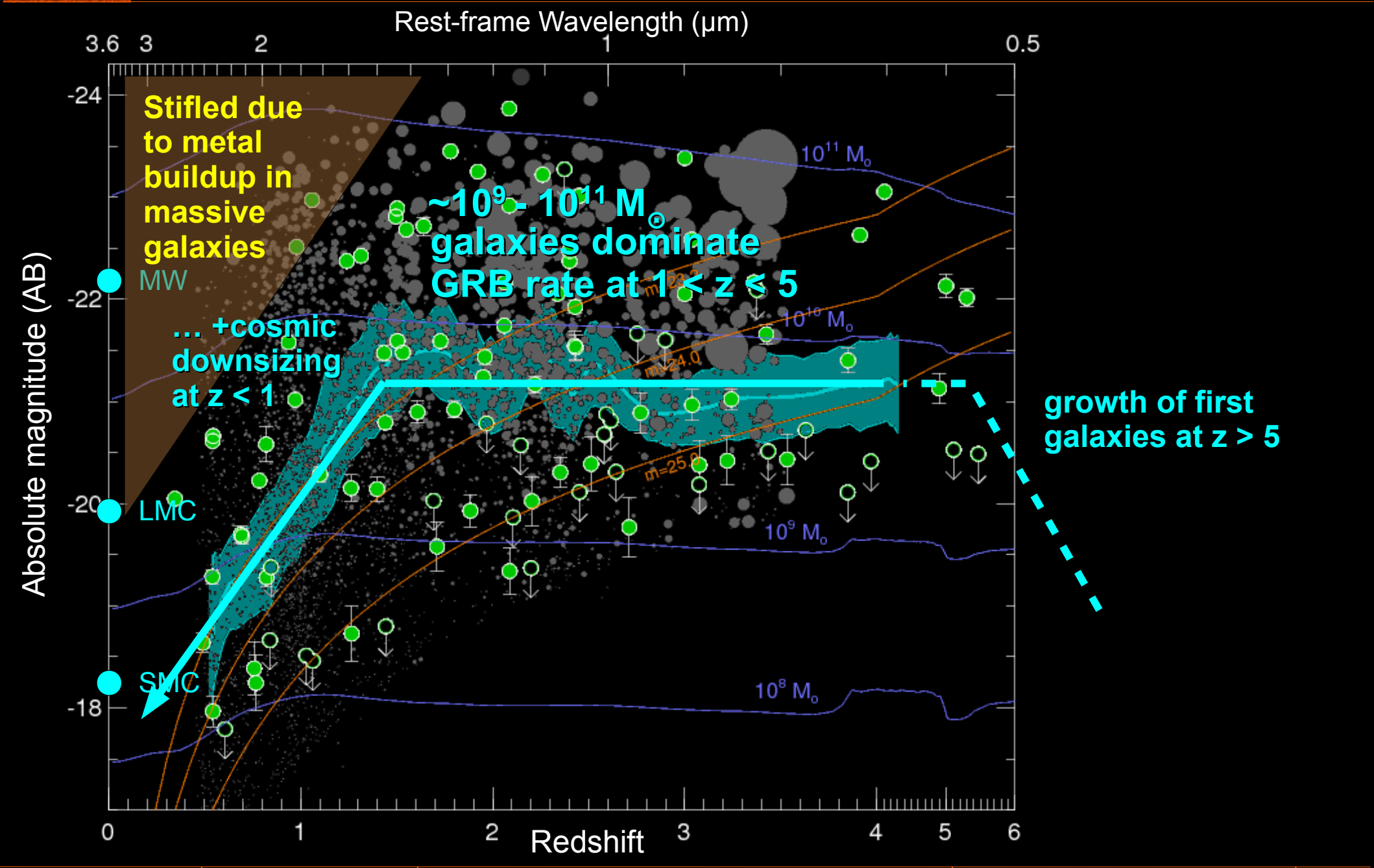
GRB host properties significantly diverge from cosmic SFR at z<1

- They strongly avoid high-mass galaxies ("cosmic downsizing on steroids")
- If due to metallicity, dependence must be sharp w/strong suppression
  - at >0.5-1.0 $Z_\odot$ (**but**, different redshifts imply different cut levels; needs further investigation)

Stay tuned for much more!

- Optical survey is almost complete: true masses, SFRs, A_V, etc.
- Actually a metallicity "cutoff", or sSFR dependence, or... ?
- New constraints on SFR at high-z and faint galaxies

GRB Hosts Over Cosmic Time



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