The Swift GRB Host Galaxy Legacy Survey

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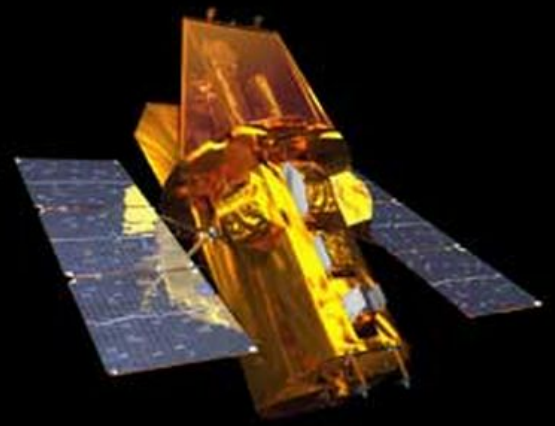
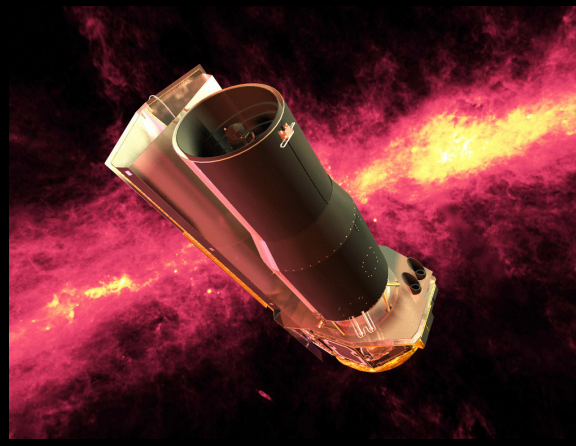
Jens Hjorth (DARK)
Nial Tanvir (Leicester)
Javier Gorosabel (IAA)
Andrew Levan (Warwick)
and many others





GRB Hosts as a Cosmological Tool

A large sample of GRB redshifts and host properties can constrain...

The History of Cosmic Star-Formation
(out to very high redshift)

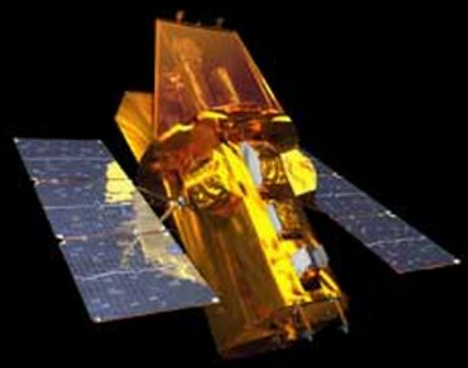
The Sites of Stellar Mass Assembly
(including the faintest galaxies)

Connections between the ISM and Stellar Population
(dust, metallicity, kinematics vs. mass, SFR, etc.)

The Nature of the GRB Progenitor
(formation conditions; single star vs. binary-channel)

The Swift Host Galaxy Legacy Survey

"SHOALS":
A *large, deep, unbiased* multiwavelength survey to include *all* host galaxies of *all* types at *all* redshifts.



Selection criteria:

- Occurred between 2005-2010
- *Swift* detected; gamma-ray fluence > 10^{-6} erg/cm^2
- *Swift* slewed immediately to the position
- Far from the Sun at time of explosion (afterglow easily observable)
- Low Milky Way foreground extinction
- No nearby bright stars
- Localized within 2"

(Similar procedure to VLT R/K-band host survey; Hjorth+2012)

→ **120** *Swift* GRBs (out of ~950 to date),
75% with predetermined redshift (usually from afterglow.)
(Currently 90% after host galaxy observations.)
Redshift range 0.03 < z < 6.3

SHOALS Selection Criteria

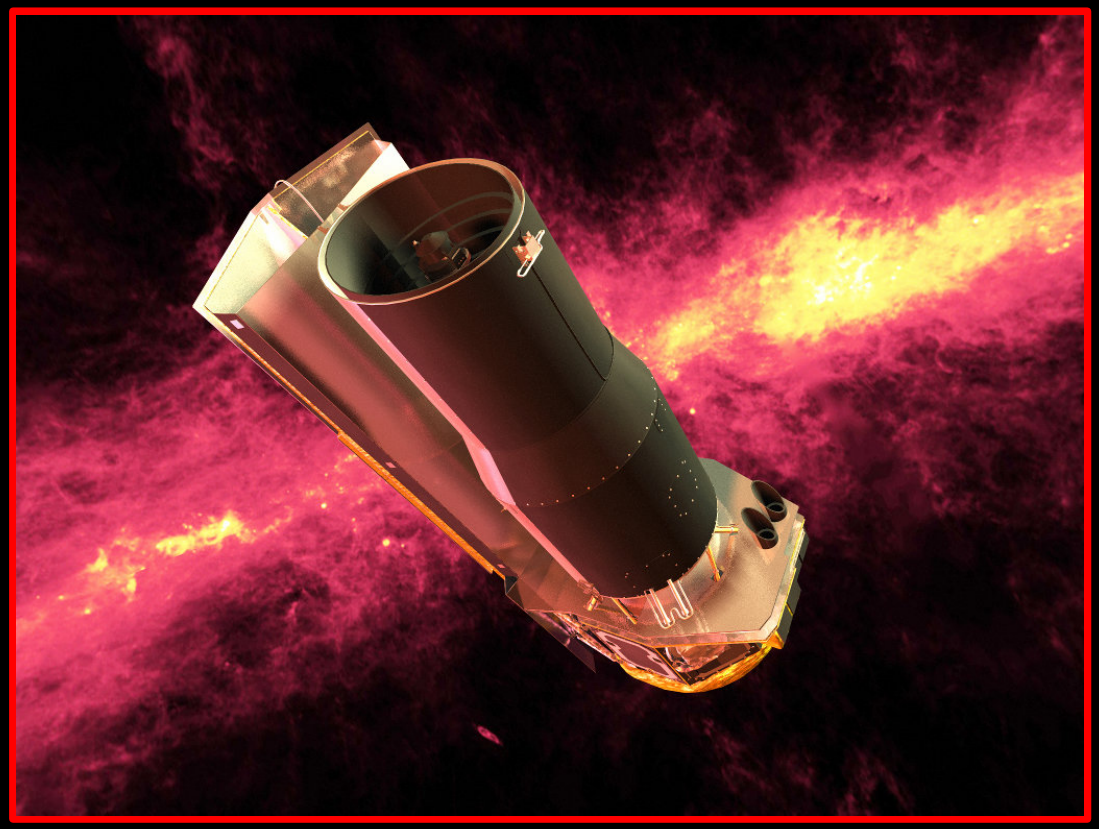
Swift Host Galaxy Legacy Survey (PI Daniel Perley)

- *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 2005-2010, *or*
  - (c) Satisfied TOUGH positional criteria
- Low Milky Way foreground extinction
- No nearby bright foreground stars
- Localized within 2”

	Total	w/redshift	completeness
All Swift bursts	855	303	35%
Jakobsson+2006	248	132	53%
SHOALS	**134**	**109**	**81%***
TOUGH sample	69	58	84%
BAT6 sample	58	53	91%

*before any additional host follow-up

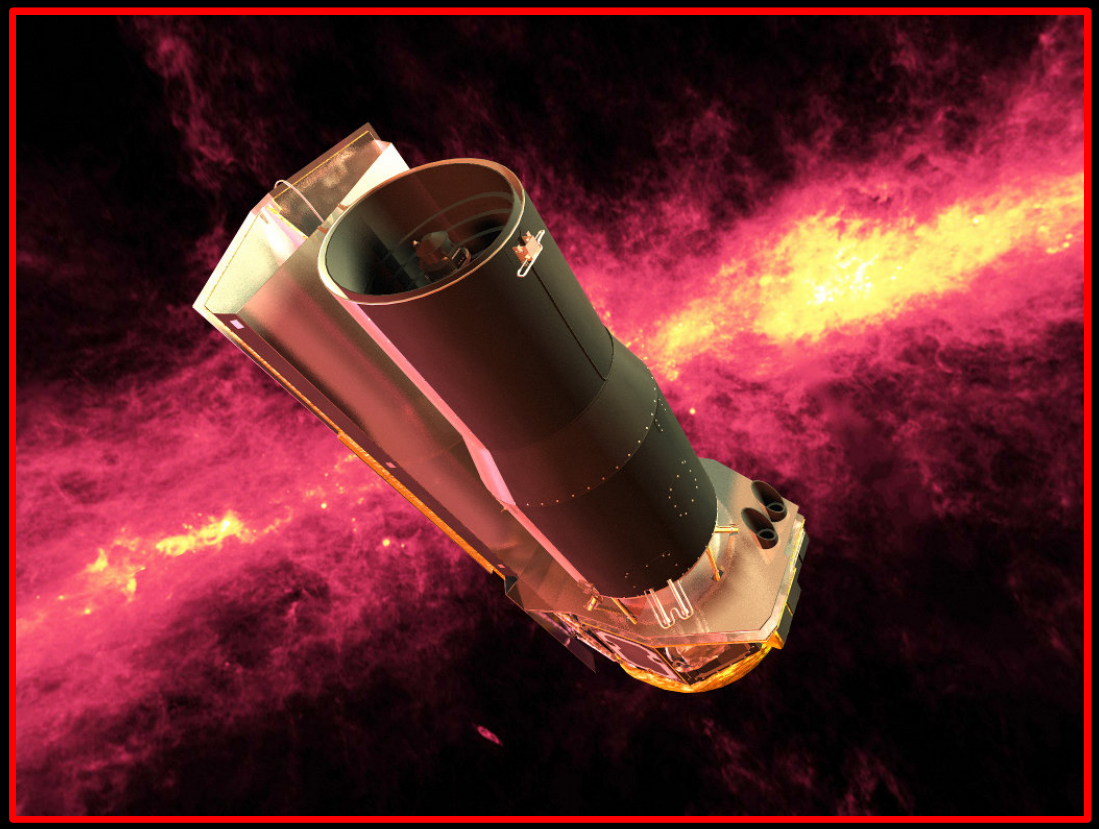
The Swift Host Galaxy Legacy Survey



Spitzer (3.6 μm imaging):
- Good **stellar mass** proxy (even with no color information);
- Sensitive to 10^{10} $M_{\odot}$ galaxies to z~5
- All targets observed to deep limits (1-6 hours/target at z>1)

VLA (3 GHz continuum):
- Dust-unbiased **SFRs**
- 90 hours to observe 32 targets (from overlapping TOUGH survey)

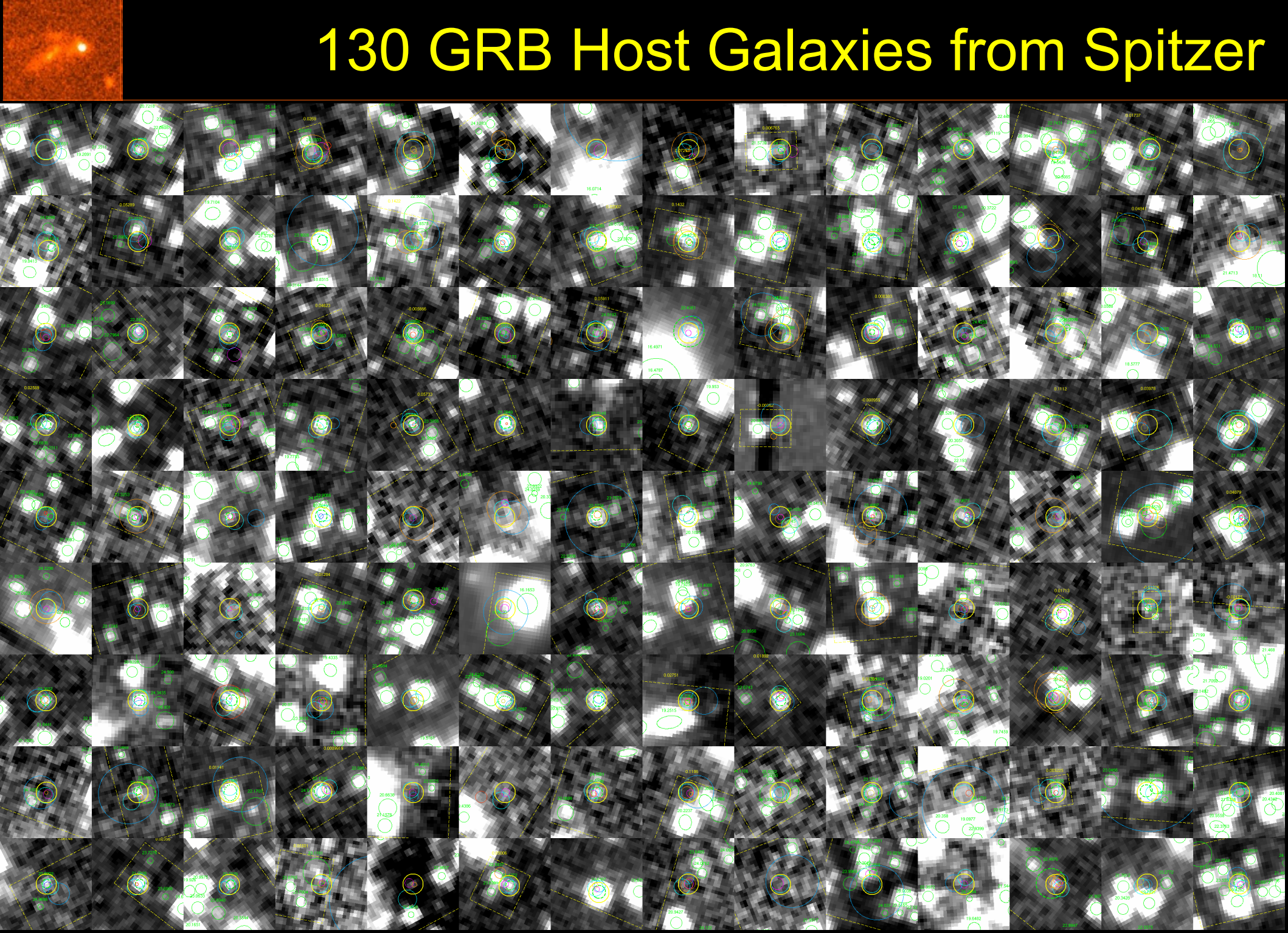
Keck, Gemini, VLT, GTC
- Optical/NIR imaging for full SED modeling (age, extinction, improved stellar masses)
- Spectroscopy to complete redshift distribution
- Numerous programs ongoing



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)
- PI D. Perley

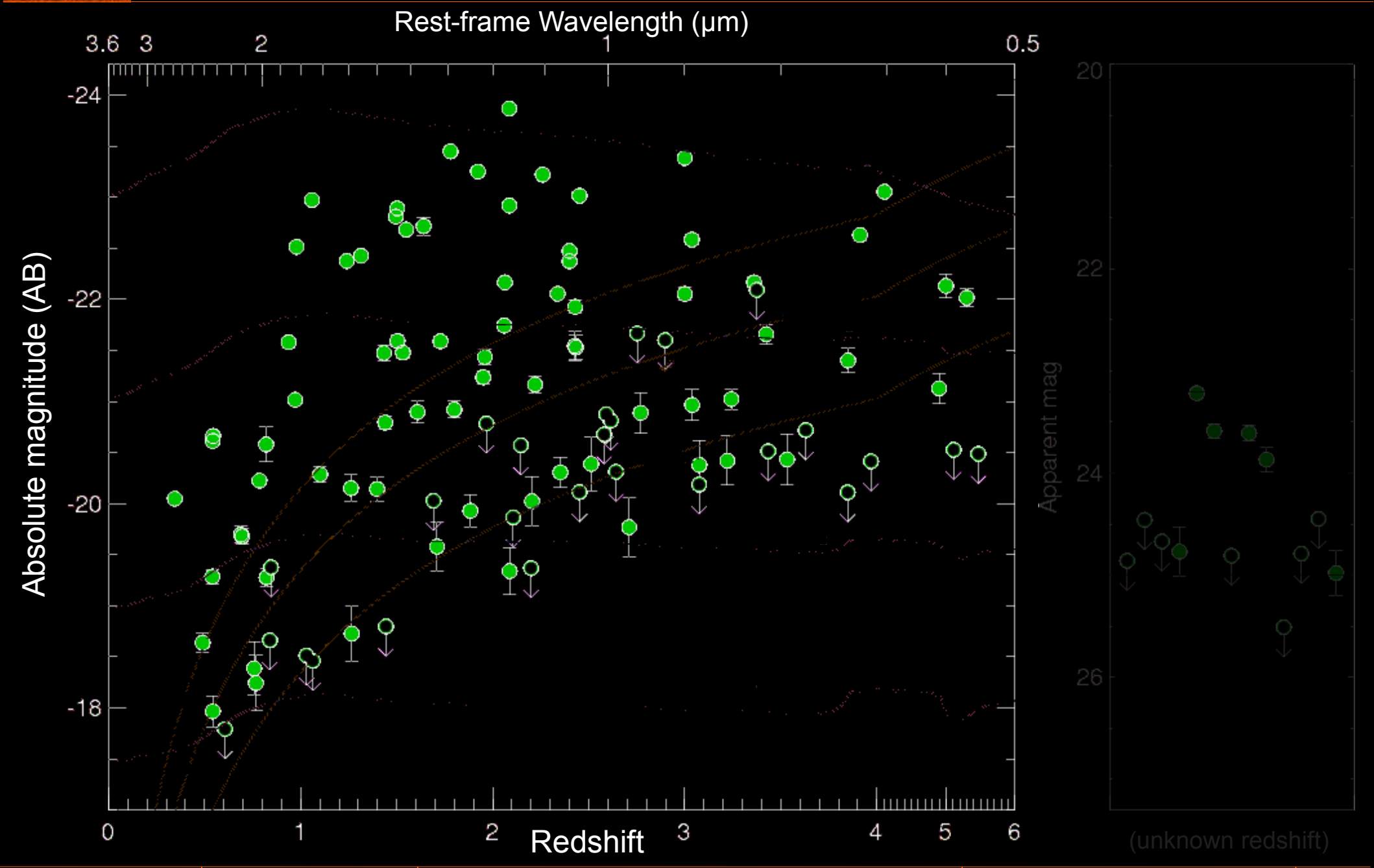
Keck, Gemini, VLT, GTC
- Spectroscopy to complete redshift distribution, measure metallicities of some galaxies
- Multicolor optical/NIR imaging for full SED modeling (age, extinction, improved stellar masses)
- Ongoing, worldwide campaign

130 GRB Host Galaxies from Spitzer

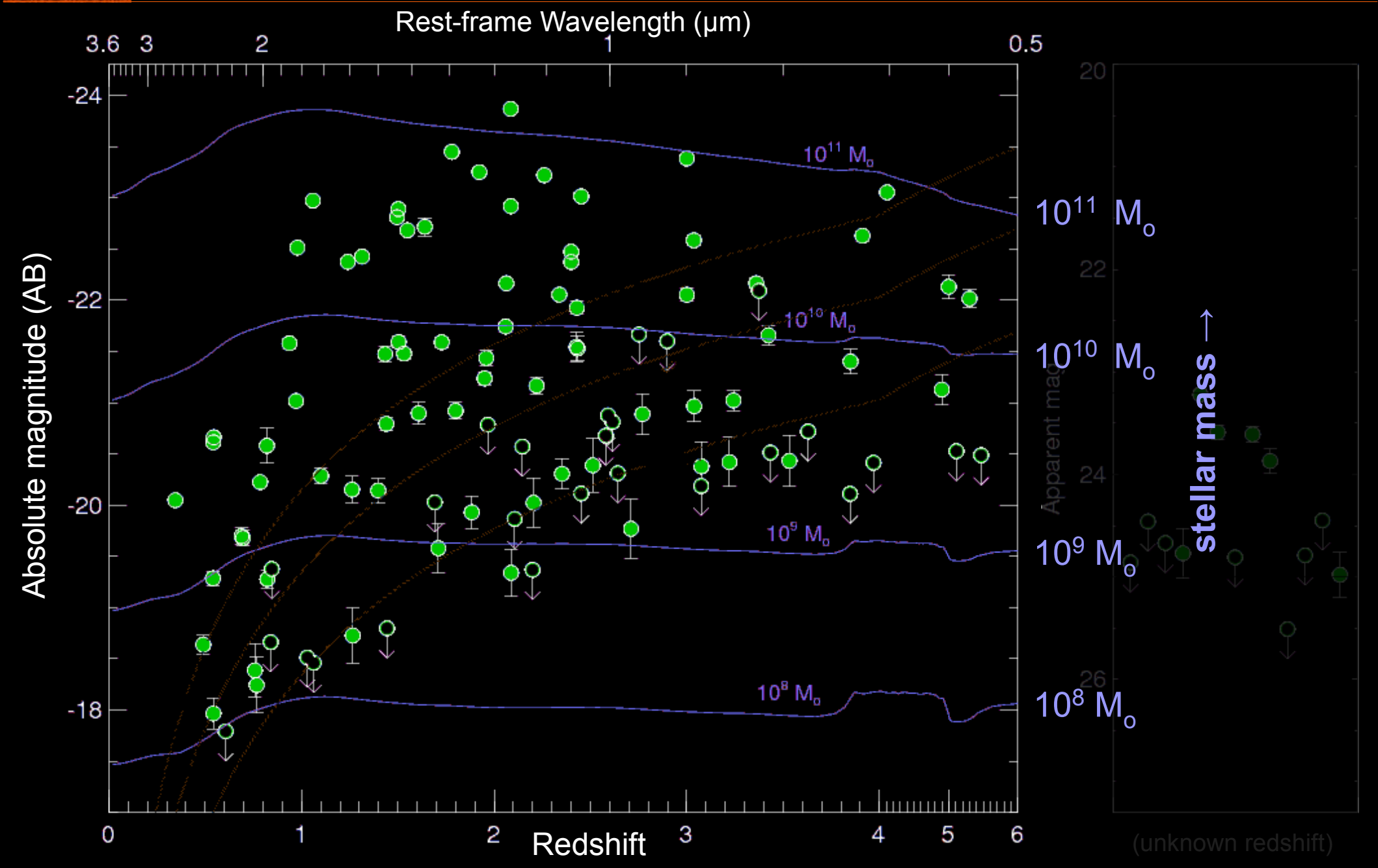


130 GRB Host Galaxies from Spitzer

GRB host NIR luminosities to z~6



GRB host stellar masses to z~6



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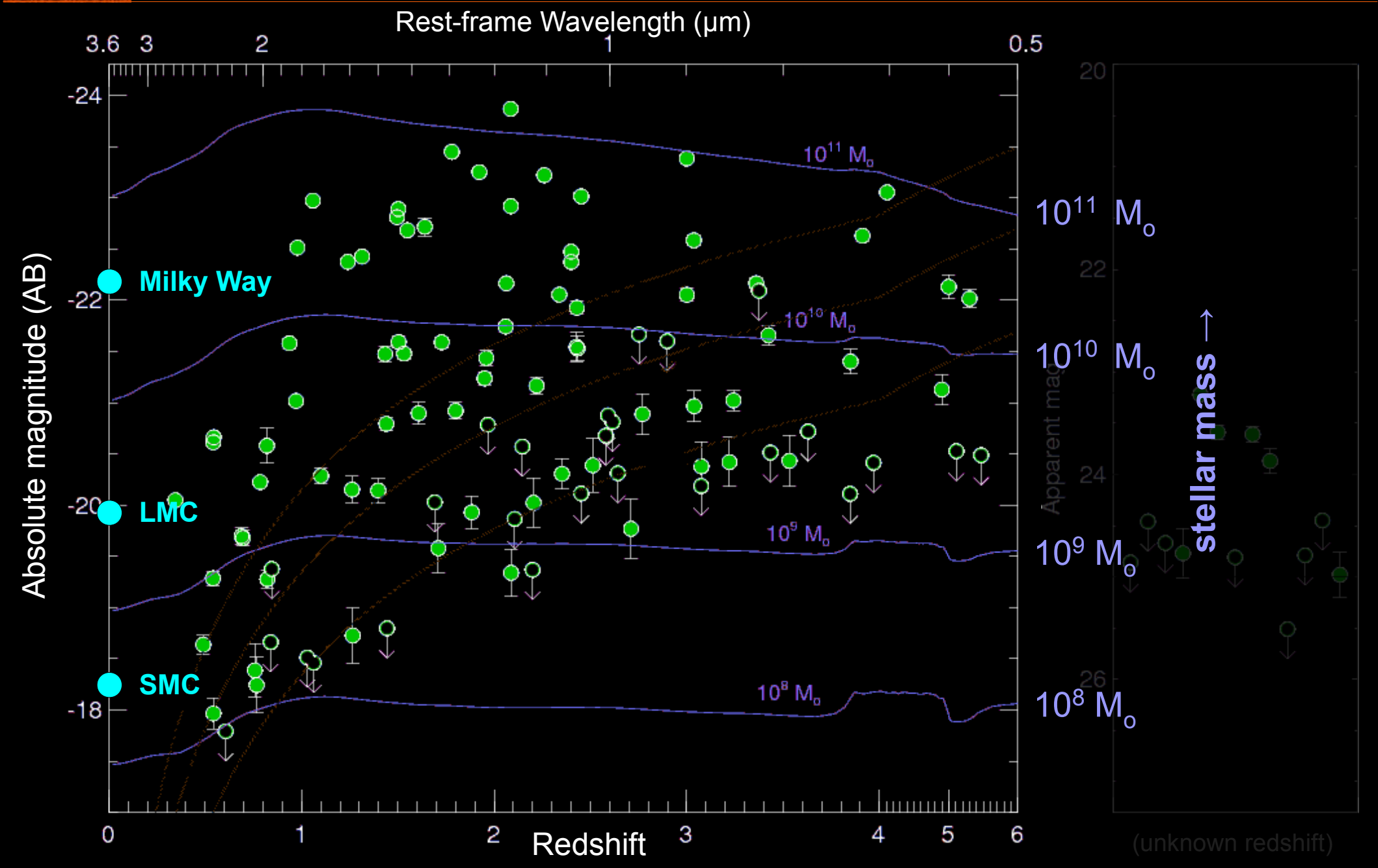

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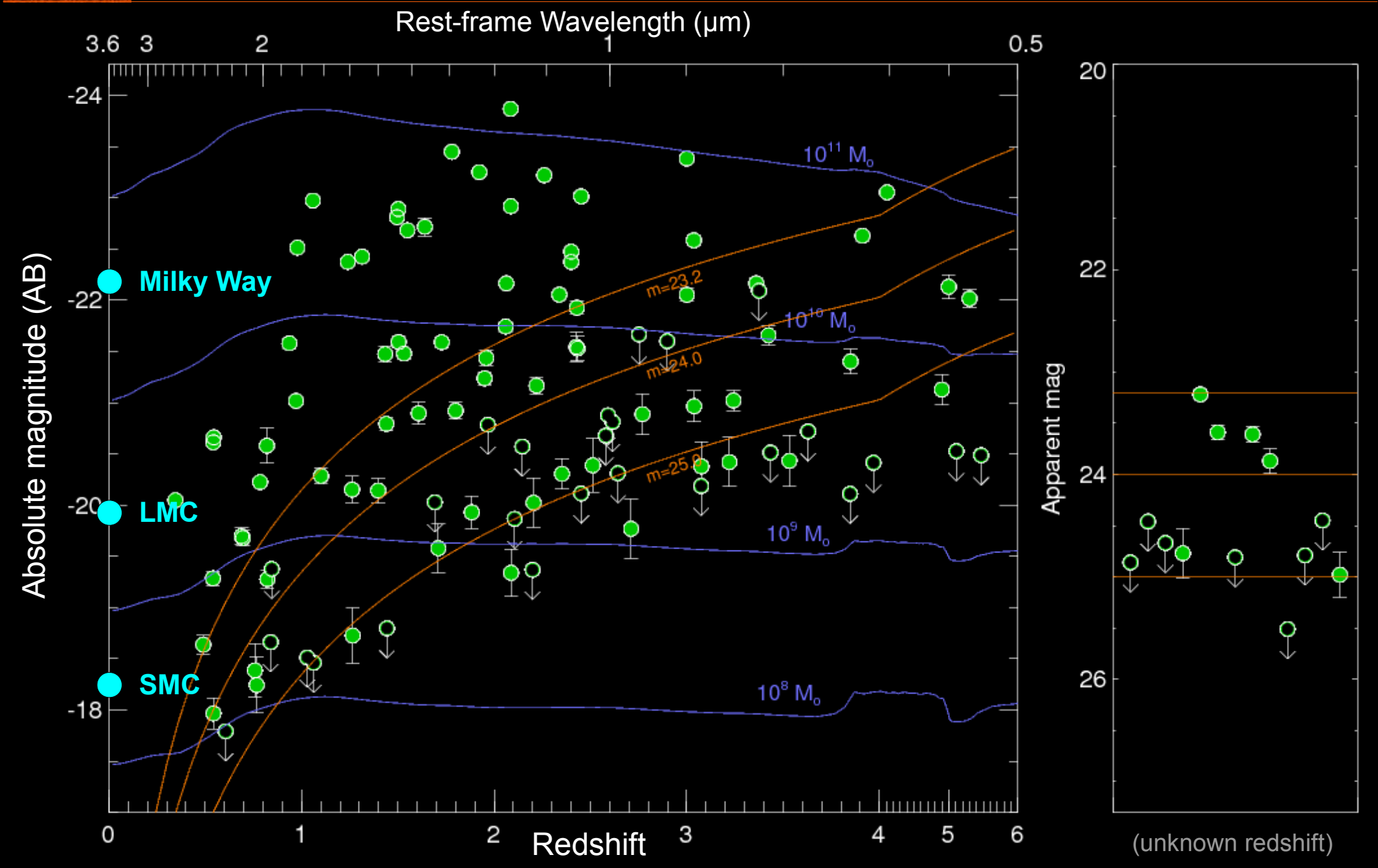

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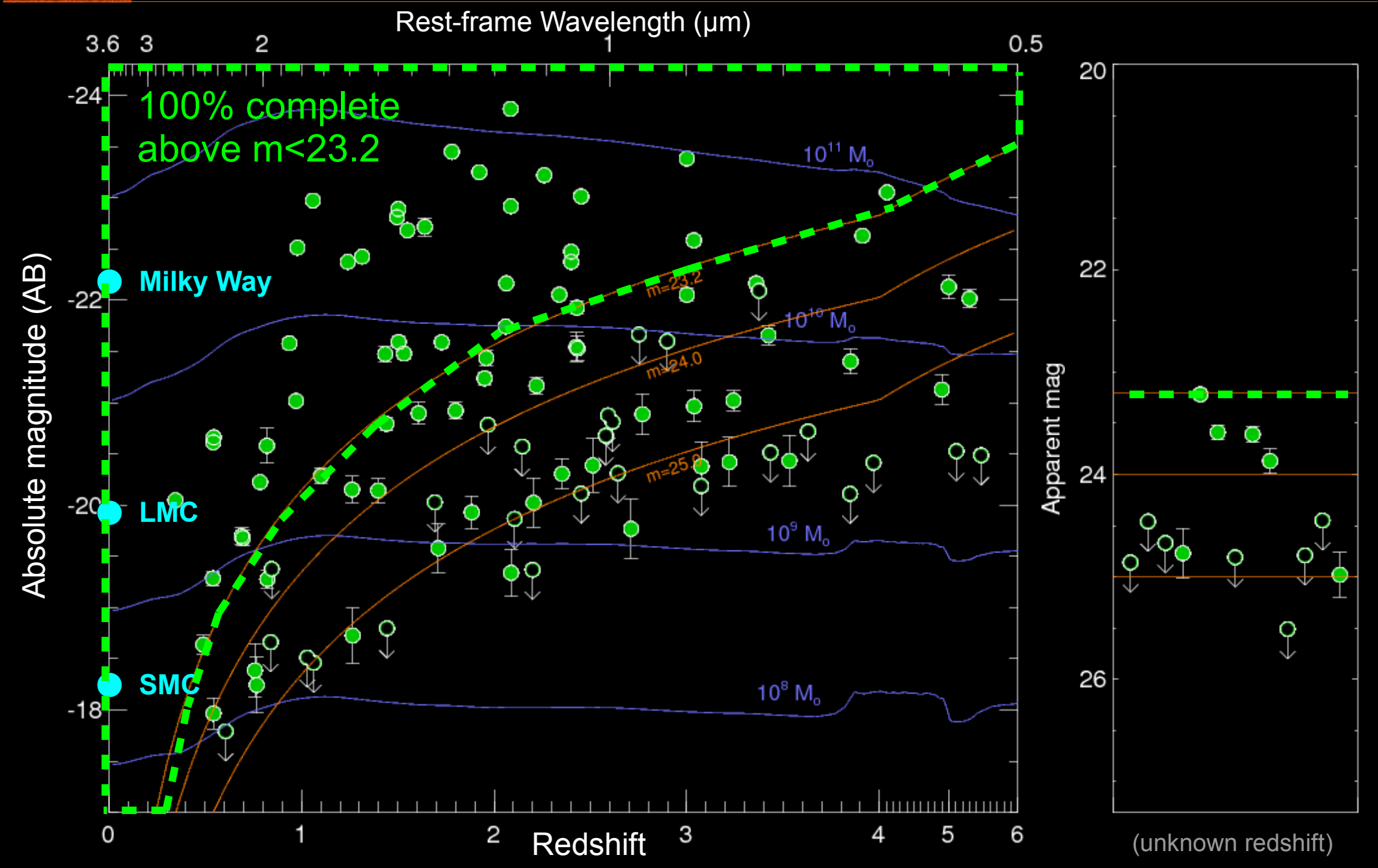

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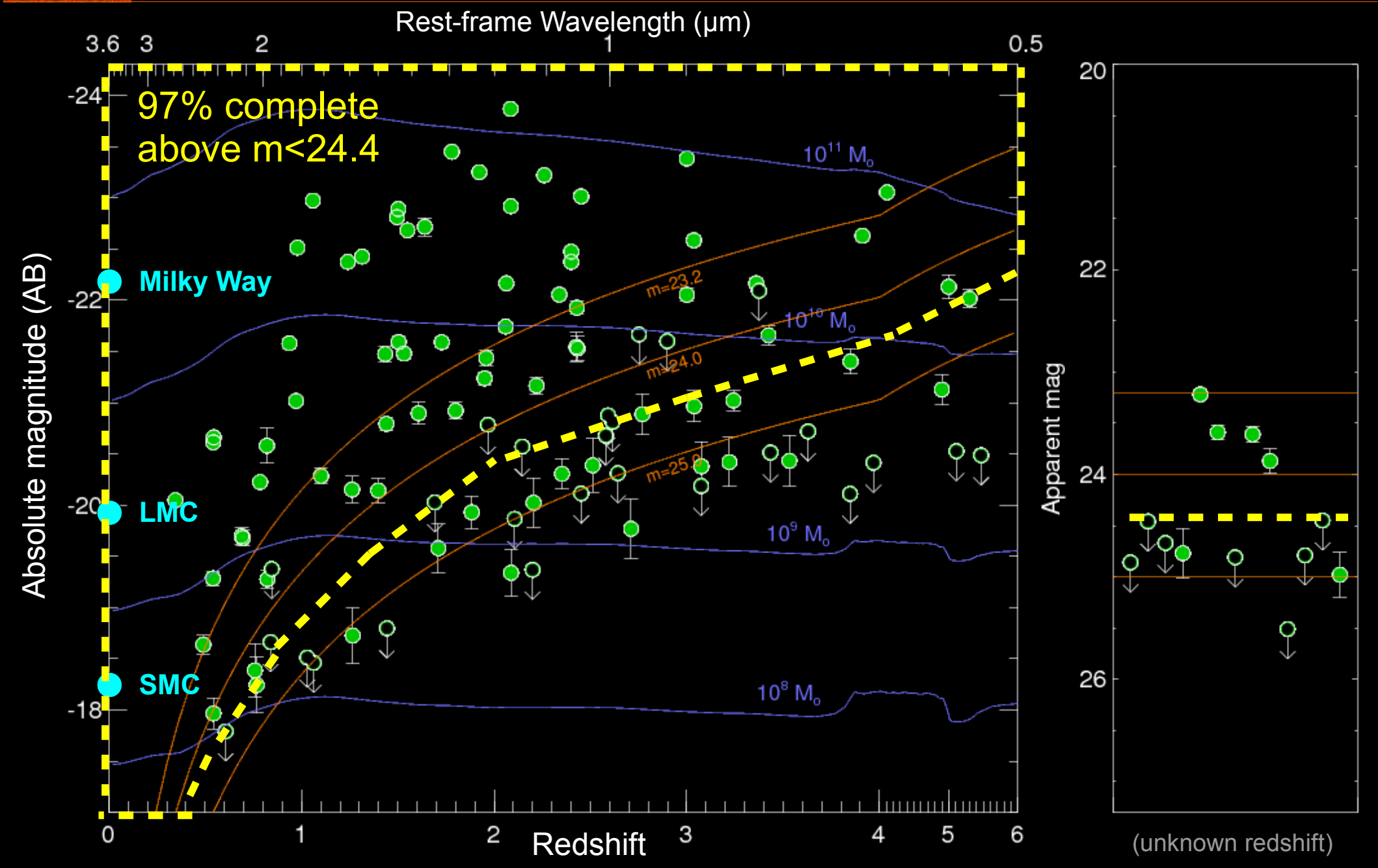

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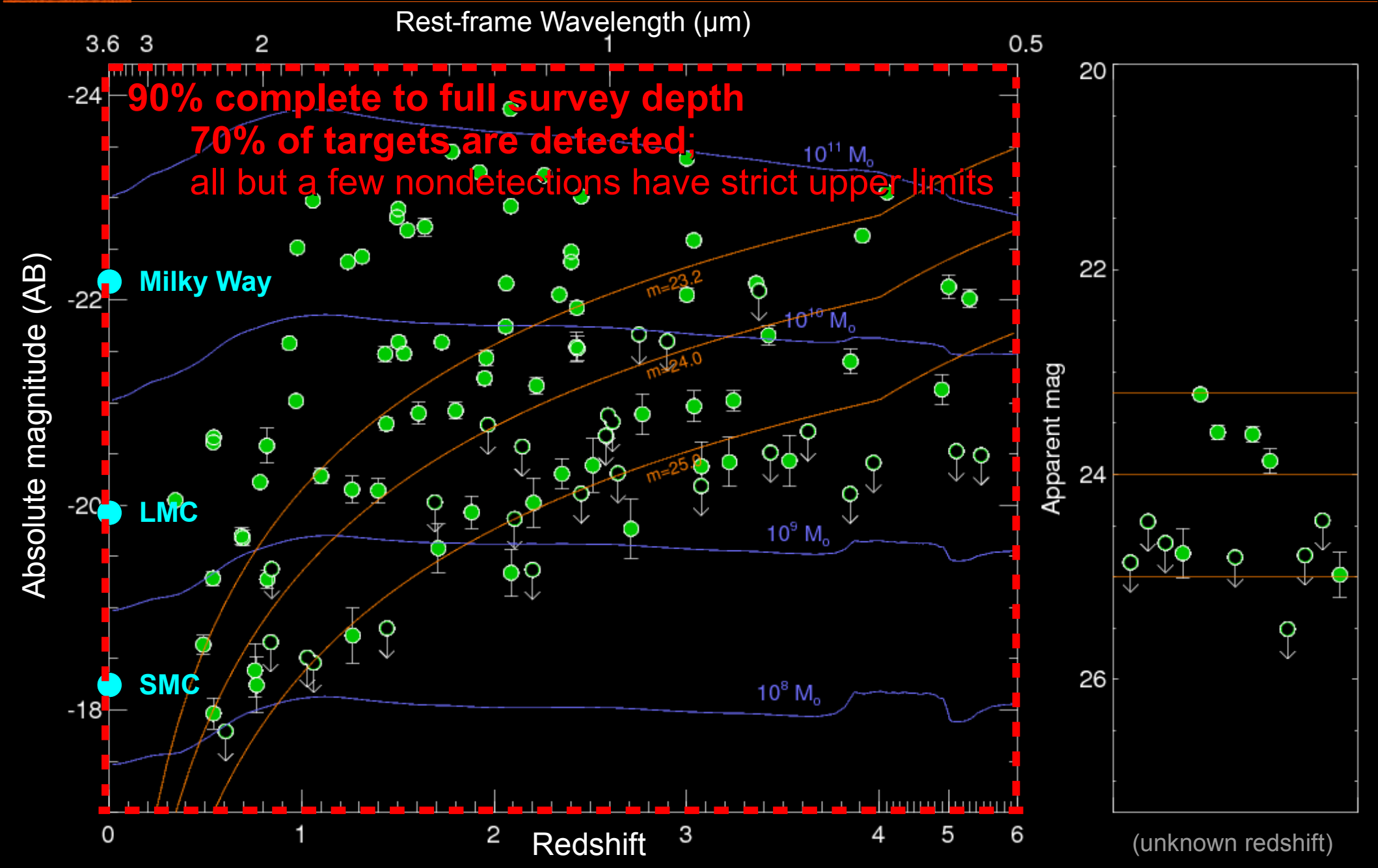

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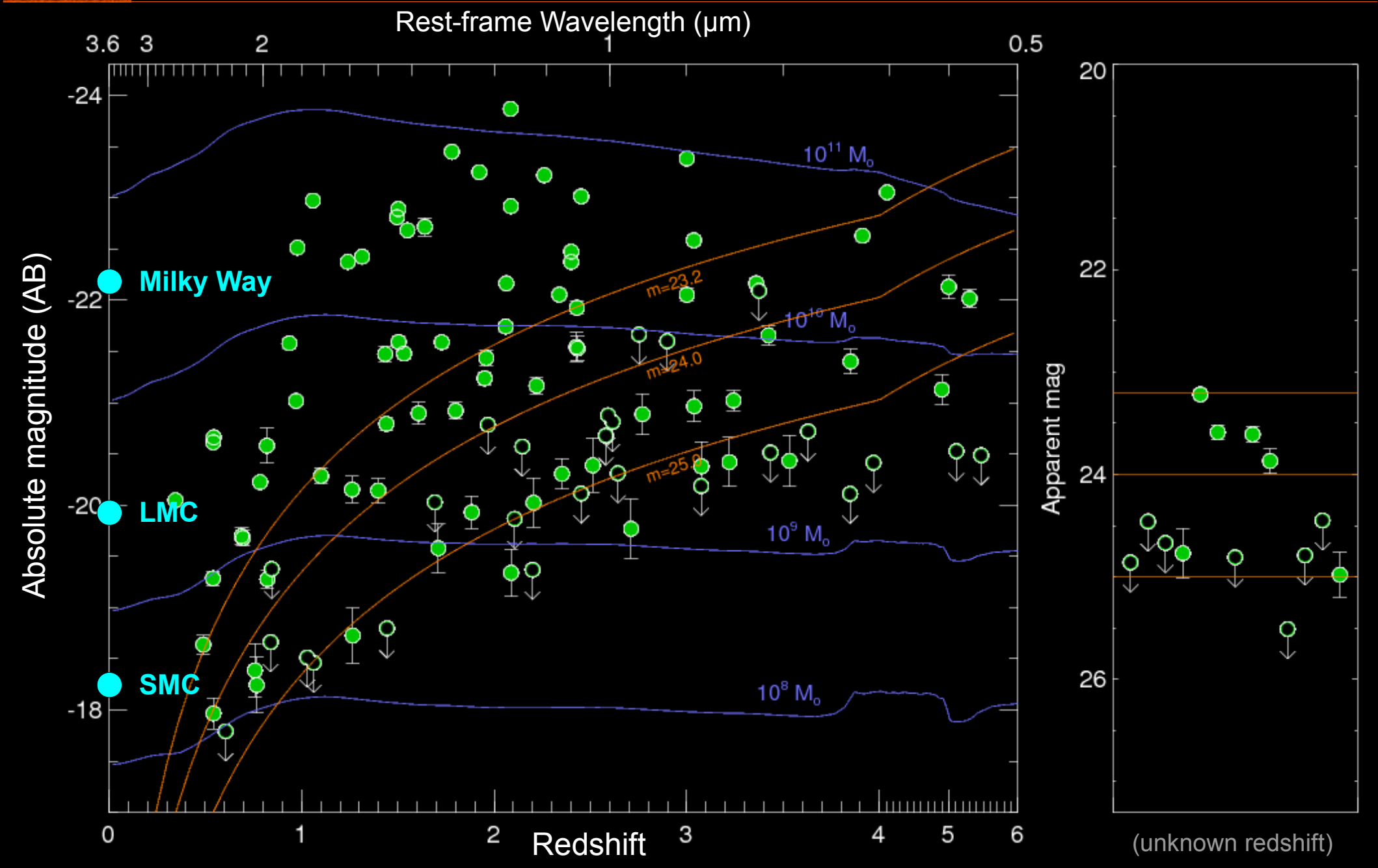
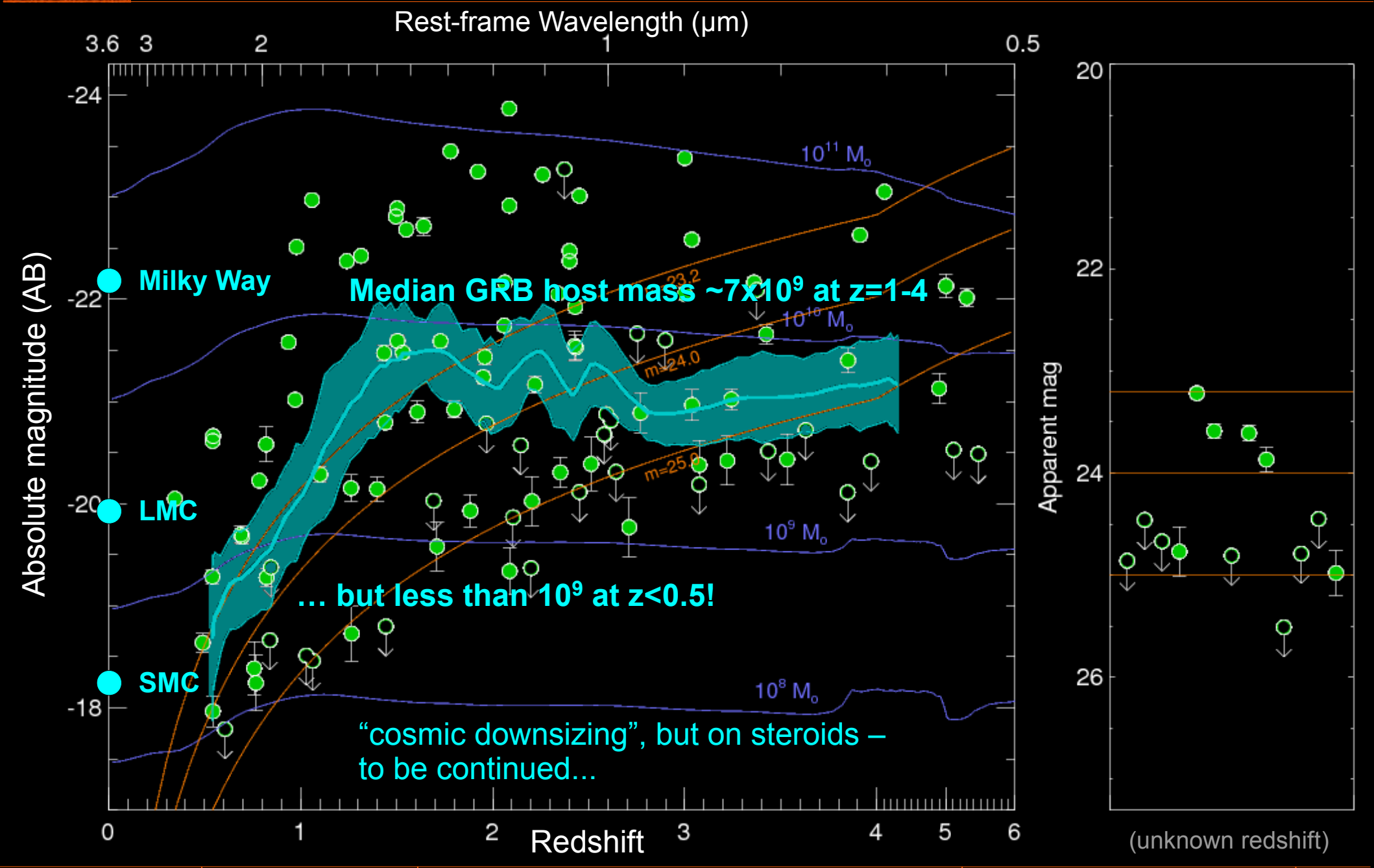


GRB host redshift evolution



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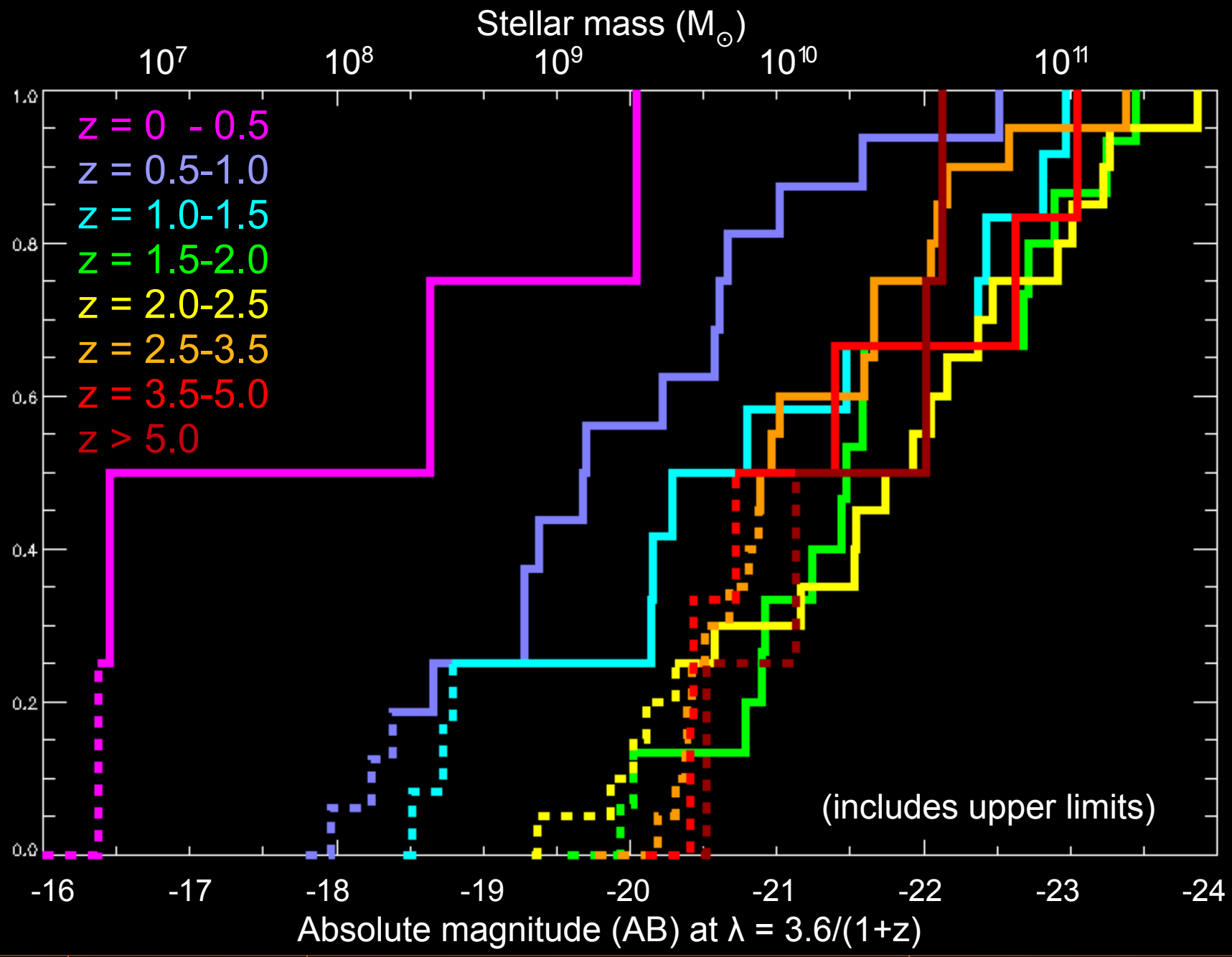
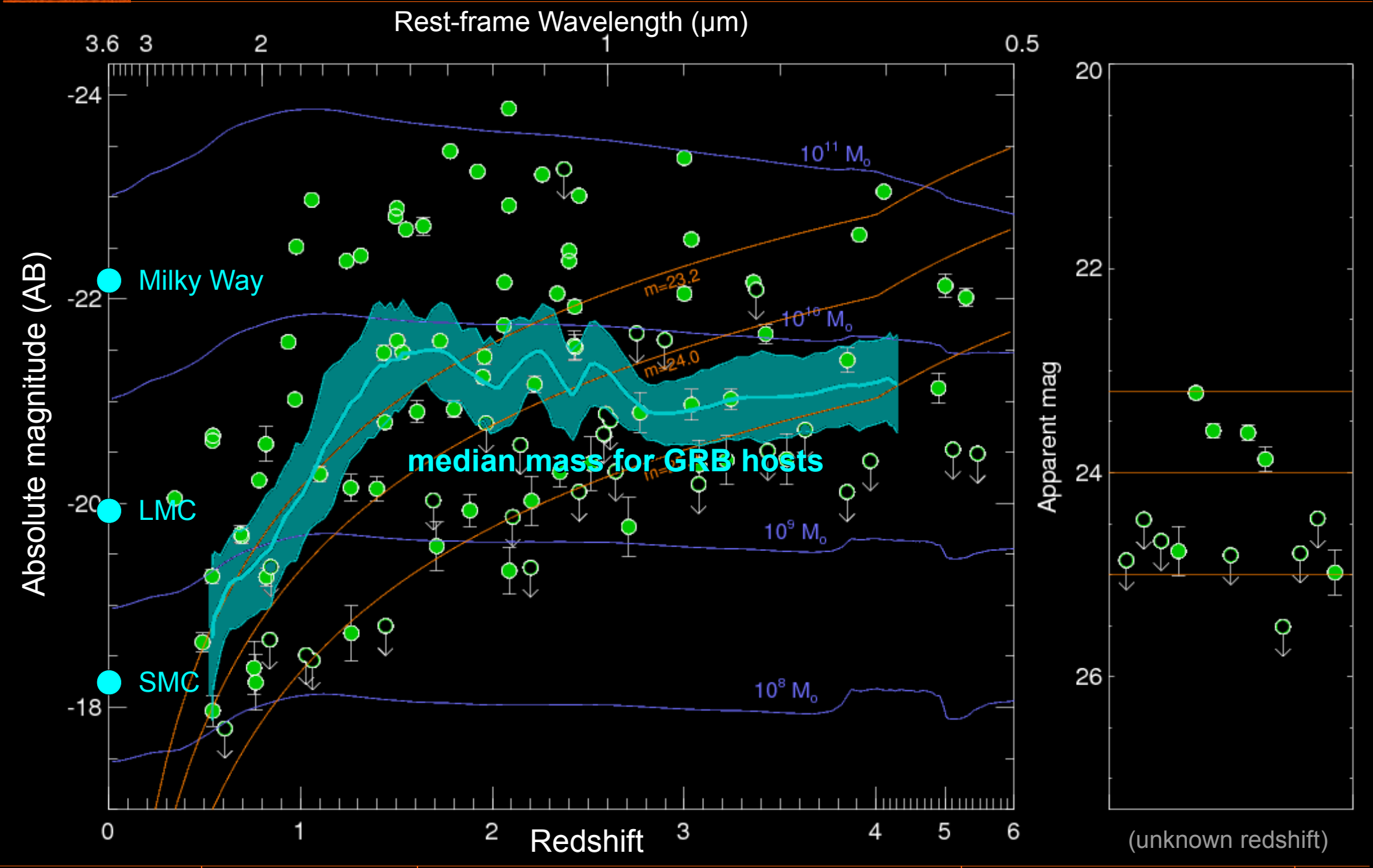


GRB hosts vs. SFR-selected galaxies



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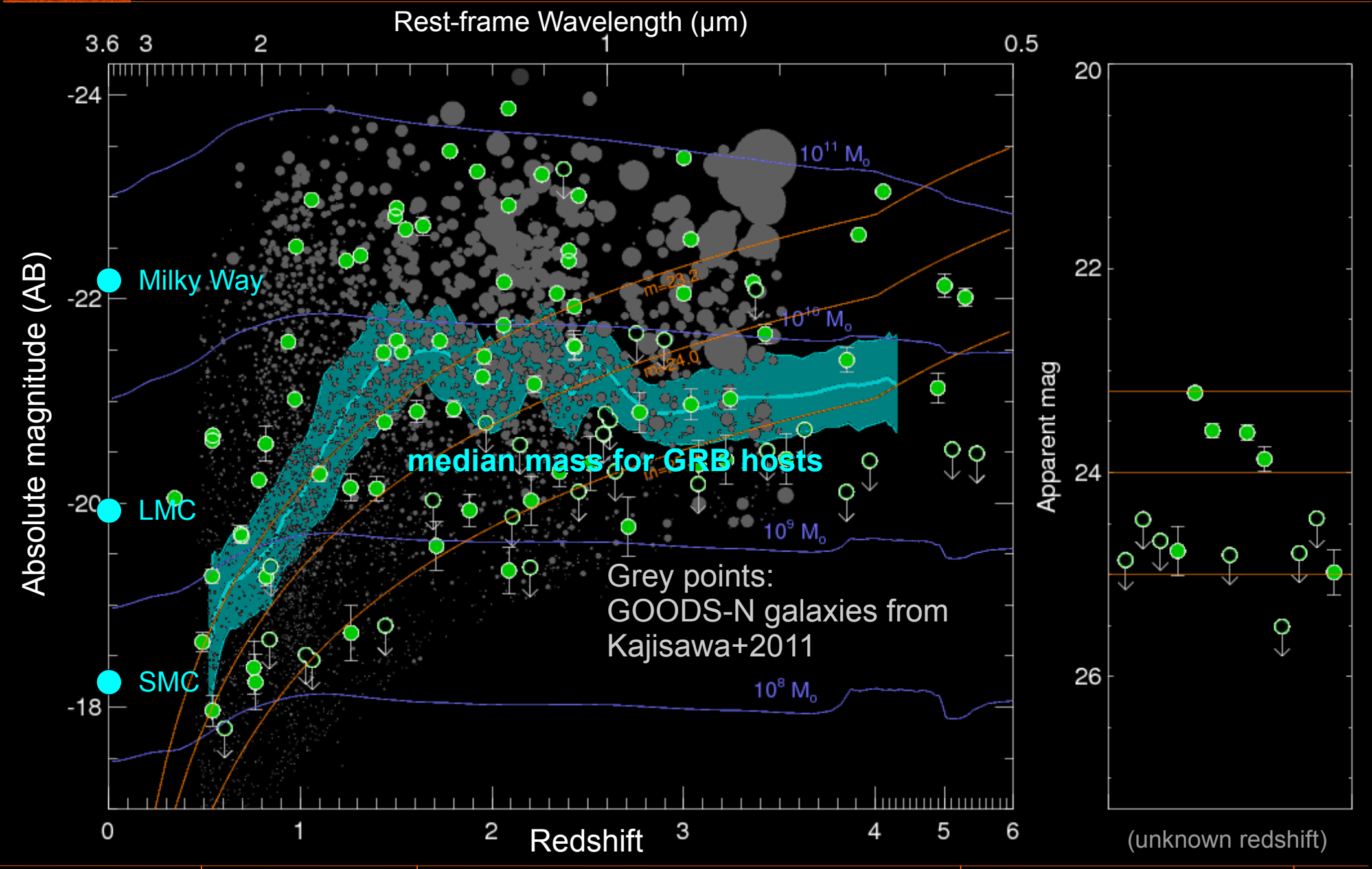

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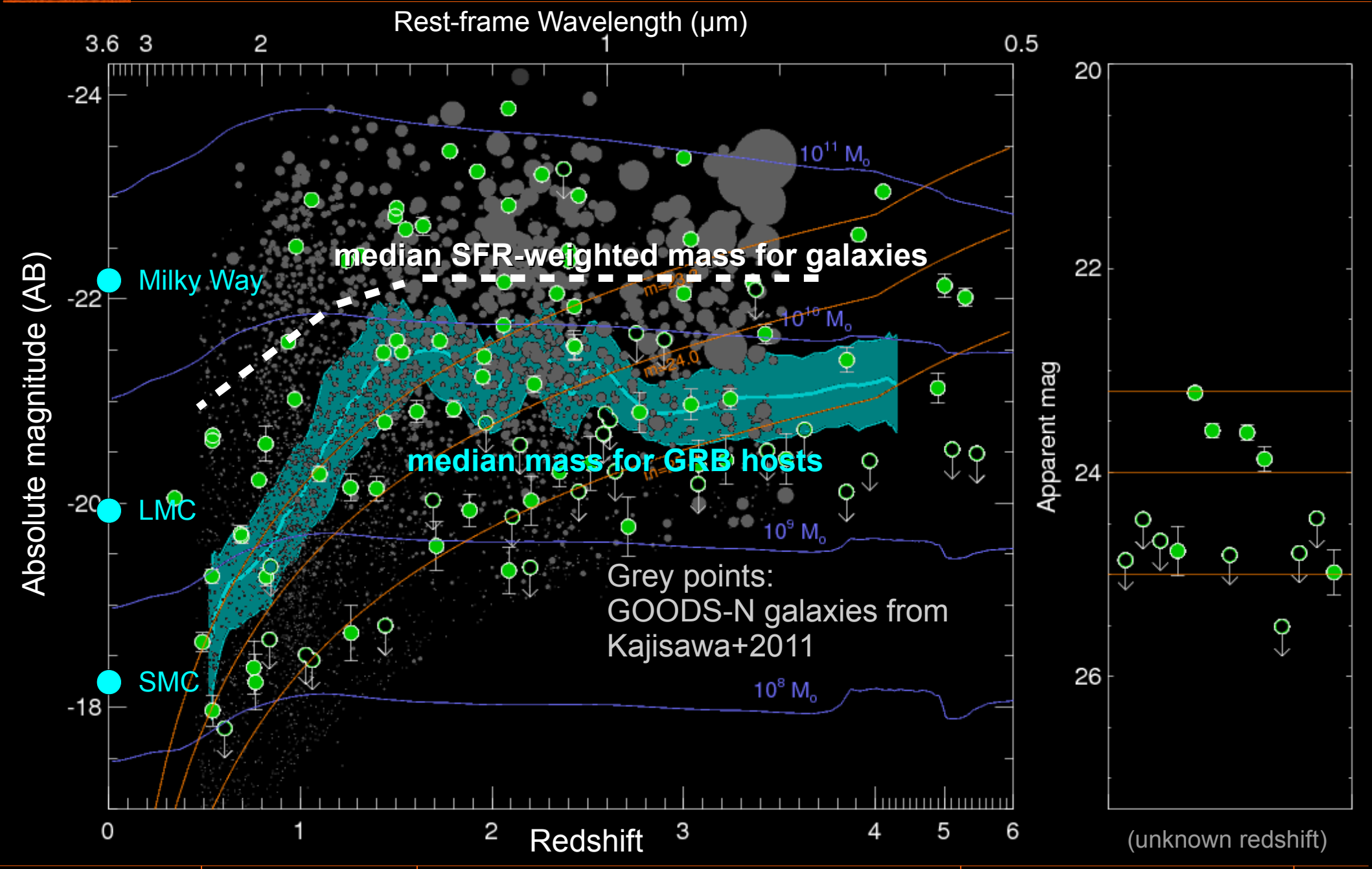

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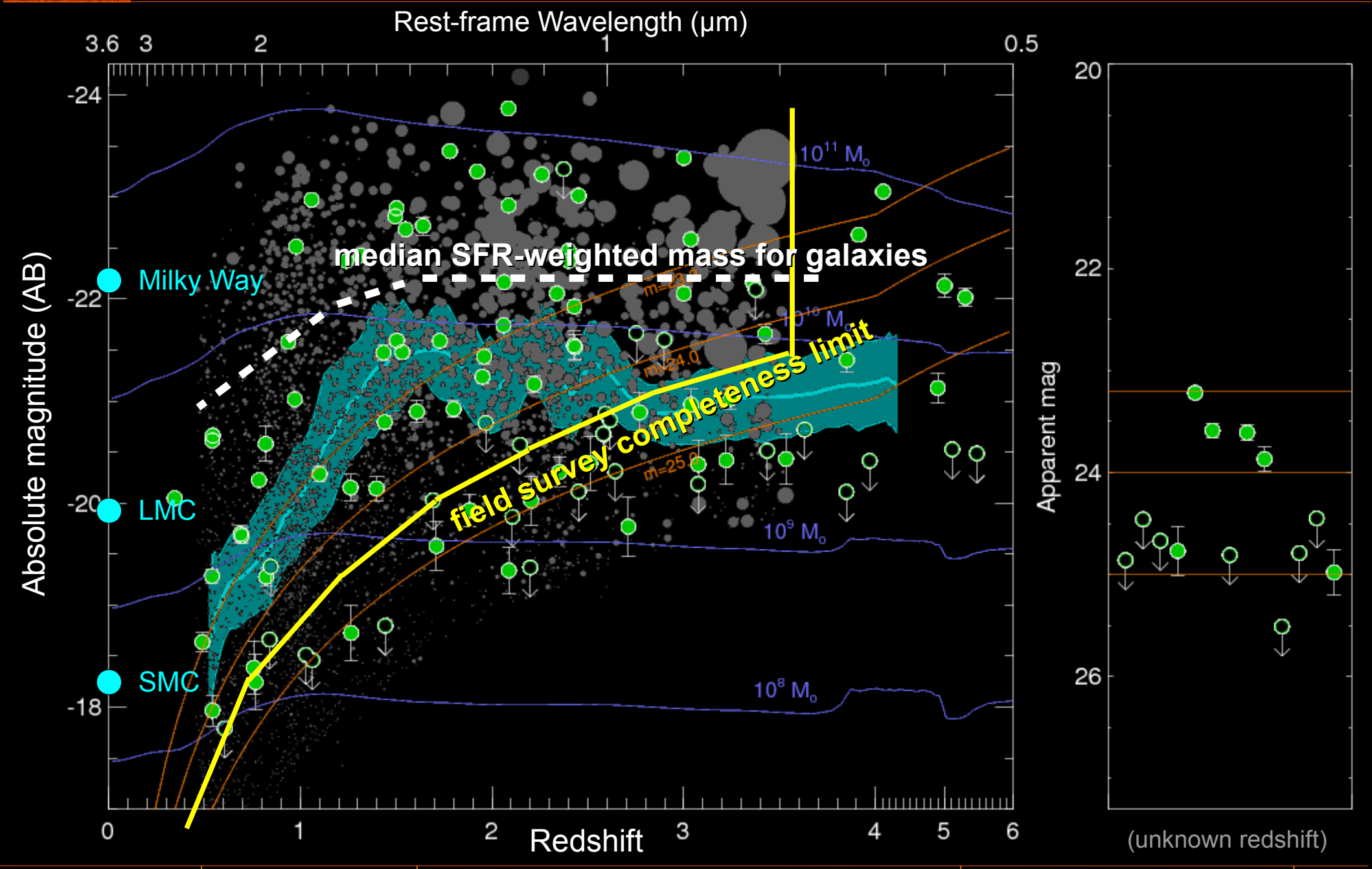

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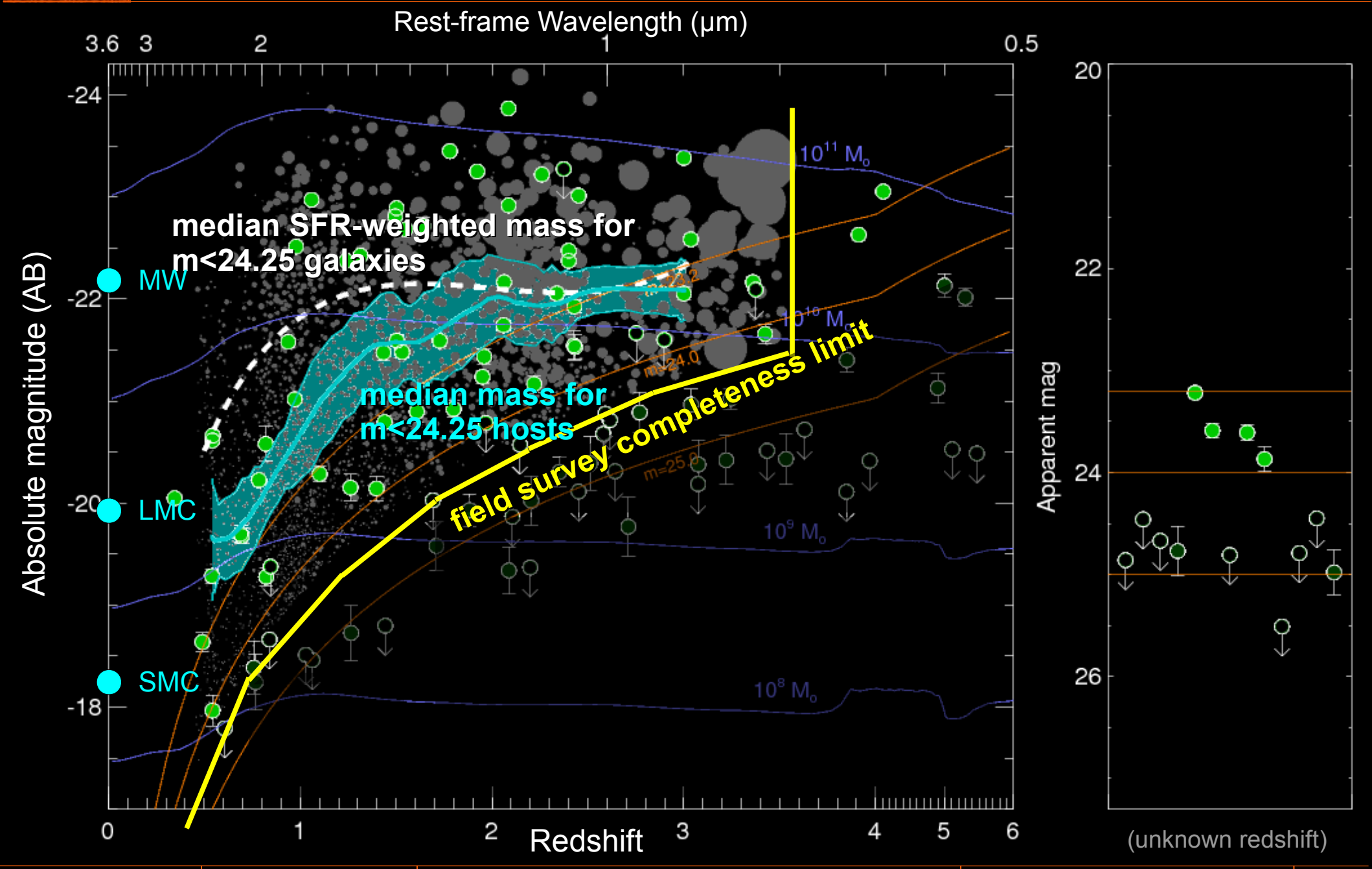

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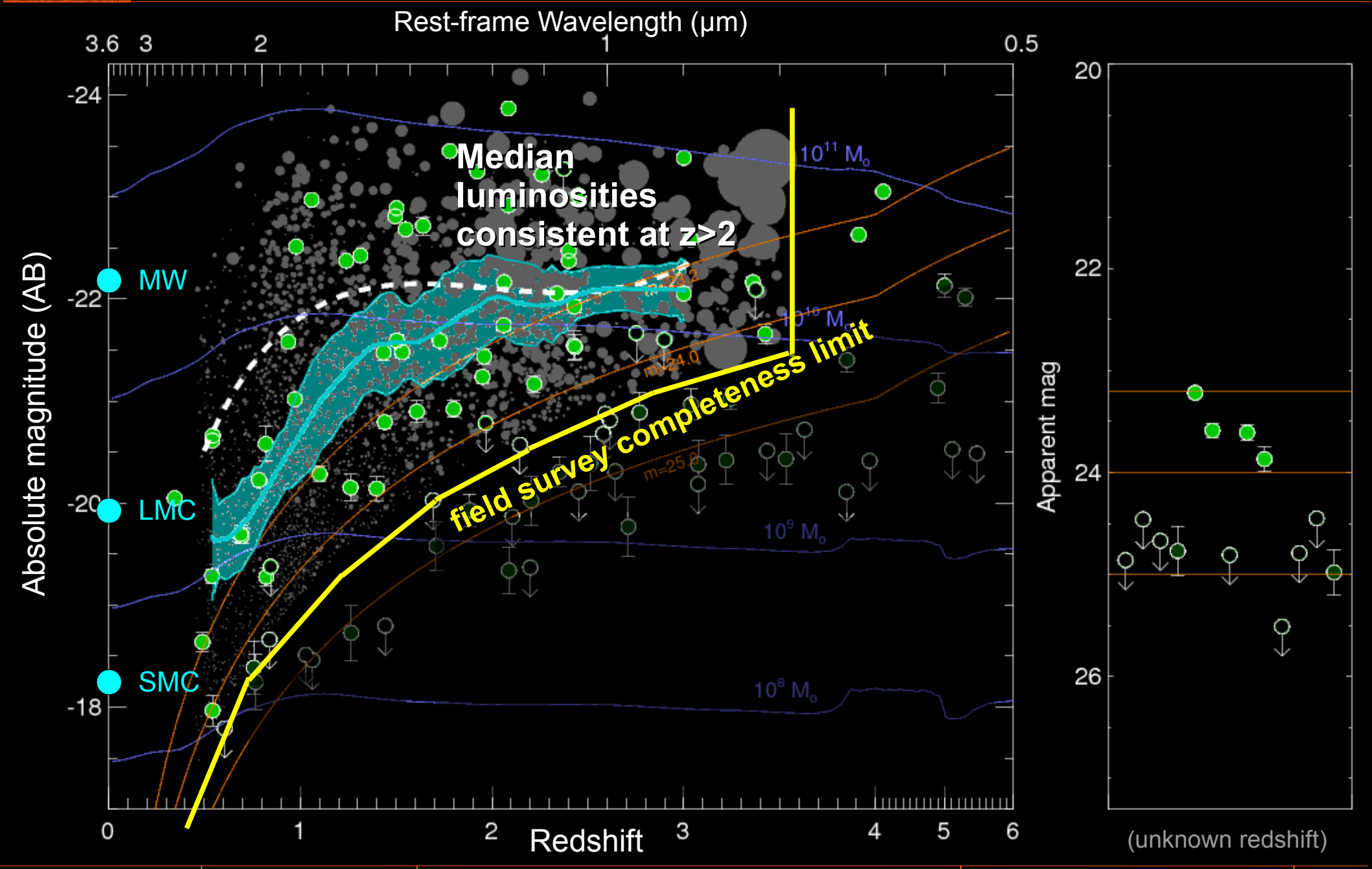

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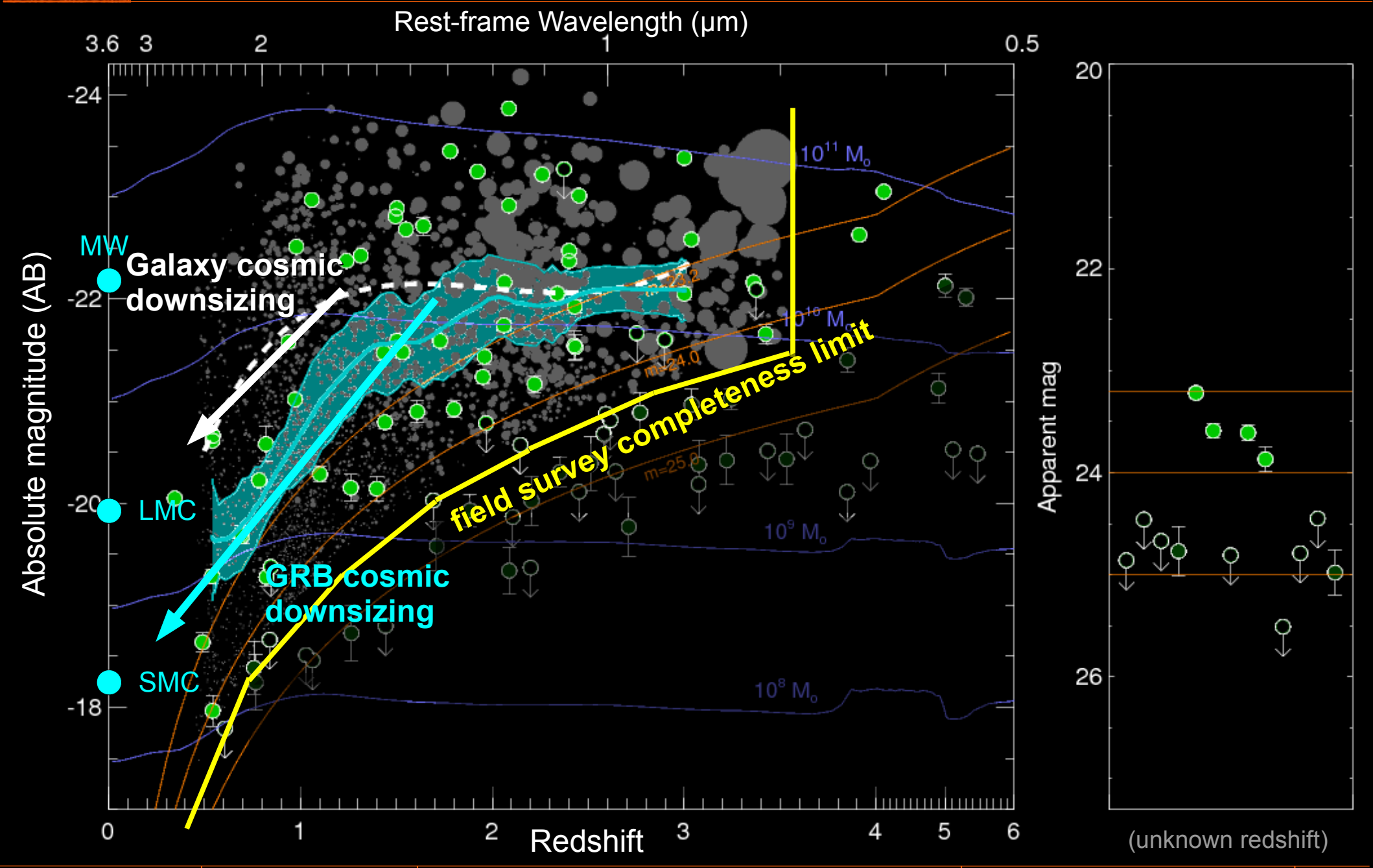

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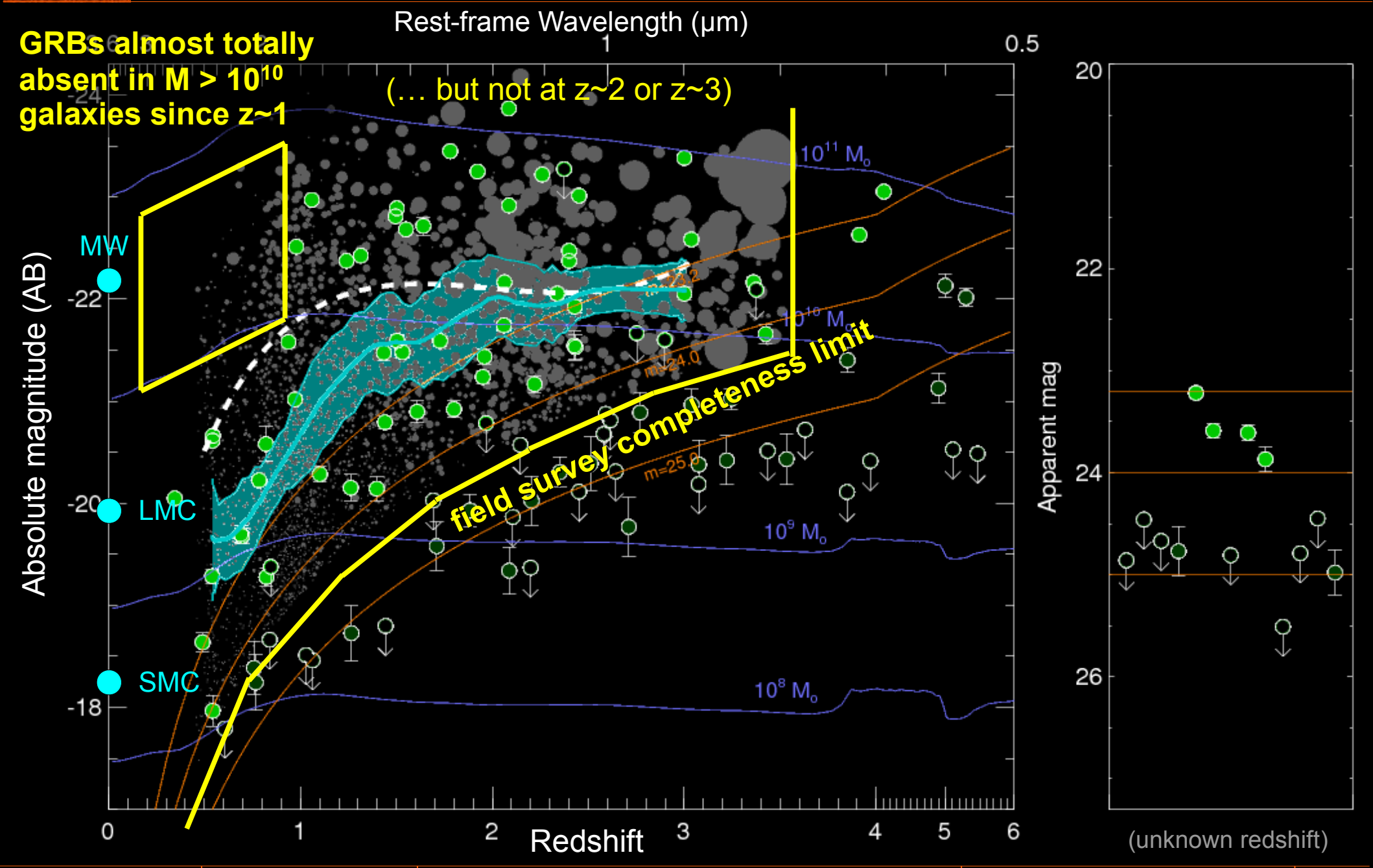
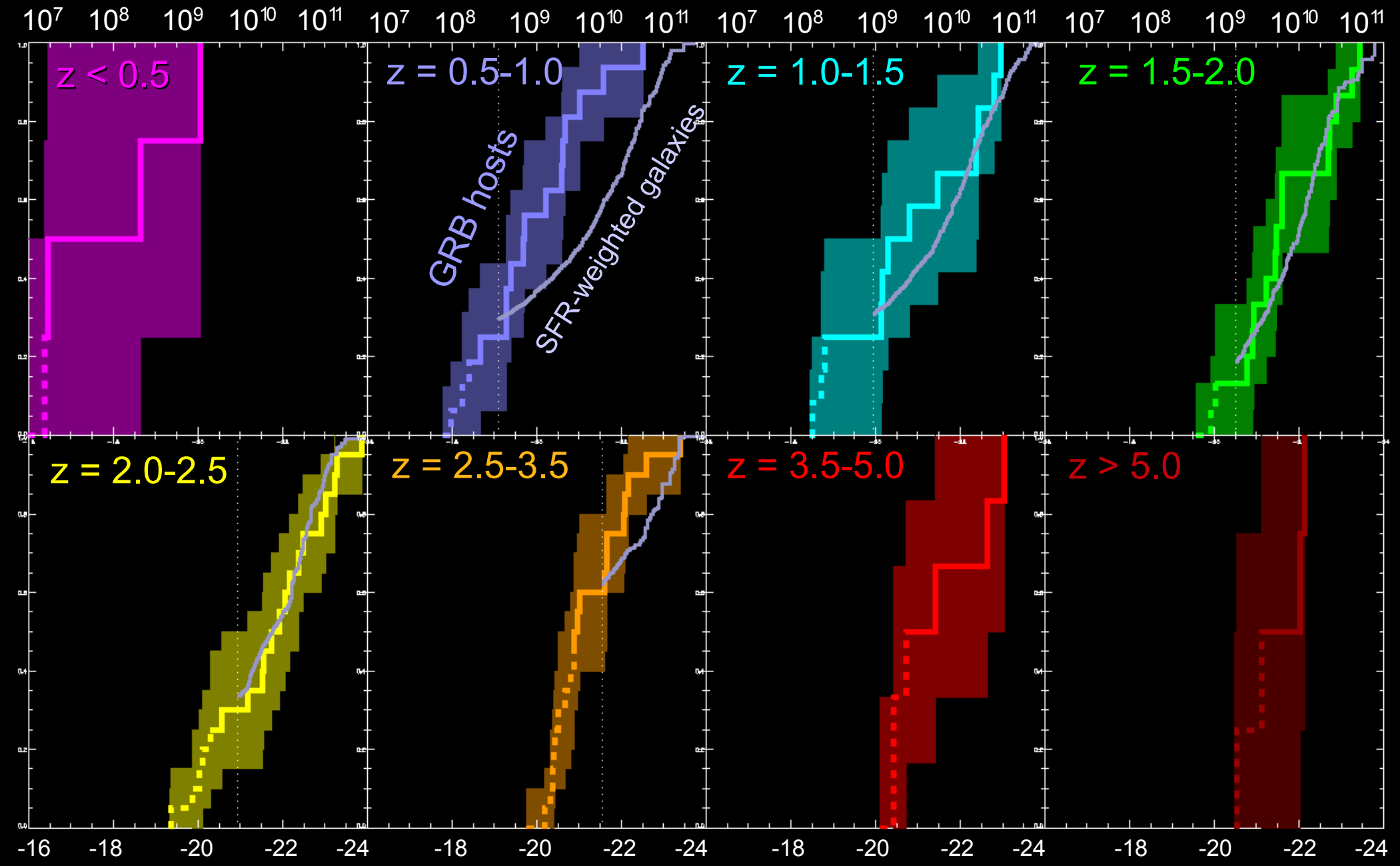


Luminosity Distribution vs. Galaxies



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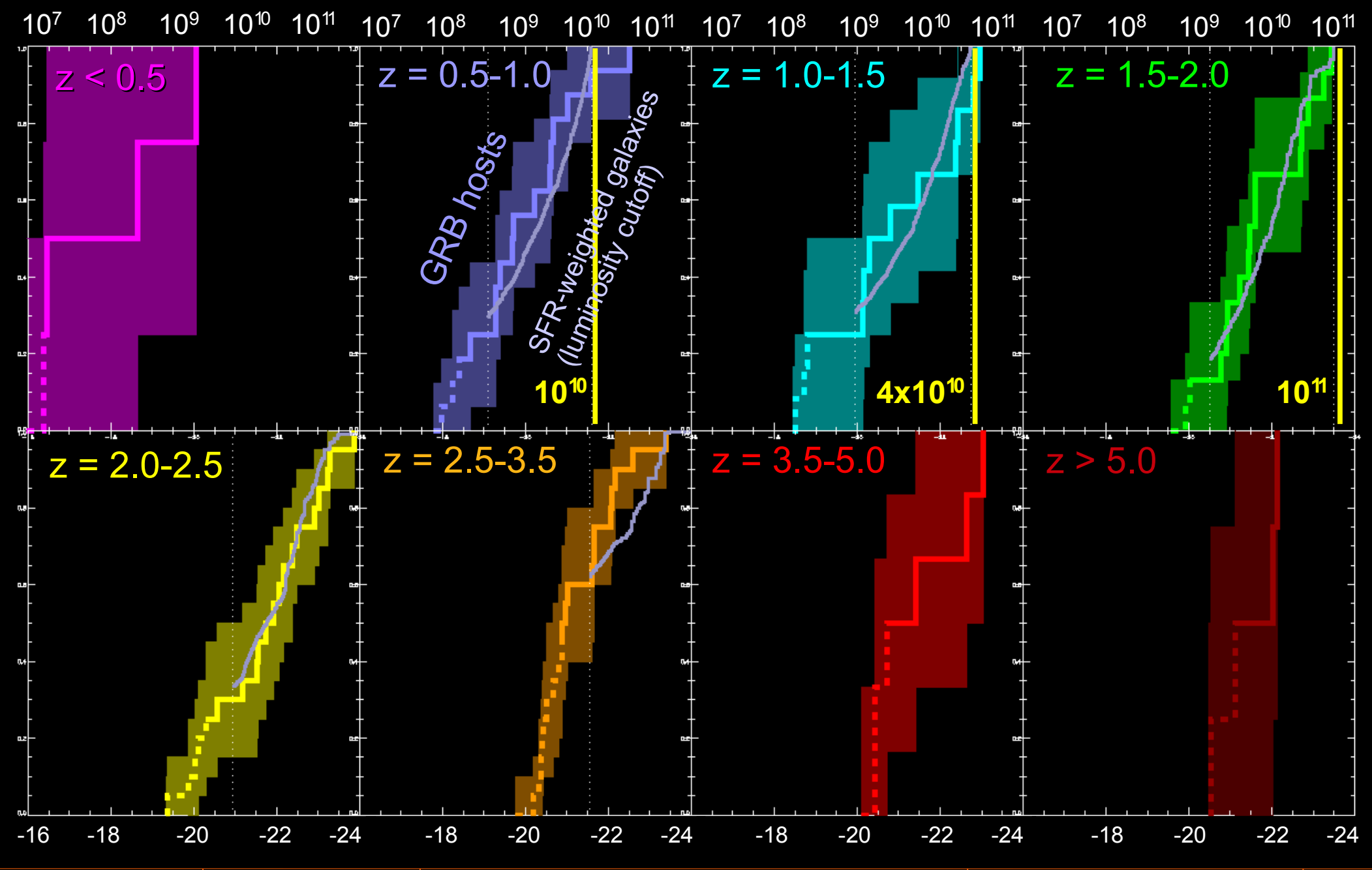
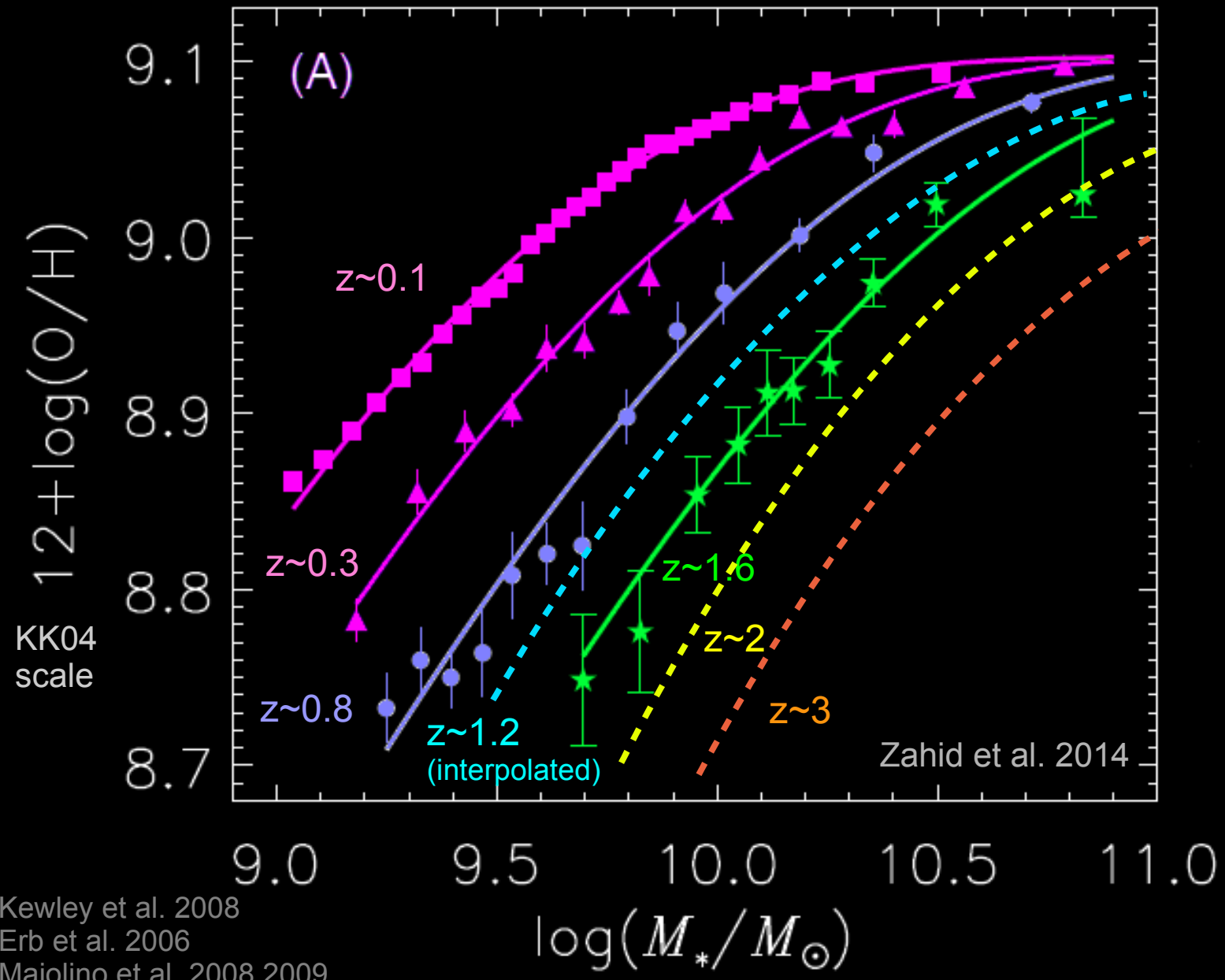


Sharp Metallicity Cutoff?



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

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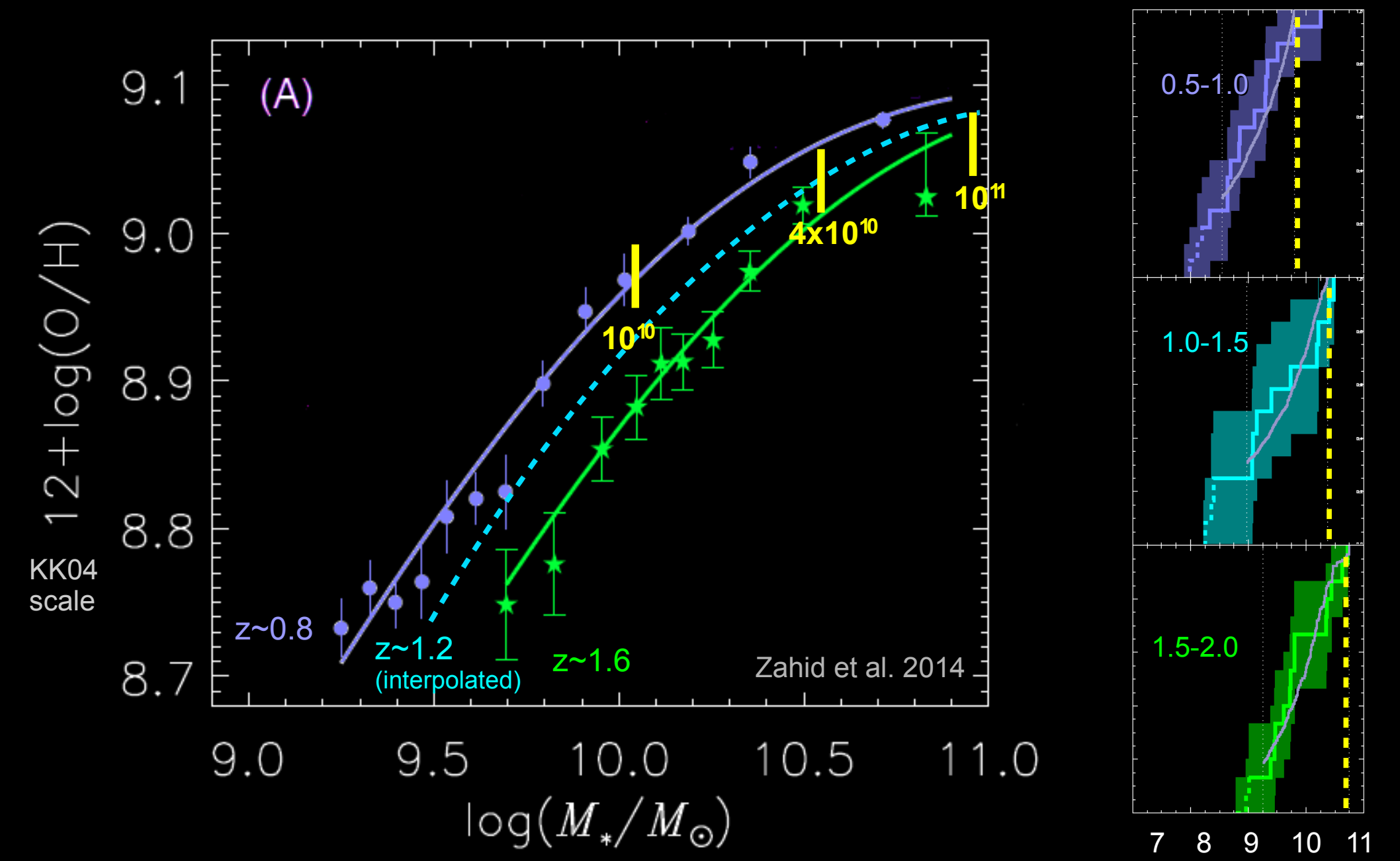

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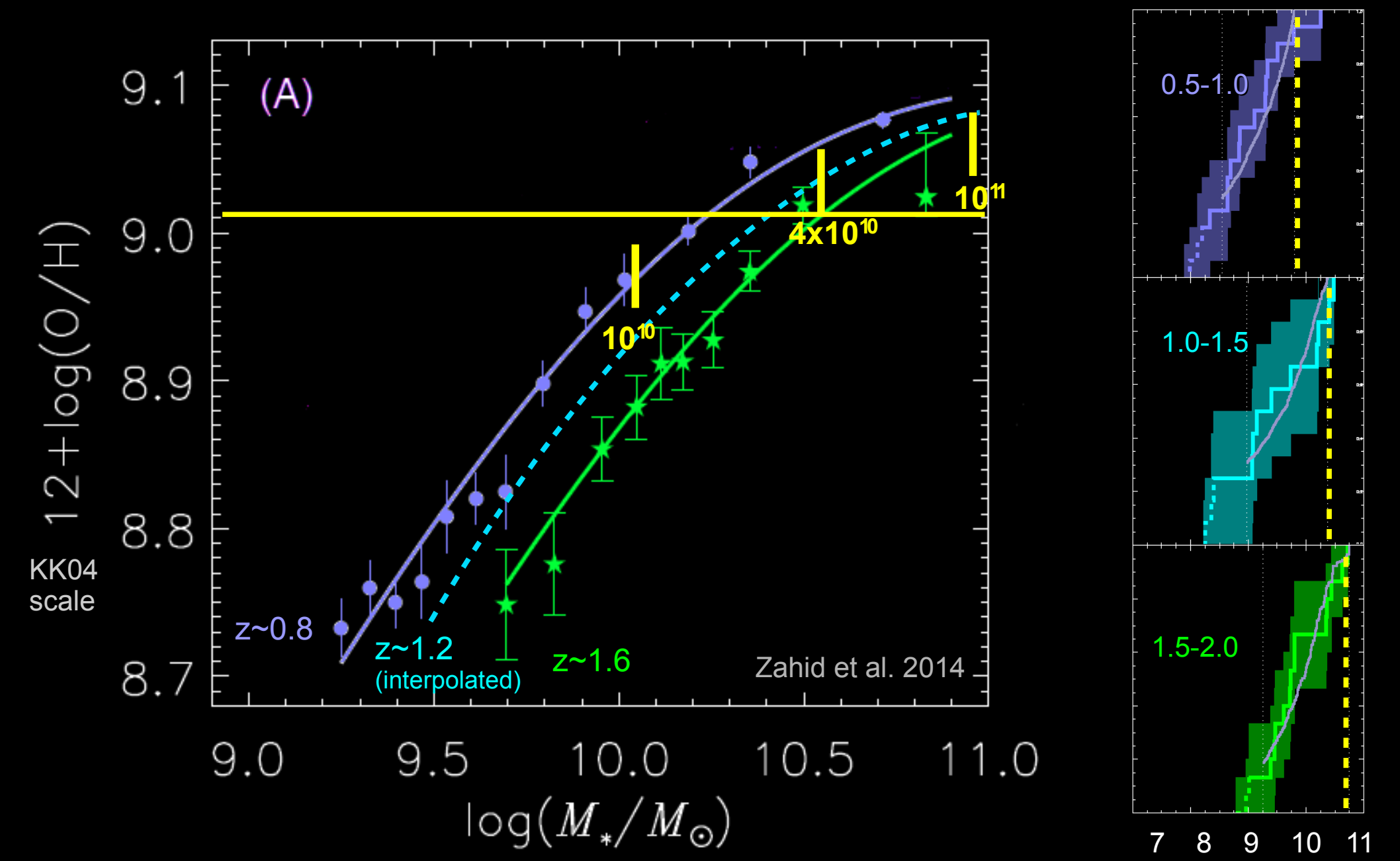

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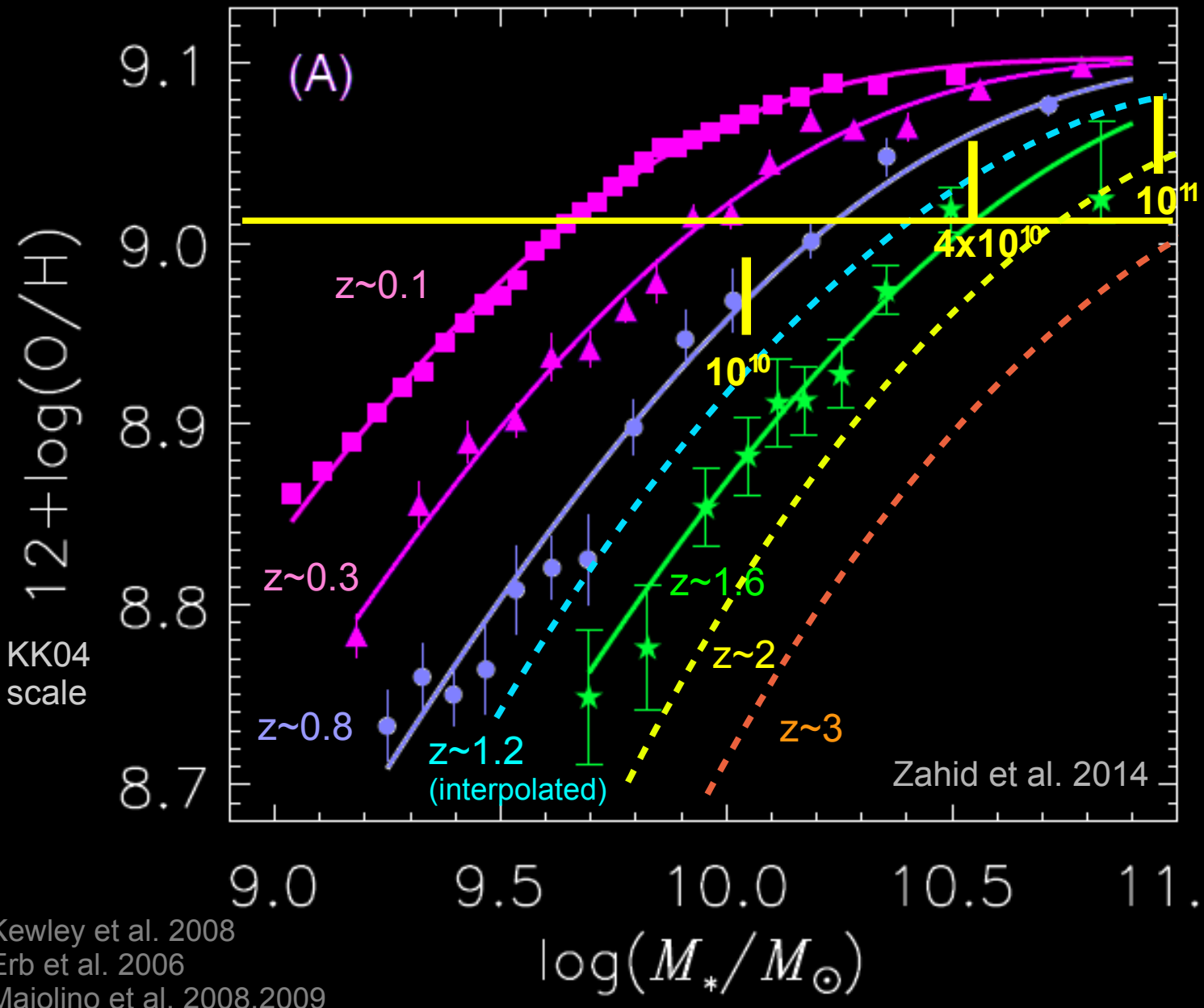

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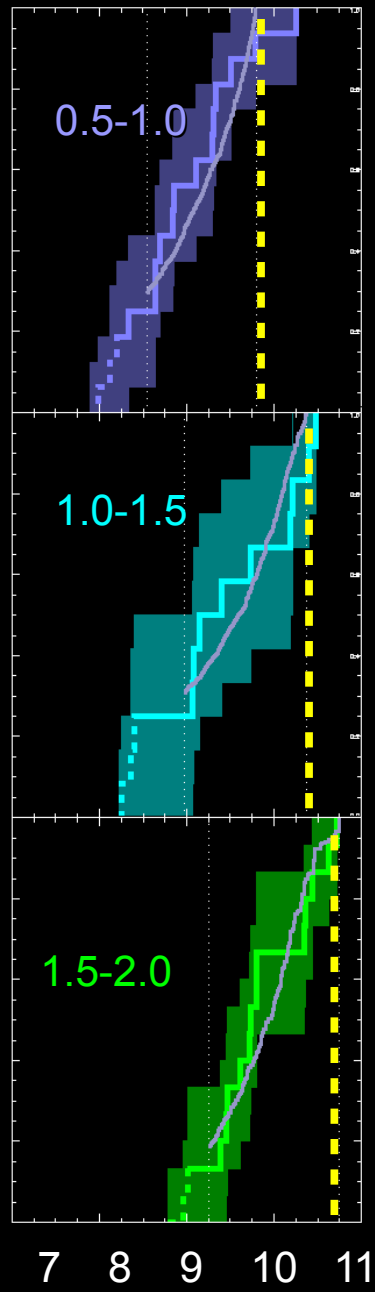

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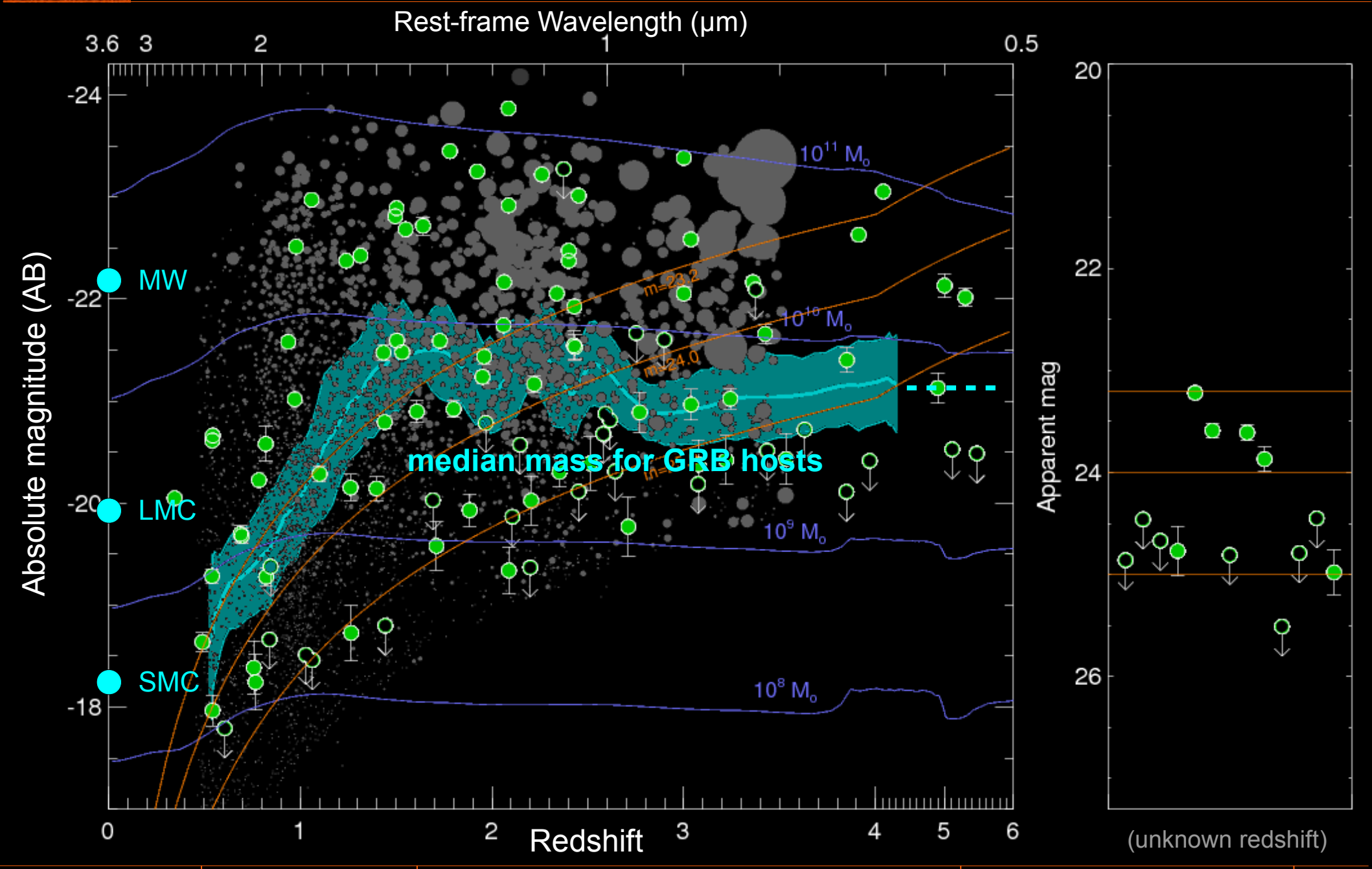

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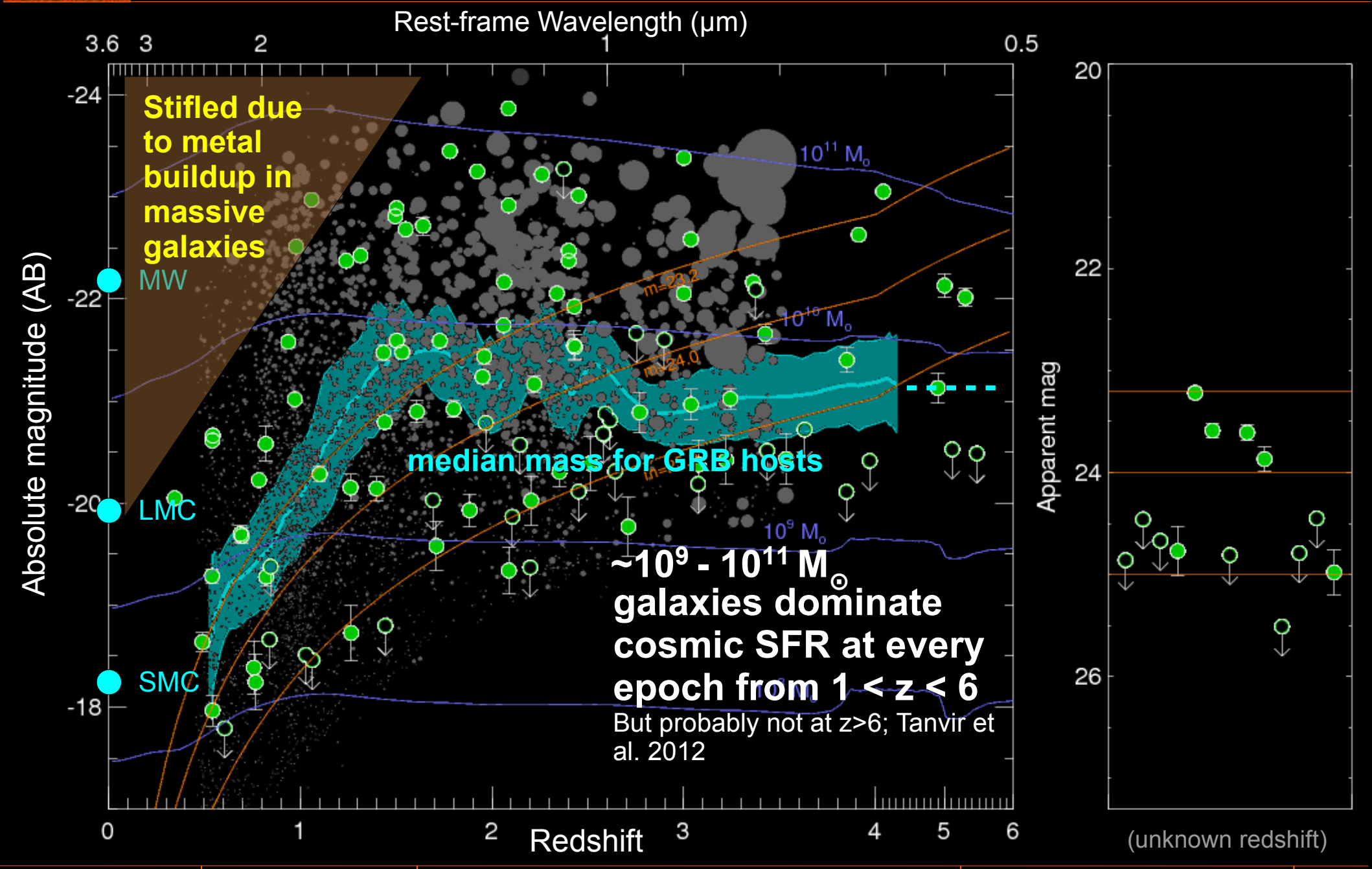
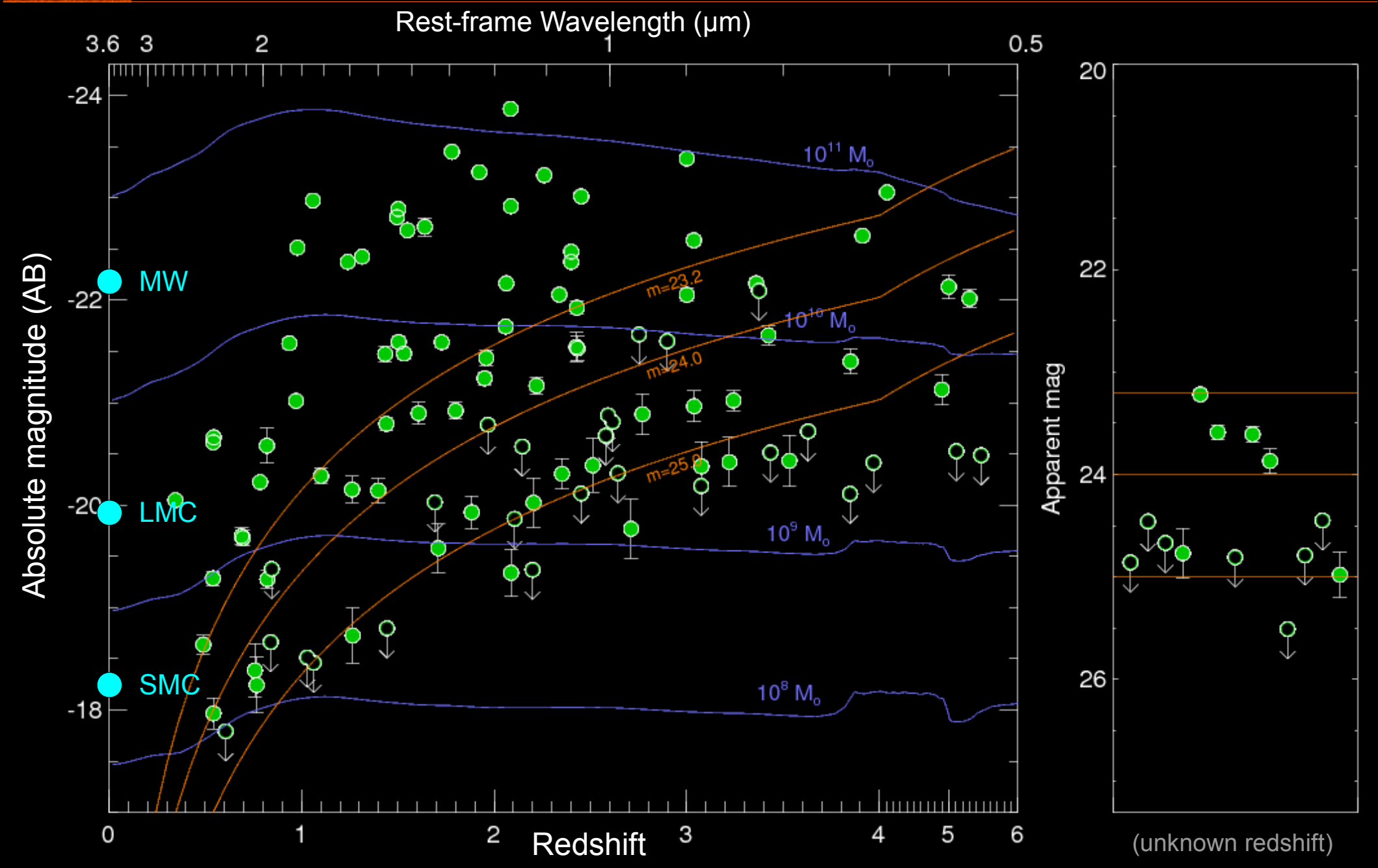


Stellar mass and dust obscuration



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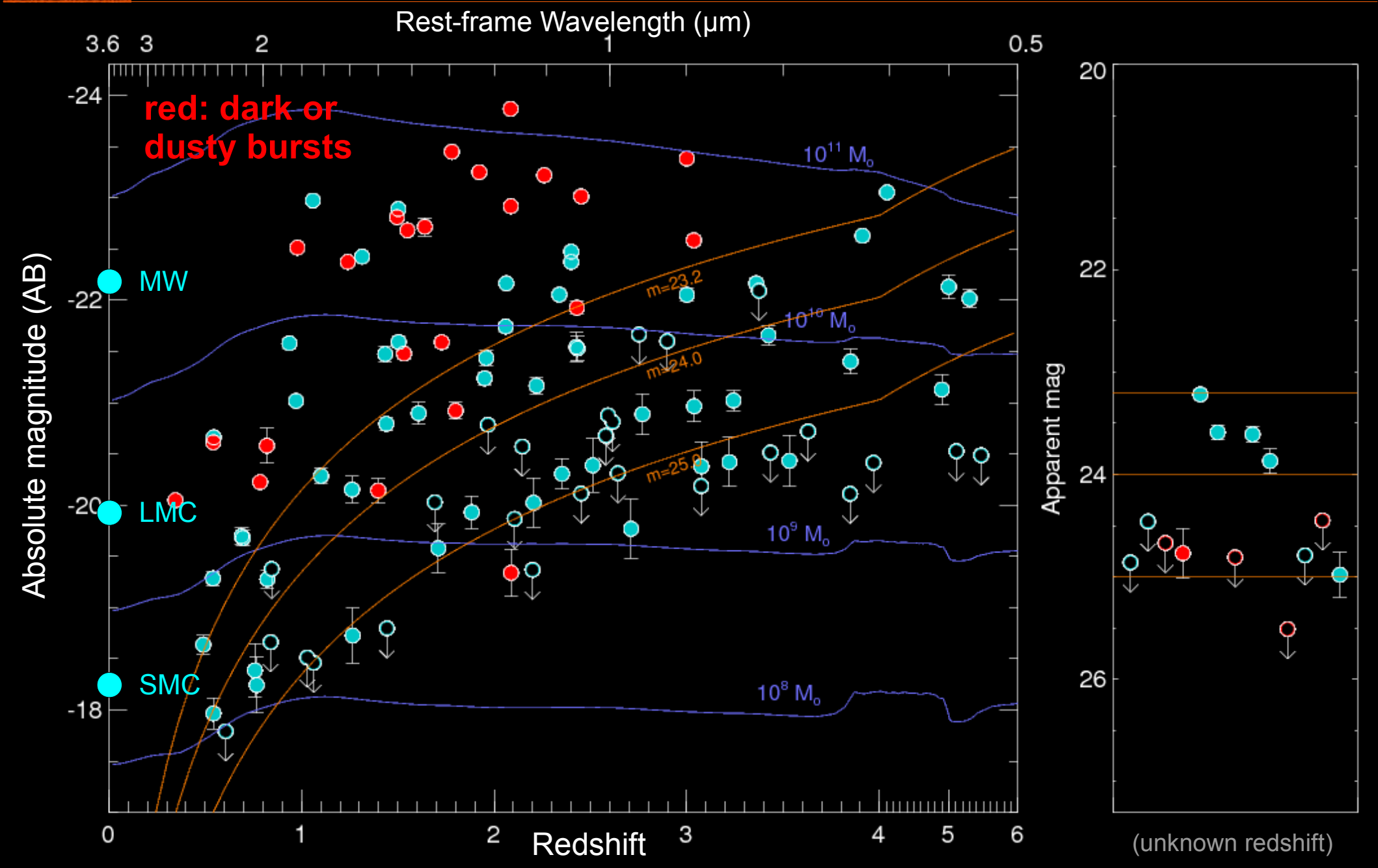

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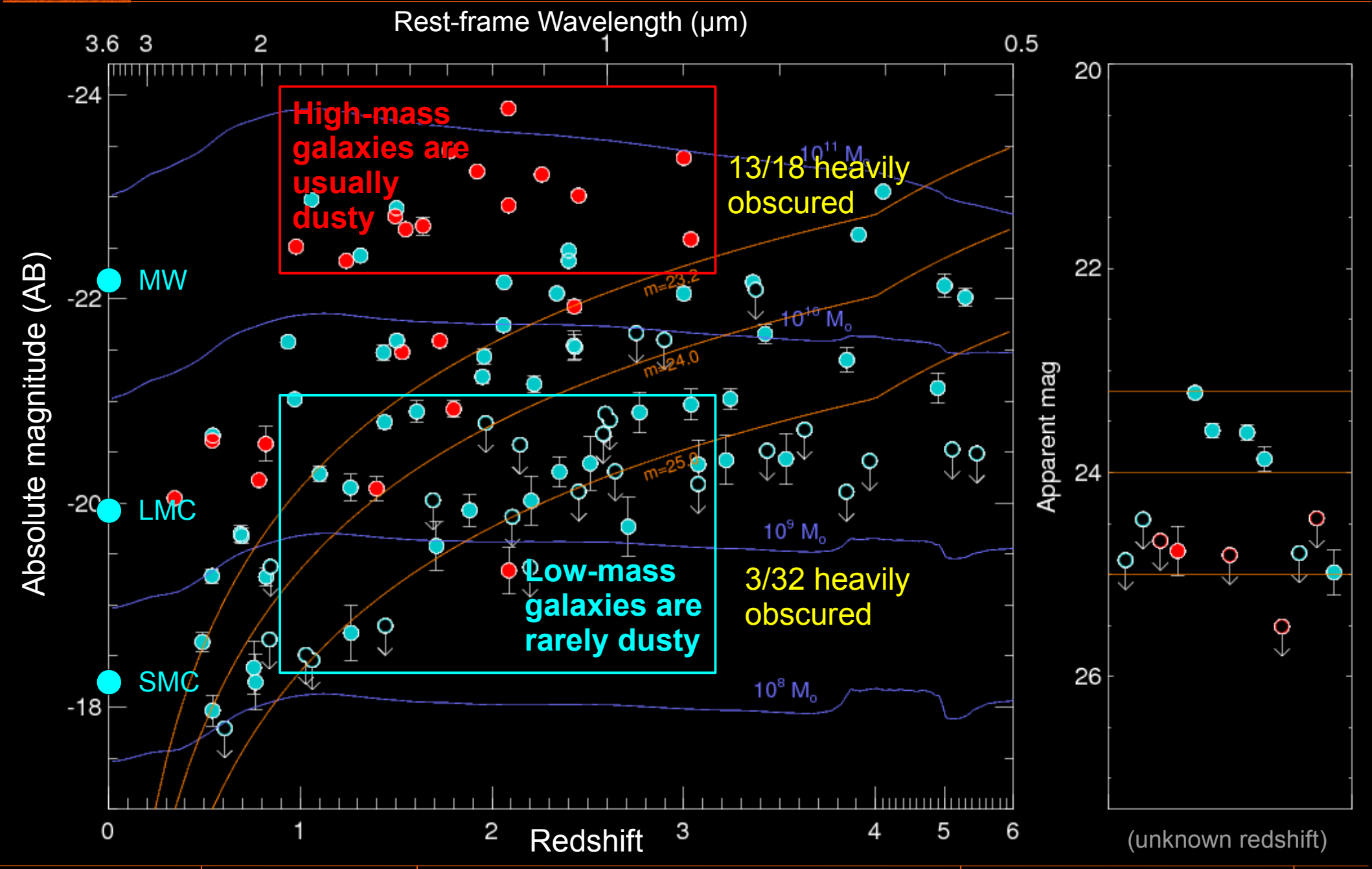


Conclusions

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.

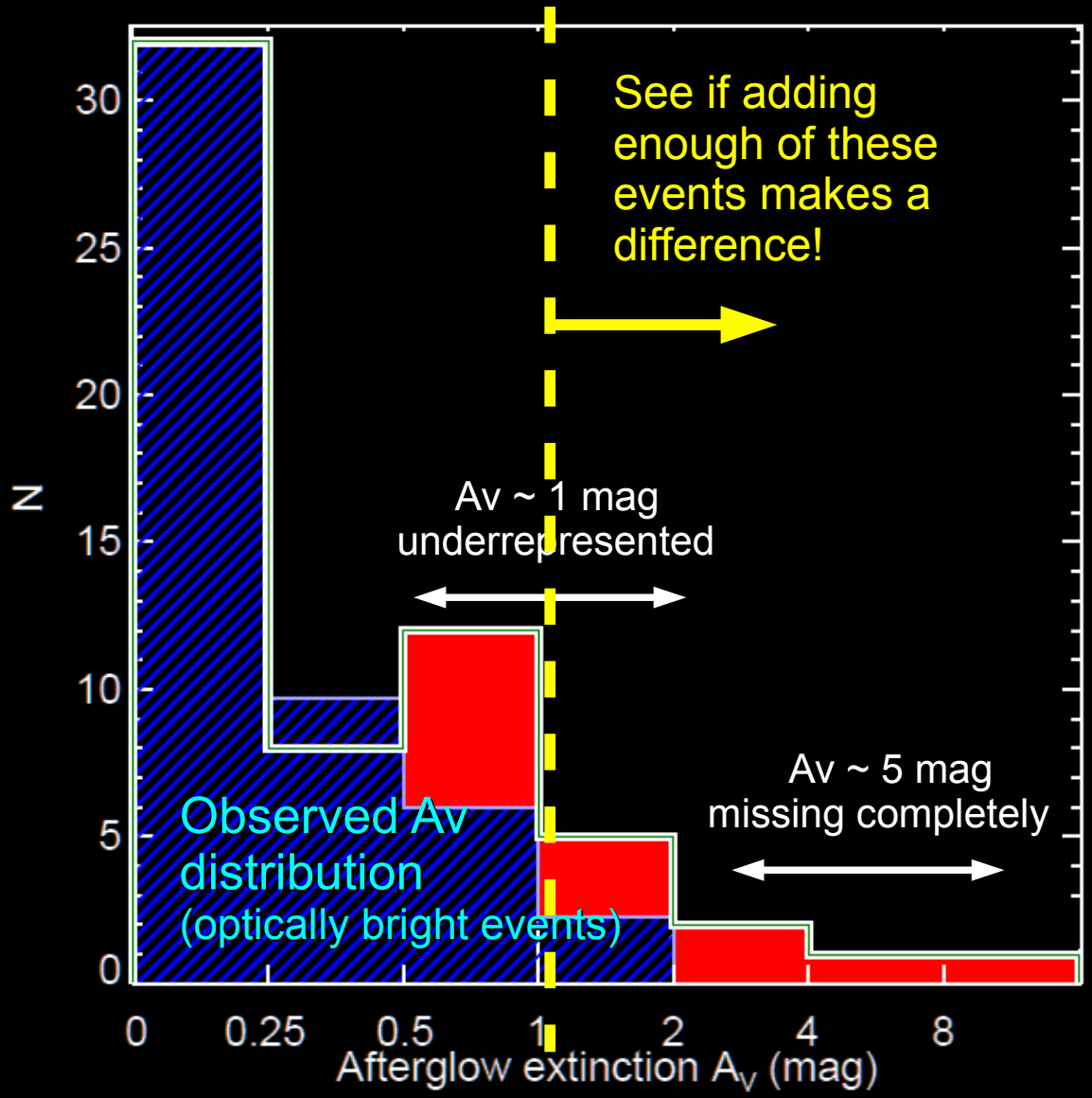
GRB host properties significantly diverge from cosmic SFR at z<1

- They strongly avoid high-mass galaxies ("cosmic downsizing on steroids")
- Suggests strong suppression above ~0.5-1.0 $Z_\odot$.
- Possible additional dependencies (sSFR?)

GRBs provide novel constraints on high-z dust.

- Low-mass galaxies contain very little dust and are optically thin;
  - high-mass galaxies have lots of dust with high covering fraction.
- No strong connection between dust and galaxy properties
  - outside Local Group.
- GRBs support a significant (but non-dominant) contribution to
  - cosmic SFR from ULIRGs at z>1.

Dust and Selection Bias

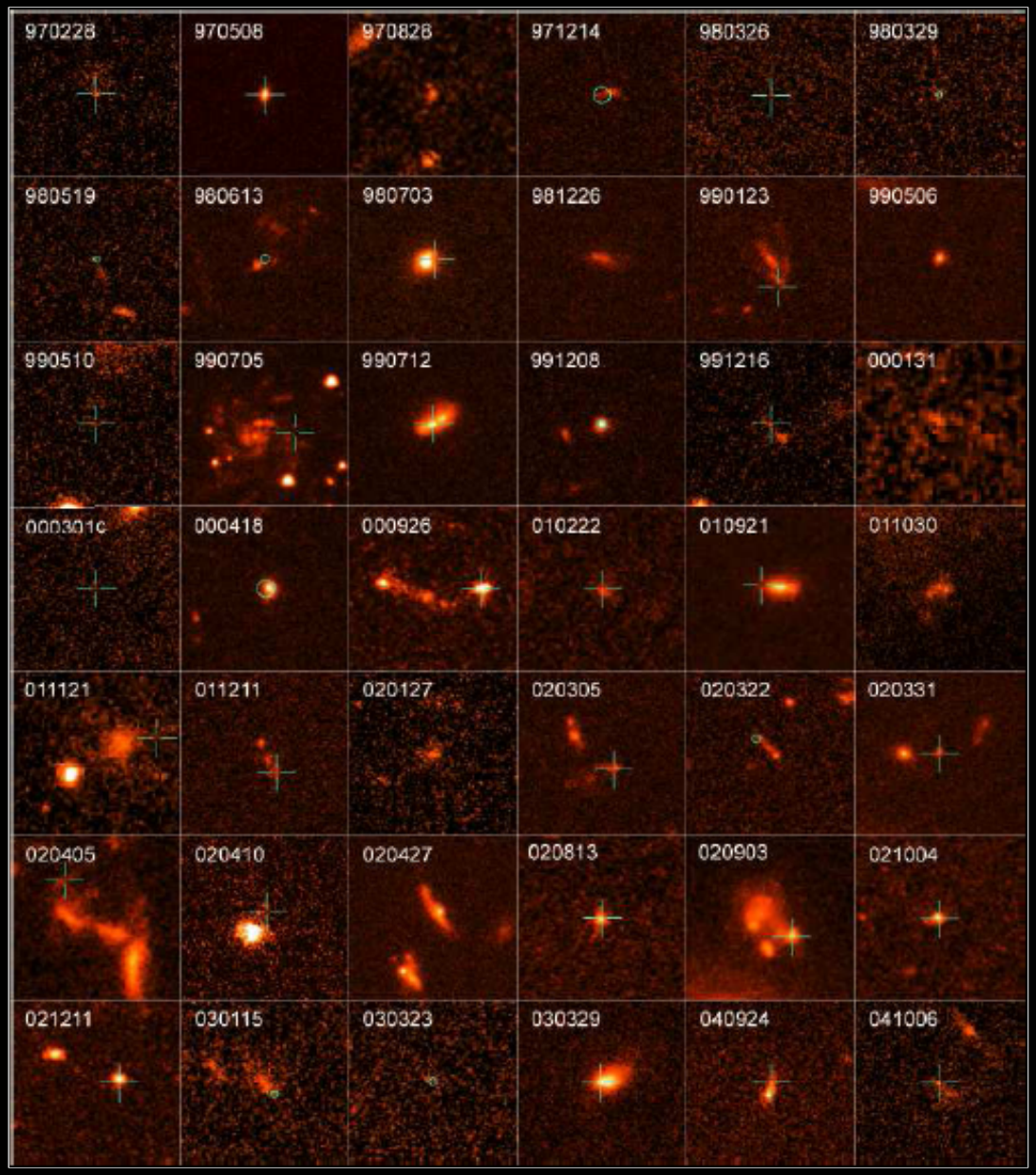


~20% of GRBs are systematically missing from optical afterglow searches as a result of dust.

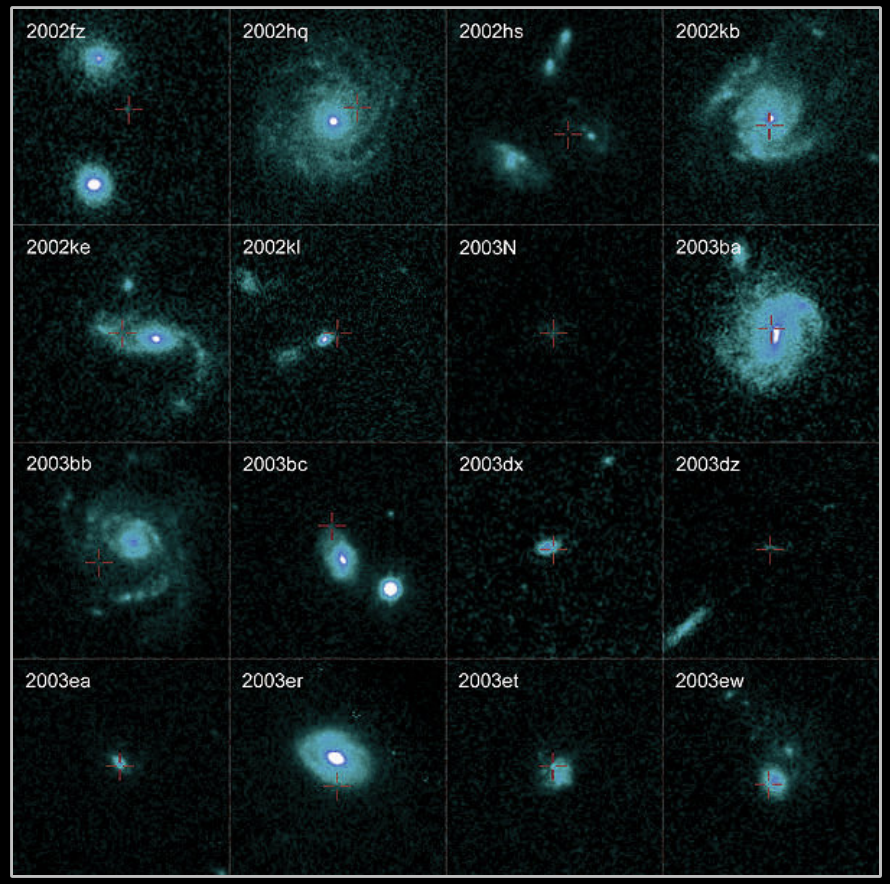
(Compiled from data in Kann et al. 2003 & 2010, Cenko et al. 2009, Perley et al. 2009, Greiner et al. 2011)

Different Host Morphologies

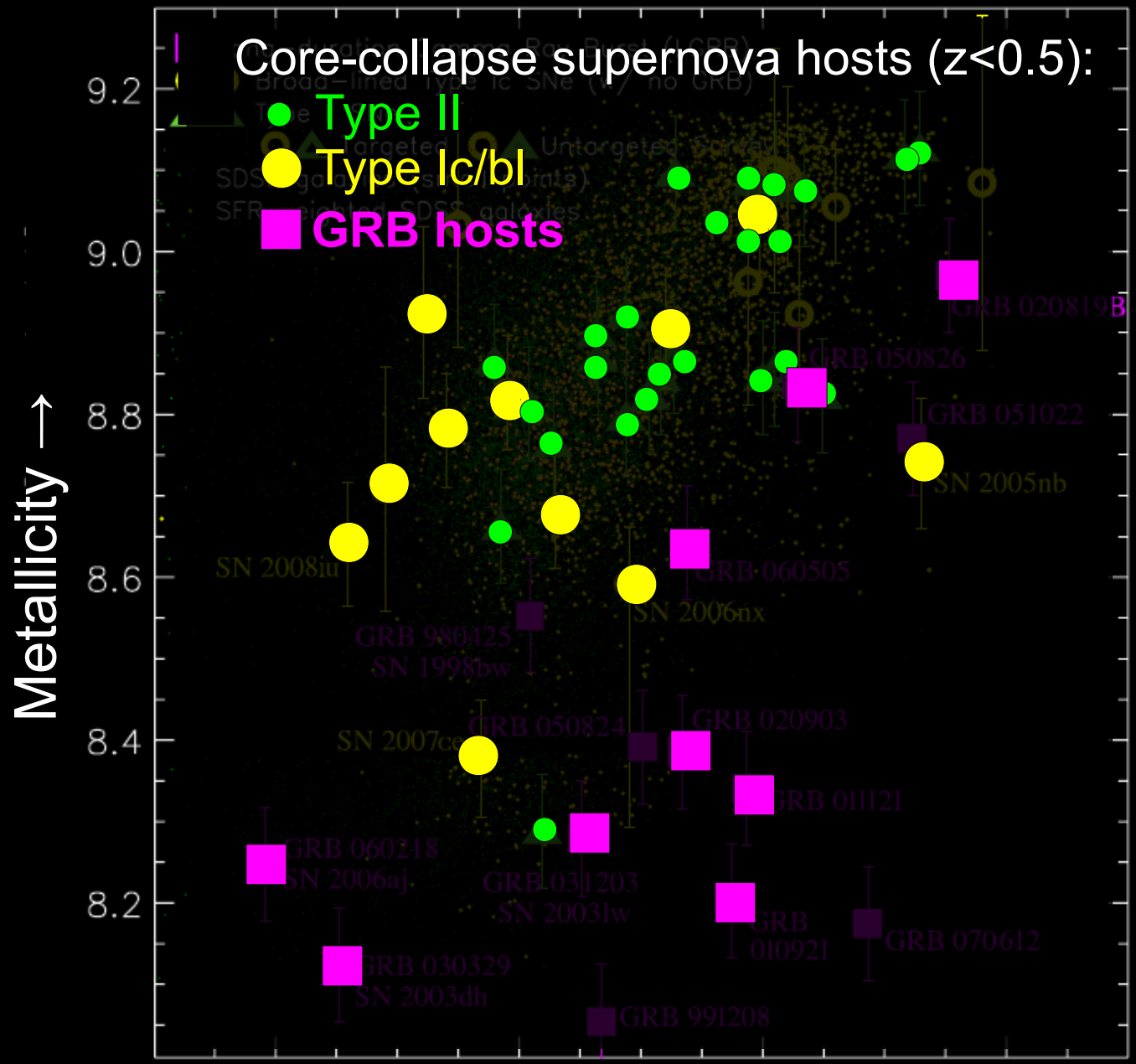
GRBs



SNe



Lower Host Metallicities



Graham & Fruchter 2013
(Levesque+2010, Modjaz+2008)

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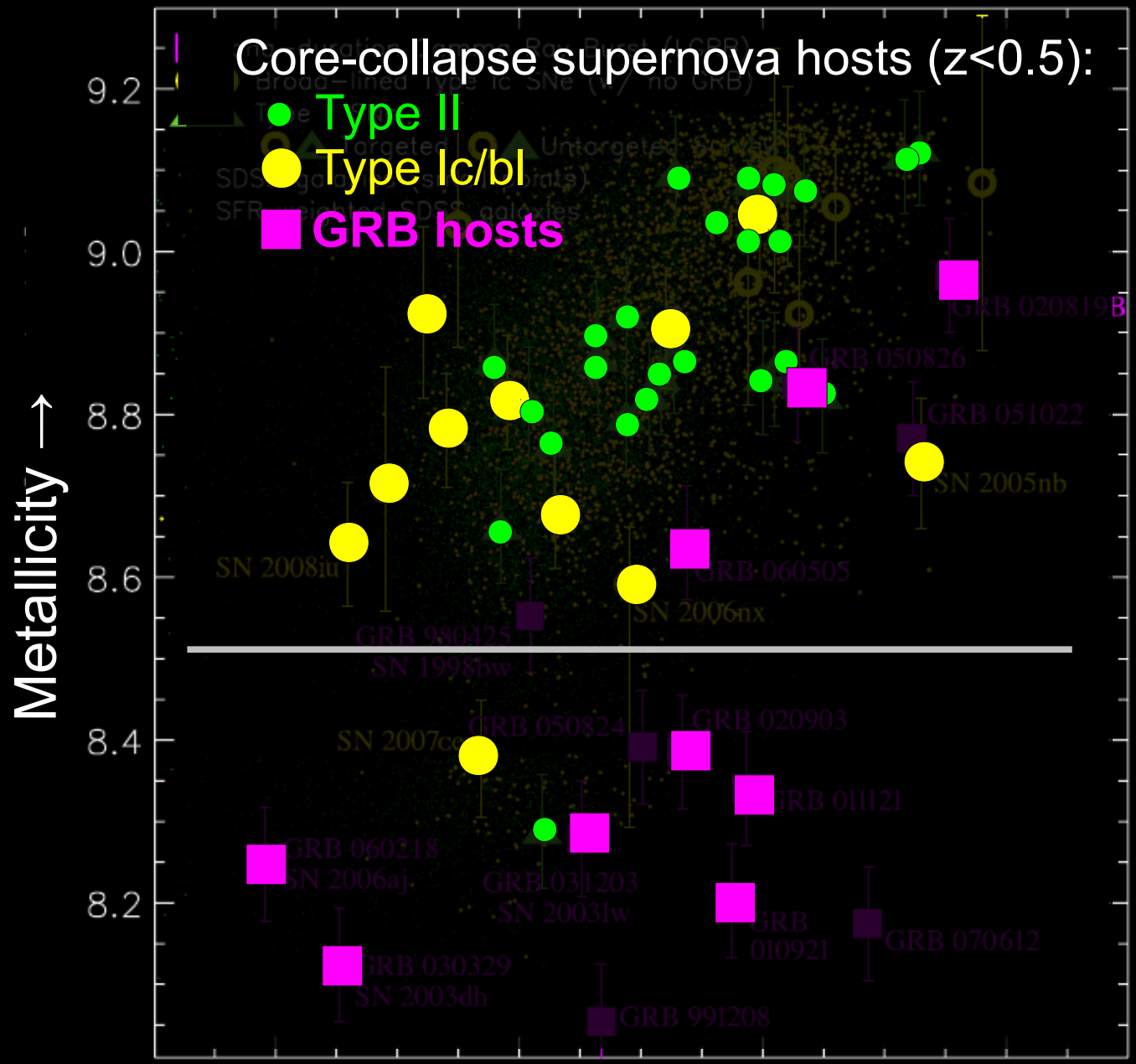

GRBs rare (~1 per 10^6 SN)

~0.7 $Z_\odot$

GRBs "common" (~1 per 10^5 SN)

Graham & Fruchter 2013
(Levesque+2010, Modjaz+2008)