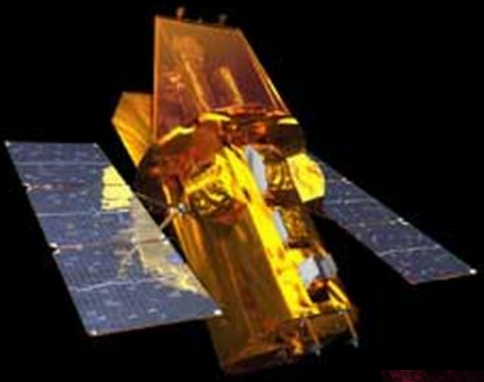
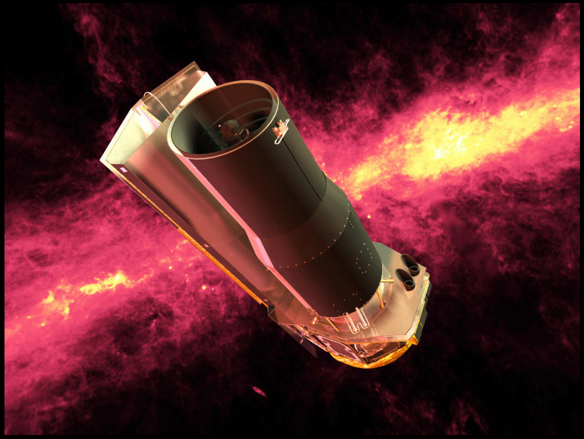
The Swift GRB Host Galaxy Legacy Survey:
New Constraints from Multiwavelength SEDs

Daniel Perley
Liverpool John Moores University

+ the SHOALS collaboration:
Antonio de Ugarte Postigo (IAA)
Steve Schulze (Weizmann)
Franz Bauer (PUC)
Edo Berger (Harvard)
S. Bradley Cenko (GSFC)
Ranga Chary (Caltech)
Antonino Cucchiara (GSFC)
Richard Ellis (ESO/UCL)
W. Fong (Arizona)
Johan Fynbo (DARK)
Javier Gorosabel (IAA)
Jochen Greiner (MPE)
Tetsuya Hashimoto (NAOJ)
Jens Hjorth (DARK)
Pall Jakobsson (Iceland)
Sam Kim (PUC)
Thomas Krühler (MPE)
Tanmoy Laskar (Harvard)
Andrew Levan (Warwick)
Daniele Malesani (DARK)
Michal Michalowski (ROE)
Bo Milvang-Jensen (DARK)
Rick Perley (NRAO)
Ruben Ramirez (PUC)
Patricia Schady (MPE)
Nial Tanvir (Leicester)
Christina Thöne (IAA)
Darach Watson (DARK)
Klaas Wiersama (Leicester)







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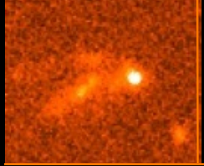
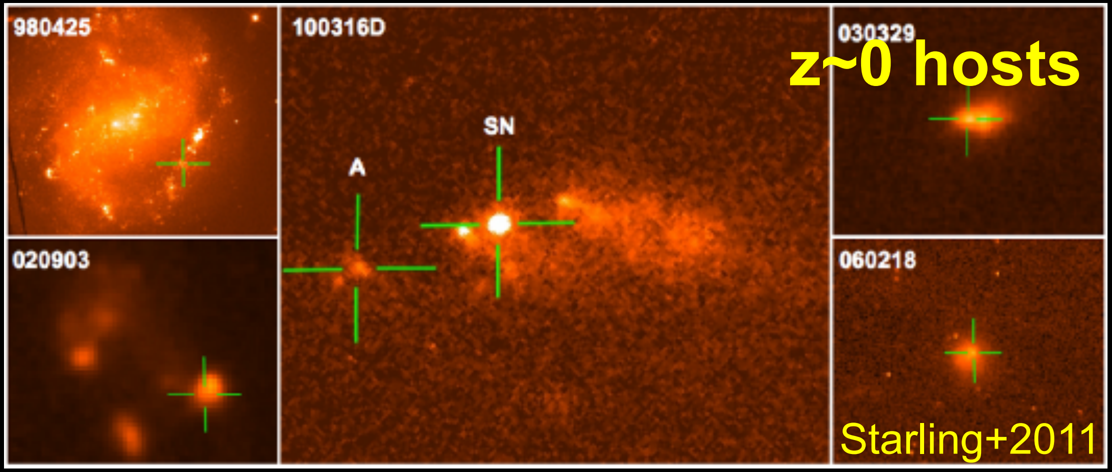


Motivations

Why study GRB host galaxies?

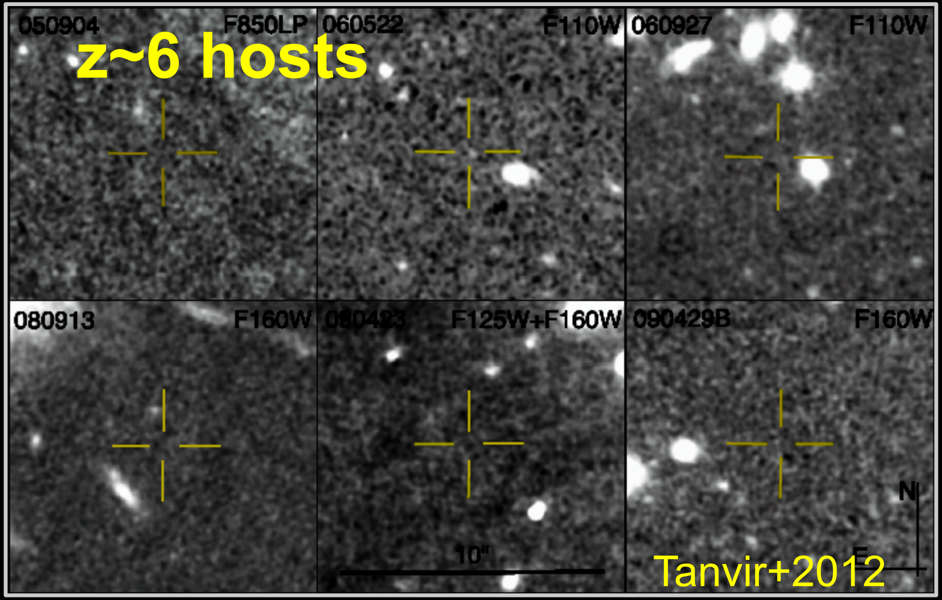
What is the GRB progenitor, and how is it formed?

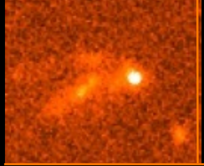
Single-star, binary?
Metallicity dependence?
Other influences?



How reliable are GRBs as cosmological probes?

What types of galaxies do they probe?
Can they trace/characterize high-z SFR? (Corrections?)





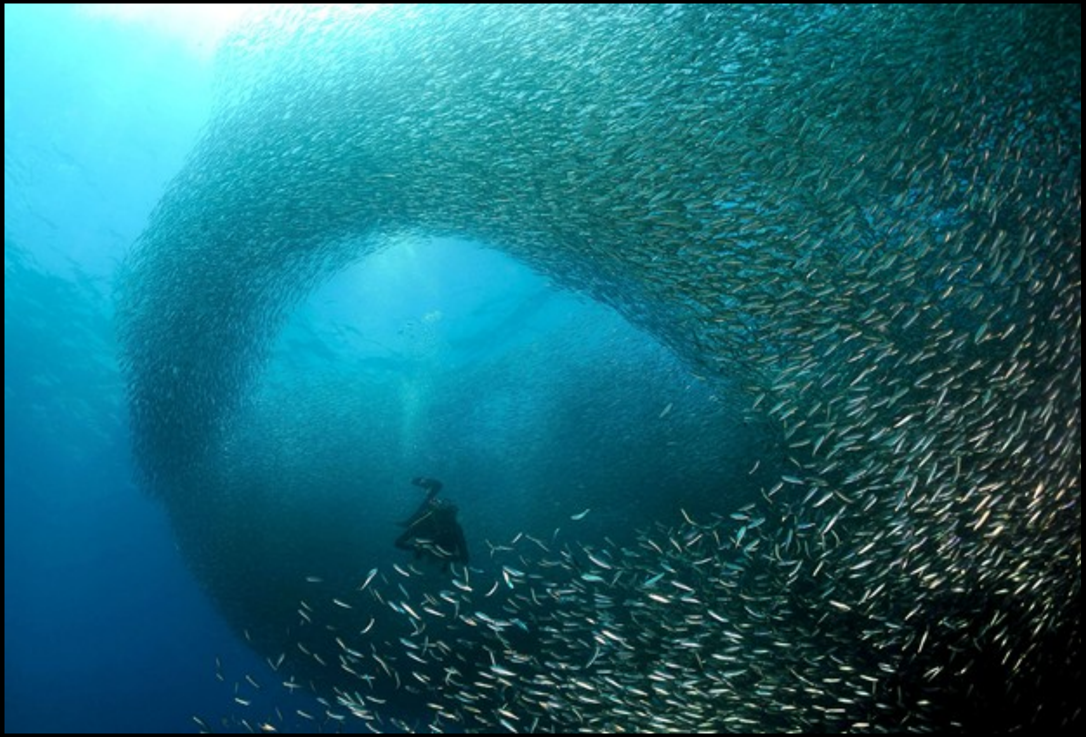
The Swift Host Galaxy Legacy Survey

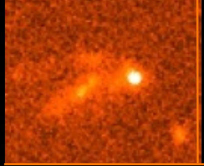
"**SHOALS**": A **large**, **uniform**, **multiwavelength** survey to study the complete demographics of *Swift* GRB hosts, at all redshifts.

large: Enough GRBs to measure redshift evolution.

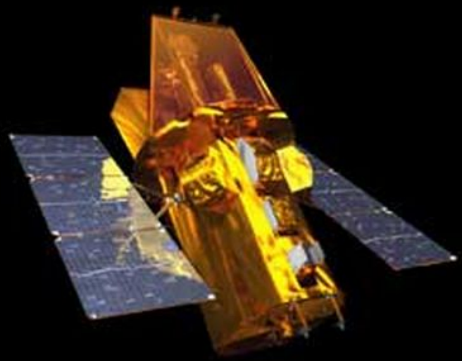
uniform: Not biased against dusty GRBs.

multiwavelength: Constrain all key physical properties (especially mass, SFR, extinction)





SHOALS Sample Selection

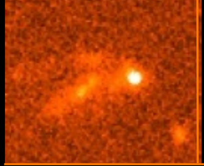


Similar design as TOUGH or BAT6 (but larger): preselect well-located *Swift* GRBs and chase any missing redshifts with deep host spectroscopy.

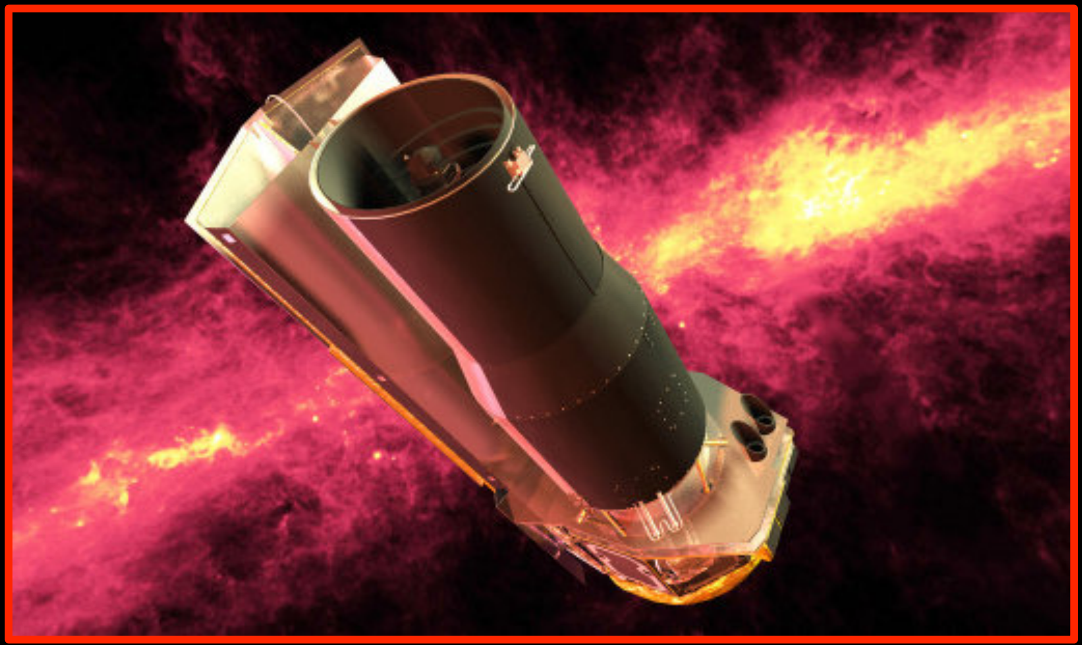
Selection criteria (core sample):
- *Swift* detected; gamma-ray fluence > 10^{-6} erg/cm^2
- *Swift* slewed immediately to the position
- Well-observed or at least well-observable:
  - (a) Autonomously triggered a 2m-class telescope, *or*
  - (b) >5 hours from Sun and between 2005-2009, *or*
  - (c)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

119 GRBs
110 measured redshifts (92%)

Numerous project extensions have secured Spitzer observations of over 400+ hosts!



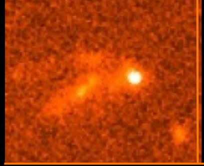
SHOALS Observations



Spitzer (3.6 μm imaging):
- Good **stellar mass** proxy
- Sensitive even to z>5 galaxies
- 230-hour large program
  - + extensions in cycles 11, 13

Keck, Gemini, VLT, GTC
- Spectroscopy to complete
  - redshift distribution, measure
  - metallicities of some galaxies
- Multicolor optical/NIR imaging
  - for full SED modeling
    - (age, extinction, stellar mass)
- 700 photometric data points

VLA and ALMA
- 3-8 GHz continuum for
  - dust-independent SFRs
- 24 high-mass galaxies (6 w/ALMA)



SHOALS Projects

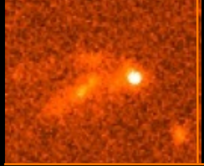
I – Sample selection, methodology and redshift distribution
(Perley+2016a)

II – *Spitzer* observations and stellar mass constraints
(Perley+2016b)

III – UV-Optical-NIR spectral energy distributions, luminosity functions, mass/SFR/age

IV – Presence and nature of heavily obscured star-formation

V – Host/afterglow correlations



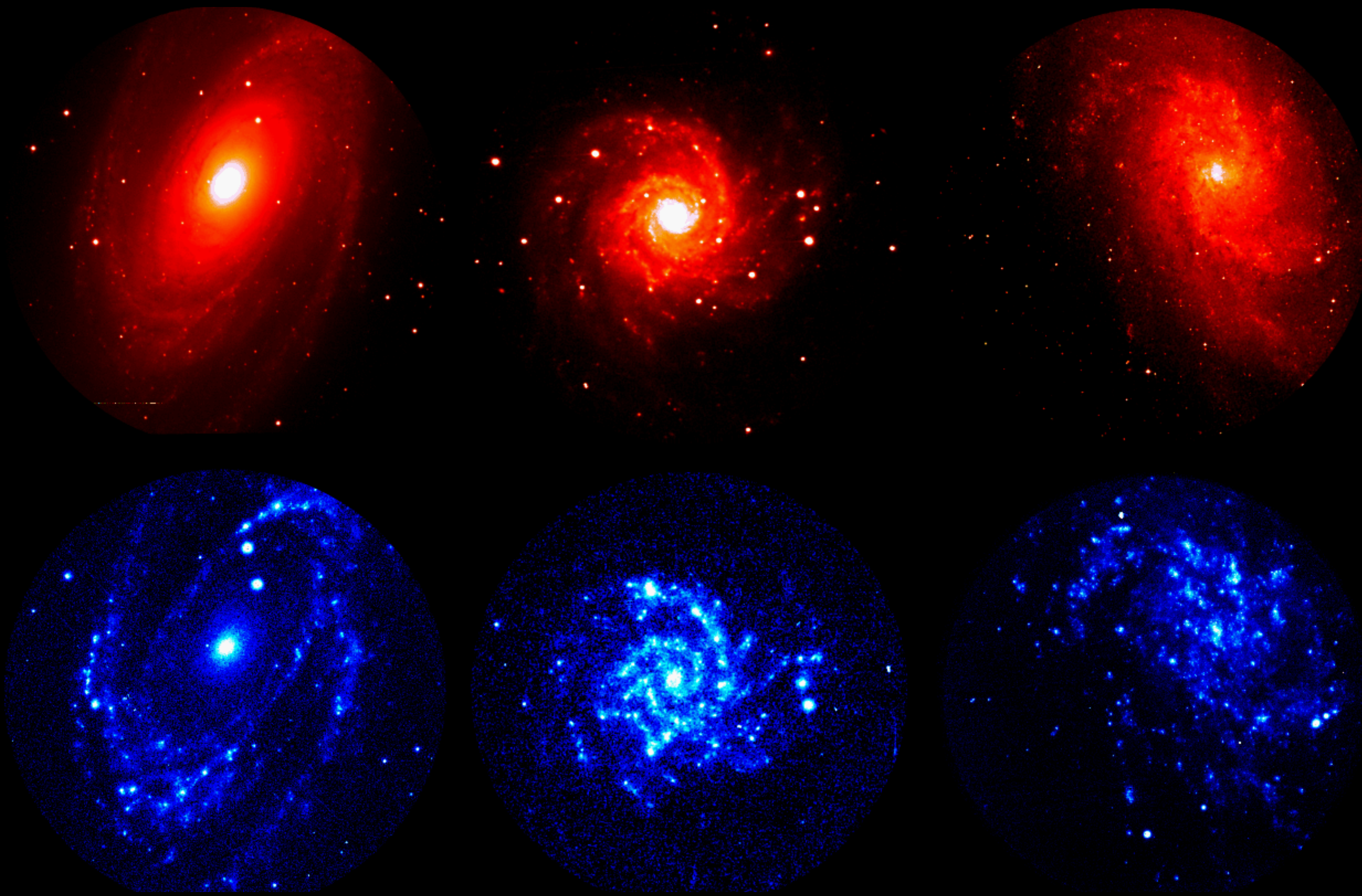
Sample SED at UV and NIR wavelengths

optical/NIR:
all stars

$L_{NIR} \propto M_*$

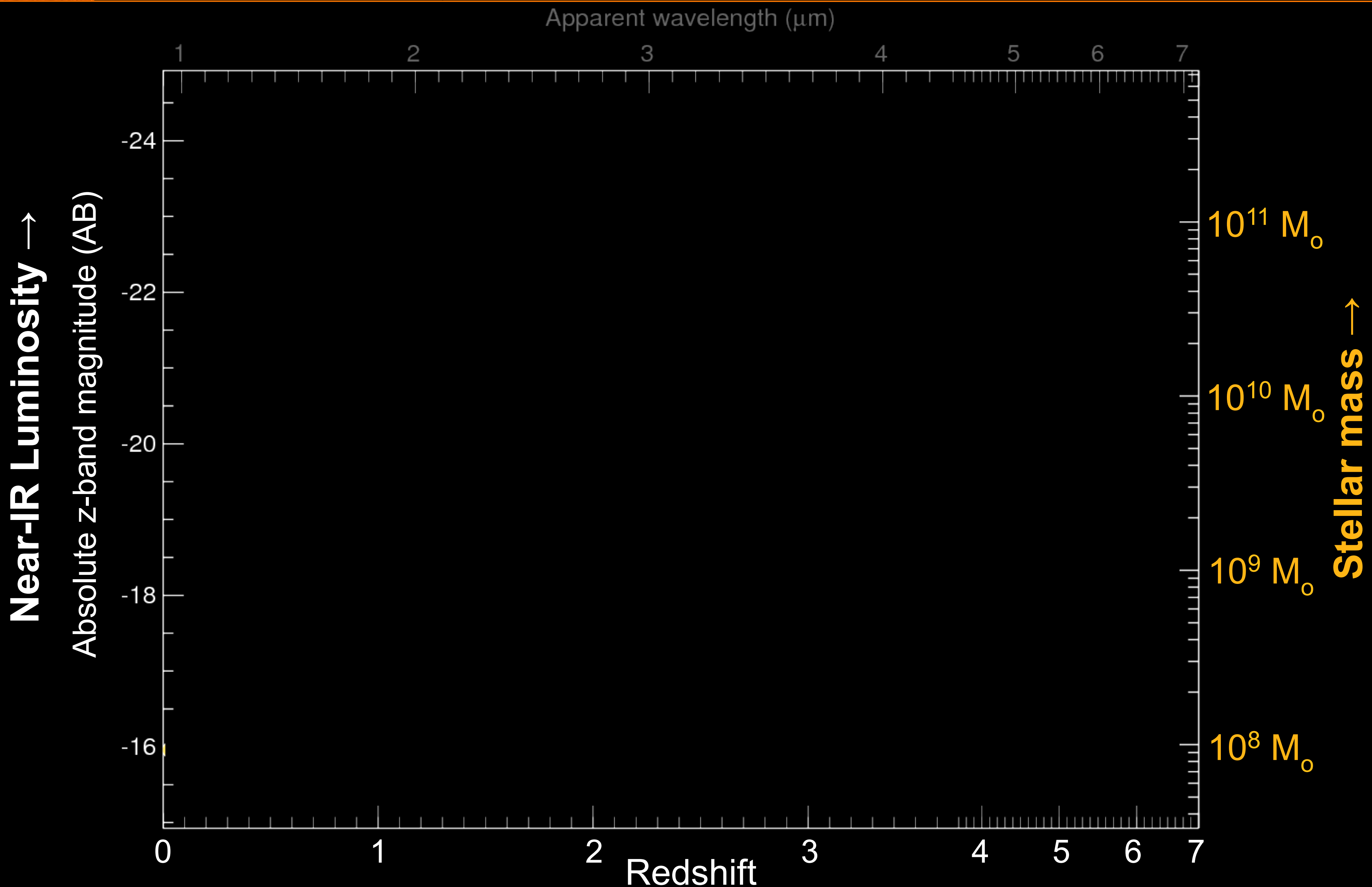
ultraviolet:
young stars

$L_{UV} \propto SFR$

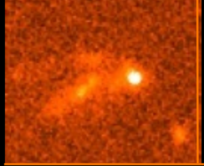


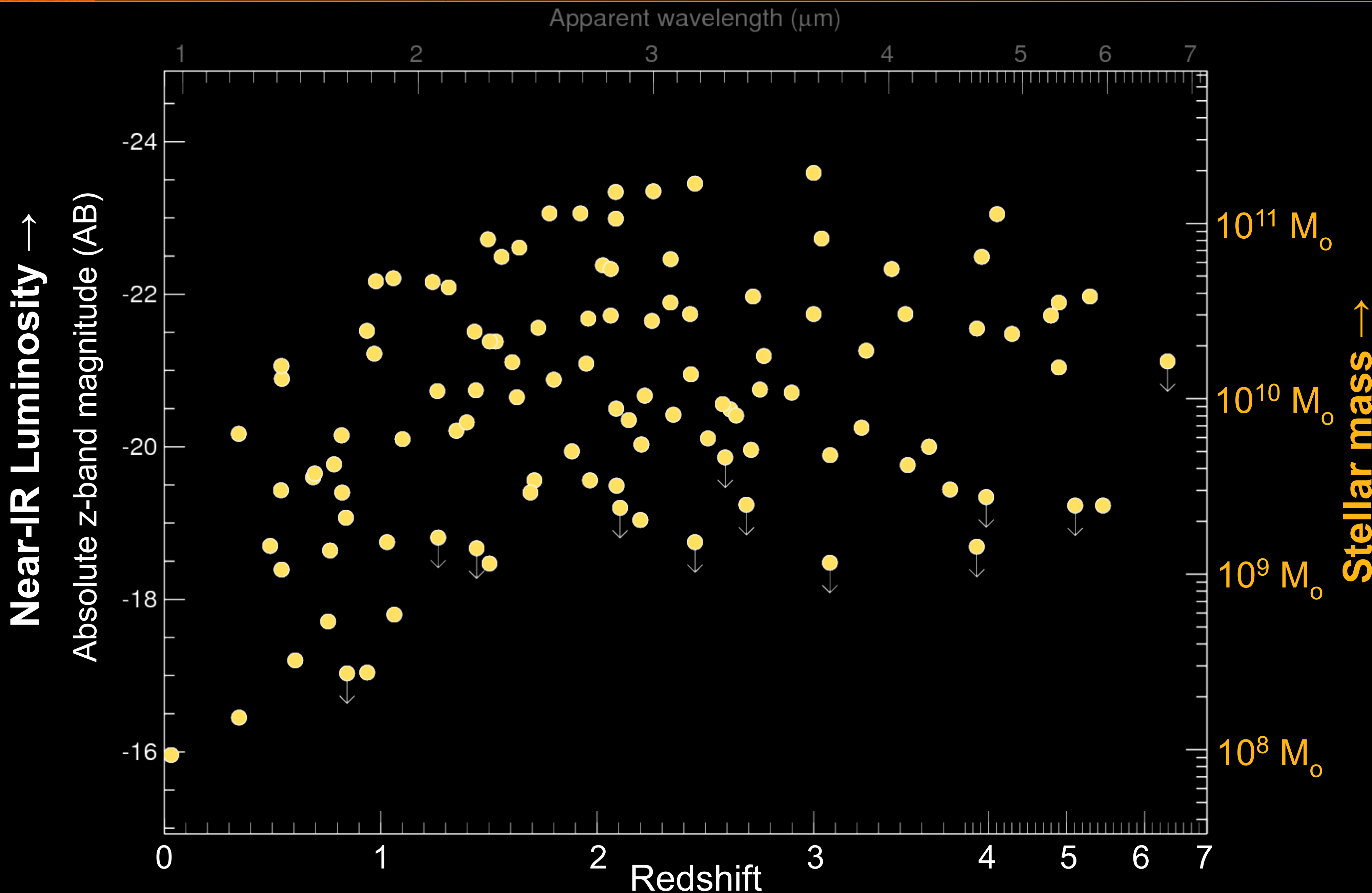
Some nearby galaxies as examples – not GRB hosts!

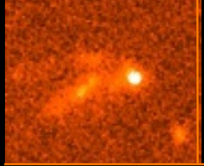
NIR luminosities / stellar masses



NIR luminosities / stellar masses







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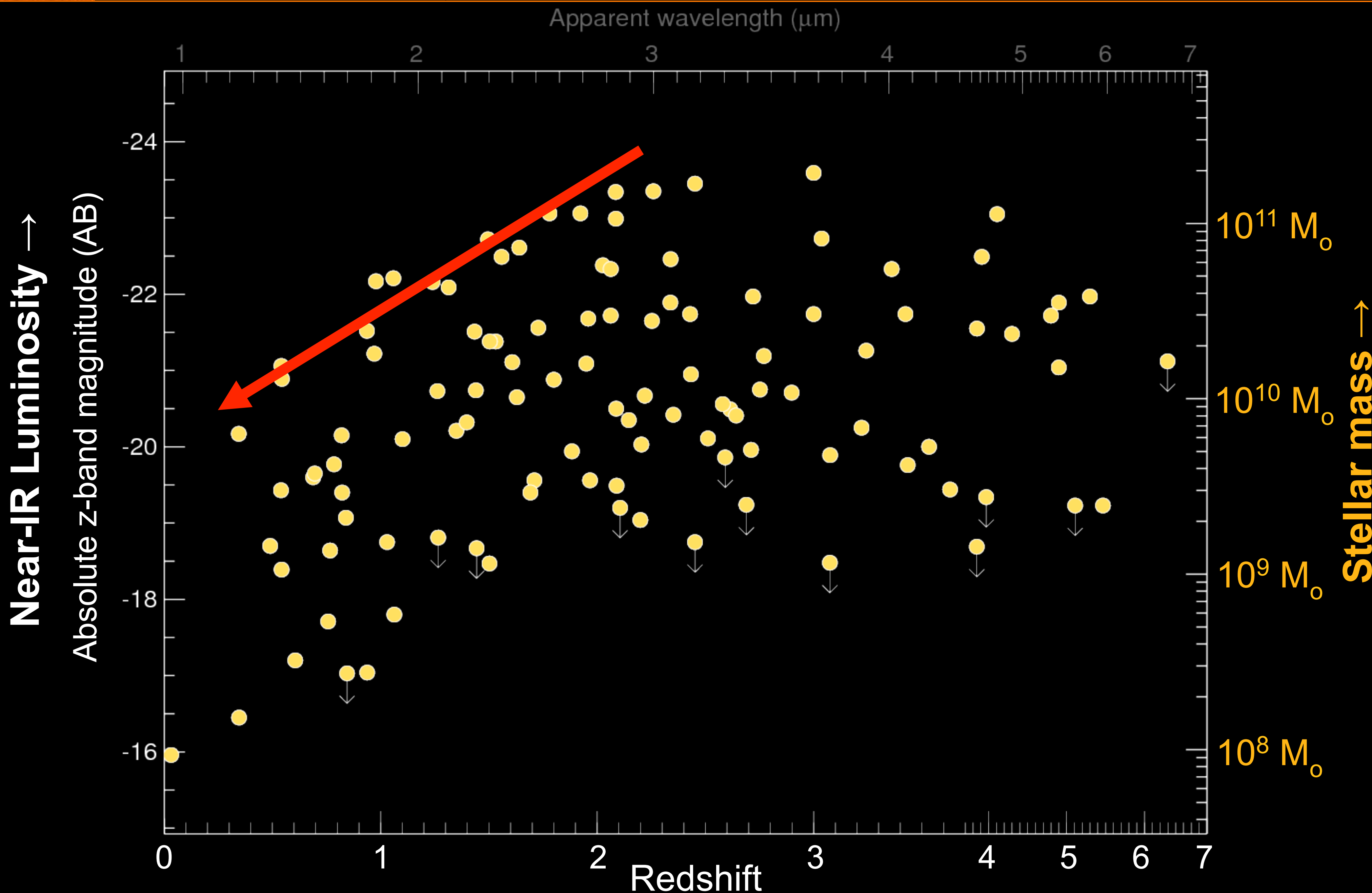
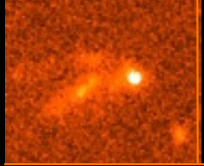
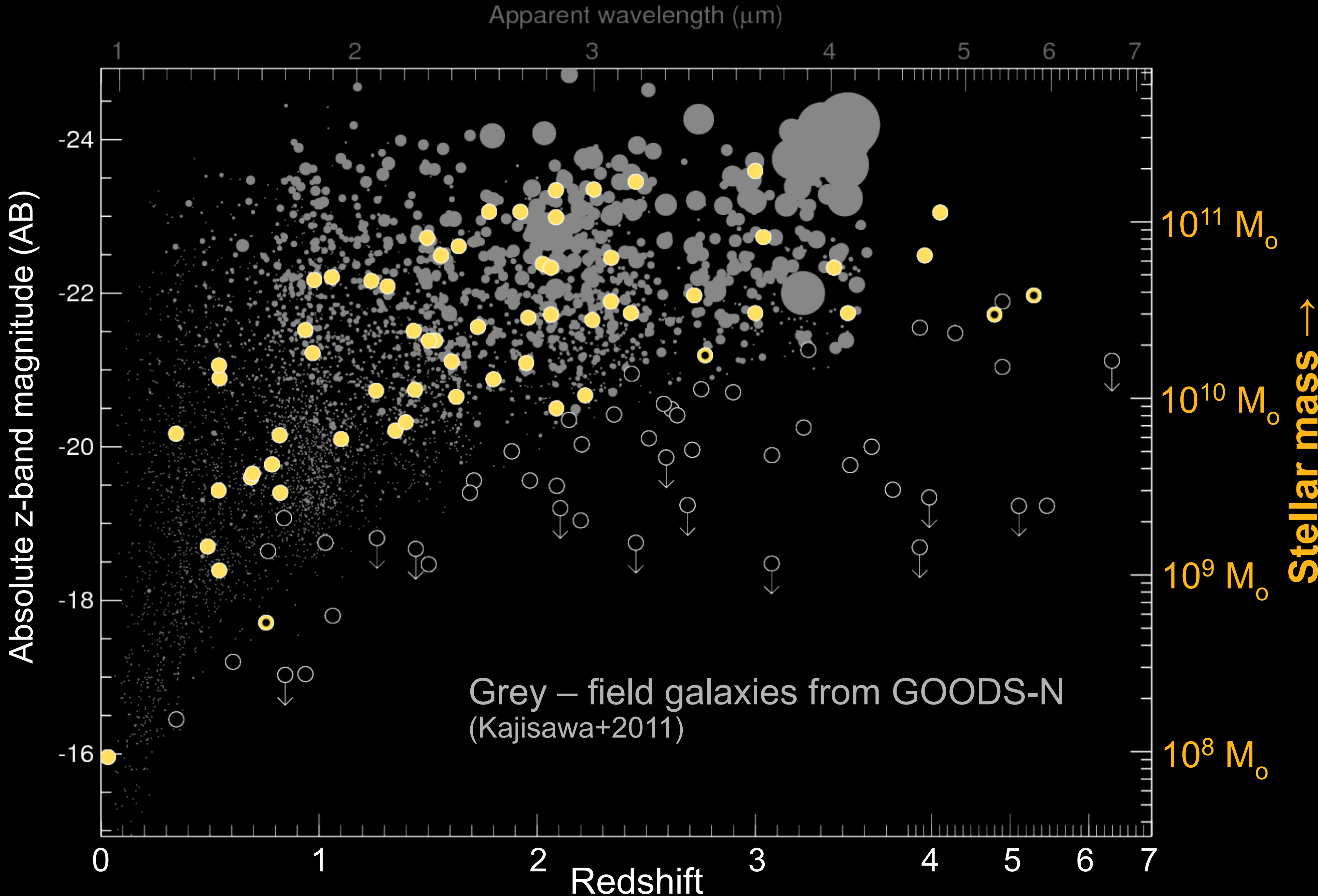
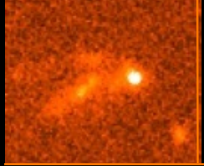


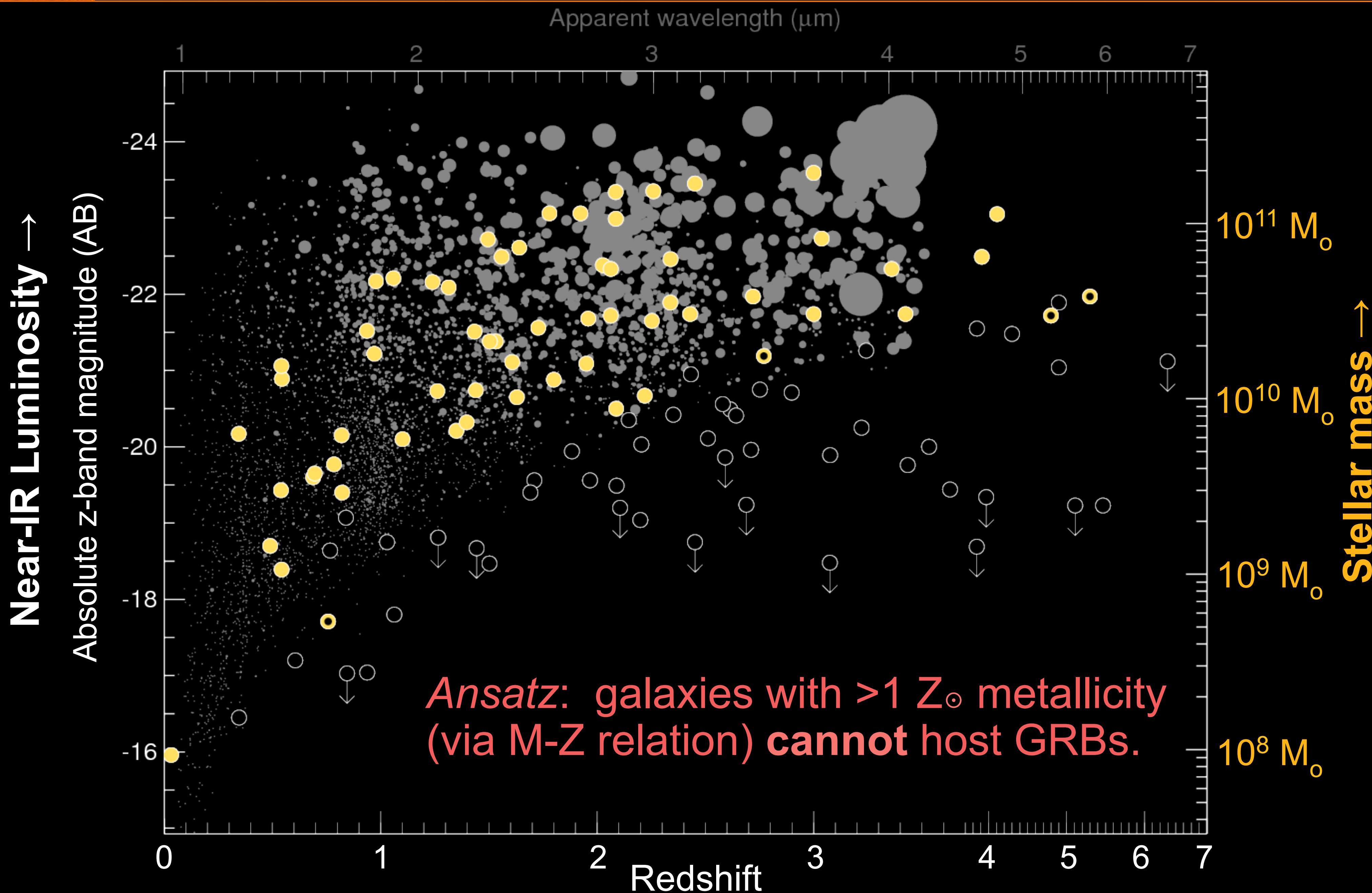


NIR luminosities / stellar masses

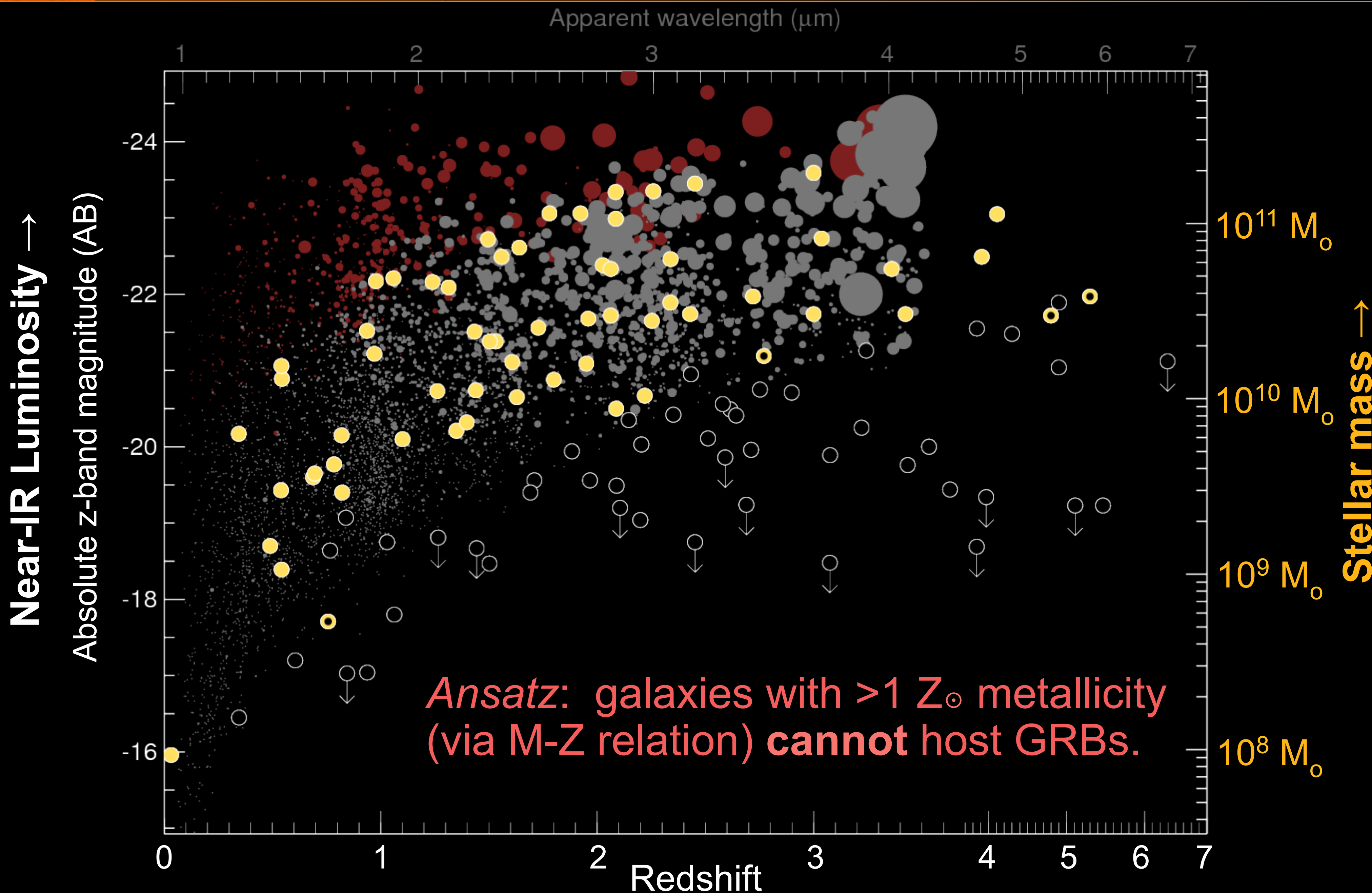




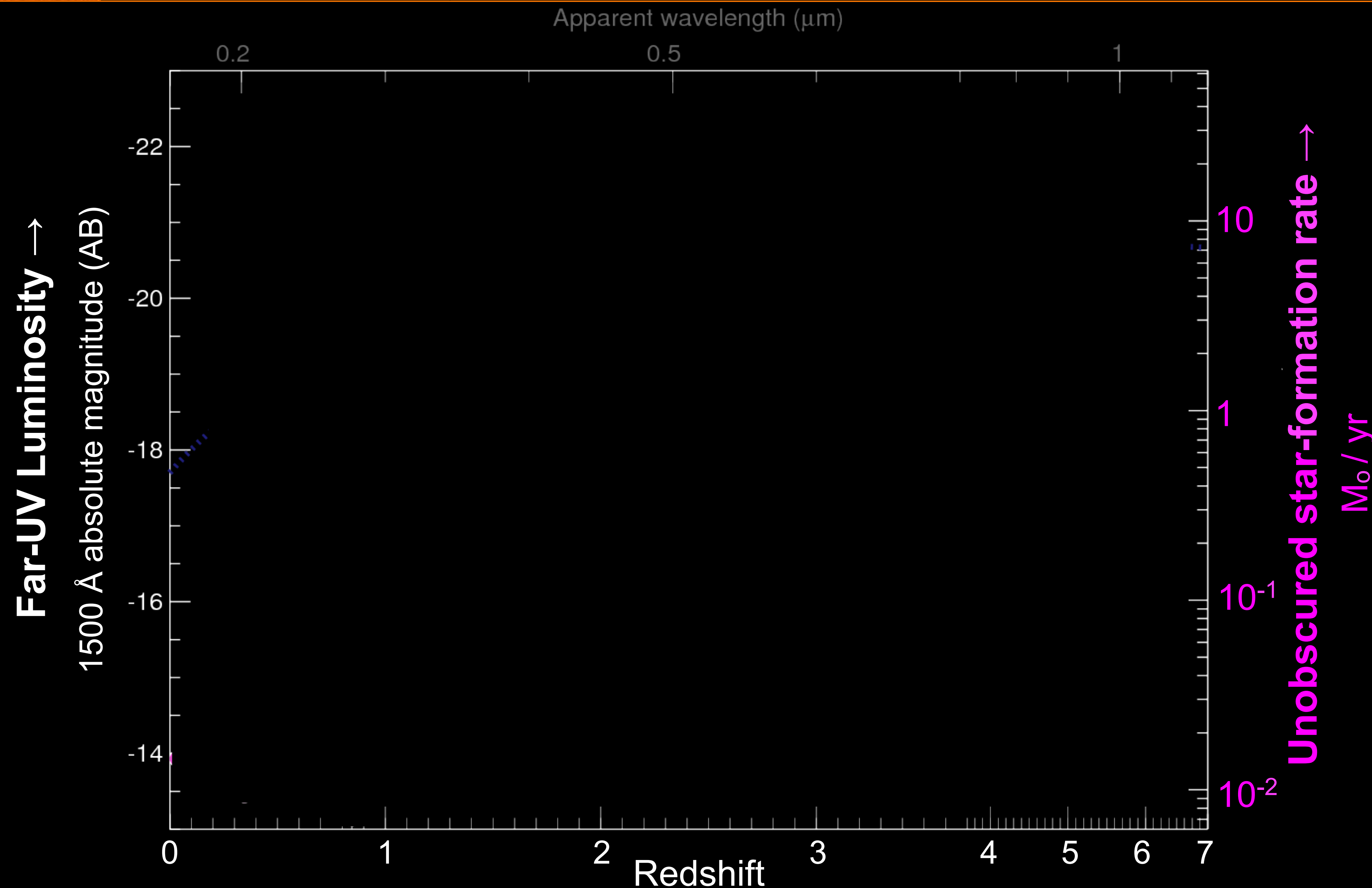
NIR luminosities / stellar masses



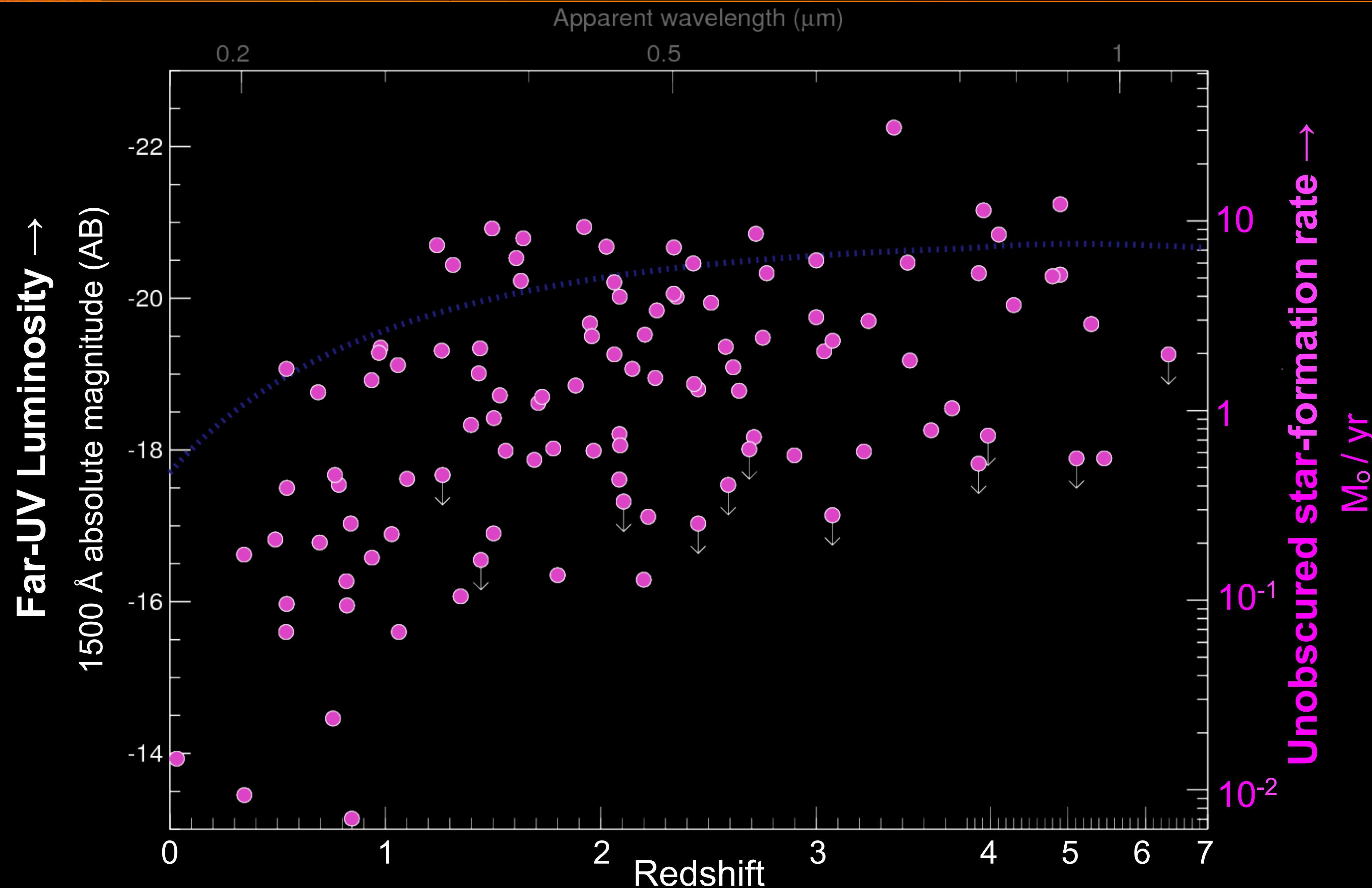
NIR luminosities / stellar masses



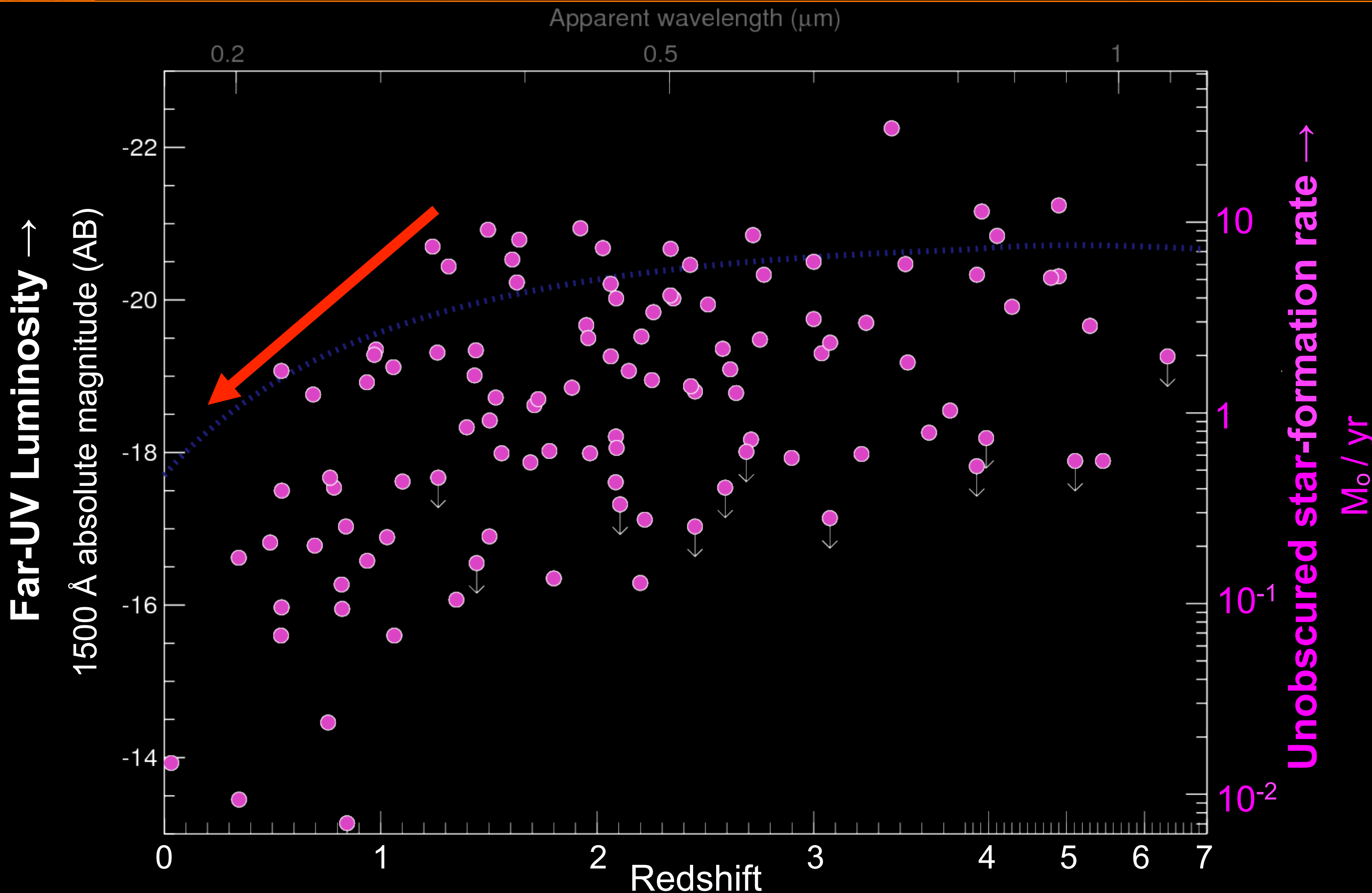
UV luminosities / star-formation rates



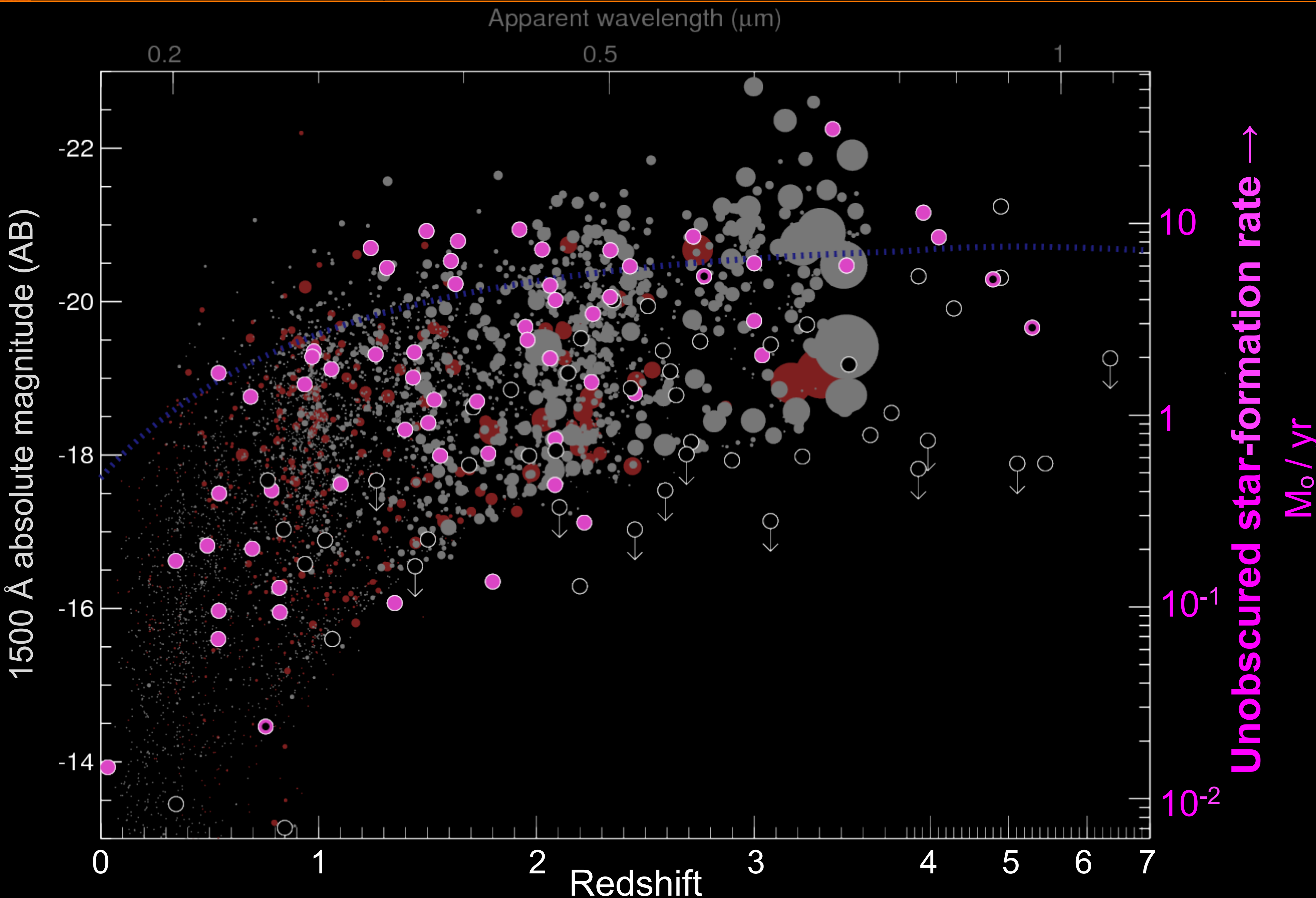
UV luminosities / star-formation rates

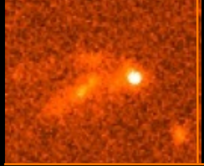


UV luminosities / star-formation rates

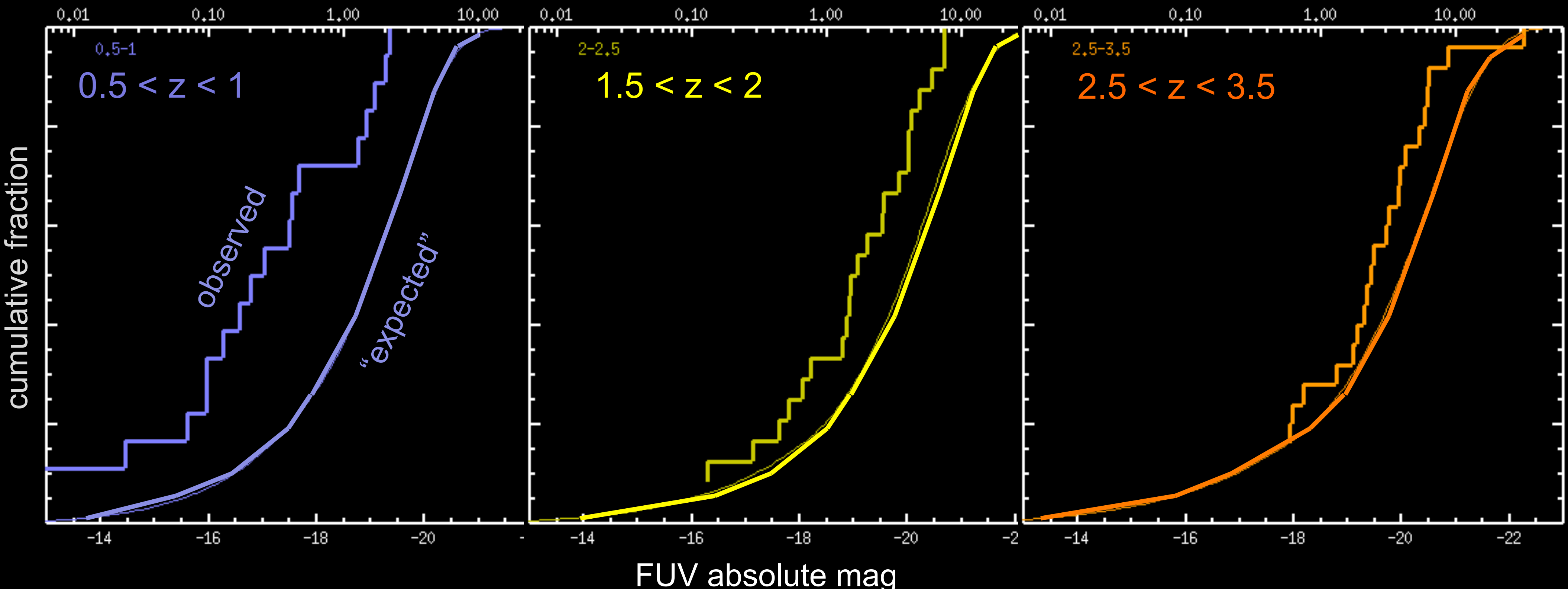


UV luminosities / star-formation rates





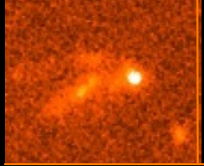
UV Luminosity Distribution



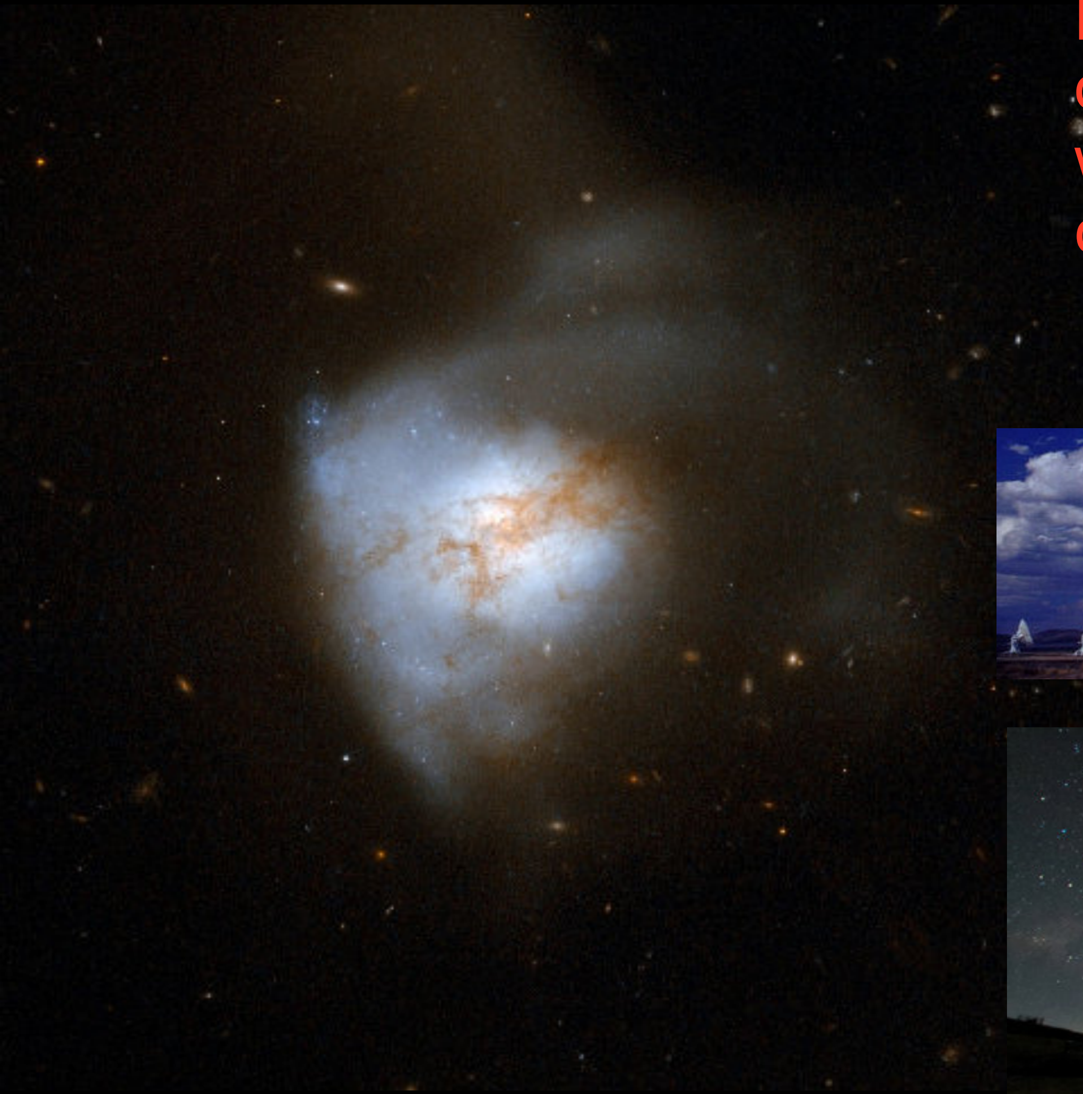
As with NIR luminosity distribution,

UV luminosity distribution converges to expectation at z>3

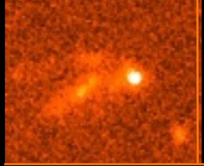
(see also Greiner+2016, no drop observed at higher-z as in Schulze+2015)



Long-wavelength observations

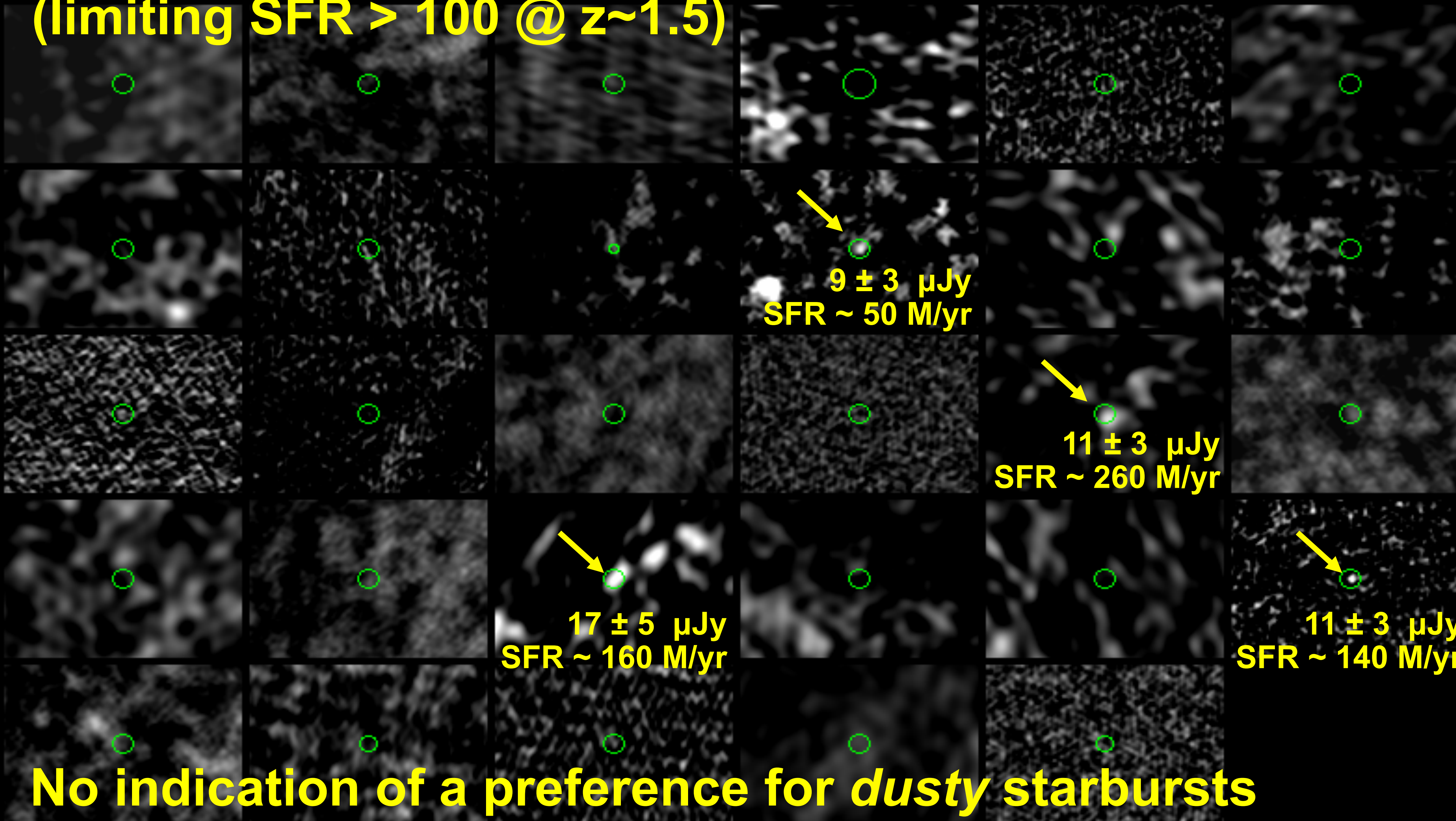


Dust-obscured galaxies require observations at dust-piercing wavelengths (radio, mm) to constrain the SFR!



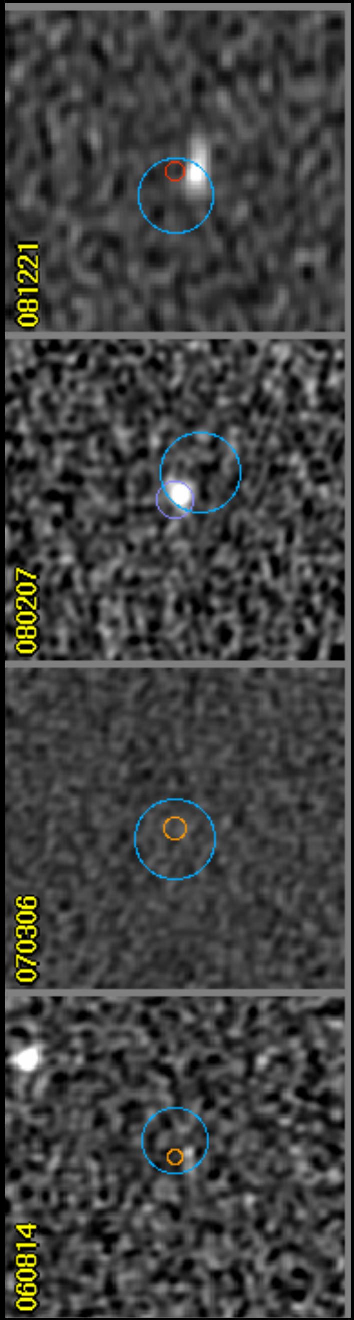
GRBs in ULIRGs: Rare

~10% detection rate in deep VLA observations (limiting SFR > 100 @ z~1.5)



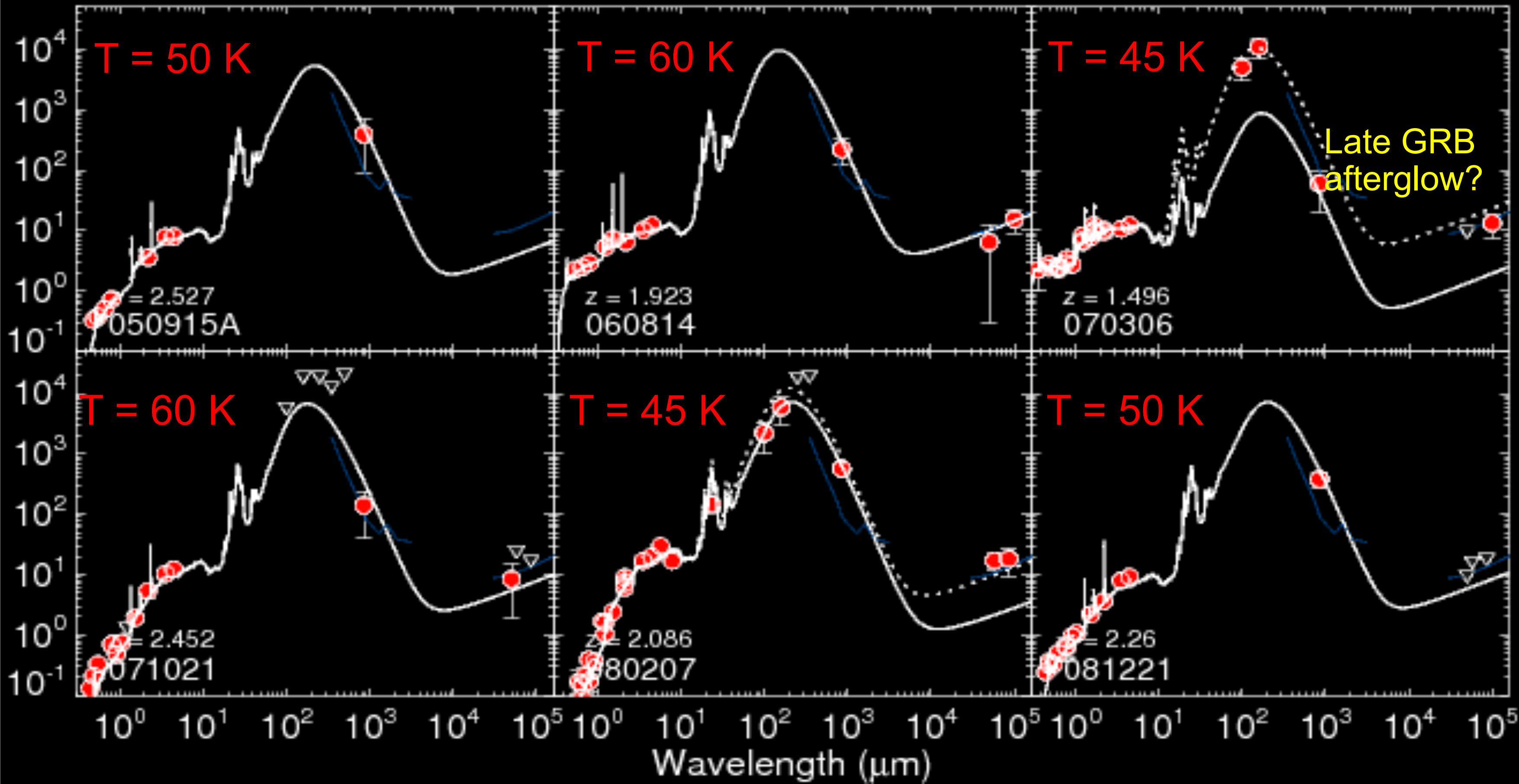
No indication of a preference for *dusty* starbursts

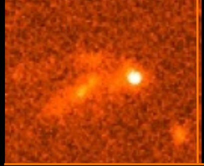
ALMA observations



Even the “best” ALMA candidates (very high optical and/or radio SFR) are suprisingly mm-faint:

hot dust and minimal highly-obscured star formation.





Conclusions

GRBs avoid massive galaxies at low-z but not high z.

Stellar mass typically 10^9 at z~0.5, but >10^{10} at z~2.5.

GRBs populate the entire UV luminosity function at all z

Somewhat rarer in UV-faint galaxies due to mass effect at z<2.5.

GRBs occur, rarely (~10%), in ULIRGs

These galaxies have limited “dust-embedded” SFR; very hot dust

Cutoff metallicity of ~ $1Z_{\odot}$ (still!) explains most observations

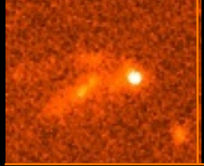
This is surely far too simple (M-Z scatter, chemical heterogeneity)
Consistent with multiple observables!

GRB hosts at high redshift (z>3) trace the SFR density

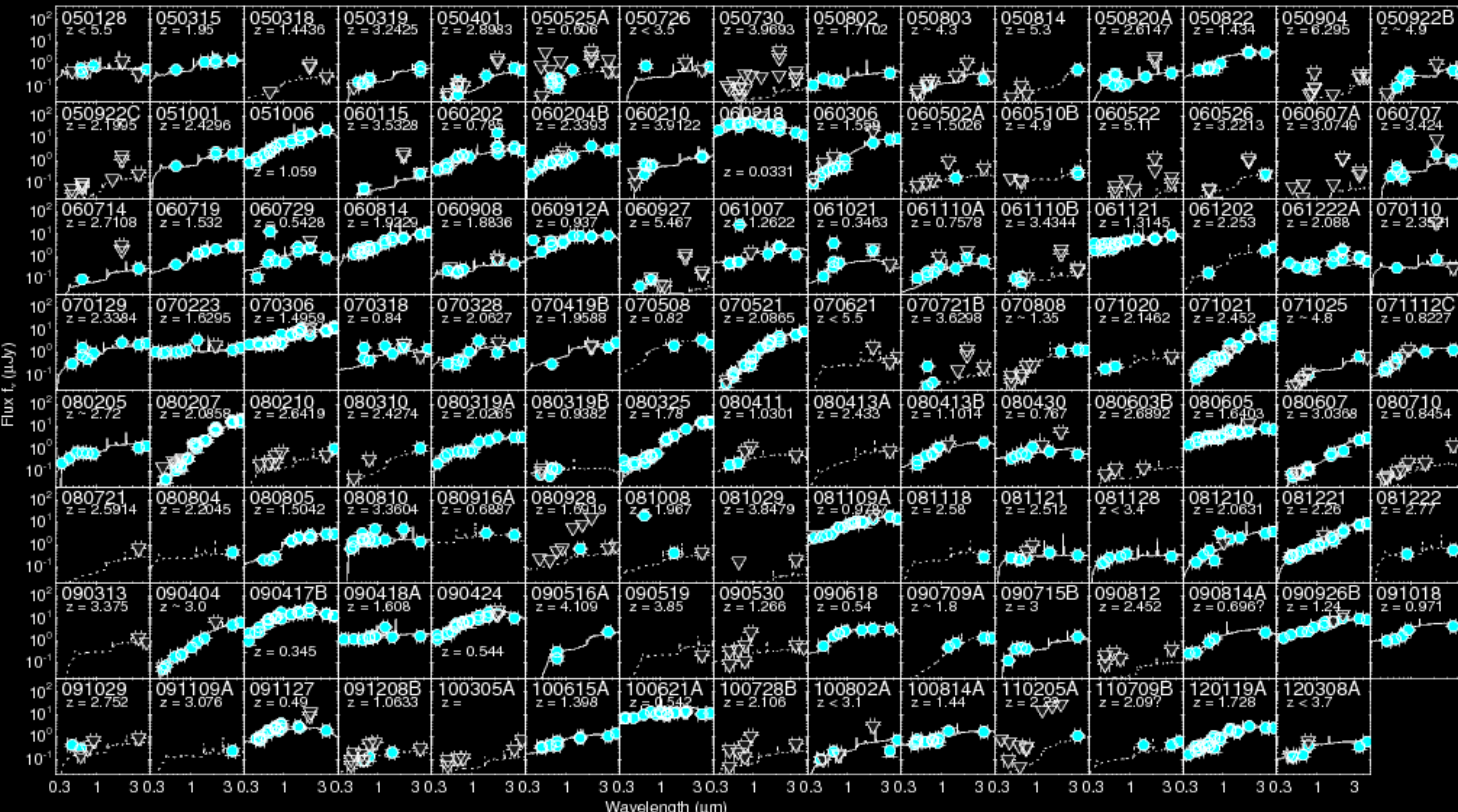
GRBs may be excellent tracers of high-redshift star-formation.

This is just the beginning for SHOALS

Expansion from ~120 to ~400 objects possible!



SEDs Galore



050128 z < 5.5
050315 z = 1.95
050318 z = 1.4436
050319 z = 3.2425
050401 z = 2.8983
050525A z = 0.606
050726 z < 3.5
050730 z = 3.9693
050802 z = 1.7102
050803 z ~ 4.3
050814 z = 5.3
050820A z = 2.6147
050822 z = 1.434
050904 z = 6.295
050922B z ~ 4.9
050922C z = 2.1995
051001 z = 2.4296
051006 z = 1.059
060115 z = 3.5328
060202
060204B z = 2.3393
060210 z = 3.9122
060218 z = 0.0331
060306 z = 1.559
060502A z = 1.5026
060510B z = 4.9
060522 z = 5.11
060526 z = 3.2213
060607A z = 3.0749
060707 z = 3.424
060714 z = 2.7108
060719 z = 1.532
060729 z = 0.5428
060814 z = 1.9229
060908 z = 1.8836
060912A z = 0.937
060927 z = 5.467
061007 z = 1.2622
061021 z = 0.3463
061110A z = 0.7578
061110B z = 3.4344
061121 z = 1.3145
061202 z = 2.253
061222A z = 2.088
070110 z = 2.3521
070129 z = 2.3384
070223 z = 1.6295
070306 z = 1.4959
070318 z = 0.84
070328 z = 2.0627
070419B z = 1.9588
070508 z = 0.82
070521 z = 2.0865
070621 z < 5.5
070721B z = 3.6298
070808 z ~ 1.35
071020 z = 2.1462
071021 z = 2.452
071025 z ~ 4.8
071112C z = 0.8227
080205 z ~ 2.72
080207 z = 2.0858
080210 z = 2.6419
080310 z = 2.4274
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080319B z = 0.9382
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080413A z = 2.433
080413B z = 1.1014
080430 z = 0.767
080603B z = 2.6892
080605 z = 1.6403
080607 z = 3.0368
080710 z = 0.8454
080721 z = 2.5914
080804 z = 2.2045
080805 z = 1.5042
080810 z = 3.3604
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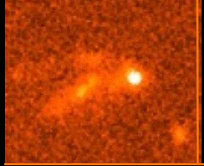
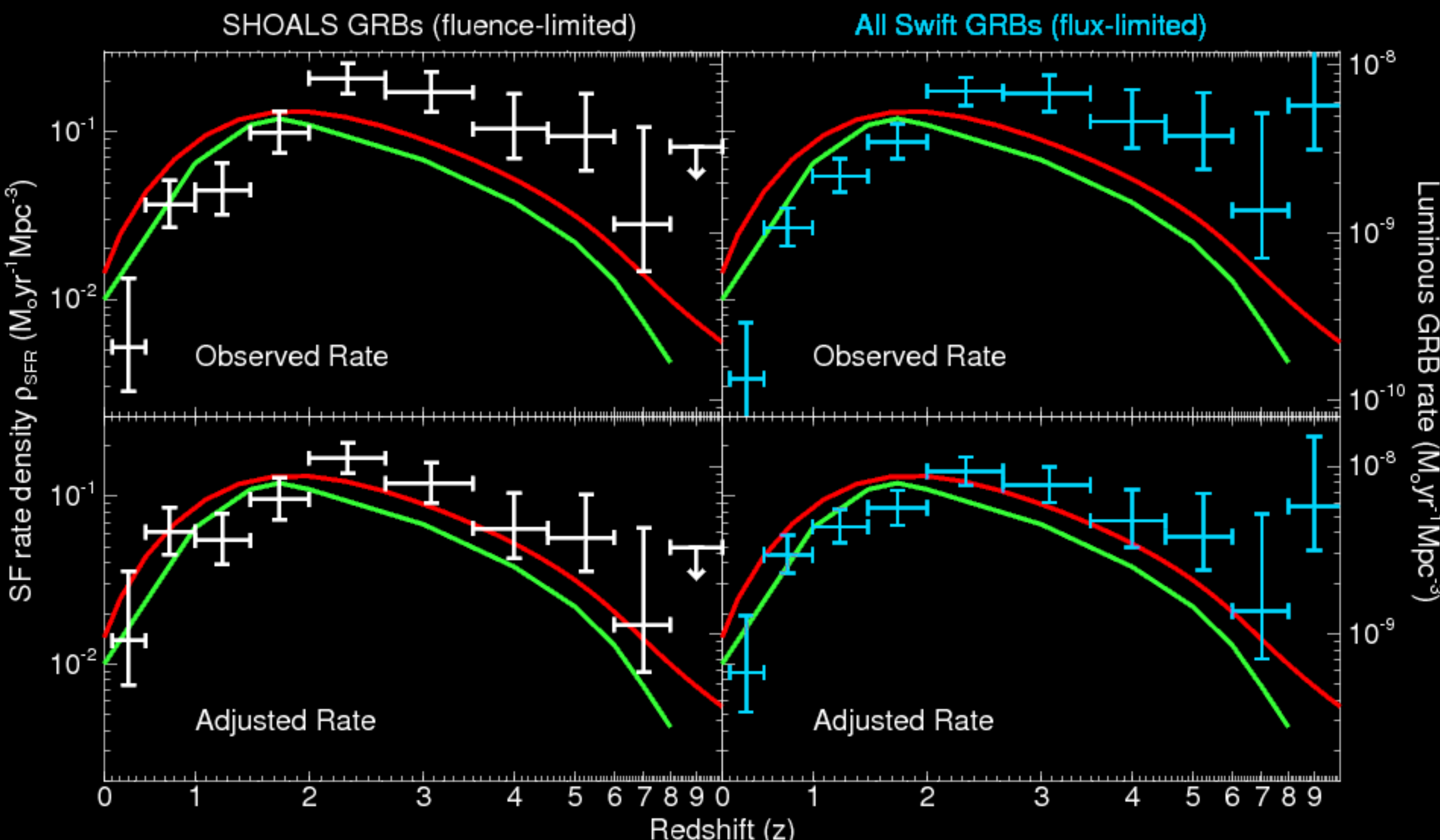
080928 z = 1.6919
081008 z = 1.967
081029 z = 3.8479
081109A
081118 z = 2.58
081121 z = 2.512
081128 z < 3.4
081210 z = 2.0631
081221 z = 2.26
081222 z = 2.77
090313 z = 3.375
090404 z ~ 3.0
090417B z = 0.345
090418A z = 1.608
090424 z = 0.544
090516A z = 4.109
090519 z = 3.85
090530 z = 1.266
090618 z = 0.54
090709A z ~ 1.8
090715B z = 3
090812 z = 2.452
090814A z = 0.696?
090926B z = 1.24
091018 z = 0.971
091029 z = 2.752
091109A z = 3.076
091127 z = 0.49
091208B z = 1.0633
100305A z =
100615A z = 1.398
100621A z = 0.542
100728B z = 2.106
100802A z < 3.1
100814A z = 1.44
110205A z = 2.22
110709B z = 2.09?
120119A z = 1.728
120308A z < 3.7
10^2
10^1
10^0
10^-1
Flux f_ν (μJy)
0.3
1
3
Wavelength (μm)



Metallicity Dependence Fixes High-z Rate



Perley+2016a