‘Review of Cosmology, Large-scale Structure and Galaxy Formation - Observations’

Karl Glazebrook

The reality

- Gemini studies of galaxy evolution

  Focus on red galaxies

  (Iwata-San, Subaru review – blue LBGs)

- Red Galaxies at 1<z<3

  What have we learned from spectroscopy?

  The peculiar problem of red nuggets

- Massive Blue galaxies at 1<z<2

  Something new from Gemini + Spitzer

  (GDDS Papers X and XII)

Cosmology Poster

PASJ: Publ. Astron. Soc. Japan , 1–**??**,
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Photometric Hα and [O II] Luminosity Function of SDF and SXDF Galaxies: Implications for Future Baryon Oscillation Surveys

Masanao Sumiyoshi,[1] Tomonori Totani,[1] Shunsuke Oshige,[1] Karl Glazebrook,[2] Masayuki Akiyama,[3] Tomoki Morokuma,[4] Kentaro Motohara,[5] Kazuhiro Shimasaku,[6,7] Masao Hayashi,[6] Makiko Yoshida,[6] Nobunari Kashikawa,[4] and Tadayuki Kodama[4]

Gemini:

Studies of red galaxies at high-z

‘Gemini Deep Deep Survey’ Team

Bob Abraham
Toronto

Isobel Hook
Oxford

Erin Mentuch
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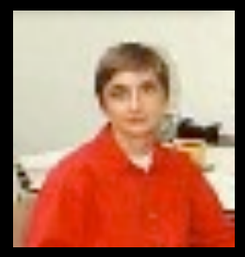
Karl Glazebrook
Swinburne

Inger Jørgensen
Gemini



Andy Green
Swinburne

Pat McCarthy
Carnegie Institution

Kathy Roth
Gemini

Ivana Damjanov
Toronto

David Crampton
Herzberg Institute

Ray Carlberg
Toronto

Greg Poole
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Ron Marzke
San Francisco State

Sandra Savaglio
MPA

Hsiao-Wen Chen
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Damien Le Borgne
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Stephanie Juneau
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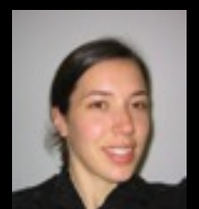
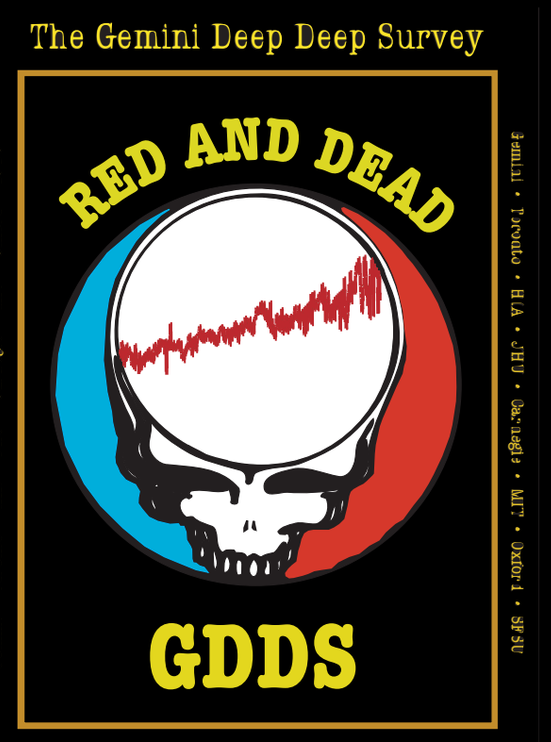


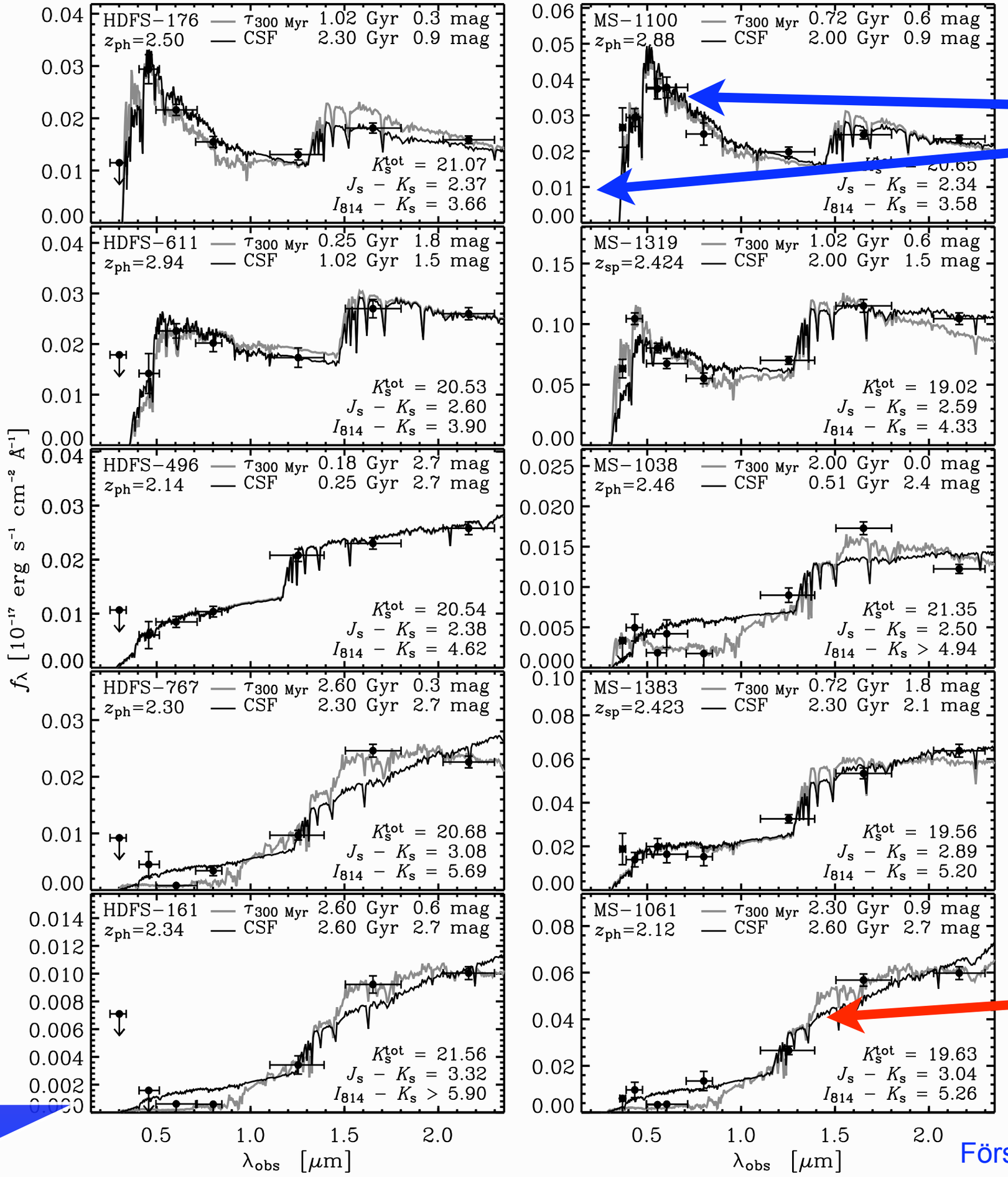


Red Galaxies 1<z<3

2000–2004

They Exist!

Lyman Break selection does not suffice.



LBGs

Blue cuum

Lyman Break

'dropout'

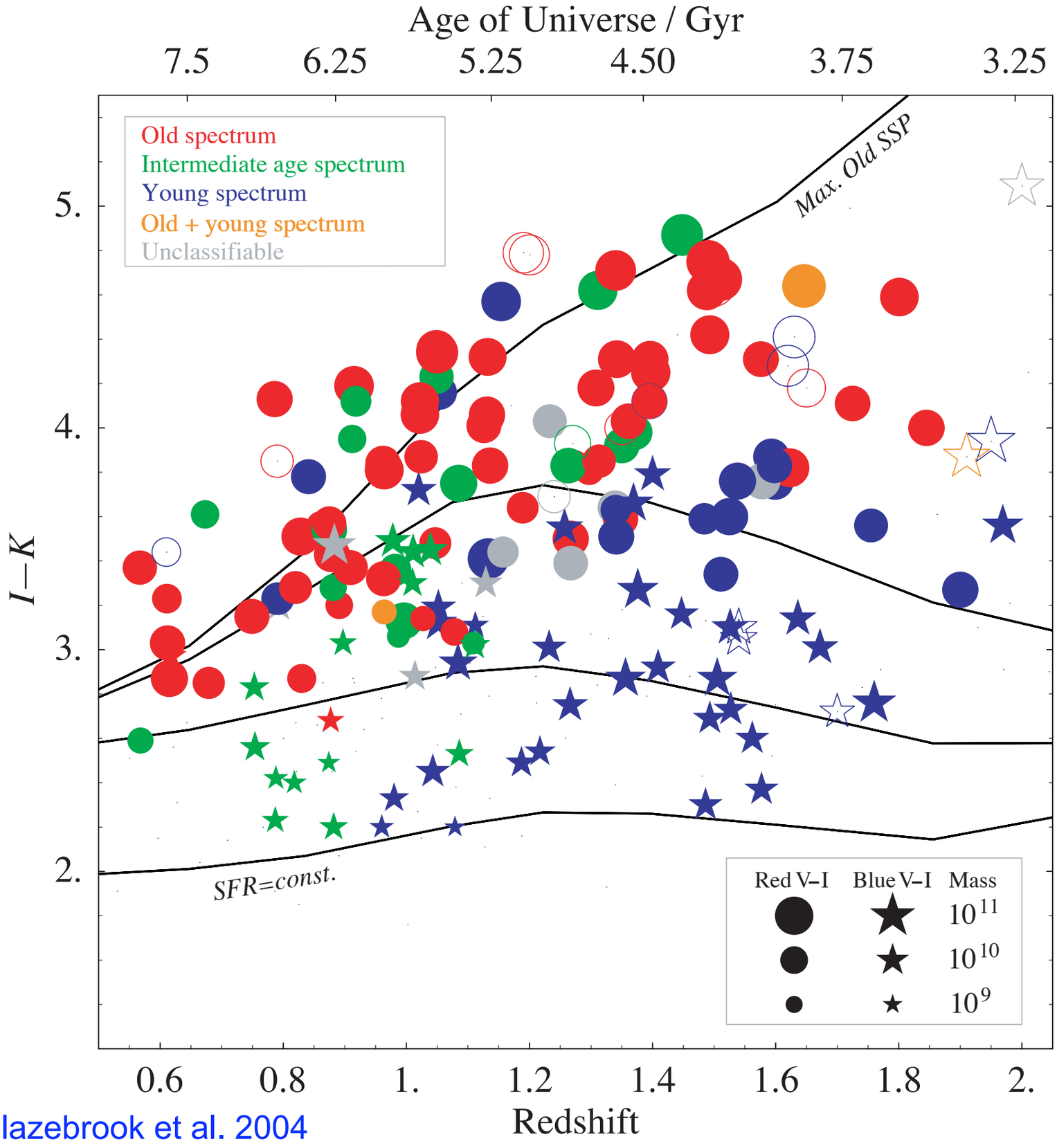
Selection

Red Galaxies

Red J–K or I–K photo-z

Förster Schreiber et al. 2004

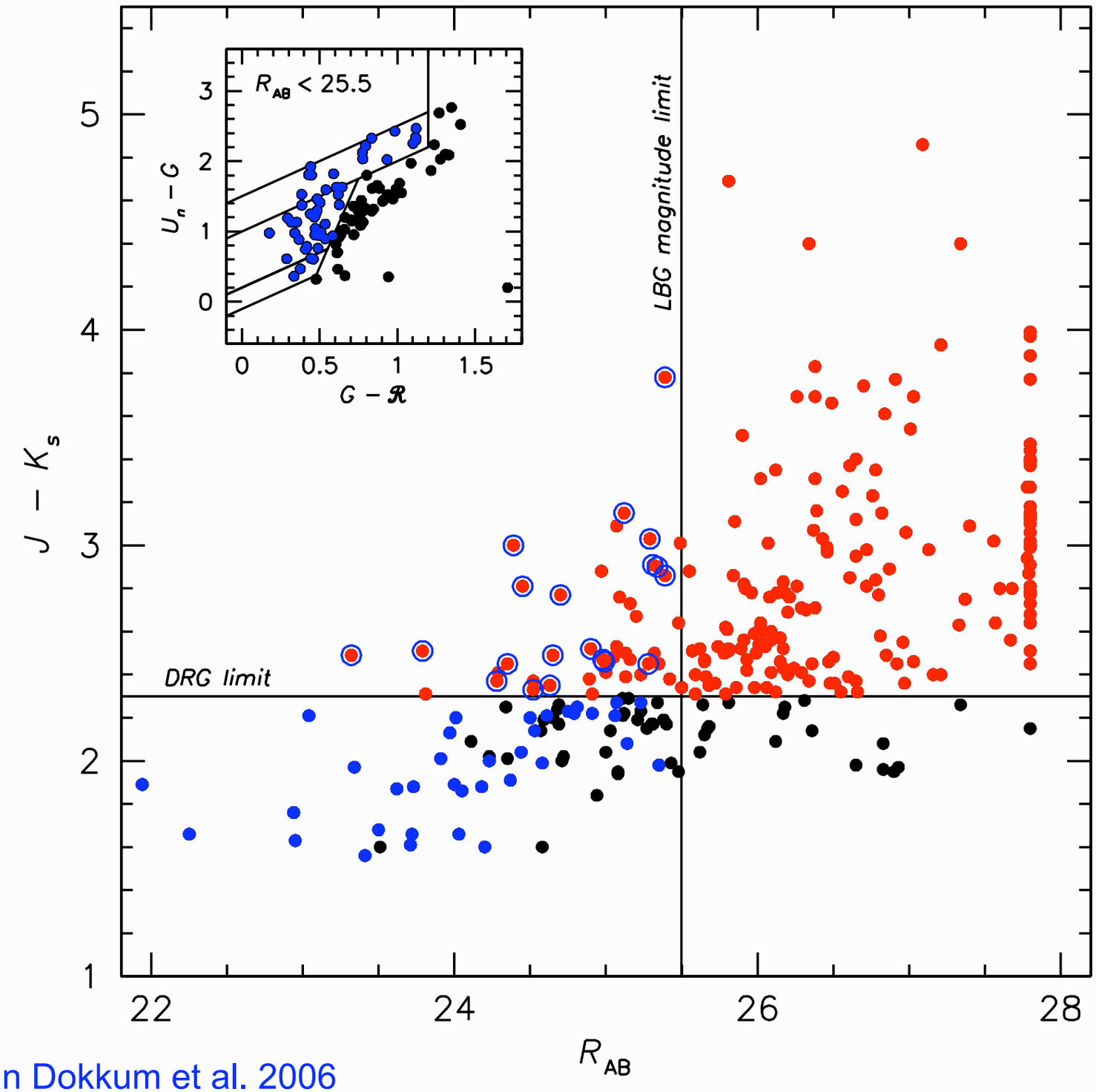
GDDS Paper III. Colours and Masses



Glazebrook et al. 2004

I–K>4 = 49% of 1.3<z<2 mass density

“Distant Red Galaxies”



Lyman Break Galaxies

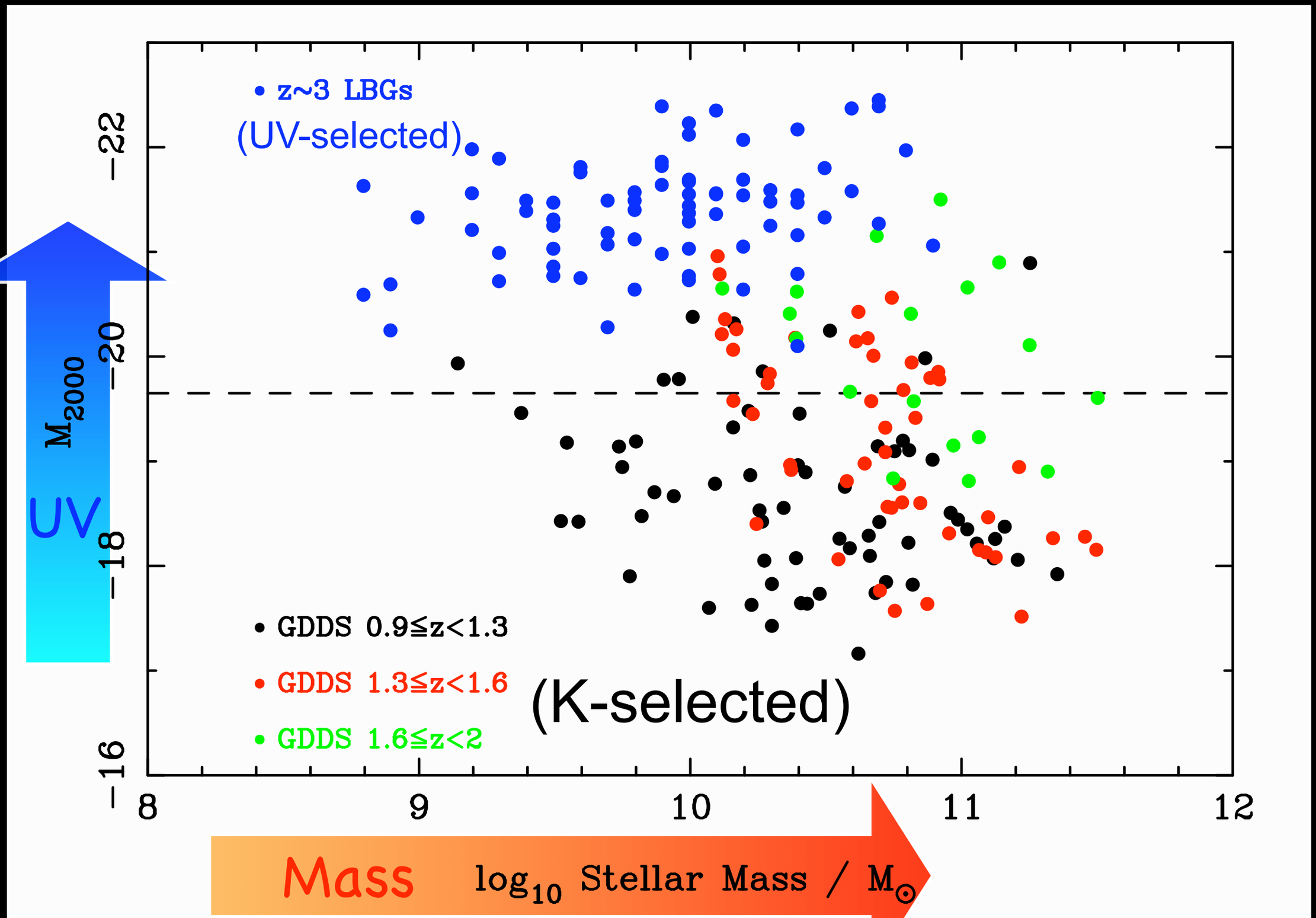
“Distant Red Galaxies” (J–K>2.3)

$2<z_{photo}<3$

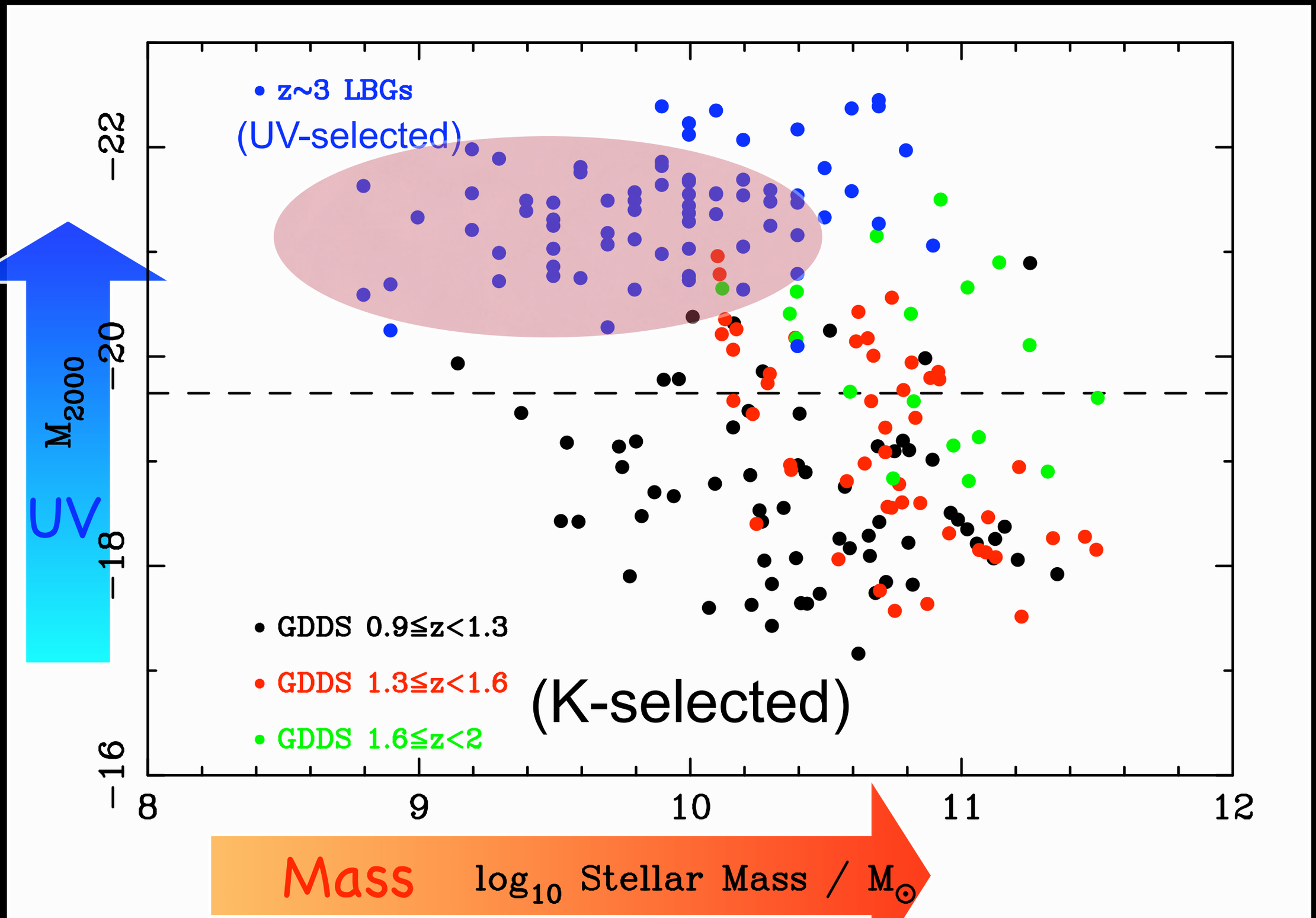
FIRES
MUSYC
GOODS/CDFS

van Dokkum et al. 2006

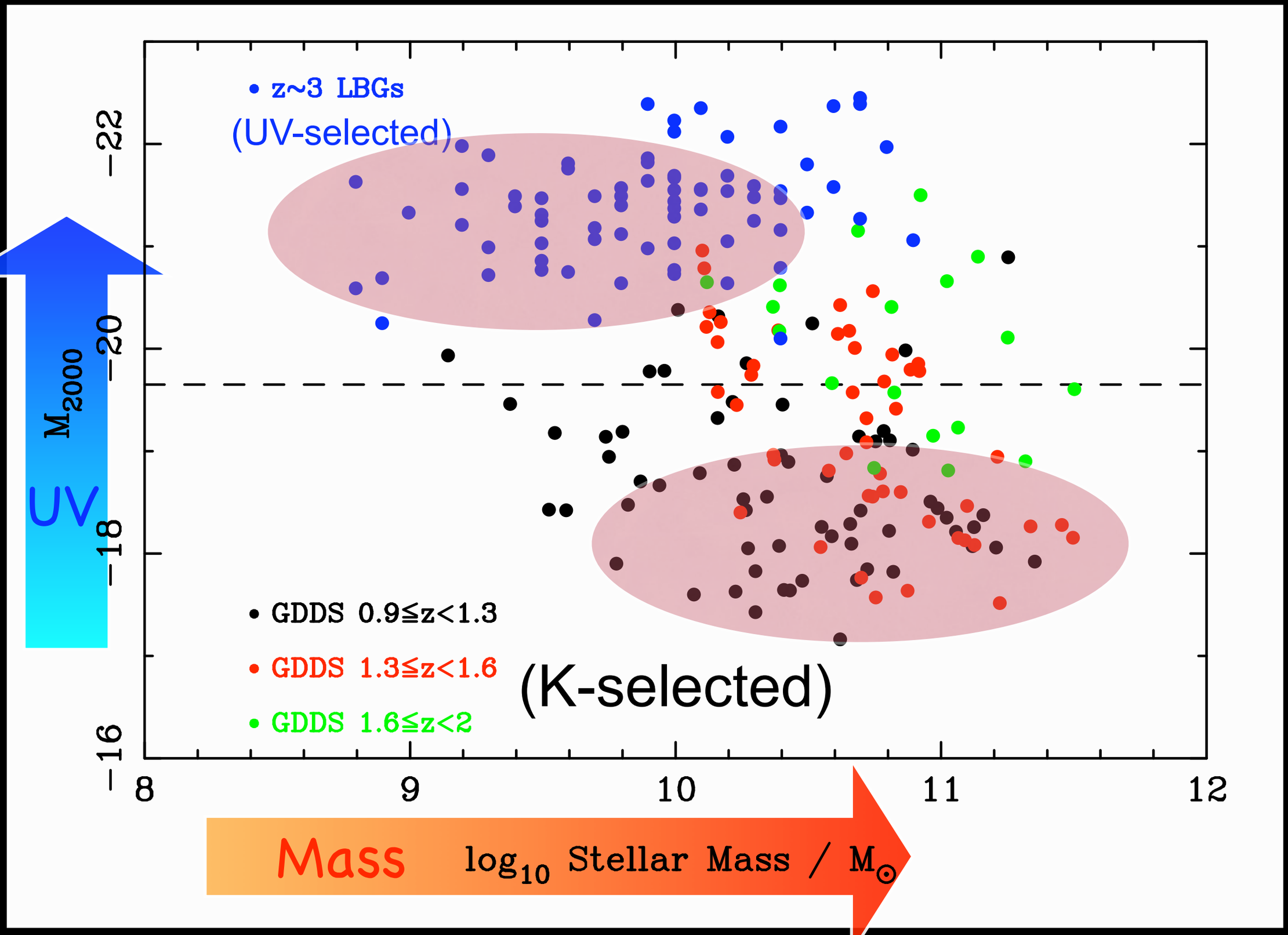
Mass vs UV output



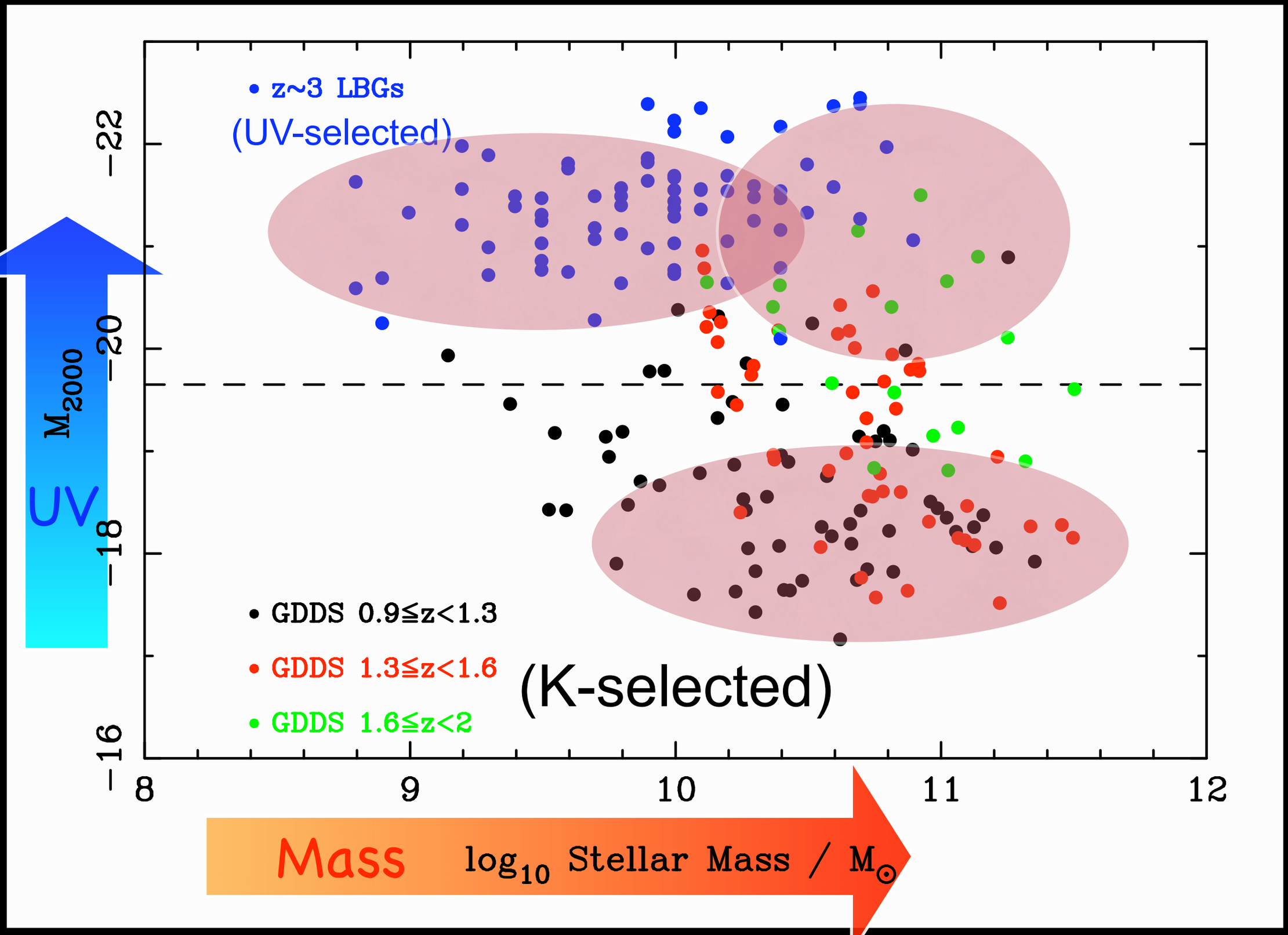
Mass vs UV output



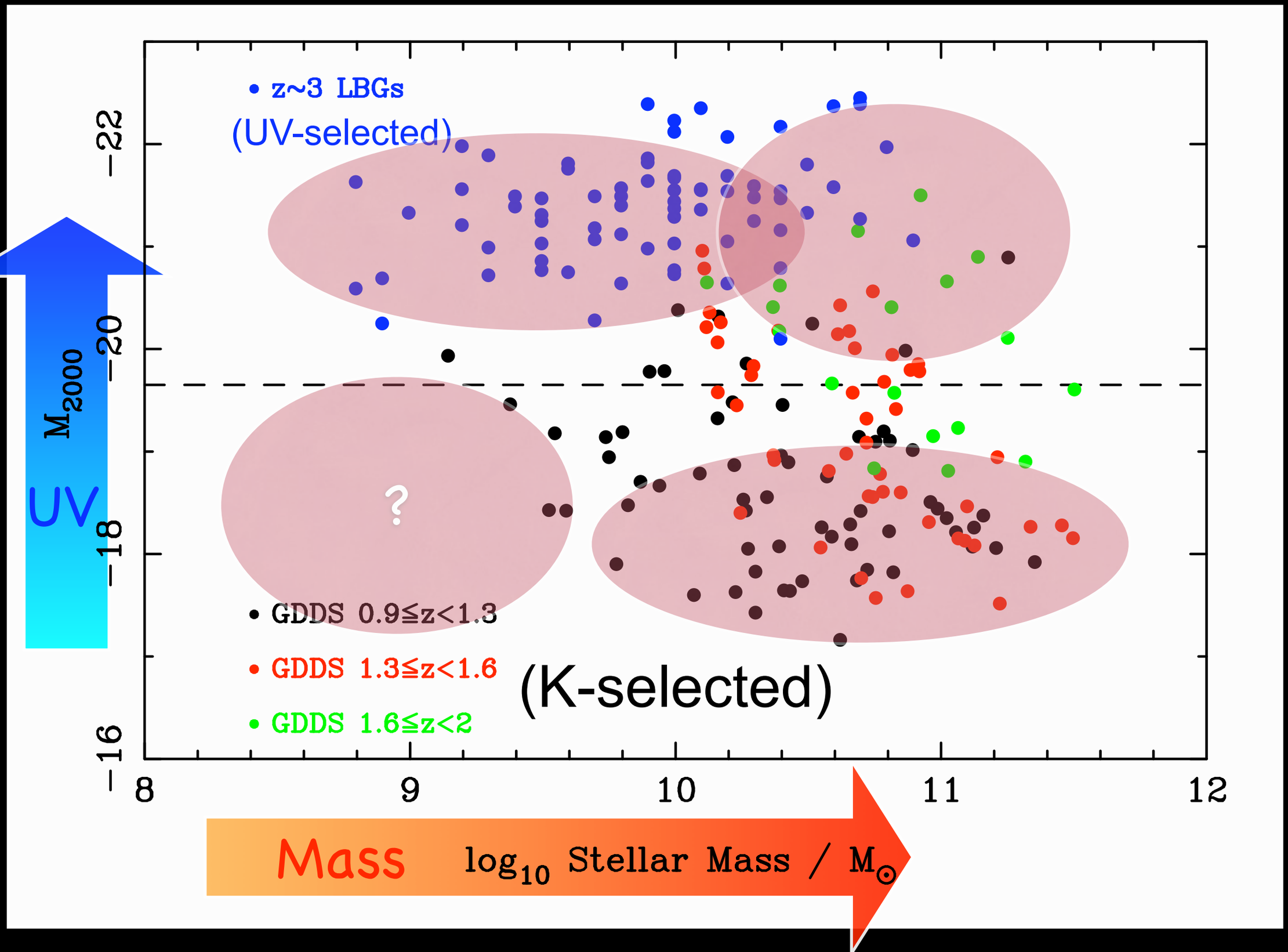
Mass vs UV output



Mass vs UV output

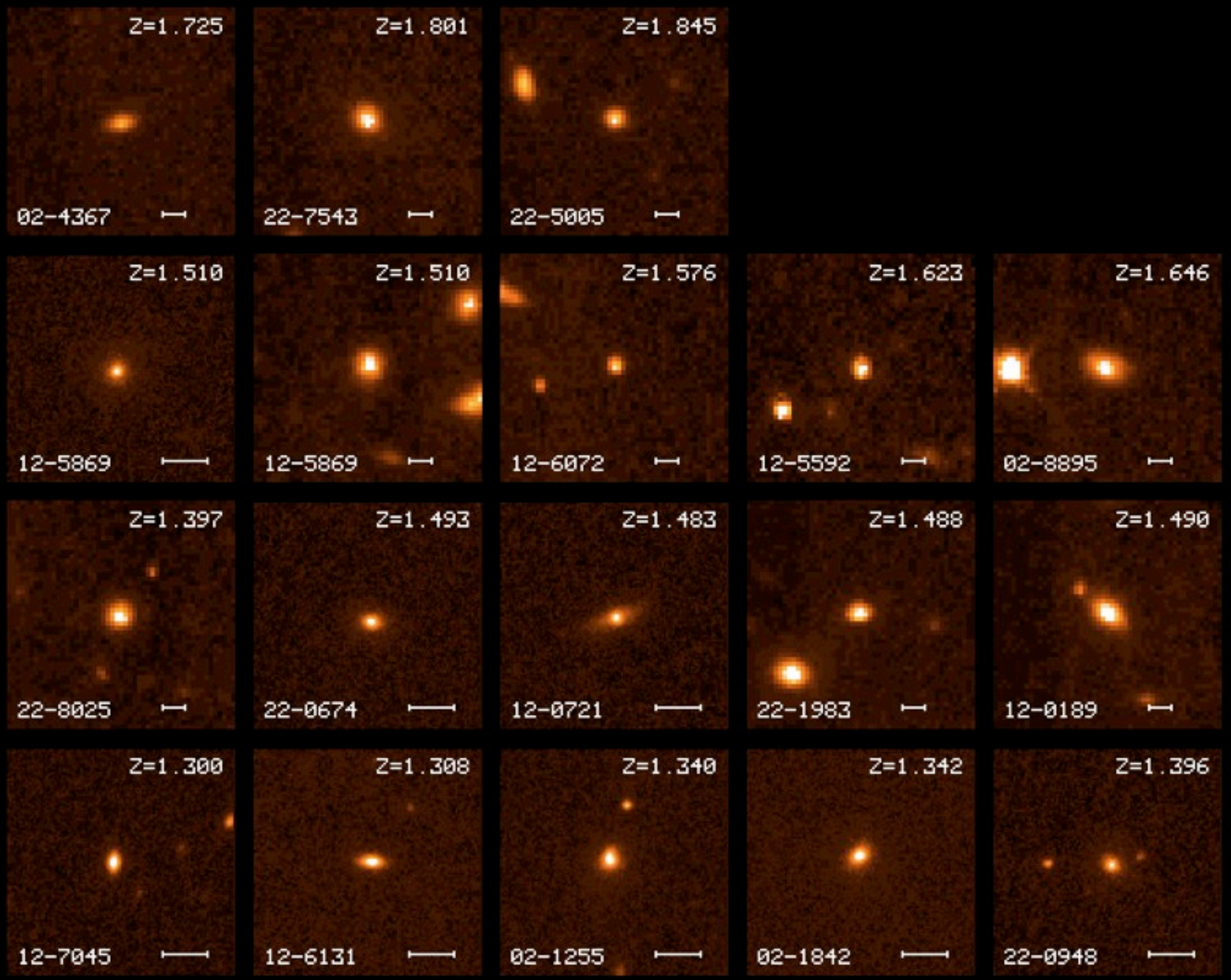


Mass vs UV output



High Mass, Red, Low SFR galaxies
What do they look like?

HST images: red & dead galaxies

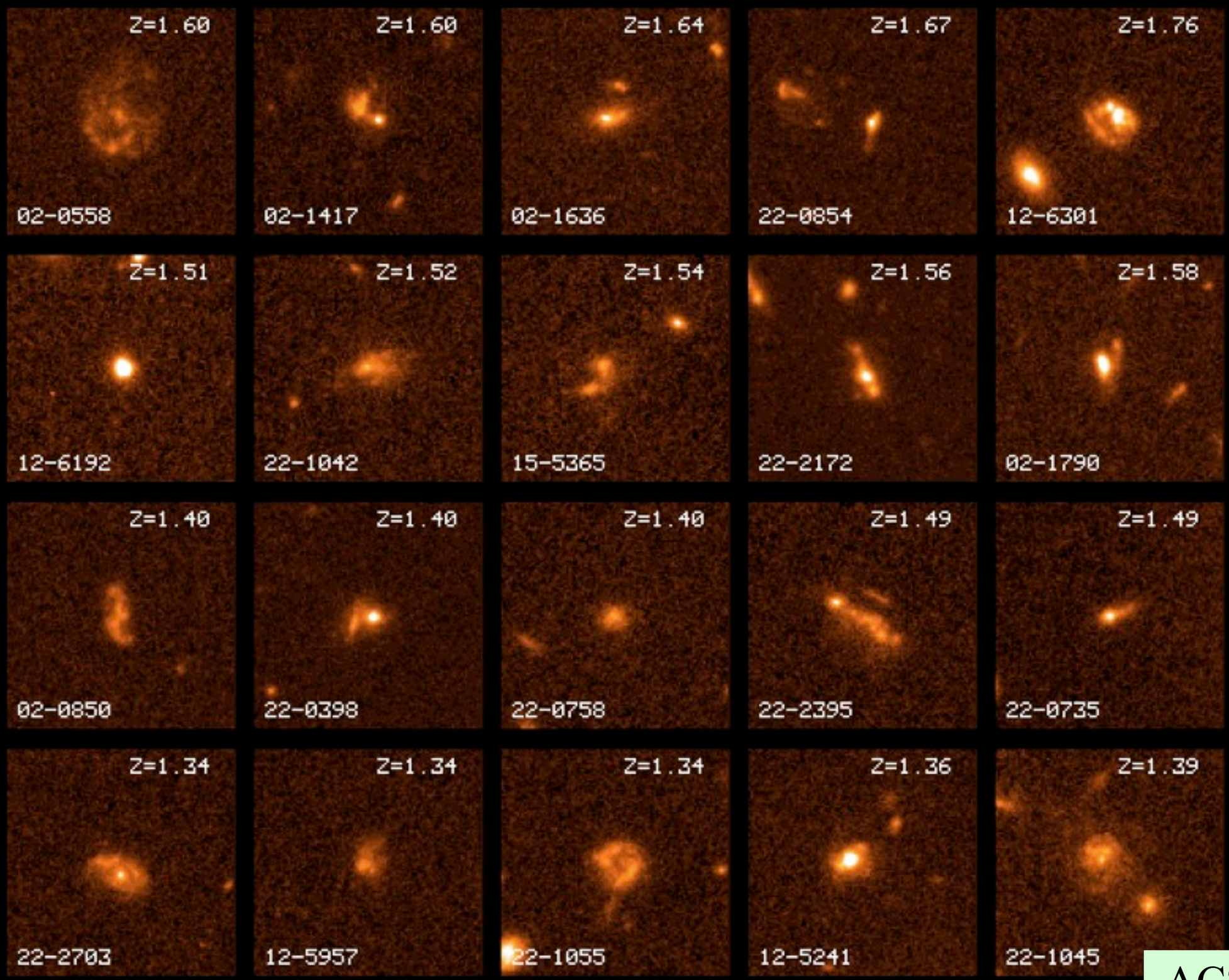


ACS
F814W

NICMOS
F160W

75-80%
Spheroids

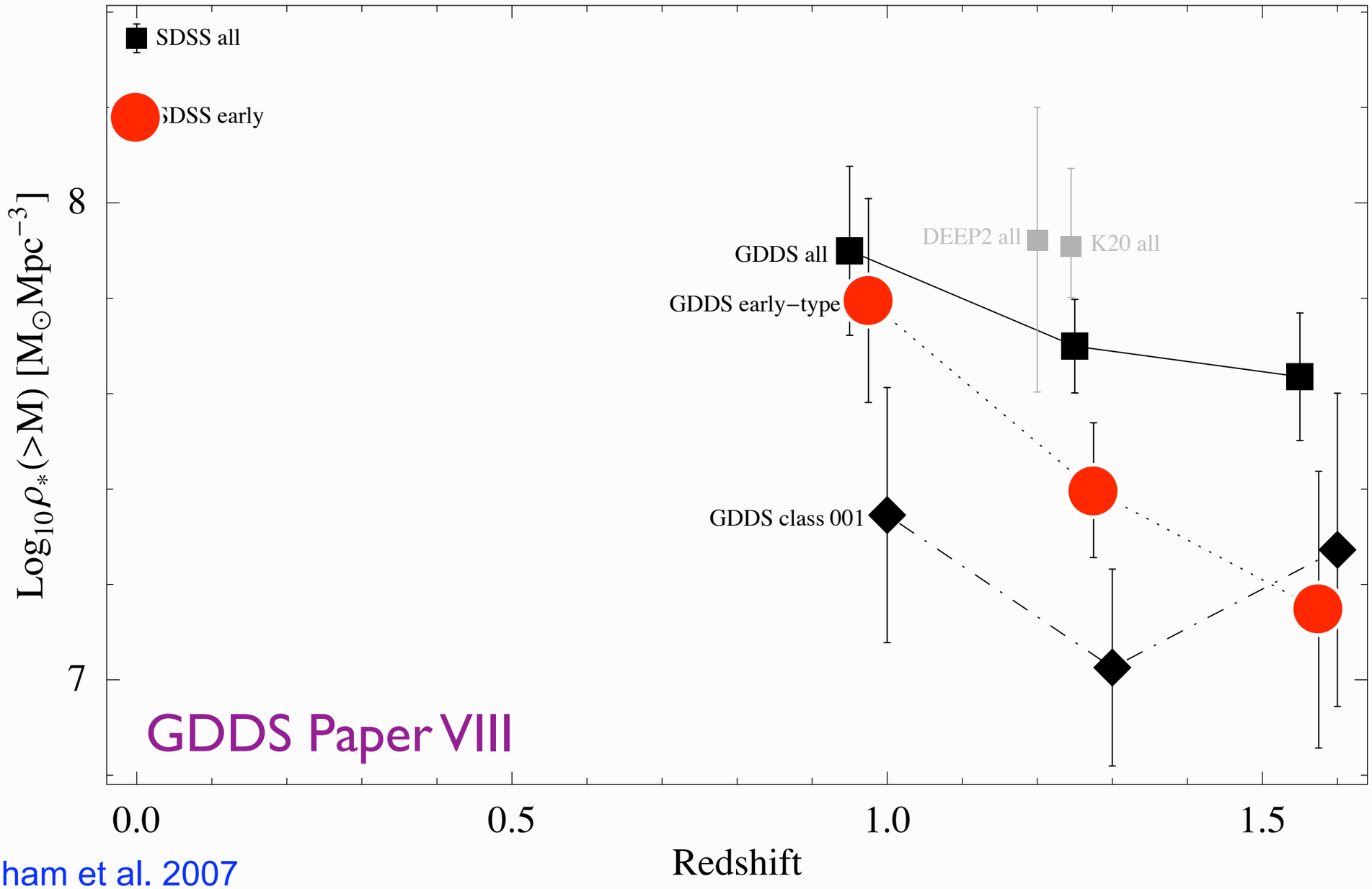
Star Forming Galaxies $1.3 < z < 2.0$



ACS F814W

Ellipticals: evolution

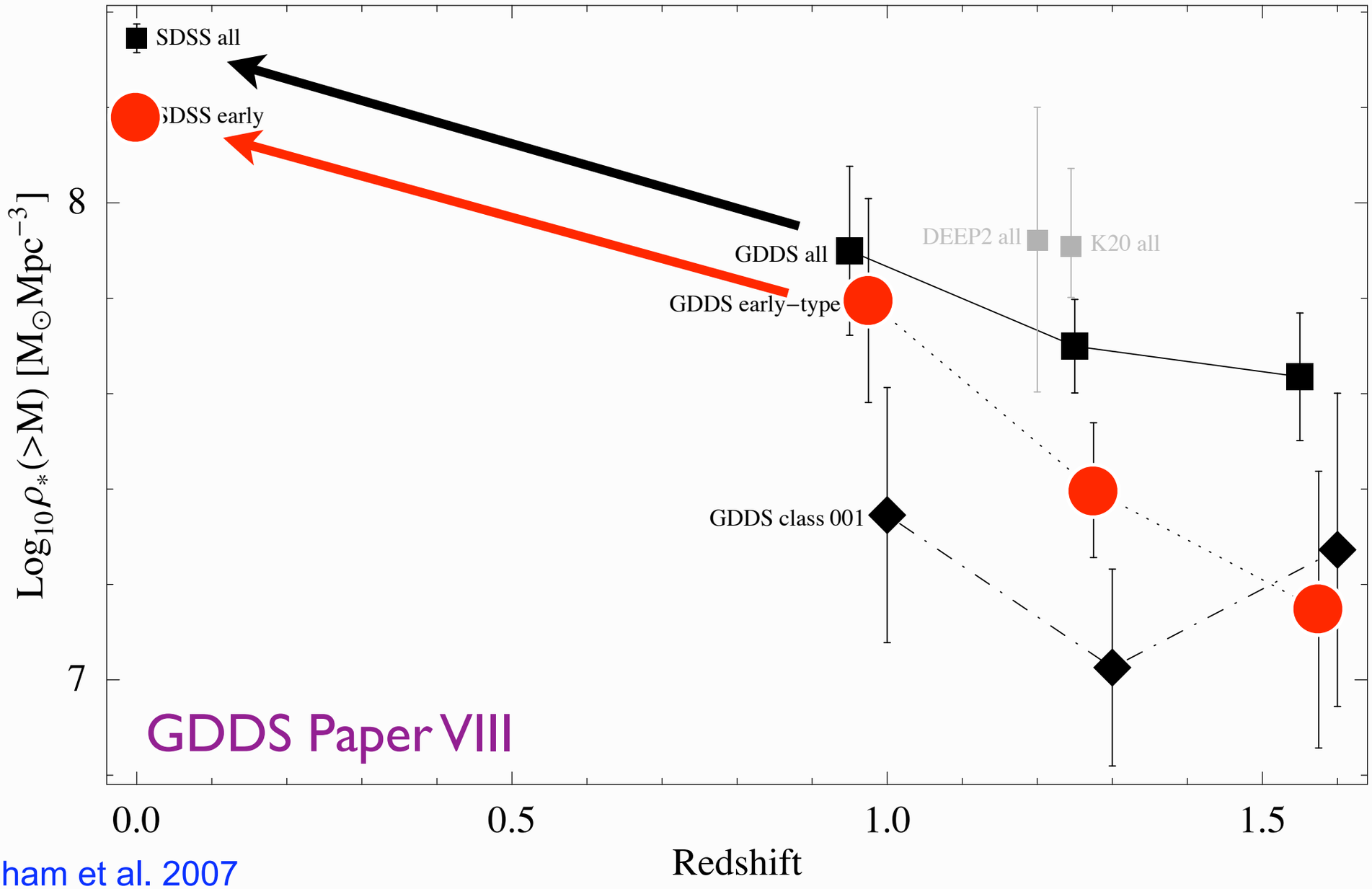
Space density evolution



Abraham et al. 2007

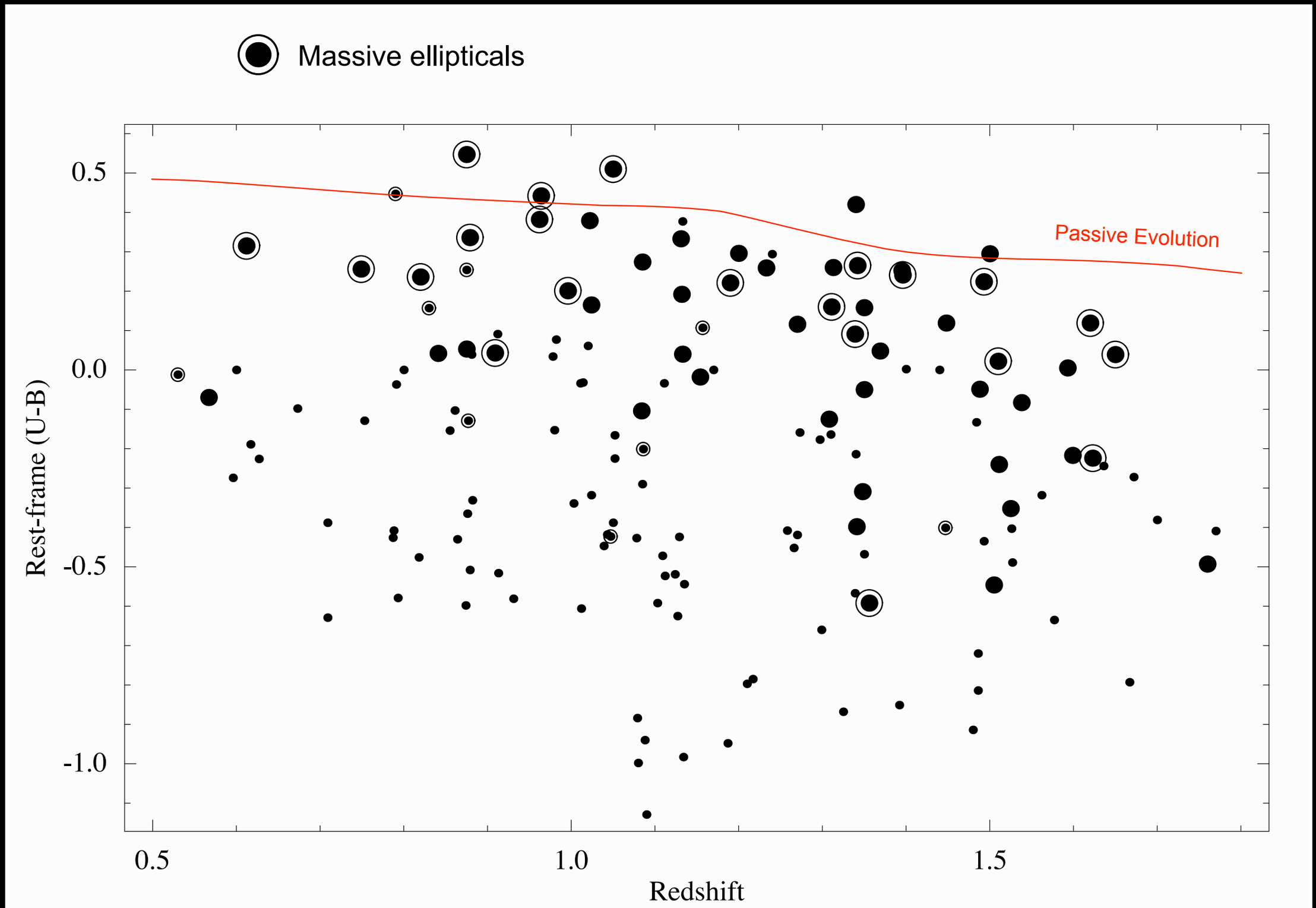
Ellipticals: evolution

Space density evolution



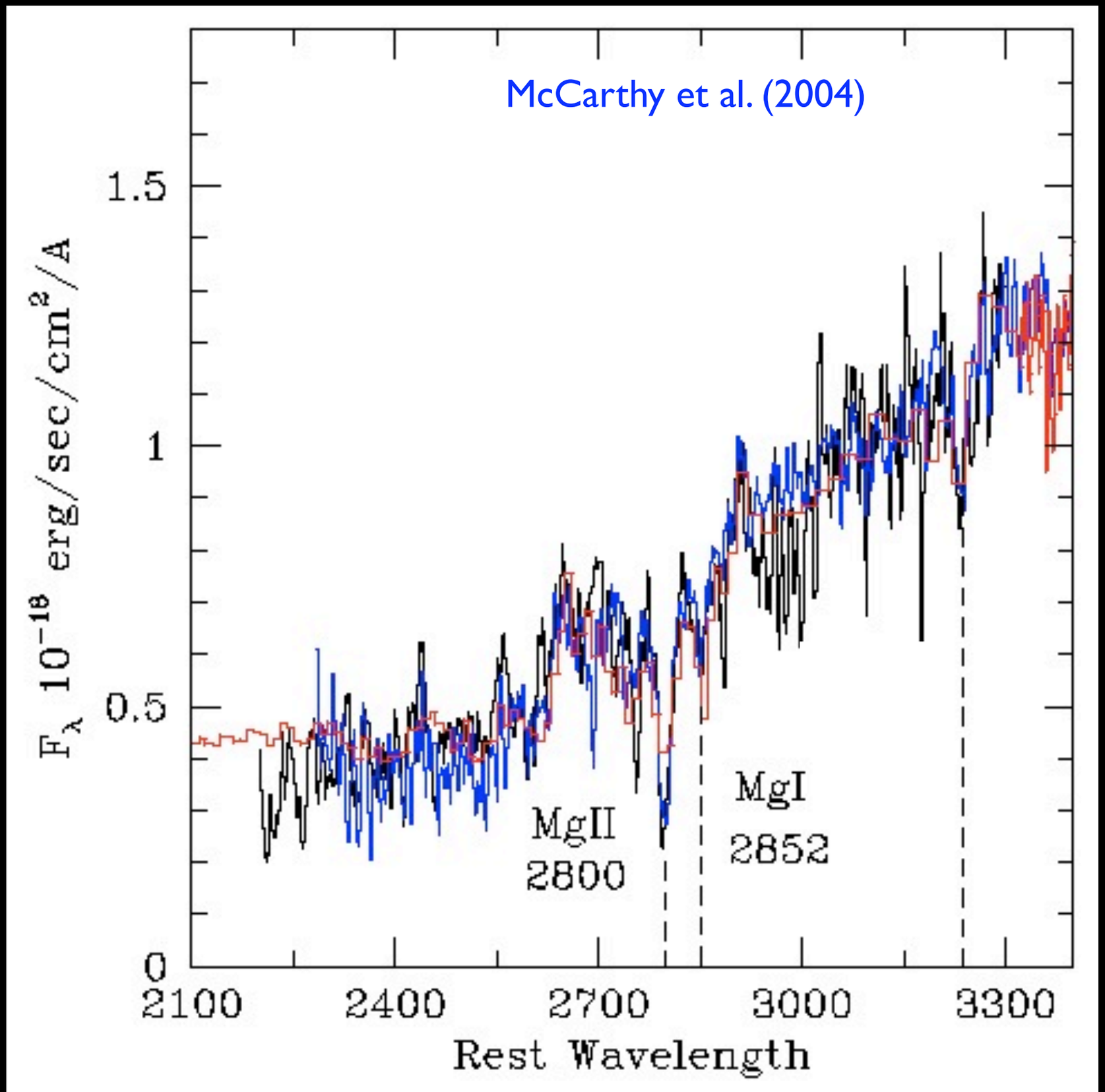
Abraham et al. 2007

Ellipticals: colour evolution



Abraham et al. 2007

Old Galaxies at 1.3 < z < 1.8



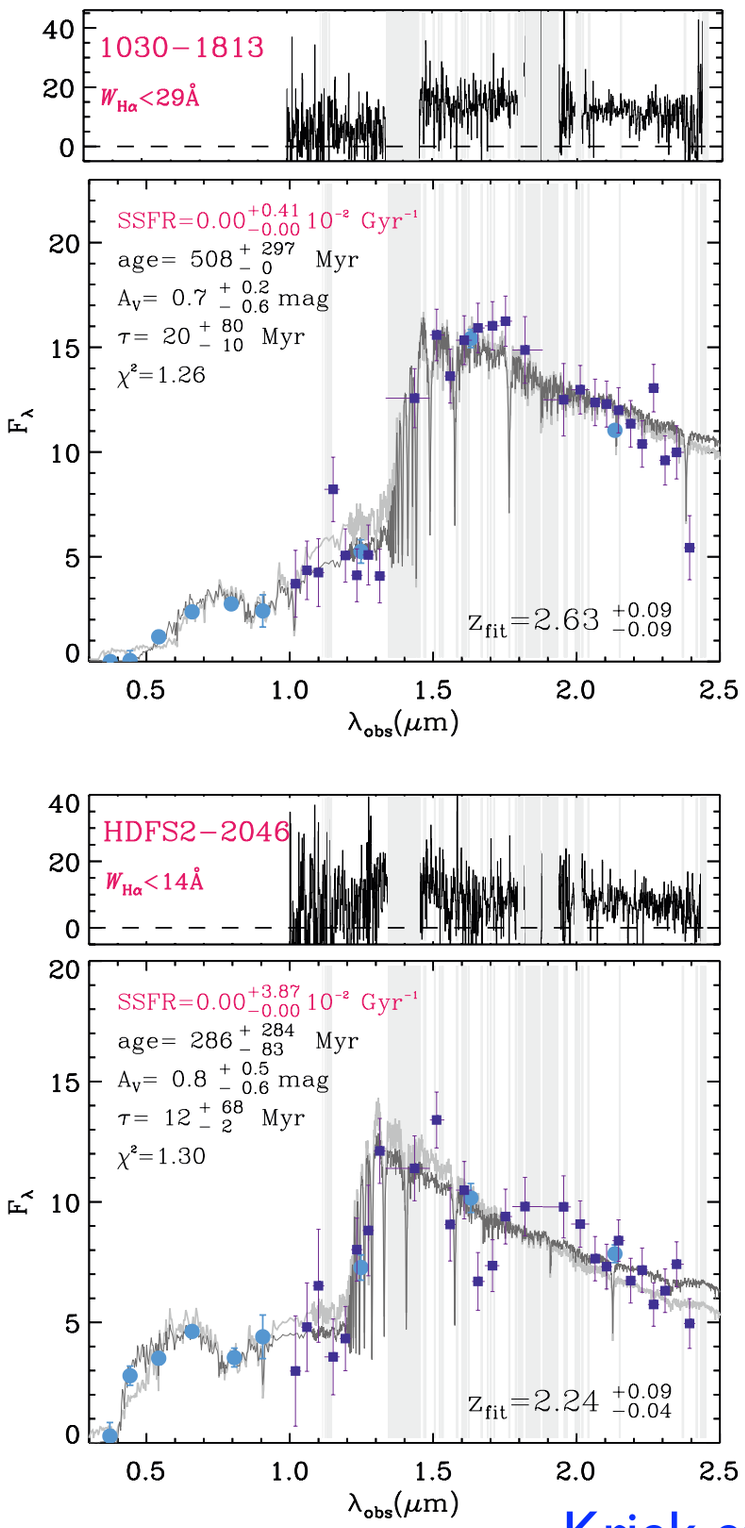
<z>=1.3

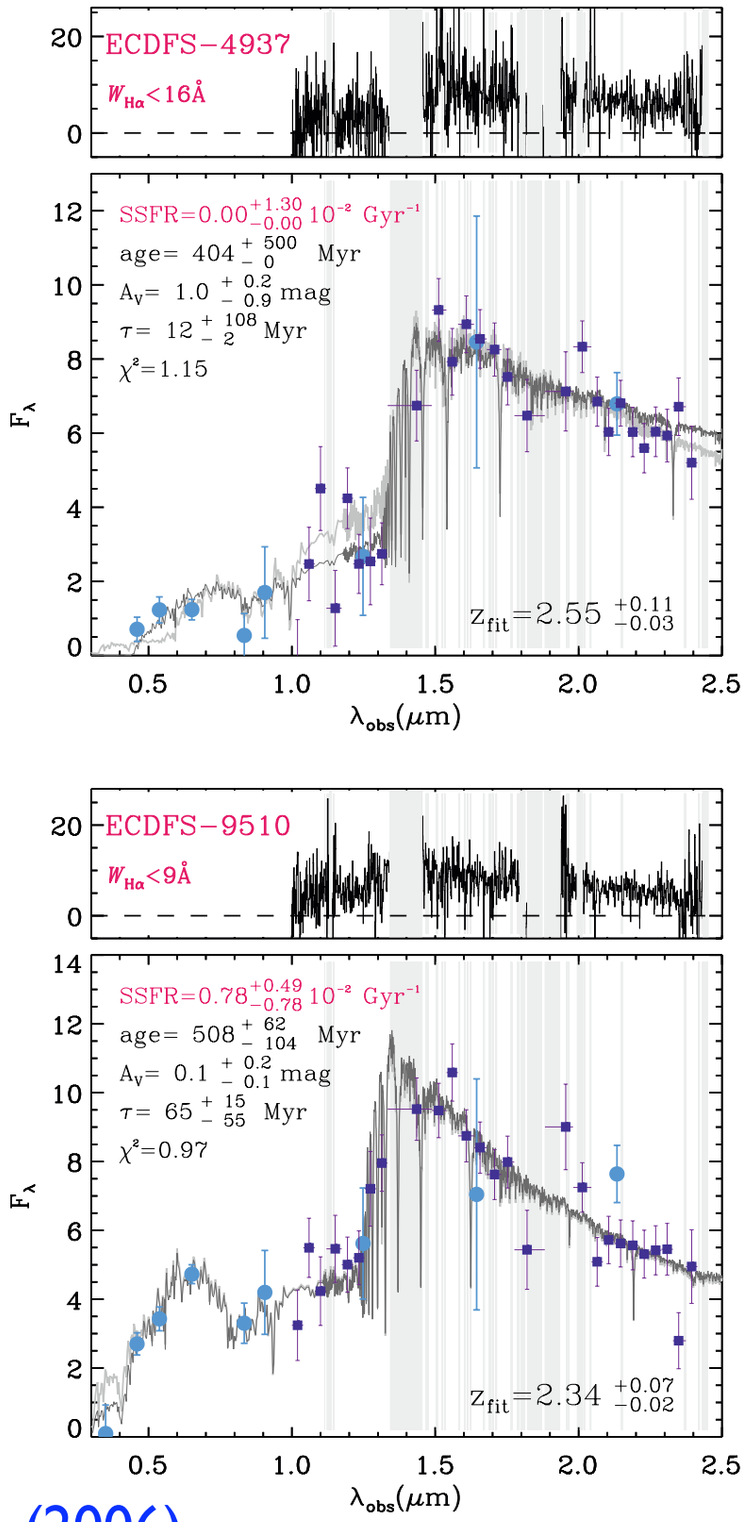
<z>=1.8

2Gyr

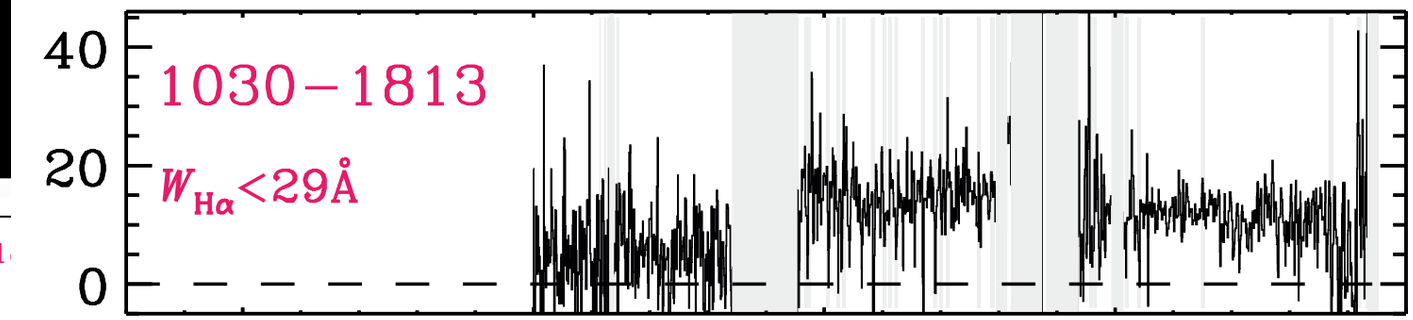
Pegase Model

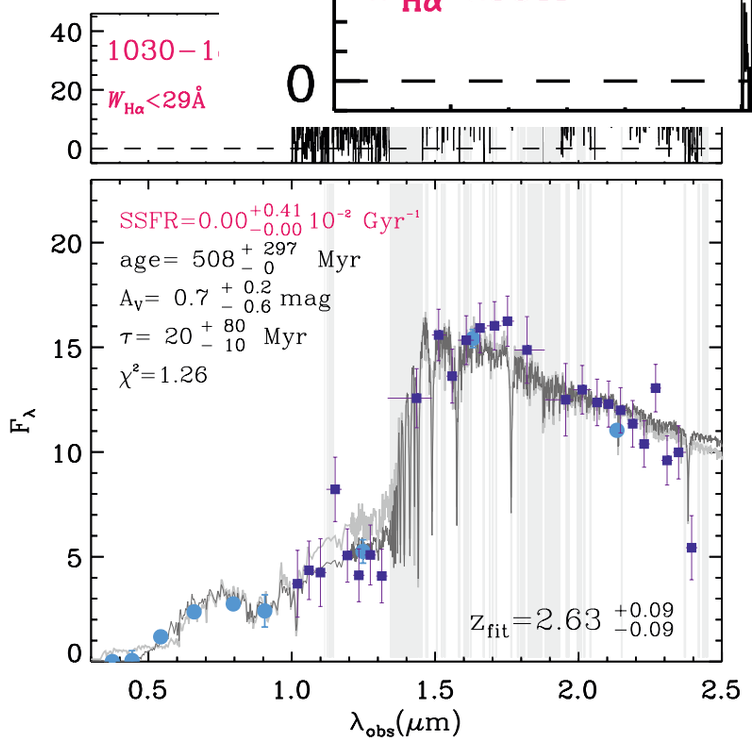
GNIRS spectra

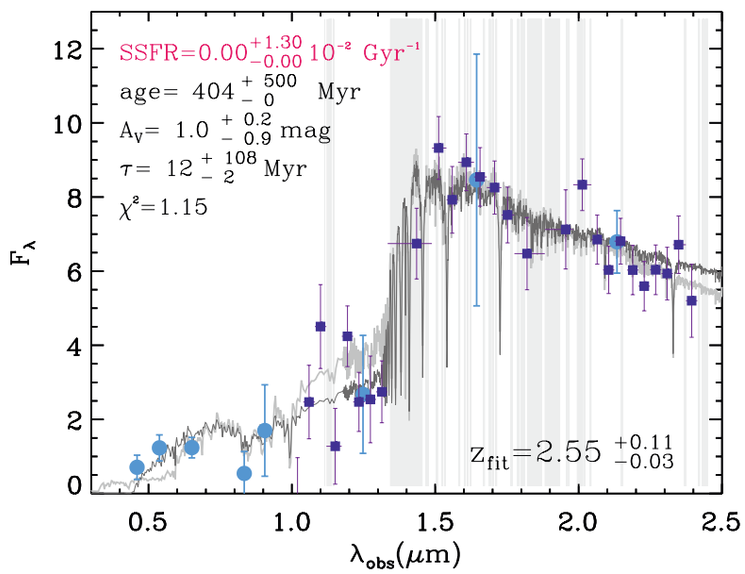


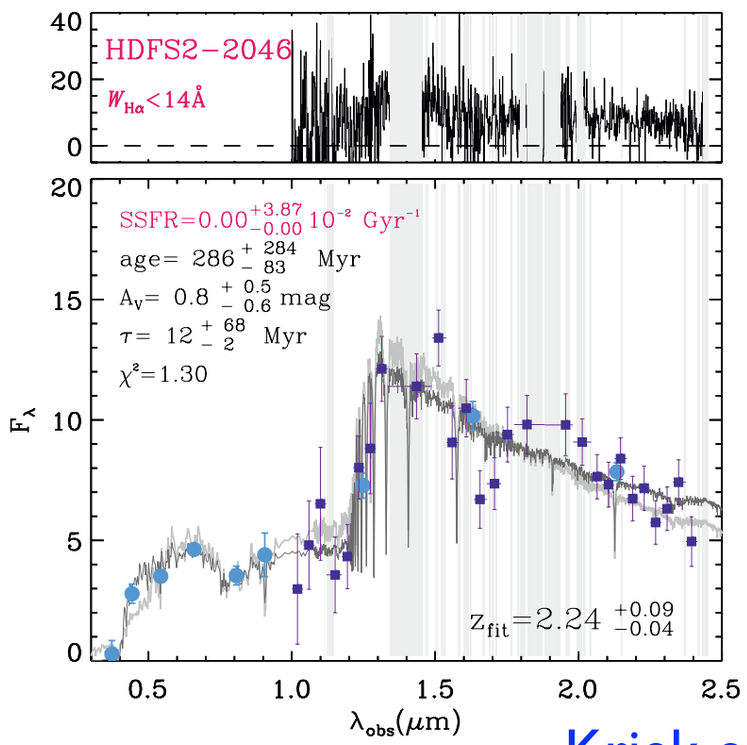


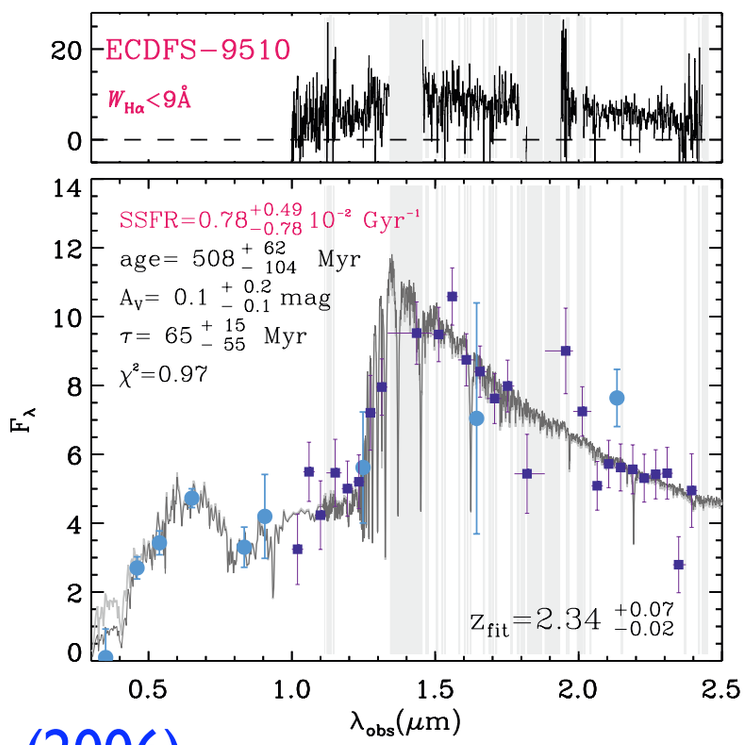
Kriek et al. (2006)





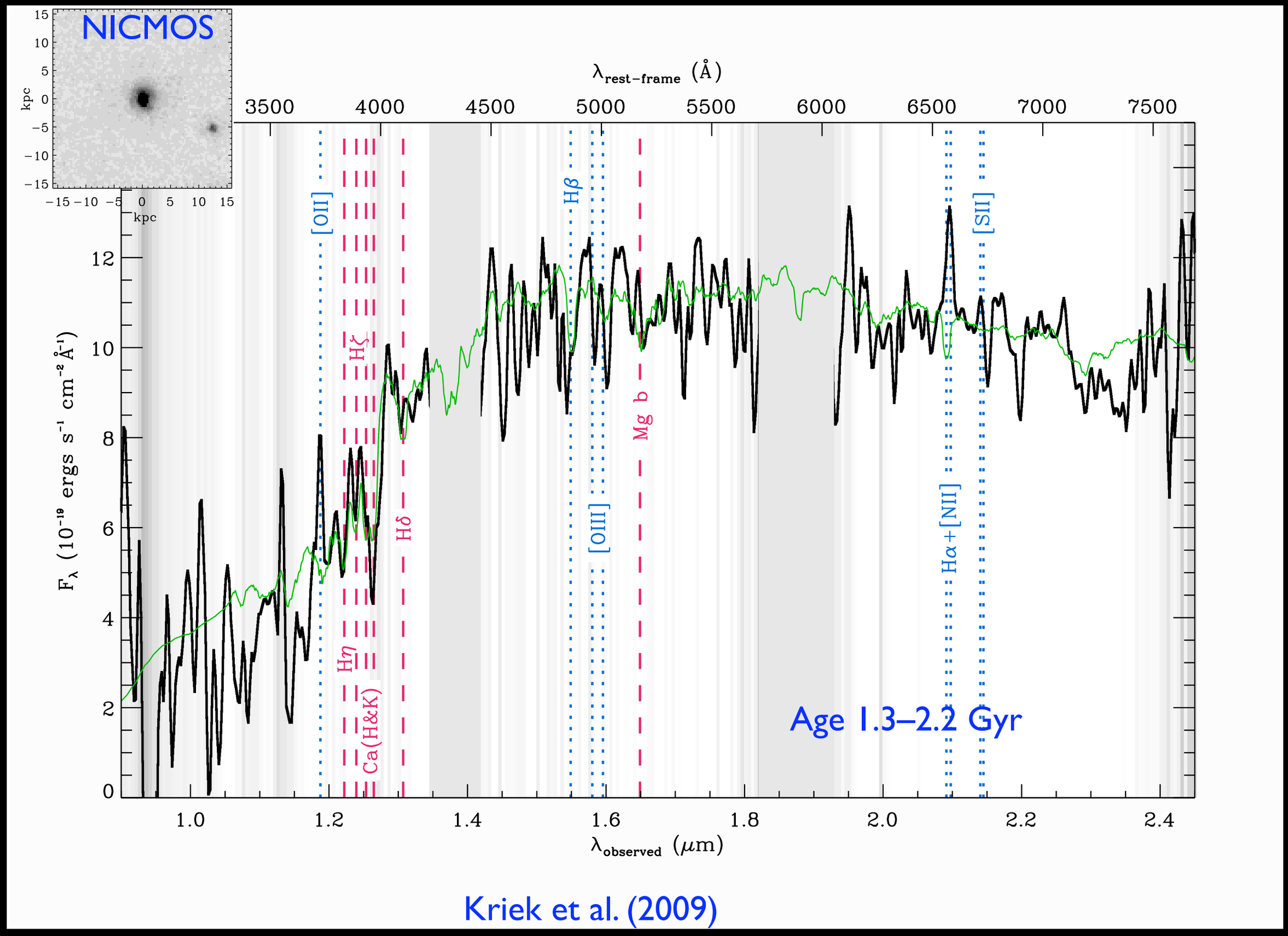






Kriek et al. (2006)

GNIRS spectra - 29h!



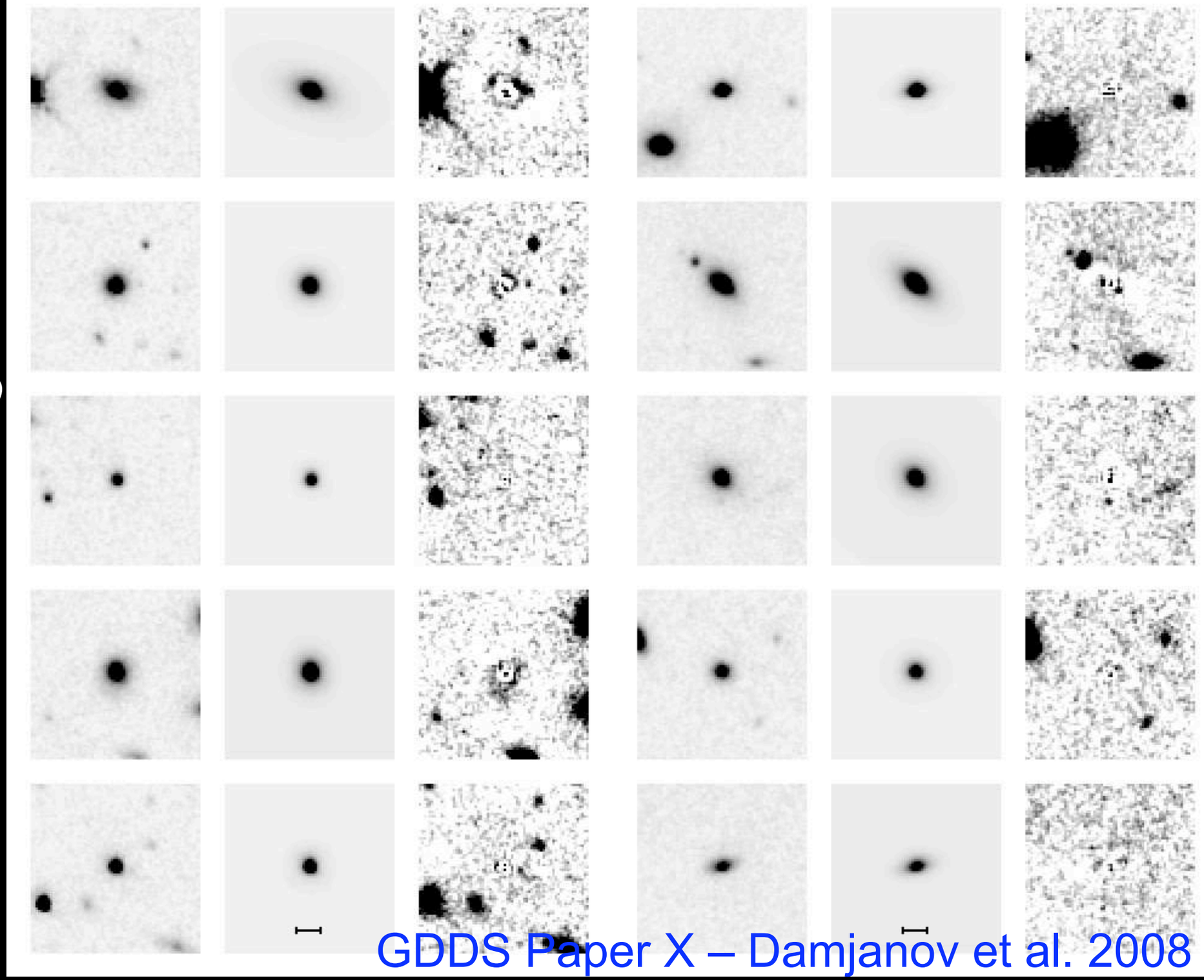
Kriek et al. (2009)

Sizes?

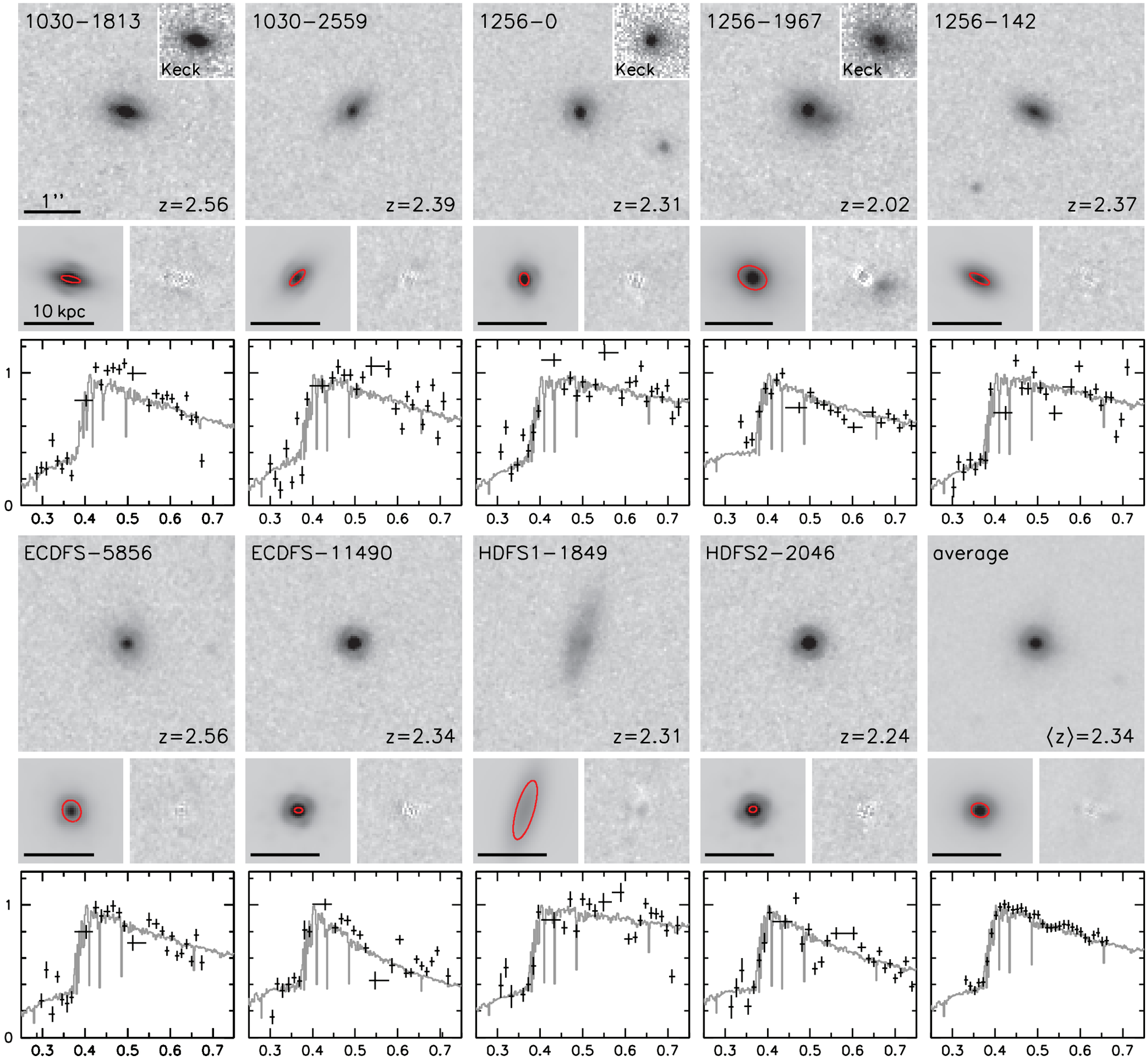
Size measurements

Image $r^{1/4}$ model diff x10 Image $r^{1/4}$ model diff x10

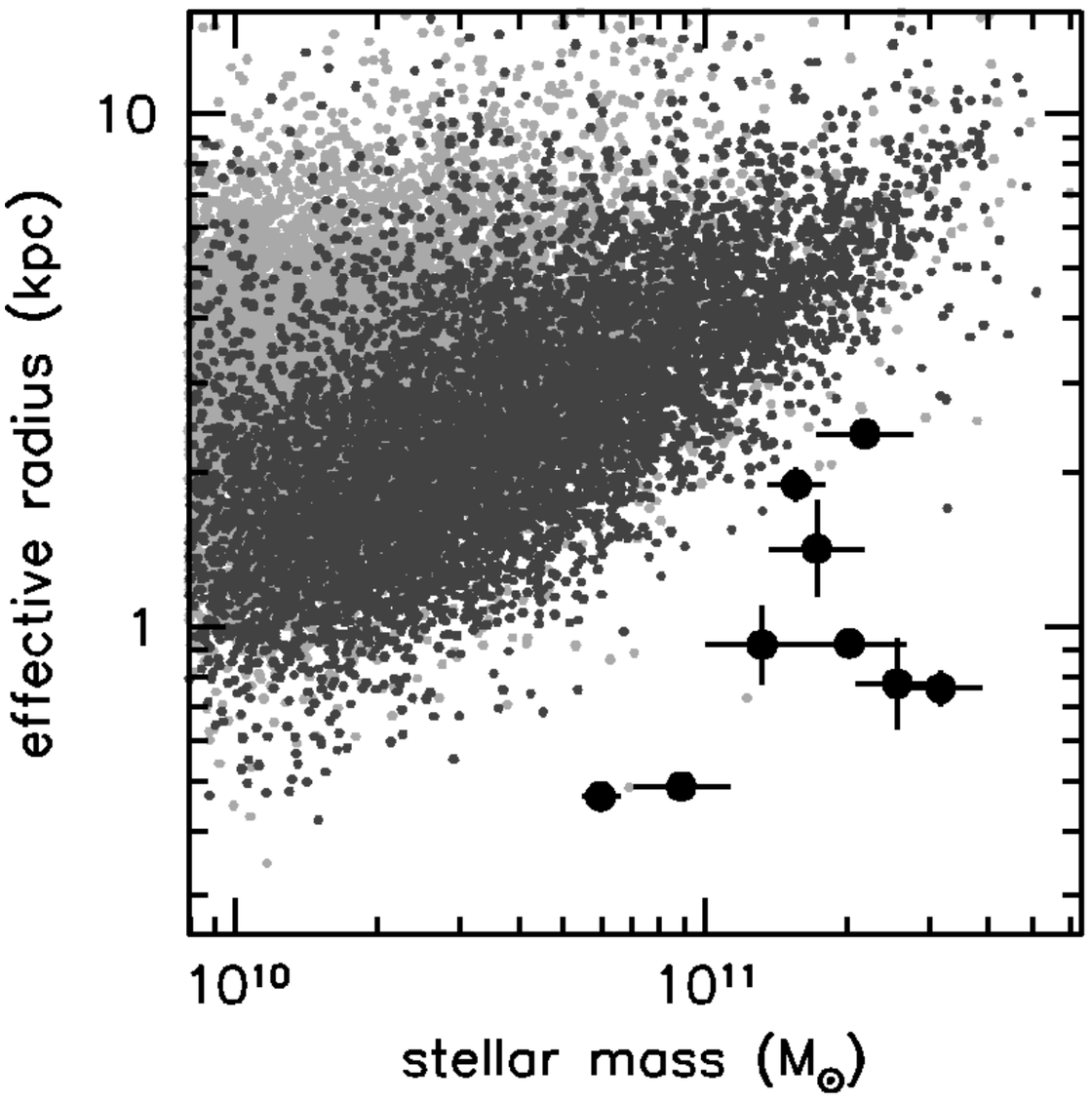
NICMOS
F160W
1.3<z<1.9

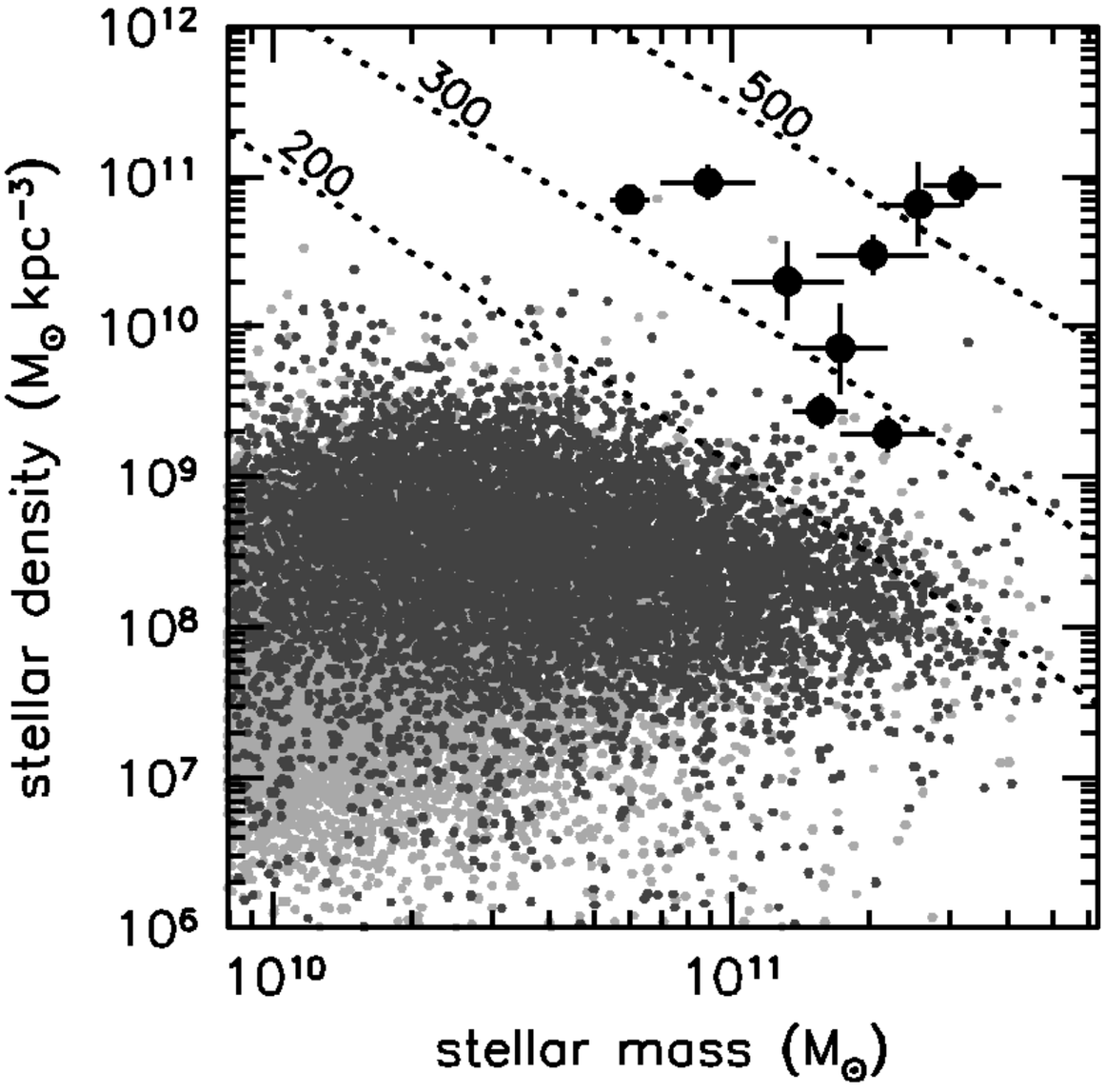


GDDS Paper X – Damjanov et al. 2008



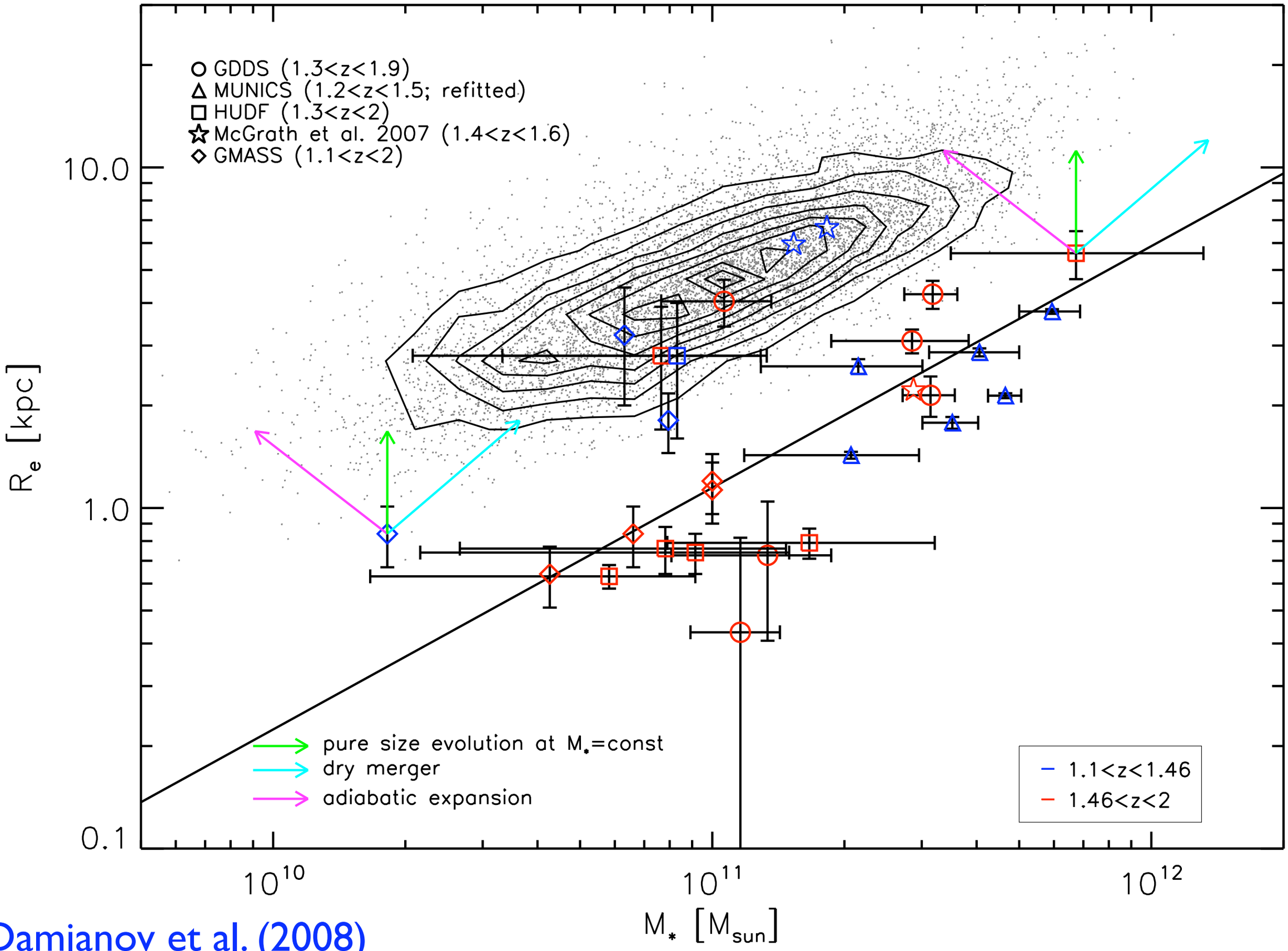
van Dokkum et al. (2008) z~2.3 NICMOS + Keck LGSAO





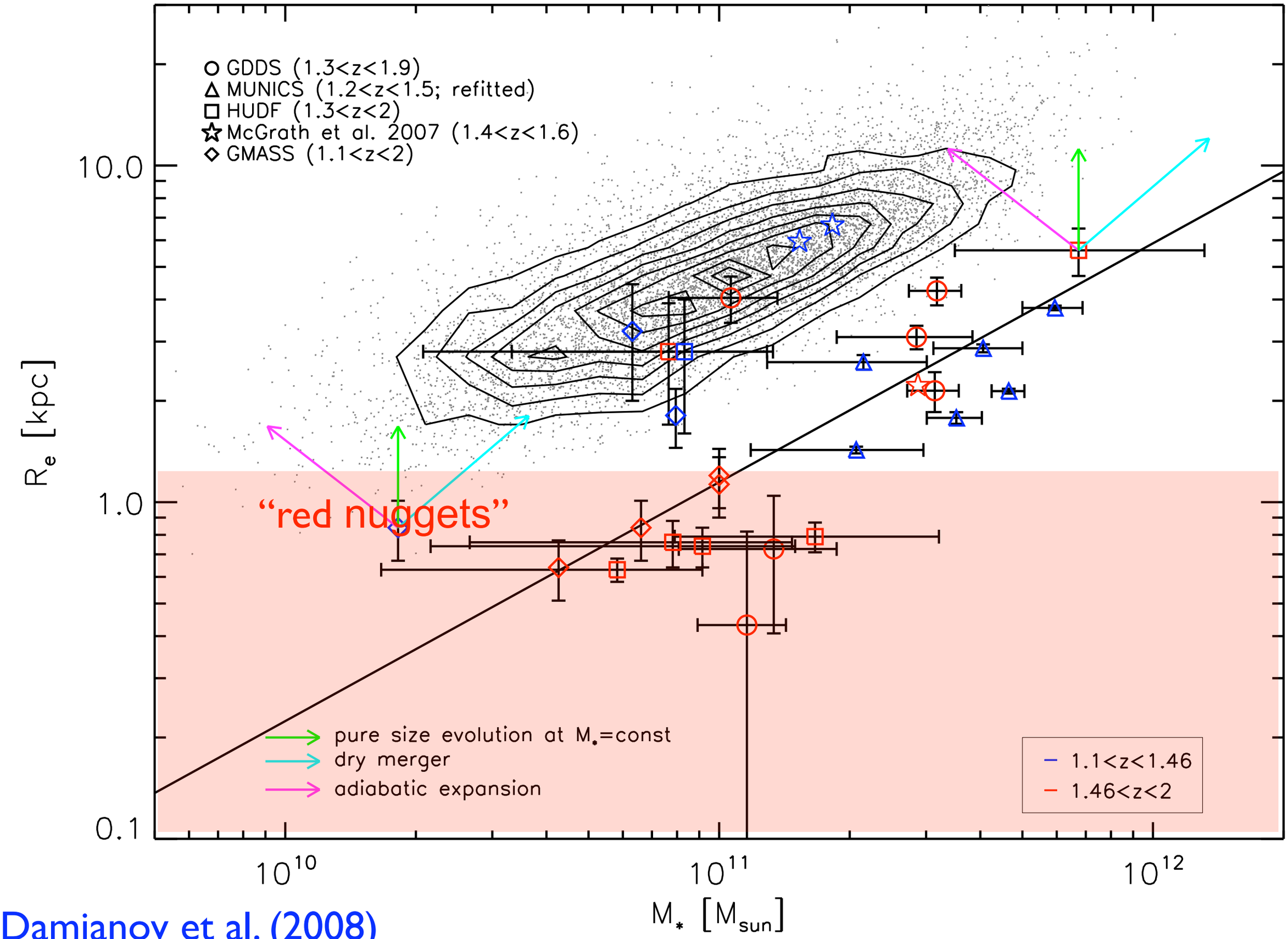
van Dokkum et al. (2008) z~2.3 NICMOS + Keck LGSAO

Size-Mass relation

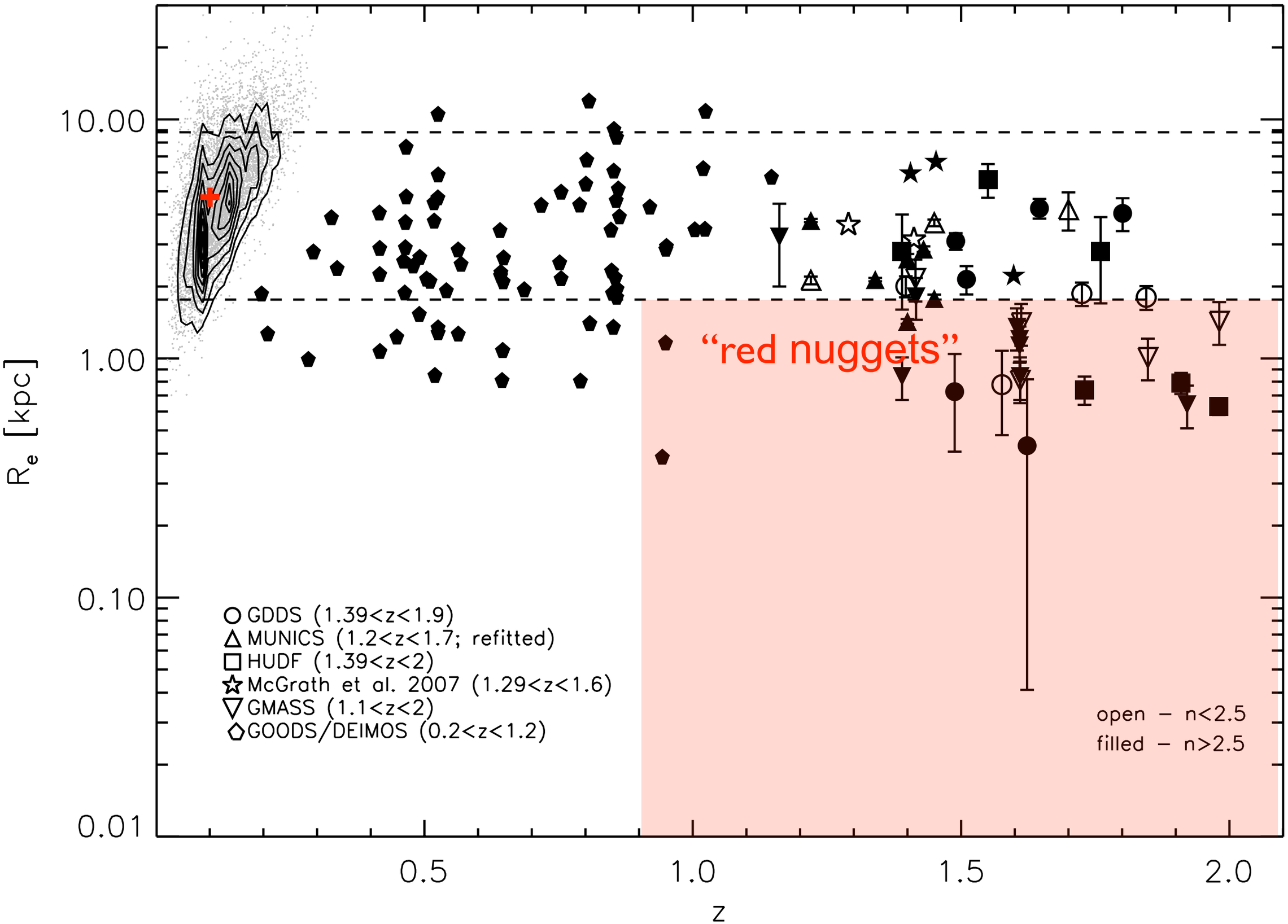


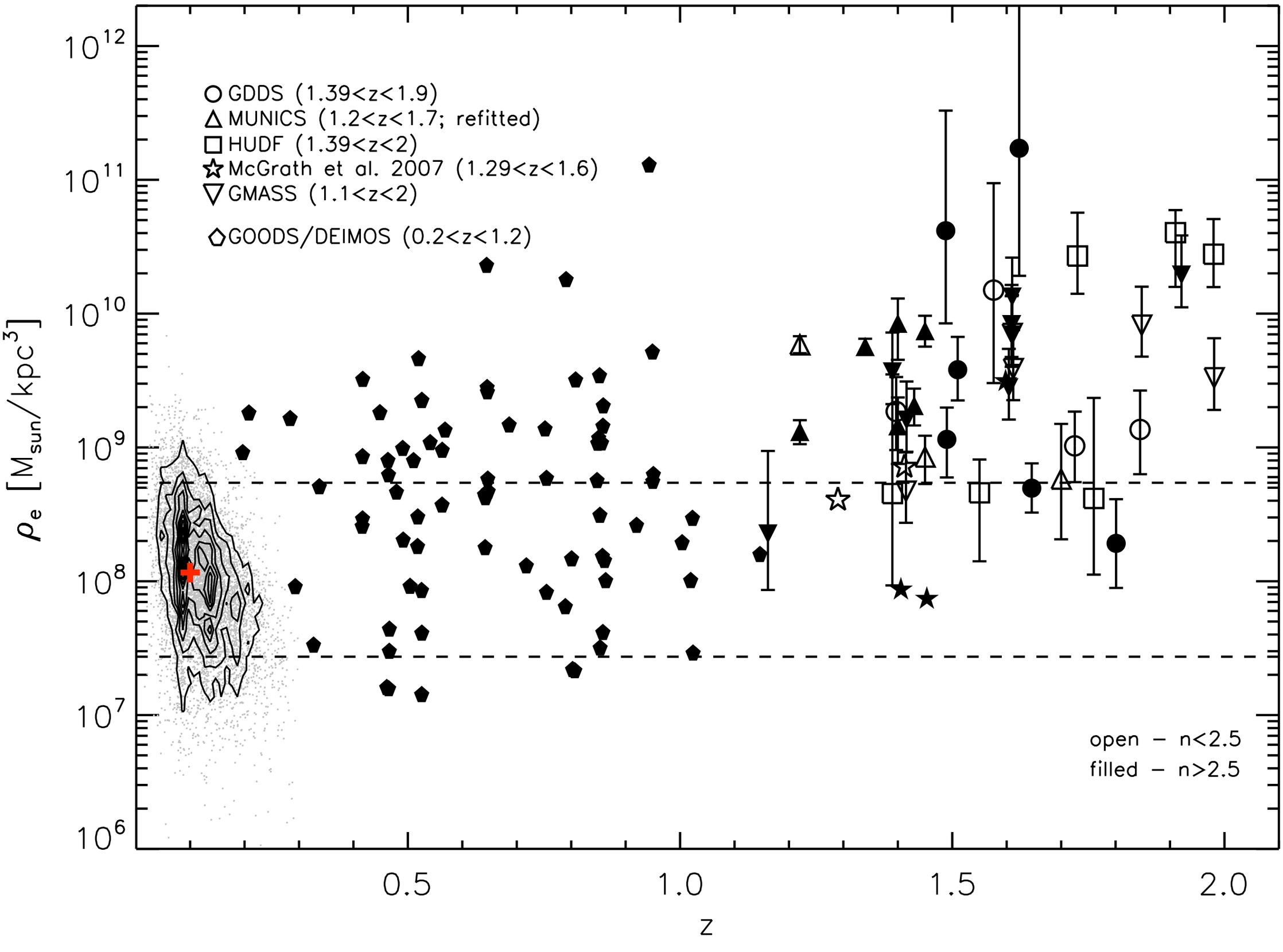
Damjanov et al. (2008)

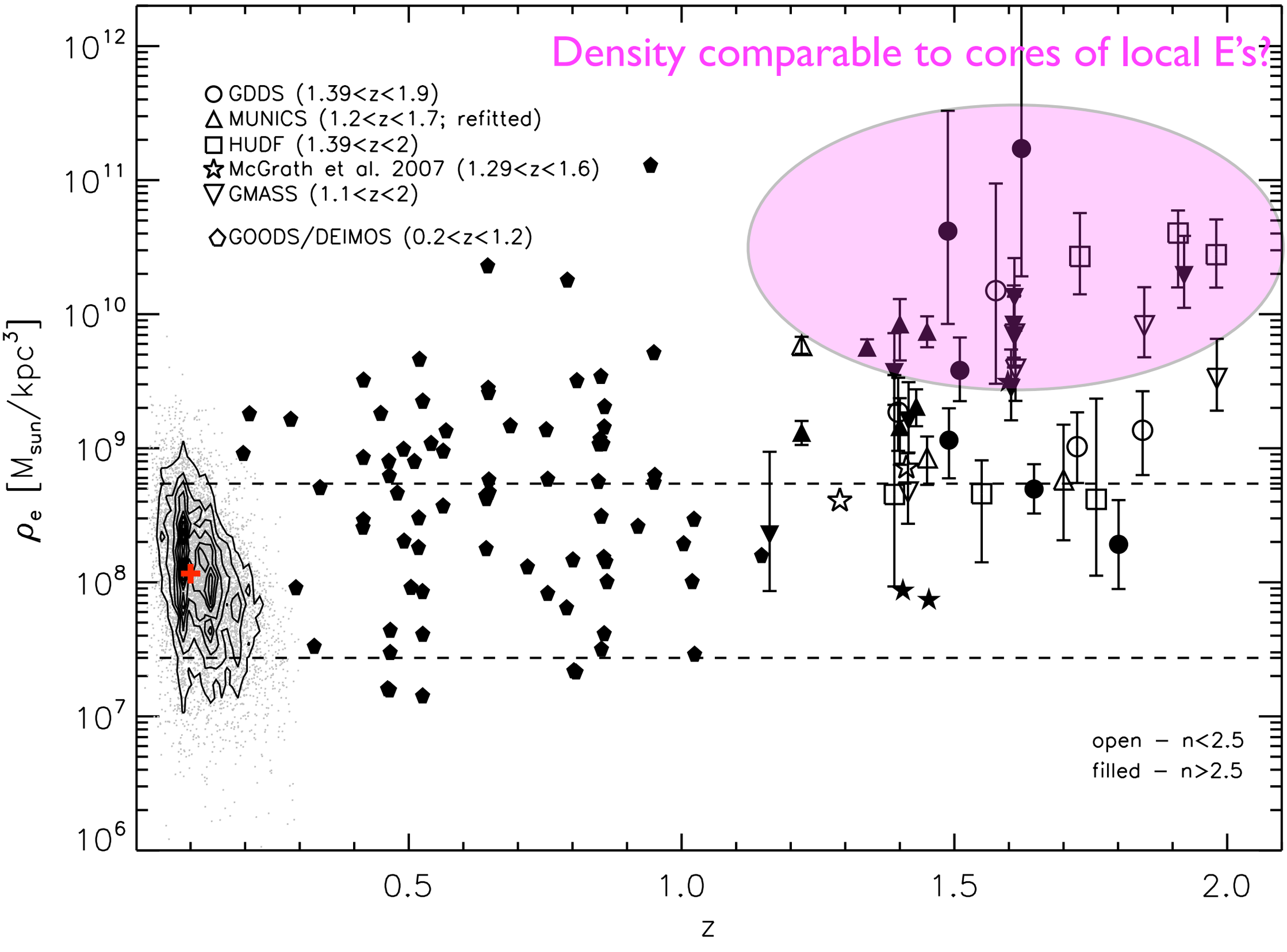
Size-Mass relation

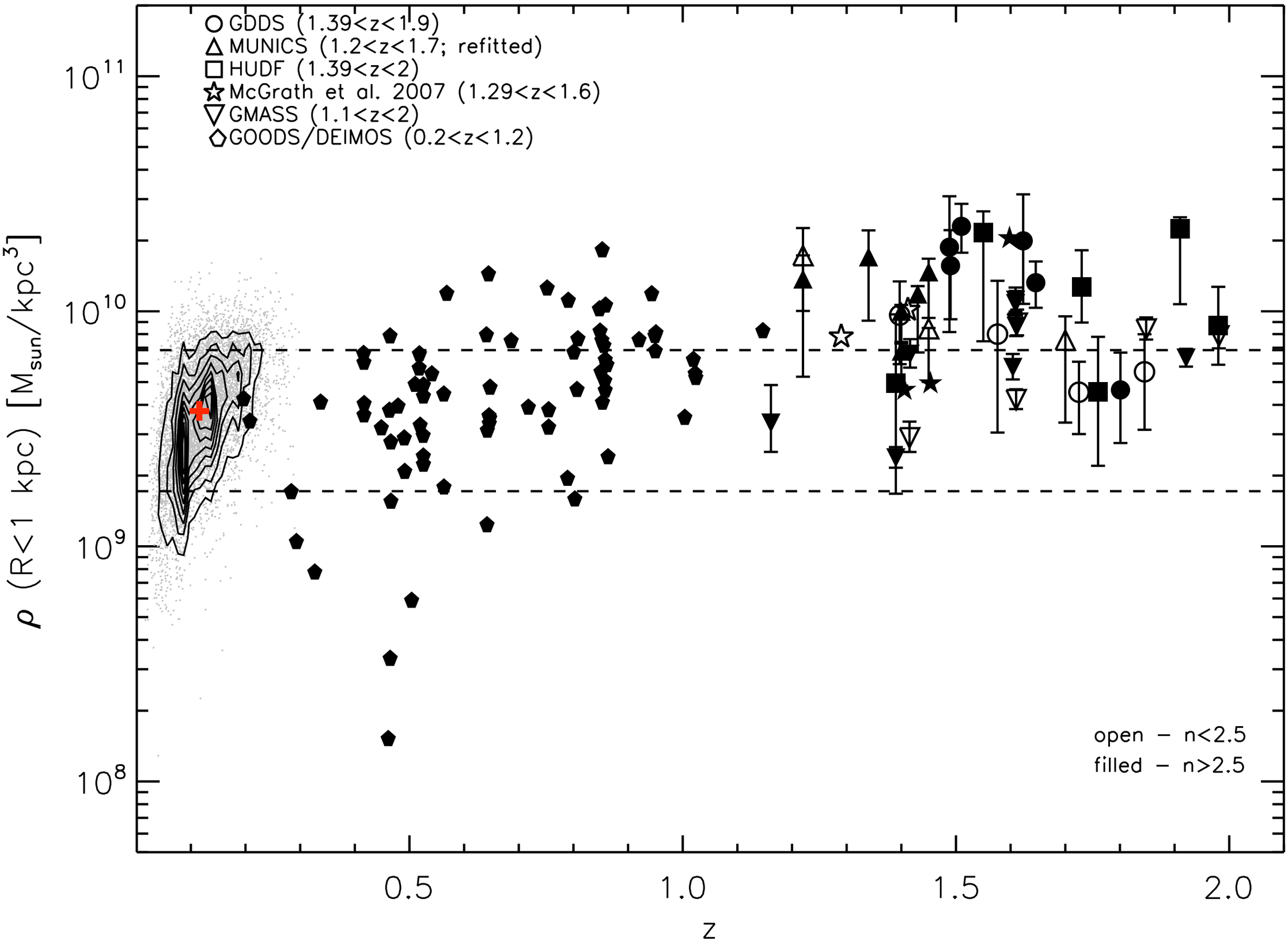


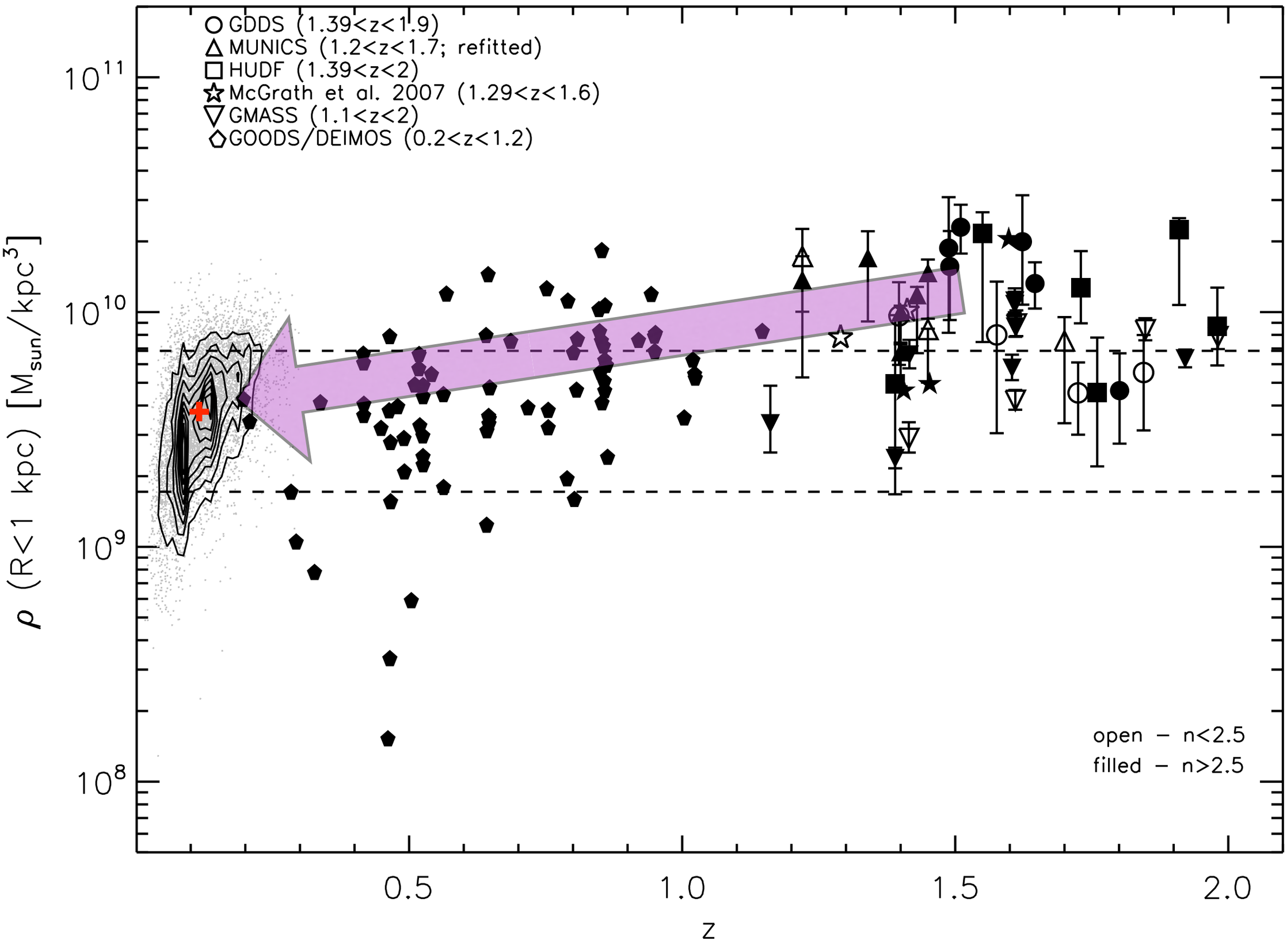
Damjanov et al. (2008)


10.00
1.00
0.10
0.01
R_e [kpc]
0.5
1.0
1.5
2.0
z
"red nuggets"
GDDS (1.39<z<1.9)
MUNICS (1.2<z<1.7; refitted)
HUDF (1.39<z<2)
McGrath et al. 2007 (1.29<z<1.6)
GMASS (1.1<z<2)
GOODS/DEIMOS (0.2<z<1.2)
open – n<2.5
filled – n>2.5


GDDS (1.39<z<1.9)
MUNICS (1.2<z<1.7; refitted)
HUDF (1.39<z<2)
McGrath et al. 2007 (1.29<z<1.6)
GMASS (1.1<z<2)
GOODS/DEIMOS (0.2<z<1.2)
open – n<2.5
filled – n>2.5
ρ_e [M_{sun}/kpc^3]
z
10^{12}
10^{11}
10^{10}
10^9
10^8
10^7
10^6
0.5
1.0
1.5
2.0


Density comparable to cores of local E's?
GDDS (1.39<z<1.9)
MUNICS (1.2<z<1.7; refitted)
HUDF (1.39<z<2)
McGrath et al. 2007 (1.29<z<1.6)
GMASS (1.1<z<2)
GOODS/DEIMOS (0.2<z<1.2)
open – n<2.5
filled – n>2.5
ρ_e [M_{sun}/kpc^3]
10^{12}
10^{11}
10^{10}
10^9
10^8
10^7
10^6
0.5
1.0
1.5
2.0
z


GDDS (1.39<z<1.9)
MUNICS (1.2<z<1.7; refitted)
HUDF (1.39<z<2)
McGrath et al. 2007 (1.29<z<1.6)
GMASS (1.1<z<2)
GOODS/DEIMOS (0.2<z<1.2)
10^{11}
10^{10}
10^{9}
10^{8}
ρ (R<1 kpc) [M_{sun}/kpc^3]
0.5
1.0
1.5
2.0
z
open – n<2.5
filled – n>2.5


GDDS (1.39<z<1.9)
MUNICS (1.2<z<1.7; refitted)
HUDF (1.39<z<2)
McGrath et al. 2007 (1.29<z<1.6)
GMASS (1.1<z<2)
GOODS/DEIMOS (0.2<z<1.2)
open – n<2.5
filled – n>2.5
ρ (R<1 kpc) [M_sun/kpc^3]
10^11
10^10
10^9
10^8
0.5
1.0
1.5
2.0
z

Star's don't evolve
(colours, spectra)

Space Density DOES

Size / physical density
DOES

「一体全体、どういうわけ？」

Ideas

- Dry mergers – no mass growth?
- Pathological IMF evolution?
- Errors in age measurements?

  Ages < 2 Gyr would help considerably

  Rest frame optical spectra (NIR)

- N:1 mergers? ‘Nuggets’ are the ‘core’ of local E’s ?

  Add lots of energy but no mass. e.g. dwarfs (Hopkins, Bezanson)

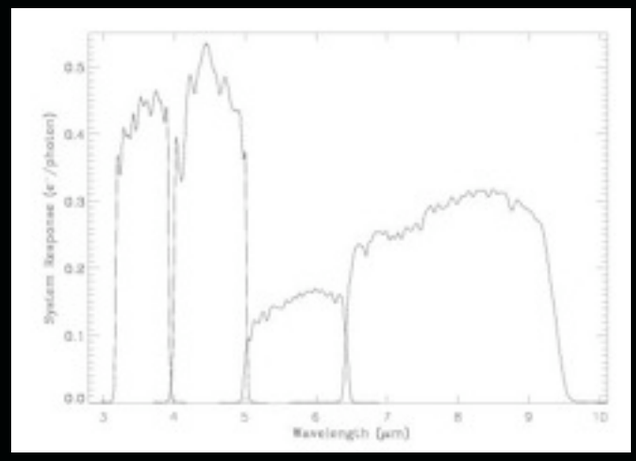
- ‘Hiding mass’ in diffuse haloes at z=0, e.g. BCGs
- Non-adiabatic (rapid) expansion (Fan L., et al. 2008)
- Wacko CDM models??

Part 2

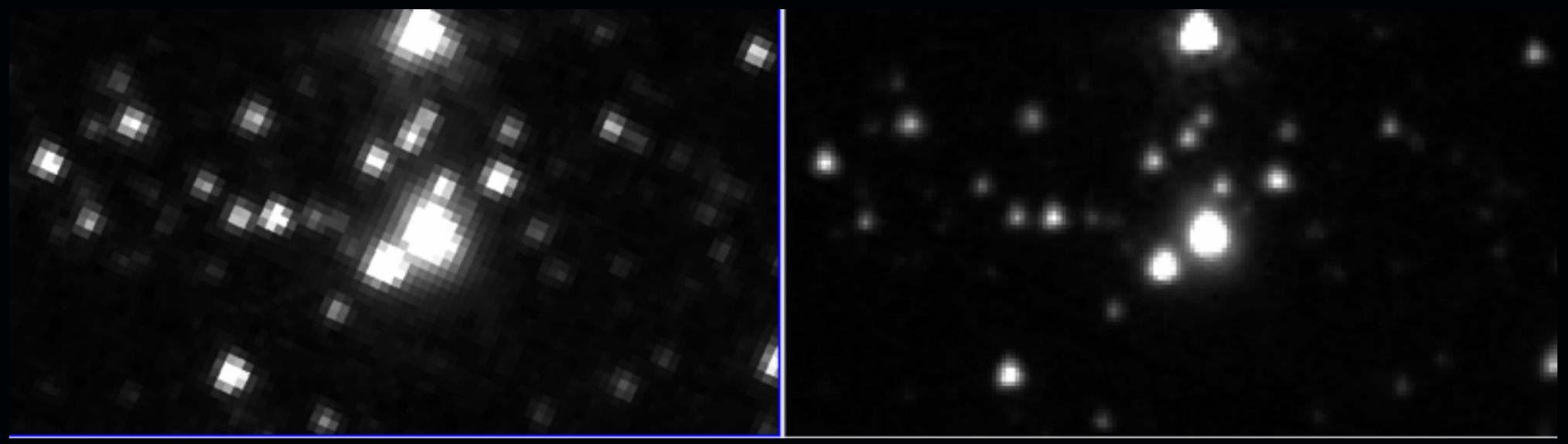
Massive Blue Galaxies – a surprise

GDDS Paper XI – Mentuch et al. (2009) sub.

Observations



- 3/4 GDDS Fields observed for 3.3 h each
  - 5'.2 x 5'.2 dithered exposures to cover whole GDDS field
- InfraRed Array Camera (IRAC)
  - 3.6, 4.5, 5.8 and 8.0 μm coverage
- Detect masses down to 5 x 10^8 $M_\odot$
- Reduced by Spitzer Post-Doc fellow Haojing Yan with current SSC tools
  - Improved spatial resolution from 1".2/pix to 0".6/pix



R F814W 3.6μm 4.5μm 5.8μm 8.0μm

GDDS020715

GDDS020558

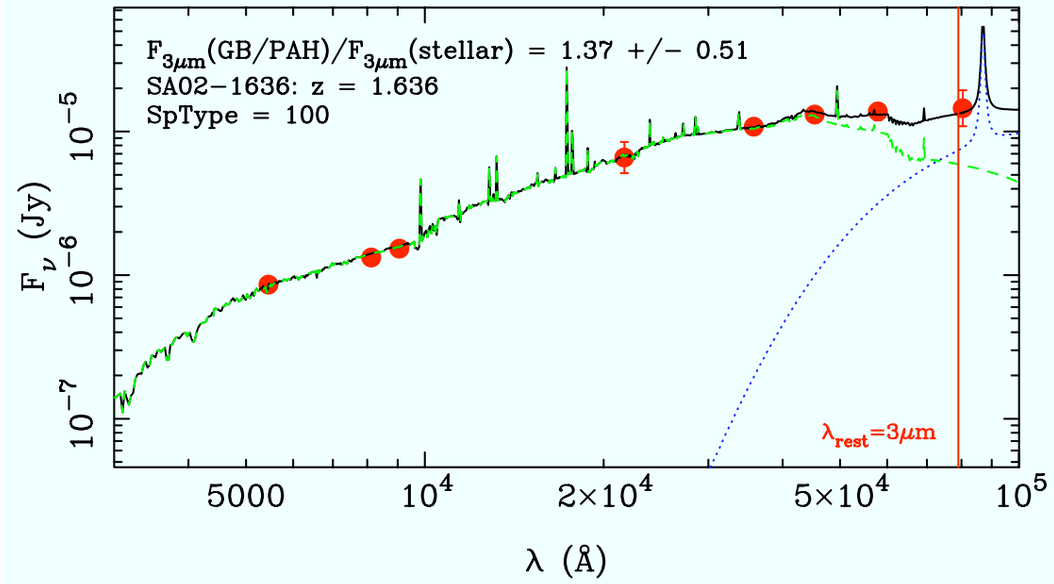
GDDS125869

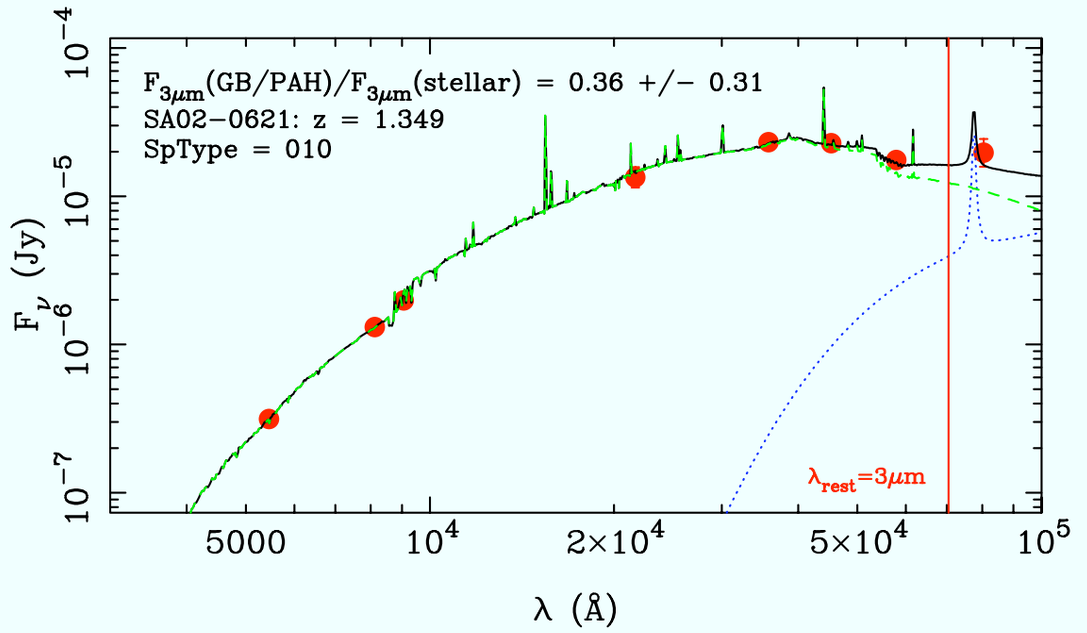
GDDS021255

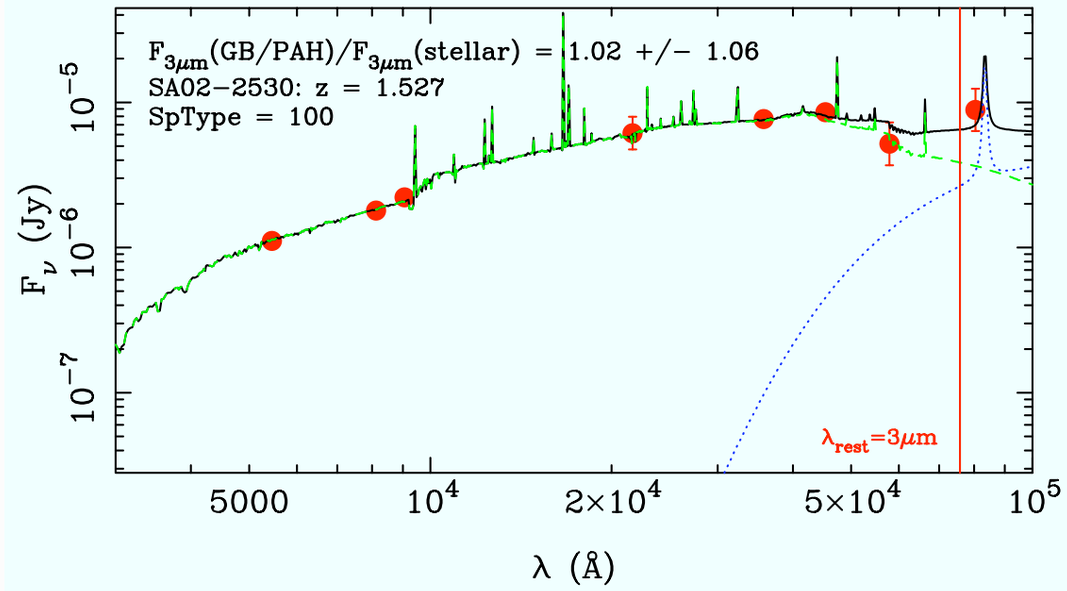
Goal:
Test stellar mass measures (rest-frame 2μm fluxes)

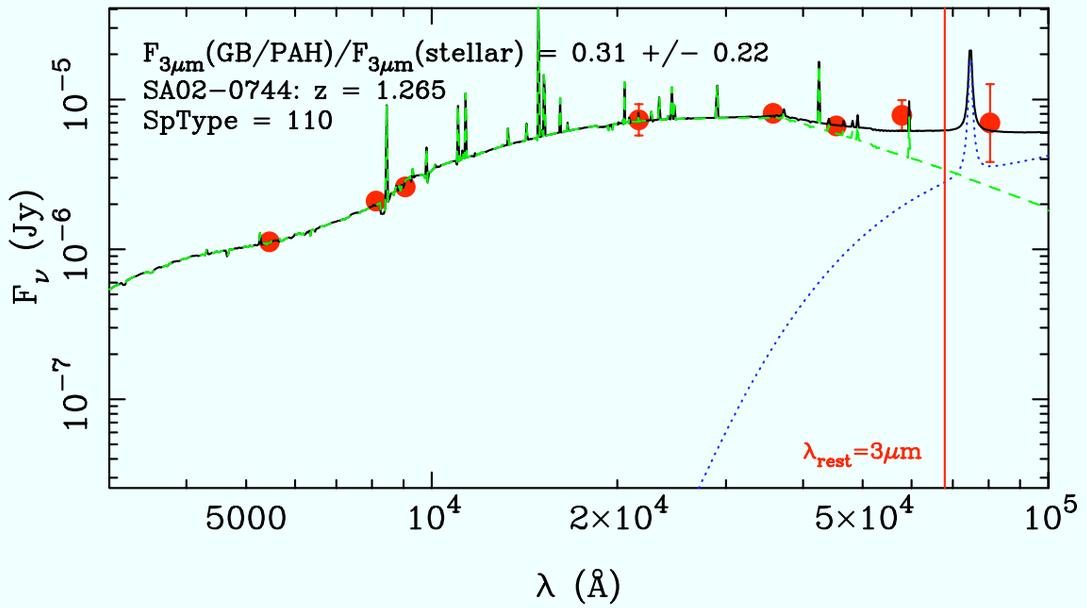
Goal:
Test stellar mass measures (rest-frame 2μm fluxes)

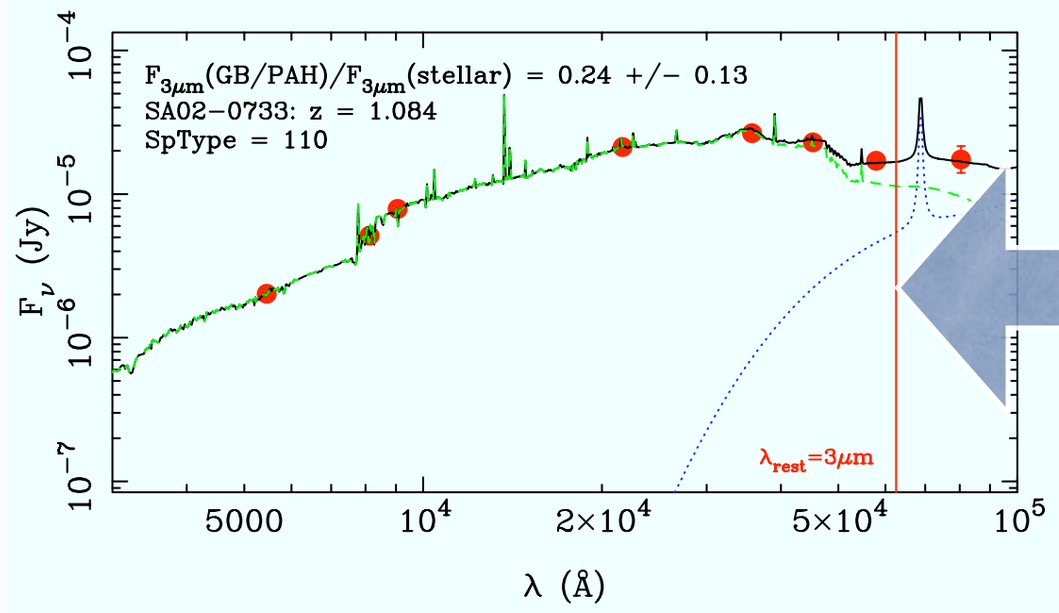
The Surprise





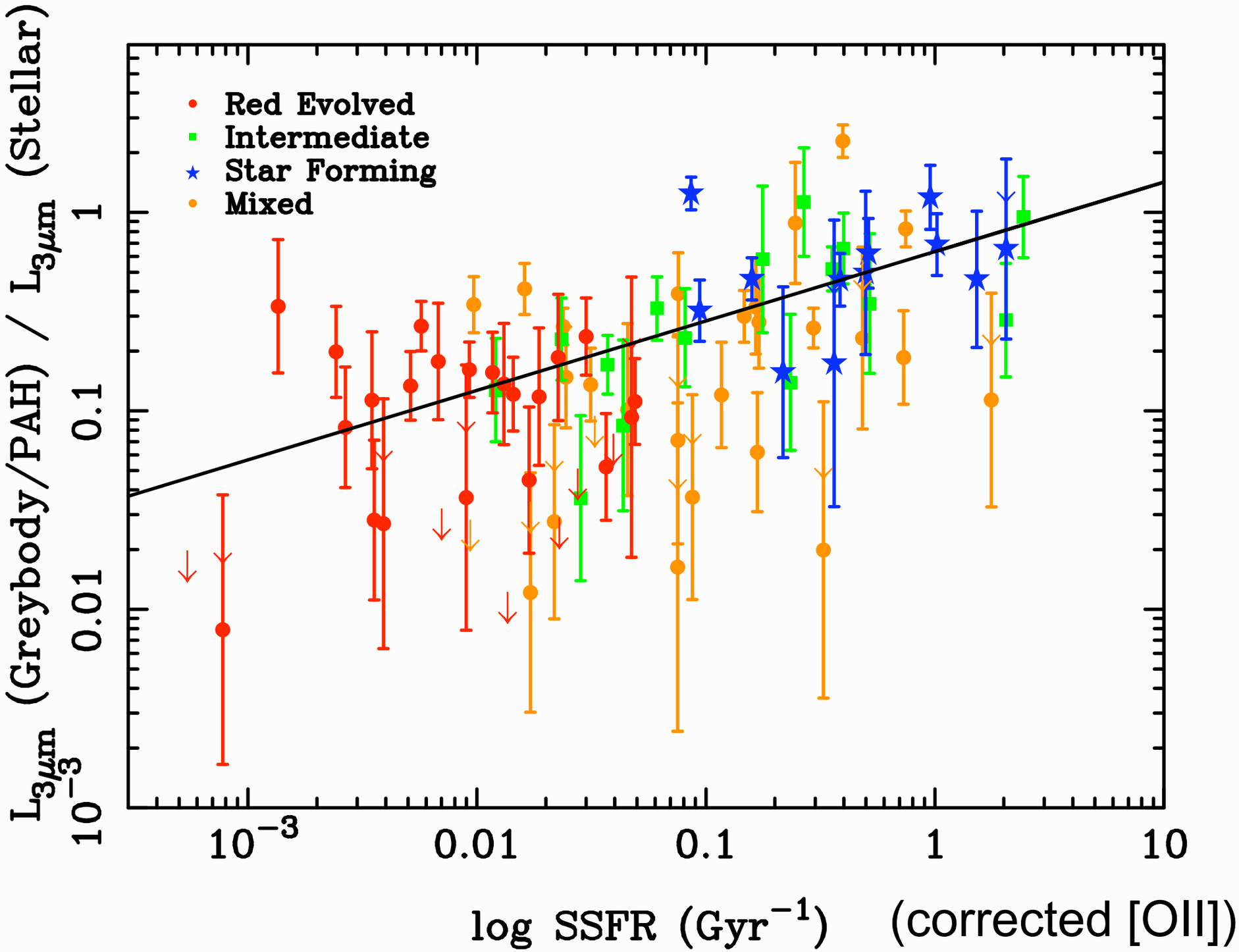




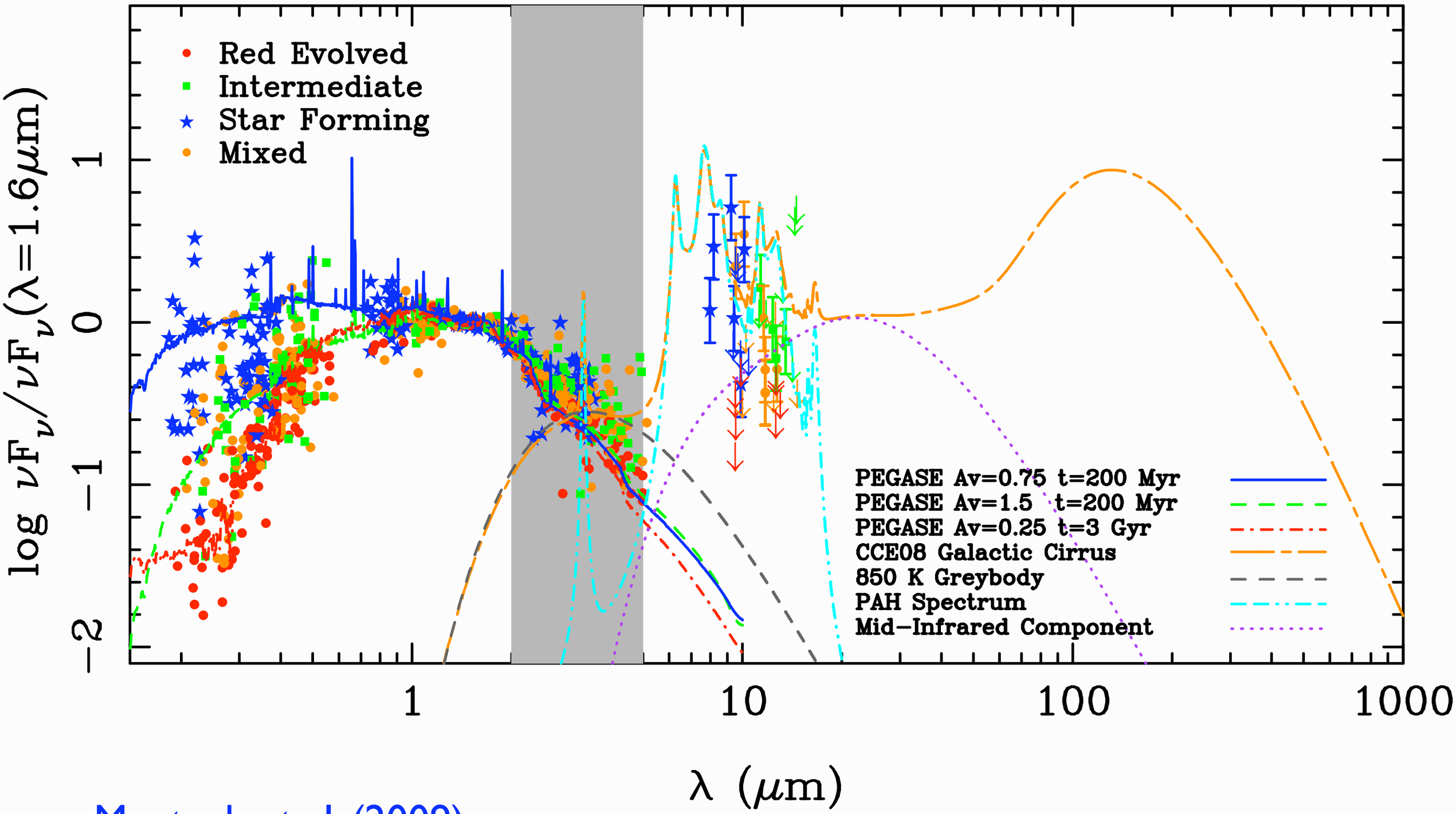


‘L-band excess’

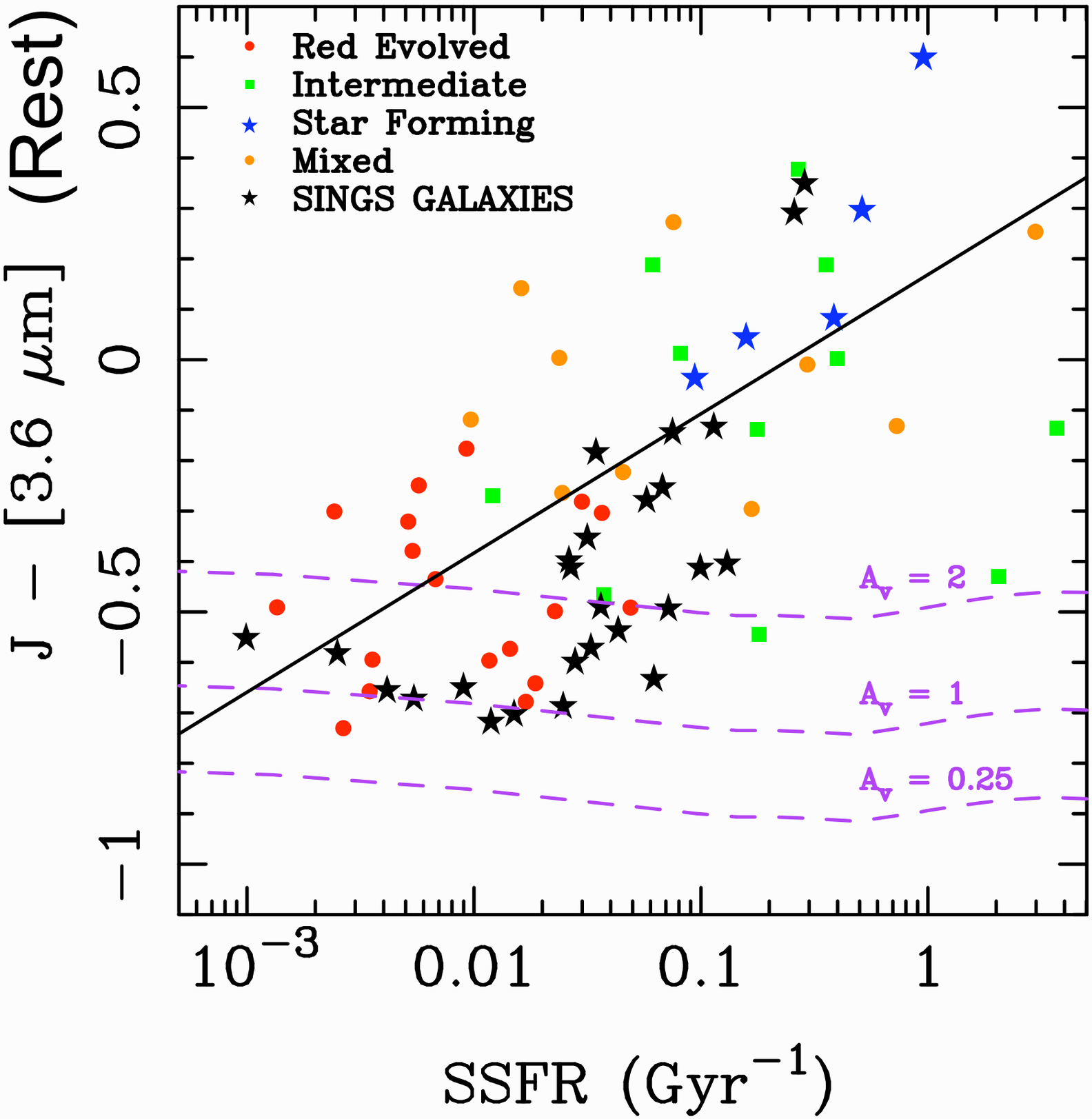
Mentuch et al. (2009) submitted



Mentuch et al. (2009)



Mentuch et al. (2009)



Stellar only

Origin of 3 micron XS?

- T~1000K (‘hot’?) component

  (noted before by numerous authors, c.f. ‘standard’ 200K (‘warm’?) and 20–50K (‘cold’) mid/far-IR dust components)

- Fits as ‘graybody’ cuum + small PAH contrib.
- Reflection nebulae?
- Cirrus?
- Dusty Post-AGB stars?

Energetics don’t work!

A new hypothesis...

The Credit

Erin Mentuch
Toronto

A new hypothesis...

The Credit

Erin Mentuch
Toronto

A new hypothesis...

Bob Abraham
Toronto

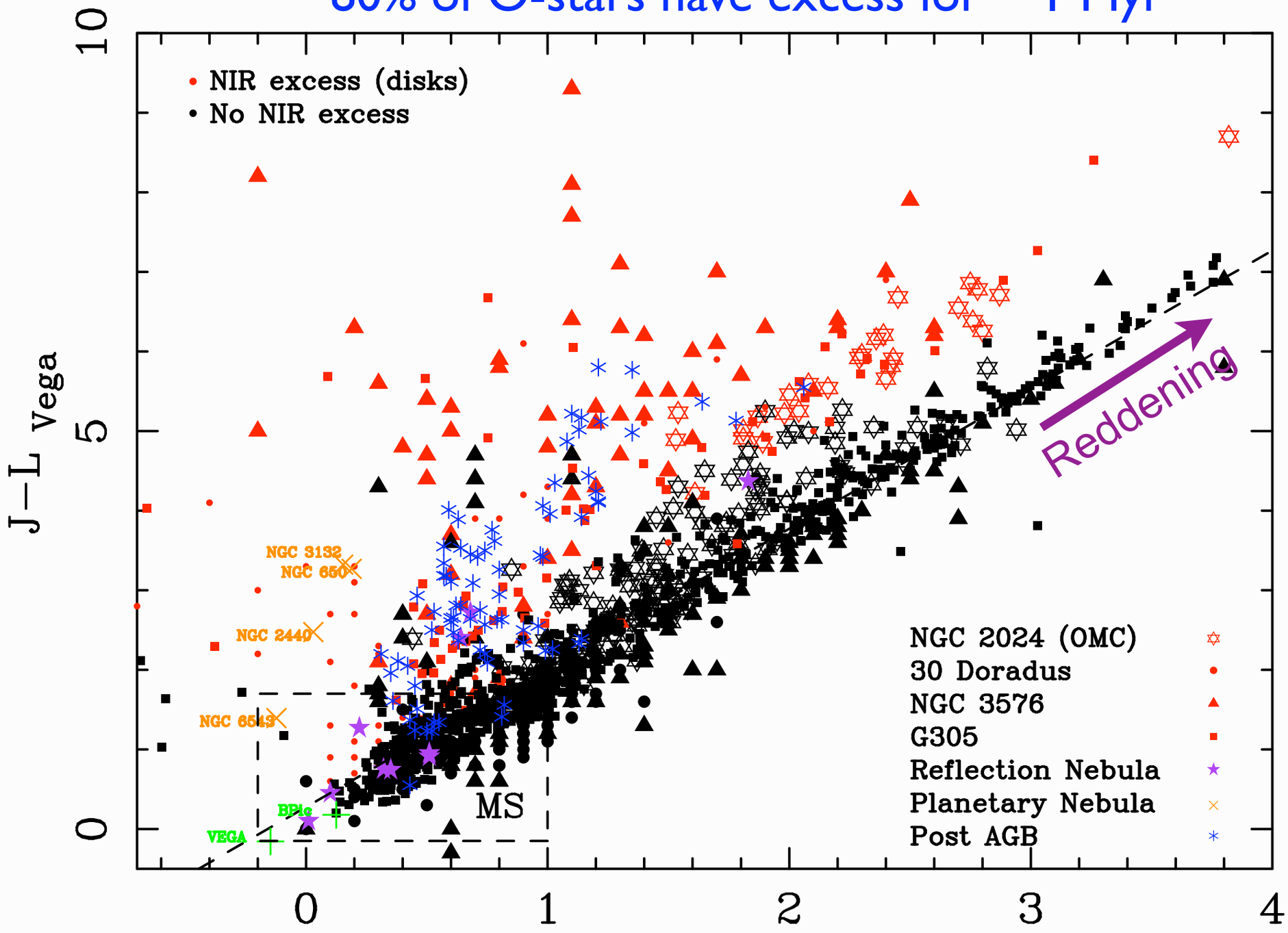
Karl Glazebrook
Swinburne

The Blame

Circumstellar disks?

Circumstellar disks?

~80% of O-stars have excess for ~ 1 Myr



Mentuch et al. (2009)

Does it work?

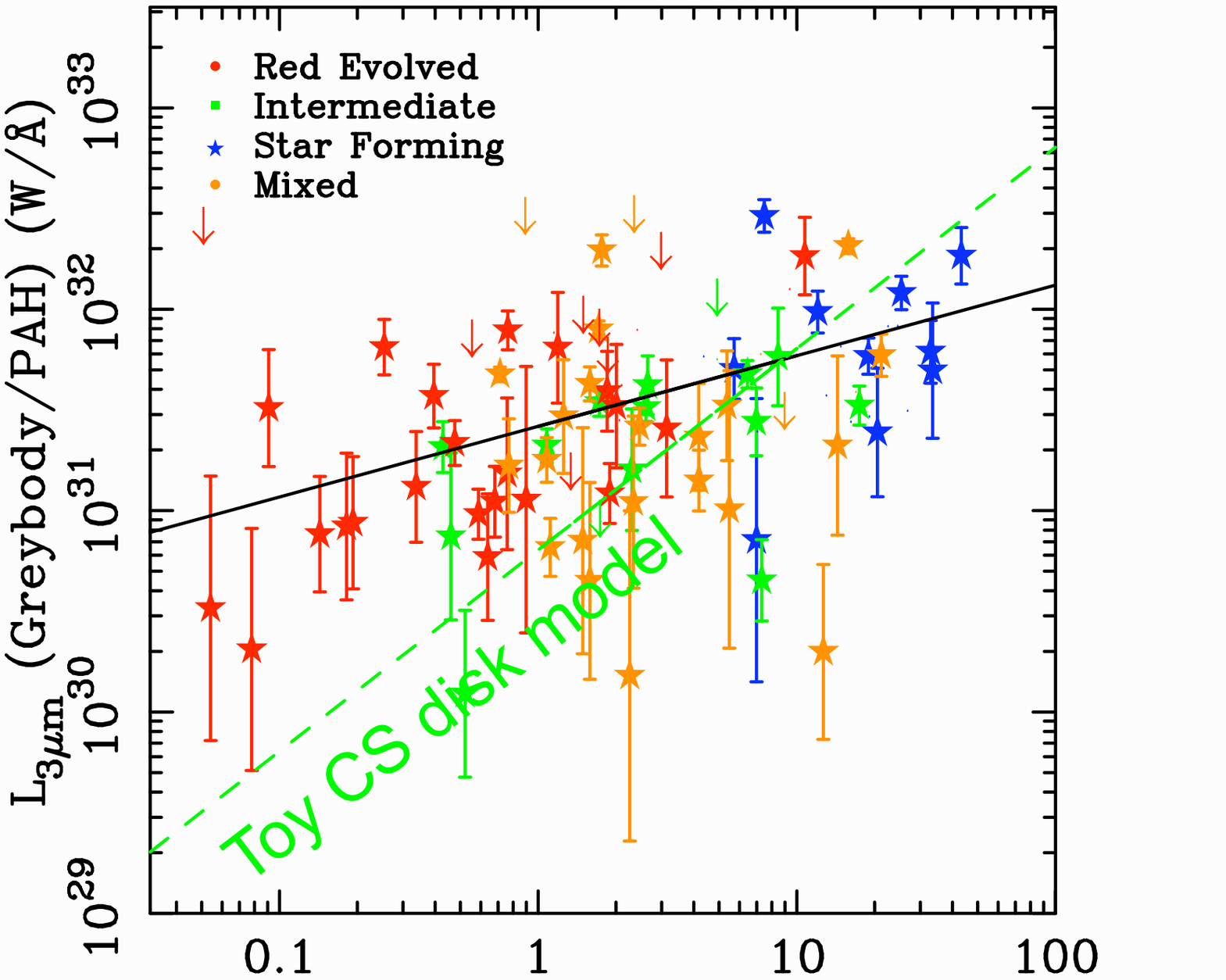
- M/L data as a f(M) for circumstellar disks
  (from Dullemond et al. 2001)
- Lifetime of 1 Myr for excess
- Feed in to SFR model with Baldry & Glazebrook (2003) IMF

Does it work?

Mentuch et al. (2009)

Does it work?

Yes!!



Mentuch et al. (2009)

Take home messages

- Can observe red galaxy build-up since z=3
- Strong size evolution in Elliptical galaxies

  Factor of 4 since z=2!

  Do we really understand galaxy evolution?

- Star-forming galaxies display L-band excess

  Circumstellar disks around O stars? → ~1000K dust?

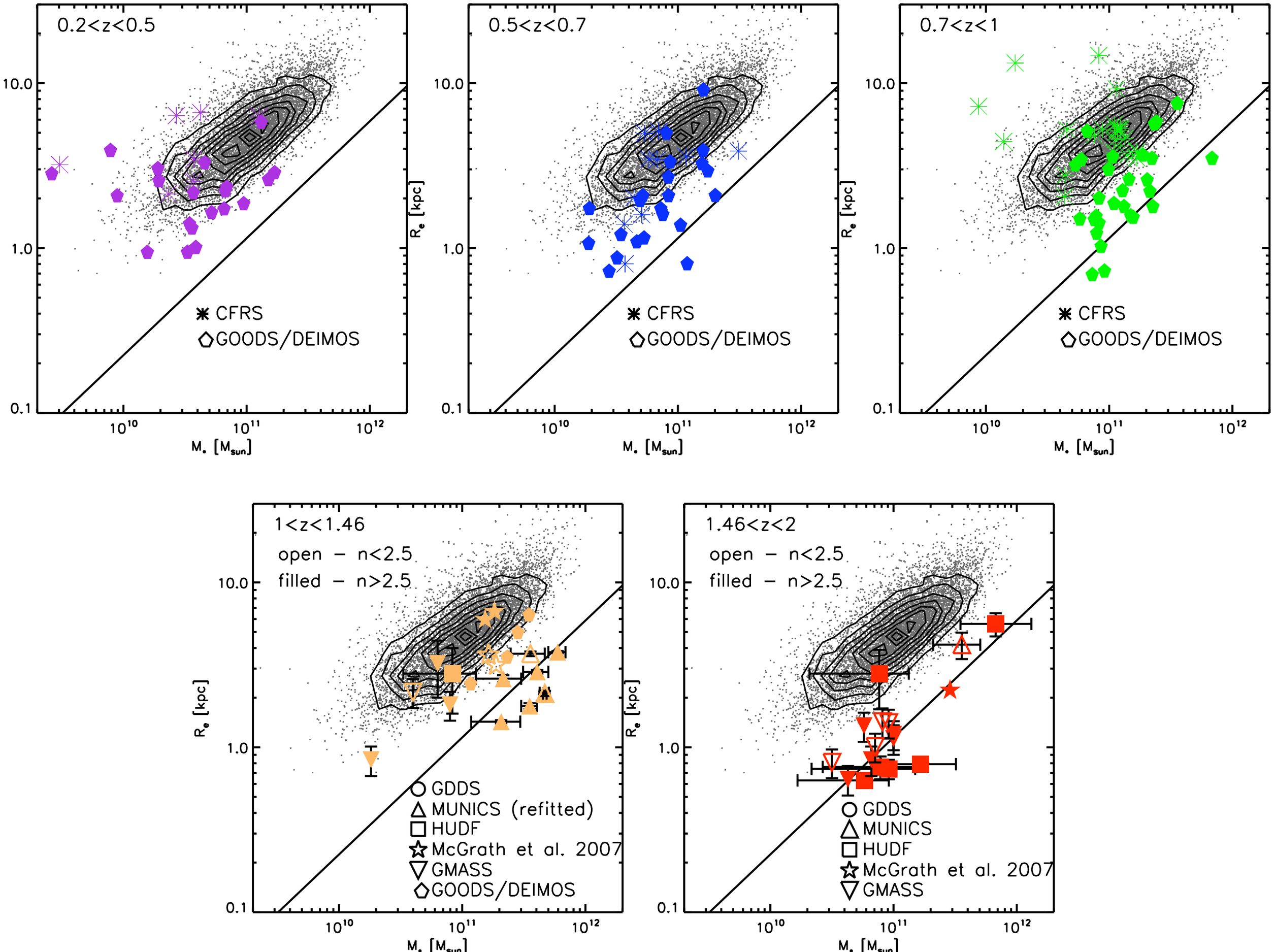
  (Note L XS light is dominated by M>20$M_\odot$ stars)

  Planet formation at z=2???

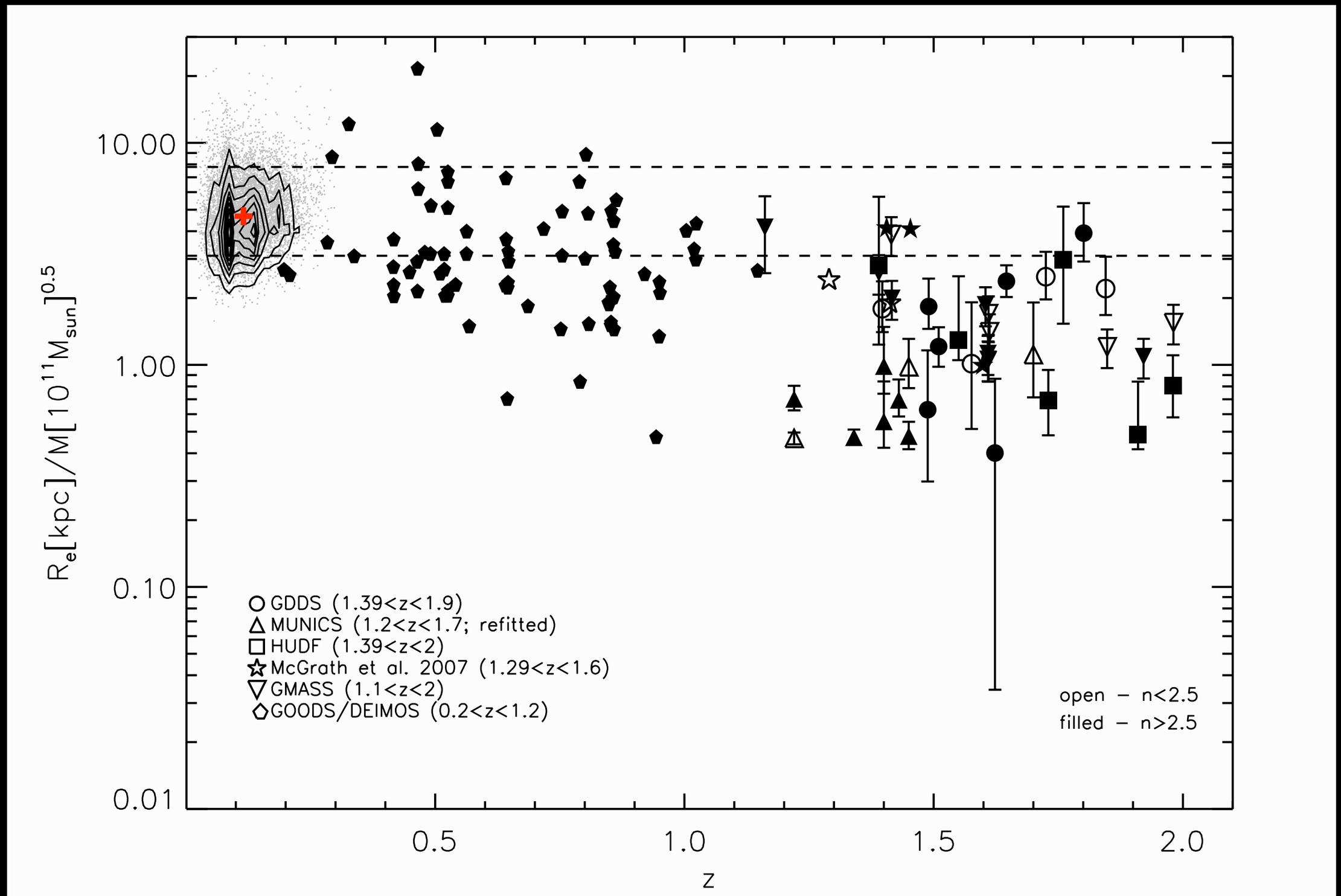
- z<4 Galaxy evolution is still INTERESTING!!!

質問の時間です。

Backup slides


0.2<z<0.5
0.5<z<0.7
0.7<z<1
1<z<1.46
1.46<z<2
open – n<2.5
filled – n>2.5
CFRS
GOODS/DEIMOS
GDDS
MUNICS (refitted)
MUNICS
HUDF
McGrath et al. 2007
GMASS
10.0
1.0
0.1
10^10
10^11
10^12
M* [Msun]
Re [kpc]

Normalized sizes



Red Evolved
Intermediate
Star Forming
Mixed

Stellar model

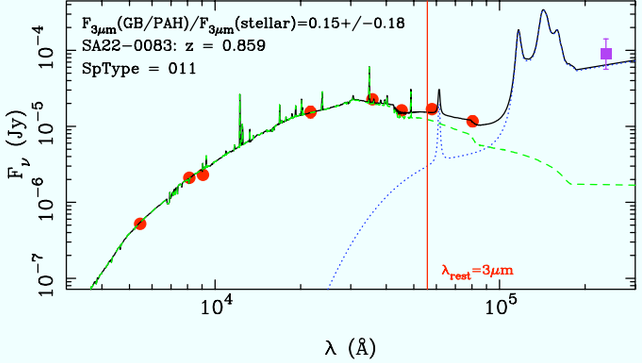
Stellar + Greybody/PAH model

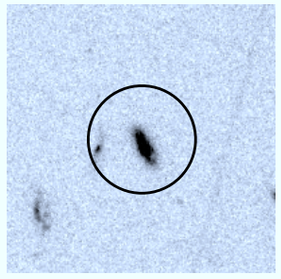
F_ν (obs.) / F_ν (model)

0.2
0.5
1
2

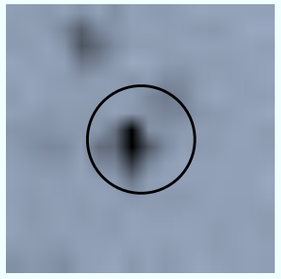
2000
5000
10^4
2×10^4
5×10^4

λ (Å)

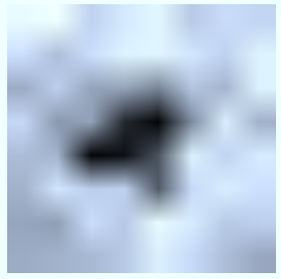




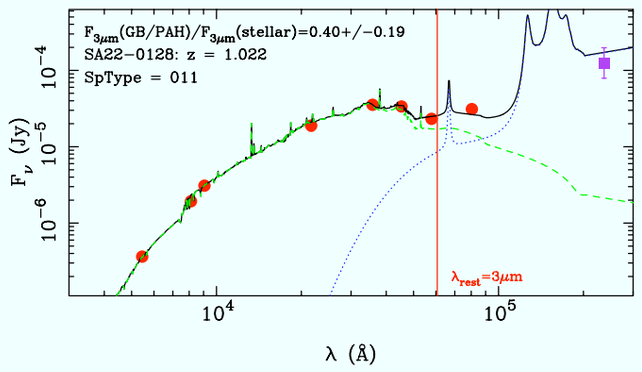
ACS [814W]

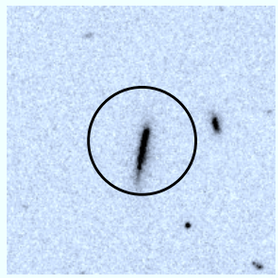


IRAC [3.6 μm]



MIPS [24 μm]





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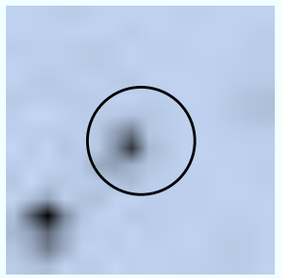
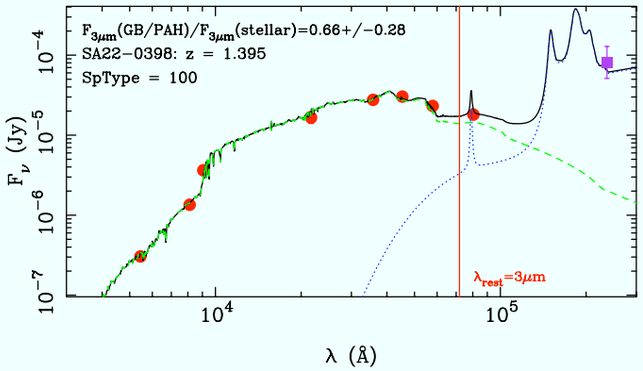
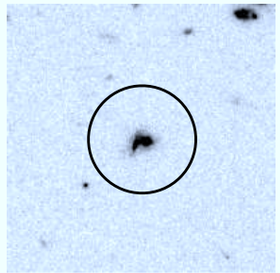


IRAC [3.6 μm]

MIPS [24 μm]





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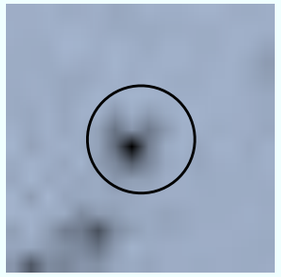

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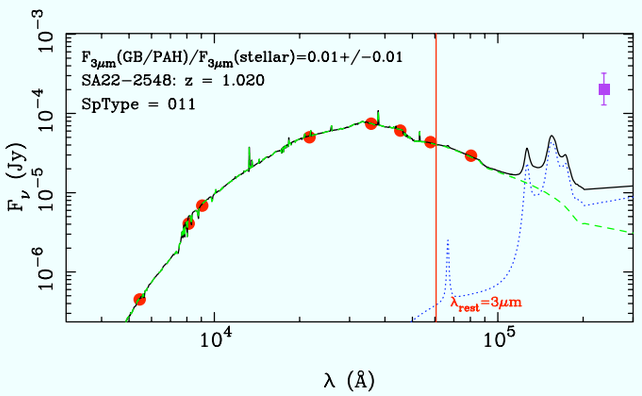
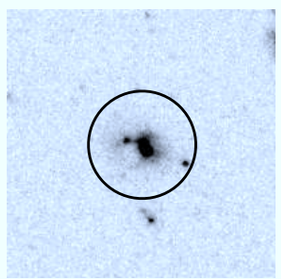
MIPS [24 μm]





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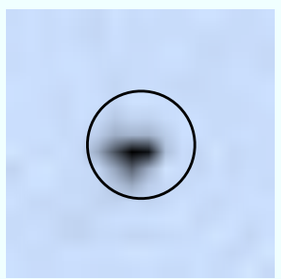

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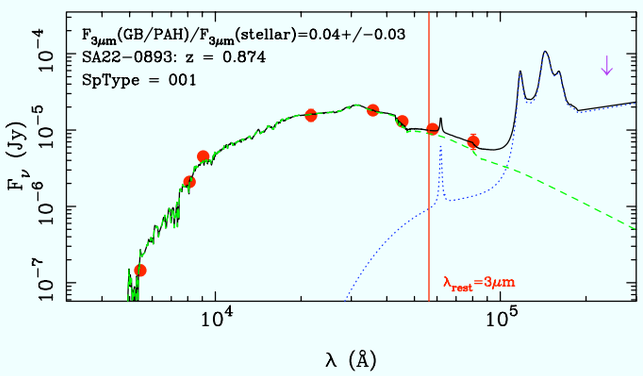

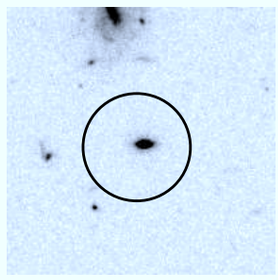

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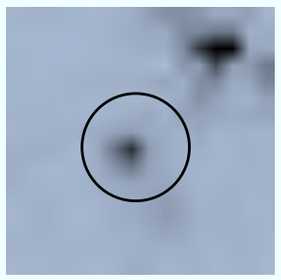

IRAC [3.6 μm]

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