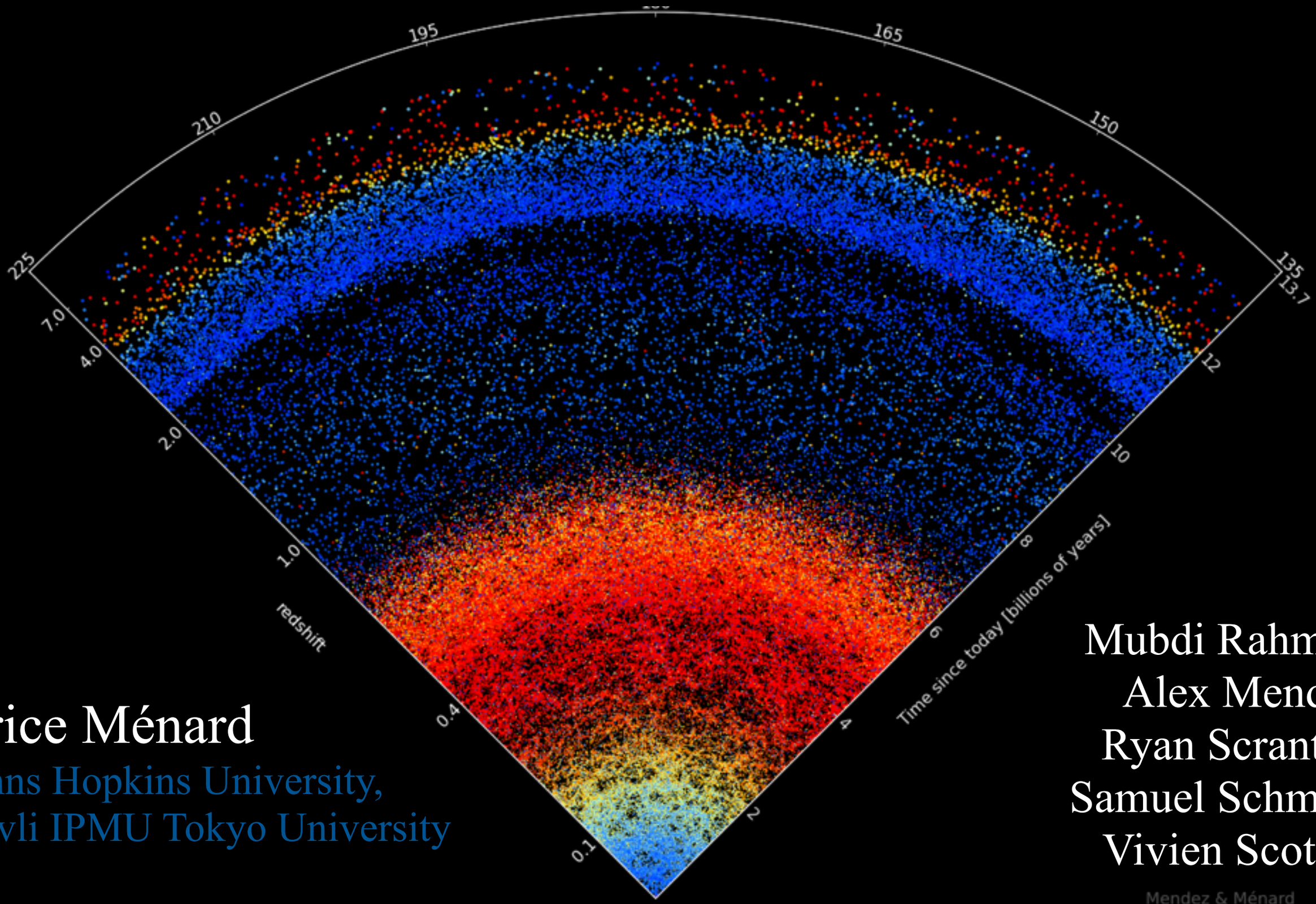
Clustering-based redshift estimation with LSST & DESI



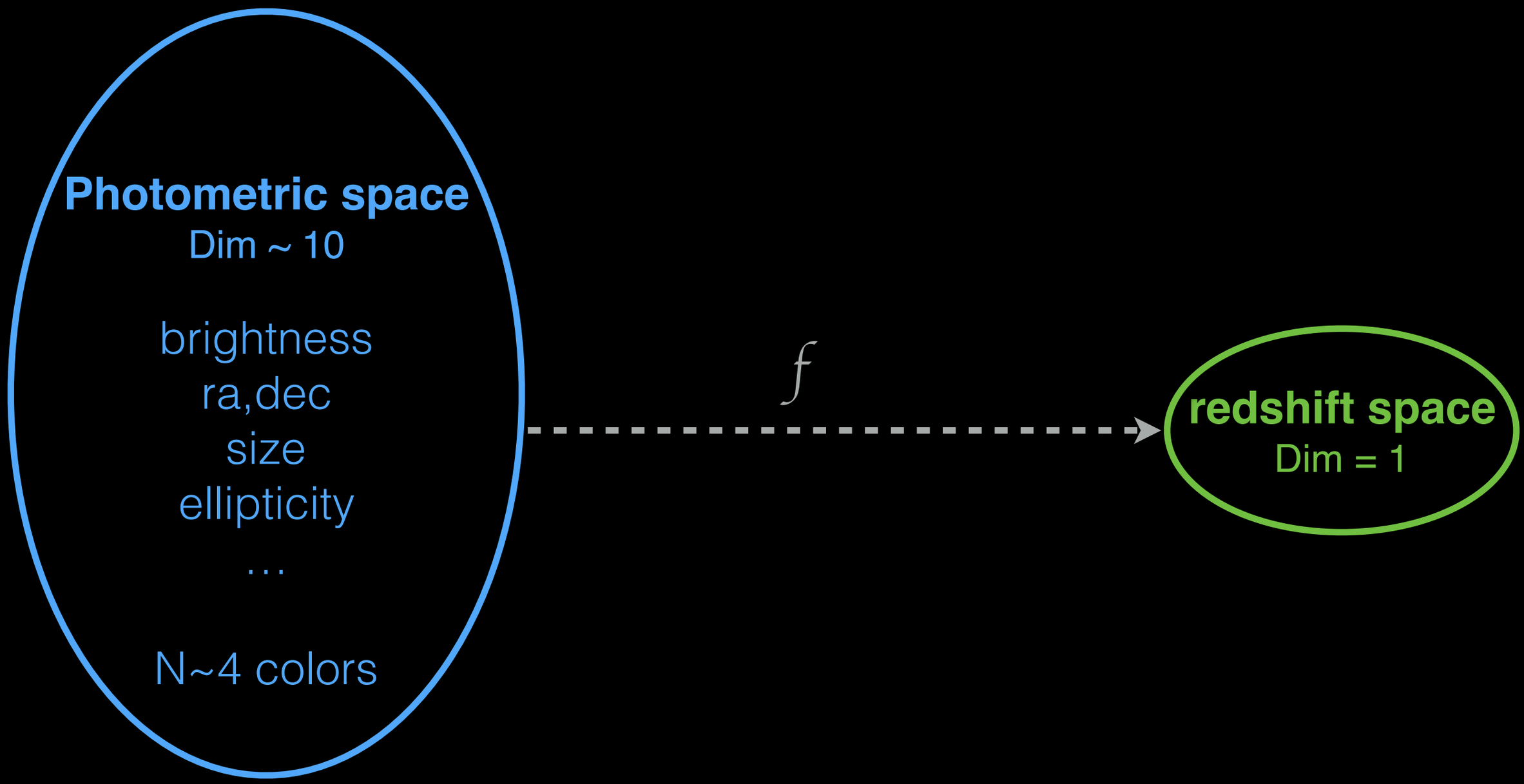
Brice Ménard
Johns Hopkins University,
Kavli IPMU Tokyo University

Mubdi Rahman
Alex Mendez
Ryan Scranton
Samuel Schmidt
Vivien Scottez

Mendez & Ménard

What is a photometric redshift?

Photometric redshift estimation is a **<u>mapping</u>** from the photometric space $\{F_i\}$ to redshift.



What is a photometric redshift?

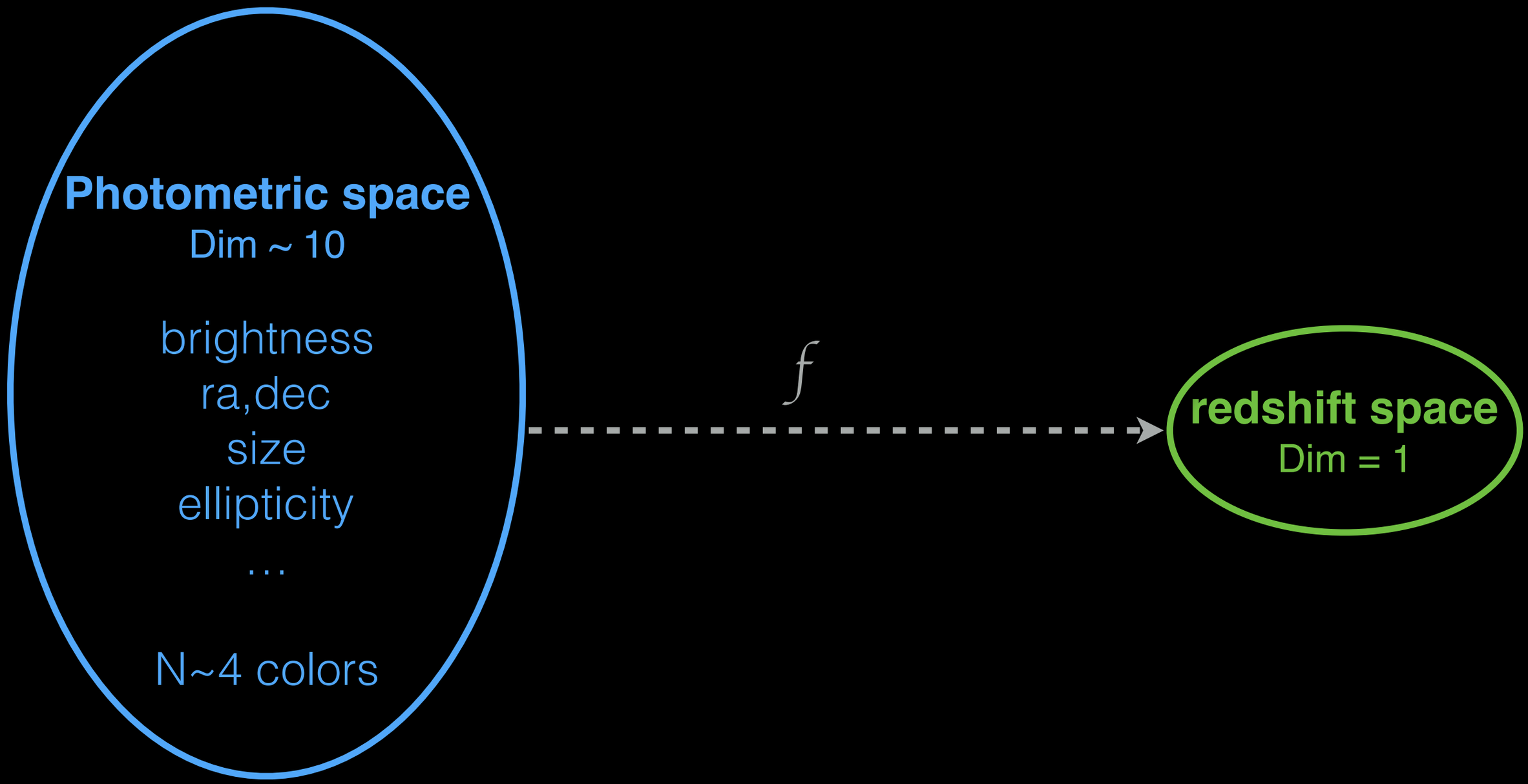
Photometric redshift estimation is a **mapping** from the photometric space $\{F_i\}$ to redshift.

Any measured property in {Fi} has an associated noise estimate. A photometric source is not just a point in {Fi} but a region defined by the noise level.

$p(z \mid \{F_i\})$ does not apply to a given object but to a class of objects statistically indistinguishable.

Color-based photometric redshifts are the same for all galaxies with similar colors (set by photometric errors).

What is a photometric redshift?



Mapping the photometric space to redshift space

Photomet

Dim

brigh

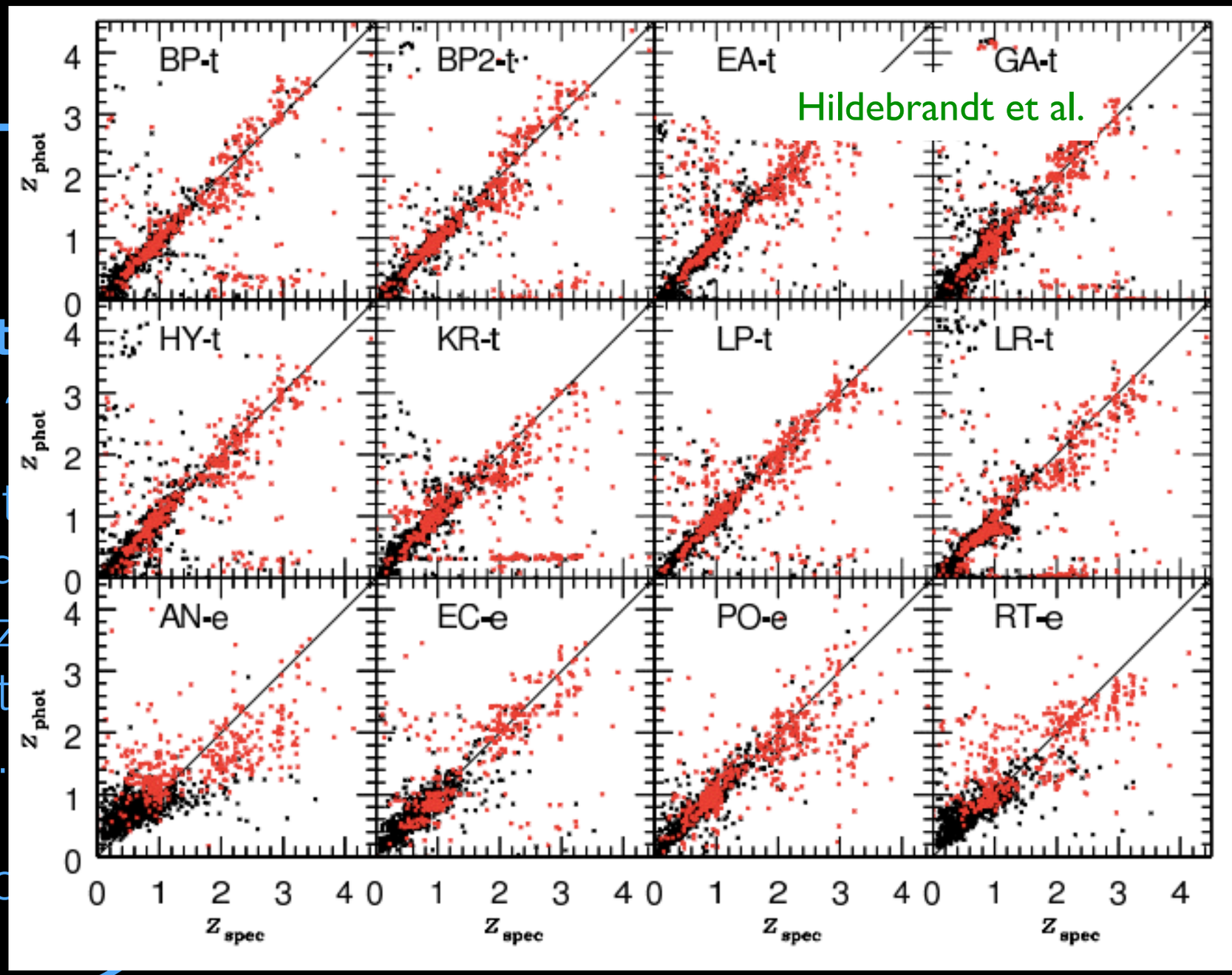
ra,c

siz

ellipt

..

N~4 c



t space

= 1

f **Photometric Redshifts**

SEDs or Training Sets

Mapping the photometric space to redshift space

Photometric space
Dim ~ 10

brightness
ra,dec
size
ellipticity
…

N~4 colors

redshift space
Dim = 1

$\hat{f}$

Photometric Redshifts
SEDs or Training Sets

Mapping the photometric space to redshift space

$\hat{f}$ **Clustering Redshifts**
Spatial Correlation with Reference Set

$< \partial \, . \, \partial_{ref}(ra,dec) >$

Schneider et al. (2006)
Ho et al. (2008)
Newman (2008, 2010)
Ménard et al. (2013)
Schmidt et al. (2013)
McQuinn & White (2013)

Photometric space
Dim ~ 10

brightness
ra,dec
size
ellipticity
…

N~4 colors

redshift space
Dim = 1

$\hat{f}$ **Photometric Redshifts**
SEDs or Training Sets

$< color \, . \, F_{ref}(\lambda) >$

?

$< \partial_i \, . \, \partial_{unknown} >$

?

$< \partial_i \, . \, \partial_{unknown} >$

Mapping the photometric space to redshift space

$\hat{f}$ **Clustering Redshifts**
Spatial Correlation with Reference Set

$< \partial \, . \, \partial_{ref}(ra,dec) > \;\; \sim \;\; b(z) \times dN/dz$

Photometric space
Dim ~ 10

brightness
ra,dec
size
ellipticity
…

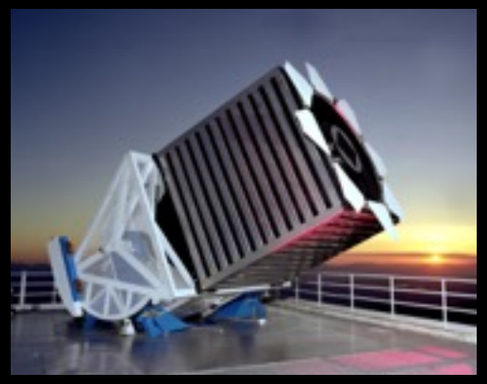
N~4 colors

redshift space
Dim = 1

$\hat{f}$ **Photometric Redshifts**
SEDs or Training Sets

$< color \, . \, F_{ref}(\lambda) >$

Applications of clustering redshifts



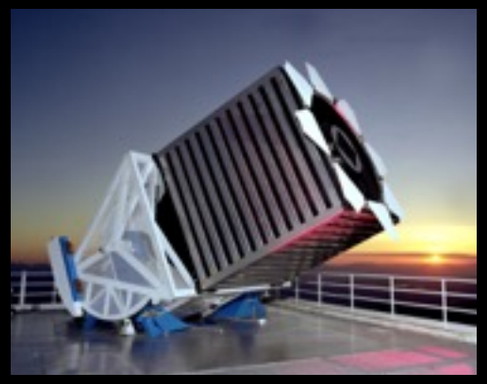
SDSS
optical

CFHT-LS
optical

2MASS
near infrared

WISE
infrared

Applications of clustering redshifts

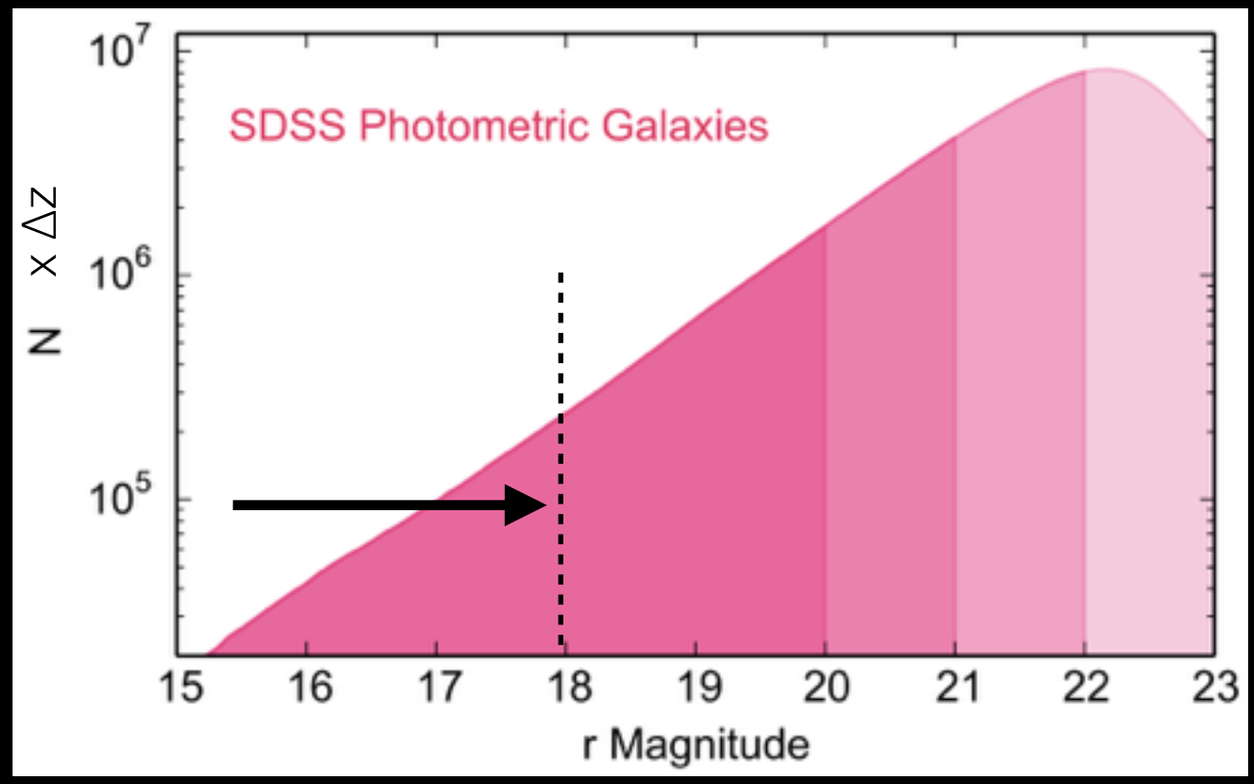


SDSS
optical

CFHT-LS
optical

2MASS
near infrared

WISE
infrared



spectroscopic galaxy sample

r < 18 mag

1 million objects

Photometrically-selected galaxies

sample 1: 0.5 < g-r < 0.6

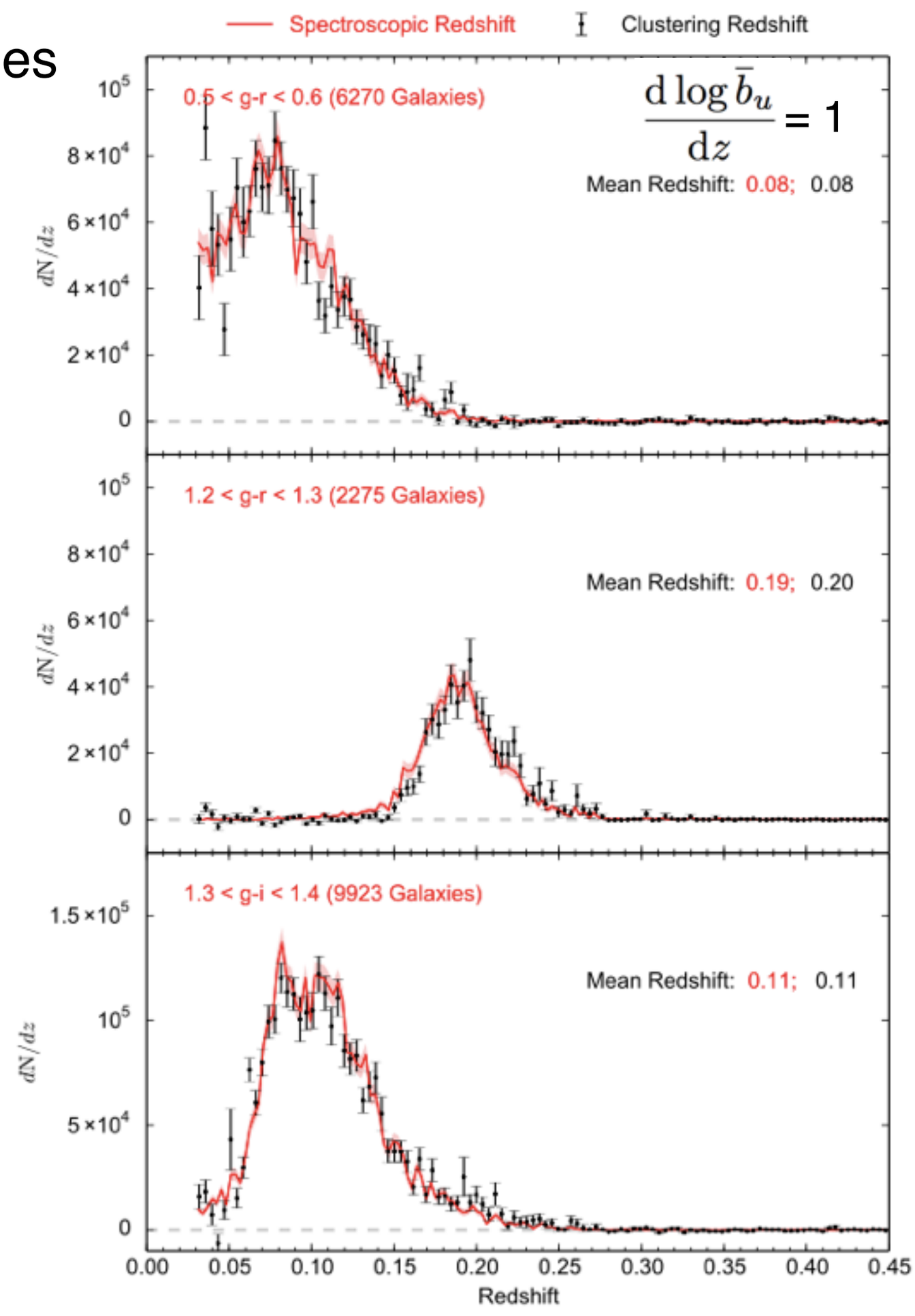
~ 6,300 galaxies

sample 2: 1.3 < g-i < 1.4

~ 10,000 galaxies

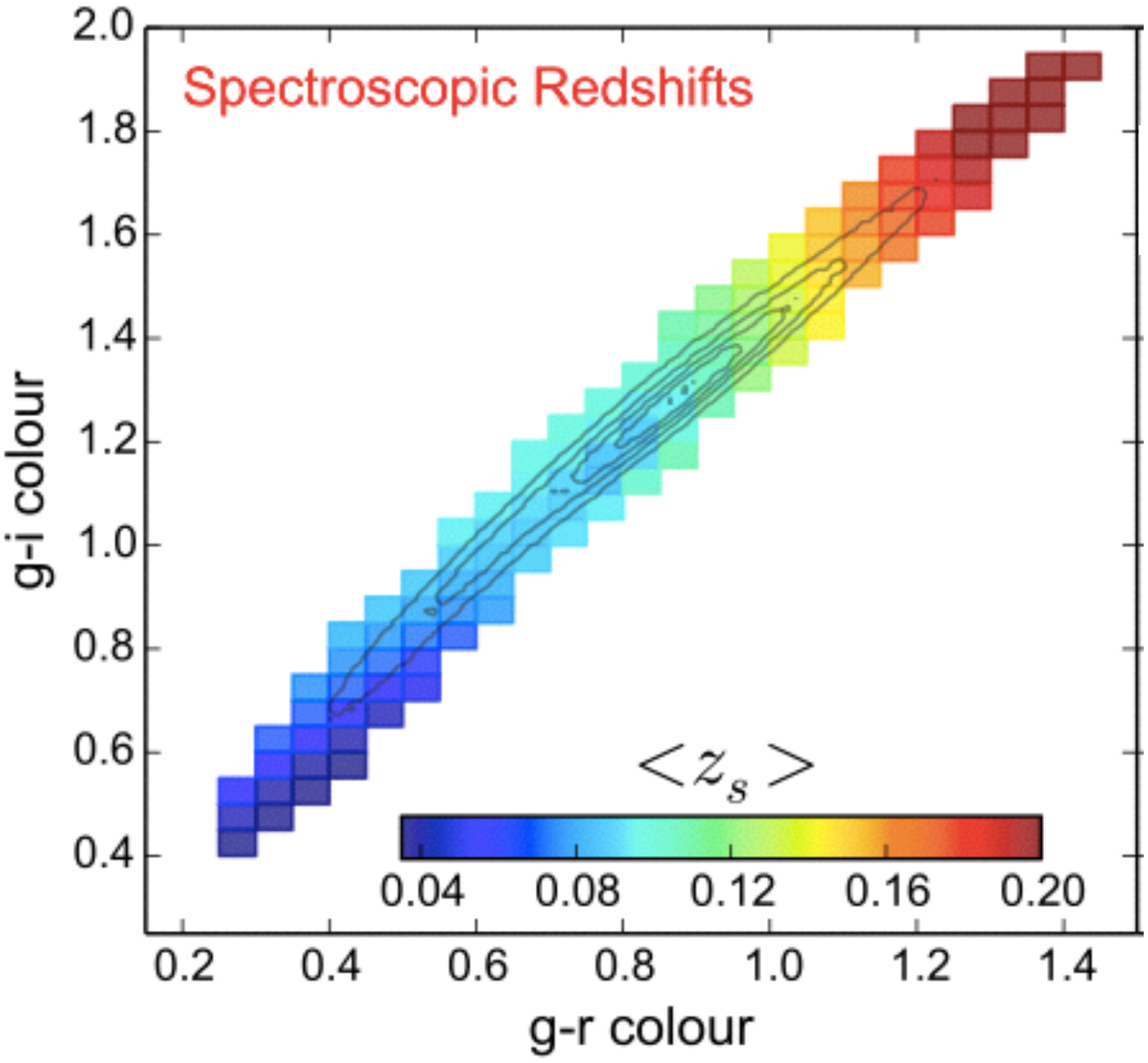
sample 3: 1.2 < g-r < 1.3

~ 2,500 galaxies



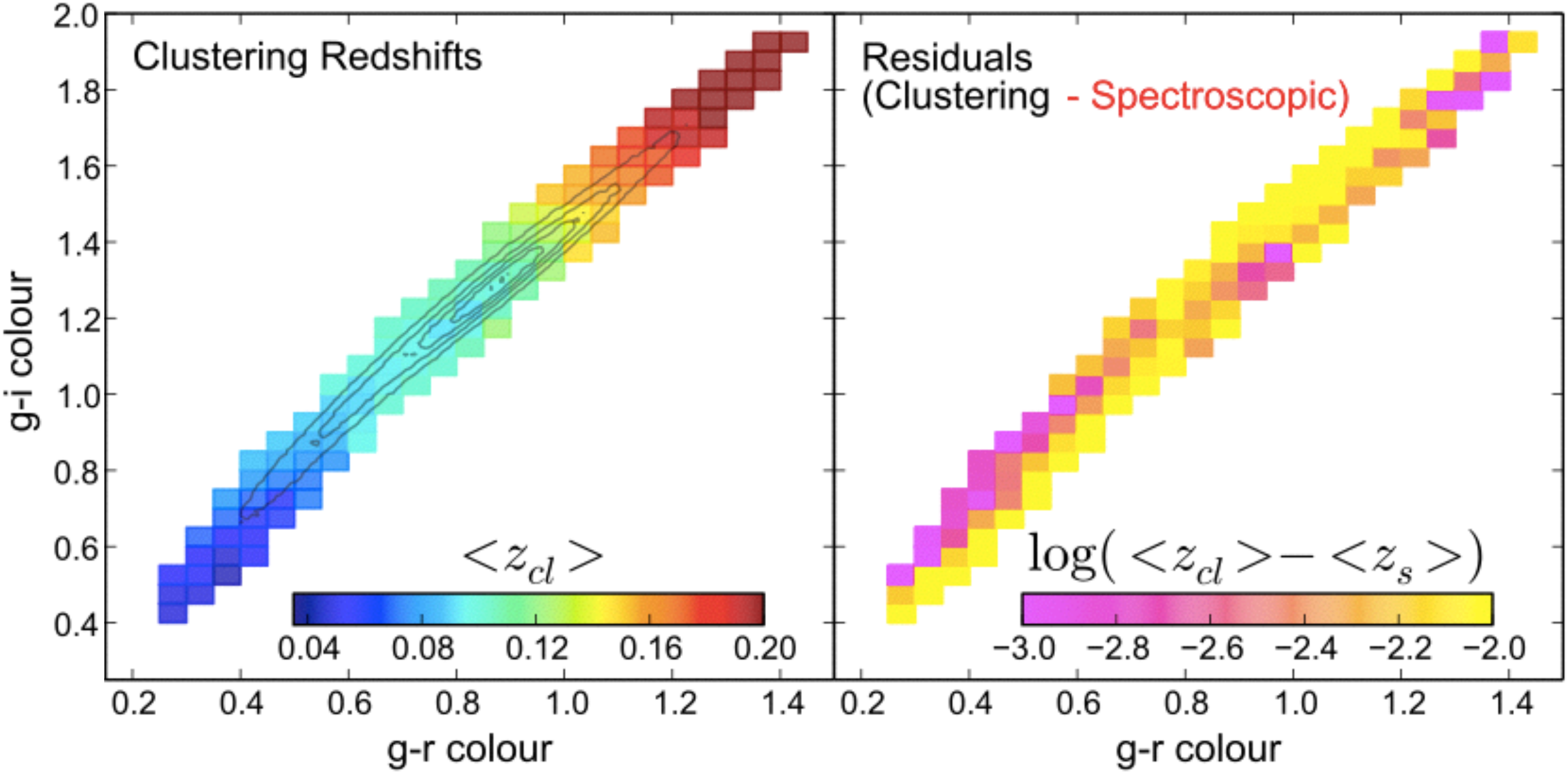
Rahman et al. (2015)

Generalization to one million galaxies



Rahman, BM et al. (2015)

Generalization to one million galaxies

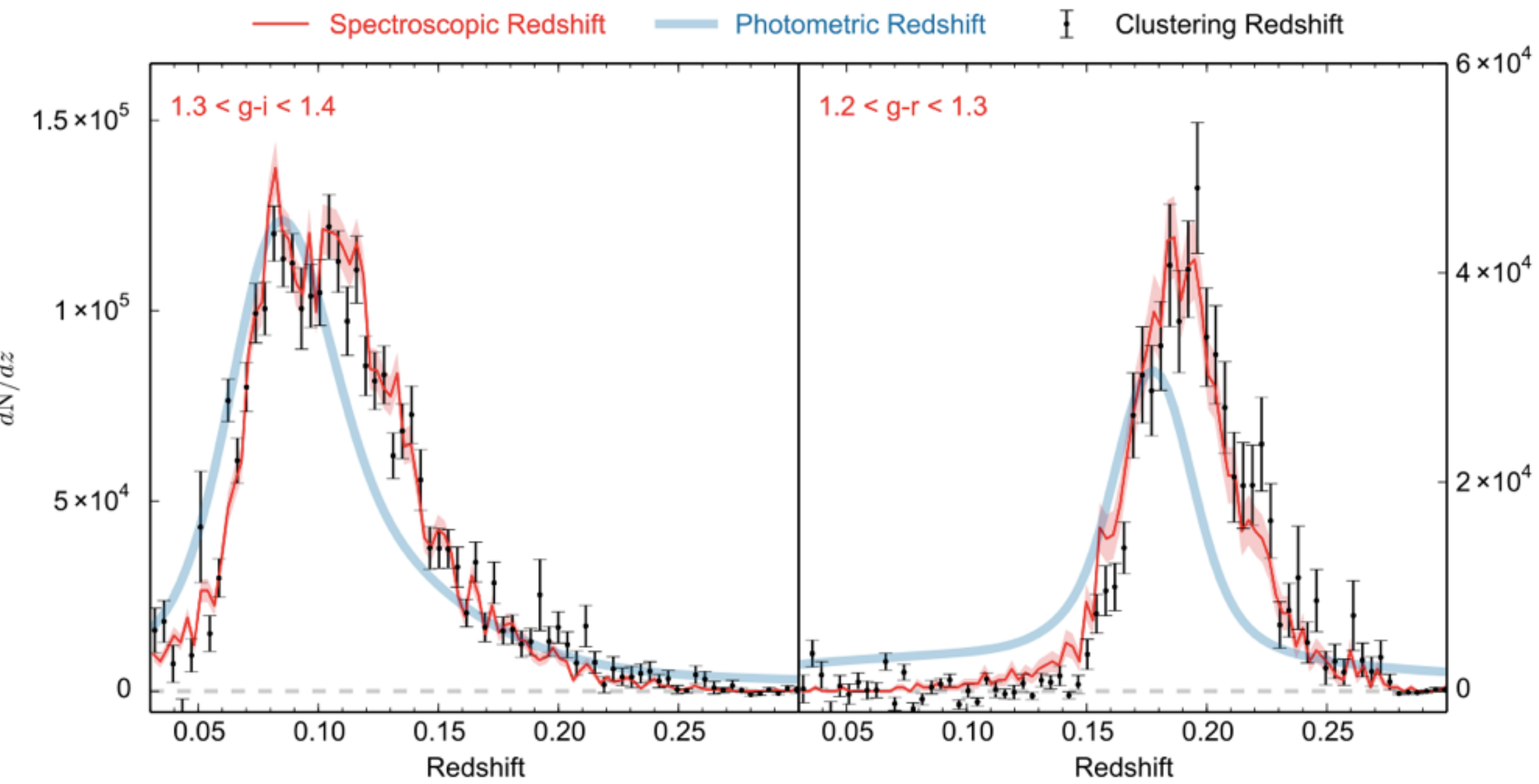


Rahman, BM et al. (2015)

Comparison to photometric redshifts

sample 2

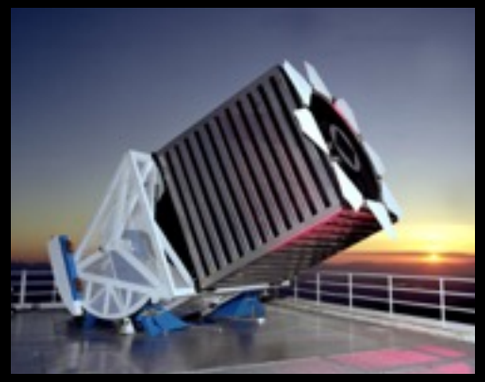
sample 3



SDSS KD-tree photometric redshifts

Rahman, BM et al. (2015)

Applications of clustering redshifts



SDSS
optical

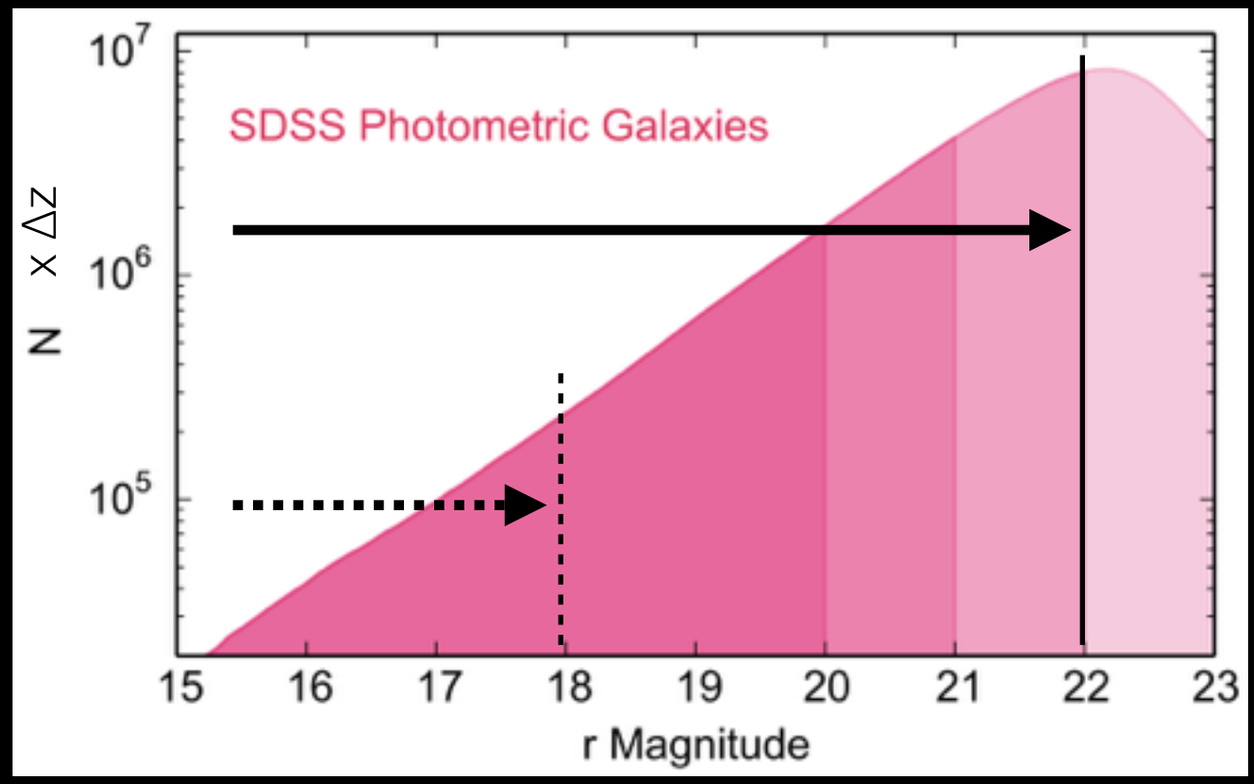
MegaPrime
CFH
MegaCam
Legacy Survey
CFHTLS

CFHT-LS
optical

2MASS
2 MICRON ALL SKY SURVEY

2MASS
near infrared

WISE
infrared



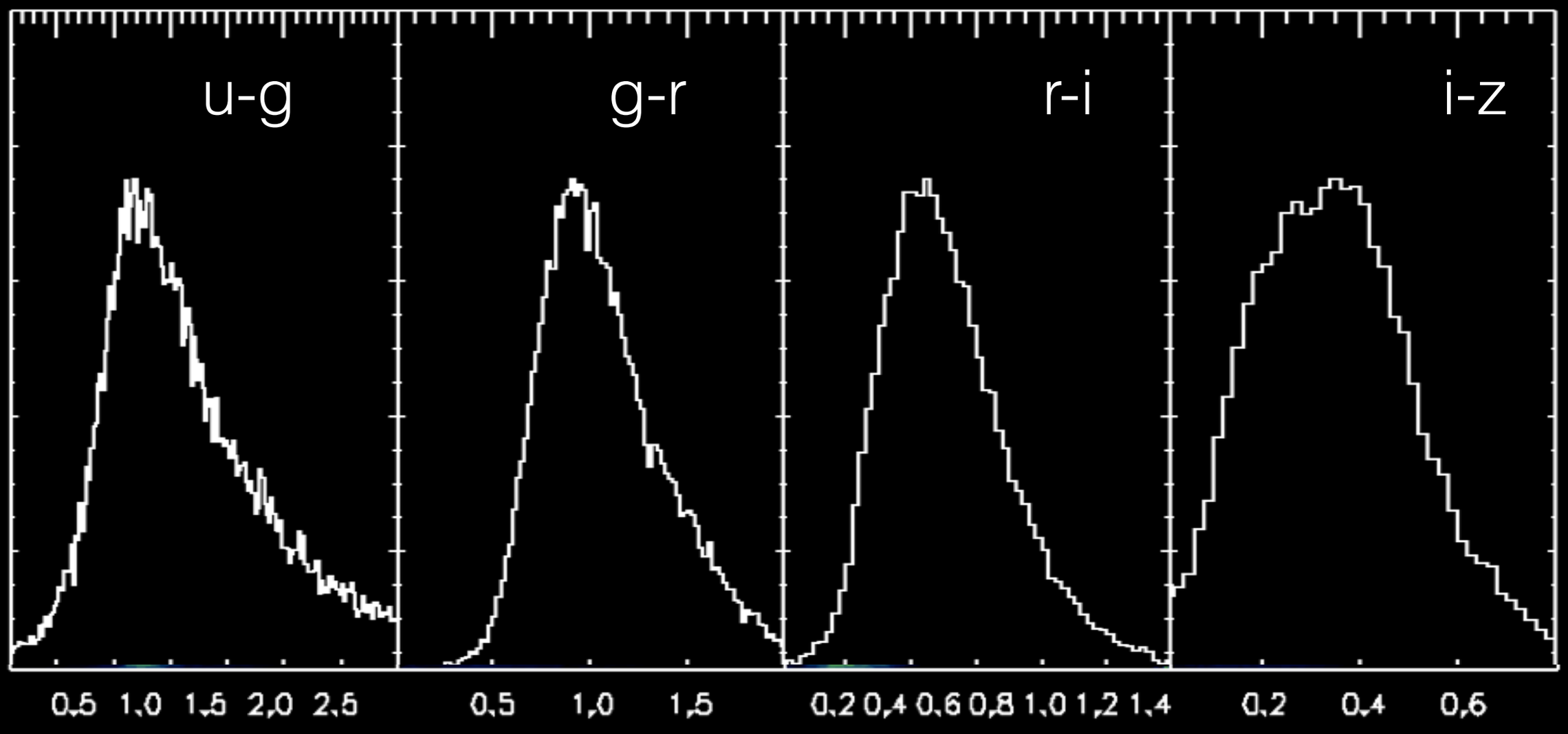
Entire photometric sample

r < 22 mag

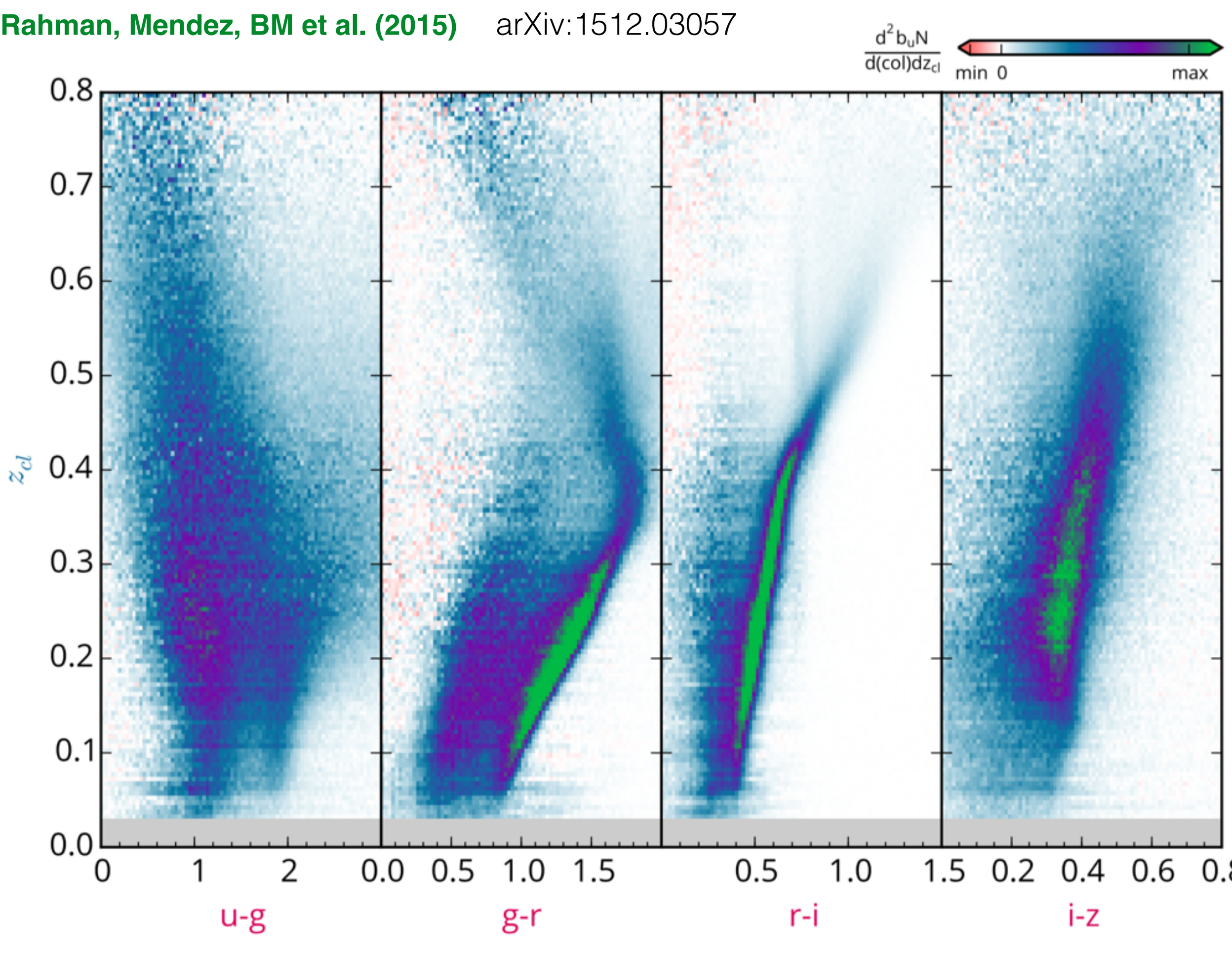
100 million objects

What can I do with 100 million photometric galaxies?

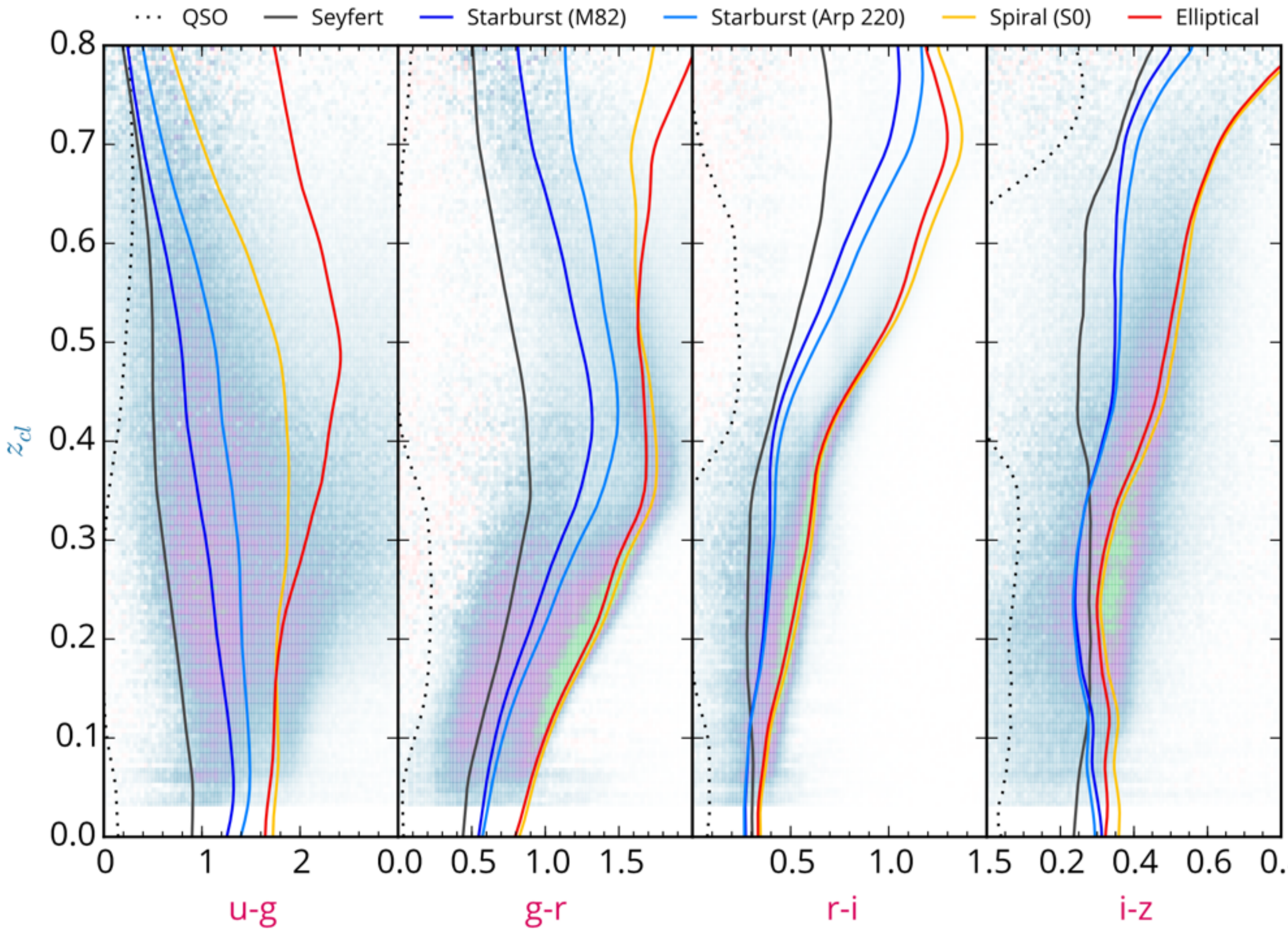
information used: (u,g,r,i,z) + (ra,dec)

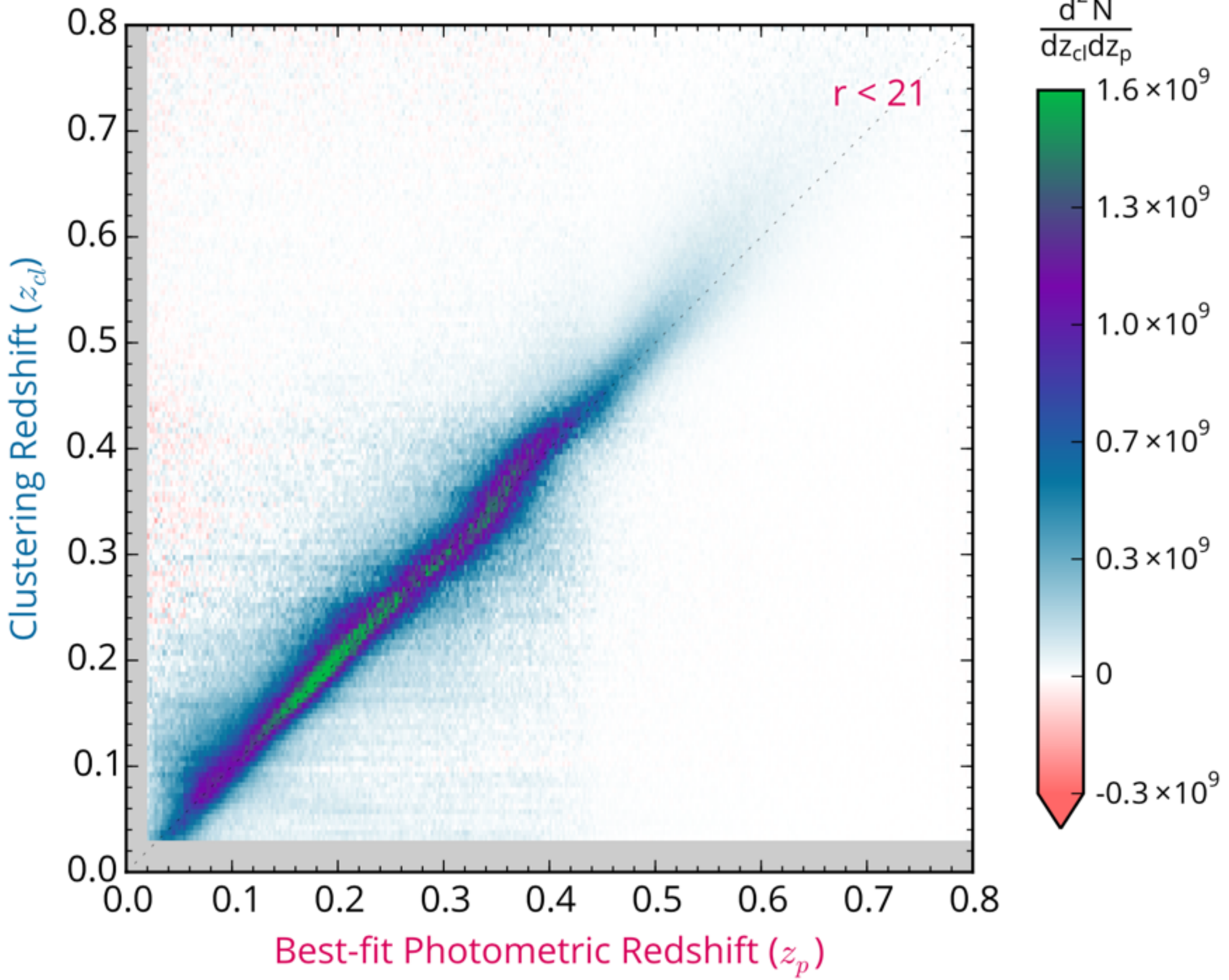


Rahman, Mendez, BM et al. (2015) arXiv:1512.03057

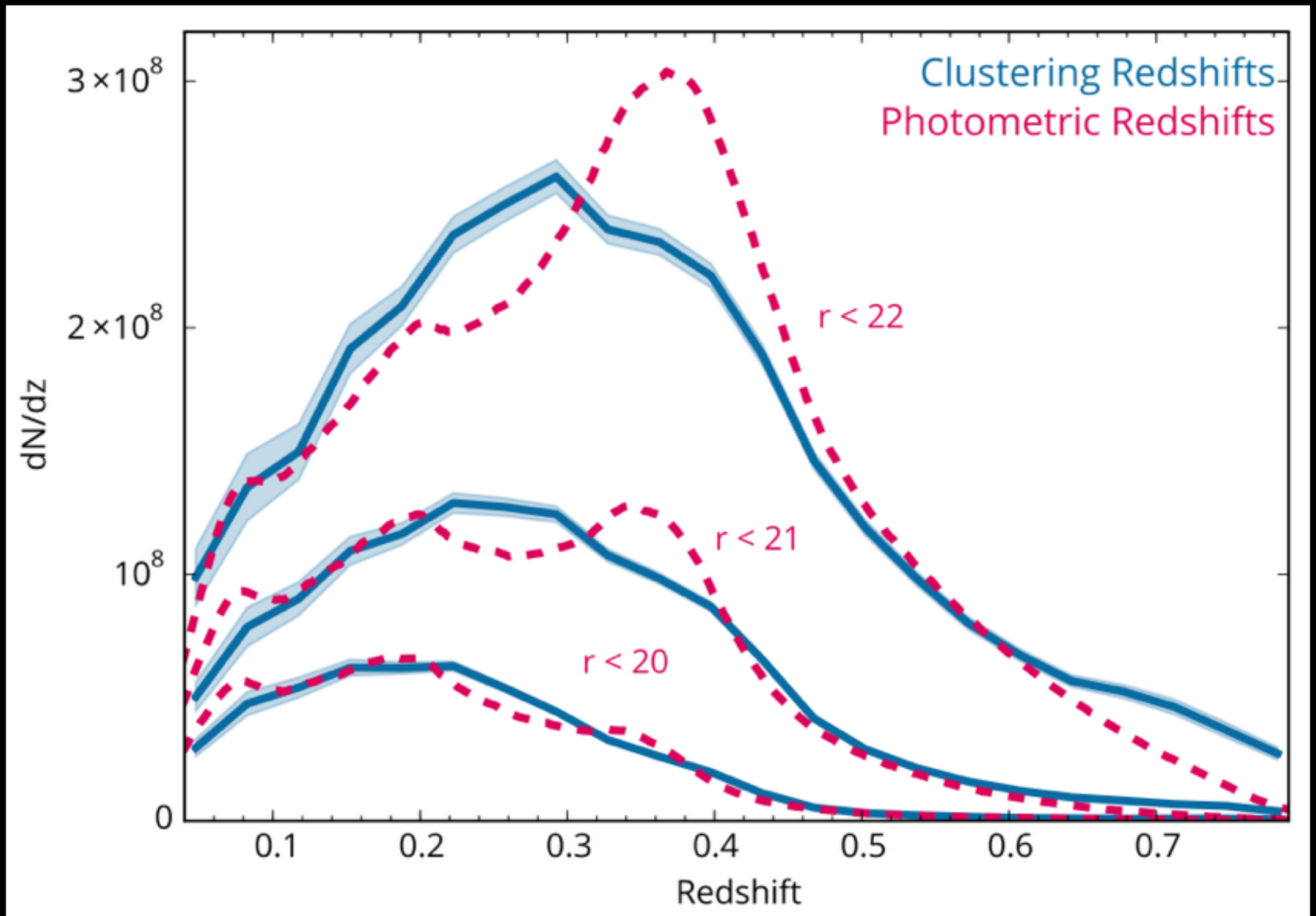


Rahman, Mendez, BM et al. (2015) arXiv:1512.03057



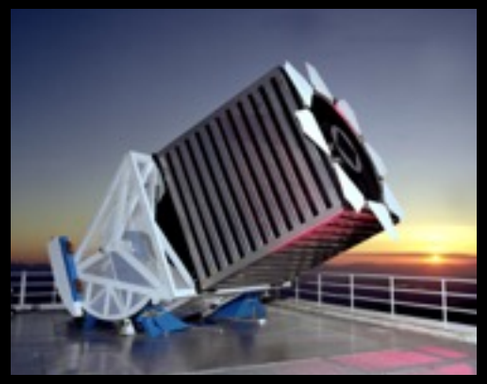

r < 21
Clustering Redshift (z_{cl})
Best-fit Photometric Redshift (z_p)
0.0
0.1
0.2
0.3
0.4
0.5
0.6
0.7
0.8
$\frac{d^2N}{dz_{cl}dz_p}$
1.6×10^9
1.3×10^9
1.0×10^9
0.7×10^9
0.3×10^9
0
-0.3×10^9

Comparison clustering-z *vs* photo-z



Rahman et al. (2015)

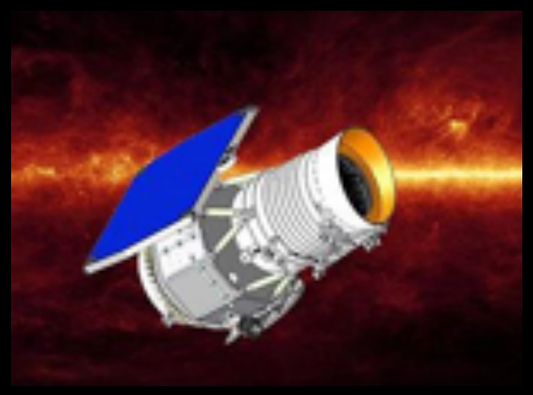
Applications of clustering redshifts



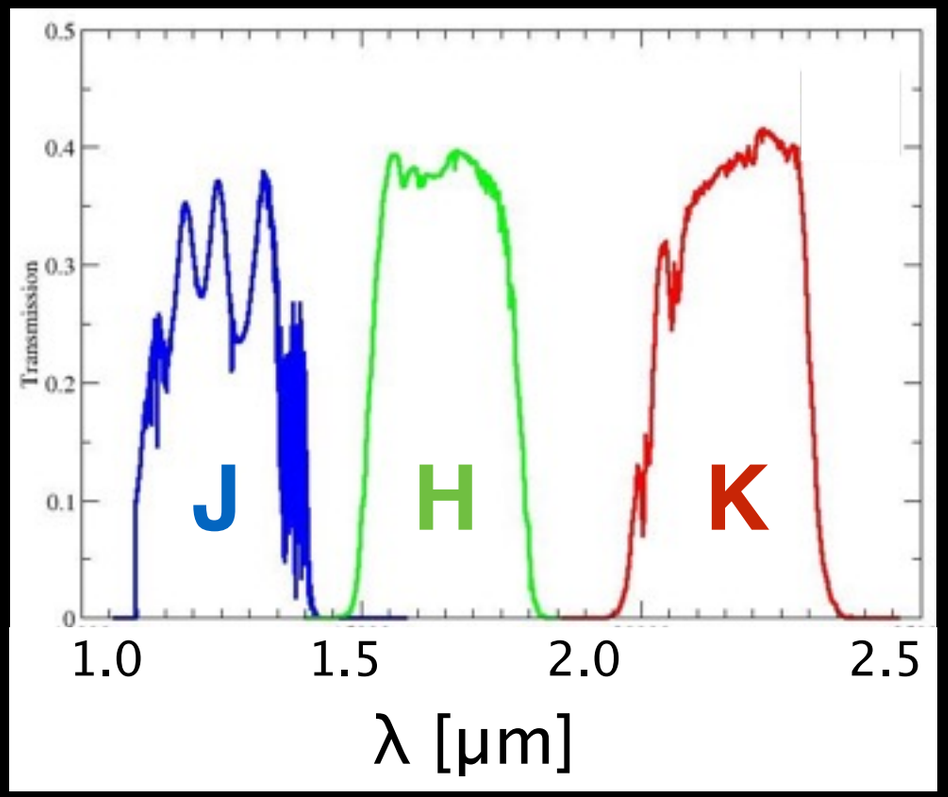
SDSS
optical

CFHT-LS
optical

2MASS
near infrared



WISE
infrared



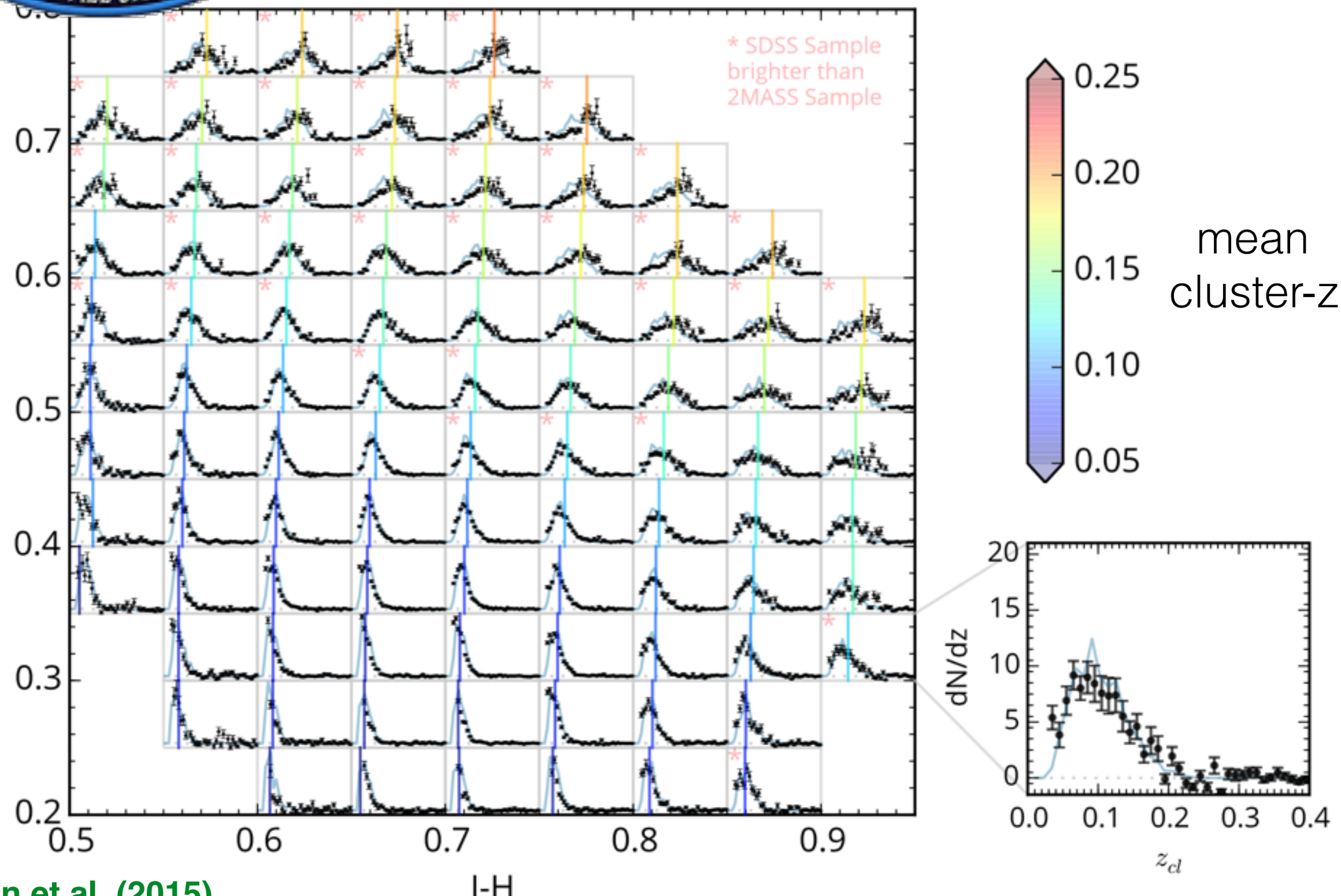
2MASS extended sources

K < 14 mag

1.5 million objects

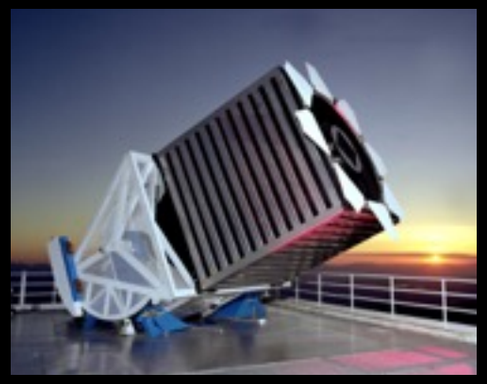
Skrutskie et al. (2006)

Observations: 1997-2001, J, H & K bands



Rahman et al. (2015)

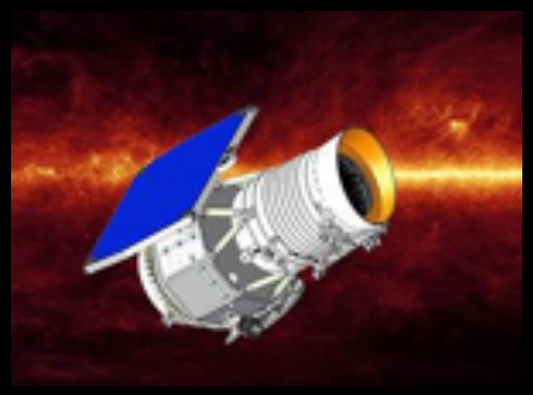
Applications of clustering redshifts



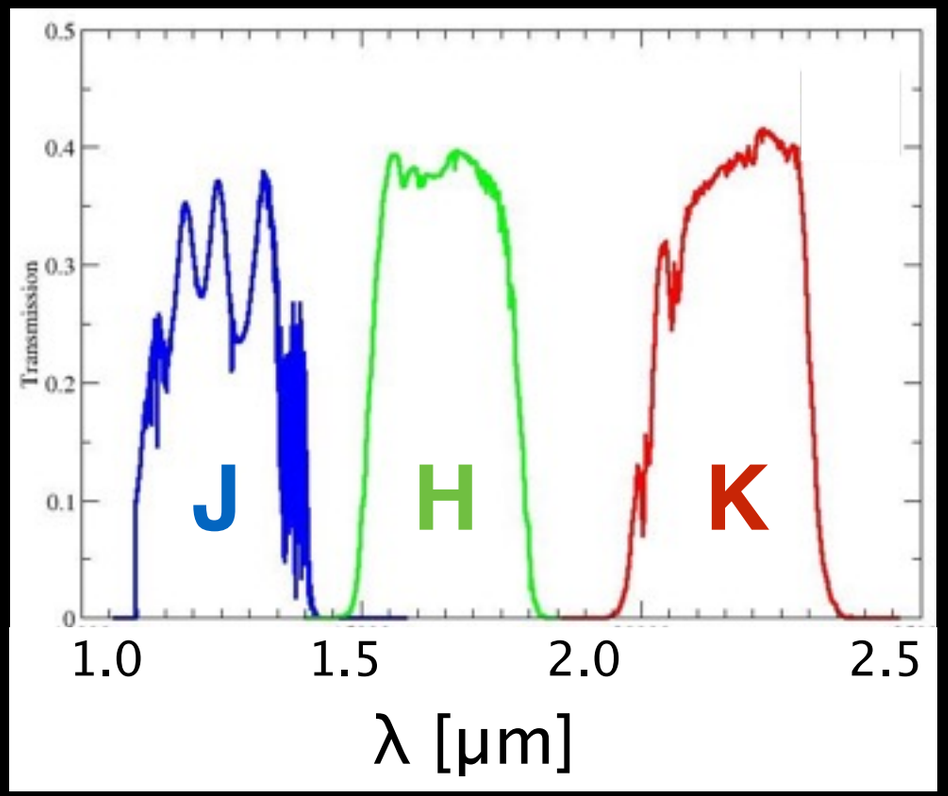
SDSS
optical

CFHT-LS
optical

2MASS
near infrared



WISE
infrared

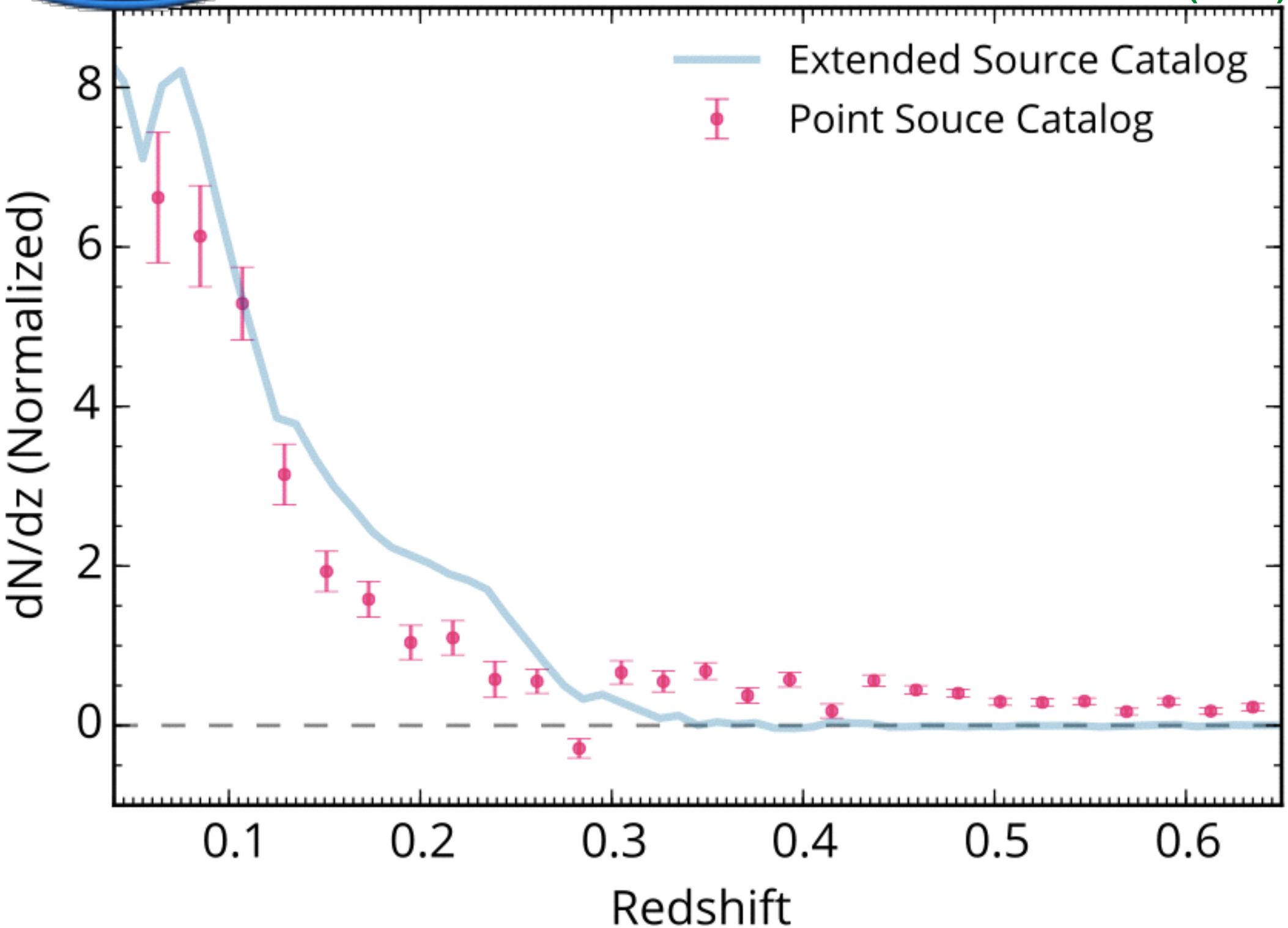


2MASS ~~extended sources~~
point sources
K < 14 mag

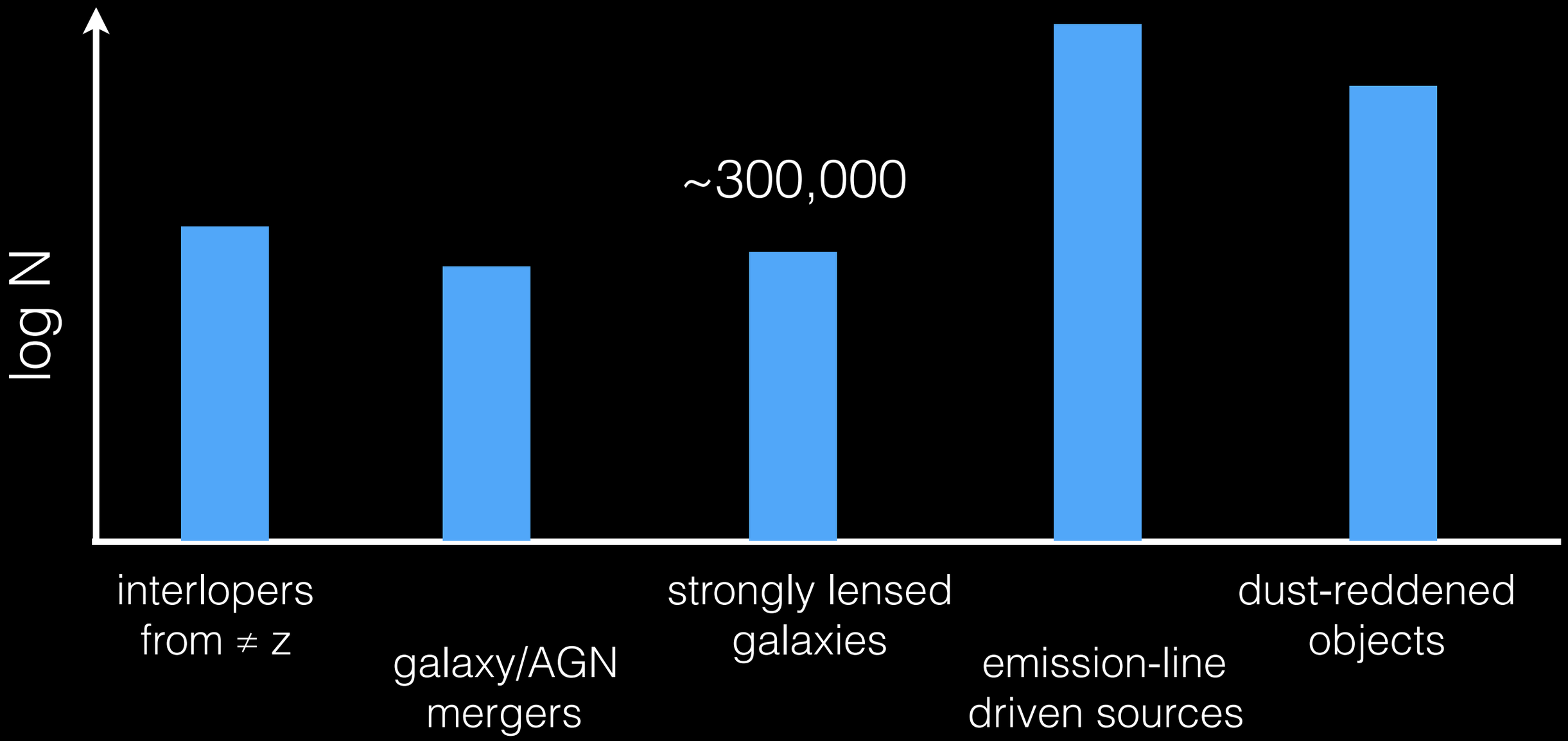
1.5 million objects

clustering redshifts for **extended** & **point** sources

Rahman et al. (2015)

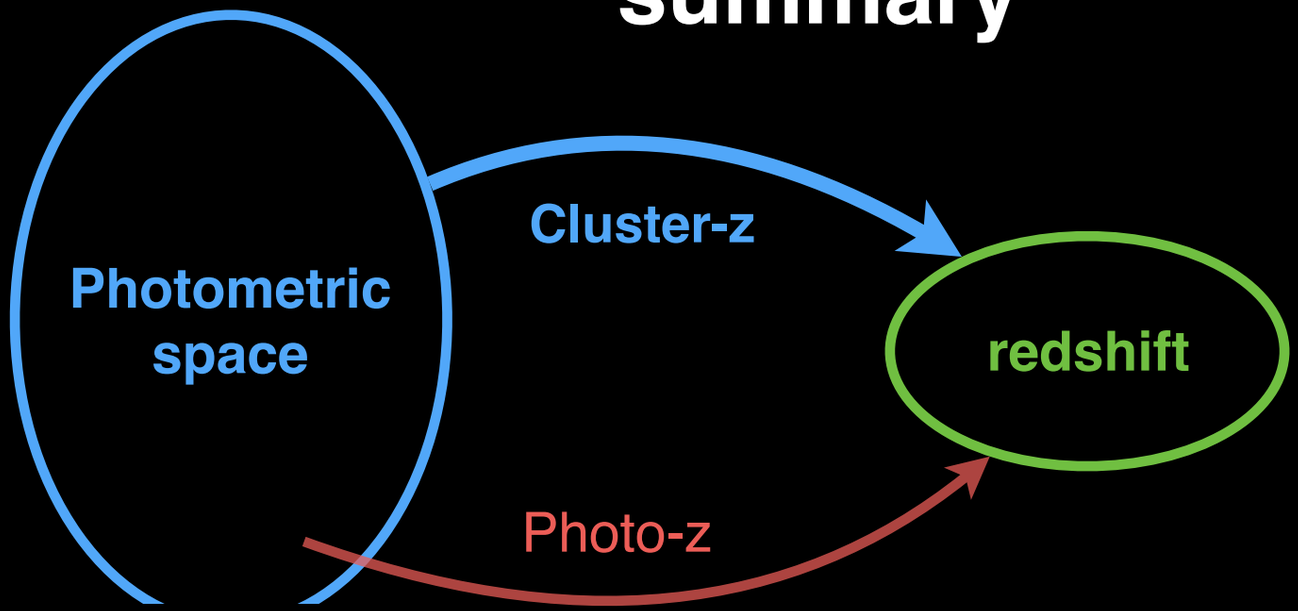


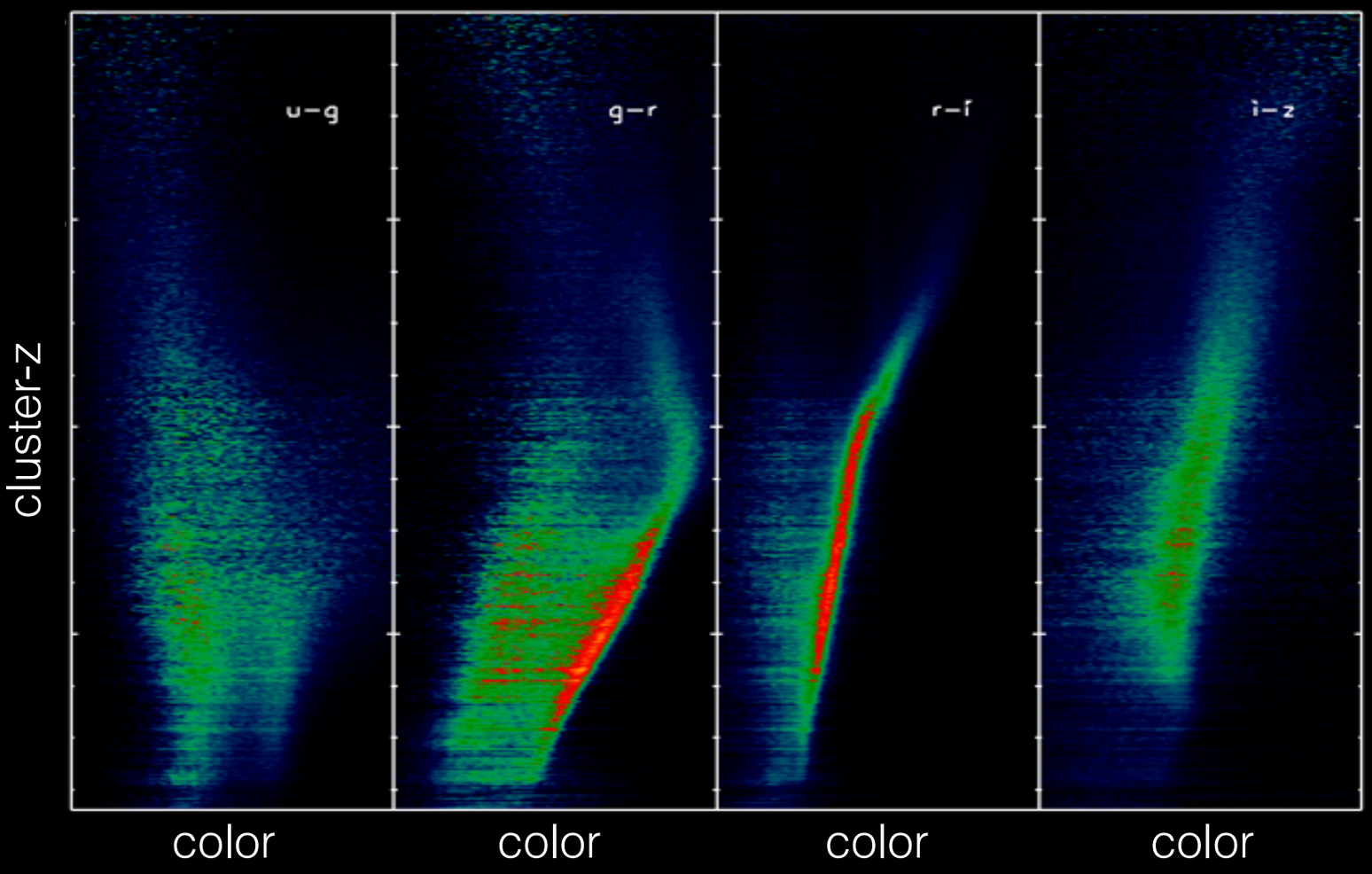
Difficult sources for photometric redshifts



Clustering redshifts summary

We have a new tool in hand to characterize the mapping between the photometric space and redshift





We can already deproject various photometric datasets

and obtain meaningful color-redshift tracks.