DARK ENERGY
SURVEY

The DES Followup Survey

Survey Strategy and Target Selection

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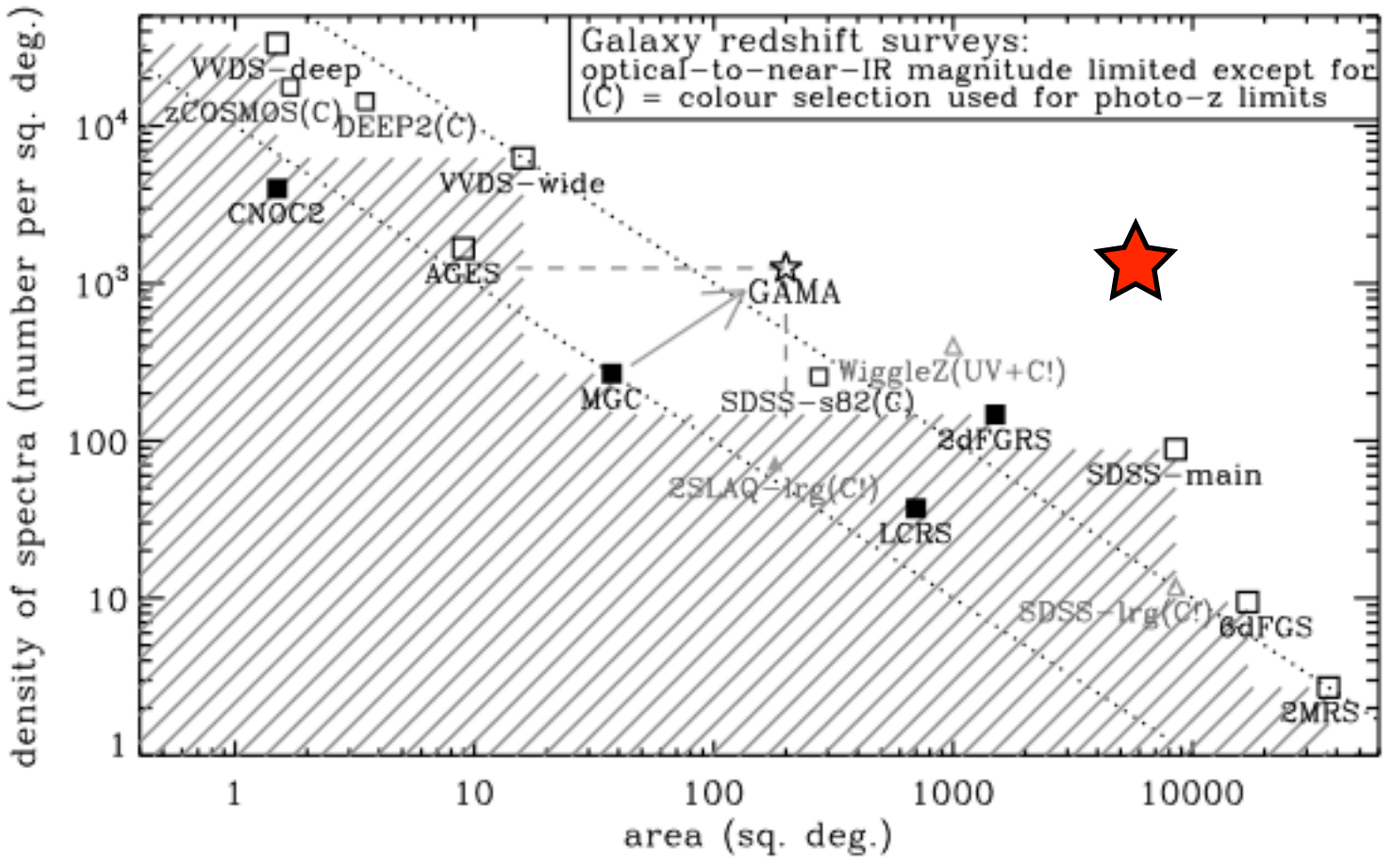
DARK ENERGY
SURVEY

Courtesy of GAMA



The survey we are talking about here is among the great astronomical surveys.

Ten million spectra over 5000 sq-degrees is enormous; we should aim to make these spectra as useful for a wide range of followups as possible.

Let us think about this survey. It is a follow up to the DES in which we endeavor to both make increase the FOM and increase the usefulness of the DES. We are considering ten of million spectra; the survey can have its greatest impact if it is more than just an experiment
1) More S/N than the bare necessary to get a redshift
2) Expend the effort to get spectrophotometry
3) Design a uniform wide survey rather than a grouping of adjacent surveys

Data Sets for Target Selection Testing

- There are a variety of ways to test target selection ideas. What leaps to mind are:

1. Simulation driven methods:
   - COSMOS mock catalogs
     - good for range of filters and redshifts
   - DES mock catalogs
     - good for connection to underlying cosmology and LSS
2. Data driven methods
   - The COSMOS data
   - The VVDS i < 24 redshift survey
   - DEEP2 survey data
   - Plausibly the DES week long mini-survey could be of use:
     - survey two of the GAMA fields on the equator in ~March
     - mock a shallow SN field on the COSMOS field as part of this.

Cosmos Simulated Catalog from Jouvel et al 2009 (most often that available on the web, sometimes a variant for DES filters courtesy of G. Bernstein) 538,000 galaxies at i < 26.5 based on ACS/HST data

Infrared Datasets for Target Selection

DES

0.9μm
5,000 sq-deg

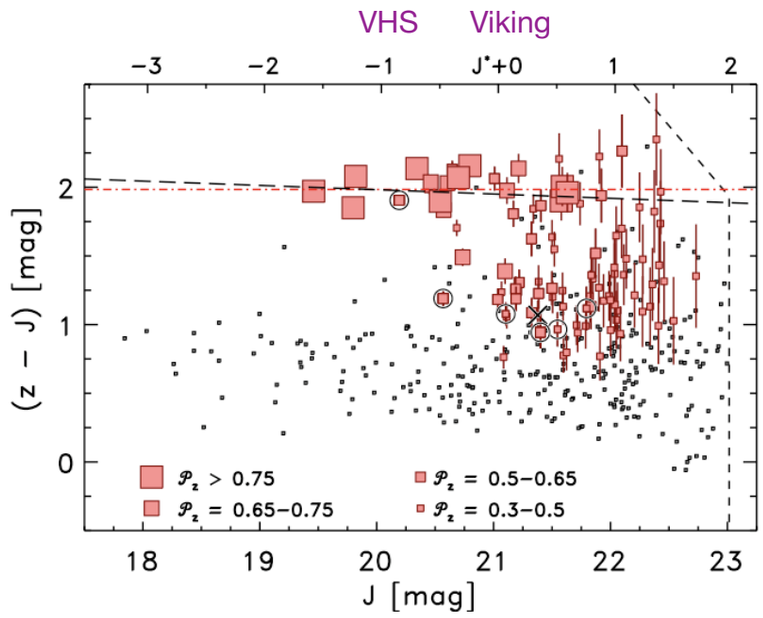
10σ extended source sensitivities:
z 0.9μm AB 23.5

VHS

1.2μm - 2.5μm
20,000 sq-deg

5σ point source sensitivities:
J 1.2μm AB 21.2
H 1.6μm AB 20.6
Ks 2.5μm AB 20.0

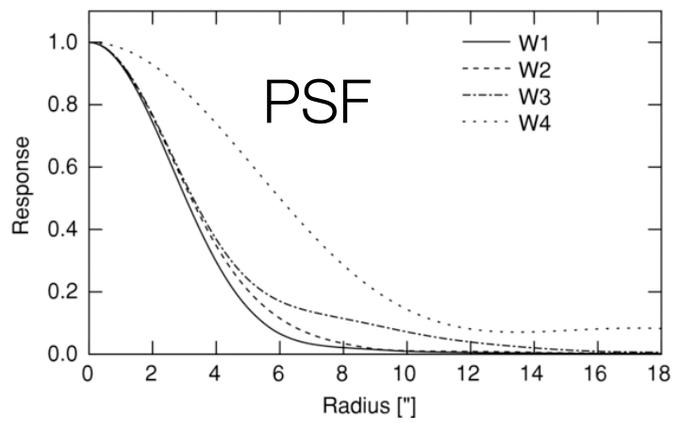
Viking, 1500 sq-deg J=22.1, H=21.5, Ks = 21.2



WISE

3.4μm - 22μm
40,000 sq-deg

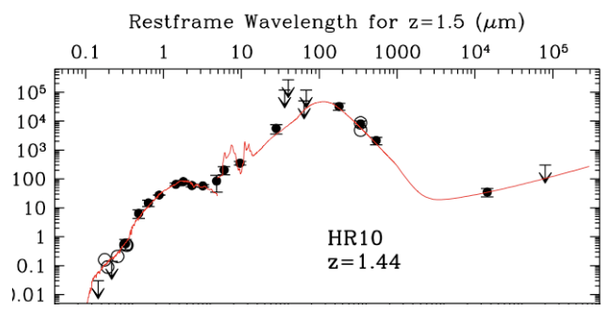
5σ point source sensitivities, 8 passes:
3.4μm 0.0 8mJy AB 19.1
4.6μm 0.11 mJy AB 18.8
12 μm 1.0 mJy AB 16.4
22μm 6.0 mJy AB 14.5



SPT

1.36mm-3.16mm
4,000 sq-deg

5σ for point source optimized map: ~7mJy
bands: 95, 150, 220 GHz
bands: 3.2, 2.0, 1.4 mm
AB: ~14.6, 14.6, 14.6



The DES is a fantastic data set from which to pick targets, and is a competitive advantage. Having said that, there are complementary infrared surveys covering the DES area that deserve to be thought about, if for no other reason that we could have only dreamed of having these at our fingertips a decade ago.

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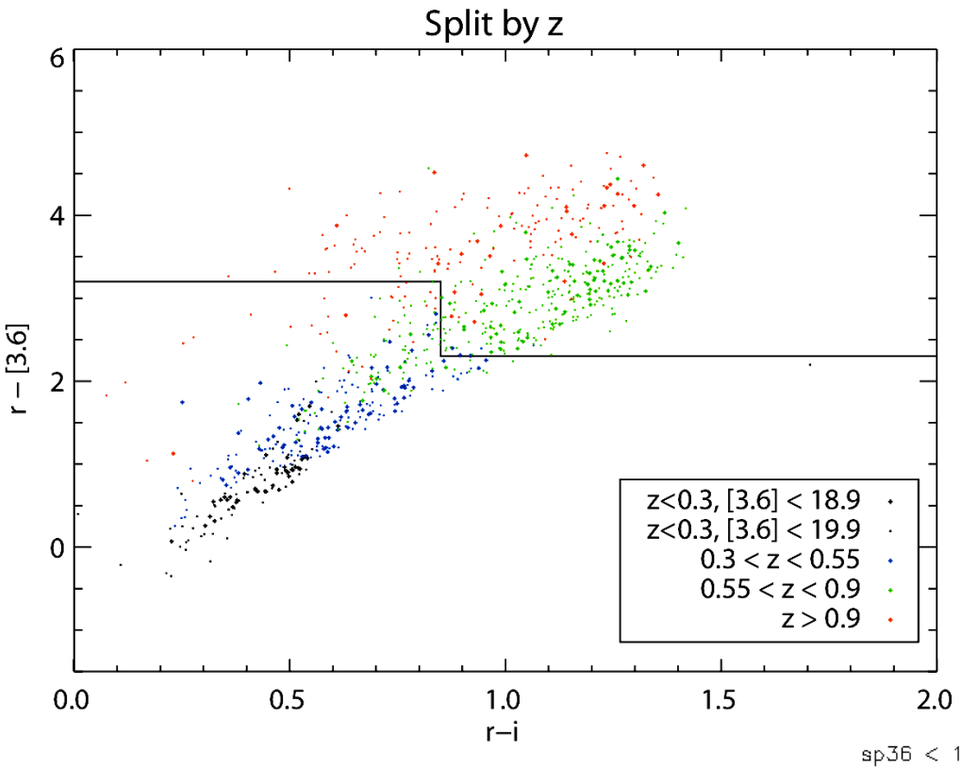
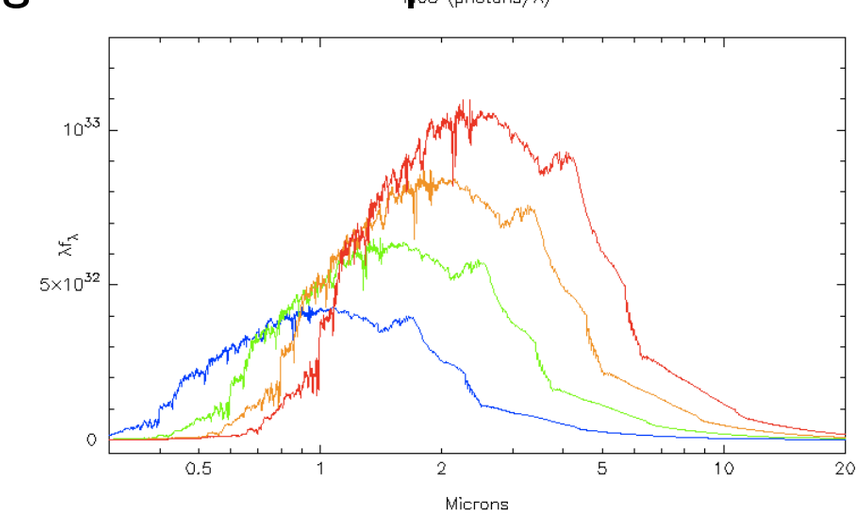
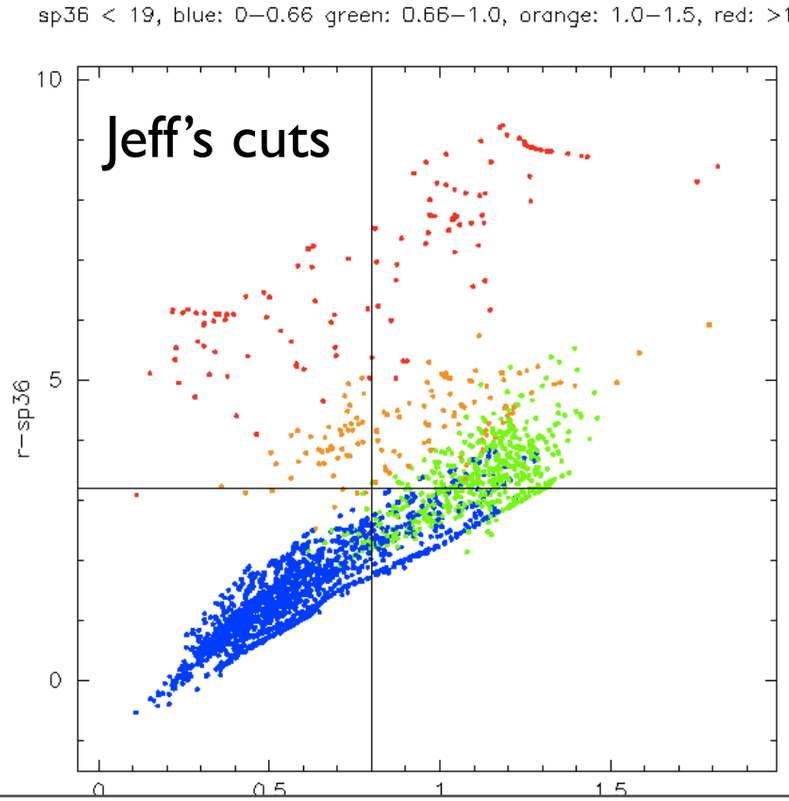
Designing a Strawman Survey

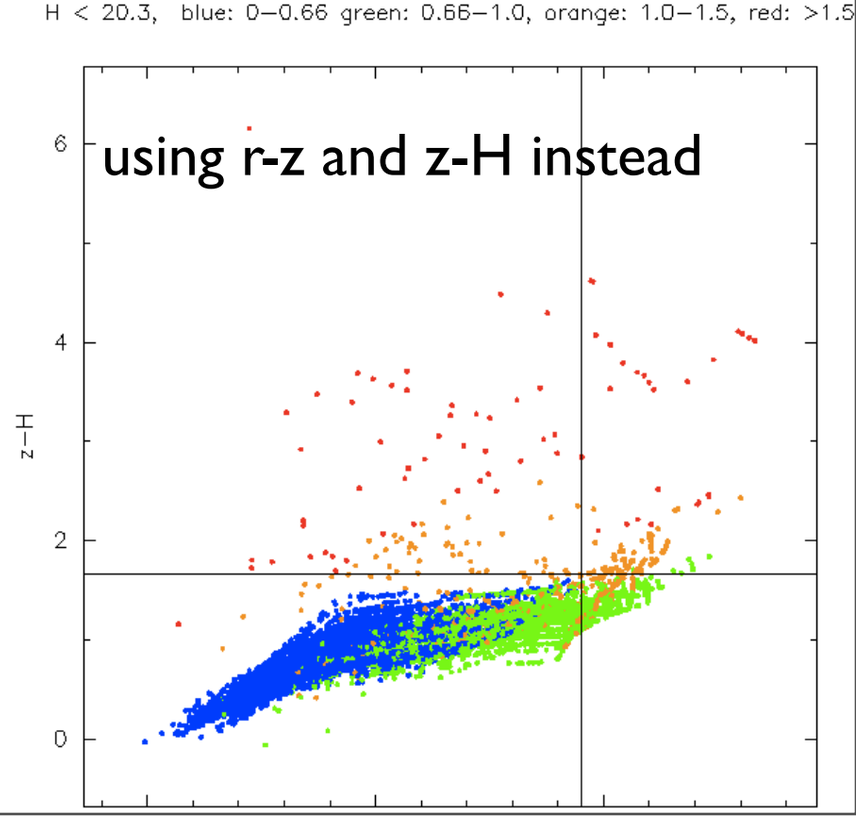


Jeff Newman's DEEP2/Spitzer data, with a cut designed to pick out red galaxies at 0.55 < z < 1.0, using the 1.6micron peak of red stellar light.



Cosmos Mock catalog





We will need to setup a strawman target selection population population in order to elucidate the survey strategy. Let us assume that

1) BAO is the most important experiment
2) There will be other experiments
3) Someone else, say Felipe, will talk about photo-z selection methods

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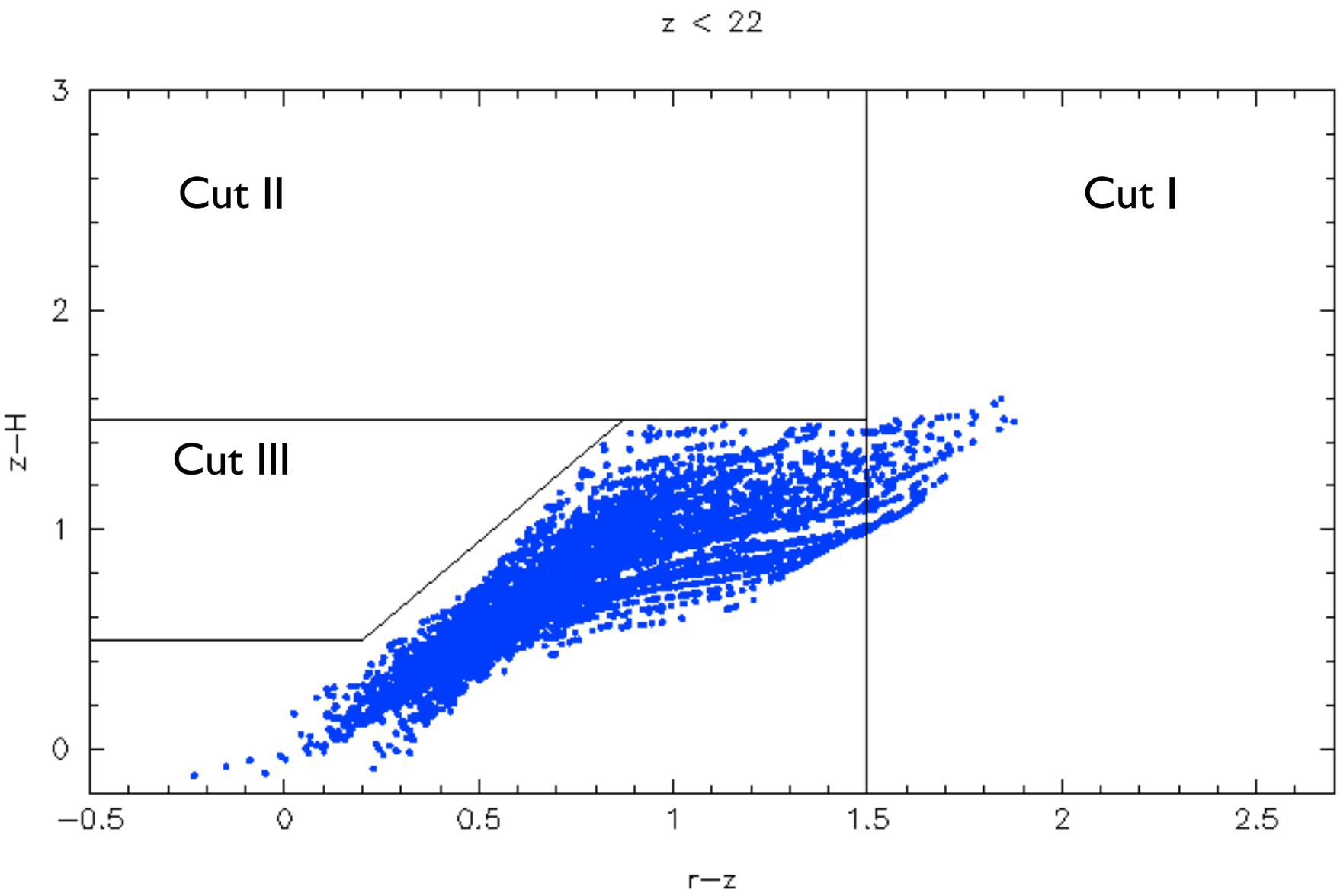
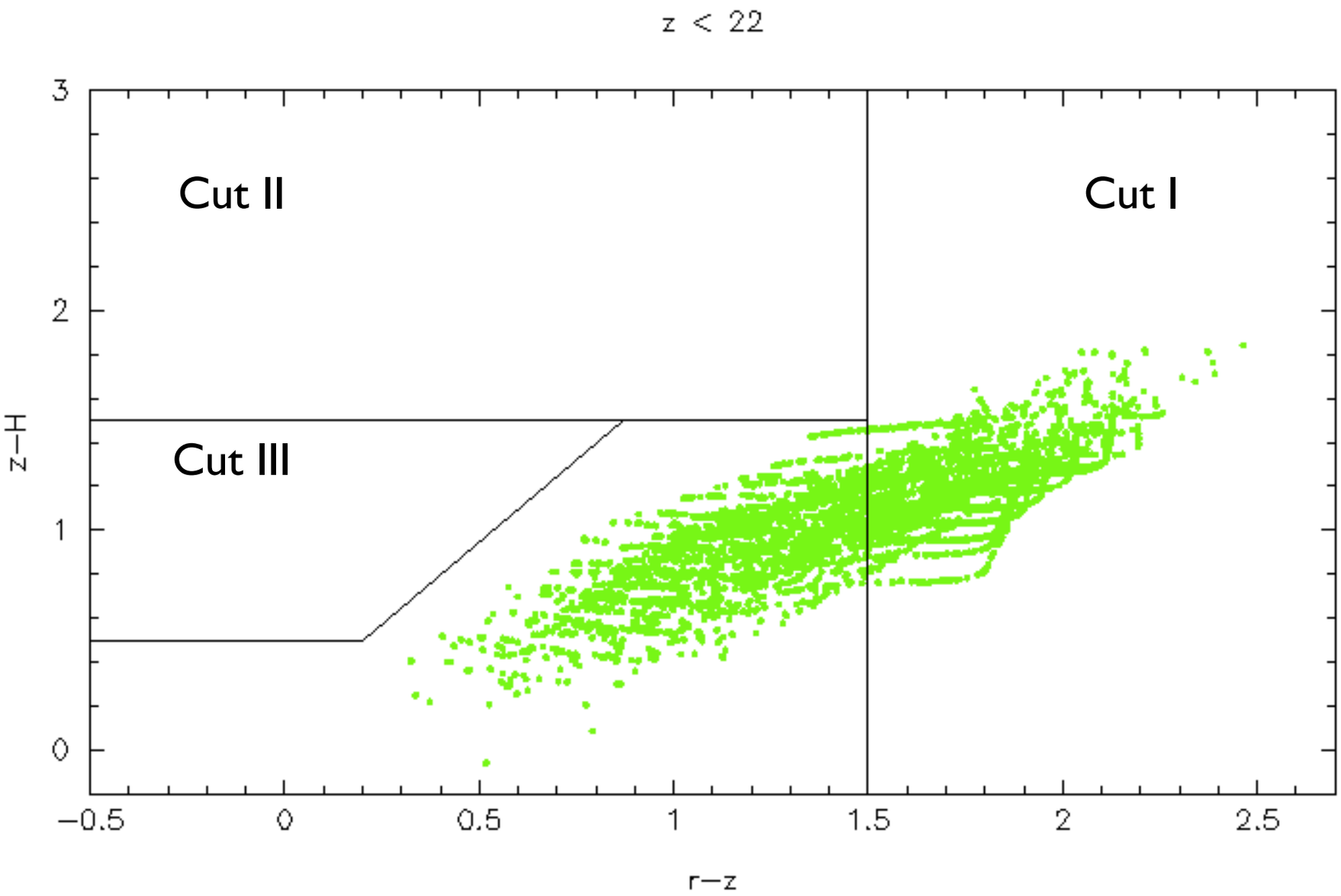
A Color Cut Target Selection



We can select a LRG sample at high redshift similar to the SDSS LRG selection. I'm attracted to this as I believe it make the samples more generically useful than photo-z selection or complicated color selection. The latter comment is based on our difficulties using DEEP2 for photo-z training samples. This plot shows where z < 0.5 galaxies lie in the r-z vs z-H plane.

A Color Cut Target Selection



This plot shows where 0.5 < z < 1.1 galaxies lie in the r-z vs z-H plane. They are much more numerous.

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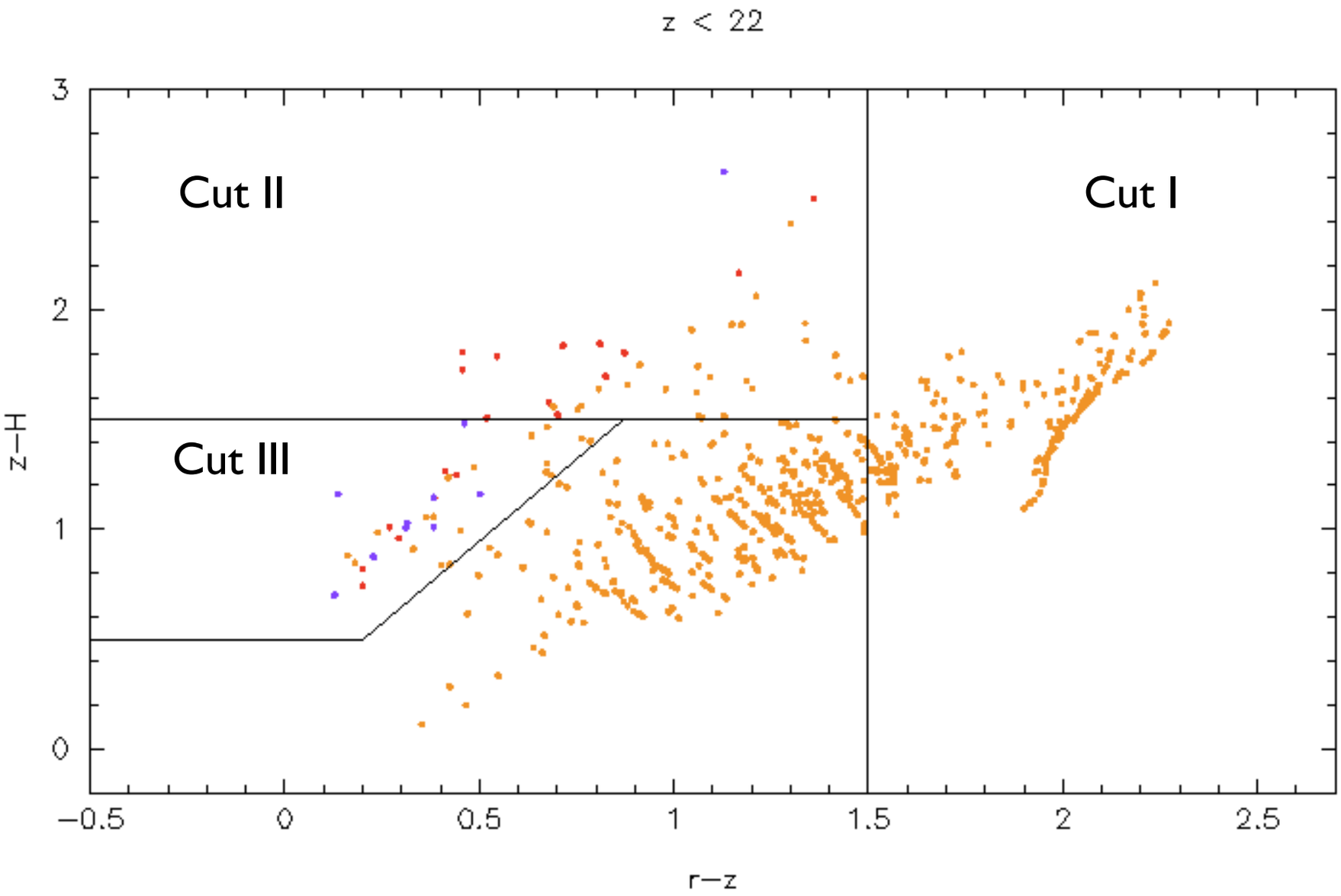
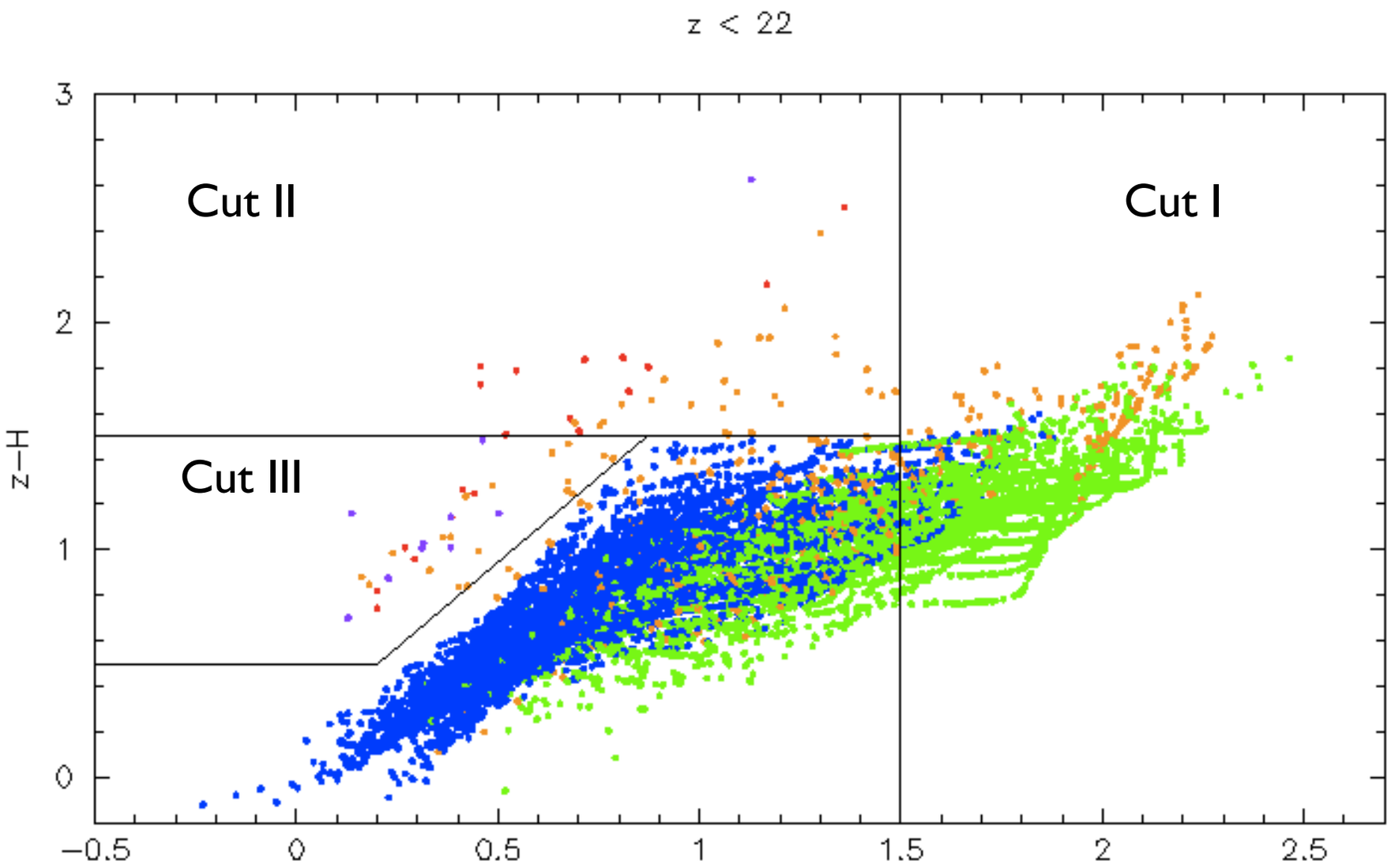
A Color Cut Target Selection



This plot shows where z > 1.1 galaxies lie in the r-z vs z-H plane. Red and purple are successively higher redshift bins.

A Color Cut Target Selection



All at z < 22

n passing the r-z cuts (21.5,1.75):

log(n) targets/deg^2 = log(1000) + 0.6*(z-21.5) slide magnitude cut

log(n) targets/deg^2 = log(1000) - 1.81*((r-z)-1.75) slide color cut (for 1.65<r-z < 1.95)

n targets/deg^2 = 1000 - 3300*((r-z)-1.75) slide color cut (for 1.45 < r-z < 2.05)

The simpliest thing to do is to choose the main sample to be Cut I, a pure DES r−z cut.
If one wishes to pursue galaxies at higher than z = 1.1, then Cut II and Cut III, using the VHS H data, bring them into the sample at successively greater numbers at z > 21.

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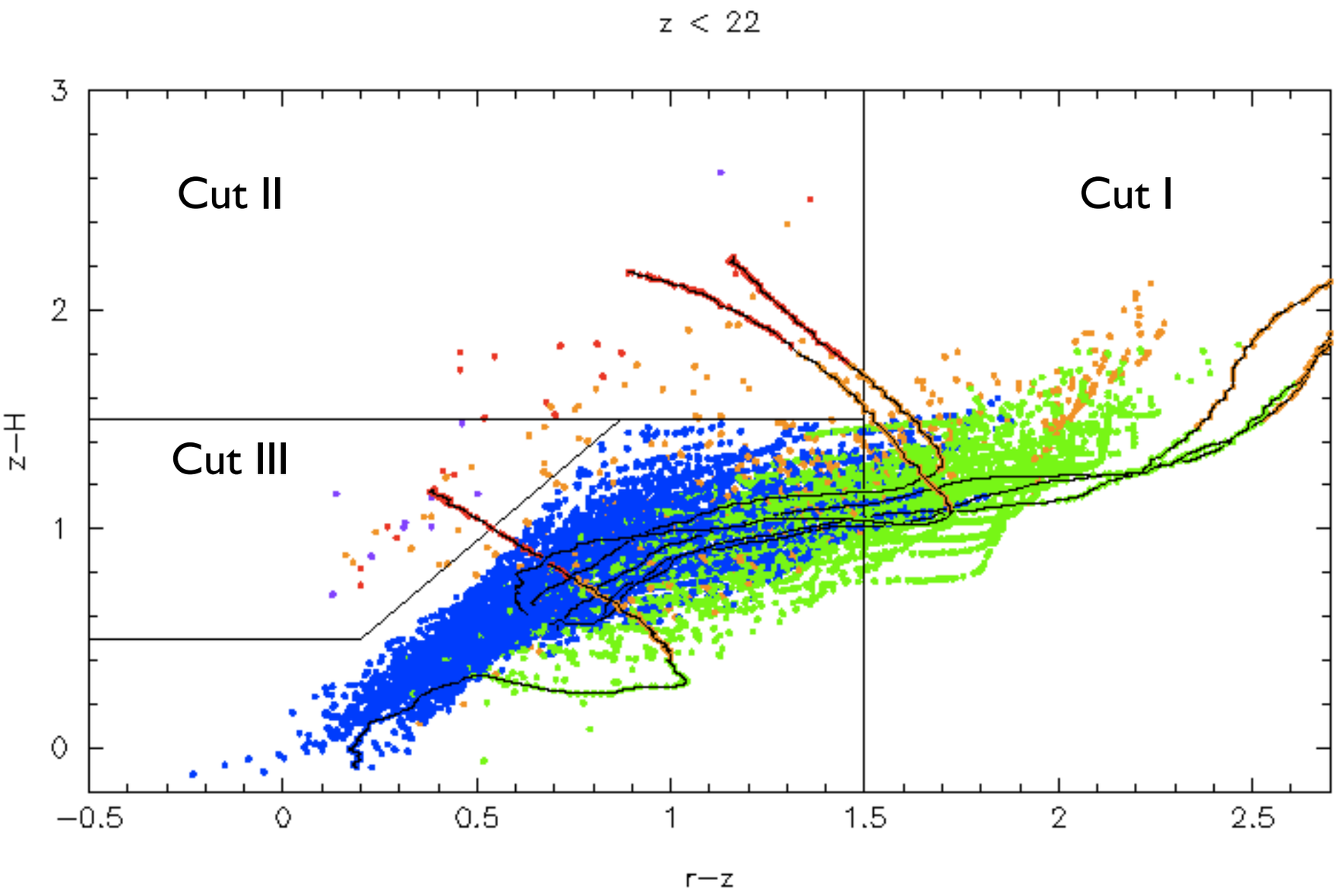
With ke correction tracks

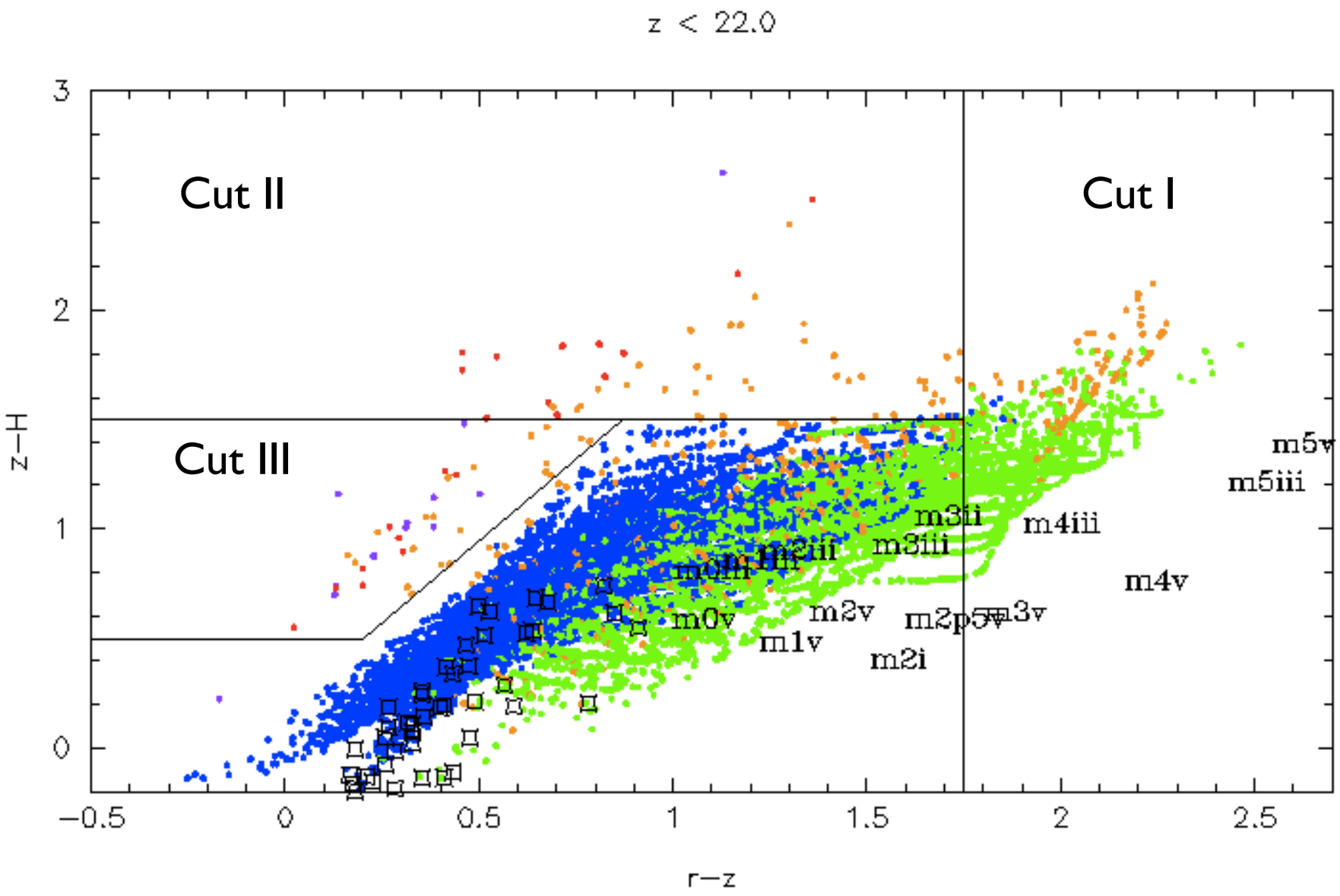


Cleary both two different non-evolving E SED and the evolving Maraston LRG SED go to red in r-z before turning up, though this could be due to the HSC bandpasses assumed in the Cosmos simulation.

tracks, left to right:
LRT Im,
ULIRG,
LRT Sbc,
LRT E,
Maraston M08 non-evolving,
Maraston M08 evolving

This plot shows a variety of spectral energy distributions seen through “DESy” filters at a variety of redshifts. In detail the z is the HSC z1 filter, which seems to be a narrow z. The r−z cut is good at selecting red galaxies at z ~ 0.8.

With stellar locus



A side benefit is that we don't really need to do star galaxy separation, especially for Cut II and Cut III.

Finally it is worth noting that stars will not be much of a problem with a cuts like these, simply because they are offset in z-H from the galaxy population.

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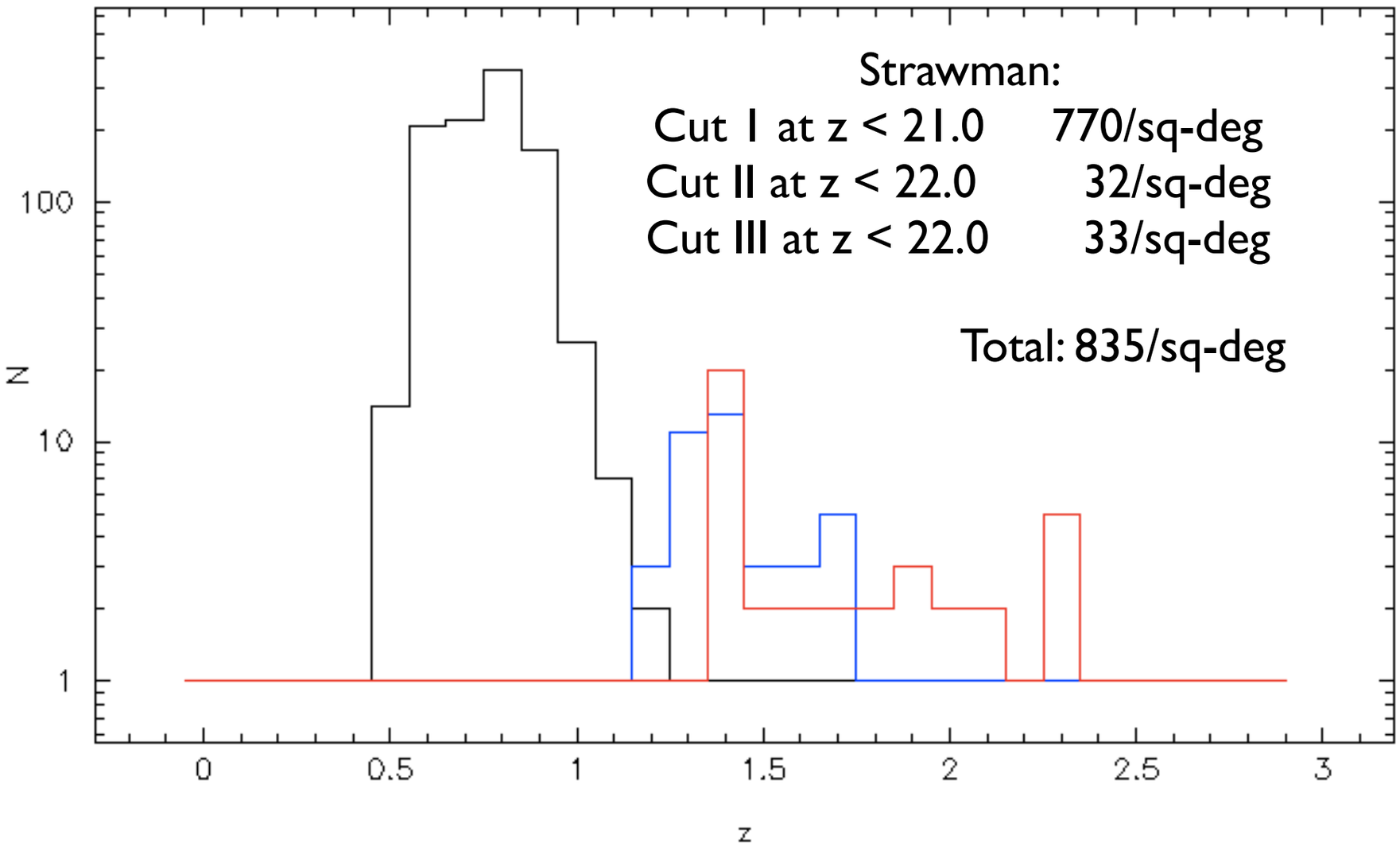
A Strawman LRG Sample

Cut I 0.5 < z < 1.2
Cut II 1.2 < z < 1.7
Cut III 1.4 < z < 2.5



Cut I z = 0.81
Cut II z < 1.50
Cut III z < 1.78

Here, then, is the strawman target selection. A simple r-z cut can provide a reasonably flat number with redshift for 0.6 < z < 1.0. Similarily, cuts in the g-r, r-i could provide a similar sample at 0.4 < z < 0.6 and at 0.3 < z < 0.45. We could, in fact, do a SDSS LRG I cut and perform a LRG sample in the deep southern galactic cap, completing the program SDSS III took up.
With the z-H cuts, using our companion survey VHS data as part of our target selection data set we can extend the pop. to z= 1.5 and z=2.0 as readily as we are wiling to let the z-band drop towards z= 23.

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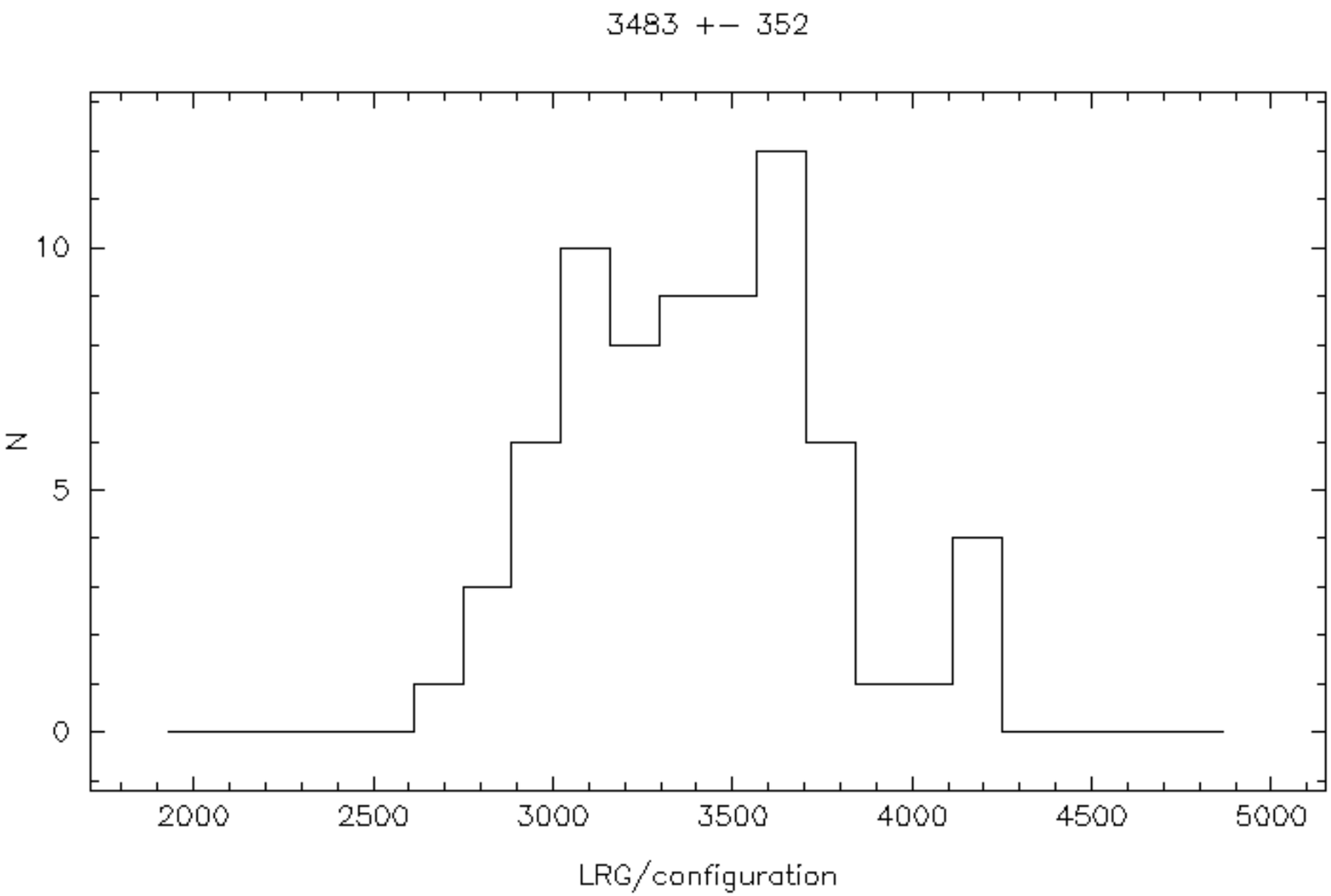
Field to Field (Hex to Hex) Variation



3 sq-degree chunks from the Busha & Weschler DES simulations run through a target selection code.

There are 1σ variations of ~300 targets.

3σ this is 300/sq-degree.

A survey strategy question is how to deal with these.

On approach is to visit multiple times or use overlapping fields.

Another approach is to have a sufficient number of fibers in a reservoir to use to when needed. Otherwise allocate to a second program.

Having set a strawman target selection and dialed the surface density to 1000 or 750/sq-degree using a combination of z and r-z cuts, we see the effects of large scale structure here. The survey strategy question is how to deal with this. I'd advocate the reservoir of fibers approach.

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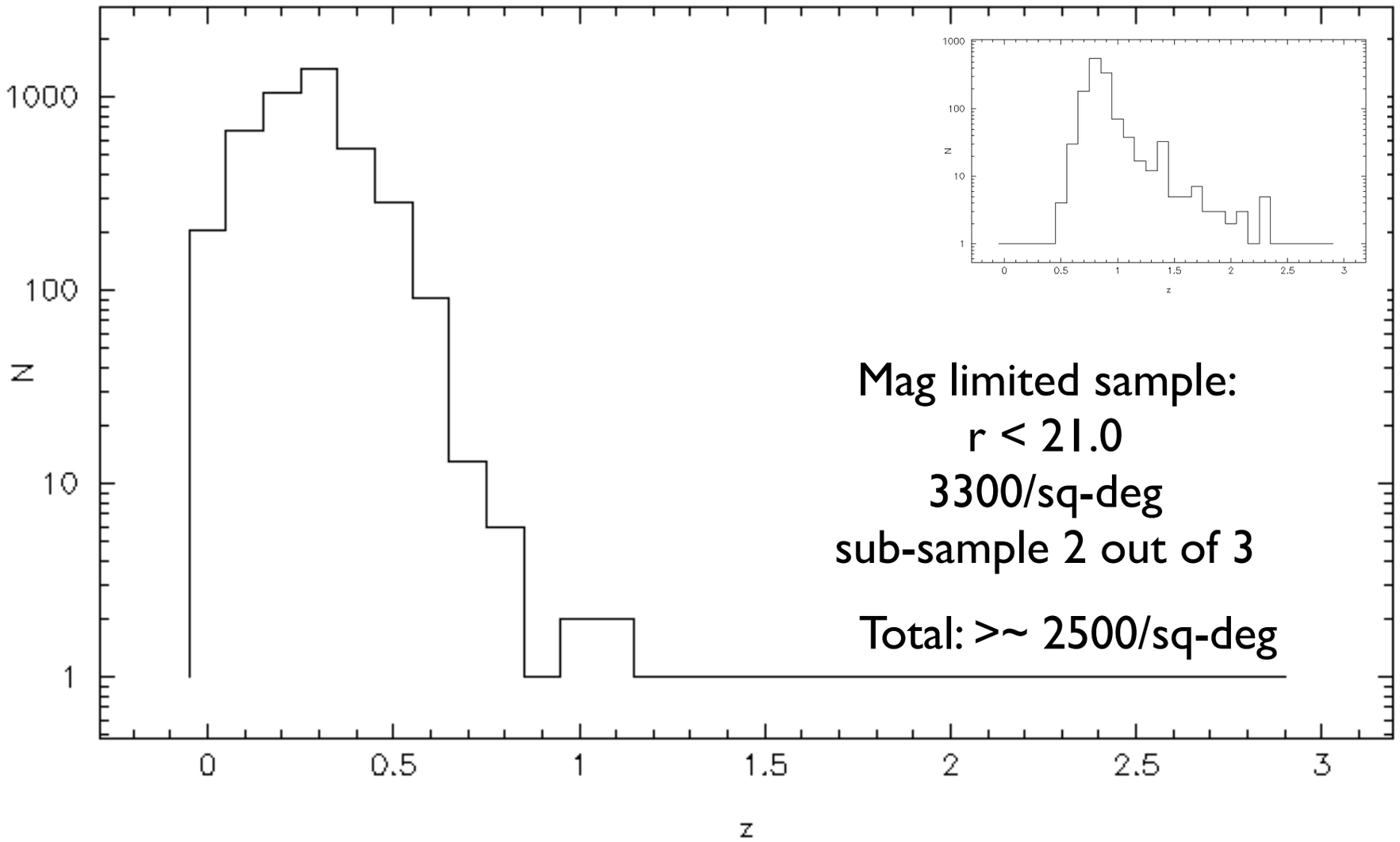
A Strawman Galaxy Sample



The reservoir is best for its design if the targets are brighter than the LRG sample.

z = 0.40

We can do this with a magnitude limited, perhaps uniformly subsampled, sample of galaxies.

Notice that the LSS of the LRG is (anti-)imprinted onto the galaxy sample. This would have to be dealt with in any analysis of the galaxy sample.

Spectroscopic Survey Guidelines

1. The DES is scheduled for 5000 square degrees, but who knows- maybe the collaboration will decide to try more. 10,000 or even 13,000 of extragalactic sky is available.
2. Any sensible strategy will be extensible in the same way DES is.
3. The DES retains flexibility by covering the entire survey area every survey year.
4. The DES receives 105 nights/year:
   - 826 hours astronomical twilight to astronomical twilight. median night is 7.7 hrs long
   - 30 year CTIO weather database gives 653 useful hours/year ⇒ 80% useful
     - q-code ≤ 3. Scale is 0 to 8, in units of 1/8 sky covered by clouds
   - there are ~1650 hexes in the DES area
   - 653/1650 hexes = 0.40 hrs/year.
   - We can allocate 24 minutes/hex for the entire observation sequence.
     - how fast can we do fiber configuration?1 minute? 4 minutes? Assume 4 minutes/hex overhead
   - 20 minutes exposure time per hex per visit.

grammar
hex: 3 sq-degree area on sky
visit: 20 minute exposure on a hex

This talk presents a strawman survey strategy. To start we need some guidelines.

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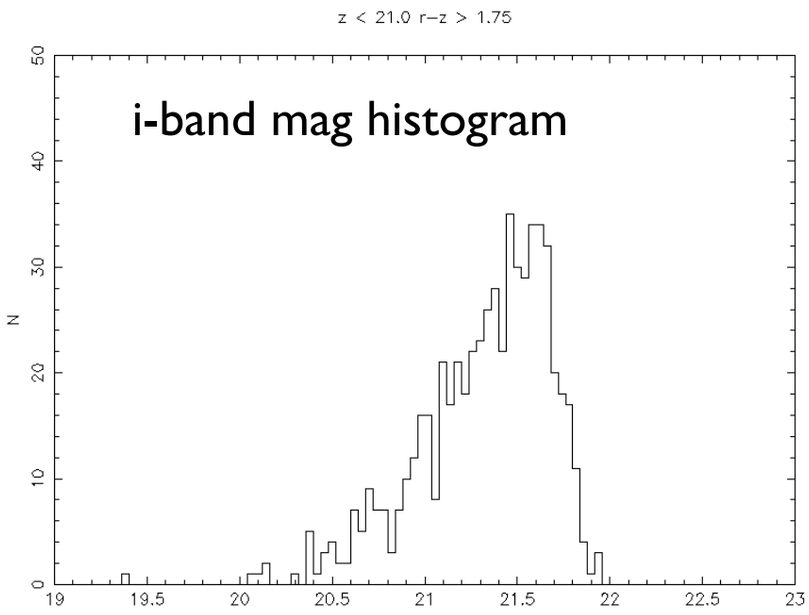
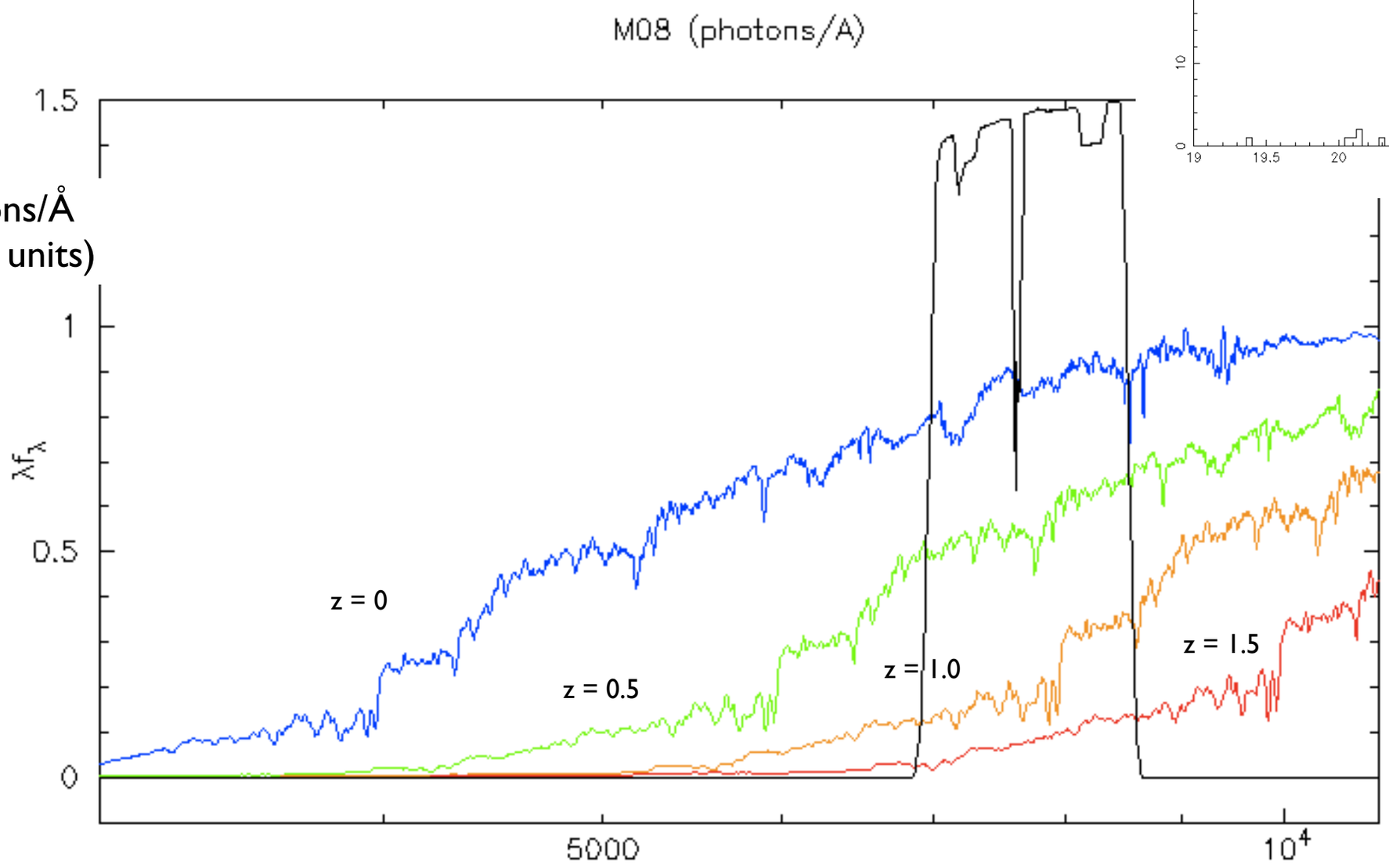
LRG Exposure Times



N photons/Å
(arbitrary units)



Only Cut I,
no Cut II or Cut III

Assume Blanco and DECam: i = 20 is about 540 photons/sec, and additional 50% of losses: 270 photons/sec. At i=21.5, 68 photons/sec.
The sky (at 1.3 airmass) is i = 20 mags/sq-arcsecond.
A 1.3" diameter fiber has 540 photons/sec, then, but it is the noise that we care about: σ = 23 photons/sec^0.5
In a 20 minute exposure, our object gets to 1200*68 photons, while the sky noise goes to 23*35 photons.
If at 7500 Å our resolution is Δλis 4 Å; we'll assume this is 4 Å per pixel, so the spectrum from z-band is spread over 375 pixels.
The object is roughly 220 photons/pixel, the sky noise is roughly σ = 41 photons/pixel. In 20 min: S/N ~5.3. 40 min: S/N=7.5

I will not dwell on exposure times other than to note that despite the LRG sample being z-band limited it is the i-band magnitude that matters as the 4000 A break is in the i-band for the most distant objects in Cut I. The objects in Cut II and Cut III will have to have emission lines to be picked up.

Survey Strategy: Configurations

- Configuration: setting up the fibers into a pattern
  1. Likely to dominate the overhead. 1^m? 4^m?
  2. how far before hand does one need to construct configuration files?
- Scenario 1
  1. One visit of 20^m/year
  2. During off-season, reduce spectra and determine which are done
  3. Remove those done from target list and recompute configuration files
- Scenario 2 (which is more realistic)
  1. Two visits of 10^m/year. Only plausible if re-configuration time is ~1^m
  2. Or: 3 exposures of 6.5^m each for CR purposes, but avoiding re-configuration time
     - imagine sunrise, changing cloud opacity, changing moon conditions
       - what does the ~10^m image cosmic ray complement look like?
  3. Need mountaintop quick reduction to check done, including combining individual exp.
  4. If we need to re-configure, can we eliminate those spectra that are already done?

The difference in packing size between

4000 fibers (5.5 x 5.5mm) and 6000 fibers (4.5 x 4.5mm)

isn't great. The more fibers the better, right? Or does the configuration time go up nonlinearly?

Now that we have our sample and our exposure times, we can examine survey strategy questions. First we should think about configurations.

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Survey Strategy: Build Out vs. Gather S/N

- Build out is the SDSS approach
  1. Complete a fraction of the survey area each year
  2. What is done is done. Flexibility lies in the ability to change the area to be covered
- Better is the gather S/N approach
  1. Cover the survey area each year
  2. Flexibility lies in the ability to decide what is done, in which objects to target
  3. What if "done" was defined to be a given S/N on a given continuum region.
     - One can determine whether a given target is done in after a exposure unit .
     - LRG need ~2 units, galaxies ~1 unit.
       - in the first year, LRG and galaxies are targeted in a given hex
       - in the second year, some of the LRG and all of the galaxies are removed from the target list
       - so the second year consists of less LRG, and completely different galaxy targets

I think the latter approach plays to the strengths of a wide field spectrograph.

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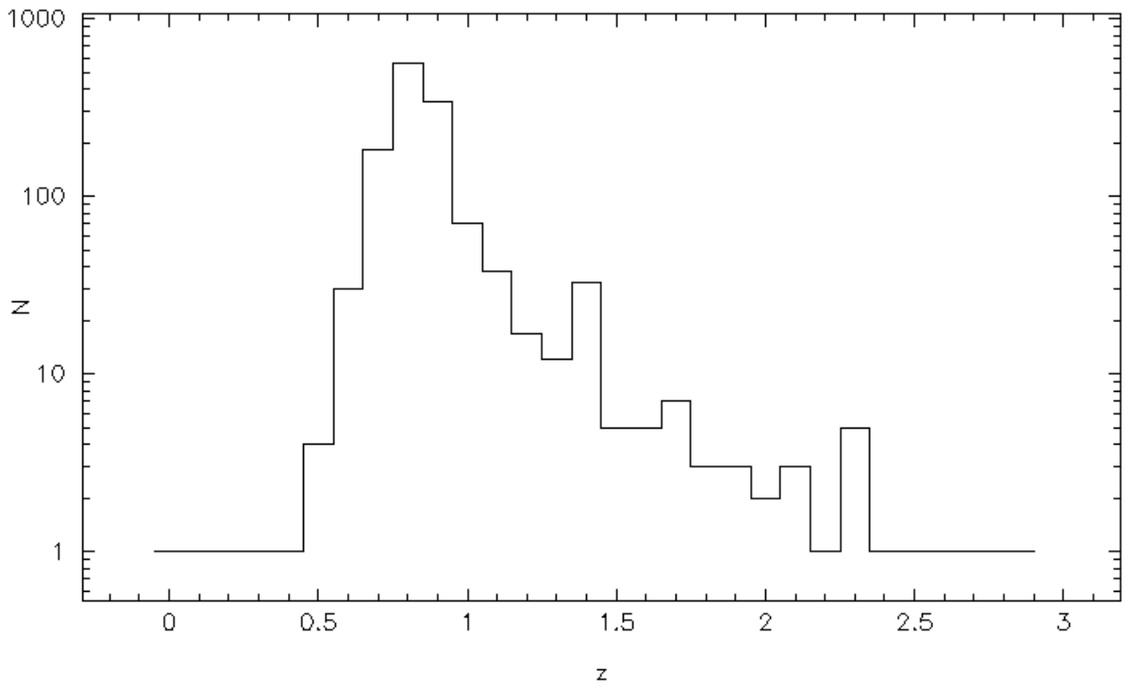
Survey Strategy: Combining Surveys

- A wedding cake survey combines surveys of differing depth by decreasing area with increasing exposure time.
- One can tier in area
  1. An example three tiered project, where each gets ~1/3 of the available time
     - ~30 sq-degrees about DES supernova fields
     - ~1000 sq-degrees on the Viking area
     - ~5000 sq-degrees on the DES area
  2. This is a collaboration of surveys
- Better is to tier in exposure time
  1. break exposure time into units, say 20^m, one visit per year per hex
  2. Samples can get 1,2,3,4 or 5 exposure units
     - LRG takes 2 units, Galaxies 1 unit
  3. This imagines the samples are spread throughout the survey area

Then one might structure surveys, whether we do disjoint surveys under an umbrella or a single survey. Clearly I have a preference for the latter. Breaking up the exposures into “units” allows one to do this.

A Strawman Galaxy Sample

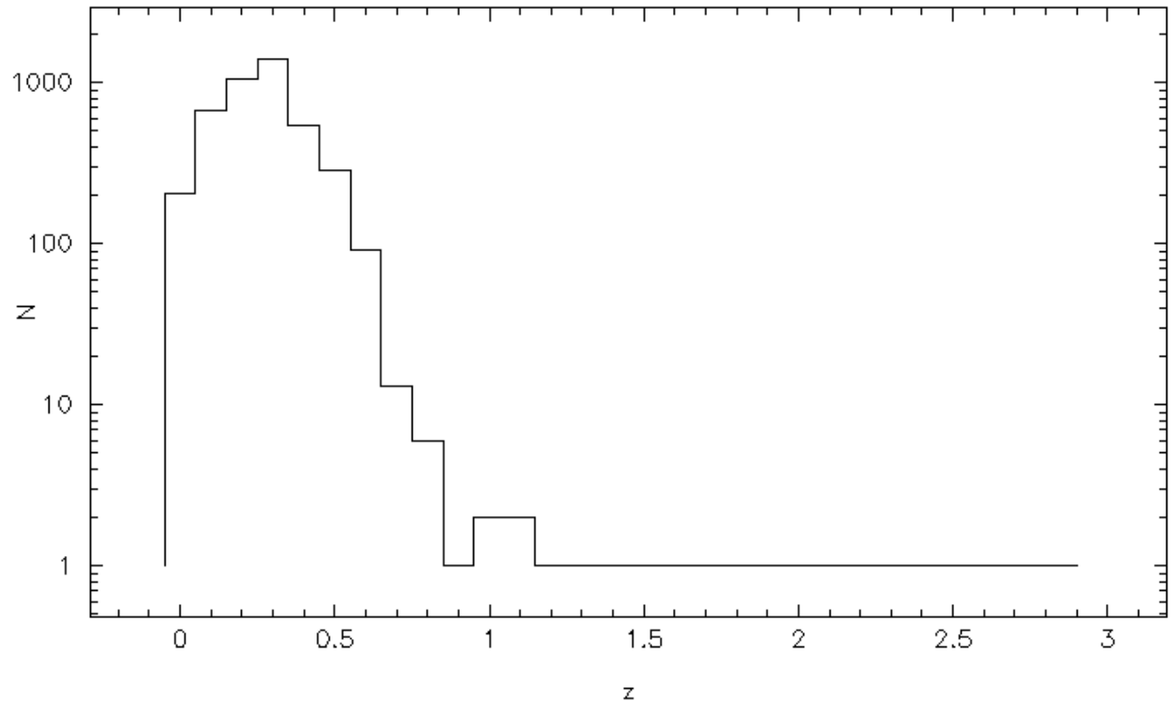


Strawman:

Cut I at z < 21.5 1000/sq-deg
Cut II at z < 22.5 45/sq-deg
Cut III at z < 22.5 30/sq-deg

Total/pointing: 1075/sq-deg

Total after 4 years: 1075/sq-deg
5.4×10^6 LRG



Strawman:
r < 21.0 3300/sq-deg

Total/pointing: 600/sq-deg

Total after 4 years: 2400/sq-deg
12.0×10^6 galaxies

Survey Strategy: Classes of Fibers

- In our strawman survey we have two classes of fibers already, LRG and galaxies
- There will be other classes
  1. Science (?)
  2. Calibration and Operations
     - Sky fibers
       - the question is how few we can get away with.
       - Spatial interpolation map of sky spectra variation
         1. SDSS over the same FOV used 32
     - F subdwarfs to act as spectrophotometric standards
       - ~5/spectrograph (SDSS had 8)
     - Other standards
       - e.g., the reddening standards (SDSS: 8), hot standards for telluric absorption correction (SDSS: 2)
     - Quality Assurance (SDSS ~2)
     - Guide star bundles

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Testing Ideas for DESpec

- A classic question is: how hard would it be?
- How hard would it be to make a mock DESpec spectra generator?
    - In HEP language, a monte carlo of the experimental apparatus is called for.
- There are interesting issues that this would flesh out:
    1. the effects of differential refraction,
    2. seeing and object size
        - the optimal fiber size should be just a function of the population object apparent size and the seeing during the survey (or during entire CTIO year?)
    3. spectral cross talk
    4. and other things that usually we study analytically or from experience.
- One would not need to feed it the right target selection population, nor would more than one spectrograph be necessary.
    1. But changing the target selection population will have effects on the success rate of obtaining spectra by, for example, changing the mean size of the objects.

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Summary

- The survey design is driven from the science case via target selection ideas
- There is ~20 minutes per hex per year available for exposure (650 hrs/year)
- It is possible to design a survey that covers the whole survey area each year,
- It should be possible to construct LRG like samples at a range of redshifts using simple color cuts. Certainly it is possible to do so with photo-zs.
    1. DES data is certainly most attractive for target selection but there are interesting IR data sets as well.
- One can combine target selection samples in interesting ways
    1. using a galaxy sample as a reservoir of fibers to handle LSS of LRG
    2. switching fibers to a galaxy sample once sufficient S/N on a LRG target is done

- Lastly, keep in mind that this is a giant spectroscopic survey and we'd do well to keep in mind the wider uses of the data. A wide wavelength coverage, good S/N, spatial homogeneity and spectrophotometry are among the keys to this.