The DES Survey Design

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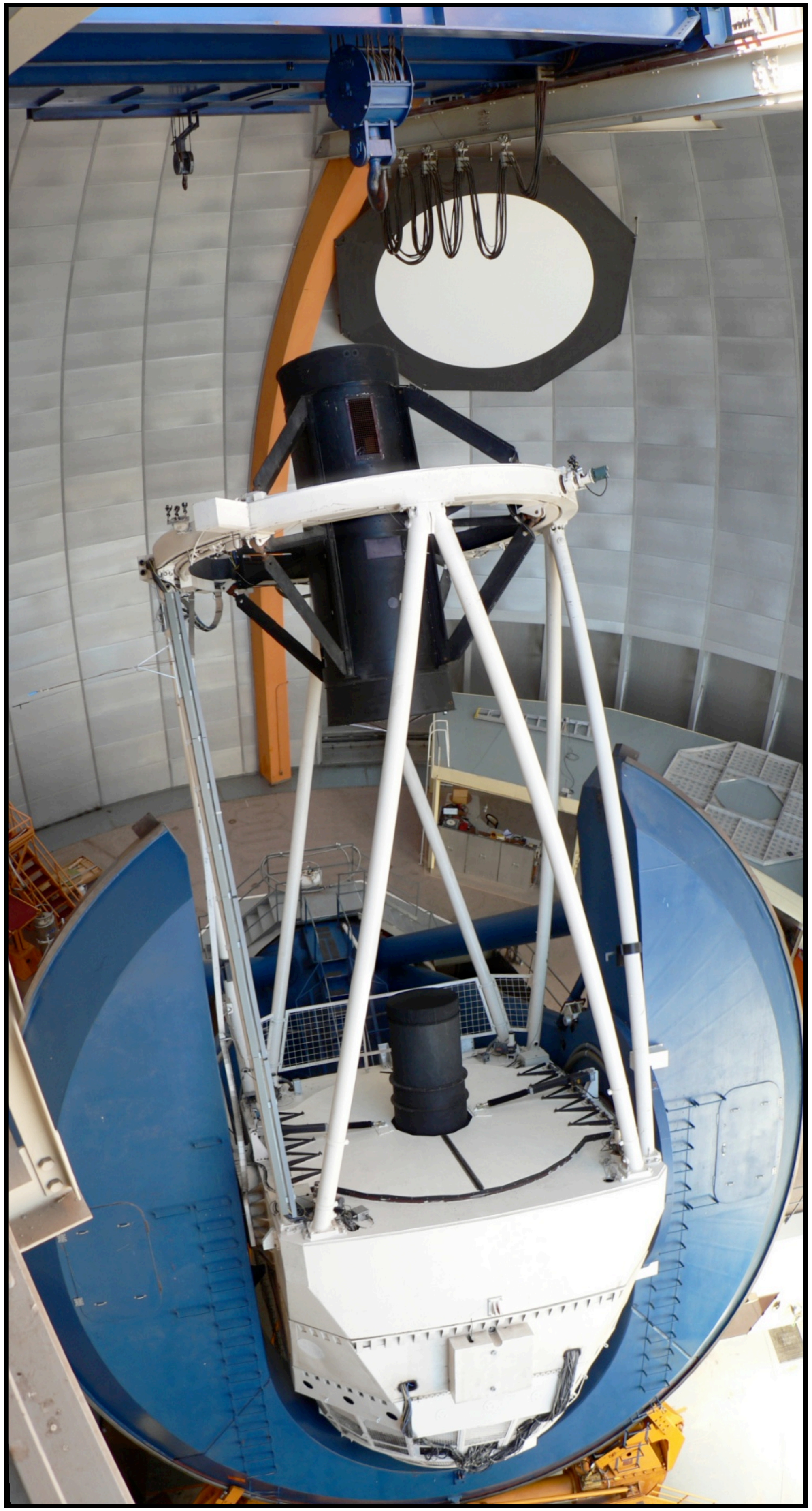
The Dark Energy Survey

- Proposal
  - Perform a 5000 sq-degree survey of the South Galactic Cap using CTIO Blanco 4m telescope
  - Measure Dark Energy with four complementary techniques.
- New Instrument: DECam
  - Replace the prime focus cage with a new 2.2° field of view corrector and a 520 megapixel optical camera.
  - Keep Cassegrain (F/8) operational
- Time Scales
  - Approvals and R&D: 2004-2008
  - Construction: 2008-2011
  - First light: October 2011
- Survey
  - 525 nights in Sept-Feb, 2012-2017
  - Overlap SPT SZ and VISTA VHS



DARK ENERGY SURVEY

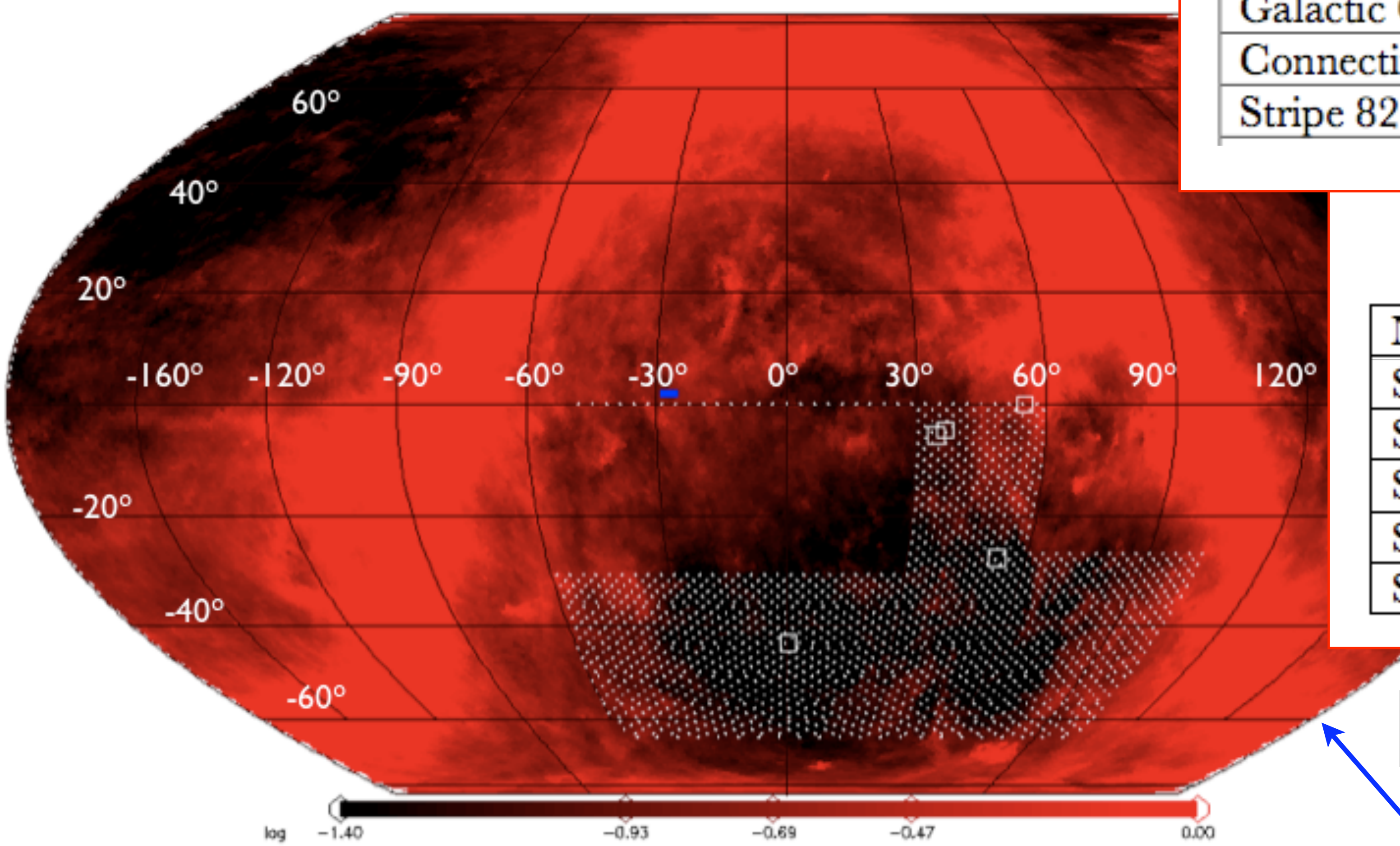
Survey Baseline

Main Survey Fields

Name	Right Ascension	Declination
SPT	-60 ≤ RA ≤ 105	-65 ≤ Dec ≤ -30
Galactic Cap	-30 ≤ RA ≤ 30	-30 ≤ Dec ≤ -25
Connecting	30 ≤ RA ≤ 55	-30 ≤ Dec ≤ -1
Stripe 82	-50 ≤ RA ≤ 55	-1 ≤ Dec ≤ 1

Supernova Fields

Name	Right Ascension	Declination
SN-1: CDF South	52.5	-27.5
SN-2: Stripe 82	48.0	0.0
SN:-3 SNLS/VIRM	36.75	-4.5
SN-4: XMM-LSS	34.5	-5.5
SN-5: Elias S1	0.5	-43.5



This is the current footprint.

This graphic reflects a slightly older footprint. It usefully shows the dust in the galactic plane, the SGP region, and an idea of our footprint.

- 1650 hexes cover the survey area = a tiling
- 2 tilings/year/bandpass
- 1st year has all filters, later years drop filters and increase exposure times
- exposure time in 1st year: 80 seconds

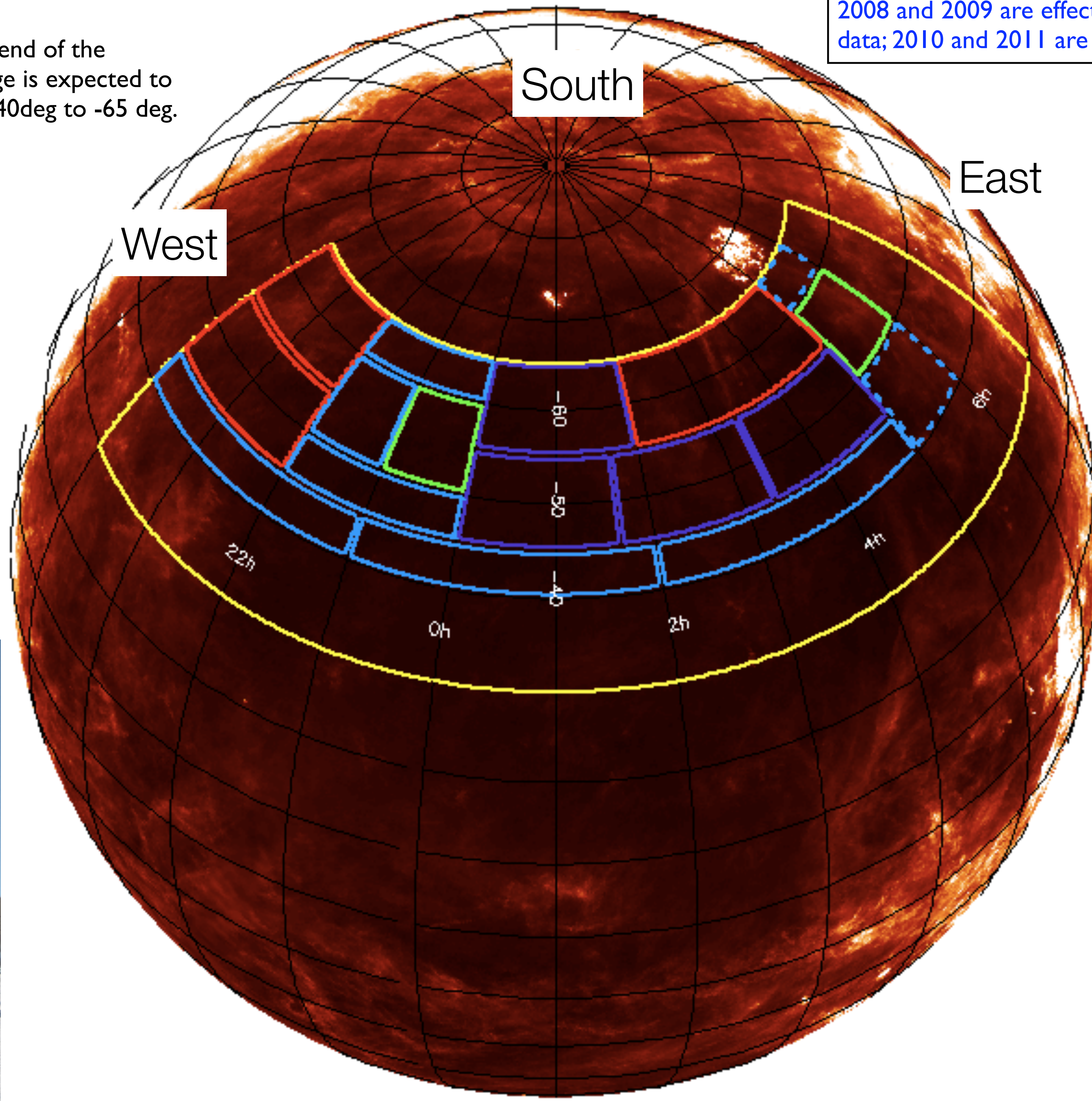
- 5 SN fields
- g,r,i,z
- 3 deep fields, 2 shallow fields
  - deep: 6600 secs per 4 filters
  - shallow: 2200 secs per 4 filters

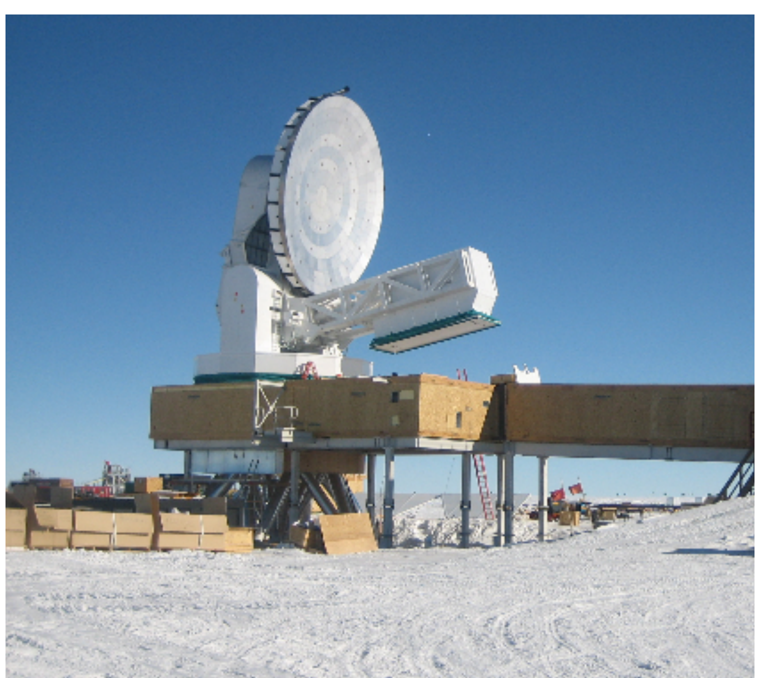
1. How did we design this survey?

We designed a cluster survey.

Footprints: The South Pole Telescope

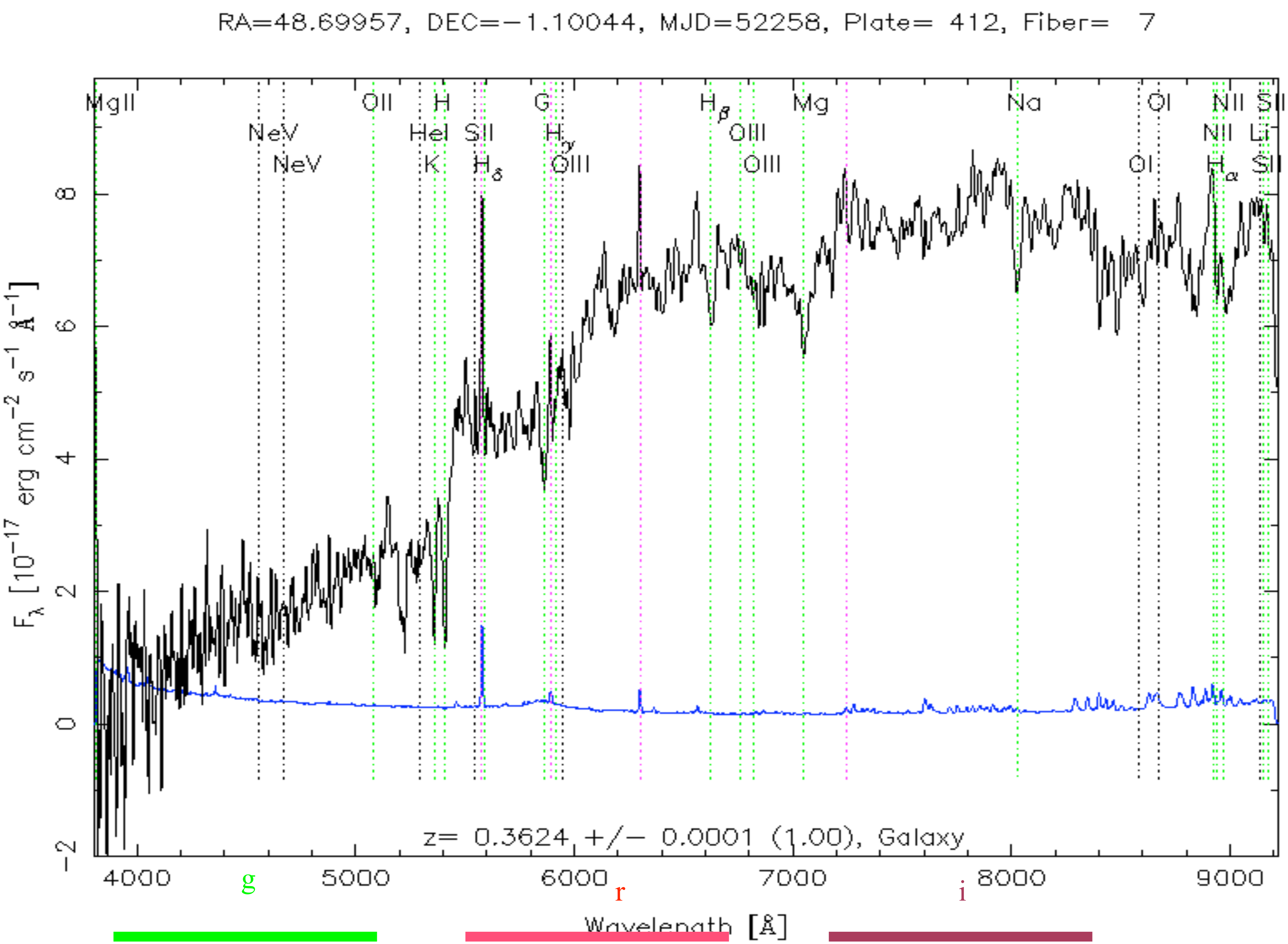
Here is a layout of the SPT footprint through end of the nominal survey period. Note that the coverage is expected to be basically between 20hr and 5hr and from -40deg to -65 deg.



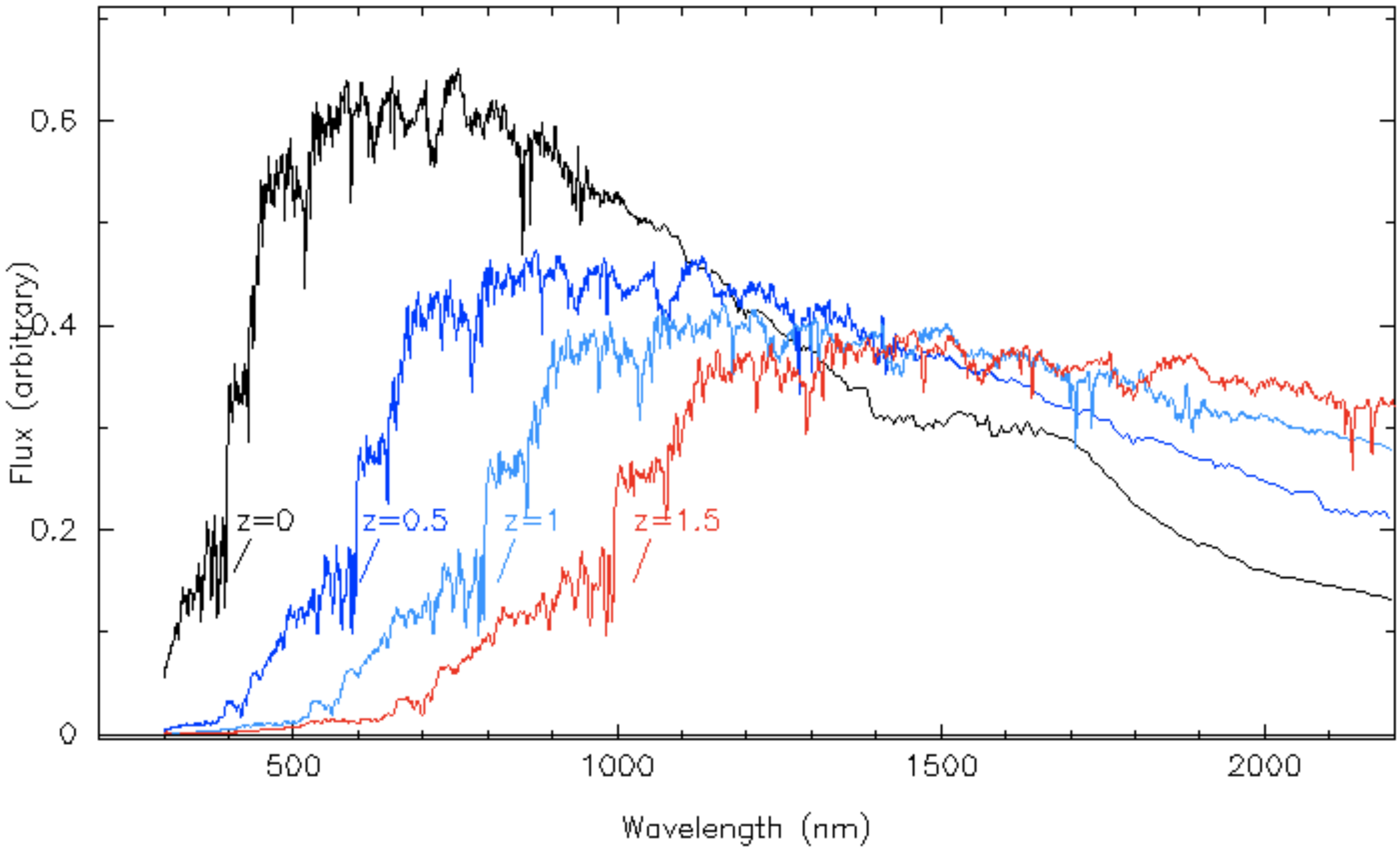


Clusters at low redshift consist entirely of red galaxies

These red galaxies all have very similar spectra



They evolve in redshift in ways that can be modeled



Spectra from Maraston et al 2009

The line is essentially a fitting function to LRG colors

L108 *C. Maraston et al.*

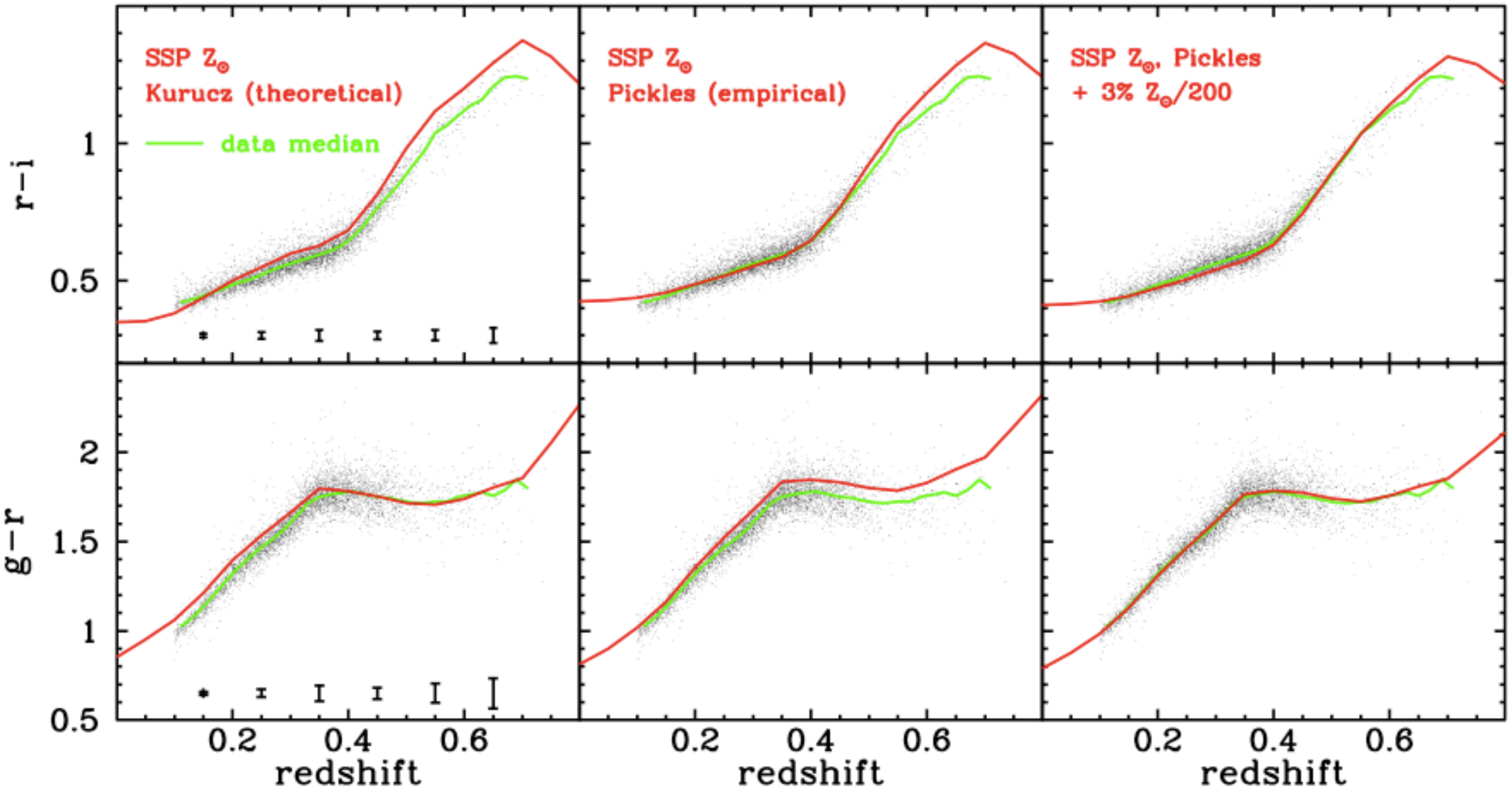
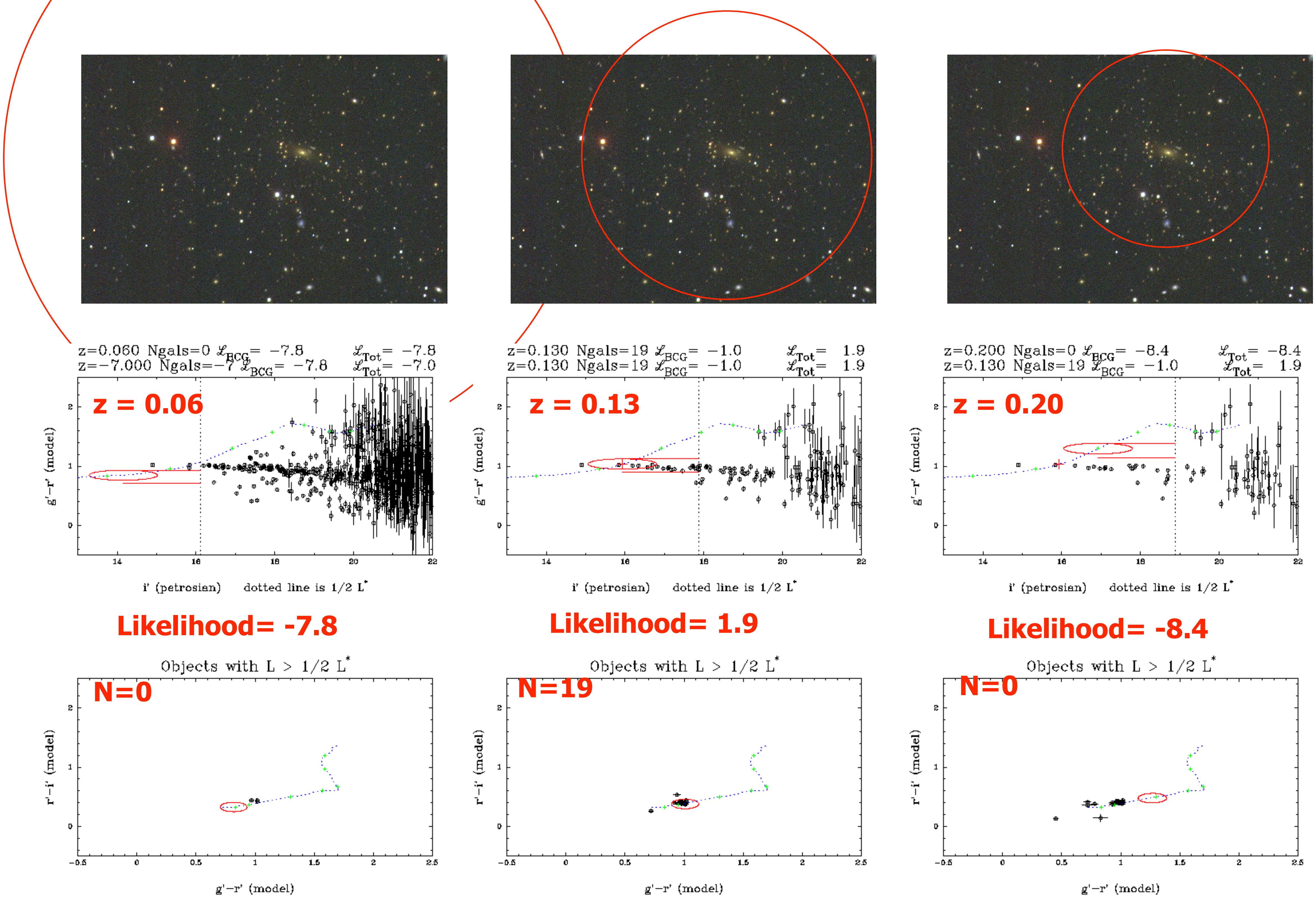


Figure 1. The $g - r$ and $r - i$ colours of LRGs as functions of redshift (points; data from W06). The median is given by the green line. Typical errors as function of redshift indicated by the error bars. Left-hand panels: a solar-metallicity passively evolving, single-burst model with an age of 12 Gyr at redshift zero (red line). Middle panels: same data as in the left-hand panel. The stellar population model uses the Pickles (1998) empirical spectral library instead of the theoretical one (see the text). Right-hand panels: same data as in the left-hand panel with a composite model with 3 per cent by mass of metal-poor [Z/H] = −2.2 stars. Both the metal-rich and the metal-poor component are 12 Gyr old at redshift zero. The metal-rich component uses the Pickles (1998) empirical spectral library.

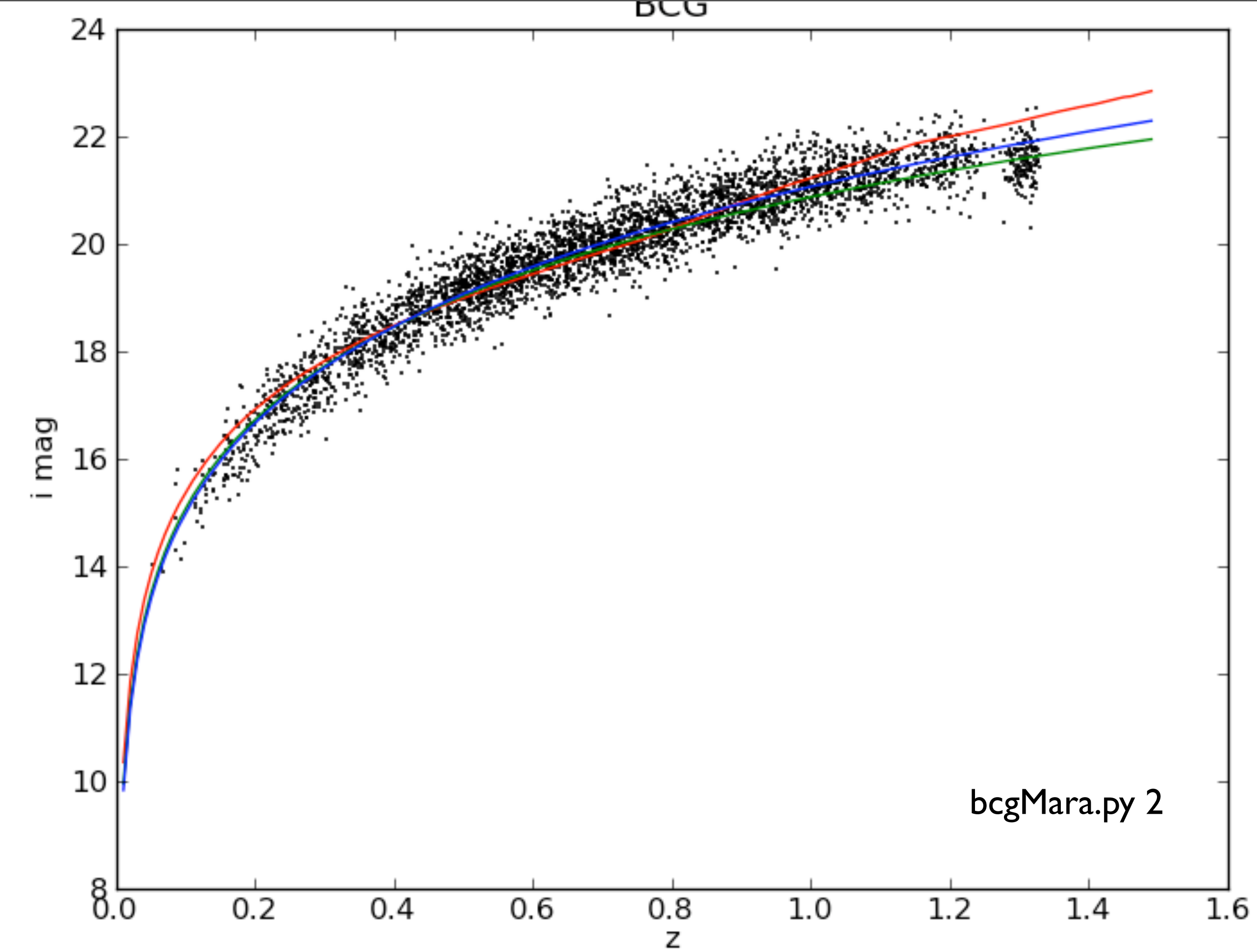
Red Sequence Cluster Finding

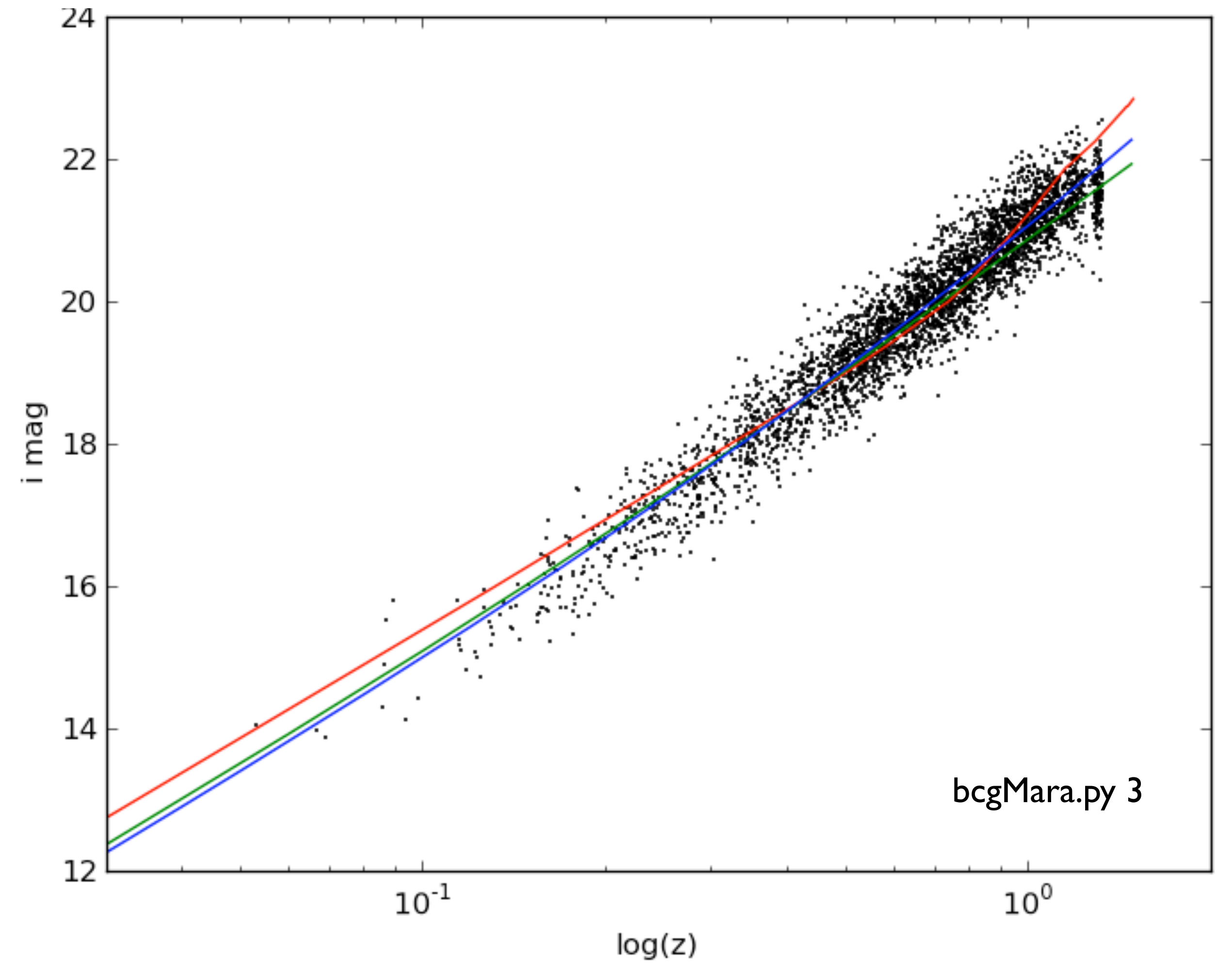


Mocks v2.13

1. i-band mag of the BCG
2. Maraston et al k-correction curves
   - in red
3. -22.45, pure luminosity distance (!)
   - in green
4. modified
   - pivot about z = 0.4
     1. Δmag = -0.1215 +0.3123*z
     2. such that
        - z = 0.1 Δmag ~ -0.35
        - log(z) = 1 Δmag ~ 0.15
   - BCG at z = 1.3 are not well fit
   - in blue
5. This fixed is in des_mara_colors.fit

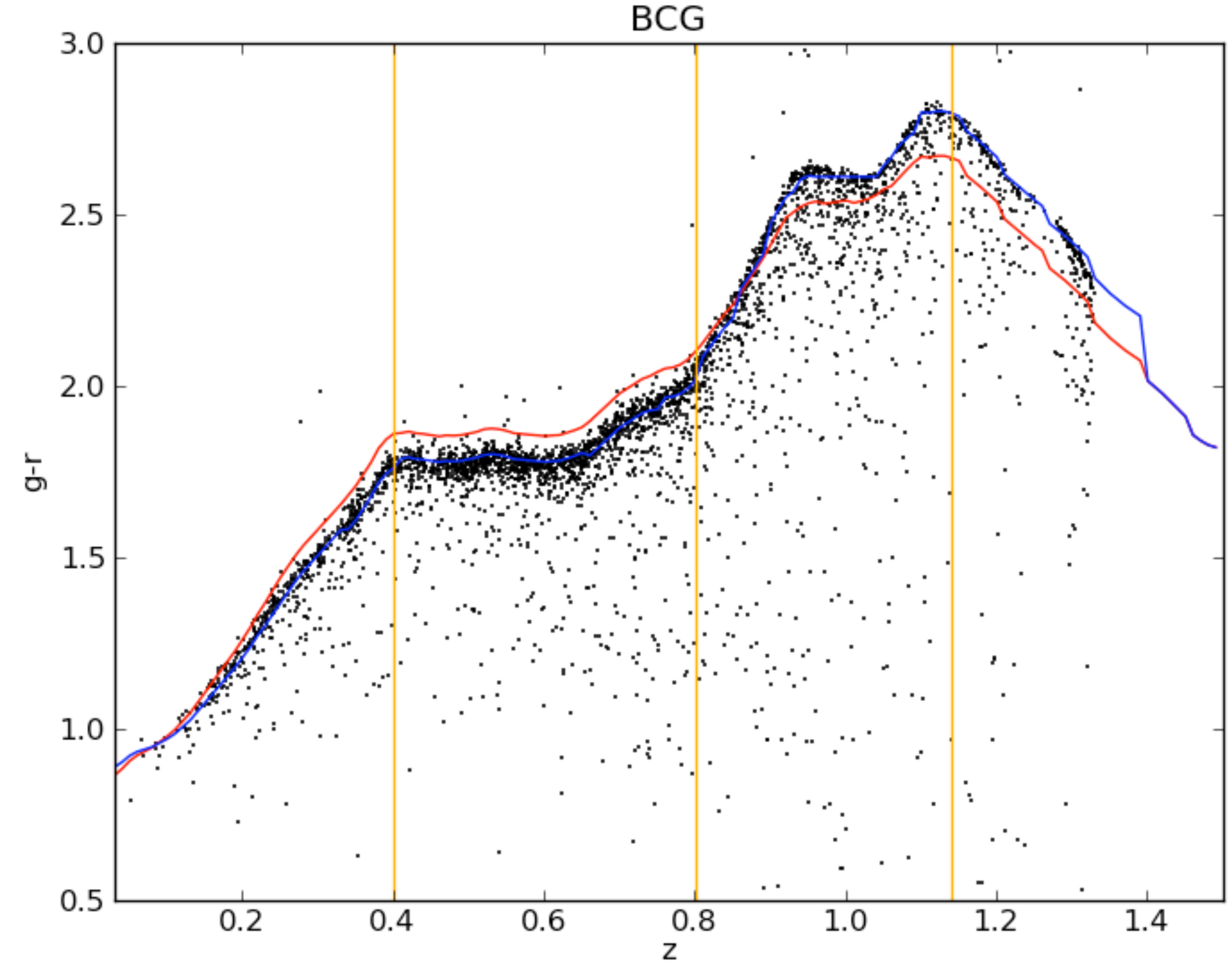
7. 0.4 L* is 2.2 magnitudes fainter than -22.45. Thus BCG are 3 L* beasts.
   - 0.2L* is 2.2+0.75 = 3.0 mags fainter



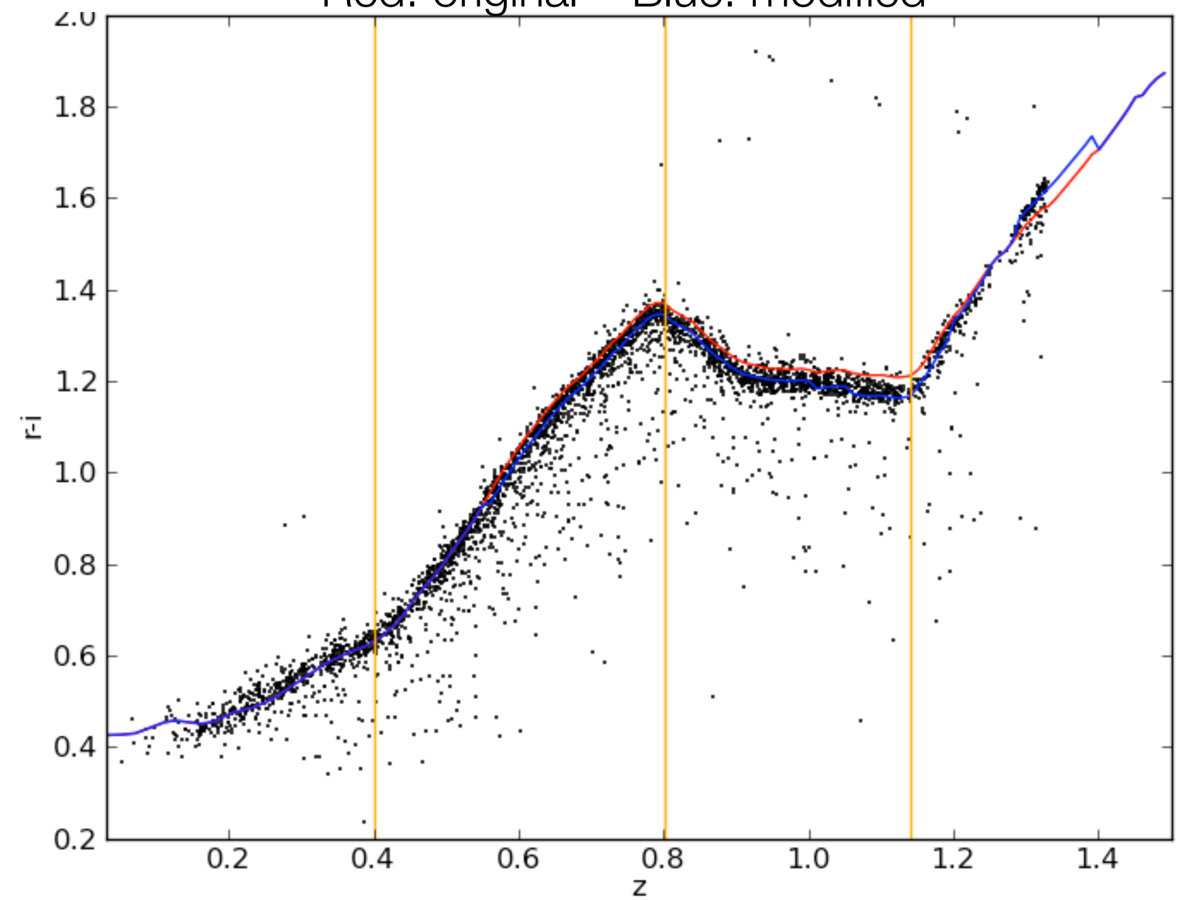


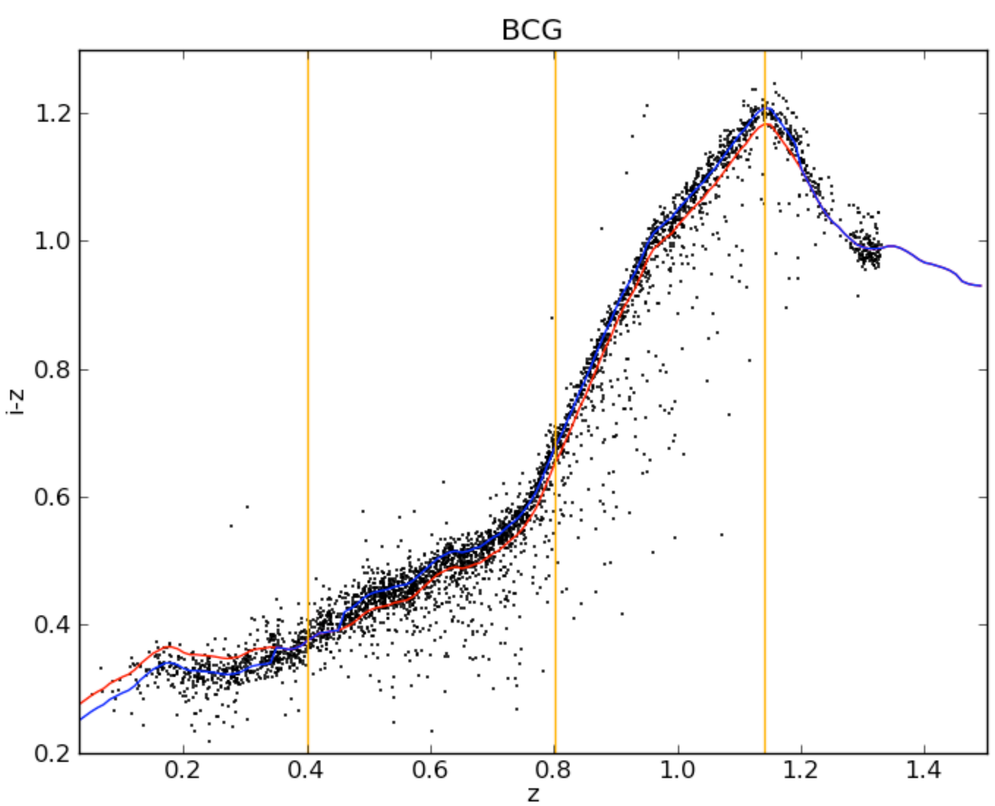
Mocks v2.13

1. Maraston et al k-correction curves
   - in red
   - modified in blue
2. g-r
   - z < 0.9: gr = gr-0.075
   - z > 0.65 && z < 0.85: gr = gr - 0.025 + 11 others
3. r-i
   - z > 0.55 && z < 1.2: ri = ri - 0.025 + 4 others
4. i-z
   - z < 0.35: iz = iz - 0.025
   - z > 0.45 && z < 1.2: iz = iz + 0.025



Red: original Blue: modified





bcgMara.py 4,5,6

DES Photometric Redshifts

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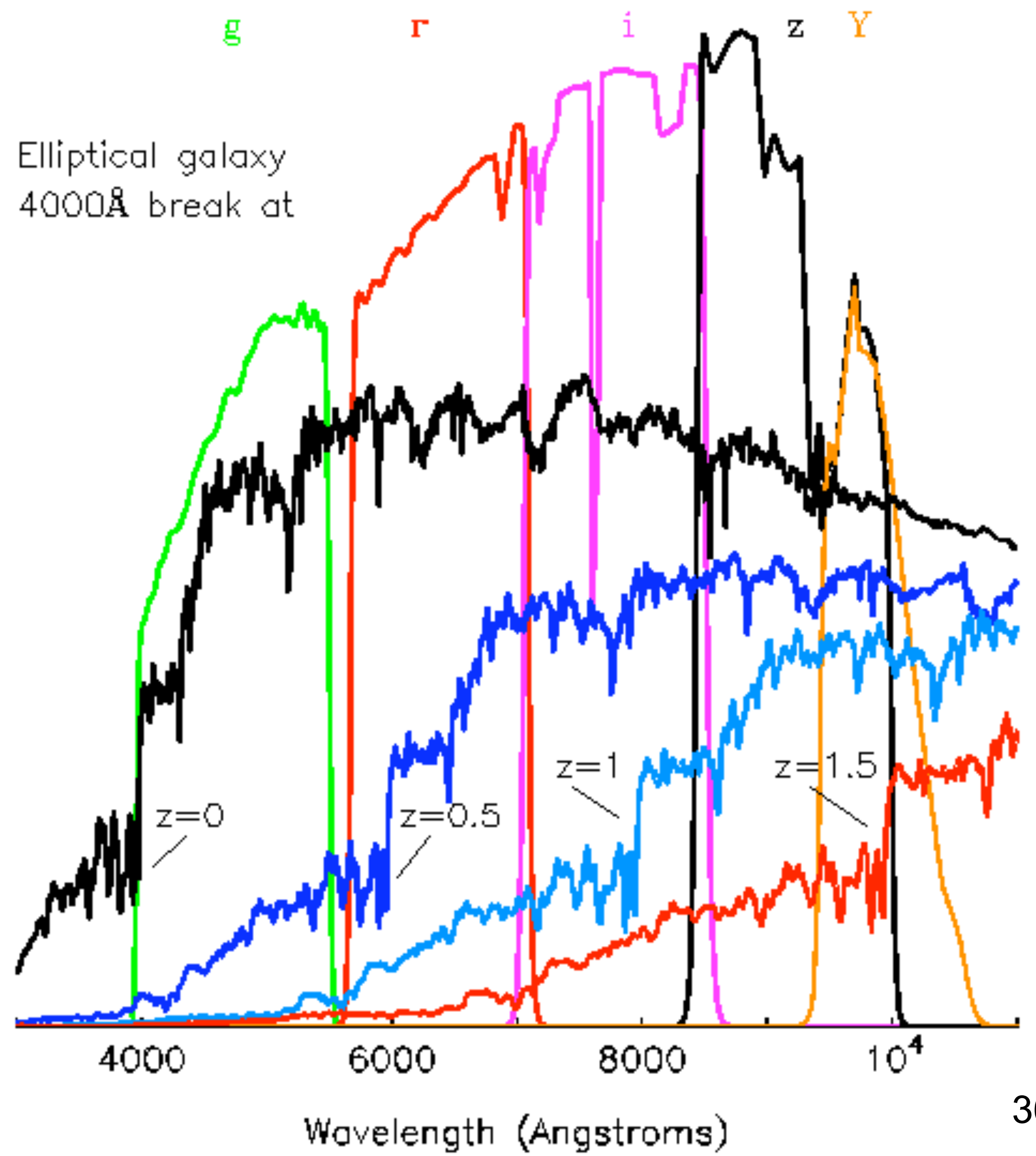
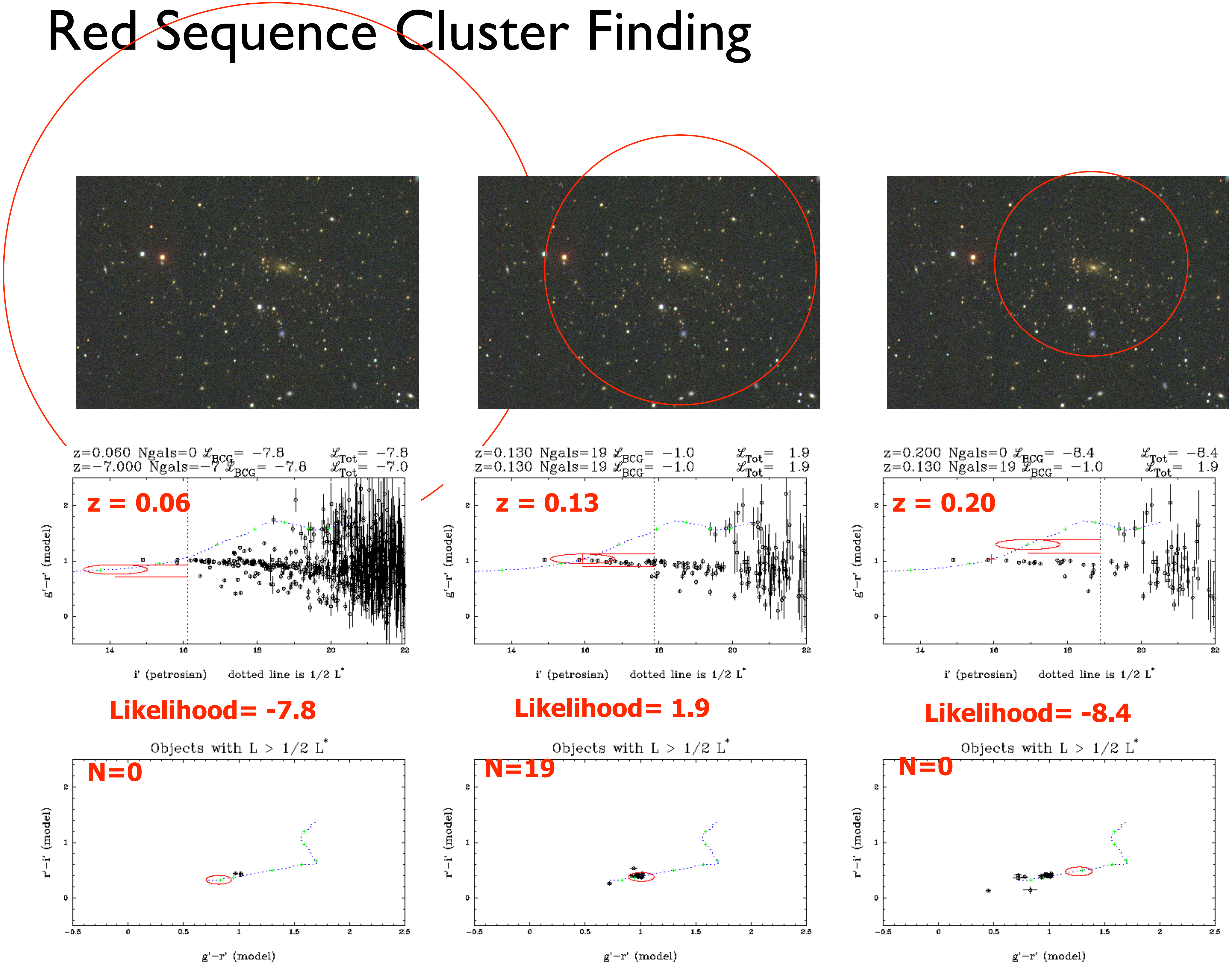
- Measure relative flux in *grizY* filters and track the 4000 A break
- Estimate individual galaxy redshifts with accuracy σ(z) < 0.1 (~0.02 for clusters)
- Precision is sufficient for dark energy probes, provided error distributions are well measured
- Good detector response in *z*-band filter needed to reach z~1.5

Elliptical galaxy spectrum



Red Sequence Cluster Finding



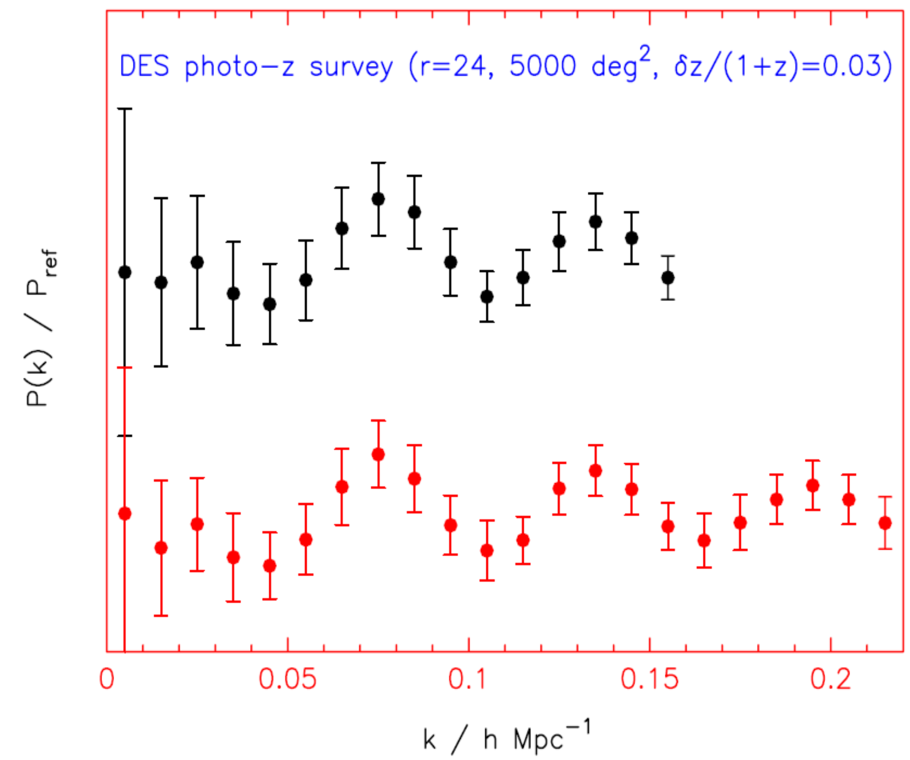
Answer:
Pick an experiment you understand and design it.

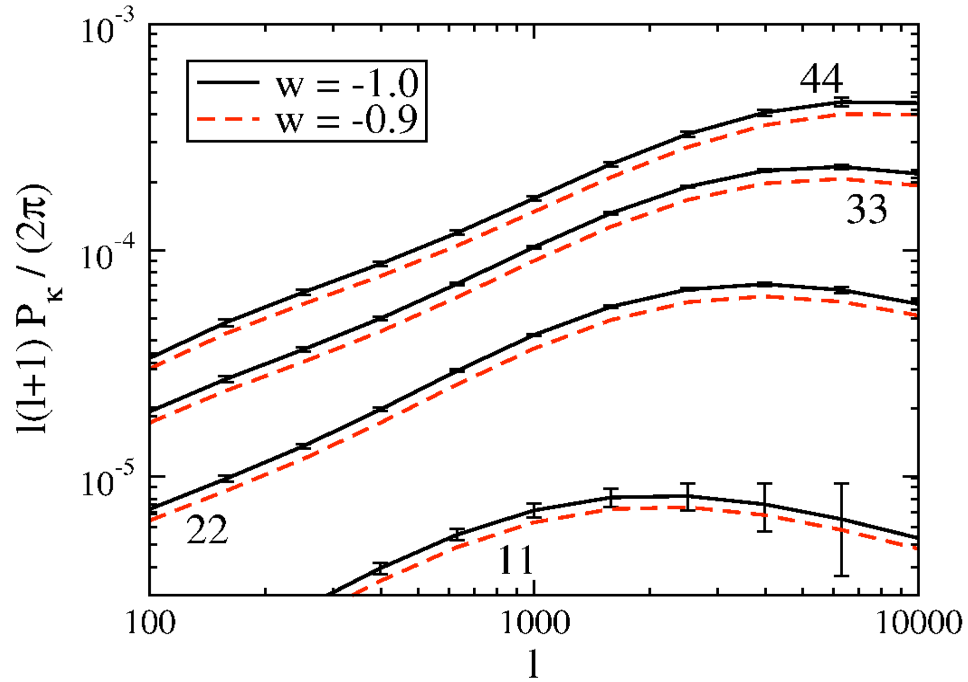
2. Add additional projects that can be done with that survey

WL, BAO, SN

1. BAO: photometric redshift based detection of the angular part of the BAO power spectrum
   - systematics: photo-z and calibrations
2. WL: weak lensing measurement of the matter power spectrum as a function of redshift
   - systematics: PSF size and instability
3. SN: time domain survey of ~3000 SN in order to make luminosity distance measurements
   - systematics: calibration, time window

Fosalba & Gaztanaga





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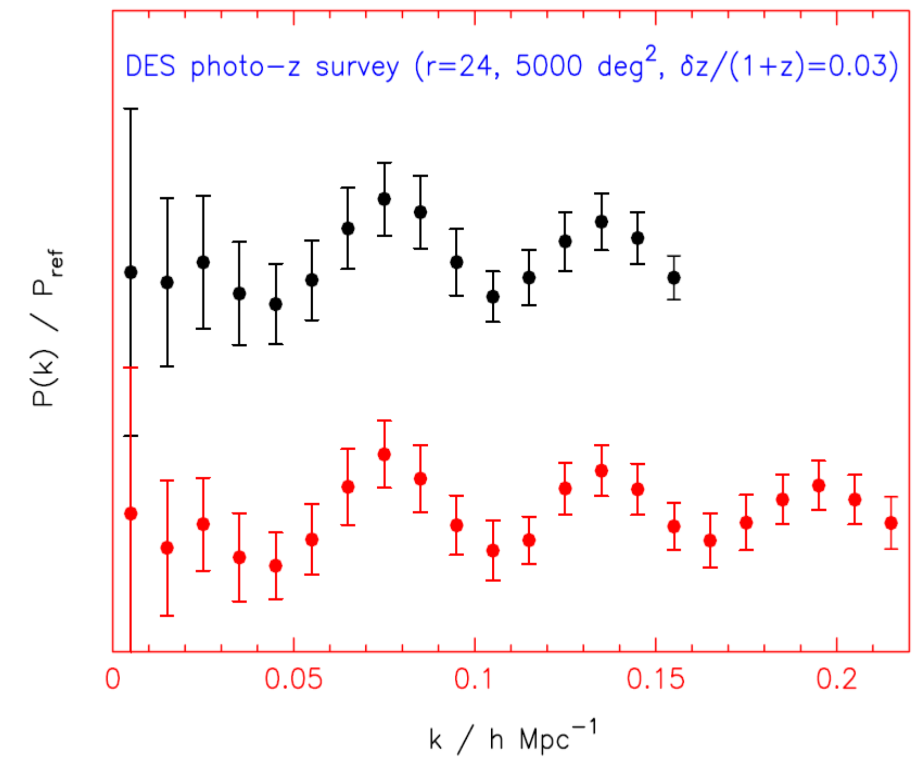
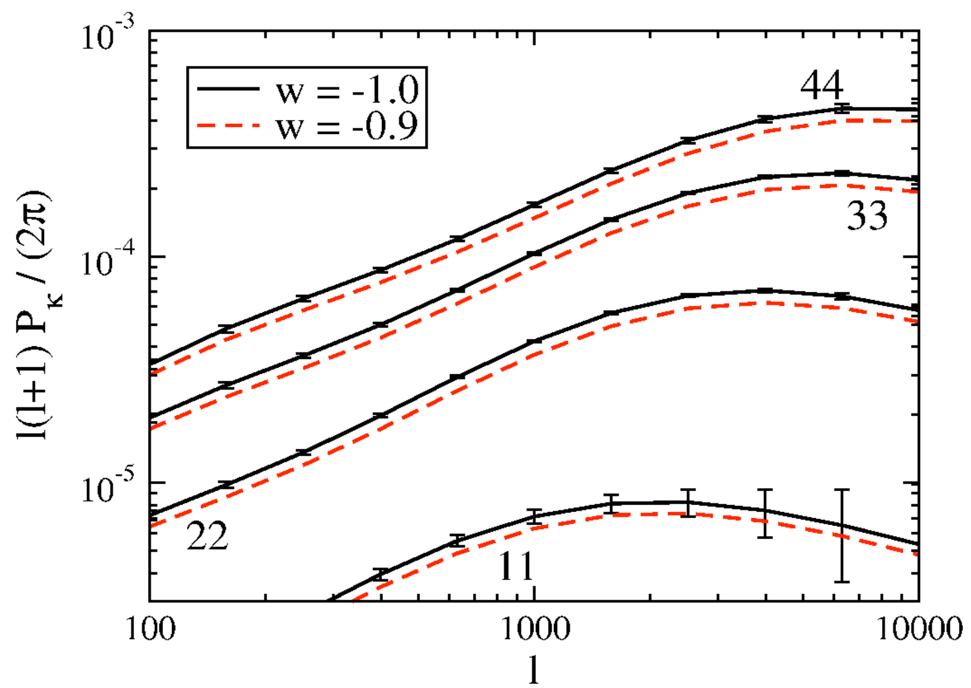


Huterer etal



Galaxy Photo-z Simulations

DES

10σ limiting magnitudes

g 24.6

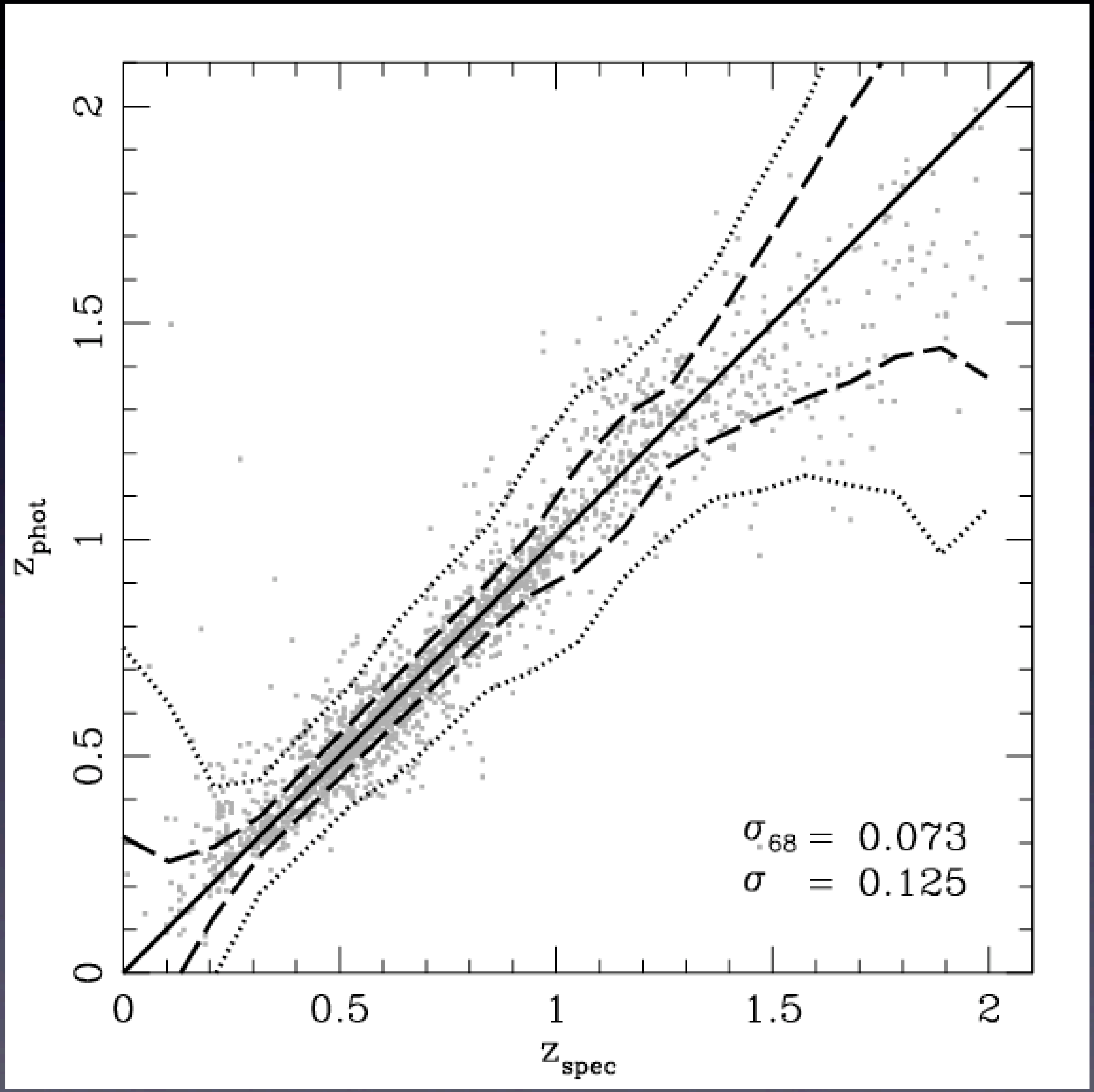
r 24.1

i 24.0

z 23.9

+2% photometric calibration error added in quadrature

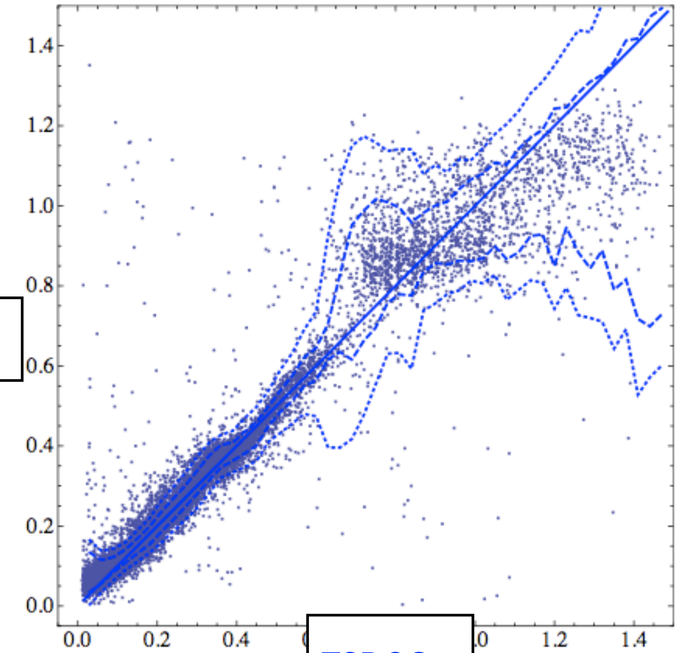
Photo-z systematic errors under control using existing data sets

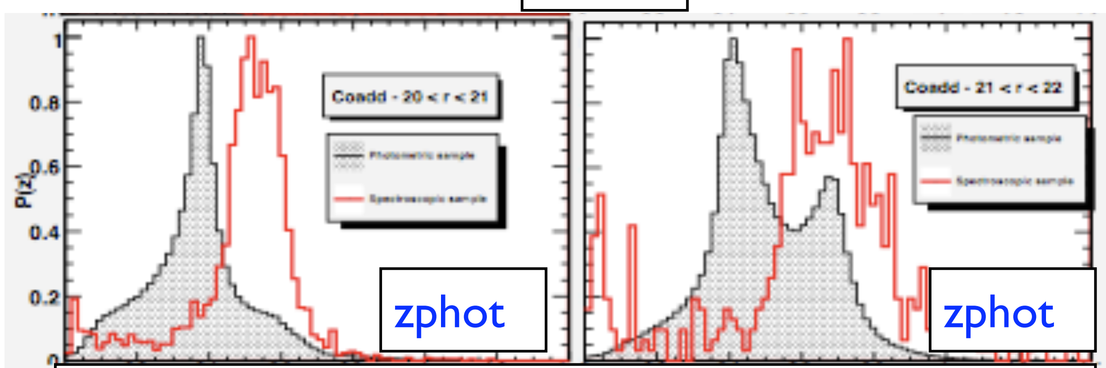


Photometric redshifts

1. Training sets are a big issue
2. Our case in point is the the SDSS Coadd, where we have 7(!) training samples:
   - SDSS DR7
   - CNOC2
   - DEEP2
   - SDSS-3/BOSS
   - WiggleZ
   - 2SLAQ
   - VVDS
3. The solution looks good, but the training samples do not cover the full magnitude and color space. Biases show in the magnitude sliced z histograms
   - one solution- only use photo-zs for objects which there are good training sets - Cunha et al 2009
   - BCG photo-zs have the advantage that the target population is the training population. (GMMBCG)
   - Or, go back to pure color methods (maxBCG)

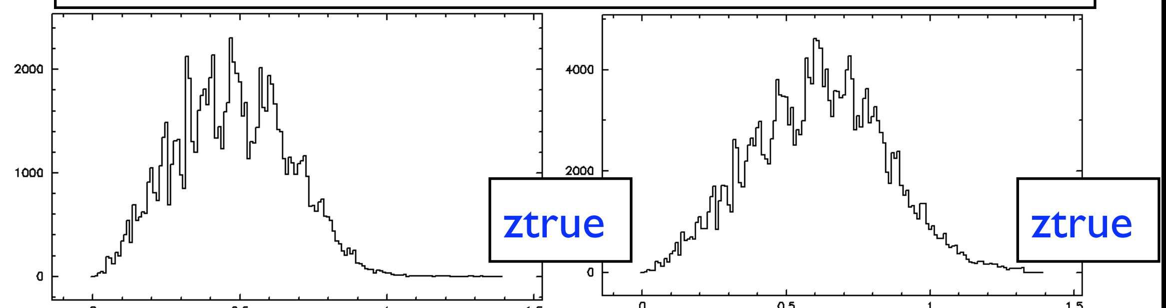
A i<24 solution for the coadd.





Red is training sample in the mag slice. Shaded is the photo-z catalog in the slice.
The way to read this is that the galaxies of this color slice exhibit degenerate with one or two redshifts.

mag slices: 20 < r < 21 21 < r < 22



From a mock catalog, these are what the shaded histograms ideally would look like,

Ribamar Reis et al in preparation

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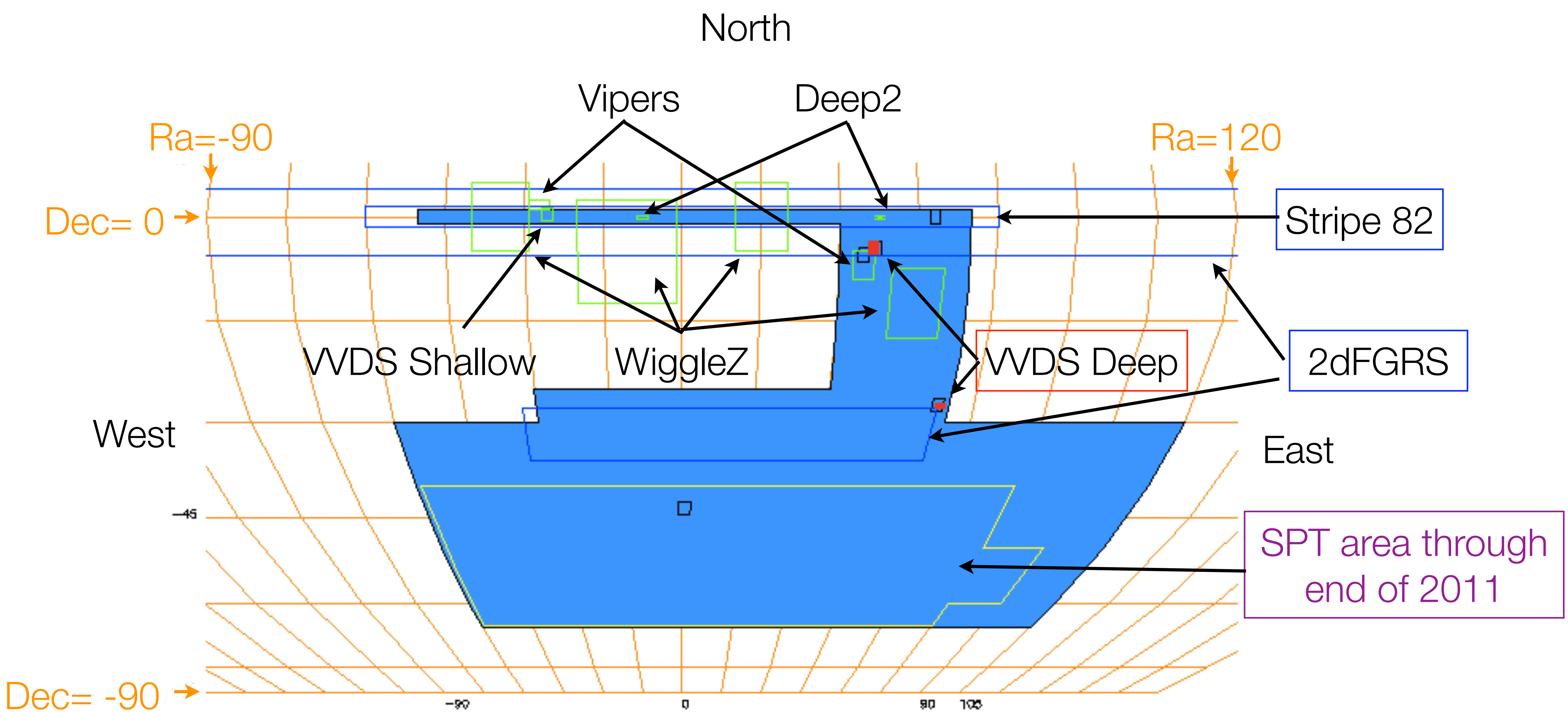
DES Footprint: Photo-z Training Areas

This plot shows a quadrant of the sky centered on the South Galactic Cap

Think:
5000 sq-degrees to i~24.



Redshift surveys:
Blue i < 20
Green i < 22
Red i < 24

Black boxes are the 5 DES SN Fields

The additional programs have to be reasonable: adding few constraints.

For us, it was photo-z and n_eff

3. Try an implementation

The next 8 slides are from 2005

DARK ENERGY SURVEY

Survey Strategy

Design Decision I:

area is more important than depth,
image the entire area multiple times

Design Decision II:

substantial science after year 1
key project papers after year 2

Design Decision III:

photometric calibration strategy rests on tiles
large offsets, not dithers
multiple tiles needed for <2% photometry

Instrumental Factors

- Telescope slew time: 35 sec
- Instrument read time: < 20 sec
- Implies: 2 filters per position to minimize overhead

Conditions

- Work during all phases of moon
  - g,r during dark time
  - i,z during bright time
    - Moonlight has little effect
- Airmass limit <= 1.5
- Seeing limit <= 1.1”

Tiling the Survey Area

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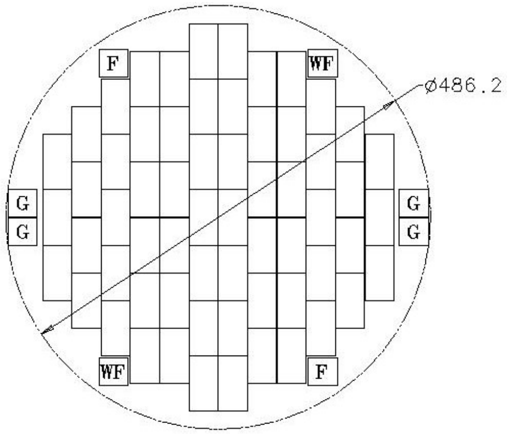
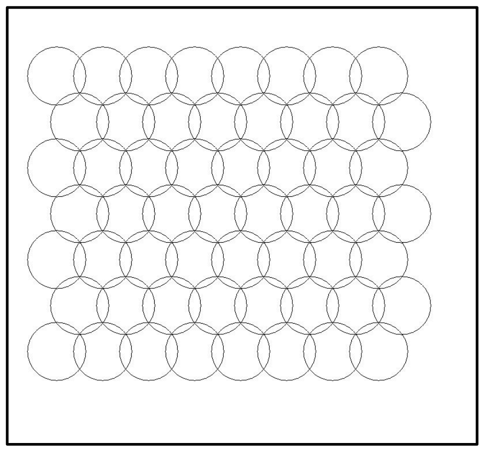
The Camera



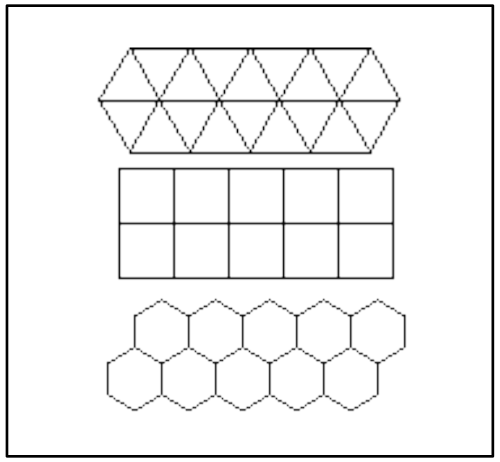
Circles tesselate

cover the area with overlaps

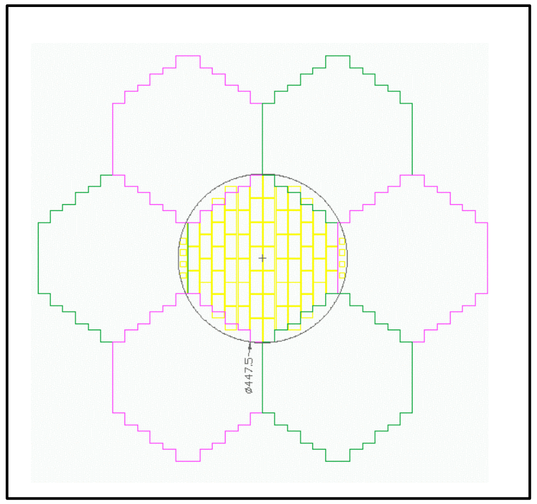


Triangles, squares, heagons tile

uniquely cover the area



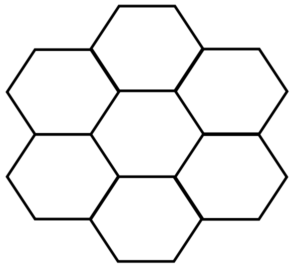
We tile the survey area twice per year per filter.



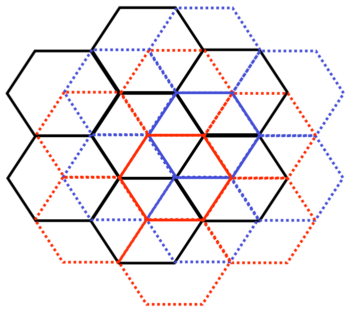
Recipe:

- Tile the plane
- Then, tile the plane with hex offset half hex over and up
- This gives 30% overlap with three hexagons
- Repeat, with different offsets

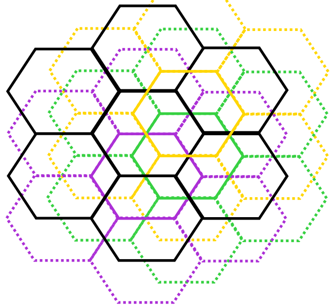
1 tiling



2 tilings



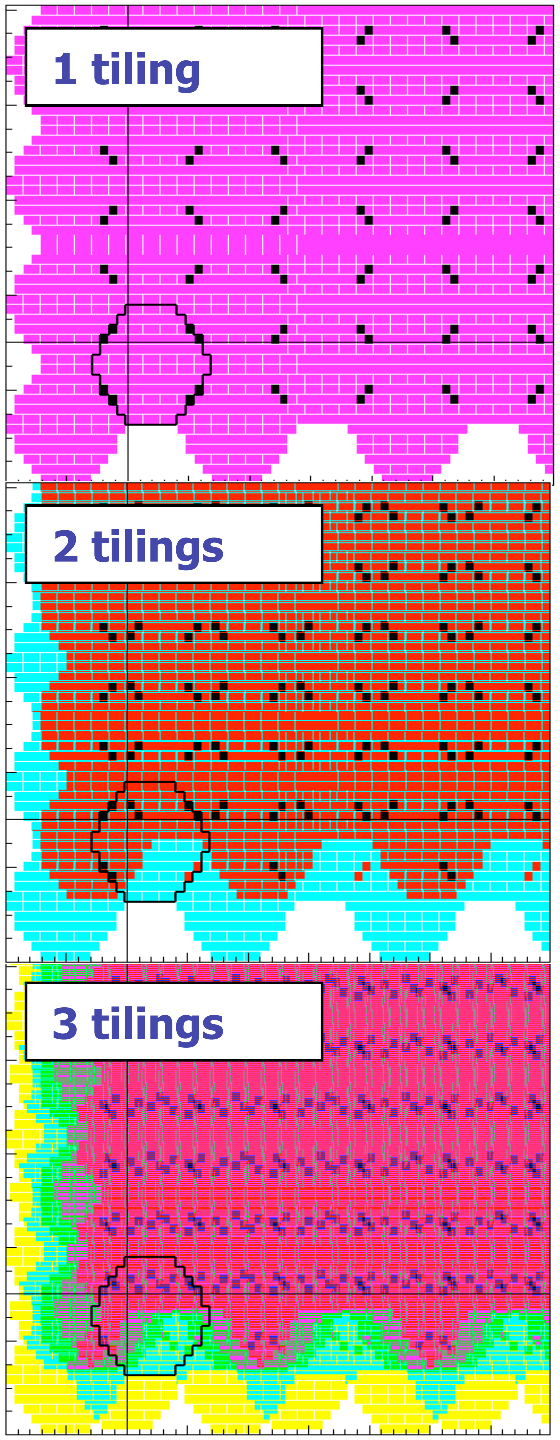
3 tilings

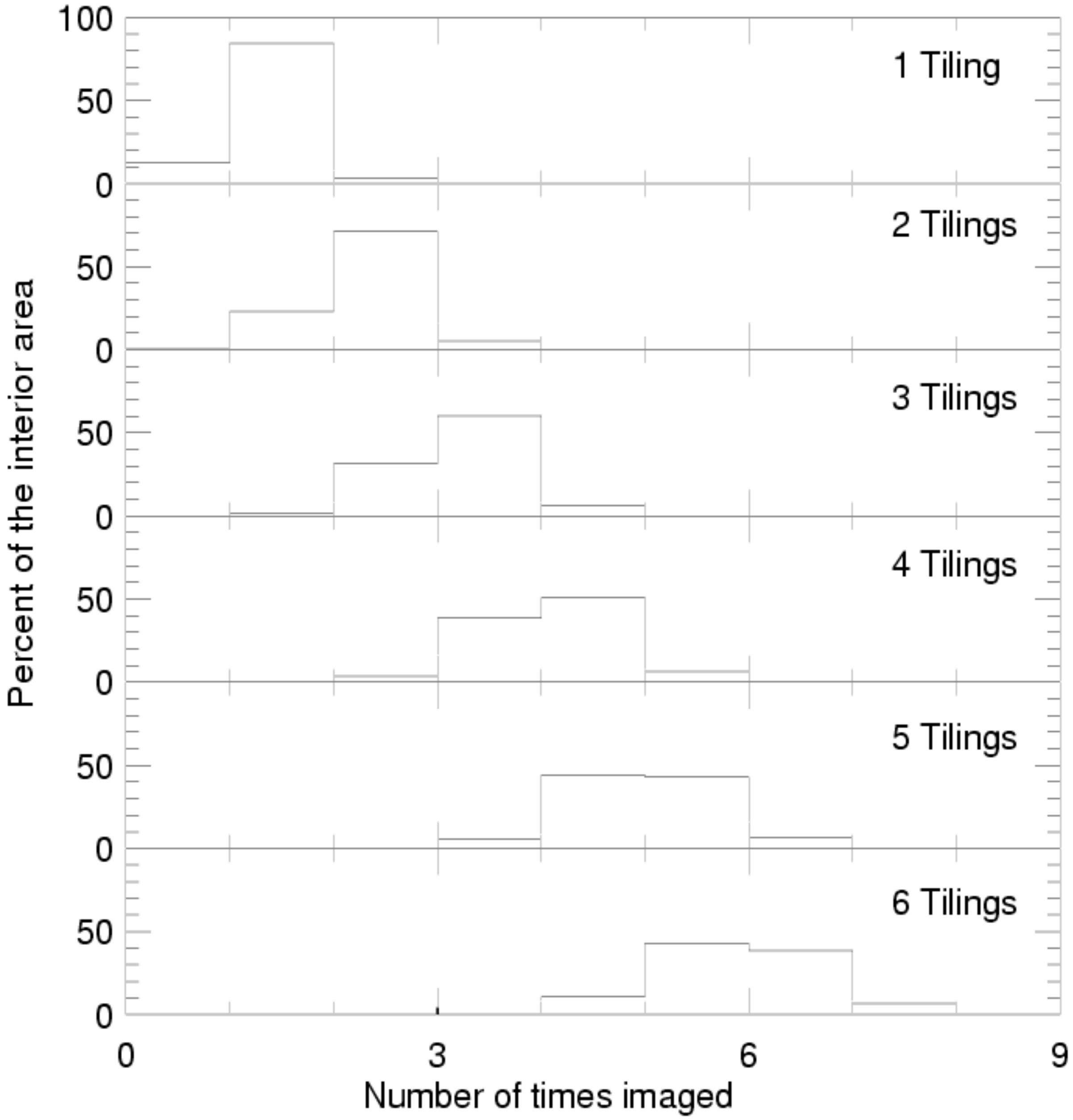


How Many Tilings I

- DECam is 10% sparse
- 10% of each tiling is uncovered

- >= 4 tilings required for every point to have 2 or more images

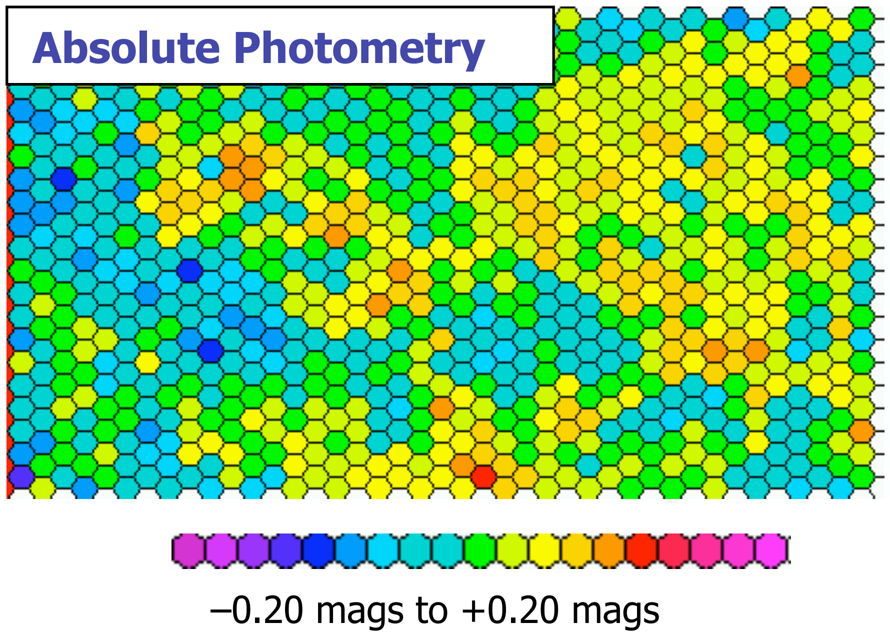




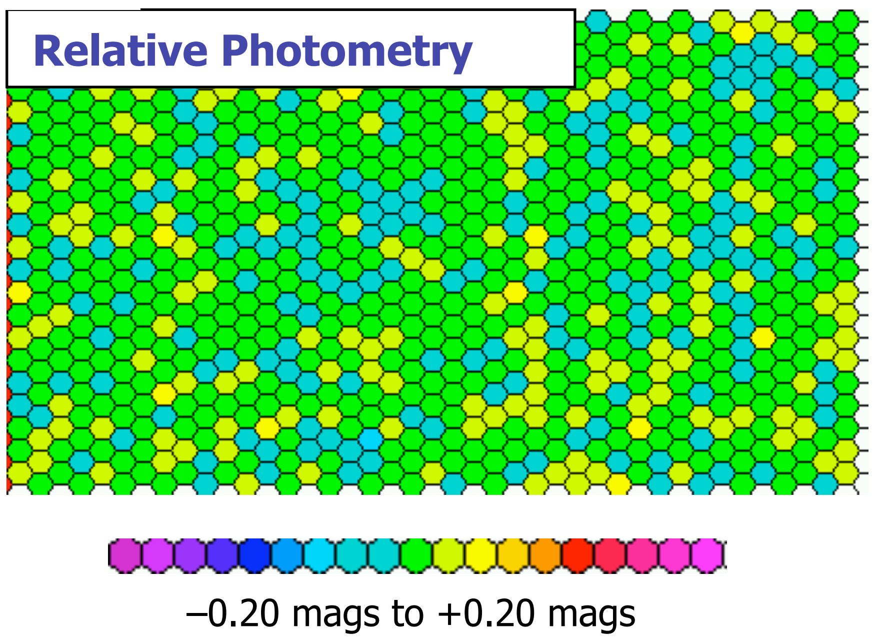
How Many Tilings II

- Multiple tilings allow CMB techniques to average down photometric errors.
- 4 tilings takes us to 0.012% relative calibration.
- Choose 4 tilings as minimum

Absolute Calibration	
Tiling	σ
N	σ /Sqrt(N)



Relative Calibration	
Tiling	σ
1	0.035
2	0.018
5	0.010



Large Area Survey Photometry

- Unique properties of large surveys:
  - Single stable instrument
  - Very large homogeneous photometric data set
  - System defined by 10^8 magnitudes of the survey
    - Placing onto a standard system is unimportant

      Though transformations to standards is very useful.

- The aim of calibration in large surveys is:
  - The magnitudes may be calculated by convolving a spectrum with good spectrophotometry with the system bandpasses, and
  - The magnitudes vary only by $2.5\log_{10}(f_1/f_2)$, independent of position

    f_1/f_2 are the ratio of the photon fluxes
  - The magnitudes have a well-defined absolute zeropoint.

Photometric Calibration Strategy

- Calibrate system response
  - Convolve calibrated spectrum with system response curves to predict colors to 2%
  - Dedicated measurement response system integrated into instrument
- Absolute calibration
  - Absolute calibration should be good to 0.5%
  - Per bandpass: magnitudes, not colors
  - Given flat map, the problem reduces to judiciously spaced standard stars

- Relative calibration
  - Photometry good to 2%
  - Per bandpass: mags, not colors
  - Use offset tilings to do relative photometry
    - Multiple observations of same stars through different parts of the camera allow reduction of systematic errors
    - Hexagon tiling:
      - 3 tilings at 3x30% overlap
      - 3 more at 2x40% overlap
  - Aim is to produce rigid flat map of single bandpass
  - Check using *colors*
    - Stellar locus principal colors

DARK ENERGY
SURVEY

The Survey in Time

The nights of the survey

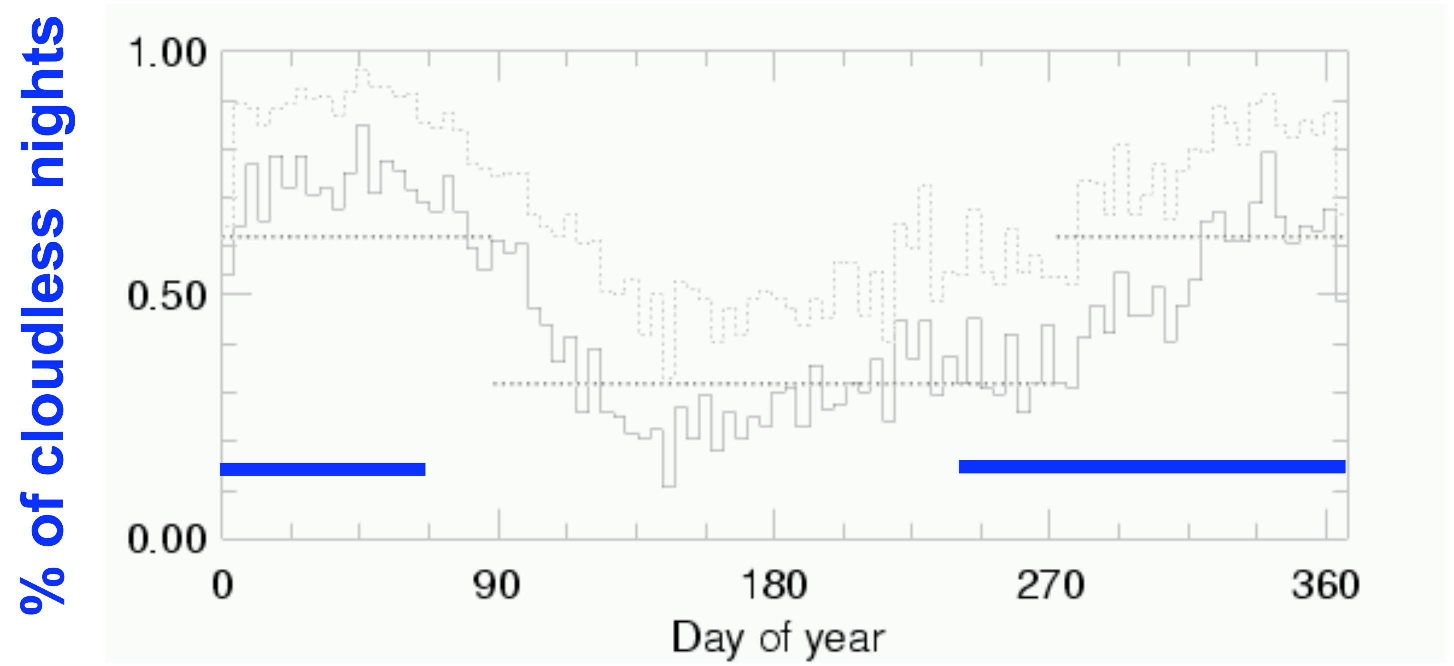
- September: 22 nights
- October: 22 nights
- November: 22 nights
- December: 22 nights
- January: 22 half nights
- February: 22 half nights

- Seeing is 0.7 during survey time
  - 1.0 outside survey time

The years of the survey

- First campaign: 2009-2010
- Last campaign: 2013-2014

The mean weather at CTIO 30 years of weather data.



Survey times in the year

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Survey Strategy II

- Year 1
  - g,r,i,z 100 sec exposures
  - g,r,i,z =24.2, 23.7, 23.3, 22.6
  - Calibration: abs=3.5% rel=1.8%
  - **Clusters to z=0.7**
  - **Weak lensing at 8 gals/sq-arcmin**
- Year 2
  - g,r,i,z 100 sec exposures
  - g,r,i,z =24.6, 24.1, 23.6, 23.0
  - Calibration: abs=2.5% rel=1.2%
  - **Clusters to z=0.8**
  - **Weak lensing at 12 gals/sq-arcmin**
- Year 5
  - z 400 sec exposures
  - g,r,i,z =24.6, 24.1, 24.3, 23.9
  - Calibration: abs=<2% rel=<1%
  - **Clusters to z=1.3**
  - **Weak lensing at 28 gals/sq-arcmin**

- Two tilings/year/bandpass

- In year 1-2, 100 sec/exp
- In year 3, drop g,r and devote time to i,z: 200 sec/exp
- In year 5, drop ii and devote time to z: 400 sec/exp

- If year 1 or 2 include an El Nino event, we lose ~1 tiling, leaving three tilings at the end of year 2. This is sufficient to produce substantial key project science.

4. Astronomy is calculable: simulate the observing

Survey Strategy Simulations I

DARK ENERGY SURVEY

- Simulation assumptions
  - astronomical twilight to astronomical twilight
  - no standard stars
  - 30 year weather statistics, used in 5 year blocks
  - Hybrid SN strategy
  - Slew time model
  - Readout+overhead = 20sec
  - Community time model:

Bright	Full moon +- 1 night
Dark	New moon +- 1 night
Gray	2, 3, or 4 nights centered on first quarter

- The New Baseline
  - Add y-band in years 1+2
  - Year 5 increases z depth by 0.25mag

95% of observations taken at airmass 1.17 +- 0.17

An unusual year- bad weather in Jan/Feb. Most scenarios show this gap in the East.

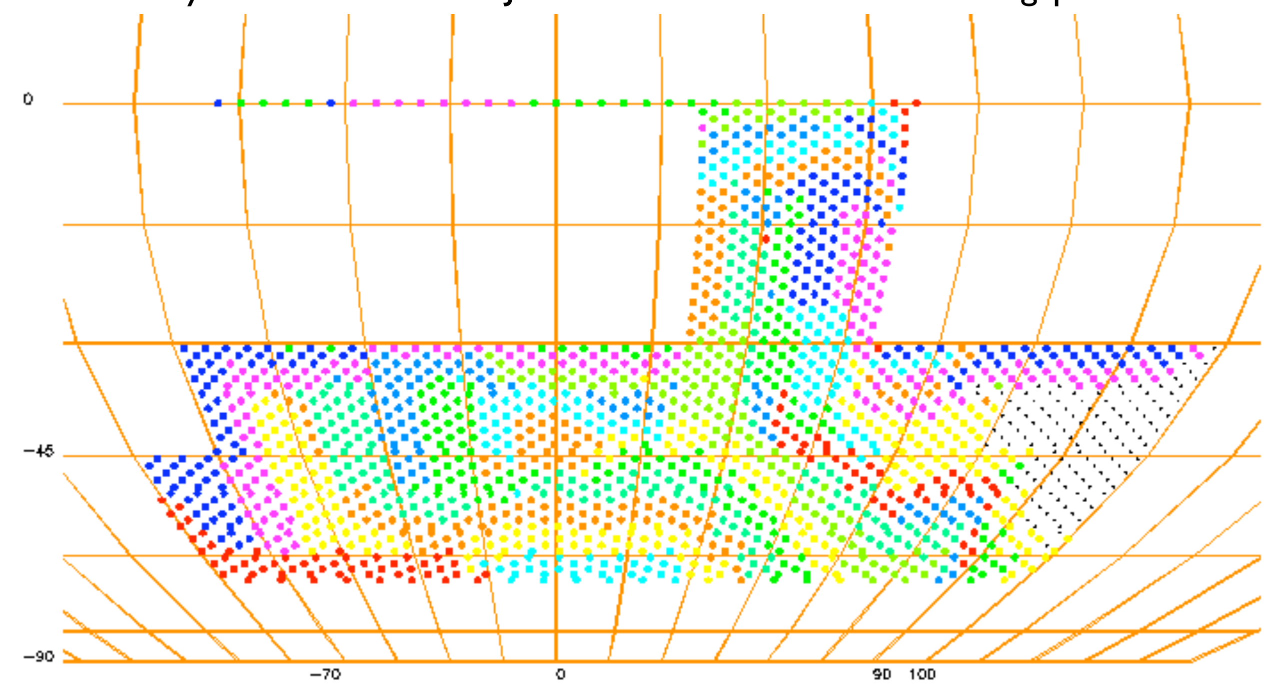


Table 3: Scenario 1 summary

Survey Year	Filters	Exposure time	Tilings	Cumulative exposure g r i z y	10σ galaxy magnitude g r i z y
2012	g r i z y	80	2	160 160 160 160 160	24.2 23.7 23.3 22.5 20.9
2013	g r i z y	80	2	320 320 320 320 320	24.6 24.1 23.7 22.9 21.3
2014	i z	200	2	720 720	24.1 23.2
2015	i z	200	2	1120 1120	24.4 23.6
2016	z	400	2	1920	23.8

Table 4: Hour use summary for 1989-1993

Year	Hrs	On-object	SN photo	SN nonpho	NonPhot	Contingency
1	834	410	37	175	57	0.2%
2	825	464	36	147	53	14%
3	832	371	17	210	90	4%
4	834	405	27	162	52	30%
5	830	387	24	146	54	30%

Table 5: Quartile distributions

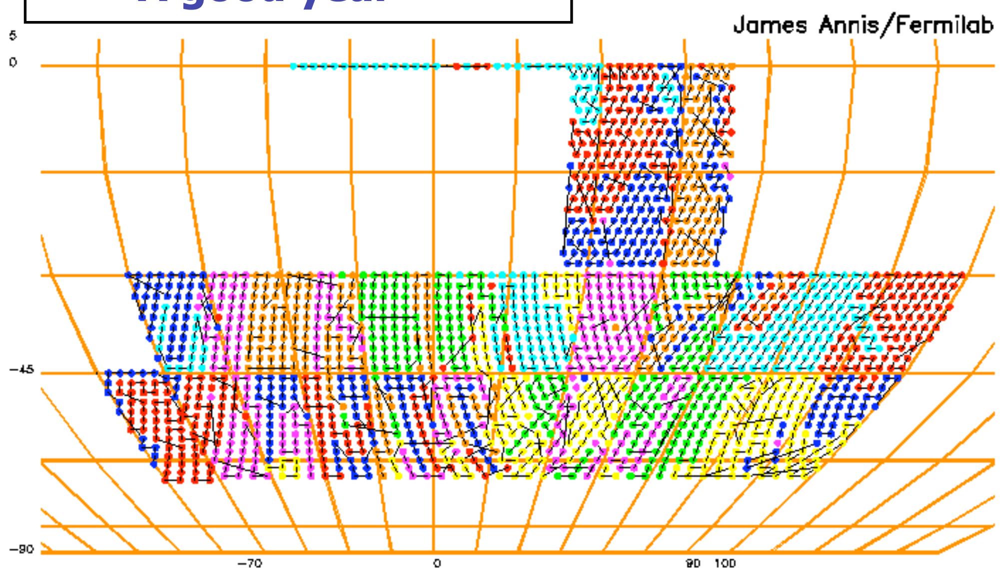
	25%	50%	75%	90%	95%
Slew (degrees)	1.8	2.0	3.1	5.9	23.1
Airmass	1.07	1.16	1.23	1.30	1.34
HA (degrees)	14	35	36	37	38

Contingency is photometric time not spent on observations

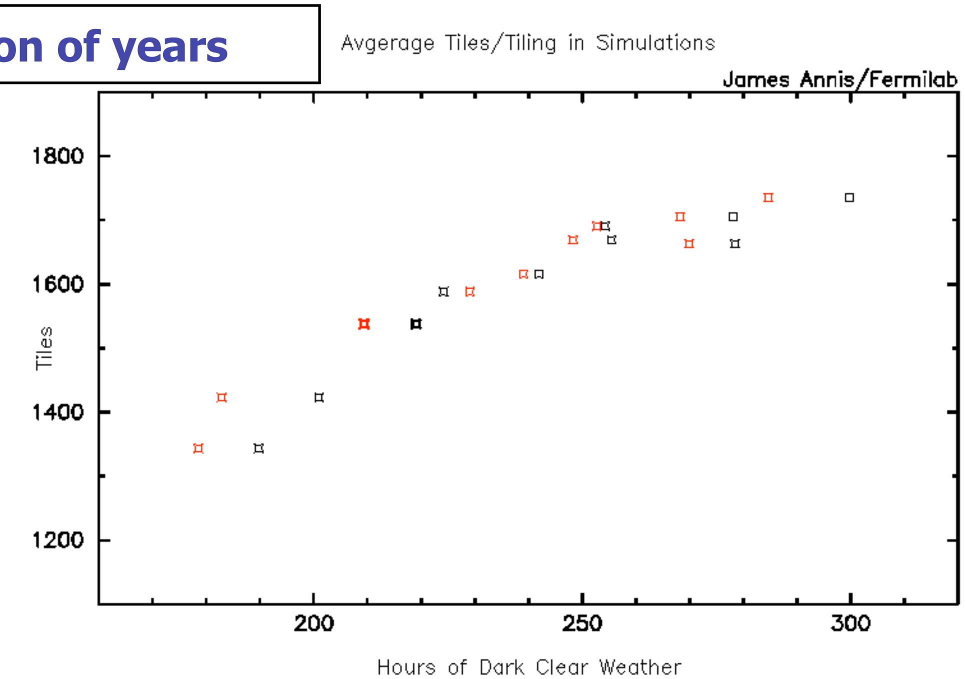
Survey Simulations

DARK ENERGY SURVEY

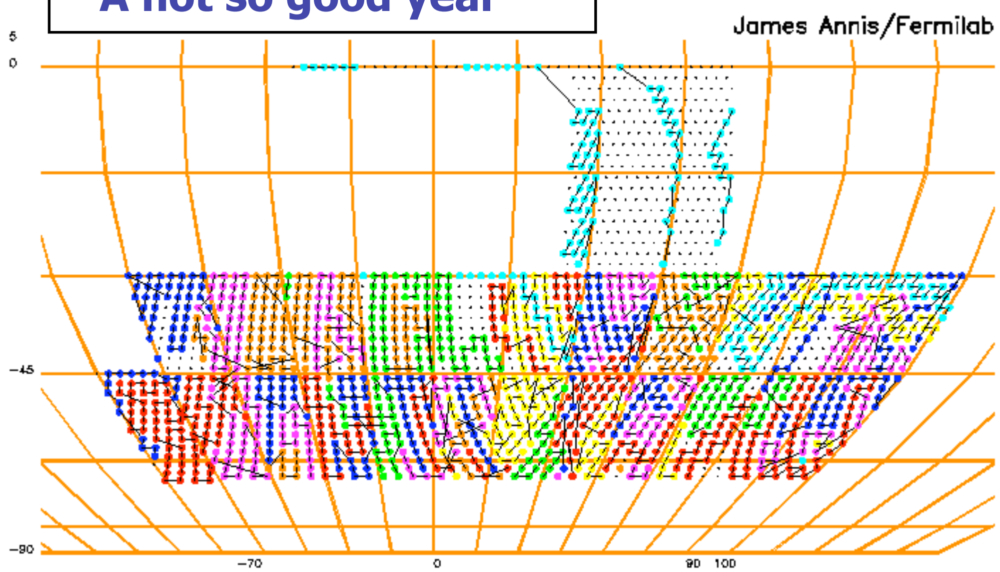
A good year



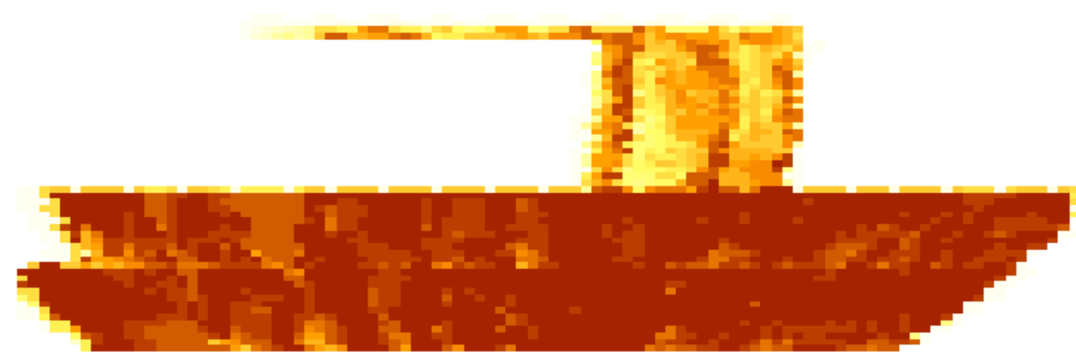
Distribution of years



A not so good year



Probability density map

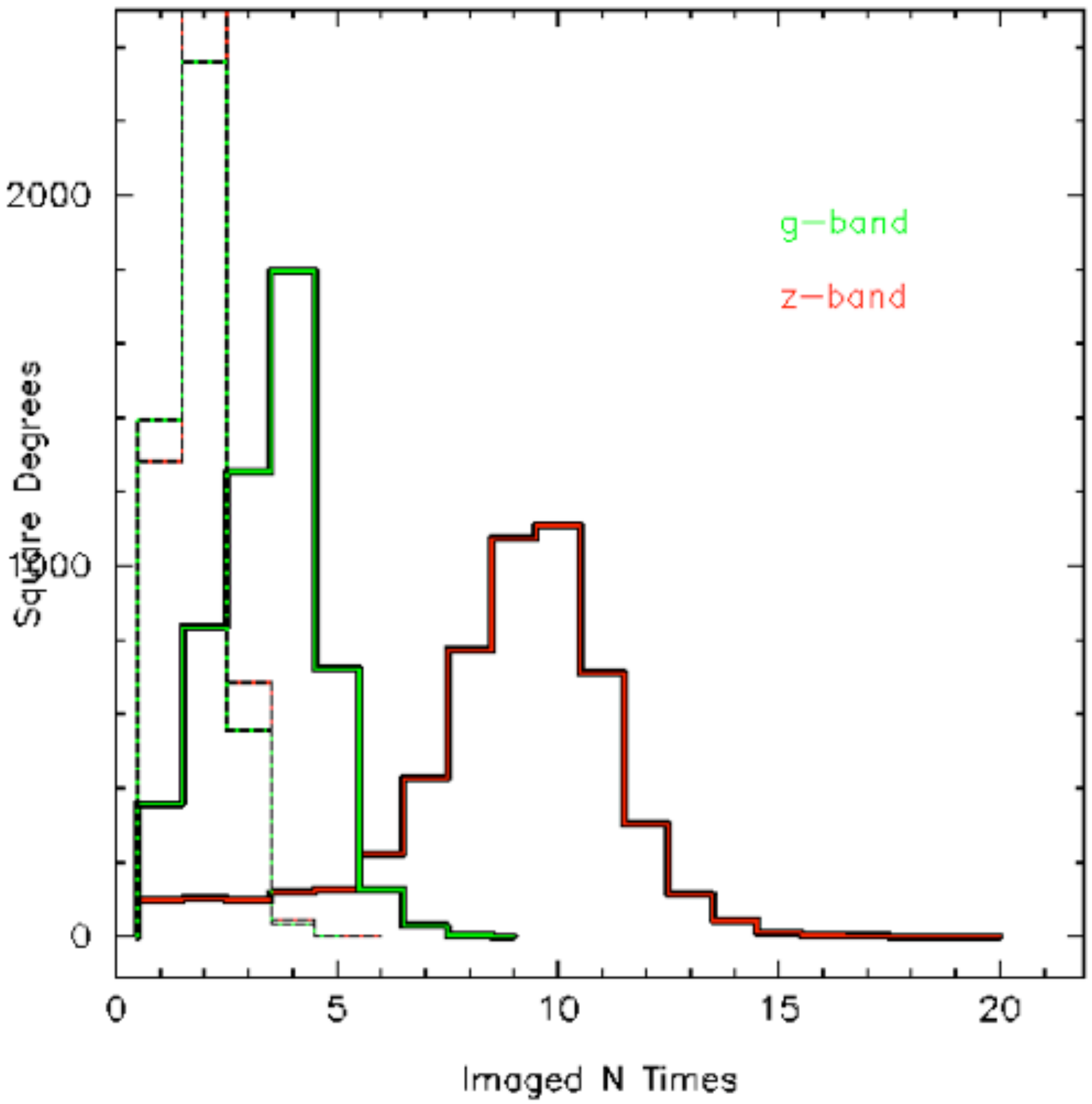


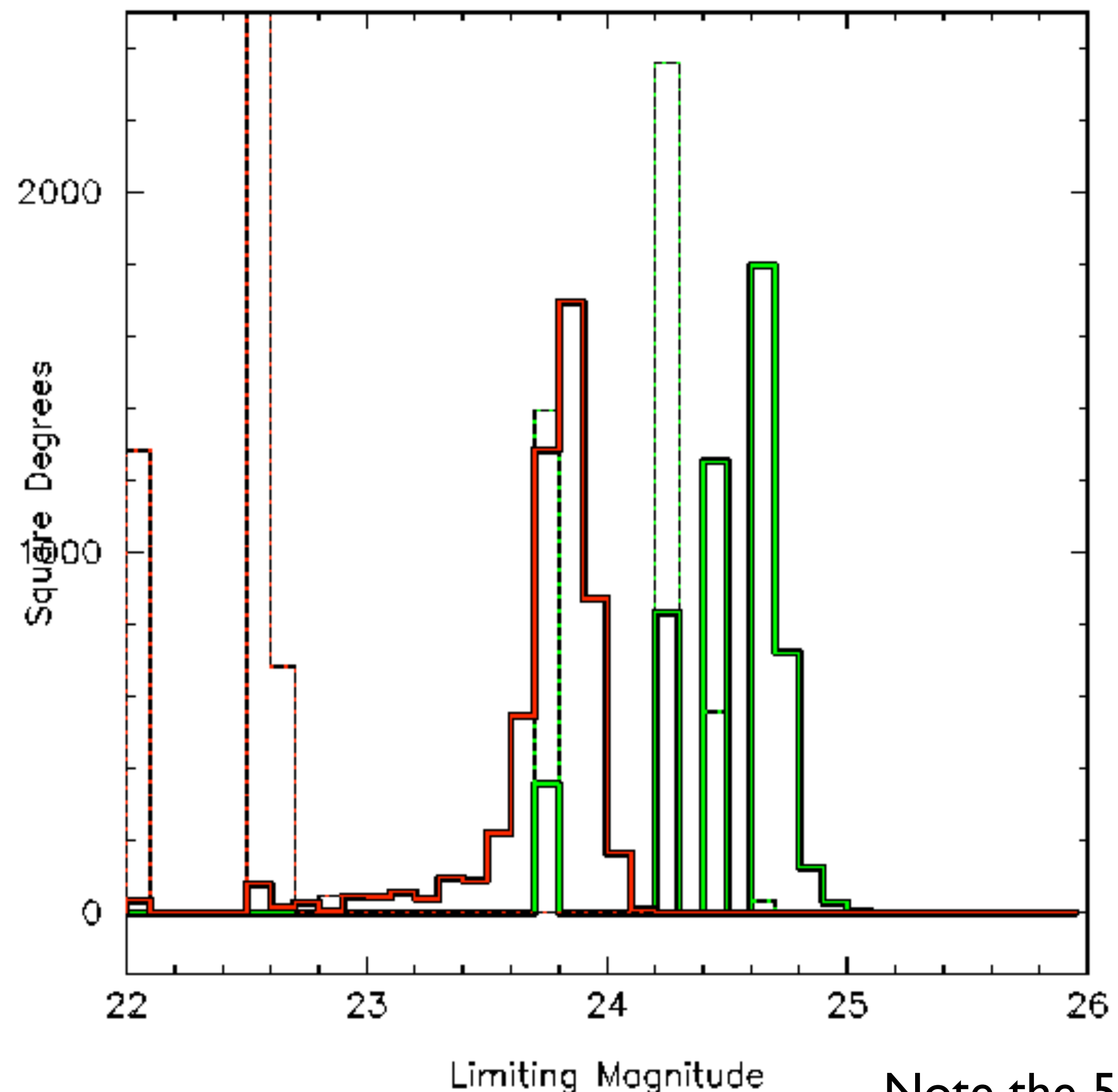
We conclude that El Ninos aside, we high probability of completing SPT area, less of connecting to SDSS-82

Scenarios

- 7 Scenarios
  1. The New Baseline
  2. Delay y-band
  3. Long proper motion baseline
  4. Rethink connection region
  5. Seeing
  6. Maximize survey area
  7. Cover SN fields + 150sq-degrees in year 1
- Evaluate using the survey simulation tool

Scenario 1: The New Baseline





Note the 5-year g-band data comes in discrete magnitudes

- The data are taken in discrete tilings
- The 1st graph shows □° as a function number of visits
- The 2nd graphs show this as function of limiting magnitude
  - red: z-band, green: g-band
  - dotted: year 1, solid: year 5

Scenario 1: The New Baseline

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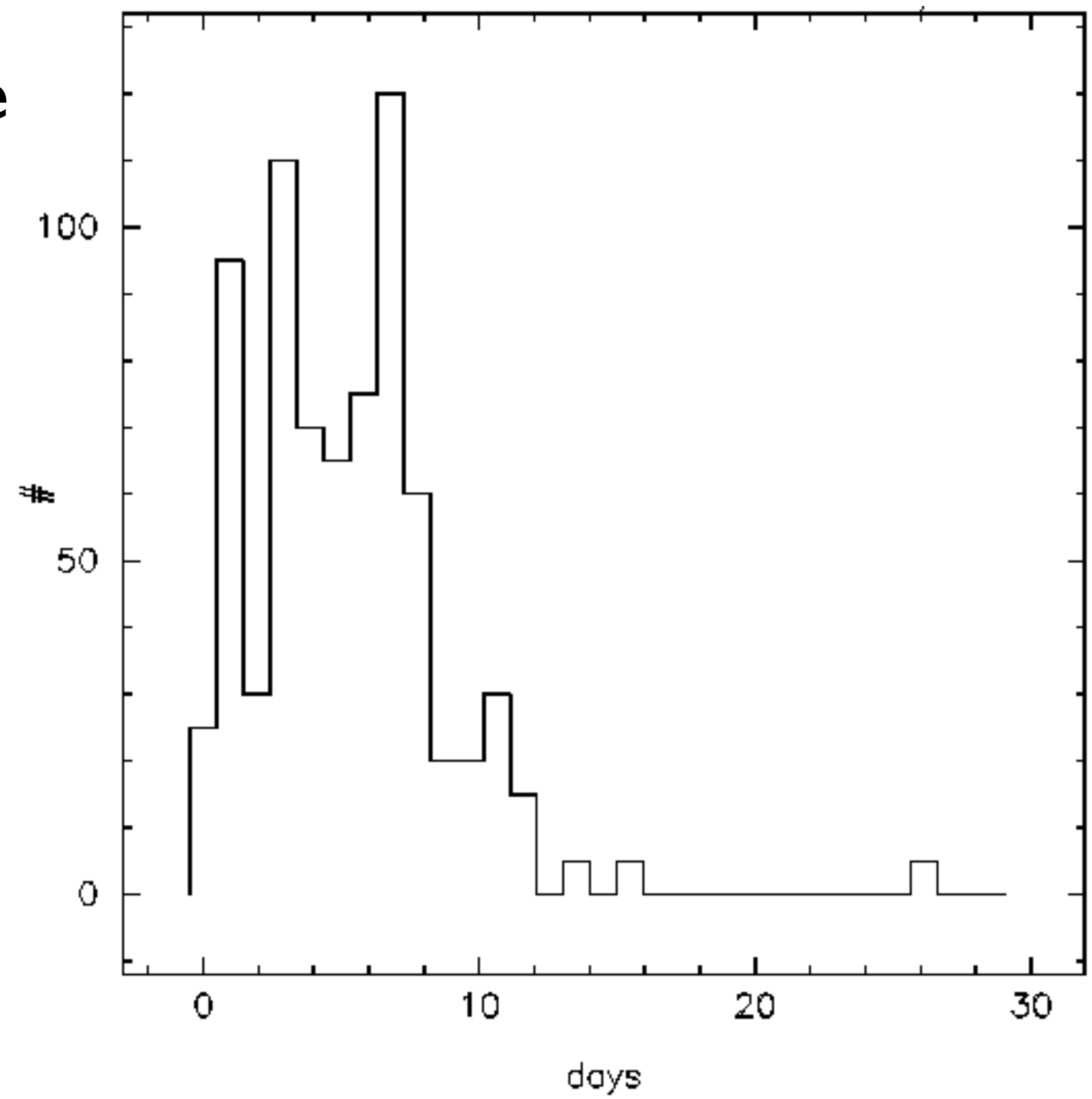
- Supernova Survey
  - five fields
  - allocate all non-photometric time to SN
    - typically 5x > photometric time
  - if time between obs > 7 days, allocate photometric time
    - only one field/night
    - not allowed in first half of night
    - ~8% of photometric time
- Successful, in all scenarios

Table 2: SN Fields

	RA (degrees)	Dec (degrees)	Exposure/visit
CDF South	52.5	-27.5	7300s in 31 images
Stripe 82	55.0	0.0	7300s in 31 images
SNLS/VIRMOS	36.75	-4.5	2430s in 18 images
XMM-LSS	34.5	-5.5	2430s in 18 images
Elais S1	0.5	-43.5	2430s in 18 images

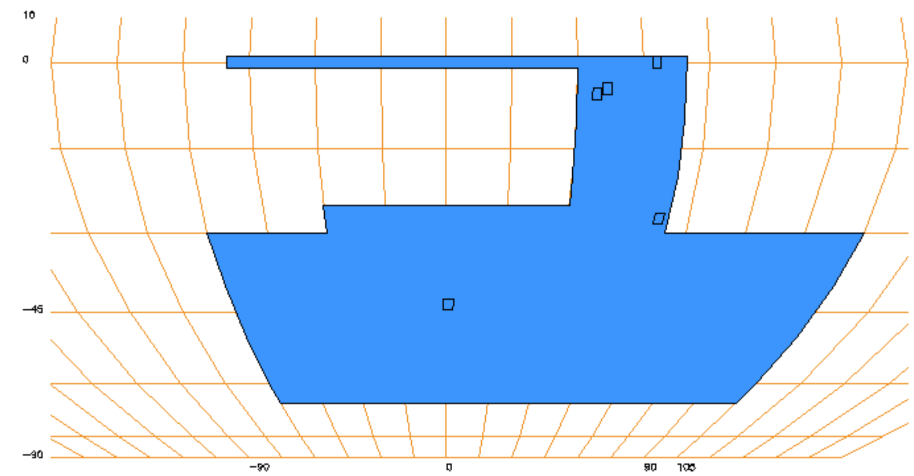


5. We had to simulate it again, as the working groups began to provide concrete requests and tools.

The DES Footprint

Current Footprint

SPT	-60 ≤ RA ≤ 105	-65 ≤ Dec ≤ -30
Galactic Cap	-30 ≤ RA ≤ 30	-30 ≤ Dec ≤ -25
Connecting	30 ≤ RA ≤ 55	-30 ≤ Dec ≤ -1
Stripe 82	-50 ≤ RA ≤ 55	-1 ≤ Dec ≤ 1



1. Constraints:
   a. Highly desirable to achieve maximal overlap with the SPT
   b. DES is to provide Y-band data for the VHS in return for VHS JHK_s data
   c. Spectroscopic training sets for photo-z are crucial

DARK ENERGY SURVEY

Survey Completion

- There are two components to the main survey completion metric.

- The first is about effective usage of time
  - Equivalent tilings
    - 40 survey area tilings of 90-second exposures

- The second is about delivered data quality
  - Effective number of galaxies, n_{eff} *
    - 216 million galaxies as per DES Science Case

*n_{eff} :This is to be considered a non-linear combination of S/N and seeing, calculated using a standard galaxy magnitude-size table.

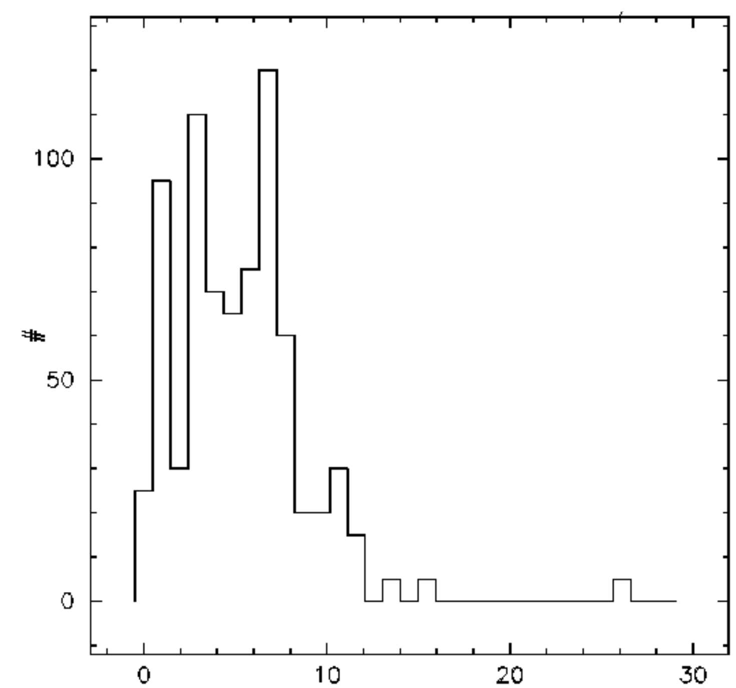
- Equivalent tiling definition:
  - 5000 sq-degrees in a single bandpass is a tiling
  - 2 tilings/year/filter * 5 years * 4 filters = 40 tilings
    - 90 second exposures
    - ignore overlaps within a tiling

- Effective number of galaxies definition:
  - Depends on limiting mag and seeing
  - Set of reasonable cuts
    - S/N >= 10
    - $r_{1/2}$ >= 1.1*PSF
    - Ellipticity uncertainty <= 0.5
  - Use COSMOS/Sim data of over 1 sq-degree as representative cosmic sample of galaxies.
  - Nominally 12 galaxies/sq-arcminute
  - 5000*3600*12 = 216 million galaxies

DARK ENERGY SURVEY

SN Survey

- Trigger on non-photometric or poor seeing conditions
  - Photometric flag determined by Rasicam, the IR cloud camera
  - Seeing determined by SISPI's Instrument Health:
  - If opaque: do system response curves
  - If !main survey conditions, perform SN observations
- SN survey
  - The Hybrid Strategy
  - 5 fields, 2 deep, 3 shallow
  - Putting emphasis on high quality light curves, few gaps.
  - Airmass < 2.0
- 2 deep fields:
  - g = 600 seconds,
  - r = 1200 seconds
  - i = 1800 seconds
  - z = 3000 seconds
- 3 shallow fields:
  - g = 200 seconds,
  - r = 400 seconds
  - i = 600 seconds
  - z = 1000 seconds



SN field time gap distribution (days)

- RA chosen to maximize light curve completeness for the largest number of SN
  - This means the fields are in the East,
  - predominately visible later in the night/observing season

DARK ENERGY SURVEY

Main Survey

- Trigger on photometric conditions or good seeing
  - Do main survey.
- SN survey in main survey time
  - > 7 days observation gap in any SN field, any filter triggers SN observation
  - Once/night, after middle of allocated night
- Nightly, at both astronomical twilights:
  - 3 standard star fields at each twilight, at a range of airmasses
- Main survey cadence:
  - ~80 second exposures, changes as number of filters change
  - In dark time:
    - slew
    - image in g,r
    - slew
  - In bright time
    - slew
    - image in i,z,Y
    - slew
- Observation strategy: multiple tilings of survey area
  - A tiling covers the survey area
  - 2 tilings/year/bandpass
  - Different tilings taken on different nights
  - Tilings associated with the year of observation

The easiest way to think about the DES survey strategy is that we will cover the survey area twice per year per bandpass.

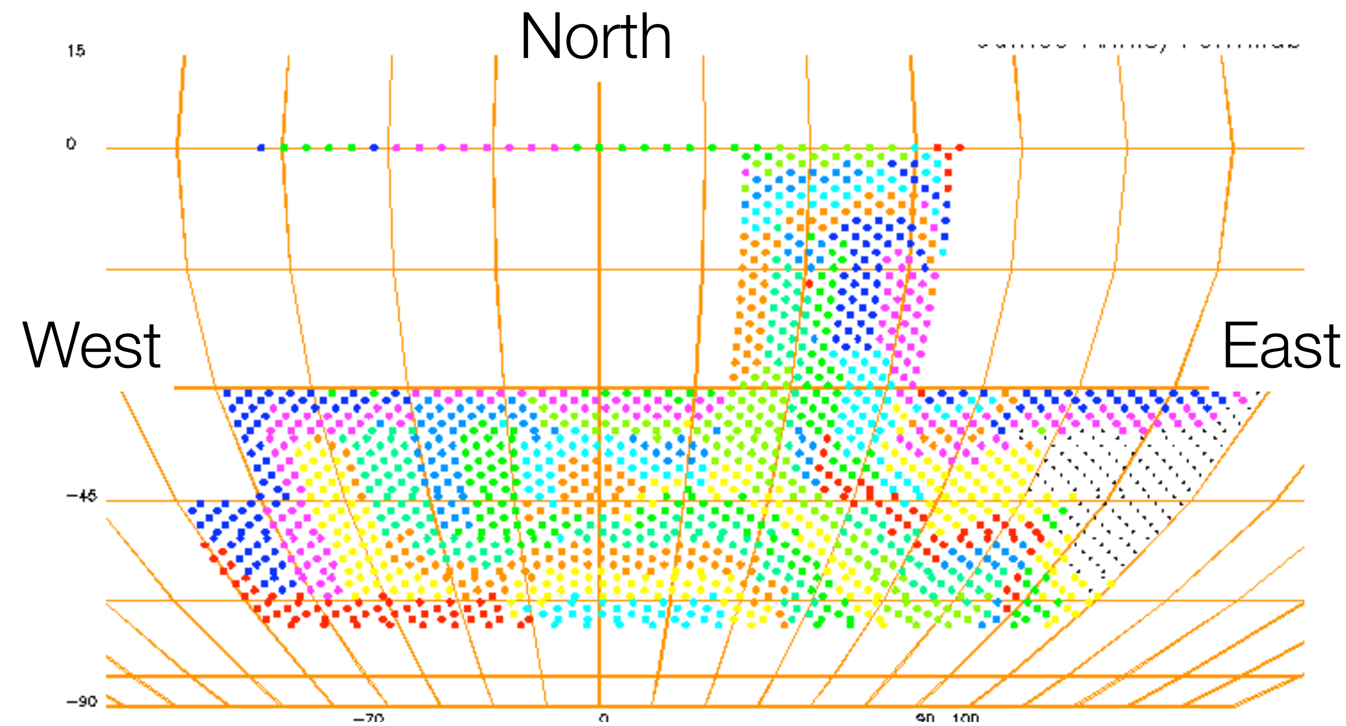
DARK ENERGY SURVEY

SN Trigger I: The survey design till this year

1. If the night is non-photometric, do SN
   - Unless, of course, the time gap since the last observation is too long, in which case one uses main survey time for SN observations.

Baseline Survey

DARK ENERGY SURVEY



An unusual year- bad weather in Jan/Feb. Most scenarios show this gap in the East.

1. Simulation assumptions

- astronomical twilight to astronomical twilight
- no standard stars
- 30 year weather statistics, used in 5 year blocks
- Hybrid SN strategy
- Slew time model
- Readout+overhead = 20sec
- Community time model:

Bright	Full moon +- 1 night
Dark	New moon +- 1 night
Gray	2, 3, or 4 nights centered on first quarter

2. The New Baseline

- Add y-band in years 1+2
- Year 5 increases z depth by 0.25mag

This is one of a suite of simulations of various observing scenarios.

Table 3: Scenario 1 summary

Survey Year	Filters	Exposure time	Tilings	Cumulative exposure g	r	i	z	y	10σ galaxy magnitude g	r	i	z	y
2012	g r i z y	80	2	160	160	160	160	160	24.2	23.7	23.3	22.5	20.9
2013	g r i z y	80	2	320	320	320	320	320	24.6	24.1	23.7	22.9	21.3
2014	i z	200	2			720	720				24.1	23.2	
2015	i z	200	2			1120	1120				24.4	23.6	
2016	z	400	2				1920					23.8	

Table 4: Hour use summary for 1989-1993

Year	Hrs	On-object	SN photo	SN nonpho	NonPhot	Contingency
1	834	410	37	175	57	0.2%
2	825	464	36	147	53	14%
3	832	371	17	210	90	4%
4	834	405	27	162	52	30%
5	830	387	24	146	54	30%

Table 5: Quartile distributions

	25%	50%	75%	90%	95%
Slew (degrees)	1.8	2.0	3.1	5.9	23.1
Airmass	1.07	1.16	1.23	1.30	1.34
HA (degrees)	14	35	36	37	38

Contingency is photometric time not spent on observations

Eric Nielsen and JTA

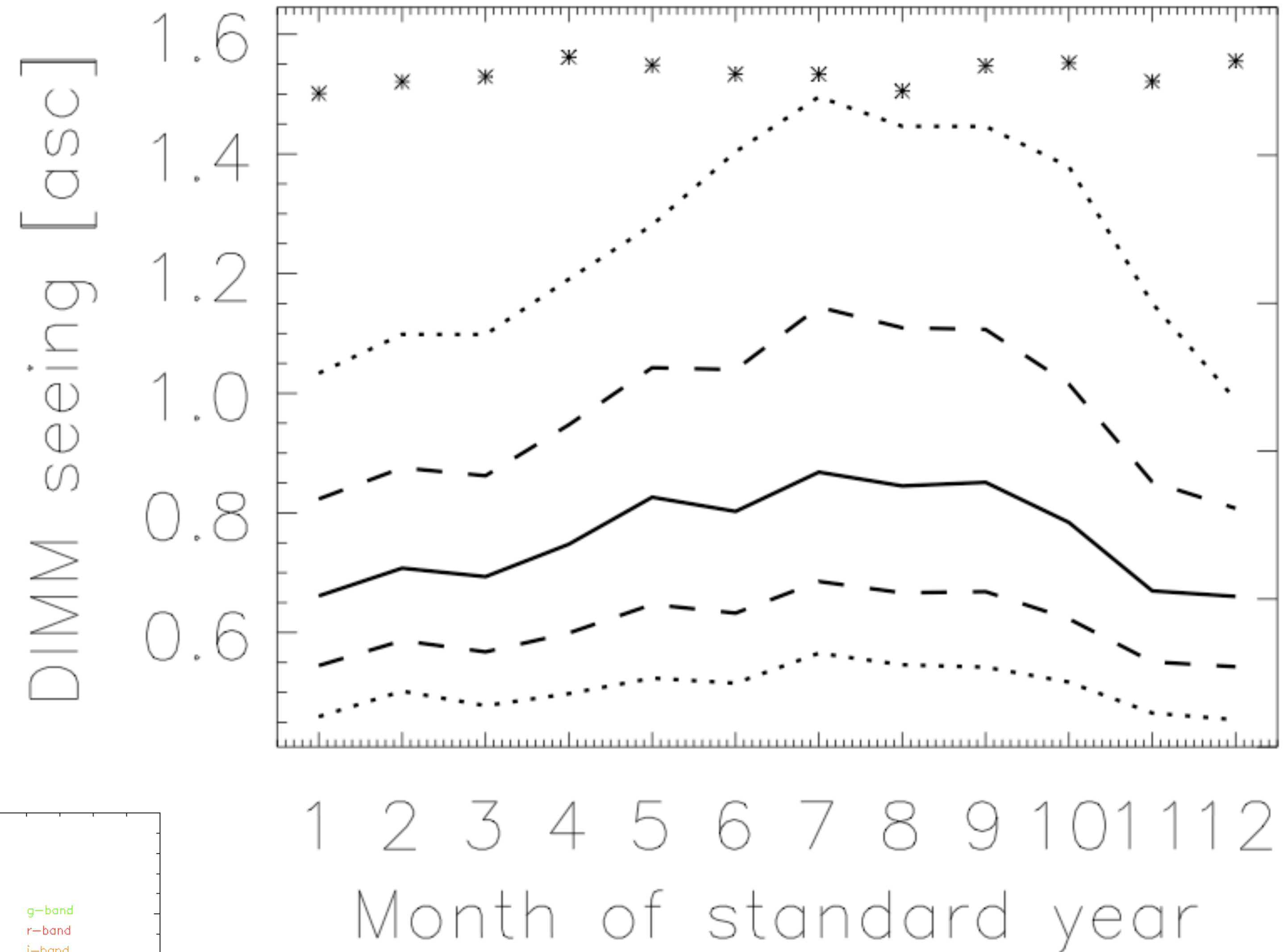
SN Trigger II: the survey design in the draft observing plan

1. Instead, follow WL requirement to take data in < 1.1” seeing.
2. Then, if the seeing is >= 1.1”, do SN
   - Unless, of course, the time gap since the last observation is too long, in which case one uses main survey time for SN observations.

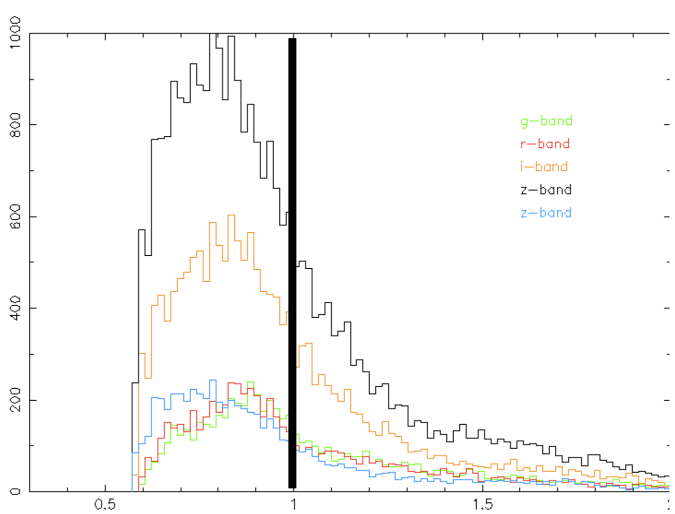
Survey Strategy Simulations II: Seeing

- Els et al 2009: Four years of optical turbulence monitoring at CTIO
- Camera+Optics requirement: 0.55”
- various other small adjustments: λ, sec(z), dome (0.2”)
- Coadd: harmonic mean seeing

$$H = \frac{n}{\frac{1}{x_1} + \frac{1}{x_2} + \cdots + \frac{1}{x_n}} = \frac{n}{\sum_{i=1}^{n} \frac{1}{x_i}},$$

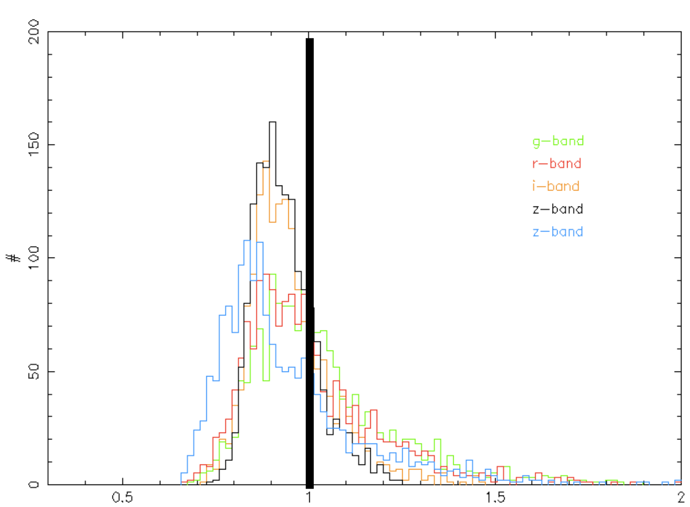


All individual tiles, 5 years



1”

Coadded



1”

Seeing

The new main survey / SN parameters

- SN survey done if:
  - seeing > 1.1”
  - || if gap > 7 && seeing <= 1.1” IF
  - 1) <= 6 filter-fields have been observed tonight
  - 2) during Sept-Dec, if it is past mid-night (not midnight!)

- Main survey done if:
  - seeing < 1.1”
  - && not interrupted by SN gap trigger

DARK ENERGY SURVEY

Side Effects: There is Less Main Survey Time

The imposition of these seeing cuts caused a net decrease in main survey time of ~25%.

About 10% of that can be recovered by optimizing the community time distribution (slide 18) . Some of the rest can be found by reducing the exposure time from 400 seconds to 360 seconds (below). The rest must be accommodated by a smaller footprint (slide 17).

- Main survey cadence:
  - There are 12* minutes/hex/year of time to allocate between filters
  - If 2 tilings per year, 360 seconds/hex/tile/year
  - For five filter years:
    - g 60 seconds
    - r 60 seconds
    - i 80 seconds
    - z 80 seconds
    - y 80 seconds
  - At 60 exposures overhead is becoming important. Even at 80 seconds; survey completion becomes noticeably easier in four filter years.

*How is this number known?
Analytics based on 30-year weather patterns suggest 400 seconds per hex/year. Simulations including seeing and moon position/phase that use 360 sec/hex/year have good rates of survey completions.

Best seeing is in November and December, so, examine making the schedule more compact this causes the SN survey to find ~25% less SN- SN WG is exploring optimizing this style of compact survey

DARK ENERGY SURVEY

Observing Plan III: Dates

This compact schedule is unrealistic in the sense that the community will probably push to have more than 2 nights in Nov-Dec. It is best to regard this as a extreme- they survey cannot be more compact than this.

- **Set in stone**
  - 525 nights total
  - 105 nights/year
- **Baseline**
  - Nights spread over 6 calendar months
  - September, October, November, December
    - 21 nights/month
    - 9,10,9,8 nights community time
  - January, February
    - 21 half nights/month, sunset till middle of night
    - 10, 8 half nights are community time
  - Preferred community time distribution:

Bright	Full moon +- 1 night
Dark	New moon +- 1 night
Gray	2, 3, or 4 nights centered on first quarter

These dates are offset by about a month from the optimal local sidereal times for the current survey footprint.

- **Compact**
  - Deweight September and February
  - No community time in Dec, Jan.
    - Dec 23,31 still downtime
  - Sept-January community time as before
  - except that community time from Dec is pushed into the first nights of Sept and the community time from Jan is pushed into Feb.
  - DES observing examples:
    - 2012-2013
    - Sept 11-13, 17-20, 24-27
    - Oct 1-13, 17-19, 24-27
    - Nov 1-10, 13-30
    - Dec 1-23, 25-30
    - Jan 1-31 (half nights)
    - Feb 1 (half night)
    - 2013-2014
    - Sept 20-30
    - Oct 1-2, 6-8, 13-16, 20-31
    - Nov 3-30
    - Dec 1-23, 25-30
    - Jan 1-31 (half nights)
    - Feb 1 (half night)
  - The survey time is concentrated in the important Nov, Dec, Jan months.

Going with these dates buys us on average 0.5 tilings: this is roughly 600 sq-degrees in all filters, every year. If I could find another factor this big, I could get us back to 5000 sq-degrees.

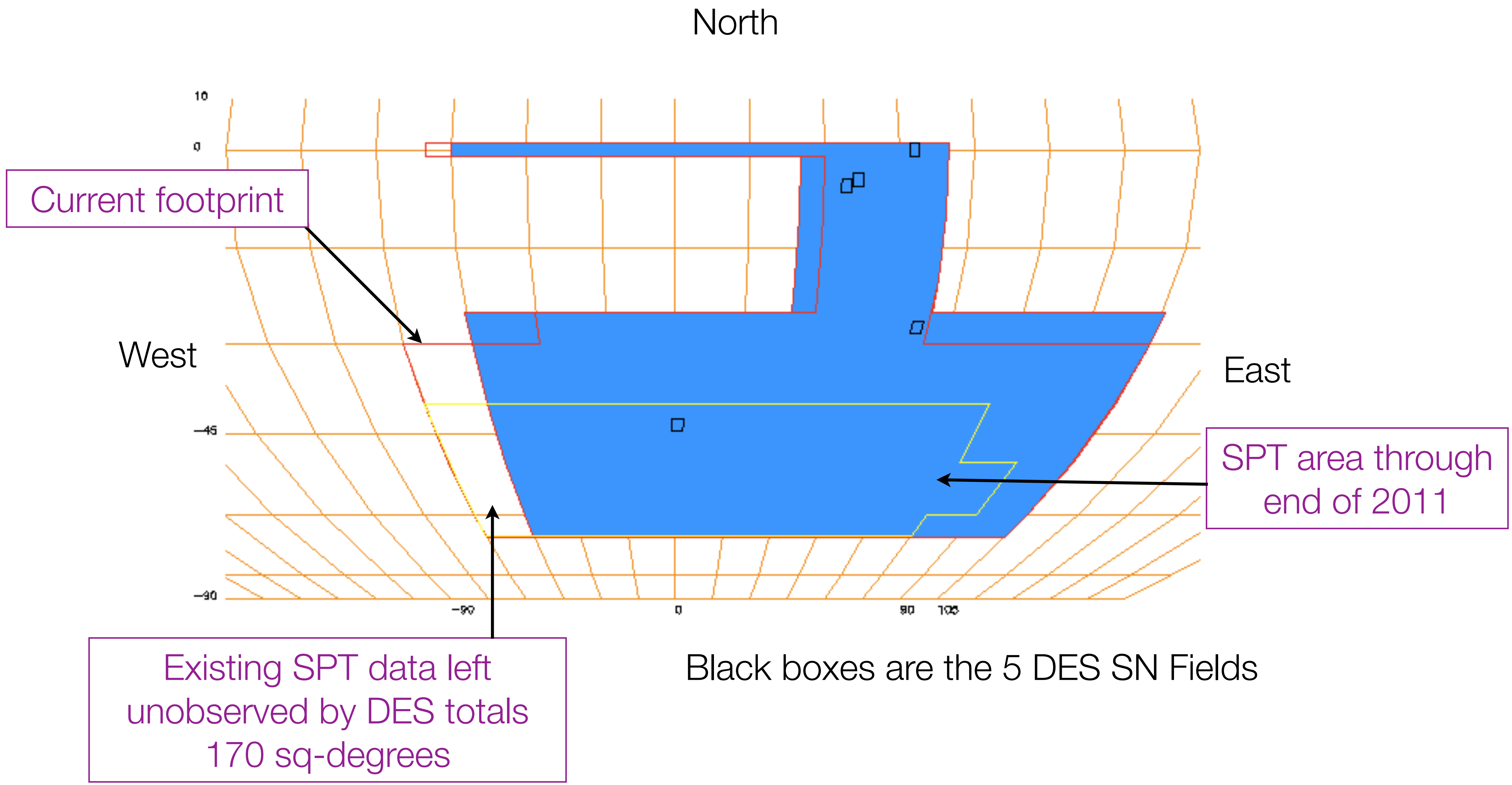
Footprints: Option 3, with extended area

DARK ENERGY SURVEY

Removing area in the West and in the East makes the survey area a) more compact, and b) better aligned with the mid-Sept through end of January observing nights in the "optimal time distribution".

The survey just completes this footprint, given a median weather year and averaged over seeing runs using 360 seconds/hex/year total exposure.

Area: 4886 sq-degrees

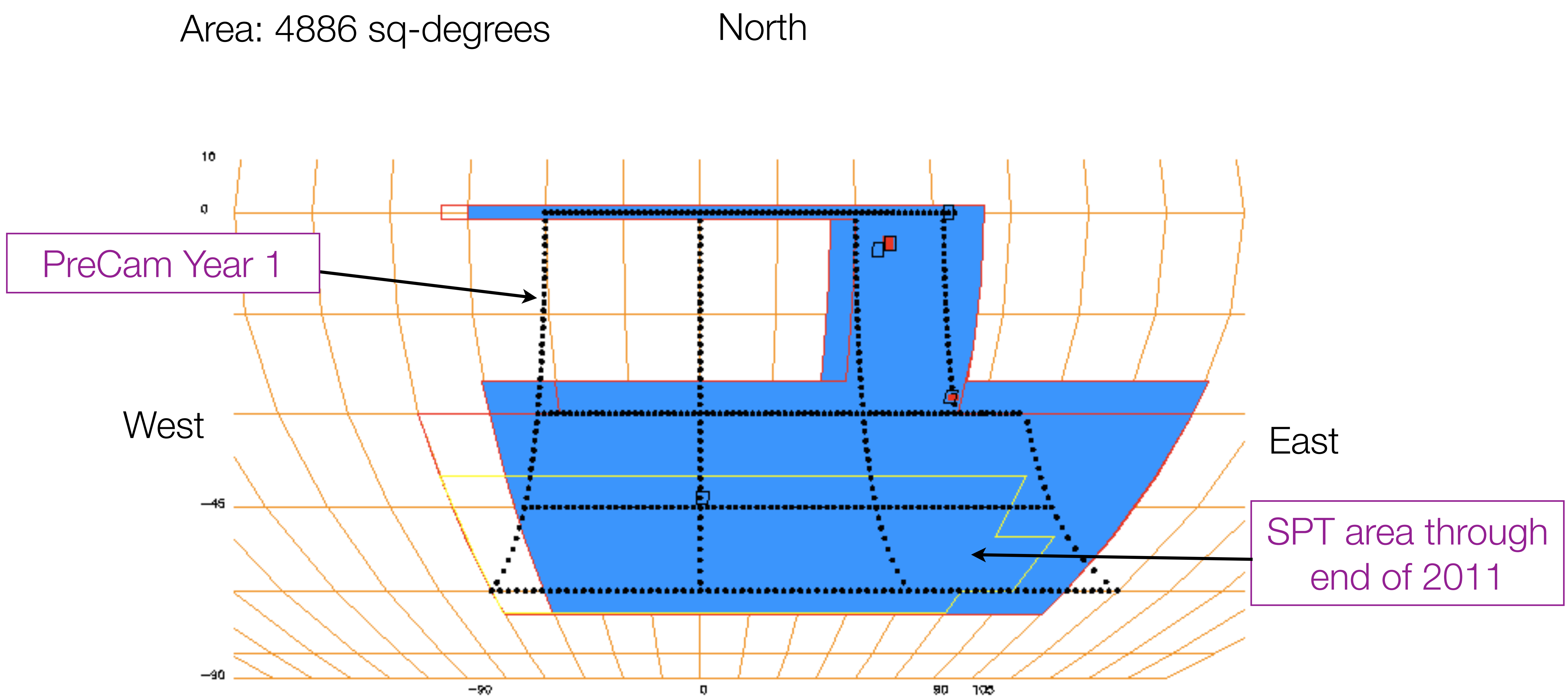


Black boxes are the 5 DES SN Fields

DARK ENERGY SURVEY

Footprints: Option 3, Calibration Plans

Area: 4886 sq-degrees



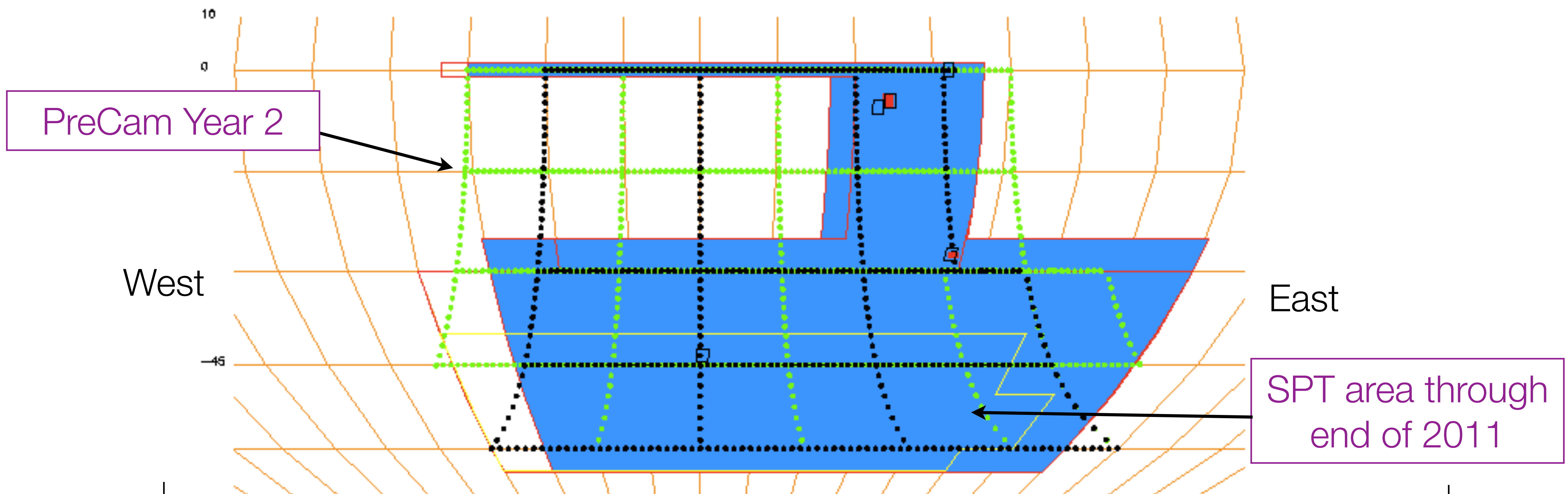
Black boxes are the 5 DES SN Fields

DARK ENERGY SURVEY

Footprints: spatial calibration data

Area: 4886 sq-degrees

Black boxes are the 5 DES SN Fields



The SN field observations have ~1" dithers.
The main survey covers the SN fields with 4-10 tilings.
It is worth investigating increasing the number of tilings on the SN area in order to combine the precision of the many repeat observations with the accuracy that can be obtained by moving stars around on the focal plane.

6. And now we are pursing a full optimization against the DETF figure of merit

A survey optimization group is pursuing this

DARK ENERGY SURVEY

Competition for time

Photometric time:

- **Area vs Depth**
- **Filter vs Filter**
- **Main fields vs SN fields vs Ancillary fields**

About 8-22% of SN survey

Non-photometric time:

To first-order, only used by SN survey, but

- **Area vs Depth**
- **Filter vs Filter**

Carried out by SN WG

- **Main fields vs SN fields**

Useful for WL, if seeing is good.

Calibration time?

- **Goal of survey strategy WG is to reduce calibration time to zero.**
- **Calibration = fixed systematic floor in optimization.**

DARK ENERGY SURVEY

Survey Optimization II: Grid of Scenarios

- Grid of Scenarios
  - Fiducial is 5000 sq-degrees, 525 nights
    - Holding 525 nights constant
      - 4000 sq-degrees
      - 8000 sq-degrees
    - Holding depth constant
      - 8000 sq-degrees
      - 10,000 sq-degrees
  - For each of these 5, do a set of three exposure models: baseline, proper motion, constant exposure time
  - Evaluate at year 1 and year 5

Baseline

Survey Year	Filters	Exposure time	Tilings	Cumulative exposure g	r	i	z	y	10σ galaxy magnitude g	r	i	z	y
2012	g r i z y	80	2	160	160	160	160	160	24.2	23.7	23.3	22.5	20.9
2013	g r i z y	80	2	320	320	320	320	320	24.6	24.1	23.7	22.9	21.3
2014	i z	200	2			720	720				24.1	23.2	
2015	i z	200	2			1120	1120				24.4	23.6	
2016	z	400	2				1920					23.8	

Proper Motion

Survey Year	Filters	Exposure time	Tilings	Cumulative exposure g	r	i	z	y	10σ galaxy magnitude g	r	i	z	y
2012	g r i z y	80	2	160	160	160	160	160	24.2	23.7	23.3	22.5	20.9
2013	g r i z y	80	2	320	320	320	320	320	24.6	24.1	23.7	22.9	21.3
2014	i z	200	2			720	720				24.1	23.2	
2015	i z	200	2			1120	1120				24.4	23.6	
2016	g r z y	100	2	520	520		1320	520	24.9	24.3		23.6	21.5

Constant(-ish) Exposures

Survey Year	Filters	Exposure time	Tilings	Cumulative exposure g	r	i	z	y	10σ galaxy magnitude g	r	i	z	y
2012	g r i z y	80	2	160	160	160	160	160	24.2	23.7	23.3	22.5	20.9
2013	g r i z y	80	2	320	320	320	320	320	24.6	24.1	23.7	22.9	21.3
2014	g r i z	100	2	520	520	520	520	320	24.9	24.4	24.0	23.2	
2015	g r i z	100	2	720	720	720	720	320	25.1	24.6	24.2	23.4	
2016	g r i z	100	2	920	920	920	920	320	25.3	24.7	24.3	23.5	

Exposures and Magnitudes

525 nights constant: 4000 sq-degrees 4/5 => 5/4 exp time
b+p+c 1yr: g,r,i,z,y: 200 200 200 200 200 and 24.3 23.9 23.5 22.7 21.0
baseline 5yr: g,r,i,z,y: 400 400 1400 2400 400 and 24.8 24.3 24.5 24.1 21.5
proper 5yr: g,r,i,z,y: 650 650 1400 1650 650 and 25.1 24.5 24.5 23.8 21.7
constant 5yr: g,r,i,z,y: 1150 1150 1150 1150 400 and 25.4 24.9 24.4 23.7 21.5

525 nights constant: 8000 sq-degrees 8/5 => 5/8 exp time
b+p+c 1yr: g,r,i,z,y: 100 100 100 100 100 and 23.9 23.5 23.0 22.3 19.4
baseline 5yr: g,r,i,z,y: 200 200 700 1200 200 and 24.3 23.9 24.2 23.7 21.0
proper 5yr: g,r,i,z,y: 325 325 700 825 325 and 24.6 24.2 24.2 23.5 21.3
constant 5yr: g,r,i,z,y: 575 575 575 575 200 and 25.0 24.5 24.1 23.3 21.0

DARK ENERGY SURVEY

Use mock catalogs to get at photo-z & cluster finding for each scenario

Risa Weschler and Carlos Cunha

Procedure & limitations

Gal catalog → Calculate: N_{eff}, photo-z, n(z) / Assume: Nspect(z), shape noise → FoM, γ

Limitations:

1) Nspect(z) is put in by hand
2) Photo-z PDF is assumed to be Gaussian
3) Only explore a handful of cases vary area, filter time allocation and inclusion of faint galaxies.

DARK ENERGY SURVEY

Zhaoming Ma and Carlos Cunha

Run Fisher Matrix Analysis

Fisher code

- **Observables:**
  1) γ-γ, γ-g, g-g power spectra
  2) Photo-z training set
  3) Galaxy distribution in photo-z
- **Parameters:**
  1) 9 cosmological parameters - w_0, w_a, Ω_k, γ, …
  2) 31 zbias, 31 σ_z
  3) 30 parameters for true galaxy z distribution
  4) Galaxy bias
- **Priors:**
  1) Planck

DARK ENERGY SURVEY

Survey configurations

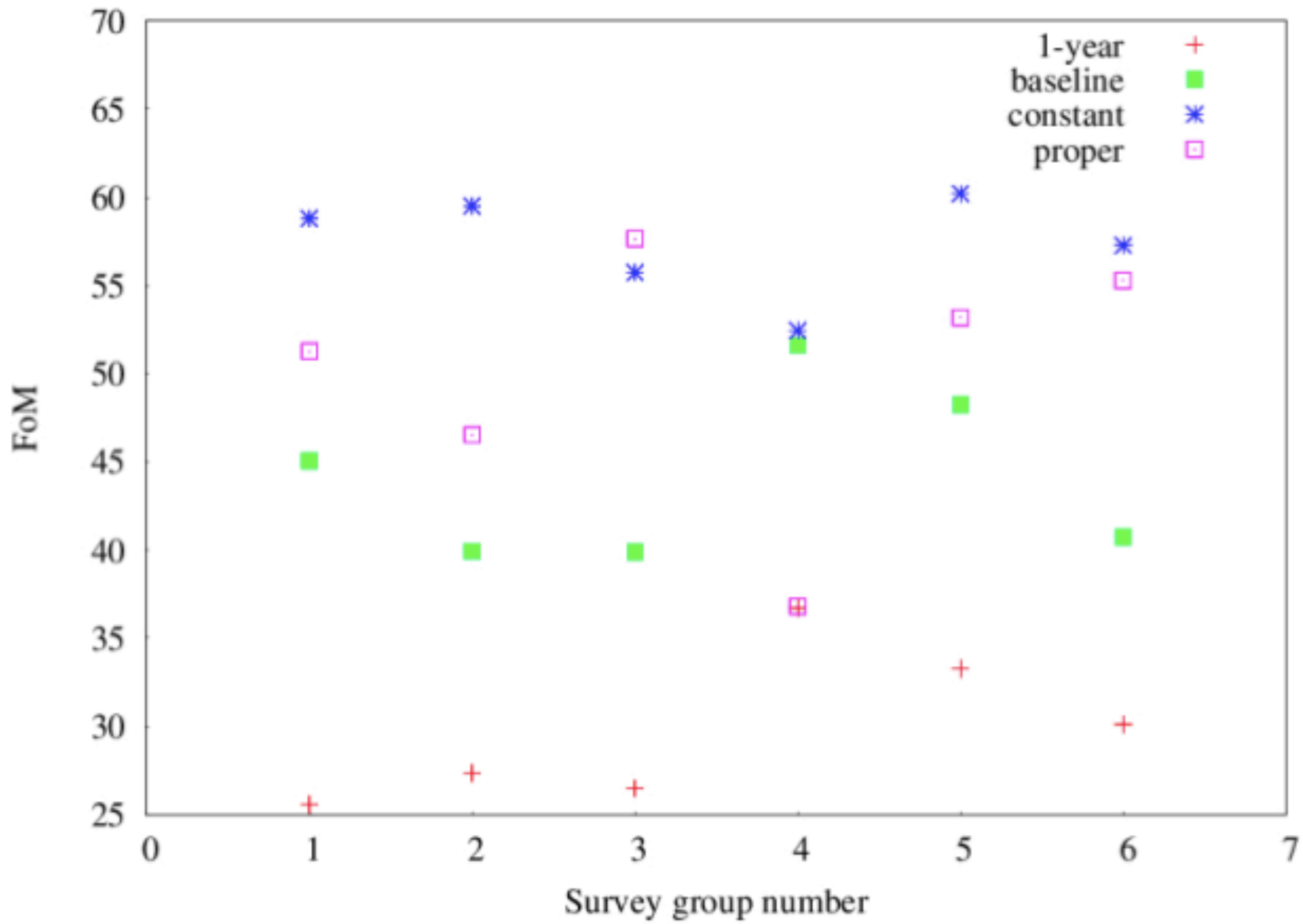
Fixed: 525 Nights over 5 years (except for the 1 year cases)

Area	Configuration	Exposure Times g	r	i	z	Y	Magnitude Limits g	r	i	z	Y	survey group
4000 deg²	1-year	200	200	200	200	200	24.3	23.9	23.5	22.7	21.0	1
	baseline	400	400	1400	2400	400	24.8	24.3	24.5	24.1	21.5	
	constant	1150	1150	1150	1150	400	25.4	24.9	24.4	23.7	21.5	
	proper	650	650	1400	1650	650	25.1	24.5	24.5	23.8	21.7	
5000 deg²	1-year	160	160	160	160	160	24.2	23.7	23.3	22.5	20.9	2
	baseline	320	320	1120	1920	320	24.6	24.1	24.4	23.8	21.3	
	constant	920	920	920	920	320	25.3	24.7	24.3	23.5	21.3	
	proper	520	520	1120	1320	520	24.9	24.3	24.4	23.6	21.5	
8000 deg²	1-year	100	100	100	100	100	23.9	23.5	23.0	22.3	19.4	3
	baseline	200	200	700	1200	200	24.3	23.9	24.2	23.7	21.0	
	constant	575	575	575	575	200	25.0	24.5	24.1	23.3	21.0	
	proper	325	325	700	825	325	24.6	24.2	24.2	23.5	21.3	

Two scenarios: I<24 & I band 10 sigma detection

DARK ENERG
SURVEY

Figure of merit



- Forget about 1 year
- "constant" wins - best time allocation
- Larger area doesn't show advantage; offset by photo-z & neff.
- No clear trend on I<24 vs 10 sigma
- Photo-z width is the lead factor.
- What about γ?

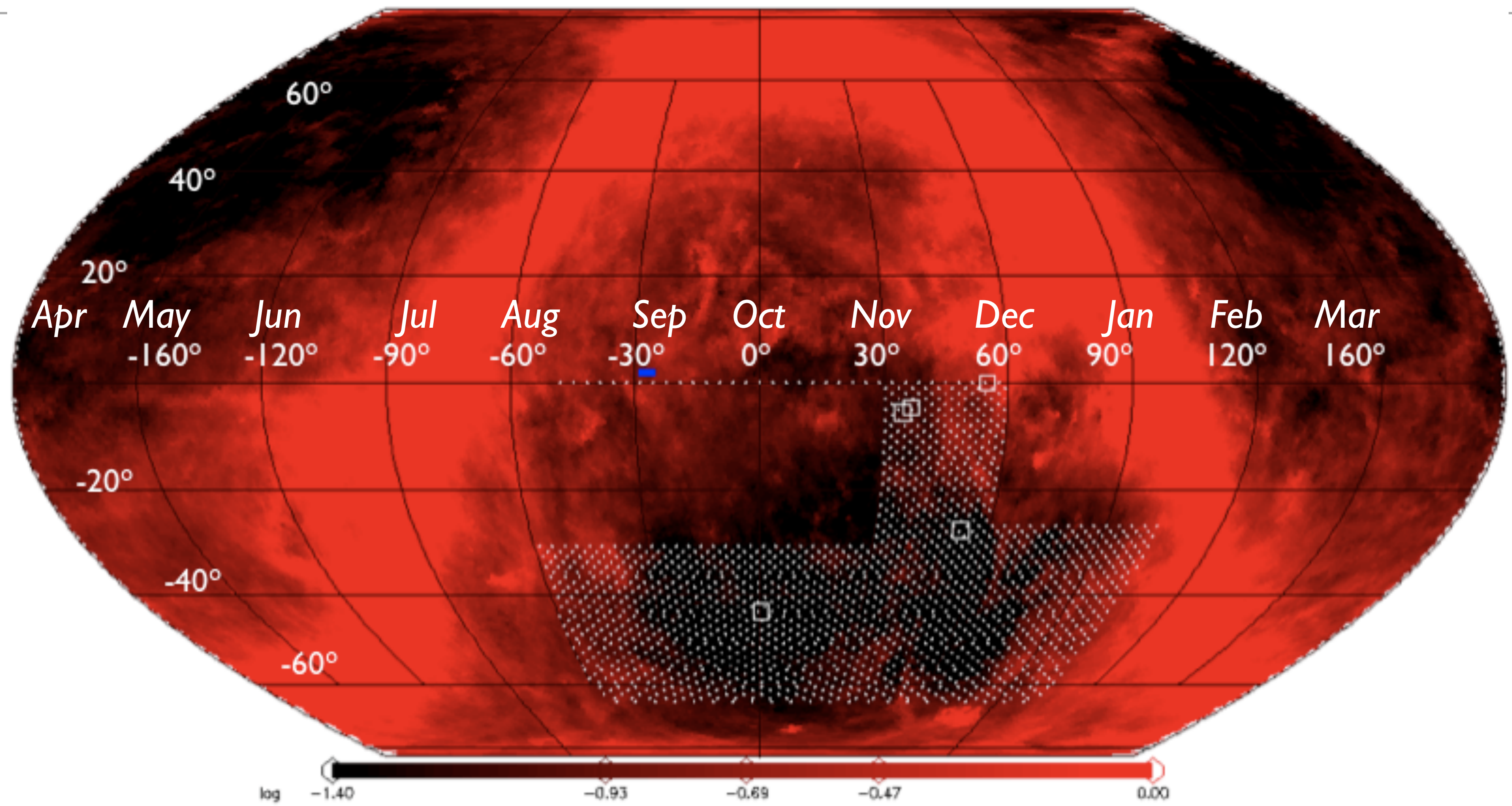
7. Lastly- prepare for first data by preparing for a ~5% area early survey

DARK ENERGY SURVEY

DES Science Verification: a mini survey

Seeing
0.6-0.71: Nov, Dec, Jan, Feb, Mar
0.72-0.8: Apr, Oct
0.8-0.9: May, Jun, Jul, Aug, Sept

Months label the RA that is overhead at midnight midmonth

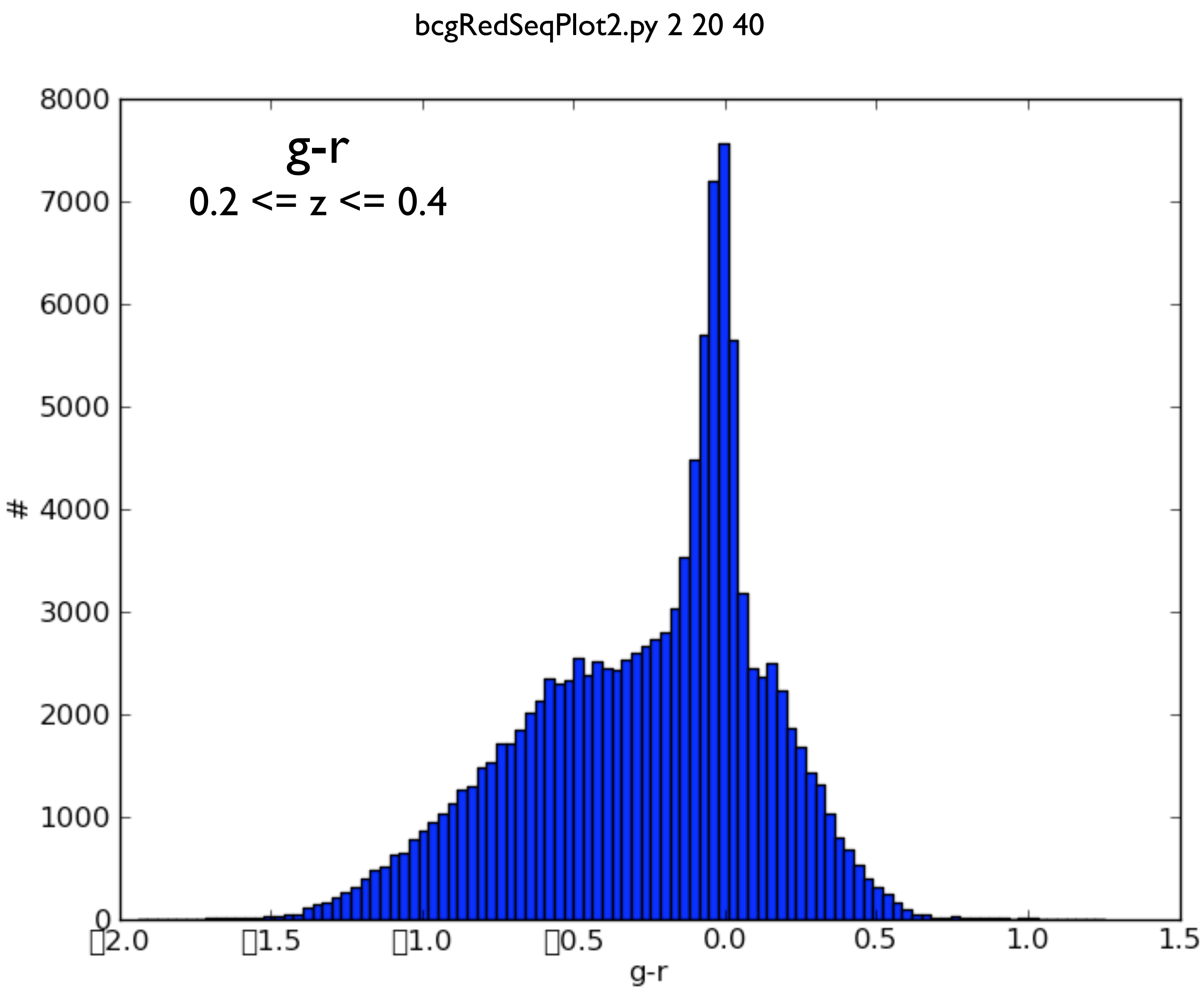


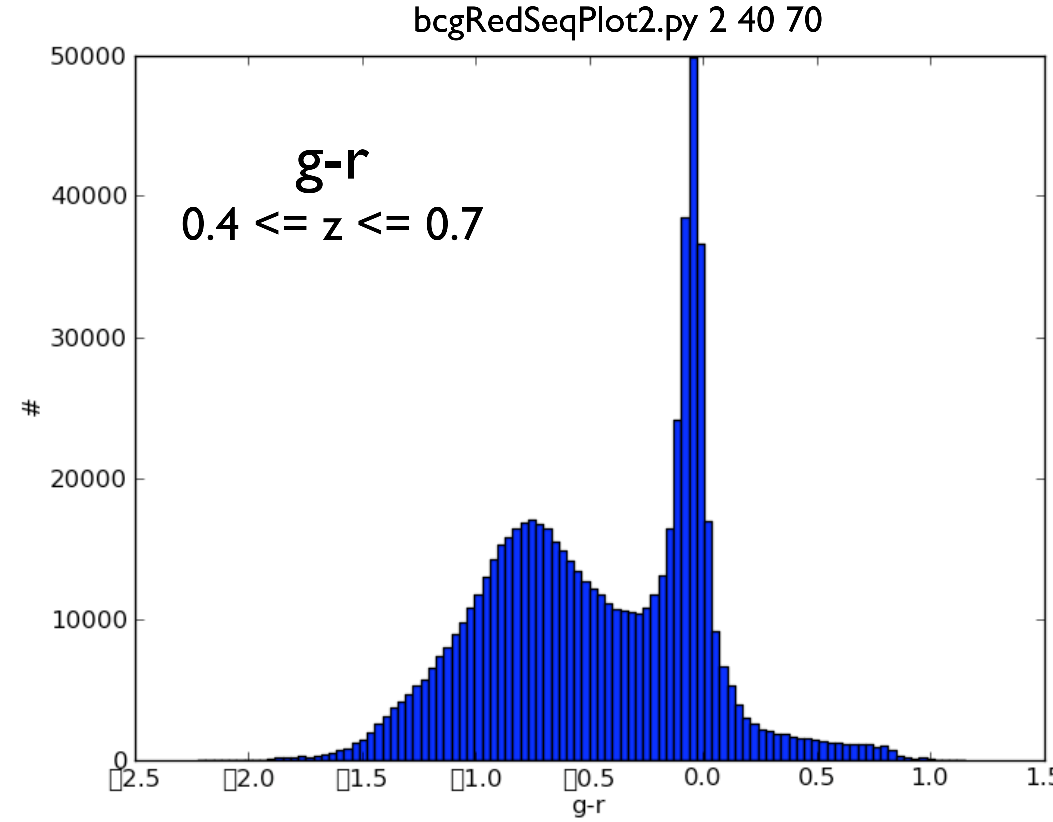
- First light in Oct-Nov 2011.
- 2-3 months of DECam System commissioning, F/8 observing, engineering
- 2 weeks of Community Science Verification time
- DES Science Verification time: likely in Feb 2012.
- Feb is non-optimal for DES area
- COSMOS field: ra,dec=150°,2°
- Imagine 200 sq-degrees about COSMOS field
- About 20 nights to reach full survey depth.

Survey design begins with an experiment that you understand, grows by adding additional low cost experiments, and matures by bringing in collaborators to provide fuller evaluations.

Mocks v2.13

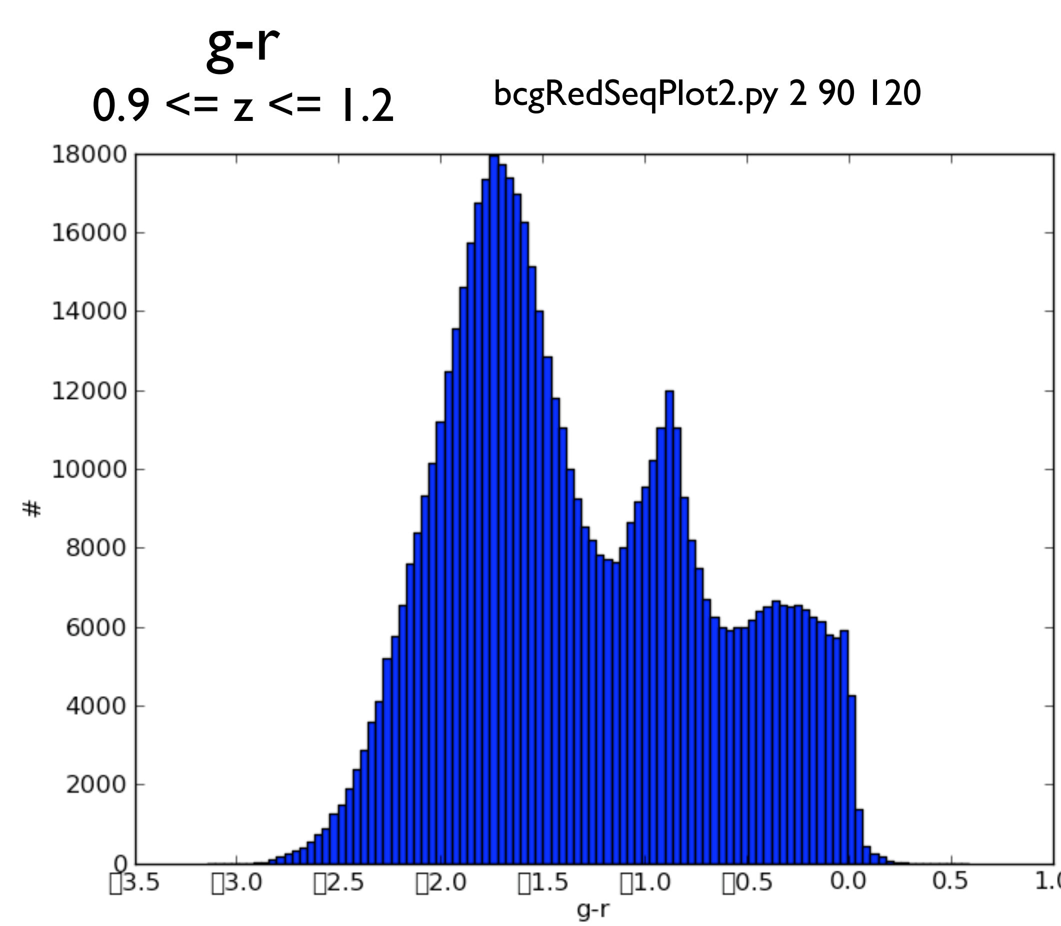
1. The colors of the fields about the bcgs





0.7 < z < 0.8 is a bit of a disaster, broad colors

0.8 < z < 0.9 is a bit of a disaster, broad colors

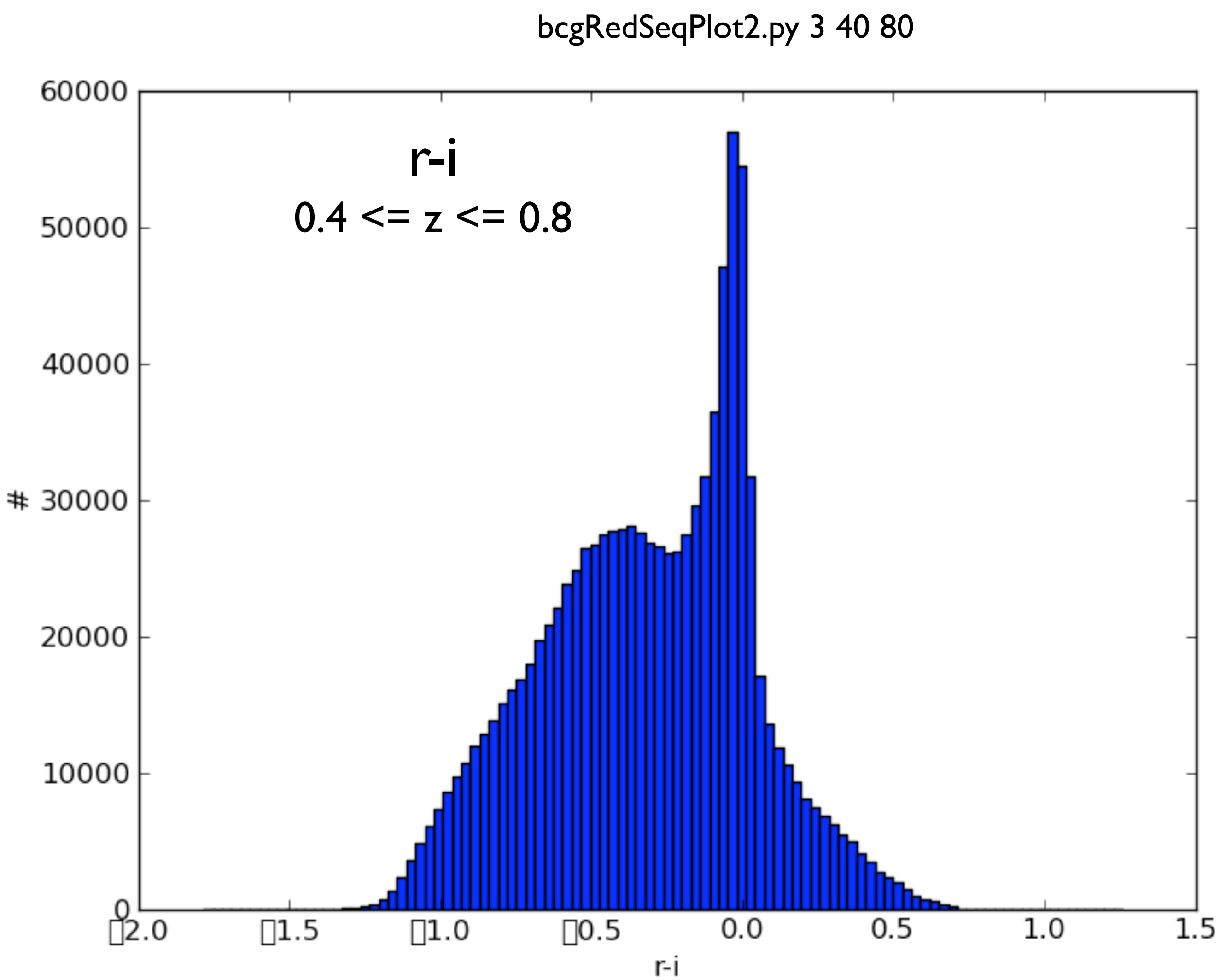


Reasonably well behaved.

kcorrection is subtracted

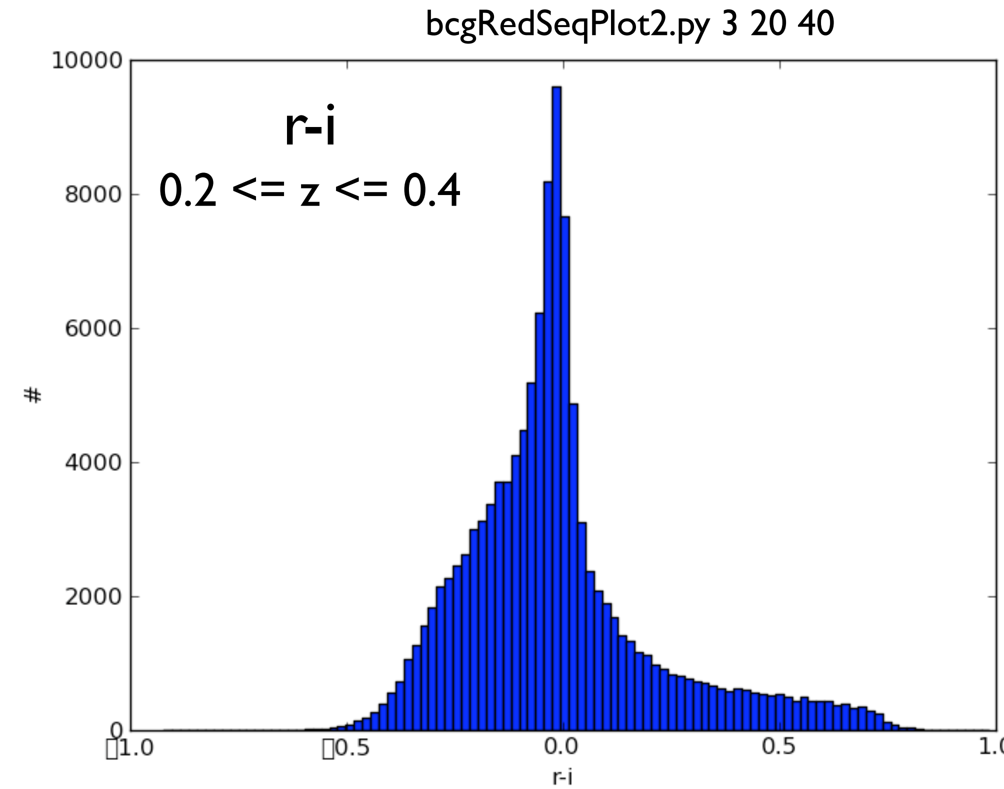
Mocks v2.13

1. The colors of the fields about the bcgs

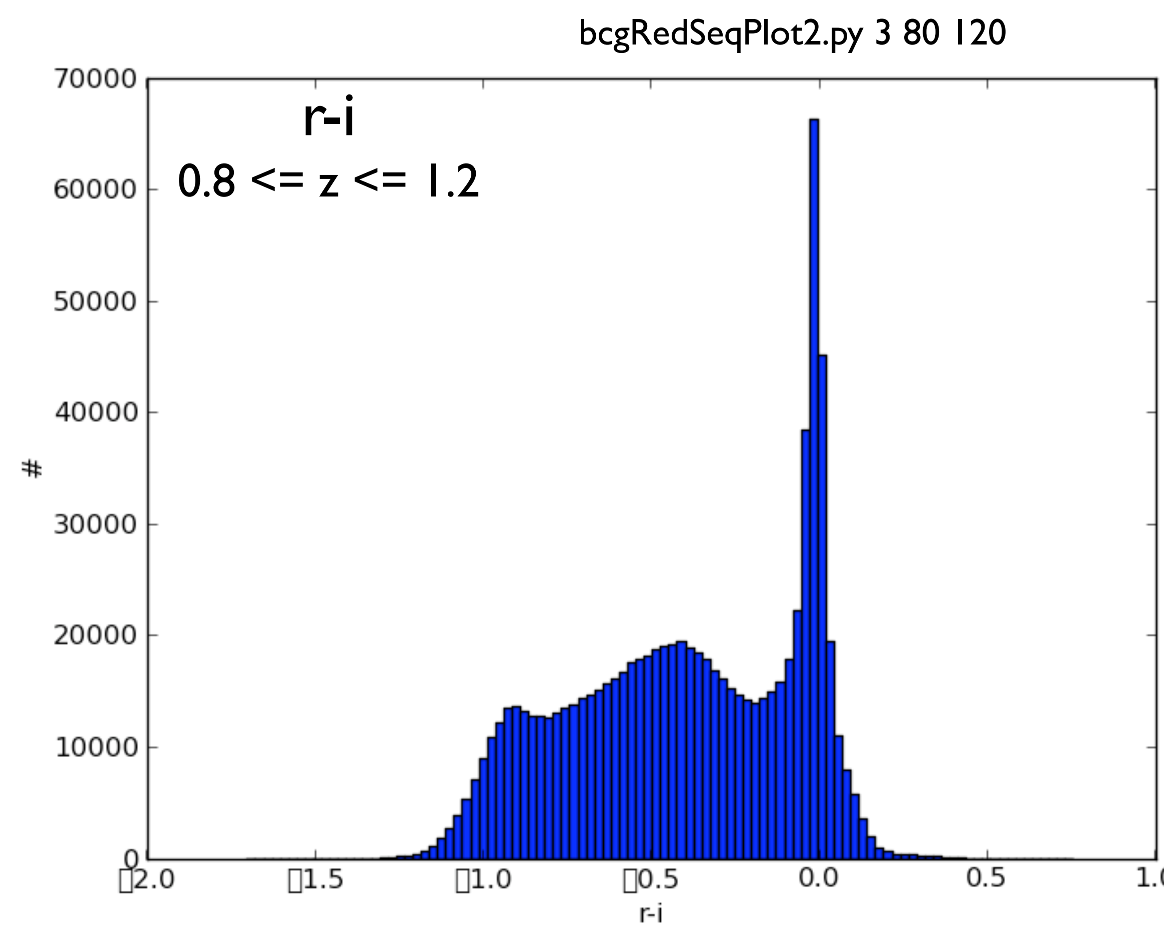


Reasonably well behaved.

kcorrection is subtracted

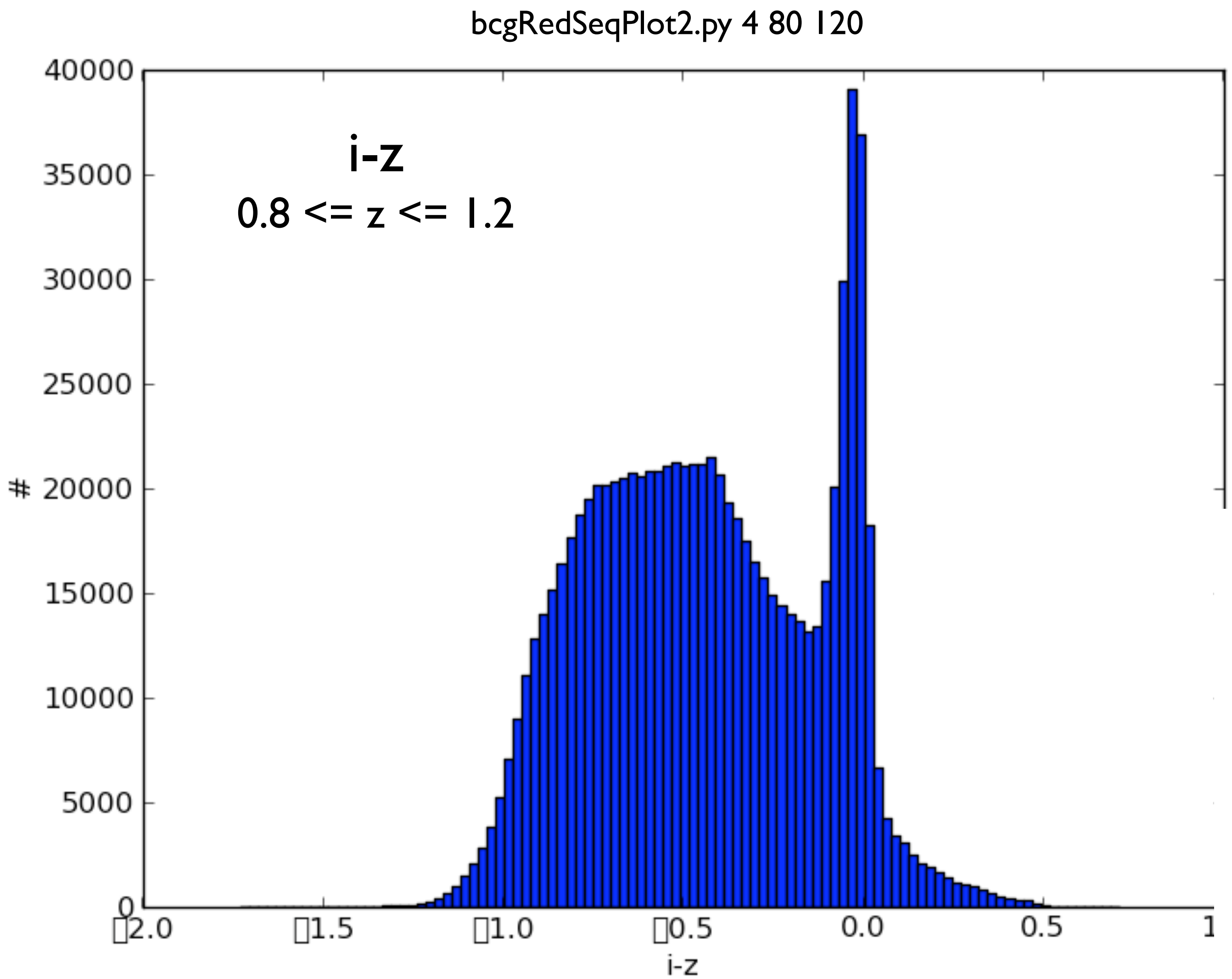


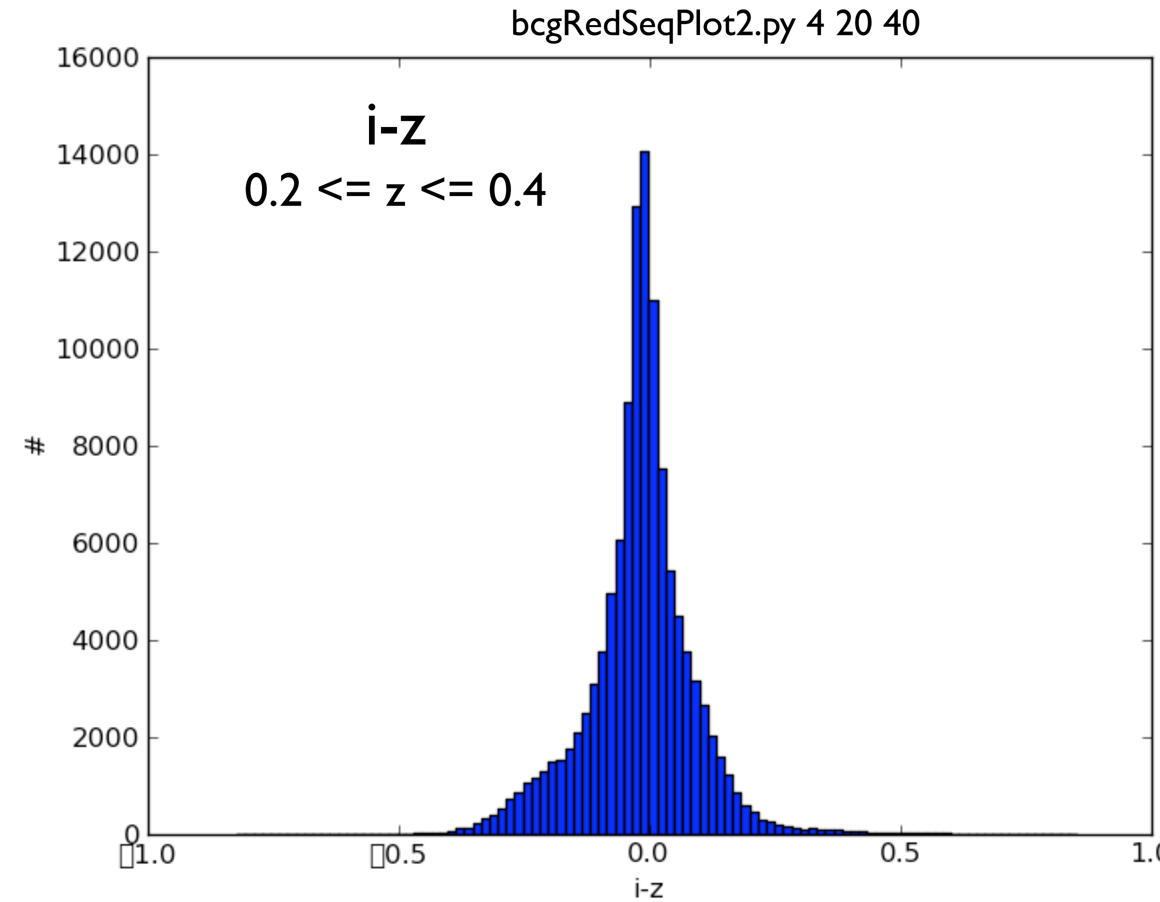
0.9 < z < 1.1 is cleaner

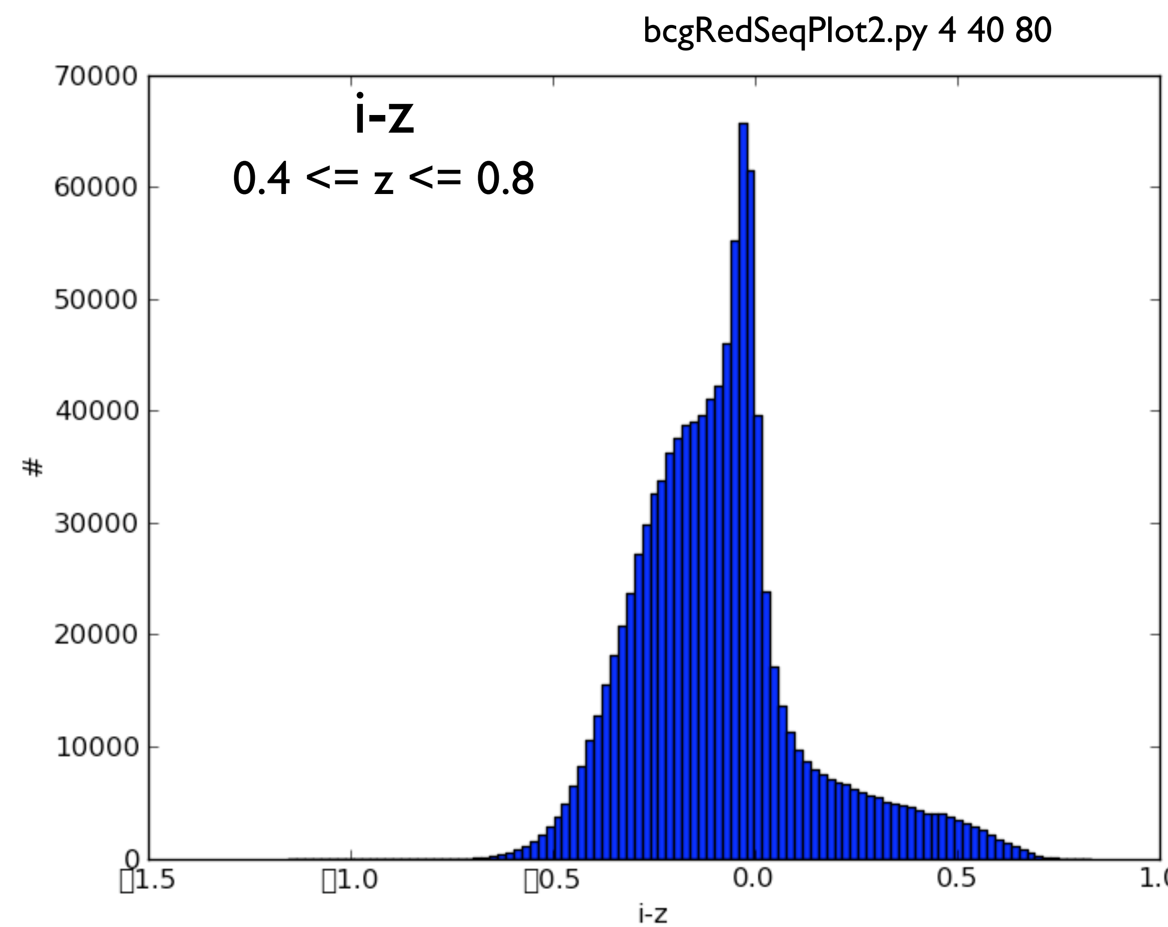


Mocks v2.13

1. The colors of the fields about the bcgs







Reasonably well behaved.

kcorrection is subtracted