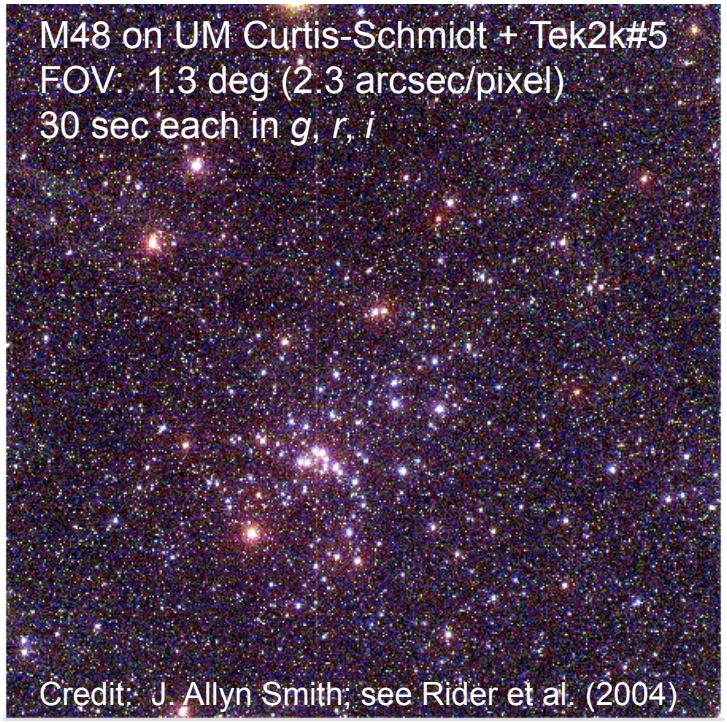
The PreCam Full DES Footprint Strategy

DARK ENERGY SURVEY



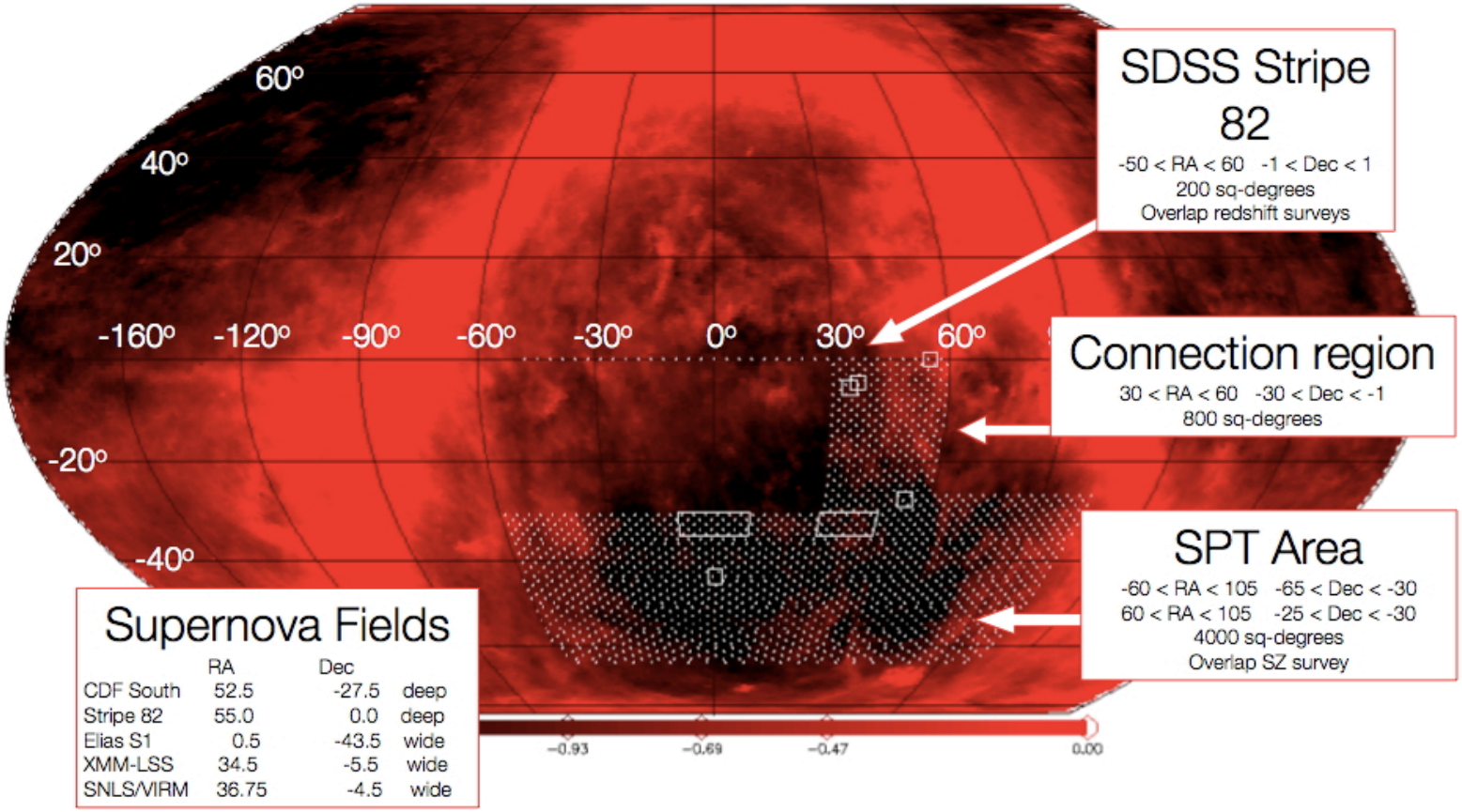
Douglas L. Tucker
(FNAL)

PreCam Workshop
17 September 2009

Goal of the Full Footprint Plan

DARK ENERGY SURVEY

- To observe the entire 5000 sq deg of the DES footprint in a single pass (with large overlaps) in *grizY* down to 1.5 mag fainter than the point-source saturation limit of a nominal 100-sec DES science exposure.



Time to Complete Full Footprint Plan: I. Number of Pointings

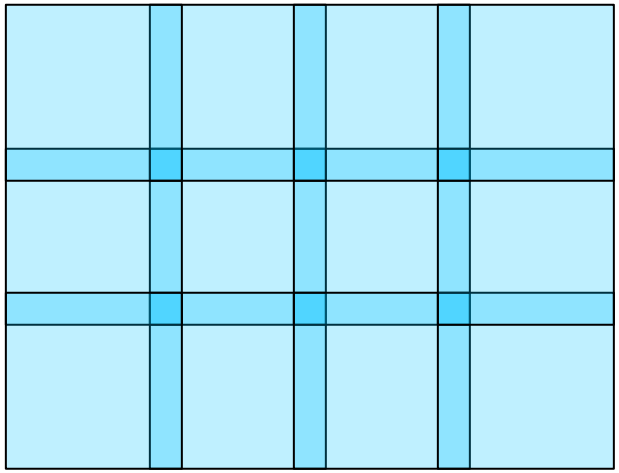
DARK ENERGY SURVEY

- The baseline instrument is a 2x2 mosaic of DECam 2k x 2k CCDs.

- On the Curtis-Schmidt, the field-of-view of this baseline instrument would be 1.6° x 1.6° (2.56 sq deg).
  - 15 micron pixels → 1.43 arcsec/pixel x 4096 pixels = 1.6°.

- 5000 sq deg / 2.56 sq deg = 1953 pointings.

- For good pointing-to-pointing overlap, increase number of pointings by a 1.5x.
  - ~ 11% overlap on each of four sides.
  - 1.5 x 1953 pointings = **2930 pointings**.



DARK ENERGY SURVEY

Time to Complete Full Footprint Plan: II. Exposure Times

- Use a “home-grown” Exposure Time Calculator to estimate:

  1. saturation limits of nominal DES (Blanco+DECam) 100-sec science exposures

  2. Curtis-Schmidt+PreCam exposure times to achieve S/N=50 for point sources 1.5 mag fainter than the saturation limits from item 1

  3. Curtis-Schmidt+PreCam saturation limits for the exposure times in item 2

  4. Curtis-Schmidt+PreCam point-source detection limits (S/N=5) for exposure times in item 2

- Use SDSS and UKIDSS data to estimate the stellar density at the Galactic Poles between DES saturation and DES saturation + 1.5 mag.

DARK ENERGY SURVEY

Time to Complete Full Footprint Plan: II. Exposure Times

Baseline PreCam Survey Point-Source Magnitude Limits (optimized to achieve S/N=50 at DES saturation + 1.5mag)

Band	PreCam Exposure Time [seconds]	PreCam saturation limit	DES saturation limit (100s exposure)	PreCam mag limit (S/N=50)	PreCam detection/ mag limit (S/N=5)	# Stars per sq deg, DES sat to PreCam S/N=50)
(1)	(2)	(3)	(4)	(5)	(6)	(7)
g	36	12.8	16.3	17.8	20.9	186
r	51	13.2	16.3	17.8	20.7	265
i	65	13.4	16.2	17.7	20.5	344
z	162	14.1	16.0	17.5	20.1	317
Y	73	11.6	14.3	15.8	18.5	150

Total Exposure Time for all 5 filters: 387 sec (6.45 min)

DARK ENERGY SURVEY

Time to Complete Full Footprint Plan: II. Exposure Times

Baseline PreCam Survey Point-Source Magnitude Limits (optimized to achieve S/N=50 at DES saturation + 1.5mag)

Band	PreCam Exposure Time [seconds]	PreCam saturation limit	DES saturation limit (100s exposure)	PreCam mag limit (S/N=50)	PreCam detection/ mag limit (S/N=5)	# Stars per sq deg, DES sat to PreCam S/N=50)
(1)	(2)	(3)	(4)	(5)	(6)	(7)
g	36	12.8	16.3	17.8	20.9	186
r	51	13.2	16.3	17.8	20.7	265
i	65	13.4	16.2	17.7	20.5	344
z	162	14.1	16.0	17.5	20.1	317
Y	73	11.6	14.3	15.8	18.5	150

Filters *i*, *z*, and *Y* can be done in bright time.

DARK ENERGY SURVEY

Time to Complete Full Footprint Plan: III. Overheads

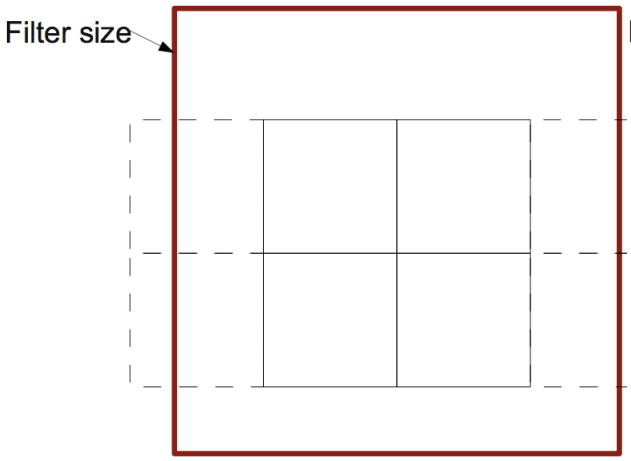
Item	Amount	Sub-total
Total exposure time per pointing	387 sec	387 sec
Readout time	+ 5 filters x 10 sec/filter	437 sec
Slew time	+ 30 sec/pointing	467 sec
Total number of pointings	X 2930 pointings	1368310 sec
Conversion to hours	X 1 hour/3600 sec	380 hours
Conversion to nights	X 1 night/7 hours	54.3 nights
Observing Inefficiencies	X 1.25	67.9 nights
Non-Photometric conditions	X 1.3	88.2 nights
TOTAL:		**88.2 nights**

Time to Complete Full Footprint Plan: IV. Alternatives

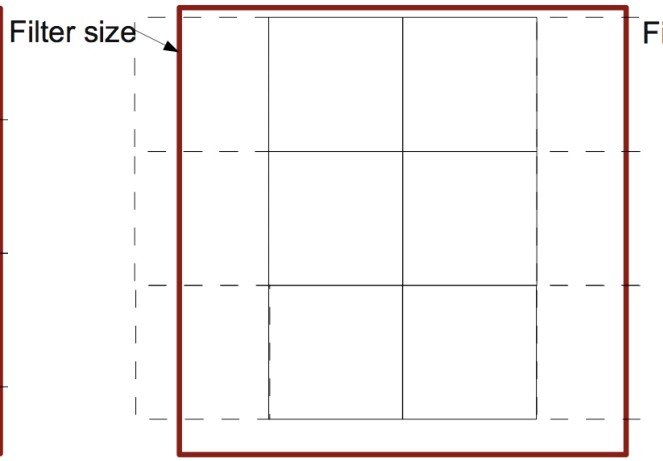
DARK ENERGY SURVEY

Configuration	Readout Time	Area	Survey Time
Four 2Kx2K	10s	2.56 sq. deg.	88 nights
Six 2Kx2K	10s	3.84 sq. deg.	59 nights
Four 2Kx4K	20s	5.12 sq. deg.	49 nights

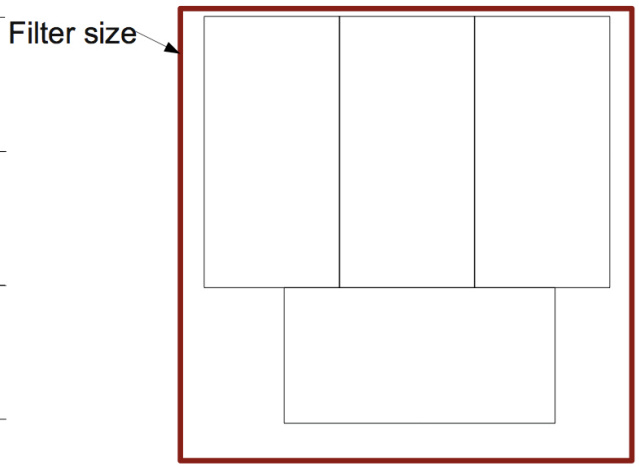
Four 2kx2k



Six 2kx2k



Four 2kx4k



Credit: S. Kuhlmann

DARK ENERGY SURVEY

Advantages to a Full Footprint PreCam Survey I (Darren DePoy)

Here are reasons that observing the entire DES area during the PreCam campaign is preferable to other, more restrictive, strategies:

1. Complete coverage of the DES footprint would allow calibration of each DECam CCD. This would be true even in the presence of clouds that partially (or differently) obscure parts of the focal plane. Therefore, unique photometric transformations can be accomplished even in relatively poor weather. Any other strategy will be vulnerable to unknown atmospheric transmission across the focal plane.

2. Complete coverage is the most efficient manner of obtaining calibration information. No "special" calibration observations would be necessary, so no time will be lost moving to specific calibration regions.

DARK ENERGY SURVEY

Advantages to a Full Footprint PreCam Survey II (Darren DePoy)

3. Observations with the Schmidt are likely to be systematic noise limited. Previous measurements suggest that achieving 1-2% photometric precision is probably the limit for observations with the Schmidt telescope, probably due to a combination of inter-pixel sensitivity variability and the relatively large size of the pixels on the sky (so a seeing limited image will be roughly the same size as a pixel). Thus, repeated measurements of a small region are unlikely to give superior photometric precision calibration. Repeated measurements could allow measurement of fainter stars to the systematic limit, but the full coverage plan contains adequate stars to calibrate all CCDs already.

4. The complete census of bright stars on the DES area would enhance various science projects (galactic archaeology in particular). First epoch positions would be available for many stars, which would also extend the time baseline and hence proper motion sensitivity of the DES survey as well.

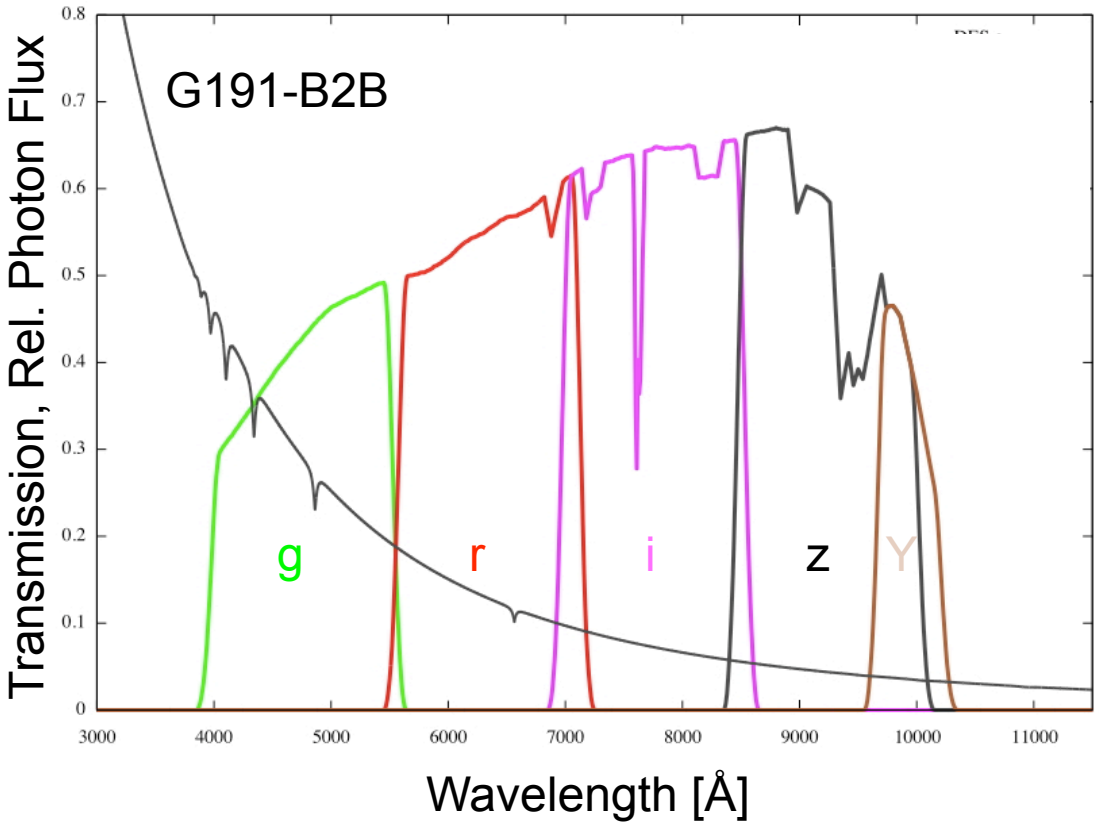
DARK ENERGY
SURVEY

Extra Slides

Basic Exposure Time Calculator

DARK ENERGY SURVEY

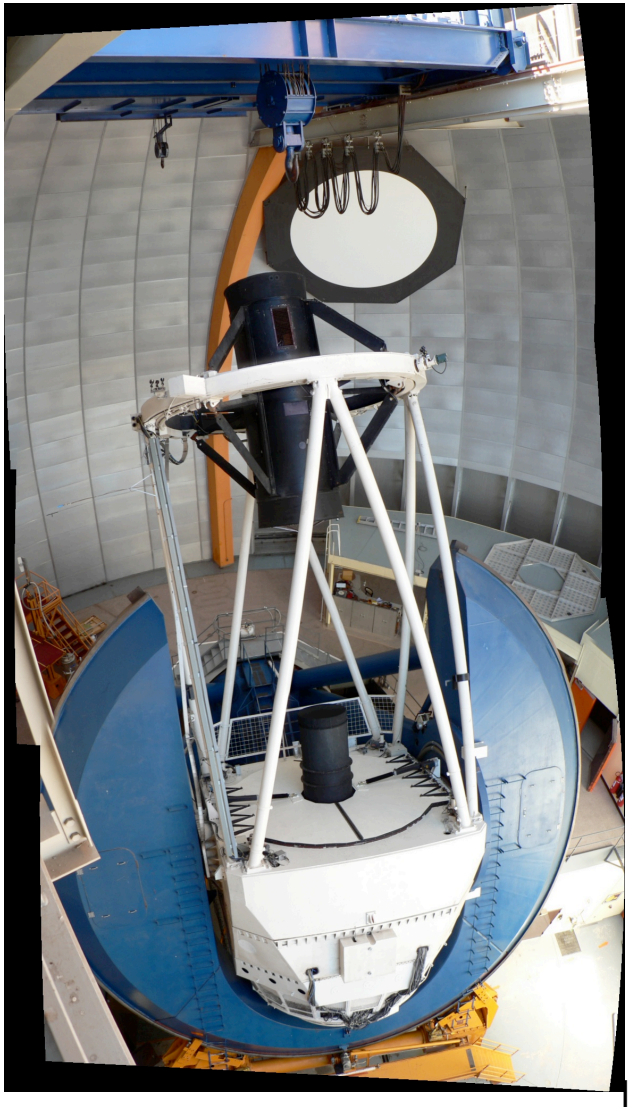
- Take the current best estimate of the total filter responses for the DES filters (from Huan Lin).
- Take a spectrophotometric standard from the HST CalSpec database (e.g., G191-B2B).
- For each filter, calculate the total detected photon counts per second for a m_{AB}=20 object.
- For aperture photometry, assume point sources have a Gaussian profile, and use an aperture of radius = 1.0*FWHM for S/N calculations.



Assumptions for DES Science Exposures

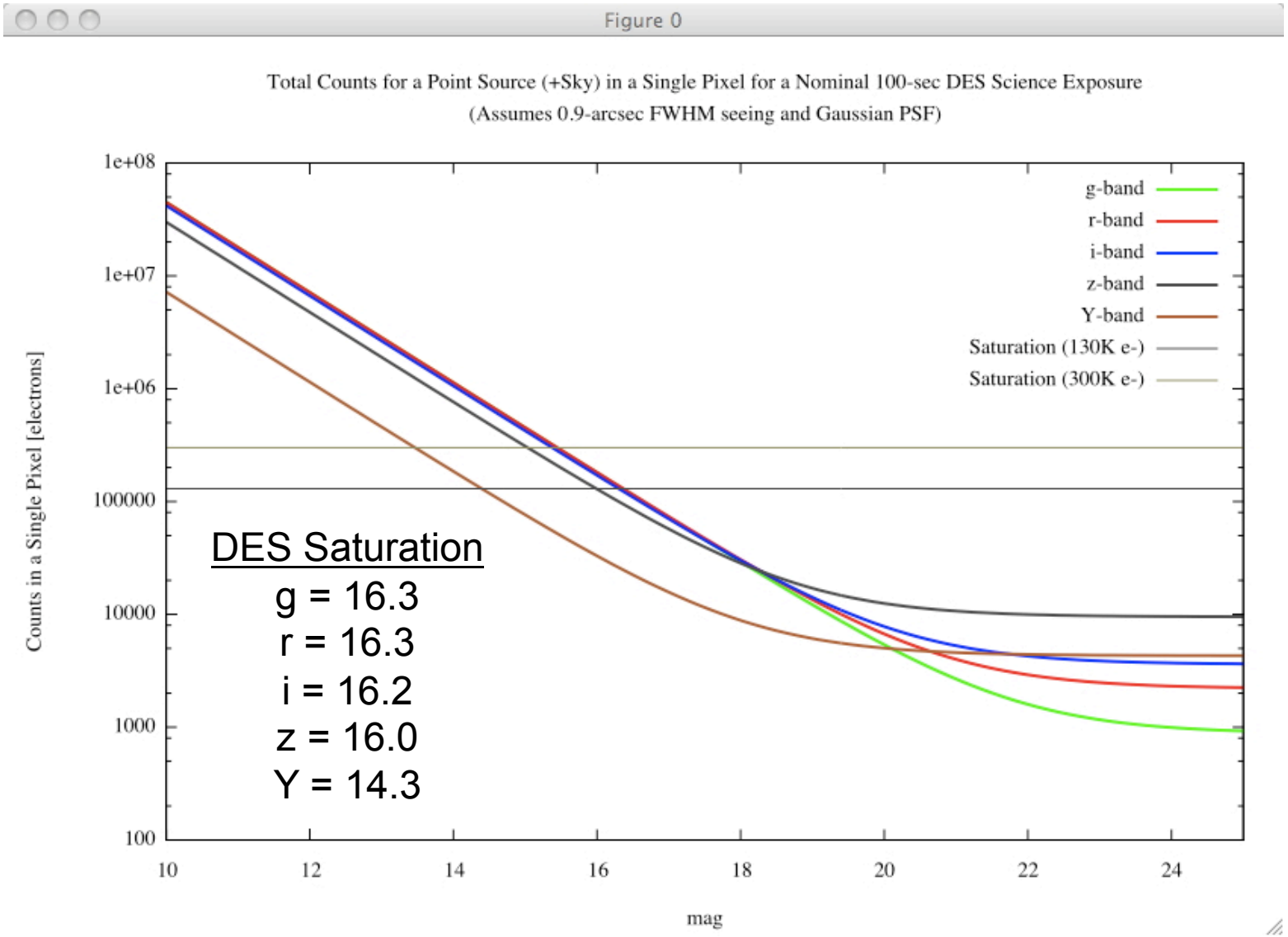
DARK ENERGY SURVEY

- 100 sec exposure times
- 10.62 m^2 effective area of primary mirror
  - 4.0m mirror with 15% obscuration
- 0.9 arcsec seeing (FWHM)
- 0.27 arcsec pixels
- Full well of 130,000 electrons (lower limit from TDR)
- Sky background of
  - g=21.7 mag/$arcsec^2$
  - r=20.7 mag/$arcsec^2$
  - i=20.1 mag/$arcsec^2$
  - z=18.7 mag/$arcsec^2$
  - Y=18.0 mag/$arcsec^2$



DES Nominal 100-sec Science Exposure Point-Source Saturation Limits

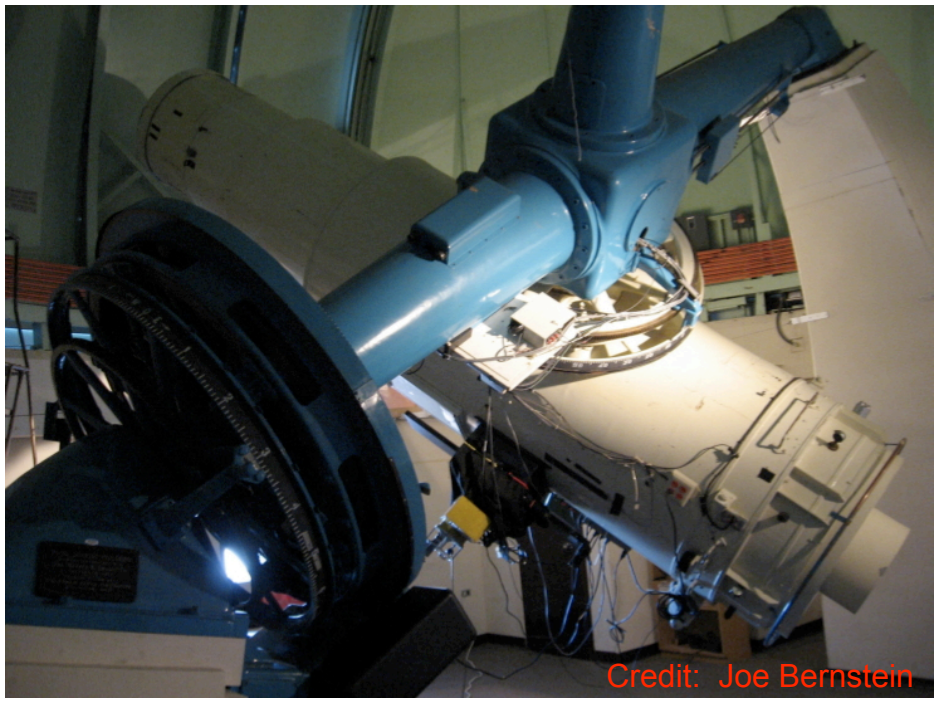
DARK ENERGY SURVEY



Assumptions for PreCam Exposures

DARK ENERGY SURVEY

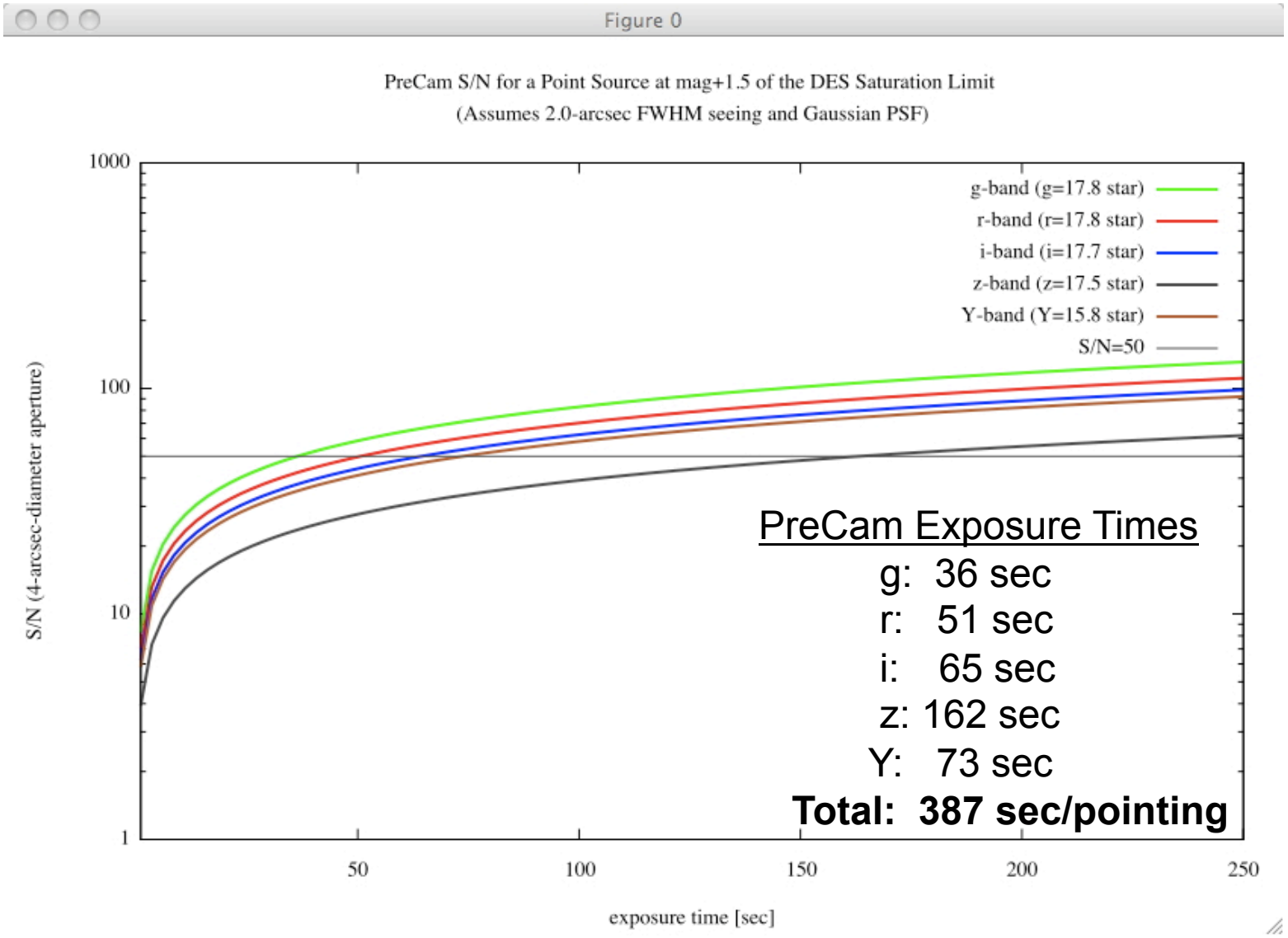
- University of Michigan Curtis-Schmidt
- 0.24 m^2 effective area for light collection
  - 0.6m aperture with 15% obscuration
- 2.0 arcsec seeing (FWHM)
- 1.43 arcsec pixels
- Full well of 130,000 electrons
- Sky background of
  - g=21.7 mag/arcsec^2
  - r=20.7 mag/arcsec^2
  - i=20.1 mag/arcsec^2
  - z=18.7 mag/arcsec^2
  - Y=18.0 mag/arcsec^2



- Optimize the exposure times so that a star that is 1.5 mag fainter than the nominal DES saturation limit will have a S/N ≥ 50.

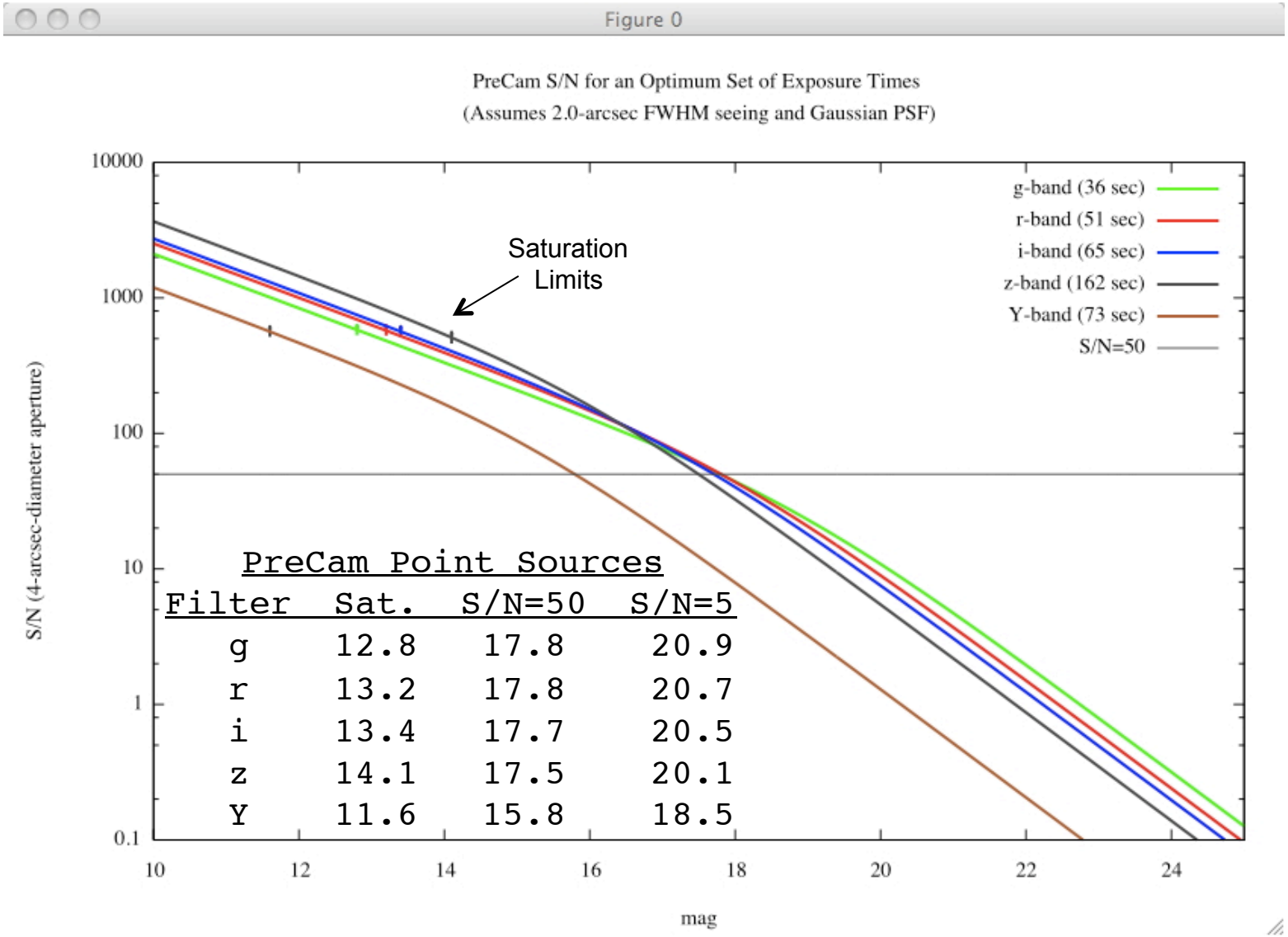
PreCam Exposure Times to Reach DES Saturation + 1.5mag (S/N=50)

DARK ENERGY SURVEY



S/N vs. Mag for PreCam Exposures (Bright Science + Overlap with DES)

DARK ENERGY SURVEY



DARK ENERGY SURVEY

Conclusions

- A point source in a nominal 100-sec DES Science exposures under dark-sky conditions will saturate at g=16.3, r=16.3, i=16.2, z=16.0, Y=14.3

- PreCam should aim for a point-source S/N ≥ 50 at g=17.8, r=17.8, i=17.7, z=17.5, Y=15.8 (i.e, 1.5 mag deeper than the point-source saturation limit for DES).

- To achieve this goal, PreCam exposure times should be at least 36 sec, 51 sec, 65 sec, 162 sec, 73 sec in g, r, i, z, Y, respectively (at least 387 sec of exposure time per pointing).

- For these exposure times, it is estimated that PreCam will achieve the following for point sources:

Filter	Saturation	S/N=50	S/N=5
g	12.8	17.8	20.9
r	13.2	17.8	20.7
i	13.4	17.7	20.5
z	14.1	17.5	20.1
Y	11.6	15.8	18.5

Count rates: DES (Blanco+DECam)

DARK ENERGY SURVEY

Filter	mag=20 object e-/sec
g	584.56
r	586.25
i	542.49
z	394.44
Y	93.67

Filter	Sky Background mag/arcsec^2	e-/sec/pixel
g	21.7	8.8
r	20.7	22.3
i	20.1	35.9
z	18.7	95.0
Y	18.0	43.1

For a mag=20 point source:

+ Multiply the "mag=20 object" count rate by 0.93738 for an aperture of radius = 1.0 FWHM (0.9 arcsec for DES).
+ Multiply the "mag=20 object" count rate by 0.07695 for an estimate of the count rate in a single pixel (assuming the point source is centered on the pixel's center). This is useful for saturation limit estimates. Note that this fractional value is different than that for the PreCam exposures.

DARK ENERGY SURVEY

Count rates: PreCam

mag=20 object		Sky Background		
Filter	e-/sec	Filter	mag/arcsec^2	e-/sec/pixel
g	13.21	g	21.7	5.6
r	13.25	r	20.7	14.1
i	12.26	i	20.1	22.8
z	8.92	z	18.7	60.2
Y	2.12	Y	18.0	27.3

For a mag=20 point source:

+ Multiply the "mag=20 object" count rate by 0.93738 for an aperture of radius = 1.0 FWHM (2.0 arcsec for PreCam).
+ Multiply the "mag=20 object" count rate by 0.37968 for an estimate of the count rate in a single pixel (assuming the point source is centered on the pixel's center). This is useful for saturation limit estimates. Note that this fractional value is different than that for the DES exposures.