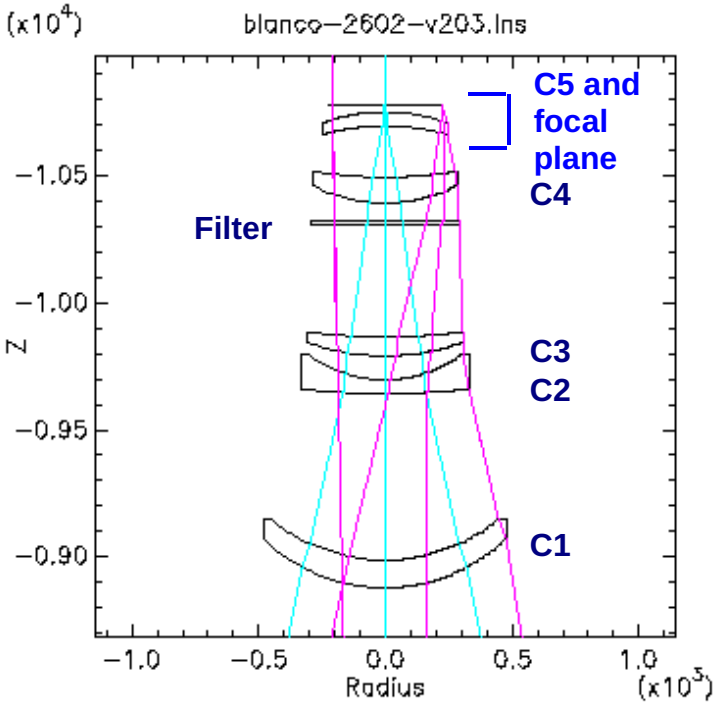
DESpec Optics

DARK ENERGY SURVEY

- I. Recap of Requirements
  - Wavelength range
  - PSF Size
    - Optimal Fiber diameter
    - Zenith Angle
  - Wavelength resolution
- II. Updated Optical Designs
  - To “ADC” or not to “ADC” - that is the question.
- III. Additional Issues
- IV. 1-arm design
- V. Summary

DECam Corrector and Camera



Recap of Notional Requirements

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- **Wavelength range**
  - **λ = 0.55 - 1.0 complete ELG redshift coverage z = 0.0-1.7 (Hα or [OII])**
- **Wavelength (2-pixel) resolution**
  - **R > 3000 @ 1.0μ Partially resolve OH night sky forest**
    - **(> 50% “clear space” between OH lines with 3A rest-frame minimum window)**
- **Airmass**
  - **sec(z) <= 1.4 (SDSS plate statistics)**
    - **But new DES footprint may alter!**
- **Acceptable Fiber size**
  - **1.5" - 2.2" for mag(i) = 22-24**
- **PSF**
  - **FWHM < 0.6" (constraint of reusing existing corrector)**

despec-v3c ADC

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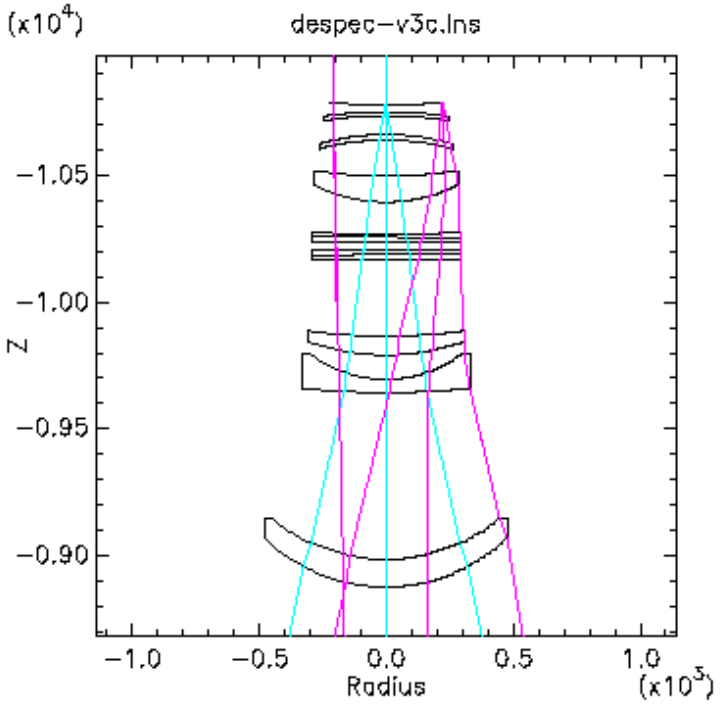
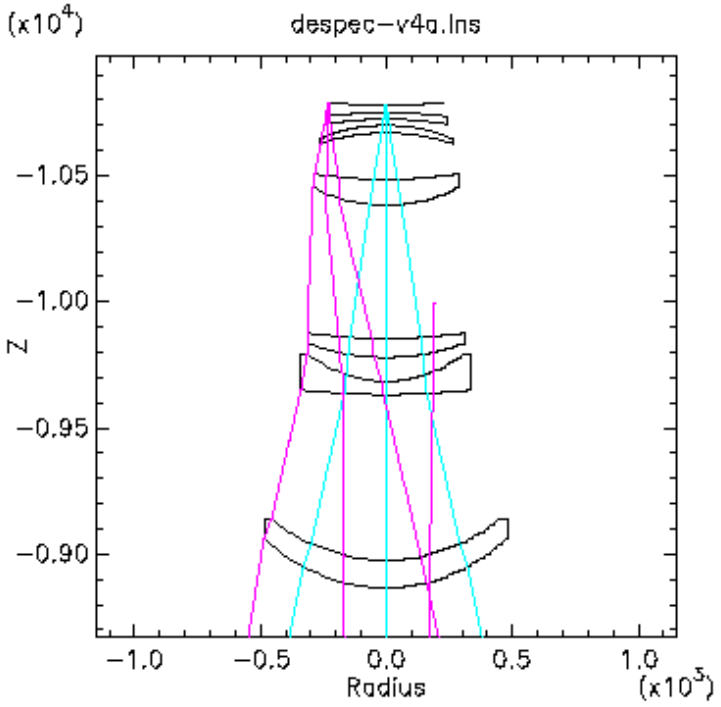
- **Features**
  - ADC with 2 powered surfaces
  - C5 => C5' + C6
  - C5' has 8th order asphere
  - 6 new glass elements total
  - FWHM (zenith configuration)
    - 0.57" RMS
  - λ range 0.50-1.08 μ
  - Nearly telecentric (max. tilt 0.44°).
- **Limitations**
  - ADC powered surfaces may be difficult
  - Lenses thin (like SDSS)



despec-v4a

DARK ENERGY SURVEY

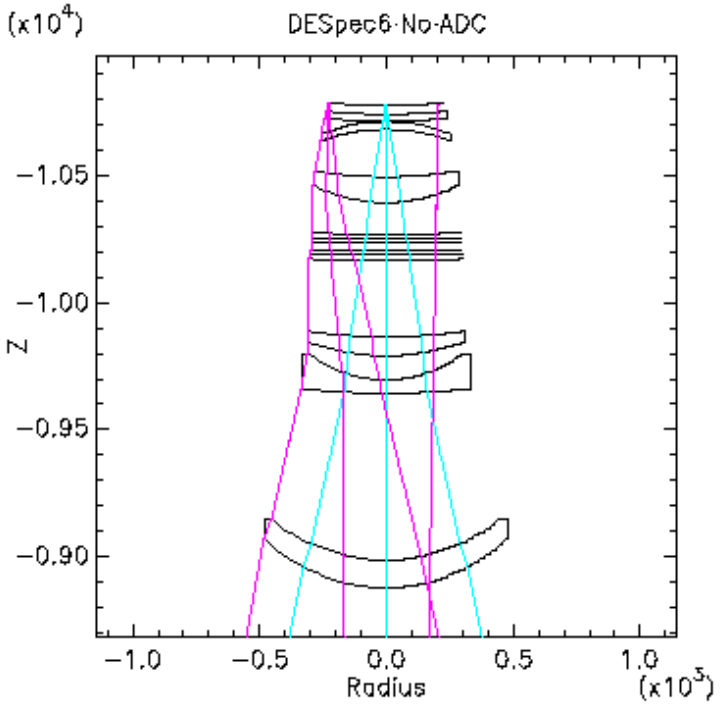
- **Features**
  - 2 new lenses total
    - C5 -> C5' (FK5)+ C6 (BK7)
  - Filter not used
  - λ range 0.50-1.08 μ
  - FWHM (zenith config)
    - 0.55''' RMS
  - Nearly telecentric (max. tilt 0.51°).
- **Limitation**
  - No ADC
    - FWHM increases to 0.79'' at sec(z) = 1.6
    - (0.69'' for λ = 0.6 - 1.0 μ)



despec6

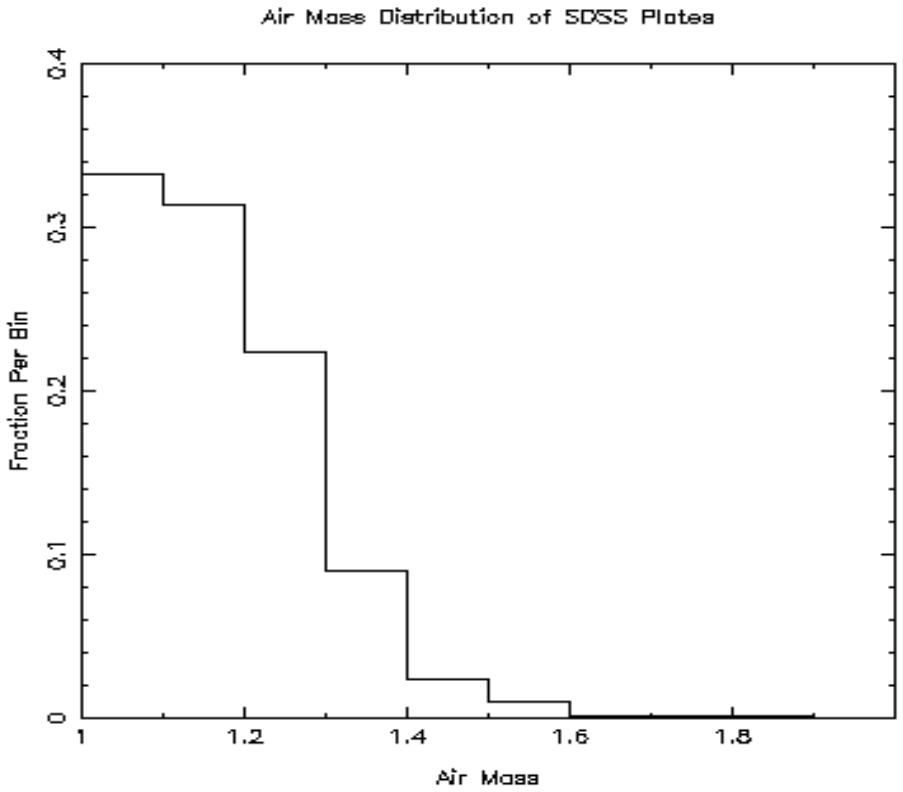
DARK ENERGY SURVEY

- **Will Saunders design**
- **Features**
  - **Aspheric focal plane**
  - **ADC in or out with same C5, C6**
  - **Improved wavelength range λ = 0.4 - 1.05 μ (NO ADC ONLY)**
  - **FWHM (zenith config)**
    - **0.60" RMS**
  - **Very telecentric (max. tilt 0.2°).**
- **Limitation**
  - **No-ADC FWHM increases to 1.2" at sec(z) = 1.6**



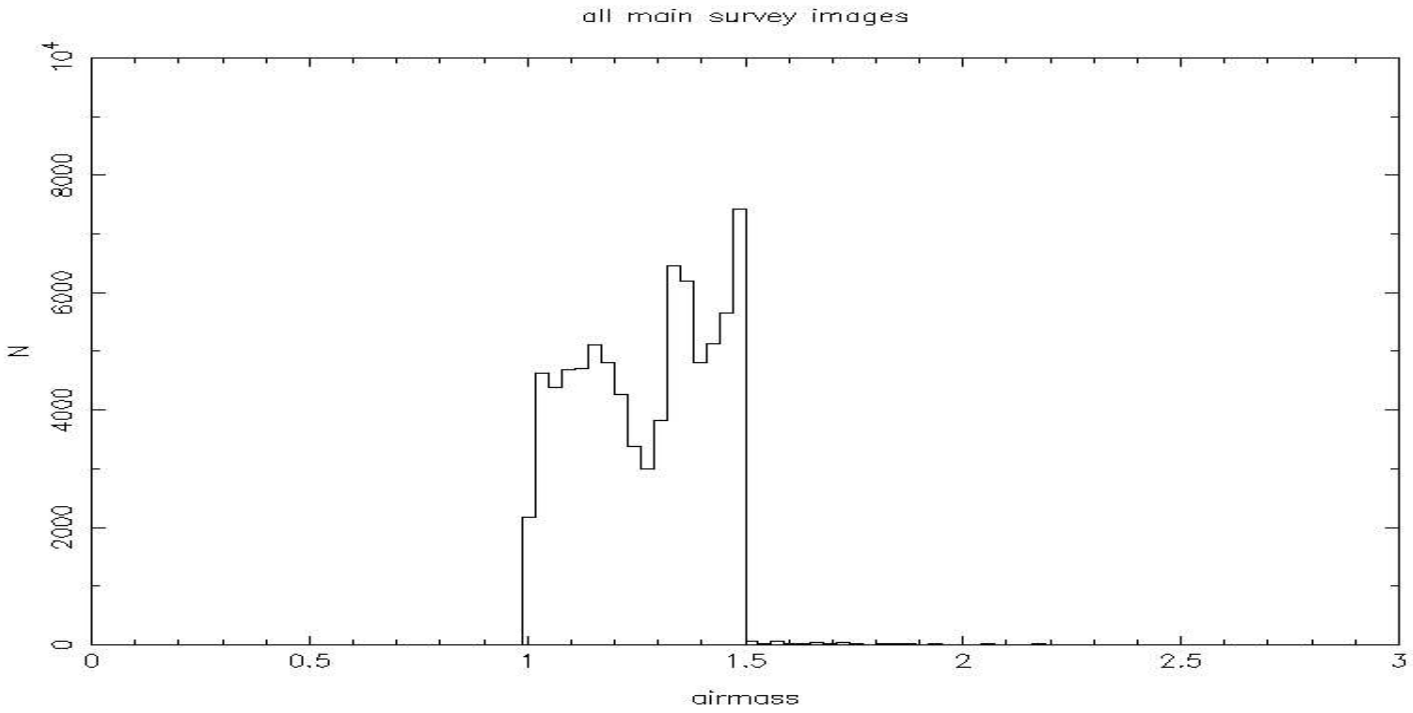
DARK ENERGY SURVEY

SDSS Plate Coverage



SDSS is an existing spectroscopic survey of ~10,000 sq. deg.
All plates (2880) airmass distribution
3% have sec(z) > 1.4

DES Sec(z) Coverage



Latest DES footprint has significant number of fields that are observed at sec(z) > 1.3. Spectroscopic survey may have similar distribution.

Atmospheric Dispersion

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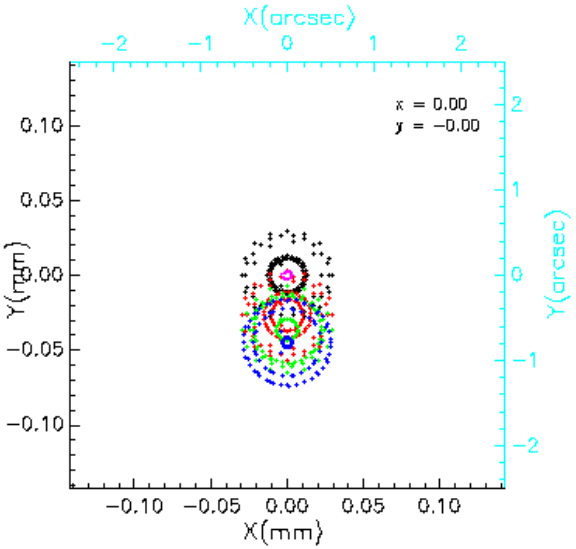
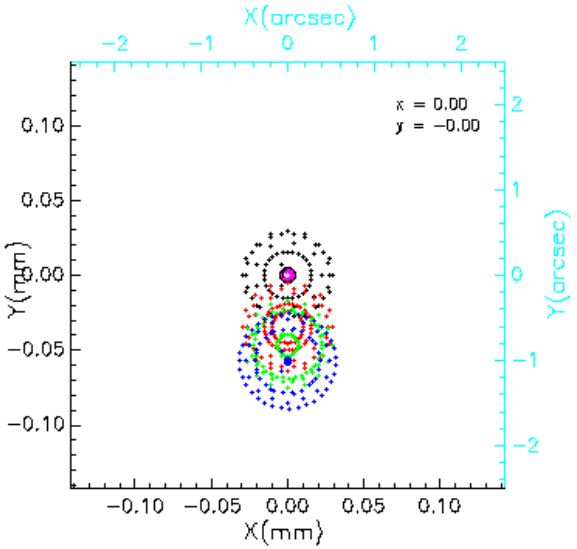
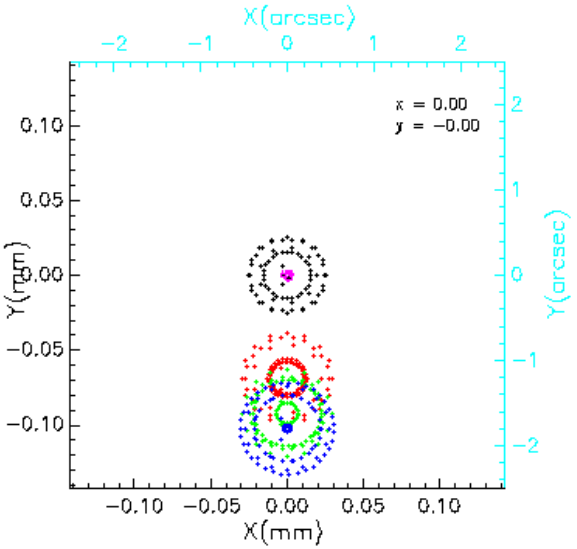


λ = 0.6 - 1.0 μ
Airmass 1.4
FWHM = 0.66”

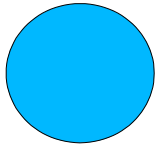


λ = 0.50 - 1.08 μ
Airmass 1.6
FWHM = 0.80”

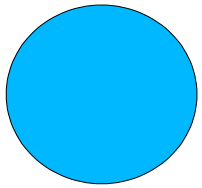


λ = 0.40 - 1.05 μ
Airmass 1.6
FWHM = 1.20”

Fiber diameter 1.4”



Fiber diameter 1.75”



Additional Issues for Wide-Field Spectroscopy

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- **Time-dependent distortions across field - worse at high airmass**
- **Polar axis misalignment (field rotation)**
- **Community science**
  - **SMC: $\delta = -75^{o}$ sec(z) = 1.4@meridian; 1.6@ ha=4 hrs**
  - **May require short exposures with fiber position adjustment to deal with 1st two effects**

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Issues That Need To Be Resolved

- **Simulation of spectra to better pin down desired R of spectra (assume FWHM > 2.25 pixels)**
  - **Is resolution of OII doublet essential?**
- **Minimum acceptable λ range (e.g., Hα and/or OII to cover z = 0 - 1.7)**
- **Optimization Studies**
  - **Spines v. twirling posts => spines have greater reach but suffer from tilt**
- **Spectrographs**
  - **What is POSSIBLE with an all-refractive design?**
  - **Same for reflective design**
  - **VPH grating feasibility**

Design for 1-armed Refractive Spectrograph

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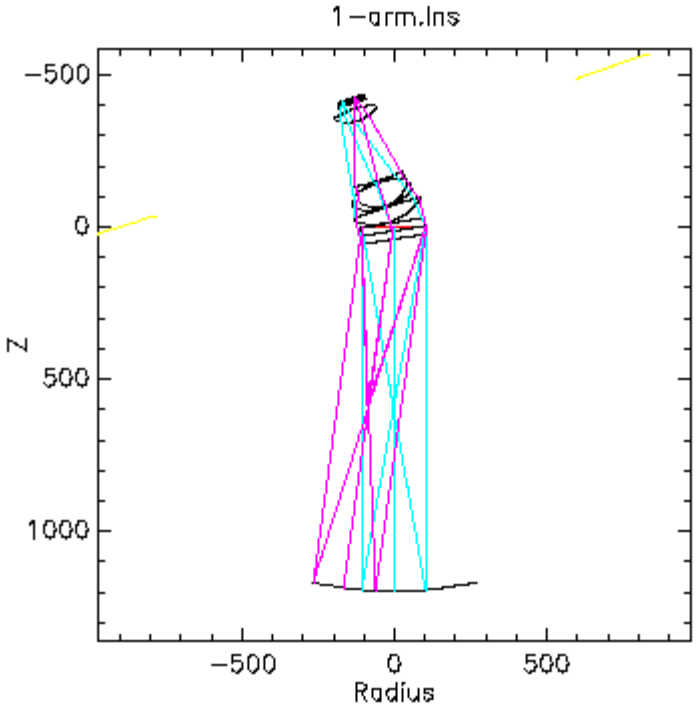

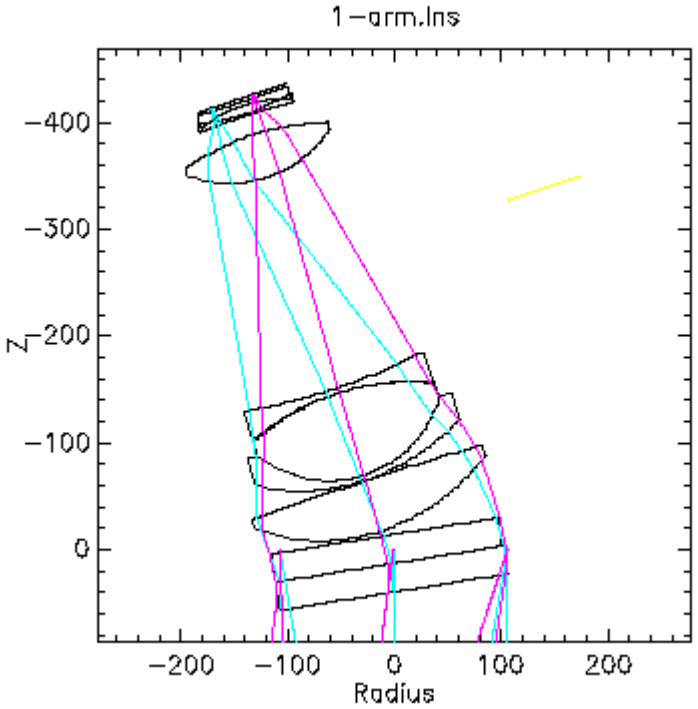

Camera Features
0.55 μ - 1.05 μ
120μ fiber diameter
R=3500
Bragg angle 6°
392 l/mm

Camera f/ratio 1.46
Beam 213 mm
Camera Focal Length 312 mm
Index modulation 0.02
Grating depth 19.4 microns

Intrinsic FWHM
15μ - 30μ
Inefficiency
0.40 (blue)
0.70 (red)

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Summary

- **Two limiting cases (not mutually exclusive)**
  - **Minimal**
    - **1-armed spectrograph**
    - **Small fibers (1.4" diameter)**
    - **Wavelength 0.6 -1.0 μ => gap in redshift coverage**
    - **Sec(z) < 1.4 (No ADC) => 5,000 sq. deg. survey**
  - **Maximal**
    - **2-armed spectrograph**
    - **Big fibers (1.7" diameter)**
    - **Wavelength 0.5-1.05 μ => no gap, go to higher z => bigger volume**
    - **No limit on sec(z) (ADC) => 15,000 sq. deg. survey**
- **Additional Considerations**
  - **no-ADC and ADC designs are interchangeable, so ADC comes later (but may be strategically undesirable).**
  - **Larger FOV - tolerate vignetting. Reaches 50% @ r = 250 mm**

DARK ENERGY
SURVEY

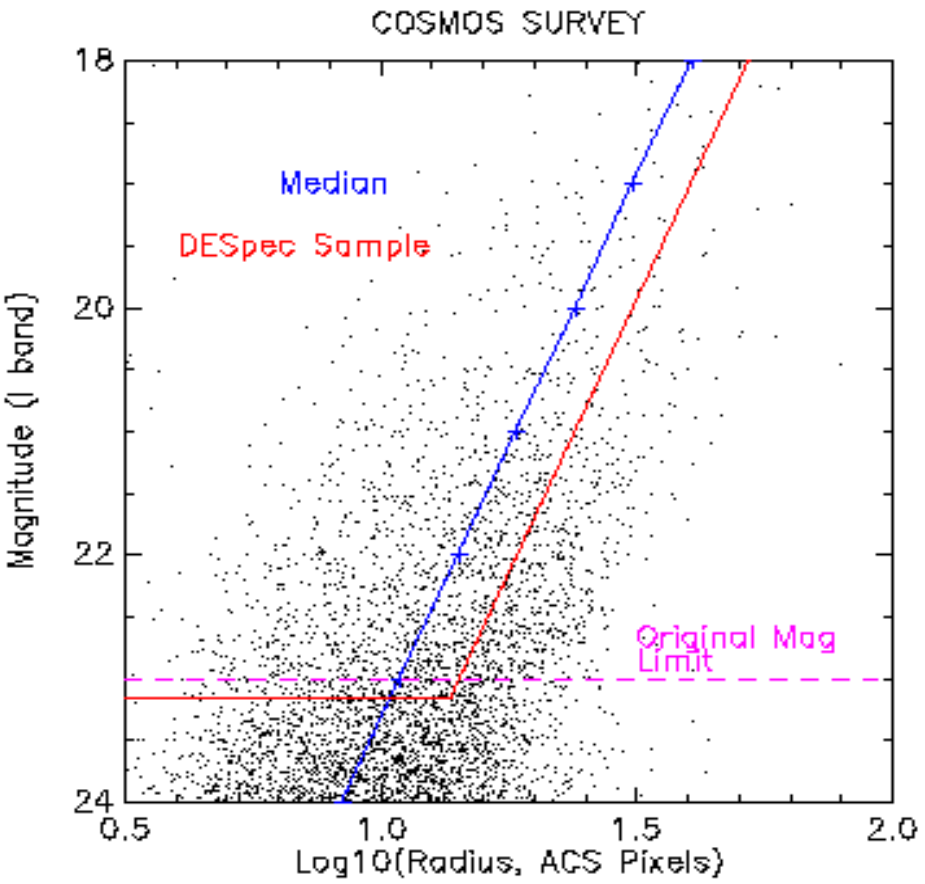
Extra Slides

DARK ENERGY SURVEY

Target Selection Strategy

- A) Select mag = m_{LIM} that achieves proper galaxy density
  - $m_{LIM} \approx 23$
- B) Go fainter by Δm and select galaxies with $r < r_{CRIT}$ such that density is unchanged. We expose to reach $S/N = (S/N)_{CRIT}$ for $m = m_{LIM} + \Delta m$, $r = r_{CRIT}$
- C) For each Δm, compute rate for collecting redshifts v. r_{FIBER}
- D) Pick Δm, r_{FIBER} that maximizes rate.
  - $\Delta m = 0.15$
  - r_{FIBER} = 0.85" to 0.9 " (diameter = 1.7" to 1.8")
  - We exclude ~ 30% of galaxies with $r_{1/2} > 0.41$"
- NOTE: Rate changes slowly as we move away from optimal
  - e.g., rate declines by 5% at r_{FIBER} = 0.73" (BigBOSS value)

Radius-Mag Relation



Night Sky Spectrum v. Resolution

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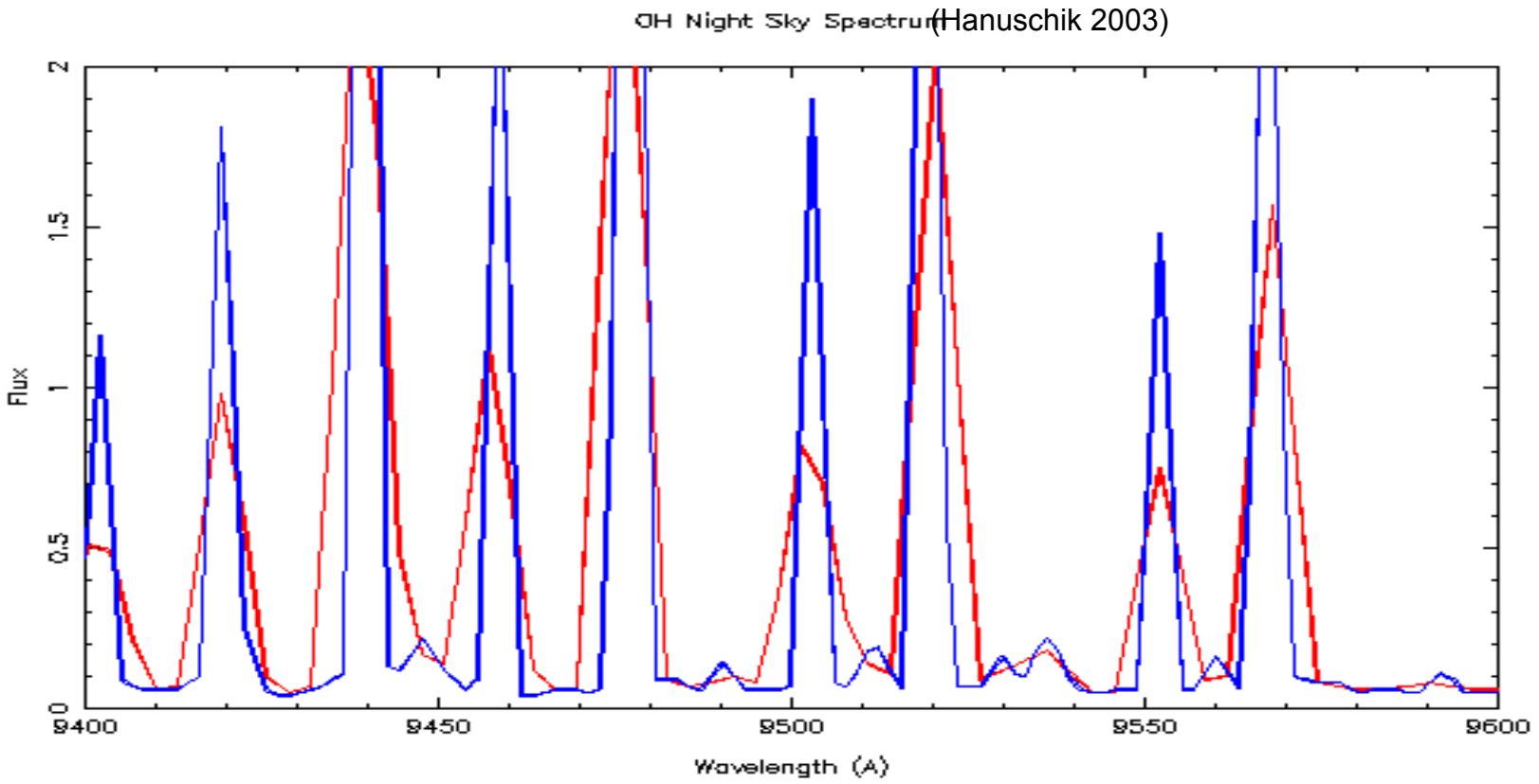
R=1500
R=3000



Signal ~ 0.04

1/4 BAO Cycle

Clear Pixels v. Resolution and Wavelength Range