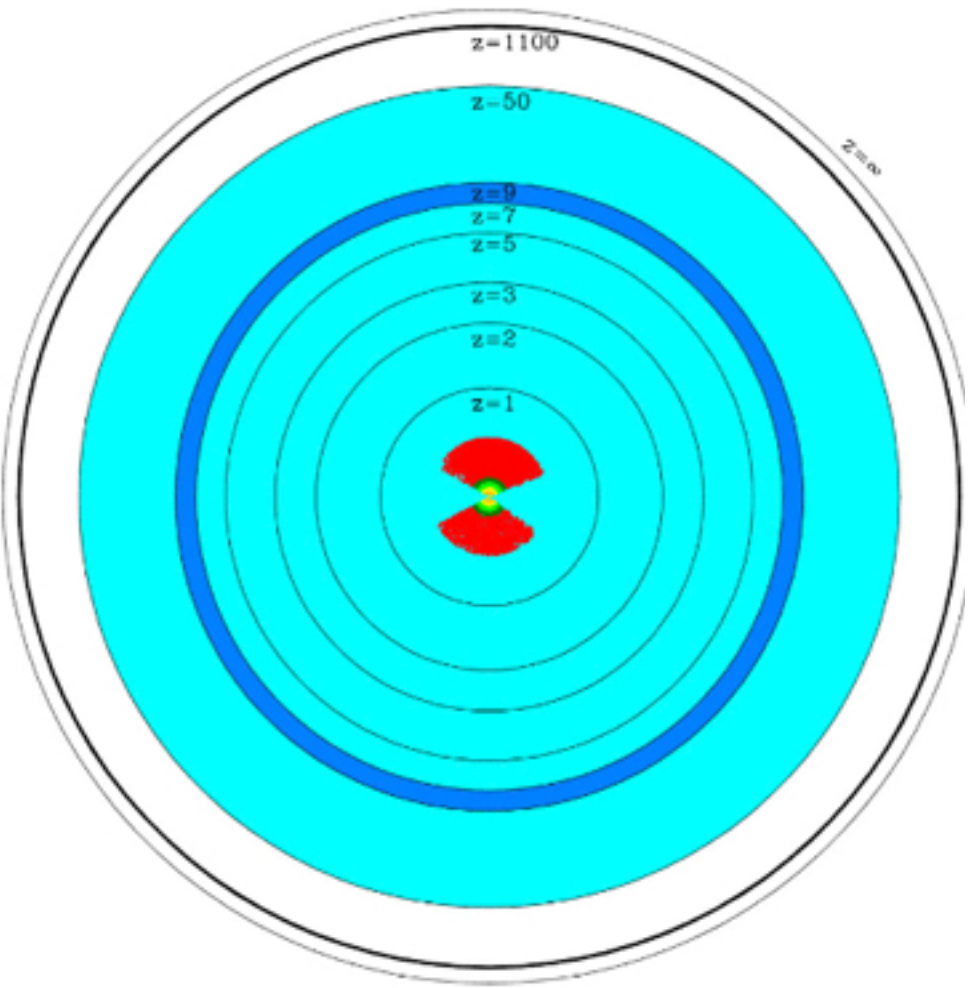
Design considerations for beyond DESI

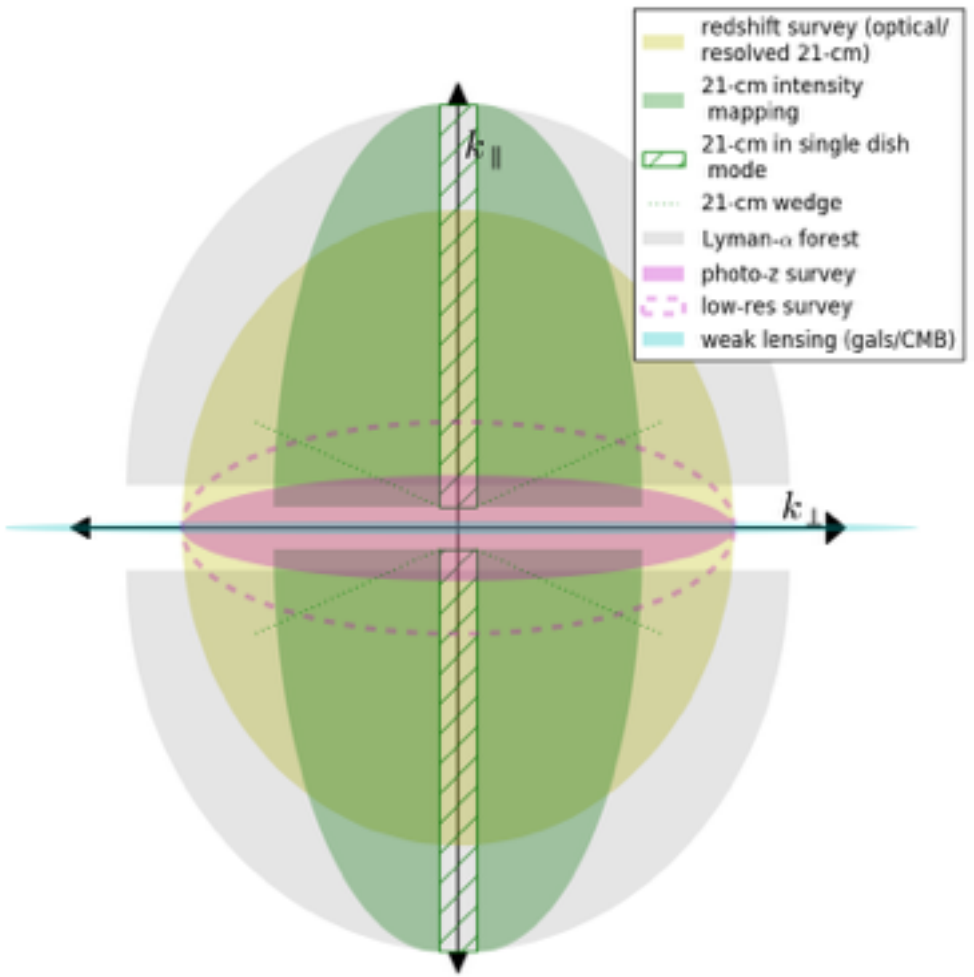
David Schlegel, Berkeley Lab

Larger maps improve all cosmological parameters

Volume



Number of modes



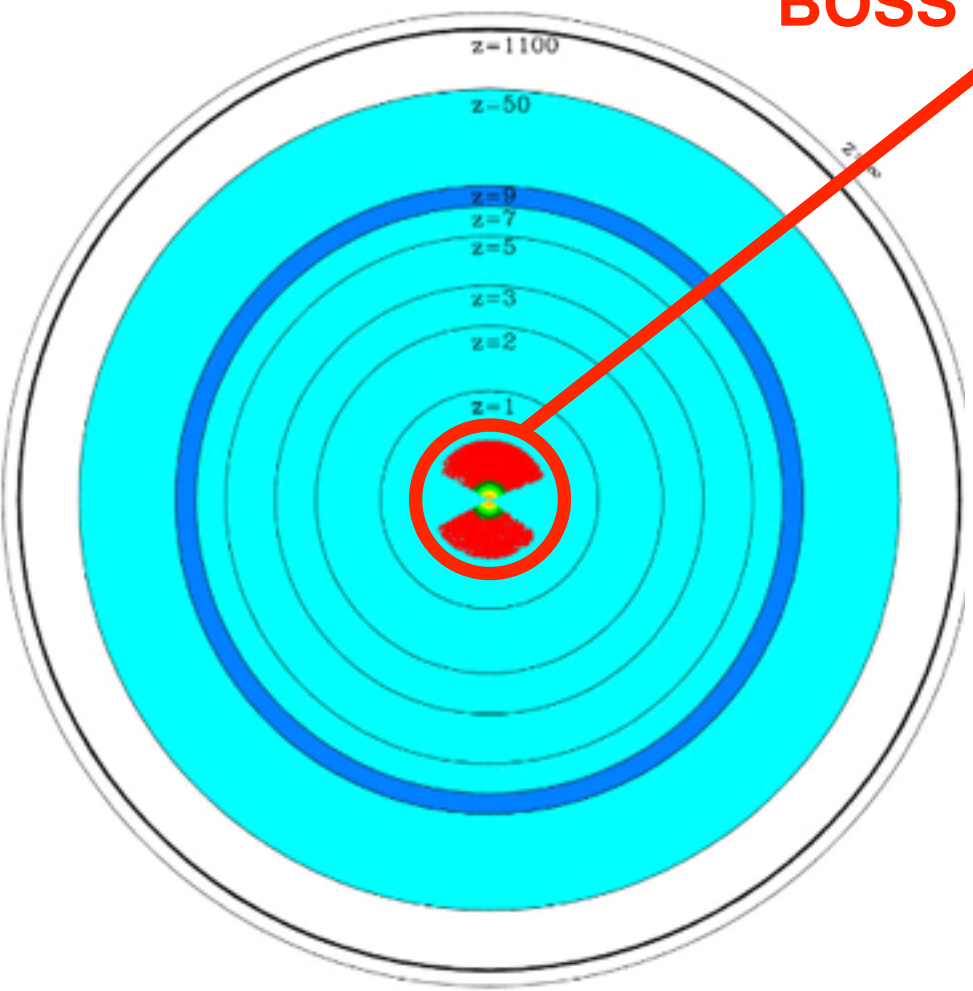
A. Slosar

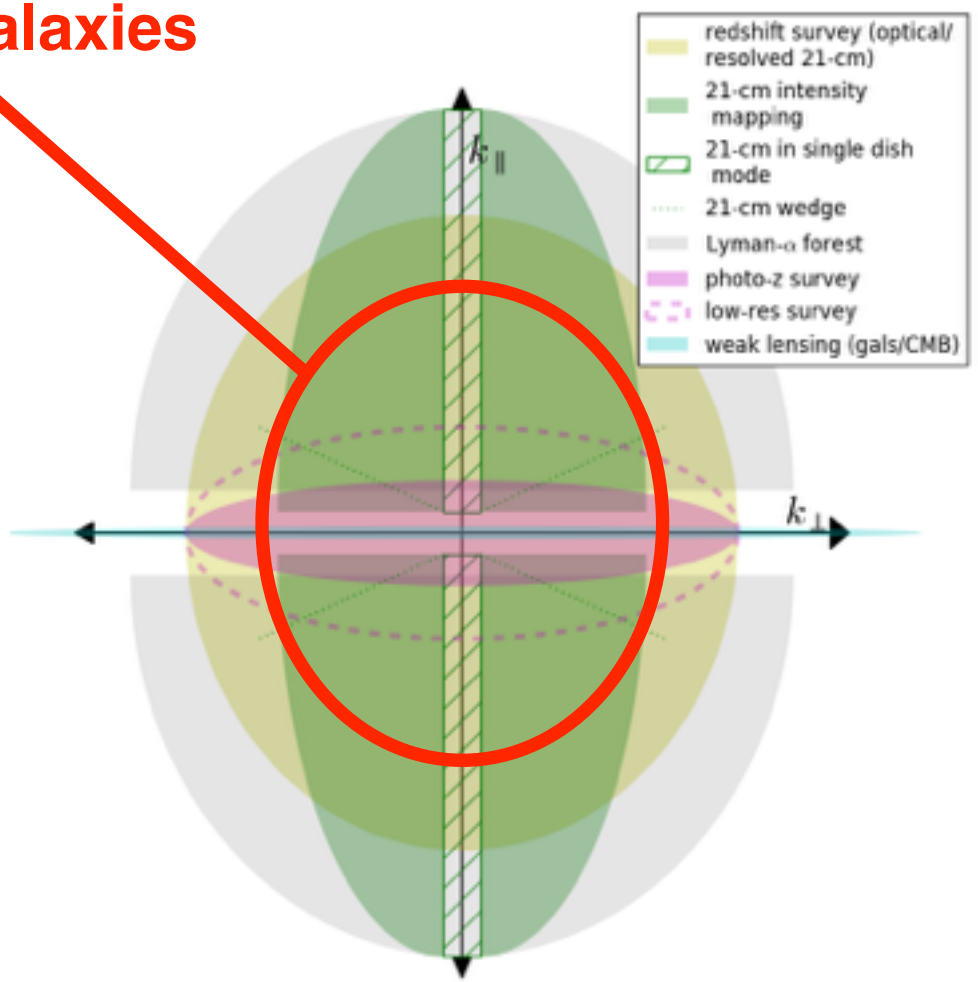
Larger maps improve all cosmological parameters

Volume

Number of modes

BOSS galaxies





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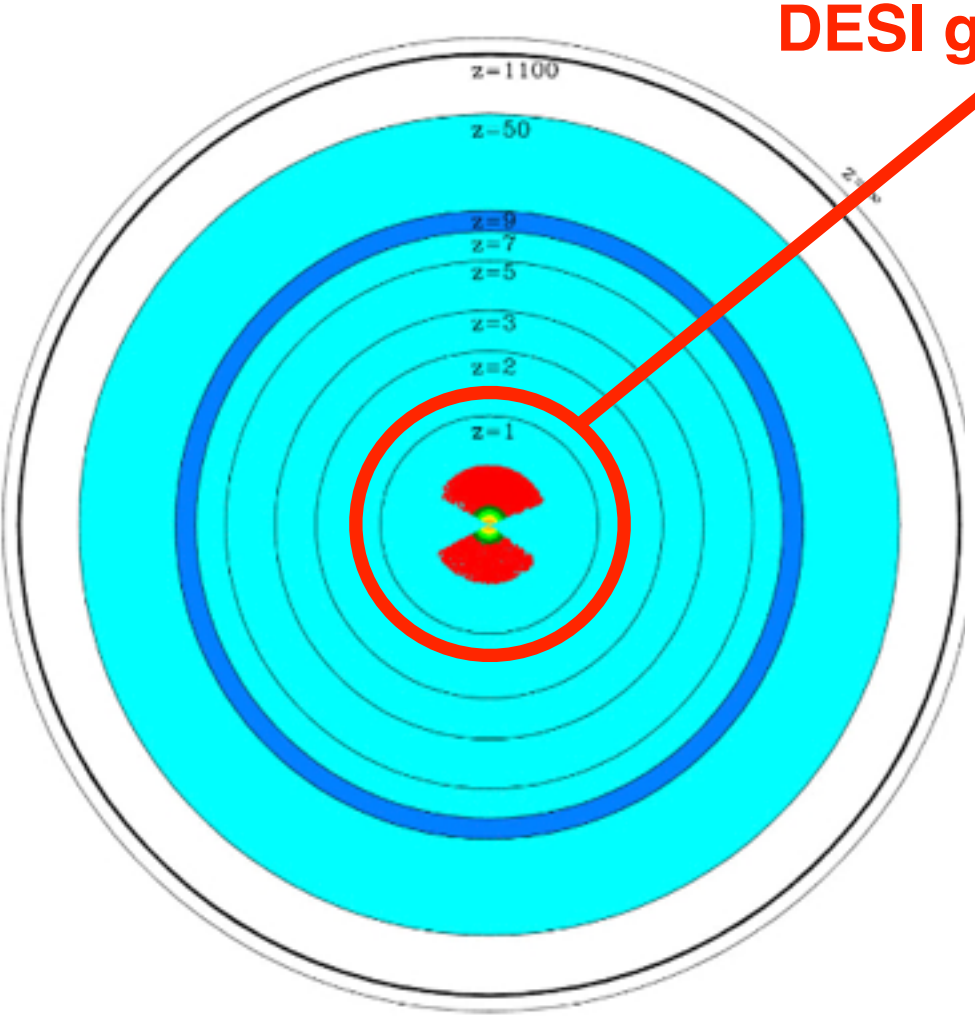
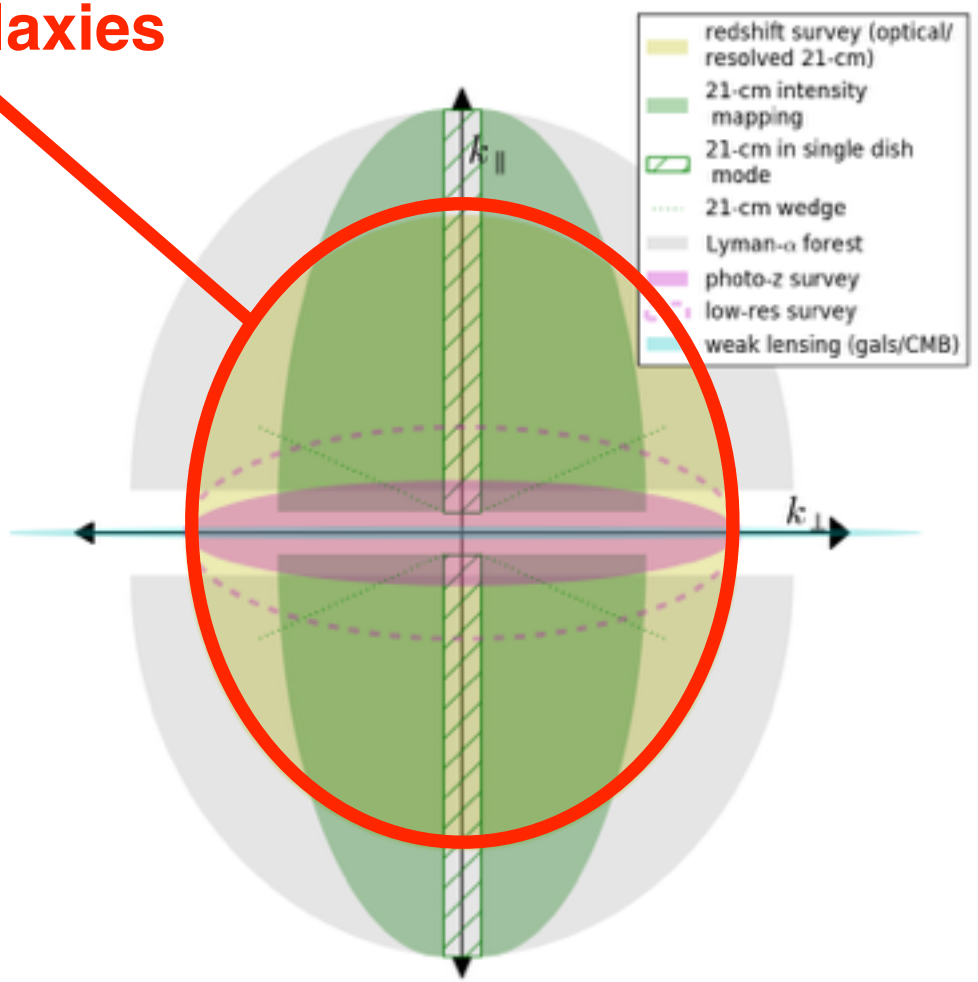
DESI galaxies





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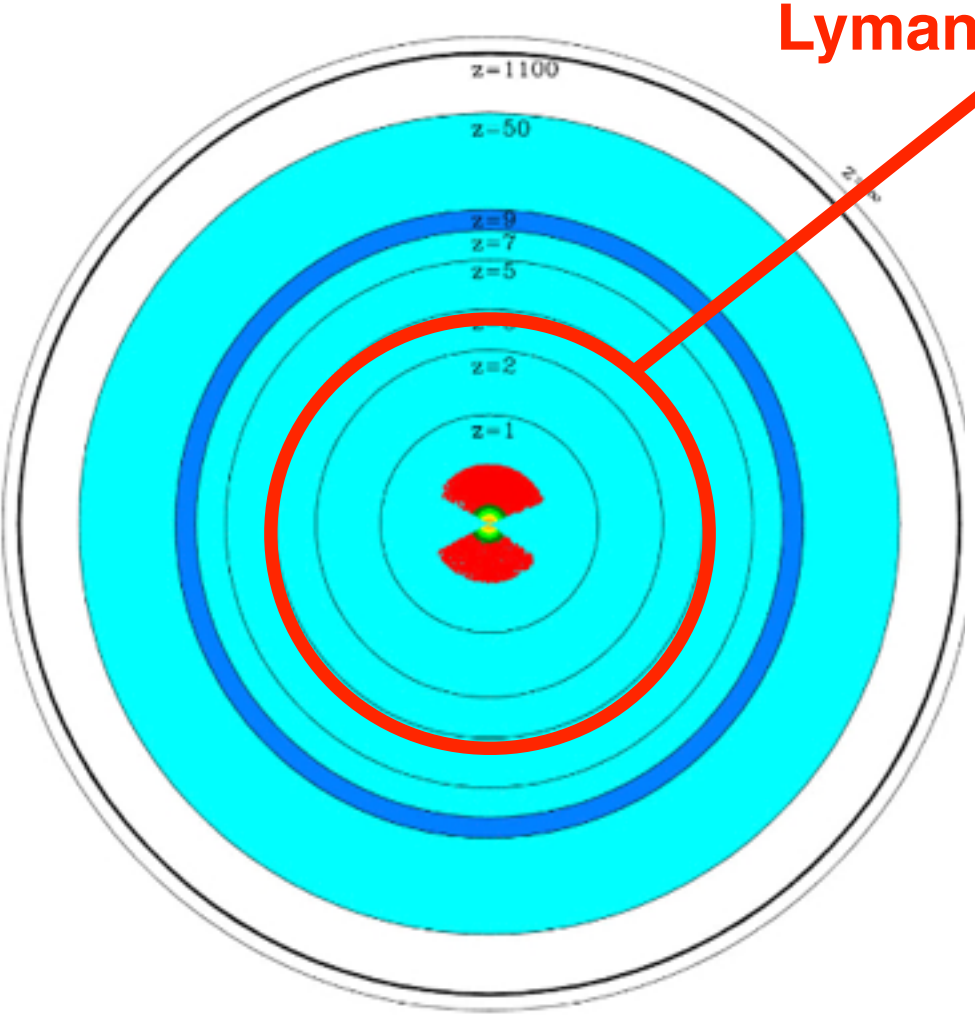
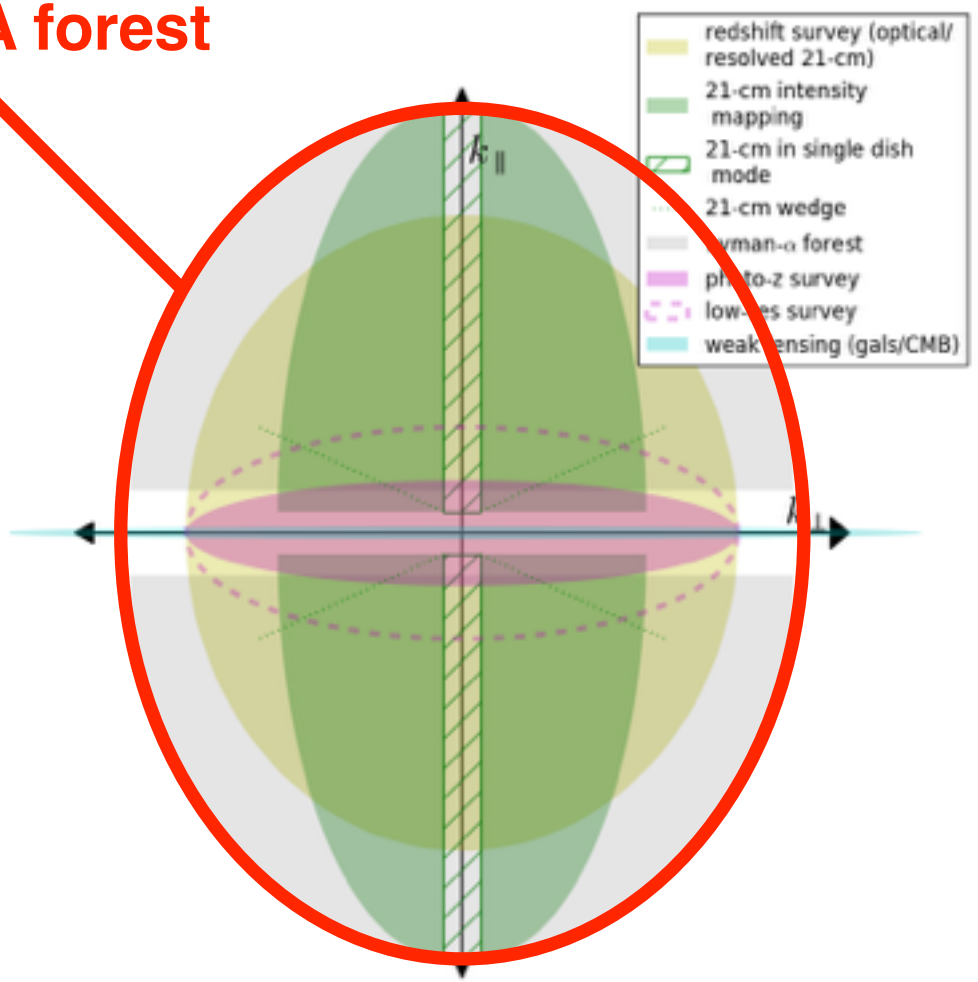
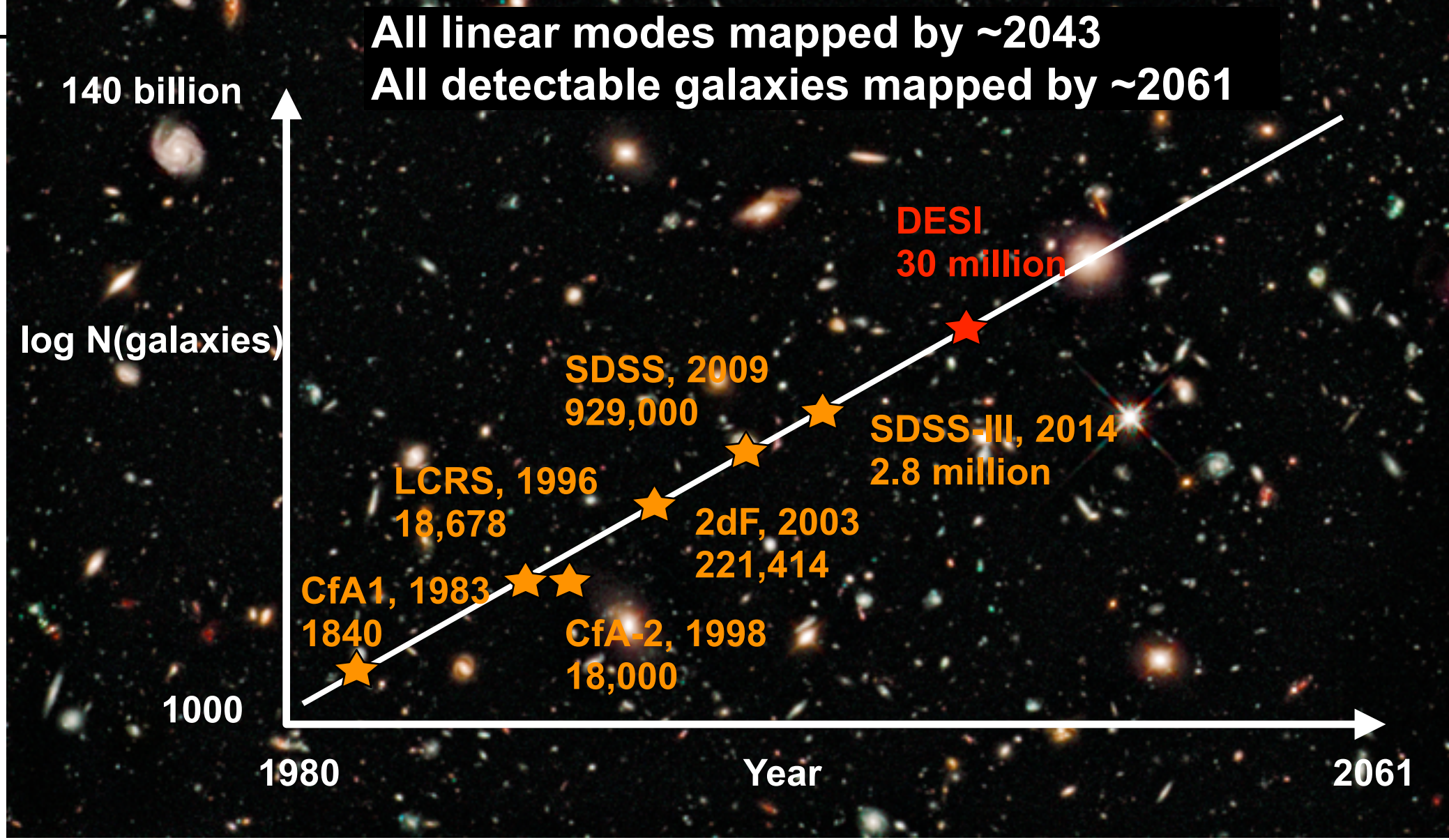
Lyman-A forest





A. Slosar

Redshift surveys increasing 10X every 10 years

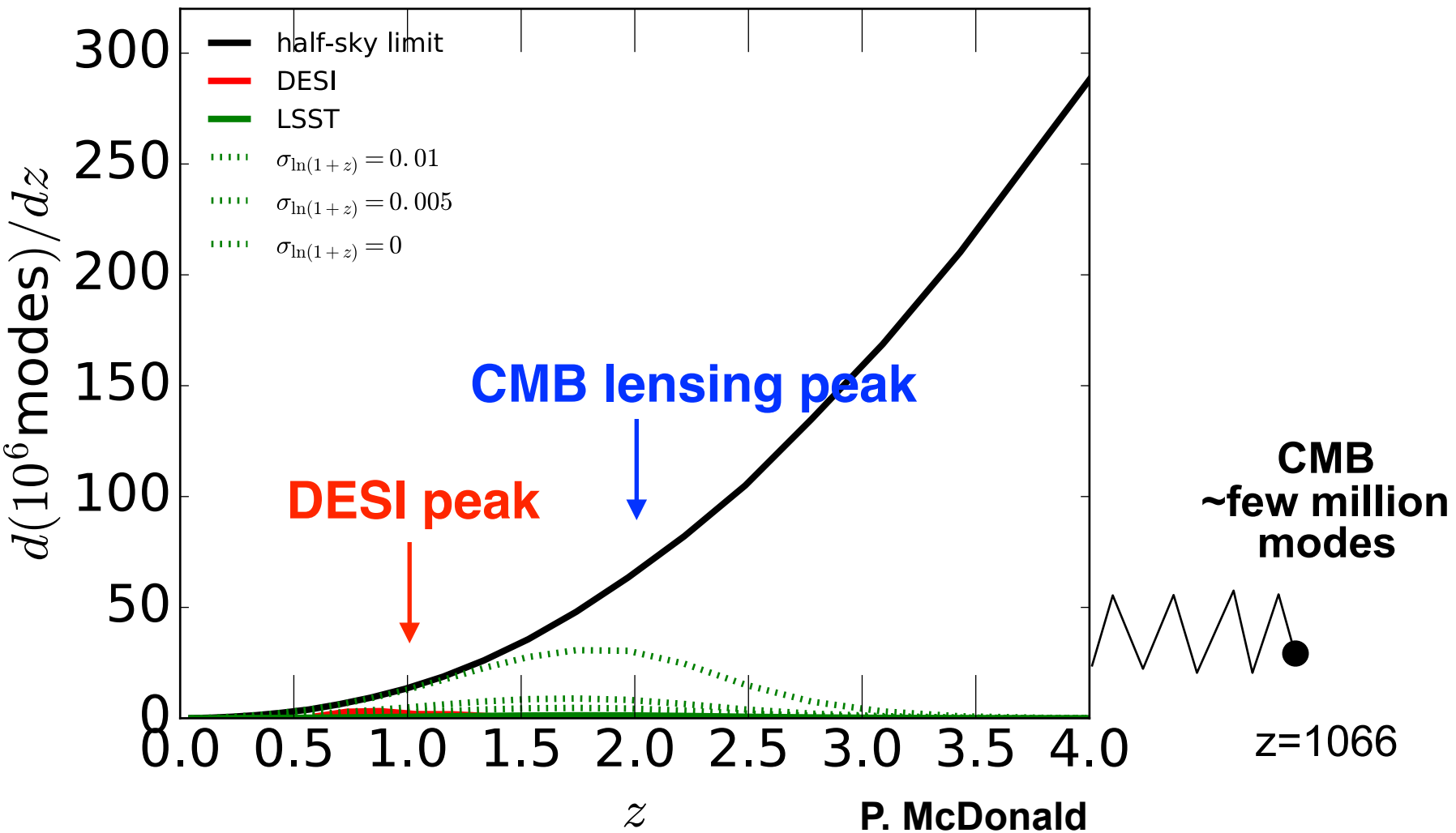


HST Ultra-Deep Field
10,000 galaxies / (11 arcmin^2)

10 million galaxies 0 < z < 0.4 → **DESI will map ~100% of these**

120 million galaxies 0 < z < 1.5 → **DESI will map ~20%**

2 billion galaxies 0 < z < 4 → **DESI will map 0.1%**



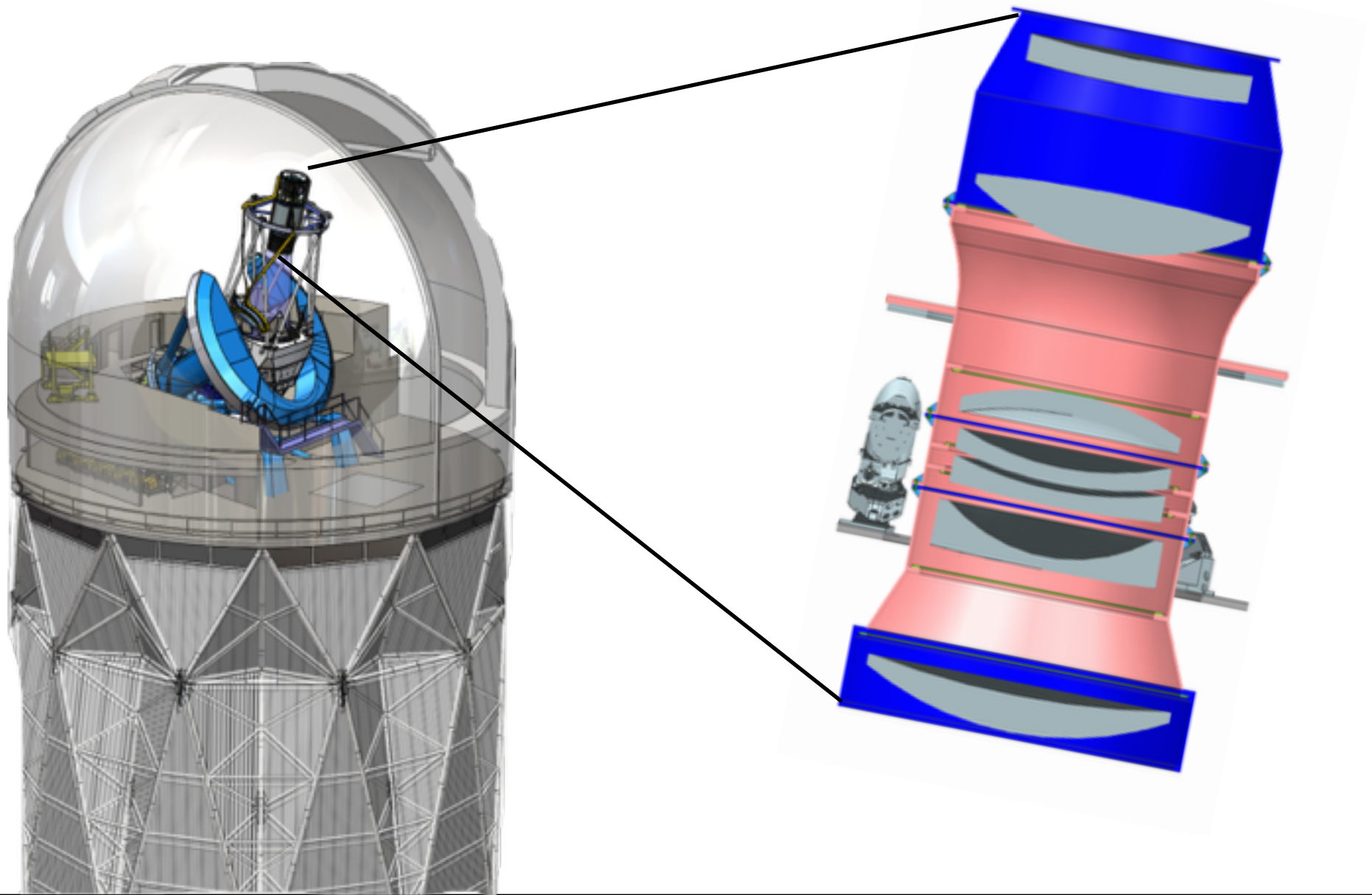
DESI Technologies

4 meter primary
1 meter diam corrector
5000 fiber-robot army
200,000 meters fiber optics
10 spectrographs x 3 cameras

Simple requirements:
Get redshifts

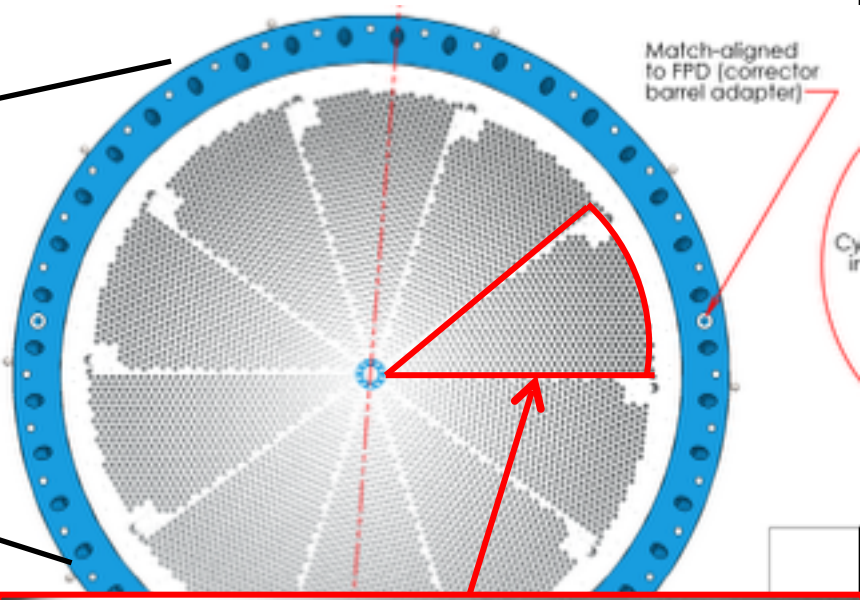
DESI Technologies

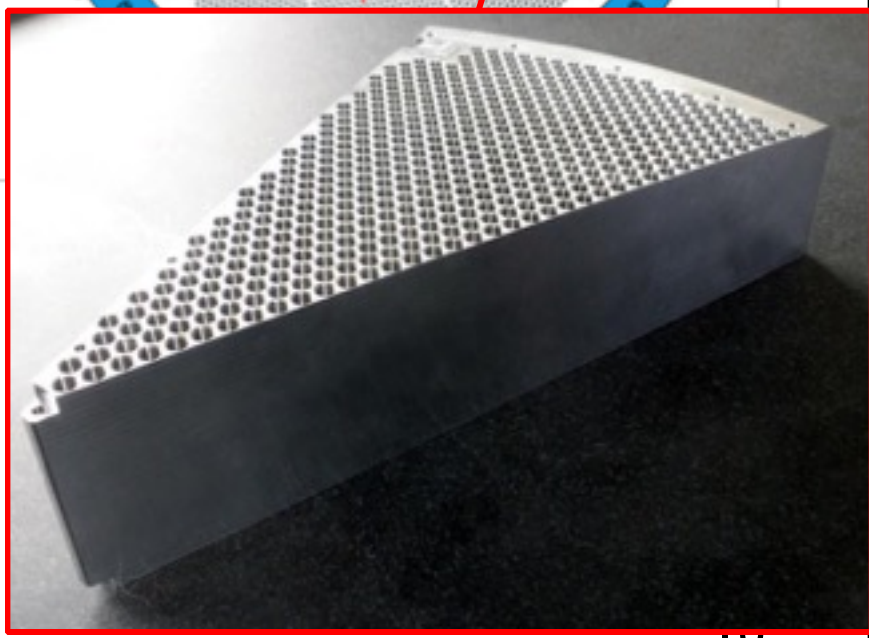
6-lens optical corrector, 1-m diameter, includes ADC



DESI Technologies

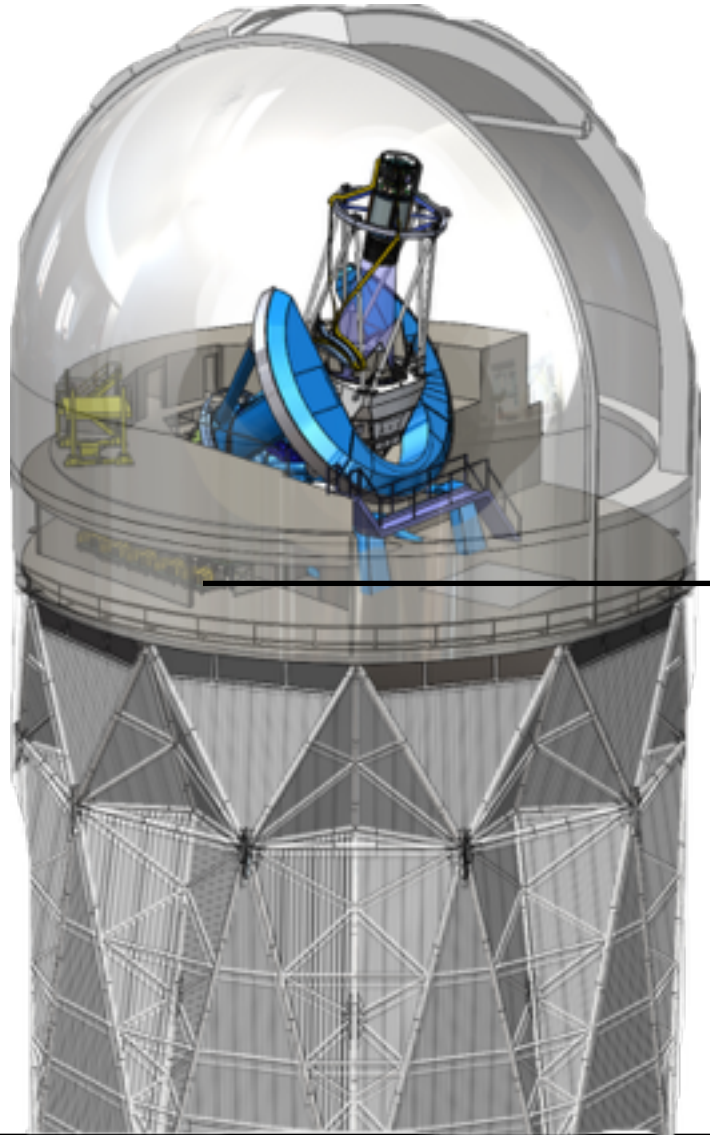
Focal plate mounting 5000 fiber robots

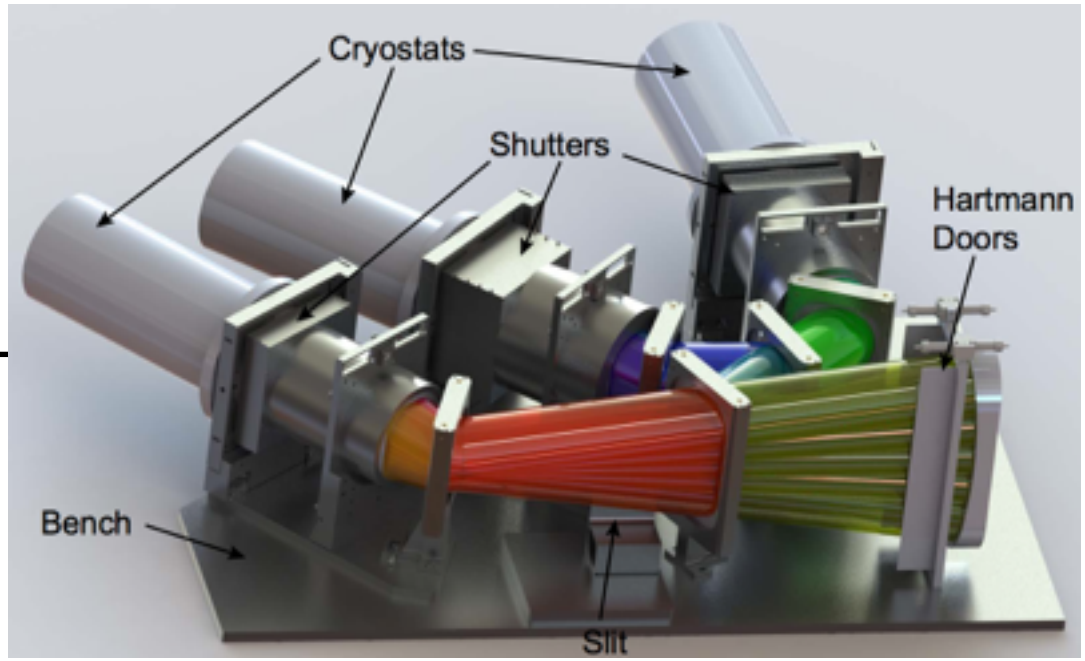




DESI Technologies

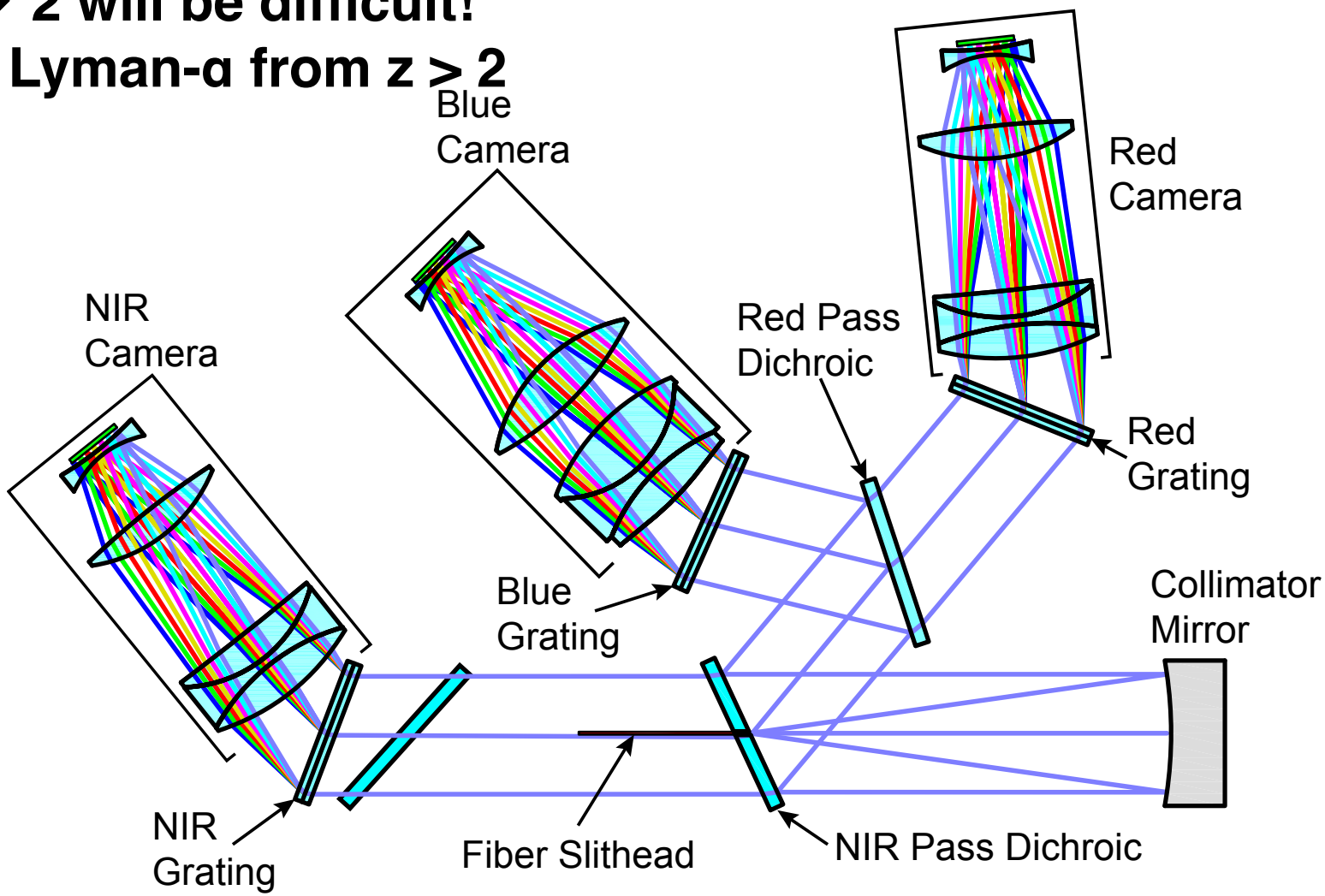
10 spectrographs X 3 cameras/spectrograph





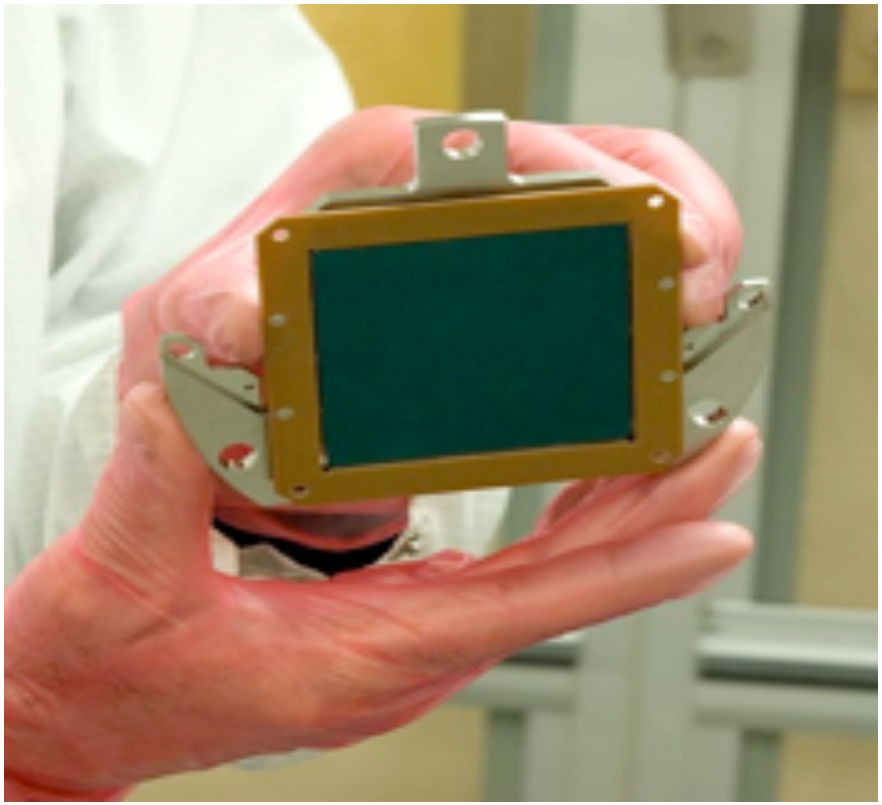
DESI spectrographs not efficient at z > 1.5

- $\lambda_{max}/\lambda_{min}$ > 3.06 to "guarantee" strong emission features
- $\lambda_{max}/\lambda_{min}$ = 980 nm / 360 nm = 2.72 for DESI
  - [OII] from z=0 → 1.6
  - z=1.6 → 2 will be difficult!
  - Sparse Lyman-α from z > 2



DESI Technologies

Wavelength range 360-980 nm
Readout system noise at ~3 e-/pix



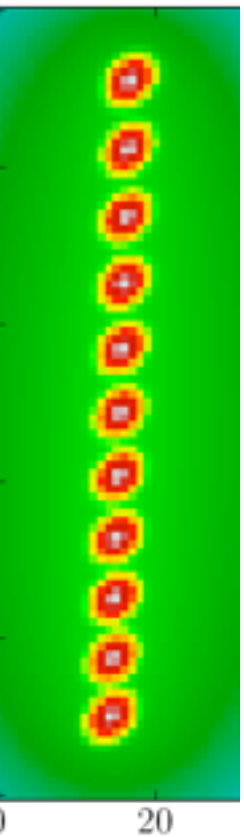
Large-format, deep-depletion CCDs

DESI Technologies

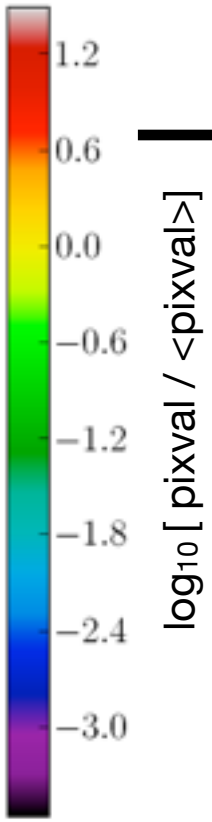
Forward-modeling of data will be a big win…

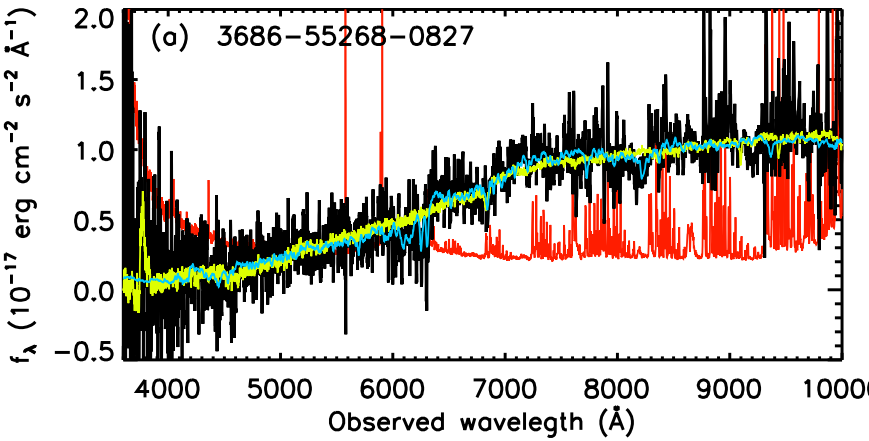
- **SDSS-I operated at S/N ~ huge**
- **SDSS-III/BOSS operated at S/N ~ 50**
- **DESI will operate at S/N ~ 10**

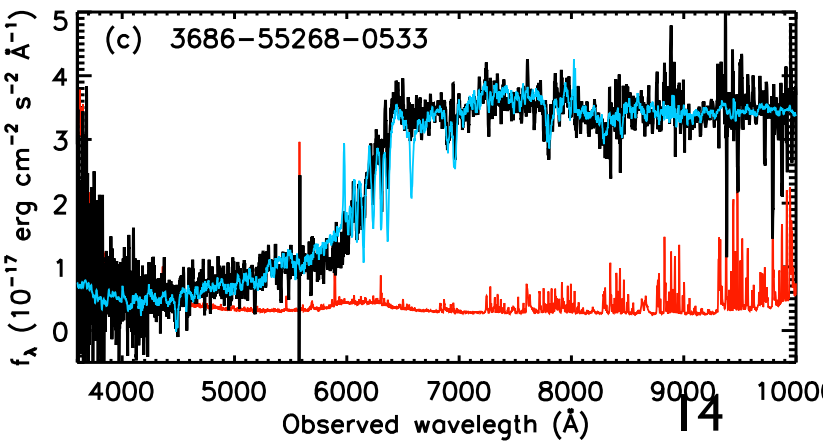
"data"



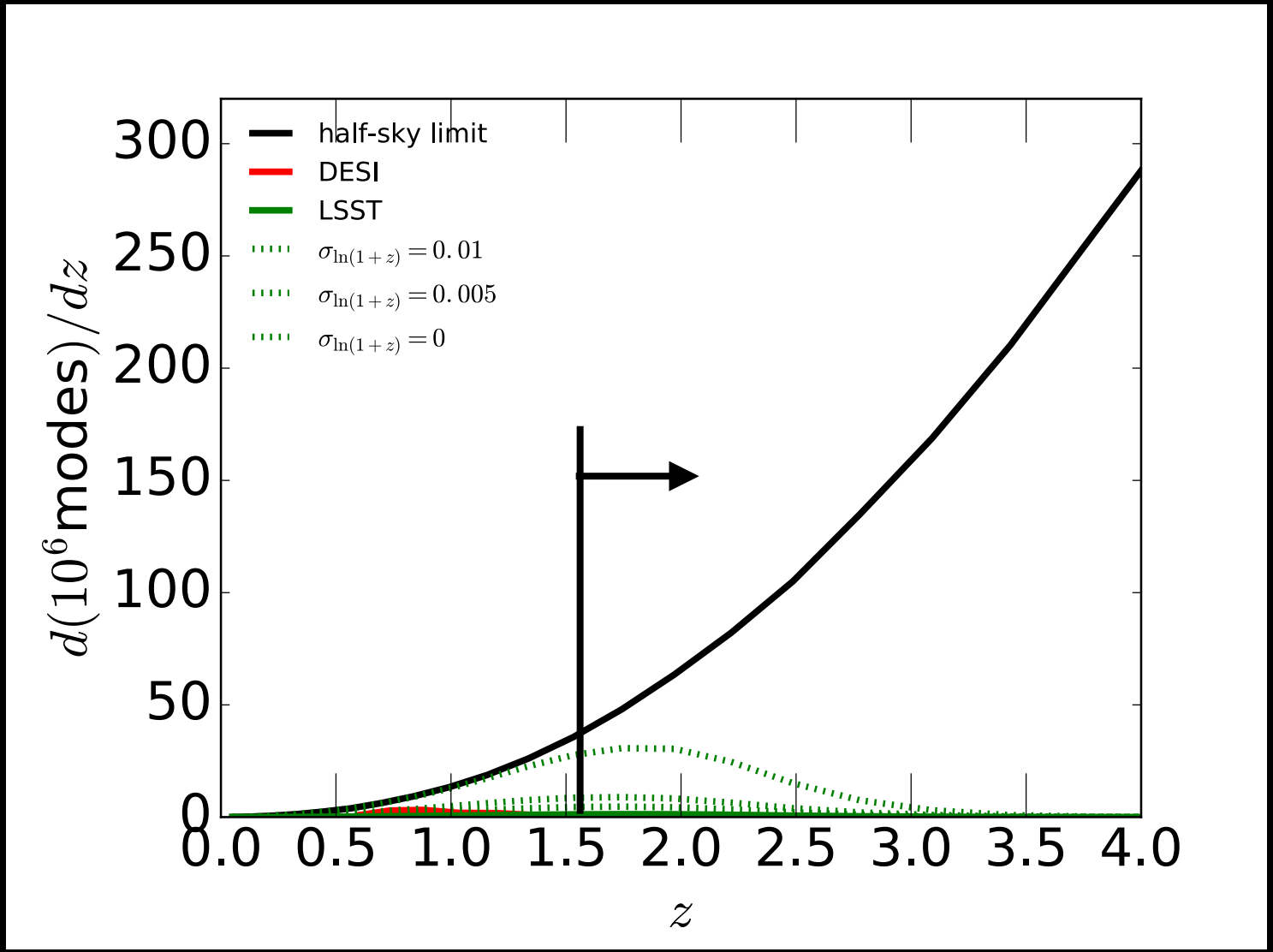
Model fiber PSF for SDSS1 @ 8500Å



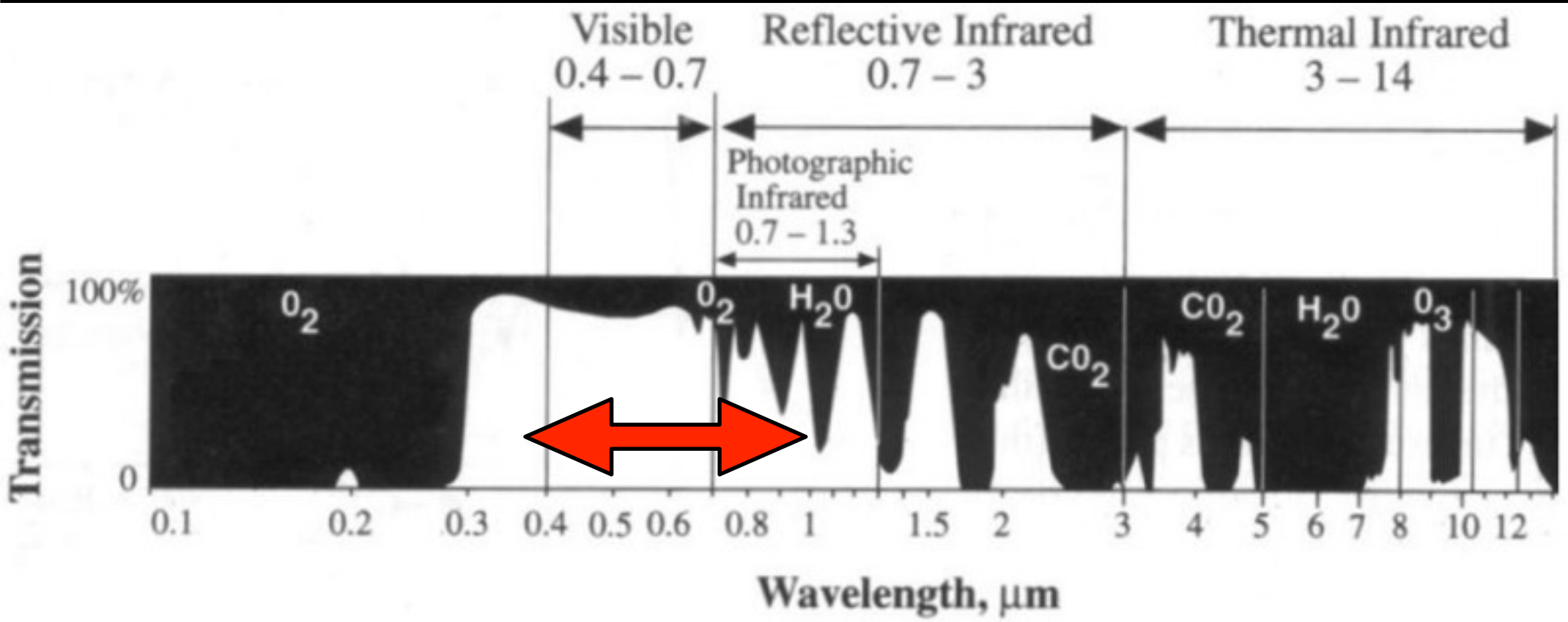




Beyond DESI
How do we efficiently map z > 1.5?

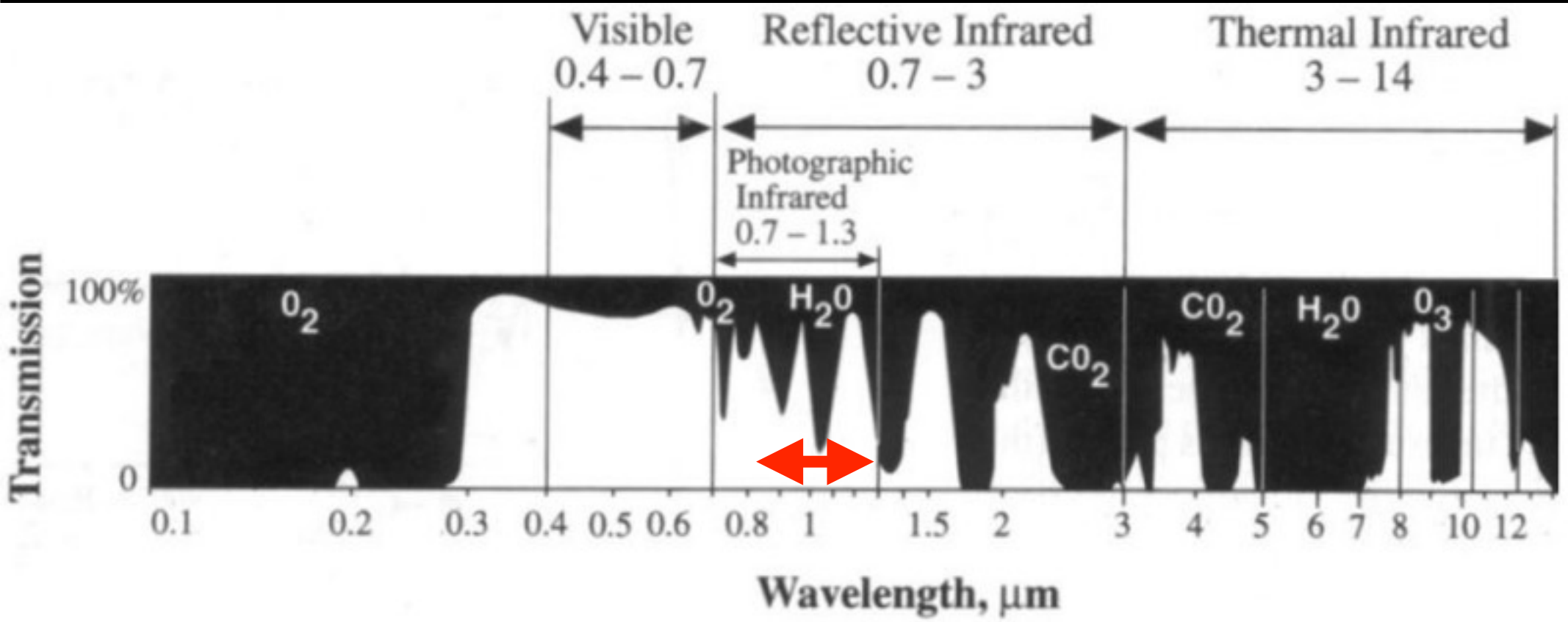


Galaxies have plenty of photons
Atmosphere defines where to look



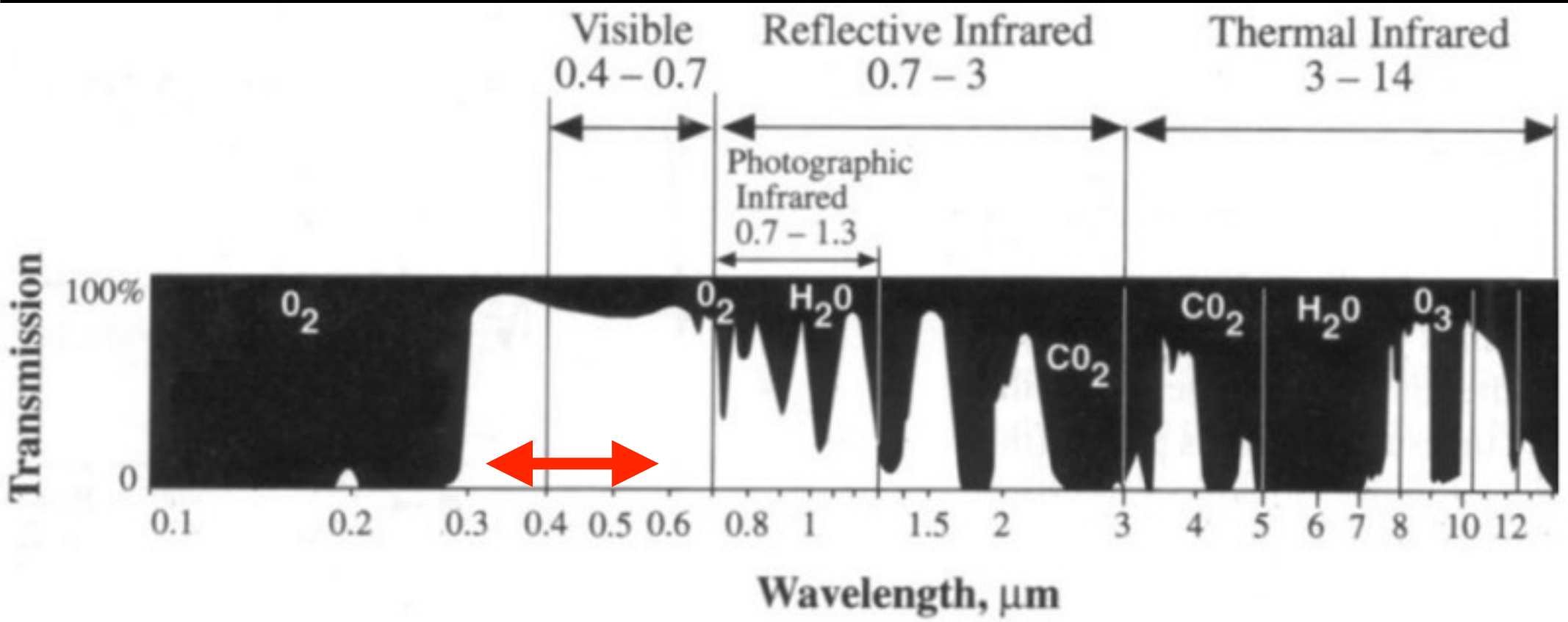
DESI will map galaxies to z=1.6
using [OII] emission line

Galaxies have plenty of photons
Atmosphere defines where to look



Could map galaxies to z~2.5 using [OII] emission line

Galaxies have plenty of photons
Atmosphere defines where to look



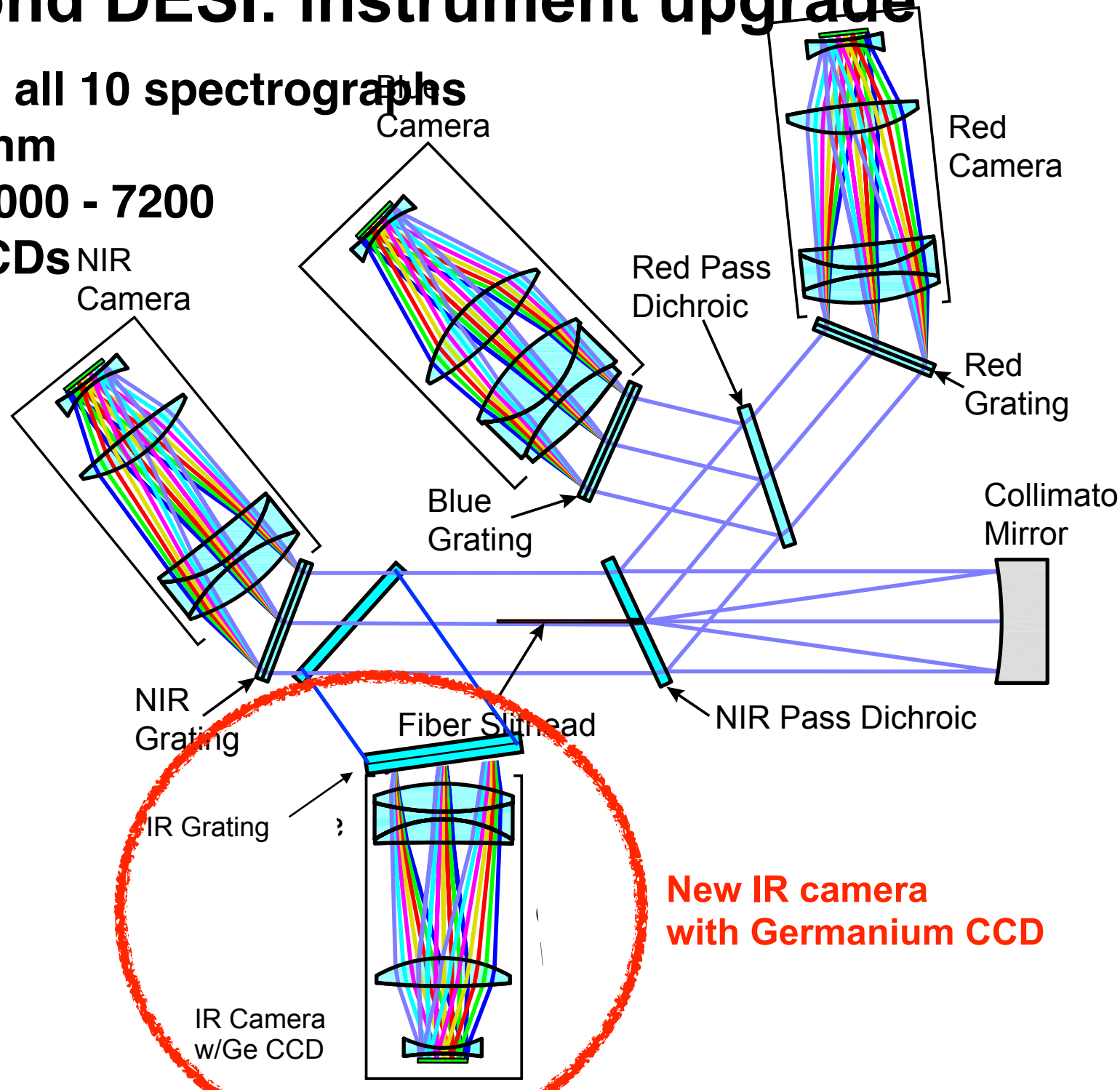
At redshifts z>2.2,
easiest to map features in the blue

Beyond DESI:

A concept to extend to ~100M galaxies
Instrument upgrade to map galaxies $1.6 < z < 2.2$
Leverage survey using LSST imaging

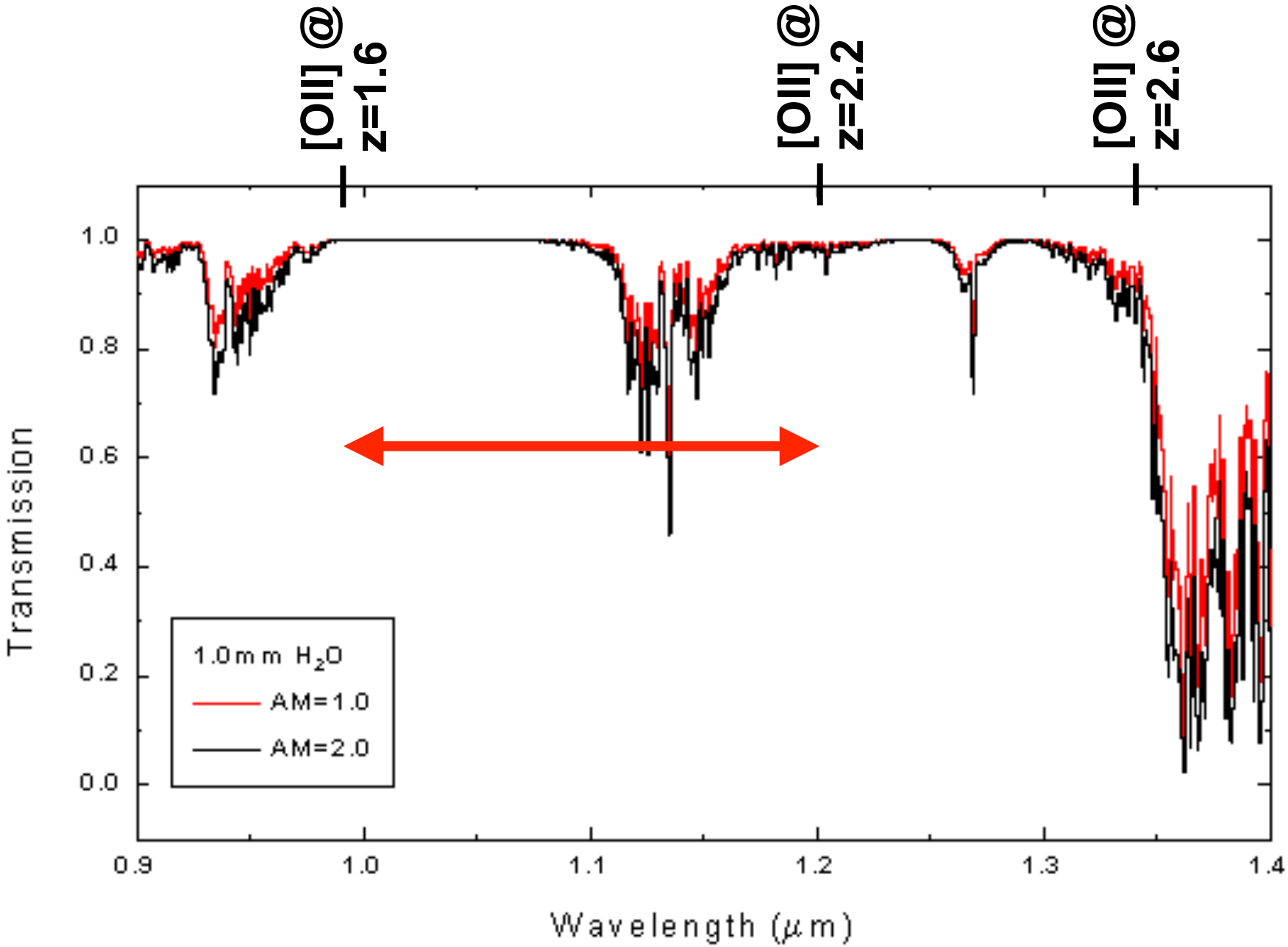
Beyond DESI: instrument upgrade

Add 4th arm to all 10 spectrographs
λ = 980 - 1200 nm
Resolution = 6000 - 7200
Germanium CCDs



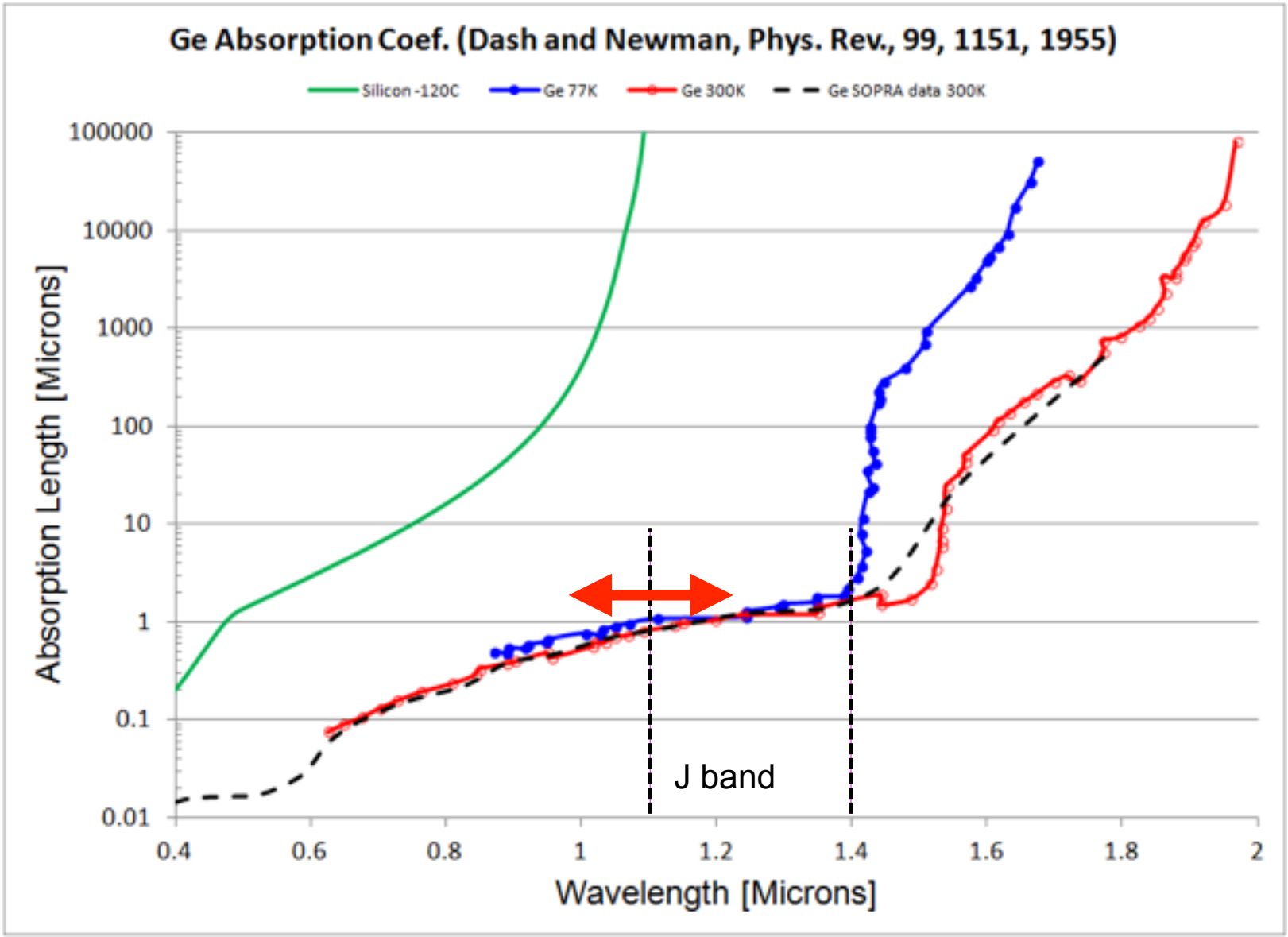
Beyond DESI: instrument upgrade

λ = 980 - 1200 nm is a good atmospheric window from the ground



Beyond DESI: instrument upgrade

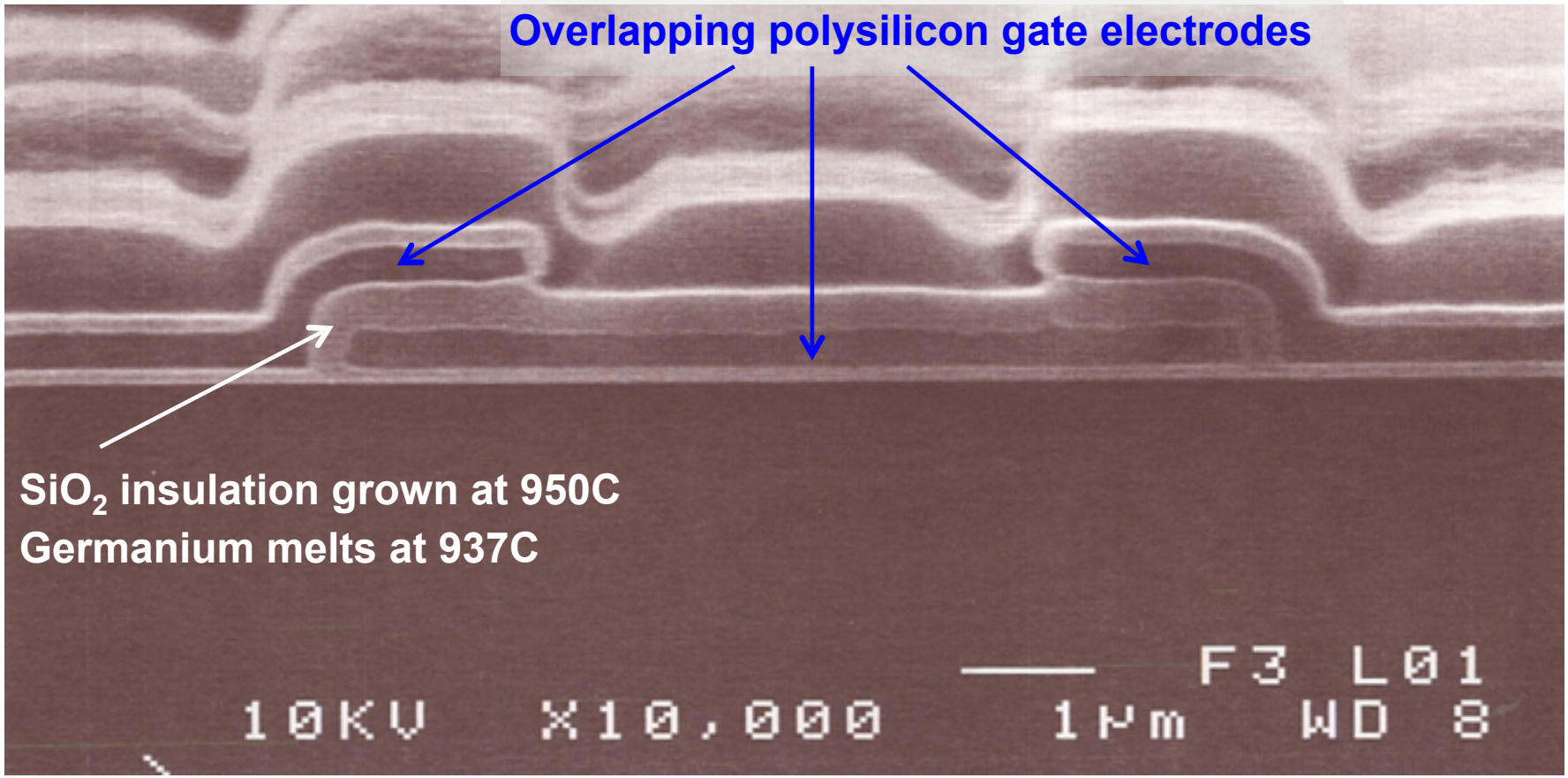
λ = 980 - 1200 nm is also well-matched to Ge CCD detectors



Beyond DESI: instrument upgrade

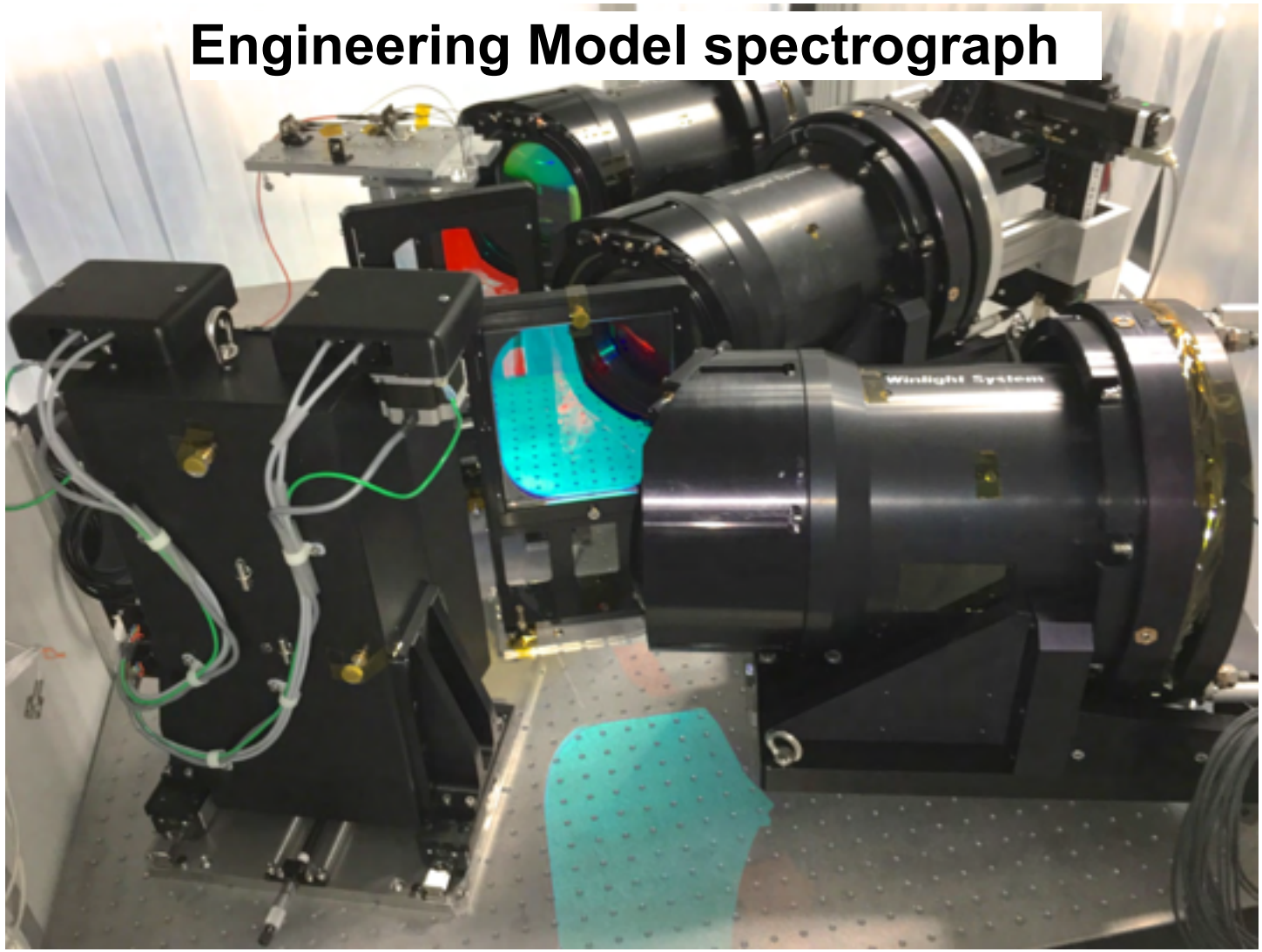
Ge CCD detectors are in development

- **Most fabrication steps identical to silicon CCDs**
- **Final processing would be at labs**
- **Readout systems would be identical to CCDs**
- **Better than HgCd detectors because thermal photons rejecte**



Beyond DESI: instrument upgrade

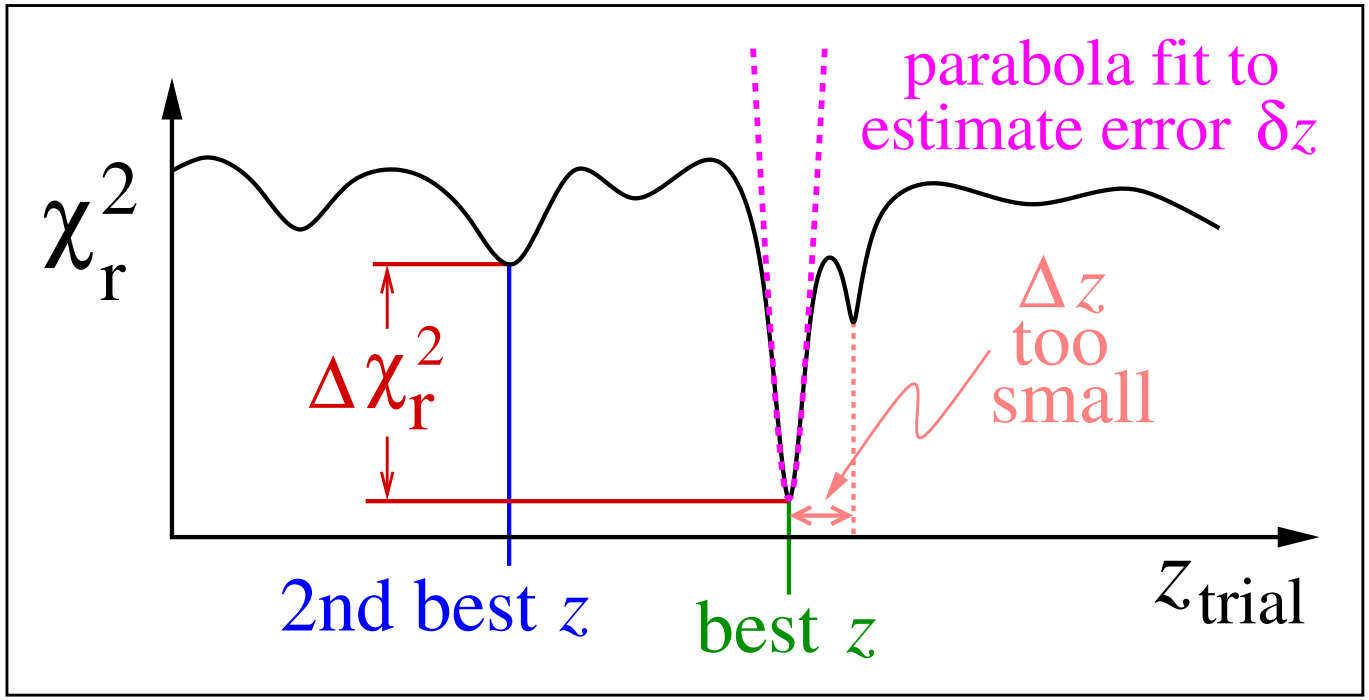
Spectrograph mechanical benches would need re-building to include a 4th camera



Beyond DESI: survey strategy

Use the full power of LSST + DESI instruments

- **Upgraded DESI to 360-1200 nm**
- **Great priors from LSST colors combine w/ low-S/N spectra**
- **Selection in color space to minimize failures (e.g., BOSS)**
- **Repeat spectra to recover failures (e.g., GAMA)**

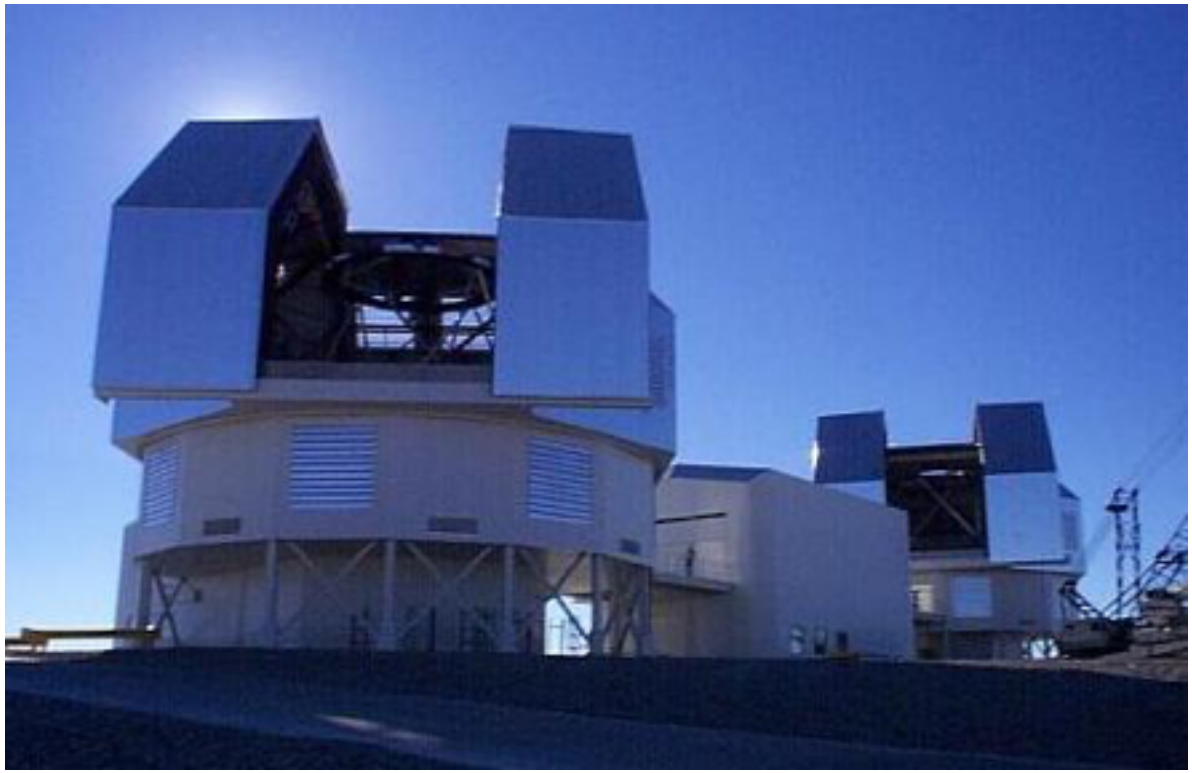


Bolton, Schlegel et al. 2012

Beyond DESI platforms

The DESI instrument, an upgrade, or a re-build would technically work well on several platforms:

- **Kitt Peak 4-m (DESI platform)**
- **Cerro Tololo 4-m (Dark Energy Survey platform)**
- **Magellan 6.5-m with existing f/5 corrector** *(limited to 2000 fibers)*
- **Magellan 6.5-m with f/3 corrector and larger FOV**
- **MMT 6.5-m or SPMT 6.5-m (twins of Magellan)**



Beyond DESI: Conclusions

DESI will map ~100% of modes at $z < 0.4$
~20% of modes at $z < 1.5$
~1% of modes at $z < 4$

DESI upgrades + LSST could map ~5X more modes
- **Better-matched to LSST lensing kernel**
- **Better-matched to CMB S-4**

For this Cosmic Visions Process…
- **DESI + LSST redshifting should be demonstrated**
- **Instrument development "incremental"**
- **Increase in science reach "dramatic"**