- SDSS spectroscopy
- SDSS/BOSS
  - *Spectra*
  - *Catalogs*
- APOGEE
  - *Spectra*
  - *Catalogs*

http://sdss3.org/dr9/spectro
http://sdss3.org/internal/branches/v5/dr10/irspec

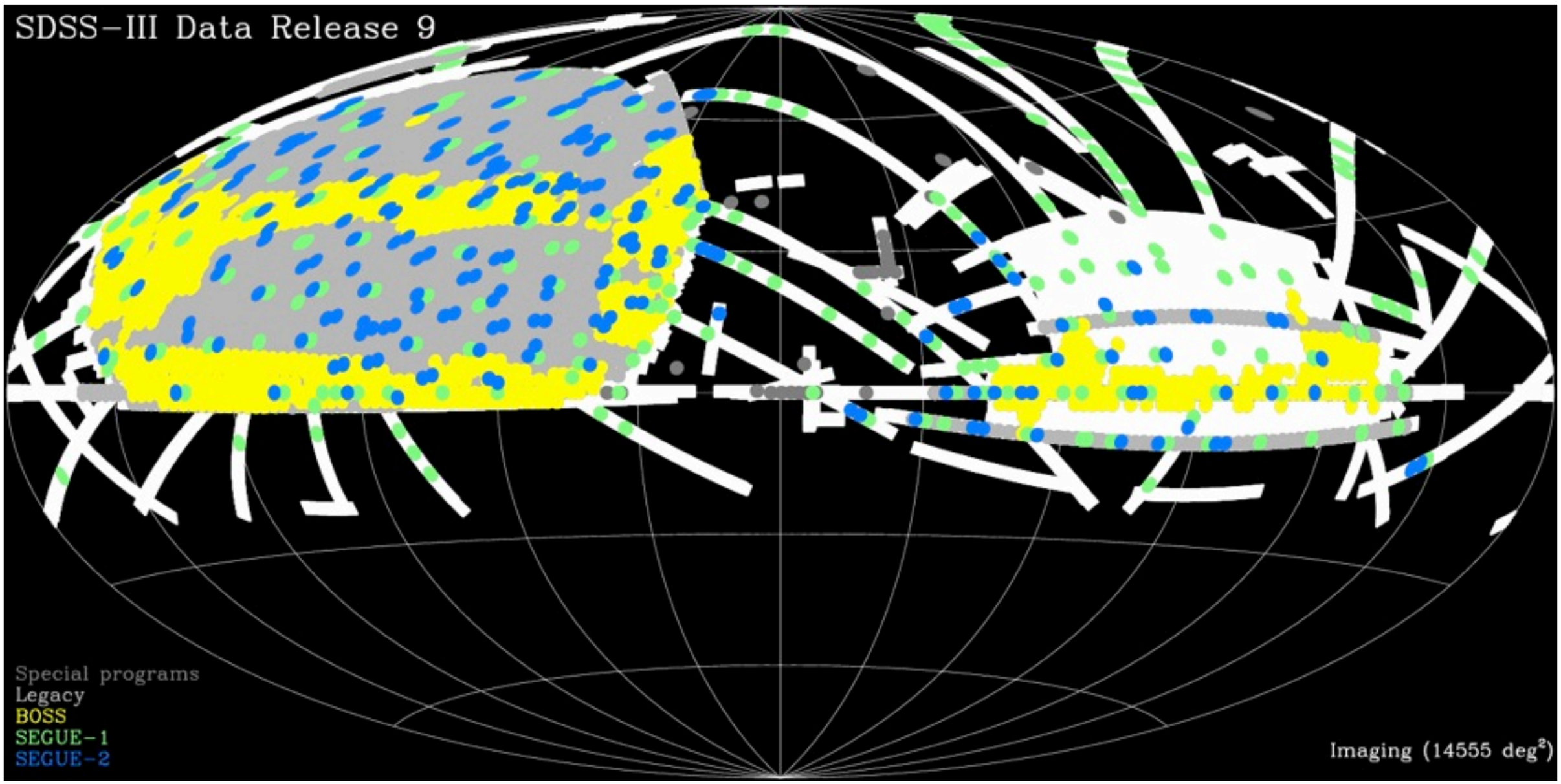
http://data.sdss3.org/datamodel

- Surveys with SDSS & BOSS spectrographs:
  - *SDSS Legacy*
  - *SEGUE-1 and -2*
  - *BOSS*
- SDSS spectrograph
  - *640 fibers*
  - *3 arcsec diameter*
  - *3800 to 9200 Ang.*
- BOSS spectrograph
  - *1000 fibers*
  - *2 arcsec diameter*
  - *3600 to 10500 Ang.*

plot coverage of each based on "survey" parameter in specObj-dr9.fits

plot SEGUE or Legacy survey spectra:

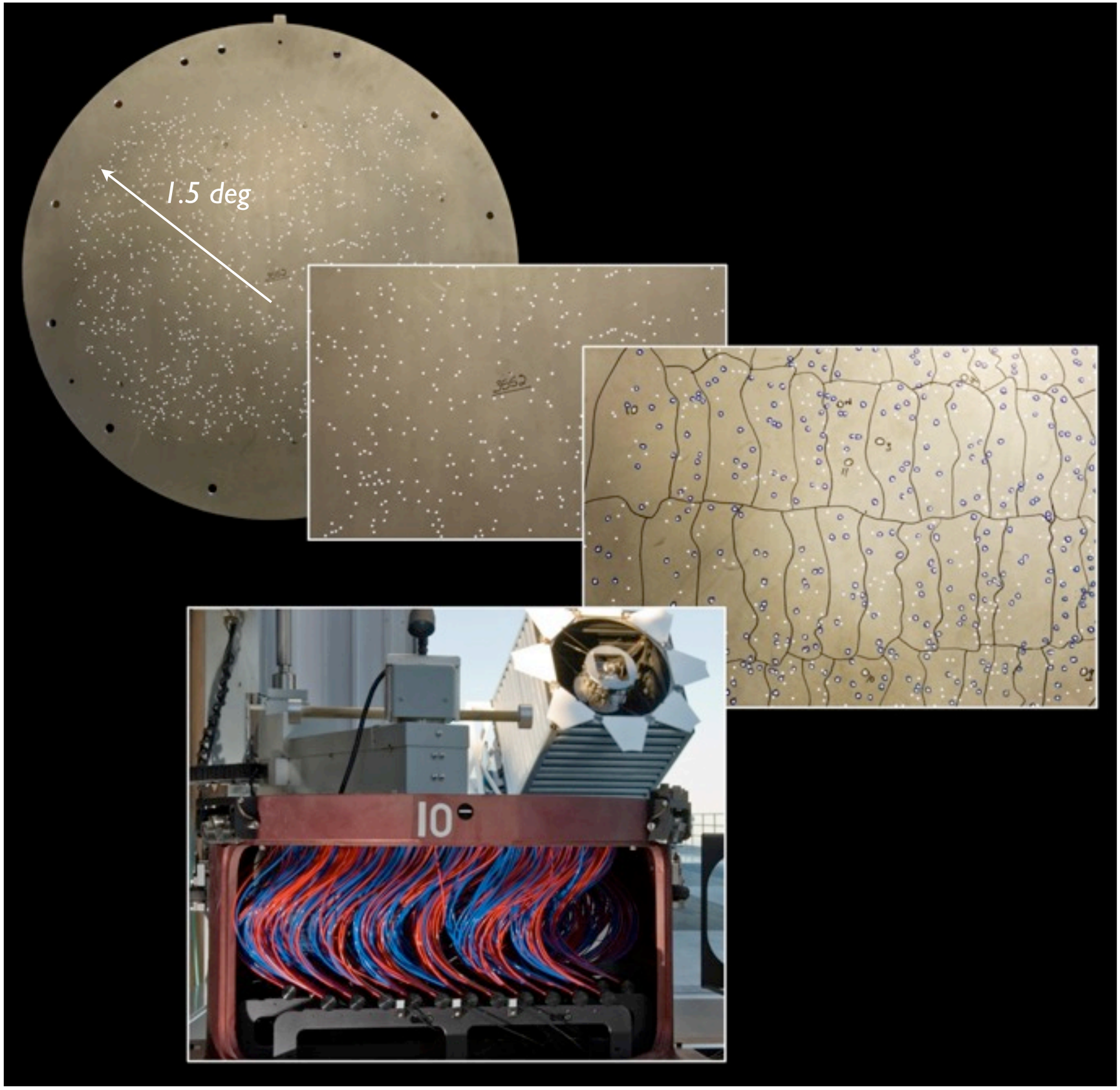
plot BOSS spectra



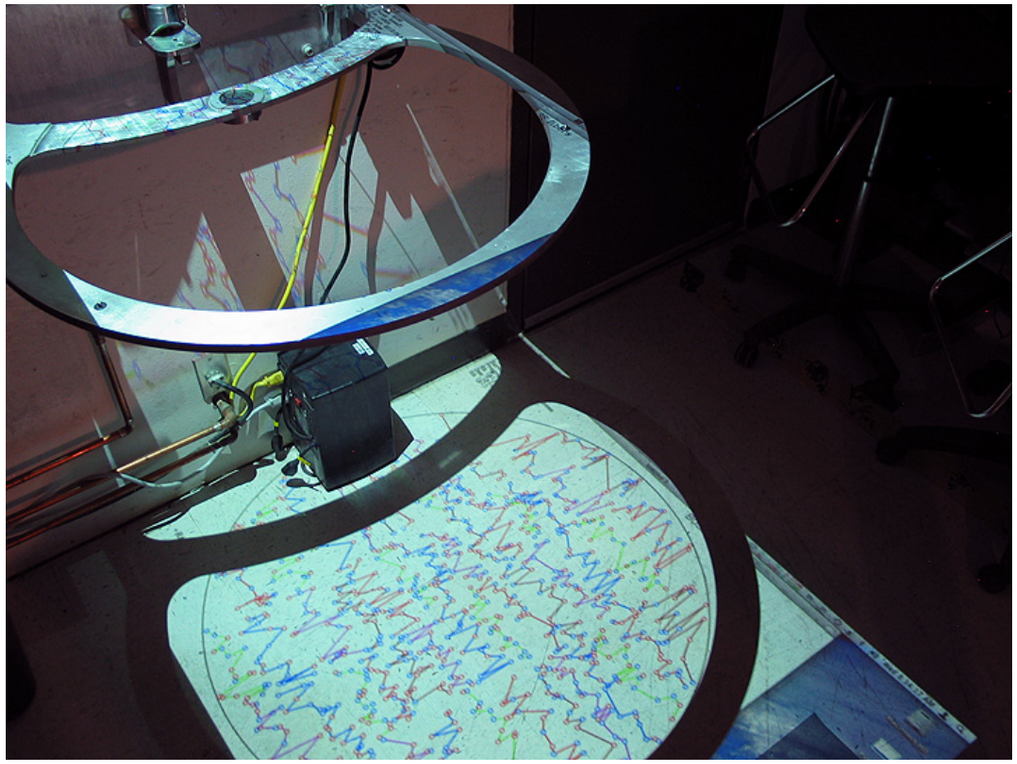
http://data.sdss3.org/sas/dr9/sdss/spectro/plates-dr9.fits

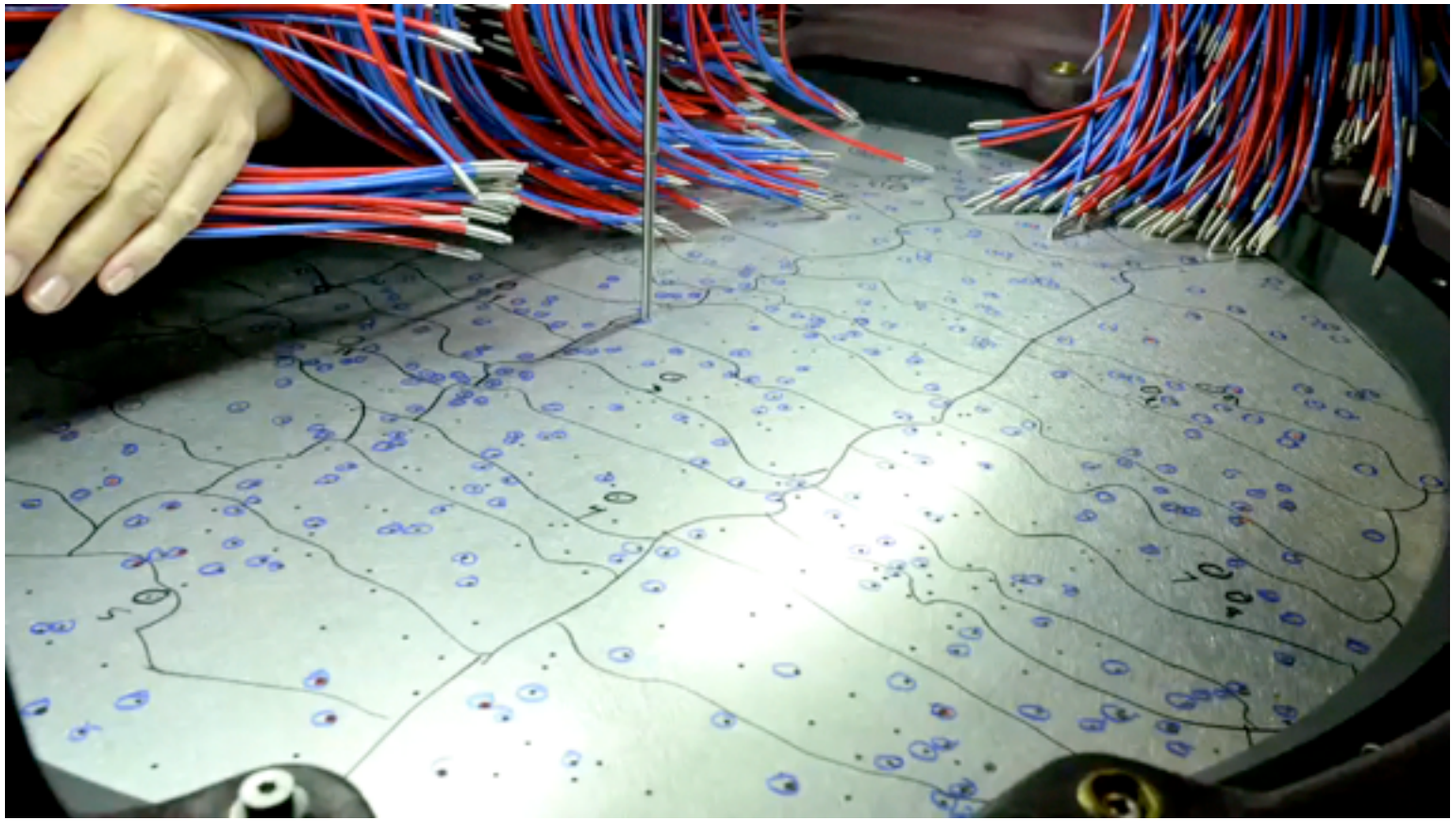
```
plates= pyfits.open('plates-dr9.fits')
print plates[1].data.columns
```

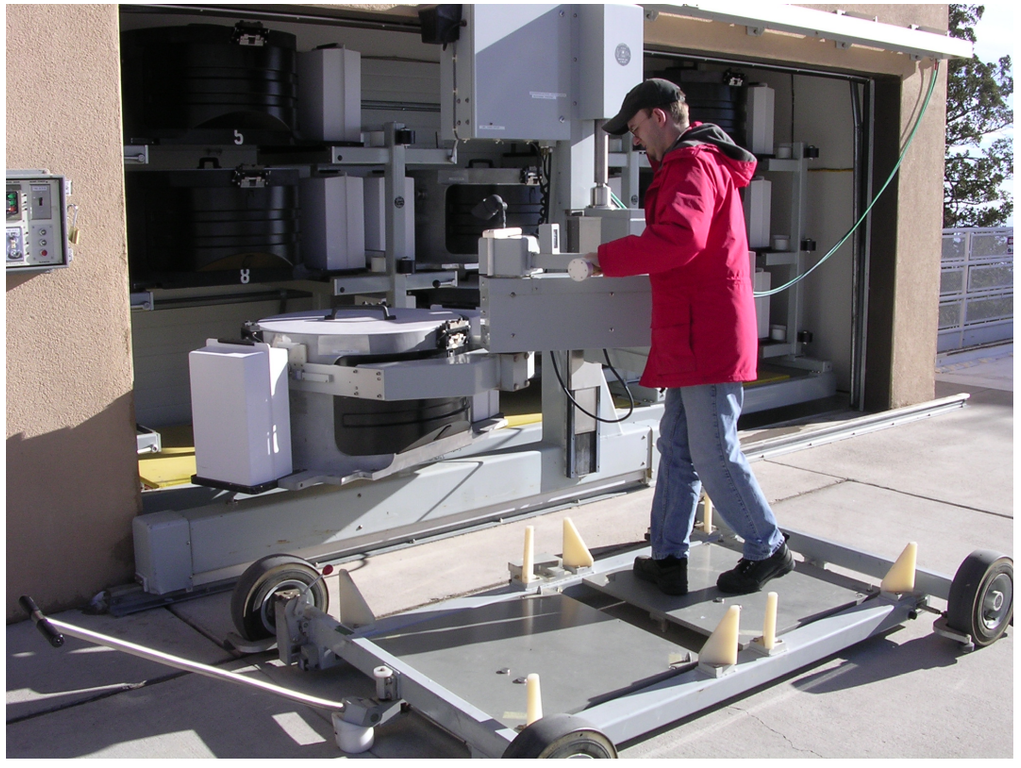
- *1000 fibers for BOSS*
- *300 fibers for APOGEE*
- *We observe 8 or 9 plates per night, on the Sloan Foundation 2.5-m Telescope.*
- *Allows rapid accumulation of spectra over a wide sky area.*
- *Real-time data reduction controls how long we spend on each plate.*
- *Full reduced catalogs available to science collaboration next day.*
- *Regular, well-documented data releases to the public (latest was DR9 on July 31, 2012).*



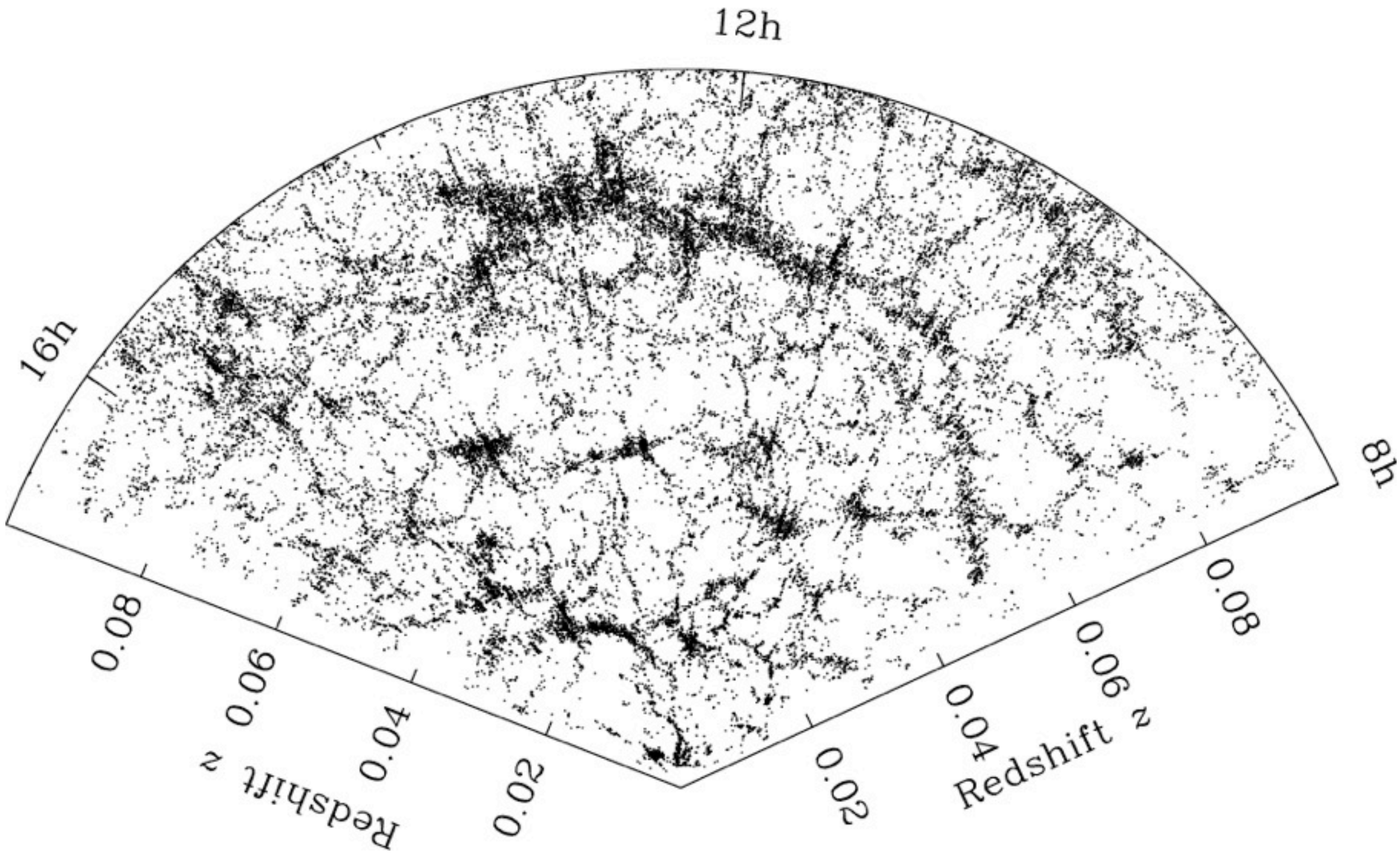
Introduction: plates plugged with optical fibers



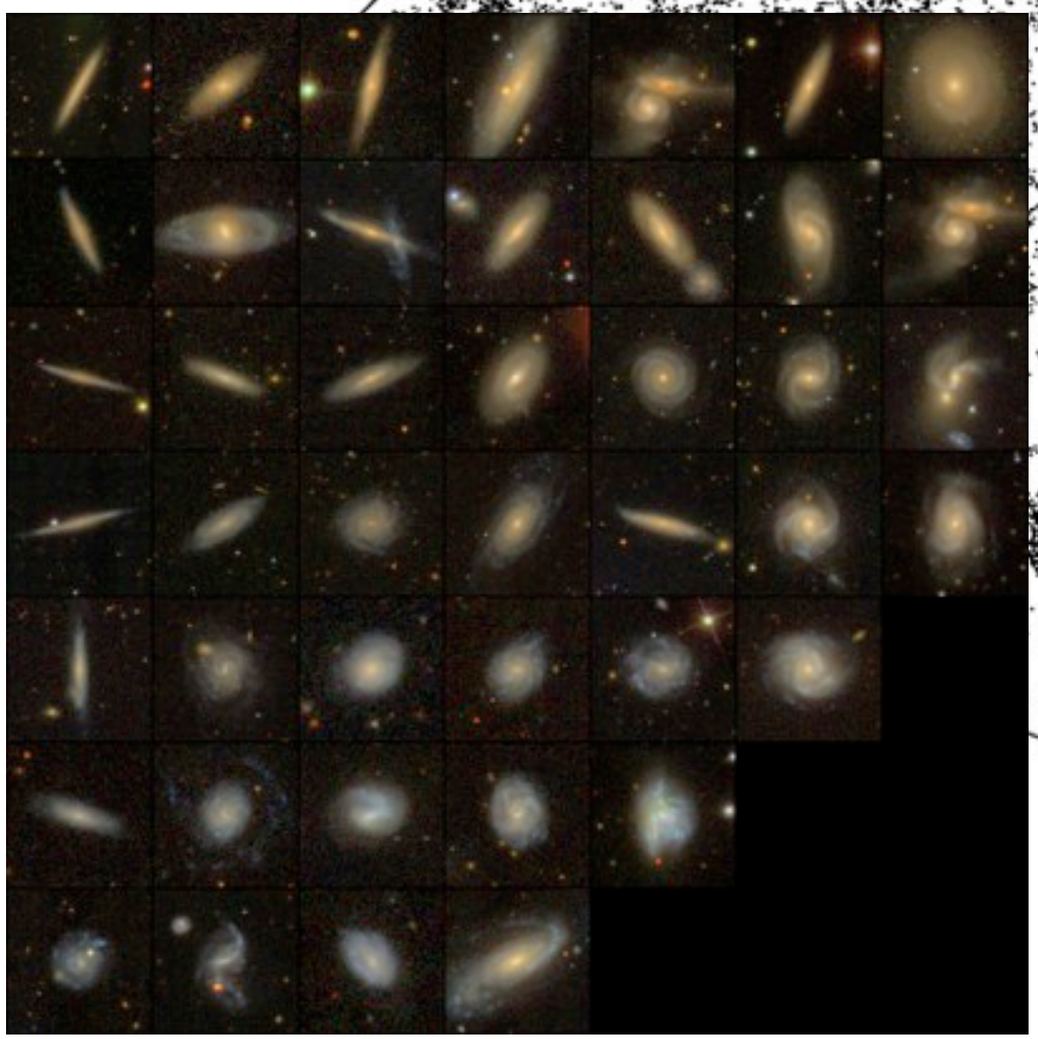


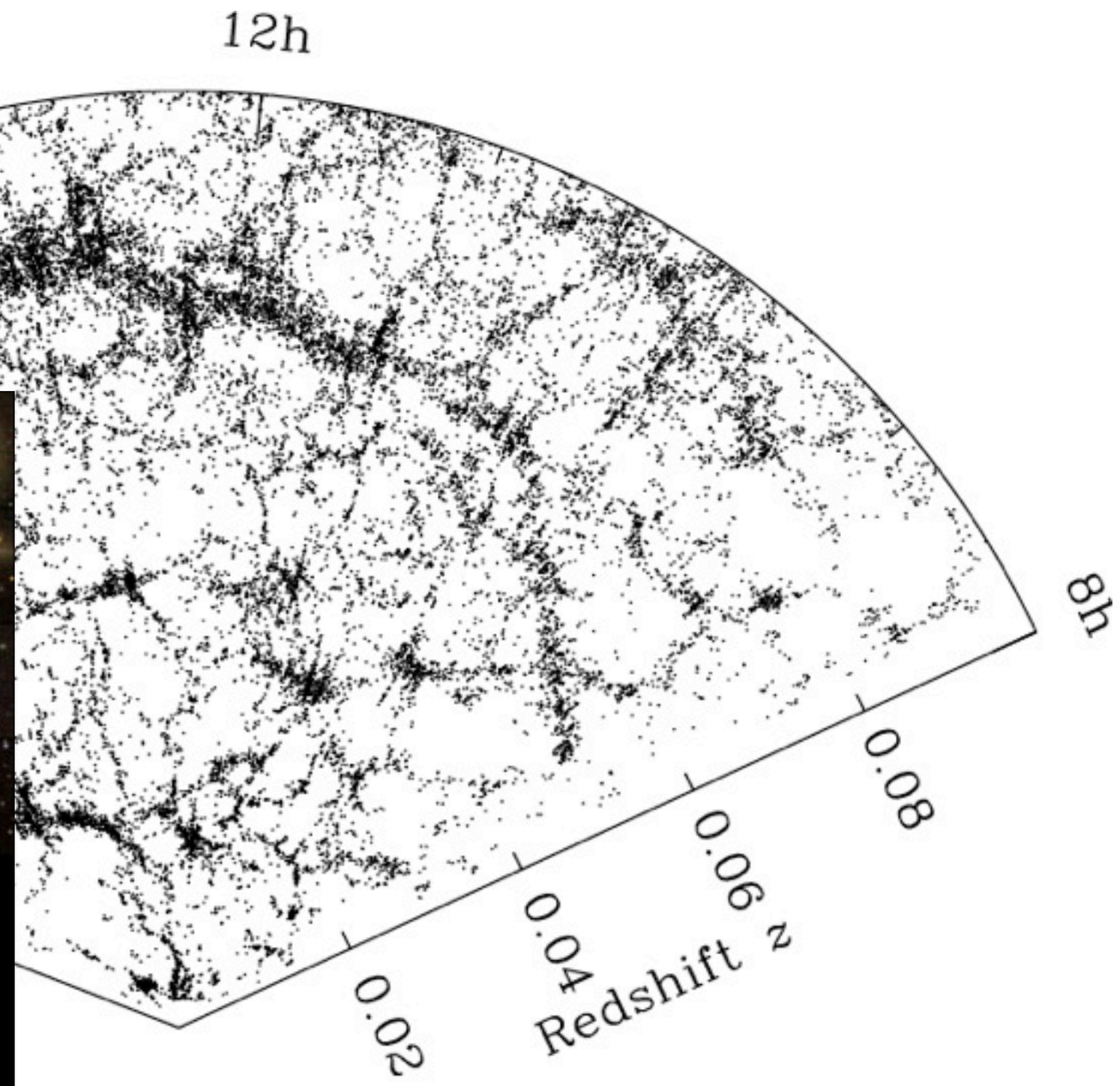


SDSS Legacy Survey (2000-2008)

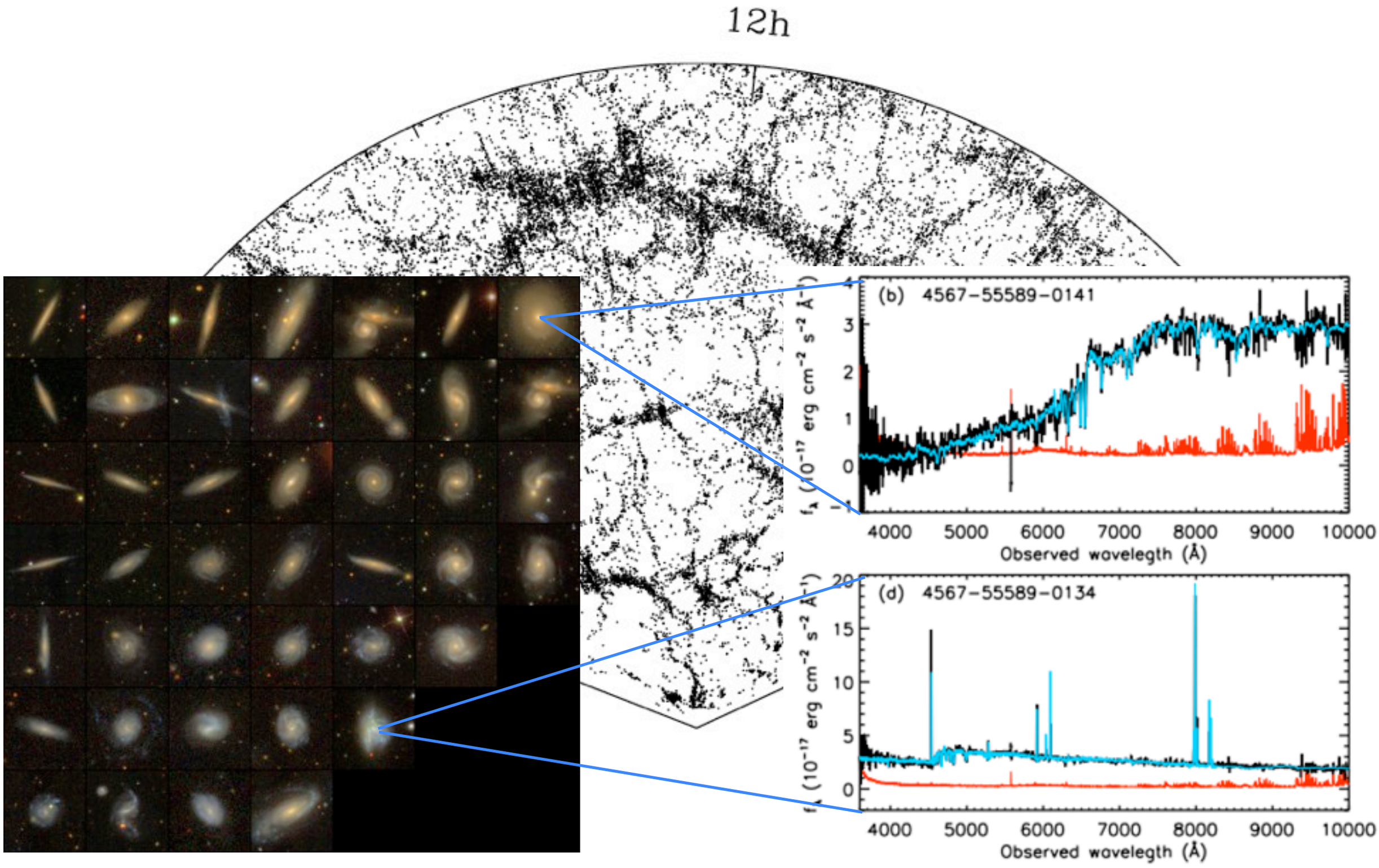


SDSS Legacy Survey (2000-2008)



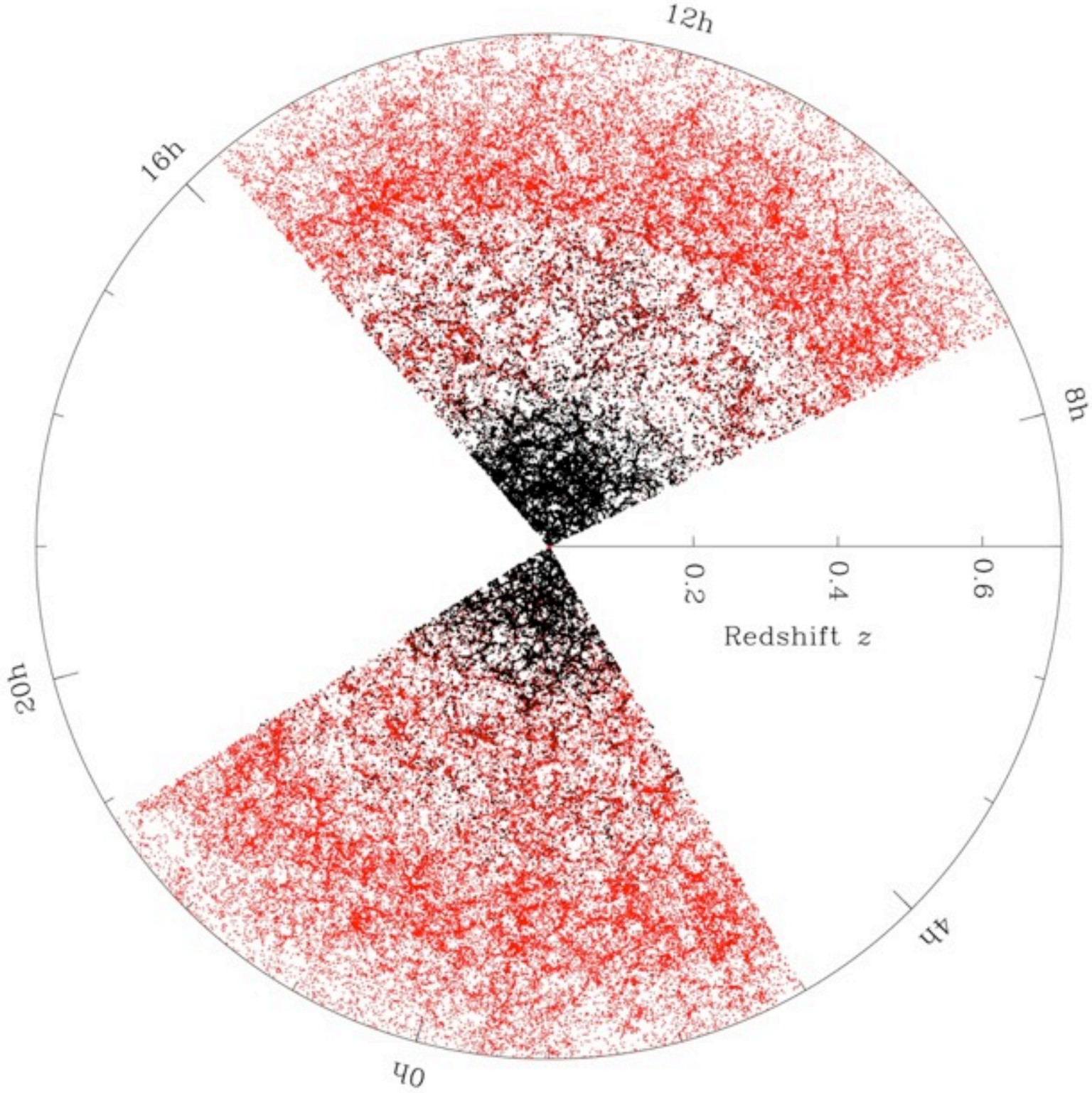


SDSS Legacy Survey (2000-2008)

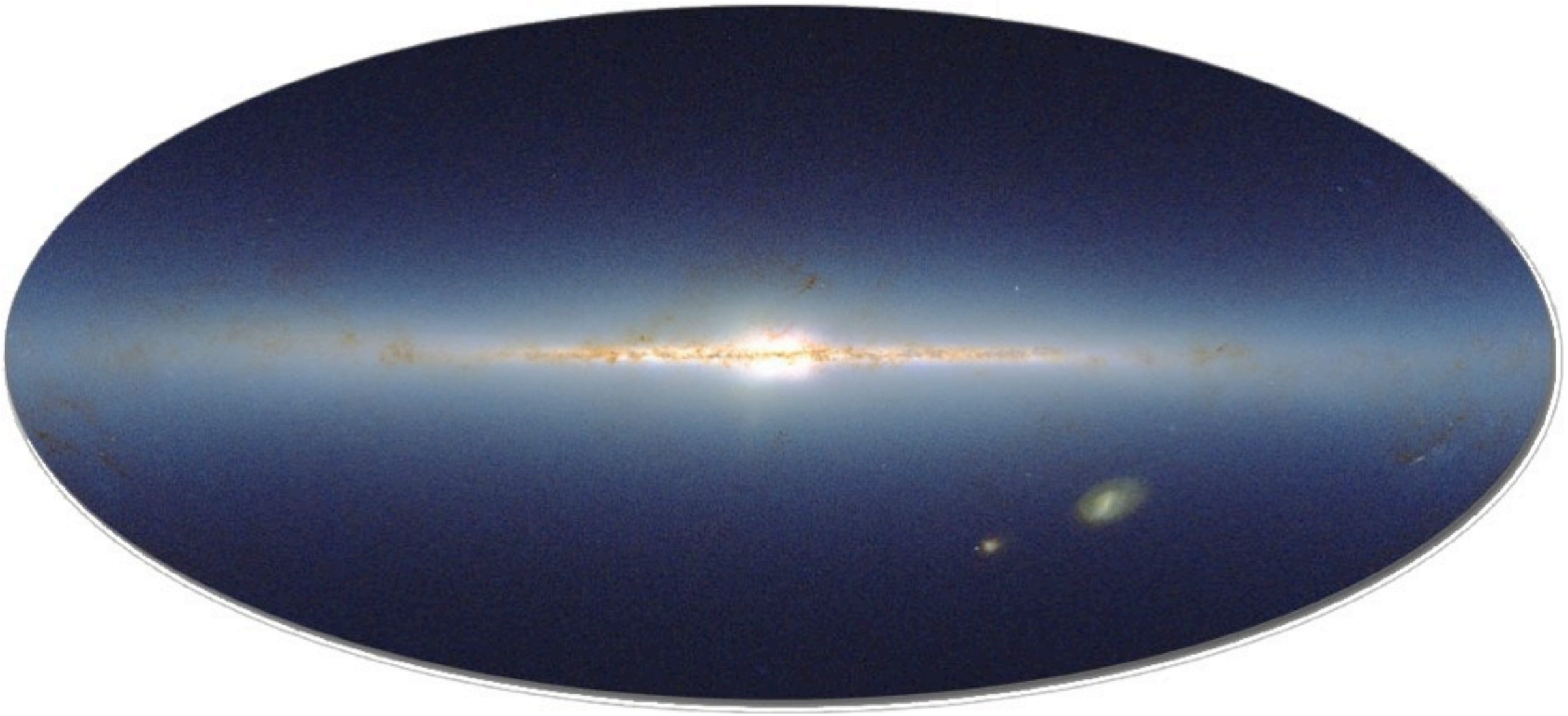


BOSS (2009-2014)

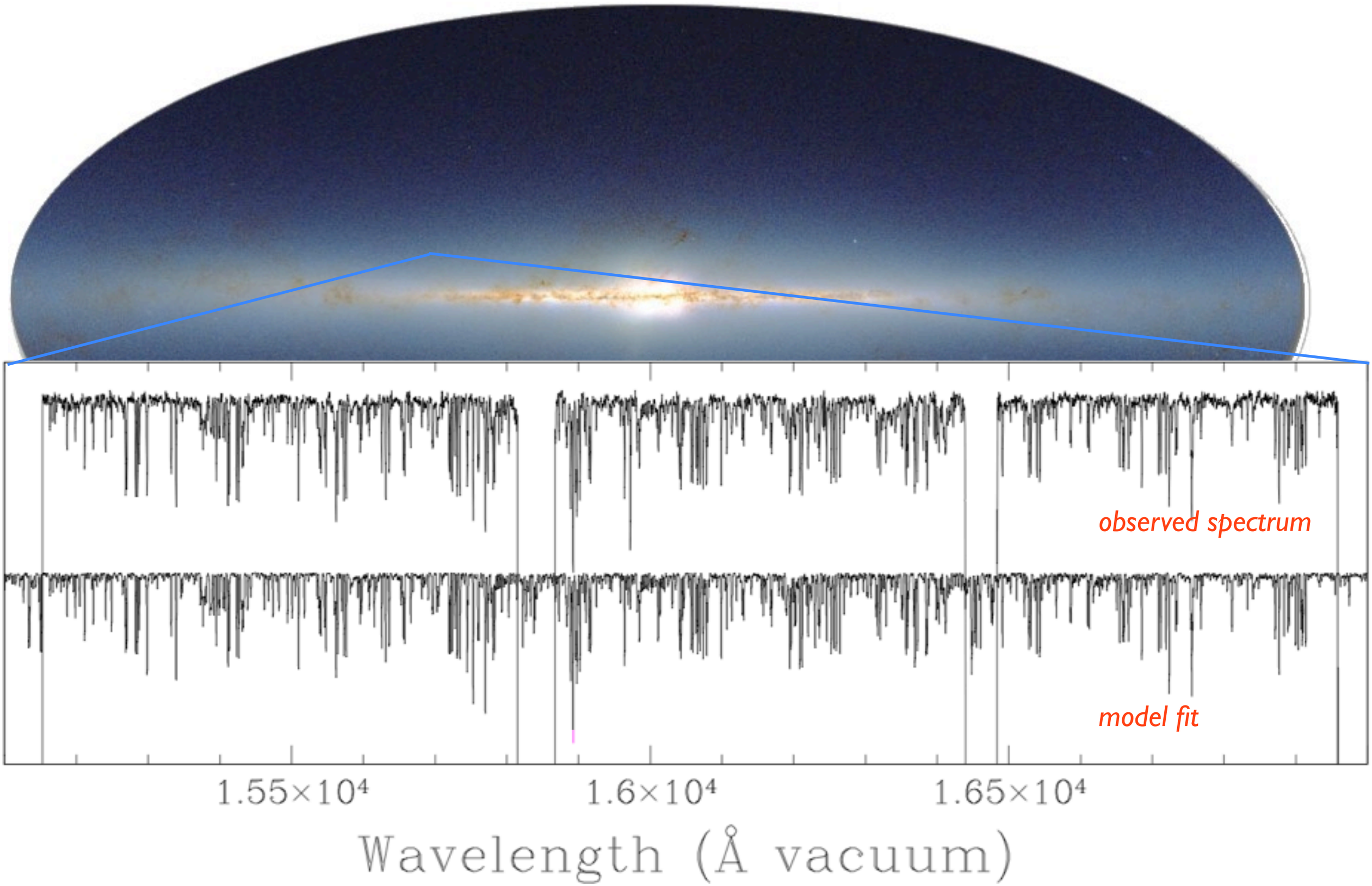
- 10,000 sq deg.
  - *1.6 million LRGs (z < 0.7)*
  - *200,000 QSOs (2.15 < z < 3)*
- Baryon Oscillations
- Large-scale structure
- Massive galaxy evolution
- Quasar evolution

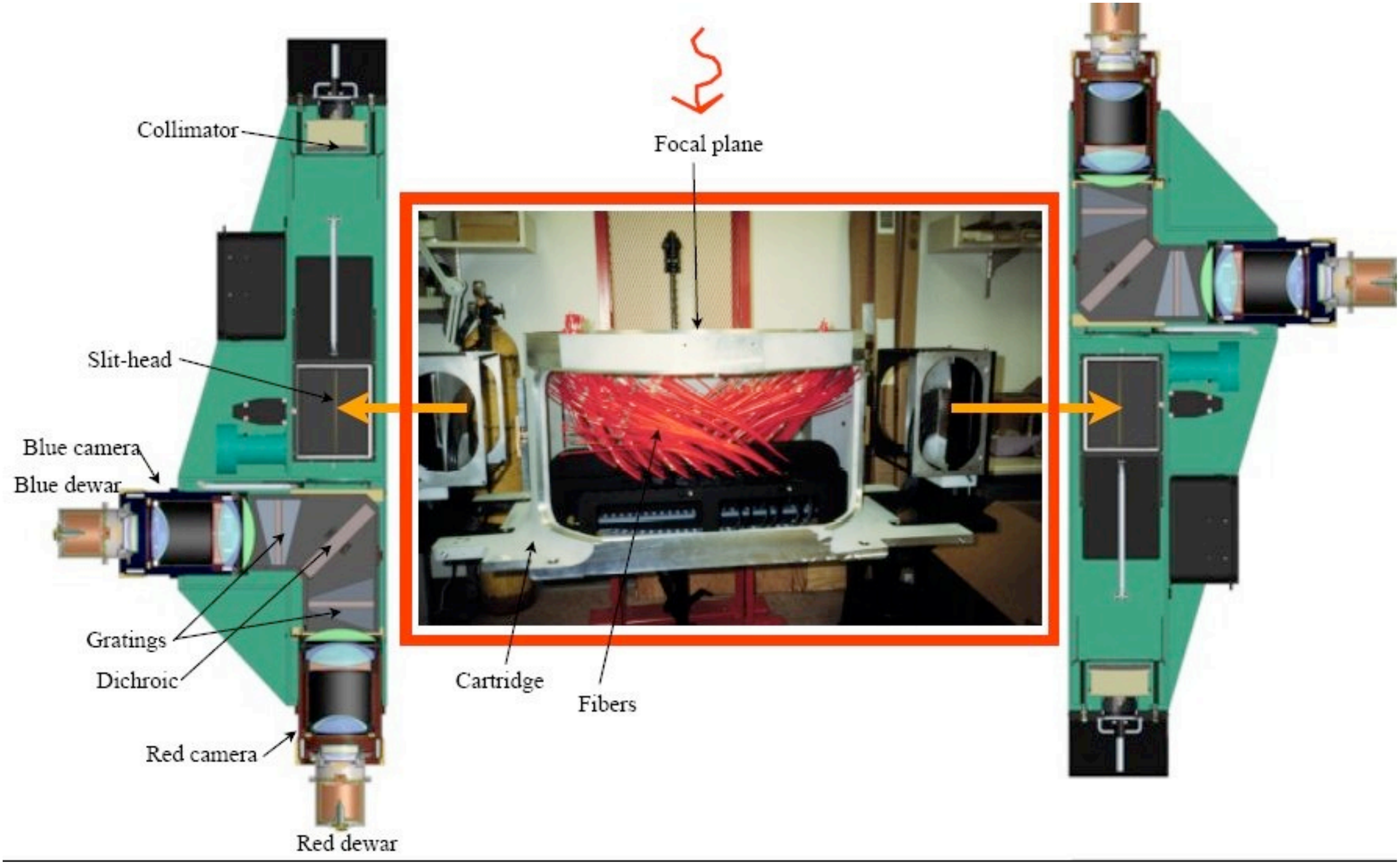


APOGEE (2011-2014)



APOGEE (2011-2014)




Collimator
Focal plane
Slit-head
Blue camera
Blue dewar
Gratings
Dichroic
Red camera
Red dewar
Cartridge
Fibers

APOGEE is off-telescope

Raw spectroscopic data

http://data.sdss3.org/sas/dr9/boss/spectro/data/55325/

sdR-r2-00114947.fit.gz

sdR-r2-00114948.fit.gz

sdR-r2-00114949.fit.gz

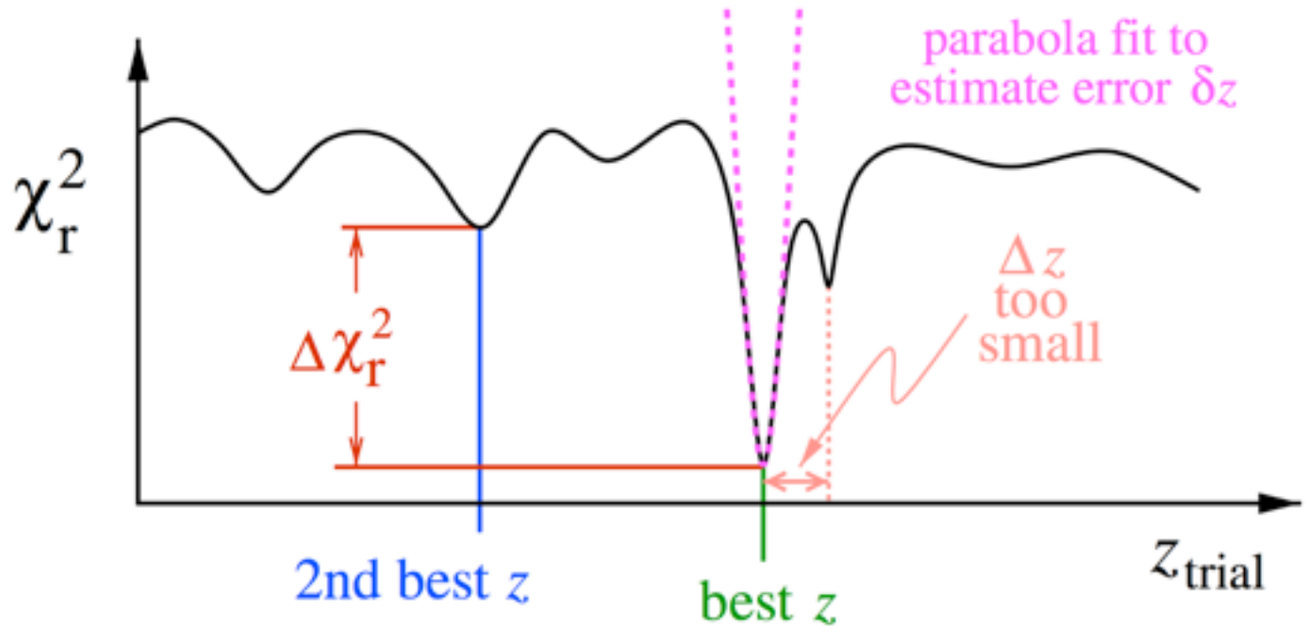
- Why is calibration so difficult?
  - *where exactly is the fiber?*
  - *every fiber is different*
  - *differential refraction effects*
- Small-scale calibration OK (at 1% level)
- Large scale calibration can be floppy at 10-20% level

- Reduced, calibrated spectra
  - *"spec" files with spectrum*
  - `http://data.sdss3.org/datamodel/files/BOSS_SPECTRO_REDUX/RUN2D/spectra/PLATE4/spec.html`
- Pick out one of your Galaxy spectra from Monday and look it up on data.sdss3.org
- Download the FITS file with the spectrum
- Plot it in python
- Estimate the flux around the H-alpha line (6563 Ang. in the rest-frame)

$$f_\lambda \rightarrow \mathrm{erg\ cm^{-2}\ s^{-1}\ \mathring{A}^{-1}}$$

- Targeting flags
  - http://sdss3.org/dr9/spectro/targets.php
  - LEGACY_TARGET1
  - SEGUE1_TARGET1
  - SEGUE2_TARGET2
  - BOSS_TARGET1
- Plot redshift distributions of following on one graph:
  - *Main sample galaxies in Legacy*
  - *LRGs in Legacy*
  - *QSOs in Legacy*
  - *"LOWZ" galaxies in BOSS*
  - *"CMASS" galaxies in BOSS*
  - *"QSO" galaxies in BOSS*
- Note that dealing with selection effects requires great care!

- Redshift finding
- Loop over three types:
  - *STAR*
  - *QSO*
  - *GALAXY*
- For stars, loop over 40 different types, and +/- 1200 km/s
- For QSOs and galaxies, loop over redshifts and fit multicomponent PCA at all redshifts
- "Best fit model" is result of this



GALAXY BASIS

Template f_λ (arbitrary units)

Rest−frame wavelength (Å)

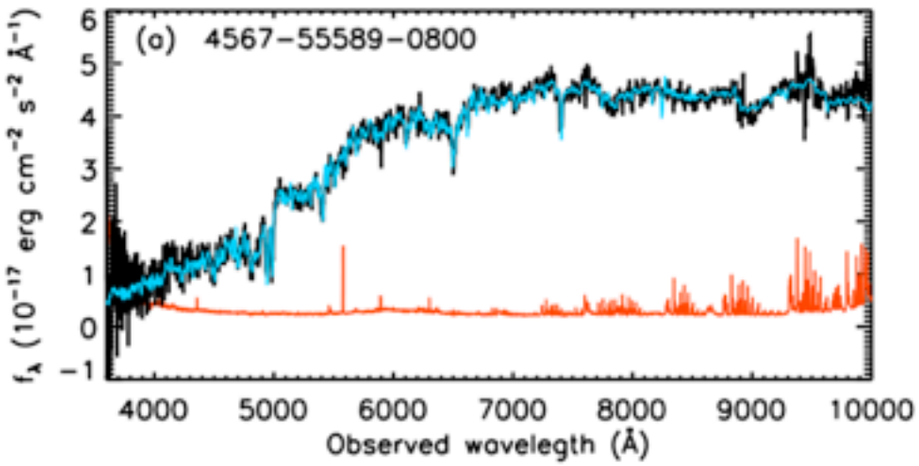
1st Eigenspectrum
2nd Eigenspectrum
3rd Eigenspectrum
4th Eigenspectrum

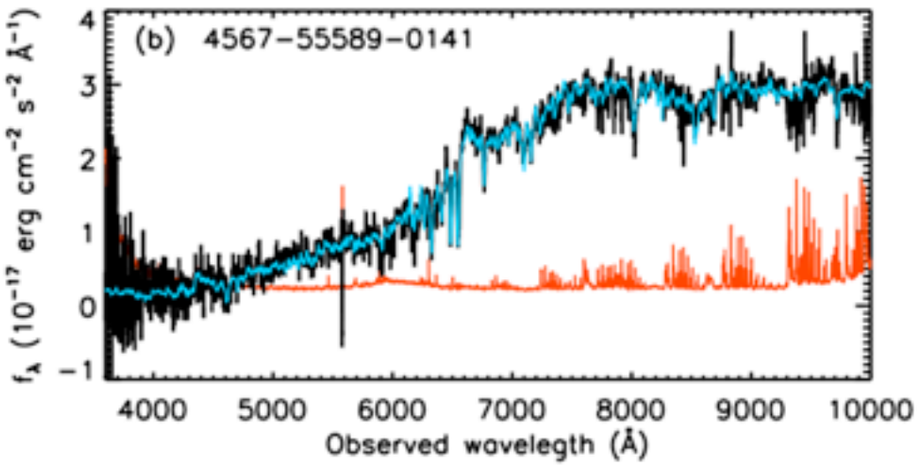
QUASAR BASIS

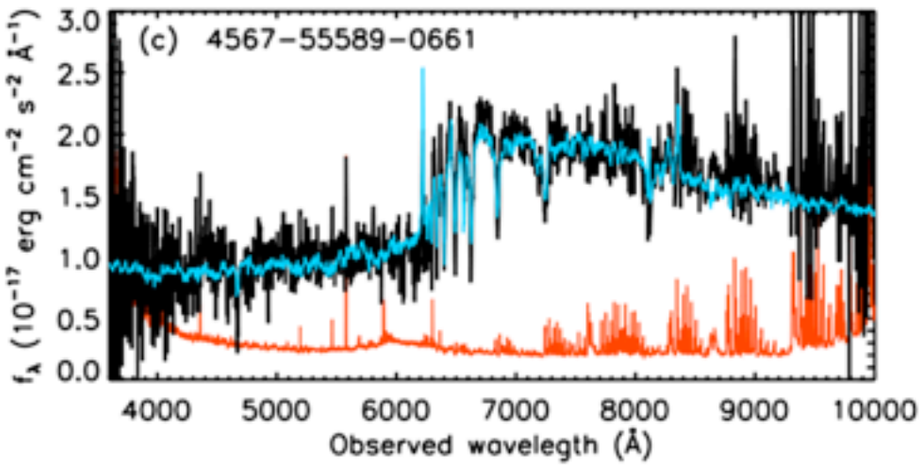
Template f_λ (arbitrary units)

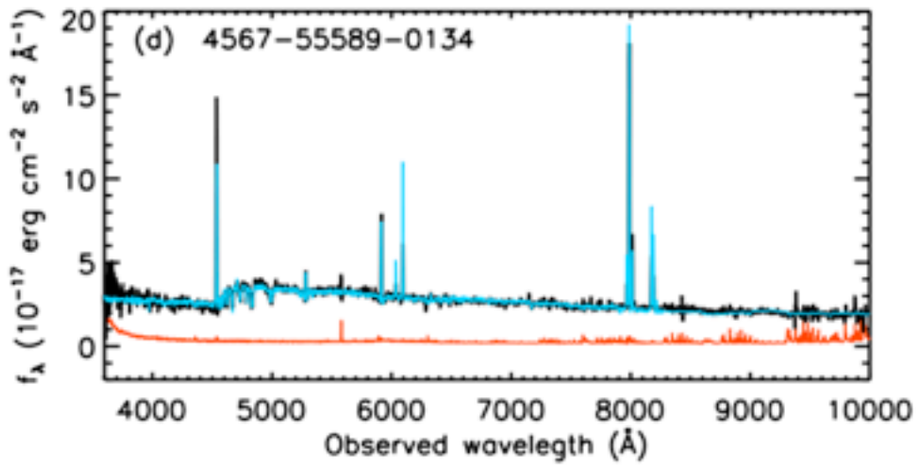
$\log_{10}$ rest−frame wavelength (Å)

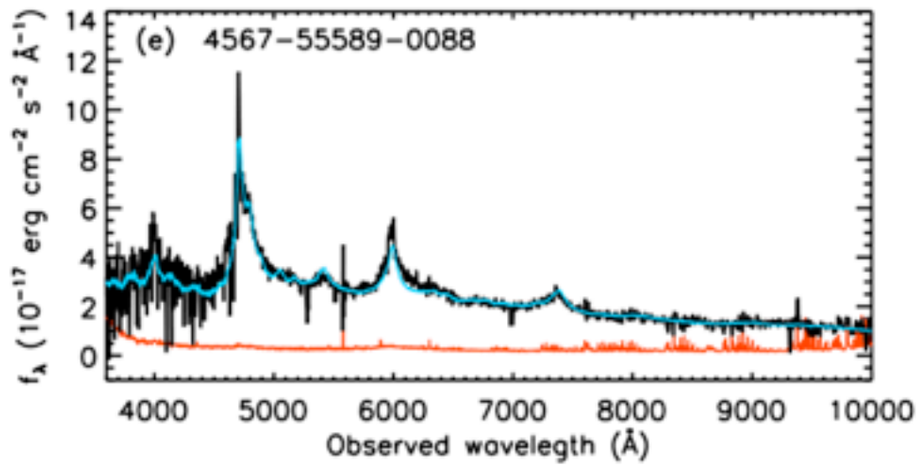
1st Eigenspectrum
2nd Eigenspectrum
3rd Eigenspectrum
4th Eigenspectrum

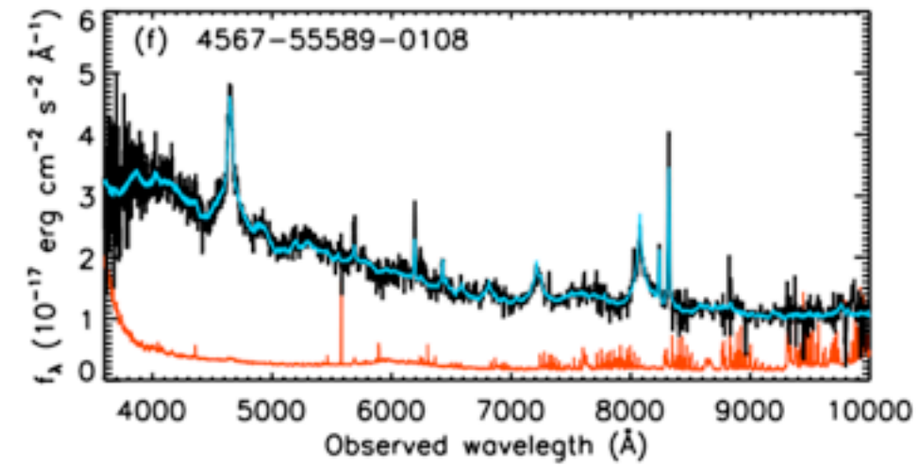

(a) 4567−55589−0800
f_λ (10^{-17} erg cm^{-2} s^{-2} Å^{-1})
Observed wavelegth (Å)

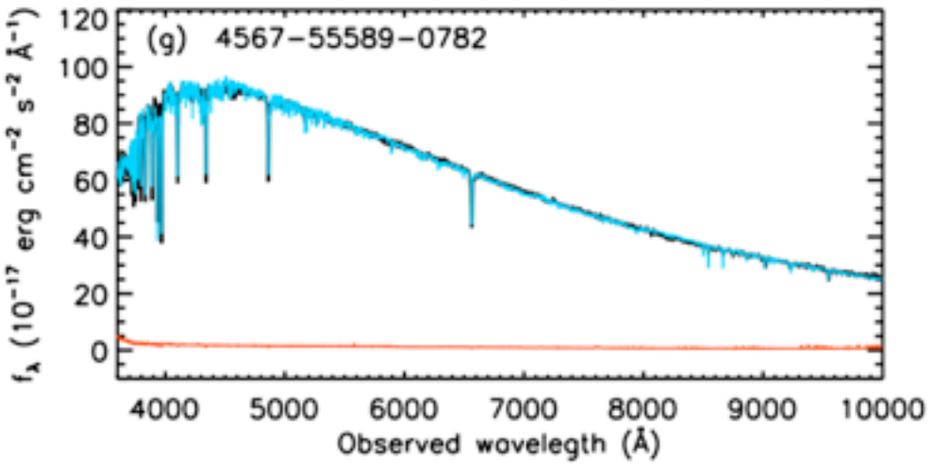

(b) 4567−55589−0141
f_λ (10^{-17} erg cm^{-2} s^{-2} Å^{-1})
Observed wavelegth (Å)

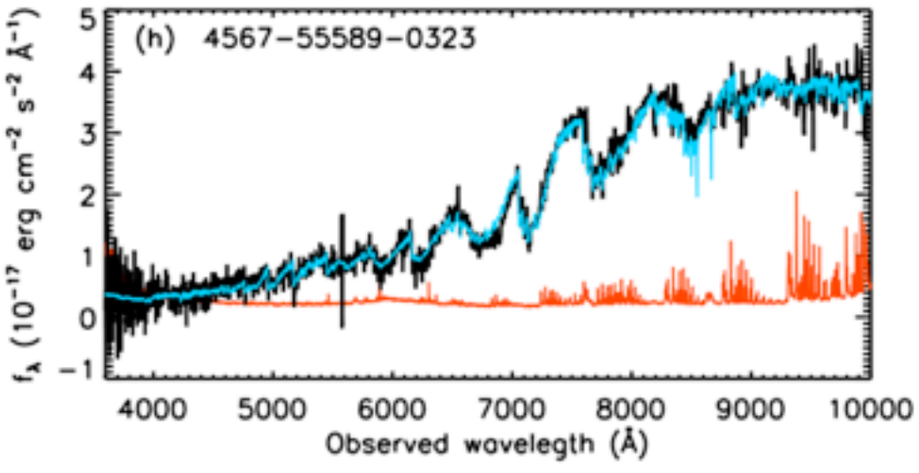

(c) 4567−55589−0661
f_λ (10^{-17} erg cm^{-2} s^{-2} Å^{-1})
Observed wavelegth (Å)


(d) 4567−55589−0134
f_λ (10^{-17} erg cm^{-2} s^{-2} Å^{-1})
Observed wavelegth (Å)


(e) 4567−55589−0088
f_λ (10^{-17} erg cm^{-2} s^{-2} Å^{-1})
Observed wavelegth (Å)

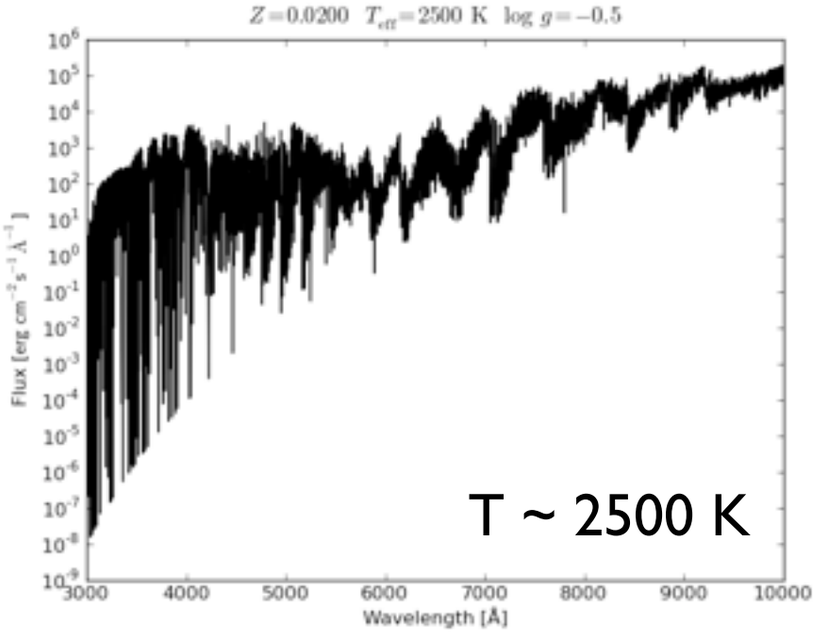

(f) 4567−55589−0108
f_λ (10^{-17} erg cm^{-2} s^{-2} Å^{-1})
Observed wavelegth (Å)

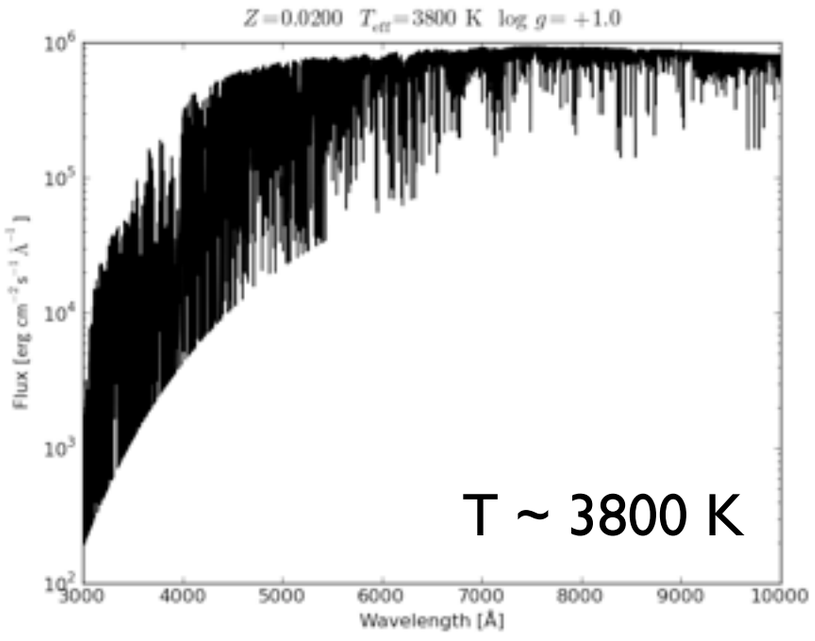

(g) 4567−55589−0782
f_λ (10^{-17} erg cm^{-2} s^{-2} Å^{-1})
Observed wavelegth (Å)

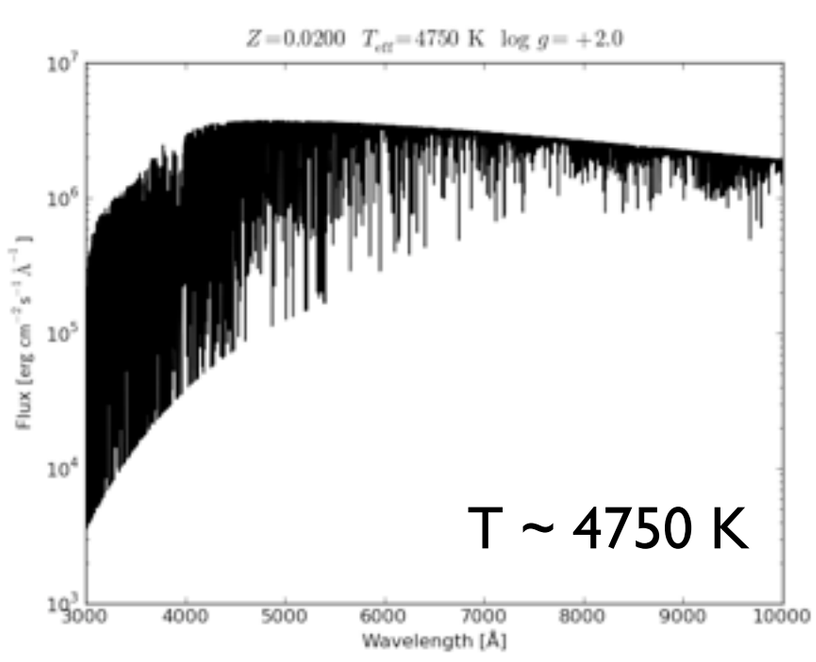

(h) 4567−55589−0323
f_λ (10^{-17} erg cm^{-2} s^{-2} Å^{-1})
Observed wavelegth (Å)

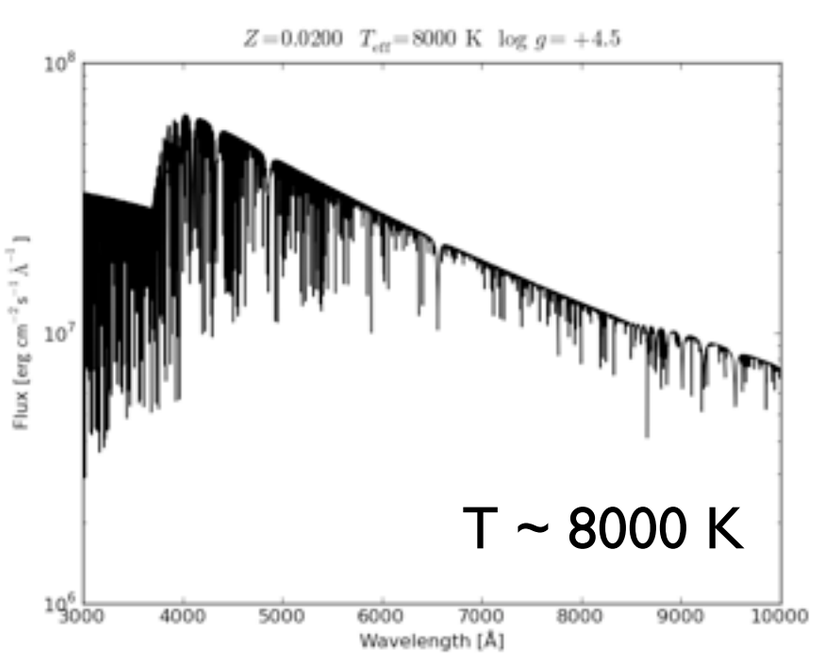
- Velocity dispersion
- Galaxies are made of stars going at many different velocities
- Velocities are related to mass and radius by virial theorem
- Measured by fitting convolved sum of high resolution stellar models to actual spectrum
- Good down to about 70 km/s (instrumental resolution)

High resolution stellar atmosphere models
(MARCS: http://marcs.astro.uu.se/)



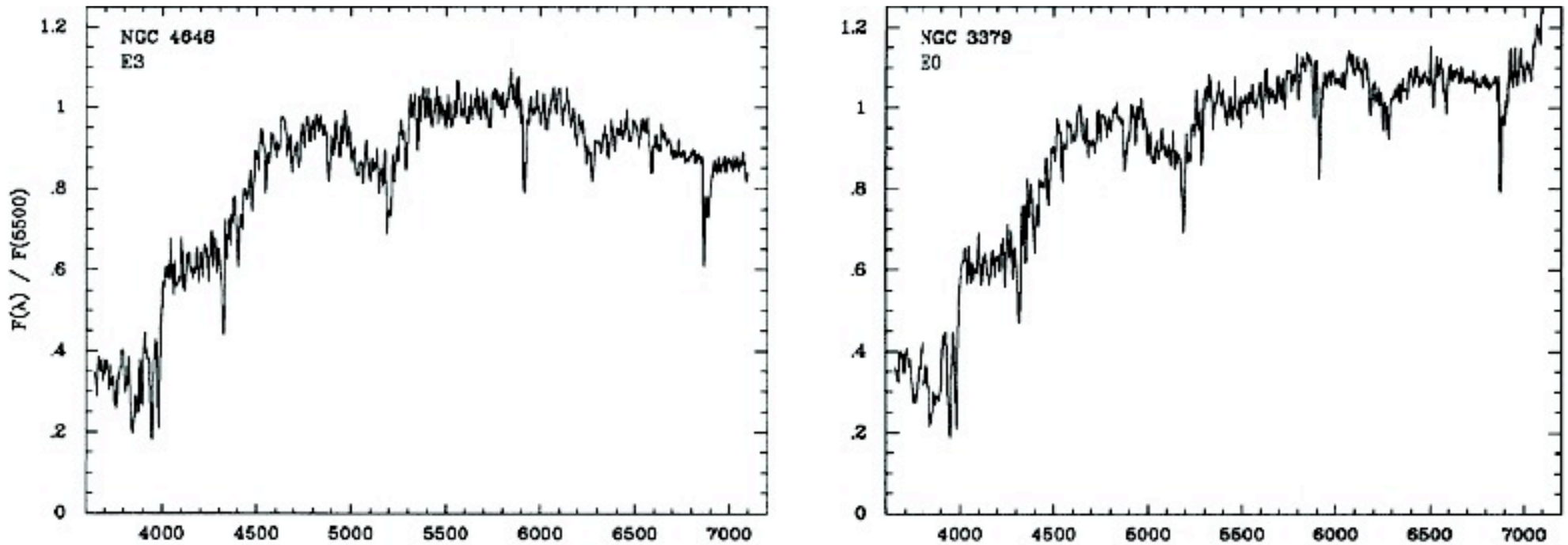






Blurred out by velocity dispersion and instrumental resolution

galaxies



K stars

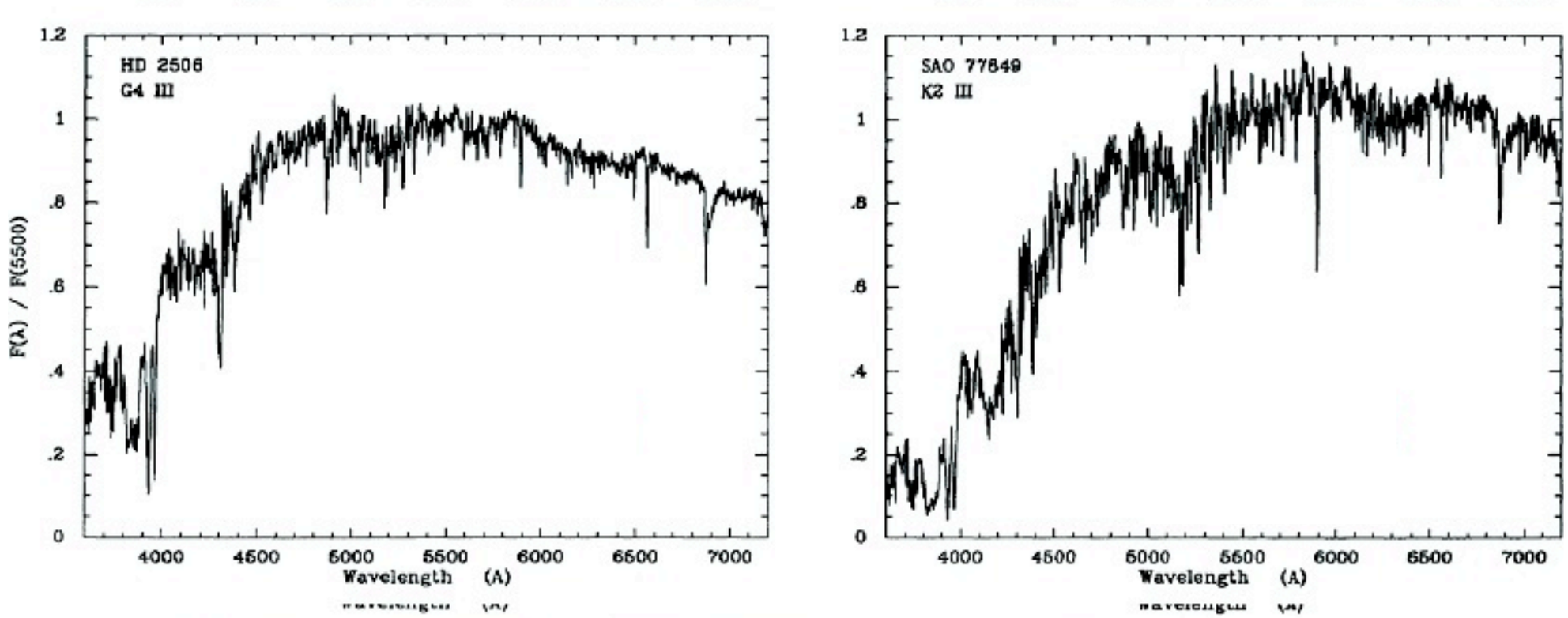
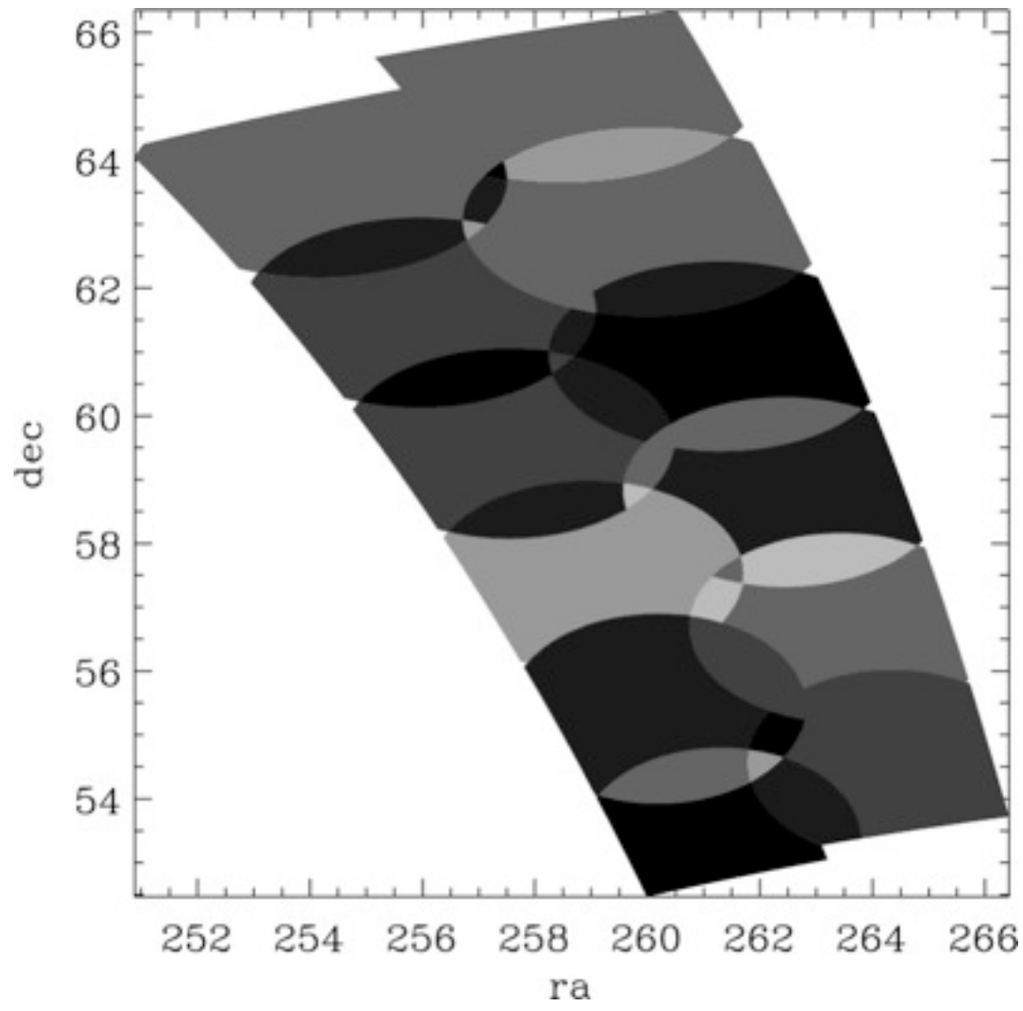


FIG. 5.—Integrated spectra of four elliptical galaxies. The spectrum of NGC 4472 (*lower right*) was obtained at lower resolution with the IRS scanner.

- Line measurements
- Gaussian fits to line profiles, with stellar continuum from velocity dispersion models
- Note that there are also detailed measurements for the galaxies, which try to determine stellar masses and (in some cases) fit emission lines too.

- Large-scale structure in SDSS & BOSS
  - http://sdss.physics.nyu.edu/vagc
  - http://www.sdss3.org/dr9/tutorials/lss_galaxy.php
- Uses very useful "mangle" utility
  - http://space.mit.edu/~molly/mangle/



- APOGEE catalog
  - http://mirror.sdss3.org/sas/testbed10/apogee/spectro/redux/r3/allStar-v302.fits
- APOGEE spectra
  - http://data.sdss3.org/datamodel/files/APOGEE_REDUX/APRED_VERS/APSTAR_VERS/ASPCAP_VERS/RESULTS_VERS/LOCATION_ID/aspcapStar.html
- Let's just take a look

Afternoon Activity

- Select up to 100 Legacy Main sample galaxies within a 1 degree and +/- 2000 km/s of the center of the Coma cluster
- Select 100 random galaxies in the same redshift range but not near Coma cluster
- Are the spectra different in any systematic way
- Stack two sets of spectra and plot together to compare