Properties of Void Galaxies

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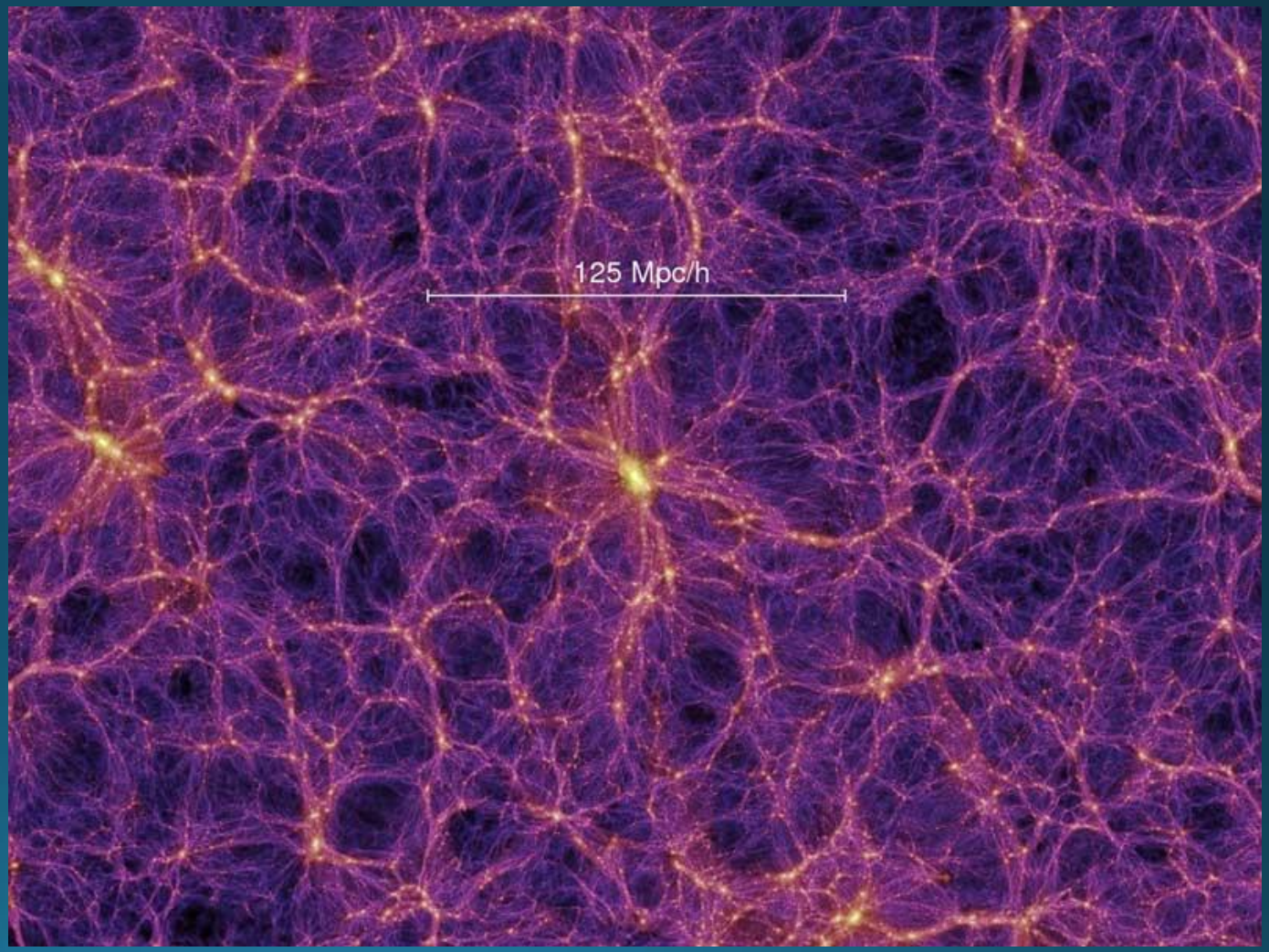
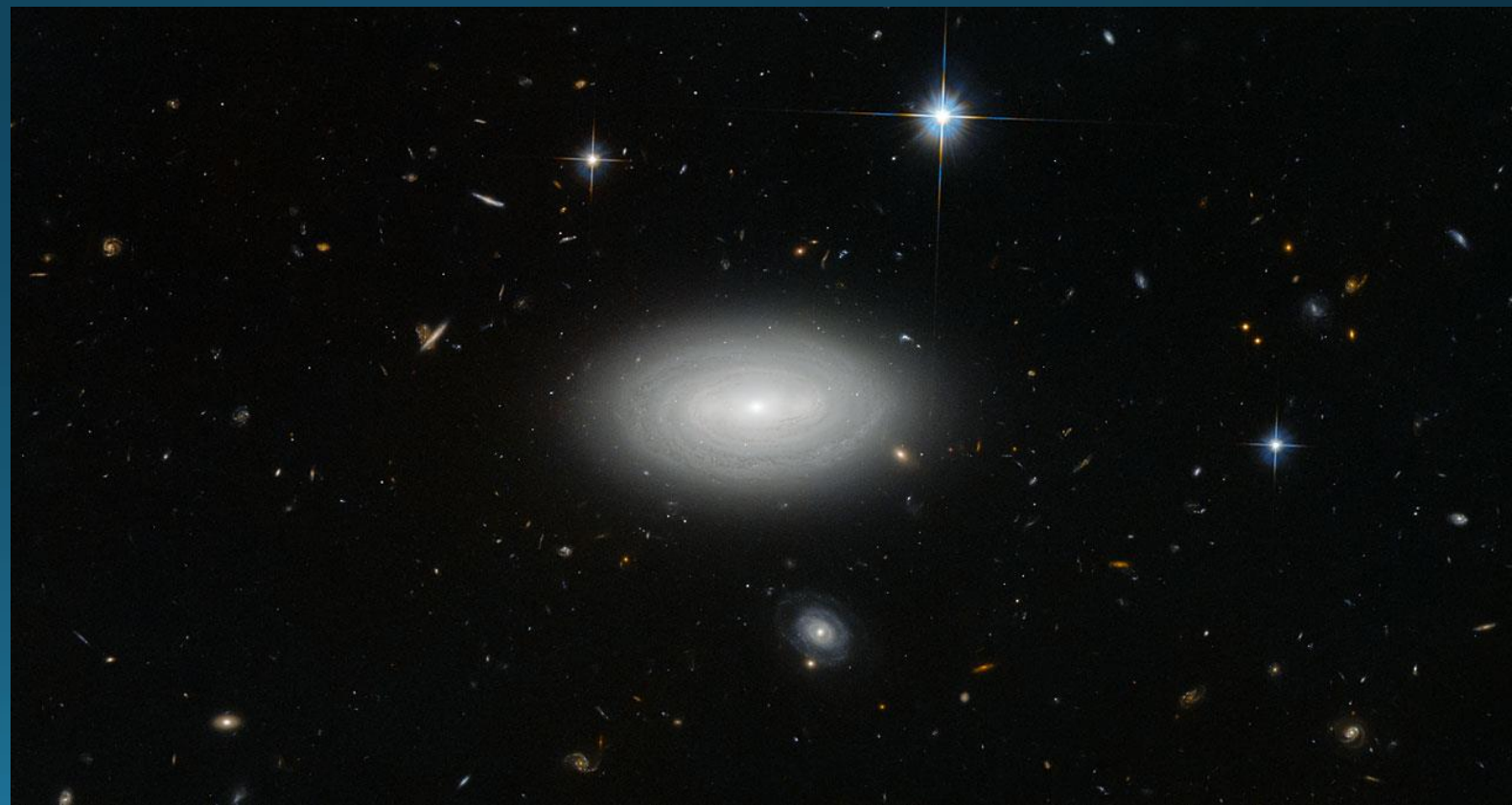
Cosmic Voids

- Voids and filaments make up the cosmic web
- Cosmic voids make up ~60% of the volume of the universe
  - Yet have only ~7% of the galaxies



Void Galaxies

- Galaxies which occupy voids
- Found to be bluer with higher star formation
- Come in all typical galaxy shapes, though there are more spirals than usual



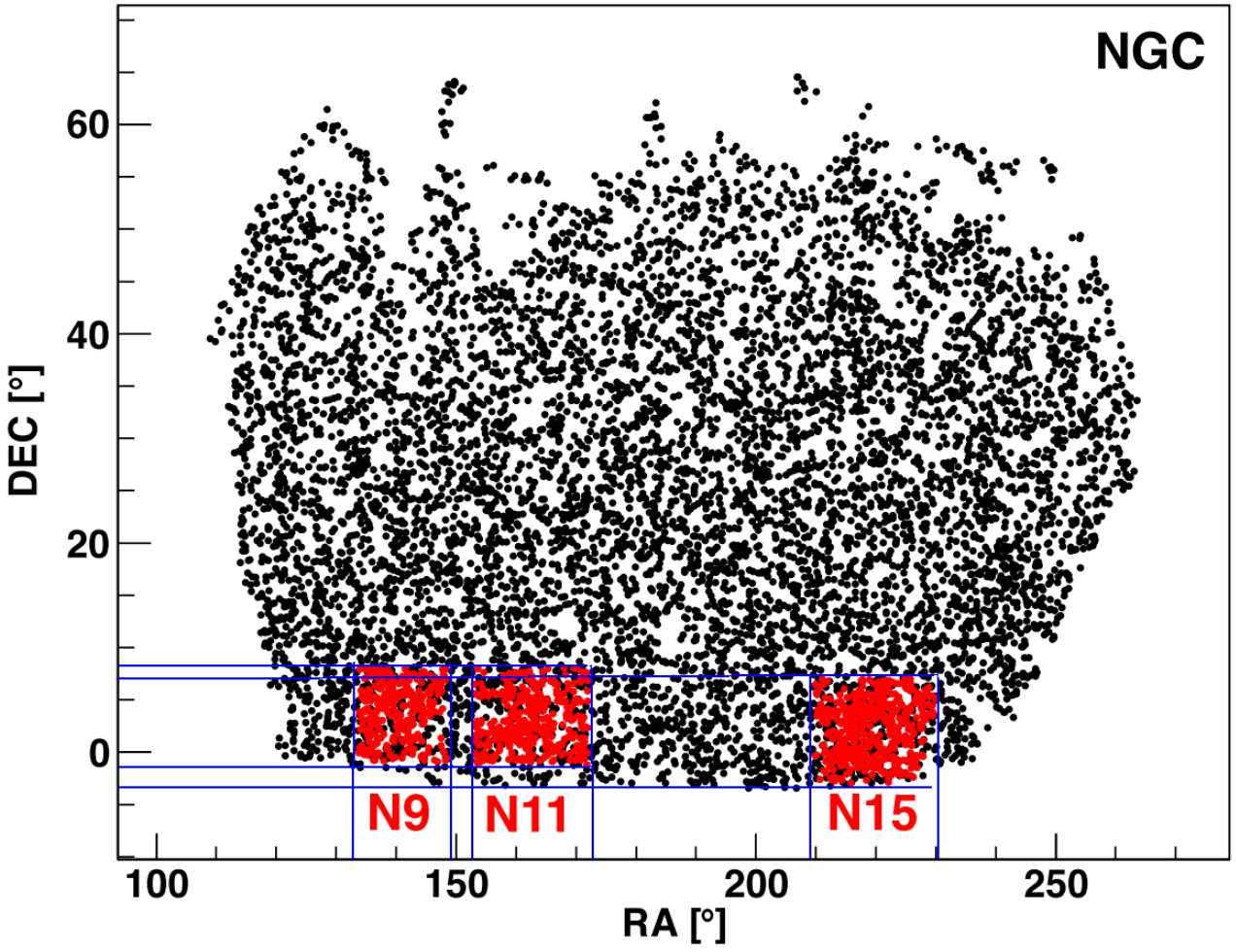
Why study void galaxies?

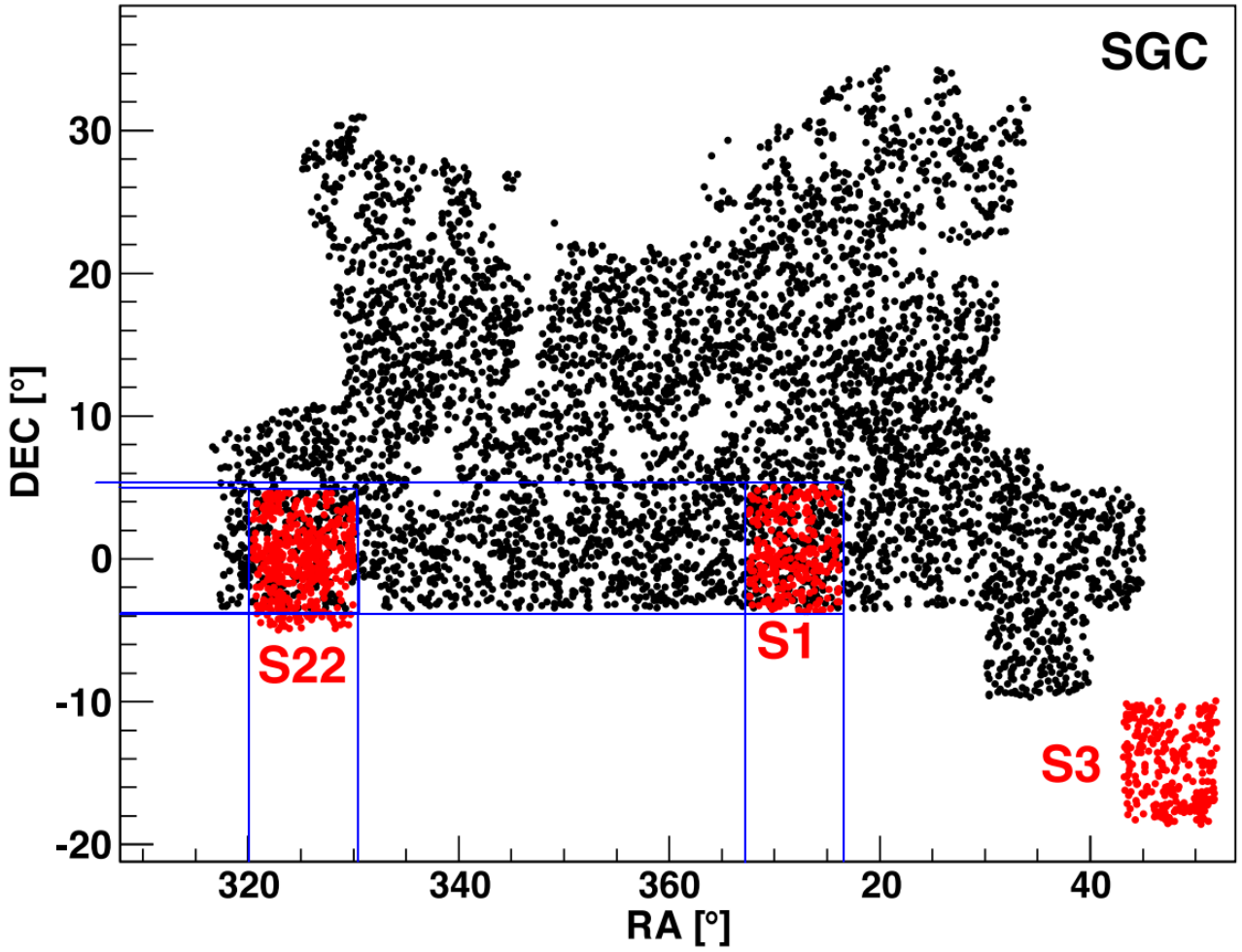
- Void galaxies have some different properties than galaxies in clusters
  - Structures form early and without neighboring interactions
    - Gives us a look at galaxy formation
  - Higher stellar formation rate
- Have some similar properties
  - Percentage of active galactic nuclei

Our Data

- Galaxy data
  - Sloan Digital Sky Survey
    - 10,000 square degrees, 1.5 million luminous red galaxies (LRG)
  - WiggleZ Dark Energy Survey
    - 1,000 square degrees, 240,000 emission line galaxies (blue)
  - Interested in overlap region—about 650 $\deg^2$

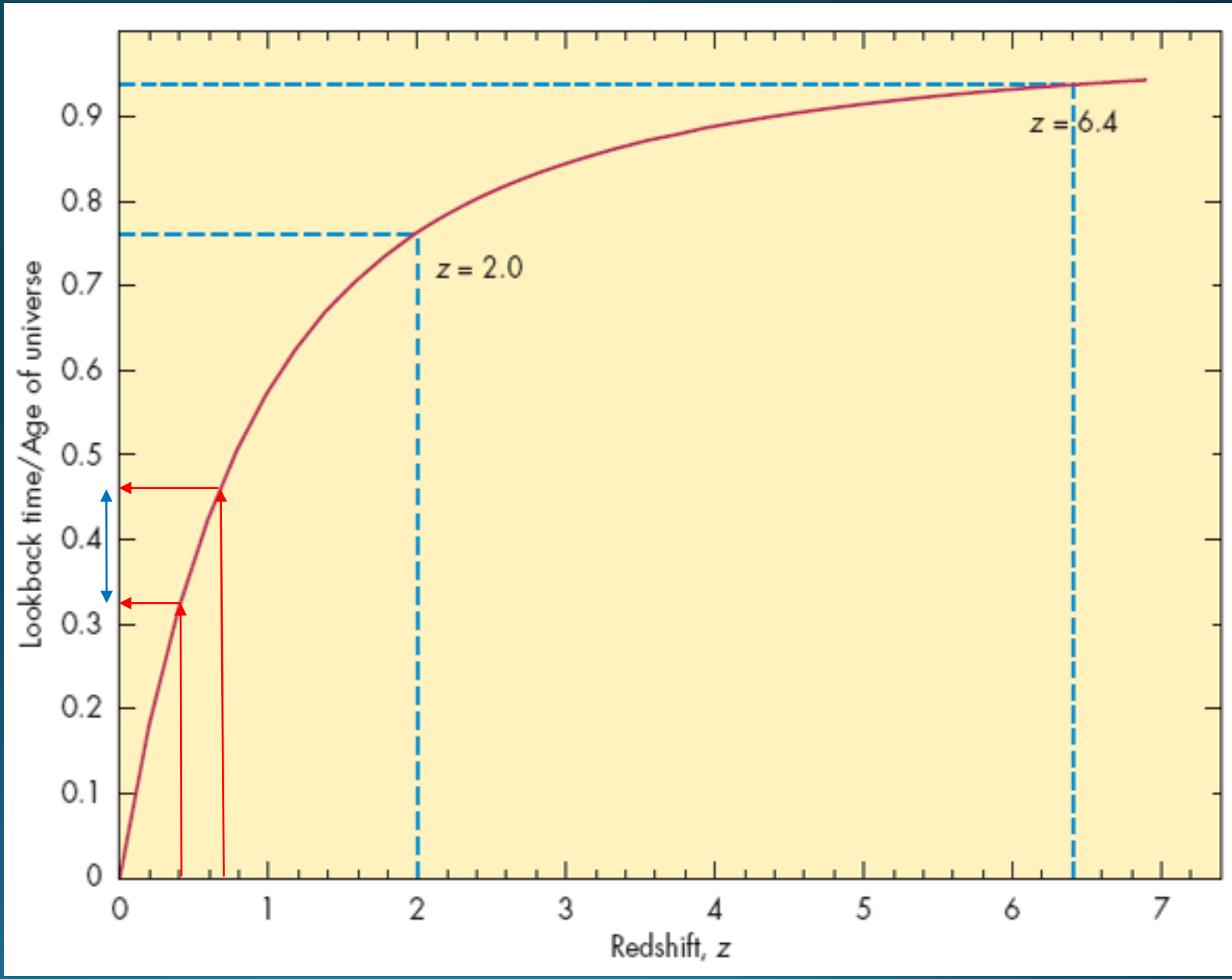
Overlap Region





Redshift

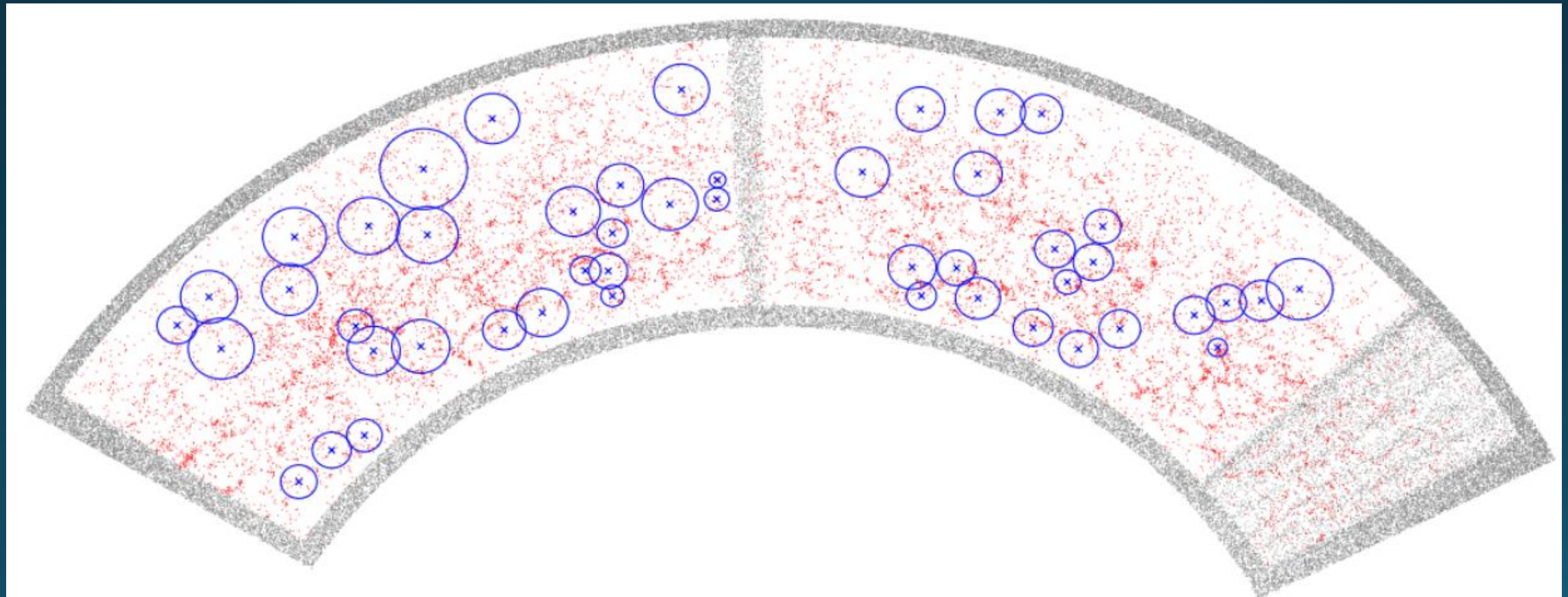
- Redshift corresponds to distance due to the Hubble Flow
- Overlap from redshift 0.43 to 0.70
  - Corresponds to a relatively uniform time in the universe



Astronomy 6th Edition. John D. Fix.

Void Catalog

- Void Catalog from Mao et al. 2016
  - Produced using SDSS 12 Data and a watershed algorithm
  - Start with 7,744voids across all CMASS sky



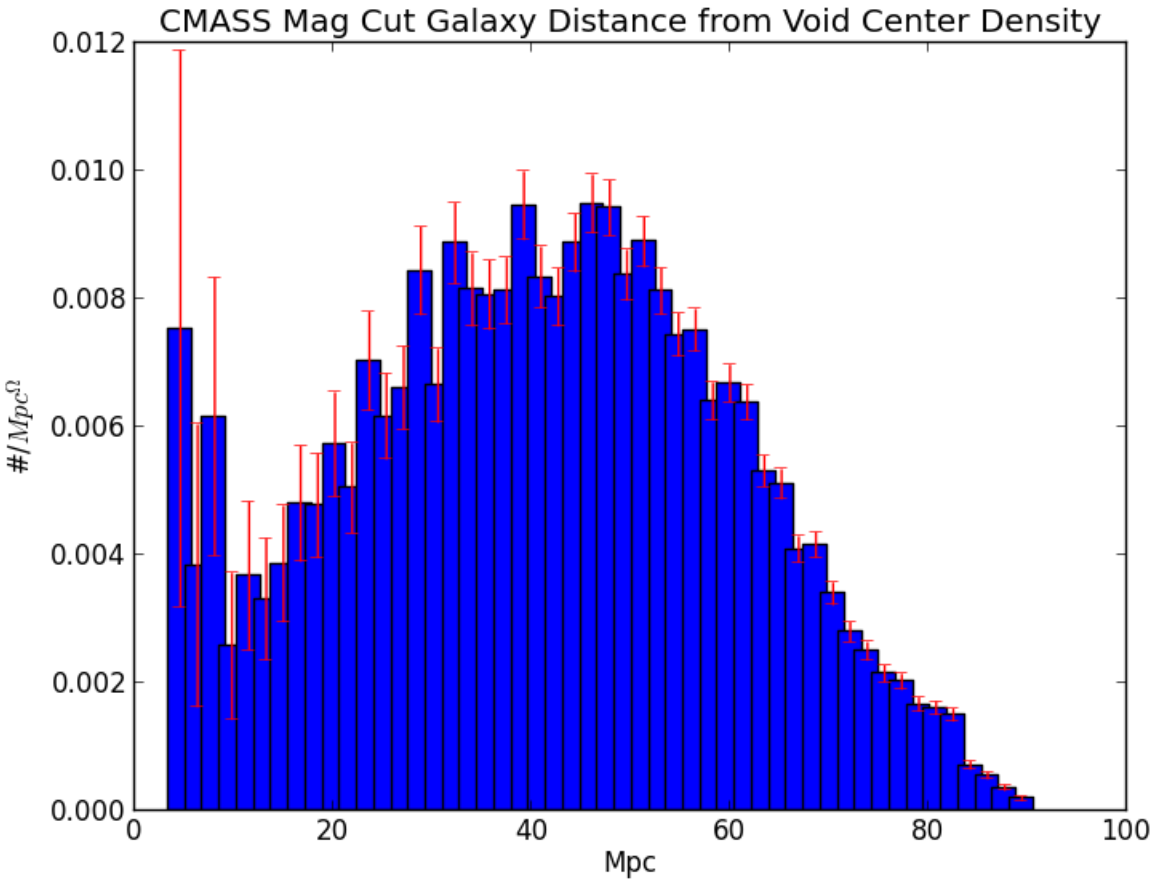
Quality Cuts

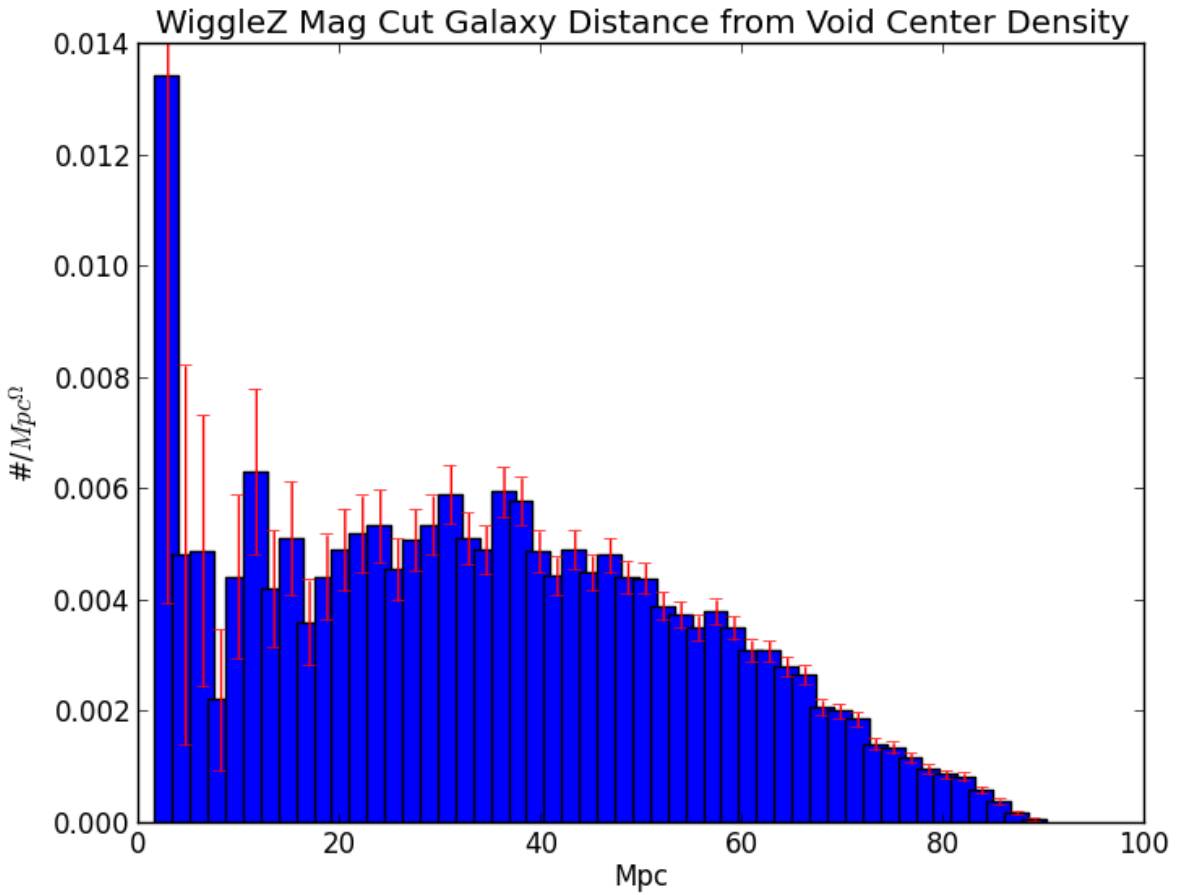
- CMASS color cut (ensure galaxies are red)
- Galaxy brightness cut
- Void effective radius cut at 60 Mpc
- True void cut (must be less than 30% chance of void being due to random probability)

Identifying Void Galaxies

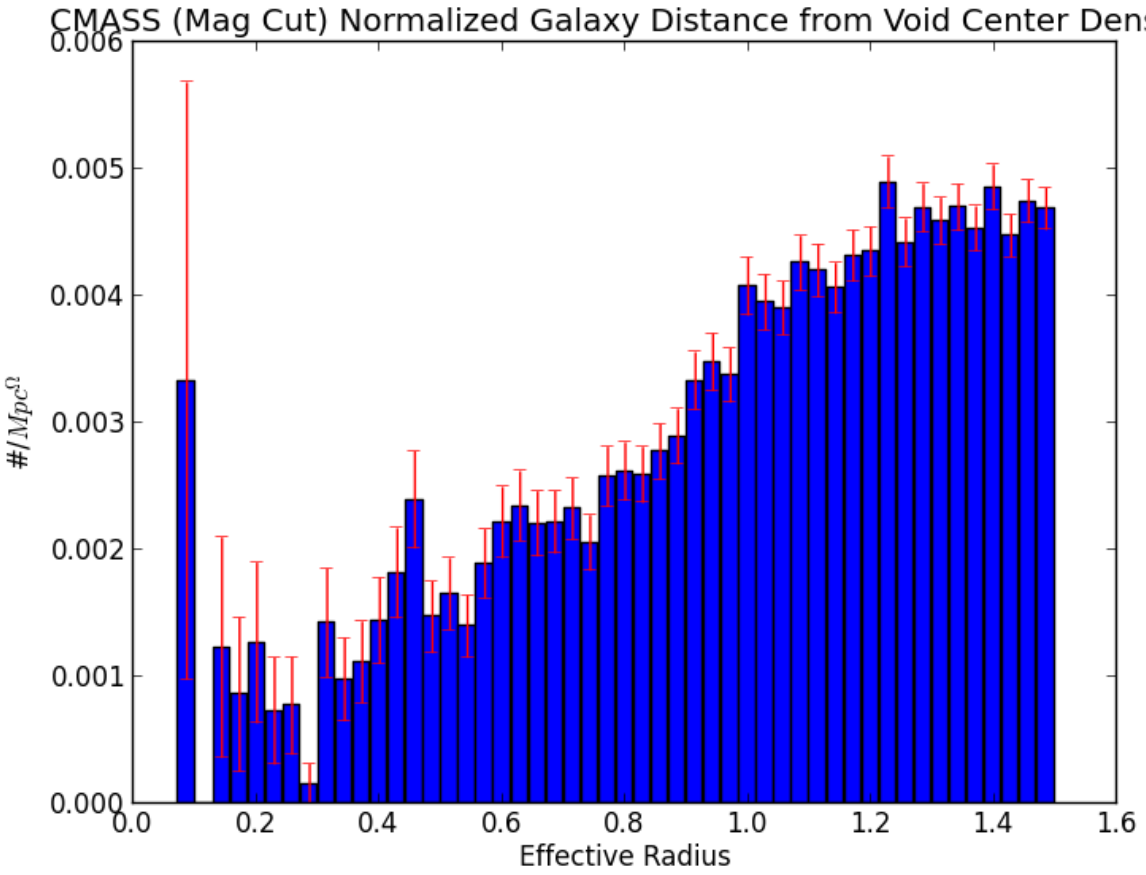
- Use sky position and redshift to convert galaxy and void locations to Cartesian coordinates
- Check if galaxies lies within 1.5_x the effective void radius
- Left with 11,962 CMASS galaxies and 6,652 WiggleZ galaxies across 188 voids

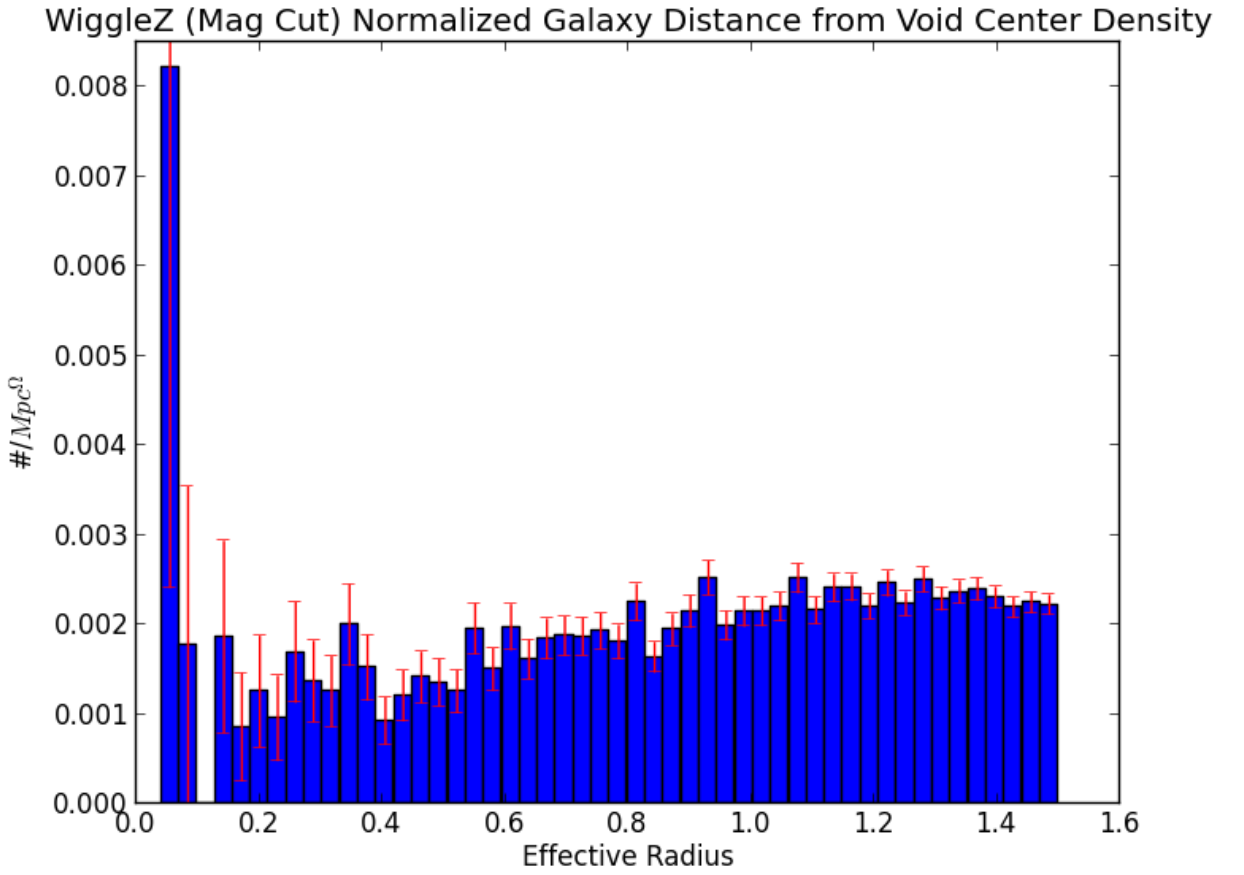
Void Check


CMASS Mag Cut Galaxy Distance from Void Center Density
0.012
0.010
0.008
0.006
0.004
0.002
0.000
#/Mpc^{Ω}
0
20
40
60
80
100
Mpc


WiggleZ Mag Cut Galaxy Distance from Void Center Density
0.014
0.012
0.010
0.008
0.006
0.004
0.002
0.000
#/Mpc^{Ω}
0
20
40
60
80
100
Mpc

Void Check

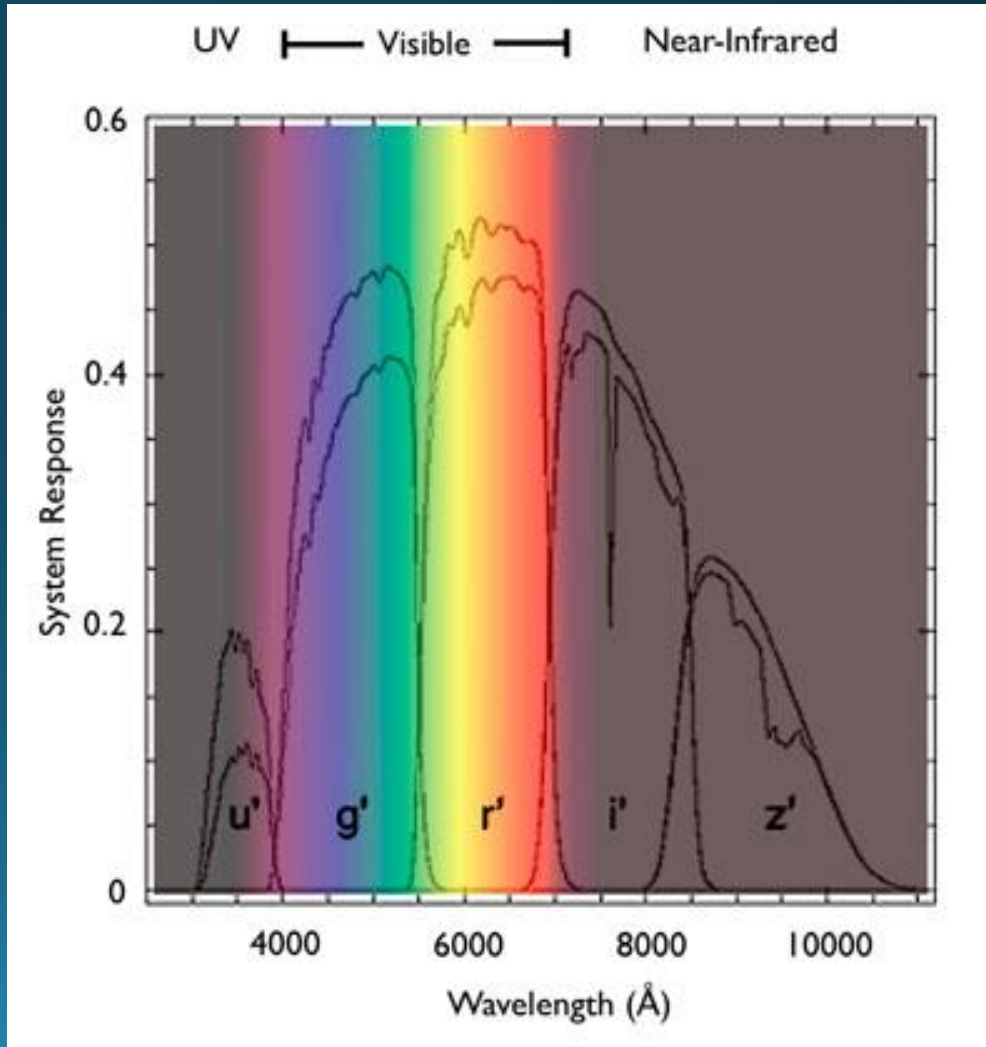

CMASS (Mag Cut) Normalized Galaxy Distance from Void Center Density
0.006
0.005
0.004
0.003
0.002
0.001
0.000
#/Mpc^Ω
0.0
0.2
0.4
0.6
0.8
1.0
1.2
1.4
1.6
Effective Radius


WiggleZ (Mag Cut) Normalized Galaxy Distance from Void Center Density
0.008
0.007
0.006
0.005
0.004
0.003
0.002
0.001
0.000
#/Mpc^Ω
0.0
0.2
0.4
0.6
0.8
1.0
1.2
1.4
1.6
Effective Radius

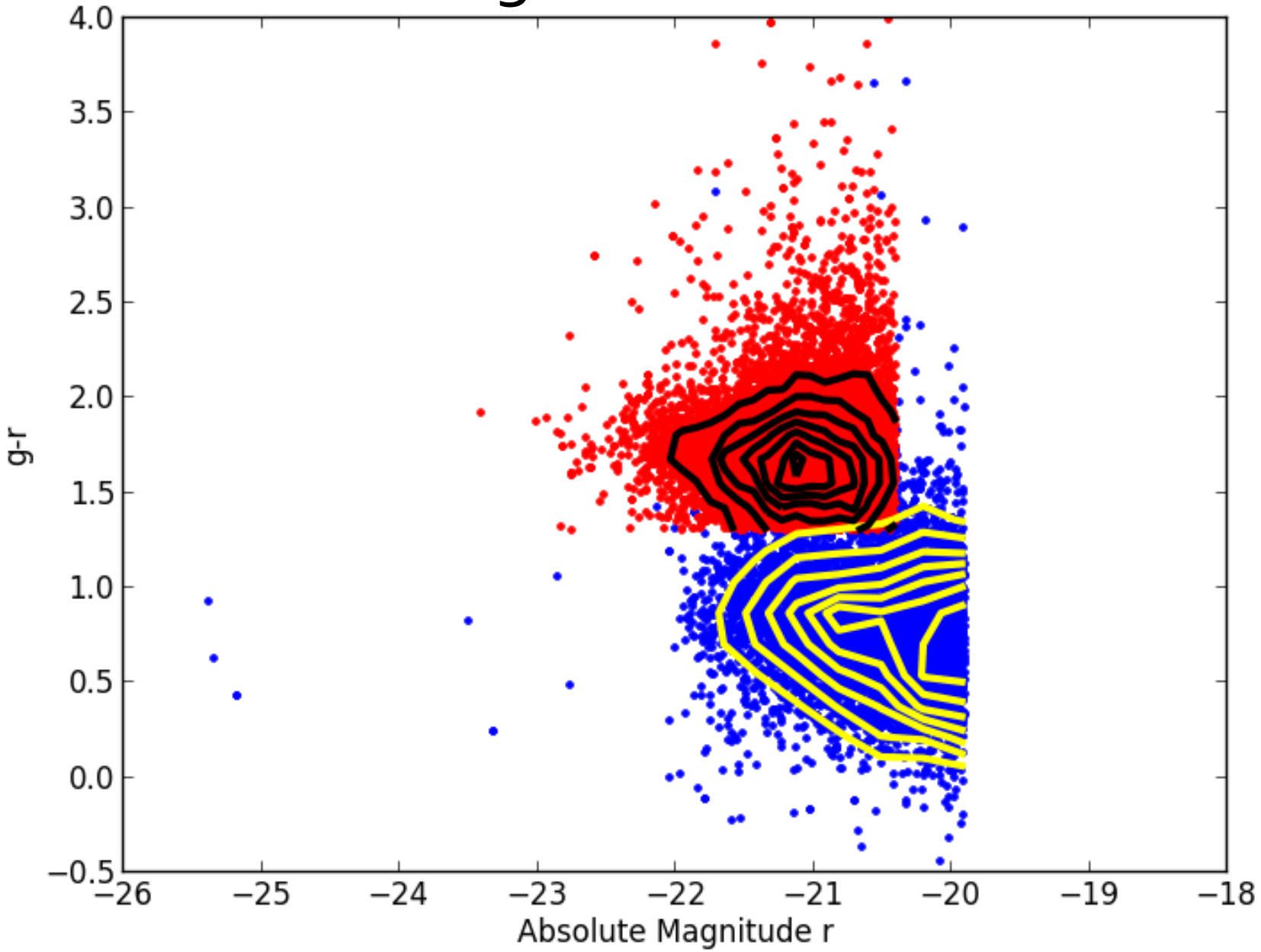
Color Magnitude Diagrams

- Plots the color of a galaxy vs its absolute magnitude
- Absolute magnitude is a measure of how bright an object is on a log base 10 scale
- The color is a measurement of difference between the amount of light in two filters
  - Use (g-r)

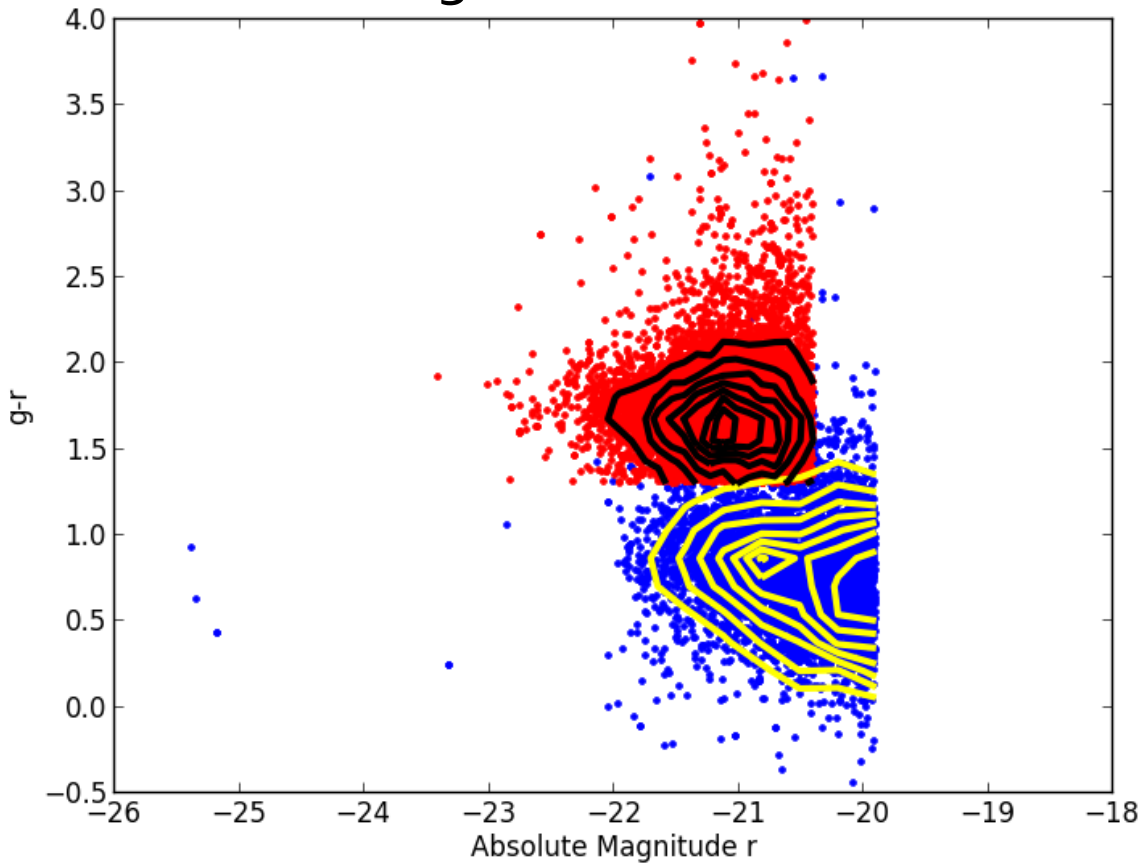
- Color magnitude diagrams can give us a rough idea of the properties of galaxies
  - Blue galaxies tend to be spiral, red tend to be elliptical
  - Blue tend to be star forming



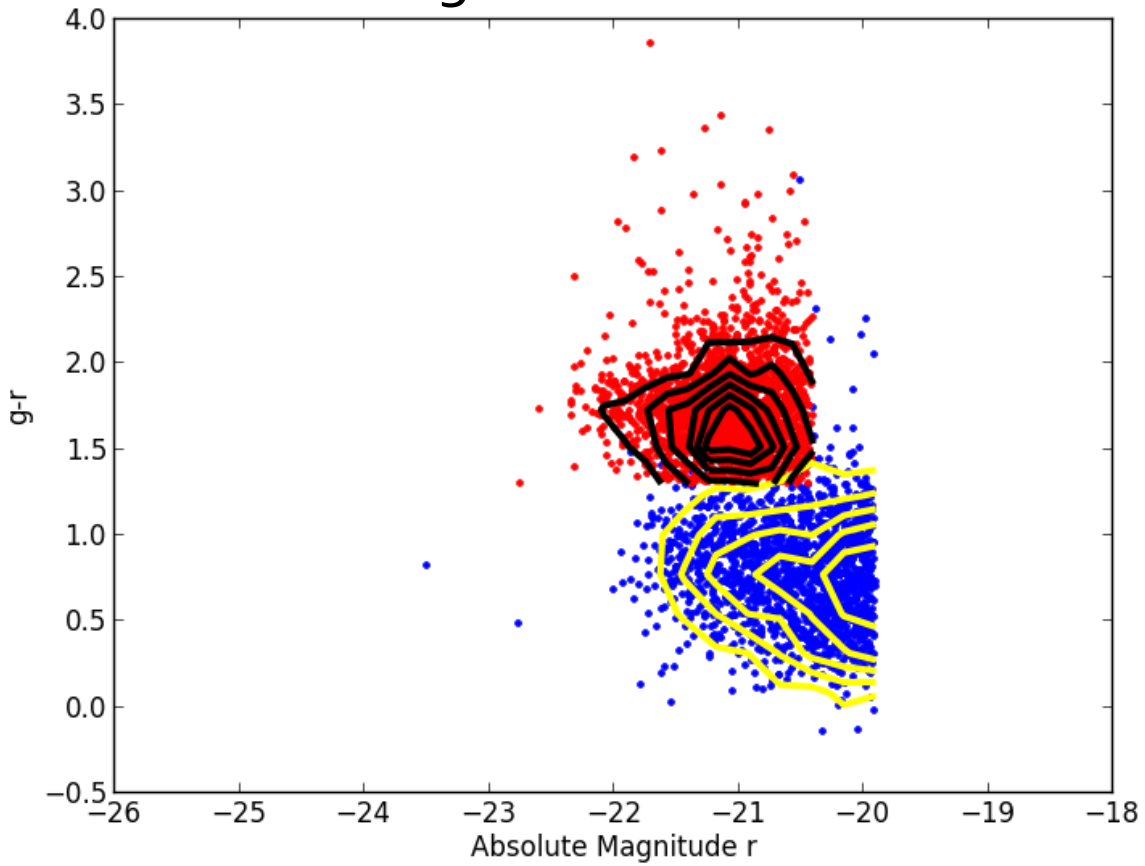
Color Magnitude All Galaxies



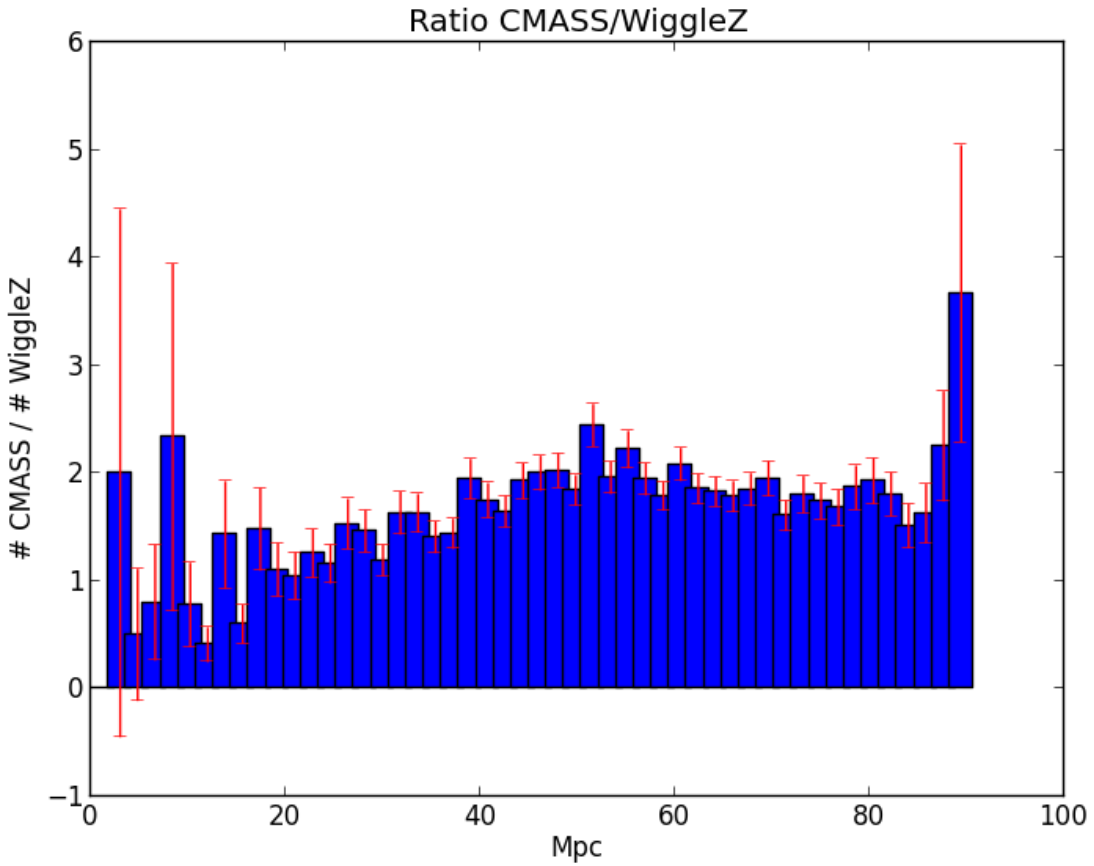
Color Magnitude Wall Galaxies

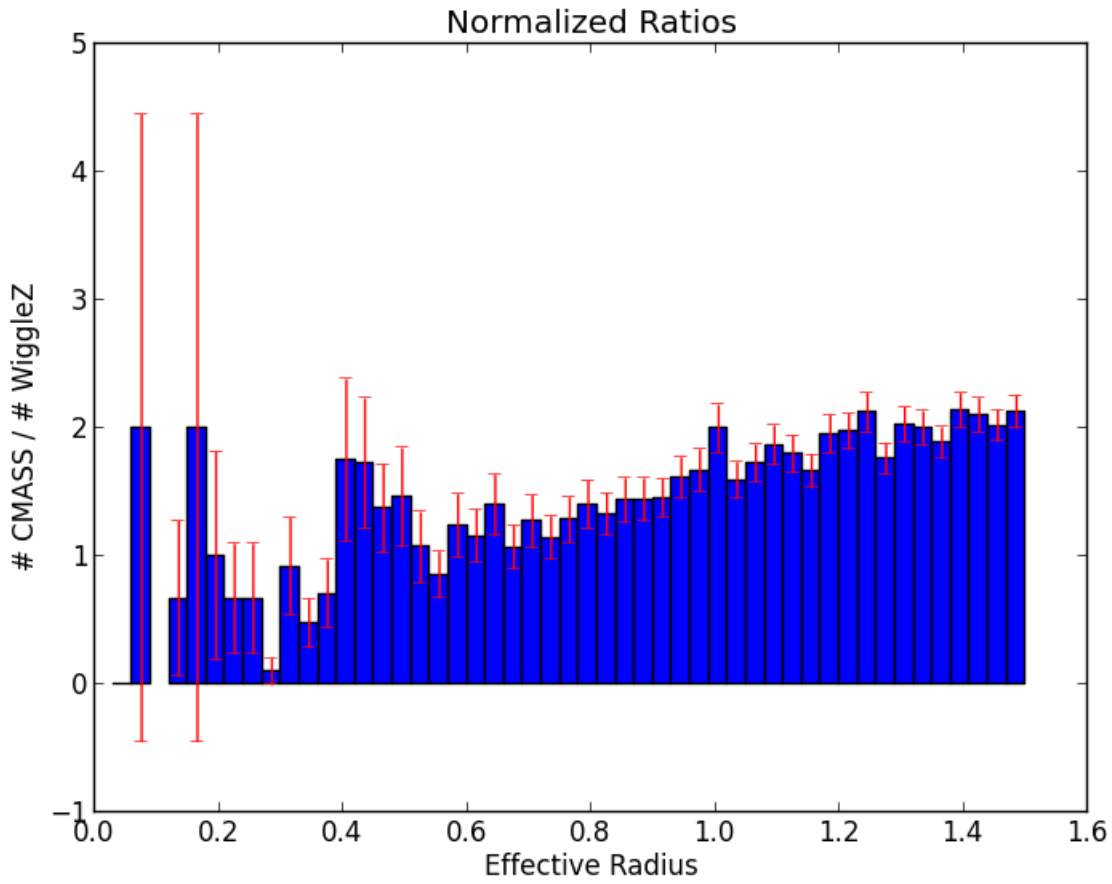


Color Magnitude Void Galaxies



Ratio $\frac{Red}{Blue}$ Galaxies





Kolmogorov–Smirnov Test

- Statistical test to measure if two samples likely came from the same population
- Find that CMASS and WiggleZ wall and void galaxy populations could have come from the same population when taken separately
- When CMASS and WiggleZ are combined, wall and void galaxies look different in both g and r
  - Further evidence of color difference

Questions?

Image Sources

Millenium Simulation

ESA/Hubble & NASA and N. Gorin (STScI) Acknowledgement: Judy Schmidt

arXiv:1506.03900

Astronomy 6th Edition. John D. Fix.

arXiv:1602.02771

http://voyages.sdss.org/filters/