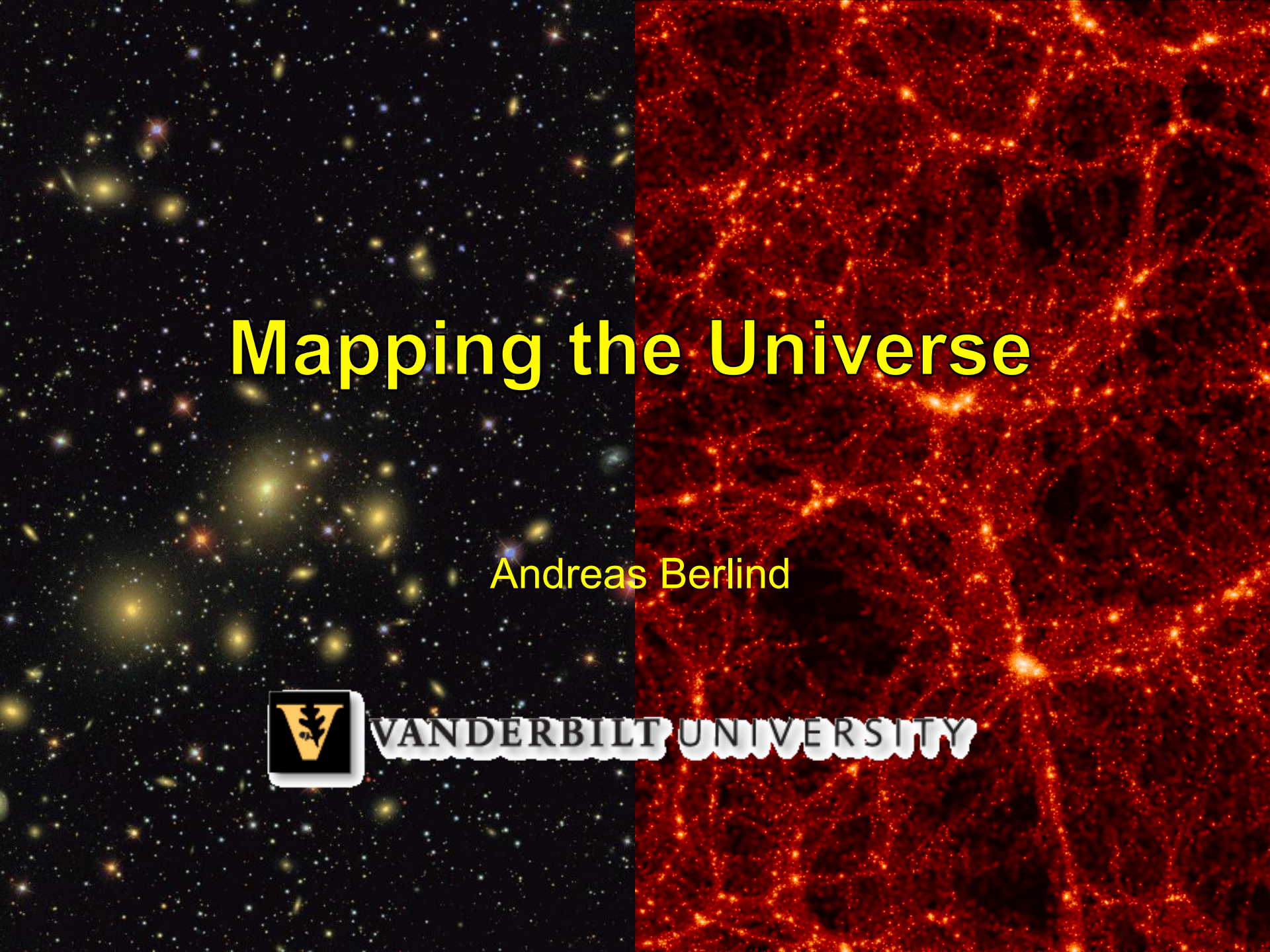
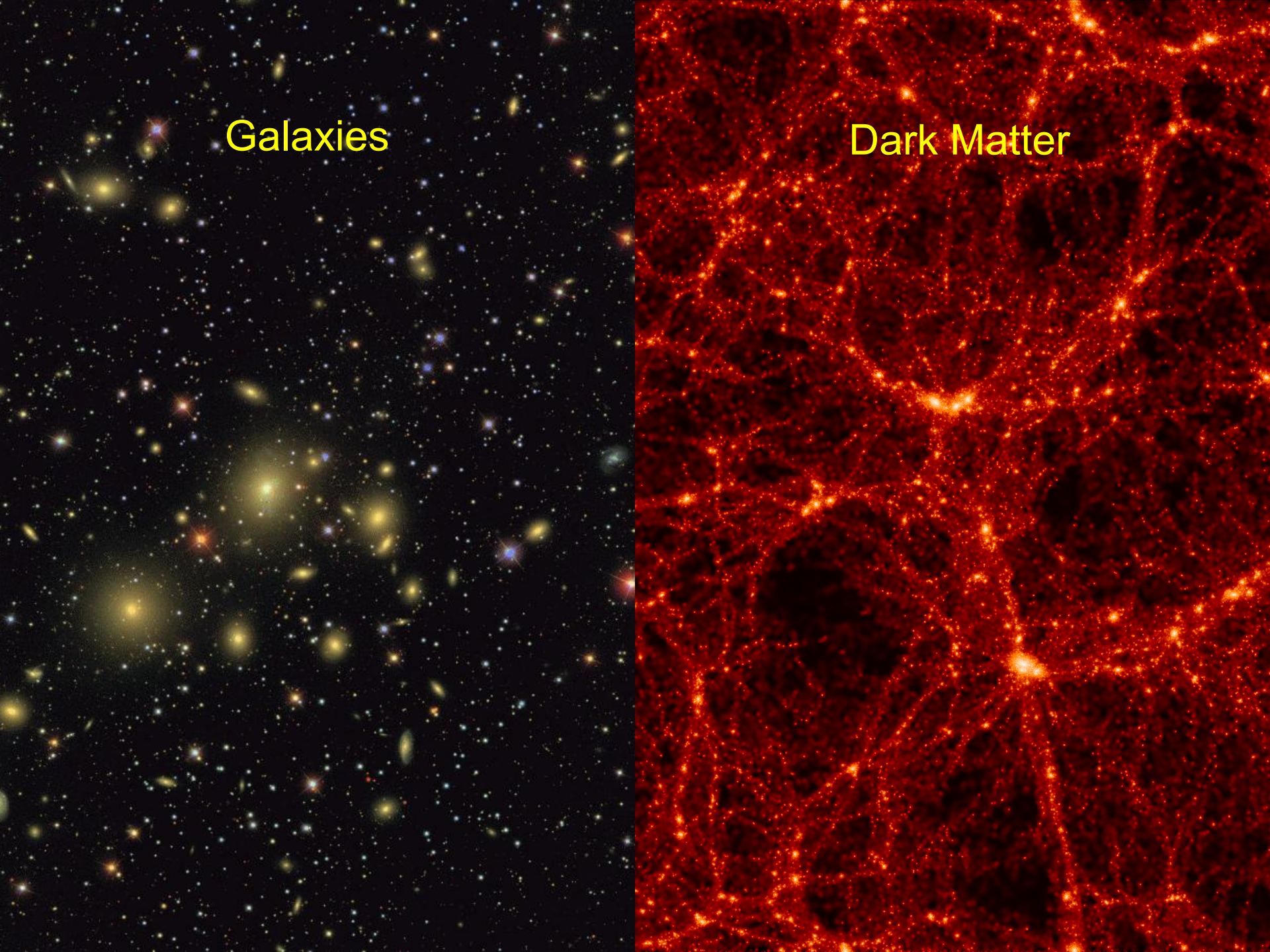


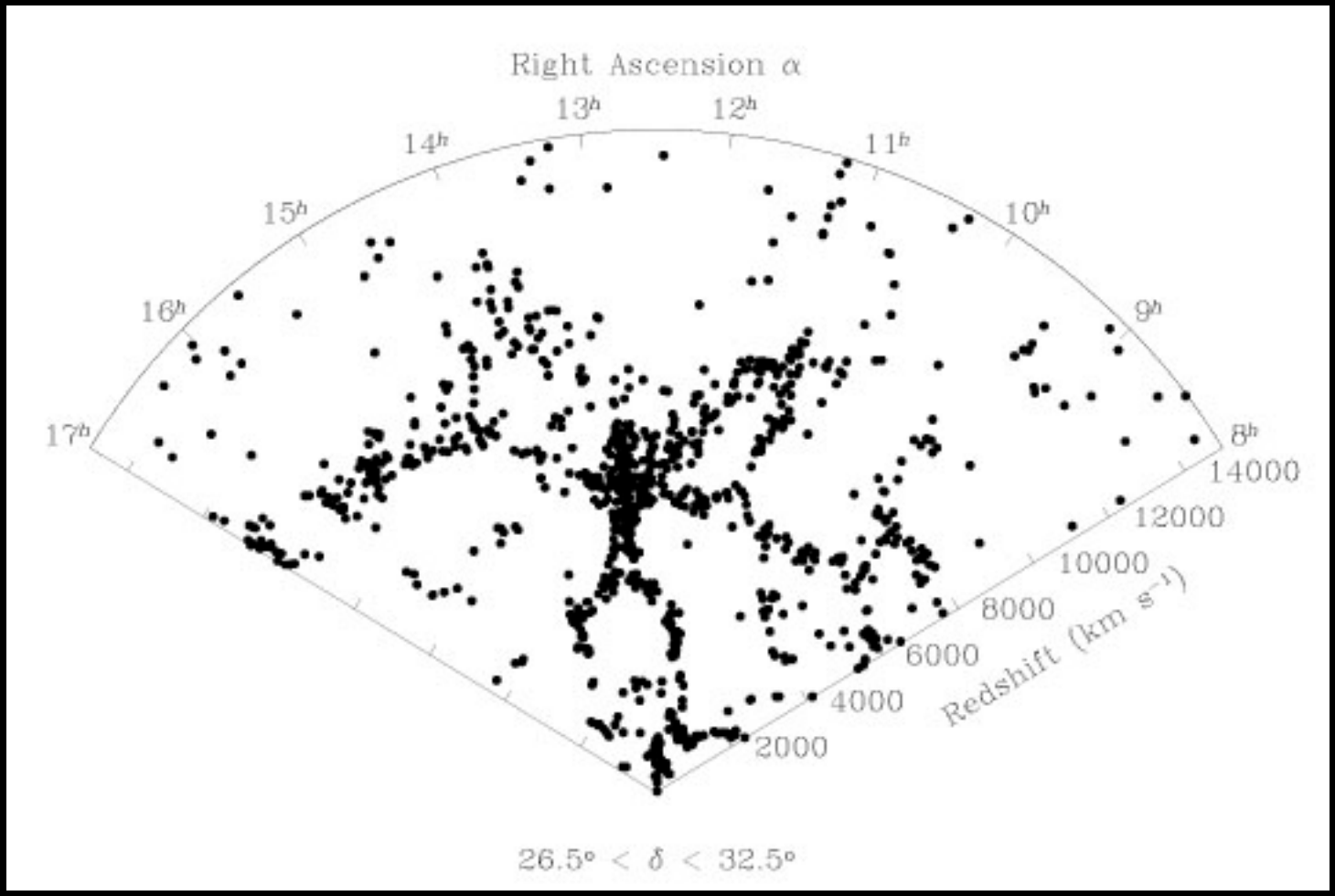
Mapping the Universe

Andreas Berlind

VANDERBILT UNIVERSITY


Galaxies
Dark Matter

Early 3-D Maps of the Universe



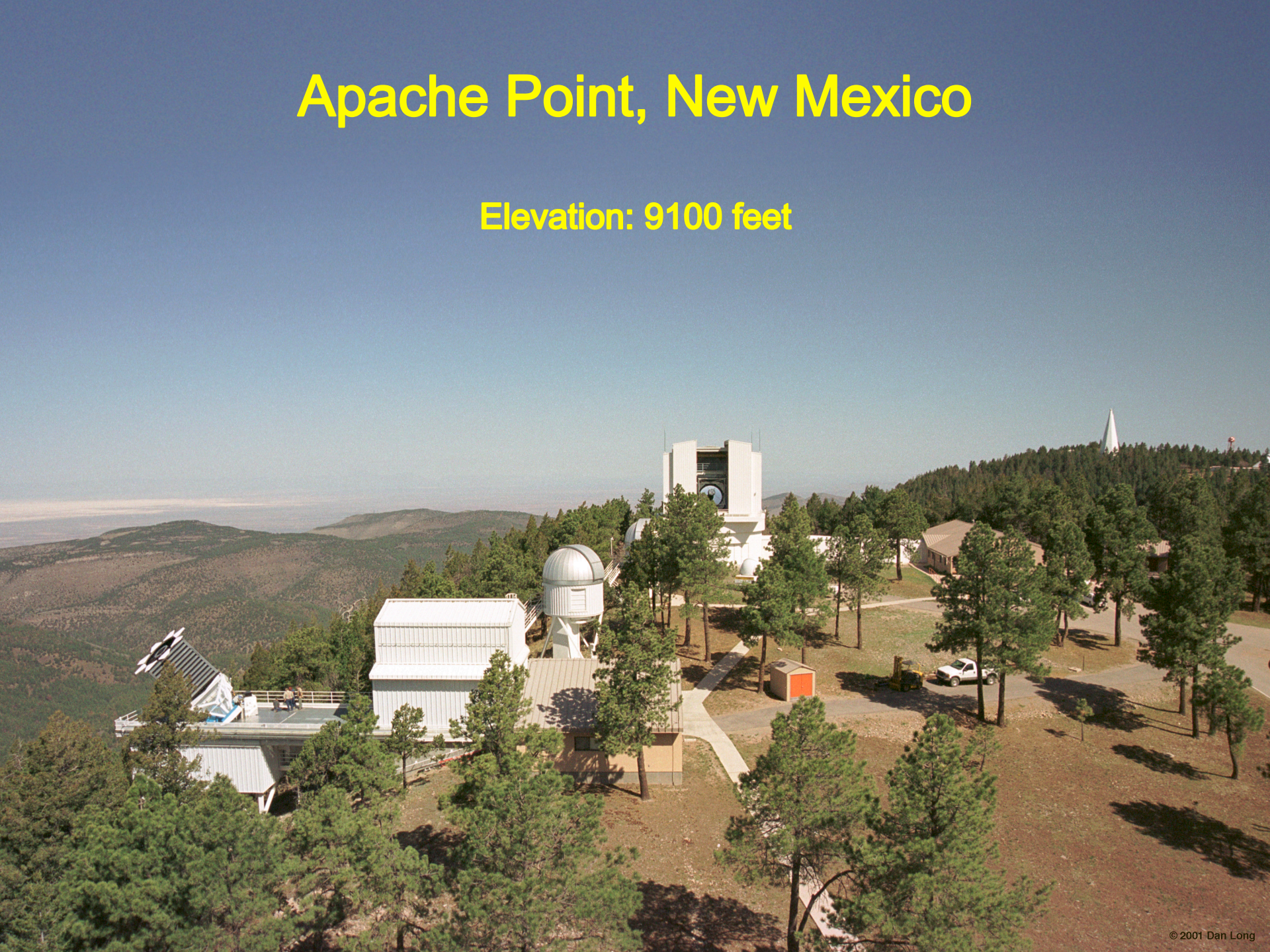
Sloan Digital Sky Survey

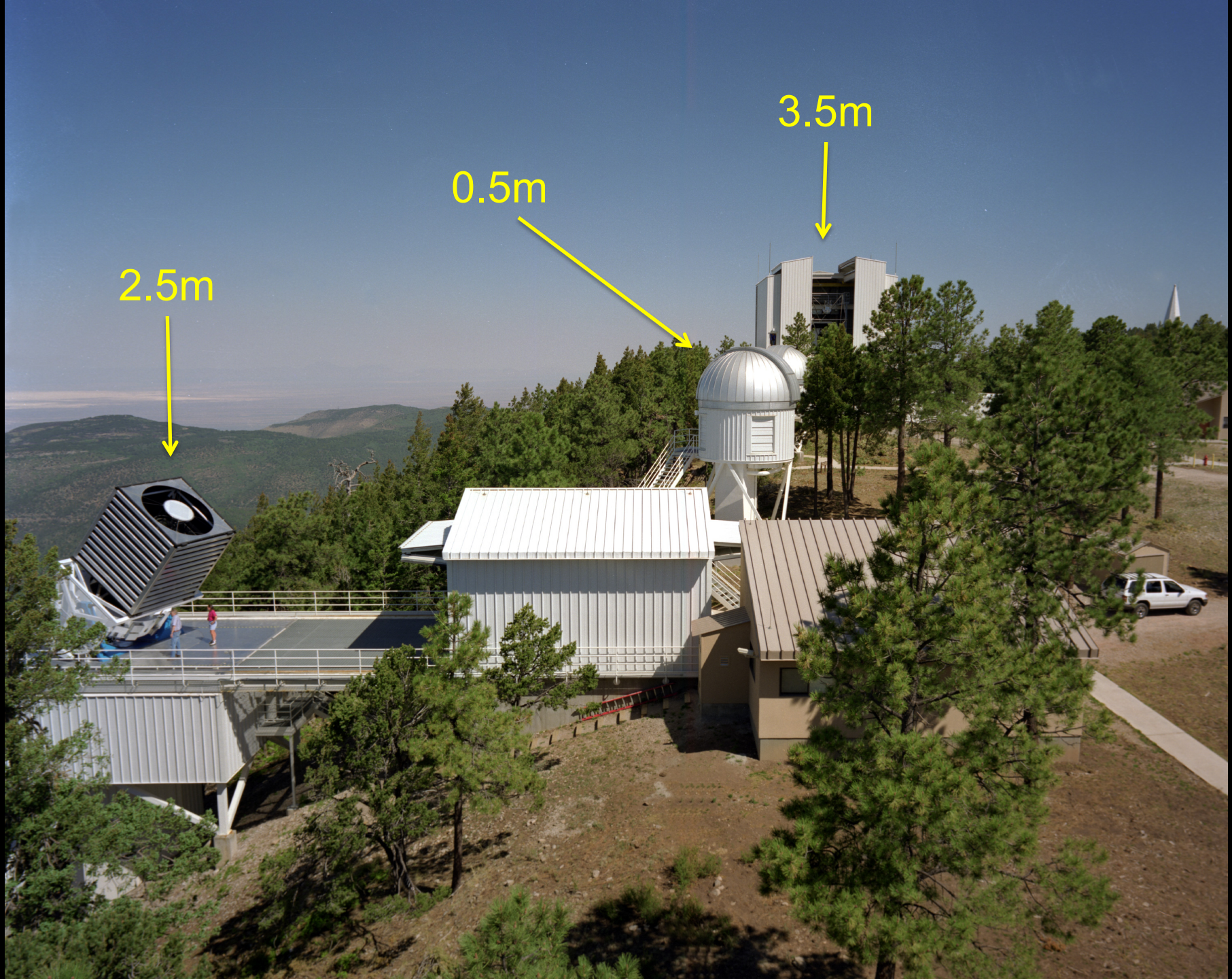
- 1988 - O'Hare airport meeting (U. Chicago, Princeton)
  Goal: to conduct a survey that would make a large 3D map of the universe (1 million galaxies).
- Apache Point, NM site selected
- 1992 - Alfred P. Sloan foundation made first commitment to project (total of $25 million)
- Eight universities join the project
  Today: 40 institutions with 200+ scientists
- Building of new telescope, camera, spectrograph
- 1998 - First light!
- 2000-2016 – Full survey operations

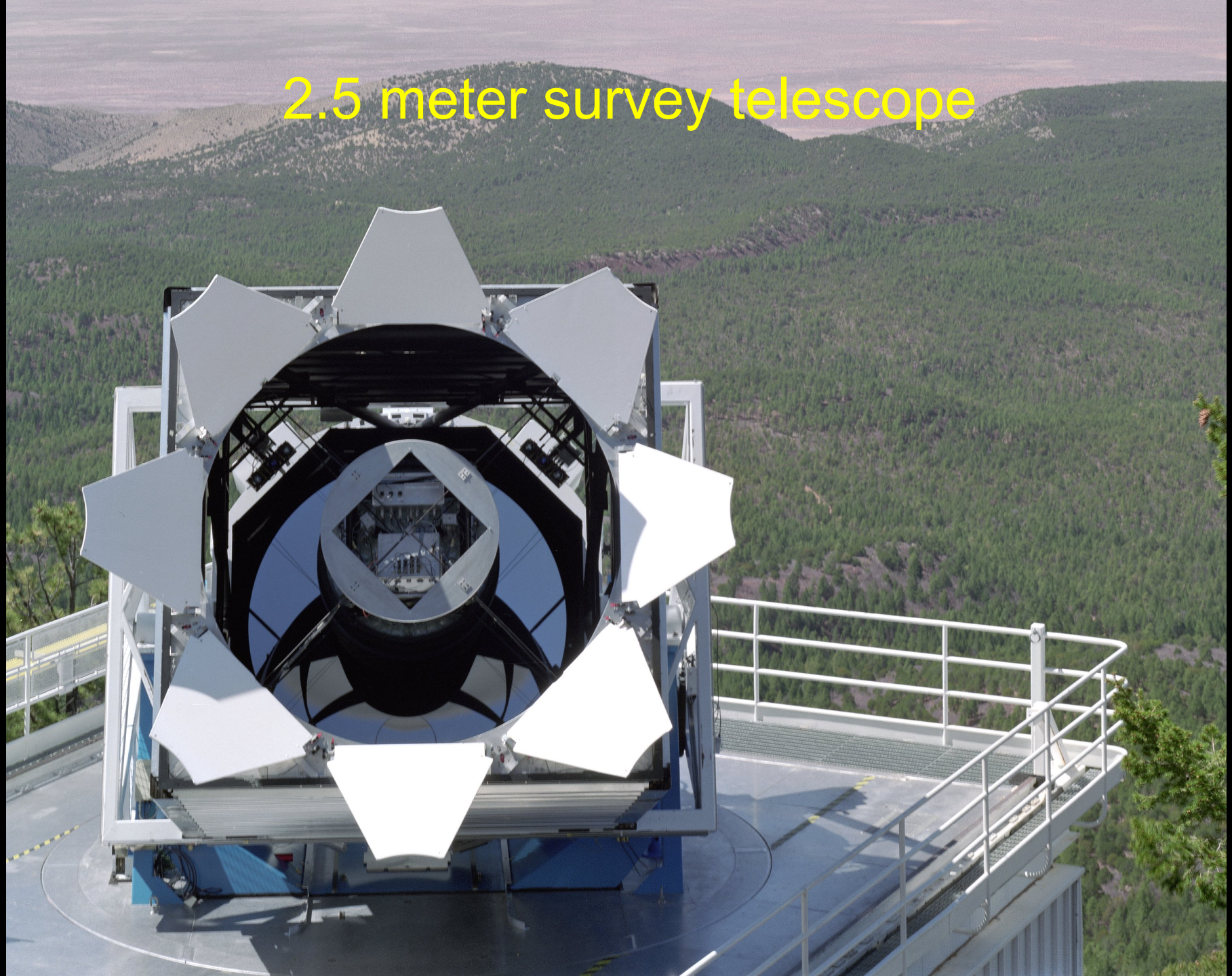

NEW MEXICO

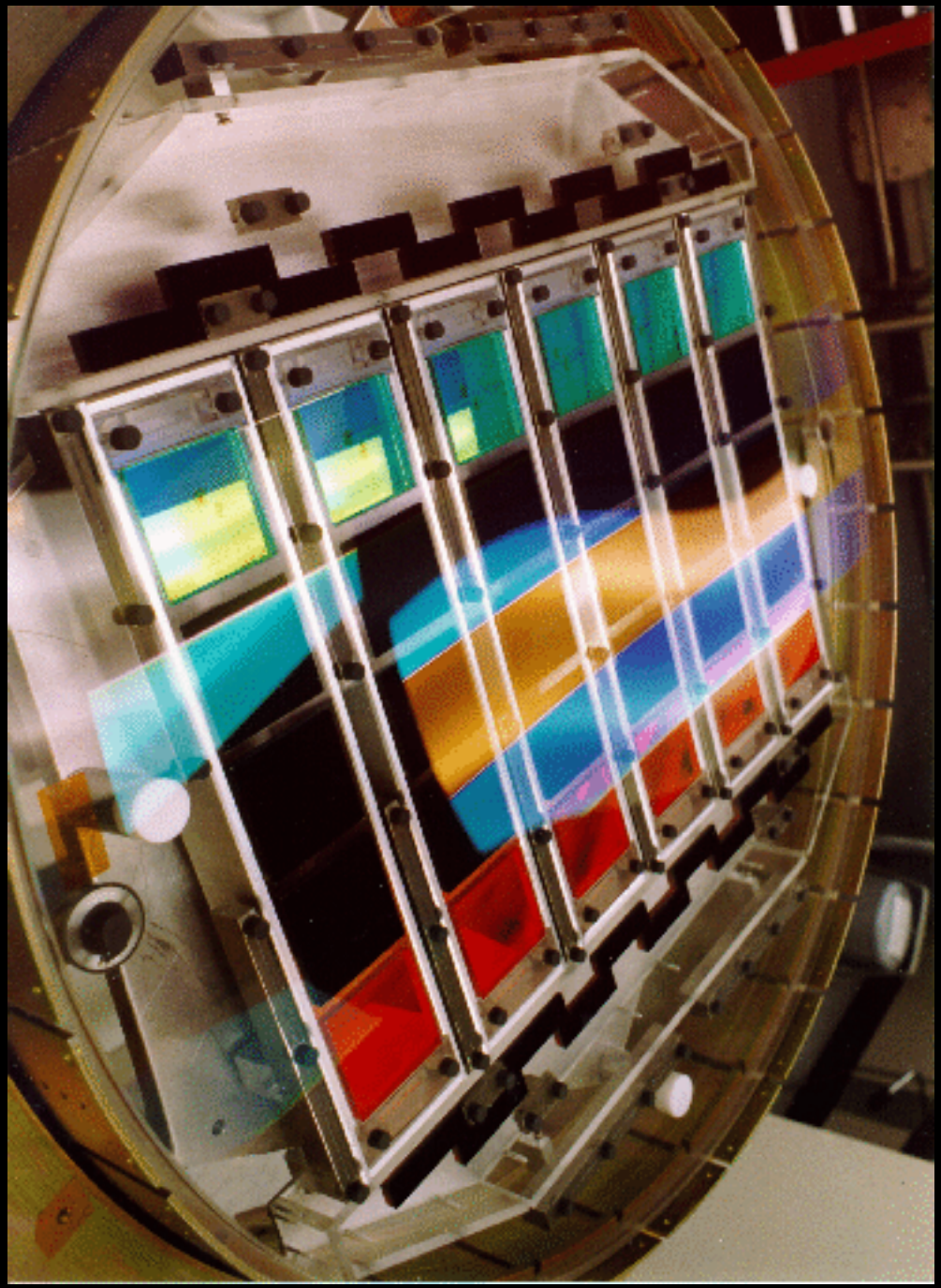
Apache Point, New Mexico

Elevation: 9100 feet




3.5m
0.5m
2.5m

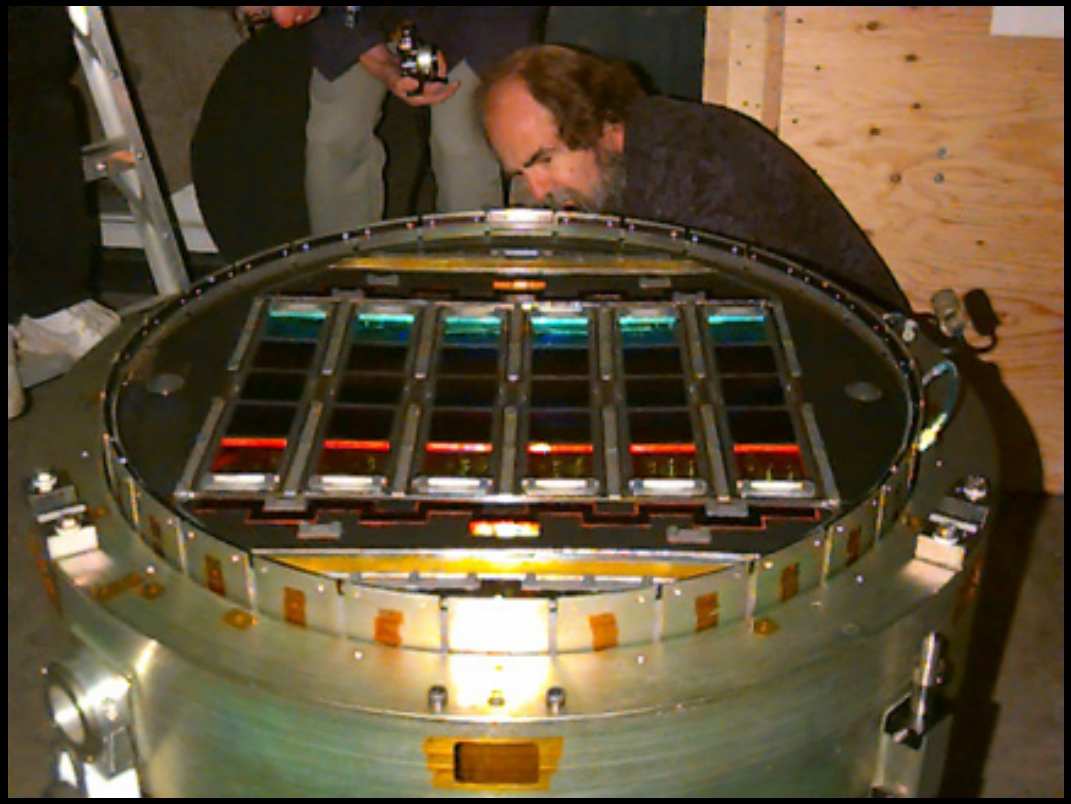

2.5 meter survey telescope



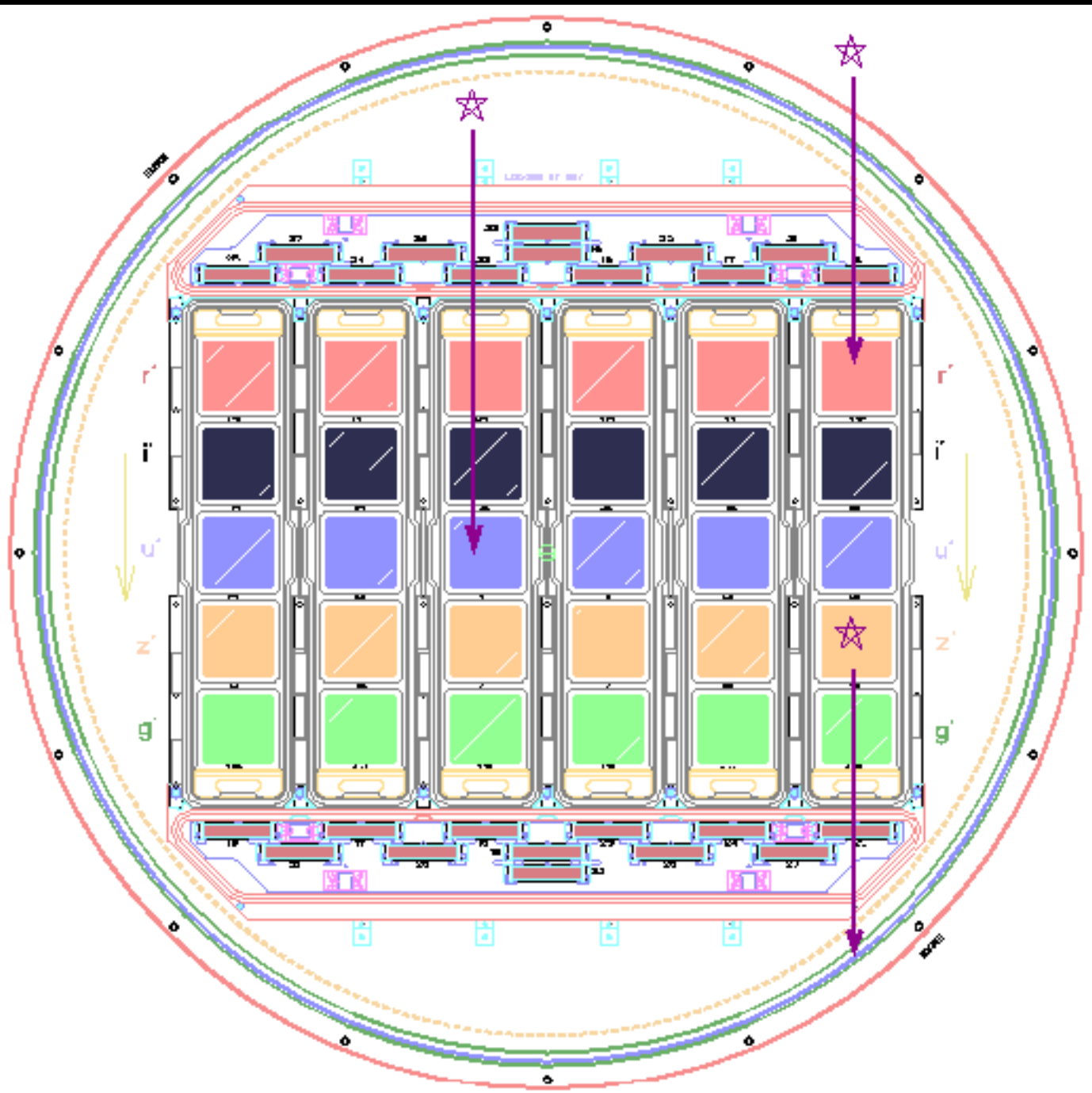
SDSS imaging camera

- 30 2048x2048 CCDs
- 5 color filters
- 126 megapixels!

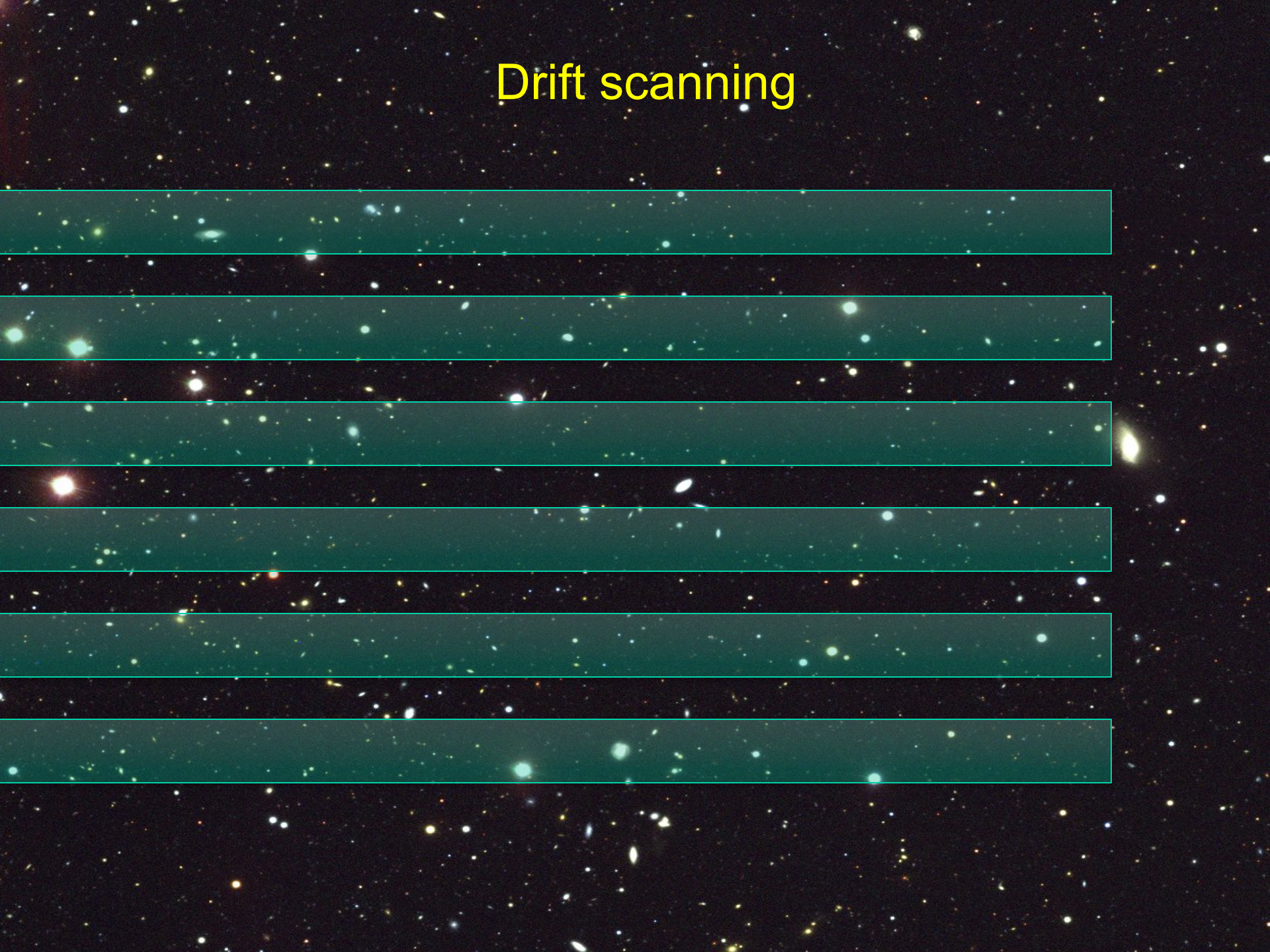
SDSS imaging camera



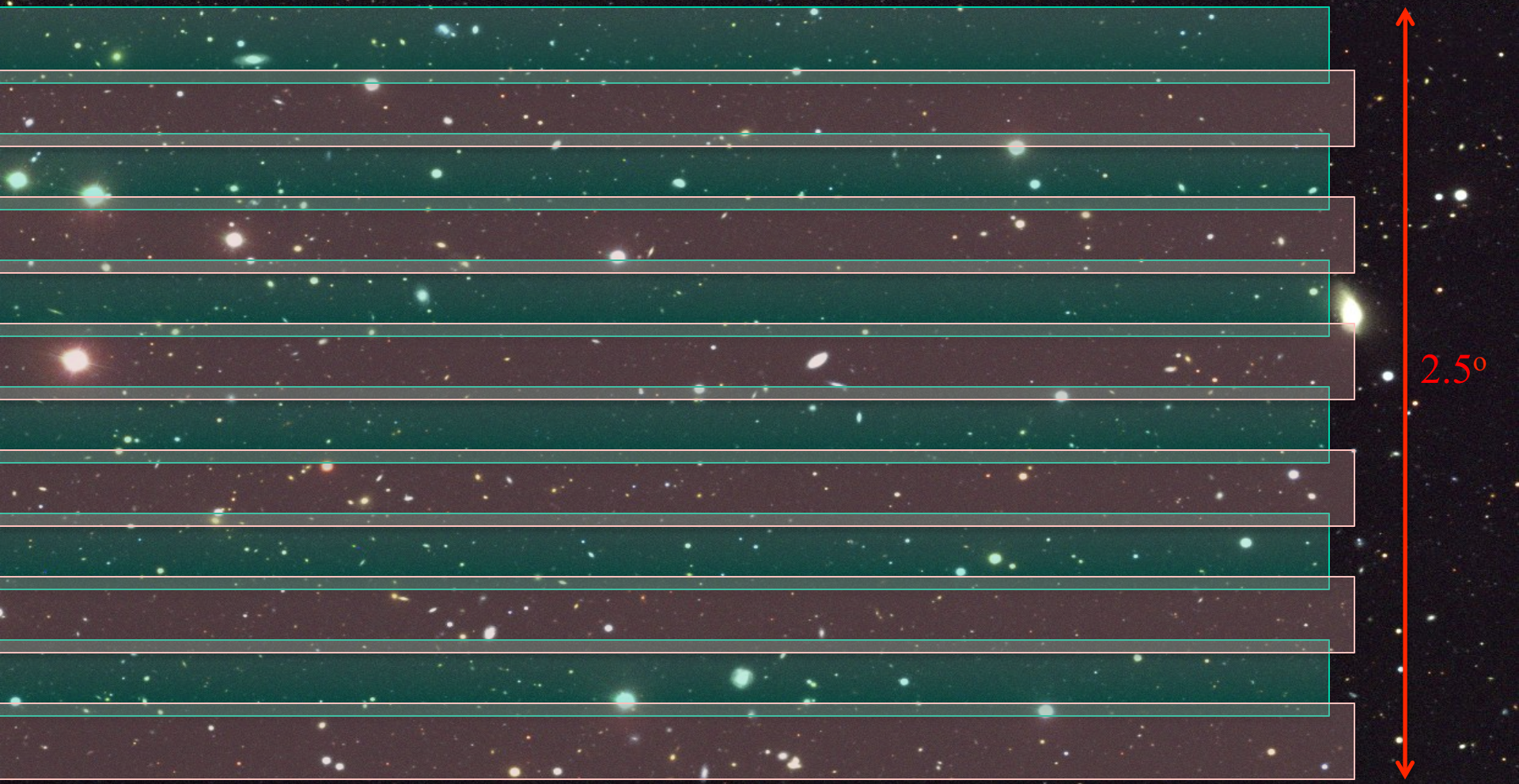
First light image! May 1998


r'
i'
u'
z'
g'
r'
i'
u'
z'
g'

Drift scanning

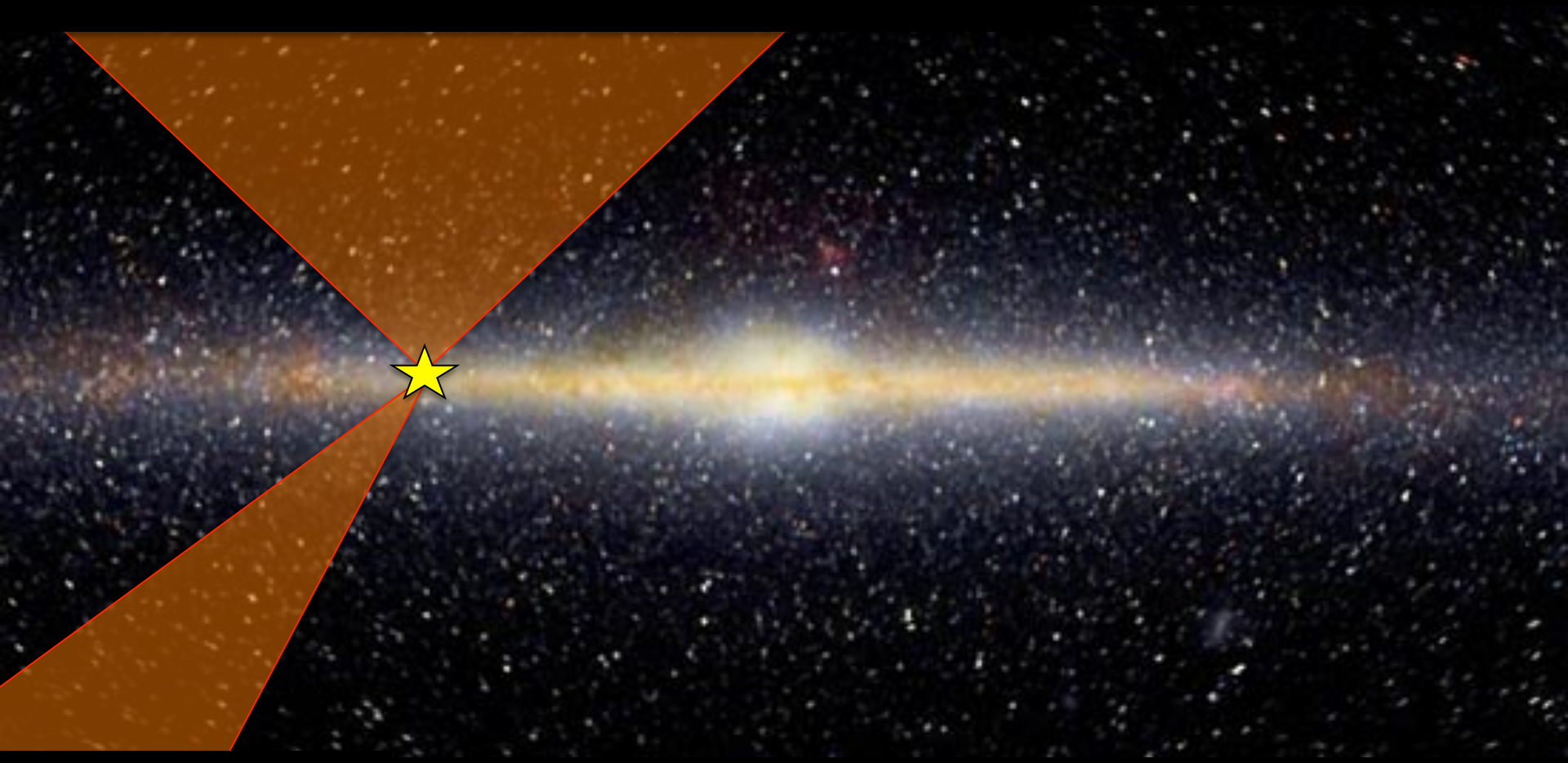


Drift scanning

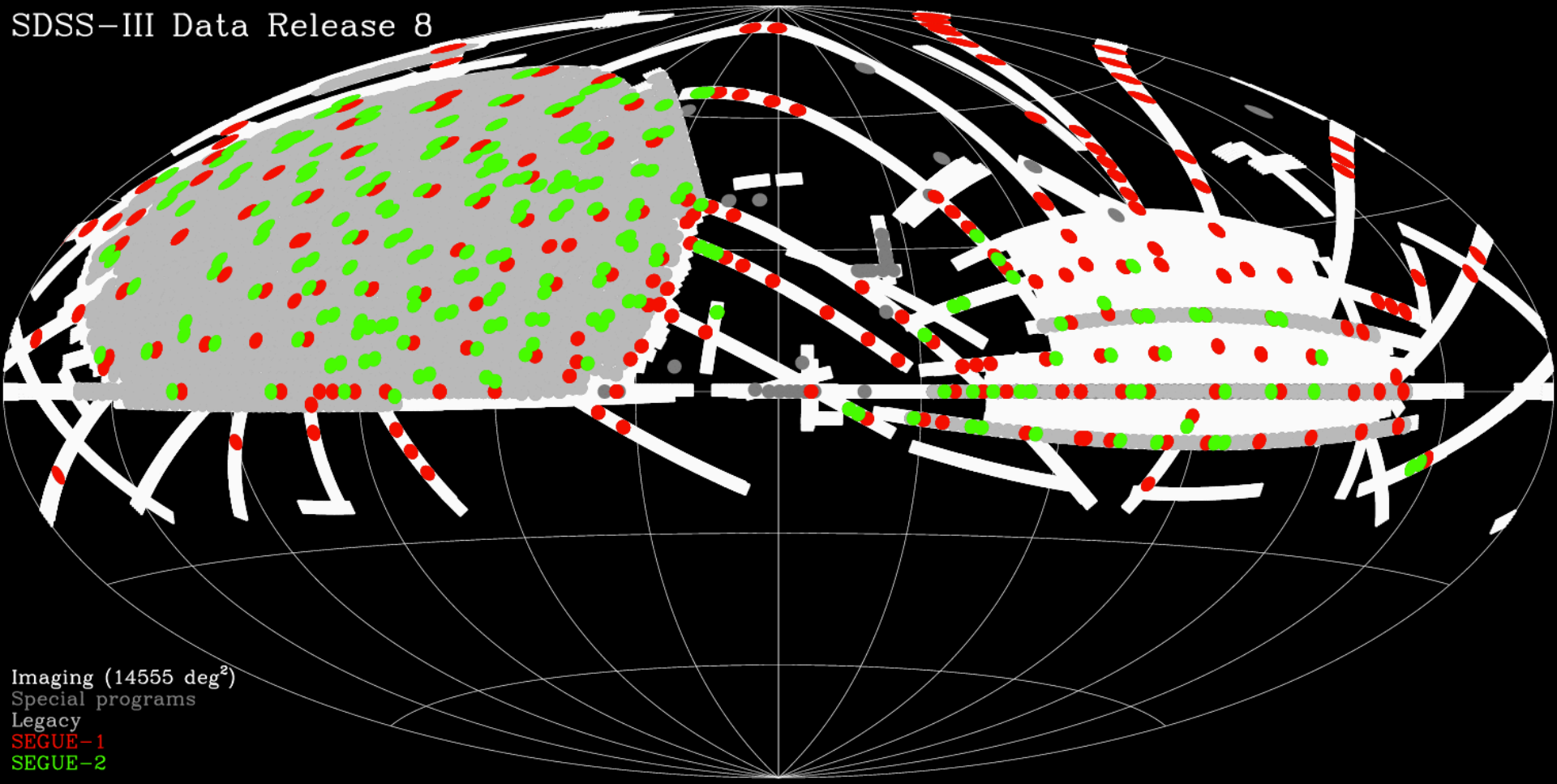


Drift scanning

2.5°

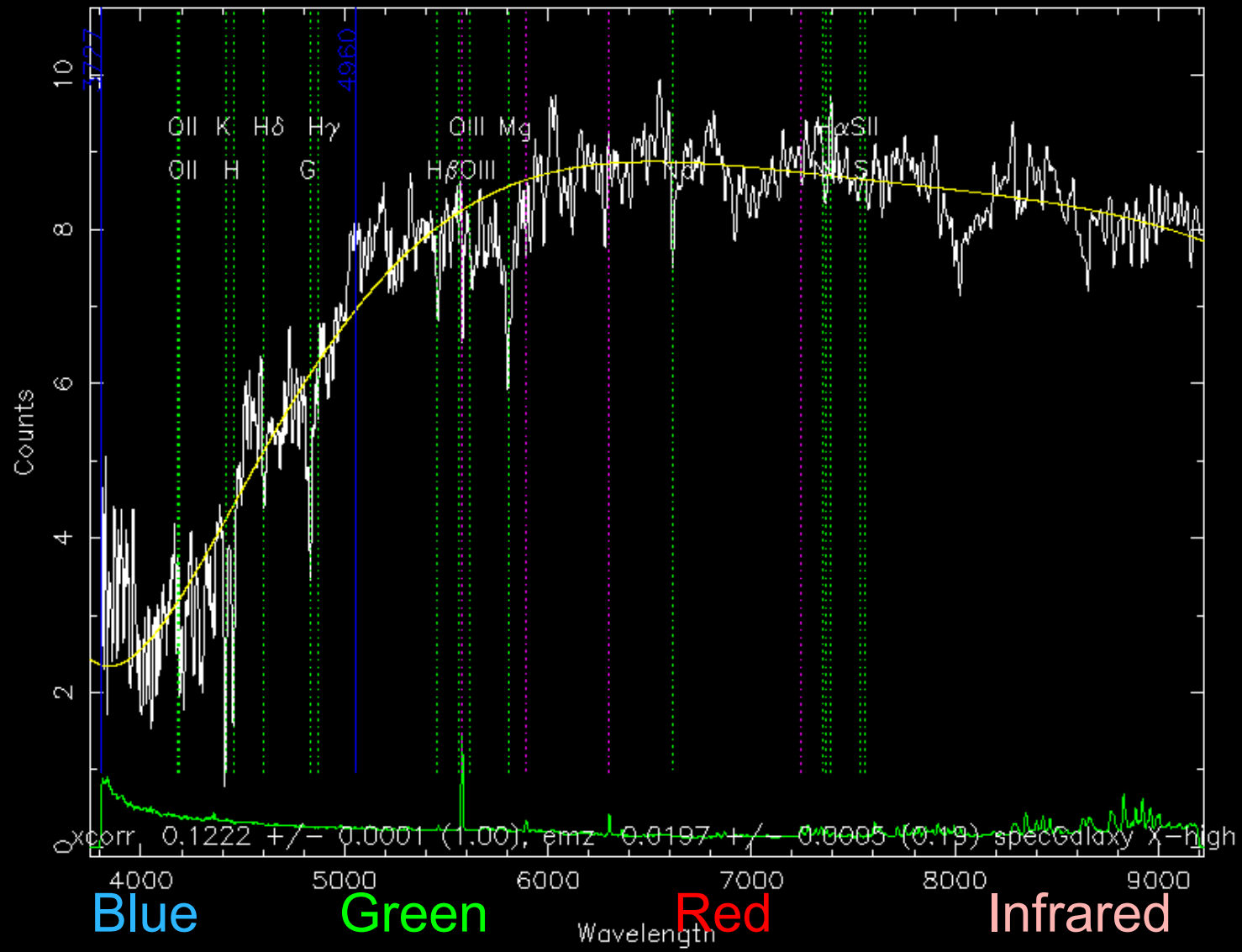


January 2011 500 million objects



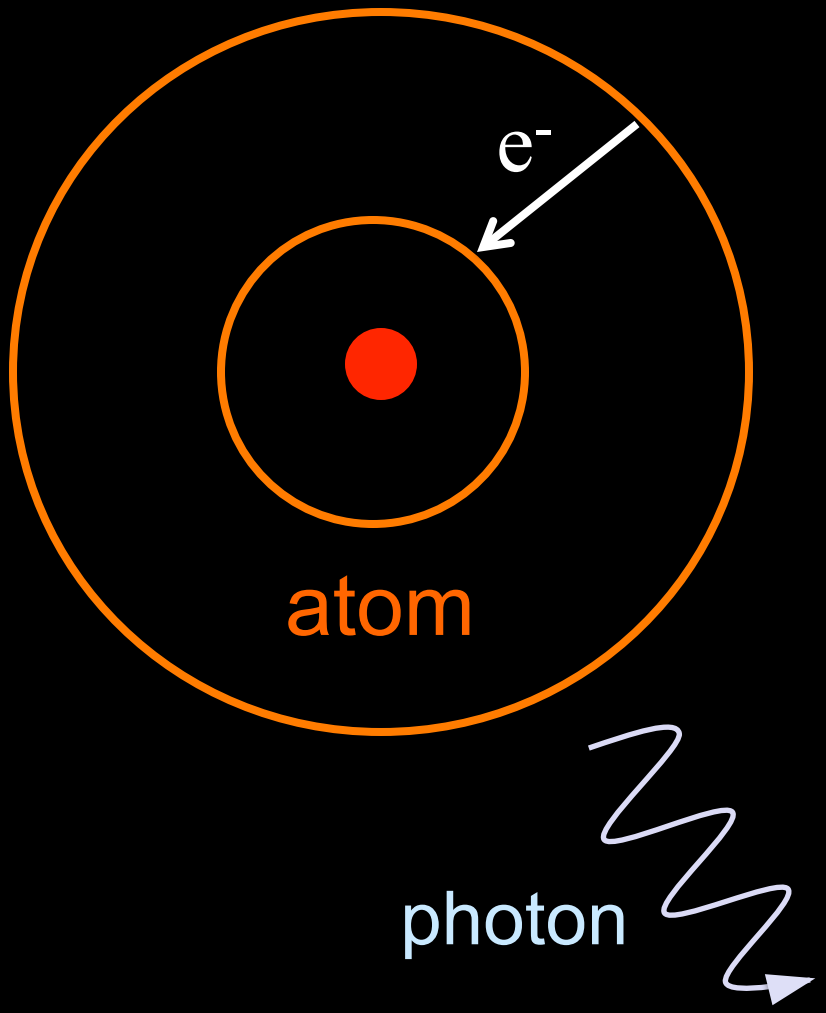

Perseus galaxy cluster

Spectrum

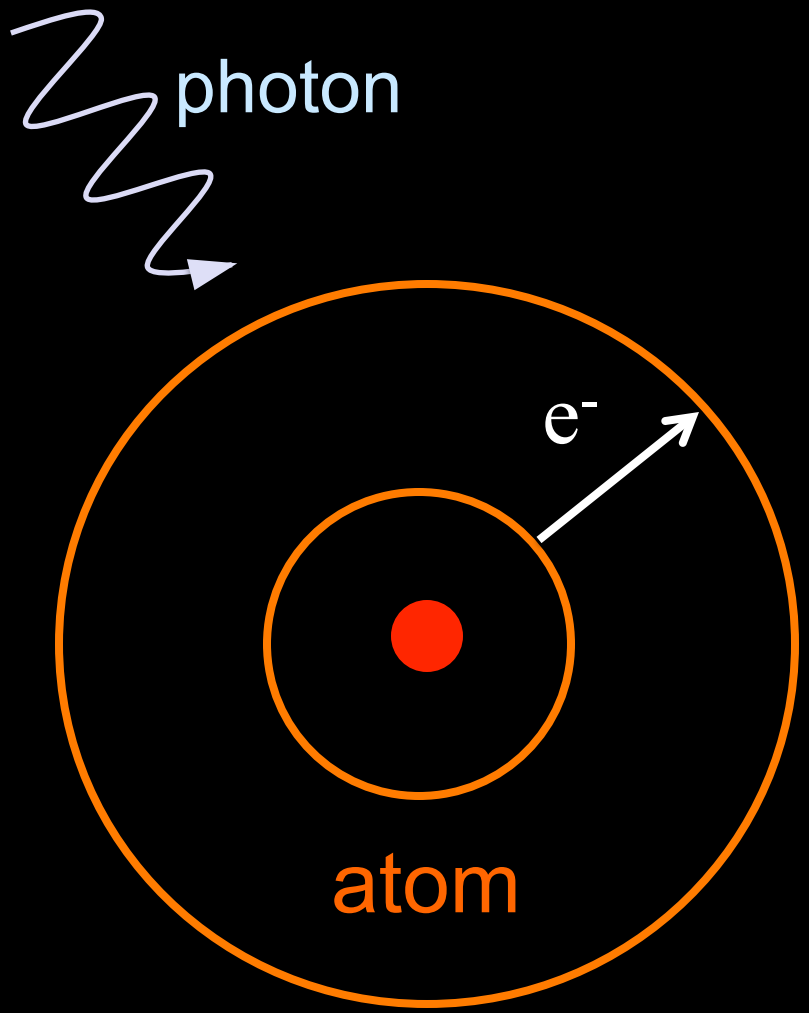


Wavelength of light

Emission of light

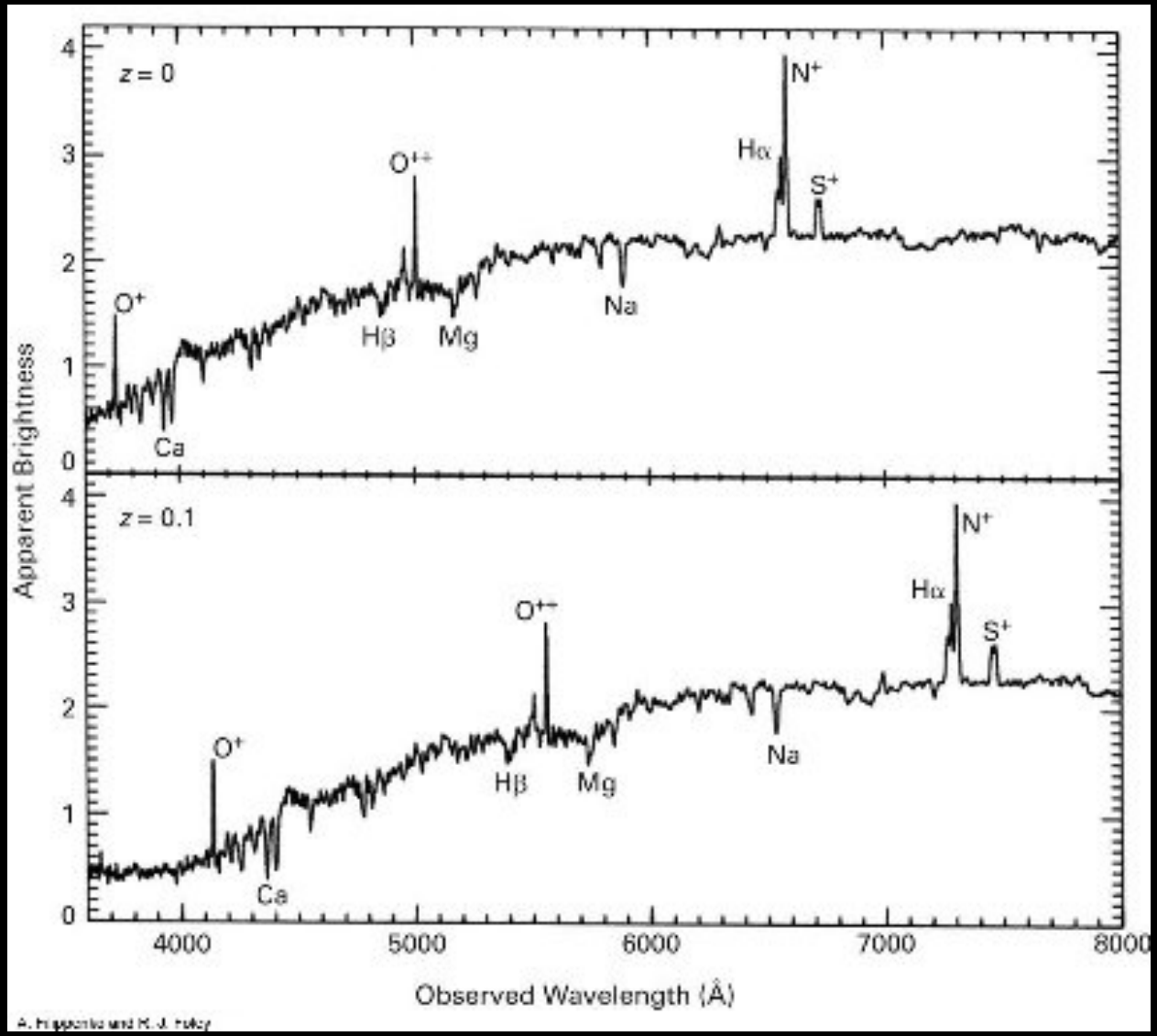


Absorption of light



The Expanding Universe

A galaxy's spectrum can tell us how far away it is.



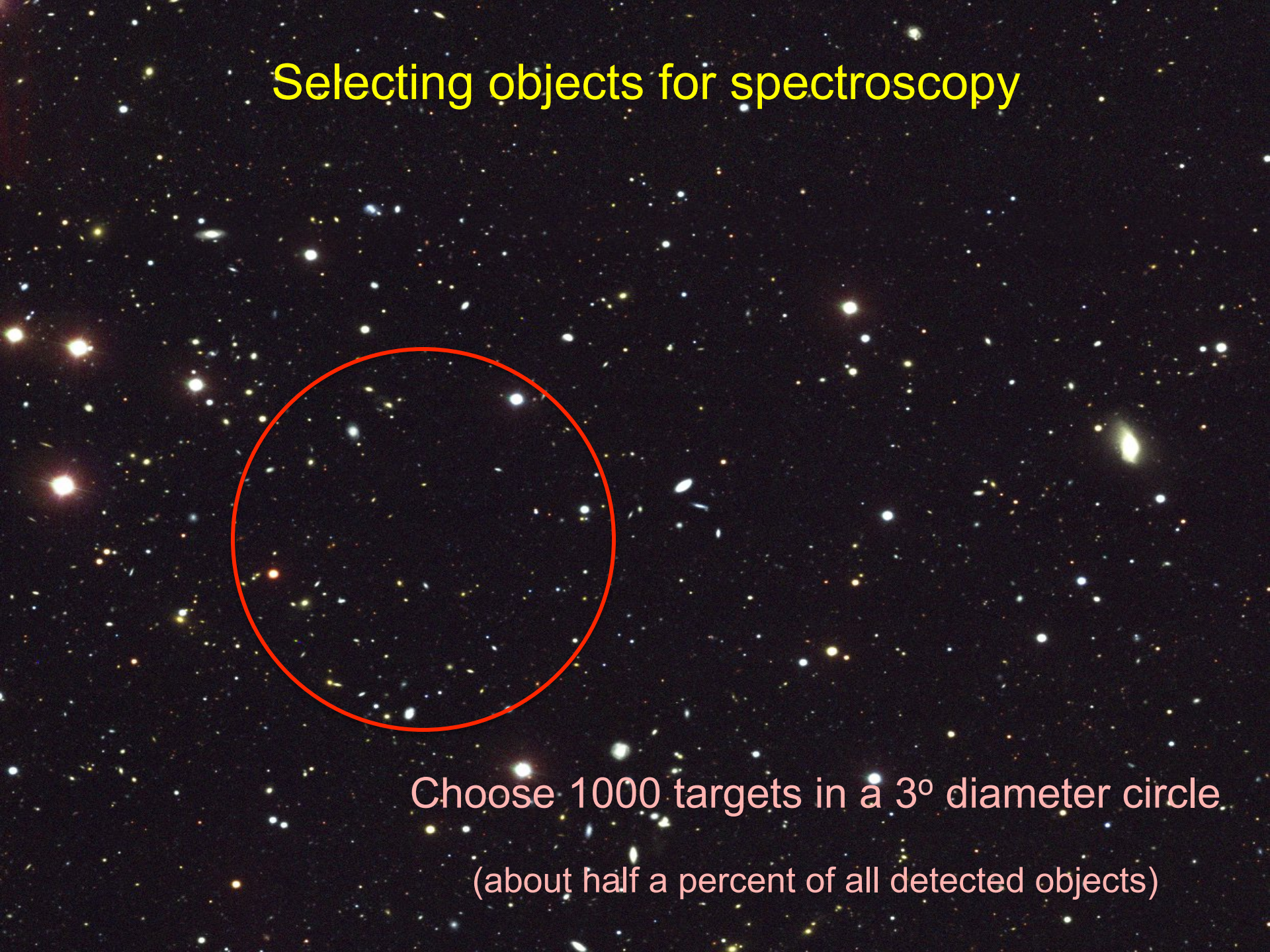
Nearby

Distant

Blue

Red

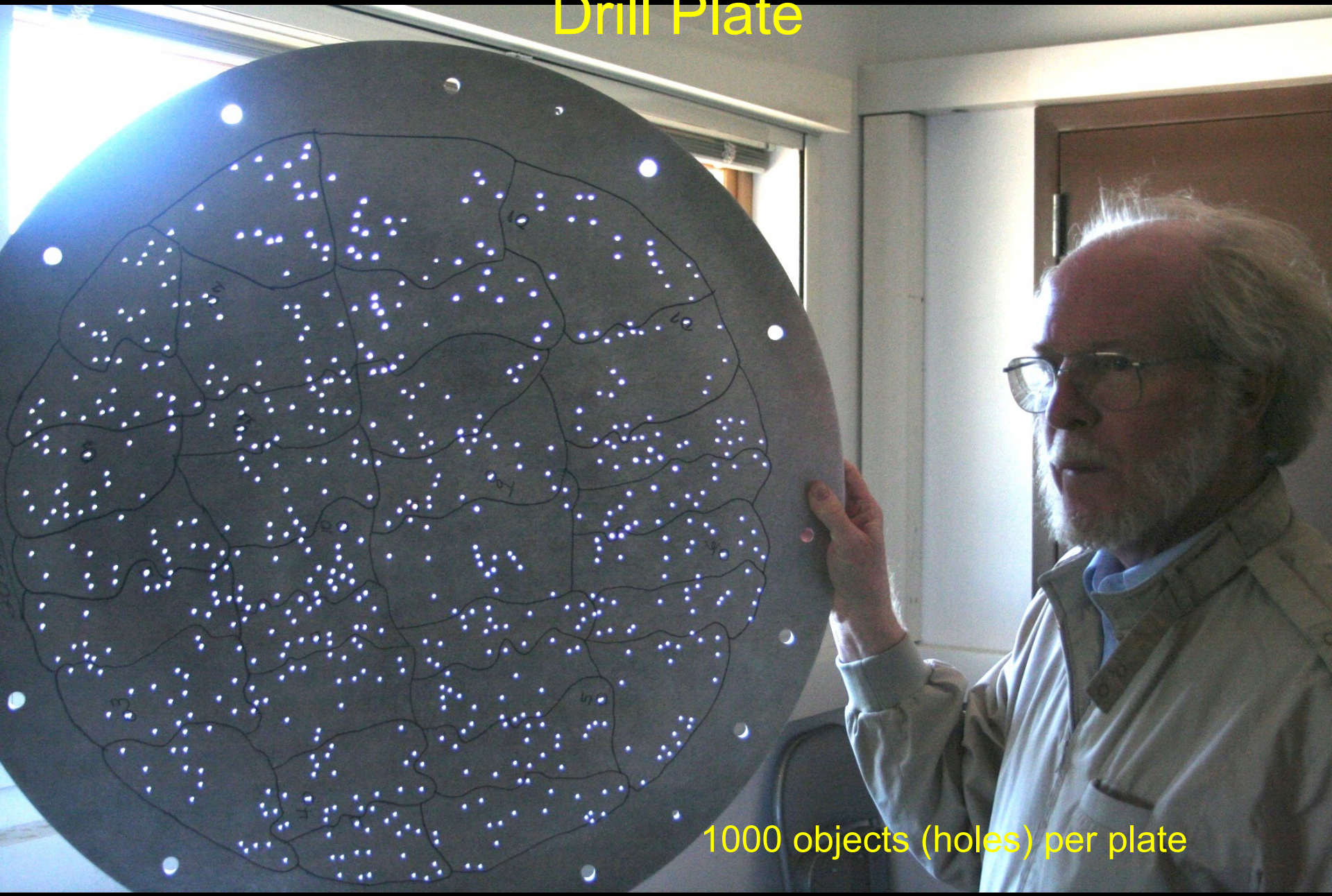
Selecting objects for spectroscopy



Choose 1000 targets in a 3^{o} diameter circle

(about half a percent of all detected objects)

Drill Plate

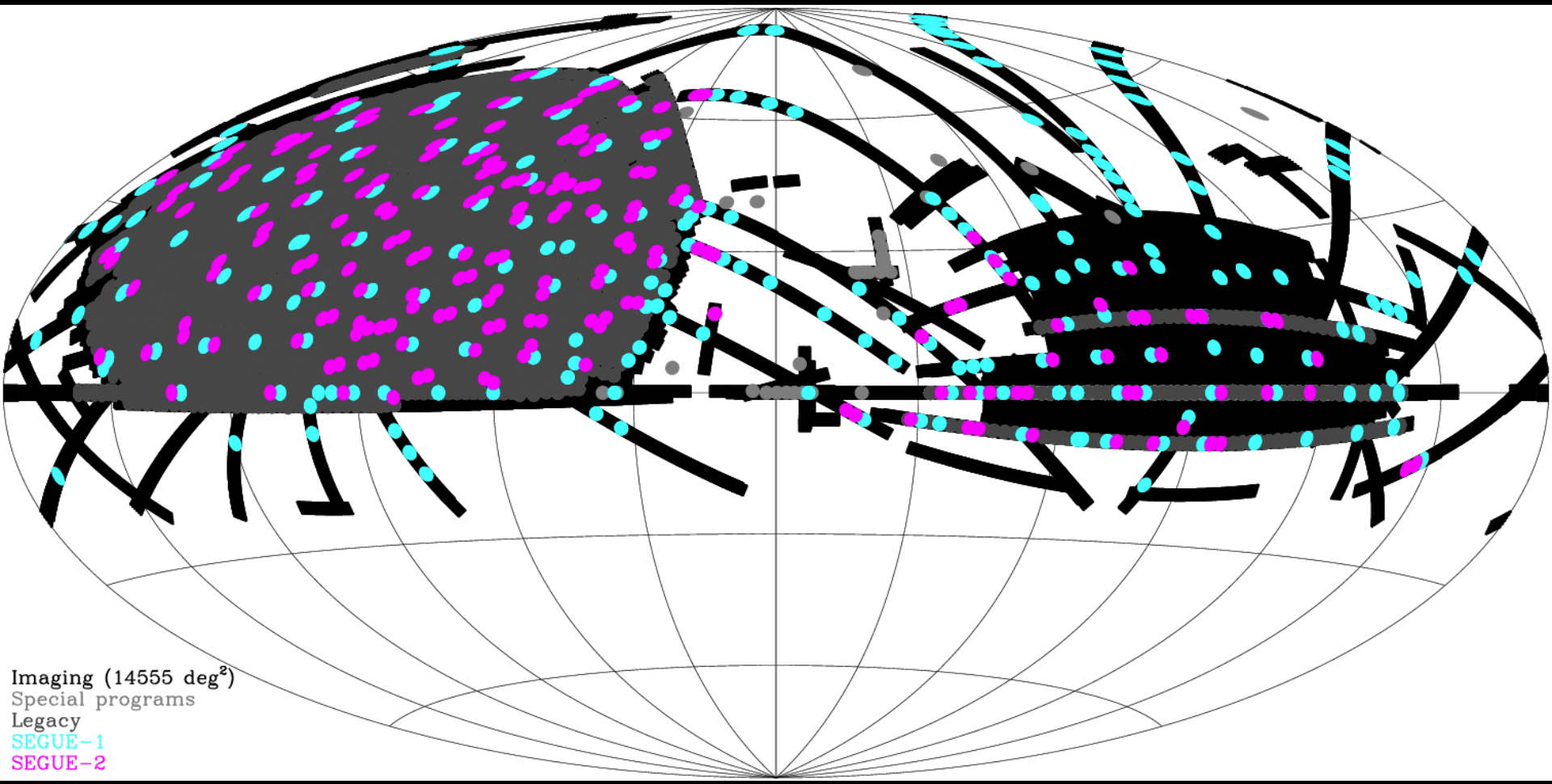


1000 objects (holes) per plate

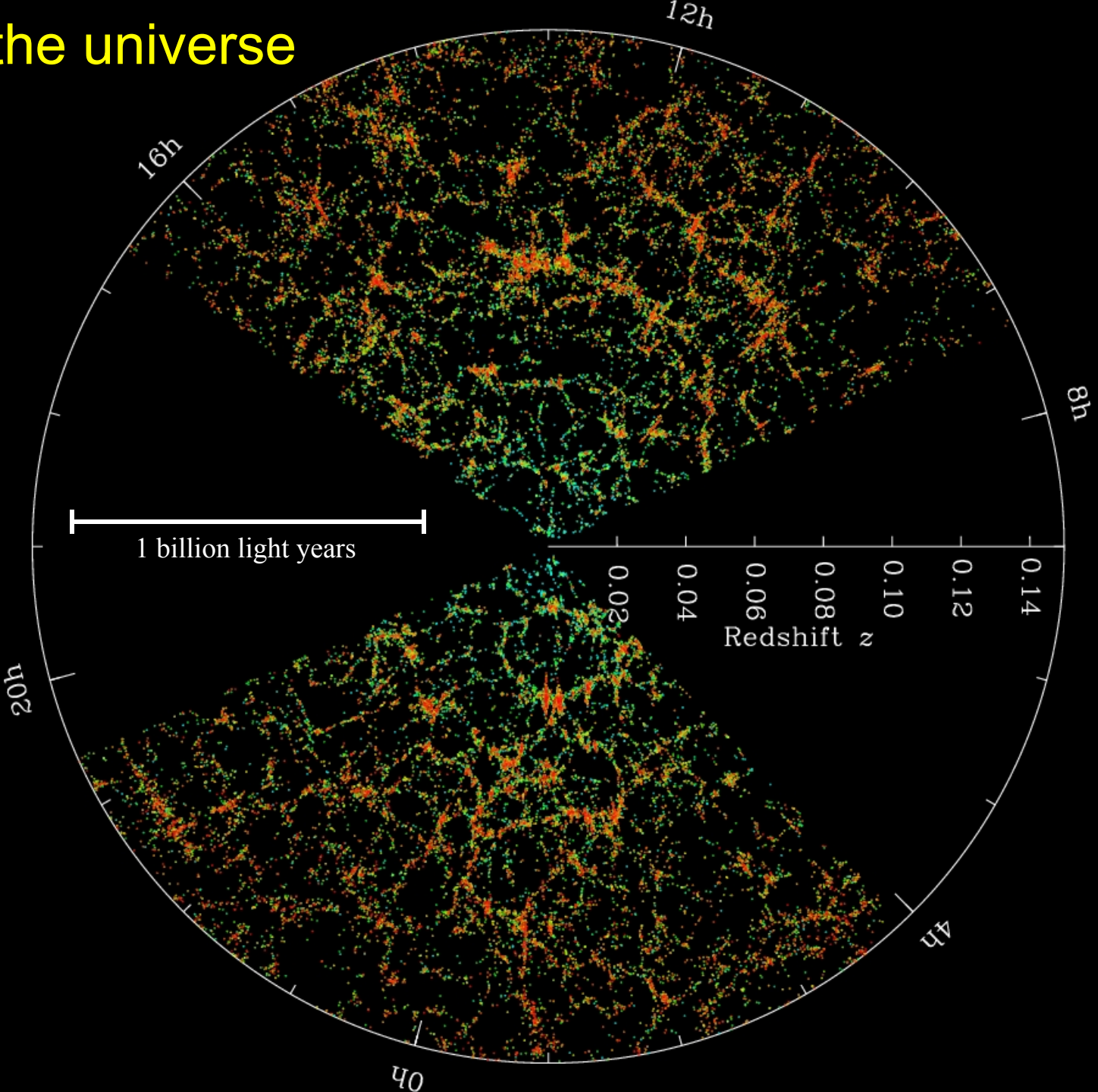
Fiber-optic cables


Over 2500 plates!

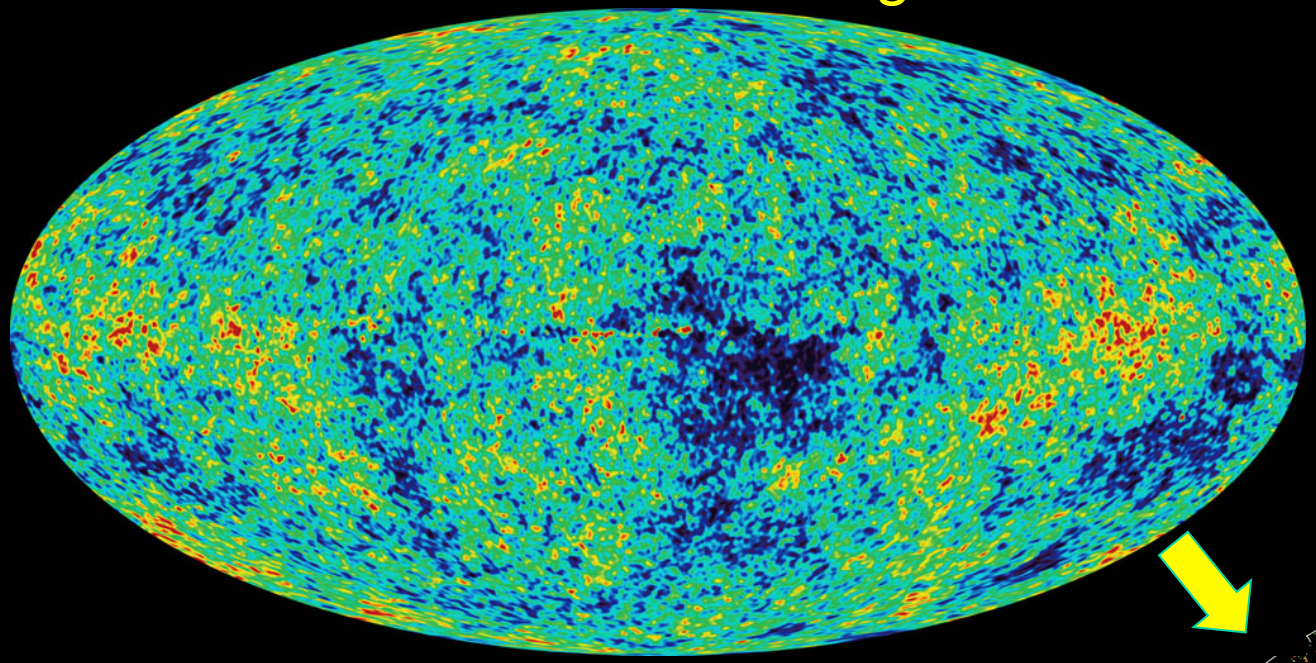
January 2015 4 million spectra



A map of the universe

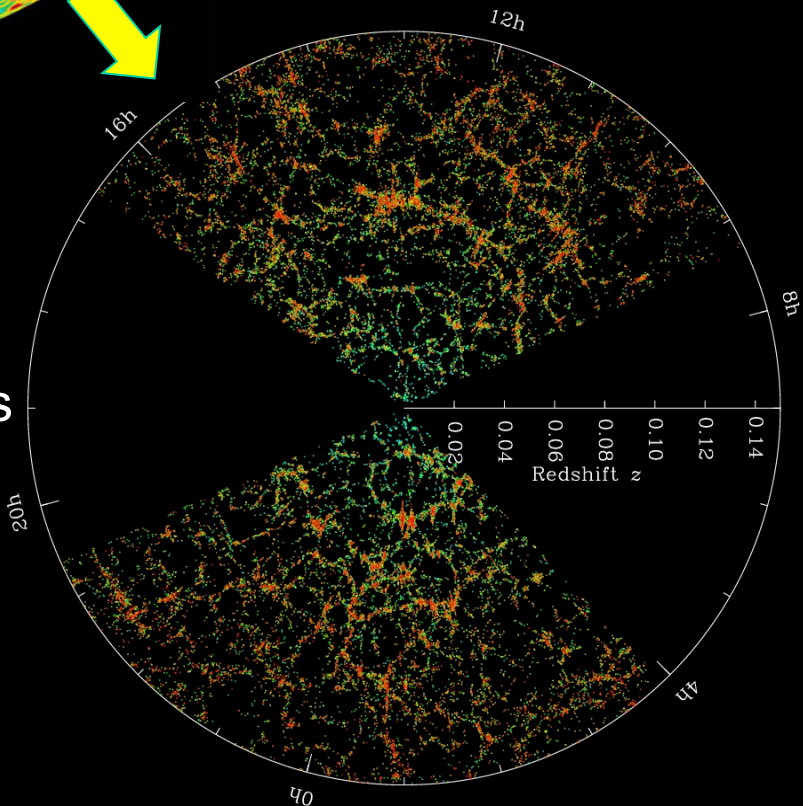


Cosmic Microwave Background

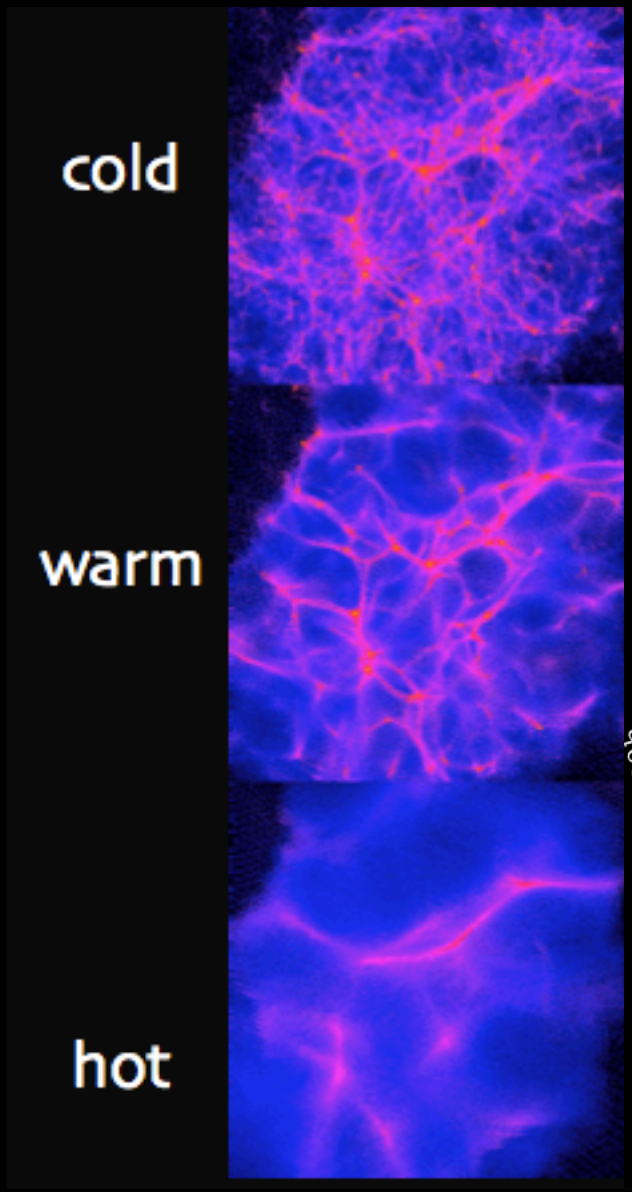


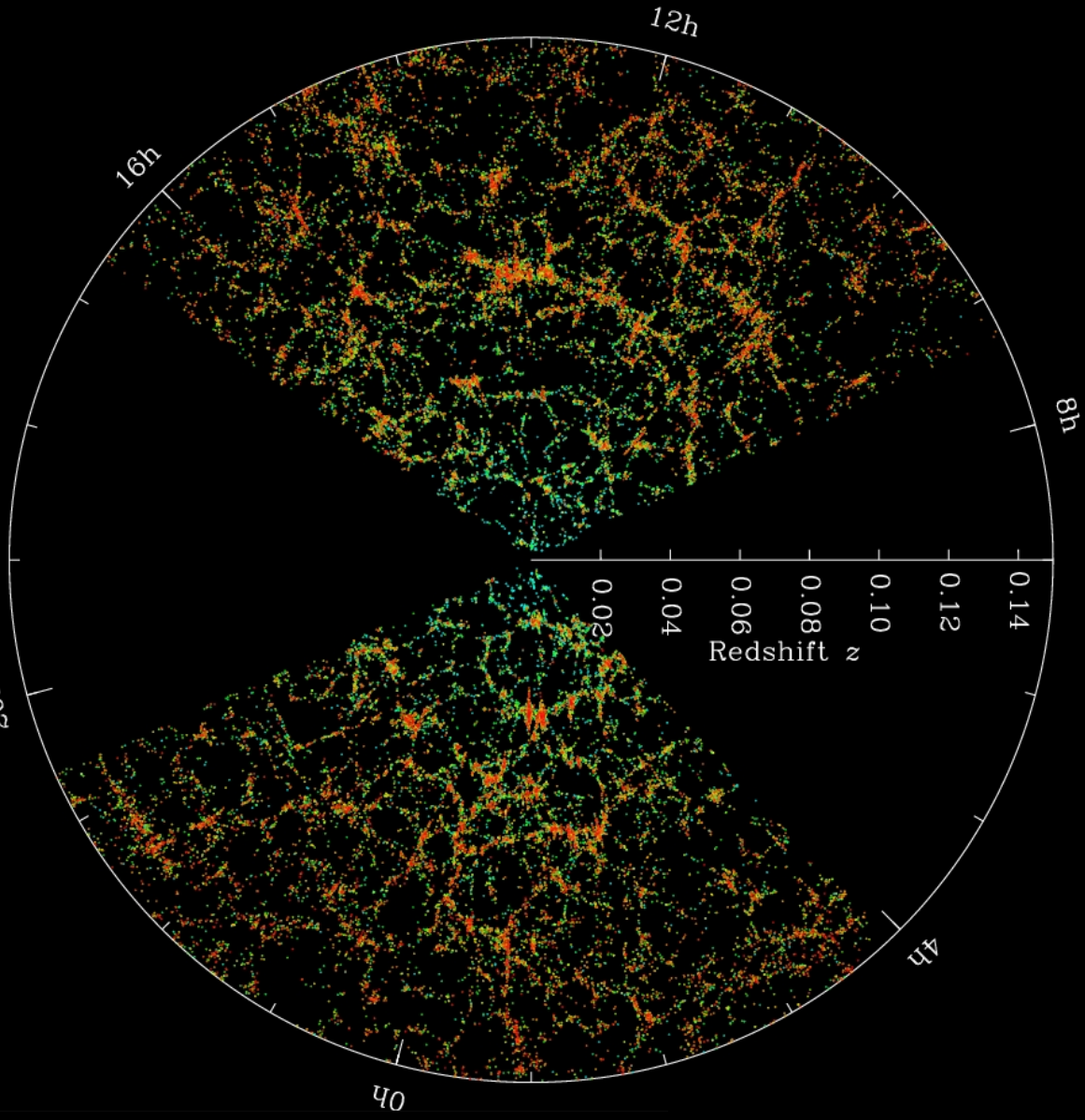
300,000 years
after Big Bang

14.6 billion years
after Big Bang

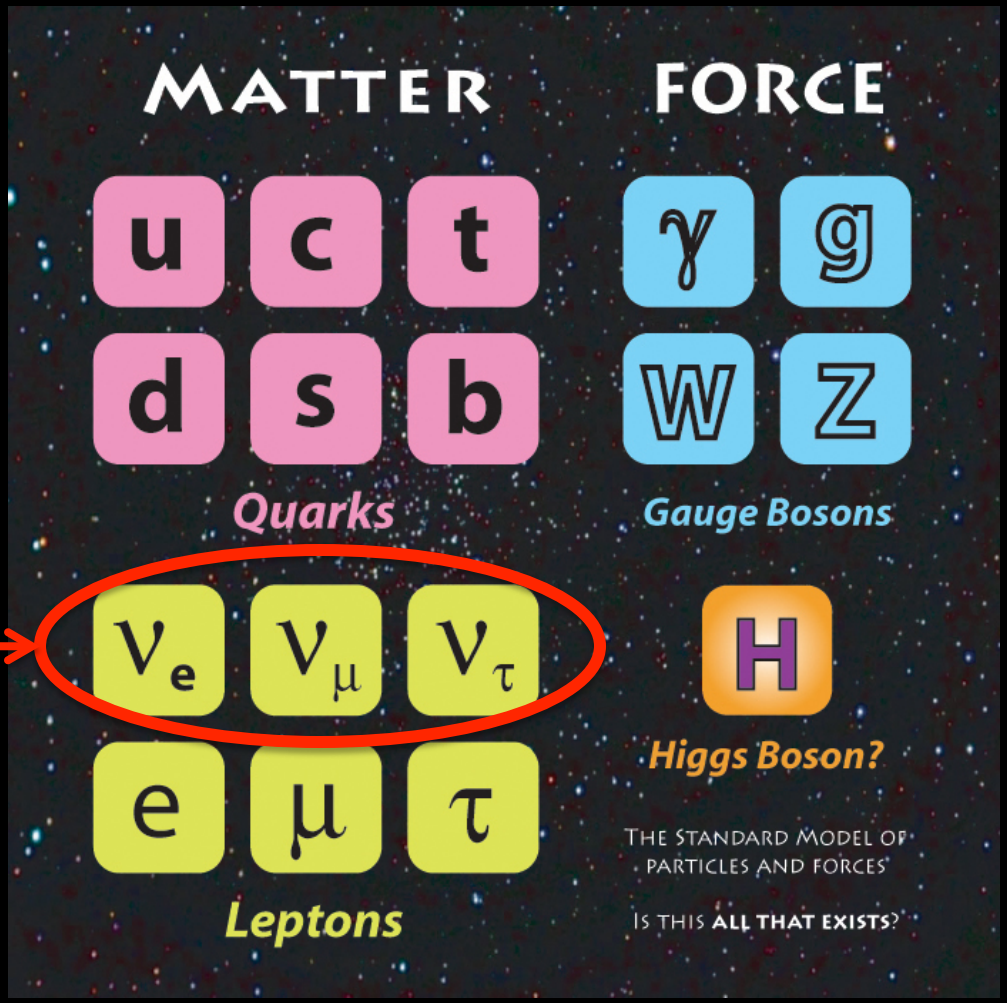


Neutrinos are ruled out as dark matter!





What Is Dark Matter Made Of ?



The Standard Model of Particle Physics