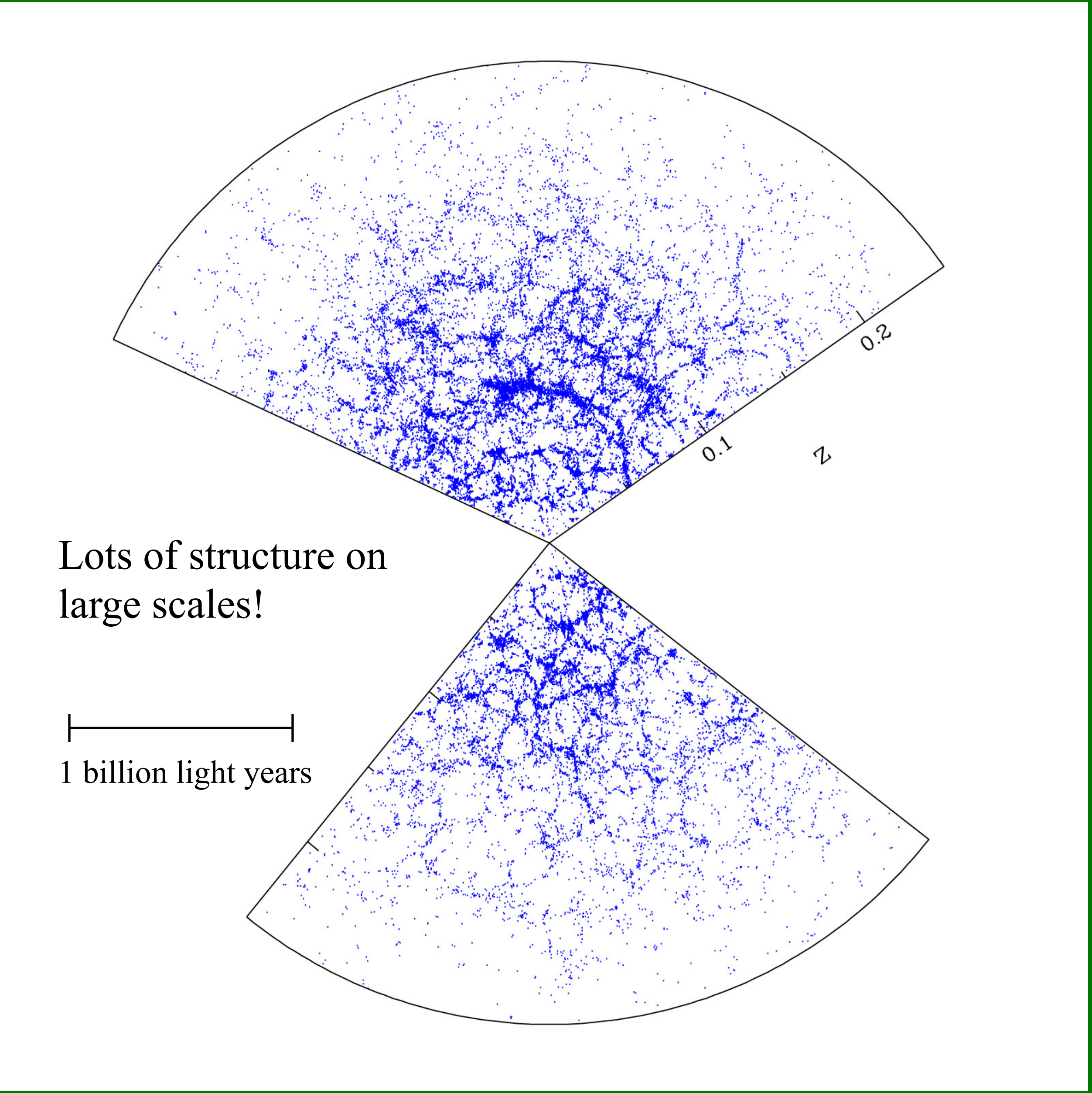
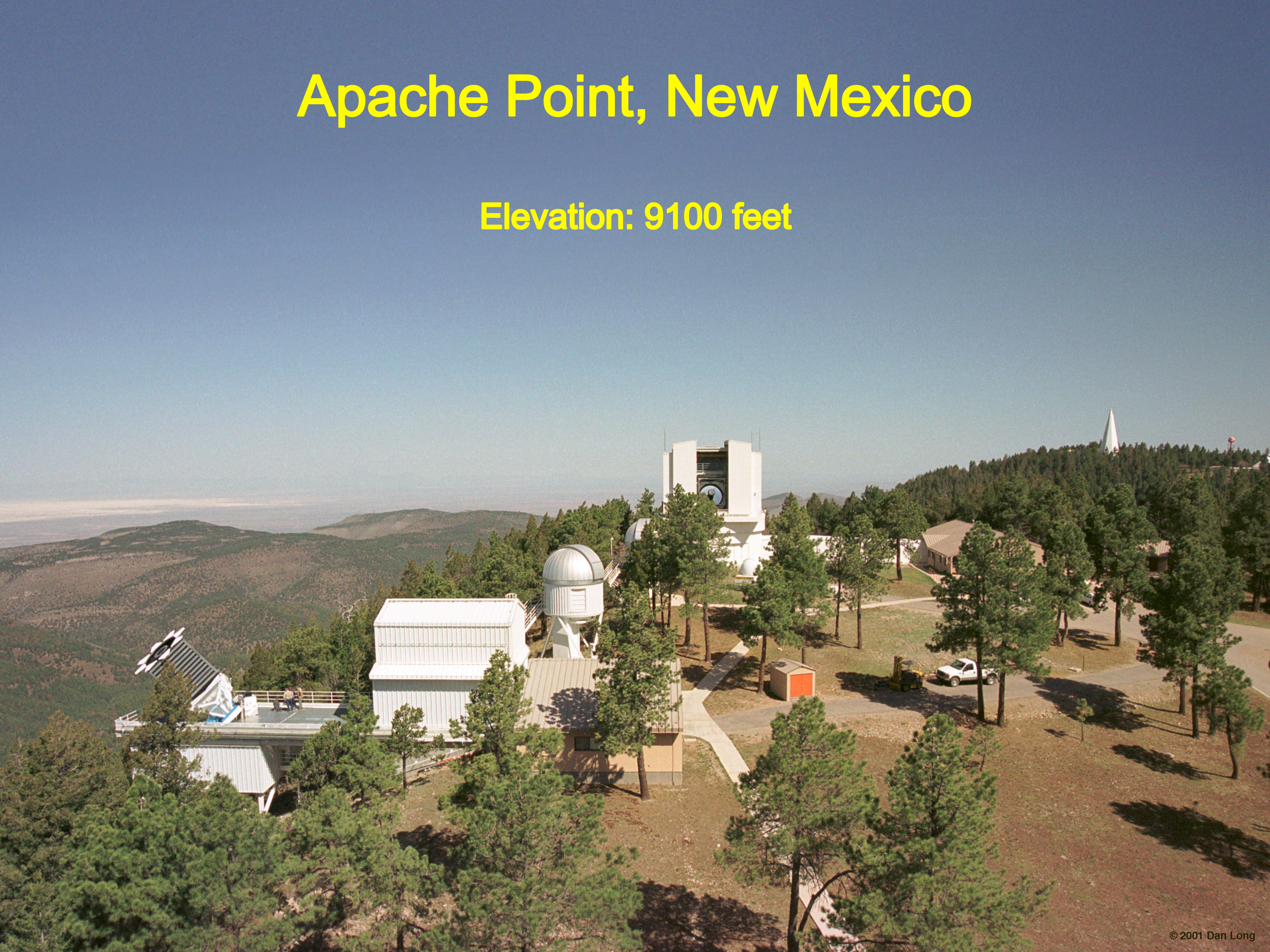
Redshift Surveys

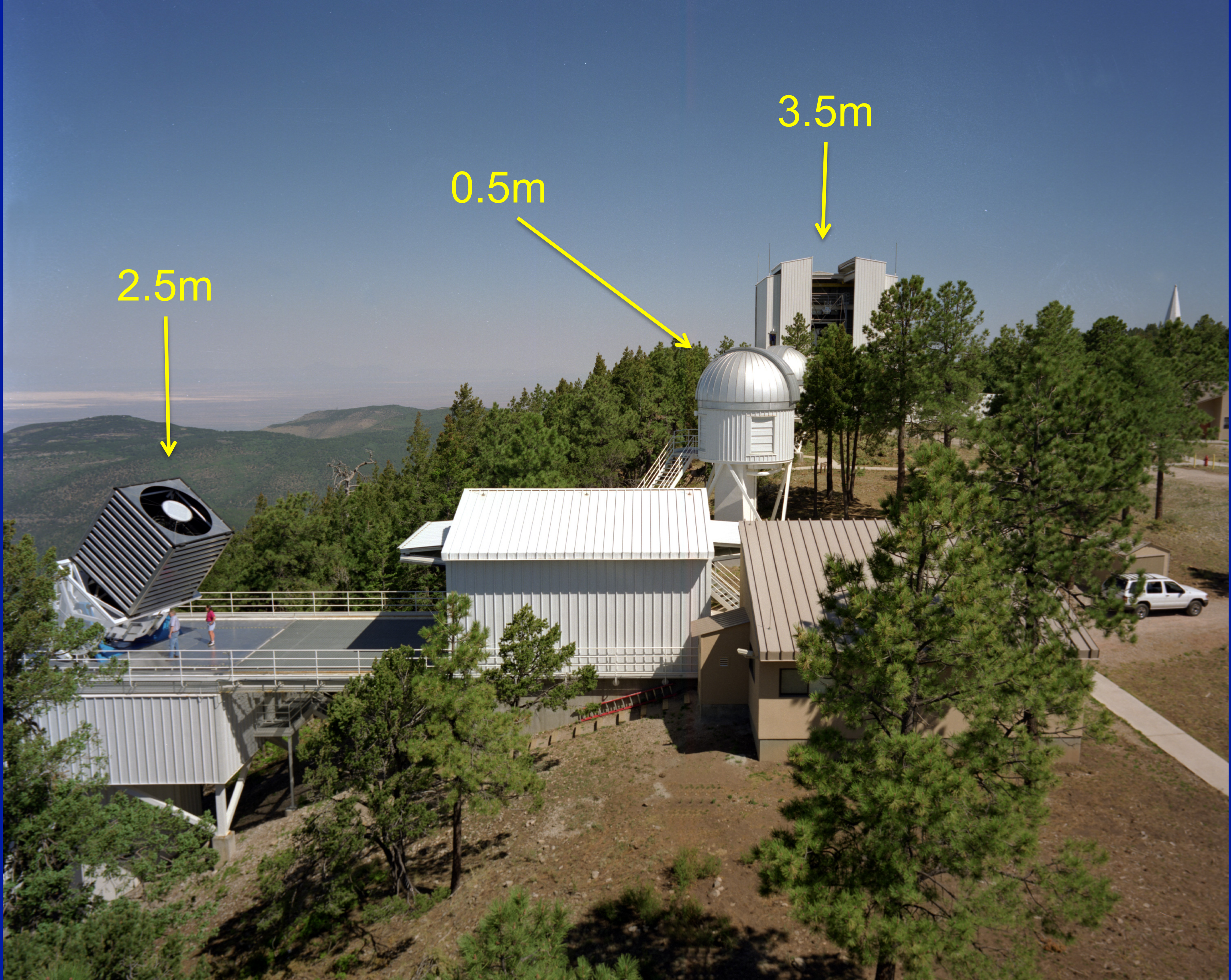


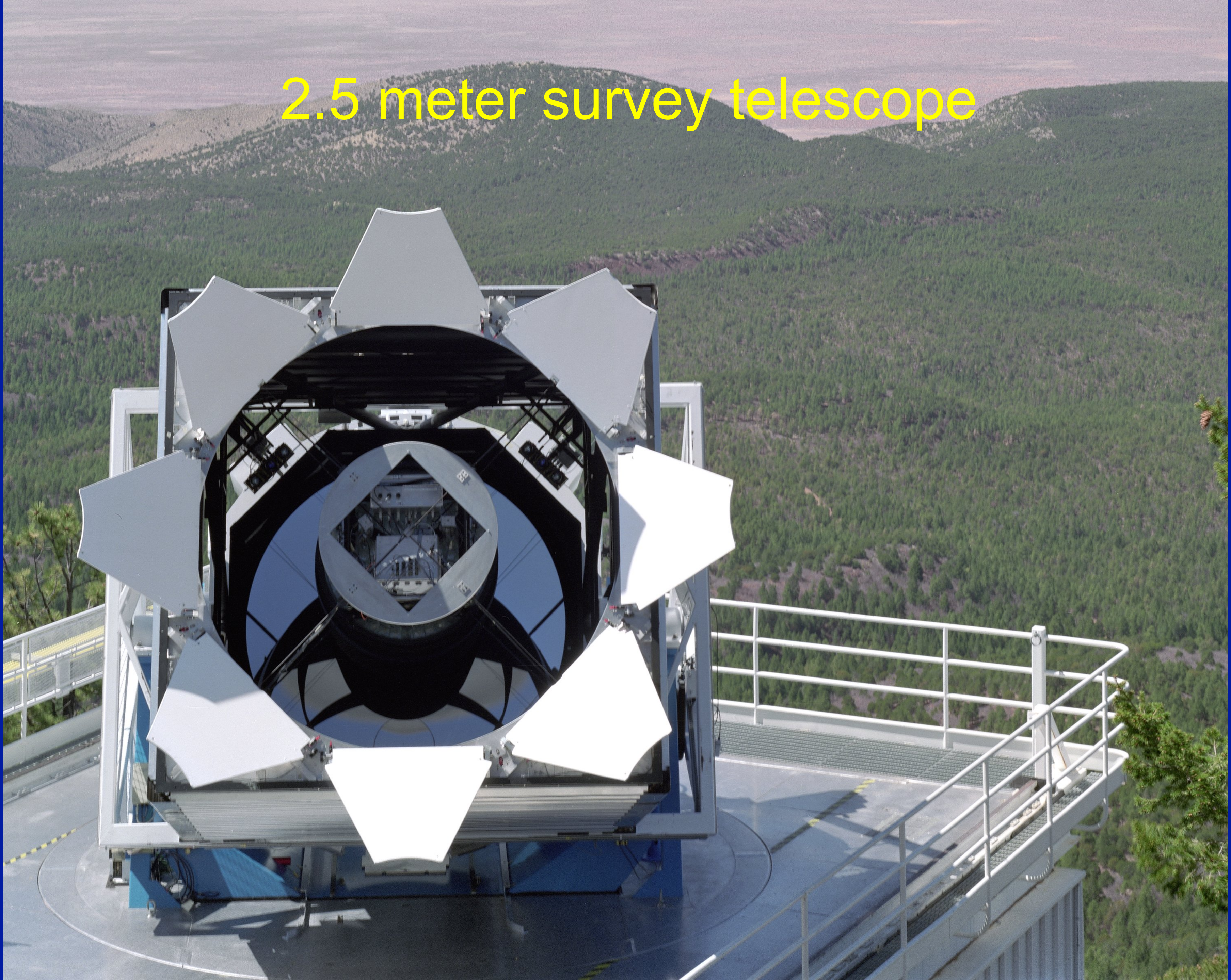
Sloan Digital Sky Survey

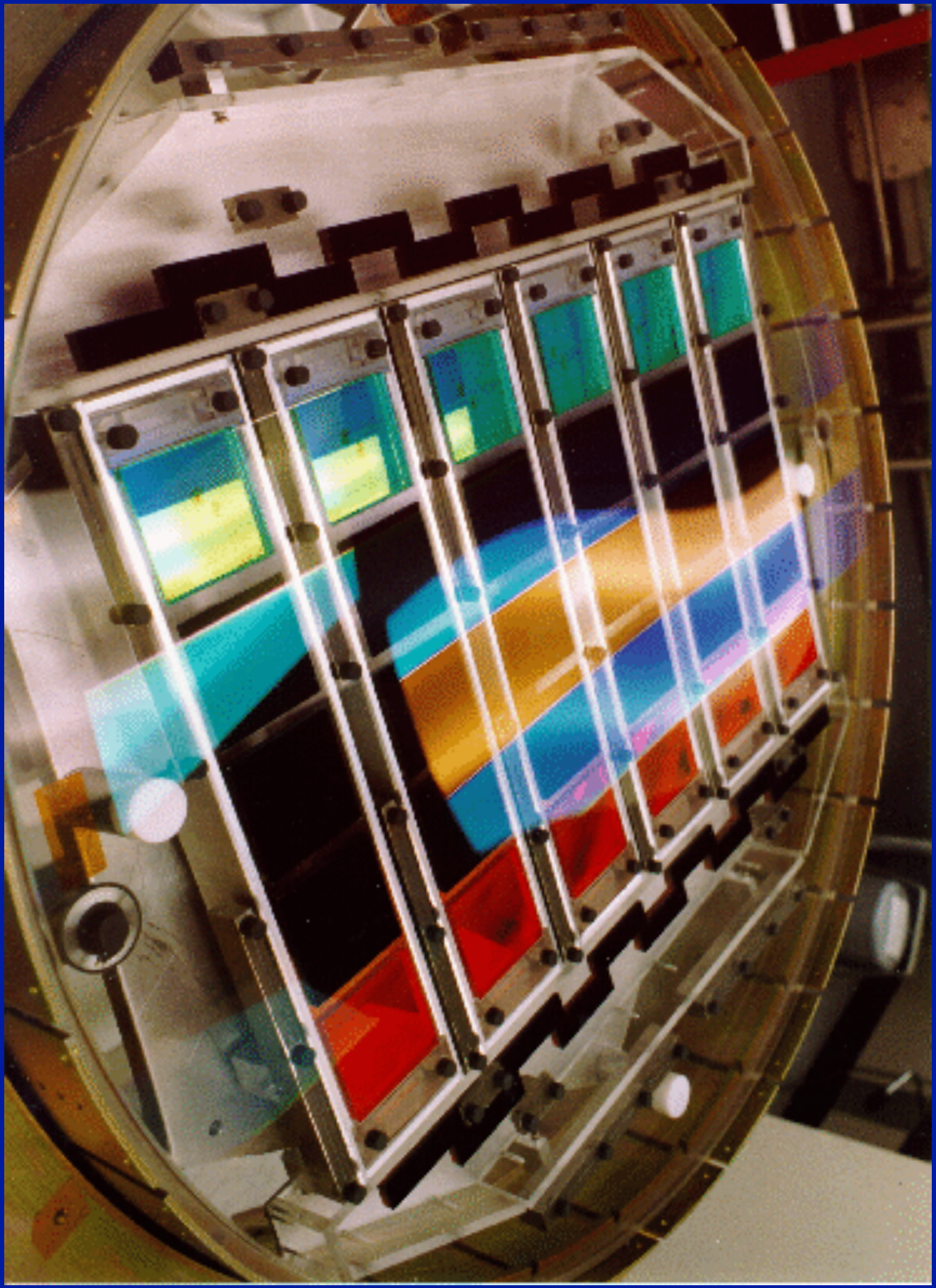
An international collaboration of 14 institutions with more than 200 involved scientists.

38 institutions including Vanderbilt


Apache Point, New Mexico
Elevation: 9100 feet
© 2001 Dan Long


3.5m
0.5m
2.5m

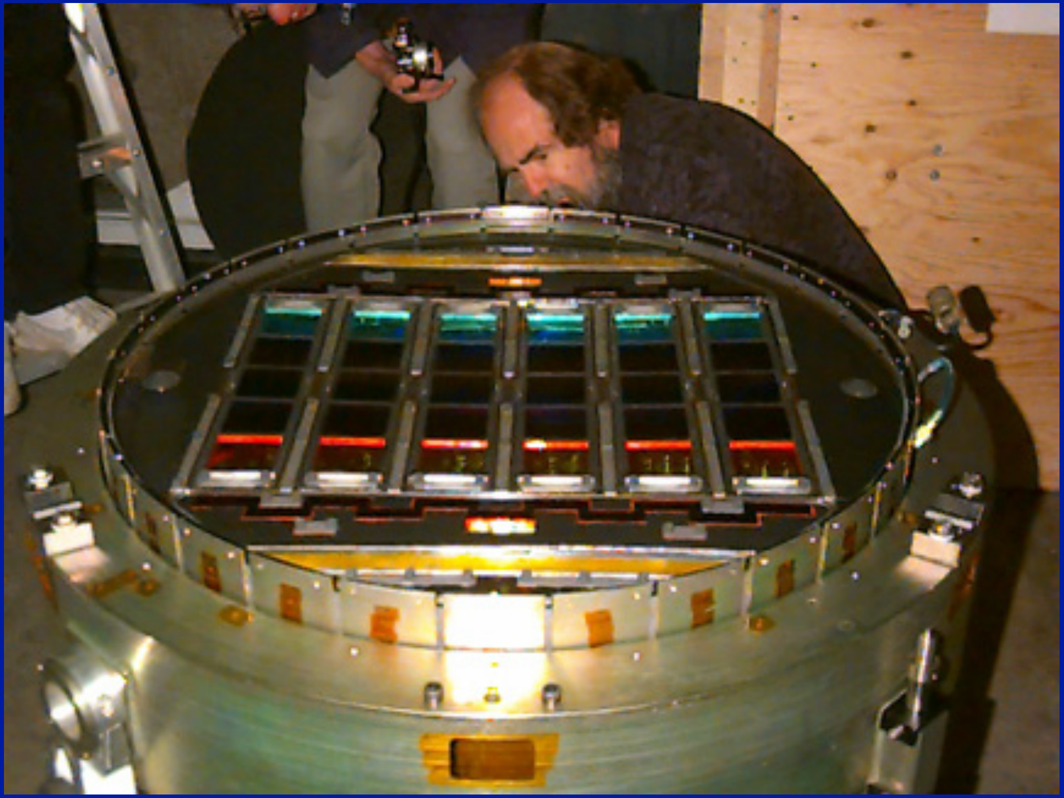

2.5 meter survey telescope



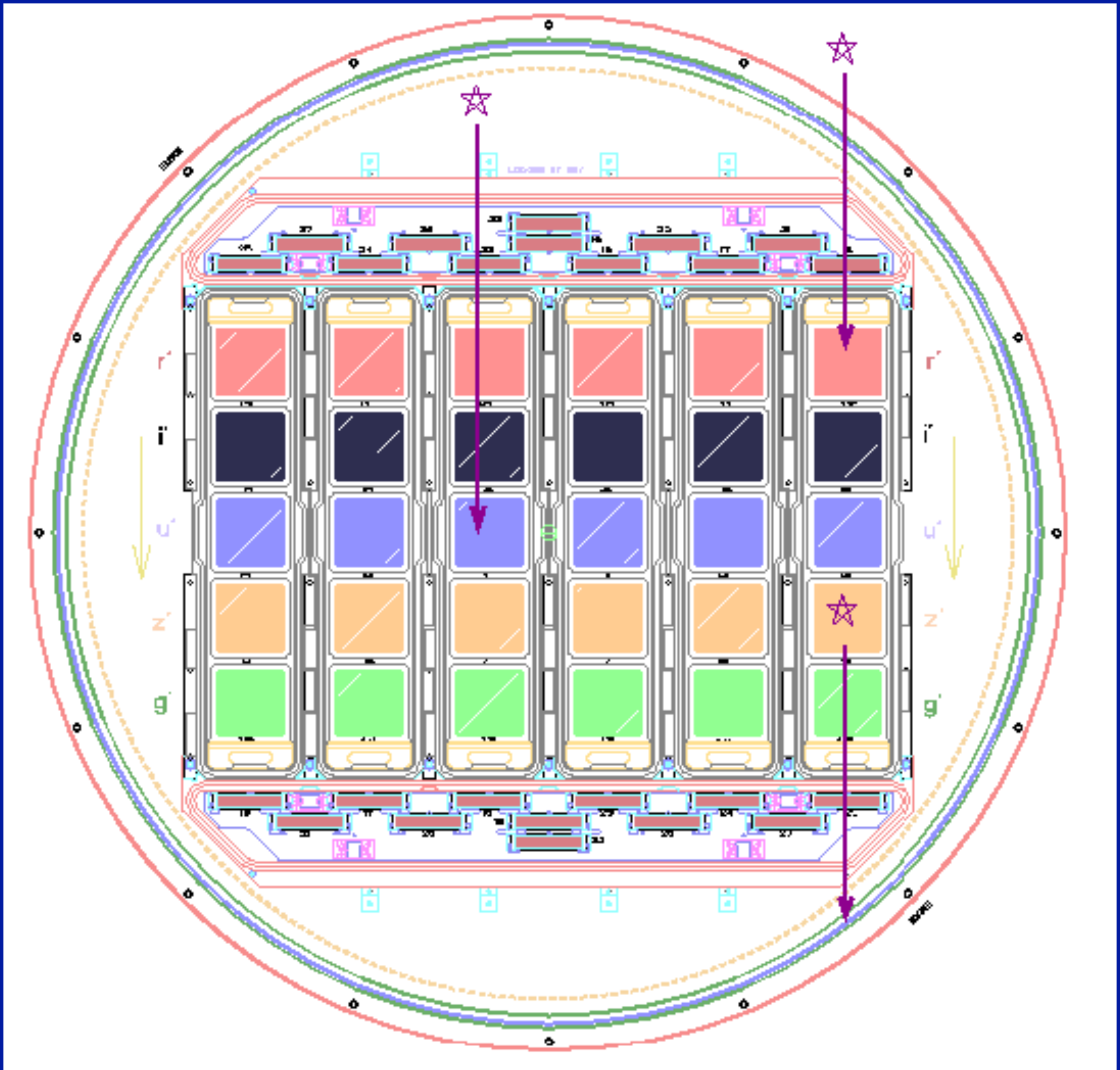
SDSS imaging camera

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

SDSS imaging camera

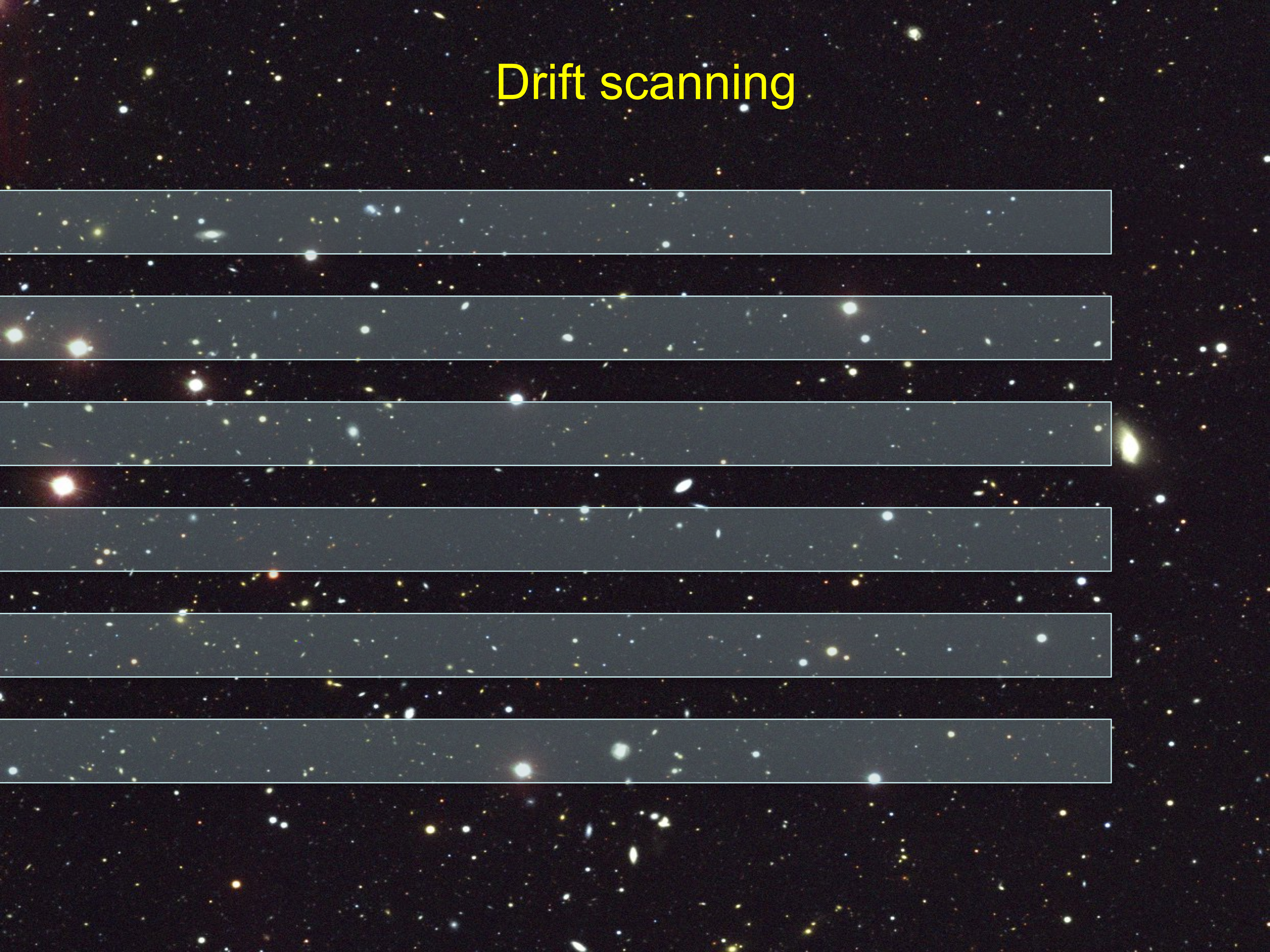


First light image! May 1998

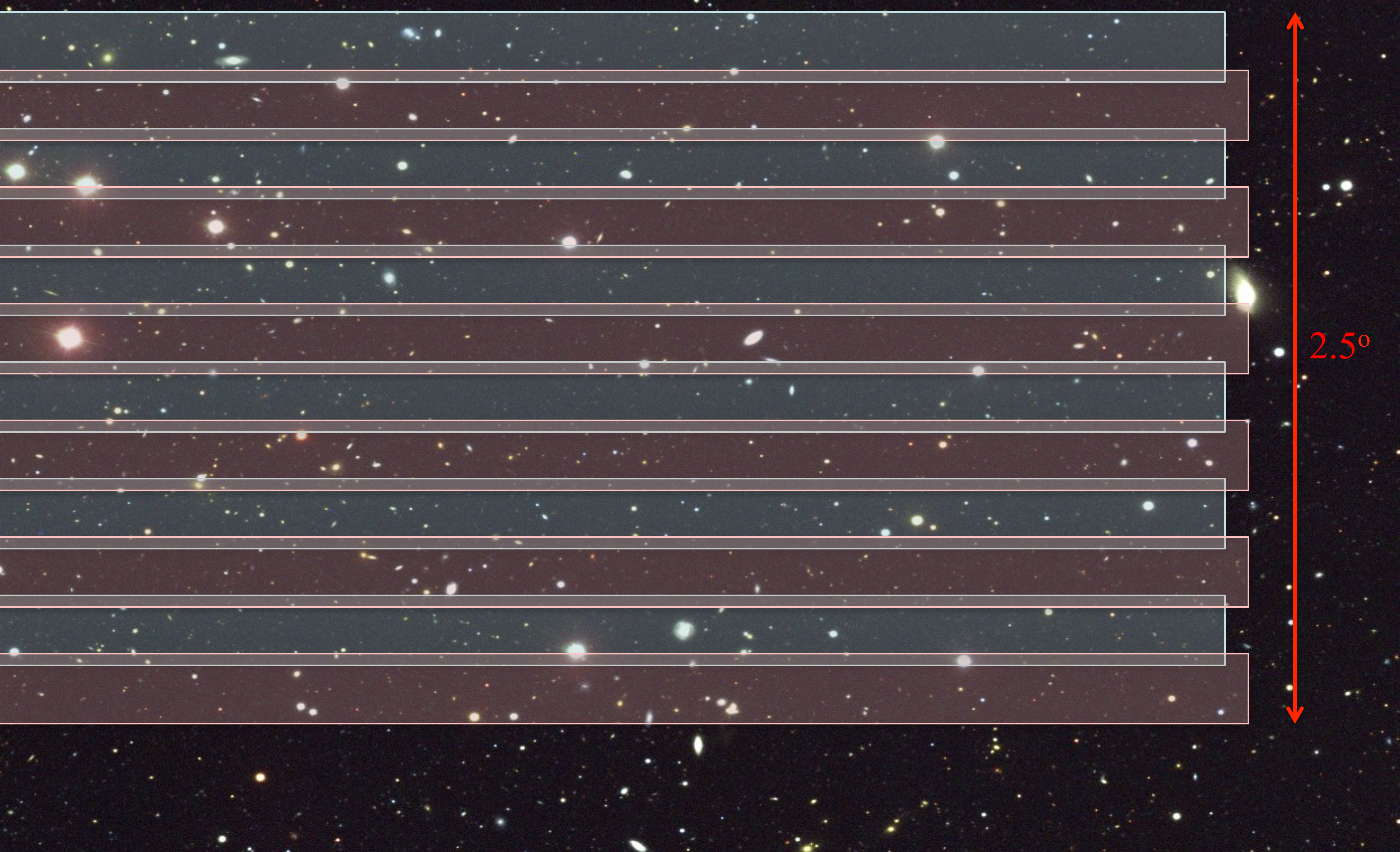


r'
i'
u'
z'
g'

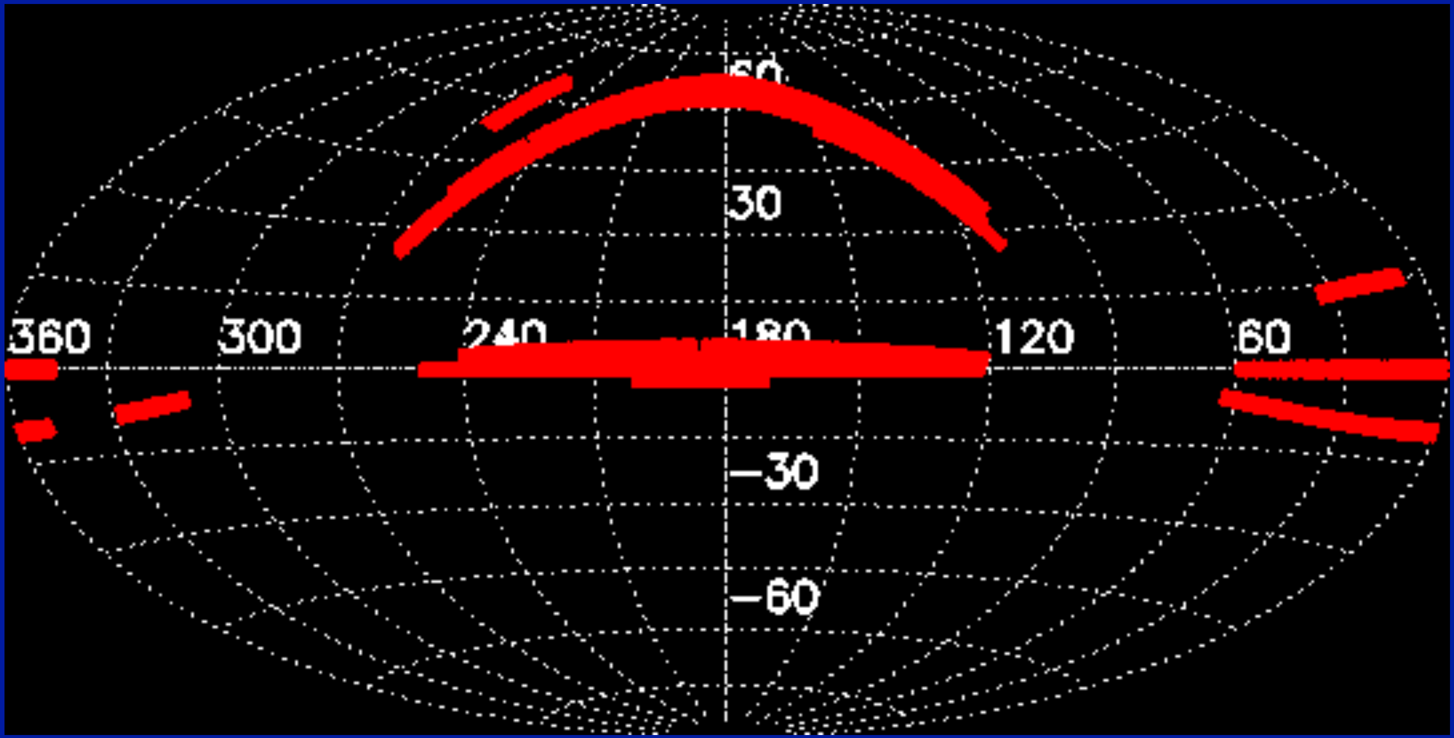
Drift scanning



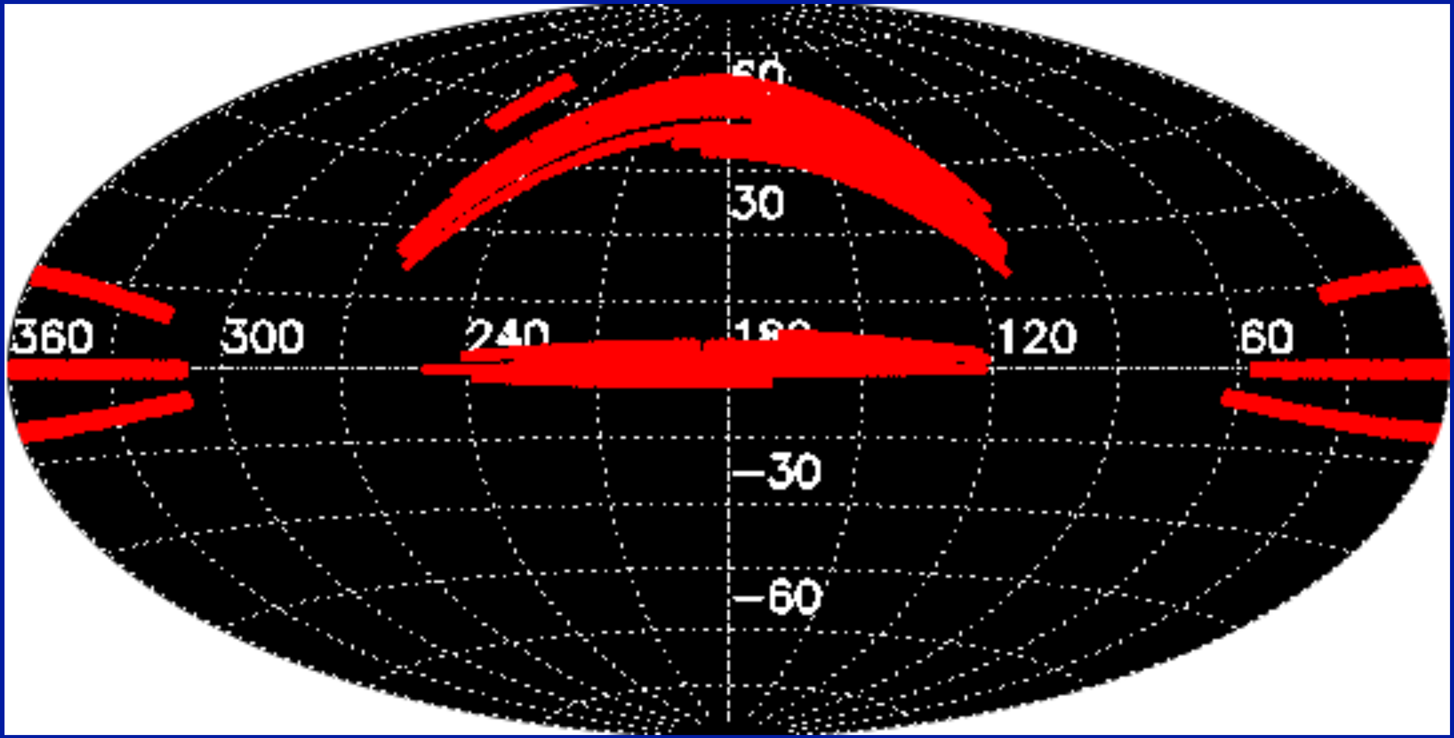
Drift scanning



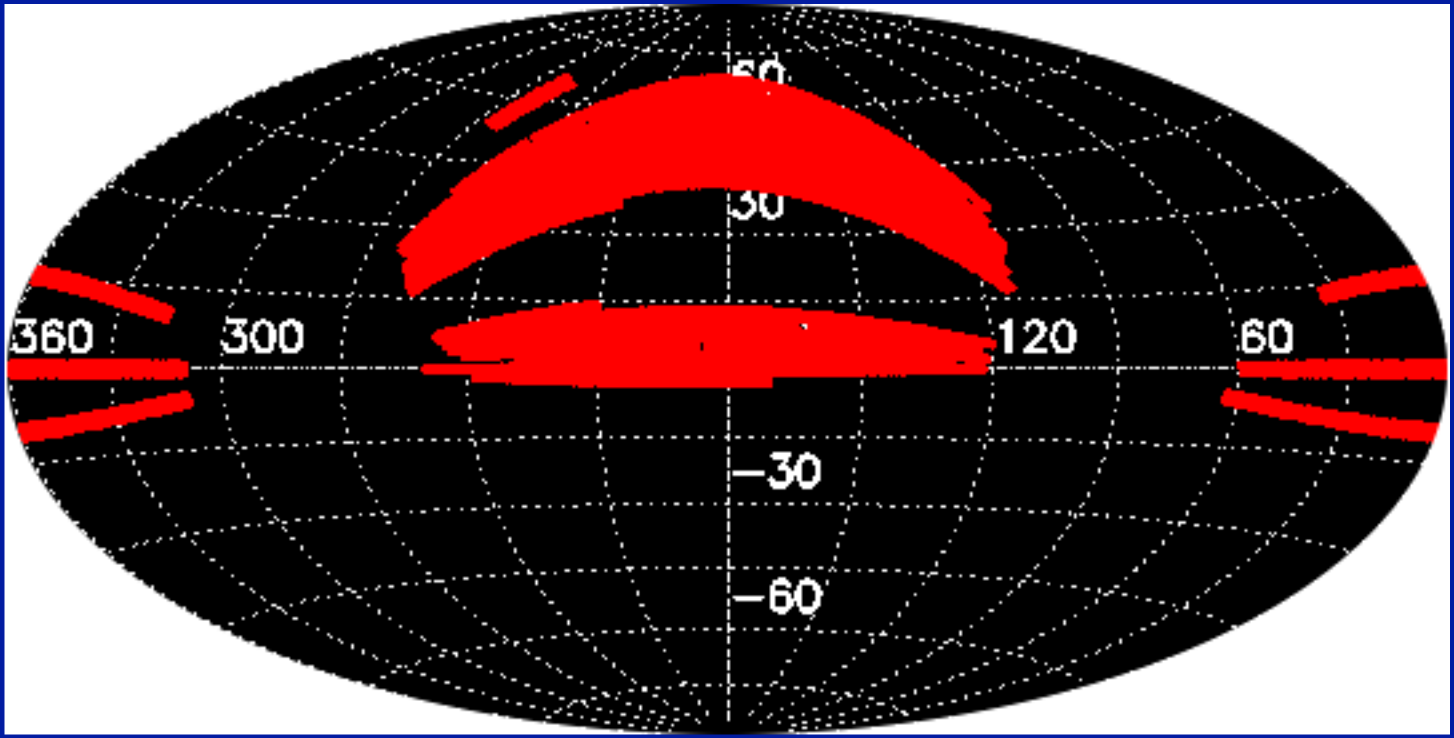
June 2003 53 million objects



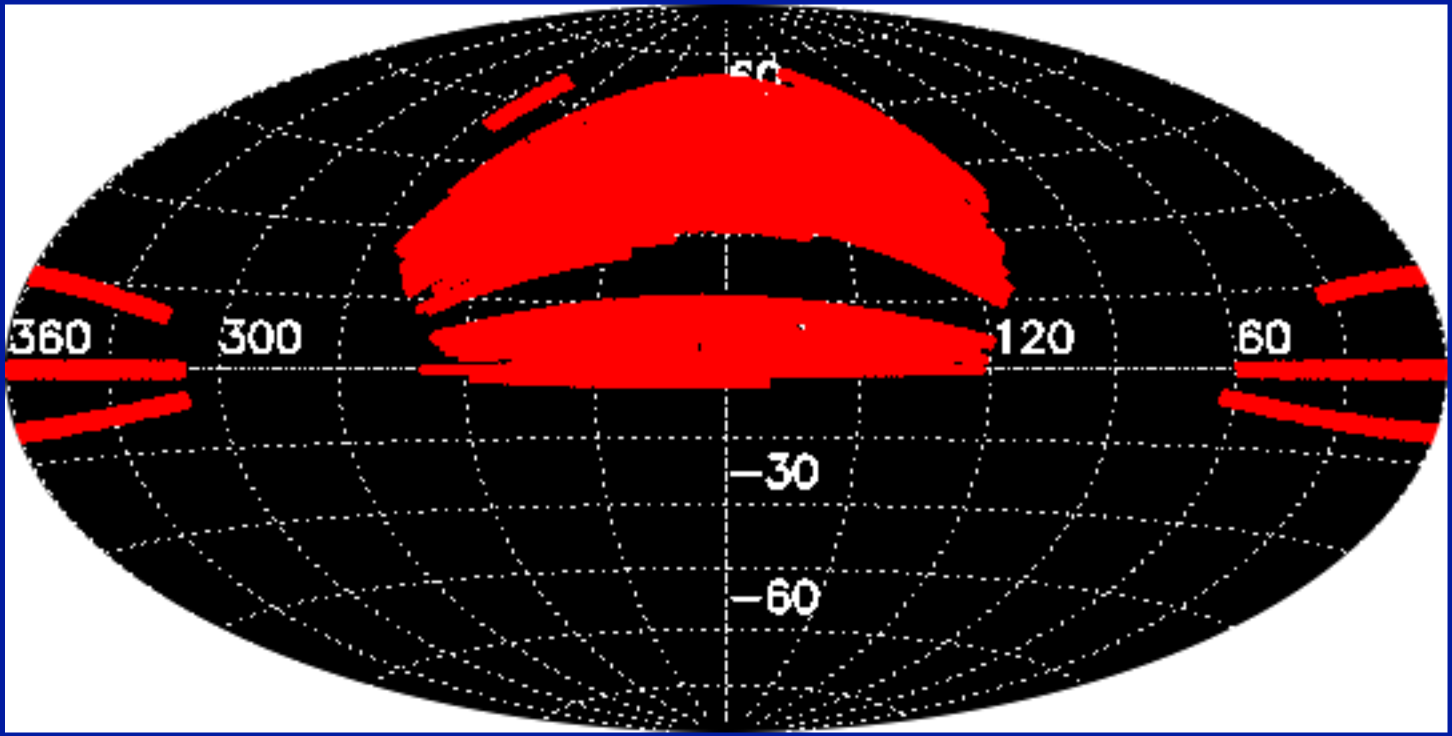
March 2004 88 million objects



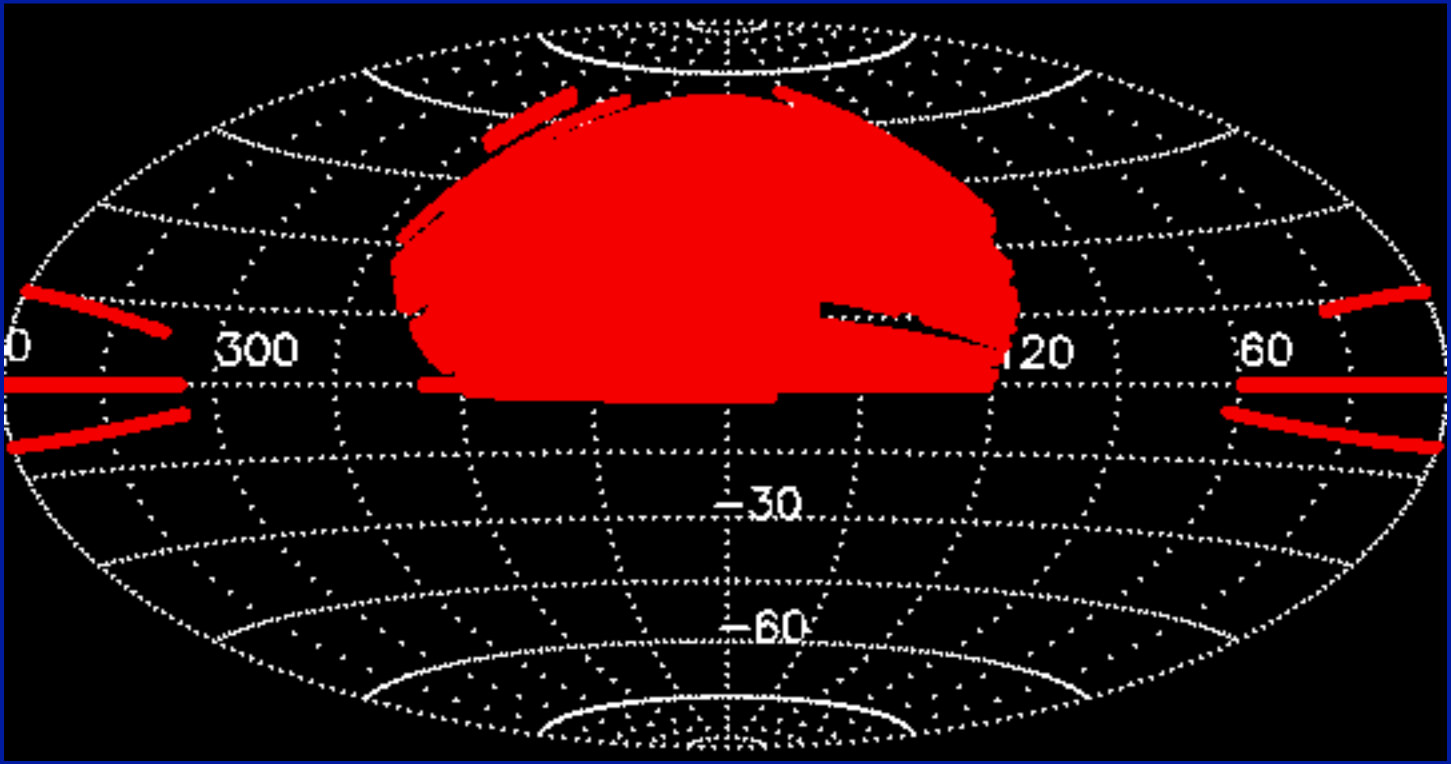
Sept 2004 141 million objects



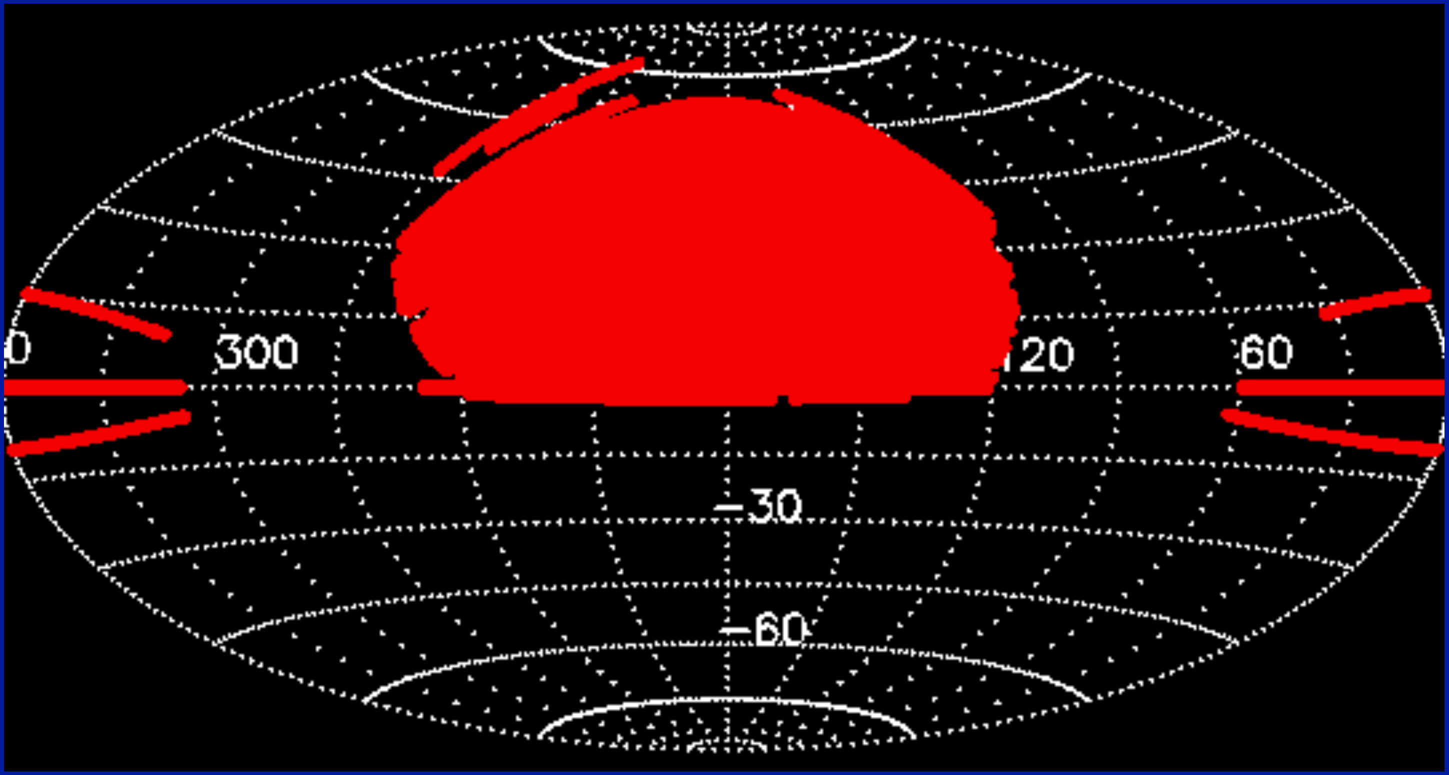
June 2005 180 million objects



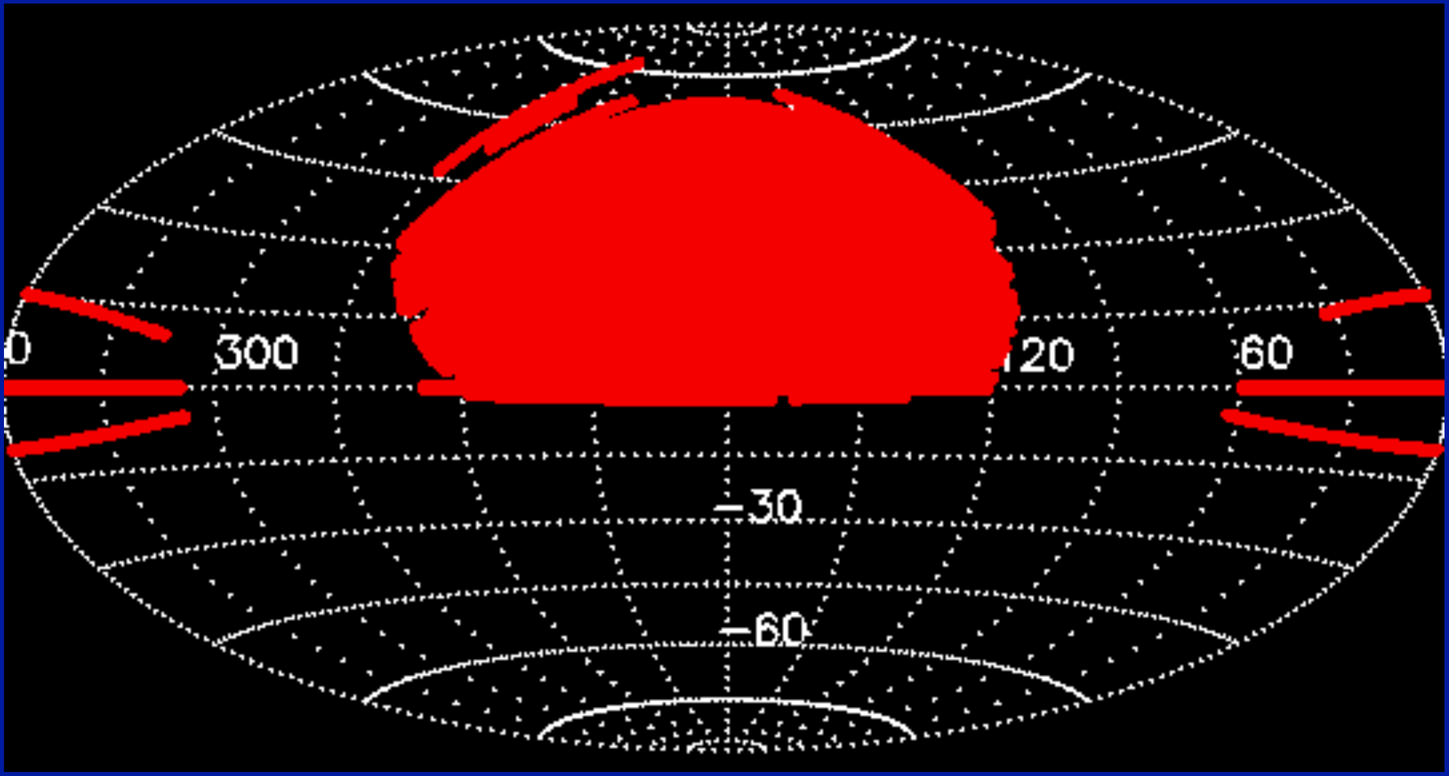
June 2006 215 million objects

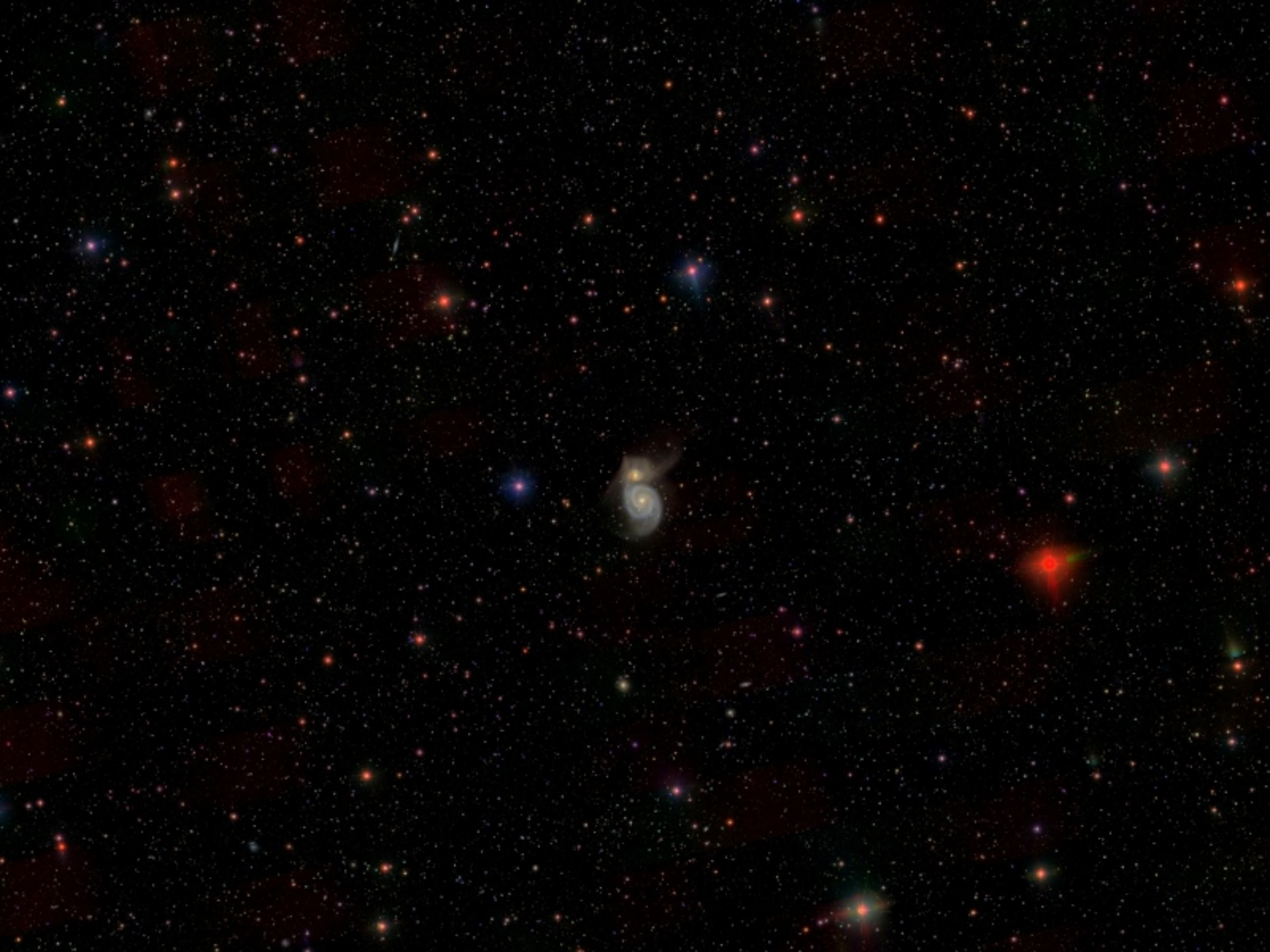


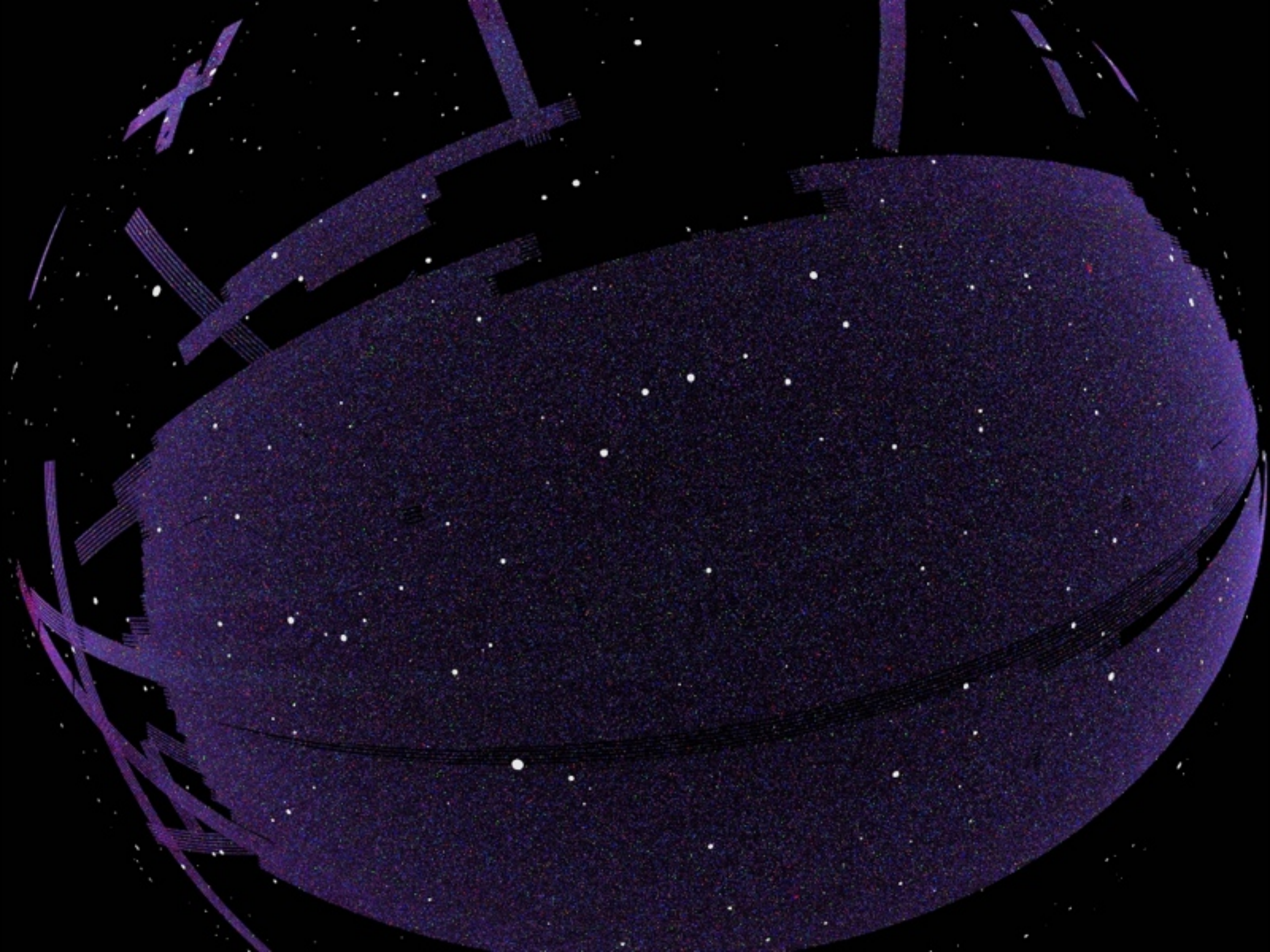
June 2007 287 million objects



Oct 2008 357 million objects

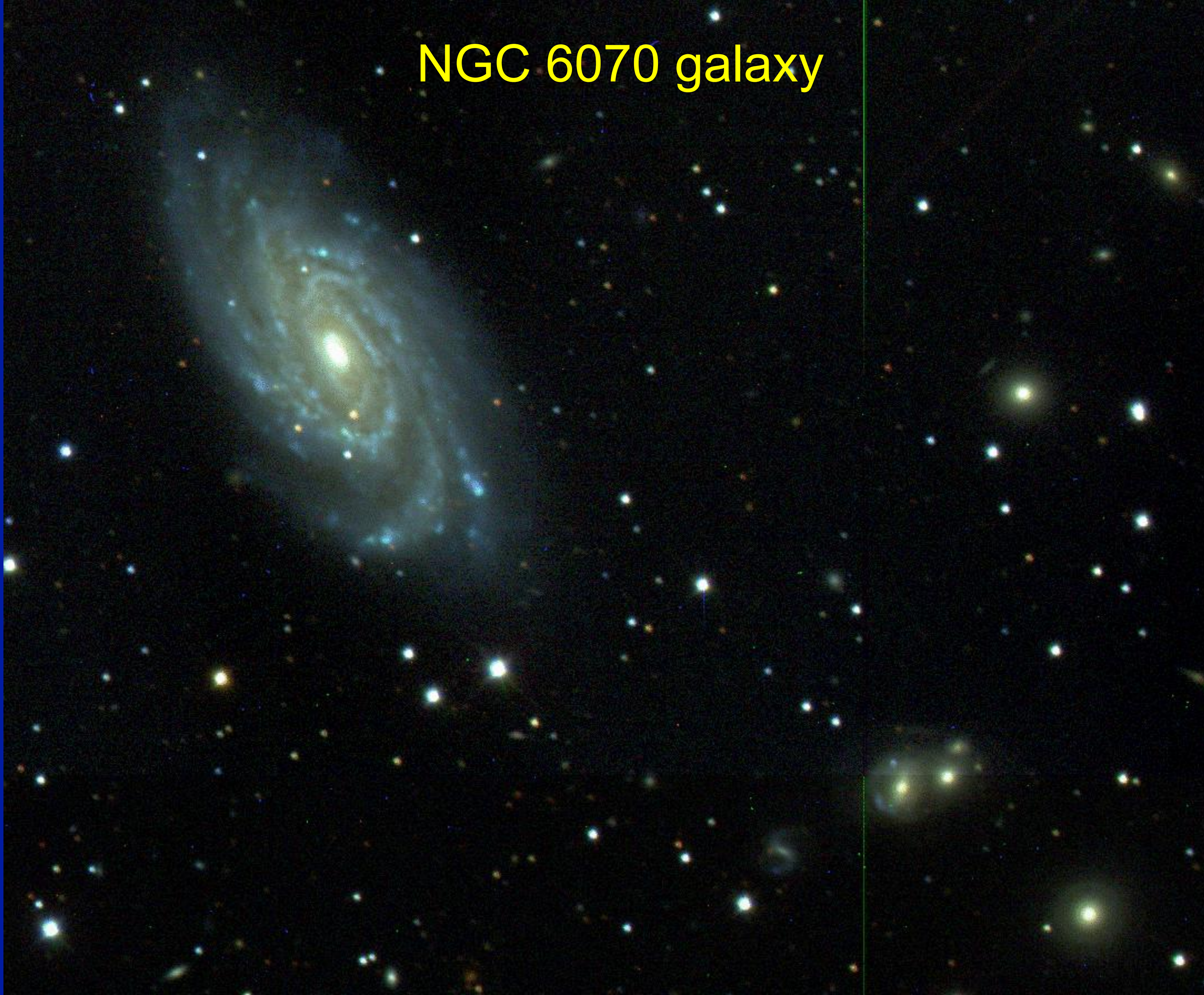




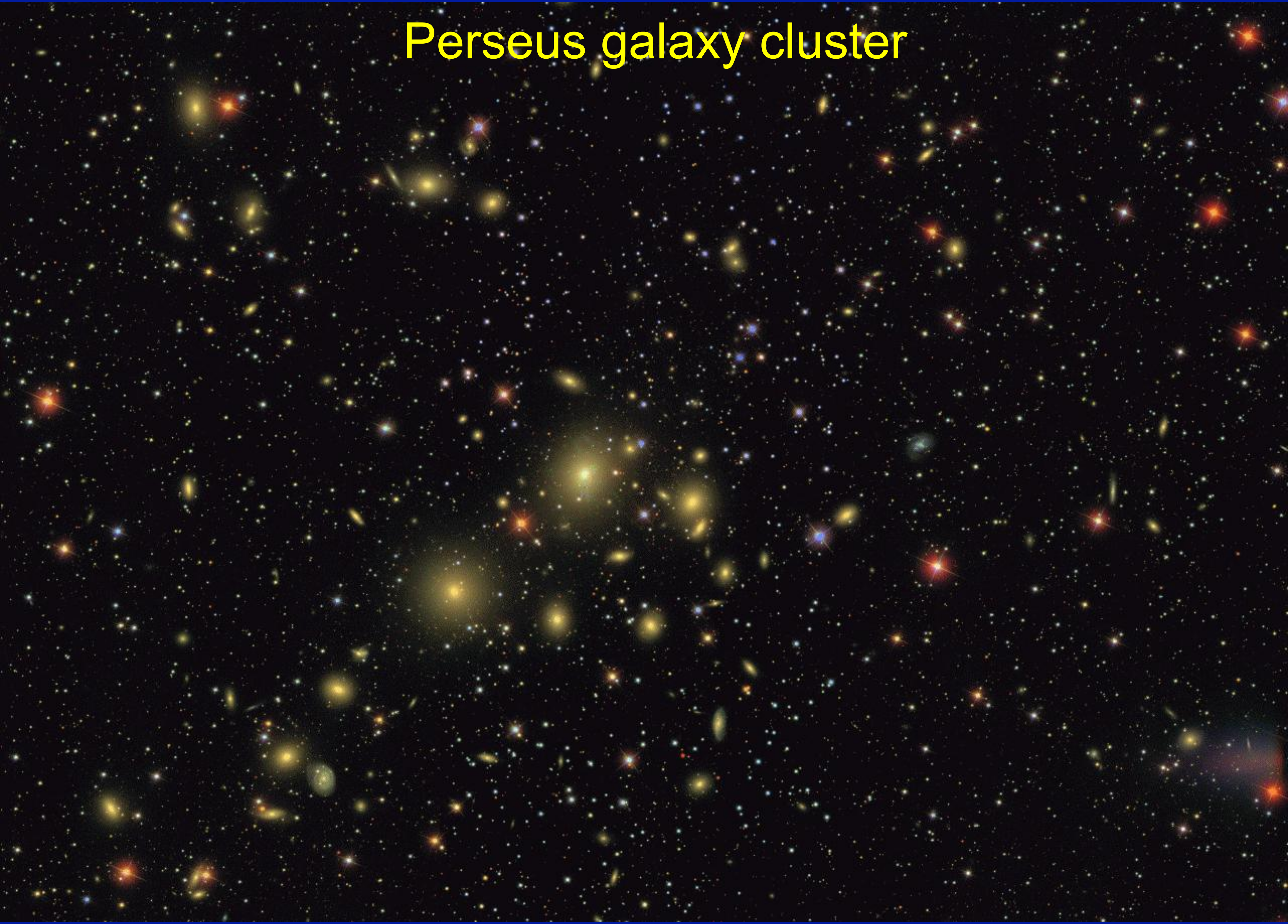



Pal 5 star cluster

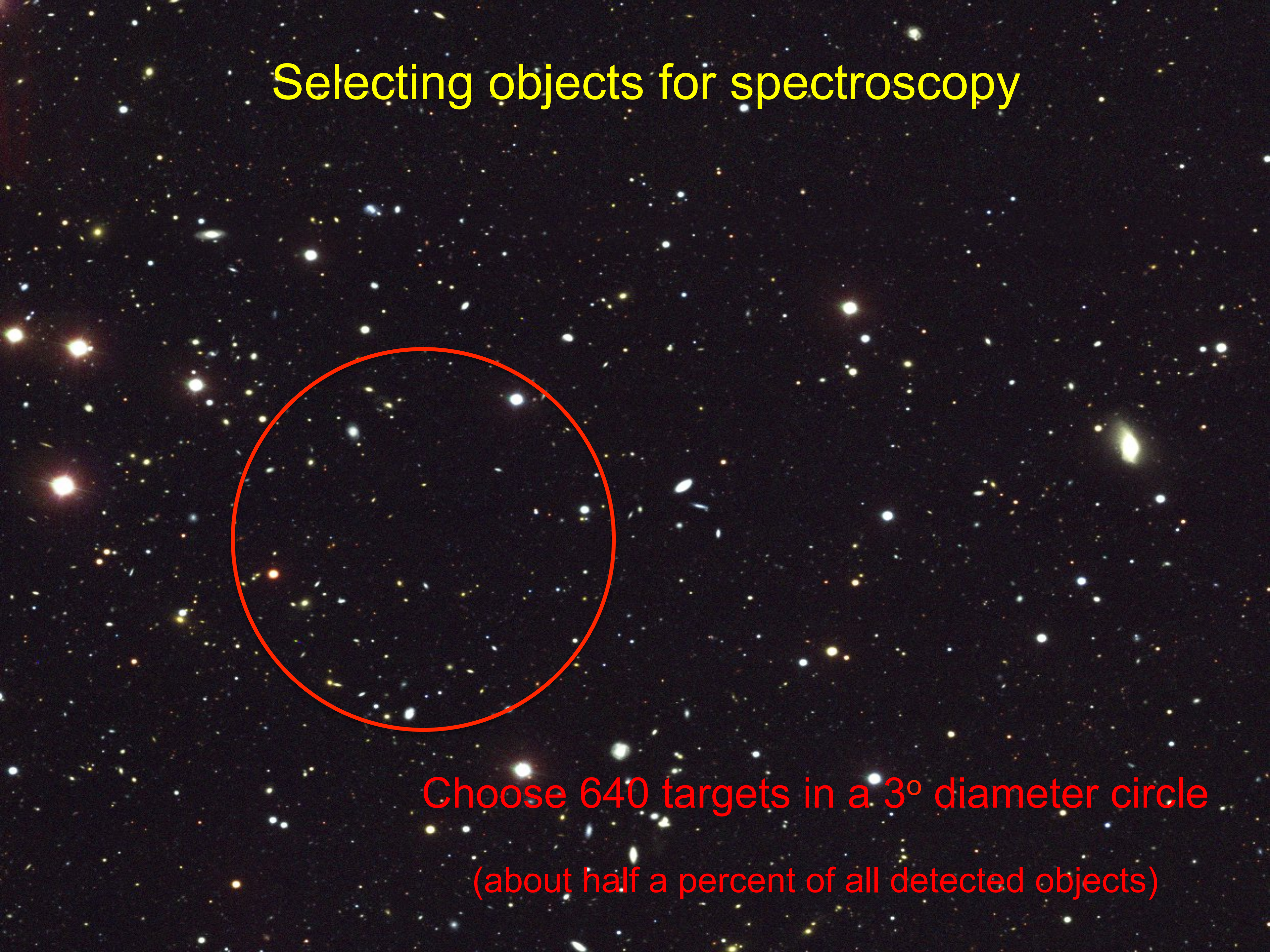
NGC 6070 galaxy



Perseus galaxy cluster



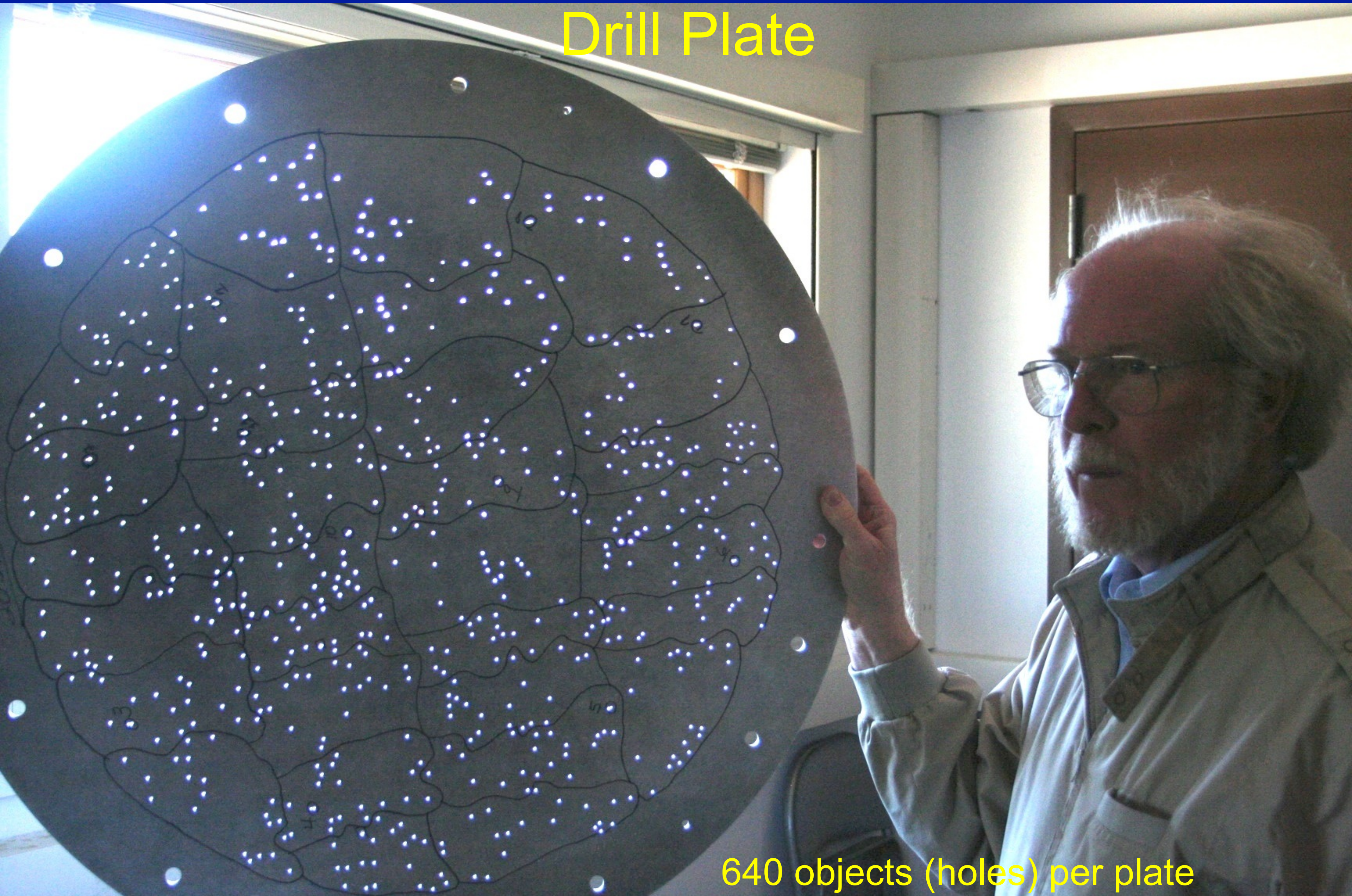
Selecting objects for spectroscopy



Choose 640 targets in a 3^{o} diameter circle

(about half a percent of all detected objects)

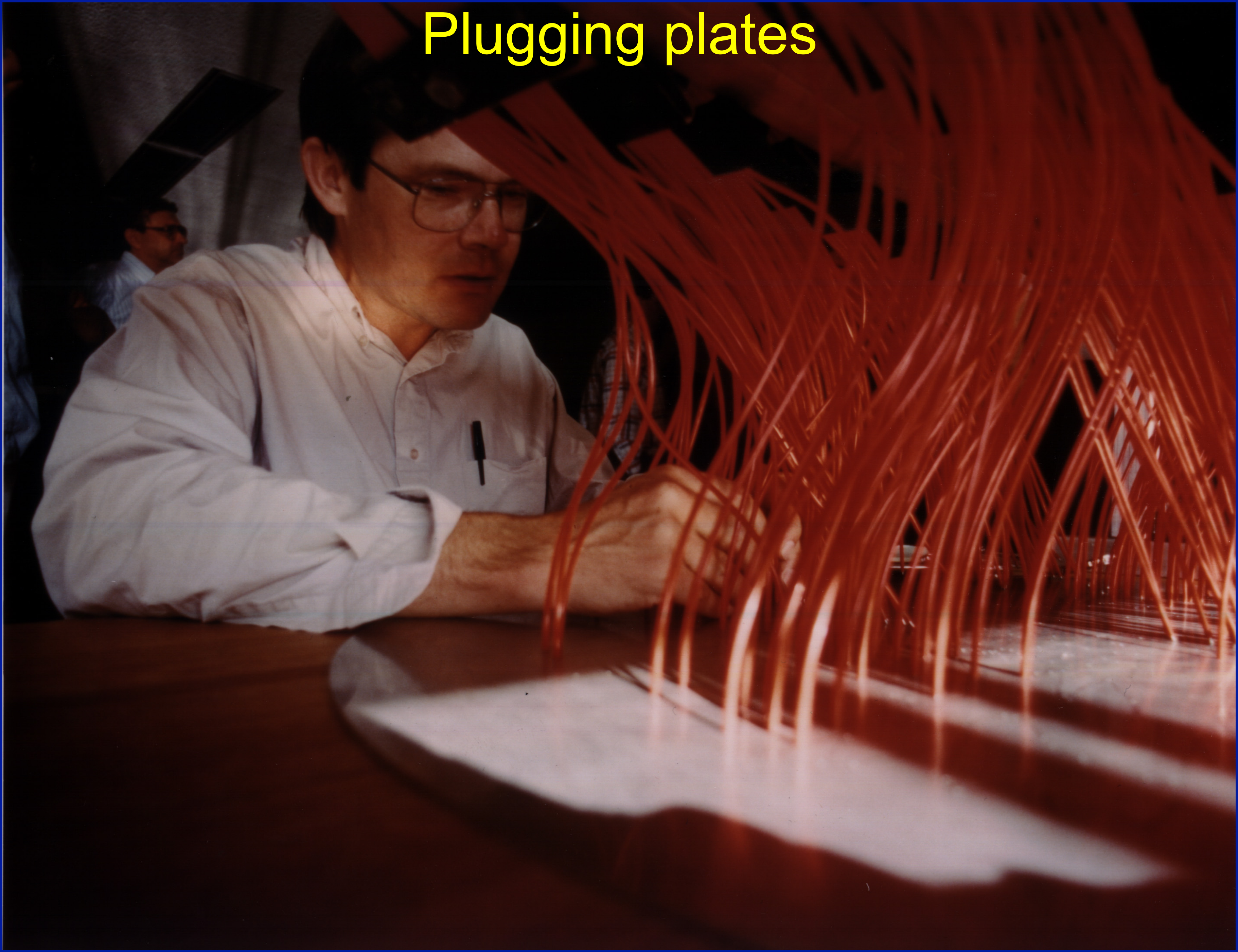
Drill Plate



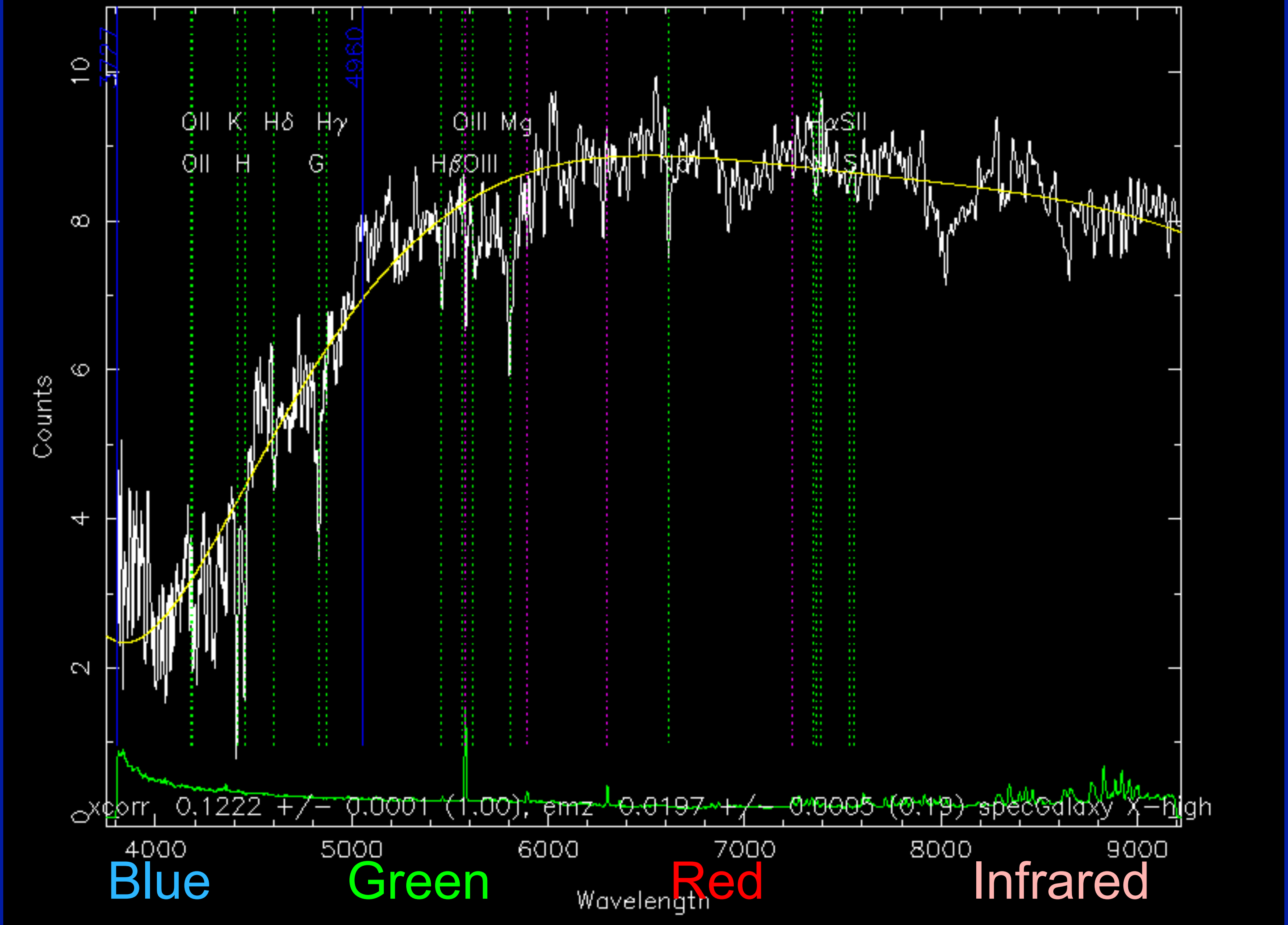
640 objects (holes) per plate

Fiber-optic cables

Plugging plates



Spectrum

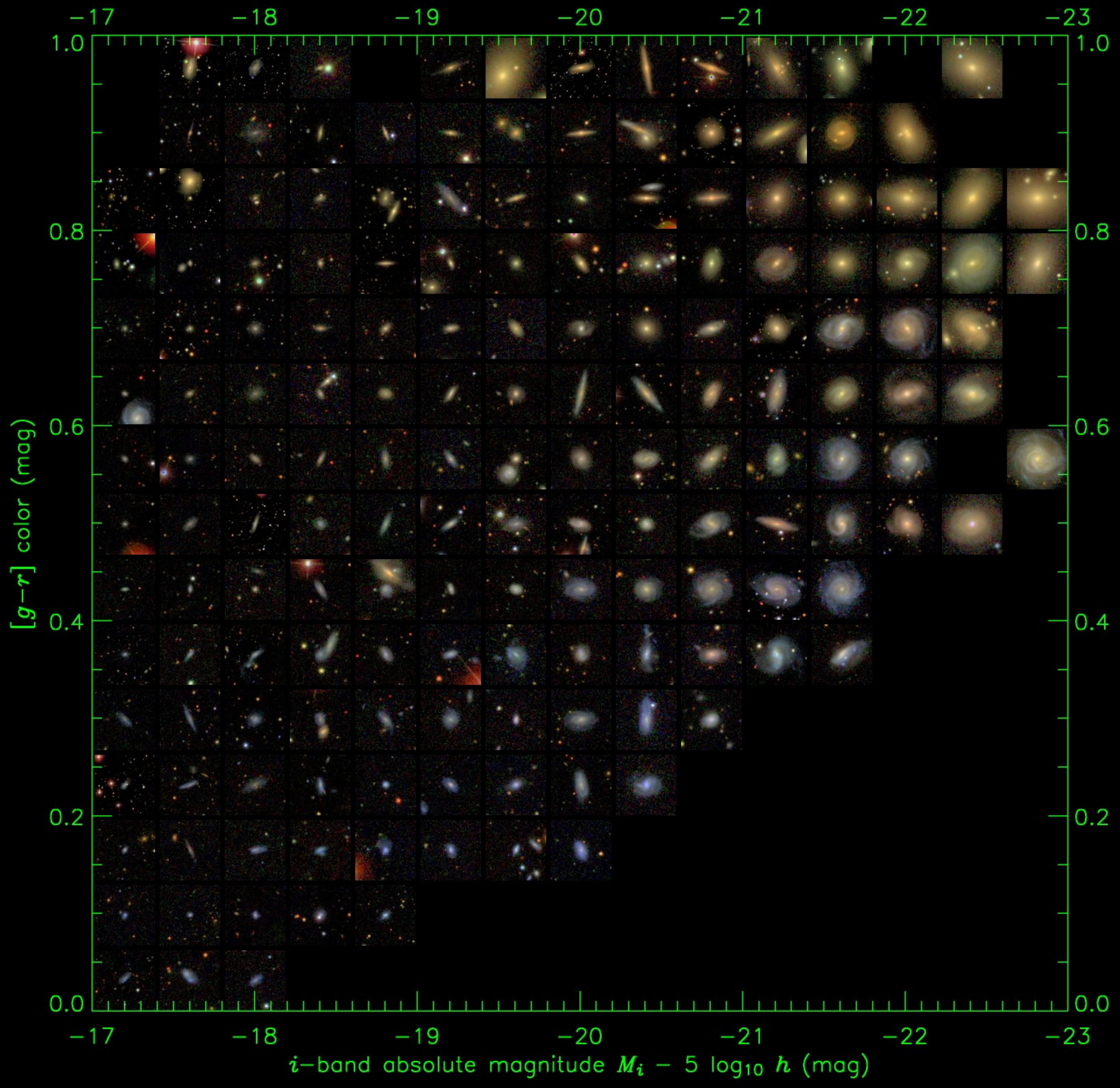


Wavelength of light


Over 2000 plates!

SDSS is state of the art!

- Imaging covering ¼ of sky : 100,000,000 galaxies detected
- Spectra of 1,500,000 galaxies and redshifts
- Also seen: stars in our galaxy, asteroids, quasars, etc…



−17 −18 −19 −20 −21 −22 −23
1.0 0.8 0.6 0.4 0.2 0.0
[g−r] color (mag)
i−band absolute magnitude $M_i - 5 \log_{10} h$ (mag)

redshift-space distortions

Most galaxies move through space due to the gravitational pull of surrounding structures.

This motion is called *peculiar* motion.

Peculiar velocities cause doppler shifts, which add to the redshift.

Hubble flow "velocity": $H_0 d$

Radial component of peculiar velocity: v_r

Total radial "velocity": $H_0 d + v_r$

redshift-space distortions

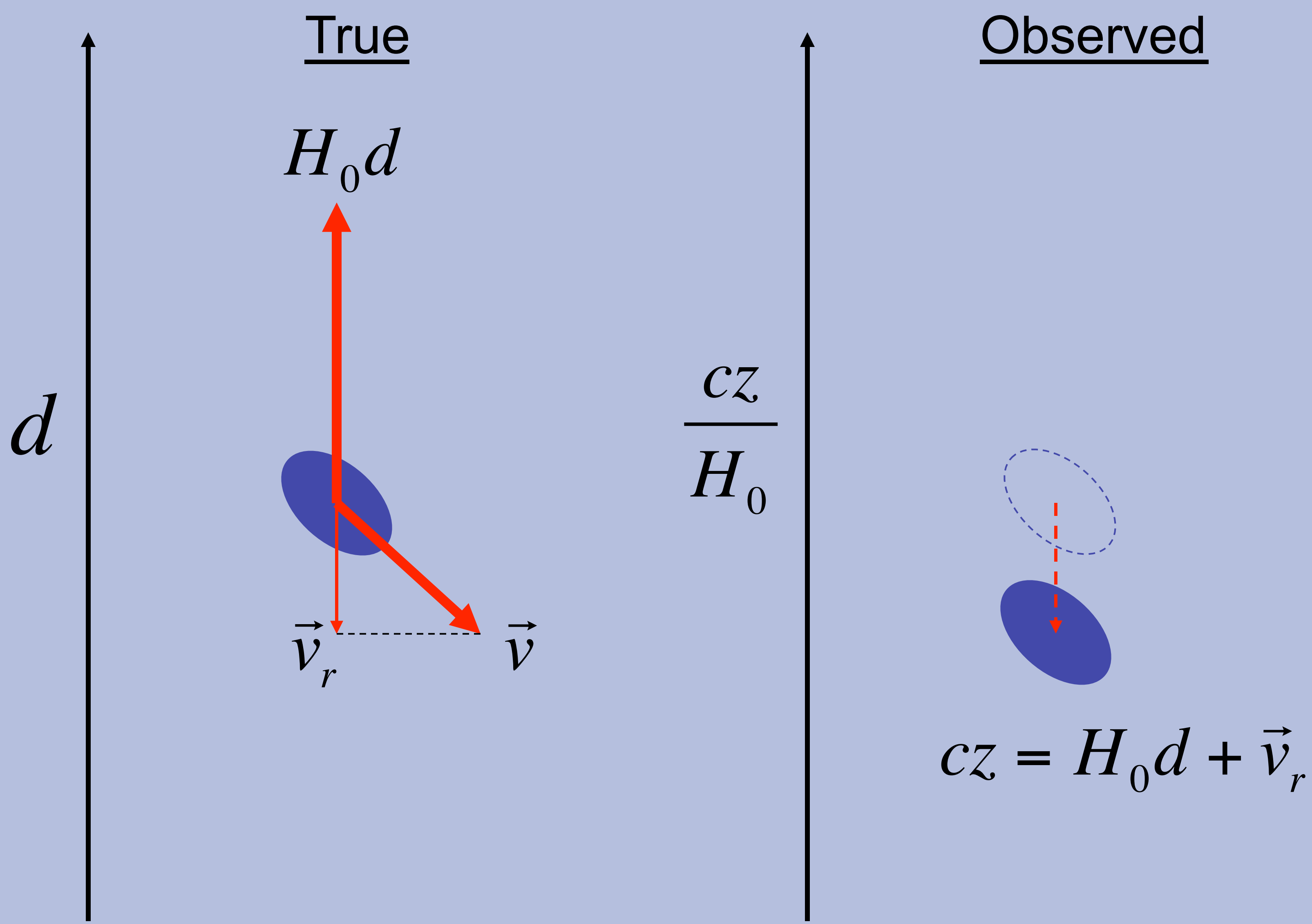
Redshift according to the doppler effect is: $z = \frac{v_r}{c}$

So the inferred velocity from a measured redshift is: cz

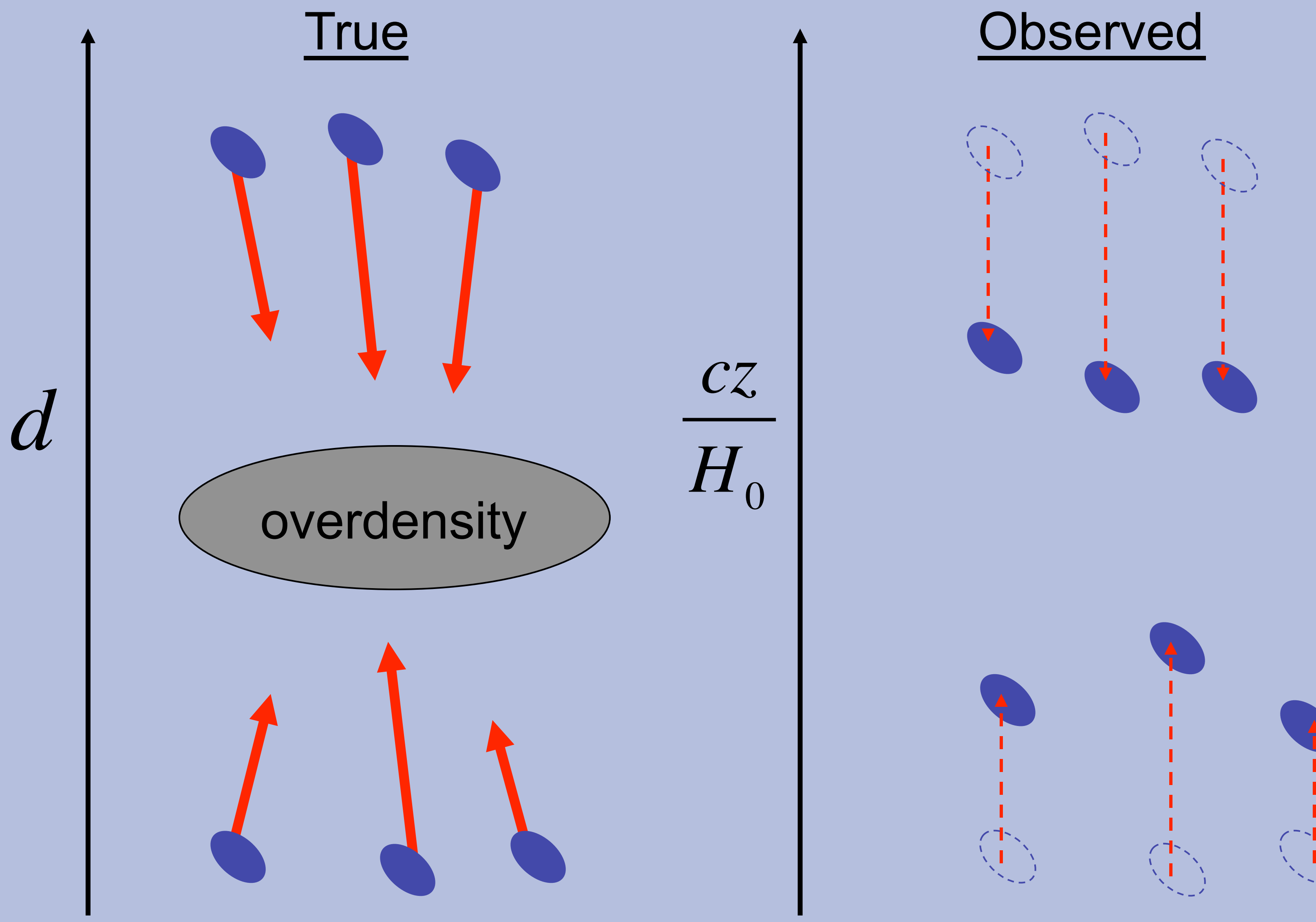
And the inferred distance is: $d = \frac{cz}{H_0}$

But what is really being measured is: $\frac{cz}{H_0} = d + \frac{v_r}{H_0}$

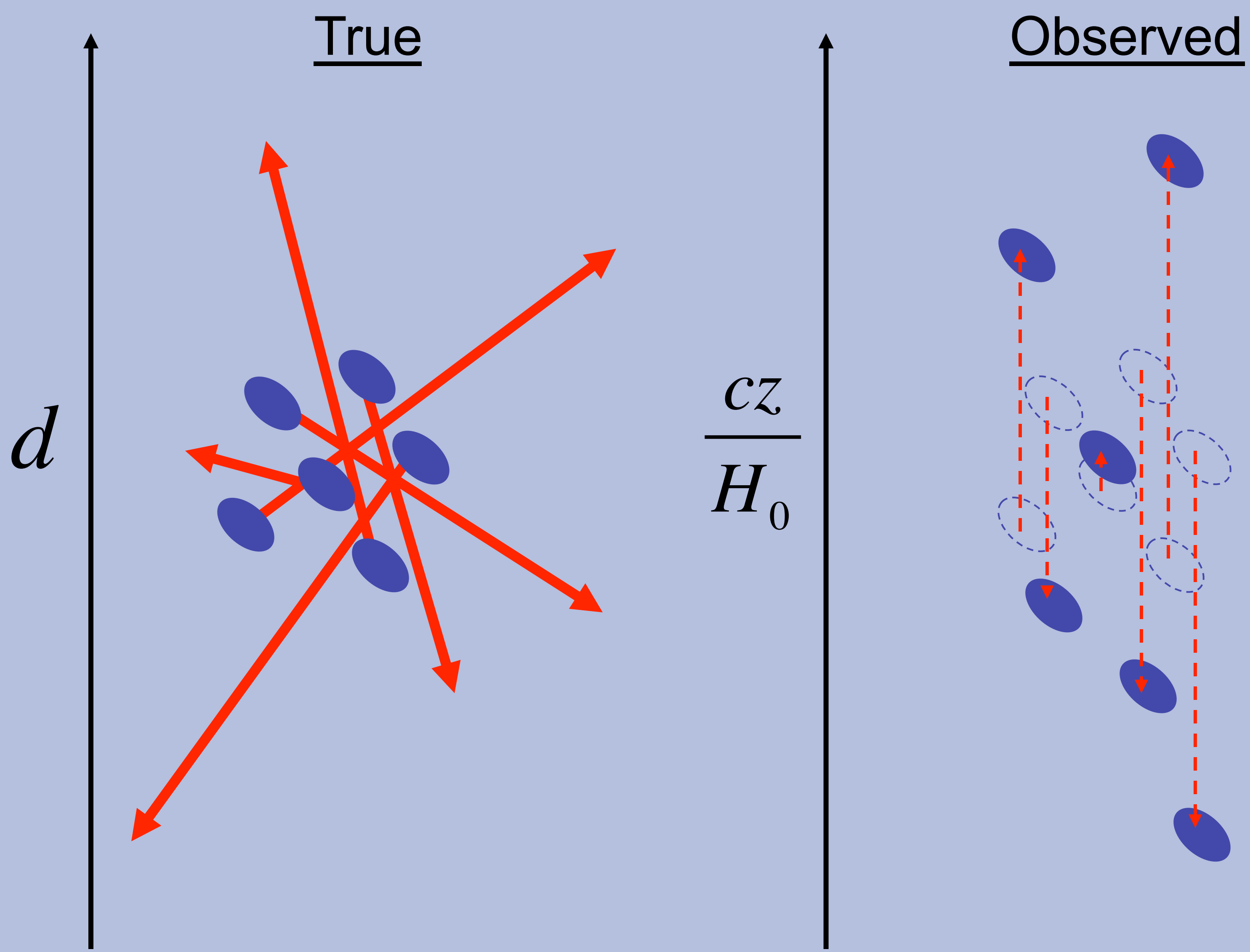
redshift-space distortions



redshift-space distortions



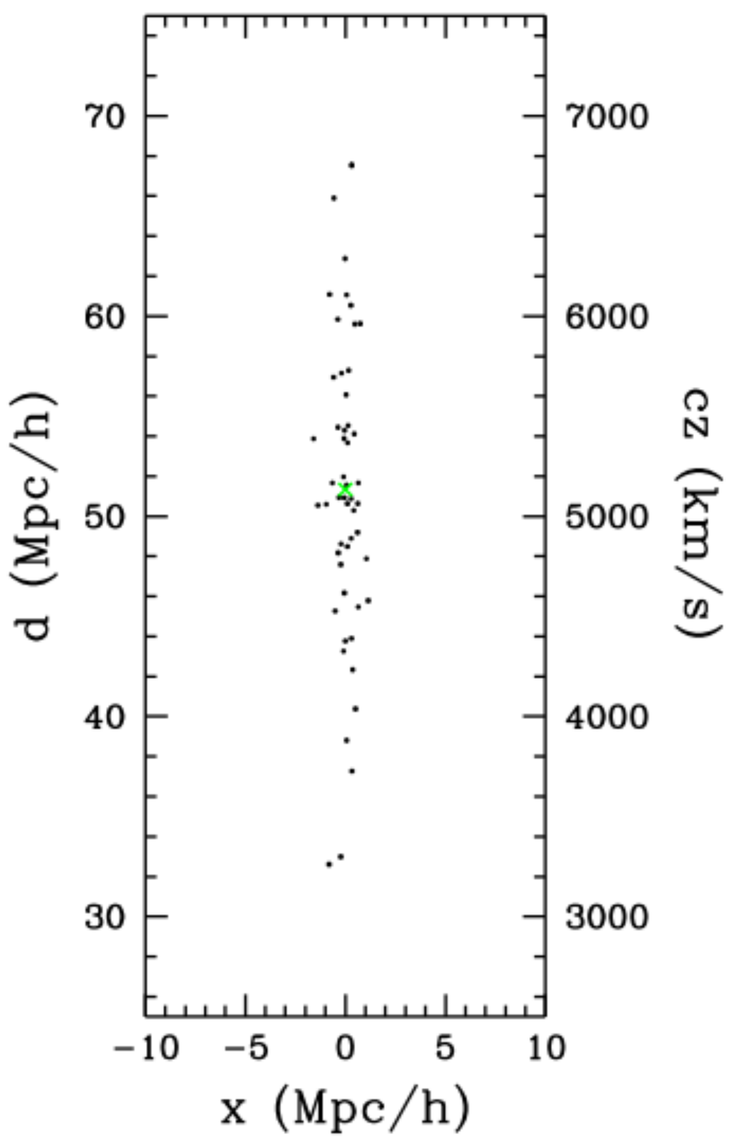
redshift-space distortions



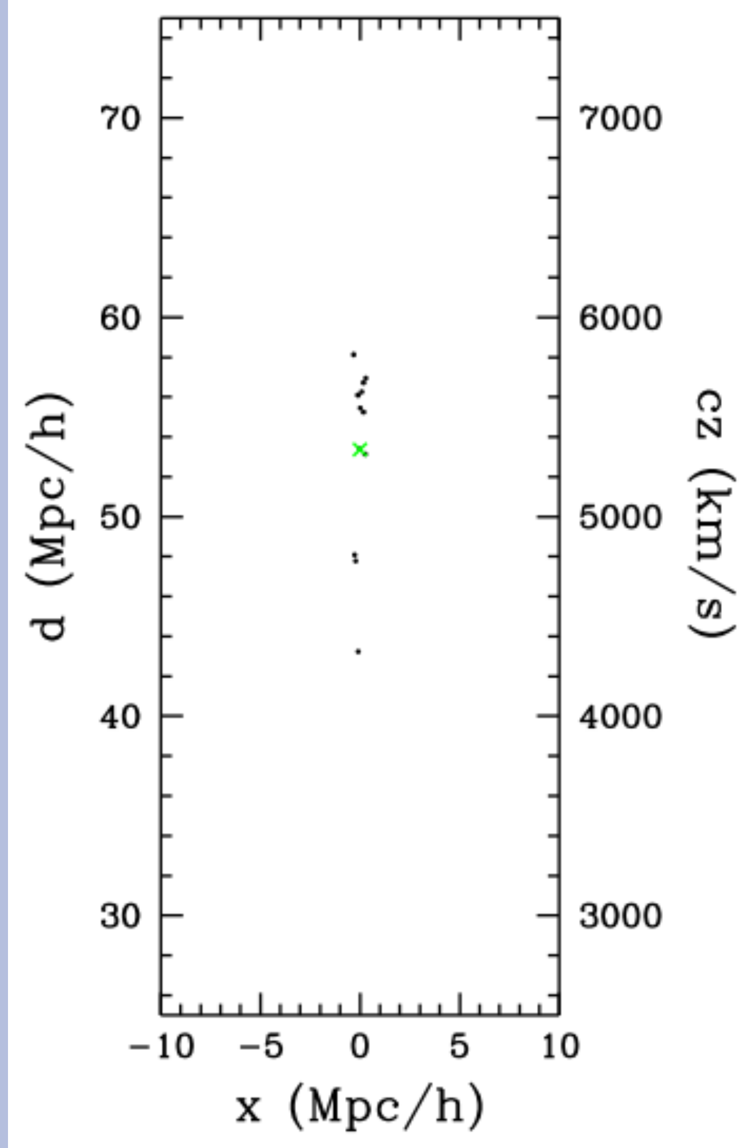
redshift-space distortions

real-space

$9.9 \times 10^{14} M_\odot$



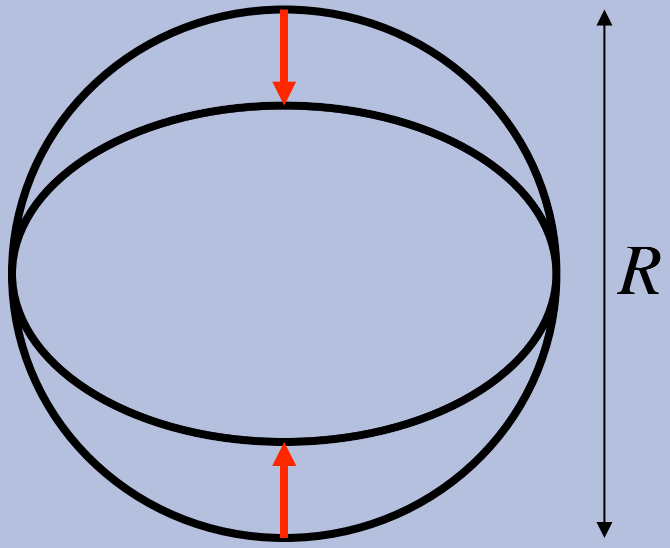
$9.5 \times 10^{13} M_\odot$



redshift-space distortions

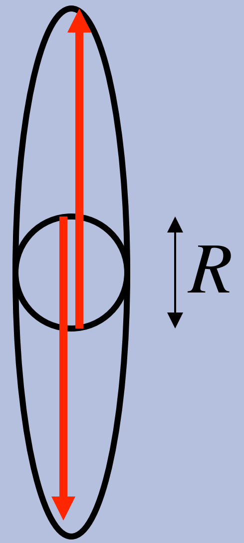
- Large scales: compression

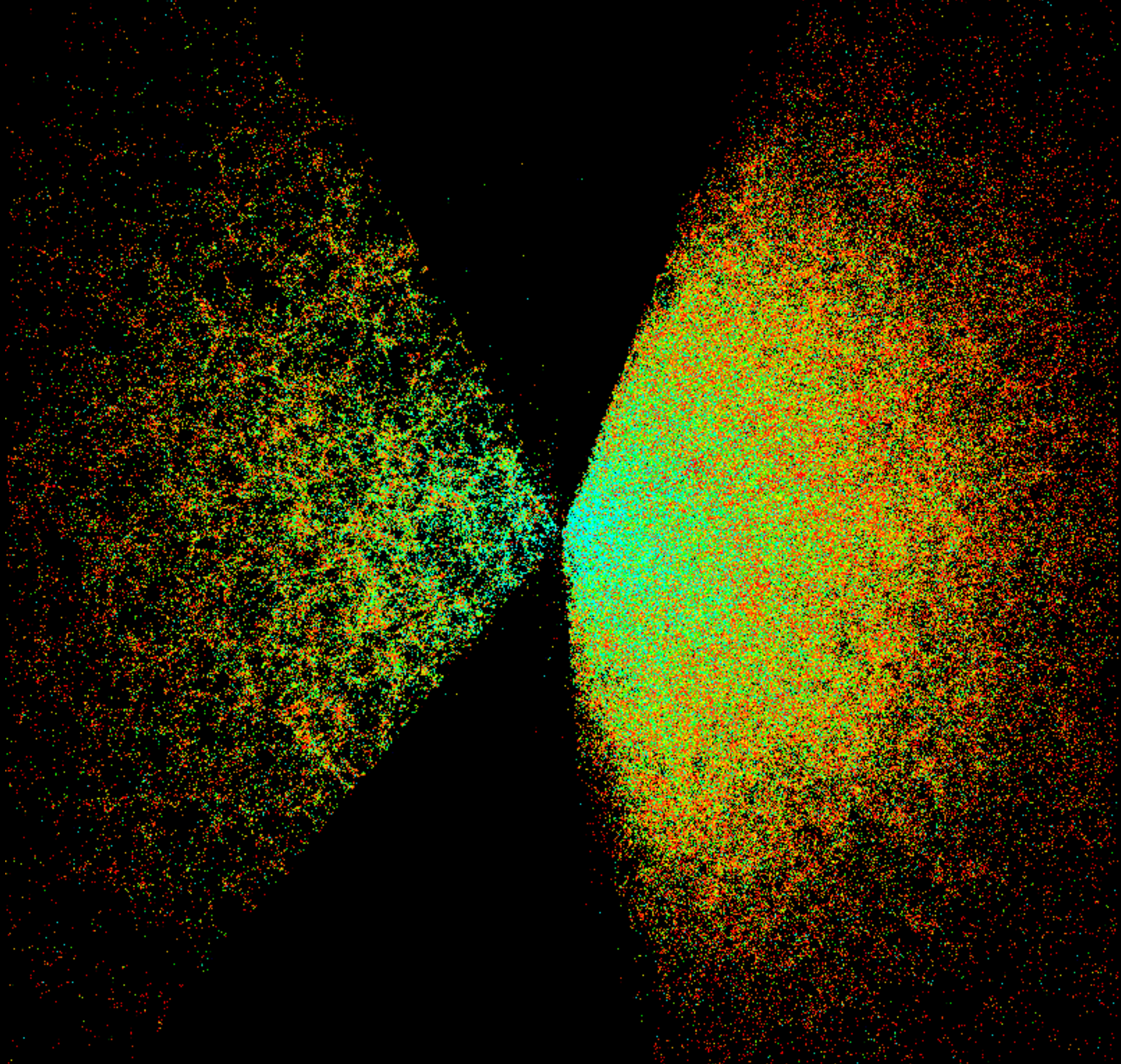
$$H_0 R > \langle v_{\rm pec} \rangle$$



- Small scales: smearing (fingers of God)

$$H_0 R < \langle v_{\rm pec} \rangle$$

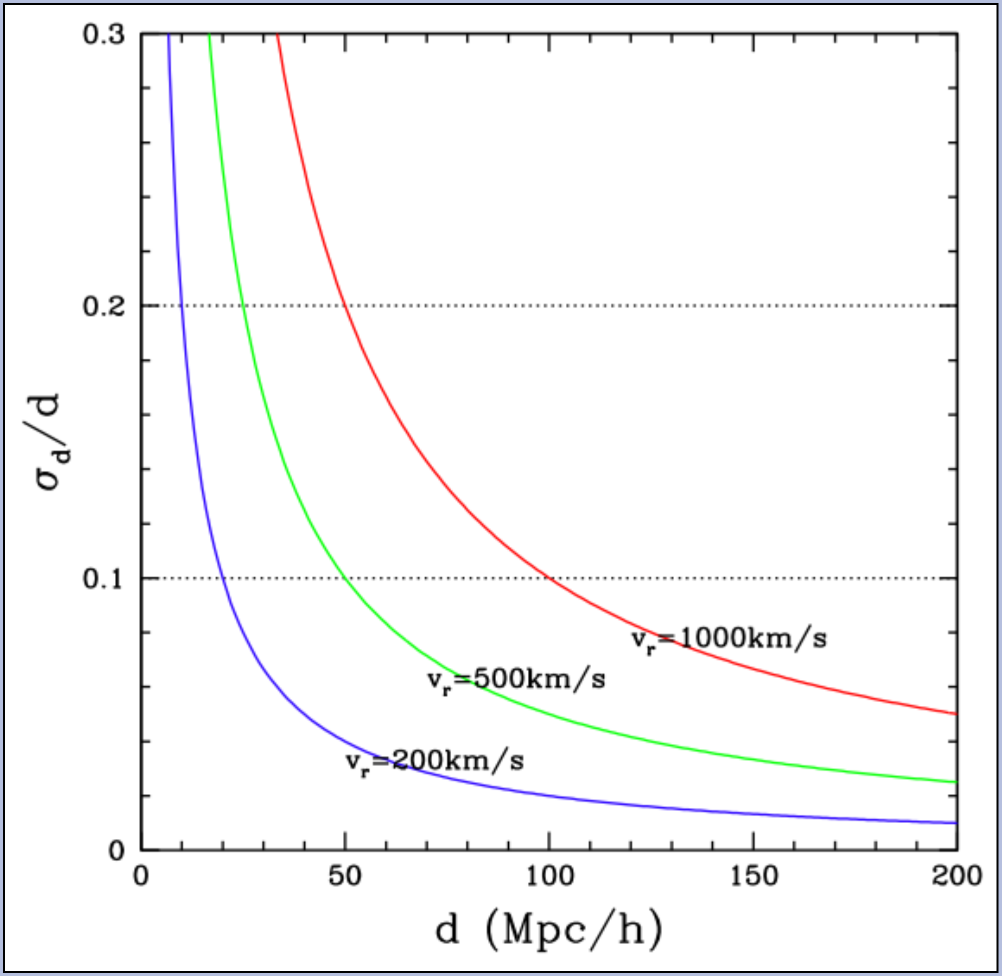




Redshift as distance estimator

$$d = \frac{cz}{H_0} - \frac{v_r}{H_0}$$

$$\sigma_d = \frac{v_r}{H_0} \rightarrow \frac{\sigma_d}{d} = \frac{v_r}{H_0 d}$$



Redshift wins over other distance indicators at large distance.

Redshift

$$1+z=\frac{\lambda_{\text{obs}}}{\lambda_{\text{emit}}}$$

Cosmological

$$1+z_{\text{cosm}}=\frac{1}{a(t)}$$

Doppler

$$z_{\text{doppler}}\simeq\frac{v_r}{c}$$

Cosmological redshift:

$$1+z_{\text{cosm}}=\frac{\lambda_{\text{stretched}}}{\lambda_{\text{emit}}}$$

Doppler shift:

$$1+z_{\text{doppler}}=\frac{\lambda_{\text{obs}}}{\lambda_{\text{stretched}}}$$

Combined effects:

$$1+z=\left(1+z_{\text{cosm}}\right)\left(1+z_{\text{doppler}}\right)$$

Redshift

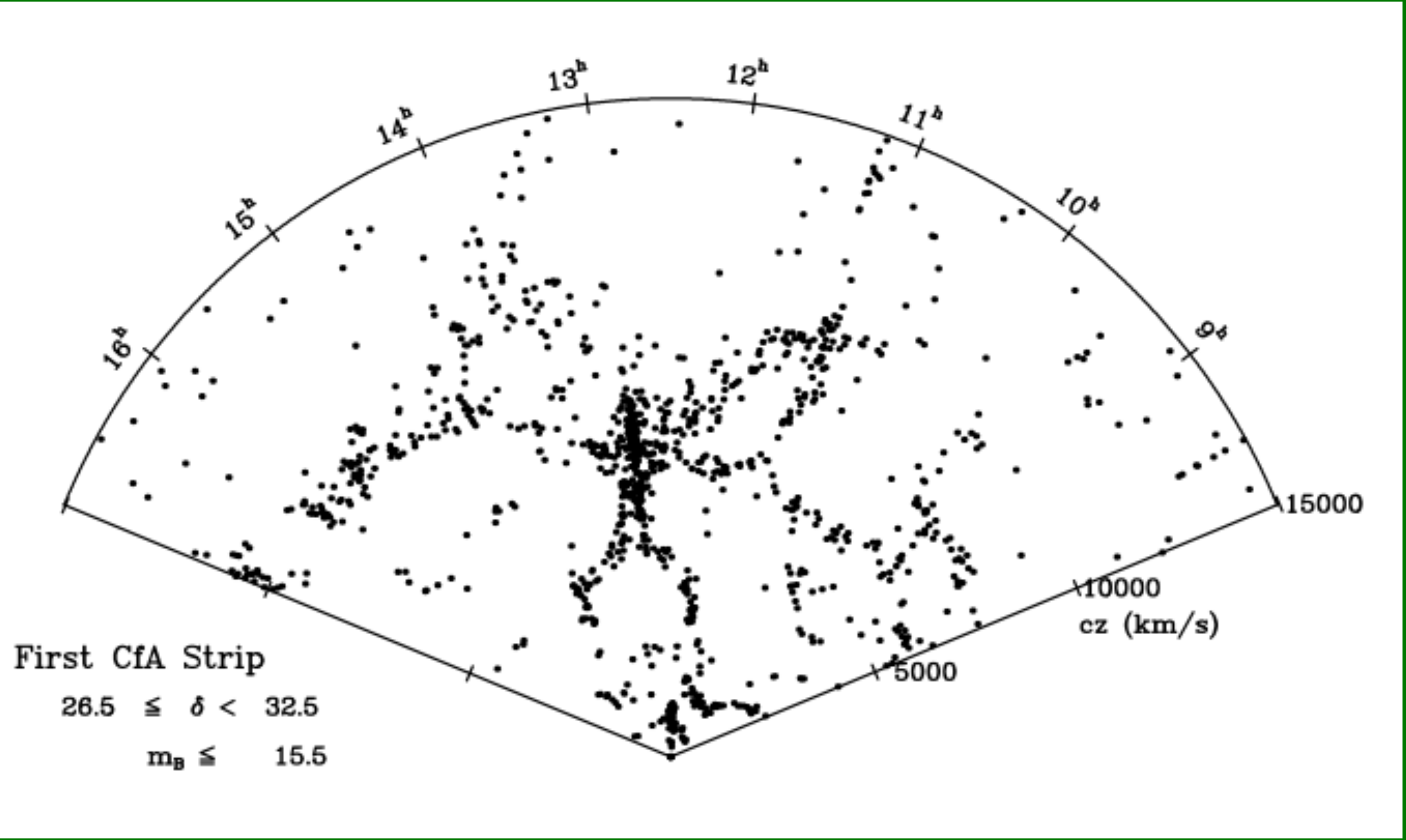
This is different from the Doppler interpretation where cosmological redshift is due to an expansion velocity.

$$v_{\mathrm{tot}} = v_{\mathrm{cosm}} + v_{\mathrm{pec}} \longrightarrow z_{\mathrm{tot}} = z_{\mathrm{cosm}} + z_{\mathrm{pec}}$$

Instead, the correct formula is:

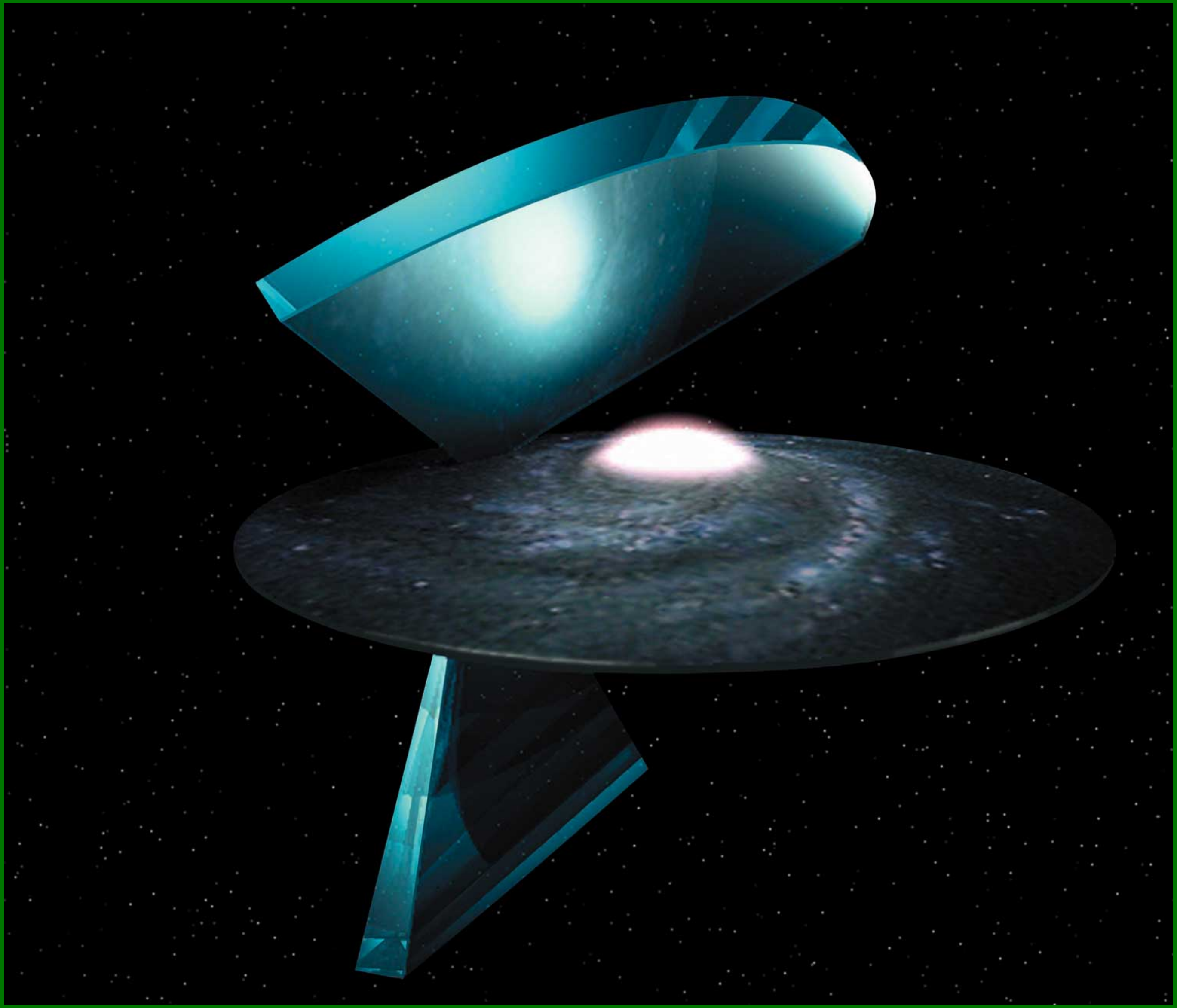
$$z_{\mathrm{tot}} = z_{\mathrm{cosm}} + z_{\mathrm{pec}} + z_{\mathrm{cosm}} \cdot z_{\mathrm{pec}}$$

Redshift Surveys



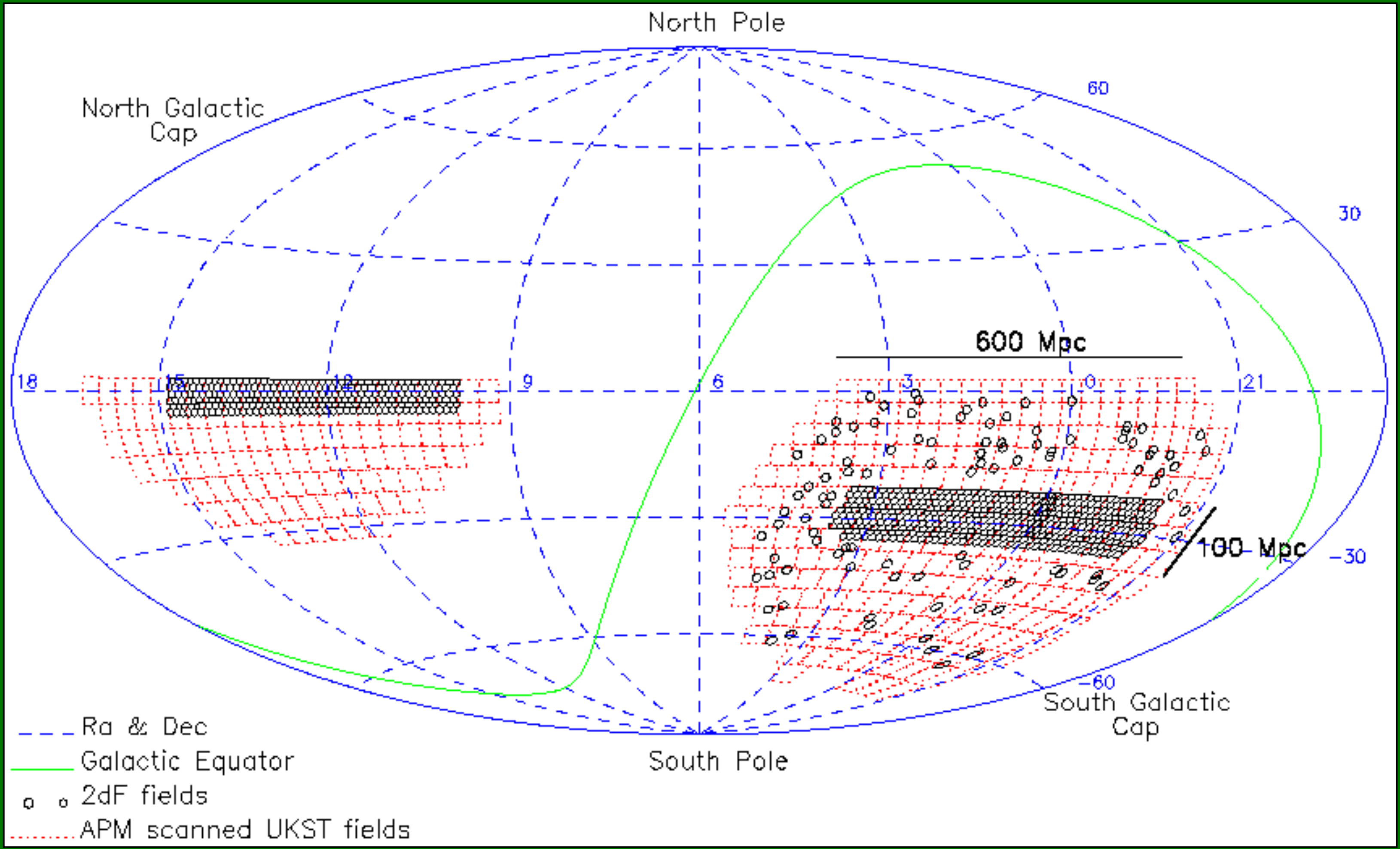
CfA survey

Redshift Surveys



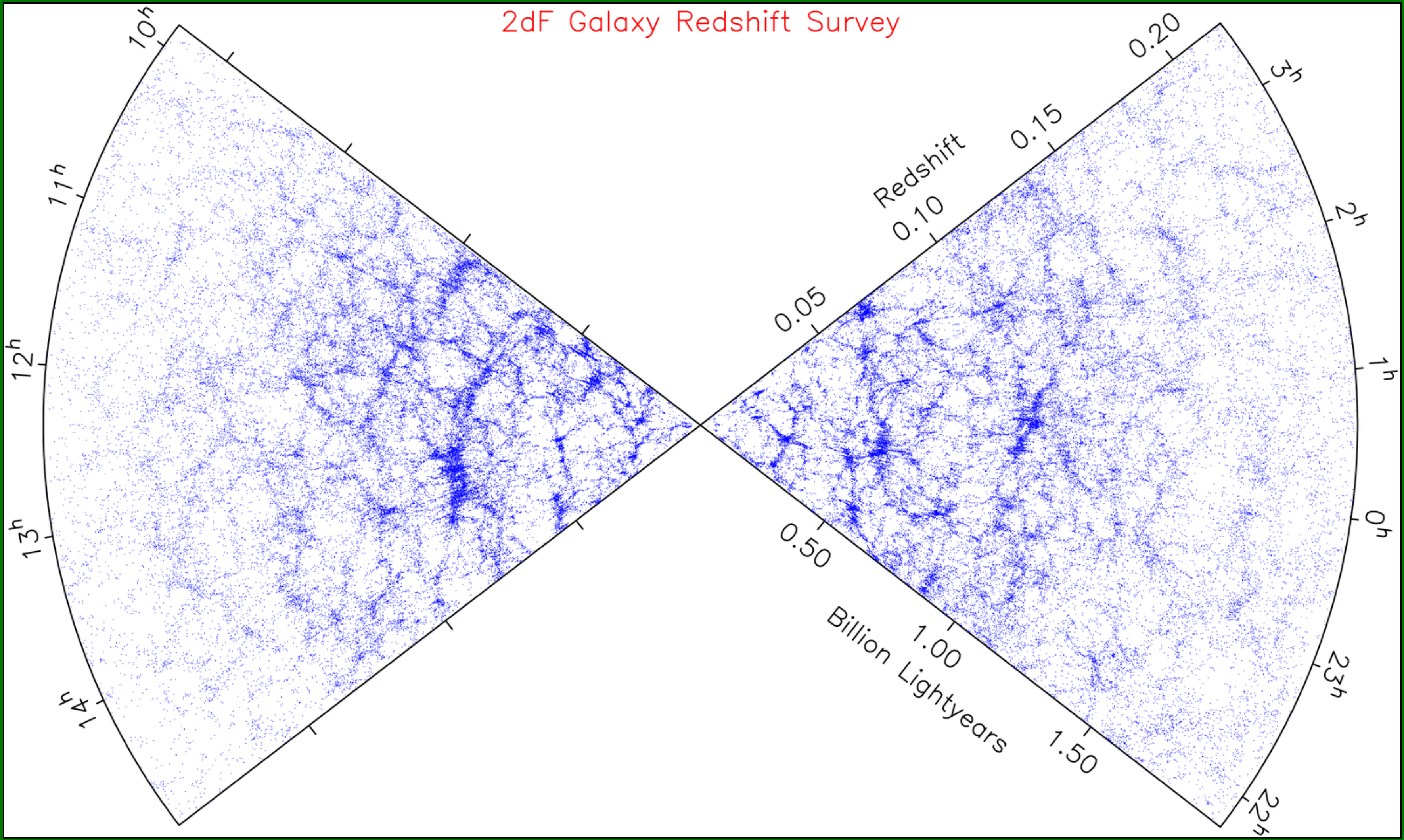
2dF survey

Redshift Surveys



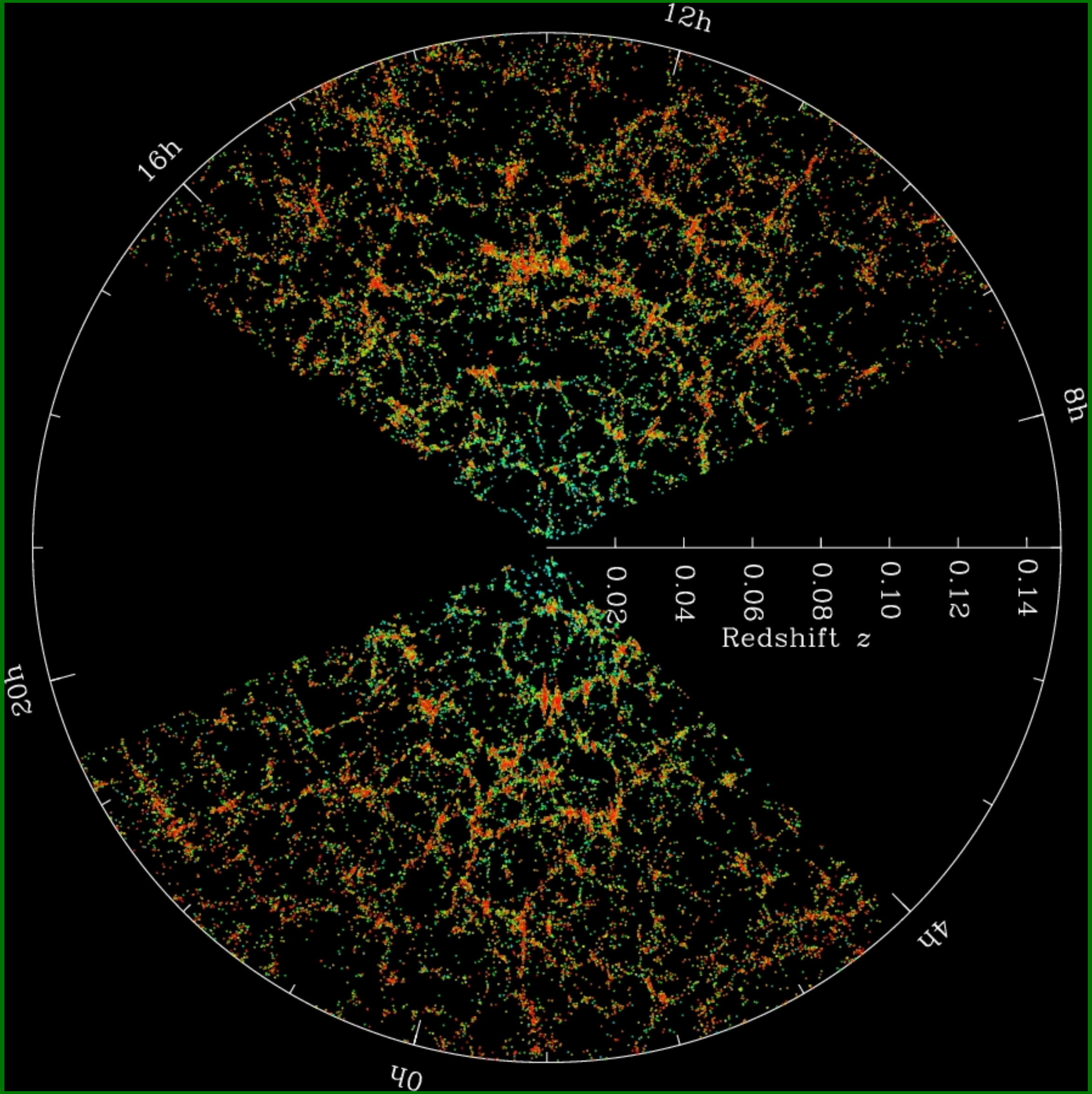
2dF survey

Redshift Surveys



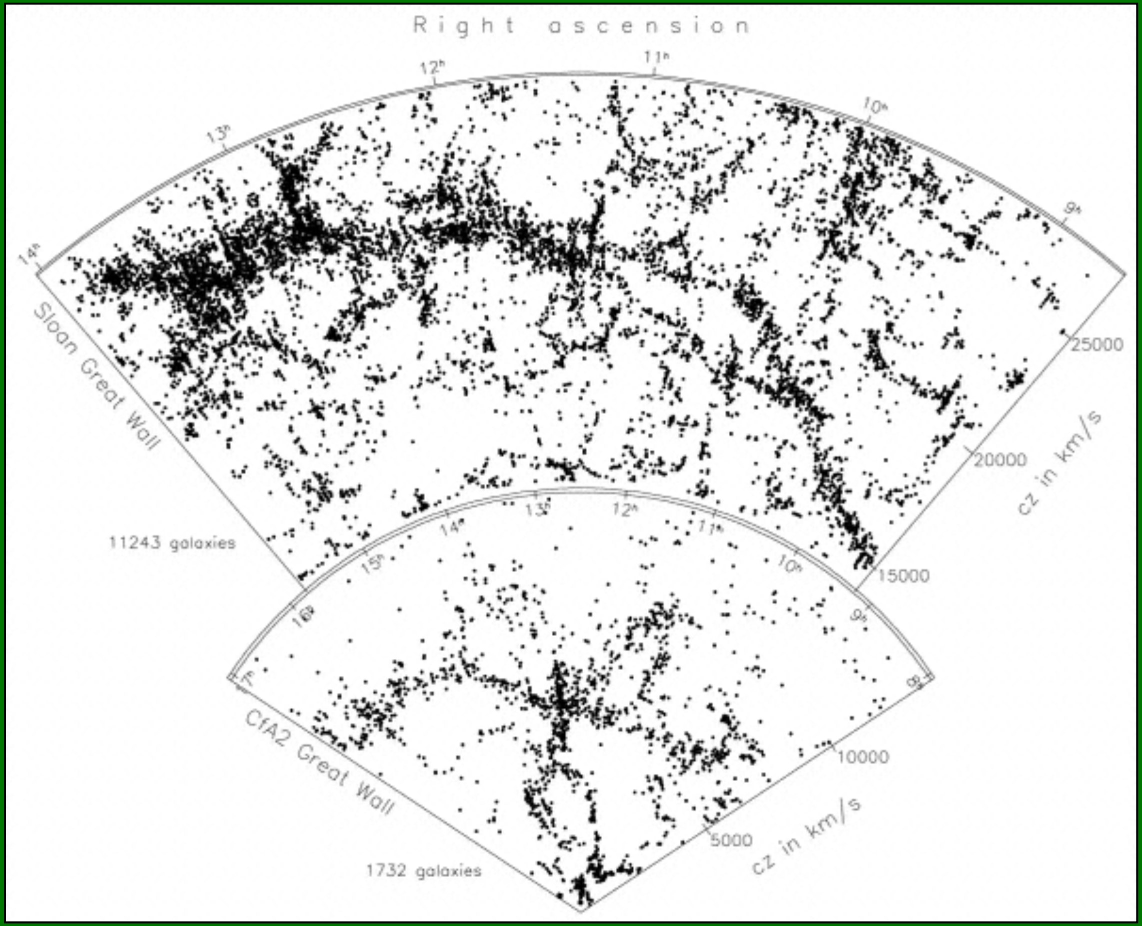
2dF survey

Redshift Surveys



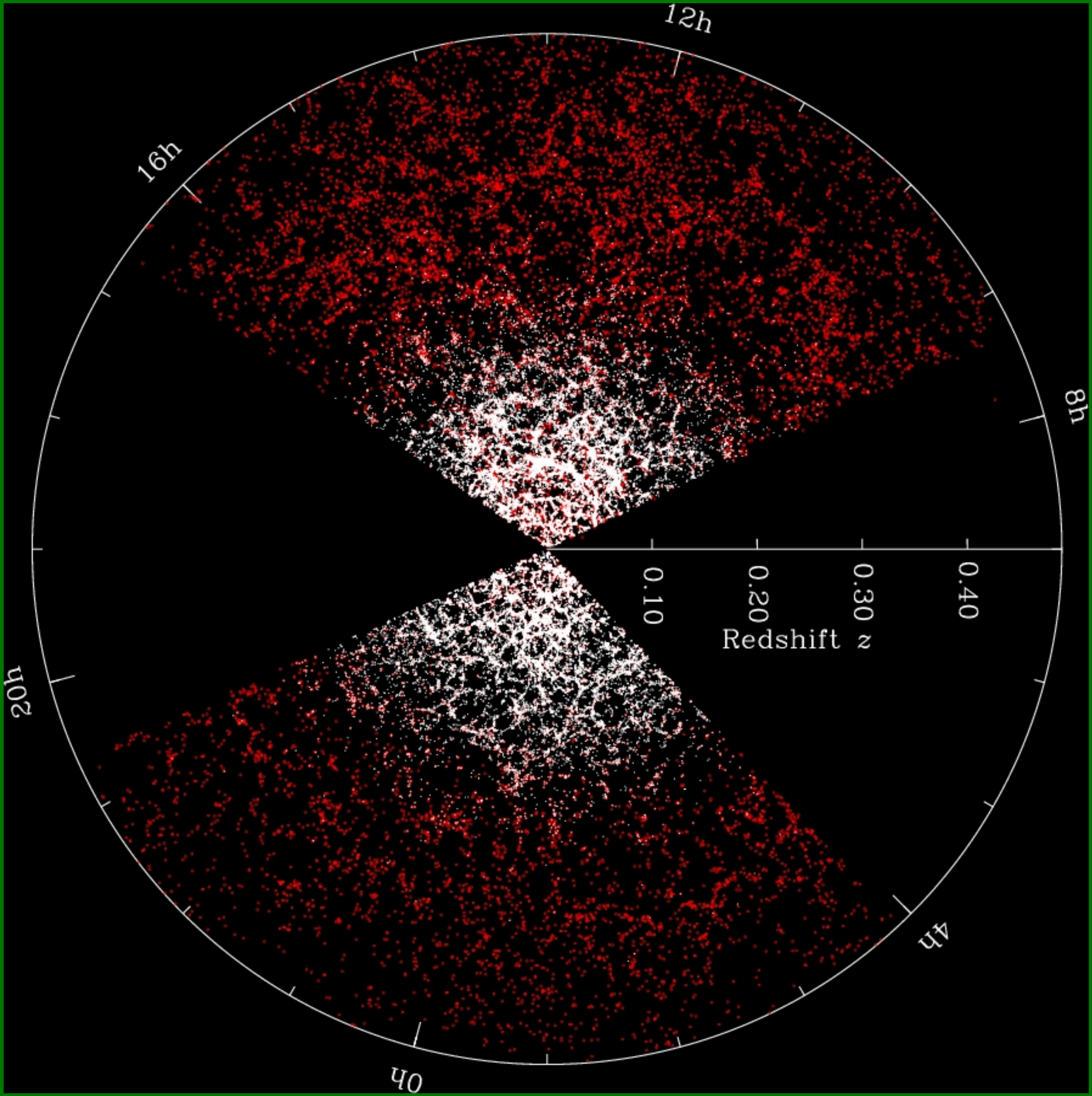
SDSS Main

Redshift Surveys



SDSS Main

Redshift Surveys



SDSS LRG

Redshift Surveys

SURVEY	YEARS	N_{gals}	d_{max}	Area
CfA	1977-1982	2,395	150 Mpc	N
CfA2	1985-1995	18,000	150 Mpc	N
SSRS2	1994	5,500	150 Mpc	S
PSCz	1998	15,000	150 Mpc	All-sky
LCRS	1996	25,000	600 Mpc	N+S Slices 700 deg^2
2dF	2001	250,000	600 Mpc	N+S 1500 deg^2
SDSS	1998-2008	1 million	600 Mpc	1/5 of sky
SDSS LRG	1998-2008	100,000	1 Gpc	1/5 of sky
DEEP2	2002-2005	50,000	2-3 Gpc	3 deg^2
VVDS	2002-2010	150,000	2-3 Gpc	16 deg^2
SDSS3 BOSS	2008-2014	1.5 million	1.8 Gpc	1/4 of sky
SDSS4 eBOSS	2014-2020	700,000	2.4 Gpc	1/4 of sky
DESI	2018-2022	20 million	5 Gpc	1/3 of sky
Euclid	2020-2026	52 million	5 Gpc	1/3 of sky

Redshift Surveys