Galaxisfelmérések: az Univerzum térképei

Kiss László
MTA KTM CSKI

Miről lesz szó?

- Hubble vagy nem Hubble?
- Galaxisok, galaxishalmazok és az Univerzum szerkezete
- A műszerfejlődés útjai
- Hogyan mérjük meg egy galaxis távolságát?

Two Nebulae with Unparalleled Velocities.—Recent observations here with the nebular spectrograph have shown that the nebulæ N. G. C. 584 and N. G. C. 936, both evidently of the spiral family, possess much the highest velocities yet observed for any objects.

A plate exposed to N. G. C. 584, (R.A. = $1^h\,27^m.3$. Dec. = —7° 16′), on the useful parts of the clear nights from December 31 to January 14, total exposure about 28 hours, gave a serviceable, although somewhat weak, spectrogram. The spectrum, approximately of the solar type, shows its lines enormously displaced toward the longer wave lengths, corresponding to the exceptional velocity of 1800 kilometers per second. The motion is away from the Sun.

Nebula N. G. C. 936, (R.A. = $2^h\,23^m$., Dec. = —1° 33′), was recently photographed for its spectrum with an exposure of about 34 hours. The resulting spectrogram, having a spectrum similar to that of the sun, exhibits also a very large displacement of the nebular lines. The provisional result from the plate is that the nebula is receding from the Sun with a velocity of fully 1300 kilometers per second.

Brief descriptions of these objects by Mr. Lampland from his direct photographs of them made with the 40-inch reflector are as follows:

> "The nebula N.G.C. 584 is of the type having a brilliant nucleus, and apparently with but little detail in the surrounding nebulous matter. In our photograph not much of the fainter outlying nebulosity is shown. Elongation is apparently in P. A. about 60°. The nucleus is catalogued in the Bonn Durchmusterung as star —7°.248, magnitude 9.7.
>
> The photograph of the nebula N.G.C. 936 shows it to be an interesting object. The most conspicuous structure is the rather large and brilliant nucleus with extensions on diametrically opposite sides, resembling somewhat the view of the ball of Saturn and the ansæ of the rings when the rings are presented at less than half their maximum opening. This brilliant part of the image is placed centrally in an oval-shaped disk of nebulosity rather faint and showing but little structure. The bright Saturn-like part is approximately 85″ in length in P. A. 80°. The elliptic disk of faint nebulosity has dimensions about 2′.5 × 3′.5 with the longer axis in P. A. about 160°. In photographs of short exposure the nucleus is small and rather well defined.
>
> Both of these nebulae should doubtless be classed with the spirals."

Lowell Observatory Observation Circular. V. M. Slipher.
Flagstaff, Arizona, January 17, 1921.

two kinds of star-aggregations is quite different. Moreover, the cluster-variables, like RR Lyræ, found isolated in the sky are evenly distributed over all galactic latitudes in spite of their faintness (generally between 9^m and 11^m). It is, therefore, probable that these variables are absolutely faint stars. This view is strengthened by the considerable proper-motion of RR Lyræ—viz., 0″·25 yearly.

I am, Gentlemen,
Yours faithfully,
EJNAR HERTZSPRUNG.

Groningen, 1917, June 7.

Radial Velocity Observations of Spiral Nebulæ.

GENTLEMEN,—

In the *Observatory*, No. 511, p. 131, Mr. Reynolds has a letter which I fear might lead the reader to suppose that little confidence should be placed in the velocity-observations of spiral nebulæ such as I initiated in 1912 and have had in progress since at the Lowell Observatory, and I beg space for a few remarks upon this work.

It is indeed true—as Mr. Reynolds points out—that the extreme faintness of the spectra of the spiral nebulæ makes very long exposures necessary, and this seriously retards the securing of plates for their spectrographic investigation. Because these spectra are continuous, their linear dispersion must be made small in order to keep the exposure-times within practicable limits. The scale of the instrument I have used is somewhat greater than that of the Mt. Wilson one referred to.

My observations of the spiral nebulæ are carried out with the same precautions as are star-velocity observations, which includes test-observations of objects whose velocities are known. The method of exposing the comparison-spectrum I employ is very different from the faulty one Mr. Reynolds mentions—namely,

in my observations a number of brief exposures to the spark are distributed throughout the long nebular exposure in order that the comparison-lines may be subjected, as far as possible, to the same influences as are the nebular lines.

In consequence of the extraordinary velocities of the spiral nebulæ, these can, in spite of the small scale of their spectra, be observed with sufficient accuracy to give trustworthy results. I have observed about thirty of these nebulæ, and find their average velocity to be about 570 km. per second. For the stars, the average velocity is about 20 km., and two observers with different instrumental means and a single plate each of an average star will sometimes differ by 20 per cent. of the quantity measured. Nebular observations may then be of equal accuracy and still differ by upwards of 100 km. While the linear scale of the Lowell nebular spectrograph is only one-fifteenth the scale of a powerful 3- or 4-prism star-spectrograph, it, on the other hand, is observing a velocity twenty-five times as great as that which the star-spectrograph is required to measure. Thus, so far as scale of the spectra is concerned, the nebular spectrograph, in consequence of the great nebular velocities, is at no disadvantage as compared with the stellar instrument. And I cannot agree to Mr. Reynolds's statement that "we are bound to recognize that the results cannot carry the same weight as those obtained on the brighter stars." One finds less discouragement in the inaccuracy of the results than in the great difficulties met in

A RELATION BETWEEN DISTANCE AND RADIAL VELOCITY AMONG EXTRA-GALACTIC NEBULAE

By Edwin Hubble

Mount Wilson Observatory, Carnegie Institution of Washington

Communicated January 17, 1929

Determinations of the motion of the sun with respect to the extra-galactic nebulae have involved a K term of several hundred kilometers which appears to be variable. Explanations of this paradox have been sought in a correlation between apparent radial velocities and distances, but so far the results have not been convincing. The present paper is a re-examination of the question, based on only those nebular distances which are believed to be fairly reliable.

Distances of extra-galactic nebulae depend ultimately upon the application of absolute-luminosity criteria to involved stars whose types can be recognized. These include, among others, Cepheid variables, novae, and blue stars involved in emission nebulosity. Numerical values depend

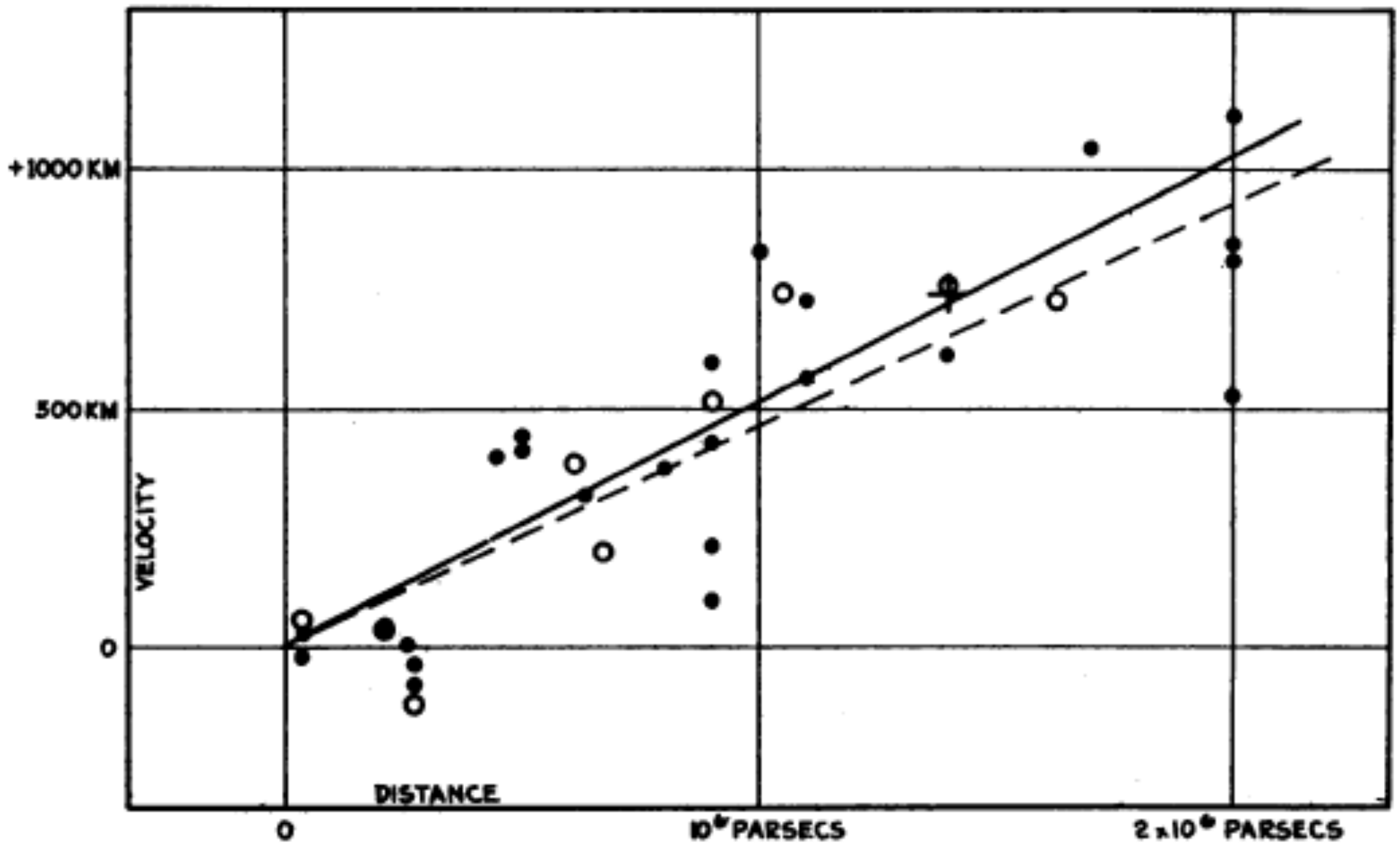
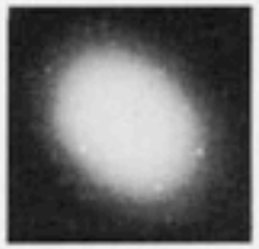
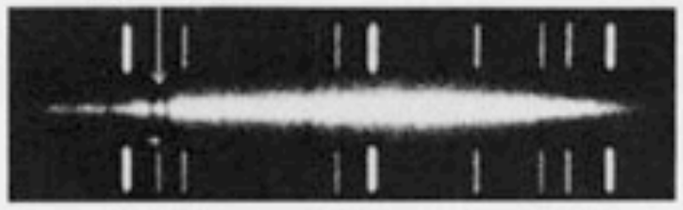
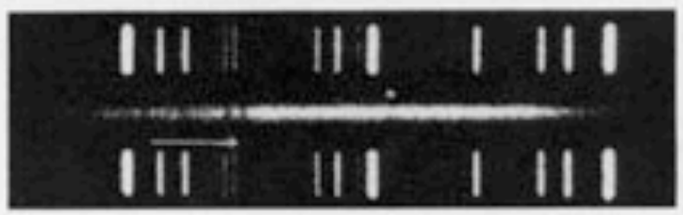
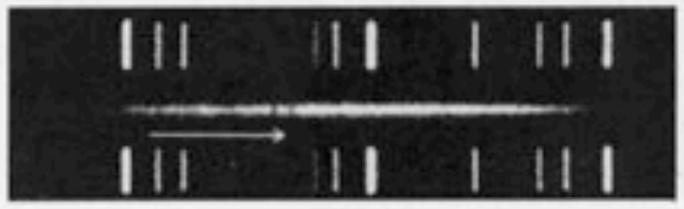
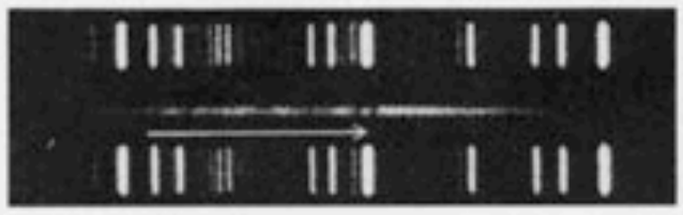
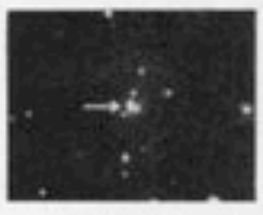
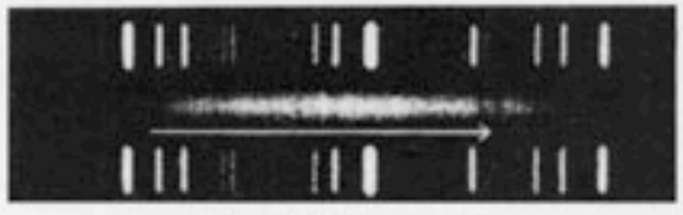
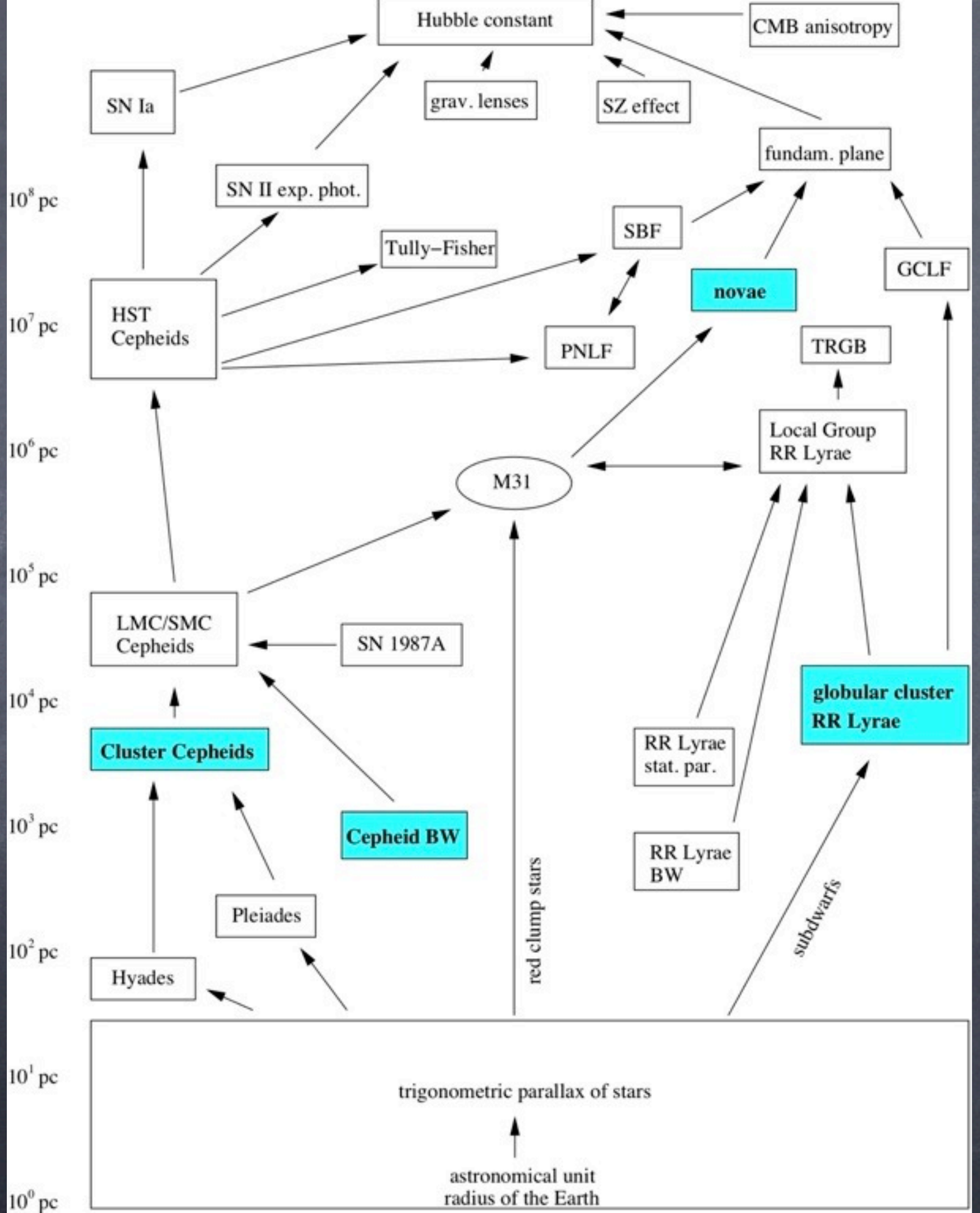


FIGURE 1

Velocity-Distance Relation among Extra-Galactic Nebulae.

Cluster nebula in	Distance in light-years	Redshifts
 Virgo	78,000,000	 1,200 km s^{-1}
 Ursa Major	1,000,000,000	 15,000 km s^{-1}
 Corona Borealis	1,400,000,000	 22,000 km s^{-1}
 Bootes	2,500,000,000	 39,000 km s^{-1}
 Hydra	3,960,000,000	 61,000 km s^{-1}

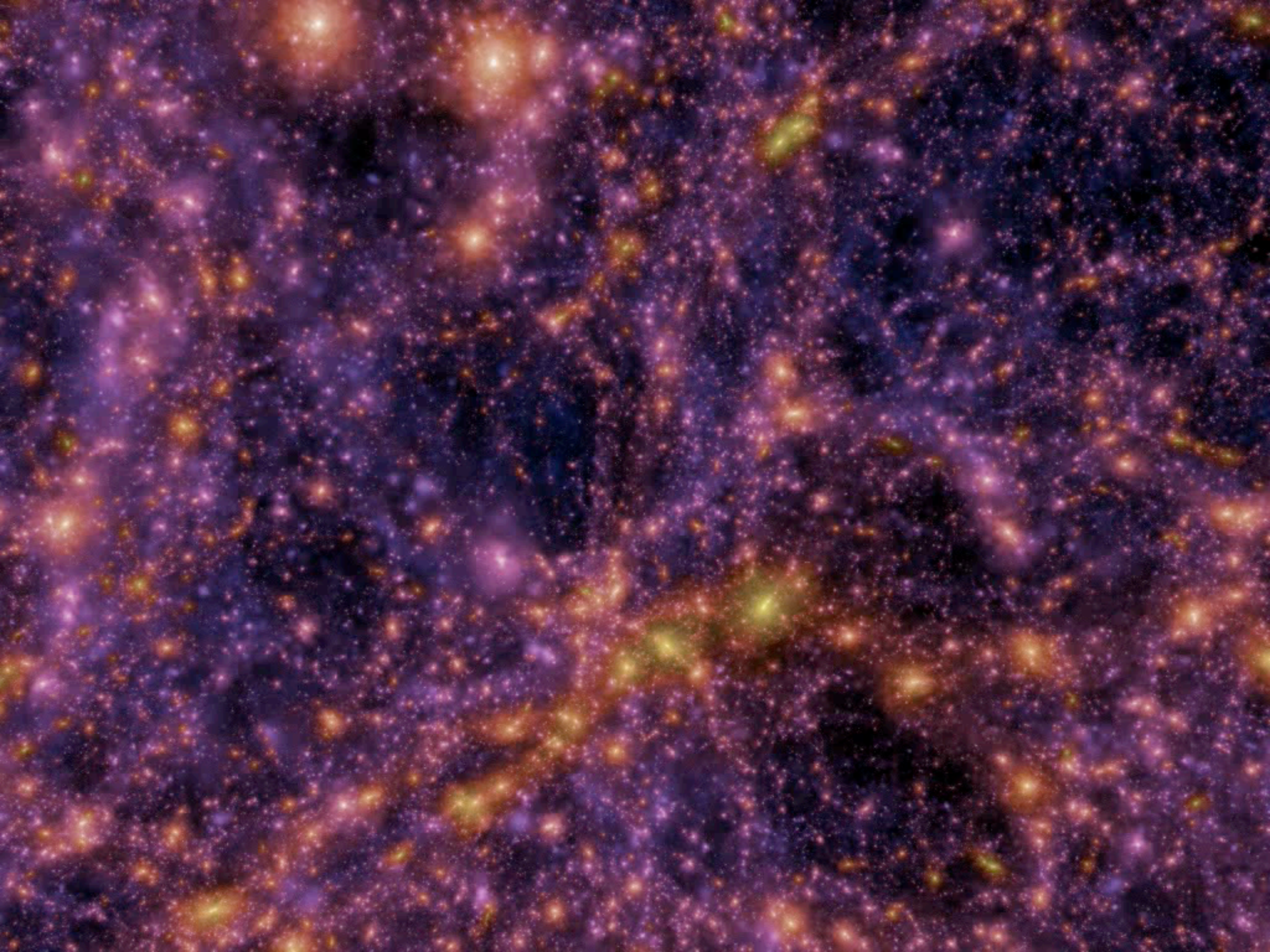

Hubble constant
CMB anisotropy
SN Ia
grav. lenses
SZ effect
fundam. plane
10^8 pc
SN II exp. phot.
SBF
Tully–Fisher
GCLF
10^7 pc
HST
Cepheids
novae
PNLF
TRGB
10^6 pc
Local Group
RR Lyrae
M31
10^5 pc
LMC/SMC
Cepheids
SN 1987A
10^4 pc
globular cluster
RR Lyrae
Cluster Cepheids
RR Lyrae
stat. par.
10^3 pc
Cepheid BW
RR Lyrae
BW
red clump stars
subdwarfs
Pleiades
10^2 pc
Hyades
10^1 pc
trigonometric parallax of stars
astronomical unit
radius of the Earth
10^0 pc

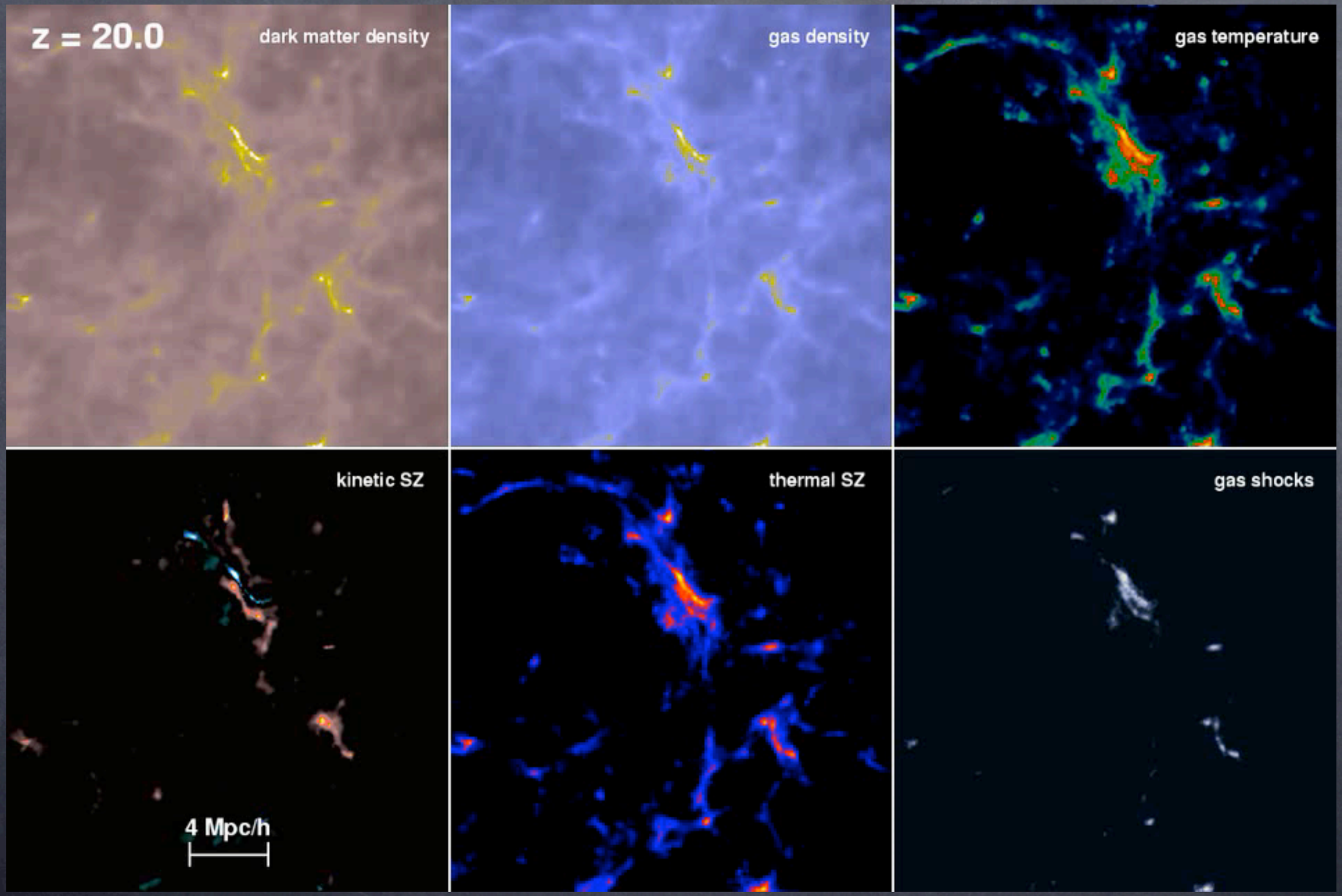
1 Gpc/h

Millennium Simulation

10.077.696.000 particles

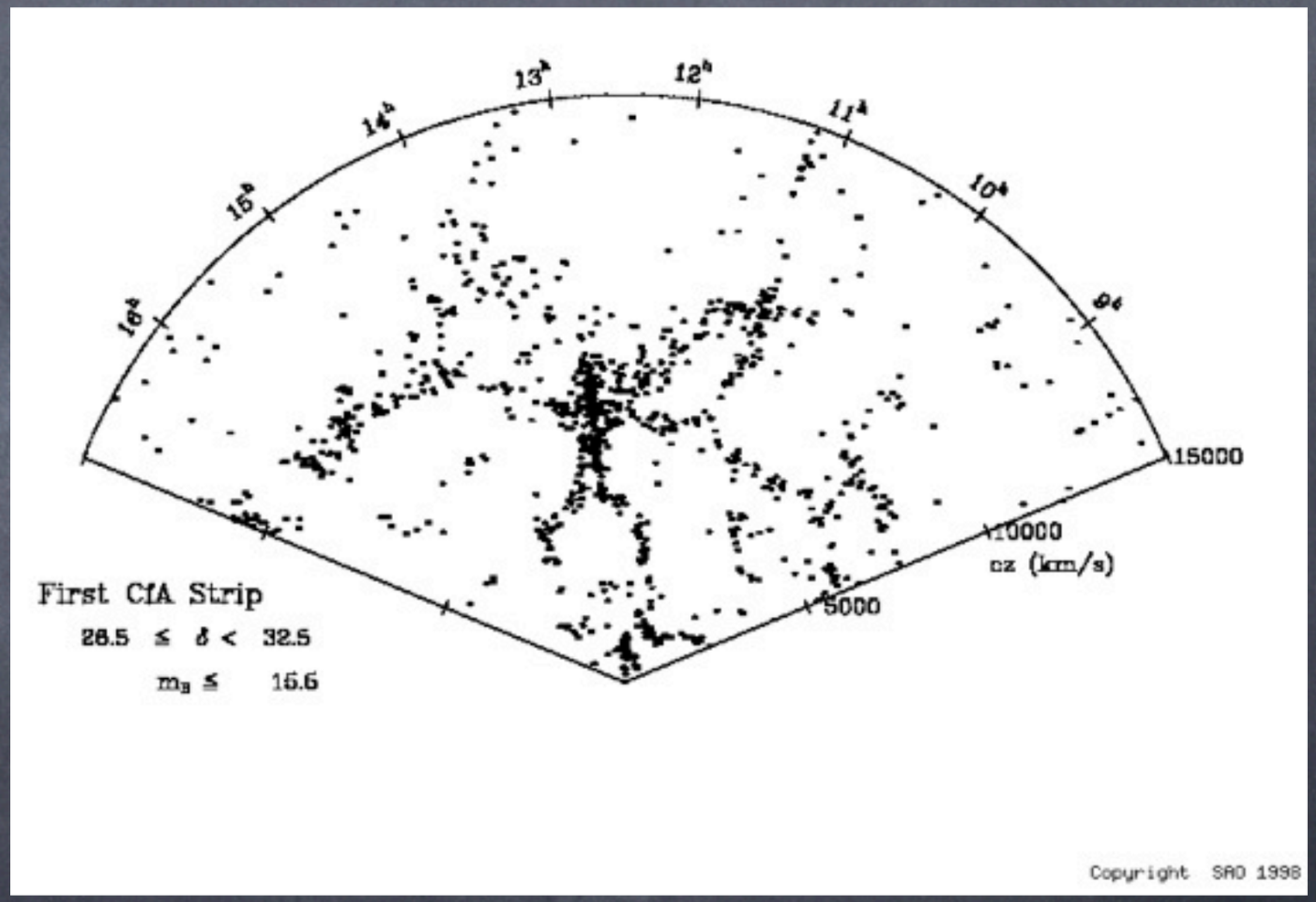
(z = 0)




z = 20.0
dark matter density
gas density
gas temperature
kinetic SZ
thermal SZ
gas shocks
4 Mpc/h

Hogyan lehet tesztelni a bonyolult szimulációkat?

- Fel kell térképezni a látható anyag eloszlását
- Kozmológiai távolságokon a galaxisok jelentik a nyomjelző tesztrészecskéket
- Probléma: RENGETEG galaxis
- Távolságok: vöröseltolódás-mérésből

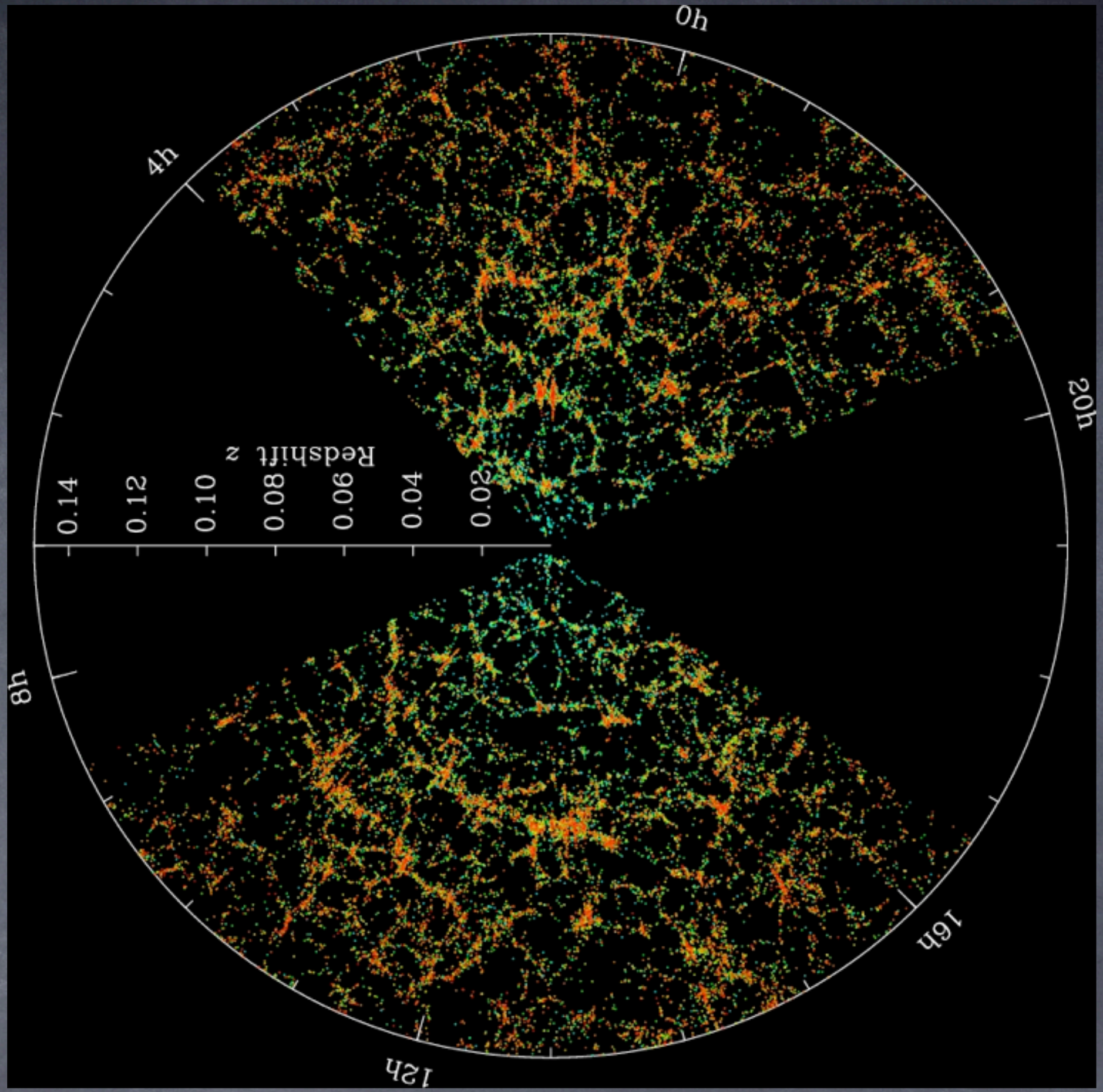


Jelentősebb galaxisfelmérések az elmúlt 30 évben

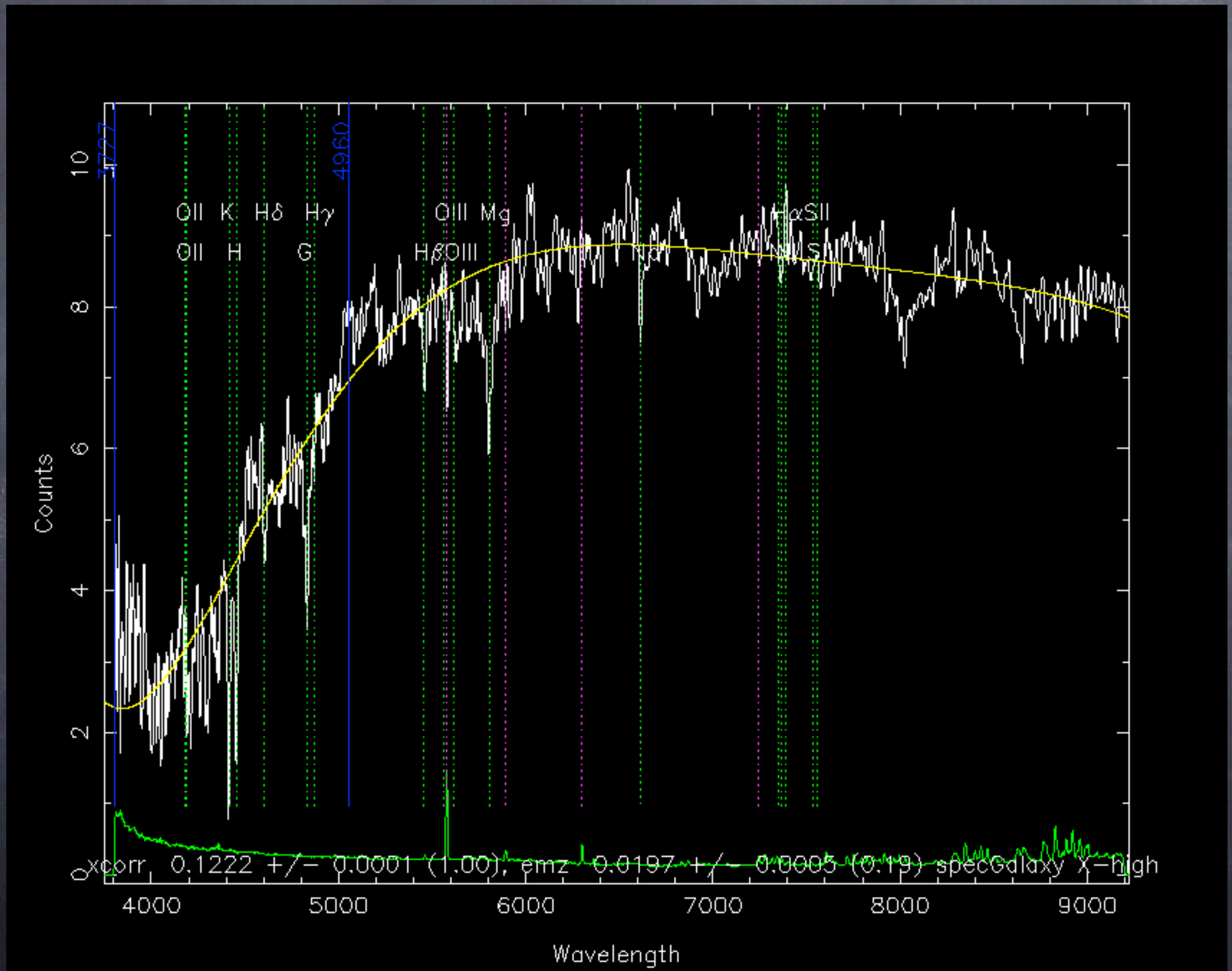
- CfA és CfA2 felmérés (Huchra, Geller, et al.). Több periódus 1977 és 1995 között, 18 ezer galaxis
- DEEP2 survey, 38 ezer galaxis (2003)
- SDSS, több felmérés, >700 ezer galaxis, spektrumok és színek (2,5m SDSS teleszkóp)
- 2dF GRS, 220 ezer galaxis, egyedi spektrumok alapján (AAT)
- 6dF, 125 ezer galaxis (UK Schmidt)
- WiggleZ, 250 ezer galaxis (AAT)
- GAMA, 126 ezer galaxis (AAT)

Sloan Digital Sky Survey

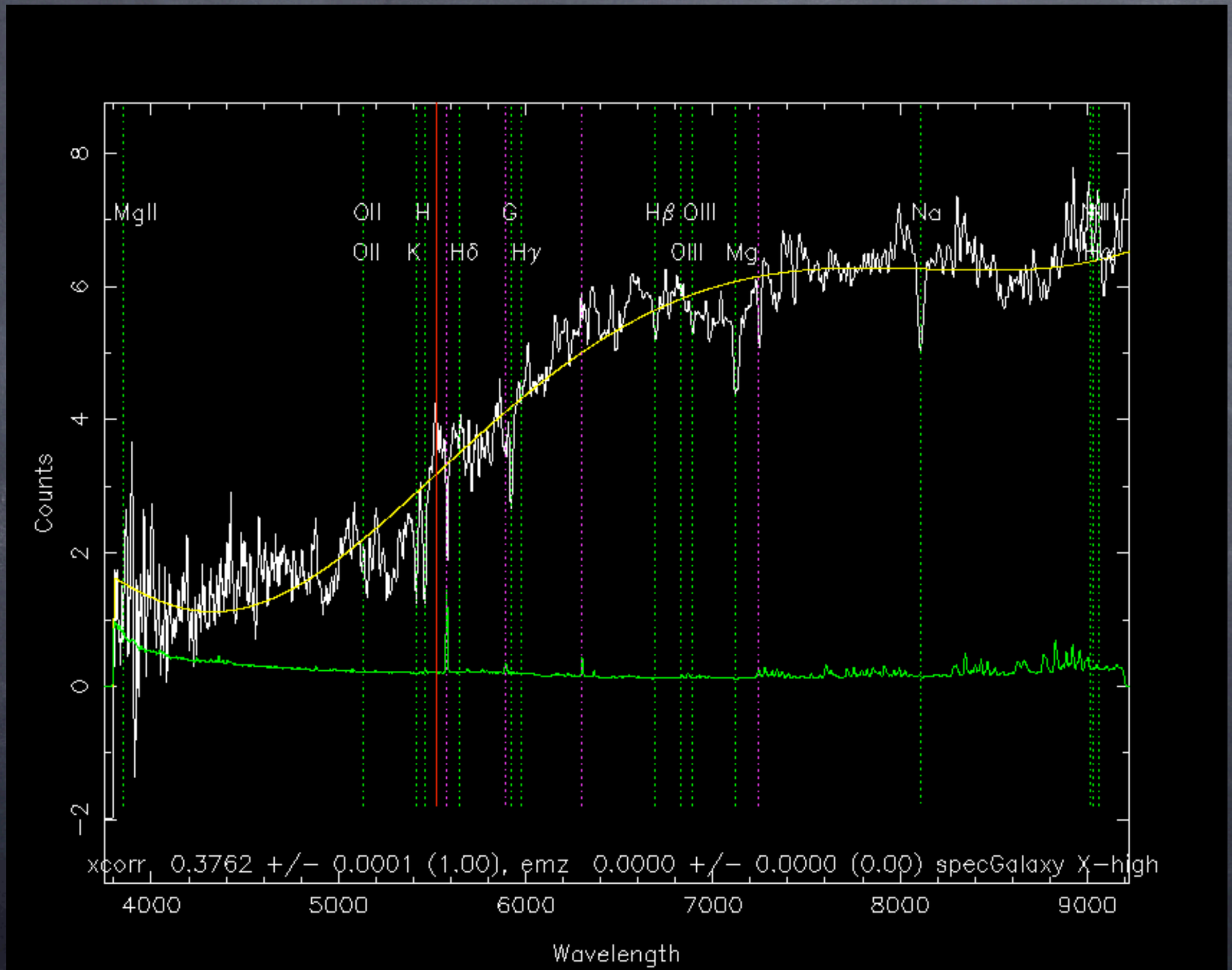
- Új-Mexikó, 2,5m-es teleszkóp Apache Pointban
- Öt színben képalkotás több mint 100 millió égitestről
- Kb. 700 ezer spektrum galaxisokról, kvazárokról és csillagokról
- Fontos magyar részvevők (Szalay Sándor, Csabai István és tanítványaik)


0h
4h
8h
12h
16h
20h
Redshift z
0.02
0.04
0.06
0.08
0.10
0.12
0.14

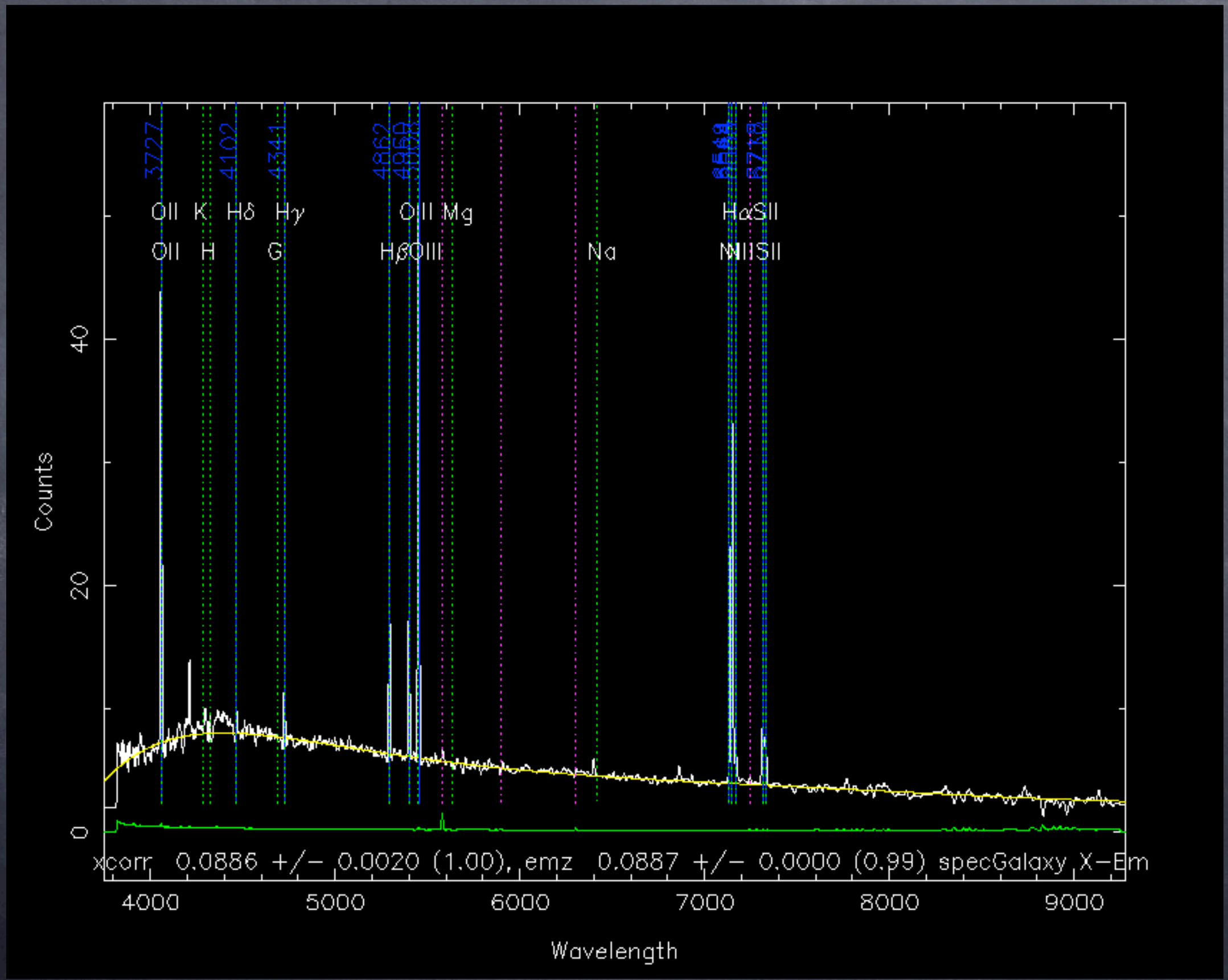
Tipikus galaxis



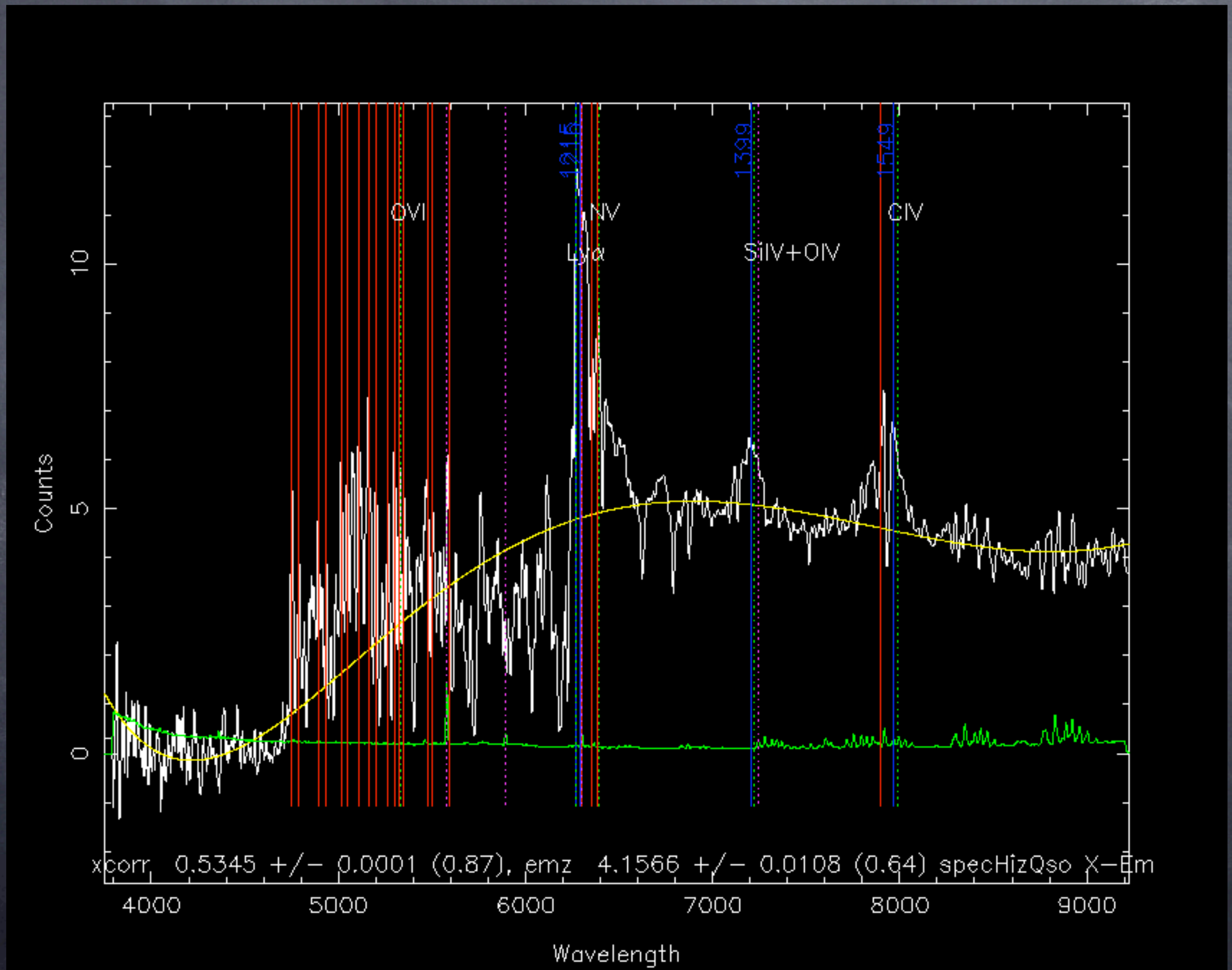
Fényes vörös galaxis



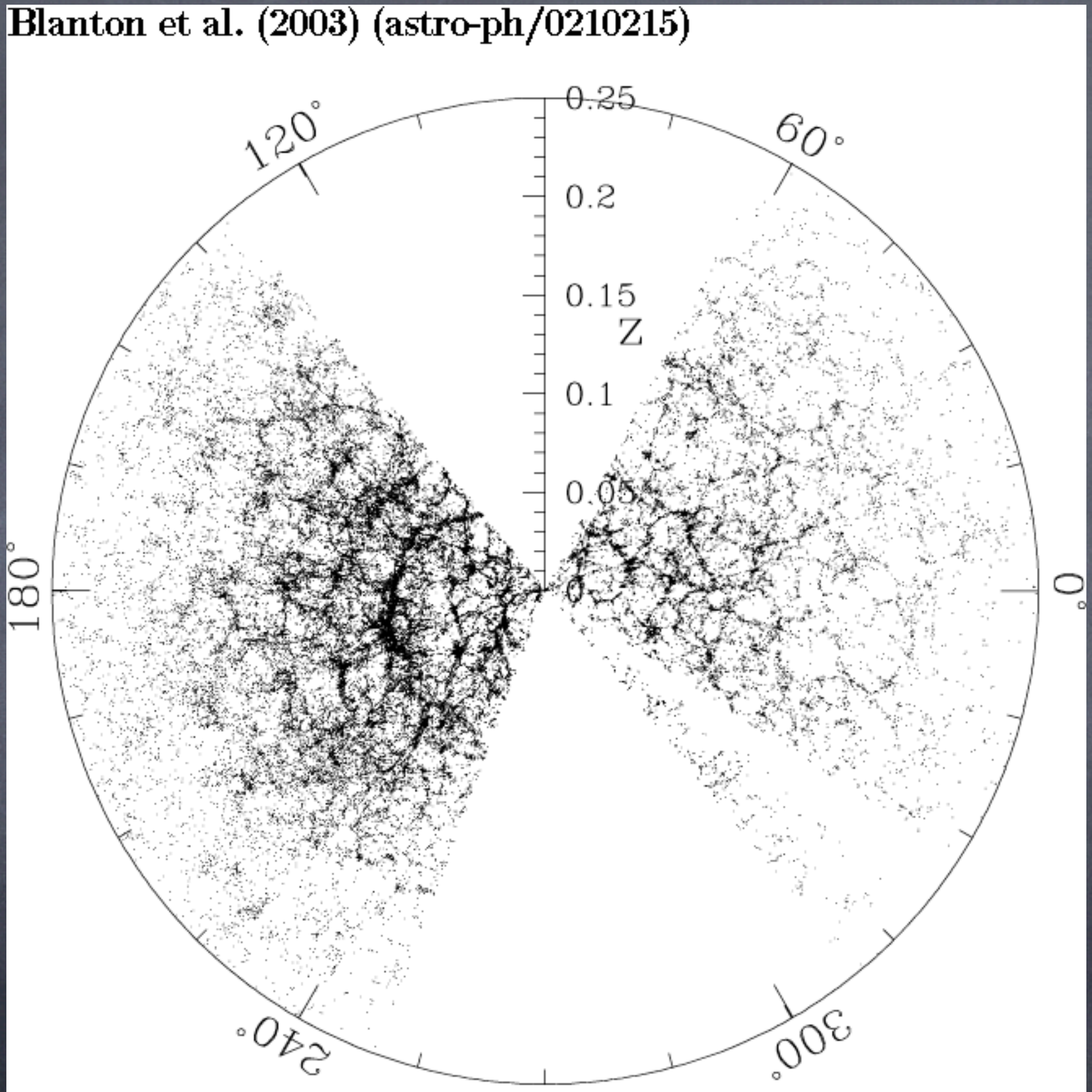
Emissziós vonalas galaxis



Nagy vöröseltolódású kvazár (z=4,16)



Blanton et al. (2003) (astro-ph/0210215)

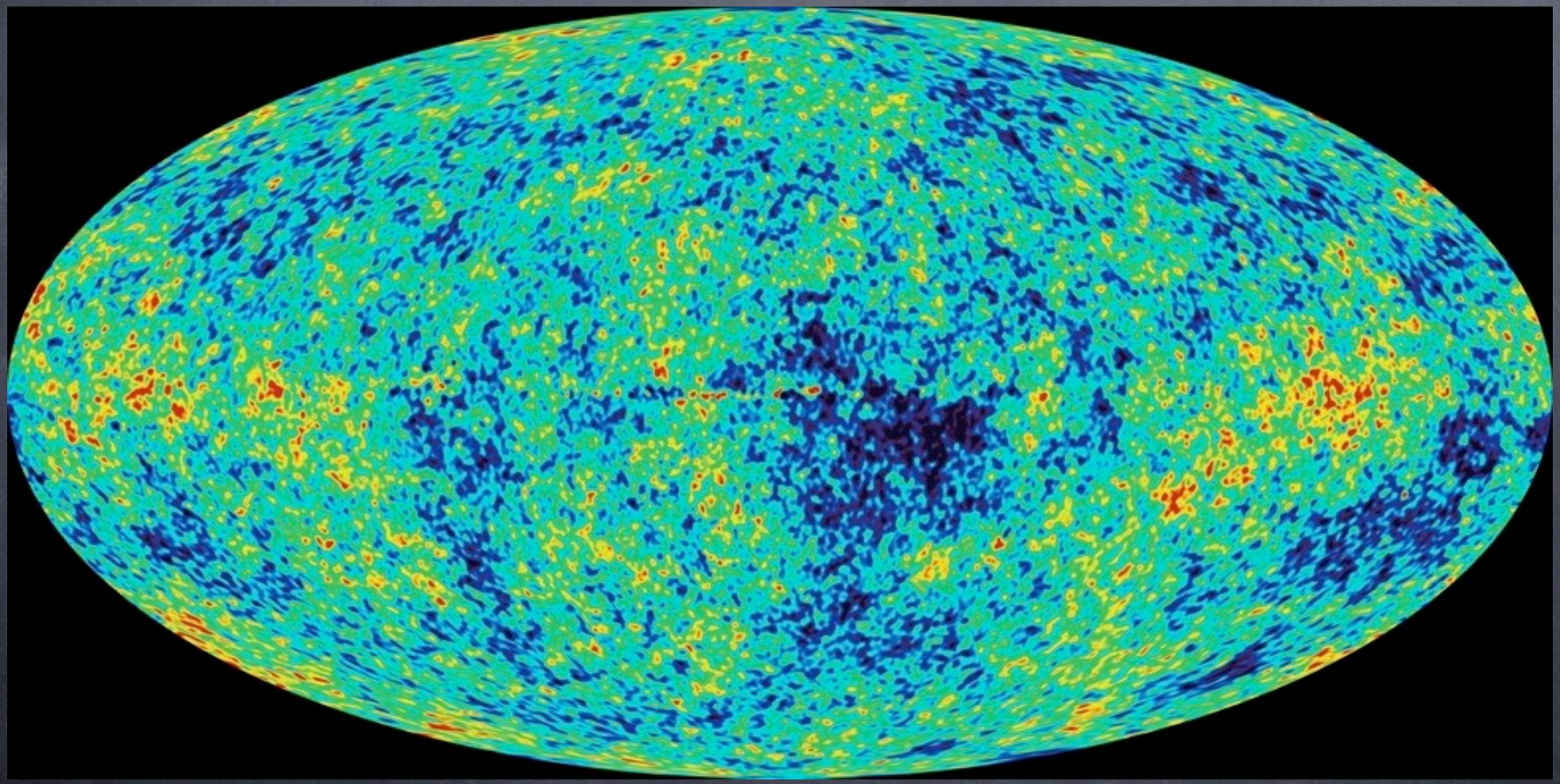


Large−Scale Structure sample10

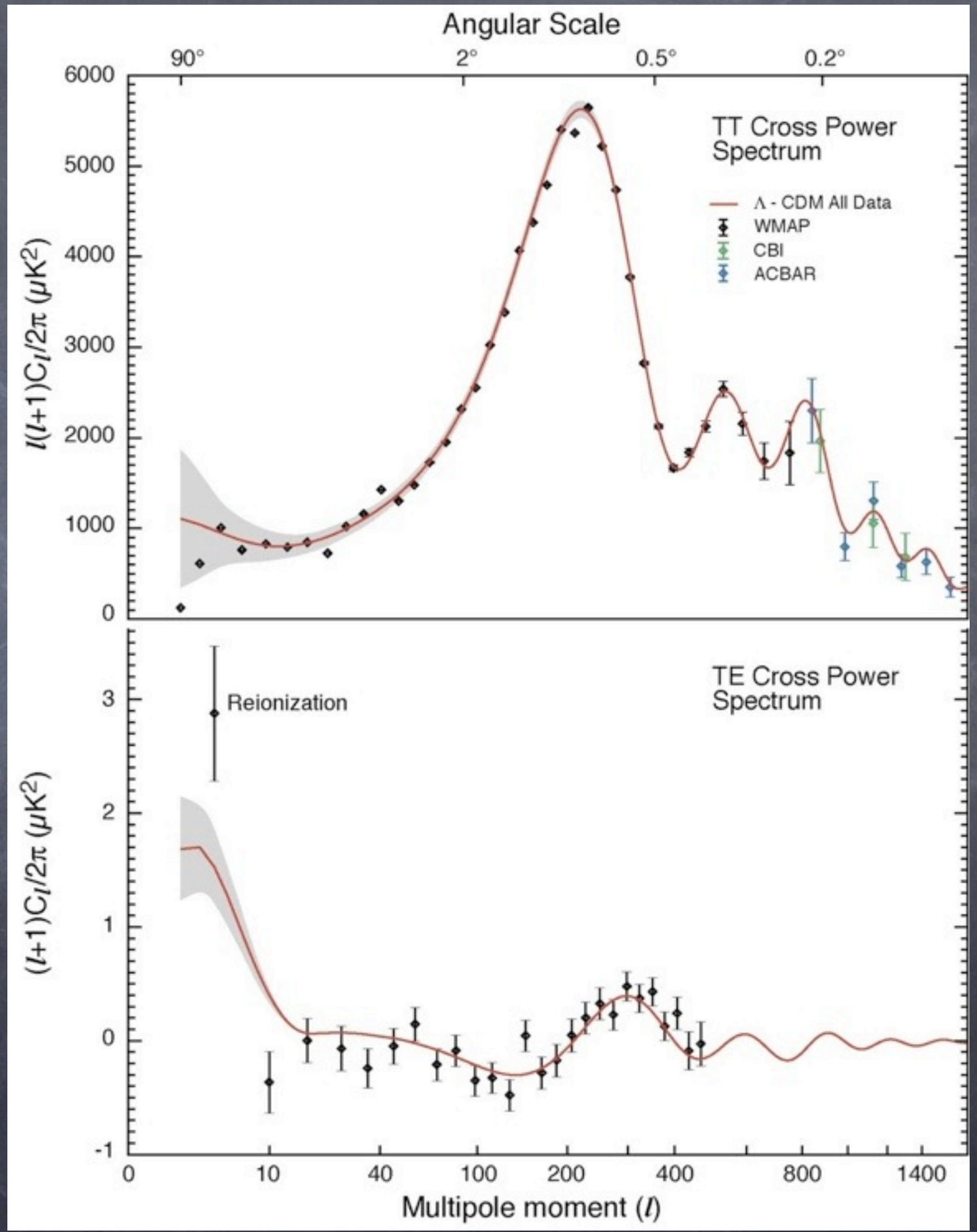
Kulcskérdések

- Miről árulkodnak a térbeli csomósodások?
- Hogyan kell figyelembe venni a kiválasztási effektusokat?
- Ezek miként módosítják az eloszlások értelmezését?
- Hogyan függ a galaxisok eloszlása a kozmológiai paraméterektől?

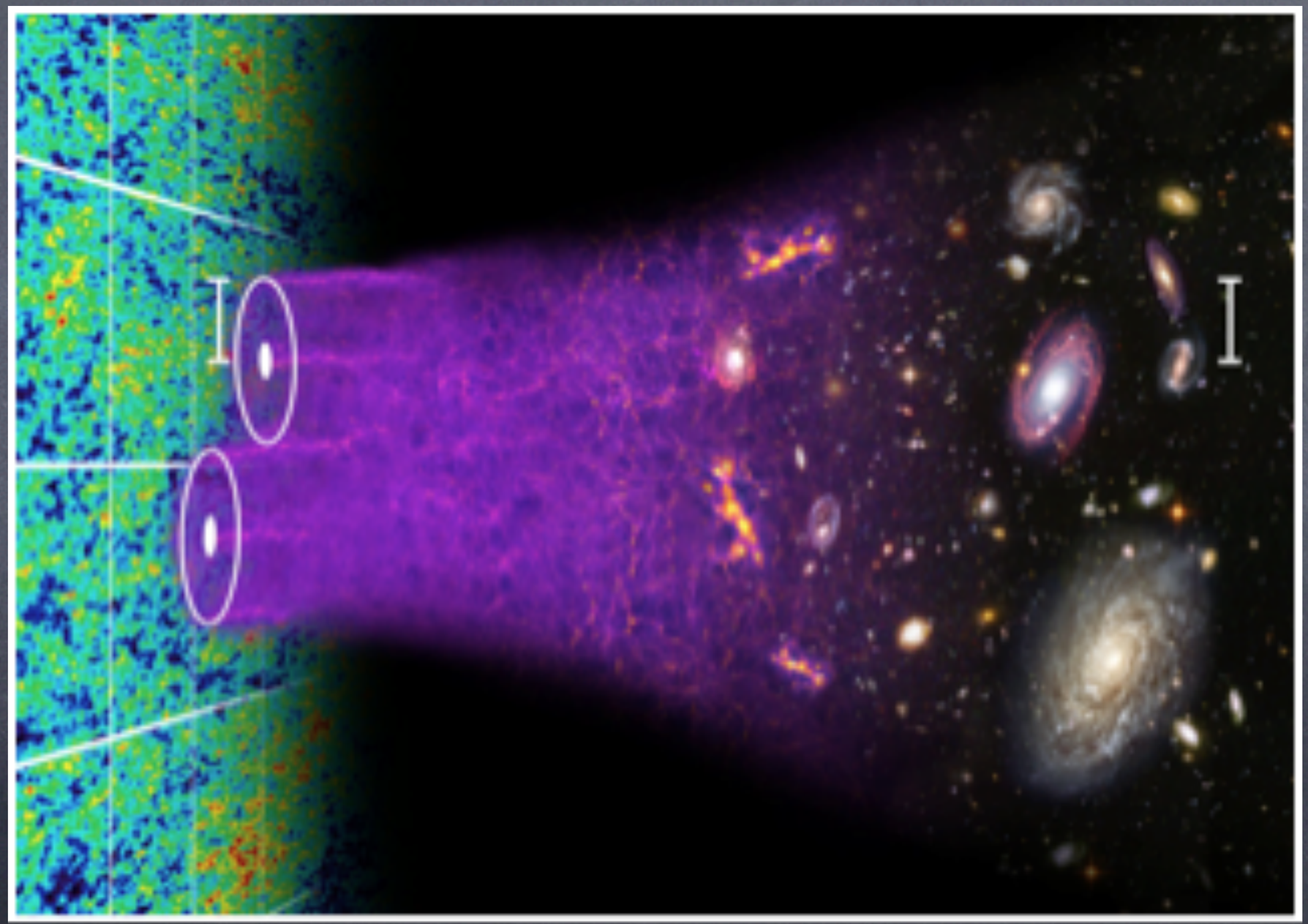
A WMAP térképe a mikrohullámú háttérsugárzásról: csomósodás irány szerint

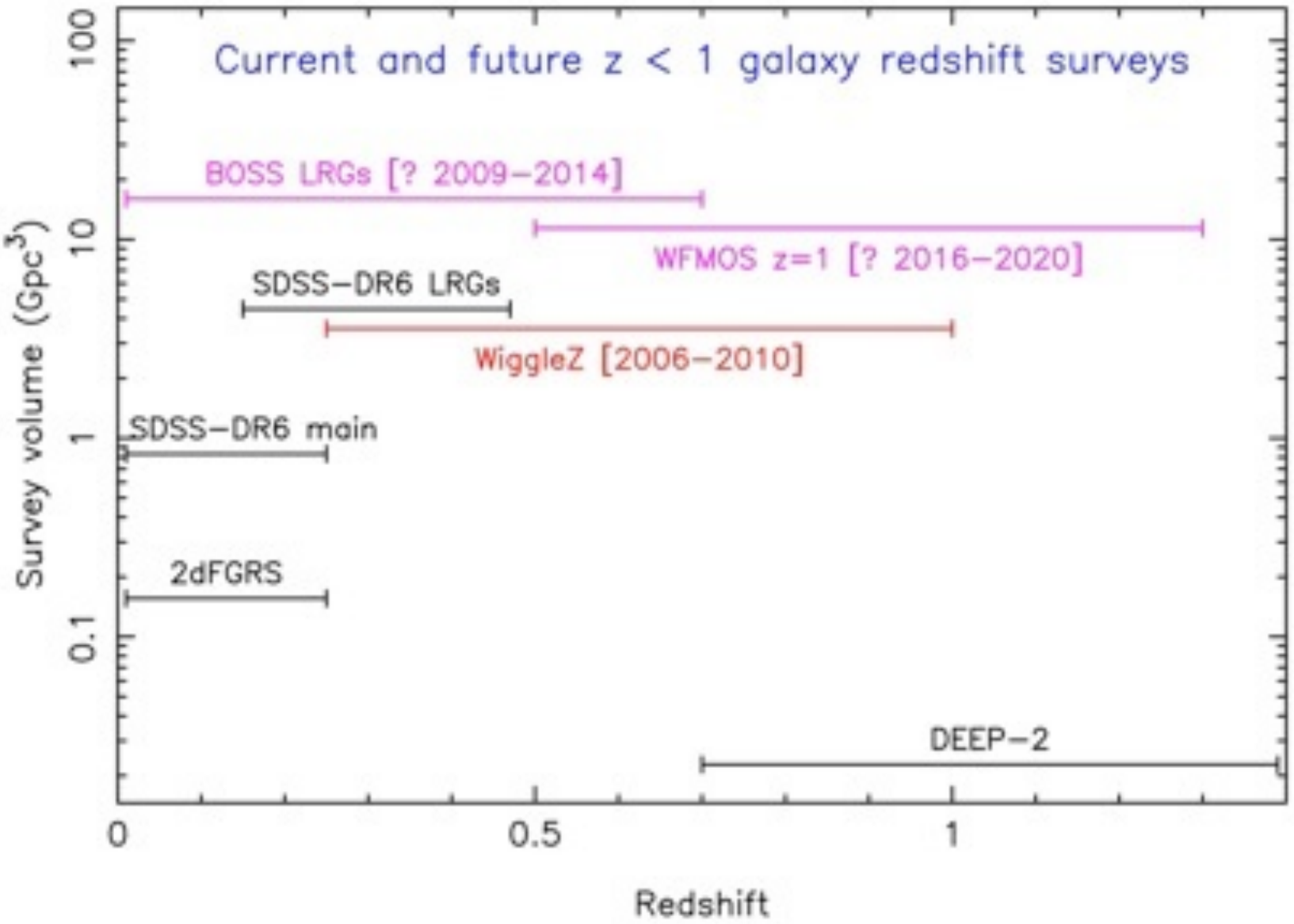


A WMAP szögspektruma

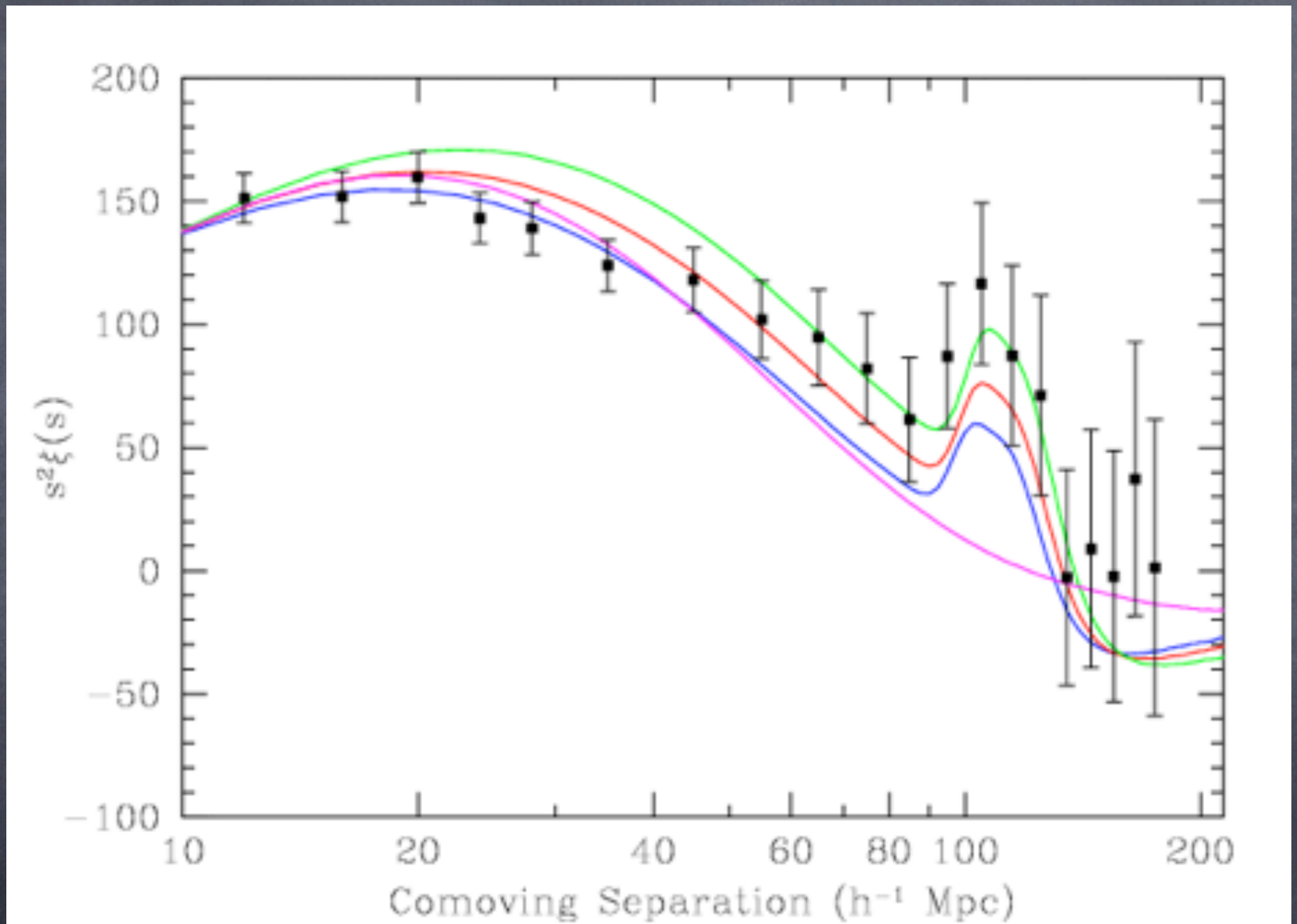


BAO: barionikus akusztikus oszcillációk

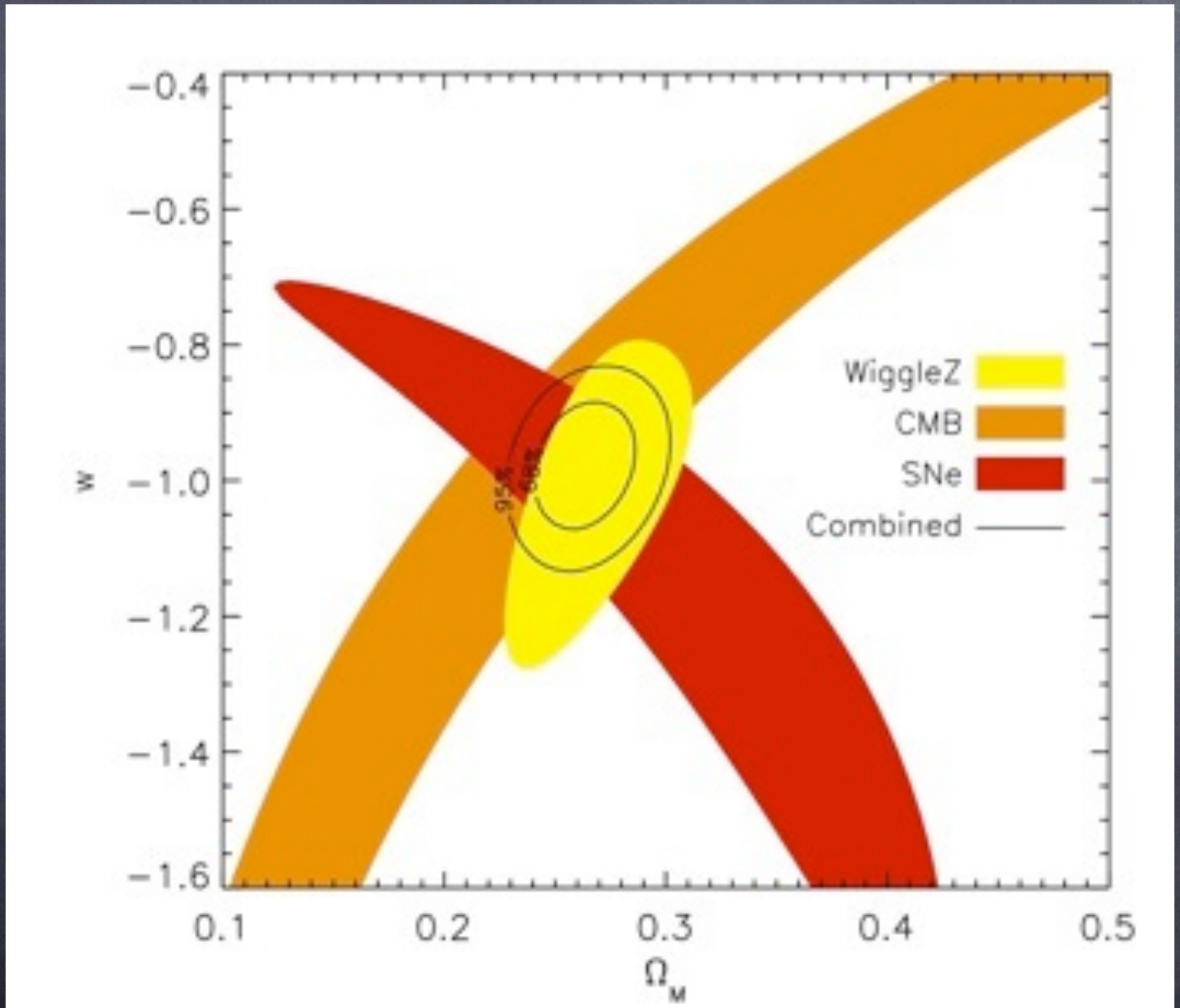



Current and future z < 1 galaxy redshift surveys
BOSS LRGs [? 2009–2014]
WFMOS z=1 [? 2016–2020]
SDSS–DR6 LRGs
WiggleZ [2006–2010]
SDSS–DR6 main
2dFGRS
DEEP–2
Survey volume (Gpc^3)
100
10
1
0.1
0
0.5
1
Redshift

SDSS LRG csomósodási skála



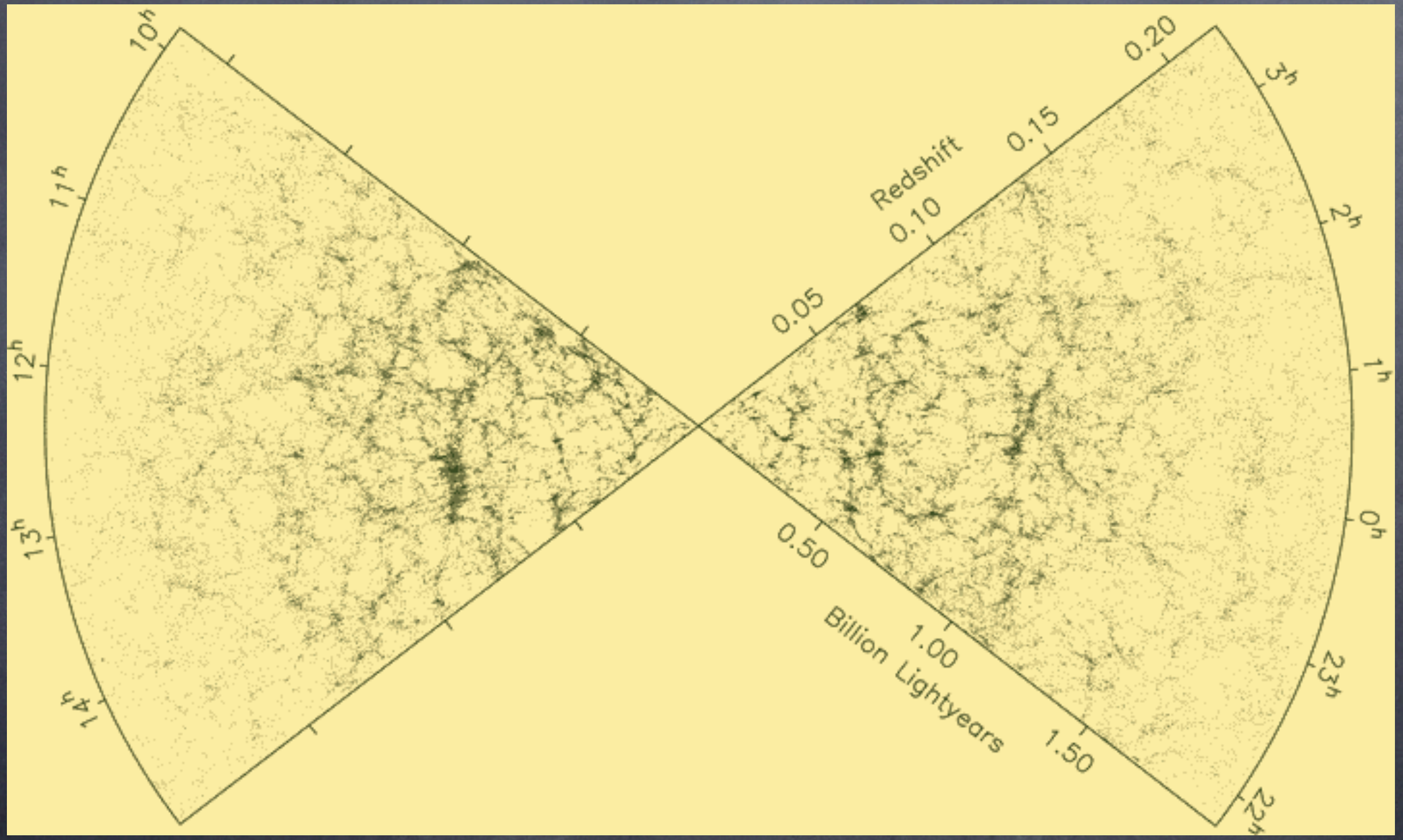
Kozmológiai paraméterek független pontosítása



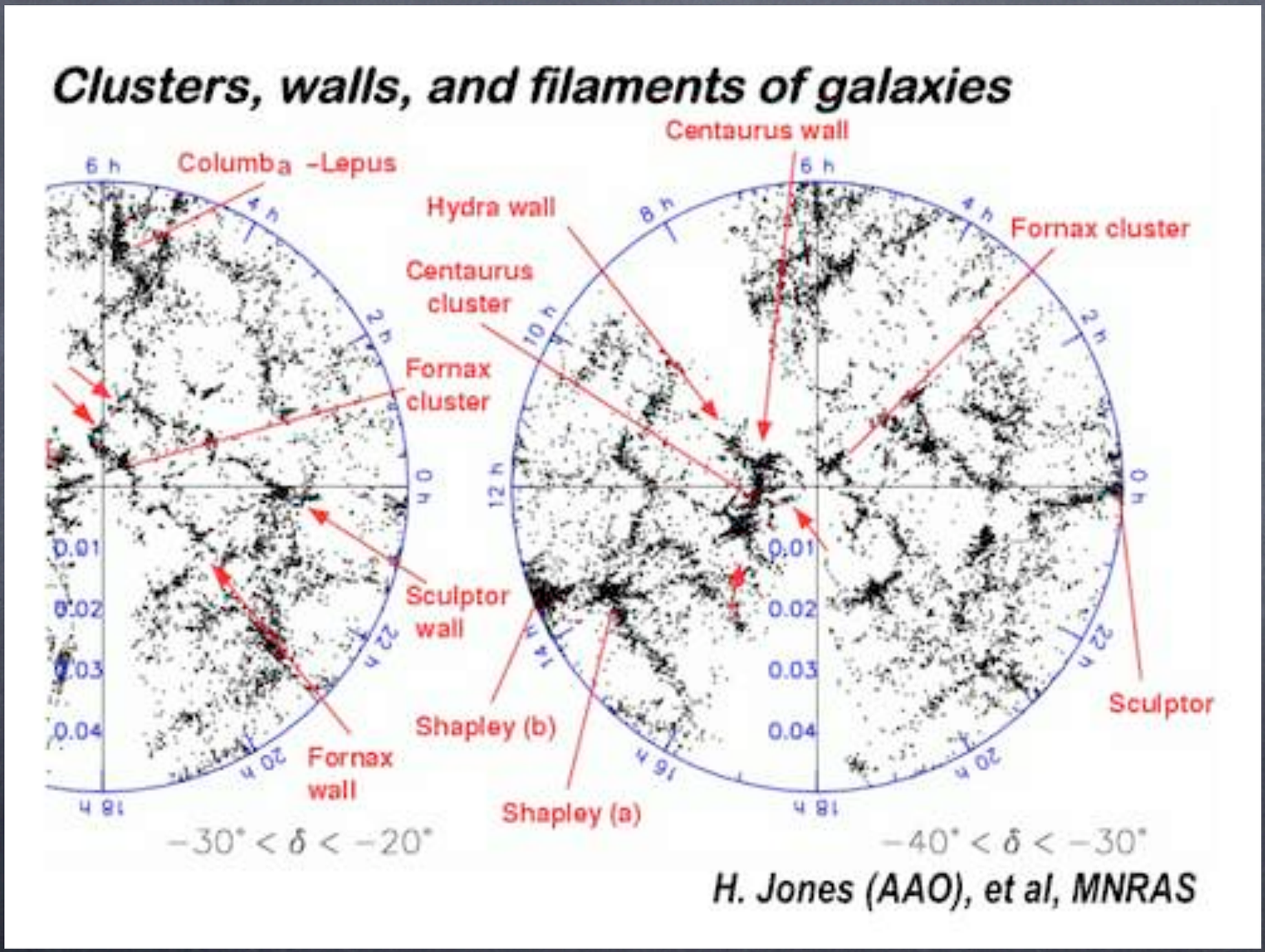
Ausztrália: vöröseltolódás-nagyhatalom

- 2dF Galaxy Redshift Survey
- 6dF Galaxy Survey
- WiggleZ
- Galaxy and Mass Assembly (GAMA)
- Mindegyik: multiobjektum-spektroszkópia
- Műszerek: 1,2 m-es UK Schmidt, 3,9m-es AAT

2dF GRS (2003)


10h
11h
12h
13h
14h
Redshift
0.05
0.10
0.15
0.20
3h
2h
1h
0h
23h
22h
0.50
1.00
1.50
Billion Lightyears

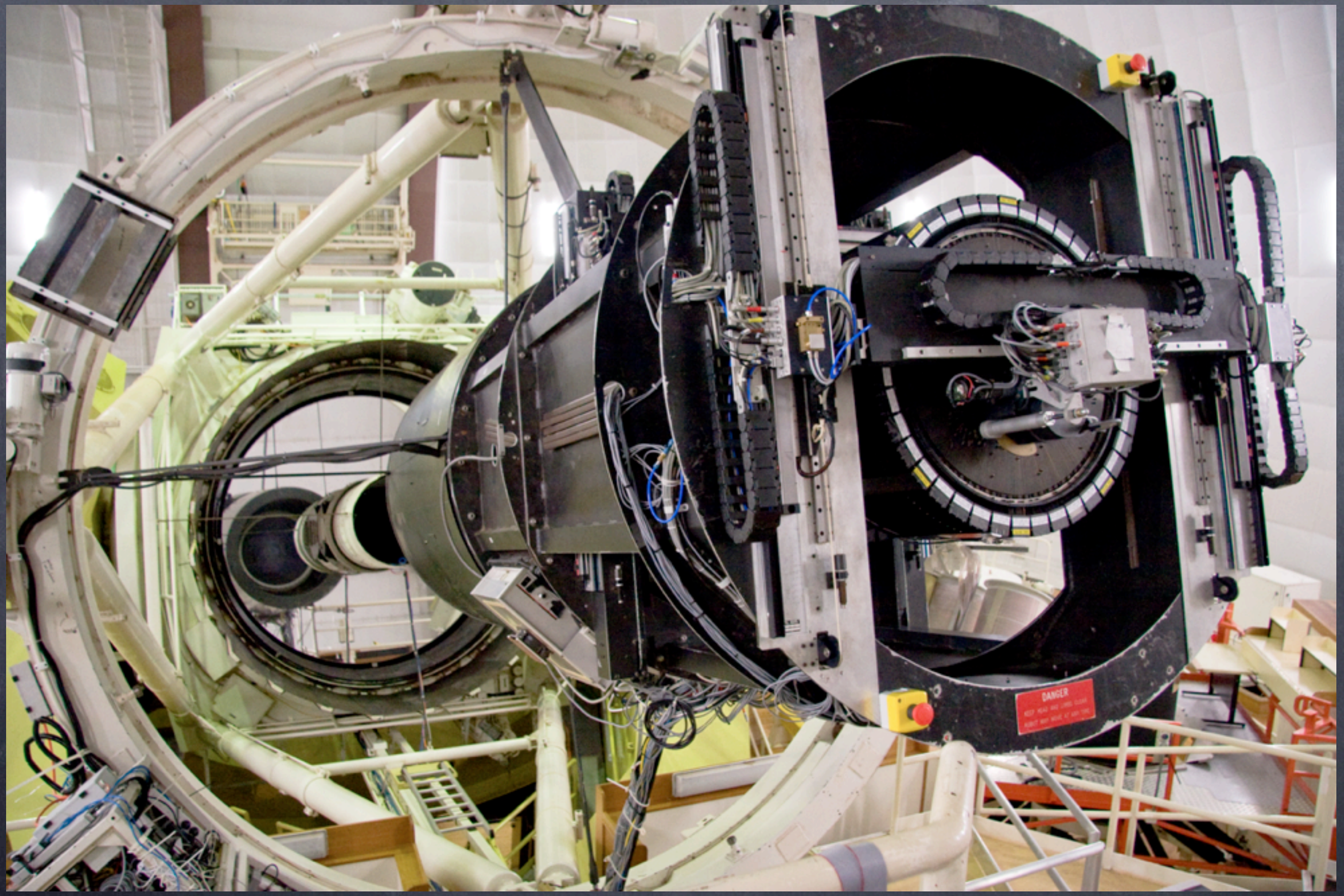
6dF Galaxy Survey

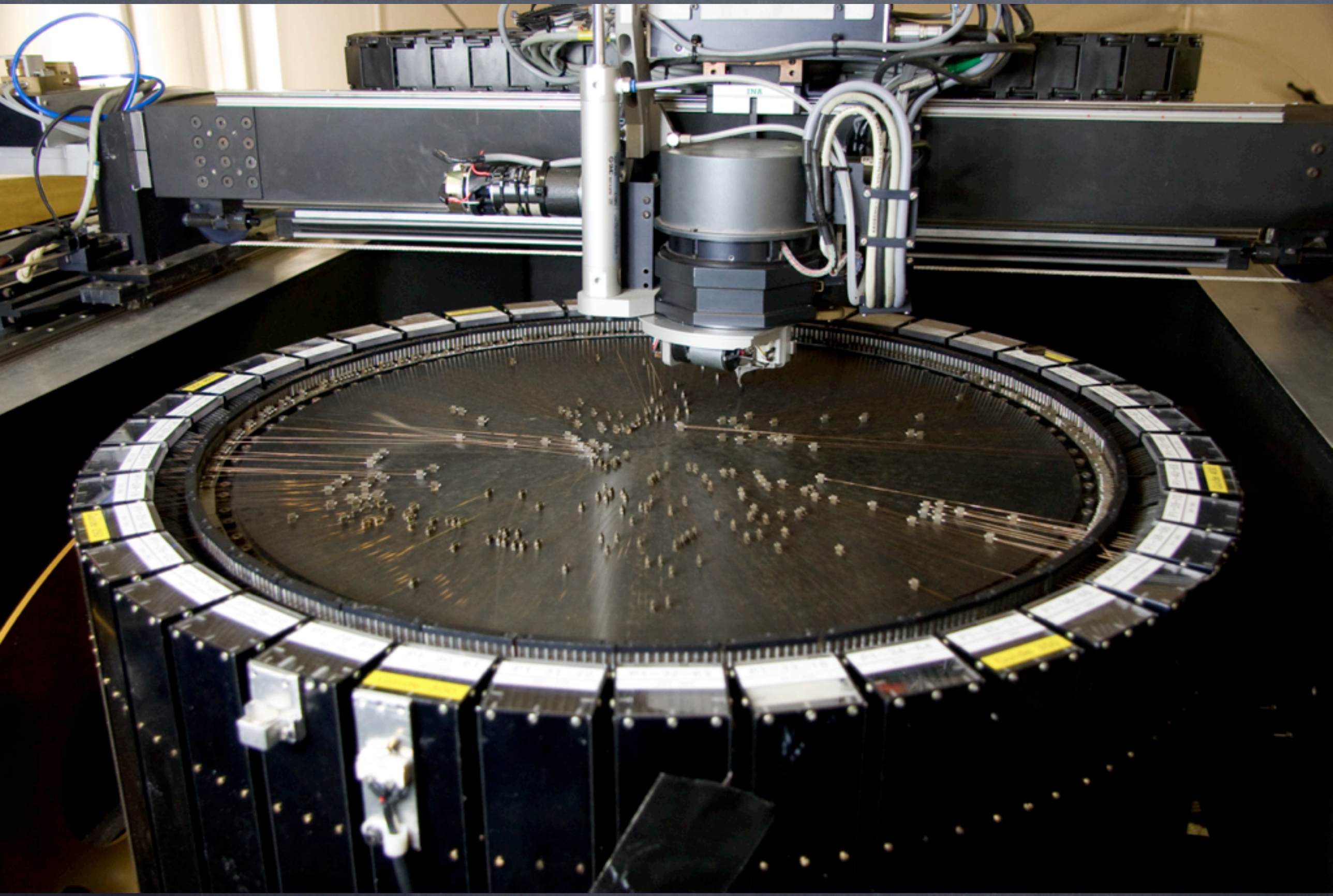


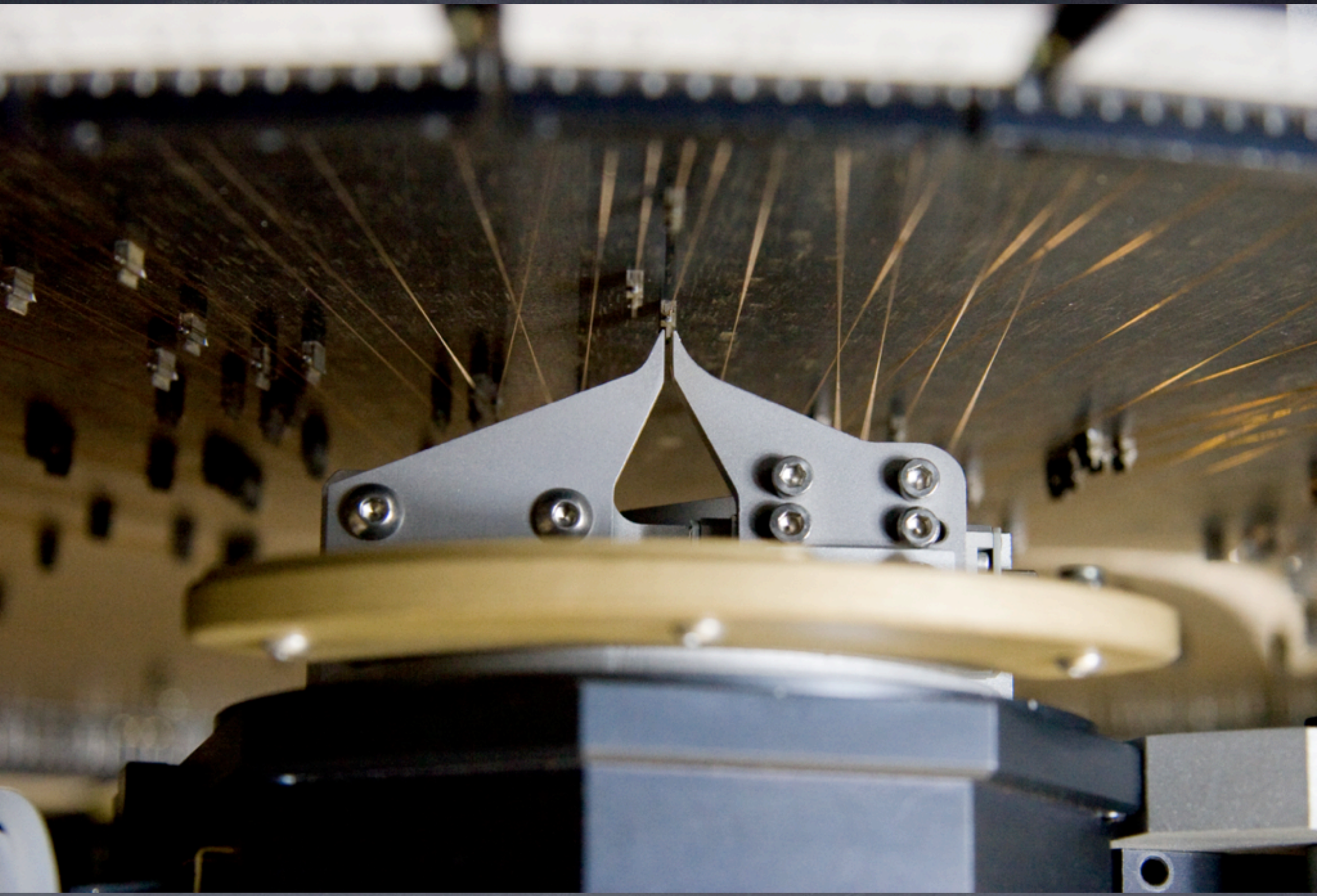
UK Schmidt telescope and 6dF robotic positioner

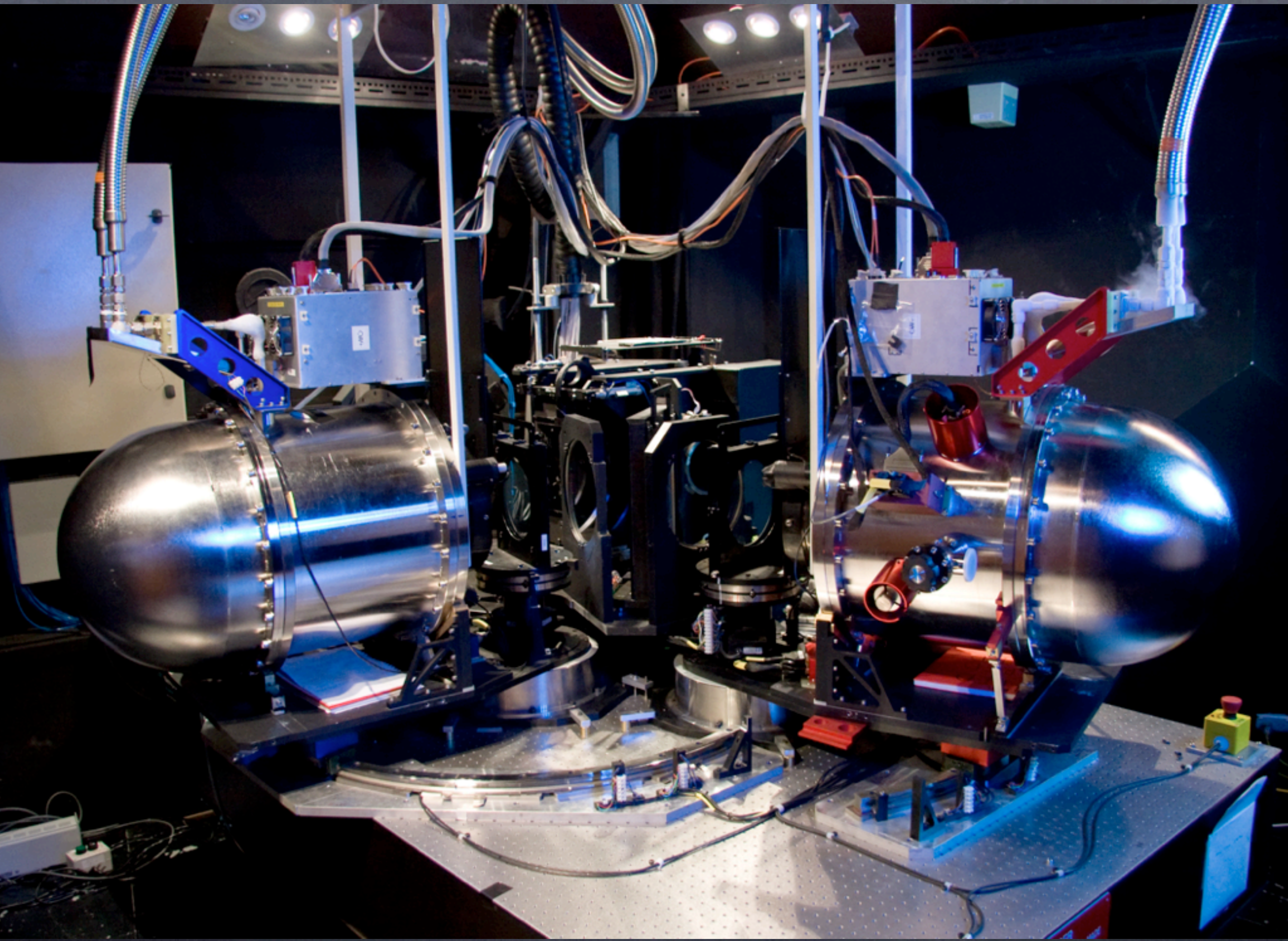
Upper Image:
Anglo-Australian
Obervatory

Lower Image:
L. Campbell


DANGER







A jövő

- Futó és újabb nagy felmérések
- Spektroszkópiai mellett fotometriai vöröseltolódással (kisebb pontosságú, de sokkal nagyobb mintákra válik lehetségessé)
- A kozmológia a spekulációk vad tudománya helyett valódi empirikus diszciplínává válik