Using Redshift

Spectroscopy Applications for Cosmological Studies

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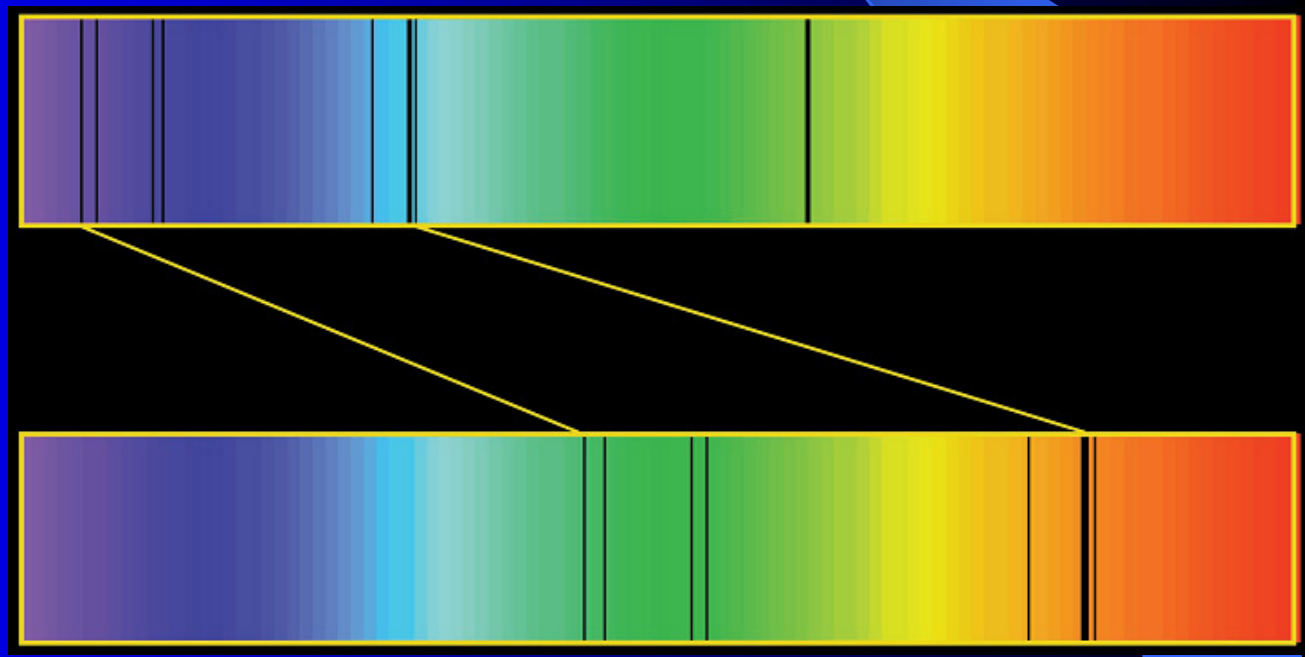
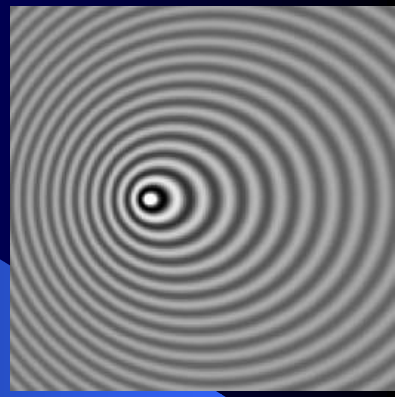


What causes redshift?

- Several effects that can increase the wavelength of electromagnetic waves
  - Doppler shift (classical and relativistic)
  - gravitational redshift
  - cosmological redshift
- Definition of z:

$$z = \frac{\lambda_0}{\lambda_e} - 1$$

Doppler Shift and Gravitational Redshift

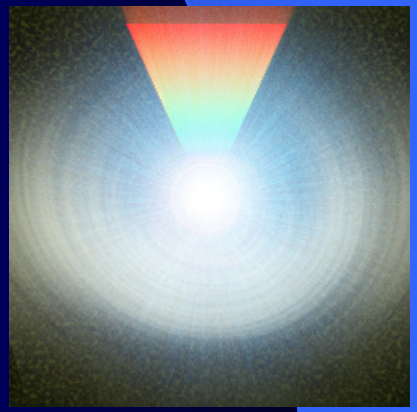


- Radiation that is emitted by a moving source is either red- or blueshifted

$$z = \left(1 + \frac{v}{c}\right)\gamma - 1$$

- Radiation under the influence of gravitation is always red- or blueshifted, as predicted by the general theory of relativity

$$z = -\frac{GM}{c^2}\left(\frac{1}{r_1} - \frac{1}{r_2}\right)$$

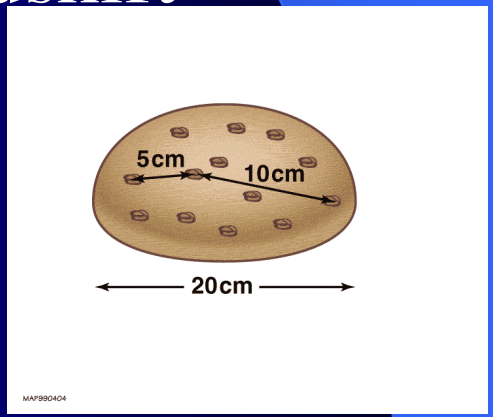


Cosmological Redshift

- Due to the expansion of the universe

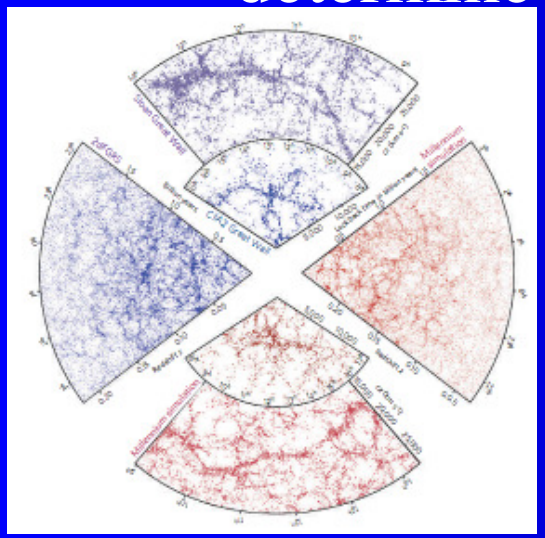
$$z = \frac{a(t_0)}{a(t_e)} - 1$$

- Defnition of a: $r(t) = a(t) \cdot x$
- „a“ changes as the universe expands (given by the Friedmann equations)
- Dominates all other sources of redshift (on cosmological scales)
  - $z_G = 0.000\ 06$ (Sirius B)
  - $z_D = 0.035$ (Quasar, AGN)



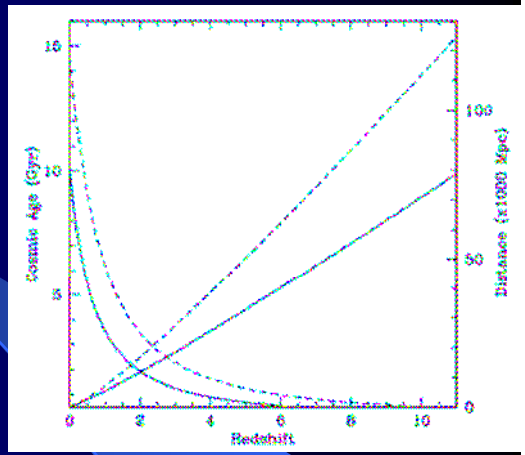
Why do we need redshift?

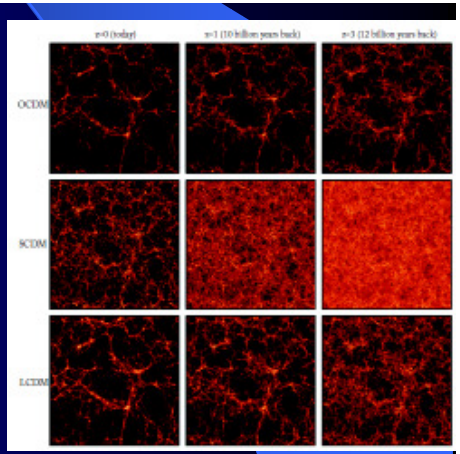
- Distance
  - large scaled structure
  - extension
  - absolute luminosity $M = m - 5 \cdot \log r[pc] + 5 - A$
  - gravitational lensing
    - determine the mass of the lensing object

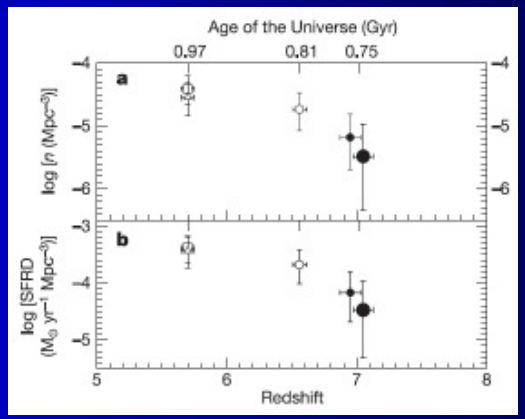


Why do we need redshift?

- „look-back time“
  - evolutional processes
    - galaxy formation (LAE density)
    - quasar evolution
    - reionisation (x_{HI})
      - Damping wing of Lyα absorption
  - distinction between different cosmological models

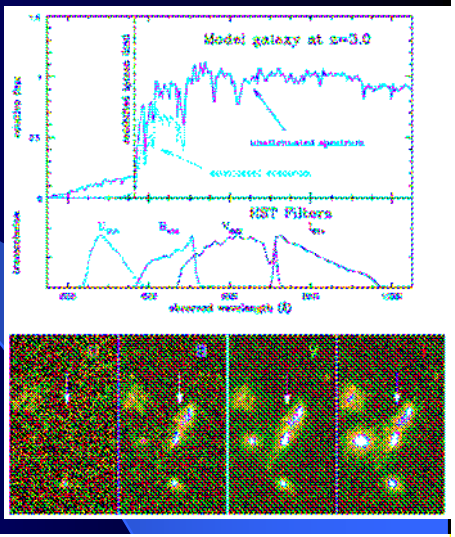


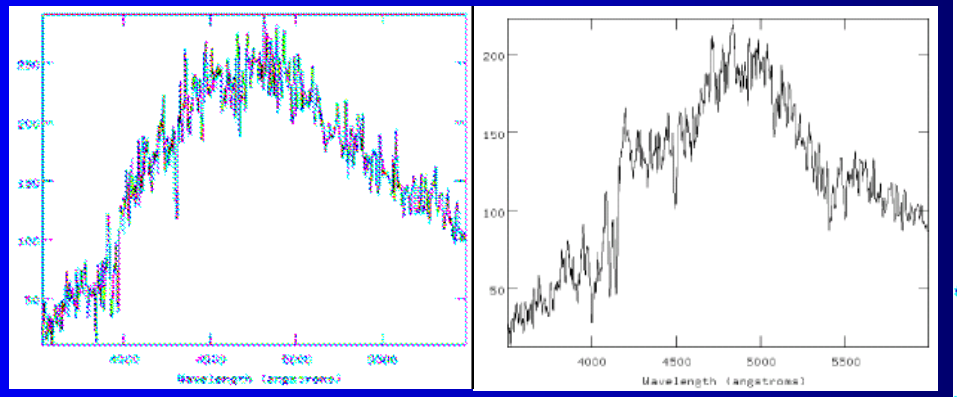


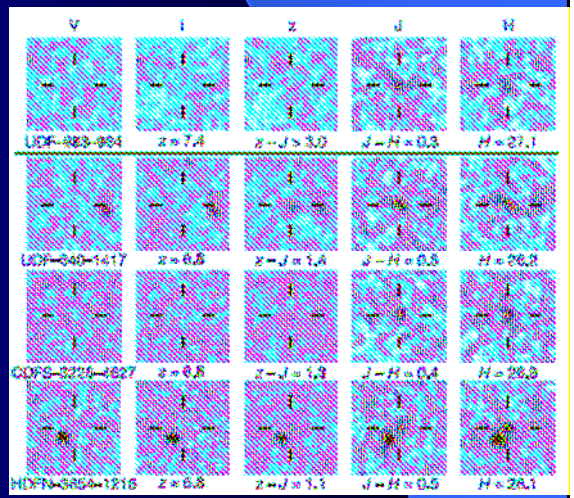


Measuring Redshift

- Photometric („dropout“ technique)
  - Lyman-break
    - first estimation of redshift
- Spectroscopy
  - optical
  - IR

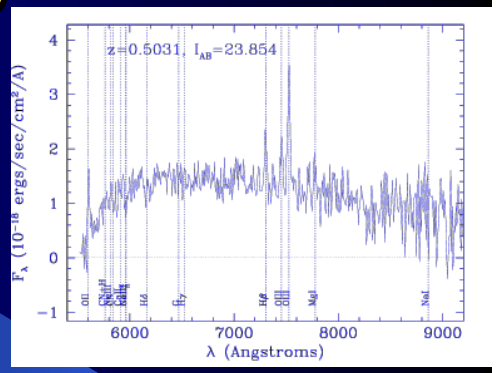


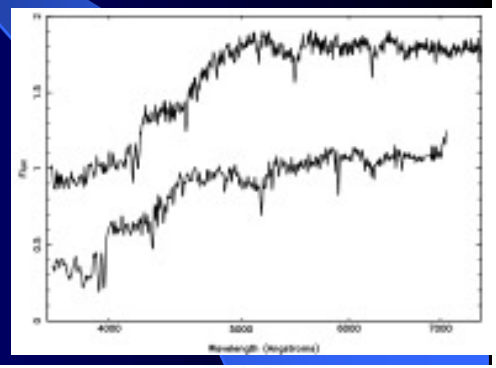


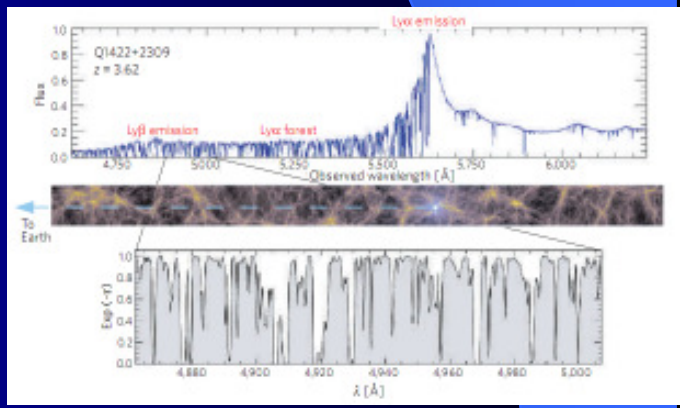


Important features

- emission lines
  - i.e. O III Doublett (ratio 3:1 from QM)
- absorption lines
- Lyman break
- Lyman forest
  - H I clouds between source and observer

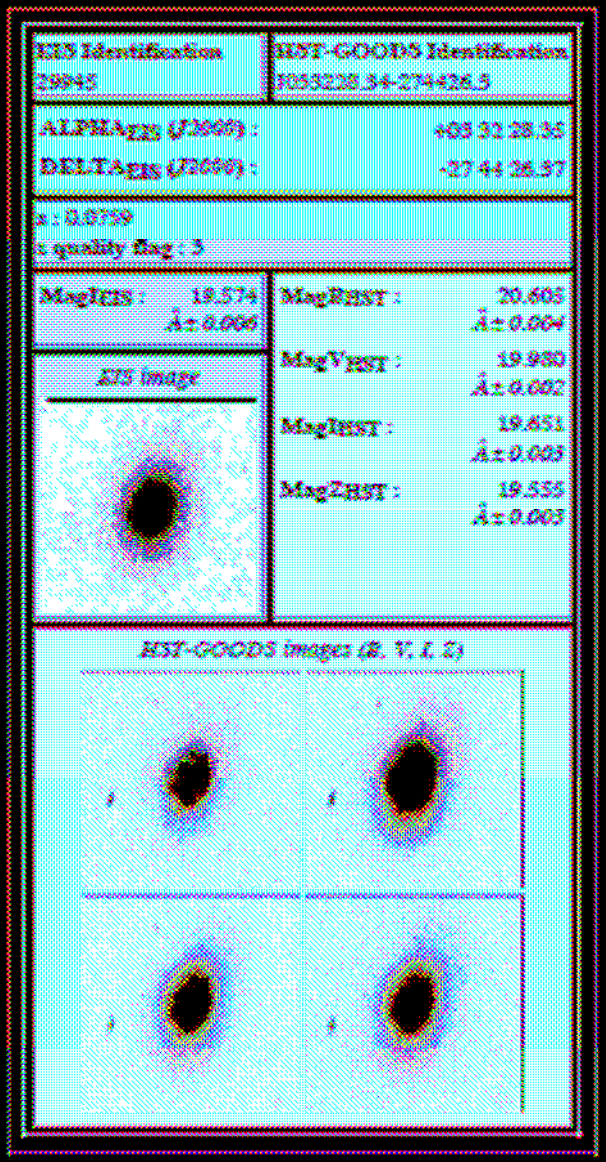


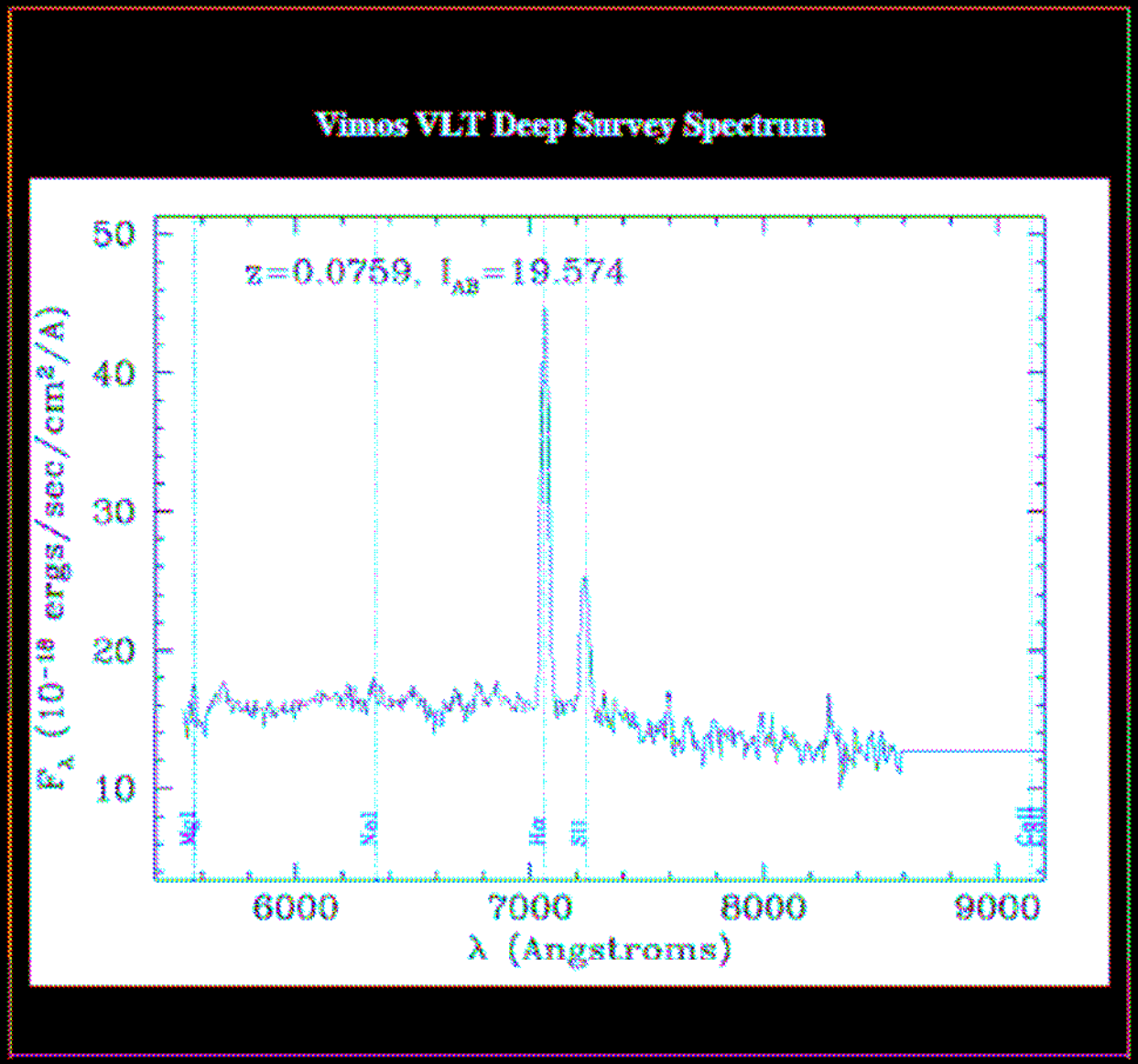


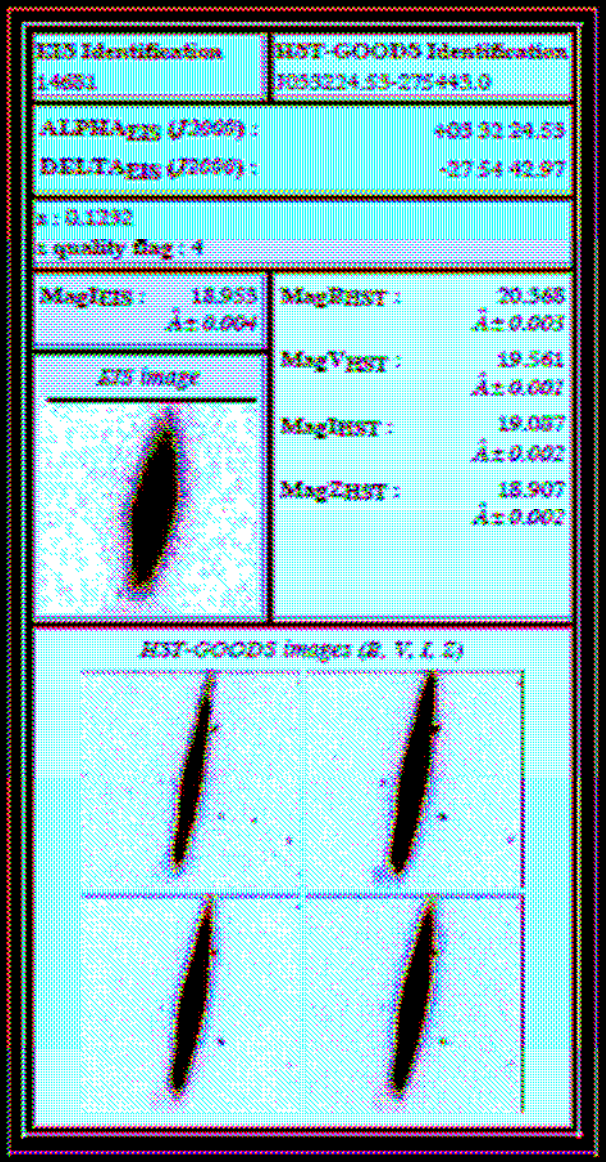


Determining the redshift from a spectrum

- typical job for a computer
- large databases with lines of different elements
- software (i.e. IRAF) uses an iterative process
  - identify a feature in the spectrum with real one (i.e. OIII Doublett)
  - calculate z
  - try to confirm this z with other features


VIS Identification
29345
HST-GOODS Identification
J033228.34-274426.3
ALPHA_VIS (J2000) : +03 32 28.35
DELTA_VIS (J2000) : -27 44 26.37
z : 0.0759
z quality flag : 3
MagVIS : 19.574
Δz: 0.000
MagBHST : 20.605
Δz: 0.004
MagVHST : 19.980
Δz: 0.002
MagIHST : 19.651
Δz: 0.003
MagZHST : 19.555
Δz: 0.003
VIS Image
HST-GOODS Images (B, V, I, Z)


Vimos VLT Deep Survey Spectrum
z=0.0759, I_AB=19.574
F_λ (10^-18 ergs/sec/cm²/A)
λ (Angstroms)
50
40
30
20
10
6000
7000
8000
9000
MgI
NaI
Hα
SII
CaII


VIRMOS-VLT Deep Survey Spectrum
z=0.1232, I_{AB}=18.953
F_λ (10^{-18} ergs/sec/cm^2/A)
60
40
20
6000
7000
8000
9000
λ (Angstroms)
CaK
CaH
MgI
NaI
Hα
SII

EIS Identification	HST-GOODS Identification
22584	J033204.98-274958.3

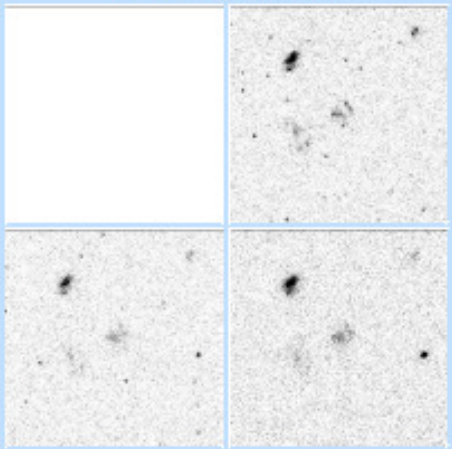
ALPHA$_{EIS}$ (J2000) :	+03 32 04.99
DELTA$_{EIS}$ (J2000) :	-27 49 58.32

z : 4.4345
z quality flag : 2

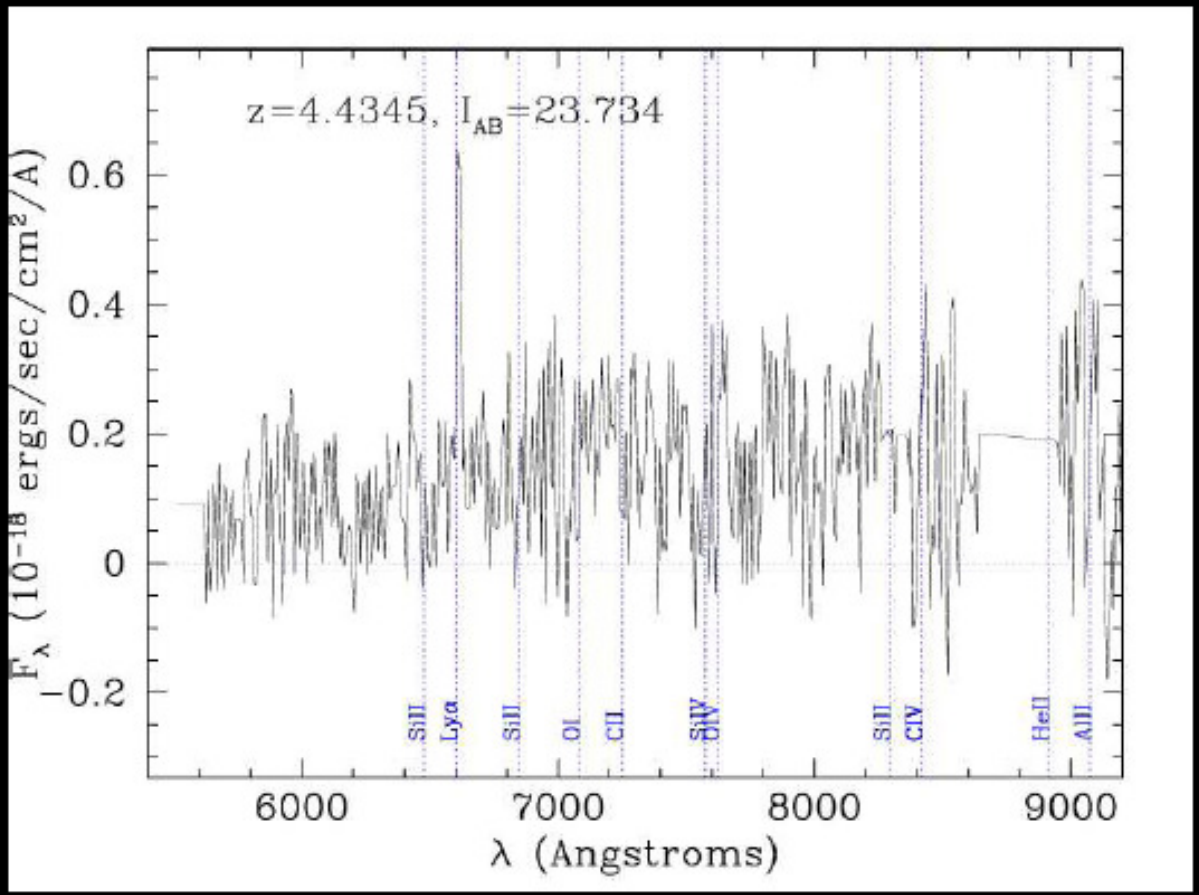
MagI$_{EIS}$:	23.734 ± 0.138	MagB$_{HST}$:	26.090 ± 0.000
		MagV$_{HST}$:	24.882 ± 0.070
		MagI$_{HST}$:	24.247 ± 0.079
		MagZ$_{HST}$:	23.915 ± 0.070

EIS image

HST images (B, V, I, Z)



Vimos VLT Deep Survey Spectrum



EIS Identification	HST-GOODS Identification
28075	J033222.70-274554.7

ALPHA$_{EIS}$ (*J2000*) : +03 32 22.71

DELTA$_{EIS}$ (*J2000*) : -27 45 54.8

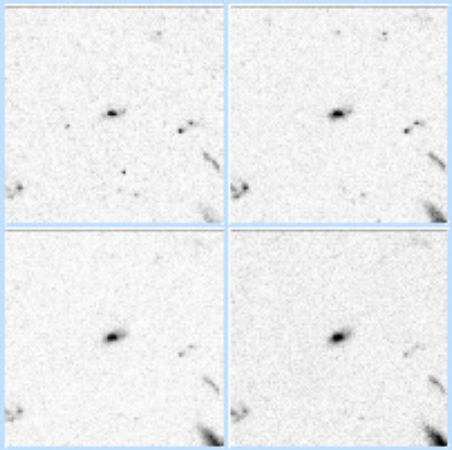
z : 4.6305

z quality flag : 9

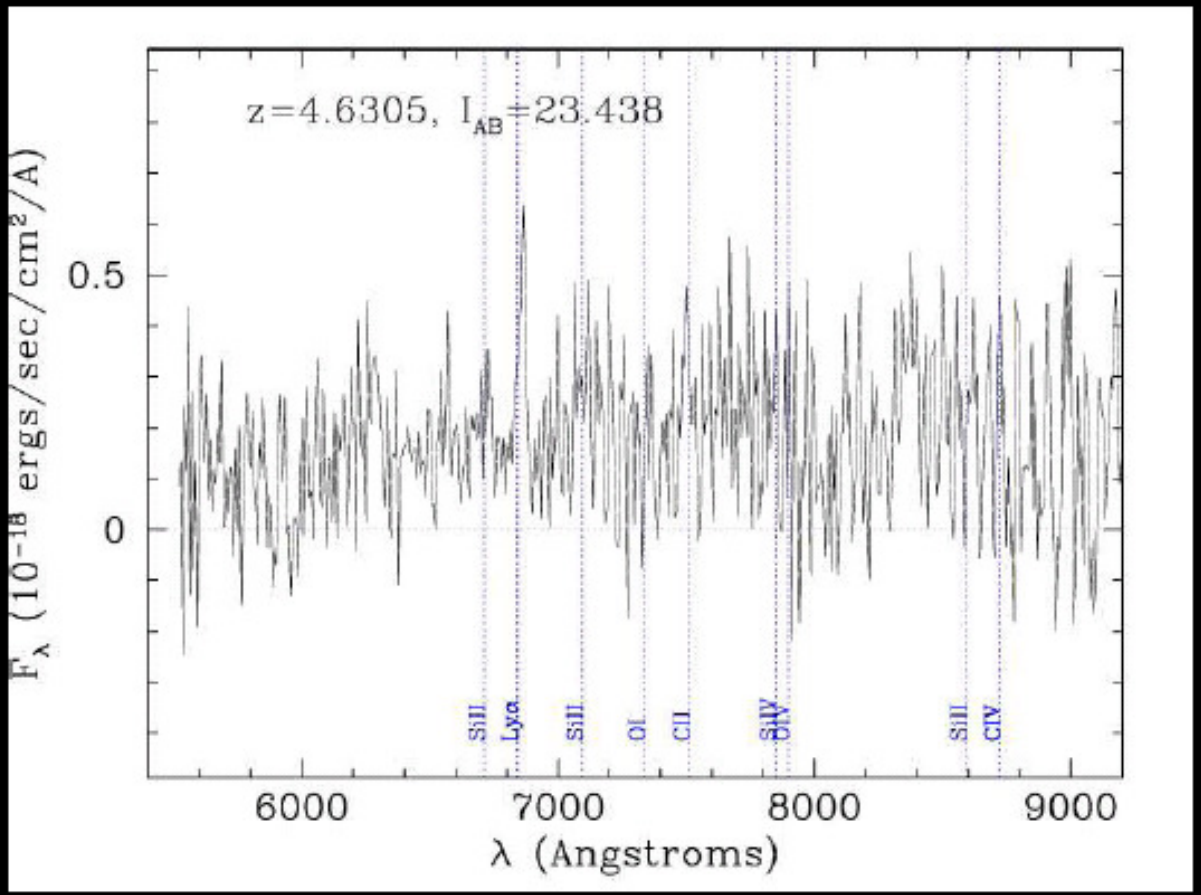
MagI$_{EIS}$:	23.438 *Å± 0.080*	MagB$_{HST}$:	24.812 *Å± 0.041*
		MagV$_{HST}$:	24.321 *Å± 0.024*
		MagI$_{HST}$:	23.487 *Å± 0.022*
		MagZ$_{HST}$:	23.251 *Å± 0.022*

EIS image

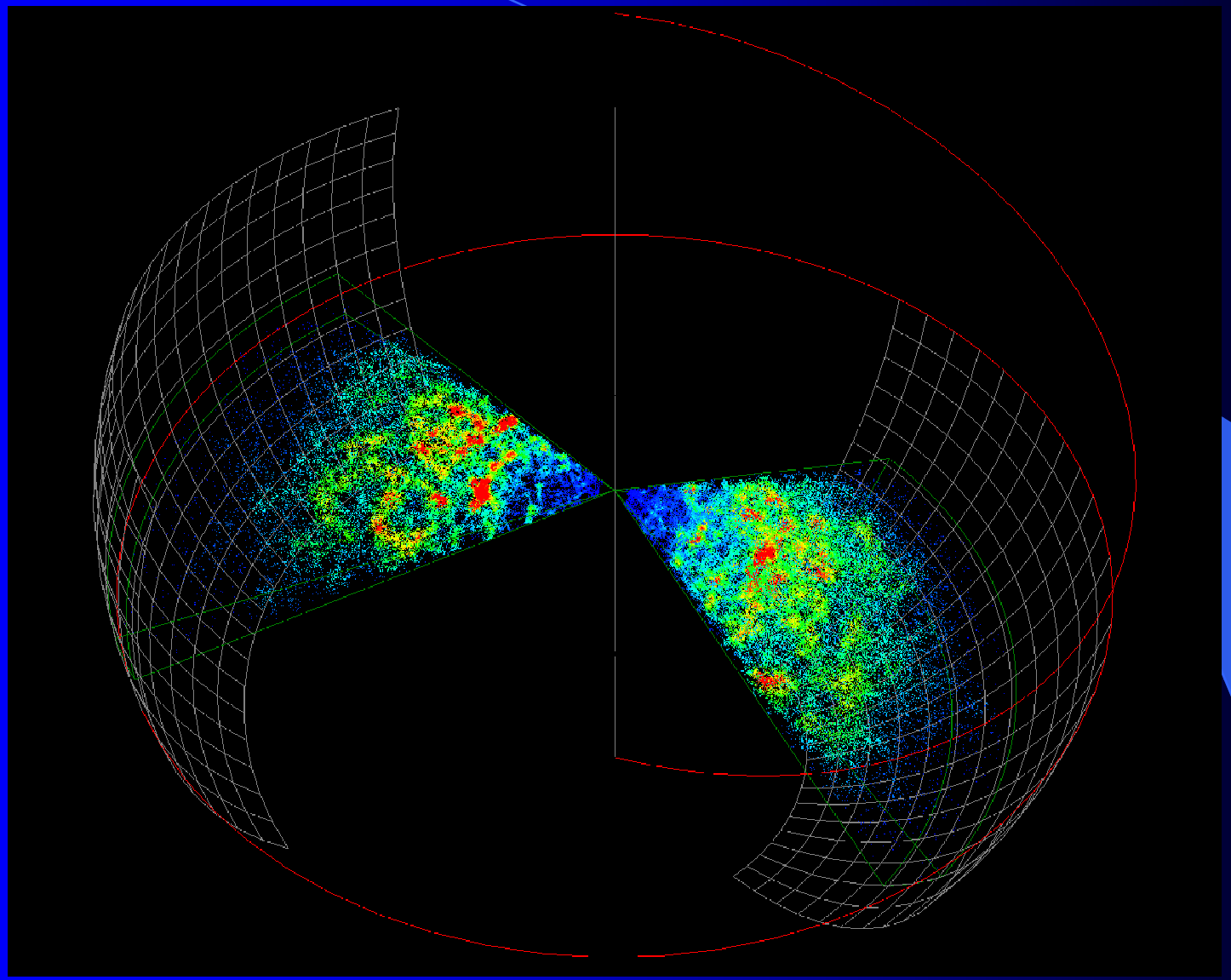
HST images (B, V, I, Z)



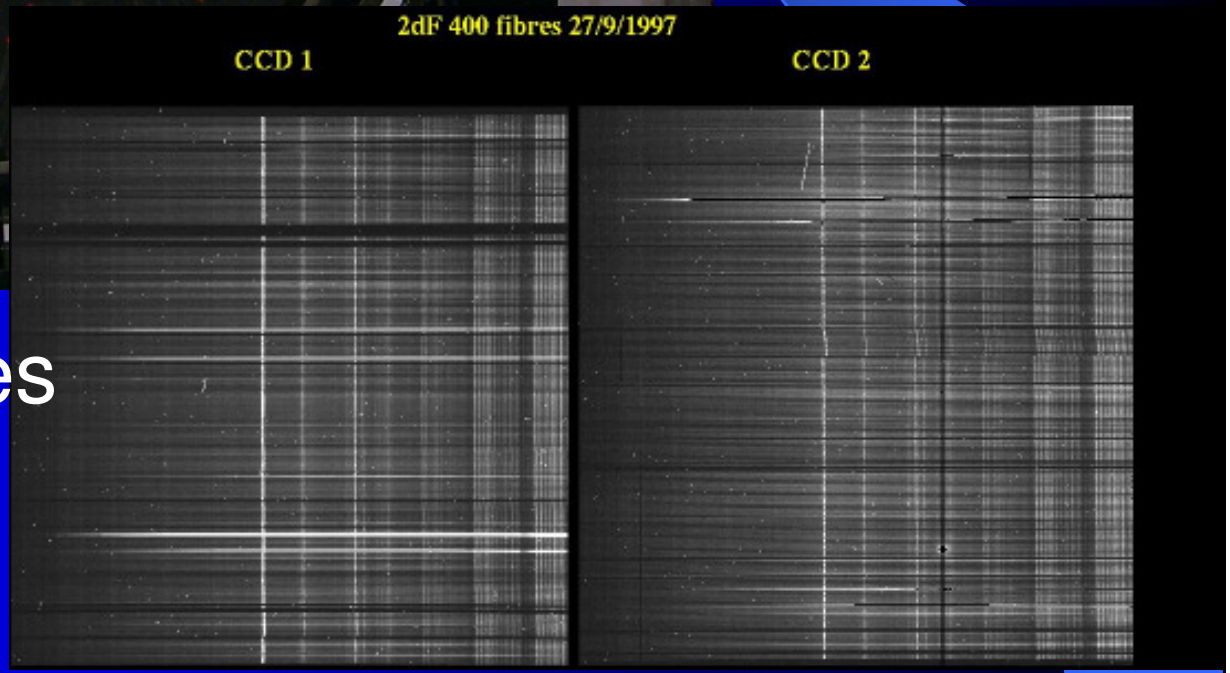
Vimos VLT Deep Survey Spectrum



2dFGRS

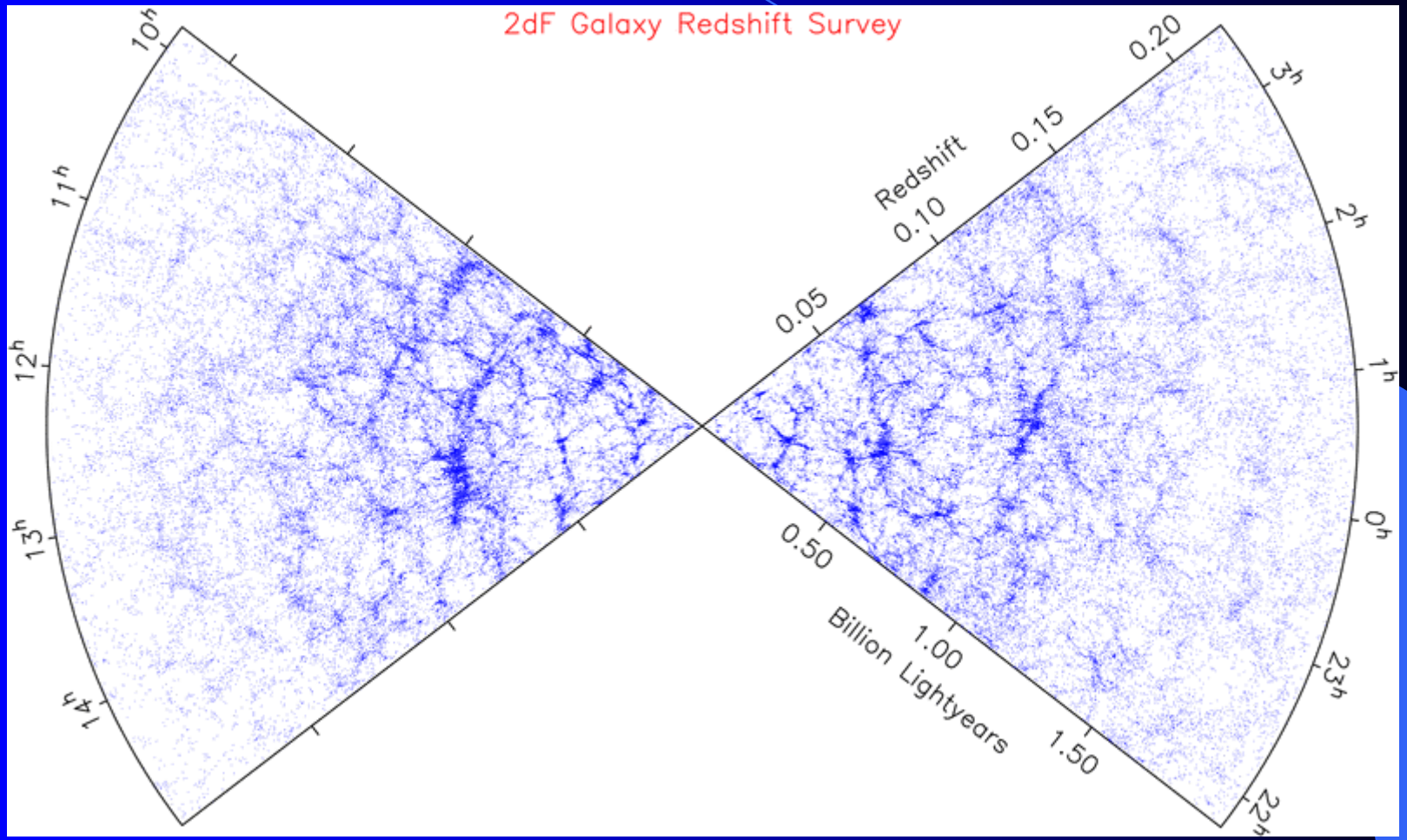


2dFGRS used masks with many optical fibres



- 221 414 galaxies
- z < 0.25

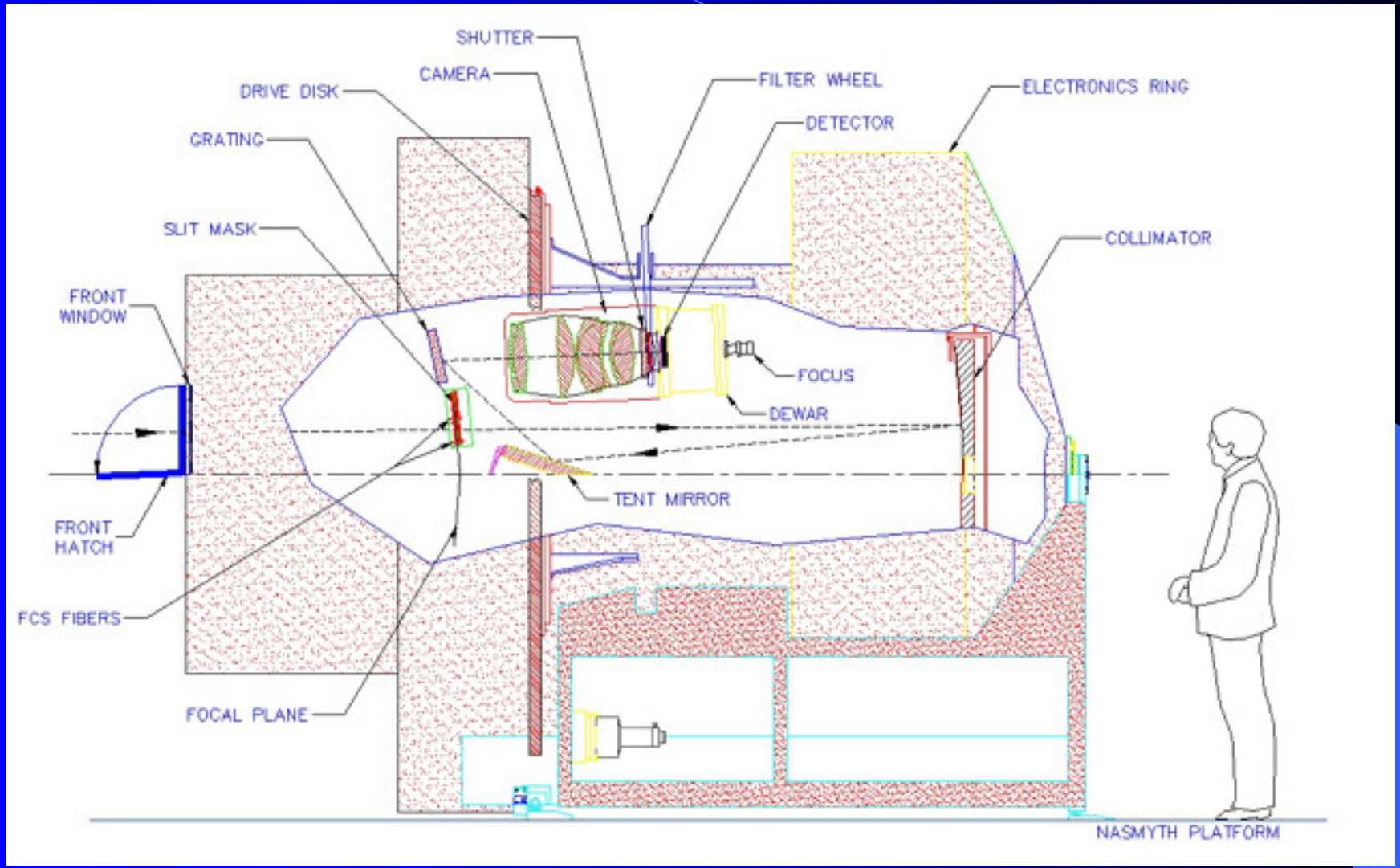
2dF Results


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

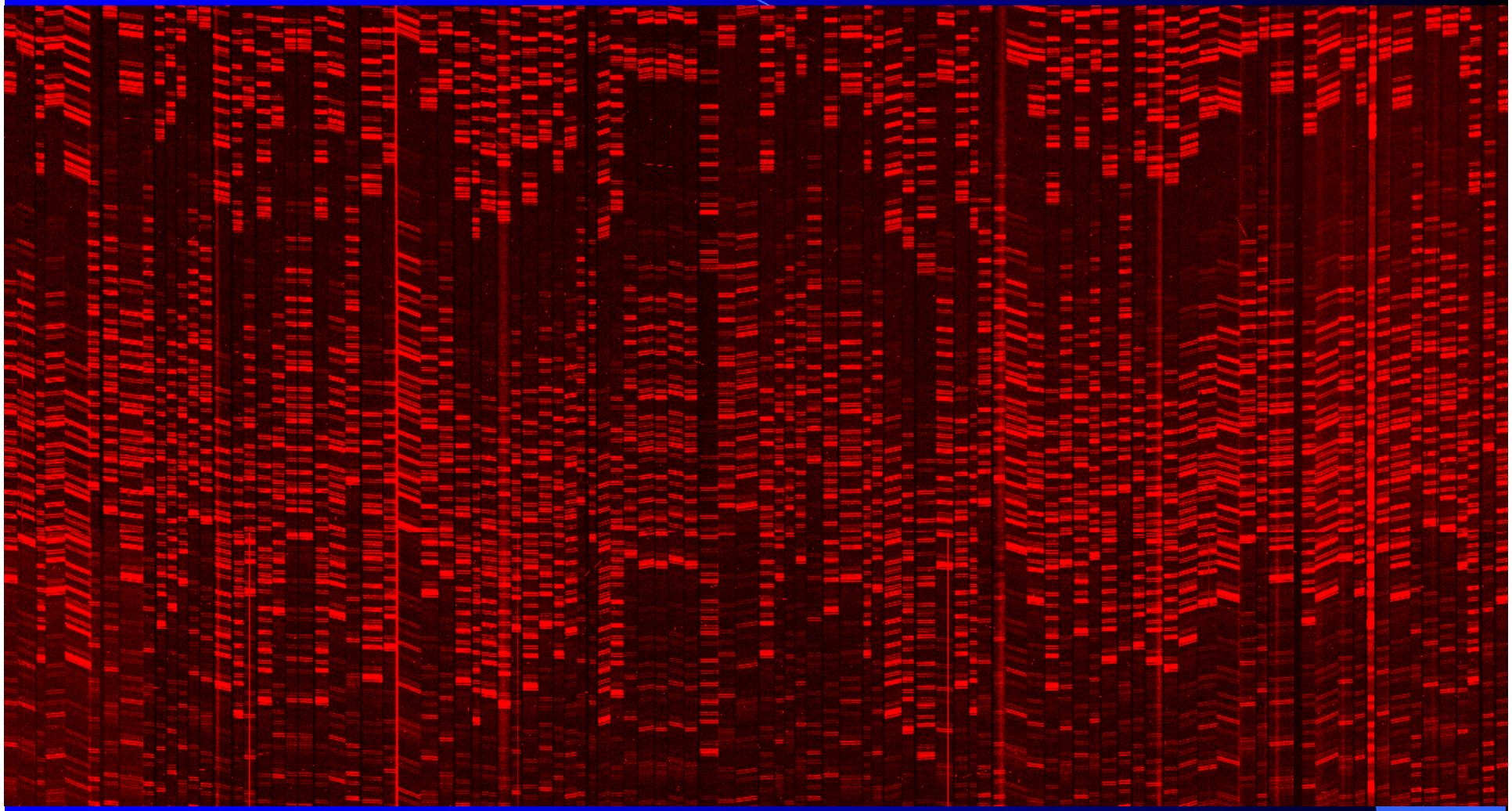
DEEP2 Survey

- 72 000 galaxies
- z = 0.7 – 1.4 (preselected by using photometric z´s)
- Multi-Slit Spectroscopy (800 simultaneous slits) using the DEIMOS Spectrograph mounted on KECK II

DEep Imaging Multi-Object Spectrograph



Slitmask Spectroscopy



References

EAA2002

Springel et.al., 2006, Nature, Bd 440, S. 1137

Iye et.al., 2006, Nature, Bd. 443, S. 186

Bouwens et.al., 2006, Nature, Bd. 443, S. 189

DEEP Database http://cencosw.oamp.fr/VVDS/CDFS.html

2dFGRS http://www.mso.anu.edu.au/2dFGRS

Wikipedia http://www.wikipedia.org