Lectures

THE LARGE SCALE DISTRIBUTION OF GALAXIES

Observational facts

Lecture plan

Part 1: Deep large scale galaxy surveys

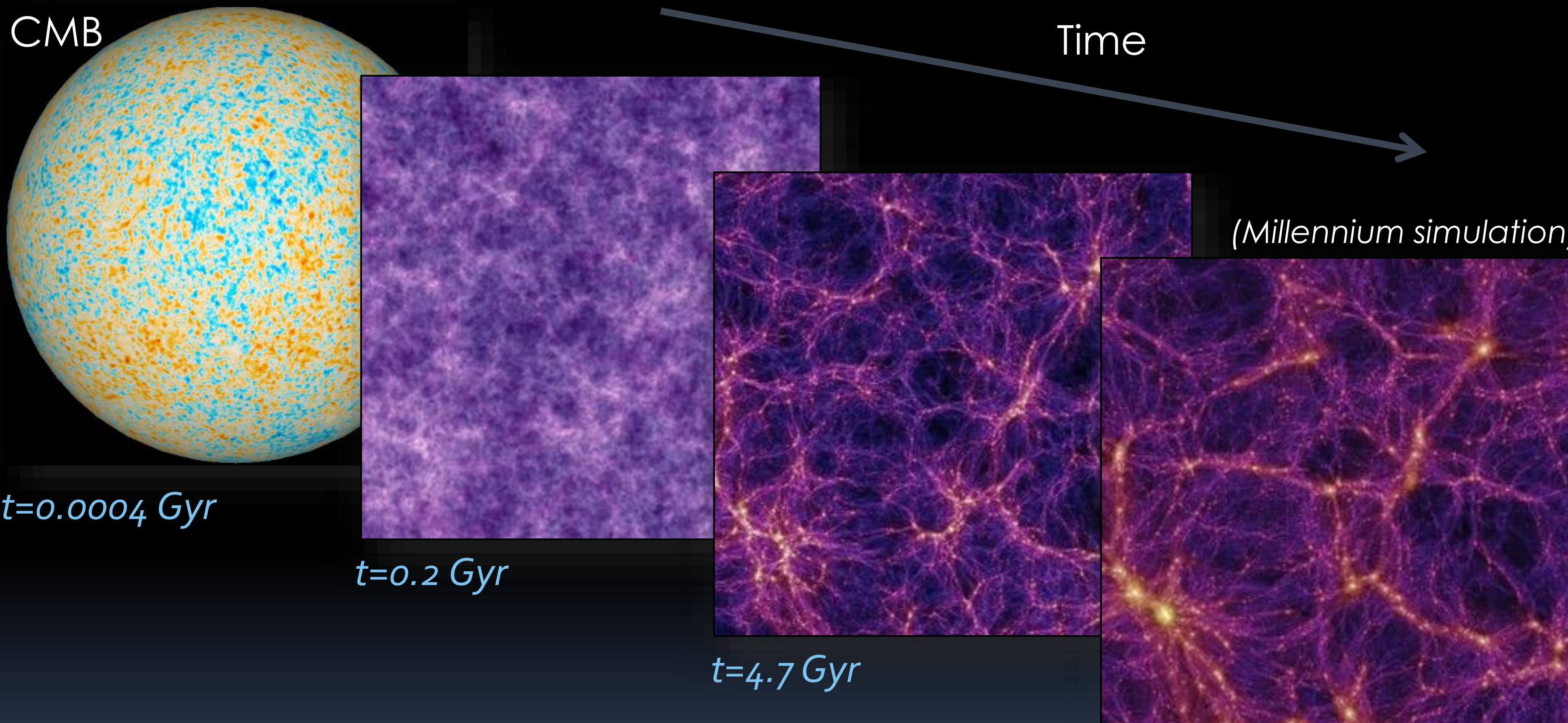
Part 2: The Universe on large scales

- Large scale structures observations
- Measuring clustering: the correlation function (and power spectrum)

Part 3: Baryon Acoustic Oscillations and Redshift space distortions

Part 4: The Euclid Surveys and galaxy clustering

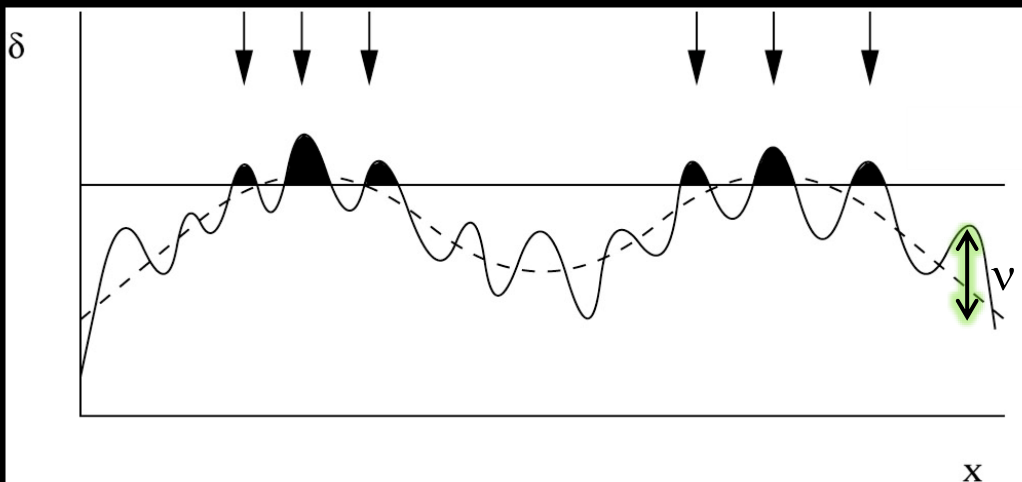
Building of the LSS



The large-scale structure of the Universe evolves through the competing effects of cosmological expansion and structure growth

Halo & galaxy bias

- Classical picture



Kaiser 1984
Bardeen et al. 1986
Cole & Kaiser 1989
Mo & White 1996

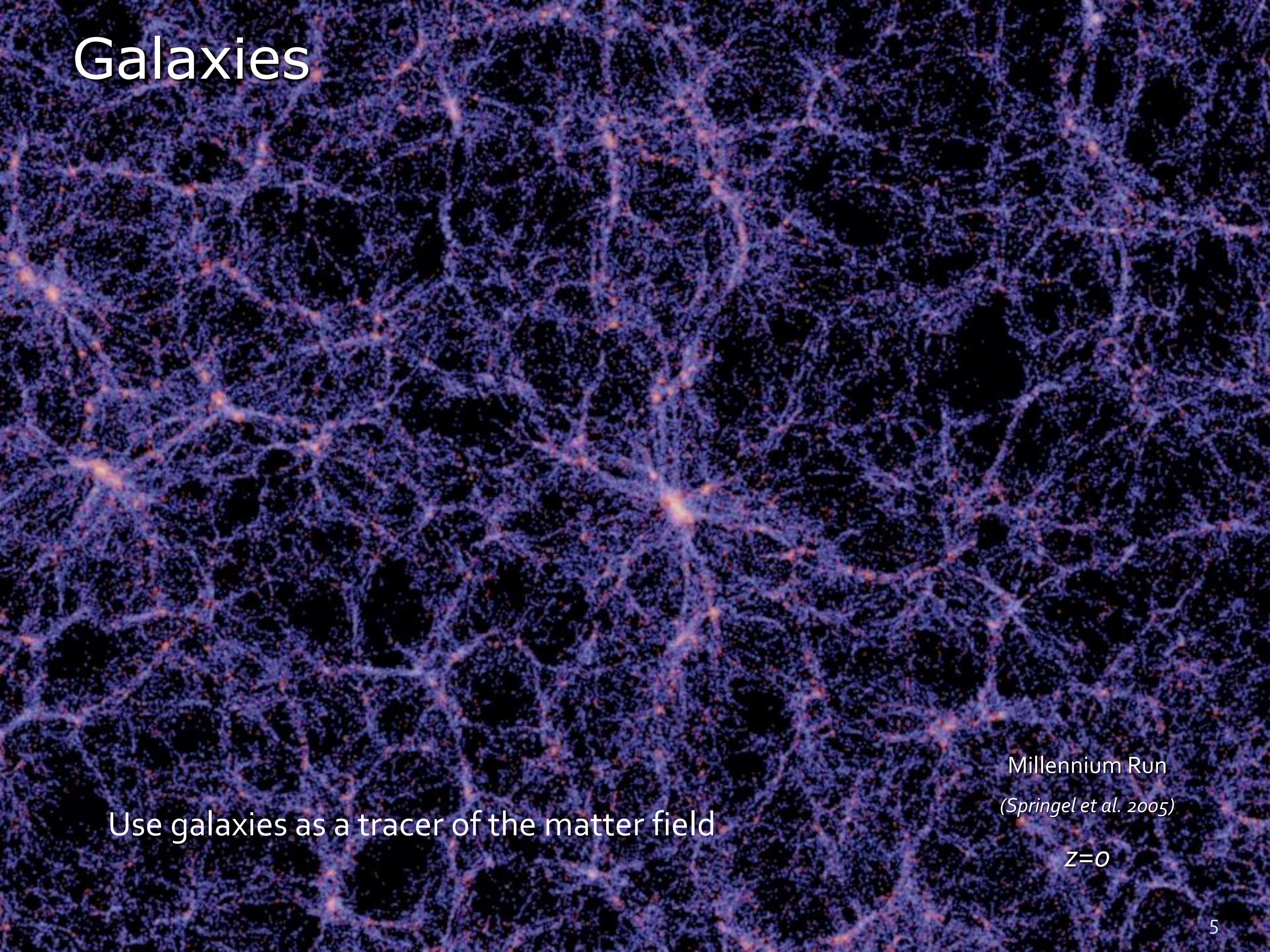
  - Large-scale density fluctuations modulate the number density of local density peaks, bringing the highest above the critical density for collapse (δ_c=1.686 in EdS model)
  - Halo large-scale bias described as $b=1+(\nu^2-1)/\delta_c$: rare objects (most massive) exhibit a higher bias

But, halo ⟺ galaxy?

- Large-scale linear bias: $b \equiv \delta_g/\delta$
  - Valid only on large scales

From de la Torre (Les Houches 2016)

Galaxies



Use galaxies as a tracer of the matter field

Millennium Run

(Springel et al. 2005)

z=0

Part 1

DEEP LARGE SCALE GALAXY SURVEYS: METHODS

Outline

1. Designing a deep survey
2. Instruments for deep surveys
3. Observational methods
4. Data processing
5. Databases and information systems
6. Comparing surveys

Cosmological probes

- Measurements sensitive to the « cosmological parameters » of the world model
  - Geometry: standard rods
  - Content: mass of the different components
- Need to combine several cosmological probes to fully constrain the full set of parameters

Probes ➡ Surveys

(Euclid = a BIG survey)

What are “deep surveys” ?

Deep galaxy surveys are observations of a part of the sky, assembling representative samples of galaxies from well defined selection criteria

Two types of complementary surveys:

- Deep photometric surveys
- Deep spectroscopic redshift surveys

Surveys rely on **large number statistics**

Surveys are used for:

- Galaxy formation and evolution
- Measuring cosmological parameters

Surveys = polls

- Ask the opinion of 1 person: always wrong
- Ask 10 persons: strong biases
- Ask 100 persons: some biases
- Ask 1000 persons: average is probably close to truth
- …
- Votes from the whole population make the truth

→ Need large samples

Designing a survey

- Science goals & strategy
- Survey parameter space
- Instrumentation
- Survey examples

How are galaxy surveys designed ?

The ‘Wedding cake’ approach

Deep / small field

Medium / large field

Shallow / all-sky

Some Principles

- Surveys need to be unbiased
  - Volume, luminosity/mass, type, environment…
  - Proper photometric catalogs
- Statistically robust
- Complete census

- Selection function control
  - Apriori hypotheses
  - Large deep imaging surveys
- Large samples
- Multi-wavelength

2 types of surveys: photometric and spectroscopic

Science goals: the starting point

- What are the science questions addressed by the survey ?
- What are the measurements to be performed ?
- What is the desired accuracy ?

Cosmology-clustering:

BAO

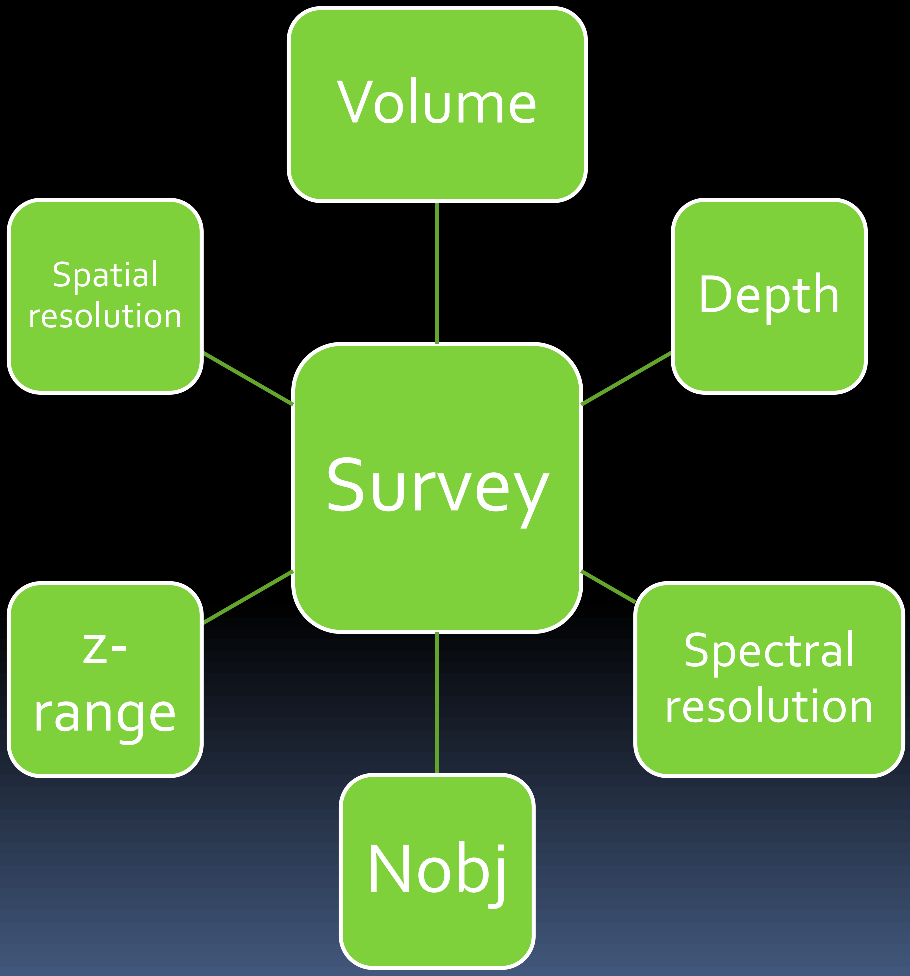
RSD

Cosmology: SNe, WL, Clusters…

Galaxy formation & evolution:
Merging, accretion, feedback,…

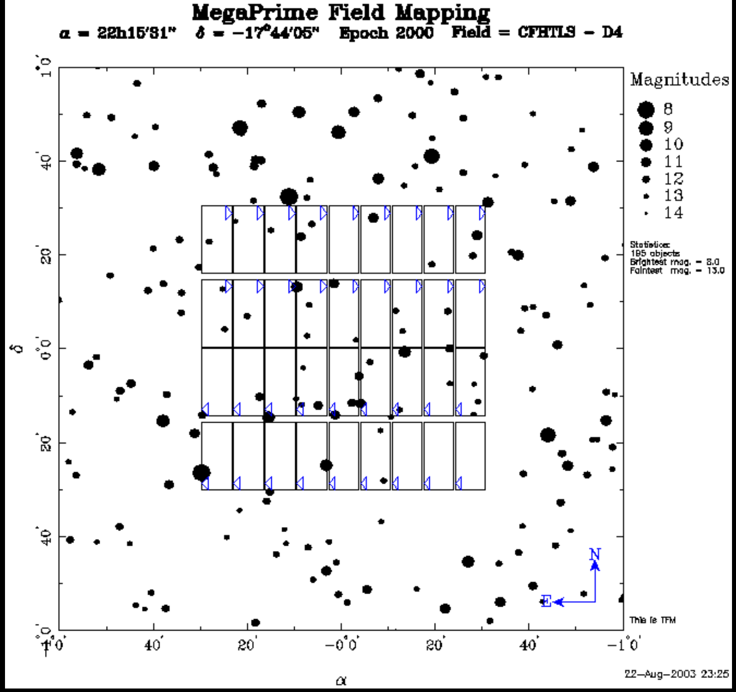
As a function of z…

Survey parameter space

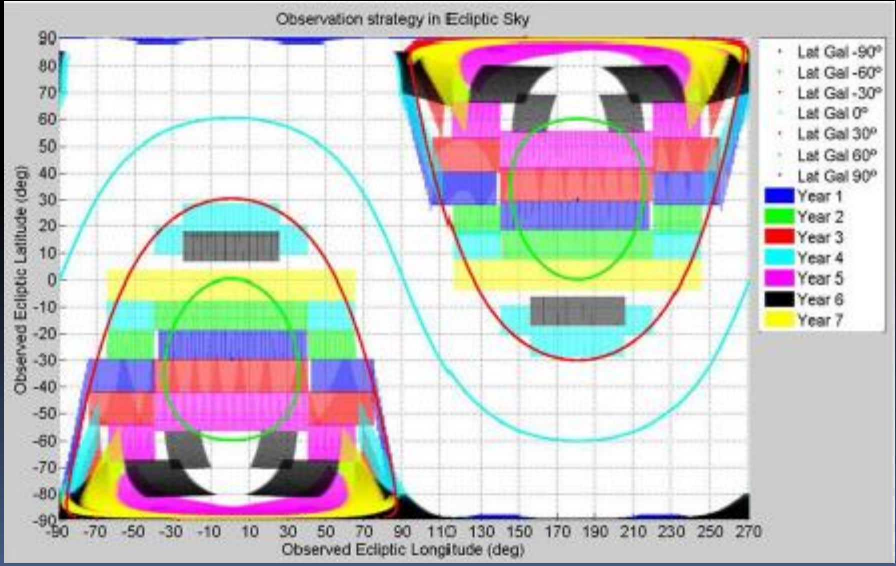


Survey volume

- $Volume \propto Area \times dz$
- Area depends on telescope+instrument
  - Etendue AΩ
- Instantaneous volume and tiling
  - One instrument pointing necessarily limited in area
  - Need tiling to implement survey



Single pointing footprint: Megacam @CFHT



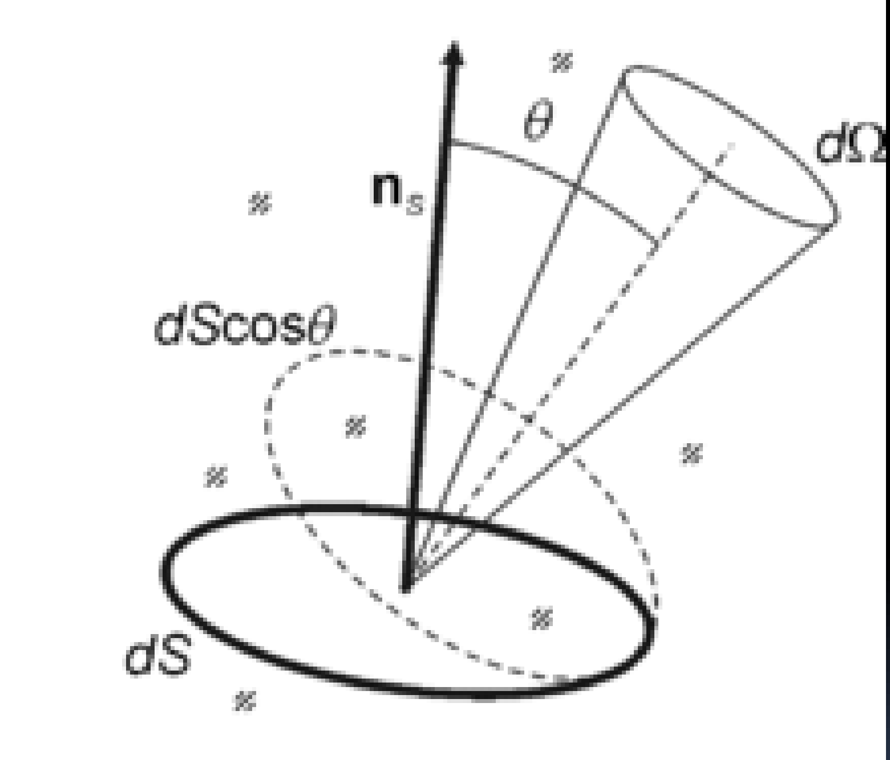
Whole sky tiling: Euclid

Etendue *(some instrumentation stuff…)*

- An instrument system is more efficient when the *Etendue* is larger

- Etendue: the area of the entrance pupil (telescope collecting area) times the solid angle the source

$$E = A\Omega$$



AΩ: a key element in instrument systems

- A = telescope collecting area
- Ω= telescope+instrument field of view
- The larger the AΩ, the more information can be accessed

These instrument systems have the same efficiency

Telescope ϕ	1m	4m CFHT	8m VLT	40m ELT
Field of view	1 deg^2	0.08 deg^2	0.02 deg^2	0.0008 deg^2
AΩ	1	1	1	1

Survey depth

- Depends on
  - Telescope diameter
  - Instrument throughput (optical efficiency)
  - Exposure time
  - Detector noise
  - Background
- Signal to noise S/N

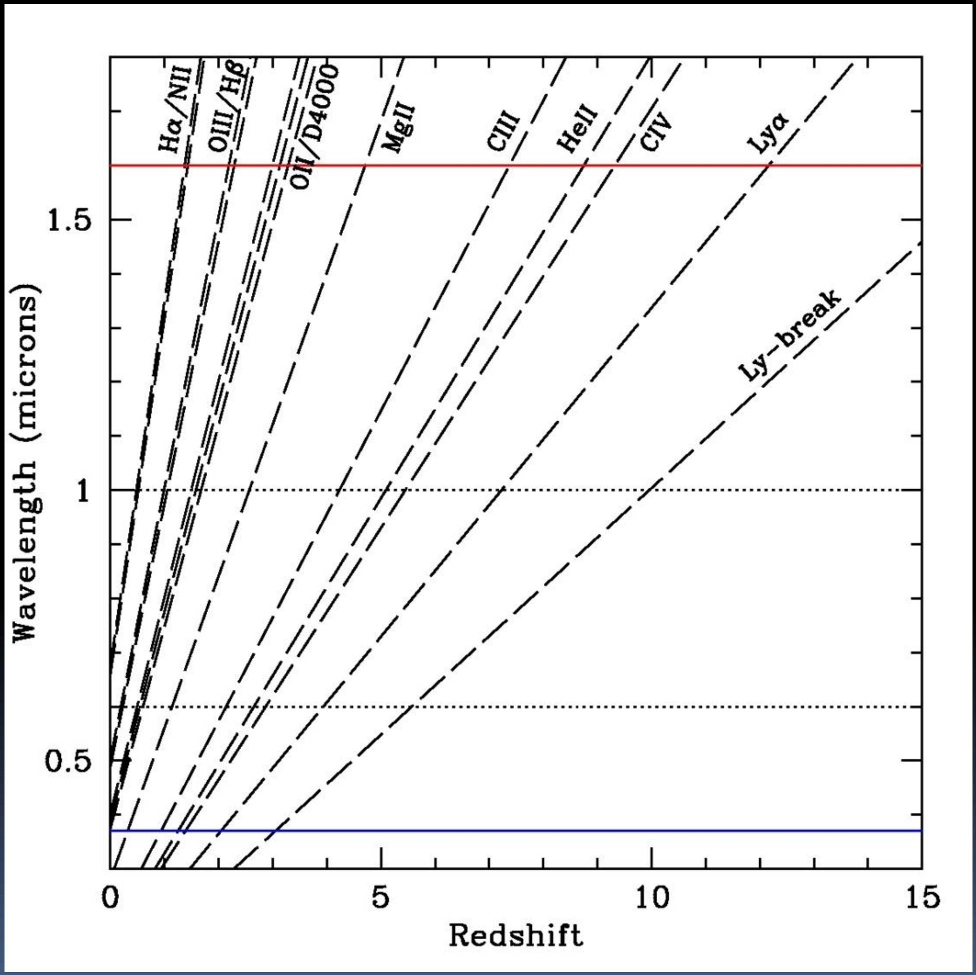
Source $N_{photons}$

$$S/N = \frac{R_* \times t}{[(R_* \times t) + (R_{sky} \times t \times n_{\rm pix}) + (RN^2 + (\frac{\mathcal{G}}{2})^2 \times n_{\rm pix}) + (D \times n_{\rm pix} \times t)]^{1/2}}$$

Source Background Detector Noise Det. Dark current

Survey redshift range

The redshift range will determine the wavelength range (and vice-versa)



Survey spectral resolution

- Ability to separate spectral features
- $R=\lambda/d\lambda$
- The higher R, the better is the velocity resolution, or velocity accuracy
- Choice depends on the spectral features you are interested into
  - Broad features (e.g. because of velocity dispersion) or narrow
- Directly linked to wavelength coverage in instrument design

Survey number of objects

- A key number: 10^5 objects

Why ?

Nobj ??

$\sim 10^5$!!

- Study evolution vs. Luminosity, color (type), environnement
- Minimise cosmic variance effects: survey several independant fields
- Several time intervals to follow evolution
- 50 galaxies per measurement bin
- **Total number of galaxies: 50 × 10 × 3 × 3 × 4 × 7 > 100000**

per bin mag.bin colors env. fields time steps

Science vs. parameter space: matrix

Science Goals	**Survey parameters**				
	Area	λ-range microns	Spectral R	Mag. Lim.	Nobj
Goal 1	1 deg^2	0.36-1	250	24.5	10000
Goal 2	0.5 deg^2	0.55-1	1000	25	6000
Goal 3	3 deg^2	0.35-0.8	250	24	50000
…					

Compile all science goals into one single survey observing strategy

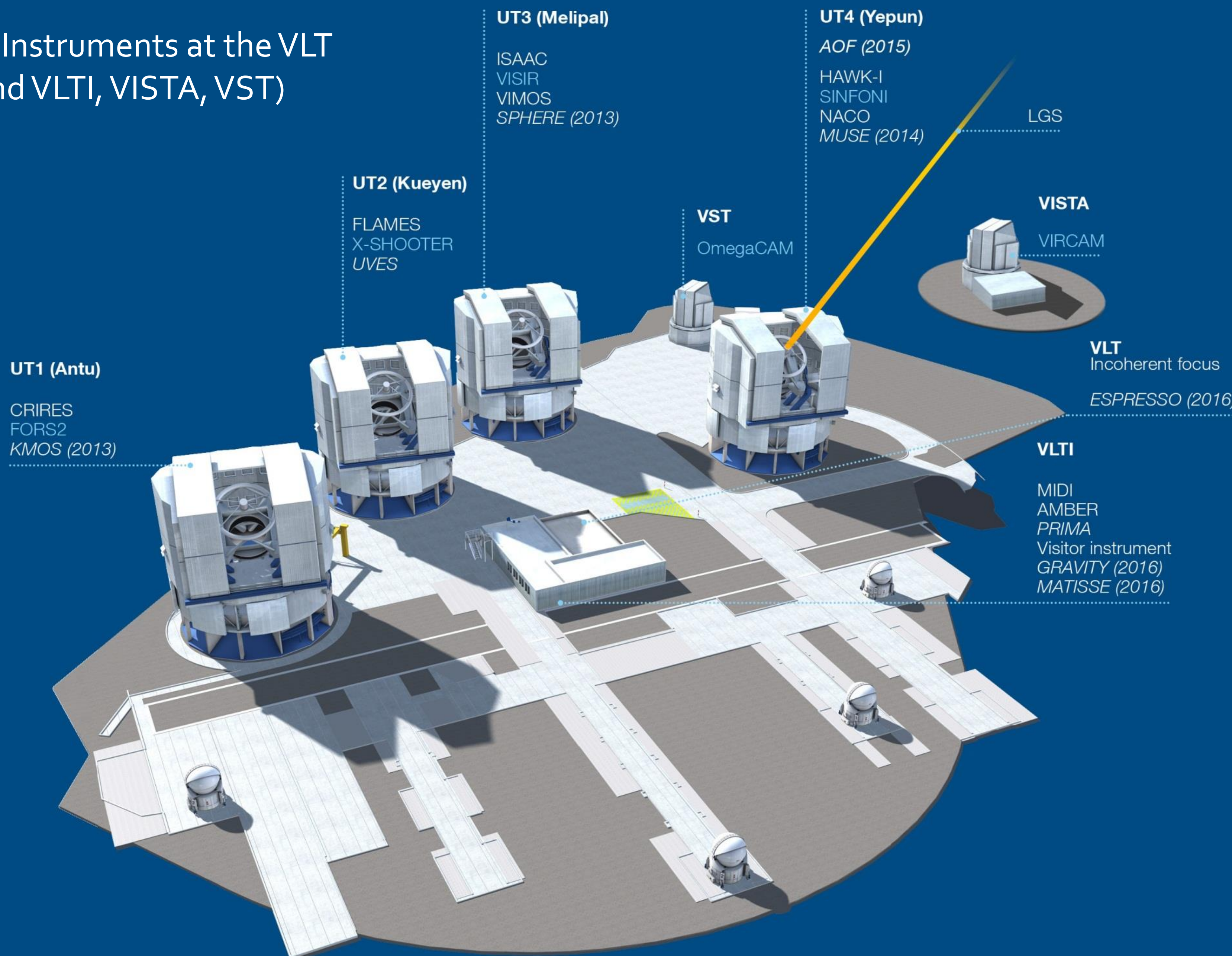
Examples of spectroscopic survey design

Survey	Survey Design Parameters					
	Area	λ-range microns	z-range	Spectral R	Mag. Lim.	Nobj
SDSS-III	10000 deg^2	0.36-0.9	0-0.5	2000	18	10^6
VVDS-Wide	8 deg^2	0.55-1	0-1.5	250	22.5	22500
VVDS-Deep	1 deg^2	0.55-1	0-5	250	24	12500
VIPERS	25 deg^2	0.5-1	0.5-1.5	250	24	10^5
VUDS	1 deg^2	0.36-1	2-6+	250	25	10^4
PFS	1400 deg^2	0.4-1.3	0.5-7	3500	25	3×10^6
DESI	14000 deg^2	0.4-1	0-1.6	4000	19.5	25×10^6
Euclid	15000 deg^2	0.95-1.8	0.8-2	300	(22)	50×10^6
WFIRST	2200 deg^2	1.35-1.9	1.1-2.7	500	(23)	20×10^6

Which instrument for my survey ?

- Imaging or spectroscopy ?
- Need both !

14 Instruments at the VLT (and VLTI, VISTA, VST)



Imaging cameras

- Based on CCDs for the visible domain
- Based on HgCdTe arrays for 1-5 microns
- Other hybrid detectors in UV and to ~25 microns
- Radio and sub-mm recievers
- X-ray cameras
- ....

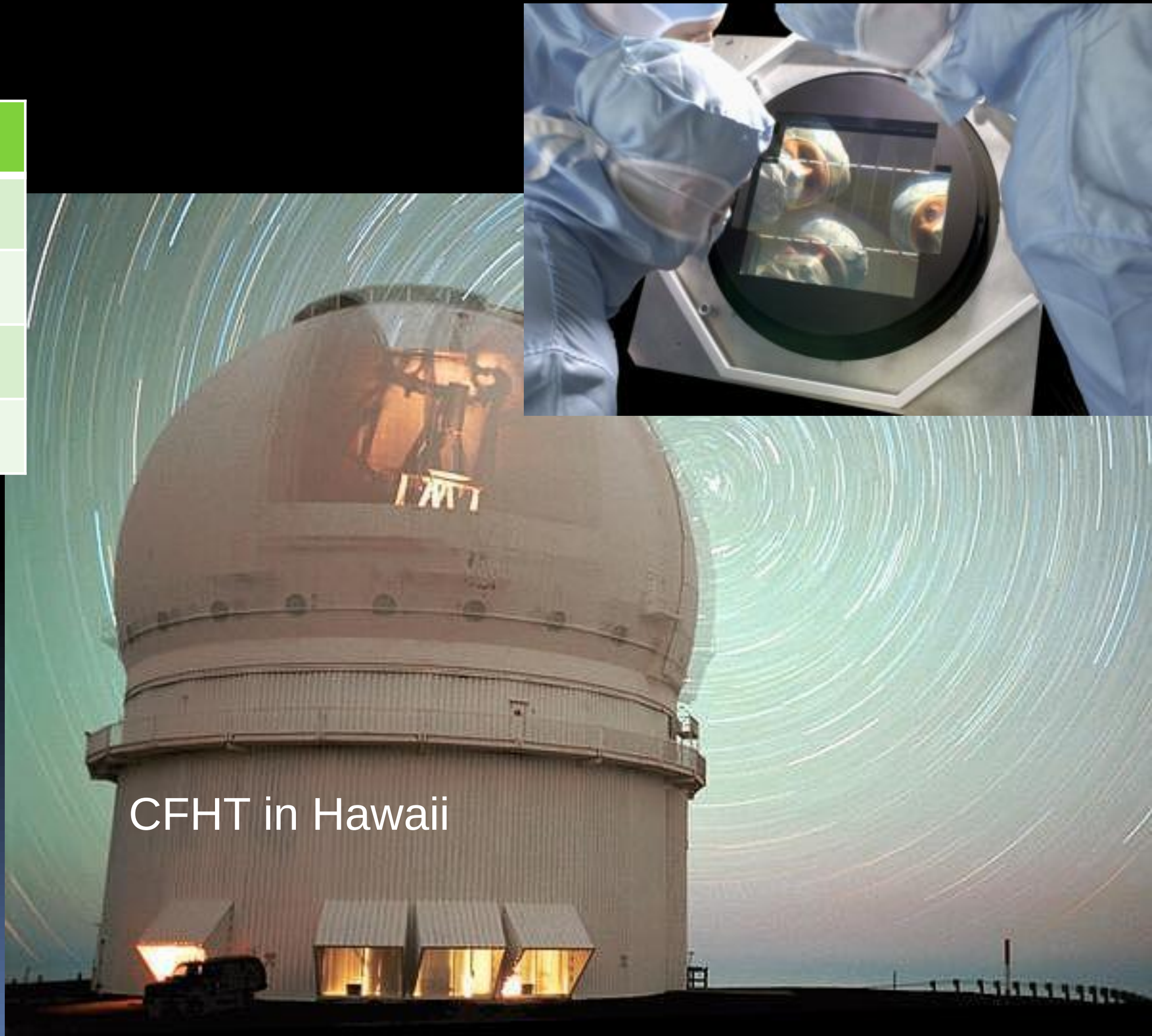
Key elements

- Field of view
- Wavelength domain
- Spatial resolution
- Throughput / Quantum efficiency

Visible cameras: CFHT 3.6m+Megacam

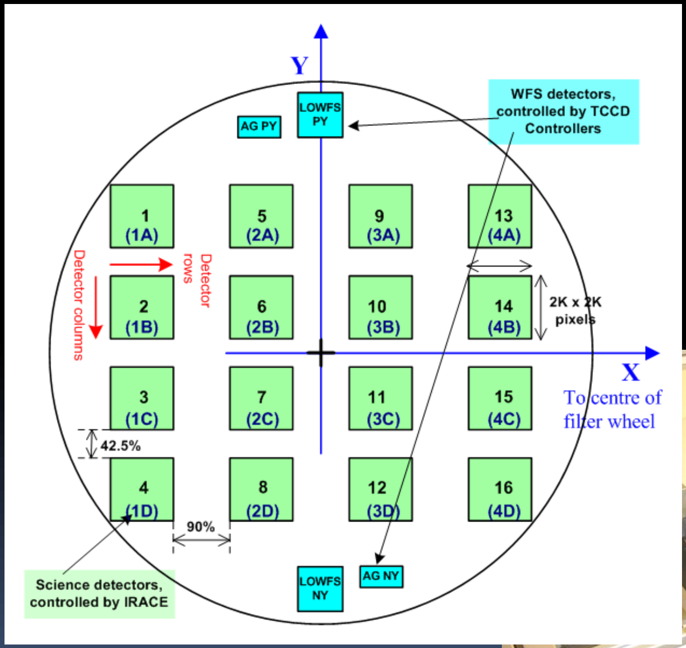
Parameter	Value
Field of view	1 deg^2
λ-range	0.33-1 microns
Pixel scale	0.2 arcsec
Filters	ugriz

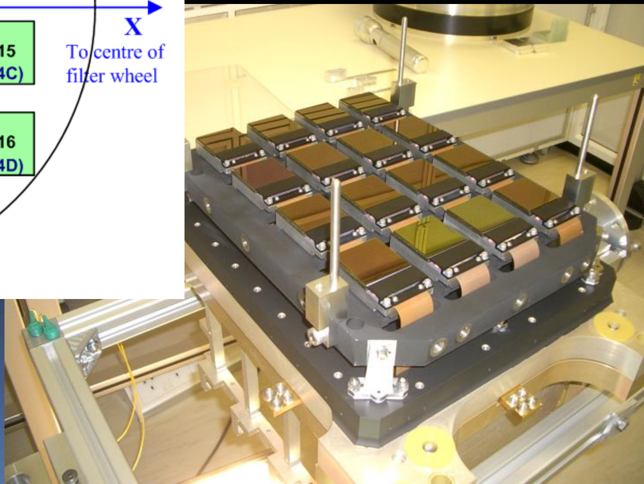
MegaCam: 256 millions pixels



IR cameras: on 4m VISTA at ESO

Parameter	Value
Field of view	0.6 deg^2
λ-range	0.8-2.5 microns
Pixel scale	0.34 arcsec
Filters	YJHK





HST imaging

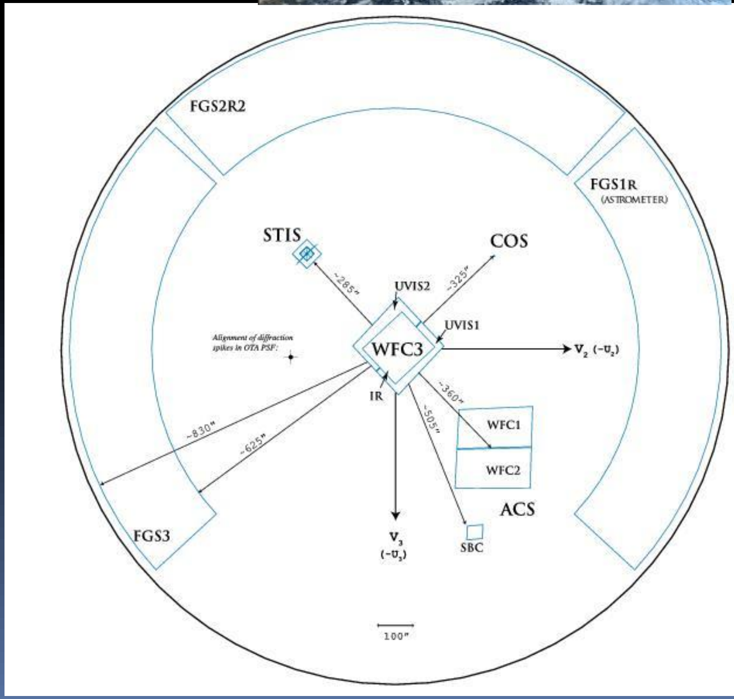
ACS

Parameter	Value
Field of view	11 arcmin²
λ-range	0.35-1 microns
Pixel scale	0.05 arcsec
Filters	Ubvriz-like

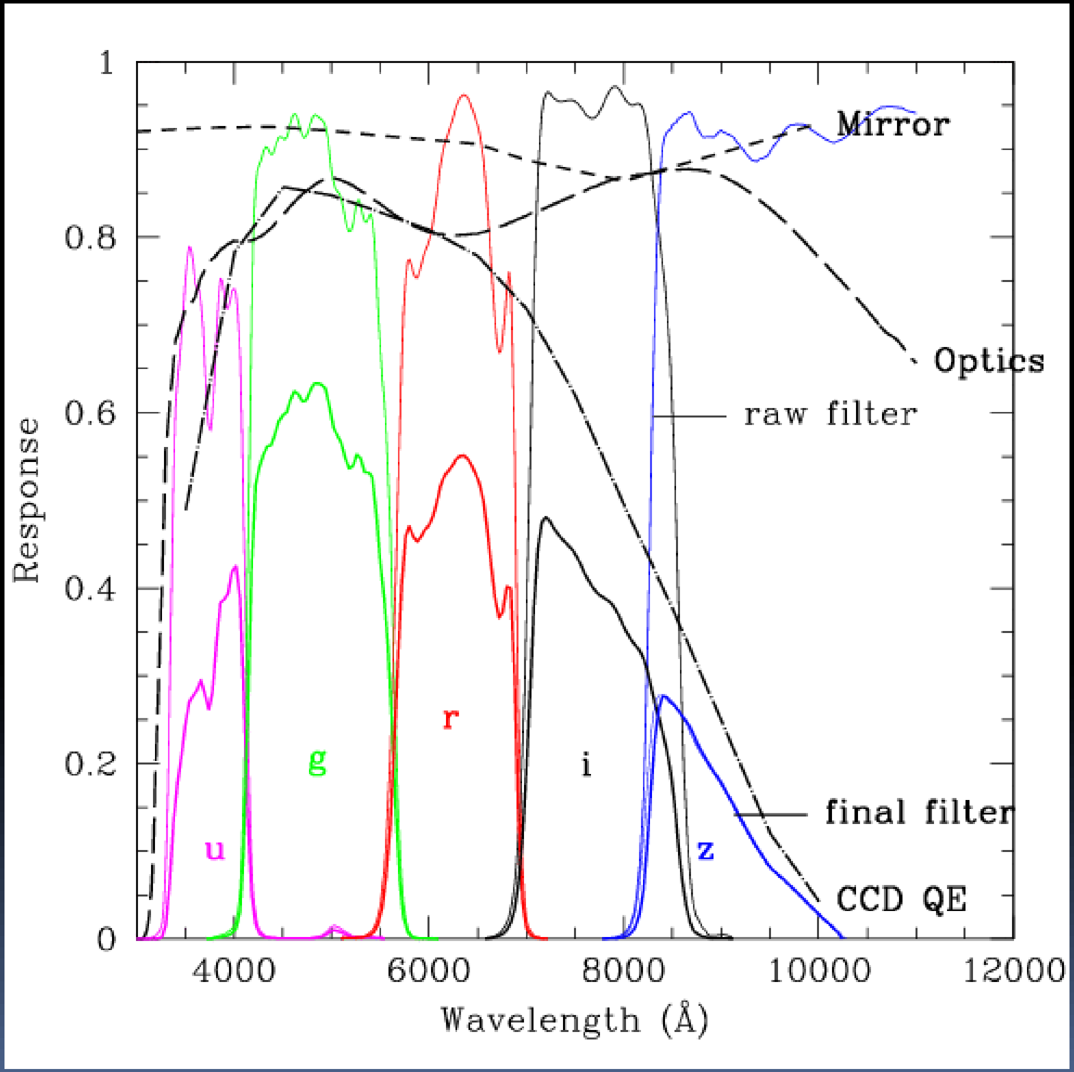
- The best resolution
- The best sensitivity
- The smallest field

WFC3

Parameter	Value
Field of view	4.6 arcmin²
λ-range	0.8-1.7 microns
Pixel scale	0.13 arcsec
Filters	zYJH



Efficiency of imaging cameras

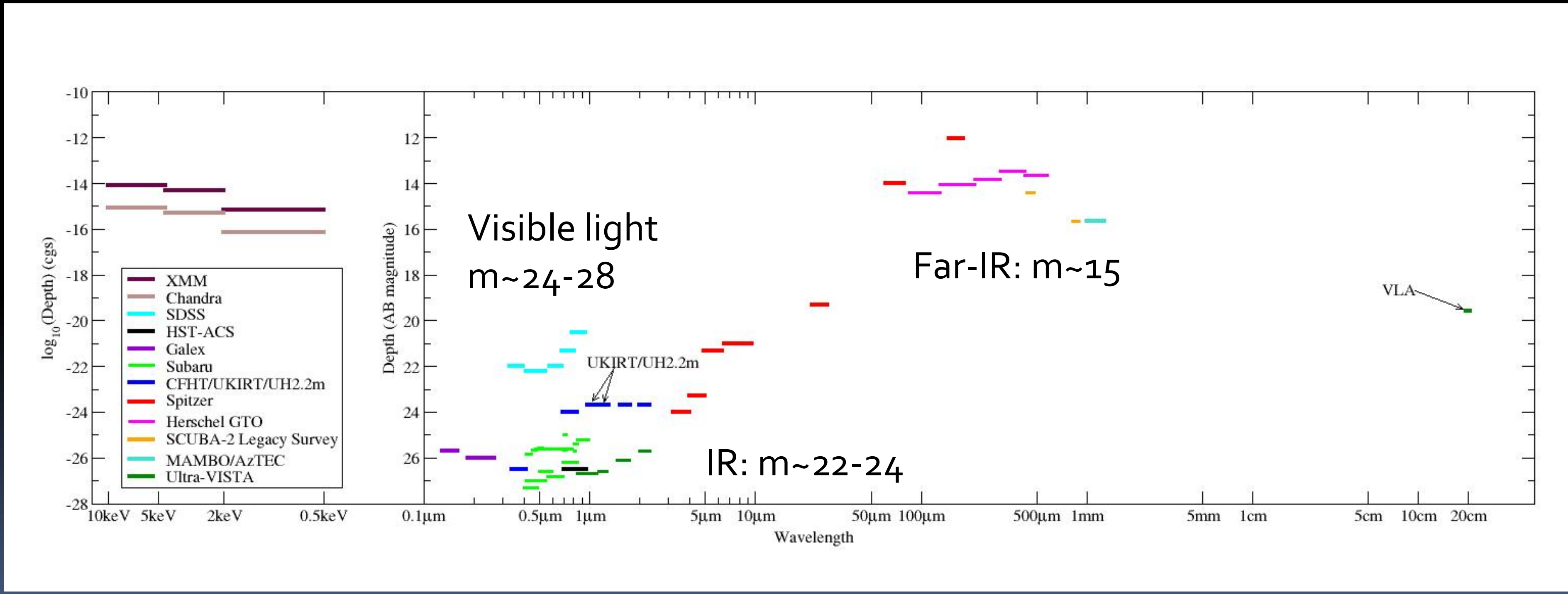


Optical filters, are interference filters, selectively transmit light in a given bandpass, while blocking the remainder.

Imaging systems have a high throughput (efficiency in catching photons)

Limiting magnitudes in imaging

- Depend a lot on the wavelength
  - Optics throughput and detector quantum efficiency
  - Background



Example of the COSMOS survey

MOS: multi-object spectrographs

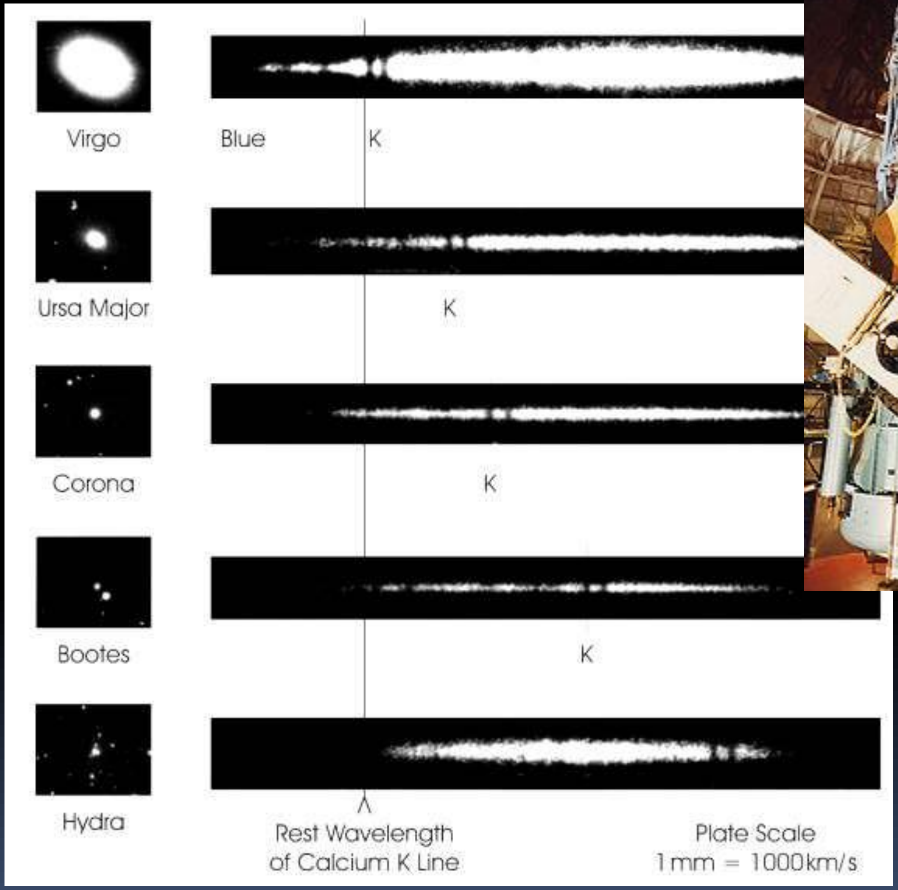
- A key invention for Cosmology !
- Principle: observe more than one object at once
  - Multiplex N_{obj}
- The multiplex is like having N_{obj} telescopes each observing 1 object
- Different types of MOS
  - Multi-slit: better sky subtraction
  - Multi-fiber: wide field
  - Multi-IFU: velocity fields

Key elements

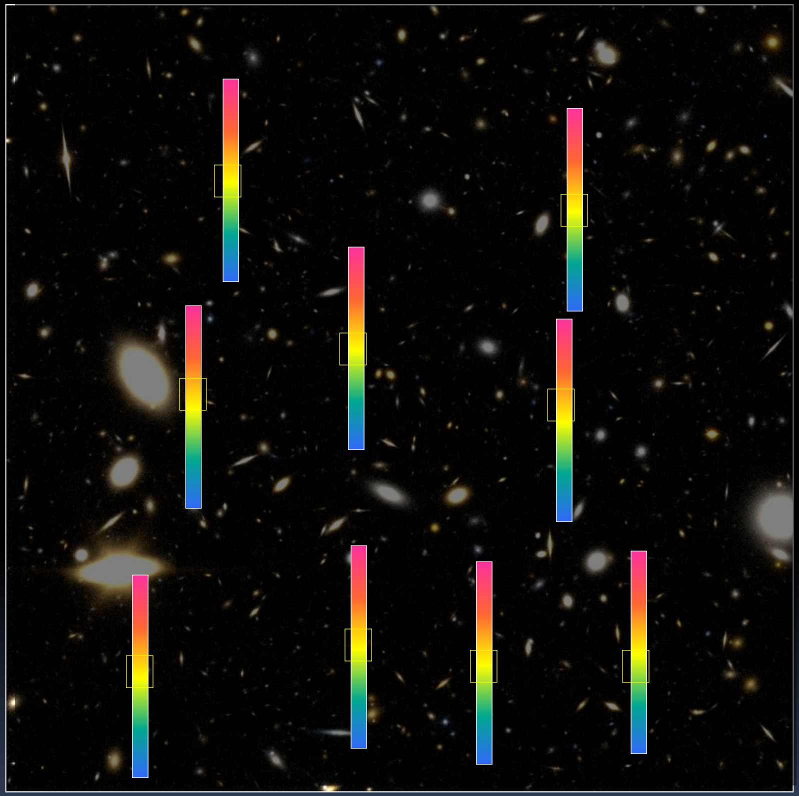
- Field of view
- Wavelength domain
- Spectral resolution
- Multiplex
- Throughput

Spectra, one by one

E. Hubble



Multi-object spectroscopy



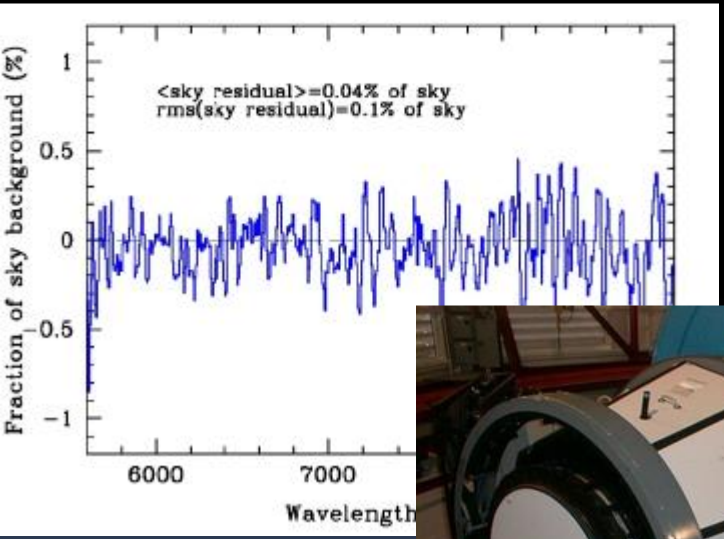
- Deep multi-color imaging
- Target selection
- Multi-object spectroscopy

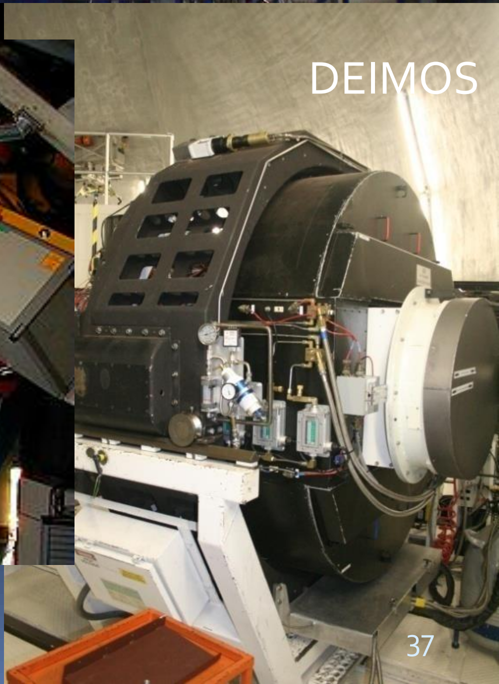
Today MOS have N_{obj} >> 100

Multiplies the efficiency of your telescope by N_{obj} !

Multi-Object Spectrograph have become the work-horse of many observatories

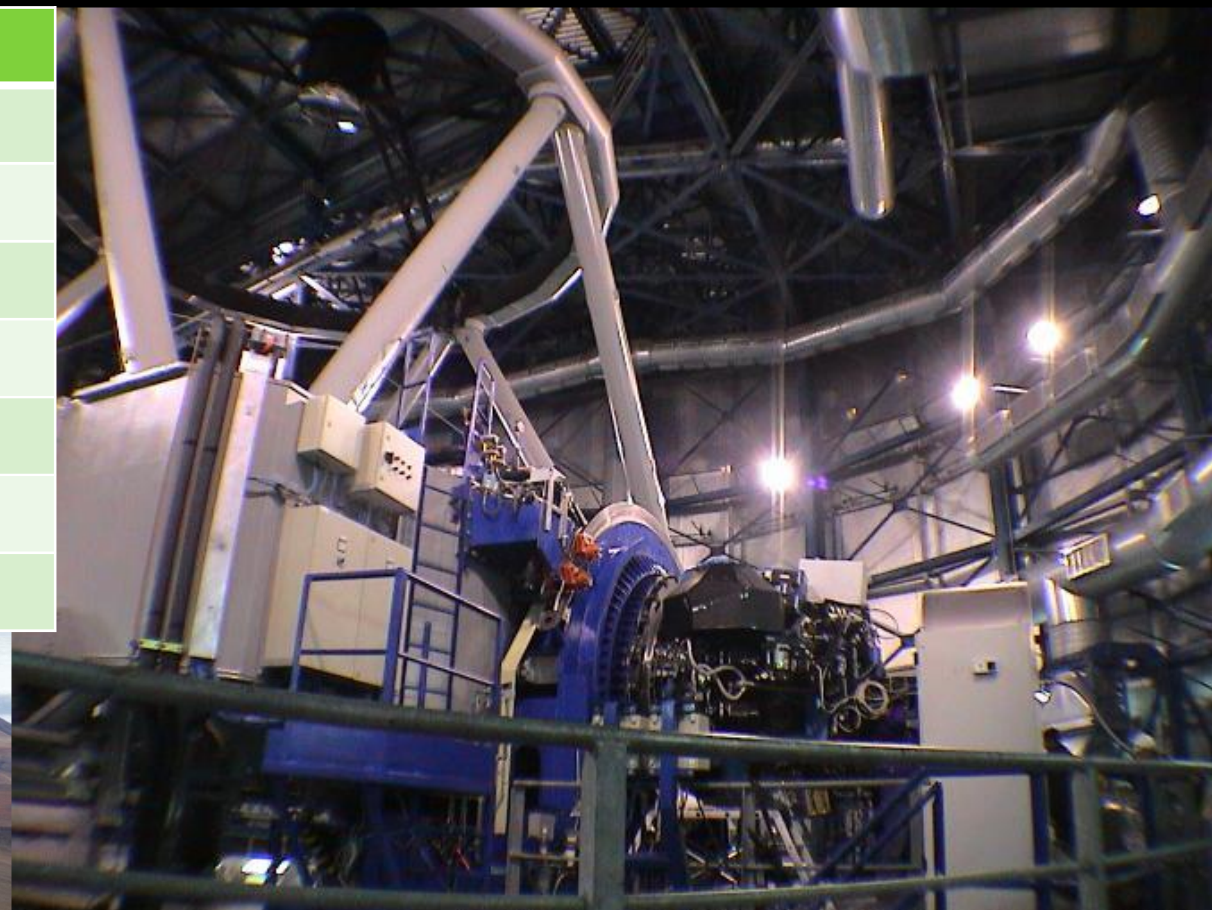
- In all major observatories: SDSS survey, CFHT-MOS/SIS, Keck-LRIS, VLT-FORS, GMOS, Keck-DEIMOS, VLT-VIMOS, IMACS …
- Now going to the IR: MOSFIRE, VLT-KMOS





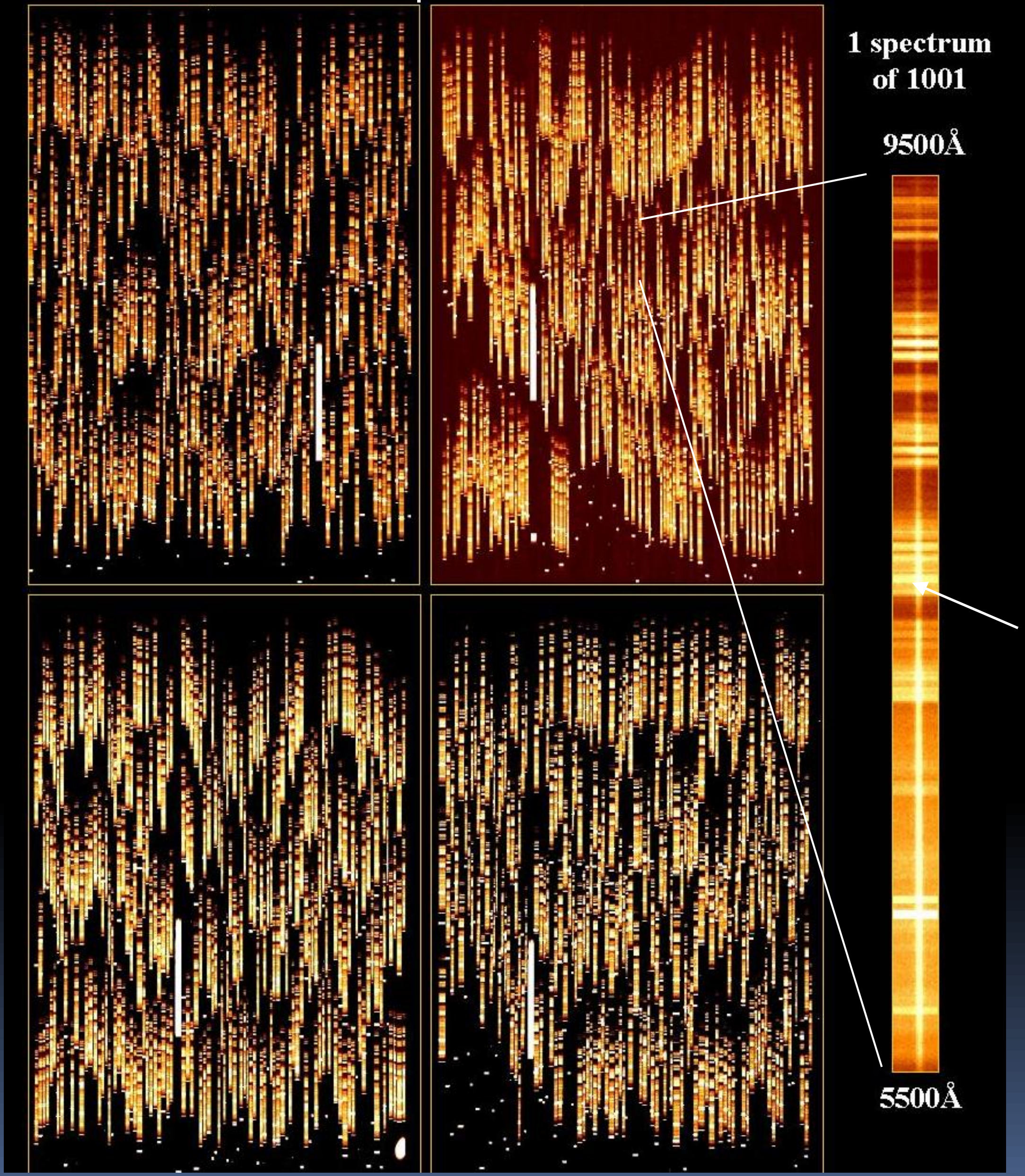
VIMOS on the VLT

Parameter	Value
Field of view	220 arcmin²
Apertures	Slit mask
λ-range	0.36-1 microns
Pixel scale	0.2 arcsec
Filters	Ugriz
Spectral R	250-2500
Number of slits	~600



Most efficient MOS
Produced high-z cosmology surveys

VIMOS: 1000 spectra in one shot



Vertical trace: one galaxy spectrum

Horizontal lines: night sky emission

DEIMOS on Keck

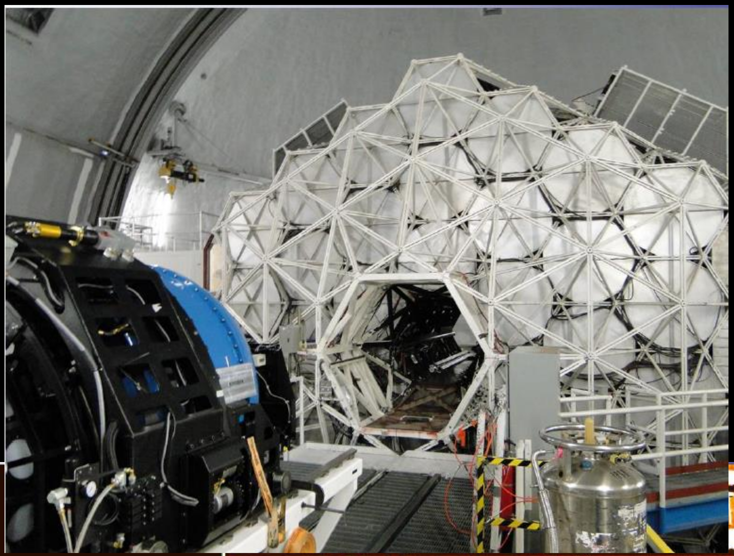
Parameter	Value
Field of view	80 $arcmin^2$
Apertures	Slit mask
λ-range	0.42-1 microns
Pixel scale	0.1 arcsec
Filters	BVRIZ
Spectral R	1500-5000
Number of slits	~120

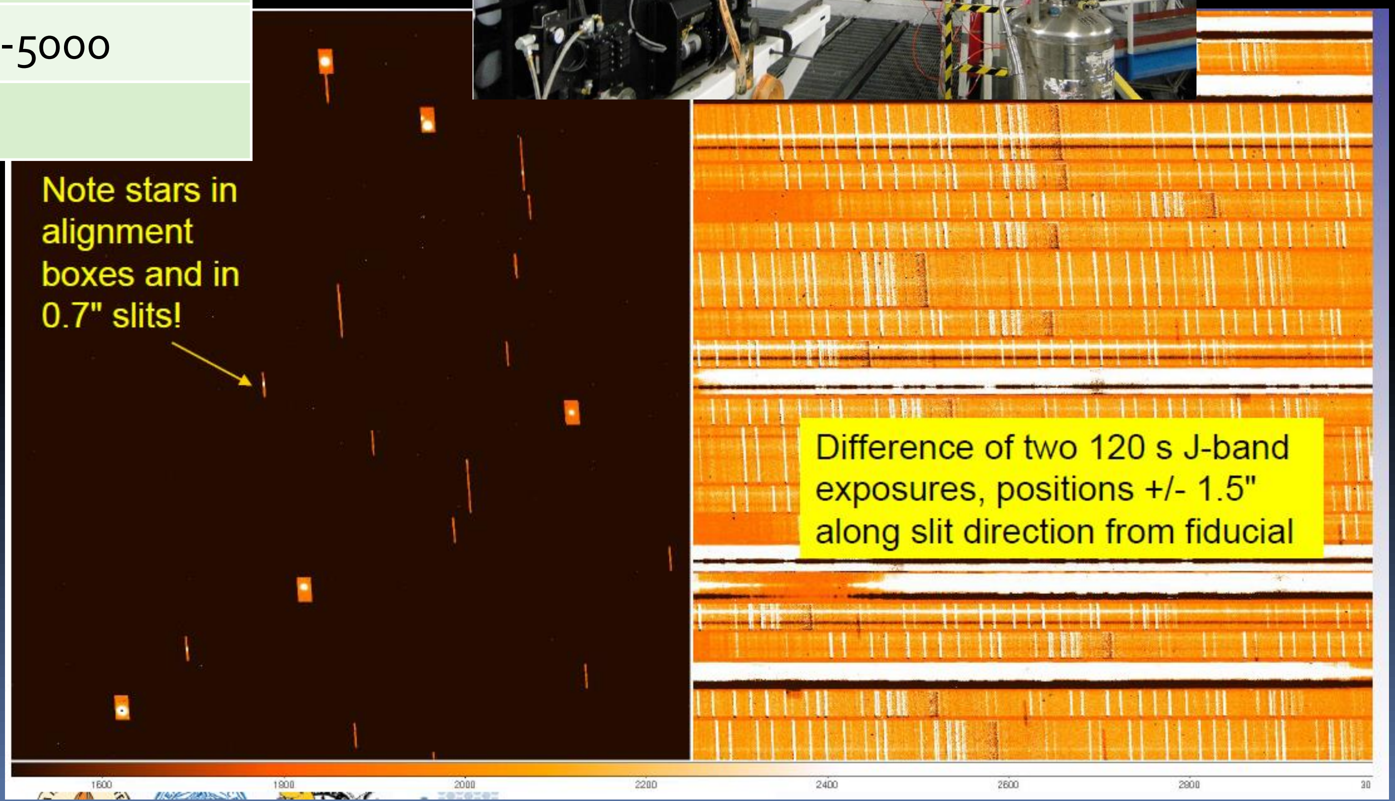
SDSS spectrograph

Parameter	Value
Field of view	7 deg^2
Apertures	Fibers
λ-range	0.38-92 microns
Fiber size	3 arcsec
Spectral R	2000
Number of fibers	~600

MOS in the IR: MOSFIRE on Keck

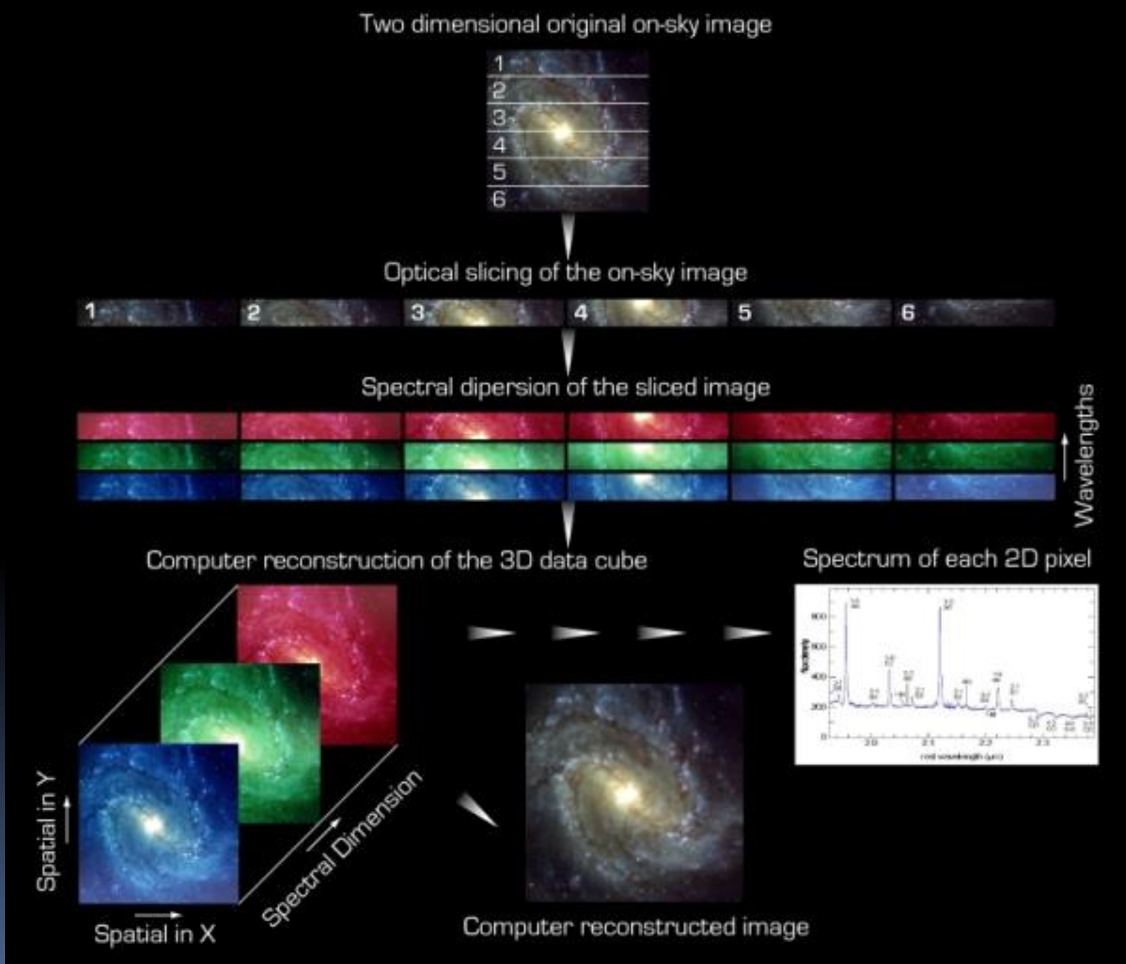
Parameter	Value
Field of view	45 arcmin²
Apertures	Moveable slits
λ-range	0.8-2.5 microns
Pixel scale	0.1 arcsec
Filters	YJHK
Spectral R	2000-5000
Number of slits	45

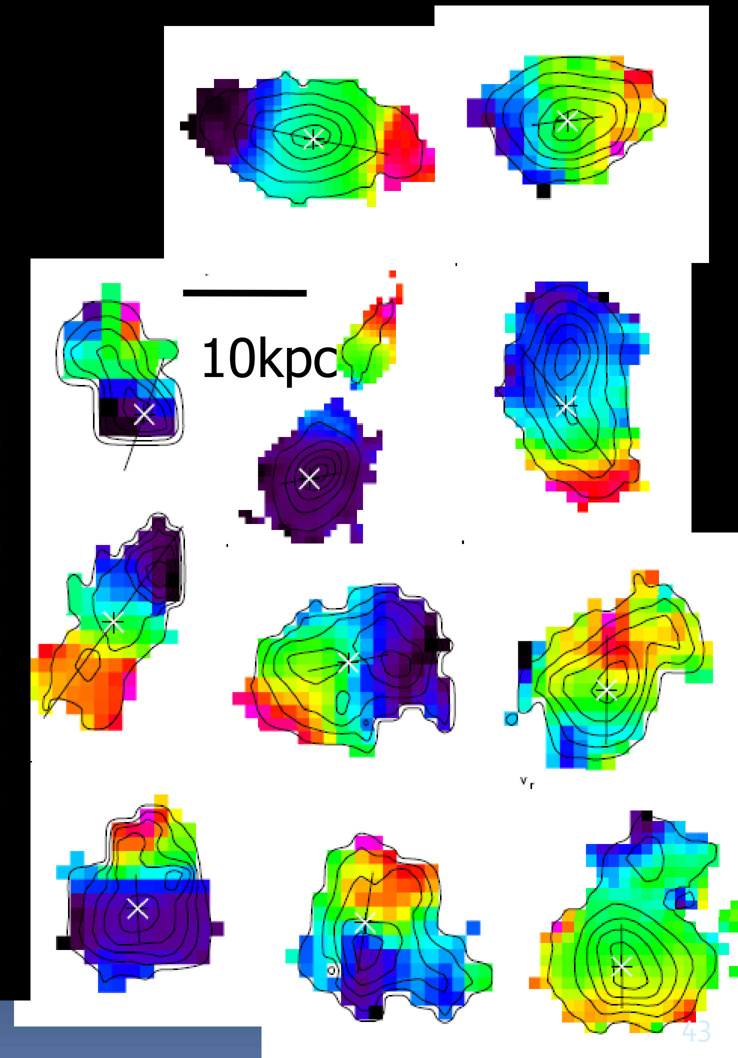




Integral field spectroscopy: velocity fields

MASSIV survey at z~1.5



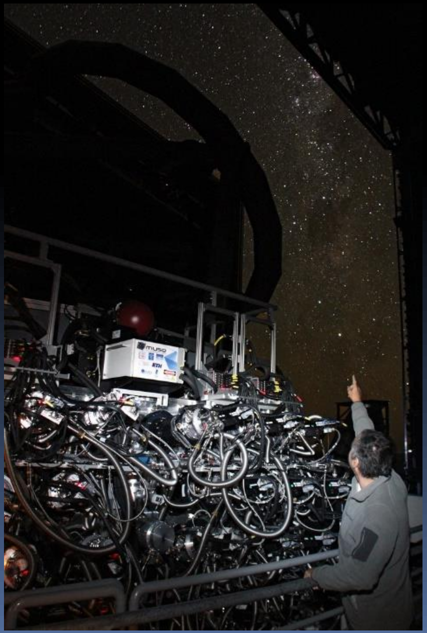


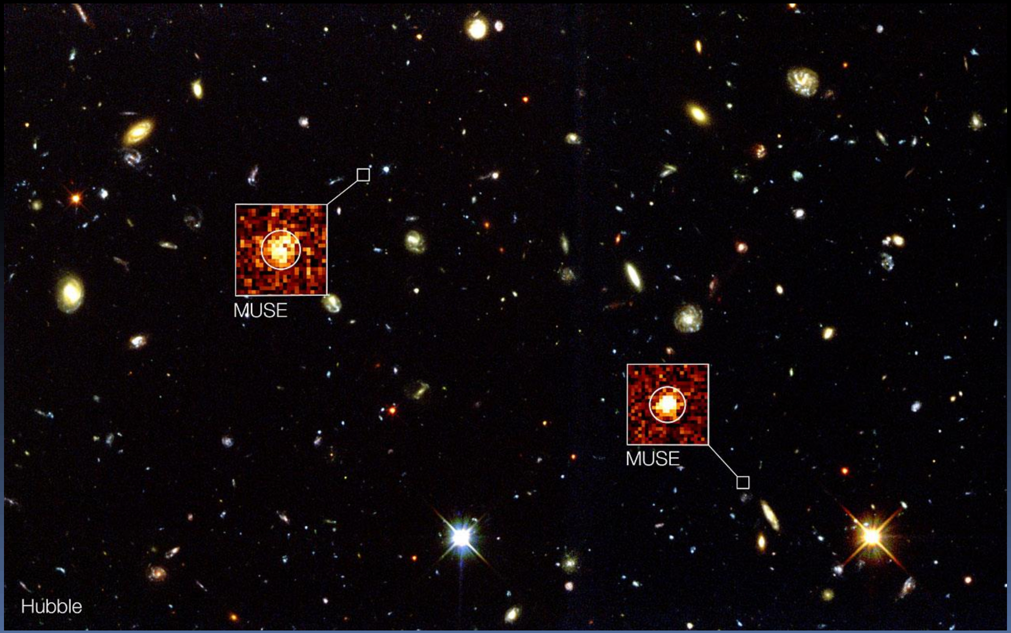
MUSE on VLT: largest IFS

www.eso.org

Large Field (for an IFS): 1x1 $arcmin^2$

Finds faint emission line galaxies (not seen by Hubble)

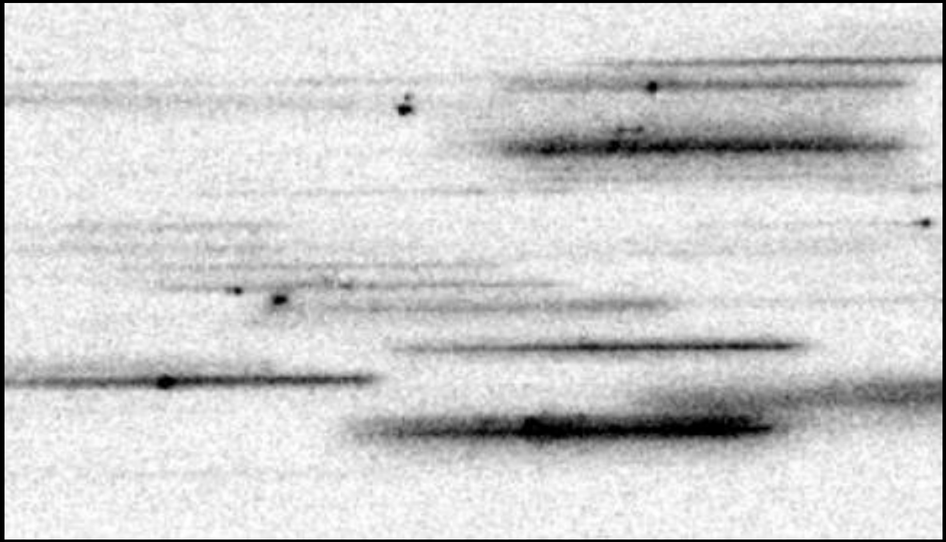


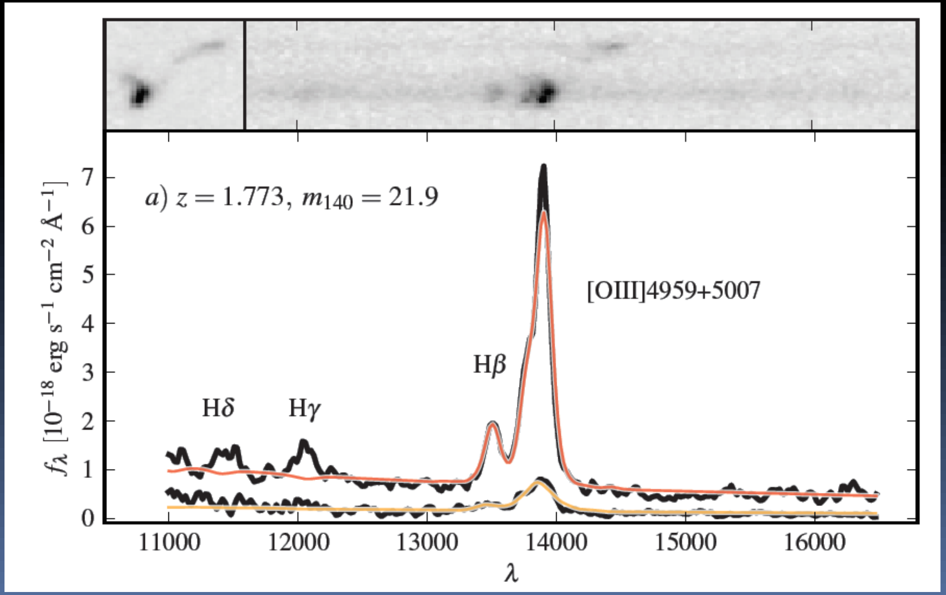


Slitless spectrographs

- Insert a prism (grism) in the beam: all objects produce a dispersed spectrum
- Pros: all objects get a spectrum
- Cons:
  - Geometric superimposition
  - Higher background
- Recent example: 3D-HST survey with the WFC3 camera on HST (600 arcmin²)

EUCLID NISP will do a slitless survey of 15000 deg²





Instrument design and development

- Instrument making is fundamental to astrophysics
- Relies on new & improved technology
  - Optics, detectors, mechanics, control (active)
  - Space technology
  - Software: data processing, databases
- Professional project development
  - Skilled instrument scientists and specialty engineers
  - Project management
- Expensive telescopes (~1G€) and instruments (~15-80M€ ground-based / ~150M€ space-based)

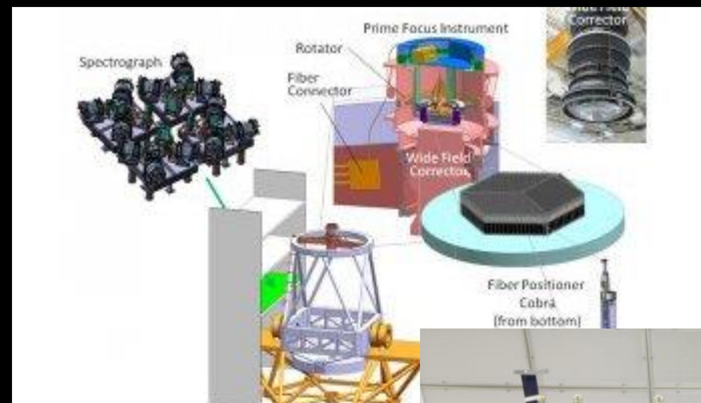
Instrument development cycle

- Define science goals: science requirements — T_0
  - Survey volume, number of objects, redshift
- Derive technical requirements
  - Field of view, wavelength, resolution, throughput — T_0+1y
  - Global performances
- Produce strawman opto-mechanical design
- Identify new technology developments: grating, detectors,… — T_0+2y
  - Produce prototypes
- Manufacture all parts — T_0+4y
- Assembly, integration and tests — T_0+5y
  - Measure performances, calibrate
- First light — T_0+6-7y

SPACE instruments: 2x longer !

Preparing future instrumentation for surveys

- Ground
  - PFS
  - DESI
  - LSST
  - ELTs
- Space
  - JWST
  - Euclid
  - WFIRST



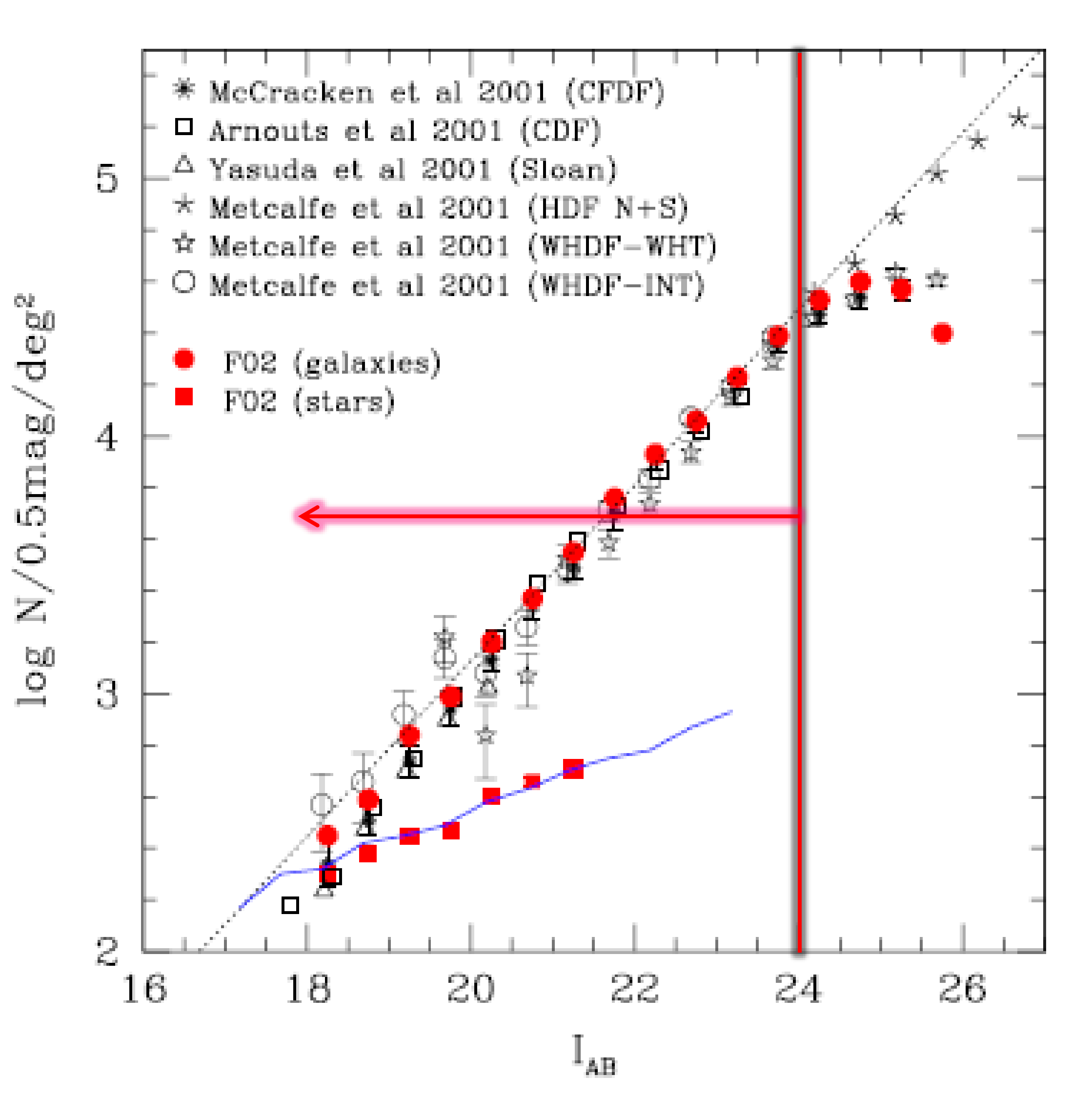
Observational methods

- Sample selection
- Observations preparation and follow-up
- Measuring the sample selection function

Sample selection

- Magnitude or flux selection
- Color selection
- Color-color selection
- Photometric redshift selection
- Line flux selection (Hα, Lyα,…)

Magnitude / flux selection

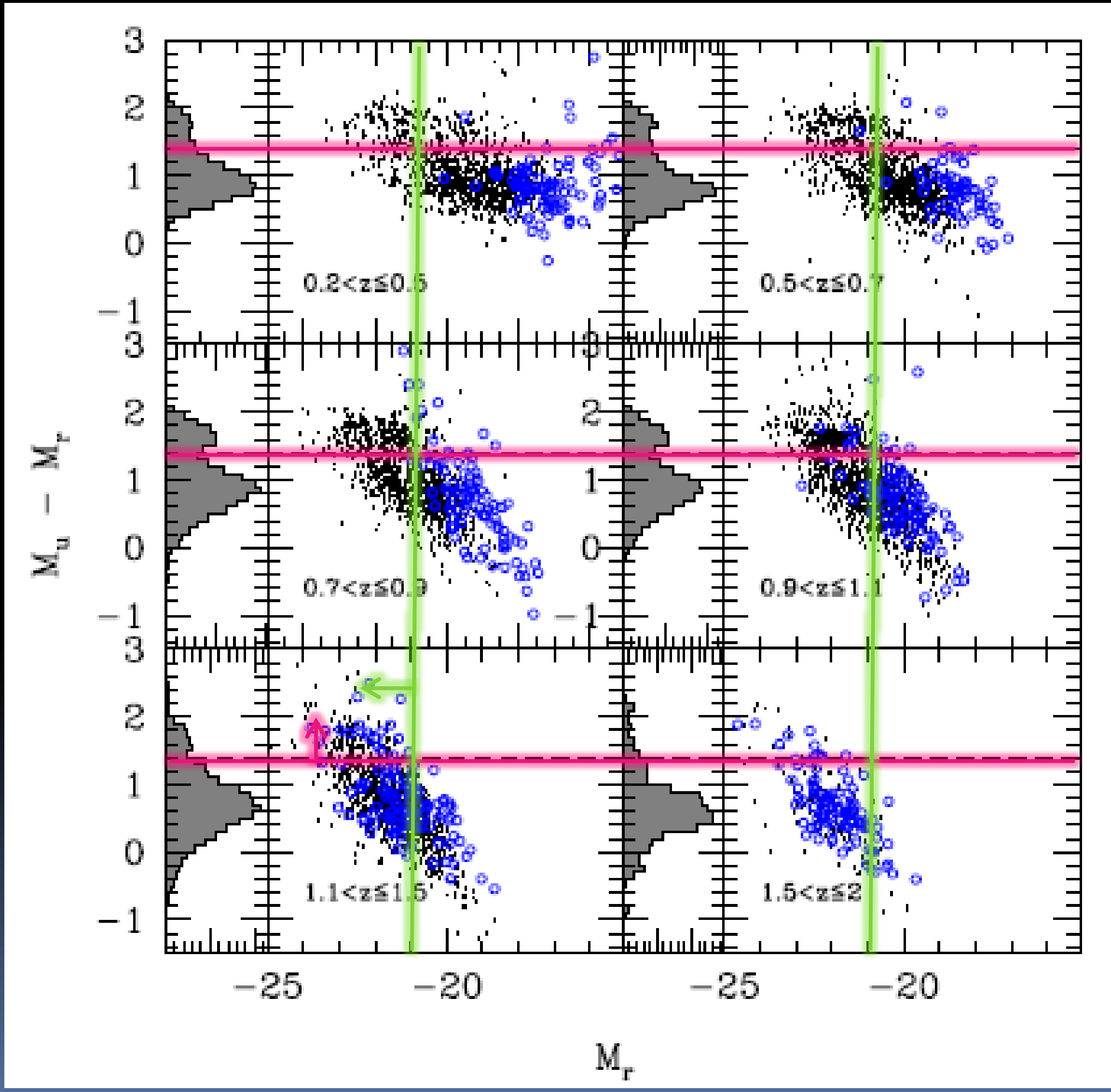


Observe all galaxies brighter than a limit

Here: $I_{AB} \leq 24$

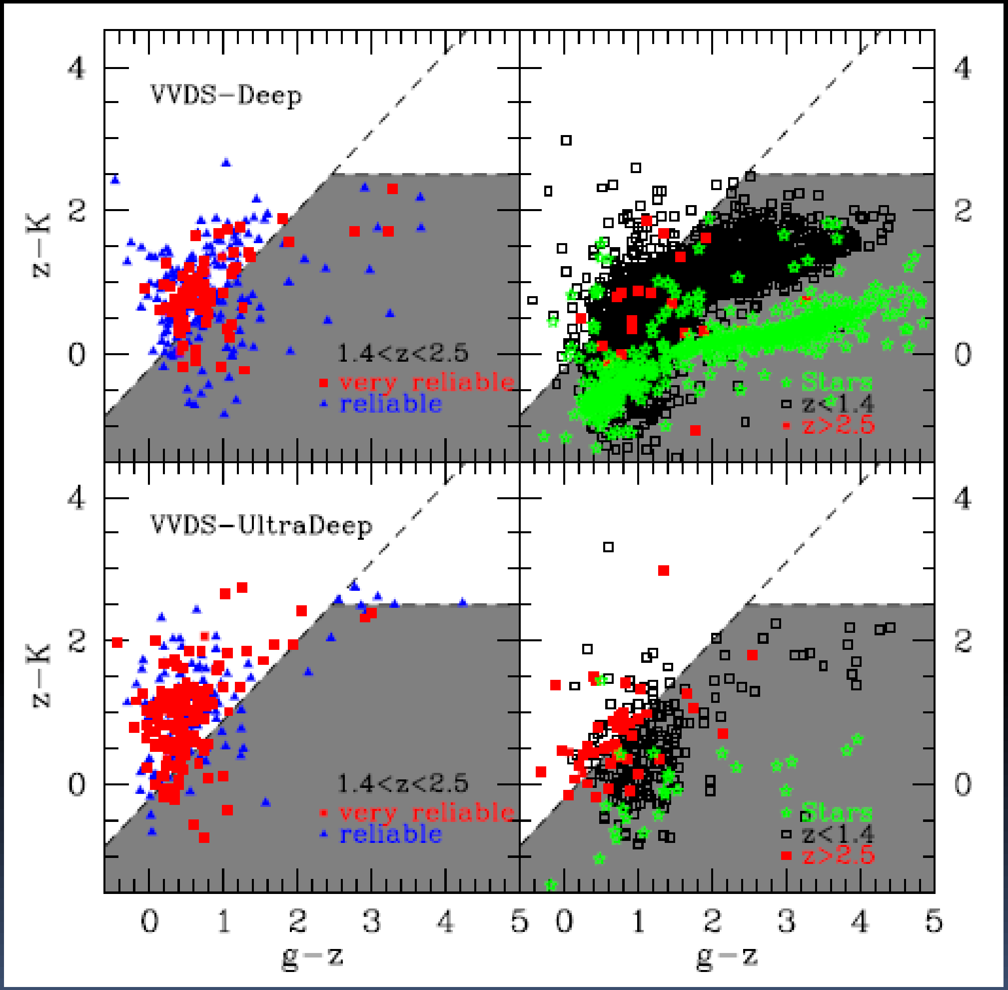
Color selection

- Apply a color cut
- Color=difference between two photometric bands
- Here (magenta) select the red galaxies with M_u-M_r>1.4
- Can add a magnitude selection on top (green): select all red <u>and</u> bright galaxies



Color-color selection

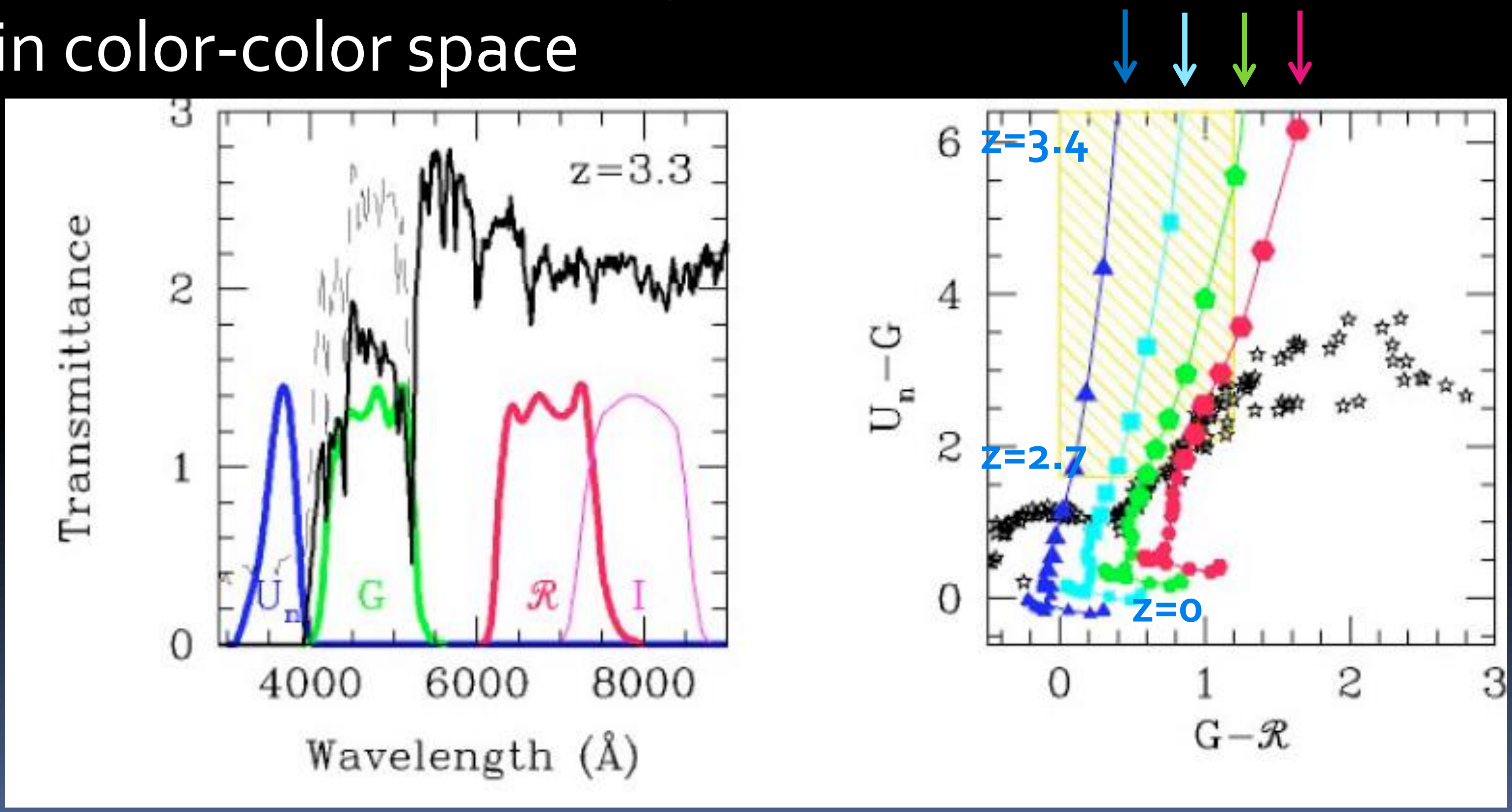
- Select objects in a part of a color-color diagram
- Most known: Lyman-break galaxy selection (LBG)
- Here is shown a gzK diagram to select galaxies at z~2



Lyman-break galaxy selection

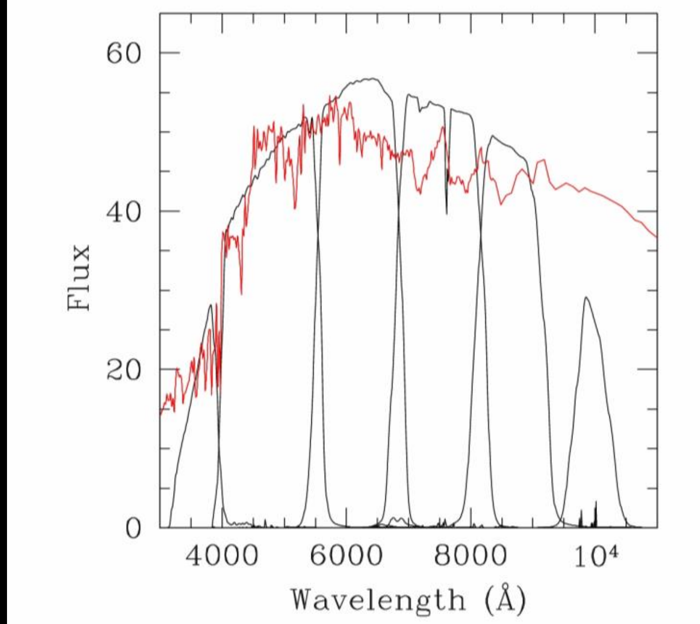
- Use predicted galaxy tracks vs. Redshift to isolate galaxies in color-color space

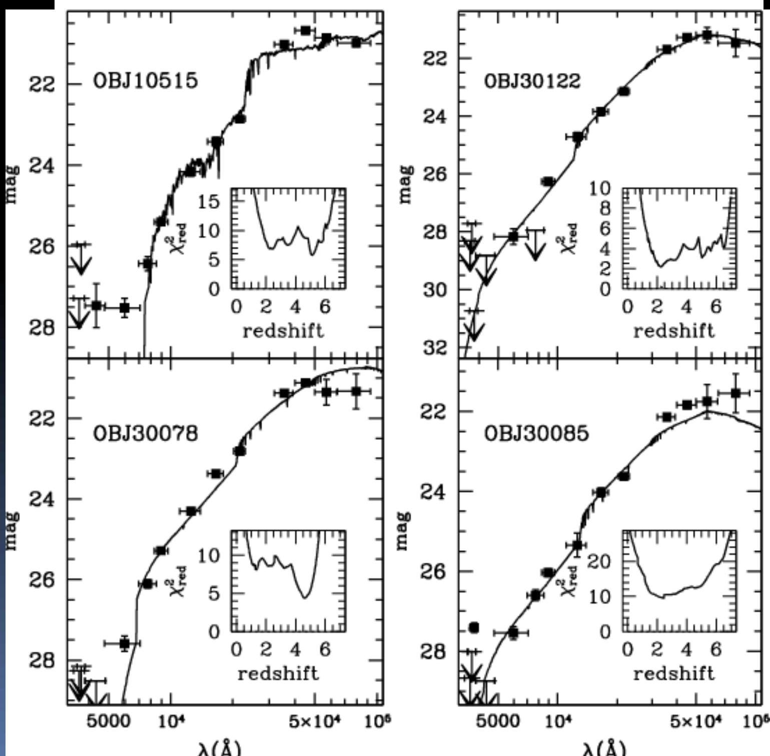
Different types of galaxies



Photometric redshifts

- Photo-z is a redshift derived from photometric data
- Uses the SED (Spectral Energy Distribution)
- Correlate against a set of templates
- Same process gives *-mass, SFR, age, etc.
- Accuracy $\delta z \sim 3\text{-}5\%$
  - Probability distribution function
- Pb of catastrophic redshifts

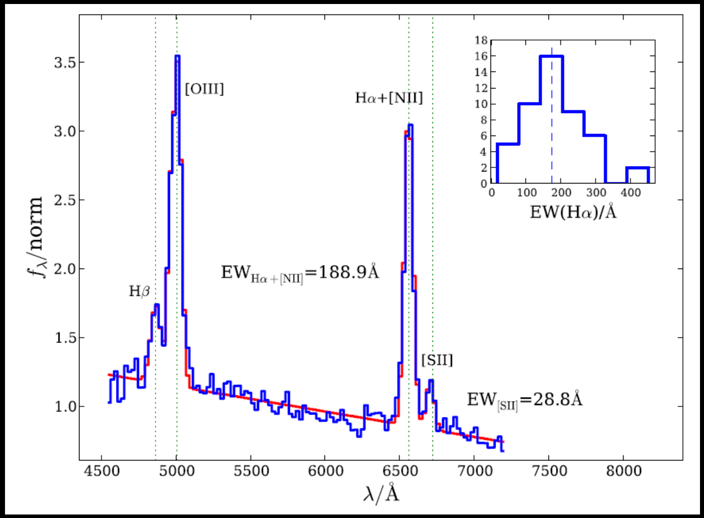


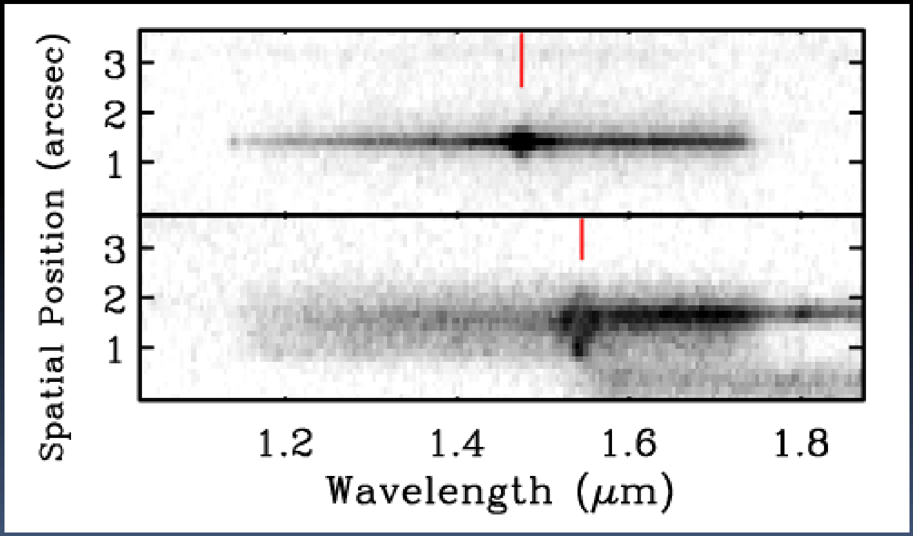


Hα selection

- Hydrogen Hα transition 6562Å: the strongest emission at optical wavelengths
- Direct tracer of star formation rate
- Hα Flux selected survey: equivalent to a selection of star-forming galaxies
- Pros: strong emission easy to detect
- Cons:
  - Traces star-forming galaxies only
  - Degeneracies with other (single) line emitters: OII-3727, Lyα-1215

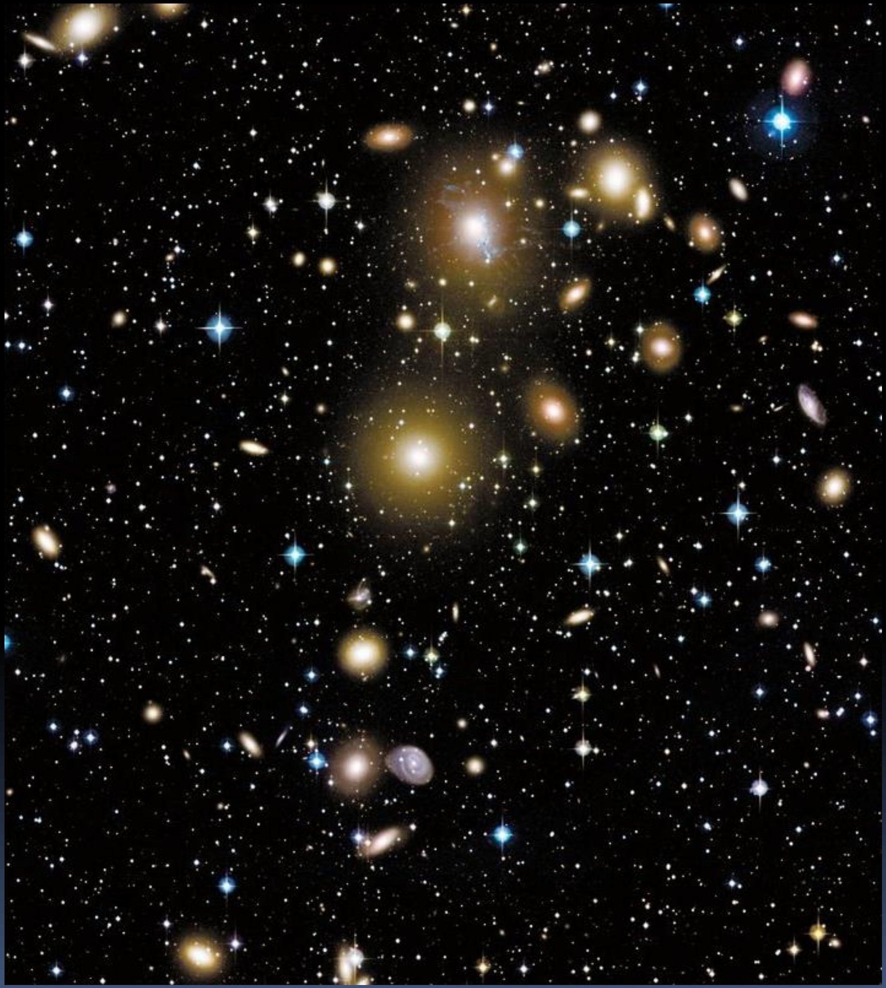
EUCLID-NISP survey will be Hα-selected



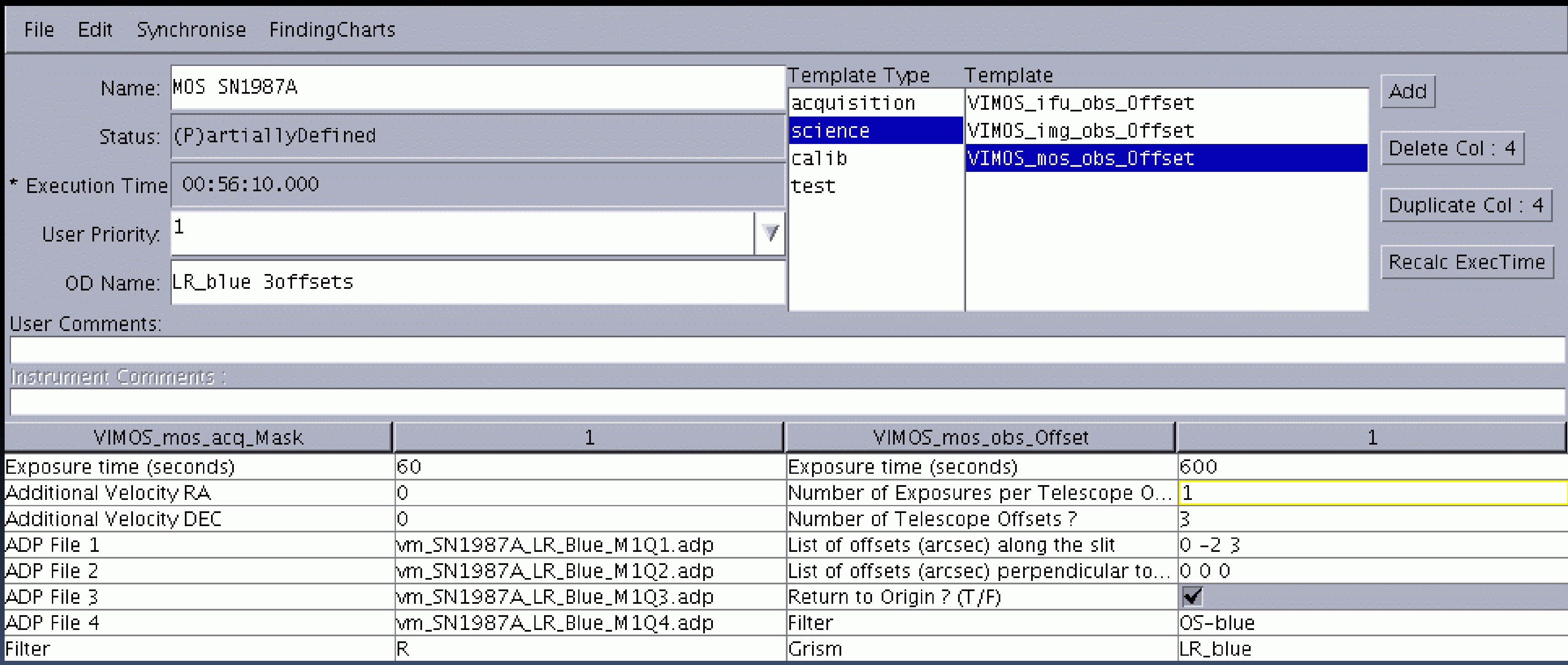


Survey observations preparation and follow-up

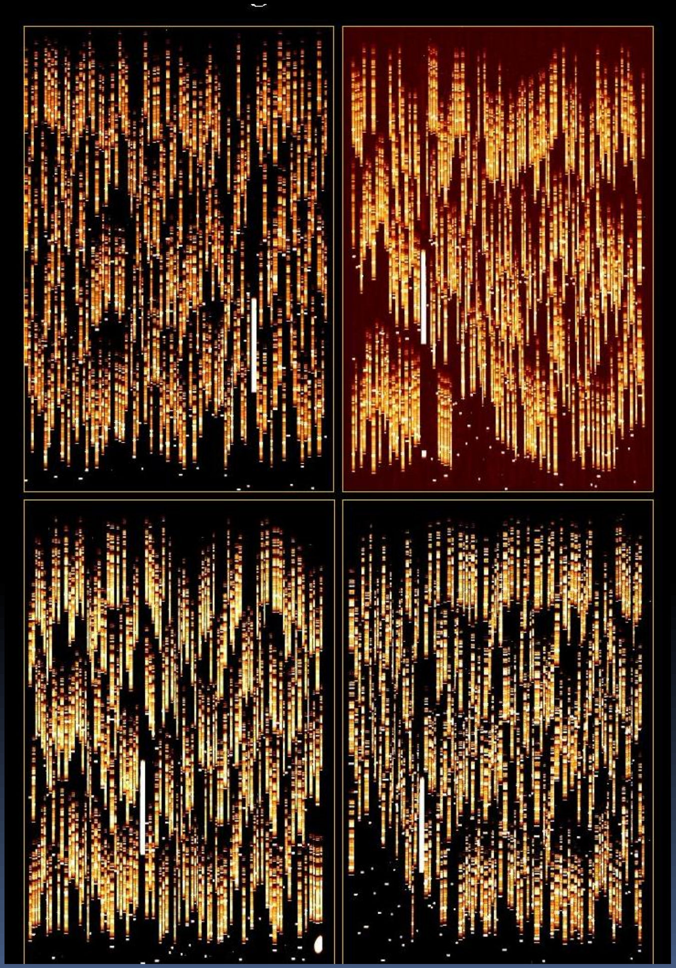
- Produce a reference photometric catalog based on your selection
  - The “parent catalog”
- Produce a list of objects to be observed
  - Satisfying your selection criteria
- Anticipate the geometric constraints of the instrument
- Produce a survey plan
  - Tilling to cover survey area
  - Exposure time, dithering
- Execute observations
- Follow with database



Observing blocks at VLT



Resulting observations



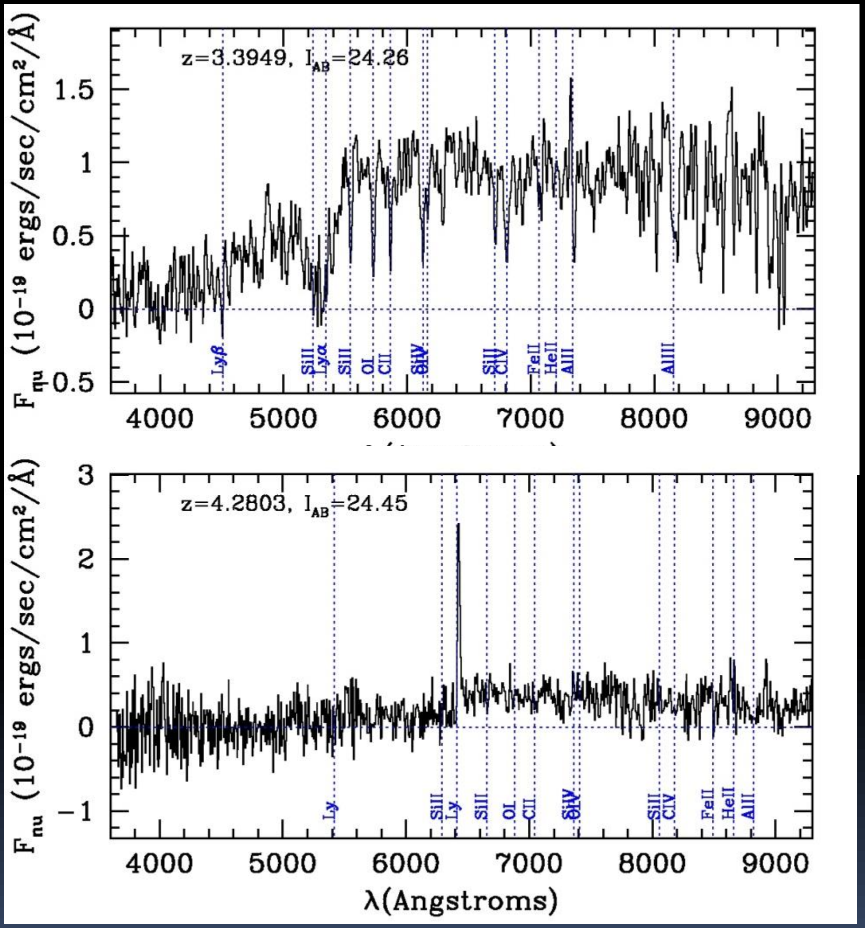
4. Data processing

- Imaging and spectroscopy generate hundreds of Gb of data per night
- Process from raw uncalibrated data to instrument-corrected and calibrated data
- A very important step
- Data processing packages available for each instrument
  - Need to invest time before using them to the best

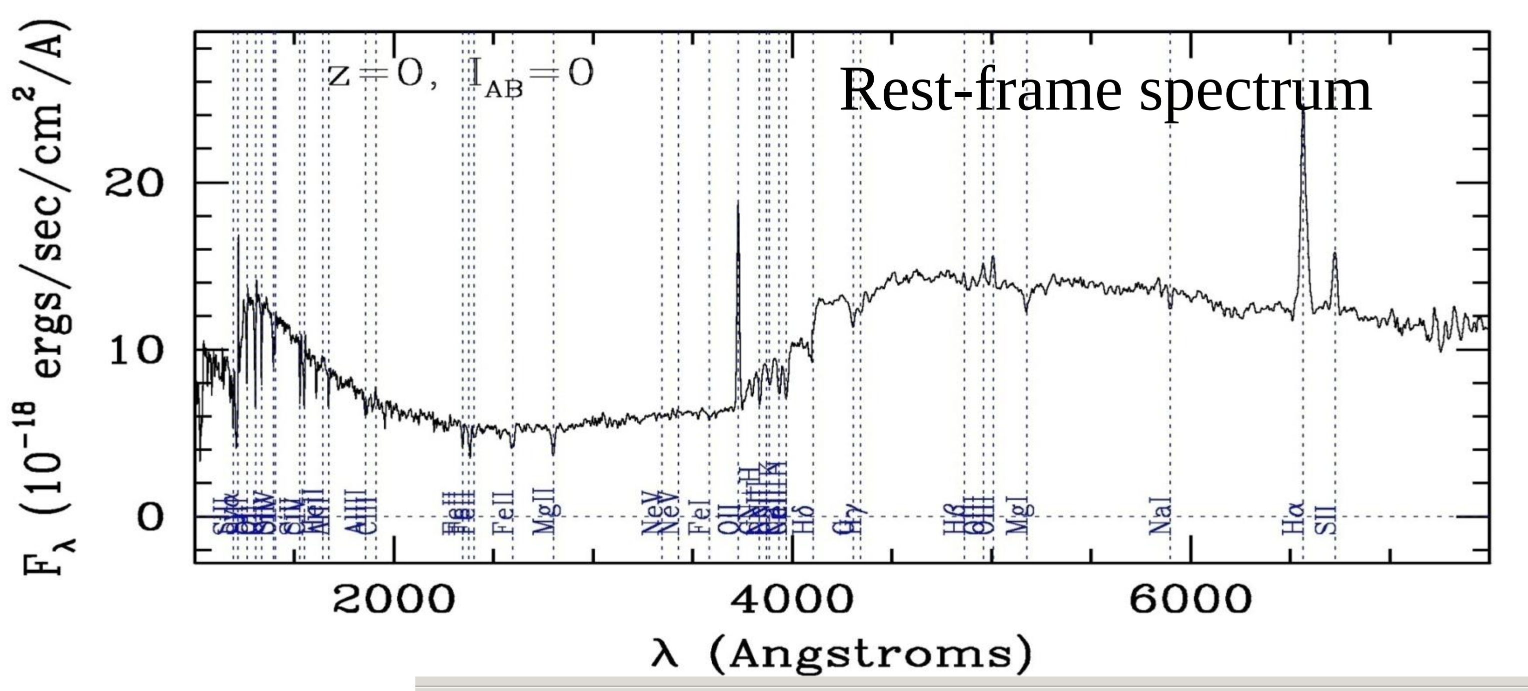
Measure spectroscopic redshifts

Identify observed spectral features to rest-frame known features

- Identify emission / absorption features
- Take continuum into account

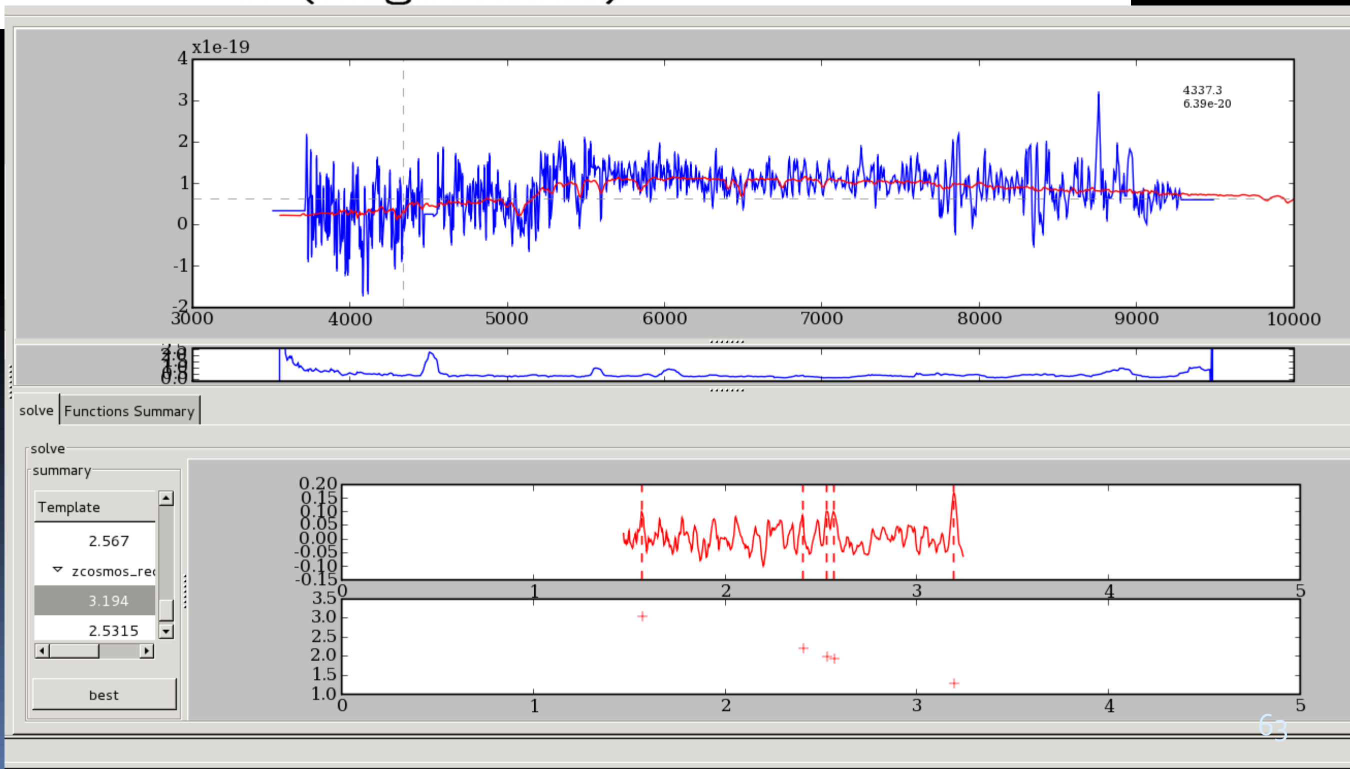


Cross-correlation to galaxy templates (Tonry & Davis, 1979, AJ, 84, 1511)



EZ engine:
Garilli et al., 2010,
PASP, 122, 827

Euclid development in progress: AMAZED



5. Information system, Databases

- Data volume from surveys is huge, many Tb
- Information system: the management of all survey data
  - Data flow
- Includes all steps: from design to observations, to data processing, to final measurements
- Easy access to data
  - Query oriented
- Long term access, and reference
- Virtual observatory compatible

Follow the observations and data processing

Field	#z mesured	Fraction Planned	Fraction Observed	Fraction Reduced	Fraction Mesured
vvds2h *(5 pointings)*	598	100%	80%	75%	25%
cosmos *(8 pointings)*	1261	100%	100%	90.625%	31.25%
ecdfs *(2 pointings)*	590	100%	100%	50%	50%

VUDS All Pointings

Name	Epoch	RA	DEC	Q1	Q2	Q3	Q4	Readme
COSMOSP01	1	09:59:02.39	+01:54:36.0	Mesured	Mesured	Reduced[B+R]	Mesured	
COSMOSP02	1	10:00:04.08	+01:54:36.0	Mesured	Mesured	Mesured	Reduced[B][R][B+R]	
COSMOSP03	2	10:01:05.76	+01:54:36.0	Reduced[B][R][B+R]	Observed[B][R]	Reduced[B][R][B+R]	Reduced[B][R][B+R]	
COSMOSP04	2	09:59:02.39	+02:12:41.4	Observed[B][R]	Reduced[B][R][B+R]	Reduced[B][R][B+R]	Reduced[B][R][B+R]	
COSMOSP05	1	10:00:04.08	+02:12:41.4	Mesured	Mesured	Reduced[B][R][B+R]	Mesured	
COSMOSP06	2	10:01:05.76	+02:12:41.4	Reduced[B][R][B+R]	Reduced[B][R][B+R]	Reduced[B][R][B+R]	Reduced[B][R][B+R]	
COSMOSP07	1	10:00:04.08	+02:30:46.7	Reduced[B][R][B+R]	Mesured	Reduced[B][R][B+R]	Reduced[B][R][B+R]	
COSMOSP08	2	10:01:05.76	+02:30:46.7	Reduced[B][R][B+R]	Reduced[B][R][B+R]	Reduced[B][R][B+R]	Observed[B][R]	
ECDFS_P01	1	03:32:25.99	-27:41:59.9	Mesured	Mesured	Mesured	Mesured	
ECDFS_P02	2	03:32:34.00	-27:53:59.9	Observed[B][R]	Observed[B][R]	Observed[B][R]	Observed[B][R]	
VVDS02P01	1	02:26:44.51	-04:16:42.8	Mesured	Mesured	Mesured	Mesured	
VVDS02P02	2	02:25:40.34	-04:16:42.8	Reduced[B][R][B+R]	Reduced[B][R][B+R]	Reduced[B][R][B+R]	Reduced[B][R][B+R]	
VVDS02P03	2	02:26:44.51	-04:34:50.3	Reduced[B][R][B+R]	Reduced[B][R][B+R]	Reduced[B][R][B+R]	Reduced[B][R][B+R]	
VVDS02P04	2	02:25:40.34	-04:34:50.3	Reduced[B][R][B+R]	Mesured	Observed[B][R]	Reduced[B][R][B+R]	
VVDS02P05	2	02:24:36.14	-04:44:57.9	Planned	Planned	Planned	Planned	

Vimos Ultra Deep Survey

The Survey ▾ | The Team | News | Data Products ▾ | Observations handling | VUDS WIKI | Public Site

Search by general criteria

FIELD

- (•) VVDS2H
- ( ) COSMOS
- ( ) ECDFS

Spectroscopic Redshift

z — min 3 max 3.3

z Flag pre-defined range — all primary objects with very reliable redshifts (zfag=3-4)

Magnitude i_{AB} — min 17.5 max 25

Submit the request | Reset

View your results

Search by criteria :

- Magl between 17.5 and 25
- Redshift Spectroscopic between 3 and 3.3
- Redshift Spectroscopic quality flag in (3,4)

23 objects selected

Objects : 1 to 23 / 23 - Page 1/1

PREV NEXT

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PREV NEXT

Spectra	VUDS id	ID_IAU	Alpha_J2000	Delta_J2000	Z	Zflag	pointing	quad	slit	obj	MagI
	520390210	VUDS-J022711.64-041828.23	36.798521	-4.307844	3.1183	3	F52P001	4	111	1	24.087
	520393071	VUDS-J022715.88-04189.16	36.816174	-4.302547	3.2573	3	F52P001	4	132	1	24.734
	520445512	VUDS-J022615.69-041234.26	36.565376	-4.209518	3.2583	3	F52P001	2	15	1	24.844

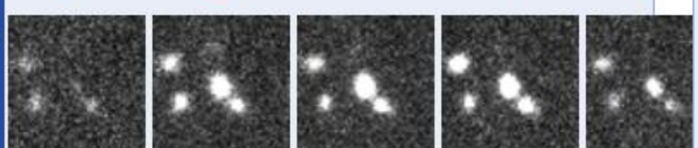
Photometric Data

Retrieve All Stamps

MagU_CFHTLS	26.652 ± *0.167*
MagG_CFHTLS	24.645 ± *0.018*
MagR_CFHTLS	23.966 ± *0.013*
MagI_CFHTLS	23.749 ± *0.015*
MagZ_CFHTLS	23.739 ± *0.037*
MagJ_WIRDS	23.712 ± *0.125*
MagH_WIRDS	22.806 ± *0.08*
MagK_WIRDS	22.672 ± *0.074*

CFHTLS_D_T0007
[5"x5"]

u g r i z

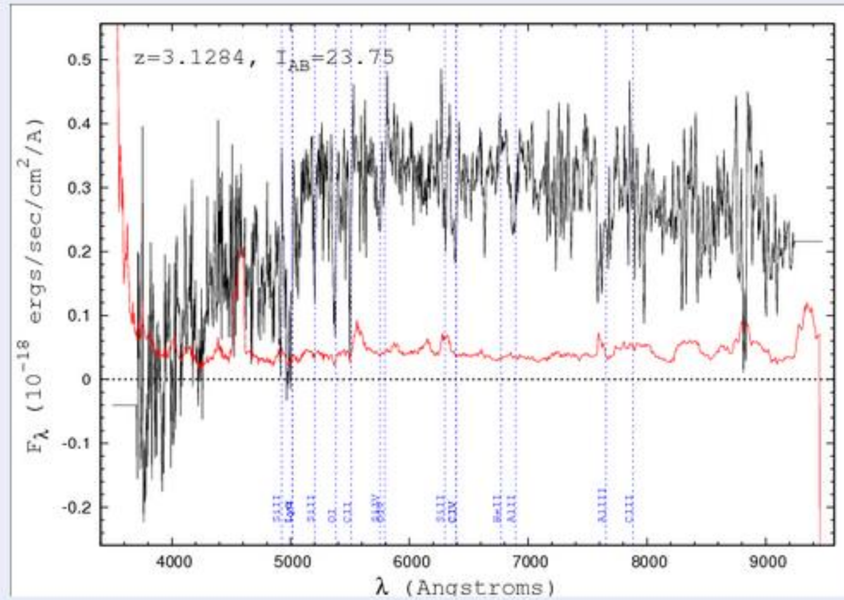


Spectroscopic Data

Retrieve Spectra

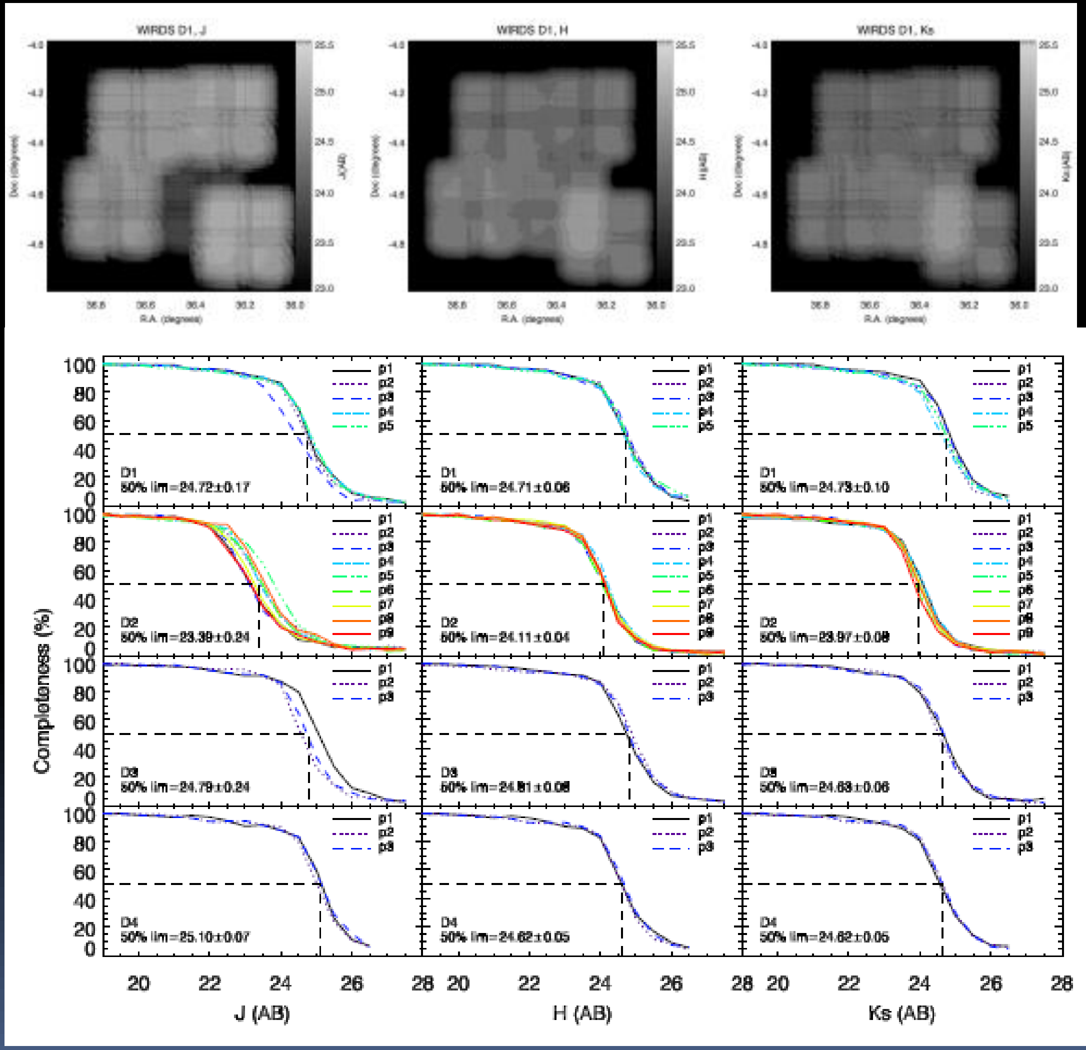
Ident	Redshift	Redshfit quality flag
520441696	3.1284	4

sc_520441696_F52P001_join_A_75_1_atm_clean.fits



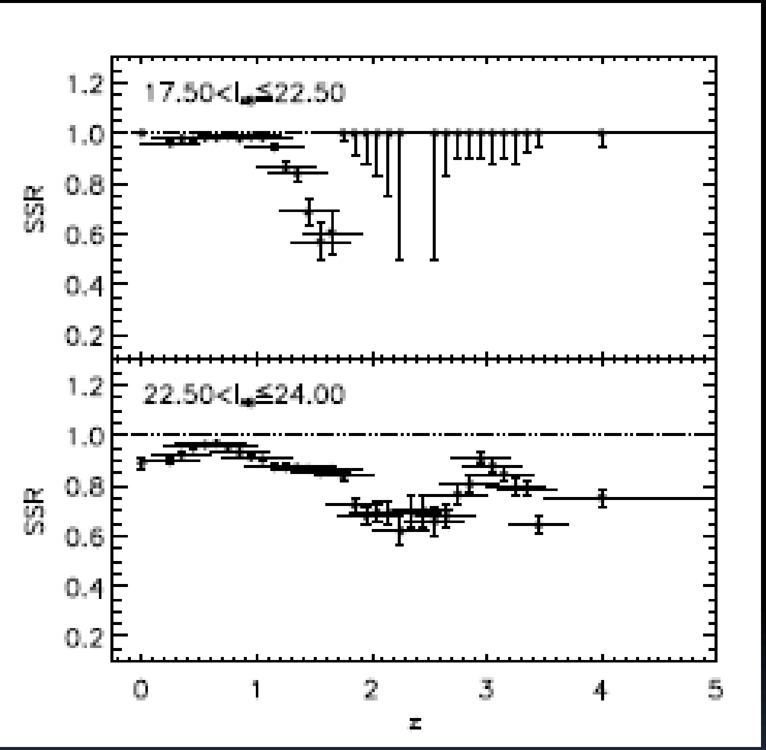
6. Measuring the selection function

- Estimate the ability of the survey to detect galaxies satisfying the selection criteria
- Target Sampling rate
  - Which fraction of the galaxy population satisfying the criteria is observed
  - Masking bad regions
- Limiting magnitude
  - Limiting magnitude (at 5σ or at 90% completness)



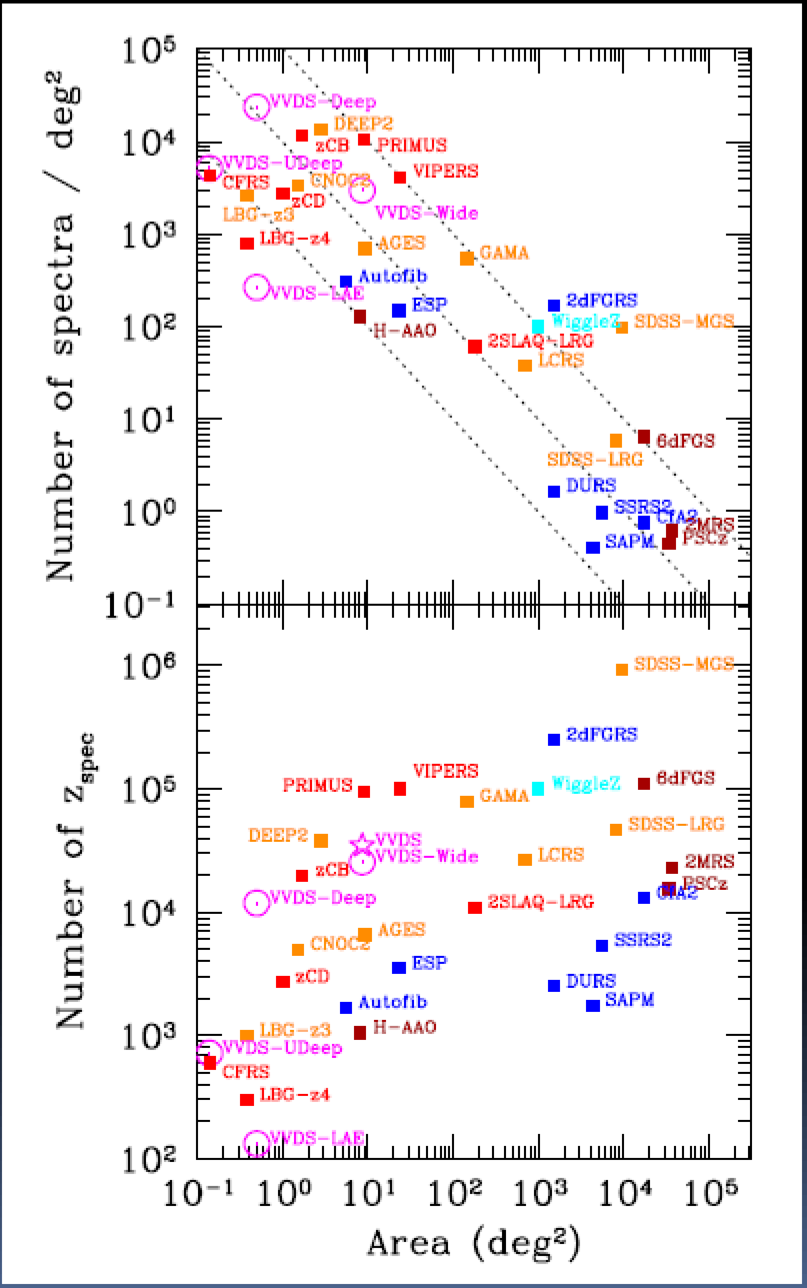
Measuring the selection function

- Spectroscopic success rate
  - Fraction of targeted objects that deliver a measurement (redshift, line,…)
  - As a function of magnitude
  - As a function of redshift
  - …
- Selection function can be complex Sel(mag,z,type,α,δ)

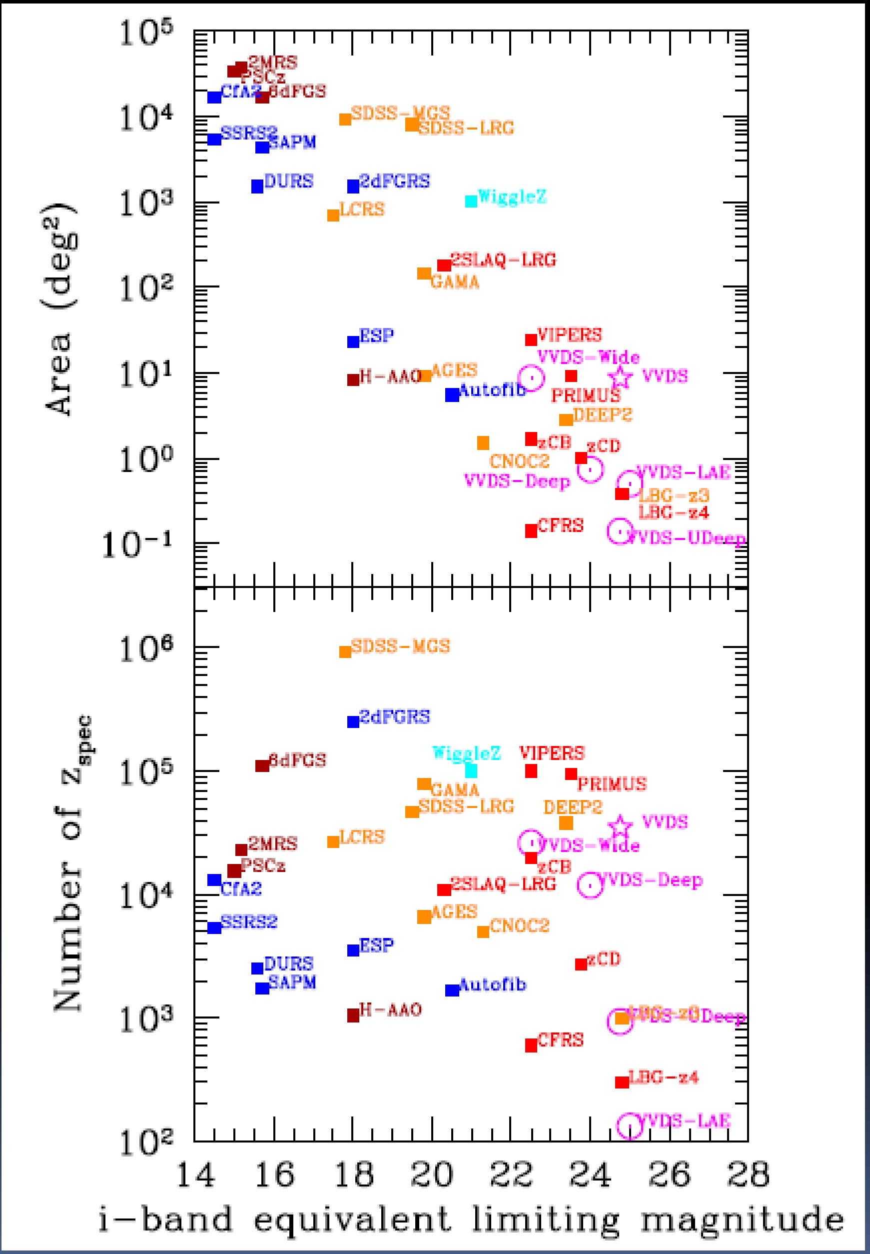


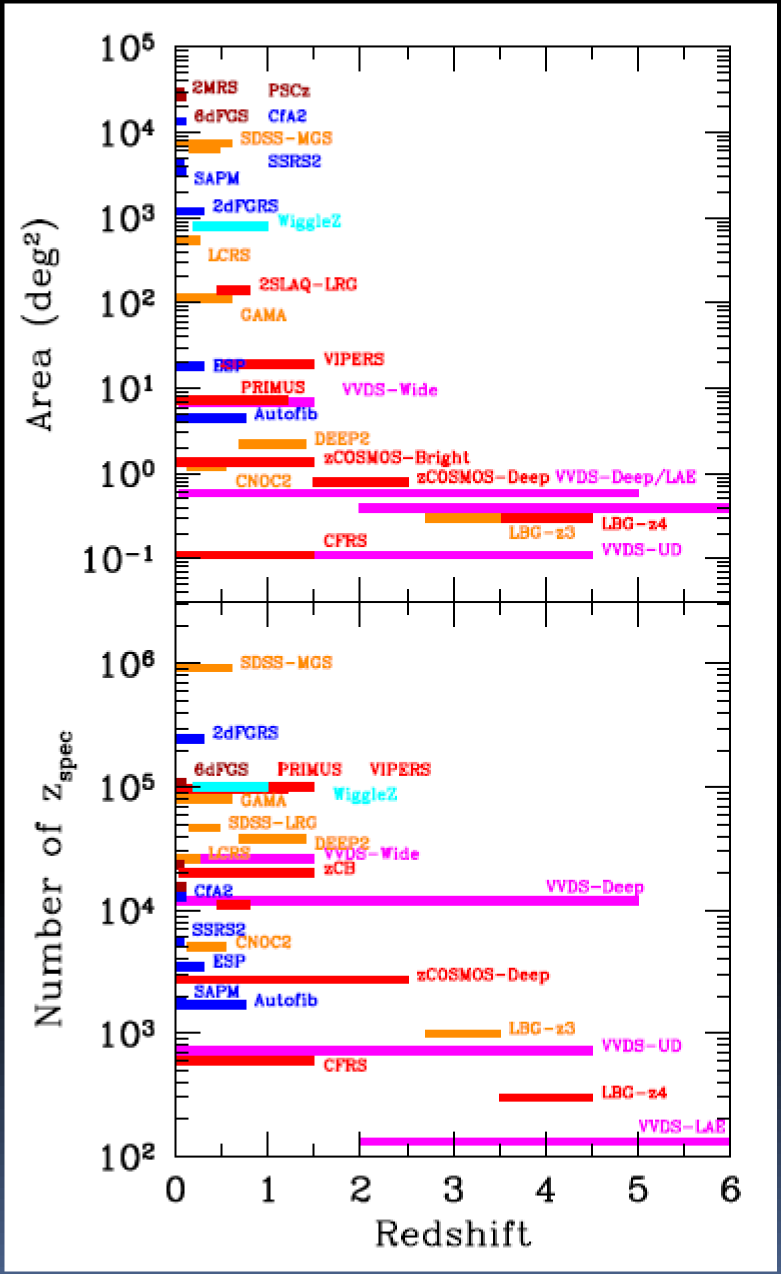
6. Comparing surveys

- Not so easy because the selection functions can be very different
- Look at the parameter space
  - Nobj vs. Area and vs. Magnitude
  - Area vs. Magnitude
  - Nobj and Area vs. Redshift
  - …



Number of spectra / deg²
VVDS-Deep
DEEP2
zCB
PRIMUS
VVDS-UDeep
VIPERS
CFRS
CNOC2
zCD
LBG-z3
VVDS-Wide
LBG-z4
AGES
GAMA
Autofib
VVDS-LAE
ESP
2dFGRS
H-AAO
WiggleZ
SDSS-MGS
2SLAQ-LRG
LCRS
6dFGS
SDSS-LRG
DURS
SSRS2
CfA2
2MRS
SAPM
PSCz
Number of z_spec
VVDS
Area (deg²)


Area (deg²)
Number of z_spec
i−band equivalent limiting magnitude
2MRS
PSCz
CfA2
6dFGS
SDSS−MGS
SDSS−LRG
SSRS2
SAPM
DURS
2dFGRS
WiggleZ
LCRS
2SLAQ−LRG
GAMA
ESP
VIPERS
VVDS−Wide
H−AAO
AGES
Autofib
PRIMUS
VVDS
DEEP2
zCB
zCD
CNOC2
VVDS−Deep
VVDS−LAE
LBG−z3
LBG−z4
CFRS
VVDS−UDeep



Area (deg²)
2MRS
PSCz
6dFGS
CfA2
SDSS-MGS
SSRS2
SAPM
2dFGRS
WiggleZ
LCRS
2SLAQ-LRG
GAMA
VIPERS
ESP
PRIMUS
VVDS-Wide
Autofib
DEEP2
zCOSMOS-Bright
CNOC2
zCOSMOS-Deep
VVDS-Deep/LAE
LBG-z4
LBG-z3
CFRS
VVDS-UD
Number of z_{spec}
SDSS-MGS
2dFGRS
6dFGS
PRIMUS
VIPERS
WiggleZ
GAMA
SDSS-LRG
DEEP2
LCRS
VVDS-Wide
zCB
VVDS-Deep
CfA2
SSRS2
CNOC2
ESP
zCOSMOS-Deep
SAPM
Autofib
LBG-z3
VVDS-UD
CFRS
LBG-z4
VVDS-LAE
Redshift

Past and present deep spectroscopic surveys

Survey	**Instrument**	**redshift**	**# galaxies**
2dFGRS	2dF/AAT	$0<z<0.5$	220000
SDSS	SDSS/Apache Point	$0<z<0.5$	930000
CFRS – 1995	CFHT-MOS	$0<z<1.2$	600
LBG – 1999	KECK-LRIS	$2.5<z<4.5$	1000
DEEP2, 2005+	KECK-DEIMOS	$0.7<z<1.4$	50000
VVDS, 2005+	VLT-VIMOS	$0<z<5$	50000
zCOSMOS, 2007+	VLT-VIMOS	$0<z<1.2$ $1.4<z<3$	20000 10000
VIPERS, 2009+	VLT-VIMOS	$0.5<z<1.2$	100000
VUDS , 2010+	VLT-VIMOS	$2.5<z<6.7$	10000
GOODS	VLT FORS2	$0<z<7.1$	1000

And more !