# Large Scale Structure observations

# Large Scale Structure surveys

-Study the large scale structure distribution in the Universe to deduce its expansion rate, dynamics and energy content: $H_0$, $\Omega_m$, $\Omega_\Lambda$ and w (dark equation of state)

-Mainly observations of distant galaxies and quasars (extremely massive black holes at high redshift)

-At least four independent cosmological observational proofs:

1. Supernova Ia : nearly standard candles
2. Matter power spectrum and BAO (standard ruler)
3. Weak lensing
4. Cluster counts and structure growth

-Observations in the optical and IR domain using photometry and spectroscopy

- ➡Large optical and IR telescopes 300 - 2000 nm
- ➡Multi-object spectrographs
- ➡Very large CCD cameras, up to few $10^9$ pixels in total

-We discuss here only few examples of experiments SDSS-BOSS, SNLS, LSST and Euclid

# Dedicated SN surveys

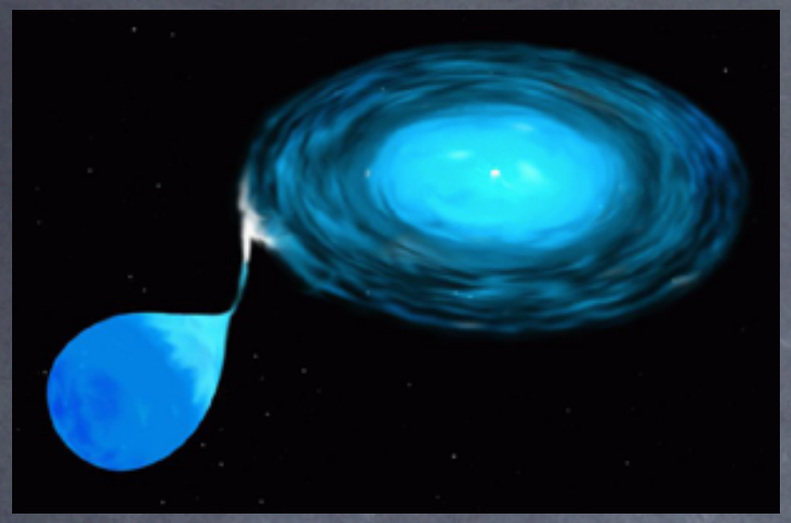
2 observables :
flux: $f$
Redshift: z

$d_L^2 = \mathcal{L}/4\pi f$

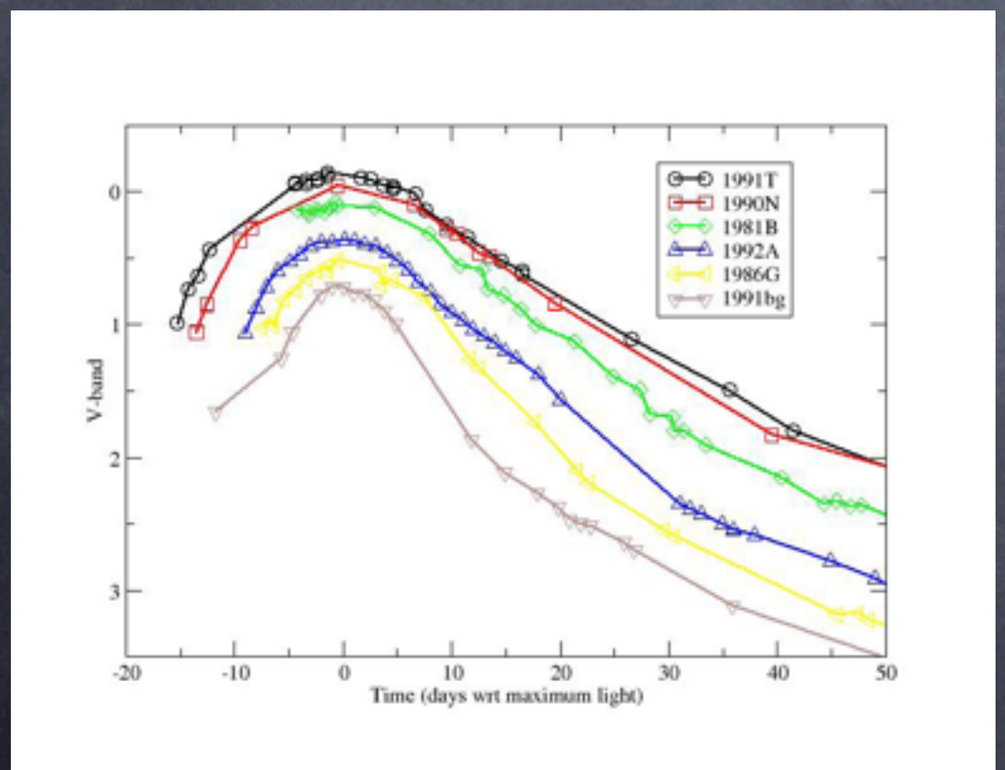
- Use supernova type Ia as distance indicators to measure the luminosity distance, $d_L$
- dL is sensitive to the expansion rate and the energy content of the Universe
- Dedicated surveys are used in order to search for SNIa
- Need to have many of them at different redshift for precise cosmology

# SNIa are NOT standard candles

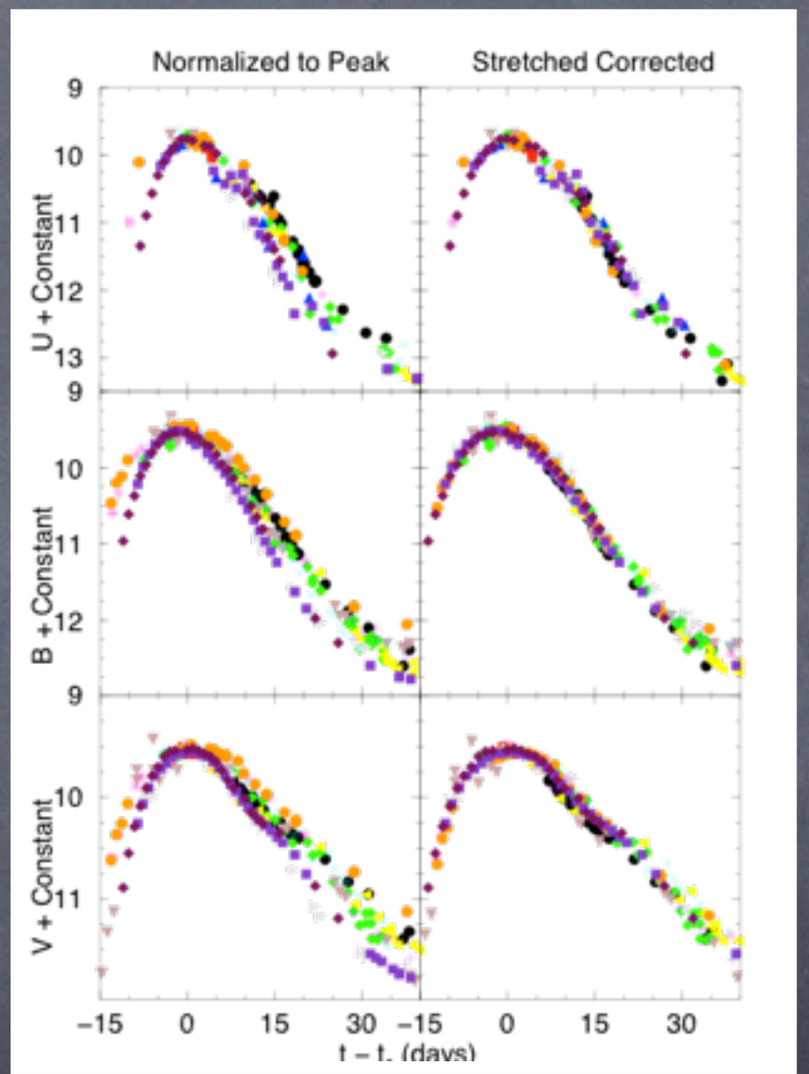
- SNIa are very luminous



- Show little luminosity dispersion




- Need to recalibrate luminosity curves for cosmology



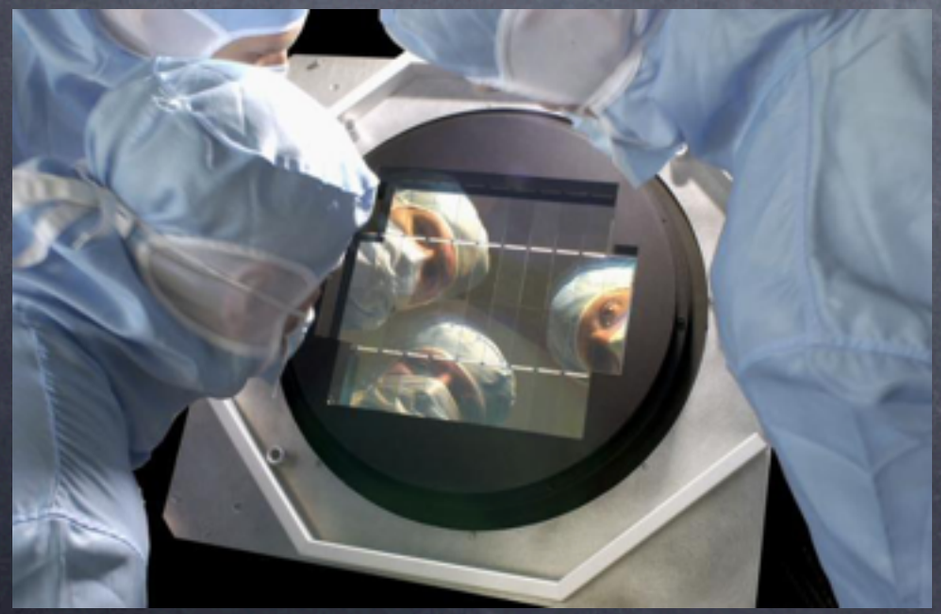

- SNIa do not measure H0, need to start with an absolute distance scale (Cepheids for example)

# SNLS - The Supernova Legacy Survey

- A large imaging survey at CFHT
  the CFHT Legacy Survey detected and monitored about 1000 supernovae with Megaprime at the Canada-France-Hawaii telescope .

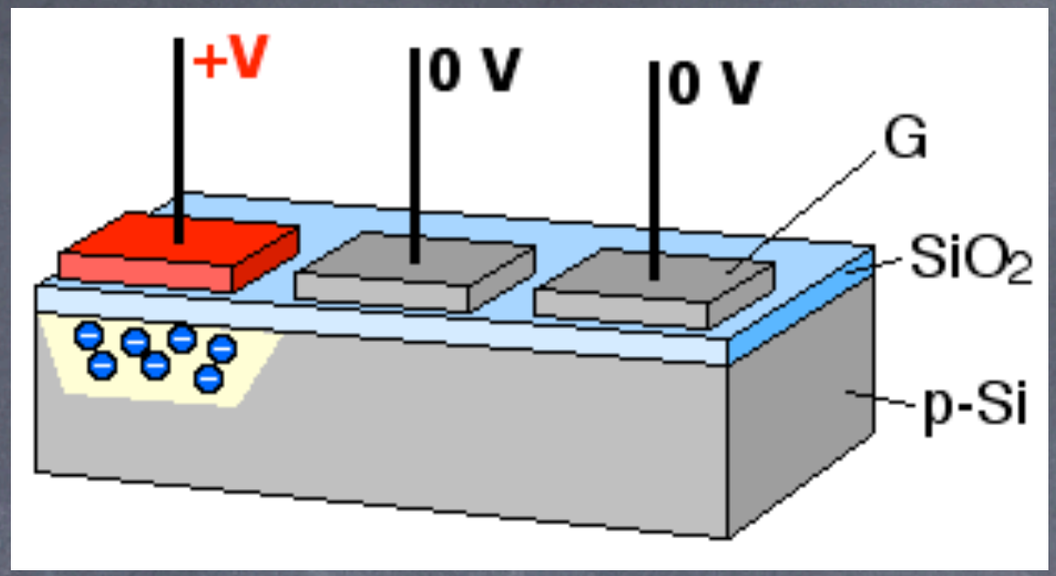
- A large spectroscopic survey
  Type Ia SNe were observed on 8m class telescopes (Gemini, VLT, Keck).

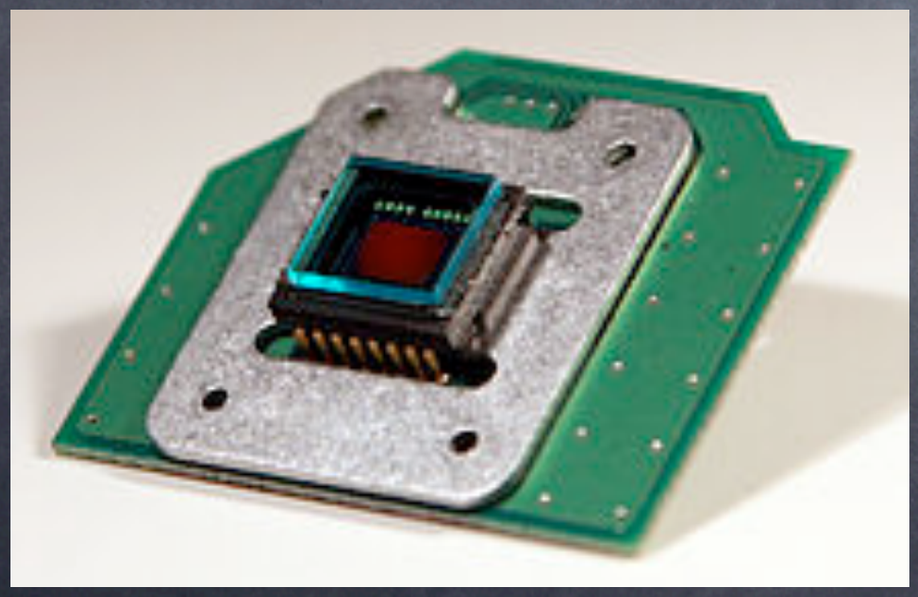
"Rolling Search" survey with MegaCam

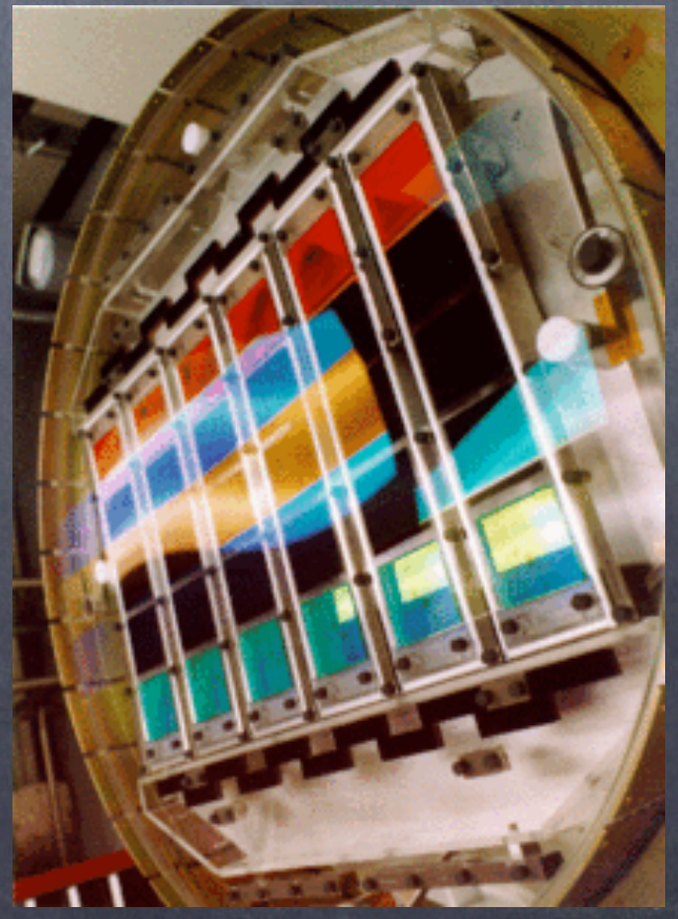


Each lunation (~18 nights) :
repeated observations
(every 3-4 night) of
2 fields in four bands (griz)+u
for as long as the fields stay
visible (~6 months)
=> ~500 SN Ia identified
(+ ~300 « photometric »)
observed between 2003 and 2008

# CCD cameras



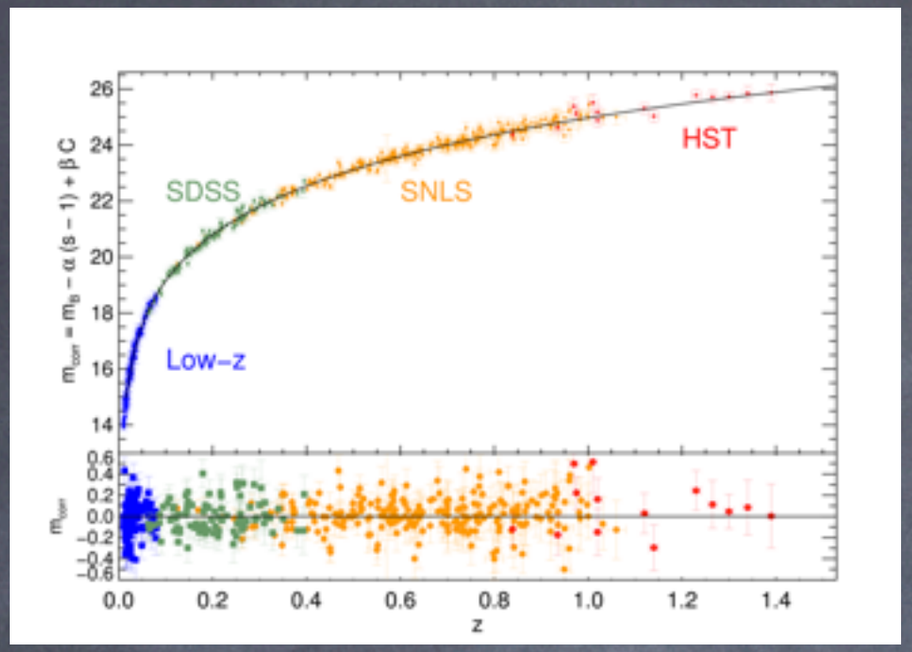



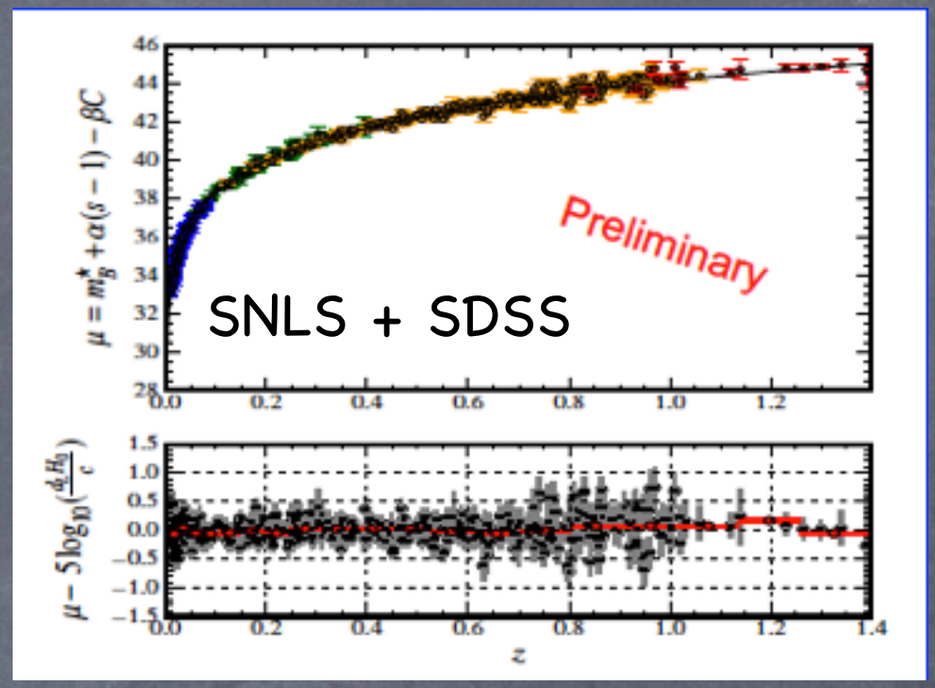


# SDSS supernovae

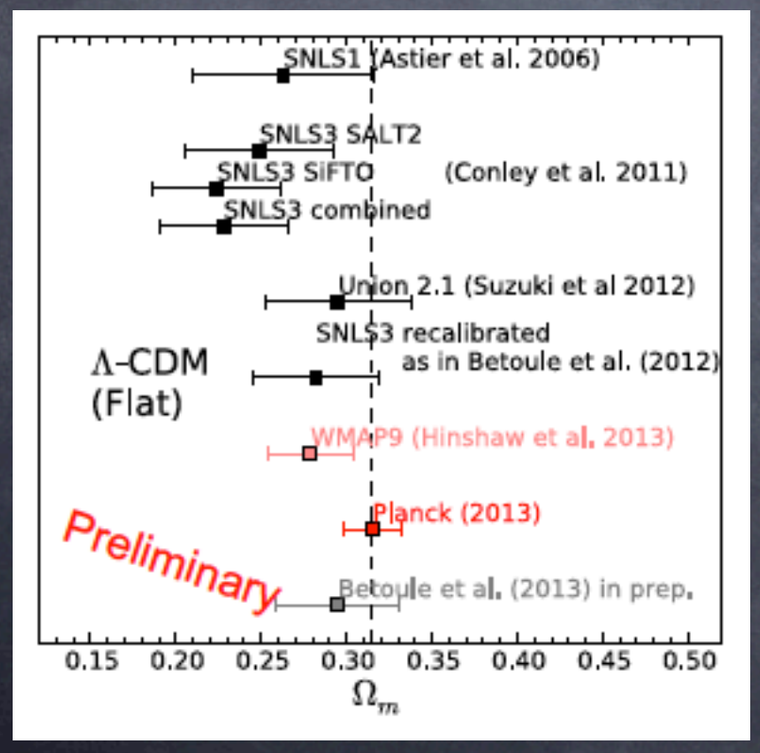
# Cosmological constraints with SNIa

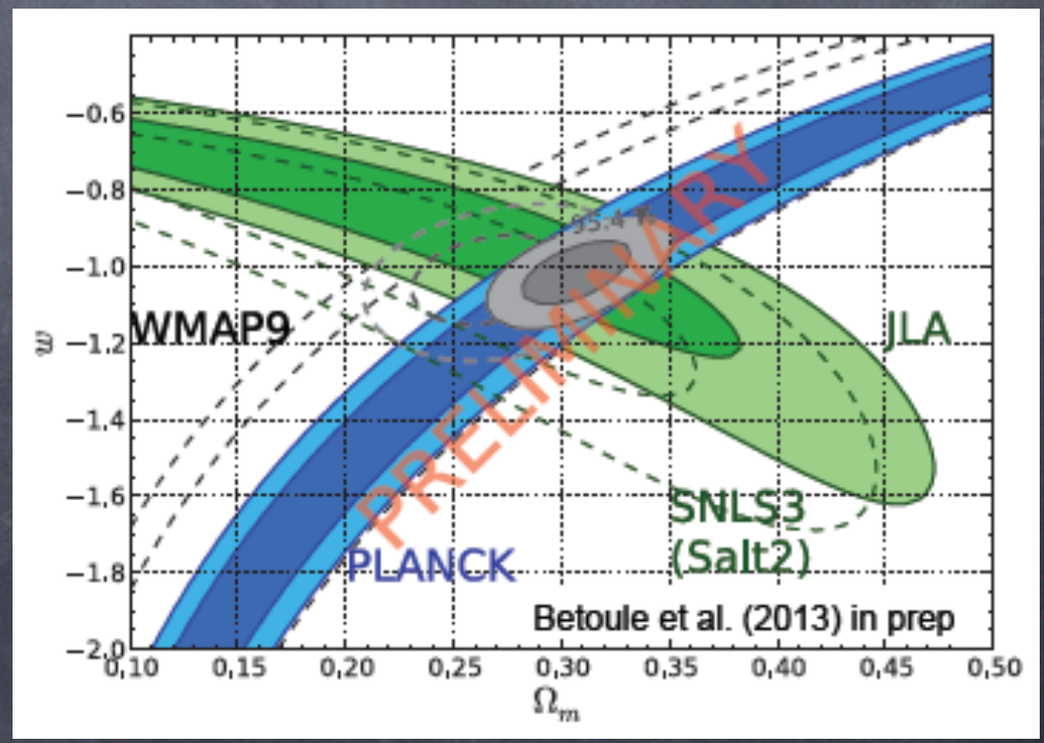
Hubble diagram measurements



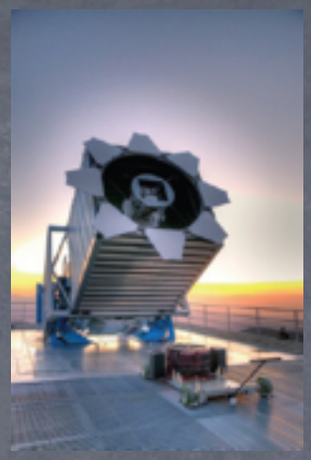




-Constraints on $\Omega_m$ and the equation of state of dark energy

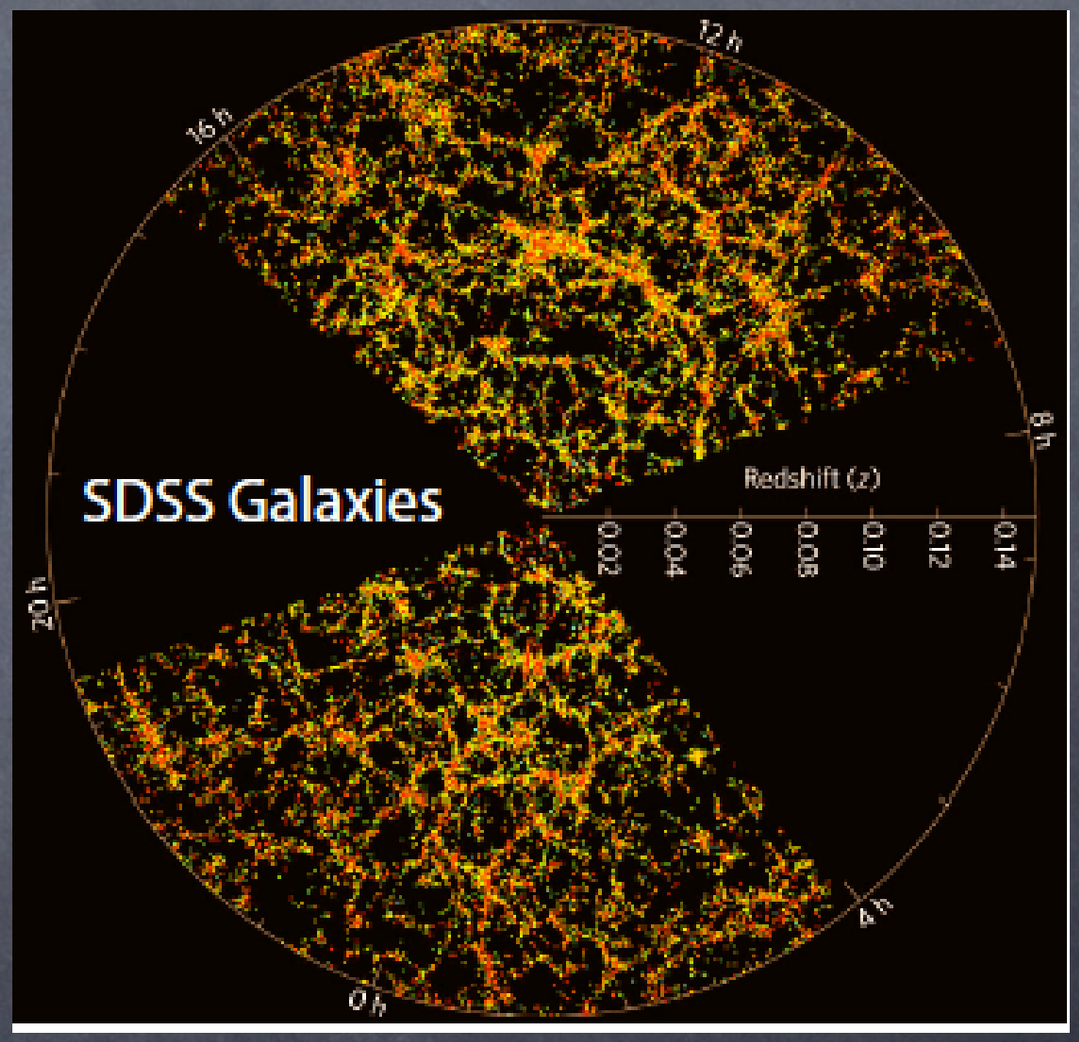


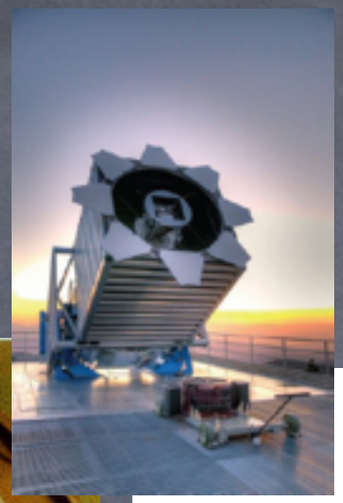
# SDSS (Sloan Digital Sky Survey)



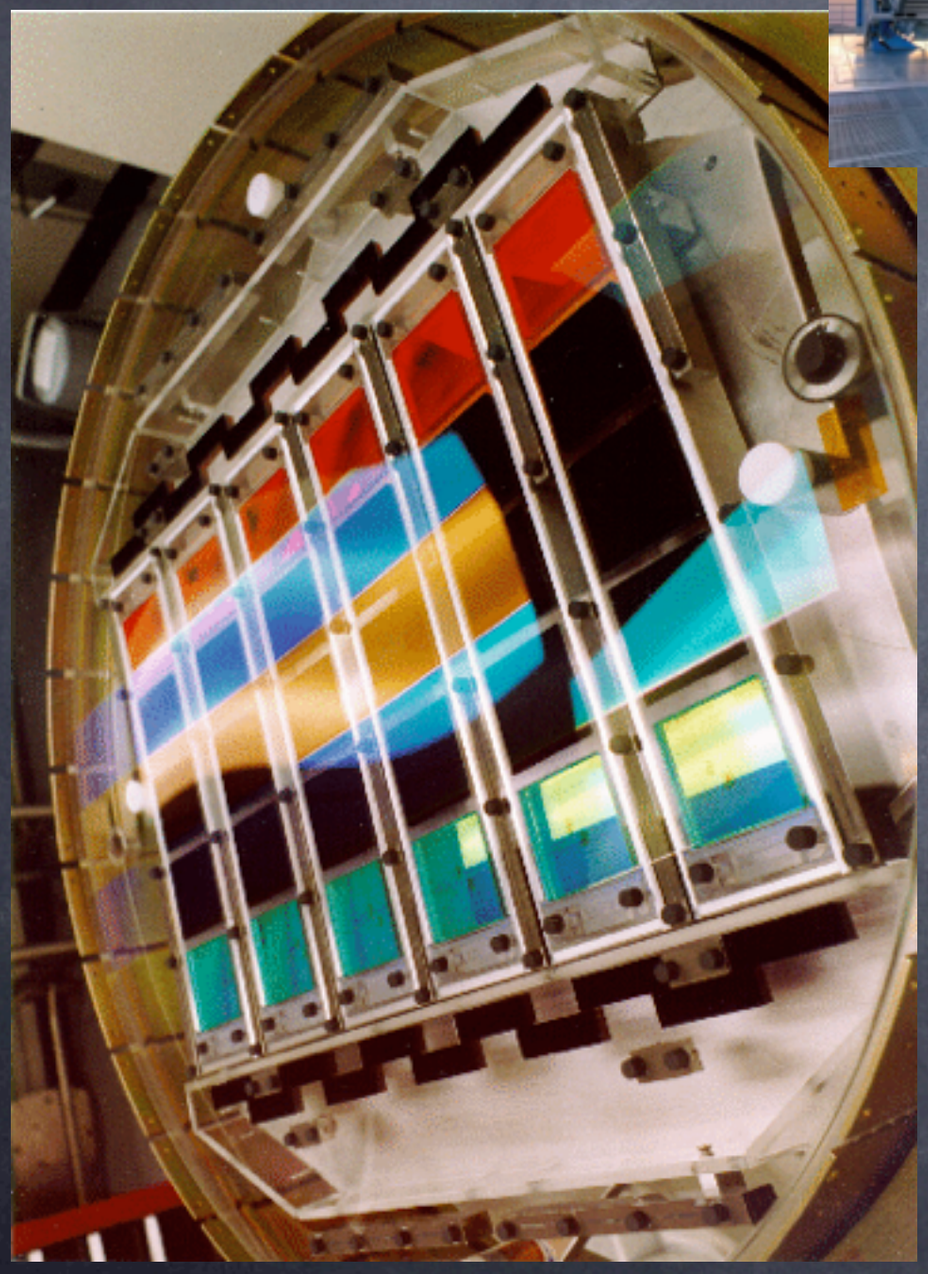
- 2.5 m telescope in the APO (New Mexico)
- Photometric survey using SDSS-III
- Spectroscopy survey using BOSS
  - Two spectrographs with 1000 optical fibers
    - 3600 A to 10000, R = 3000
- 10000 squares degrees survey
  - 1.5 Millions LRG galaxies up to z=0.7
  - 150000 quasars for Ly-α up to z=2.5
- Obtain position of the BAO peak to best than 1 %



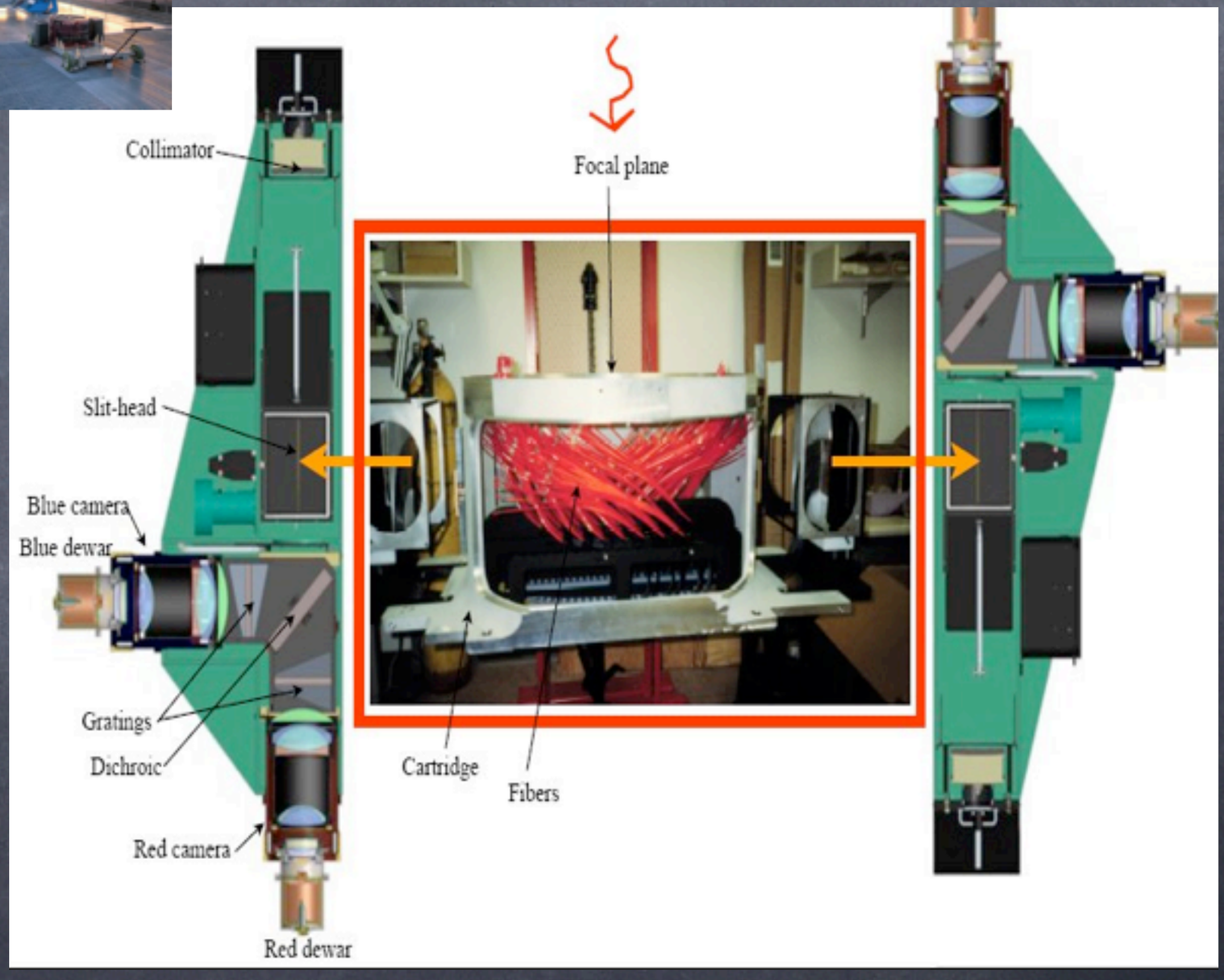
# SDSS technology



Photometric camera

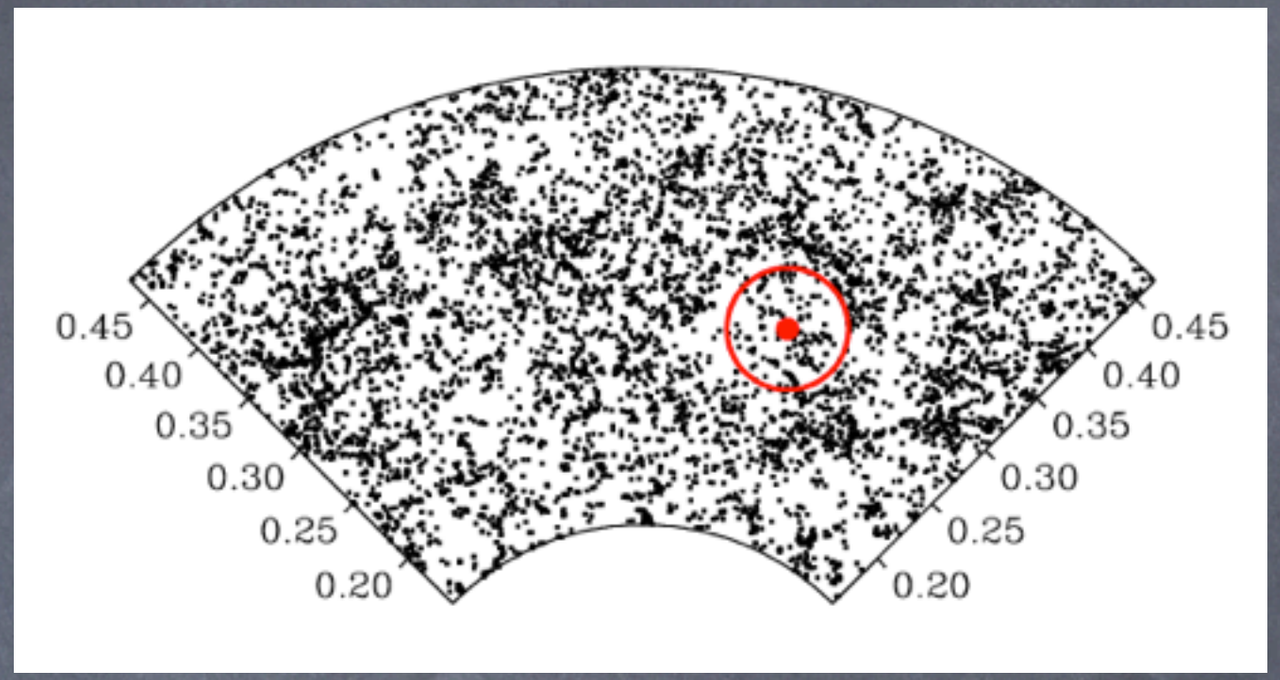


Spectrograph

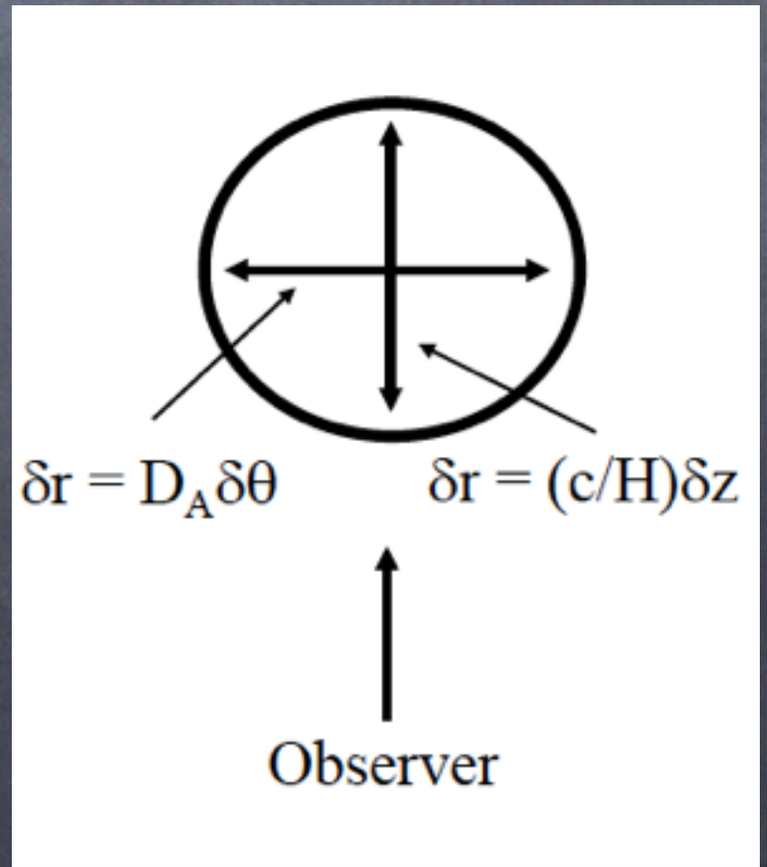


# Observing BAO

➡BAO defines a preferred scale for galaxy distribution
➡We expect an excess in the number of galaxies at 150 Mpc scales
➡This scale is defined by the CMB BAO (peaks in the spectrum)

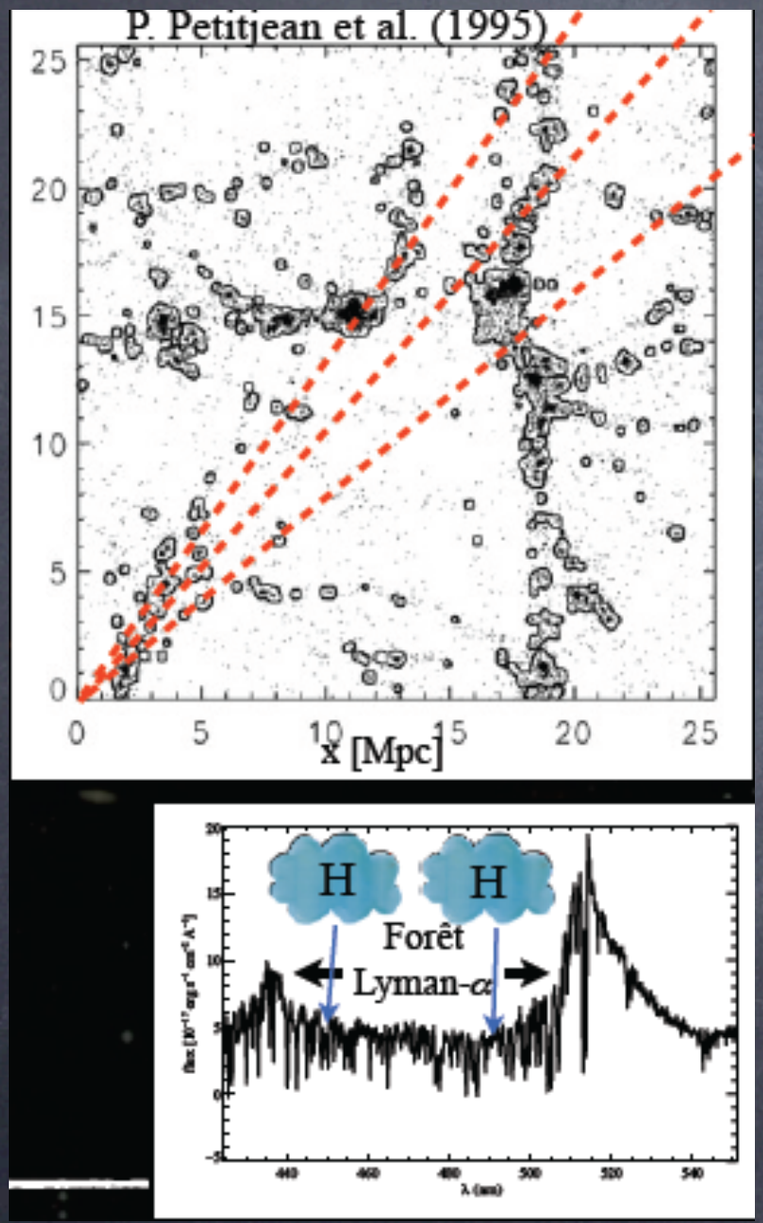


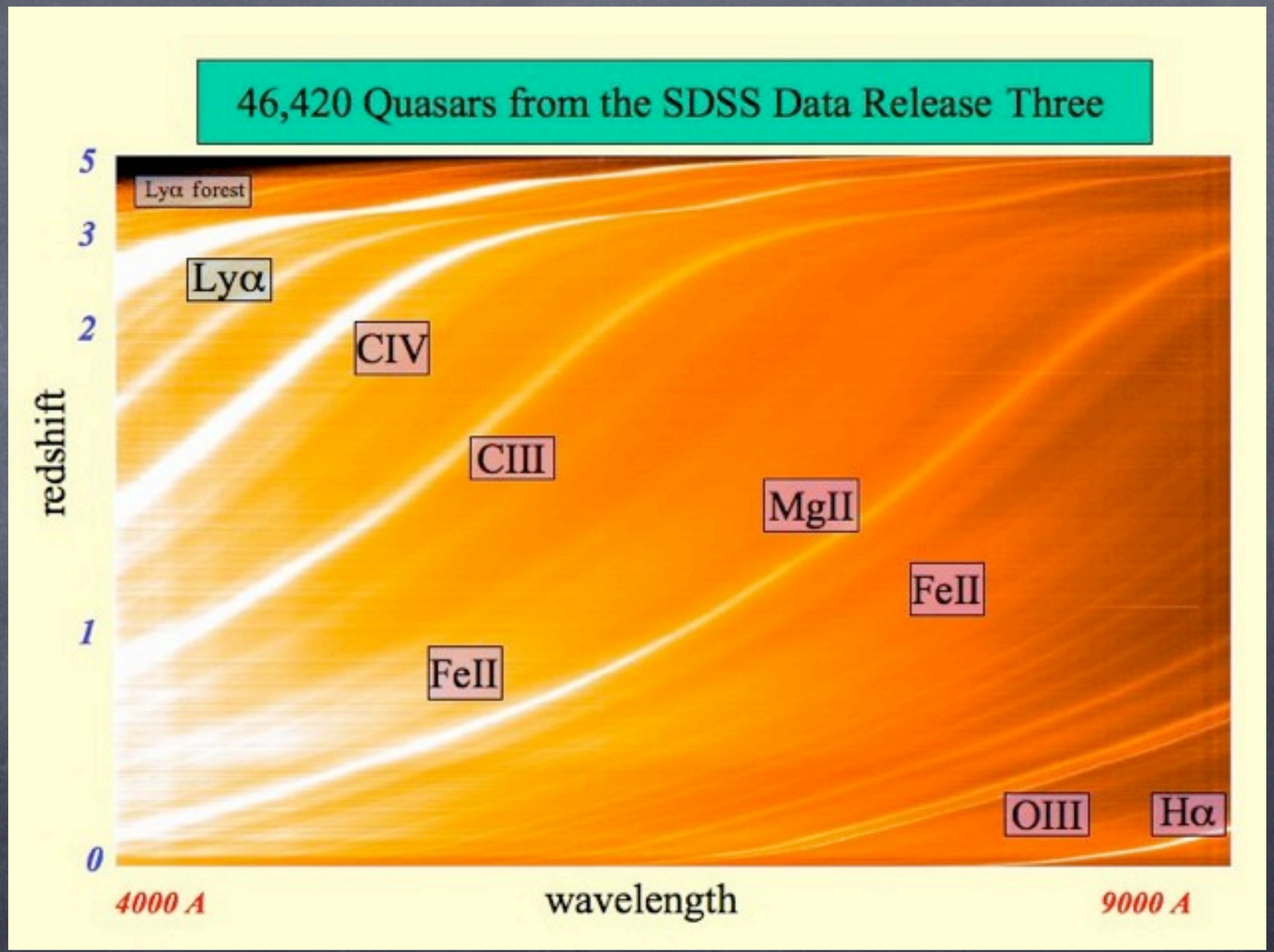

- In a LSS survey we can study BAO along and across the line-of-sight
- We can use LRG galaxies at low redshift and quasars Ly-α forest at high redshift
-We measure both the angular distance and the Hubble constant



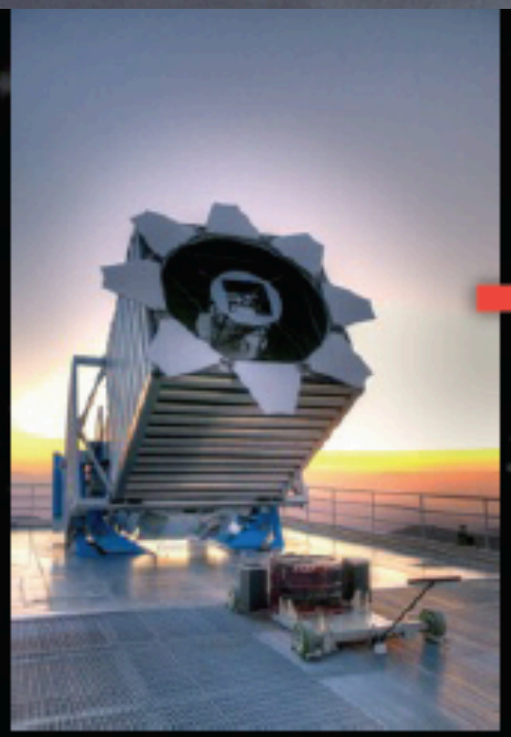
# Why quasars ?

We study hydrogen absorption of  in the Ly-α forest

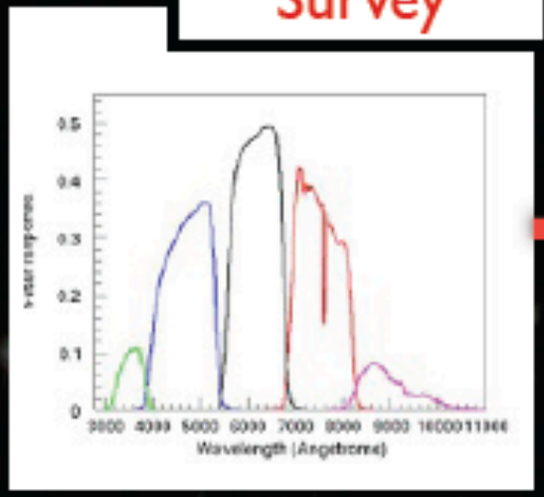


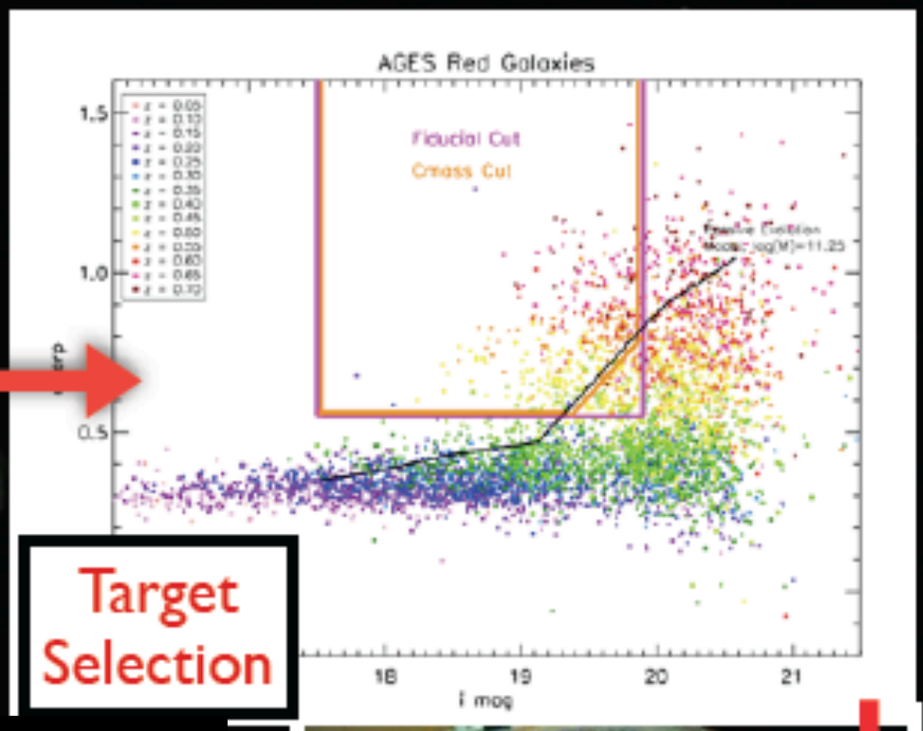



# BAO with BOSS

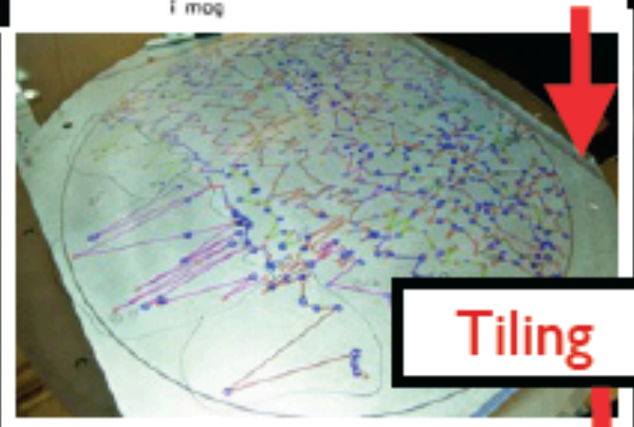


Photometric Survey



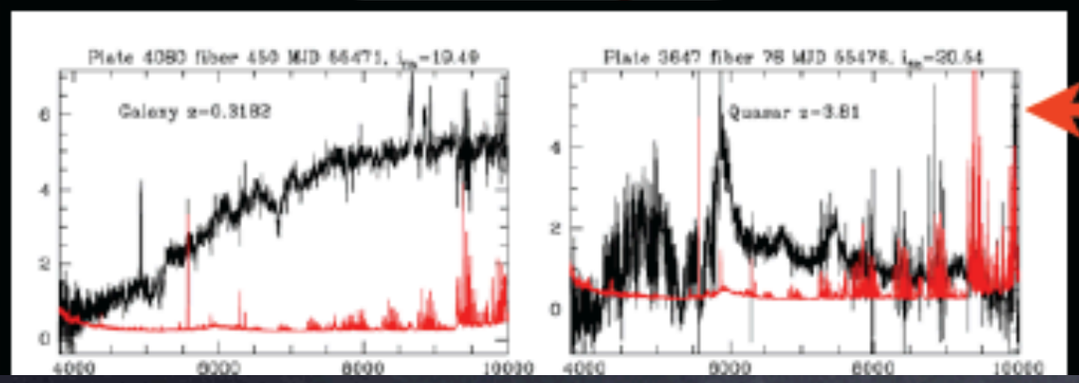



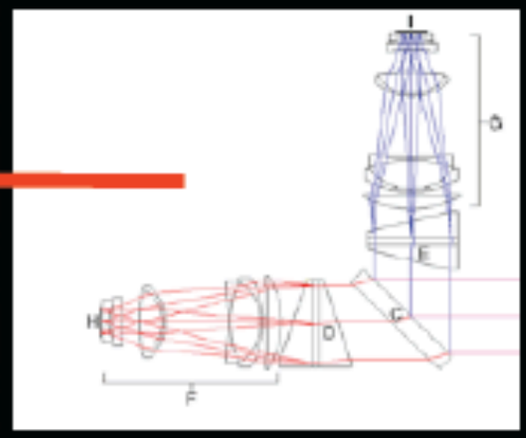

Target Selection



Tiling

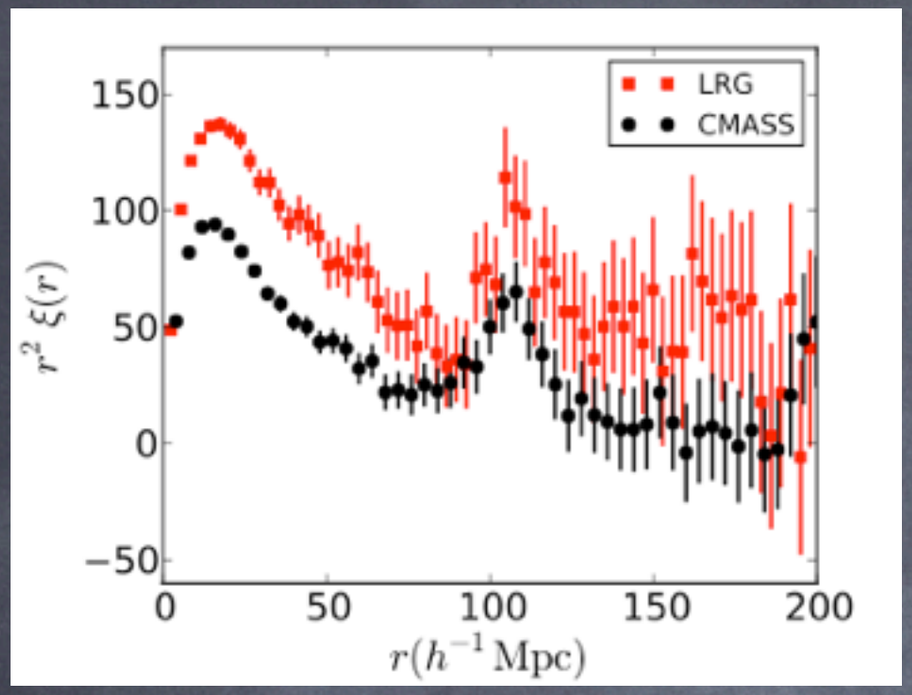
Spectroscopic Survey



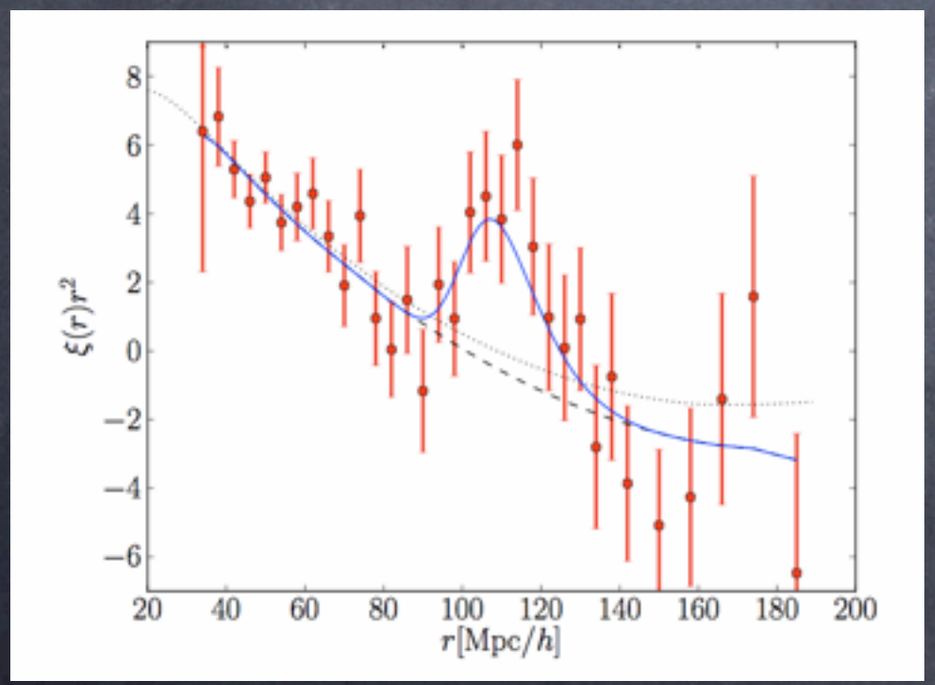



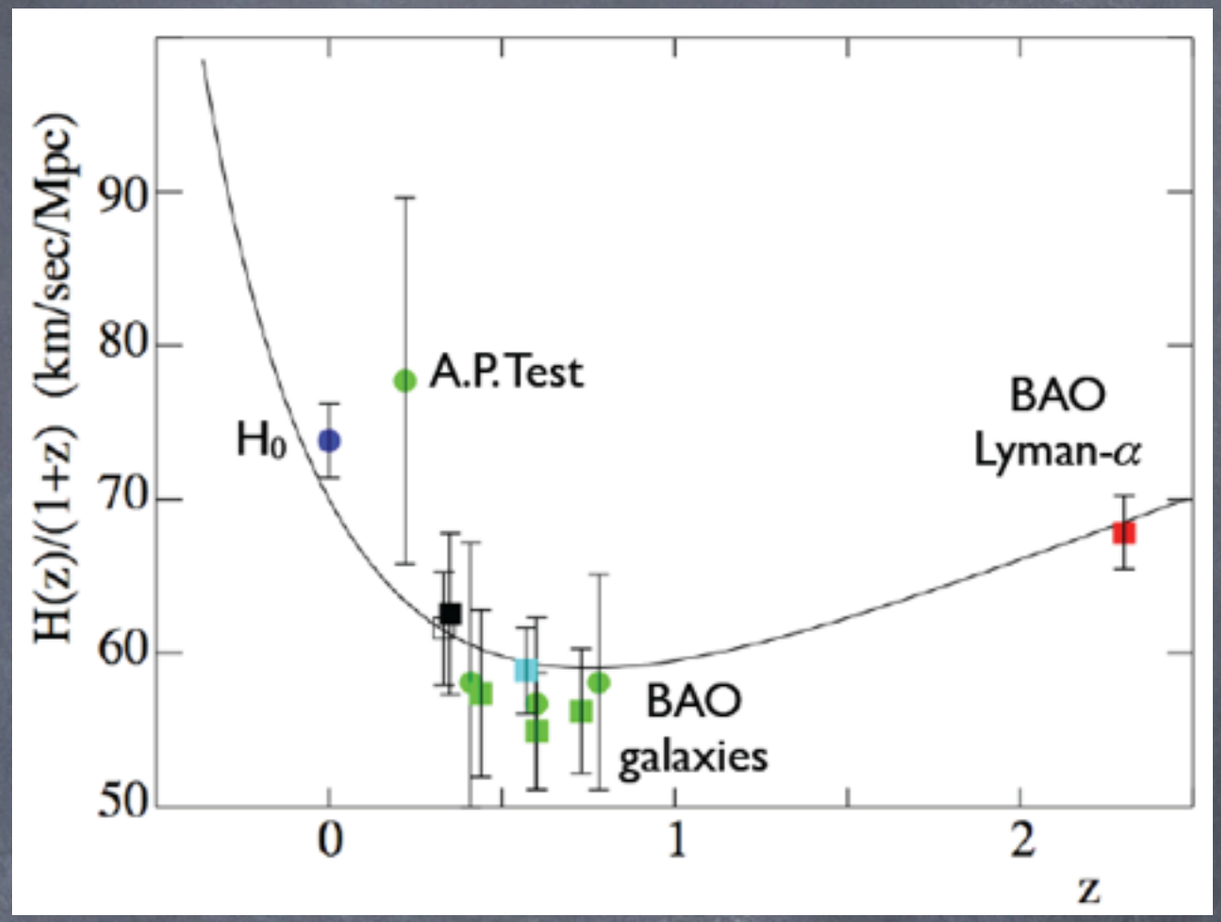
# Main BAO results

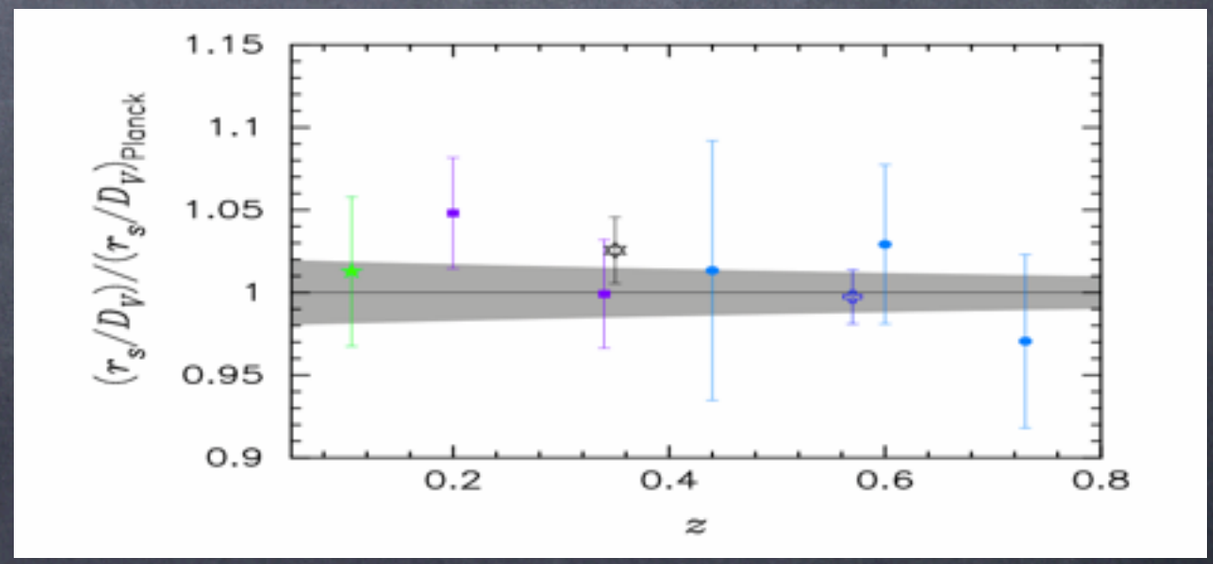
galaxies



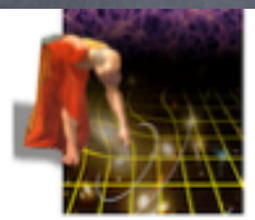

quasars



# New generation

**Euclid** 

FoM ~ 1500(WL&Galaxie)-4000 (all)
~ 900 members
European lead project / ESA
Space telescope / 1.2 m mirror
Launch : 2019
Mission length : 6 years
1 exposure depth : 24 mag
Survey Area : 15 000 square degrees (.36 sky)
Filters : 1 Visible(550-900nm)+ 3 IR(920-2000 nm)
+ NIR spectroscopy (1100 – 2000 nm)

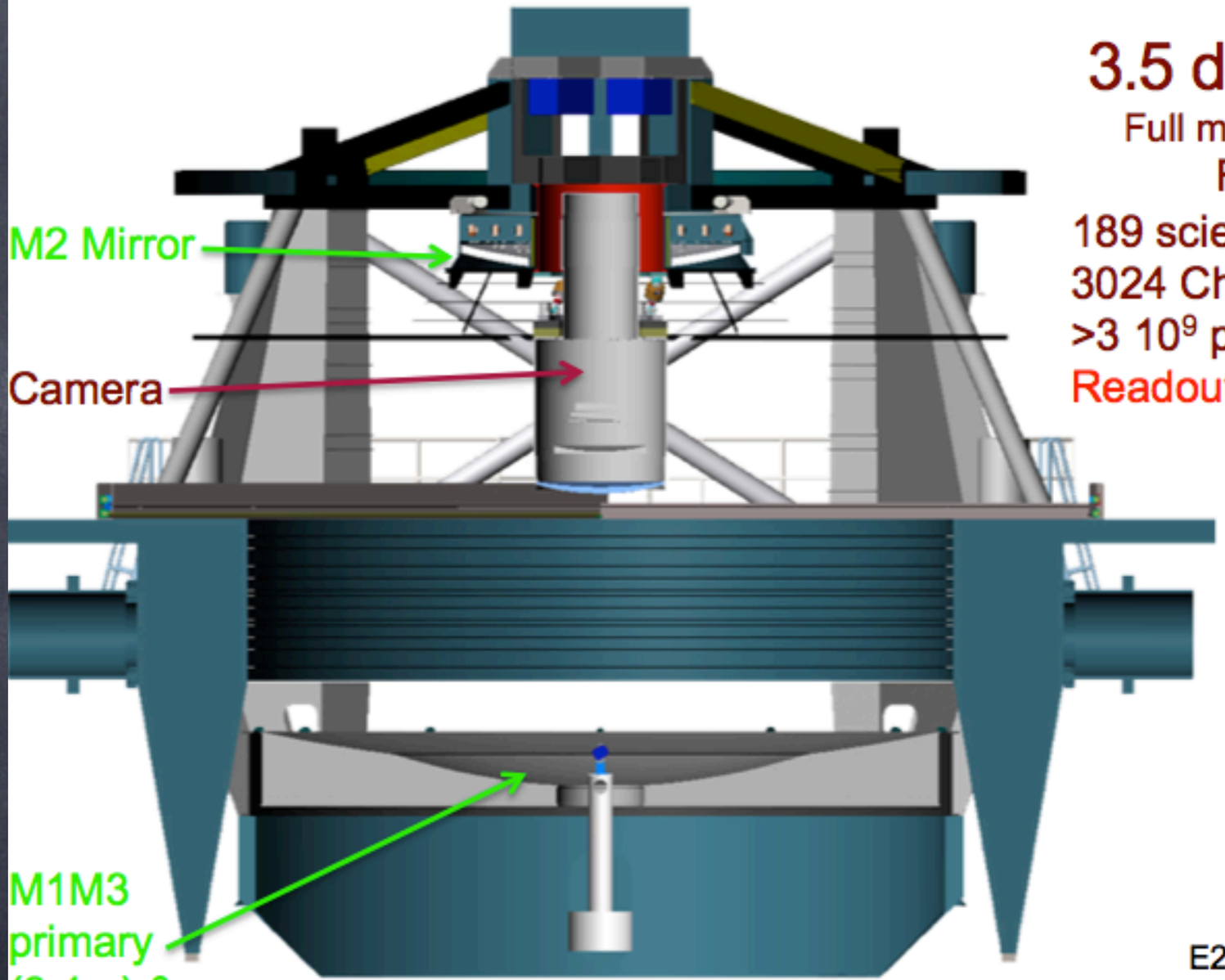
&

LSST
Large Synoptic Survey Telescope

FoM > 800 (WL,BAO, SN )
~ 450 Core members + 450 to come
US lead project / NSF-DOE
Ground Telescope / 6.5 m effective mirror
1st light : 2019
Observation length : 10 years
1 exposure depth : 24 mag (i) (~27 in 10 years)
Survey Area : 20 000 square degrees (.48 sky)
Filters : 6 filters (320-1070 nm)

→2 complementary approaches to address the question of the acceleration of the Universe and the nature of the Dark Energy in the next decade.

# Large Synoptic Survey Telescope




Moving Structure 350 tons
60 tons optical systems

Field of view :

3.5 deg (9.6 deg$^2$ =.023% sky sphere)

Full moon = 0.5 deg = 4.8 $10^{-6}$ of sky sphere

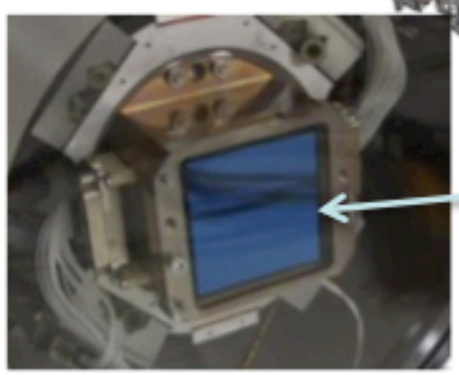
Focal plane diameter : 64 cm

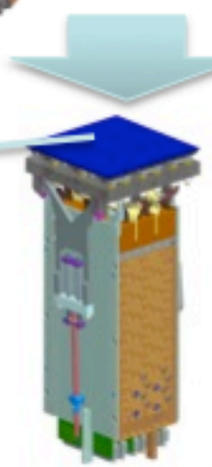
189 science CCD (21 rafts)

3024 Channels

>3 $10^9$ pixels

Readout: 2s

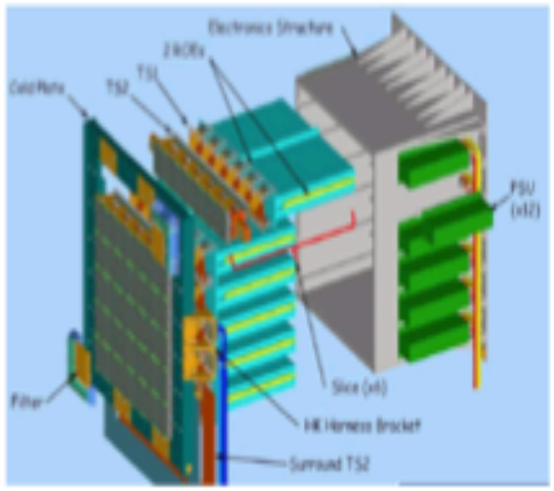


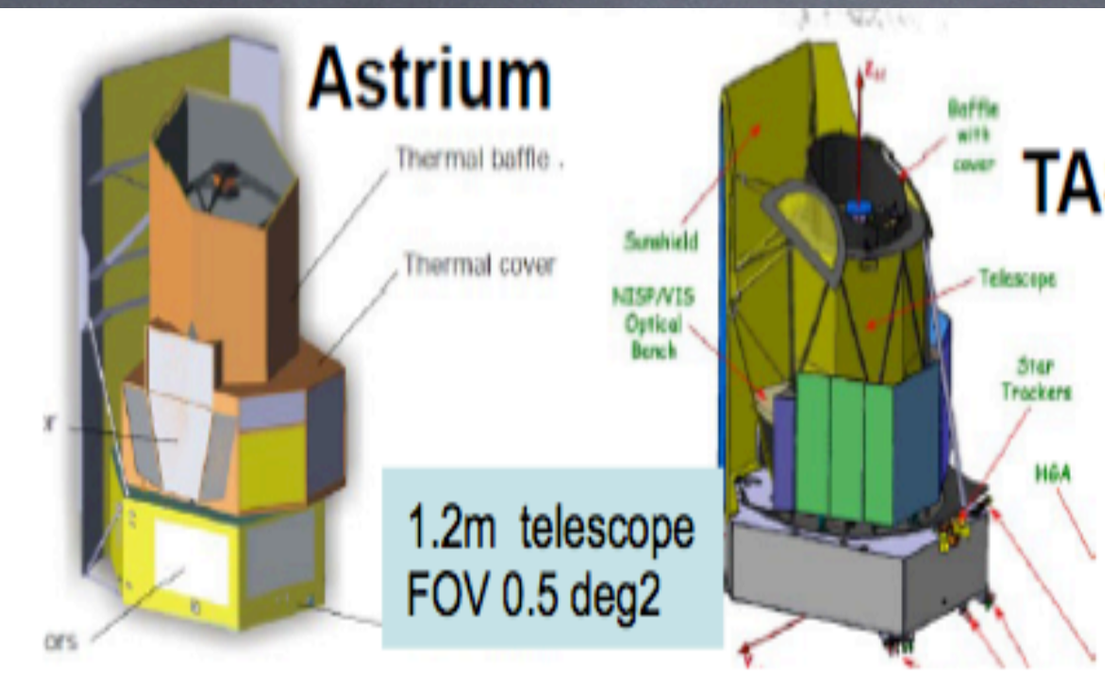


E2v CCD 250 ,
4kx4k , 10 µm pixels
100 µm deep depleted
UV to IR sensitive
16 channels output
Designed by Dedicated
R&D for LSST

1 raft = 3x3 CCD
150 M pixels
(1/2 Megacam)$_{10}$

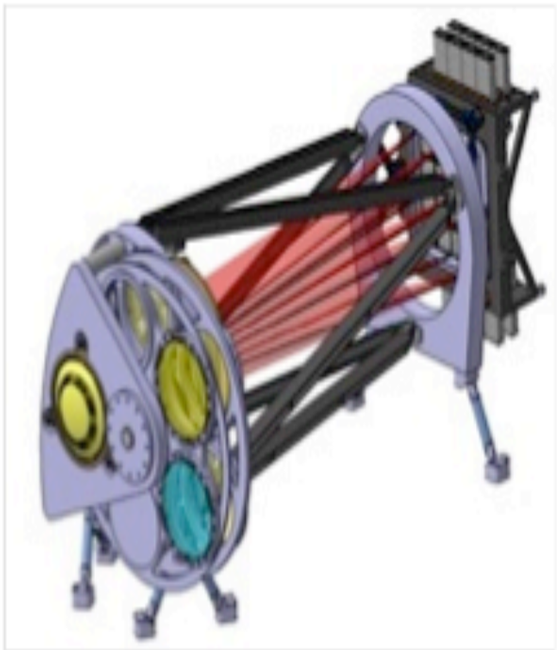
# Euclid satellite mission









The Visible imager (VIS)
36 E2V CCD, 0,1"PSF
1 broad band R+I+Z (550-900nm)

The Infrared spectro/photometer (NISP)
16 H2Rg infra red pixel detectors,0,3" PSF,
3 IR bands Y,J,H (920-2000 nm)
NIR slitless spectroscopy (1100 – 2000 nm) R ~ 350