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, Ω_m, Ω_Λ 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

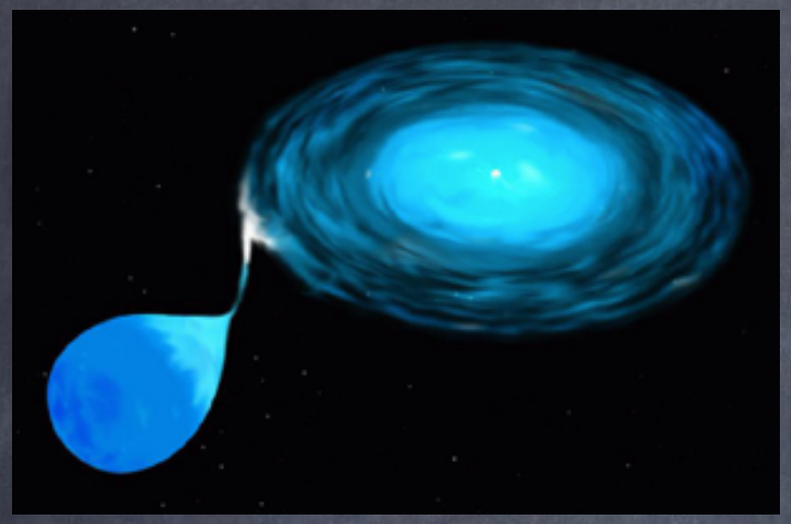
2 observables :
flux: f
Redshift: z

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

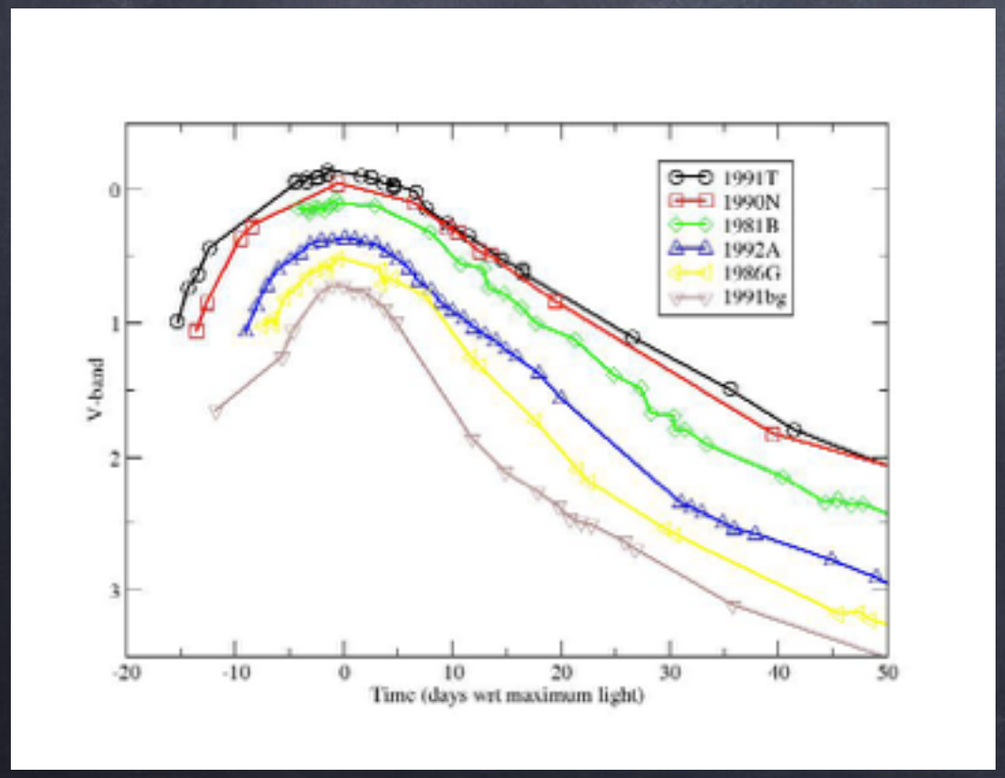
- Use supernova type Ia as distance indicators to measure the luminosity distance, d_L
- dL is sensitive to the expansion rate and the energy content of the Universe
- Dedicated surveys are used in order to search for SNIa
- Need to have many of them at different redshift for precise cosmology

SNIa are NOT standard candles

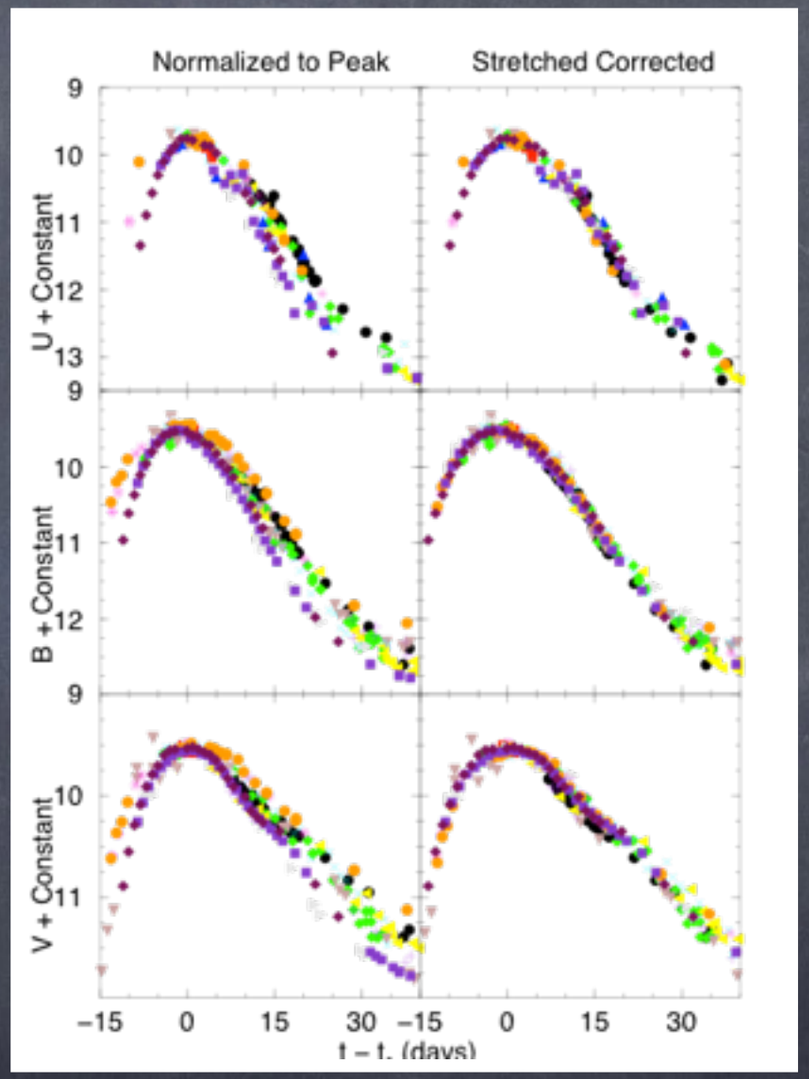
- SNIa are very luminous



- Show little luminosity dispersion



- Need to recalibrate luminosity curves for cosmology



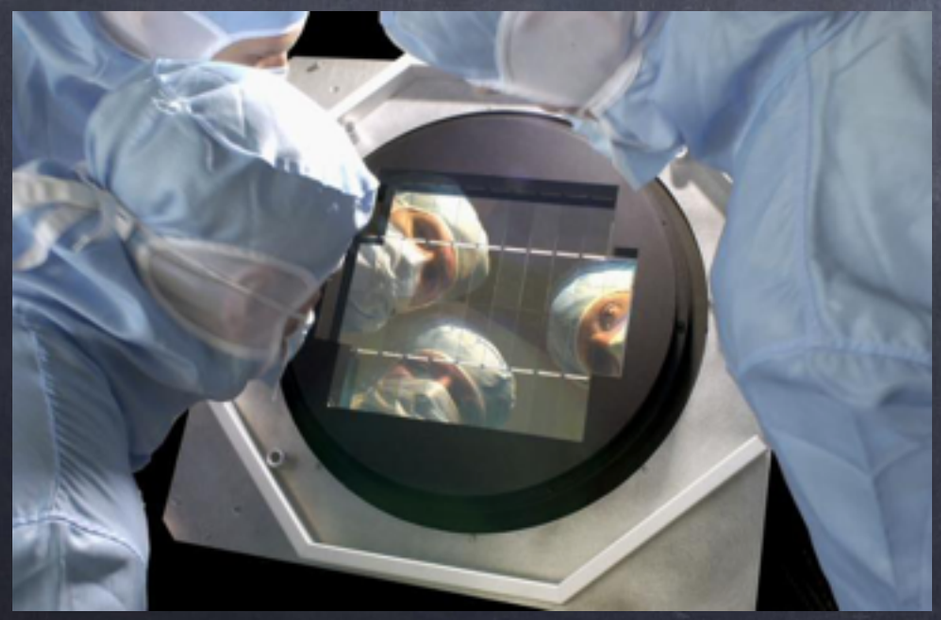
- SNIa do not measure H0, need to start with an absolute distance scale (Cepheids for example)

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 .

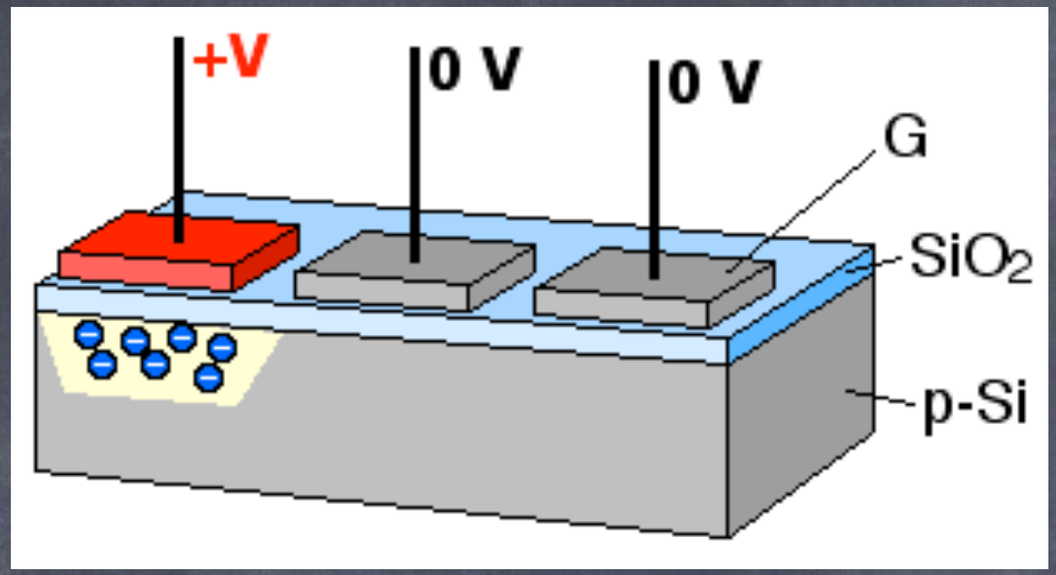
- A large spectroscopic survey
  Type Ia SNe were observed on 8m class telescopes (Gemini, VLT, Keck).

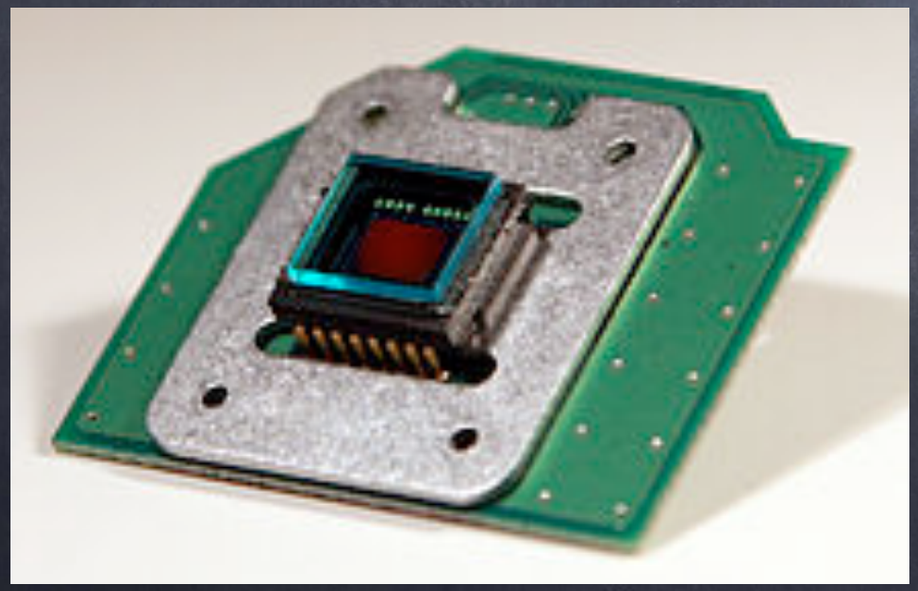
"Rolling Search" survey with MegaCam

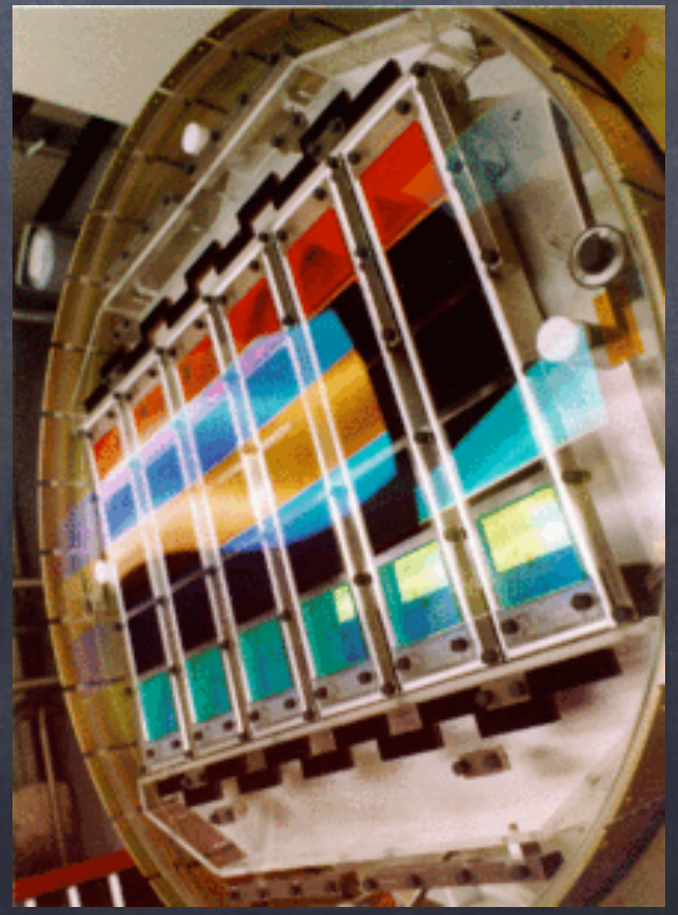


Each lunation (~18 nights) :
repeated observations
(every 3-4 night) of
2 fields in four bands (griz)+u
for as long as the fields stay
visible (~6 months)
=> ~500 SN Ia identified
(+ ~300 « photometric »)
observed between 2003 and 2008

CCD cameras



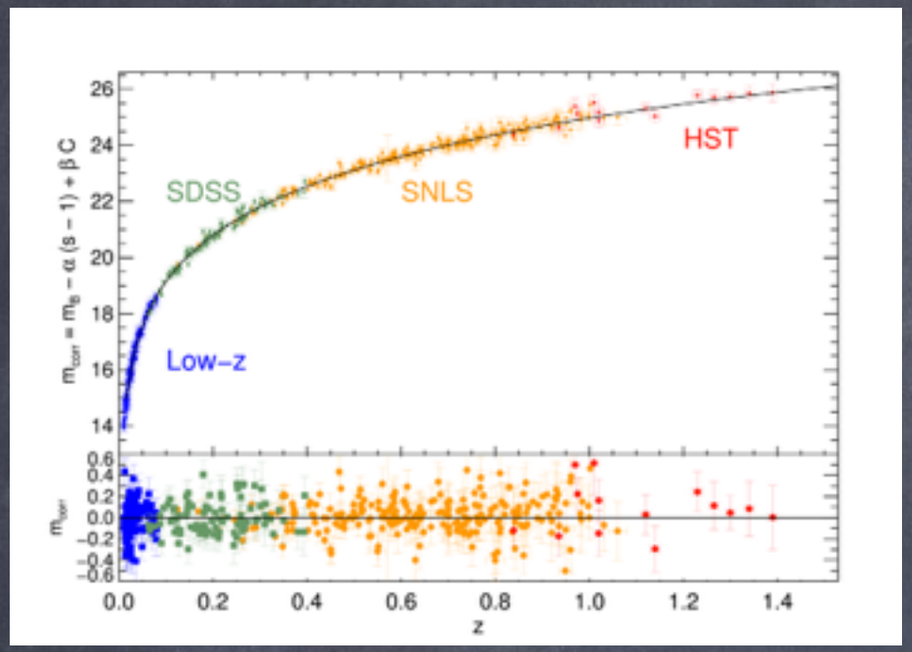


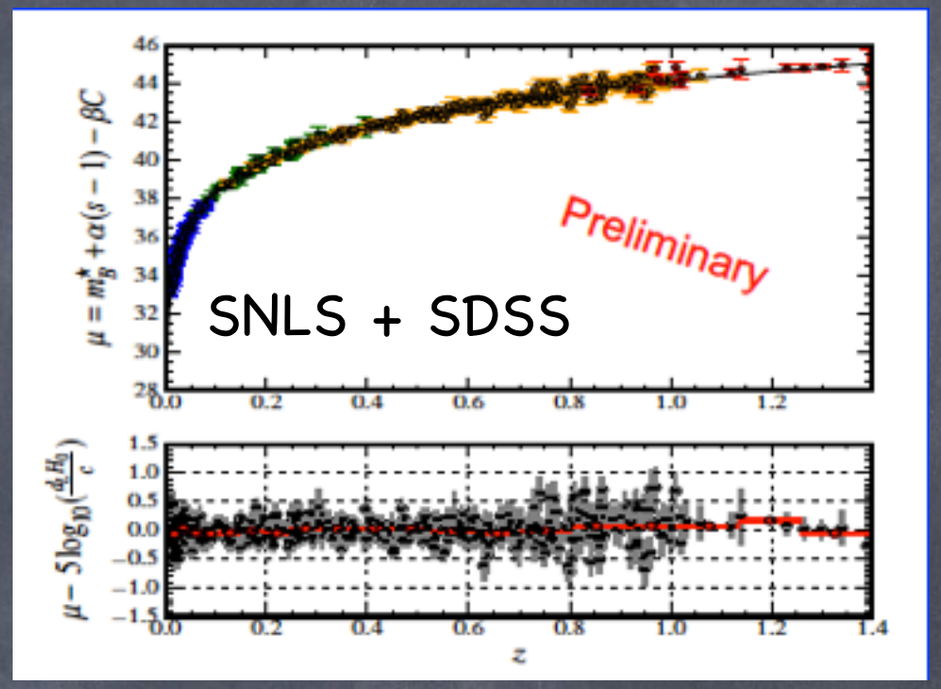


SDSS supernovae

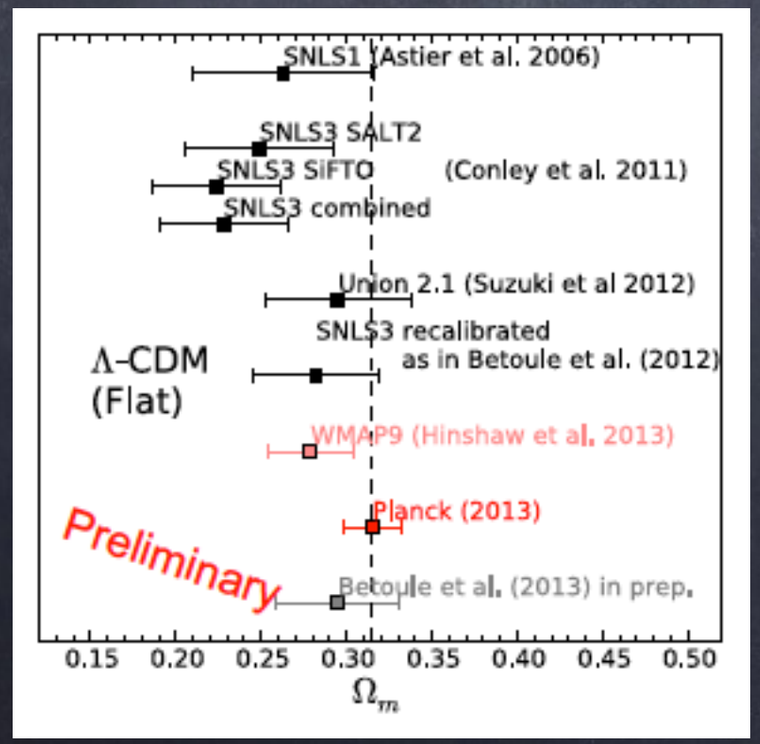
Cosmological constraints with SNIa

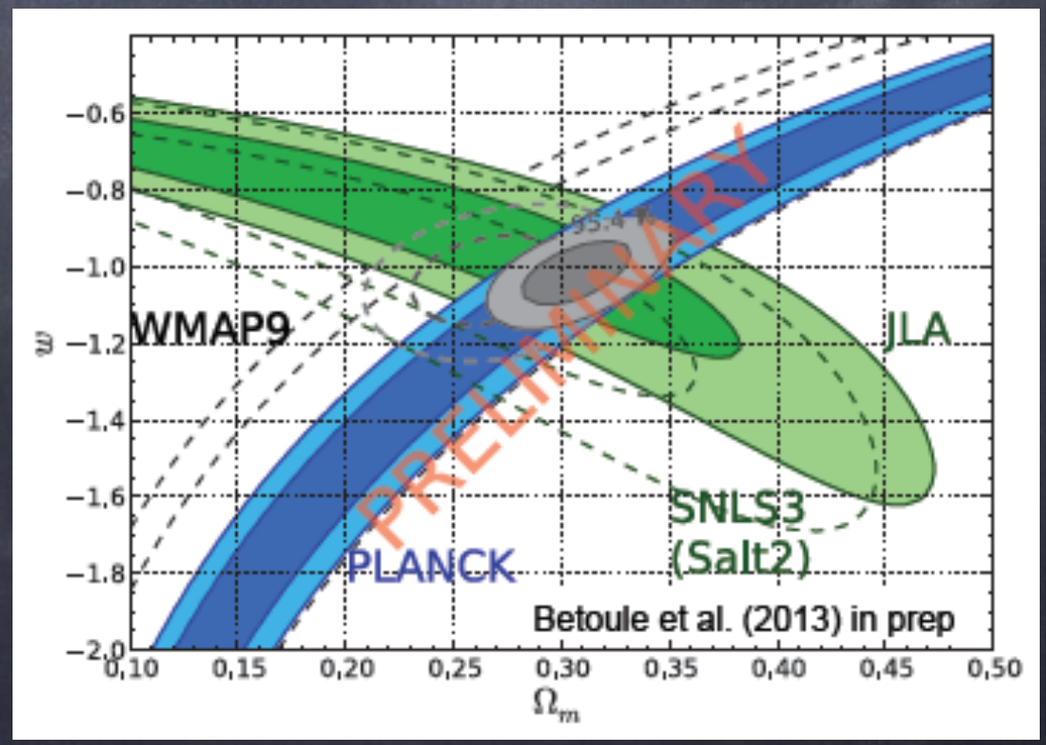
Hubble diagram measurements



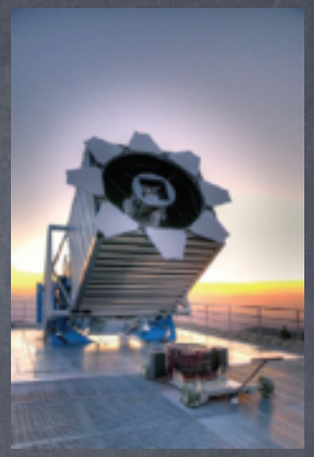


–Constraints on Ω_m and the equation of state of dark energy

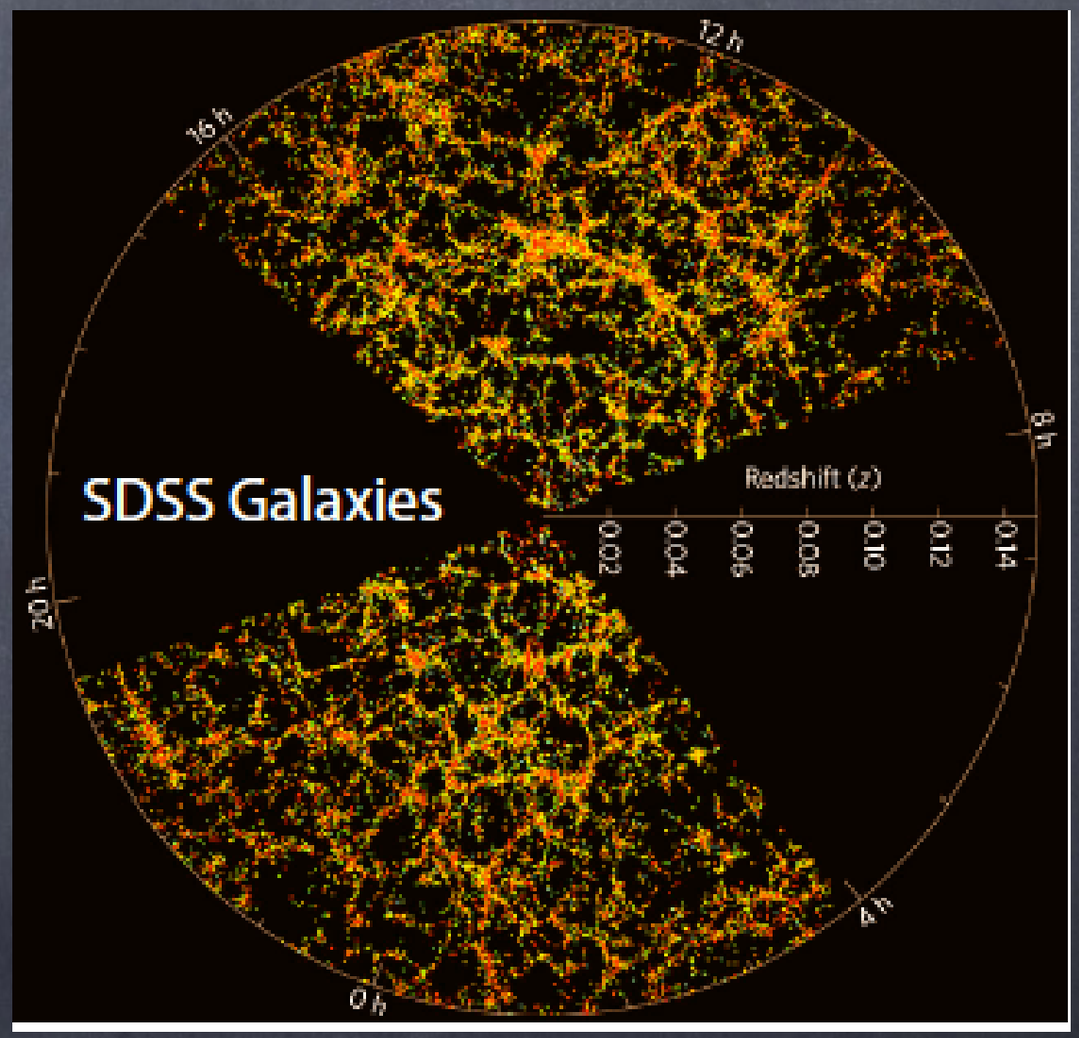




SDSS (Sloan Digital Sky Survey)

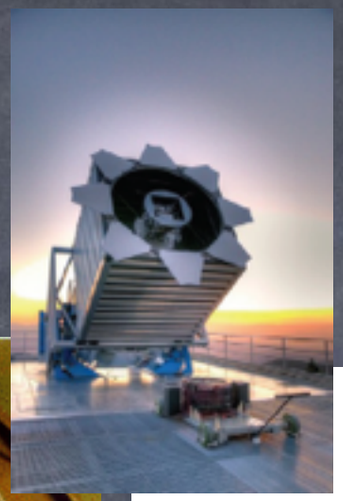


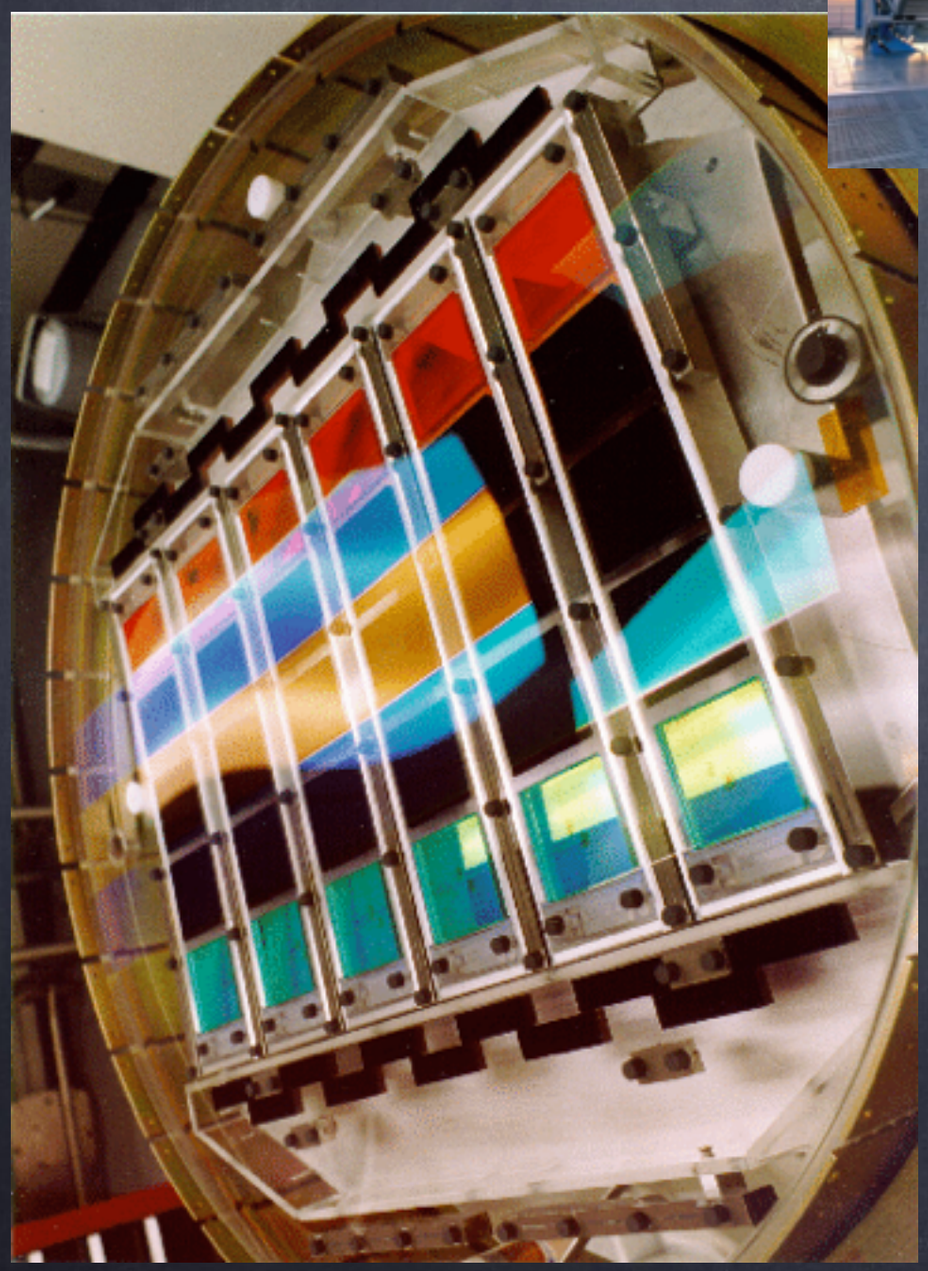
- 2.5 m telescope in the APO (New Mexico)
- Photometric survey using SDSS-III
- Spectroscopy survey using BOSS
  - Two spectrographs with 1000 optical fibers
  - 3600 A to 10000, R = 3000
- 10000 squares degrees survey
  - 1.5 Millions LRG galaxies up to z=0.7
  - 150000 quasars for Ly-α up to z=2.5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



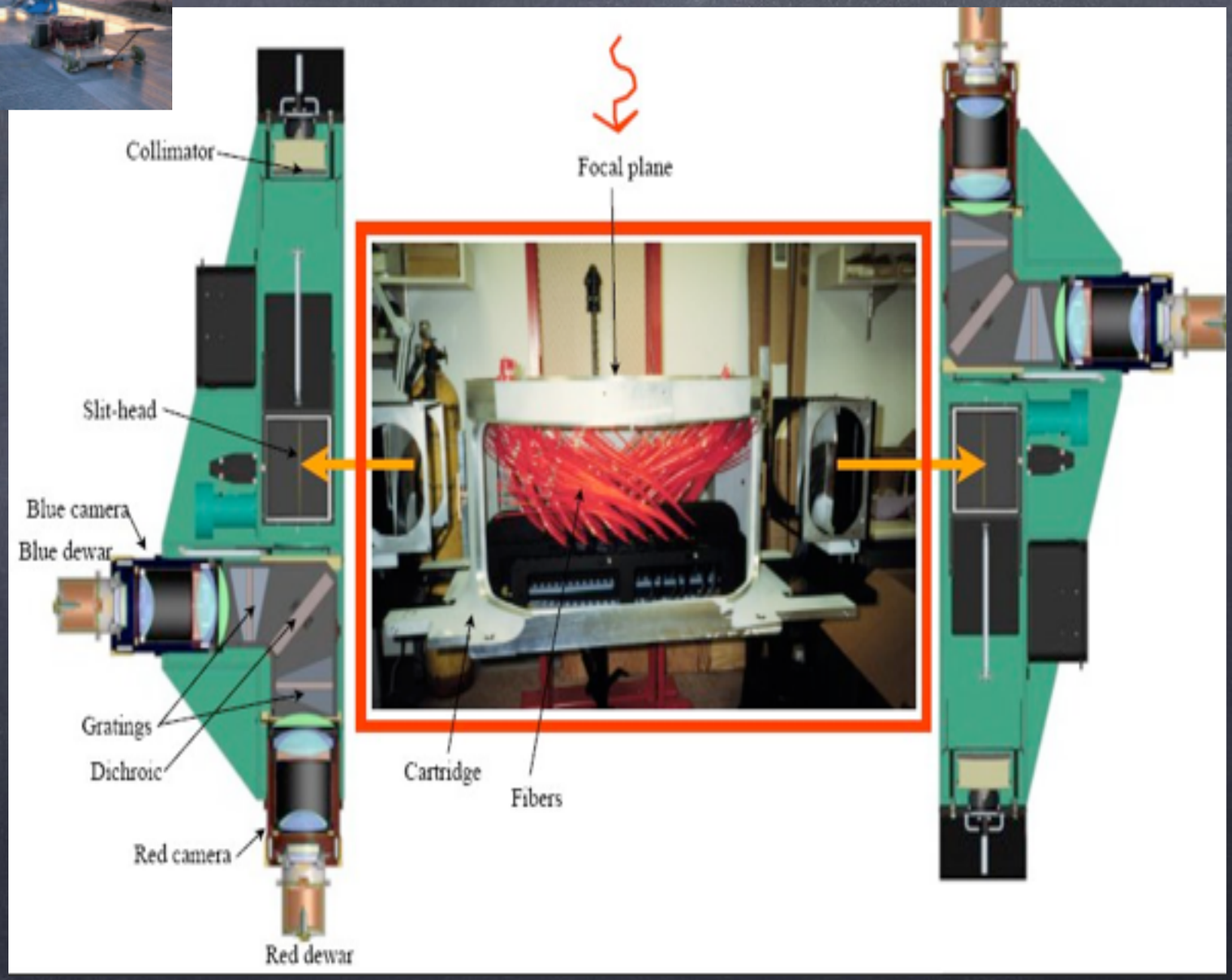
SDSS technology

Photometric camera



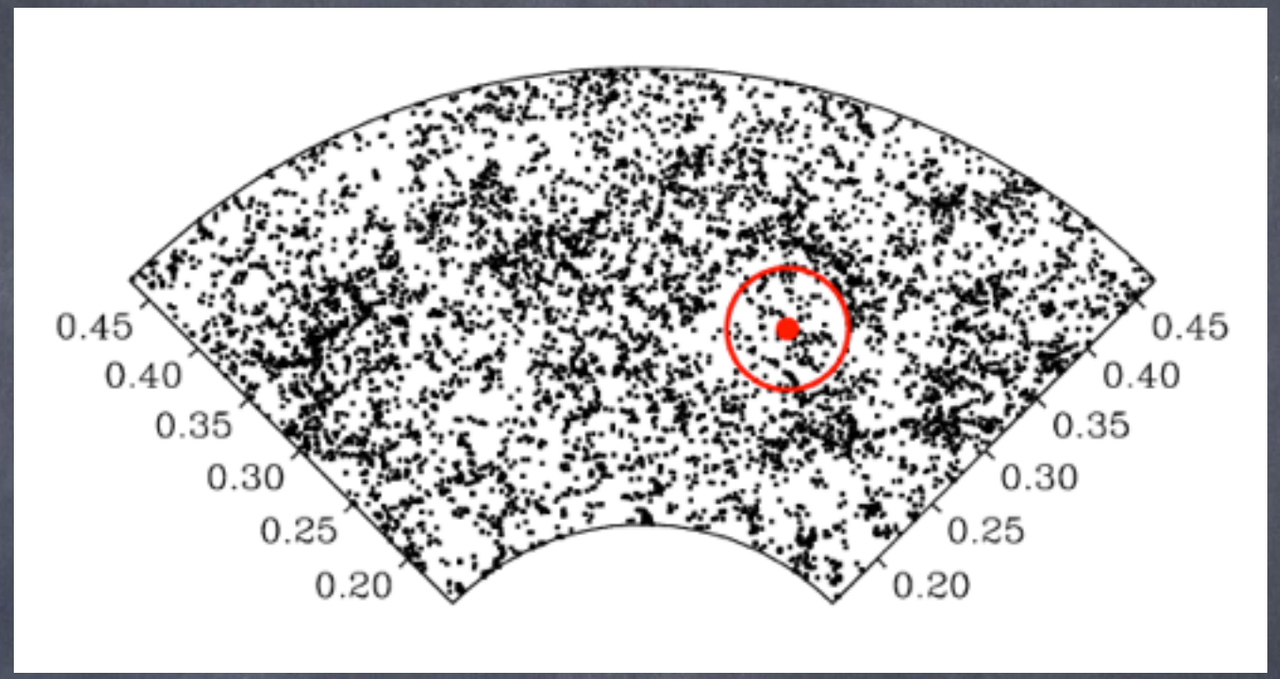


Spectrograph

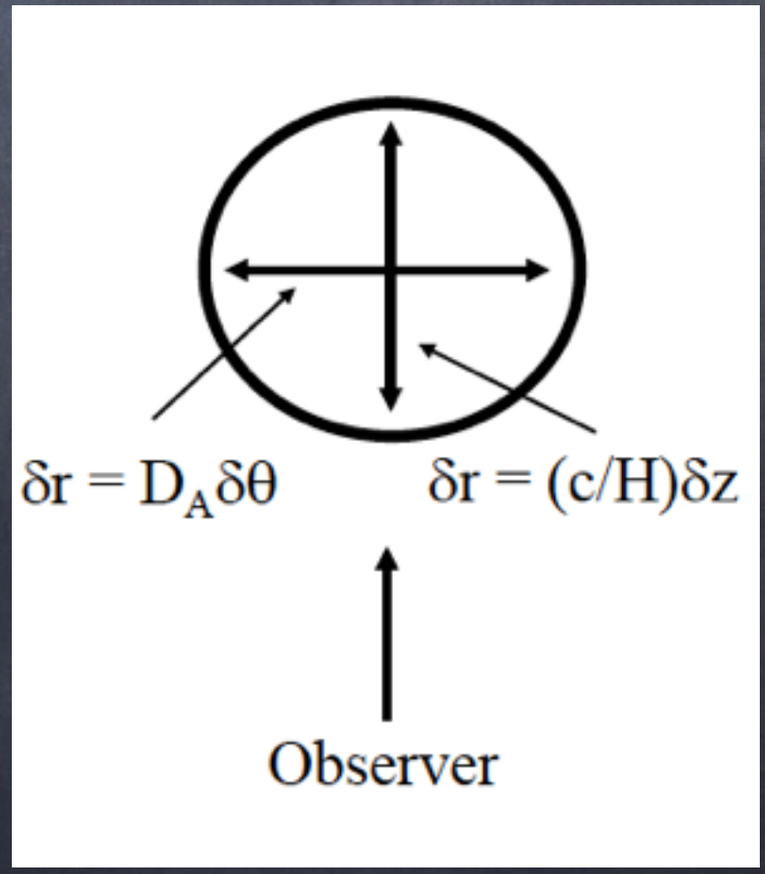


Observing BAO

➡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)

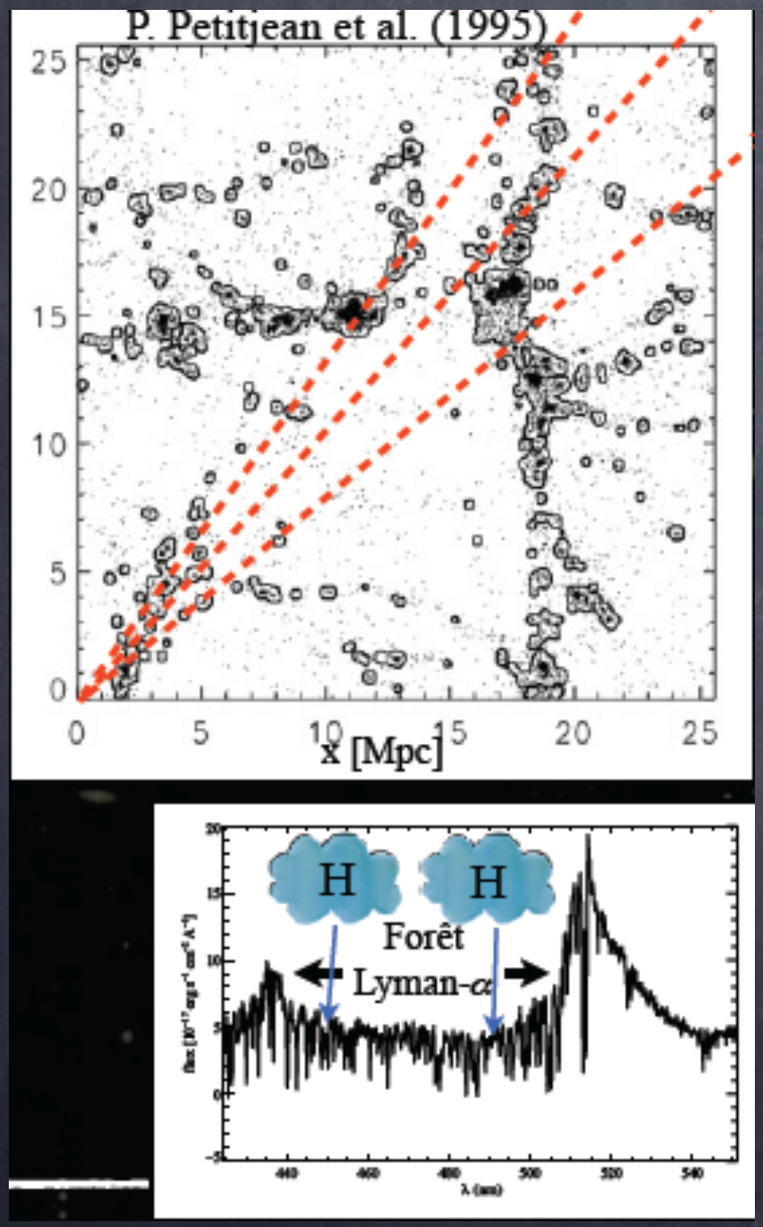


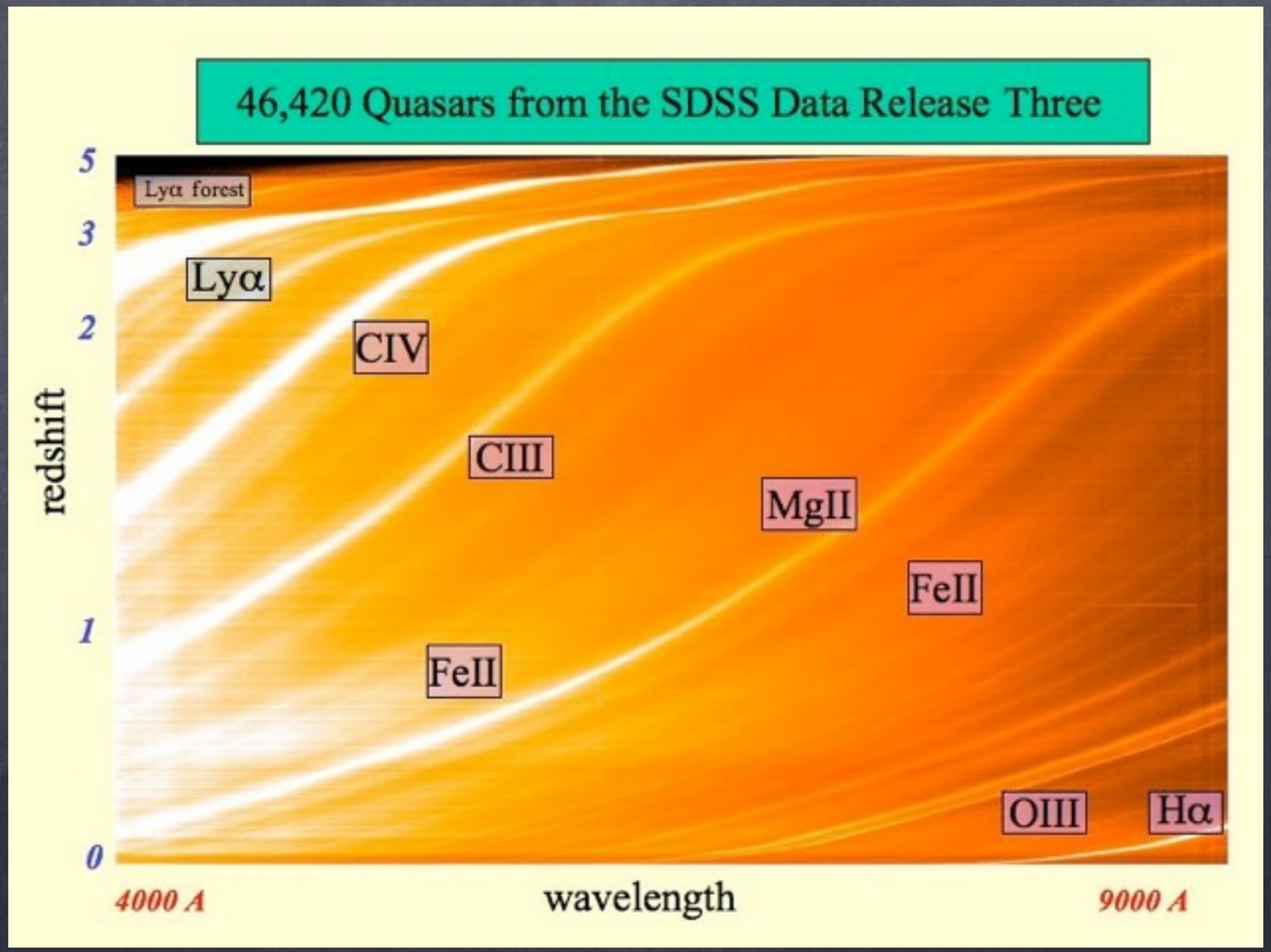
- In a LSS survey we can study BAO along and across the line-of-sight
- We can use LRG galaxies at low redshift and quasars Ly-α forest at high redshift
-We measure both the angular distance and the Hubble constant



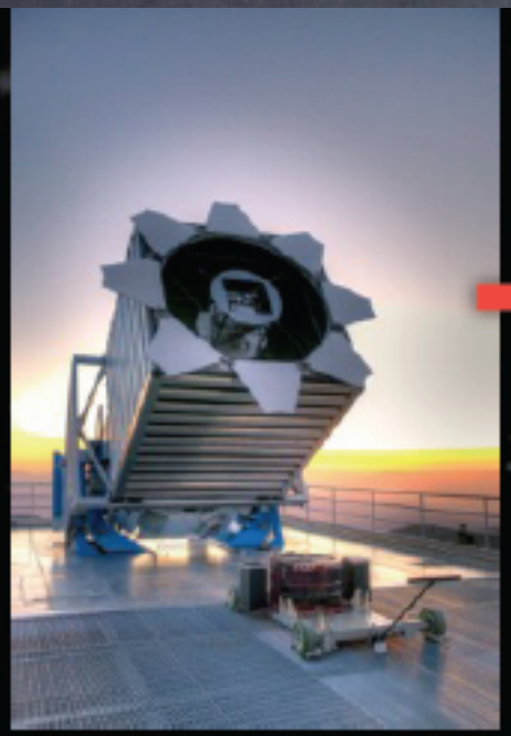
Why quasars ?

We study hydrogen absorption of in the Ly-α forest

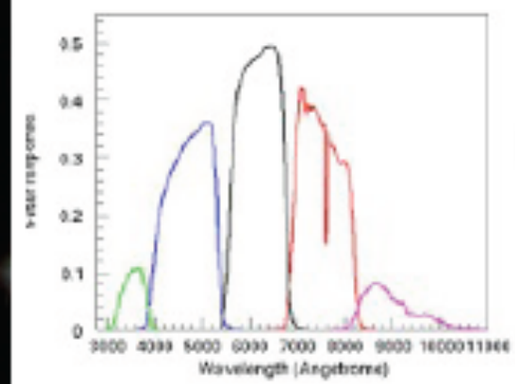


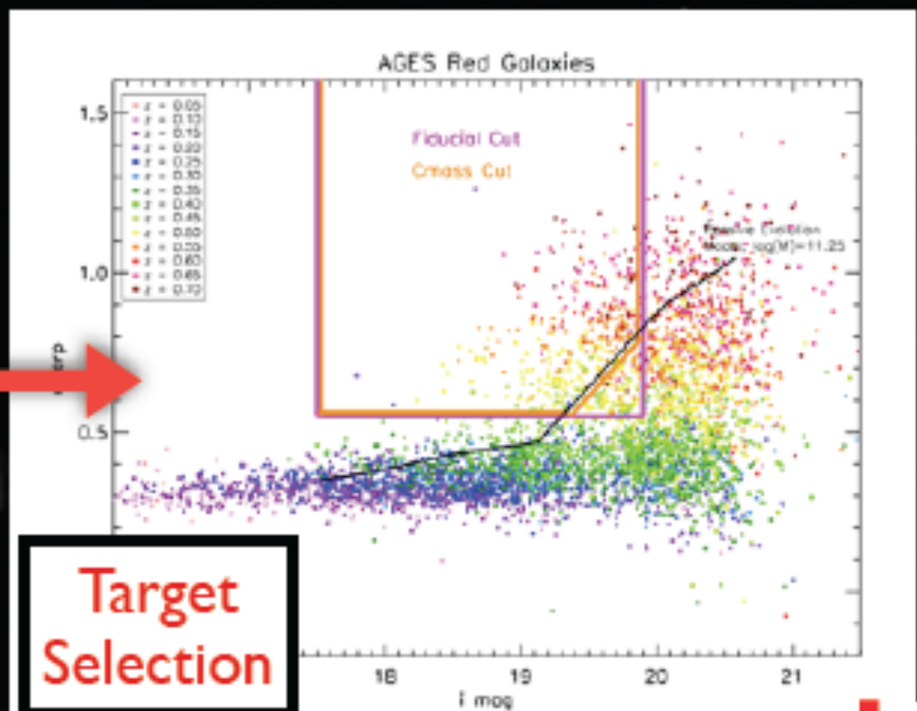


BAO with BOSS

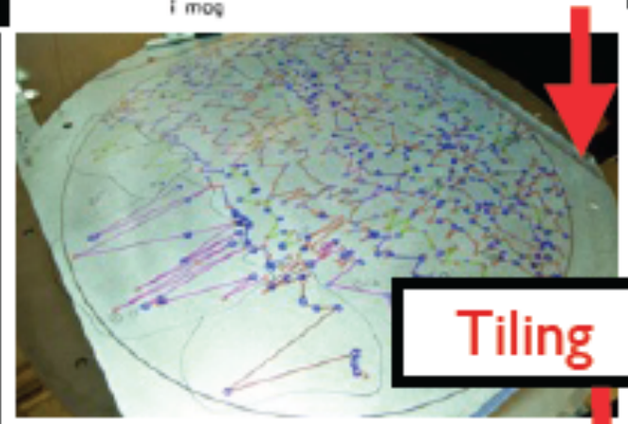


Photometric Survey



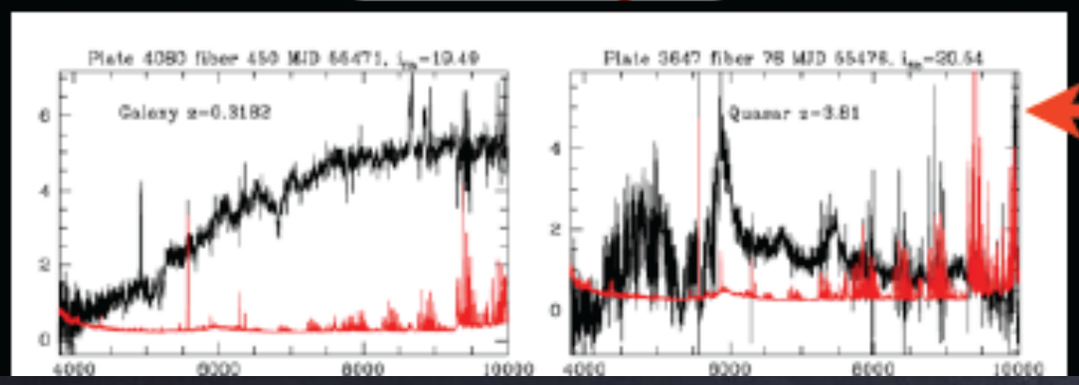


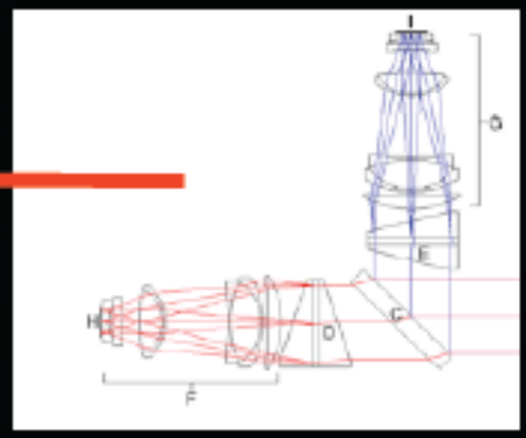
Target Selection

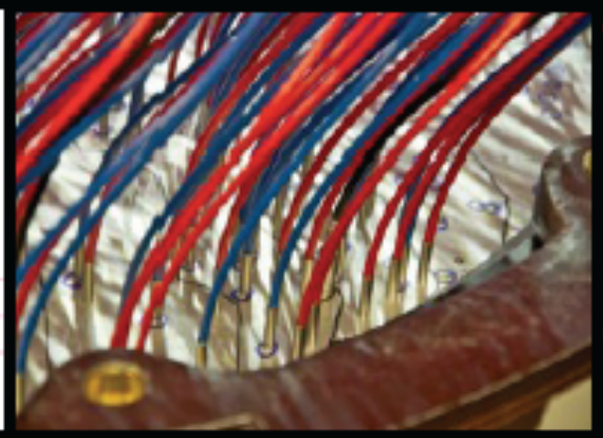


Tiling

Spectroscopic Survey

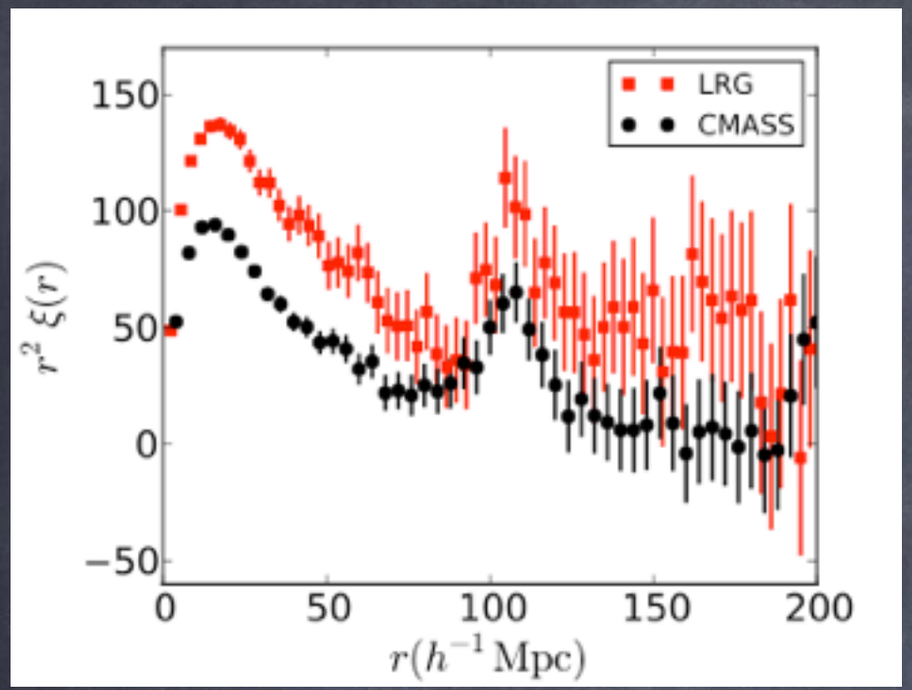




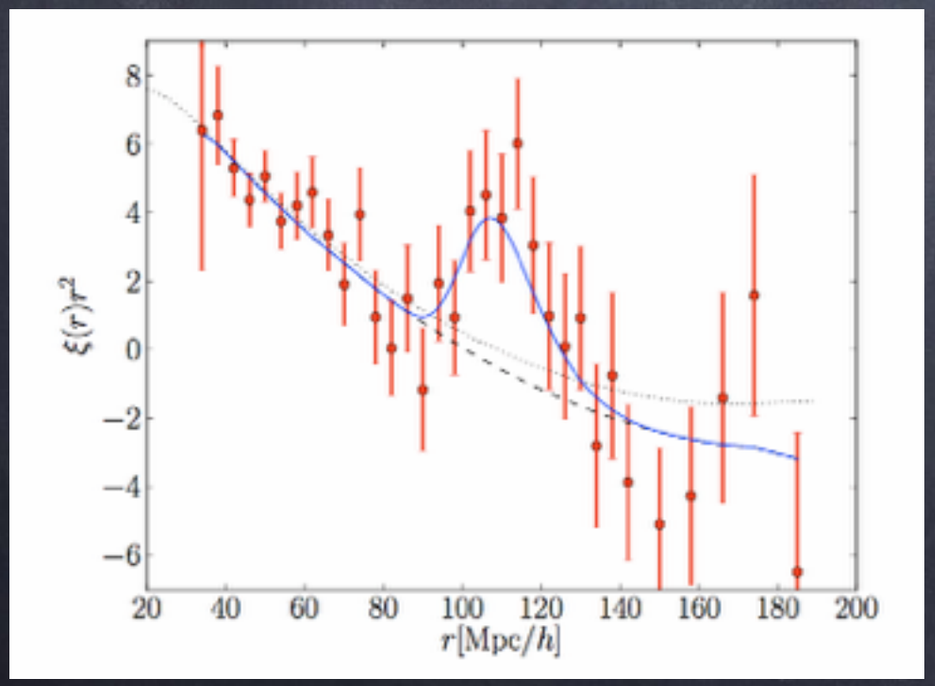


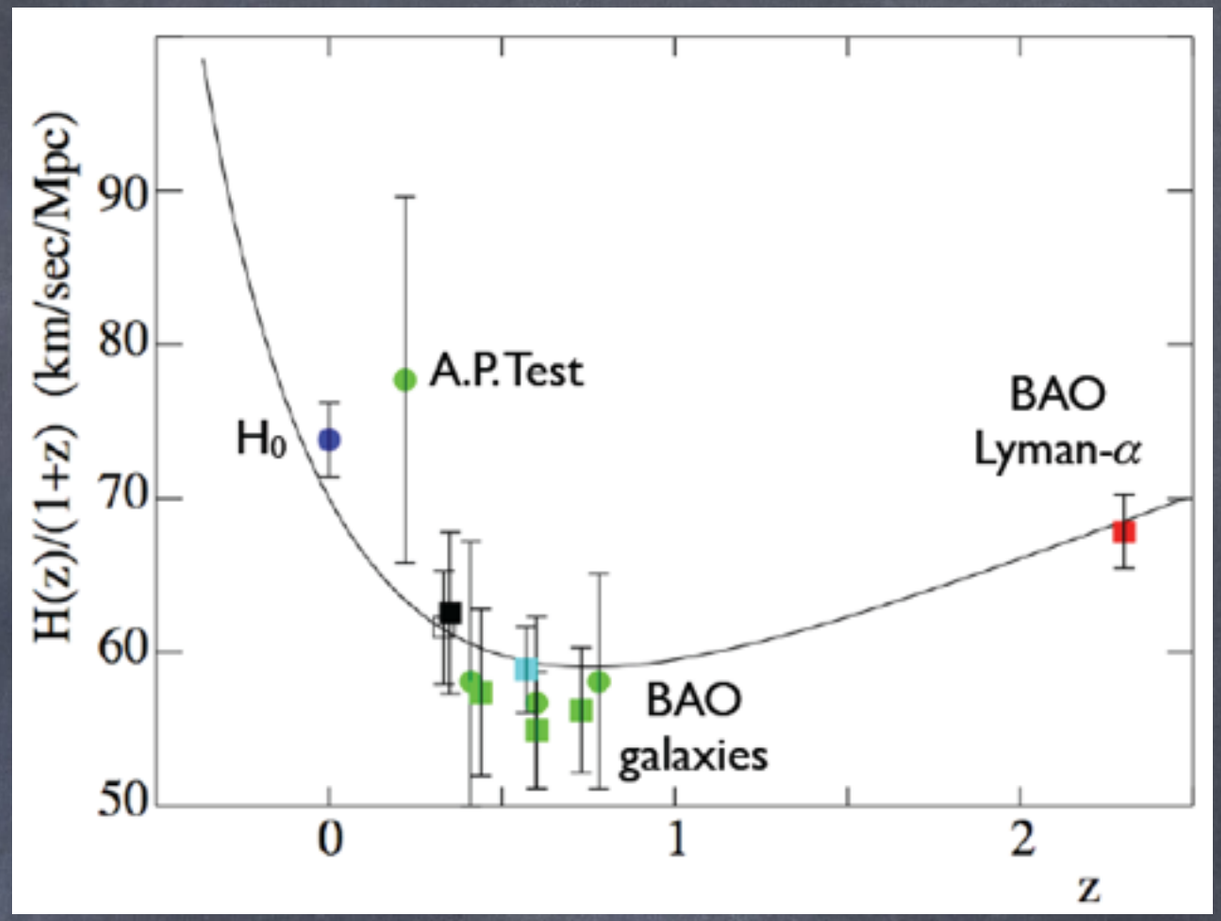
Main BAO results

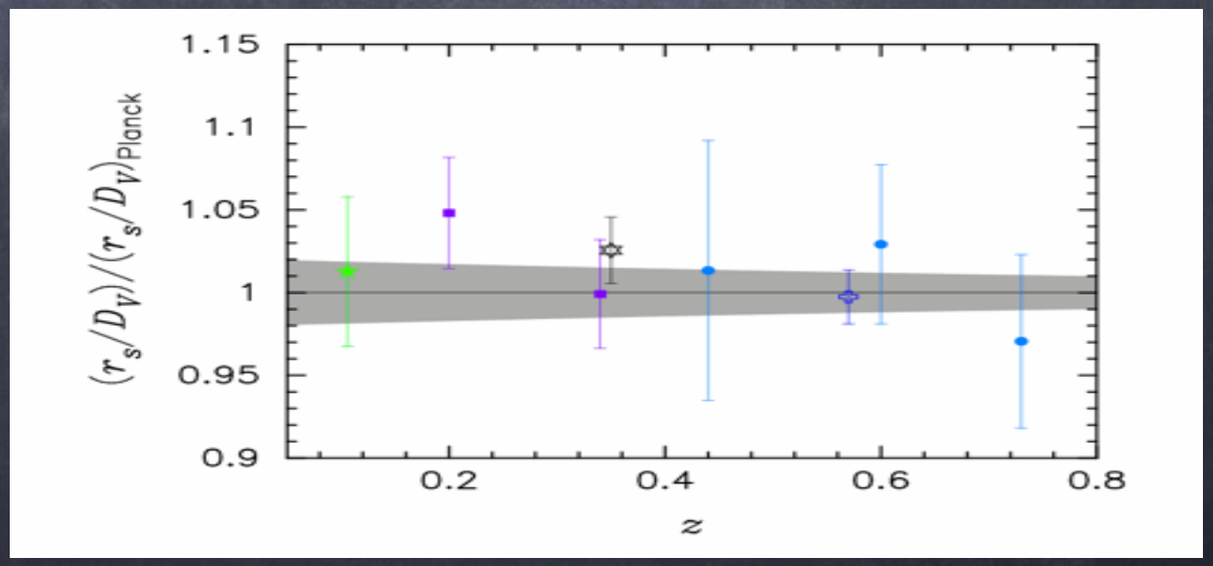
galaxies



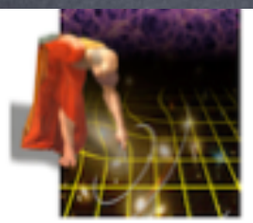
quasars







New generation

Euclid 

FoM ~ 1500(WL&Galaxie)-4000 (all)
~ 900 members
European lead project / ESA
Space telescope / 1.2 m mirror
Launch : 2021
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)

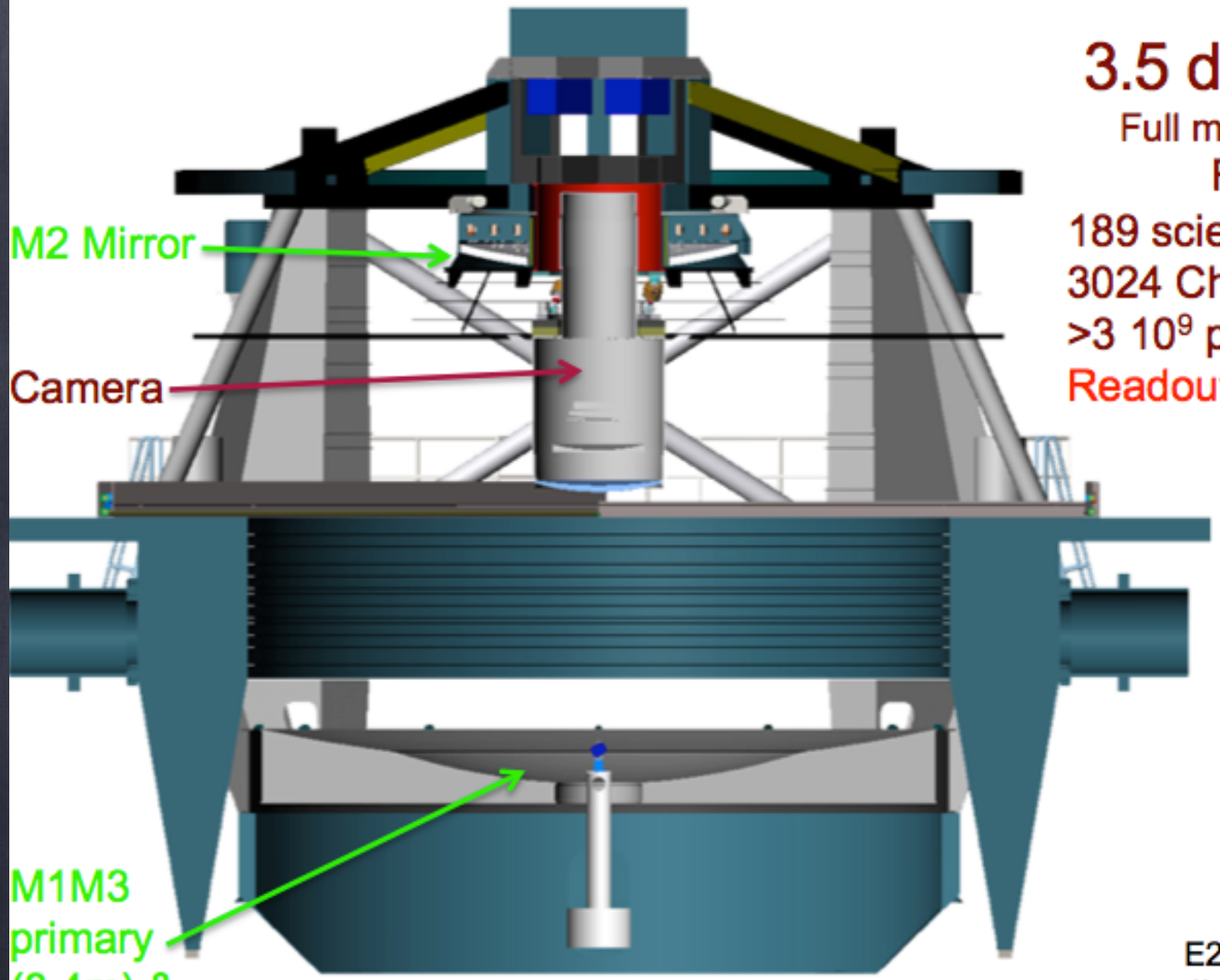
&

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 : 2020-2021
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

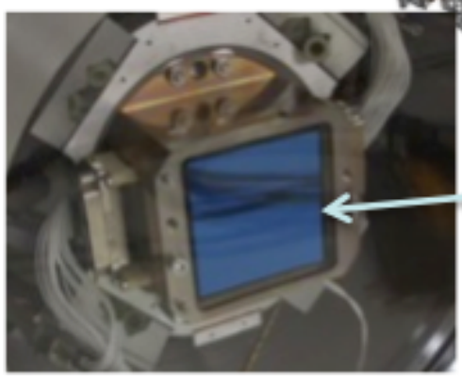
Focal plane diameter : 64 cm

189 science CCD (21 rafts)

3024 Channels

>3 10^9 pixels

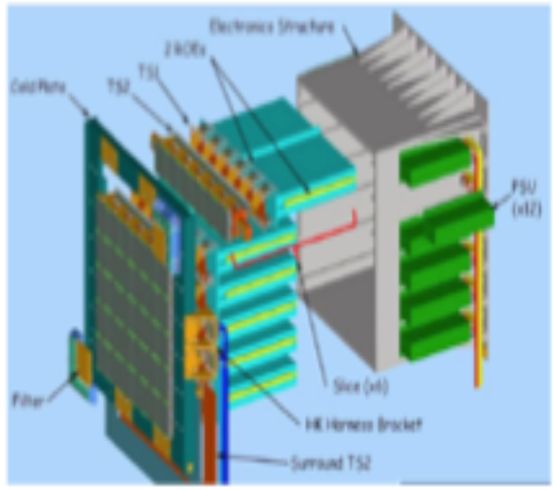
Readout: 2s

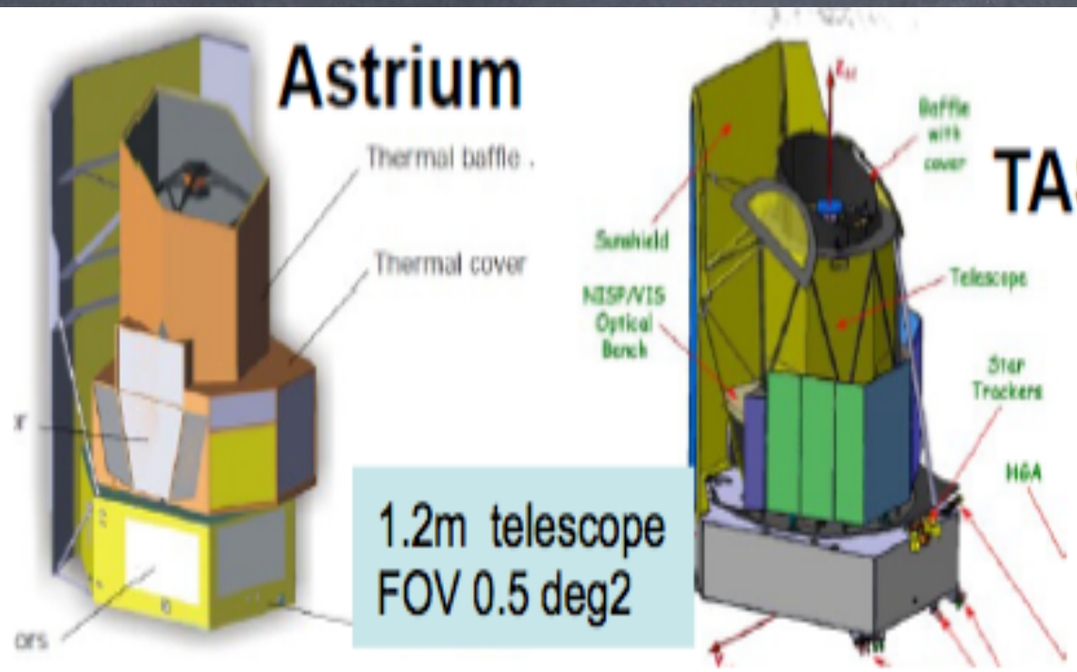


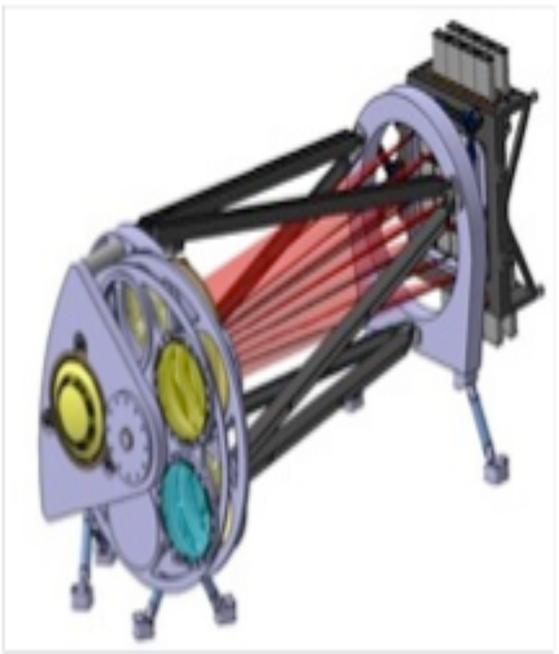
E2v CCD 250 ,
4kx4k , 10 µm pixels
100 µm deep depleted
UV to IR sensitive
16 channels output
Designed by Dedicated
R&D for LSST

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