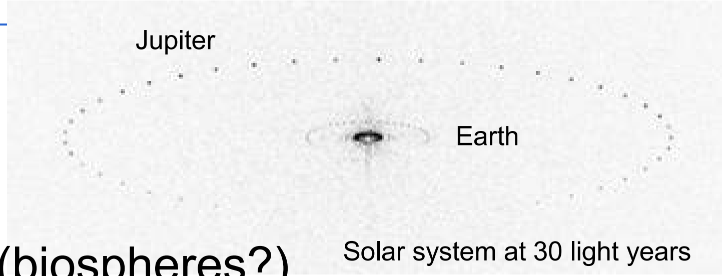
Science case

(Presented by R. Gilmozzi)

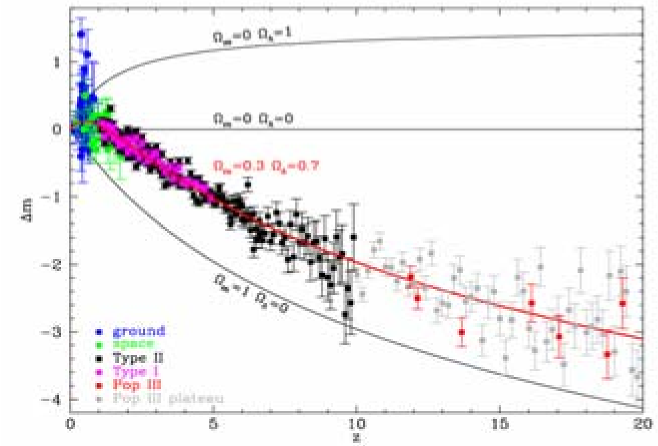

EXTREM
COPES:
The nex
e Universe
The science case for the European
EXTREMELY LARGE TELESCOPE:
The next step in mankind's quest for the Universe

The science case is breathtaking

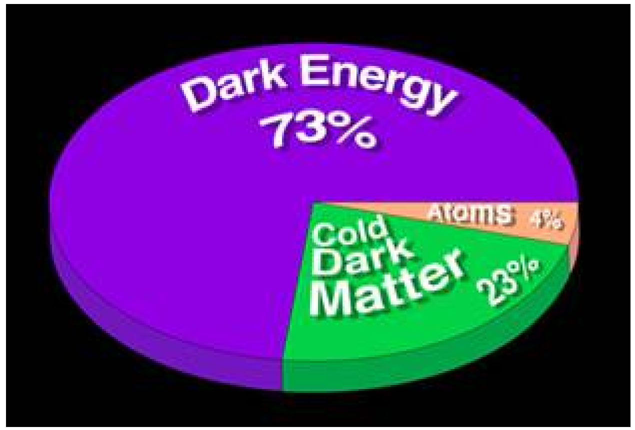
- Planets in other stellar systems
  - Imaging ***and*** spectroscopy
  - Earth-like planets become accessible (biospheres?)



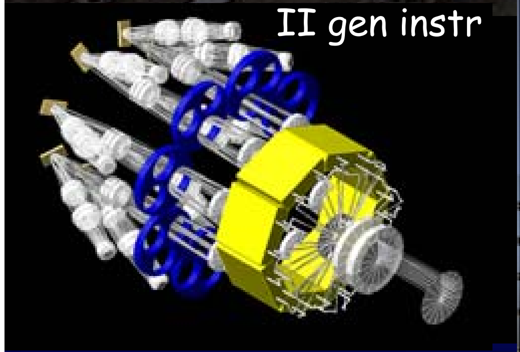
- Stellar populations
  - In galaxies inaccessible today (e.g. ellipticals in Virgo cluster)
  - Across the whole history (i.e. extent) of the Universe

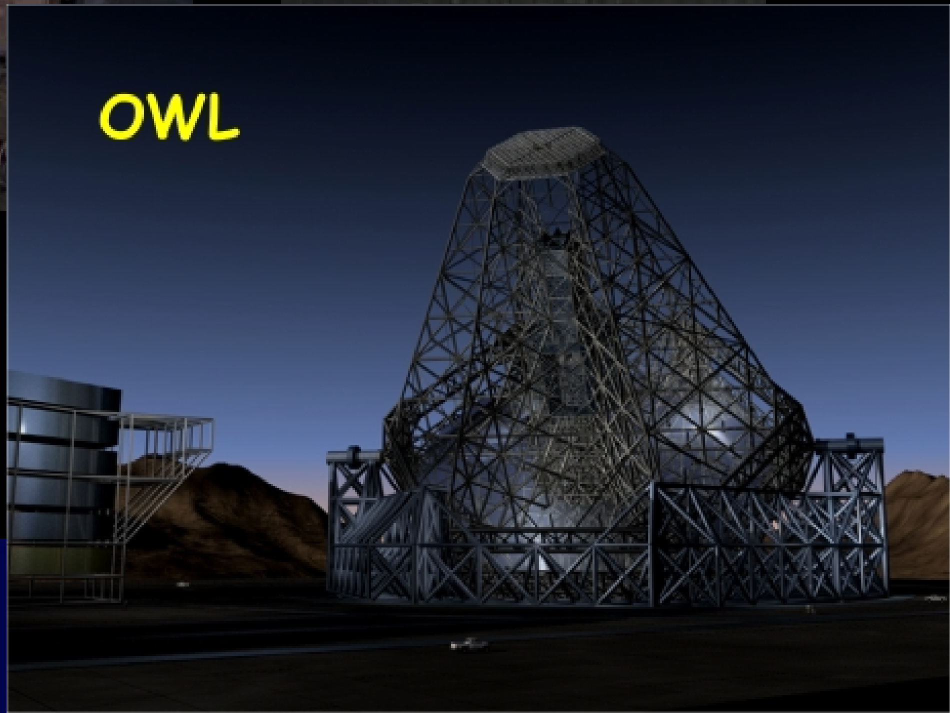


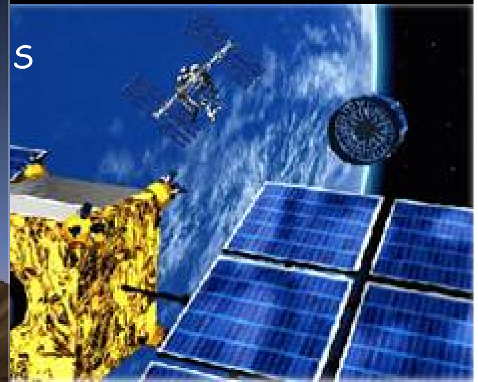
- Cosmology
  - The first stars/galaxies
  - Direct measure of deceleration
  - Evolution of cosmic parameters
  - Dark matter, dark energy

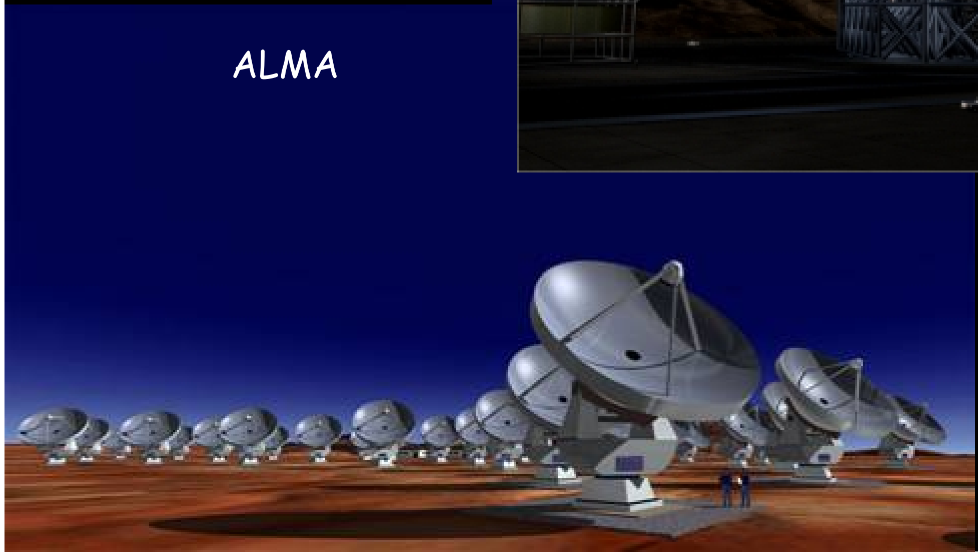


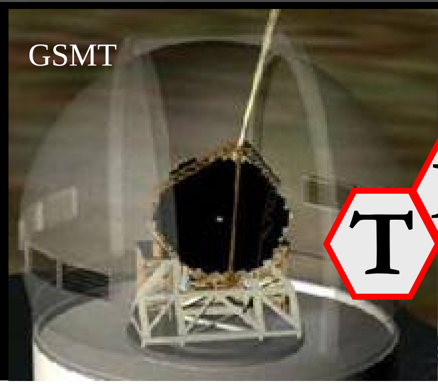
CONTEXT:
II decade, III millennium AD

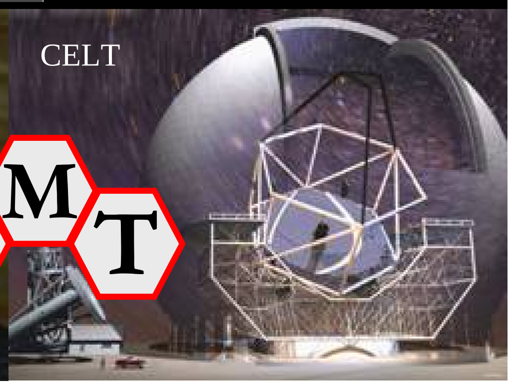












Primary science cases

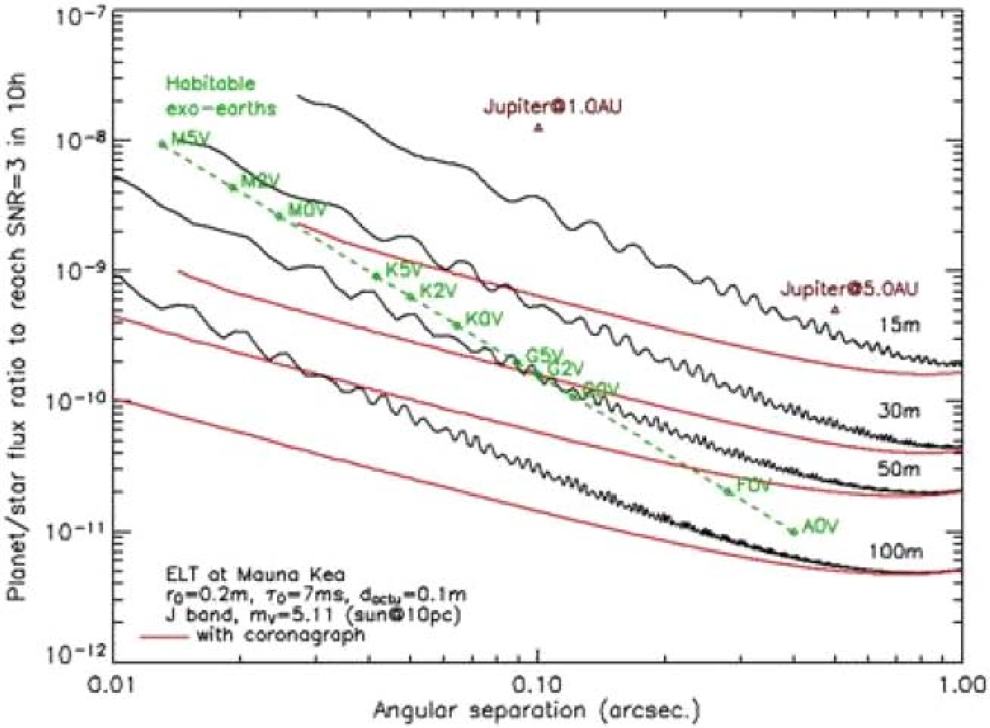
Are there terrestrial planets orbiting other stars?	Direct detection of earth-like planets in nearby extra-solar systems and a first search for bio-markers (e.g. water and oxygen) may become feasible.
How typical is our Solar System? What are the planetary environments around other stars?	Direct detection of proto-planetary disks will become possible around many nearby very young stars. In mature planetary systems, detailed spectroscopic analysis of Jupiter-like planets, determining their composition and atmospheres, will be feasible. Study of the planets and small bodies in our Solar System will complement space missions.
When did galaxies form their stars?	When and where did the stars now in galaxies form? Precision studies of individual stars determine ages and the distribution of the chemical elements, keys to understanding galaxy assembly and evolution. Extension of such analyses to a representative section of the Universe is the next challenge in understanding the visible Universe.
How many super-massive black holes exist?	Do all galaxies host central monsters? When and how did super-massive black holes form and evolve in the nuclei of galaxies? Extreme resolution and sensitivity is needed to extend these studies to normal and low-mass galaxies in order to address these key puzzles.
When and where did the stars and the chemical elements form?	Can we meet the grand challenge to trace star formation back to the very first star ever formed? By finding and analyzing distant galaxies, gas clouds, and supernovae, the history of star formation and of the creation of the chemical elements can be fully quantified.

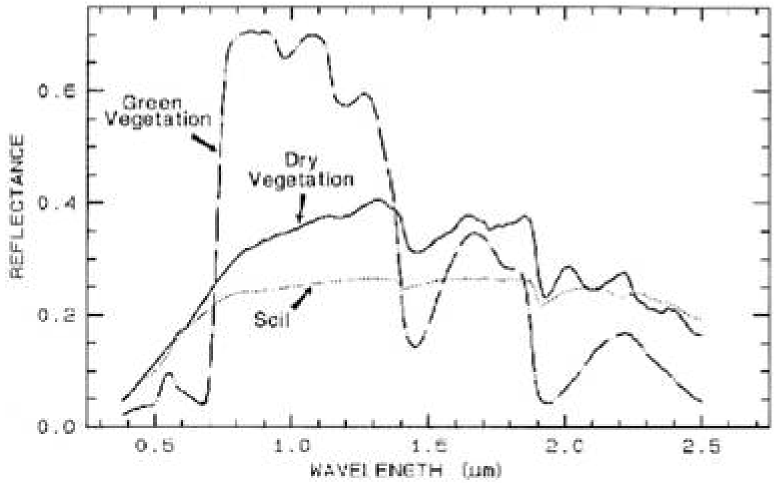
Primary science cases

What were the first objects?	Were stars the first objects to form? Were these first stars the source of the ultraviolet photons which re-ionized the Universe some 200 million years after the Big Bang, and made it transparent? These objects may be visible through their supernovae/hypernovae or their surrounding ionization zones.
How many types of matter exist? What is dark matter? Where is it?	Most matter does not emit any electromagnetic radiation and can be identifed only through its gravitational pull on surrounding visible objects. By mapping the detailed growth and kinematics of galaxies out to high redshifts, we can observe dark-matter structures in the process of formation.
What is dark energy? Does it evolve? How many types are there?	Direct mapping of space-time topology, using the most distant possible tracers, is the key to defining the dominant form of energy in the Universe. This is arguably the biggest single question facing not only astrophysics but also fundamental physics as a whole.
Extending the age of discovery	In the last decades astronomy has revolutionized our knowledge of the Universe and established it as the ultimate physics laboratory. The next big steps are likely to be discoveries of unimagined new physical processes.

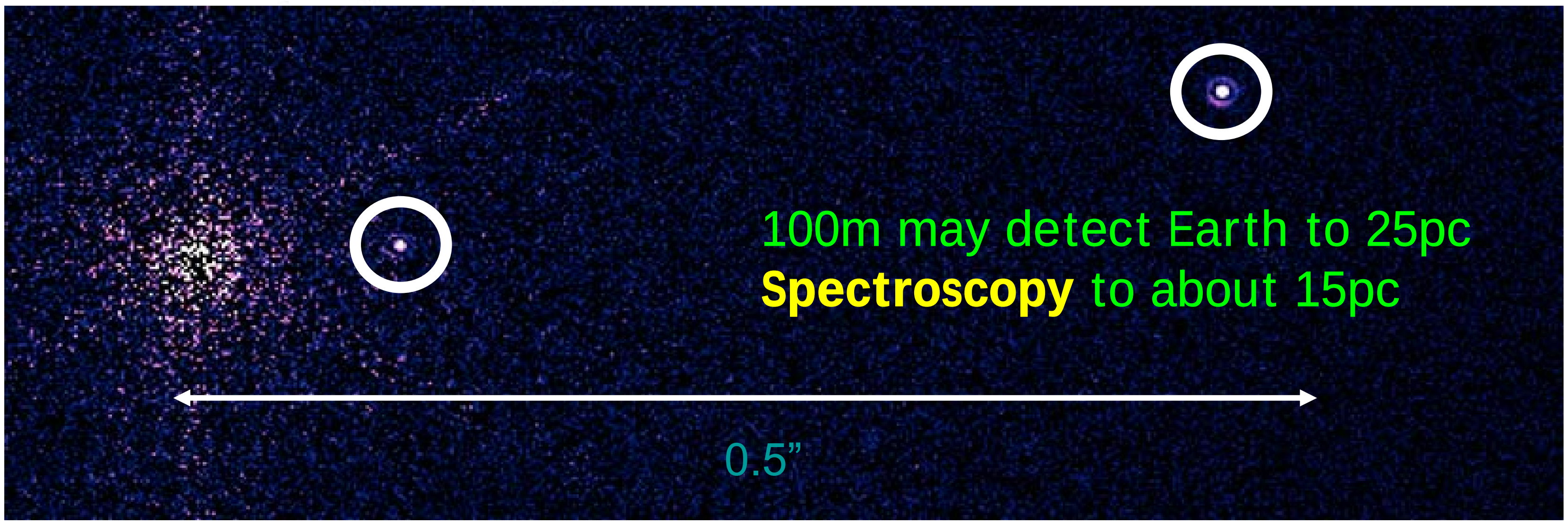
- Highlight science cases:
  - Terrestrial exo-planets,
  - Resolved stellar populations in a representative section of the Universe,
  - First lights and the re-ionization history of the Universe

To detect exo-earths one needs large diameter

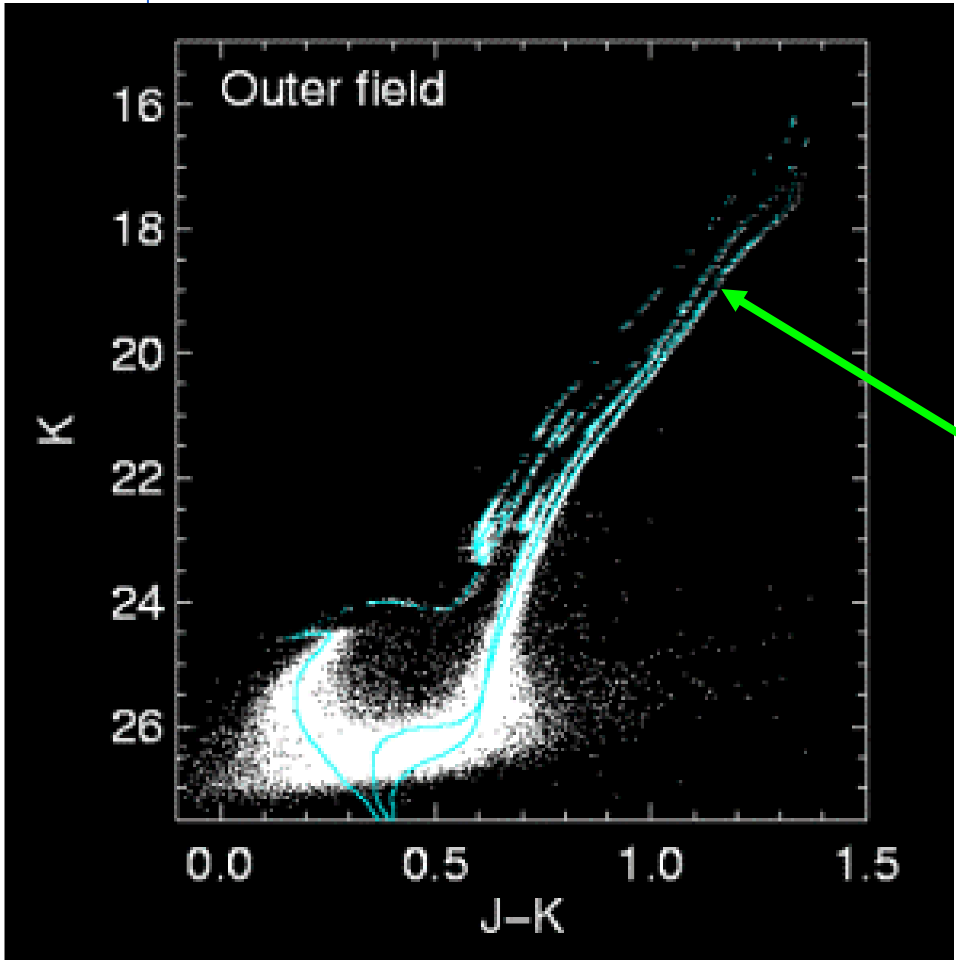




Possible life signatures in spectrum



Resolved Stellar populations and Galaxy Formation



Simulated M32 CM Diagram Observed with 30-m Telescope *from GSMT study*

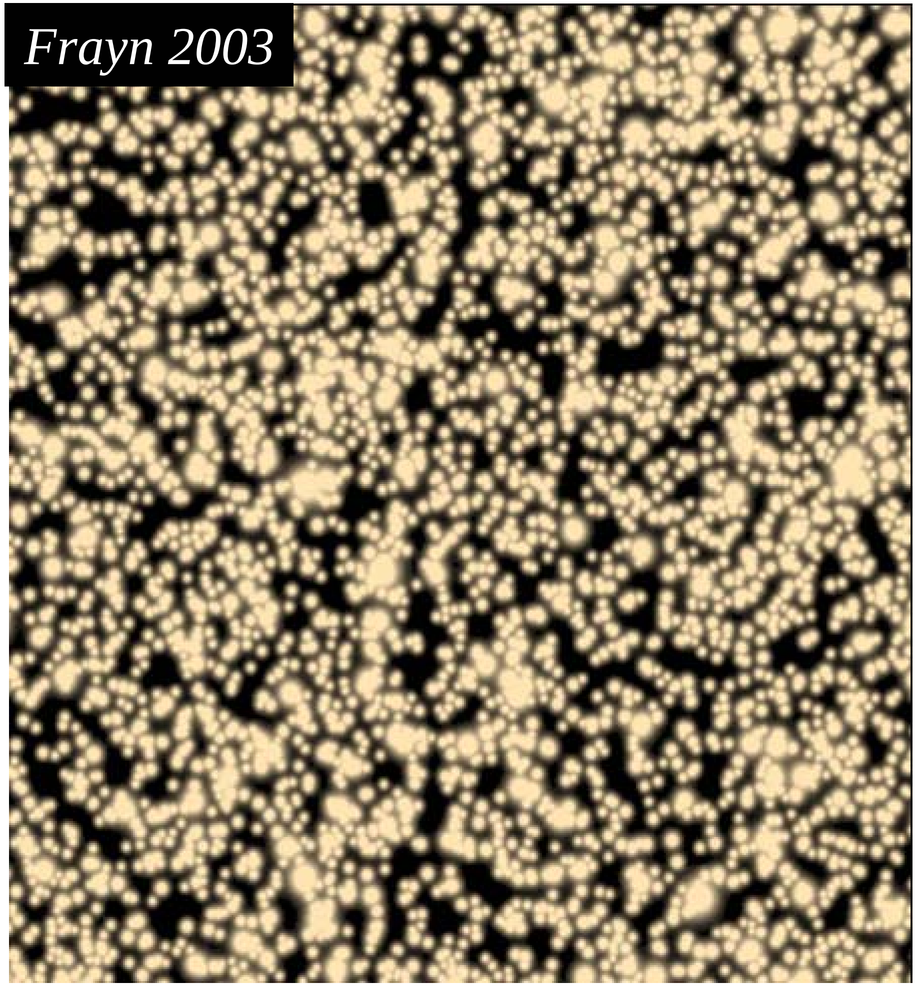
- We can learn a lot about the formation and evolution of our nearby neighbours with a 30-m telescope

E.g. Colour-mag diagram reveals multiple stellar pops

- What about a more representative slice of the Universe?

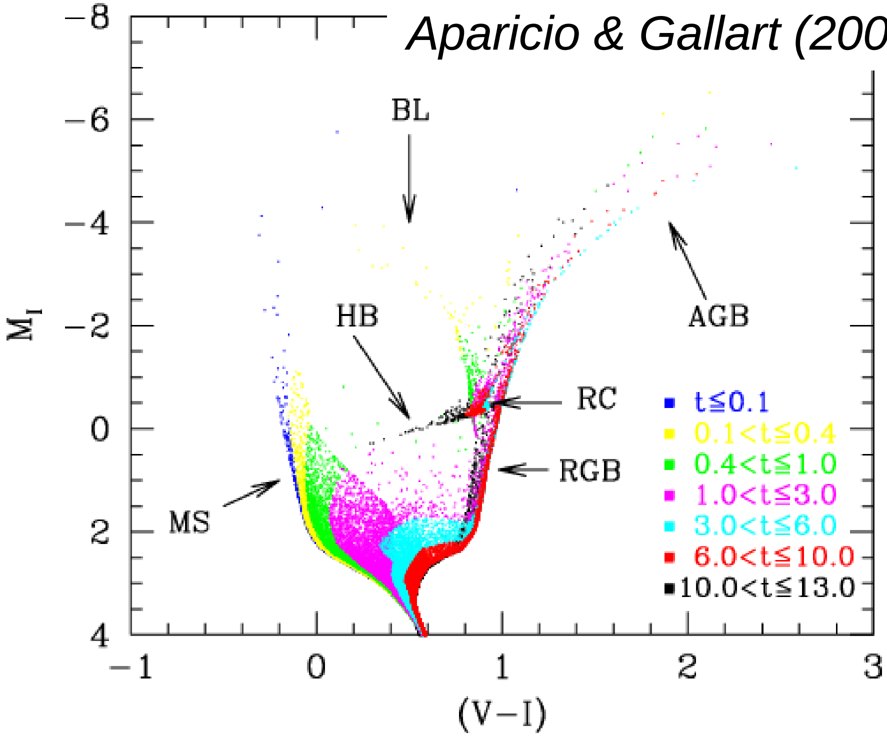
Simulated M87 field

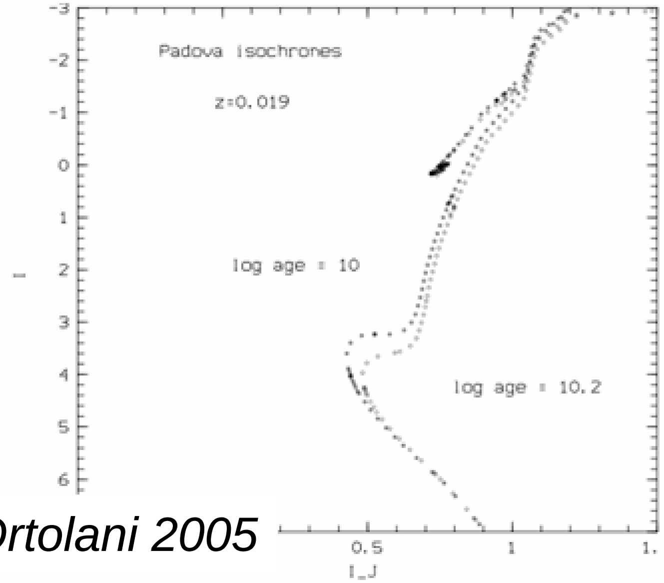
Frayn 2003



- 3 hour exposure
- Diffraction-limited observation
- Outer field (μI = 28)
- Realistic IMF plus population synthesis to two magnitudes below MSTO

Aparicio & Gallart (2004)





Ortolani 2005

Primordial Stellar Populations

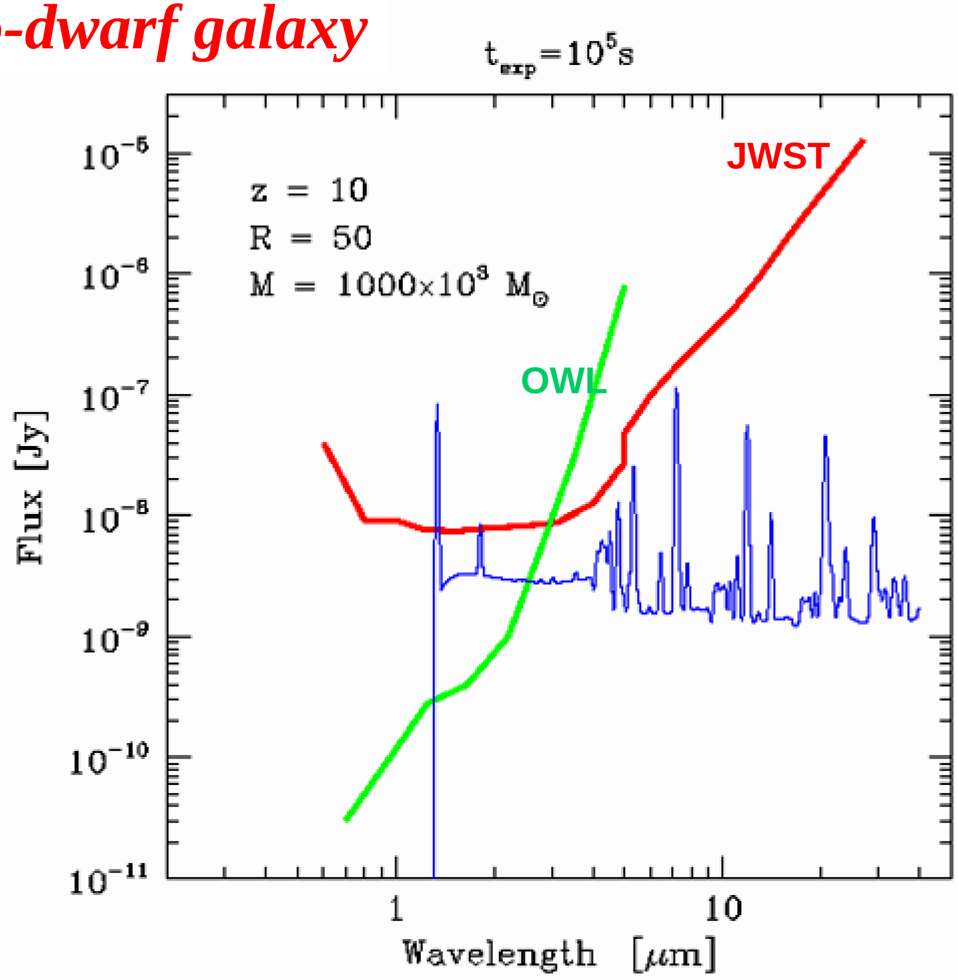
- Primordial stars (aka population III stars) form before re-ionization, say, at z=10-20
- They are hot and massive, and may form preferentially in dwarf-galaxy class overdensities $\Rightarrow M \approx 10^6\text{-}10^7\ M_\odot$
- Their spectra are characterized by strong emission lines of H and He and strong nebular continuum

Primordial Stellar Populations

A typical proto-dwarf galaxy

Both continuum and line spectrum can accurately be studied with OWL at high z

Thus detecting and characterizing the first-light objects in the Universe

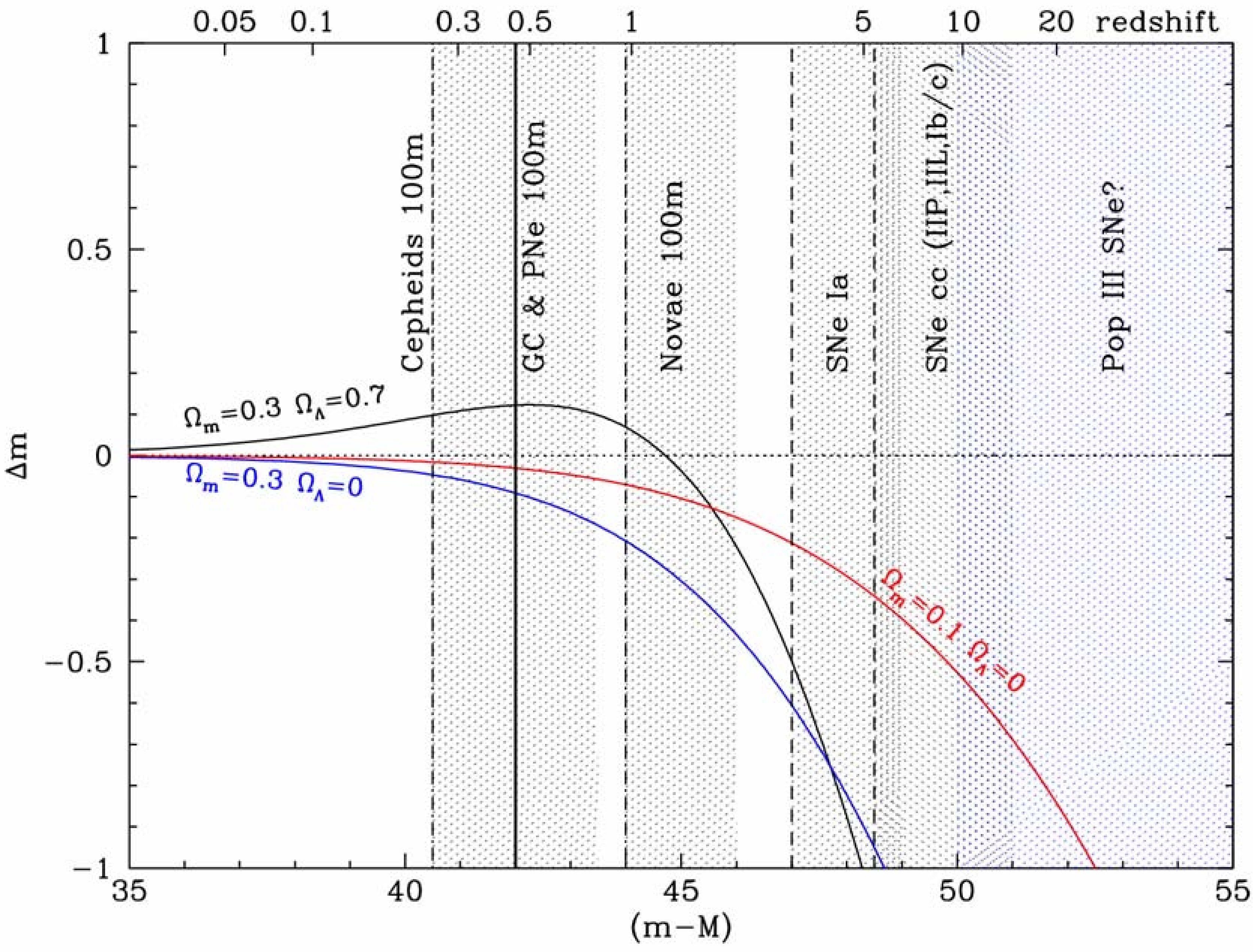


Cosmological parameters

- Measure of cosmic parameters with primary distance indicators
  - Note: NOT H_NOT ☺
  - Complex SNe Ia calibration
    - Derived + calibrated standard candles
    - Phillips relationship (1993):
      - Empirical relation M_{max} *vs* rate of decline
      - Difficult to calibrate at high *z*
    - Progenitors: single or double degenerate?
- OWL provides several alternatives

Cosmological parameters cont'd

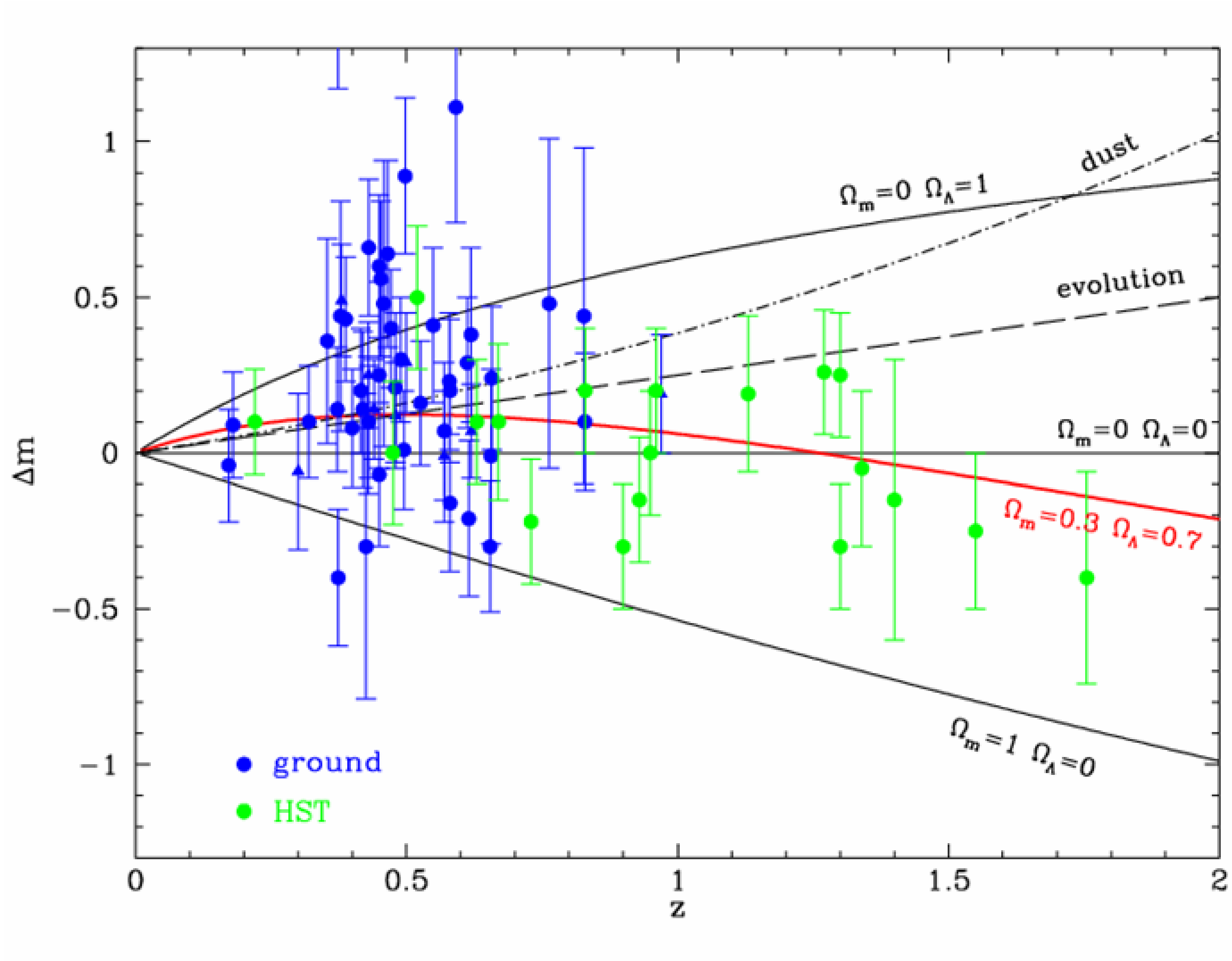
- Disentangling models at $z \sim 1$
  - **Domain of <u>primary</u> indicators:**
    - **Cepheids**: P-L
      - (direct SFR; analog to HST@Virgo)
    - **Globular Clusters**: turnover mag of LF
    - **Bright PNe**: cutoff mag of LF
    - **Novae**: MMRD
      - (visible in *all* galaxy types)



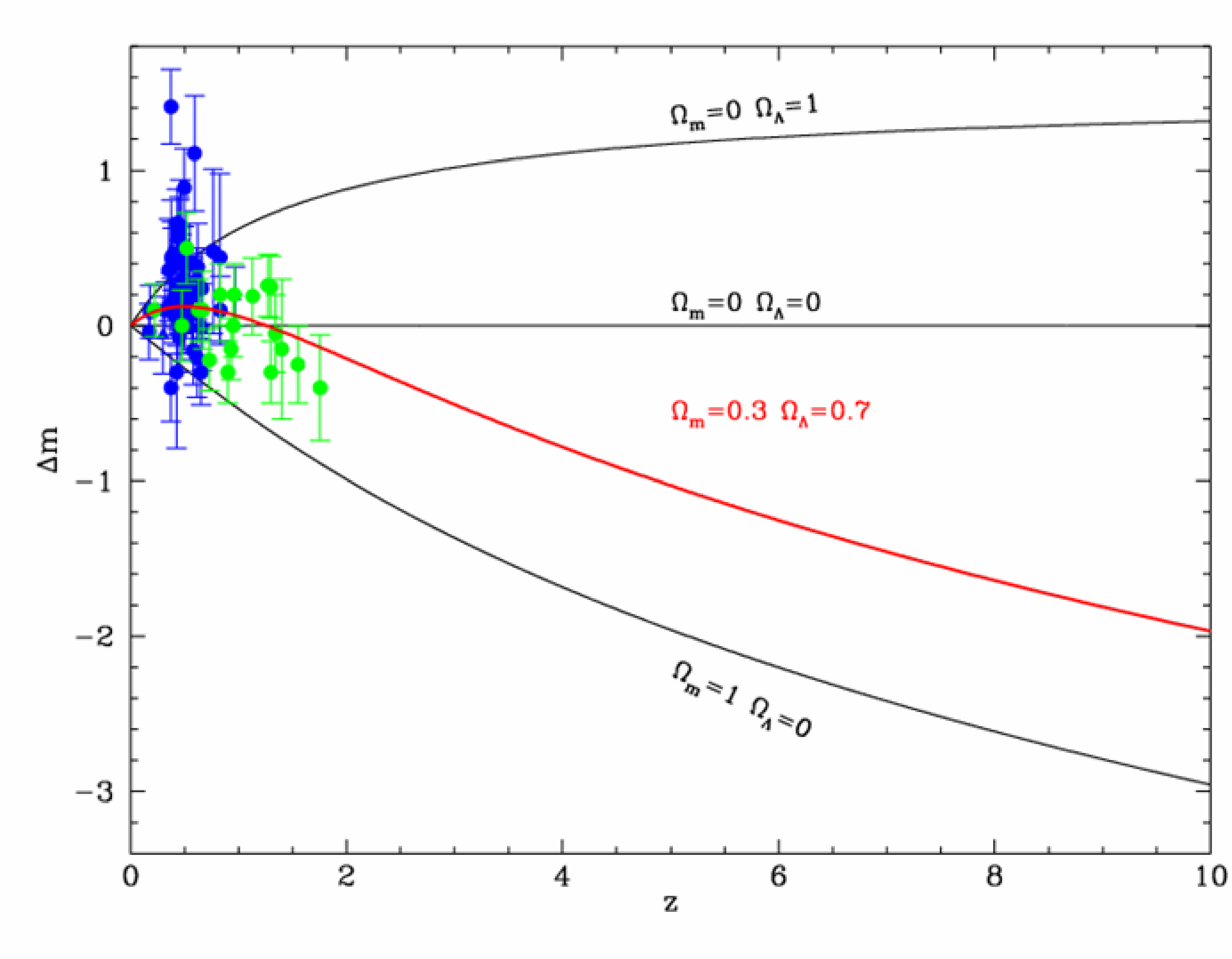
0.05
0.1
0.3
0.5
1
5
10
20
redshift
Cepheids 100m
GC & PNe 100m
Novae 100m
SNe Ia
SNe cc (IIP,IIL,Ib/c)
Pop III SNe?
Ω_m=0.3 Ω_Λ=0.7
Ω_m=0.3 Ω_Λ=0
Ω_m=0.1 Ω_Λ=0
Δm
(m−M)
1
0.5
0
−0.5
−1
35
40
45
50
55

Science with OWL: a practical case

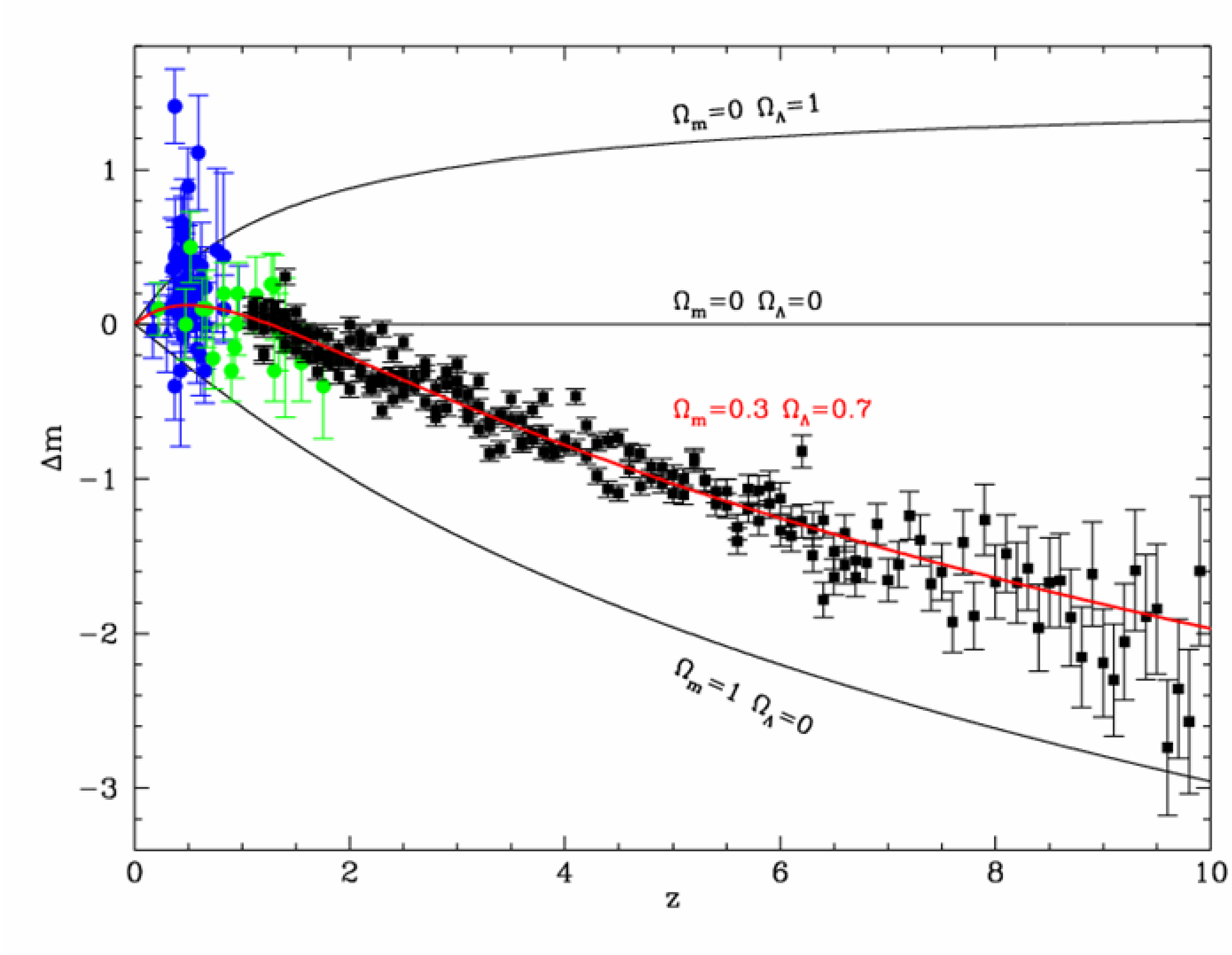
- The cosmic SN rate up to z ~ 10
  - Simulations of OWL observations yield:
    - Jx3+Hx3+Kx7: ≥ 200 SNe (extrapolating Miralda & Riess 1997) or ≥ 400 SNe (MDP 1998)
      - Light curves, photometric redshifts (galaxy & SN)
    - Spectroscopy $\Re$~50: ~ 50-100 SNe at z < 4.5
  - Spectral classification:
    - **SNe Ia visible up to z ~ 5**
      - Blind below 2400A, K last useful band
    - **SNe II visible up to z ~ 10**
      - Strong UV emitters (time-dilated UV flash)
    - **Pop III SNe (?)**
      - Possibly much brighter and visible to z ~ 20



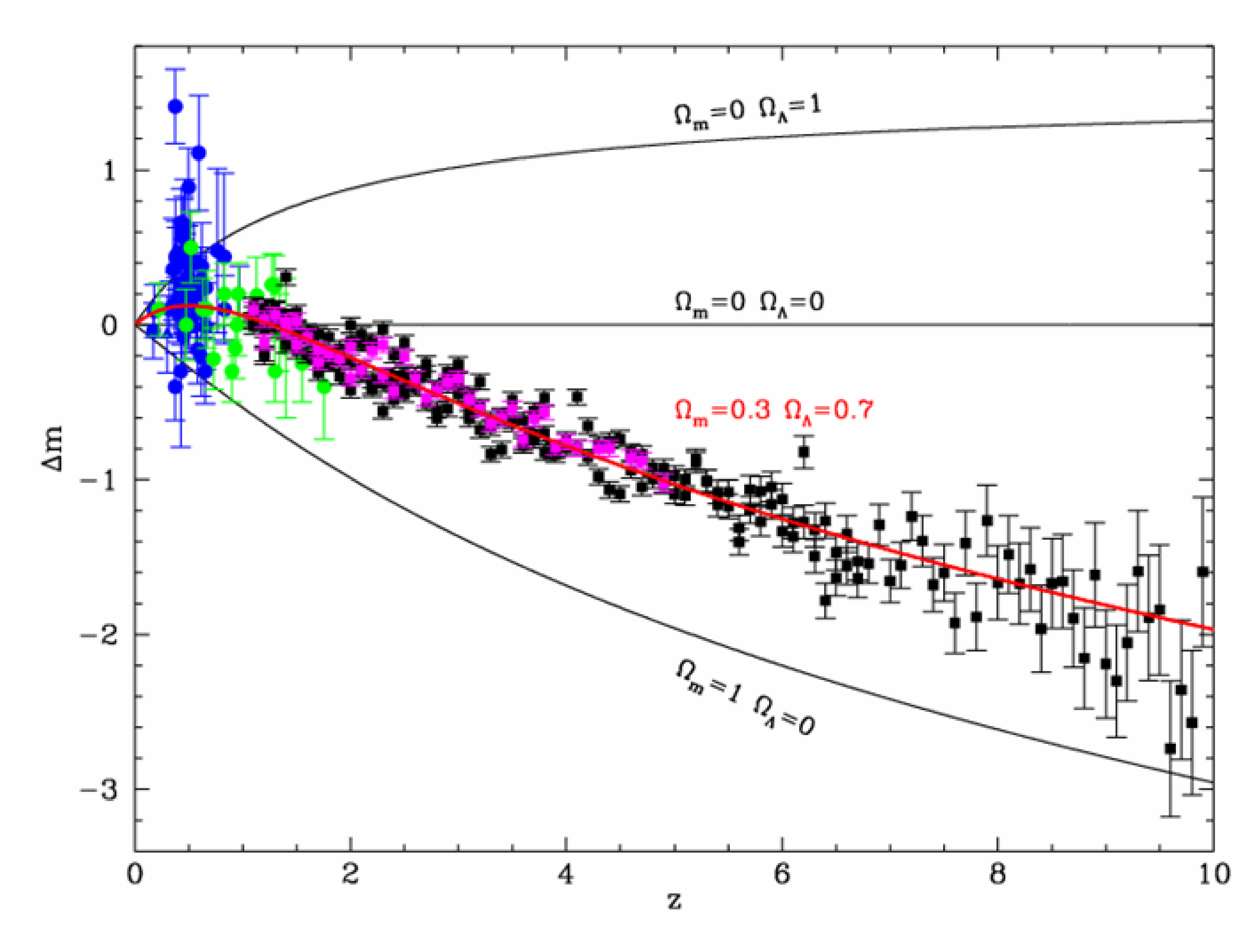
1
0.5
0
−0.5
−1
Δm
0
0.5
1
1.5
2
z
dust
Ωm=0 ΩΛ=1
evolution
Ωm=0 ΩΛ=0
Ωm=0.3 ΩΛ=0.7
Ωm=1 ΩΛ=0
ground
HST



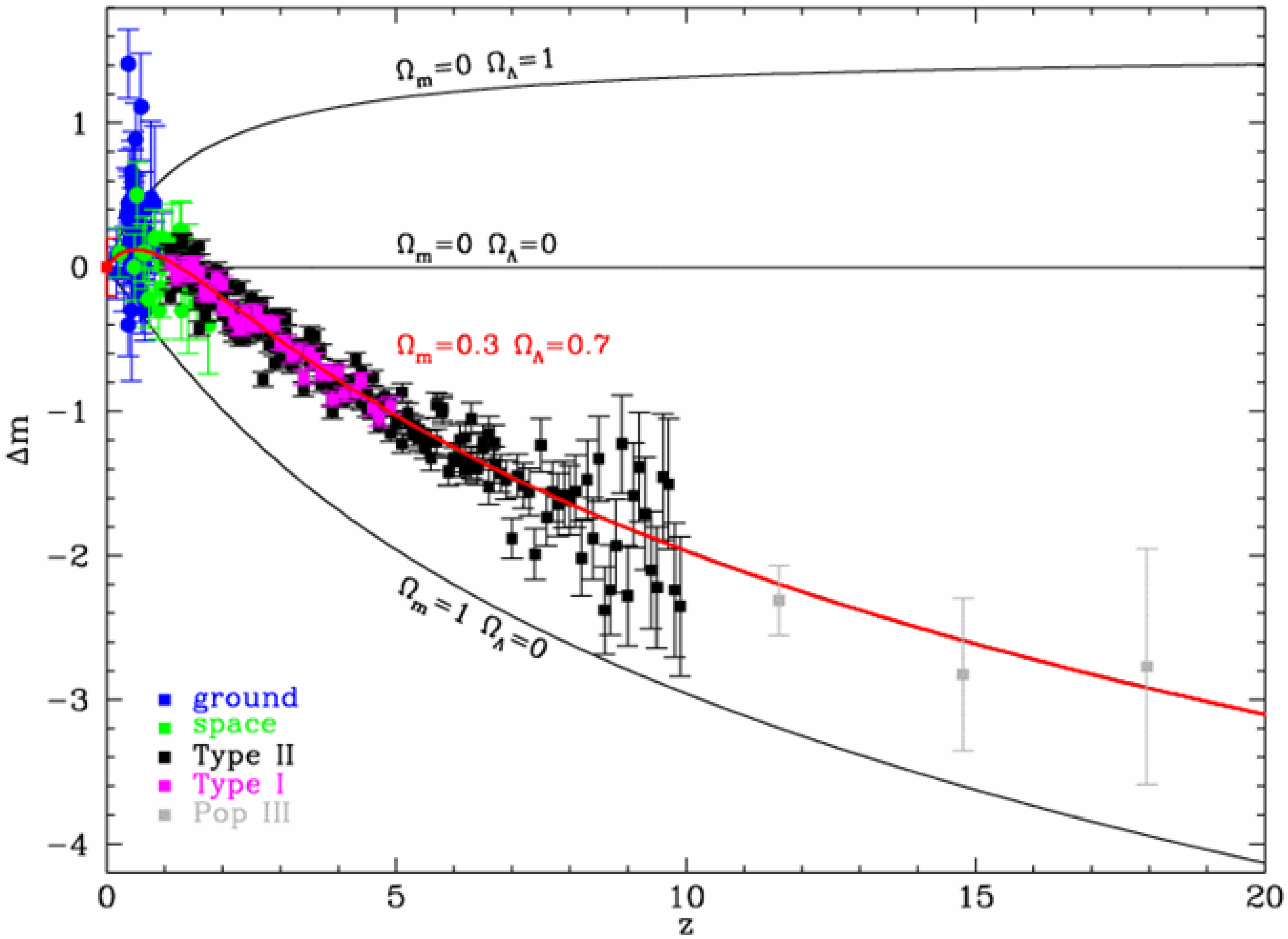
$\Omega_m=0\ \Omega_\Lambda=1$
$\Omega_m=0\ \Omega_\Lambda=0$
$\Omega_m=0.3\ \Omega_\Lambda=0.7$
$\Omega_m=1\ \Omega_\Lambda=0$
Δm
z
1
0
−1
−2
−3
0
2
4
6
8
10



$\Omega_m=0$ $\Omega_\Lambda=1$
$\Omega_m=0$ $\Omega_\Lambda=0$
$\Omega_m=0.3$ $\Omega_\Lambda=0.7$
$\Omega_m=1$ $\Omega_\Lambda=0$
Δm
z
1
0
−1
−2
−3
0
2
4
6
8
10

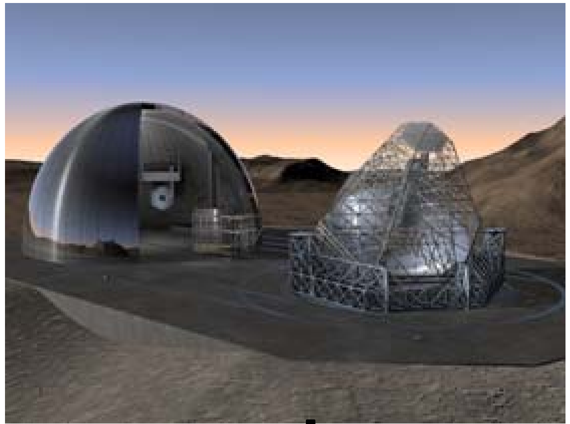


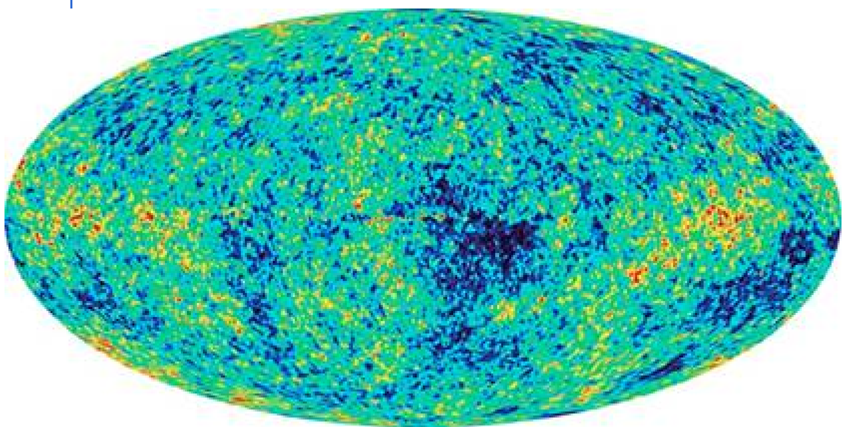
$\Omega_m=0$ $\Omega_\Lambda=1$
$\Omega_m=0$ $\Omega_\Lambda=0$
$\Omega_m=0.3$ $\Omega_\Lambda=0.7$
$\Omega_m=1$ $\Omega_\Lambda=0$
Δm
z

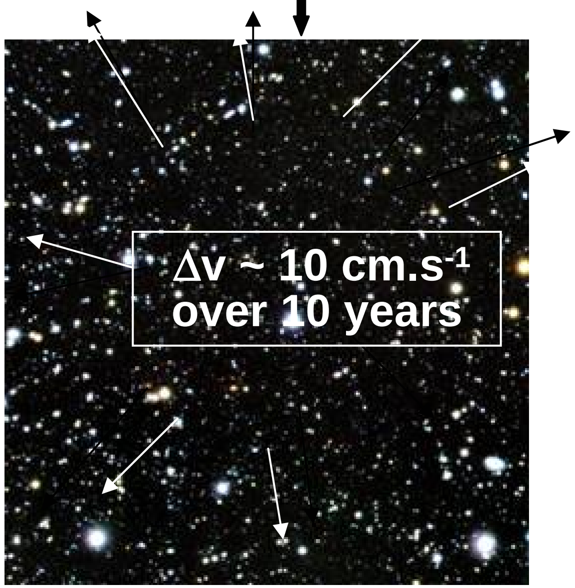


$\Omega_m=0\ \Omega_\Lambda=1$
$\Omega_m=0\ \Omega_\Lambda=0$
$\Omega_m=0.3\ \Omega_\Lambda=0.7$
$\Omega_m=1\ \Omega_\Lambda=0$
ground
space
Type II
Type I
Pop III
Δm
z
1
0
−1
−2
−3
−4
0
5
10
15
20

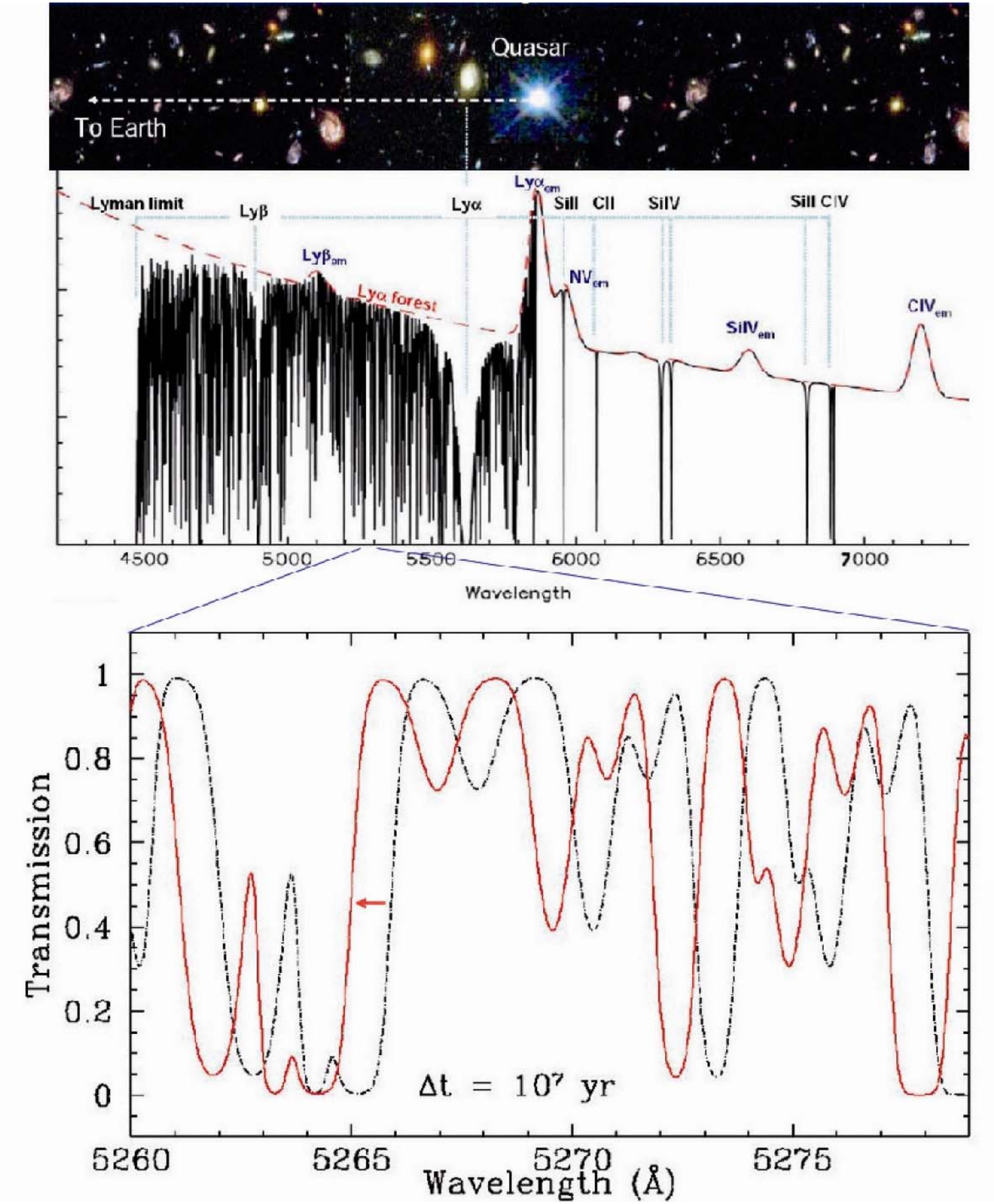
Direct Measurement of *q*



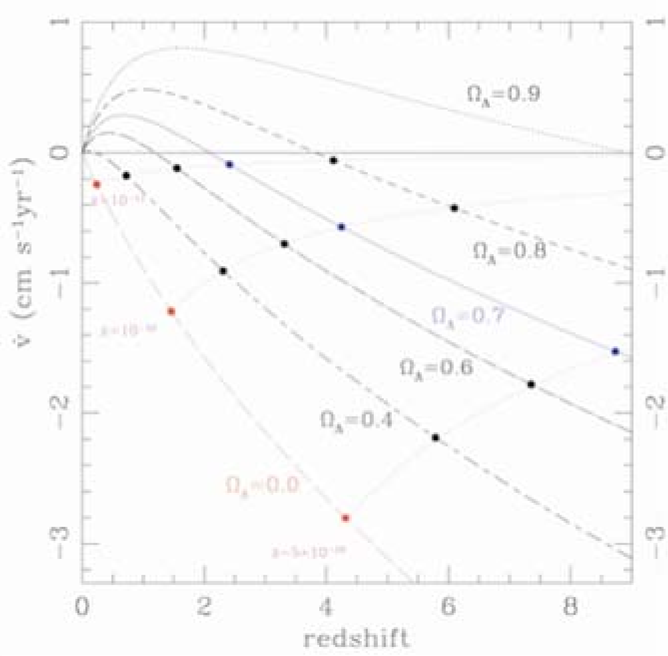




As for WMAP, this experiment with OWL would provide a direct cosmological measurement , albeit a different one: the Universe acceleration around z ~ 5



Accuracy ~ 1 cm s^{-1} yr^{-1}



Legacy program