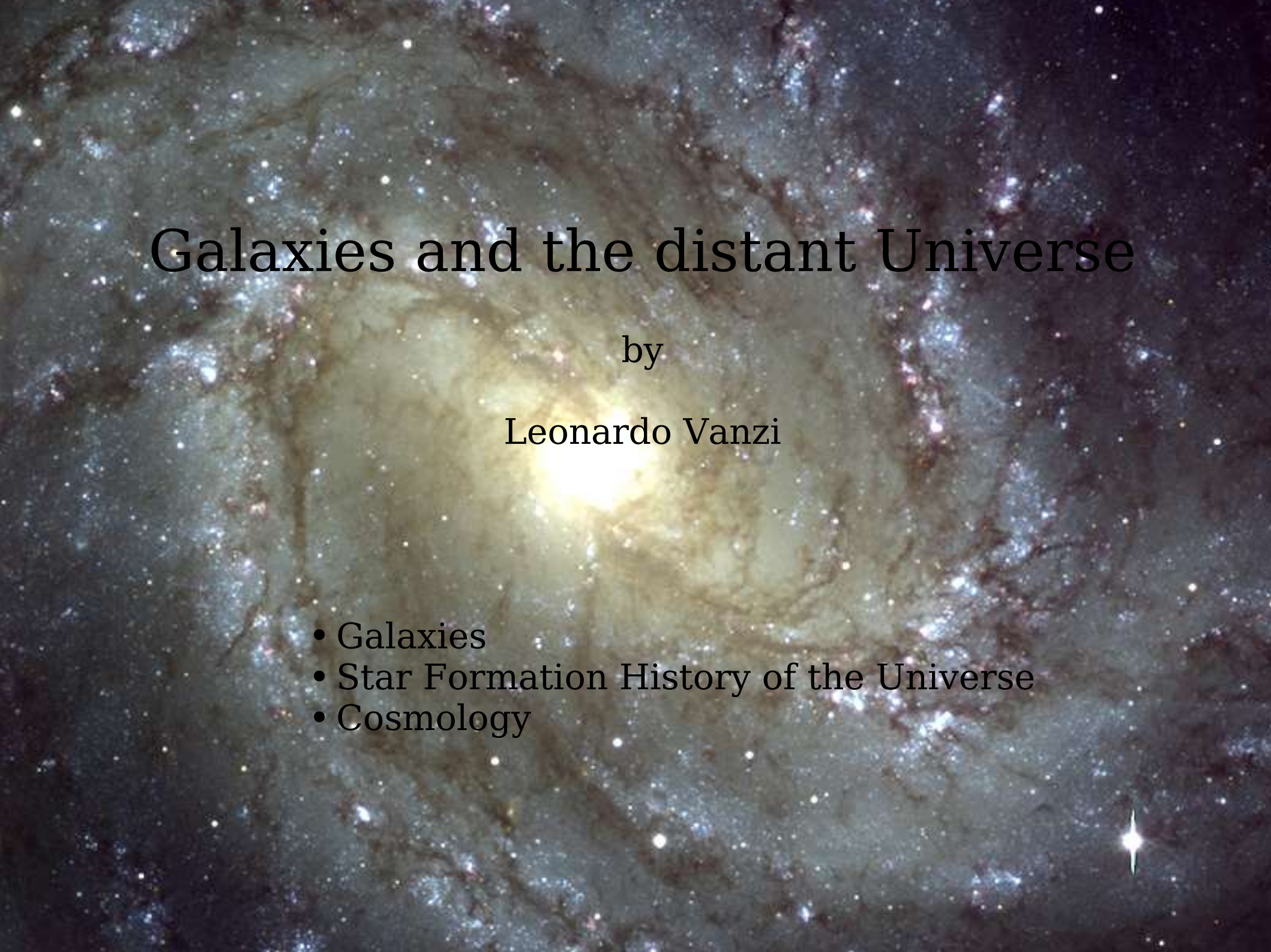


Galaxies and the distant Universe

by

Leonardo Vanzi

- Galaxies
- Star Formation History of the Universe
- Cosmology

History:

1610 – Galileo resolved the Milky Way in a multitude of stars

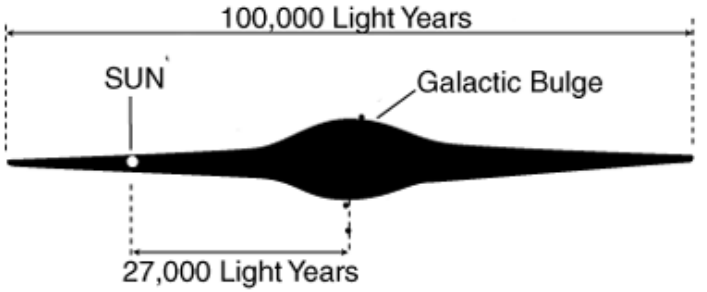
1781 – Messier published a catalog of 110 deep sky objects

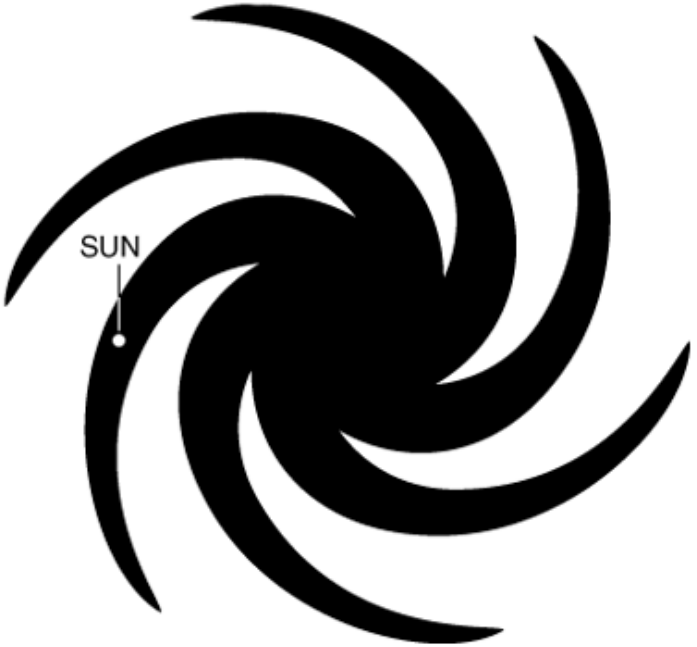
1845 – Lord Rosse observed spirals and ellipticals

1910 – Slipher obtained spectra of… spiral nebula

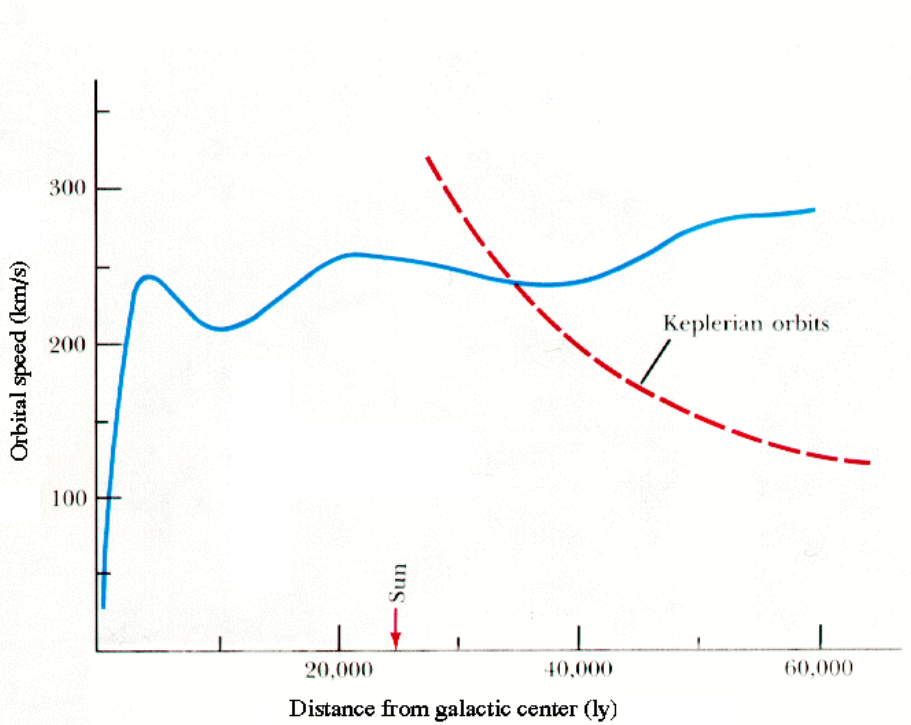
1930 – Hubble measured the distance of M31 and other… galaxies!

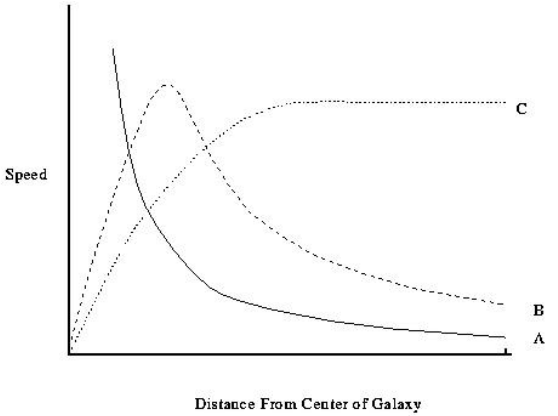
1951 – Observation of HI at 21 cm


100,000 Light Years
SUN
Galactic Bulge
27,000 Light Years


SUN

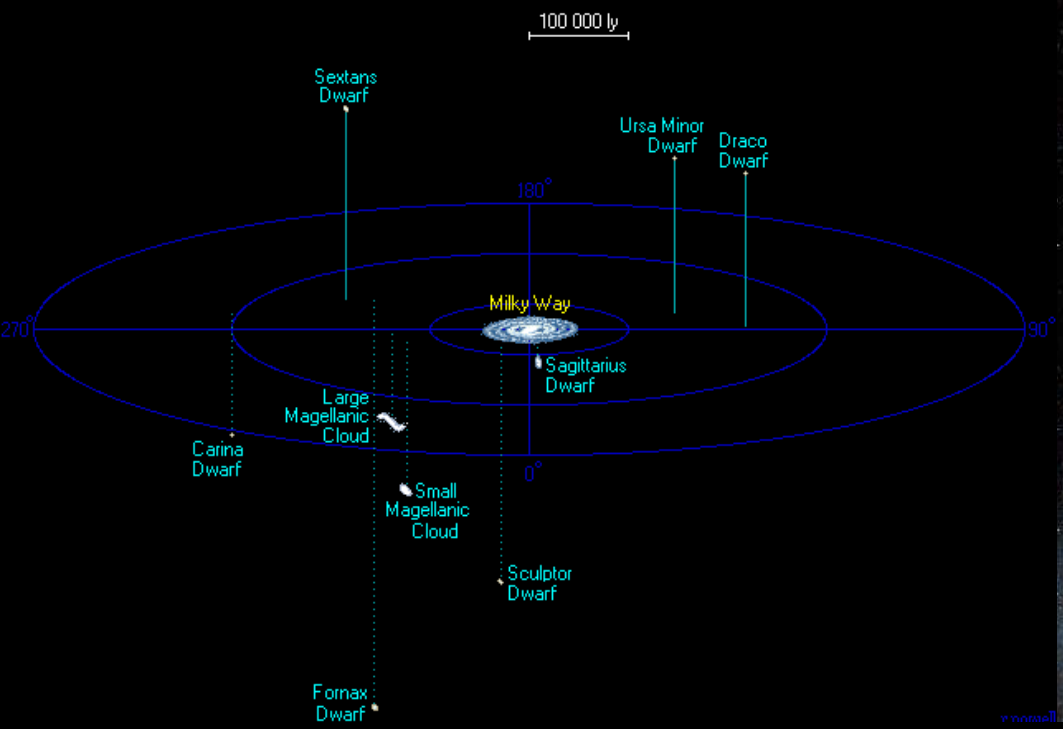
Concept 1 – Dark Matter

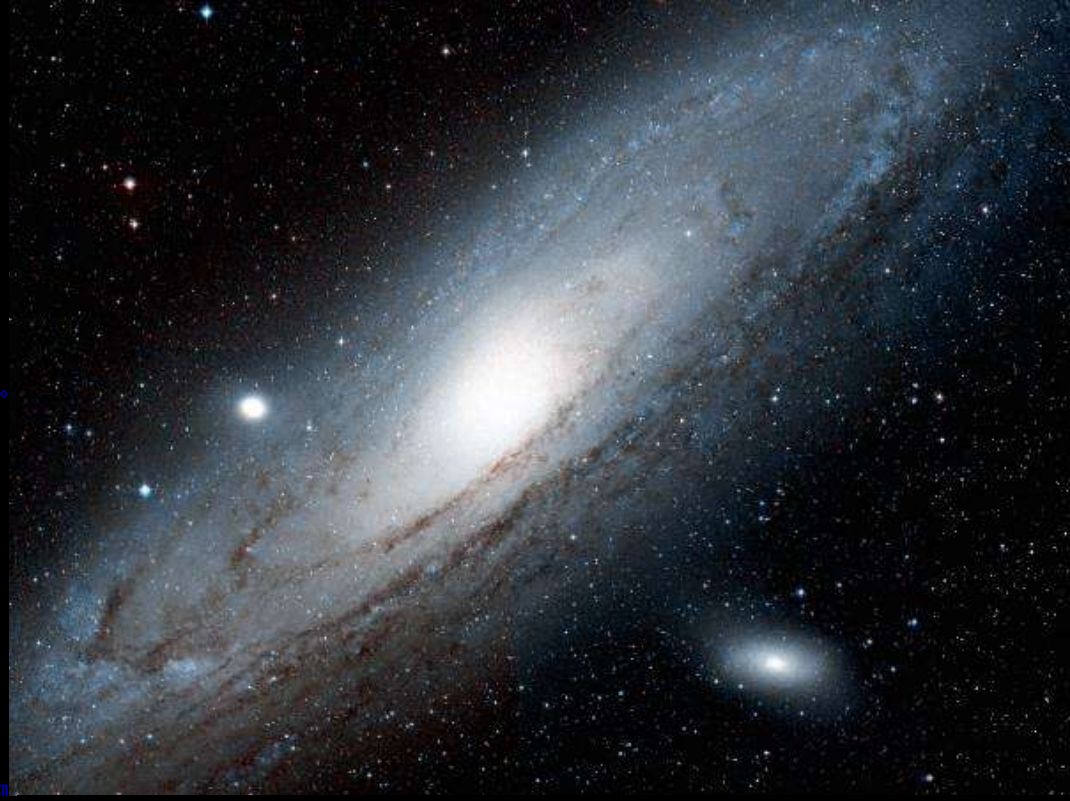




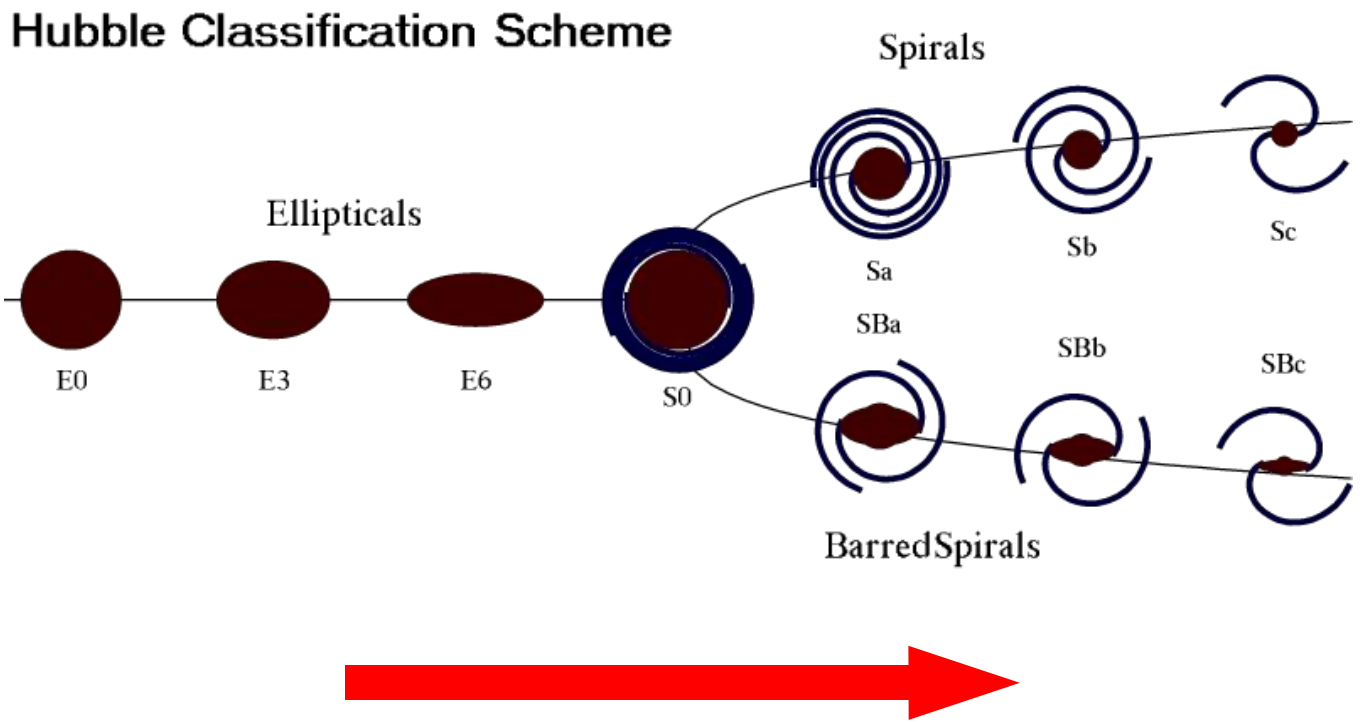
$M_{vis} = 2\ 10^{11}\ M_{sun}$

$M_{tot} = 6\ 10^{11}\ M_{sun}$

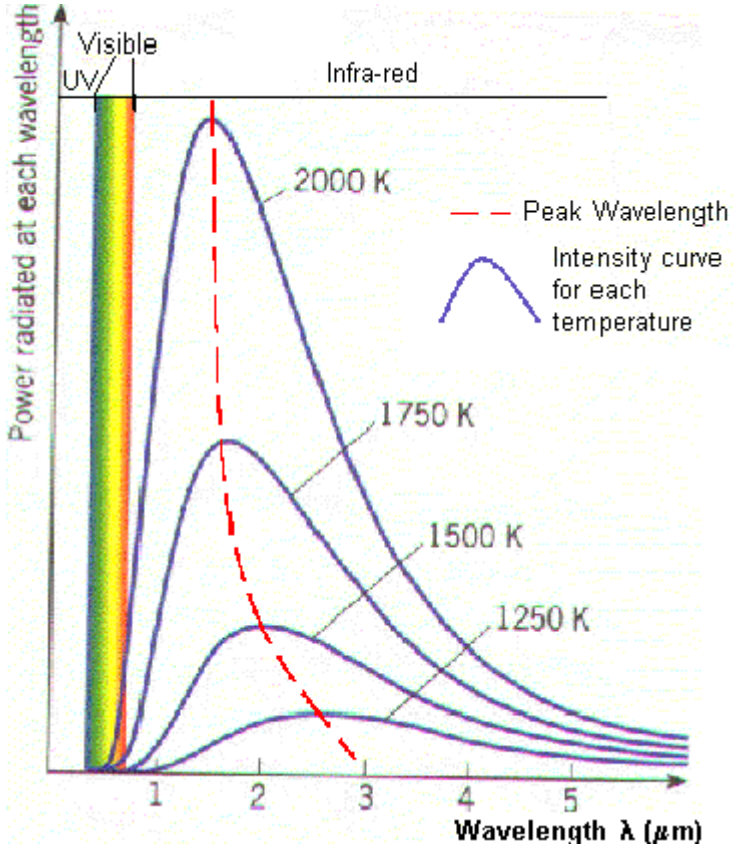

100 000 ly
Sextans Dwarf
Ursa Minor Dwarf
Draco Dwarf
180°
Milky Way
270°
90°
Sagittarius Dwarf
Large Magellanic Cloud
Carina Dwarf
0°
Small Magellanic Cloud
Sculptor Dwarf
Fornax Dwarf

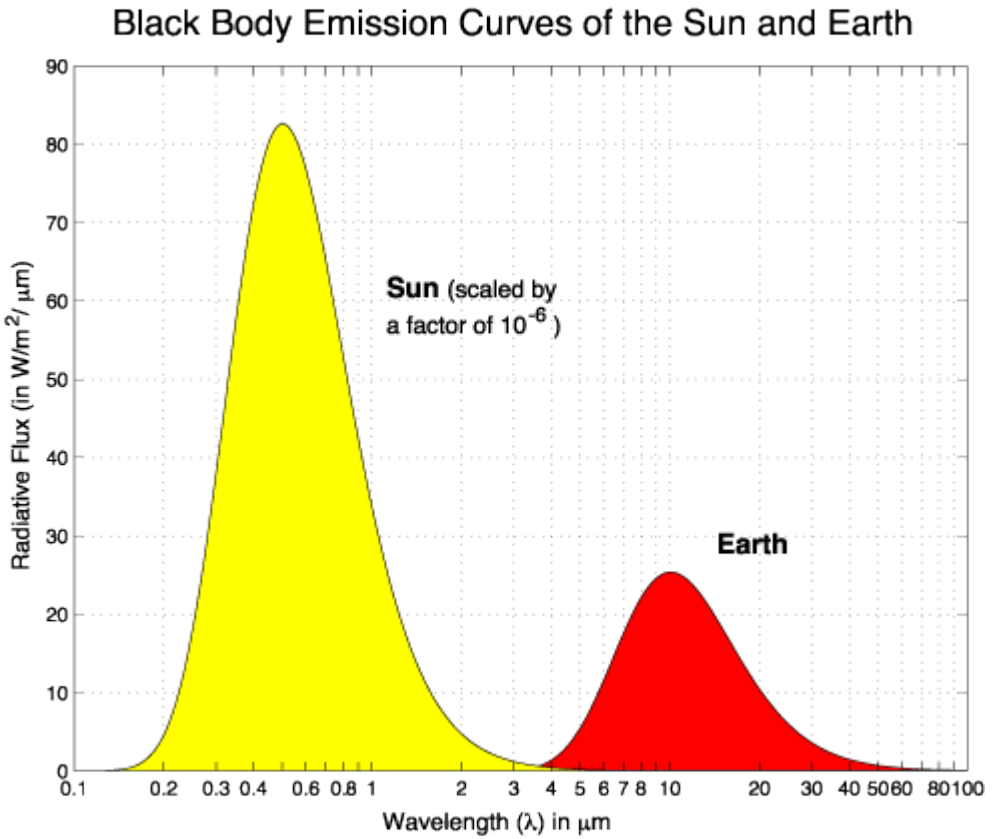


Sextans A
Sextans B
1 millllion ly
Leo A
NGC 3109
Antlia Dwarf
180°
Leo I
Leo II
NGC 185
NGC 147
M110
IC 10
II
Milky Way
270°
90°
Andromeda Galaxy
NGC 6822
M32
Triangulum Galaxy
Andromeda II, III and I
Phoenix Dwarf
0°
Pegasus Dwarf
IC 1613
Tucana Dwarf
Cetus Dwarf
LGS 3
Aquarius Dwarf
WLM
Sagittarius Dwarf Irregular


Hubble Classification Scheme
Spirals
Ellipticals
E0
E3
E6
S0
Sa
Sb
Sc
SBa
SBb
SBc
BarredSpirals

Concept 2 - Black Body Radiation

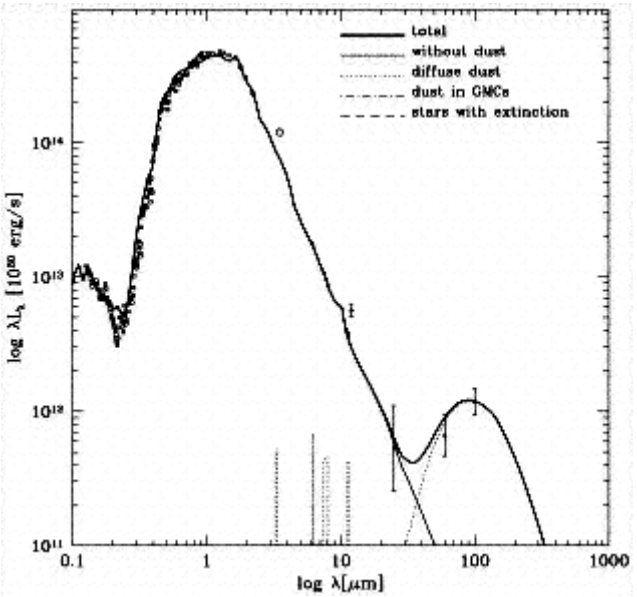


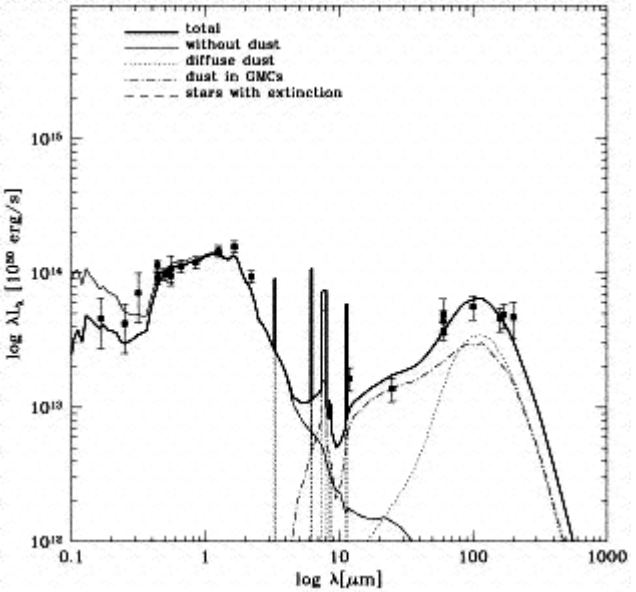


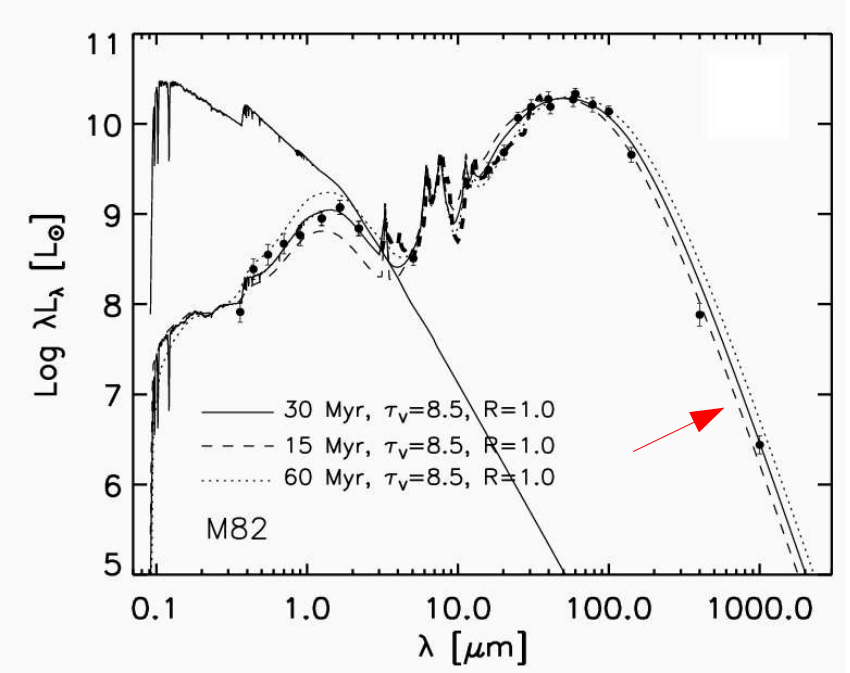
Wien's law:

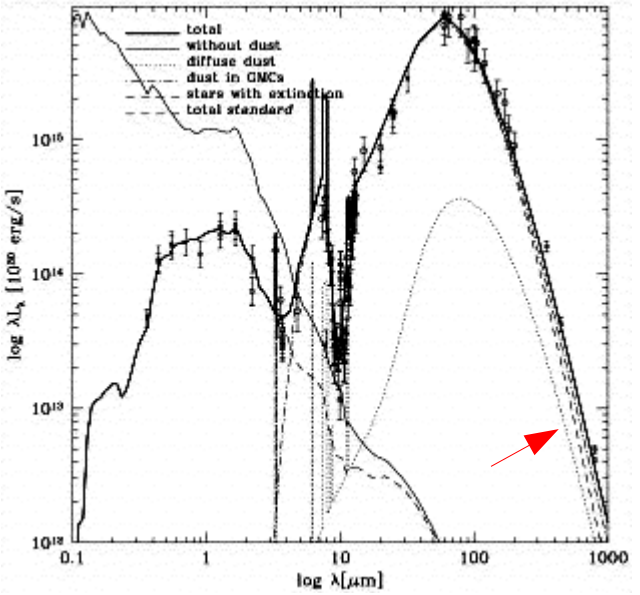
$\lambda_{max}(\mu m)=2898/T$

The Spectral Energy Distribution (SED)

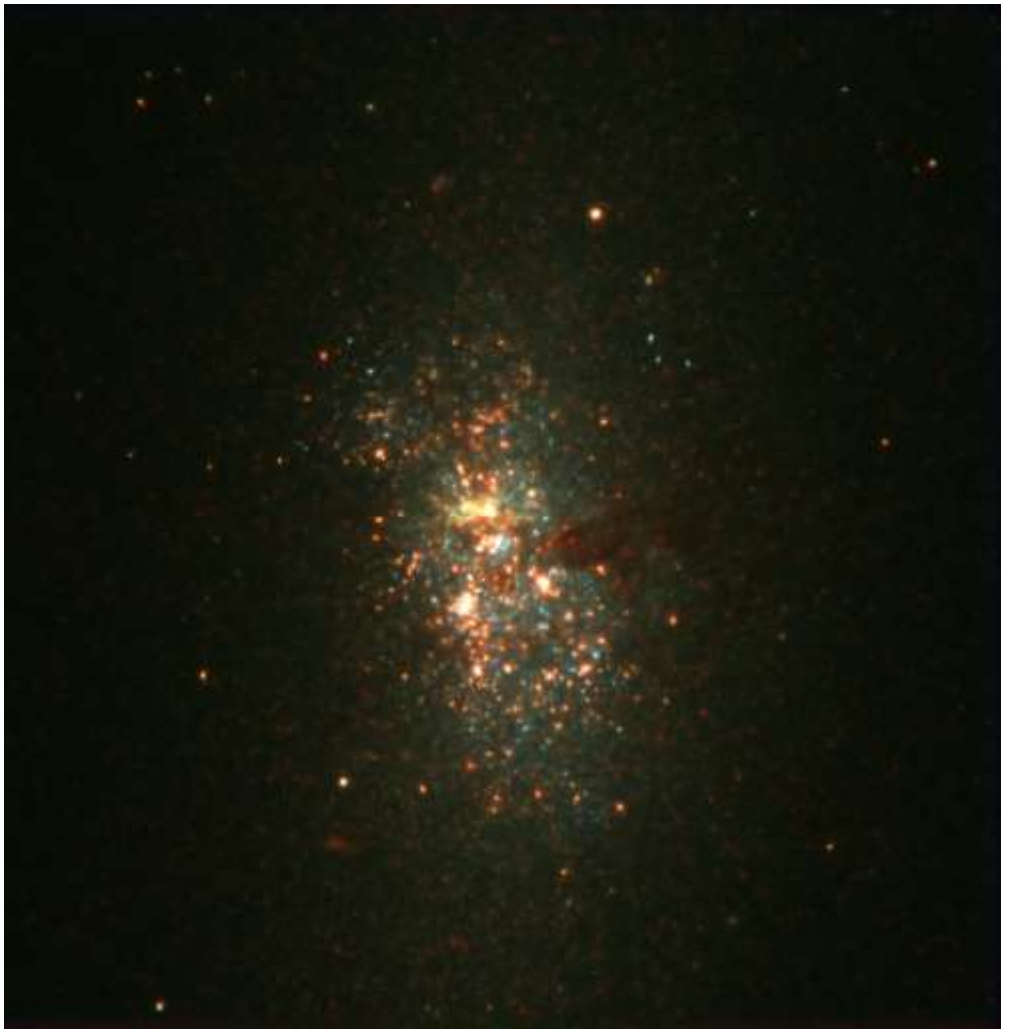


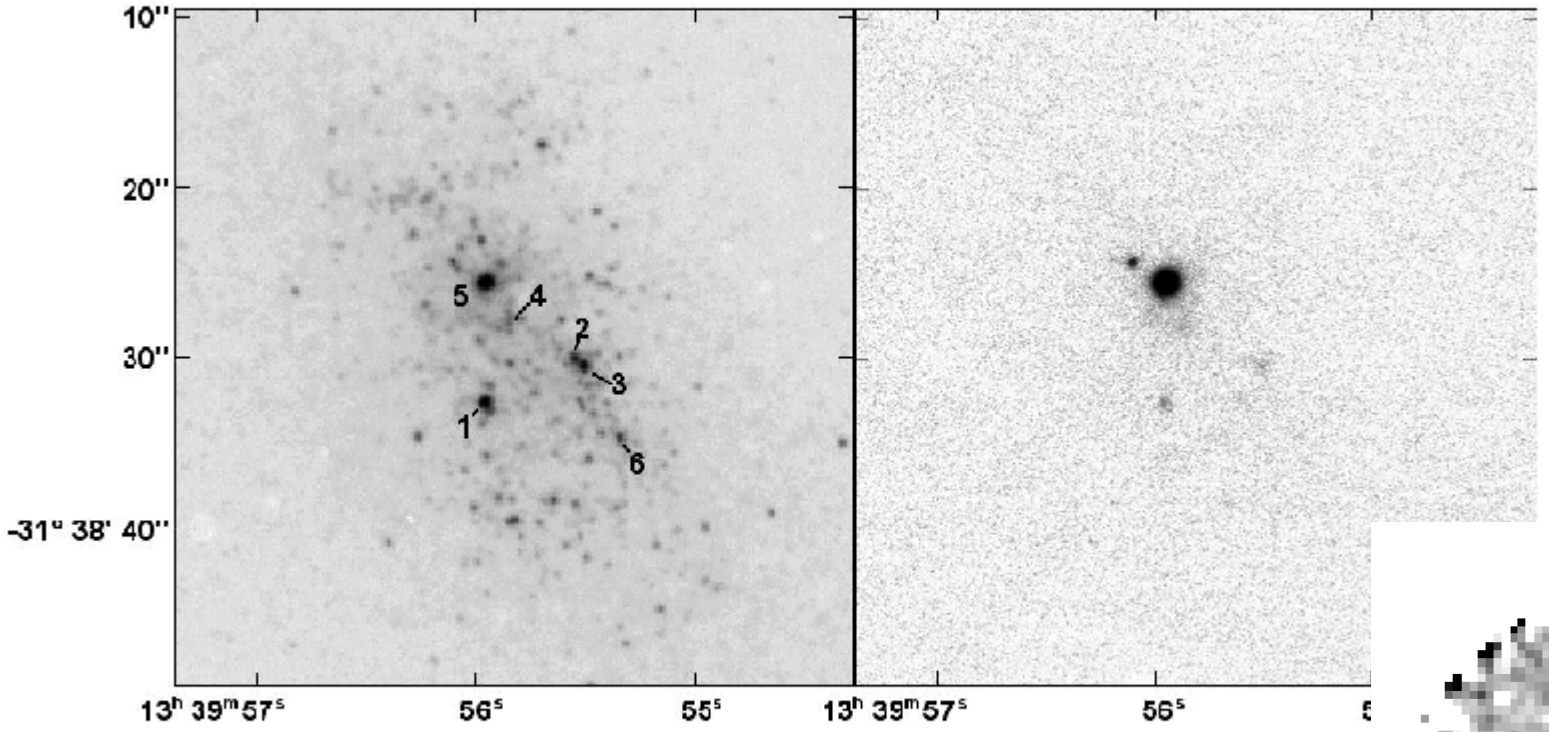


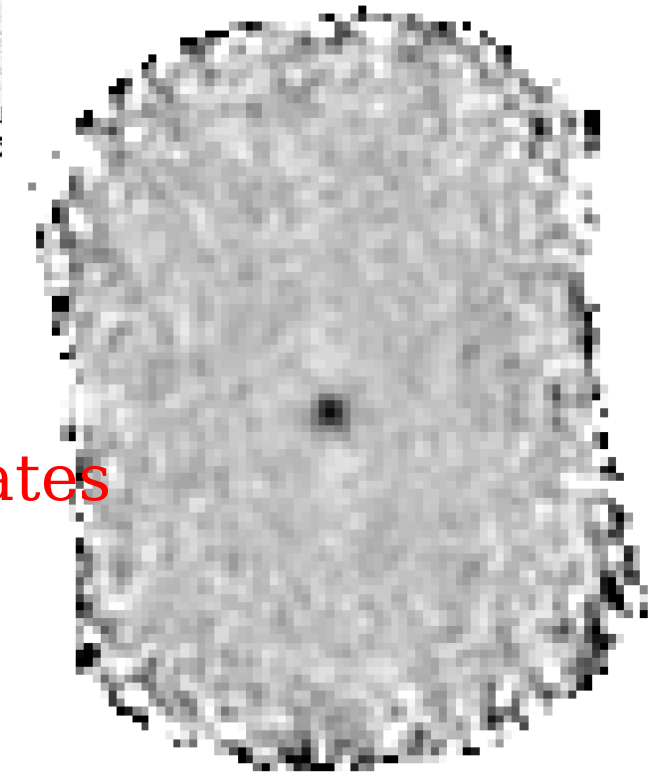




Star Formation in Dwarf Galaxies – NGC 5253



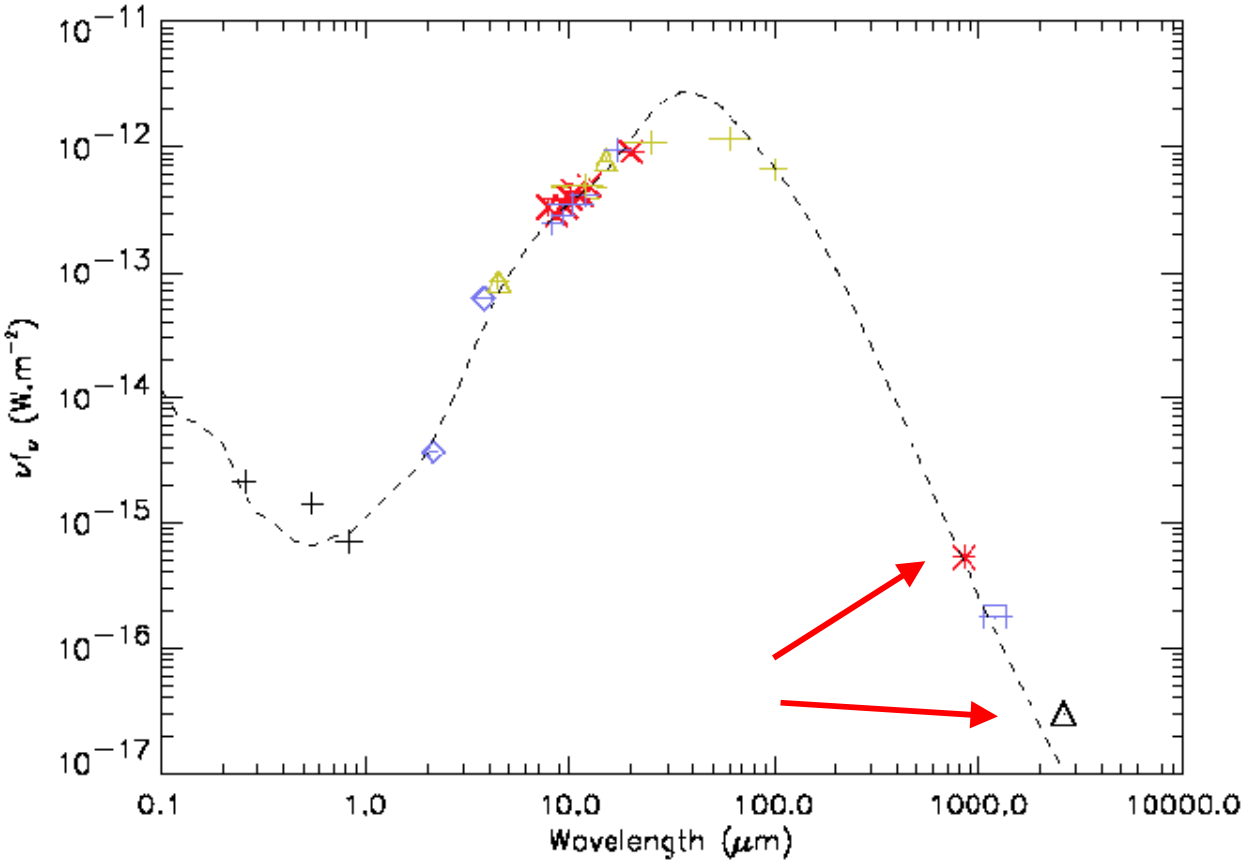




Beyond 2 μm one bright source dominates the emission from NGC 5253

Vanzi & Sauvage 2004

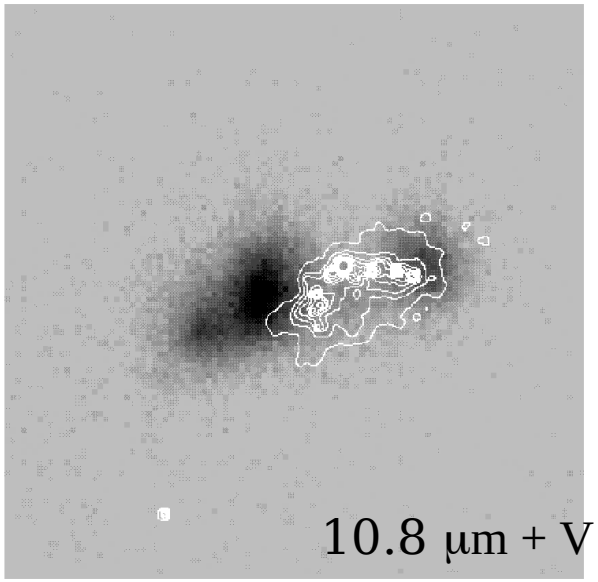
The SED of NGC5253 - 5

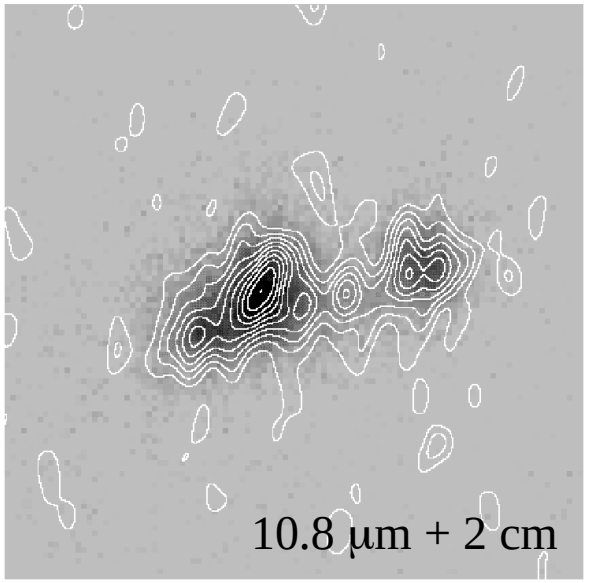


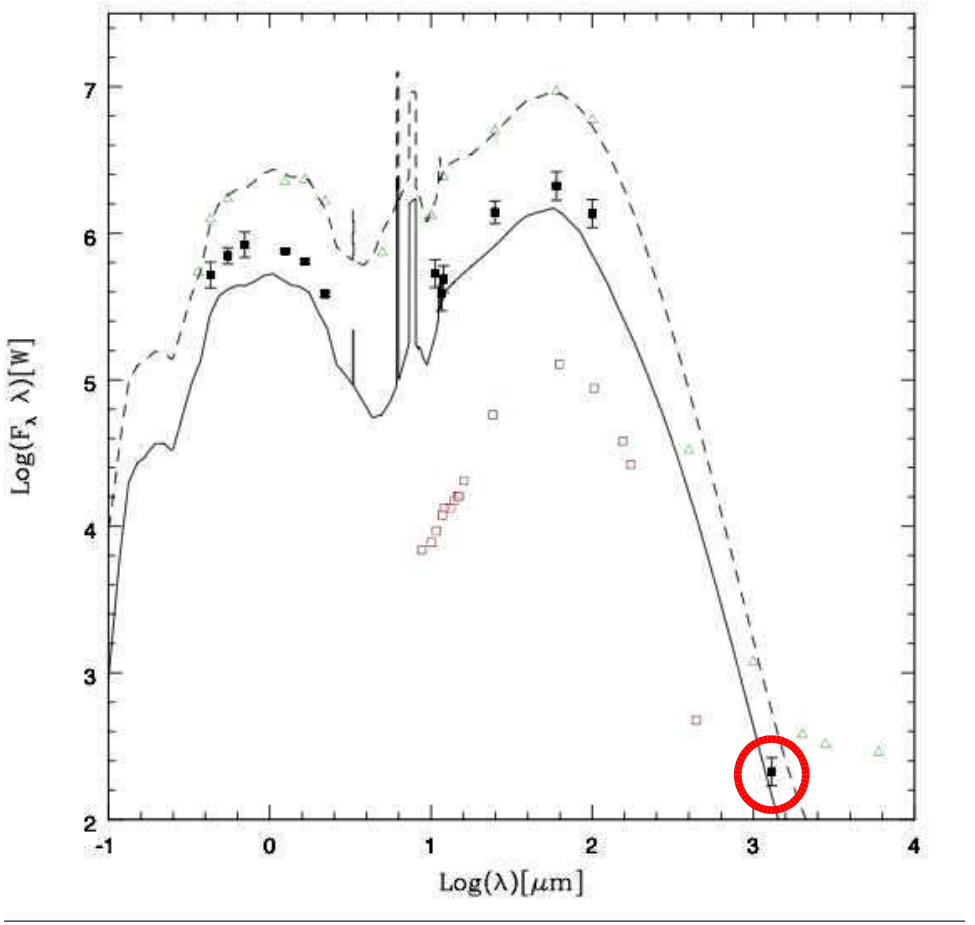
Vanzi & Sauvage 2004

- the sub-mm points help constraining the dust properties

He2-10

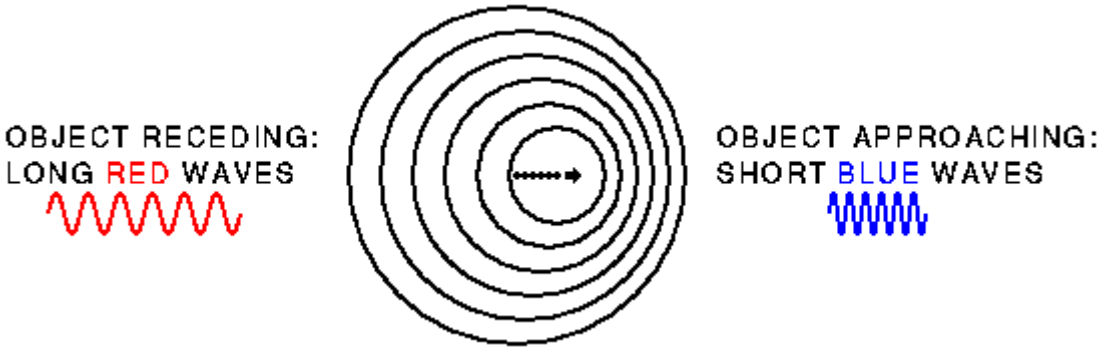






SED --> age, mass, dust and gas content, extinction, dust composition, star formation history, etc.

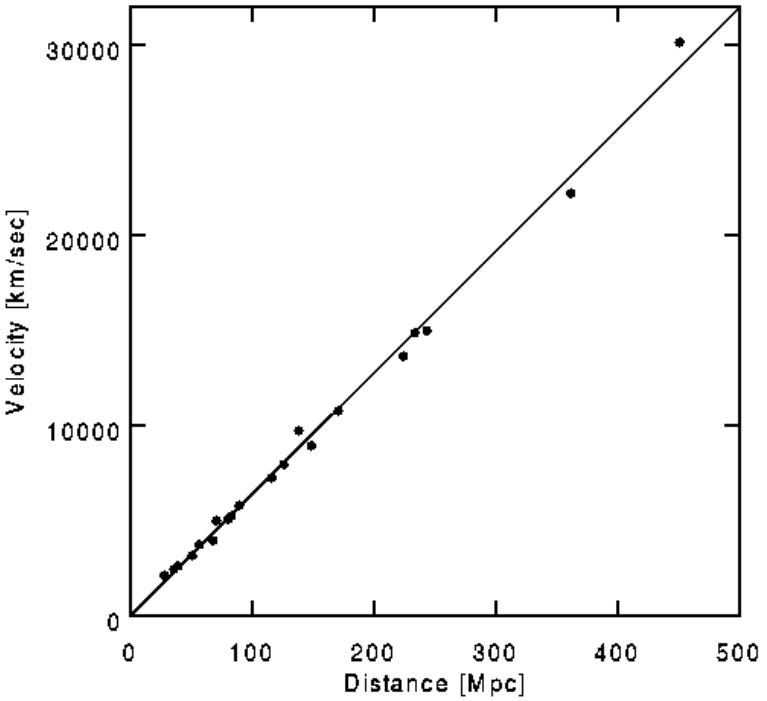
Concept 3 – Redshift and Hubble law



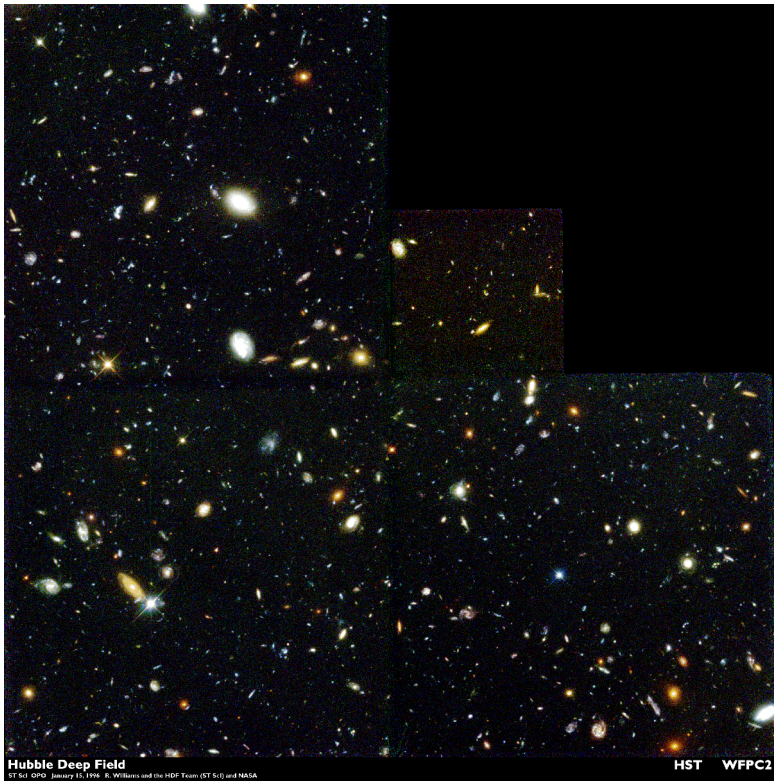
$$z = (\lambda - \lambda_0)/\lambda_0 \approx v/c$$

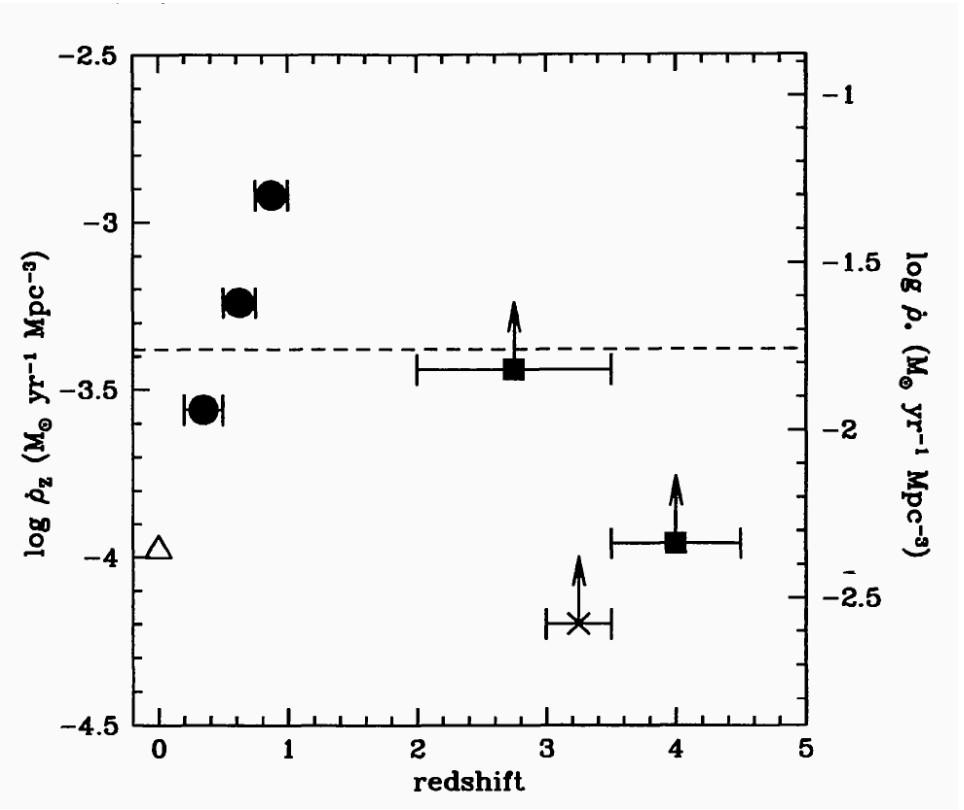
$$V = H_0 d$$

$$H_0 = 70 \text{ Km/s/Mpc}$$



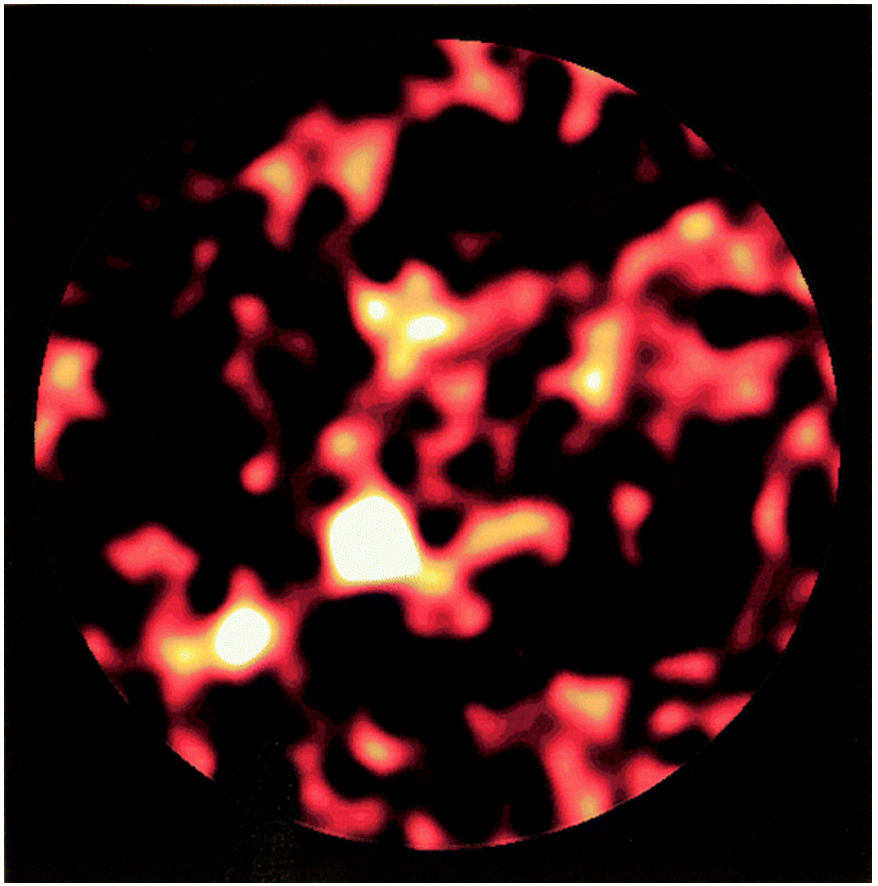
The Star Formation History of the Universe

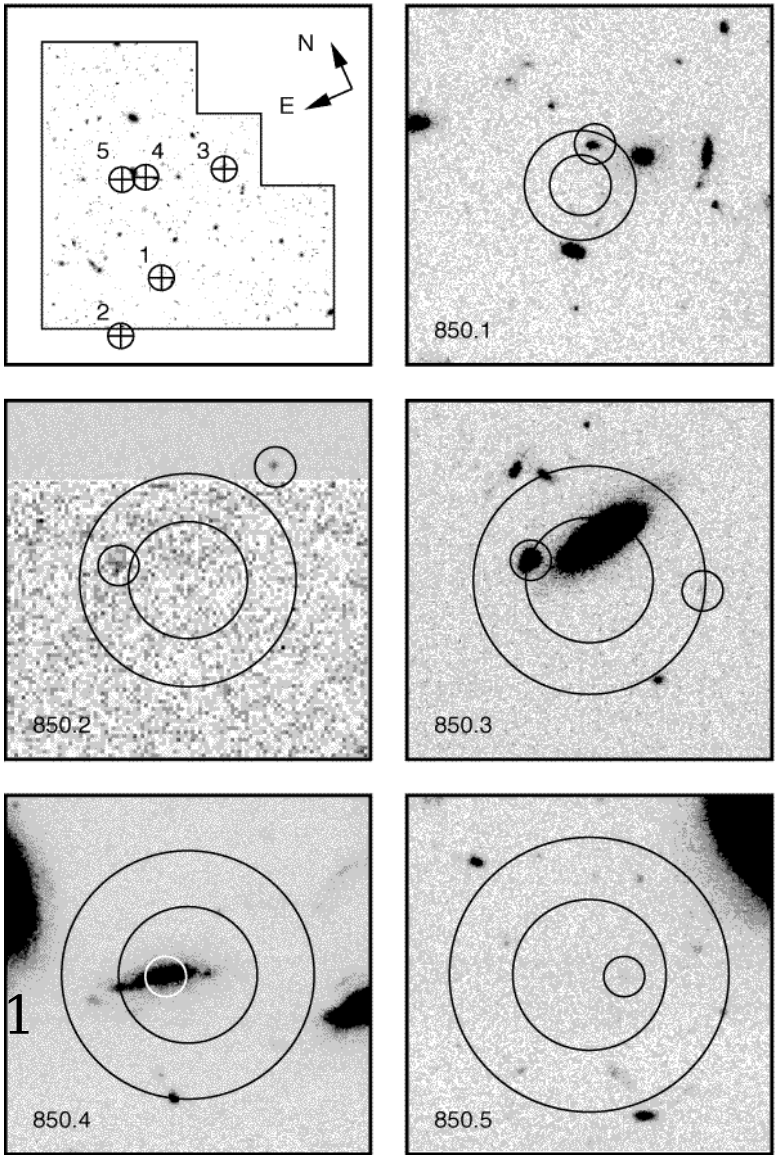




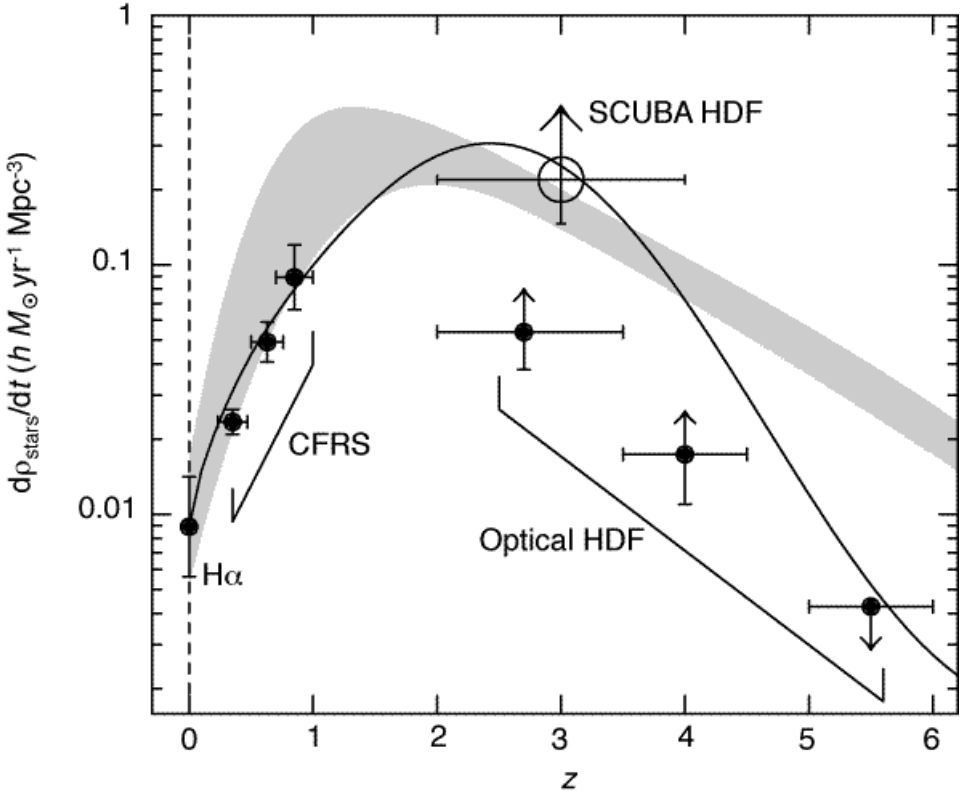
Madau et al. 1996, MNRAS 283, 1388

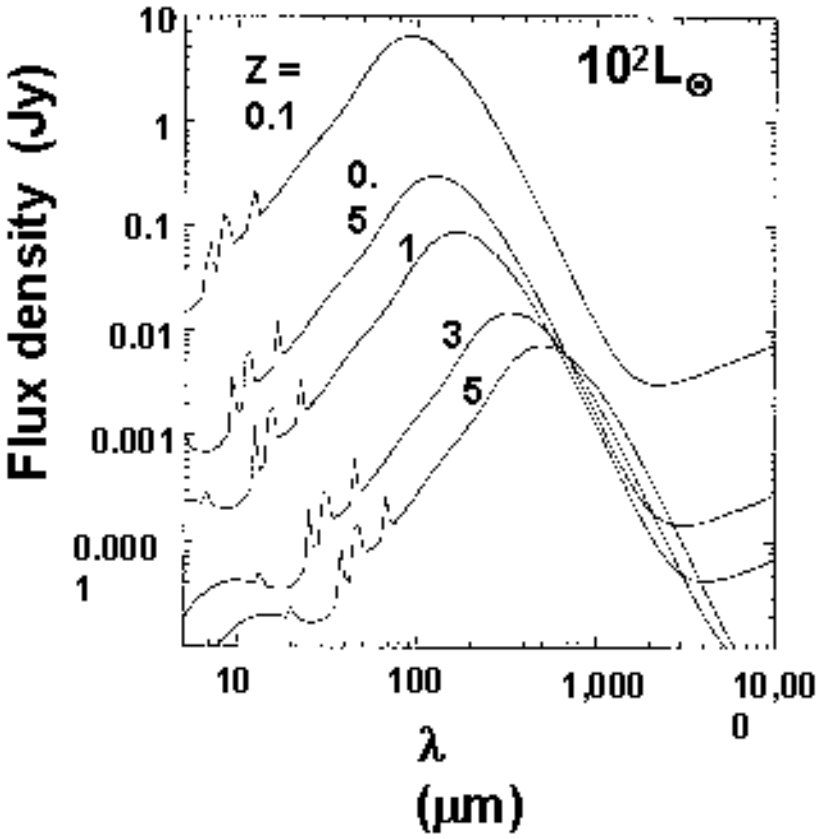
SCUBA observation of the HDF





Hughes et al. 1998, Nature 394, 241





- the negative K correction opens the sub-mm study of high-z objs

- sub-mm observations change the view of the SF history of the Universe

Fundaments of Cosmology:

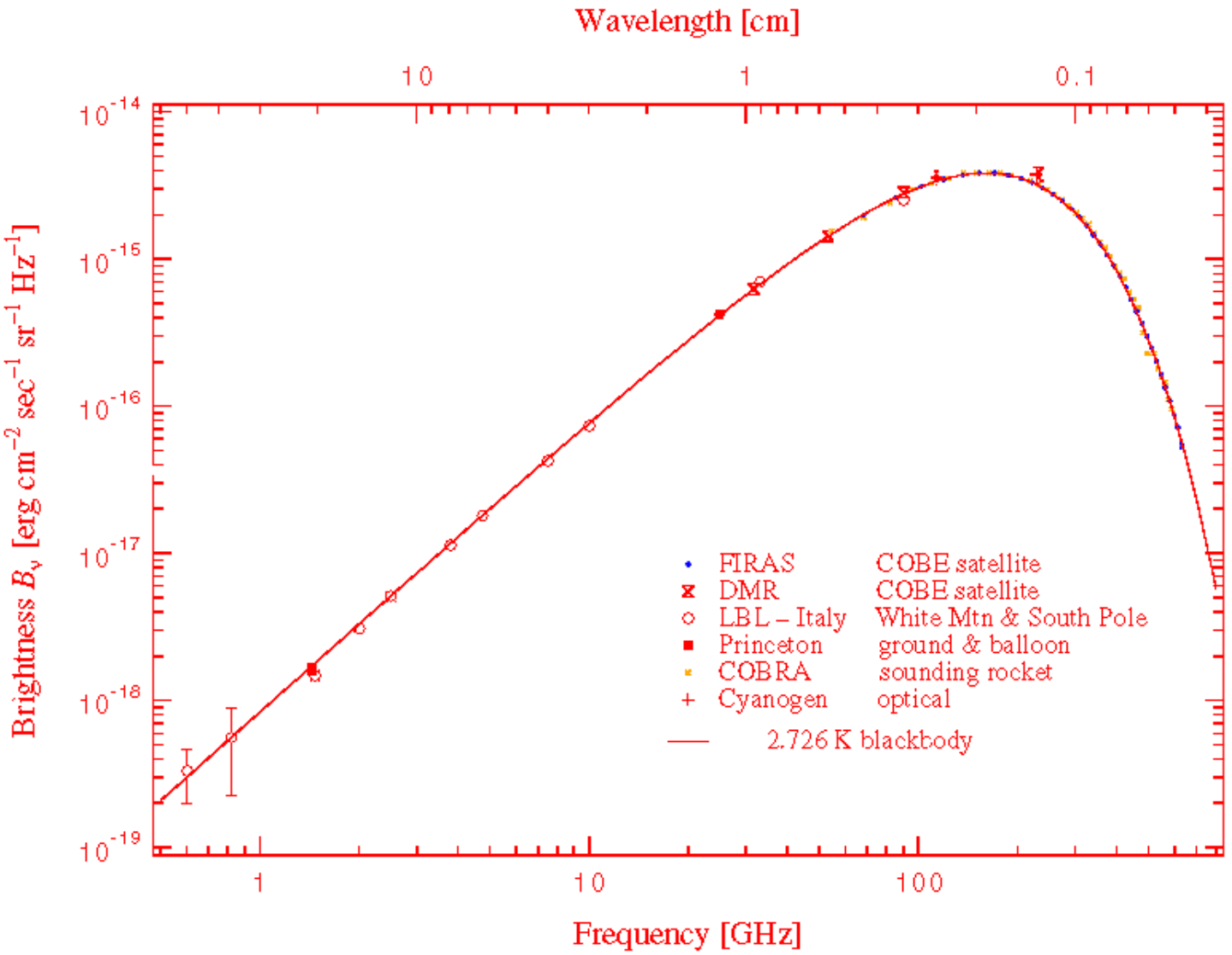
- Expansion of the Universe

- Cosmic Microwave Background

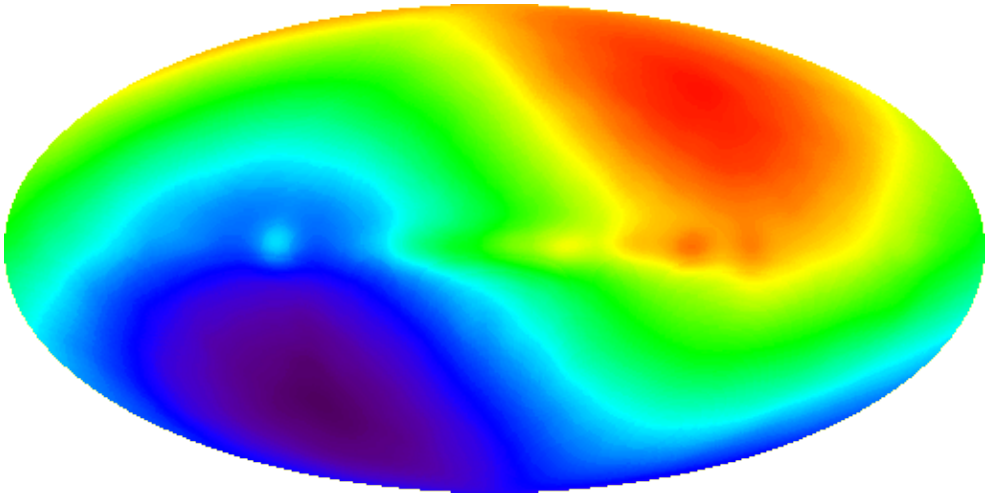
- Primordial Abundances

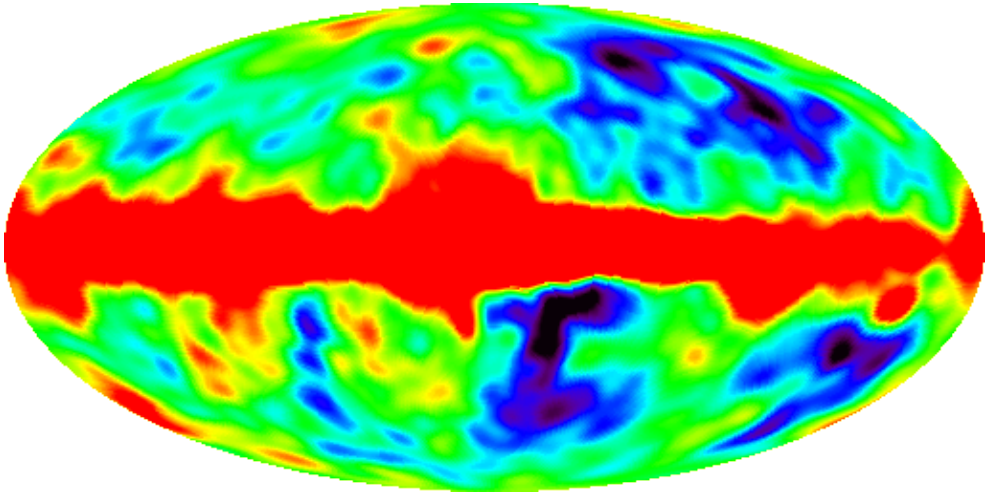
Big Bang Theory

Cosmic Microwave Background (CMB)

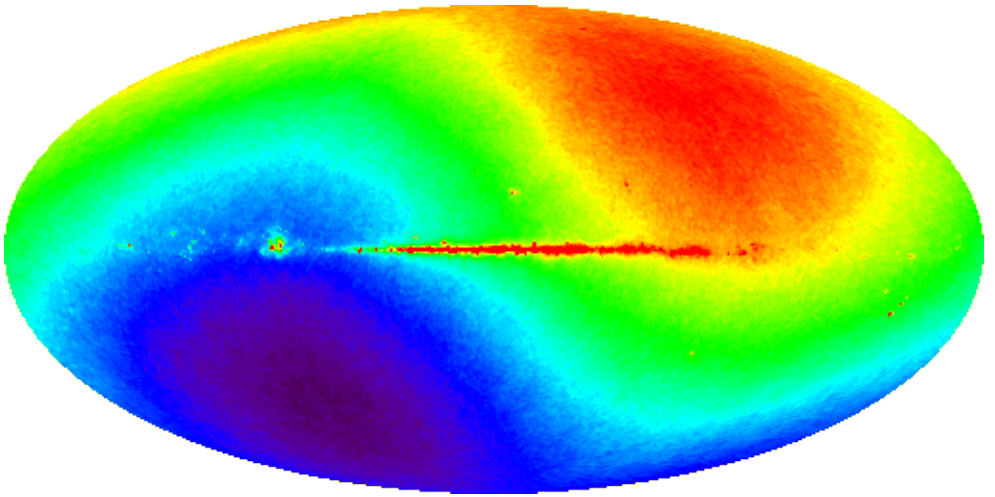


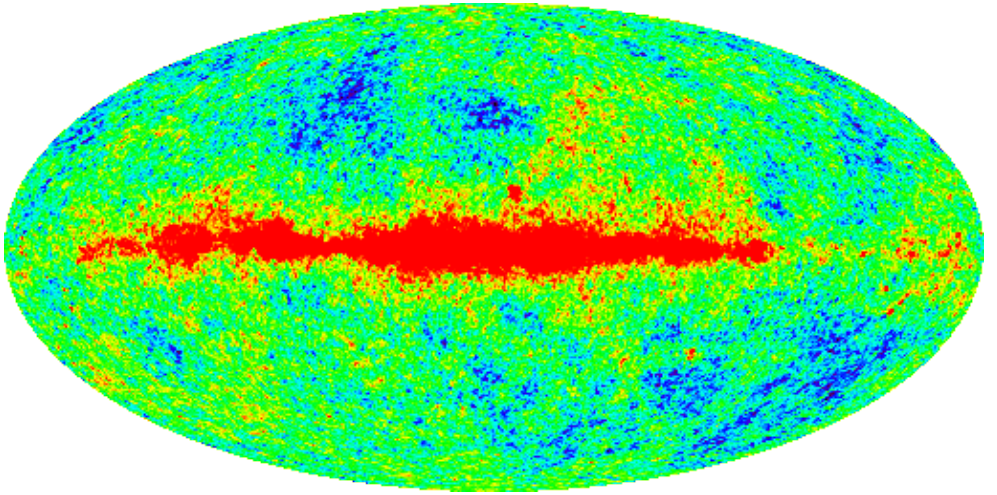
COBE (1989)

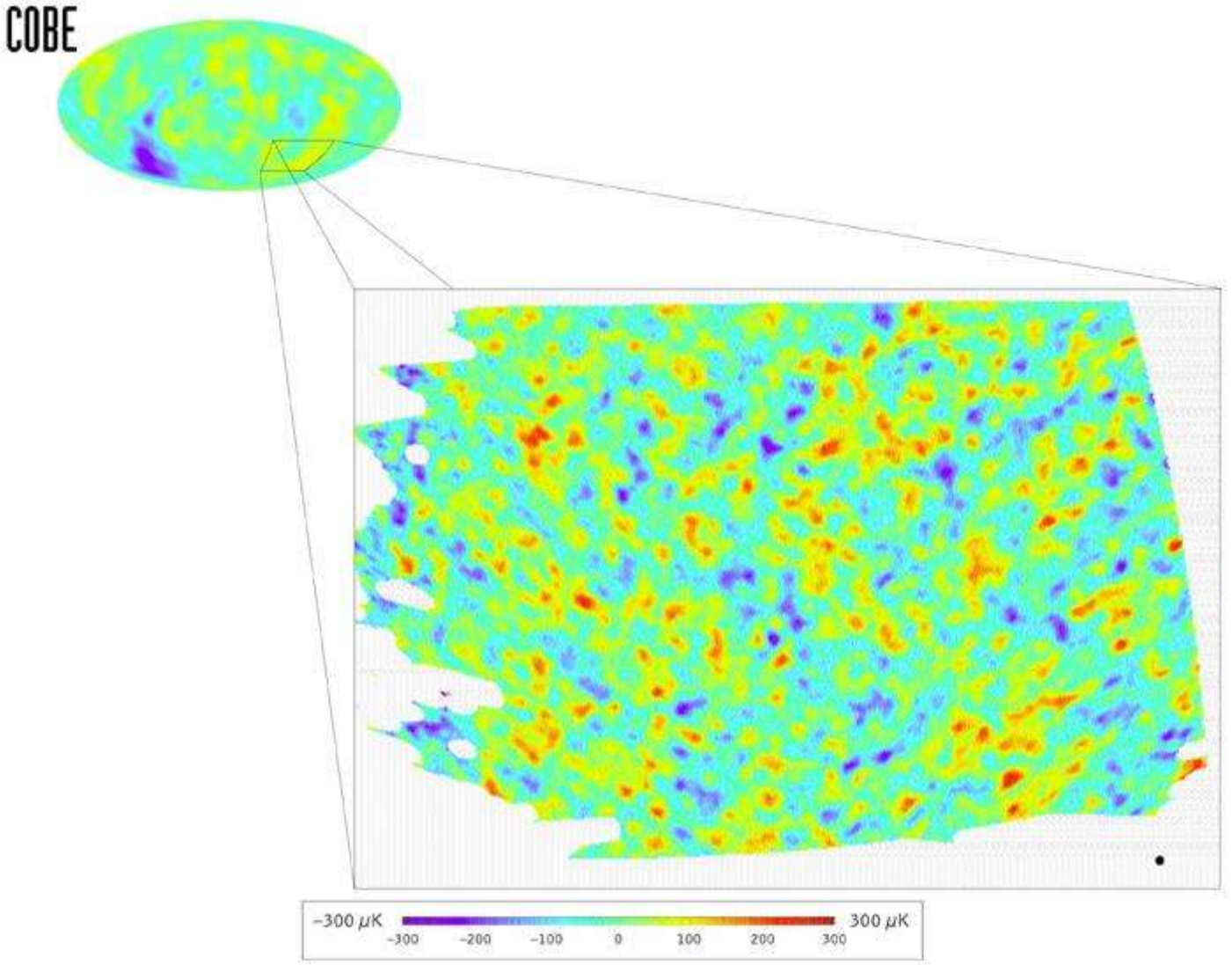




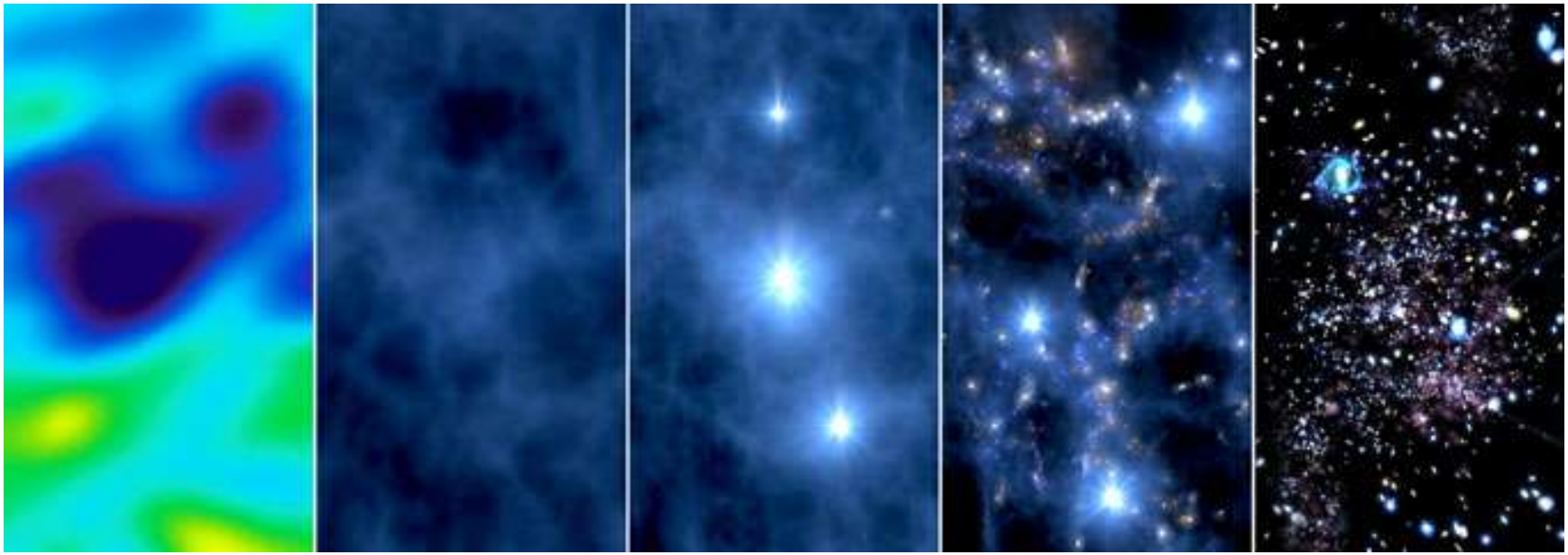
WMAP (2001)






COBE
−300 μK
300 μK
−300
−200
−100
0
100
200
300

The History of the Universe



400.000 yr
z=1000

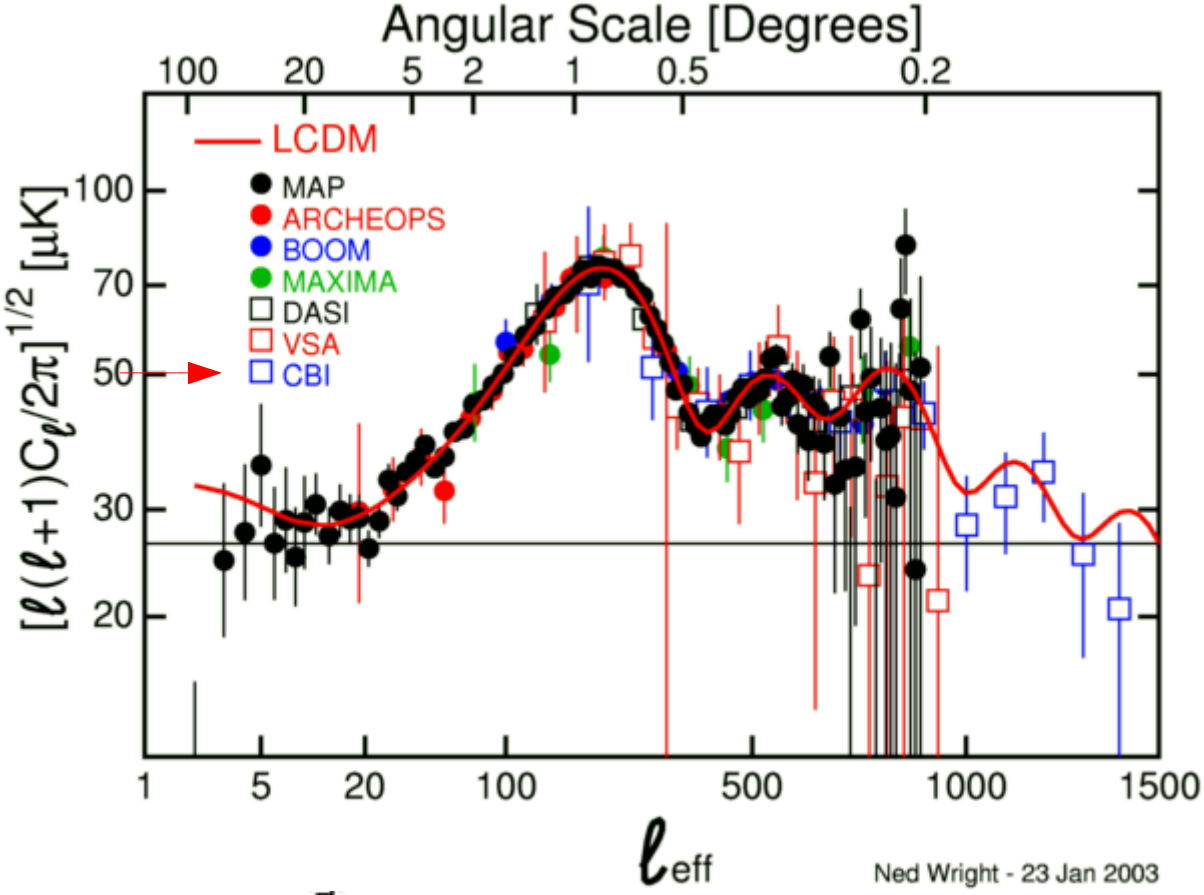
2 Gyr
z=3

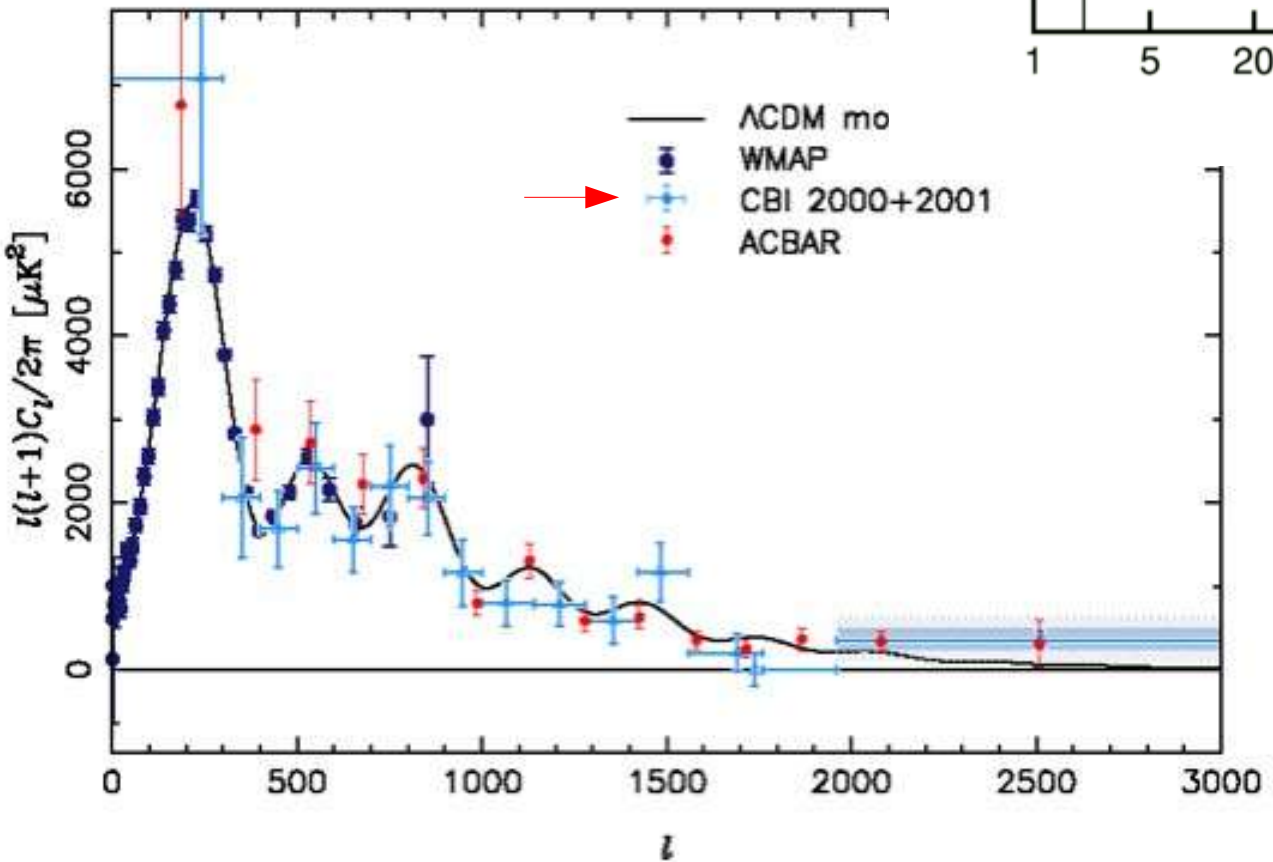
10 Gyr
z=1

13.7 Gyr
z=0

0 yr
z=∞

CMB Power Spectrum





→ Ω_0, H_0

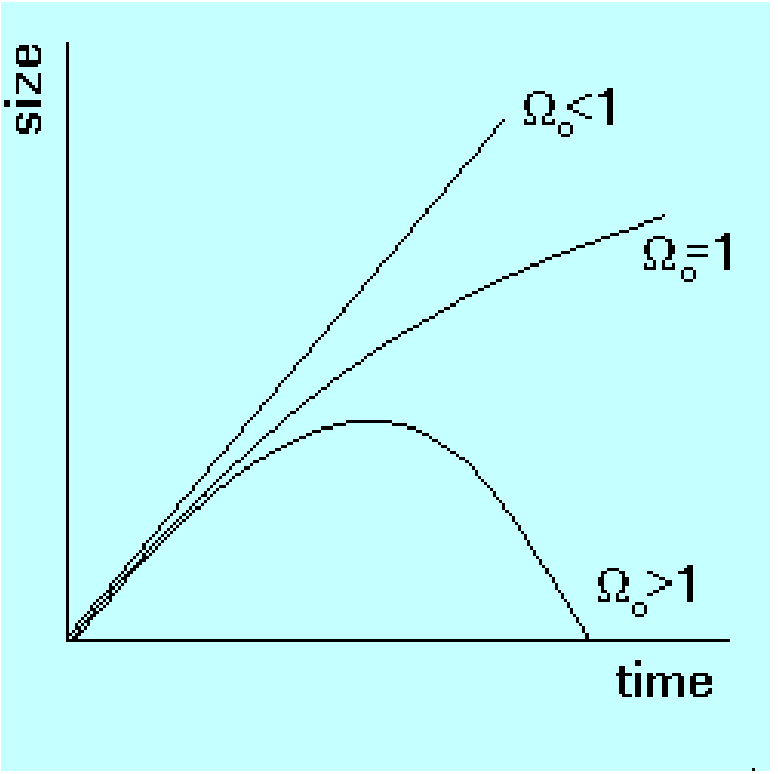
Concept 4 – Density of the Universe

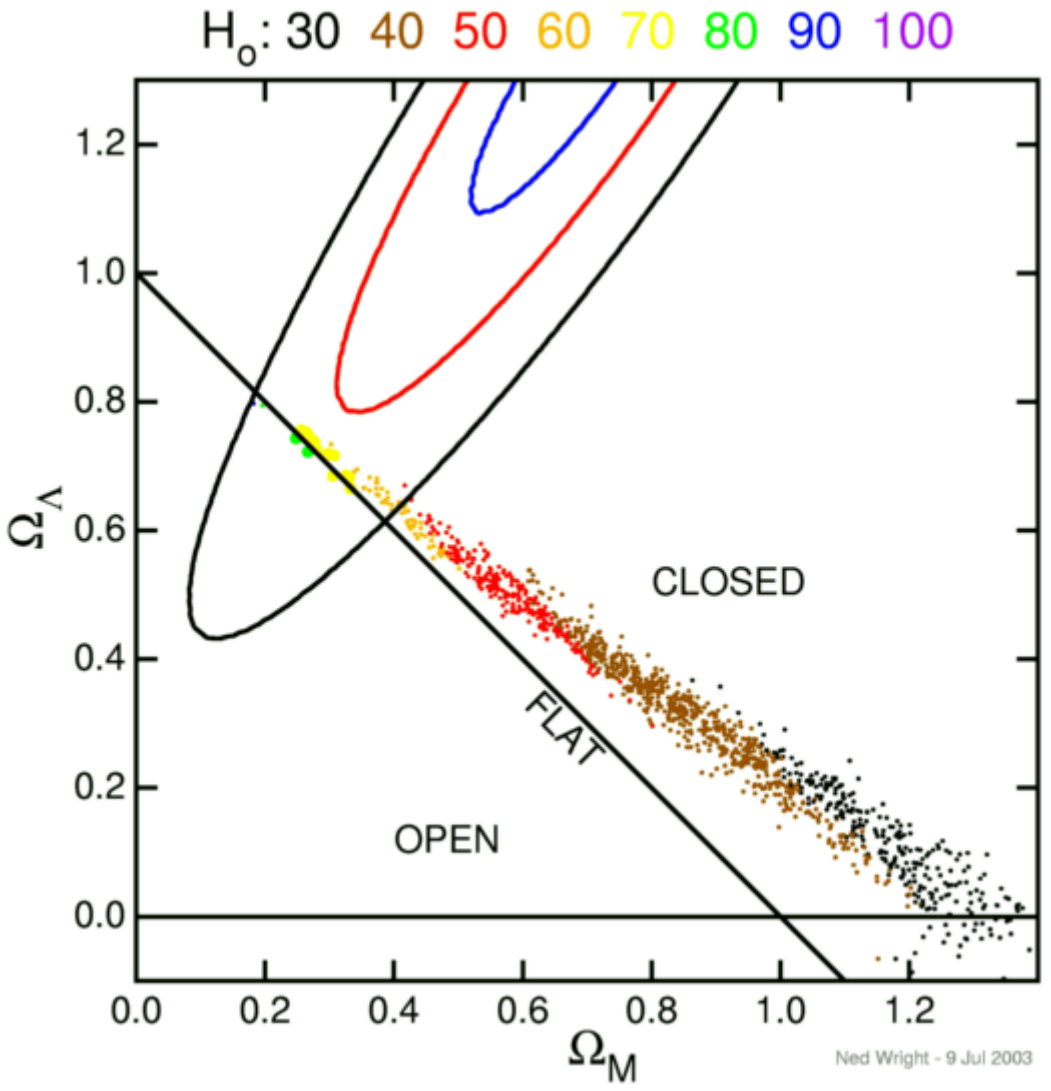
$\Omega_0 = \rho/\rho_c \quad \rho_c = 10^{-30}$ **g/cm^3**

$$\Omega_0 = \Omega_M + \Omega_\Lambda$$

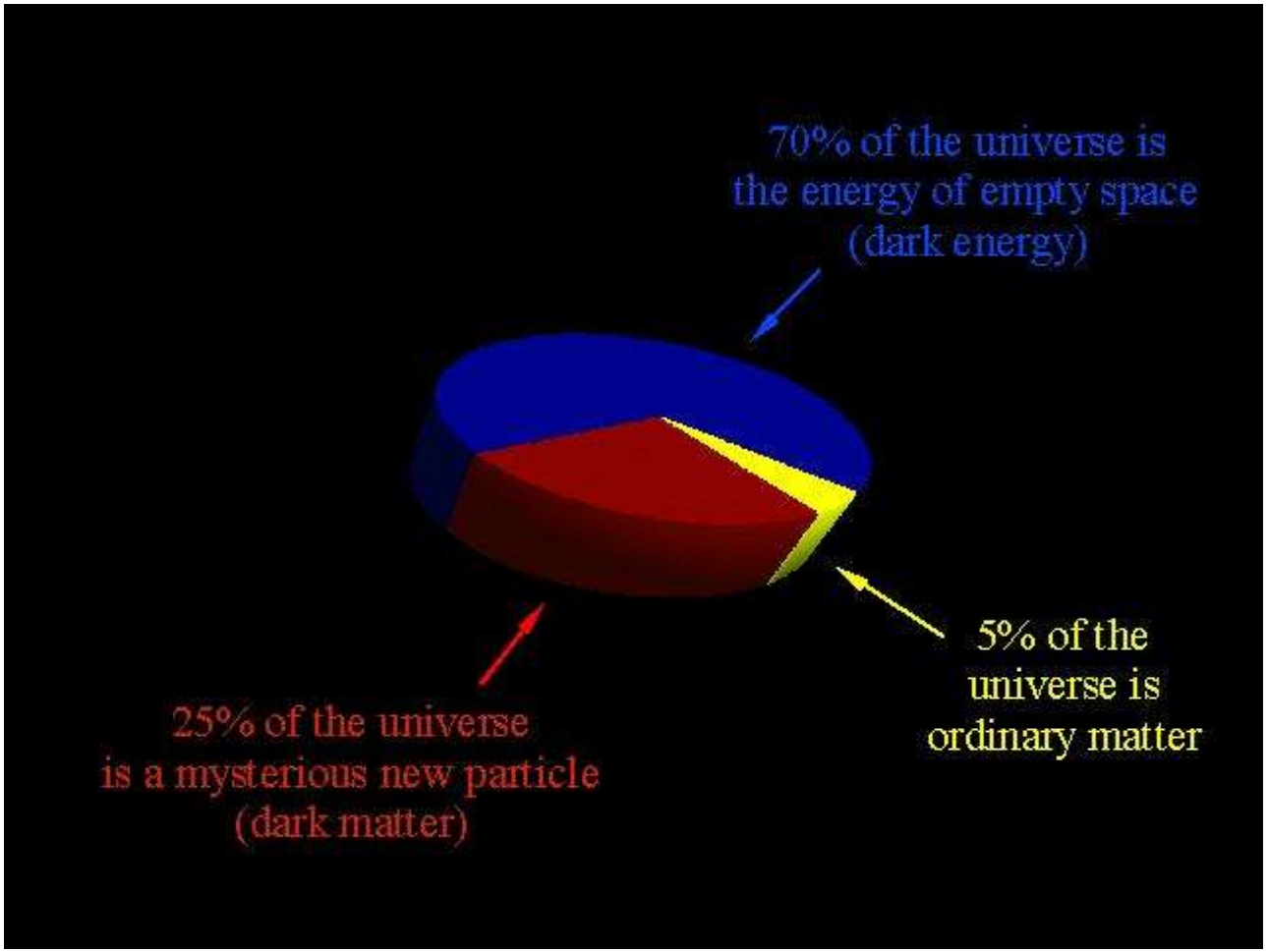
Visible matter < 0.05
Dark matter ≈ 0.25

$\Omega_M \leq 0.30$
$\Omega_\Lambda = 0$




H$_o$: 30 40 50 60 70 80 90 100
1.2
1.0
0.8
0.6
0.4
0.2
0.0
Ω_Λ
CLOSED
FLAT
OPEN
0.0 0.2 0.4 0.6 0.8 1.0 1.2
Ω_M
Ned Wright - 9 Jul 2003

What is the Universe made of ?



What is dark matter?

What is dark energy?

Conclusions:

1) Galaxies are complex stellar systems, studying their SED we can derive their properties, the mm tells about the dust content and star formation.

2) Going far we look back in time and we can learn about the history of the Universe, the mm allows to observe objects to z=10.

3) The CMB is the footprint of the early Universe, it gives constraints on the cosmological parameters and tells us about the structure and fate of the Universe. What is the Universe made of ?

Conclusions:

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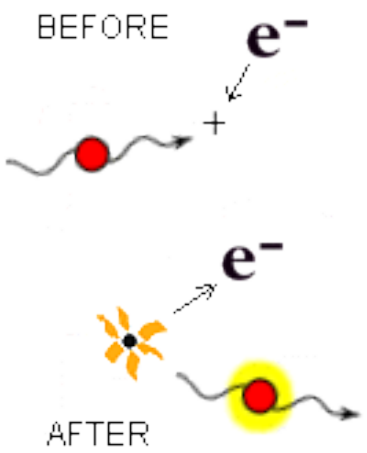
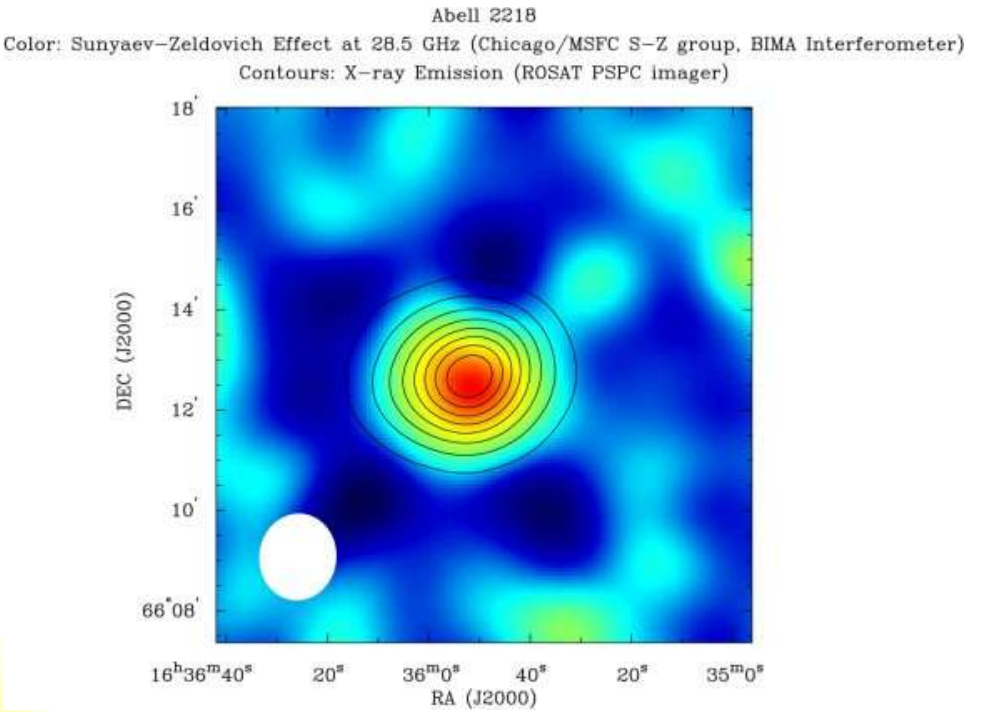
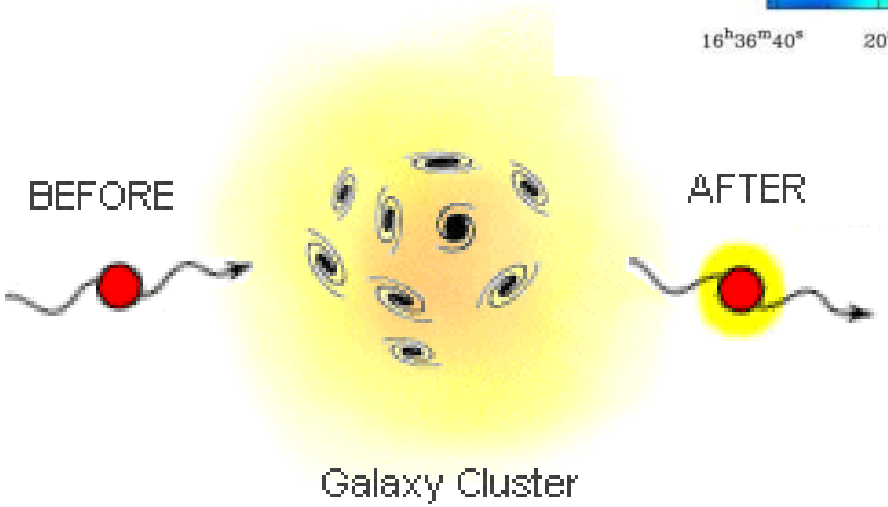
3) The CMB is the footprint of the early Universe, it gives constraints on the cosmological parameters and tells us about the structure and fate of the Universe. What is the Universe made of ?

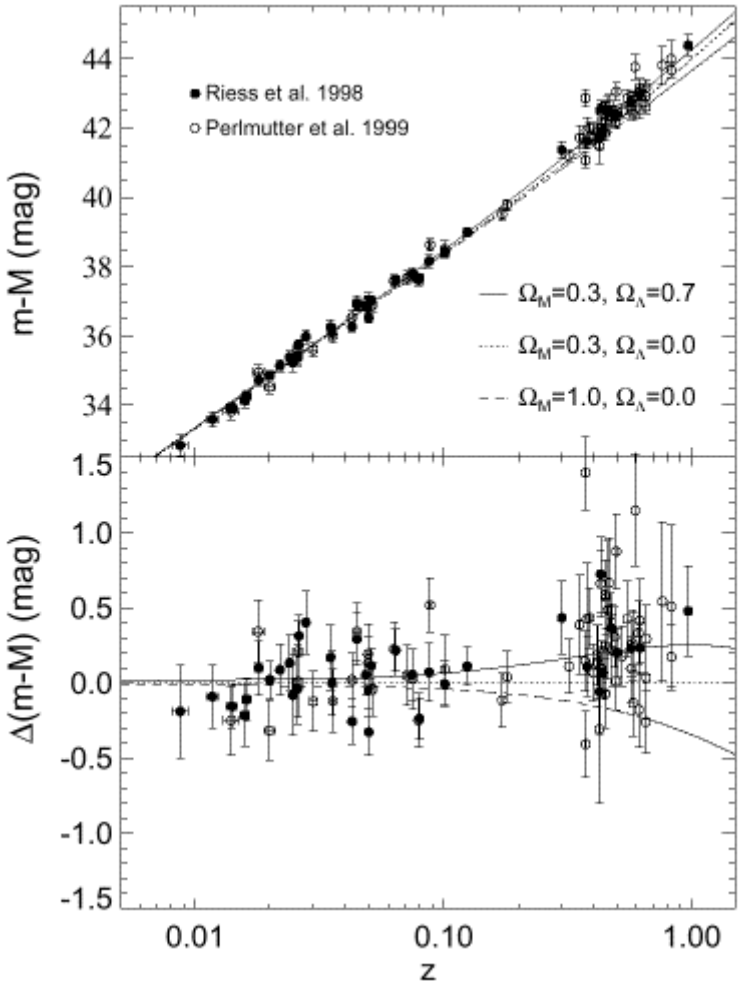
What is the point of all this?

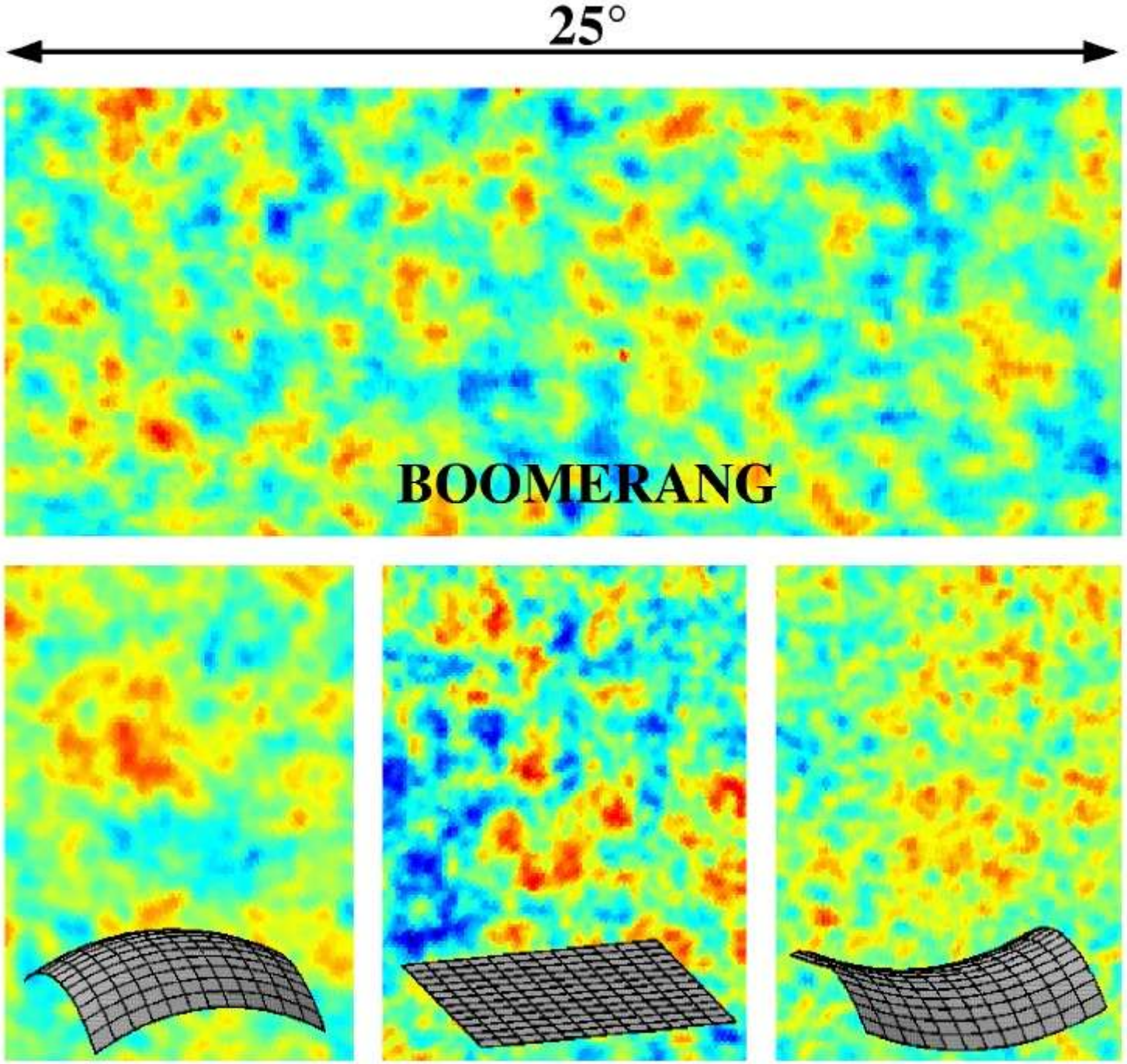
Sunyaev – Zeldovich Effect

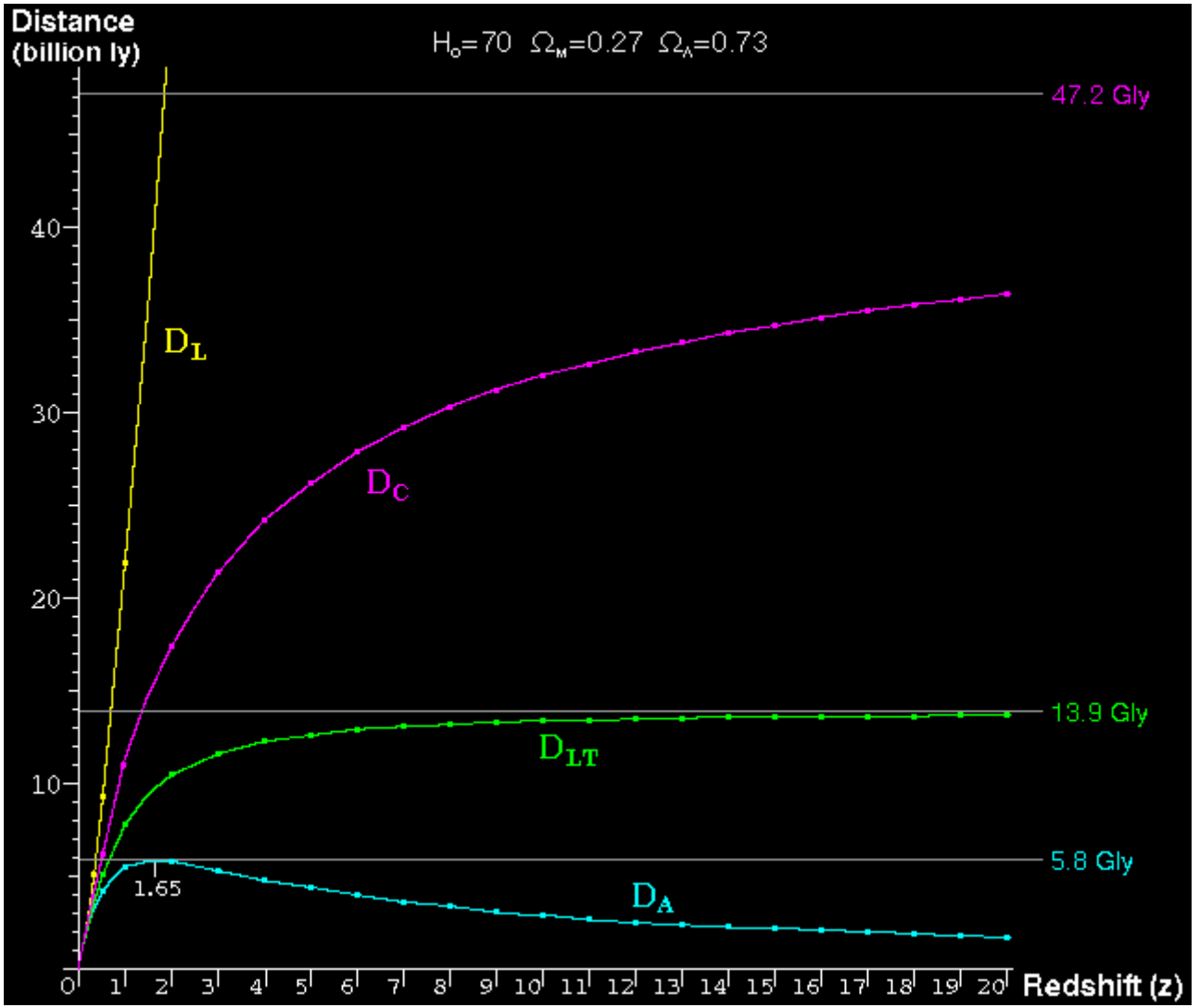







Riess et al. 1998
Perlmutter et al. 1999
Ω_M=0.3, Ω_Λ=0.7
Ω_M=0.3, Ω_Λ=0.0
Ω_M=1.0, Ω_Λ=0.0
m-M (mag)
Δ(m-M) (mag)
z
0.01
0.10
1.00
34
36
38
40
42
44
1.5
1.0
0.5
0.0
-0.5
-1.0
-1.5


25°
BOOMERANG


Distance
(billion ly)
H₀=70 Ω_M=0.27 Ω_Λ=0.73
47.2 Gly
13.9 Gly
5.8 Gly
D_L
D_C
D_LT
D_A
1.65
40
30
20
10
0
1
2
3
4
5
6
7
8
9
10
11
12
13
14
15
16
17
18
19
20
Redshift (z)