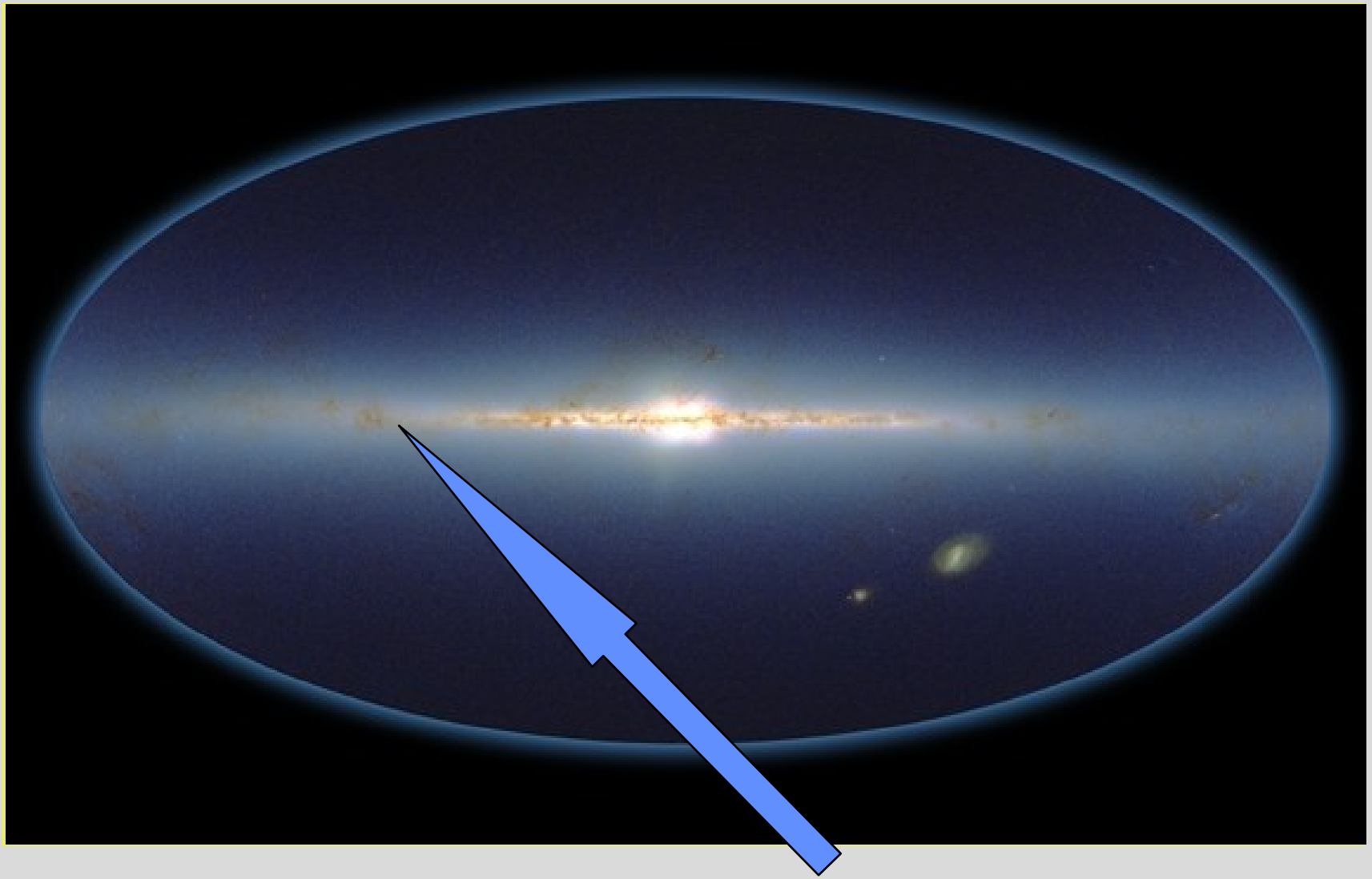
Cosmic Explorers : mapping the Universe

ROYAL OBSERVATORY EDINBURGH

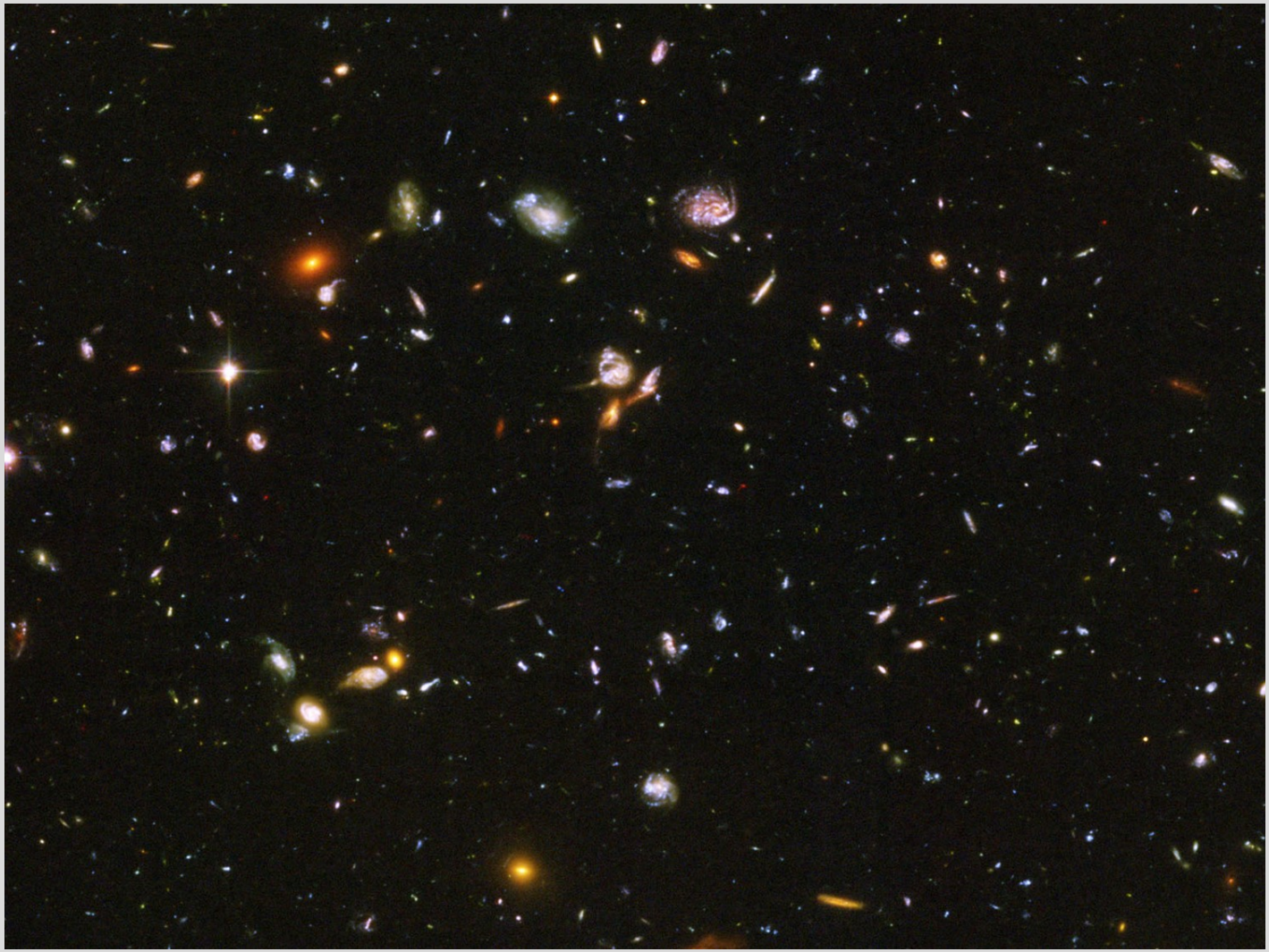
Earth from space : a sense of perspective

Milky Way in Infrared (2MASS project)



you are here ...

Deep Sky (Hubble Deep Field)



and somewhere here ...

- History
- Deeper and Deeper
- The Universe in 3D
- Testing Theory
- Whats next ?

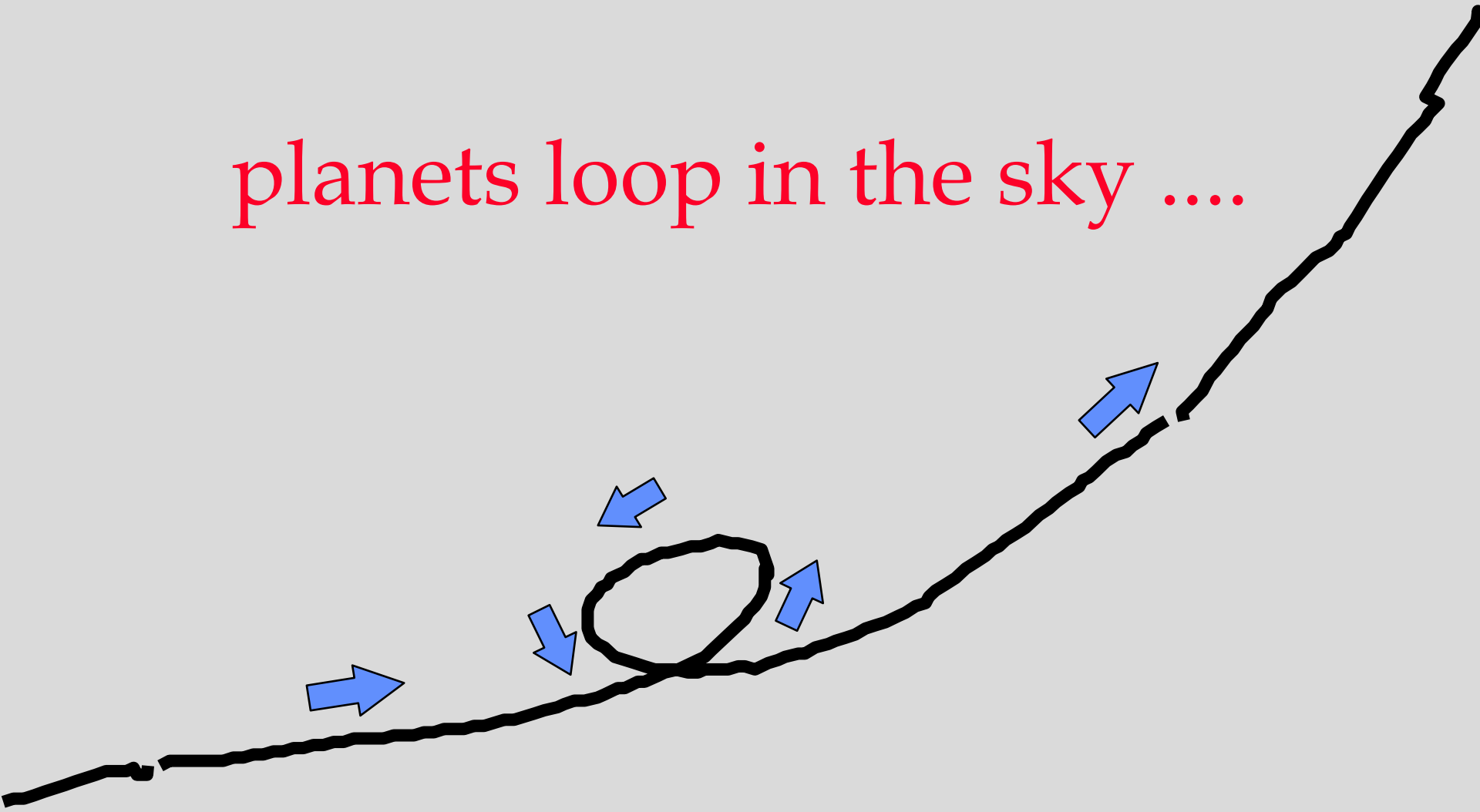
Part One
History

The Greek Universe

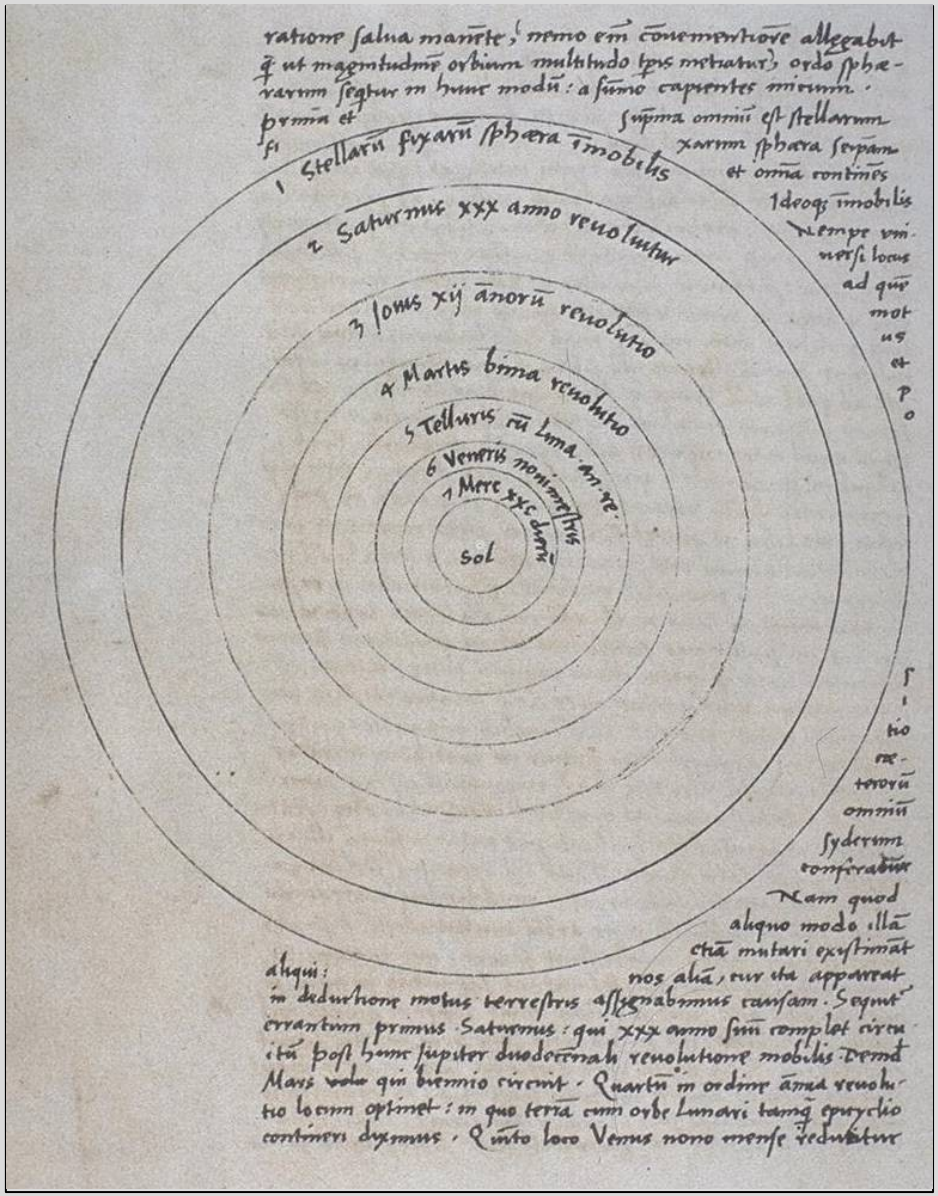
Petrus Apianus 1539 "Cosmographia"

Apianus manuscript
at Royal Observatory

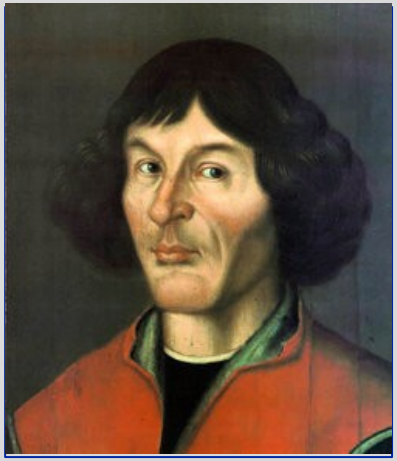
planets loop in the sky ....

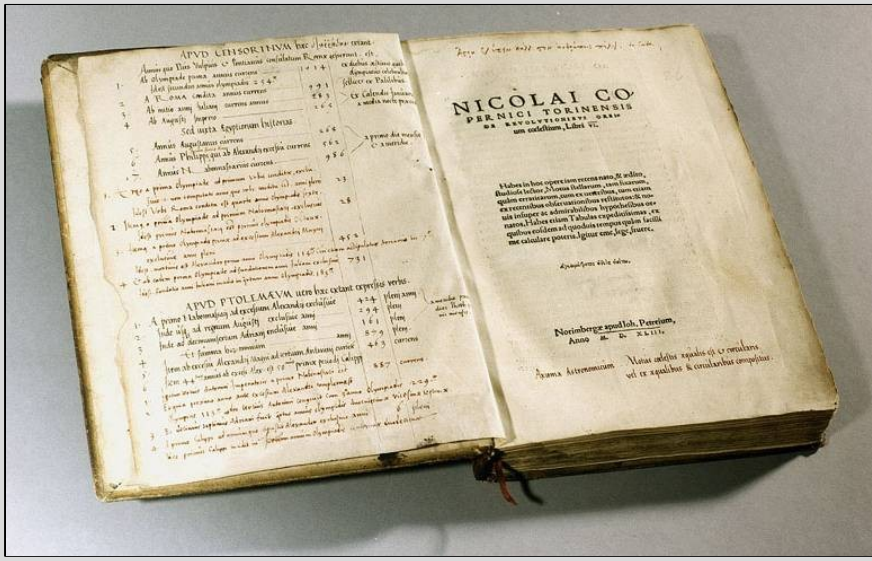


The Copernican Universe



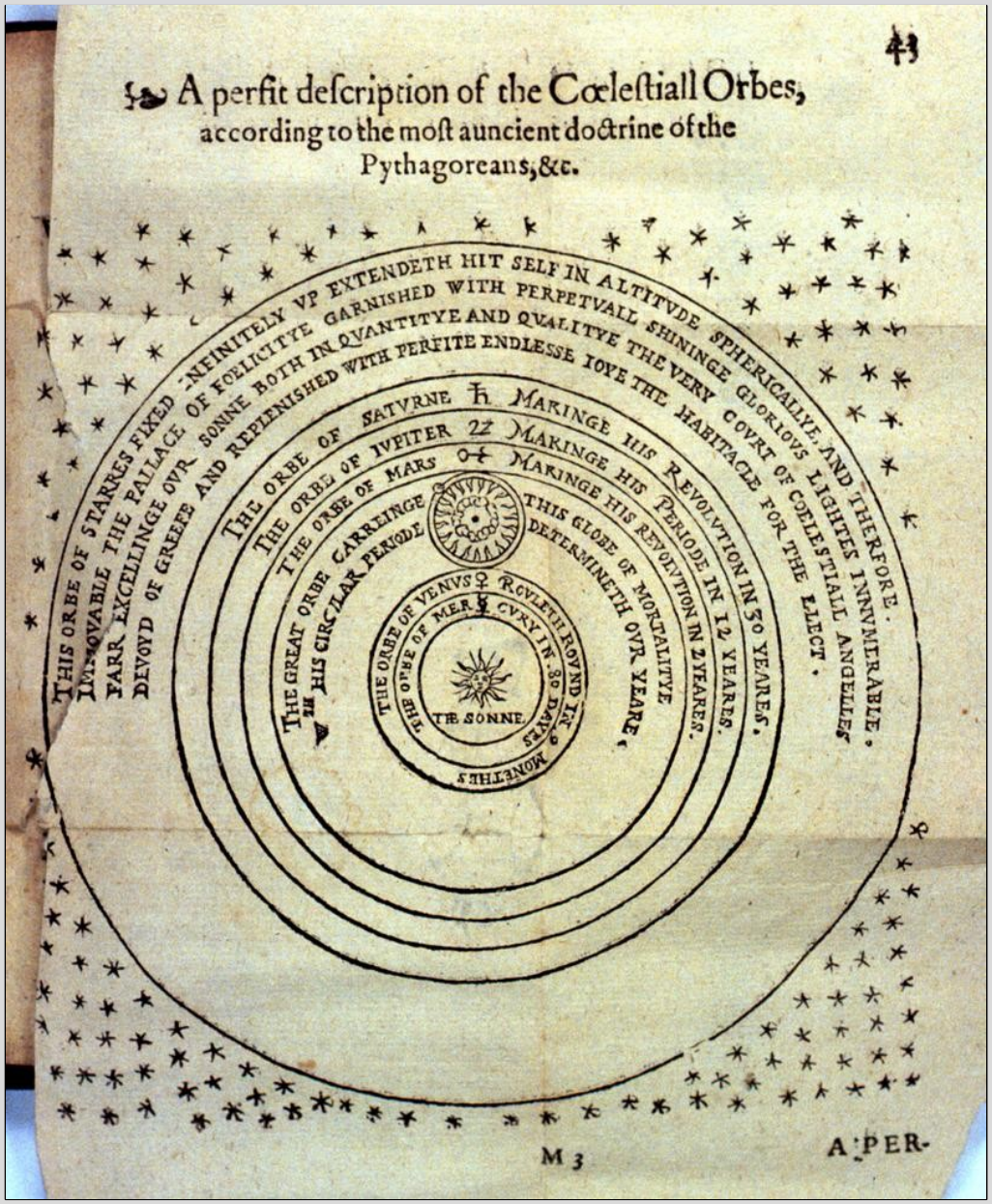
Manuscript version of "De Revolutionibus" 1543





First edition at Royal Observatory

The Sea of Stars



Thomas Digges 1576
"A perfit description of the Coelestial Orbes"

The stars spread through space .. but how far away ?

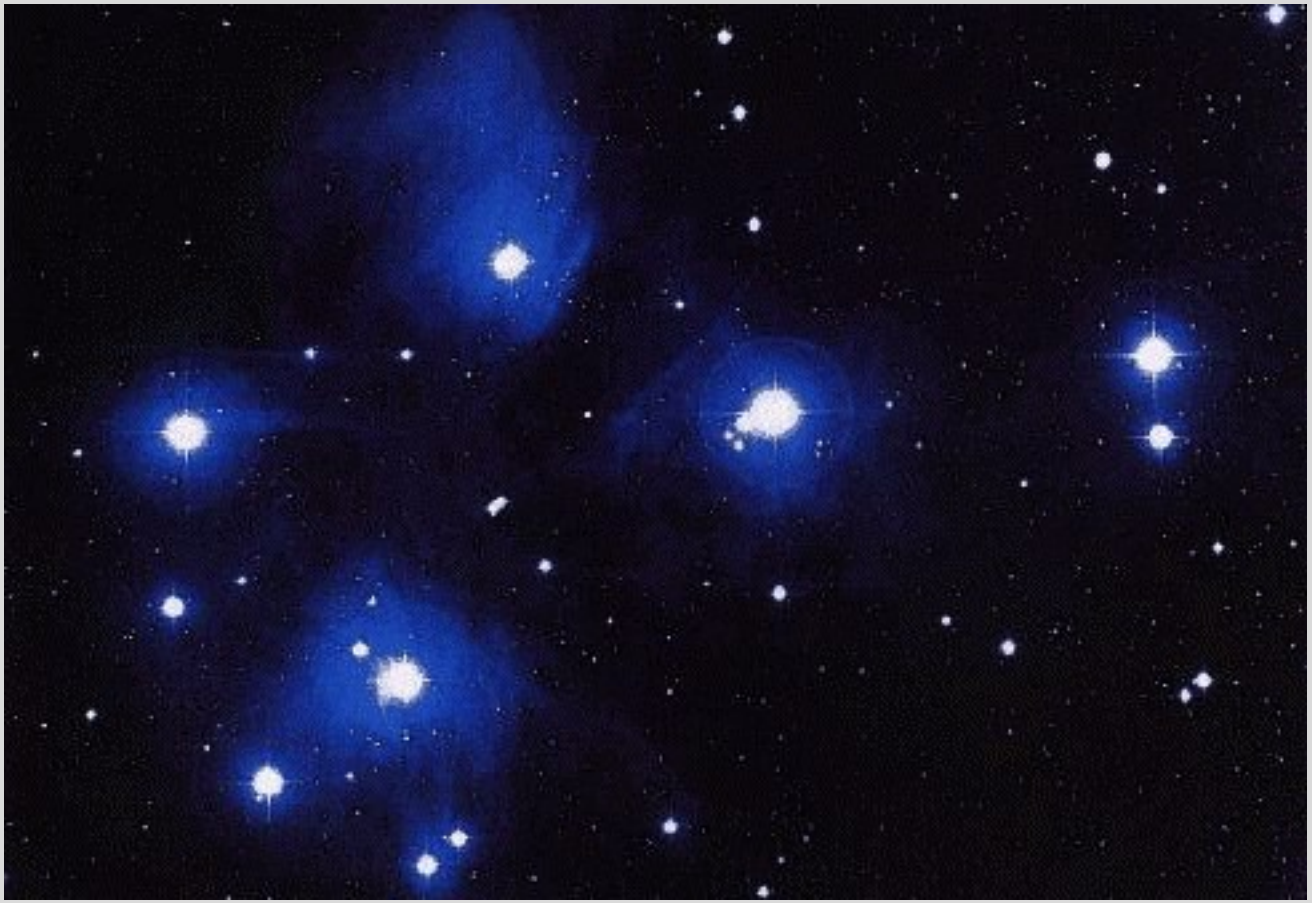
...watch them wiggle ....

Discoverers of Parallax 1839

Thomas Henderson
Alpha Centauri

Friedrich Bessel
61 Cygni

Nearby Star Cluster - the Pleiades

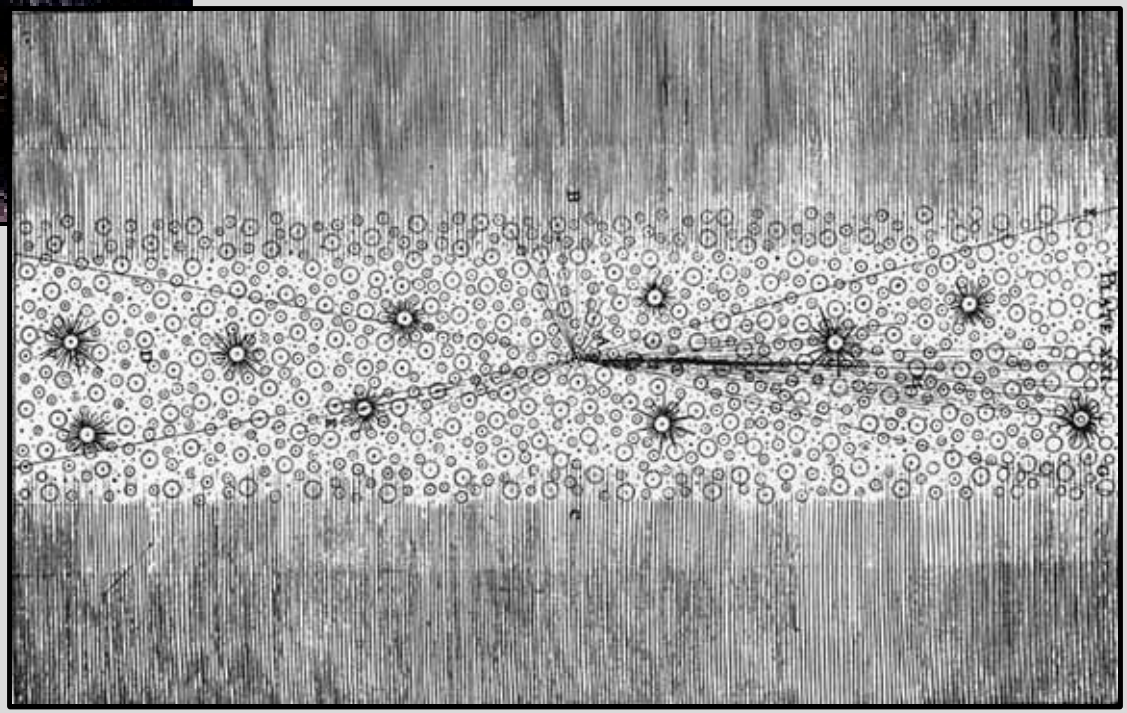


nearest star α Centauri : 6841 x further than Pluto

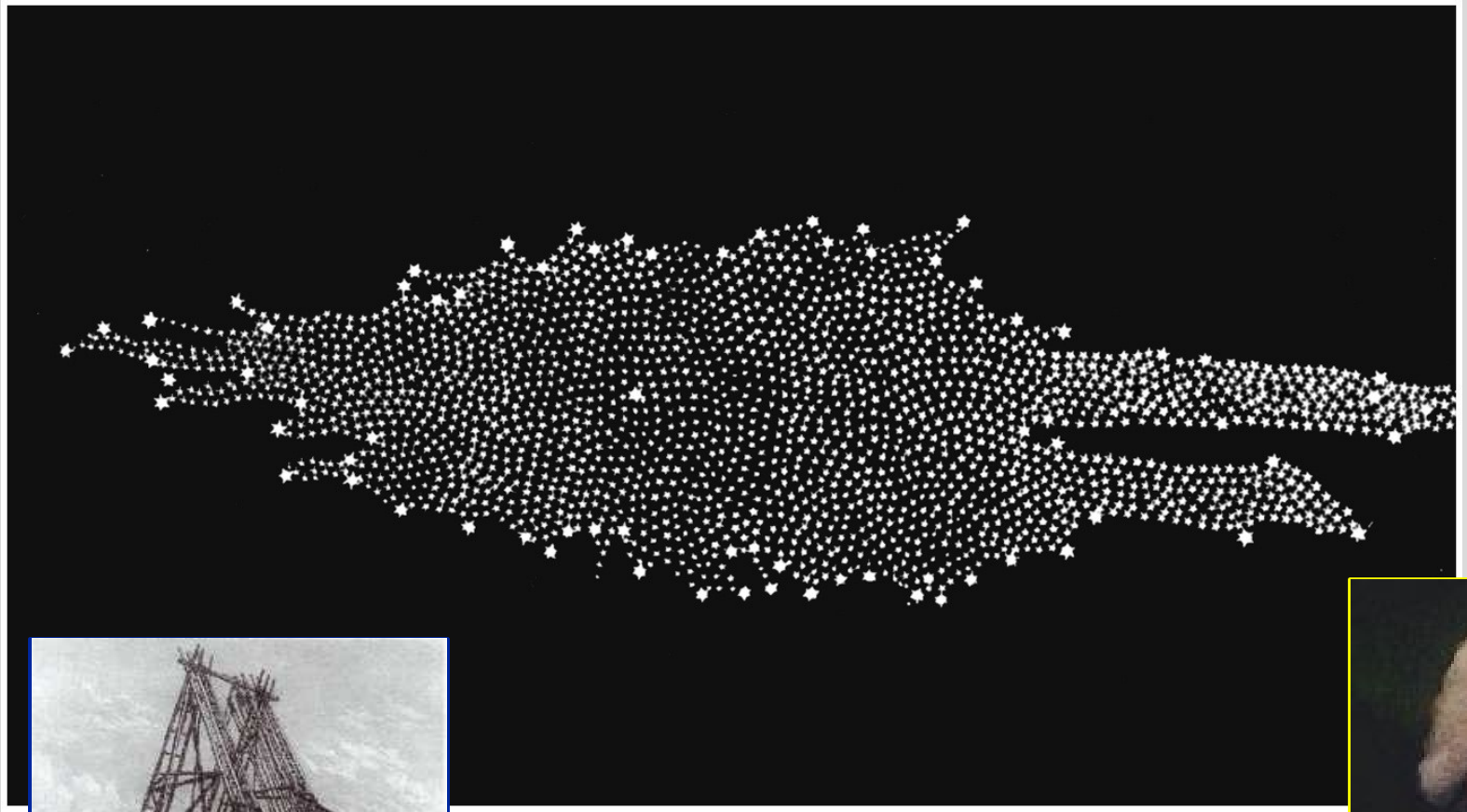
The Milky Way

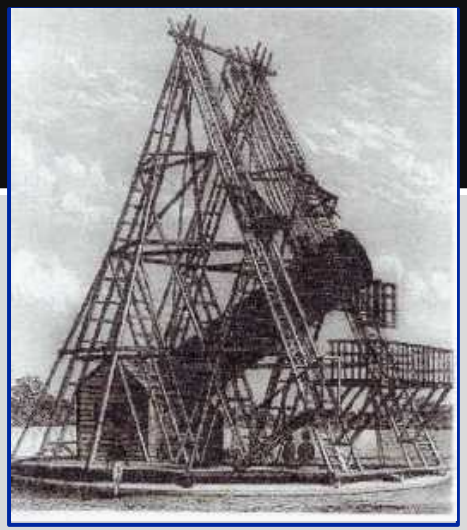
Modern photograph
(Sylvestre Lacblanc)

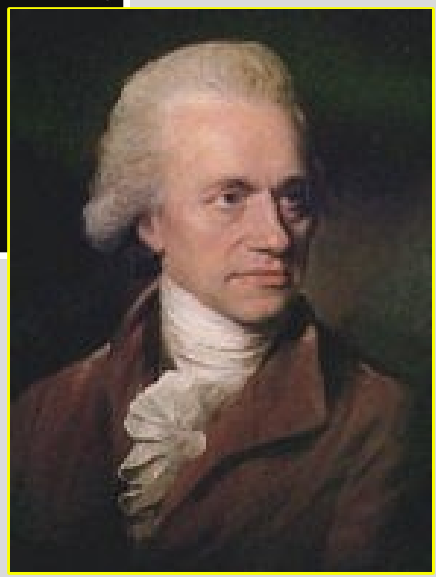
Disk Universe
(Thomas Wright 1750)



Mapping the Milky Way : star counts

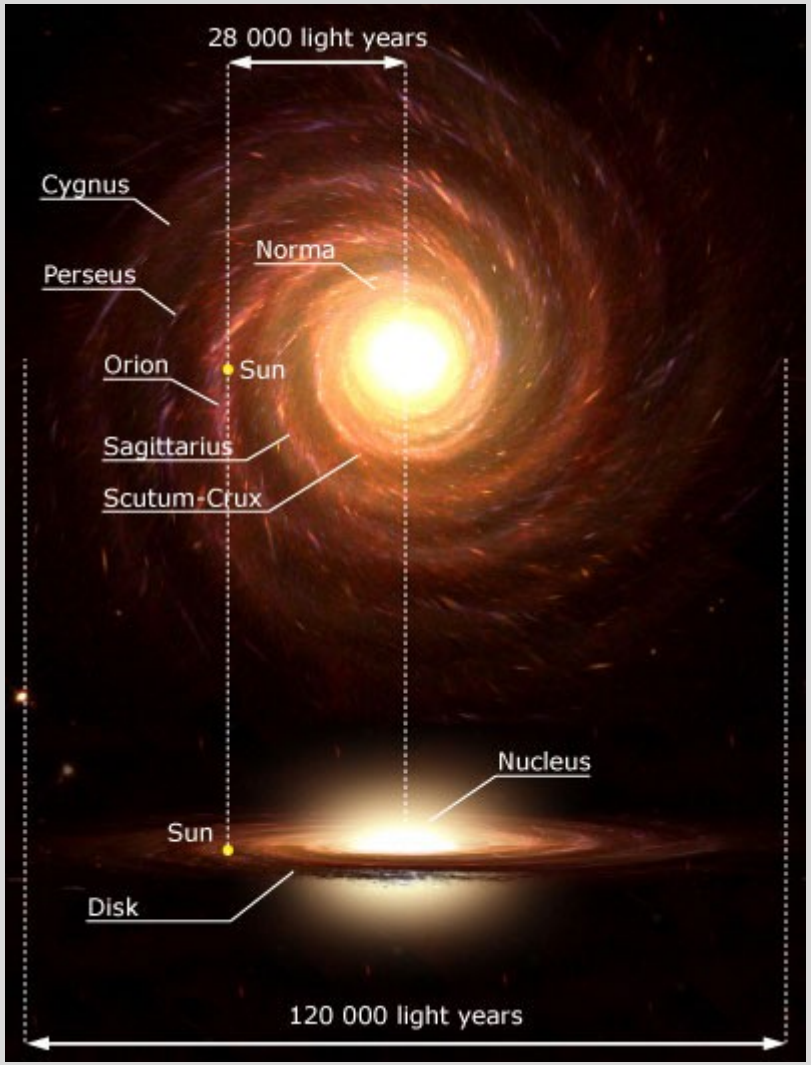




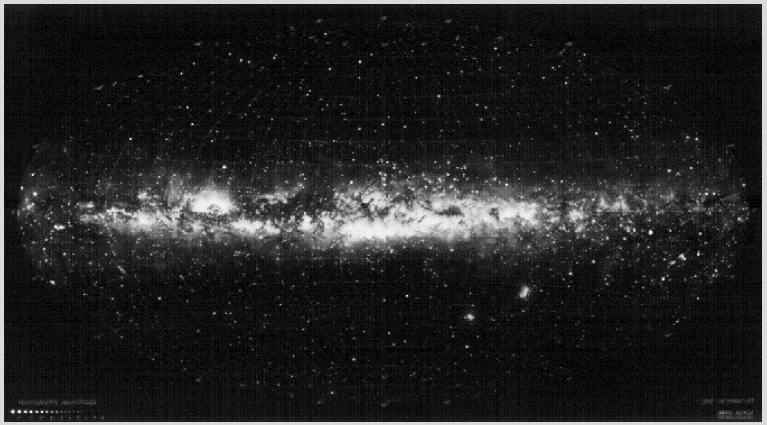


William Herschel
starmap 1785

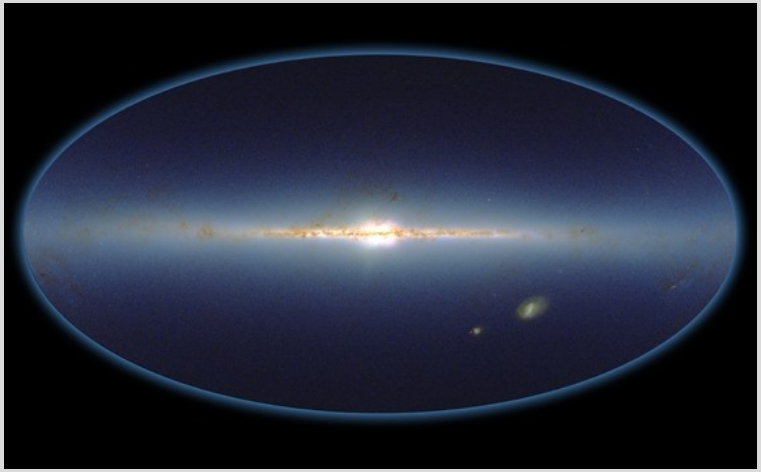
The modern Milky Way



Artist sketch of Milky Way (ESA)



Whole sky picture (Lund Observatory) ....dark patches caused by dust



Infra-red picture (2MASS project) ..cuts through the dust

The mystery of the Nebulae

Orion Nebula

Andromeda Nebula

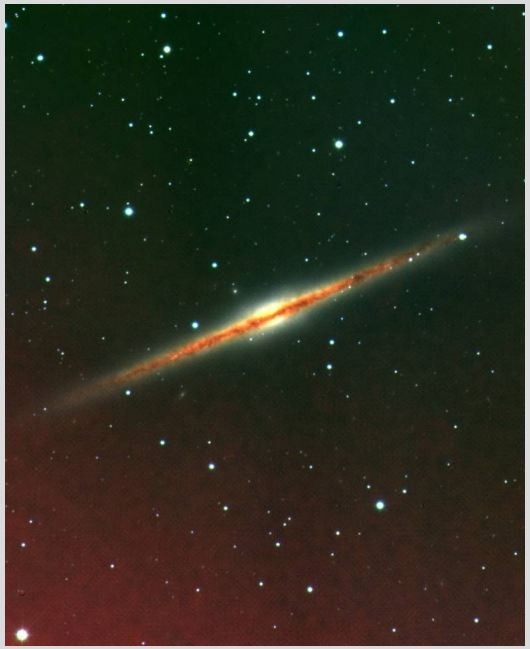
Hubble's Universe

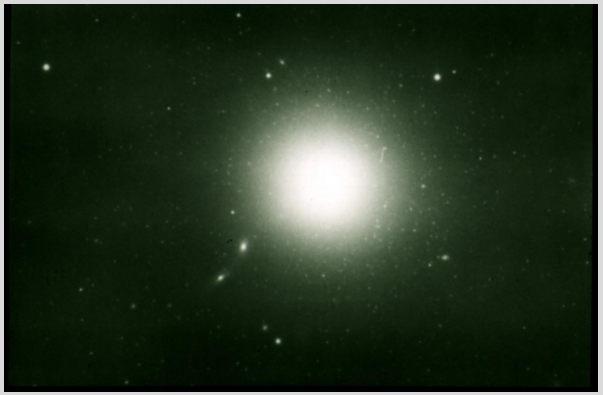
Orion Nebula
- glowing gas inside the Milky Way

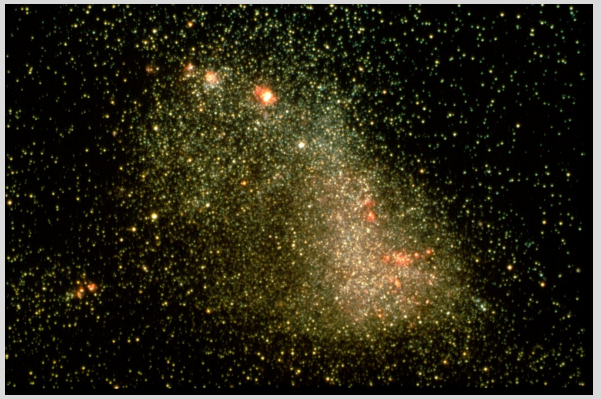
Andromeda Nebula - island universe of stars

Part Two
Deeper and Deeper

Nearby galaxies

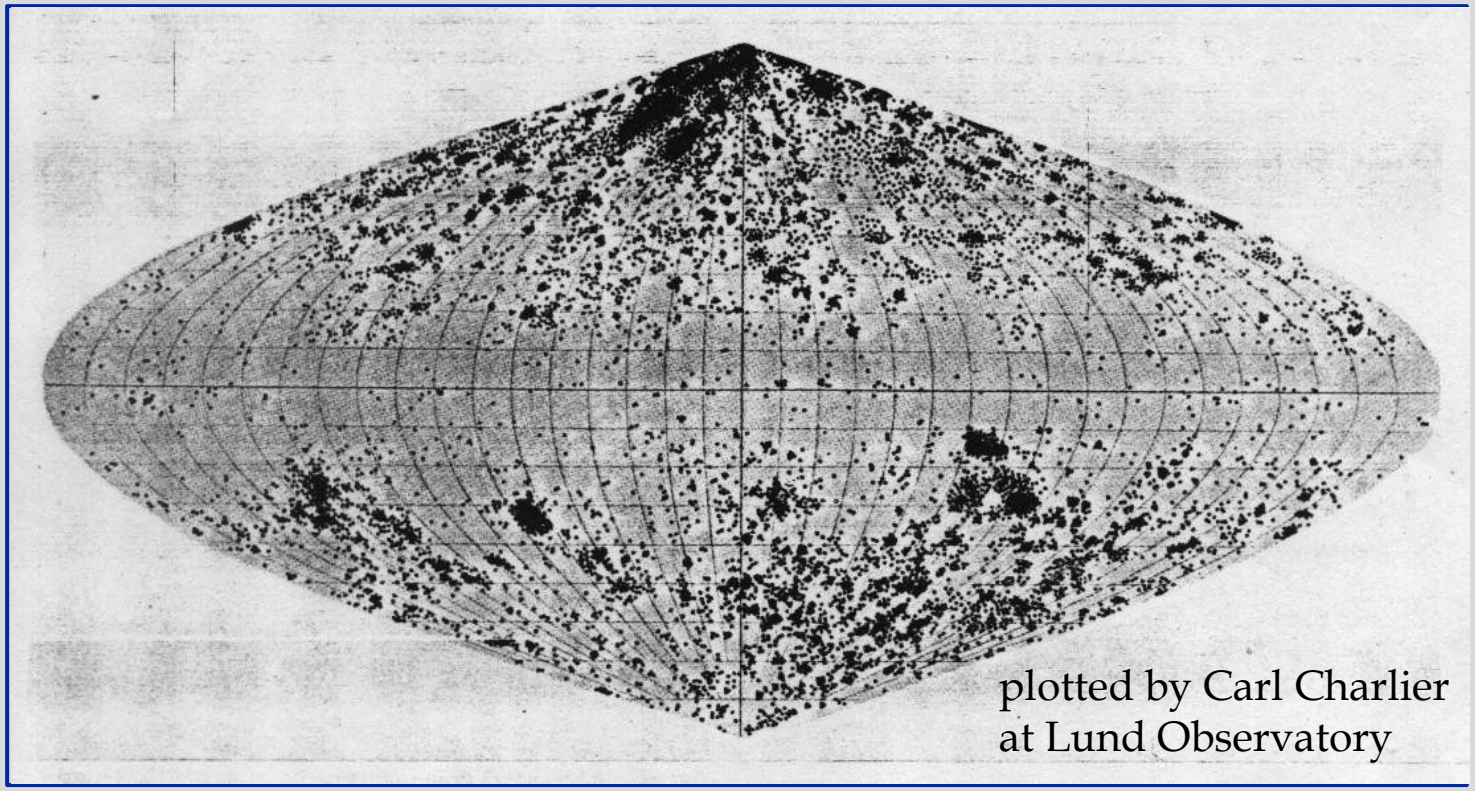






naked eye stars : 6th magnitude
nearby galaxies : 10th magnitude

1920s Universe : catalogue to 14th magnitude

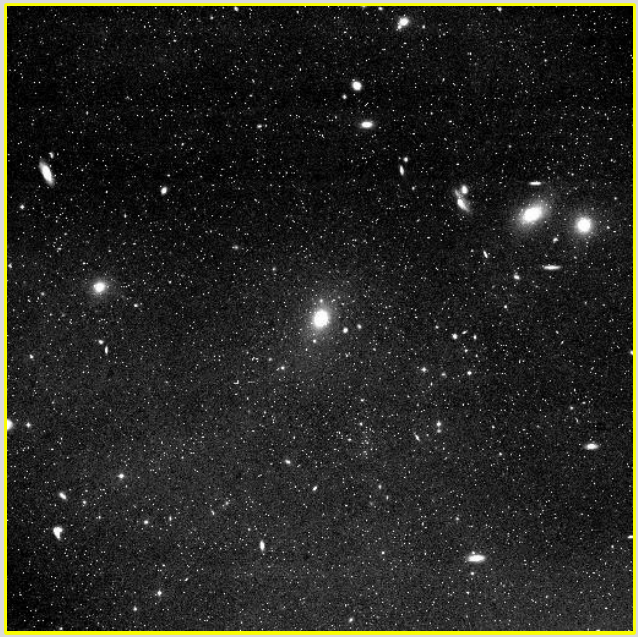


Blank strip due to Milky Way obscuration

Distribution of galaxies very **clumpy**

Clusters of galaxies

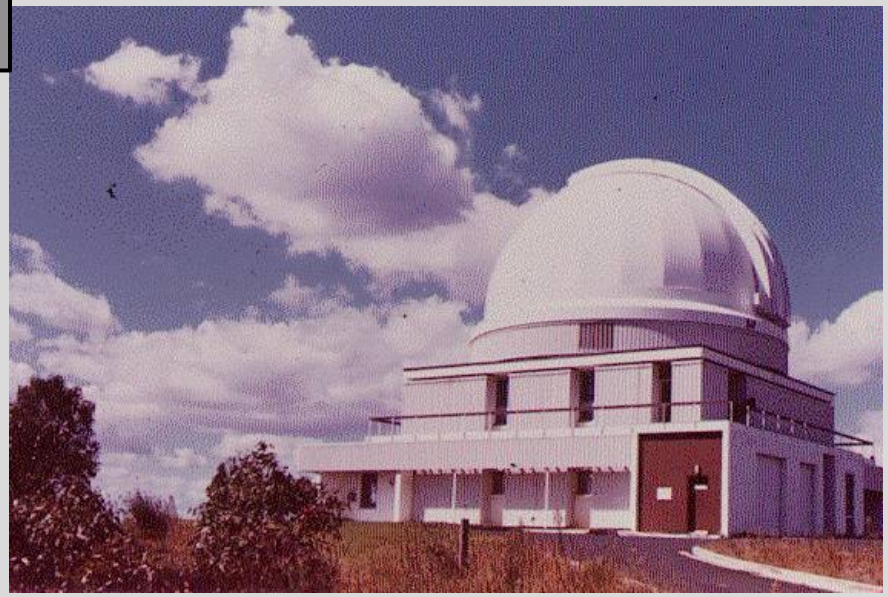
Random field

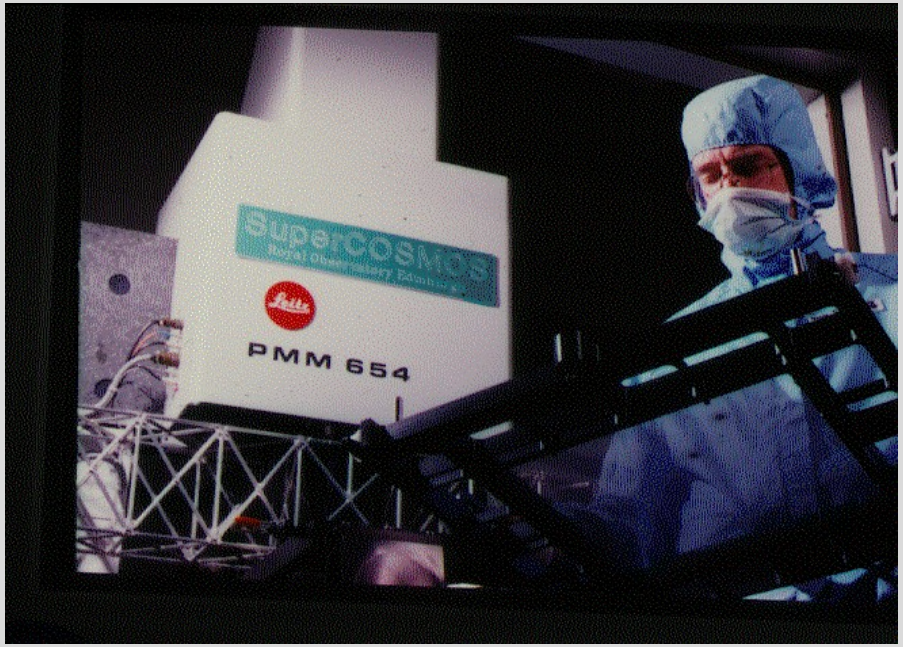


Virgo cluster

Hercules cluster

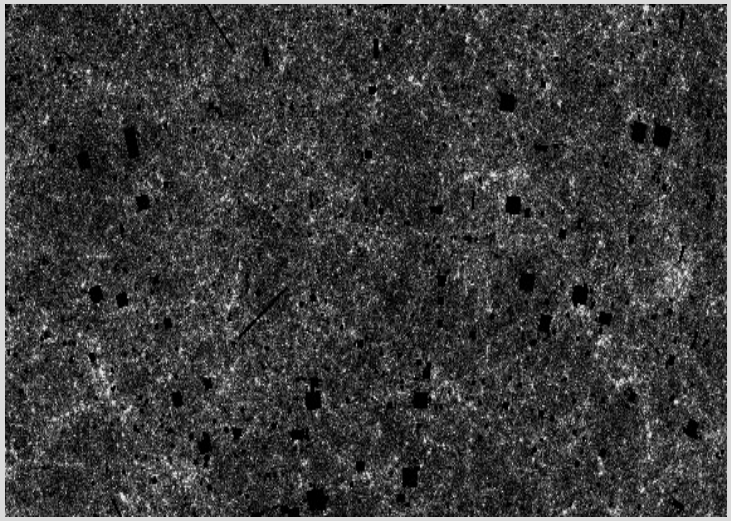
1970s : photographic surveys





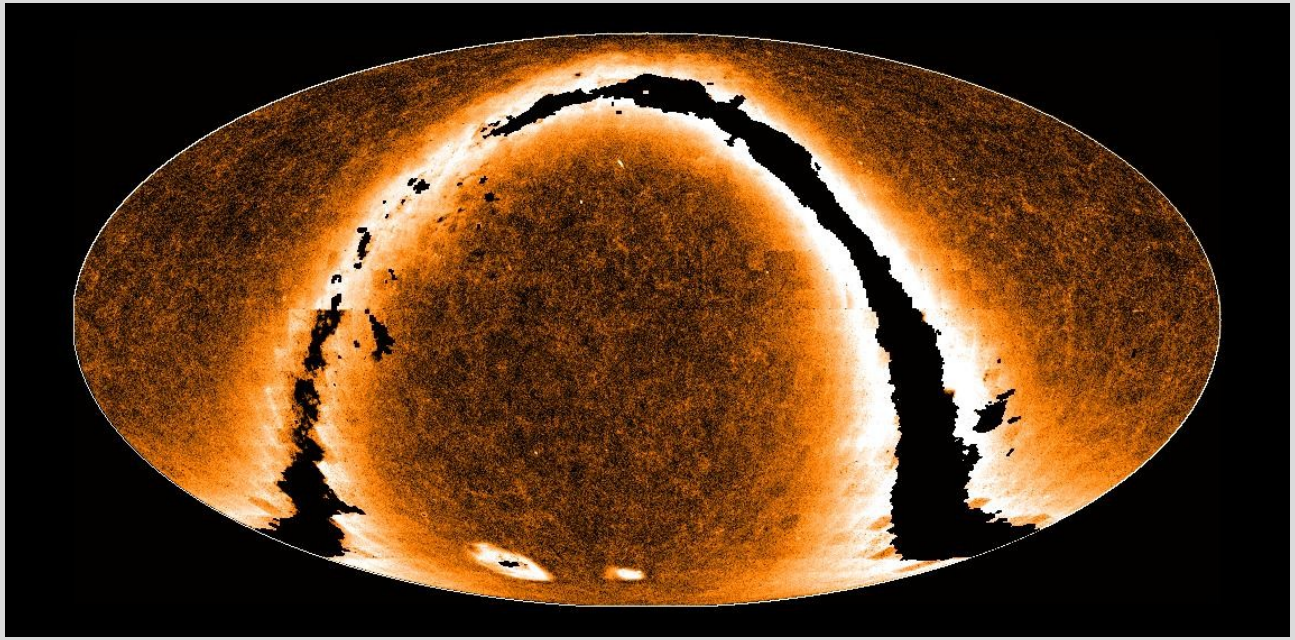
The sky to 20th magnitude

much smoother but still a "frothy" appearance



APM survey (Cambridge)

SuperCOSMOS survey (ROE)



1990s : Hubble Deep Field

1990s : Distant Radio Galaxies

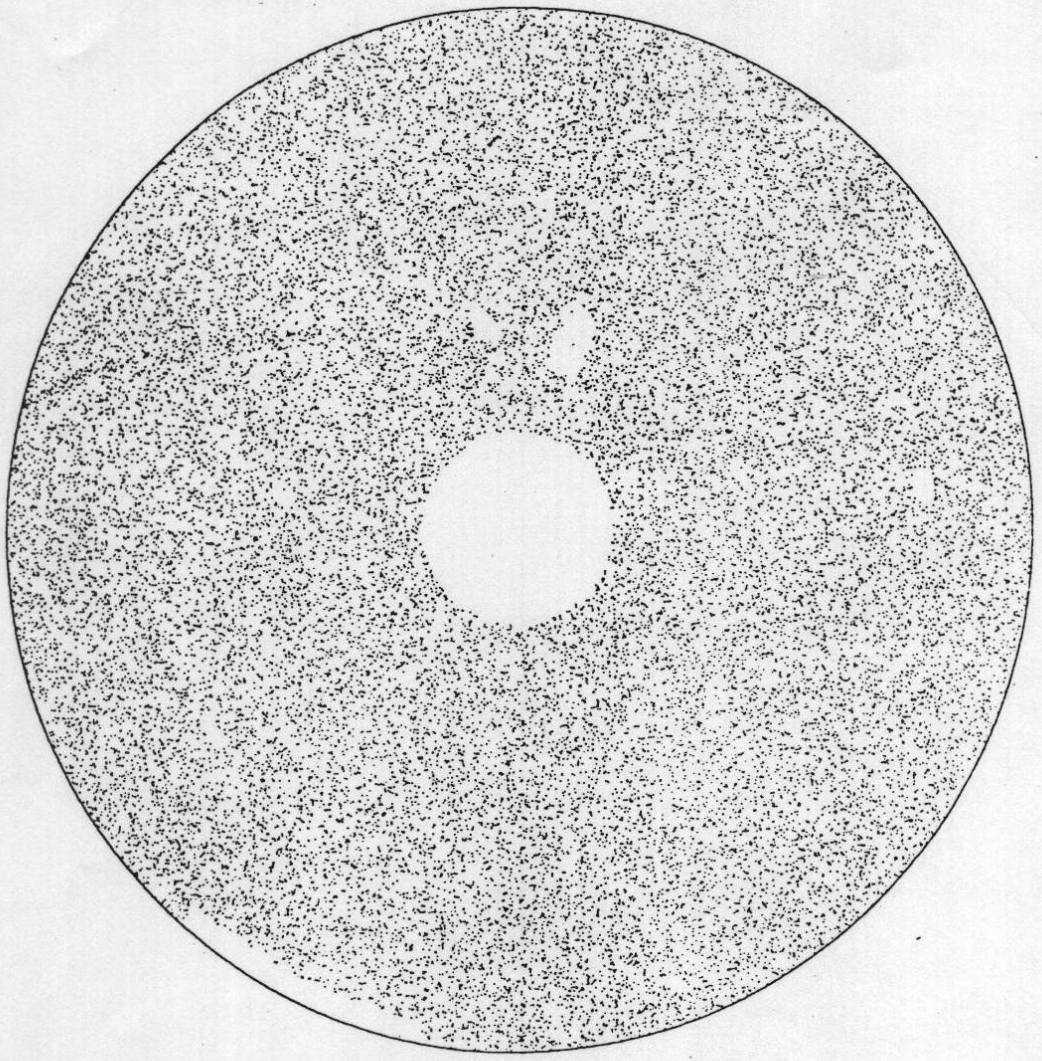
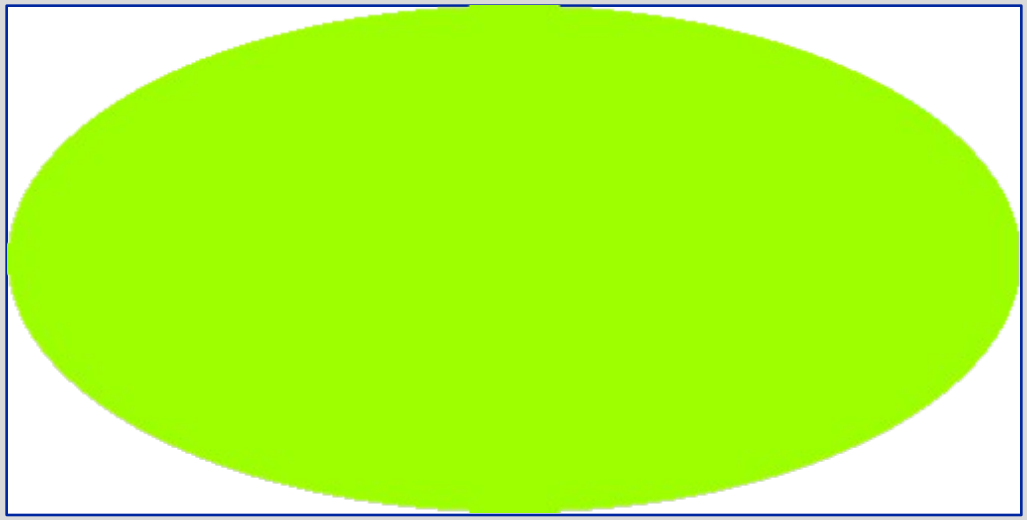


Figure 3.10. Angular distribution of the ~31,000 brightest 6 cm radio sources (Gregory and Condon 1991.)

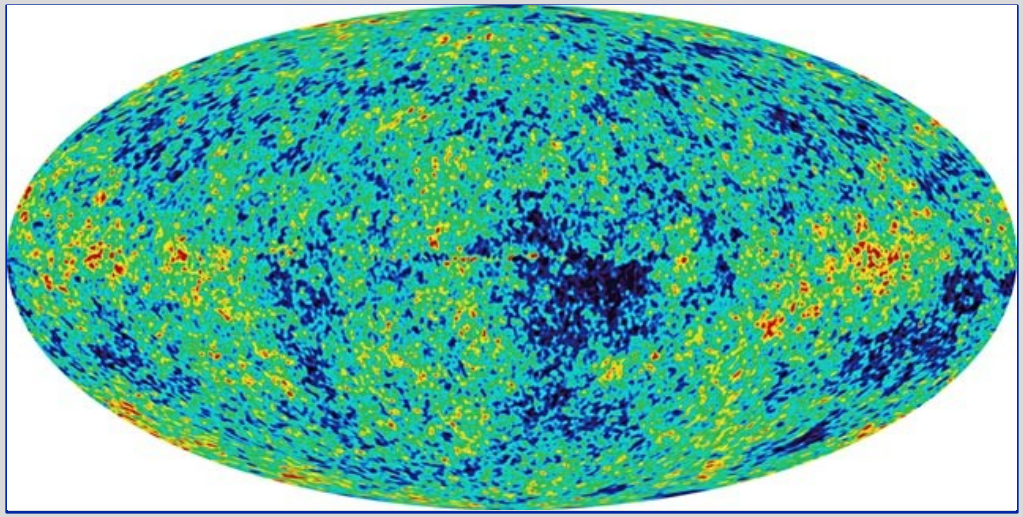
Sky looks smooth on a scale of billions of light years

Edge of observable universe



Cosmic Microwave Background **very** smooth

Same data amplified times 10,000

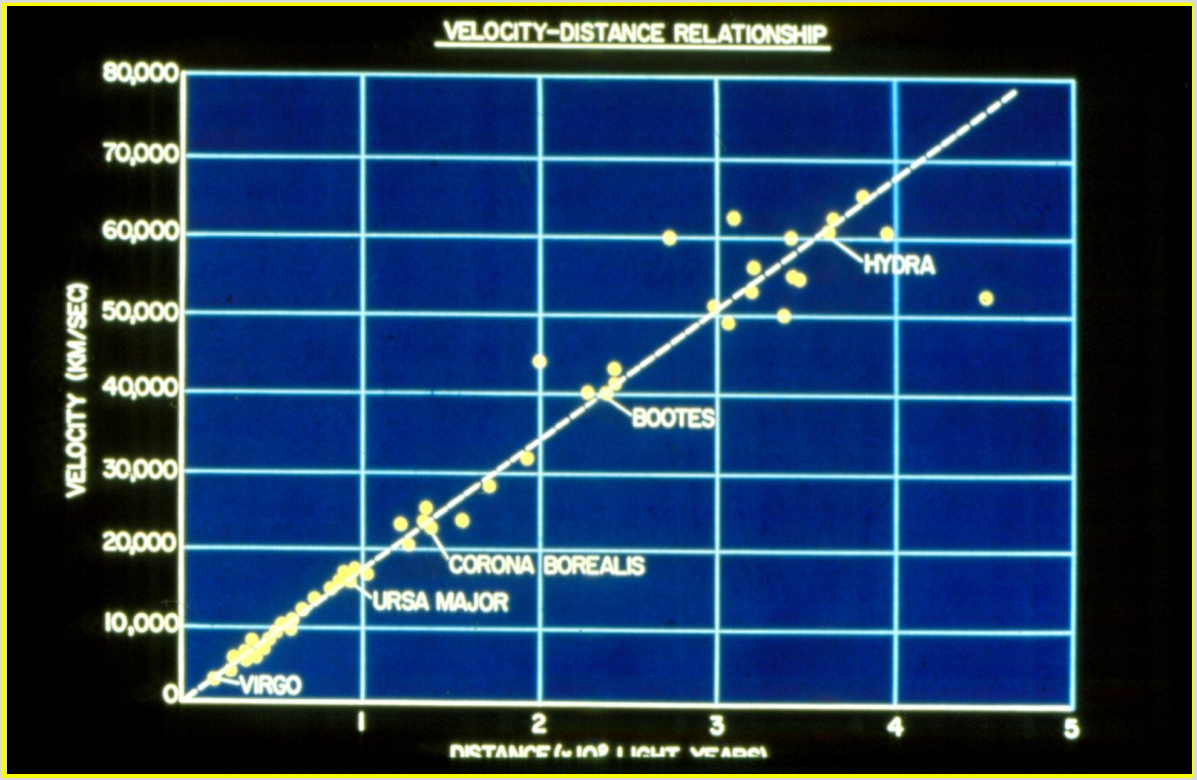


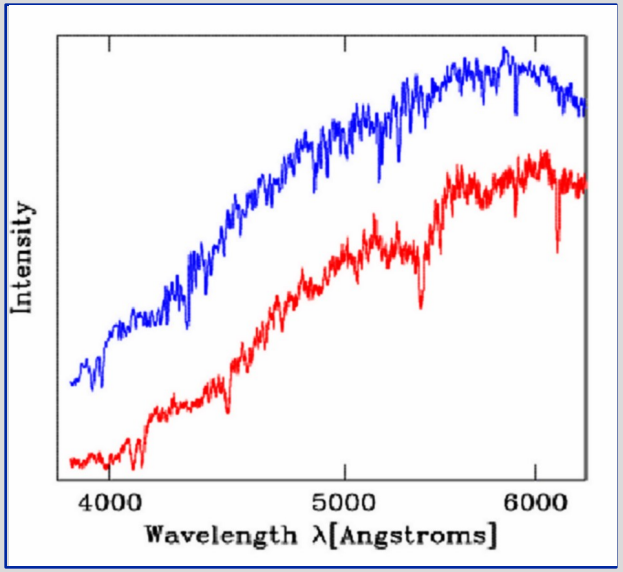
WMAP results

Part Three
The Universe in 3D

Hubble's Law

velocity-distance relation



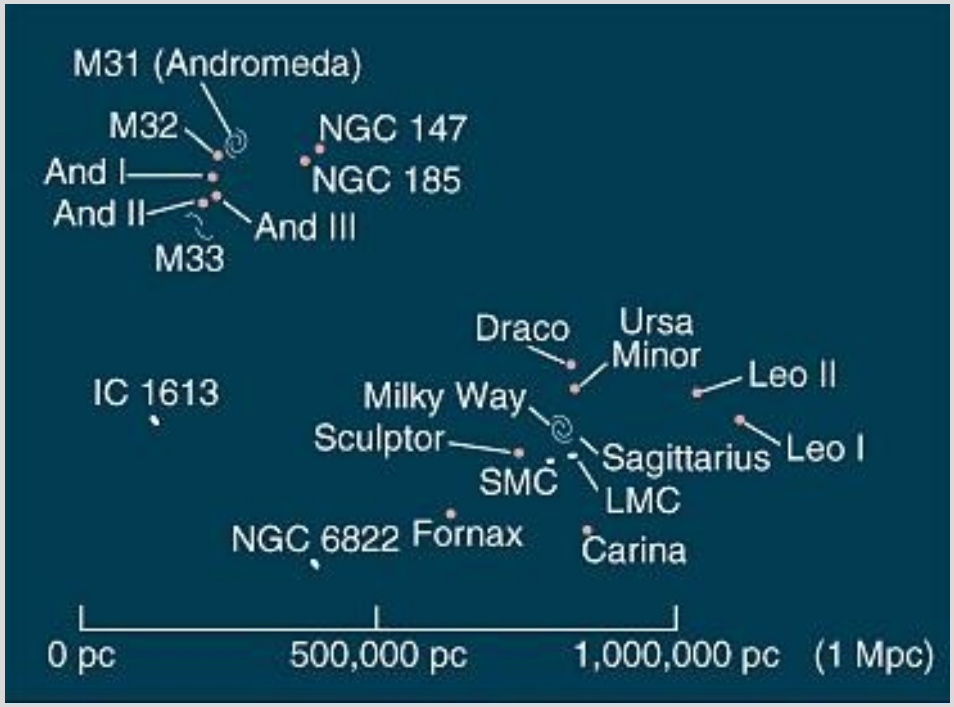


redshift

gives easy way to
estimate galaxy distances

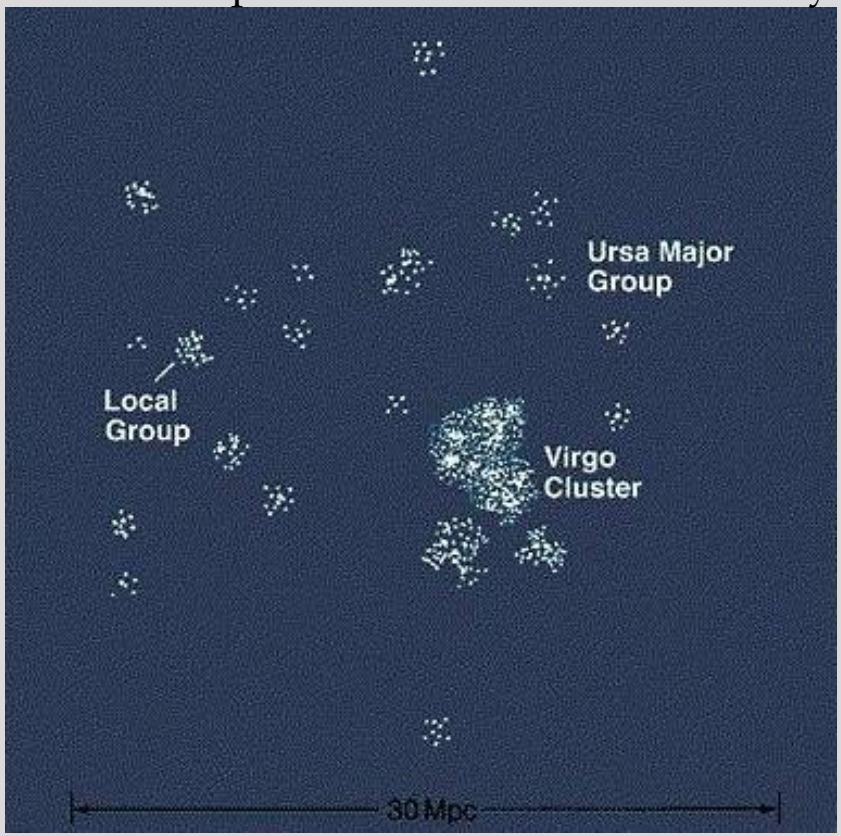
The Local Group

1 Mpc = 3 million light years
= 31 billion billion km
= 200 billion times distance to Sun



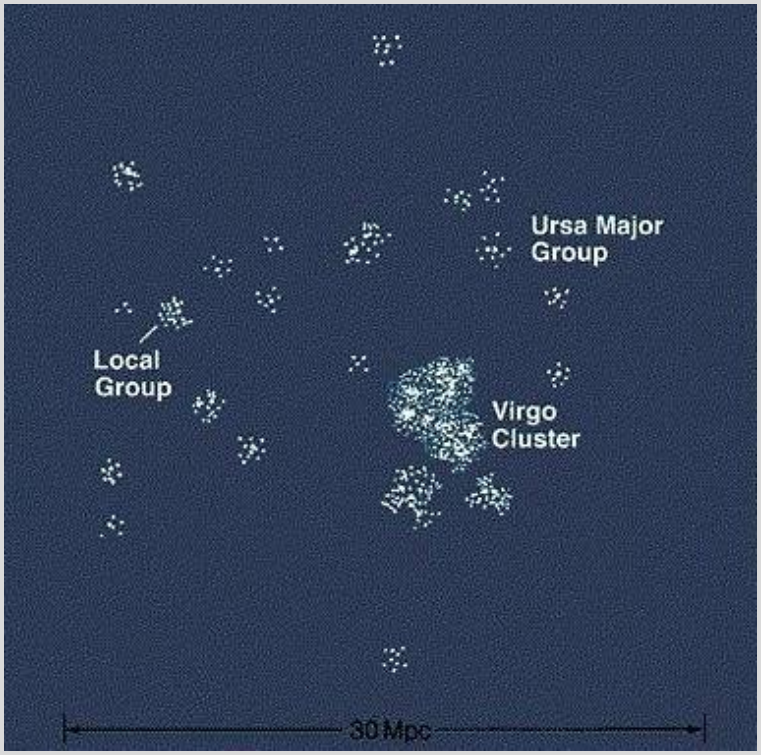
1 Mpc

plots from Rochester University

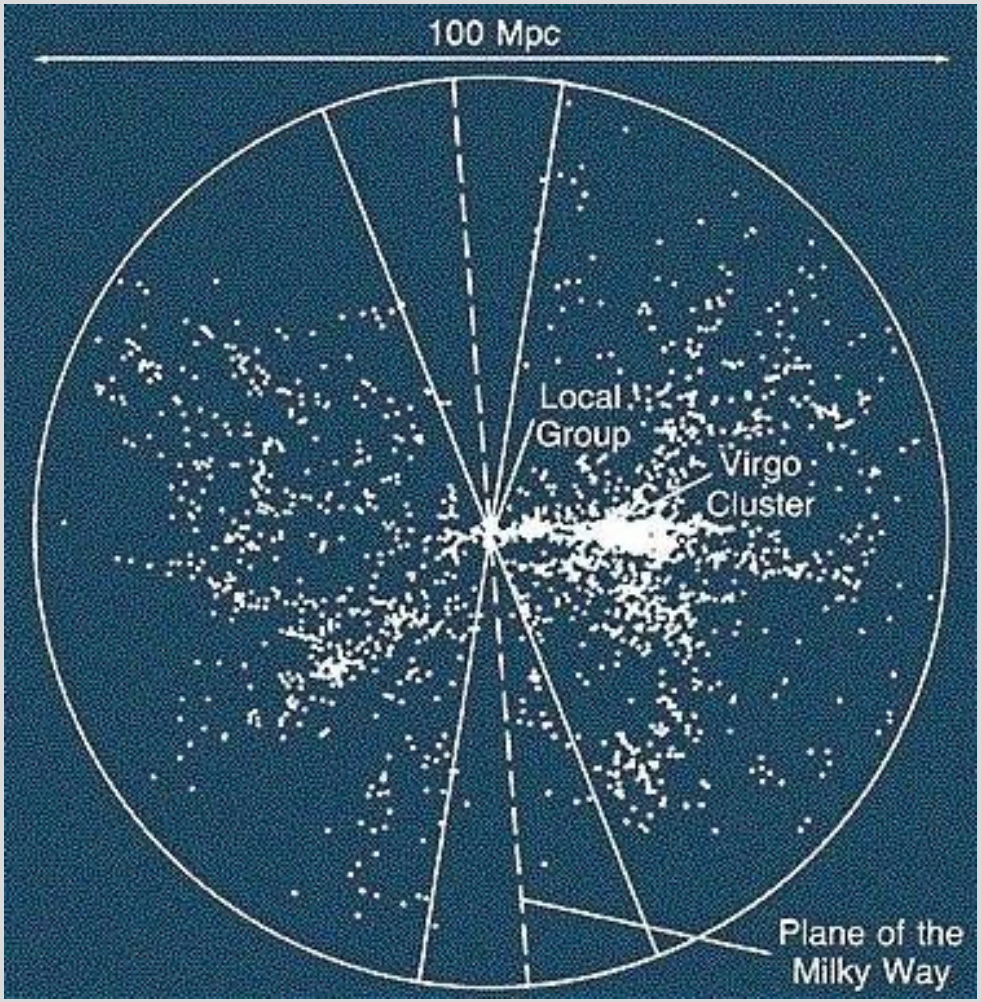


30 Mpc

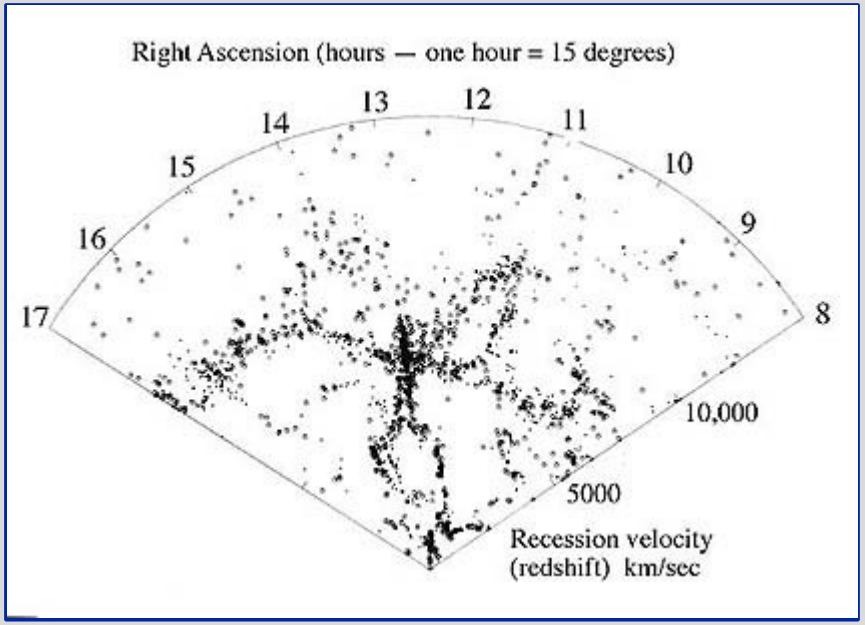
The Local Supercluster



100 Mpc

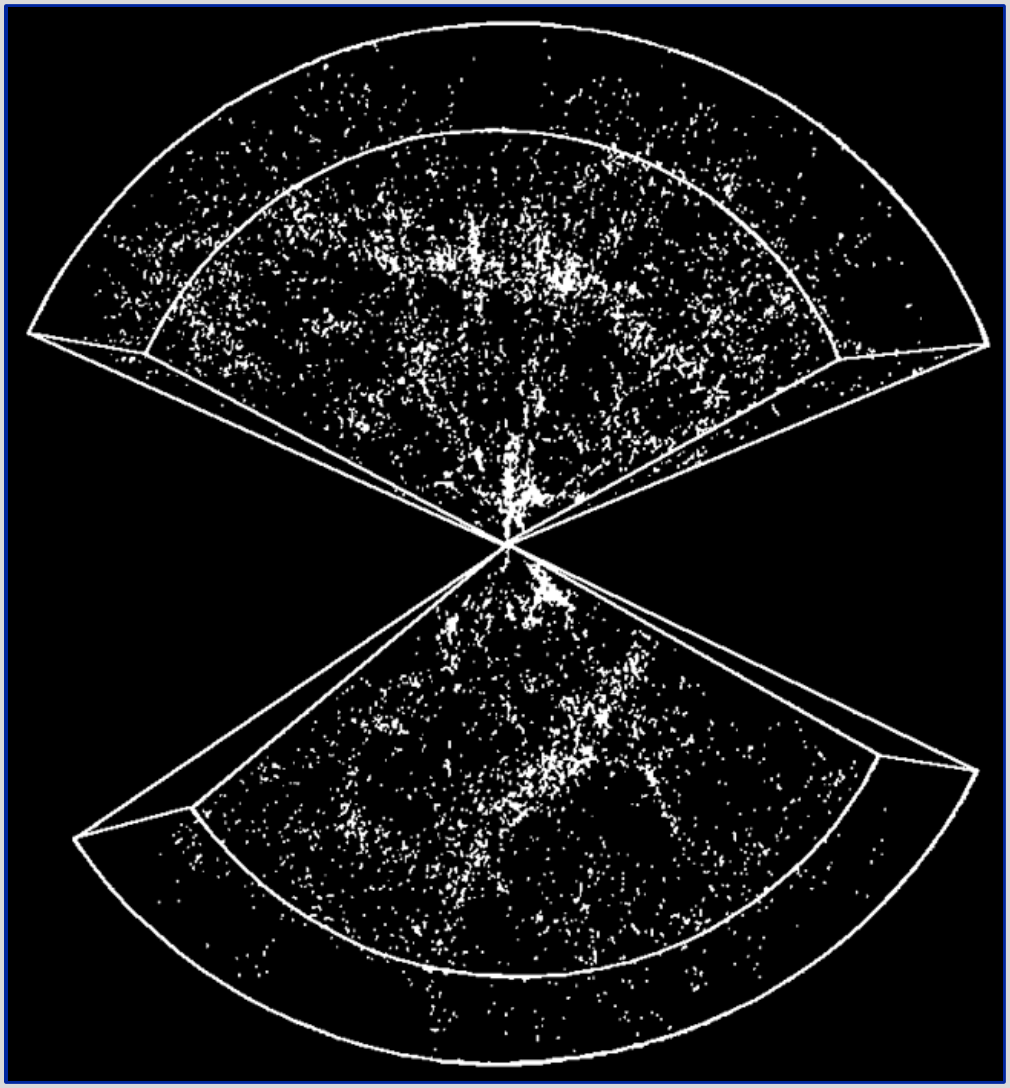


Bubbles and Walls



The CfA stickman

500 Mpc



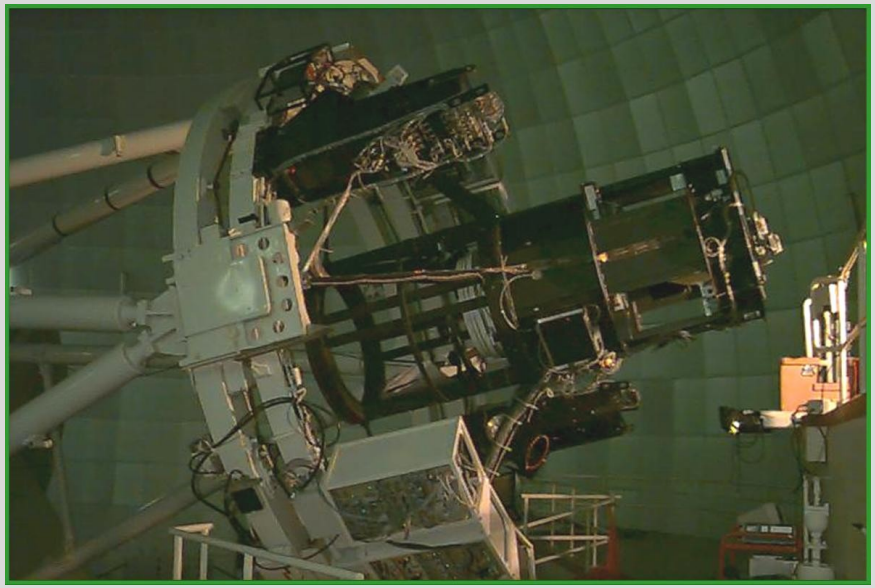
Las Campanas survey

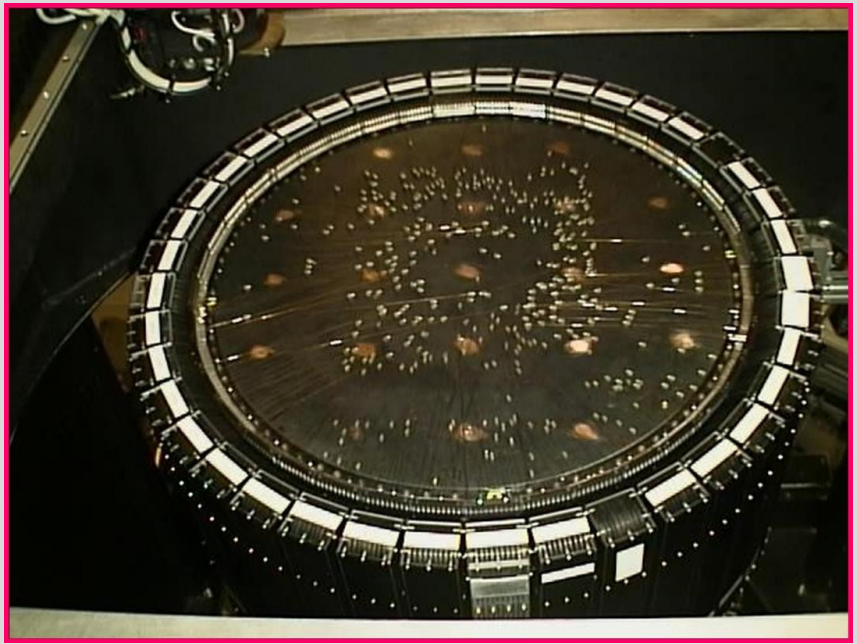
New Redshift Surveys

2dF Galaxy Redshift Survey

Sloan Digital Sky Survey

Fibre spectroscopy

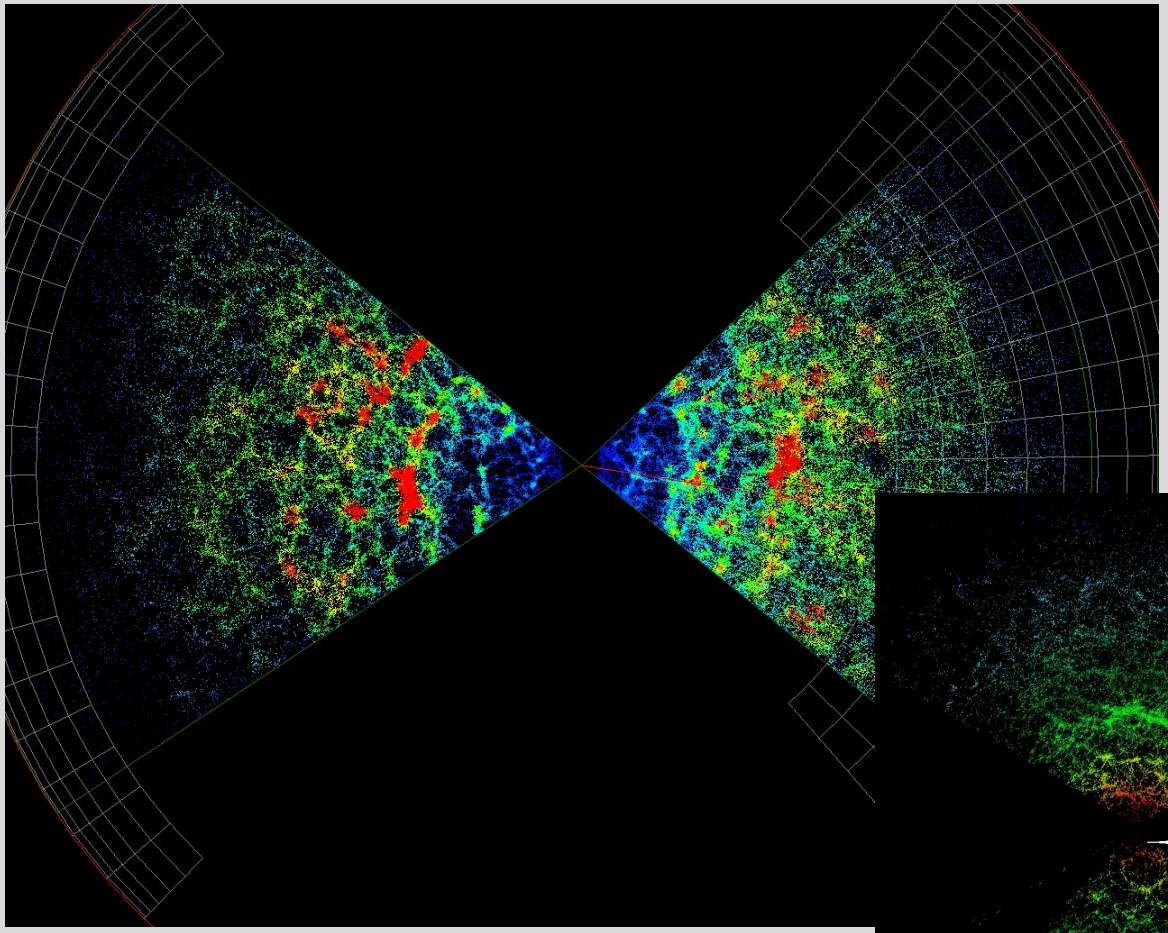




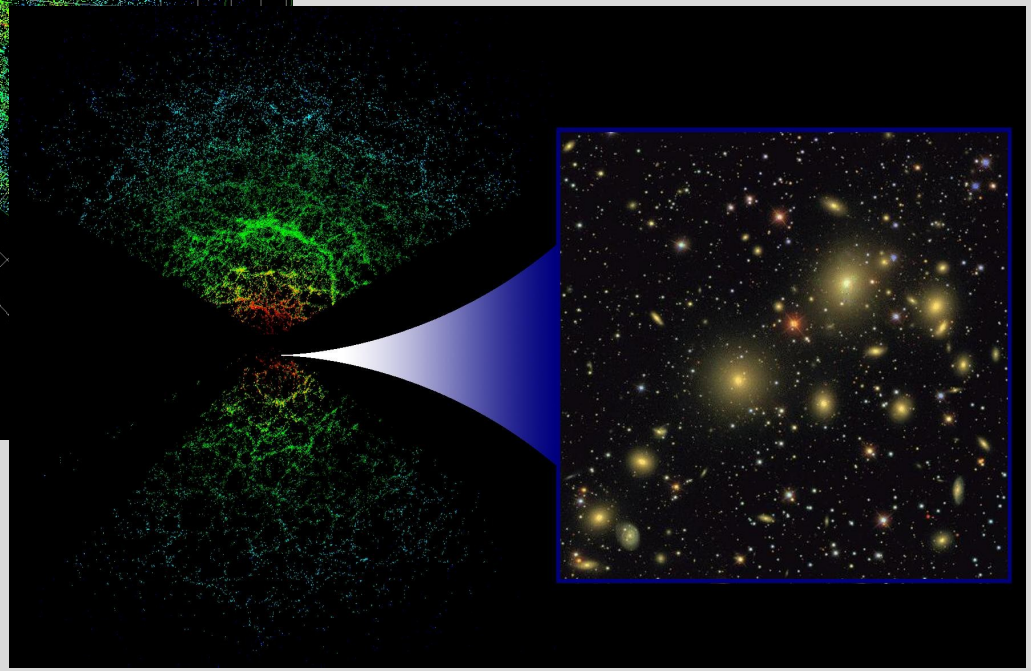
400 spectra in one shot

Latest Maps of the Universe

3000 Mpc



2dF Galaxy Redshift Survey



Sloan Digital Sky Survey

Rotating View of 2dFGRS

Part Four
Testing Theory

Can we explain what we see ?

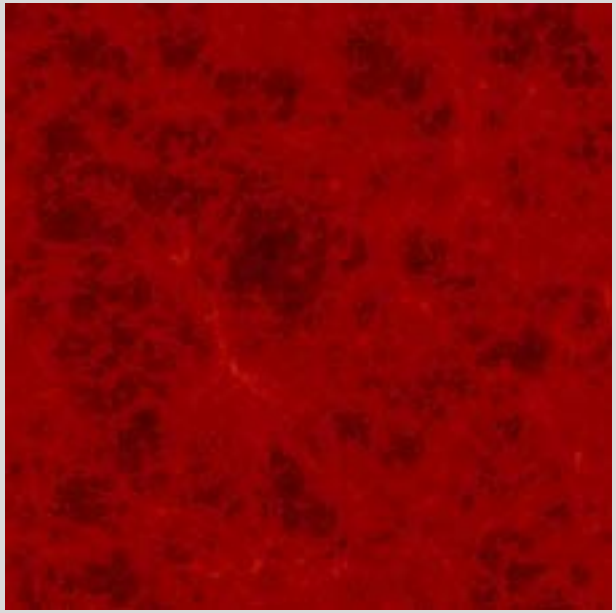
- need to explain
  - clumpiness reduces with scale
  - bubbles and filaments

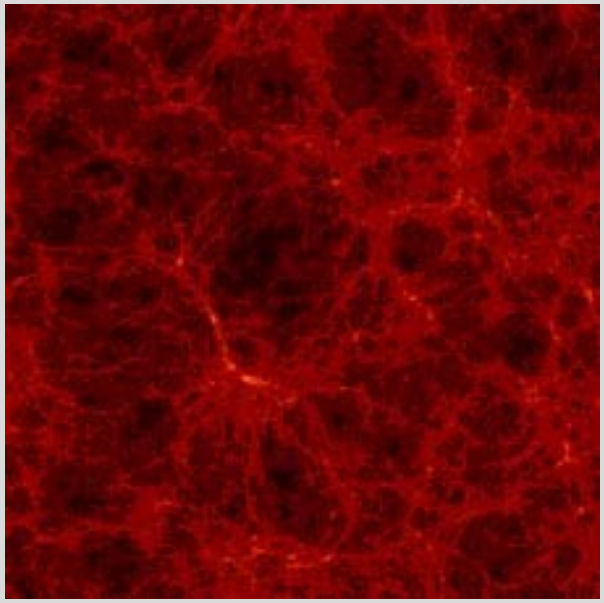
- ingredients of theory
  - Big Bang expansion theory
  - seed of clumps from quantum fluctuations
  - gravity makes clumps slowly clumpier with time

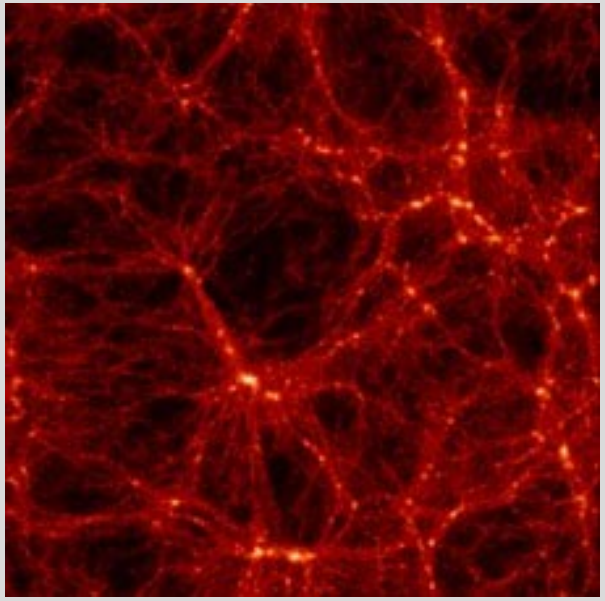
Things we choose

- density of matter
- fraction of dark matter
- type of dark matter

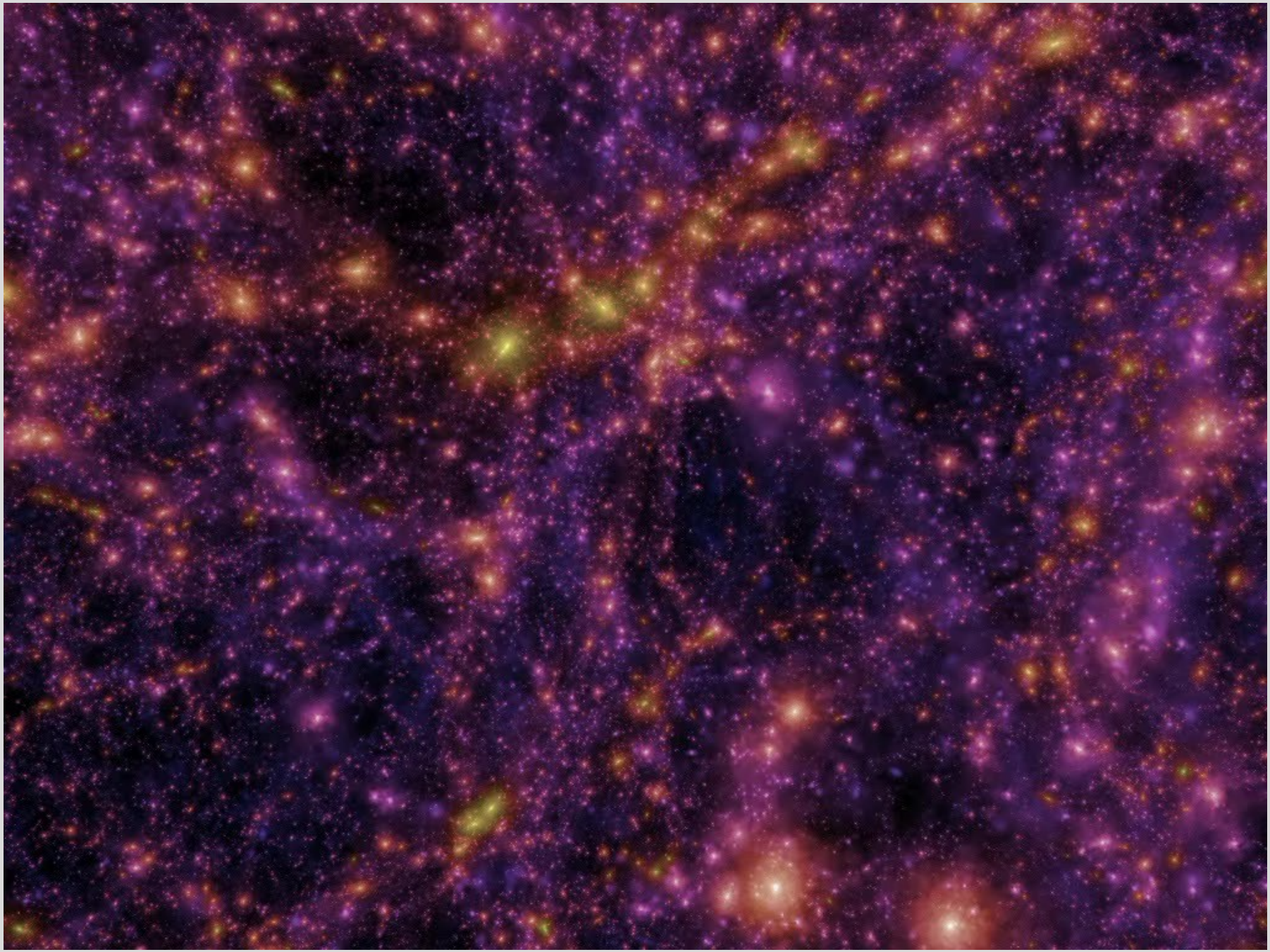
Supercomputer simulations



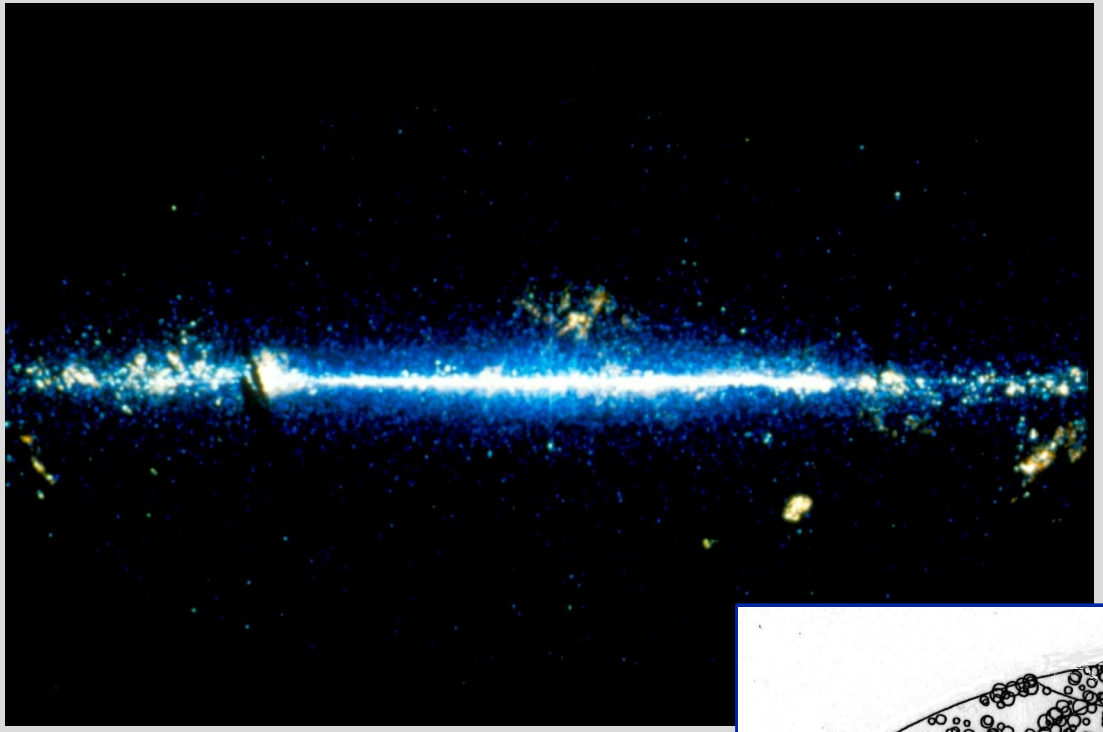




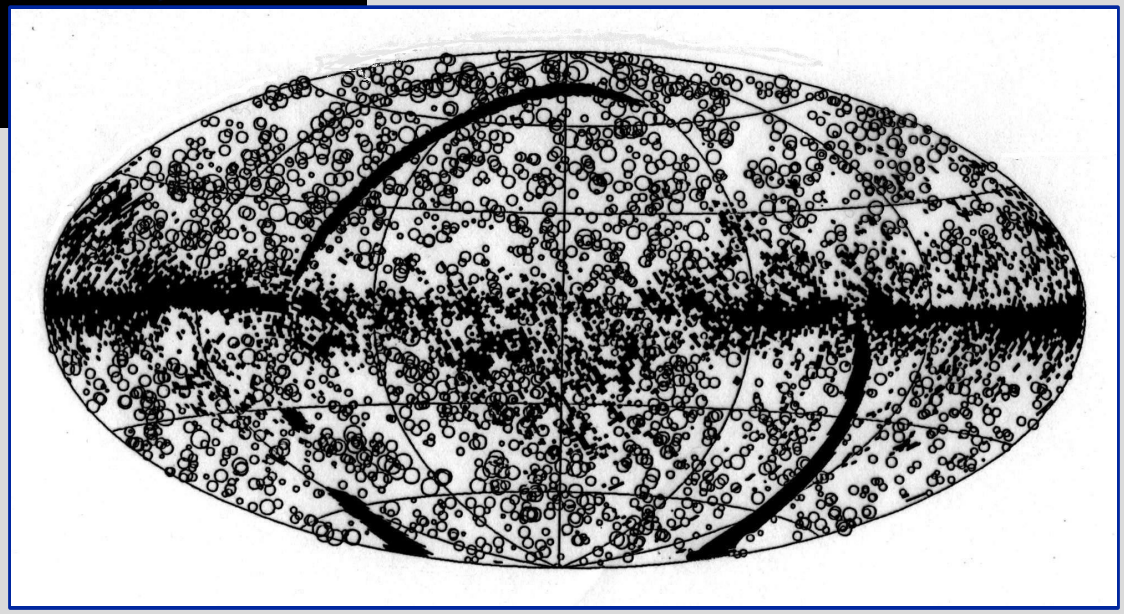
VIRGO project



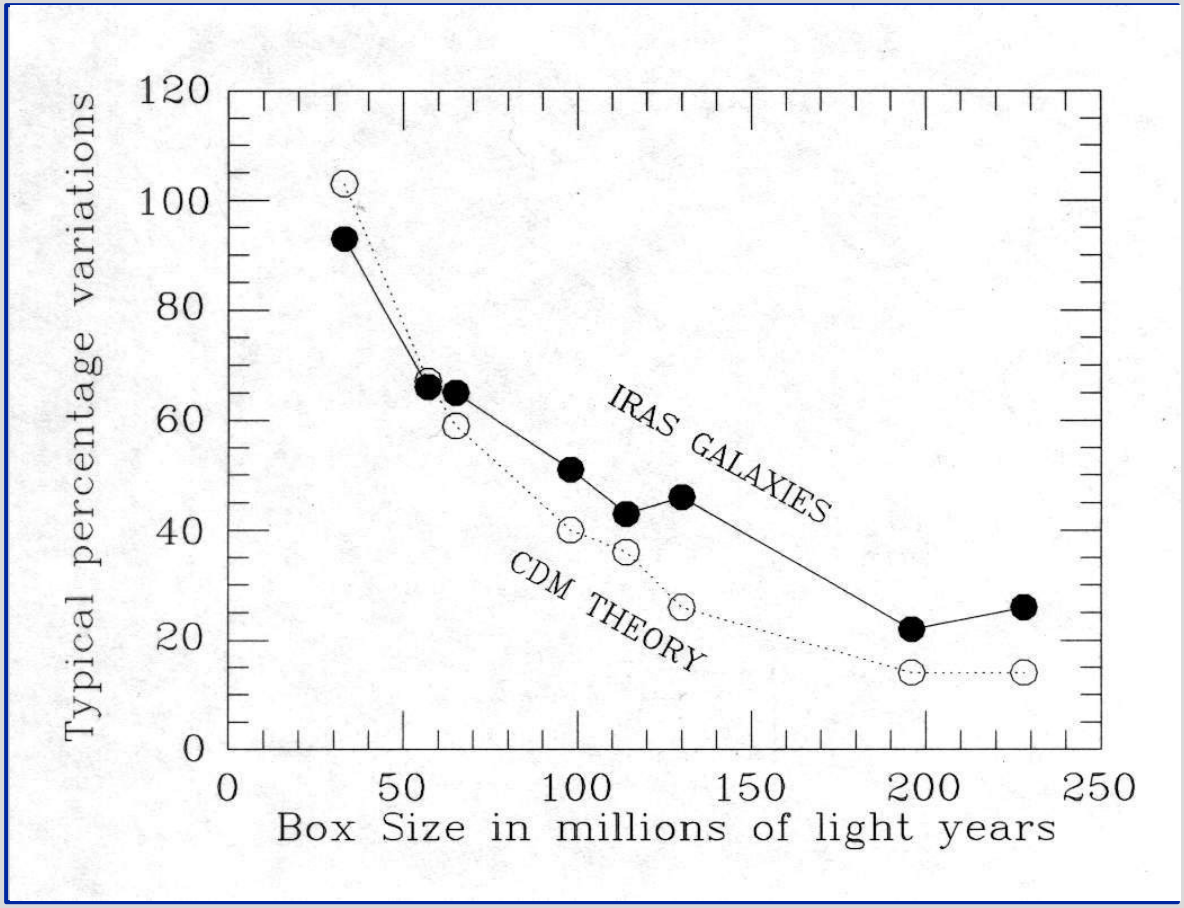
Far-IR galaxy survey



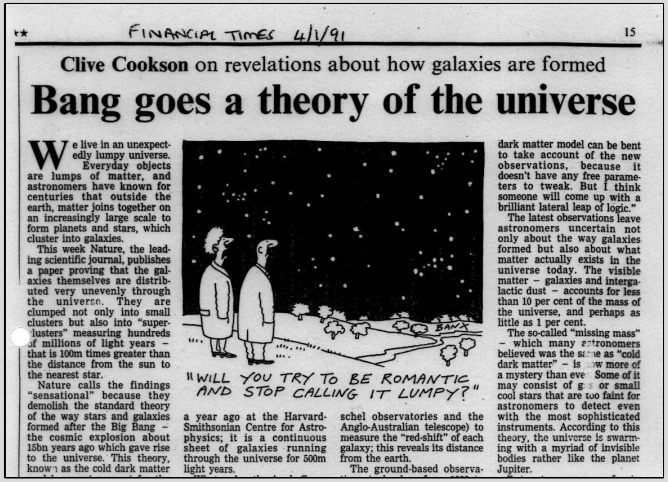
IRAS



clumpiness versus scale : IRAS galaxies



Almost explained by
"cold dark matter" universe
... but doesn't quite fit



FINANCIAL TIMES 4/1/91 15

Clive Cookson on revelations about how galaxies are formed

Bang goes a theory of the universe

We live in an unexpectedly lumpy universe.

Everyday objects are lumps of matter, and astronomers have known for centuries that outside the earth, matter joins together on an increasingly large scale to form planets and stars, which cluster into galaxies.

This week Nature, the leading scientific journal, publishes a paper proving that the galaxies themselves are distributed very unevenly through the universe. They are clumped not only into small clusters but also into "superclusters" measuring hundreds of millions of light years – that is 100m times greater than the distance from the sun to the nearest star.

Nature calls the findings "sensational" because they demolish the standard theory of the way stars and galaxies formed after the Big Bang – the cosmic explosion about 15bn years ago which gave rise to the universe. This theory, known as the cold dark matter

a year ago at the Harvard-Smithsonian Centre for Astrophysics; it is a continuous sheet of galaxies running through the universe for 500m light years.

schel observatories and the Anglo-Australian telescope) to measure the "red-shift" of each galaxy; this reveals its distance from the earth.

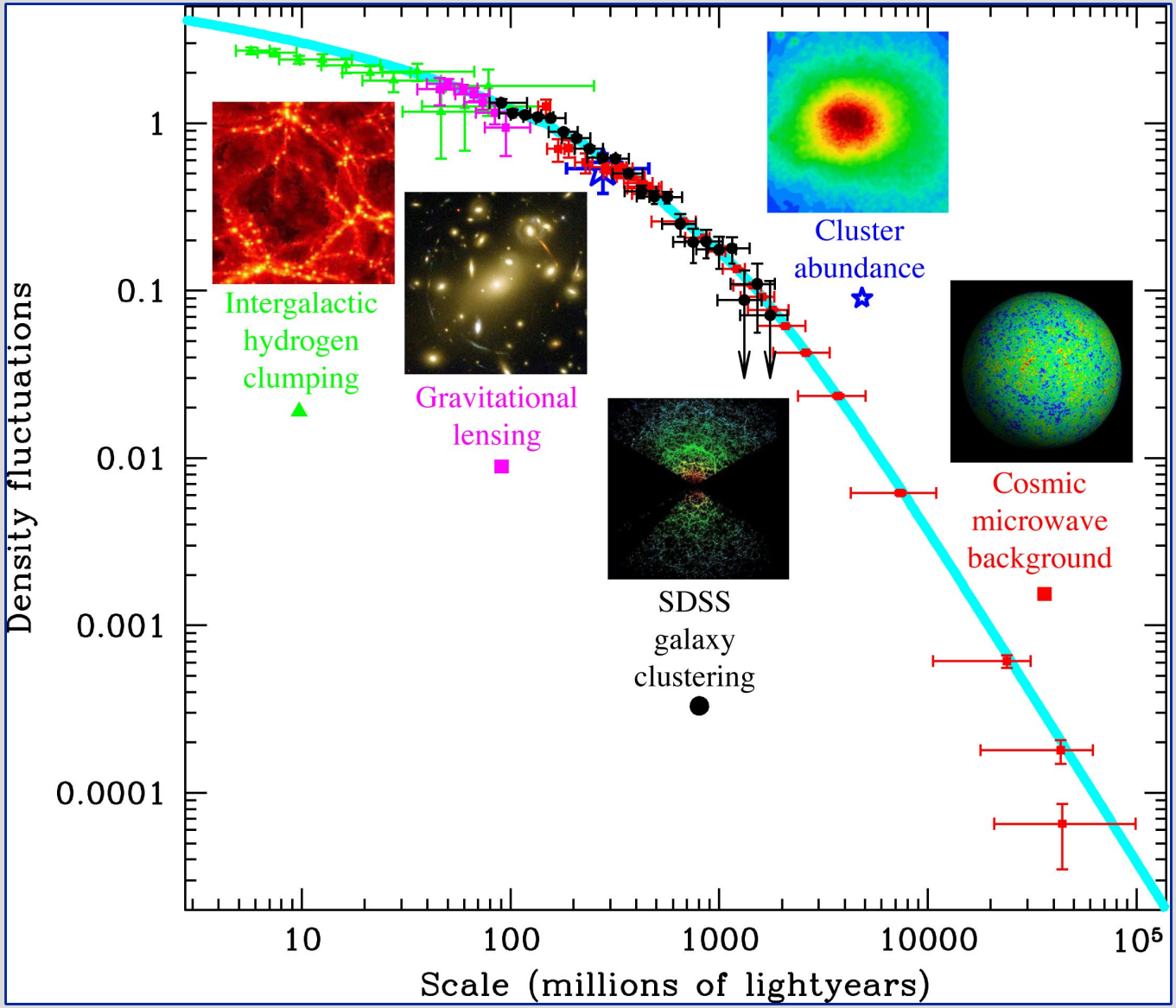
The ground-based observa-

dark matter model can be bent to take account of the new observations, because it doesn't have any free parameters to tweak. But I think someone will come up with a brilliant lateral leap of logic."

The latest observations leave astronomers uncertain not only about the way galaxies formed but also about what matter actually exists in the universe today. The visible matter – galaxies and intergalactic dust – accounts for less than 10 per cent of the mass of the universe, and perhaps as little as 1 per cent.

The so-called "missing mass" – which many astronomers believed was the same as "cold dark matter" – is now more of a mystery than ever. Some of it may consist of giant or small cool stars that are too faint for astronomers to detect even with the most sophisticated instruments. According to this theory, the universe is swarming with a myriad of invisible bodies rather like the planet Jupiter.

clumpiness versus scale : fibre surveys

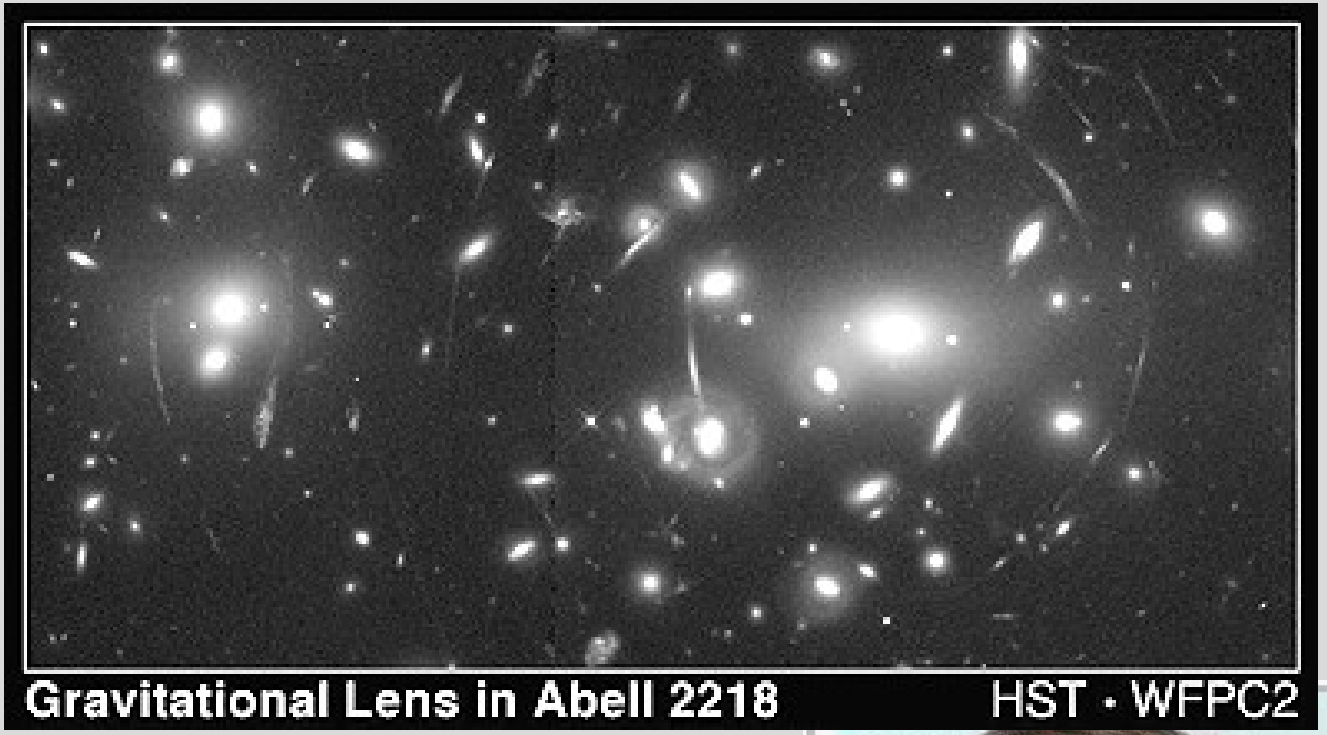


beautiful fit... needs

1% matter
29% dark matter
70% vacuum energy

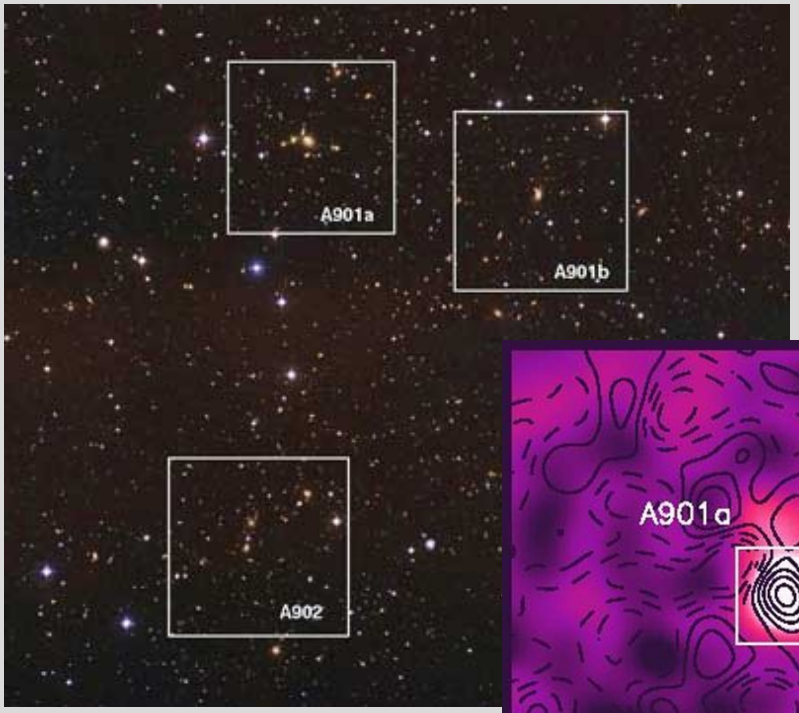
Part Five
What's next ?

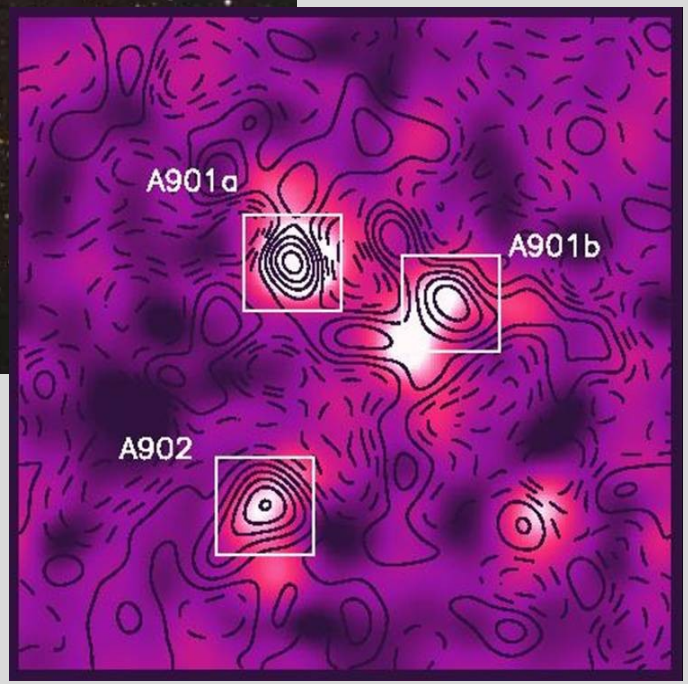
dark matter bends light

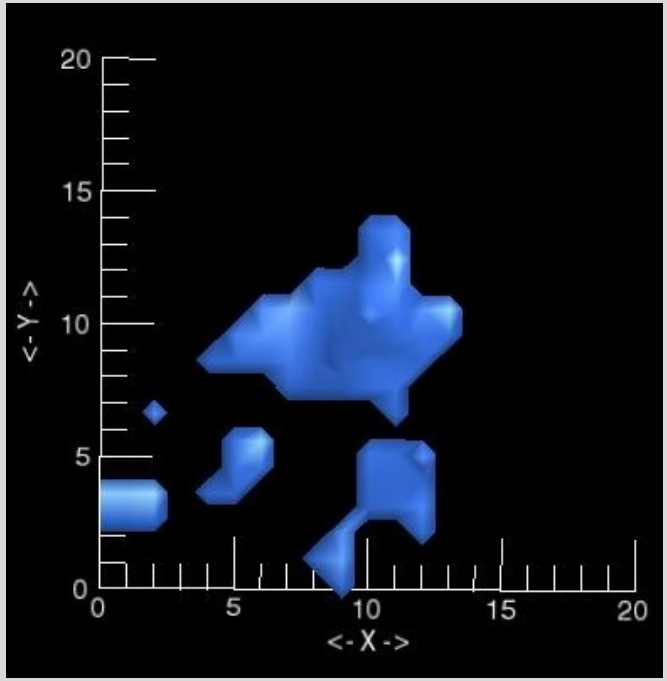


distortions tell us
the shape of the
dark matter lens

mapping the dark matter



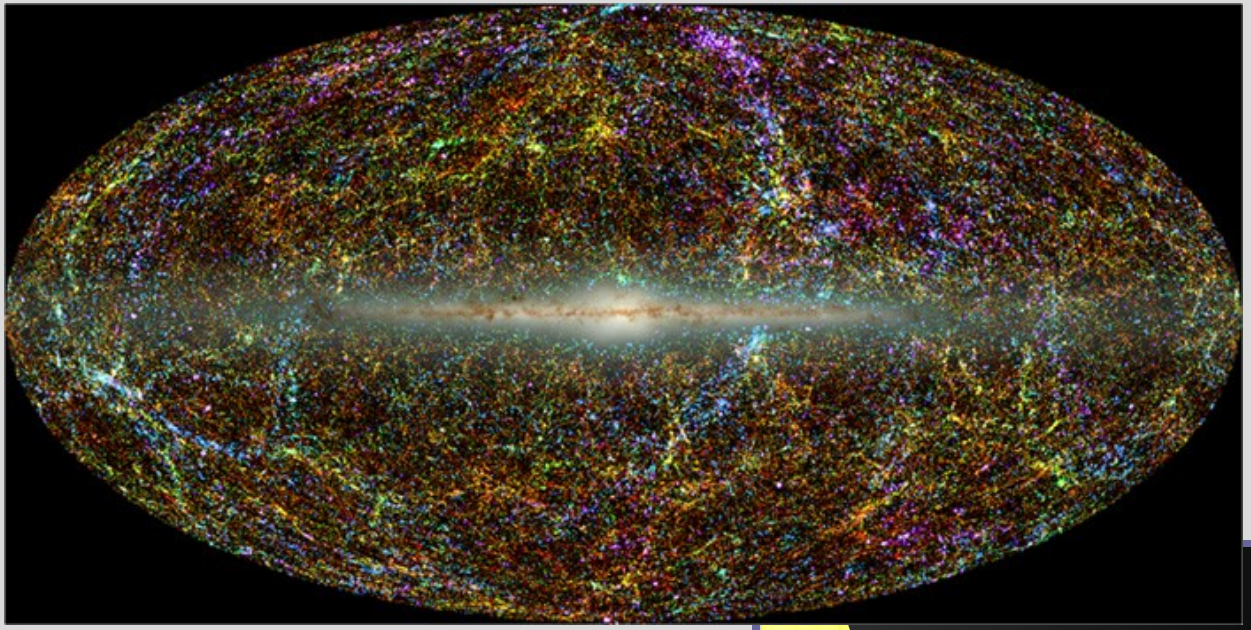




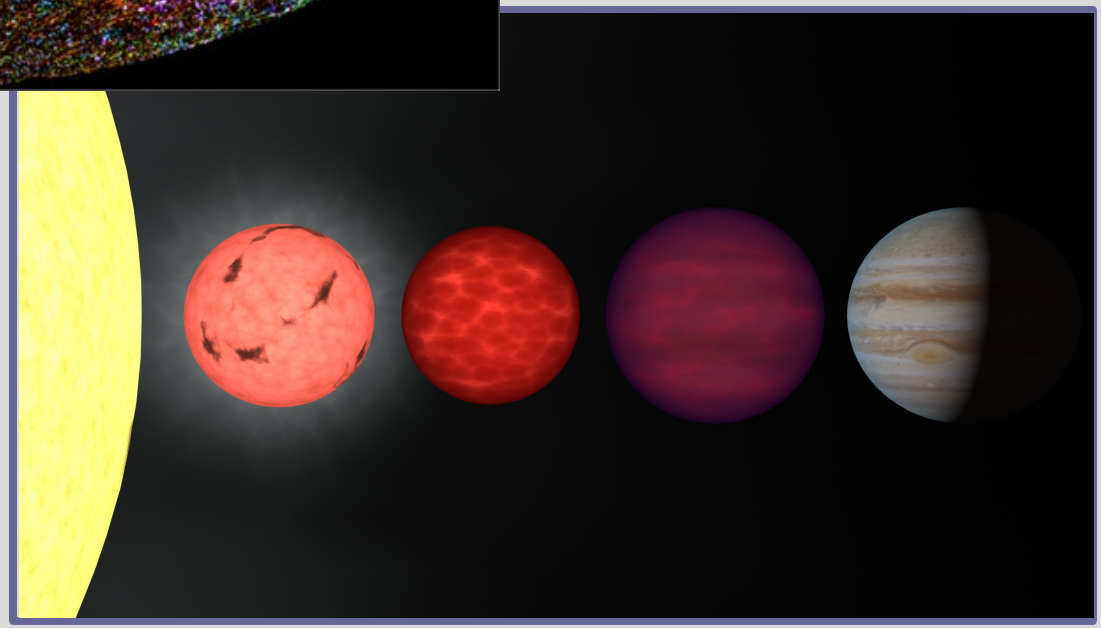
tracking weaker distortions maps out the **dark matter**

Infra-red surveys

(1) Distant objects : growth of clumping
(2) Cold objects : the nearest stars



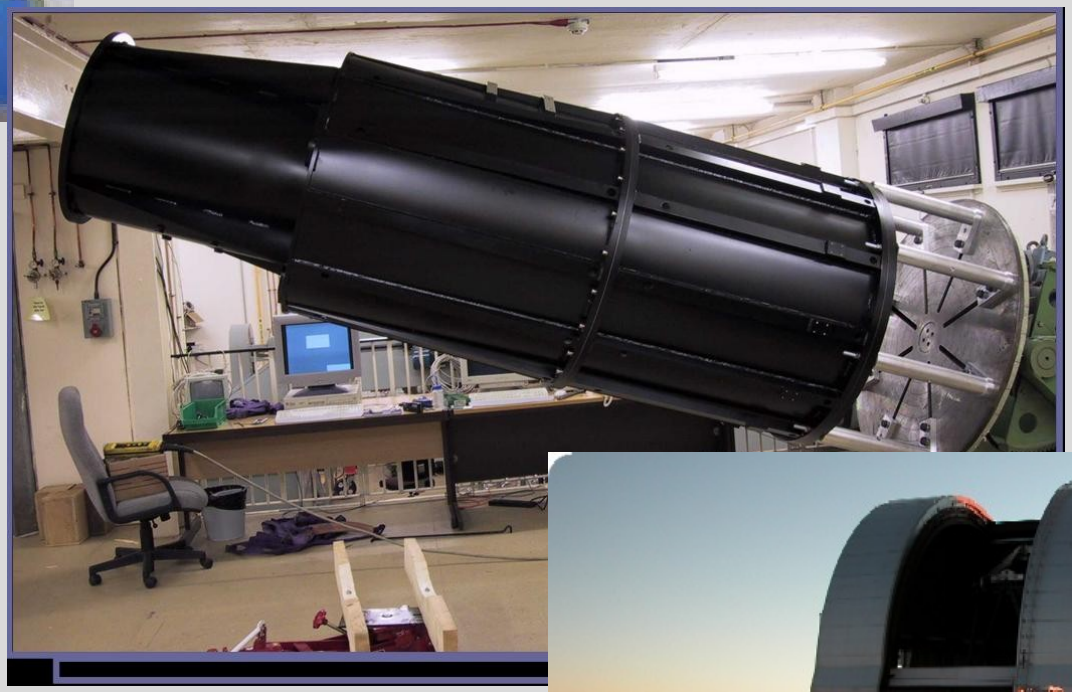
2MASS skymap

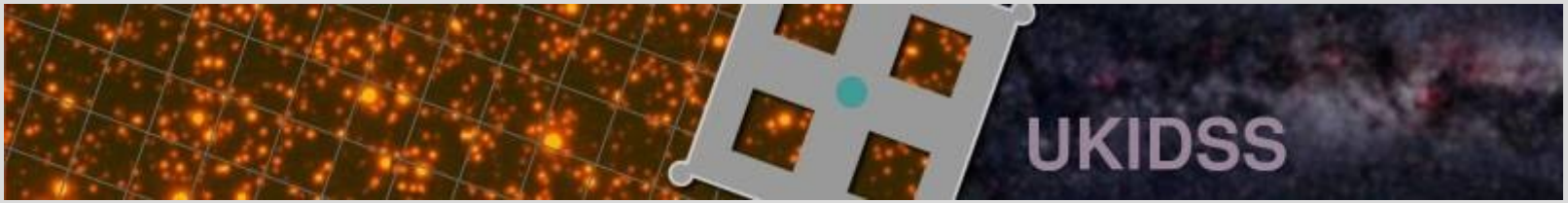


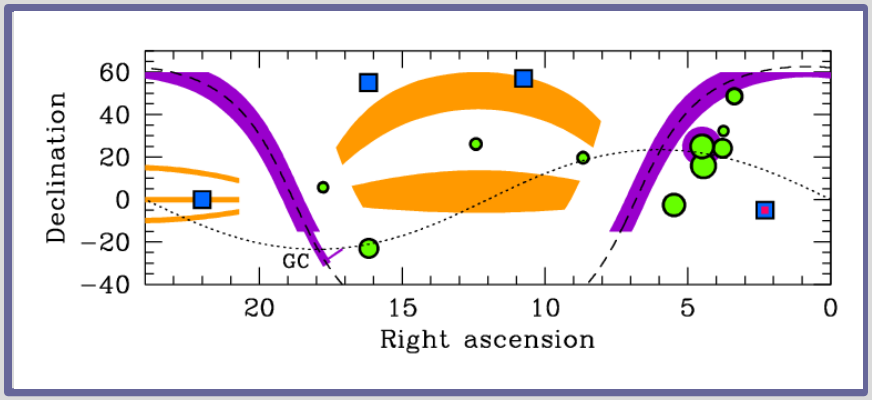
brown dwarf graphic from Kirkpatrick

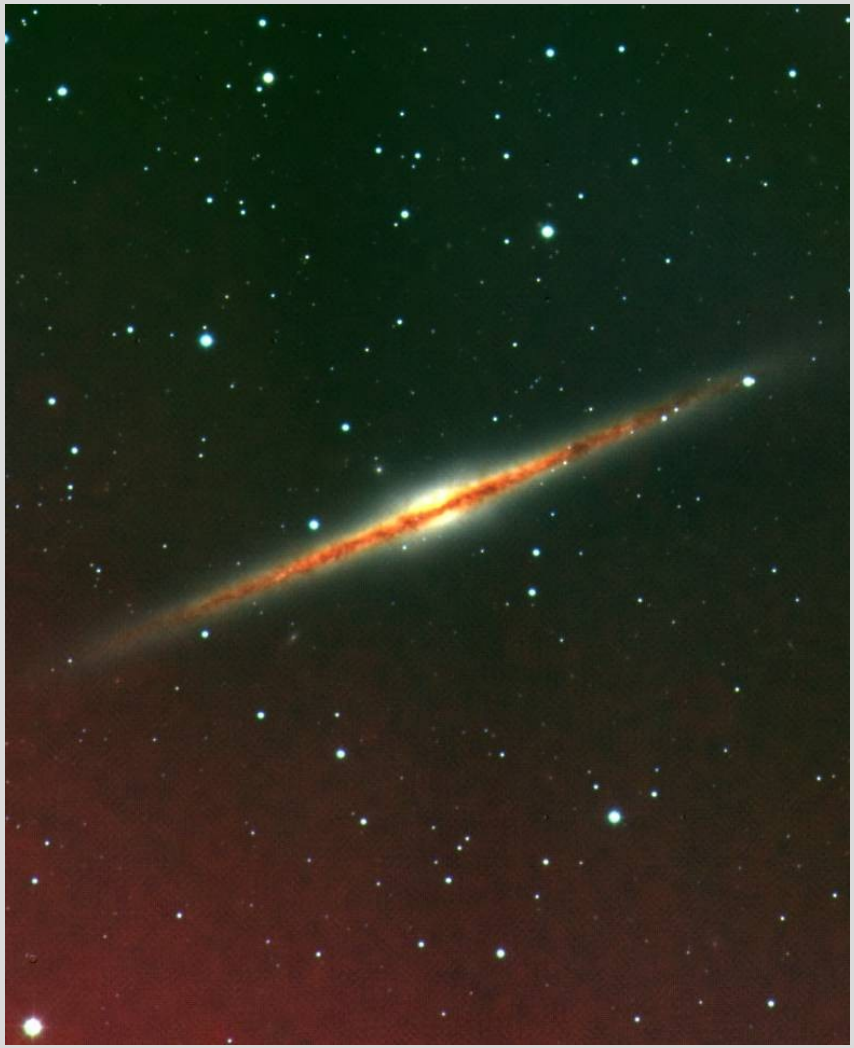
UKIRT Wide Field Camera

100 times faster than 2MASS




UKIDSS


Declination
60
40
20
0
−20
−40
GC
20
15
10
5
0
Right ascension

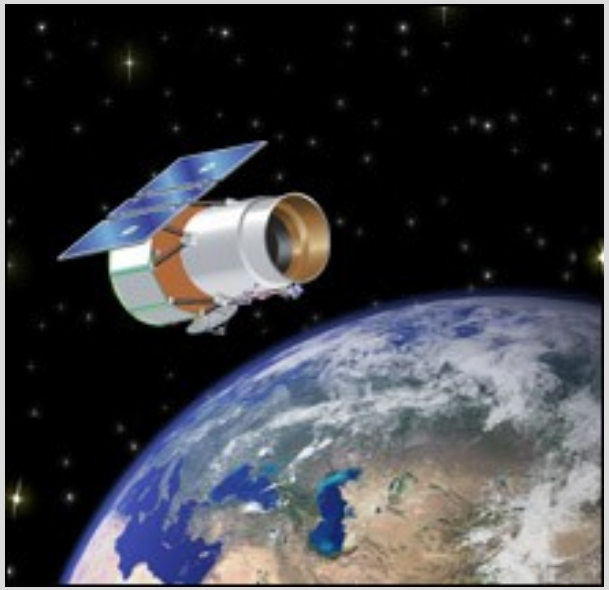


Future Skymapping Projects

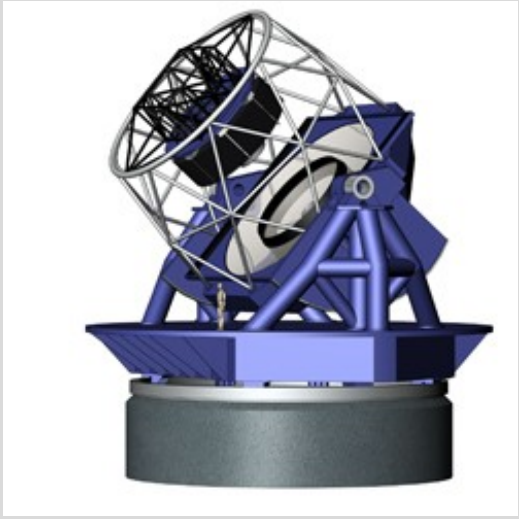
VISTA

VST

PanStarrs



WISE



LSST

any surprises left ..?

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