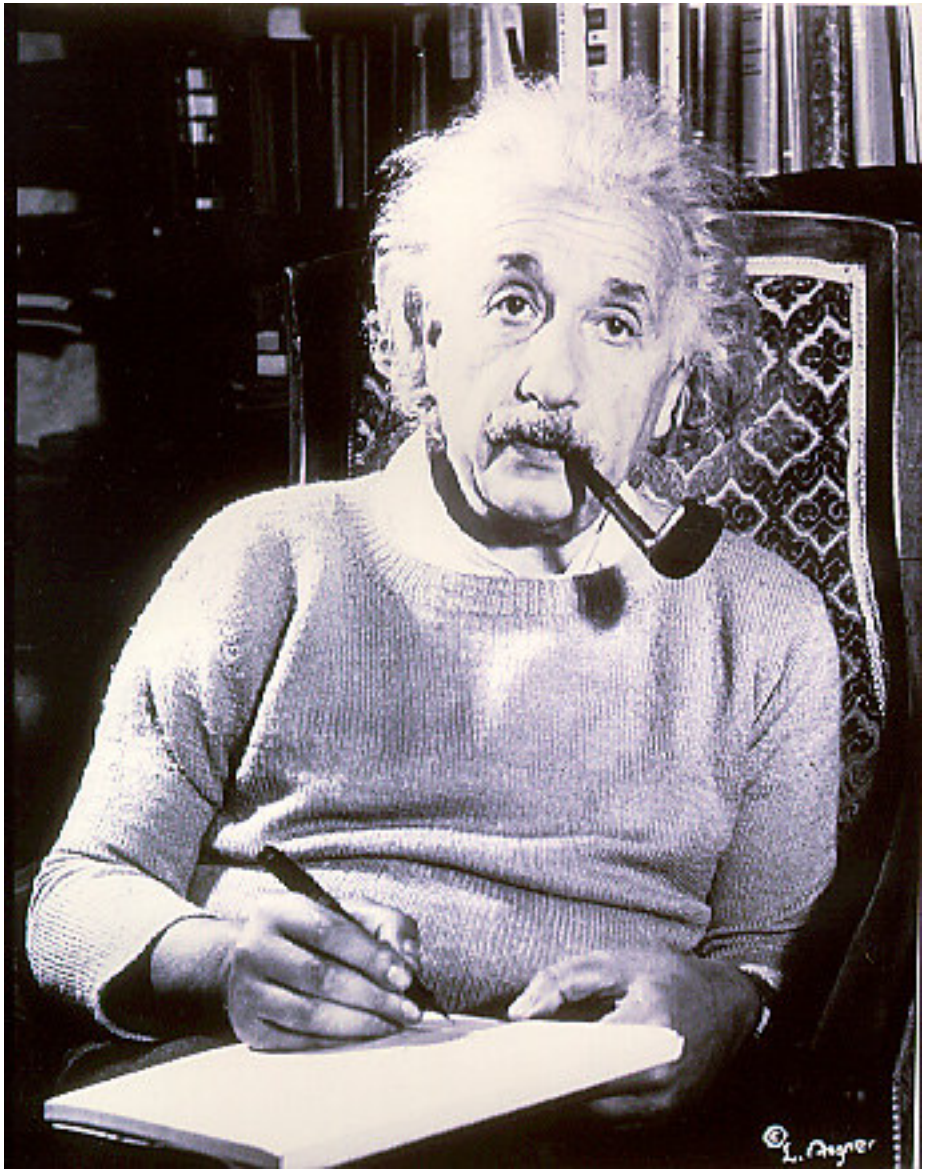
2005

YEAR OF PHYSICS …. EINSTEIN YEAR



What is the matter in the Universe?

R.J.Cashmore
Principal Brasenose College,Oxford
and
Dept of Physics,Oxford

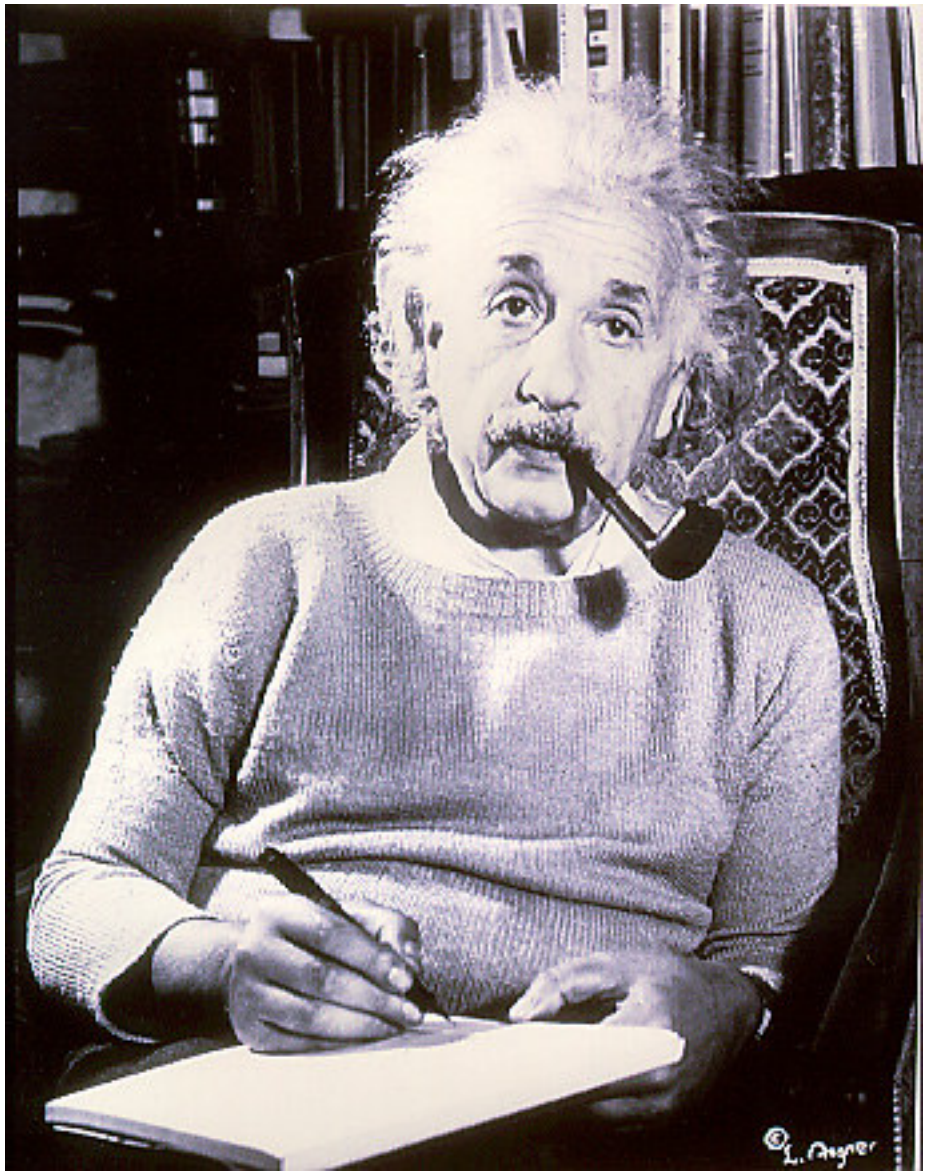
Matter in the Universe

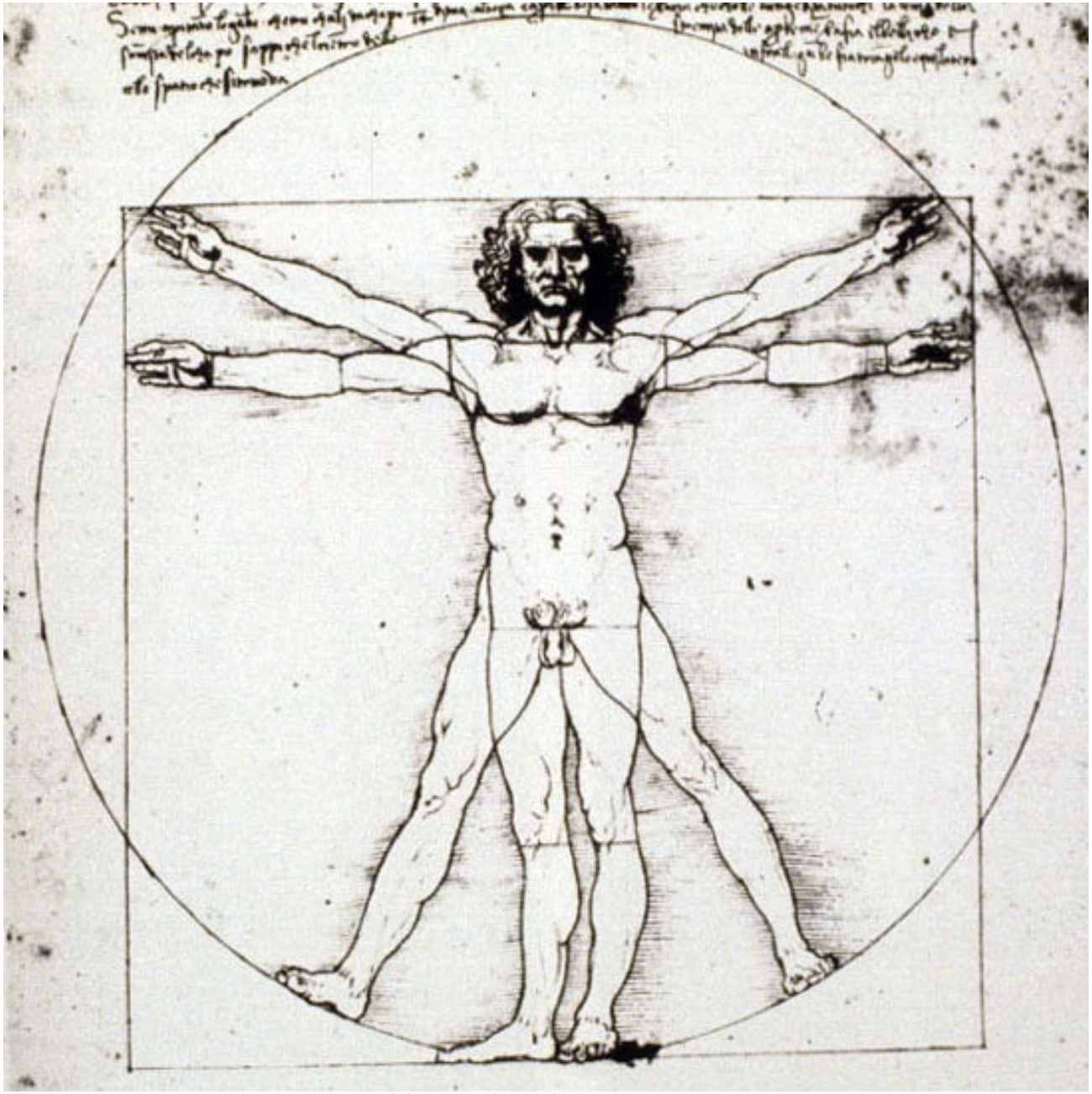
- The Matter of the Universe
- The Origin of Mass

Mass and Energy

$$E = mc^2$$

Energy measured in eV (electronVolts)


© L. Auger



Obvious Questions

1. Of what is he made?

2. Why is he the size he is?

Of what is he made?

.Cells

.Molecules

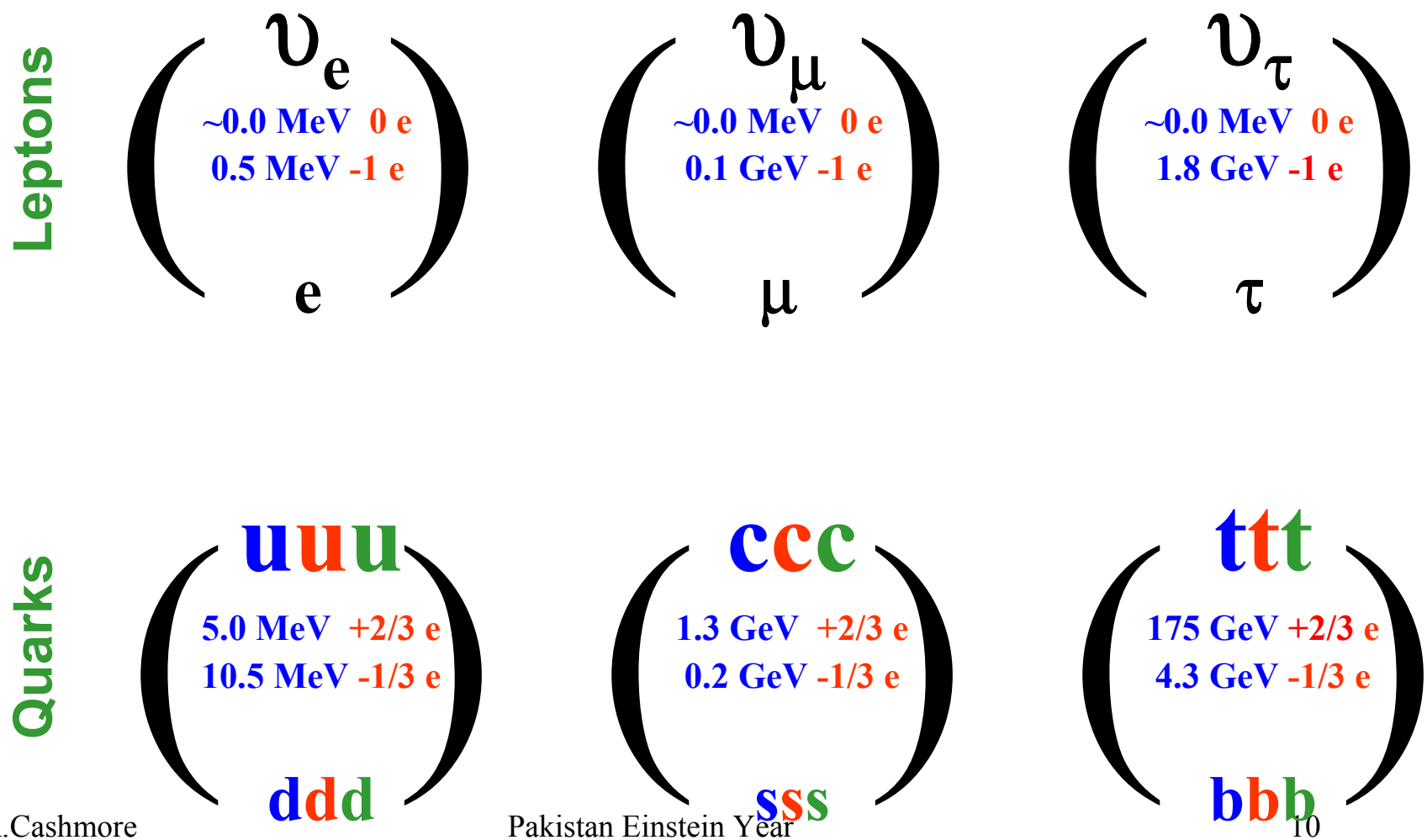
.Atoms

.nucleus and electrons

.p and n

.u, d quarks

The Fundamental Particles



The Particles of the Standard Model
Bosons

γ (Photon)	0.0 MeV	0 e	Electro-magnetism
$W^{+/-}$	80 GeV	+/-1 e	Nuclear Decay
Z^0	91 GeV	0 e	Electro-weak
g (8 gluons)	0.0 MeV	0 e	Strong Force

Why is he the size he is?

$$\text{Size of atom } \alpha \quad \frac{1}{M_e}$$

Mass important to understand

MAJOR PROBLEM

Mass of all particles is **0**

ELEGANT SOLUTION

(due to Peter Higgs)

New Interaction (field) with all particles

Fields have quantum excitations

(eg. the photon)

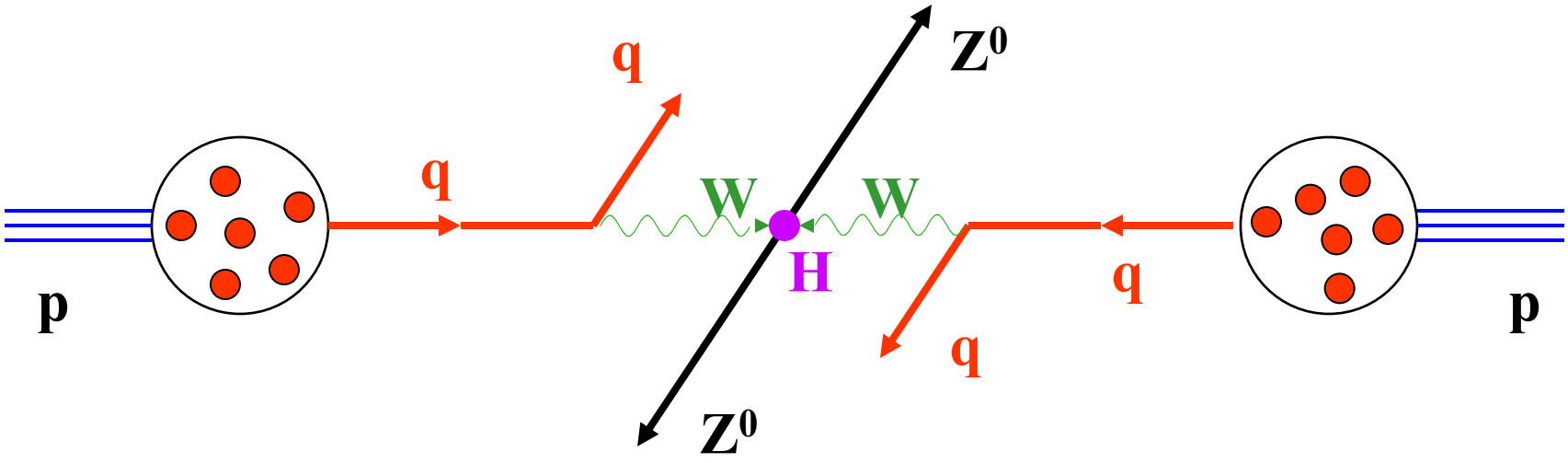
Search for the HIGGS BOSON

HIGGS BOSON

- **Mass unknown**
- **Mass <1000 GeV**

$$E = mc^2$$

↙ $E \geq 1000$ GeV



$M_H \sim 1000$ GeV

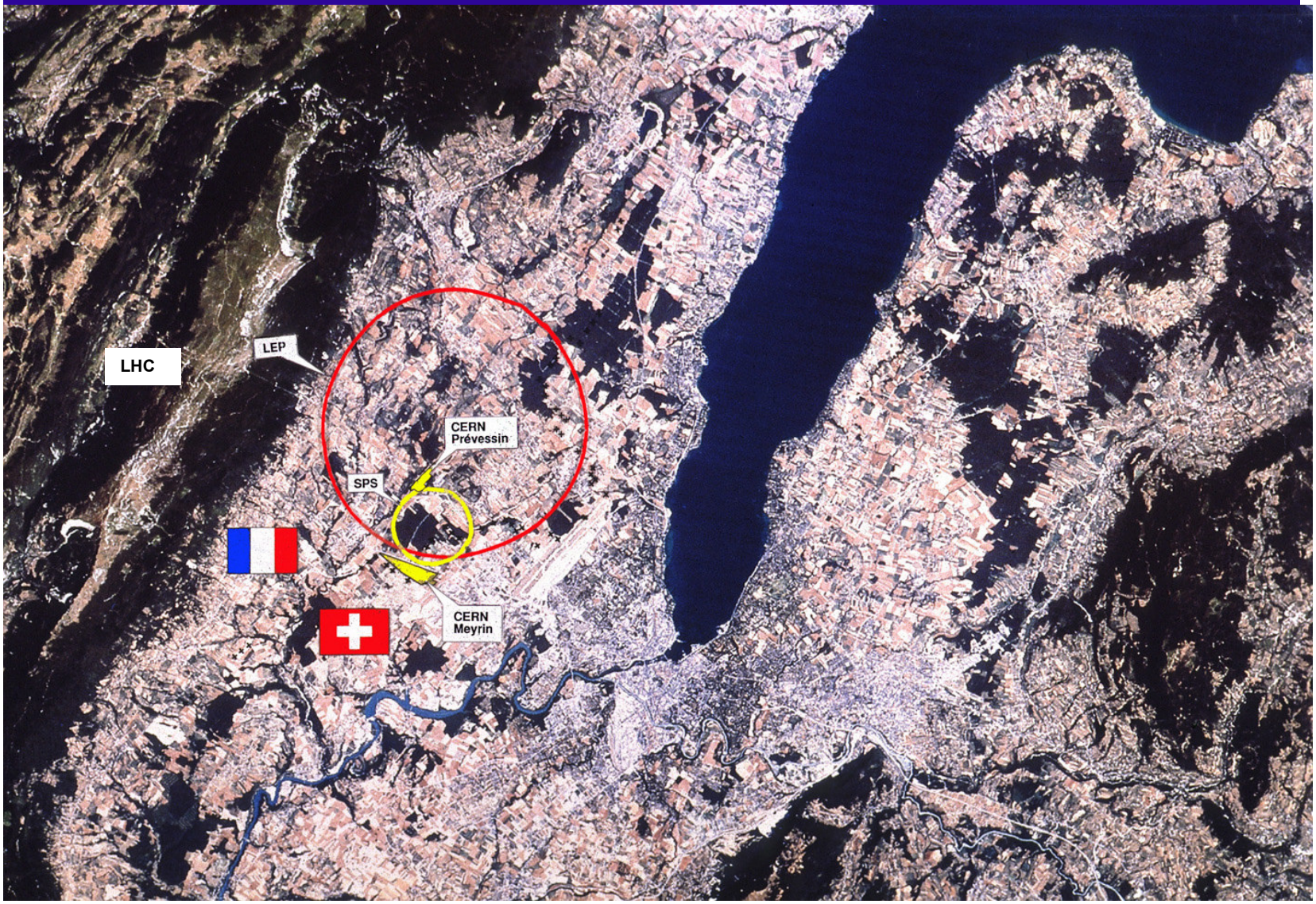
↙ $E_W \geq 500$ GeV

↙ $E_q \geq 1000$ GeV (1 TeV)

↙ $E_p \geq 6000$ GeV (6 TeV)

⇧ **LHC $E_p \geq 7$ TeV**

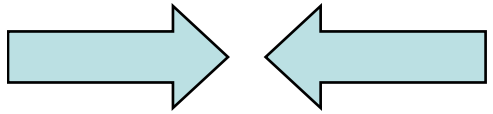
Satellite view of Geneva and CERN site



The Large Hadron Collider in the LEP Tunnel

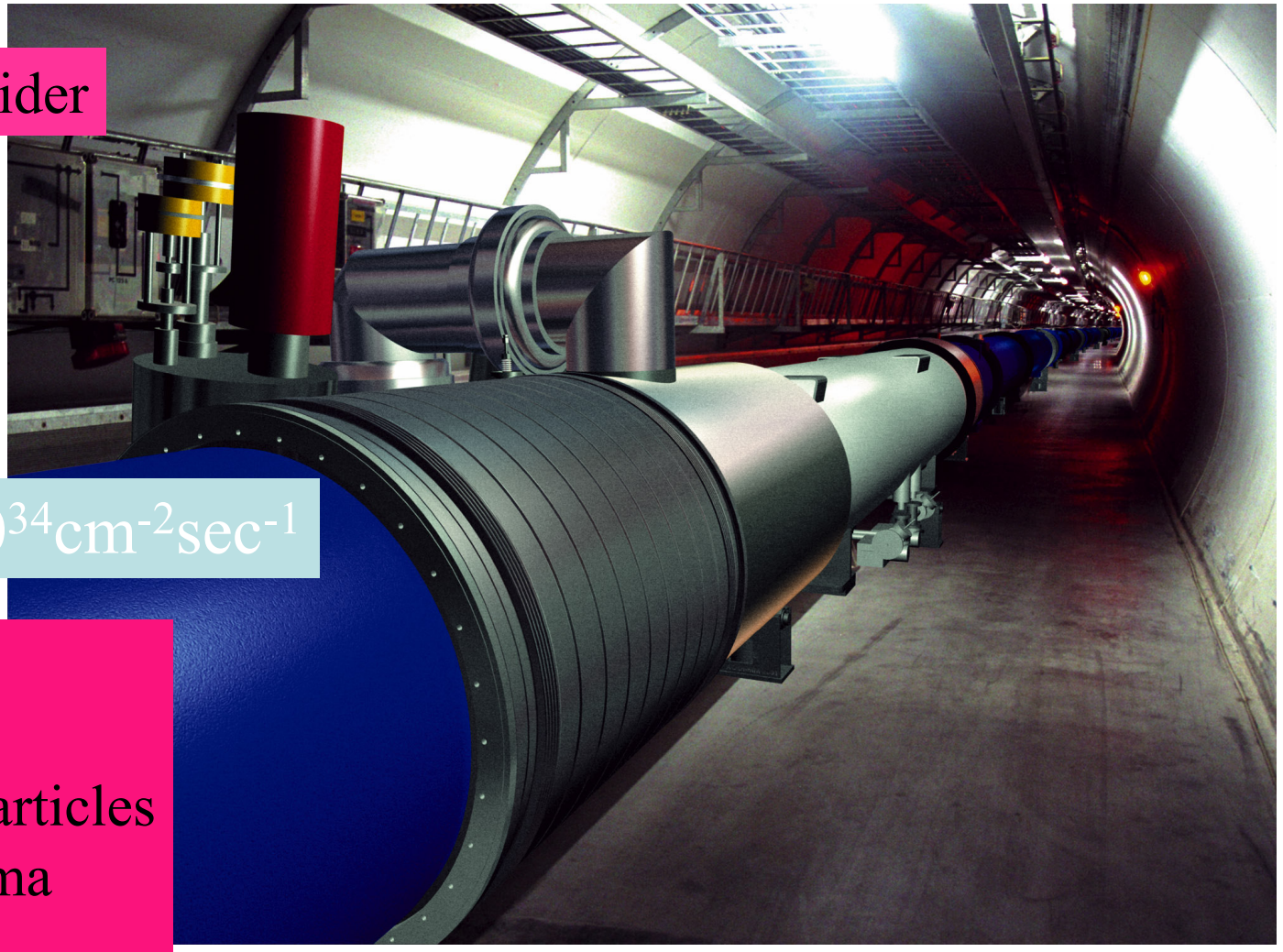
Proton- Proton Collider

7 TeV + 7 TeV

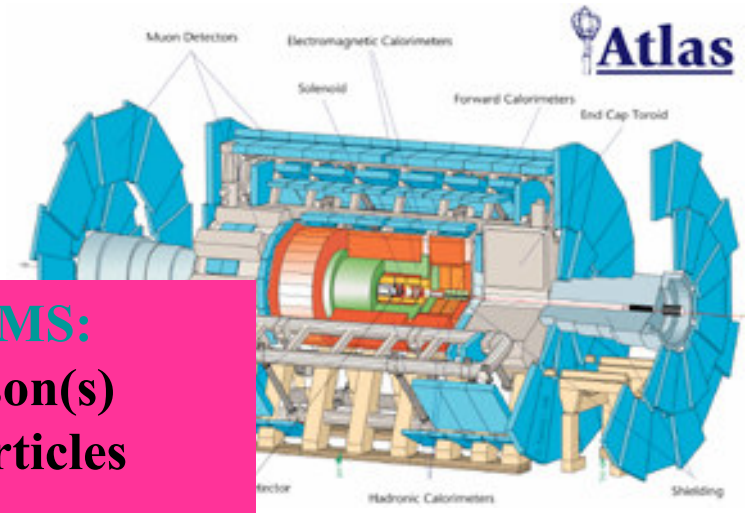


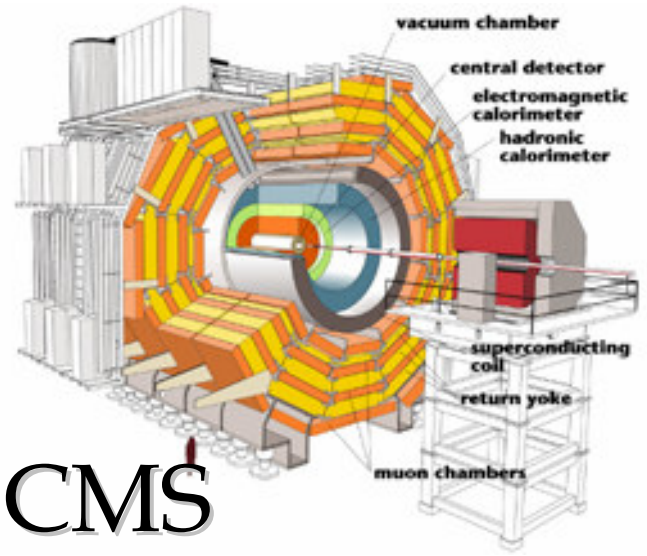
Luminosity = $10^{34}cm^{-2}sec^{-1}$

The Physics:
- Higgs boson (s)
- Supersymmetric Particles
- Quark-Gluon Plasma
- CP violation in B



LHC Experiments





ATLAS, CMS:

- Higgs boson(s)

- SUSY particles

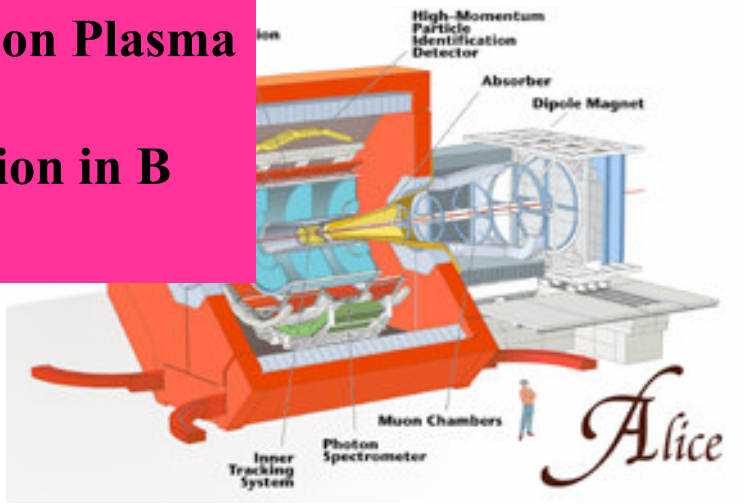
- …??

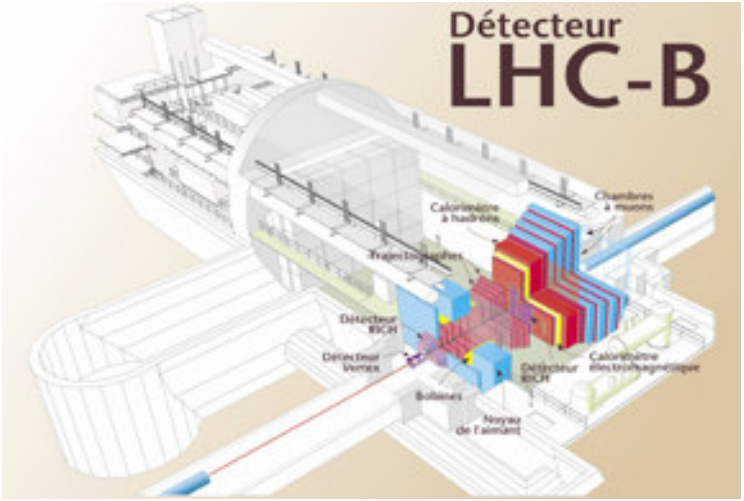
ALICE:

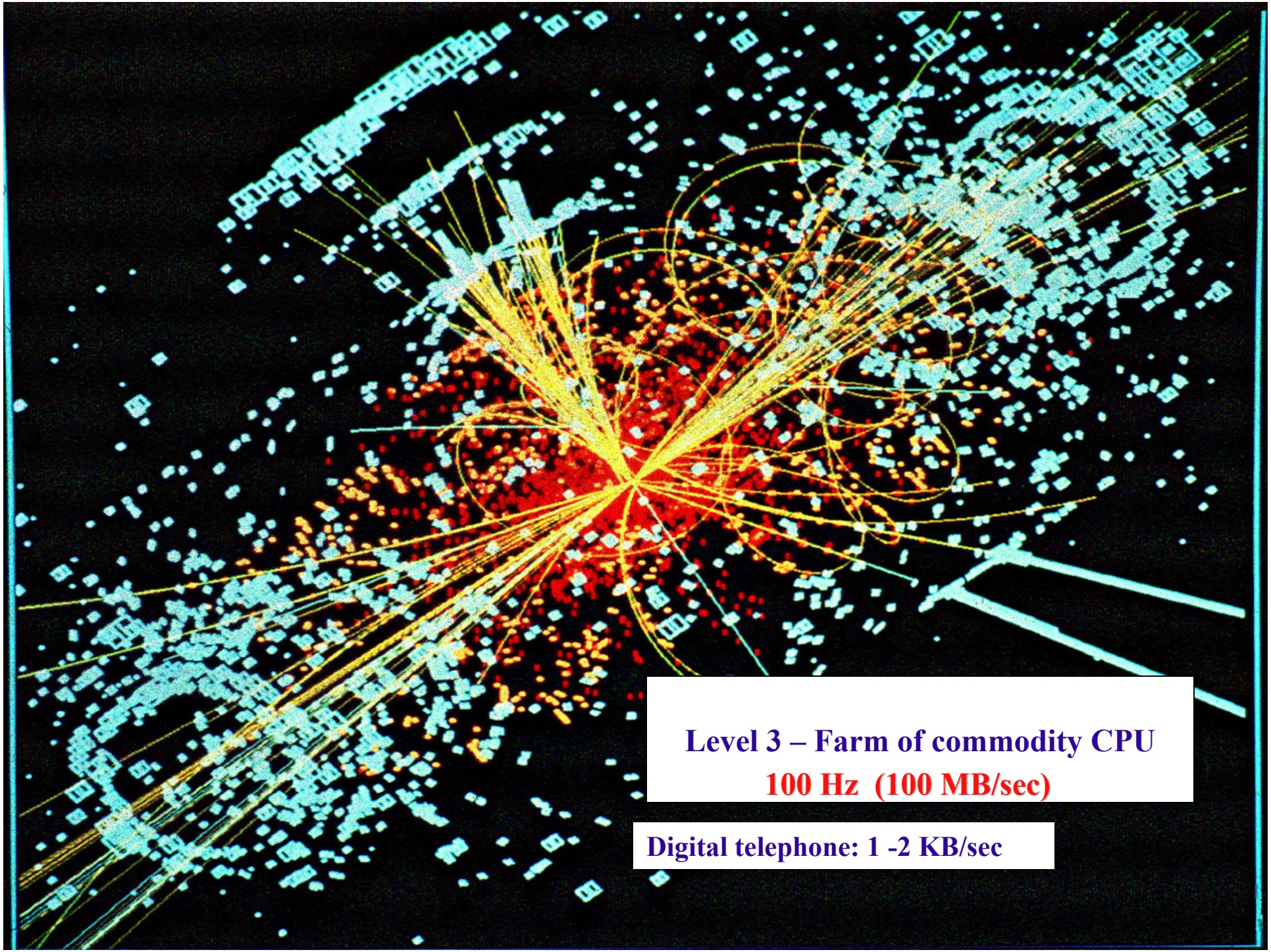
Quark Gluon Plasma

LHC-B:

- CP violation in B

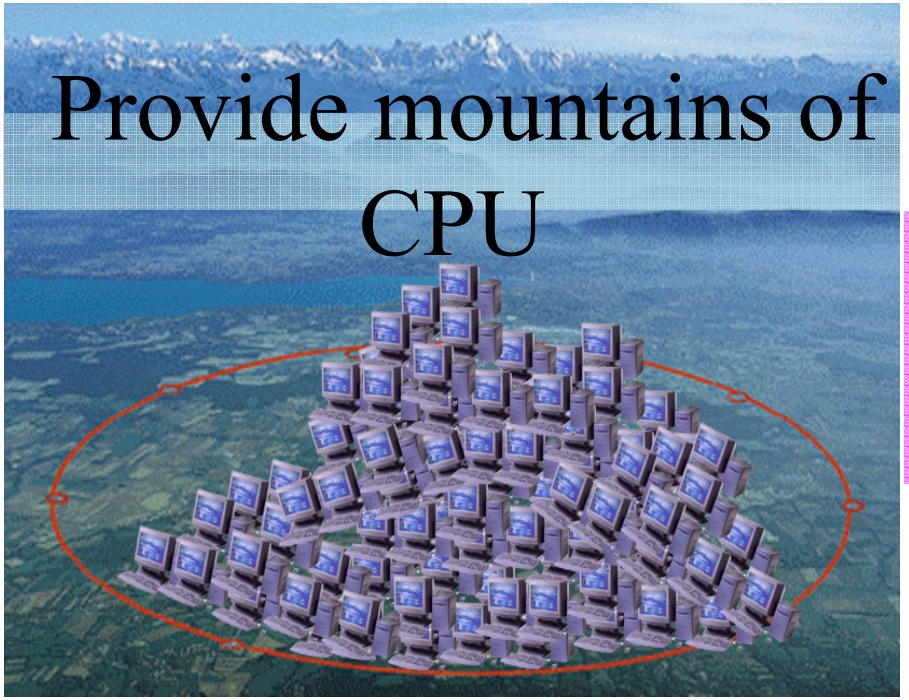





Level 3 – Farm of commodity CPU
100 Hz (100 MB/sec)
Digital telephone: 1 -2 KB/sec

LHC: Compute Capacity-Data Volumes
"to analyse all LHC data"

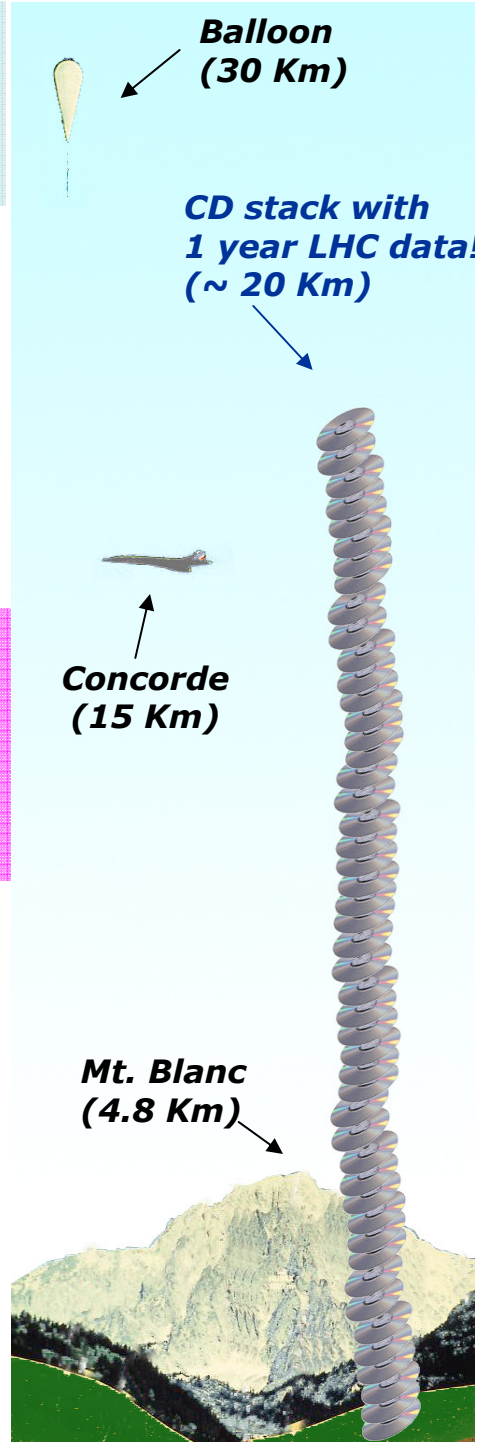
Calibration, Reconstruction, Simulation, Analysis



For LHC computing, some 100 Million SPECint2000 are needed!

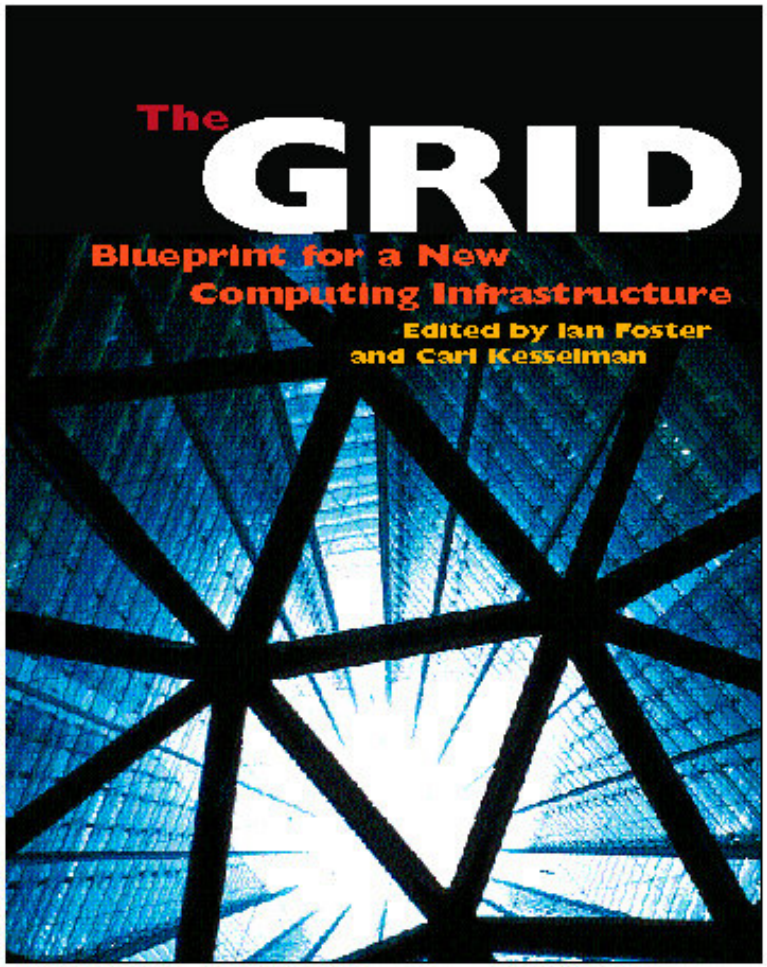
a 3 GHz Pentium 4 has ~ 1000 SPECint2000 → 100K PCs

- Annual data storage:
- 12-14PetaBytes/year

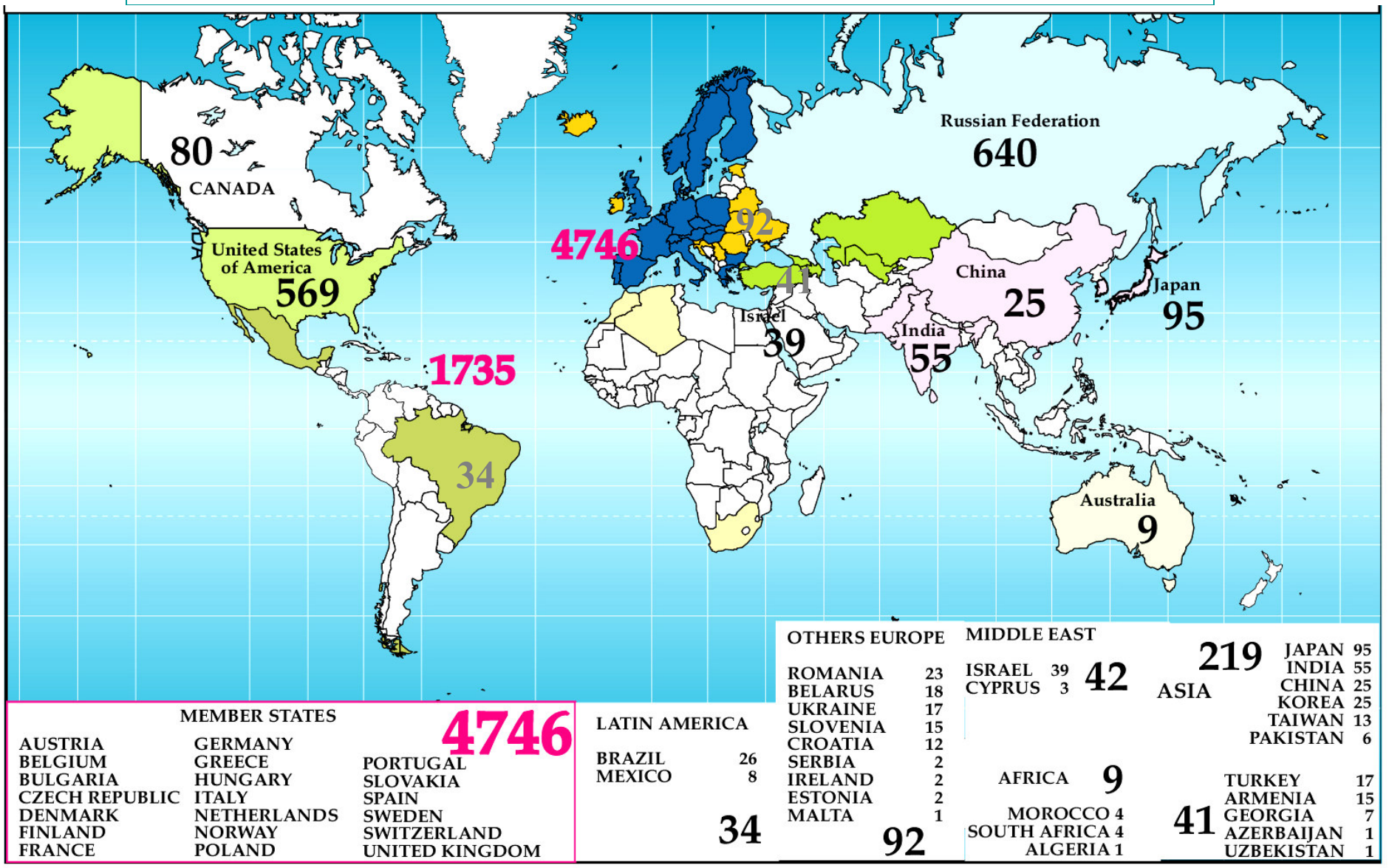


Five Emerging Models of Networked Computing From *The Grid*

- Distributed Computing
  - || synchronous processing
- High-Throughput Computing
  - || asynchronous processing
- On-Demand Computing
  - || dynamic resources
- Data-Intensive Computing
  - || databases
- Collaborative Computing
  - || scientists



Worldwide Scientific Collaboration



MEMBER STATES — 4746

AUSTRIA	GERMANY	PORTUGAL
BELGIUM	GREECE	SLOVAKIA
BULGARIA	HUNGARY	SPAIN
CZECH REPUBLIC	ITALY	SWEDEN
DENMARK	NETHERLANDS	SWITZERLAND
FINLAND	NORWAY	UNITED KINGDOM
FRANCE	POLAND	

LATIN AMERICA — 34

BRAZIL	26
MEXICO	8

OTHERS EUROPE — 92

ROMANIA	23
BELARUS	18
UKRAINE	17
SLOVENIA	15
CROATIA	12
SERBIA	2
IRELAND	2
ESTONIA	2
MALTA	1

MIDDLE EAST — 42

ISRAEL	39
CYPRUS	3

AFRICA — 9

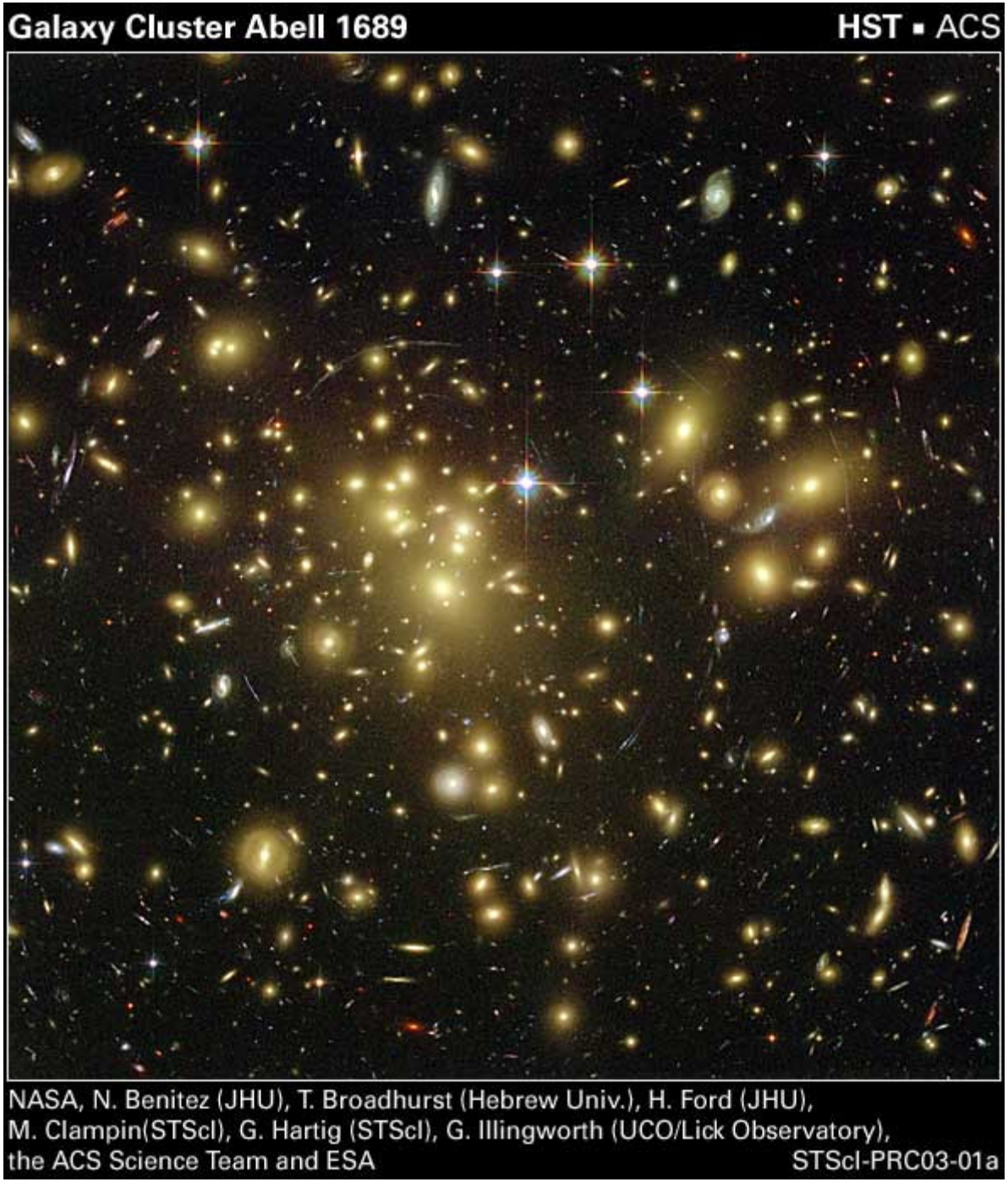
MOROCCO	4
SOUTH AFRICA	4
ALGERIA	1

ASIA — 219

JAPAN	95
INDIA	55
CHINA	25
KOREA	25
TAIWAN	13
PAKISTAN	6

41

TURKEY	17
ARMENIA	15
GEORGIA	7
AZERBAIJAN	1
UZBEKISTAN	1

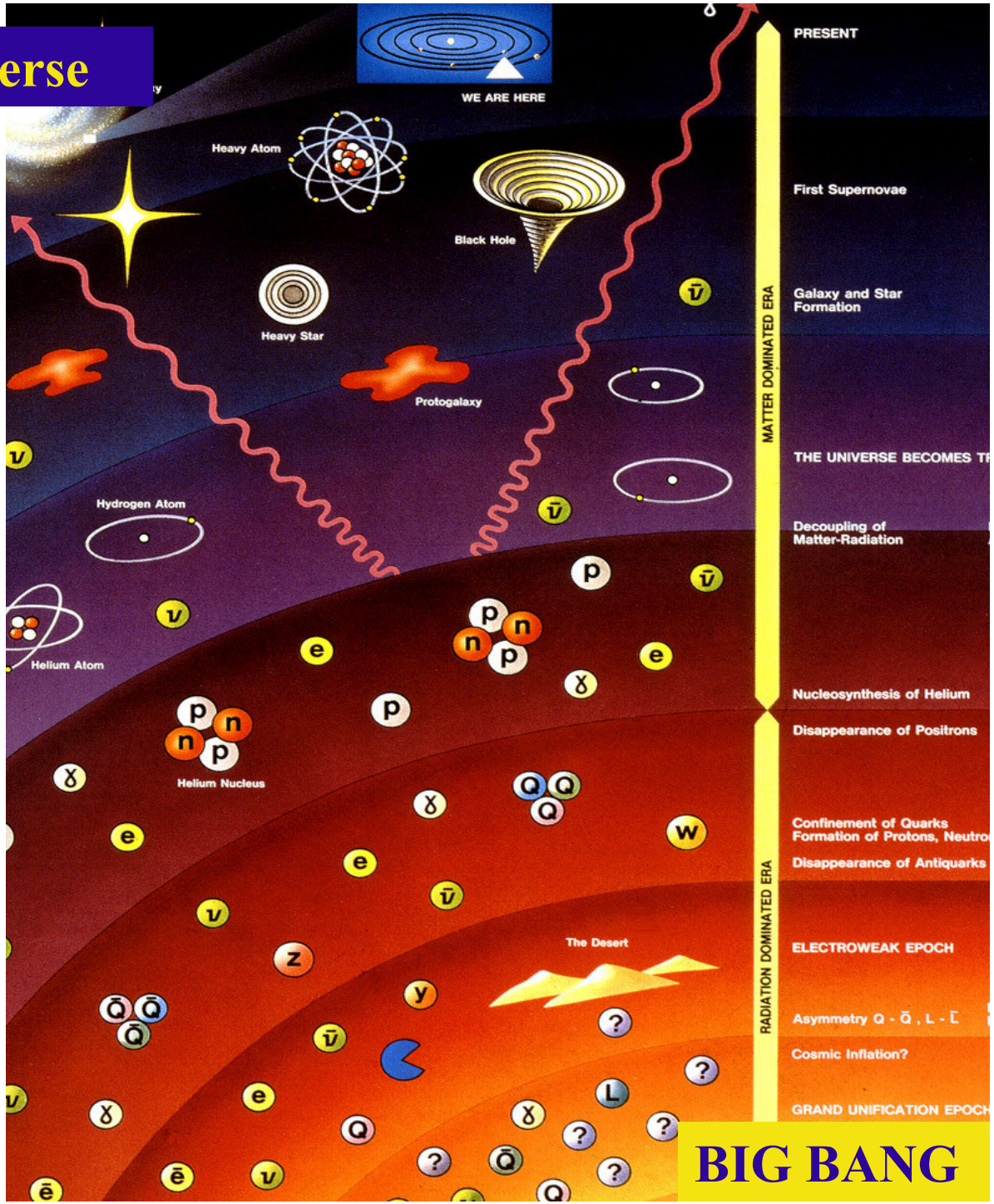

Galaxy Cluster Abell 1689
HST ▪ ACS
NASA, N. Benitez (JHU), T. Broadhurst (Hebrew Univ.), H. Ford (JHU),
M. Clampin(STScI), G. Hartig (STScI), G. Illingworth (UCO/Lick Observatory),
the ACS Science Team and ESA
STScI-PRC03-01a

The Mystery of the Universe

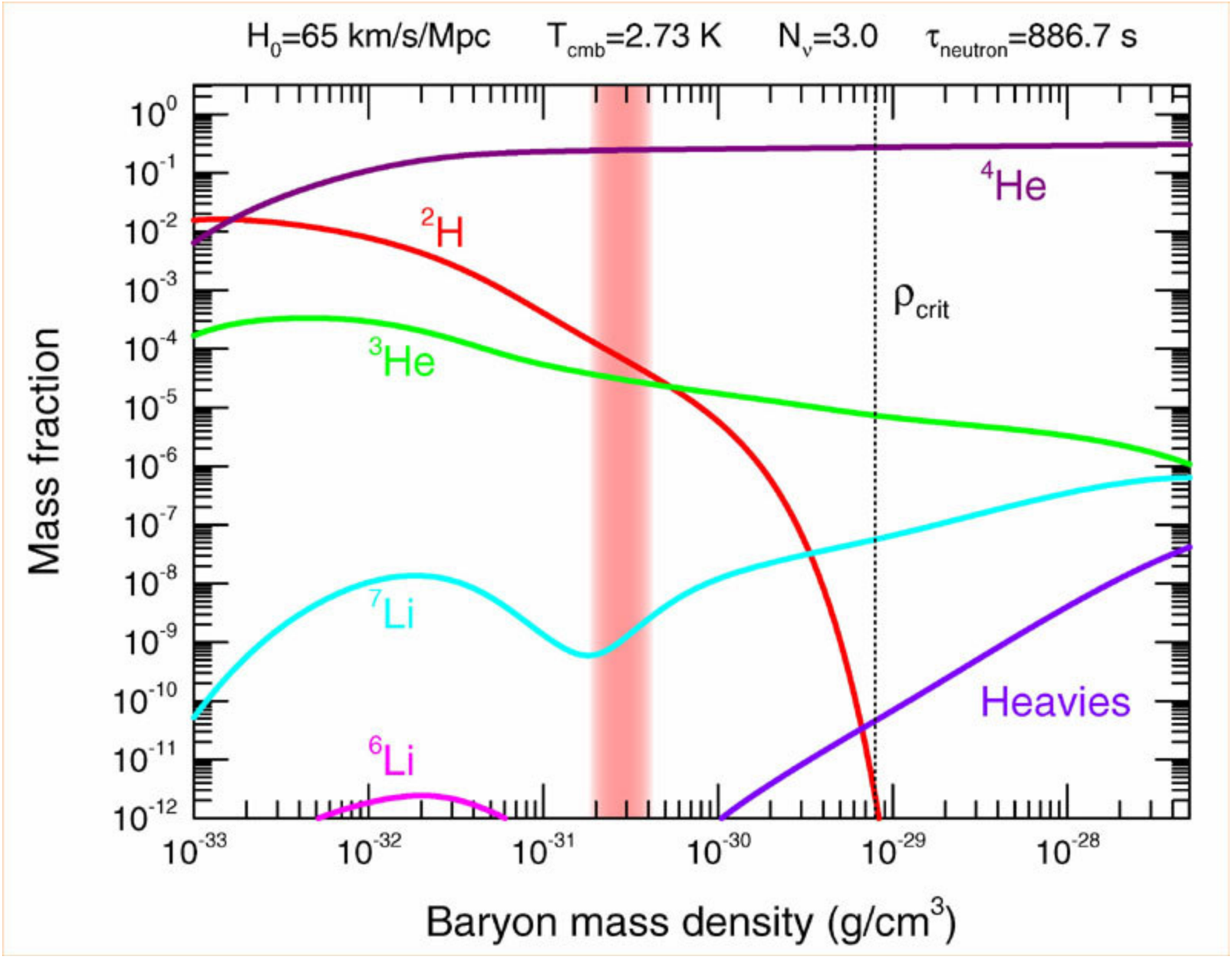
- What really is the Matter in the Universe?

The History of the Universe

Time

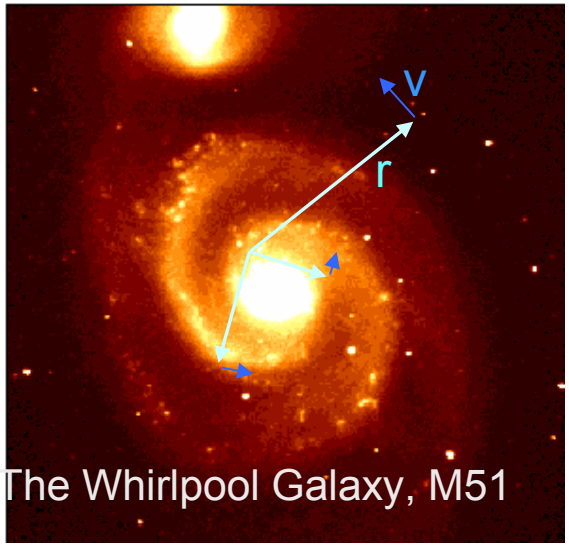


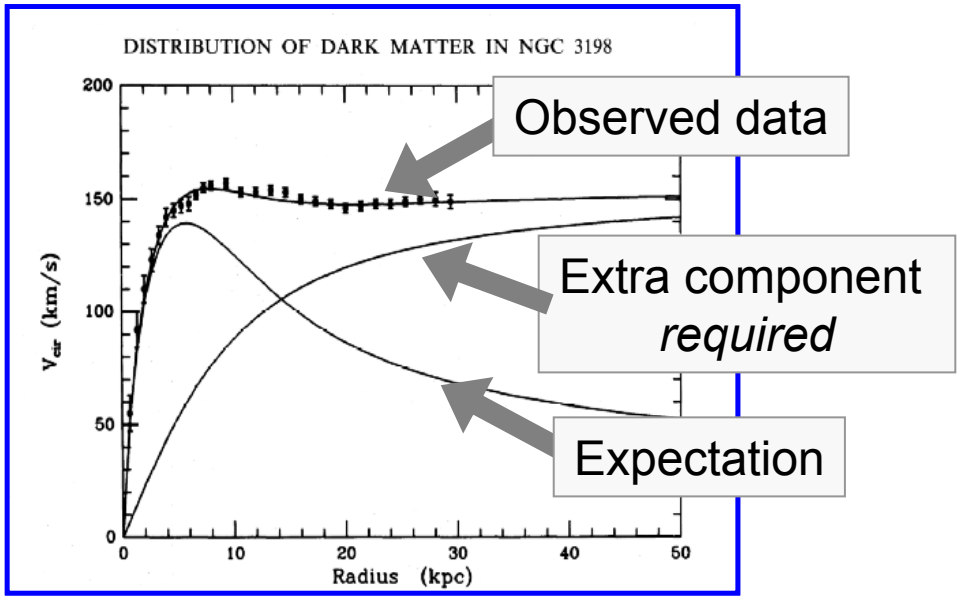
R.Cashmore


H0=65 km/s/Mpc
Tcmb=2.73 K
Nν=3.0
τneutron=886.7 s
Mass fraction
Baryon mass density (g/cm3)
4He
2H
3He
7Li
6Li
Heavies
ρcrit

Rotation Curves

- Look at how stars move around galaxies





- To match what is observed we need an extra invisible matter

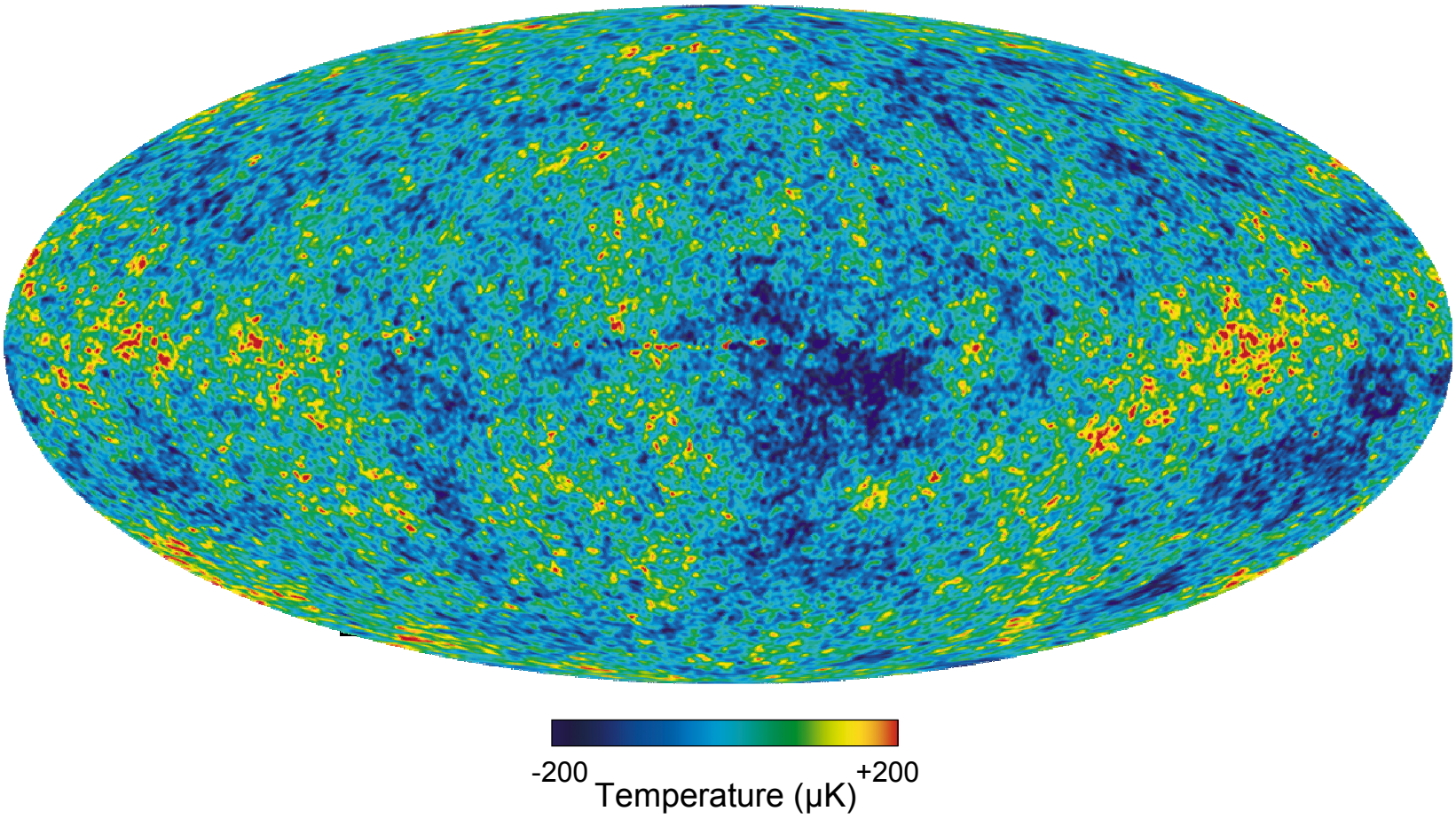
Rotation curves…

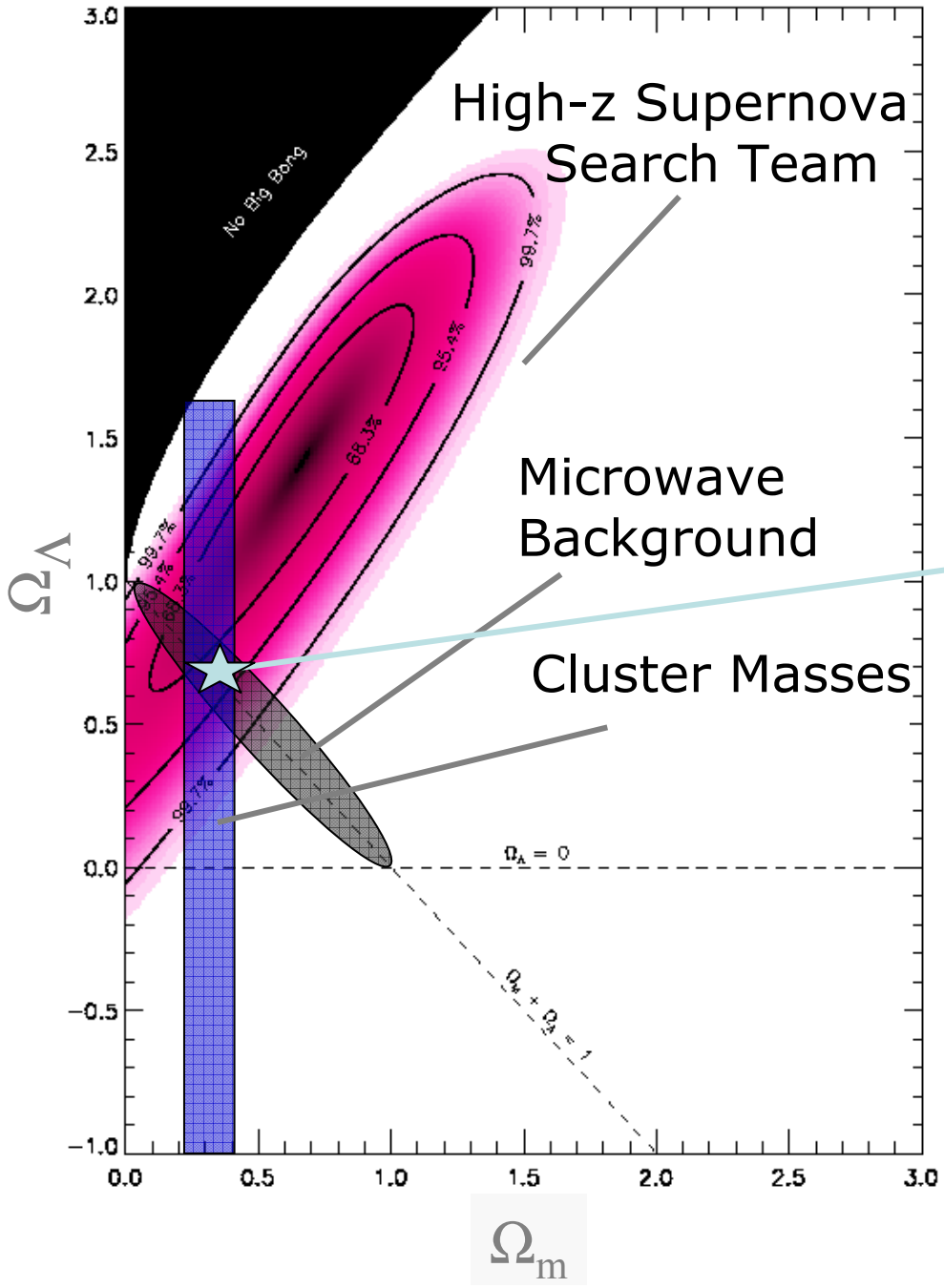
- Rotation curves are similar for ***all*** available data sets (galaxies *and* clusters).
- The data suggest ~90% of the mass of a galaxy is dark, and is distributed in an extensive spherical halo

"The distribution of mass in this system appears to bear almost no relation to the light"

Jen Oort 1940

WMAP: Wilkinson Microwave Anisotropy Probe



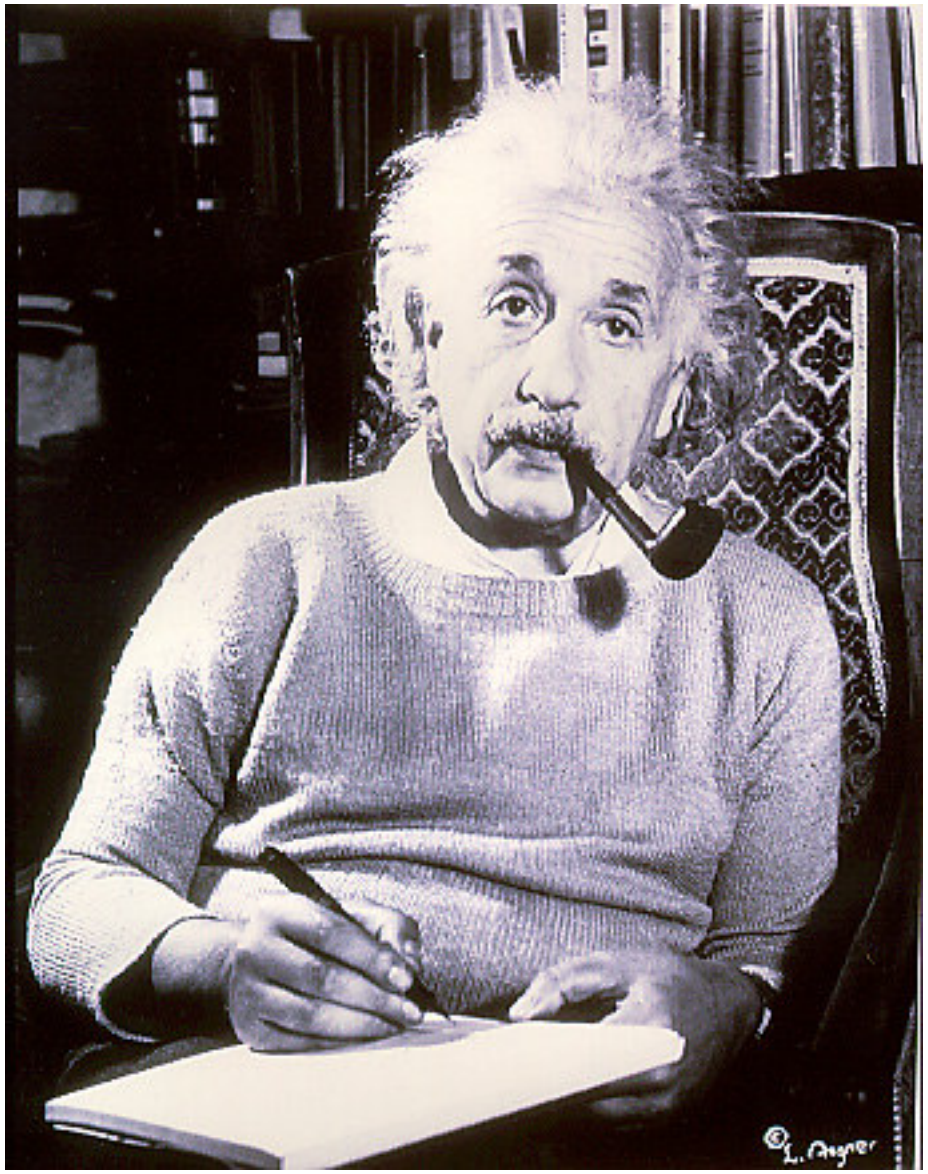


Best fit:

$\Omega_{mass} \sim 0.3$

$\Omega_\Lambda \sim 0.7$

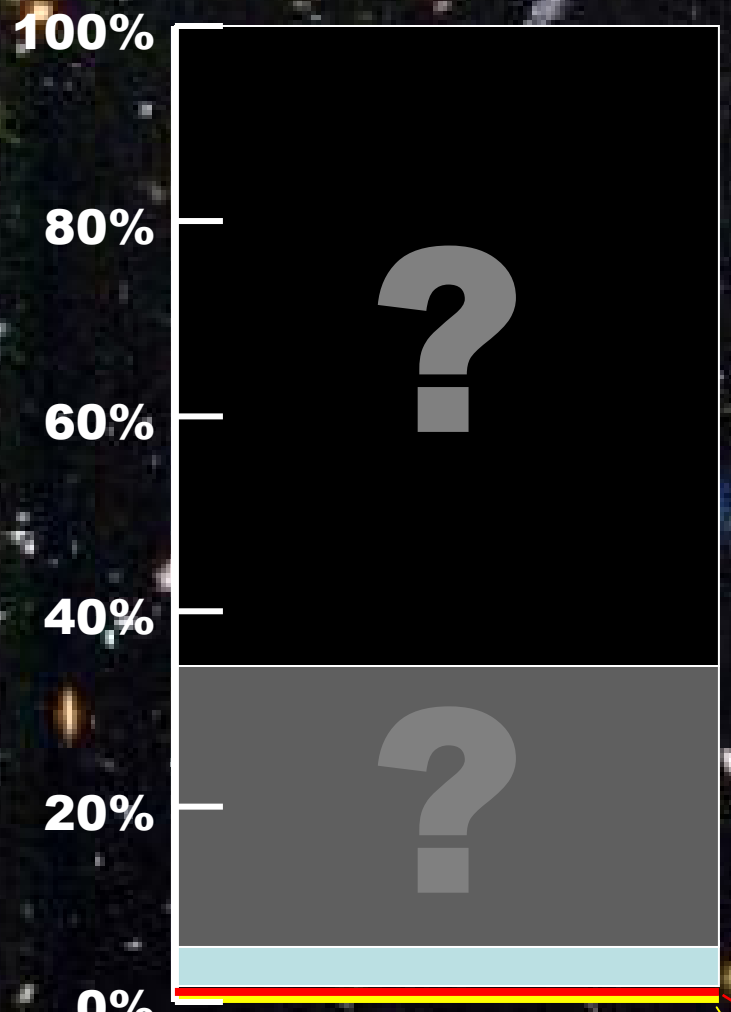
Λ?



Λ?

A bad idea

Our view of the Universe

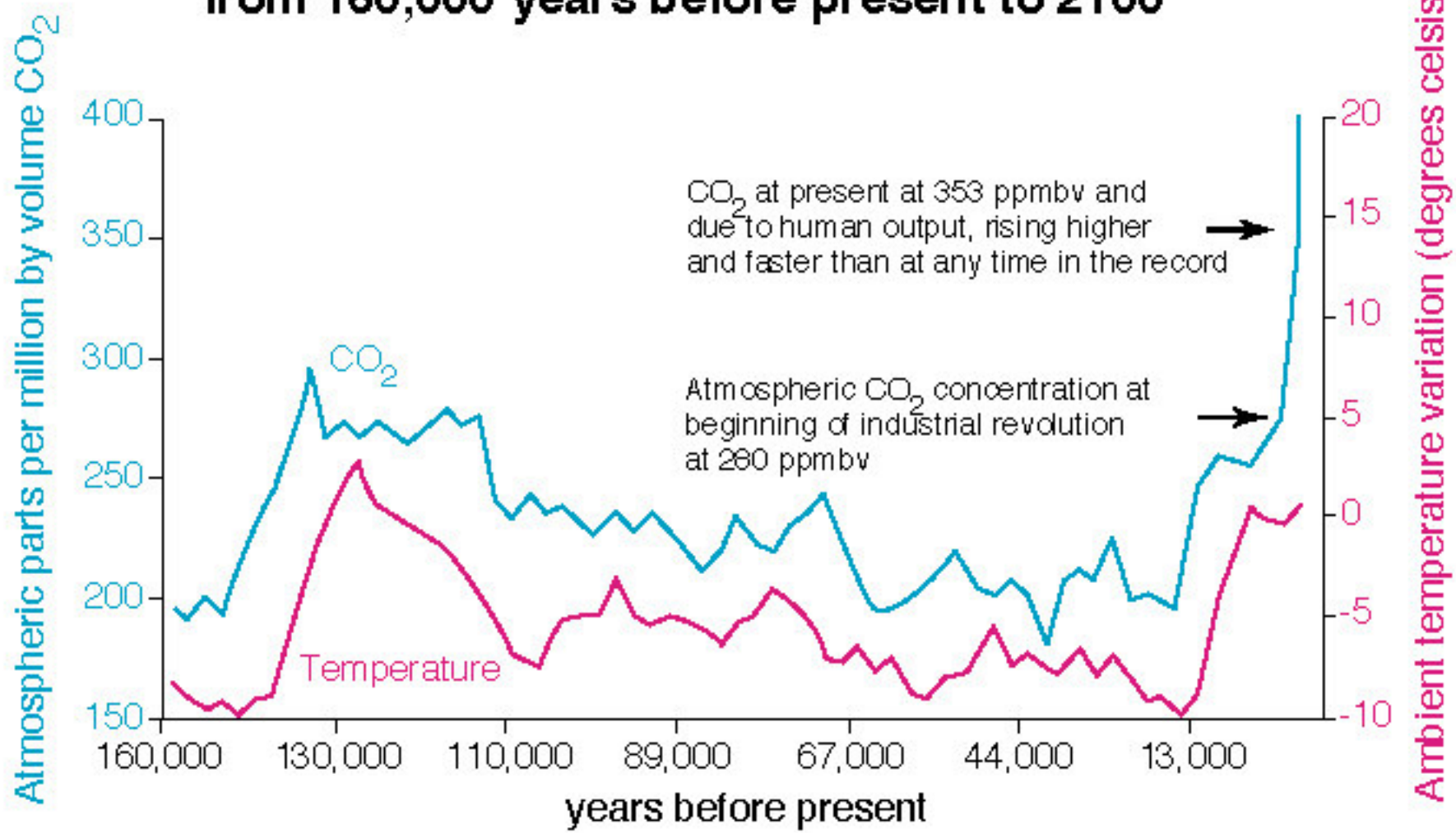


Man's reach should exceed his grasp
Or what's heaven for?

Robert Browning

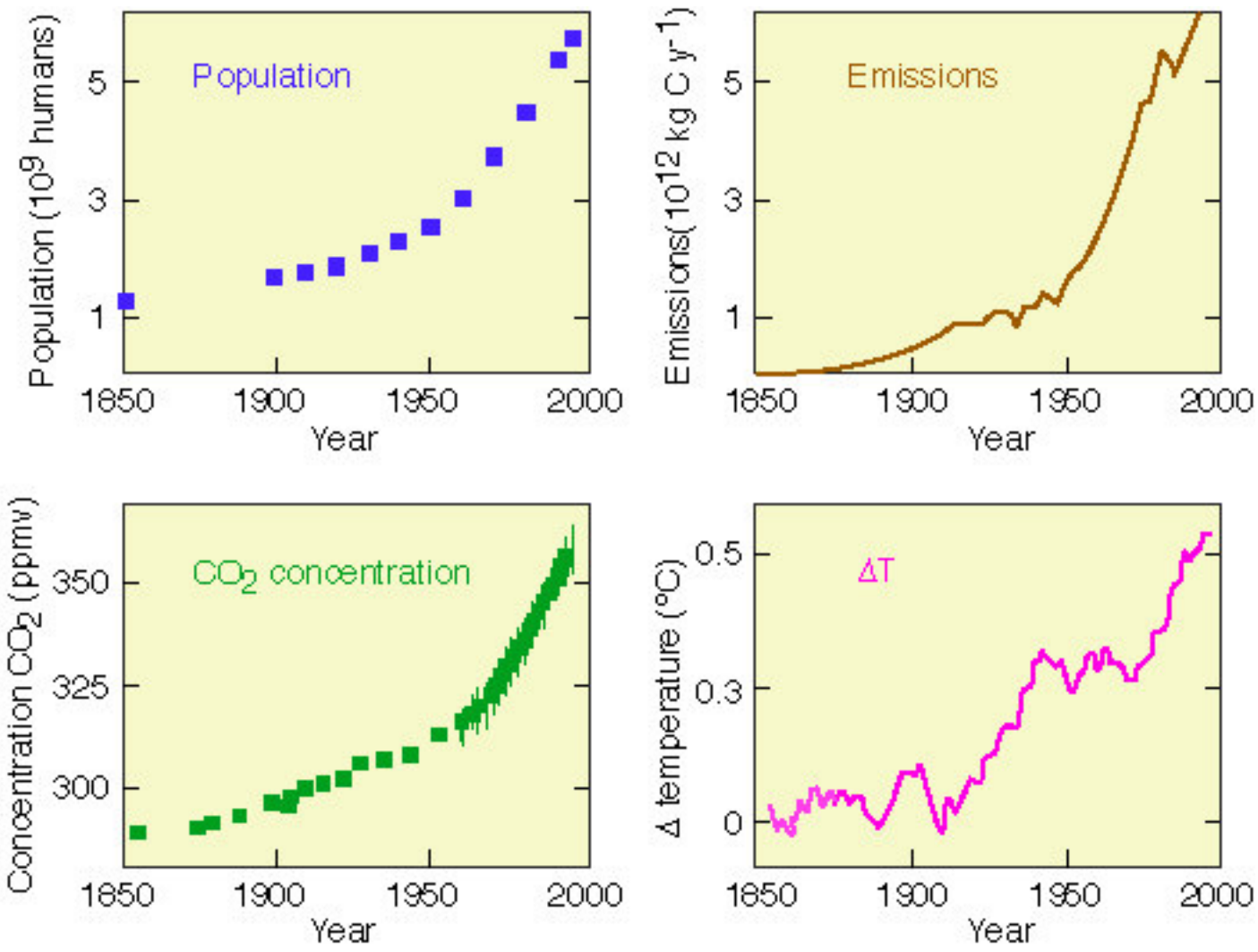
Energy: An issue for the 21st century

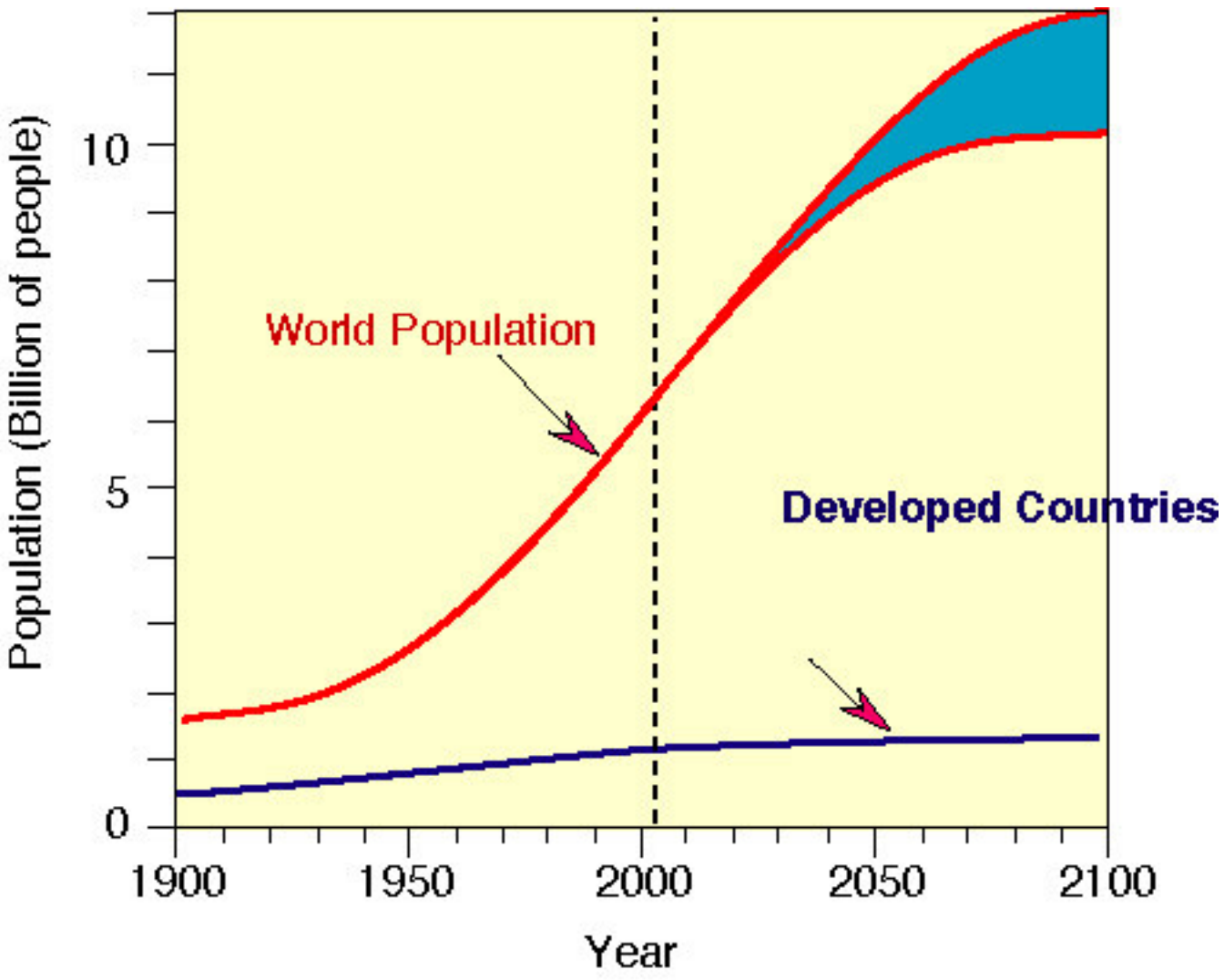
Correlation* of CO_2 and Temperature Variation from 160,000 years before present to 2100



*** From the study of ice at the Pole**

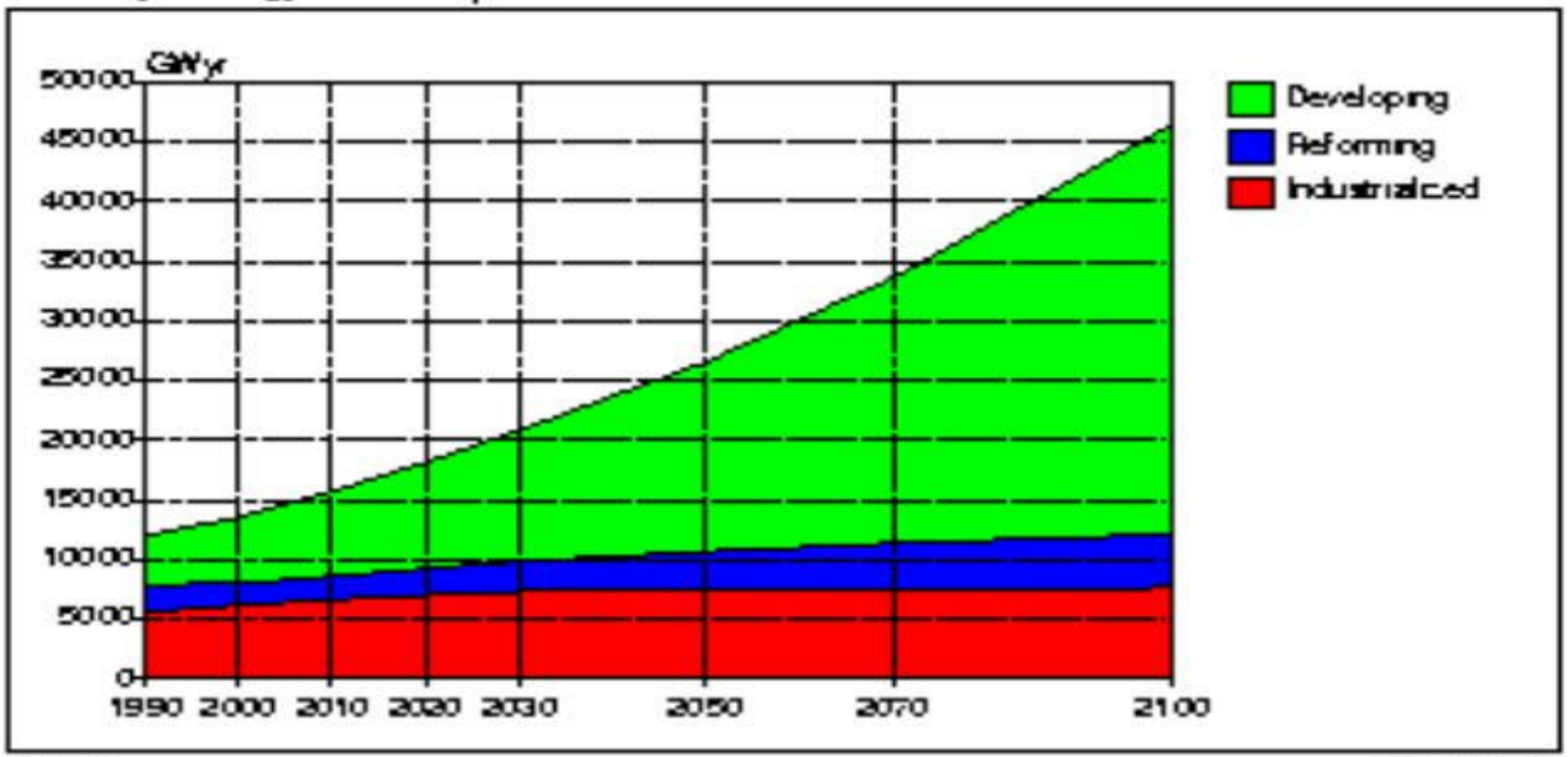
(Source: H. Lehmann, Wuppertal Institut für Klima, Umwelt, Energie)


Population
Population (10^9 humans)
1
3
5
1850
1900
1950
2000
Year
Emissions
Emissions (10^{12} kg C yr^{-1})
1
3
5
1850
1900
1950
2000
Year
CO_2 concentration
Concentration CO_2 (ppmv)
300
325
350
1850
1900
1950
2000
Year
ΔT
Δ temperature (°C)
0
0.3
0.5
1850
1900
1950
2000
Year

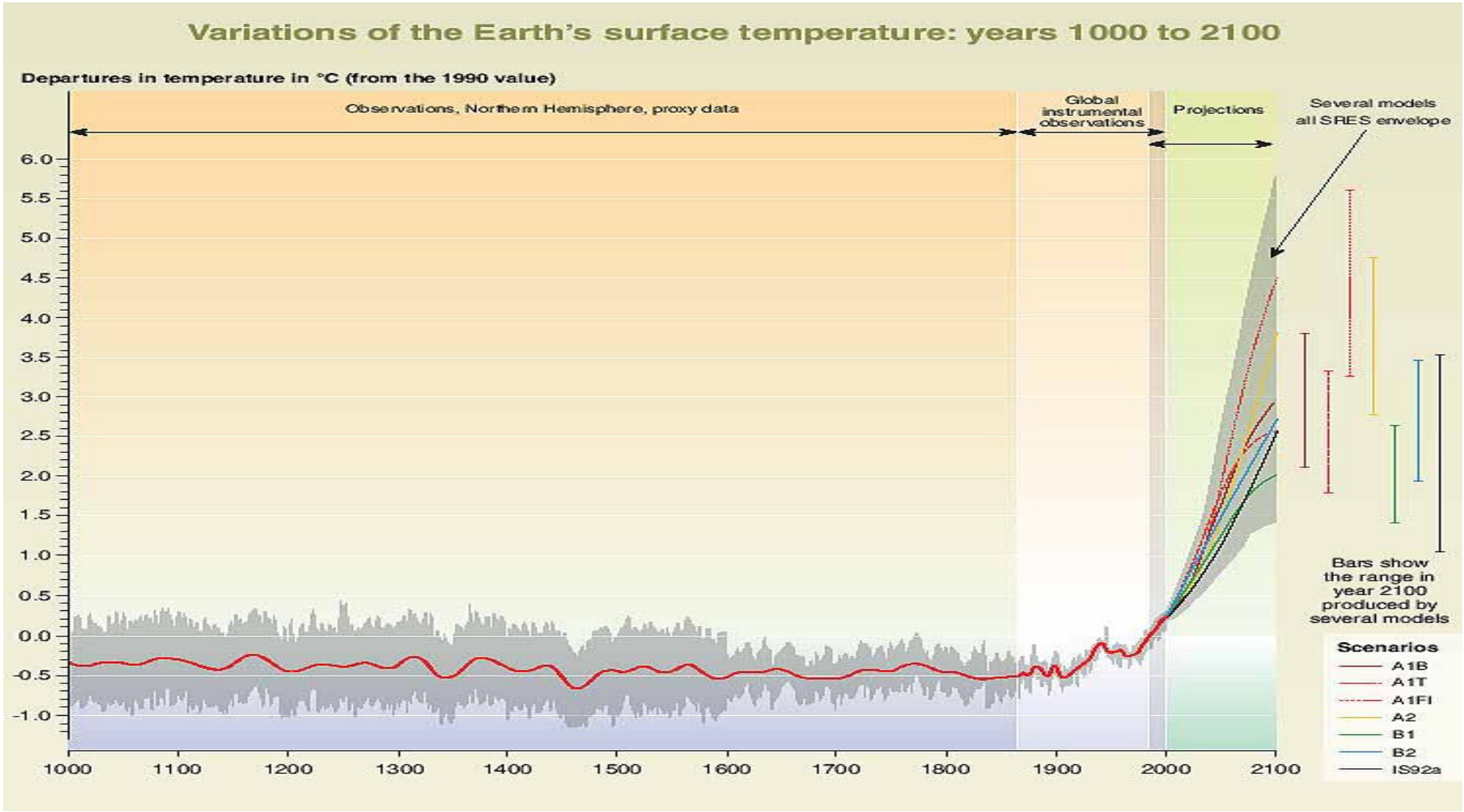

Population (Billion of people)
10
5
0
World Population
Developed Countries
1900
1950
2000
2050
2100
Year

3 Regions , Scenario B

Primary energy consumption: Total,

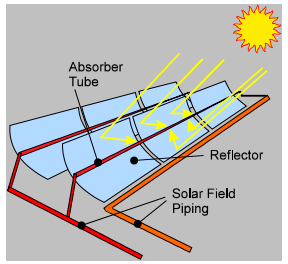


Climate Change 2001: Synthesis Report



Options for Carbon-free Energy

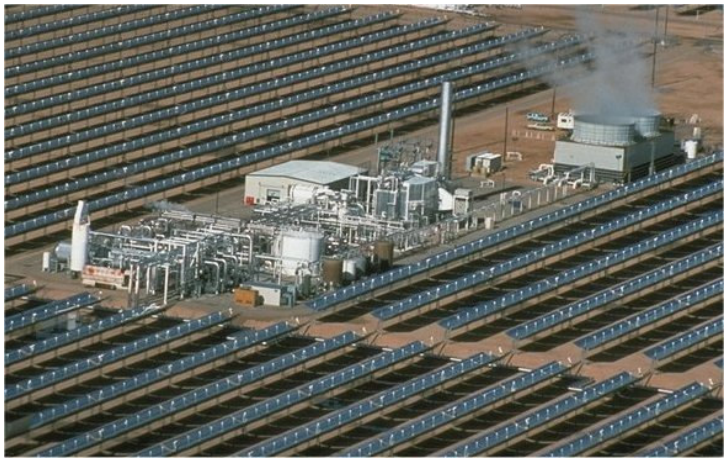
- Large Scale, Ready Now:
  - Conservation and Efficiency
  - Nuclear
- Renewables:
  - Hydro
  - Biomass
  - Wind
  - Geothermal
  - Solar
  - Fuel Cells
- Long-term Possibility:
  - Fusion



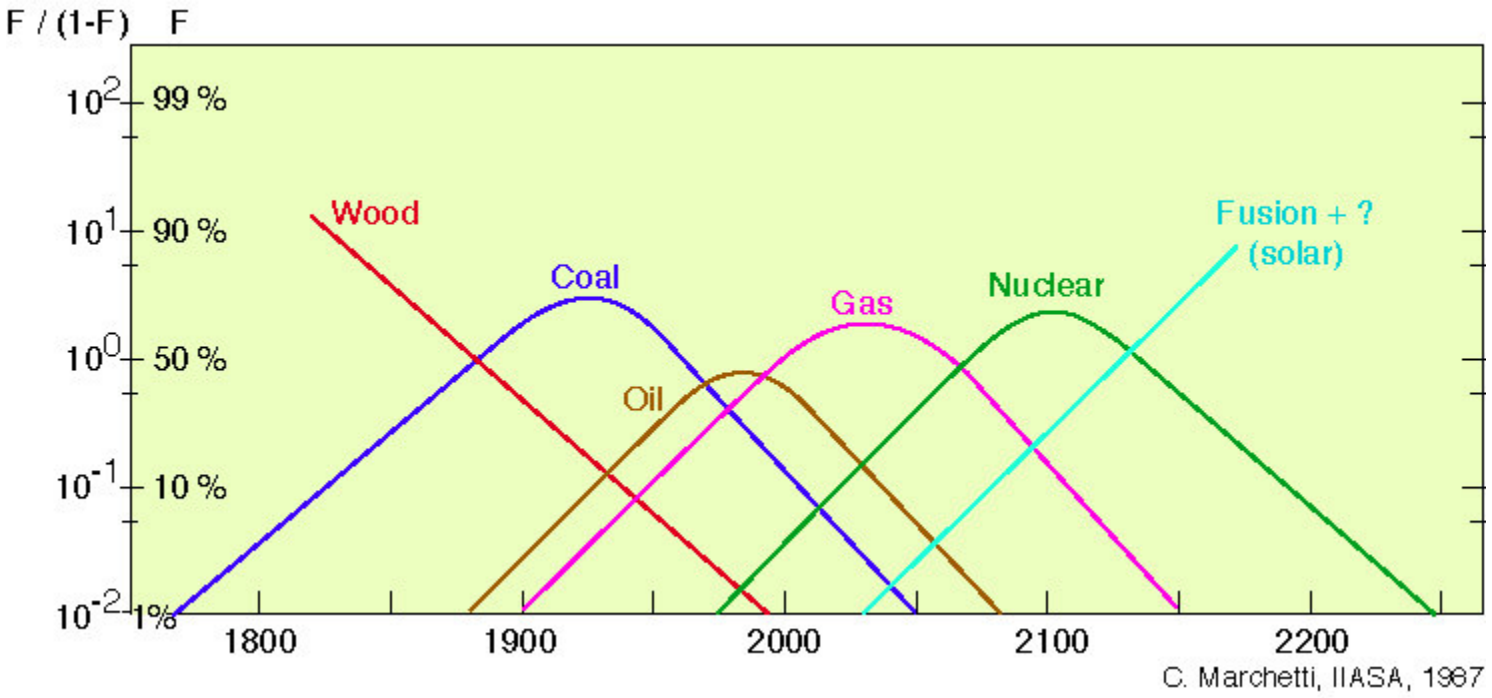
Parabolic Trough

It is the mainly mature technology for the high scale commercial production

Actually in the USA (California), 7 plants (14, 30, and 80 MW) are in operation for an installed power of 354 MW



Kramer Junction Plant

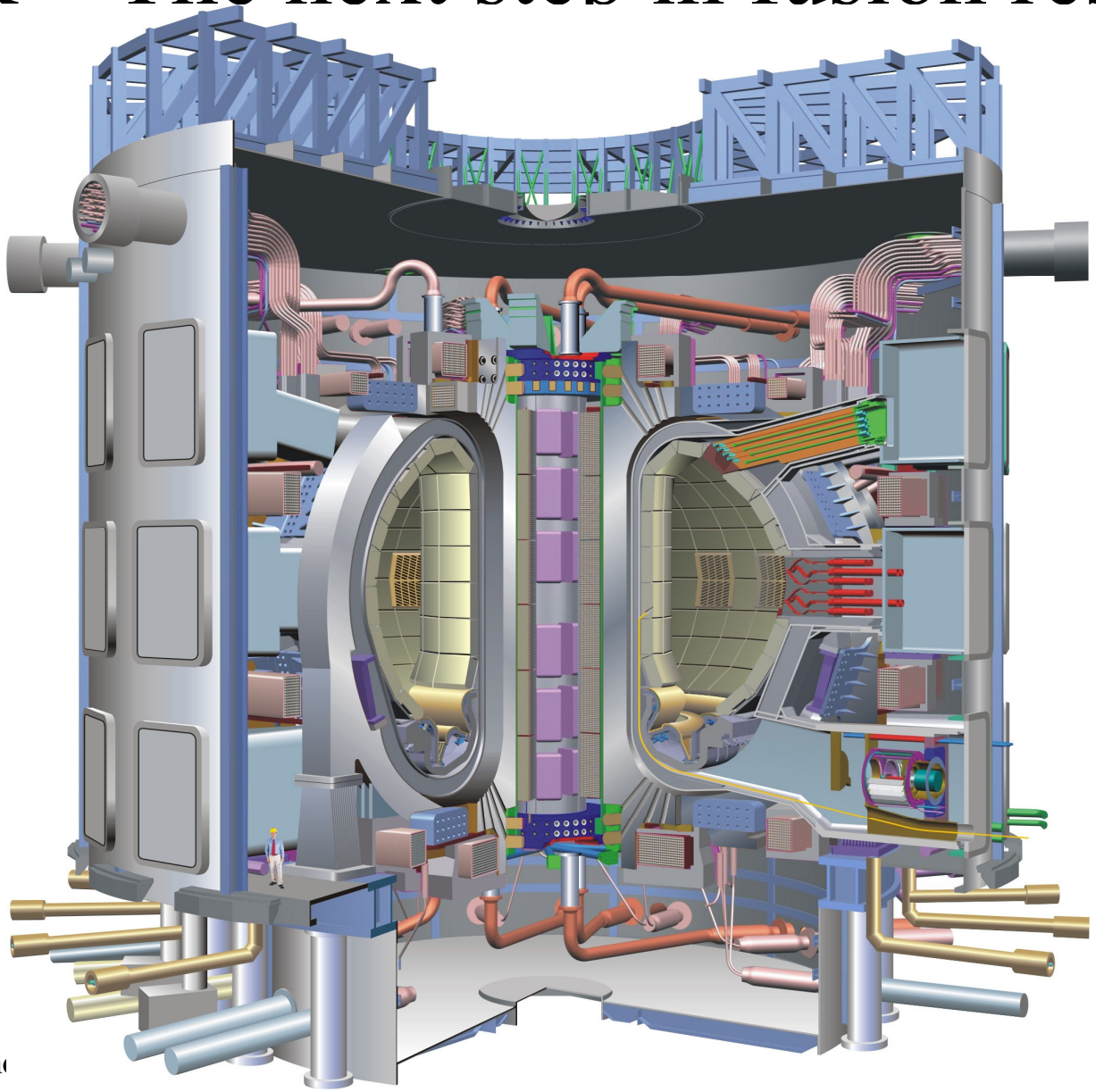

F / (1-F)
F
10^2
99 %
10^1
90 %
10^0
50 %
10^-1
10 %
10^-2
1%
Wood
Coal
Oil
Gas
Nuclear
Fusion + ?
(solar)
1800
1900
2000
2100
2200
C. Marchetti, IIASA, 1987

Radiation Exposures

Source	Radiation Dose Millirem/year
Natural Radioactivity	240
Natural in Body (75kg)*	40
Medical (average)	60
Nuclear Plant (1GW electric)	0.004
Coal Plant (1GW electric)	0.003
Chernobyl Accident (Austria ~1988)	24
Chernobyl Accident (Austria 1996)	7

*Included in the Natural Total

ITER The next step in fusion research



Fusion Energy Development Timetable

Item	Time (years)
International Agreement and Site Selection	2
Construct ITER	10
Operate and Learn	10
Design and Build Prototype Power Plant	10
Operate Prototype	10
Total Time to Start of Design of First Power Plant	**42**

Climate Change is our grand-children's problem, but they are too young to do anything about it.

To echo President Musharraf …

No man is an Island

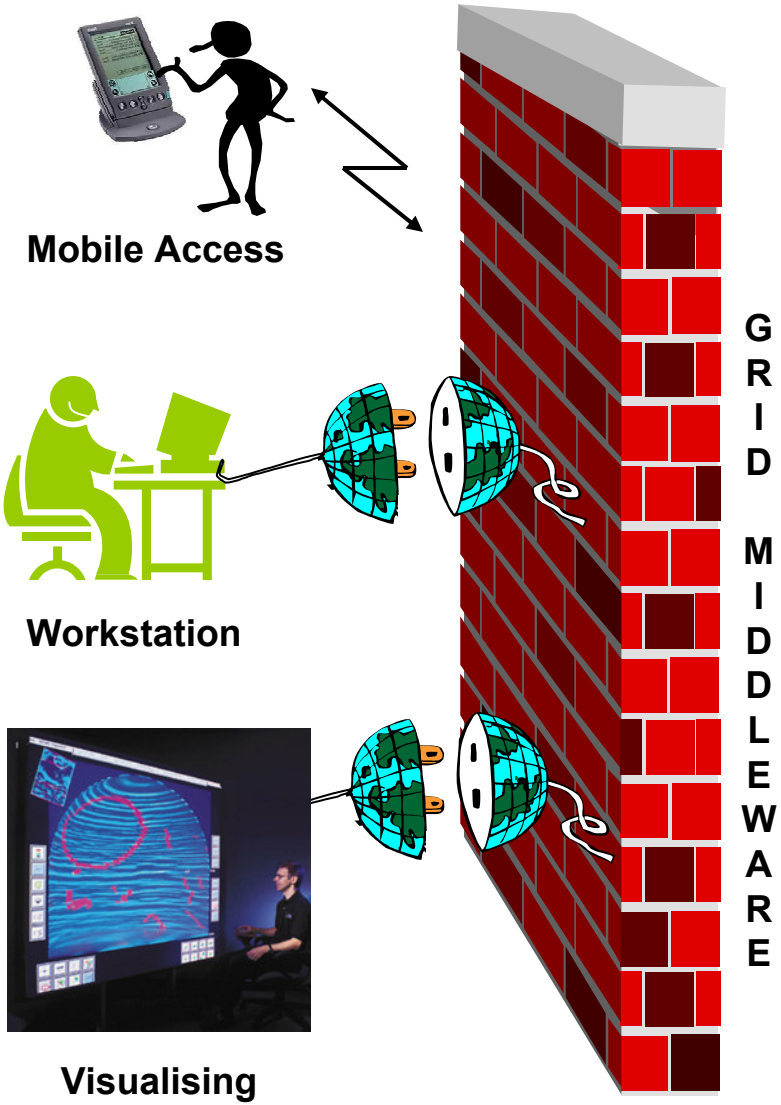
John Donne

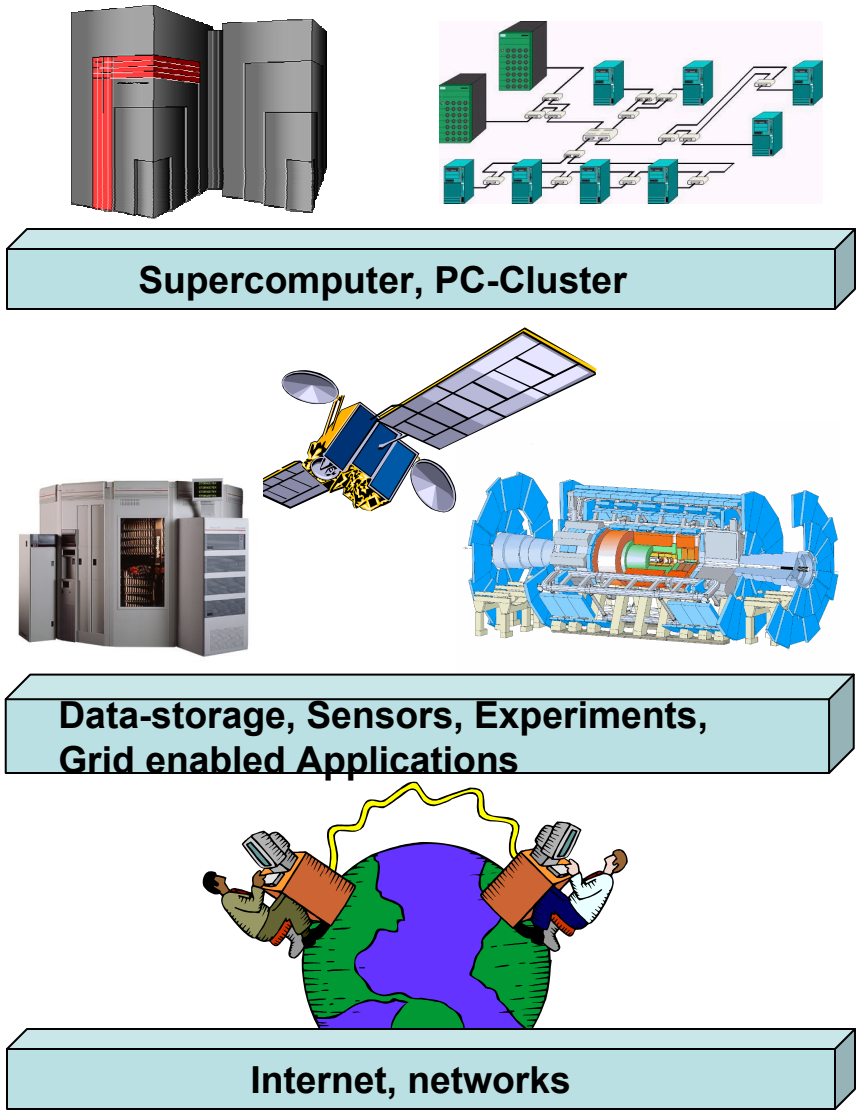
The Information Society

- Harnessing data worldwide
- Harnessing computers worldwide
- Harnessing information worldwide

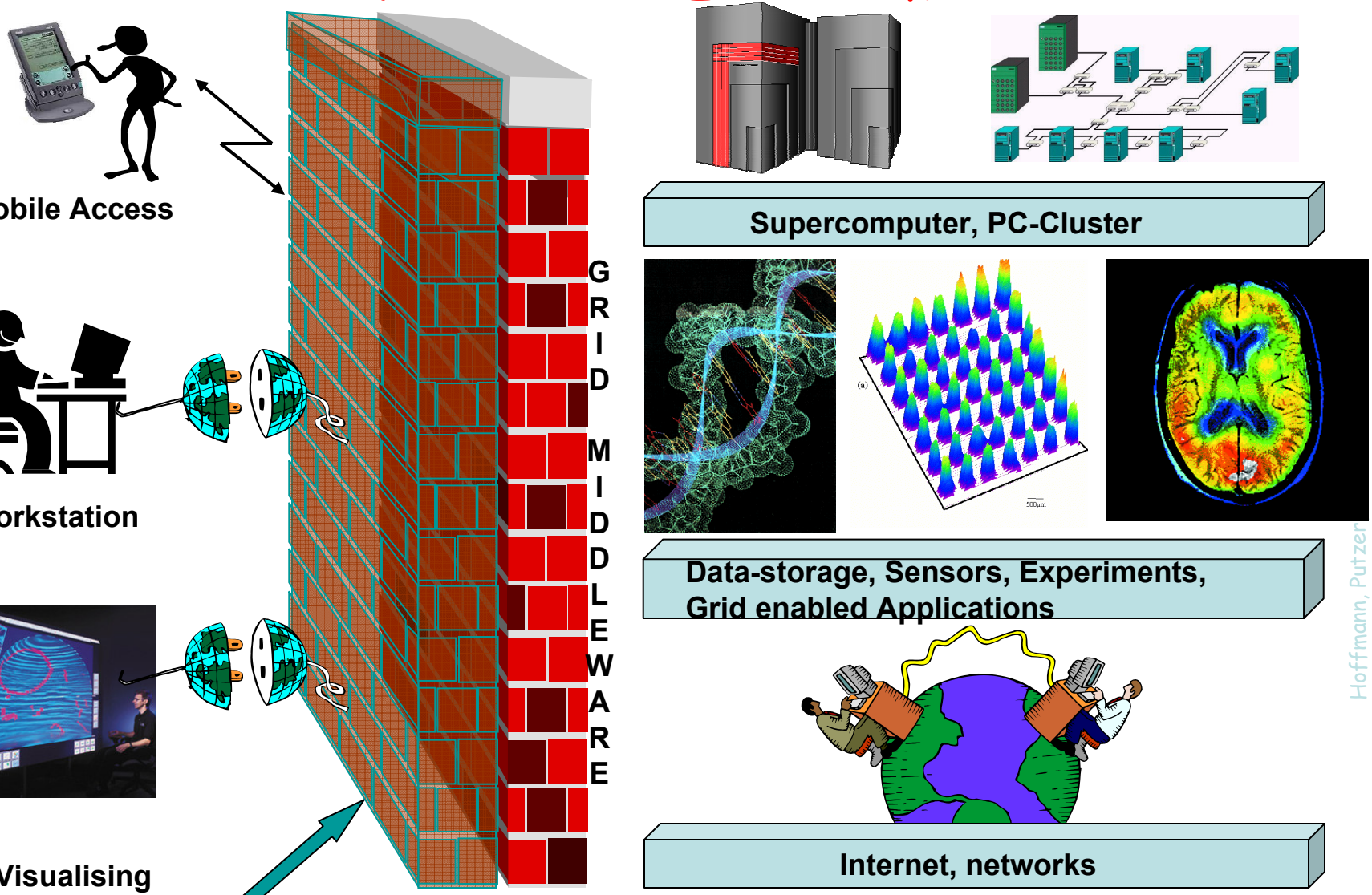
- For the benefit of science and society

The "One-Stop Shopping" view of the GRID





The User connects to his "Virtual Laboratory" or "Workbench Environment"



Integrating framework middleware

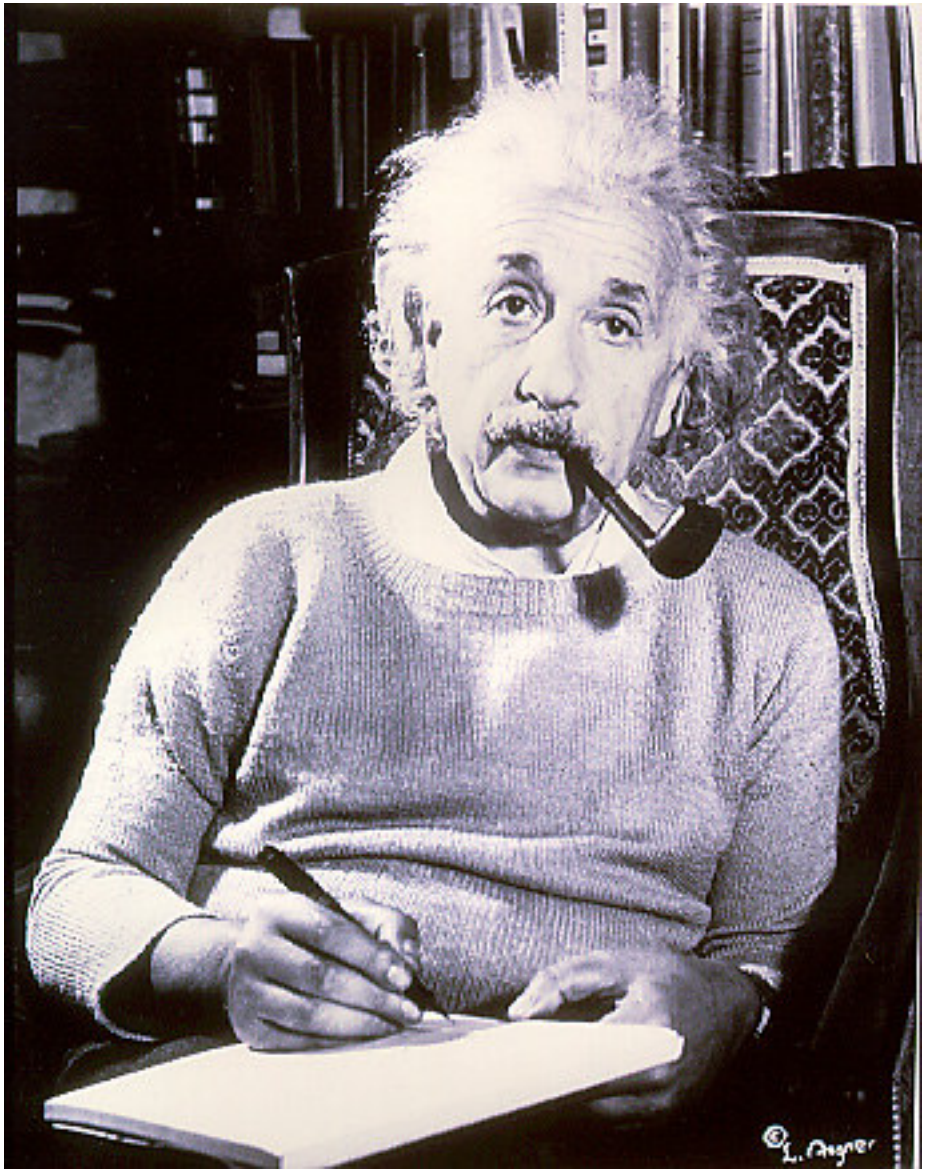
PHYSICS and PHYSICISTS

An understanding of

the universe and our place in the universe
and
our physical terrestrial problems
with
some solutions

International Collaboration

2005
INTERNATIONAL YEAR OF PHYSICS

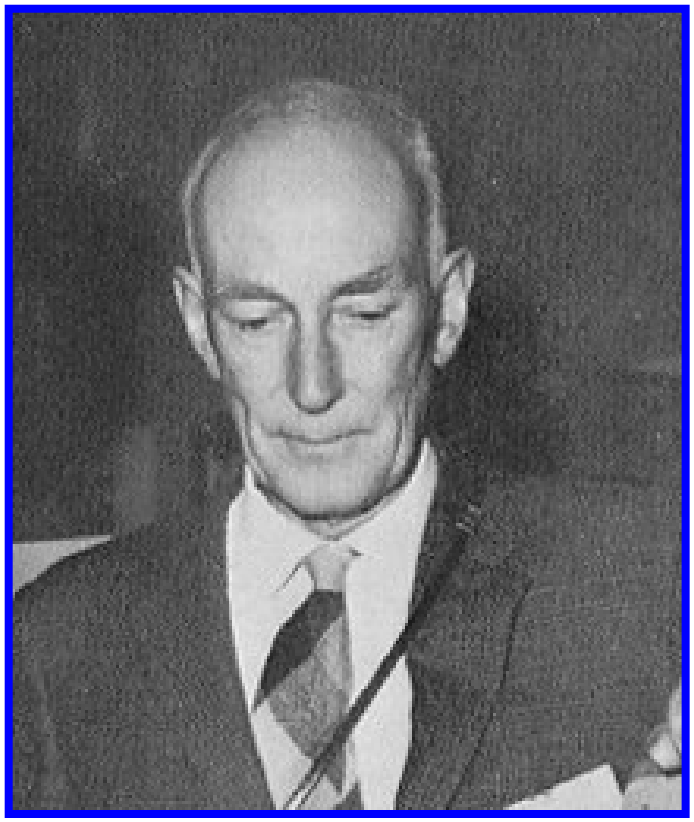


Mysteries of the Universe

- The Matter of the Universe
- The Origin of Mass
- Towards an understanding?
- Incorporating Gravity

Our story begins in 1932…

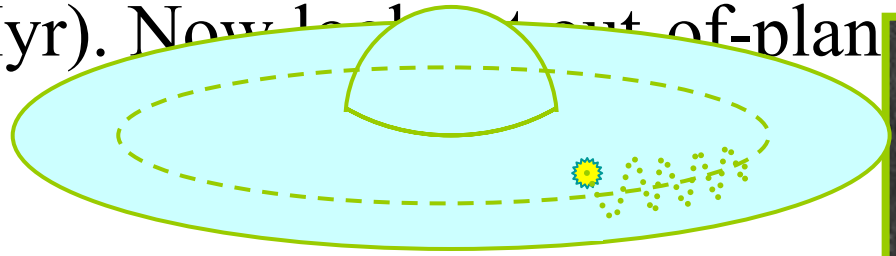
- 1932. Jan Oort
  - Has recently proven that our Galaxy is rotating
  - once every 250 million yr!

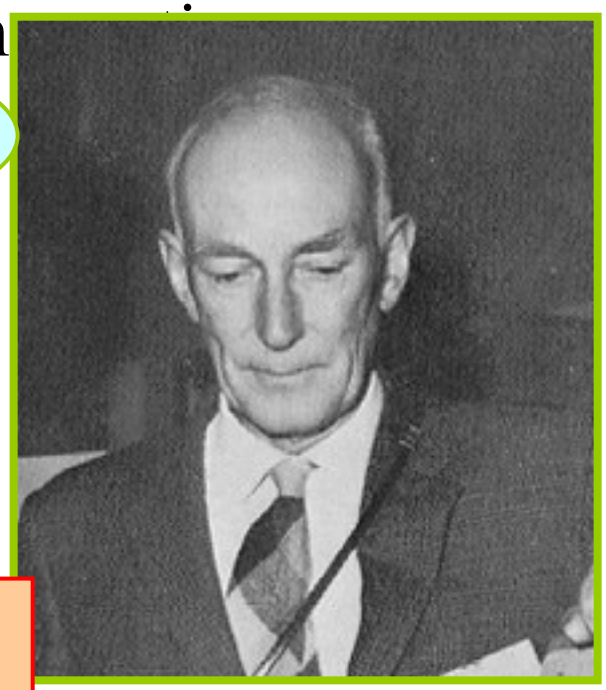


- He now looks at the out-of-plane motion of stars in the Milky Way

First evidence – 1930's observations…

- 1932. Jan Oort – recently having proven that our Galaxy is rotating (~once every 250 Myr). Now looked out-of-plan

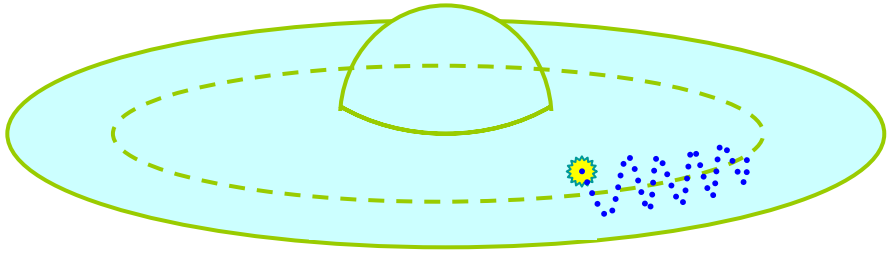


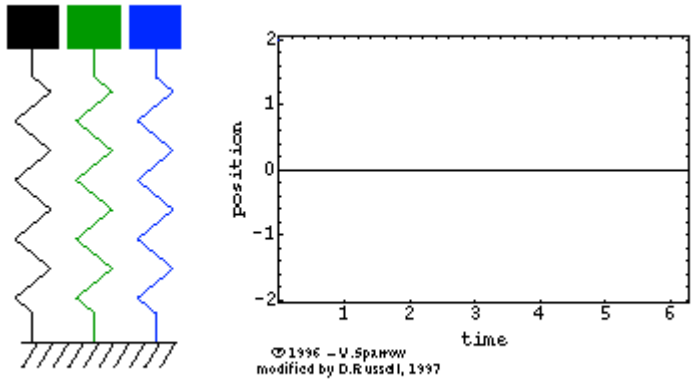


- Out-of-plane motion is approximately SHM!
- Observation was that the with mass distribution expected from visible stars

At the time, it was simply thought that more stars/planets/asteroids were yet to be seen.

First evidence – 1930's observations…



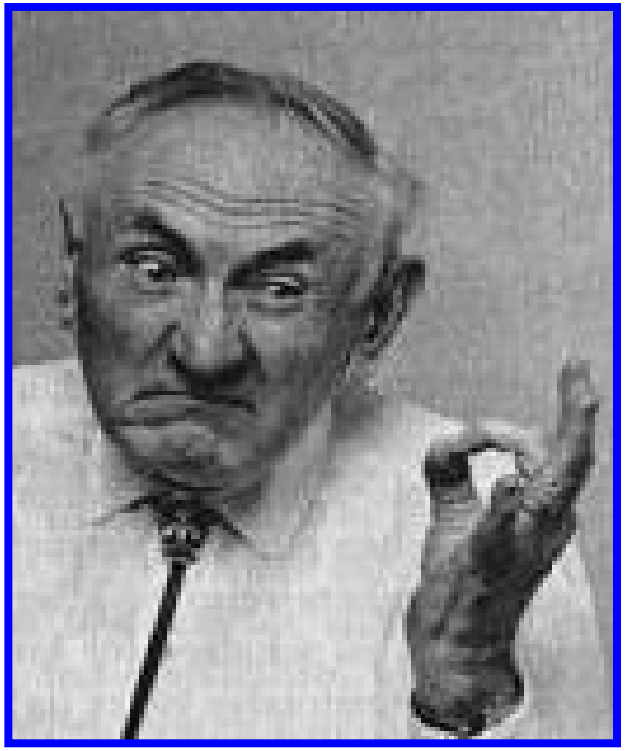


- Out-of-plane motion is approximates `Simple Harmonic Motion'
- Movement is faster than expected
- The implication is that there must be more mass in the disc → more Gravity providing a stronger force

At the time, it was simply thought that more stars/planets/asteroids were yet to be seen.

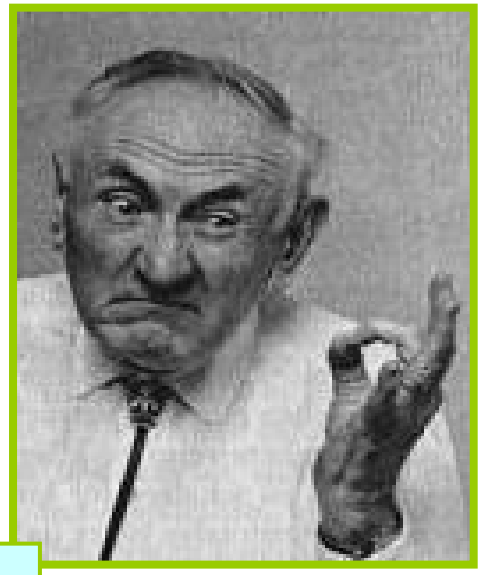
First evidence – 1930's observations…

- 1933. Fritz Zwicky
  - A *brilliant* physicist
  - Neutron stars
  - Supernovae
  - Cosmic rays
  - Gravitational lenses
  - Etc …
- A *controversial* character
  - '*introverted', 'egotistical', 'prickly', 'difficult', 'nasty', 'spiteful',...*
- He now measures the velocities of 8 galaxies in the Coma Cluster…



First evidence – 1930's observations…

- 1933. F. Zwicky measured the velocities of 8 galaxies in the Coma Cluster.



- He found their mean velocity to be much higher than expected [applet]. This has

"If this [over-density] is confirmed we would arrive at the astonishing conclusion that dark matter is present [in the Coma cluster] with a much greater density than luminous matter"
Zwicky, 1933

The implications were generally not accepted at the time…

- The inference is that the gravitational well must be

More evidence – things moving *fast*

Sinclair Smith 1936

Observed galaxies in the Virgo cluster moving 'very fast'

Horace Babcock, 1939

Observed that individual stars in M31 (Andromeda) moving 'very fast'

Q: So, what is 'very fast'?

A: Well in excess of the expected escape velocity

$$Vesc = \sqrt{\frac{2GM}{R}}$$

→ Need more mass to bind those stars to the galaxy/cluster!

The Coma Cluster (Abell 1656)

- 300 million light years away
- A cluster of 1000s of galaxies
- And each galaxy has billions of stars…

Zwicky's work

- He finds the average velocity of the galaxies to be much higher than expected.
- …Implies there must be much more mass there [illegible] higher forces).

"If this is confirmed we would arrive at the astonishing conclusion that dark matter is present with a much greater density than luminous matter"
Zwicky, 1933

The implications were generally not accepted at the time…

Rotation curves

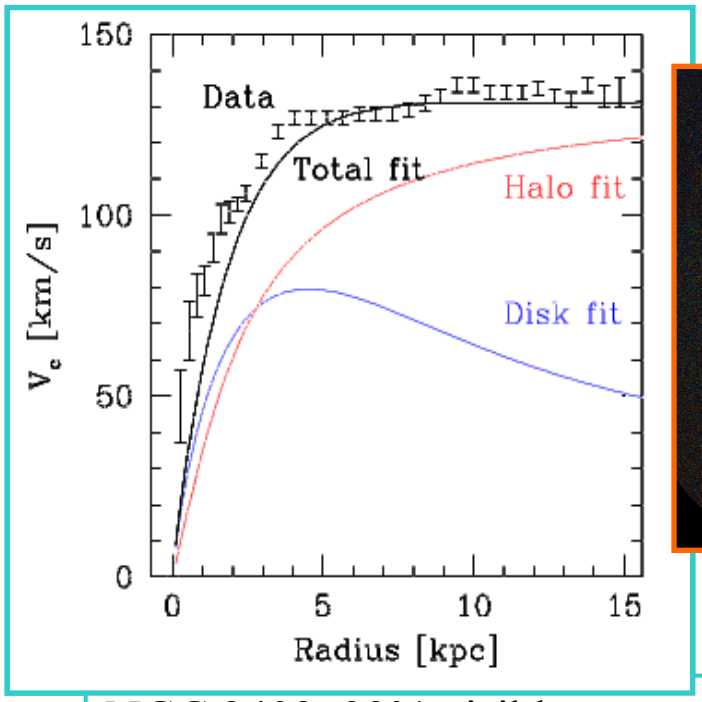
The rotation curve of a galaxy is a graph of

rotational speed against **radius**

- Newtonian gravity:
  - If 'test particle' inside mass distribution, 'tidal locking' $v \propto$
  - Otherwise, equate $GM/r^2 = v^2/r$ → $v \propto 1/\sqrt{r}$

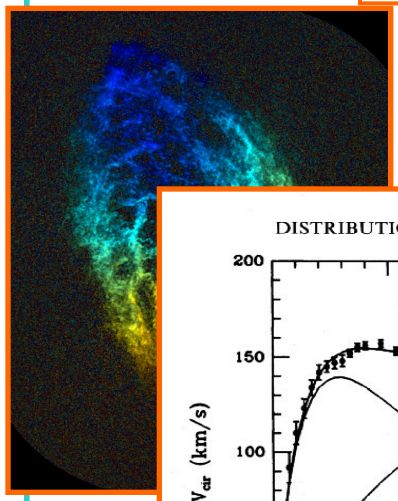
- Oort (1940) studied the edge on

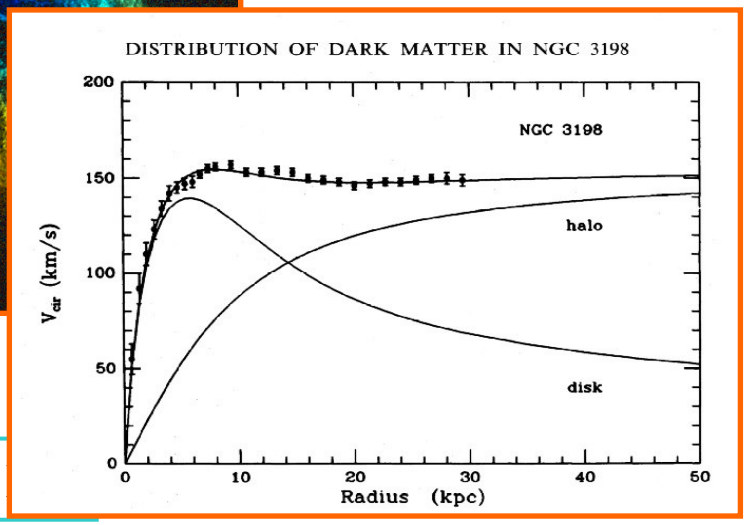
Rotation curves II



NGC 2403, 99% visible mass at <15

NGC 3198





Rotation curves III

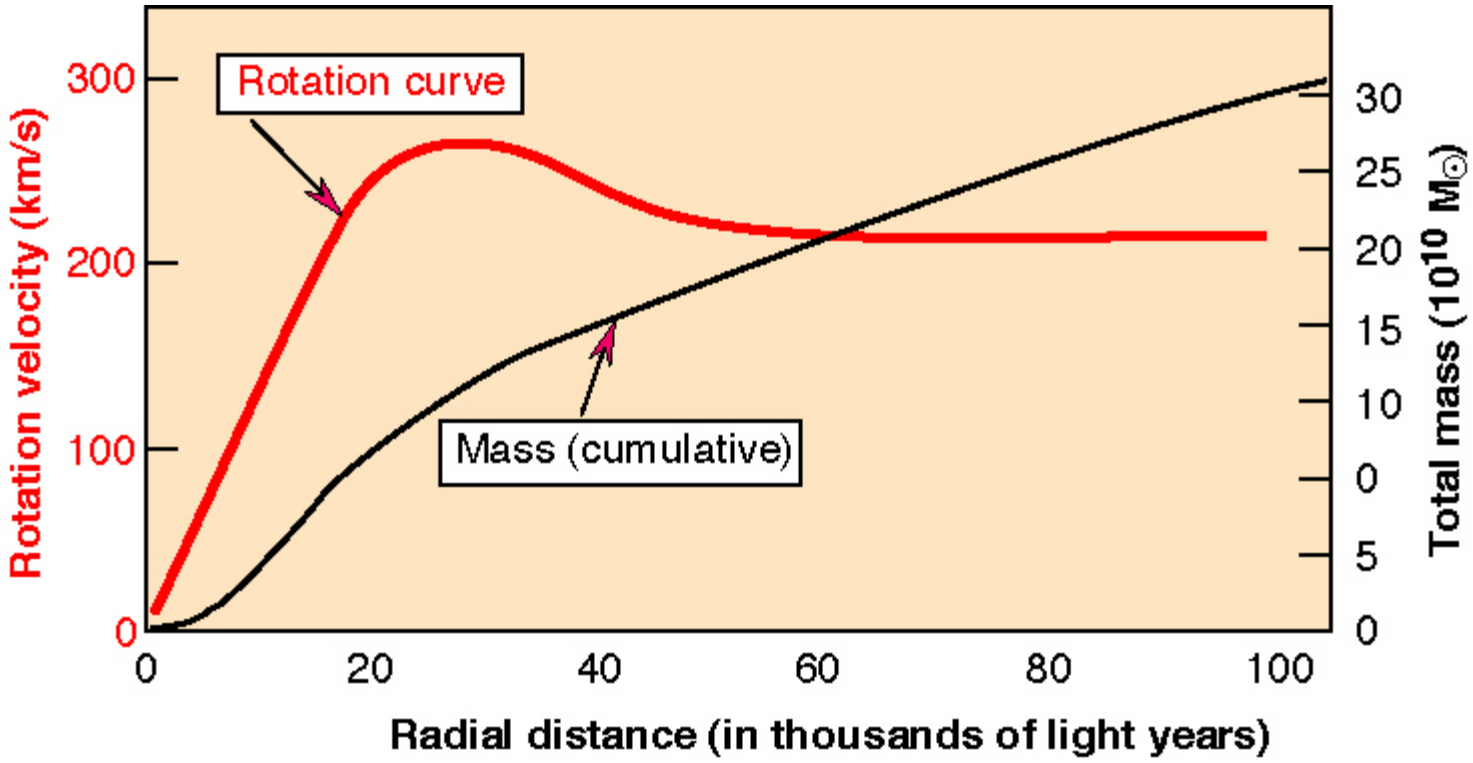
- Rotation curves similar for *all available data* (galaxies and clusters).

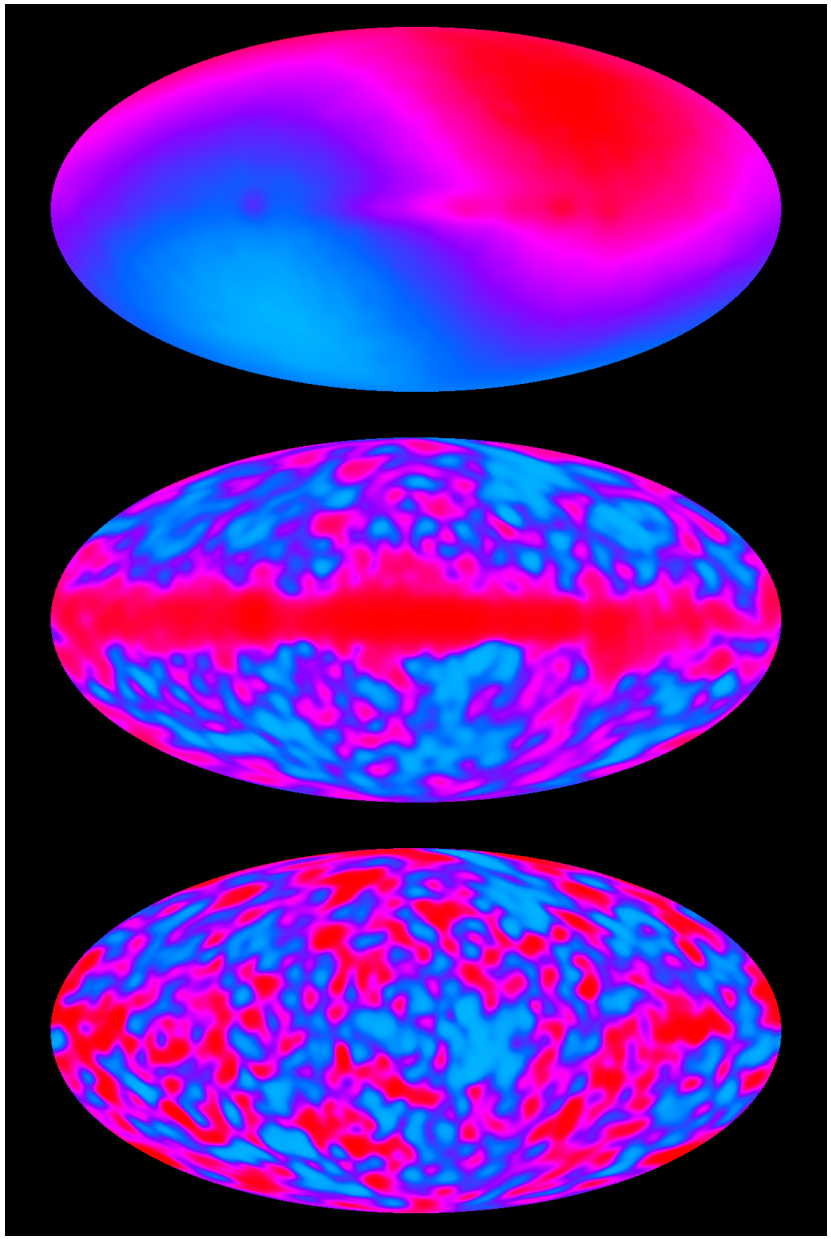
- Fits … of mass is ‘dar… spher…

“The distribution of mass in this system appears to bear almost no relation to the light”

Jen Oort 1940

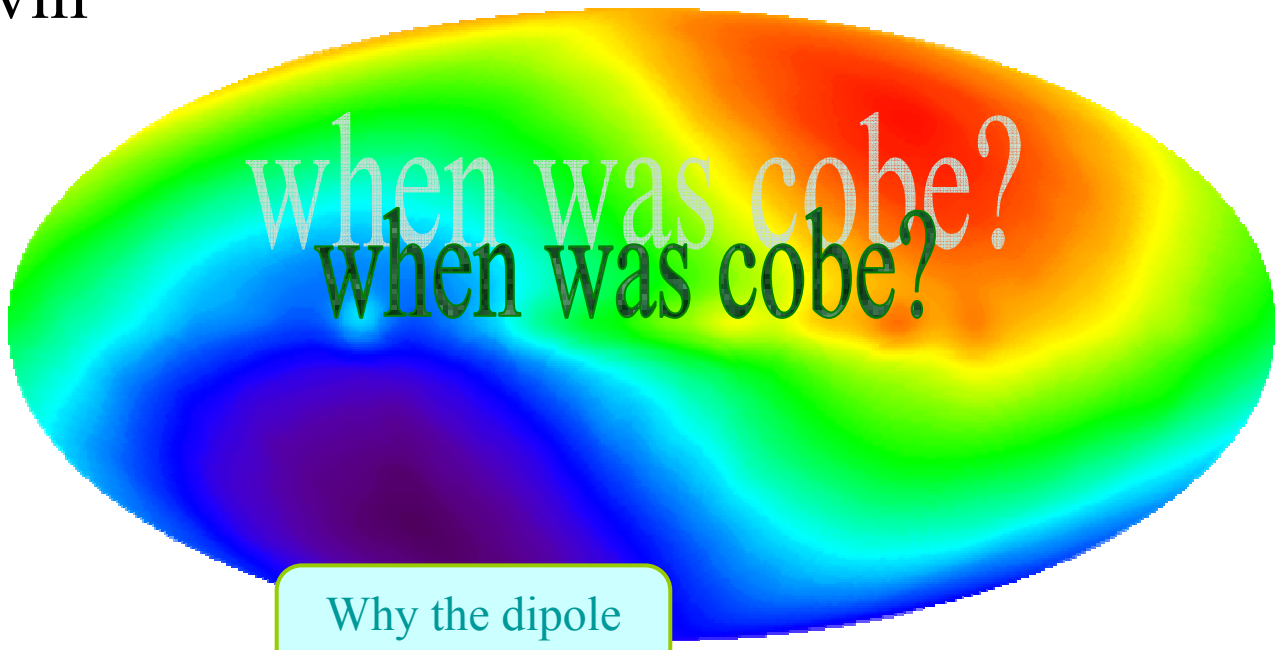
Link with Zwicky’s observations not made until much later…


Rotation curve
Mass (cumulative)
Rotation velocity (km/s)
300
200
100
0
0
20
40
60
80
100
Radial distance (in thousands of light years)
30
25
20
15
10
0
5
0
Total mass (10^{10} $M_\odot$)



COBE Microwave sky

- The sky temperature with range from 2.724 - 2.732 Kelvin



Why the dipole asymmetry?

The sun is moving with respect to the CMBR

Image courtesy COBE homepage.

COBE microwave sky

The sky temperature ranging from 2.7279 to 2.7281 Kelvin.

Dipole removed.

Real fluctuations i… from Milky Way of 1 part in …

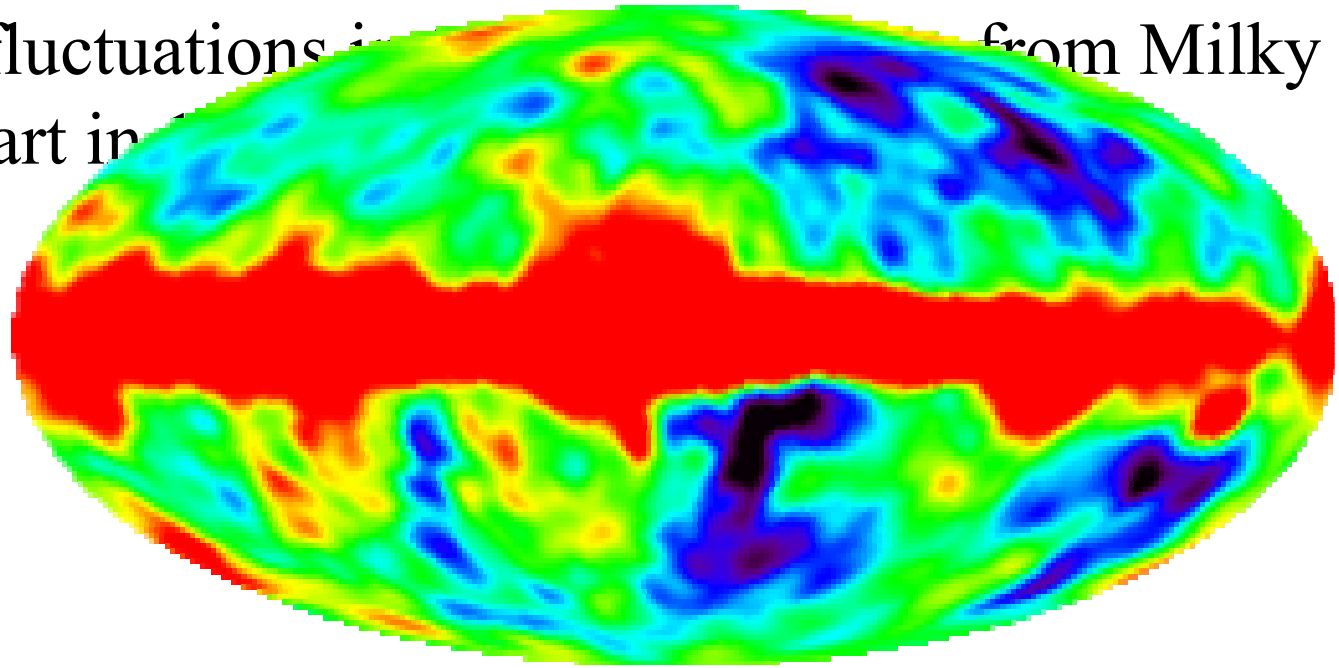
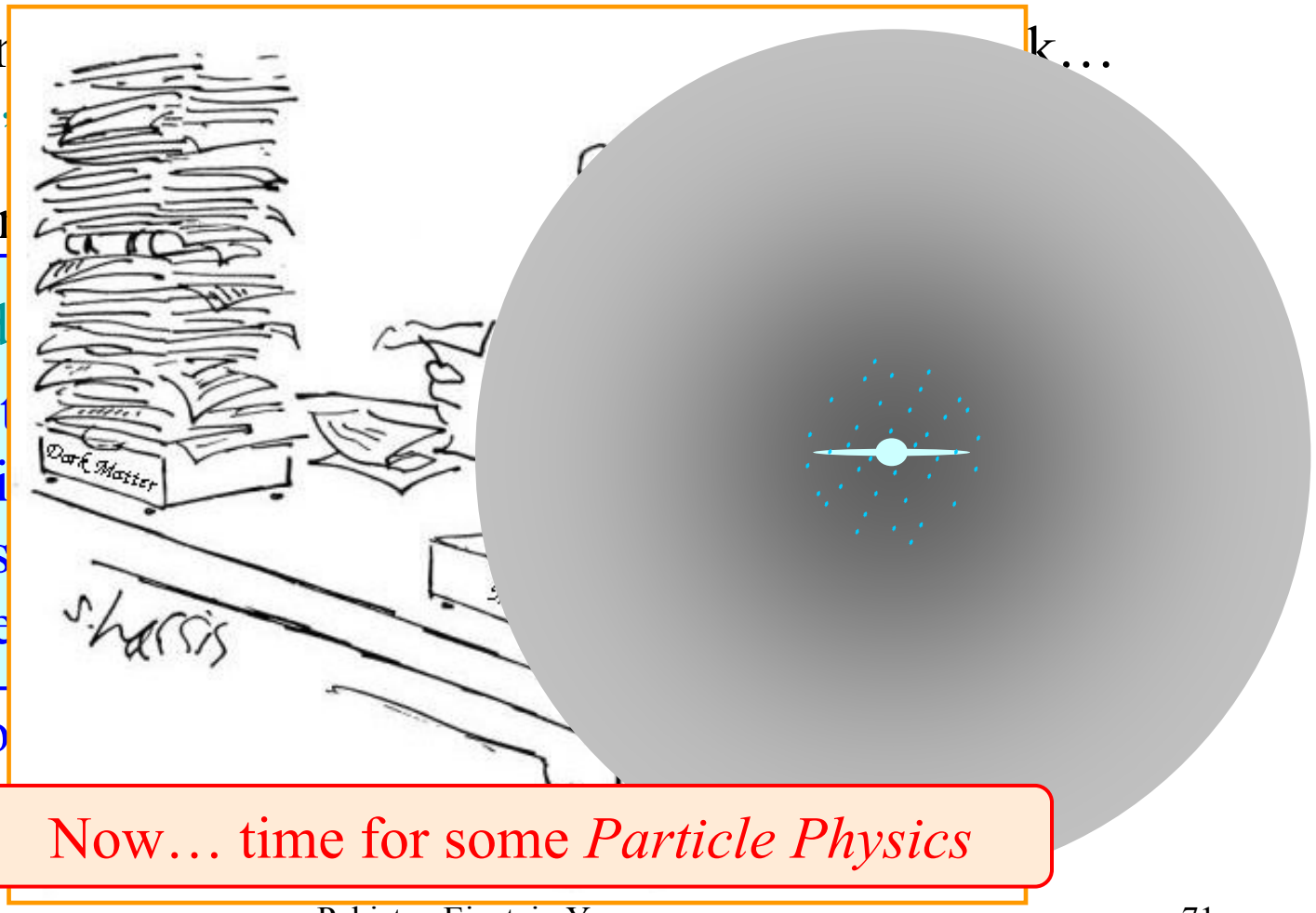


Image courtesy COBE homepage.

What might the Dark Matter be?

- Non-exister…
  - 'MoND'
- Unseen plar
- So, the evid… 9/10th of t… Universe i… clumpy gas… neve…
  - In the fo…



Now… time for some *Particle Physics*

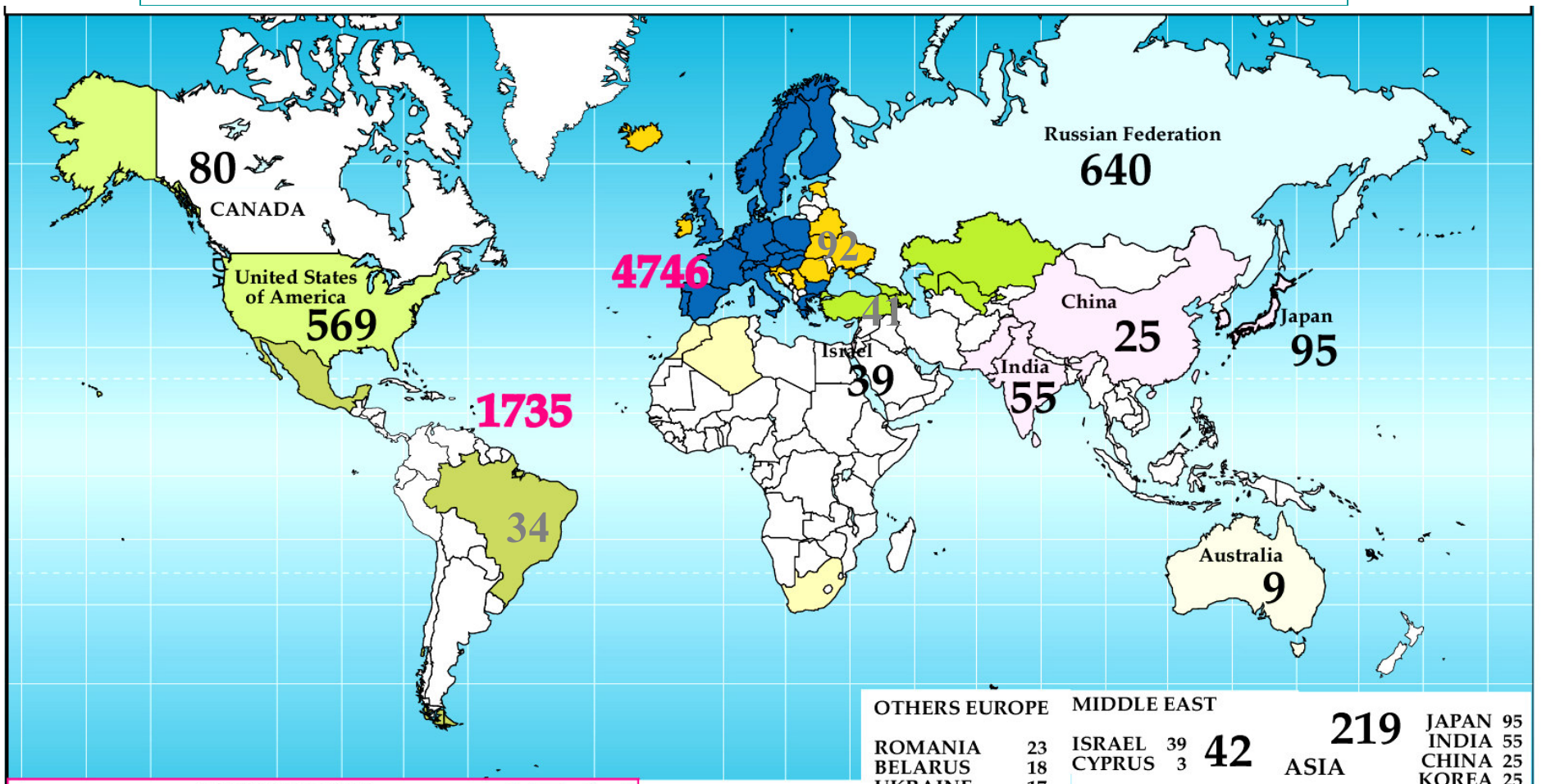
Weakly Interacting Massive Particles

- The lightest of these new particles is an ideal candidate for dark matter
- Would have been created in the Big Bang
- A ***natural*** solution – makes it extremely attractive!

Now we need to detect these particles!

Particle type	Particle	Super partner
Fermion	Quark	Squark
	Neutrino	Sneutrino
	Electron	Selectron
	Muon	Smuon
	Tau	Stau
Boson	W	Wino
	Z	Zino
	Photon	Photino
	Gluon	Gluino
	Higgs	Higgsino

Worldwide Scientific Collaboration



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FINLAND	NORWAY	UNITED KINGDOM
FRANCE	POLAND	

LATIN AMERICA — 34

BRAZIL	26
MEXICO	8

OTHERS EUROPE — 92

ROMANIA	23
BELARUS	18
UKRAINE	17
SLOVENIA	15
CROATIA	12
SERBIA	2
IRELAND	2
ESTONIA	2
MALTA	1

MIDDLE EAST — 42

ISRAEL	39	
CYPRUS	3	
AFRICA		9
MOROCCO	4	
SOUTH AFRICA	4	
ALGERIA	1	

ASIA — 219

JAPAN	95
INDIA	55
CHINA	25
KOREA	25
TAIWAN	13
PAKISTAN	6
TURKEY	17
ARMENIA	15
GEORGIA	7
AZERBAIJAN	1
UZBEKISTAN	1

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