

Curved Space and Compassion

George Ellis

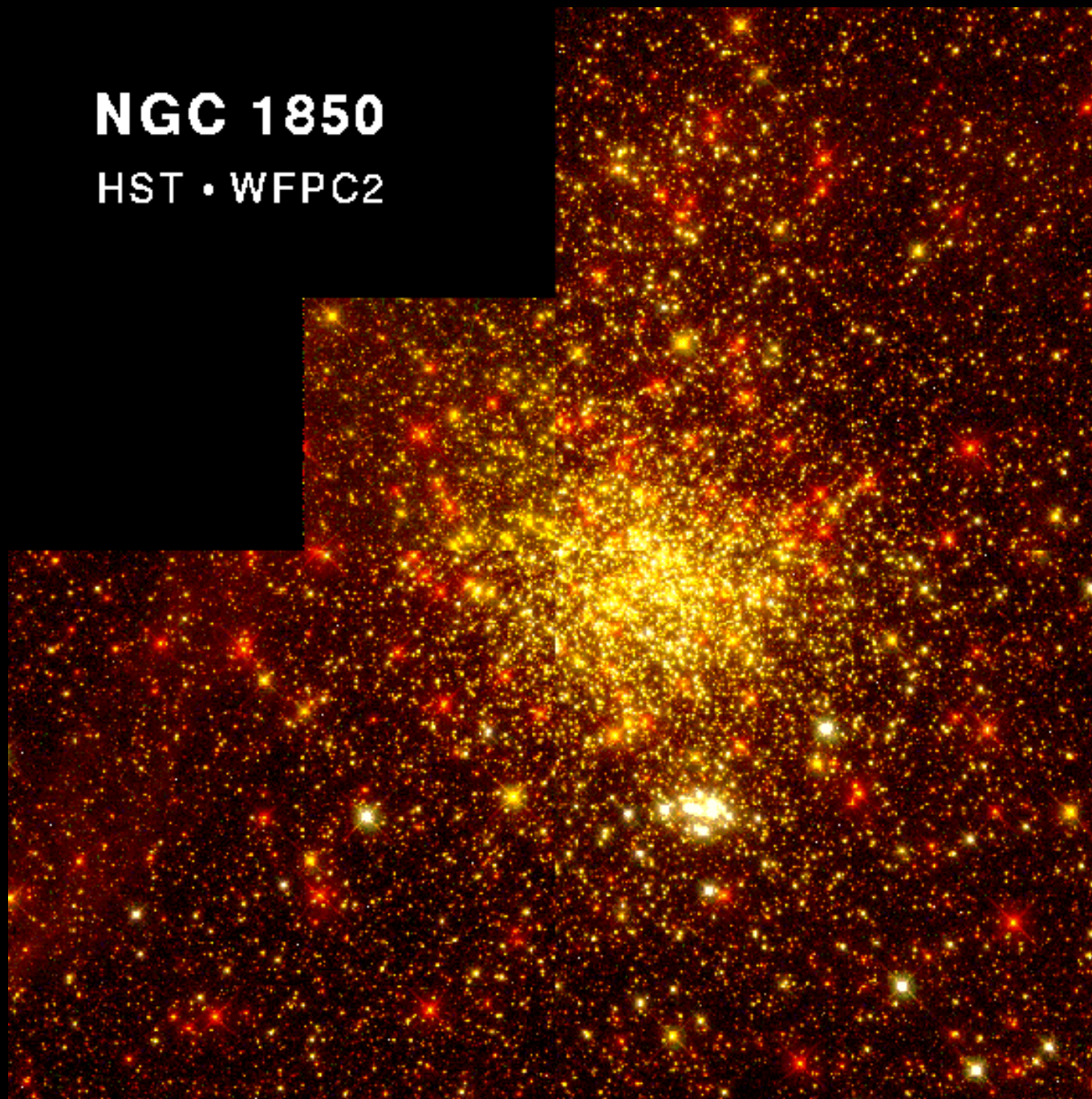
A brief review of cosmology today will be given, followed by some reflections on how it is that the universe allows intelligent life to come into existence and what if anything all this has to do with the concepts of morality and compassion. This relates to the key issue of ethics and survival of the human race.

1: The Universe

- The universe is of vast scale
- It is expanding
- It started off in a Hot Big Bang
- Structures such as galaxy clusters formed by gravitational attraction
- Stars and planets formed in this environment

NGC 1850

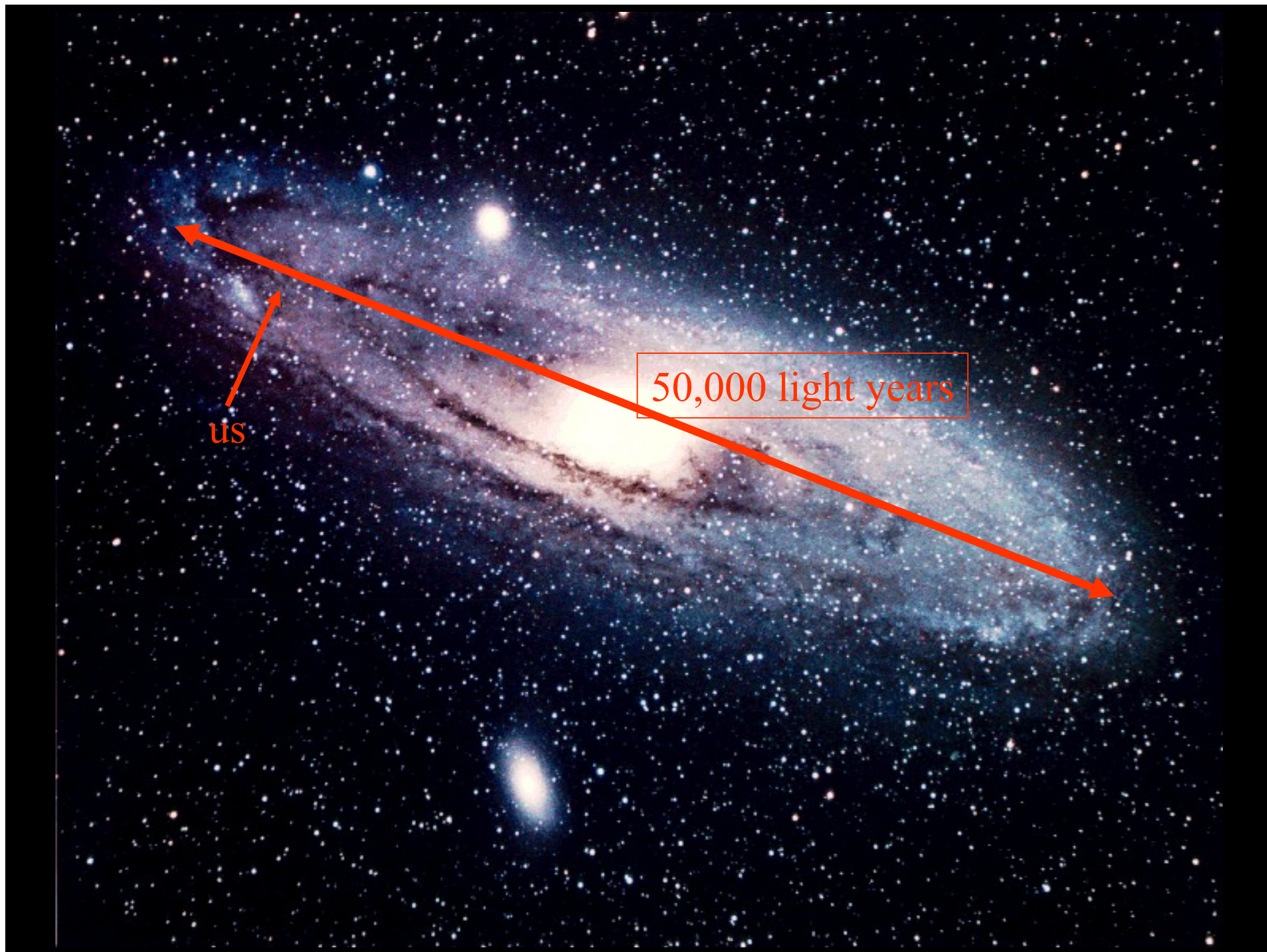
HST • WFPC2



The Milky Way

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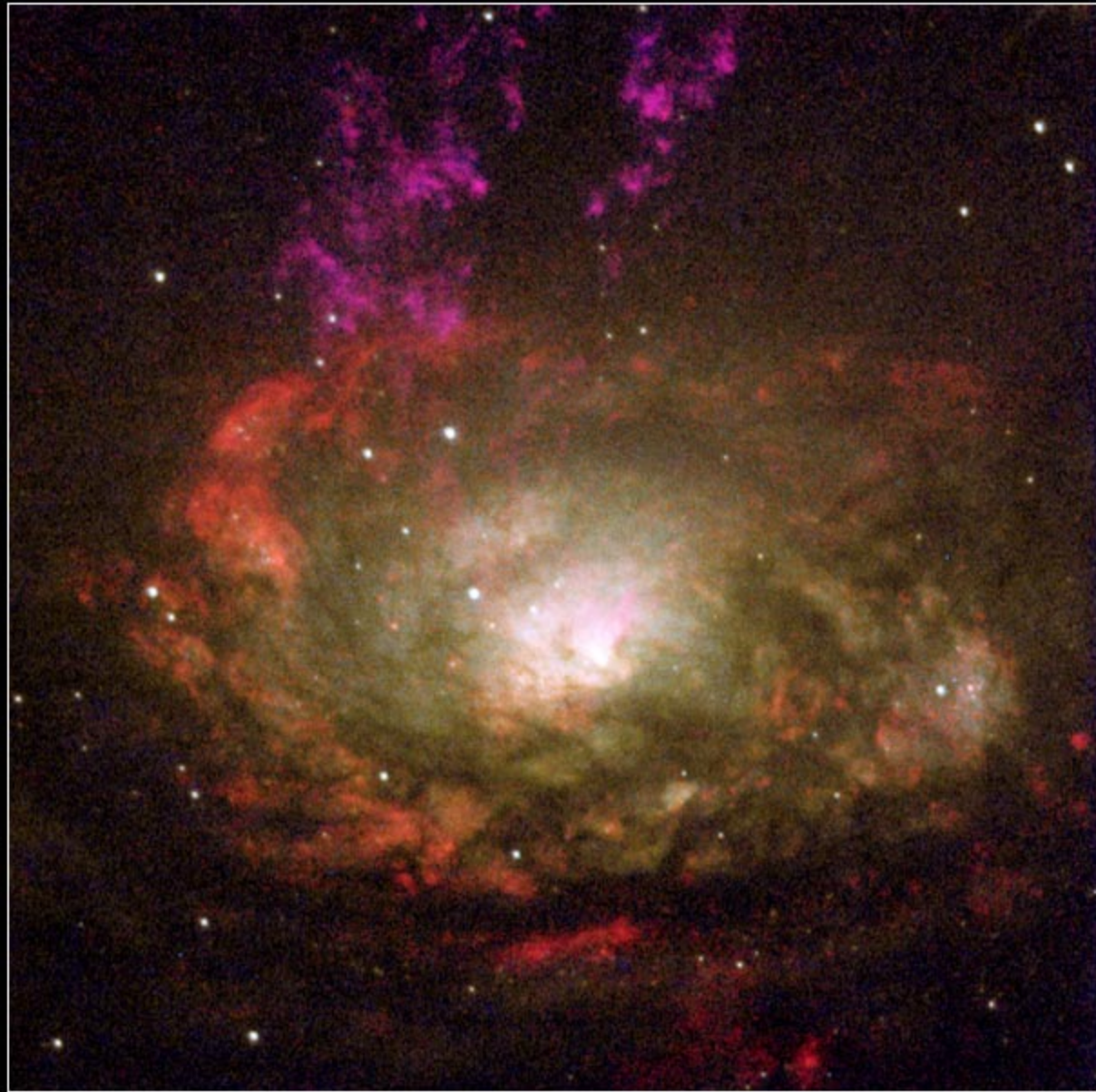




us

50,000 light years





Circinus Galaxy

Hubble Space Telescope • WFPC2

NASA and A. Wilson (University of Maryland) • STScI-PRC00-37



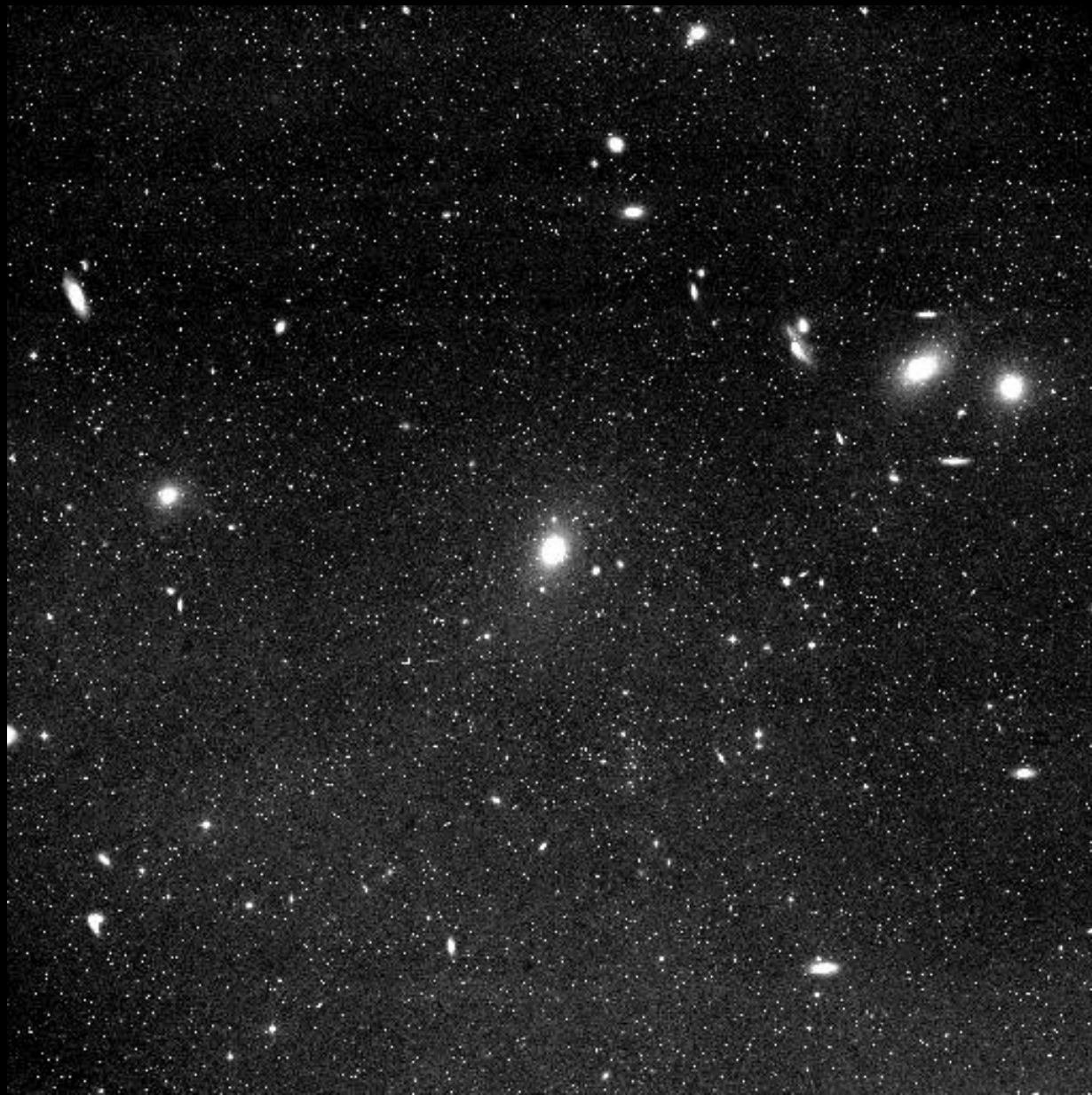
M87 © Anglo-Australian Observatory
Photo by David Malin



Coma cluster

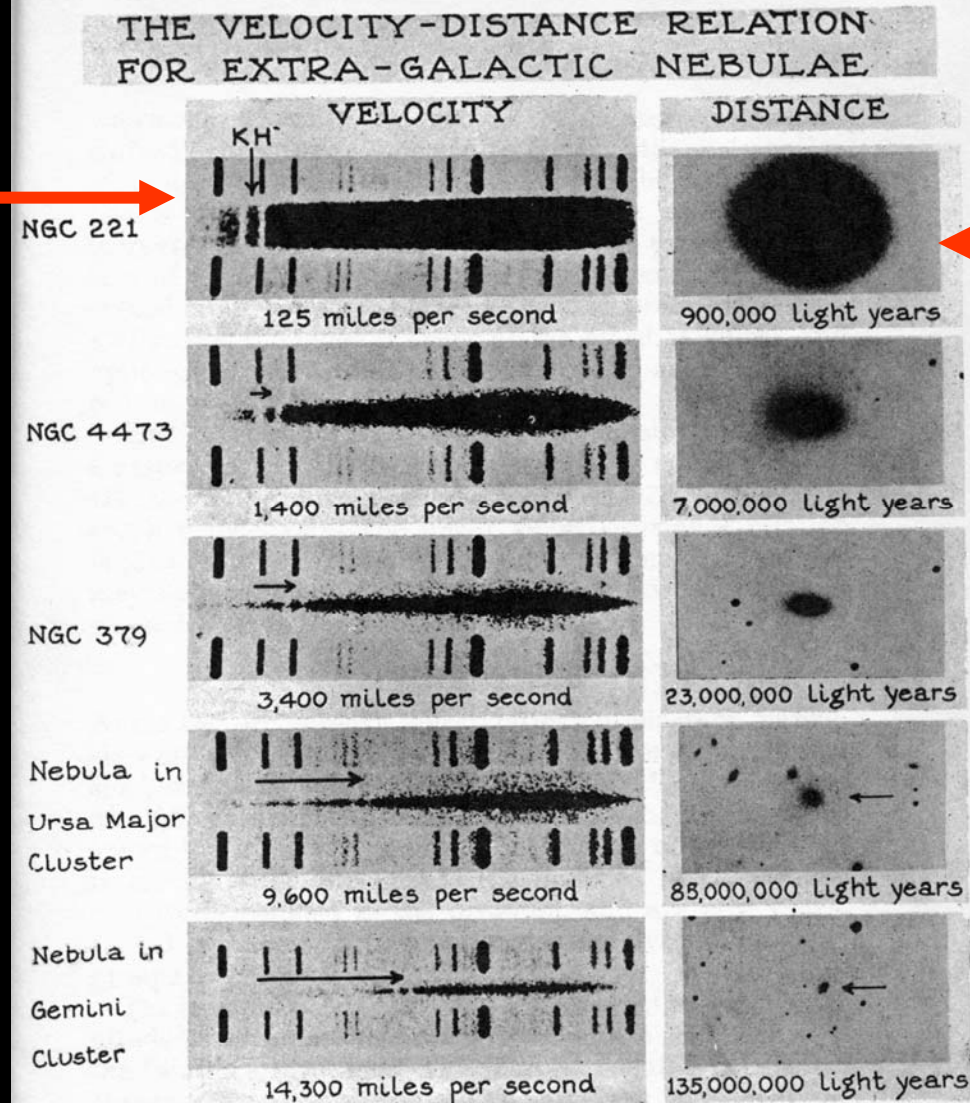


Virgo
cluster



**Redshift
gives velocity**

Edwin
Hubble,
1929



**Apparent
size gives
distance**

The arrows above the nebular spectra point to the H and K lines of calcium and show the amounts these lines are displaced toward the red end of the spectra. The comparison spectra are of helium.

The direct photographs (on the same scale and with approximately the same exposure times) illustrate the decrease in size and brightness with increasing velocity or red-shift.

NGC 4473 is a member of the Virgo cluster and NGC 379 is a member of a group of nebulae in Pisces.

Hubble's data

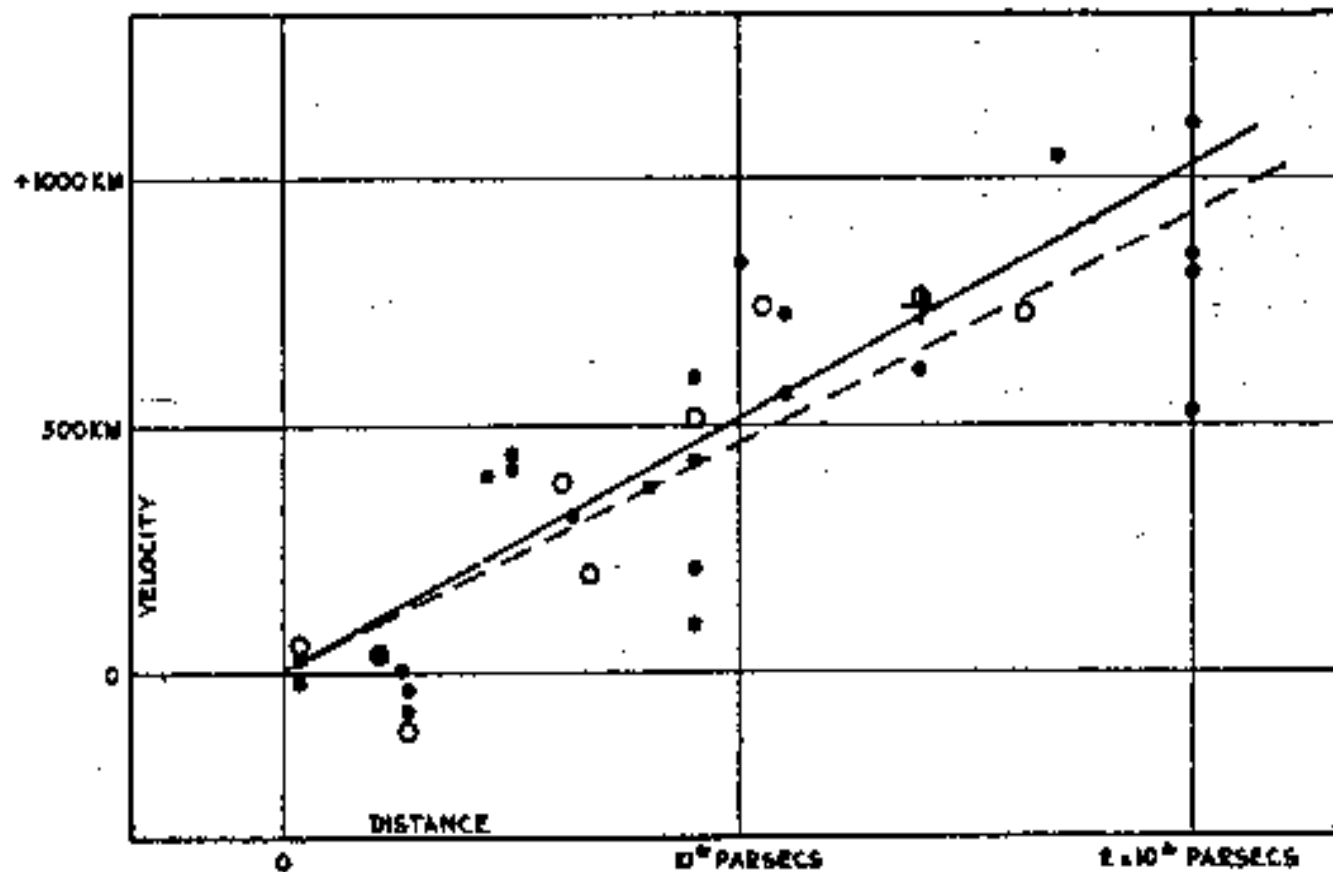


FIGURE 1

Velocity

Distance

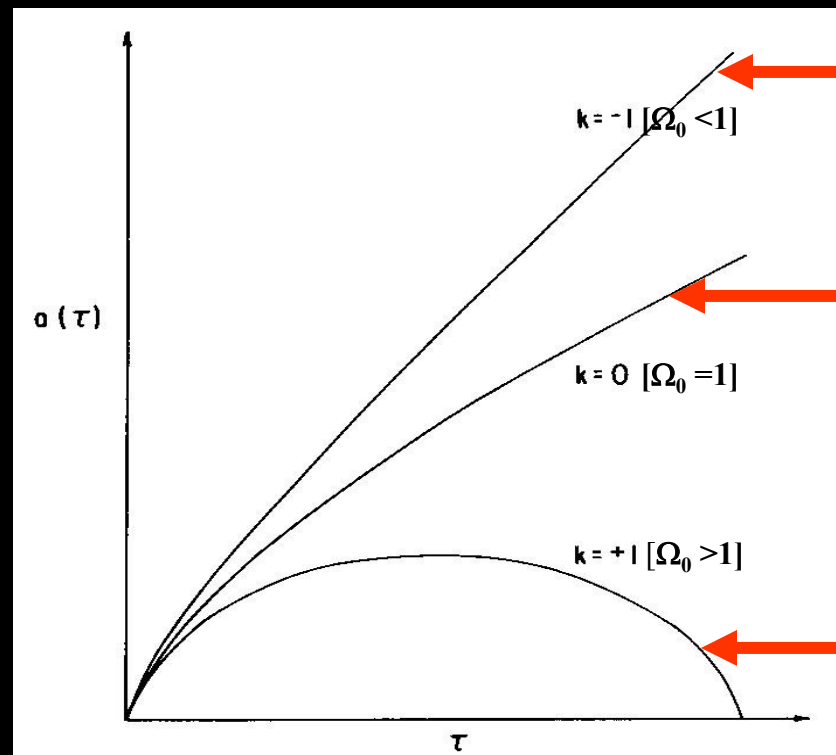
Velocity is proportional to distance

Size of universe vs time ($\Lambda = 0$)

Gravity is expressed in space-time curvature,
and determines the evolution of space-time:

**Dimensionless
Density
parameter:**

$$\Omega_0 = \kappa \rho / 3H_0^2$$



Negatively
curved 3-spaces

Flat 3-spaces

Positively
curved 3-spaces

If $\Lambda = 0$ the critical density $\Omega_0 = 1$ separates the ever-expanding from recollapsing. [More complex when Λ is non-zero].

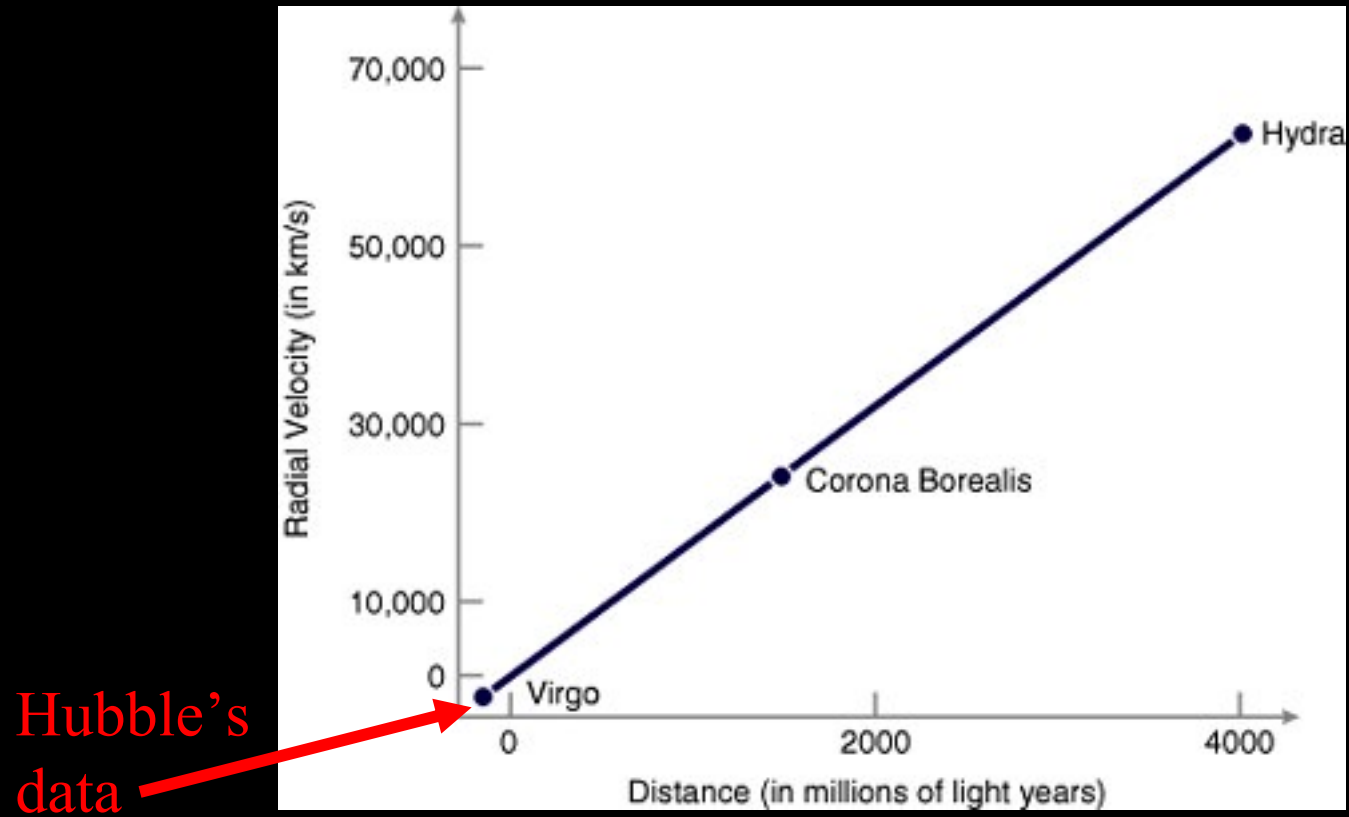
Observational relations

- *galaxy number counts*: (n, m)
- *galaxy magnitude – redshift relation*: (m, z)
applied to ‘standard candles’
- Major observational programmes

BUT: No good standard candles

- *Source evolution* [we are looking back in time]
- *Source statistics/ variation* [sources are not uniform]
prevented determining deceleration parameter

Velocity-distance relation

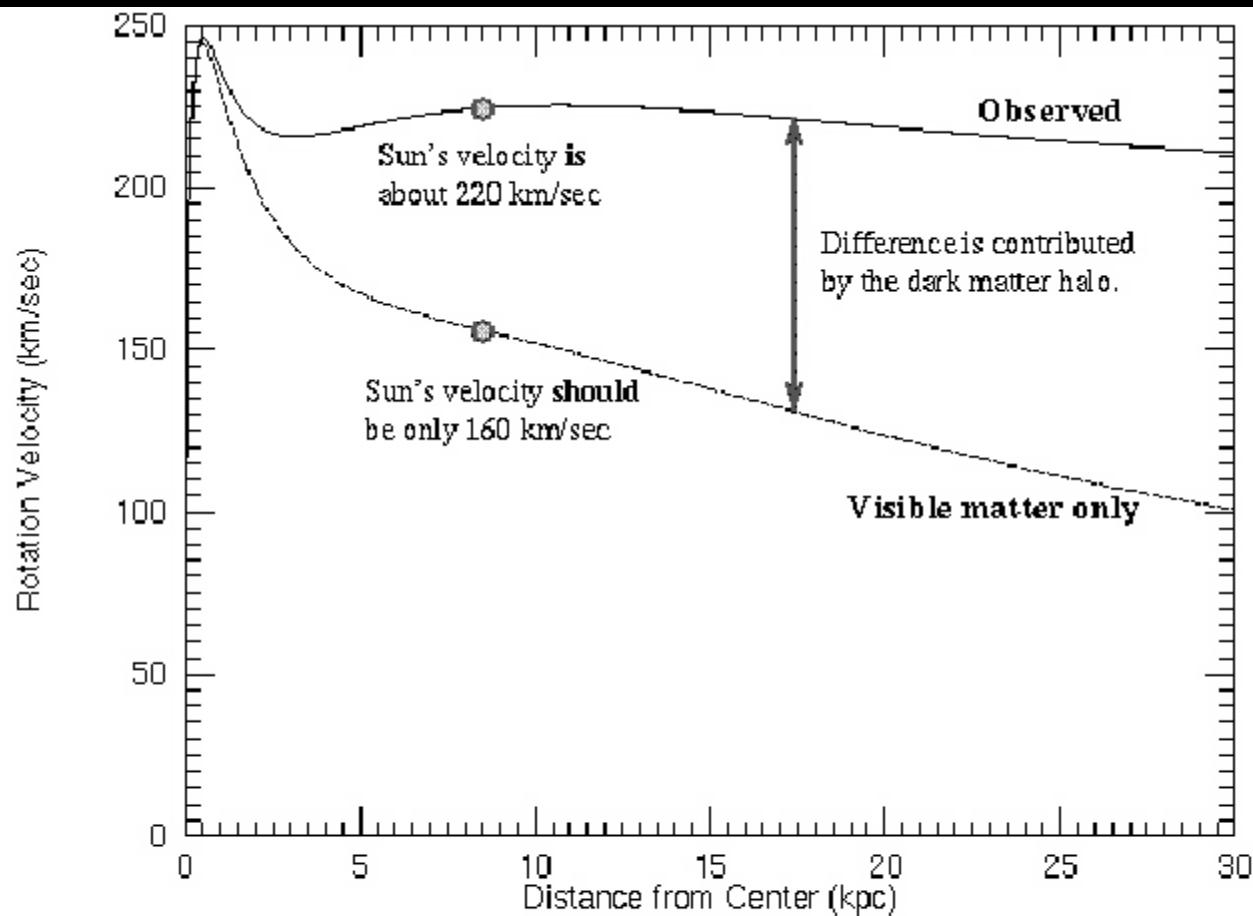


But consistent with linearity to large distances ...

Key Discovery

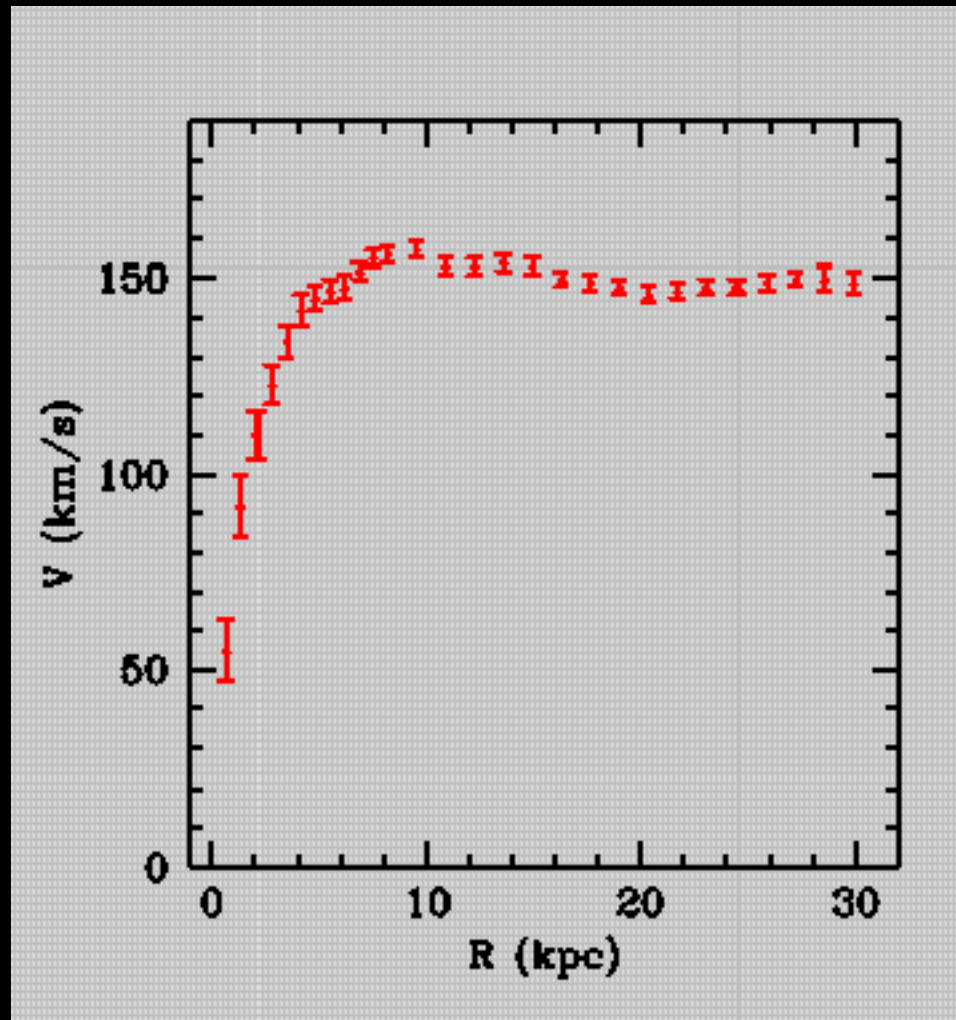
- Rotation curves of galaxies and motions of galaxies in clusters indicate *presence of dark matter*
- Unseen – does not radiate – but felt through its gravitational field
- Density of dark matter varies with scale; cosmologically contributes about $\Omega_0 \sim 0.3$
- Density of luminous (visible) matter much lower: about $\Omega_0 \sim 0.015$

Our own galaxy

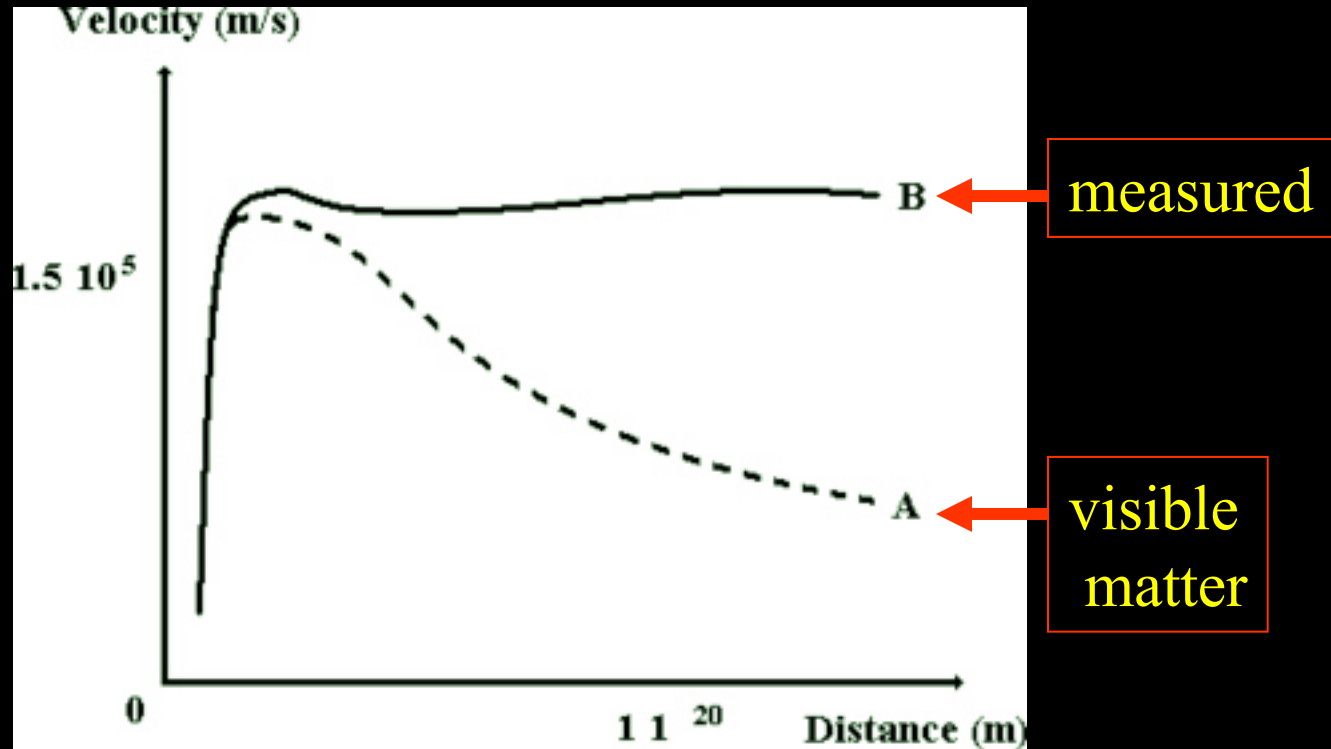


The gravity of the visible matter in the Galaxy is not enough to explain the high orbital speeds of stars in the Galaxy. For example, the Sun is moving about 60 km/sec too fast. The part of the rotation curve contributed by the visible matter only is the bottom curve. The discrepancy between the two curves is evidence for a **dark matter halo**.

Other galaxies



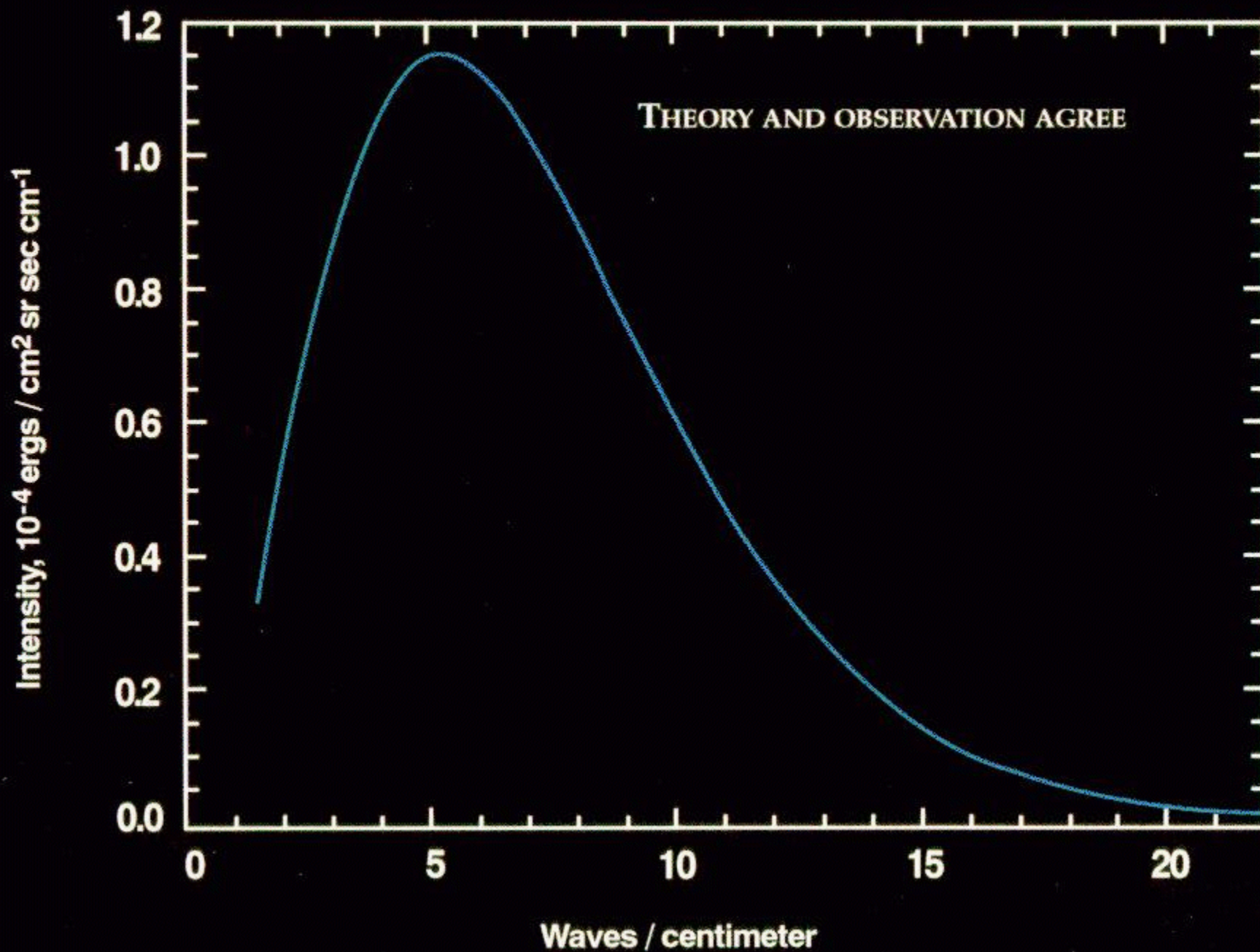
Dark matter is required ...



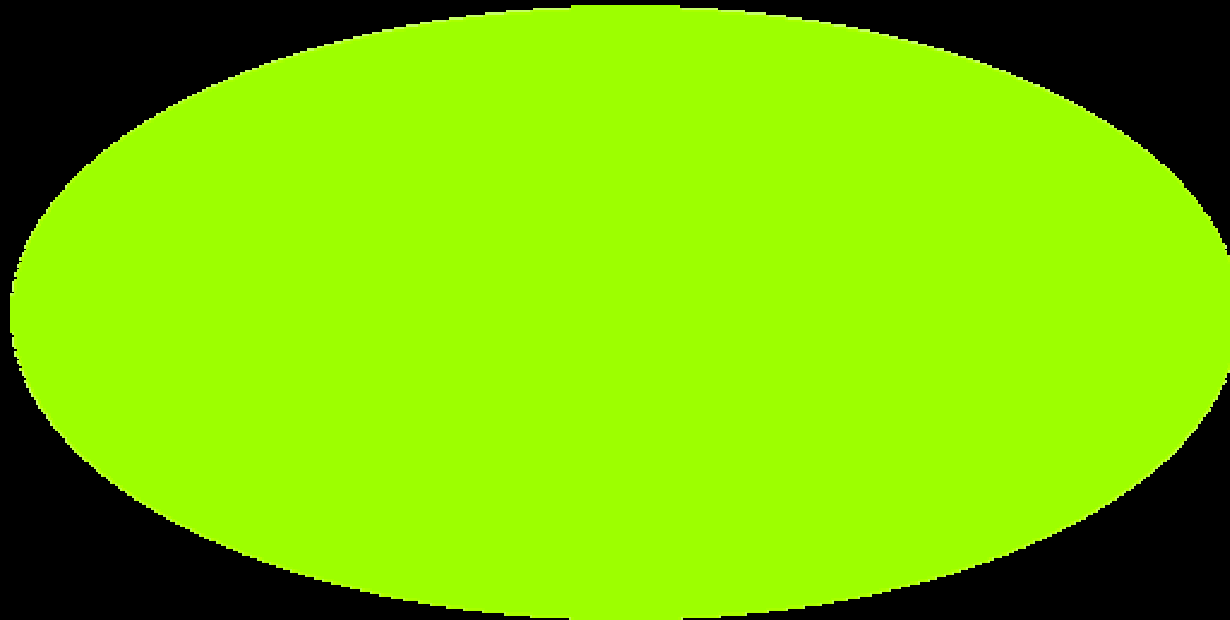
Hot Big Bang

- Follow universe back in time: heats up; hence, ***Hot Big Bang (HBB)*** era in early universe
- Equilibrium occurs between matter and radiation, hence ***Cosmic Blackbody Radiation (CBR)*** left over as a remnant of the HBB era; observationally discovered in 1965 at a temperature of ***2.75K***
- Vindicates application of standard physics to the early Universe
- CBR reaches us from *surface of last scattering at a temperature* of 4000K [a redshift of 1100]

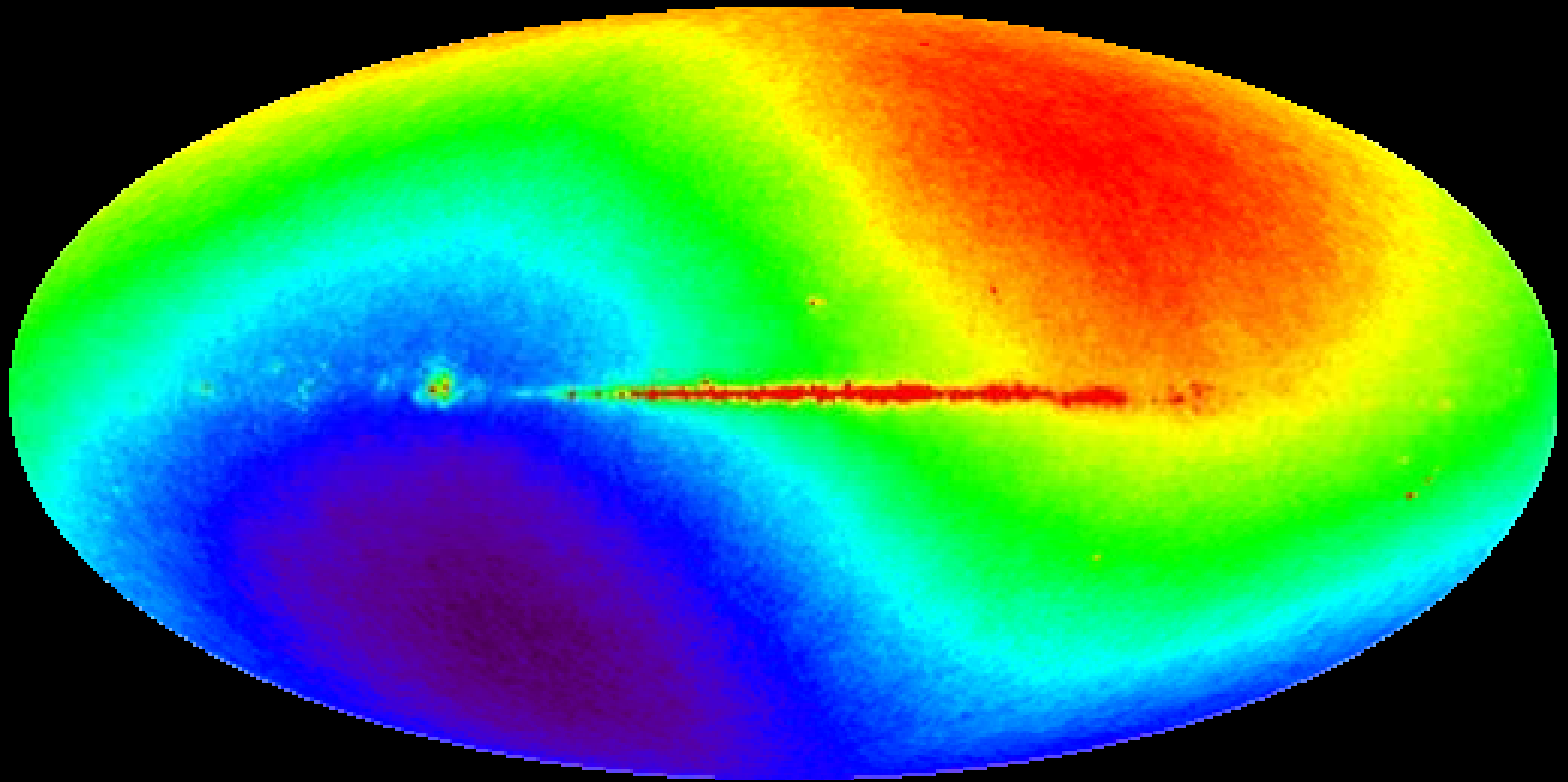
COSMIC MICROWAVE BACKGROUND SPECTRUM FROM COBE



CBR isotropy 1

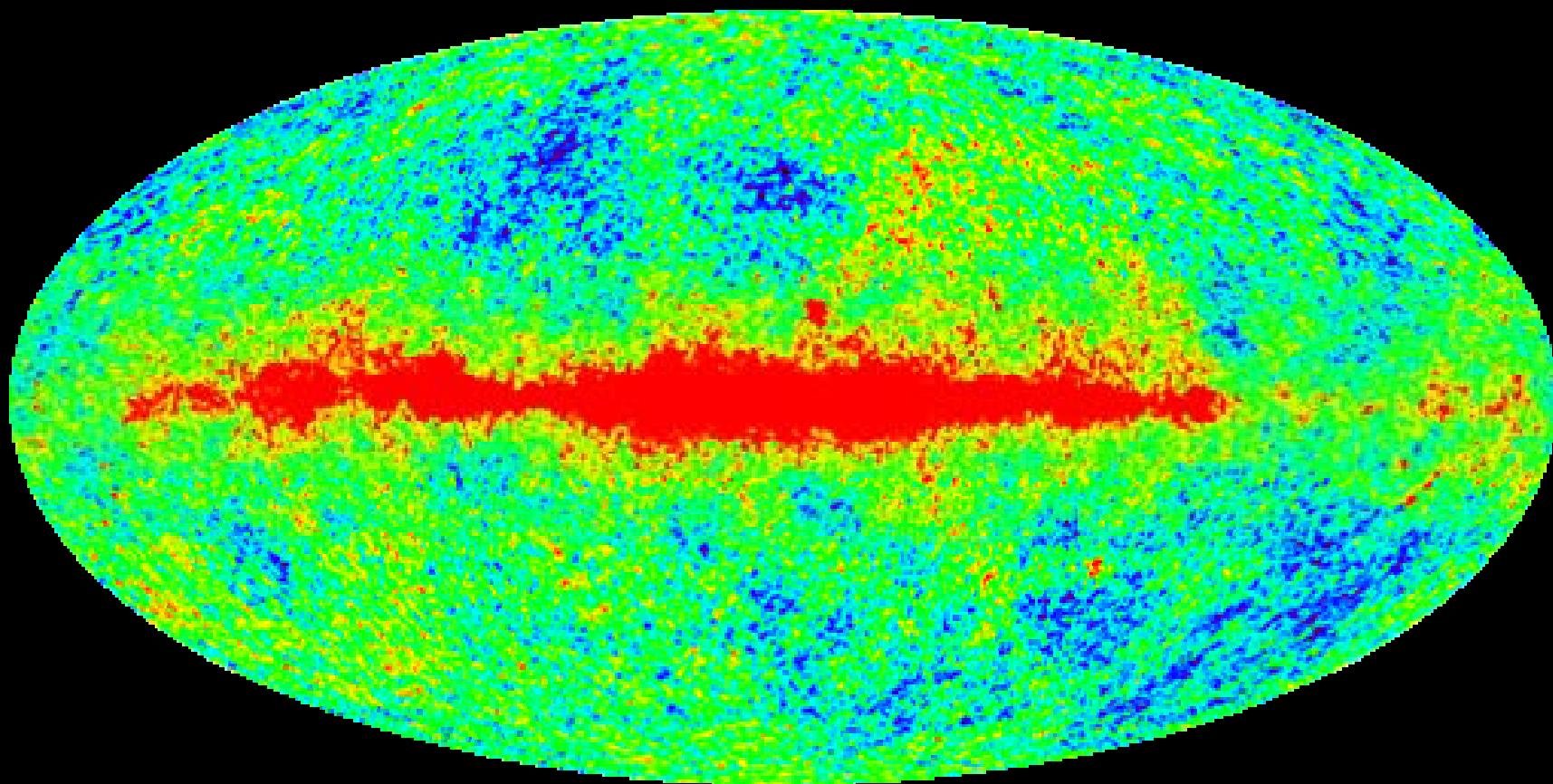


Isotropic at 1 part in 100



Microwave background radiation anisotropy: dipole measured by MAP

**Anisotropy at 1 part in 1000:
Our motion relative to the universe**



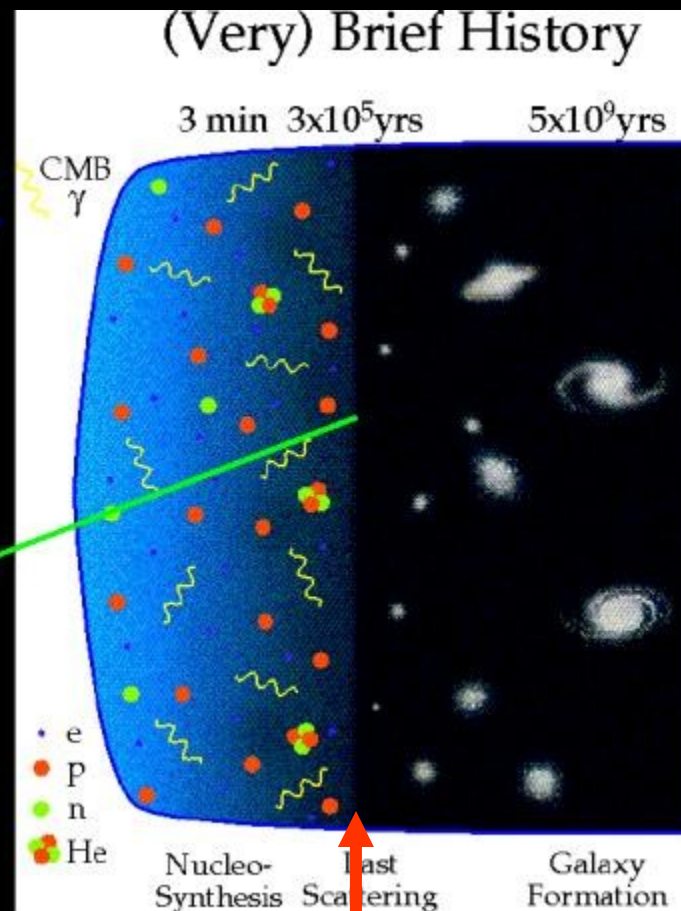
Microwave background radiation anisotropy: dipole removed

Anisotropy at one part in 100,000

This radiation is due to the CMB photons that are now arriving from the "last scattering surface", red shifted by a factor of 1000 or so.



About 1% of the "snow" on a tv is due to CMB photons.



← opaque transparent →

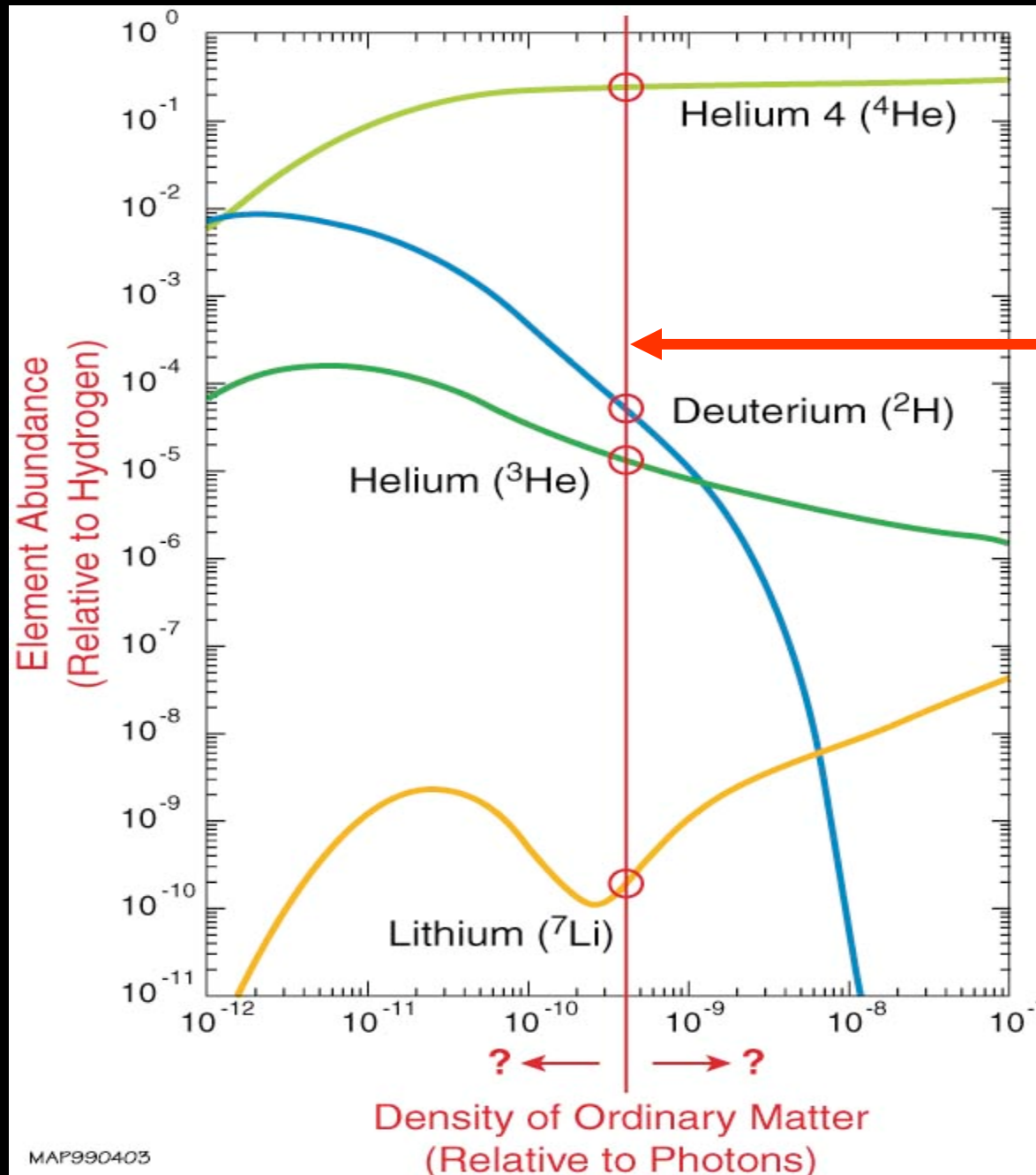
Last scattering surface

Origin of the elements

- nuclear physics processes during the HBB era
- The unbounded temperature in this era implies *matter-radiation equilibrium*:

Previous state is then **irrelevant**

- an epoch of *nucleosynthesis* when the **light elements** form in the early Universe at a temperature of about 10^9K [neutrons and protons combine to form nuclei]
- **heavy elements** form much later in stars



All
four
observations
agree

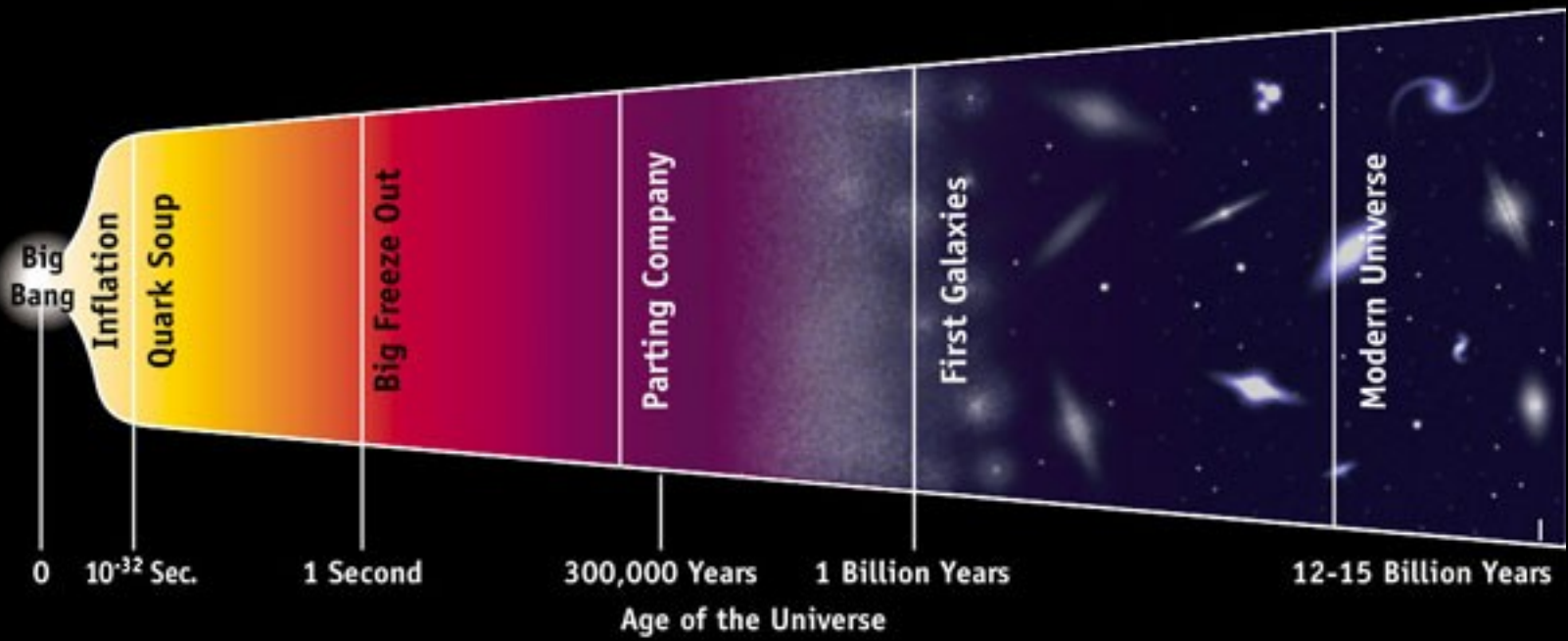
Relation to observations

- nucleosynthesis *theory and element abundance observations agree* provided the baryon density in the early Universe is low: $\Omega_{b0} \sim 0.044$
- together with the density estimates from astrophysical cosmology $\Omega_0 \sim 0.3$, provides evidence for *much more non-baryonic dark matter than baryonic matter* in the Universe
- requires there be *no more than three neutrino species*, a conclusion confirmed later by experiments at CERN

Particle cosmology and inflation

- In the very early Universe particle physics plays a major role.
- Because quantum field theory allows a violation of the standard energy condition $\rho + 3p > 0$, at very early times there can be a *period of accelerated expansion* driven by scalar fields
- ‘*inflation*’ with expansion accelerating rapidly takes place through many e-foldings before a subsequent HBB era begins (when the inflationary field has decayed to ordinary matter and radiation).

← Radius of the Visible Universe →



time

Quantum cosmology

- Before the inflationary era, some kind of quantum gravity effects will dominate the dynamics of the Universe and provide the initial conditions for inflation

Attempts to describe this **quantum cosmology era** include:

- the *wave function of the Universe*, either through the Wheeler-DeWitt equation or path integral methods
- ‘*pre-big bang*’ theory based on string dualities
- *brane cosmology* : our Universe lives on a 4-dimensional ‘brane’ imbedded in a 5-dimensional spacetime
- the *ekpyrotic universe* where two such branes collide

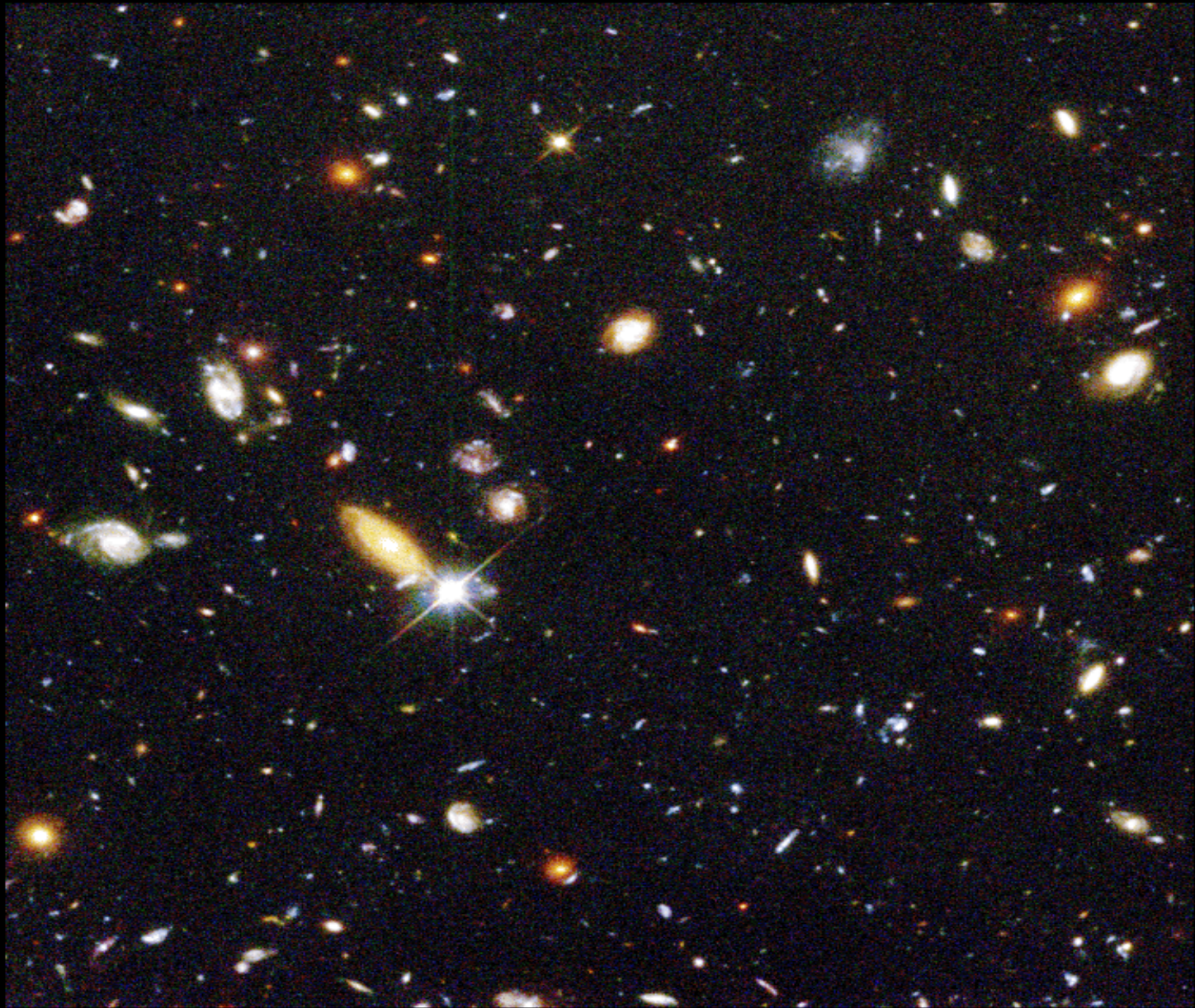
Quantum cosmology

- In all cases the problem is making a solid link to observational tests, because the proposed particle interactions and/or extension of classical gravitational theory is not directly testable
- however, these theories are indirectly testable via their effects on the inflationary perturbation spectrum, and so on structure formation
- there is no fully formulated theory of quantum gravity
- *In the end we do not know if there was a start to the universe or not*

Observational transformation

Since the 1960's, observational cosmology has gone through a major transformation: **discovery** of quasi-stellar objects, X-ray sources, gravitational lenses, and so on. This has been made possible by a revolution in observational technology

- **new telescopes**, both ground-based (e.g. Keck) and borne aloft in balloons and satellites (e.g. IRAS, the Hubble Space Telescope)
- operating at all wavelengths from radio to γ -ray
- with features such as multiple-mirrors and adaptive optics
- **improved detectors** have allowed much deeper observations and number counts than before e.g. CCD's.

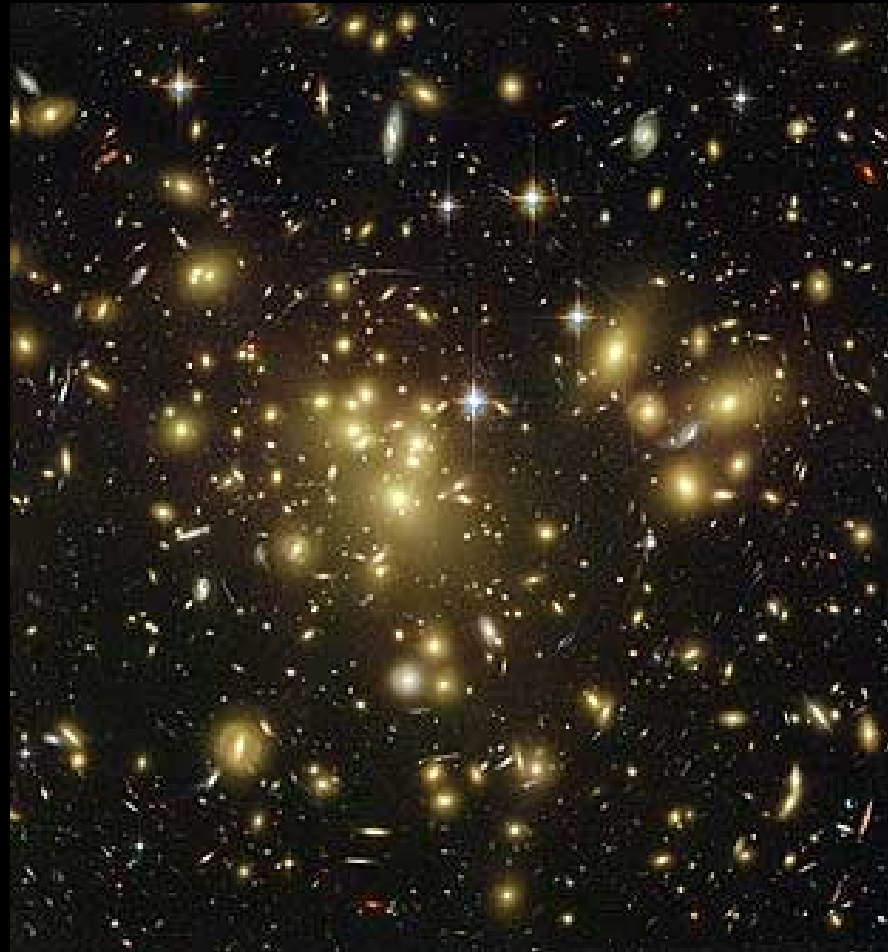


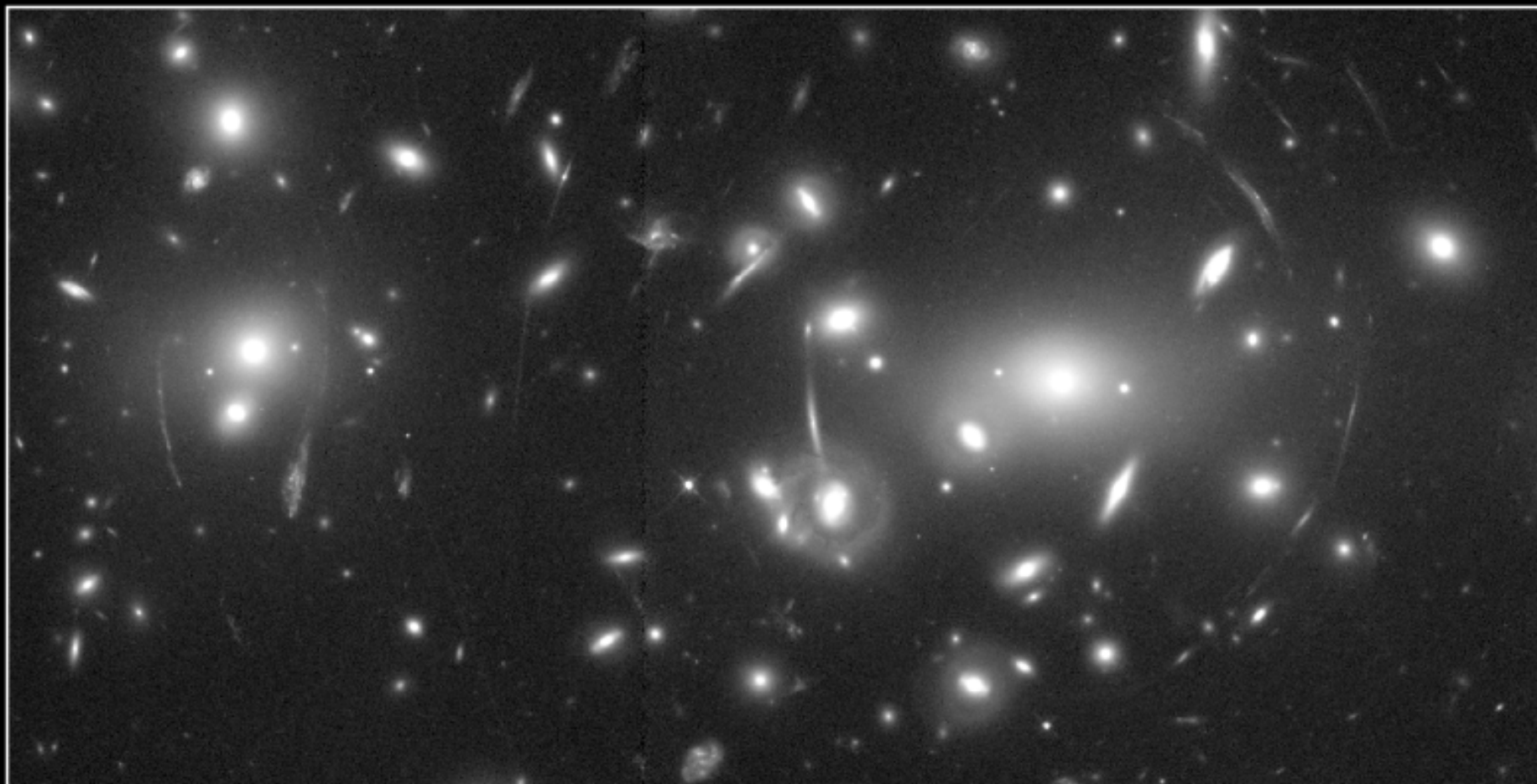
Hubble Deep Field

HST • WFPC2

PRC96-01a • ST ScI OPO • January 15, 1996 • R. Williams (ST ScI), NASA

Gravitational lensing





Gravitational Lens in Abell 2218

HST • WFPC2

PF95-14 • ST ScI OPO • April 5, 1995 • W. Couch (UNSW), NASA

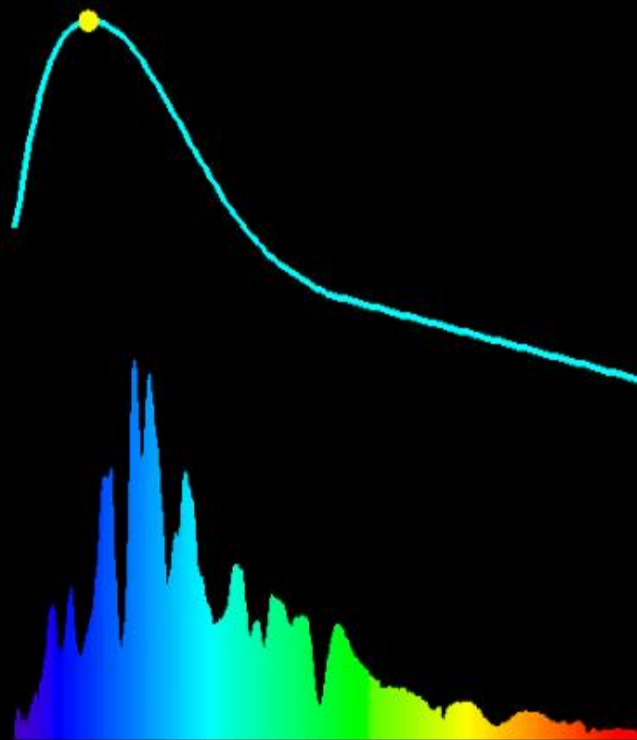
First key set of observations:

Study of decay of supernovae in distant galaxies provides a usable standard candle (because the maximum brightness is correlated to its decay rate)

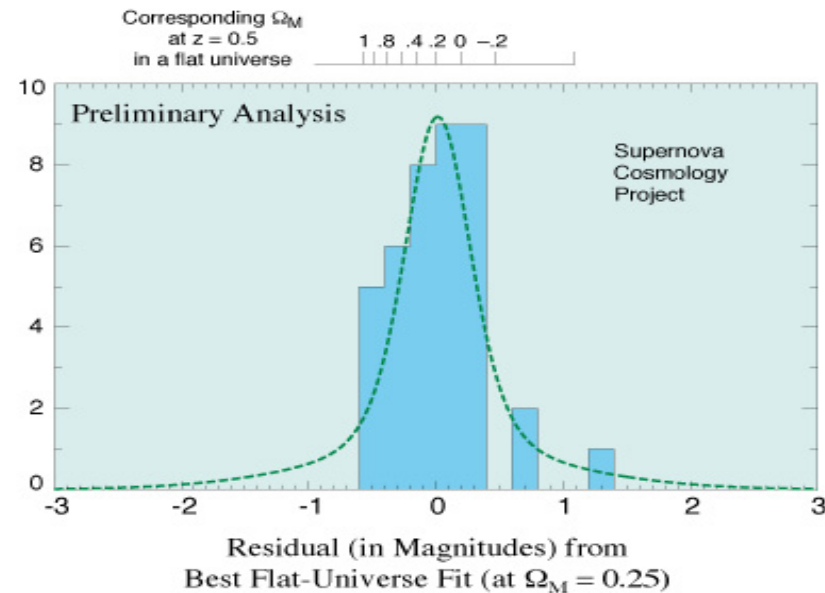
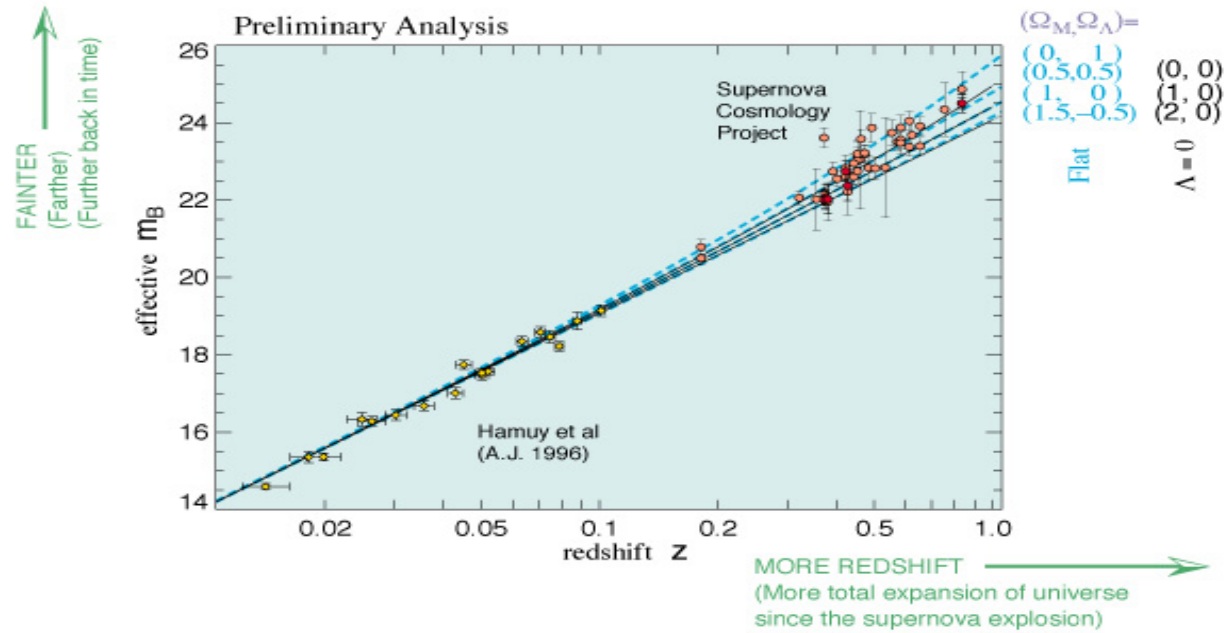
- with their redshifts, gives the first reliable detection of the deceleration parameter q_0 showing the universe is *presently accelerating*

- consequently there is presently an effective positive cosmological constant with $\Omega_\Lambda \sim 0.7$

- ‘dark energy’ or ‘quintessence’



Hubble Plots

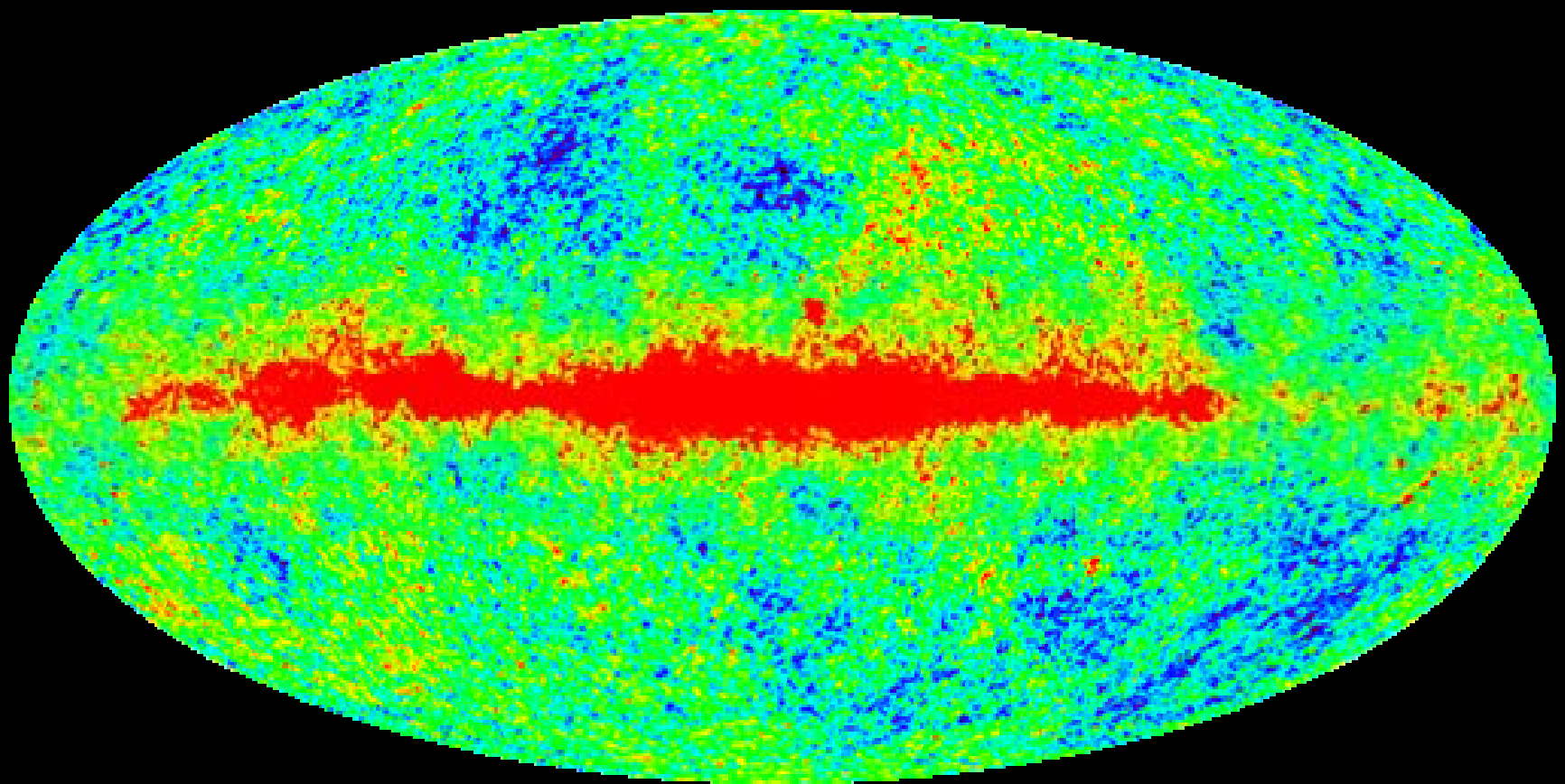


← Brighter than best fit Fainter than best fit →

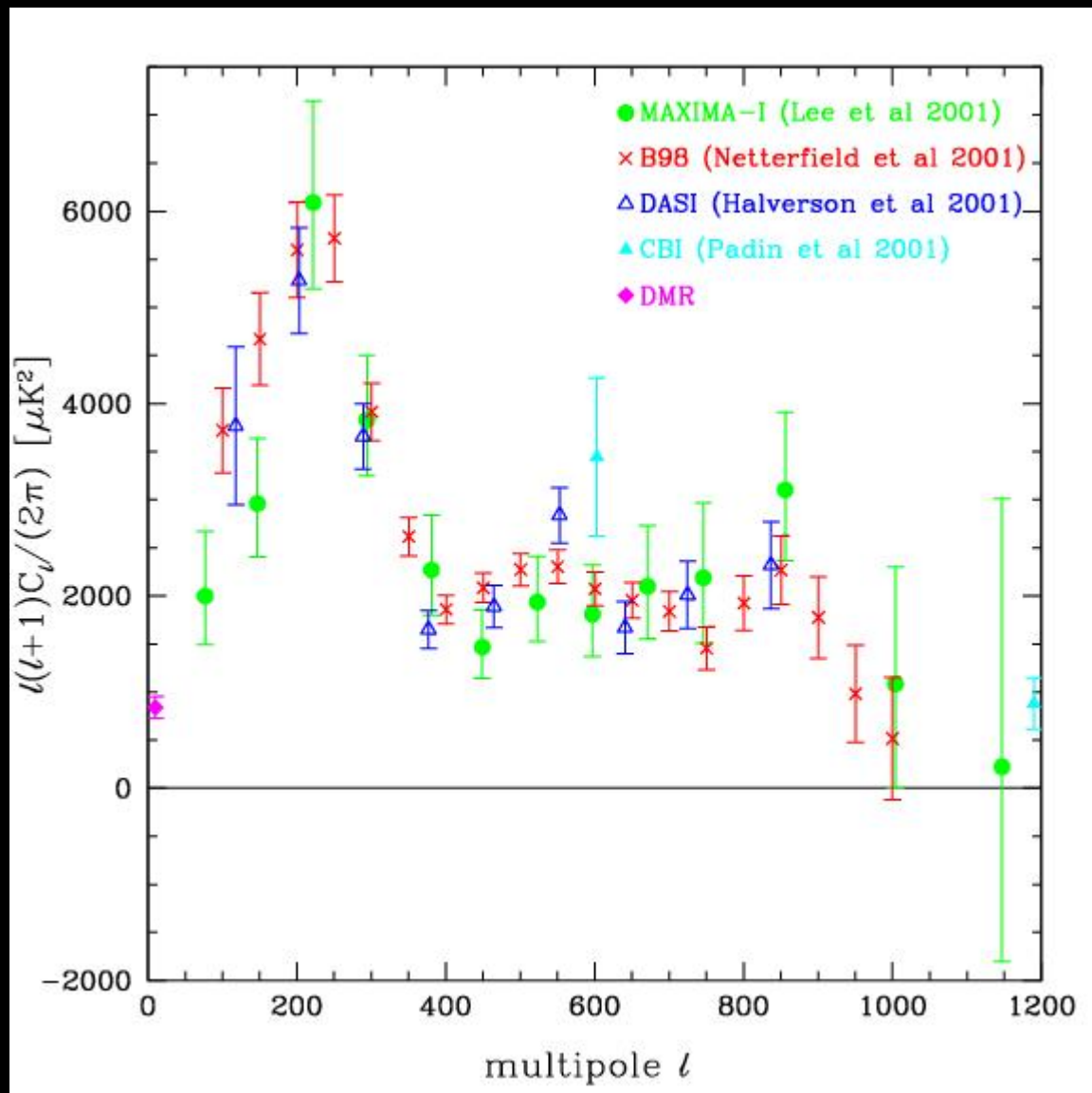
Second key set of observations:

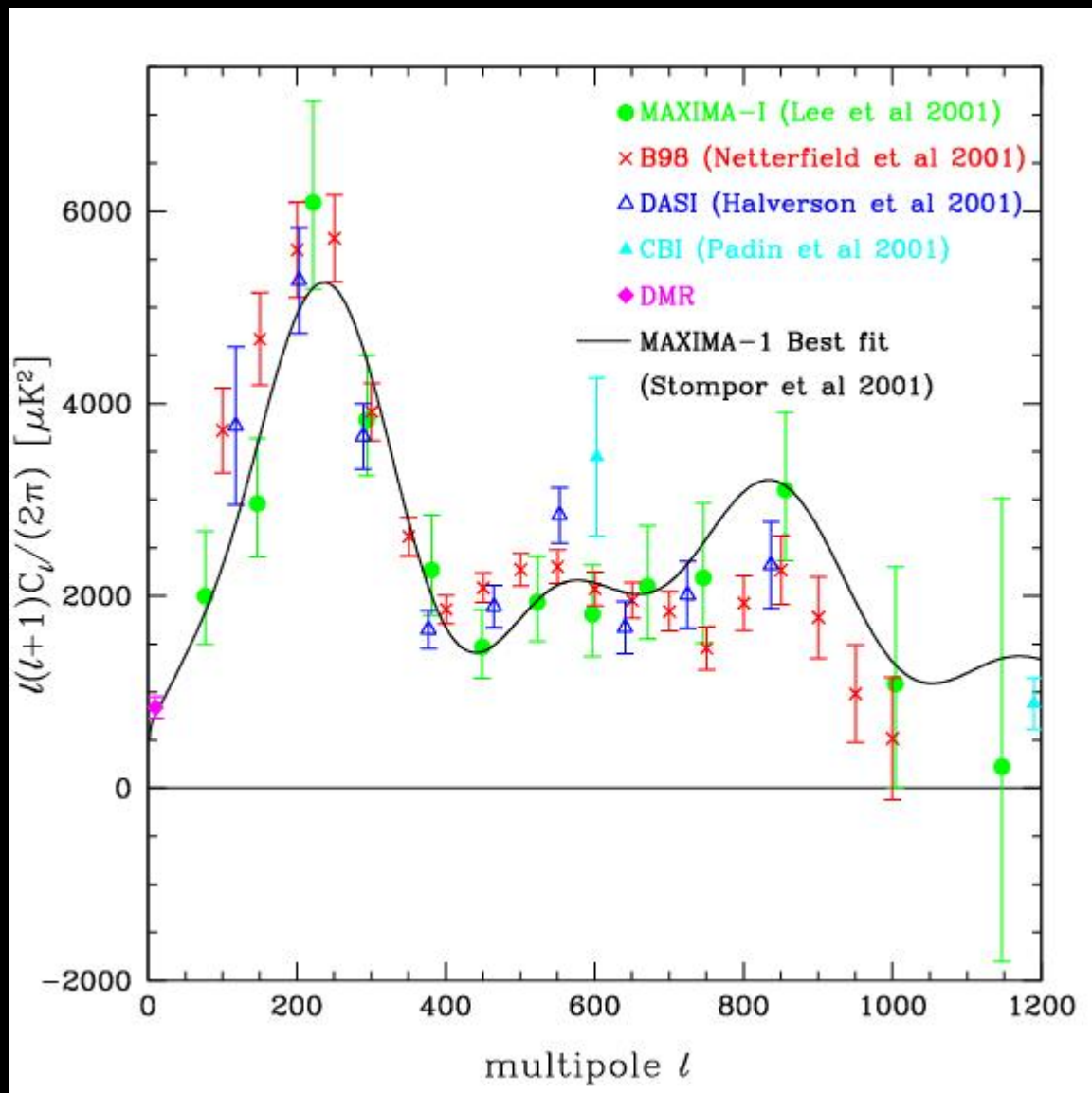
Measurements of the spectrum and anisotropy of the CBR by the COBE satellite and Boomerang and Maxima balloons

- extraordinarily accurate *Black Body spectrum*
- reliable detection of
 - *the quadrupole anisotropy*
 - *angular power spectrum peaks*
 - *predicted polarisation*

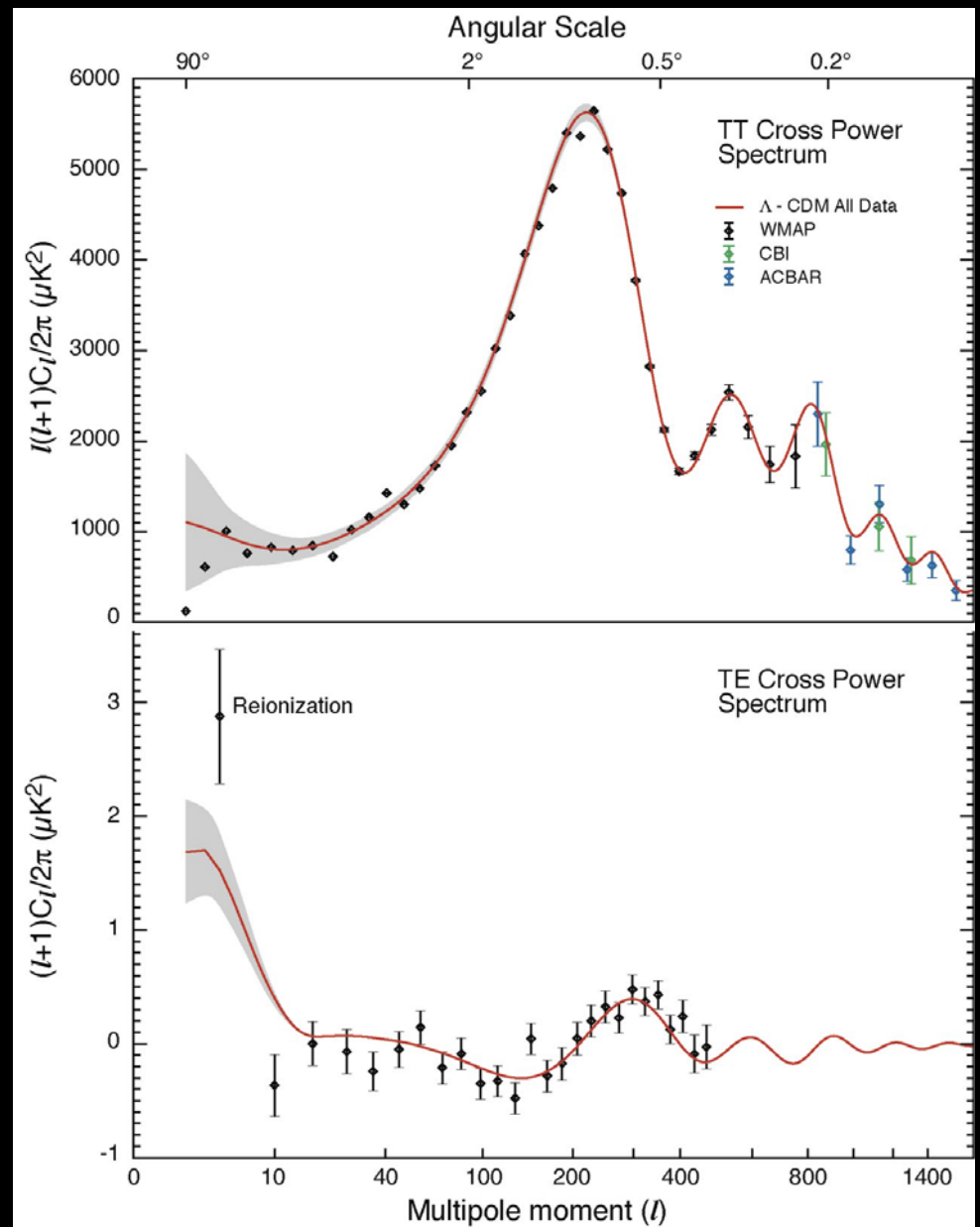
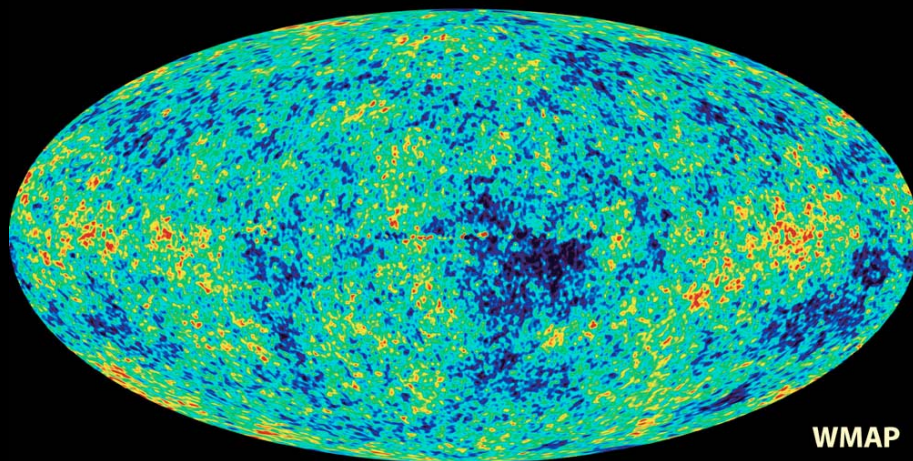
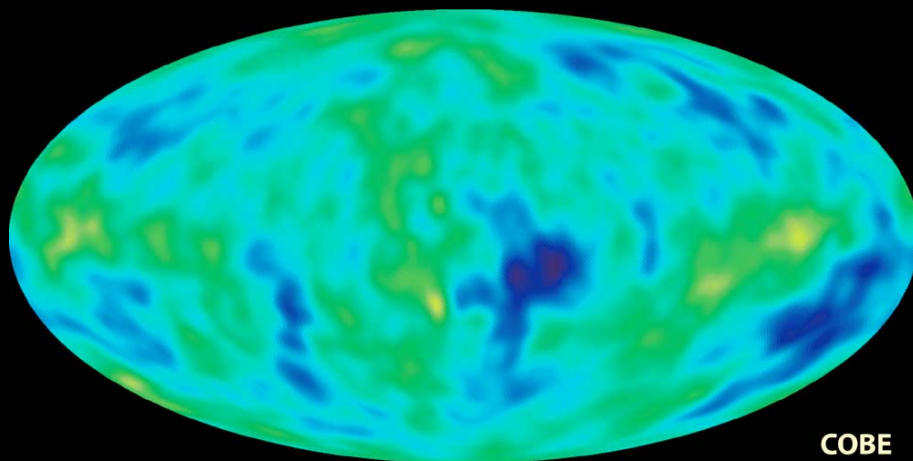


Microwave background radiation anisotropy: dipole removed





WMAP main results



low-redshift galaxy surveys : 2dFGRS

Agrees with CBR results

- collaboration of 30 astronomers split between Australia and the UK
- survey is now complete and has measured redshifts for 220000 galaxies in the local Universe (b-band selection)



Results consistent with CBR measurements: theory works!

Hence, concordance model:

- Expanding Friedmann-Lemaître model
- Evolves from hot big bang era when nucleosynthesis took place, preceded by inflation
- The Universe has nearly flat space sections, as expected on the basis of inflationary theory

$$\Omega_0 = \Omega_{m0} + \Omega_\Lambda$$
$$\sim 0.3 + 0.7 \sim 1.0$$

- Both dark matter and dark energy at late times

$$H_0 \sim 66 \pm 10 \text{ km/sec/Mpc}, \quad t_0 \sim 1.4 \pm 0.2 \times 10^{10} \text{ years}$$

Context for humanity

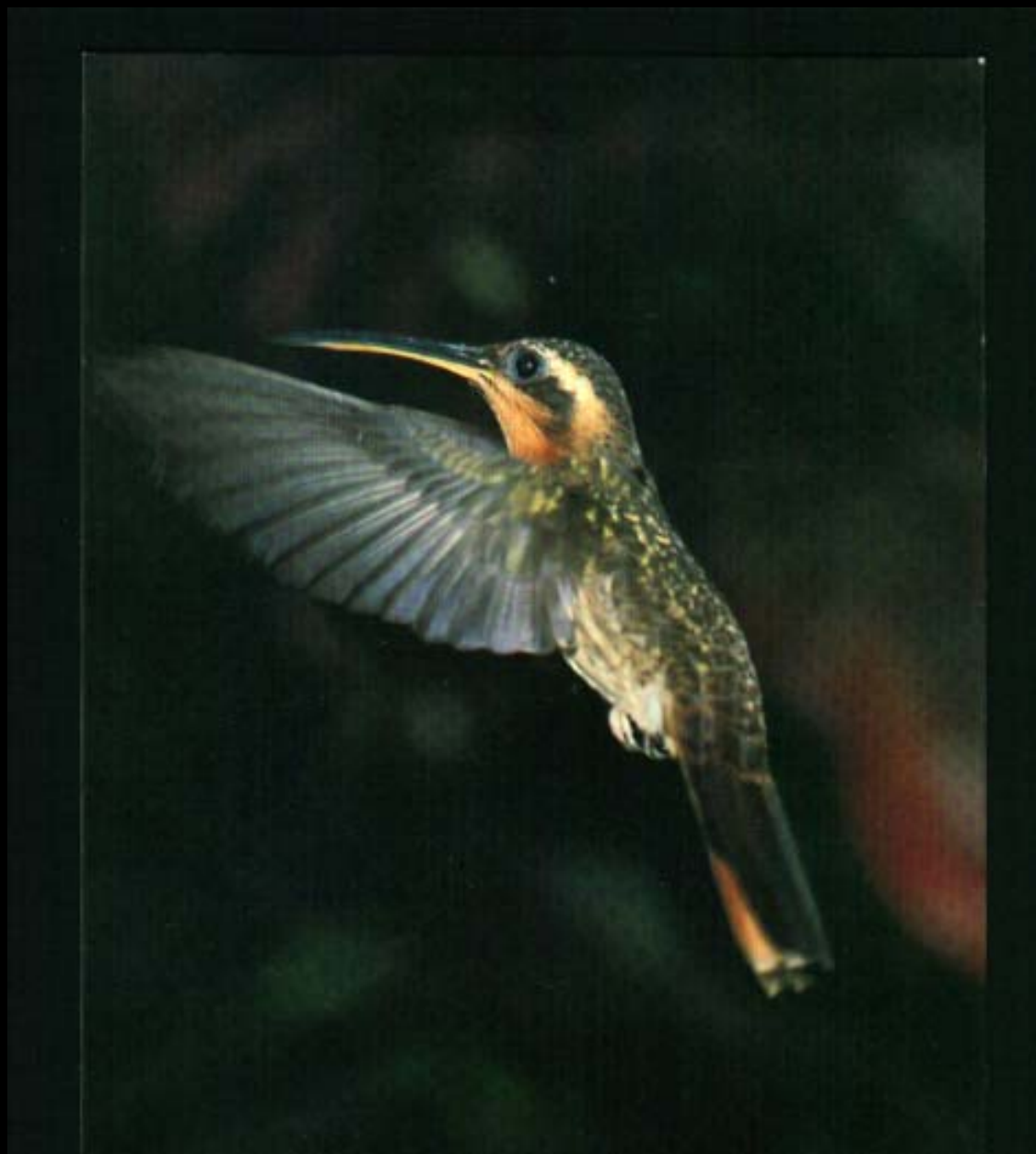
Life occurs in this context:

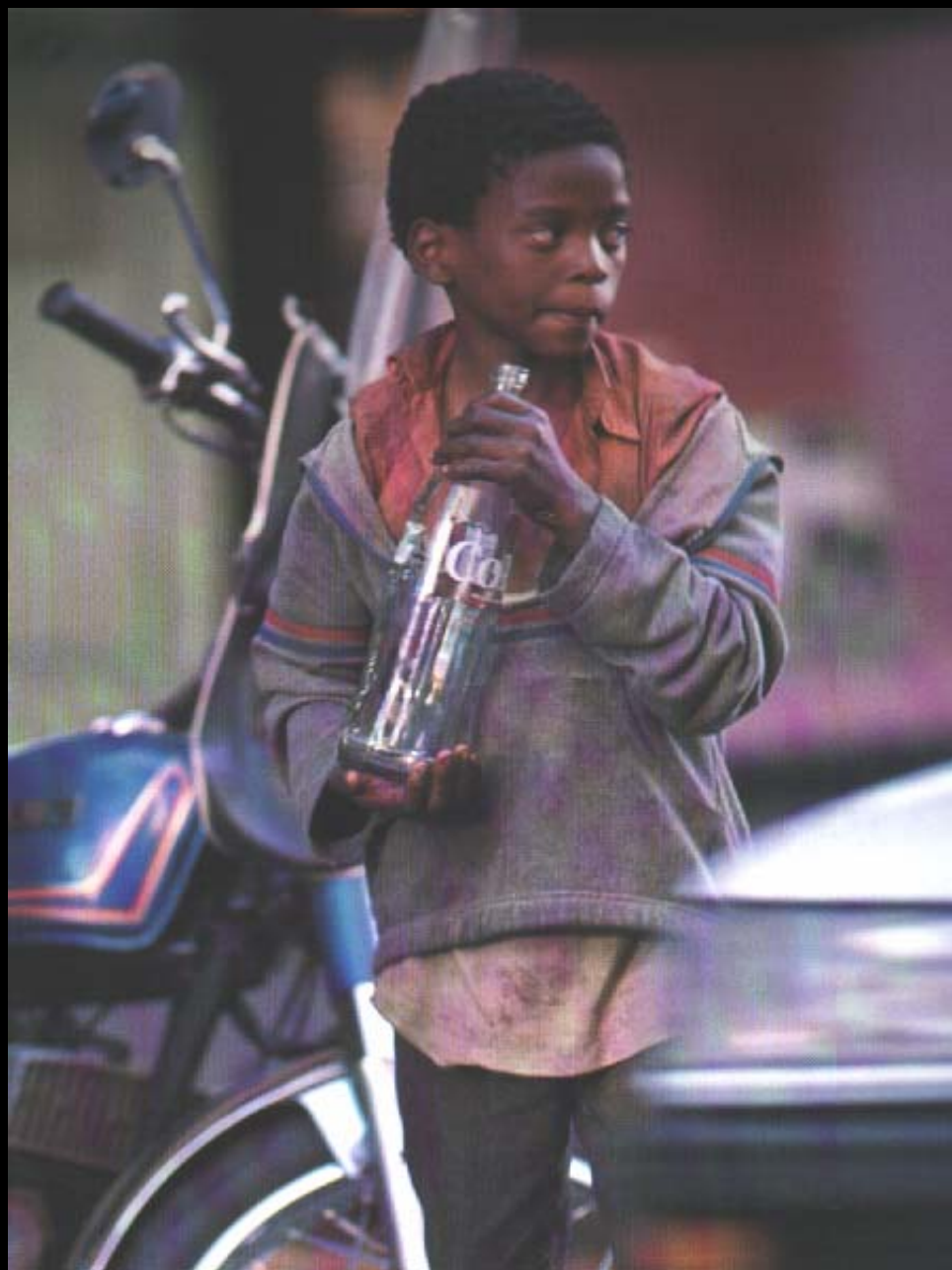
The laws of physics plus boundary conditions for the universe allow life to exist

First life by accident then continual improvement by Darwinian processes – continual accretion of biological information and creation of higher order structures: emergence of complexity

Eventual emergence of mind and consciousness then language society and social constructions





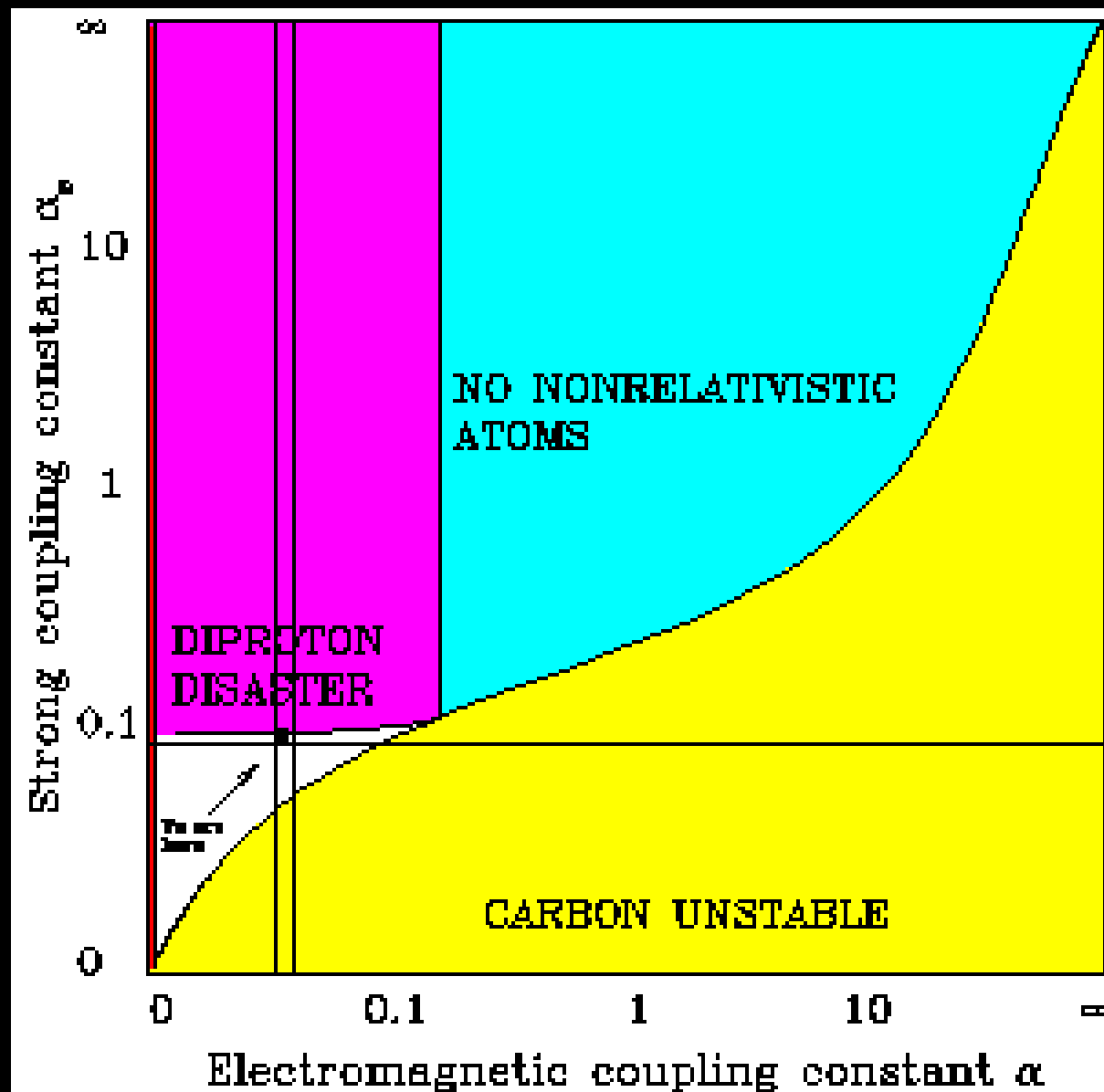




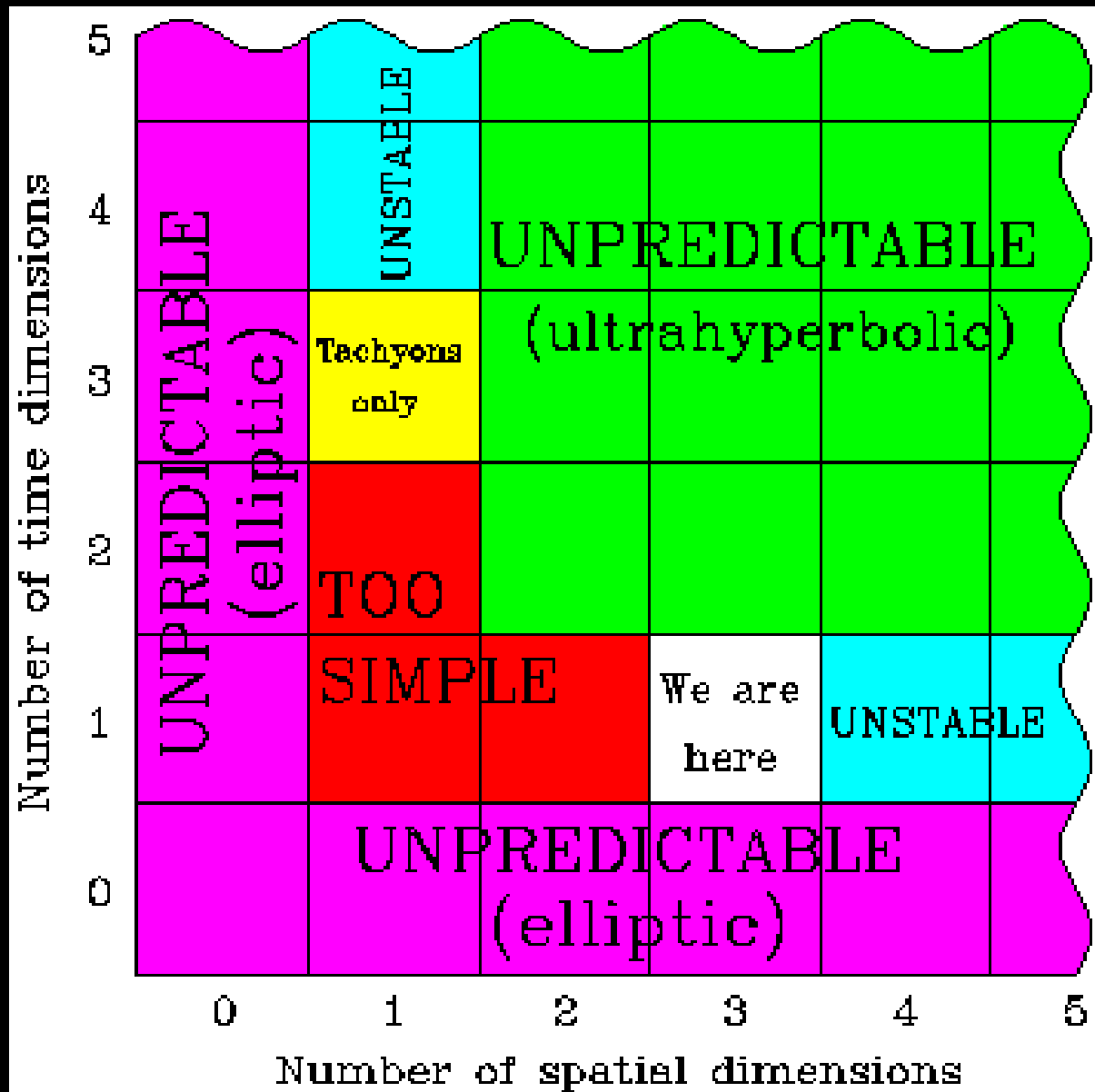
The conditions for the existence of life

Significant alteration of either physical laws or boundary conditions at the beginning of the universe would prevent the existence of intelligent life as we know it in the universe.

If physical laws were altered by a remarkably little amount, no evolutionary process at all of living beings would be possible; so these laws appear fine-tuned to allow the existence of life.



Limits on physics allowing complex structures [Max Tegmark]



Only special dimensions allow complex systems [M Tegmark]

Fine tuning: *Just Six Numbers* [Martin Rees]

- 1. $N = \text{electrical force/gravitational force} = 10^{36}$
- 2. $E = \text{strength of nuclear binding} = 0.007$
- 3. $\Omega = \text{normalized amount of matter in universe}$
 $= 0.3$
- 4. $\Lambda = \text{normalised cosmological constant} = 0.7$
- 5. $Q = \text{inhomogeneous seeds for cosmic structures} = 1/100,000$
- 6. $D = \text{number of spatial dimensions} = 3$

Emergence and the Laws of Nature

- Laws of nature underlie this
- Permit but do not completely causally control what happens
- Hence are of *fine-tuned nature*
- How they do it is not fully clear – what fine-tunings at the lower levels are needed for the entire higher level hierarchy to exist
- Whatever the reason: they do have this fine-tuned nature that allows/prefers life to exist

Existence of other life

Are we alone?

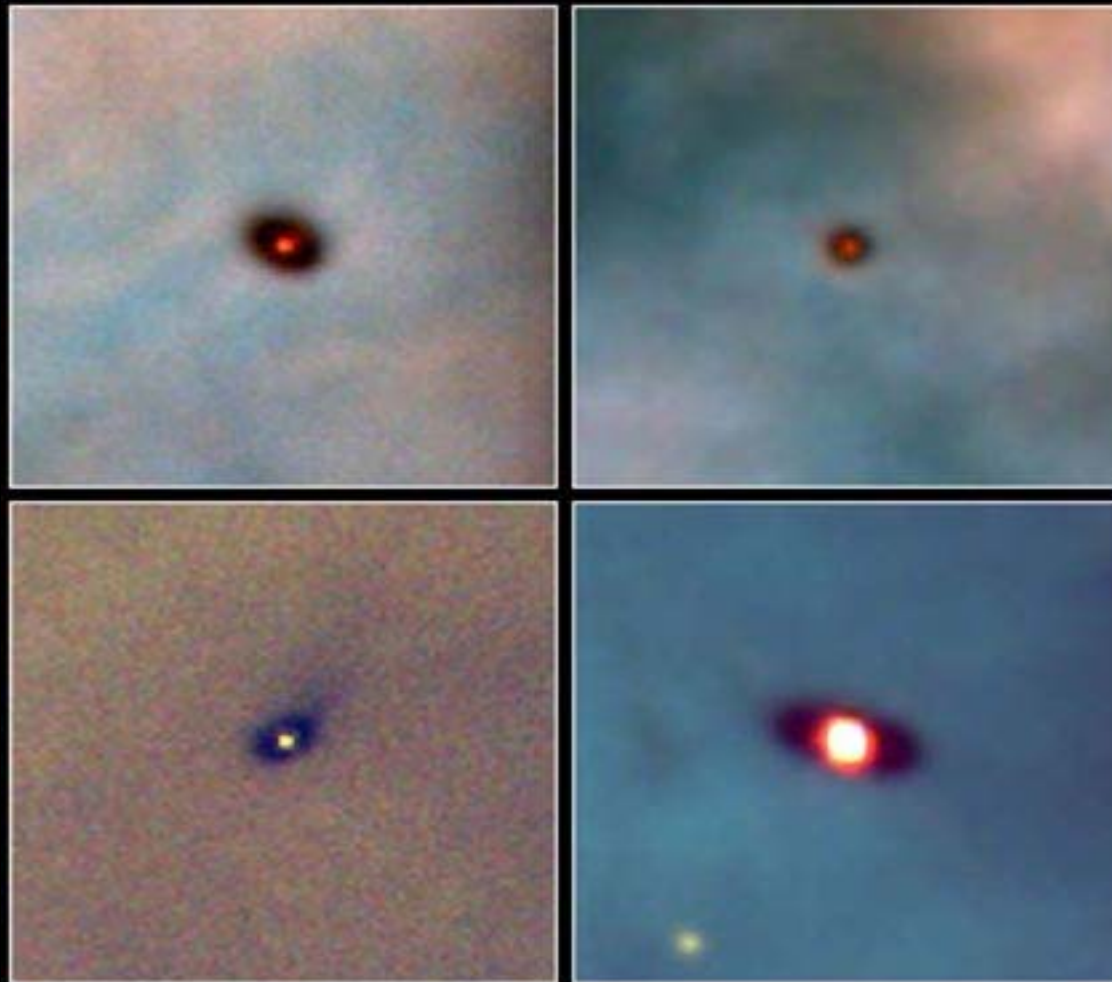
- Given these laws and existence of planets, life is almost inevitable
- Almost certainly we are not alone: there are many others out there
- But they may not be in communicable distance
- If they are there how like us will they be? Will we still be alone even if they exist?

Existence of other planets



Planetary proto disk

Existence of other planets



Protoplanetary Disks
Orion Nebula

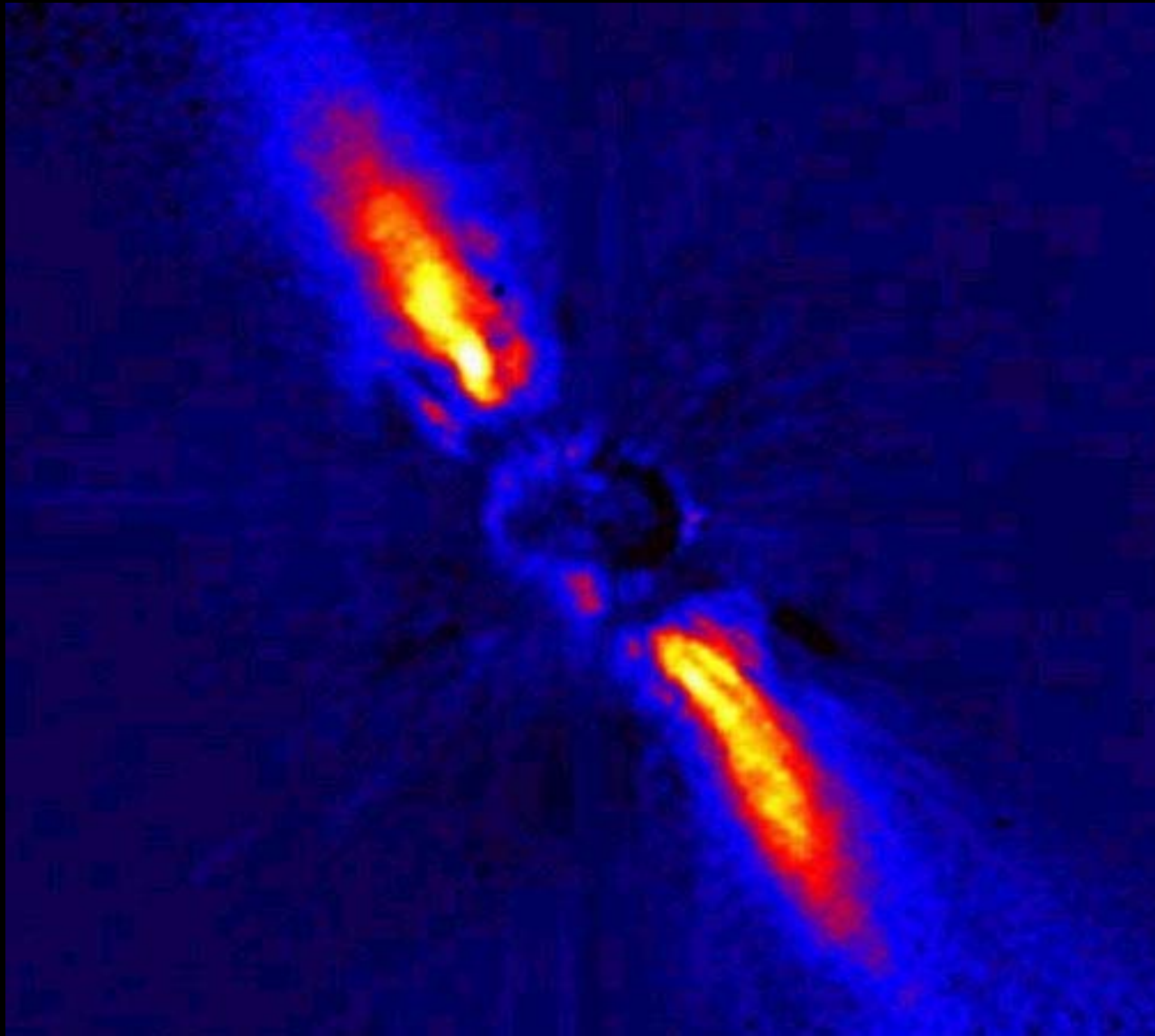
HST · WFPC2

PRC95-45b · ST ScI OPO · November 20, 1995

M. J. McCaughrean (MPIA), C. R. O'Dell (Rice University), NASA

Existence of other planets

β pictoris



Existence of other life

Are we alone?

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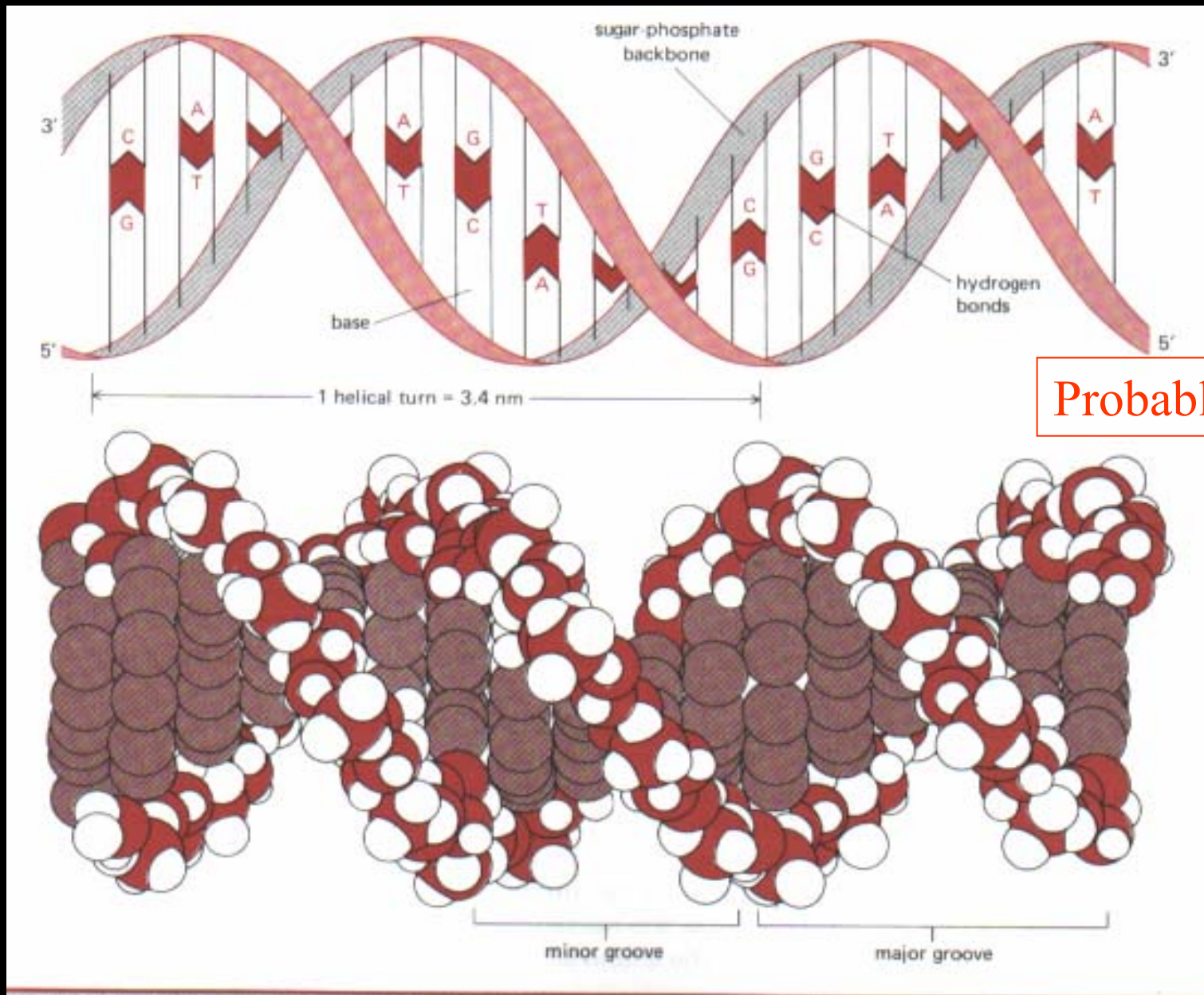
Nature of life

- ***Convergence of biochemistry and of mechanics of life***
- Only a restricted number of ways to solve the problems of life which has universal necessities
- Simon Conway Morris, *Life's Solution: Inevitable Humans in a Lonely Universe*
- S. Vogel: *Cats' Paws and Catapults: Mechanical Worlds of Nature and People*
- ***almost certainly Carbon-based, RNA, DNA***
- ***convergent microbiology, e.g. citric acid cycle***
- senses: eyes ears smell, brain
- limbs, food ingestion, waste disposal

Hierarchical structure of life

- **The biosphere** - Global resource cycles
- **Biomes** - Energy and material interchange
- **Ecosystems** - Species interdependence
- **Animal populations** - Competition and the food chain
- **Individual organisms** - Physiological functioning
- **Limbs, physiological systems** - Organism homeostasis
- **Tissues** - Growth, maintenance, repair
- **Cells** - Growth, specialisation, death
- **Organelles** - Cell homeostasis
- **Macro Molecules** - Folding, recognition, binding
- **Building Block Molecules** - Combine to form polymers
- **Chemical elements** - Chemical binding

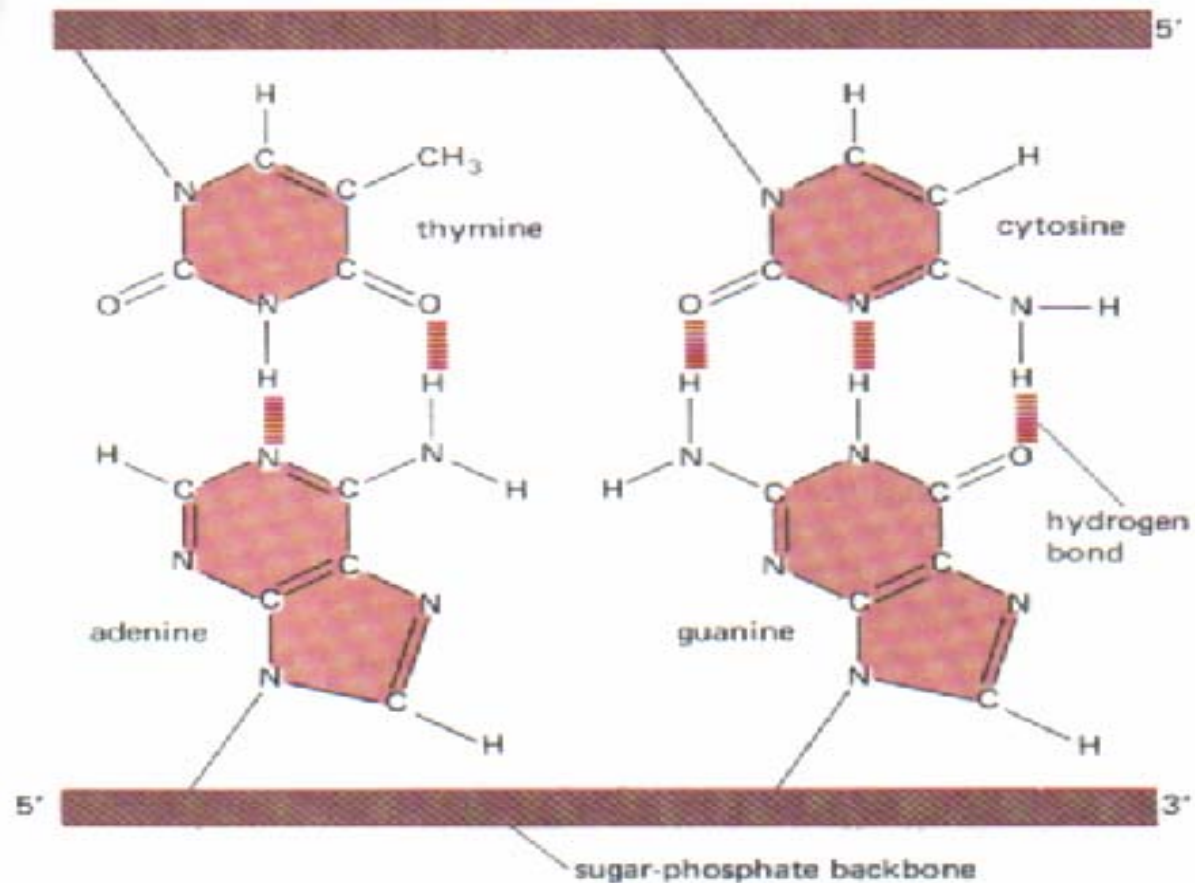
- probably duplicated



Probably unique

The DNA double helix with complementary base pairs

FOUR BASES AS BASE PAIRS OF DNA



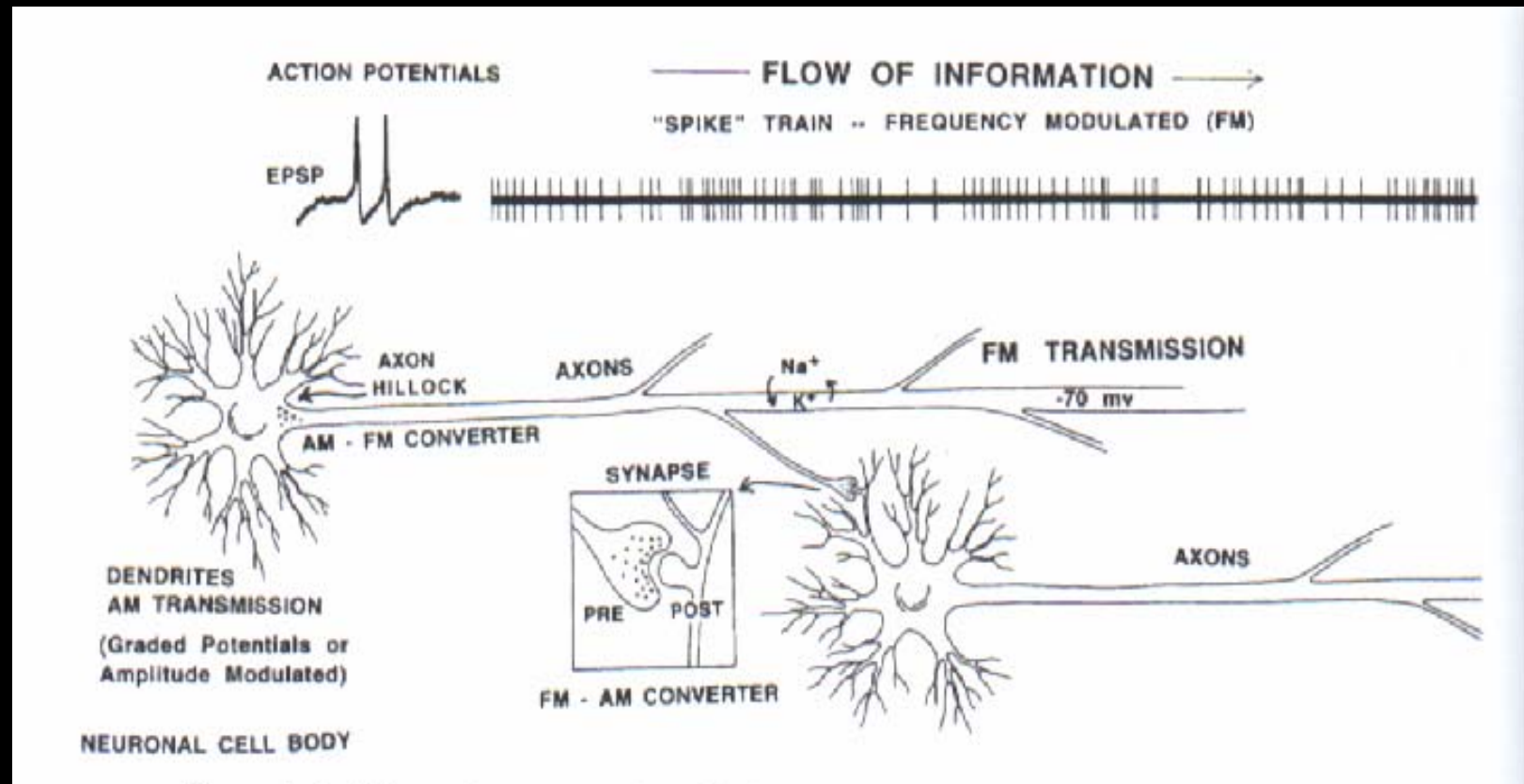
Specific hydrogen bonding between G and C and between A and T (A and U in RNA) generates complementary base-pairing.

Complementarity of base pairs: maybe duplicated

1st position (5' end) ↓	2nd position				3rd position (3' end) ↓
	U	C	A	G	
U	Phe Phe Leu Leu	Ser Ser Ser Ser	Tyr Tyr STOP STOP	Cys Cys STOP Trp	U C A G
C	Leu Leu Leu Leu	Pro Pro Pro Pro	His His Gln Gln	Arg Arg Arg Arg	U C A G
A	Ile Ile Ile Met	Thr Thr Thr Thr	Asn Asn Lys Lys	Ser Ser Arg Arg	U C A G
G	Val Val Val Val	Ala Ala Ala Ala	Asp Asp Glu Glu	Gly Gly Gly Gly	U C A G

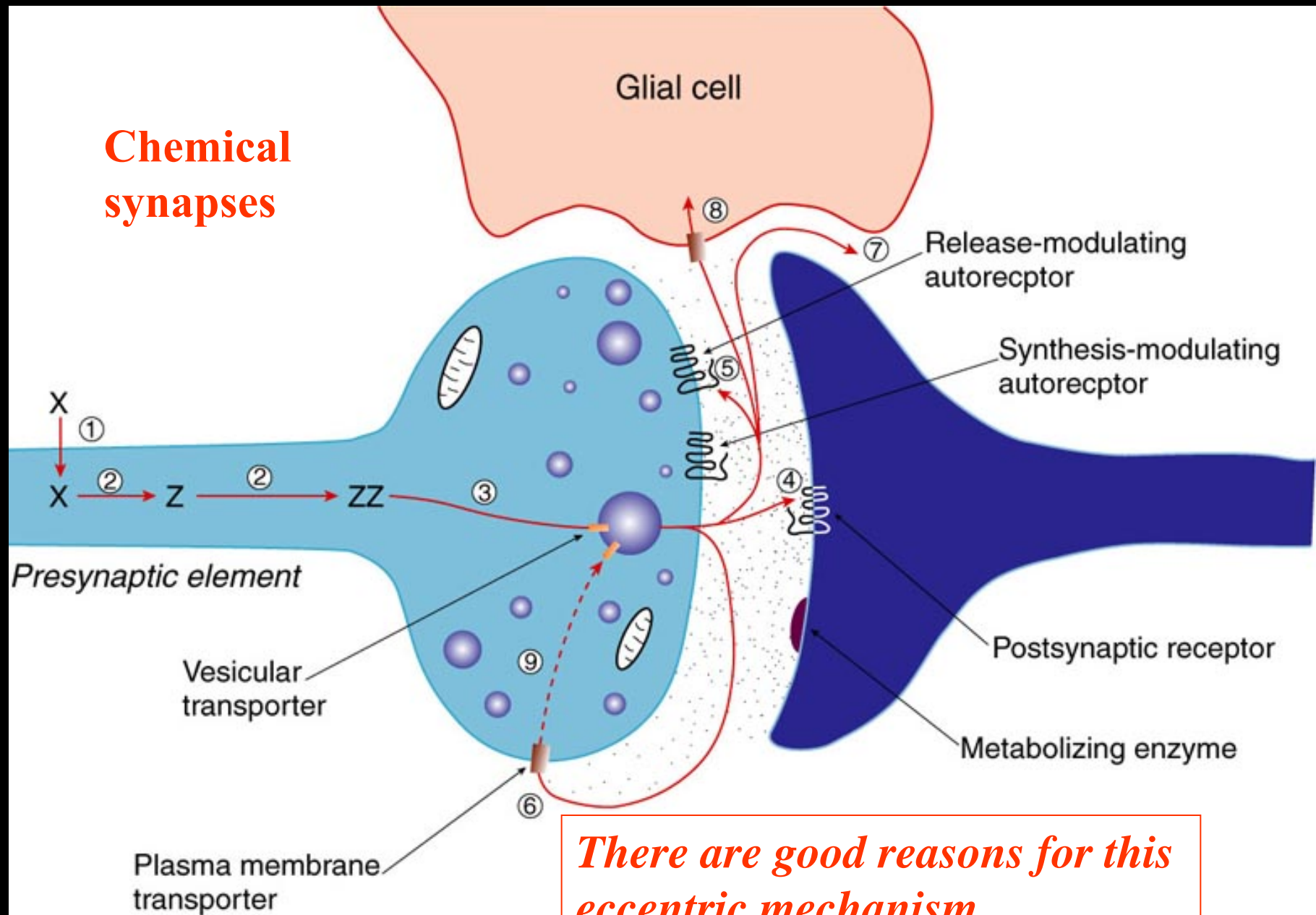
Figure 3-15 The genetic code. Sets of three nucleotides (codons) in an mRNA molecule are translated into amino acids in the course of protein synthesis according to the rules shown. For example, the codons GUG and GAG are translated into valine and glutamic acid, respectively. Note that those codons with U or C as the second nucleotide tend to specify the more hydrophobic amino acids (compare with Panel 2-5, pp. 54-55).

The genetic code: triplets of bases code for amino acids that form proteins: *not necessarily unique*



Information flows: dendrites to nucleus to axon to synapse
 - Somewhat ideosyncratic?

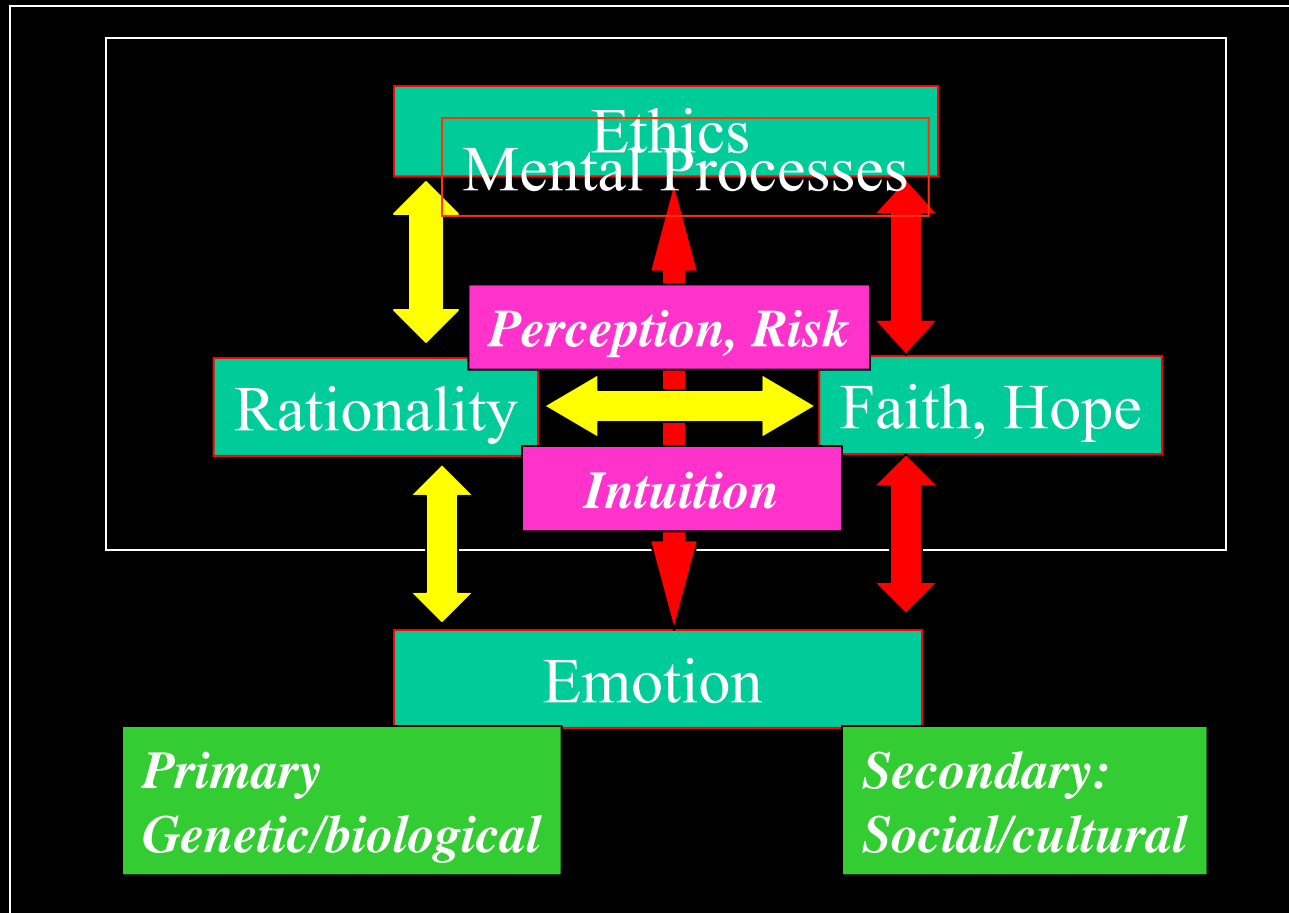
Chemical synapses



There are good reasons for this eccentric mechanism

“Are we alone ?”

- Convergence also of way brain works – to meet universal necessities
- “Are we alone” – will we find them companionable beings or total aliens??
- *Psychological universals*: may well find them similar in psychological makeup as well
- The processes here are probably universal



Each of Rationality, Emotions, Ethics, Faith and Hope are influenced by each of the other, with reason being the key player trying to bring the others into harmony.

These may be universal.

What kind of ethics will they obey?

- But this does not determine what kind of ethics they may obey. Will we have to fear them or not?

Is there any reason to believe they will have the same kind of ethics as we have? ET or Judgement Day?

- *Well will we be friendly? What is the nature of our ethics?*

- *As important: What kind of ethics will they think we obey?*

The evidence available to them is very negative!

Sphere of TV programmes surrounding us :

constantly projecting image of homicidal aggression [*Contact*]

- *How can we approach them in a way that will make them think we are friendly/compassionate?*

- *the first step is that we indeed become so!*

What kind of ethics do we obey?

- What is the future life span of the human race?
- *We will only survive if we make an ethical transition*
- Is that likely to happen ?
- *Actually we have by and large been making progress
– but not enough to have any certainty we will survive another
thousand years: Touch and go, on the edge*
- But science by itself cannot provide the needed ethical transition to a compassionate way of life. Scientific and reductionist views of humanity are if anything promoting a dehumanising view of humanity. We need more human ethics-based approach to survive.

What is the true nature of deep ethics?

There are many options that have been advanced through the ages for the nature of ethics: that it is based on wealth, power, or intellectual certainty, for example.

The claim I will make is that deep ethics is *kenotic* or *self-emptying*: that is, it is based in generosity, compassion, and love, and involves the capacity and willingness for forgiveness and reconciliation, which in turn means giving up the need for revenge, in order to attain the greater good.

On occasion it can involve the ultimate of sacrifice on behalf of the other, even the enemy, because that is the way to turn the hardened heart, to convert an enemy to a friend, and so to create the true security that comes from being surrounded by friends rather than enemies.

The implication is not that one is always sacrificing on behalf of others, but rather that one is prepared to do so when the context is such that a move of this kind can have a transformational quality.

This moves ethics to a totally new regime: the arena of deep ethics that can indeed transform context and situation, in a way that is paradoxical because what was impossible in the old context becomes possible in the new, for the hardened heart can indeed on occasion be touched and transformed.

This is the only ethics that can create true security by fundamentally transforming the situation. It is recognised as an aspect of the highest good by all the major religions; and one can suggest therefore *that it is indeed the true nature of a realist universal ethic, deeply imbedded in the nature of the universe*, that would indeed be recognised as such by ethically advanced intelligent beings anywhere in the universe.

In all actions, *the means used are as important as the ends*, because you cannot attain ends based on one kind of values through means based on different values; and so the means used should be kenotic in nature in order to attain the good we envisage. Habitual use of this method transforms character.

What kind of ethics will we and they obey?

We need a world wide campaign to transform our ethics to a kenotic/compassionate ethics in order that we survive;

- world economics that shares resources and cares for the poor
- programmes to alter resentment to forgiveness

[Tutu and the *Truth and Reconciliation Commission*]

- programmes to support deep ethics against fundamentalism

If we can meet aliens on this basis, we can hope they will respond

-If they have survived long enough to undertake interstellar travel then there is a good probability they will have made the needed ethical transition

- Or at least: they will not feel they have to destroy us if we do not manifestly threaten their survival

Conclusions on life

- It is the overall set of laws and initial conditions that make our own existence possible.
- *There is a considerable degree of fine-tuning of initial conditions and laws that underlies this existence.*
- The ultimate reason this is so is a metaphysical issue that is undecidable through any scientific experimentation.
- *Positive Ethics (sympathy/compassion) is crucial to our survival on a cosmological timescale, on our own and in a possible interstellar interaction:*
- *This is not attainable by science alone*





Free will and responsibility

In order for ethical choices to be meaningful, it is crucial that the human mind has "free will"; that is, the individual can make choices expressing both their nature and their conscious decisions about the way they want to act. We must be responsible for our actions in some serious sense for our lives to be meaningful.

Many scientists in various ways deny that free will exists, because of the way that physics and chemistry underlie neuronal functioning and hence brain activity, as outlined above. It seems as if our brain is a computer that computes output according to immutable laws of physics, its operations shaped by either our evolutionary history or our culture in such a way that consciousness is a mere epi-phenomenon superimposed on its unconscious operations, with disastrous implications .

“In behaviourism, there was no such thing as a talent or and ability. Watson had banned them from psychology, together with the contents of the mind, such as ideas, beliefs, desires, and feelings. To a behaviourist, the only legitimate topic for psychology is overt behaviour and how it is controlled by the past and present environment...

Behaviourists believed that behaviour could be understood independently of the rest of biology, without attention to the genetic makeup of the animal or the evolutionary history of the species. ..”

Pinker, The Blank Slate, p. 19

“In *The Behaviour of Organisms* [Skinner], the only organisms are rats and pigeons”

“Watson wrote an influential child-rearing manual recommending that parents establish rigid feeding schedules for their children and give them a minimum of attention and love”

Pinker, *The Blank Slate*, p. 20/21

“Hardliners, led by a vanguard of rather voluble philosophers, believe not merely that consciousness is limited, as experimentalists have been saying for years, but that it *plays no significant role in human cognition*. They believe that we think, speak, and remember entirely outside its influence. Moreover, the use of the term ‘consciousness’ is viewed as pernicious because (note the theological undertones) it leads us into error ...

They support the downgrading of consciousness to the status of an epiphenomenon ..

A secondary byproduct of the brain’s activity, a superficial manifestation of mental activity that plays no role in cognition”

Merlin Donald, *A Mind so Rare*, pages 29, 36.

“[Daniel] Dennett is actually denying the biological reality of the self. Selves, he says, hence self-consciousness, are cultural inventions. ... the initiation and execution of mental activity is always outside conscious control...

Consciousness is an illusion and we do not exist in any meaningful sense. But, they apologize at great length, this daunting fact Does Not Matter. Life will go on as always, meaningless algorithm after meaningless algorithm, and we can all return to our lives as if Nothing Has Happened.

This is rather like telling you your real parents were not the ones you grew to know and love but Jack the Ripper and Elsa, She-Wolf of the SS. But not to worry”.

Merlin Donald, *A Mind so Rare*, pages 31, 45.

The devastating effect of dehumanising psychological/philosophical views:

“The practical consequences of this deterministic crusade are terrible indeed. There is no sound biological or ideological basis for selfhood, willpower, freedom, or responsibility.

The notion of the conscious life as a vacuum leaves us with an idea of the self that is arbitrary, relative, and much worse, totally empty because it is not really a conscious self, at least not in any important way”

Merlin Donald, *A Mind so Rare*, page 31.

This dehumanising view is not necessary.

Reductionism only understands part of the overall picture – holistic views are more satisfactory and correct.

Physics does not give a causally complete understanding of the world - it does not comprehend human intention or indeed any adaptive behaviour.

Higher levels of emergent order such as the mind have autonomous causal powers independent of the lower levels of causation (physics, chemistry).

A proper account of humanity takes higher level causes and understandings into account as well as mechanistic aspects.

The response to this deterministic and reductionist denial of the core of personhood is multiple. This view is based on laboratory results that fail to take into account the timescales and complexity of real-life interactions, and it does not adequately represent the way the human mind develops and functions as part of a distributed cognitive network . It fails to take into account top-down action in the brain, together with the causal effectiveness of consciousness.

And above all, if it were actually true, then science would not be possible, because we would not have the power to assess theories on the basis of their internal consistency and compatibility with the data.

Our brains would be computing output in some internally determined way that would not necessarily relate to any concept we might have of rationally deciding whether theories are scientifically acceptable or not. The whole supposed basis of the scientific enterprise would turn out to be a charade.

Initial data and our existence

The initial data for the observed universe is on the last scattering surface

Key issue: to what degree does it determine the nature and behaviour of what we see around us?

For instance: does that data determine what I am saying and what you are thinking at this moment?

No: that does not make sense: meaning cannot be directly implied by random initial data

Autonomously effective mind has to come into being as an emergent phenomenon

Philosophical issues

Relation of observations to theory:

Because of the existence on the one hand of visual and causal horizons and on the other of the physics horizon, there are many limits on what can be observationally proven in cosmology

Which has priority in one's cosmological theory: physical explanation or observation and testability? Depending on one's attitude leads to different priorities.

For example, in the chaotic inflation proposal, theory takes precedence over geometrical and physical testability.

Also a major tension between theory and testability arises as regards the issue of the multiverses

Ensembles/Multiverses

Why does the Universe have the peculiar properties that allow intelligent life to exist? (the anthropic issue)

It is claimed by some that this is because of the physical existence of ensembles of universes, or 'multiverses'.

This is being increasingly defended, because it is the only purely scientific approach to solving the puzzles raised by the anthropic issue: if enough variety of properties occur then somewhere conditions will be right

For example, this argument has been used to explain the value of the cosmological constant [Weinberg]

Probability and ensembles

This potentially brings cosmology within the realm of statistical analysis, giving a basis for probability

This provides the only scientific basis for attempts to use the anthropic principle to determine the values of parameters such as the cosmological constant, for which we otherwise have no plausible explanation:

BUT it is completely unverifiable –
metaphysics rather than physics

- It denies the uniqueness of the universe

Fundamental physics

- *What feature of physics is the key to existence of truly complex structures?*
- What for example allows **modular separation** of sub-nuclear, nuclear, atomic, and molecular properties from each other in such a way as to allow the development and functioning of DNA, RNA, proteins, and living cells?
- Whatever it is, this must claim to be the '**truly fundamental**' **feature of physics**
- *what physics underlies supramolecular chemistry?*
- it is the foundation of the complexity we see

The Hierarchy of Structure:

Psychology/ Behaviour

Botany/zoology/physiology

Cell biology

Biochemistry

Chemistry

Physics

Particle physics

Separation of structural levels, independence of levels

Fundamental physics

Is the key:

- the general nature of *quantum theory* (e.g. superposition, entanglement, decoherence) and its classical limit?
- the specific nature of *quantum field theory* and *quantum statistics* [Yes: stability of matter] and/or Yang-Mills *gauge theory* ?
- the specific *potentials* and *interactions* of the standard particle physics model and its associated *symmetry groups* ?
 - *basic particle properties* (existence of three families of quarks, leptons, and neutrinos, for example)?
 - *basic properties of forces* (effective existence of four fundamental forces; their unification properties)?

Fundamental physics

Is the key:

- the specific *masses* and *force strengths* involved?
- the value of *specific constants* such as the fine structure constant?

Or is it

- *The combination of all of these?*

[Craig Hogan: *out of the twenty parameters of the standard model, complexity depends on just five of its parameters.*

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- But then why do they work together so cunningly?
- *they are the foundation of human life and of the brain*