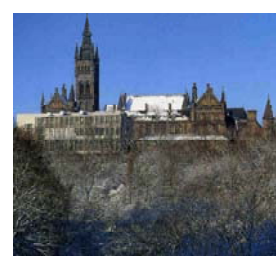


# Life in the Cosmos

Dr Martin Hendry  
Dept of Physics and Astronomy



UNIVERSITY  
of  
GLASGOW



Life in the  
Cosmos:  
Feb 2006

## 3 Big Questions:

1. Why are we here?
2. Where is everybody?
3. What is life anyway?

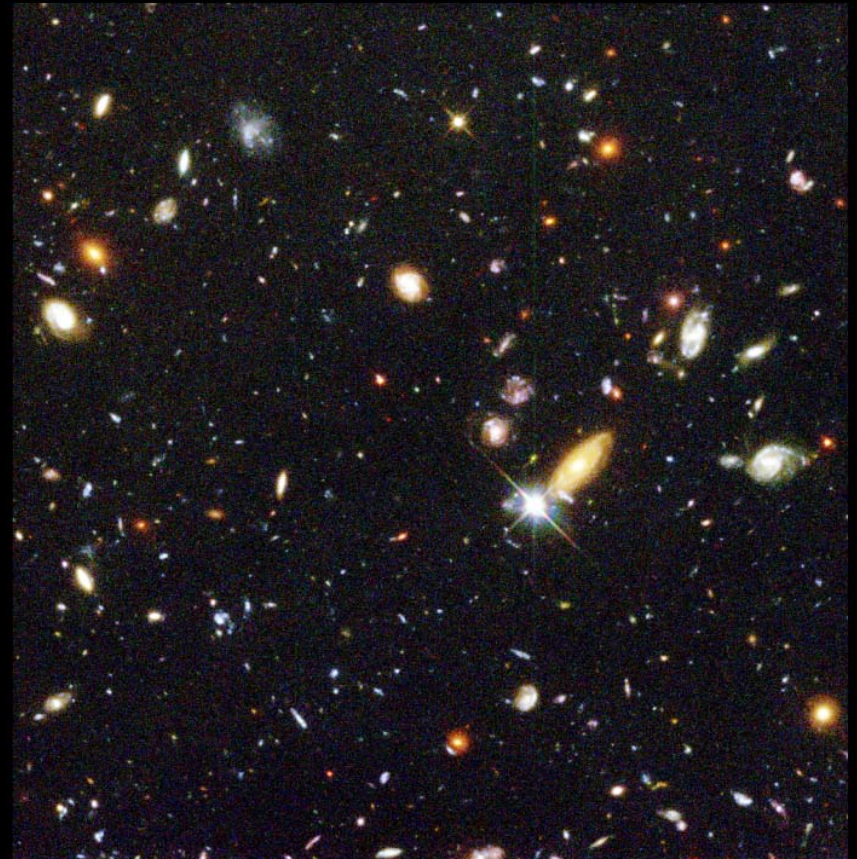
# *Why are we here?....*

Many astrophysical parameters appear to be 'finely tuned': if their values were even slightly different, the existence of (life on) the Earth would not be possible.

This 'fine tuning' is particularly apparent in *cosmology*

# *Cosmology - the study of the Universe as a whole:*

- Origin
- Evolution
- Eventual Fate



# State of the Universe - March 2004

The expansion of the Universe will continue indefinitely. There is not enough matter in the Universe to make it recollapse again.

The expansion is *accelerating*

Cosmologists refer to this picture as the *Concordance Model*

*What is driving the cosmic acceleration?...*

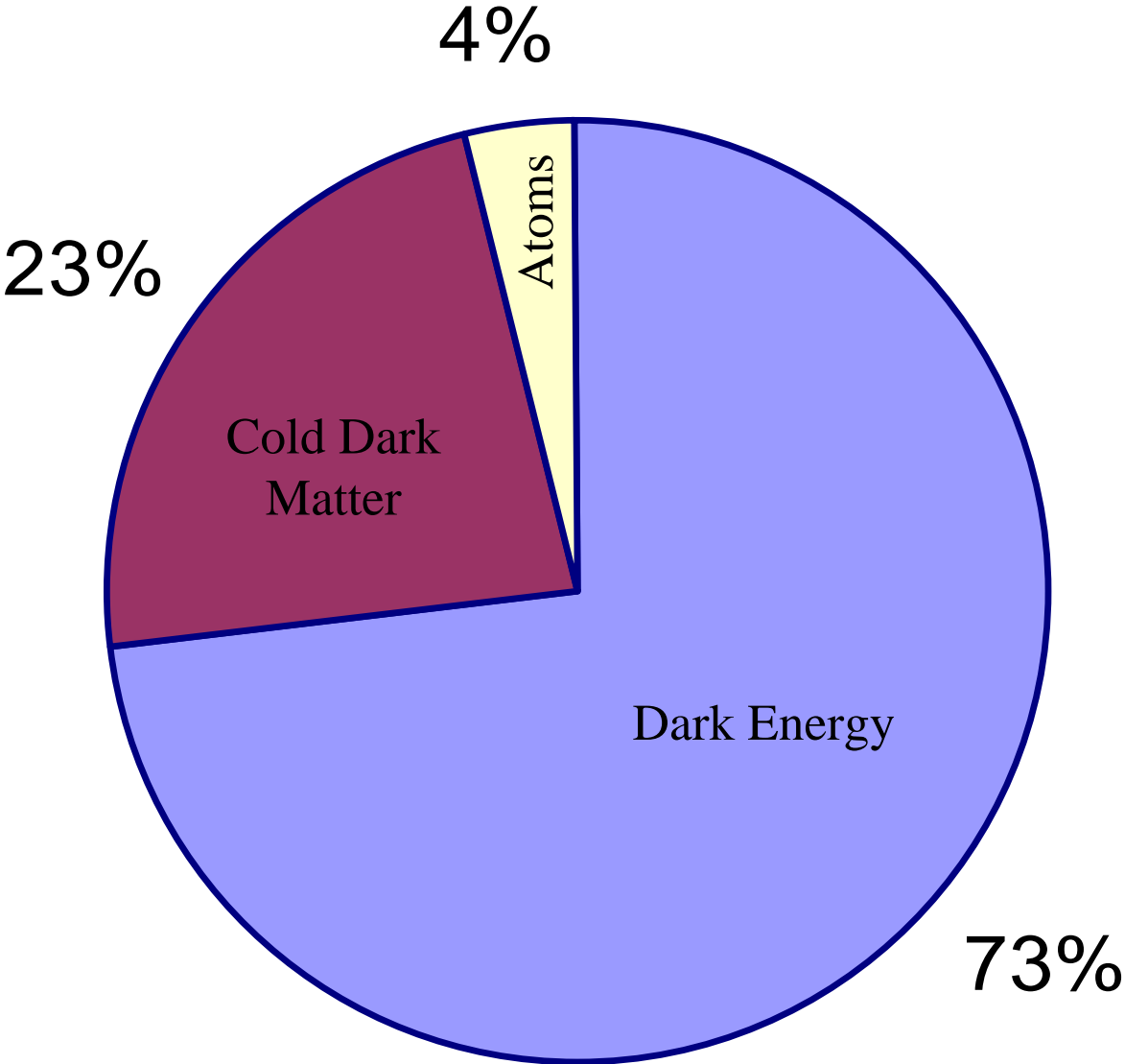


# Dark Energy

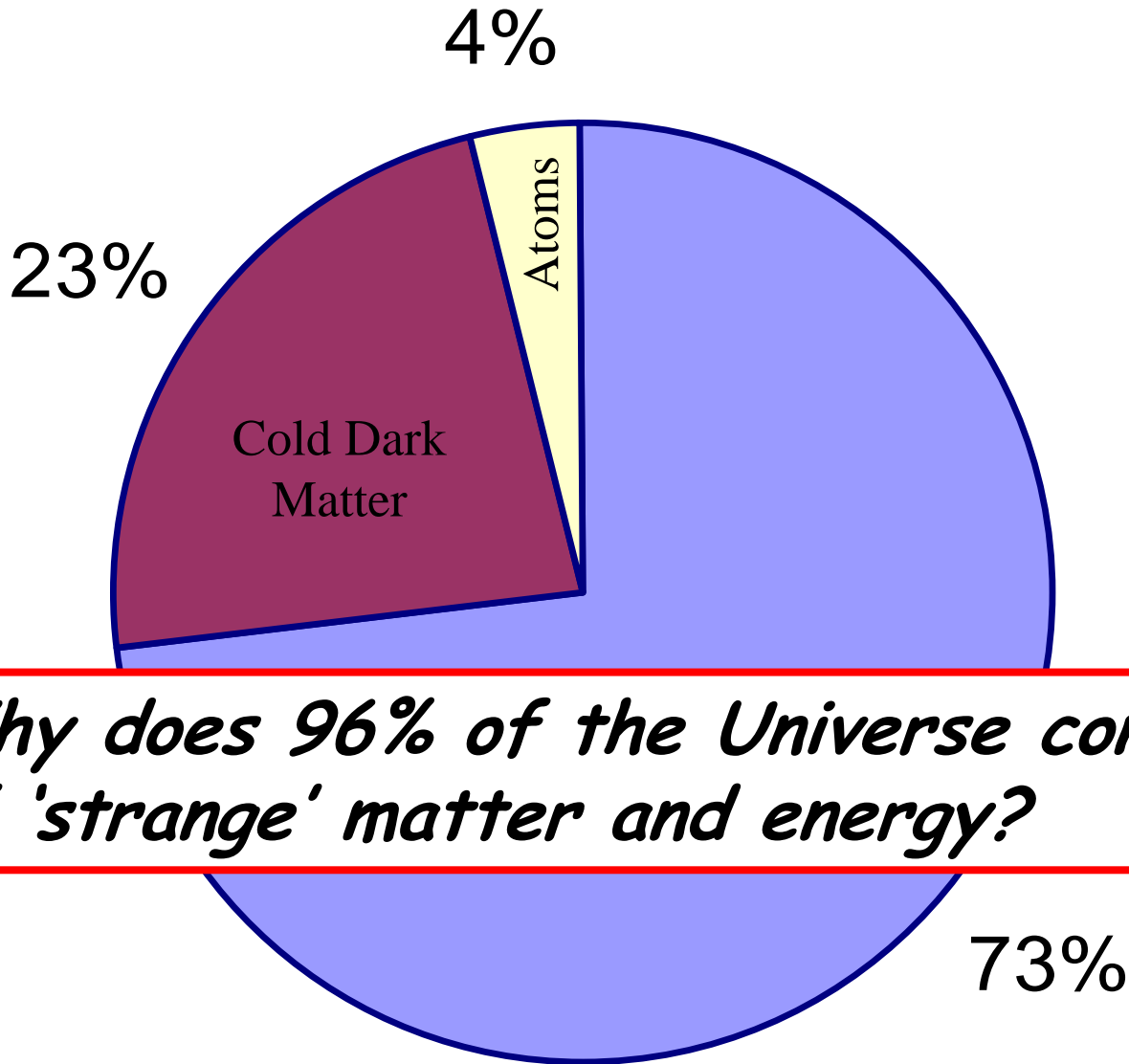
Dark Energy

**Cosmological Constant?  
Quintessence?**

# State of the Universe - Feb 2006



# State of the Universe - Feb 2006



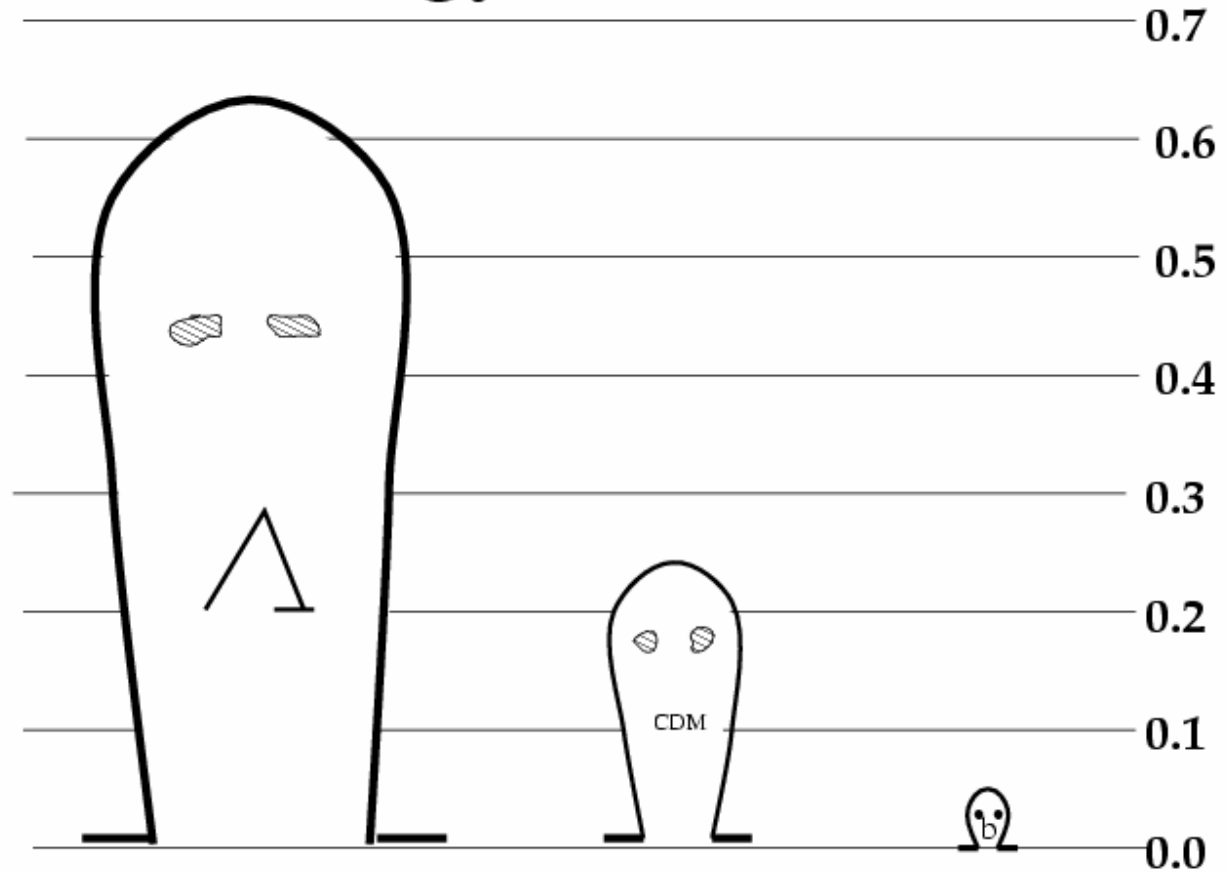
*Why does 96% of the Universe consist of 'strange' matter and energy?*



# $\Lambda$ CDM

## Cosmology's Most Wanted

**Figure 3. A line up of cosmological culprits**  
 $\Omega_\Lambda$  is the big shot controlling the Universe. He's going to make it blow up.  $\Omega_{CDM}$  would like to make the Universe collapse but can't compete with  $\Omega_\Lambda$ .  $\Omega_b$  just follows  $\Omega_{CDM}$  around. Like all dangerous criminals, one can never be sure of  $\Omega_\Lambda$  until he is behind bars. The CMB police is being beefed up. Hundreds of heroic CMB observers are now planning his capture.



$\Omega_\Lambda$	$\Omega_{CDM}$	$\Omega_b$
cosmological constant energy of the vacuum He never clumps His evil plan is to blow up the Universe	cold dark matter He likes to clump but has never been detected directly His evil plan is to make the Universe collapse	normal baryonic matter a pawn in the cosmic game who just follows CDM around. He thinks he's a complex life form but is really just a bunch of hydrogen

From Lineweaver (1998)

# The Anthropic Principle

The probability that astrophysical parameters take particular values is conditioned by the fact that we are here as intelligent observers

The existence of intelligent life on Earth may *require* that our Universe be 'special'

*Is this an argument for design?*

(c.f. Paley's "Watchmaker" argument)

**Probably not, but...**

# *Is this an argument for design?*

(c.f. Paley's "Watchmaker" argument)

## **Probably not, but...**

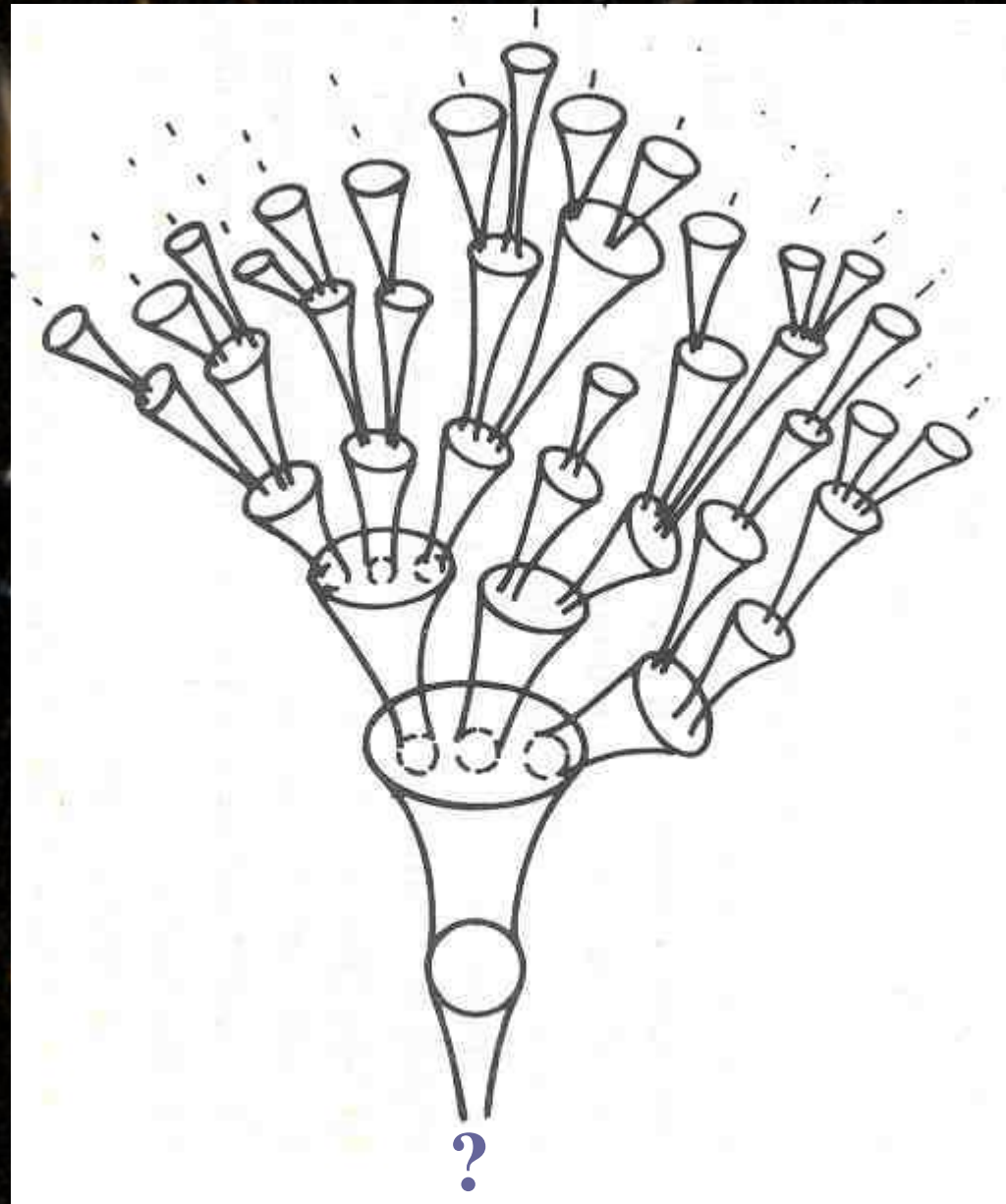
- o *Could* our Universe have been different?
- o Is our Universe unique, or is there a multitude of universes, each with (possibly random) astrophysical parameters?

# Eternal Inflation

Our observable Universe is (a tiny part of) a single inflationary 'bubble', in an infinite cascade of bubbles extending indefinitely into the future (and possibly the past), all with different physical conditions

## A 'Multiverse'?...

*How does this idea sit with Occam's Razor?*



In the multiverse model, no matter how unlikely our existence may appear, it shouldn't surprise us that we exist.

Difference between *a priori* and *a posteriori* measures of probability



Smolin (1997) suggests a form of 'cosmological natural selection'

**Singularity also found inside the *event horizon* of a Black Hole**

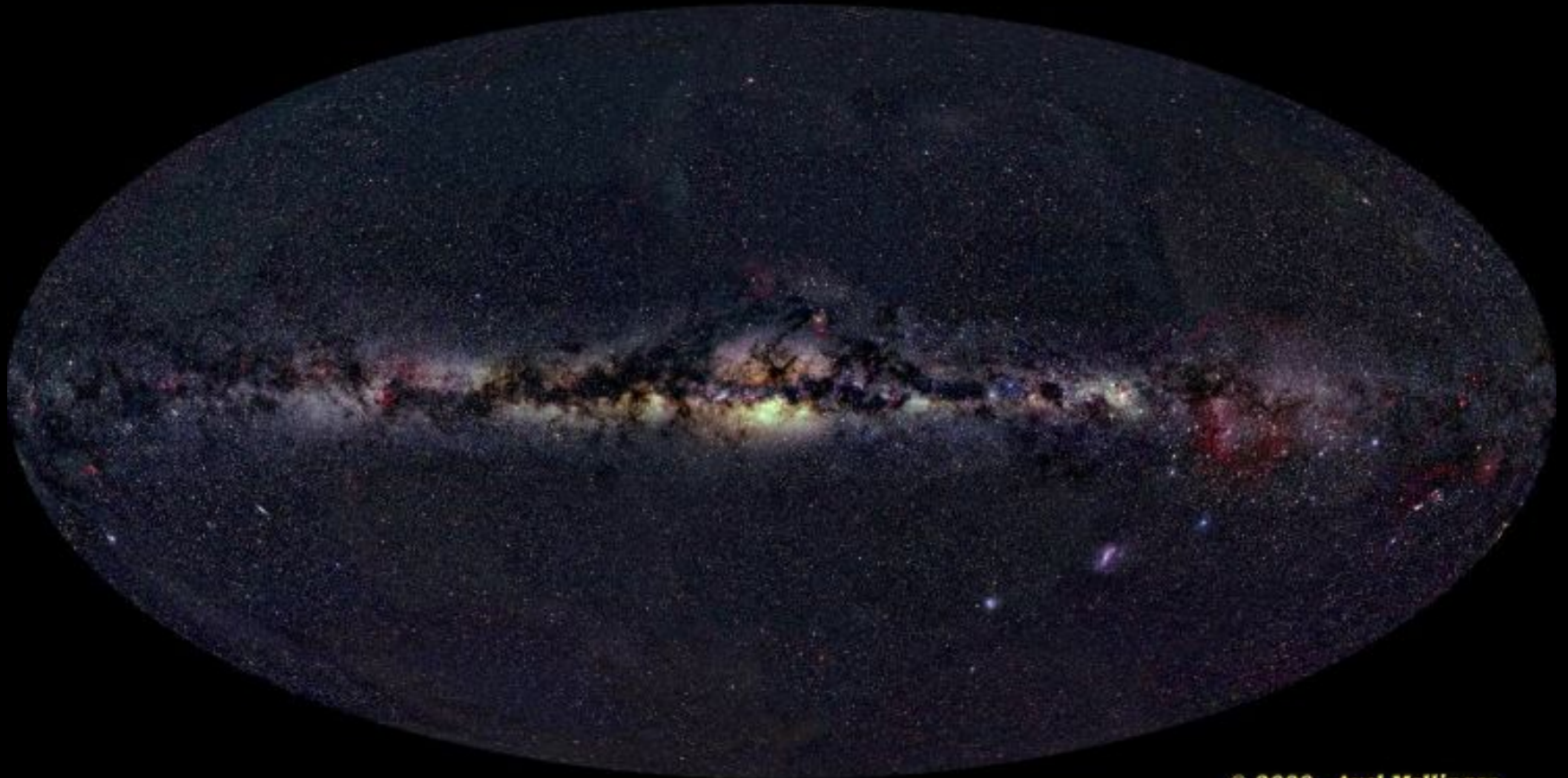
*Birthplace of a baby Universe?....*

**Could astrophysical parameters 'evolve' to maximise the production of Black Holes?**

**Can this explain why we are here?....**

*If anthropic arguments can explain the 'fine tuning' of Universe we live in.....*

*.....What's so special about *us*?*





If anthropic arguments can explain the 'fine tuning' of Universe we live in.....

.....What's so special about *us*?

The question is not so much:

"why are we here?"

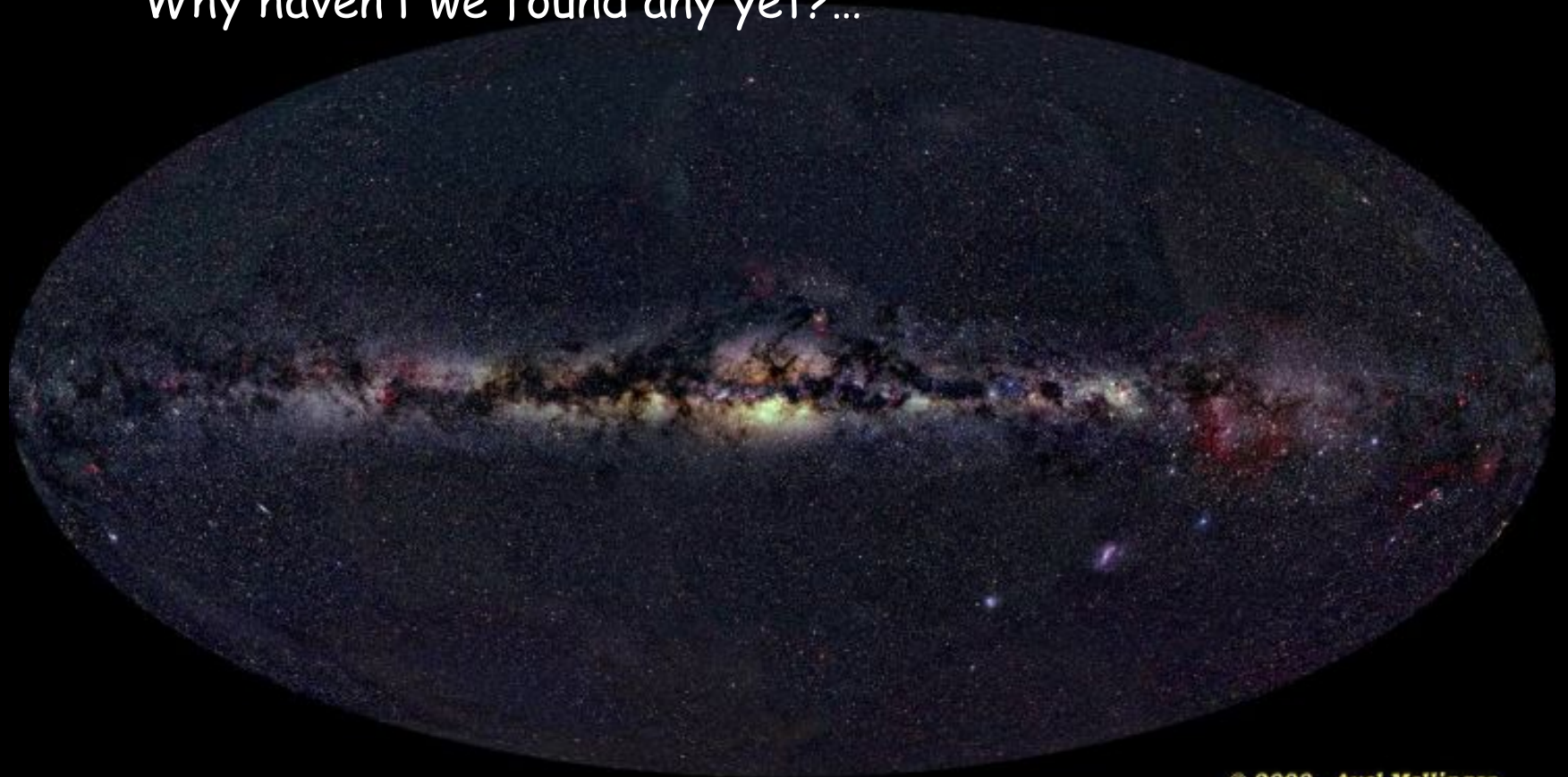
but

"why are we (and only we) here?"

*This leads us to our second big question:*

If the properties of Universe are finely tuned for life like us, shouldn't the Galaxy be teeming with intelligent life?

Why haven't we found any yet?...



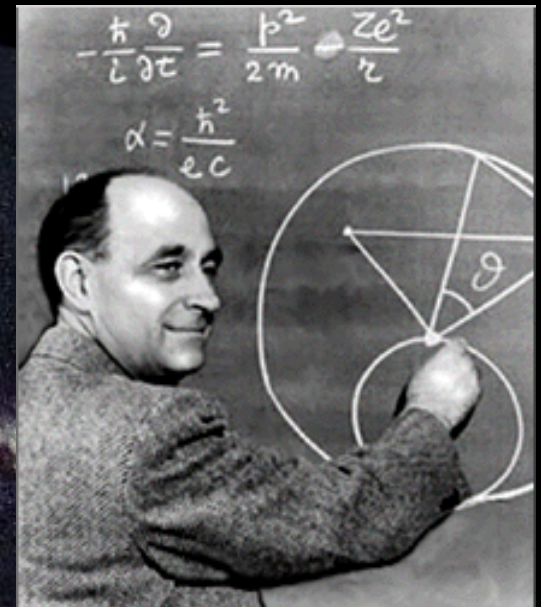
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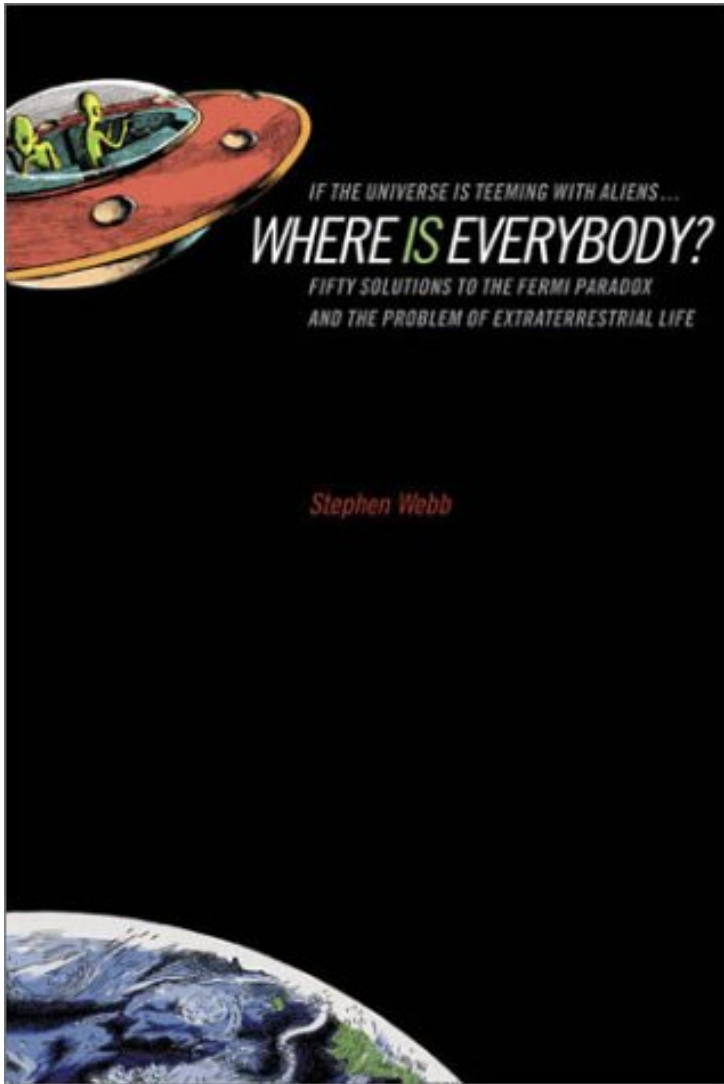
If the properties of Universe are finely tuned for life like us, shouldn't the Galaxy be teeming with intelligent life?

Why haven't we found any yet?...

Fermi's Paradox:

**"Where is Everybody?....."**



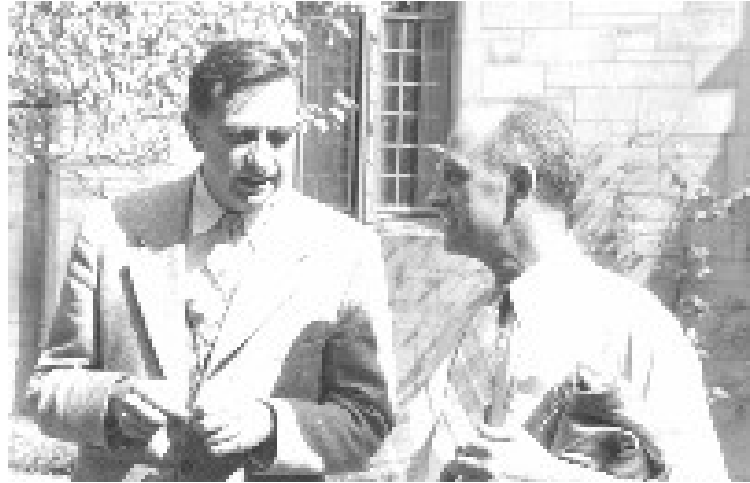


Fifty solutions to the Fermi Paradox and the problem of extraterrestrial life:

- o They are here
- o They exist but have not yet communicated
- o They do not exist

"Where is Everybody?"  
by Stephen Webb  
(Praxis, 2002)

➤ They are here and they call themselves Hungarians.



Edward Teller



Eugene Wigner



Leo Szilard



John Von Neumann

- They are here and are meddling in Human affairs

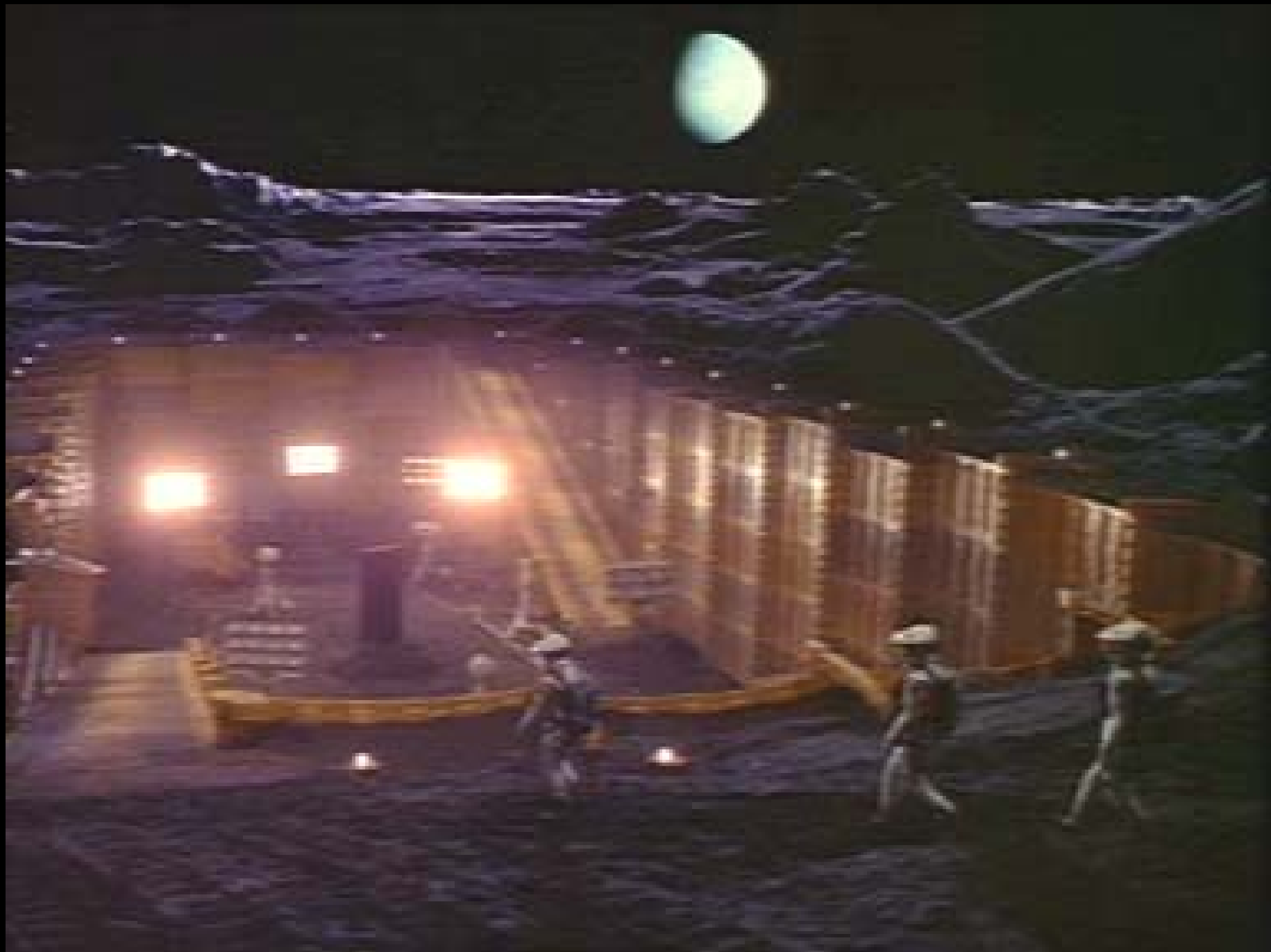


- They were here, and left evidence of their presence

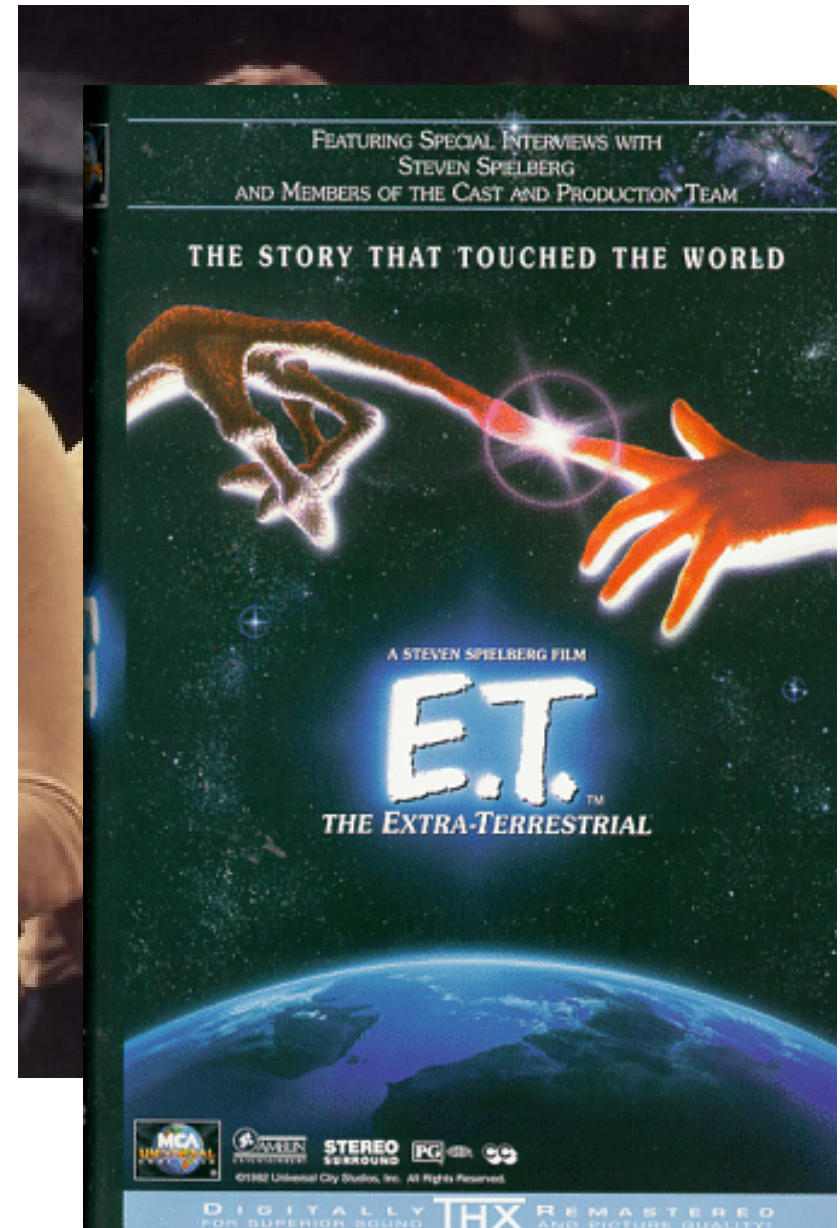








## ➤ The Zoo Hypothesis



They exist but have not communicated

They exist(ed) but have not (yet) communicated

They exist(ed) but have not (yet) communicated

# The Drake Equation

$$N = R_* \cdot f_p \cdot n_e \cdot f_l \cdot f_i \cdot f_c \cdot L$$

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$N$  = Number of communicating ETCs in the Galaxy

$R_*$  = Annual star formation rate in the Galaxy

$f_P$  = Fraction of stars that possess planets

$n_e$  = Number of planets with environments suitable for life

$f_l$  = Fraction of planets on which life actually develops

$f_i$  = Fraction of these planets in which *intelligent* life develops

$f_c$  = Fraction of intelligent life-forms that develop into ETCs

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$N$  = Number of communicating ETCs in the Galaxy

$R_*$  = Annual star formation rate in the Galaxy = **1**

$f_P$  = Fraction of stars that possess planets = **0.5**

$n_e$  = Number of planets with environments suitable for life = **2**

$f_l$  = Fraction of planets on which life actually develops = **1**

$f_i$  = Fraction of these planets in which *intelligent* life develops = **1**

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# They exist but have not yet communicated

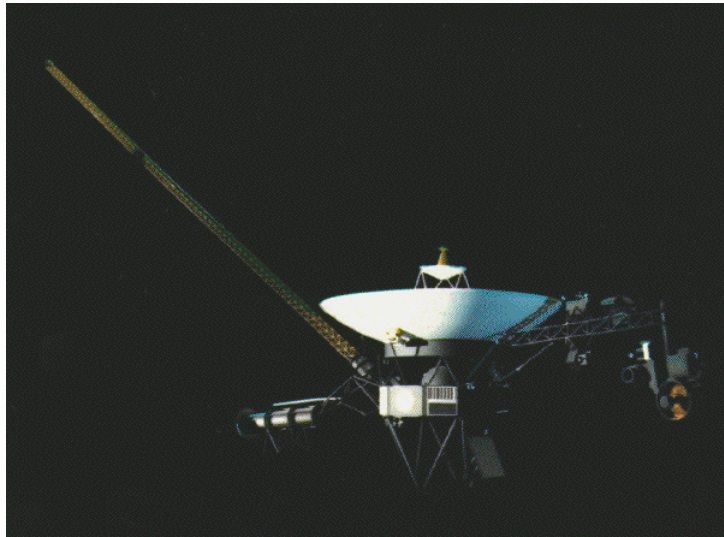
- The stars are very far away / they have not had time to reach us



Voyager 1 would take ~75000 years to reach Proxima Centauri.....

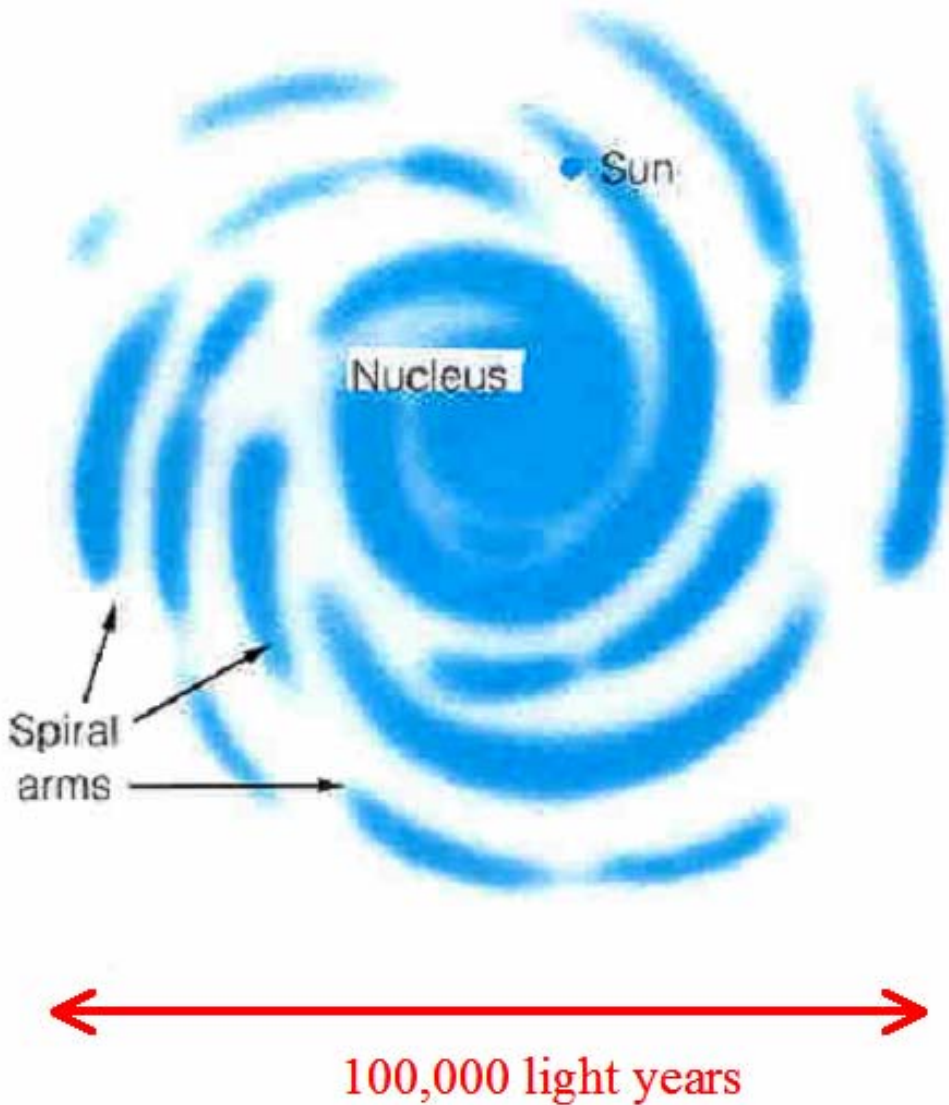
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Voyager 1 would take ~75000 years to reach Proxima Centauri.....

.....but this is less than 100,000<sup>th</sup> of the age of the Galaxy



Suppose 'colonisation wavefront' moves at 10% of light speed.

'Colonisation time' ~ 1 million years

Take *Galaxy* age = 1 year

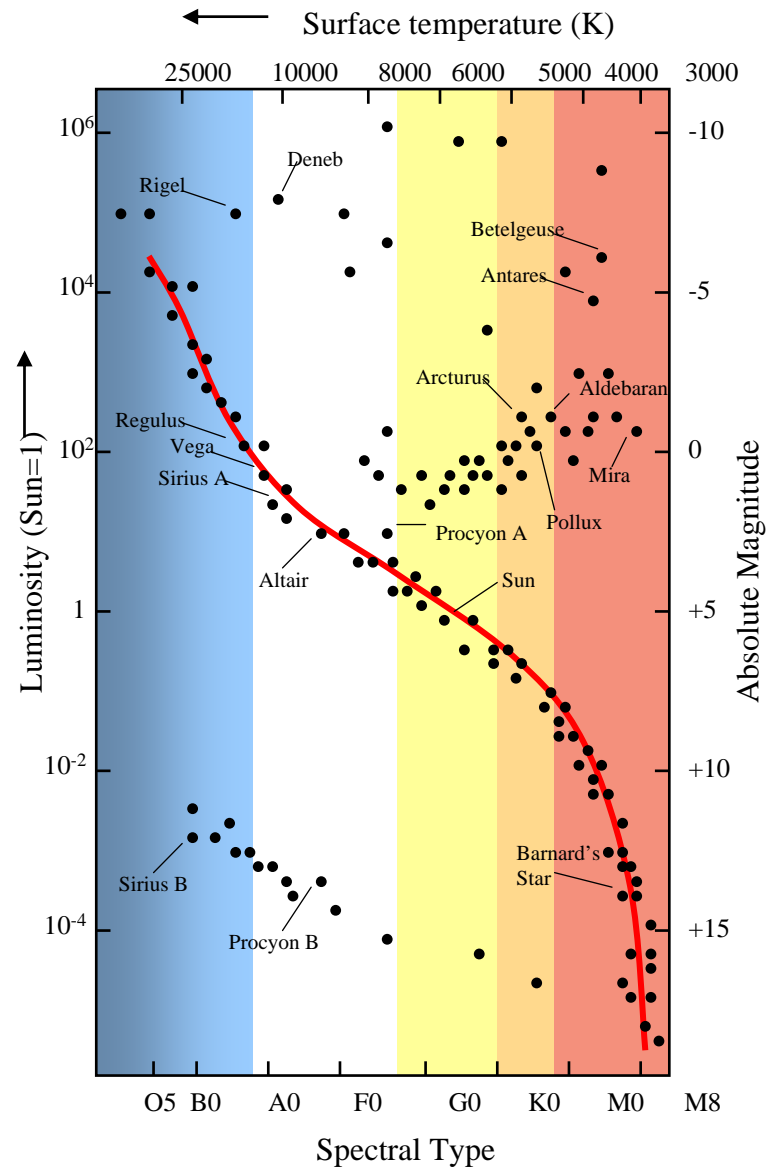
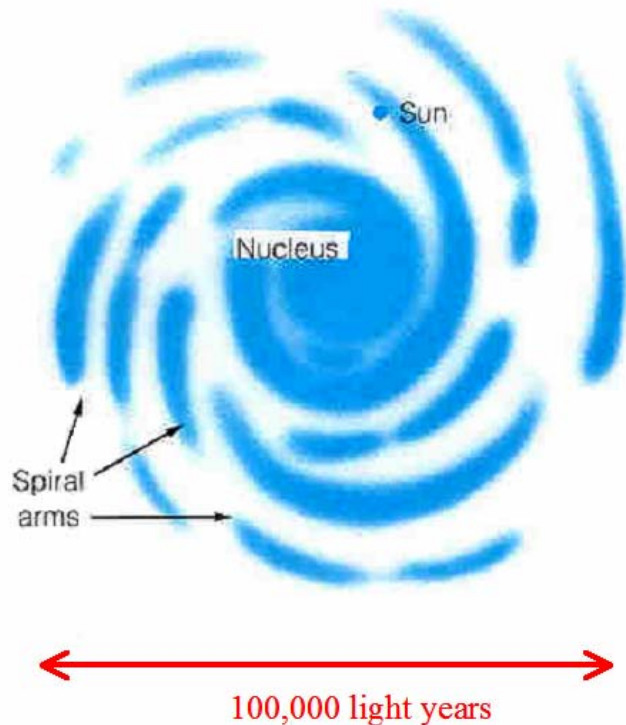
⇒ C.T. ~ 40 minutes !!

First intelligent civilisations begin to appear in late April, yet no ETCs by 11:20pm on Dec 31<sup>st</sup>?...

# They exist but have not yet communicated

## ➤ We are Solar chauvinists

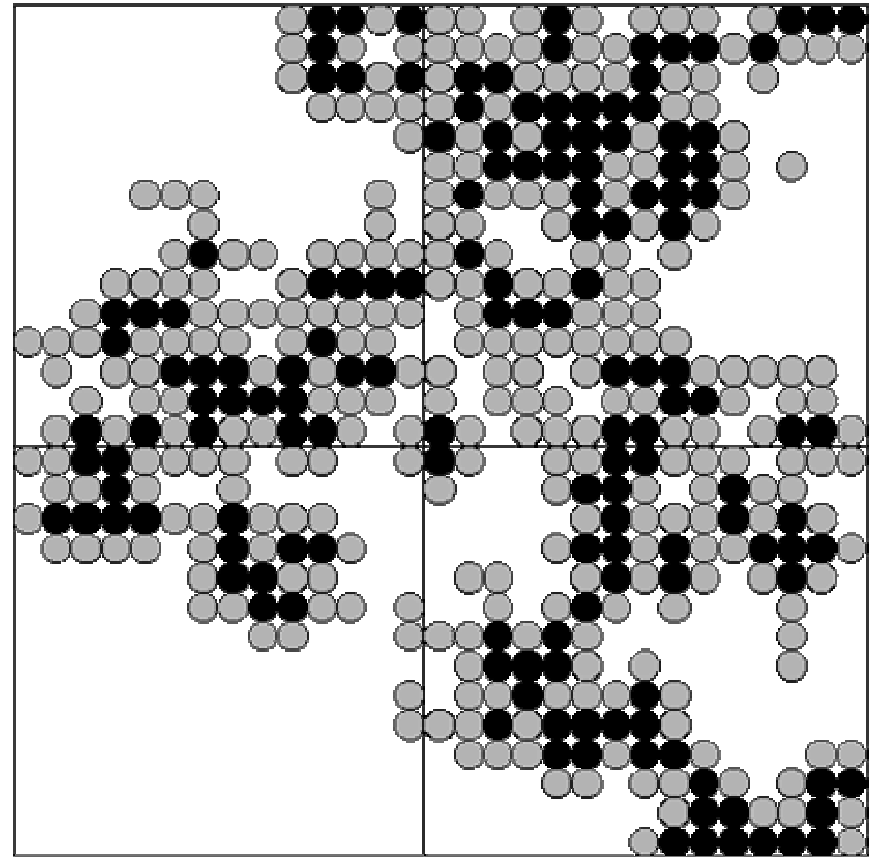
Perhaps there are simply too many other interesting places to visit?...



# They exist but have not yet communicated

## ➤ Colonisation follows a 'percolation' model

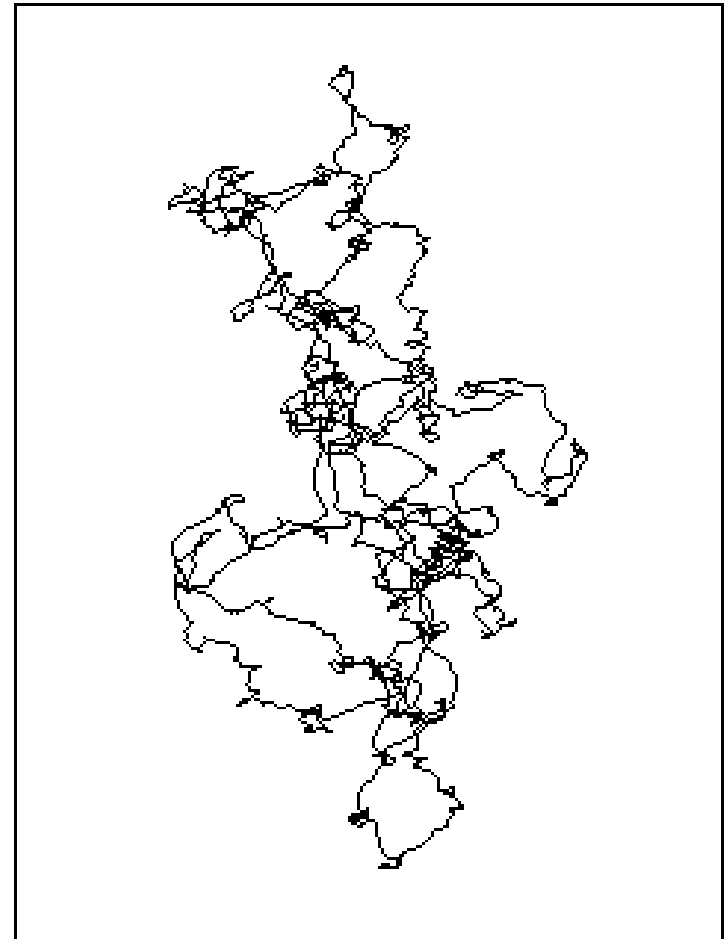
- o Interstellar travel is not impossible, but is very hard.
- o Diffusion through galaxy follows probabilistic rules - game of 'life'
- o No 'invasions'
- o Depending on transition rules, can have large regions which reach equilibrium - no colonisation.
- o Is the Solar System in one such region?...



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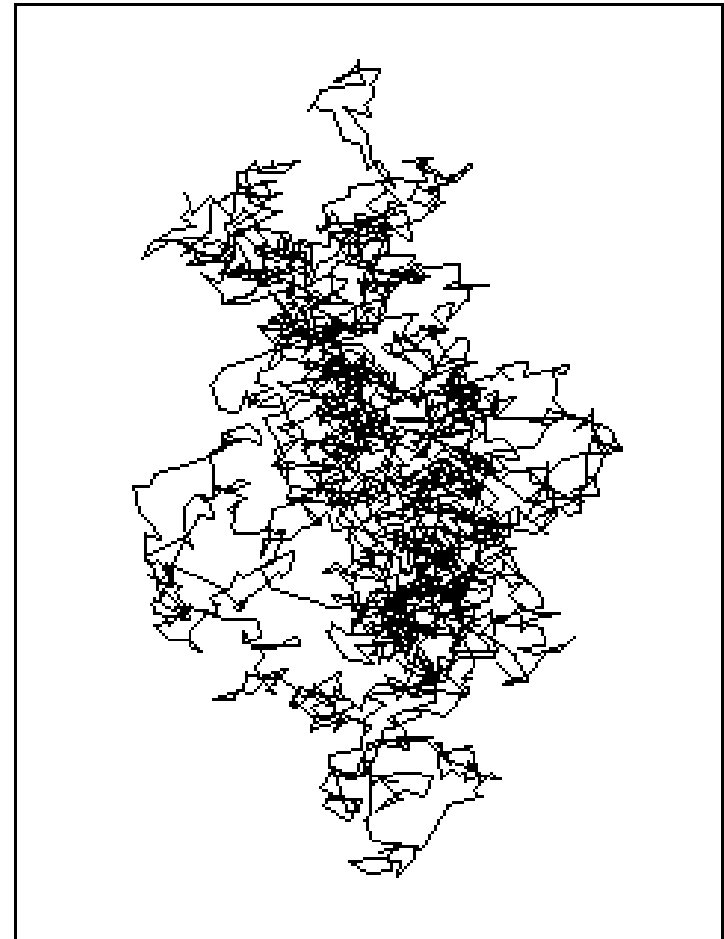
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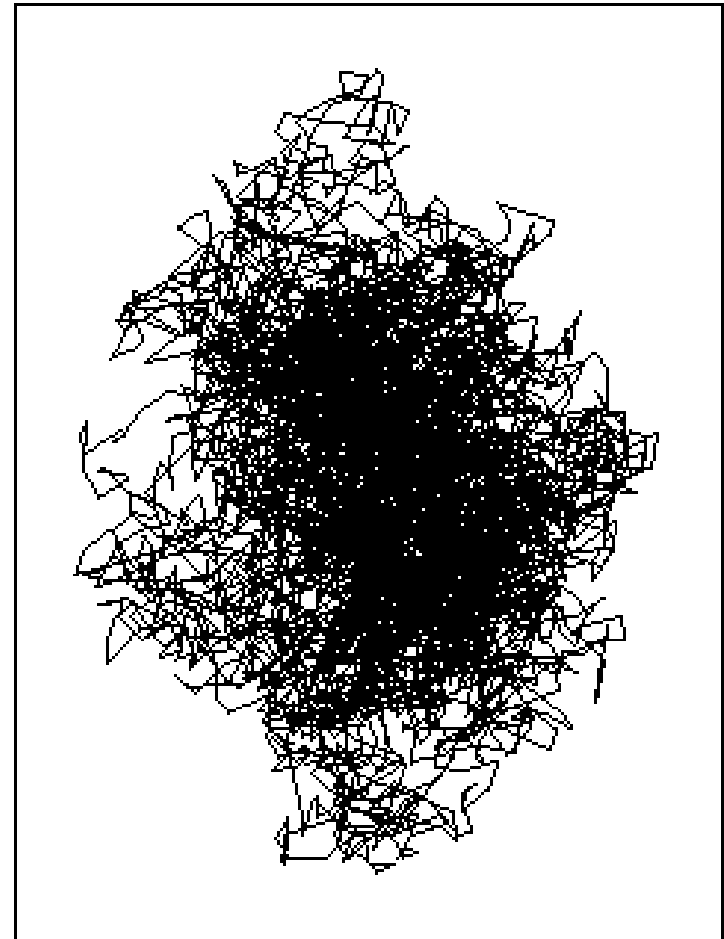




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See e.g. latest models at <http://www.sff.net/people/Geoffrey.Landis/percolation.htm>

# They exist but have not yet communicated

➤ They stay at home...



# They exist but have not yet communicated

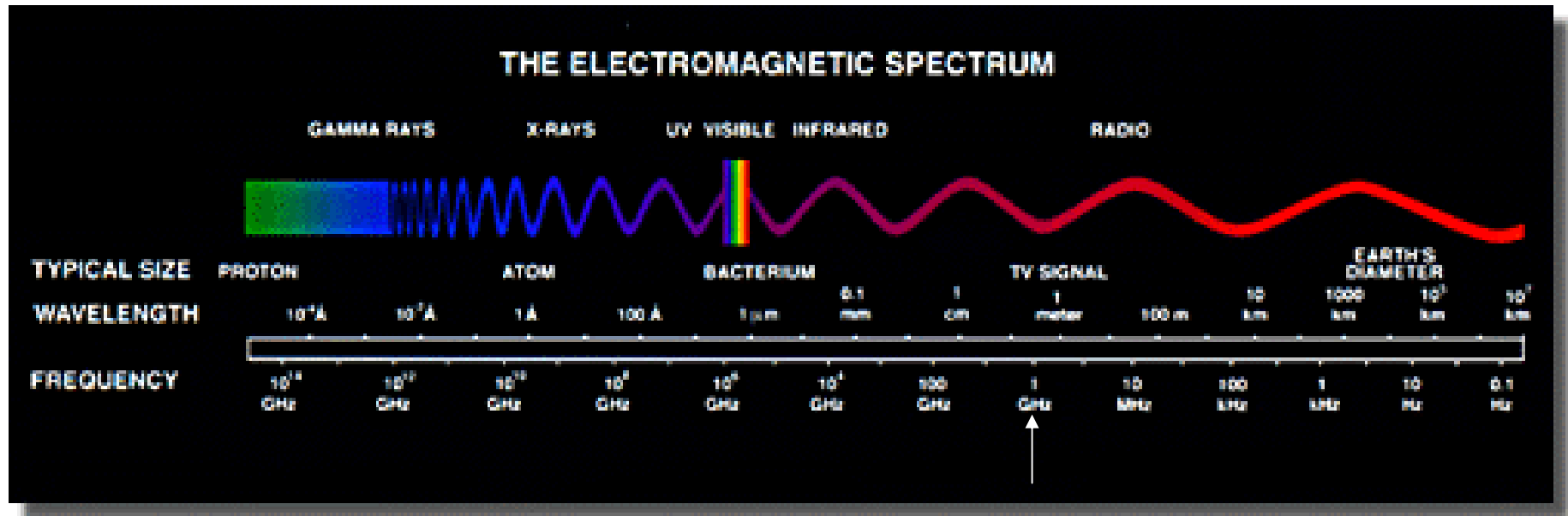
- They stay at home...



...and surf the net

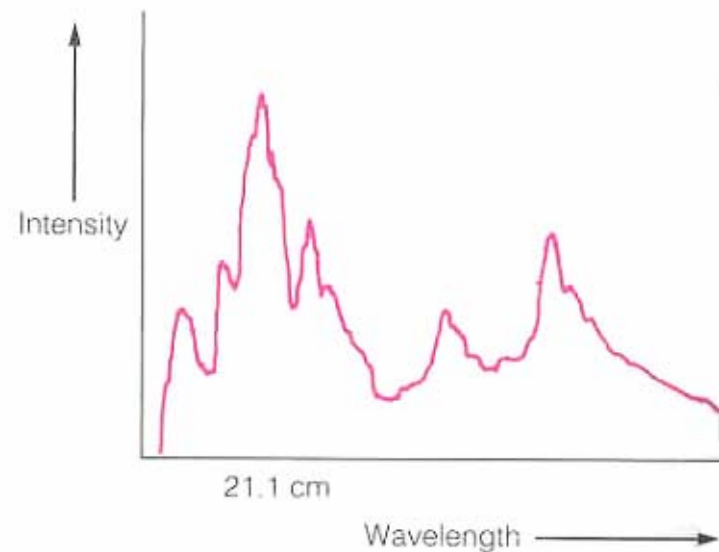
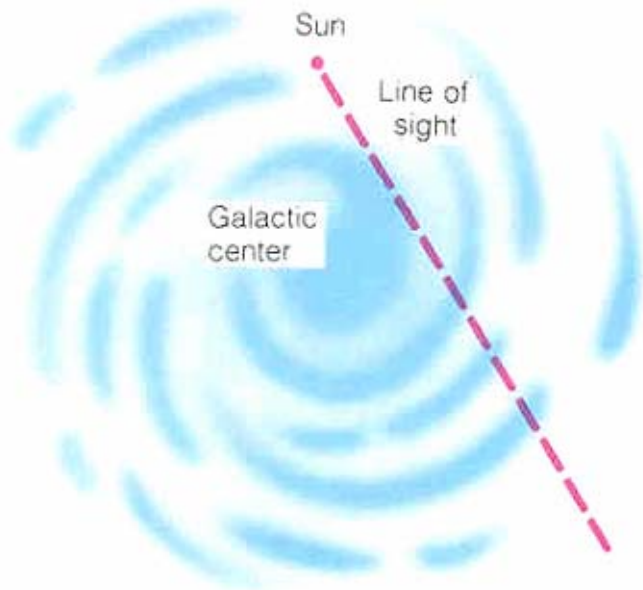
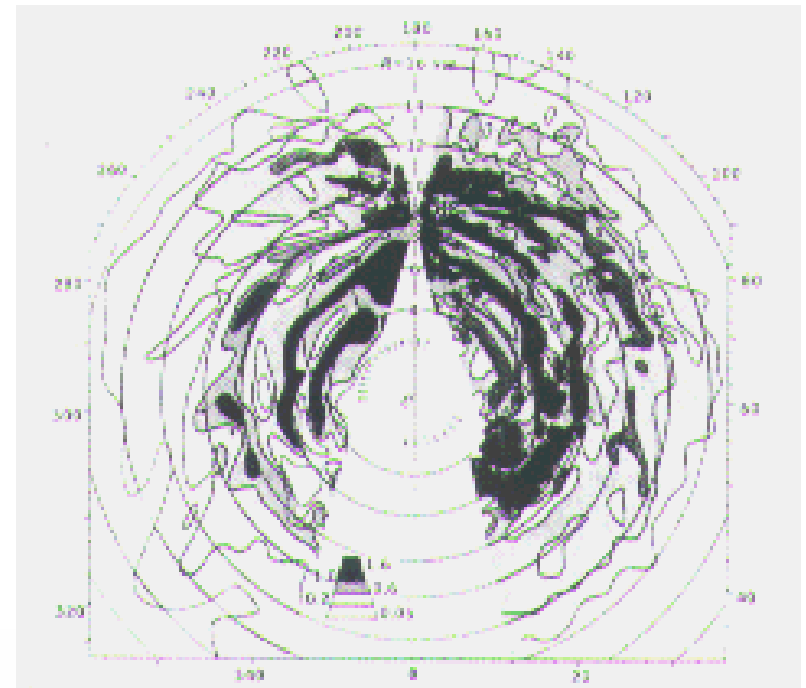
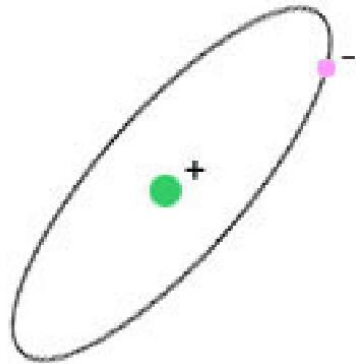
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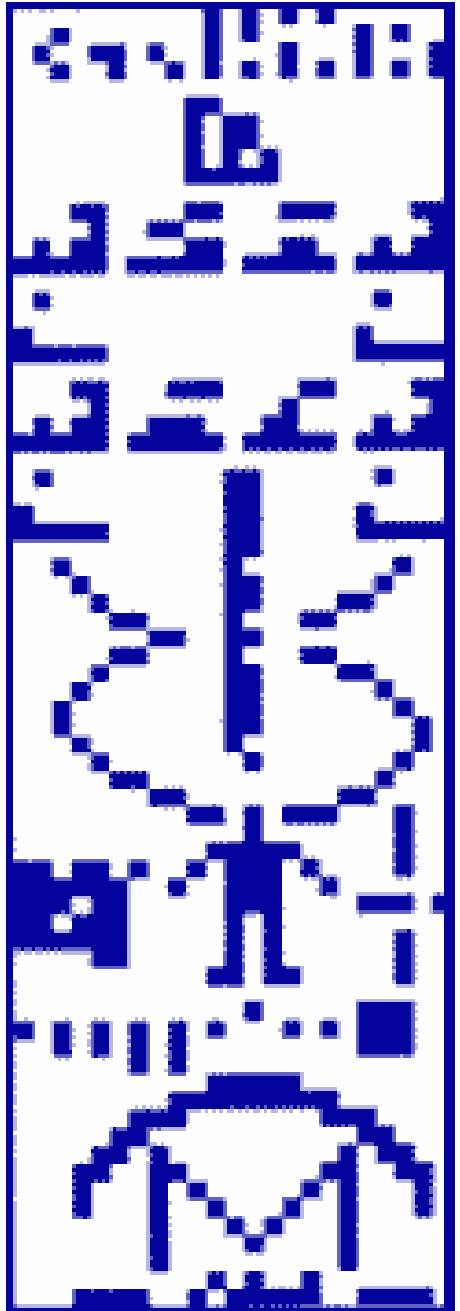
➤ They are signalling but we don't know how to listen



The 'Waterhole': strong H and OH emission between 1.42 GHz and 1.64 GHz

The 'Waterhole': strong H and OH emission between 1.42 GHz and 1.64 GHz









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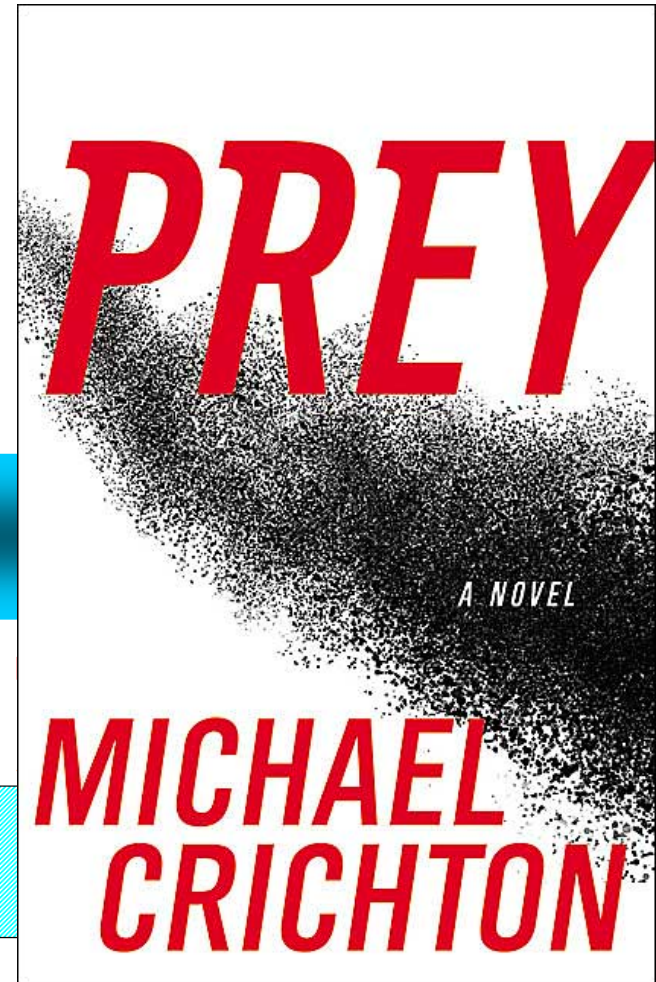
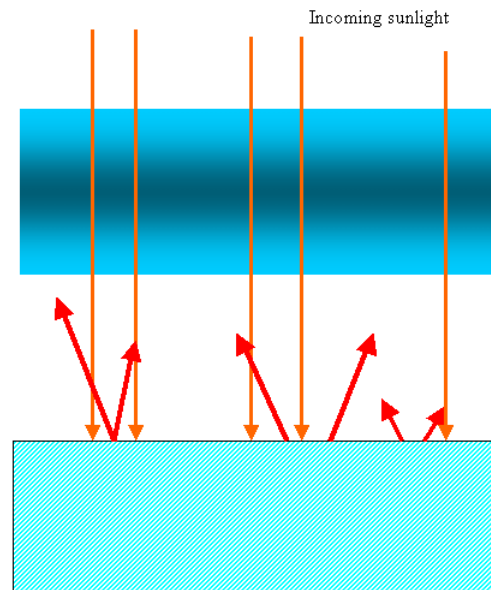
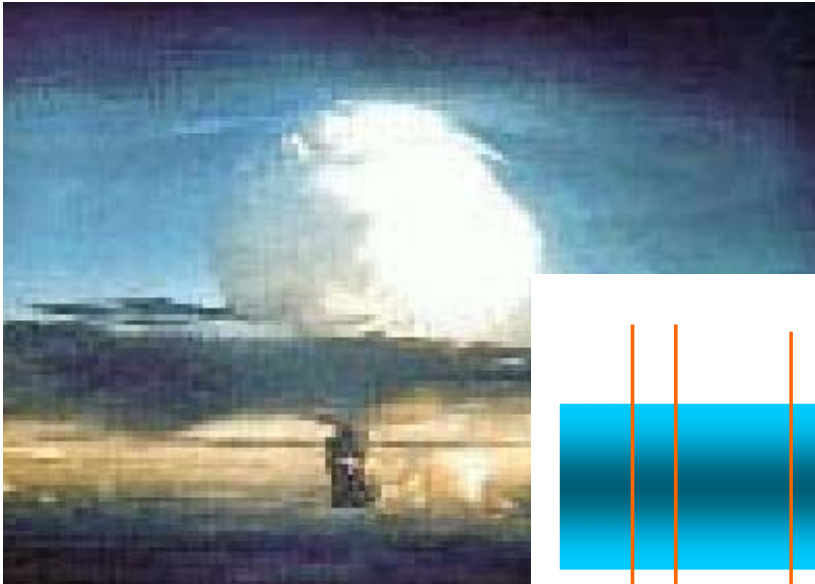
100%





They exist but have not yet communicated

- Self-induced catastrophes ( $L$  is small)



# They exist but have not yet communicated

➤ Cloudy skies are common!



# They do not exist

- Evolution involves a series of difficult steps:
  - o The time for intelligent life to emerge on Earth is comparable to the lifetime of the Sun - why ?...
  - o Maybe evolutionary timescale is typically much *longer* than the age of the Solar System. The WAP then helps explain why we emerged so late in the day.
  - o It is also then easier to explain why we should be the first (almost) ETC.

# They do not exist

## ➤ Perhaps emergence of *Life depends* on astrophysics

- o e.g. carbon-based life should appear at peak in cosmic carbon production?
- o This peak occurred ~ 7 billion years ago.
- o Still leaves a ~ 3 billion-year 'head start' for some ETC
- o This should give plenty of time to colonise the galaxy



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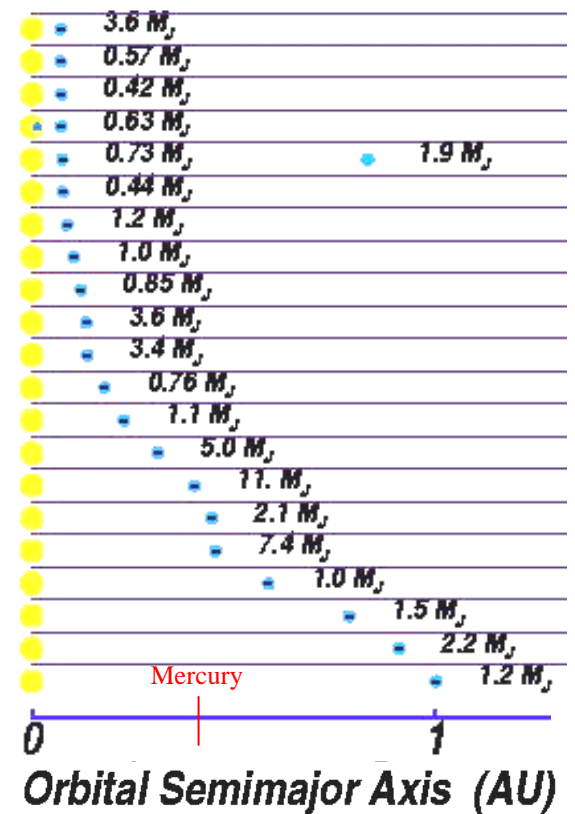


# They do not exist

➤ Rocky planets are rare

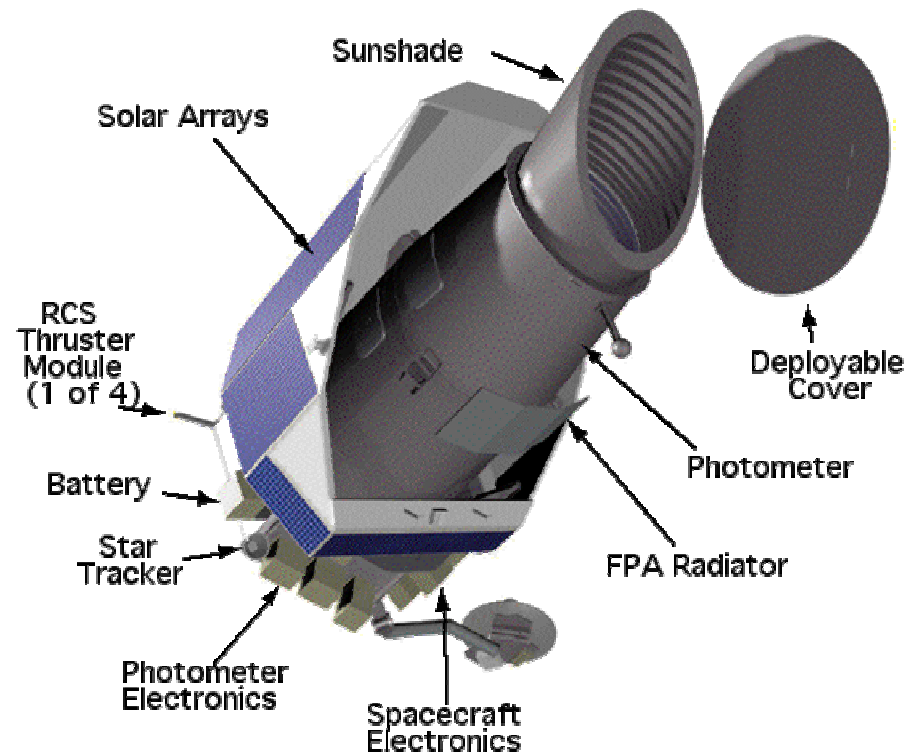


TauBoo  
HD187123  
HD75289  
HD209458  
Ups And  
51Peg  
HD217107  
HD130322  
55Cnc  
GL86  
HD195019  
HD192263  
RhoCrB  
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HD37124  
HD134987  
IotaHor  
HD177830



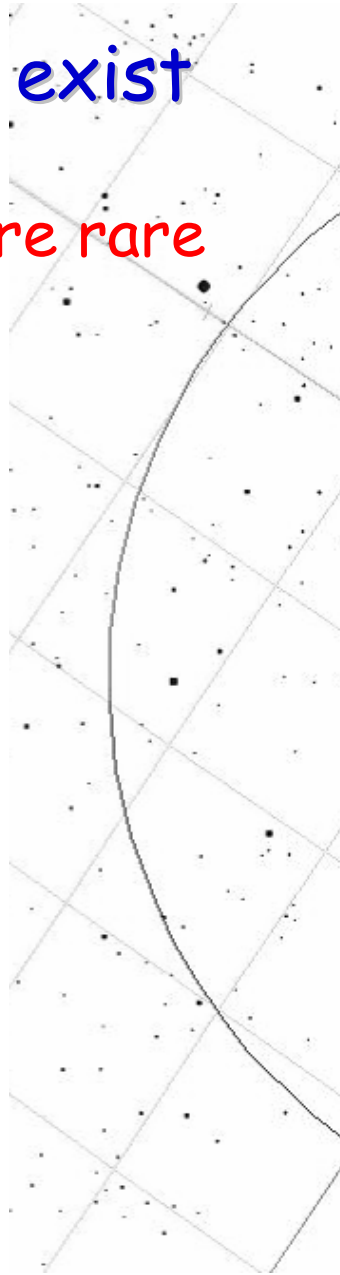
They do not exist

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They do not exist

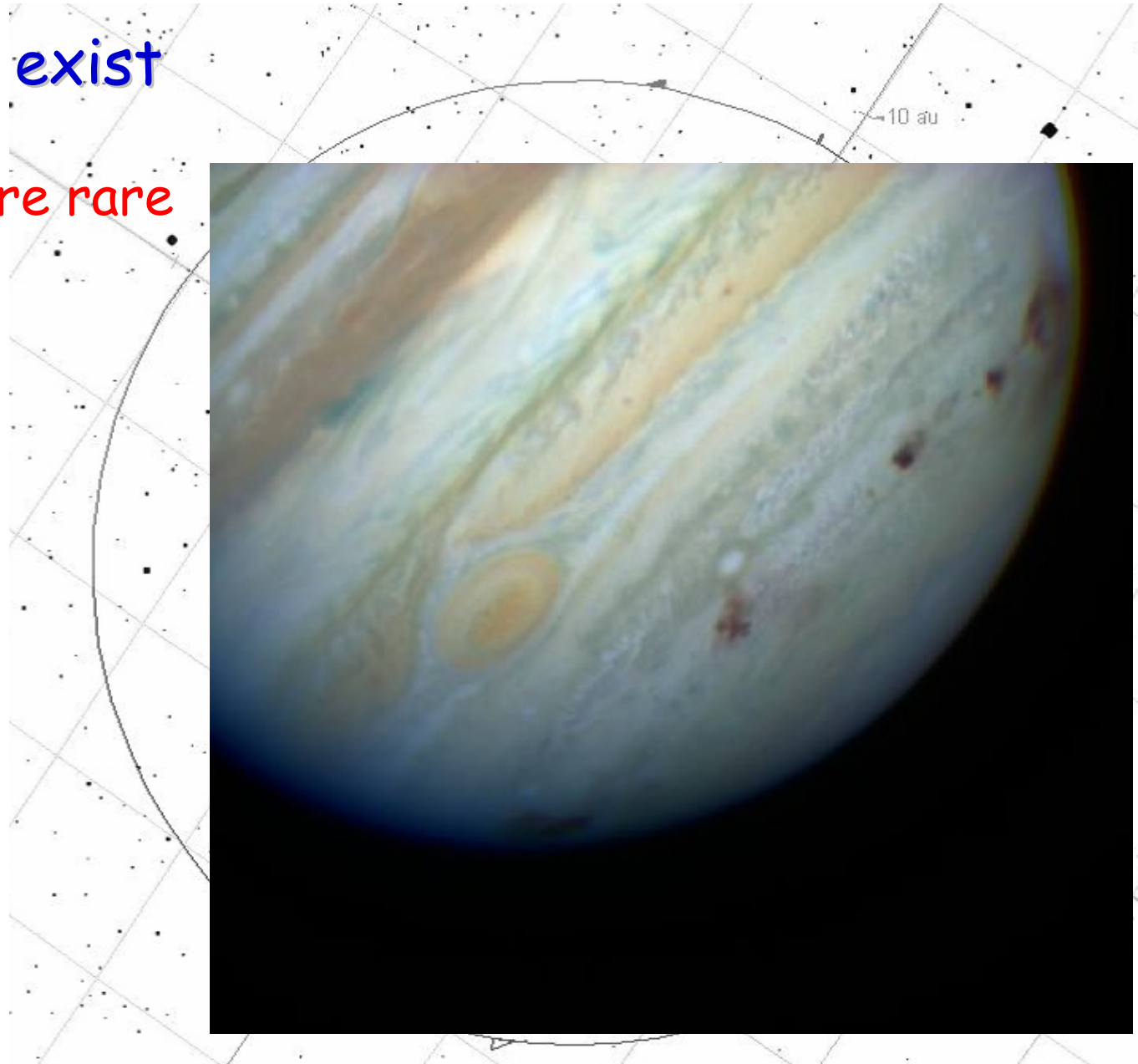
➤ Jupiters are rare





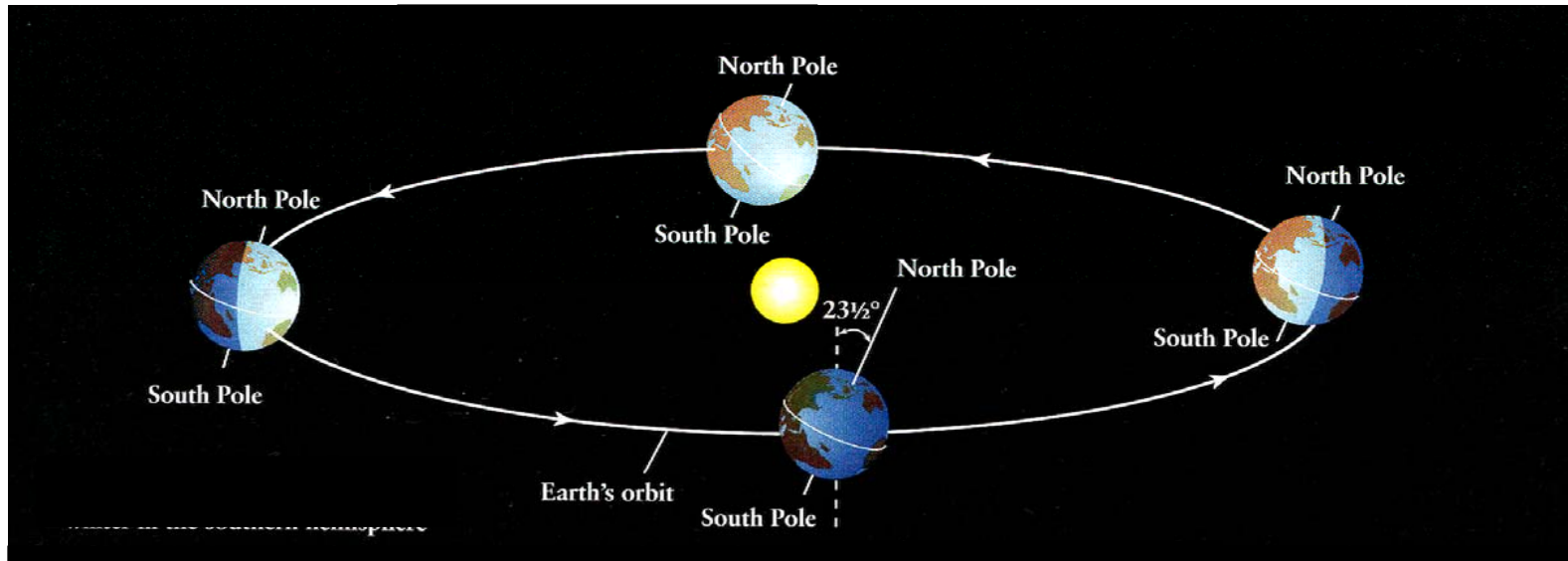
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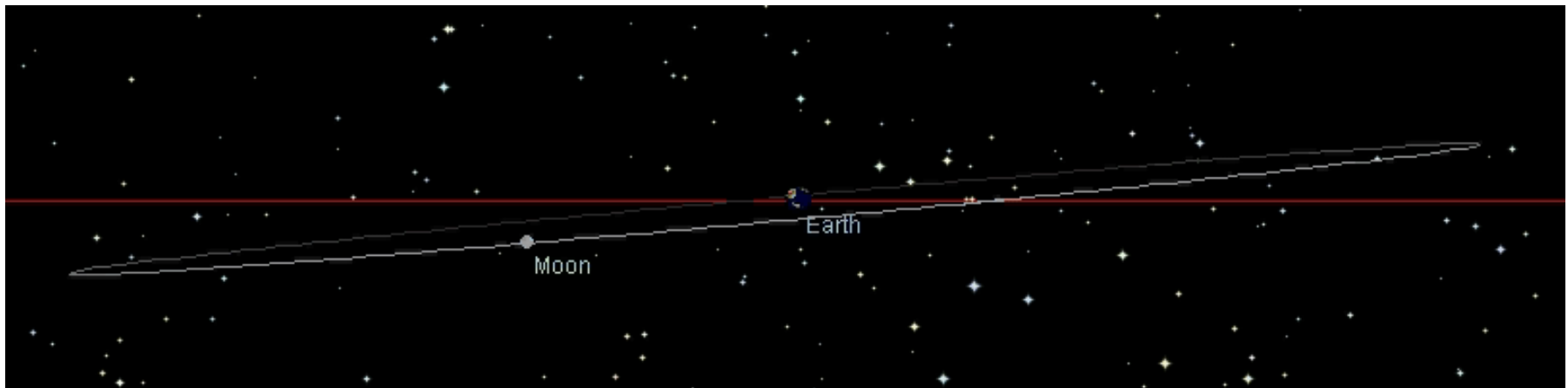
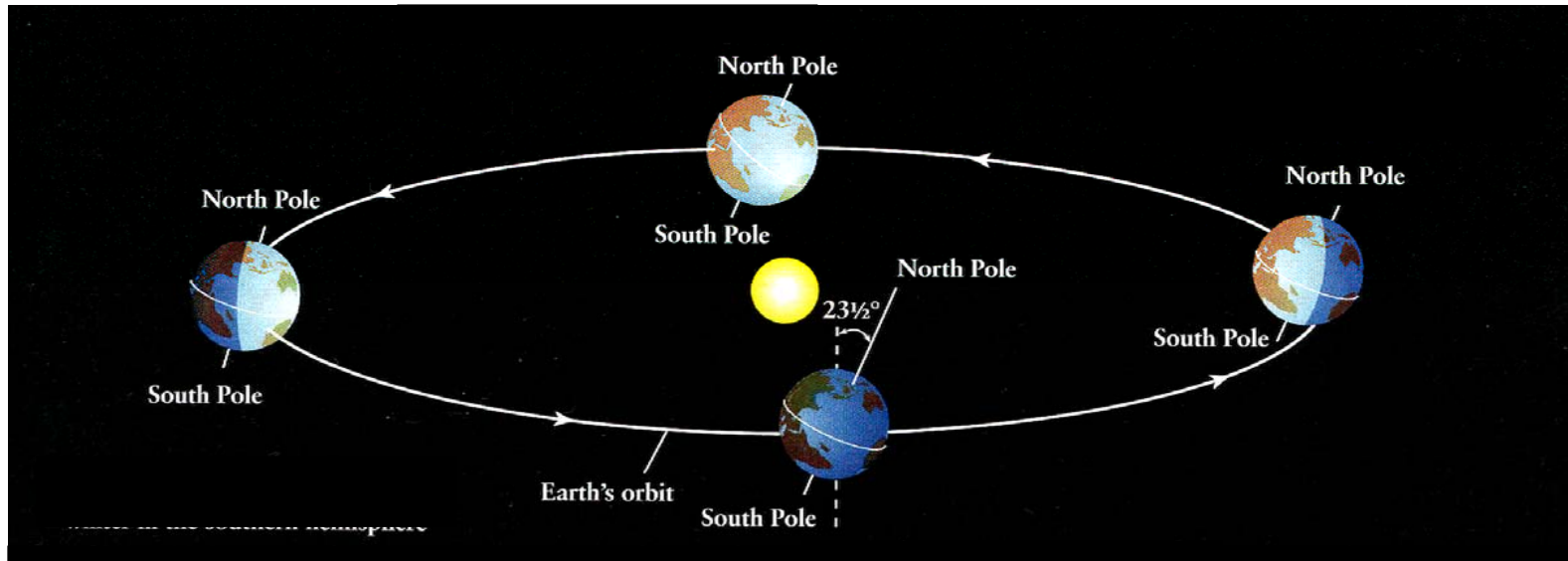
# They do not exist

➤ The Moon is unique



# They do not exist

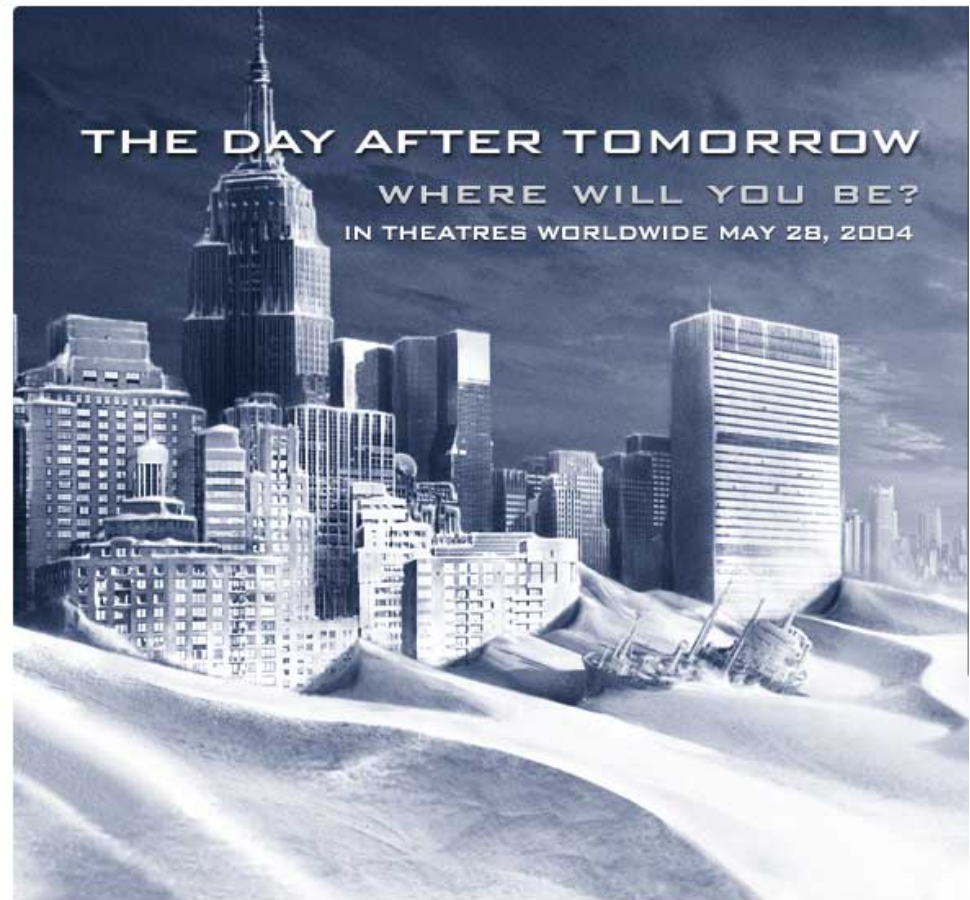
- The Moon is unique



# They do not exist

## ➤ The Moon is unique

It stabilises the Earth's axial tilt, and limits the severity of 'Snowball Earth' scenarios



# They do not exist

➤ The emergence of {  
life  
eukaryotic cells  
toolmaking species  
intelligence  
language  
science and technology

is rare

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# *What is life anyway?.....*

- It is probably good science to look first for life like ourselves
- If there is life out there that is very *different* from us, would we even recognise it as life?

What defines a living organism?

Metabolism

Reproductive capability

Evolution

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Are these characteristics universal?



