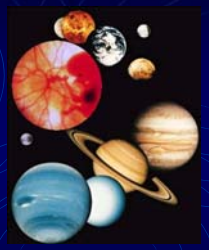
# Search for Extraterrestrial Life

Wen-Ping Chen
National Central University, Taiwan
2014.10.15 to BITS

## Astrobiology

**A legitimate discipline**

- NASA Astrobiology Institute (NAI)
- Penn State, Stanford, U Washington, UCLA, UT Austin, Arizona State, U Colorado, Cornell, U Edinburgh, Stockholm U., U New S Wales, McGill U, etc.

**To look out for extraterrestrial life and intelligence, and to facilitate terrestrial life in space …**

## What will NOT be covered …

- Space travel
- Pyramids, crop circles, paranormals
- The Roswell event, Area 51, UFOs …
- Alien abduction




## Outline

- Making sense
- What is life?
  *(Search for what?)*
- The extraterrestrial worlds
  *(Where to search?)*
- "Where is everybody?"
  *(How to search? Are they here? Are we they?)*



## Do you believe in aliens?

the existence of

somewhere, sometime

*There is no right or wrong for what you believe.*

*Yes or no, you should have a reason.*

*If you believe they should exist, then, how many kinds of aliens are there? 1 million? 1 thousand? 1?*



## Do you believe in ghosts?

*Is it "safer" to say yes?*

*If not, what about those "stories"?*
*that we have seen in the news, that we heard from a friend who allegedly heard it from a relative of her friend …*

*When this were asked two hundred years ago? Higher-up all-mighty savior who knows it all …*
*rainfall, thunders, rotten food …*

*Legitimate questions, legitimate answers.*
*(What is the purpose of life?)*
*Religion, philosophy, science*



## Do you believe in bacteria?

*Is to see to believe?*

I've never met my great-great grand mother, but never ever doubted her existence.

*"Our knowledge is limited. There are still a lot of things we do not know, so we should be humble confronting Nature."* --- so they say

**But science is not to play safe, it is an adventure.**



## Most believe in aliens … because the Universe is enormous, and because we should be "humble".

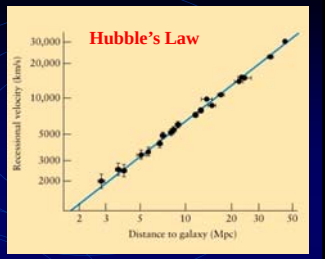
Jodie Foster as "Ellie" in ***Contact*** (1997)


***If we are alone in the Universe, then it is an awful waste of space.*** — Carl Sagan

## Myth: Everything is possible.

## Fact 1: The Universe is finite.

The Universe was created in a hot dense state some 13.8 billion years ago, in which this space and time we live in began to exist, and continues to expand.


- Expanding Universe
- Ubiquitous microwave background radiation
- Cosmic light elements
- No "real old" objects

In a finite world, not everything would have happened, even if there is a possibility for it to happen.

*cf buying lottery*

Making sense Life Space Search

## Fact 2: Probability can be misleading.

*There is always someone winning the lottery. If we buy, there is a (minute) chance. If we don't, the expectation value is zero.*

*"medicine from the air"*

*If someone challenges you 100 times straight heads in tossing a coin. Do you bet?*

$P = (½)^{100}$

*"No way"*

*If someone asks to trade you with $2 for his $1 coin that will become a $10 coin when dropped. Do you trade?*

$P = 0$

*"No way"*

**These are different levels of no way.**

Making sense Life Space Search

## Fact 3: One cannot prove inexistence.

*One person asserts that ghosts exist, while the other insists not.*

*Which side are you on?*

*Equal (50%) chances?*

*The person who bets on existence will never lose.*

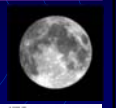
*The person who bets on nonexistence can never win.*

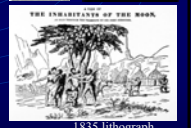
*How can one prove that ghosts do not exist anywhere any time?*

**Extraordinary claims require extraordinary evidence. The burden of proof falls upon the positive.** Alan Hale

Making sense Life Space Search

There has been a long record of aliens in human history … Why not? Every "new world" seemed populated.




1835 lithograph

## Moon people (selenites)

**The Great Moon Hoax** (1835)

Media (!) had it that Sir John Herschel (a creditable source!) saw lunar civilization (published in a scientific journal!) using a new and novice telescope (so was not known before!)

Nowadays, some still claimed Apollo landings were faked.

Aliens have moved from center of the Earth (the Bermuda Triangle), to the farkside of the Moon, to the center of the Moon.

Making sense Life Space Search

## Martians

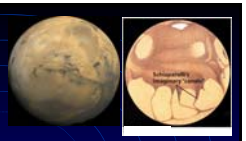
Astronomer Schiaparalli (1877) claimed to have seen "canali" (nominally "channel" in Italian) under exceptionally good sky condition (!).
It was mistranslated to "canal".

H. G. Wells (1898) "*War of the Worlds*"

Edgar Rice Burroughs (1912) "*Under the Moons of Mars*" → The little green men

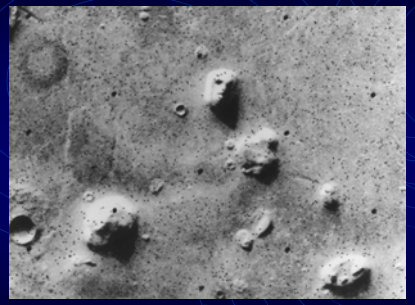
Percival Lowell (1855-1916) fascinated by, and started to chart out, the canals. There was good scientific reasoning for the canals, because Martian poles froze out.

Orson Welles (1938) radio show dramatized landing of Martians.





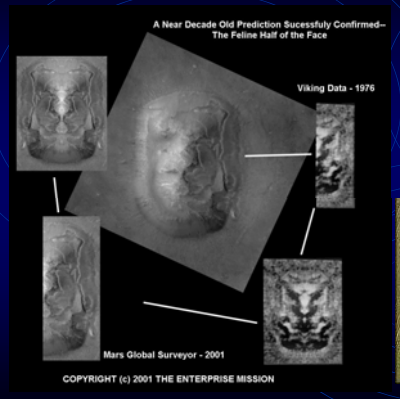
- *Mariner* 4 in 1965, two *Viking orbiter in 1976* did not see Martians, but …

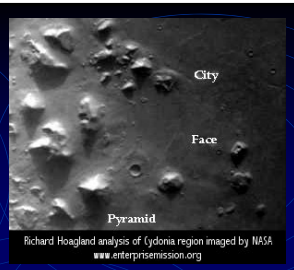



Human brain → connecting dots to lines, and associating with something we are familiar with.

Making sense Life Space Search

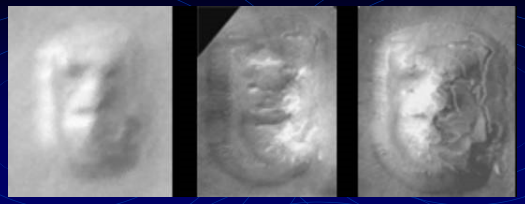
## Cydonia City?



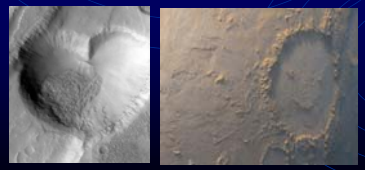




Making sense Life Space Search

## Marians start to lose face ☹



*Viking* (1976) *Mars Orbiter Camera* (MOC) onboard *Mars Global Surveyor* in 1998 (left) and 2001 (right)



Conscious recognition tends to make association with human faces.

Making sense Life Space Search

## pareidolia

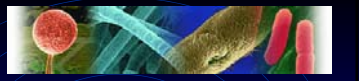
Orchis italica

**New York Time** article http://www.nytimes.com/2007/02/13/health/psychology/13face.html?pagewanted=1&_r=1

http://educ.jmu.edu/~johns2ja/illusion/illusion.htm

http://thesituationist.wordpress.com/2008/02/23/seeing-faces/

## What is life?



- An assembly of atoms and molecules? *What kinds?* Fundamentally all physics and chemistry? *How about "Spirits"?*
- Any definition finds counter examples, but we know it when we see one?

- ☐ To reproduce
- ☐ To evolve

Necessary (but not sufficient) properties

Making sense Life Space Search

## Chemical Compositions

| Sun | | Earth | | Earth Mantle | |
|---|---|---|---|---|---|
| H | 90.99% | O | 50% | O | 47% |
| He | 8.87 | Fe | 17 | Si | 28 |
| O | 0.078 | Si | 14 | Al | 8.1 |
| C | 0.033 | Mg | 14 | Fe | 5.0 |
| Ne | 0.011 | S | 1.6 | Ca | 3.6 |
| N | 0.010 | Ni | 1.1 | Na | 2.8 |

| Earth Atmosphere | | Bacteria | | Humans | |
|---|---|---|---|---|---|
| N | 78% | H | 63% | H | 61% |
| O | 21 | O | 29 | O | 26 |
| Ar | 0.93 | C | 6.4 | C | 10.5 |
| C | 0.03 | N | 1.4 | N | 2.4 |
| Ne | 0.0018 | P | 0.12 | Ca | 0.23 |
| He | 0.00052 | S | 0.06 | P | 0.13 |

## Chemical Compositions

| Sun | | Earth | | Earth Mantle | |
|---|---|---|---|---|---|
| H | 90.99% | O | 50% | O | 47% |
| He | 8.87 | Fe | 17 | Si | 28 |
| O | 0.078 | Si | 14 | Al | 8.1 |
| C | 0.033 | Mg | 14 | Fe | 5.0 |
| Ne | 0.011 | S | 1.6 | Ca | 3.6 |
| N | 0.010 | Ni | 1.1 | Na | 2.8 |

| Earth Atmosphere | | Bacteria | | Humans | |
|---|---|---|---|---|---|
| N | 78% | H | 63% | H | 61% |
| O | 21 | O | 29 | O | 26 |
| Ar | 0.93 | C | 6.4 | C | 10.5 |
| C | 0.03 | N | 1.4 | N | 2.4 |
| Ne | 0.0018 | P | 0.12 | Ca | 0.23 |
| He | 0.00052 | S | 0.06 | P | 0.13 |

## Life … as we know it (Earthlings) in terms of chemical composition

- It resembles more the Sun than the Earth; it is made up of the most ordinary, and hence most abundant, elements in the Universe

*… so are universally available*
*Life is precious but Mother Nature did not make us with "precious/rare" elements.*

- Other parts of the Universe seem to obey the same set of physical and chemical laws.

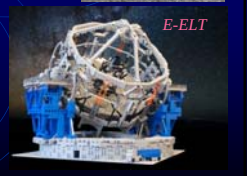
*… so space really should be teeming with life.*



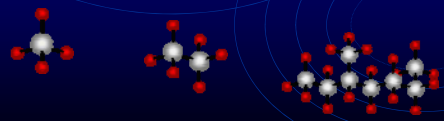
- Most life forms on Earth are composed of a few simple kinds of molecules, operated in complex and selective ways.

… Legos

- Carbon atoms (valence of 4)
  - ✓ *strong, yet still readily breakable*
  - ✓ *long, complex molecules (info carriers)*
  - → *diversity and versatility of life*



E-ELT





- How about silicon? (also valence of 4)
  - ✓ *OK, (Is computer a life form? Why not?)*
  - ✓ *$CH_4$, CO, CN, $CO_2$ … but $SiO_2$ (silica) is solid*
  - ✓ *Si is less abundant than C. Normally if Si can do it, C would have done it.*
- Essences of life: sunshine, air, & water

"Black Smoker" hydrothermal vents

***Energy source***
Plants → photosynthesis → glucose
But Sun is not the only possibility, e.g., deep ocean ecology

***To extract energy***
Respiration
$C_6H_{12}O_6 + 6O_2 \rightarrow 6CO_2 + 6H_2O$
e organisms do not gen.

Anaerobic bacteria

***How about water?***



- Life is a (con)sequence of chemical reactions.
- Liquids react as efficiently as gases, and can be easily confined (controllable) as solids.

*sugar + $H_2O$*

- Some kind of a liquid goes a long way.
- **Water** serves well. It is copious (*availability*), has a high heat capacity and latent heat, a wide temperature range in liquid form (*stabilizing surroundings*), and expands when freezing.

*As a pond froze out, primordial life forms under the ice layers could be spared.*

## Life in terms of energy source

- ✓Our life and ecology relies on energy ultimately from the Sun.
- ✓The Sun produces energy in interior by thermonuclear fusion reactions.
- ✓Plants store energy in chemical bonds.
- ✓We eat plants (or eat the animals which eat plants) to take out the energy.
- ✓ The processes (life) undergo at atomic and molecular levels.

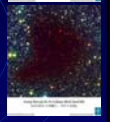
*We eat chicken, but do not end up looking like a chicken!*

Making sense Life Space Search

## Life of our Sun as a star

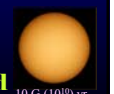
Interstellar cloud of gas and dust

Collapse
→ Fragmentation
→ Individual stars
→ A star cluster



100 M ($10^8$) yr

- ☐ Massive stars → luminous, hot, bluish color **die young**
- ☐ Low-mass stars → faint, cool, reddish color **long lived**



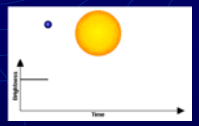
10 G ($10^{10}$) yr

Making sense Life Space Search

## Planets form around a star

Dust growth → 4.6 Ga asteroids, comets
→ coagulation *(heavy bombardment)*
→ molten Earth → Solid Earth
3.8 Ga First life prokaryote ~3.6 Ga

**Life on Earth emerged readily.**
systems (exoplanets) found so far



Solid planets as a platform for liquid chemistry *(beakers in a lab)*

Distance from the star → liquid
Circular orbit → temp. range
Size → atmosphere

*Kepler* space telescope finds transiting exoplanets

Making sense Life Space Search

## Habitable zone = liquid zone

a massive star → wide zone; lots of energy but die young


Sun-like stars are our best bet.

... hundreds of millions in the Milky Way.

a low-mass star→ narrow zone; active

Making sense Life Space Search

## Cosmic life cycle

A star ends its life when it exhausts the nuclear fuel at the center

Nuclear synthesis
→ **energy** and **complex elements**

A star like our Sun dies quietly
→ a compact corpse + an expanding nebula

A massive star dies explosively
→ shedding complex elements to space


Planetary nebula


Before the explosion


Supernova


A dying star

→ next-generation stars, planets and life



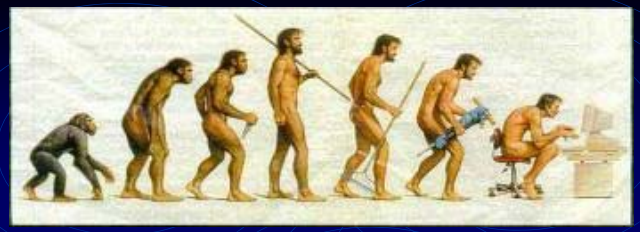
## Lessons:

*Mediocrity rules*

- Life as we know it is made of **ordinary** matter universally available.
- Terrestrial life appeared as soon as the planet became habitable.
- Liquid chemistry is advantaged. *membrane, cell wall, blood vessel, solid planets*
- Our Sun is an **ordinary** star, supplying sufficient and steady energy for billions of years for life to flourish and to develop intelligence and civilization.
- Our ecosystem relies on a star as the ultimate energy source.

**Life sustains and evolves on cosmic time scales.**



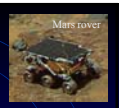


*What a journey; what a luck.*

The Earth was in a molten state in the first few hundred Myr after formation.
Life soon emerged and has undertaken an enduring evolution.



## About the Search


Mars rover

- Efforts in the solar system in vain
  *… gratifying even with microorganisms*
- Really want to go and meet in person the "little green men" *Or, do we?* *risky, dangerous, and costly … what about problems at home?*
- Current (and foreseeable future) technology
  → face-to-face contact unlikely. *… unless they come to visit us.*

→ radio contact (1) "***Hello, here we are!***" to broadcast
(2) "***Where are you?***" to listen

# Space Travel

✓ **Technology**

| | Speed | Nearest Star | Nearest Life |
|---|---|---|---|
| Jet liner | 1000 km/h | 4 Myr | 10 × ~ 1 million ×? |
| Dreamer rocket | 10% c | > 40年 | 10 × ~ 1 million ×? |

✓ **Physics**

faster → less time ... and time slows down

*(General Relativity to the rescue)*

But mass increases → difficult to speed up, and requires ever much more energy

*Location, location, location* *Energy, energy, energy!*



We are already capable of space travel, albeit not efficient, safe, or elegant enough.

- ☐ Prolonged human lifespan
- ☐ Using robots *so expect robot aliens?*
- ☐ Self-replicating Von Newman probes *around the Milky Way in 2 Myrs*
- ☐ New technology. *… and new physics*

*Where are we heading?*
*What are we doing there?*
*Who should worry about all these?*

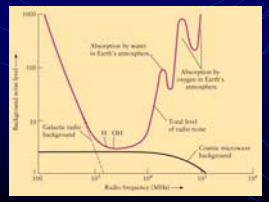


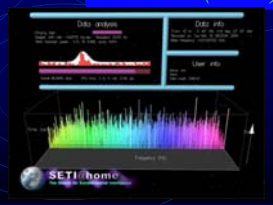
# Eavesdropping


**SETI** (Search for Extraterrestrial Intelligence)

Monitoring nearby sun-like stars, at frequencies quiet of "natural" noises (e.g., in terrestrial microwave 'window', near H and OH lines, dubbed **'water hole'**) for suspicious signals.

*intentional (beacon) or unintentional*

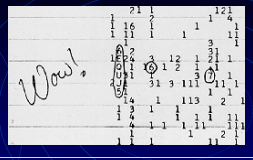




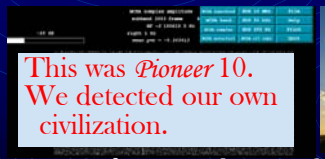



1977.08.15 --- 'Wow!' signal 6EQUJ5 origin?

Ohio State Univ. Big Ear Obs.




**Project Phoenix** started 1995.02





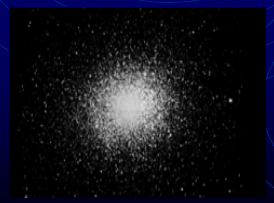

2004.03 → no evidence of ET signals after monitoring 800 nearby (< 200 ly) sun-like stars

# Let us make the call

1974.11.6
Arecibo antenna in Puerto Rico (D = 300 m)

$10^6$ W @ 2.38 GHz (width 10 Hz )

To globular cluster M13 25,000 ly away, with 300,000 old stars



*Before we ask*
*What/who/where are you?*

*We have to answer*
*What/who/where are we?*



# Arecibo message (devised by F. Drake, C. Sagan et al.)

1679 "zeros" and "ones";
transmitted at 10 bits/s; duration < 3 min

1679: a semiprime = a prime number × a prime number



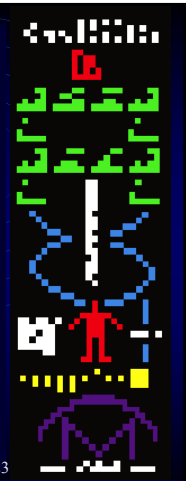
# Will they understand it?

If we receive this, will we understand it?

**Numbers of 1 to 10**

**Atomic number of key biological elements**

**Formulas for sugars and bases in nucleotides of DNA**



If … civilizations there
If … equipment sensitive

if 23 × 73 … scrabbling in 25,000 years

if 73 × 23



# All boils down to probability …

If chance of winning a lottery is 1 in 10 millionth, buying 1 ticket …. 1000, 100,000, 10 million tickets?

**Drake Equation** (1961 by Frank Drake)

$$N = N_* f_s f_p f_e f_l f_i f_c L/L_{MW}$$

- ✓ How many stars in the Milky Way …
- ✓ Among these, the fraction suitable for life (proper planets) …
- ✓ … the fraction to actually bear life …
- ✓ … the fraction to develop civilization …
- ✓ … the fraction to be communicable …
- ✓ … how long the civilization lasts
- ✓ …

More uncertain

➔ number of communicable civilization now in the Milky Way

Conditional probability … subjective …a guesstimate?

## Were they here? Are they still here?

UFO clip


*Why do they all look so much like humans?*

*Often the evidence is circumstantial.*

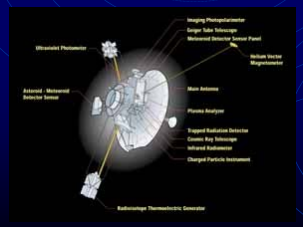
*One should not attempt to explain an unknown with another unknown.*



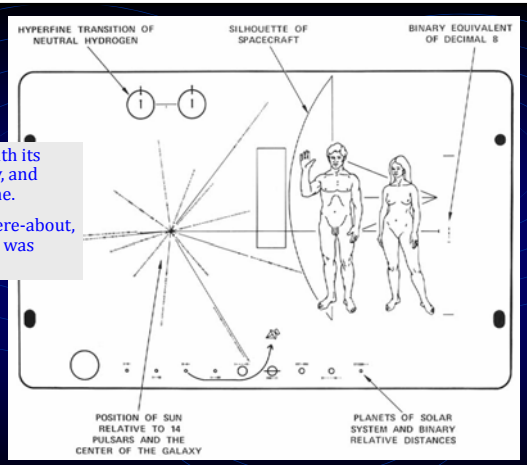
## Message out in a bottle

- Onboard *Pioneer* 10 (1972) and *Pioneer* 11 (1973) 6" × 9" (15.2 cm × 22.8 cm) plaques (0.13 cm thick) , designed by C. Sagan & F. Drake

*"Who we are, where we live, when we live, how much we know ..."*





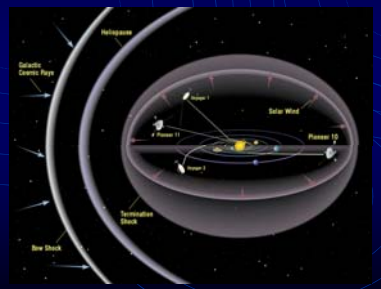



Each pulsar emits with its own pulse frequency, and slows down with time.

So this gives our where-about, and when this probe was launched.



- *Pioneer* 10 was swung by Jupiter to fly outwards, and will reach a "nearby" star toward Taurus in 100,000 years
- Will it be picked up by a civilization? Will they understand our message? Will they look for us? Will we be around when they do?



## More messages out

- *Voyager* 1 and *Voyager* 2 (late 1970s)
- 2" copper disk in an aluminum box, coated with $U^{238}$ (can be dated), containing 116 pictures, 55 languages to greet, a variety of sounds (natural or artificial) and music



If these will ever be found, and "they" are capable in grasping what we intend to convey … hopefully they will agree …

*"This came from a civilization worth contacting."*

*Do you agree?*



## Conclusions

- ✓ So far we have not found any alien life in the solar system, other than us ourselves.
- ✓ Radio contact beyond the solar system is underway. In the meantime, we ponder … *How ordinary and lucky we are to be here …*
- ✓ Life should be ubiquitous. It should therefore not be surprising if we find extraterrestrial life some day. In fact it is puzzling of not finding any. *Are we still young?*
- ✓ Science is not above everything, but scientific thinking is useful. Scientists strive to realize their imagination, and tell us what/where/how to find life, intelligence, and civilization.
- ✓ *"Learning without thinking is to be confused; thinking without learning is to be dubious." --- Confucius*

## Let the search continue … stay tuned

Chart out the new world map, now that we know us ourselves better, to look for aliens, and to look for the next home …

We may not find any even if we try hard, but sure will find nothing if we try not.

धन्यवाद्