

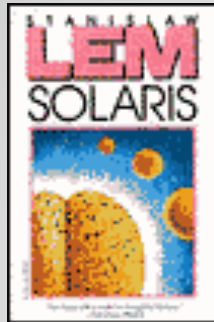
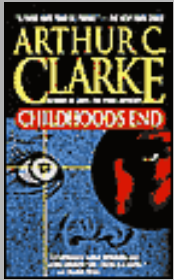


LIFE ON
OTHER
WORLDS:

ARE WE
ALONE?

STEVEN J. DICK

ET in Popular Culture





100% MASON'S
WARRANTY NO 100
NO 100% MASON'S
MASON'S



BEVANDA
CASA
CASA

OSTERIA ROMANESCA

CELESTI

PIZZERIA

PIZZERIA

PIZZERIA

PIZZERIA

PIZZERIA

PIZZERIA



Libreria Fahrenheit 451



www.fahrenheit.it



ROMA 1999

RAZIONE
Racchi Gioielli
DE ENTRANCE





The New
Frontier

The Infinite
Ocean

13.7 Billion
Years Old

45 Billion
Light Years
Radius

Hubble Ultra Deep
Field, 2004

Life in the Universe

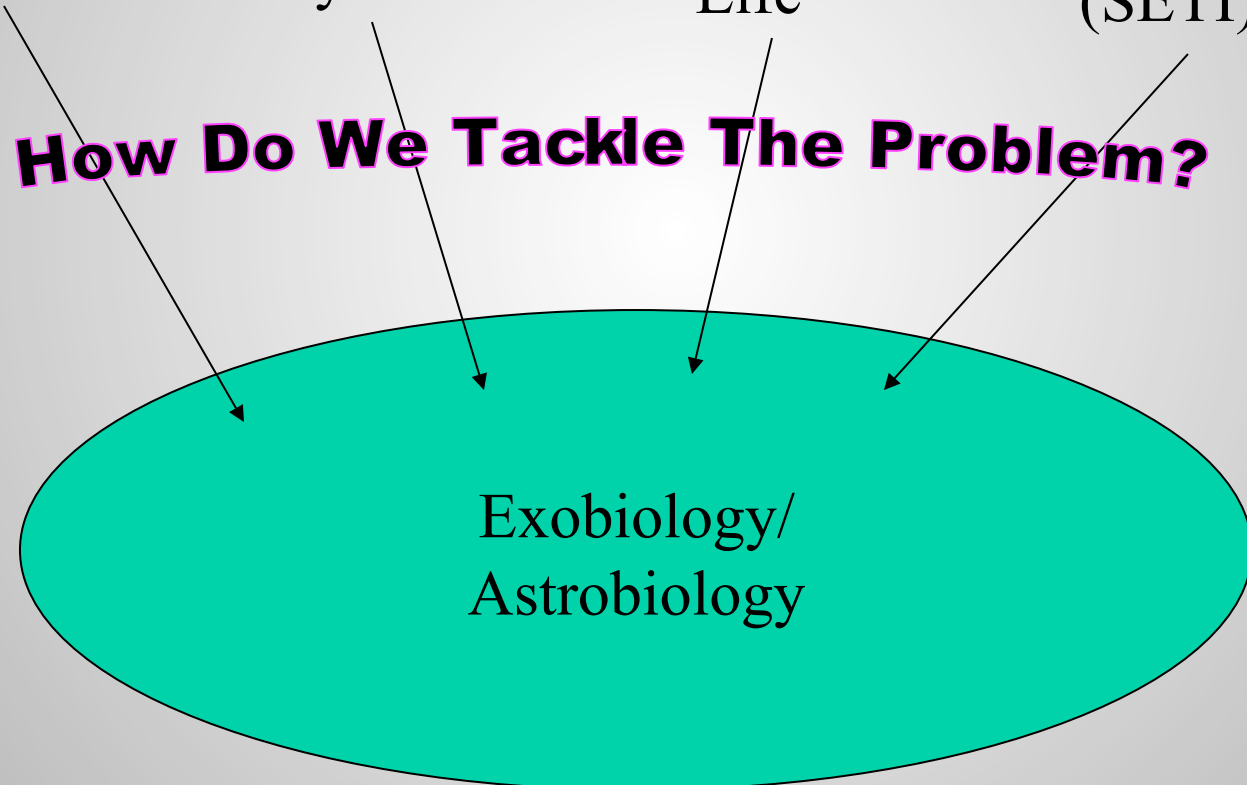
Planetary
Science

Planetary
Systems

Origins of
Life

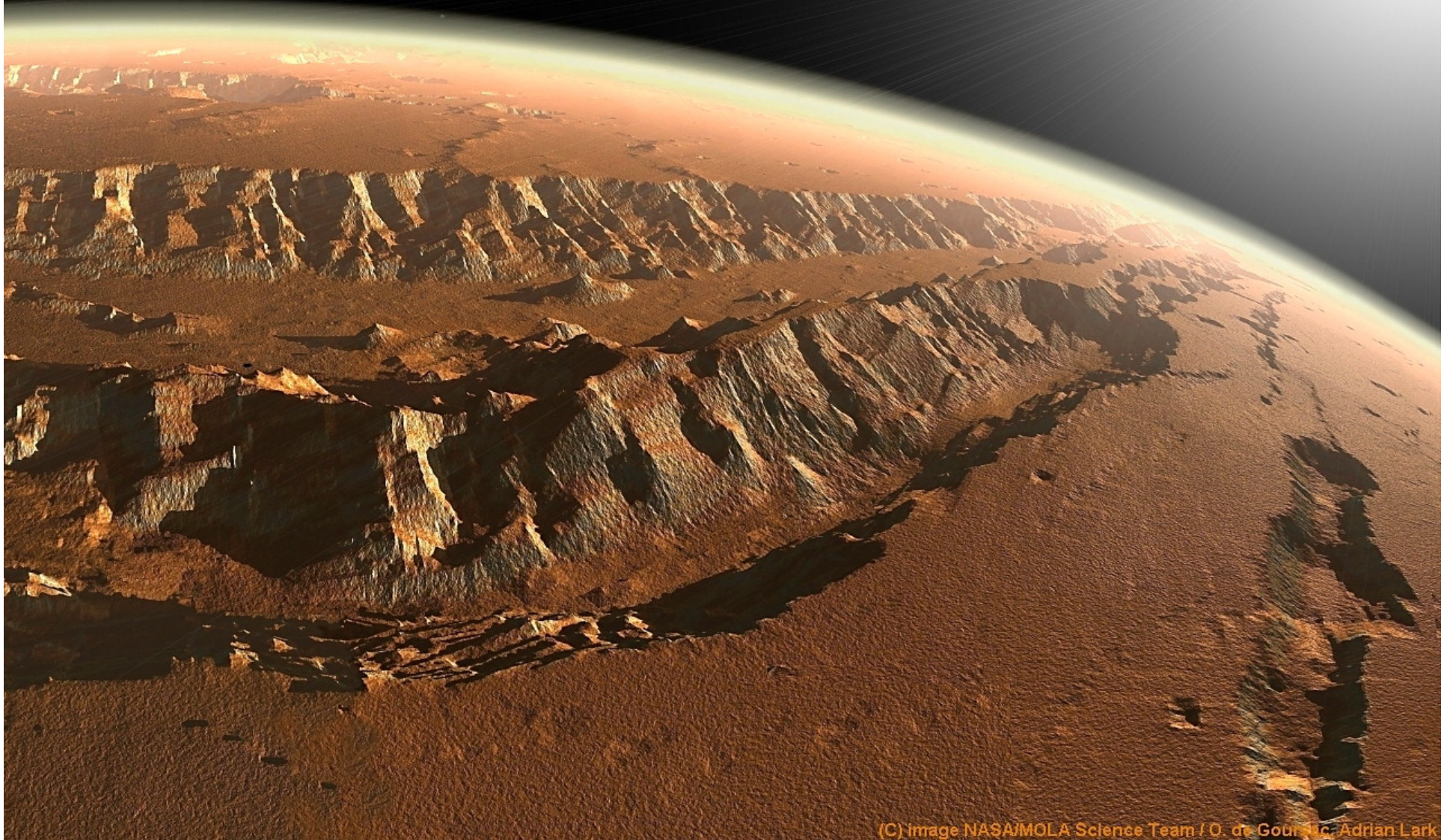
Search for
Extraterrestrial
Intelligence
(SETI)

How Do We Tackle The Problem?



Exobiology/
Astrobiology

PLANETARY SCIENCE



(C) image NASA/MOLA Science Team / O. de Goutts / C. Adrian Lark

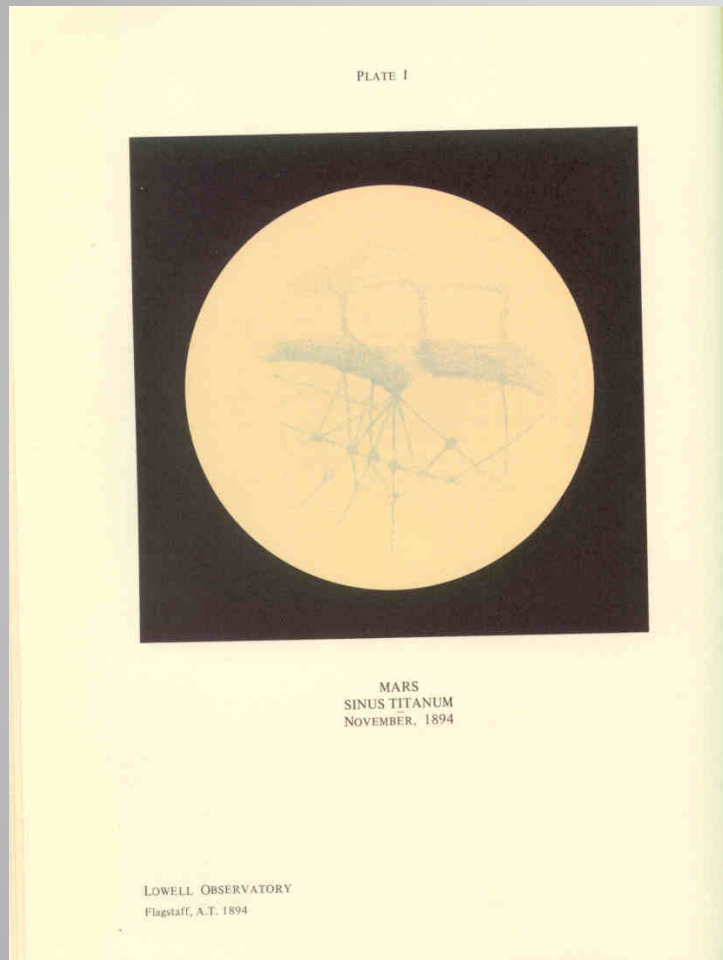
Planetary Science: The Copernican Foundation



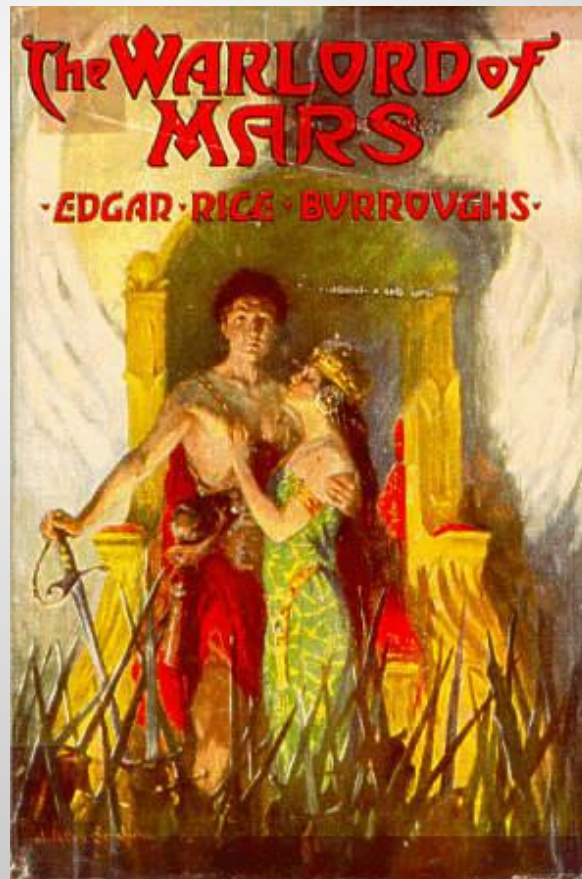
John Wilkins, *Discourse Concerning a new World And Another Planet* (1640)

The Moon and the planets
Are potential Earth-like worlds

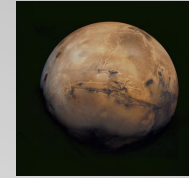
Evidence of Life on Mars, 1894



Canals on Mars?
Percival Lowell,
Mars (1894)

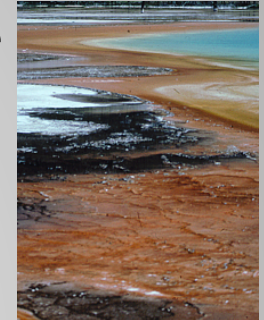


Why Focus on Mars?



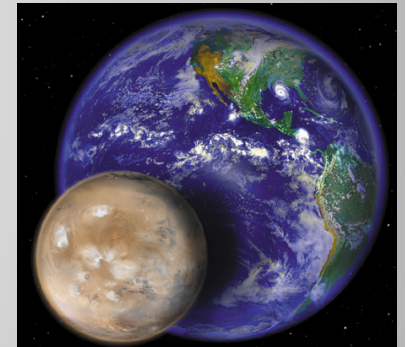
Mars is the nearest planet for which the search for evidence of Life is justified:

- Earliest Mars preserves record of conditions and materials from which LIFE could have started on Mars or on Earth
- Even today there are places on Mars that are “habitable”



Mars is much like Earth, yet surprisingly different

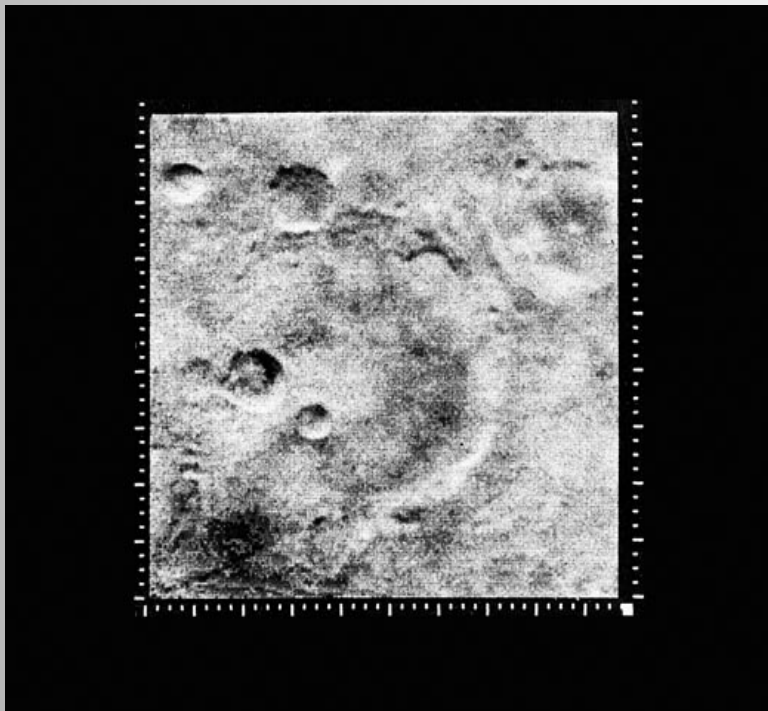
- Silicate planet with an atmosphere, hydrosphere, and climate
- Potentially allows for comparative climatology with Earth
- Natural “control experiment” for key state variables



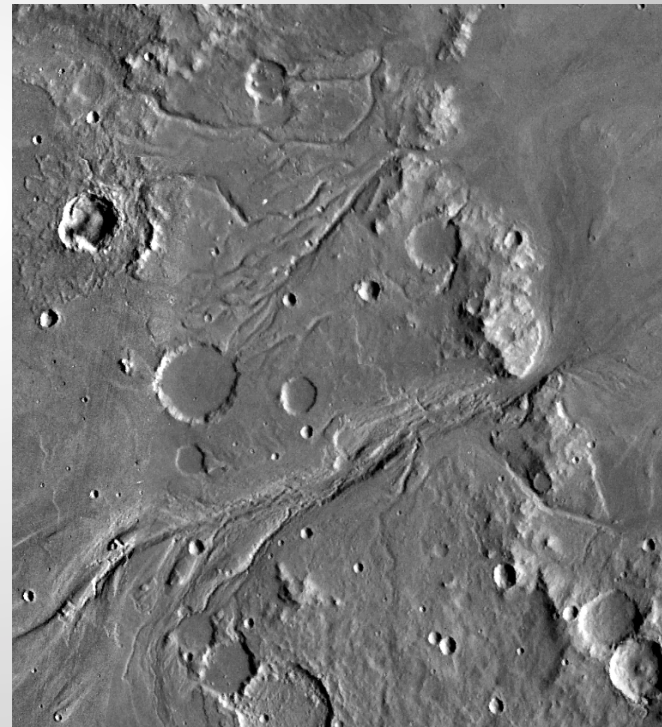
Mars inspires, both scientifically, and as a tangible frontier

Mars: Dead or Alive?

- **Mariner 4 reaches Mars, 1965 - craters on Mars – dead planet?**
- **Mariner 9 reaches Mars, 1971 - dry riverbeds on Mars – life?**



First close-up image of Mars,
Mariner 4, July 15, 1965
Range 17,000 km



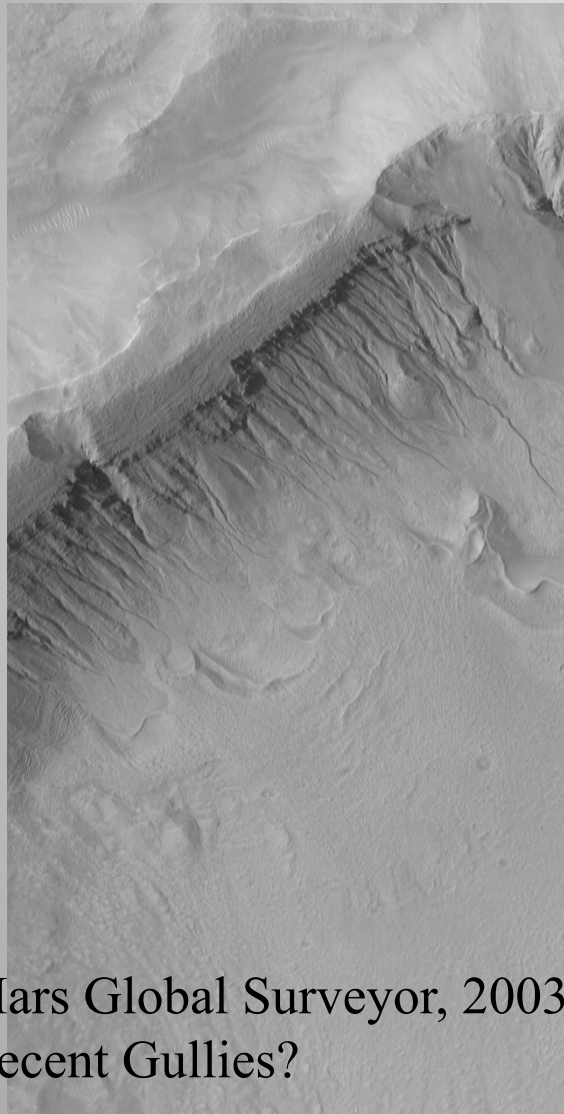
Mariner 9 image
225 km across

Viking Landers, 1976

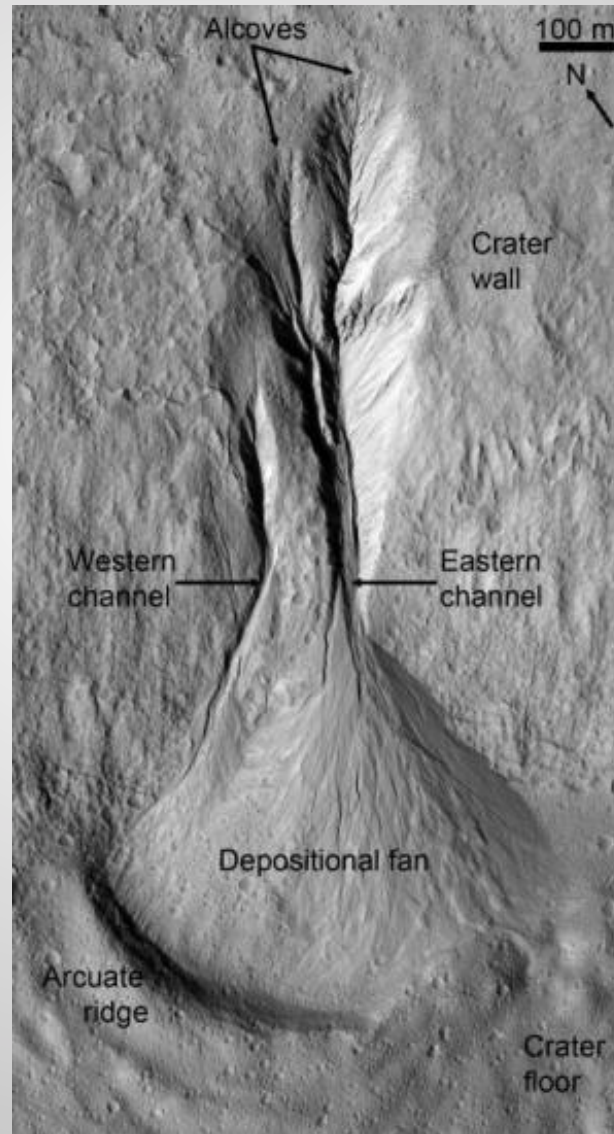


Results: No Organic Molecules found on Mars down to
Parts Per Billion – No organic molecules = No Life on Mars
BUT: Viking Orbiters found huge Dry River Valleys
AND: Recent Chris McKay et al experiments with perchlorate

GULLIES on Mars: Evidence of Water?



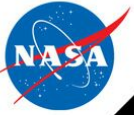
Mars Global Surveyor, 2003:
Recent Gullies?



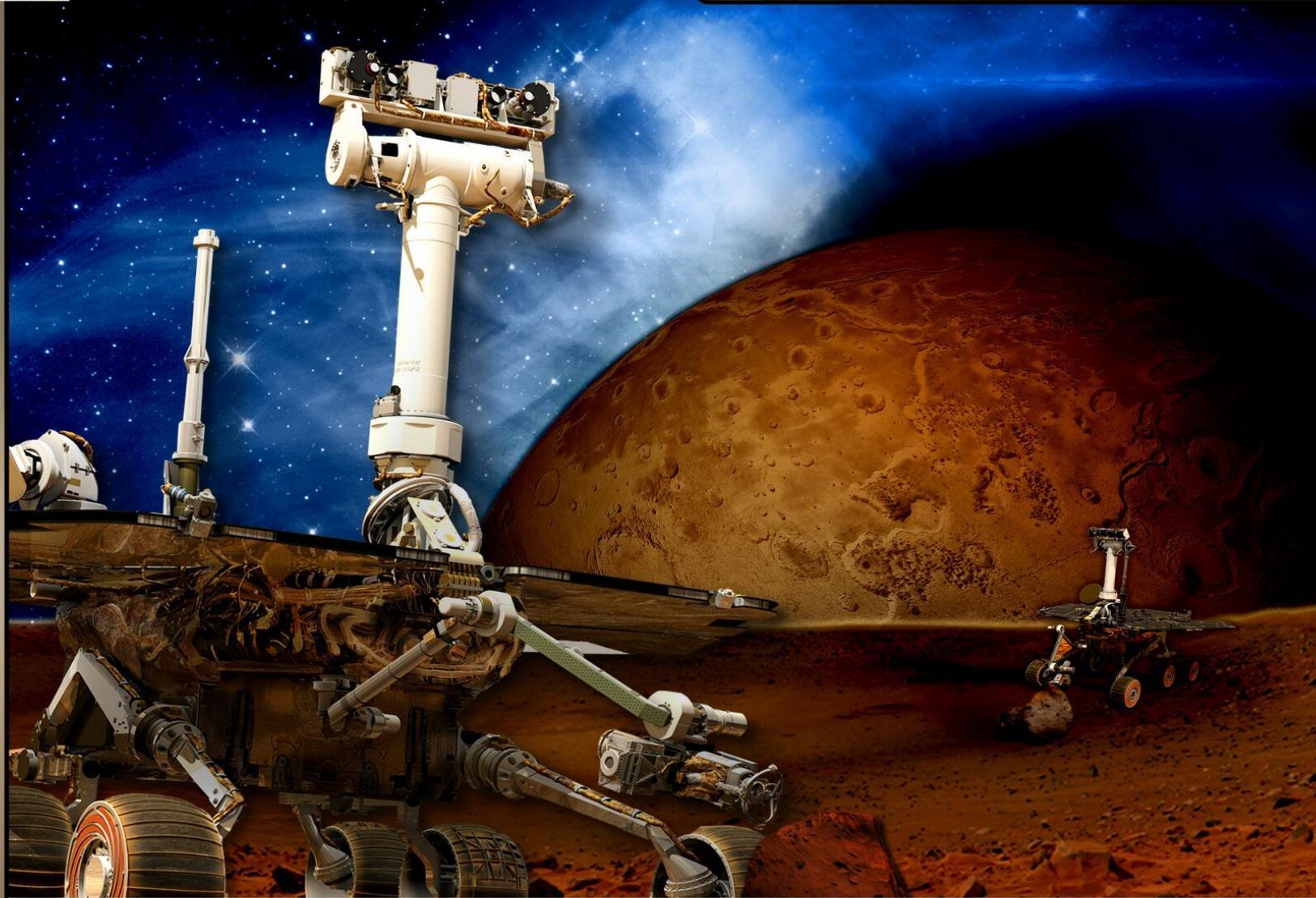
Mars
Reconnaissance
Orbiter, 2009

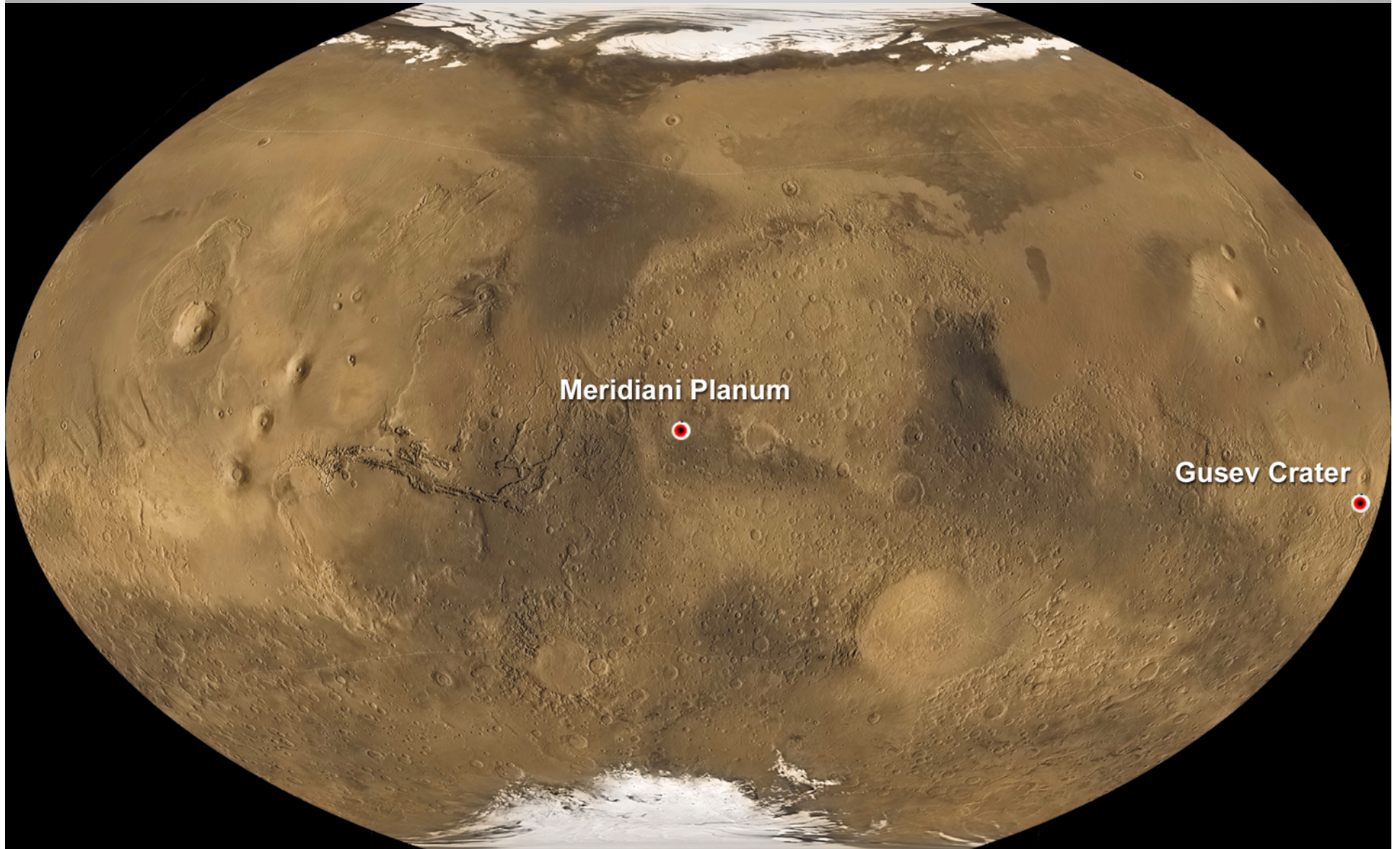
Gullies
Formed
1.25 Million
Years ago

The Voyages of the MER Twins...continue...



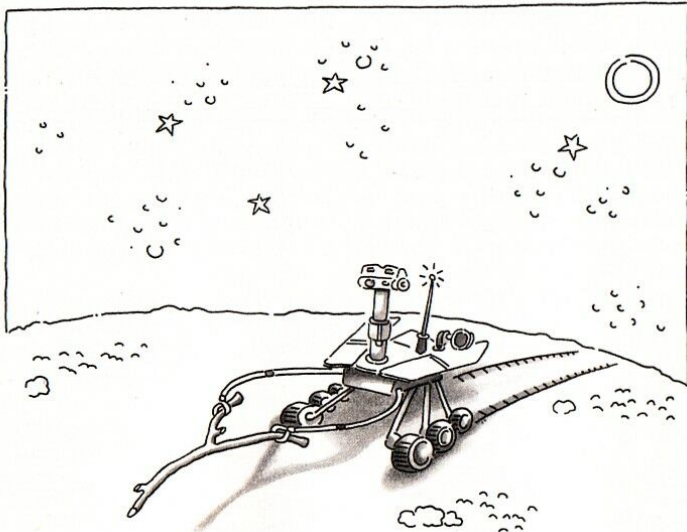
SPIRIT AND OPPORTUNITY ON THE RED PLANET





Where we landed... And are exploring a new world...

Mars Strategy: Follow the Water

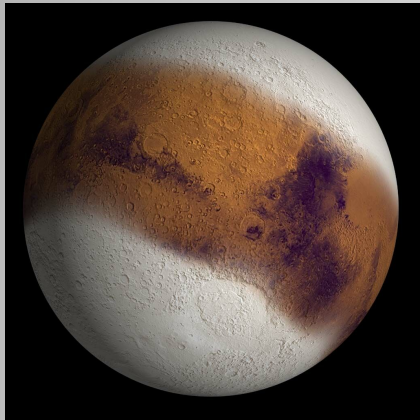


New Yorker
Magazine

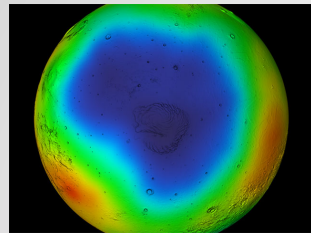


“Blueberries” = Hematite = Past Water

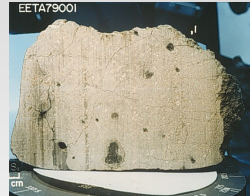
Plenty of Evidence For Past Water on Mars But ... No Evidence for Life (Yet)



Climate Change
Seasonal H₂O₂ variation



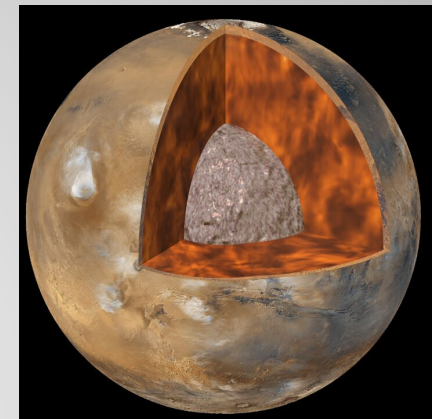
Polar icy soils



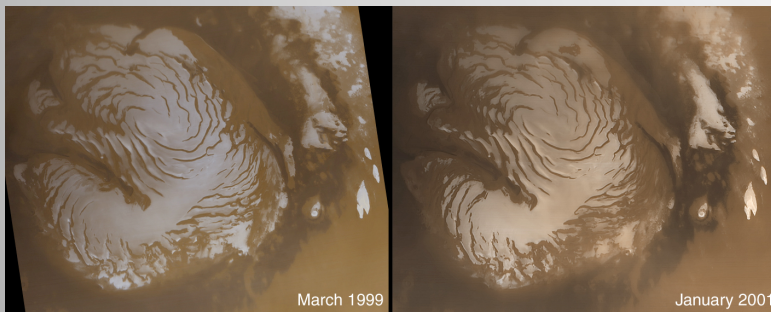
Water in meteorites



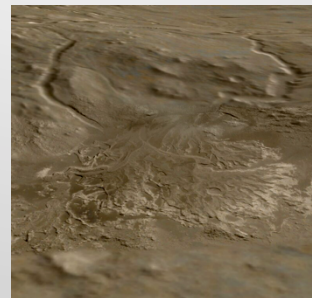
Water ice at surface



State of Martian core?



Inter-annual climate variability on Mars

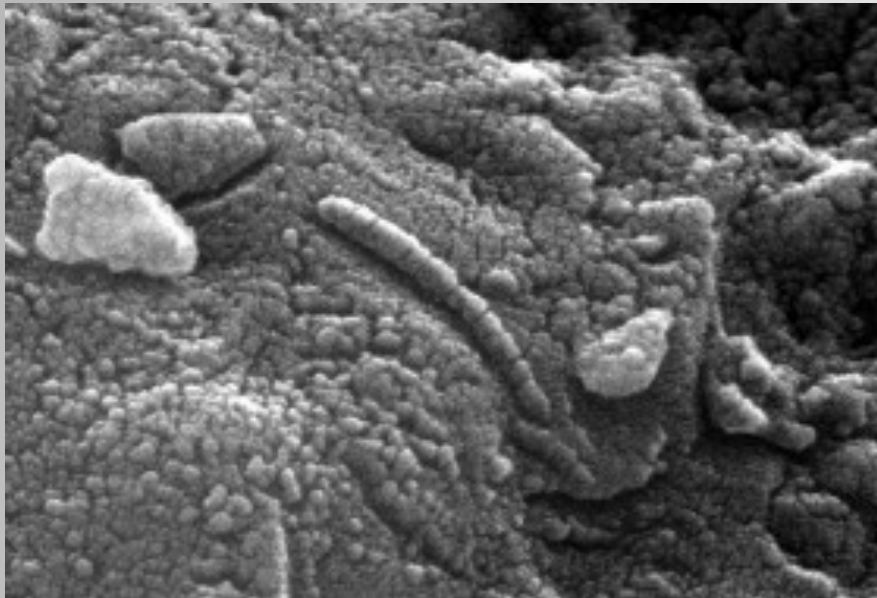


Martian delta:
Standing H₂O bodies?



Water-lain rocks : *Opportunity*

The Mars Rock

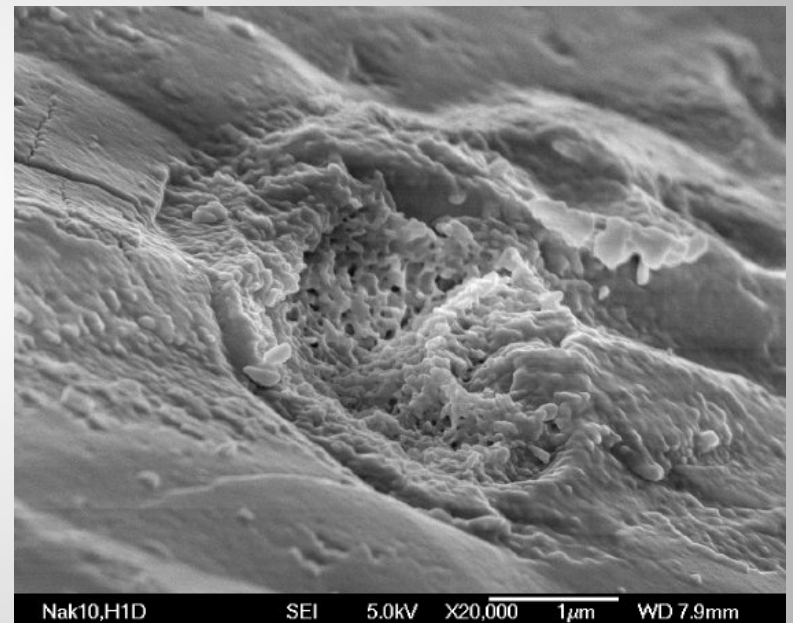


1996 -- Mars Rock fossils?
ALH 84001

D. McKay,
K. Thomas-Keprta, R. Zare

Malin Space Science Systems, MGS,
JPL, NASA

Back In
The News



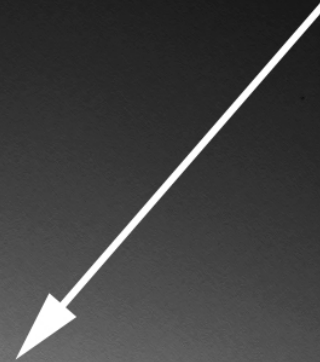
2010 – Biomorphs = mini- fossils?

The Media Will Keep Us Up-To-Date ...

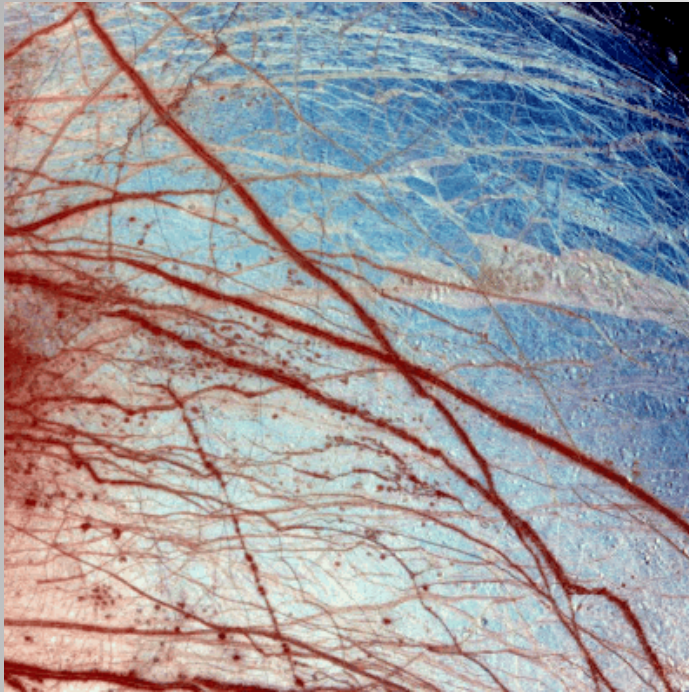


A Long Way from HOME

You are here



Other Solar System Habitats: Oceans of Europa



Cracked Ice Plains of Europa
Galileo Project, JPL, NASA

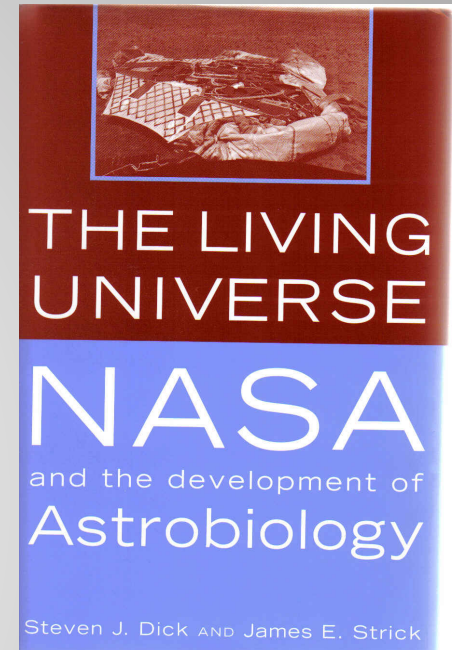
Malin Space Science Systems, MGS,
JPL, NASA

- 1,900 miles in diameter – slightly smaller than the Moon
- Thick layer of ice – a few miles?
- Tidally generated heat
- Liquid ocean beneath ice – salty?
- An abode for life?
- “Drill Baby Drill!”

NASA and the Post-Viking Revolutions

Exobiology Program Funded:

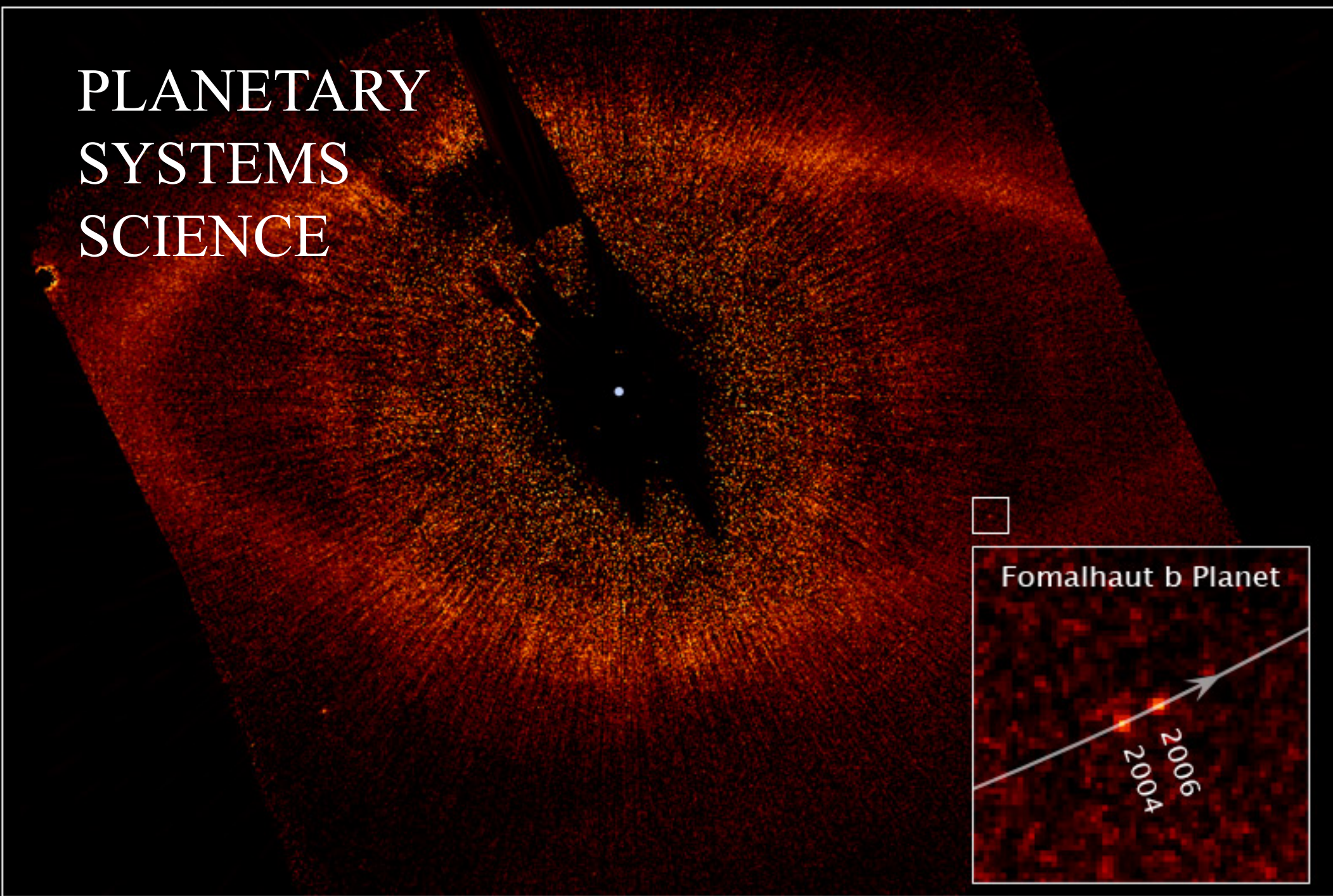
- ❖ Three Domains of life Research (Woese)
- ❖ Precambrian microfossils (Barghoorn and Schof)
- ❖ Gaia hypothesis (Lovelock and Margulis)
- ❖ Mass extinction work (Alvarez, Raup and Sepkoski)
- ❖ Exogenous Delivery (Sagan and Chyba)
- ❖ Pre-RNA world (Miller/NSCORT group)



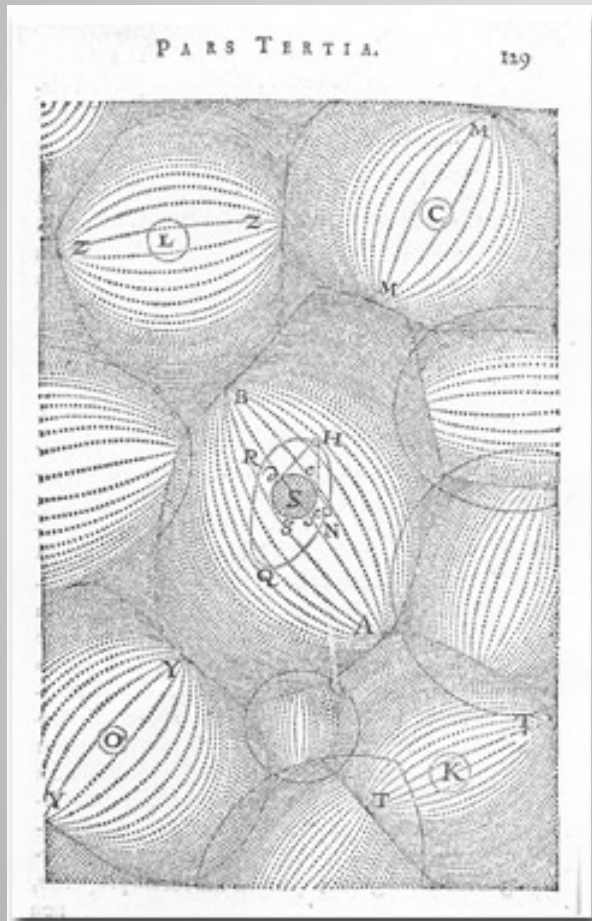


50th Anniversary of NASA Exobiology
October 14, 2010

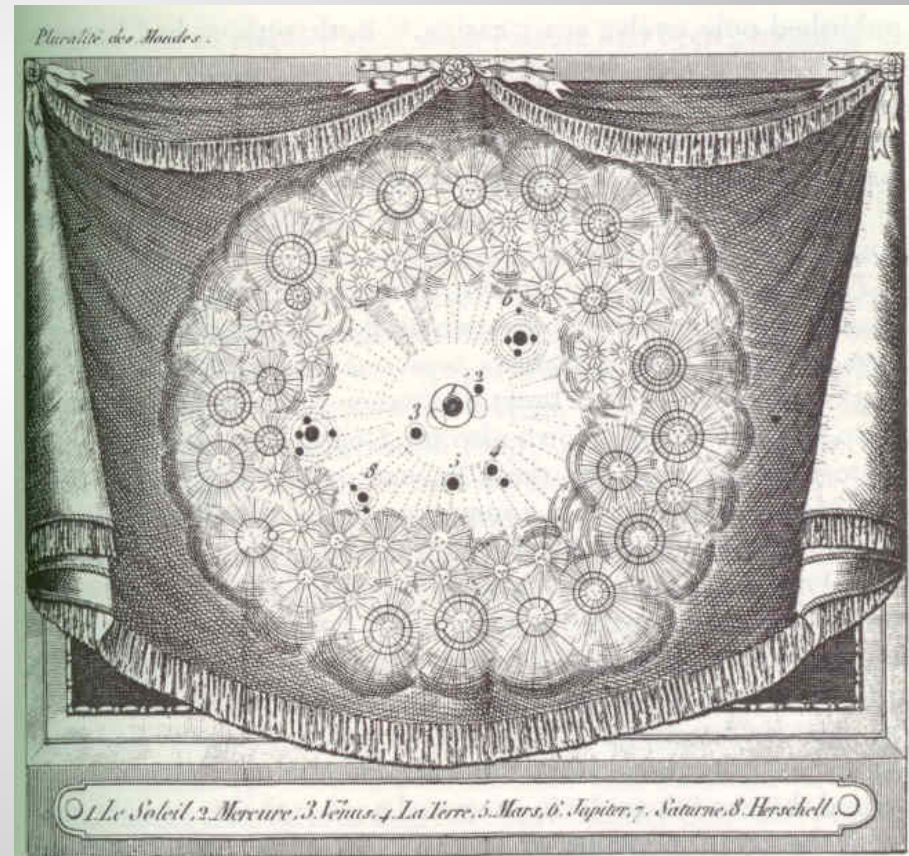
PLANETARY
SYSTEMS
SCIENCE



Planetary Systems – The 17th Century Foundation

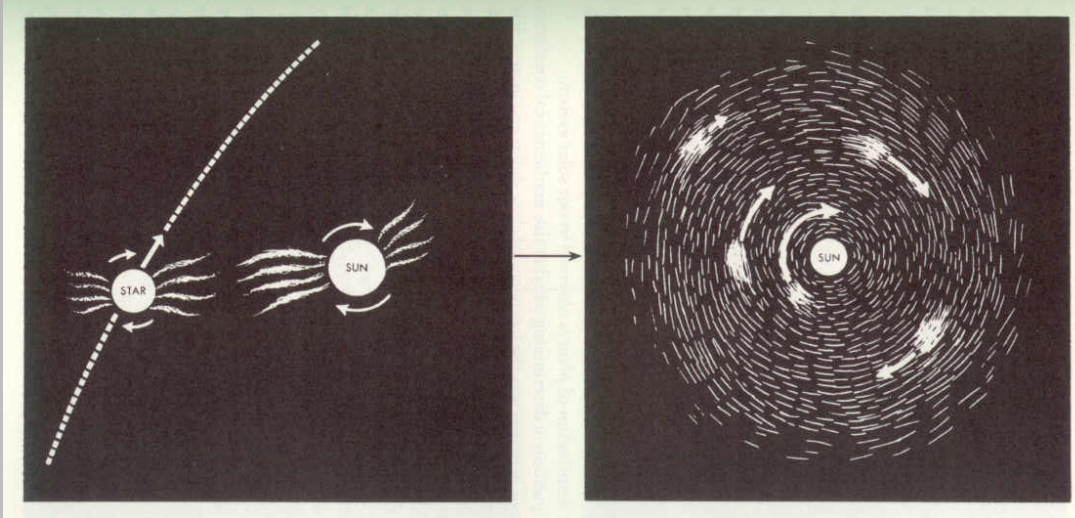


Descartes, 1644

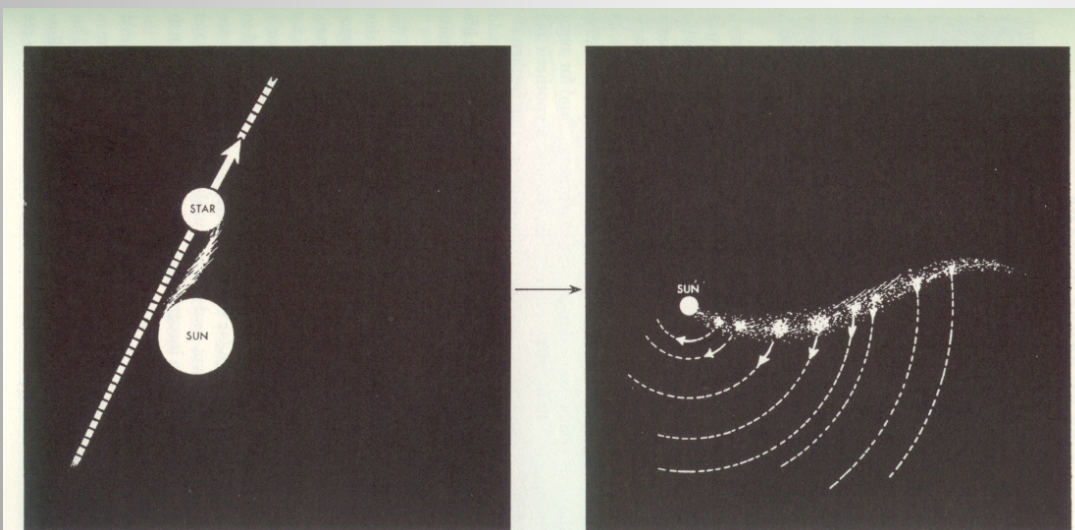


Fontenelle, 1686 (1821 ed.)

Tidal Hypothesis vs Nebular Hypothesis



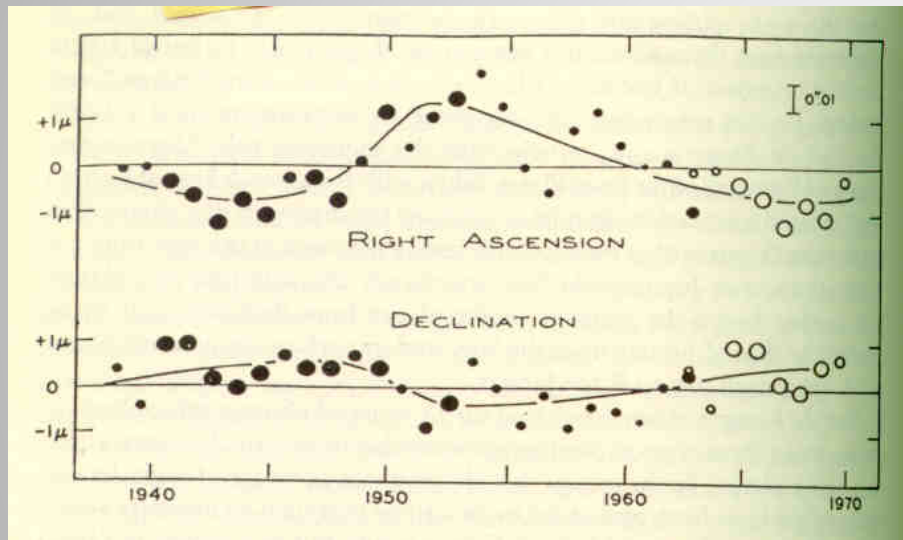
Chamberlin-Moulton
(1905)



Jeans-Jeffreys
(1917)

From Thornton Page,
Physics Today (October, 1948)

Van de Kamp's Claim



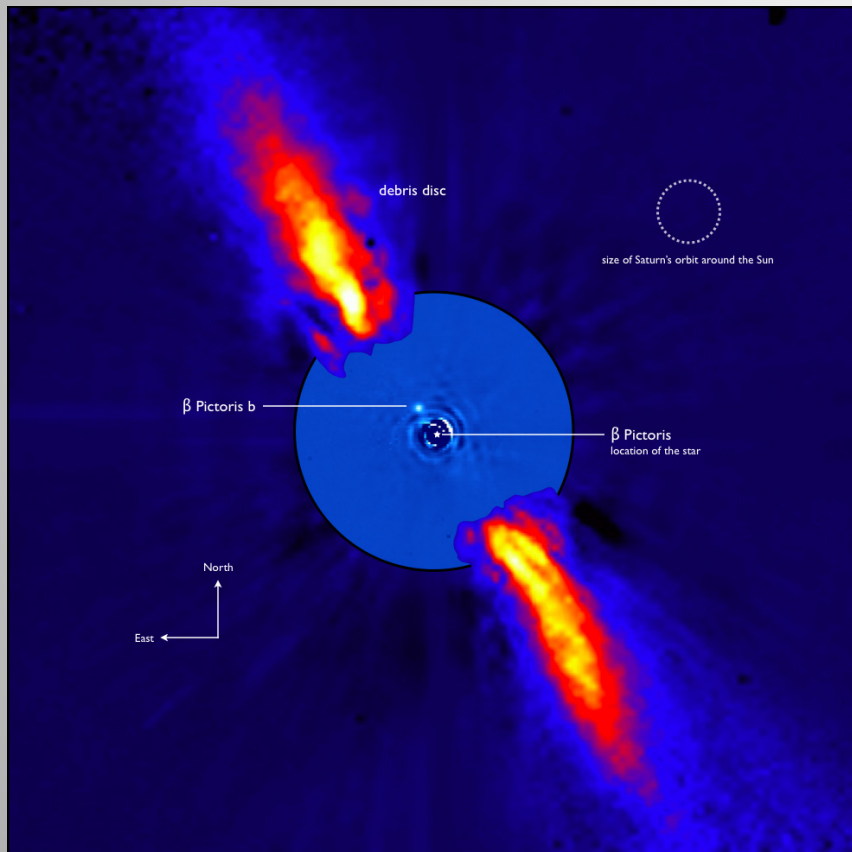
“Another Solar System Is Found
36 Trillion Miles From the Sun”

New York Times,
Friday, April 19, 1963

Motion of Barnard's star

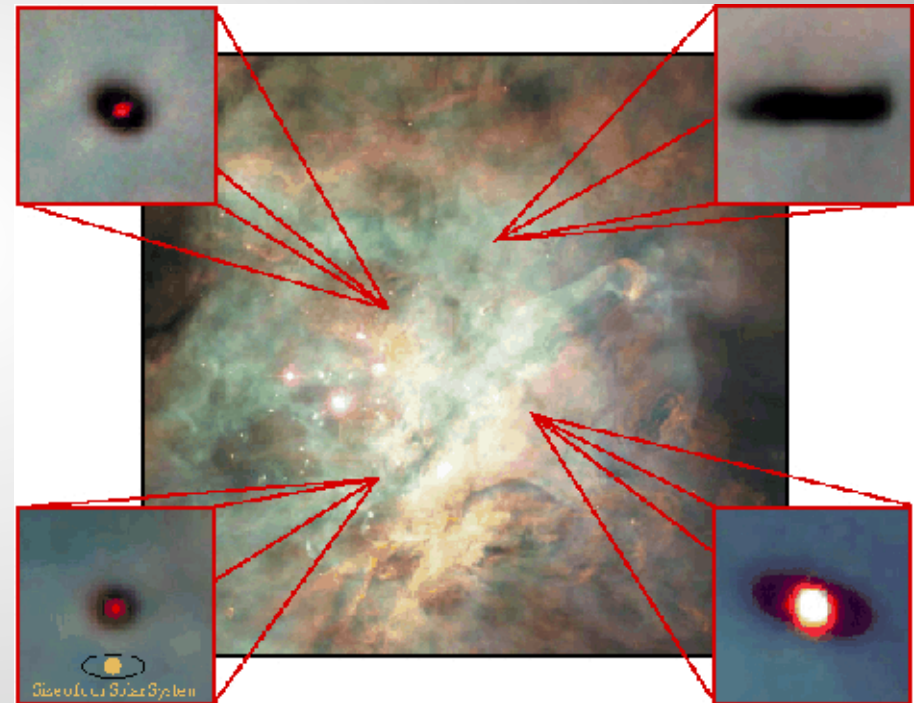
Circumstellar disks – 1980s/1990s

Beta Pictoris



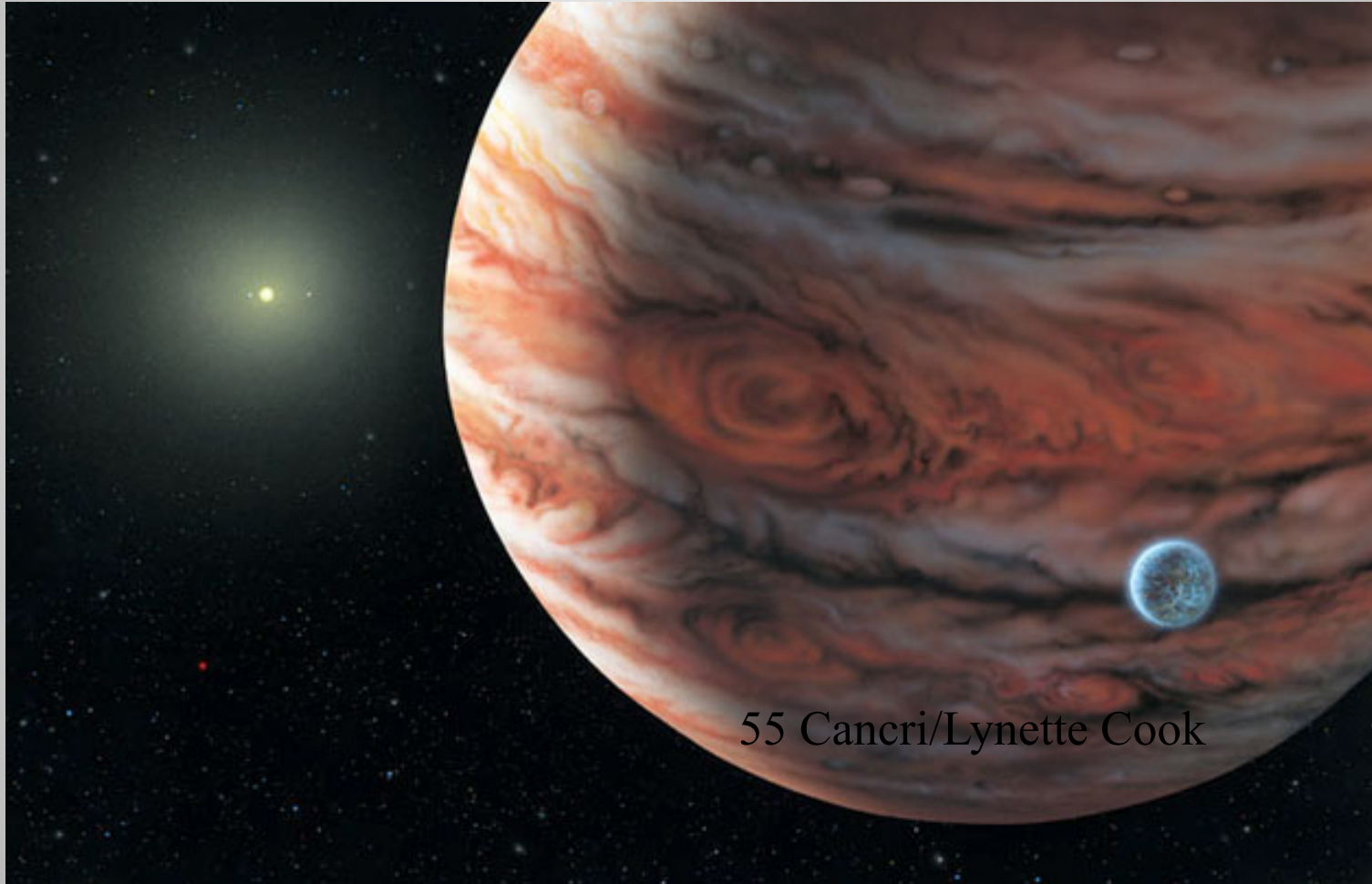
A. M. Lagrange et al. (Grenoble Obs.), ESO

Proplyds in Orion Nebula



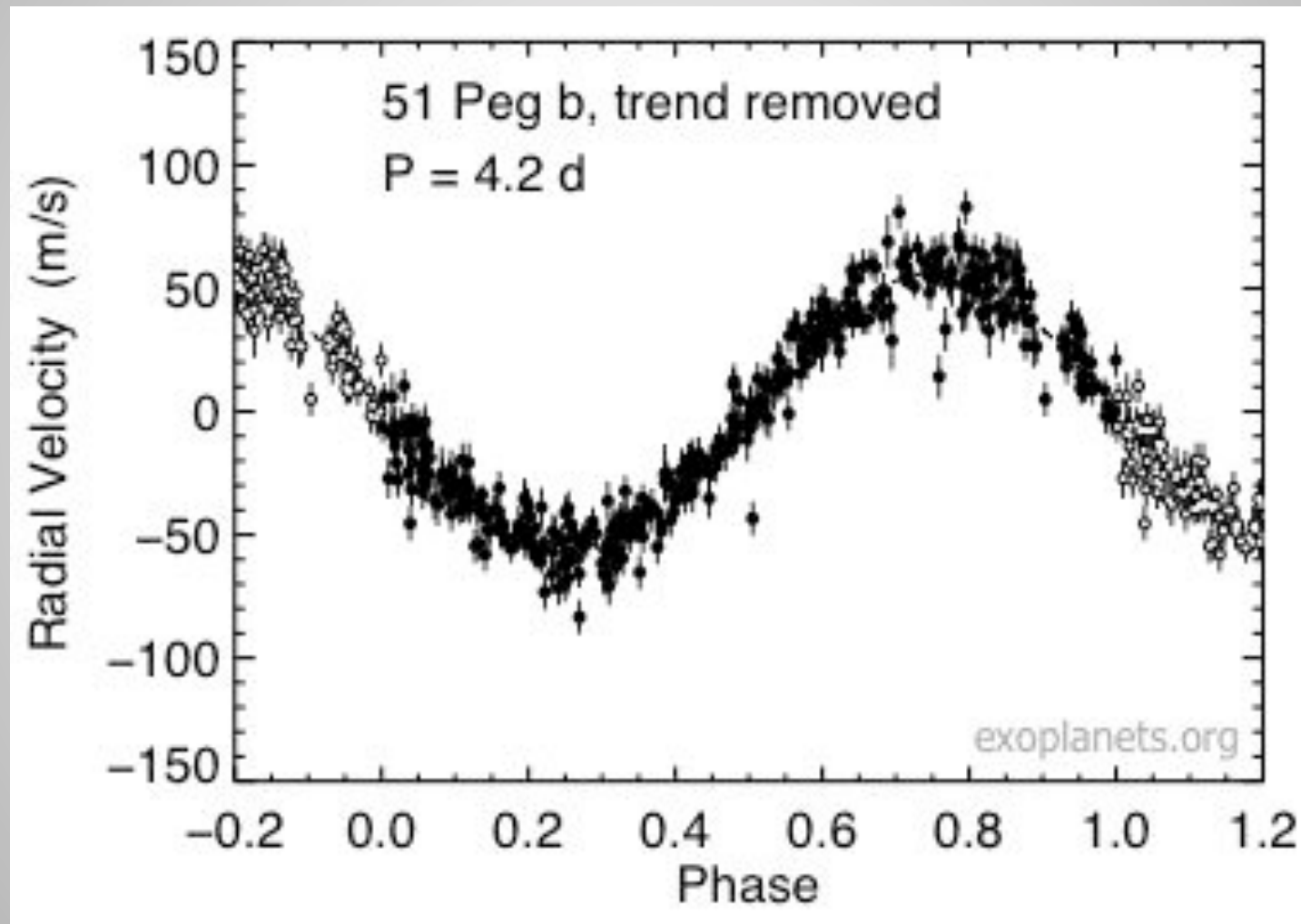
C. R. O'Dell and S. K. Wong, Rice U., WFPC2, HST, NASA

Real Planets! - 1995

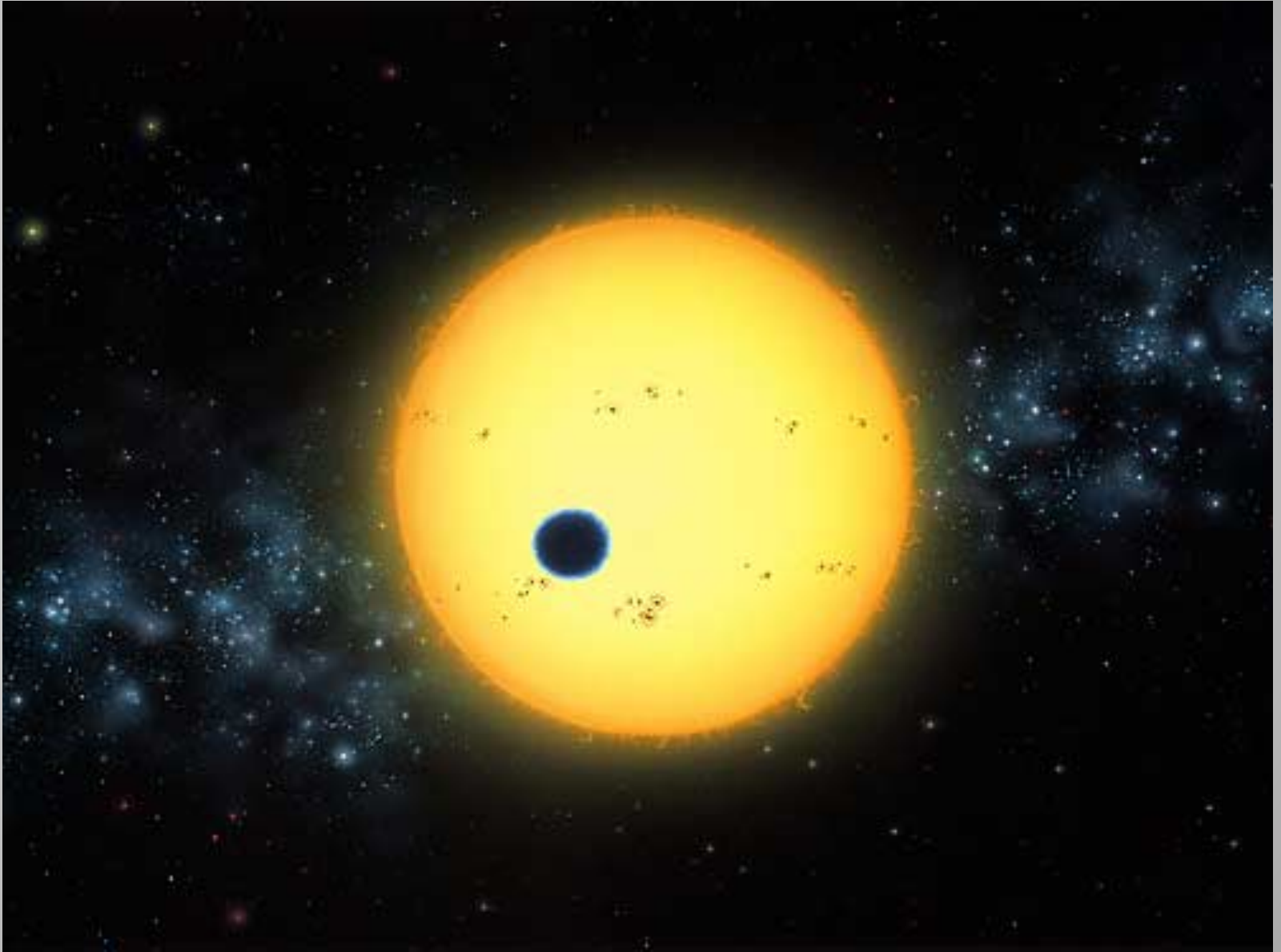


55 Cancri/Lynette Cook

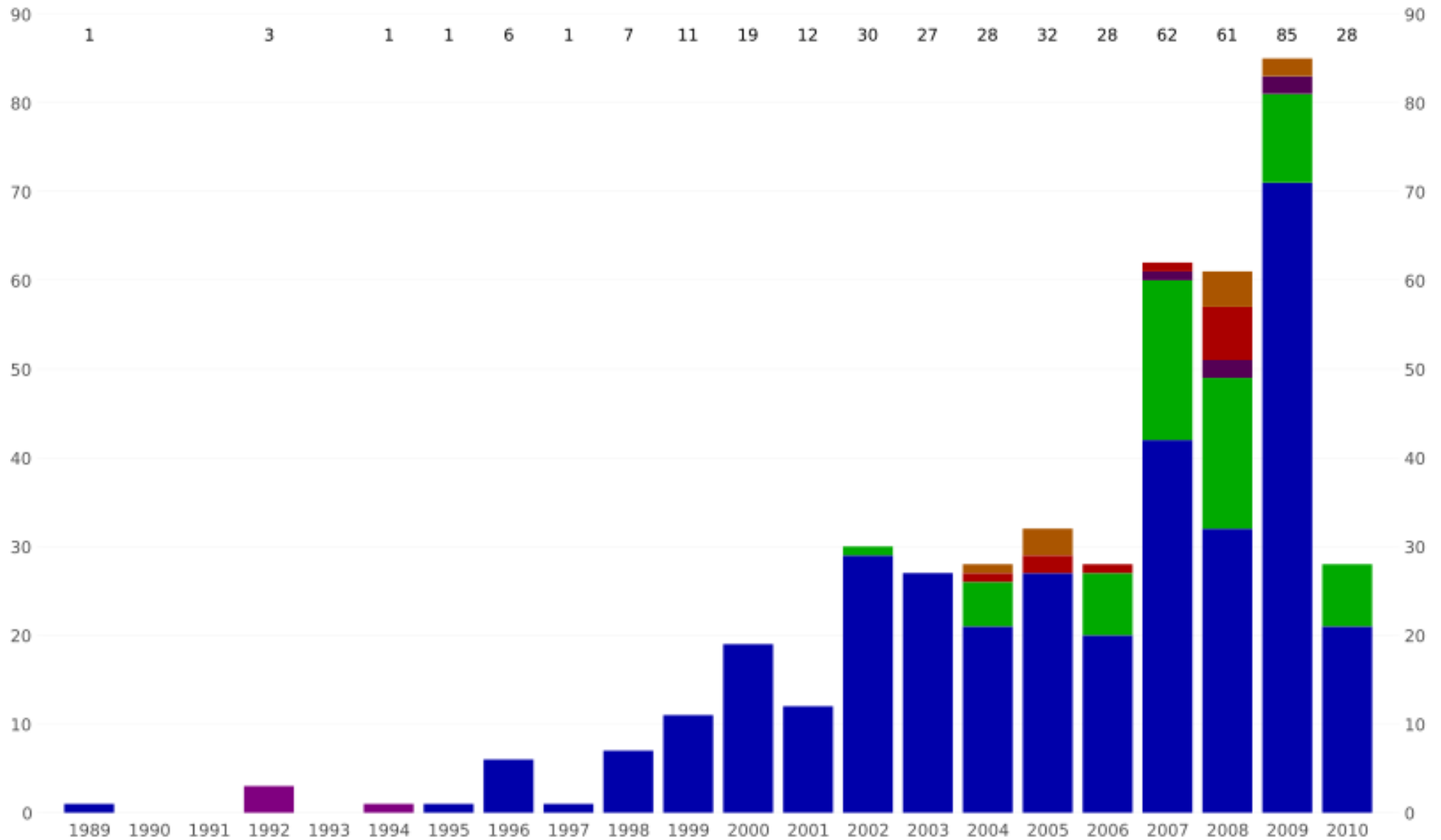
51 Peg – First Planet Around Solar-Type Star



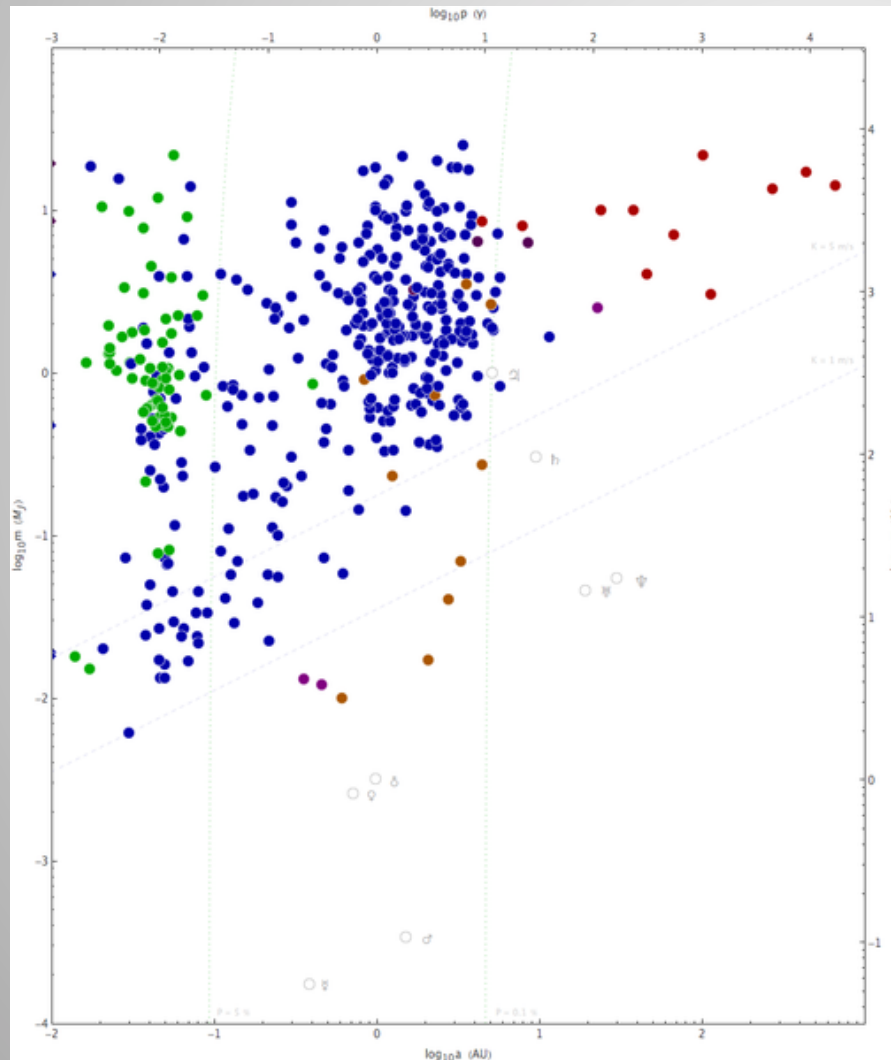
Photometry – Another Method



Discovery of Extrasolar Planets



DISCOVERY METHODS FOR EXTRASOLAR PLANETS

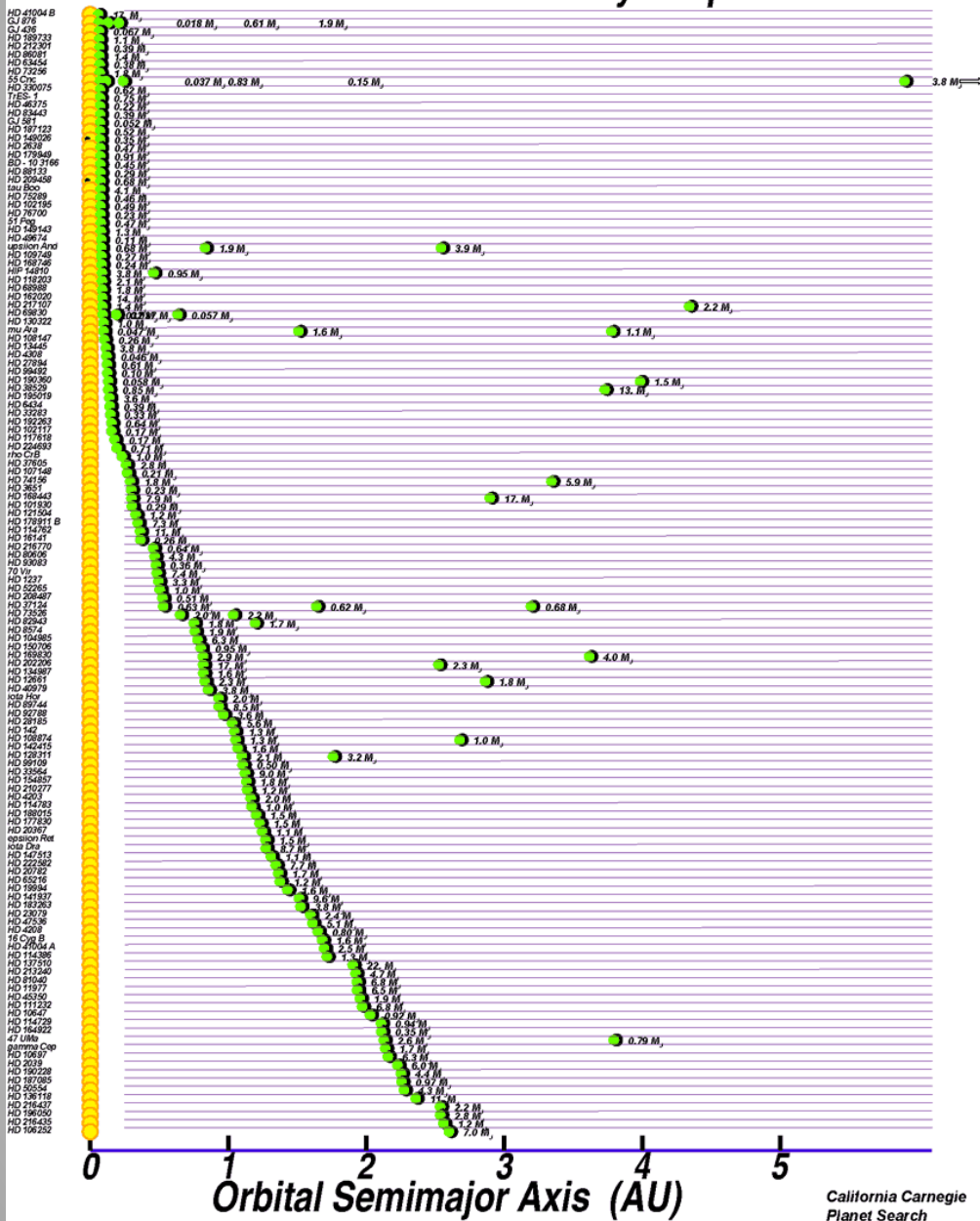


- Blue = Radial Velocity
- Green = Transit
- Red = direct visual
- Gray – planets in our SS

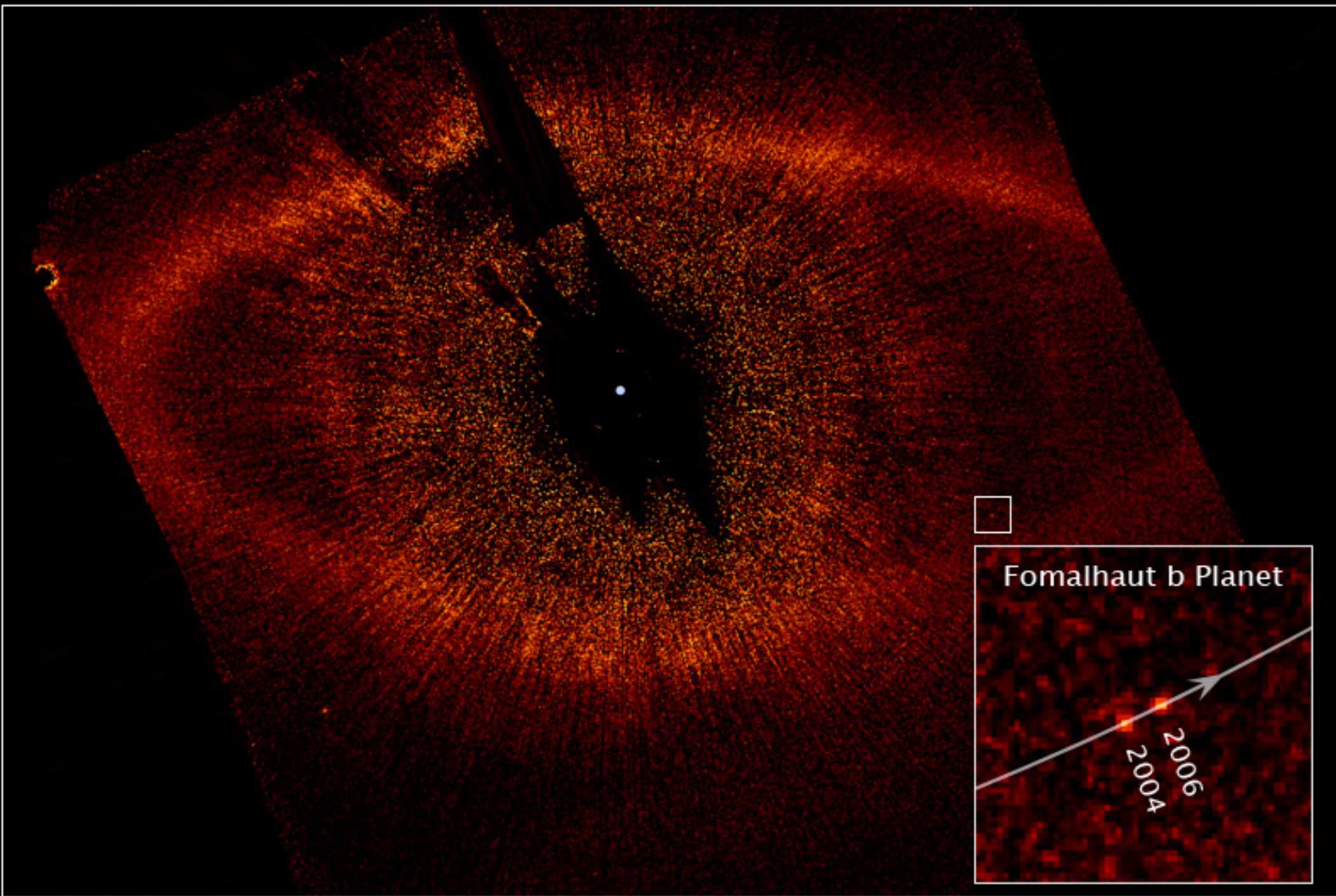
Vertical axis = mass

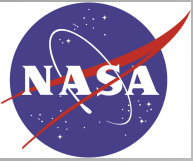
Horizontal axis = distance from
parent star

The 178 Known Nearby Exoplanets



- PREDOMINANCE OF “HOT JUPITERS” CLOSE TO PARENT STAR
- SOME SYSTEMS DETECTED

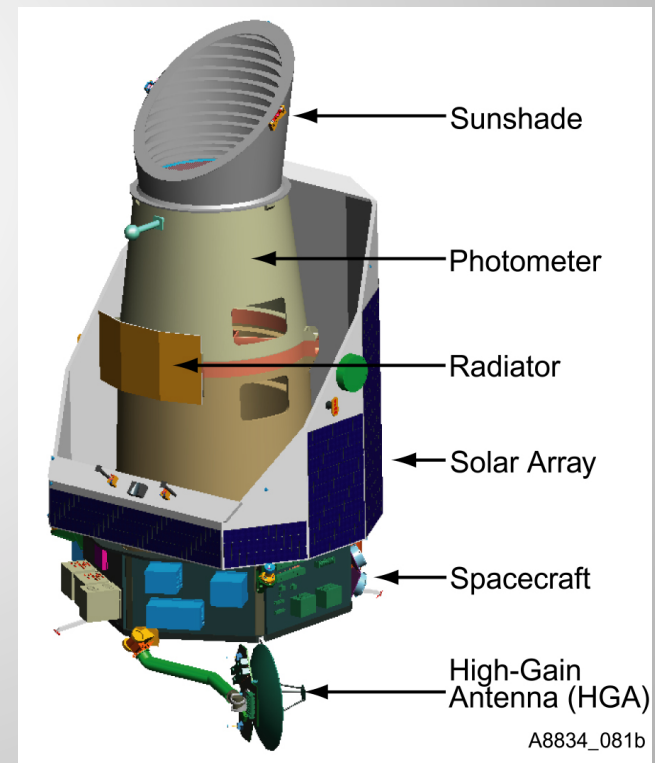
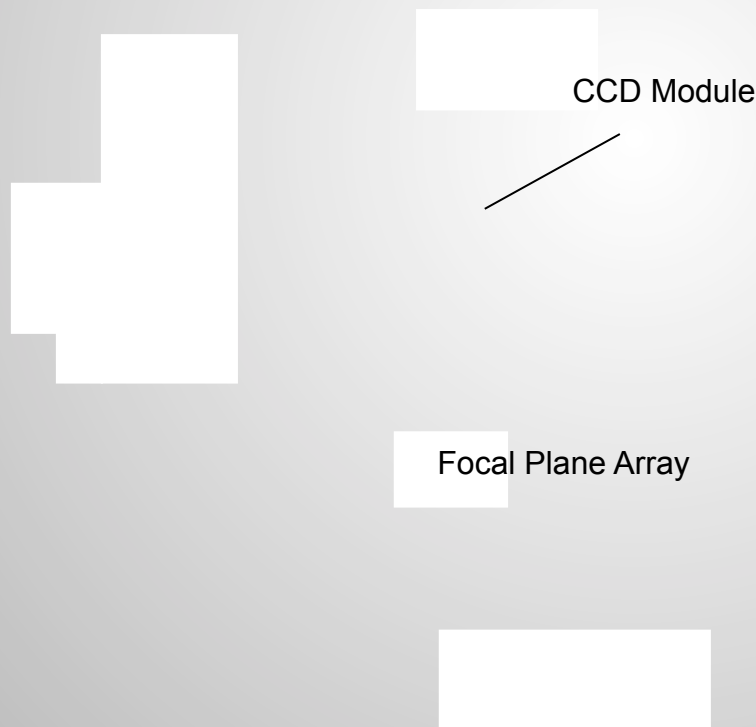




The *Kepler* Mission

Use transit photometry to detect Earth-size planets

- Wide field-of-view 0.95-meter (3-foot) diameter telescope
- Monitor 100,000 stars (every 15 minutes) for 4 years
- Enough precision (20 ppm) to detect transits of Earth-size planets
- Launches 2007



21 CCD Modules are the Heart of the Kepler Mission

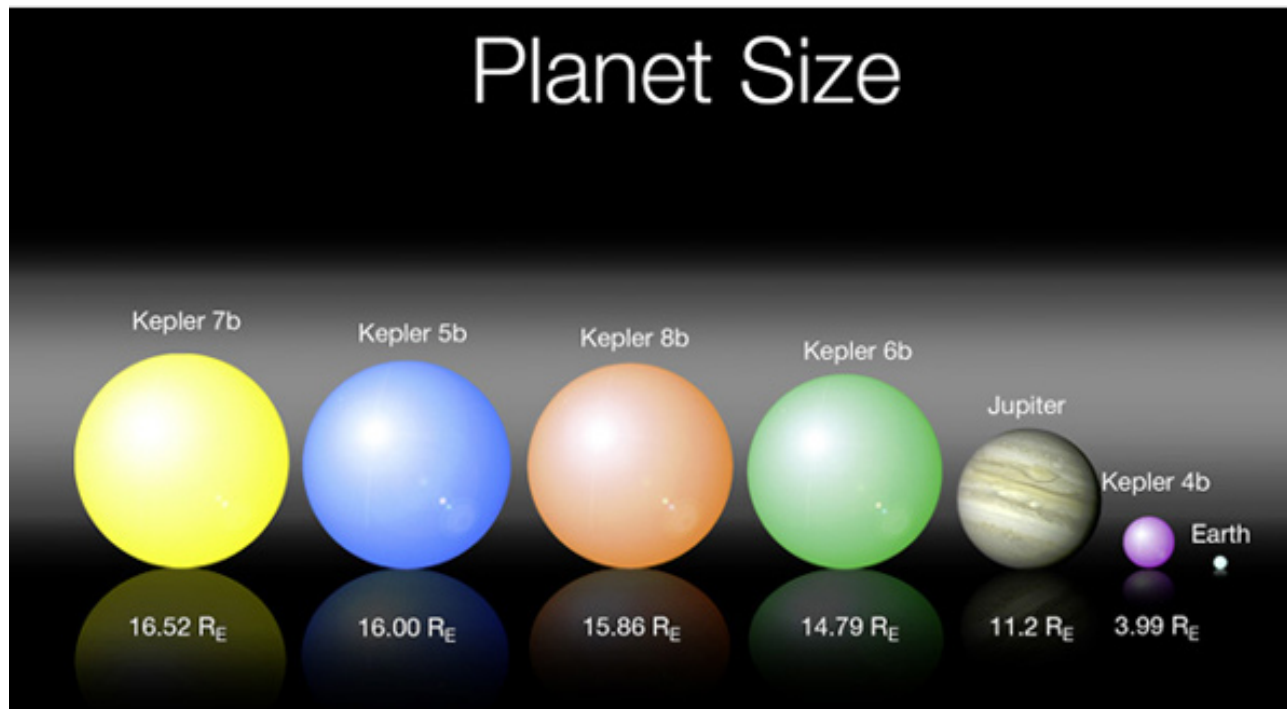
Kepler Mission First Results – 2010

- All hotter than molten lava

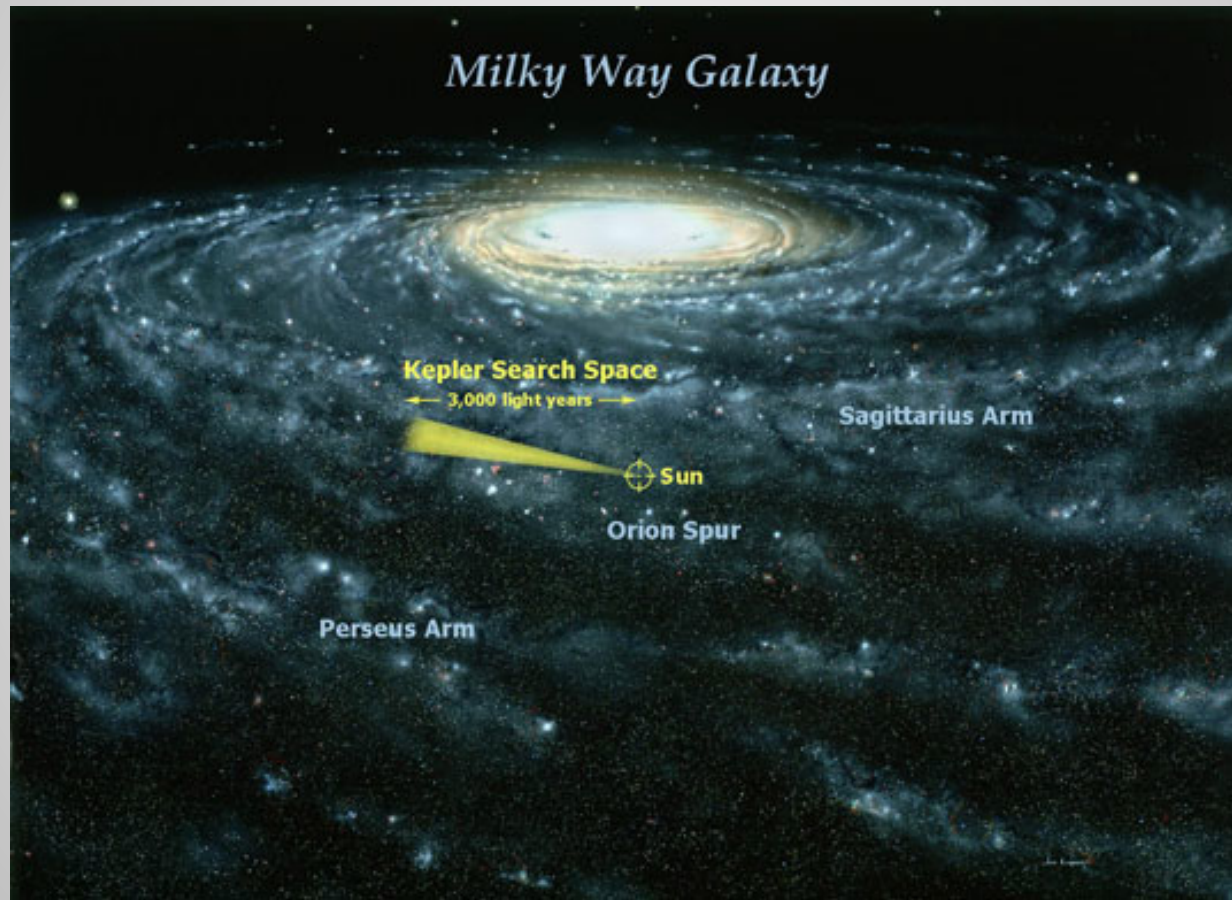
- Kepler 4b is 4 times diameter of Earth

- Kepler 7b is a “styrofoam planet” 1/10 as dense as Jupiter!

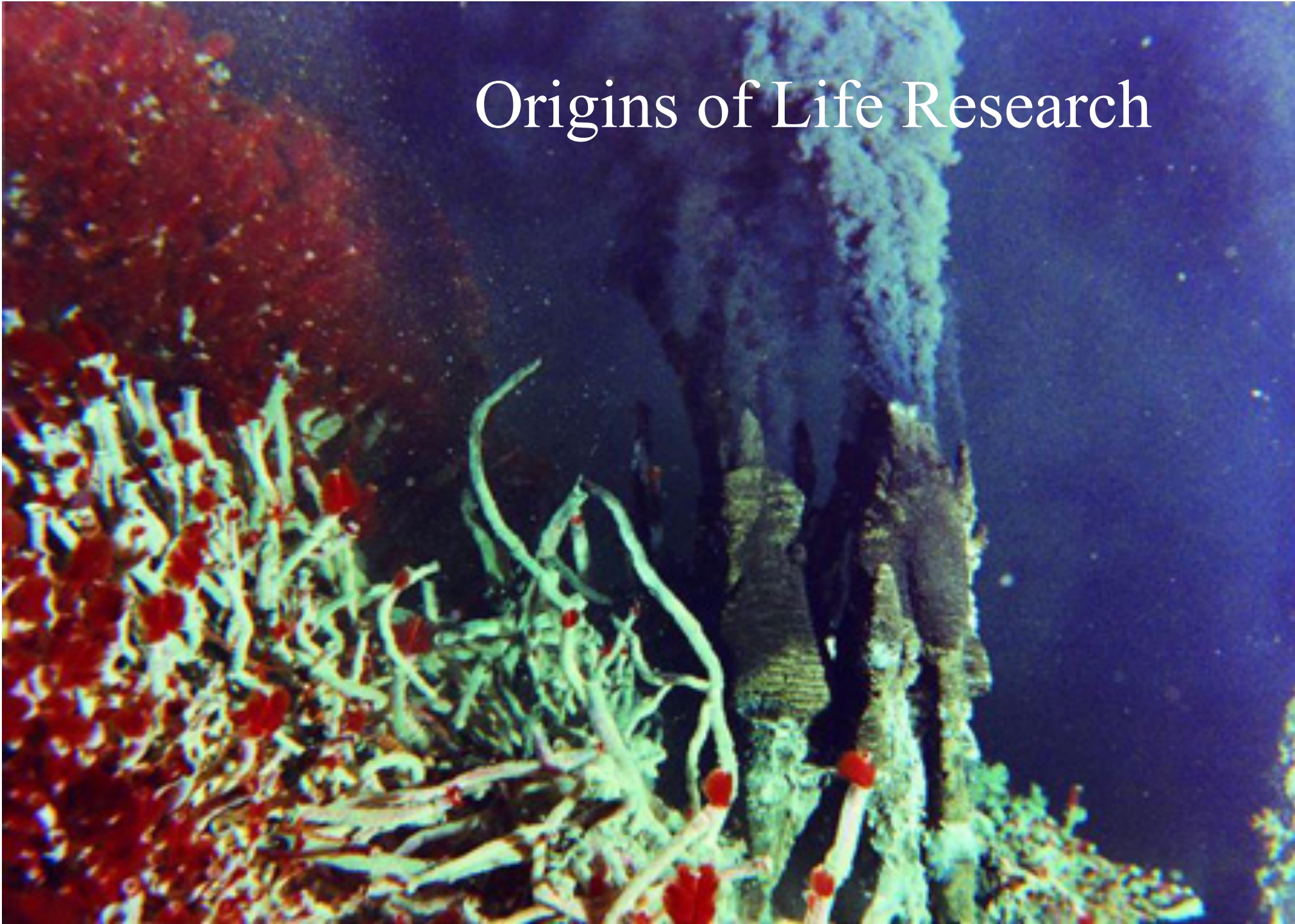
- Kepler 9b and 9c 2 Saturn-sized planets orbiting same star
[Science, Oct 1, 2010]



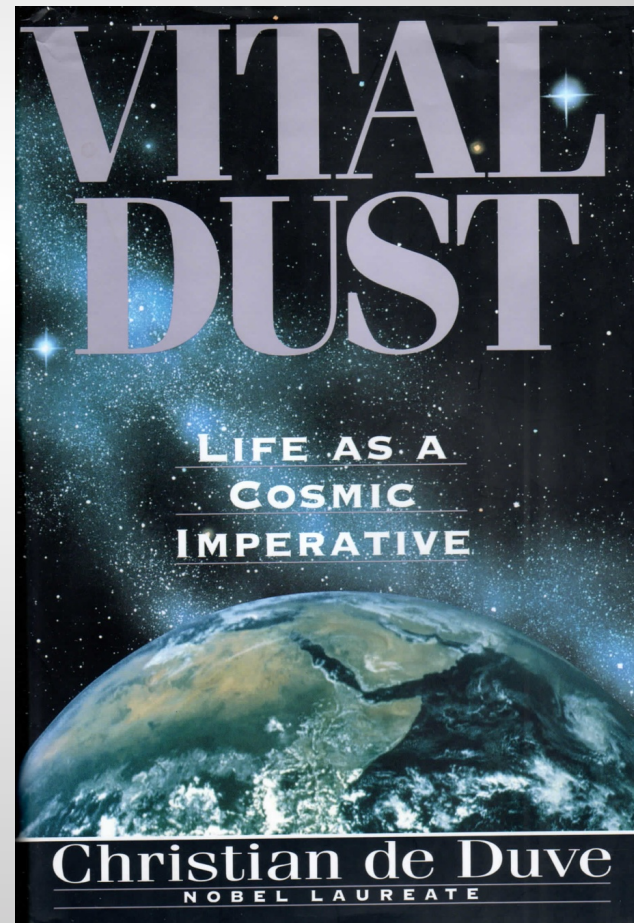
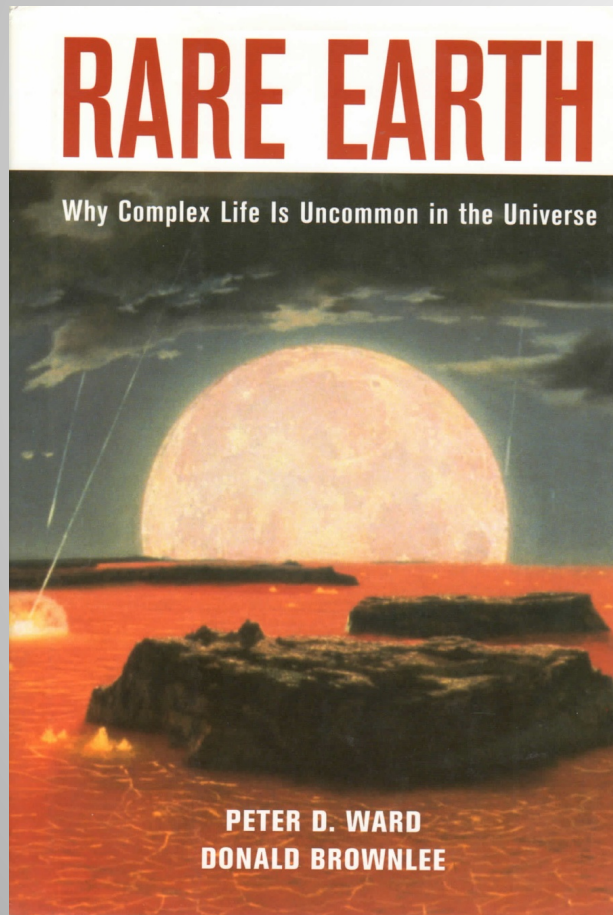
Planet Hunt – A Big Job!



Origins of Life Research



LIFE: SIDE SHOW OR COSMIC IMPERATIVE?



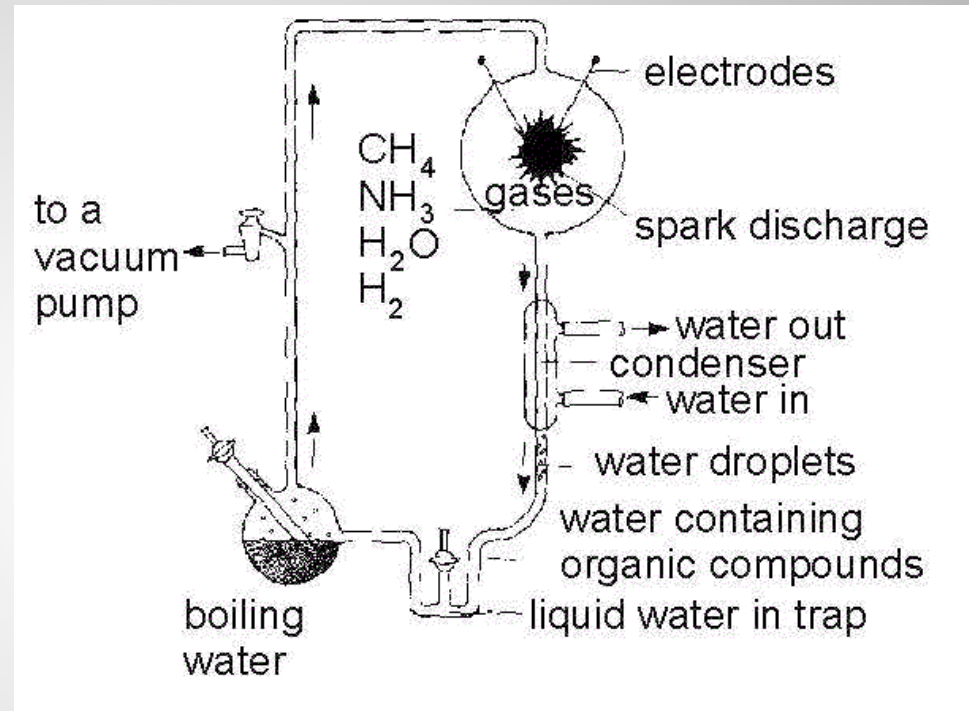
Origins of Life on Earth

- When? 3.5 to 4 billion years ago
- Where? Unknown, but earliest evidence 3.5 billion years ago in Australia
- How? The Big Question



Life in the Laboratory?

Miller-Urey Experiment, 1953



Synthesis of amino acids in a presumed primitive Earth atmosphere (methane, ammonia, water, hydrogen)

Little Progress Since Then: A Long Way from Life!

New Research on Origins of Life



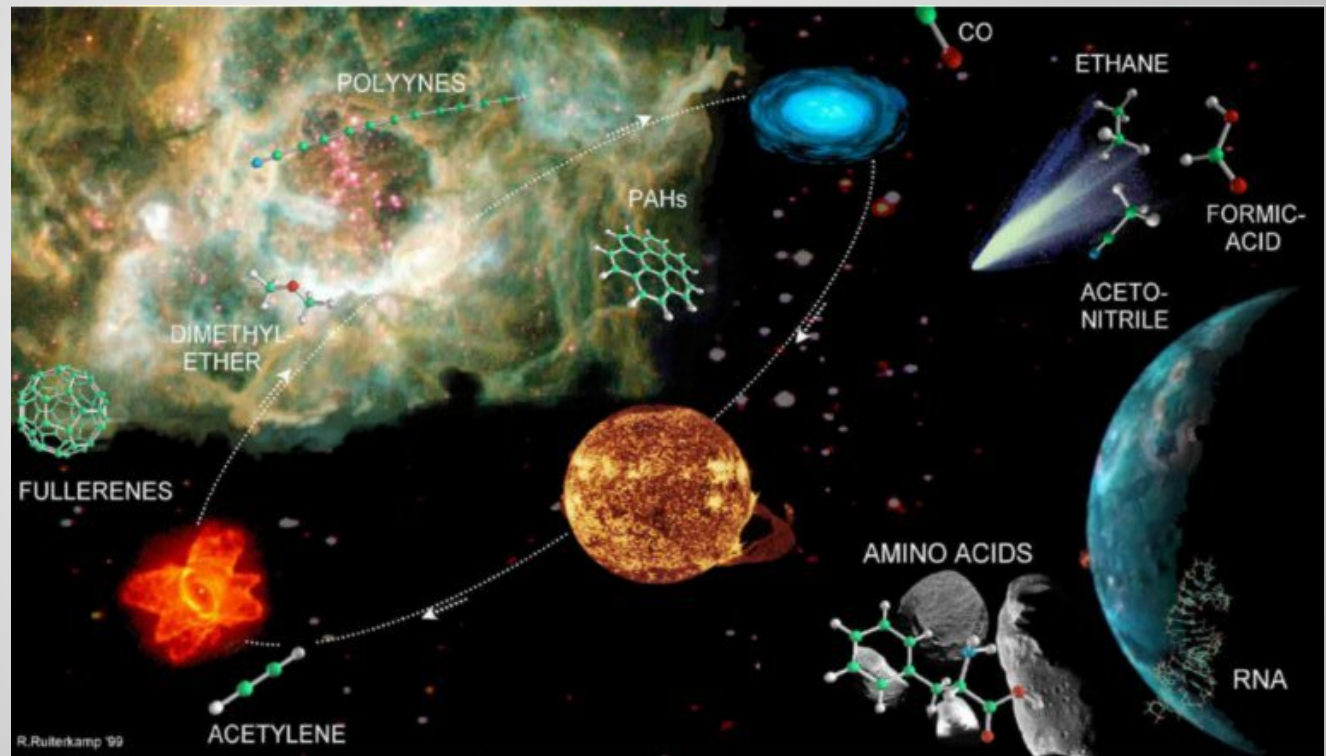
Hydrothermal Vent
University of Victoria



Tube Worms
punaridge.org



Extremophiles – food chain based on bacterium
Deriving energy from hydrogen sulfide =
Chemosynthesis rather than photosynthesis



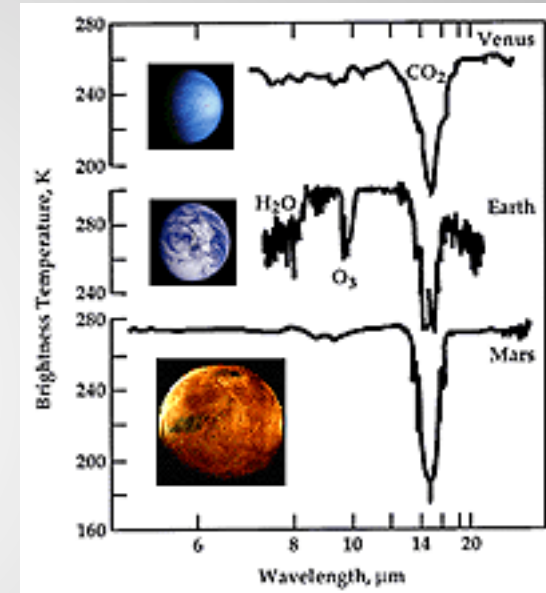
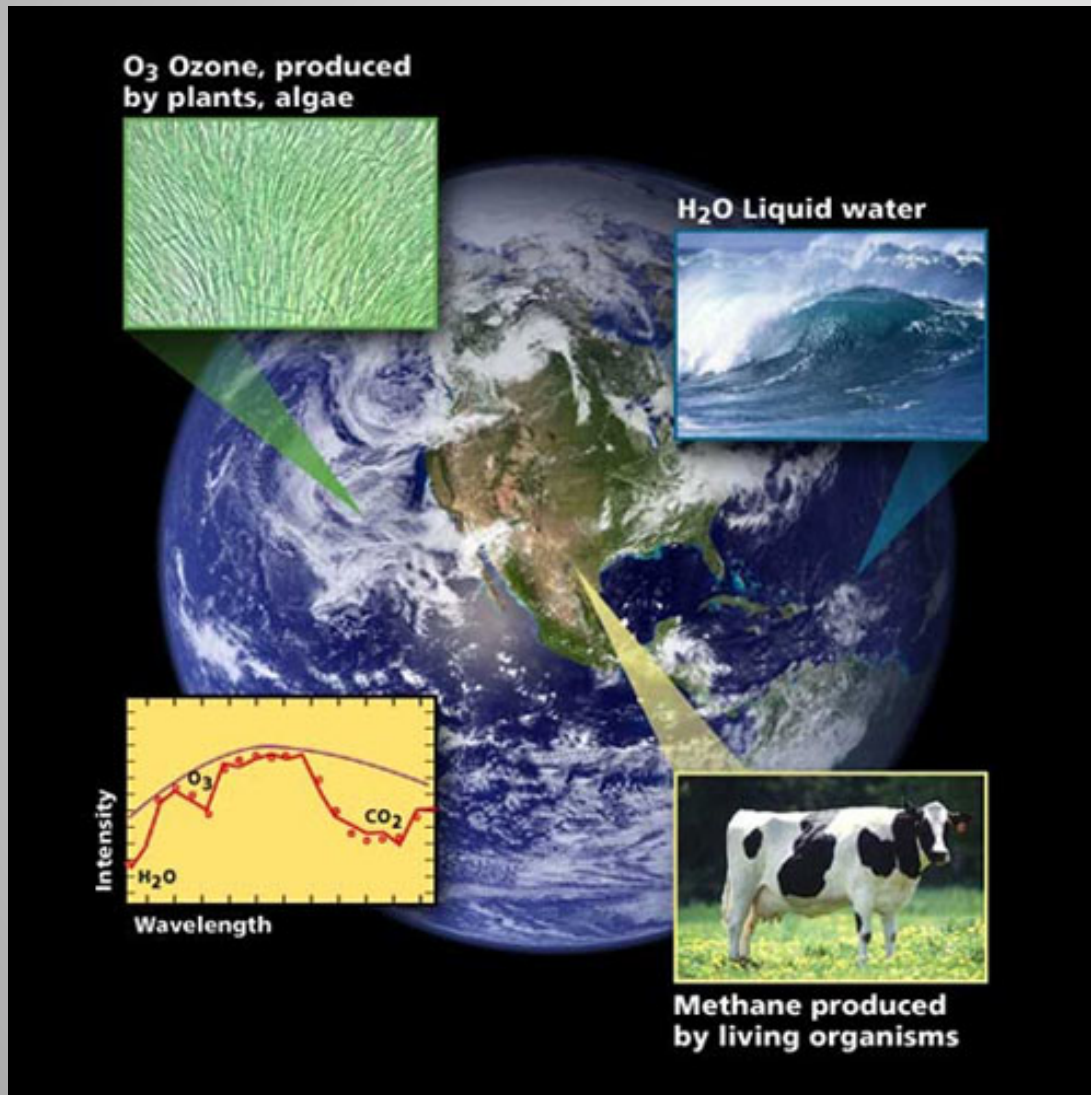
Interstellar Organics

Suggestive, but not Proof of Cosmic Imperative!

Delivery From Beyond Earth?



BioSignatures



Search for Extraterrestrial Intelligence



RADIO TO STARS, MARCONI'S HOPE

Inventor Says Waves of Ether
Are Eternal and Can Reach
Other Planets.

GETS STRANGE SIGNALS NOW

These, He Declares, Might Con-
ceivably Have Proceeded
from Other Worlds.

Special Cable to THE NEW YORK TIMES.
LONDON, Jan. 20.—The Daily Chroni-
cle publishes an interview which Harold
Begbie had with William Marconi, in
the course of which the latter discussed
the possibility of communicating by
wireless with the stars.

Mr. Begbie asked him if he thought
that waves of ether were eternal. Mr.
Marconi replied:

"Yes, I do. Messages that I sent off
ten years ago have not yet reached some
of the nearest stars. When they ar-
rive there why should they stop? It is
like an attempt to express one-third as
a decimal fraction; you can go on for-
ever without coming to any sign of an
end. That is what makes me hope for a
very big thing in the future."

"What is that?" asked Mr. Begbie.

SETI - Search for Extraterrestrial Intelligence

SHORT WAVE & TELEVISION for DECEMBER, 1937

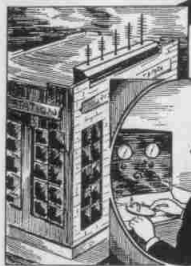
Can We Signal MARS

The Possibility of Interplanetary

Including the Views of Dr. Lee de Forest and Nikola Tesla

THE possibility that intelligent life exists somewhere else in the universe than on earth is an intriguing subject. The possibility that we might in some way or other achieve inter-planet communication with some other planet is even more exciting. The astronomer, in replying to questions about life in the universe—and scarcely a week passes but that he meets the query in some form—is forced to rely on cold scientific facts. He does not believe in the validity of the argument so frequently advanced that the earth, being so insignificant, could hardly have been selected as the only place in the universe for the development of life. This argument proves nothing. One might quite as logically reason in the reverse direction, and say that man is so much more insignificant that the presence of life is an improbable accident that could scarcely happen twice in an otherwise well-ordered universe. When we approach the problem of possible planetary life and interplanetary communication scientifically, we are forced first to study (even if we cannot answer) the question "What is life?" On the earth, we find a multitude of living organisms, ranging from minute single-celled organisms bacteria to the highly complex *homo sapiens* (man). If we limit the consideration to intelligent life, then the problem becomes still more difficult. There is no simple way of finding an answer, especially for those people for whom "seeing is believing." No telescope yet built or under construction is sufficiently powerful to show the form of even the largest mammal, even if it were located on as near an object as the moon. Meteors and meteorites, our only direct messengers from space, have shown no evidence of the existence of living organisms beyond. Our

Uranus, Neptune, and Pluto may also be removed from the realm of possibility. These planets, being so far from the sun are all too cold for water to exist in the liquid state. The temperature that has been found for Jupiter, the planet nearest to the sun of this group, is more than a hundred degrees below zero centigrade. The temperatures of the other planets are even lower. The possibility of life on these planets is therefore ruled out. The picture at the left indicates that a veritable world of life is required in order to receive a short-wave signal to a planet such as Mars. Experts compute that a veritable world of life would be required to receive a short-wave signal to a planet such as Mars. Experts compute that a veritable world of life would be required to receive a short-wave signal to a planet such as Mars. Experts compute that a veritable world of life would be required to receive a short-wave signal to a planet such as Mars.



approach obviously, must be indirect. First of all, we may survey the known planets and regard the relative likelihood of their being inhabited. There is one prime test for the existence of life, as we know it on the earth; the existence of liquid water. Water, apparently, is the one most important constituent of all cells. Oxygen is not necessary, since plants exist on carbon dioxide. Not even carbon is absolutely necessary, since certain bacteria have been found that are composed chiefly of sulphur. Presumably, however, carbon would be necessary for any higher form of life, owing to the peculiar chemical property of that element in being able to string itself together with atoms of oxygen and hydrogen into long and complex chains to form protoplasm cell-bases. But water, in the liquid state, is absolutely necessary. Water, because of its peculiar physical and chemical properties, could not be replaced by any other solvent. Consequently, when we wish to examine the possibility of the planets being inhabited, we must first investigate whether liquid water could exist on their surfaces. For that reason, both the moon and Mercury can be discounted on their outward side and too cold on the night side. We may also eliminate the smaller planets, the asteroids, which are so small that water would have completely disappeared from their surfaces. Jupiter, Saturn, Uranus, Neptune, and Pluto may also be removed from the realm of possibility. These planets, being so far from the sun are all too cold for water to exist in the liquid state. The temperature that has been found for Jupiter, the planet nearest to the sun of this group, is more than a hundred degrees below zero centigrade. The temperatures of the other planets are even lower. The possibility of life on these planets is therefore ruled out. The picture at the left indicates that a veritable world of life is required in order to receive a short-wave signal to a planet such as Mars. Experts compute that a veritable world of life would be required to receive a short-wave signal to a planet such as Mars. Experts compute that a veritable world of life would be required to receive a short-wave signal to a planet such as Mars.

liquid air. We could have dimmed these major planets on other grounds, mainly the presence of such gases as ammonia and methane in their atmospheres, which would not be very conducive to the existence of life. Mars and Venus In the solar system there remain, aside from the earth, only two possibilities—Mars and Venus. Of these, Mars has been the most publicized concerning the possibility of its being inhabited. We can study Mars much more readily than we can Venus because the atmosphere of Mars is very thin and our telescopes can penetrate to its surface. From the meager observational data at our disposal, we can construct the following picture of the surface of Mars. Most of the planet consists of bare red rock, possibly broken, and possibly red sand. I like to think of this condition as approaching that of our painted desert in Arizona. At either pole of the planet we find water, congealed in the form of bear front. These polar caps divide in size with the Martian summer and consequently we have reason to suspect that liquid water is present on certain portions of the planet at some time during the year. There are, also, dark markings, most prominent in the neighborhood of the Martian equator. The most surprising fact is that these dark markings change in size and also in color with the season. Sometimes they are grey-green and at other times brown. The changing form and coloration could, perhaps, be explained as the result of natural causes. It has been suggested, for example, that the changes are due to the presence of dust which, on absorbing water, changes its reflecting power. This explanation is entirely reasonable, but I prefer to account for the changes as the result of Martian vegetation as the Martians themselves would view it. We do not know whether the vegetation is in the form of trees, shrubbery, or merely minute organisms like algae. Of course, where there is life, there is also water. It is inconceivable that the entire surface of Venus is covered by an ocean. But our conclusions are mere conjectures and based on no rigorous scientific method. The fact that the terrestrial continents seem to have risen more by

by Short Wave?

Communication

By Dr. Donald H. Menzel
Associate Professor of Astronomy, Harvard University.

THE question of radio-communication with distant planets still holds supreme charm for all red-blooded radio experimenters. First of course, is the question of the possibility of life existing on such planets as Mars, and we have asked the well-known authority, Dr. Menzel to answer this question. The amount of radio power required would probably be about 50,000 kilowatts; the wavelength possibly on low as one centimeter (four-tenths of an inch).

accident than by design. The atmosphere of Venus contains an abundance of carbon dioxide and no traces of oxygen have been found. Green vegetation on earth lives on carbon dioxide and gives off oxygen as a by-product. We might infer that plant life, as we know it, does not exist on Venus. As for life elsewhere, where in the universe, no scientific data are available. We do not know whether planets are born as the natural result of a collision or a near collision of two stars, then planets must be rare, and life, accordingly, an even rarer phenomenon.

Dr. Lee de Forest's Opinion on Signaling Mars

IT has been quite conclusively demonstrated that since short radio waves, in the neighborhood of 1 meter or less, are ordinarily not reflected by the ionosphere, but penetrate to the surface of the earth, they would be reflected by the surface of Mars, when that planet is near the earth. The question then becomes: how much power would be required to transmit signals from such a distance to the distance of Mars? Then comes the question as to whether or not the very dense atmosphere surrounding Mars, then, reflecting that a certain extremely small fraction of all projected energy should penetrate the Martian atmosphere, have the inhabitants of Mars a sufficiently sensitive detector and amplifier to receive a message in whether or not Mars is inhabited by beings who might transmit astronomical evidence and outside news from their planet to the earth. But our conclusions are mere conjectures and based on no rigorous scientific method. The fact that the terrestrial continents seem to have risen more by



Fig. 1, above, shows drawing of the antenna as it appeared on August 15, 1911; drawing at right shows the antenna as it appeared on August 15, 1911. The drawing at right shows the antenna as it appeared on August 15, 1911. The drawing at right shows the antenna as it appeared on August 15, 1911.

Nikola Tesla's Opinion on Mortion Communication

NIKOLA TESLA, one of the greatest electrical and radio inventors of all time, recently made the statement that he believed that he had heard signals from a distant planet, nearly forty years ago. In about the year 1895, he was making a series of aerial lightning tests in a short wave, when he heard a series of signals which had a periodic measured cadence, and which were repeated many times. Dr. Tesla's interpretation of these signals was that they spelled out "S-O-L-A-R". It is his opinion that these signals had been sent by Martians, they had used numbers in an attempt to indicate communication with the earth, for the great reason that numbers are common to a very broad spectrum of languages. Dr. Tesla was one of the earliest investigators of abnormal phenomena, and about fifty years ago—was before the year 1895—he was producing short-wave in his electrical laboratories in New York. Without a shade of doubt a great part of the credit of the early establishment of radio should go to Dr. Tesla. His early papers and patents were—without a doubt—of the remarkable character. He had had long hair, and he had a very high forehead. He had a very high forehead. He had a very high forehead. He had a very high forehead.

Menze, Shortwave & Television, 1937
Marconi, New York Times, 1920

RADIO TO STARS, MARCONI'S HOPE

Inventor Says Waves of Ether
Are Eternal and Can Reach
Other Planets.

GETS STRANGE SIGNALS NOW

These, He Declares, Might Con-
ceivably Have Proceeded
from Other Worlds.

Special Cable to THE NEW YORK TIMES.
LONDON, Jan. 20.—The Daily Chroni-
cle publishes an interview which Harold
Begbie had with William Marconi, in
the course of which the latter discussed
the possibility of communicating by
wireless with the stars.

Mr. Begbie asked him if he thought
that waves of ether were eternal. Mr.
Marconi replied:

"Yes, I do. Messages that I sent off
ten years ago have not yet reached some
of the nearest stars. When they ar-
rive there why should they stop? It is
like an attempt to express one-third as
a decimal fraction; you can go on for-
ever without coming to any sign of an
end. That is what makes me hope for a
very big thing in the future."

"What is that?" asked Mr. Begbie.

Marconi,
New York Times, 1920

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NY Times May 5, 1933

VOL. LXXXII...No. 27,495.

Entered as Second-Class Matter,
Postoffice, New York, N. Y.

Copyright

NEW Y

NEW RADIO WAVES TRACED TO CENTRE OF THE MILKY WAY

Mysterious Static, Reported
by K. G. Jansky, Held to
Differ From Cosmic Ray.

DIRECTION IS UNCHANGING

Recorded and Tested for More
Than Year to Identify It as
From Earth's Galaxy.

ITS INTENSITY IS LOW

Only Delicate Receiver is Able to
Register—No Evidence of
Interstellar Signaling.

Discovery of mysterious radio
waves which appear to come from
the centre of the Milky Way galaxy
was announced yesterday by the
Bell Telephone Laboratories. The
discovery was made during re-
search studies on static by Karl G.
Jansky of the radio research de-
partment at Holmdel, N. J., and
was described by him in a paper
delivered before the International
Scientific Radio Union in Wash-
ington.

The galactic radio waves, Mr.
Jansky said, differ from the cosmic
rays and also from the phenomenon
of cosmic radiation, described last
week before the American Philo-
sophical Society at Philadelphia by
Dr. Vesto M. Slipher, director of
the Lowell Observatory at Flag-
staff, Ariz.

Unlike the cosmic ray, which
comes from all directions in space,
does not vary with either the time
of day or the time of the year, and
may be either a photon or an elec-
tron, the galactic waves, Mr. Jansky
pointed out, seem to come from a
definite source in space, vary in
intensity with the time of day and

Flier Asks Blame in Crash, But Inquest Absolves Him

By The Canadian Press.

LONDON, May 4.—A chival-
rous attempt to assume responsi-
bility for the fatal crash of a
Royal Air Force plane on May
1, in which Viscount Knebworth,
pilot, and Aircraftman Harrison
lost their lives, was made by
Flight Lieutenant Eric Hobson
at the inquest today. Despite
Lieutenant Hobson's action, a
verdict of "death due to misad-
venture" was returned.

Lieutenant Hobson, the leader
of the section of which Lord
Knebworth was a member, de-
scribed how he unaccountably
lost his height and at the end of a
2,000-foot dive got dangerously
near the ground.

"The error in judgment was
certainly not due to carelessness
or recklessness," said Lieutenant
Hobson, adding that Lord Kneb-
worth was "absolutely blameless
for what had happened, but had
simply followed him according to
orders."

KIDNAPPERS URGED TO ANSWER PLEAS

New Yorker Named to Act as
Secret Agent for Return
of McMath Child.

FRIEND READY AS HOSTAGE

Watch Kept at Detroit and in
Tryon, N. C.—Massachusetts
Police Refuse 'Armistice.'

Special to THE NEW YORK TIMES.

HARWICHPORT, Mass., May 4.
—Desperate at the failure of all at-
tempts to establish a contact with
the kidnapers of Margaret Mc-
Math, abducted from her school
here Tuesday, William Lee, spokes-
man for the family, tonight offered
himself as a hostage to those who
had taken the girl.

BIG NEW INVASION PLANNED BY JAPAN ON ROAD TO PEIPING

Larger-Scale Offensive Than
Last Is Announced to Open
Soon in North China.

CHIANG RUSHES AID NORTH

Famous Units That Fought at
Shanghai Are Dispatched
to Help 50,000 at Front.

BRITISH QUIT MANCHURIA

Concerns Assert the Open Door In
Commerce Is Being Rapidly
Shut Against Foreigners.

By HALLETT ABEND.

Wireless to THE NEW YORK TIMES.

TIENSIN, May 4.—Partially re-
vealing Japan's plans for renewed
military incursion in North China,
an official spokesman at the head-
quarters of the military attaché
said today:

"Active preparations are under
way for an attack on a much larger
scale than ever before, especially
through the participation of air-
planes."

The main invasion is planned
from Kupai Pass through Miyun,
said the spokesman, frankly reveal-
ing that the adversaries principally
sought were 50,000 of General
Chiang Kai-shek's own troops at
present in the Miyun area under
the direct command of General Ho
Ying-ching, the War Minister.

Declaring the Japanese assault
was scheduled for "a very early
date," the spokesman admitted that
smaller simultaneous engagements
were likely south of other portions
of the Jehol frontier.

"Decisive action has become nec-
essary," he added. "The present

League Reserve C By Drop in I

Special Cable to THE NEW YORK TIMES.
GENEVA, May 4
of Nations supervi-
tee dispersed today
its already difficul-
ancing the Leagu
budget made much
dollar leaving gold.

Practically all of
reserves, totaling
kept in dollars. W
moratorium was
League officials, at
bankers, decided t
dollar. They have
a paper loss of ne
and have had to
of the reserve at
tween 15 and 20 p

The committee l
study until the Jul
ther drastic cuts
tivities including
cent reduction in t
section.

FARM BILL BLOCKS AG

Conferees React
All Except th
Production

PEEK' SLATED

Illinois' Equipme
Roosevelt's Ch
Administ

Special to THE NEW
WASHINGTON,

and House confer
complete agreement
the farm relief bill t
cost-of-production
clash over the one s-
reconsideration of
the House on Mond
quent delay of the
gram incorporated
ment to this measur

Modern Foundations of SETI: Cocconi & Morrison, 1959

SEARCHING FOR INTERSTELLAR COMMUNICATIONS

By GIUSEPPE COCCONI* and PHILIP MORRISON†

Cornell University, Ithaca, New York

NO theories yet exist which enable a reliable estimate of the probabilities of (1) planet formation; (2) origin of life; (3) evolution of societies possessing advanced scientific capabilities. In the absence of such theories, our environment suggests that stars of the main sequence with a lifetime of many billions of years can possess planets, that of a small set of such planets two (Earth and very probably Mars) support life, that life on one such planet includes a society recently capable of considerable scientific investigation. The lifetime of such societies is not known; but it seems unwarranted to deny that among such societies some might maintain themselves for times very long compared to the time of human history, perhaps for times comparable with geological time. It follows, then, that near some star rather like the Sun there are civilizations with scientific interests and with technical possibilities much greater than those now available to us.

* Now on leave at CERN, Geneva.

† Now on leave at the Imperial College of Science and Technology, London, S.W.7.

To the beings of such a society, our Sun must appear as a likely site for the evolution of a new society. It is highly probable that for a long time they will have been expecting the development of science near the Sun. We shall assume that long ago they established a channel of communication that would one day become known to us, and that they look forward patiently to the answering signals from the Sun which would make known to them that a new society has entered the community of intelligence. What sort of a channel would it be?

The Optimum Channel

Interstellar communication across the galactic plasma without dispersion in direction and flight-time is practical, so far as we know, only with electromagnetic waves.

Since the object of those who operate the source is to find a newly evolved society, we may presume that the channel used will be one that places a minimum burden of frequency and angular discrimi-

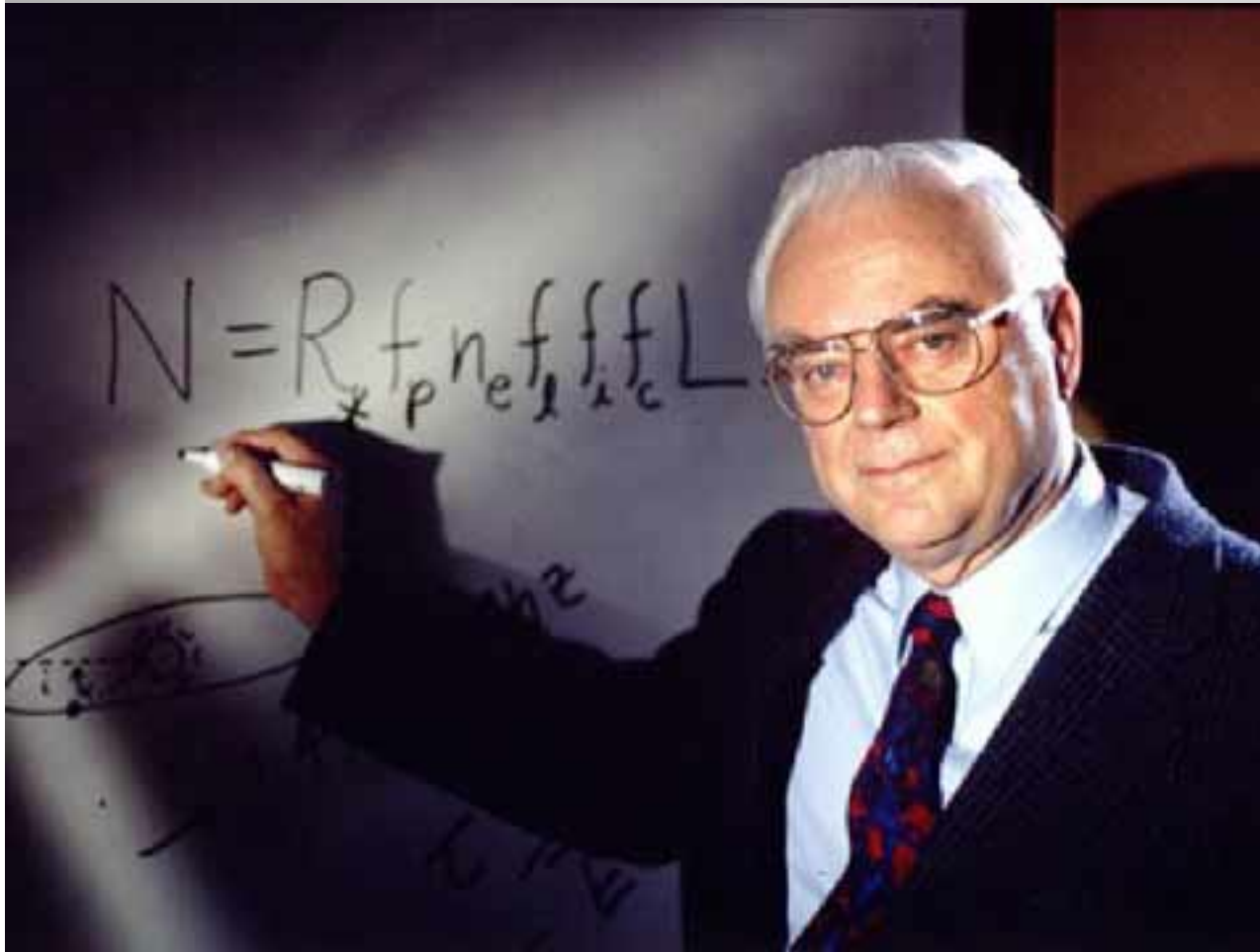


Cocconi

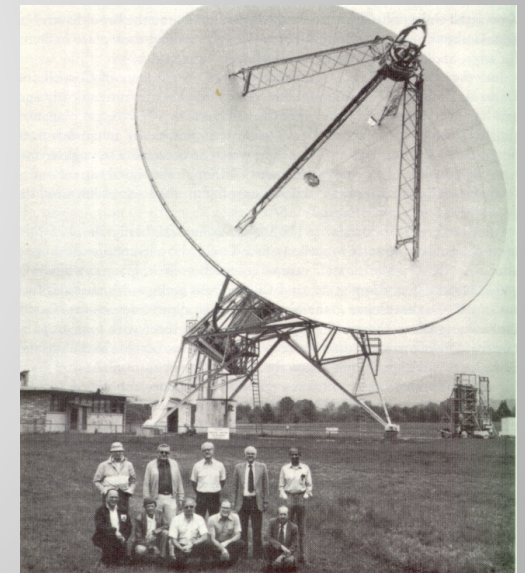


Morrison

SETI – Project Ozma, 1960



Frank Drake



Project Ozma Team reassembled for 25th anniversary, 1975 in front of the 85-foot Tatel telescope, Green Bank WV.

OZMA 50TH ANNIVERSARY



GREEN BANK, WVA SEPTEMBER 14, 2010

Modern Foundations of SETI

The Green Bank Conference (1961)

Sponsored by SSB of National Academy of Sciences



Sagan



Calvin



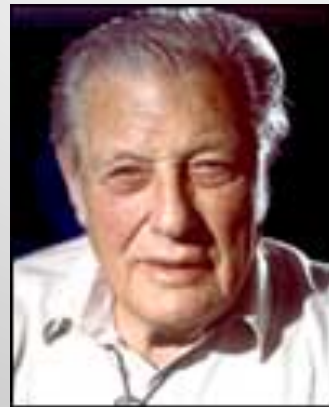
Lilly



Cocconi



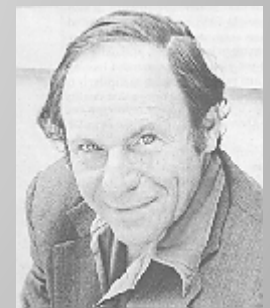
Drake



Oliver



Struve



Morrison

The Drake Equation

Astronomical

Biological

Cultural

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

Green Bank Conclusions

- ❖ Electromagnetic signals in radio spectrum most useful, ranging from 1-3 GHz
- ❖ N might range from 1 (us) to 1 billion technological civilizations
- ❖ Most participants favored the higher number
- ❖ Highly dependent on L!

Sagan: “It was wonderful ... we’ve finally penetrated
The ridicule barrier.”

Problems:

SETI Programs

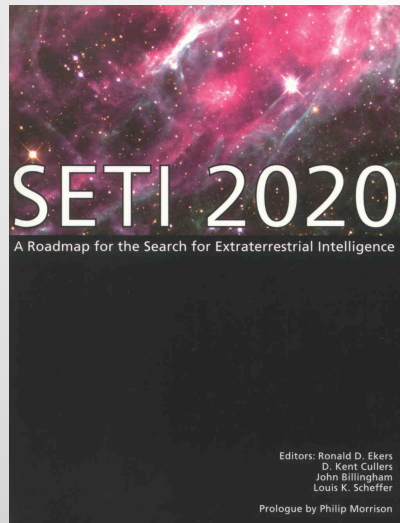
Where to Look?



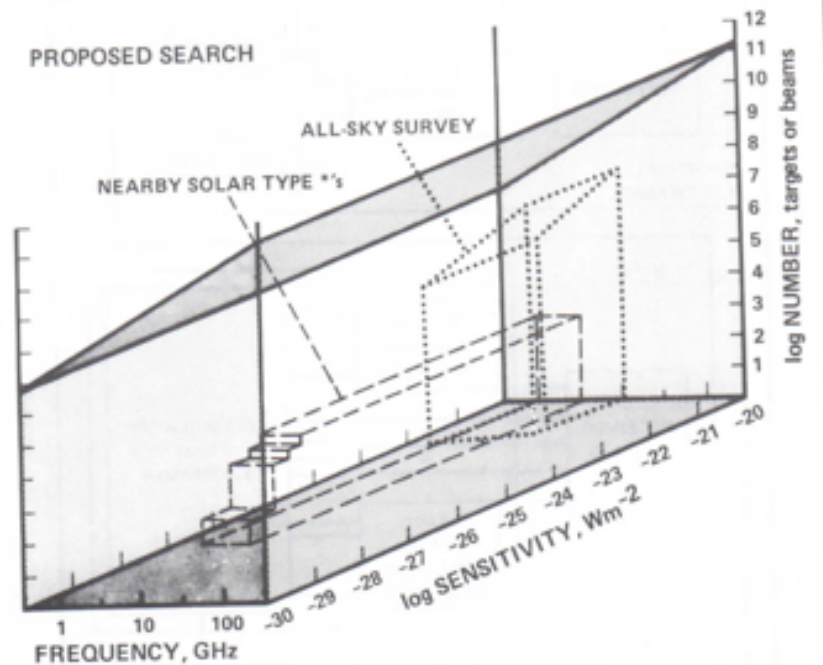
Allen Array



Square Kilometer Array



- What Frequency?
- Why Would They Aim a Beacon at Us?
- Would They Use Radio?

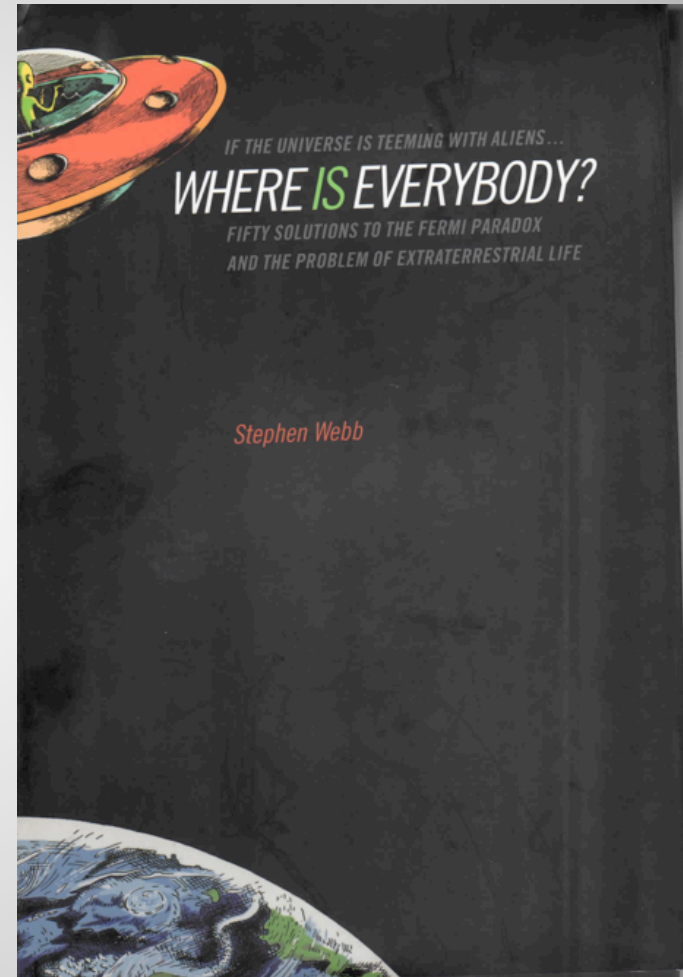




SETI Pioneers at NASA Ames Research Center during the Microwave Observing Project (MOP),” 1989, later the “High Resolution Microwave Survey, (HRMS),” L to R: Seeger, Tarter, Drake, Oliver, Billingham

The Fermi Paradox – Where Are They?

1. They are Here! UFOs
2. The Zoo Hypothesis –
Waiting for us to get smarter
3. Interstellar Travel is Impossible
4. They aren't Interested in Us!
5. Lack of Funding –
Gridlock in ET Congress!
6. They Don't Exist!



Coalescence of a New Discipline

Planetary Systems

Circumstellar Disks
Extrasolar Planets
Kepler, SIM, TPF
Biosignatures
Theoretical studies

Origins of Life

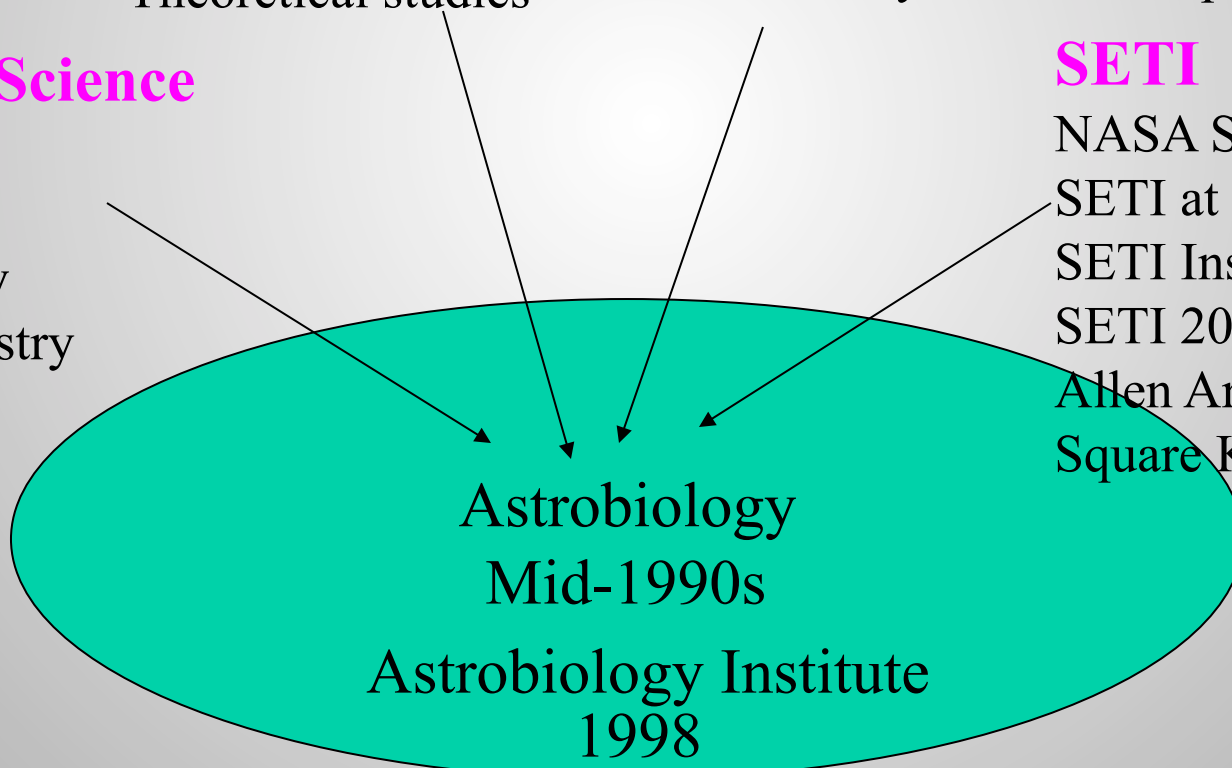
Genomics/Phylogenetic relationships
Life in Extreme Environments
Complex Organics Simulations and Obsns
Laboratory Prebiotic Experiments

Planetary Science

Mars Rock
Europa
Geochemistry
Biogeochemistry

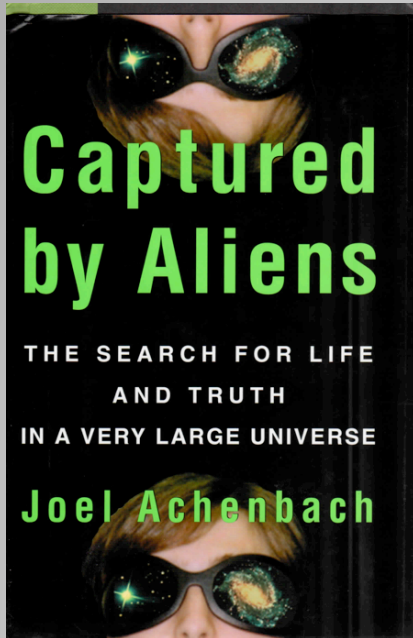
SETI

NASA SETI
SETI at Home
SETI Institute
SETI 2020 Roadmap
Allen Array
Square Kilometer Array



IAU Bioastronomy Commission 51 Triennial Meetings, 1984-

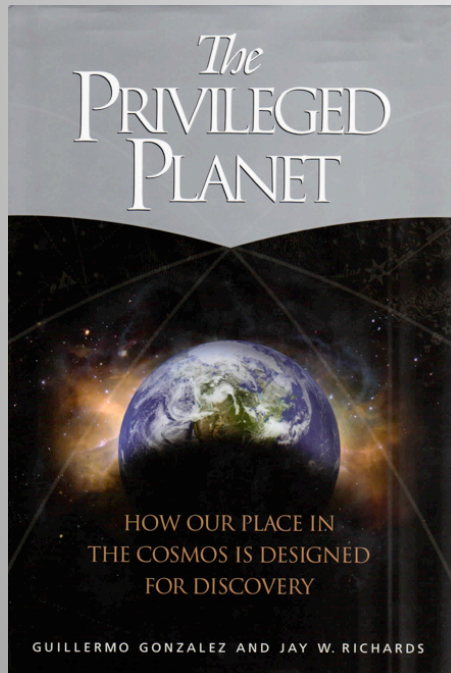
Cautionary Notes



Achenbach:

“The topic of extraterrestrial life is thoroughly Contaminated by wishful thinking.”

Carl Sagan’s “Assumption of Mediocrity” may Need to be retired for a while.



Gonzalez and Richards:

The Copernican Principle called into question
In the context of Intelligent Design



SOME
CHALLENGING
QUESTIONS

(And My Answers)

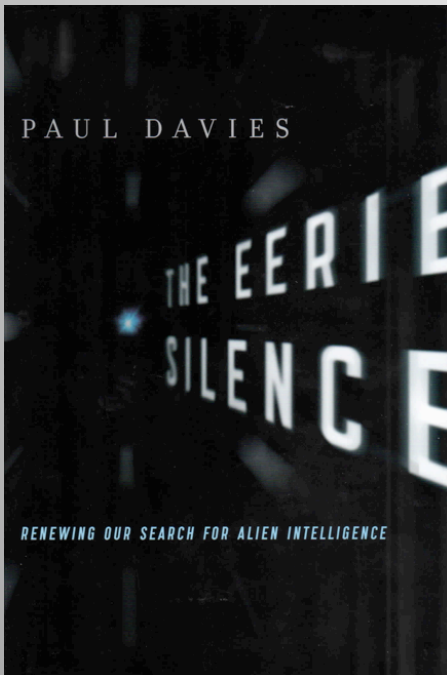
WHAT ABOUT UFOs?



- 95% ARE EXPLAINABLE
- HOW ABOUT THE REST?
- The Nature of Evidence

Carl Sagan: “Extraordinary Claims Require Extraordinary Evidence”

SHOULD WE COMMUNICATE?



- SETI vs METI

Controversy within IAA SETI Permanent Study Group

- Should we reveal the position of our nice home planet? (Hawking says NO!)
(Martin Ryle too!)
(And George Wald!)
(And David Brin!)

- Who speaks for Earth?

- What do we say?

Royal Society Debate – October 4, 2010

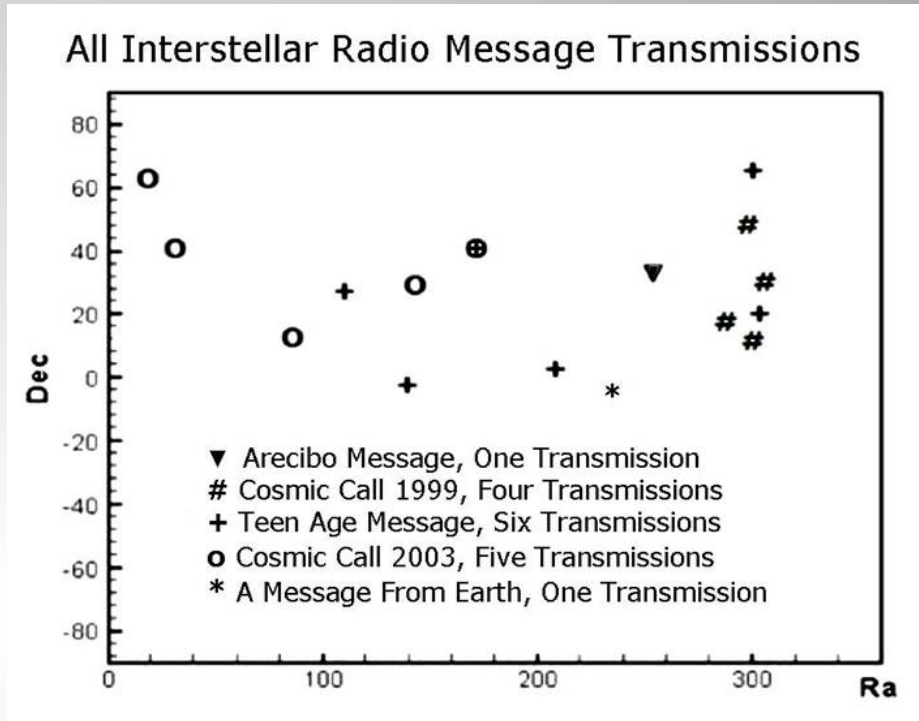
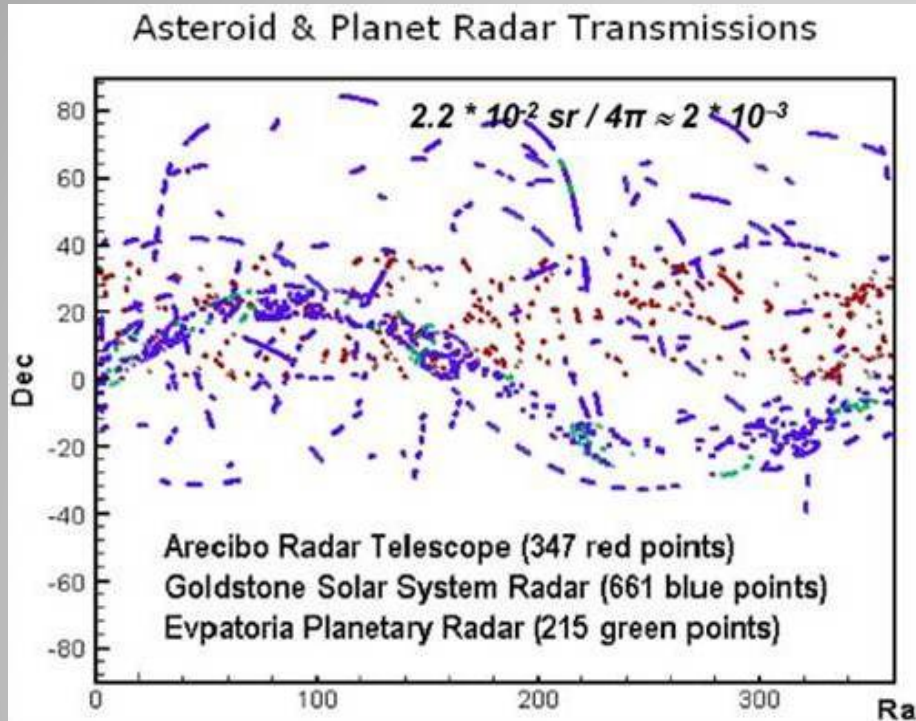
I think, "*weighty arguments*" adduced by creator and adduced by critic possess different weight.

To create something, you must be a professional, but to prohibit – just enough to be a dilettante...

Alexander Zaitsev



Radar Astronomy Transmissions versus Messaging to ETIs [Zaitsev]



$$S_{\text{RADAR}} / S_{\text{METI}} \sim 2000, T_{\text{RADAR}} / T_{\text{METI}} \sim 500,$$

where S is the total area of the sky, illuminated by transmissions and T is the total duration of both transmissions.

Therefore, the probability to detect the radar astronomy transmissions by a hostile super-civilization is $(2000 \times 500) = 1,000,000$ times higher than that of the METI transmissions.

And it is very important to understand: “addressless” RADAR transmissions and targeted METI are absolutely equivalent, because

Next Step in METI

70-m dish in Ussurijsk, Russia

This Asteroid Radar Telescope we plan to put into operation in 2013

It will have 4 modes of operation:

- 1) Radar Study of Planets and MBAs
- 2) Radar Study of NEOs
- 3) Radar Study of Space Debris
- 4) **Transmission of Interstellar Radio Messages**

This new Radar Telescope will be about 10 times more powerful



What are ETs Like? Classic Version



GOOD GUYS



BAD GUYS

What are ETs Like? Modern Version



GOOD GUYS



BAD GUYS

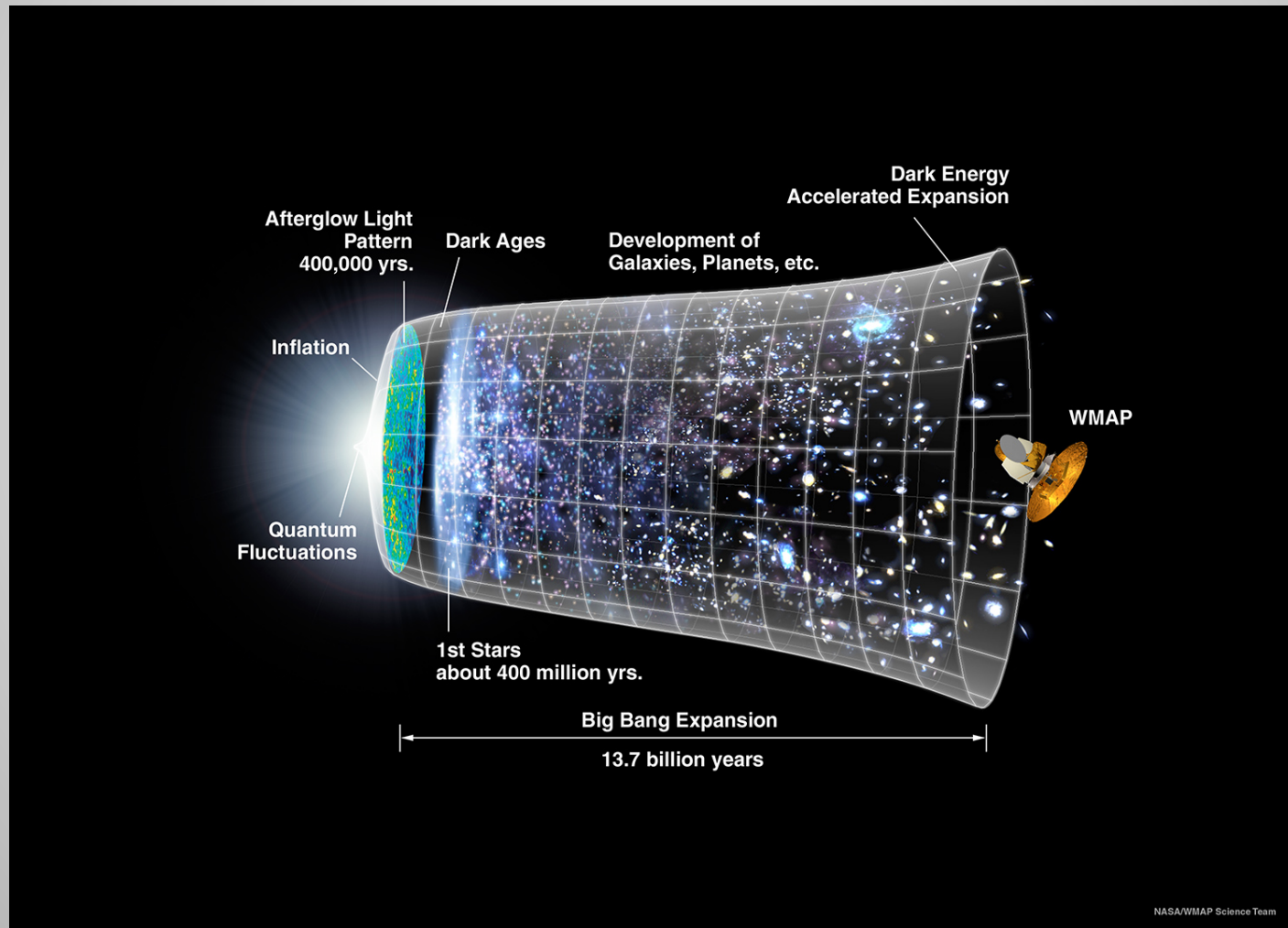
A More Systematic Approach to the Nature of ET?

Long-term “Stapledonian” Thinking Is Necessary To Understand the Nature of Intelligence In the Universe Today, if it is Indeed Widespread

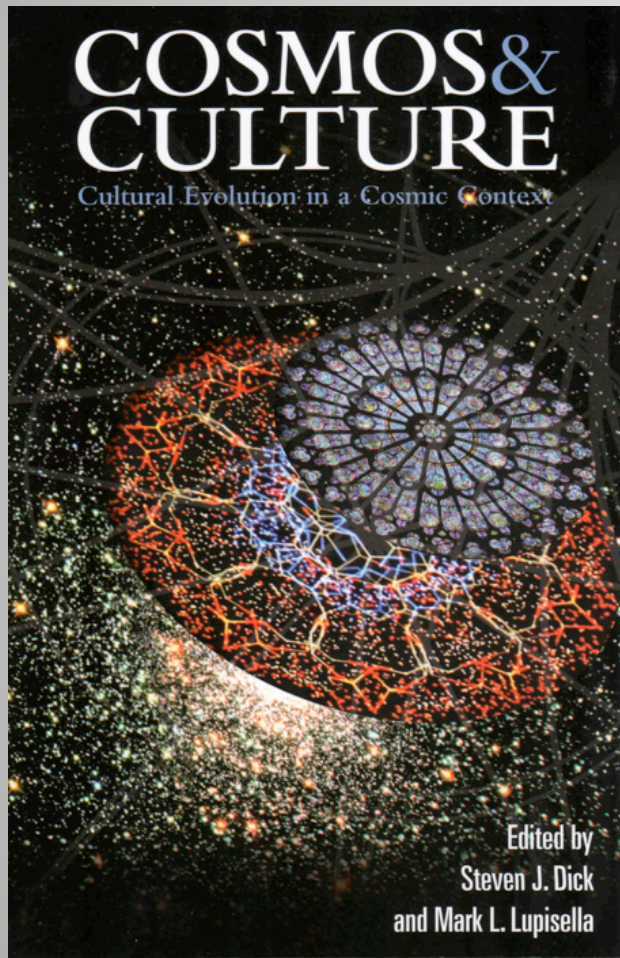
Humans not Accustomed to Thinking on Cosmic Time Scales for Biology and Culture.



Cosmic Evolution – The Ultimate Master Narrative

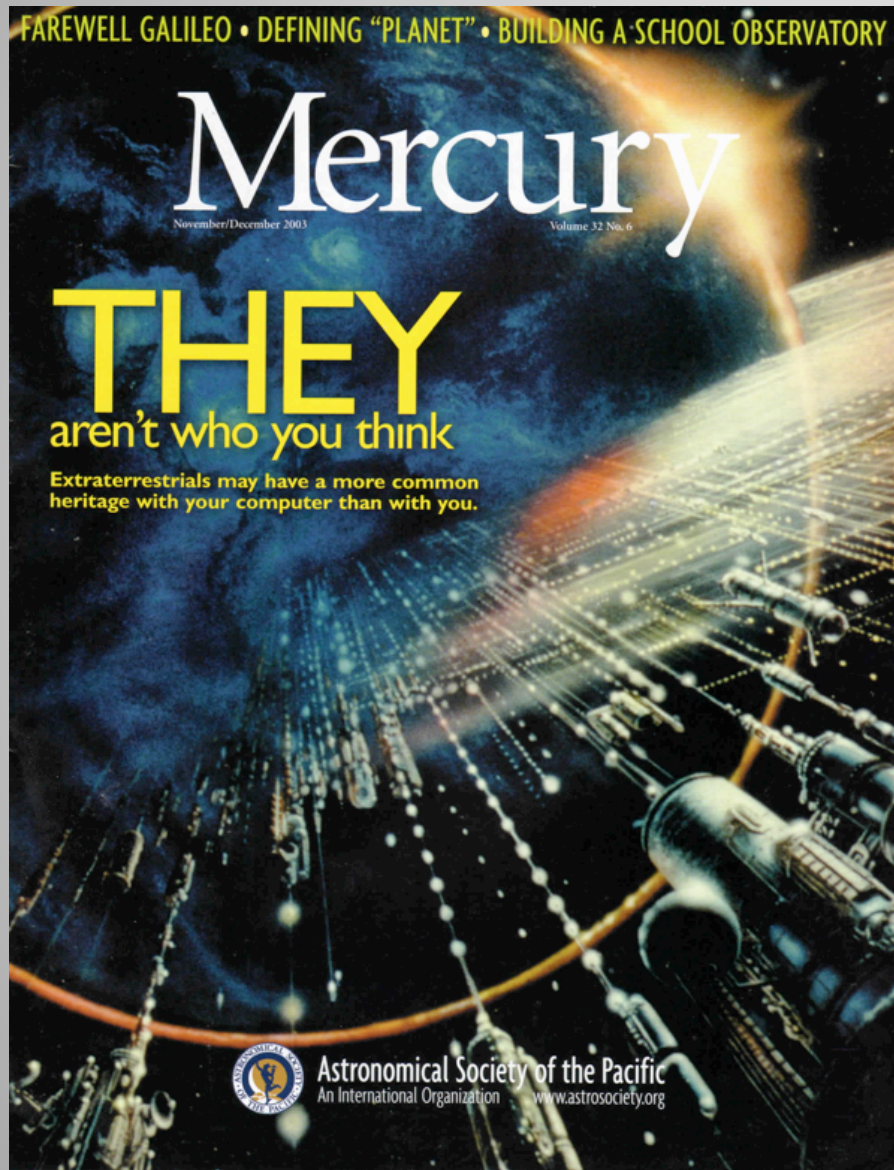


Bringing Culture to Cosmos – A Postbiological Universe?



- 1) **The Maximum Age (A) of ETI is Several Billion Years**
- 2) **The Lifetime (L) of a Technological Civilization is > 100 Years and Probably Much Larger**
- 3) **In the Long Term Cultural Evolution Supersedes Biological Evolution, and Would Produce Something Far Beyond Biology**

Effects of Cultural Evolution



Cultural Evolution Has Resulted in a Postbiological Universe, with Implications for SETI Strategies

S. J. Dick, “Cultural Evolution, the Postbiological Universe and SETI,”
International J. of Astrobiology, 2 (2003), 65-74

Mercury, November-December, 2003

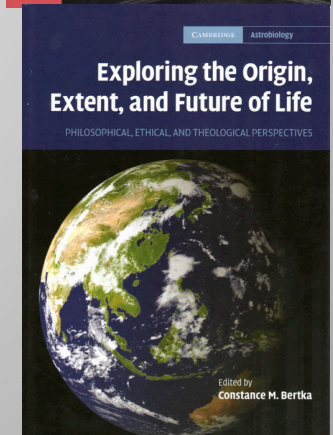
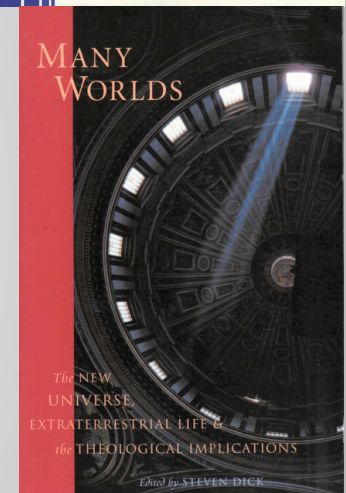
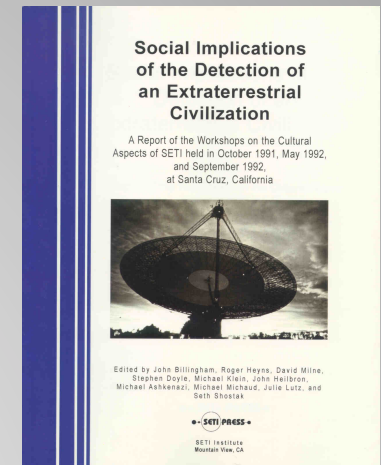
What are The Implications of Discovery of Extraterrestrial Life?

- Will depend on scenario (microbial or intelligent; near or remote, good or bad, etc)
- Will vary in different cultures
- Will affect religious doctrines in different ways (a long history of discussion)
- Will determine our place in the universe

Q3. Studies of Implications of Astrobiology



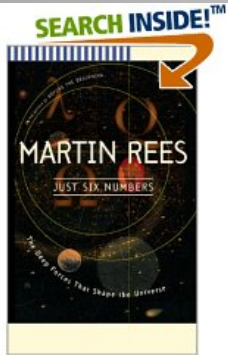
- 1991-1992 NASA CASETI Workshops (Billingham et al)
- 1999 NASA Workshop on Societal Implications of Astrobiology (Connell, Dick et al)
- Templeton Foundation Workshops (Dick et al)
- AAAS Program of Dialogue Between Science/Religion (Bertka et al)
- Astrobiology Societal Issues Roadmap, 2009 (Race et al)
- IAA Permanent SETI Committee and its SETI Post-Detection Task Force (Davies et al)



Why is the Universe Fine-Tuned for Life?

“The realization that the possibility of biological evolution is strongly dependent upon the global structure of the Universe is truly surprising and perhaps provokes us to consider that the existence of life may be no more, but no less, remarkable than the existence of the Universe itself .”

The Anthropic Cosmological Principle
Barrow and Tipler, 1986



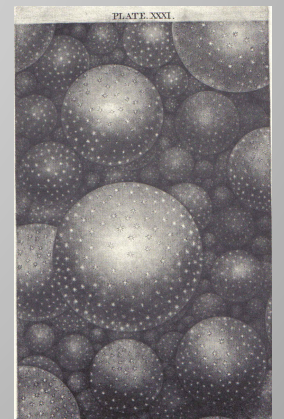
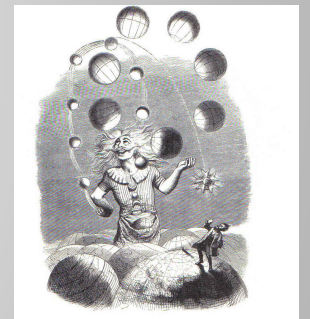
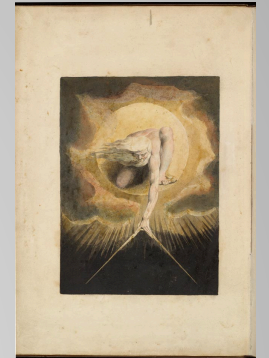
Cosmic Coincidences?

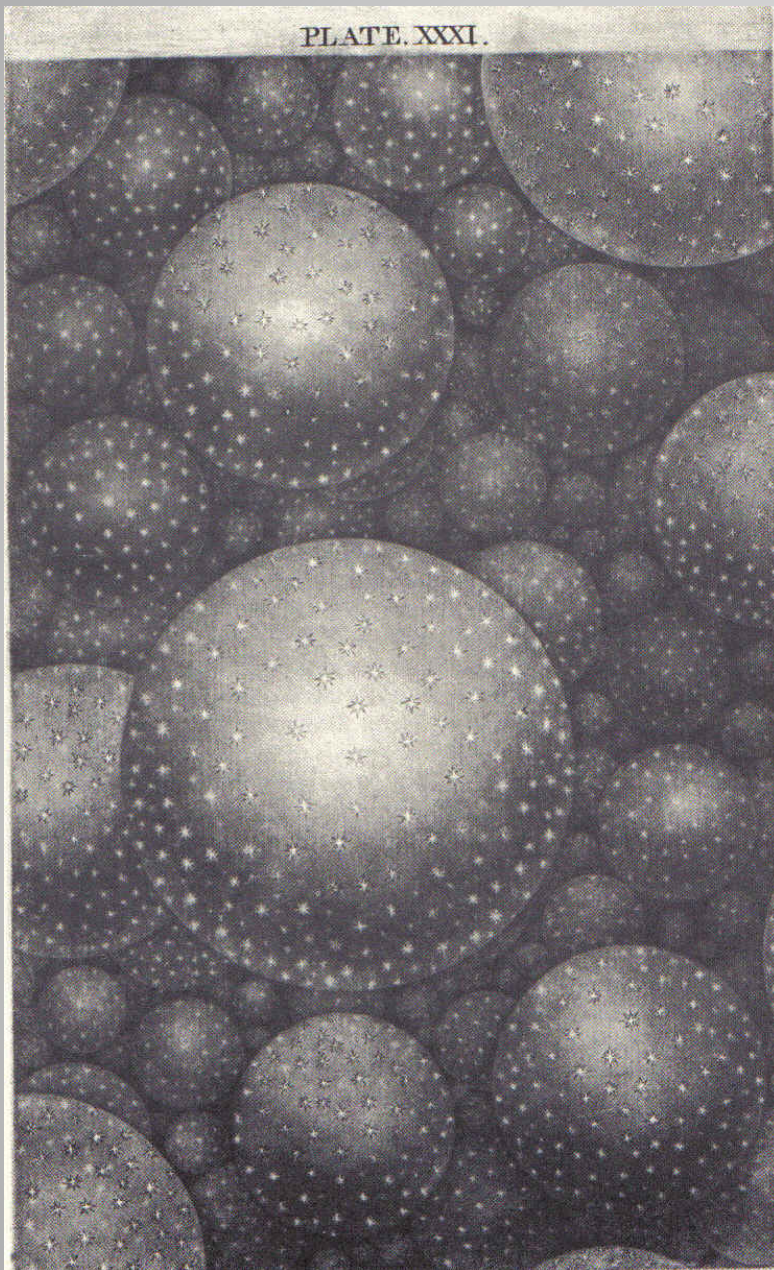
Martin Rees, *Just Six Numbers* (1997)

- 1) $N_e = 10^{36}$ = ratio of electrical to gravitational forces — a measure of the weakness of gravity
[a few less zeroes and only short-lived mini-universes; no time for evolution of life]
[if gravity stronger, then stars would be smaller]
- 2) ϵ , Epsilon, = .007 = binding power of nuclei, controlling transmutation of elements
[if .006 or .008 elements for life would not exist; determines stellar lifetime]
- 3) ω , Omega = amount of material in our universe, a measure of gravity vs expansion rate [if expansion too slow, no galaxies and stars; if too fast, collapse long ago]
- 4) λ , Lambda, cosmic antigravity, also controls expansion rate. [= accelerating universe, discovered in 1998; Einstein's Cosmological Constant]
- 5) $Q = 1/100,000$ [after WMAP 1/10,000,000] = accounts for all cosmic structure
[non-uniformities in cosmic background radiation temperature, "primordial seeds"]
- 6) $D = 3$ = number of spatial dimensions
[life could not exist if D were 2 or 4 – Flatland notwithstanding!]

Explanations for Biofriendly Universe

- A supernatural intelligence fine-tuned the universe (the God hypothesis)
- A highly-evolved natural intelligence fine-tuned the universe
- A “multiverse” exists, an ensemble of universes, and we happen to live in one suitable for life
- It’s just a coincidence!





The Multiverse

“the possibility that there could be other universes (either connected or disconnected from ours) in which the constants of physics (and perhaps even the laws of nature) are different ...”

- Carr, 2007

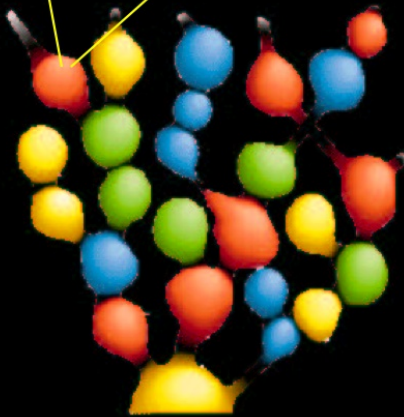
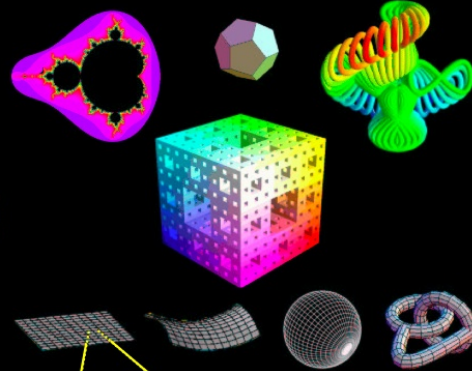
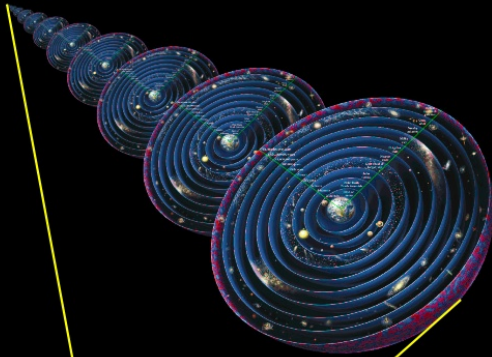
Thomas Wright of Durham,
*An Original Theory
or New Hypothesis of the Universe* (1750)

Level 1: Regions beyond our cosmic horizon

Features: Same laws of physics, different initial conditions
Assumptions: Infinite space, ergodic matter distribution
Evidence:
- Microwave background measurements point to flat, infinite space, large-scale smoothness
- Simplest model

Level 4: Other mathematical structures

Features: Different fundamental equations of physics
Assumption: Mathematical existence = physical existence
Evidence:
- Unreasonable effectiveness of math in physics
- Answers Wheeler/Hawking question: "why these equations, not others"



Level 2: Other post-inflation bubbles

Features: Same fundamental equations of physics, but perhaps different constants, particles and dimensionality
Assumption: Chaotic inflation occurred
Evidence:
- Inflation theory explains flat space, scale-invariant fluctuations, solves horizon problem and monopole problems and can naturally explain such bubbles
- Explains fine-tuned parameters

Level 3: The Many Worlds of Quantum Physics

Features: Same as level 2
Assumption: Physics unitary
Evidence:
- Experimental support for unitary physics
- AdS/CFT correspondence suggests that even quantum gravity is unitary
- Decoherence experimentally verified
- Mathematically simplest model

Why A Multiverse?

Major Problem:
Unverifiable!

Max Tegmark –
Four Levels of Multiverse

Is This Science?

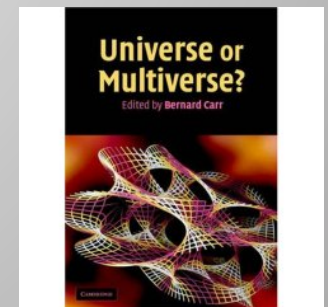
“The influence of the anthropic principle on contemporary cosmological models has been sterile. It has explained nothing and it has even had a negative influence. I would opt for rejecting the anthropic principle as needless clutter in the conceptual repertoire of science.”

Heinz Pagels, *Perfect Symmetry*, 1985

Is This Science?

“The idea is highly speculative and, from both a cosmological and a particle physics perspective, the reality of a multiverse is currently untestable. Indeed, it may always remain so, in the sense that astronomers may never be able to observe the other universes with telescopes and particle physicists may never be able to observe the extra dimensions with their accelerators.”

Bernard Carr, *Universe or Multiverse?* 2007

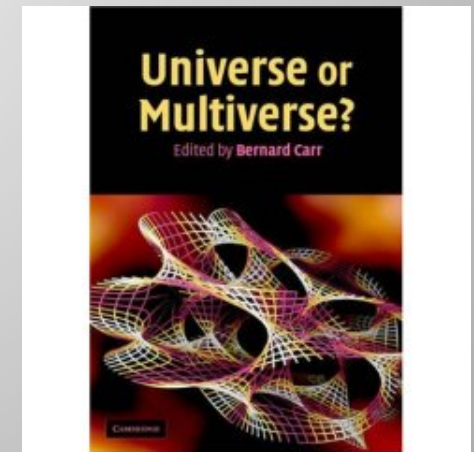


Is This Science?

But ...

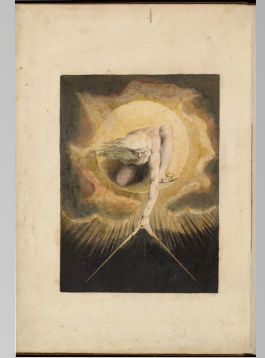
There has been a fundamental change in the epistemological status of the multiverse proposal and the anthropic principle because of the many ways in which we now realize other universes could originate ...

Carr, Universe or Multiverse? 2007

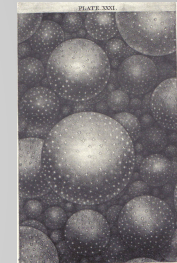


So, Why is the Universe Biofriendly?

1) God Hypothesis – unverifiable



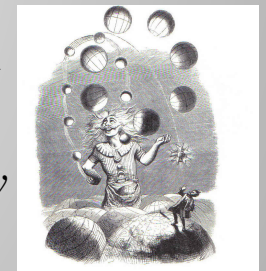
2) Multiverse – unverifiable



3) Highly evolved natural intelligence –
verifiable in principle, but difficult!

The Matrix? Humans are a computer simulation created by an advanced civilization good with computers!

- See Fred Hoyle, James Gardner's *Biocosm*, Steve Dick's *Cosmotheology*
- Sherlock Holmes: When you have eliminated the impossible, whatever remains, however improbable, must be the truth ...



4) It's a Coincidence!

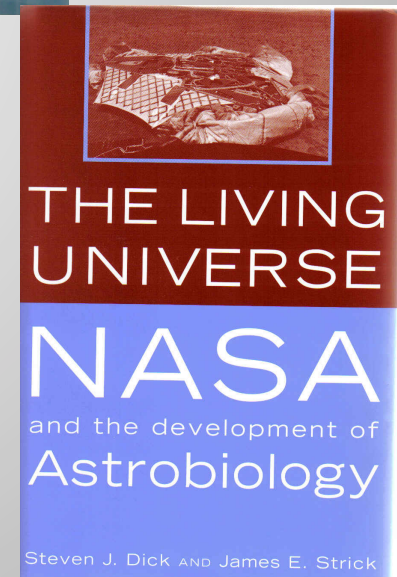
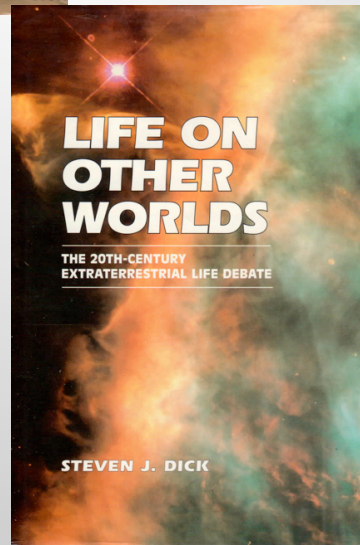
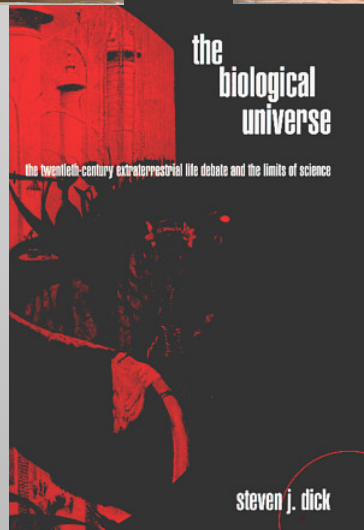
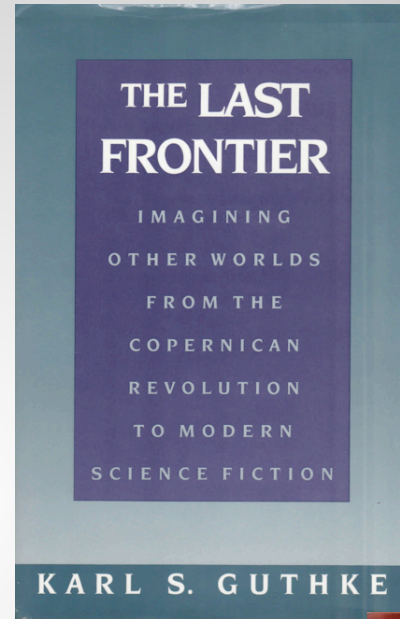
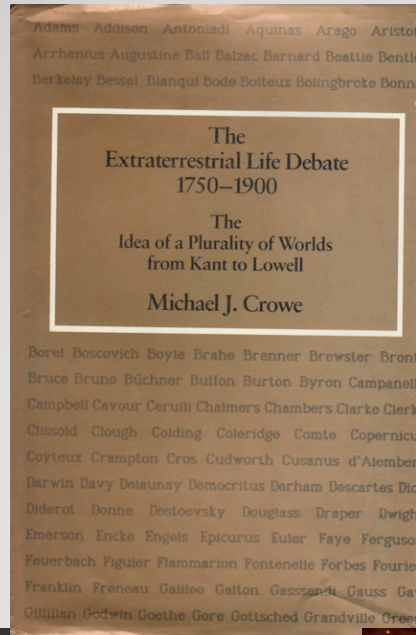
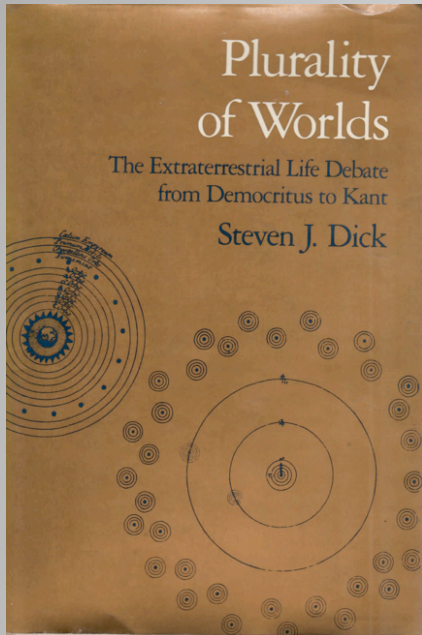
Prospect ...

“The prospects are bright for a future-oriented science, joining together in a disciplined fashion the resources of biology and cosmology.”

Freeman Dyson, *Infinite in All Directions*, 1988

Fine tuning and the multiverse may prove central to this task

Deep History of ETL Debate





THANK YOU!