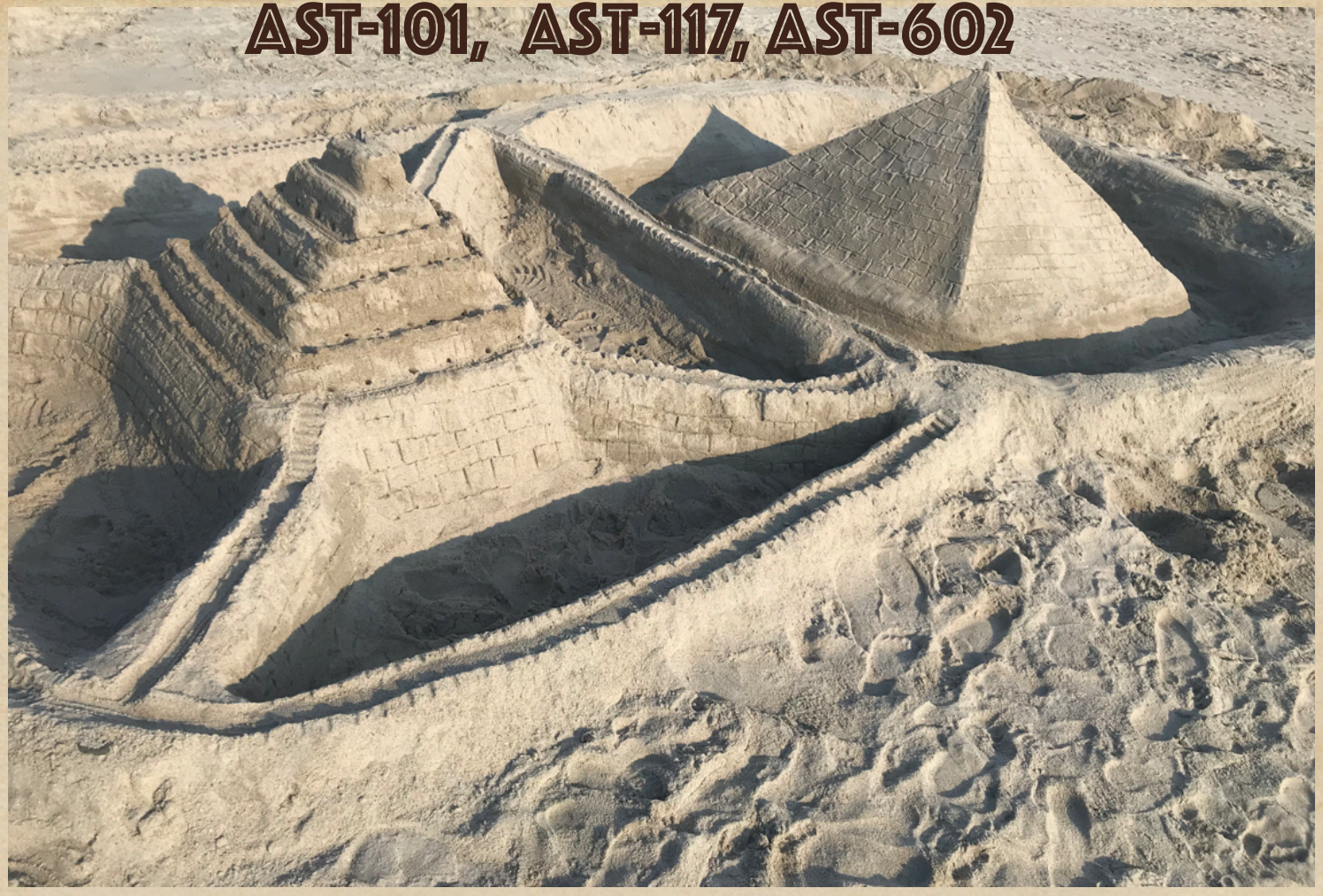
AST-101, AST-117, AST-602

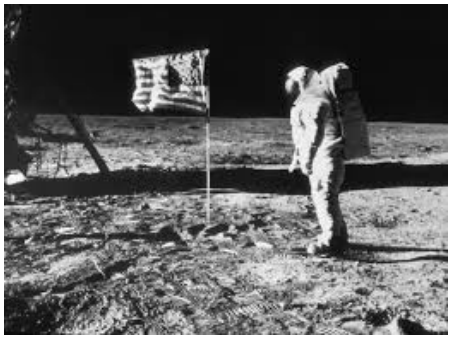


Space colonization and the Fermi paradox

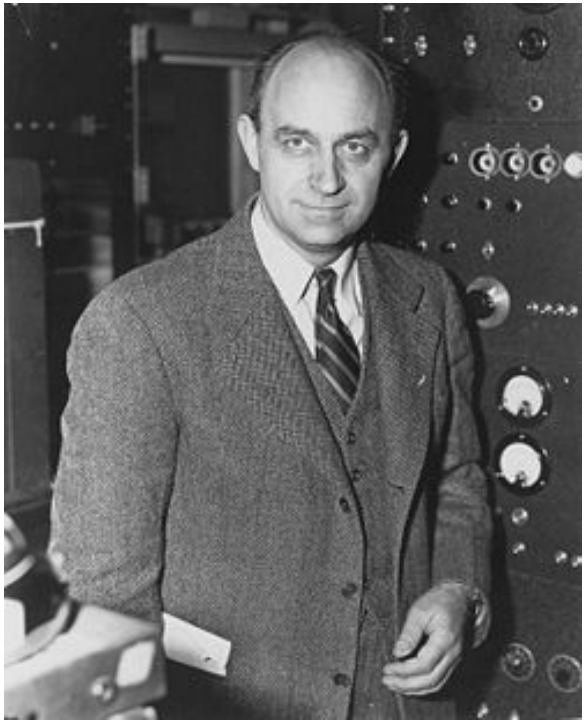
Luis Anchordoqui

On May 25, 1961 President Kennedy's announcement to put a man on the moon and bring him back safely before the end of the decade set the advent of human exploration of space for NASA, culminating to the landing on the Moon on July 16, 1969.

It is difficult to believe that this is the only time such an event has ever happened in the history of the universe.



The Fermi Paradox



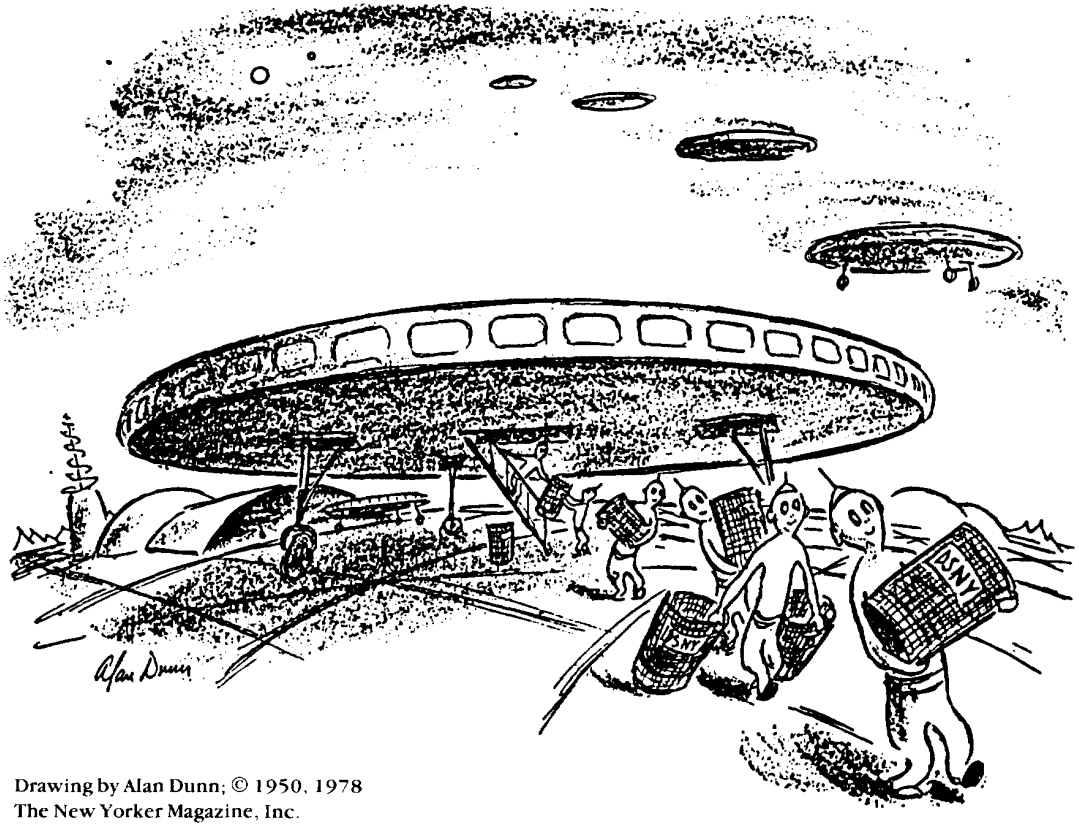
Enrico Fermi: Italian physicist (1901-1954)

On the other hand

If intelligent life is common, where is everyone?

Fermi paradox

Discrepancy between strong likelihood of alien intelligent life
(emerging under a wide variety of assumptions)
and absence of any visible evidence for such emergence



Drawing by Alan Dunn; © 1950, 1978
The New Yorker Magazine, Inc.

The Fermi Paradox according to Sherlock Holmes

“Is there any point to which you wish to draw my attention?”
“To the curious incident of the dog in the night-time.”
“The dog did nothing in the night time.”
“That was the curious incident,” remarked Sherlock Holmes.

-- *Silver Blaze*, A. Conan Doyle

Which of the following is not considered a potential solution to the question of why we lack any evidence of a galactic civilization?

A. there is no galactic civilization because we are the first species ever to achieve the ability to study the universe
B. the galactic civilization probably is undetectable because they operate under different laws of physics from the ones we know
C. the galactic civilization is deliberately avoiding contact with us
D. there is no galactic civilization because all civilizations destroy themselves before they achieve the ability to colonize the galaxy

Which of the following is not considered a potential solution to the question of why we lack any evidence of a galactic civilization?

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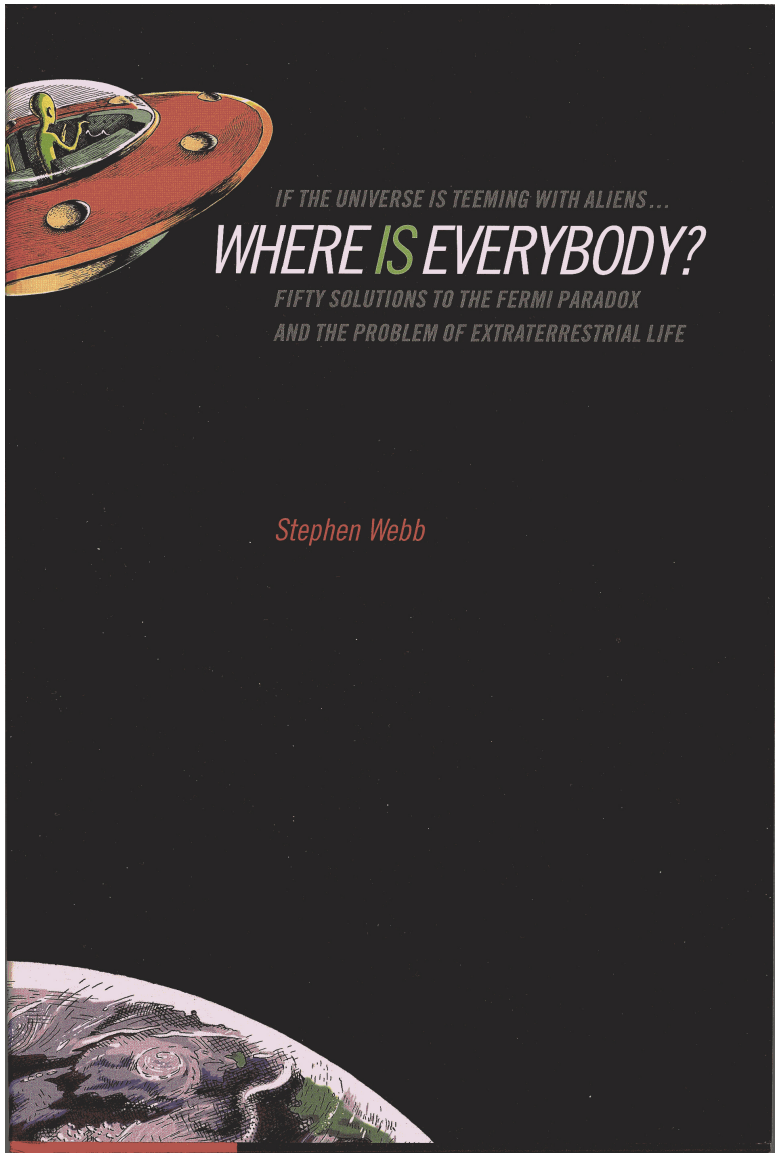


Types of answers:

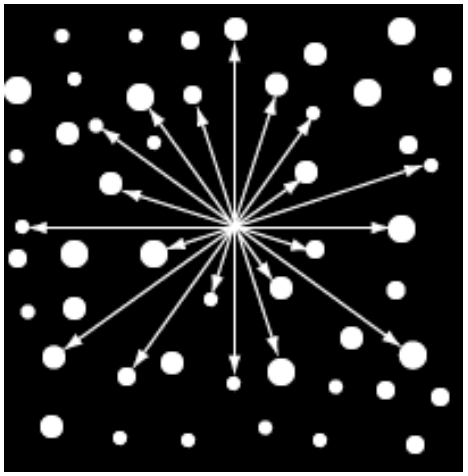
1. They do not exist.
2. They exist but have not yet communicated with us.
3. They are here.

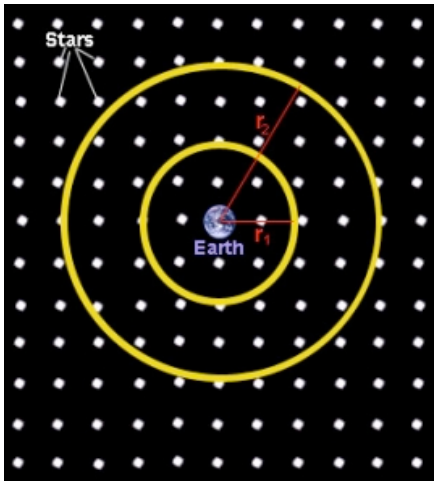
An Analogy

Recall Olbers' paradox:

An infinite universe that is infinitely old should be infinitely bright.

So why is the night sky dark?





The night sky is dark because the universe is finite both spatially and temporally.

Though the number of stars is huge, the universe is essentially sparse.

Fermi Paradox

- The FP may have a similar solution:
- “N” may be large (lots of civilizations) but the Galaxy is too large for the likelihood of one civilization encountering another.
- … yet.

- The smaller N is, the more sparse the Galaxy.

Whose paradox asks why the sky is not ablaze with starlight if the universe is infinite in extent and uniformly filled with stars?

A. Olber's

B. Fermi's

C. Schuller's

D. Miller's

Whose paradox asks why the sky is not ablaze with starlight if the universe is infinite in extent and uniformly filled with stars?

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B. Fermi's

C. Schuller's

D. Miller's


AD ASTRA
SPACE
EXPLORATION INNOVATION BROUGHT DOWN TO EARTH

PURPOSE?

Although I could find more reasons, I think the best reason is, because we simply can!

Fly me to the Moon

Which unlucky Apollo lunar landing was canceled after an oxygen tank exploded?

A. Apollo 13

B. Apollo 11

C. Apollo 17

Which unlucky Apollo lunar landing was canceled after an oxygen tank exploded?

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Which was the first manned landing mission on the moon?

A. Apollo 13

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In what year did Neil Armstrong make his historic walk on the Moon?

A. 1959

B. 1969

C. 1979

D. 1999

In what year did Neil Armstrong make his historic walk on the Moon?

A. 1959

B. 1969

C. 1979

D. 1999

How many people have set foot on the Moon?

A. 1

B. 0

C. 1000

D. 12

How many people have set foot on the Moon?

A. 1

B. 0

C. 1000

D. 12

How many manned moon landings have there been?

A. 1

B. 2

C. 3

D. 6

E. 10

F. 12

How many manned moon landings have there been?

A. 1

B. 2

C. 3

D. 6

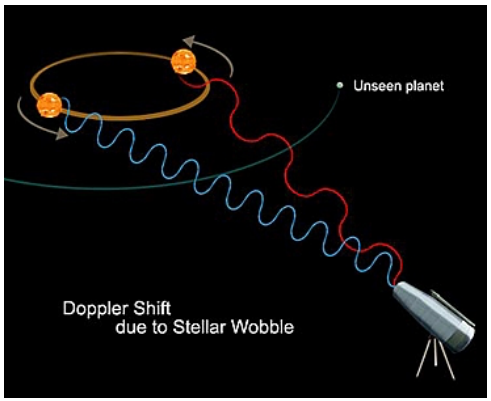
E. 10

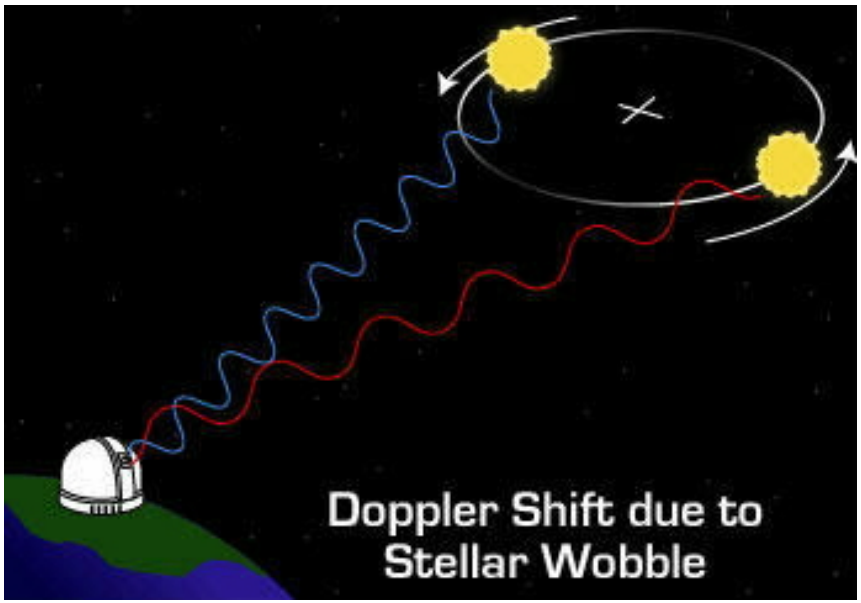
F. 12

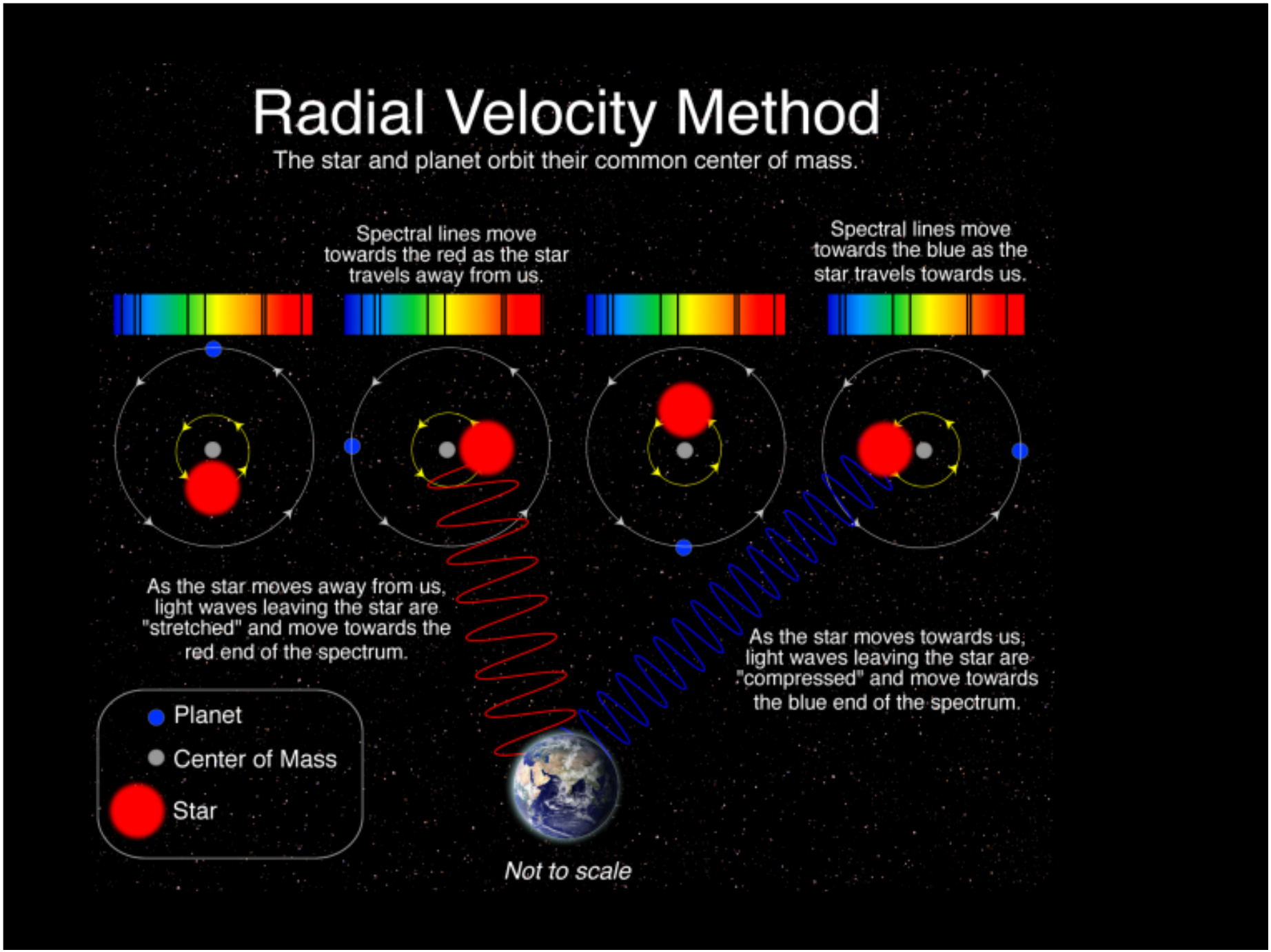
A home away from home

EXTRASOLAR HABITABILITY: EARTH-LIKE PLANETS?

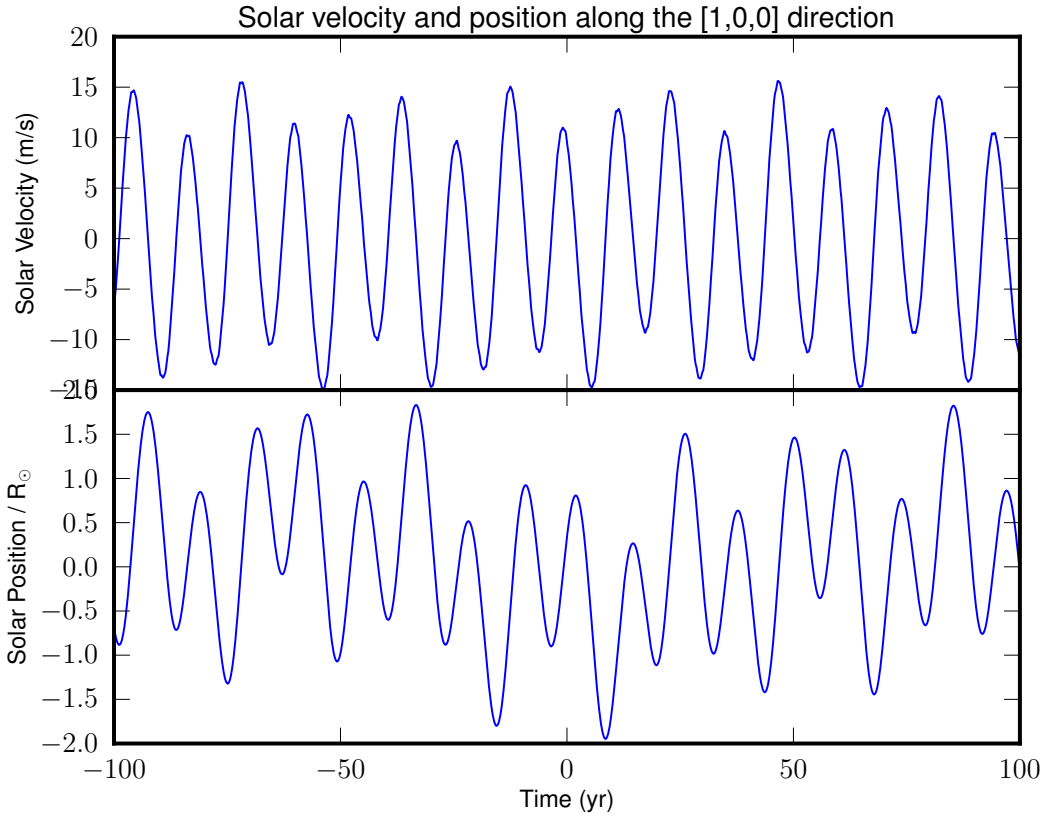
DETECTING EXOPLANETS WITH RADIAL VELOCITY MEASUREMENTS


Unseen planet
Doppler Shift
due to Stellar Wobble


Doppler Shift due to
Stellar Wobble


Radial Velocity Method
The star and planet orbit their common center of mass.
Spectral lines move towards the red as the star travels away from us.
Spectral lines move towards the blue as the star travels towards us.
As the star moves away from us, light waves leaving the star are "stretched" and move towards the red end of the spectrum.
As the star moves towards us, light waves leaving the star are "compressed" and move towards the blue end of the spectrum.
Planet
Center of Mass
Star
Not to scale

If ETs were measuring the radial velocity of the Sun …



All planets in the solar system contribute to the Sun's motion.

This is the distance of the Sun from the solar system's barycenter in units of the Sun's radius.

A Jupiter-mass companion to a solar-type star

Michel Mayor & Didier Queloz

Geneva Observatory, 51 Chemin des Maillettes, CH-1290 Sauverny, Switzerland

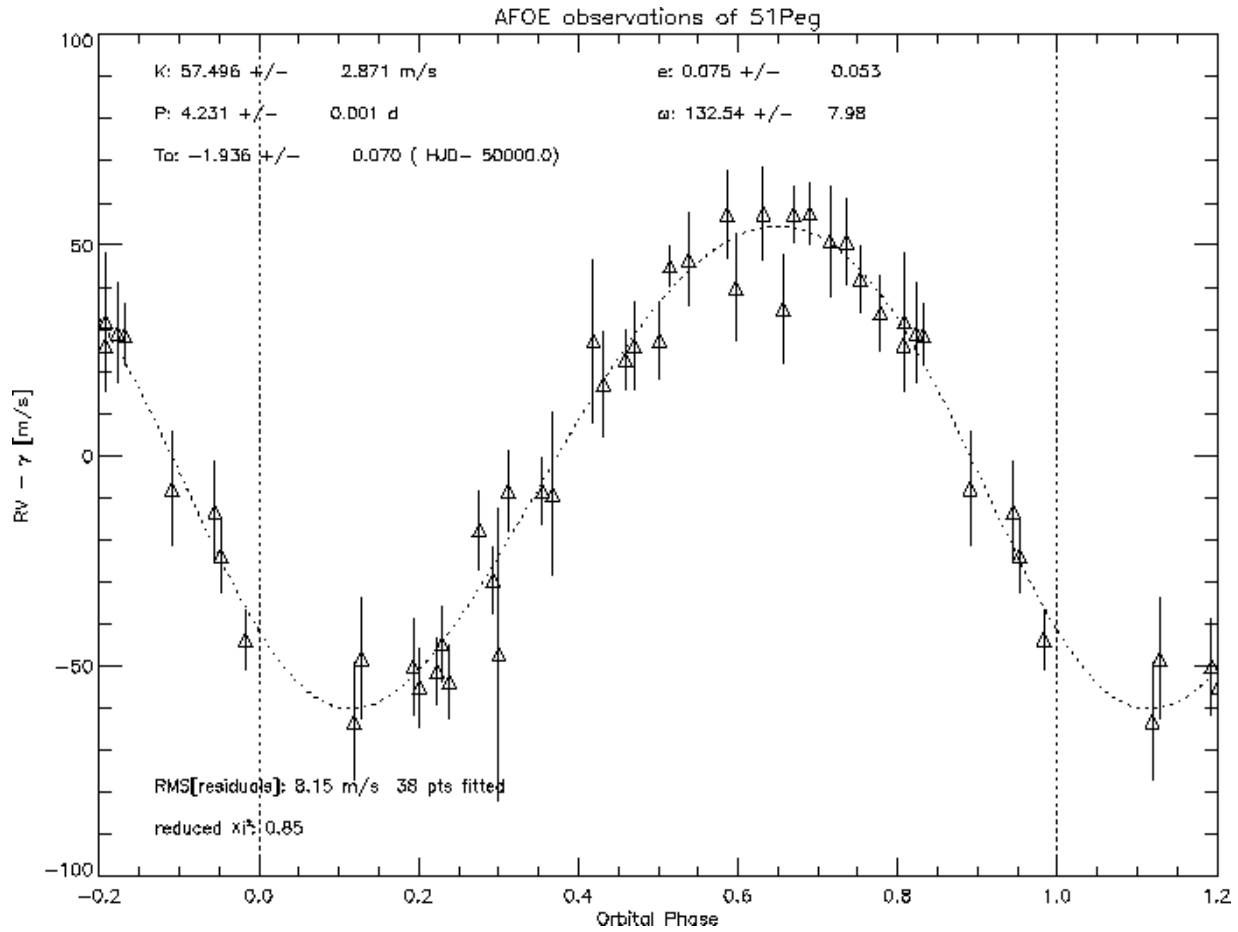
The presence of a Jupiter-mass companion to the star 51 Pegasi is inferred from observations of periodic variations in the star's radial velocity. The companion lies only about eight million kilometres from the star, which would be well inside the orbit of Mercury in our Solar System. This object might be a gas-giant planet that has migrated to this location through orbital evolution, or from the radiative stripping of a brown dwarf.

FOR more than ten years, several groups have been examining the radial velocities of dozens of stars, in an attempt to identify orbital motions induced by the presence of heavy planetary companions[1–5]. The precision of spectrographs optimized for Doppler studies and currently in use is limited to about 15 m s^{-1}. As the reflex motion of the Sun due to Jupiter is 13 m s^{-1}, all current searches are limited to the detection of objects with at least the mass of Jupiter (M_J). So far, all precise Doppler surveys have failed to detect any jovian planets or brown dwarfs.

Since April 1994 we have monitored the radial velocity of 142 G and K dwarf stars with a precision of 13 m s^{-1}. The stars in our survey are selected for their apparent constant radial velocity (at lower precision) from a larger sample of stars monitored for 15 years[6,7]. After 18 months of measurements, a small number of stars show significant velocity variations. Although most candidates require additional measurements, we report here the discovery of a companion with a minimum mass of 0.5 M_J, orbiting at 0.05 AU around the solar-type star 51 Peg. Constraints originating from the observed rotational velocity of 51 Peg and from its low chromospheric emission give an upper limit of 2 M_J for

NATURE · VOL 378 · 23 NOVEMBER 1995

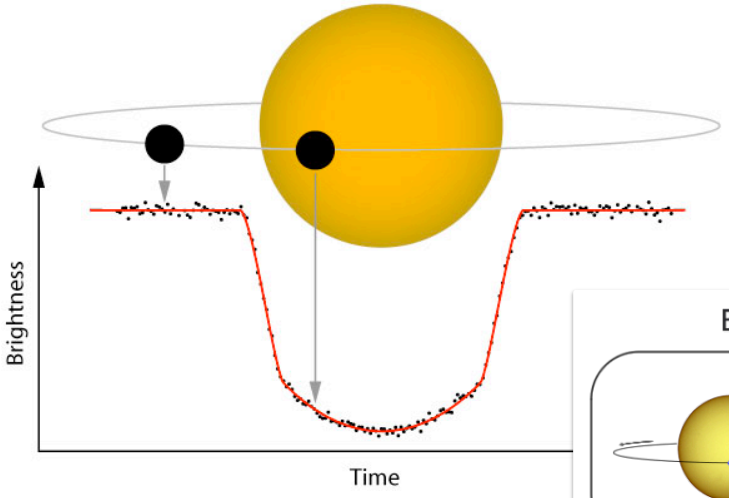
51 Pegasi observations

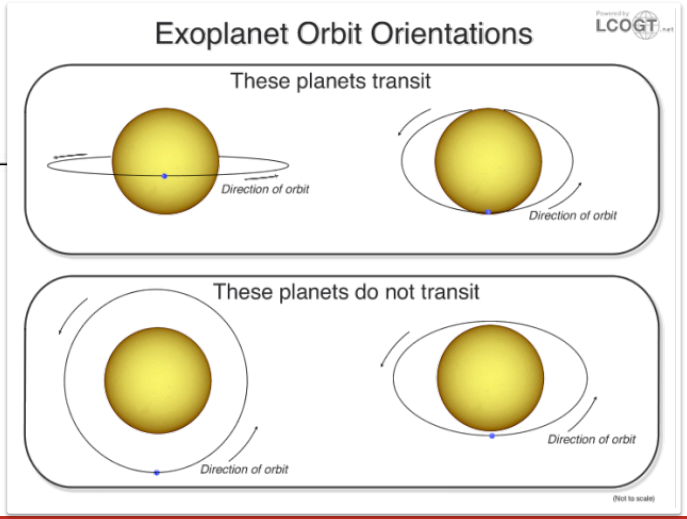


The Kepler mission

DETECTING EXOPLANETS WITH PLANETARY TRANSITS

Planetary Transits





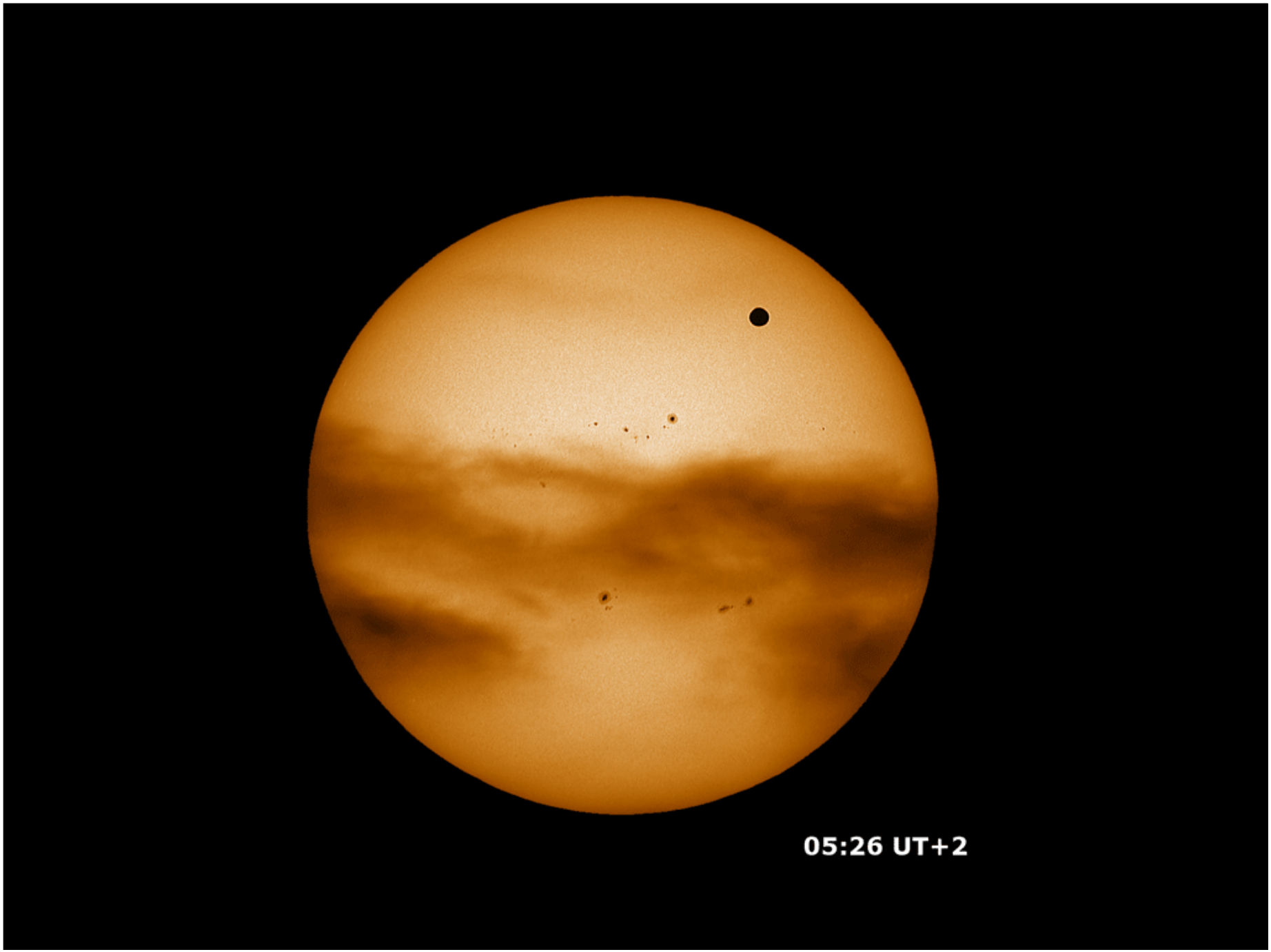

Transit of Venus (2012)

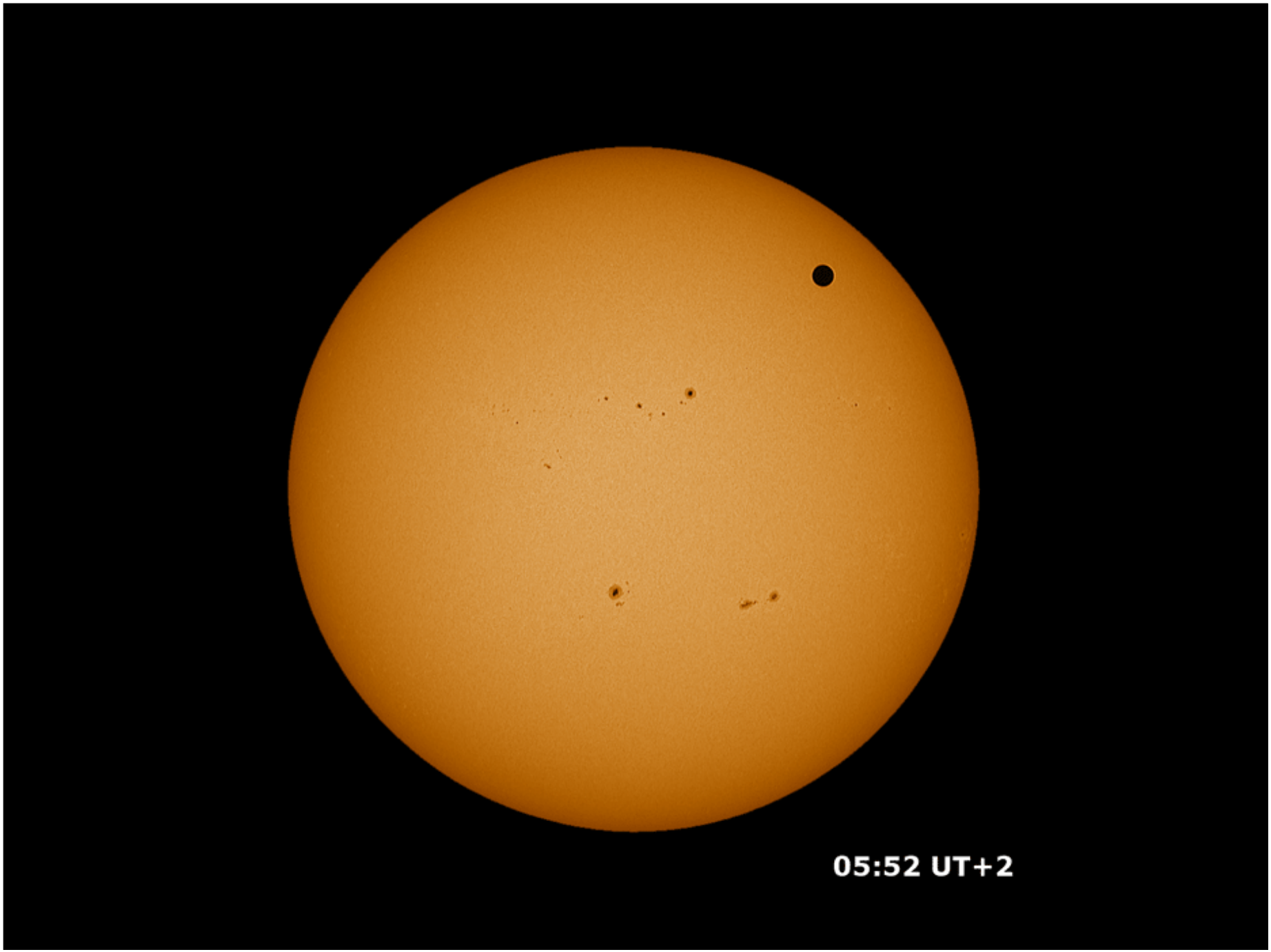
a planet that transits = unique opportunity to observe an exoplanet's

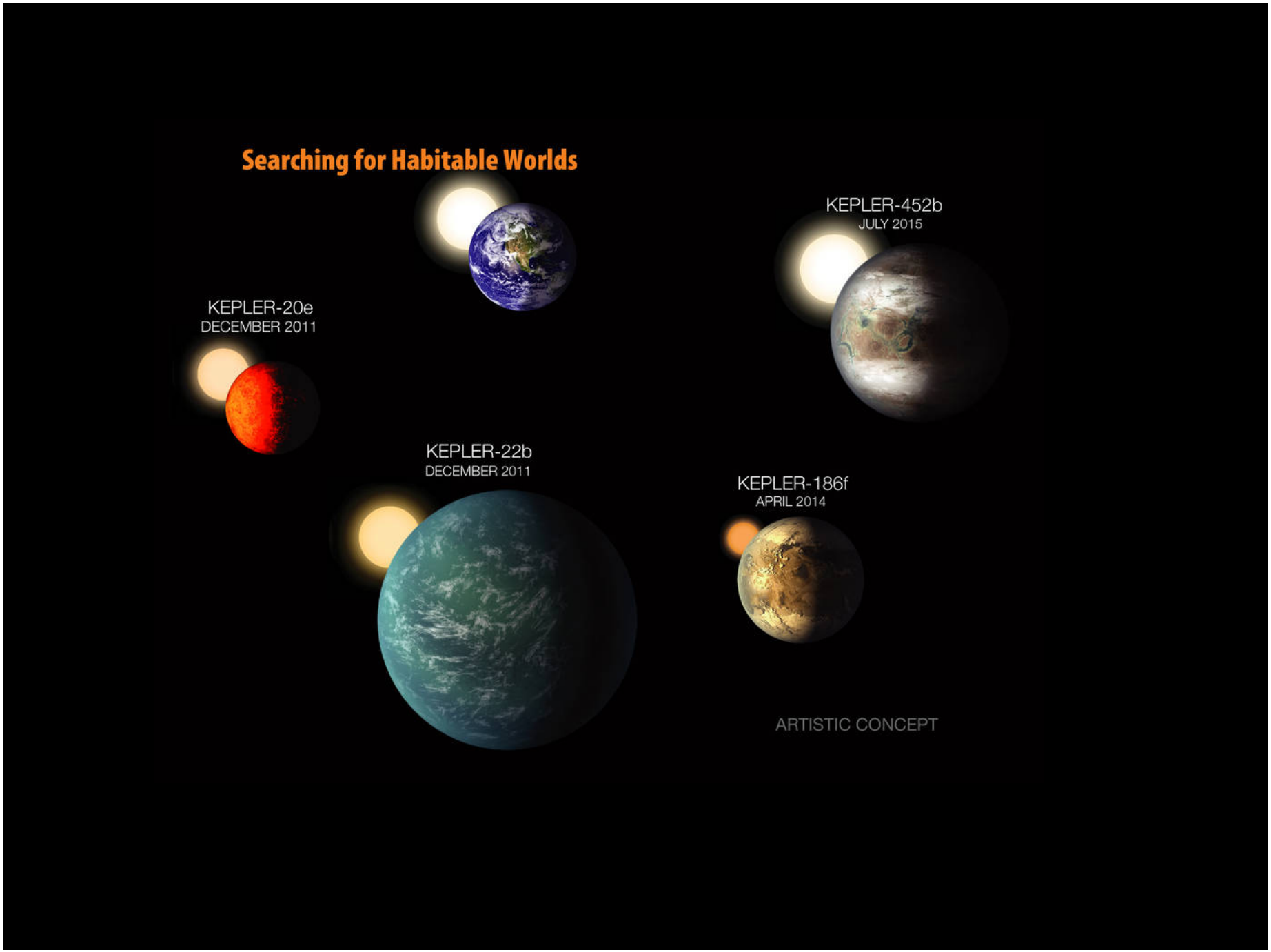
radius
+
orbit
+
mass
+
atmosphere

Is it like Earth?
Is it habitable?
Is it inhabited?

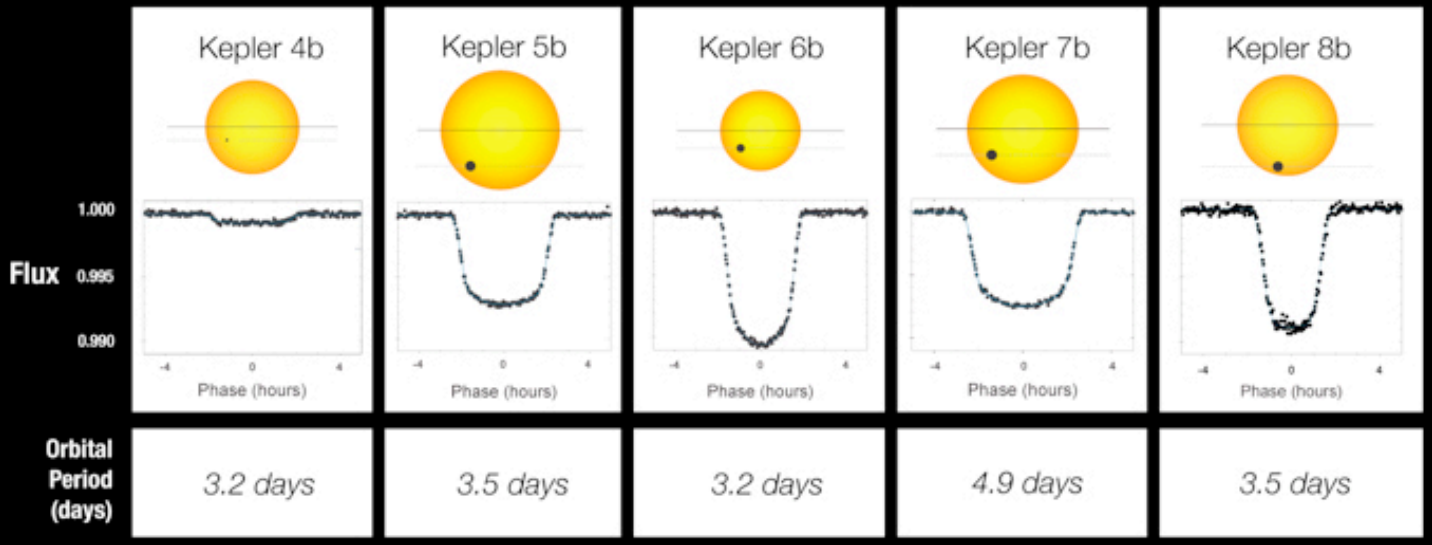

04:42 UT+2


05:26 UT+2


05:52 UT+2

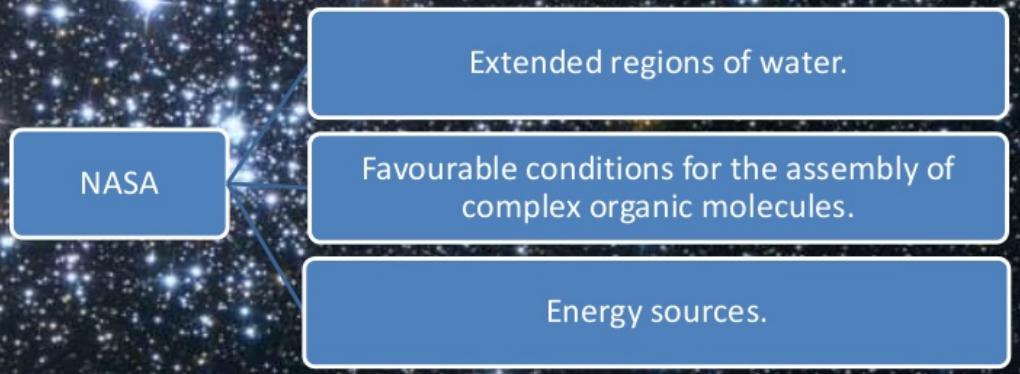

Searching for Habitable Worlds
KEPLER-452b
JULY 2015
KEPLER-20e
DECEMBER 2011
KEPLER-22b
DECEMBER 2011
KEPLER-186f
APRIL 2014
ARTISTIC CONCEPT

Transit Light Curves



Planet Habitability

- Potential of a planet to develop and sustain life.
- Largely agreed on an extrapolation of Earth's and Sun's characteristics.



- HZ: Habitable zone.

- All organisms living on Earth
  require C-based chemistry in liquid water
- According to hot Big Bang model ☞ life (as we know it)
  could not have appeared earlier than $t \sim 10\,\mathrm{Myr}$ after the Bang
  'cause Universe was bathed in thermal radiation background
  above boiling temperature of liquid water
- After $10 \lesssim t/\mathrm{Myr} \lesssim 17$ Universe cooled down
  to habitable comfortable temperatures ☞ $273 \lesssim T/\mathrm{K} \lesssim 373$
- Each star is surrounded by an habitable zone
  defined as the orbital range around star
  within which surface liquid water could be sustained
- Since water is essential for life as we know it
  search for biosignature gases naturally focuses on planets
  located in habitable zone of their host stars

- Total energy flux $\mathscr{F}$ (energy per unit area per unit time) passing through a region can be related to effective temperature T

$$\mathscr{F} = \sigma_{\mathrm{SB}}\, T^4$$

  Stefan-Boltzmann constant ☞ $\sigma_{\mathrm{SB}} \approx 5.67 \times 10^{-8}\ \mathrm{W\,m^{-2}\,{}^{\circ}K^{-4}}$
- Luminosity (energy per unit time) of star is L and flux at distance r from the star are related by

$$\mathscr{F} = \frac{L}{4\pi r^2}$$

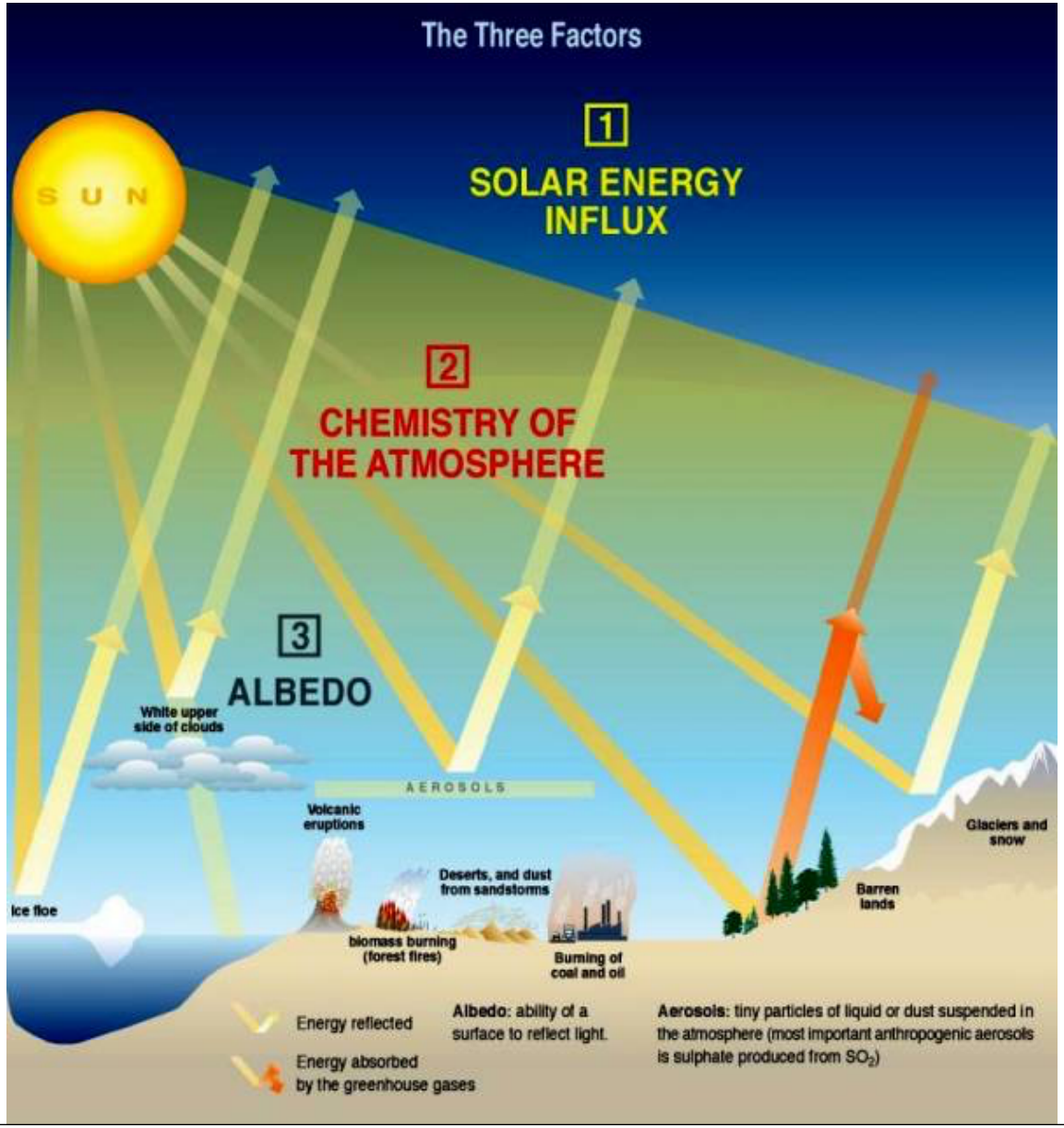
  because area of sphere of radius r is $A = 4\pi r^2$ and flux is luminosity divided by area
- Quick estimate of T at given r from

$$\sigma_{\mathrm{SB}}\, T^4 = \mathscr{F} = \frac{L}{4\pi r^2}$$

  For solar system ☞ σ_{SB}, 4π, $L_\odot$ are constants

$$T^4 \propto \frac{1}{r^2} \Rightarrow T \propto r^{-1/2}$$

ALBEDO


The Three Factors
1
SOLAR ENERGY INFLUX
SUN
2
CHEMISTRY OF THE ATMOSPHERE
3
ALBEDO
White upper side of clouds
AEROSOLS
Volcanic eruptions
Deserts, and dust from sandstorms
Glaciers and snow
Barren lands
Ice floe
biomass burning (forest fires)
Burning of coal and oil
Energy reflected
Energy absorbed by the greenhouse gases
Albedo: ability of a surface to reflect light.
Aerosols: tiny particles of liquid or dust suspended in the atmosphere (most important anthropogenic aerosols is sulphate produced from SO_2)

The word Albedo refers to which of the following?

A. the wobbling motion of a planet

B. the amount of light a planet reflects

C. the phase changes of a planet

D. the brightness of a star

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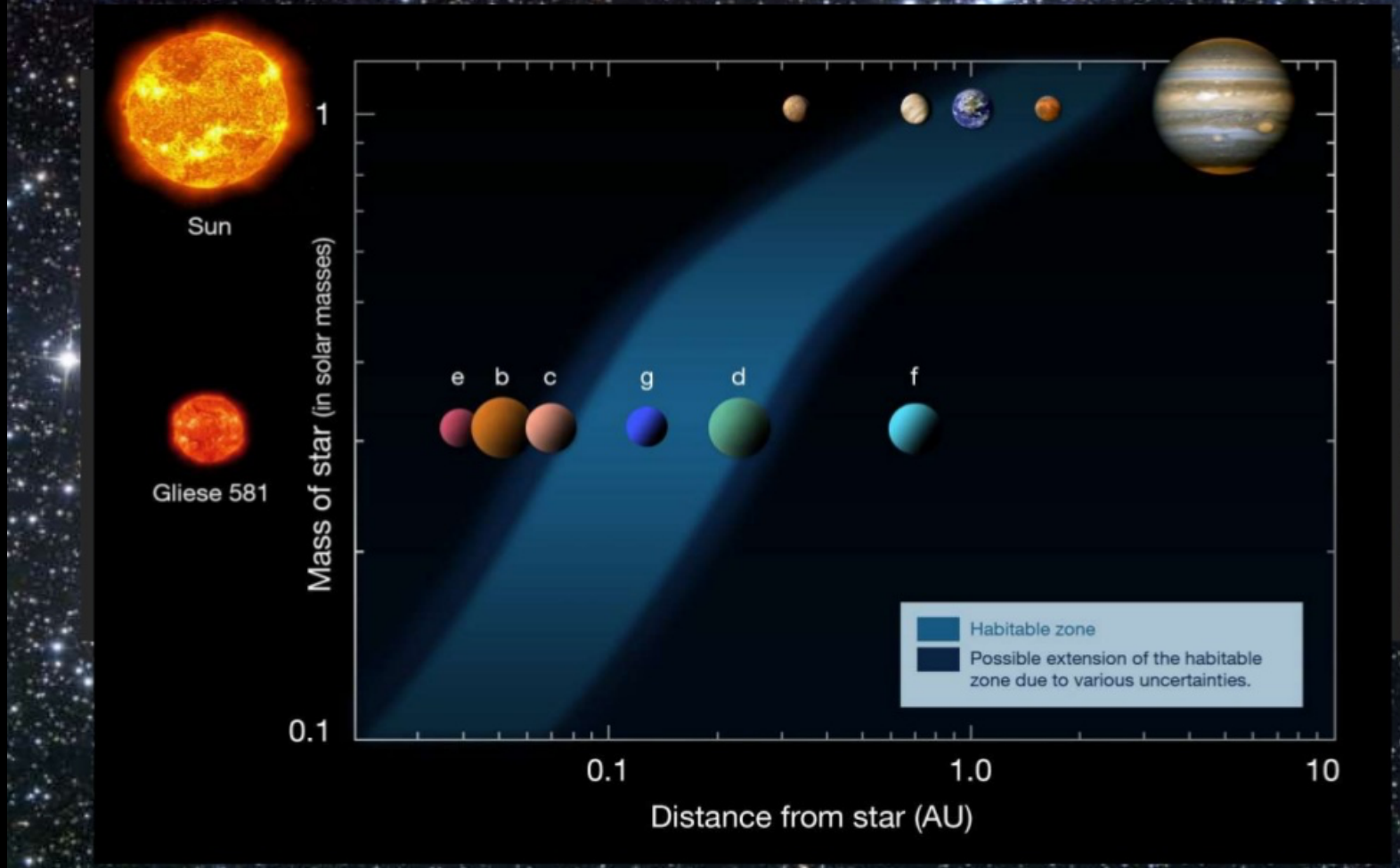
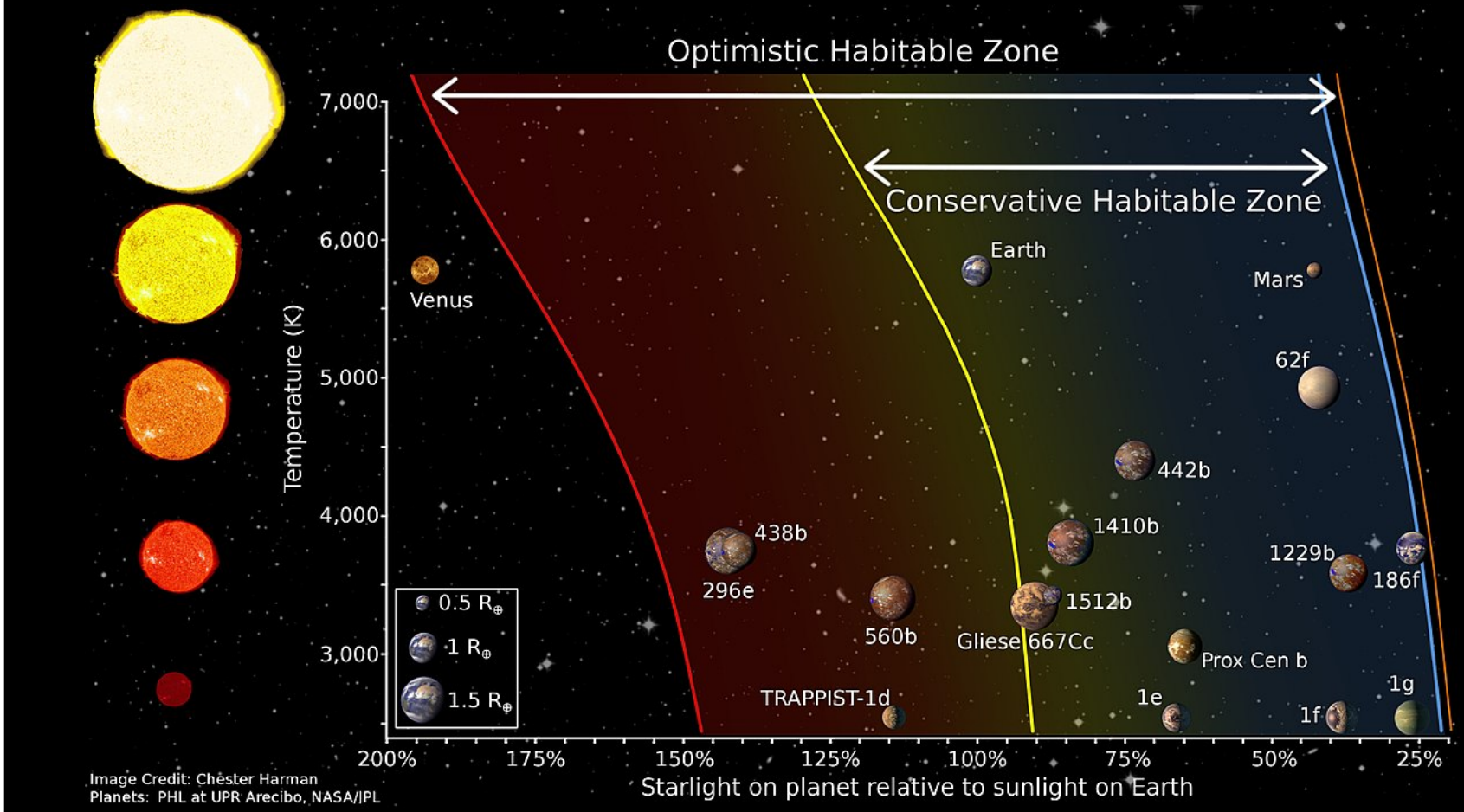
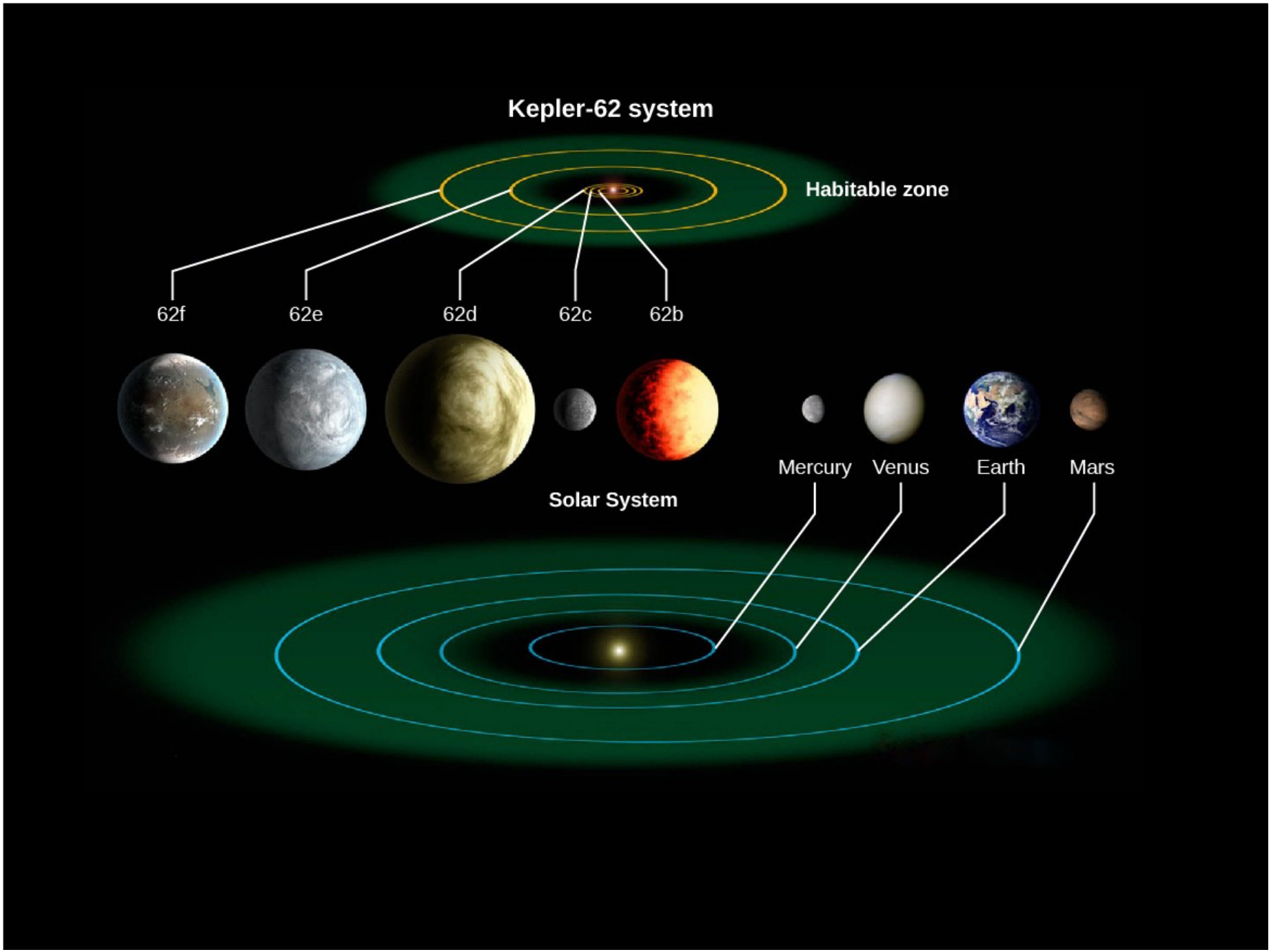
Goldilock's zone



Habitable zone regions




Kepler-62 system
Habitable zone
62f
62e
62d
62c
62b
Mercury
Venus
Earth
Mars
Solar System

What defines the habitable zone around a star?

A. the region around a star where rocky planets form
B. the region around a star where humans can survive
C. the region around a star where liquid water can potentially exist on planetary surfaces
D. the region around a star where the ultraviolet radiation does not destroy organisms on a planetary surface
E. the region around a star where life exists

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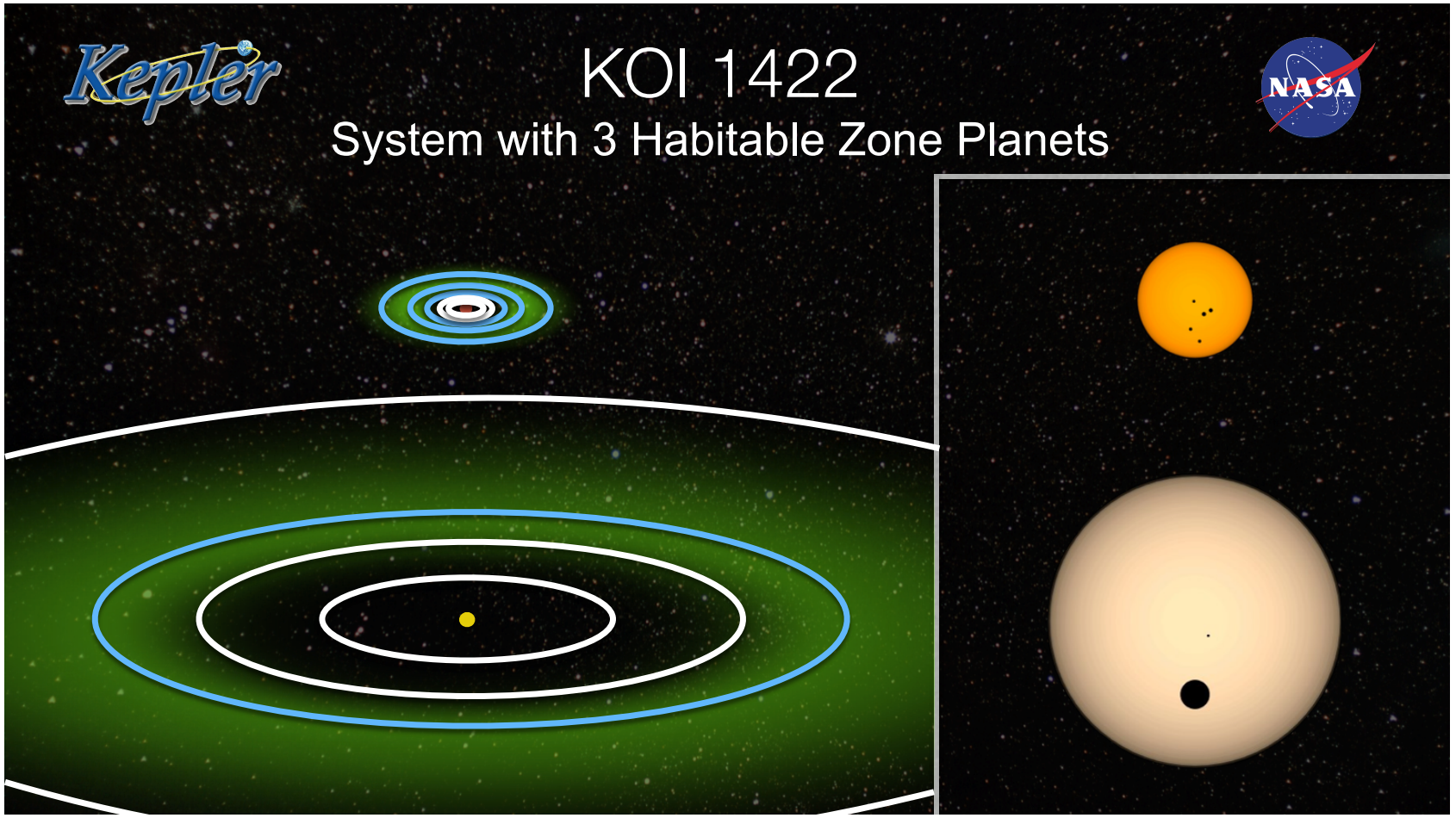
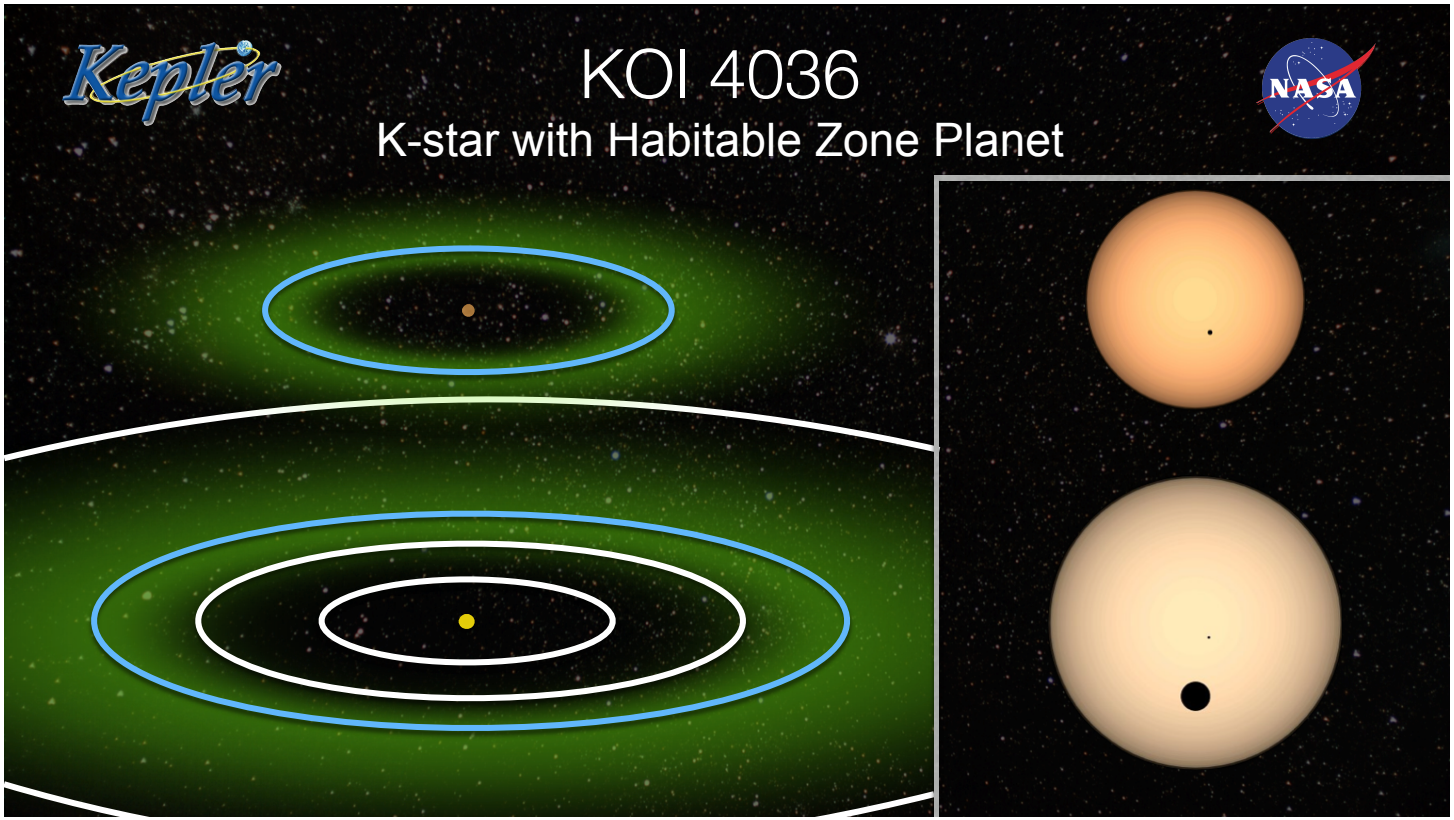
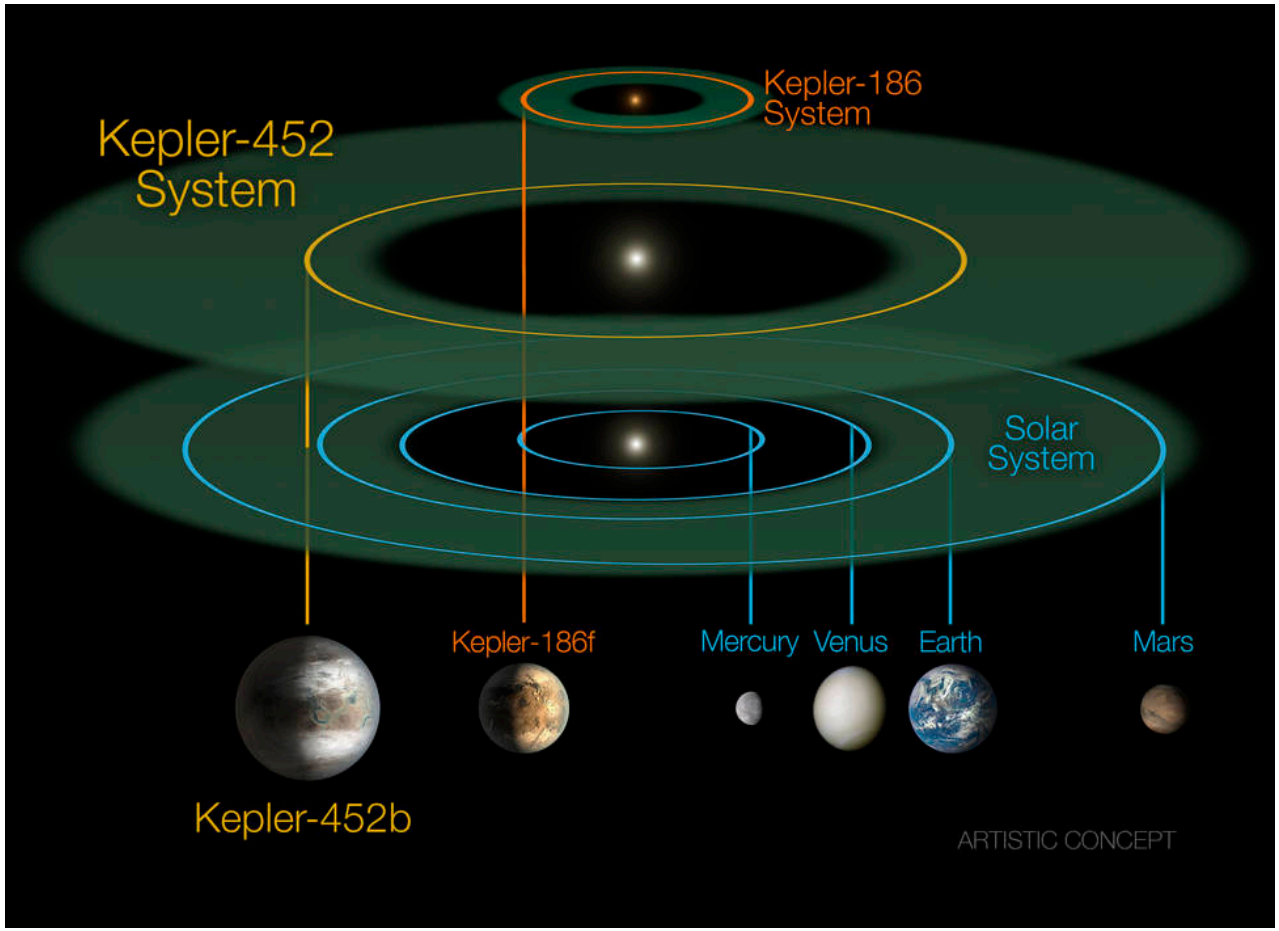
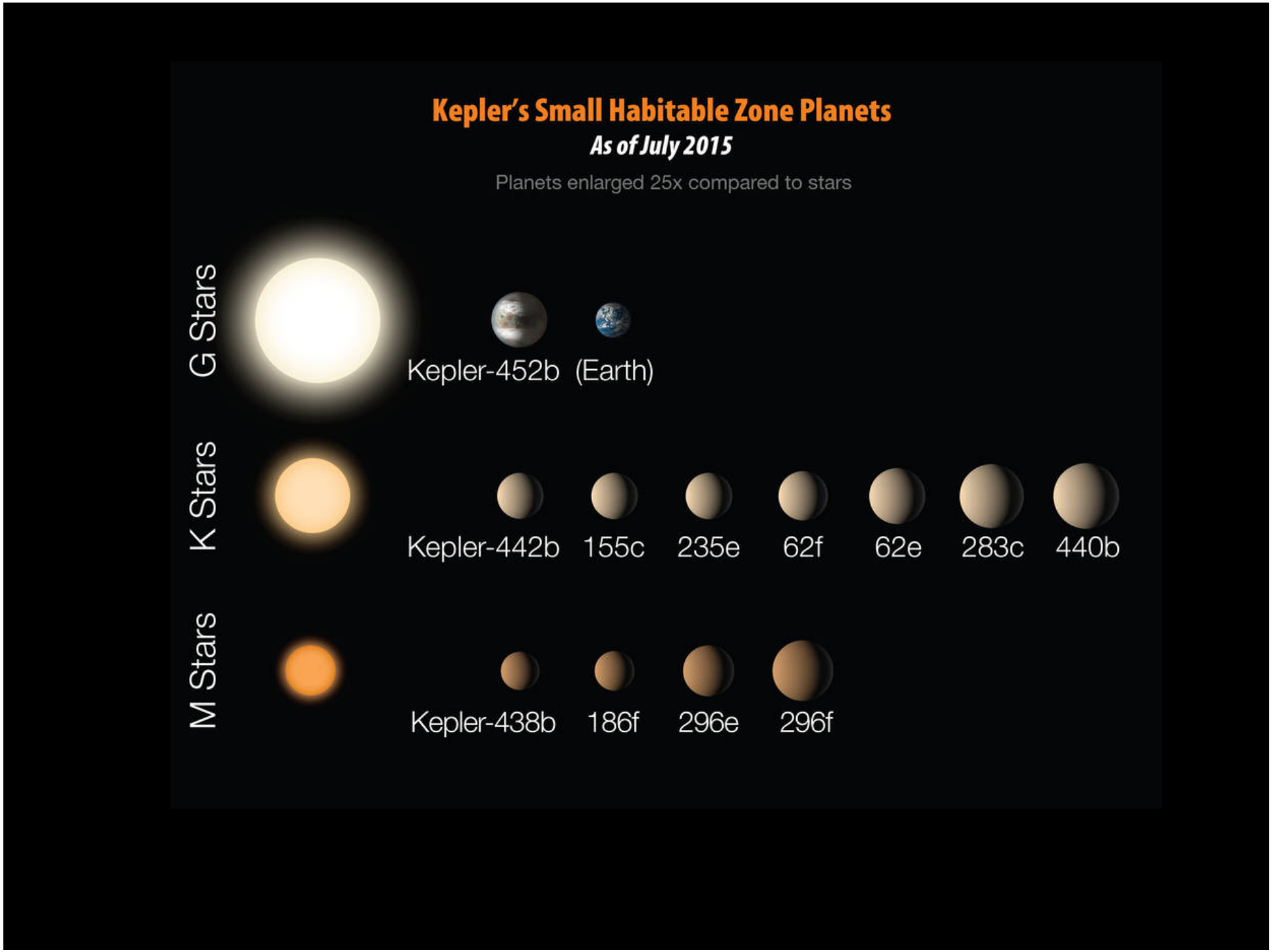

Kepler
KOI 1422
System with 3 Habitable Zone Planets
NASA


Kepler
KOI 4036
K-star with Habitable Zone Planet
NASA


Kepler-452
System
Kepler-186
System
Solar
System
Kepler-186f
Mercury
Venus
Earth
Mars
Kepler-452b
ARTISTIC CONCEPT


Kepler's Small Habitable Zone Planets
As of July 2015
Planets enlarged 25x compared to stars
G Stars
Kepler-452b
(Earth)
K Stars
Kepler-442b
155c
235e
62f
62e
283c
440b
M Stars
Kepler-438b
186f
296e
296f

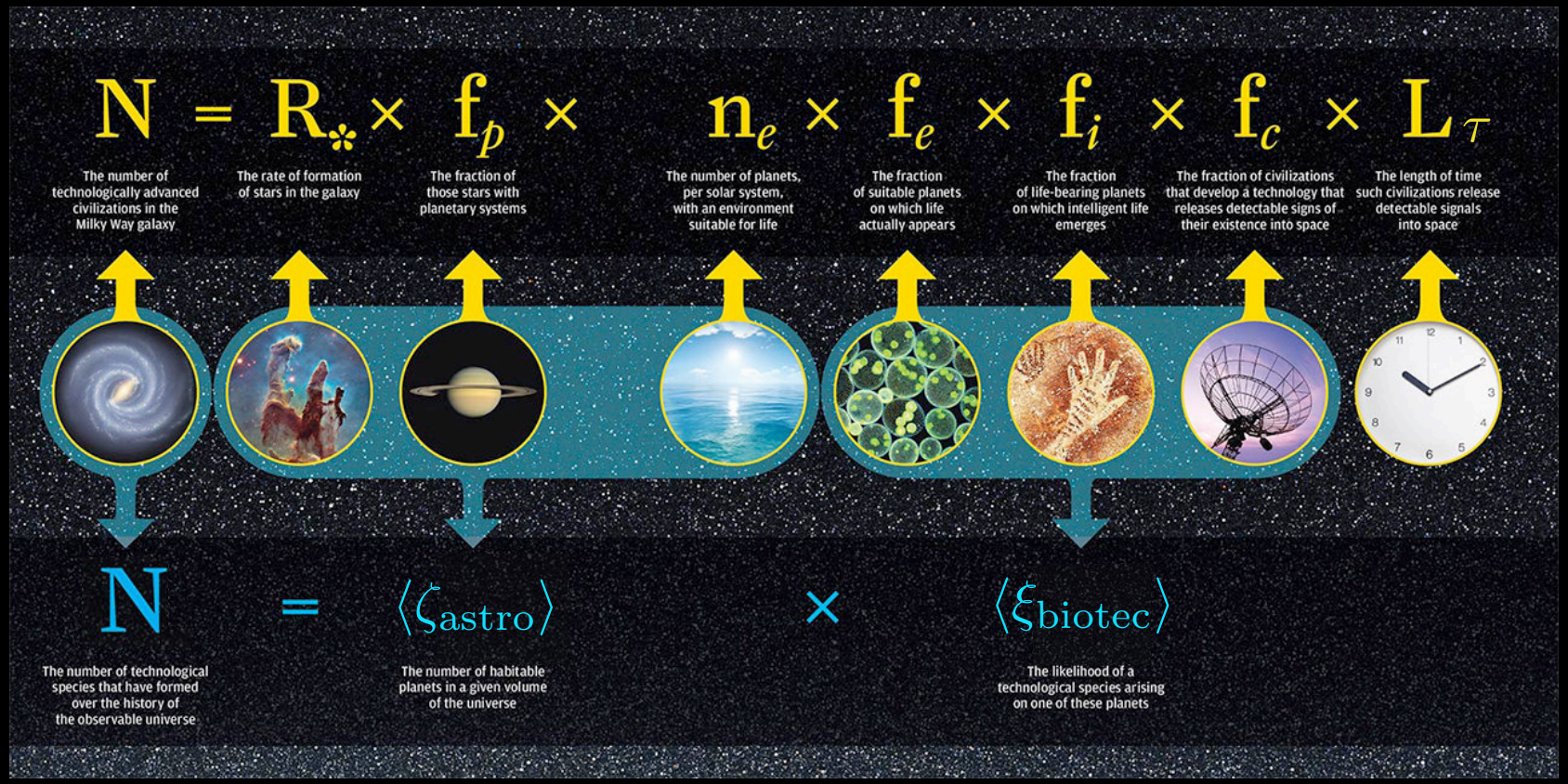
Why search? Assessing the Odds

- **The astrophysical case:**
  p (habitable planets | Galaxy)

- **The biological case:**
  p (life | habitable planets)

- **Complexity:**
  p (technology | life)
  p (extroversion | technology)

Drake's equation



- $\langle \zeta_{\rm astro} \rangle \sim 0.002\ {\rm yr}^{-1}$ and $\xi_{\rm biotec} \leq 1$
- If the communicative phase is smaller than 500 years
  there would be no paradox

How Many Planets are in the Galaxy?

- There are approximately 100 billion F,G,K stars.
- About 2/3 of these are in binaries with other stellar companions (not ideal for planets – but see Kepler results).
- Most of the ~30 billion isolated stars likely have planetary systems (and so do some binary systems).
- If 1% of these have planets that are habitable and on which life has formed there could be N_p= 300 million planets with the potential of harboring life.
- With these numbers, the nearest life-bearing planet could be <10 pc away. (cf. Kepler numbers discussed earlier.)

Which of the following parameters in the Drake Equation do we have sufficient data on such that the value we might assign when calculating the Drake equation goes beyond pure speculation?

A. the number of habitable planets per planetary system

B. the fraction of habitable planets on which life arises

C. the rate of star formation

D. the average lifetime of a technological civilization

E. the fraction of life-bearing planets on which intelligence arises

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E. the fraction of life-bearing planets on which intelligence arises

One reason that might be valid for not expecting life on a planet orbiting a very high-mass (blue, spectral type O) star is

A. no habitable zone possible—star is too hot

B. habitable zone too far from the star

C. the lifetime of the star is probably too short for life to begin

D. too much ultraviolet radiation

E. no habitable zone possible—star is too luminous

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Which of the following statements best reflects our current knowledge about the term flife in the equation

Number of Civilizations = Np × f_life × f_civilization × f_now?

A. the value of flife must be either 0 percent or 100 percent
B. the value of flife is between 0 percent and 100 percent
C. the value of flife is between 0 percent and 1 percent
D. the value of flife is roughly 50 percent
E. the value of flife is presently unknown but should be well known within just a few years

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Are we alone?

Now is the time to find out

Is There Anybody Out There?

What do we look for?
Reciprocity: what do we radiate?

Transmission from Arecibo (1974),
beamed once towards M13 (8 kpc)
at 2.4 GHz.

1679 bits = 23 × 73 grid.

Can you decode it?

The message consists of seven parts that encode the following (from the top down):

- The numbers one (1) to ten (10) (white)
- The atomic numbers of the elements hydrogen, carbon, nitrogen, oxygen, and phosphorus, which make up deoxyribonucleic acid (DNA) (purple)
- The formulas for the sugars and bases in the nucleotides of DNA (green)
- The number of nucleotides in DNA, and a graphic of the double helix structure of DNA (white & blue)
- A graphic figure of a human, the dimension (physical height) of an average man, and the human population of Earth (red, blue/white, & white respectively)
- A graphic of the Solar System indicating which of the planets the message is coming from (yellow)
- A graphic of the Arecibo radio telescope and the dimension (the physical diameter) of the transmitting antenna dish (purple, white, and blue)

In 1974, a radio message was sent out from the Arecibo observatory in Puerto Rico.

How far has it gotten, approximately?

A. just beyond our Solar System

B. not even to the nearest stars

C. just a miniscule fraction of the distance across the Milky Way

D. almost to the center of the Milky Way

E. beyond the Milky Way, to the Andromeda galaxy

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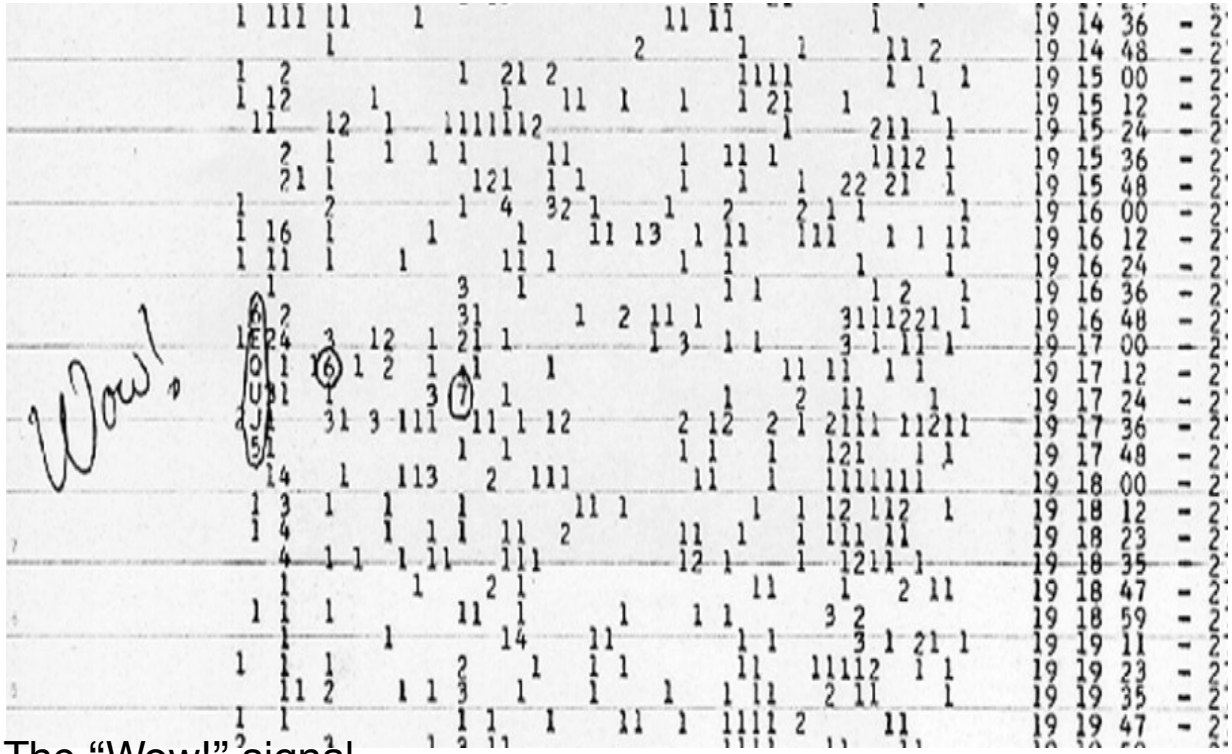
A Famous SETI False Alarm (?)



The “Wow!” signal,
Jerry Ehman, Big Ear radio telescope, Ohio State 1977.

At present, what is the primary way that the search for extraterrestrial intelligence (SETI) is carried out?

A. by searching for planets around distant stars

B. by using large X-ray telescopes to search for signals from extraterrestrial civilizations

C. by using radio telescopes to search for signals from extraterrestrial civilizations

D. by analyzing high-resolution images of nearby stars in search of evidence of structures that could not have developed naturally

E. by seeking access to the secret records and alien corpses kept at Area 51

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Principles and Paradox

Copernican principle

- We find ourselves on an ordinary planet around an ordinary star in an ordinary galaxy.
- AKA the assumption of mediocrity (we're mediocre & there must be lots more like us).

Anthropic principle

- The universe necessarily has properties that allow complex beings like ourselves and life generally to have evolved.
- Is the universe ordinary?

Fermi Paradox

- Given CP + AP, if N is large, *where is everybody*?

The only place outside of Earth where there is irrefutable evidence for (ancient, microbial) life is

A. the Moon

B. Mars

C. Europa

D. Titan

E. None of the above–there is no irrefutable evidence for life beyond Earth

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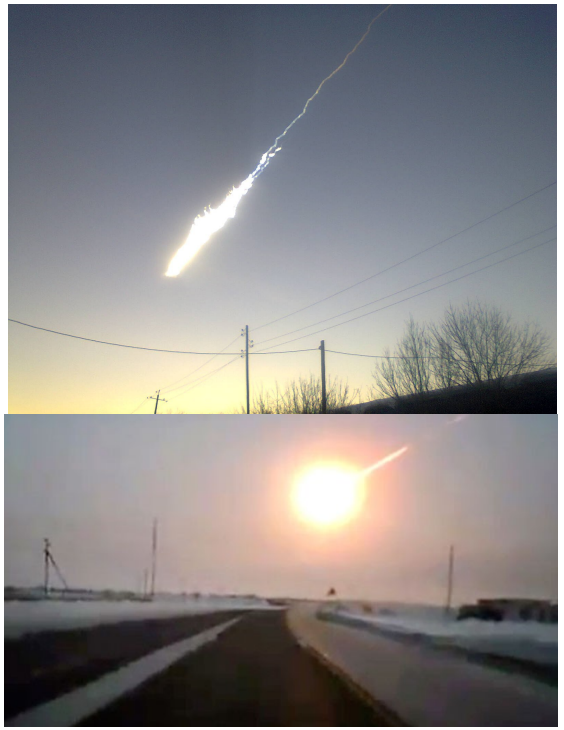
What about UFOs?

…?

What about UFOs?

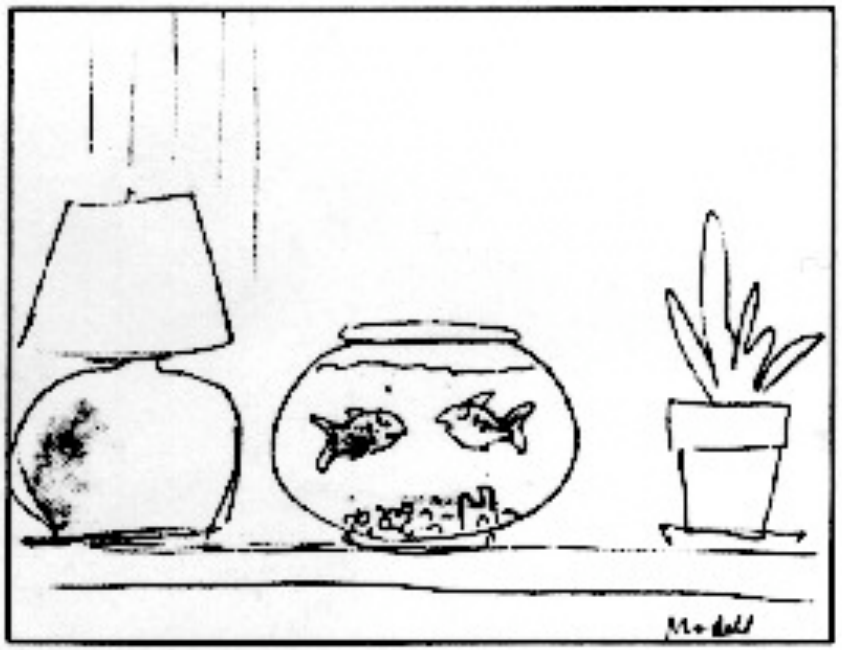
- Smartphones are common today – photo + video recording at fingertips.
- “Dashcams” capture continuous footage: e.g. Chelyabinsk meteor, 2013.
- Robotic survey telescopes continuously monitor night sky.



… Did UFOs become shy <u>just as</u> our ability to record them became commonplace?

Given rates implied by UFO sighting claims in the past, we should have high quality photo / audio / video recordings routinely today.

➔ Not plausible.



"I'll tell you something else I think. I think there are other bowls somewhere out there with intelligent life just like ours." Drawing by Frank Modell; © 1987 The New Yorker Magazine, Inc.

AST-101, AST-117, AST-602

That's all folks