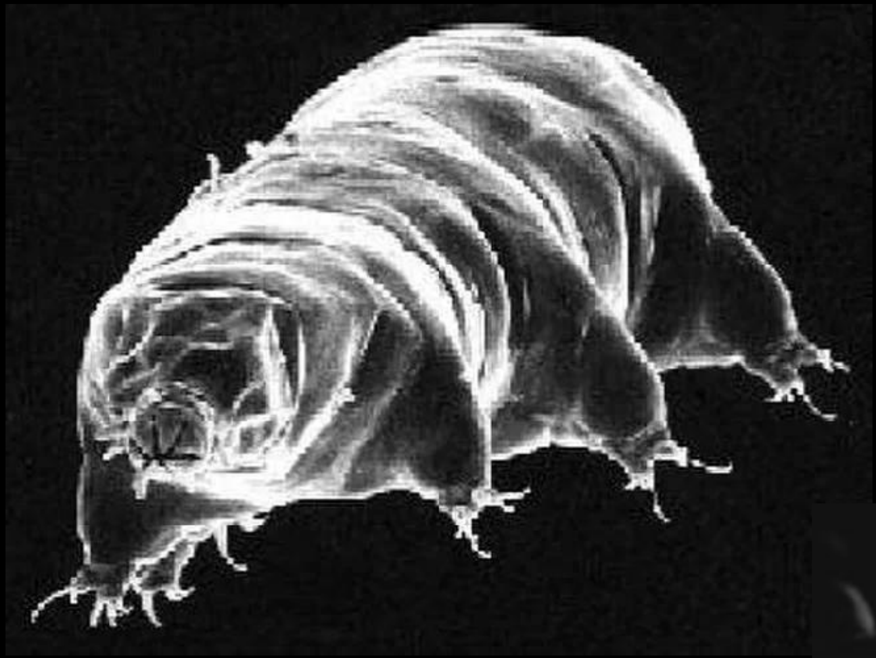
(Interstellar) panspermia Revisited

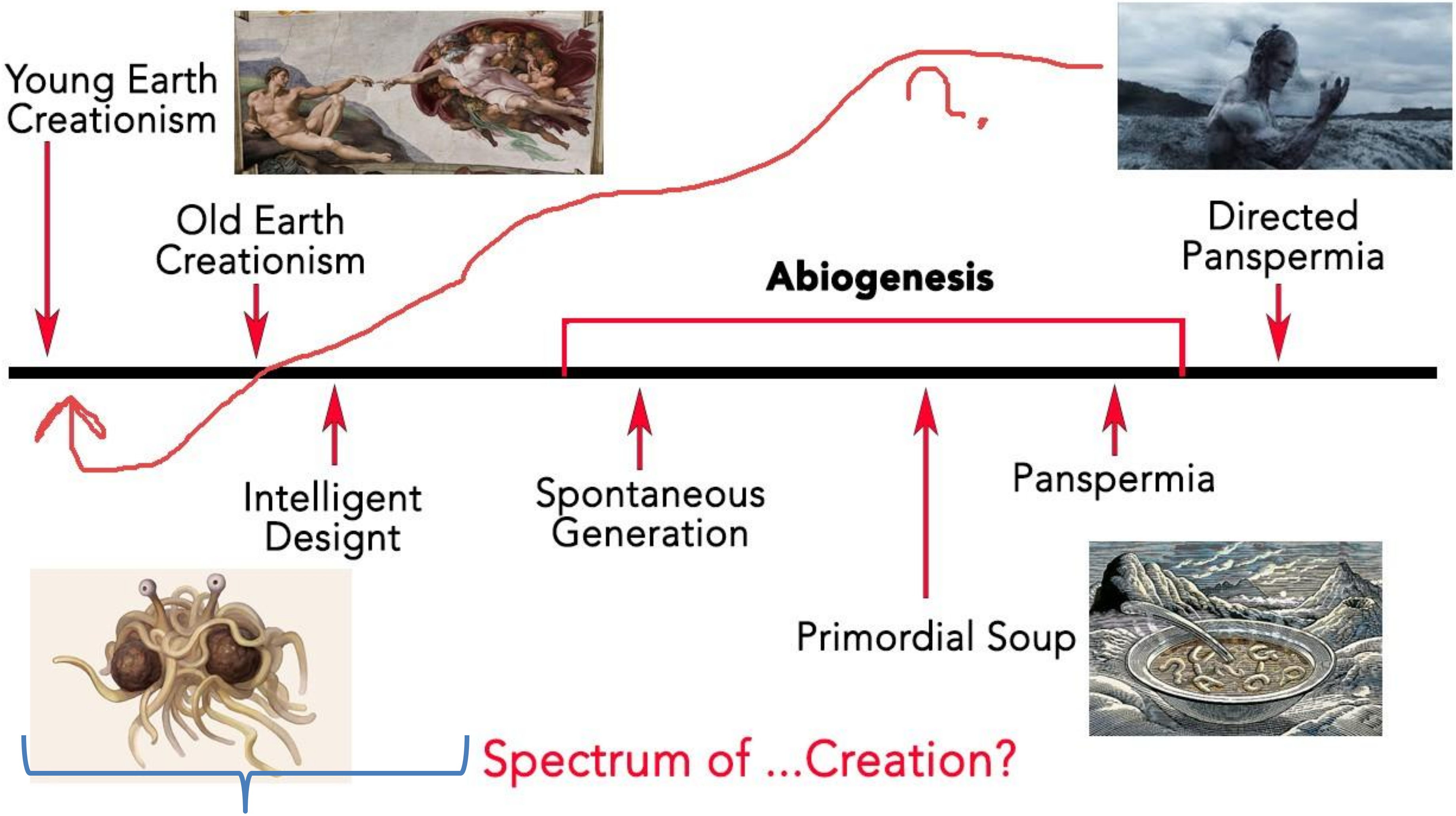


“Tardigrades are one of the most resilient known animals, with individual species able to survive extreme conditions that would be rapidly fatal to nearly all other known life forms, such as exposure to extreme temperatures, extreme pressures (both high and low), air deprivation, radiation, dehydration, and starvation’.

Noah Brosch

Tel Aviv University


WHERE DID WE COME FROM?

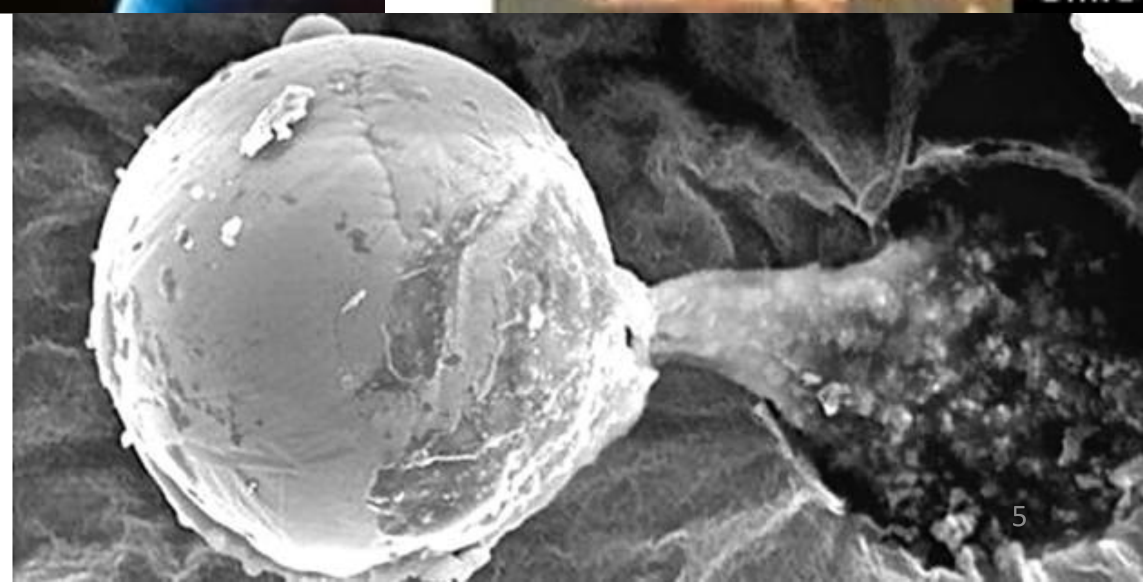


Young Earth Creationism
Old Earth Creationism
Abiogenesis
Directed Panspermia
Intelligent Designt
Spontaneous Generation
Panspermia
Primordial Soup
Spectrum of ...Creation?

Three Variations of Panspermia

- ***Lithopanspermia*** **or** ***interstellar panspermia***
- ***Ballistic panspermia*** **or** ***interplanetary panspermia***
- ***Directed panspermia***

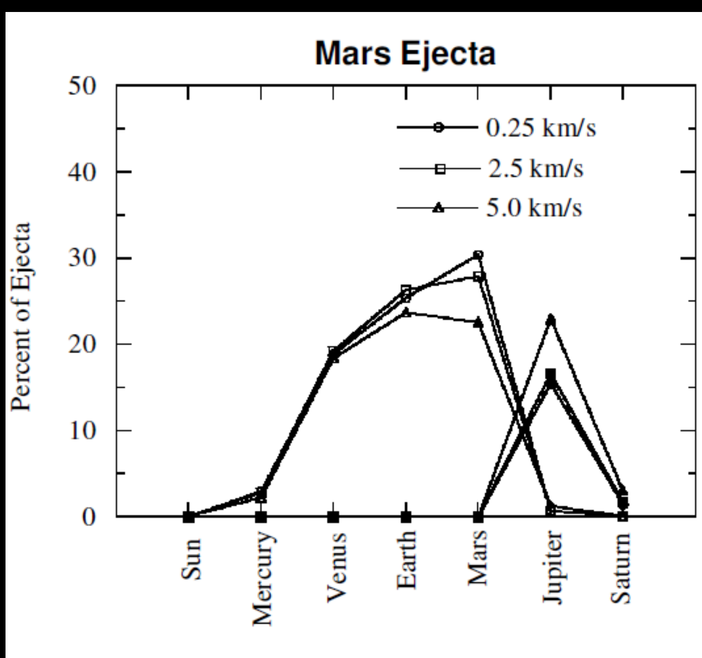
The University of Buckingham reports that the minuscule metal globe was discovered by astrobiologist Milton Wainwright and a team of researchers who examined dust and minute matter gathered by a high-flying balloon in Earth's stratosphere. "It is a ball about the width of a human hair, which has filamentous life on the outside and a gooey biological material oozing from its centre"

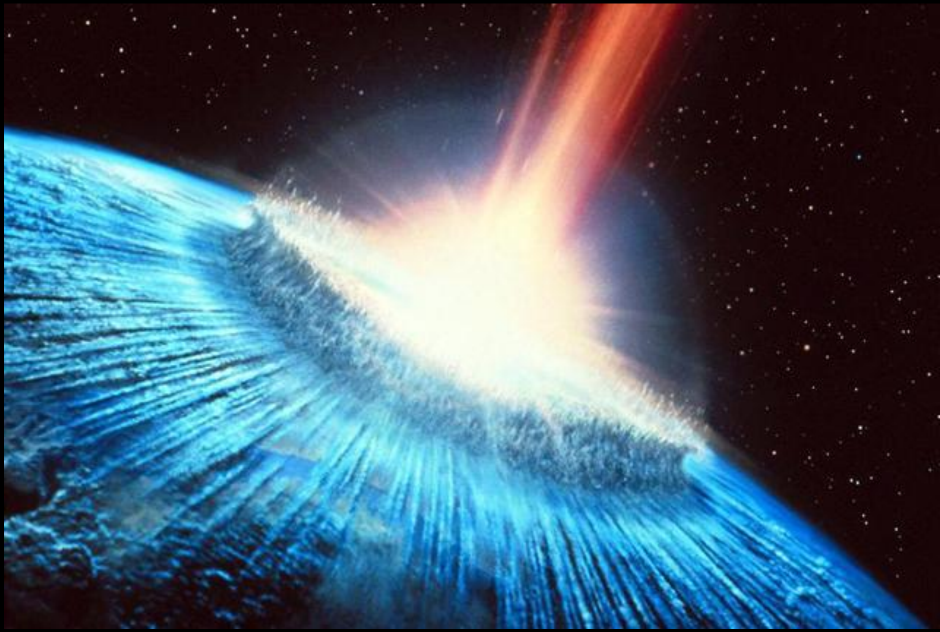


Ballistic panspermia

- Also known as interplanetary panspermia
- impact-expelled rocks from a planet's surface serve as transfer vehicles for spreading biological material from one planet to another within the same solar system
- Assumes microorganisms survive:
  - the impact ejection process from the planet of origin
  - travelling through space, and
  - landing on a planet in another solar system.

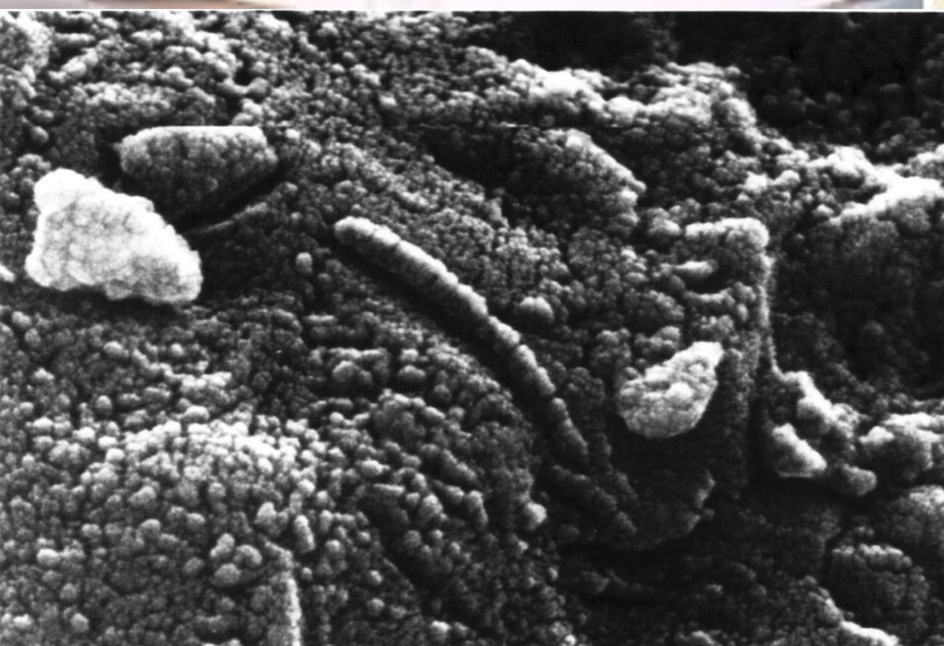
Possible according to simulations by Melosh (2003) between Venus, Earth & Mars.

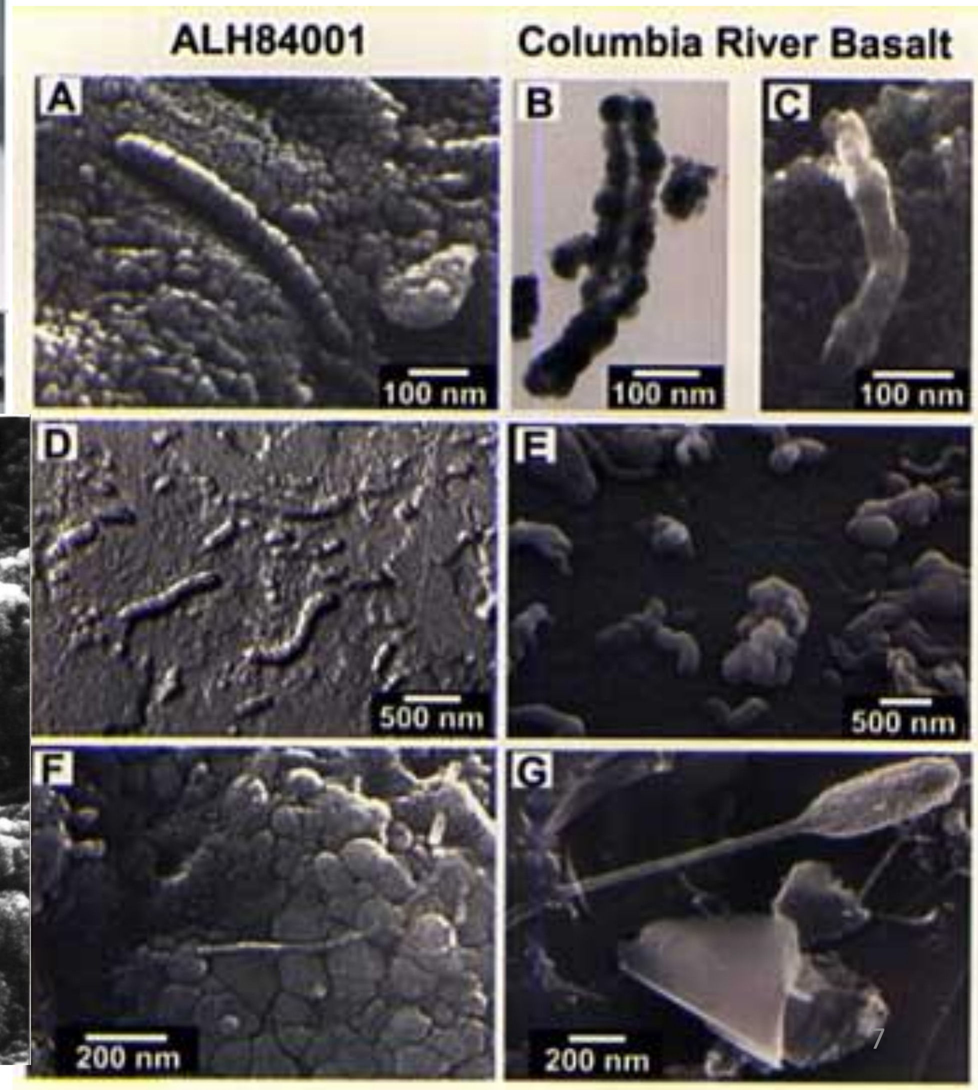




Fossil bacteria from Mars?

(Controversial)

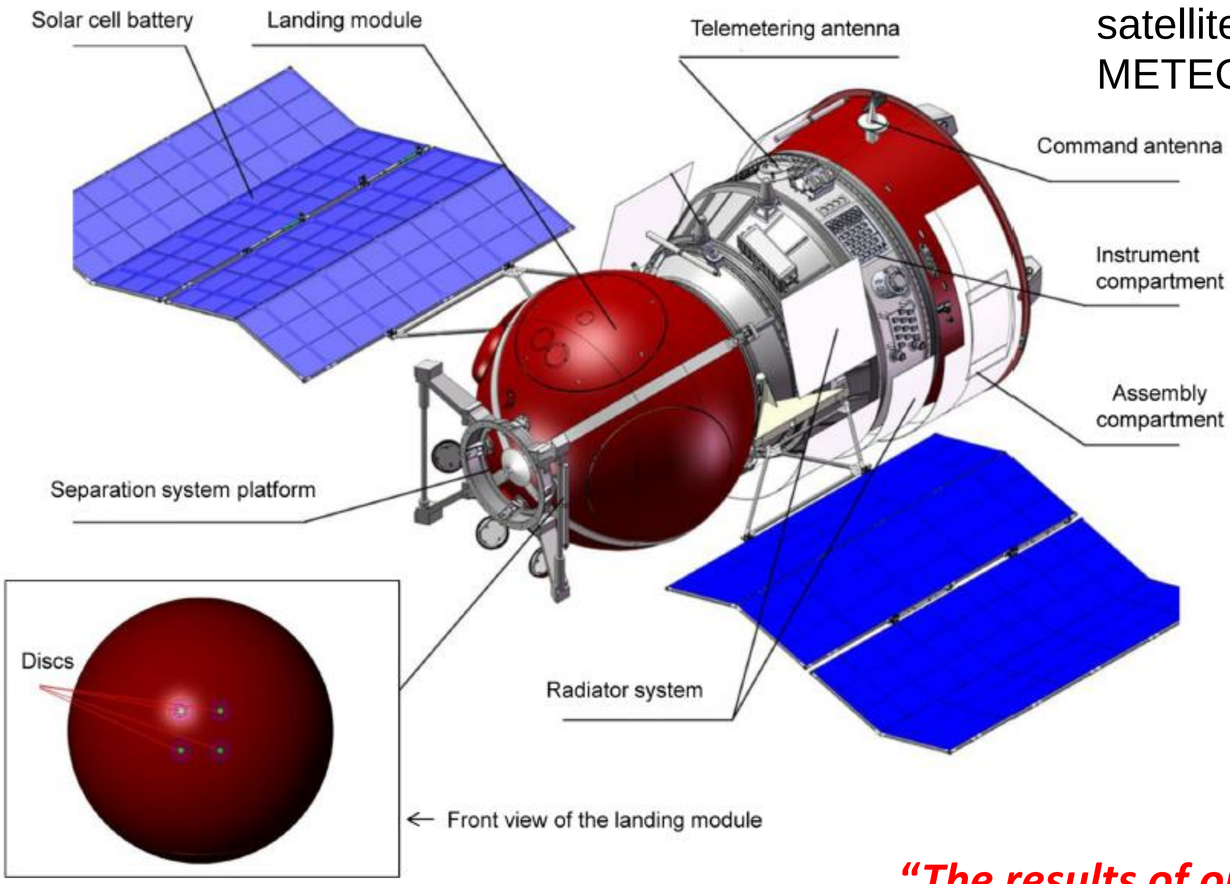


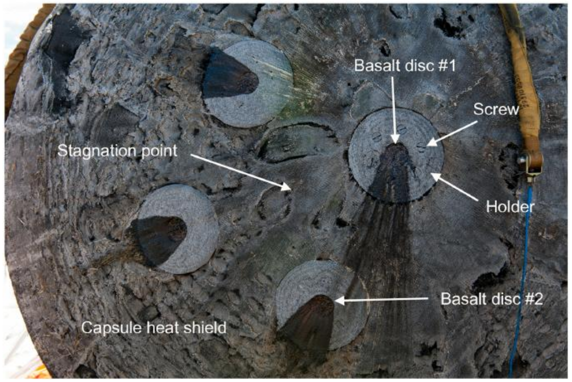


Atmospheric entry survival?

One of the key conditions of the lithopanspermia hypothesis is that microorganisms situated within meteorites could survive hypervelocity entry from space through the Earth's atmosphere.

Schematic illustration of FOTON-M4 satellite showing the position of the METEORITE experiment payload.





"The results of our study demonstrate that the spore-forming thermophilic anaerobic bacterium Thermoanaerobacter siderophilus survived entry into the Earth's atmosphere"

Slobodkin et al. (2015)

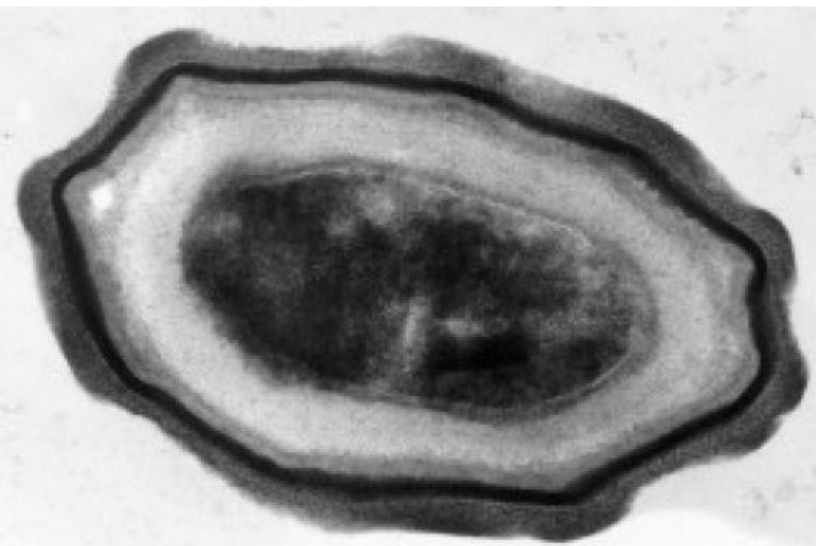
Lithopanspermia

- Also known as interstellar panspermia
- impact-expelled rocks from a planet's surface serve as transfer vehicles for spreading biological material from one solar system to another.
- Assumes microorganisms survive:
  - the impact ejection process from the planet of origin
  - travelling through space, and
  - landing on a planet in another solar system.

Table 1. Maximum total survival time of *D. radiodurans* – like bacteria inside ejecta in interstellar space (ISS), and their maximum viable travel length at velocities ≤ 0.5 km/s, for seven size groups of ejecta caused by impactors bombarding a Mars-like planet, and approximate numbers of ejecta per Myr per size group.

Size group	Radius range defining size groups (m)	Shielding column density (g cm^{-2})	Maximum total survival time in ISS (Myr) $t_{ISS}=\frac{1.33\ln(10^{15})}{\alpha F/Myr+0.075/Myr}$	Maximum viable travel length in ISS at $v=0.5 km/s$ (pc)	N° of ejecta (T≤100°C) from a Mars-like planet, caused by impactors in the range 0.5 – 20 km, per Myr
I	II	III	IV	V	VI
1	0.00 – 0.03	0 - 10	12 – 15	6 – 7.5	Burn in atmosphere
2	0.03 – 0.67	10 – 200	15 – 40	7.5 – 20	Many of size group 2 burn in atmosphere 9.4×10^{8}
3	0.67 – 1.00	200 – 300	40 – 70	20 – 35	3.0×10^{7}
4	1.00 – 1.67	300 – 500	70 – 200	35 – 100	1.8×10^{7}
5	1.67 – 2.00	500 – 600	200 – 300	100 – 150	2.8×10^{6}
6	2.00 – 2.33	600 – 700	300 – 400	150 – 200	1.5×10^{6}
7	2.33 – 2.67	700 – 800	400 – 500	200 – 250	1.0×10^{6}
					$\Sigma=10^{9}$

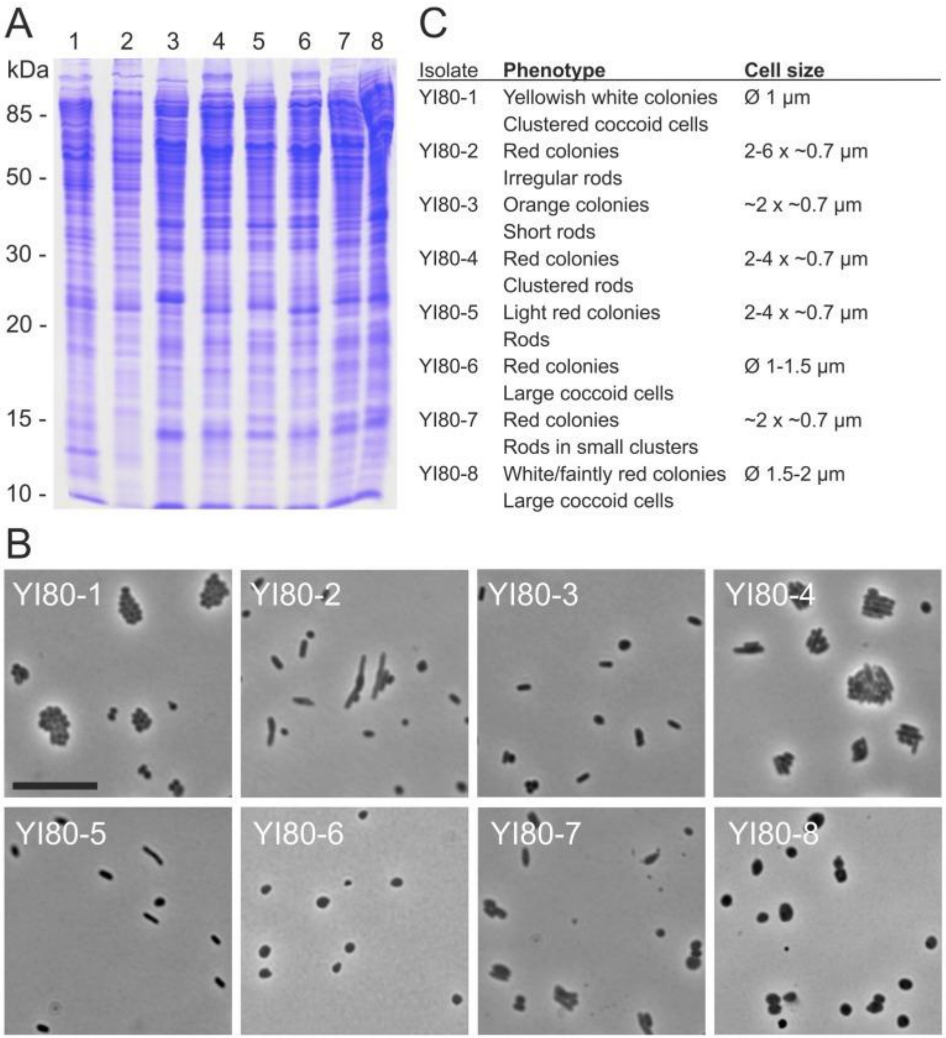
From Valtonen et al. (2008)



Electonmicrograph of a spore of *B. subtilis* with the inner core containing the DNA
surrounded by protective layers, the long axis of the spore is 1.2 mm, the core area 0.25 mm² (Horneck et al.)

Possible, but low probability

Yes, they can survive entry, but can they survive an interstellar journey



Isolate	Phenotype	Cell size
YI80-1	Yellowish white colonies Clustered coccoid cells	Ø 1 µm
YI80-2	Red colonies Irregular rods	2-6 x ~0.7 µm
YI80-3	Orange colonies Short rods	~2 x ~0.7 µm
YI80-4	Red colonies Clustered rods	2-4 x ~0.7 µm
YI80-5	Light red colonies Rods	2-4 x ~0.7 µm
YI80-6	Red colonies Large coccoid cells	Ø 1-1.5 µm
YI80-7	Red colonies Rods in small clusters	~2 x ~0.7 µm
YI80-8	White/faintly red colonies Large coccoid cells	Ø 1.5-2 µm

Microbes isolated from rock salt drill core sample from the depth of 800 m (Yunying Depression)**.**
(Jaakkola et al. PLoS One. 2014; 9(10)

Apparently YES

Alive...after 250 million years

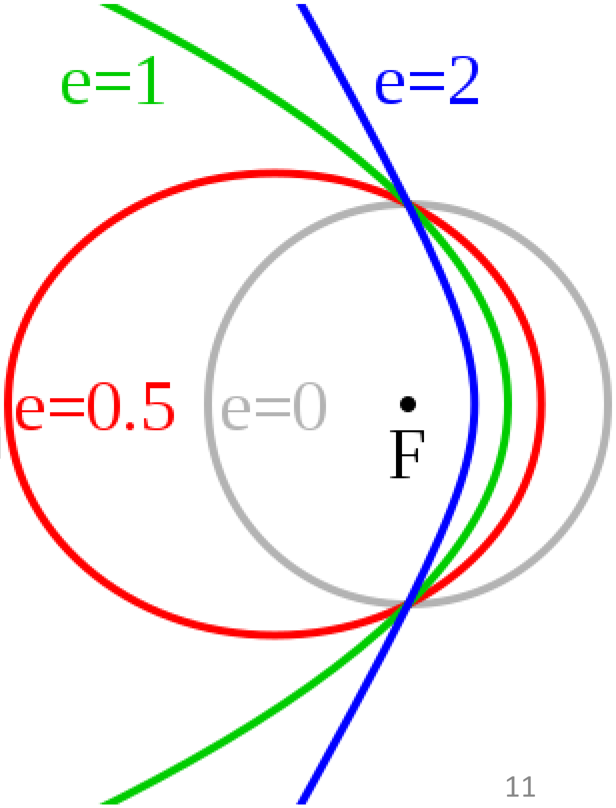
The salt crystal that contained the organisms

Vreeland, Rosenzweig & Powers 2000 Nature 407(6806) 897

Are there interstellar bodies in the Solar System?

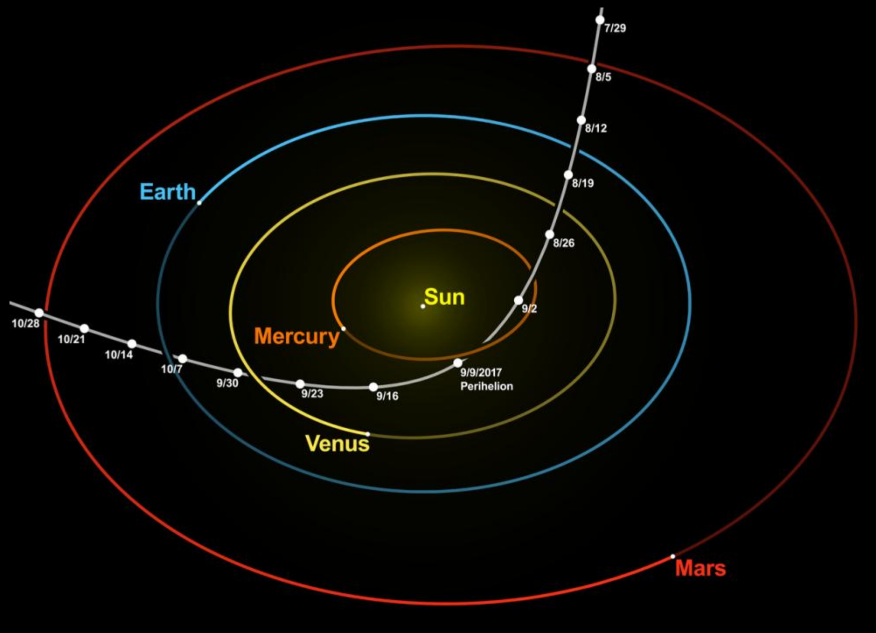
Are there any extrasolar meteorites? Answer: None are known at present. The true population of interstellar meteoroids within our Solar System remains unknown (Wiegert 2014). There is, however, considerable evidence of the presence of discrete extrasolar system materials within many known meteorites. Discrete mineral grains that are unequivocal samples of non-solar system minerals have been analyzed and discussed at considerable length over the last twenty years.

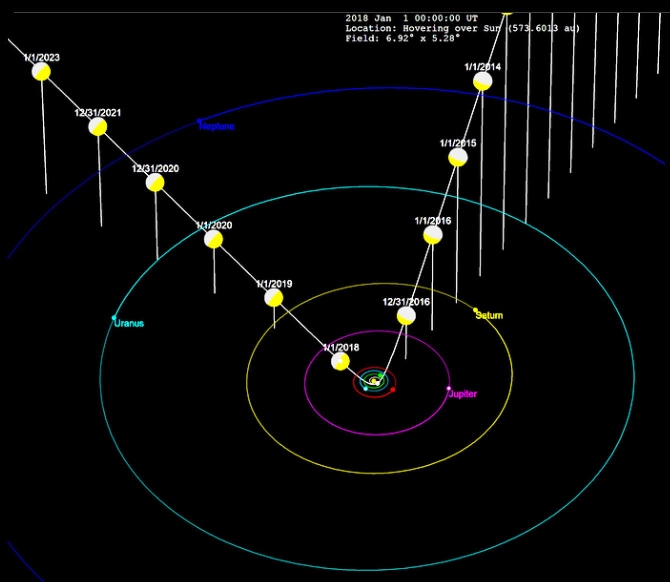
Meteoroids entering the atmosphere of the Earth and coming from the interstellar medium have heliocentric velocities v(H) > v(p) , where v(p) is the parabolic velocity with respect to the Sun, and the hyperbolicity of their orbits (with semimajor axis a<0 and eccentricity e>1) is not caused by planetary perturbations inside the Solar System.



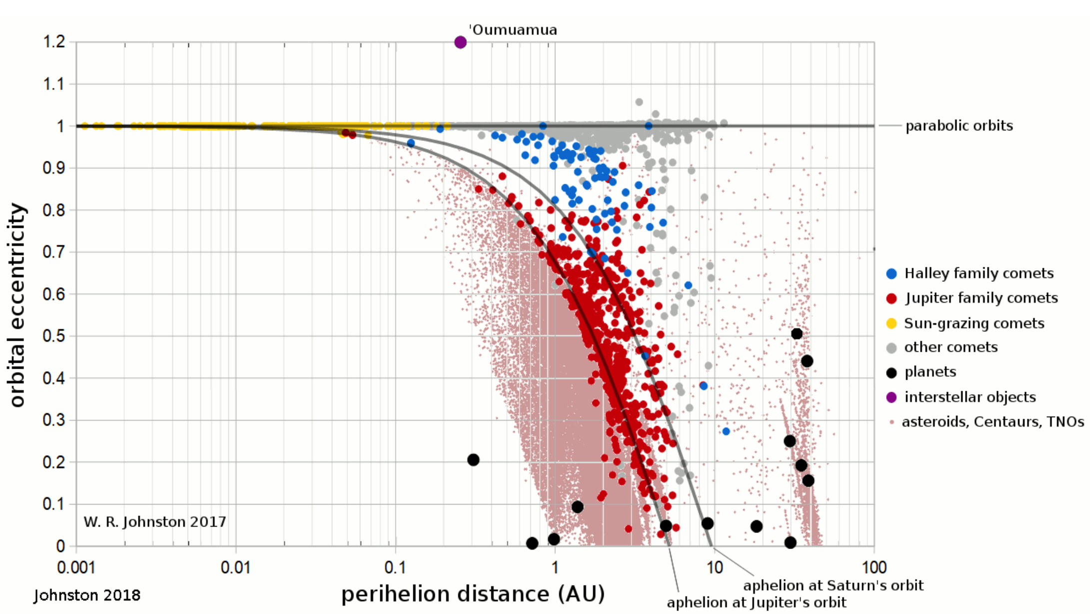
"The proportion of hyperbolic meteors in the data decreased significantly (from 11.58% to 3.28%) after a selection of quality orbits…we are led to conclude that, seen statistically, **the vast majority of hyperbolic orbits** from the Japanese TV catalog (SonotaCo 2009), even those of the highest quality, **have been caused by erroneous velocity determination**". (Haydukova et al. 2014)

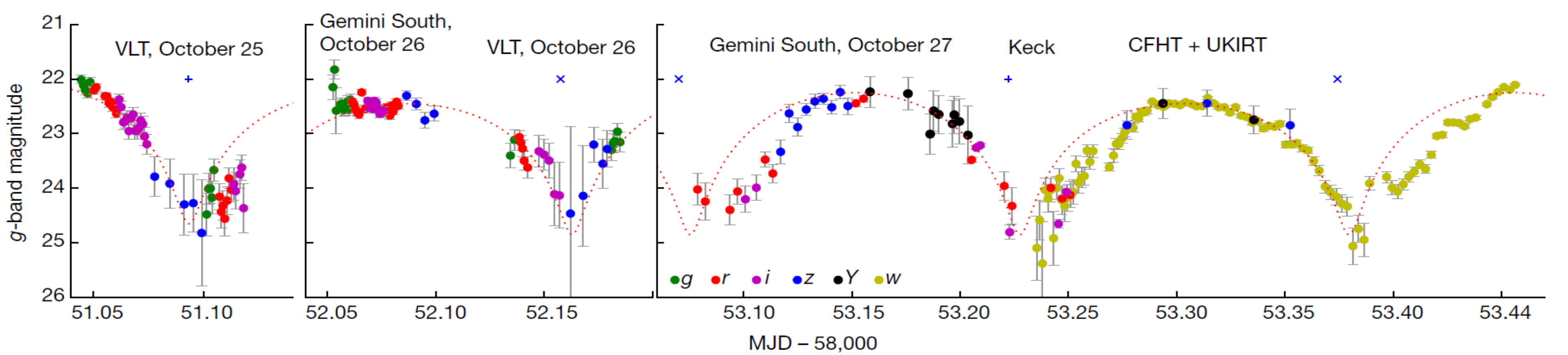
And then came 1I/2017 U1 (‘Oumuamua)





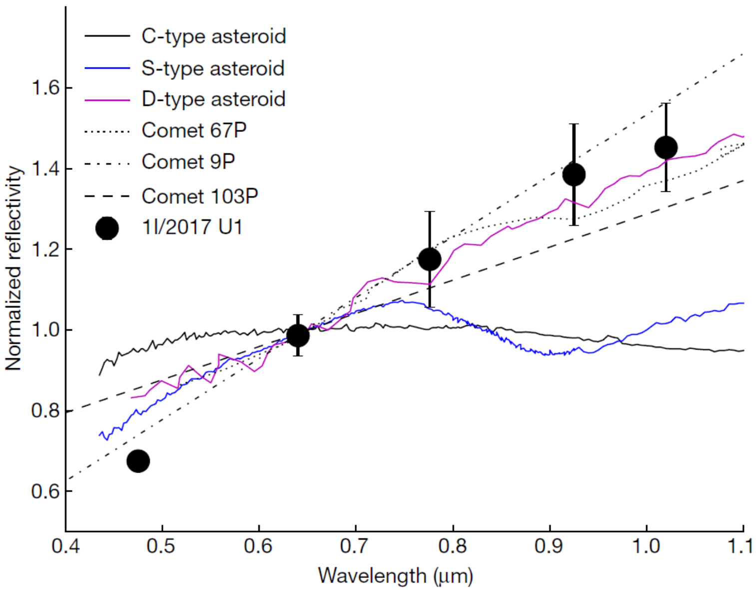
A dim object was discovered on October 19, 2017 by the Pan-STARRS telescope, at an apparent magnitude of 20. The observations showed that it follows a strongly hyperbolic trajectory around the Sun at a speed greater than the solar escape velocity, in turn meaning that **it is not gravitationally bound to the Solar System and likely to be an interstellar object** ‘Oumuamua has an eccentricity of 1.199, which is the highest eccentricity ever observed for any object in the Solar System





This plot shows how the interstellar asteroid `Oumuamua varied in brightness during three days in October 2017. The large range of brightness — about a factor of ten (2.5 magnitudes) — is due to the very elongated shape of this unique object, which rotates every 7.3 hours. The different coloured dots represent measurements through different filters, covering the visible and near-infrared part of the spectrum. The dotted line shows the light curve expected if `Oumuamua were an ellipsoid with a 1:10 aspect ratio, the deviations from this line are probably due to irregularities in the object's shape or surface albedo (Meech et al. 2018)

`Oumuamua is probably dense, possibly rocky or with high metal content (from its colors), **lacks significant amounts of water or ice**, and that its surface is now dark and reddened due to the effects of irradiation from cosmic rays over millions of years. It is estimated to be at least 400 m long. The object had come from the approximate direction of the bright star Vega, in the constellation of Lyra, at ~26 km/s.

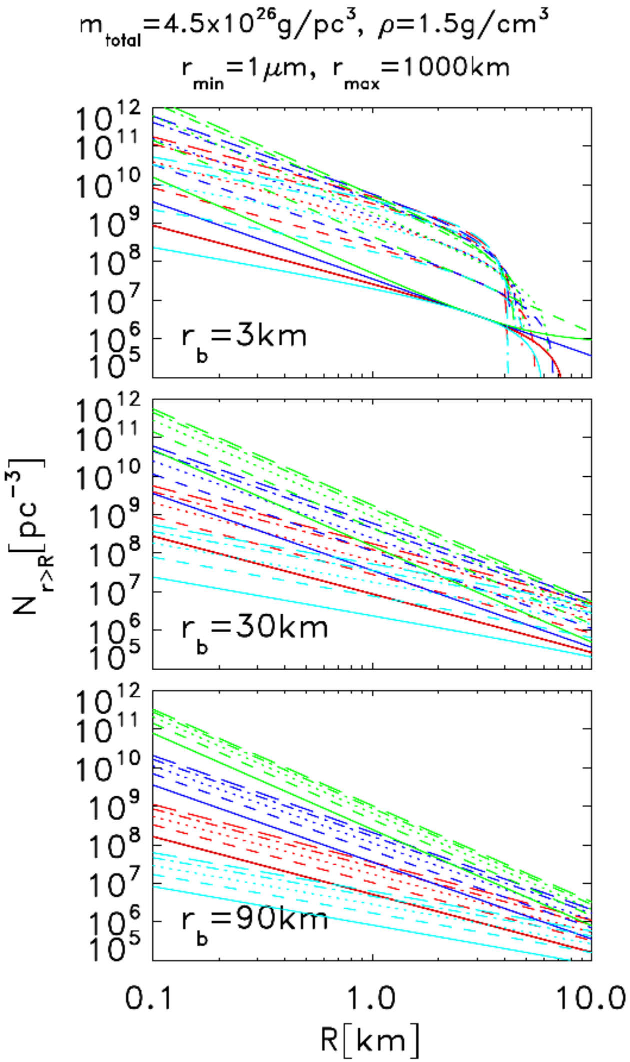


Paradigm change

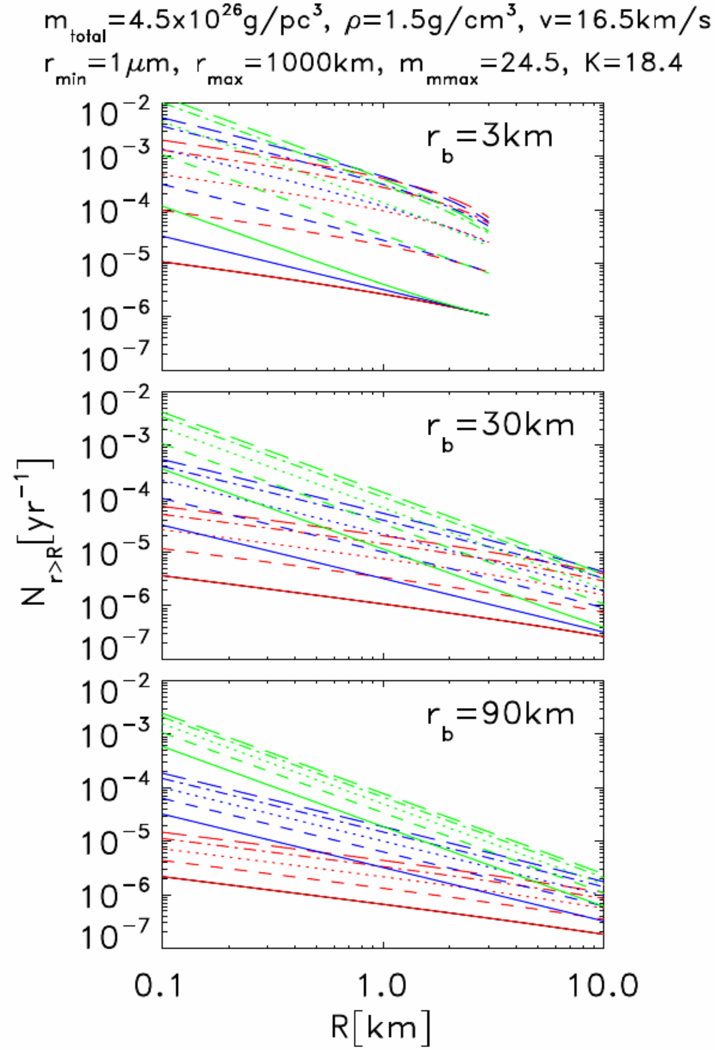
There was no hint of cometary activity despite an approach within 0.25 astronomical units of the Sun. The presence of ‘Oumuamua in the Solar System suggests that previous estimates of the number density of interstellar objects, based on the assumption that all such objects were cometary, were pessimistically low. There are probably additional ISOs in the Solar System; **at any given time there is always about one ISO of about 250 m diameter (assuming an albedo of 0.04) within one astronomical unit of the Sun**

Conclusions:

1. **Several studies showed that micro-organisms can survive for very long periods in space provided they are embedded a few meters in rock and can survive entry into a planetary atmosphere.**
2. **Ejection from planets has been shown to be possible both in the Solar System (meteorites) as well as from exoplanets (theoretically).**
3. **The discovery of `Oumuamua, and the estimate of a large number of similar objects present in the Solar System indicates that the possibility of interstellar panspermia should be seriously considered.**
4. **No implications from this on ETs, "ancient astronauts", Gods from outer space, etc.**

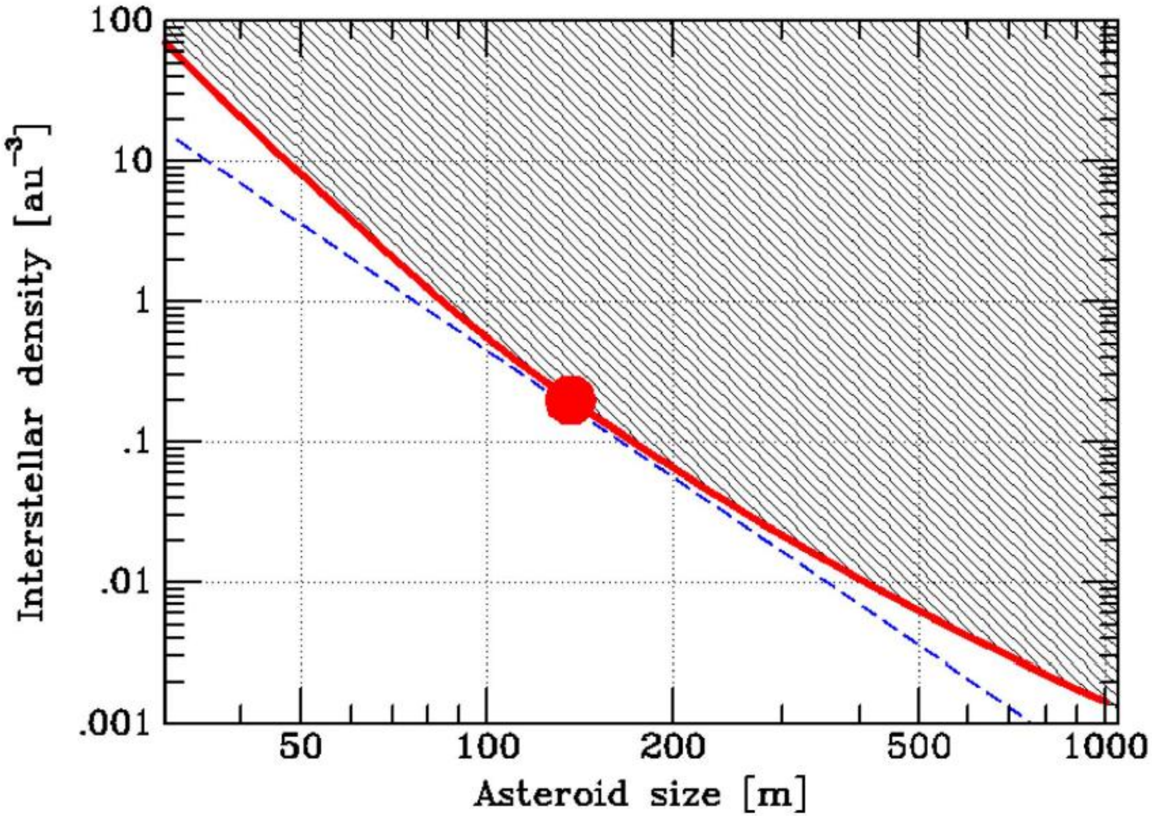


Total number density of planetesimals per pc [3] with radius r > R (Moro-Martın et al. 2009)

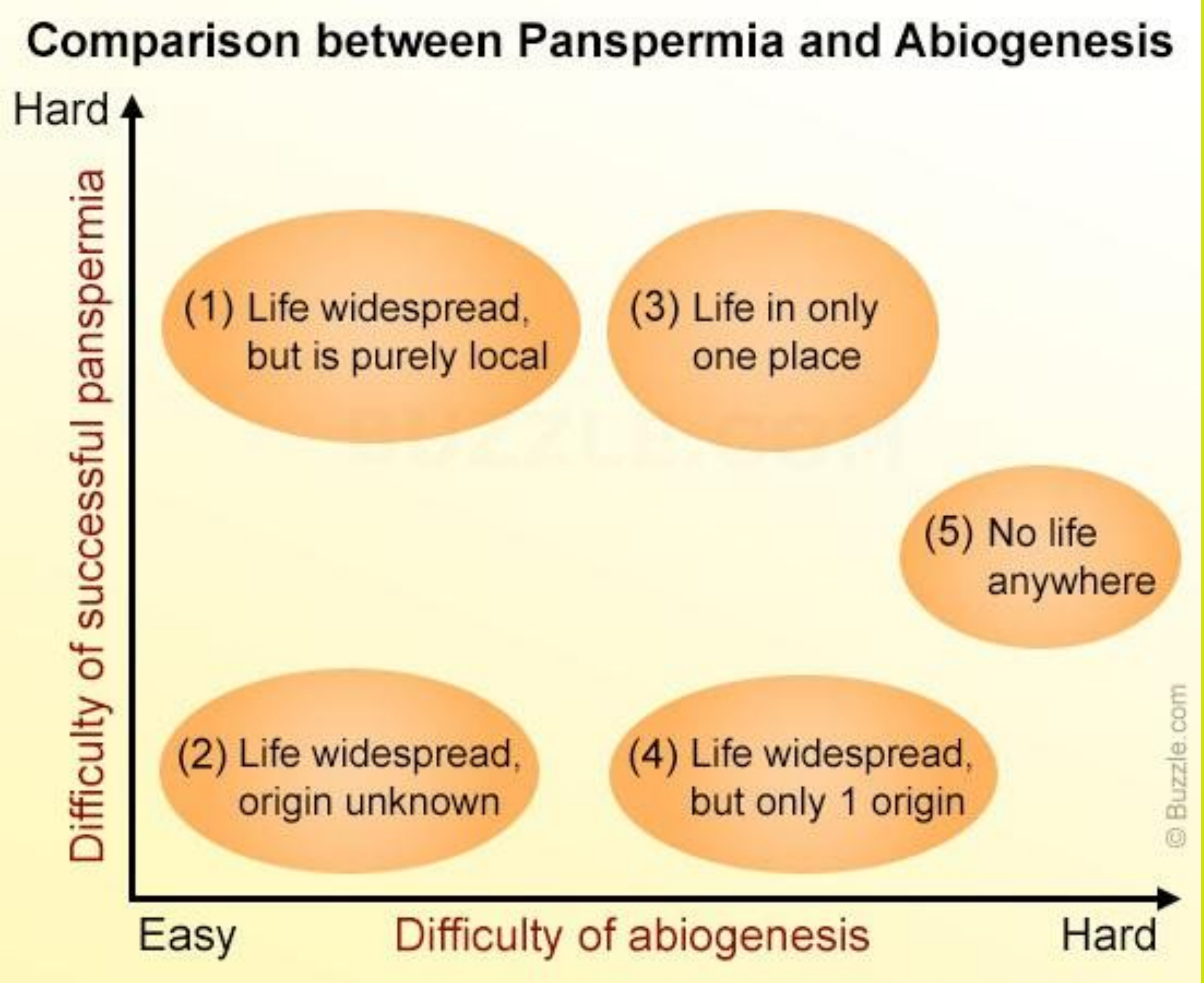


Expected number of incoming detectable extra-solar planetesimals larger than radius R, per year, for the size distributions in Figure 1 (same color code).

The derived number density of 0.2 /au ^{3} implies that **there are likely several of these objects in the inner solar system at any given time**. Comparing the cross-section of Pan-STARRS to that of the Earth, we should expect one of these interstellar interlopers to hit the Earth every ~30 Myr (Do, Tucker, & Tonry 2018). With only one detection, any inferred rate carries intrinsic uncertainty.



Limits on the cumulative interstellar number volume of interstellar objects from the Pan-STARRS survey is shown as a function of object diameter (using a nominal H=17.75 and albedo 0.14 for 1 km to convert observable H magnitude to diameter). The red curve is the inverse of the total volume surveyed by Pan-STARRS and the dot shows the detection. The actual distribution must also lie below the dashed blue curve, which shows the *n(d > D) µ D-3, where total mass diverges logarithmically.*


Comparison between Panspermia and Abiogenesis
Hard
Difficulty of successful panspermia
(1) Life widespread, but is purely local
(3) Life in only one place
(5) No life anywhere
(2) Life widespread, origin unknown
(4) Life widespread, but only 1 origin
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Easy
Difficulty of abiogenesis
Hard