Súčasné poznatky o možnostiach života vo vesmíre

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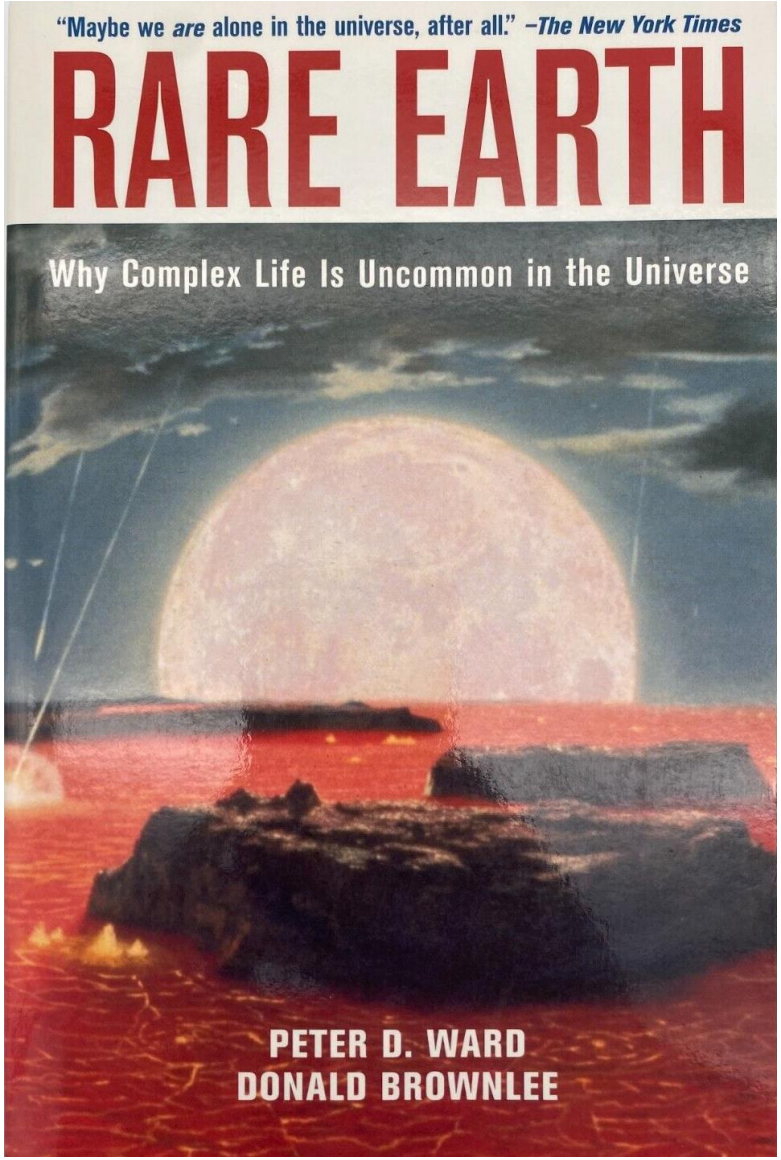
Astronomický ústav SAV, v. v. i.

1.12.2022 Space::Talk

ČO OVPLYVŇUJE VZNIK, UDRŽANIE SA ŽIVOTA?

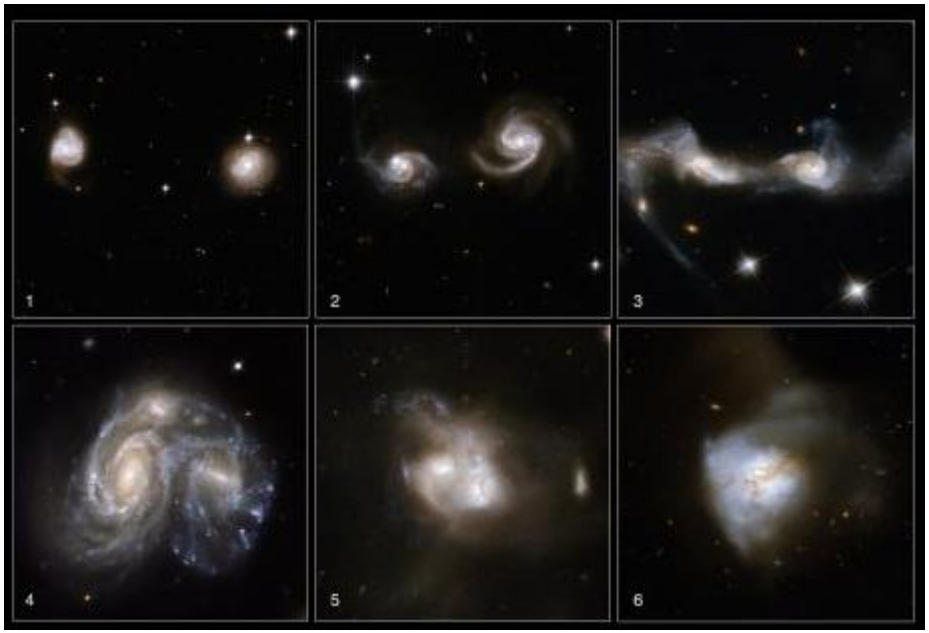
Faktory pre život (ako poznáme)

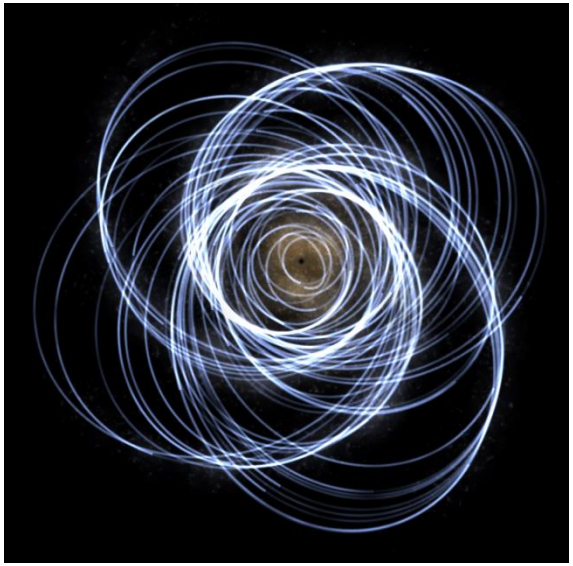
- Správna poloha v galaxii a správny typ galaxie
- Správna vzdialenosť od materskej hviezdy
- Správna hmotnosť hviezdy
- Správna hmotnosť planéty
- Stabilná obežná dráha
- Sused – Jupiter
- Sused – Mars?
- Tektonika
- Oceán
- Veľký mesiac
- Správny sklon rotácie
- Málo impaktov počas vývoja
- Dostatok uhlíka?
- Atmosféra
- Správne množstvo kyslíka



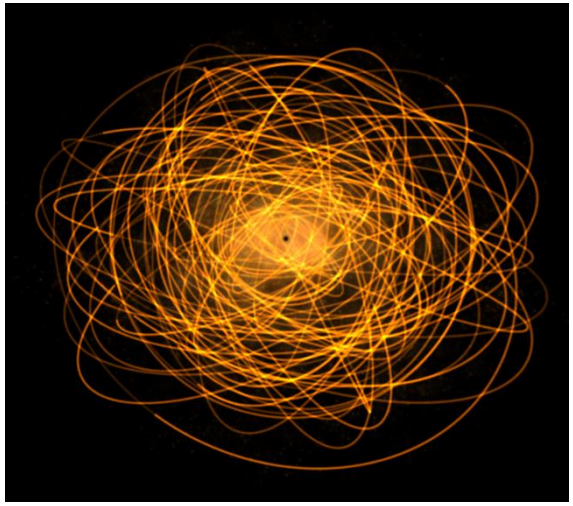
Správny typ galaxie

Zrážka špirálových galaxií



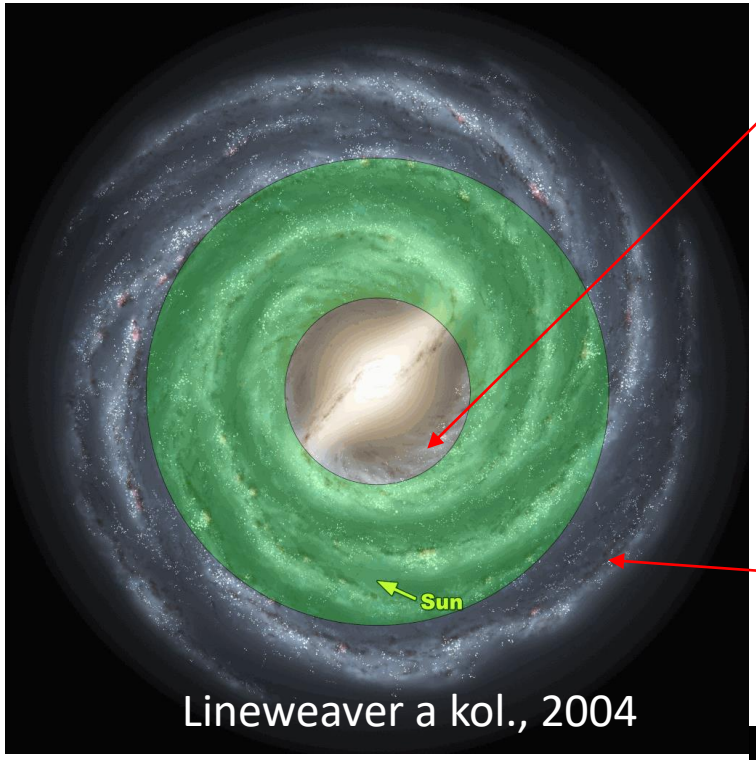


+ mladšie hviezdy
+ stabilnejšie dráhy



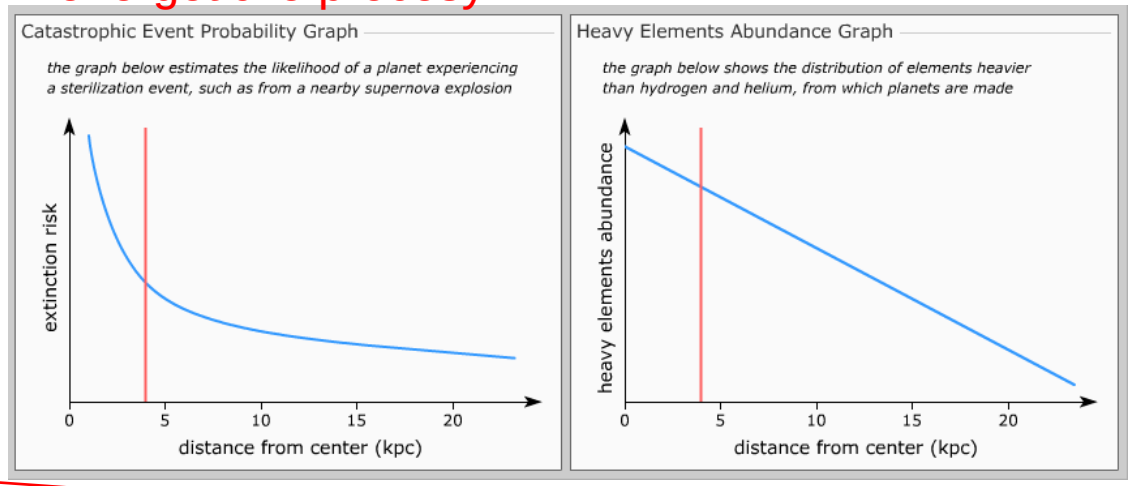
- staršie hviezdy
- nižšia metalicita
- chaotickejšie dráhy

Správna poloha v Galaxii

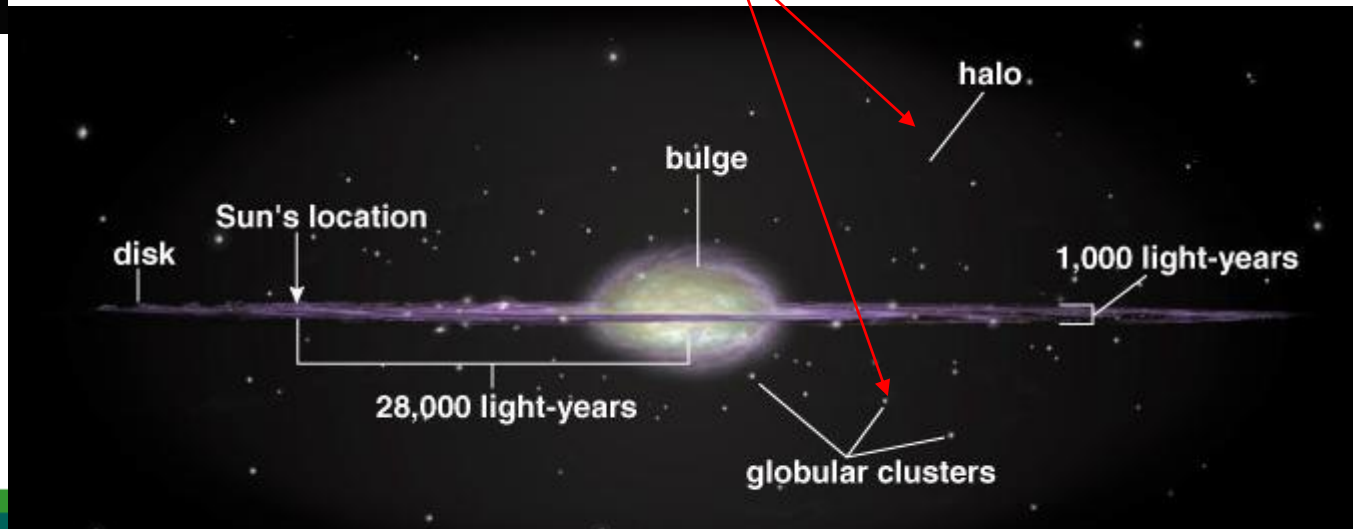


Lineweaver a kol., 2004

- vysoká hustota hviezd
- energetické procesy

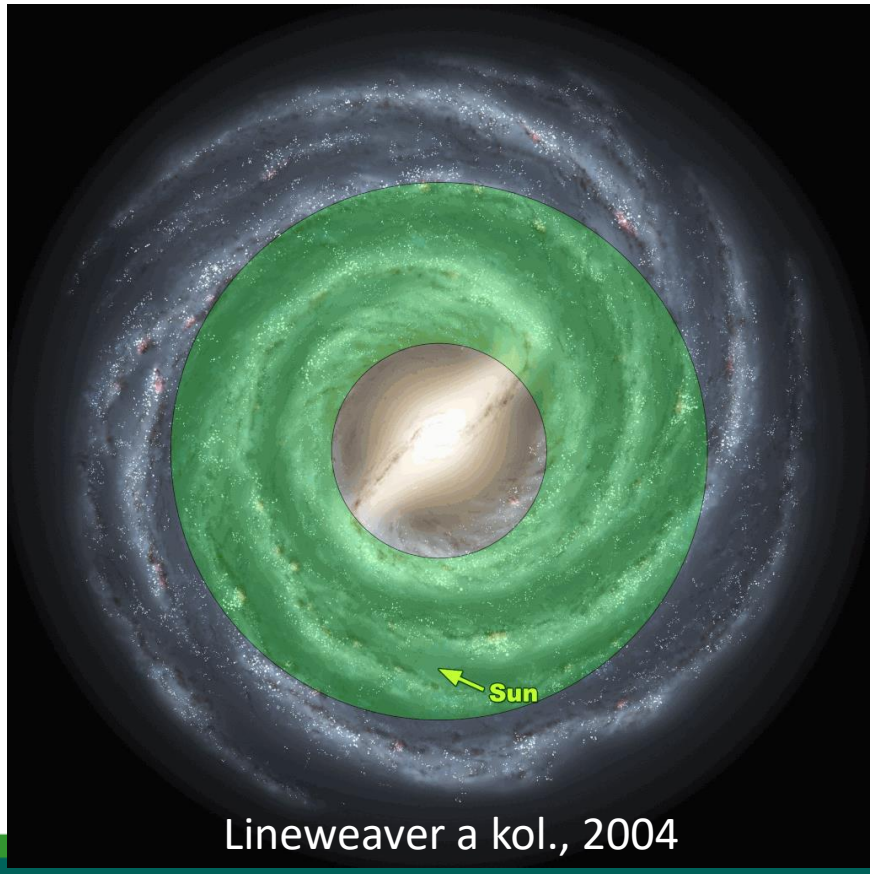


- nízka metalicita



Správna poloha v Galaxii

- metalicita hviezd [Fe/H], ale aj [C/O], [Mg/Fe], [Si/Fe], [U/H]
- málo Z – málo terestrických exoplanét, veľa Z – veľa jupiterov
- hustota hviezd (supernovy, sterilizácia asi 2/3 hviezd)
- odhad 7-9 kpc od stredu
- 0,3% hviezd v Galaxii vhodné (Gowanlock a kol., 2011)

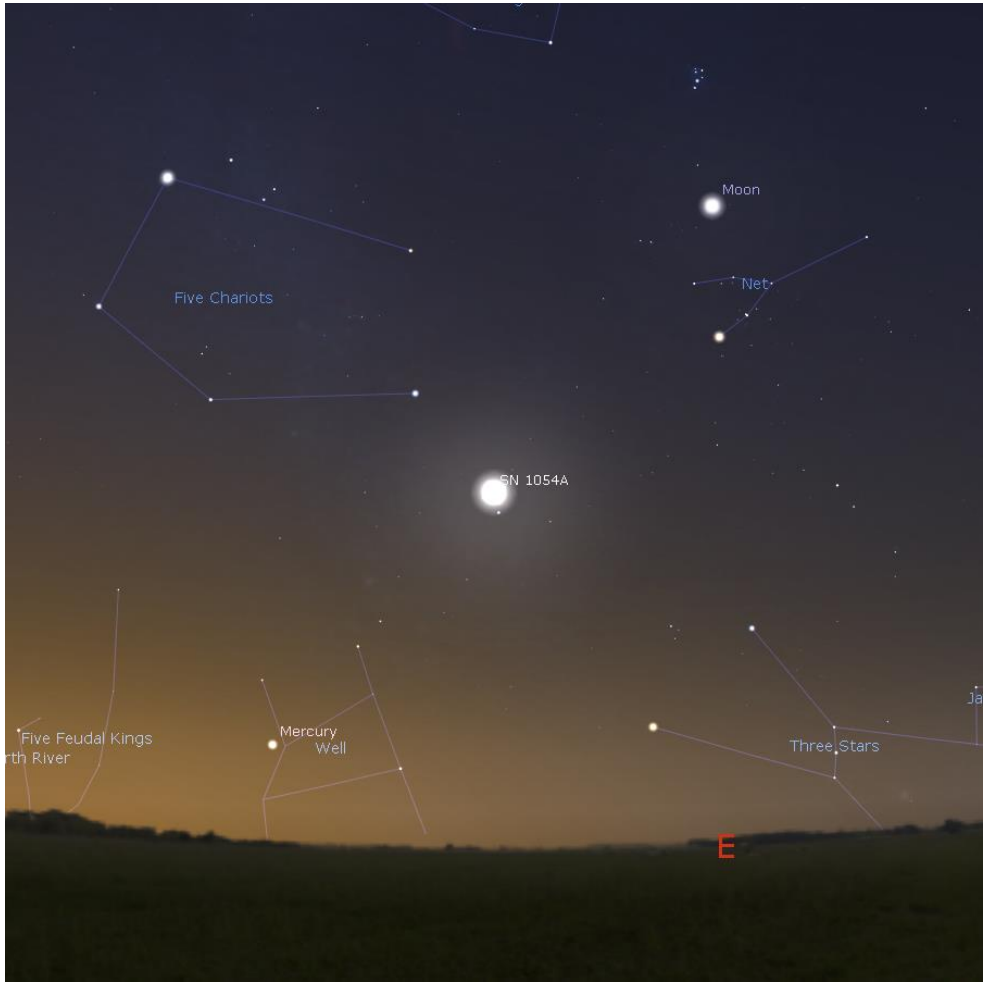


Lineweaver a kol., 2004

Správna poloha v Galaxii

Vzdialenosť: 1000 ly

- vidíme za noci i dňa

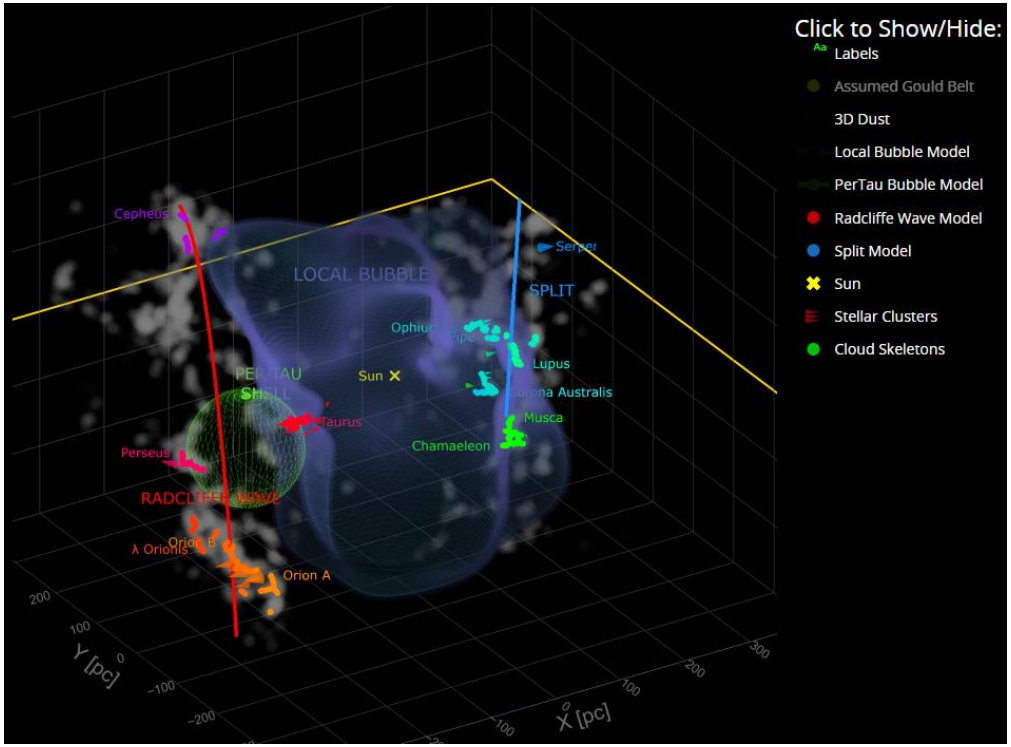


SN 1054 (D = 6500 ly)

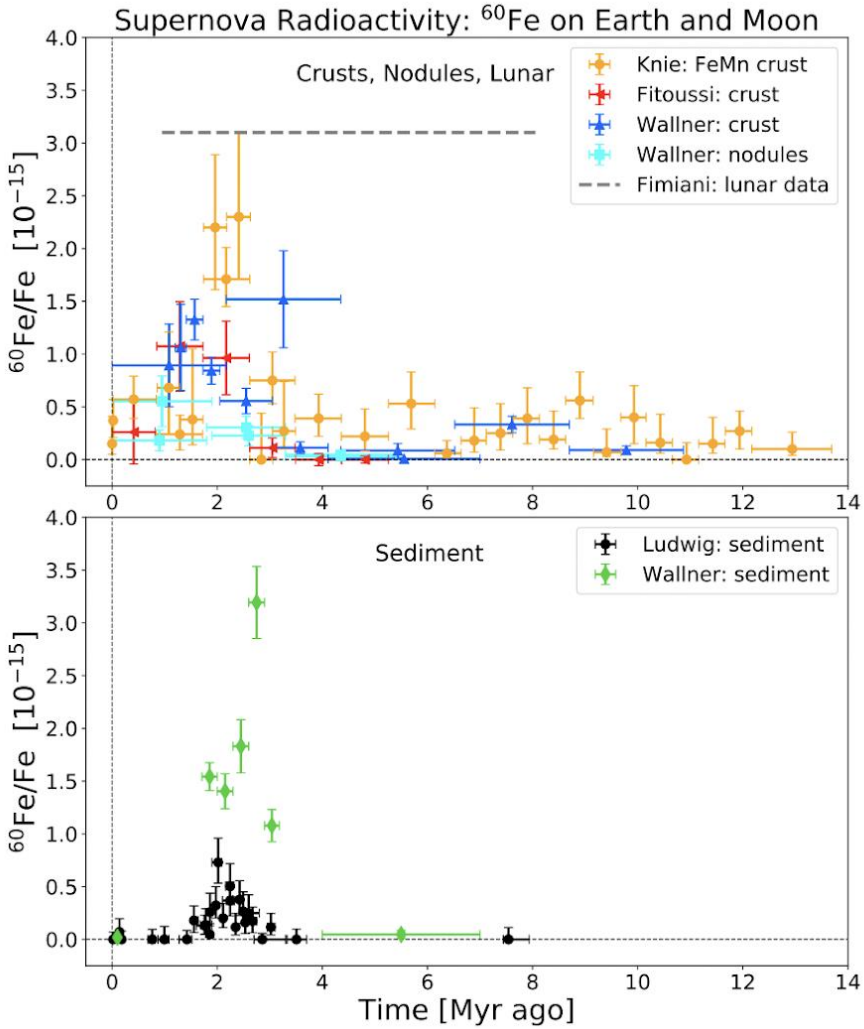
Správna poloha v Galaxii

Vzdialenosť: 300 ly

- asi raz za pár Myr (depozícia ^{60}Fe)
- „Lokálna bublina“ Ø 300 ly
- Slnko dnu vošlo asi pred 5 Myr



Zucker a kol. 2022

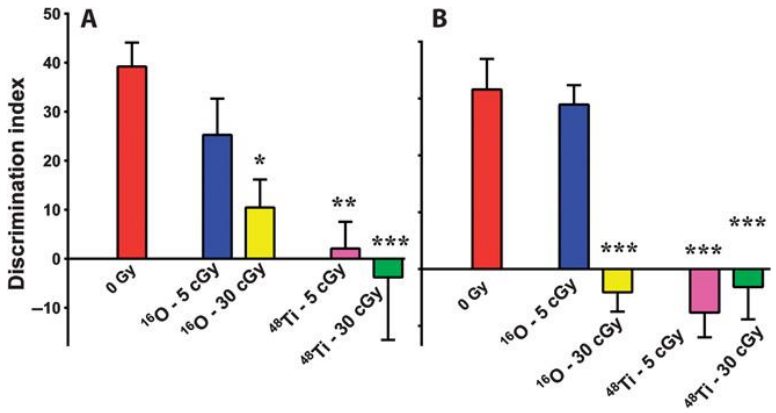


Fields a kol., 2019

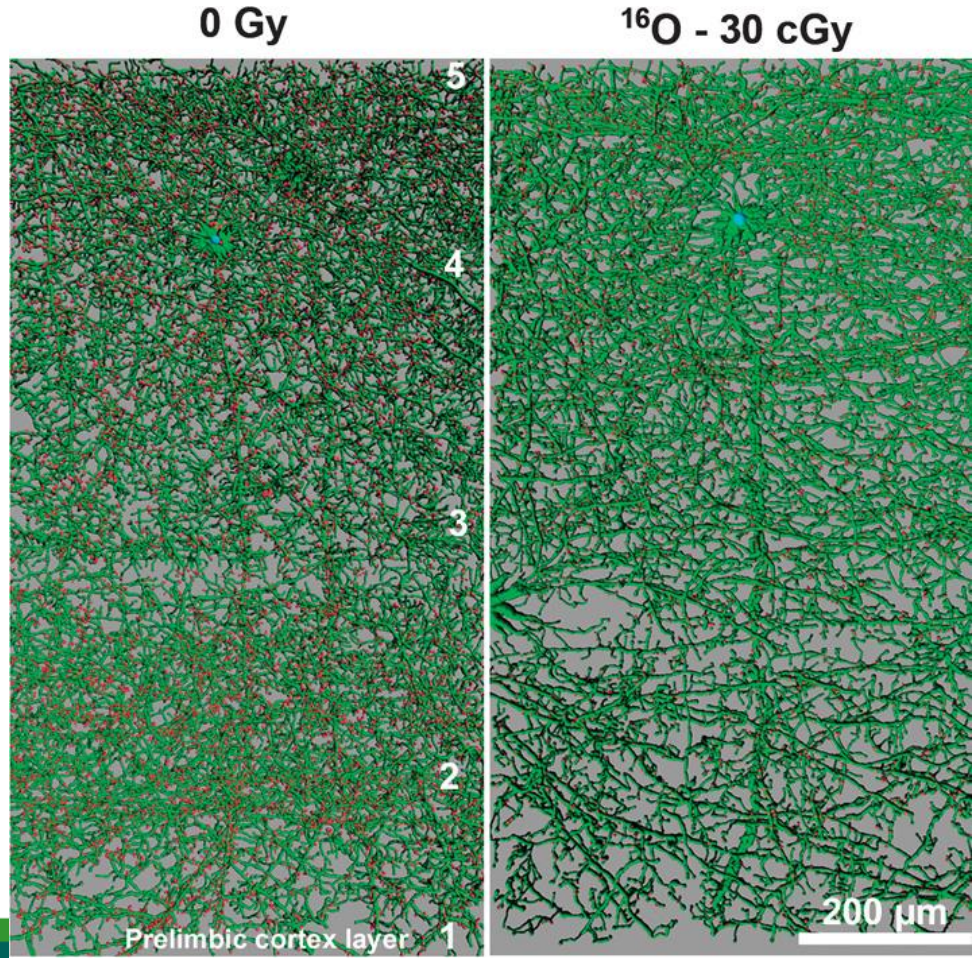
Správna poloha v Galaxii

Vzdialenosť: 150 ly

- korpuskulárne kozmické žiarenie: rakovina, vplyv na mozog
- nabité častice mimo „ochranné“ mag. pole Zeme
- môže trvať desiatky rokov



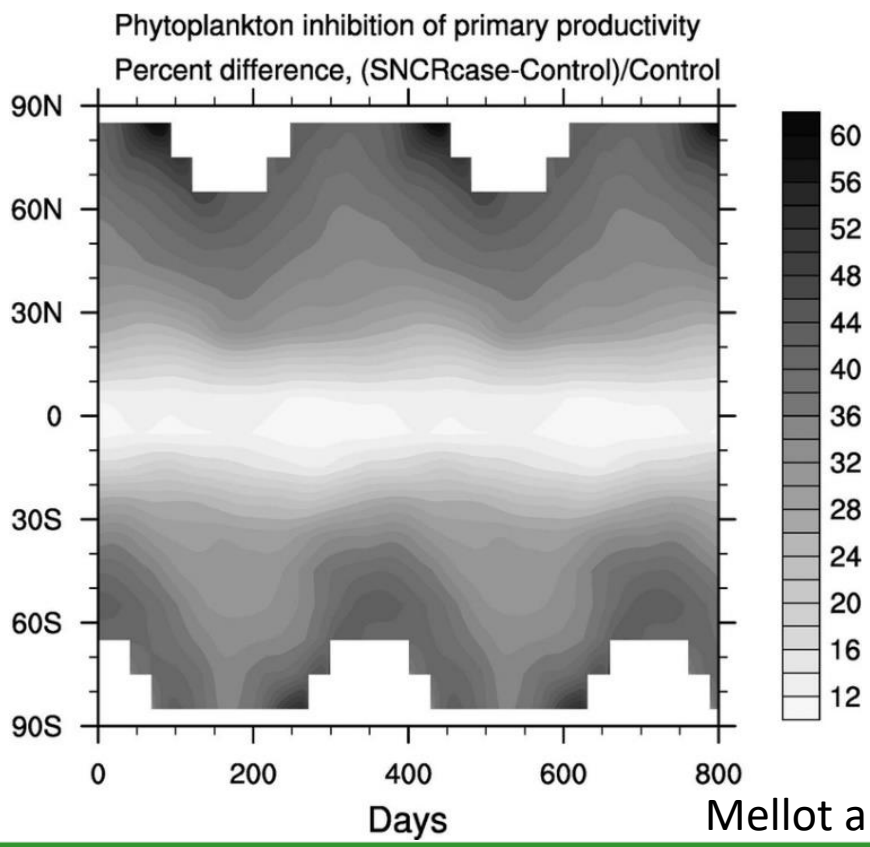
Parihar a kol. 2015

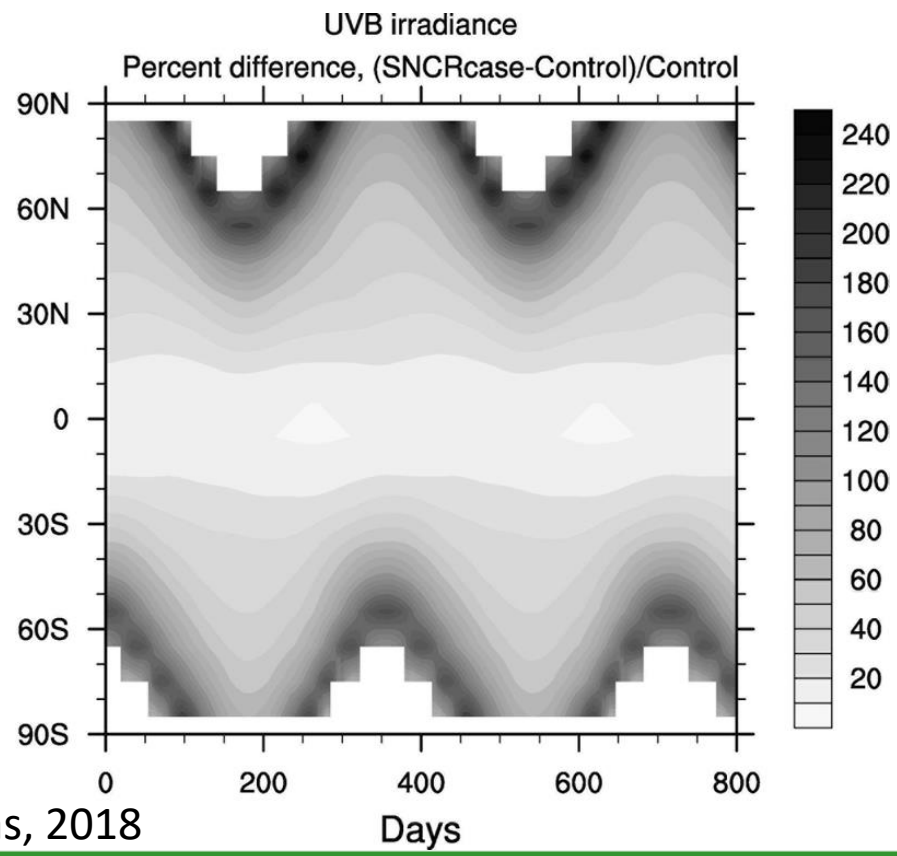


Správna poloha v Galaxii

Vzdialenosť: 100 ly

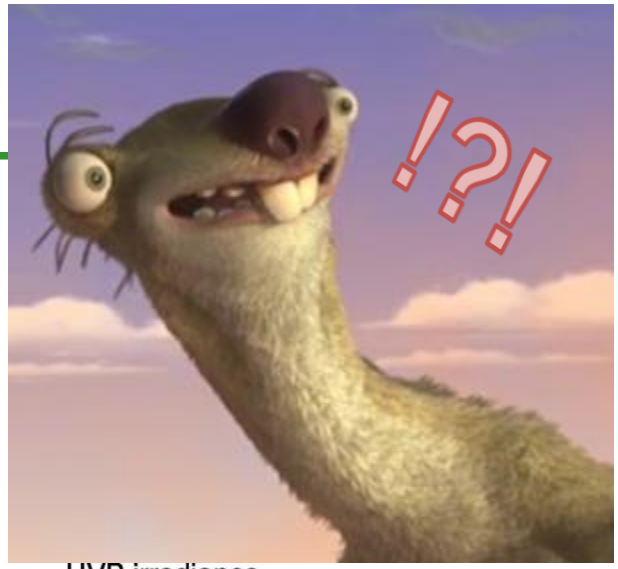
- kozmické žiarenie + UV
- vysokoenergetické γ poškodí O_3
- poškodenie planktónu





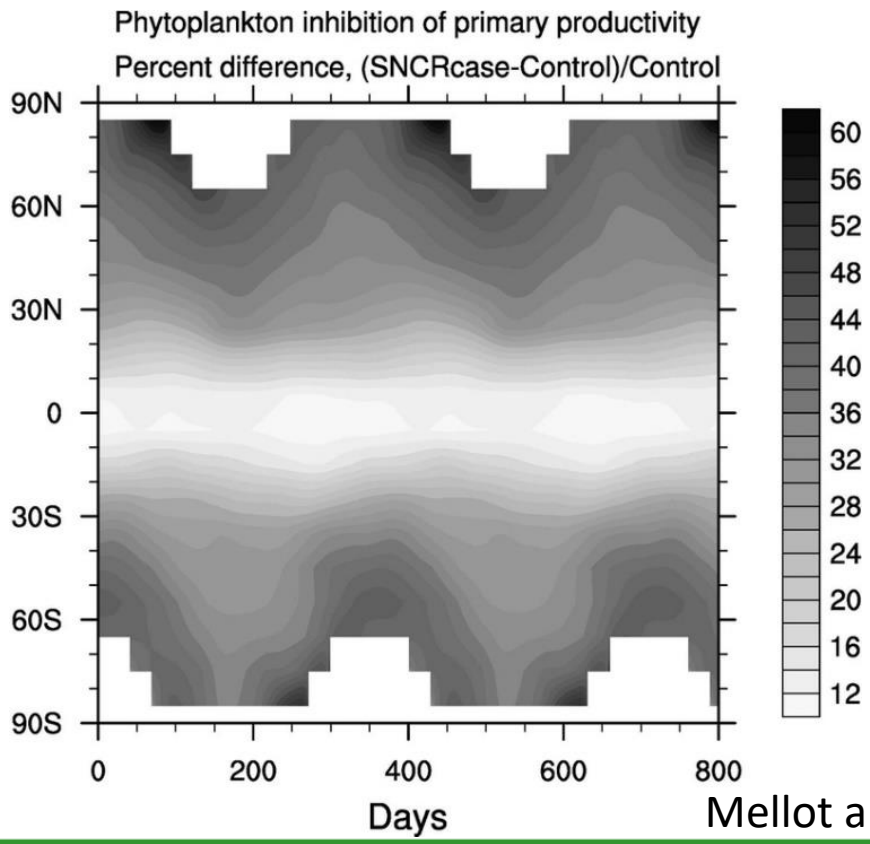
Mellot a Thomas, 2018

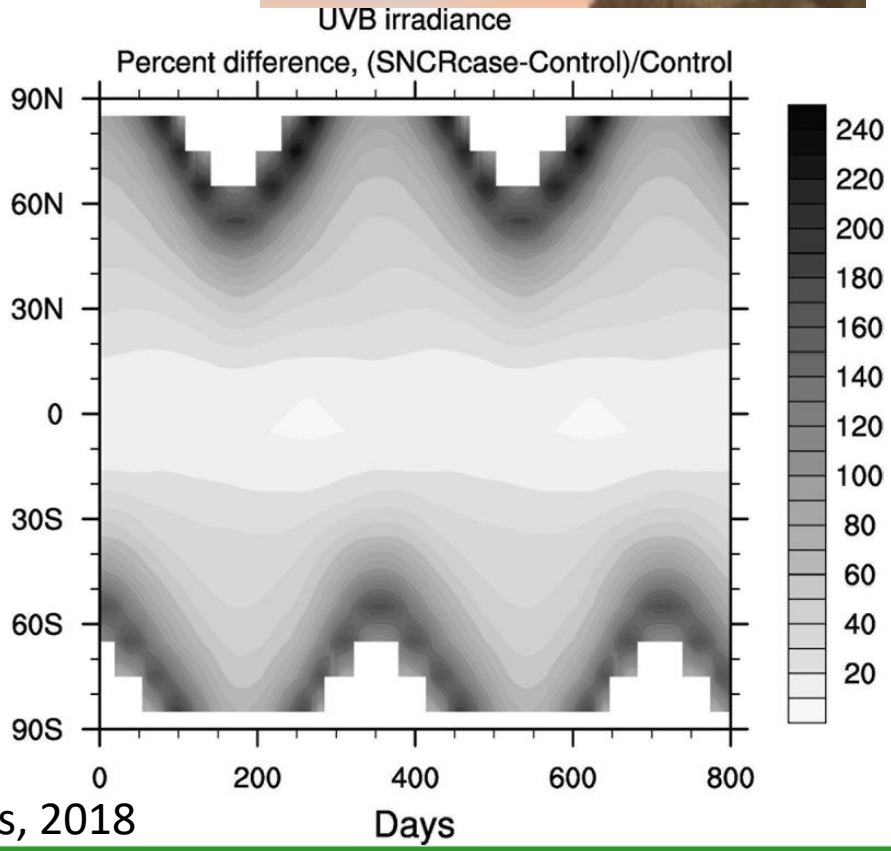
Správna poloha v Galaxii



Vzdialenosť: 100 ly

- kozmické žiarenie + UV
- *γ* poškodí O_3, *konden. mrakov? (doba ľadová?)*
- poškodenie planktónu



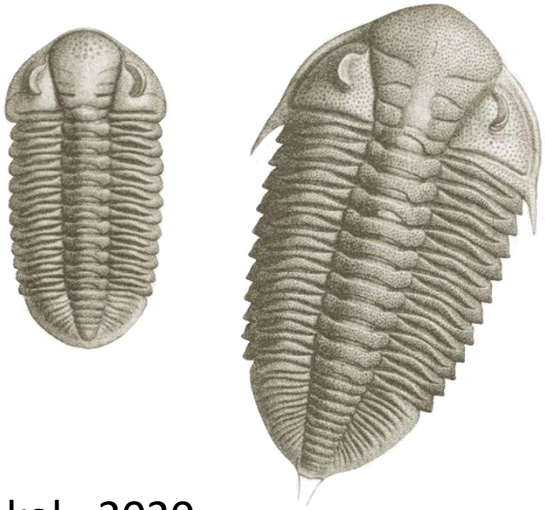


Mellot a Thomas, 2018

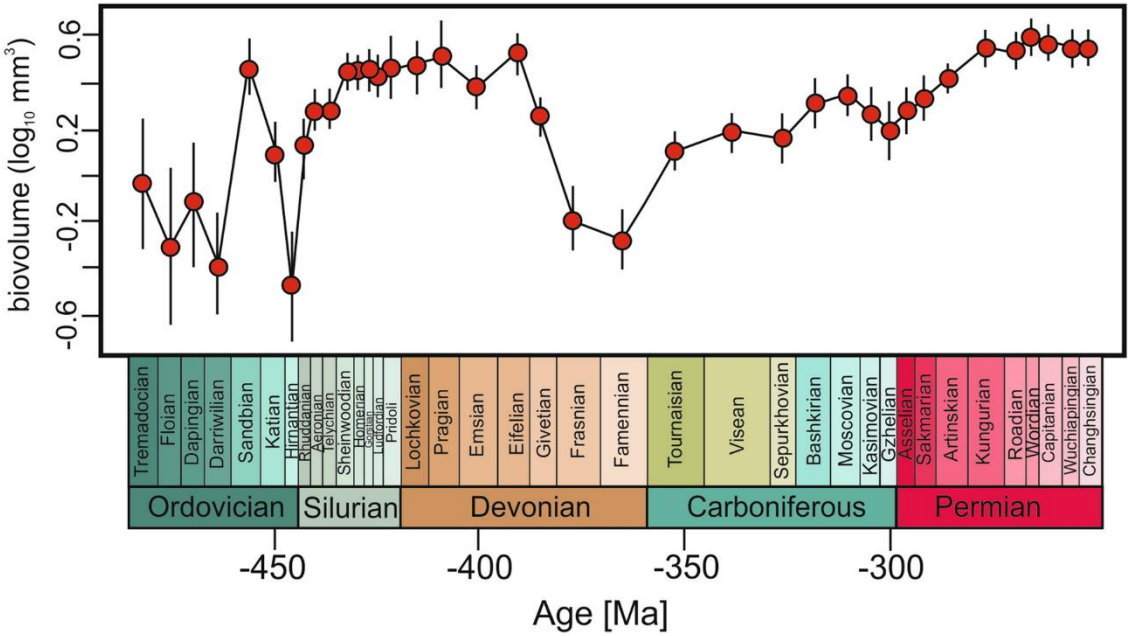
Správna poloha v Galaxii

Vzdialenosť: 25 ly

- silné kozmické žiarenie + UV, ionizácia, búrky
- vysokoenergetické *γ* zničí 50-100% O_3
- zahubenie planktónu
- *prežite? v bunkroch*
- *masové vymieranie v devóne? (360 Mya)?*



Fields a kol., 2020



Správna poloha v Galaxii

Vzdialenosť: 4 ly

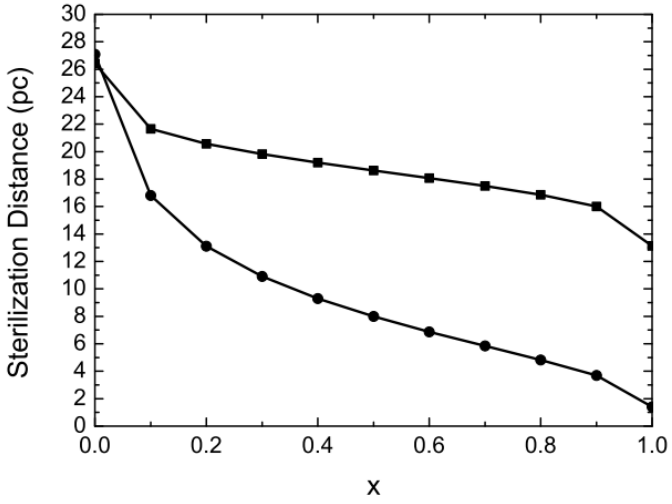
- susedná hviezda
- druhé Slnko
- spálený povrch + smrtiacia radiácia
- odpar z oceánov, prežijú hlbiny?
- *reštart života?*

Správna poloha v Galaxii

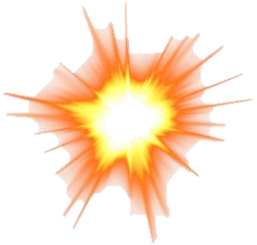
Pre upokojenie:

- do vzdialenosti 1000 ly je asi 270000 hviezd ale len 6 kandidátov na supernovu:

Hviezda	Súhvezdie	Vzdialenosť (ly)
IK Peg	Pegas	150
Spica	Panna	250
Alpha Lupi	Zajac	460
Antares	Škorpión	550
Betelgeuse	Orión	640
Rigel	Orión	860



Lineweaver a kol., 2004:
SN Ia: 18 – 22 pc ~ 60 – 70 ly
SN II: 4 –16 pc ~ 13 – 50 ly



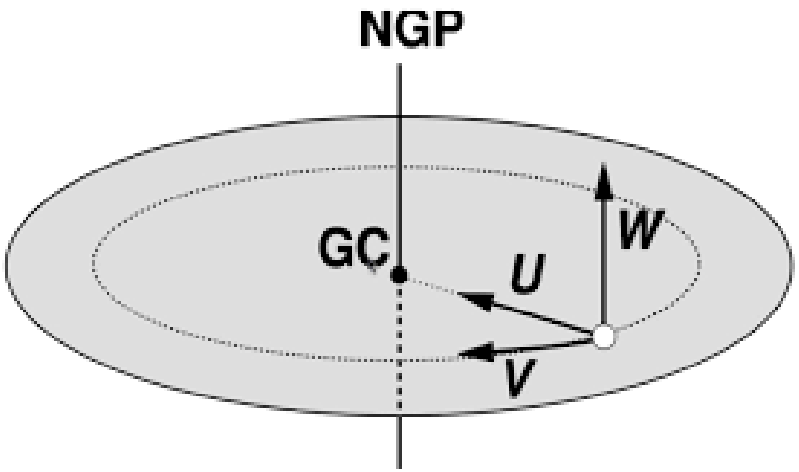
Betelgeuse: 100 tisíc až 2 mil. rokov

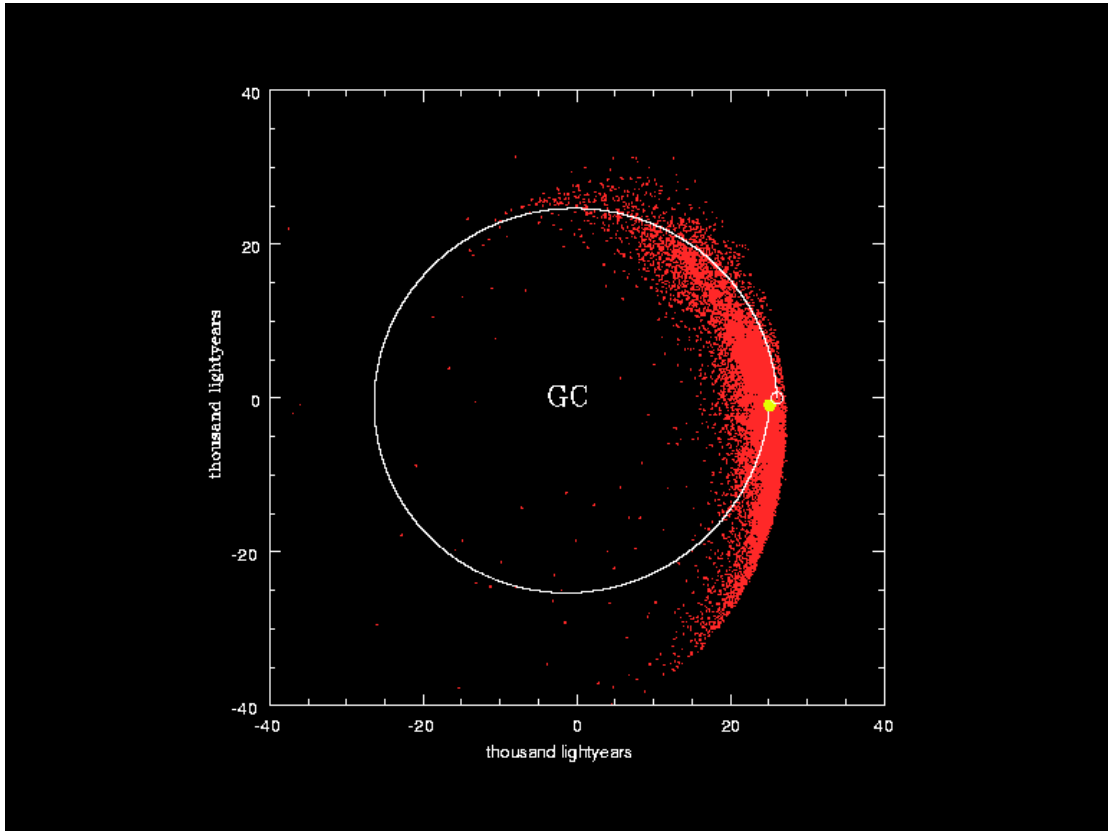
IK Peg: 2 mld. rokov

Správna poloha v Galaxii

v_T = 239 ± 9 kms^{-1} (Hunt a kol., 2016), 1 obeh ~ 230 Myr

LSR: U = 8,5 kms^{-1}, V = 13,38 kms^{-1}, W = 6,49 kms^{-1} (Coşkunoğlu a kol., 2011)



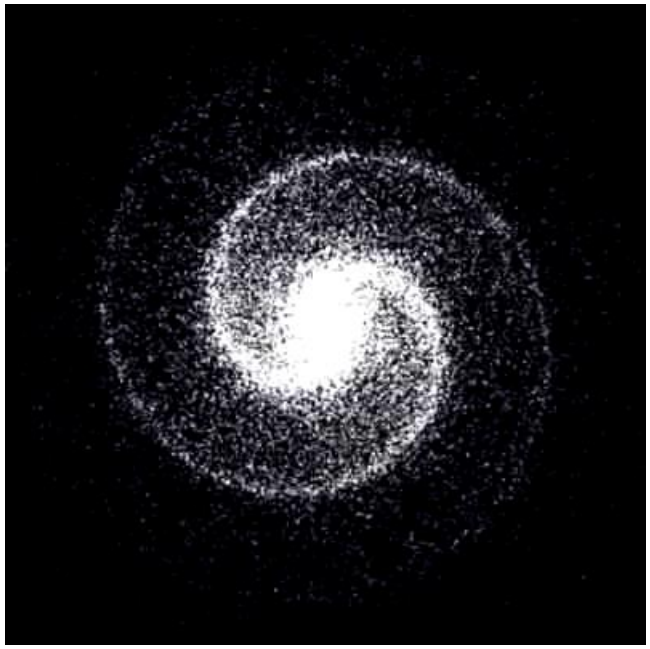


Nordström a kol., 2004

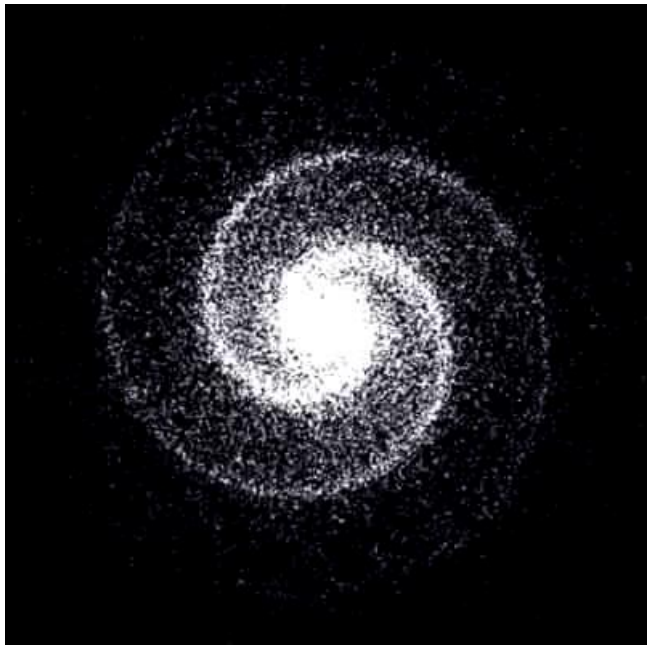
Správna poloha v Galaxii

Hustotné vlny, premiešavanie hviezd

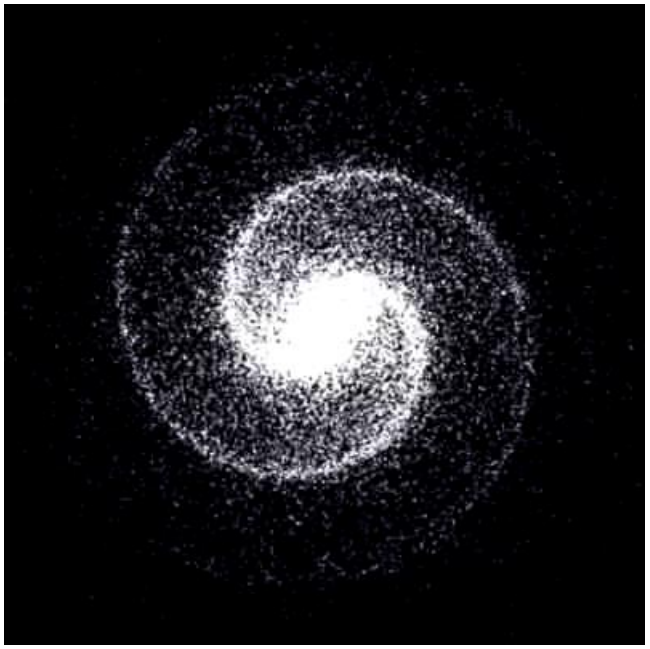
Lin a Shu, 1964



pevné
ramená



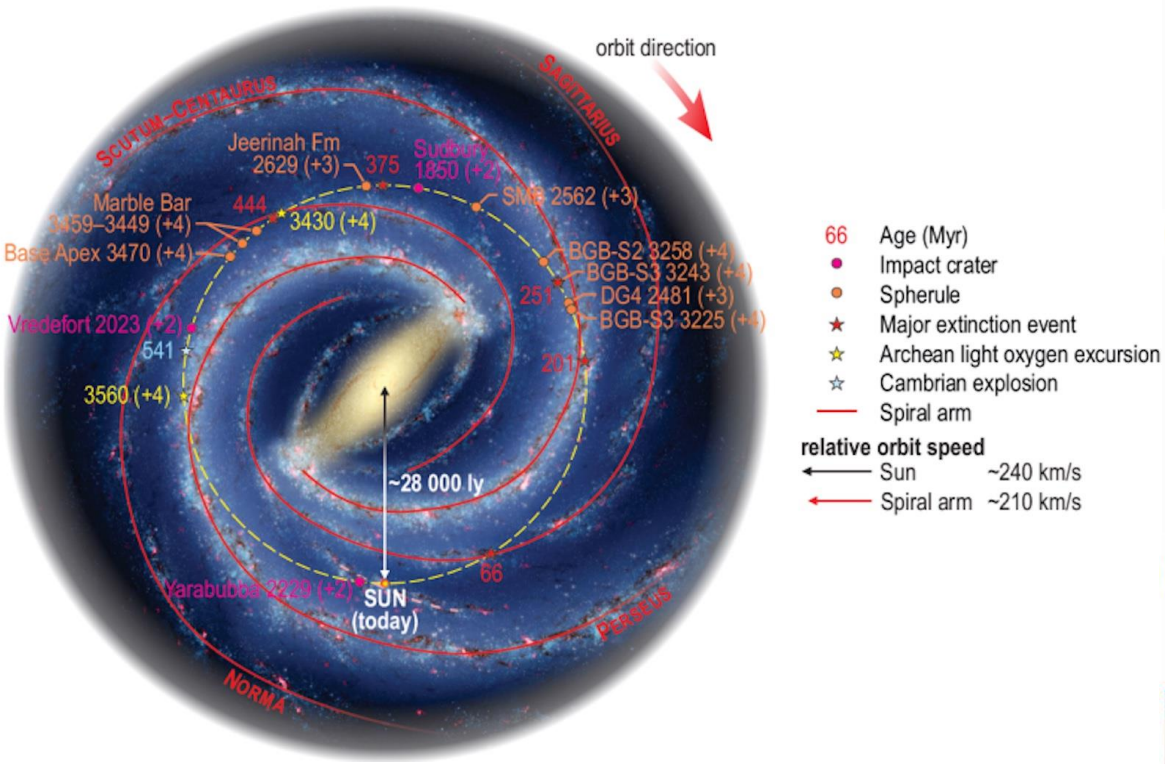
diferenciálna
rotácia

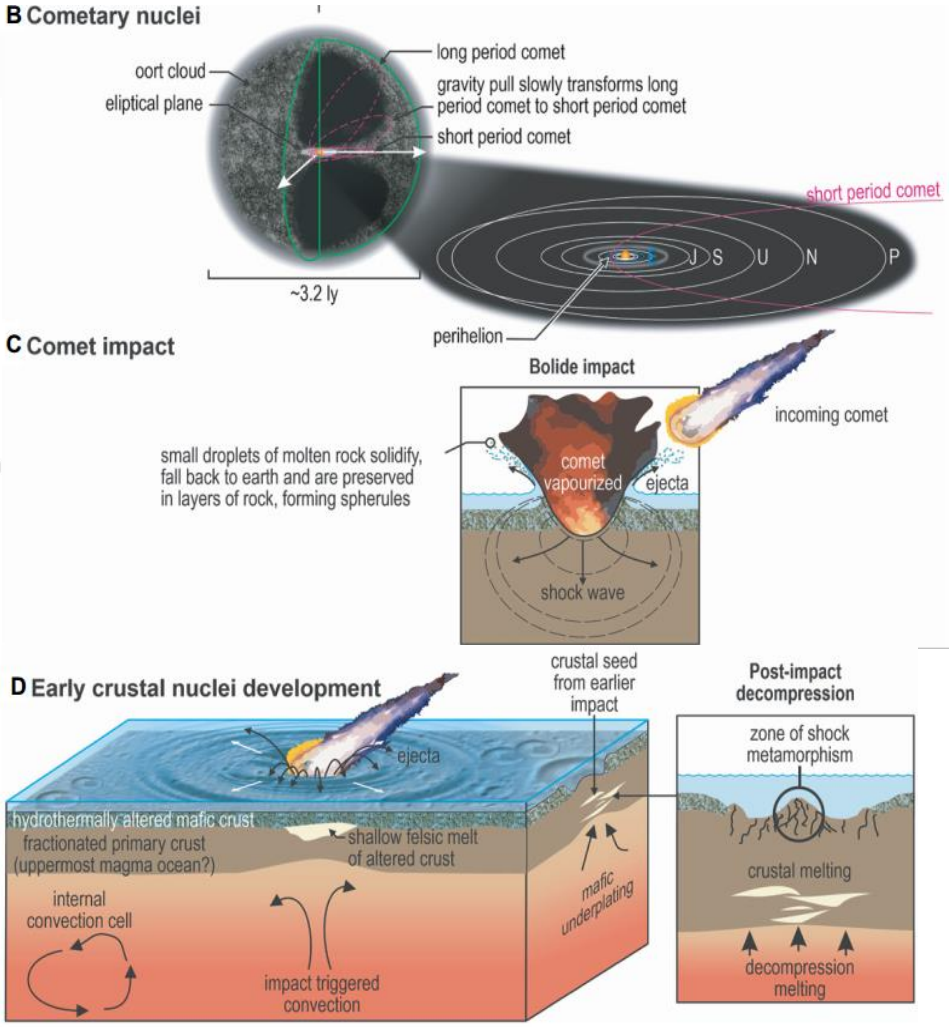


hustotné
vlny

Správna poloha v Galaxii

Prechod cez špirálové ramená súvisí s kôrou Zeme?





Kirkland a kol., 2022

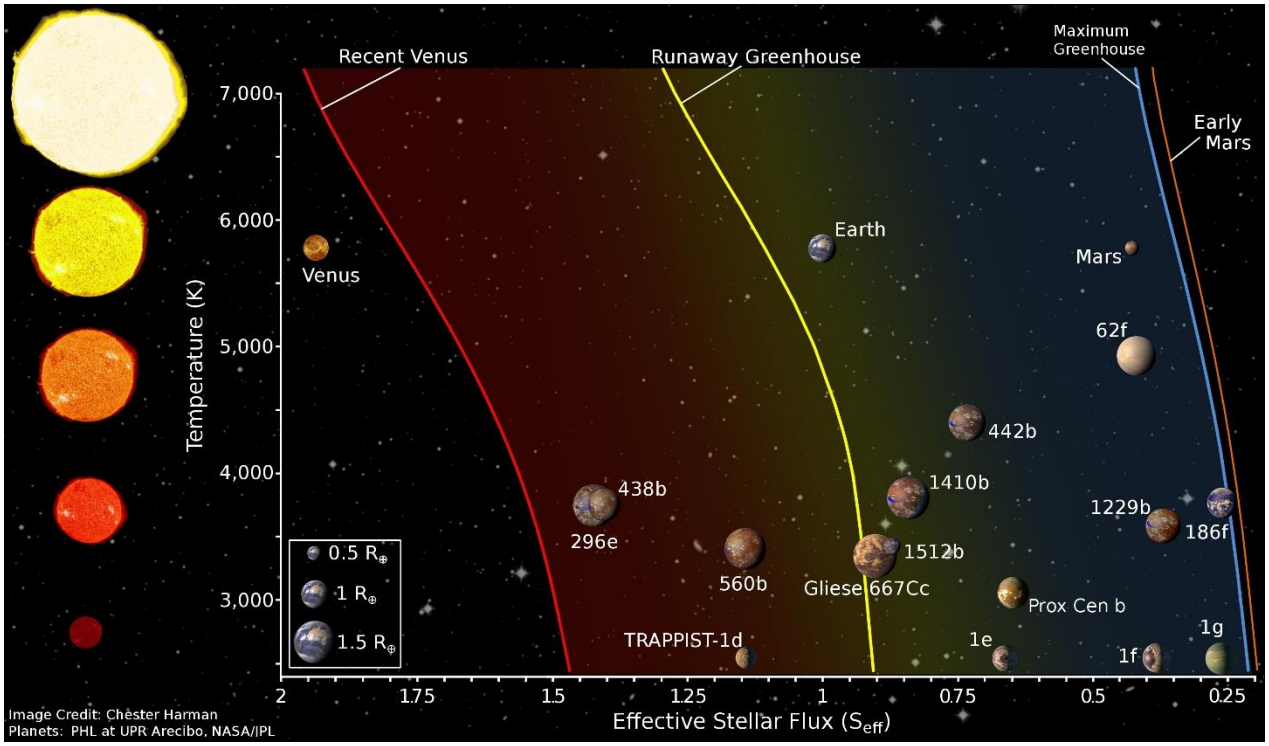
Správna vzdialenosť od materskej hviezdy

„Obývateľná zóna“

0) voda medzi 0-100°C

1) vnútorná hranica = nezvratný skleníkový jav (1,1 $L_\odot$), vonkajšia hranica = pozitívny skleníkový jav (0,36 $L_\odot$)

2) vnútorná hranica = nedávna Venuša (1,78 $L_\odot$), vonkajšia hranica raný Mars (0,32 $L_\odot$)

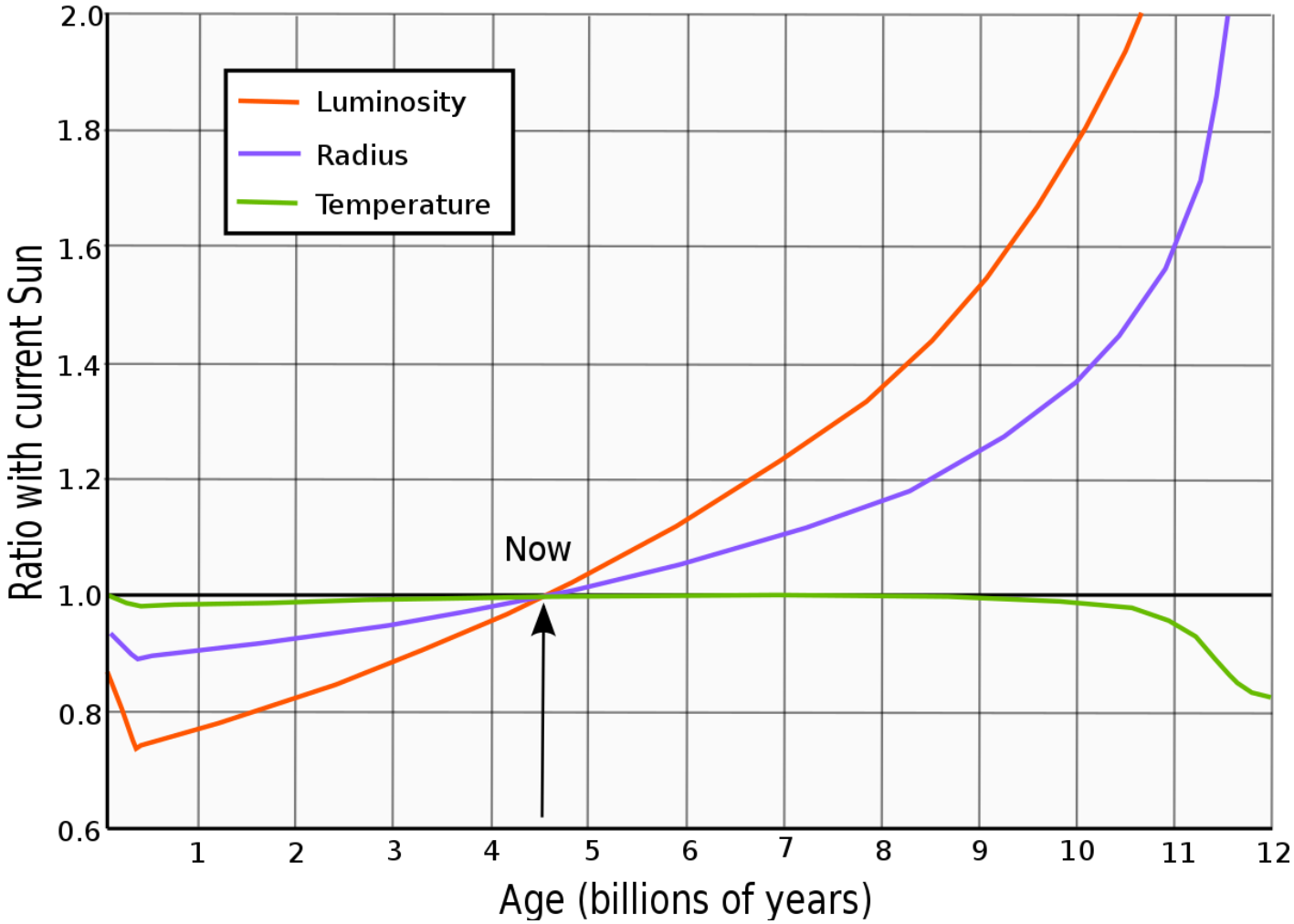


+ tajne predpokladá atmosféru podobnú Zemi a škálovanie tlaku N_2 podľa hmotnosti planéty.

Kopparapu a kol., 2013 a 2014

Správna vzdialenosť od materskej hviezdy

Kontinuálna „Obývateľná zóna“



Správna vzdialenosť od materskej hviezdy

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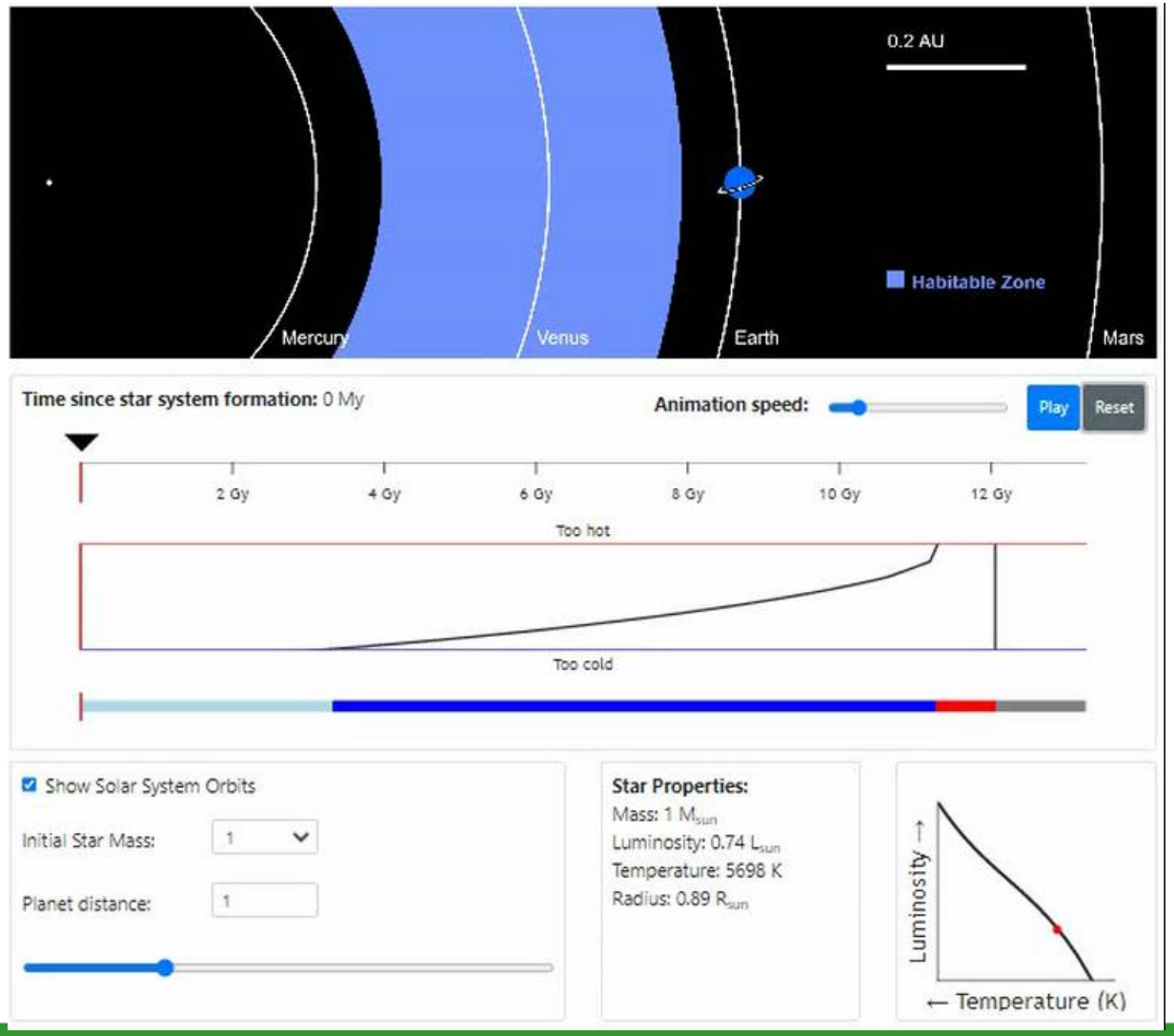
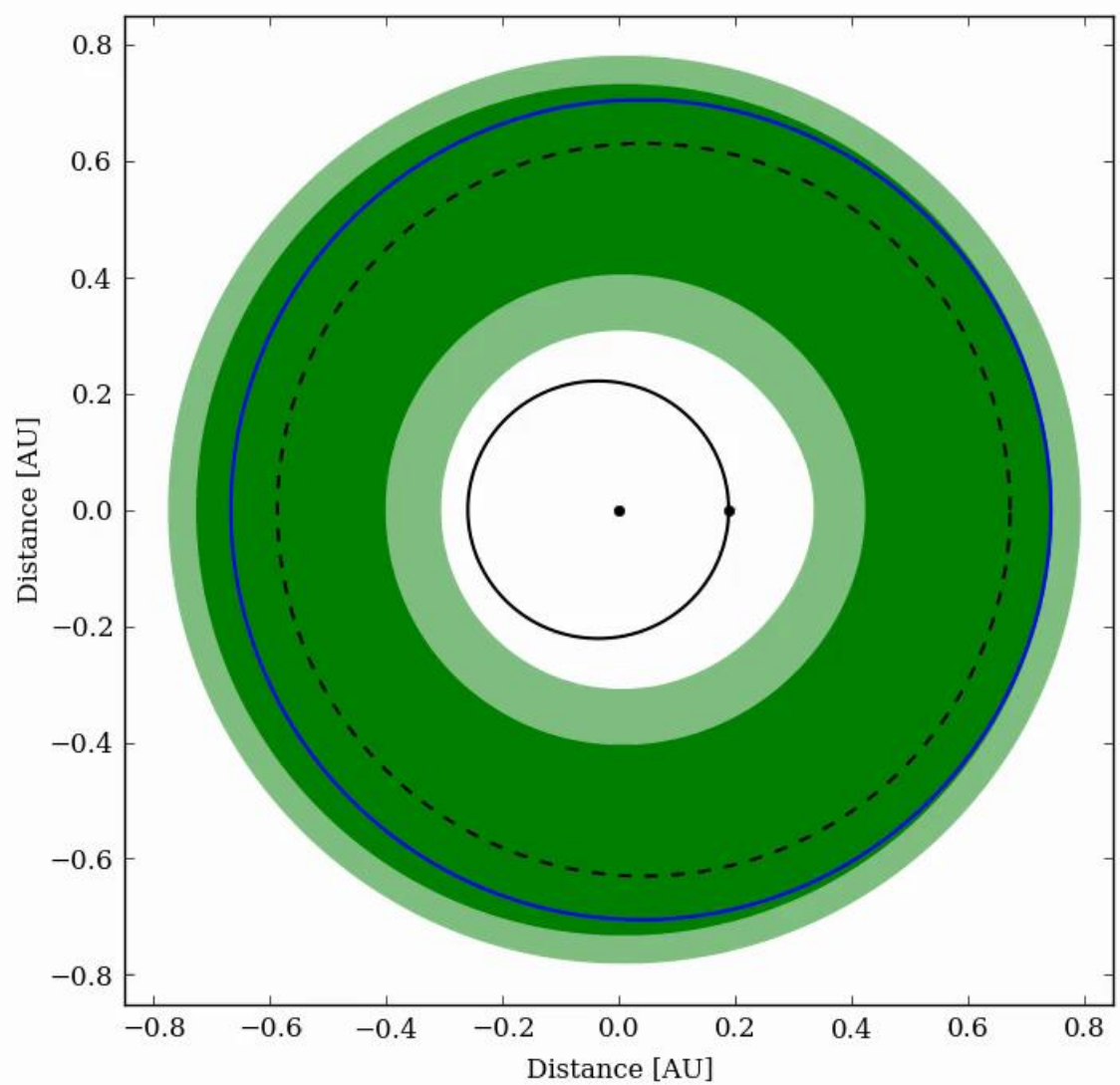


Správna vzdialenosť od materskej hviezdy

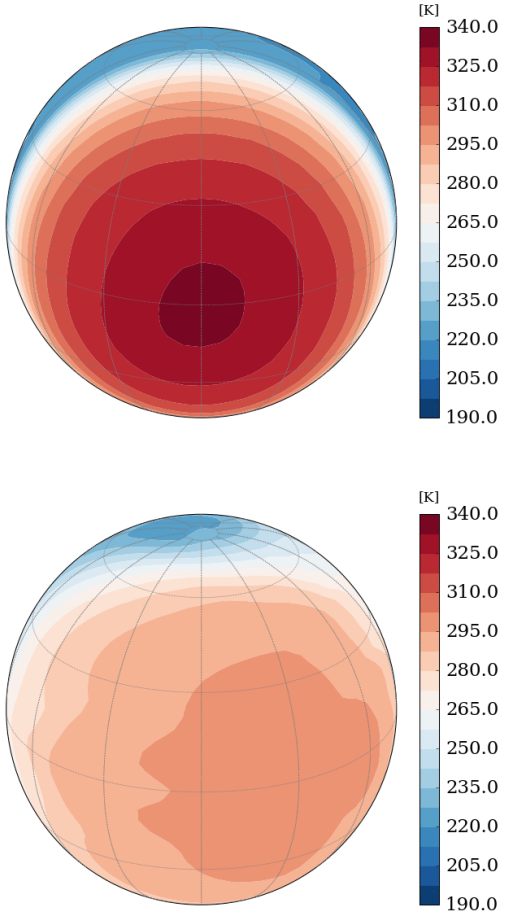
Müller a Haghighipour, 2014



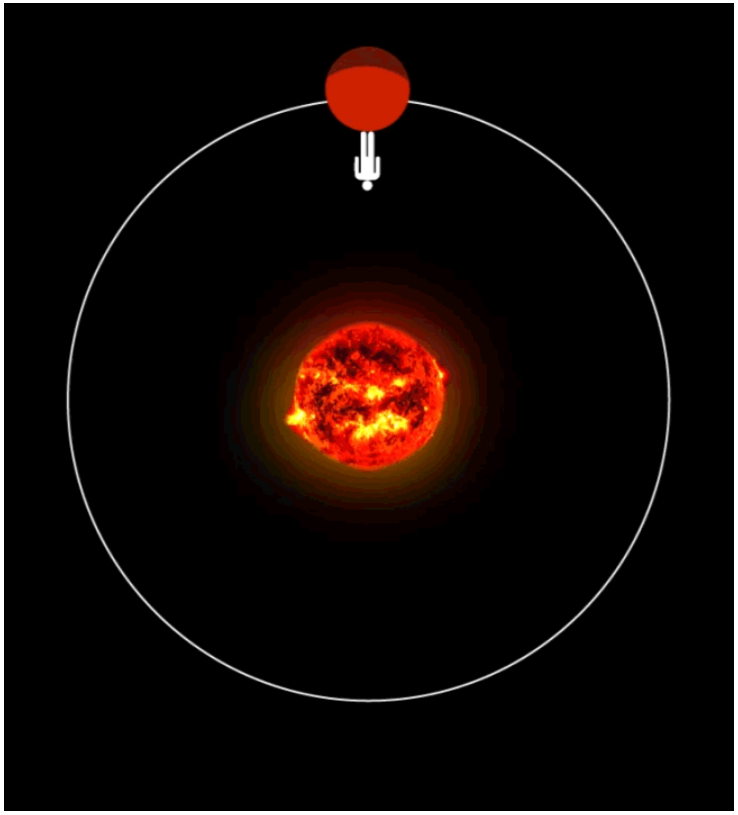
Kepler-16 (AB) b	
Objav	2011
Vzdialenosť	245 ly
Hmotnosť	0,33 M_J
Polomer	0,75 M_J
Hustota	0,96 g/cm^3
Teplota	-85°C
Gravitácia	1,55 g
Dĺžka dňa	228,8 d

Správna vzdialenosť od materskej hviezdy

Slapový zámok a teplota

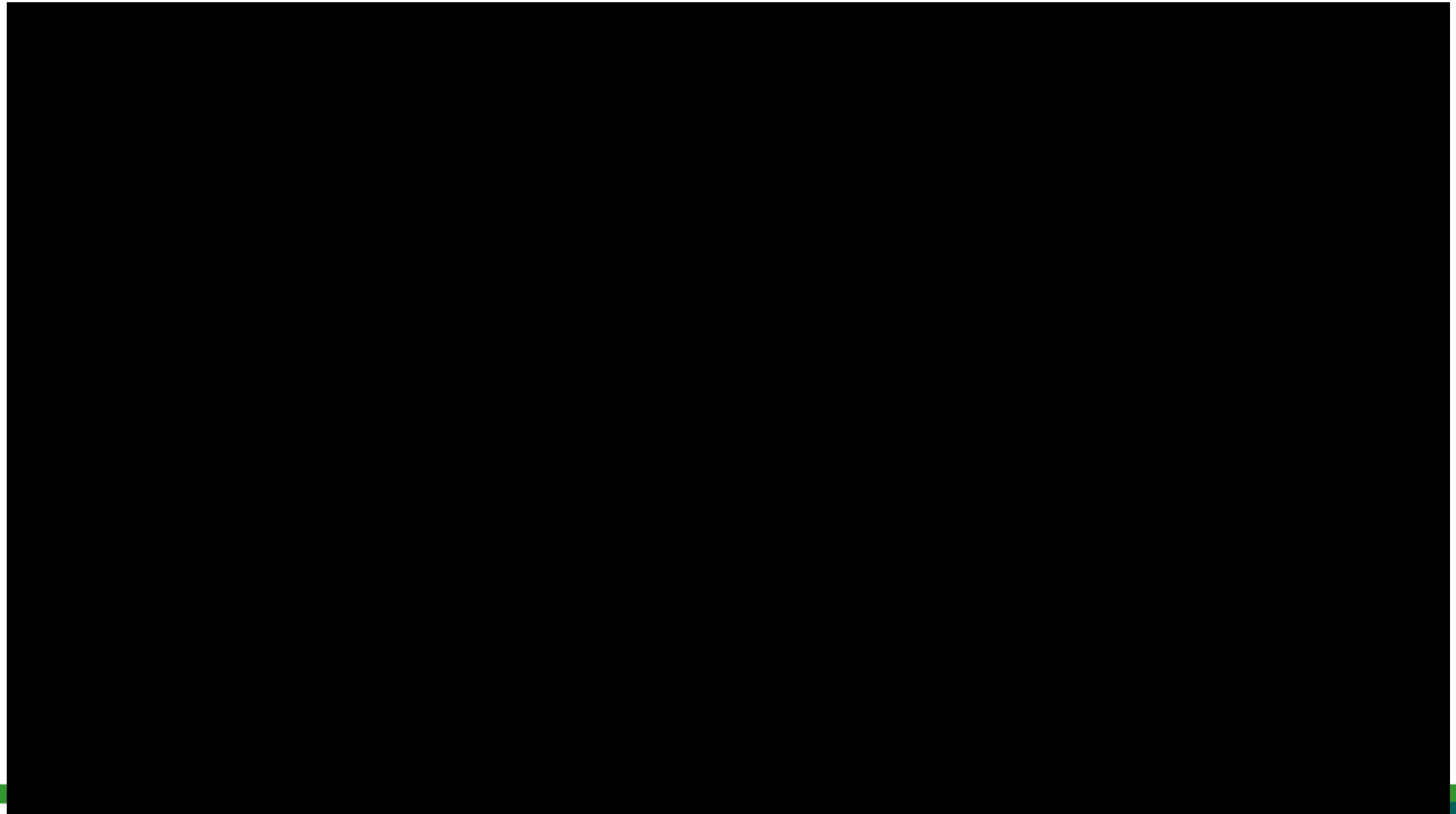


Leconte a kol., 2015



Správna hmotnosť hviezdy

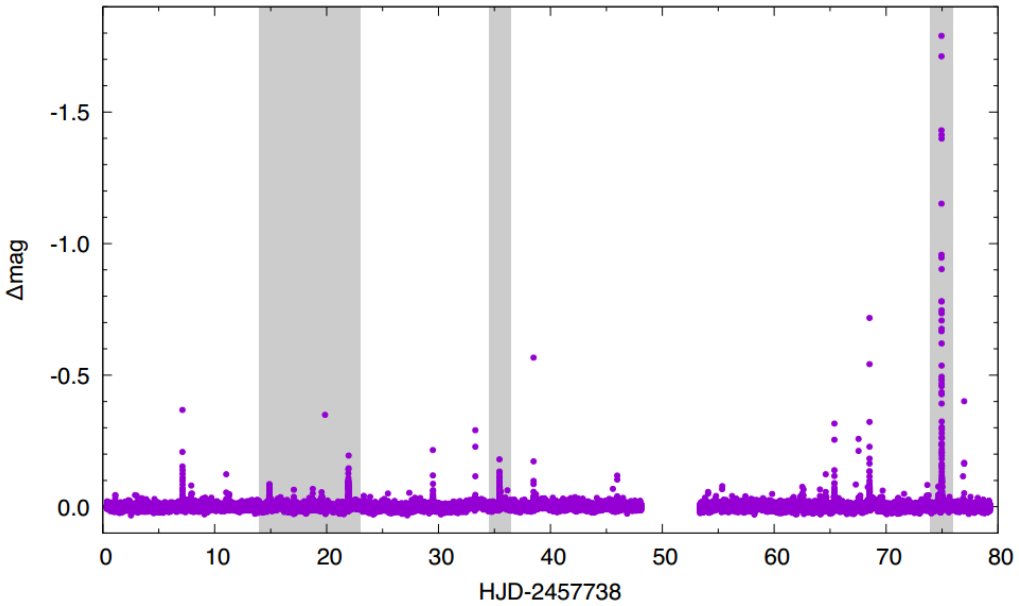
„život“ hviezdy na hlavnej postupnosti

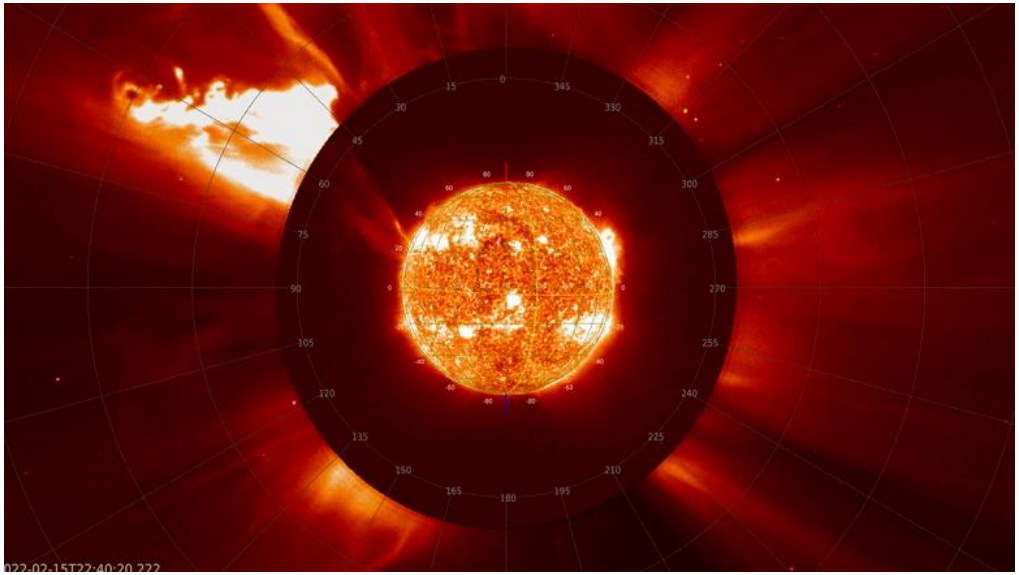


Správna hmotnosť hviezdy

Trappist-1: 42 vzplanutí / 80 dní

Rotácia hviezdy: asi 3,3 dňa (porov. Slnko: asi 25,4 dňa)





Správna hmotnosť hviezdy

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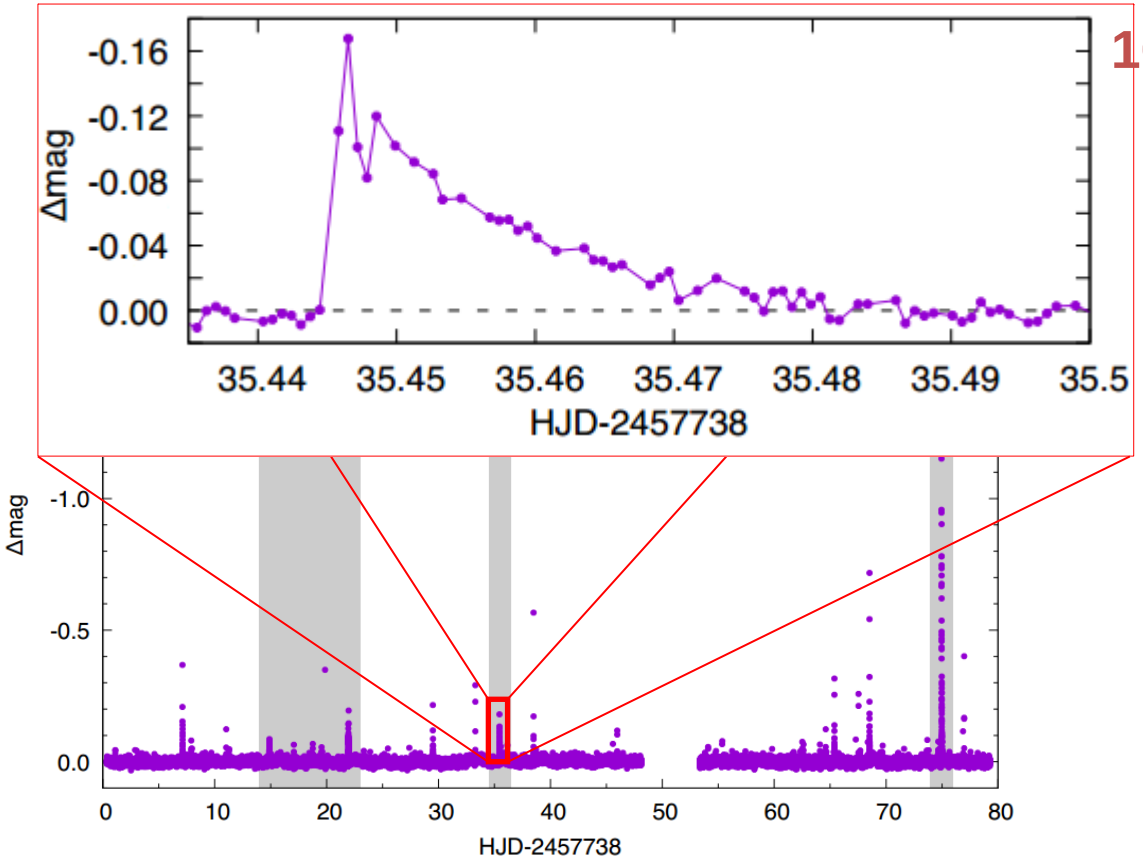
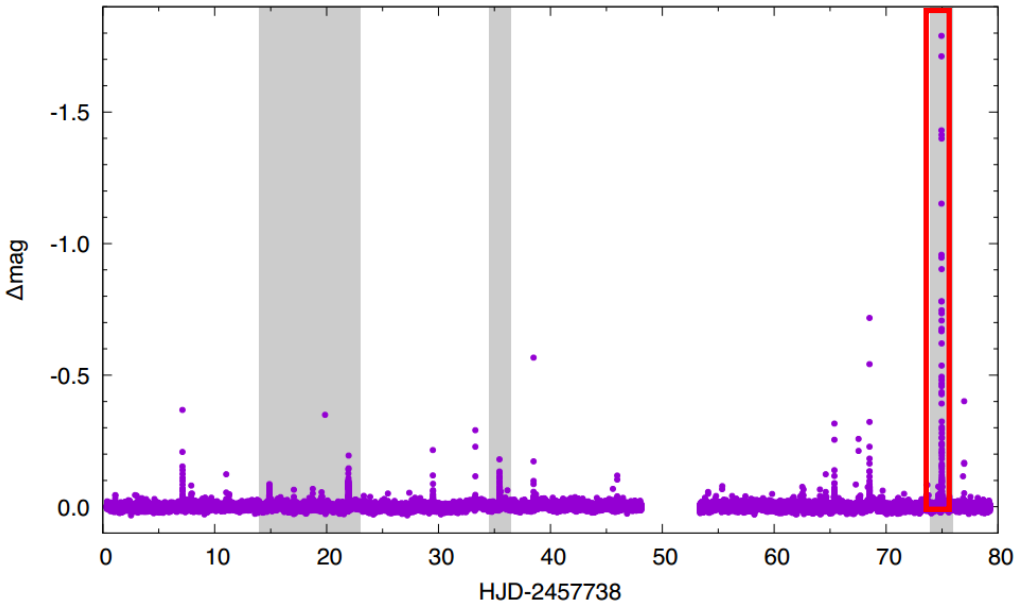


10 000 000 000

Vzplanutia červených trpaslíkov

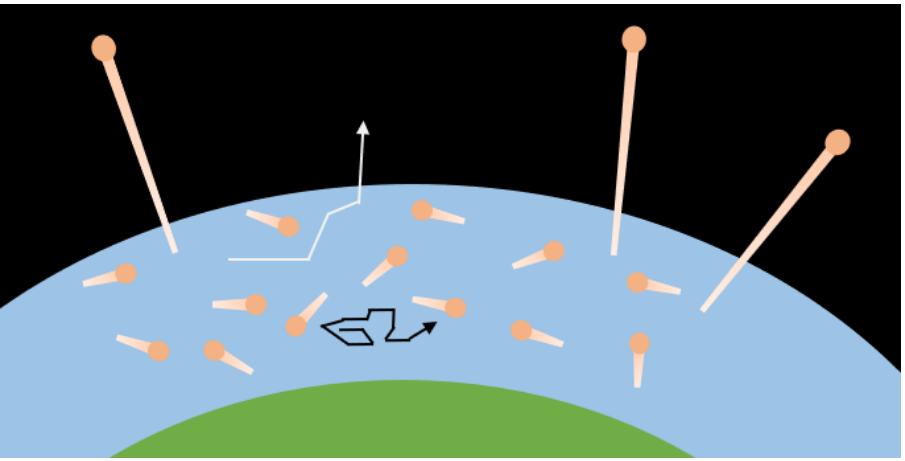
Trappist-1: 42 vzplanutí / 80 dní

Rotácia hviezdy: asi 3,3 dňa (porov. Slnko: asi 25,4 dňa)



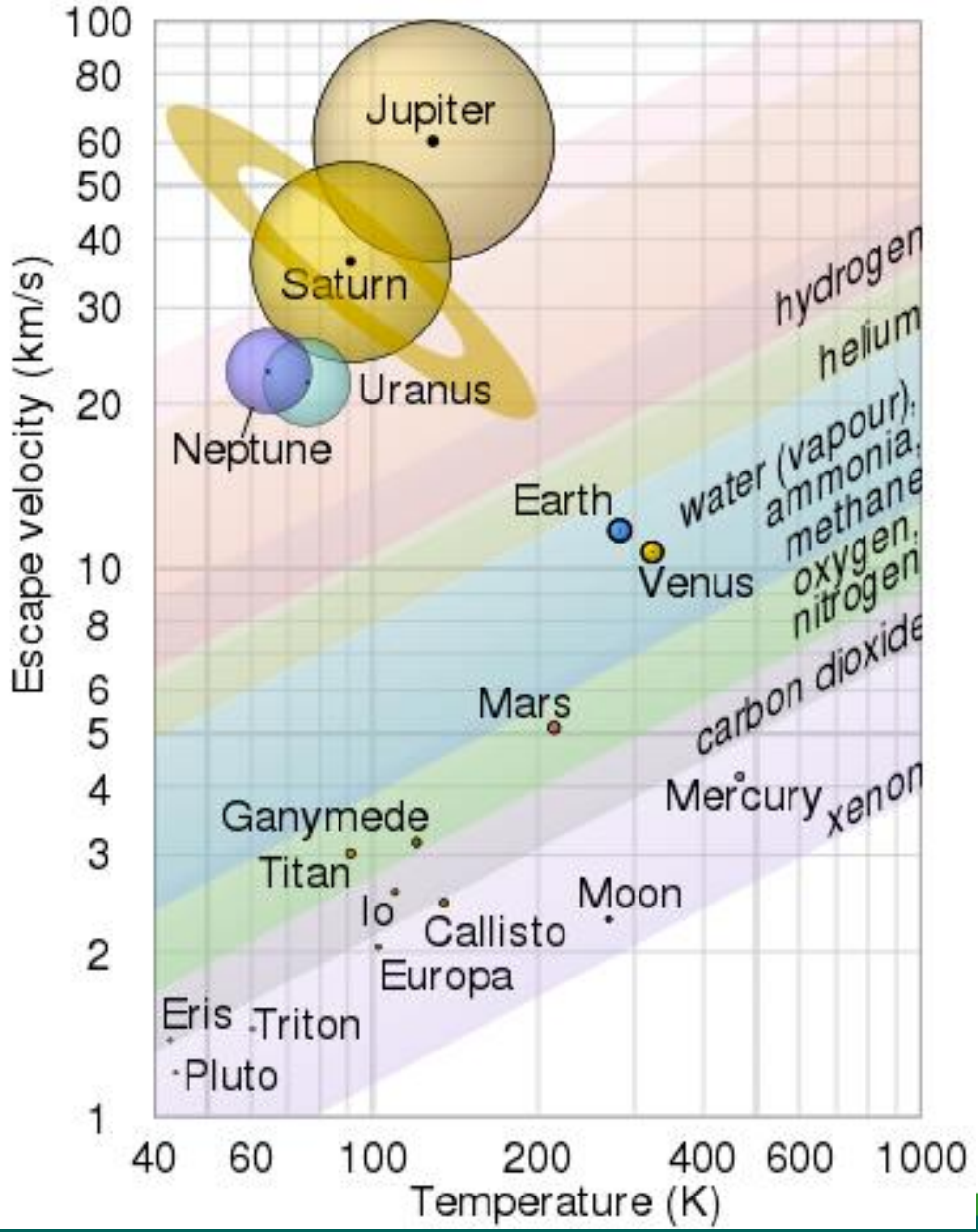
Správna hmotnosť planéty

Udržanie atmosféry a oceánu

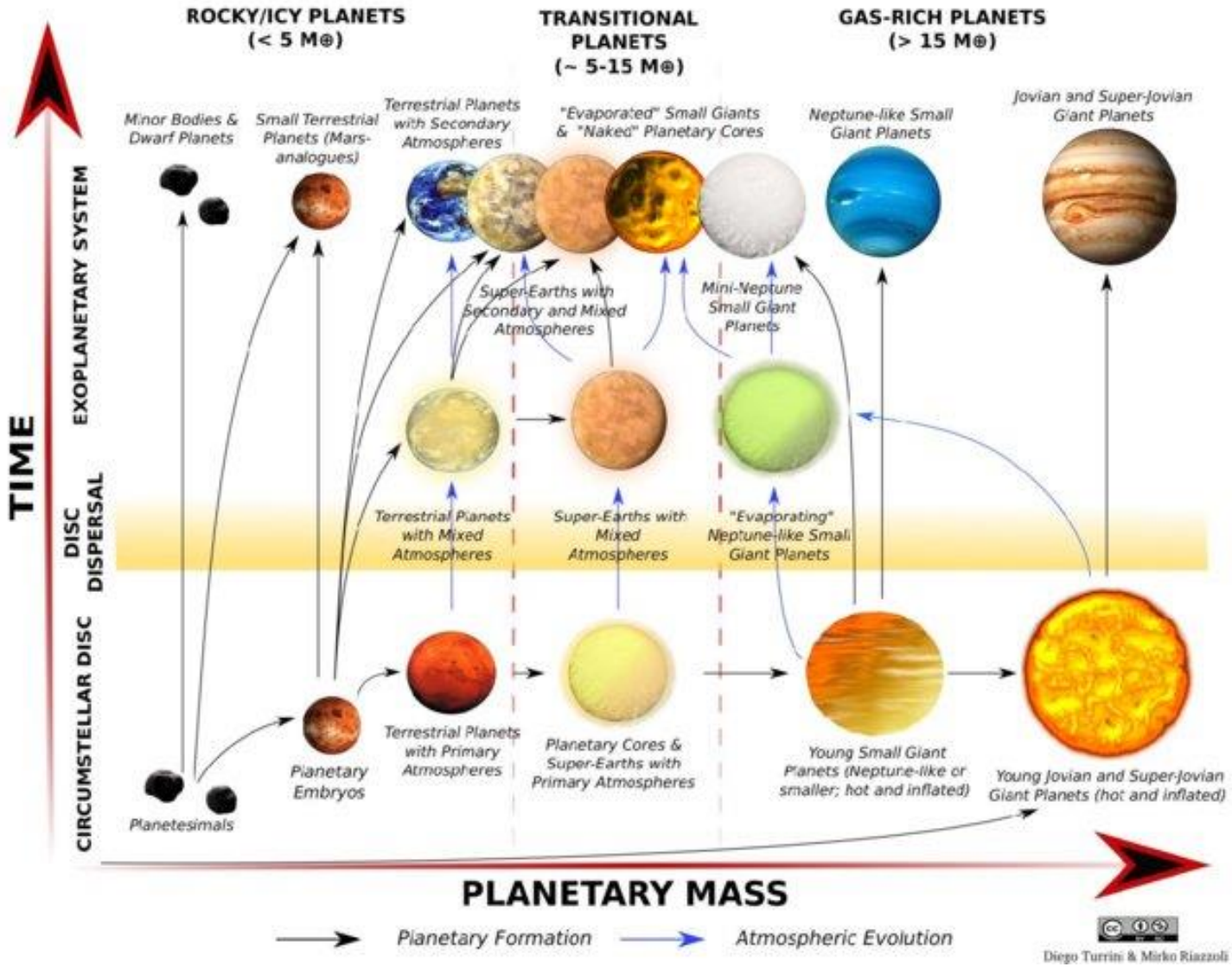


$$E_k = \frac{1}{2}mv^2 \qquad E_p = \frac{GMm}{r}$$

$$v = \sqrt{\frac{2GM}{r}}$$



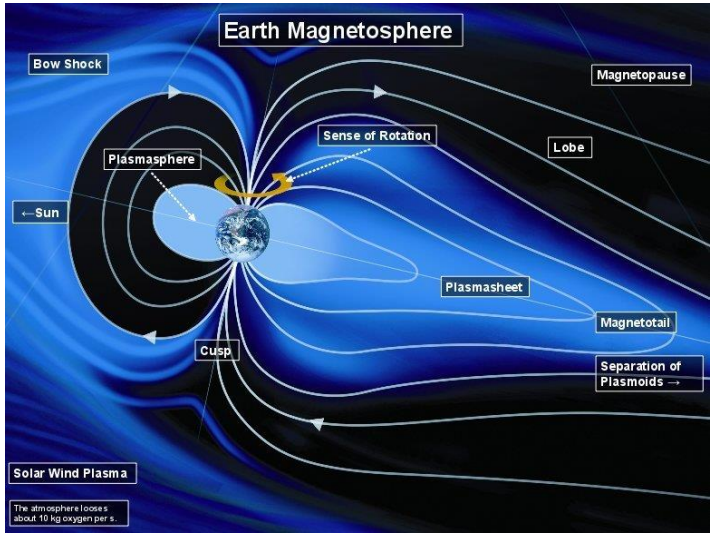
Správna hmotnosť planéty

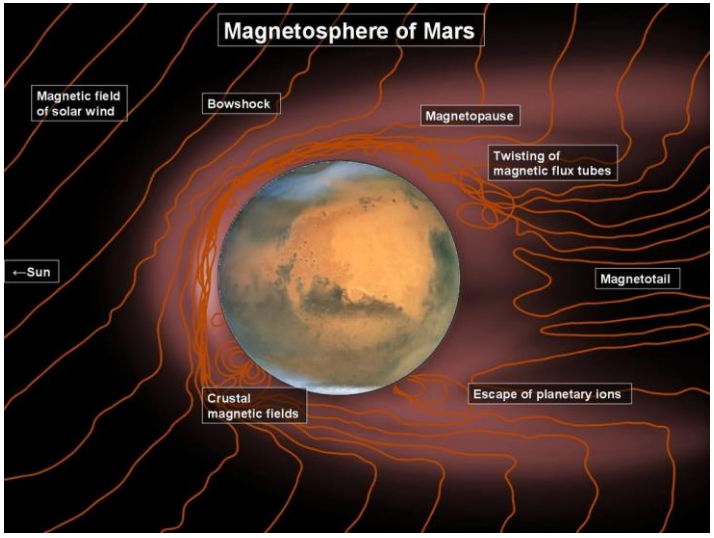


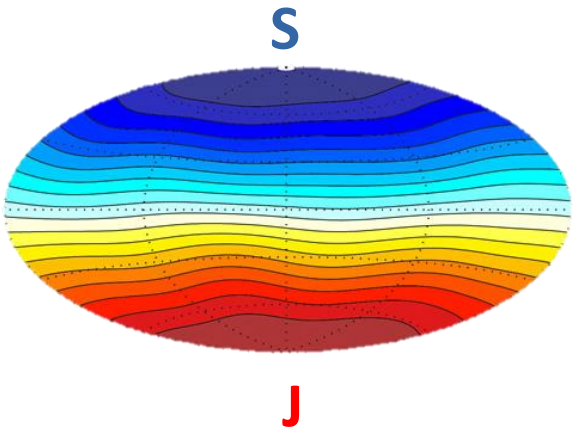
Turrini a kol., 2018

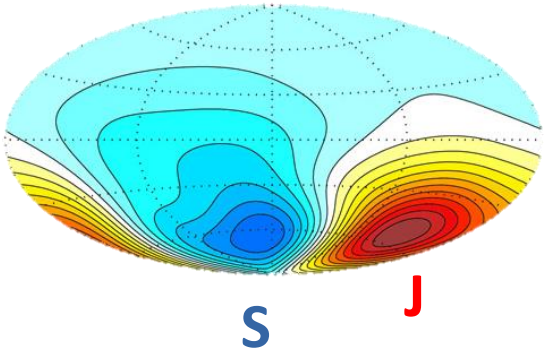
Správna hmotnosť planéty

Tekuté jadro – tektonika, magnetické pole

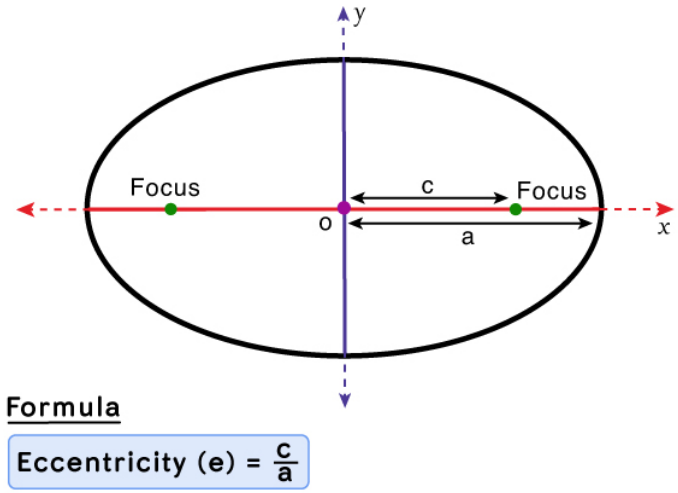




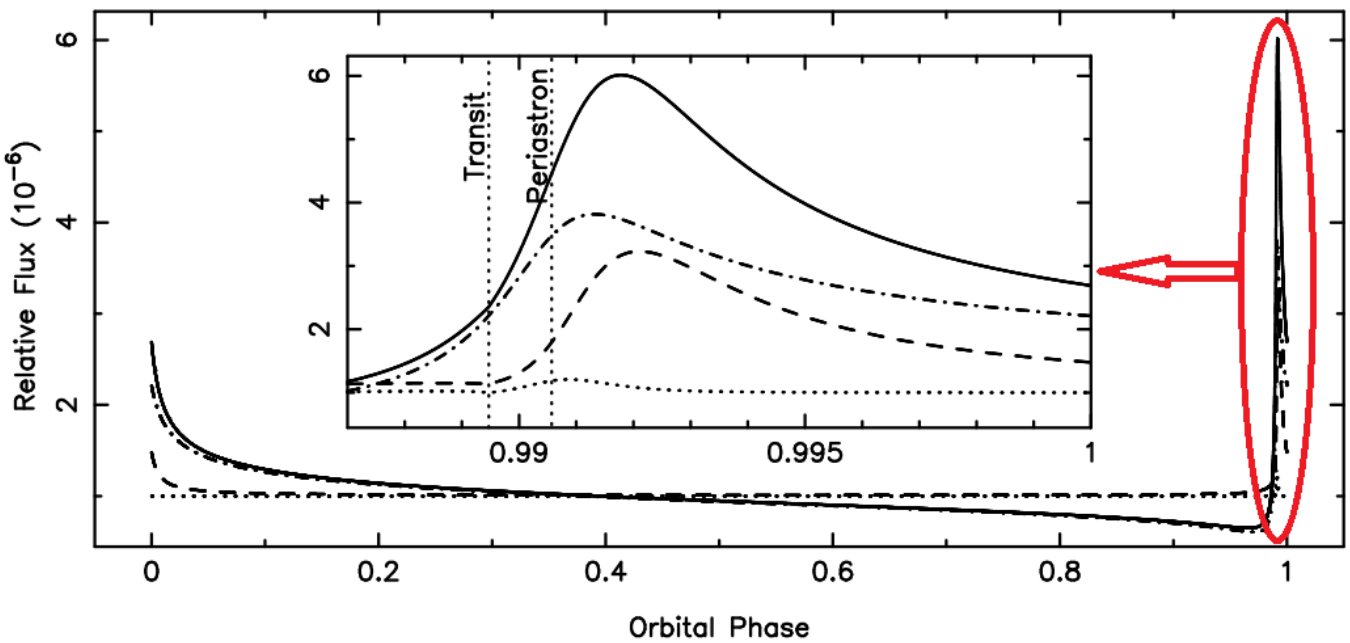


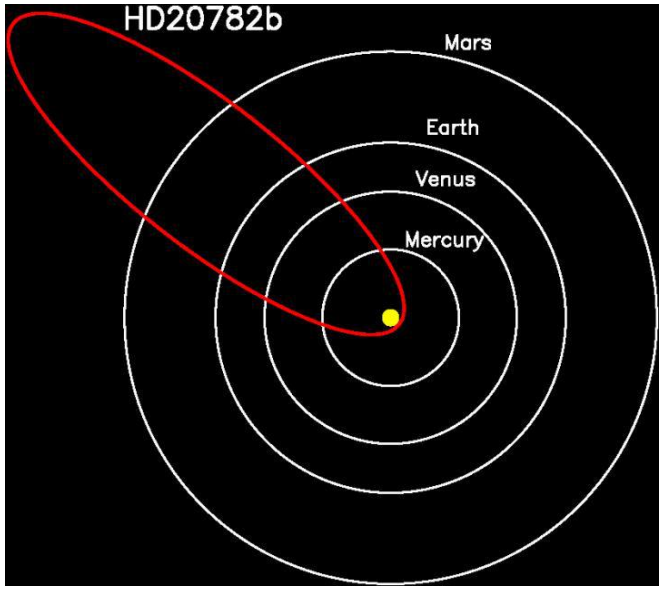


Stabilná obežná dráha

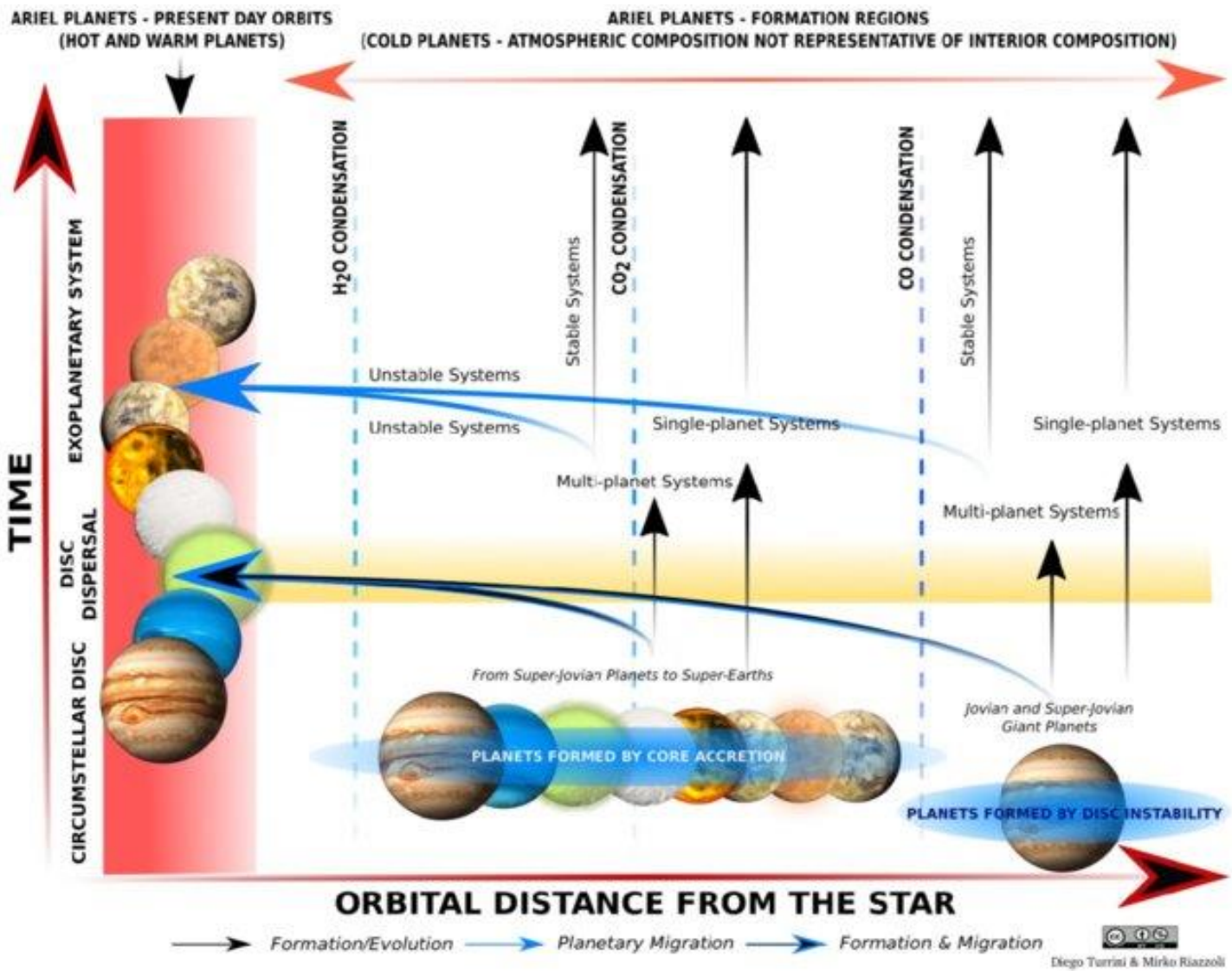


Teleso	*e*
HD 202782b	0,960
Zem	0,017
Mars	0,094
Pluto	0,249
P1-Halley	0,970





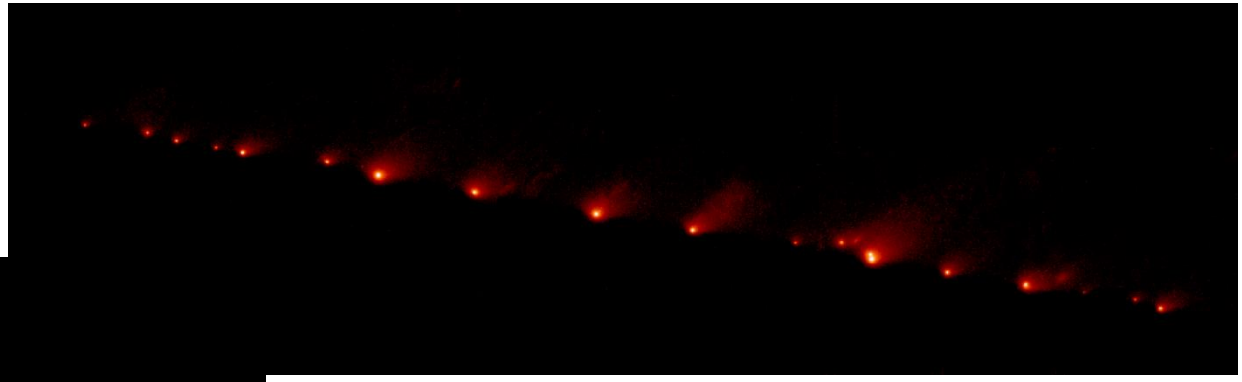
Stabilná obežná dráha



Turrini a kol., 2018

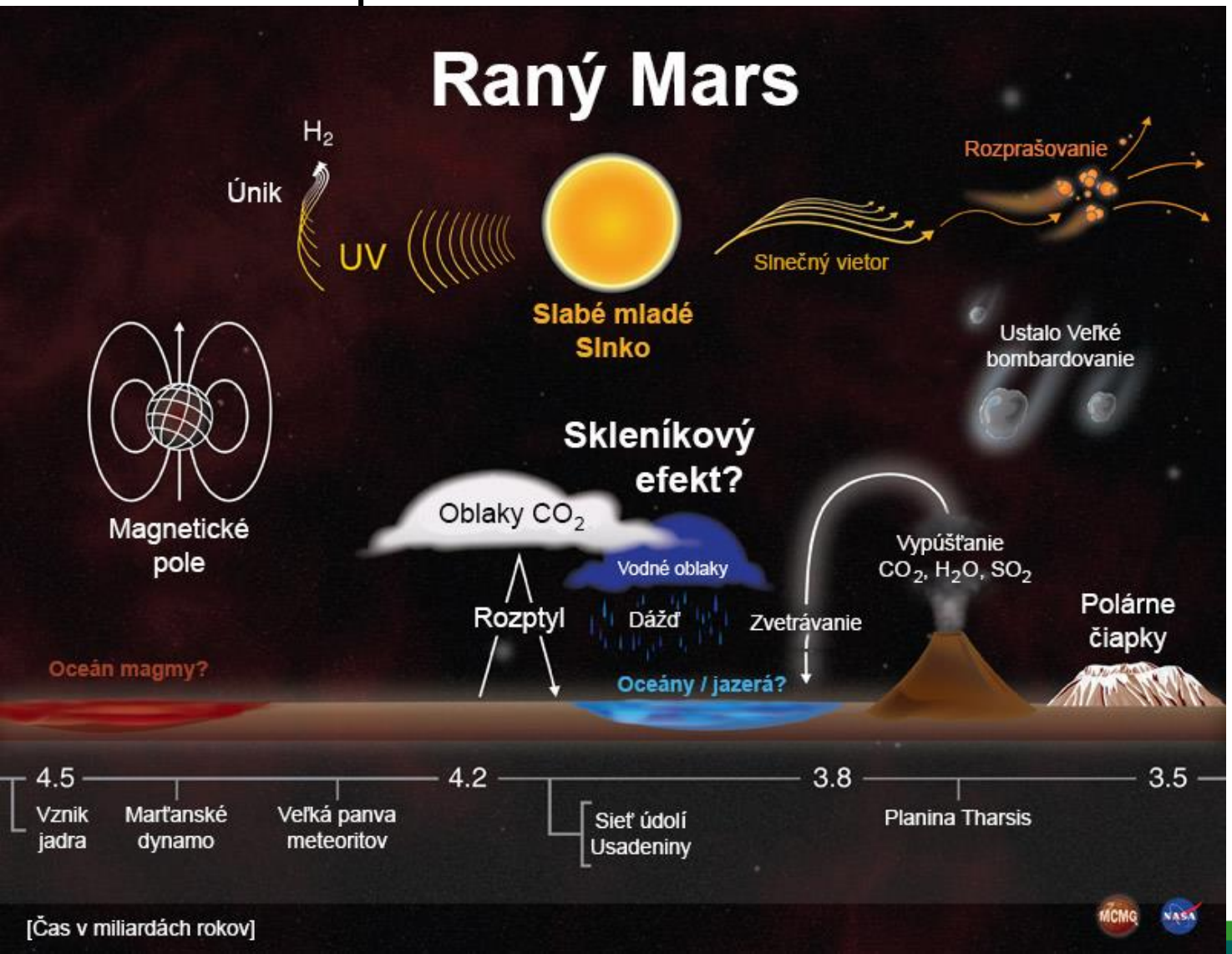
Sused - Jupiter

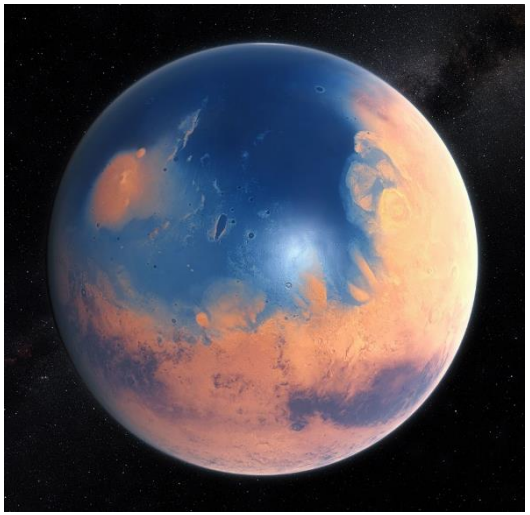
Ochrana pred kométami a asteroidmi

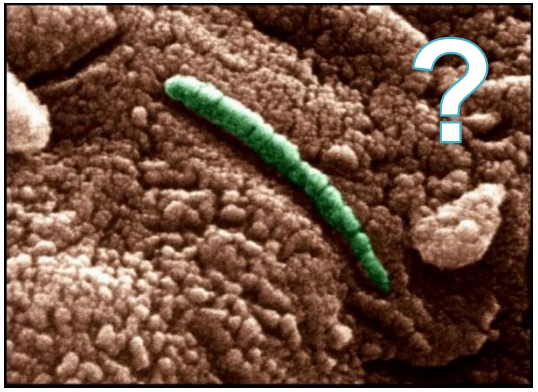


Sused - Mars

Potenciál pre osiatie životom?

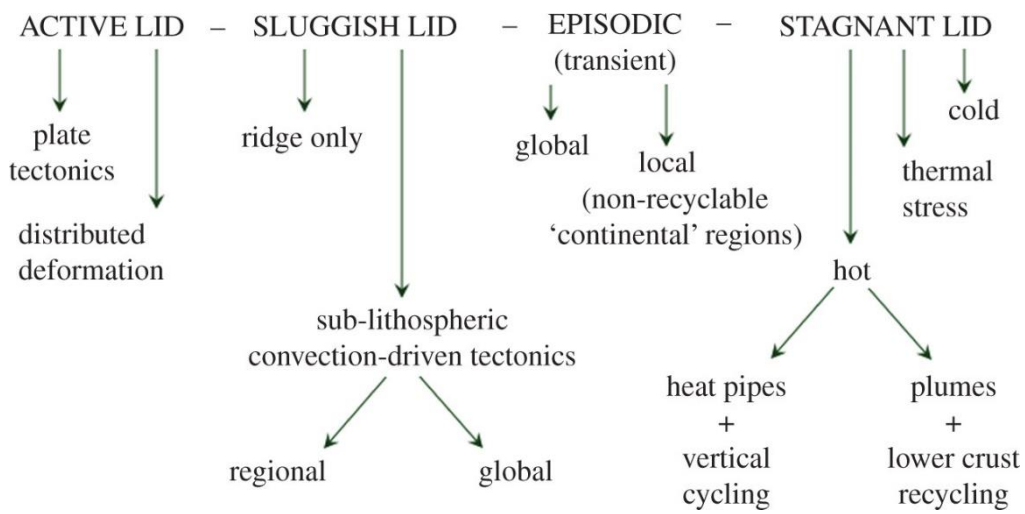




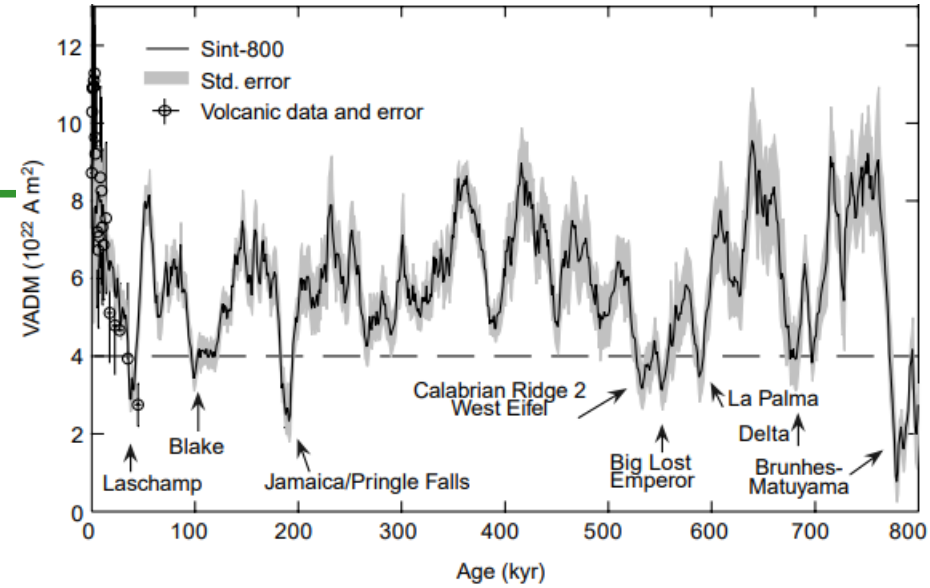


Tektonika

Tvorba pevniny, magnetické pole

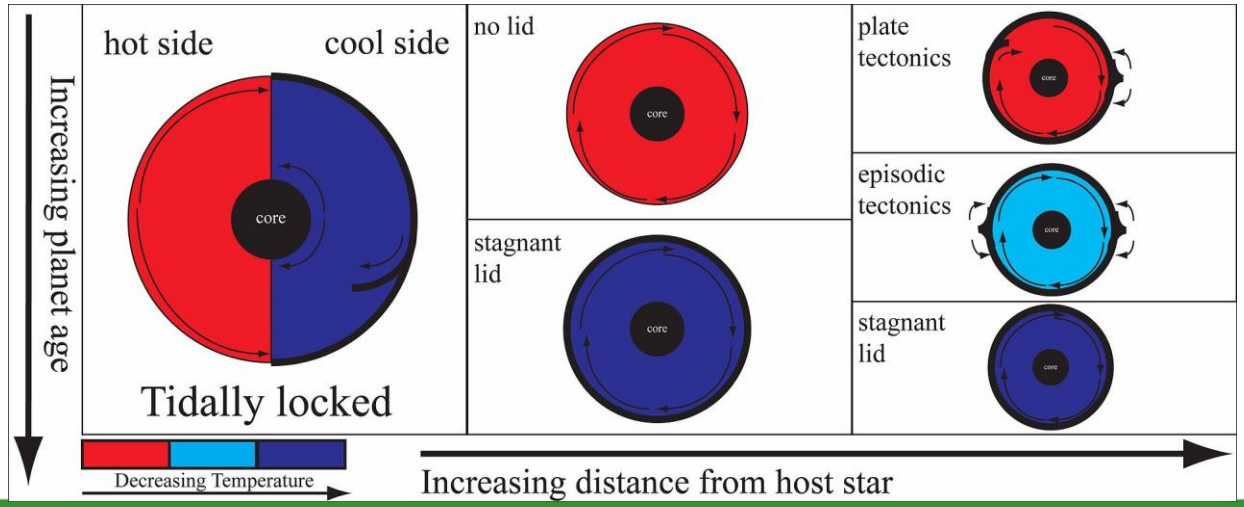


Lenardic, 2018



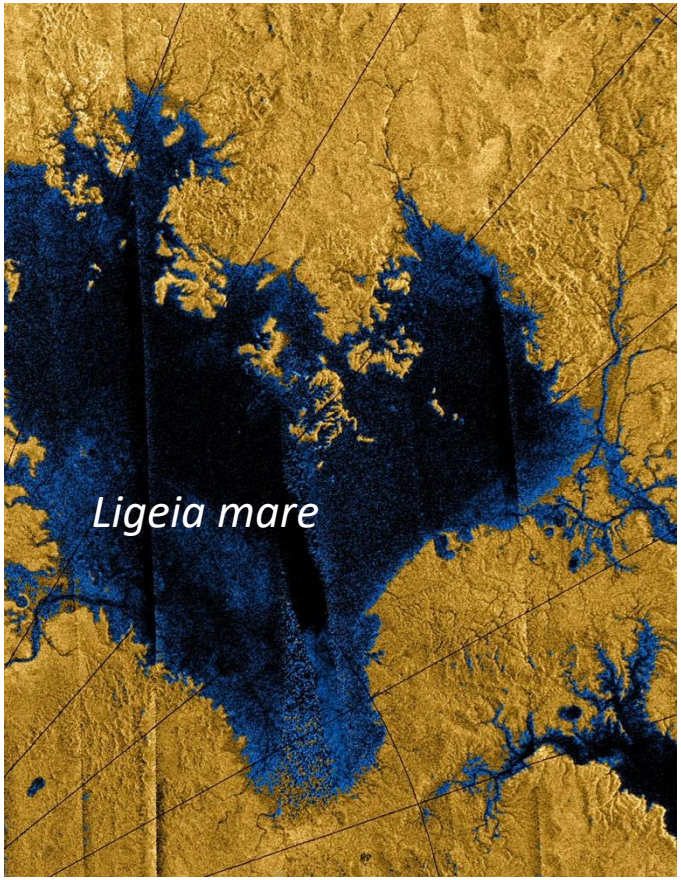
Guyodo a Valet, 1999

Van Summeren a kol., 2011



Oceán

Nie nutne vodný? Tak akurát.



Veľký mesiac

Správna vzdialenosť, stabilizácia sklonu rotácie

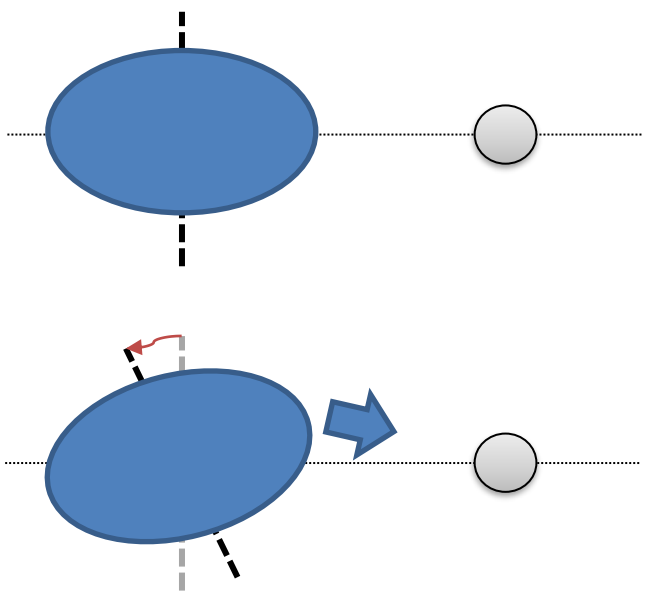
$$t_{\text{lock}} \approx \frac{\omega \boldsymbol{a}^6 I Q}{3G\boldsymbol{m_p^2} k_2 R_s^5}$$

$$I \approx 0{,}4 m_s R_s^2$$

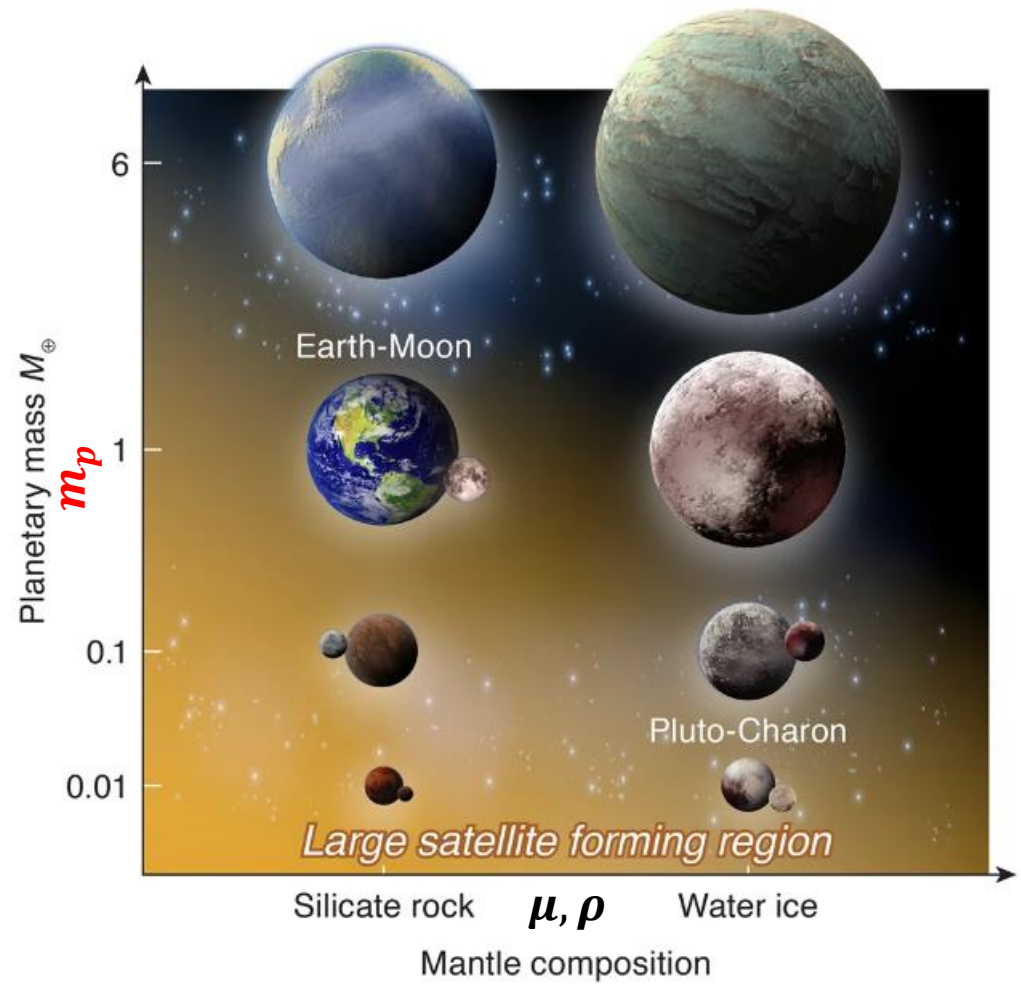
$$Q \sim 100$$

$$k_2 \approx \frac{1{,}5}{1 + \frac{19\boldsymbol{\mu}}{2\boldsymbol{\rho} g R_s}}$$

$$g \sim \frac{G m_s}{R_s^2}$$

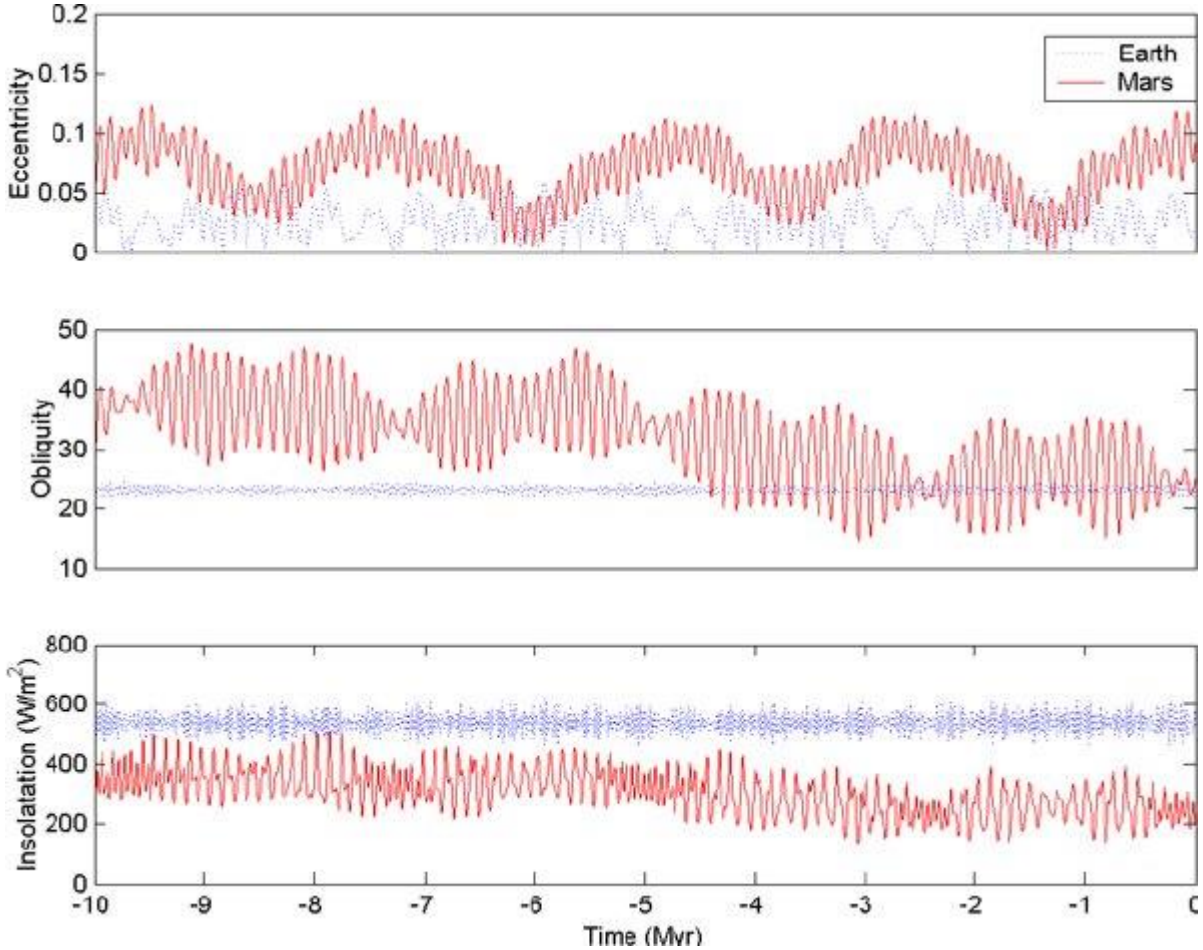


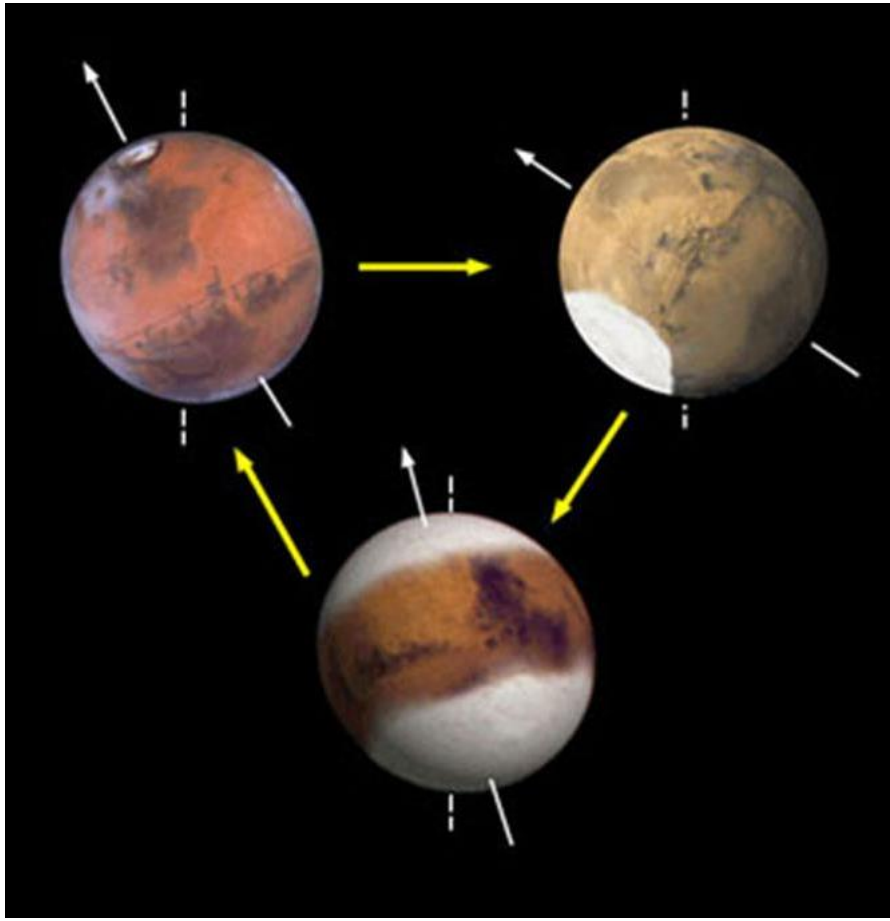
Nakajima a kol., 2022



Sklon rotácie planéty

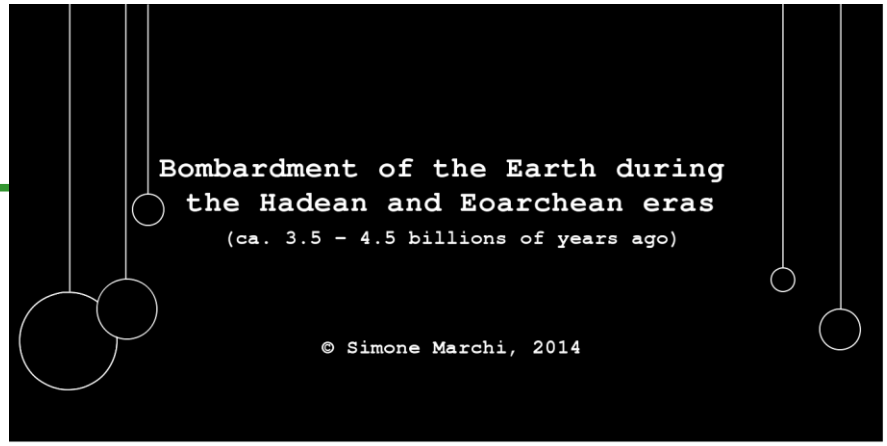
Nie príliš veľké rozdiely medzi ročnými obdobiami

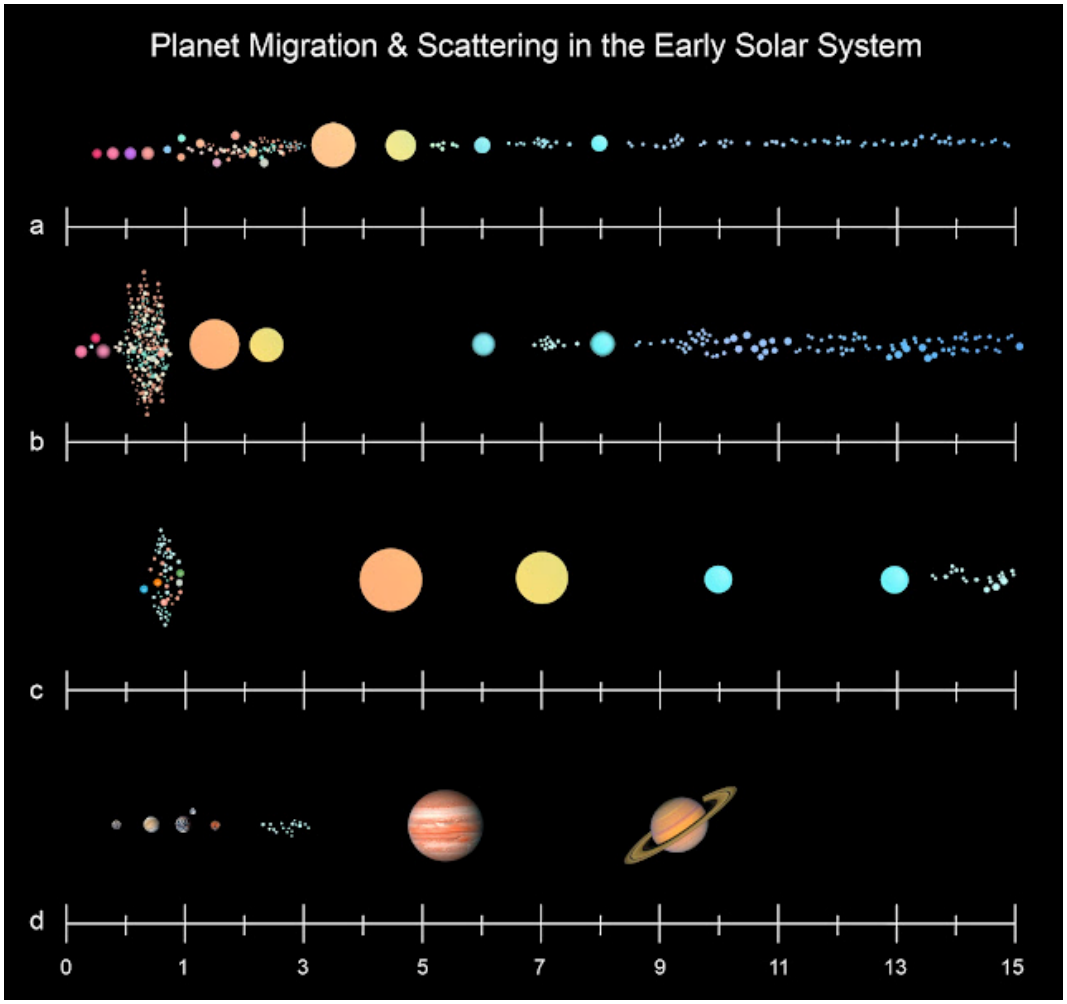




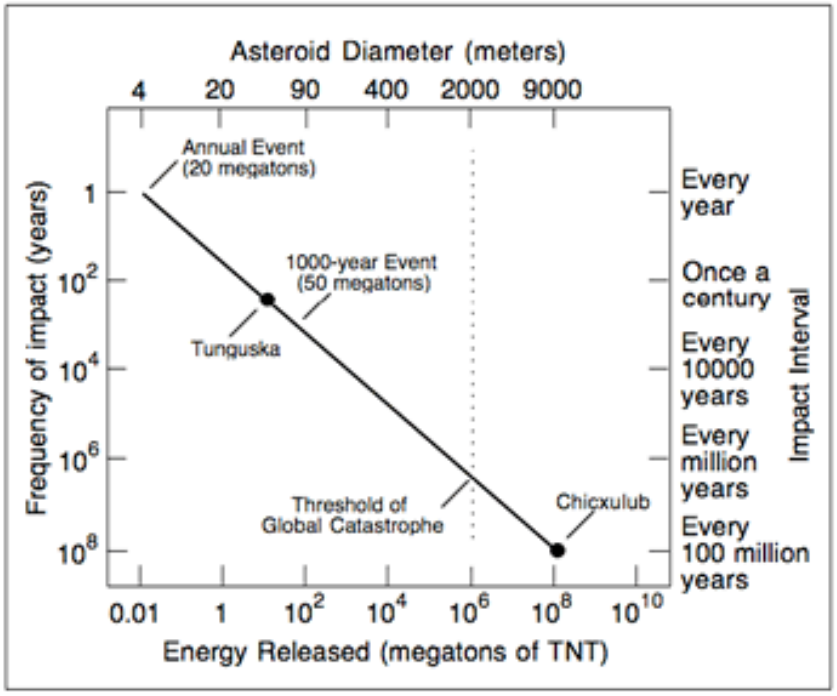
Laskar a kol., 2002, 2004

Málo impaktov





Súčasnosť

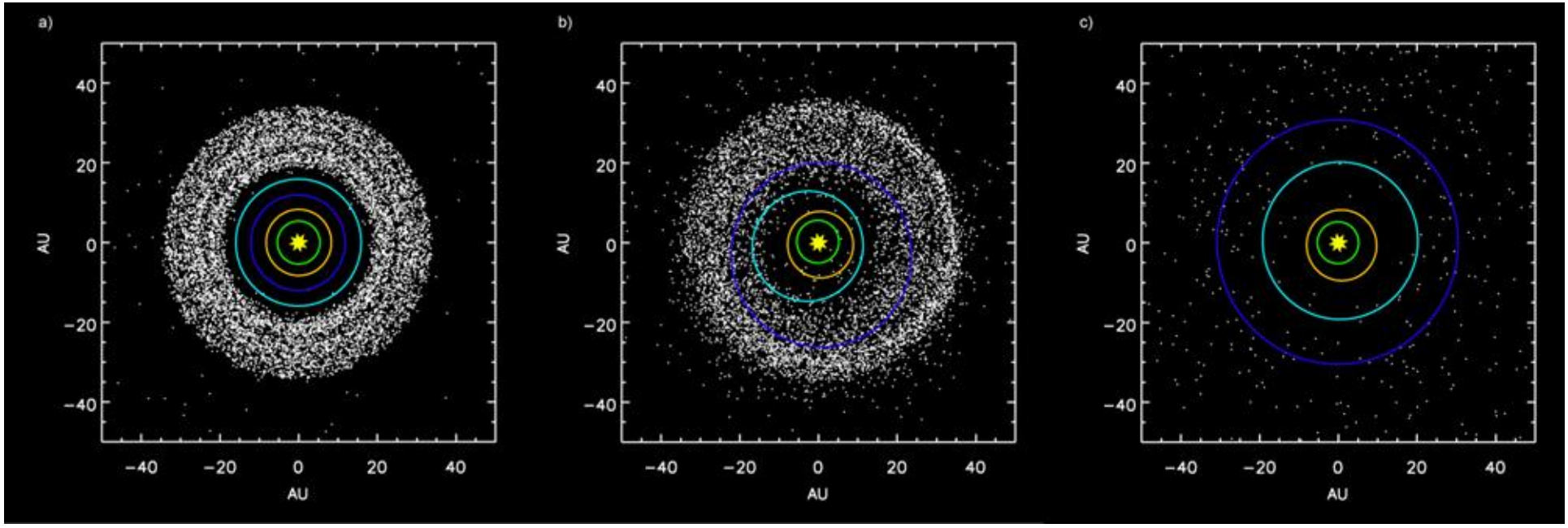


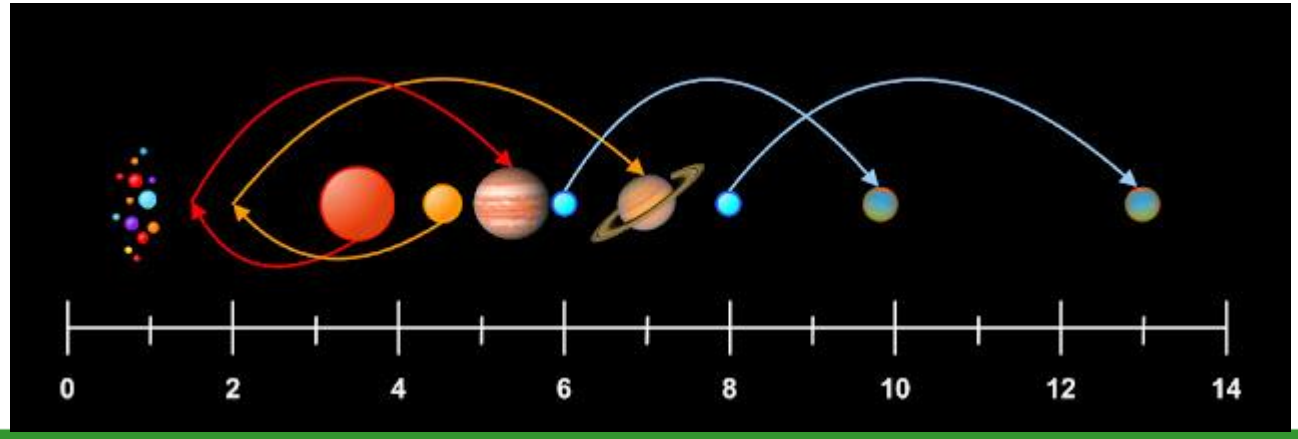
Batygin a Laughlin, 2015

Lynch, 2007 - https://geology.com/articles/near-earth-asteroids.shtml

Málo impaktov

Zmena pozícií planét („Grand Tack“ a „Grand Attack“)

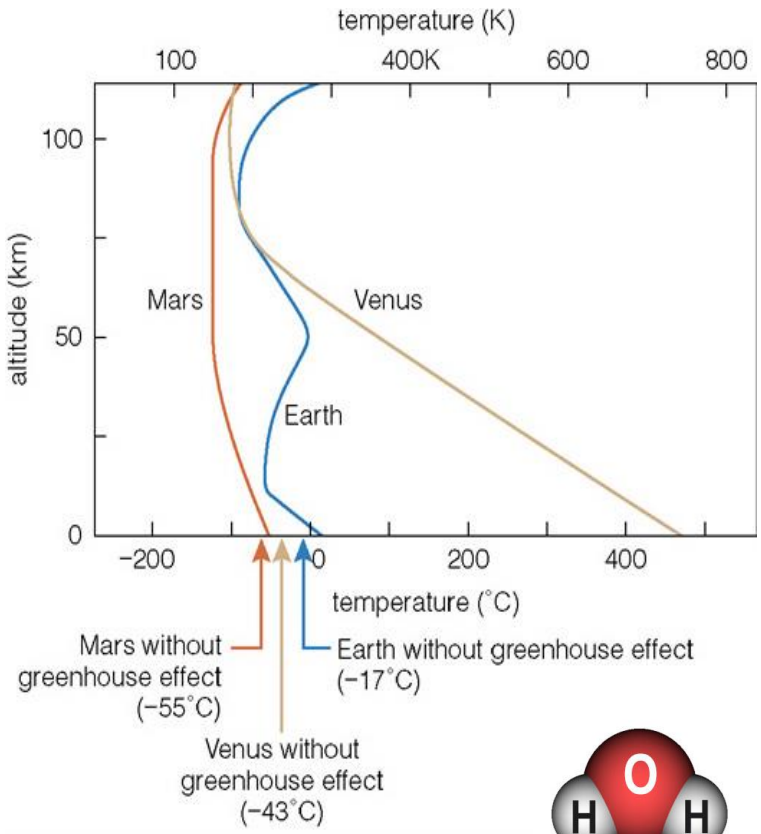


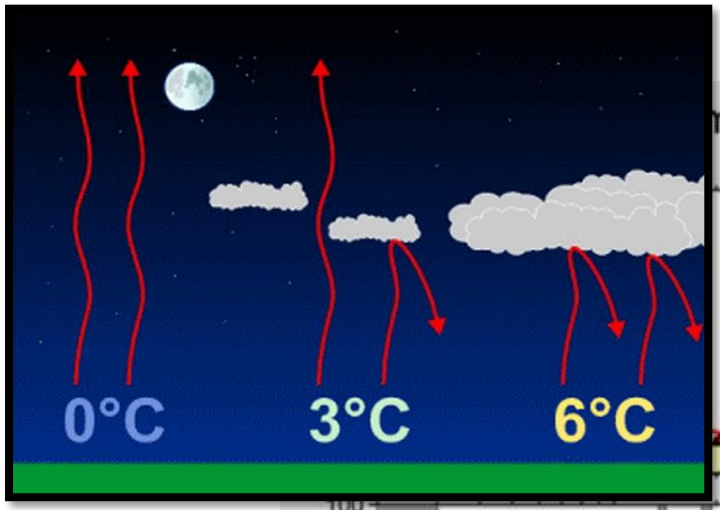


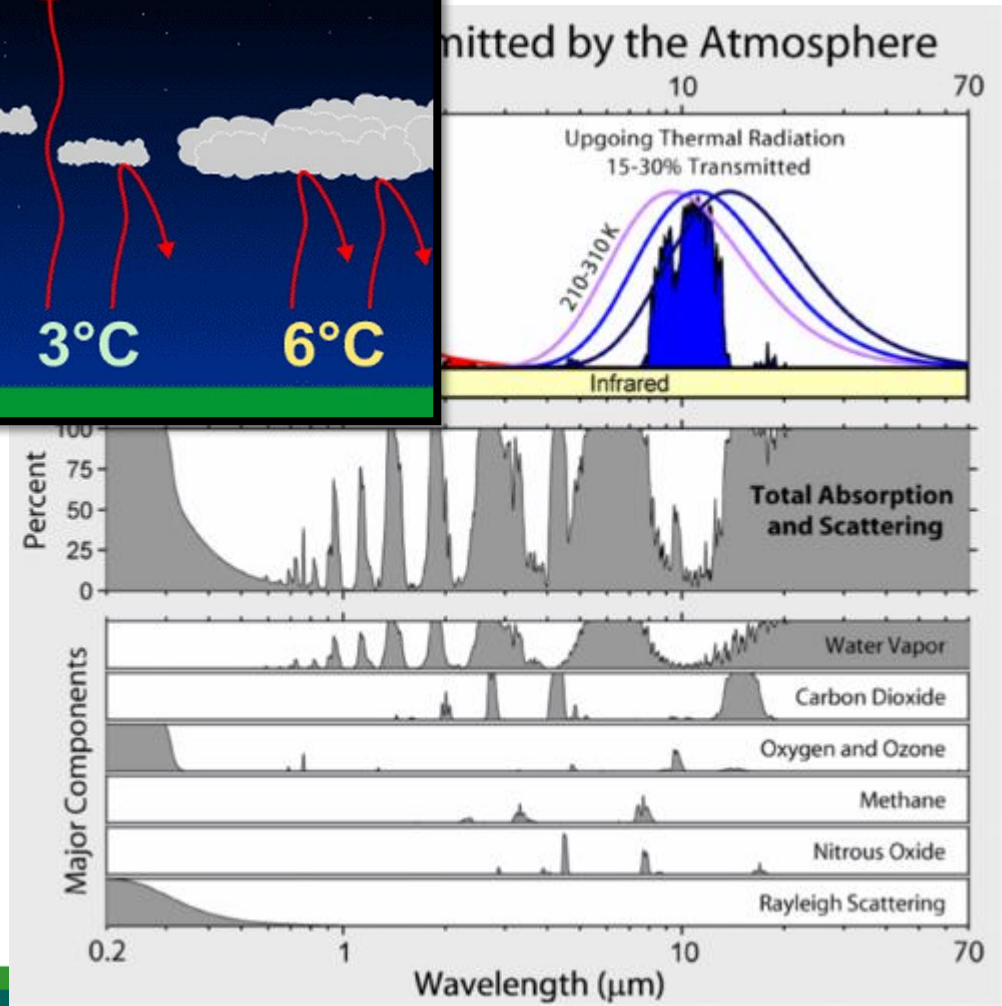
Batygin a Laughlin, 2015

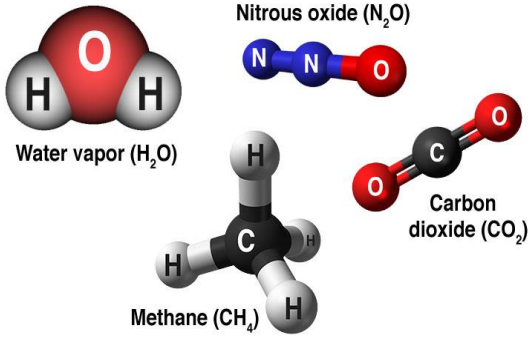
Atmosféra

Skleníkový efekt? Pre správnu teplotu, nie príliš vysoký tlak



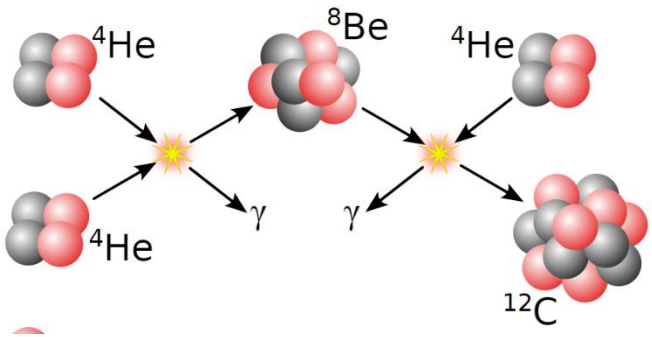






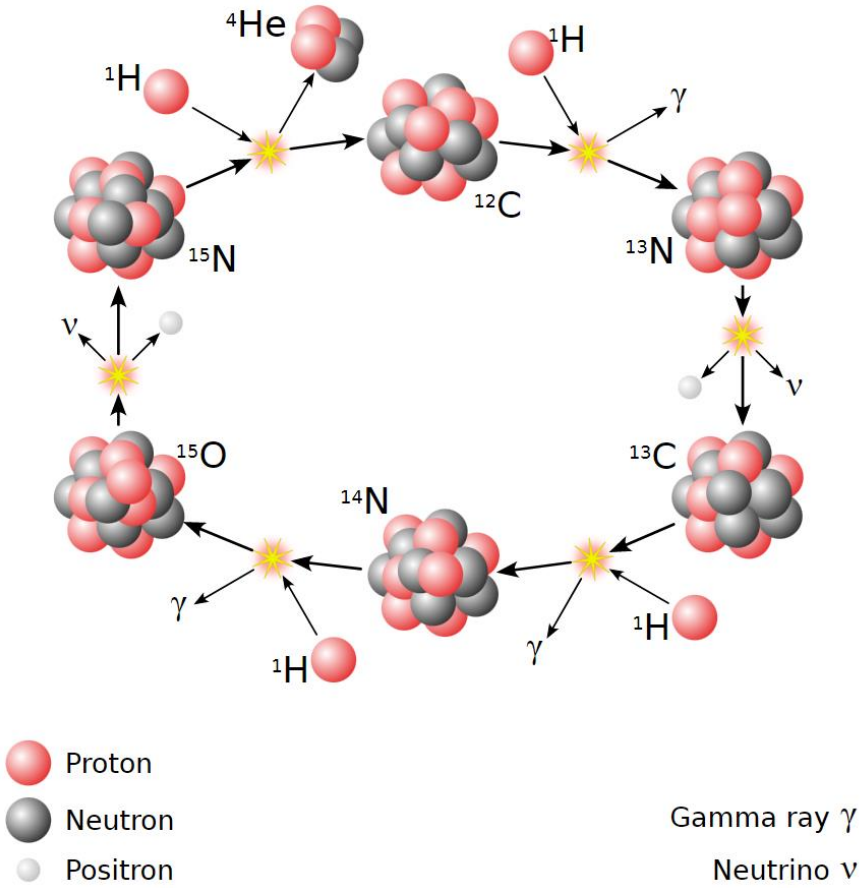
Dostatok uhlíka?

Dosť pre organické molekuly, málo pre nezastaviteľný CO_2 skleníkový efekt



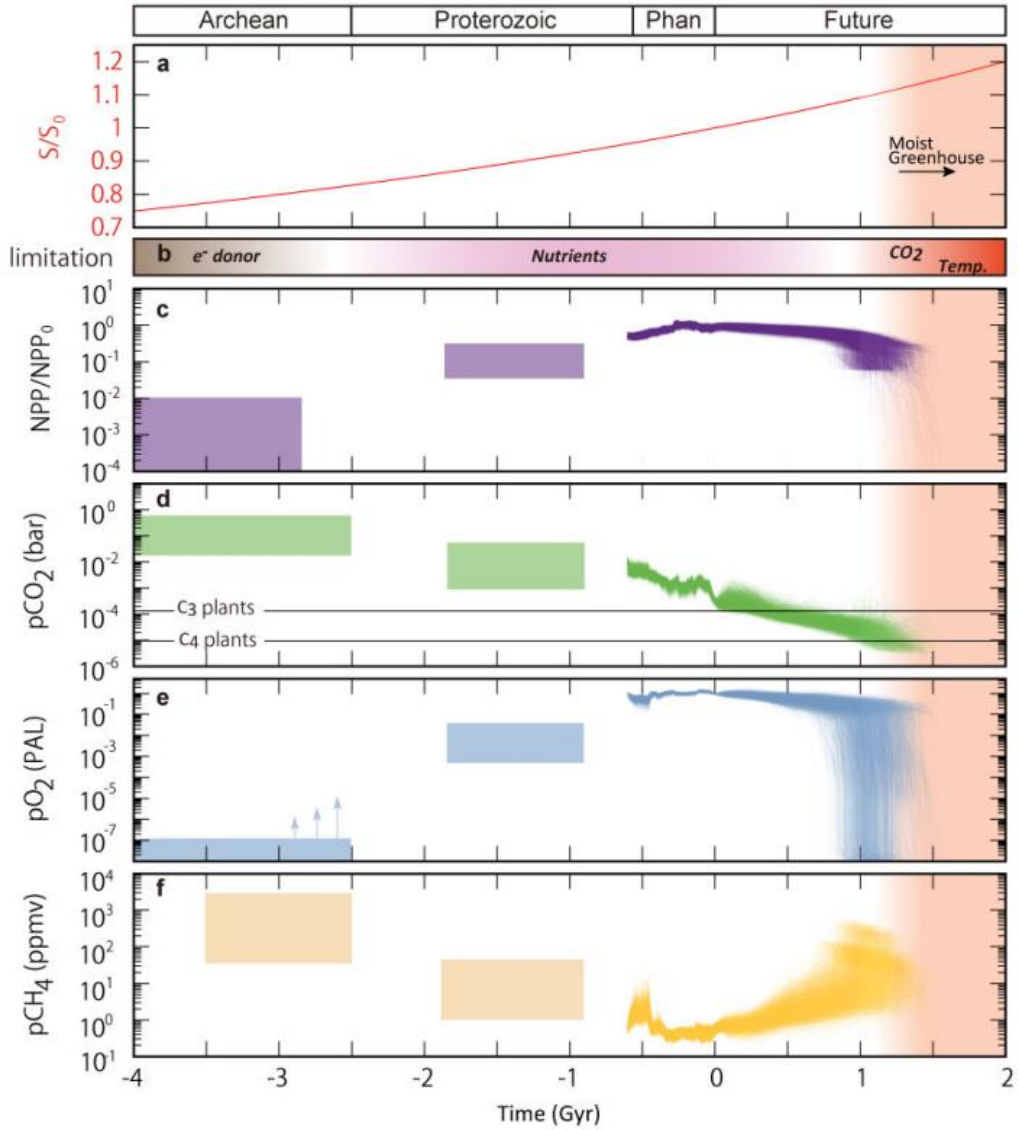
	Protosolar[1]	Earth[2]	Halley[3]	CI-CM[4]
H	71.54	3.0×10^{-2}	6.0	1.2
He	27.03			1.5×10^{-6}
C	0.25	5.2×10^{-2}	18	3.65
N	7.3×10^{-2}	1.7×10^{-4}	0.8	0.15

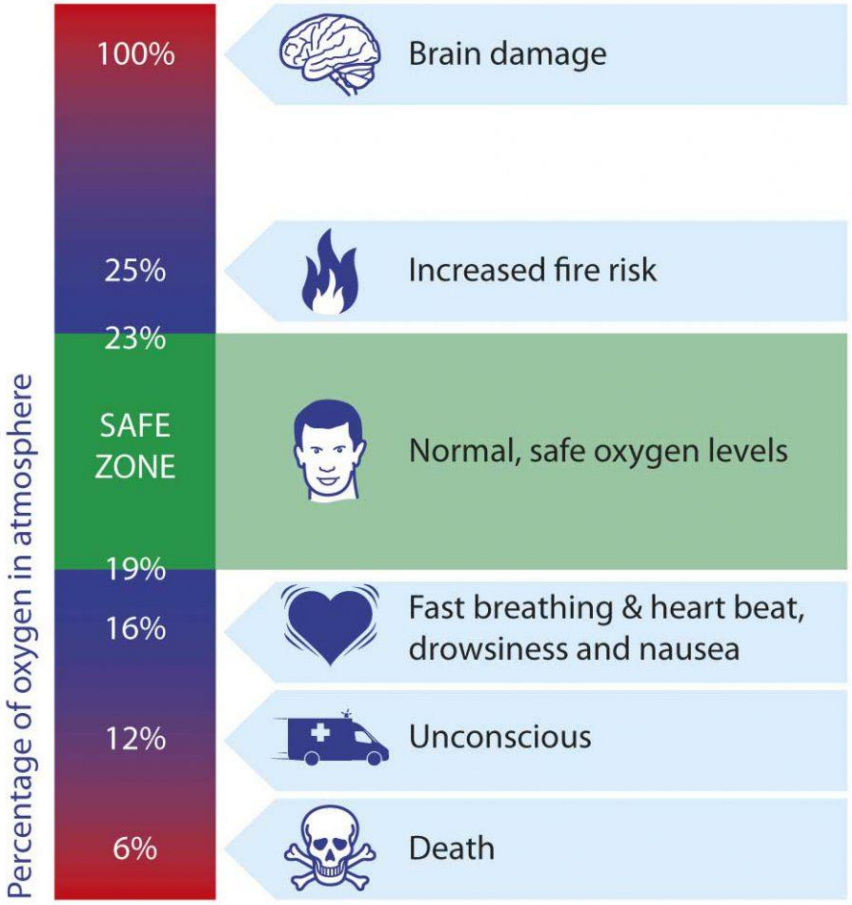
[1] Asplund et al. (2009). [2] Marty (2012). [3] Delsemme (1991) and assuming that the organics has a composition like Halley CHON particles (Kissel and Krueger 1987). [4] Alexander et al. (2012) and Marty (2012) for noble gases; averages of two carbonaceous chondrites, Murchison (CM) and Orgueil (CI).



Správne množstvo kyslíka

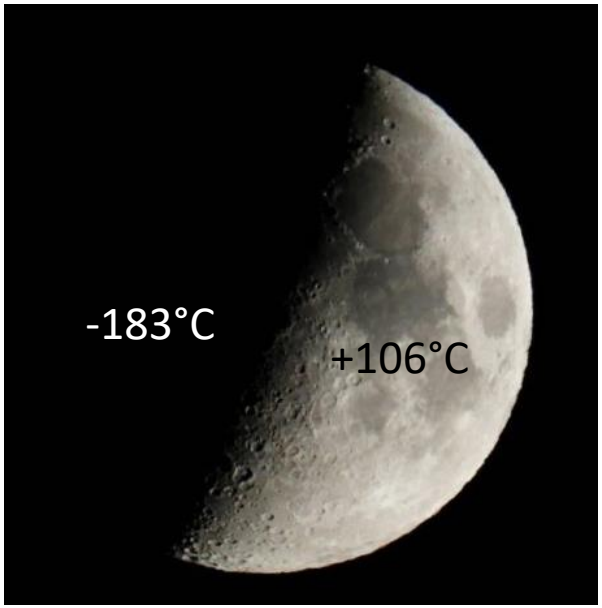
Evolúcia sekundárnej atmosféry, nie príliš veľa – požiare...



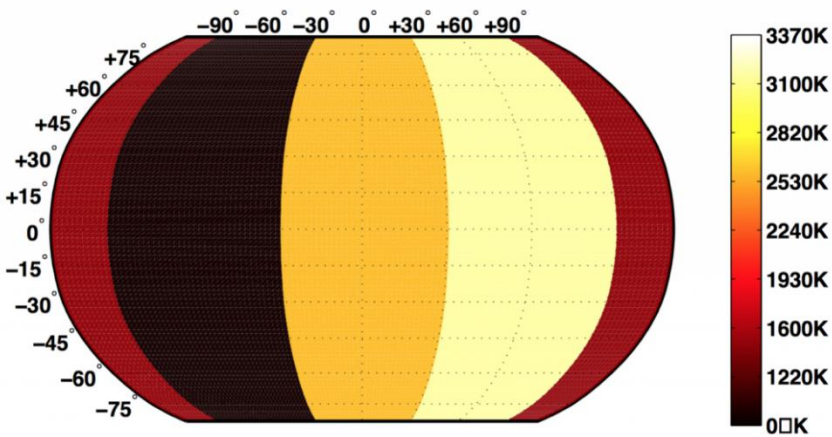


Ozaki a Reinhard, 2021

Teplota na povrchu



$$T_{eff} = \sqrt[4]{\frac{L_*(1-A)}{16\pi\sigma a^2}}$$

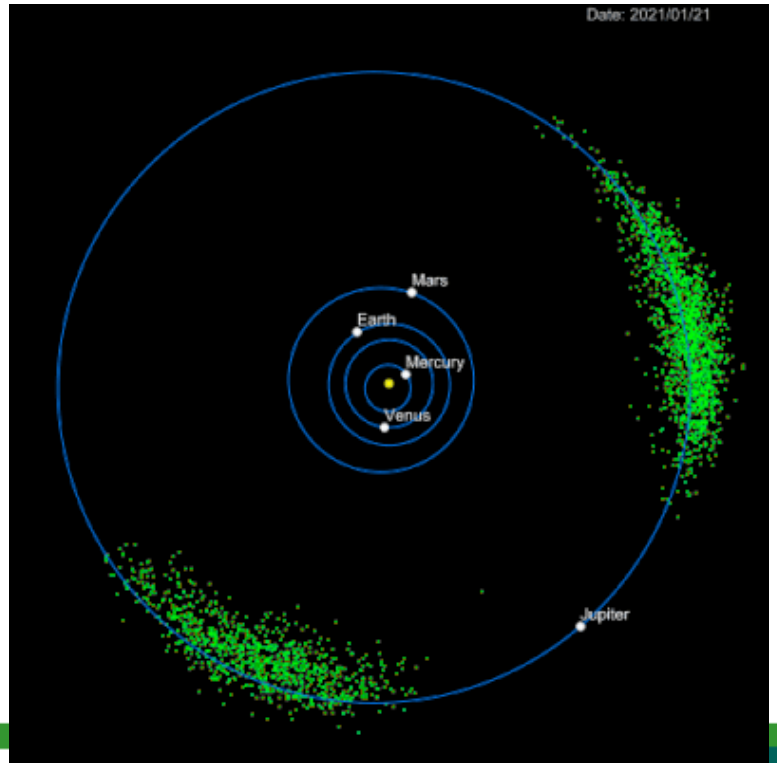


Teleso	T_{eff}	T_{mean}
Venuša (a = 0,3)	+66˚C	+464˚C
Venuša (a = 0,76)	-14˚C	+464˚C
Zem	-15˚C	+14˚C
Jupiter	-151˚C	-108˚C
HD 209458 b	+857˚C	+1900˚C
55 Cancri Ae	+1674˚C	+2436˚C

ČO NÁM HOVORÍ ASTRONÓMIA, CHÉMIA, BIOLÓGIA?

Exoplanéty

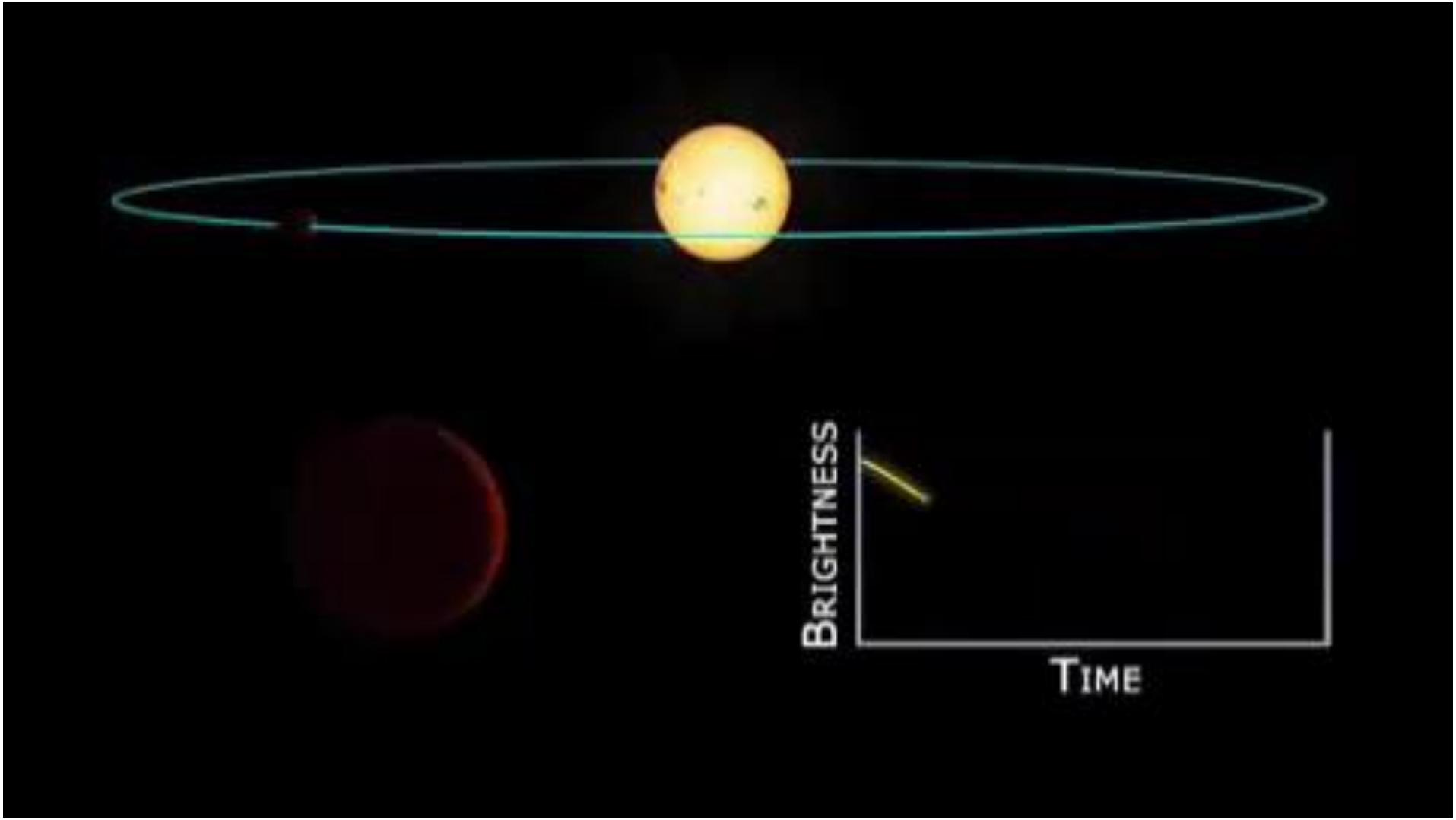
- Oficiálna definícia IAU pre planéty sa týka LEN Slnečnej sústavy
- Objekt so skutočnou hmotnosťou < limitná hmotnosť pre termojadrovú fúziu deutéria (v súčasnosti asi 13 hmotností Jupitera), ktorá obieha hviezdu, hnedého trpaslíka alebo záverečné štádiá hviezd, ktoré majú pomer hmotností s centrálnym telesom menší, ako nestabilita L4/L5: $M_P/M_C < 2/\left(25+\sqrt{621}\right) \cong 0{,}04$ bez ohľadu na to, ako vznikla.



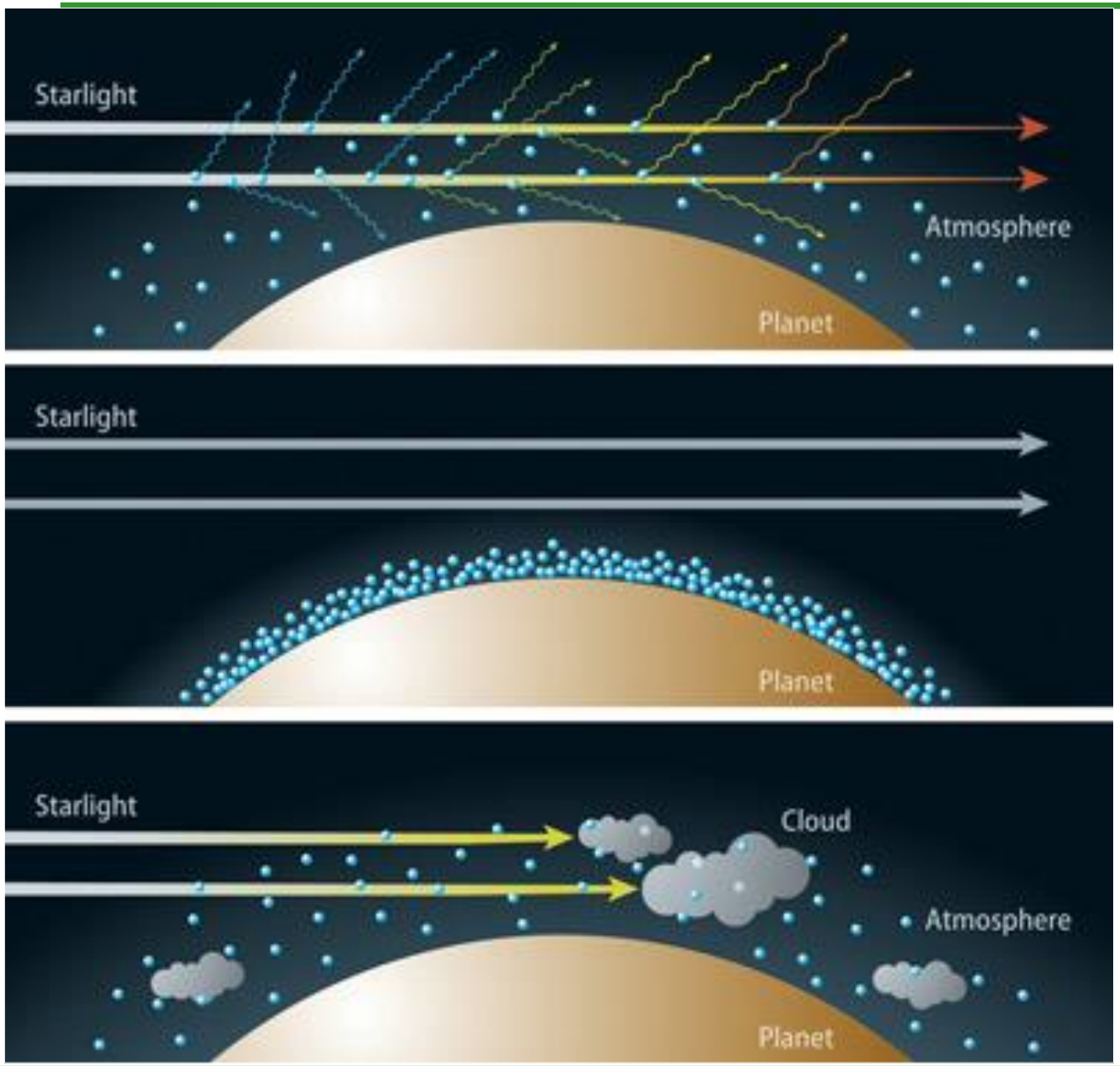
Minimálna hmotnosť/polomer by mala byť rovnaká, ako pre planéty v Slnečnej sústave (dosiahnutá hydrostatická rovnováha: $\frac{\partial p}{\partial z} + \rho g = 0$)

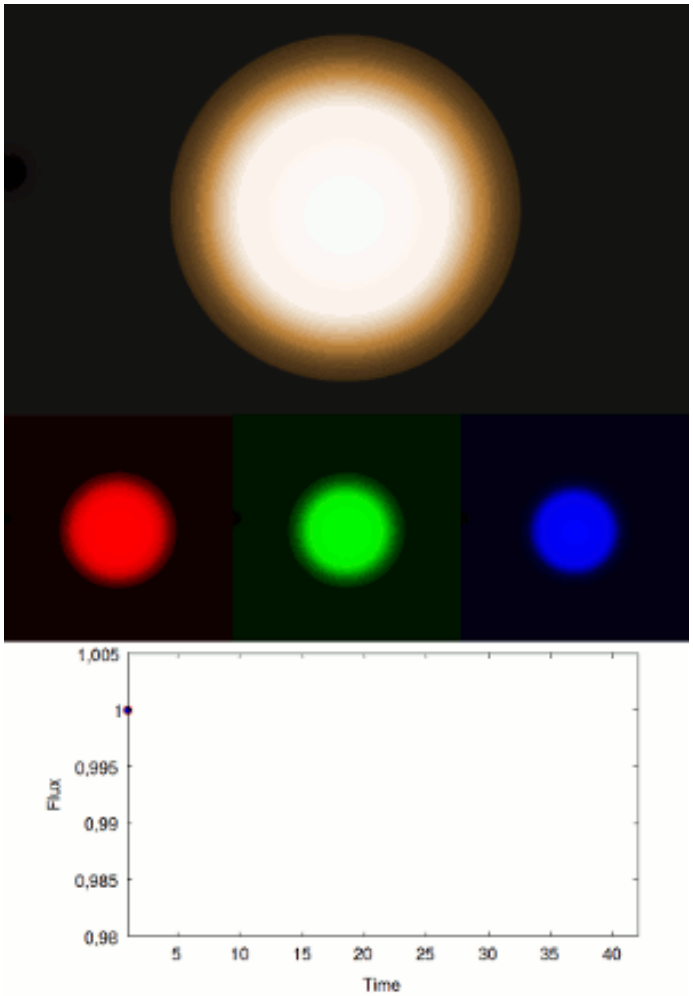
Stav exoplanét	(k 30.11.2022)
Potvrdených (z toho sústav)	5211 (3898)
Kandidátov (z toho sústav)	9116 (4000+)

Tranzity

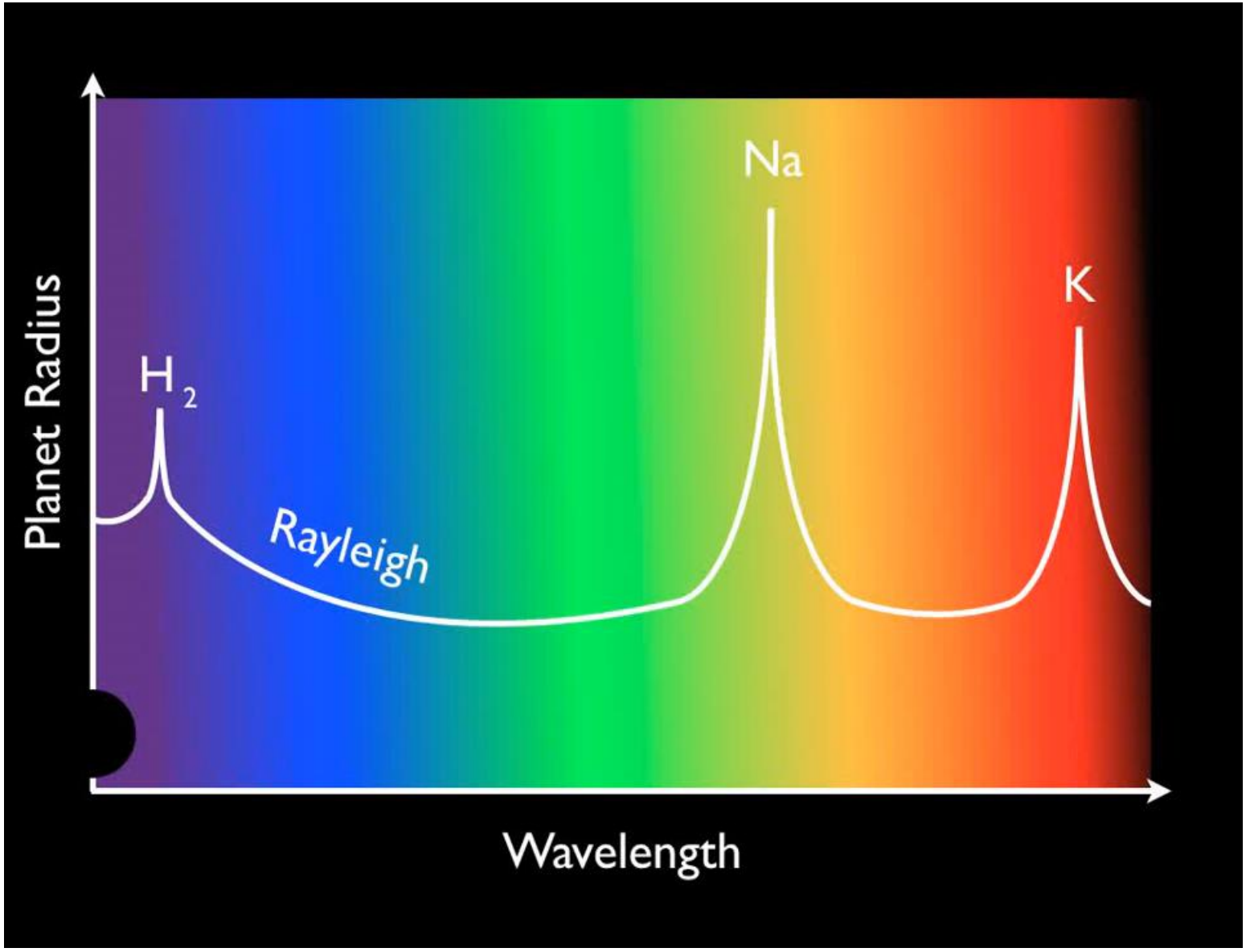


Atmosféry exoplanét

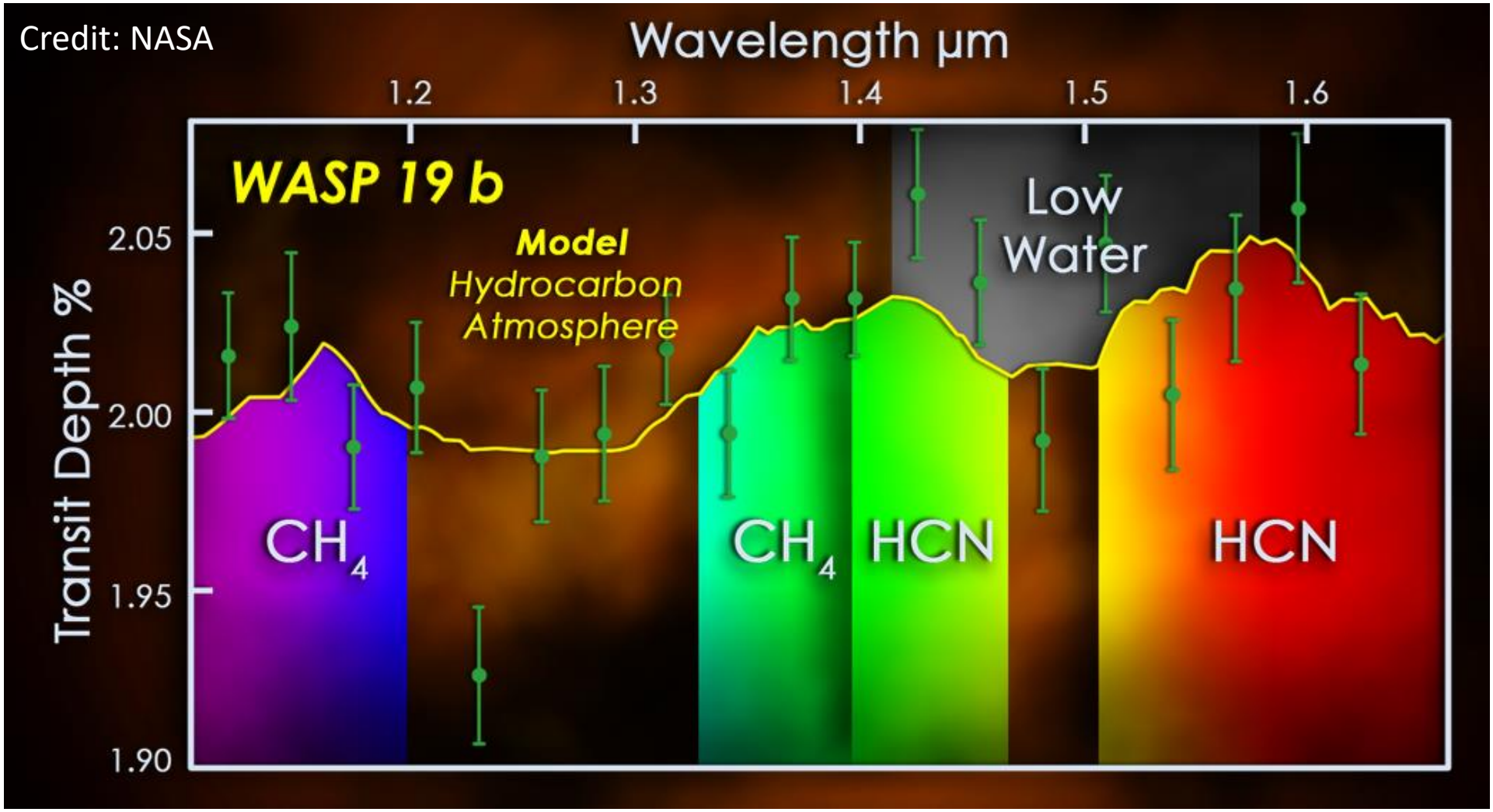




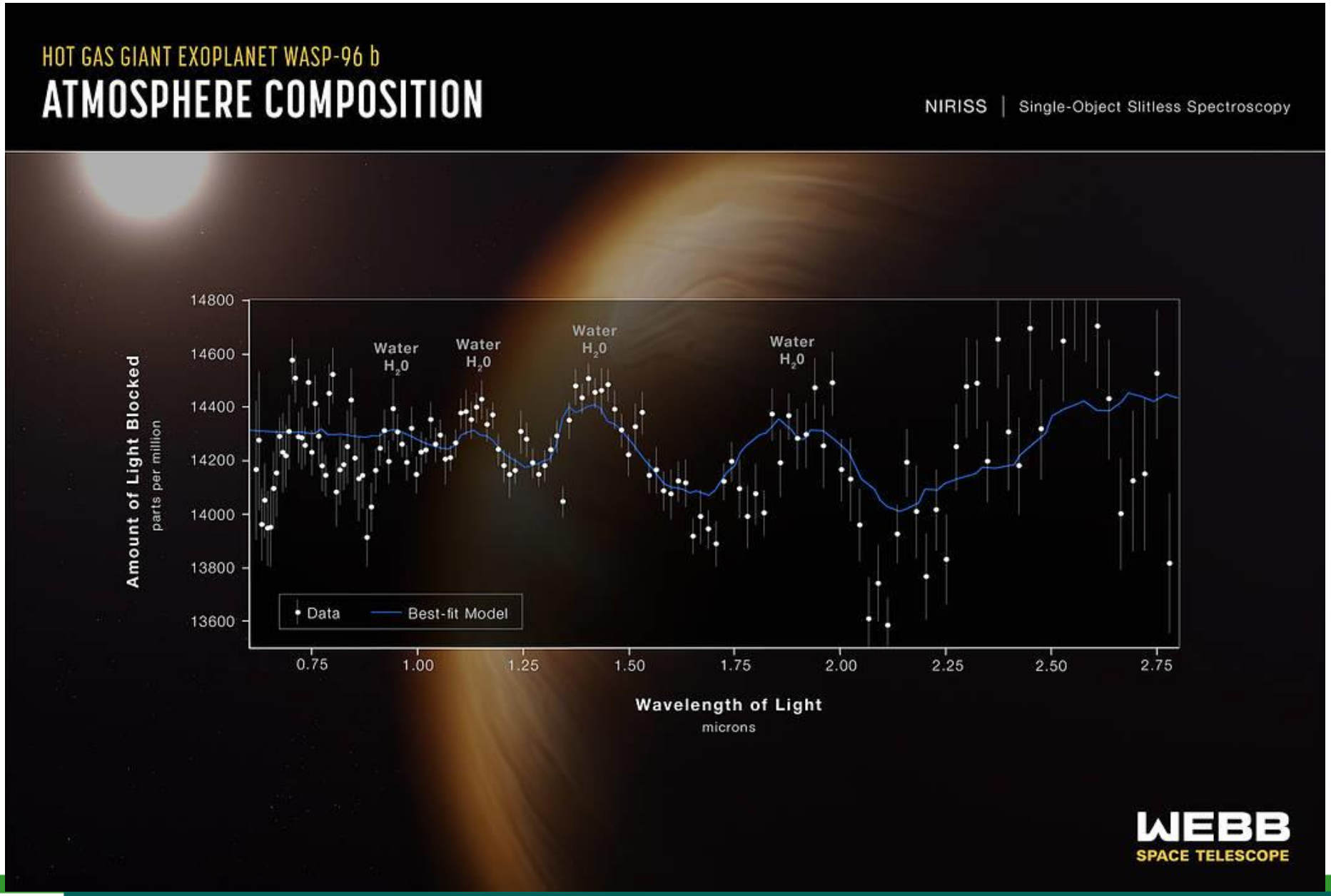
Atmosféry exoplanét



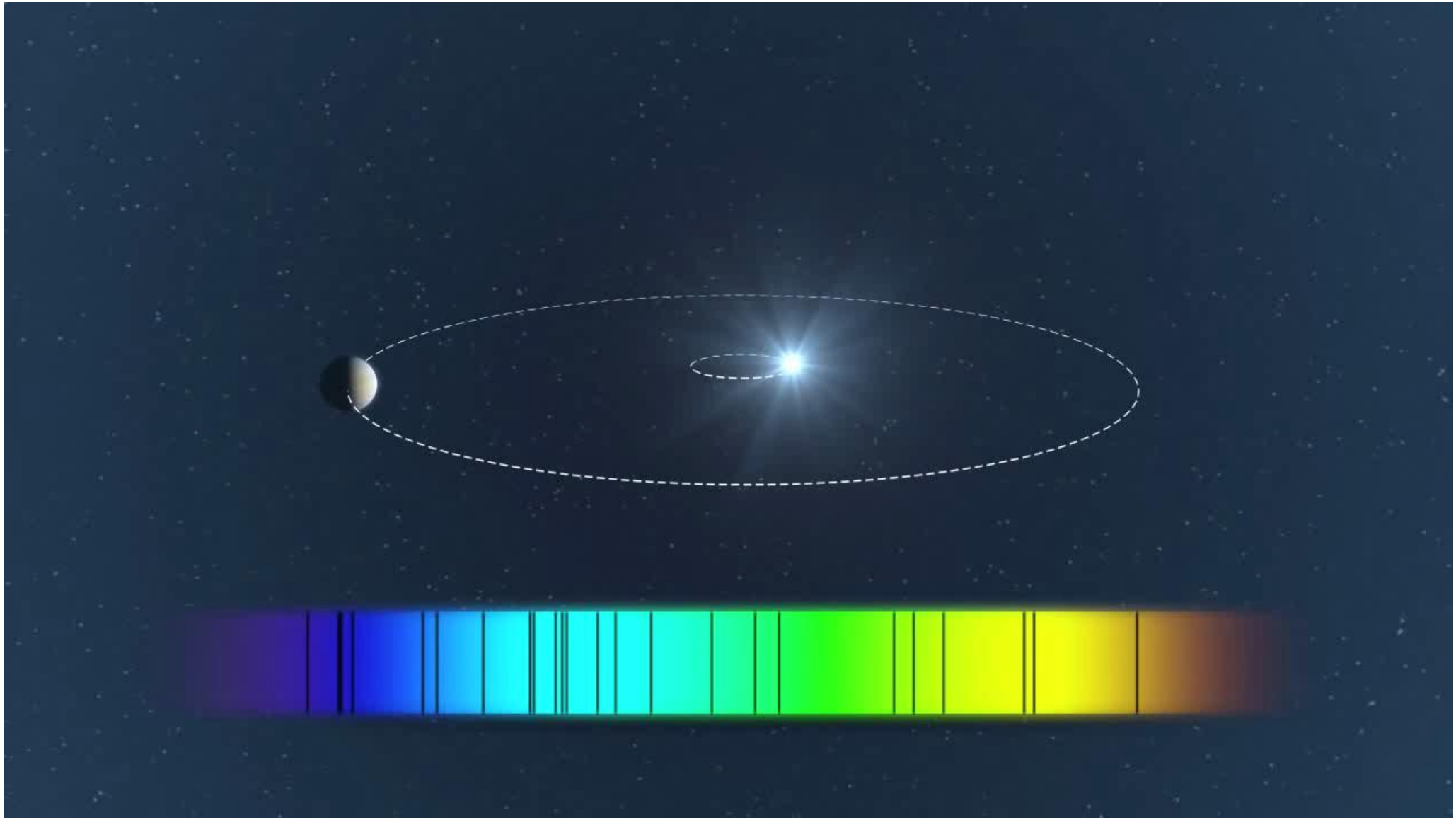
Atmosféry exoplanét



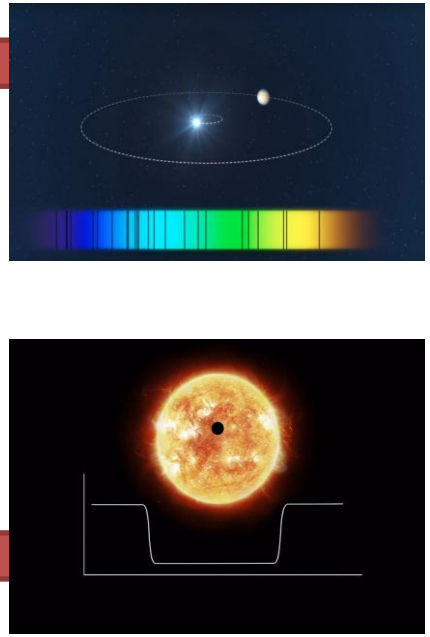
Atmosféry exoplanét



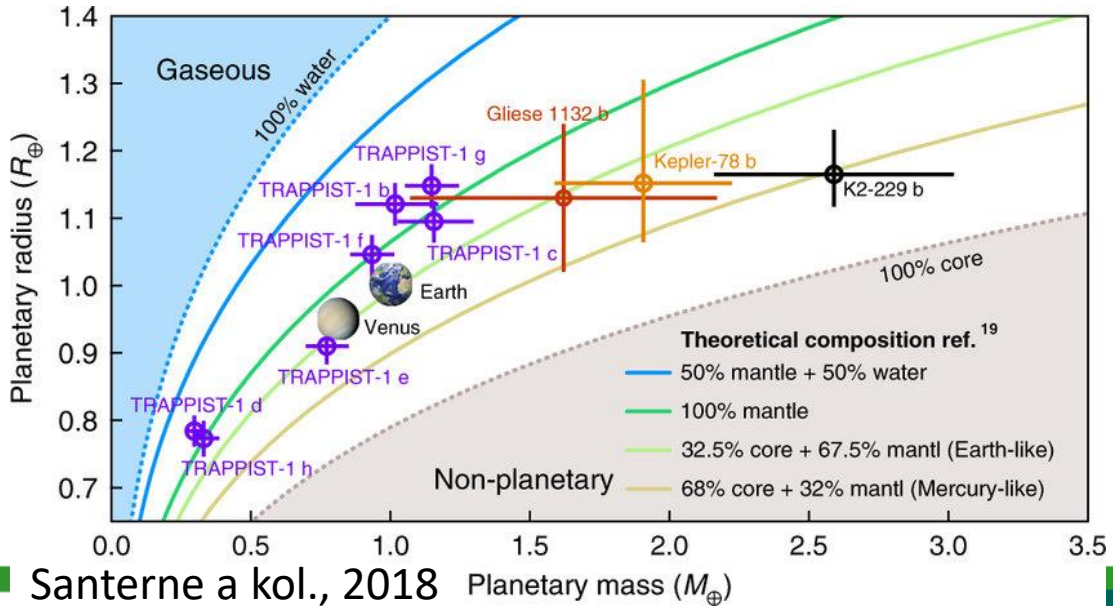
Rýchlosti



Má to pevný povrch?



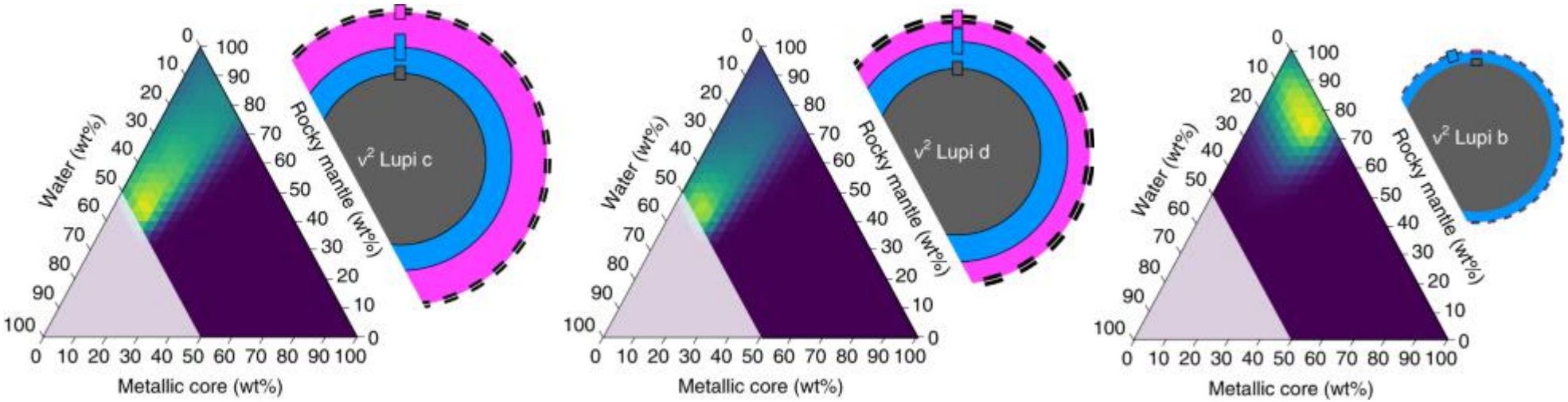
$$\rho \approx \frac{M}{V(R)}$$

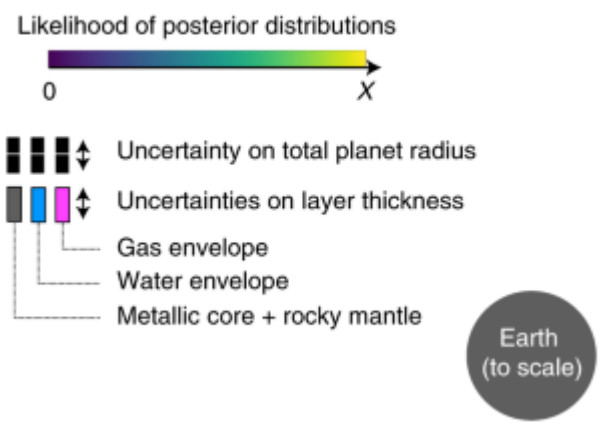


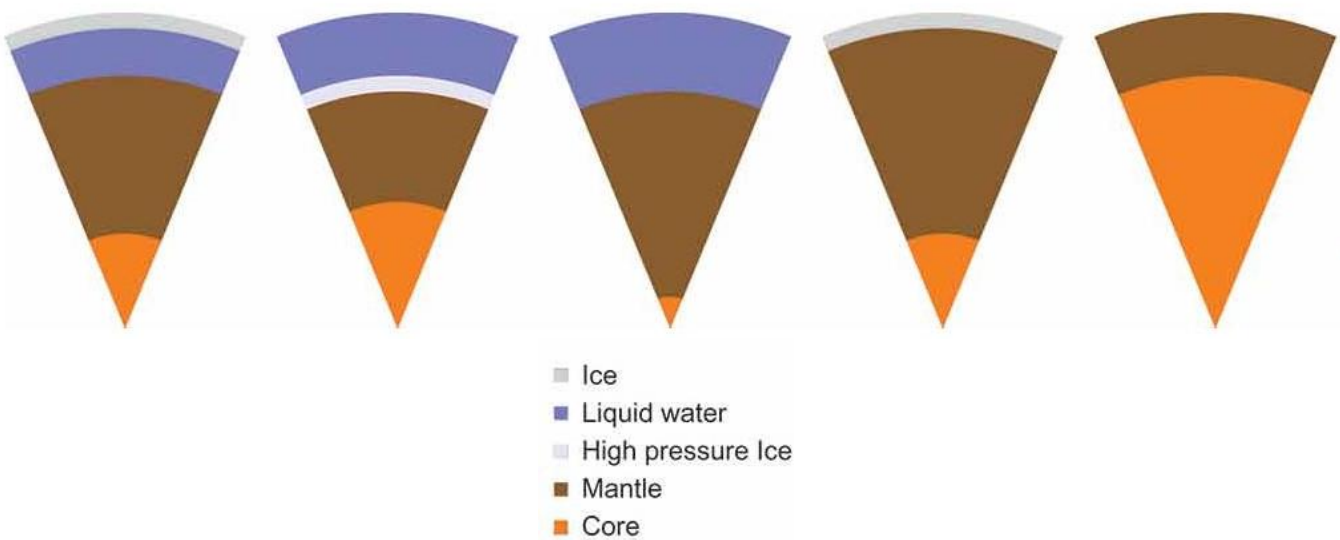
Santerne a kol., 2018

Teleso	ρ (g/cm^3)	R (R_E)	M (M_E)
Merkúr	5,427	0,383	0,055
Venuša	5,243	0,950	0,815
Zem	5,514	1	1
Mesiac	3,344	0,273	0,012
Mars	3,934	0,533	0,107
Ceres	2,161	0,074	0,000 2
Ganymedes	1,936	0,413	0,025
Titan	1,880	0,404	0,023
Triton	2,061	0,212	0,003 6
Pluto	1,860	0,187	0,002
Cháron	1,707	0,095	0,002
Jupiter	1,326	10,5	317,8
Saturn	0,687	8,55	95,16
Neptún	1,638	3,8	17,15

Tranzity… modely vnútra

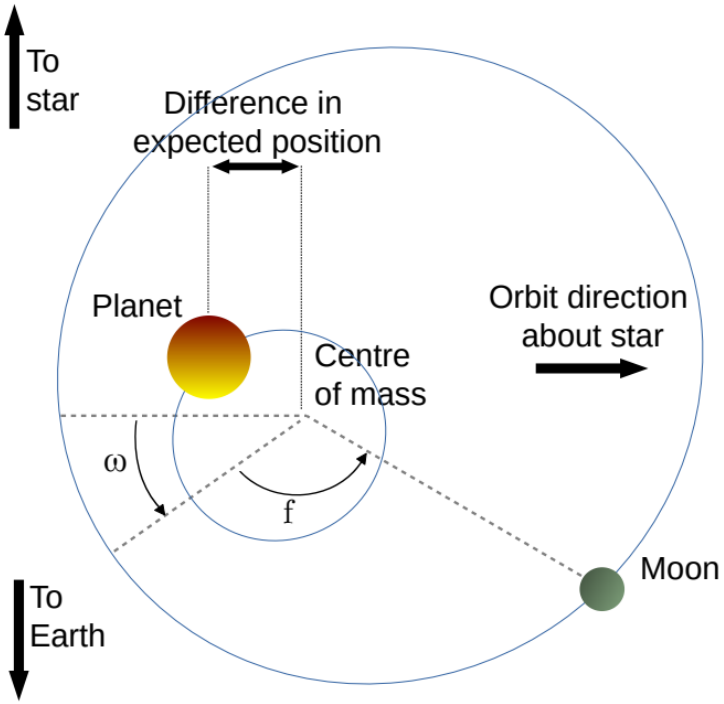






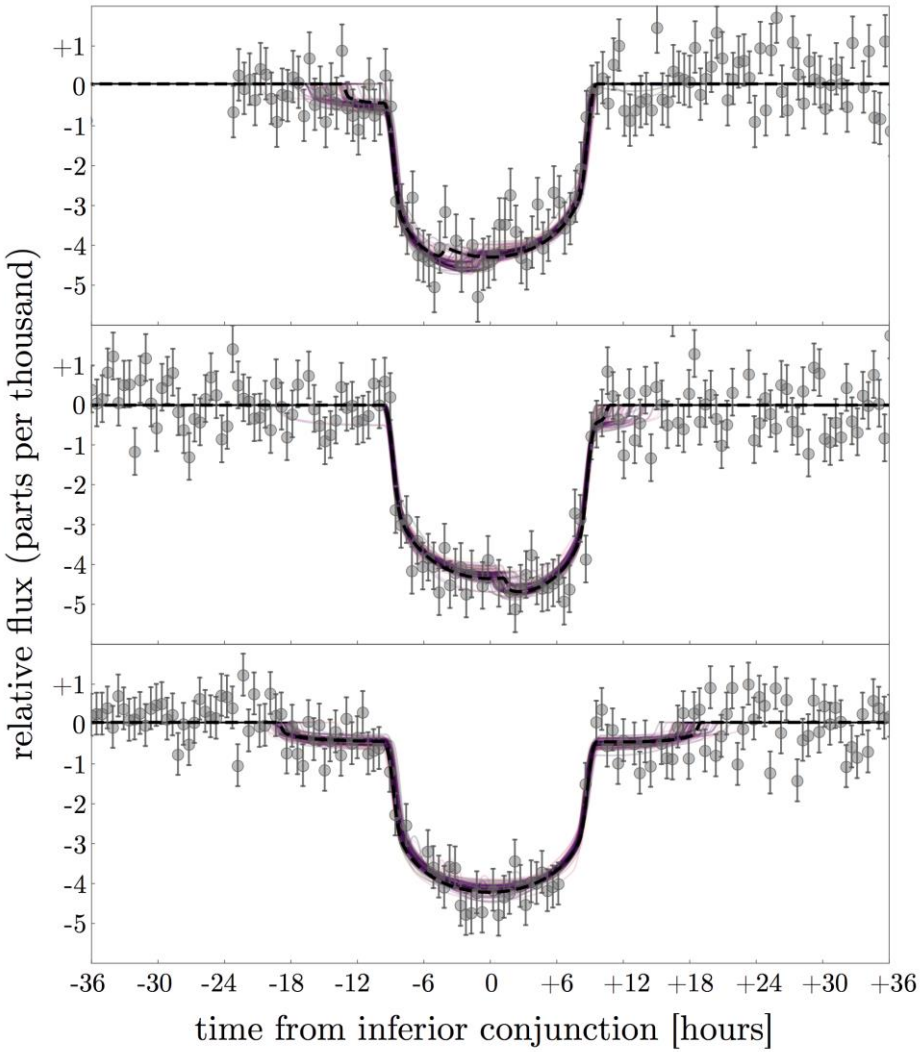
Delrezová a kol., 2021

Tranzity… exomesiacov?



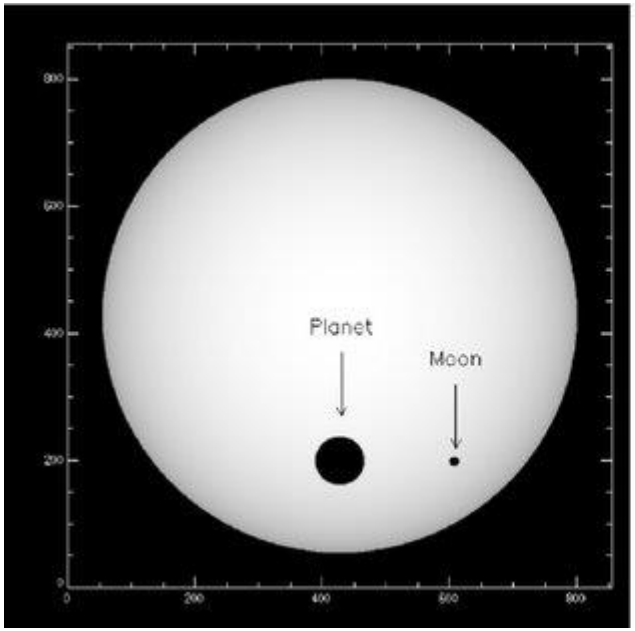
Fox a Wiegert, 2006

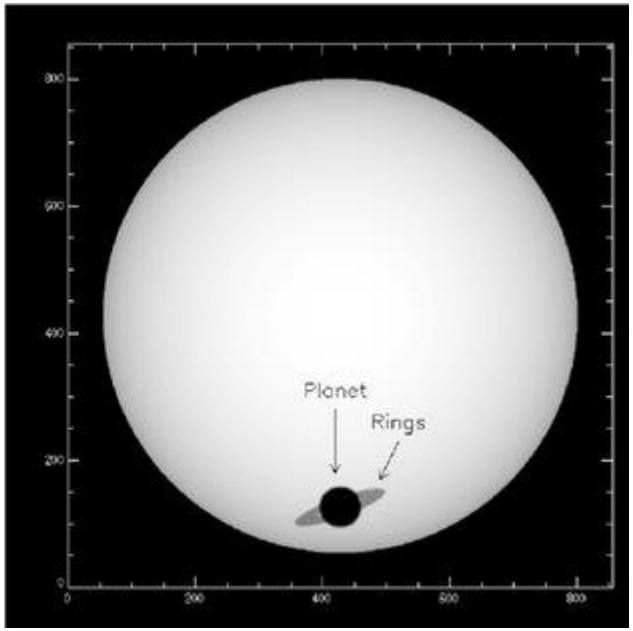
$$TTV = \left(\frac{P_p}{2\pi G M_*}\right)^{1/3} \frac{M_m a_{pm}}{M_p + M_m} \frac{(1-e^2)}{1+e\cos(f)} \sin\left(\omega + f - \frac{\pi}{2}\right)$$



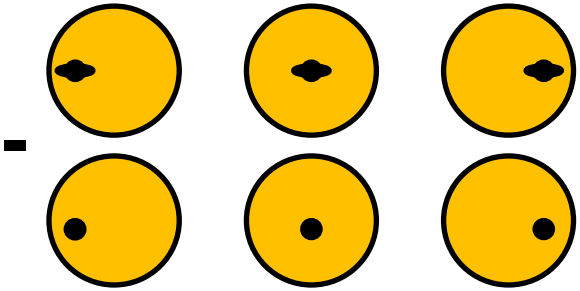
Kepler-1625b I - Teachey a kol., 2017

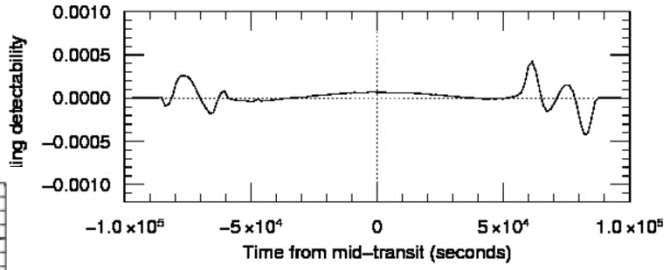
Tranzity… či exoplanét s prstencami?

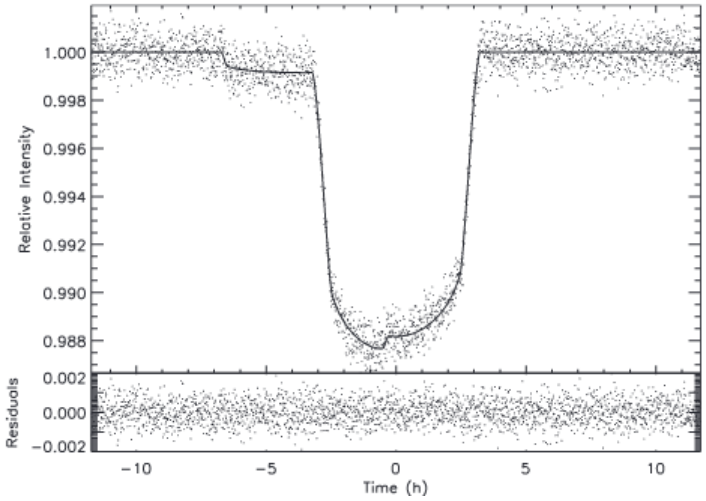


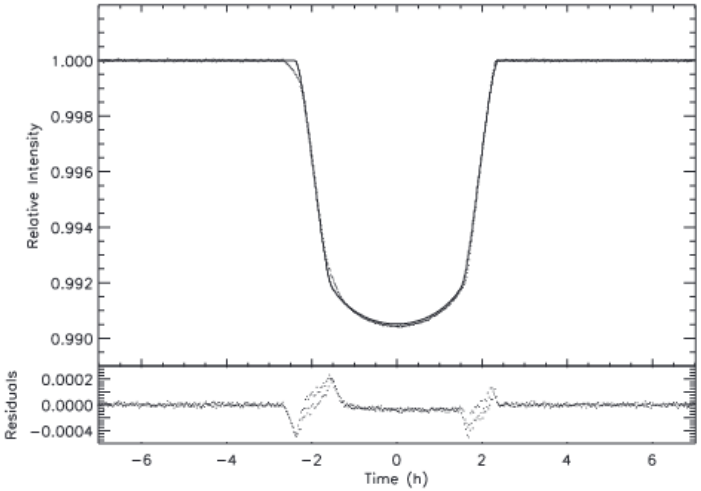


Tusnski a Valiová, 2011

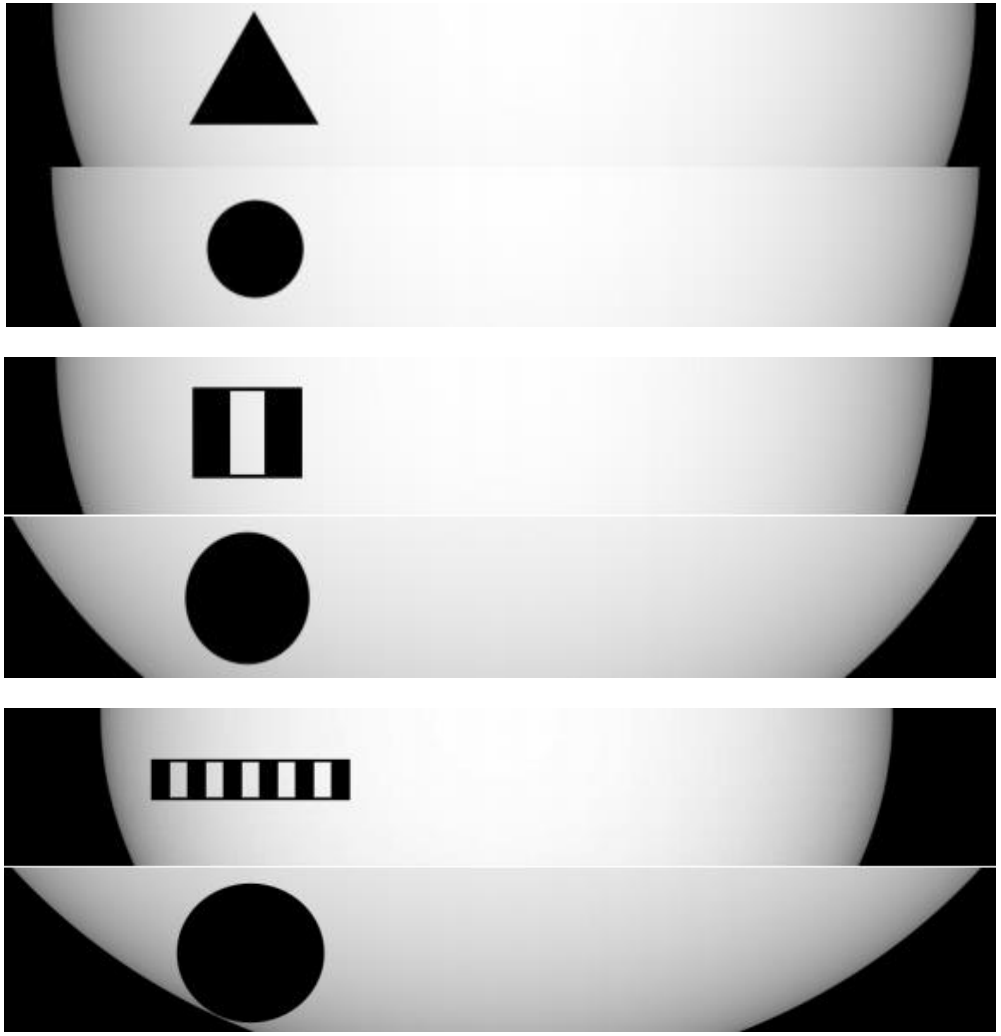






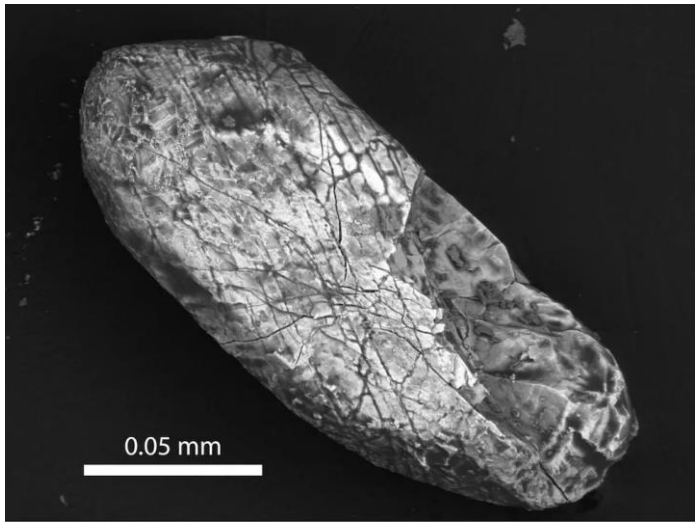


Tranzity… kozmických lodí?



Časový sled vzniku života na Zemi

13,787 Gya – vznik Vesmíru
13,463 Gya – najstaršie galaxie
8,8 (±1,7) Gya – vznik (disku) Galaxie
4,567 Gya – vznik Slnečnej sústavy
4,54 Gya - vznik Zeme
4,404 Gya – kryštály zirkónu (prvá voda)
4,1–3,8 Gya – neskoré veľké bombardovanie
4,2–3,7 Gya – abiogenéza?
3,8 Gya – LUCA?
3,5 Gya – mag. pole Zeme, prvý O_2
3,42 Gya – mikrofosílie stromatolitov
2,7 Gya – prvé eukarytoty
2,4 Gya – atmosférický O_2
2,3 Gya – ozónová vrstva
1,9 Gya – mnohobunkovce
~0,9 Gya – diferencované živočíchy
0,475 Gya – prechod rastlín na súš



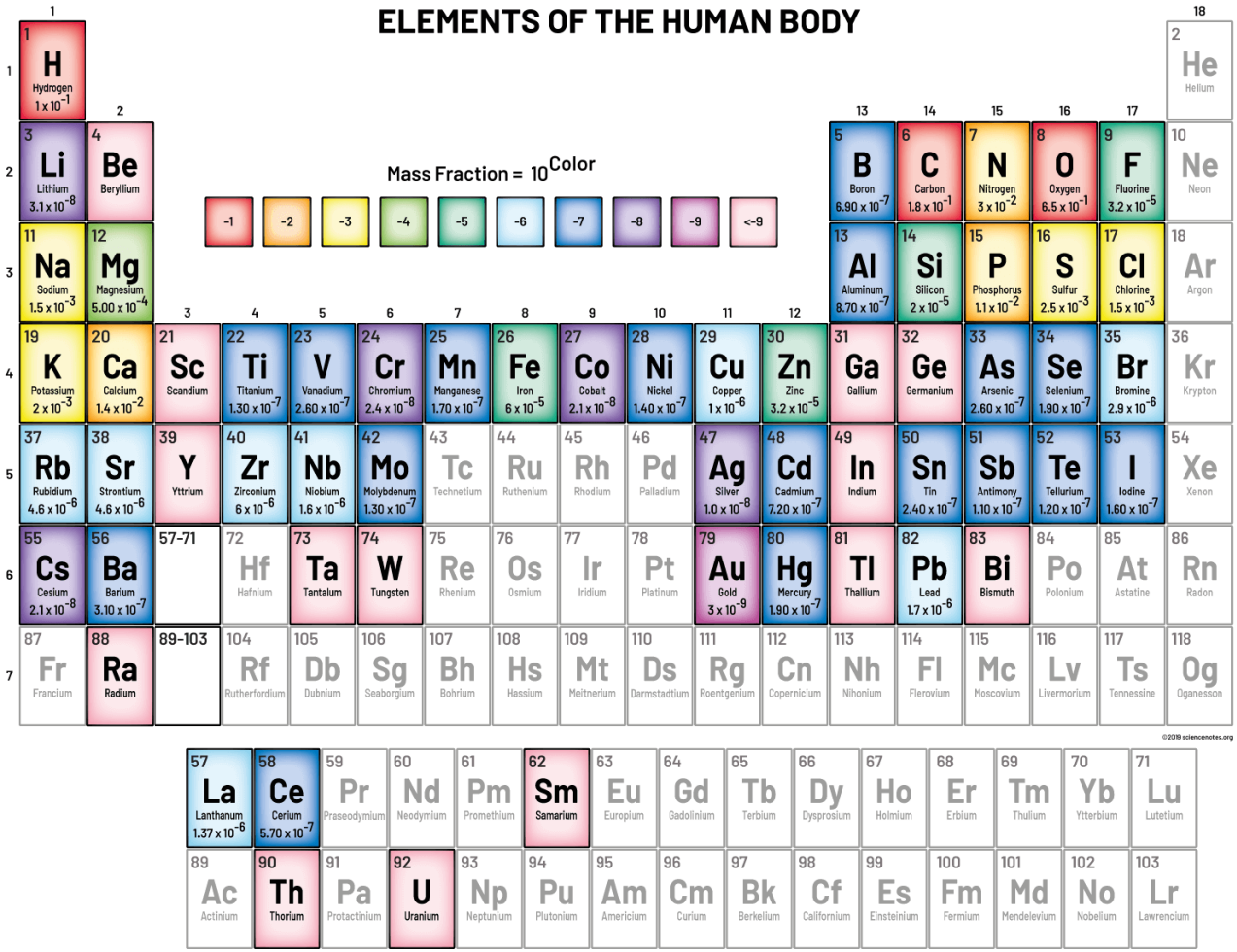
Kenny, 2016

Alternatívna biochémia?

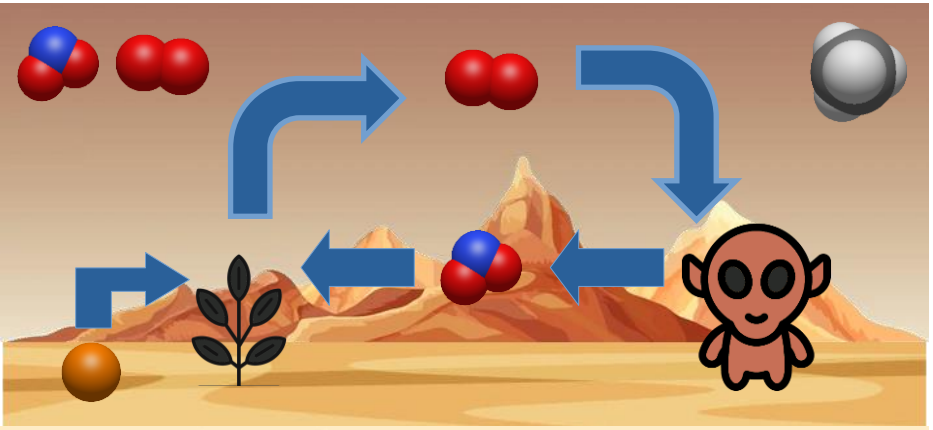
život na Zemi:

makromolekuly:
- proteíny,
- karbohydráty, lipidy,
- nukleové kyseliny
- zložené z O, C, H, N, Ca, P, S…

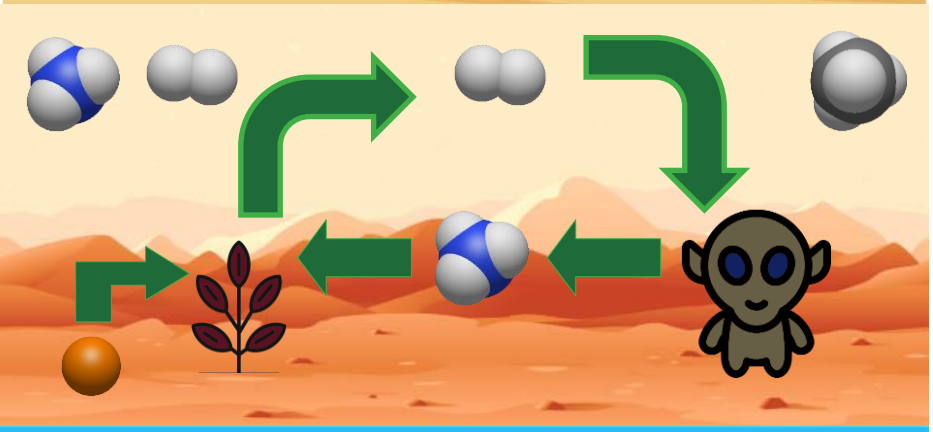
rozpúšťadlo: voda



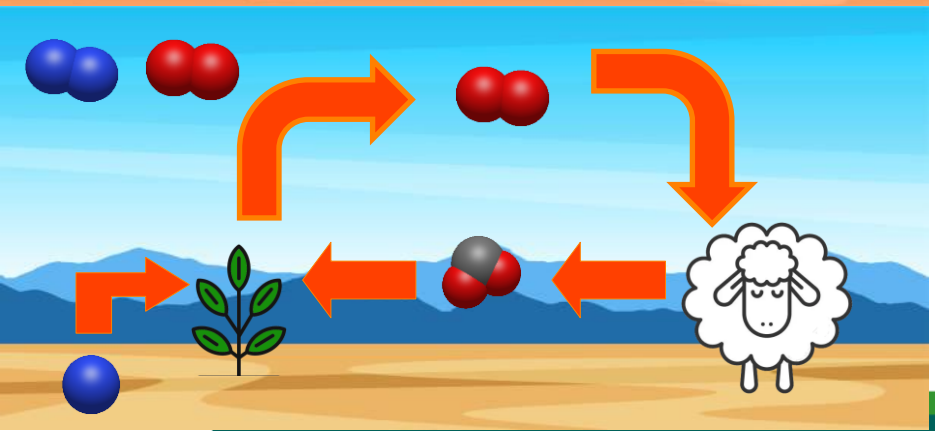
Alternatívna biochémia?



NO_2 atmosféra + P-N život:
rastliny: NO_2 z atmosféry, P z pôdy, O_2 do atmosféry
zvieratá: dýchajú O_2, vydychujú NO_2



NH_3 (redukčná) atmosféra + P-N život:
rastliny: NH_3 z atmosféry, P z pôdy, H_2 do atmosféry
zvieratá: dýchajú H_2, vydychujú NH_3



O_2 atmosféra + C-H život:
rastliny: CO_2 z atmosféry, N z pôdy, O_2 do atmosféry
zvieratá: dýchajú O_2, vydychujú CO_2

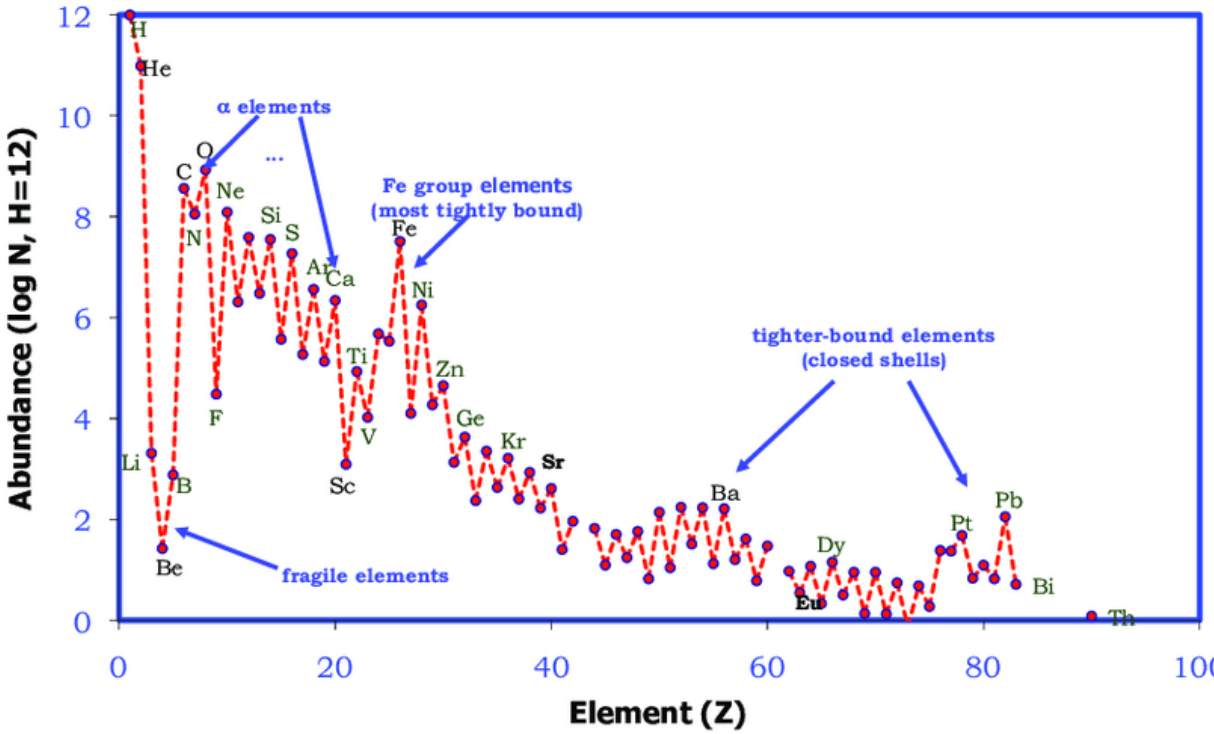
Alternatívna biochémia?

Makromolekuly	Rozpúšťadlá	Teplota pri 1 atm	Poznámky
fluorosilikóny	fluorosilikóny	400 – 500 ˚C	silány sú nestabilné, stabilizuje striedanie Si a O
fluorokarbóny	tekutá síra	113 – 445 ˚C	F nahrádza H v hydrokarbónoch, uvoľňuje O_2 do atm.
proteíny	voda	0 – 100 ˚C	odbúral sa CO_2 z primárnej atmosféry
proteíny	tekutý amoniak	-77,7 – -33,4 ˚C	CH_4, NH_3 v atmosfére? CH_4 by sa odbúraval.
poly-lipidy	tekutý metán	-183,6 – -161,6 ˚C	nepolárne rozpúšťadlo
poly-lipidy	tekutý vodík	-253 – -240˚C	nepolárne rozpúšťadlo

vesmír C : Si ~ 7 : 1

(detegované) medzihviezdne molekuly C : Si ~ 84 : 8

vesmír C : P ~ 700 : 1



Alternatívna biochémia?

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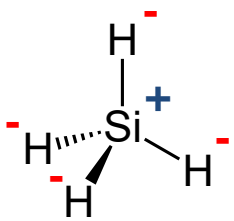

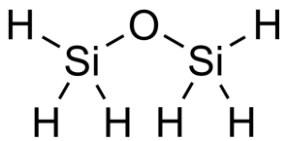

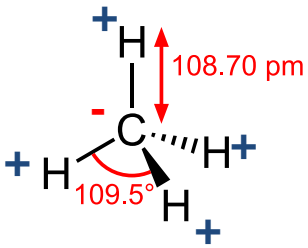

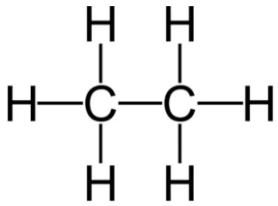

Prvky	Väzba (kJ/mol)
C-C	330
C-O	360
C-H	390
Si-Si	**222**
Si-O	452
Si-H	384
H-H	432

Alternatívna biochémia?

Makromolekuly	Rozpúšťadlá	Teplota pri 1 atm	Poznámky
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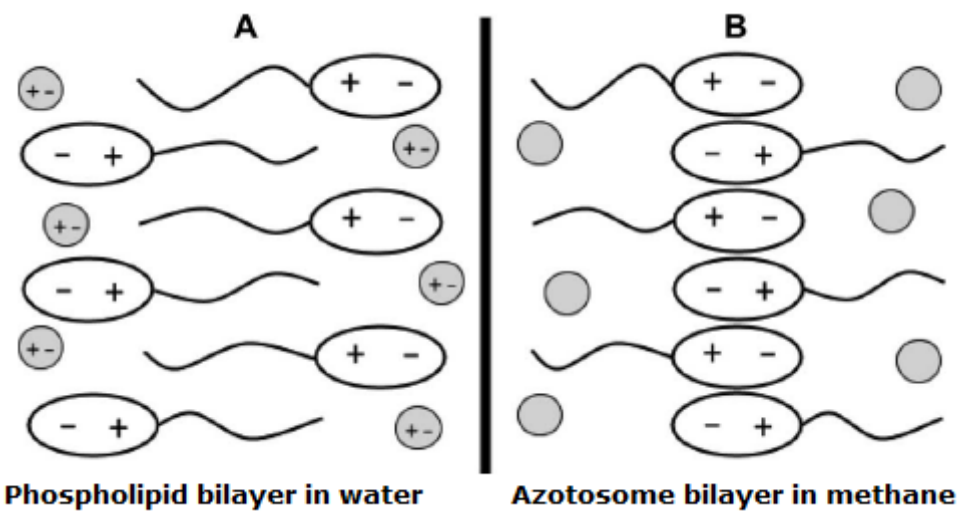
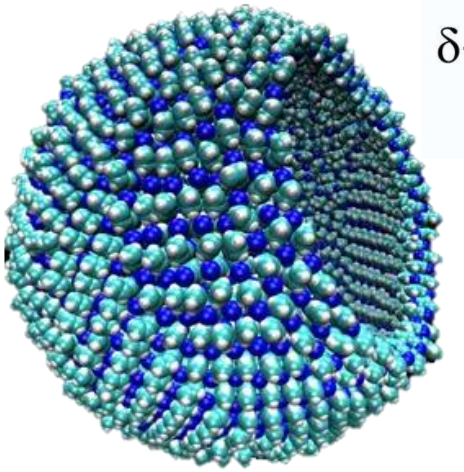
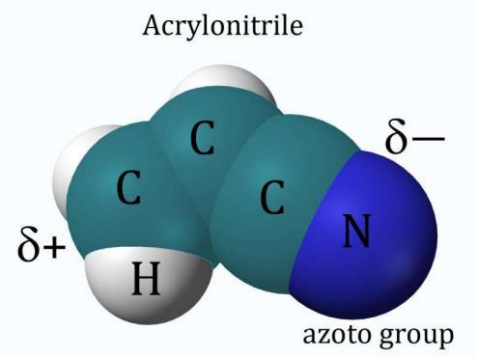
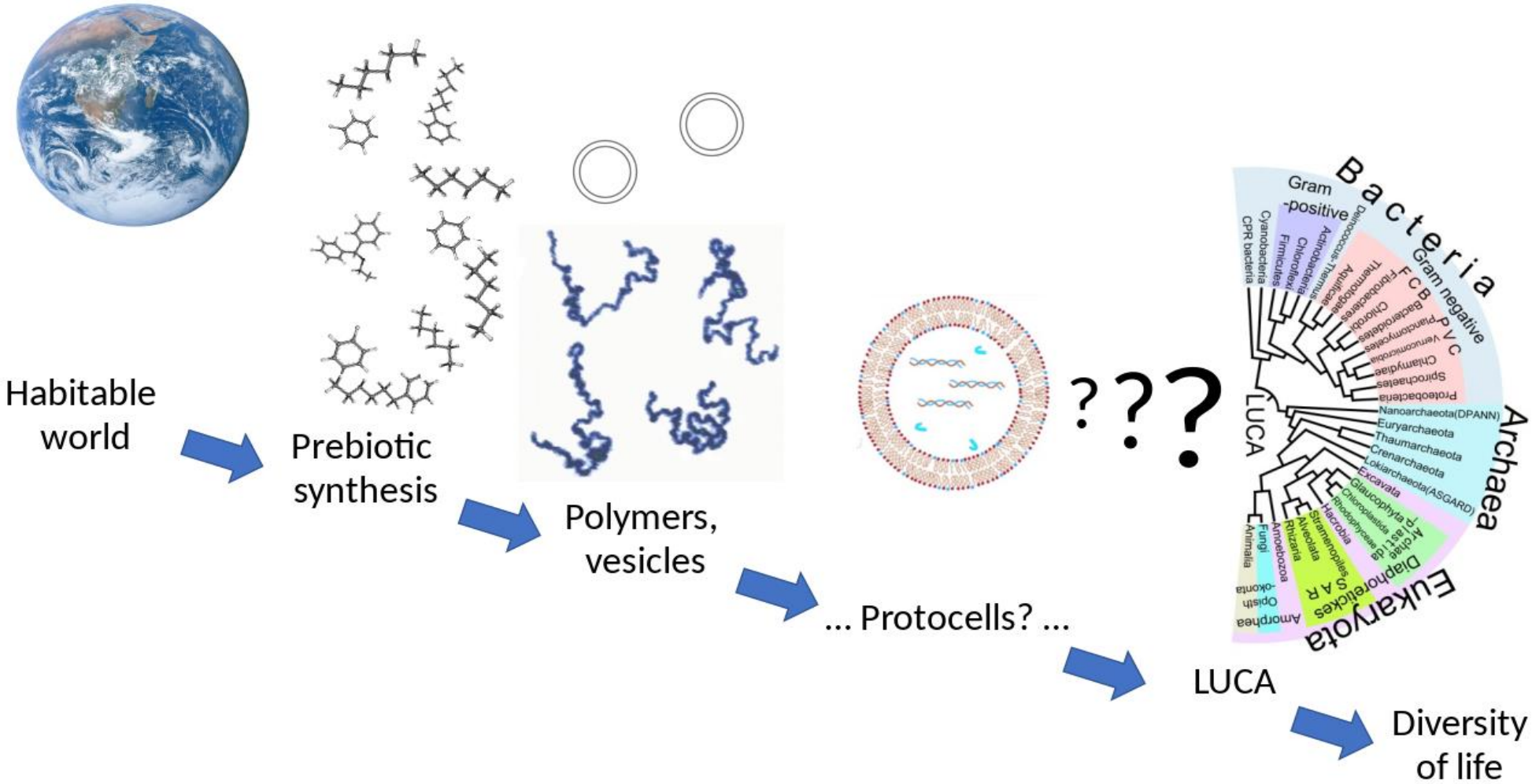


Stevenson a kol., 2015

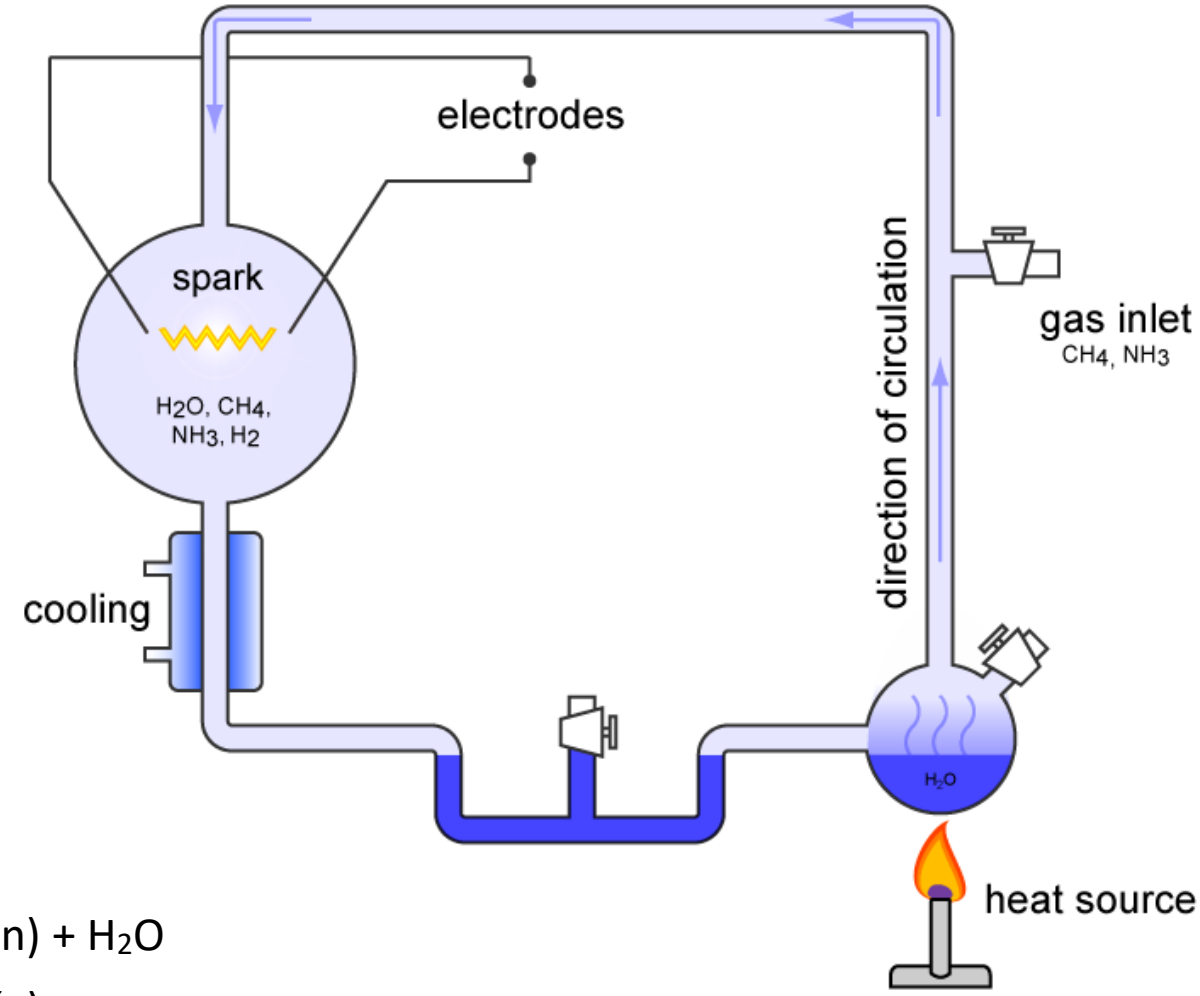




Abiogenéza


Habitable world
Prebiotic synthesis
Polymers, vesicles
... Protocells? ...
LUCA
Diversity of life
Bacteria
Archaea
Eukaryota
Gram -positive
Gram negative
LUCA
Cyanobacteria
CPR bacteria
Firmicutes
Chloroflexi
Actinobacteria
Deinococcus-Thermus
Aquificae
Thermotogae
Fibrobacteres
Chlorobi
Bacteroidetes
Planctomycetes
Verrucomicrobia
Chlamydiae
Spirochaetes
Proteobacteria
F C B
P V C
Nanoarchaeota(DPANN)
Euryarchaeota
Thaumarchaeota
Crenarchaeota
Lokiarchaeota(ASGARD)
Excavata
Glaucophyta
Chlorophyta
Rhodophyceae
Chlorophytida
Haeromonas
Archaeplastida
Stramenopiles
Alveolata
Rhizaria
S A R
Diaphoretickes
Amoebozoa
Fungi
Animalia
Opisthokonta
Amorphea

Millerov-Ureyov experiment



$CO_2 \rightarrow CO + [O]$

$CH_4 + 2[O] \rightarrow CH_2O + H_2O$

$CO + NH_3 \rightarrow HCN + H_2O$

$CH_4 + NH_3 \rightarrow HCN + 3H_2$

$CH_2O + HCN + NH_3 \rightarrow C_2H_4N_2$ (diazoetán) $+ H_2O$

$C_2H_4N_2 + 2H_2O \rightarrow NH_3 + C_2H_5NO_2$ (glycín)

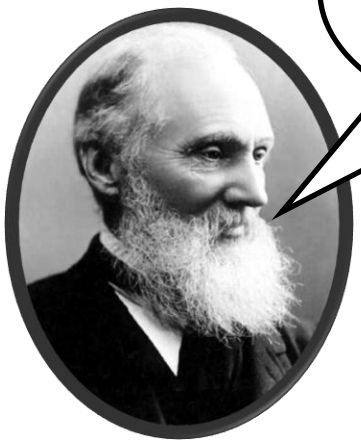
$CH_2O \rightarrow$ Butlerovova reakcia $\rightarrow C_5H_{10}O_5$ (ribóza)

Millerov-Ureyov experiment

Vulkán Chaiten, Čile
2.5.2008 (Carlos Gutierrez)

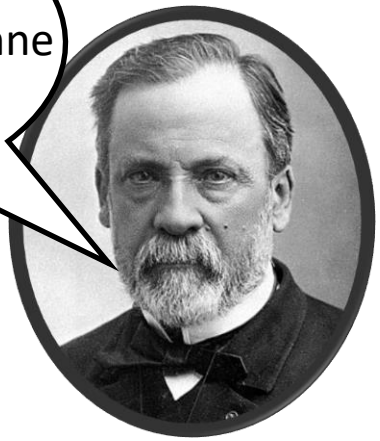
Amino acid	Produced in experiment			Proteinogenic
	Miller–Urey (1952)	Volcanic spark discharge (2008)	H_2S-rich spark discharge (2010)	
Glycine	✓	✓	✓	Yes
α-Alanine	✓	✓	✓	Yes
β-Alanine	✓	✓	✓	No
Aspartic acid	✓	✓	✓	Yes
α-Aminobutyric acid	✓	✓	✓	No
Serine	✗	✓	✓	Yes
Isoserine	✗	✓	✓	No
α-Aminoisobutyric acid	✗	✓	✓	No
β-Aminoisobutyric acid	✗	✓	✓	No
β-Aminobutyric acid	✗	✓	✓	No
γ-Aminobutyric acid	✗	✓	✓	No
Valine	✗	✓	✓	Yes
Isovaline	✗	✓	✓	No
Glutamic acid	✗	✓	✓	Yes
Norvaline	✗	✓	✗	No
α-Aminoadipic acid	✗	✓	✗	No
Homoserine	✗	✓	✗	No
2-Methylserine	✗	✓	✗	No
β-Hydroxyaspartic acid	✗	✓	✗	No
Ornithine	✗	✓	✗	No
2-Methylglutamic acid	✗	✓	✗	No
Phenylalanine	✗	✓	✗	Yes
Homocysteic acid	✗	✗	✓	No
S-Methylcysteine	✗	✗	✓	No
Methionine	✗	✗	✓	Yes
Methionine sulfoxide	✗	✗	✓	No
Methionine sulfone	✗	✗	✓	No
Isoleucine	✗	✗	✓	Yes
Leucine	✗	✗	✓	Yes
Ethionine	✗	✗	✓	No

Panspermia



Spóry z vesmíru prenášajú meteority. (litopanspermia)

William Thomson
Lord Kelvin
(1824-1907)



Experiment ukázal, že život nemôže spontánne vzniknúť zohriatím živín.

Luis Pasteur
(1822-1895)

Áno. Veď na meteoritoch sú organické molekuly a kométy pozostávajú z vodíka a uhlíka.

Hermann von Helmholtz
(1821-1894)

Nie, spóry putujú pod tlakom hviezdneho vetra. (rádiopanspermia)

Svante August Arrhenius
(1859-1927)

To je jedno. UV žiarenie aj tak spóry zabije.

Henri Becquerel
(1852-1908)

Panspermia

Fred Hoyle
(1915-2001)

Chandra
Wickramasinghe
(1939-)

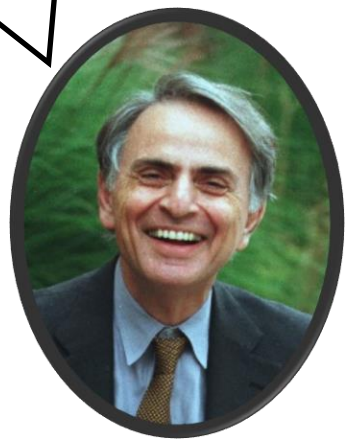
Kozmický prach obsahuje organické molekuly.

Wickramasinghe a Allen, 1980, 1981, 1983

Aby mikrób mohol tlakom žiarenia putovať od hviezdy, musí mať rozmer asi 0,2-0,6 µm. Zároveň hviezda musí mať dostatok svietivosti (cca od G5-A0). Naopak červenšia (M, K) hviezda má slabý tlak žiarenia a neodveje spóry. Stále problém so sterilizáciou UV a rtg. žiarením.

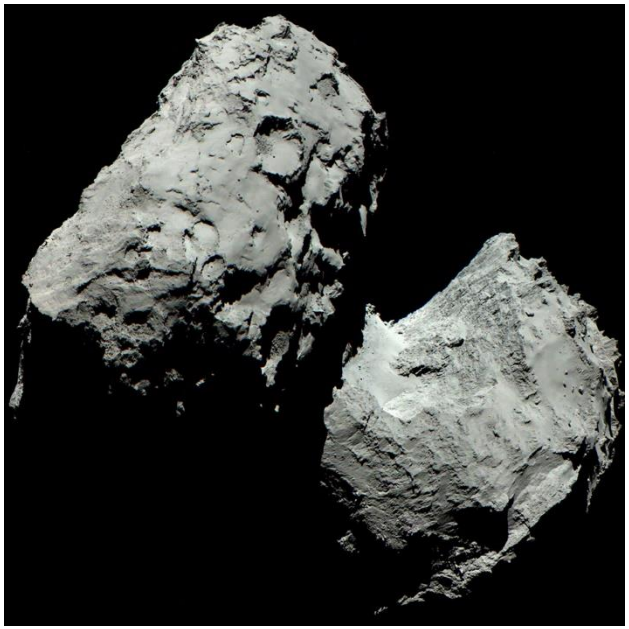
Shklovsky a Sagan, 1966

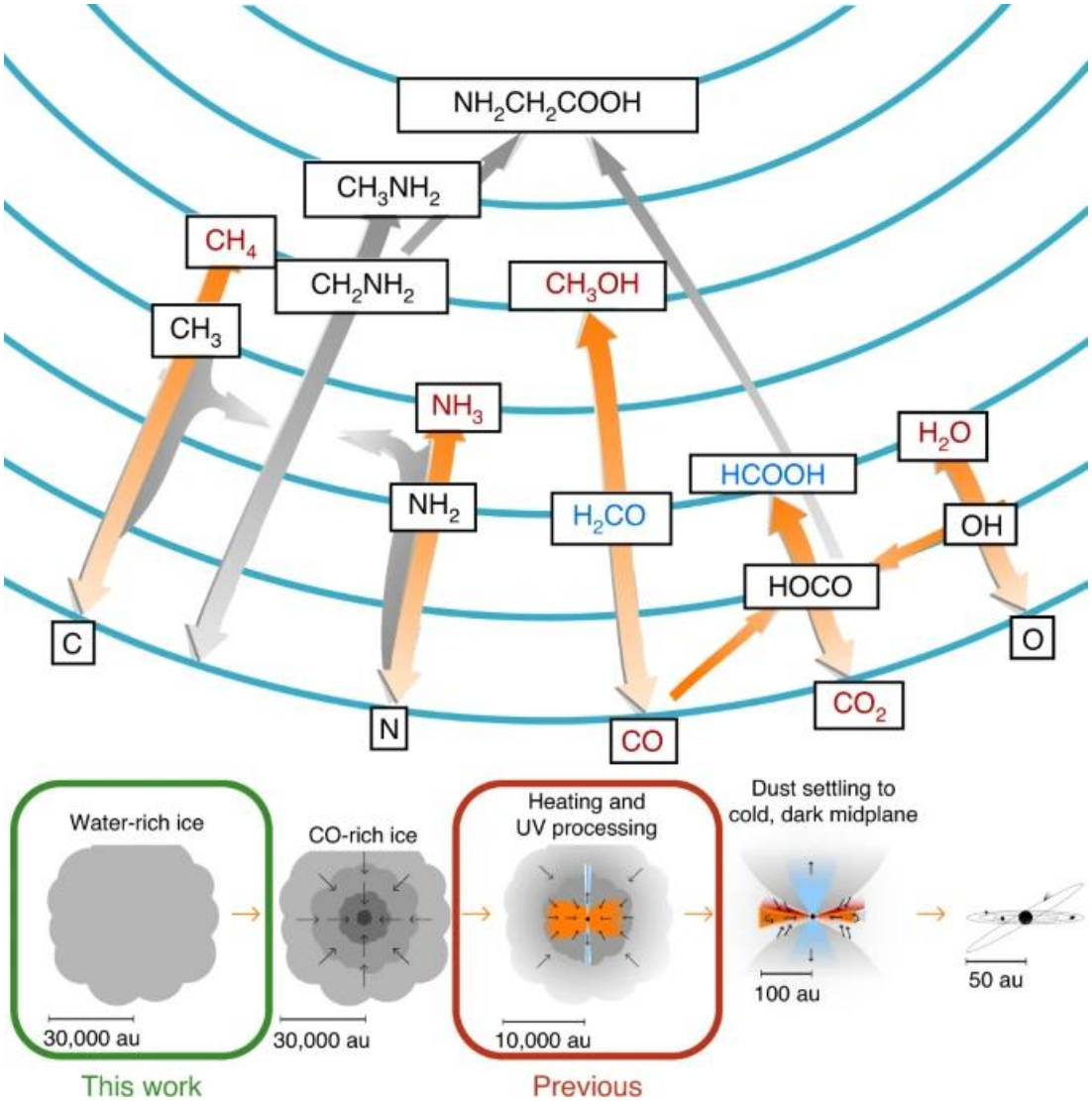
Jozif Šklovskij
(1916-1985)



Carl Sagan
(1934-1996)

Litopanspermia

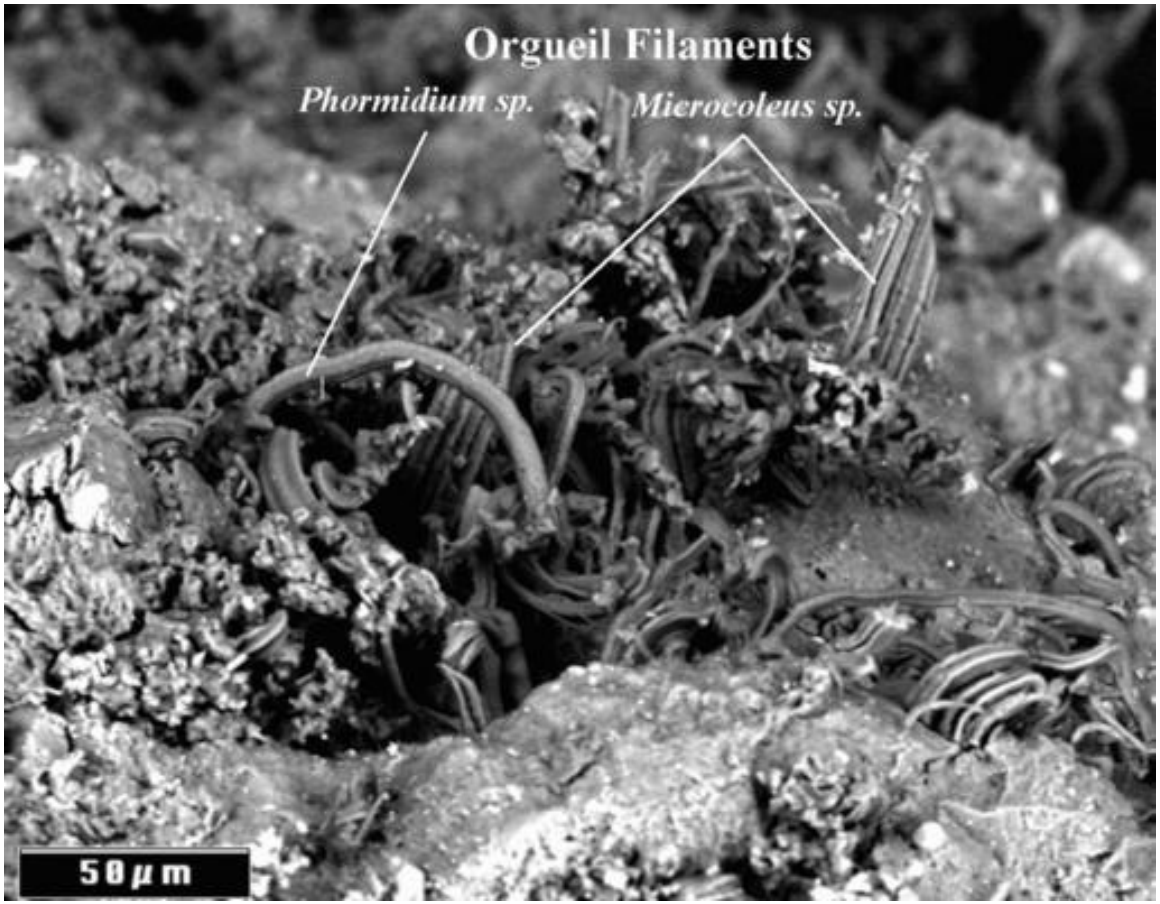




Ioppolo a kol., 2020

Litopanspermia

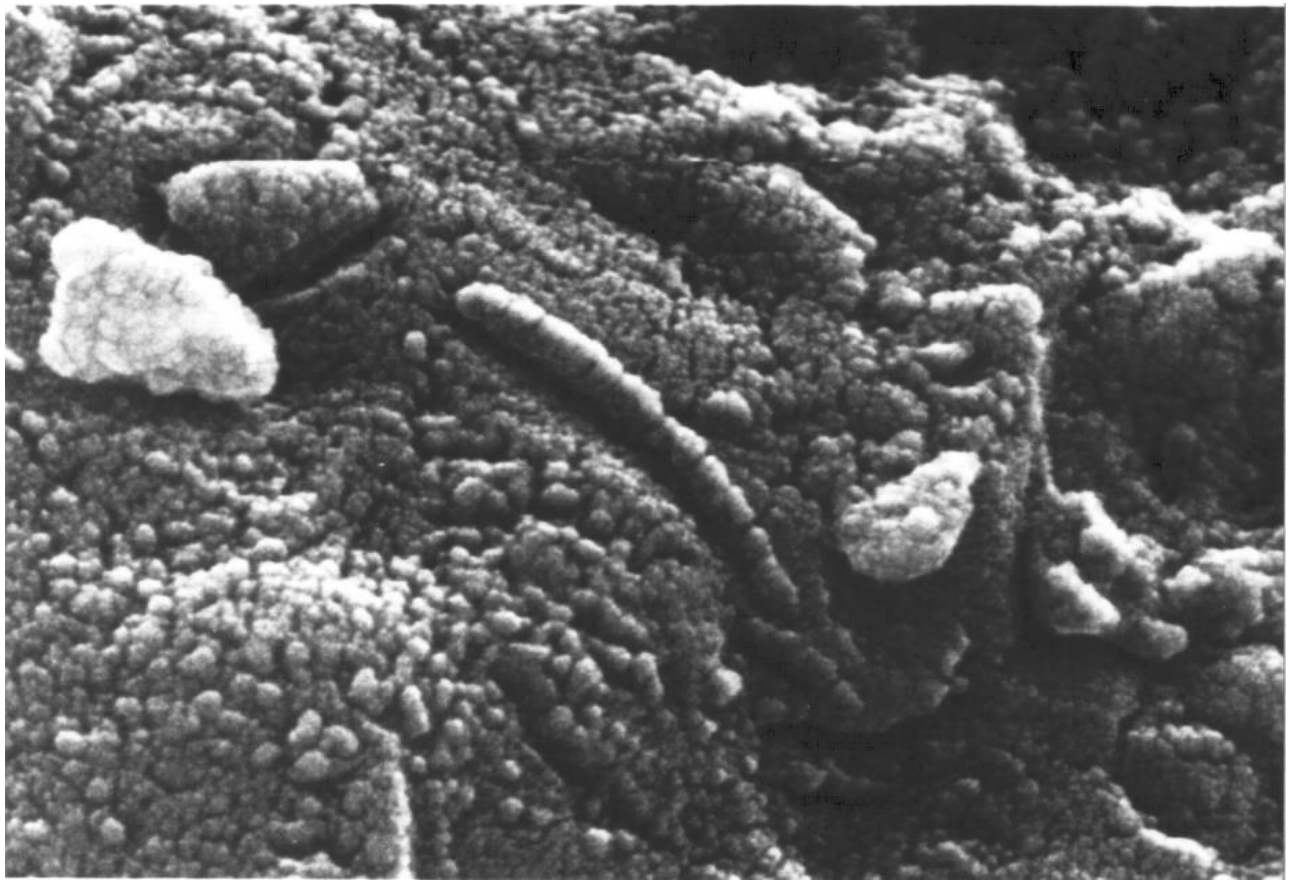
Meteorit Orgueil (Francúzsko, 14.5.1864)



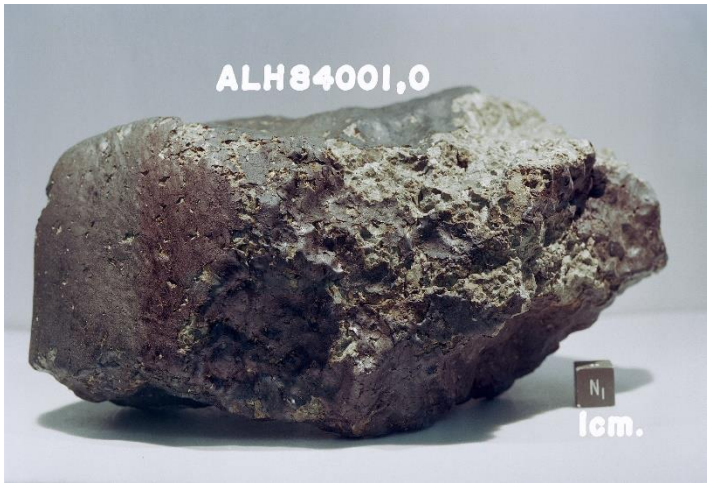
Hoover, 2009

Litopanspermia

Meteorit ALH84001 (Antarktída, 1984)



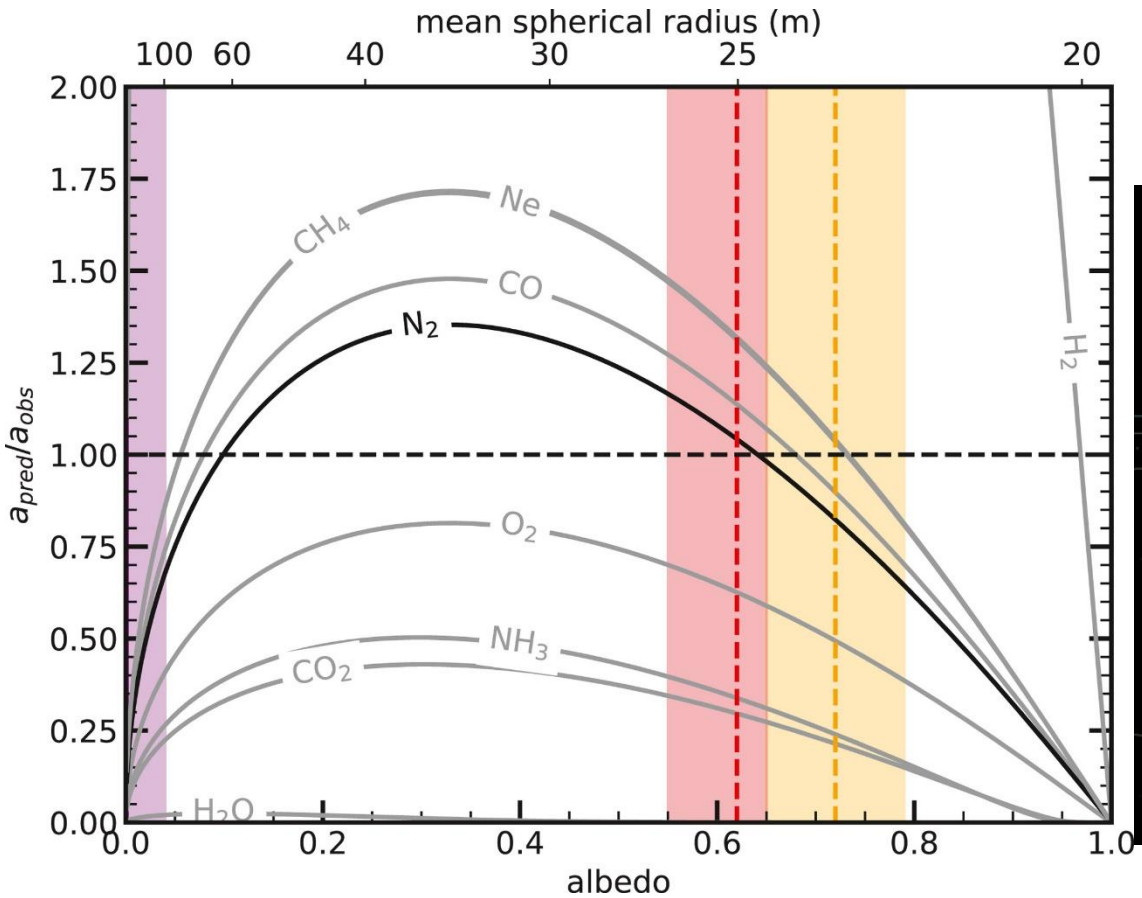
McKay a kol., 1996

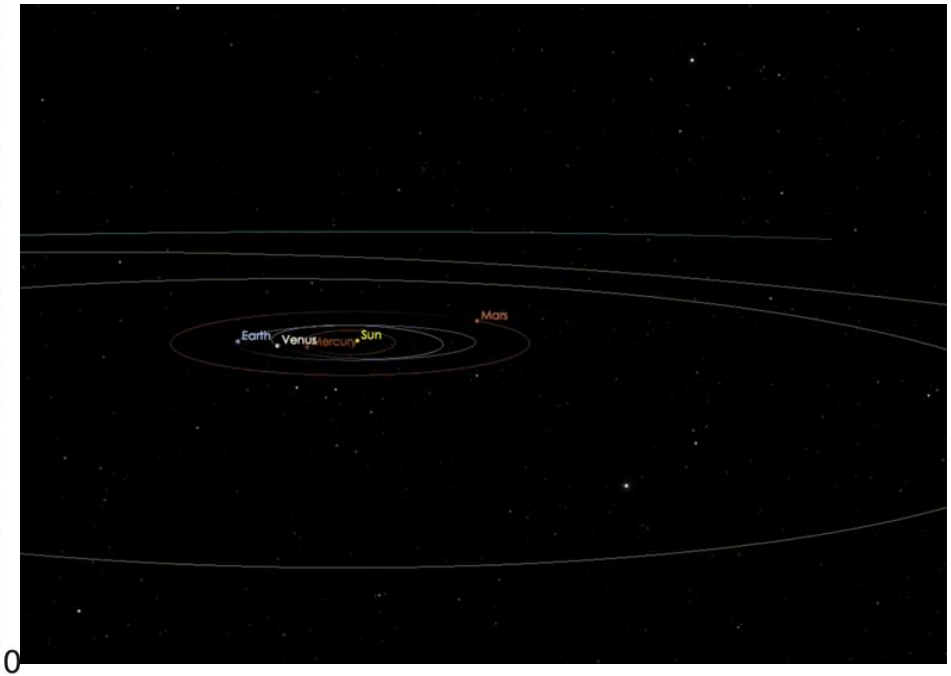


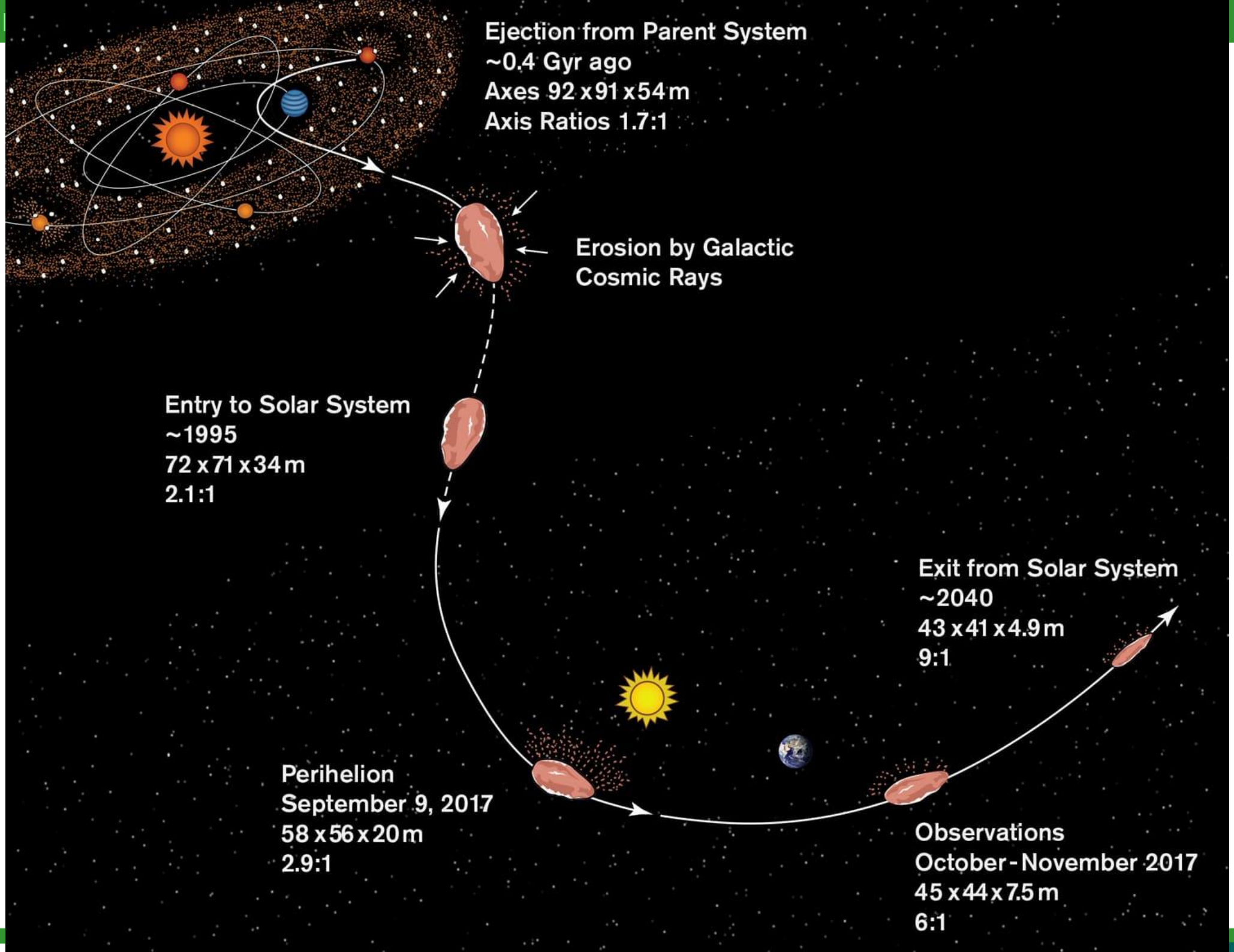
Litopanspermia

1I/'Oumuamua (2017)

Jackson a Desch, 2021

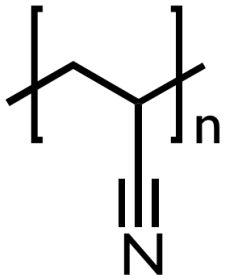


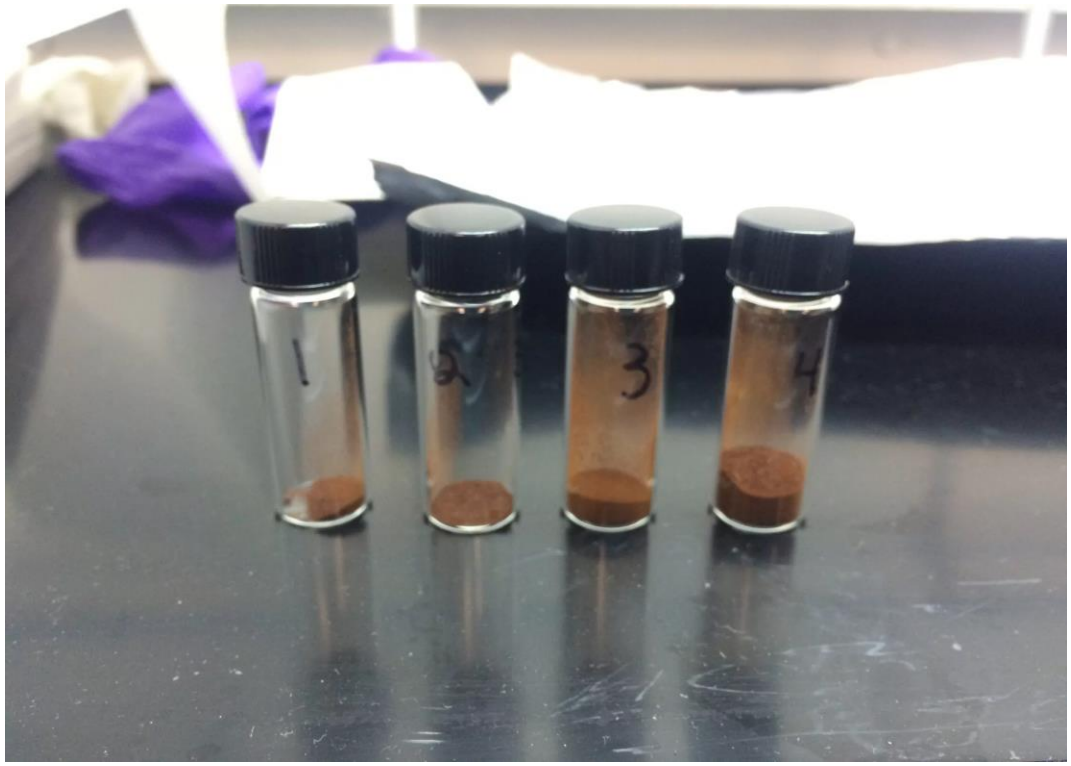



Ejection from Parent System
~0.4 Gyr ago
Axes 92 x 91 x 54 m
Axis Ratios 1.7:1
Erosion by Galactic
Cosmic Rays
Entry to Solar System
~1995
72 x 71 x 34 m
2.1:1
Exit from Solar System
~2040
43 x 41 x 4.9 m
9:1
Perihelion
September 9, 2017
58 x 56 x 20 m
2.9:1
Observations
October - November 2017
45 x 44 x 7.5 m
6:1

Organické látky vo vesmíre

Tholíny (z N_2 a CH_4)

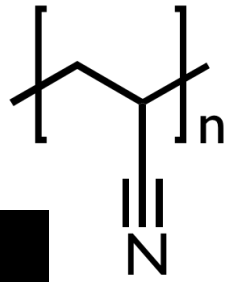


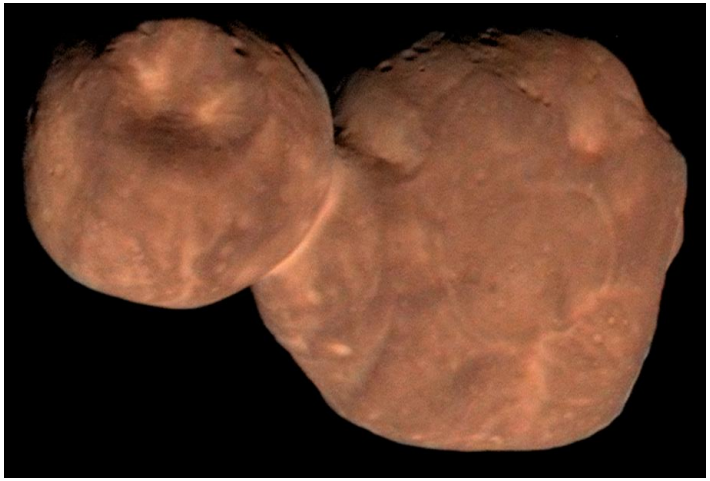


Kredit: John Hopkins University

Organické látky vo vesmíre

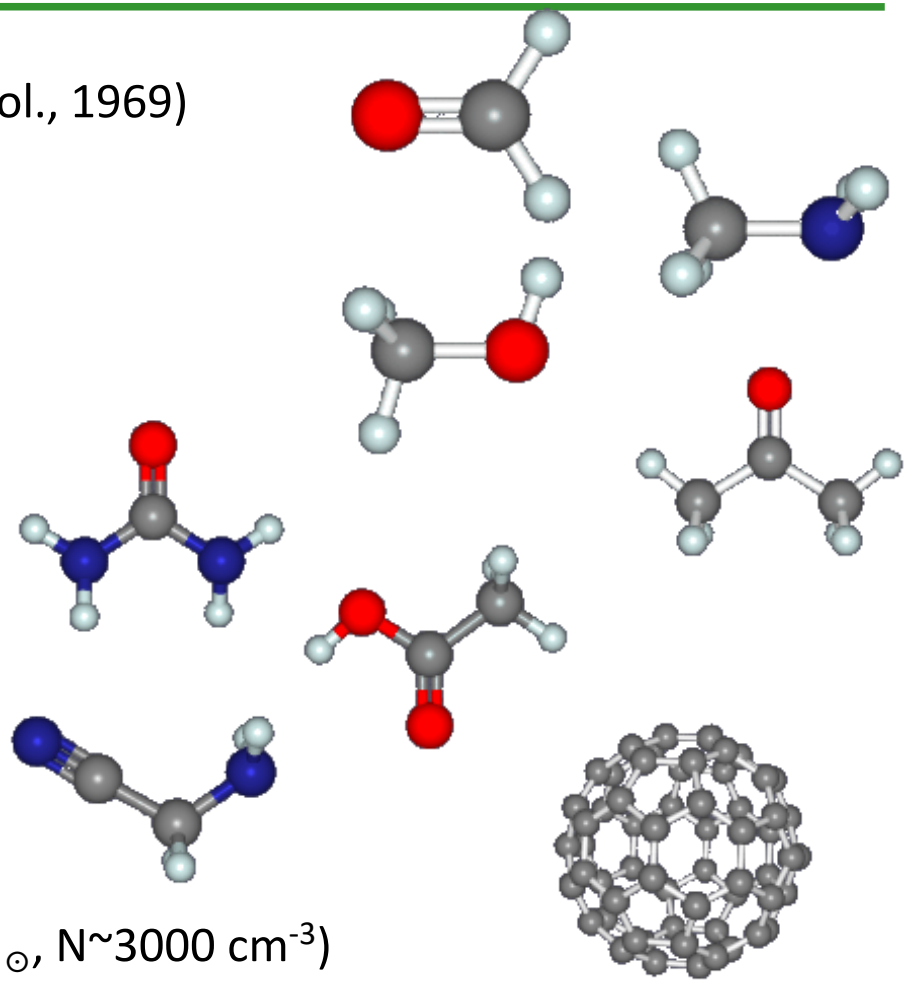
Tholíny (z N_2 a CH_4)





Pseudo-panspermia

- Astromolekuly napr: formaldehyd (Snyder a kol., 1969)
- metylamín (Kaifu a kol., 1974)
- metanol (Ball a kol., 1970)
- acetón (Combes a kol., 1987)
- močovina (Remijan a kol., 2014)
- kyselina octová (Mehringer a kol., 1997)
- Aminoacetonitril (Belloche a kol., 2008)
- fulleren / Buckyball (Cami a kol., 2010)



Sgr B2 (390 ly od centra Galaxie, ø 150 ly, $3x10^6$ $M_\odot$, N~3000 cm^{-3})

Pseudo-panspermia

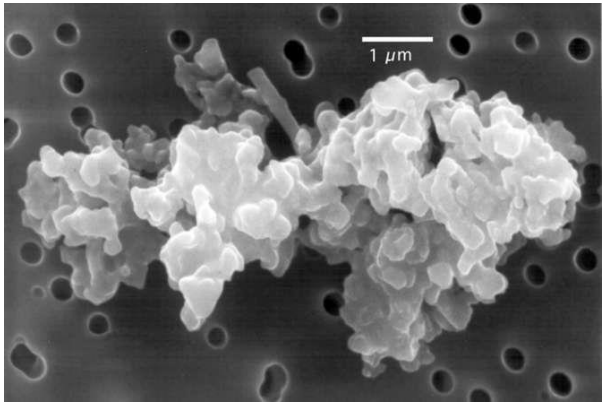
Hustota ~ 100-300 mol. cm^{-3}

~ 1 zrno cm^{-3}

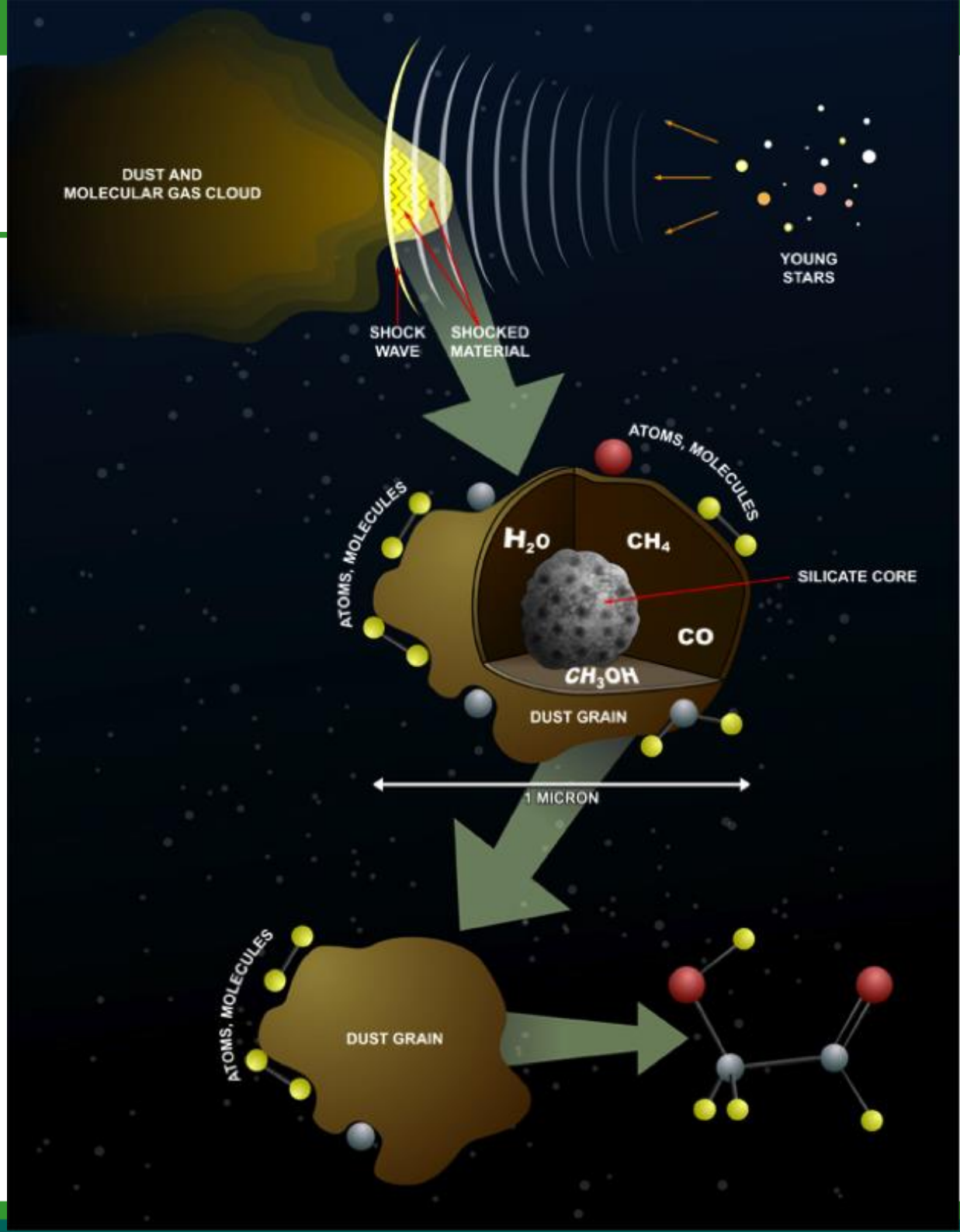
Teplota ~ 7 – 15 K

Veľkosť zŕn ~ 10-100 µm

NASA StarDust (2009): glycín



Jessberger a kol., 2001



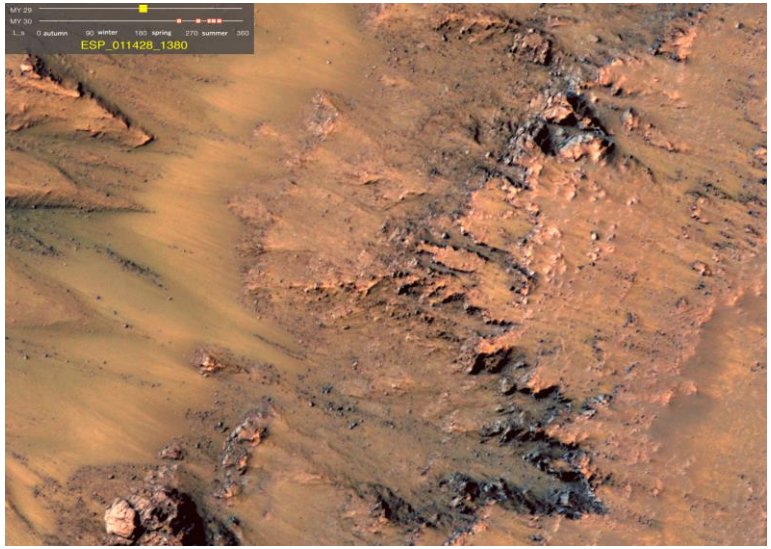
Súčasné poznatky o možnostiach života vo vesmíre

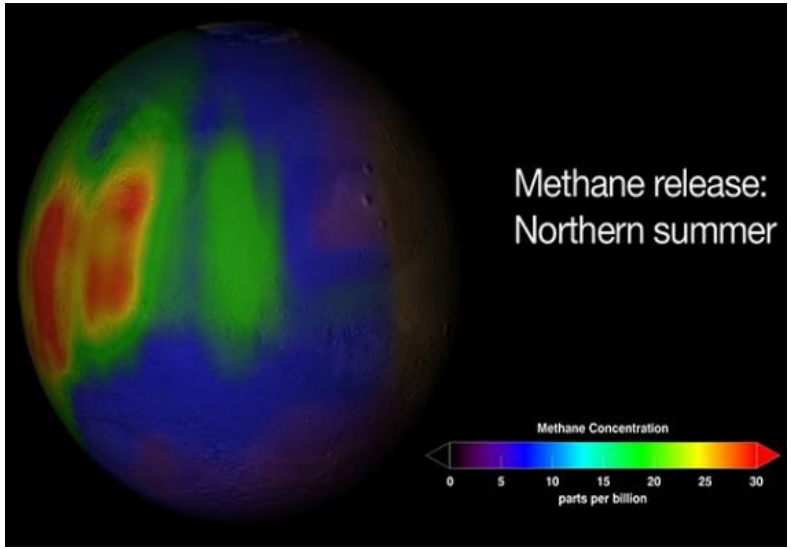
PRESTÁVKA

1.12.2022 Space::Talk

KDE A AKO HĽADAŤ MIMOZEMSKÝ ŽIVOT?

Kde hľadať – Mars



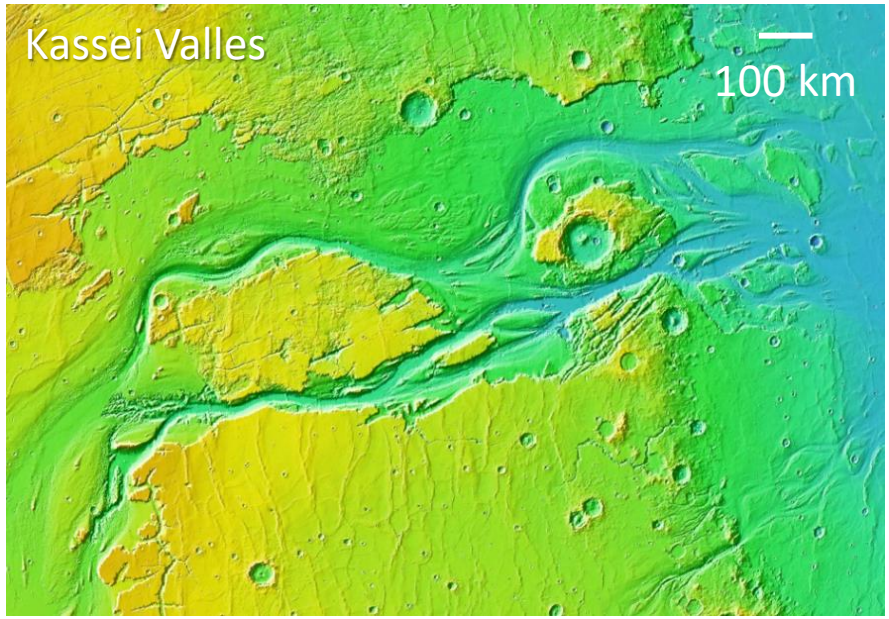


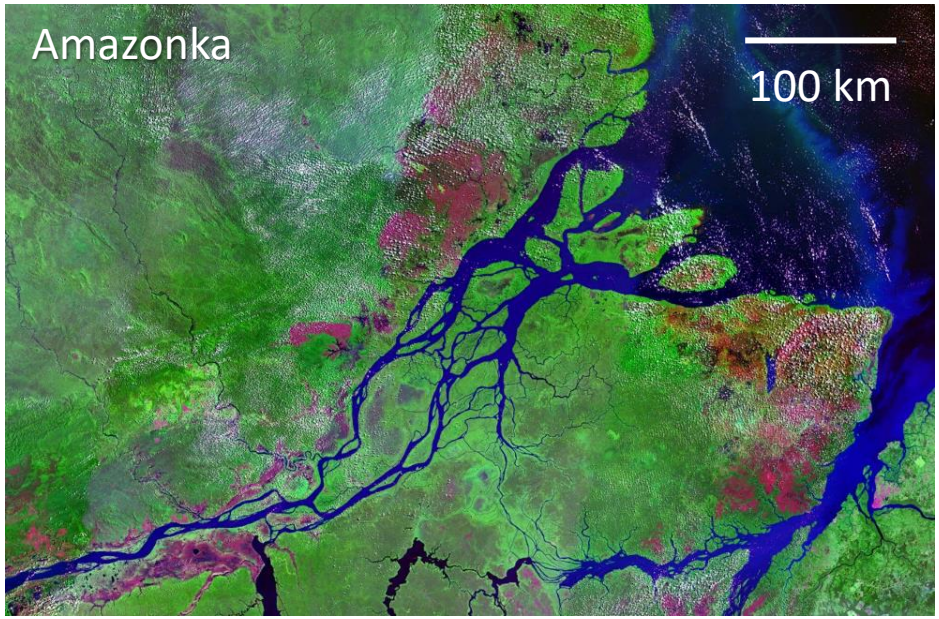
Mumma a kol., 2009

	P_{orb} (d)	P_{rot} (h)	i_{rot} (°)	a (au)	e	M (M_E)	R (R_E)	g (ms^{-2})	$F_\odot$ (Wm^{-2})	A (%)	T_{eff} (°C)
	365	1,00	1,00	1,00	0,02	1	1	9,81	1361	0,31	15
	687	1,52	1,52	1,52	0,10	0,11	0,53	3,72	589	0,25	-63

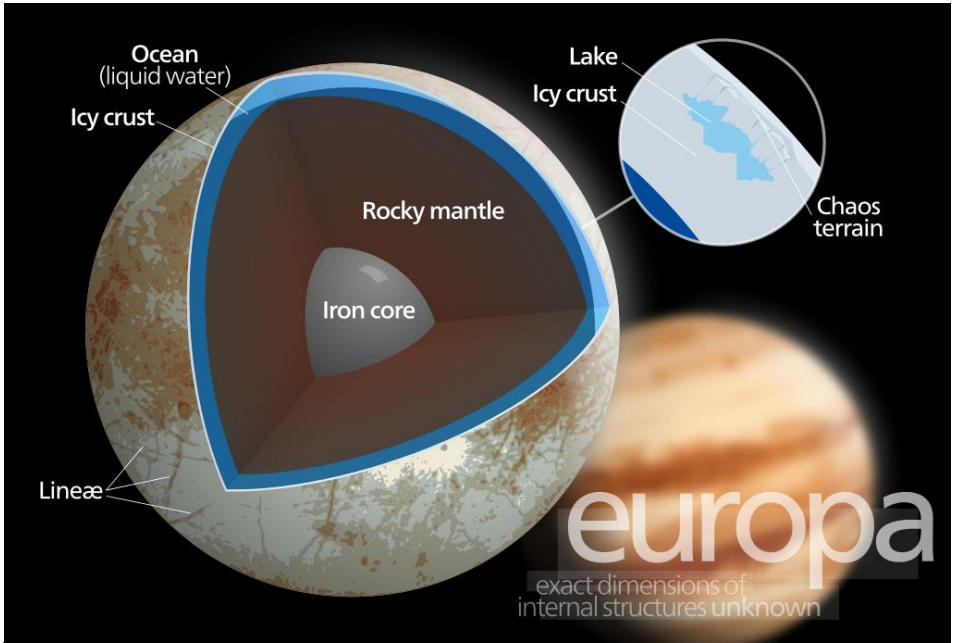
Kde hľadať – Mars

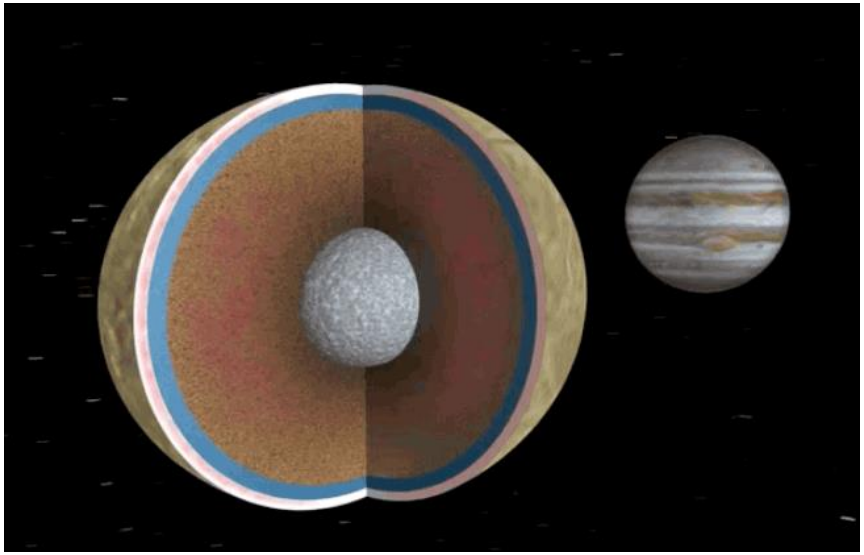
Historická voda na Marse

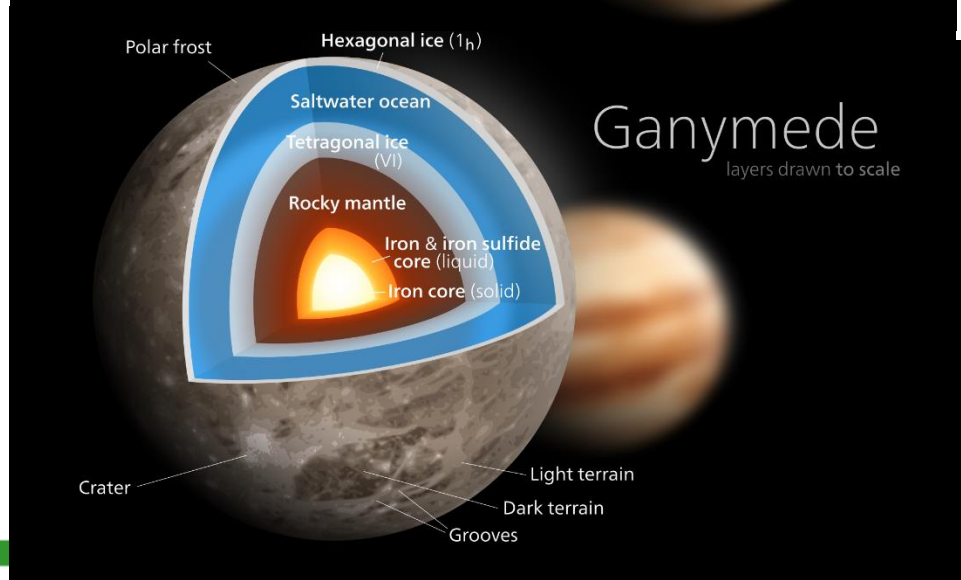


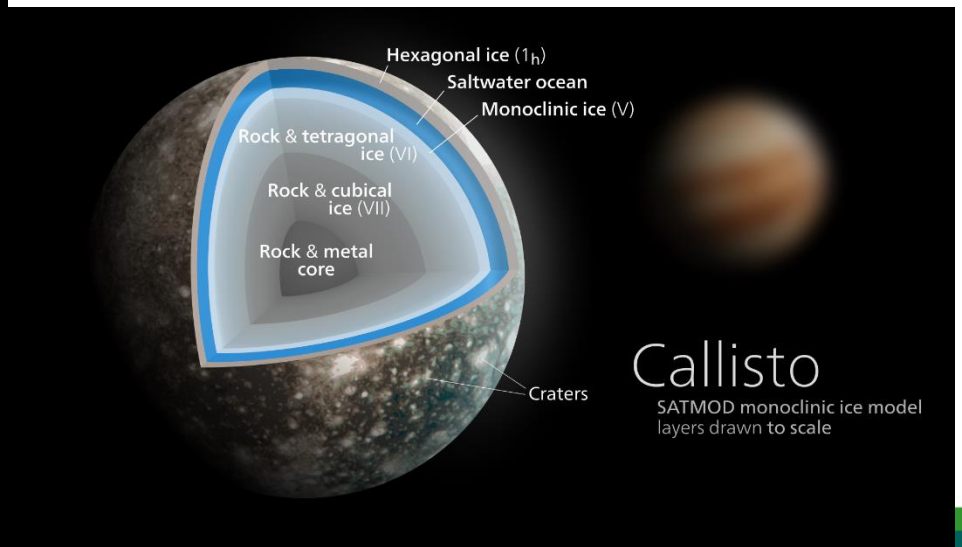


Kde hľadať – Jupiterove mesiace

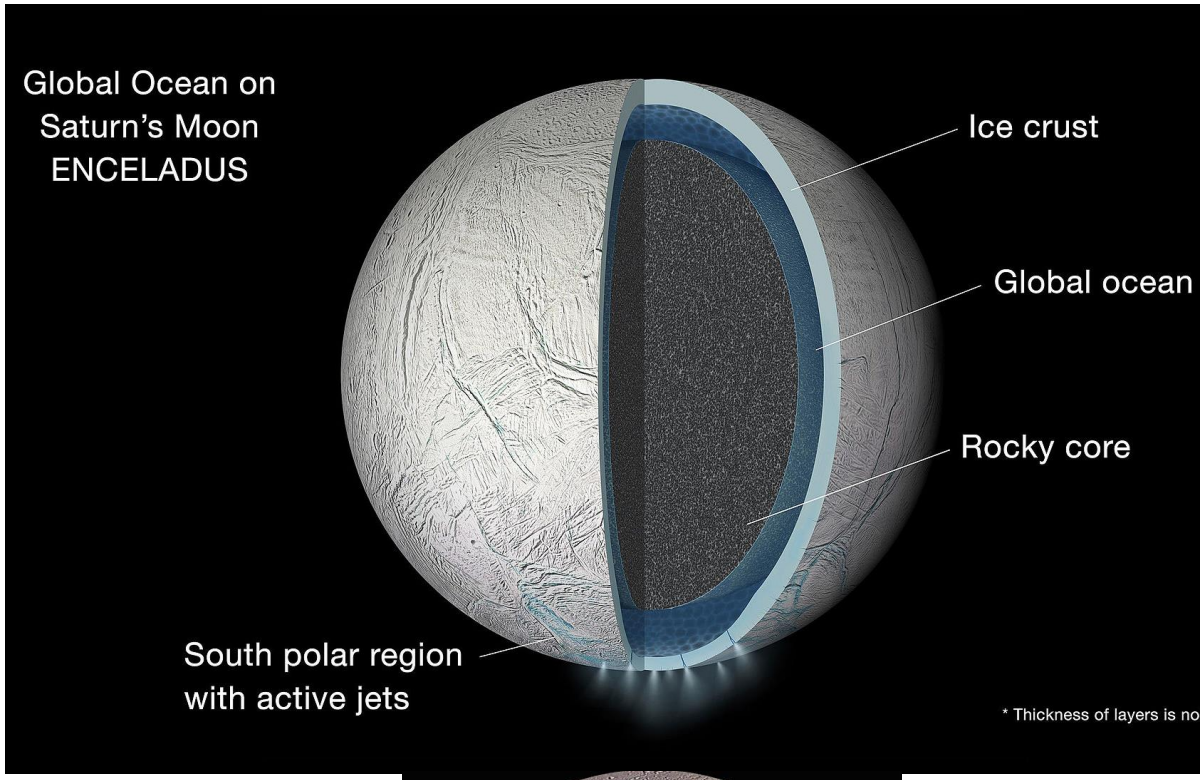


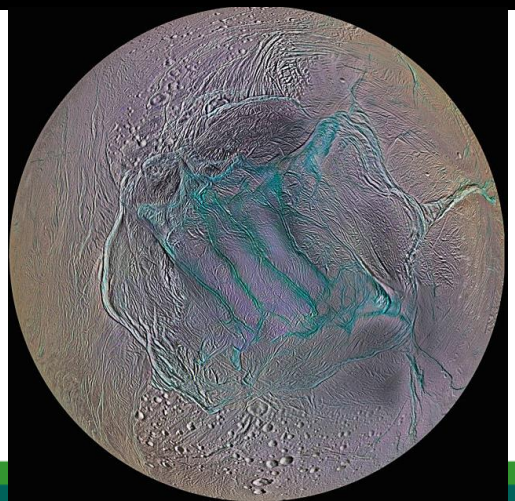


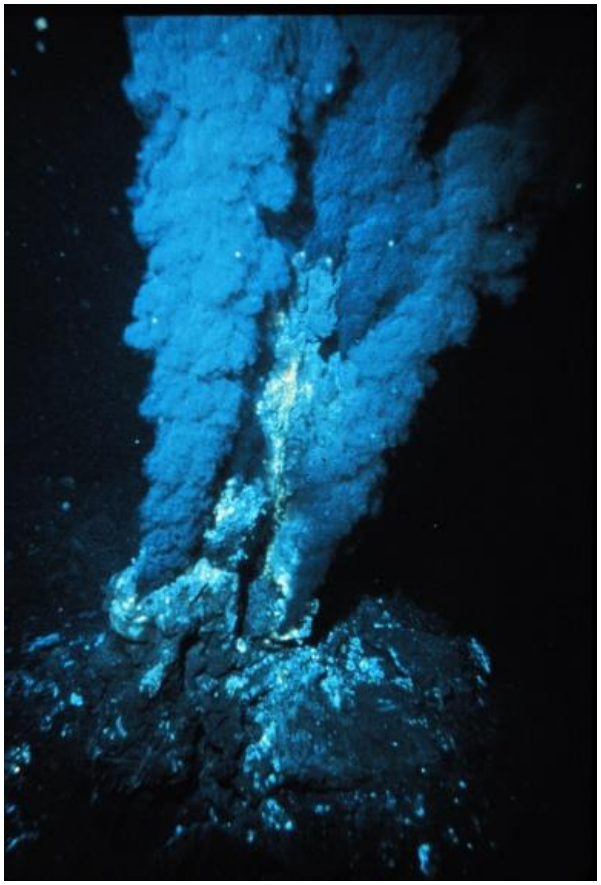




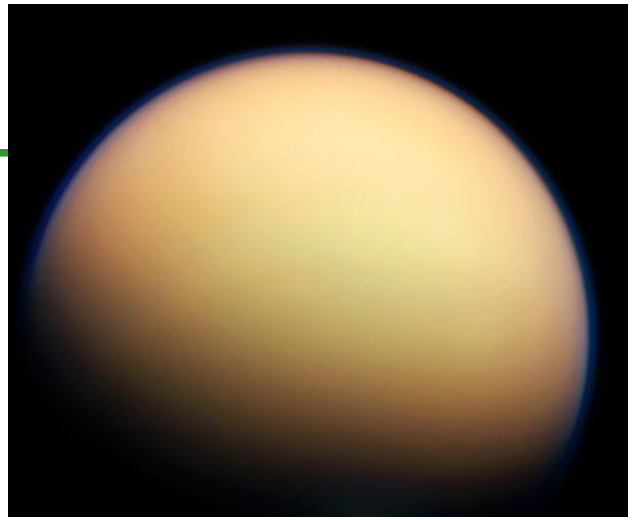
Kde hľadať – Saturnove mesiace







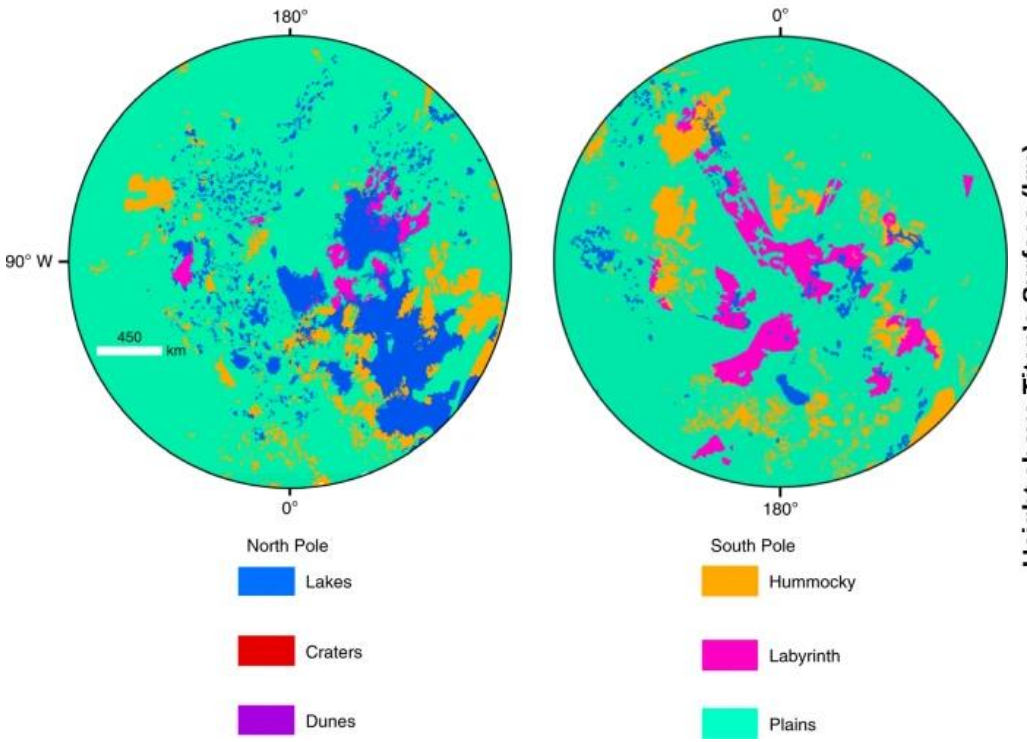
Kde hľadať – Saturnove mesiace

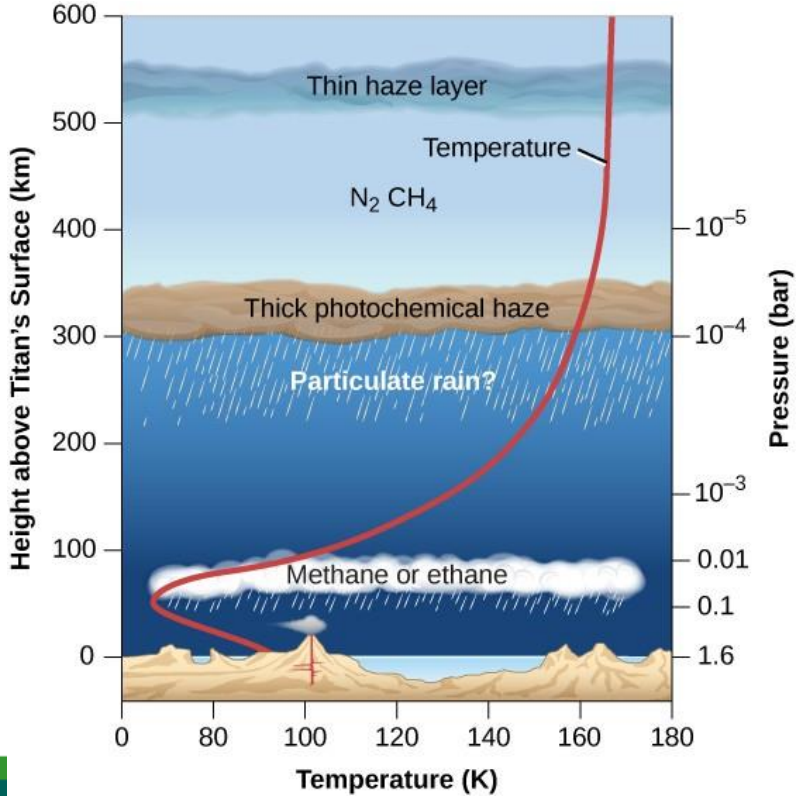


hustá atmosféra, povrchové jazerá s metánom

2010 - menej vodíka v atmosfére, ako bolo očakávané

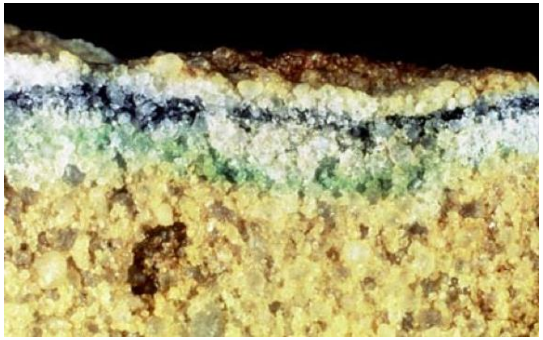
→ organizmy alebo neznámy prírodný jav?

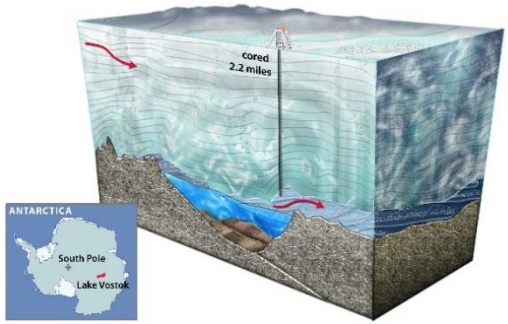




Jednoduchý = životaschopný

Teplota, sucho, kyslosť, slanosť, rádioaktivita, tlak, nehostinnosť

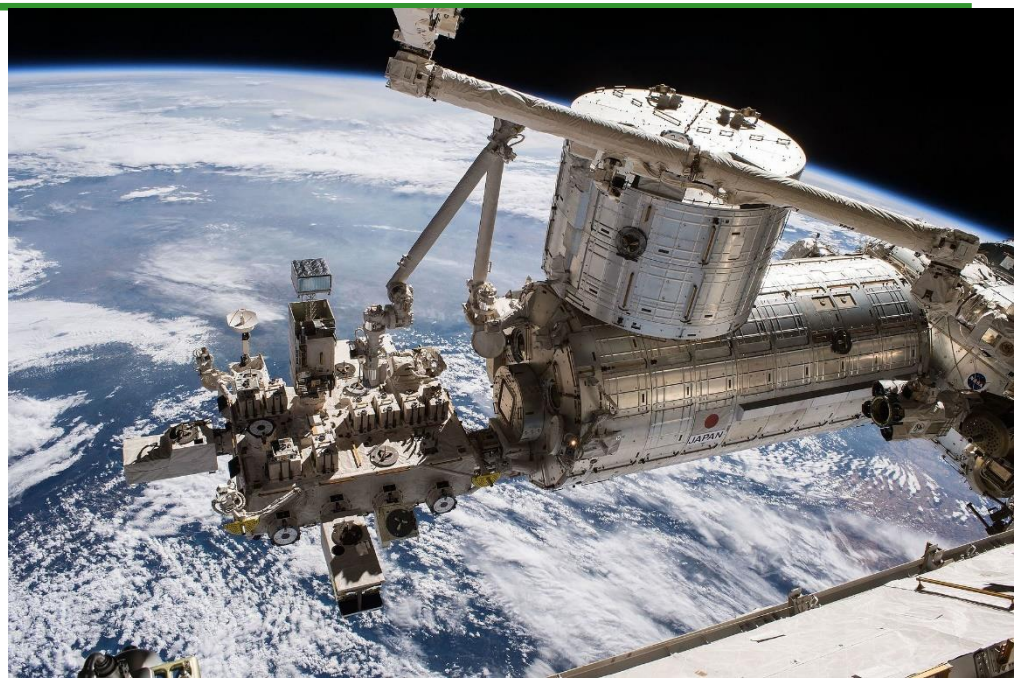


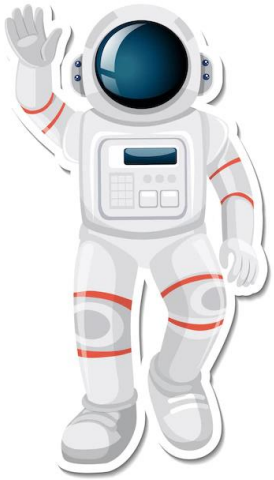


Jednoduchý = životaschopný

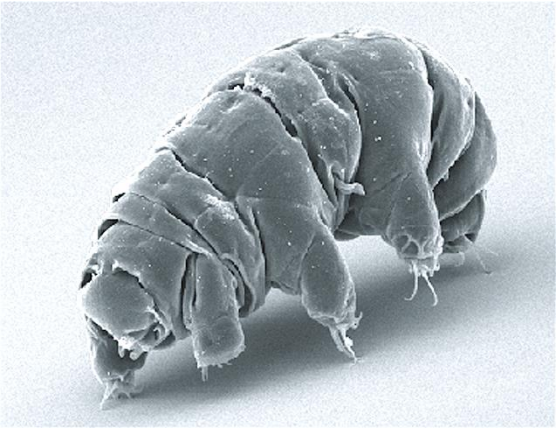
Microbispora sp. prežila haváriu raketoplánu Colulmbia (2003)

McLean a kol., 2006

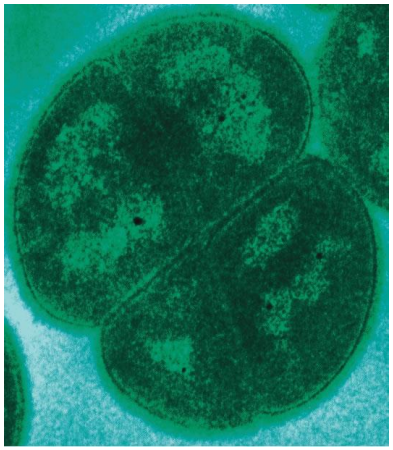




5 Gy



4000 Gy

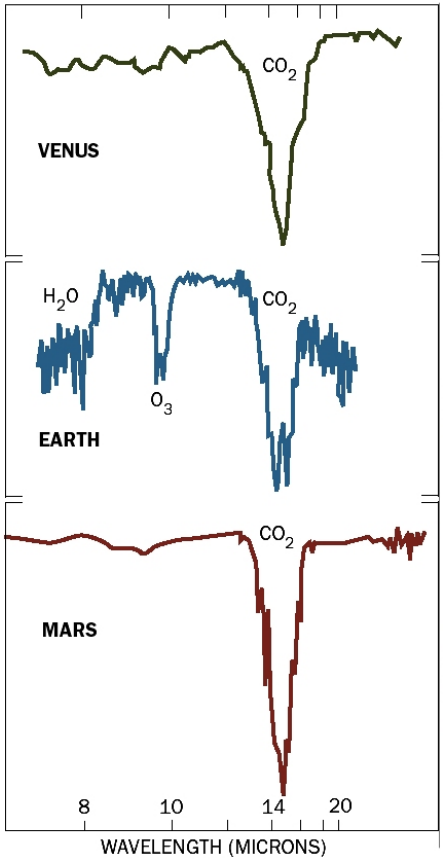


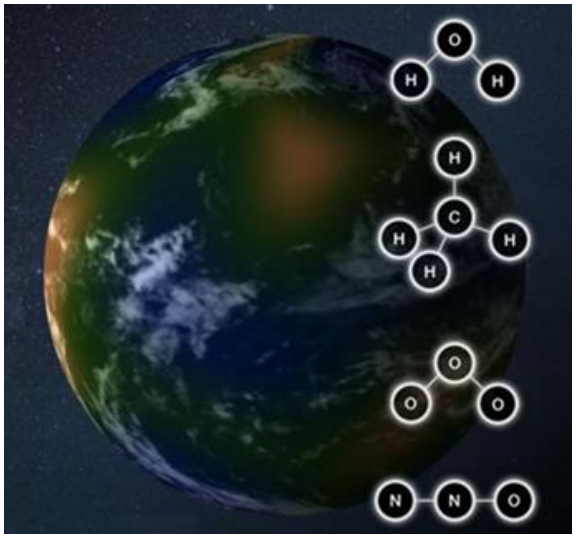
5000 Gy

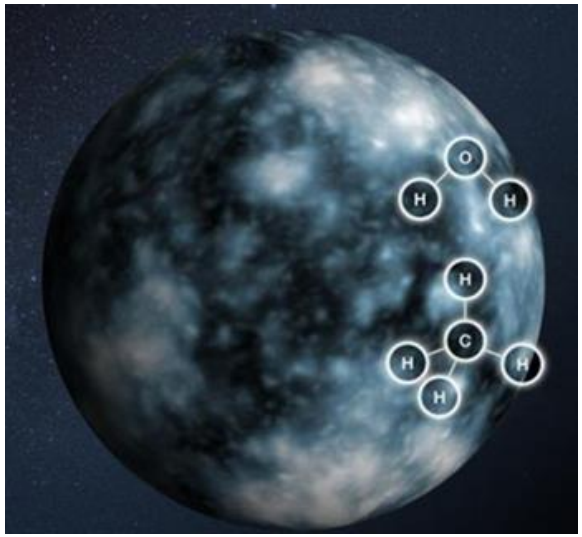
D. Radiodurans prežila vyše 3 roky na vonkajšom povrchu ISS (bez UV žiarenia)

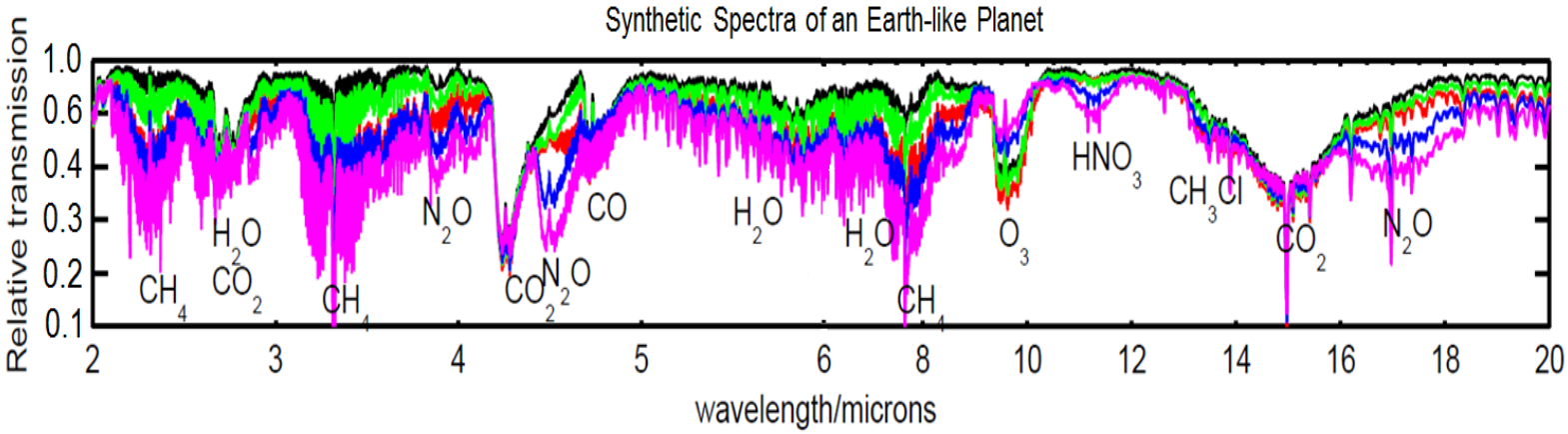
Ott a kol., 2020

Biosignatúry

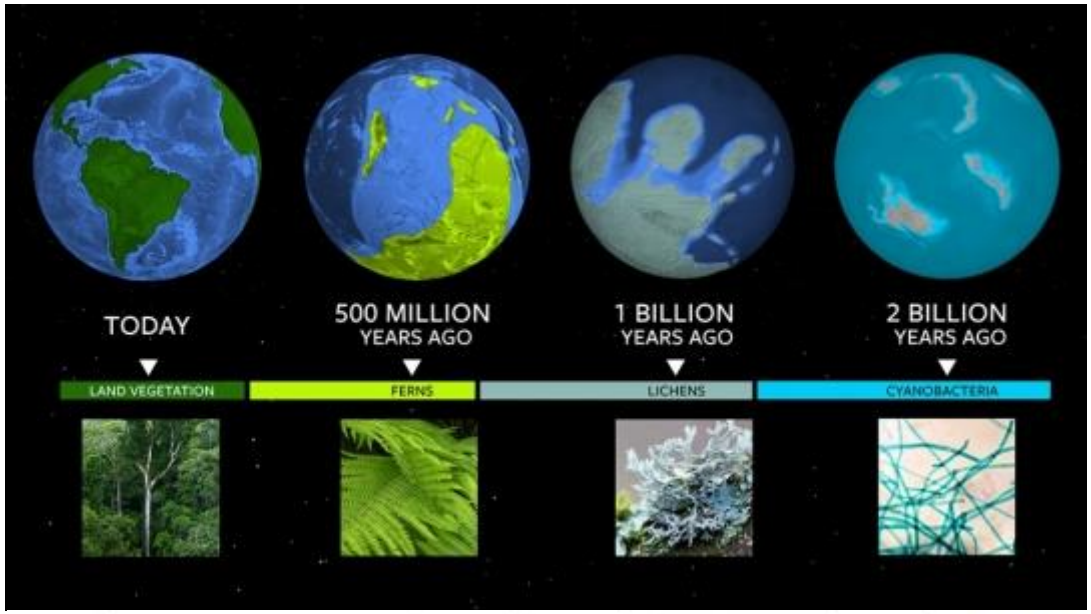


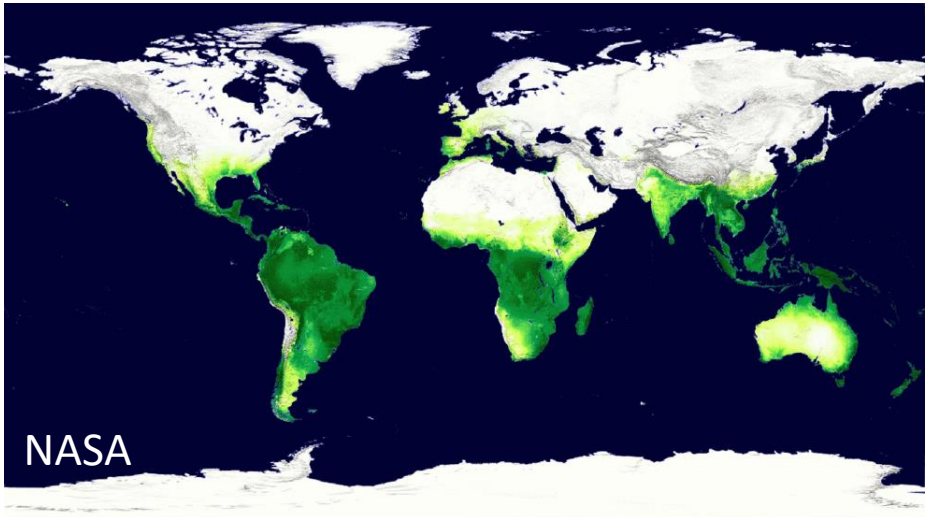


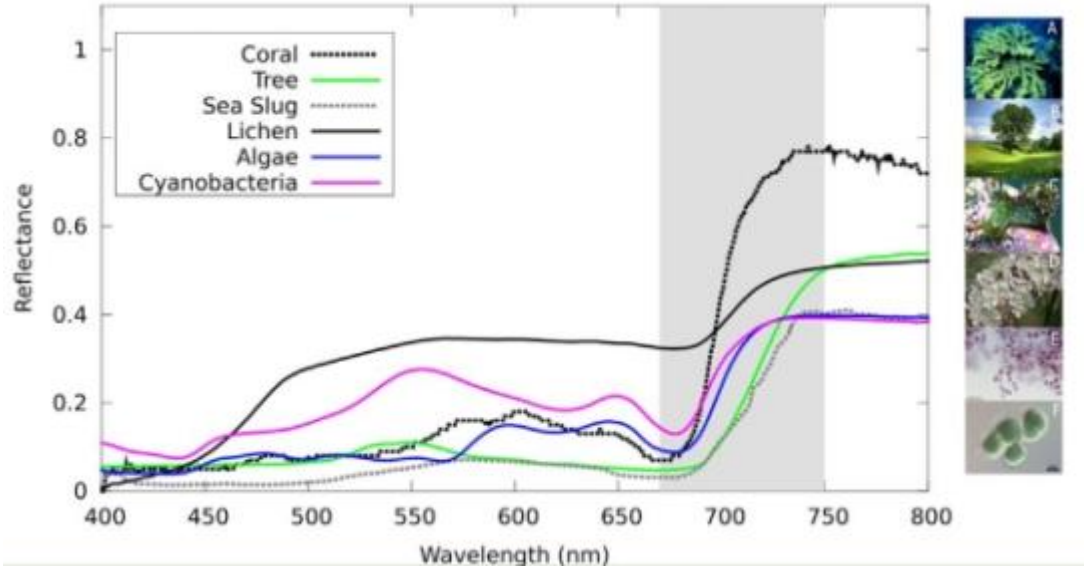




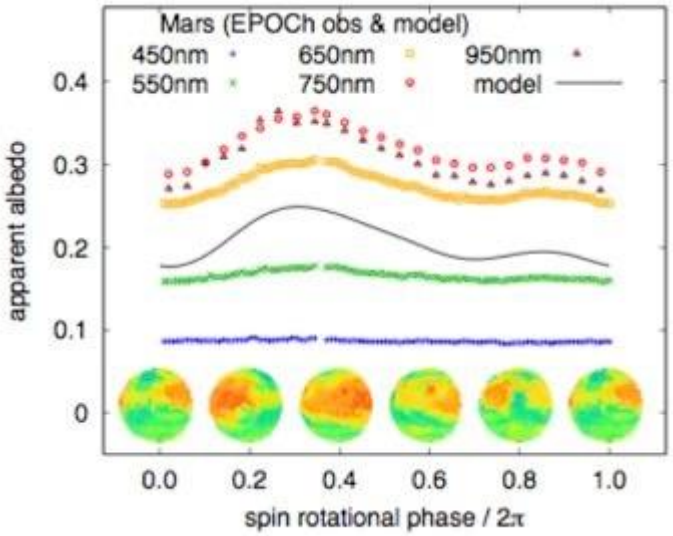
Biosignatúry





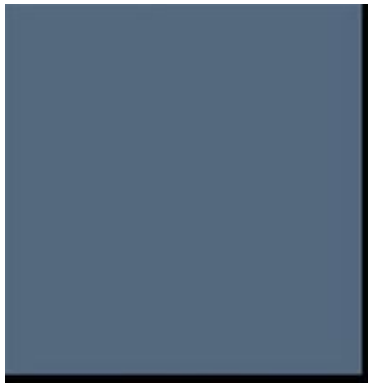


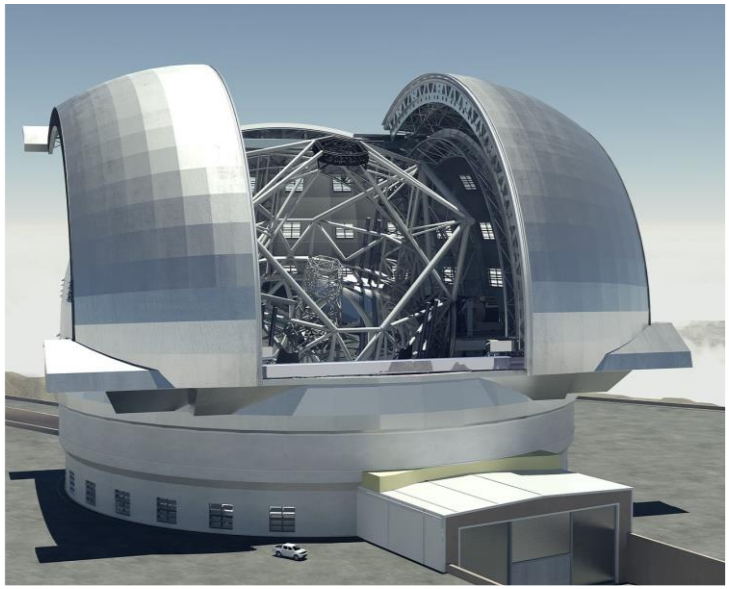
O'Malley-James a Kalteneggerová, 2019



Fujii a kol., 2014

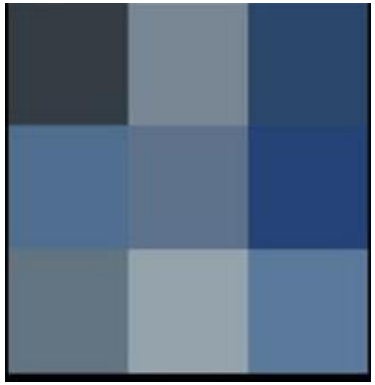
Priame pozorovanie exoplanéty?



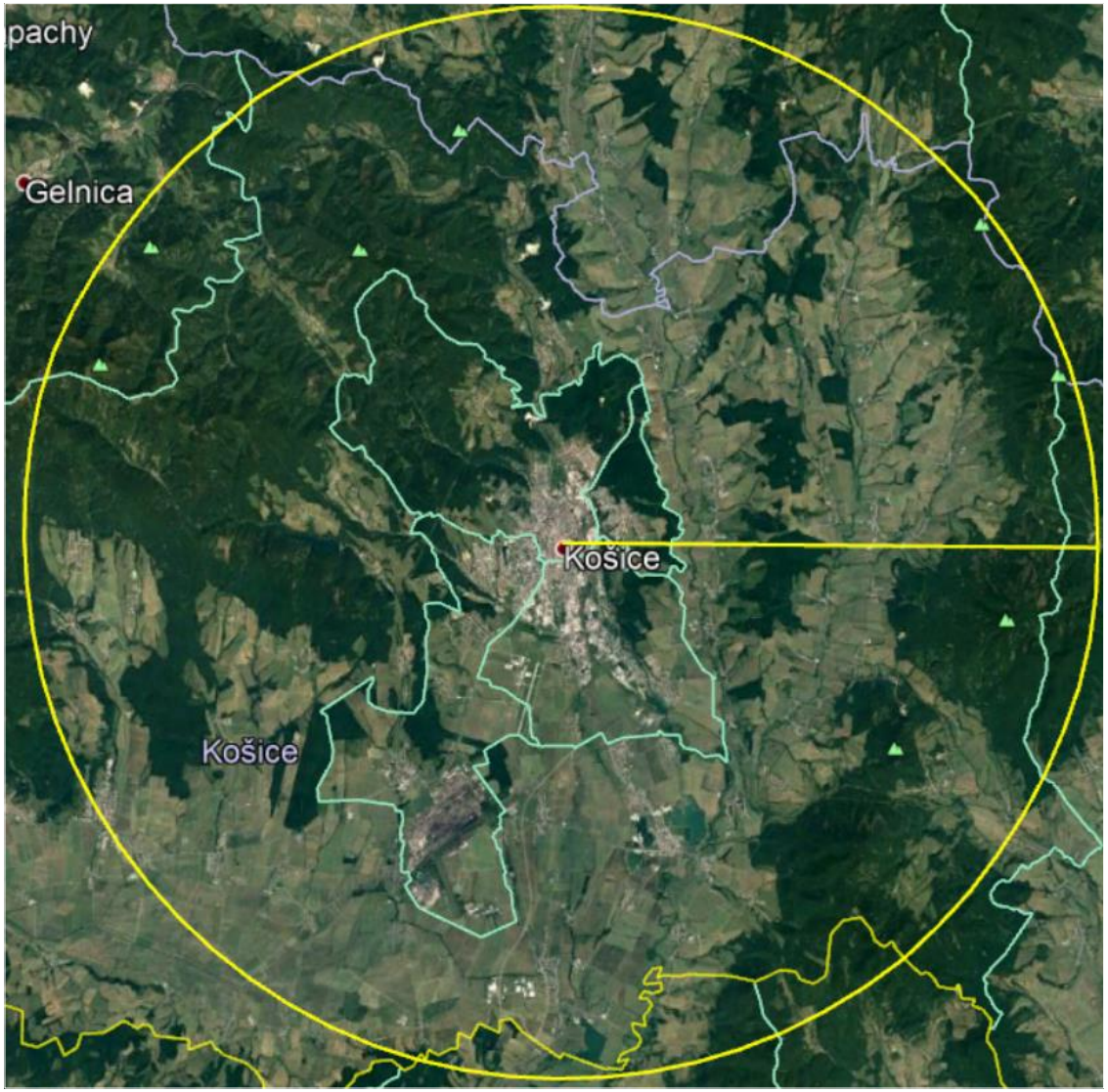


Rozlíšenie:
1 pixel
Ø teleskopu:
“hociaký”

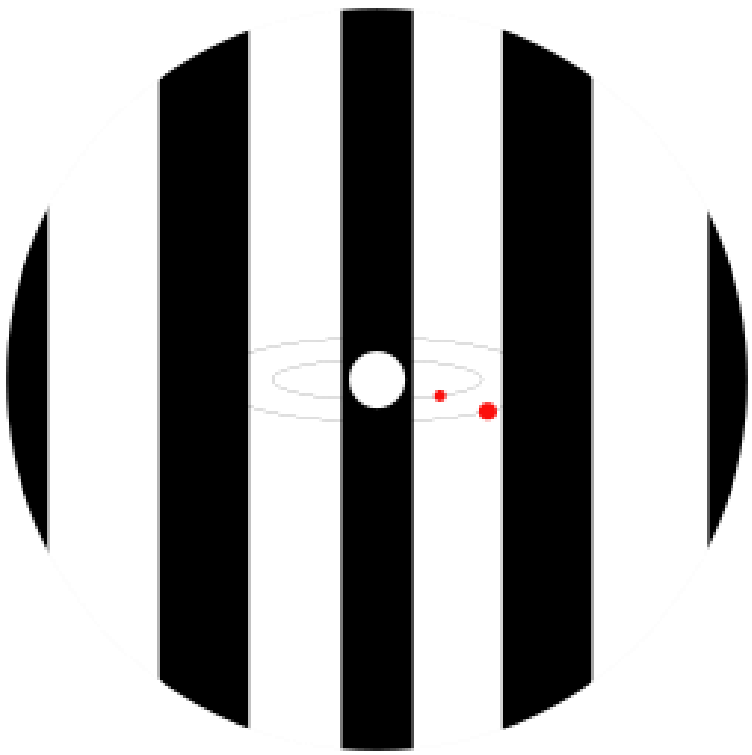
Priame pozorovanie exoplanéty?

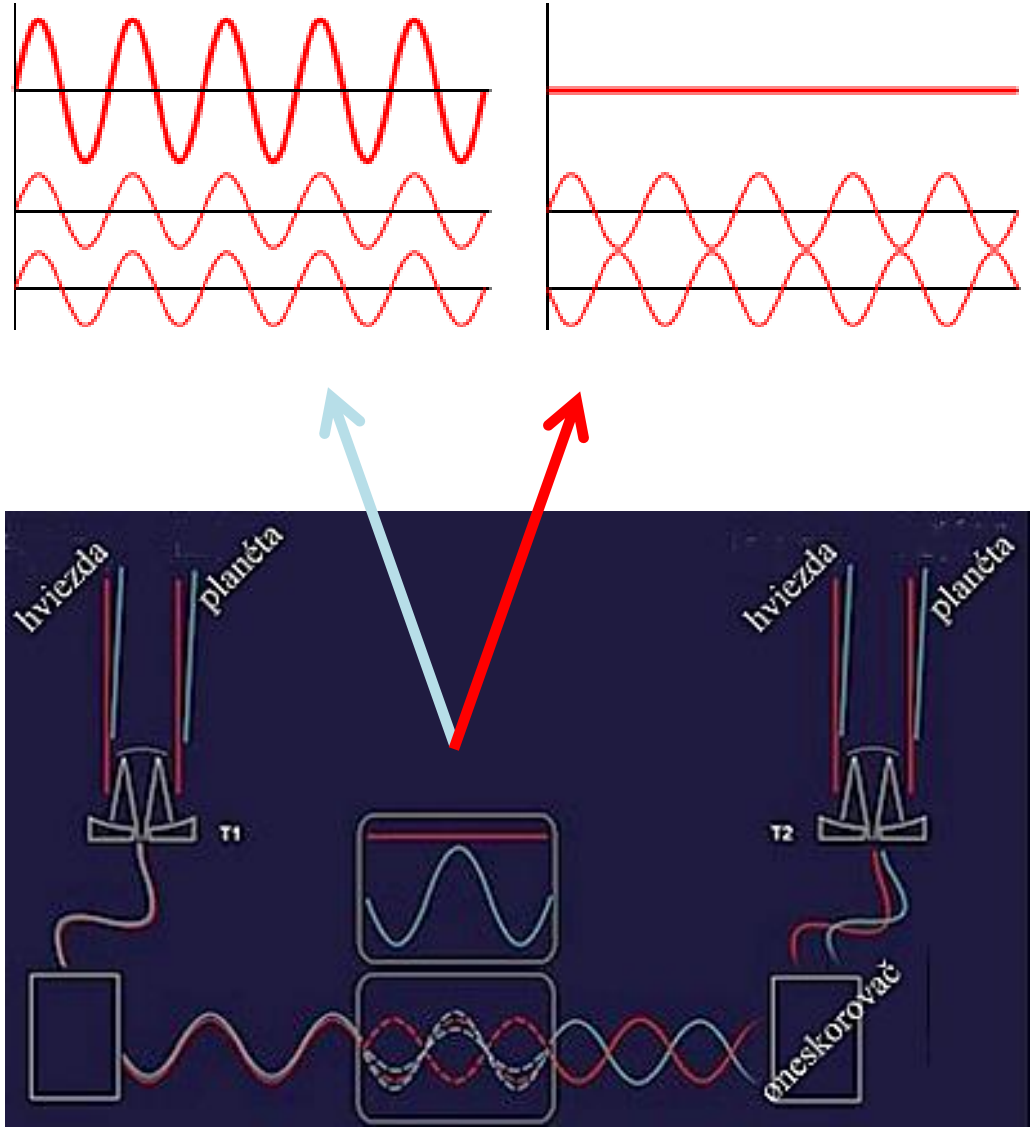


Rozlíšenie:
3 x 3 pixely
Ø teleskopu:
46 km



Priame pozorovanie exoplanéty?





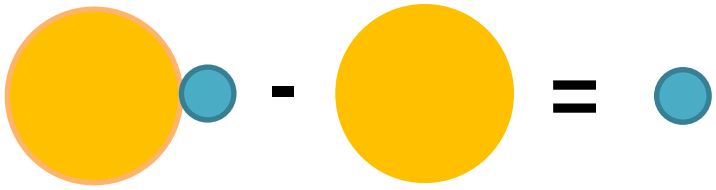
Priame pozorovanie exoplanéty?

HR8799

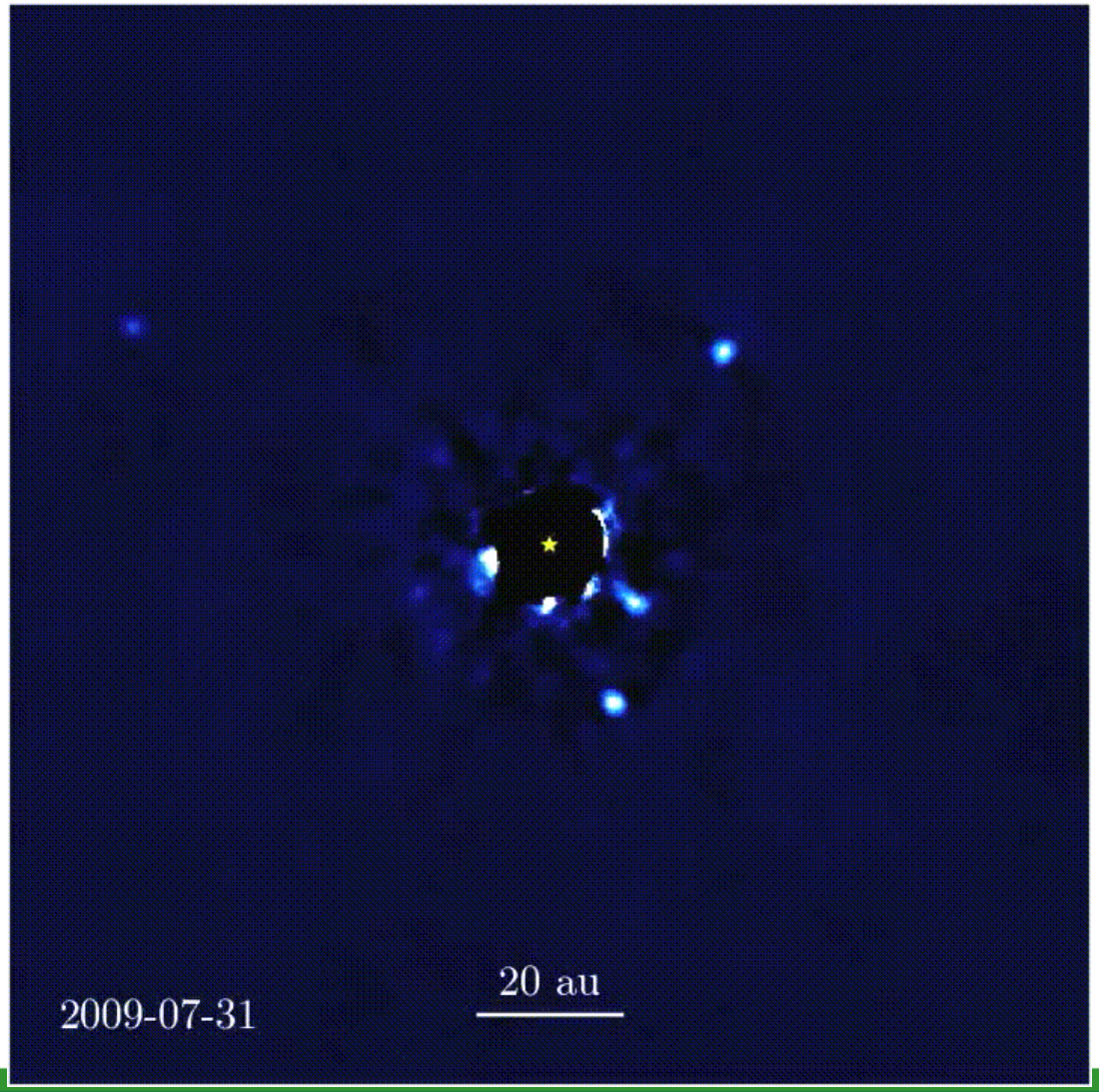
D = 129 ly

a = 14-70 au

uhol: 0,000 001°



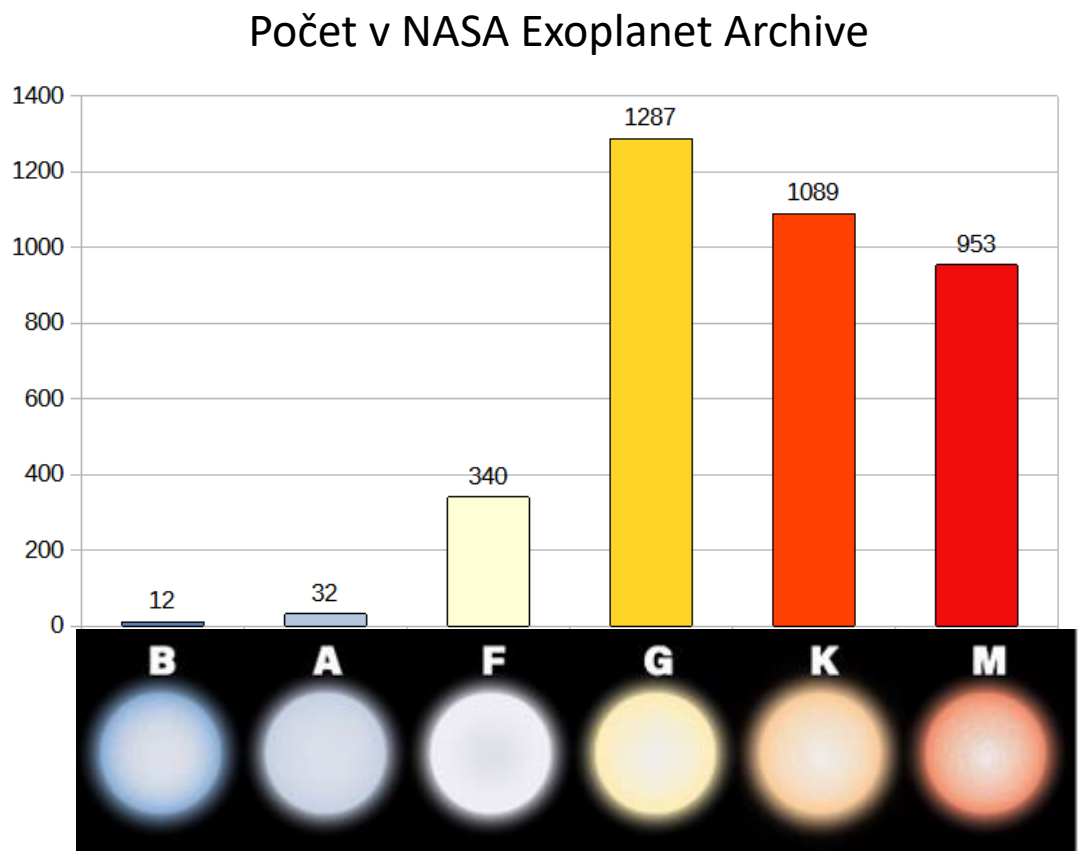
Marois a kol., 2008



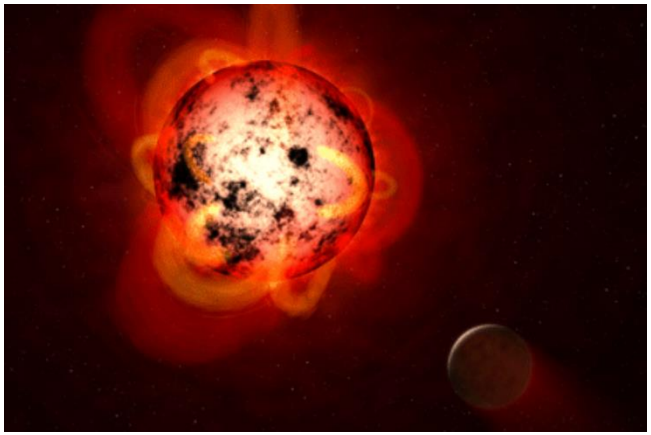
Spektrálne typy

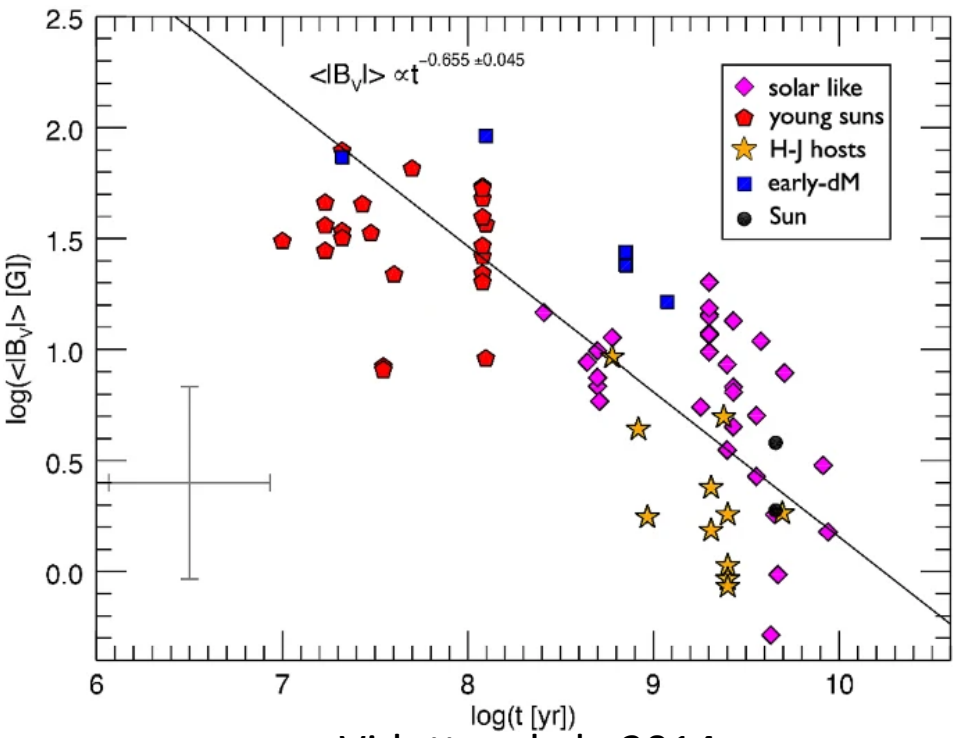
	T_{eff}	% v Galaxii
B	20 000°C	0,1%
A	8 500°C	0,7%
F	6 200°C	2,0%
G	5 500°C	3,5%
K	4 200°C	8,0%
M	3 000°C	80,0%

	L ($L_\odot$)	D (ly)	T_{MS} (Gyr)
B	730	1 510	0,1
A	26	285	1
F	4	112	5
G	1	56	10
K	1/10	18	50
M	1/150	4,5	100

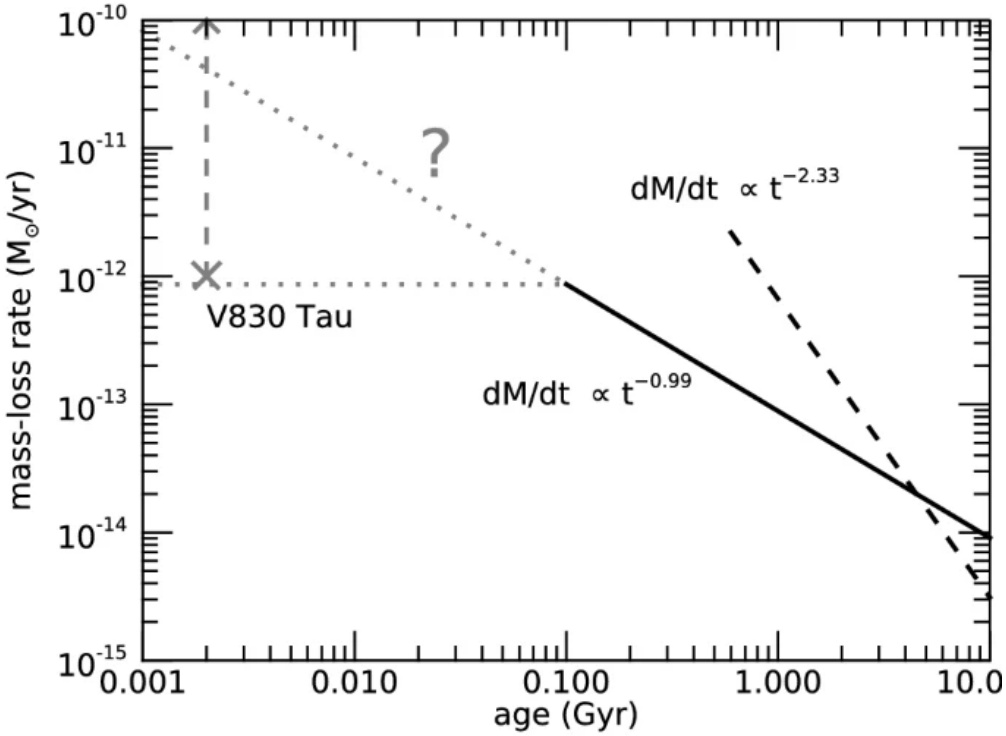


Evolúcia mladých hviezd



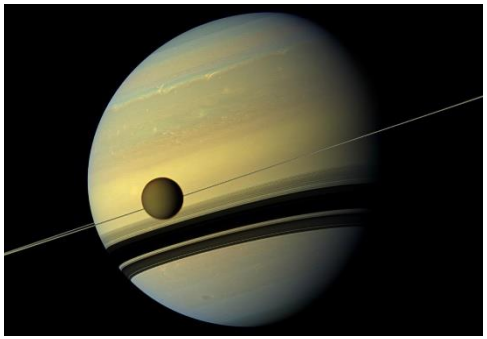


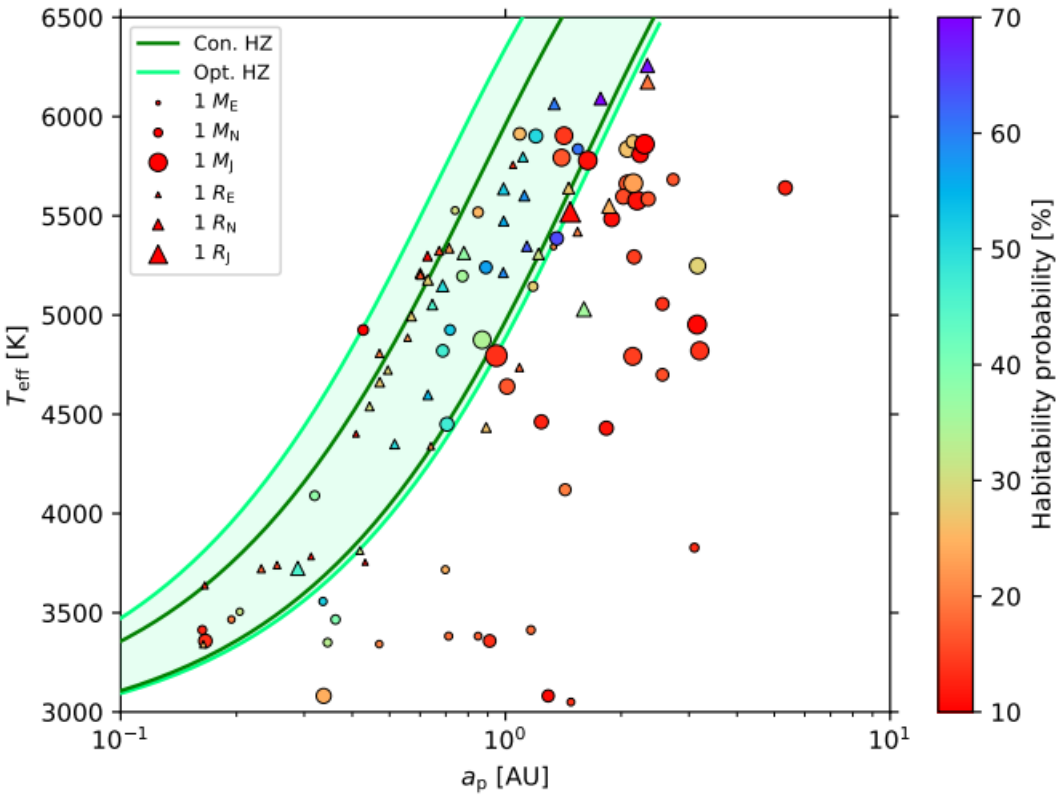
Vidotto a kol., 2014

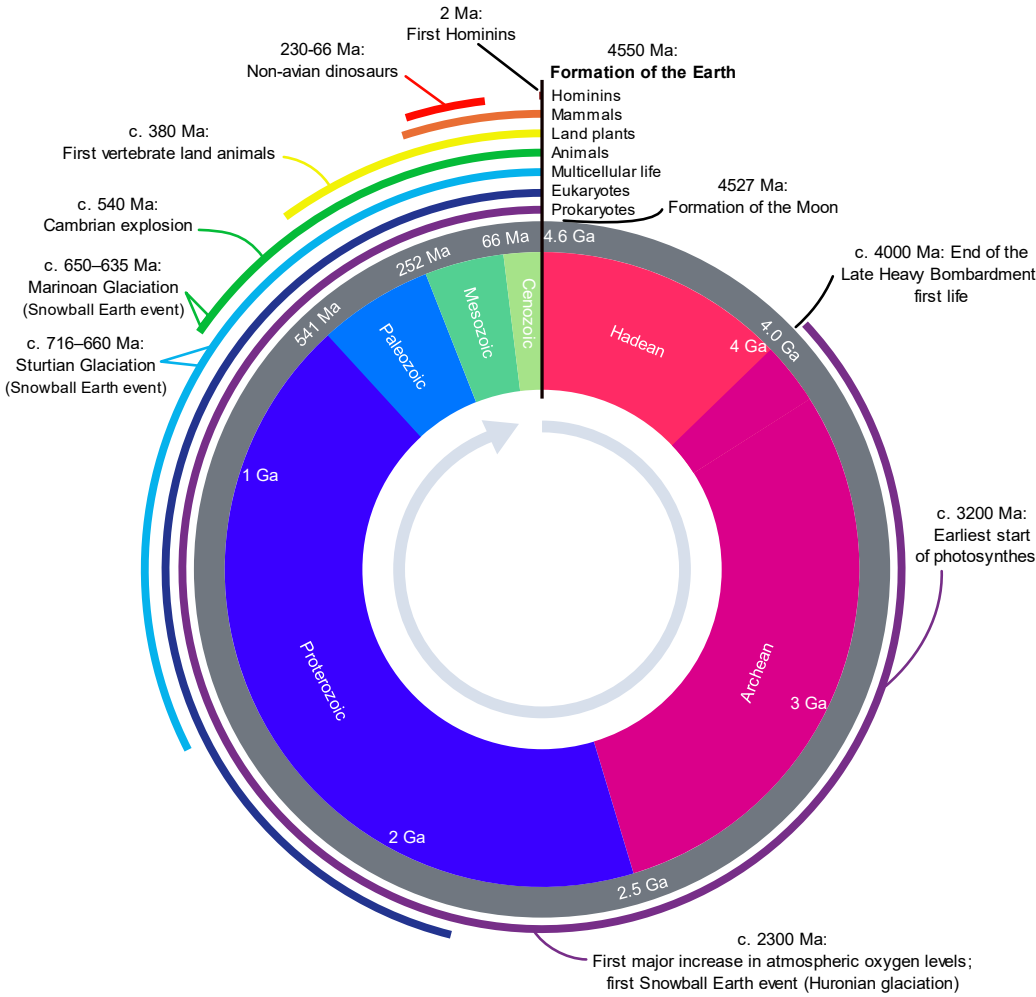


Johnstone a kol., 2015

Exomesiace a čas







Dobosová a kol., 2022

ŠTATISTICKÉ POČTY

Výber

5 farieb po 6 druhov telies s rôznym zastúpením

Výber

P_c(zelená) = 1/5

P_d(d10) = 2/7

P_n(8 alebo 80) = 1/10

Koľkokrát padne zelená d10 s číslom 8 alebo 80 z 1000 pokusov?

$$N = 1000 \times P_c \times P_d \times P_n = \frac{2000}{350} \sim 5{,}7$$

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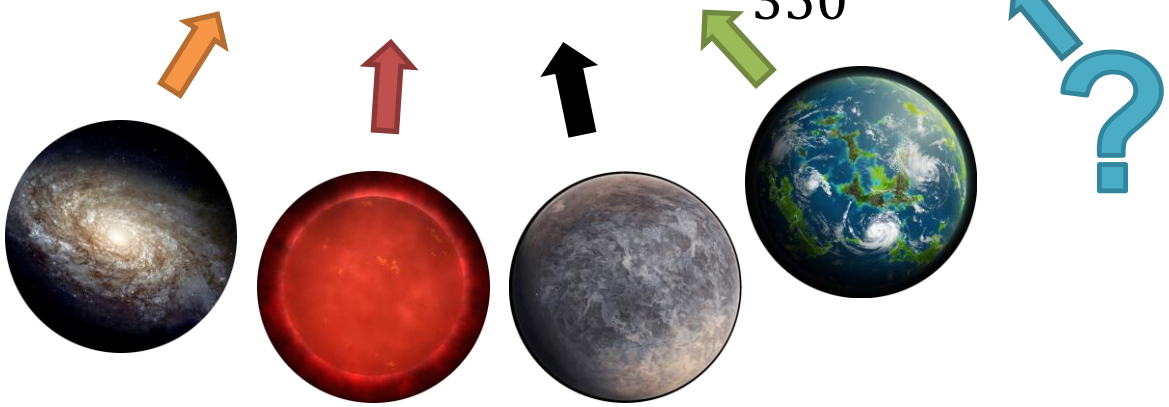


Drake-ova rovnica

$$N = R_S \times f_p \times n_e \times f_l \times f_i \times f_c \times L$$

Drake, 1961

Frank Drake
1930-2022

$$N = N_S \times f_p \times n_e \times f_l \times f_i \times f_c \times f_L$$

Drake-ova rovnica (1961)

D_k	$\langle D_k \rangle$	σD_k
N_s	$3{,}5 \times 10^{11}$	10^9
f_p	0,5	0,1
n_e	1	$1/\sqrt{3}$
f_l	0,5	0,1
f_i	0,2	0,1
f_c	0,2	0,1
f_L	10^{-6}	10^{-7}

$N = 3500$ ± 3363

D_k	$\langle D_k \rangle$	σD_k
R_s	2,25	1,75
f_p	0,9	0,1
n_e	0,4	0,3
f_l	1	0,1
f_i	10^{-9}	10^{-10}
f_c	0,2	0,1
L	304	100

$N = 4{,}92 \times 10^{-8}$ $\pm 6{,}12 \times 10^{-8}$

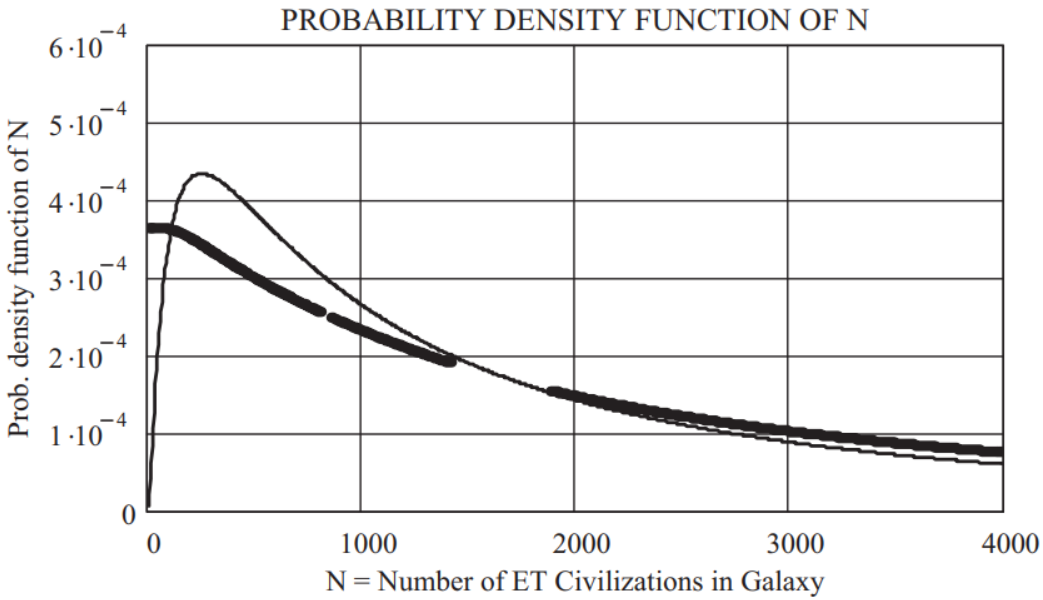
Maccone, 2010

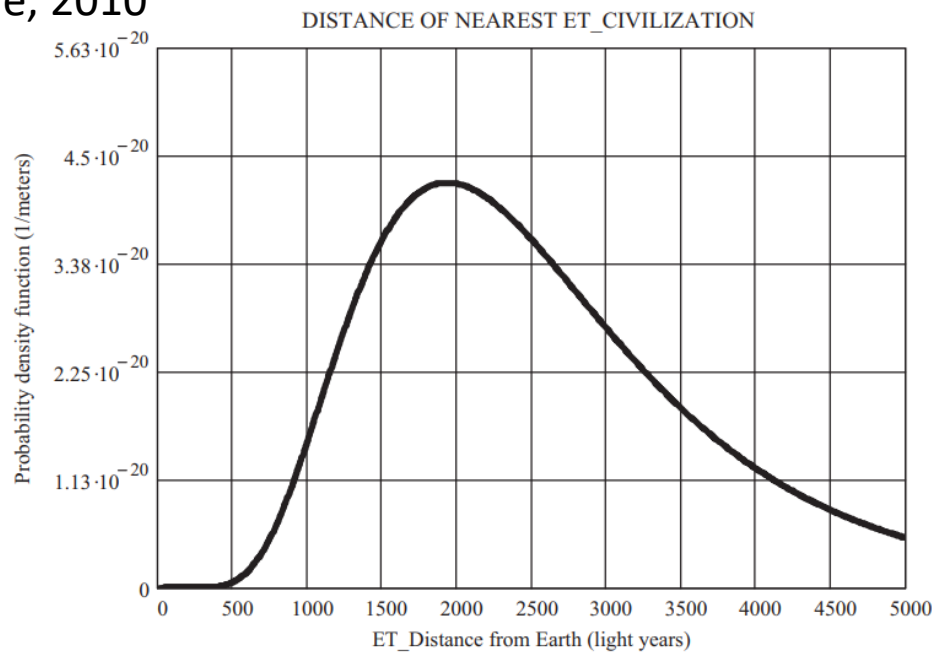
Claudio Maccone
1948-

$$N = \prod_{k=1}^{7} D_k \rightarrow Y = \ln(N) = \sum_{k=1}^{7} Y_k \ , \ N = e^Y$$

Štatistická Drake-ova rovnica

Maccone, 2010





stredná hodnota μ = 4590
smerodajná odchýlka σ = 11195
medián počtu (50:50) m = 1740

stredná hodnota μ = 2670 ly
smerodajná odchýlka σ = 1309 ly

	P	Civilizácia v tejto *D* (ly)
1σ	68%	1361 – 3979
2σ	95%	52 – 5288
3σ	99,7%	0 – 6597

https://www.aldebaran.cz/bulletin/2012_46_dra.php

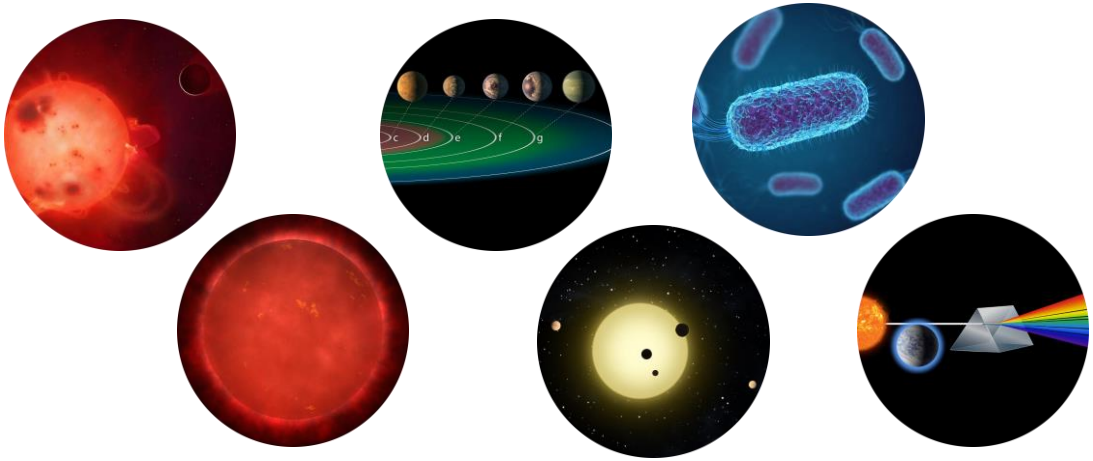
Upravená Drake-ova rovnica

Ward a Brownlee, 2000

$$N = N_S \times f_p \times f_{pm} \times n_e \times n_g \times f_l \times f_c \times f_L \times f_m \times f_j \times f_{me} \times \cdots ?$$

Seager-ovej rovnica (2013)

$$N = N_S \times f_Q \times f_{HZ} \times f_O \times f_L \times f_S$$



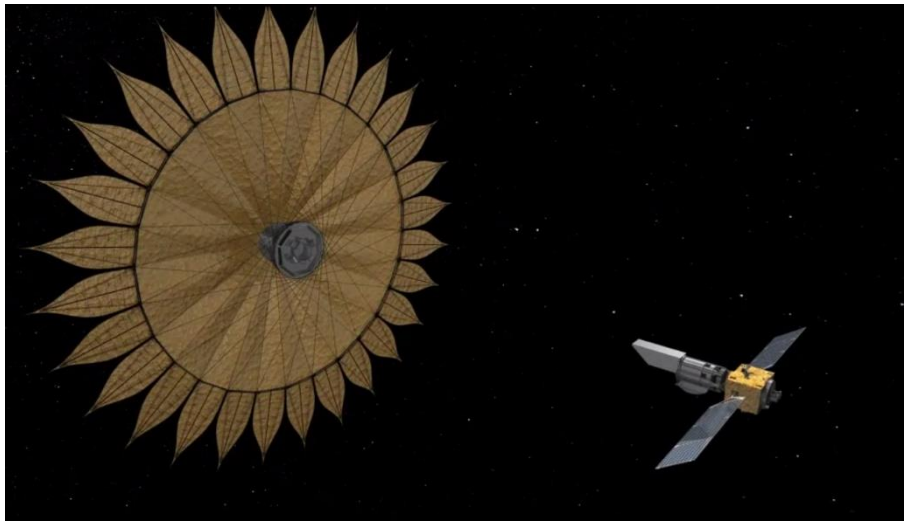
Sara Seagerová
1971-

Howard a kol., 2010:

23% hviezd majú planétu 0,5-2 M_E

Gowanlock a kol., 2011:

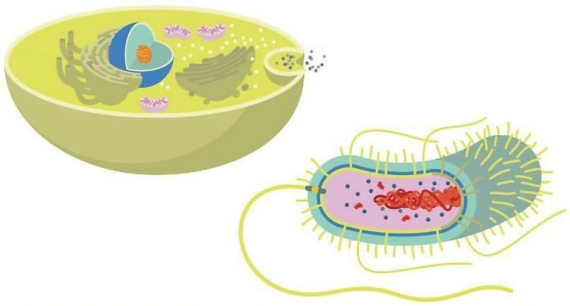
~5% hviezd má 0,1-10 M_E planétu v HZ

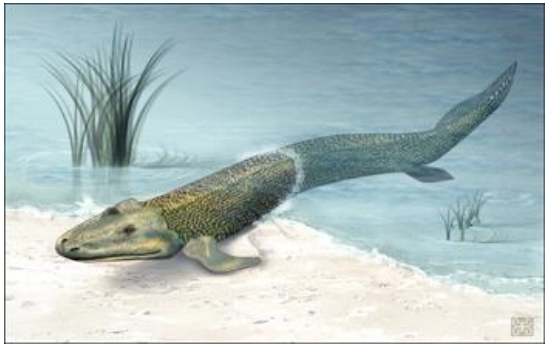


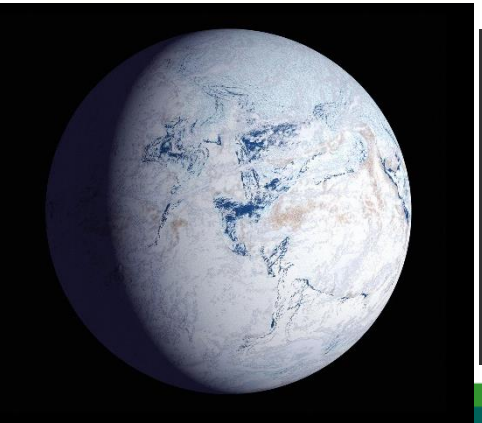
Ťažké kroky vývoja

Forgan, 2009 – existujú evolučné skoky, ktoré nie každý život zvládne, ale musí prekonať, aby dospel do inteligentného štádia

N_{stage}, τ_i, τ_{int}, $P_{i,kill}$







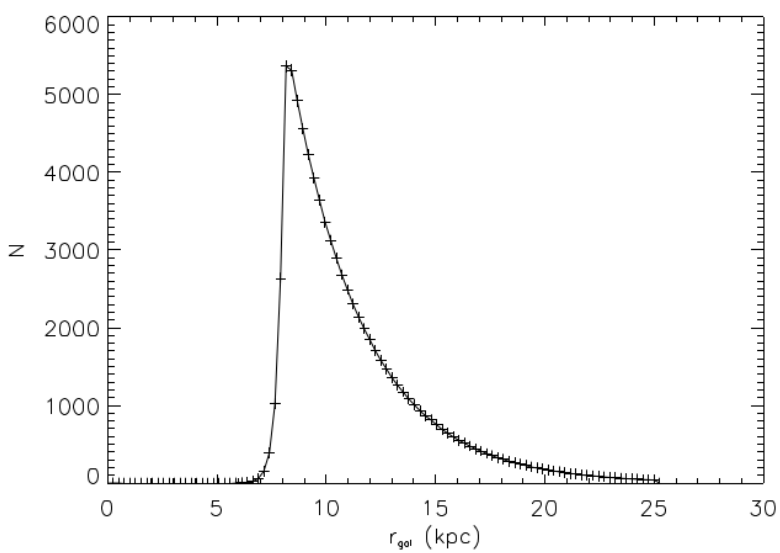
Scenár – panspermia

- susedné planéty v HZ
- nie iné hviezdy

Table 2. *Statistics for the Panspermia hypothesis*

Variable	Mean	Standard deviation
$N_{planets,total}$	4.7295×10^8	401 530
$N_{inhabited}$	690 983.63	53
$N_{fledgling}$	75 923.04	8
$N_{destroyed}$	37 958.07	11
$N_{advanced}$	37 964.97	20

Forgan, 2009



$$I_{inhabit} = \begin{cases} -1 & \text{Biosphere which has been annihilated} \\ 0 & \text{Planet is lifeless} \\ 1 & \text{Planet has primitive life} \\ 2 & \text{Planet has intelligent life} \\ 3 & \text{Planet had intelligent life, but it destroyed itself} \\ 4 & \text{Planet has an advanced civilization} \\ 5 & \text{Planet has been colonized by an advanced civilization.} \end{cases} \quad (13)$$

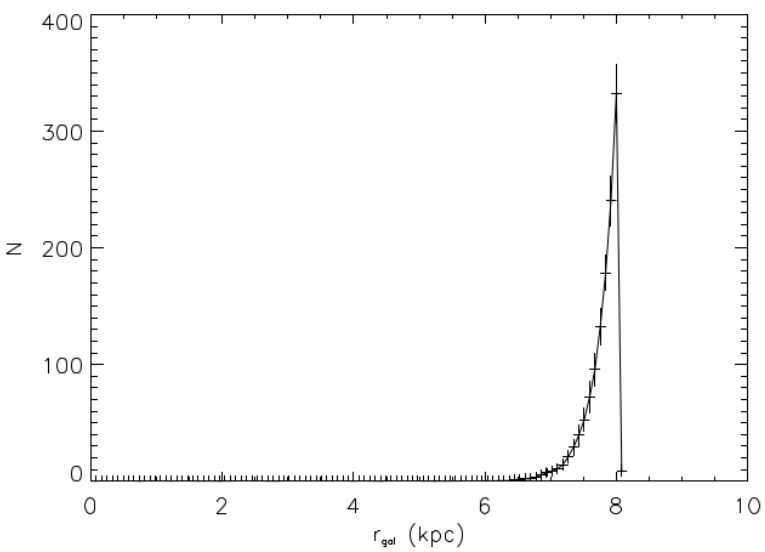
Scenár – vzácny život

- planéta v HZ
- hviezda < 2 $M_\odot$
- sused Jupiter

Table 3. *Statistics for the Rare Life hypothesis*

Variable	Mean	Standard deviation
$N_{planets,total}$	4.770×10^8	381
$N_{inhabited}$	80 090	22
$N_{fledgling}$	728.6	1
$N_{destroyed}$	367.3	0
$N_{advanced}$	361.2	2

Forgan, 2009



$$I_{inhabit} = \begin{cases} -1 & \text{Biosphere which has been annihilated} \\ 0 & \text{Planet is lifeless} \\ 1 & \text{Planet has primitive life} \\ 2 & \text{Planet has intelligent life} \\ 3 & \text{Planet had intelligent life, but it destroyed itself} \\ 4 & \text{Planet has an advanced civilization} \\ 5 & \text{Planet has been colonized by an advanced civilization.} \end{cases} \quad (13)$$

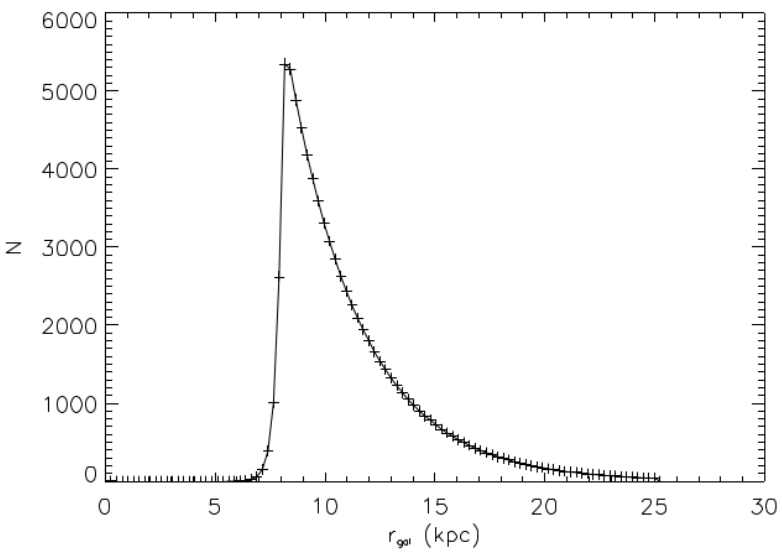
Scenár – zajac a korytnačka

- život bežný
- vývoj komplexný
- rýchlo a zbesilo
- pomaly a neisto

Table 4. *Statistics for the Tortoise and Hare hypothesis*

Variable	Mean	Standard deviation
$N_{planets,total}$	4.770×10^8	1593
$N_{inhabited}$	684 399.26	2
$N_{fledgling}$	75 200.3	20
$N_{destroyed}$	43 626.82	1
$N_{advanced}$	31 573.52	20

Forgan, 2009



$$I_{inhabit} = \begin{cases} -1 & \text{Biosphere which has been annihilated} \\ 0 & \text{Planet is lifeless} \\ 1 & \text{Planet has primitive life} \\ 2 & \text{Planet has intelligent life} \\ 3 & \text{Planet had intelligent life, but it destroyed itself} \\ 4 & \text{Planet has an advanced civilization} \\ 5 & \text{Planet has been colonized by an advanced civilization.} \end{cases} \quad (13)$$

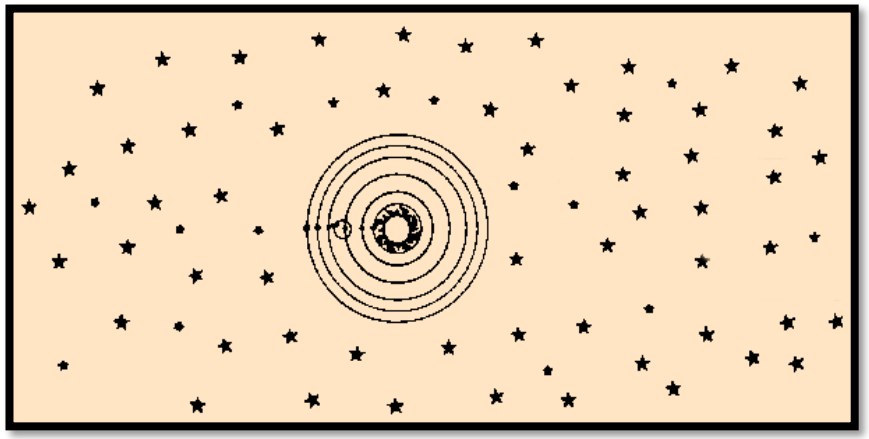
HĽADANIE MIMOZEMSKEJ INTELIGENCIE

Sme sami?

Vesmír je jediný, nekonečný, nemenný… V priestore … sa nachádza nekonečne veľa svetov rovnakých, ako ten náš… Hviezdy sú iné slnká s vlastnými planétami, ktoré majú prírodu rovnakú ako Zem a žijú tam zvieratá a obyvatelia

-- O nekonečnom vesmíre a svetoch, 1584

Giordano Bruno
(1548-1600)



GIORDA-
NO BRVNO
Nolano.

De l' infinito vniuerſo
et Mondi.

All' illuſtriſsimo Signor di
Mauuiſsiero.

Stampato in Venetia.
Anno. M. D. LXXXIIII.

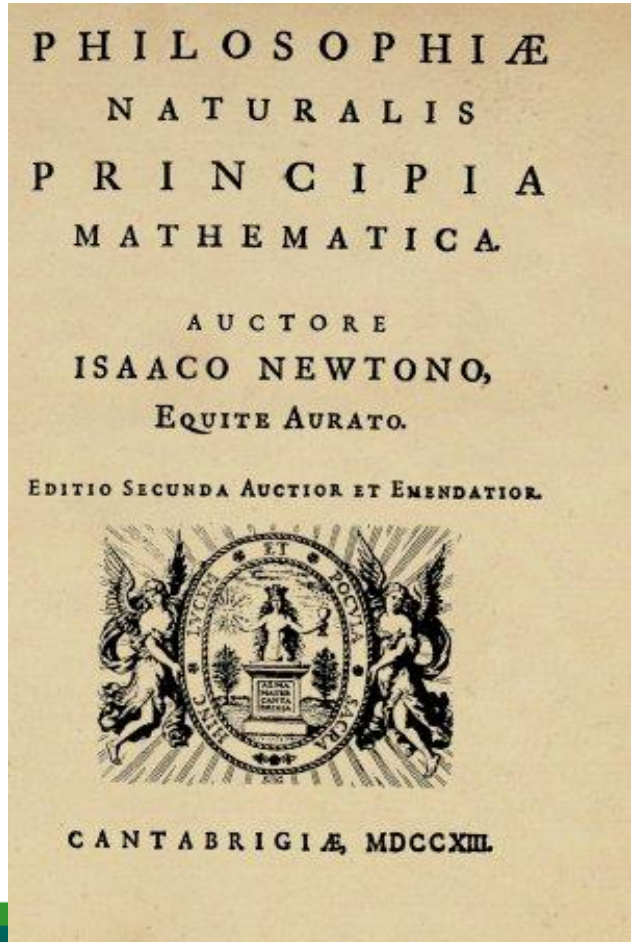
[N. 69].

Sme sami?

Ak sú nehybné hviezdy stredmi podobných sústav, budú vystavané podľa podobného návrhu a podriadené vôli Boha.

-- Philosophiæ Naturalis Principia Mathematica, 1713

Isaac Newton
(1643-1727)



PHILOSOPHIÆ
NATURALIS
PRINCIPIA
MATHEMATICA.

AUCTORE
ISAACO NEWTONO,
EQUITE AURATO.

EDITIO SECUNDA AUCTIOR ET EMENDATIOR.

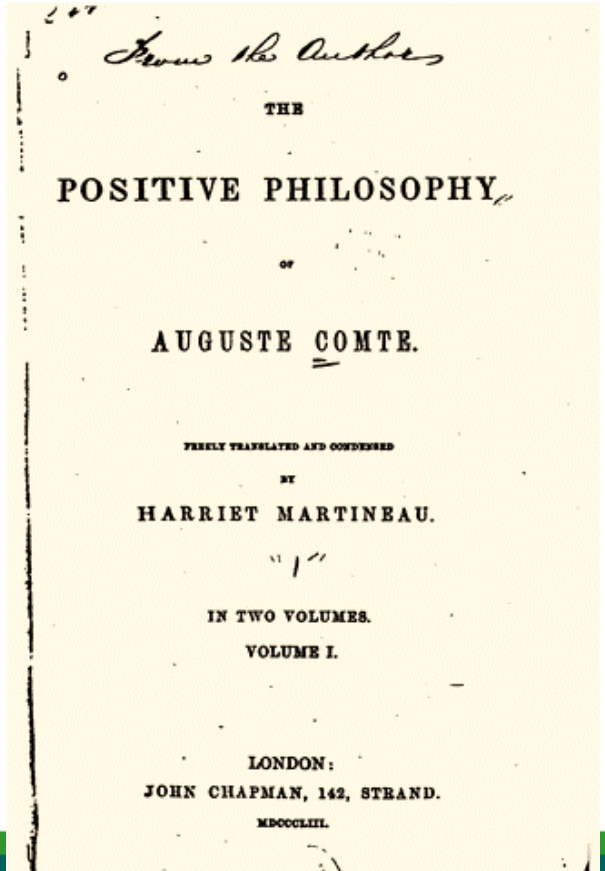
CANTABRIGIÆ, MDCCXIII.

Sme sami?

Vidíme, ako možno určiť ich tvary, vzdialenosti, veľkosti a ich pohyby, ale nikdy nebudeme vedieť nič o ich chemickom alebo mineralogickom zložení, a ešte menej, či na ich povrchu žije organizovaný život. Všetky fyzikálne, chemické, fyziologické a sociálne výskumy sú v prípade planét nepodstatné.

-- Pozitívna filozofia, 1853

Auguste Comte
(1798-1857)



From the Author

THE

POSITIVE PHILOSOPHY

OF

AUGUSTE COMTE.

FREELY TRANSLATED AND CONDENSED

BY

HARRIET MARTINEAU.

IN TWO VOLUMES.

VOLUME I.

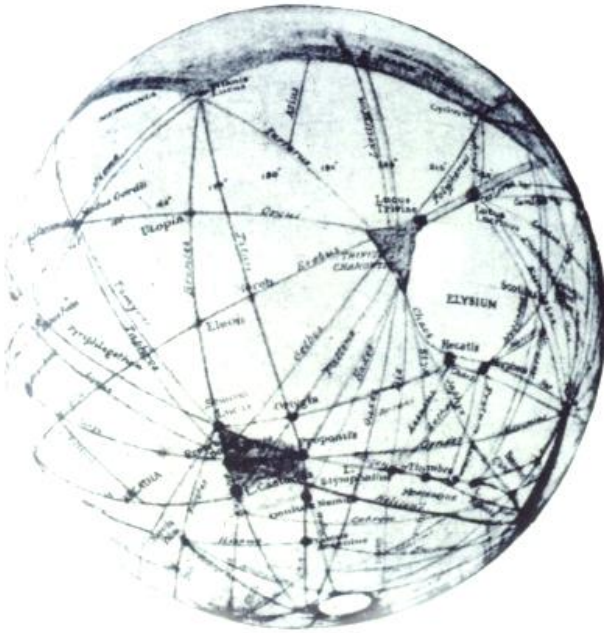
LONDON:
JOHN CHAPMAN, 142, STRAND.
MDCCCLIII.

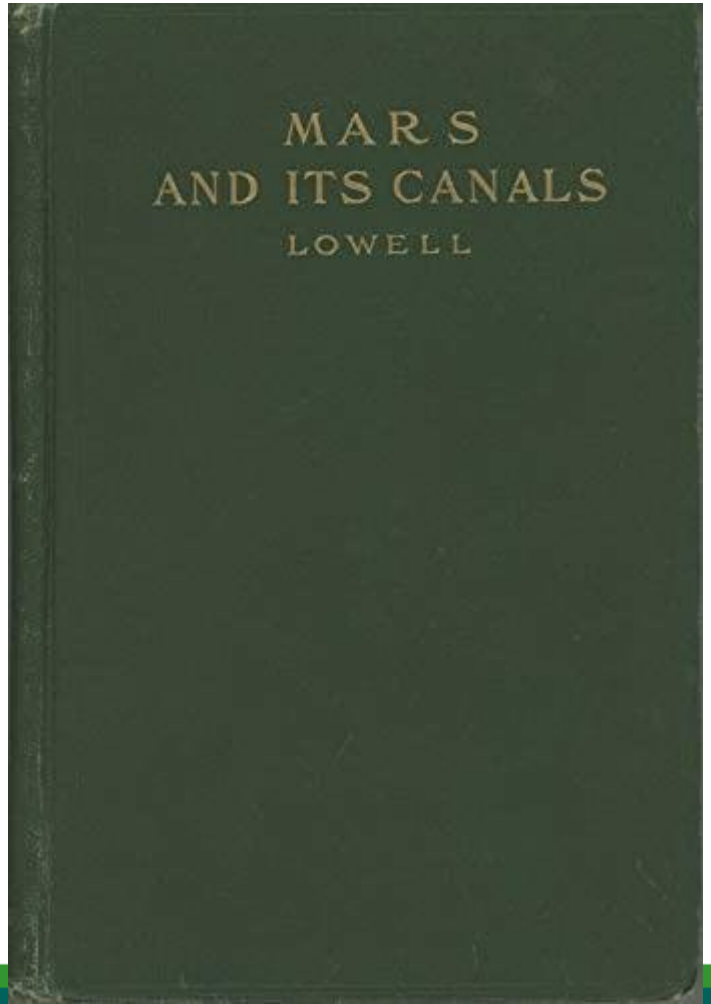
Sme sami?

Obyvatelia by Mars museli zavlažovať... Nepoznáme prírodnú teóriu, ktorá by vysvetľovala výskyt týchto čiar.

-- Mars, 1895

Percival L. Lowell
(1855-1916)

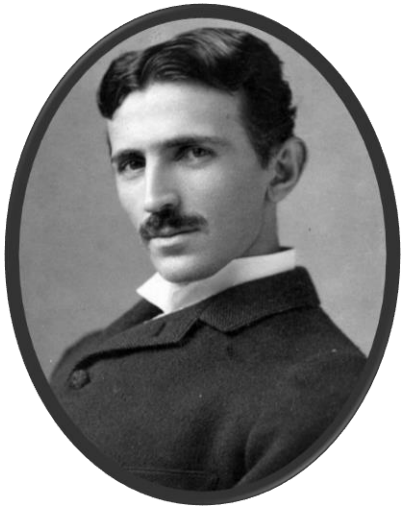




Sme sami?

1896: Bezdrôtová elektrická prenosová sústava by mohla byť použitá na kontakt s Marsom

1899: Pri experimentoch sa mu zdalo, že zachytil opakujúci sa signál



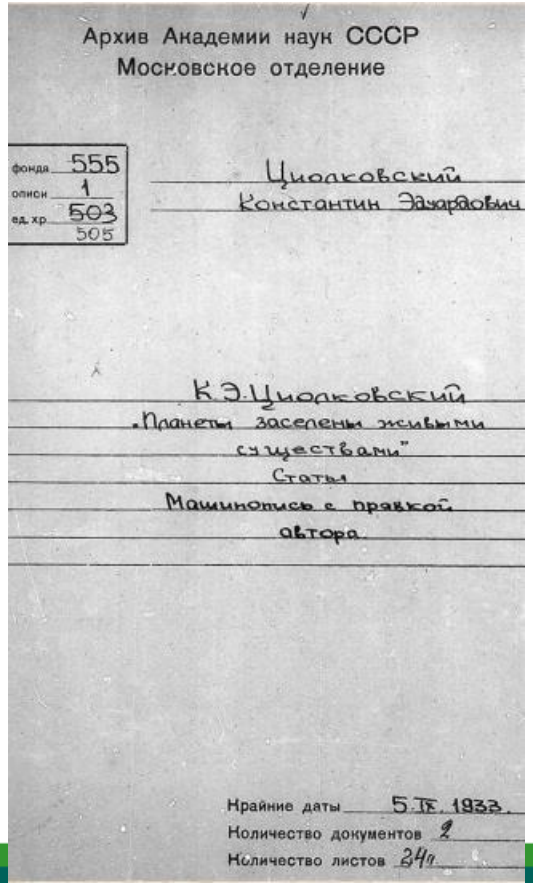
Nikola Tesla
(1856-1943)

Sme sami?

Ľudia popierajú prítomnosť inteligentných bytostí na planétach vesmíru lebo: 1) Ak existujú, už by Zem navštívili, 2) Ak také civilizácie existovali, poskytli by nám náznaky svojej prítomnosti.

-- Planéty obývajú živé bytosti, 1933

Konstantin E. Ciolkovskij
(1857-1935)



Архив Академии наук СССР
Московское отделение

фонда 555
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ед. хр. 503
505

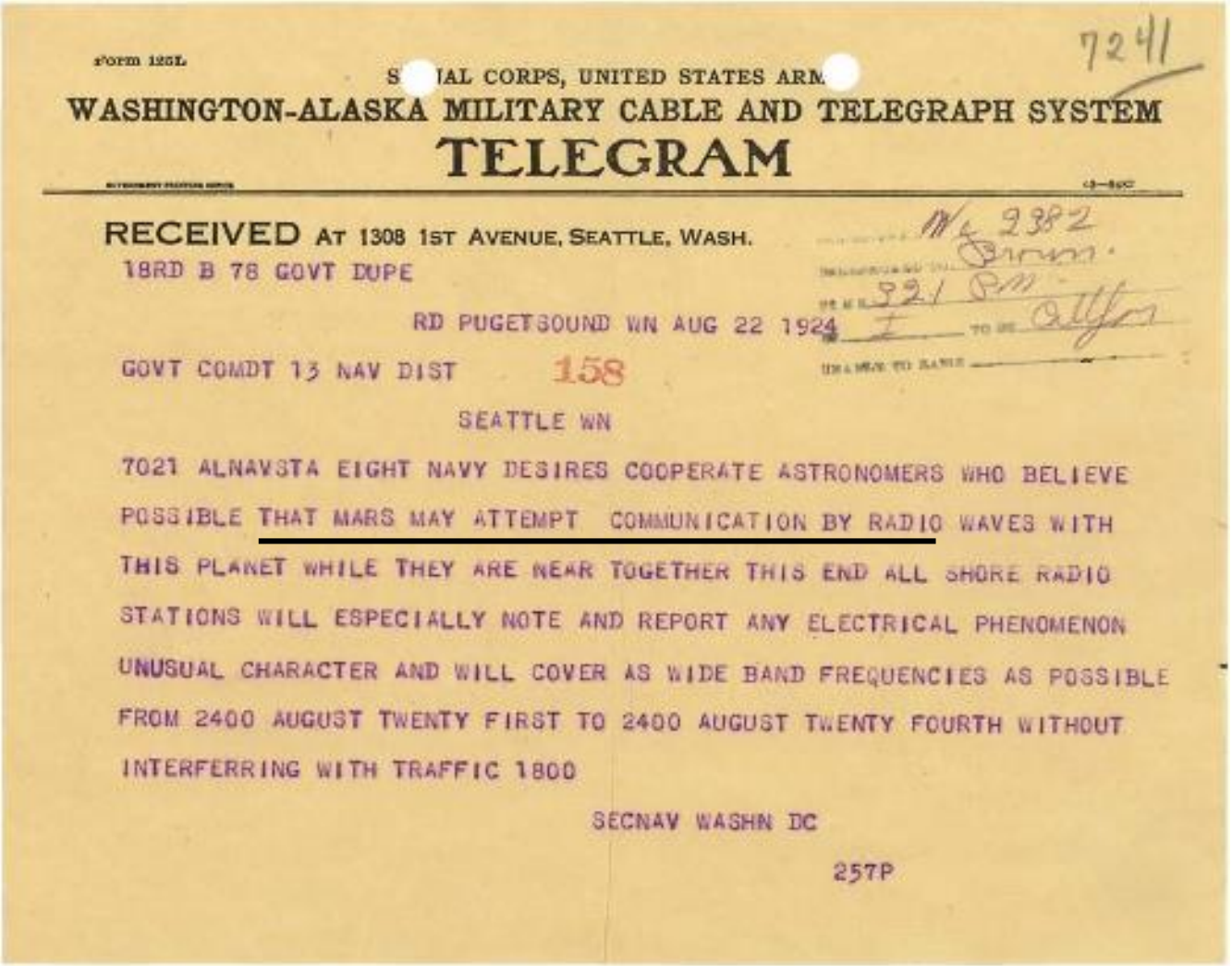
Циолковский
Константин Эдуардович

К.Э.Циолковский
„Планеты заселены живыми существами"
Статья
Машинопись с правкой автора

Крайние даты 5 IX. 1933.
Количество документов 2
Количество листов 34

Sme sami?

1934: USA sa pokúšajú zachytiť signály z Marsu



FORM 125L

SIGNAL CORPS, UNITED STATES ARMY

WASHINGTON-ALASKA MILITARY CABLE AND TELEGRAPH SYSTEM

TELEGRAM

7241

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18RD B 78 GOVT DUPE

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SEATTLE WN

7021 ALNAVSTA EIGHT NAVY DESIRES COOPERATE ASTRONOMERS WHO BELIEVE POSSIBLE THAT MARS MAY ATTEMPT COMMUNICATION BY RADIO WAVES WITH THIS PLANET WHILE THEY ARE NEAR TOGETHER THIS END ALL SHORE RADIO STATIONS WILL ESPECIALLY NOTE AND REPORT ANY ELECTRICAL PHENOMENON UNUSUAL CHARACTER AND WILL COVER AS WIDE BAND FREQUENCIES AS POSSIBLE FROM 2400 AUGUST TWENTY FIRST TO 2400 AUGUST TWENTY FOURTH WITHOUT INTERFERRING WITH TRAFFIC 1800

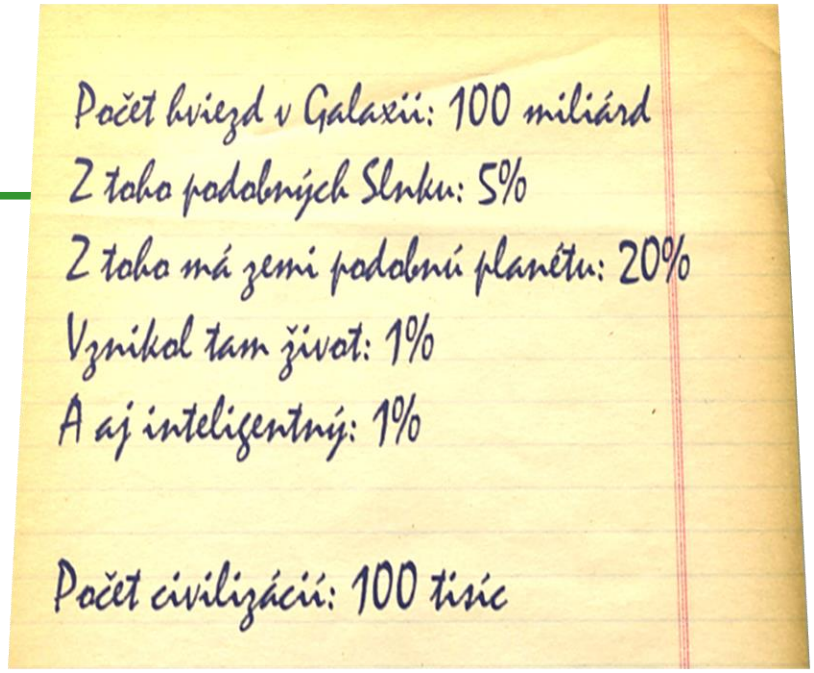
SECNAV WASHN DC

257P

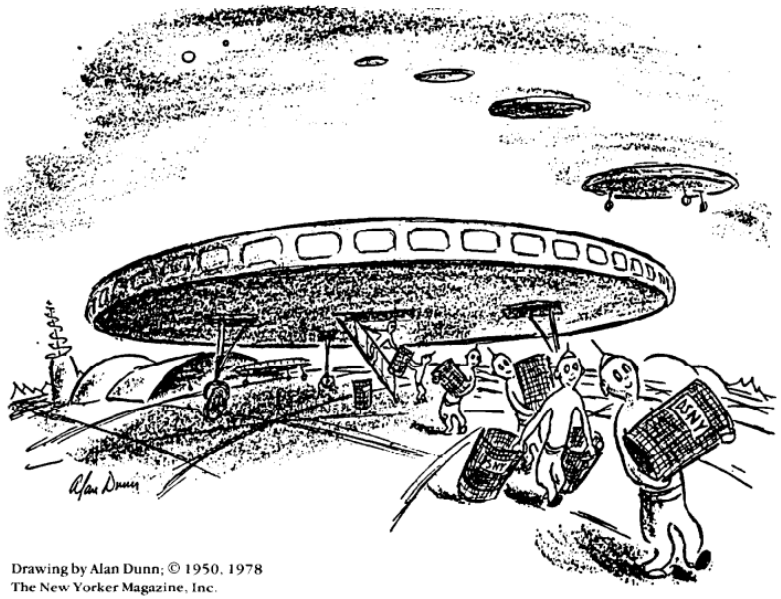
Sme sami?

Kde všetci sú?

-- Konverzácia počas cesty na obed, 1950

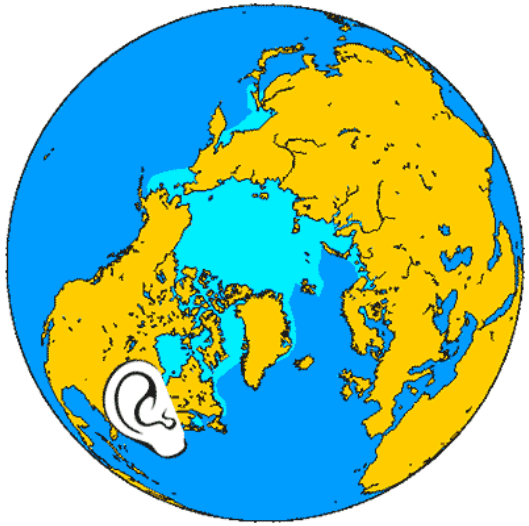


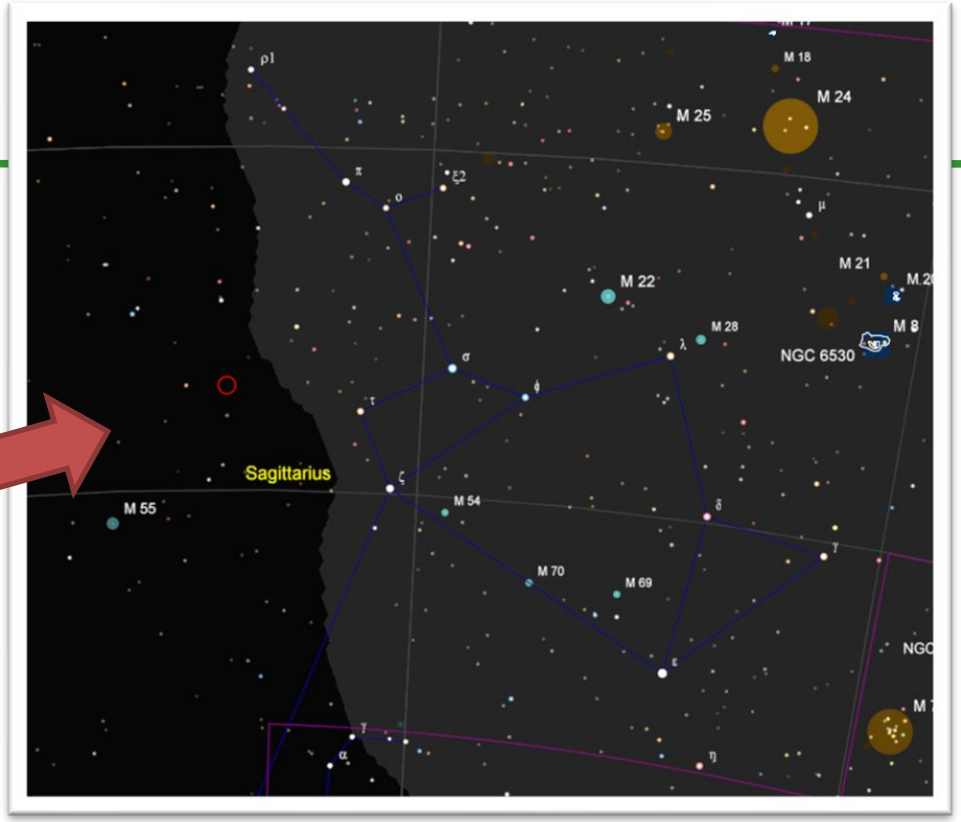
Enrico Fermi
(1901-1954)

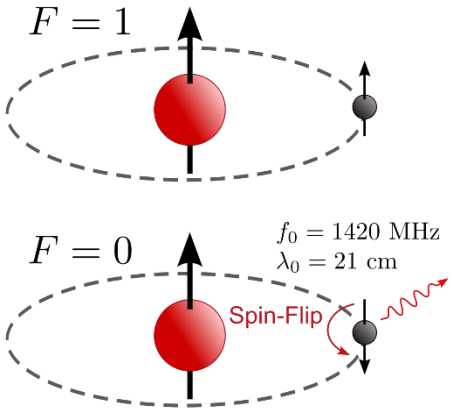


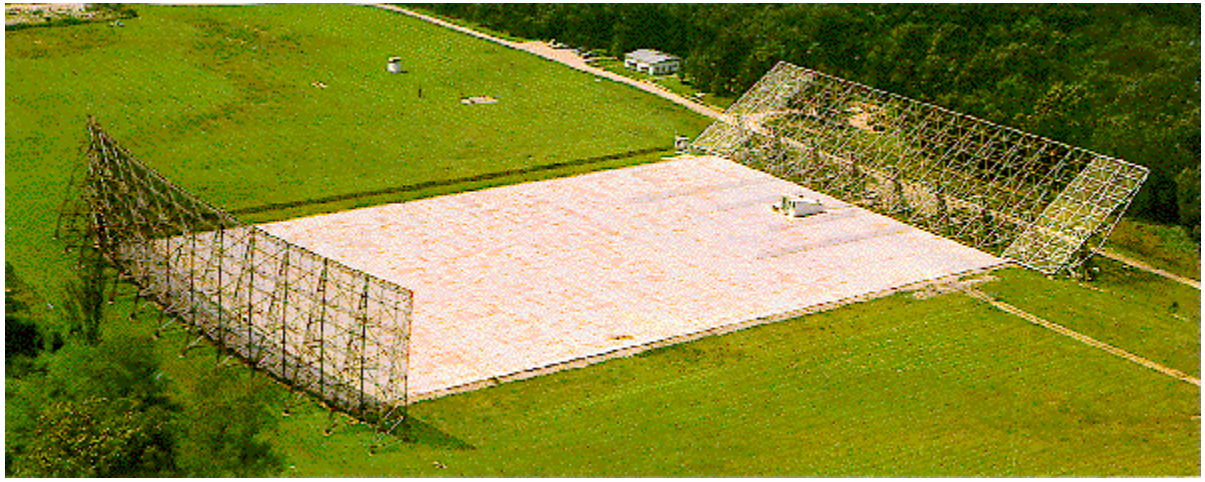
WOW signál

Big Ear Ohio State



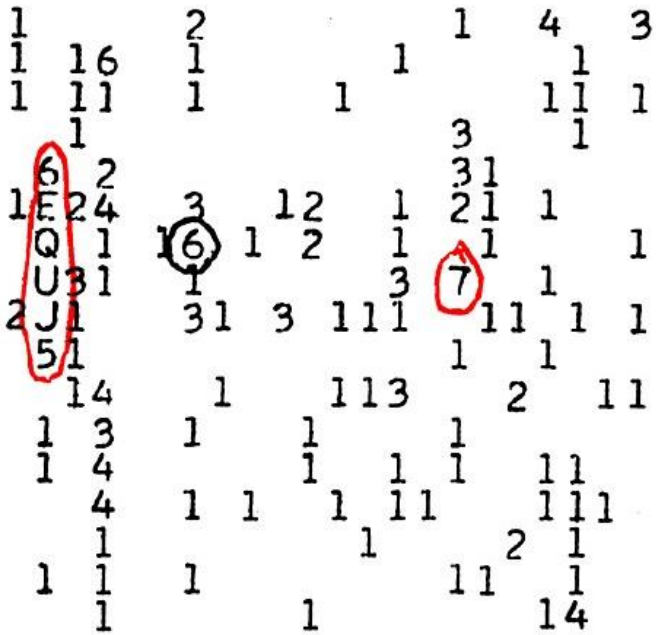


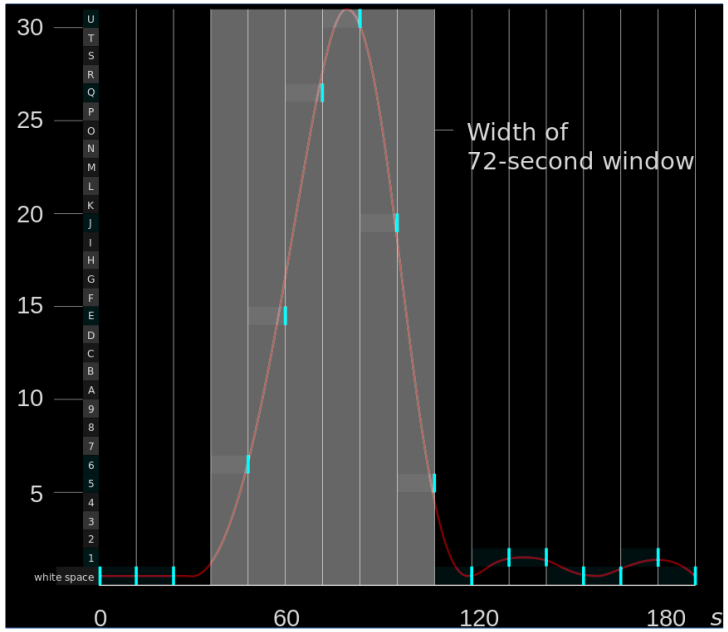


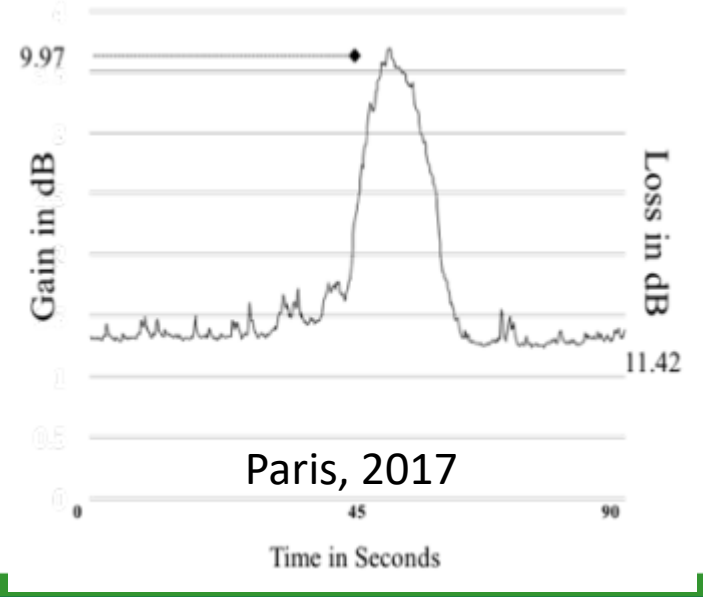


WOW signál

16.8.1977





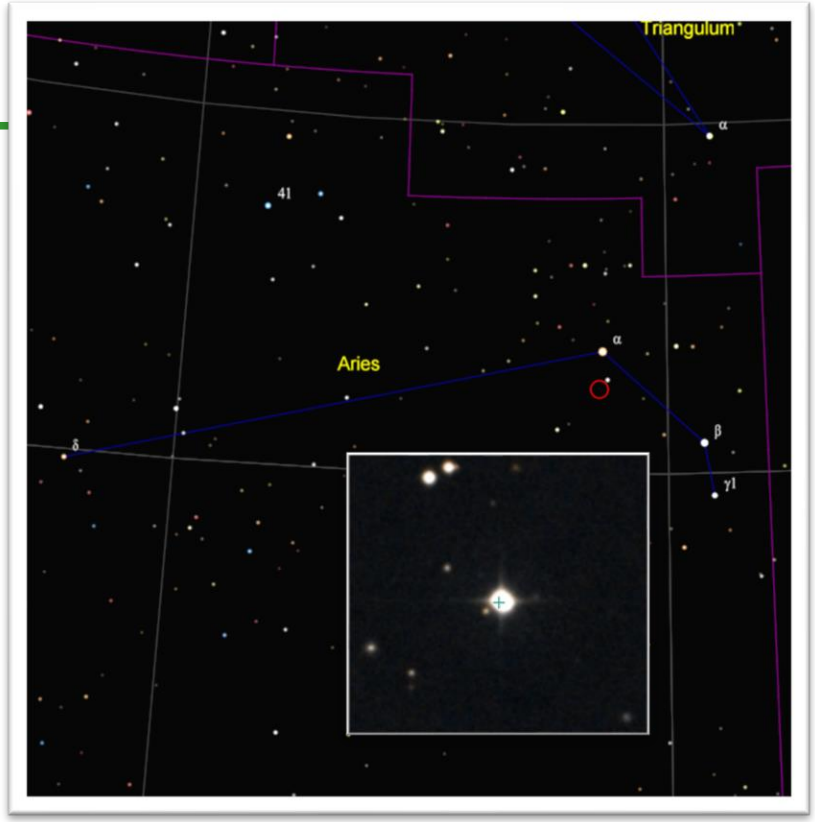


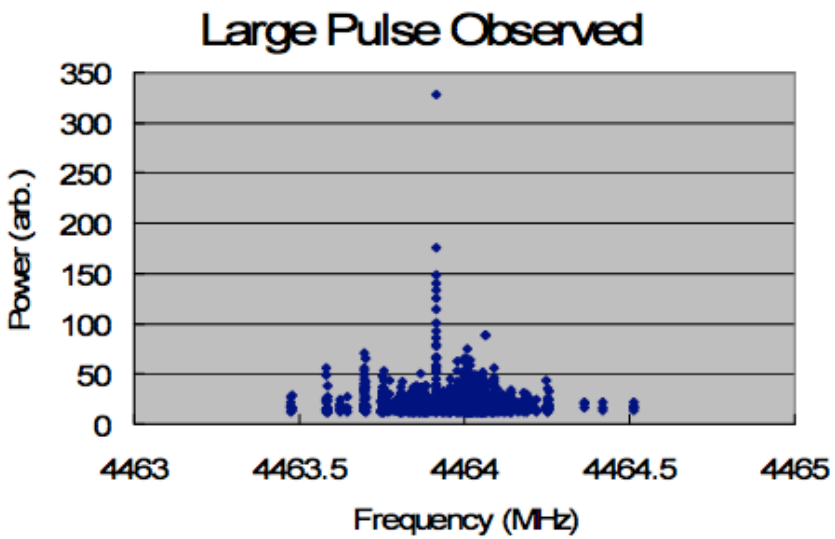
Paris, 2017

?

WOW signál č.2

Allen Telescope Array, 2010

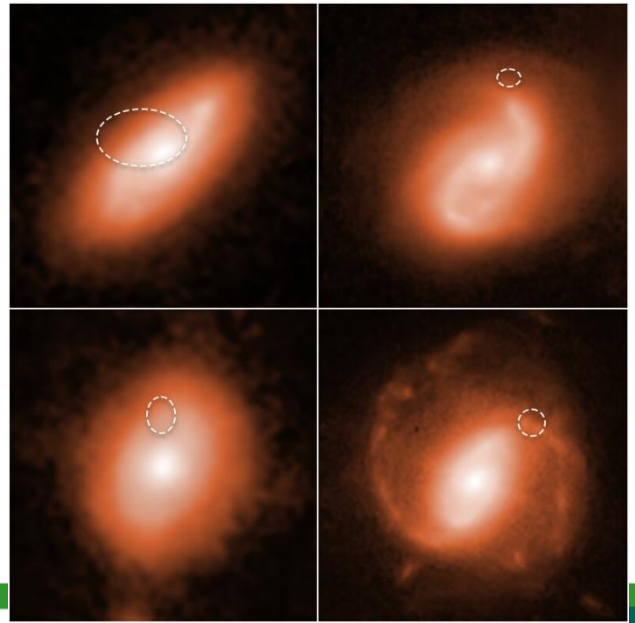


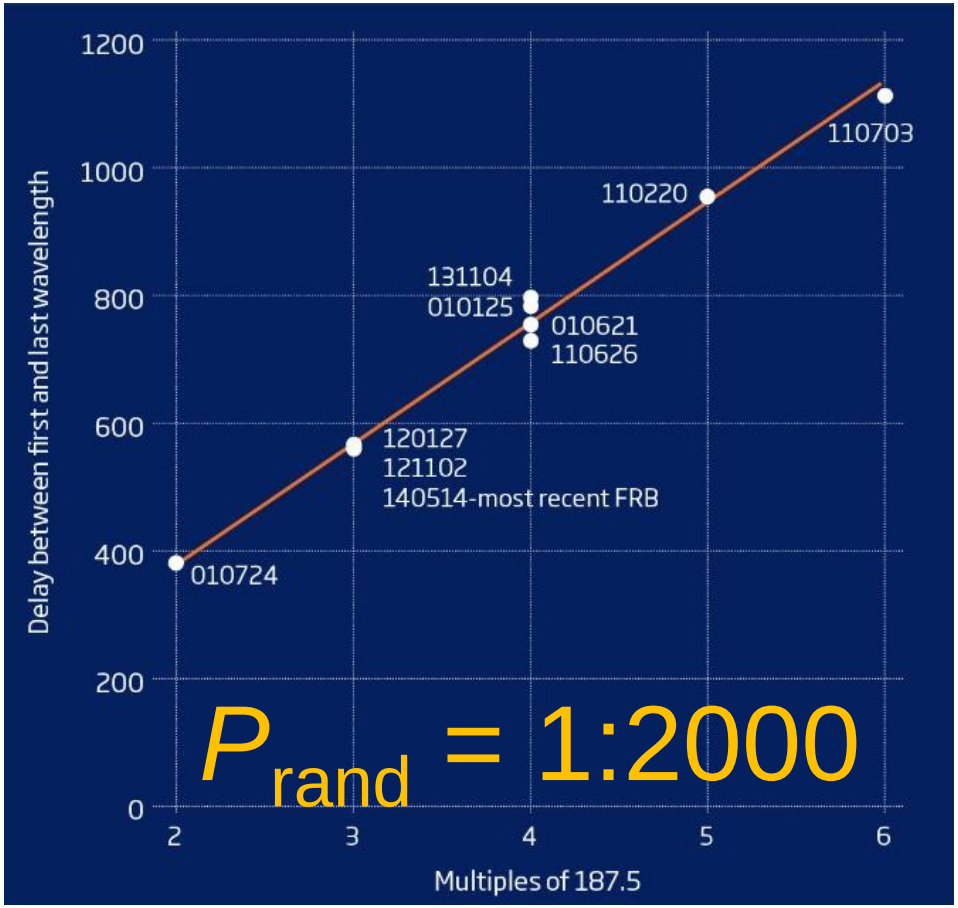


$\pi \times 1420{,}4$ MHz

WOW signál č.3

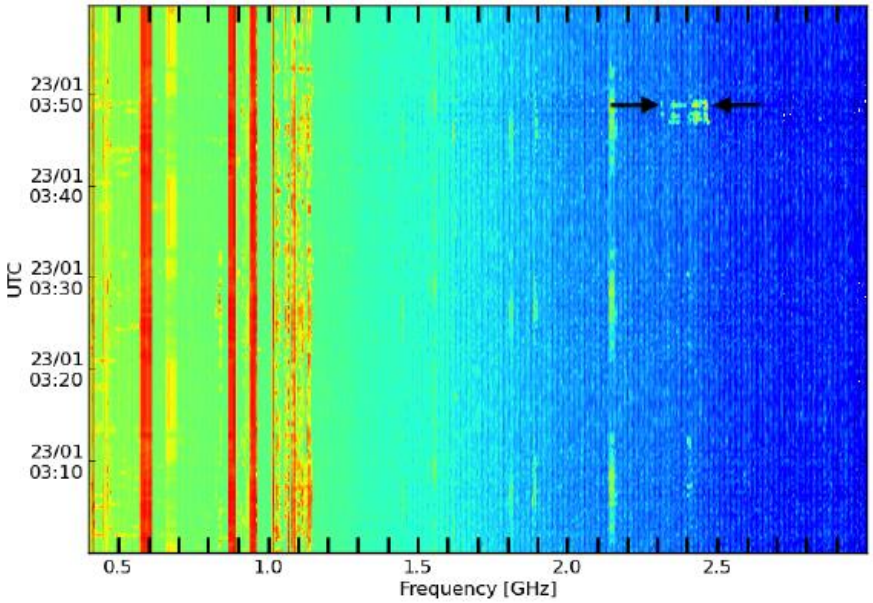
Parkes, 2001-2014

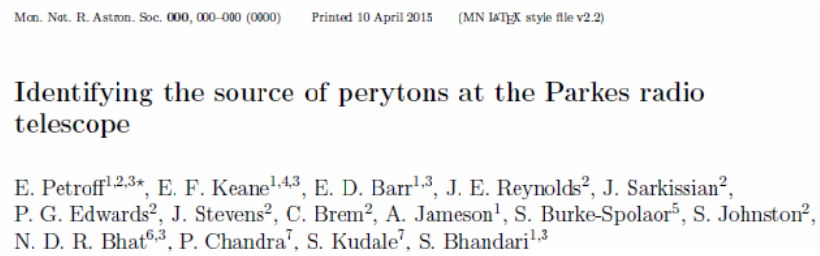




WOW signál č.4

Parkes, 1998-2015





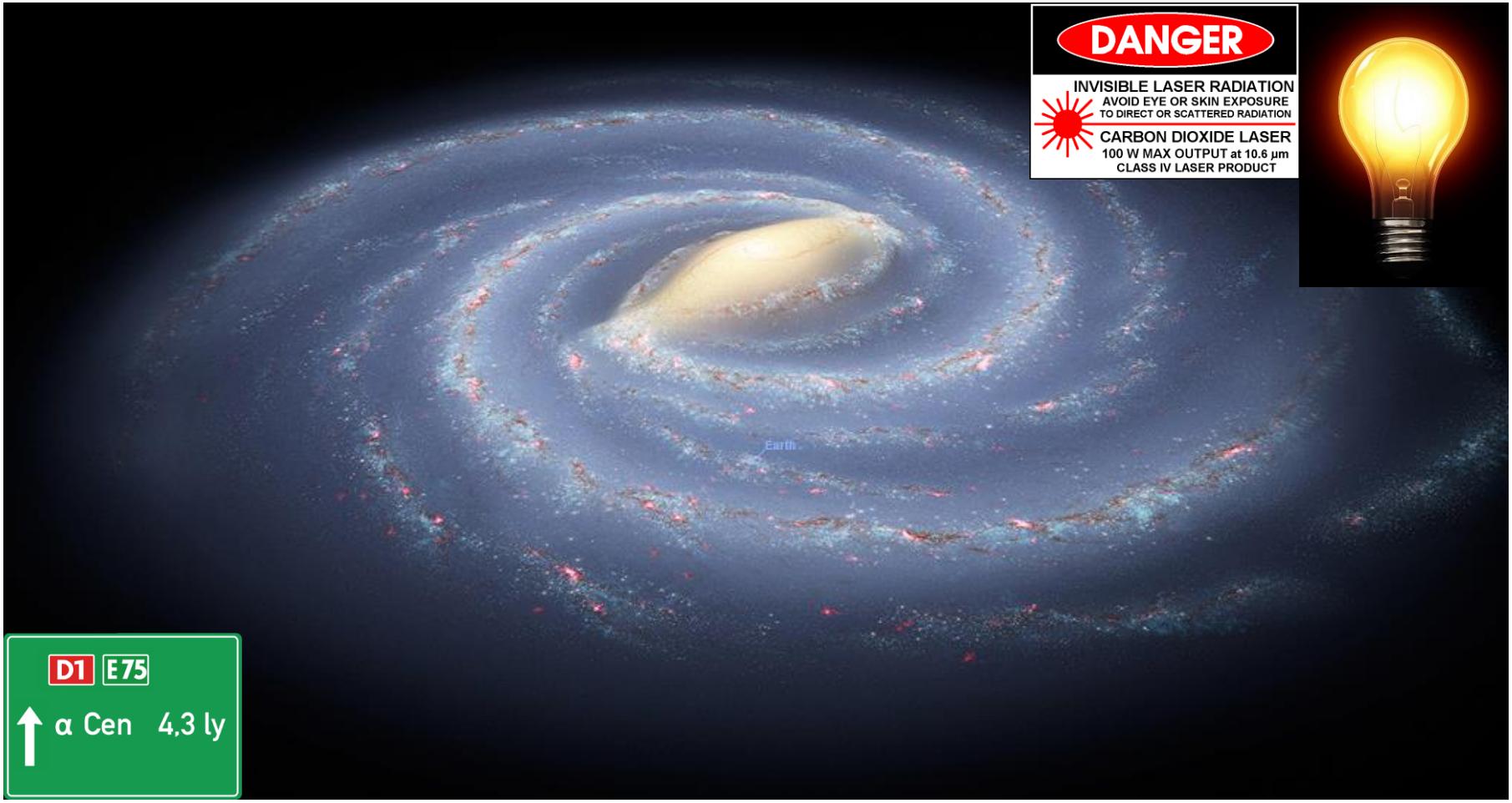
Mon. Not. R. Astron. Soc. **000**, 000–000 (0000) Printed 10 April 2015 (MN LaTeX style file v2.2)

Identifying the source of perytons at the Parkes radio telescope

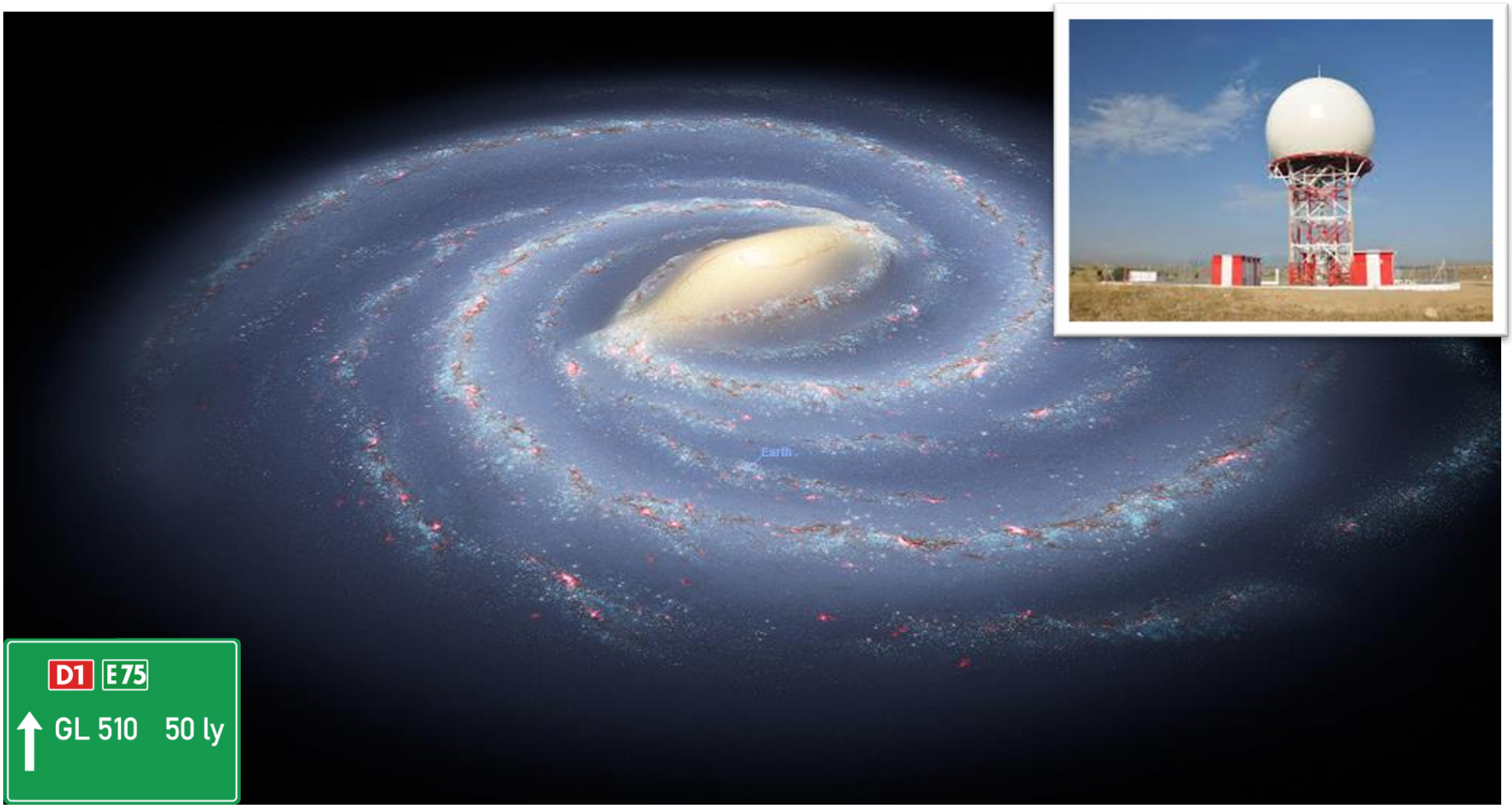
E. Petroff[1,2,3*], E. F. Keane[1,4,3], E. D. Barr[1,3], J. E. Reynolds[2], J. Sarkissian[2], P. G. Edwards[2], J. Stevens[2], C. Brem[2], A. Jameson[1], S. Burke-Spolaor[5], S. Johnston[2], N. D. R. Bhat[6,3], P. Chandra[7], S. Kudale[7], S. Bhandari[1,3]

Petroff a kol, 2016

Nechcú komunikovať?

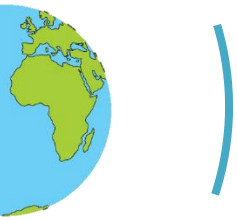


Nechcú komunikovať?



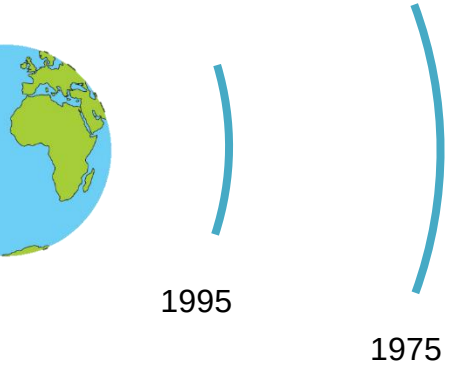
Nechcú komunikovať?

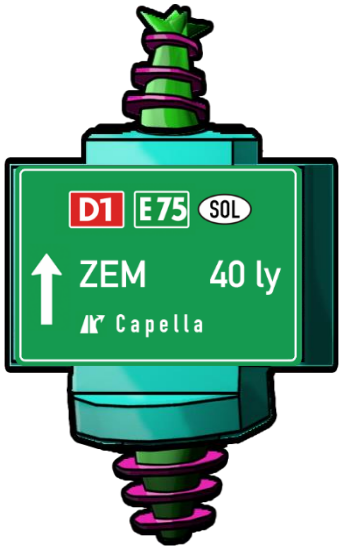
Rádiový hluk



1995

Rádiový hluk





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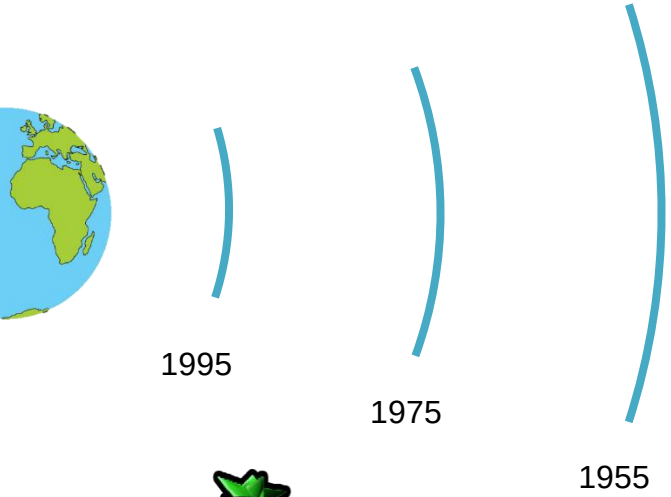

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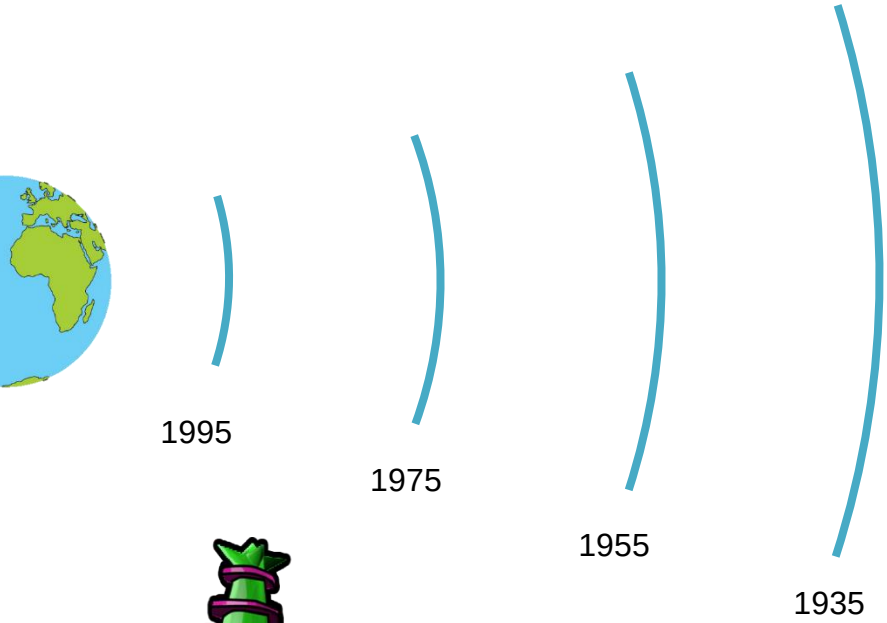
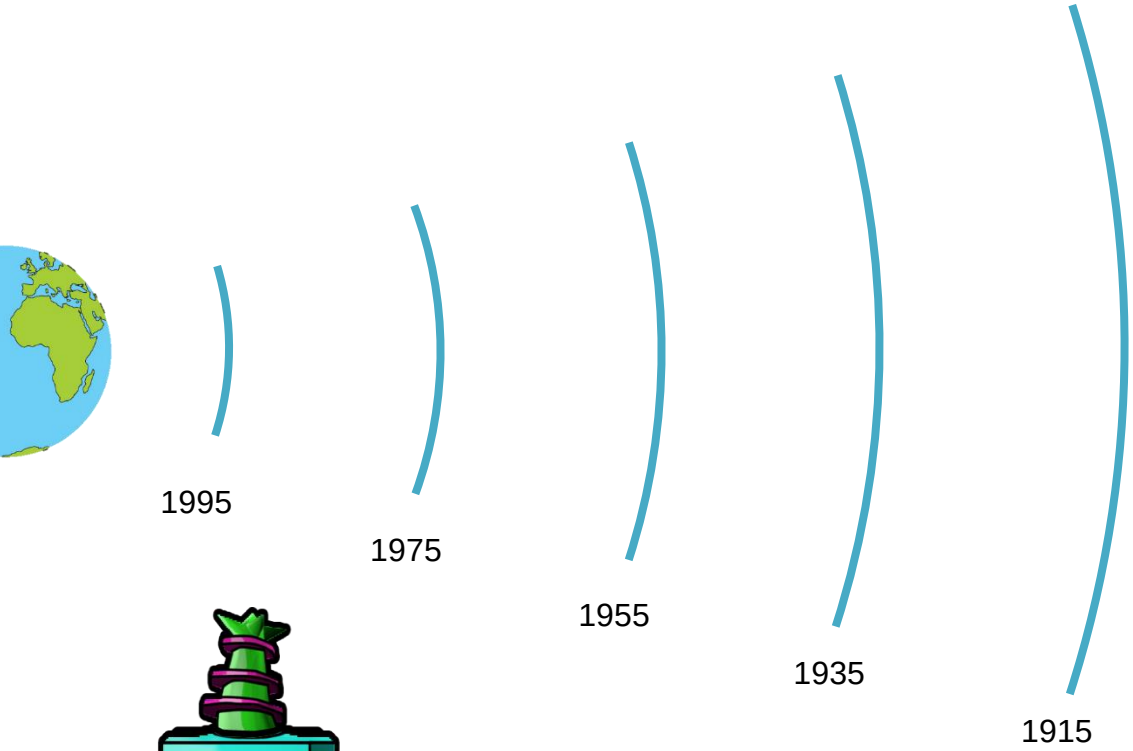
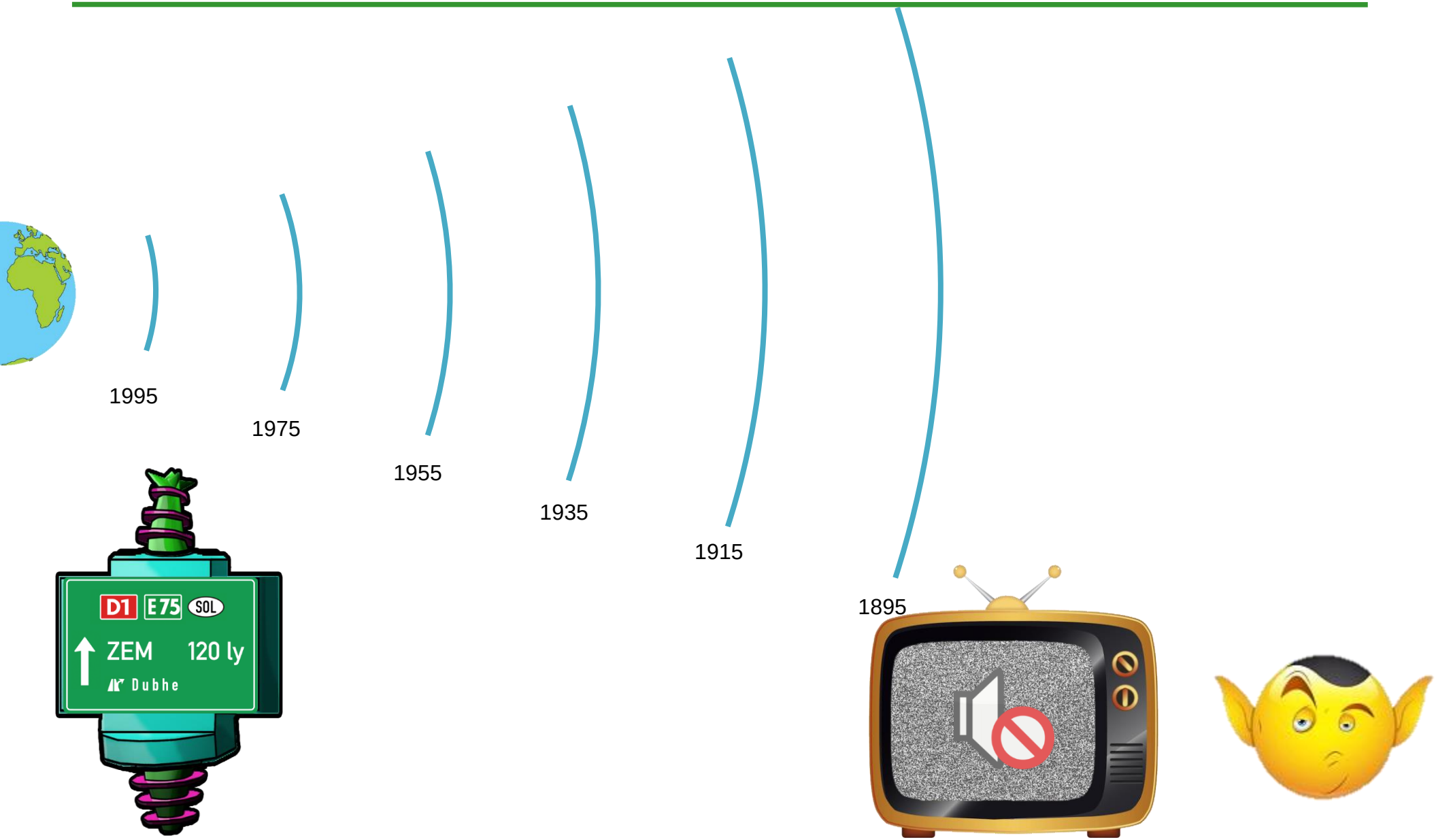


Rádiový hluk



Rádiový hluk



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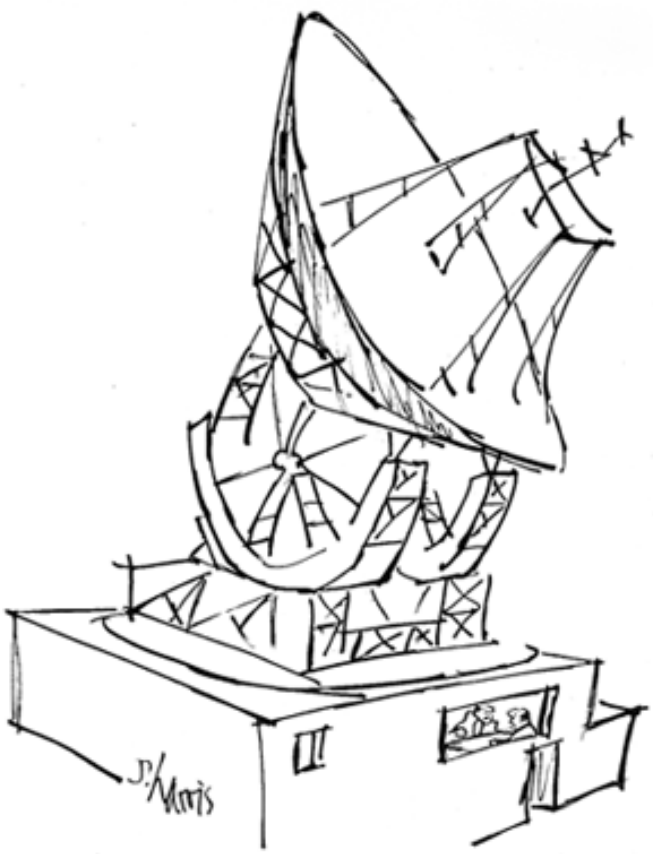
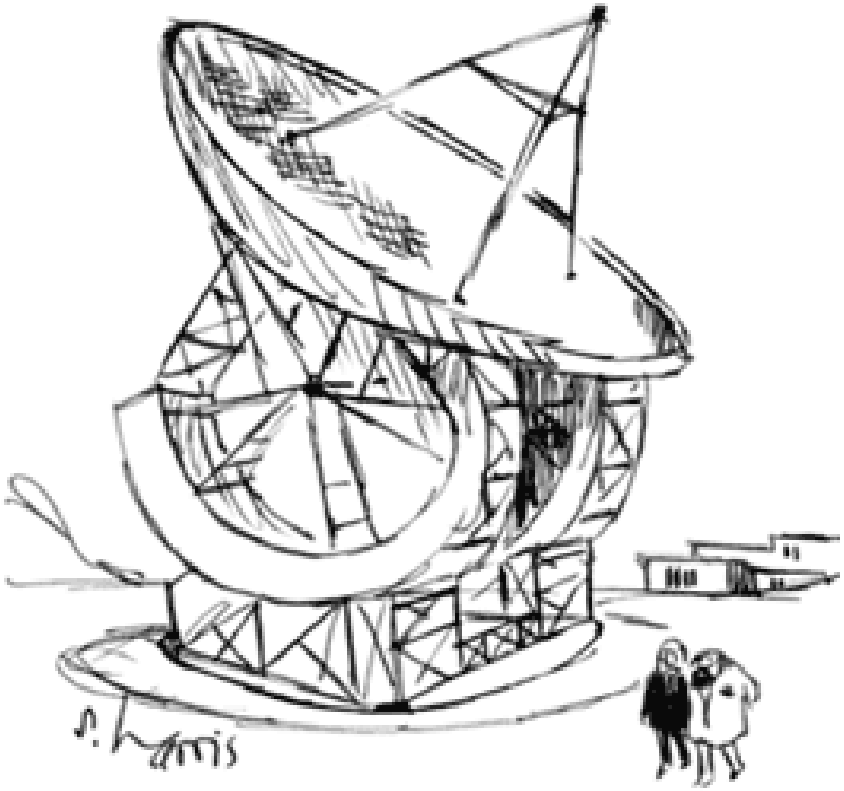
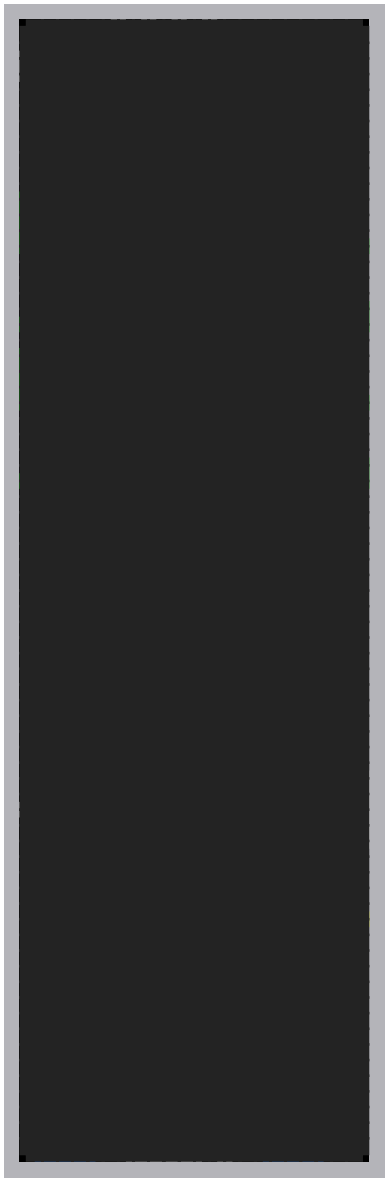


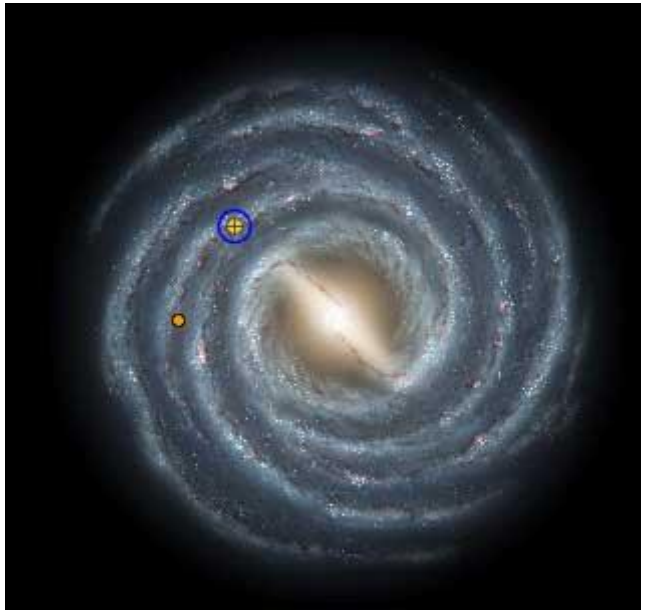
Ak tomu dobre rozumiem, žiadajú okamžitú odpoveď. Problém je, že správu poslali pred 3 miliónmi rokov.

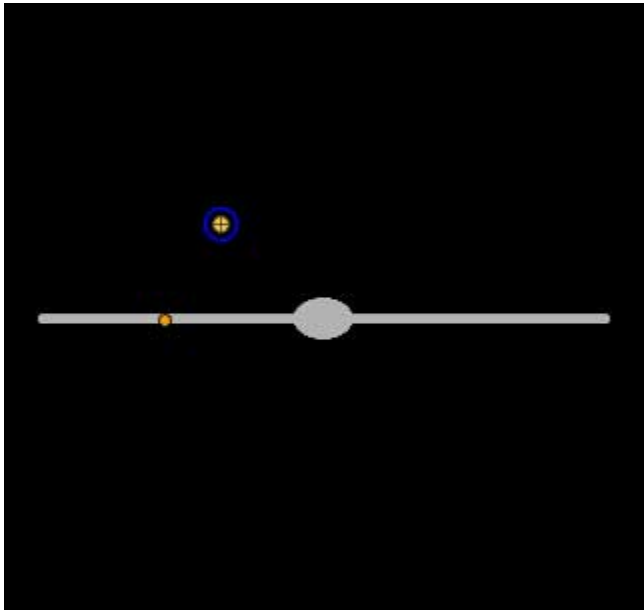


Poslali sme správu mimozemšťanom. Zahytili ju vo Veľkej Británii. Nerozumeli jej.

Správa z Areciba

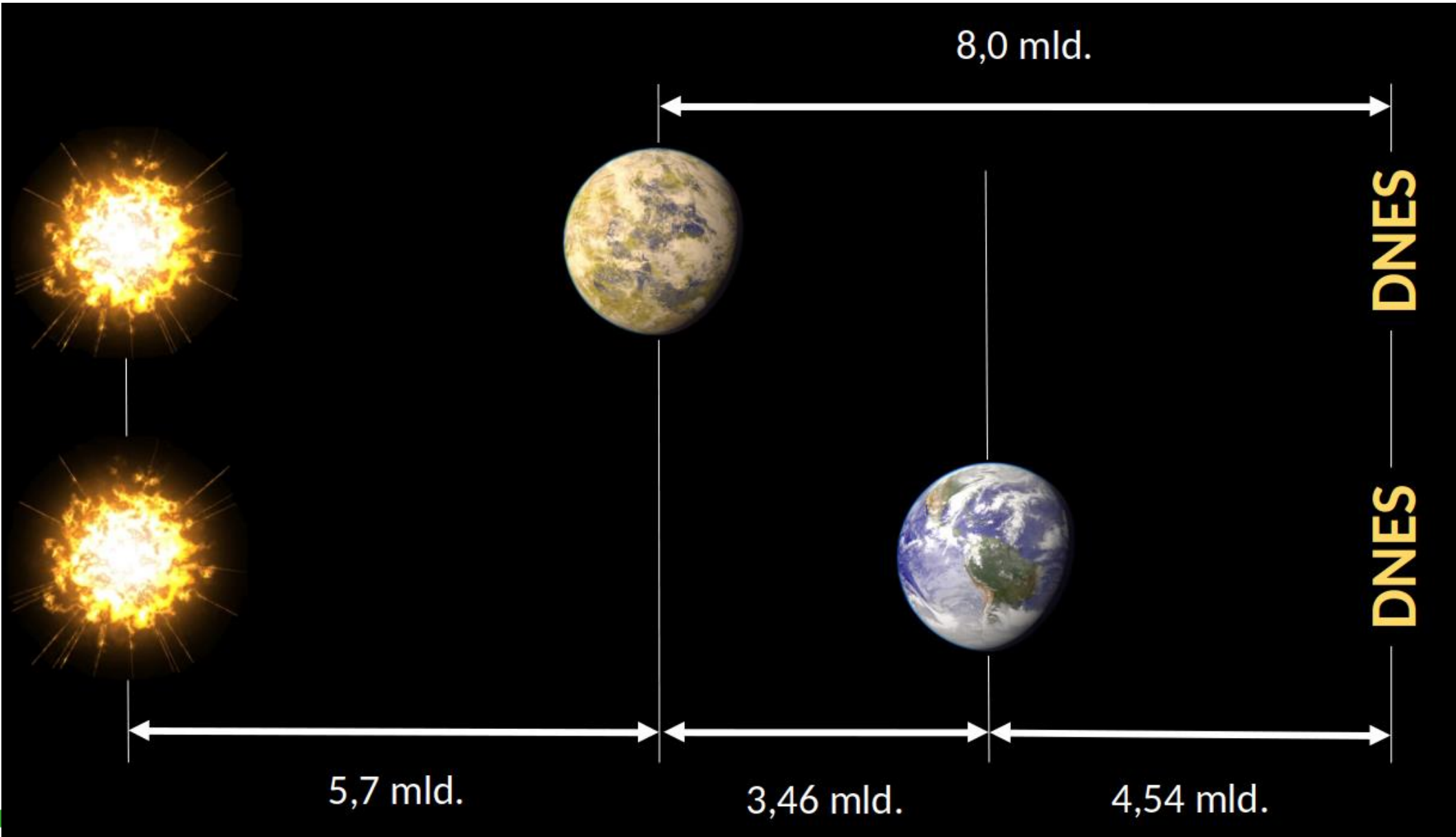






Kontaktovať?

Kontaktovať?



Kardašovova škála

Kaku – nie energia, ale ekonomika

Nikolaj S. Kardašov
(1932-2019)

Typ I – spotreba energie planéty (P =10^{16} W)
Typ II – spotreba energie hviezdy (P = 10^{26} W)
Typ III – spotreba energie galaxie (P = 10^{36} W)

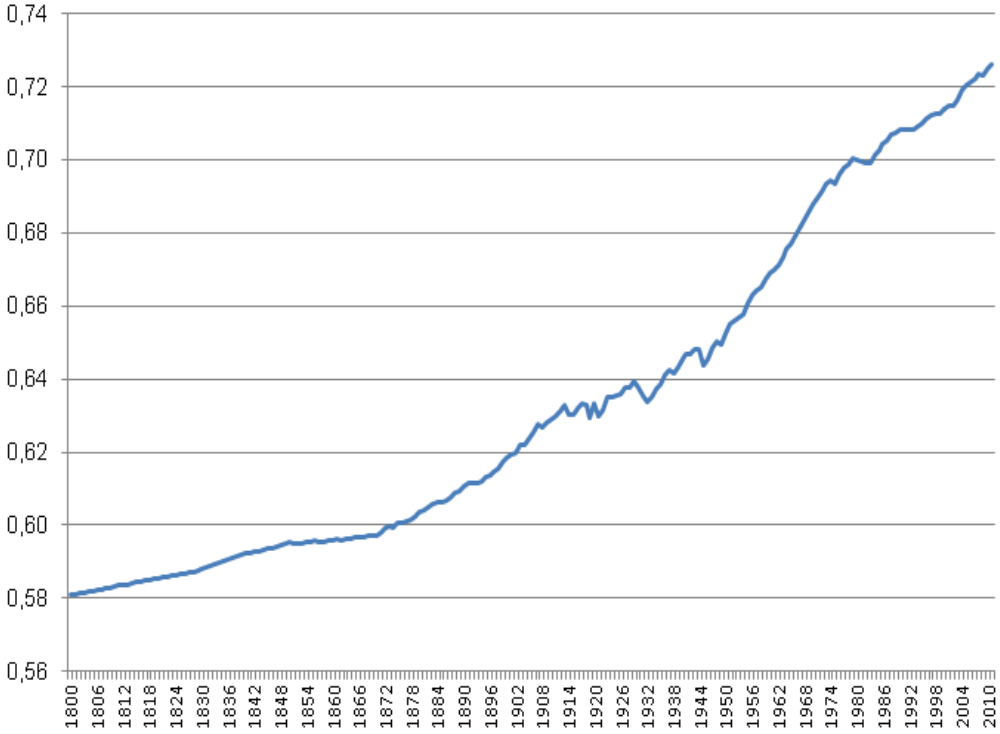
Kardašov, 1964

Typ 0 – praľudia? (P =1 MW)

$$K = 0{,}1(\log_{10} P - 6)$$

Sagan, 1973

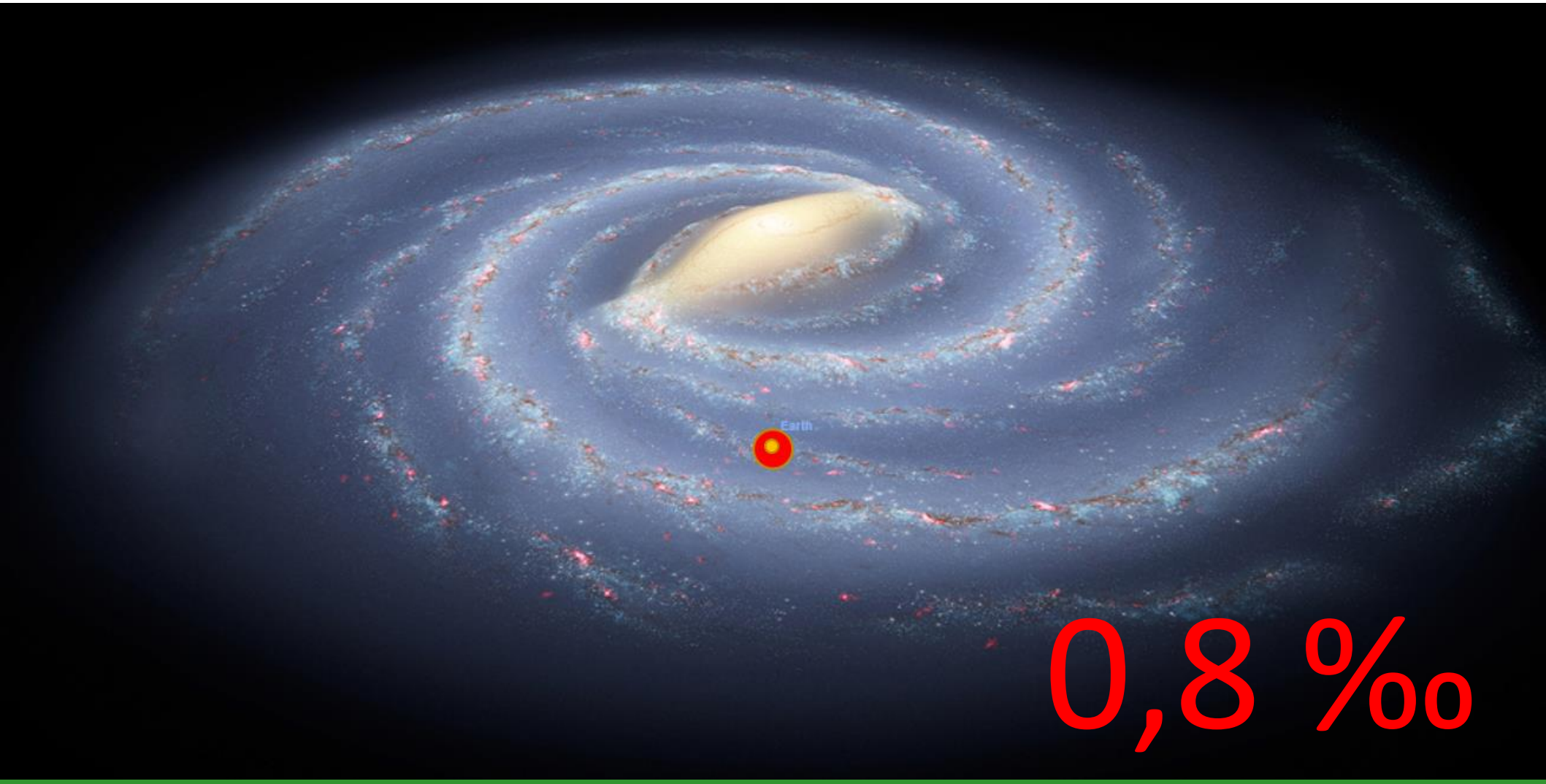
Carl Sagan
(1934-1996)



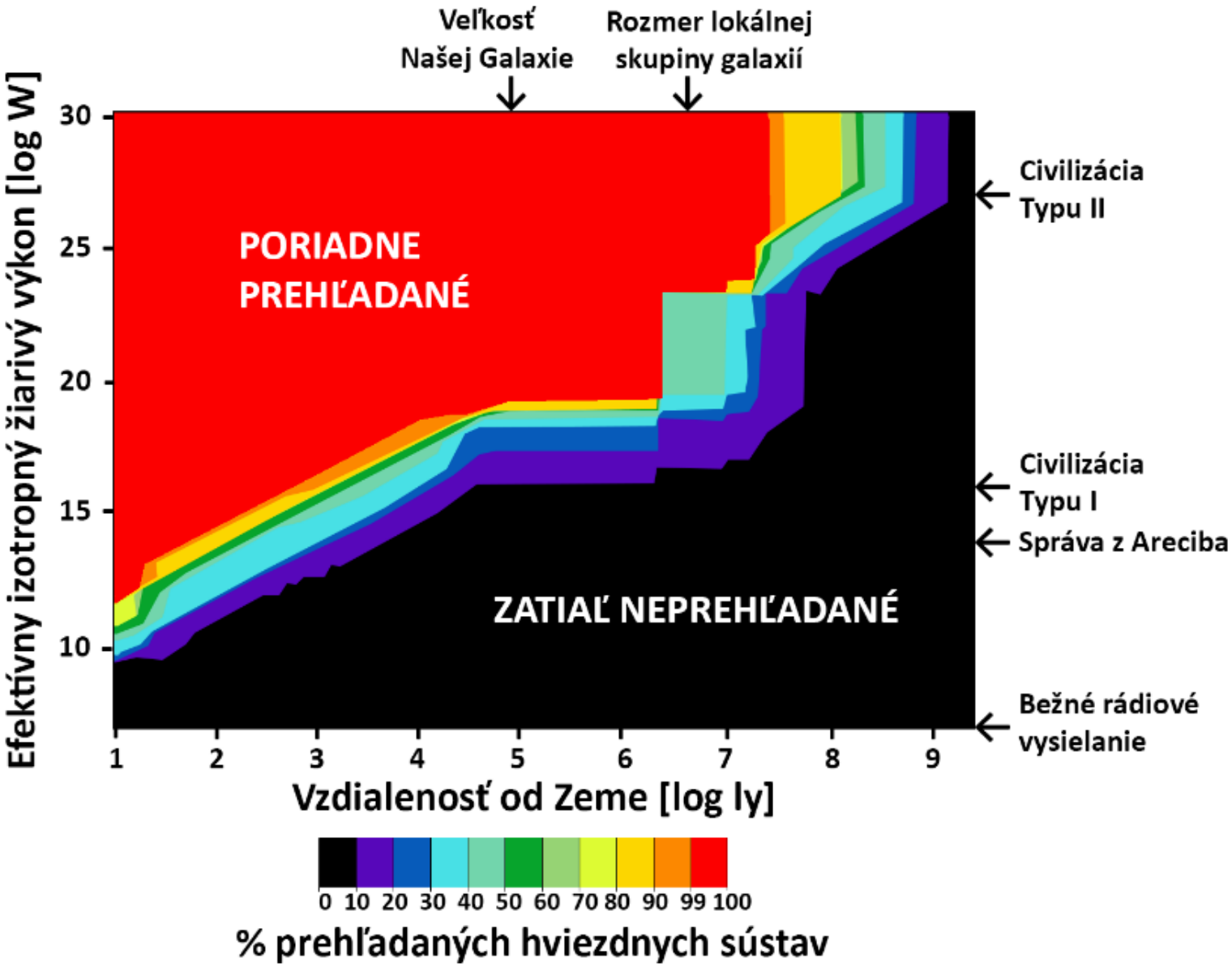
Typ I dosiahne ľudstvo za 100-200 rokov pri 3% raste. A okrem toho, nie energia, ale ekonomika je dôležitá…

Michio Kaku
(1947-)

Prehliadka okolia



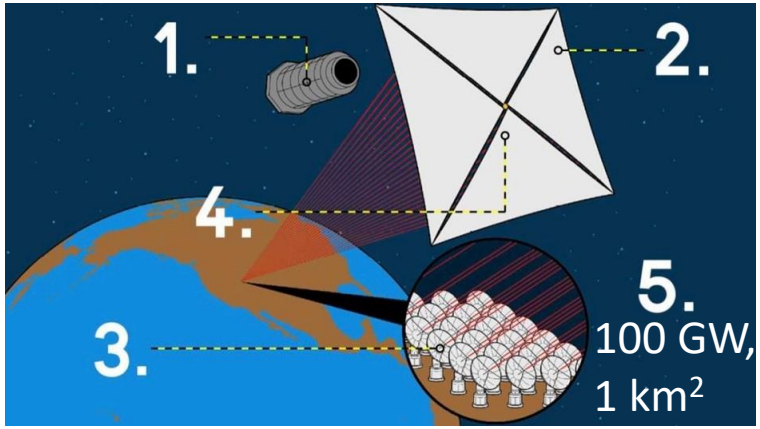
Prehliadka okolia

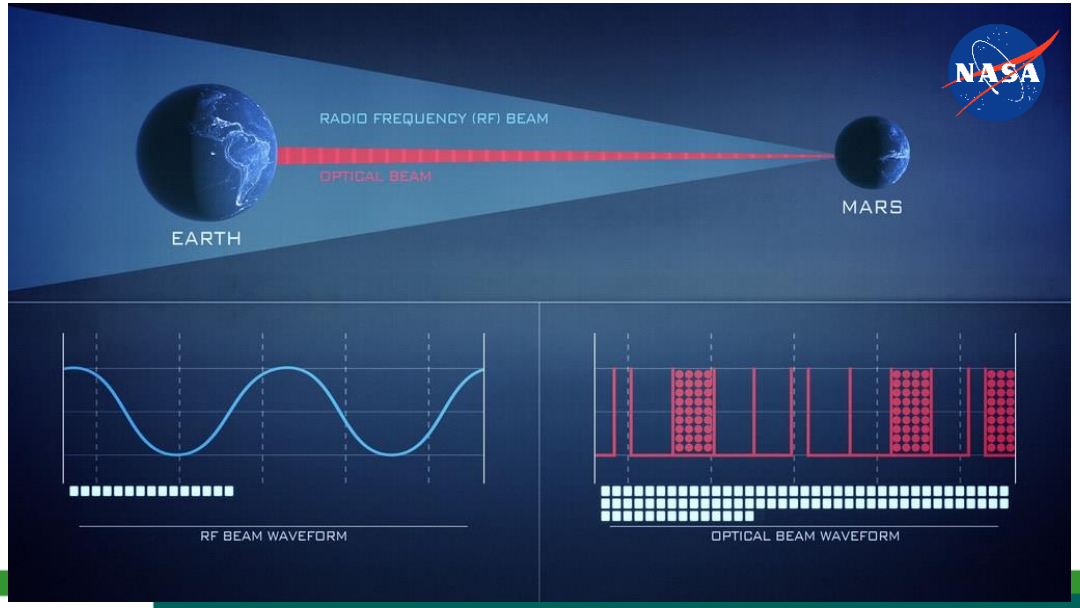


Lasery

Yuri Milner
1961-

BREAKTHROUGH
INITIATIVES

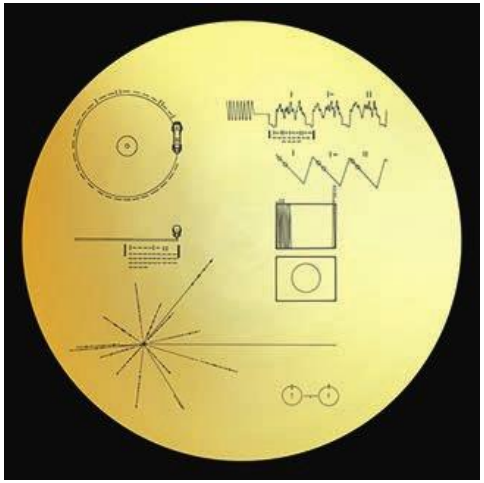




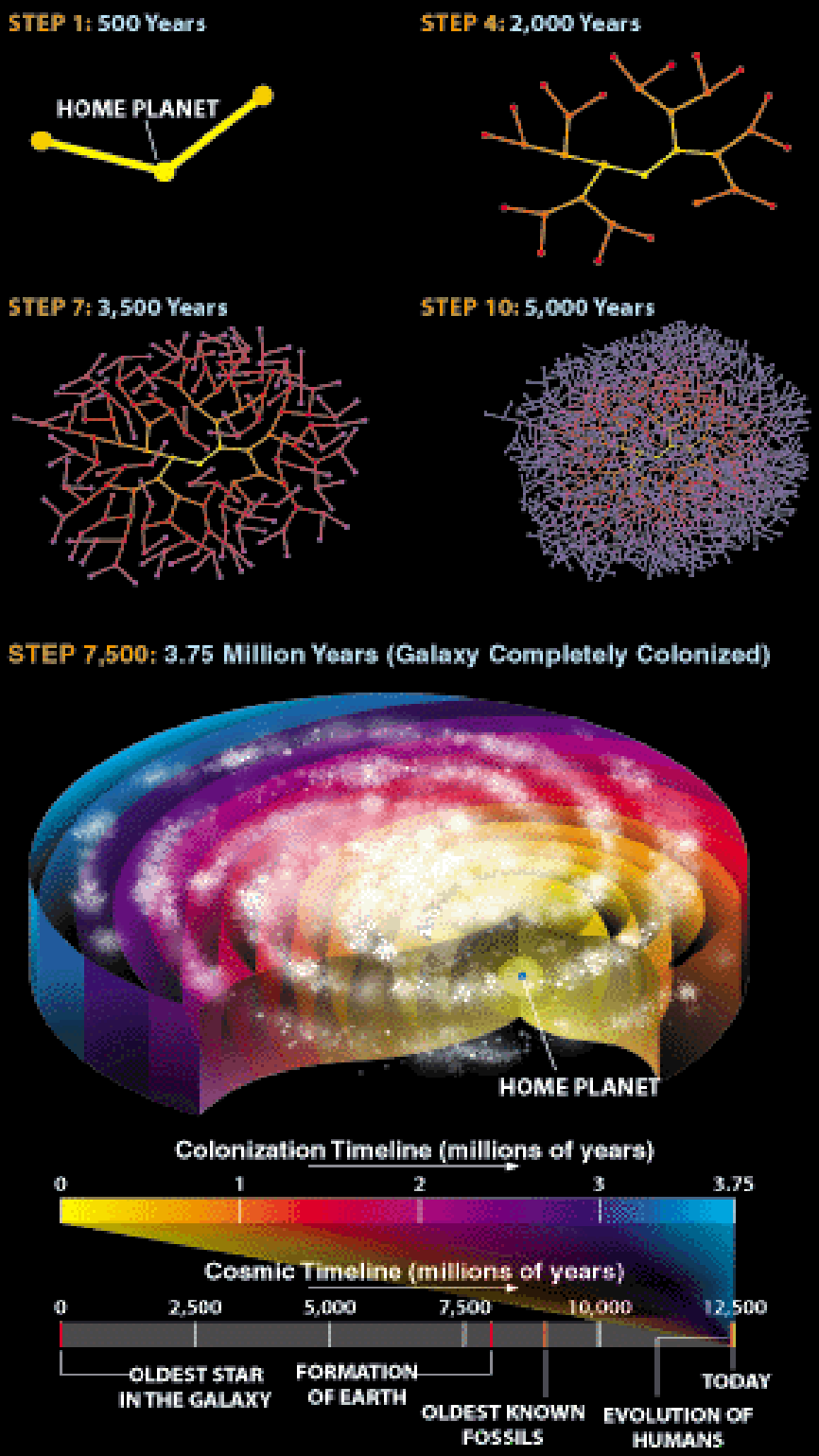
Von Neumannove stroje

= autonómne roboty schopné samoreplikácie a kolonizácie

John von Neumann
(1903-1957)



*Bracewellove stroje – samoreplikujúce sa sondy s posolstvom



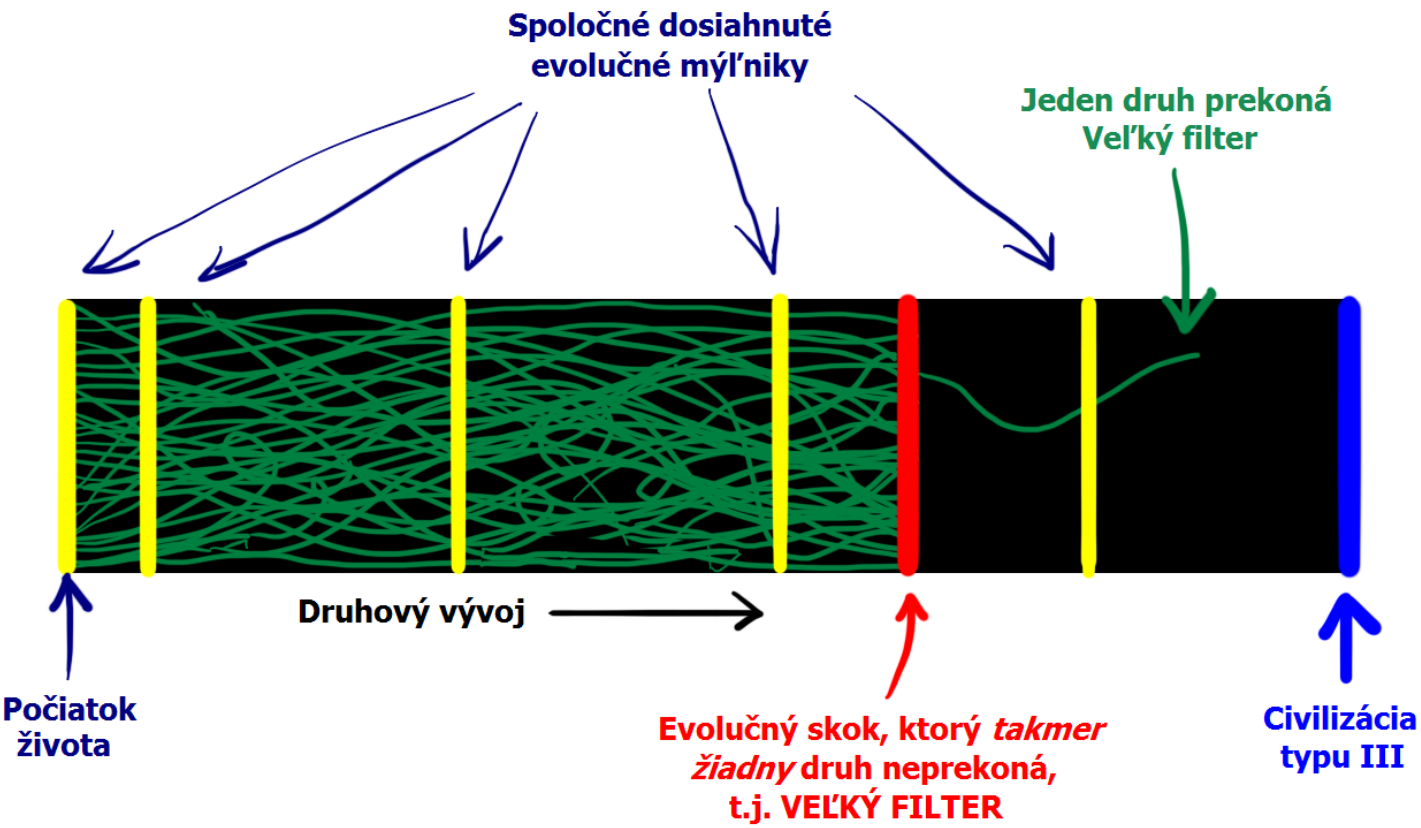
Kde teda sú?

Prečo nevidíme dôkazy civilizácii typu II a III?

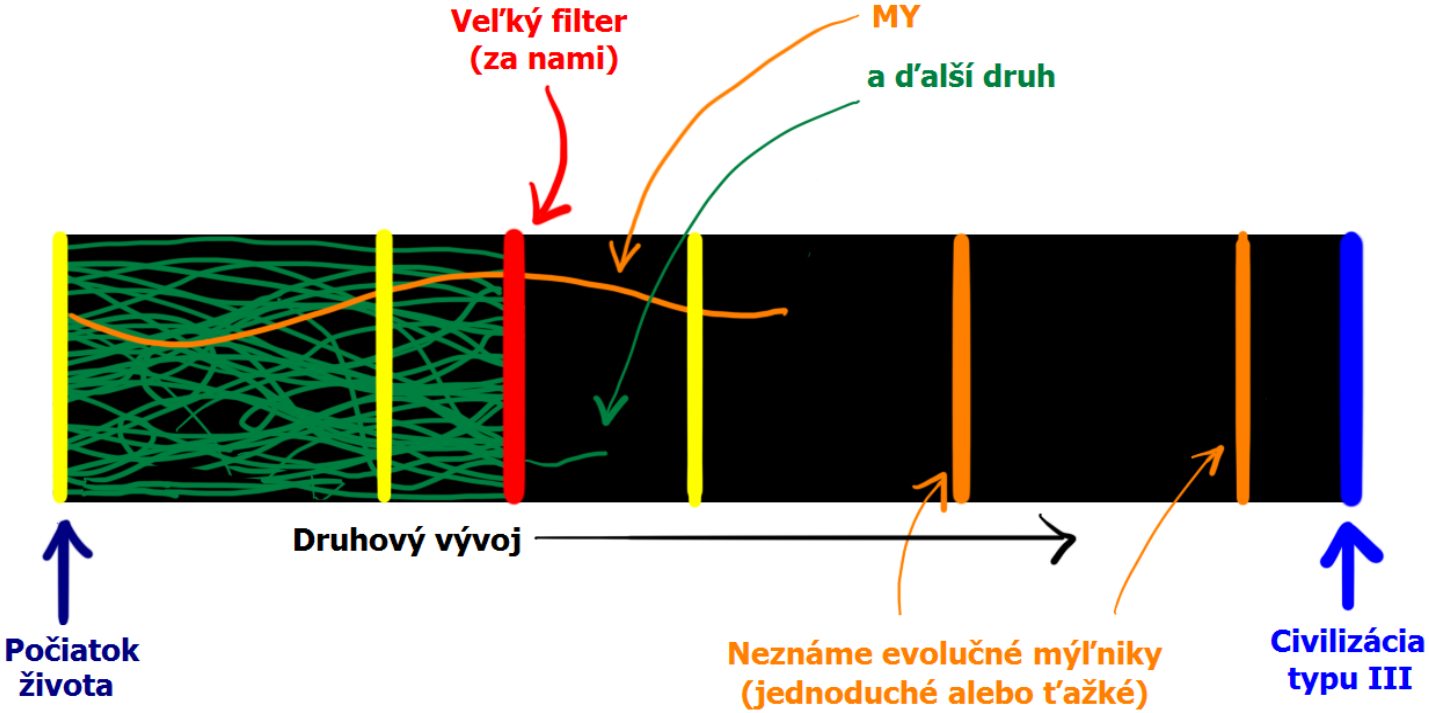
1) Lebo také nie sú

2) Sú, ale z rôznych dôvodov to taja

Veľký filter

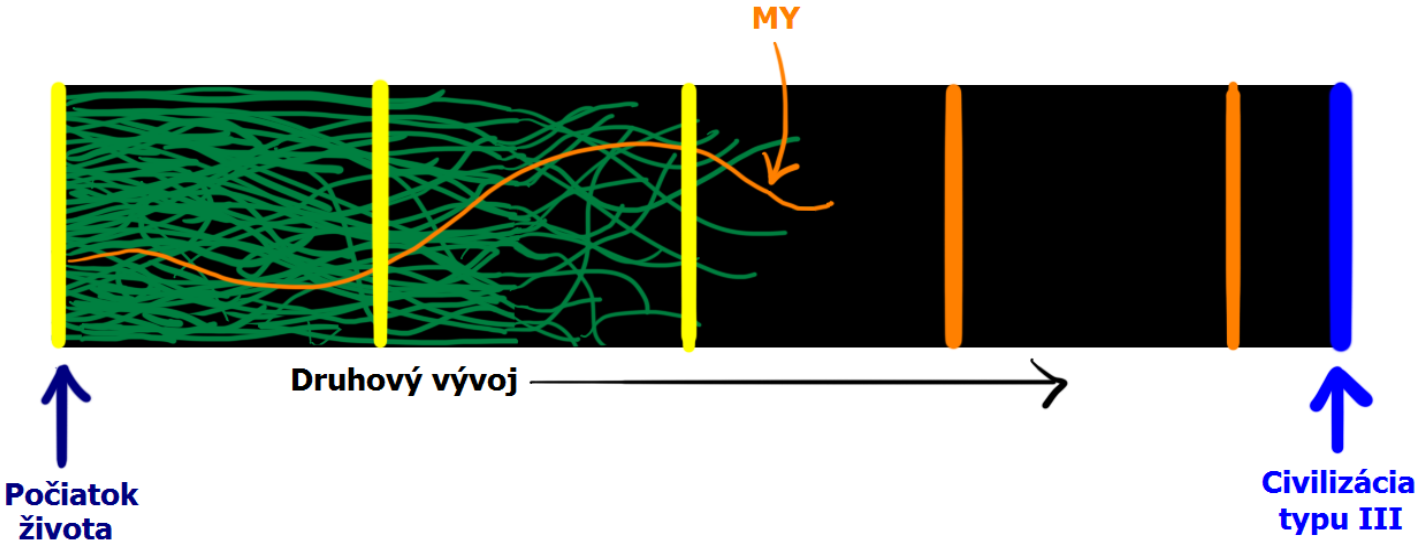


Život je vzácny

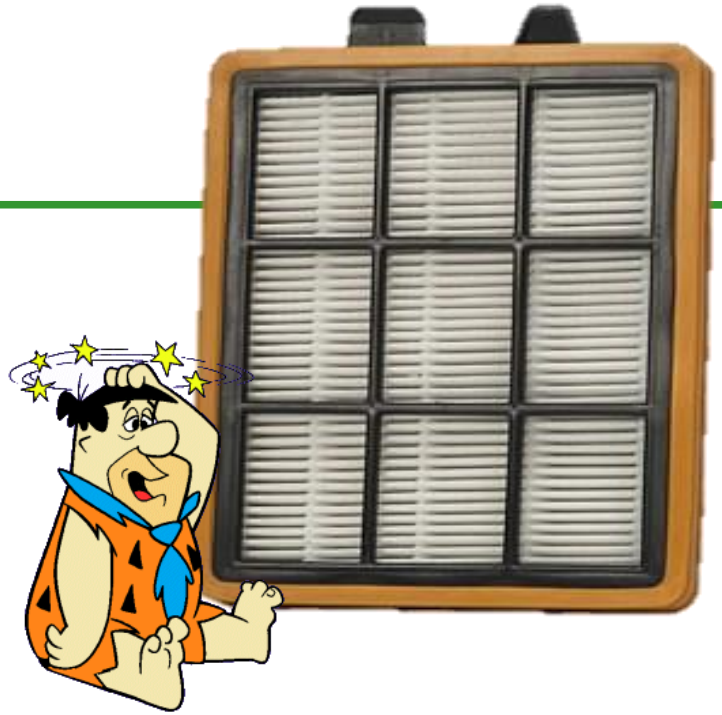


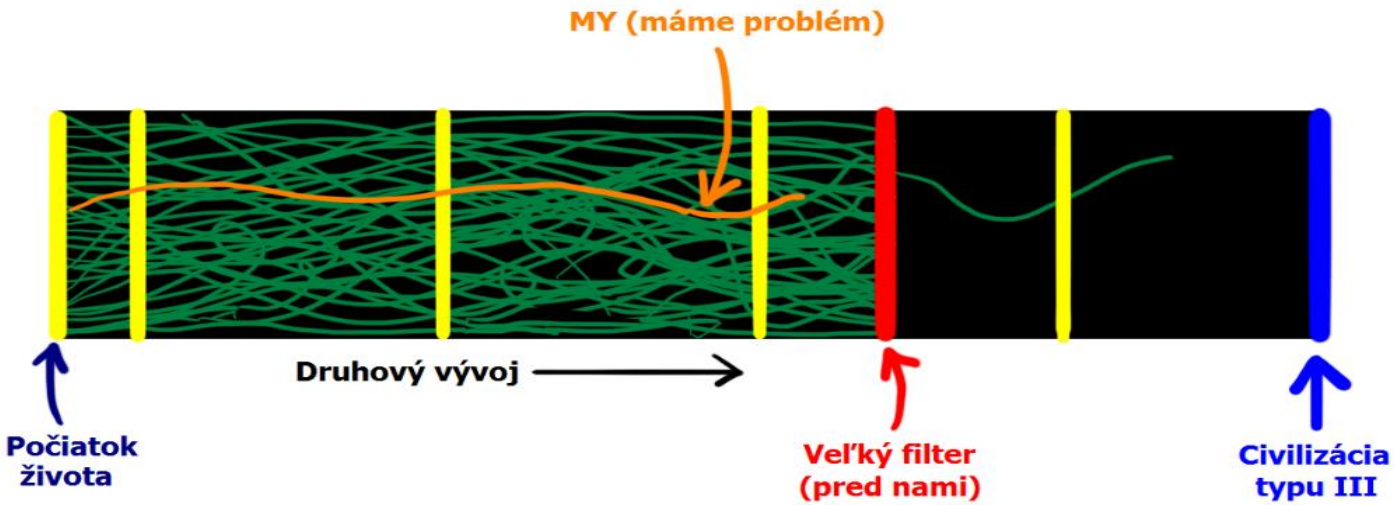
Sme prví

Prvá uvedomelá mravčia kolónia odvolala hľadanie mimomraveniskovej inteligencie.



Sme nahratí?



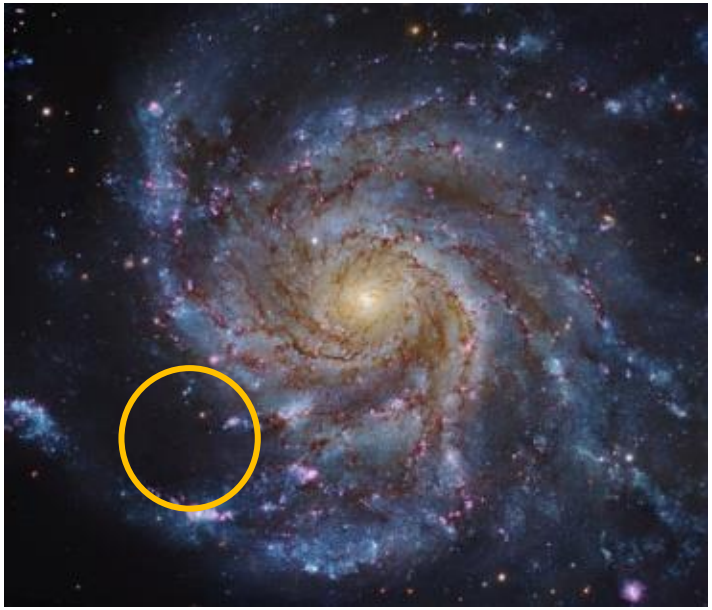

MY (máme problém)
Druhový vývoj
Počiatok života
Veľký filter (pred nami)
Civilizácia typu III

Majú na to svoje dôvody?

- Boli tu v minulosti

Majú na to svoje dôvody?

- Boli tu v minulosti
- Galaxia je osídlená, ale my žijeme v pustej časti



Majú na to svoje dôvody?

- Boli tu v minulosti
- Galaxia je osídlená, ale my žijeme v pustej časti
- Prekonali fyzické obmedzenia (singularita)

Majú na to svoje dôvody?

- Boli tu v minulosti
- Galaxia je osídlená, ale my žijeme v pustej časti
- Prekonali fyzické obmedzenia (singularita)
- Sú opatrní / utiahnutí

Majú na to svoje dôvody?

- Boli tu v minulosti
- Galaxia je osídlená, ale my žijeme v pustej časti
- Prekonali fyzické obmedzenia (singularita)
- Sú opatrní / utiahnutí
- Existuje superpredátor, ktorý ničí konkurenciu

Majú na to svoje dôvody?

- Naša technológia je primitívna / sme tu krátko

Majú na to svoje dôvody?

- Naša technológia je primitívna / sme tu krátko
- Sú medzi nami (konšpiračná teória)

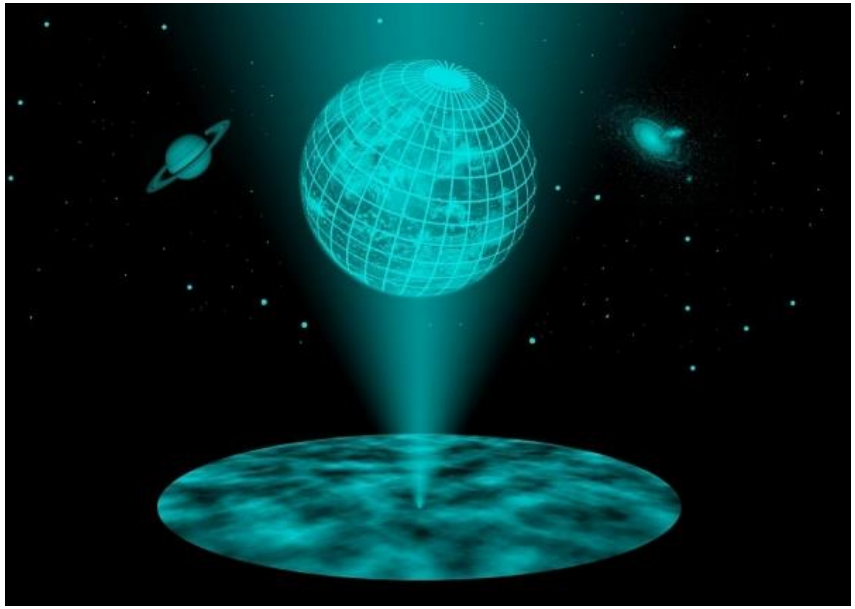
Majú na to svoje dôvody?

- Naša technológia je primitívna / sme tu krátko
- Sú medzi nami (konšpiračná teória)
- Sme v zoo

Minulý mesiac všetci vyrezávali hlavu zo zeleniny a teraz odzadu vypchávajú pečeného vtáka. Je to čudná planéta!

Majú na to svoje dôvody?

- Naša technológia je primitívna / sme tu krátko
- Sú medzi nami (konšpiračná teória)
- Sme v zoo
- Možno sa úplne mýlime o vesmíre („matrix“)



Pre každý prípad...

- 1958 – Vznikla komisia na mierové využívanie vesmíru
- 1992 – Transformovala sa na UNOOSA

UNITED NATIONS
Office for Outer Space Affairs

- Využitie vesmíru a právne záležitosti
- Sledovanie vypustených vesmírnych telies
- Potenciálne záležitosti s mimozemšťanmi

Viac podrobností

3 skupiny riešení:

- mimozemšťania tu sú alebo boli
- existujú, ale ešte sa nám neozvali
- neexistujú

Ucelený pohľad na tento paradox

Tradičné ale aj šokujúce teórie

Je len na Vás, ktorú si vyberiete

Súčasné poznatky o možnostiach života vo vesmíre

Existujú dve možnosti: buď sme vo Vesmíre sami, alebo nie sme. Obidve sú rovnako desivé.

-- Arthur C. Clarke

1.12.2022 Space::Talk