POTOVANJE PO VESOLJU

Z DVIGNJENIM PALCEM IN BRISAČO

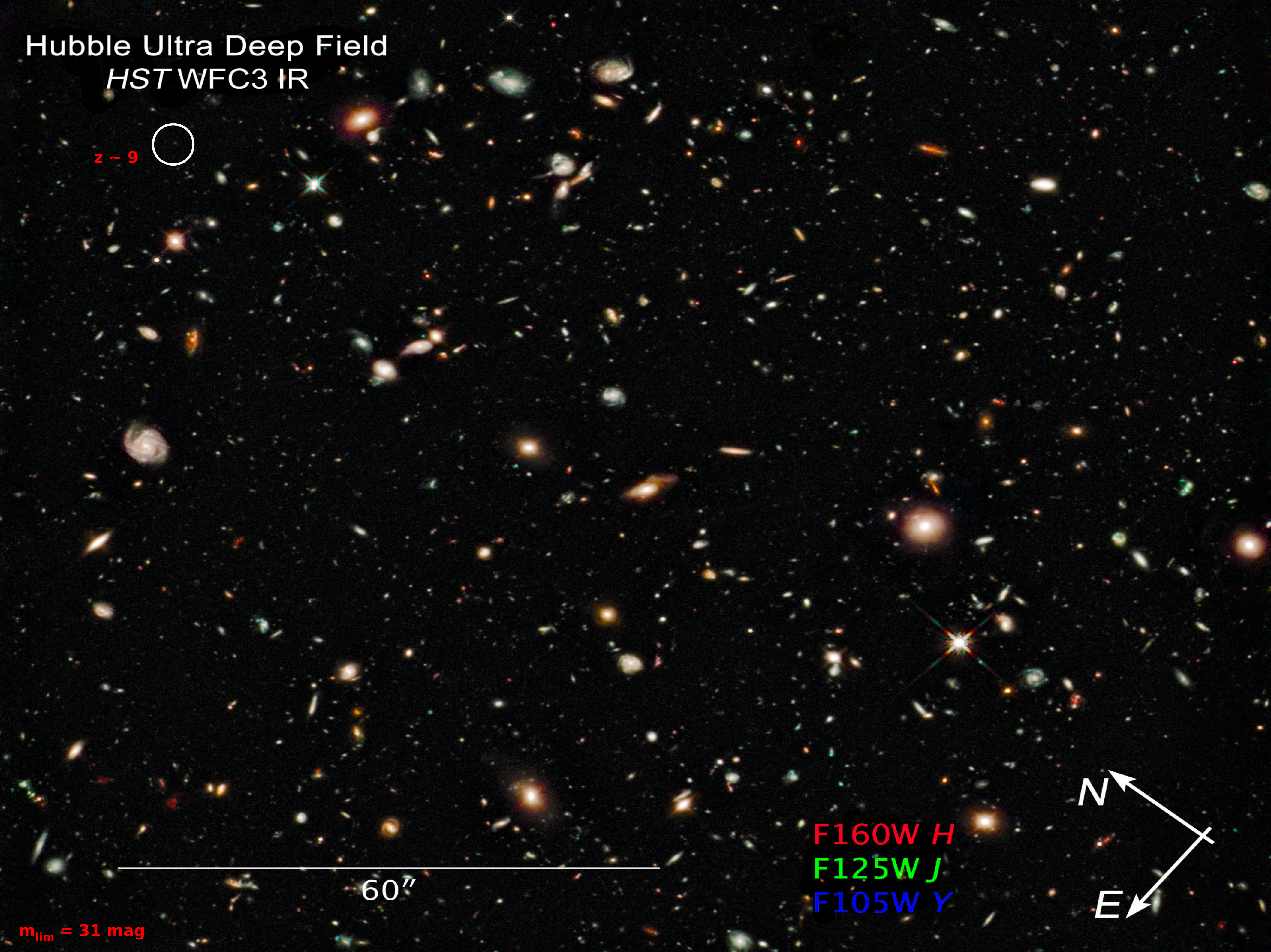
DREJC KOPAČ, FMF, 3. 4. 2014

Univerza *v Ljubljani*
Fakulteta za *matematiko in fiziko*

PORTAL v VESOLJE

PRIRODOSLOVNI MUZEJ SLOVENIJE

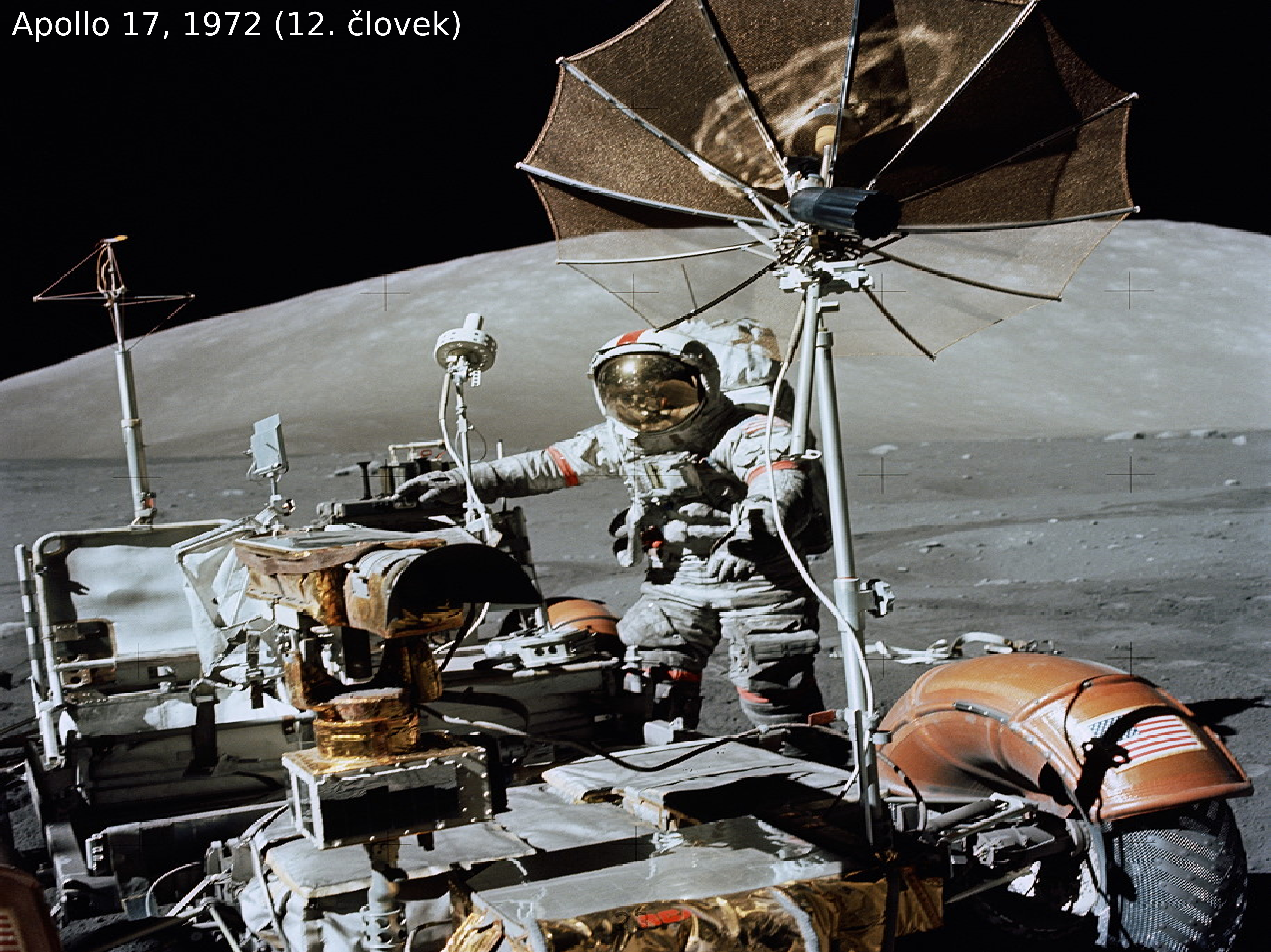
PANORAMICUNIVERSE.COM

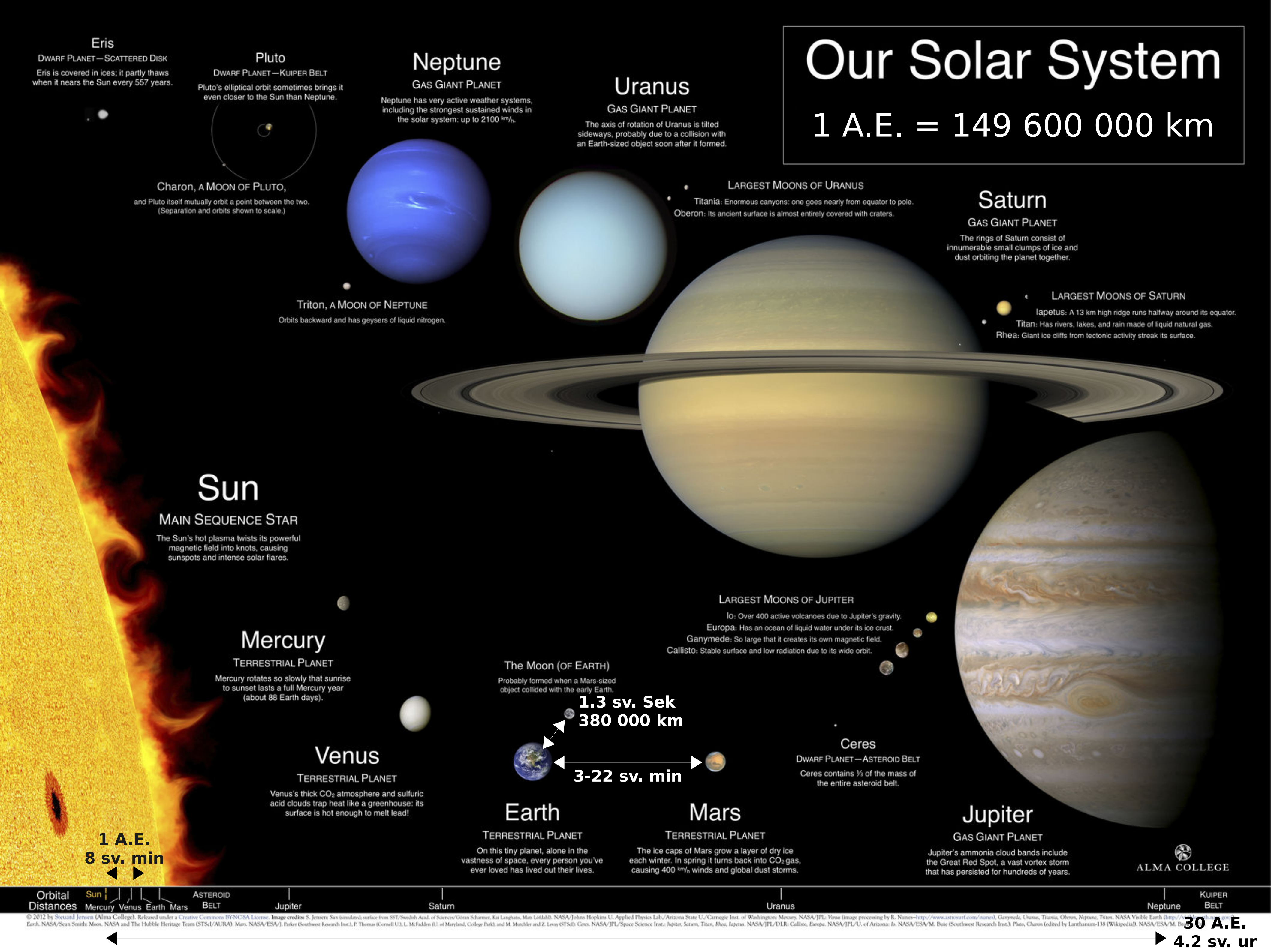

Hubble Ultra Deep Field
HST WFC3 IR
z ~ 9
60″
F160W *H*
F125W *J*
F105W *Y*
N
E
m_{lim} = 31 mag


THE HITCHHIKER'S GUIDE TO THE GALAXY
DON'T LEAVE EARTH WITHOUT IT
NOW PLAYING!
©2005 Touchstone Pictures. All Rights Reserved.

Apollo 11, 1969

Apollo 17, 1972 (12. človek)



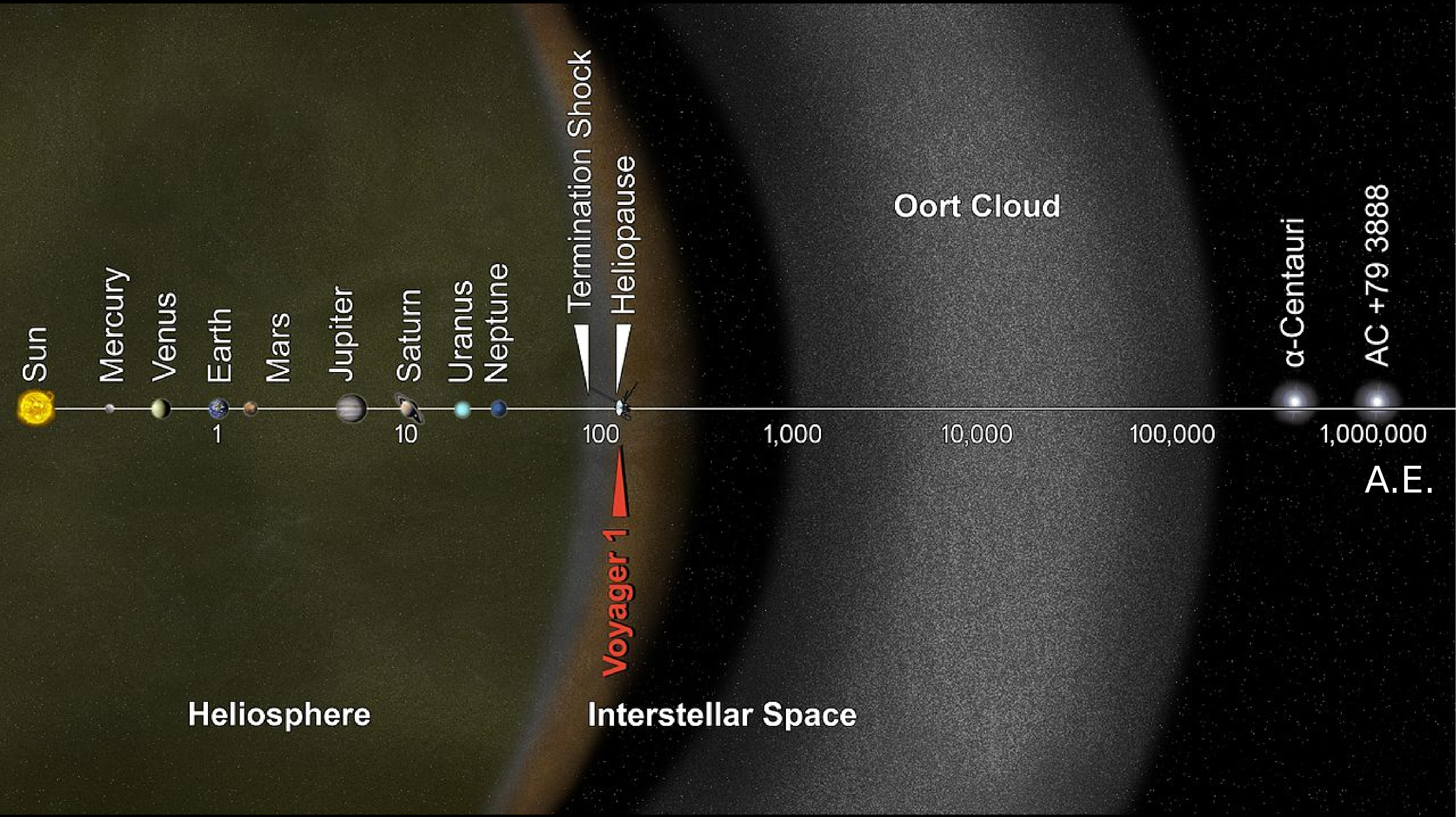


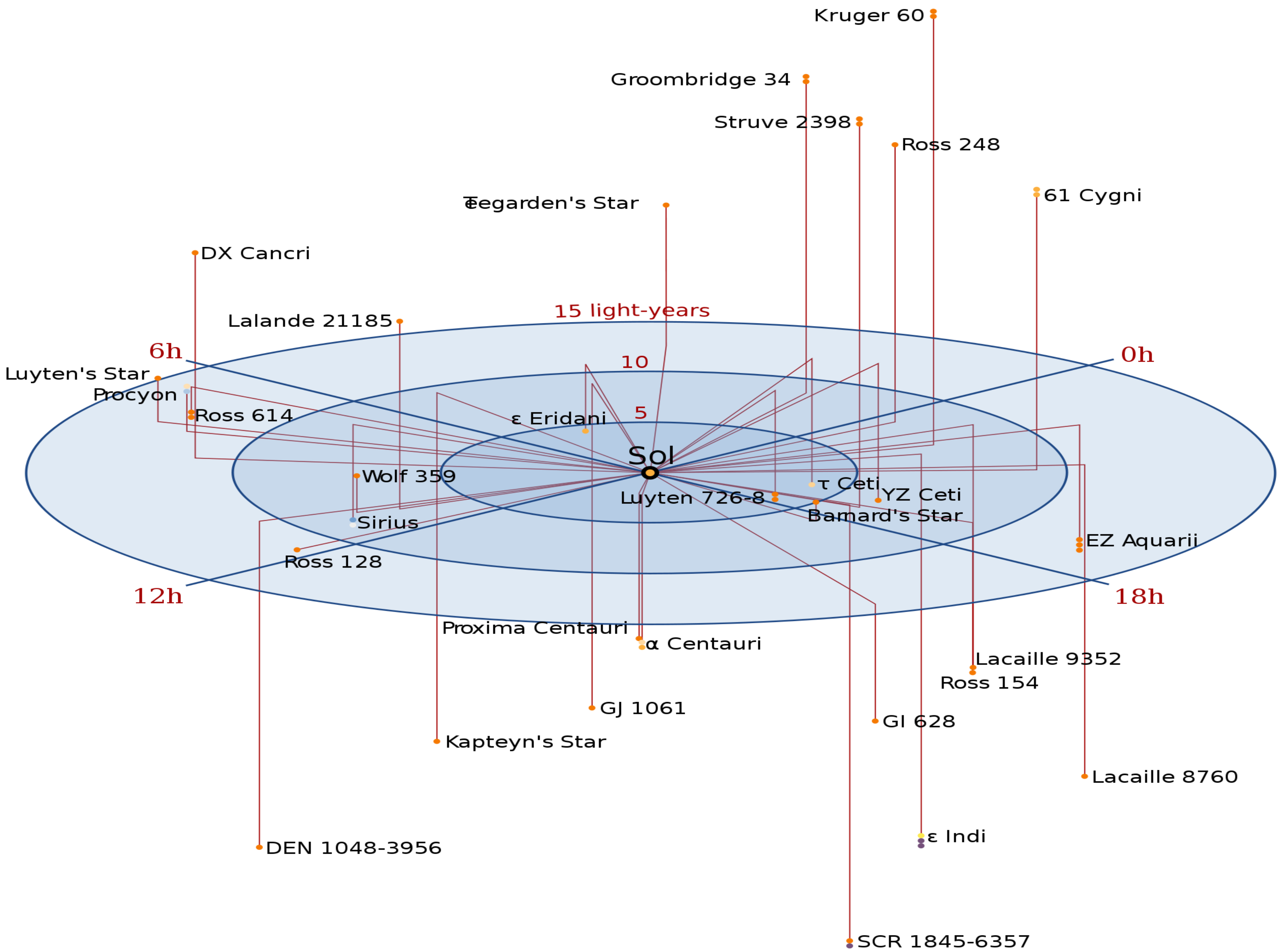
Our Solar System
1 A.E. = 149 600 000 km
Eris
Dwarf Planet—Scattered Disk
Eris is covered in ices; it partly thaws when it nears the Sun every 557 years.
Pluto
Dwarf Planet—Kuiper Belt
Pluto's elliptical orbit sometimes brings it even closer to the Sun than Neptune.
Charon, a Moon of Pluto,
and Pluto itself mutually orbit a point between the two. (Separation and orbits shown to scale.)
Neptune
Gas Giant Planet
Neptune has very active weather systems, including the strongest sustained winds in the solar system: up to 2100 km/h.
Triton, a Moon of Neptune
Orbits backward and has geysers of liquid nitrogen.
Uranus
Gas Giant Planet
The axis of rotation of Uranus is tilted sideways, probably due to a collision with an Earth-sized object soon after it formed.
Largest Moons of Uranus
Titania: Enormous canyons: one goes nearly from equator to pole.
Oberon: Its ancient surface is almost entirely covered with craters.
Saturn
Gas Giant Planet
The rings of Saturn consist of innumerable small clumps of ice and dust orbiting the planet together.
Largest Moons of Saturn
Iapetus: A 13 km high ridge runs halfway around its equator.
Titan: Has rivers, lakes, and rain made of liquid natural gas.
Rhea: Giant ice cliffs from tectonic activity streak its surface.
Sun
Main Sequence Star
The Sun's hot plasma twists its powerful magnetic field into knots, causing sunspots and intense solar flares.
Largest Moons of Jupiter
Io: Over 400 active volcanoes due to Jupiter's gravity.
Europa: Has an ocean of liquid water under its ice crust.
Ganymede: So large that it creates its own magnetic field.
Callisto: Stable surface and low radiation due to its wide orbit.
Mercury
Terrestrial Planet
Mercury rotates so slowly that sunrise to sunset lasts a full Mercury year (about 88 Earth days).
The Moon (of Earth)
Probably formed when a Mars-sized object collided with the early Earth.
1.3 sv. Sek
380 000 km
3-22 sv. min
Ceres
Dwarf Planet—Asteroid Belt
Ceres contains ⅓ of the mass of the entire asteroid belt.
Venus
Terrestrial Planet
Venus's thick CO2 atmosphere and sulfuric acid clouds trap heat like a greenhouse: its surface is hot enough to melt lead!
Earth
Terrestrial Planet
On this tiny planet, alone in the vastness of space, every person you've ever loved has lived out their lives.
Mars
Terrestrial Planet
The ice caps of Mars grow a layer of dry ice each winter. In spring it turns back into CO2 gas, causing 400 km/h winds and global dust storms.
Jupiter
Gas Giant Planet
Jupiter's ammonia cloud bands include the Great Red Spot, a vast vortex storm that has persisted for hundreds of years.
Alma College
1 A.E.
8 sv. min
Orbital Distances
Sun
Mercury
Venus
Earth
Mars
Asteroid Belt
Jupiter
Saturn
Uranus
Neptune
Kuiper Belt
30 A.E.
4.2 sv. ur

Bližnje vesolje

Oddaljenost Proksima Kentavra: ~ 270 000 A.E. = 4.24 sv. let = 1.3 Pc

Oddaljenost Alfa Kentavra: ~ 275 000 A.E. = 4.37 sv. let = 1.34 Pc

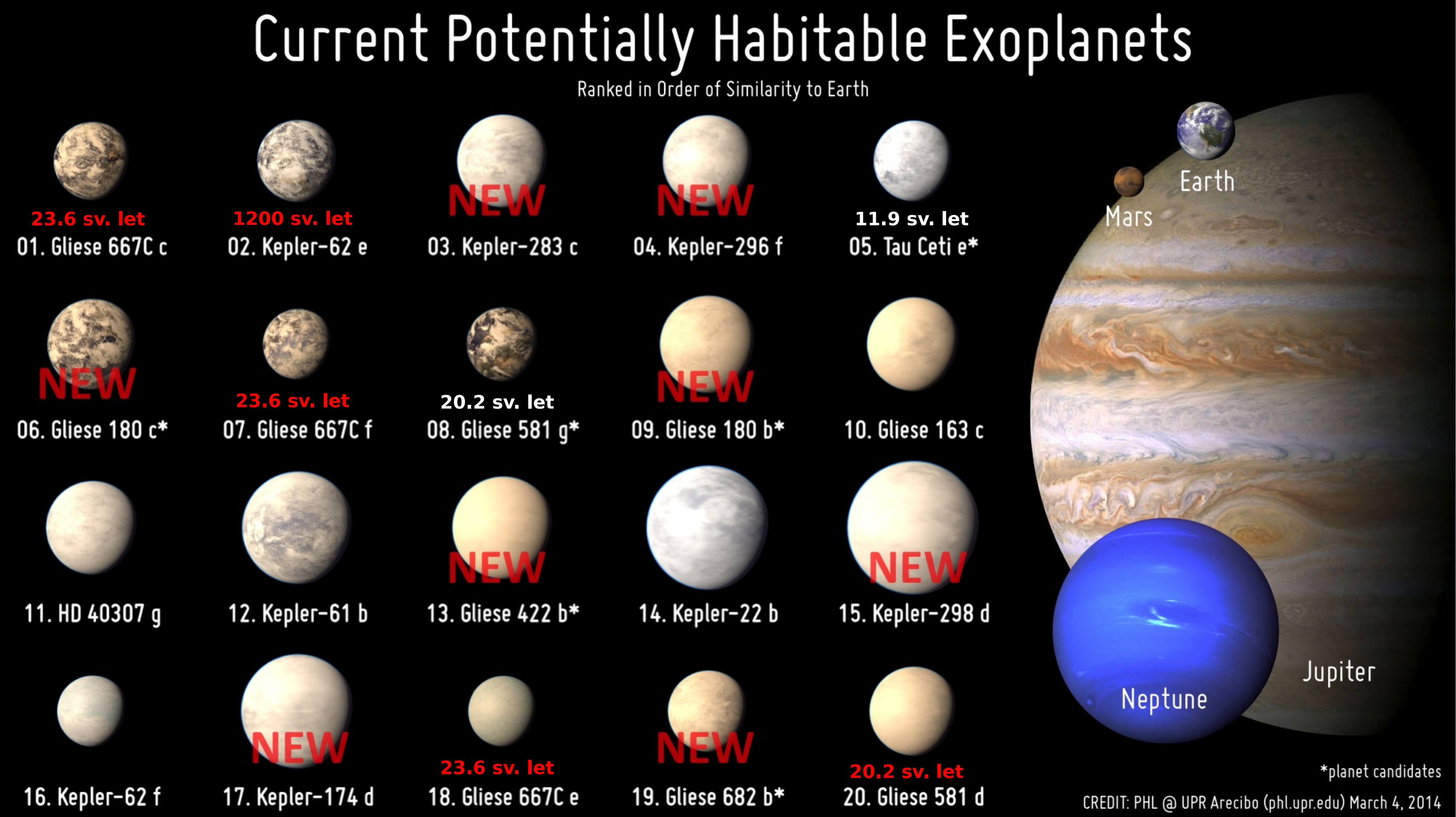


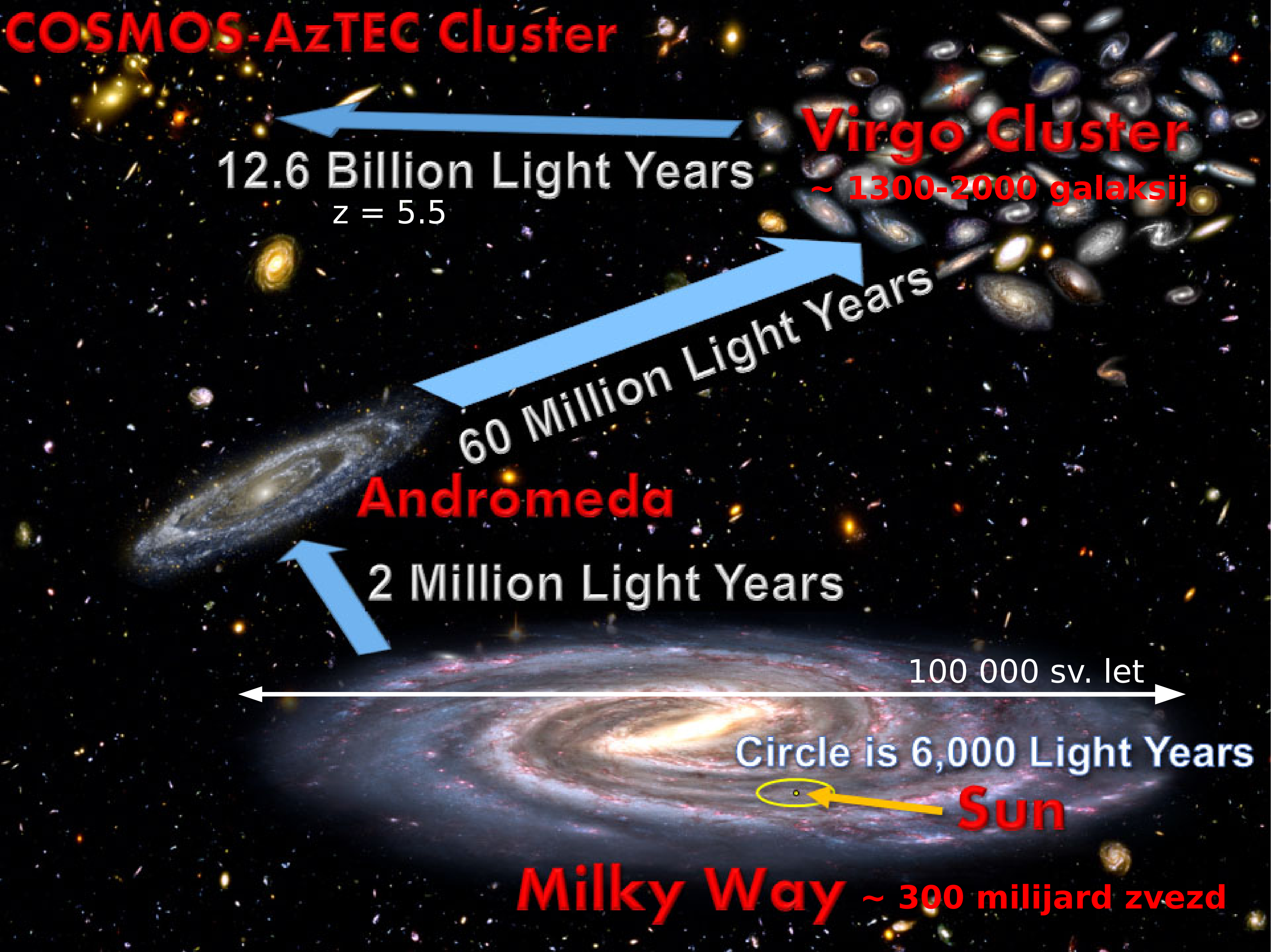


Kruger 60
Groombridge 34
Struve 2398
Ross 248
61 Cygni
Teegarden's Star
DX Cancri
Lalande 21185
15 light-years
6h
0h
10
Luyten's Star
Procyon
Ross 614
ε Eridani
5
Sol
Wolf 359
τ Ceti
Luyten 726-8
YZ Ceti
Barnard's Star
Sirius
EZ Aquarii
Ross 128
12h
18h
Proxima Centauri
α Centauri
Lacaille 9352
Ross 154
GJ 1061
Gl 628
Kapteyn's Star
Lacaille 8760
ε Indi
DEN 1048-3956
SCR 1845-6357

Eksoplaneti

- Do danes odkritih okrog 1800 eksoplanetov (Kepler)
- Vsaka zvezda naj bi imela vsaj en eksoplanet
- Okrog 1 / 4 Soncu podobnih zvezd naj bi imela planet velikosti Zemlje




COSMOS-AzTEC Cluster
Virgo Cluster
~ 1300-2000 galaksij
12.6 Billion Light Years
z = 5.5
60 Million Light Years
Andromeda
2 Million Light Years
100 000 sv. let
Circle is 6,000 Light Years
Sun
Milky Way
~ 300 milijard zvezd

Space Shuttle – 135 poletov

Soyuz – več kot 100 poletov


SpaceShipTwo: h = 110 km
Virgin
Virgin
VIRGIN GALACTIC
GALACTIC
IMAGE DESIGN & GALACTIC GIRL BY SKY26

Fizika

Če vržemo kamen v zrak, pade na tla. S kolikšno hitrostjo ga moramo izstreliti v zrak, da uide gravitacijskemu privlaku Zemlje? Odgovor: z ubežno hitrostjo.

Ubežna hitrost za Zemljo:

v_e = 11.2 km/s (= 40 320 km/h)

Krožilna hitrost v nizki orbiti:

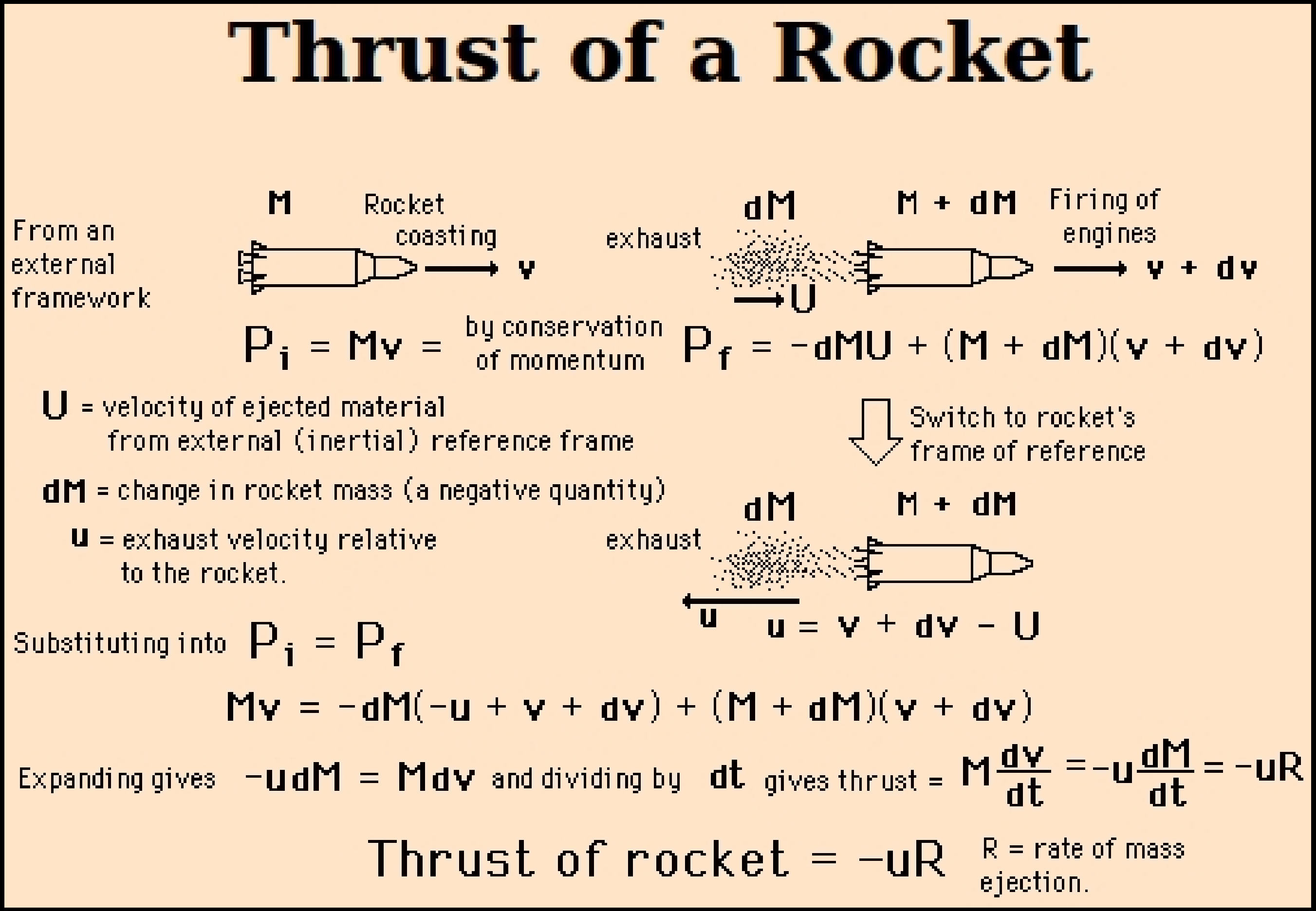
$v_{orb} = v_e$ / sqrt(2) = 7.9 km/s

Ko se osvobodimo privlaka Zemlje, ostaja še gravitacijski privlak Sonca:

v_e^{Sonce} = 42.1 km/s v_{orb}^{Sonce} = 29.8 km/s

Fizika - pogon

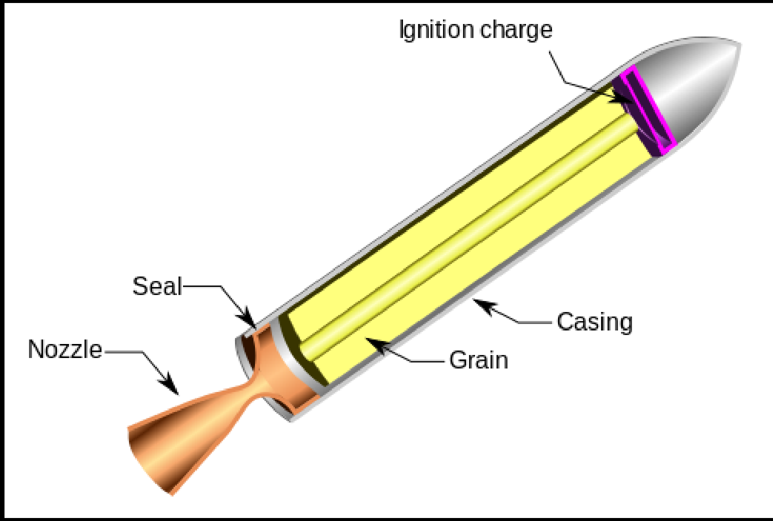
2. in 3. Newtonov zakon (z upoštevanjem spreminjanje mase goriva) ter zakon o ohranitvi gibalne količine (m*v = konst.)



Pomembno vlogo odigra oblika izpušne šobe (de Laval-ova šoba)

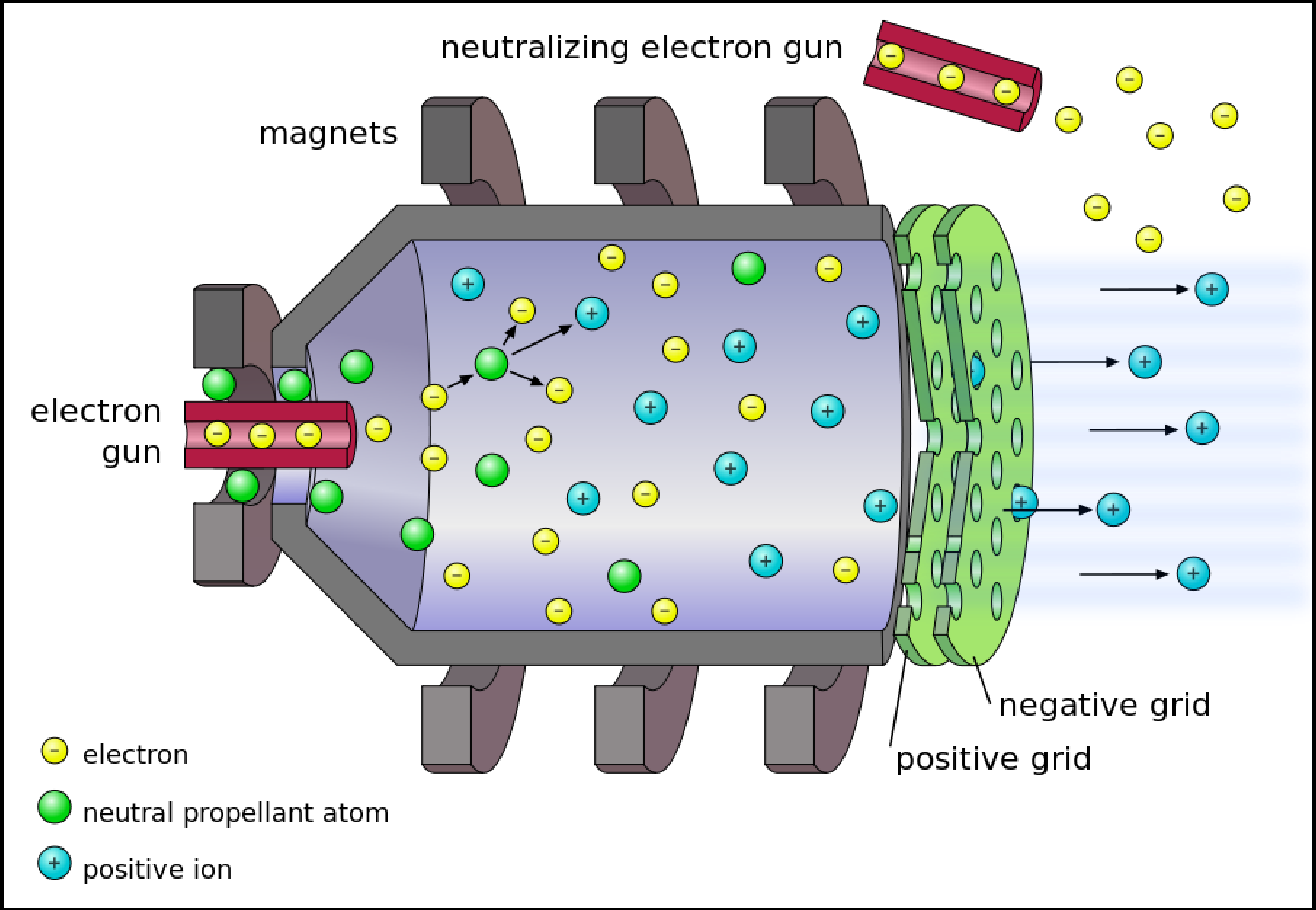
Kemični pogon

- Sposoben zagotoviti dovolj potiska, hiter vžig
- Več stopenj
- Problem je masa goriva
- V uporabi rakete na trda goriva (mešanica goriva in oksidanta) in tekoča goriva (gorivo in oksidant se mešata sproti)

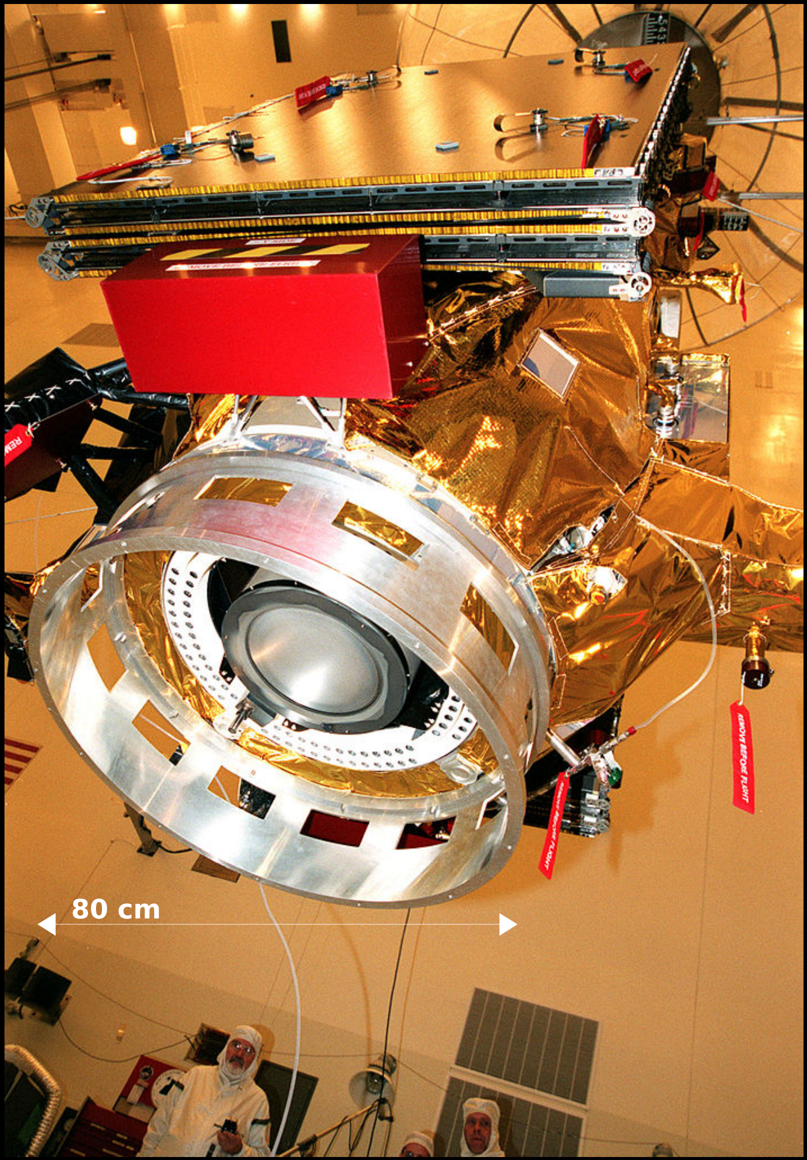


Ionski, Hallov pogon

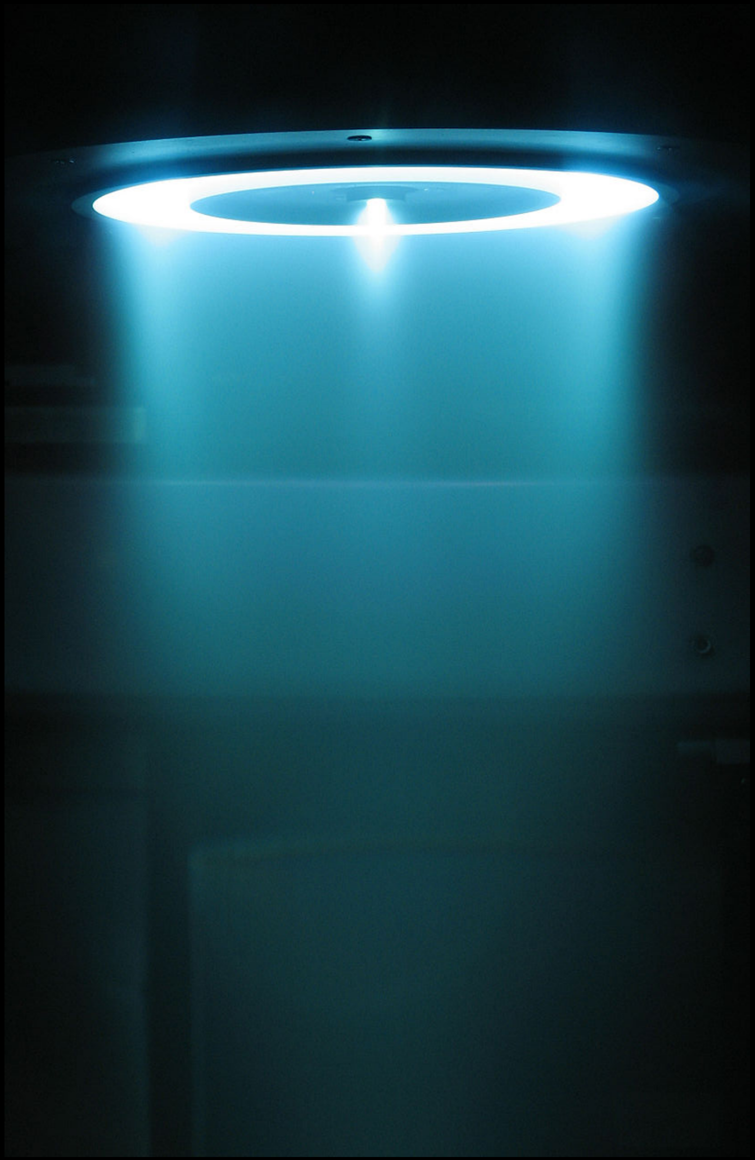
- Velika hitrost ionov, majhen potisk (zato primeren za pogon v vesolju)
- Problem je zagotoviti dovolj elektrike za dolgotrajno delovanje



Ionski, Hallov pogon



Deep Space 1 (1998), mimolet asteroida in kometa

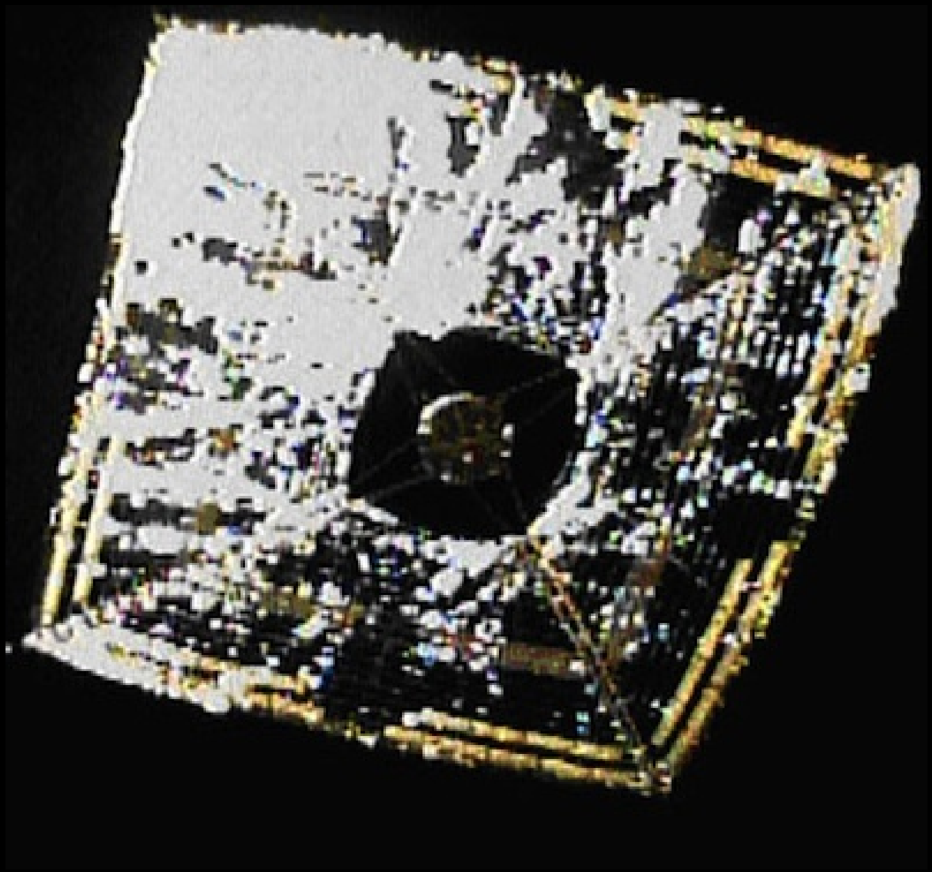


6kW Hallov pogon – testiranje

Solarna jadra

Izkoriščajo sevalni tlak fotonov – njihovo gibalno količino.
Majhen efekt, zato potrebujemo veliko površino.

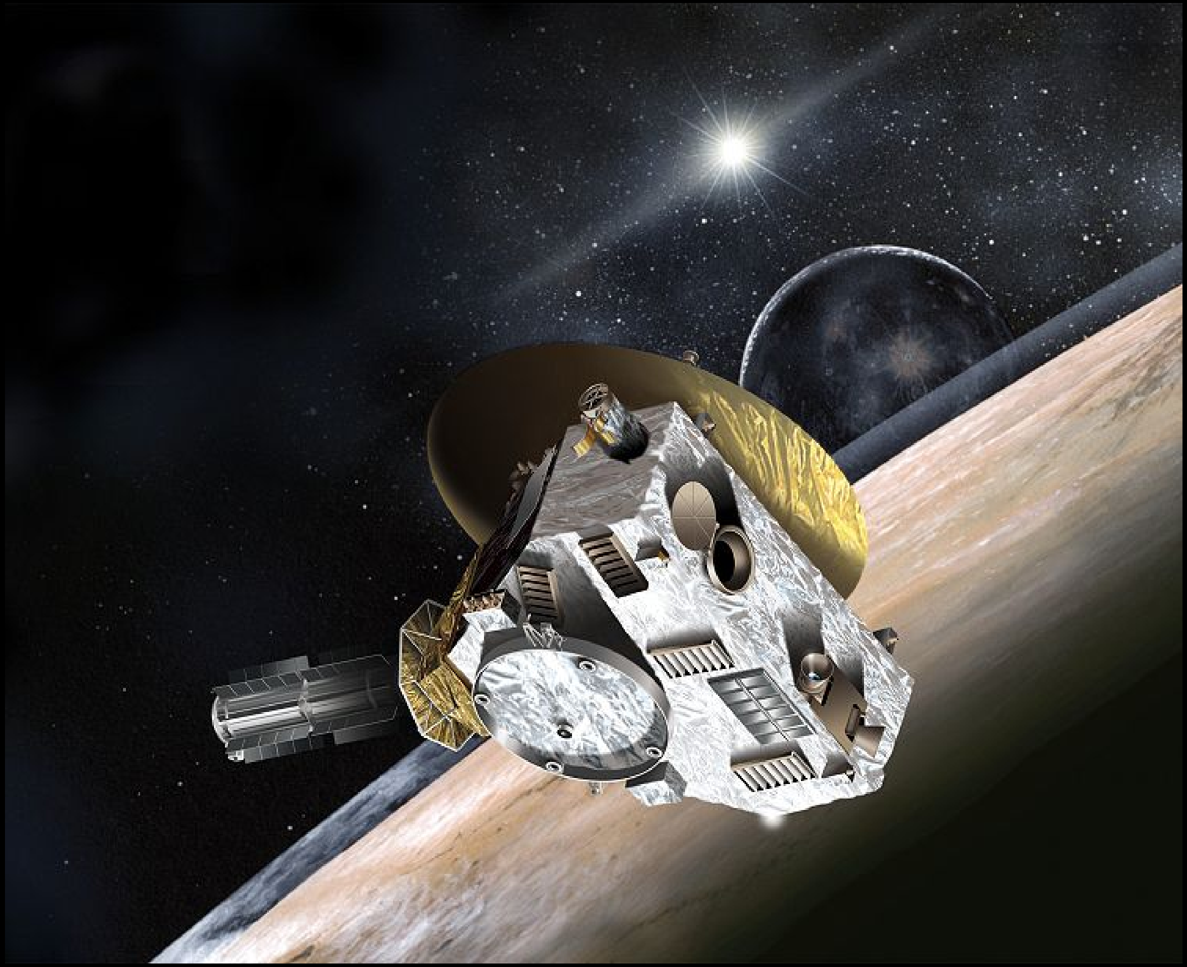
Problemi: material, kontrola orientacije (relativno premikanje CMS in CPS)

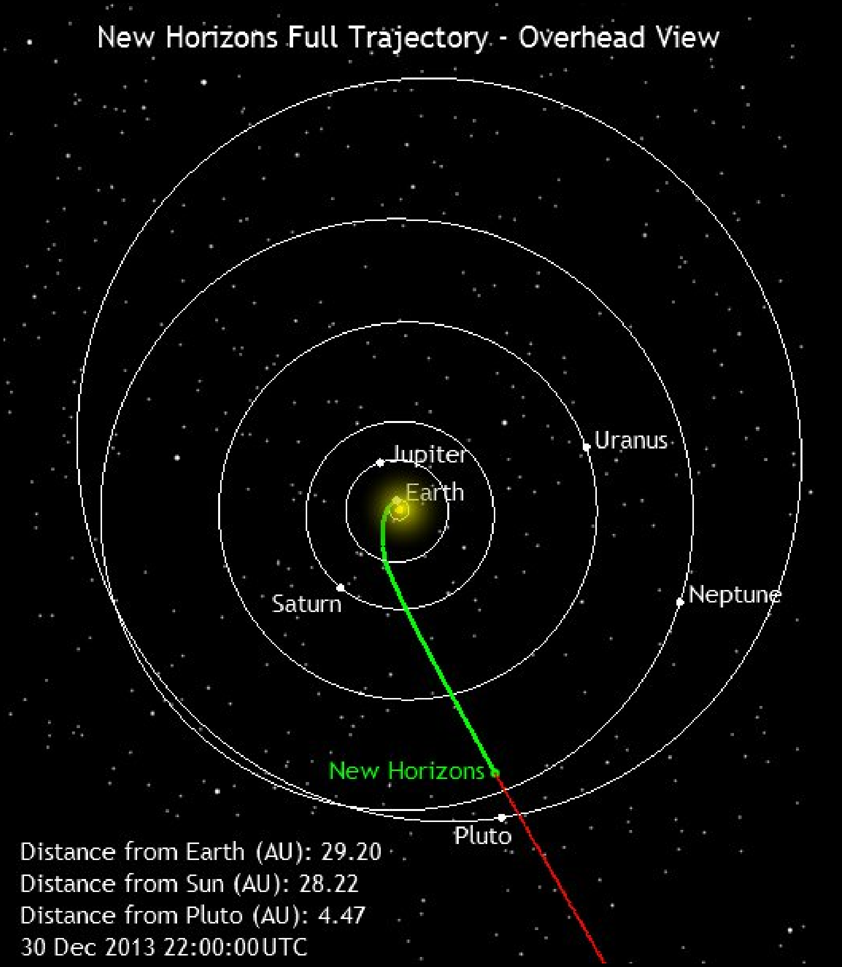


Satelit IKAROS (2010 -): 20m diagonala jadra

Propulsion methods					
Method	Effective Exhaust Velocity (km/s)	Thrust (N)	Firing Duration	Maximum Delta-v (km/s)	Technology readiness level
Solid-fuel rocket	<~ 2.5	<~ 10^7	minutes	~ 7	9:Flight proven
Hybrid rocket			minutes	> 3	9:Flight proven
Monopropellant rocket	1 - 3[citation needed]	0.1 - 100[citation needed]	milliseconds-minutes	~ 3	9:Flight proven
Liquid-fuel rocket	<~ 4.4	<~ 10^7	minutes	~ 9	9:Flight proven
Electrostatic ion thruster	15 - 210[22][full citation needed]		months/years	> 100	9:Flight proven
Hall effect thruster (HET)	8 - 50[citation needed]		months/years	> 100	9:Flight proven[23]
Resistojet rocket	2 - 6	10^{-2} - 10	minutes	?	8:Flight qualified[24]
Arcjet rocket	4 - 16	10^{-2} - 10	minutes	?	8:Flight qualified[citation needed]
Field Emission Electric Propulsion (FEEP)	100[25]-130	10^{-6}[25]-10^{-3}[25]	months/years	?	8:Flight qualified[25]
Pulsed plasma thruster (PPT)	~ 20	~ 0.1	~2,000-10,000 hours	?	7:Prototype demoed in space
Dual mode propulsion rocket	1 - 4.7	0.1 - 10^7	milliseconds-minutes	~ 3 - 9	7:Prototype demoed in space
Solar sails	299790:Light 145-750:Wind	9/km^2 @ 1 AU 230/km^2@0.2AU 10^{-10}/km^2@4 ly	indefinite	> 40	9:Light pressure attitude-control flight proven 6:Deploy-only demoed in space 5:Light-sail validated in lit vacuum
Tripropellant rocket	2.5 - 5.3[citation needed]	0.1 - 10^7[citation needed]	minutes	~ 9	6:Prototype demoed on ground[26]
Magnetoplasmadynamic thruster (MPD)	20 - 100	100	weeks	?	6:Model-1 kW demoed in space[27]
Nuclear thermal rocket	9[28]	10^7[28]	minutes[28]	> ~ 20	6:Prototype demoed on ground
Mass drivers (for propulsion)	0 - ~30	10^4 - 10^8	months	?	6:Model-32MJ demoed on ground
Tether propulsion	N/A	1 - 10^{12}	minutes	~ 7	6:Model-31.7 km demoed in space[29]
Air-augmented rocket	5 - 6	0.1 - 10^7	seconds-minutes	> 7?	6:Prototype demoed on ground[30][31]
Liquid air cycle engine	4.5	10^3 - 10^7	seconds-minutes	?	6:Prototype demoed on ground
Pulsed inductive thruster (PIT)	10[32]-80[32]	20	months	?	5:Component validated in vacuum[32]
Variable Specific Impulse Magnetoplasma Rocket (VASIMR)	10 - 300[citation needed]	40 - 1,200[citation needed]	days - months	> 100	5:Component-200 kW validated in vacuum
Magnetic field oscillating amplified thruster	10 - 130	0.1 - 1	days - months	> 100	5:Component validated in vacuum
Solar thermal rocket	7 - 12	1 - 100	weeks	> ~ 20	4:Component validated in lab[33]
Radioisotope rocket	7 - 8[citation needed]	1.3 - 1.5	months	?	4:Component validated in lab
Nuclear electric rocket(As electric prop. method used)	Variable	Variable	Variable	?	4:Component-400kW validated in lab
Orion Project (Near term nuclear pulse propulsion)	20 - 100	10^9 - 10^{12}	several days	~30-60	3:Validated-900 kg proof-of-concept[34][35]
Space elevator	N/A	N/A	indefinite	> 12	3:Validated proof-of-concept
Reaction Engines SABRE[19]	30/4.5	0.1 - 10^7	minutes	9.4	3:Validated proof-of-concept
Magnetic sails	145-750:Wind	70/40Mg[36]	indefinite	?	3:Validated proof-of-concept
Magnetic sail#Mini-magnetospheric plasma propulsion	200	~1 N/kW	months	?	3:Validated proof-of-concept[37]
Beam-powered/Laser(As prop. method powered by beam)	Variable	Variable	Variable	?	3:Validated-71m proof-of-concept
Launch loop/Orbital ring	N/A	~10^4	minutes	>>11-30	2:Technology concept formulated
Nuclear pulse propulsion (Project Daedalus' drive)	20 - 1,000	10^9 - 10^{12}	years	~15,000	2:Technology concept formulated
Gas core reactor rocket	10 - 20	10^3 - 10^6	?	?	2:Technology concept formulated
Nuclear salt-water rocket	100	10^3 - 10^7	half hour	?	2:Technology concept formulated
Fission sail	?	?	?	?	2:Technology concept formulated
Fission-fragment rocket	15,000	?	?	?	2:Technology concept formulated
Nuclear photonic rocket	299,790	10^{-5} - 1	years-decades	?	2:Technology concept formulated
Fusion rocket	100 - 1,000[citation needed]	?	?	?	2:Technology concept formulated
Antimatter catalyzed nuclear pulse propulsion	200 - 4,000	?	days-weeks	?	2:Technology concept formulated
Antimatter rocket	10,000-100,000[citation needed]	?	?	?	2:Technology concept formulated
Bussard ramjet	2.2 - 20,000	?	indefinite	~30,000	2:Technology concept formulated
Gravitoelectromagnetic toroidal launchers	299,790:GEM[clarification needed]	?	?	<299790[citation needed]	1:Basic principles observed & reported

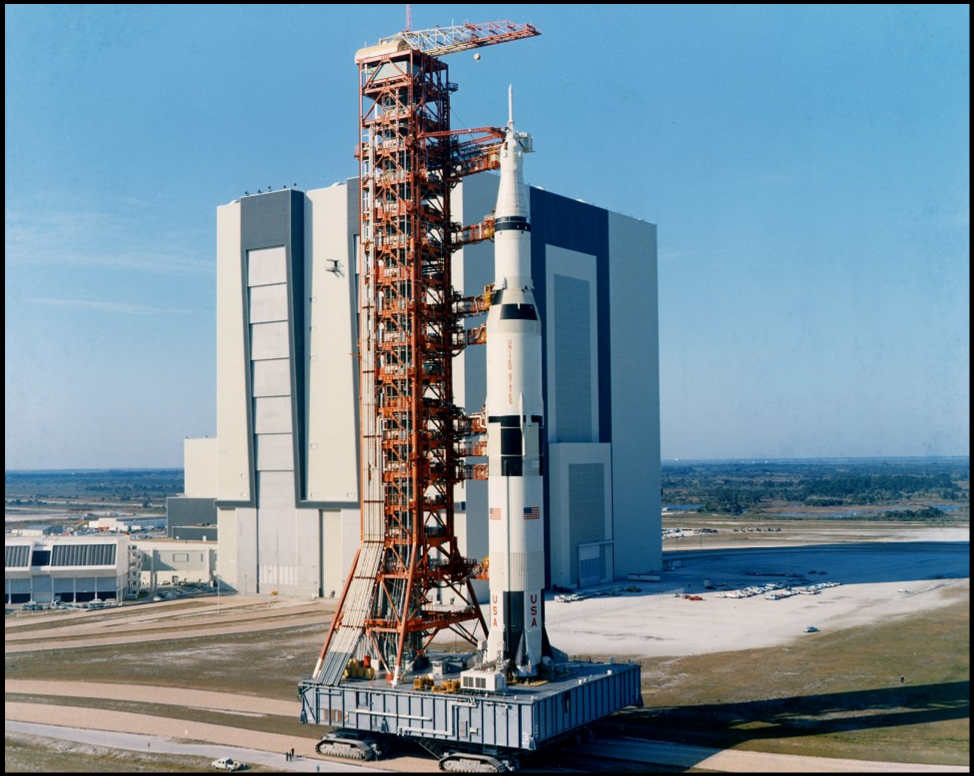
Zanimive misije: rekordi hitrosti



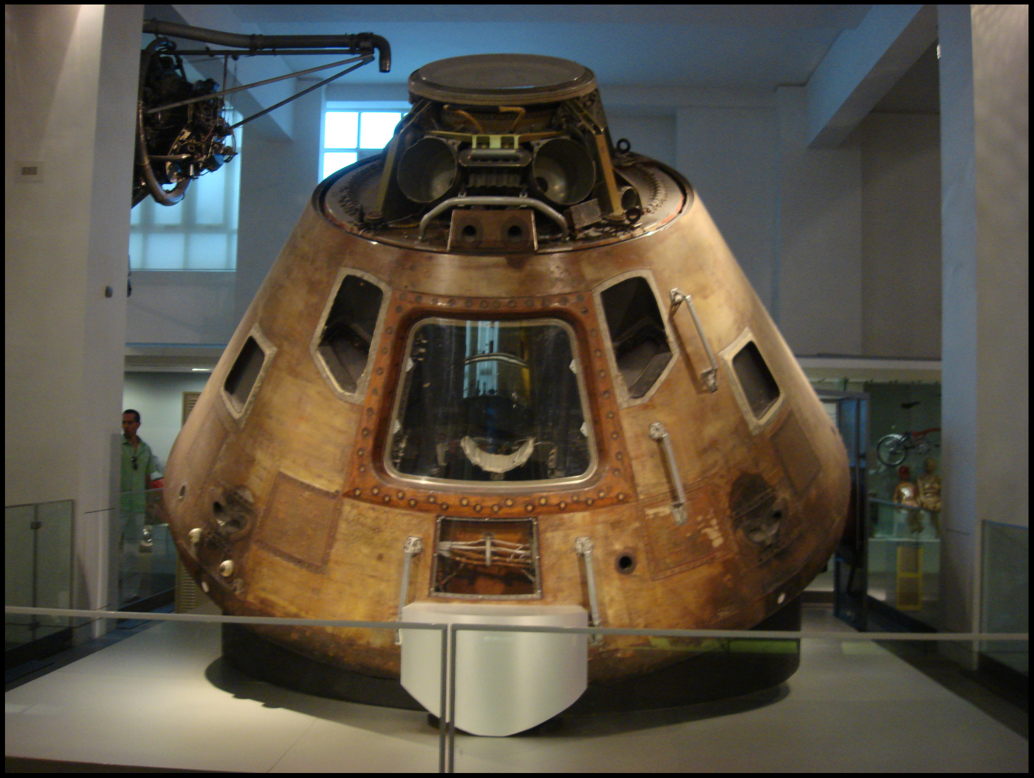


New Horizons (Pluton + Kuiperjev pas)
- izstrelitev: 2006
- hitrost izstrelitve: **16.26 km/s** (mimo Lune v 9 urah, mimo Marsa v 78 dneh)
- Mars (2006), Jupiter (2007), Saturn (2008), Uran (2011), Pluton (2015)
- Hitrost pri Plutonu (relativno glede na Sonce): **14 km/s**

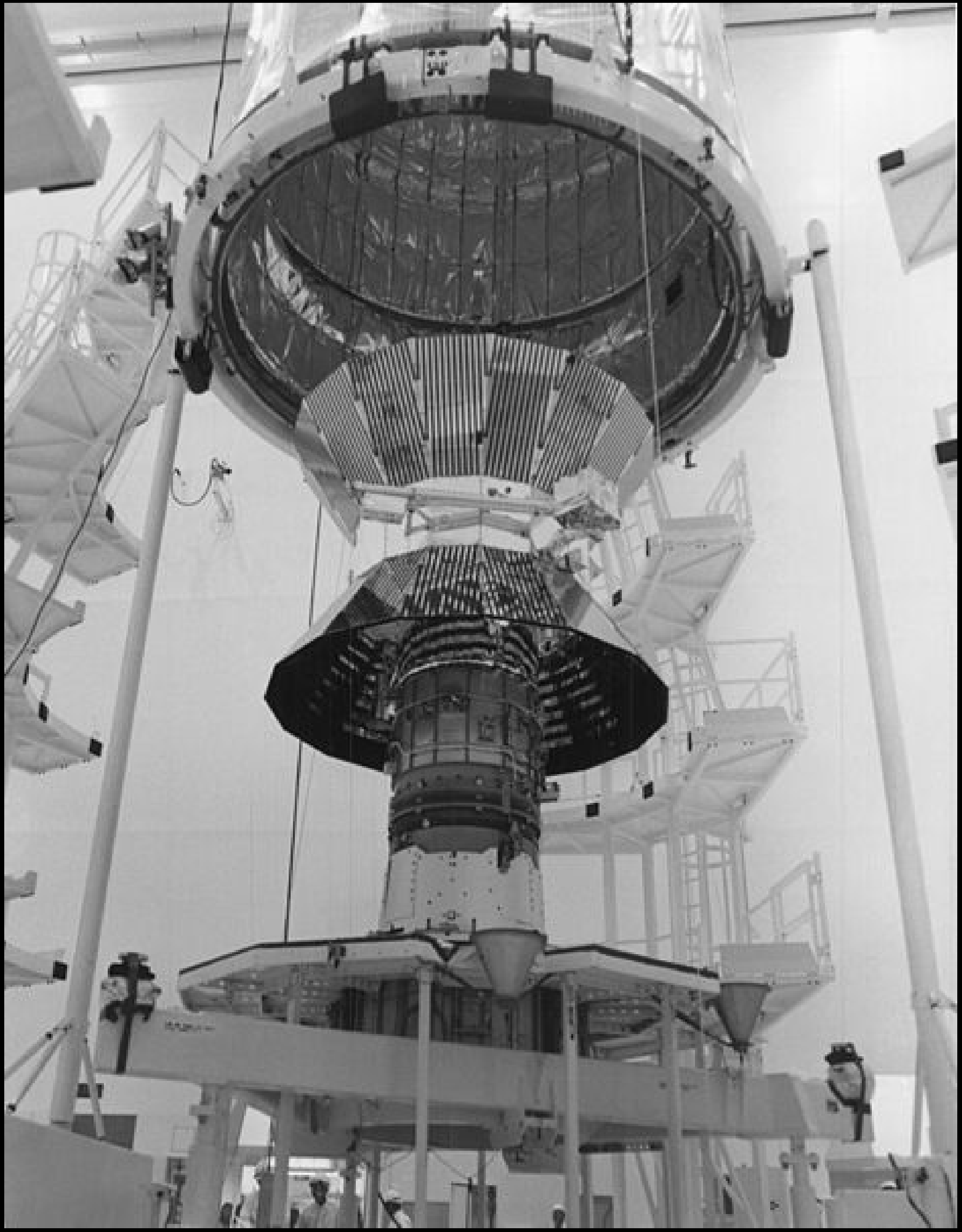
Zanimive misije: rekordi hitrosti



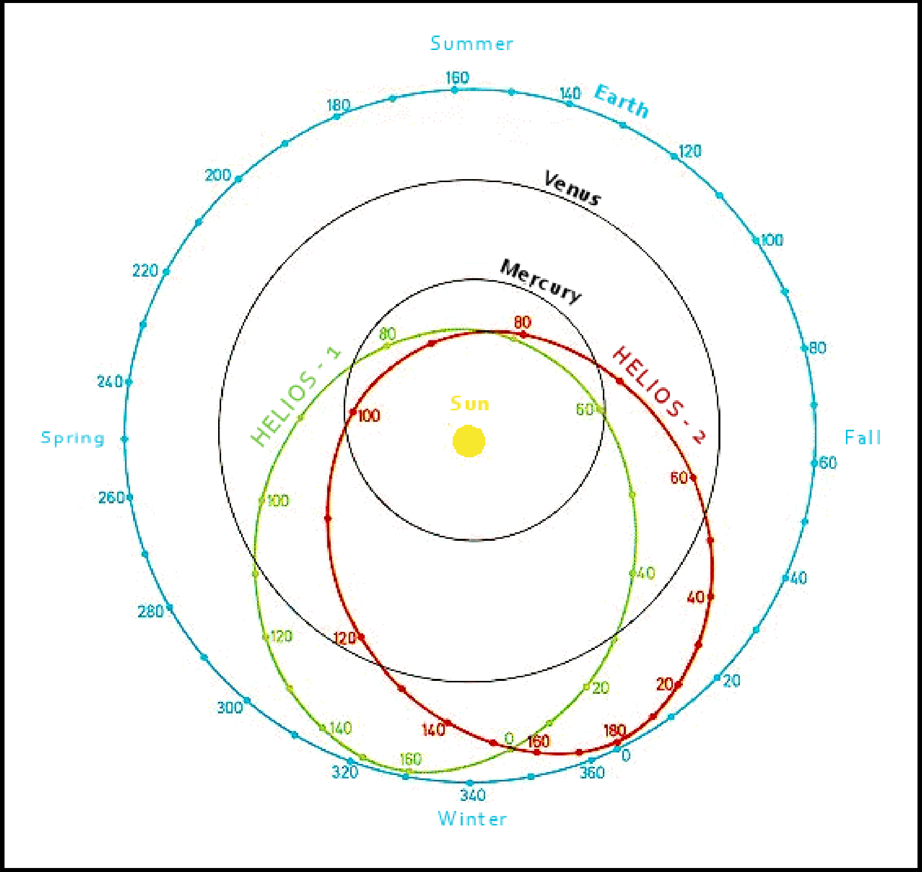
Apollo 10:
- priprava za Luno
- najhitrejše plovilo s človeško posadko
- izstrelitev: maj 1969
  (Apollo 11 = julij 1969)
- hitrost (pri povratku): **11.08 km/s**



Zanimive misije: rekordi hitrosti

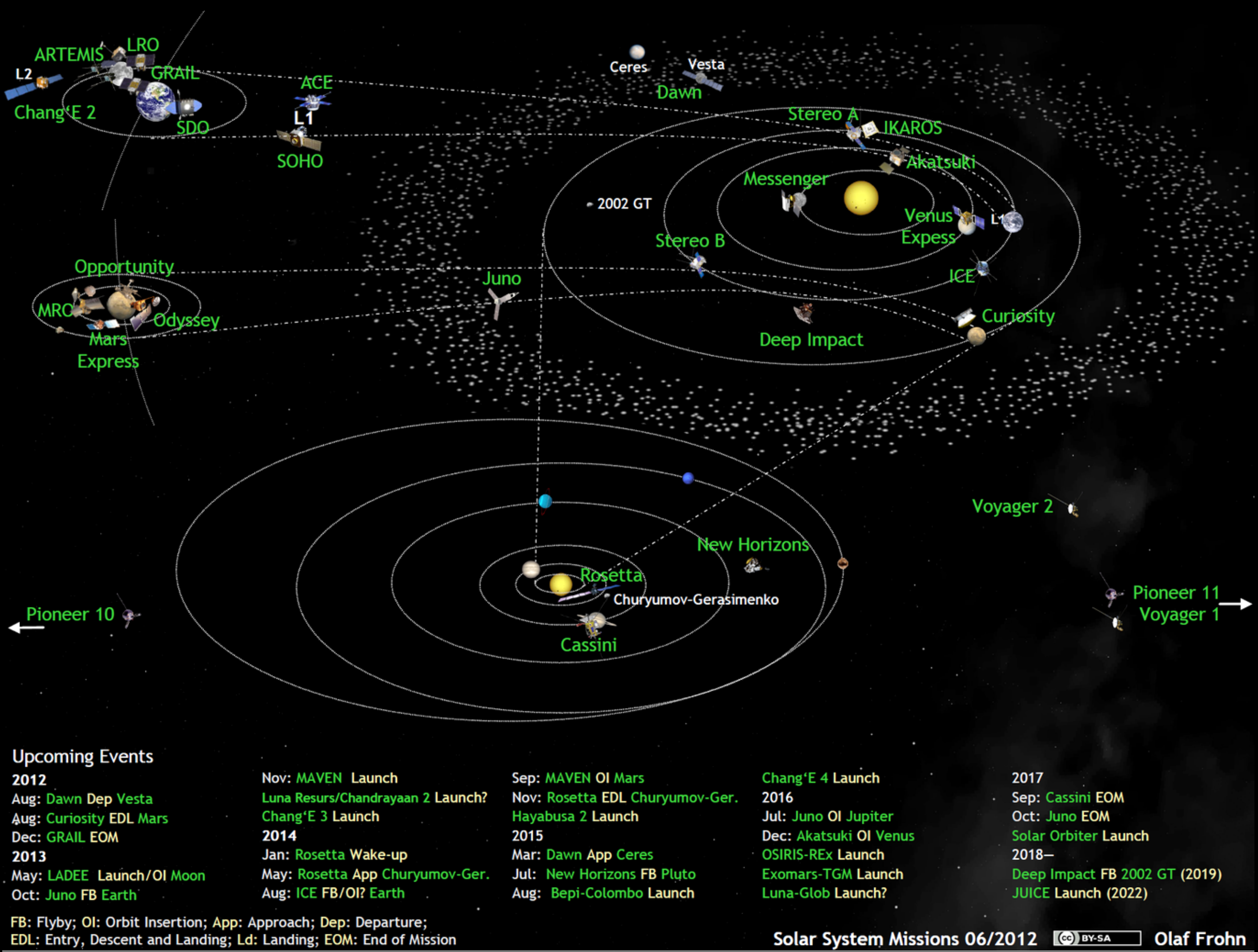


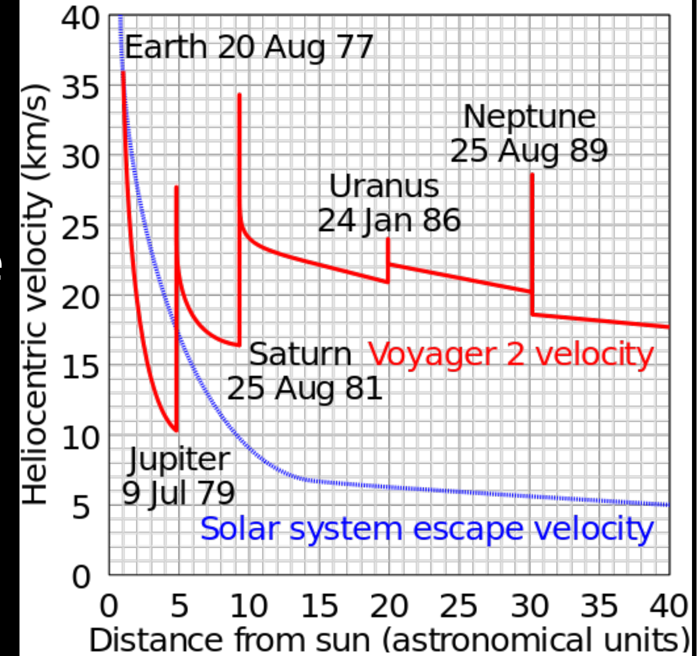
Helios 2
- Izstrelitev: 1976
- v_{orb} = **70 km/s**
- Perihelij: 0.29 A.E.
- Solar Probe+ (2018): P = 0.034 A.E.
  v_{orb} ~ **200 km/s**

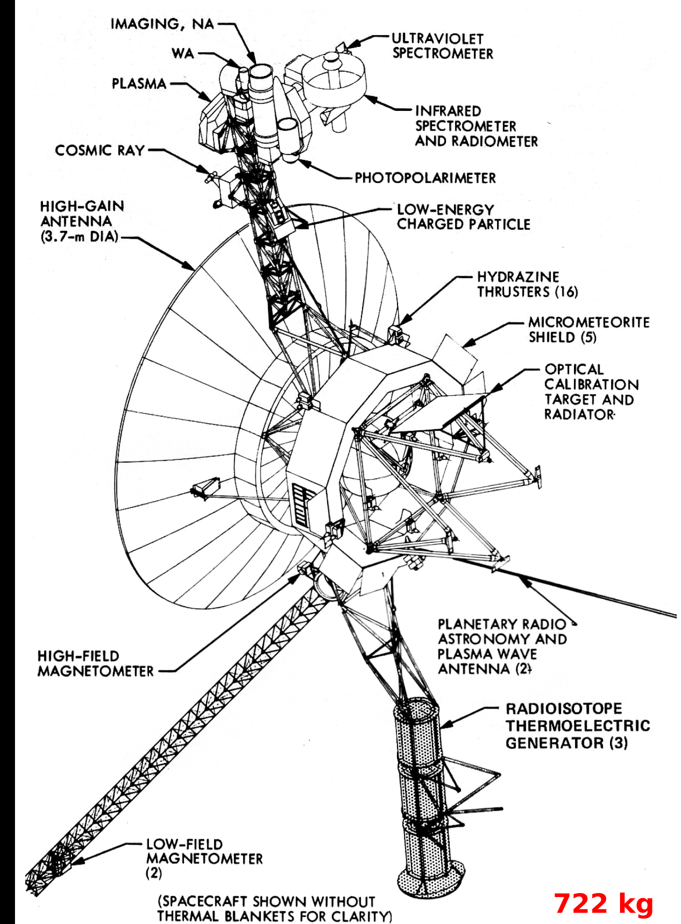


Rekordi dosega

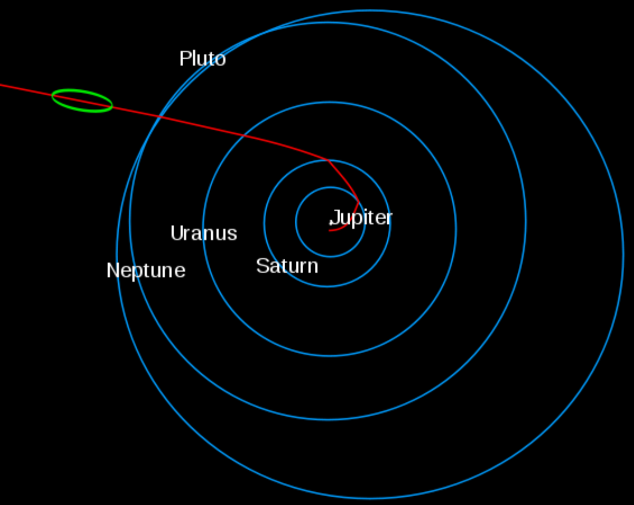
- Voyager 1, Voyager 2, Pioneer 10, Pioneer 11
- Voyager 1 (izstreljen 1977) 2012 'preko' heliopavze
- pri 121 A.E. se oddaljuje od Sonca s 17km/s



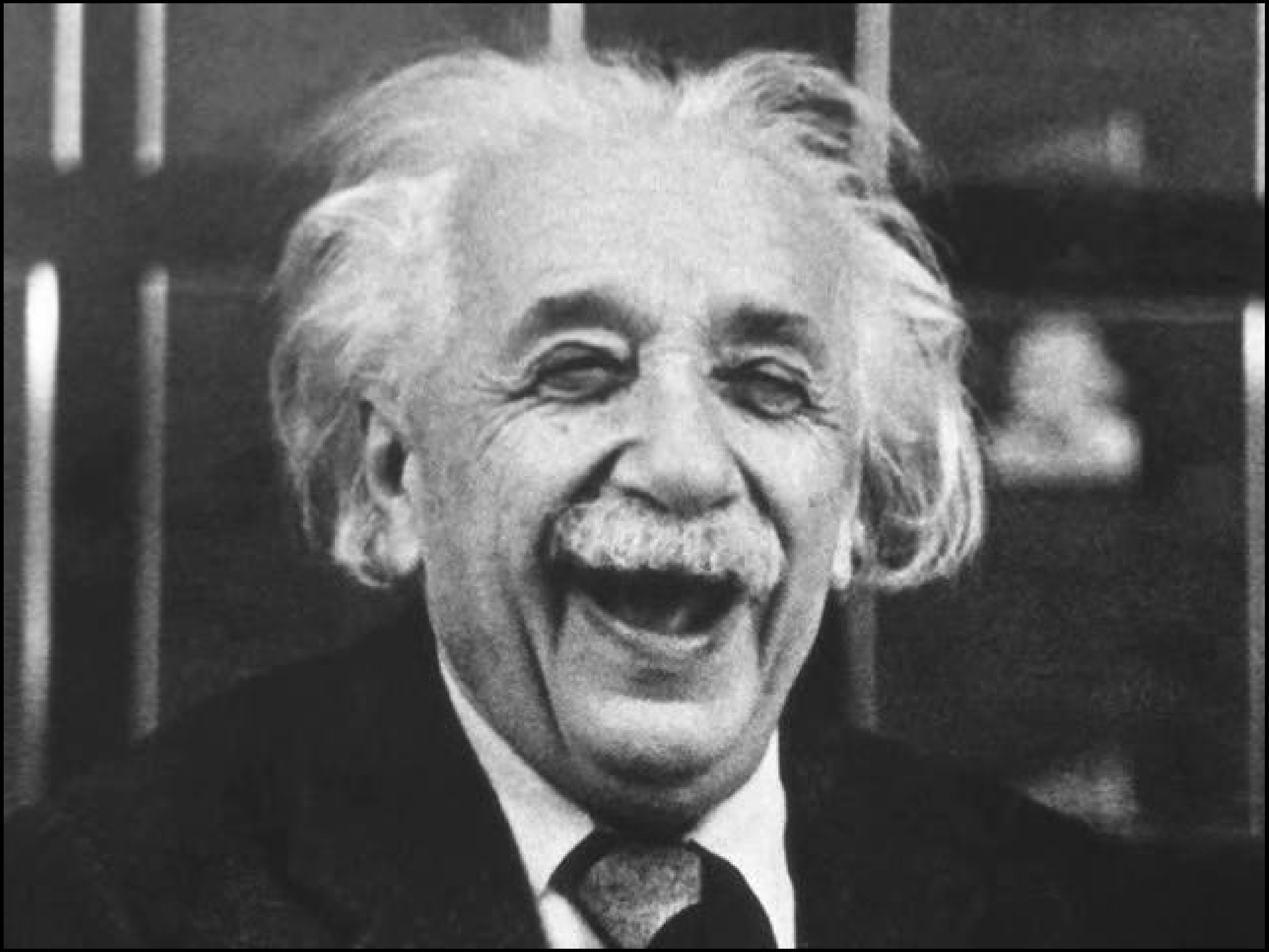




Voyager 1: Pale Blue Dot (1990)



POLICIJA STOP



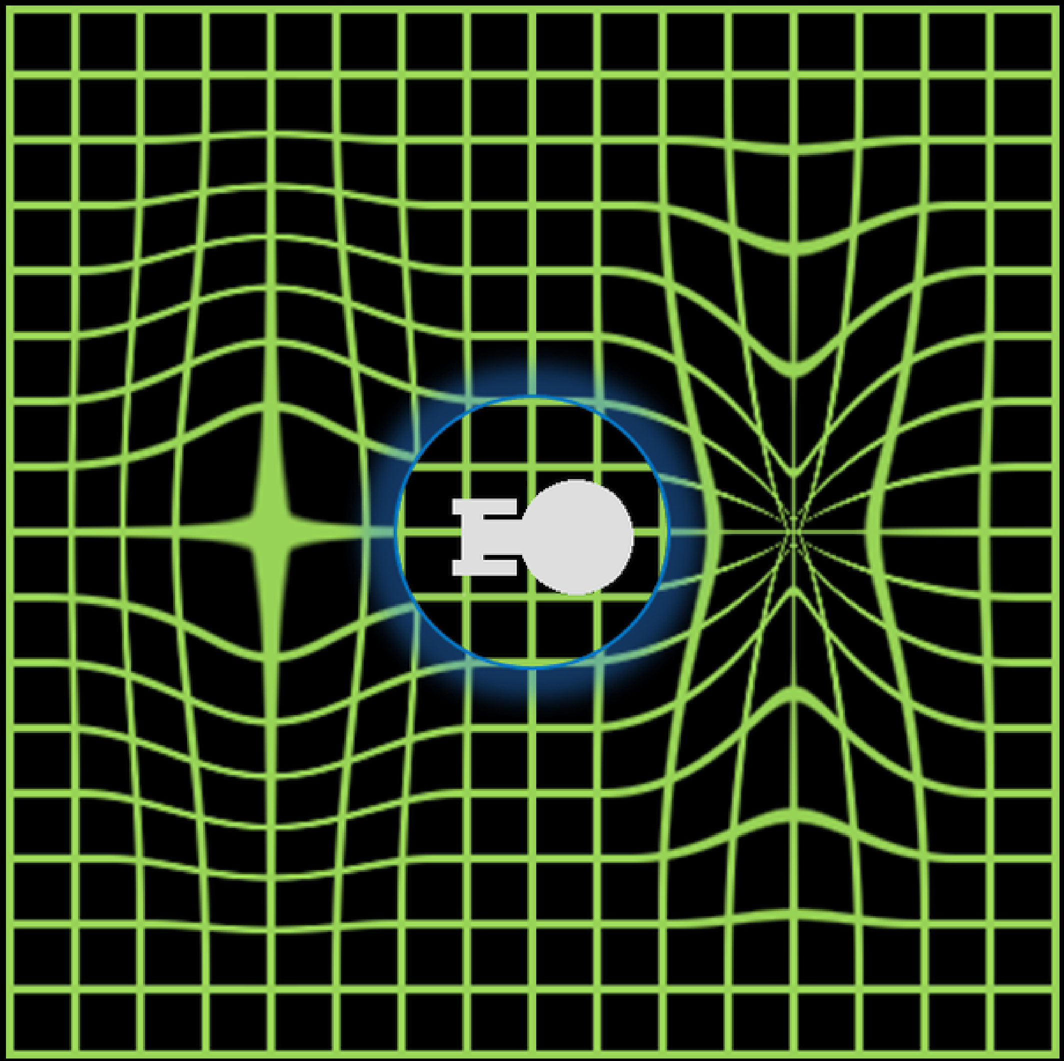
Fizikalno vesolje in nova fizika

Delovanje sil (interakcij) in ohranitveni zakoni - teoretične omejitve

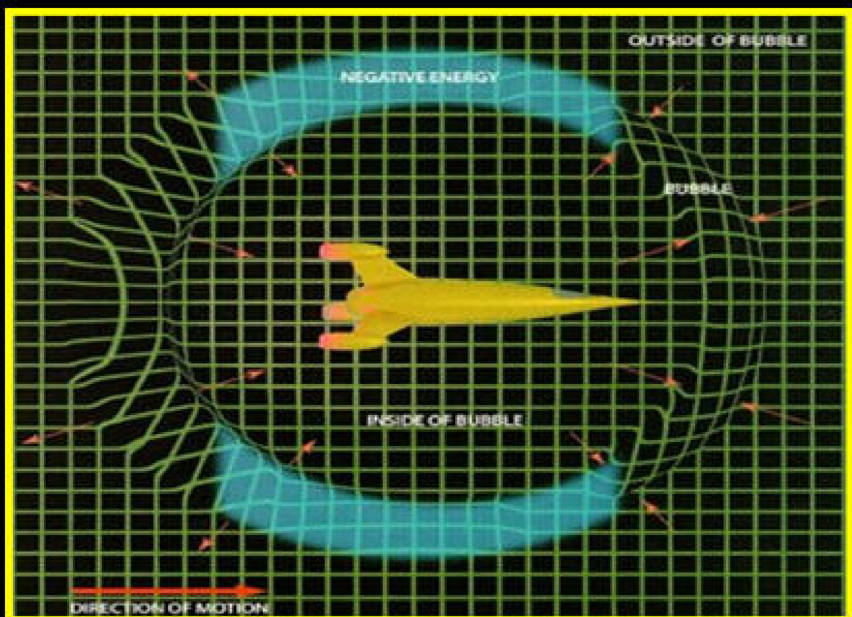
Za udobno in hitro potovanje po vesolju je potrebno:
- biti hitrejši kot svetloba
- iznajti pogon ki ne potrebuje goriva (Bussard ramjet)

“Hitreje” od svetlobe – warp

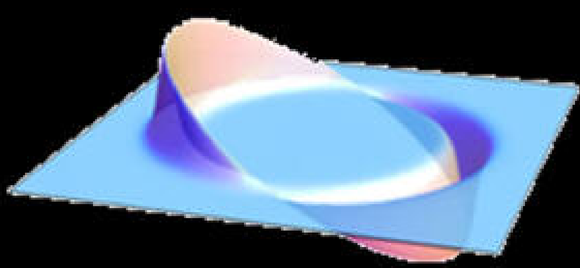
- Potrebujemo negativno maso
- Potrebujemo mehanizem, kako spraviti to negativno maso pred raketo
- Enačbe teorije relativnosti pri $v>c$ divergirajo: neskončna (∞) energija



Alcubierre Warp Drive



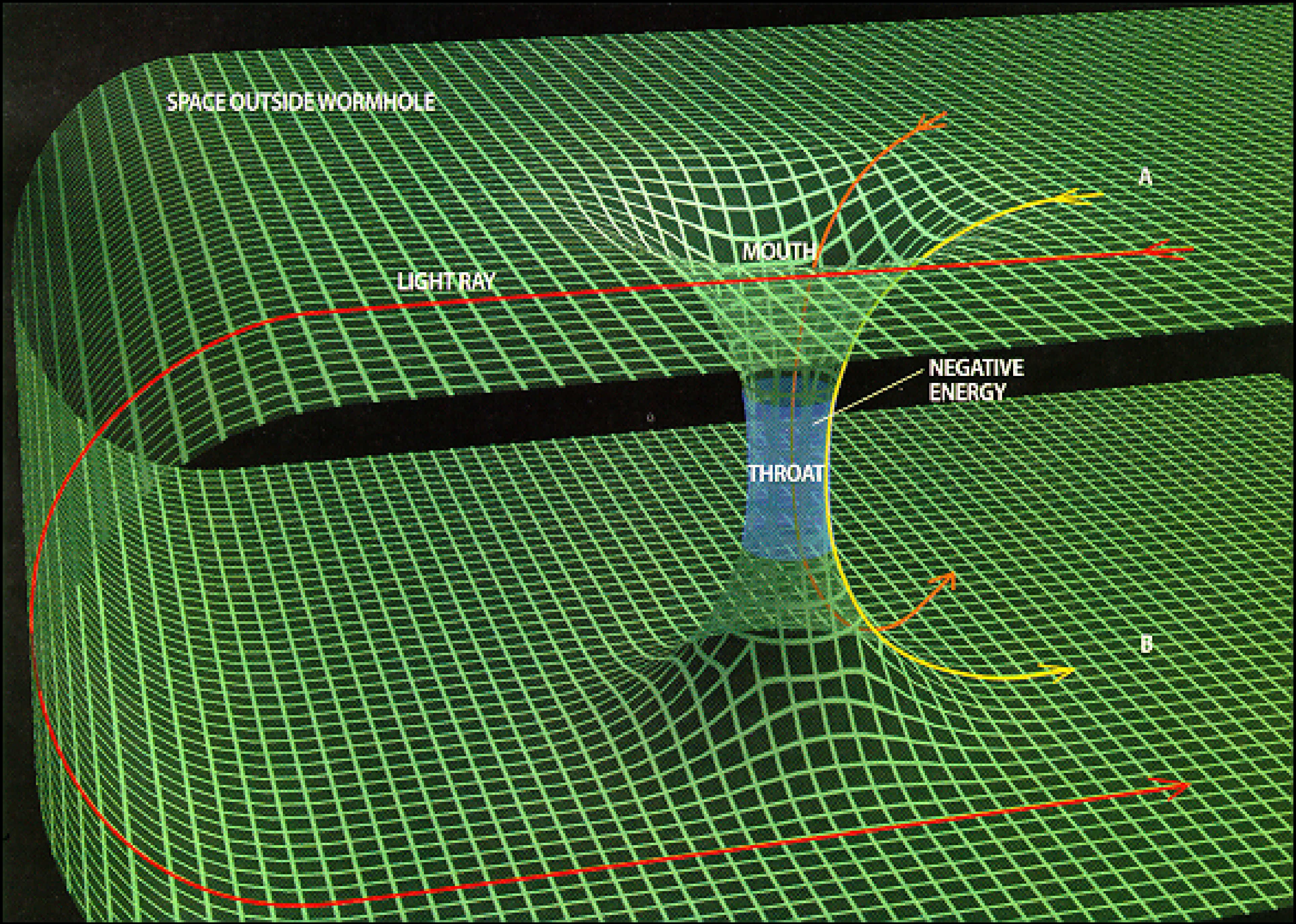
- Effect: GENERAL RELATIVISTIC
- Speed: SUBLUMINAL
- Special Spacetime Geometry: YES
- ✔ Time Travel to Future: YES
- ✘ Time Travel to Past: NO
- ✔ Matter Transport: YES
- ✔ Information Transport: YES
- ✔ Technically Viable: YES
- ✔ Possible w/o Exotic Materials: YES
- ✔ Low Input Power: YES



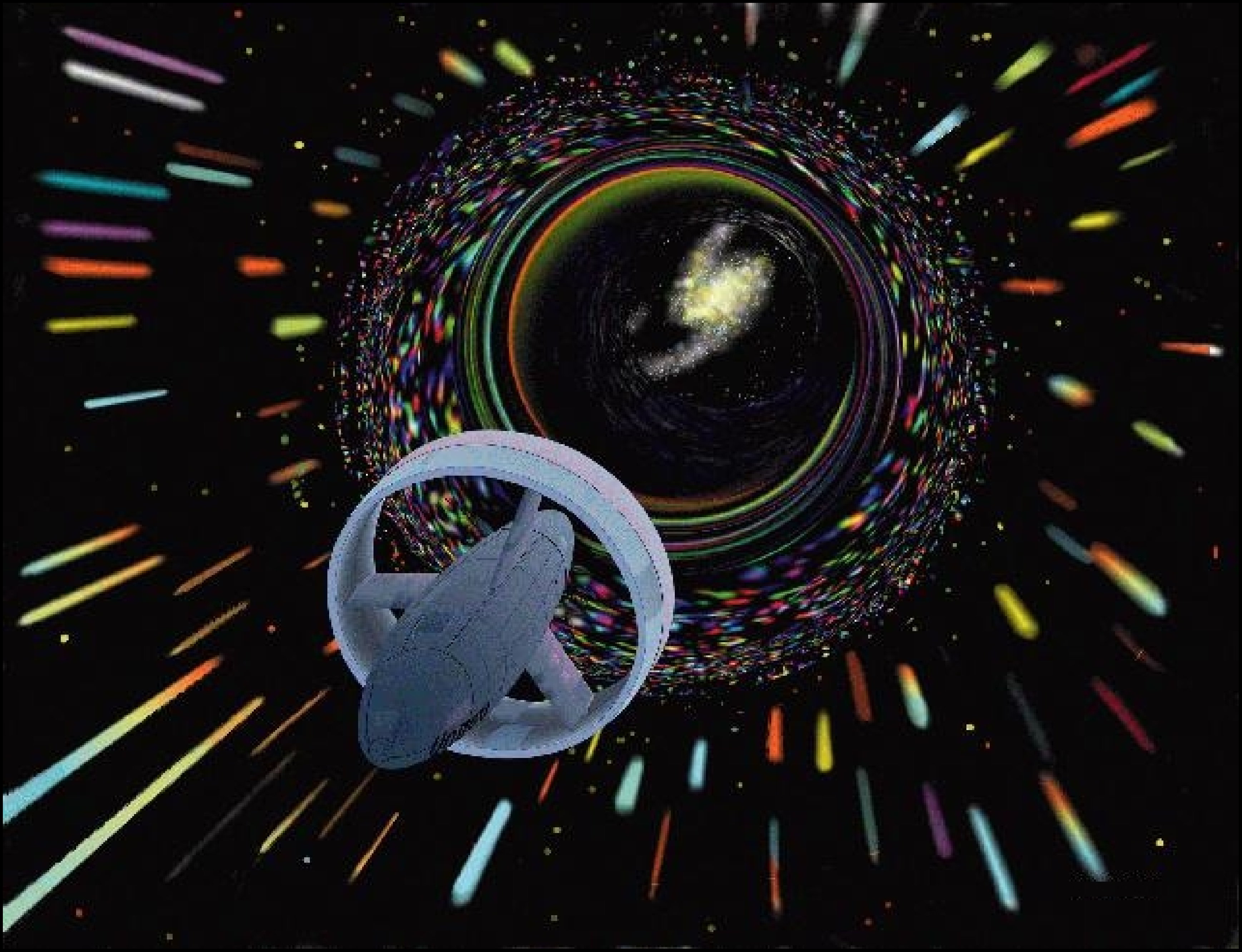
“Hitreje” od svetlobe – warp

“Hitreje” od svetlobe – warp

Črvine, hiperprostor

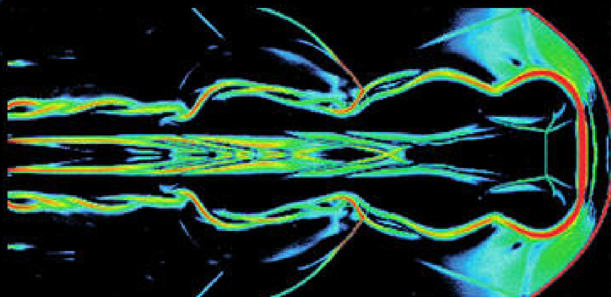


Črvine, hiperprostor

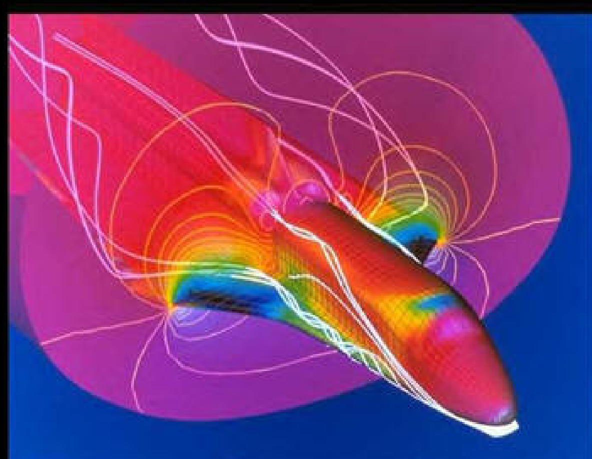


Potovanje skozi čas

Near-Lightspeed Travel

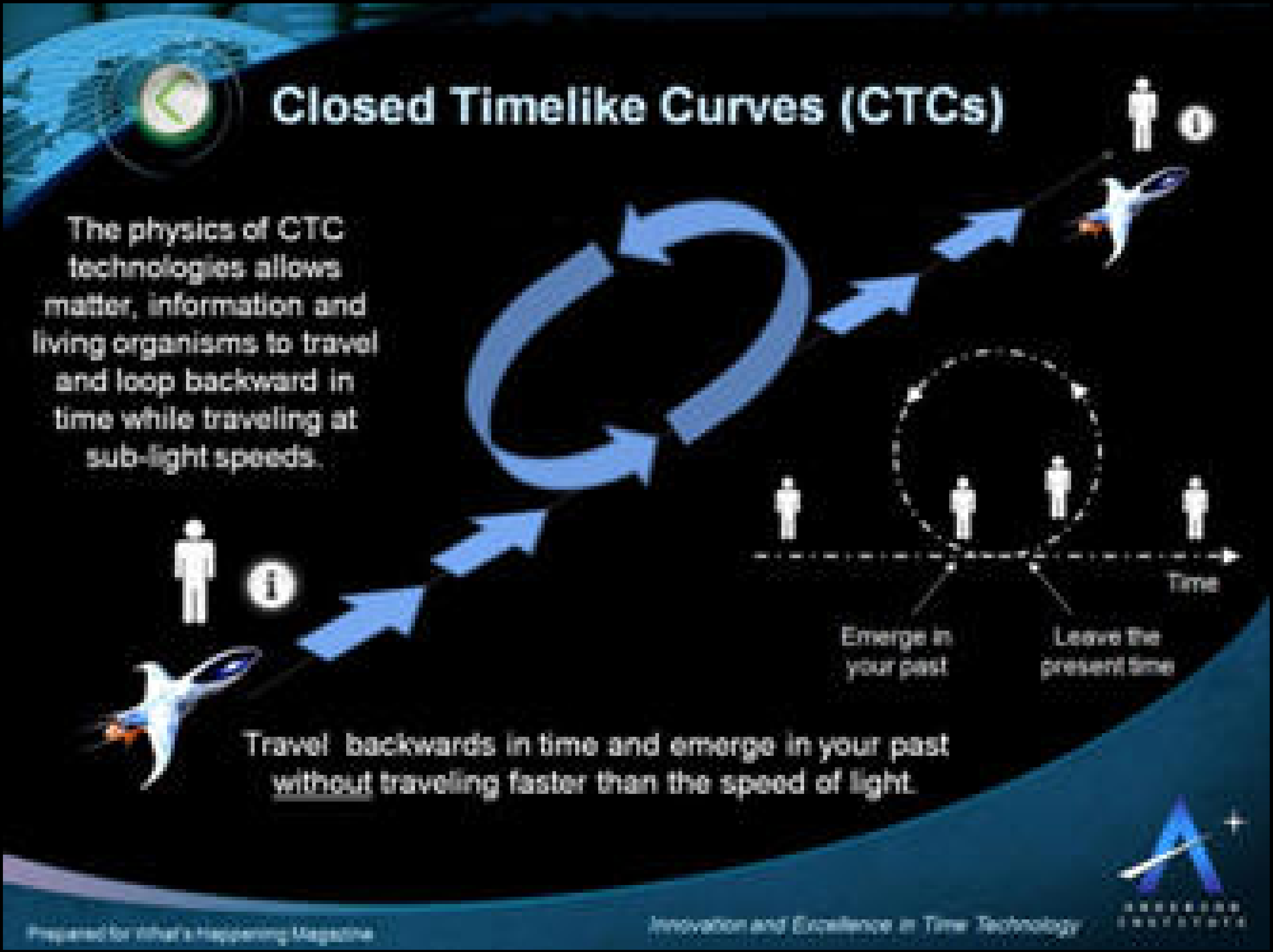


Computer simulation of a jet of photons and electrons traveling at 98 percent of light speed ramming and mixing with interstellar material

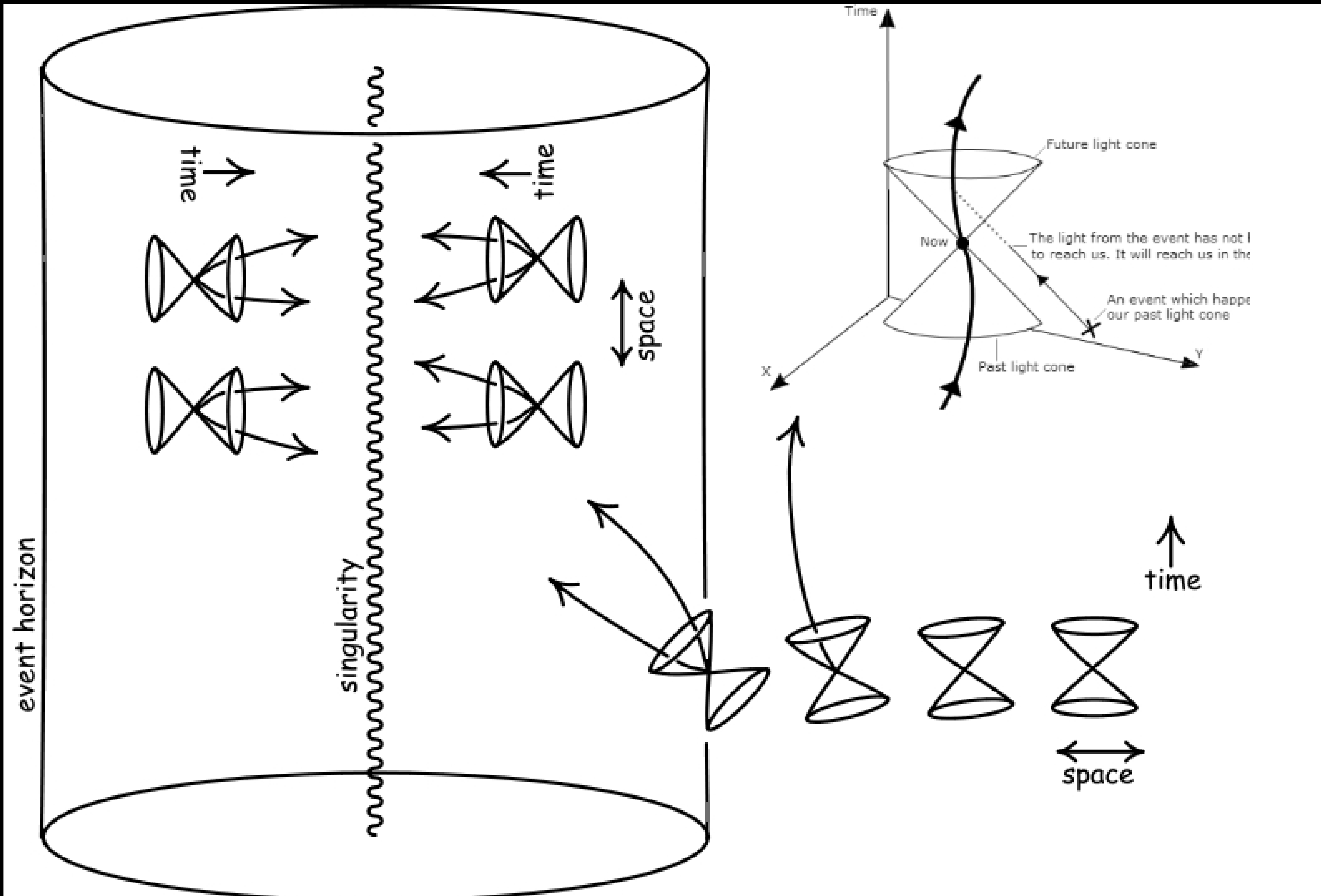


- Effect: SPECIAL RELATIVISTIC
- Speed: NEAR/FTL
- Special Spacetime Geometry: NO
- ✔ Time Travel to Future: YES
- ✘ Time Travel to Past: NO
- ✔ Matter Transport: YES
- ✔ Information Transport: YES
- ✔ Technically Viable: YES
- ✔ Possible w/o Exotic Materials: YES
- ✘ Low Input Power: NO

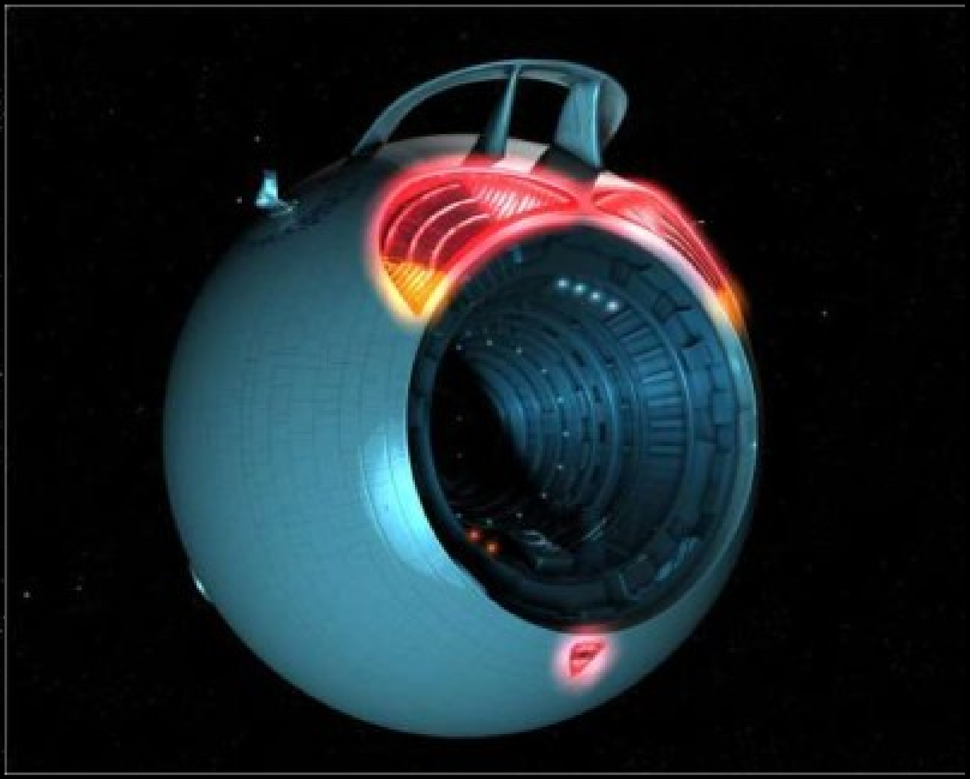
Potovanje skozi čas



Potovanje skozi čas



Neskončno neverjetnostni pogon

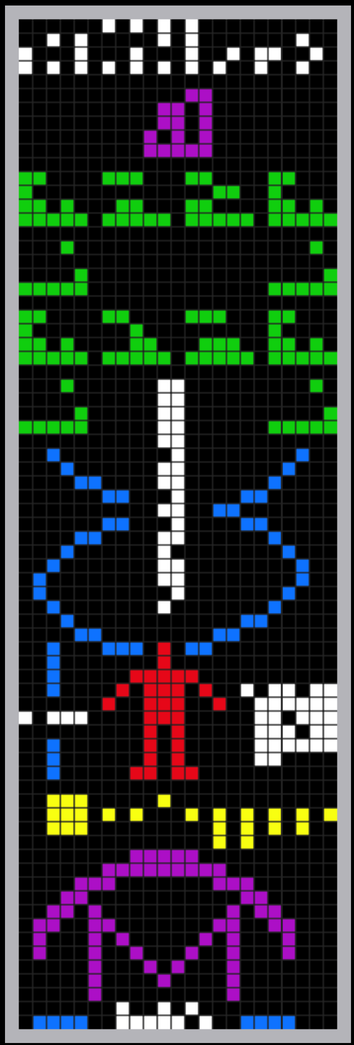


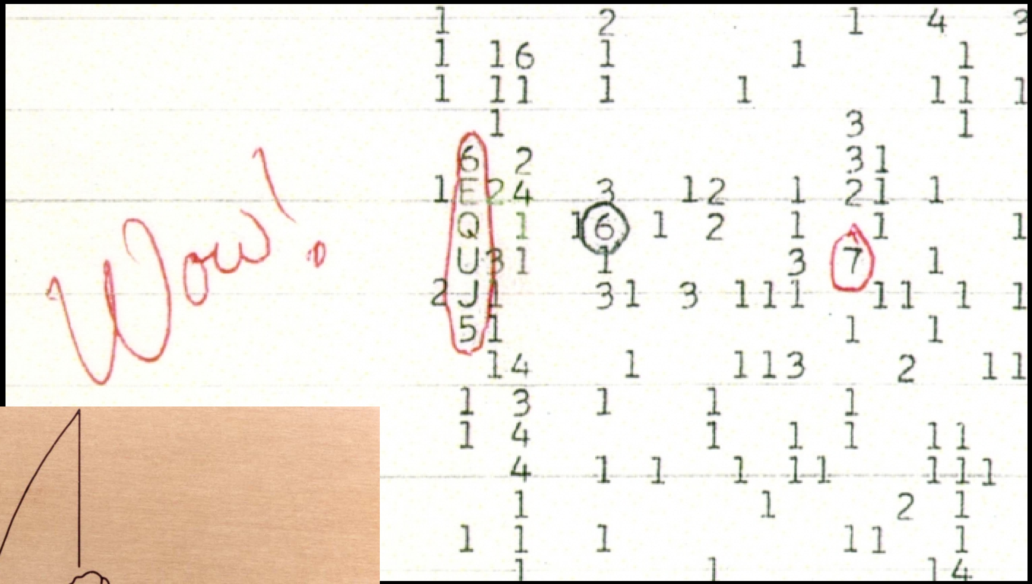
- Vsakemu dogodku lahko pripišemo neko verjetnost
- Na primer, verjetnost da se bomo v naslednji sekundi pojavili v Andromedi je $P \sim 10^{-x}$, kjer je $x >> 1$
- Če bi imeli nadzor nad to verjetnostjo, bi lahko še tako neverjetno stvar obrnil sebi v prid
- POZOR: Pomanjkljivost tega pogona je, da ni zanesljiv in zato se lahko znajdemo kjerkoli drugje, zato je pomembno biti primerno oblečen!

Konec: iskanje vesoljcev

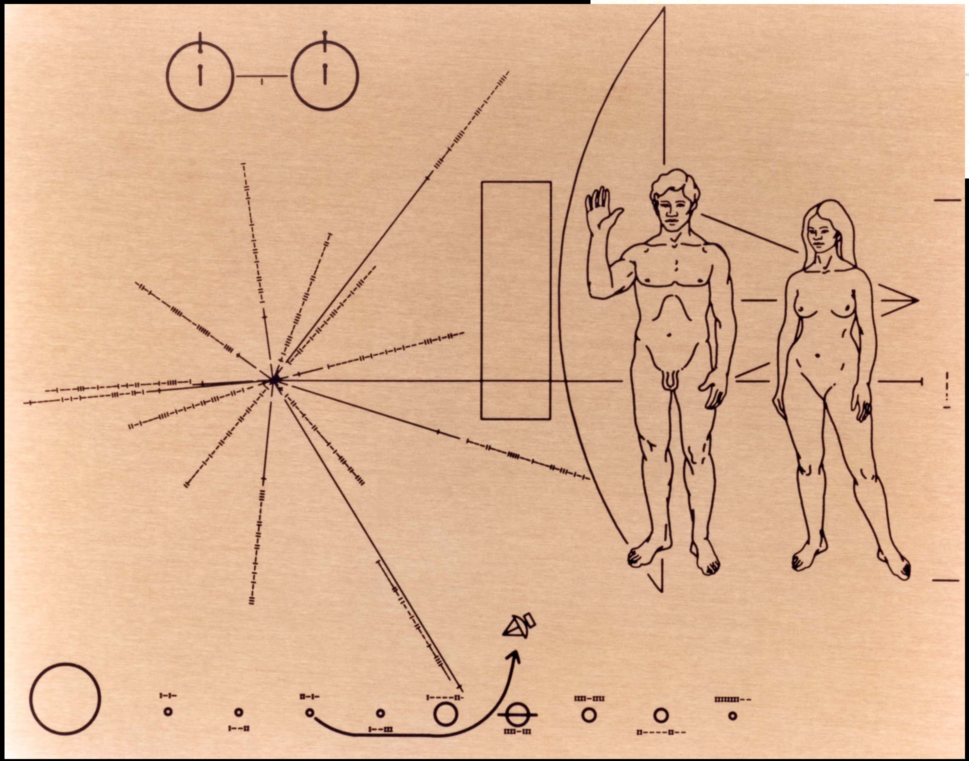
- SETI (Wow! signal. 1977), Arecibo sporočilo (1974)
- Von Neumannov samo-replikativni stroj

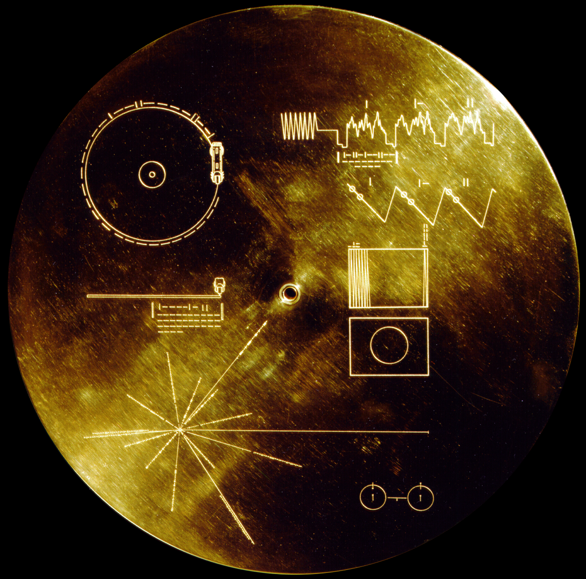
Sporočilo iz Areciba proti kopici M13 (d = 25 000 sv. let)





Plošča na Pioneer 10/11



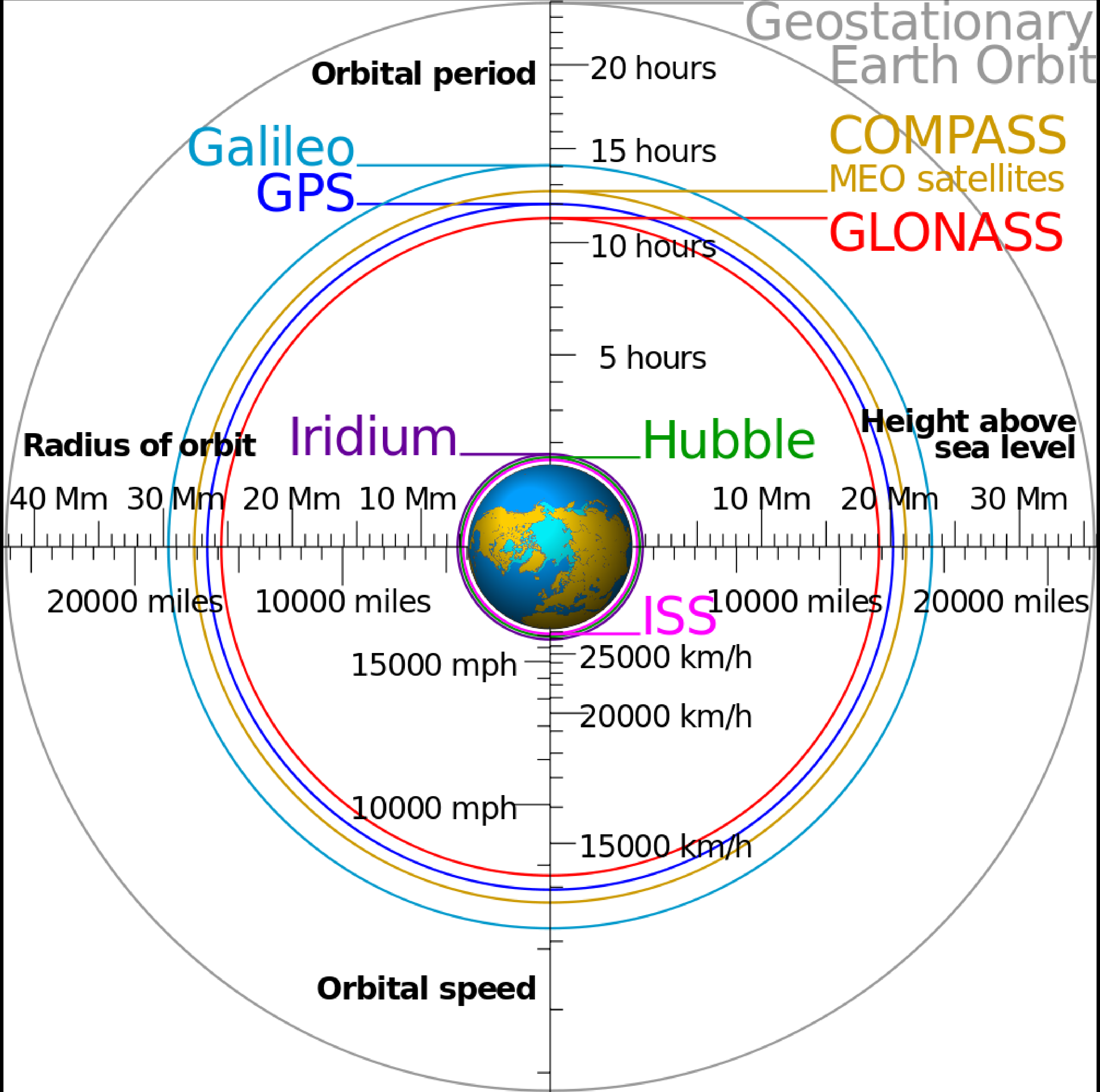


Zlata vinilka na Voyager 1/2

Konec

?

Konec


Geostationary
Earth Orbit
Orbital period
20 hours
15 hours
10 hours
5 hours
Galileo
GPS
COMPASS
MEO satellites
GLONASS
Iridium
Hubble
ISS
Radius of orbit
Height above
sea level
40 Mm
30 Mm
20 Mm
10 Mm
10 Mm
20 Mm
30 Mm
20000 miles
10000 miles
10000 miles
20000 miles
15000 mph
25000 km/h
20000 km/h
10000 mph
15000 km/h
Orbital speed