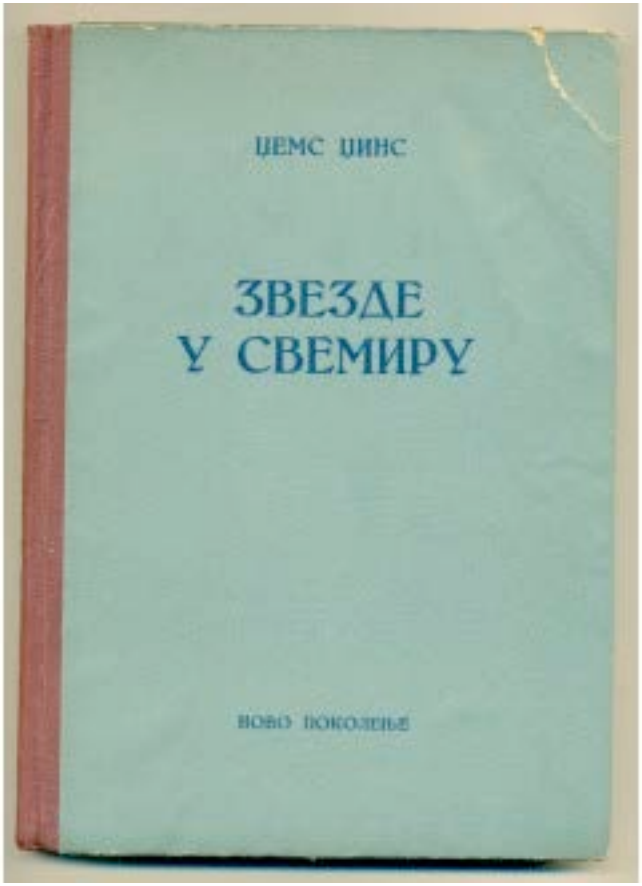
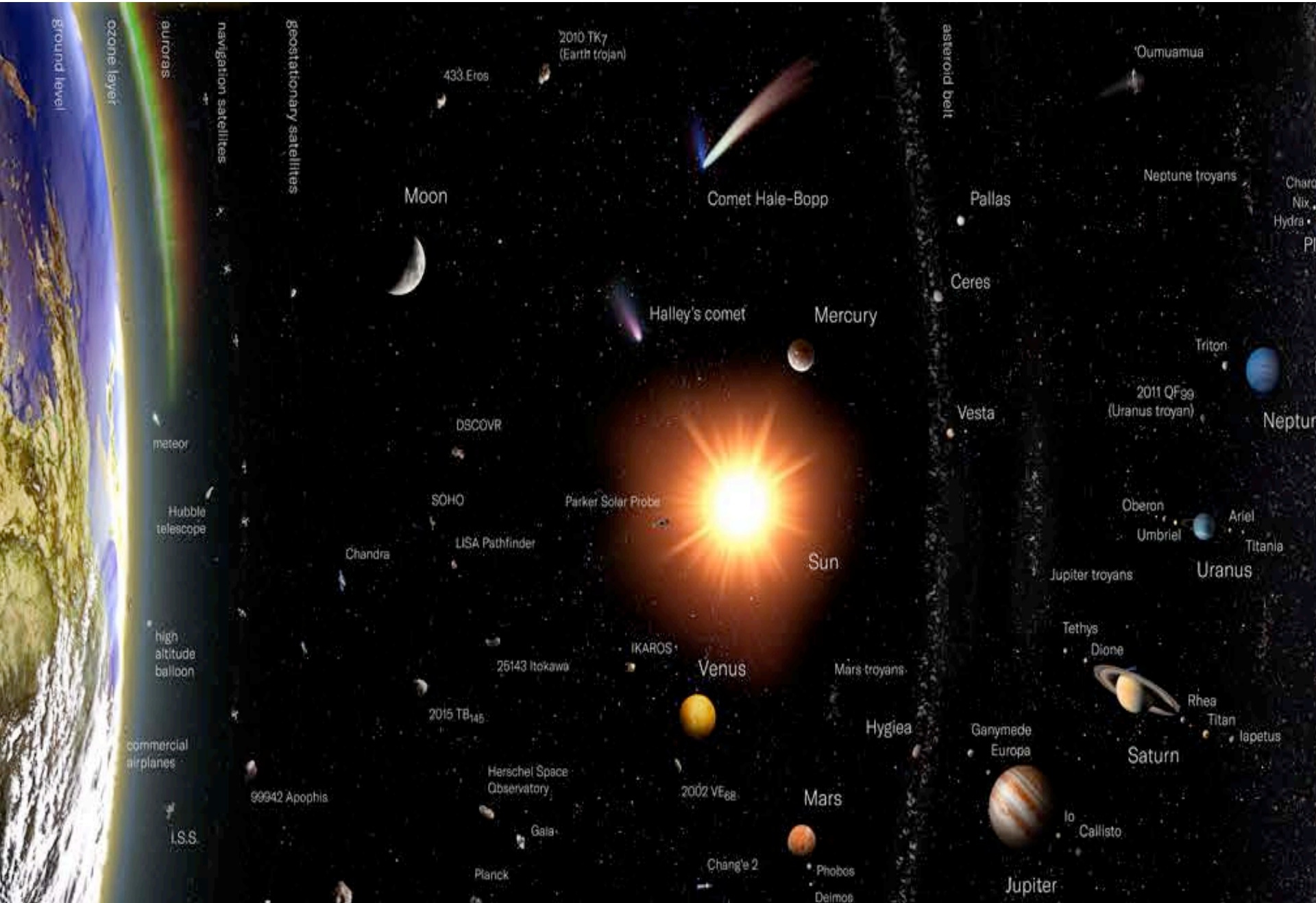
Шта ће најзад бити с нама (и са свемиром)?

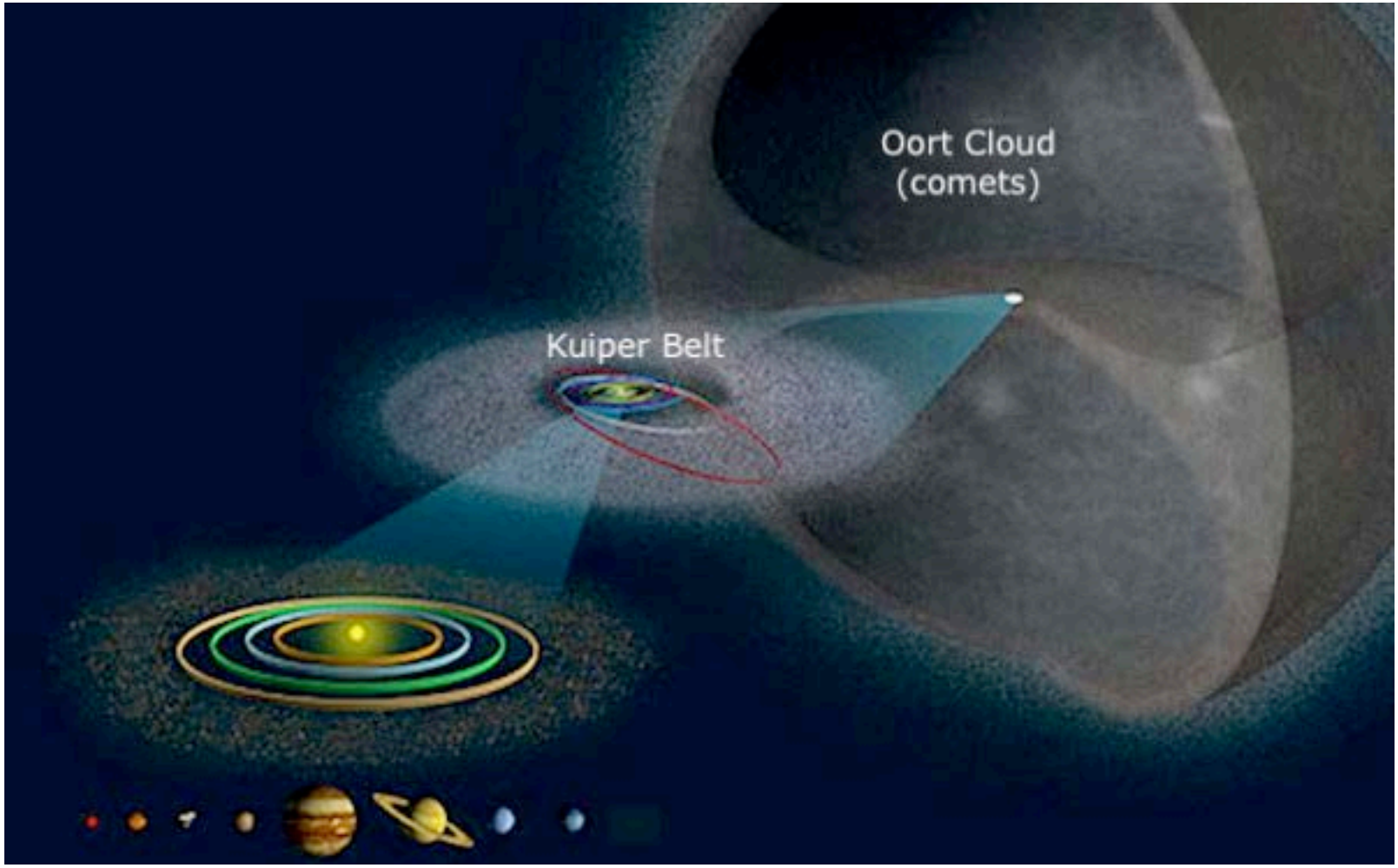
Н. Швракић

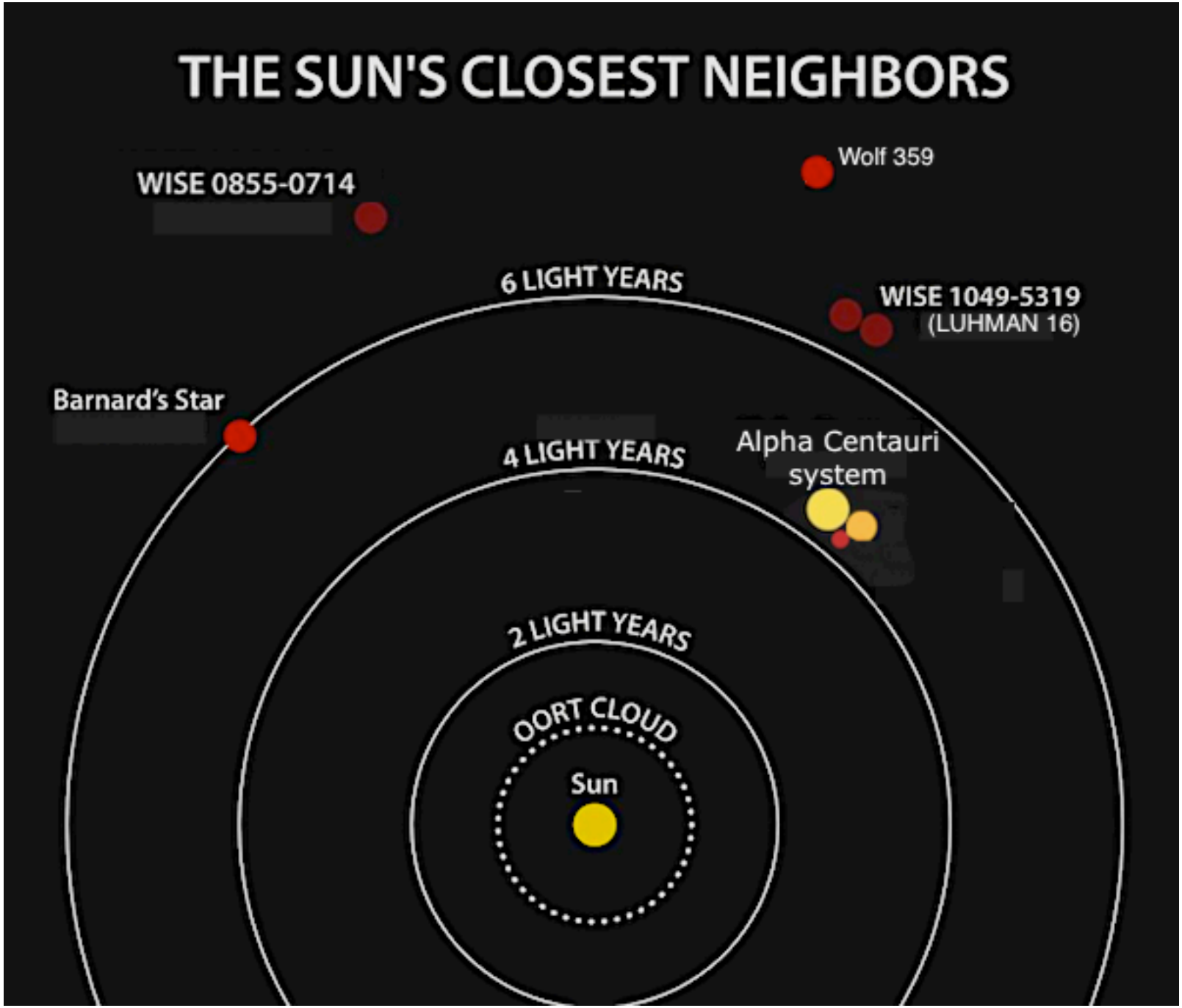
The universe is full of magical things,
patiently waiting for our wits to grow sharper. –
Eden Philpotts

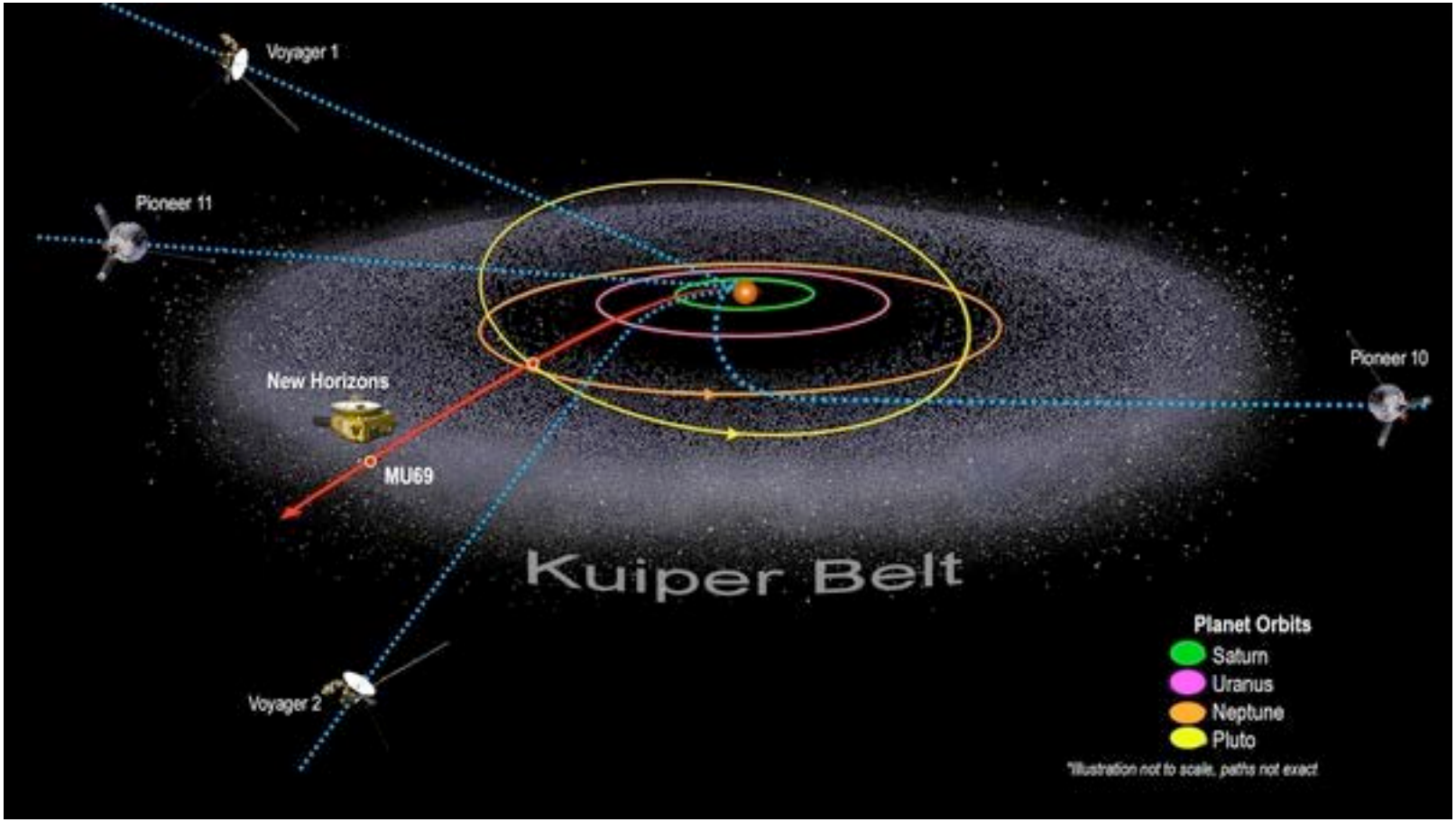
This is the way the world ends
Not with a bang but a whimper.
(T.S. Eliot, The Hollow Men)


ЏЕМС ЏИНС
ЗВЕЗДЕ
У СВЕМИРУ
НОВО ПОКОЛЕЊЕ

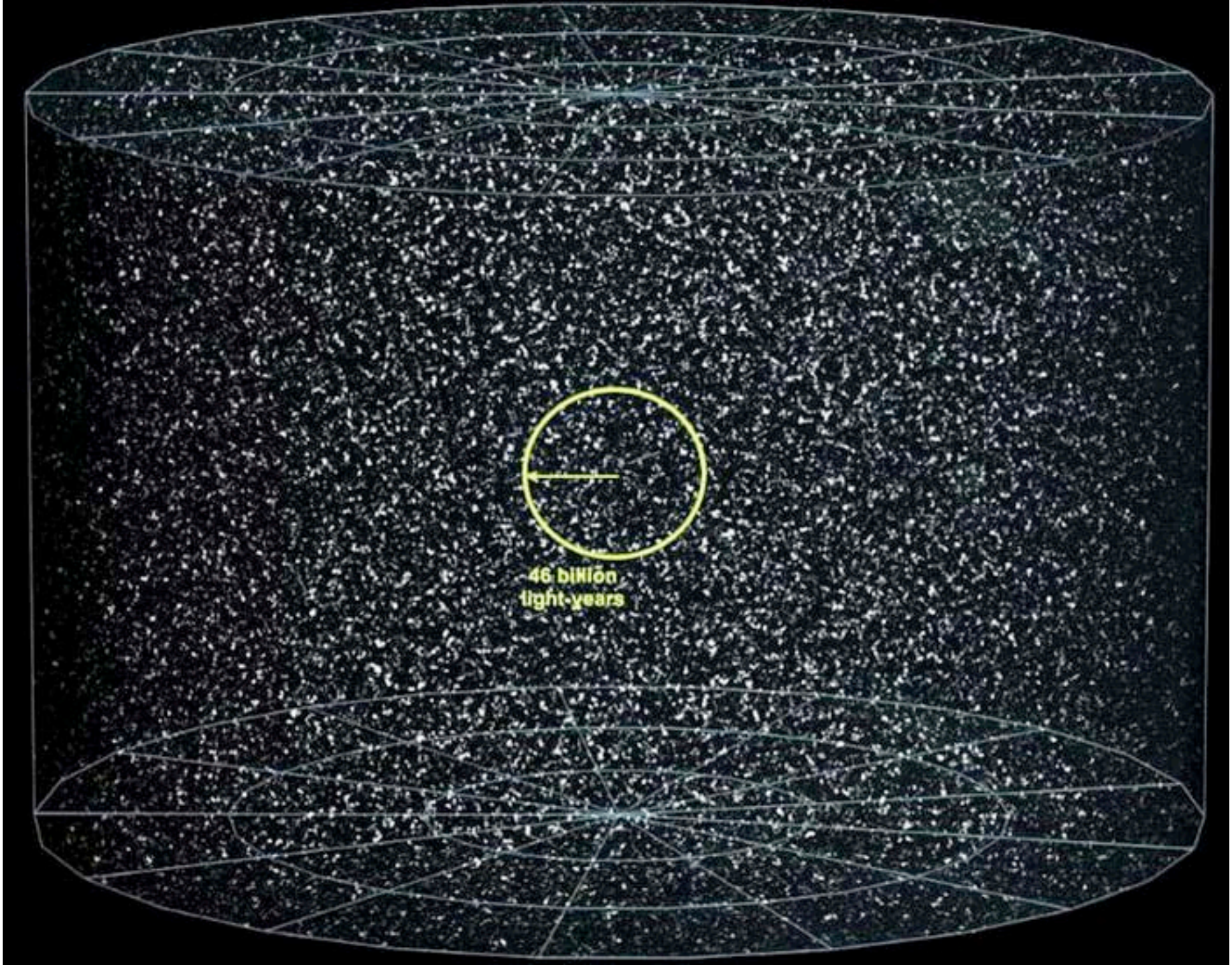

ground level
ozone layer
auroras
navigation satellites
geostationary satellites
meteor
Hubble telescope
high altitude balloon
commercial airplanes
I.S.S.
2010 TK7 (Earth trojan)
433 Eros
Moon
Comet Hale-Bopp
Halley's comet
Mercury
DSCOVR
SOHO
Parker Solar Probe
Chandra
LISA Pathfinder
Sun
IKAROS
25143 Itokawa
Venus
2015 TB145
Harschel Space Observatory
99942 Apophis
2002 VE68
Mars
Gaia
Planck
Chang'e 2
Phobos
Deimos
asteroid belt
'Oumuamua
Pallas
Ceres
Vesta
Mars troyans
Hygiea
Neptune troyans
Triton
2011 QF99 (Uranus troyan)
Oberon
Umbriel
Ariel
Titania
Uranus
Jupiter troyans
Tethys
Dione
Rhea
Titan
Iapetus
Saturn
Ganymede
Europa
Io
Callisto
Jupiter

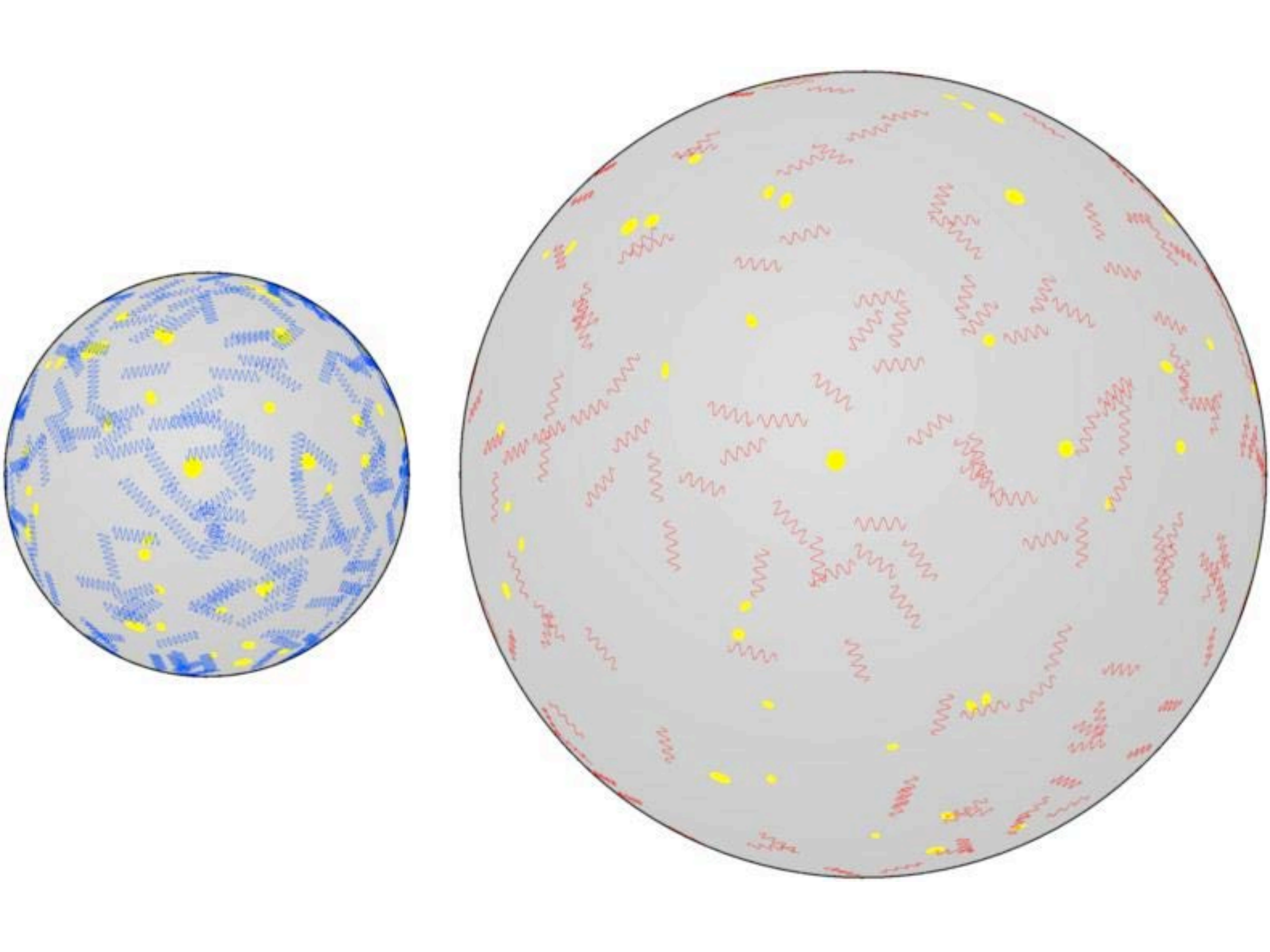

Oort Cloud
(comets)
Kuiper Belt


THE SUN'S CLOSEST NEIGHBORS
Wolf 359
WISE 0855-0714
6 LIGHT YEARS
WISE 1049-5319
(LUHMAN 16)
Barnard's Star
4 LIGHT YEARS
Alpha Centauri
system
2 LIGHT YEARS
OORT CLOUD
Sun

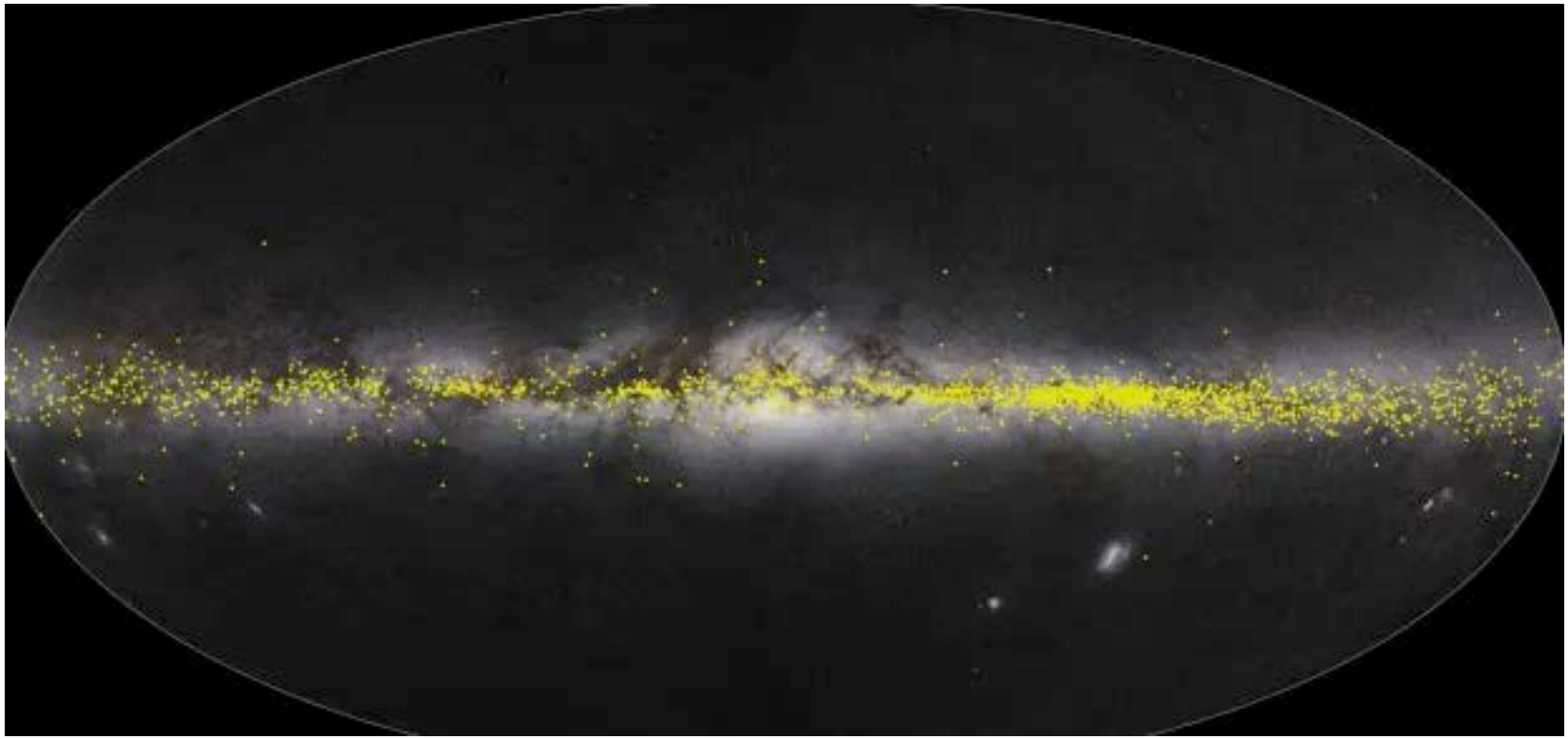

Voyager 1
Pioneer 11
New Horizons
MU69
Pioneer 10
Kuiper Belt
Voyager 2
Planet Orbits
Saturn
Uranus
Neptune
Pluto
*Illustration not to scale, paths not exact


Moon

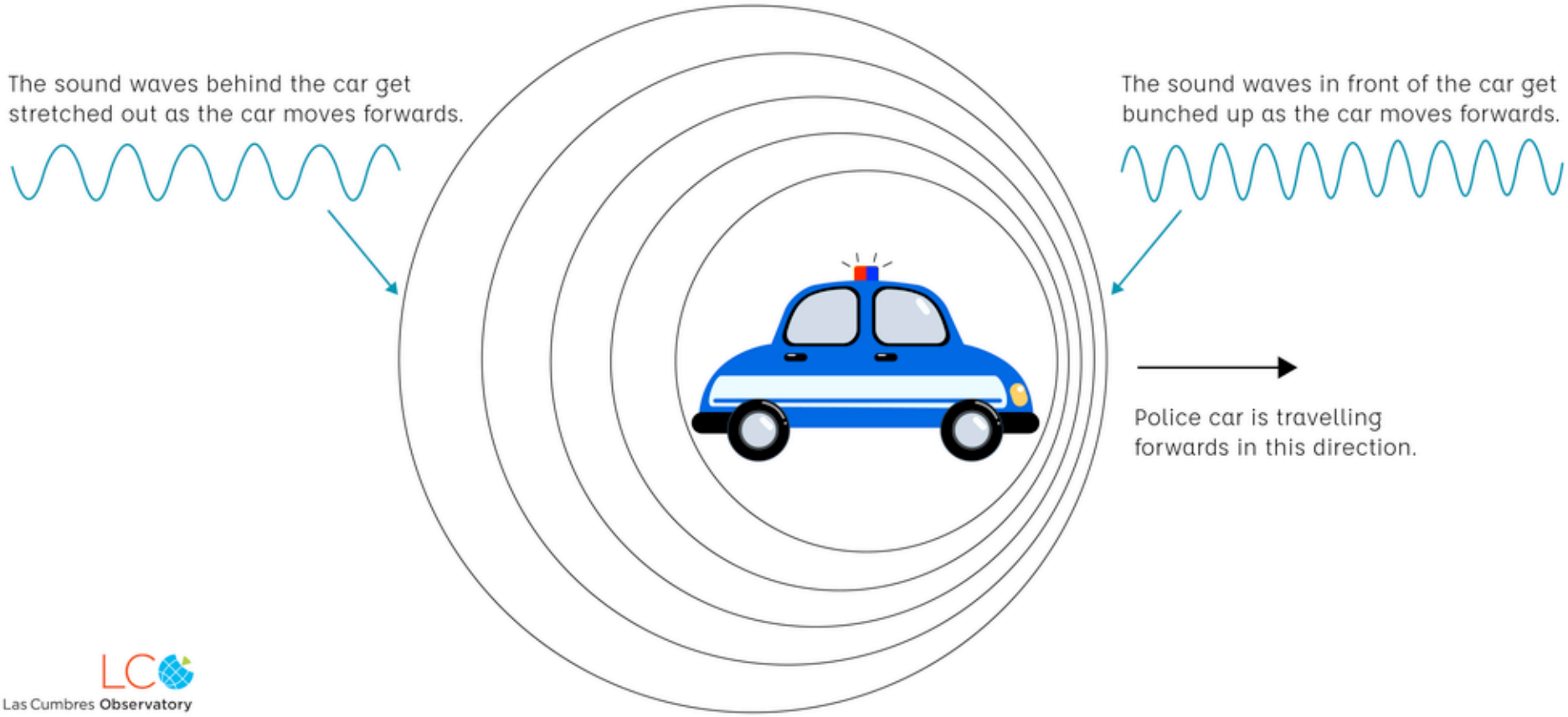

46 billion
light-years



Cefeidi u Mlečnom putu



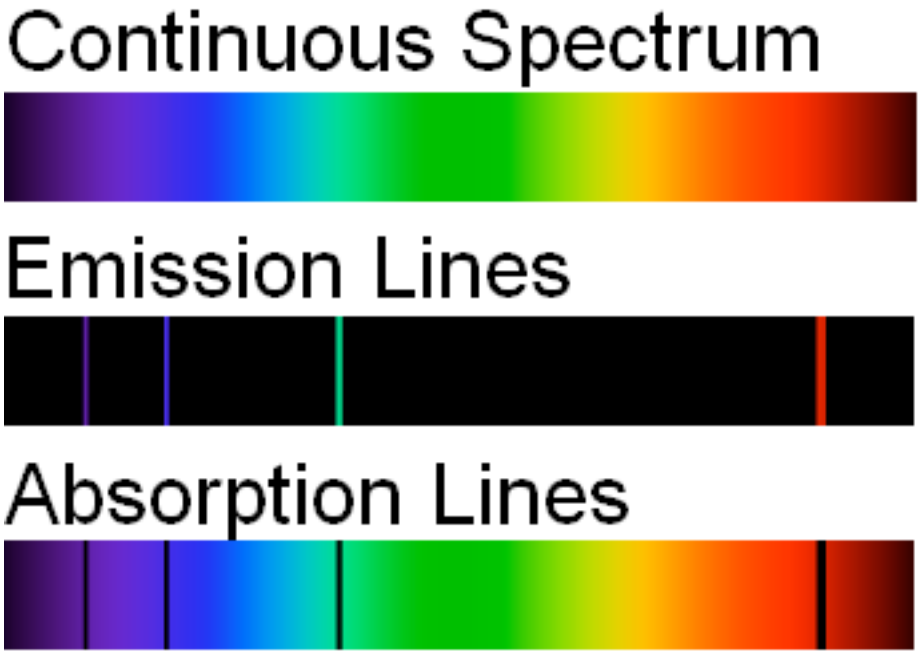
Doppler effect example: Sound waves from a police car siren



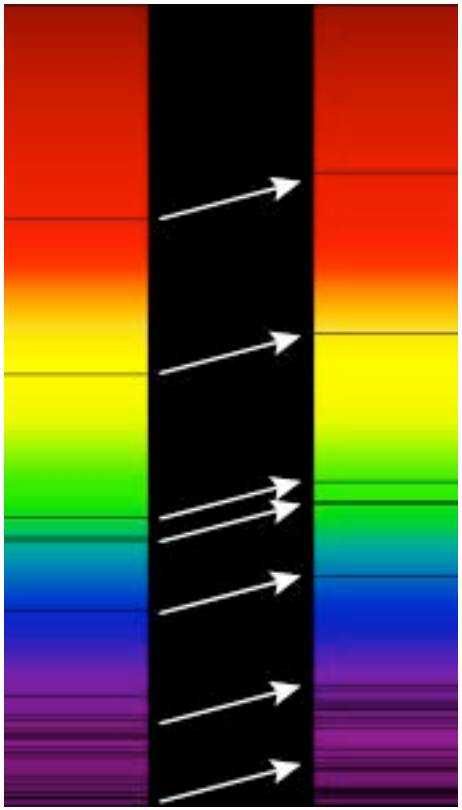
Las Cumbres Observatory

$$z = (\lambda_{observed} - \lambda_{rest}) / \lambda_{rest}$$

Spektralne linije



Pomeranje spektralnih linija ka crvenom delu spektra

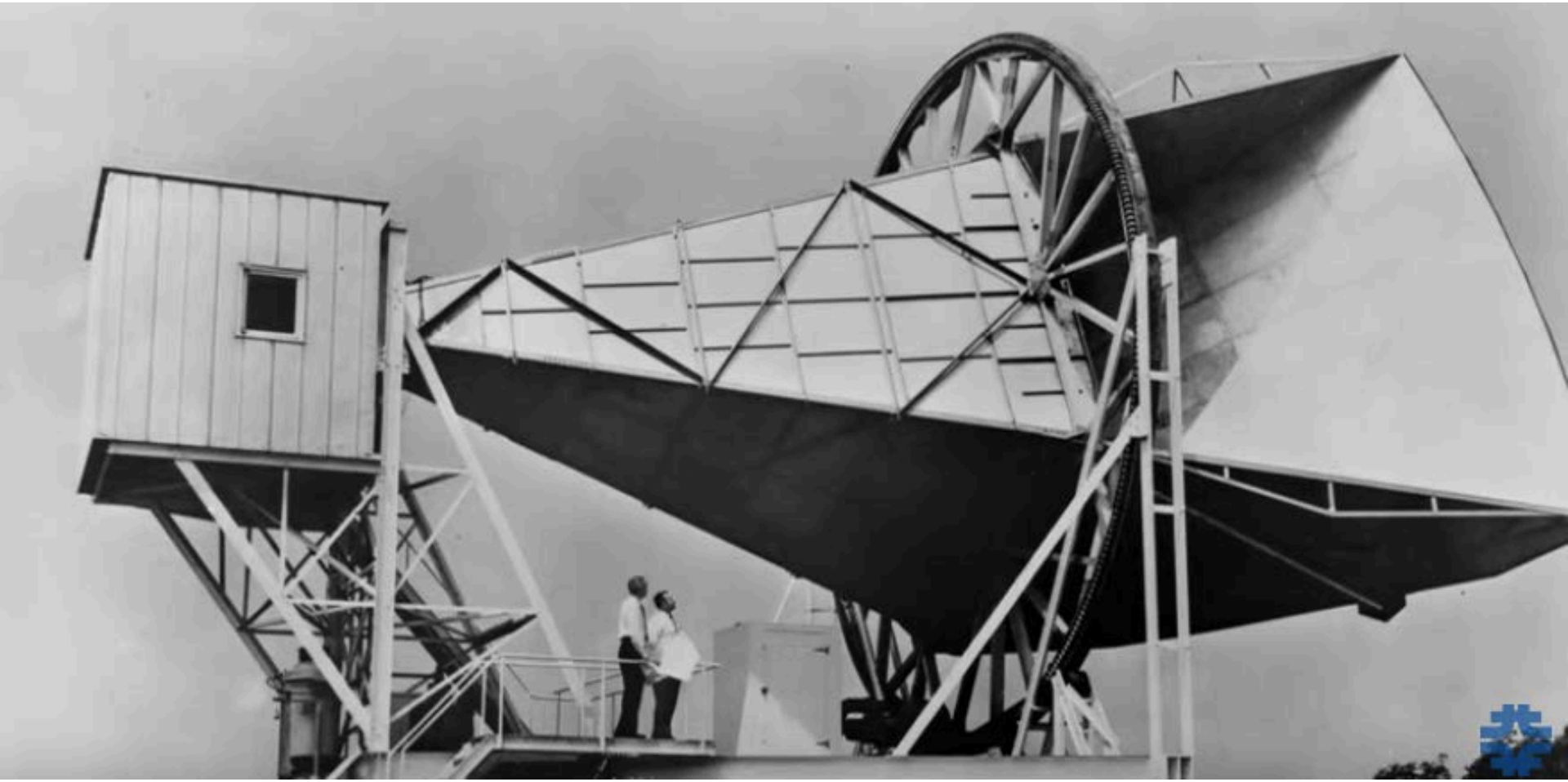


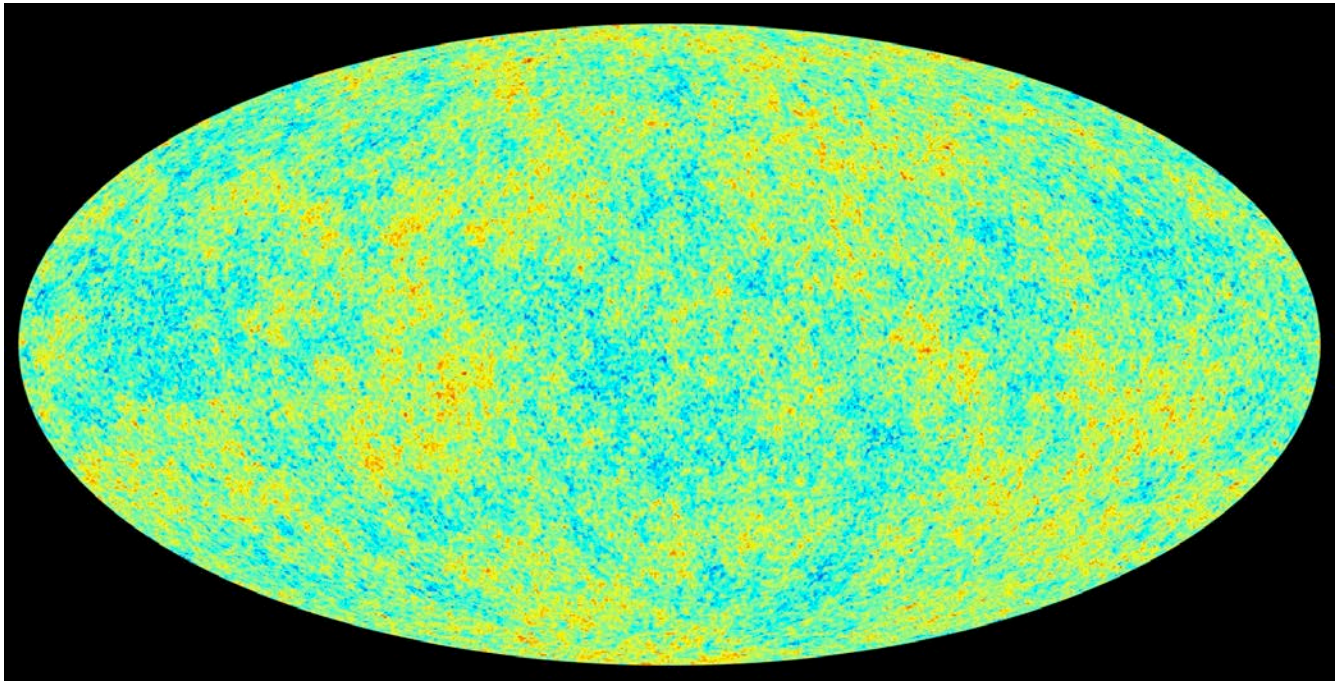
$$z = (\lambda_{observed} - \lambda_{rest}) / \lambda_{rest}$$

Henrietta Swan Leavitt discovered the Period-Luminosity Relation by observing Cepheid variable stars with the Small Magellanic Cloud. This "Cloud" is a satellite galaxy to the Milky Way at an estimated distance of 160,000 light years from Earth.

Mlečni put i Magelanovi oblaci

z	Time the light has been traveling	Distance to the object now
0.0000715	1 million years	1 million light years
0.10	1.286 billion years	1.349 billion light years
0.25	2.916 billion years	3.260 billion light years
0.5	5.019 billion years	5.936 billion light years
1	7.731 billion years	10.147 billion light years
2	10.324 billion years	15.424 billion light years
3	11.476 billion years	18.594 billion light years
4	12.094 billion years	20.745 billion light years
5	12.469 billion years	22.322 billion light years
6	12.716 billion years	23.542 billion light years
7	12.888 billion years	24.521 billion light years
8	13.014 billion years	25.329 billion light years
9	13.110 billion years	26.011 billion light years
10	13.184 billion years	26.596 billion light years





Svemir se širi i **svemir se hladi**

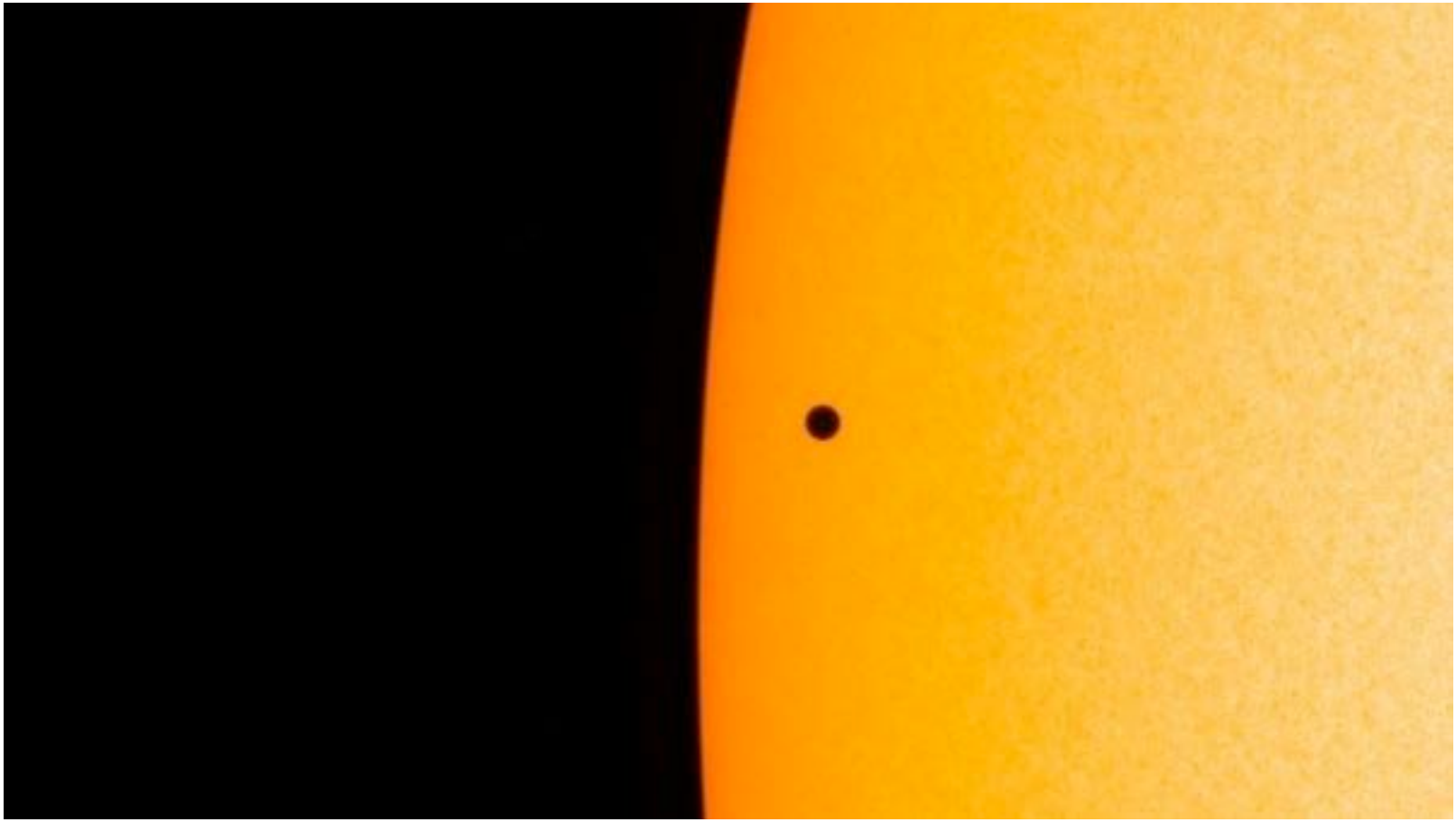
Šta je bilo PRE Velikog Praska?

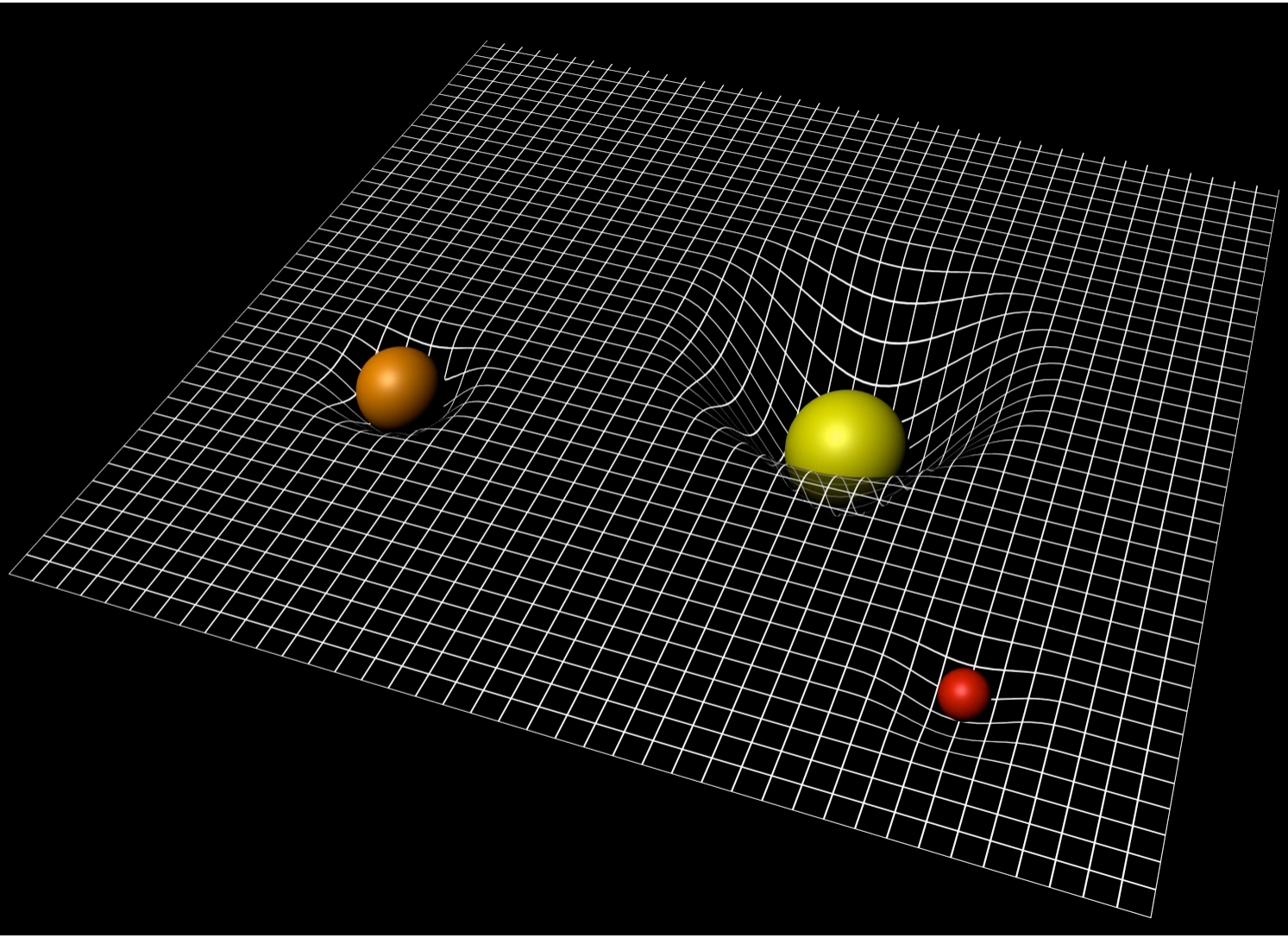
O onome o čemu je nemoguće govoriti, treba ćutati.
L.Witgenstein Tractatus 7 propozicija

Whereof One Cannot Speak, Thereof One Must Be Silent.

Andromeda

Merkur prolazi ispred Sunca





Key Ideas

Hubble's Law

Galaxies are receding from us.

Recession velocity gets larger with distance.

The Hubble Parameter (H0)

Measures the present-day rate of expansion of the Universe.

Cosmological Redshifts

Due to the expansion of space

Redshift distances

Redshift maps of the Universe

Discovery of Expansion

1917: work by Vesto Slipher at Lowell Observatory

Measured radial velocities from spectra of 25 galaxies.

Found:

21 of the 25 show a redshift

speeds of some >2000 km/sec

Most galaxies are rapidly receding from us.

Hubble's Discovery

1929: Edwin Hubble measured distances to 25 galaxies:

Used cepheids for Andromeda and Local Group

Used brightest stars in the others

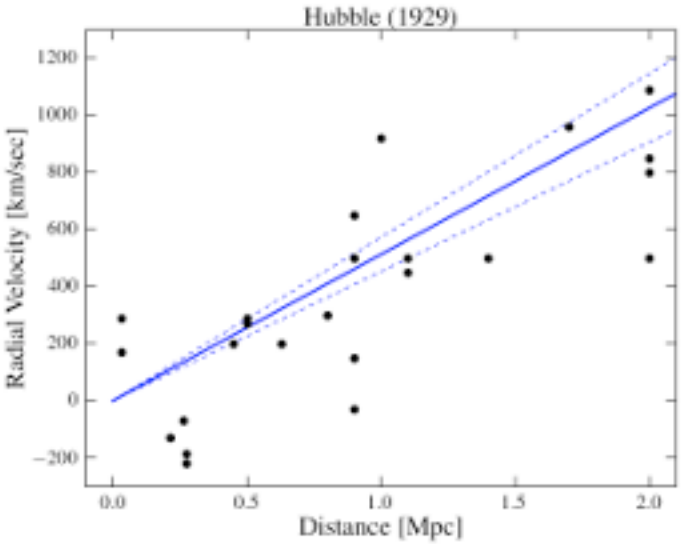
Compared distances with recession velocities.

Discovered:

Recession velocity gets larger with distance.

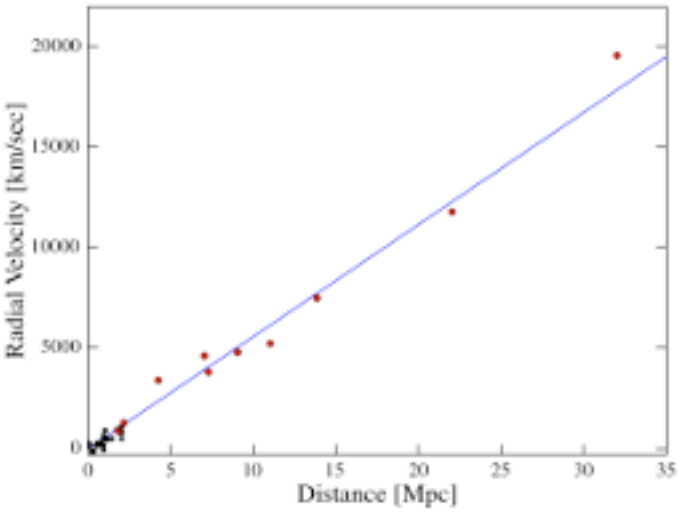
Systematic expansion of the Universe.

Hubble's Data in 1929



Edwin Hubble's 1929 expansion data

Hubble and Humason's Data in 1931



Refined version by Hubble & Humason in 1931

[Modern plots using the original data.]

Hubble's Law

$$v = H_0 \times d$$

v = recession velocity in km/sec d = distance in Mpc H_0 = expansion rate today (**Hubble Parameter**) **In words**:

The more **distant** a galaxy, the **faster** its recession velocity.

Nature of the Expansion

General Expansion of Spacetime:

All observers in different galaxies see the **same** expansion around them.

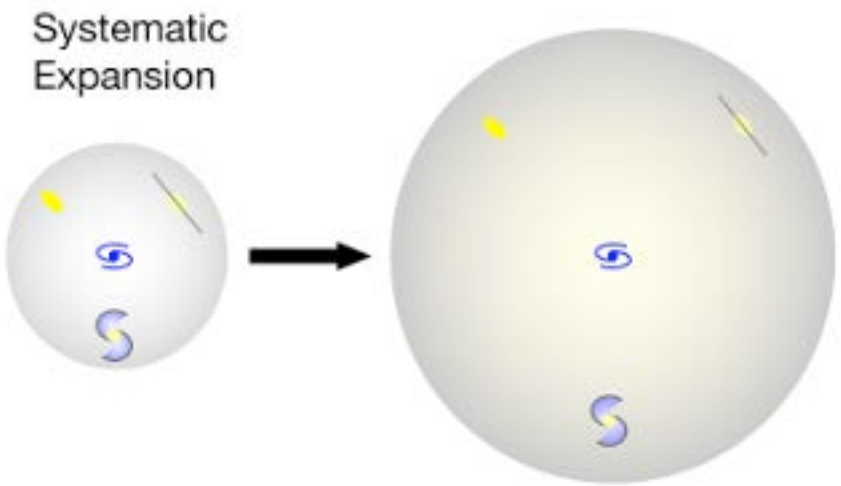
No center - all observers **appear** to be at the center.

What is the recession velocity?

NOT motion through space...

Expansion **of** spacetime: galaxies carried along.

While the d**istances** between galaxies increase over time, the **sizes** of the galaxies remain the same. This is because galaxies are bound together by gravitation locally, and so do not share in the global expansion of spacetime around them.



Measures the rate of expansion of the Universe today.

H0 = 70 +/- 7 km/sec/Mpc

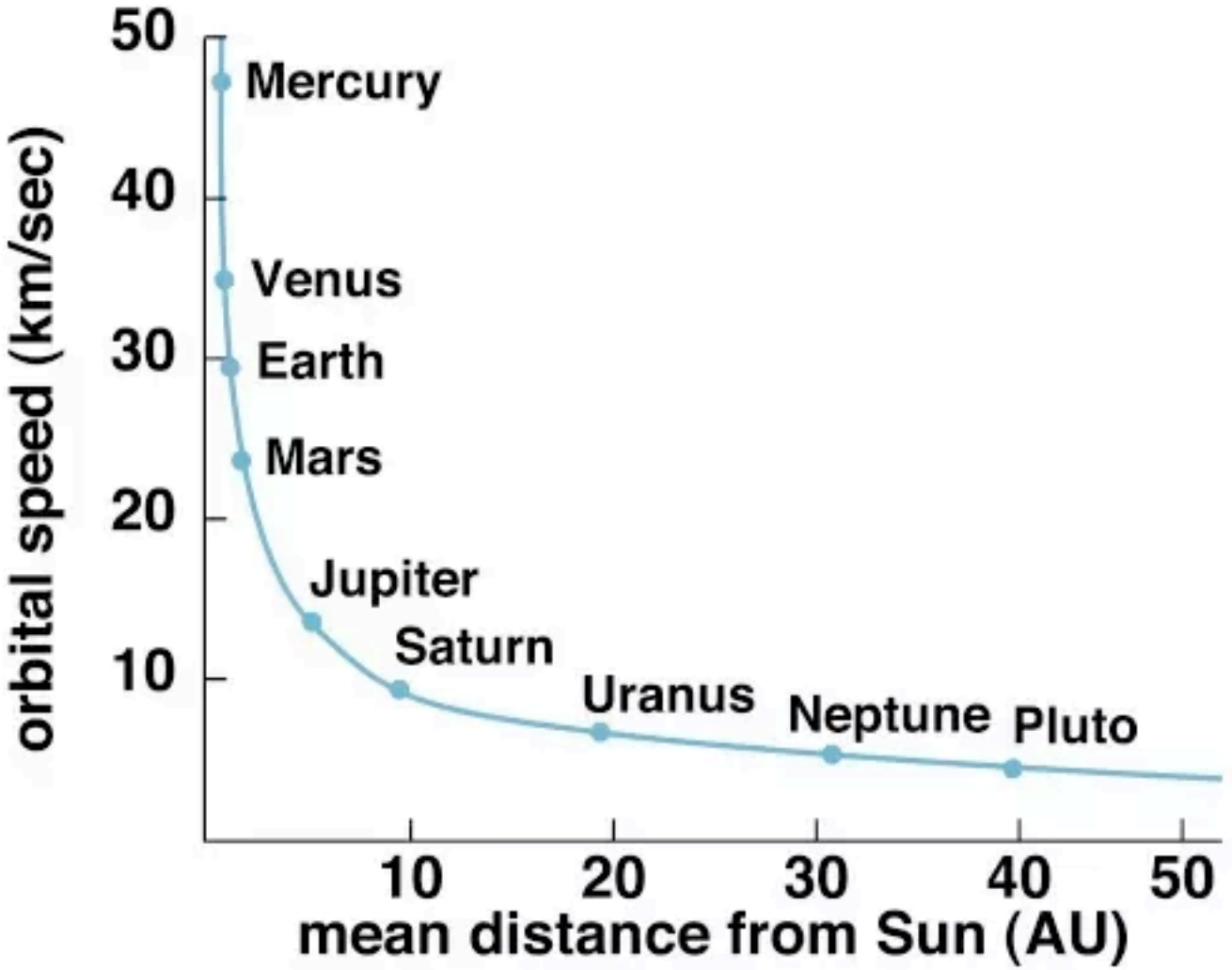
Best measurement to date is from the Hubble Key Project to measure Cepheids in nearby galaxies.

H0 is very hard to measure

Recession speeds are easy to measure from the shifts of spectral lines.

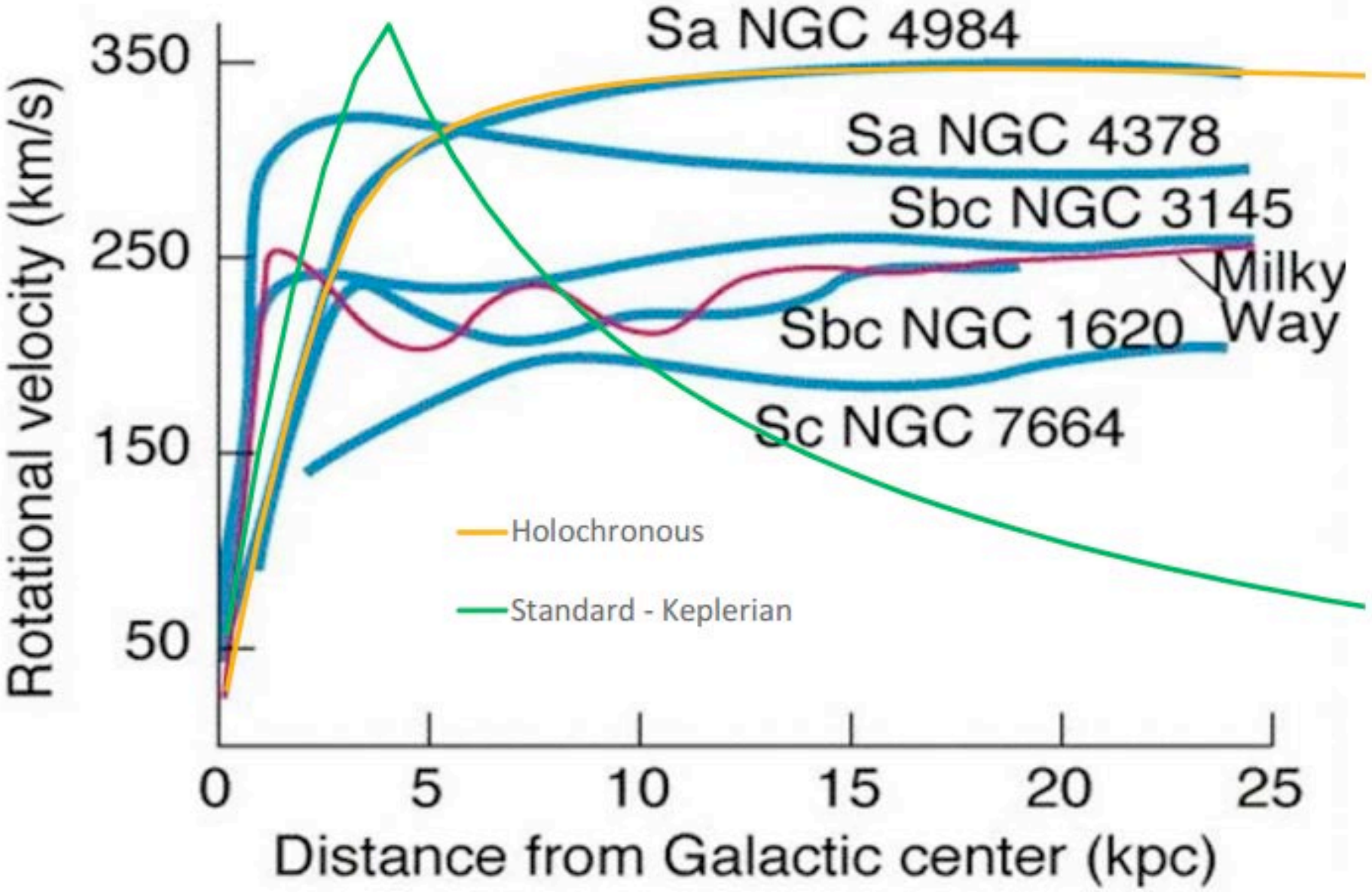
But, distances are very hard to measure.

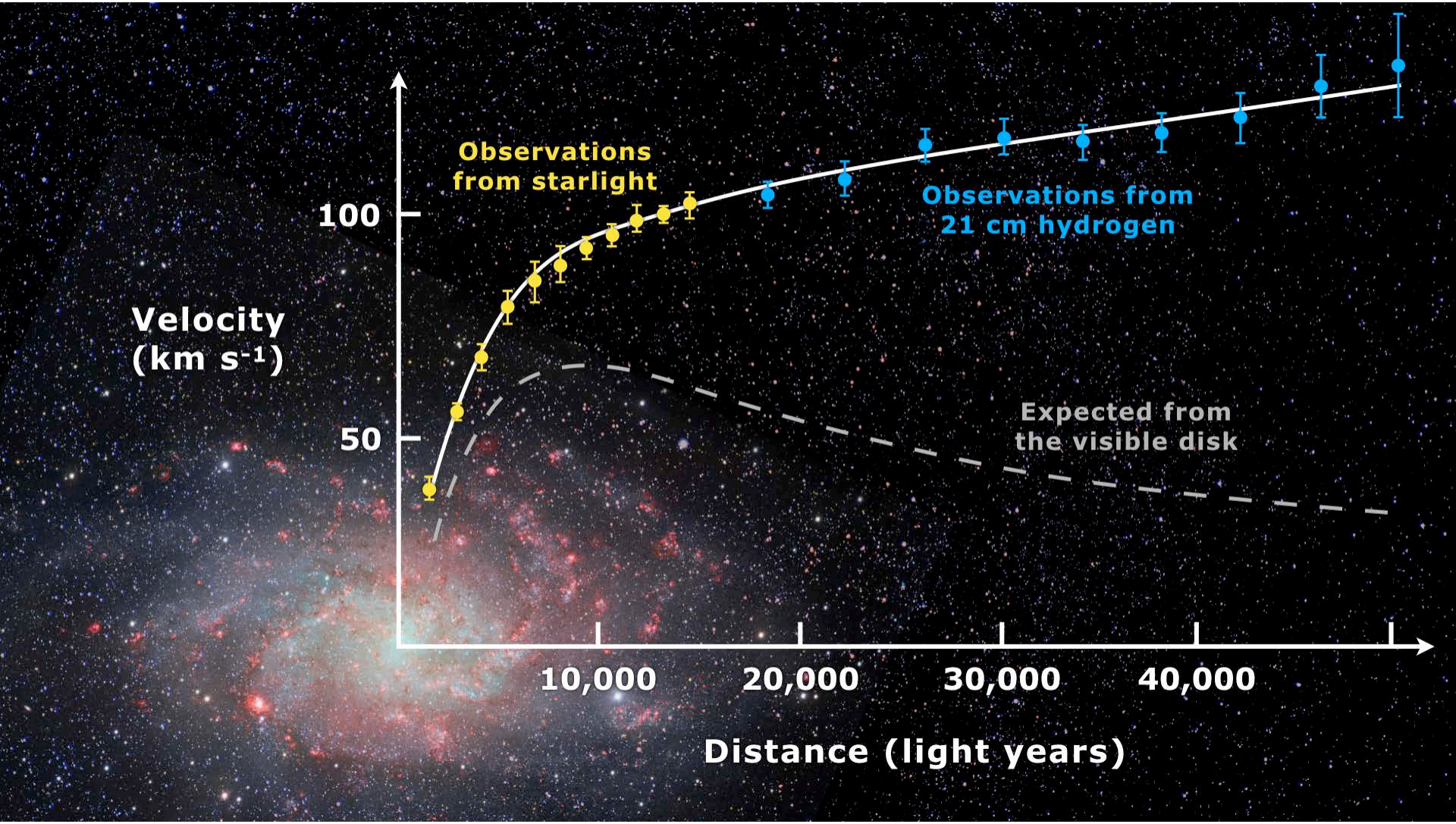
Galaxies also have extra (non-cosmological) motions that must be taken into account.



(b)

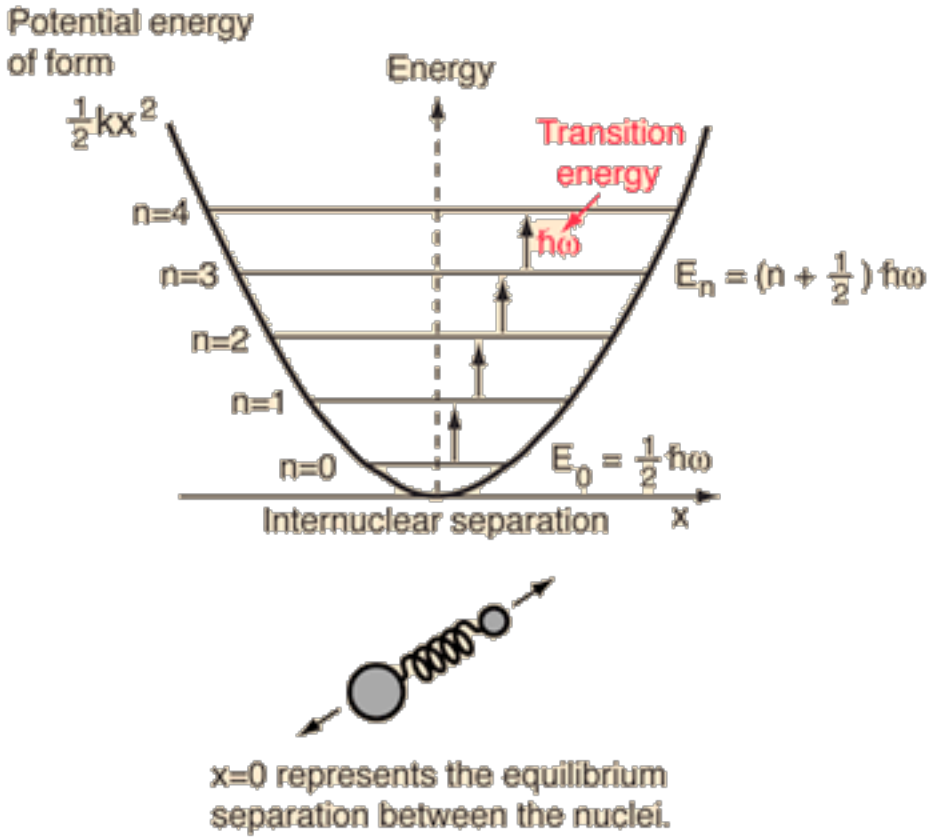
Postojanje tamne materije




Observations
from starlight
Observations from
21 cm hydrogen
Expected from
the visible disk
100
50
Velocity
(km s-1)
10,000
20,000
30,000
40,000
Distance (light years)

Postojanje tamne energije

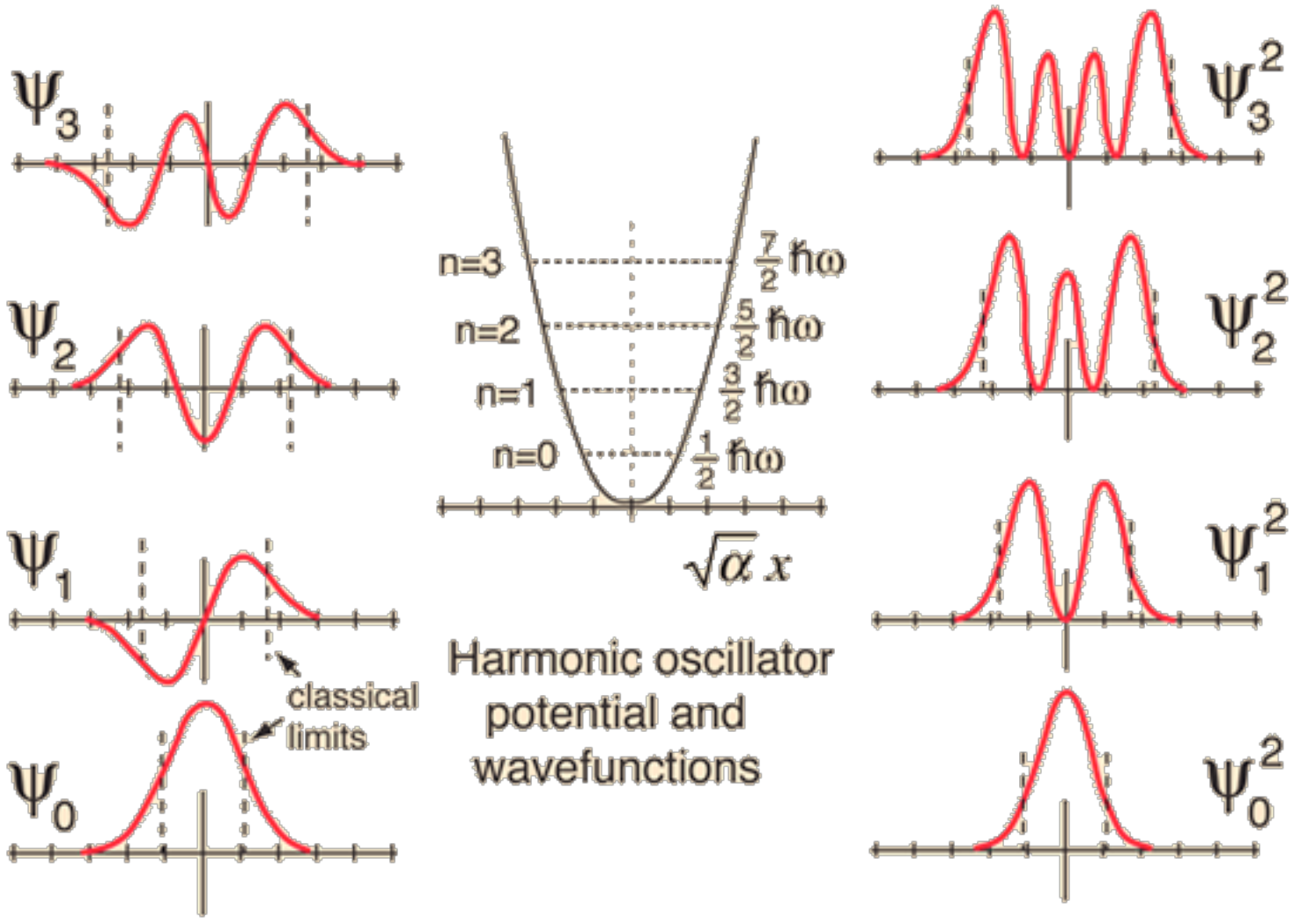
Energija Vakuuma

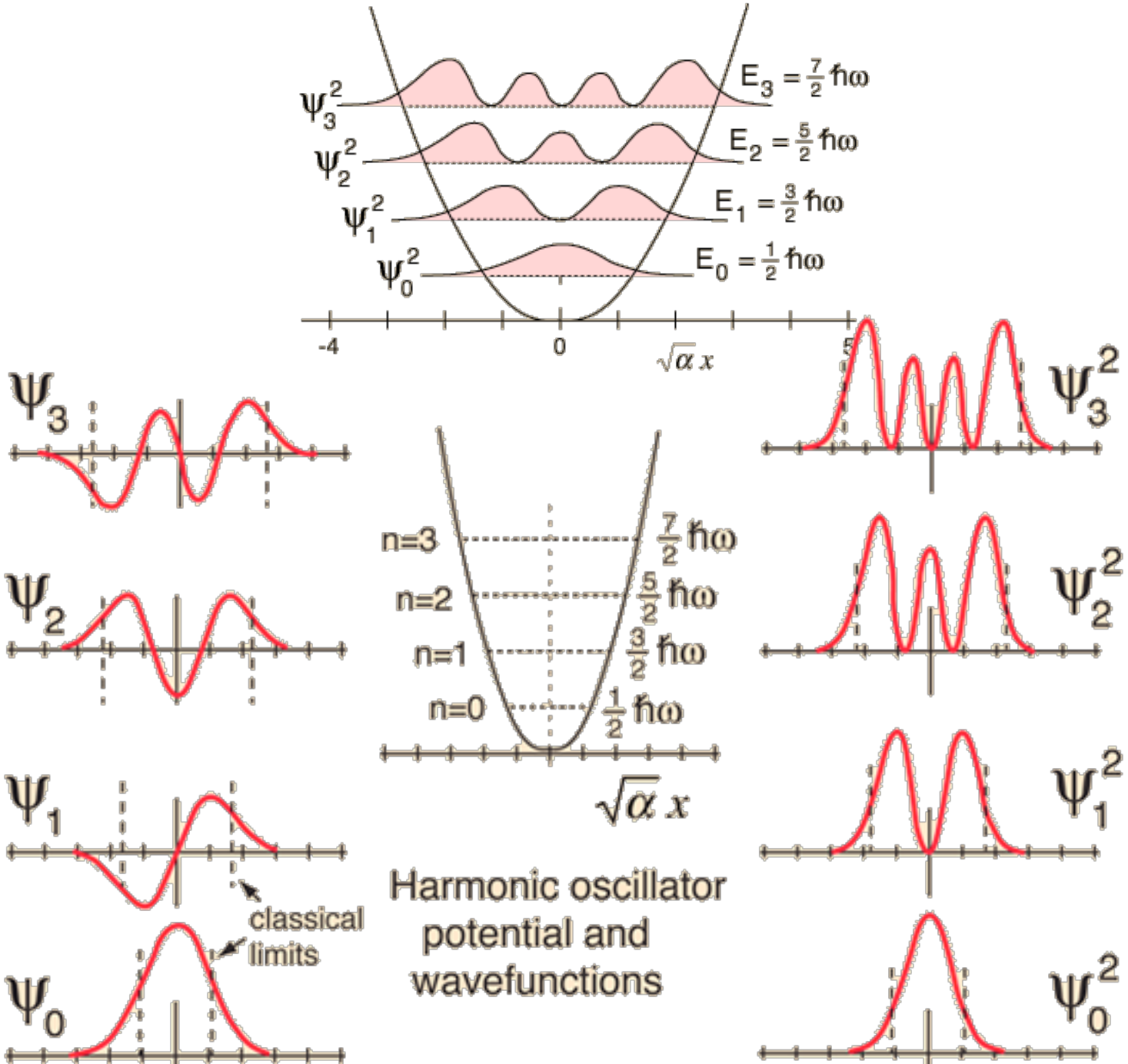


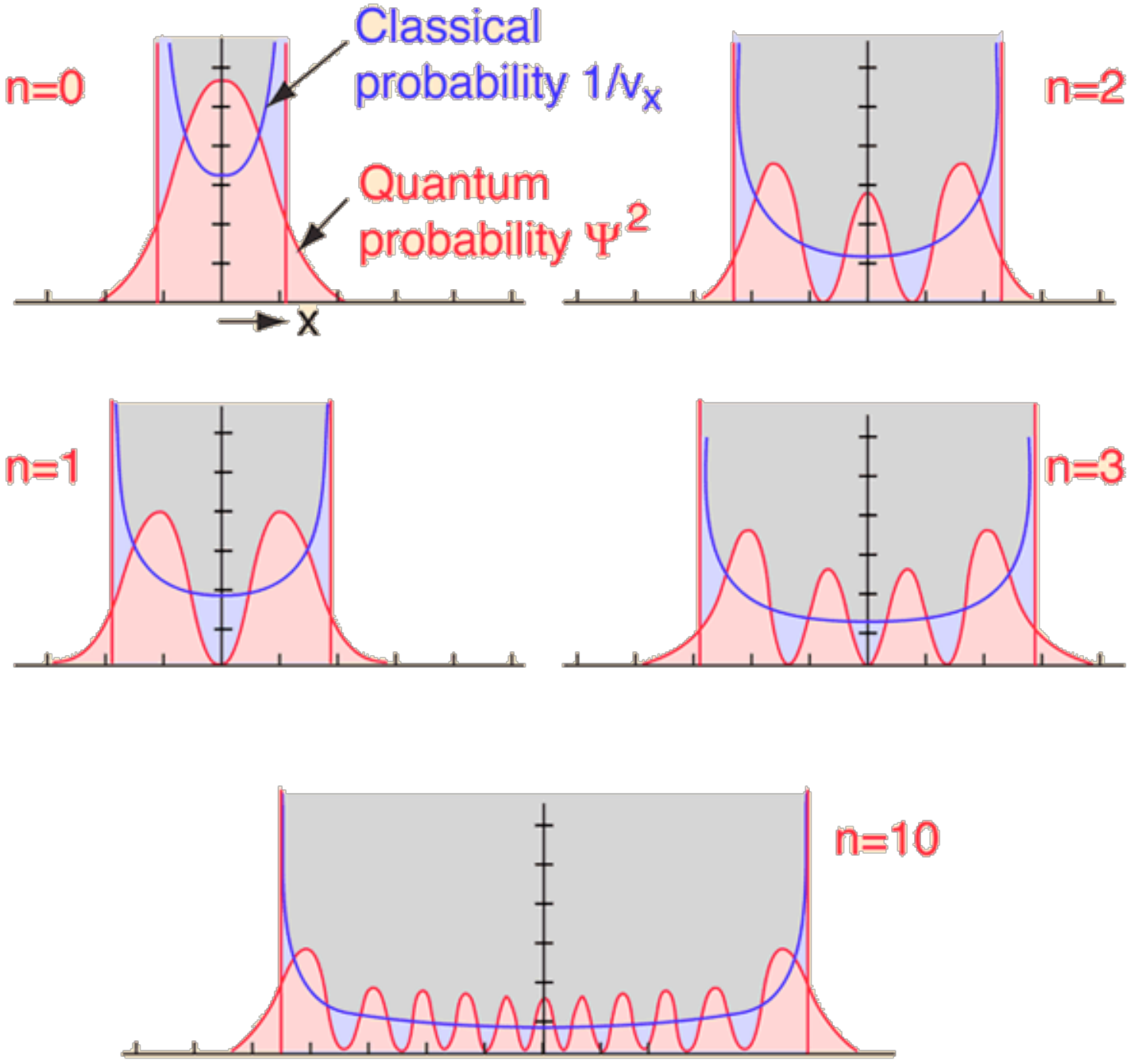
$$E_n = (n + \tfrac{1}{2})\hbar\omega \qquad n = 0,1,2,3 \ldots$$

$\omega = 2\pi \cdot$frequency

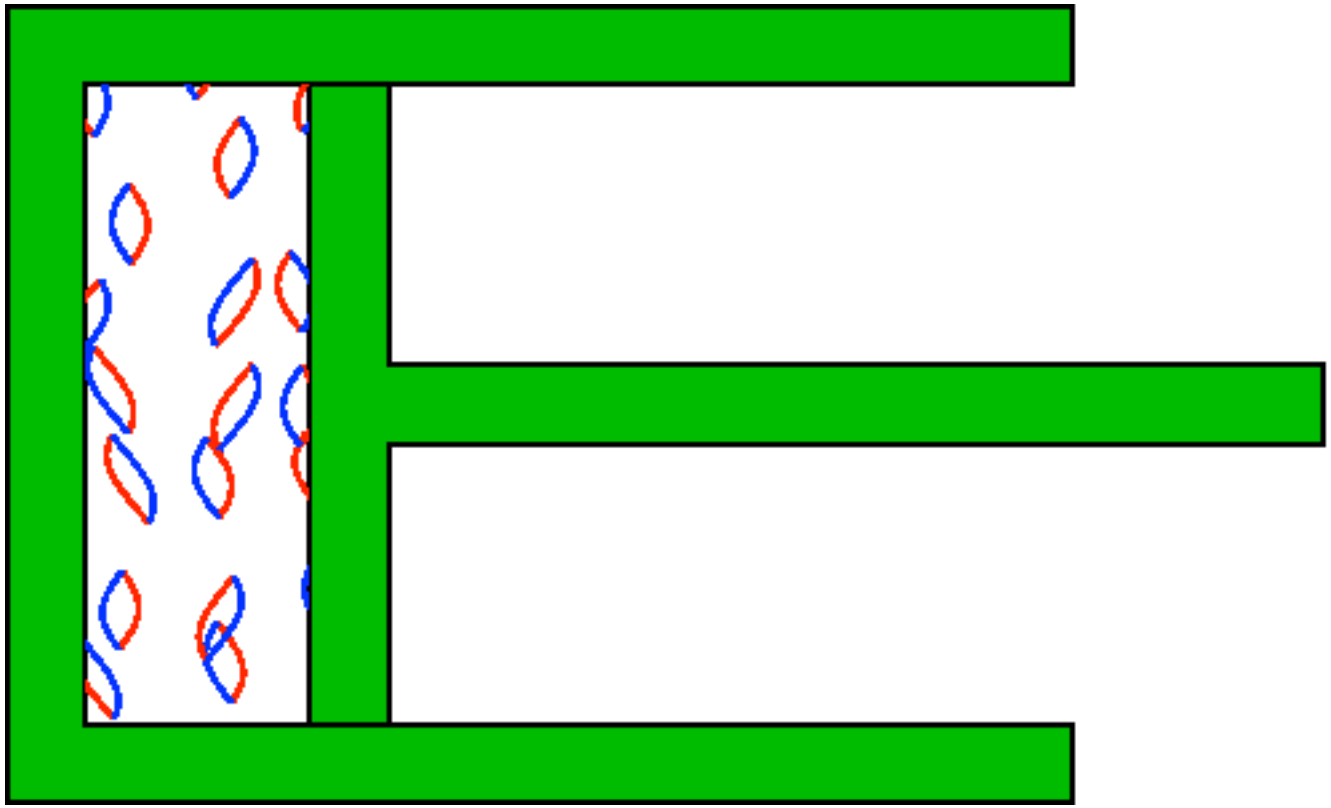
$\hbar =$ Planck's constant $/2\pi$

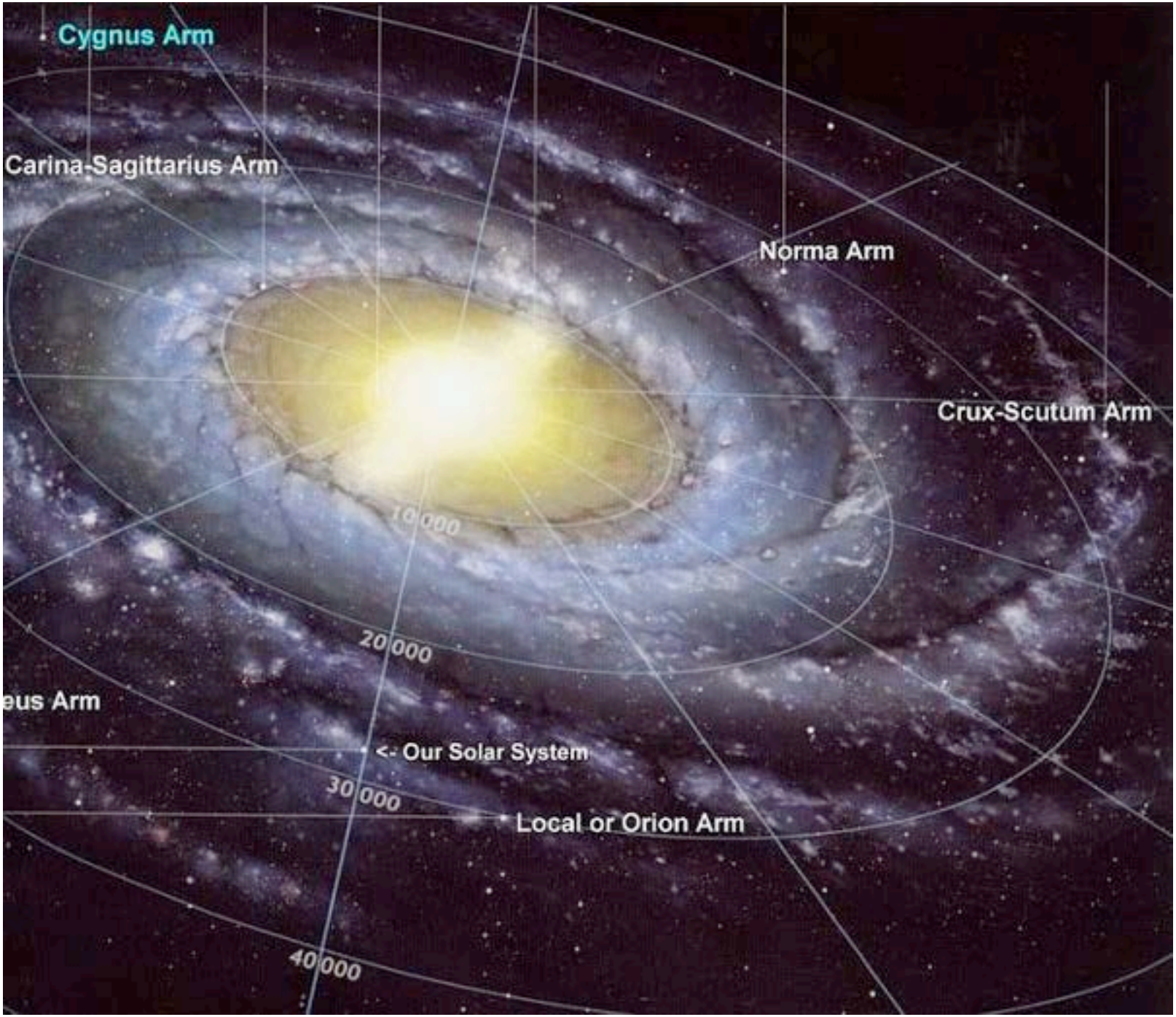

ψ3
ψ2
ψ1
ψ0
classical
limits
n=3
n=2
n=1
n=0
7/2 ħω
5/2 ħω
3/2 ħω
1/2 ħω
√α x
Harmonic oscillator
potential and
wavefunctions
ψ3²
ψ2²
ψ1²
ψ0²


ψ_3^2
ψ_2^2
ψ_1^2
ψ_0^2
$E_3 = \frac{7}{2}\hbar\omega$
$E_2 = \frac{5}{2}\hbar\omega$
$E_1 = \frac{3}{2}\hbar\omega$
$E_0 = \frac{1}{2}\hbar\omega$
-4
0
$\sqrt{\alpha}\,x$
ψ_3
ψ_2
ψ_1
ψ_0
classical limits
n=3
n=2
n=1
n=0
$\frac{7}{2}\hbar\omega$
$\frac{5}{2}\hbar\omega$
$\frac{3}{2}\hbar\omega$
$\frac{1}{2}\hbar\omega$
$\sqrt{\alpha}\,x$
Harmonic oscillator potential and wavefunctions
ψ_3^2
ψ_2^2
ψ_1^2
ψ_0^2

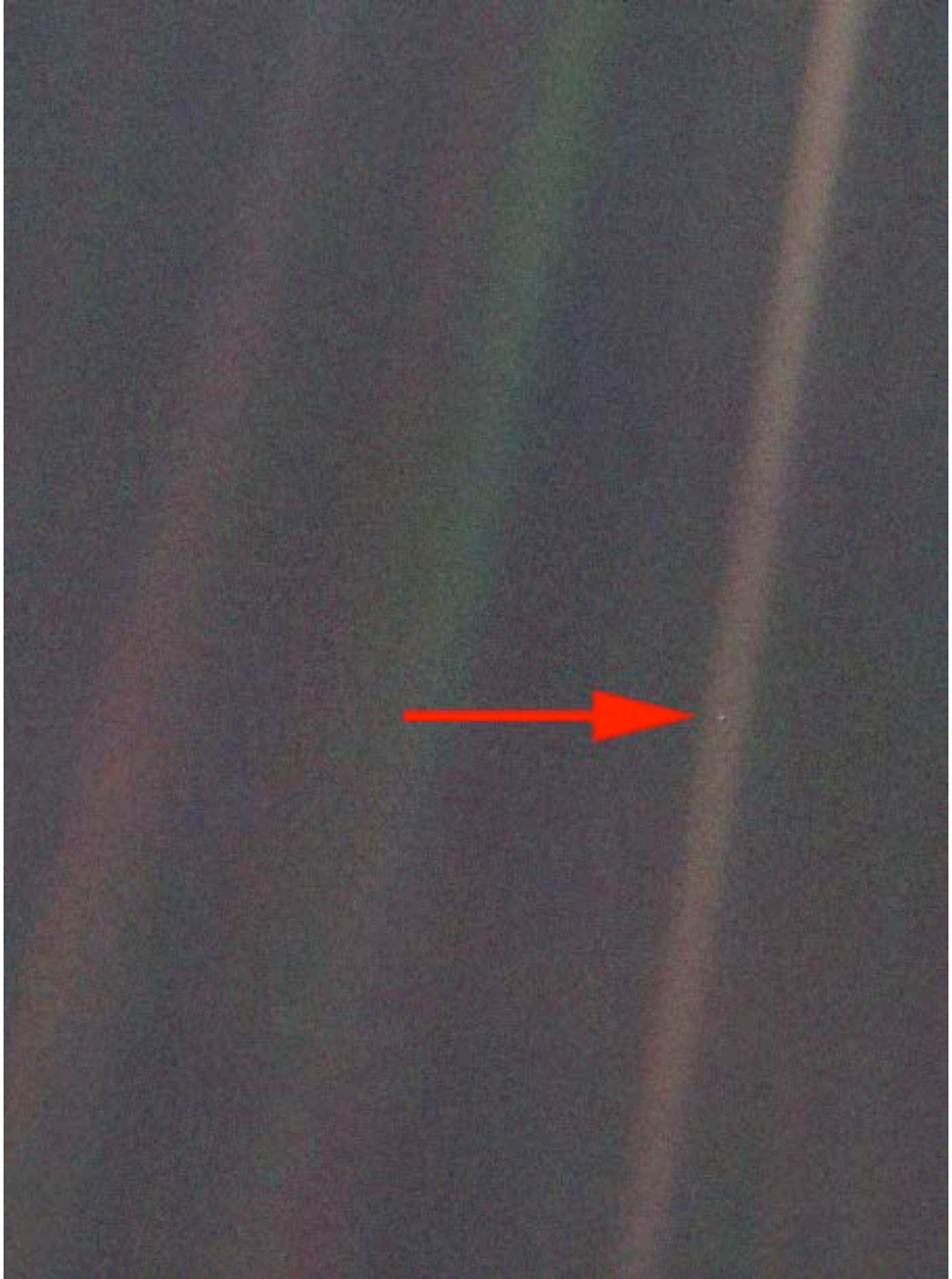

Classical
probability $1/v_x$
Quantum
probability Ψ^2
n=0
n=1
n=2
n=3
n=10
x

If the vacuum has positive energy density, the expansion of the universe will tend to speed up! This is what people see. And, vacuum energy is currently the most plausible explanation known for what's going on.




Cygnus Arm
Carina-Sagittarius Arm
Norma Arm
Crux-Scutum Arm
10 000
20 000
eus Arm
<- Our Solar System
30 000
Local or Orion Arm
40 000

CENTAR MLEČNOG PUTA



Sudar

Šta će biti s nama i svemirom?

Na kratke staze:

Za oko 250 miliona godina kontinenti na Zemlji će se sudariti

Za 1.1 milijardu godina Sunce će postati 10% sjajnije I započe će
Zagrevanje Zemlje od koga će okeani ispariti

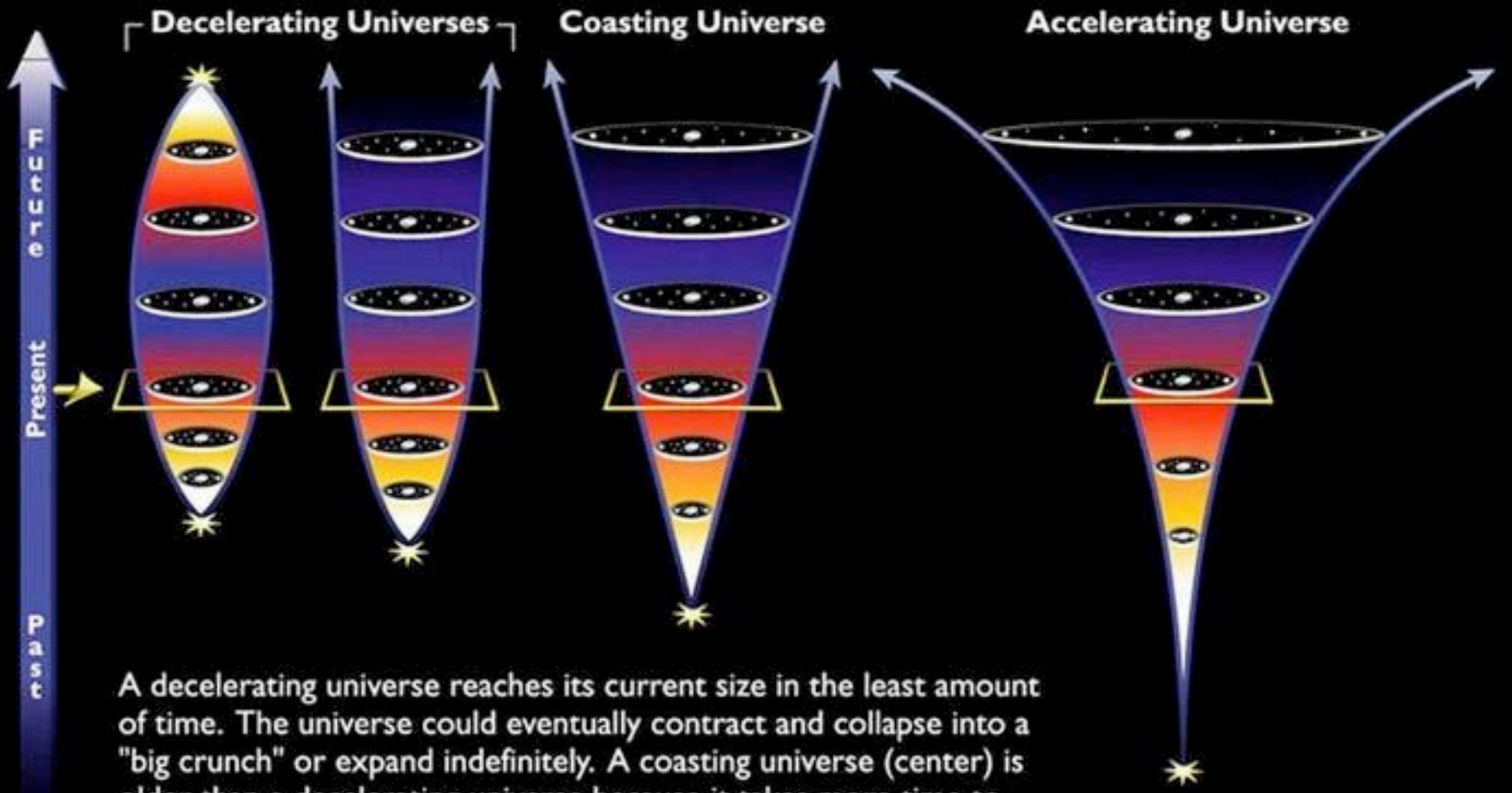
Za 3 milijarde godina, galaksija Andromeda će se sudariti sa našom galaksijom
i mnogi planetarni sistemi će biti uništeni

Sunce će postati beli patuljak za 7.8 milijardi godina.

Pitanje za danas je: *šta će biti kasnije, kako će izgledati kraj svega?*

Sadašnja merenja ukazuju na to da se svemir ubrzano širi I da će tako
Nastaviti u nedogled.

Possible Models of the Expanding Universe



A decelerating universe reaches its current size in the least amount of time. The universe could eventually contract and collapse into a "big crunch" or expand indefinitely. A coasting universe (center) is older than a decelerating universe because it takes more time to reach its present size, and expands forever. An accelerating universe (right) is older still. The rate of expansion actually increases because of a repulsive force that pushes galaxies apart.

Šta će biti tokom prvih 10^{23} godina?

Prvo, galaksije će nastaviti da se sudaraju. Ovi sudari će uništiti spiralne galaksije –
One će da se stope u eliptičke galaksije. Za oko 7 milijardi godina, Andomeda I Mlečni put će
Obrazovati veliku eliptičku galaksiju. Bez spiralnih krakova u galaksijama, prestaće stvaranje
novih zvezda.
Sve preostale zvezde će da izgore. Najdugovečniji su crveni patuljci, sa masom od oko 0.08
Mase Sunca.Oni će potrošiti sav vodonik za oko 10^13 godina.

Za oko 10^14 godina, rađanje normalnih zvezda će prestati I kosmos će uglavnom
Da se sastoji od 55% belih patuljaka, 45% braon patuljaka I malog broja neutronskih zvezda.
Crne rupe će postepeno progutati neoprezne objekte koji se nađu u blizini. Ovo je spor
proces, ali kompjuterske simulacije pokazuju da će oko 90% završiti u crnim rupama.
Za oko 10^{23} godina, mrtve zvezde će "ispariti" iz galaktičkog centra, a pozadinsko zračenje
Se se ohladiti do 10^-13 K.
Znači preostaće izolovani crni patuljci, neutronske zvezde I crne rupe, zajedno sa molekulima
gasa, prašine ohlađenih do skoro apsolutne nule. Ako tamna energija funkcioniše kao što
očekujemo, rastojanje između tela koja nisu gravitaciono povezana će da se udvostručuje
svakih 12 milijardi godina.
Kada sva galktička jata ispare, svemir će uvećati za faktor $10^{10^{13.}}$

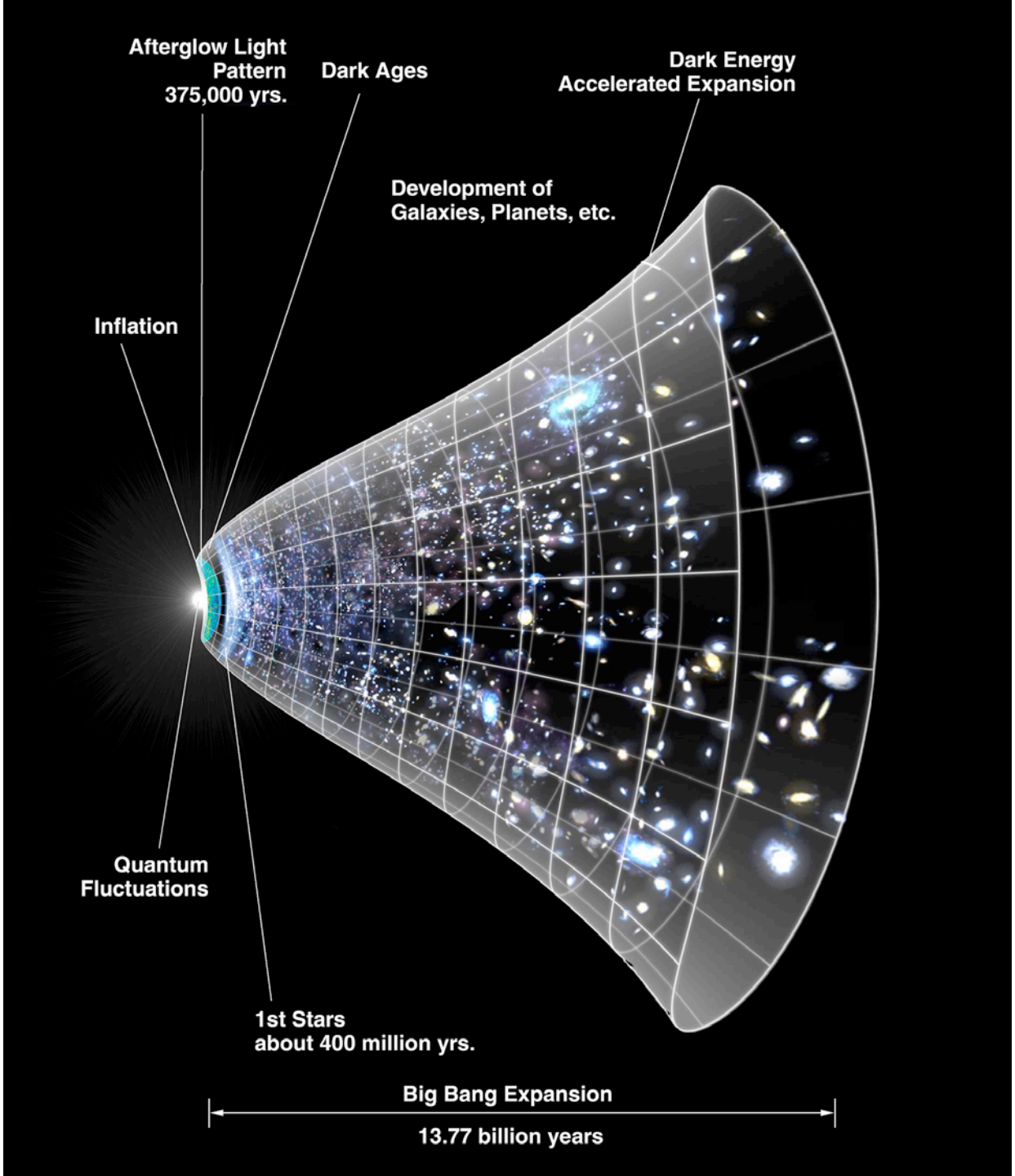
I šta će dalje biti?

Sve kompleksnije strukture će se raspasti, gustina materije postaje
Skoro nula.
Ako svemir nastavi da se širi svaki par slobodno padajućih posmatrača će
Da izgubi kontakt jer će pomakom ka crvenom da isčeznu iz vidokruga, tj.
Iz “kosmološkog horizonta”.
Šta će biti sa crnim rupama? One će da ispare procesom **Hokingovog zračenja**.
Ovo će potrajati između 10^{67} i 10^{99} godina, u zavisnosti od veličine.

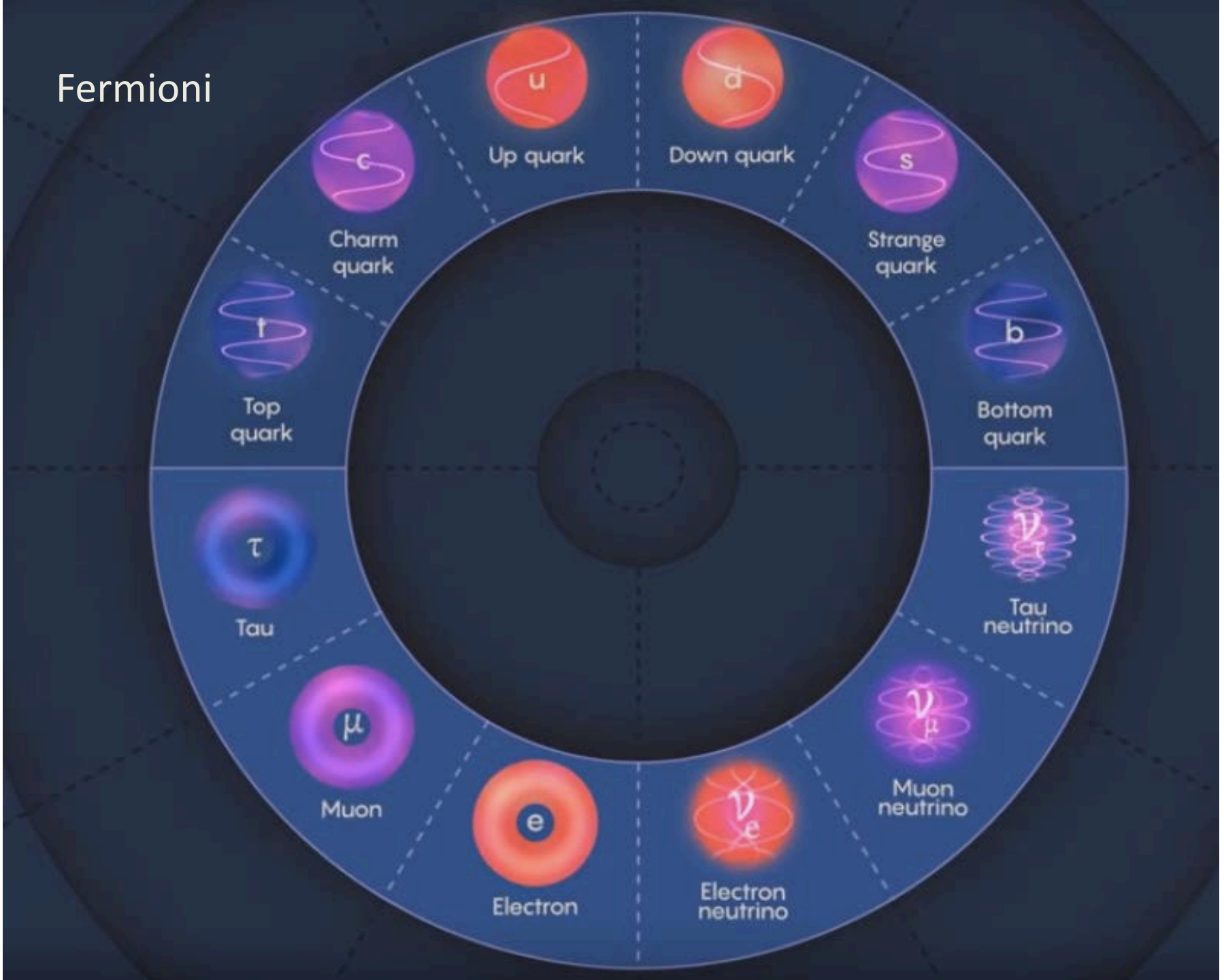
Kad se taj proces završi, kosmos će biti zaista hladan I sasojaće se od stabilnih
Čestica – elektrona, neutrina i protona. Ako svemir nastavi da se širi, gustina ovih
čestica će težiti nuli, I ove česice neće moći da utiču jedne na druge. Sve interakcije
će prestati ništa se neće dešavati I vreme će da stane.
Tako će svemir da umre.

A sa nama, šta će biti sa nama? (Kako reče Skarlet).

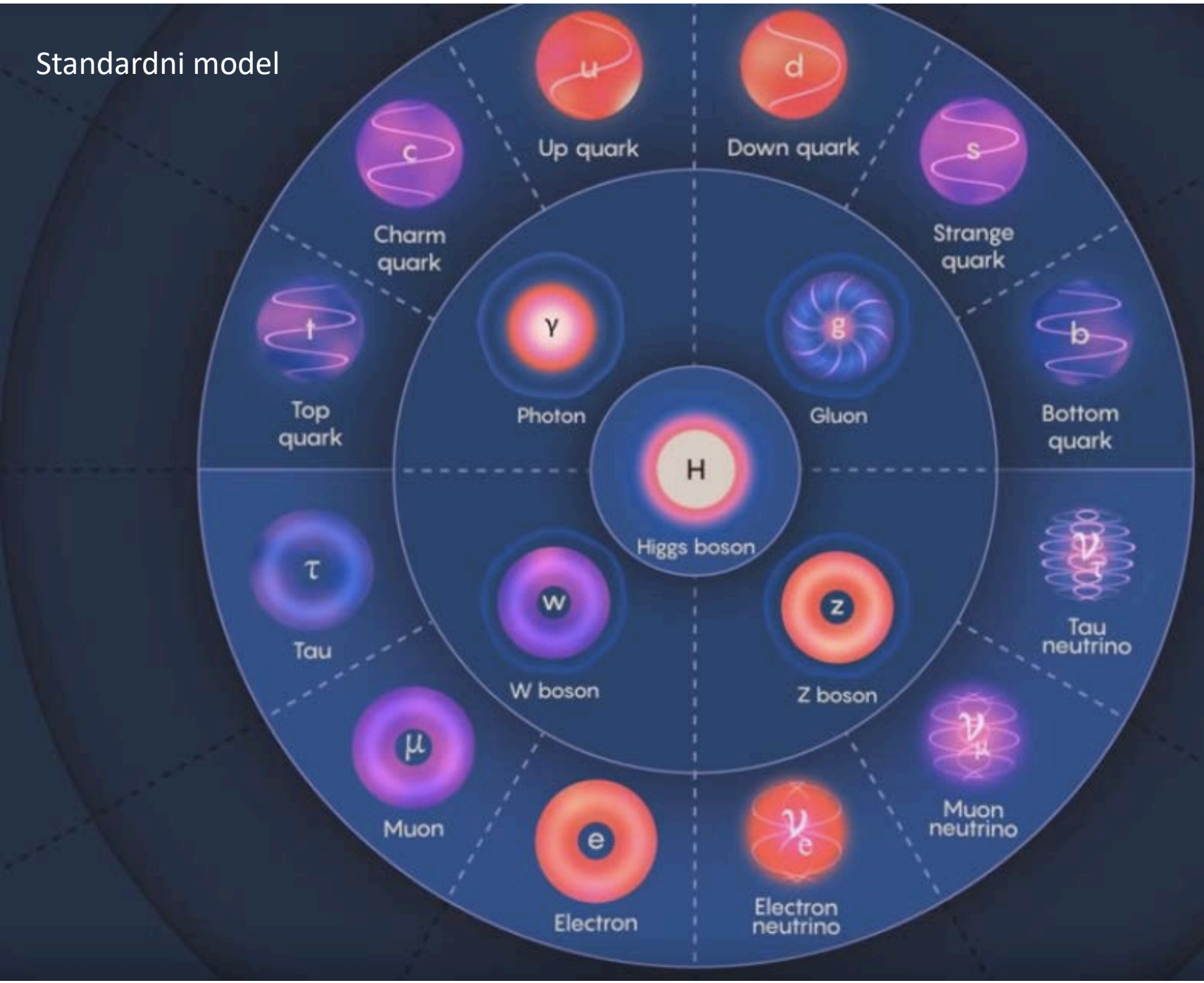
U jednom starom radu, Friman Dajson je izračunao da, u suštini, inteligentan život
Može da traje večno I da proizvodi neograničen broj misli – istina sve sporije I sprije.


Afterglow Light Pattern 375,000 yrs.
Dark Ages
Dark Energy Accelerated Expansion
Development of Galaxies, Planets, etc.
Inflation
Quantum Fluctuations
1st Stars about 400 million yrs.
Big Bang Expansion
13.77 billion years

Fermioni

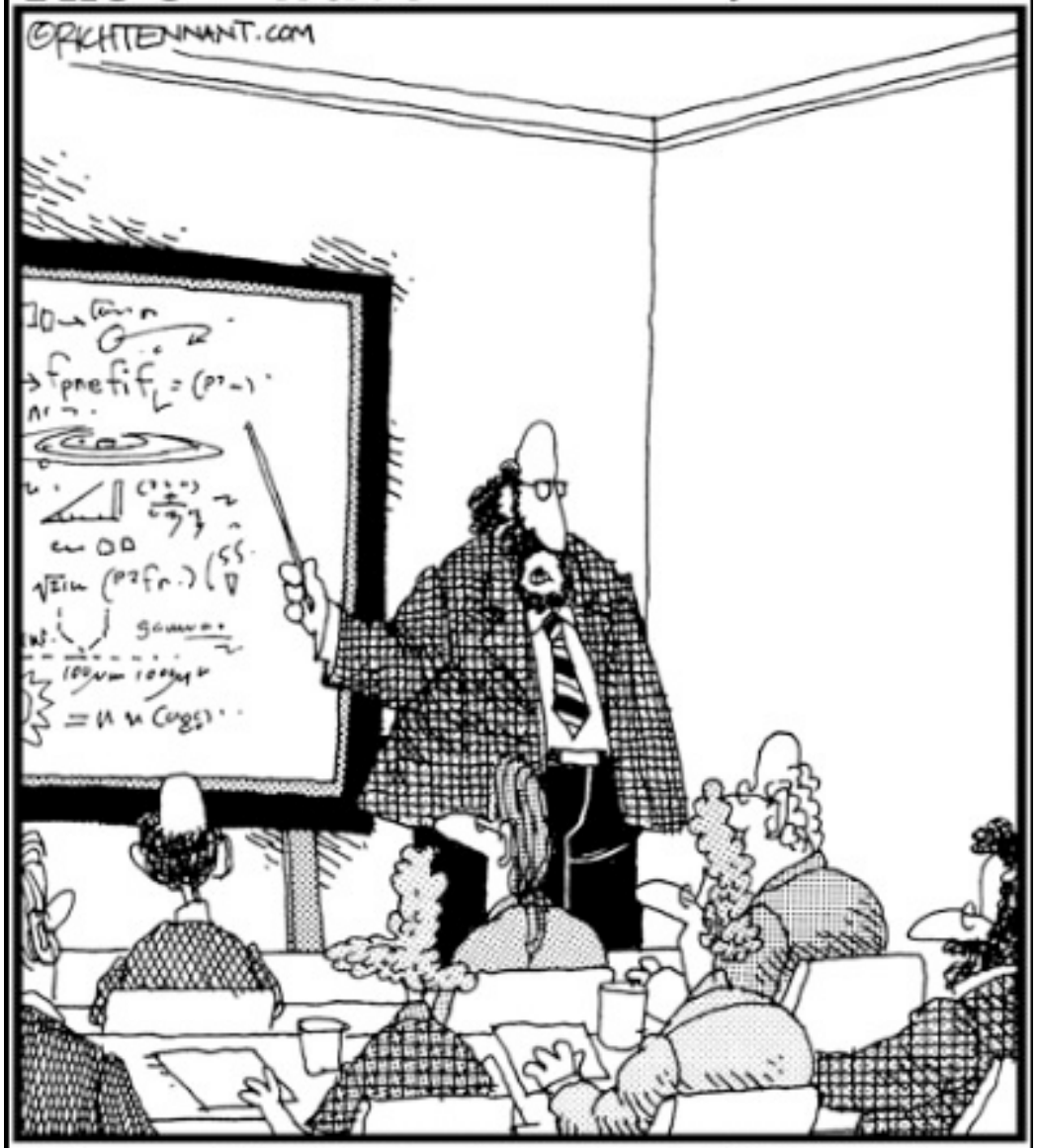

u
Up quark
d
Down quark
c
Charm quark
s
Strange quark
t
Top quark
b
Bottom quark
τ
Tau
Tau neutrino
μ
Muon
Muon neutrino
e
Electron
Electron neutrino

Standardni model



The 5th Wave

By Rich Tennant



"Along with 'Antimatter,' and 'Dark Matter,' we've recently discovered the existence of 'Doesn't Matter,' which appears to have no effect on the universe whatsoever."


THE WORLD IS NOT COMING TO AN END
THEREFORE, YOU MUST SUFFER ALONG AND LEARN TO COPE.
Dana Fradon