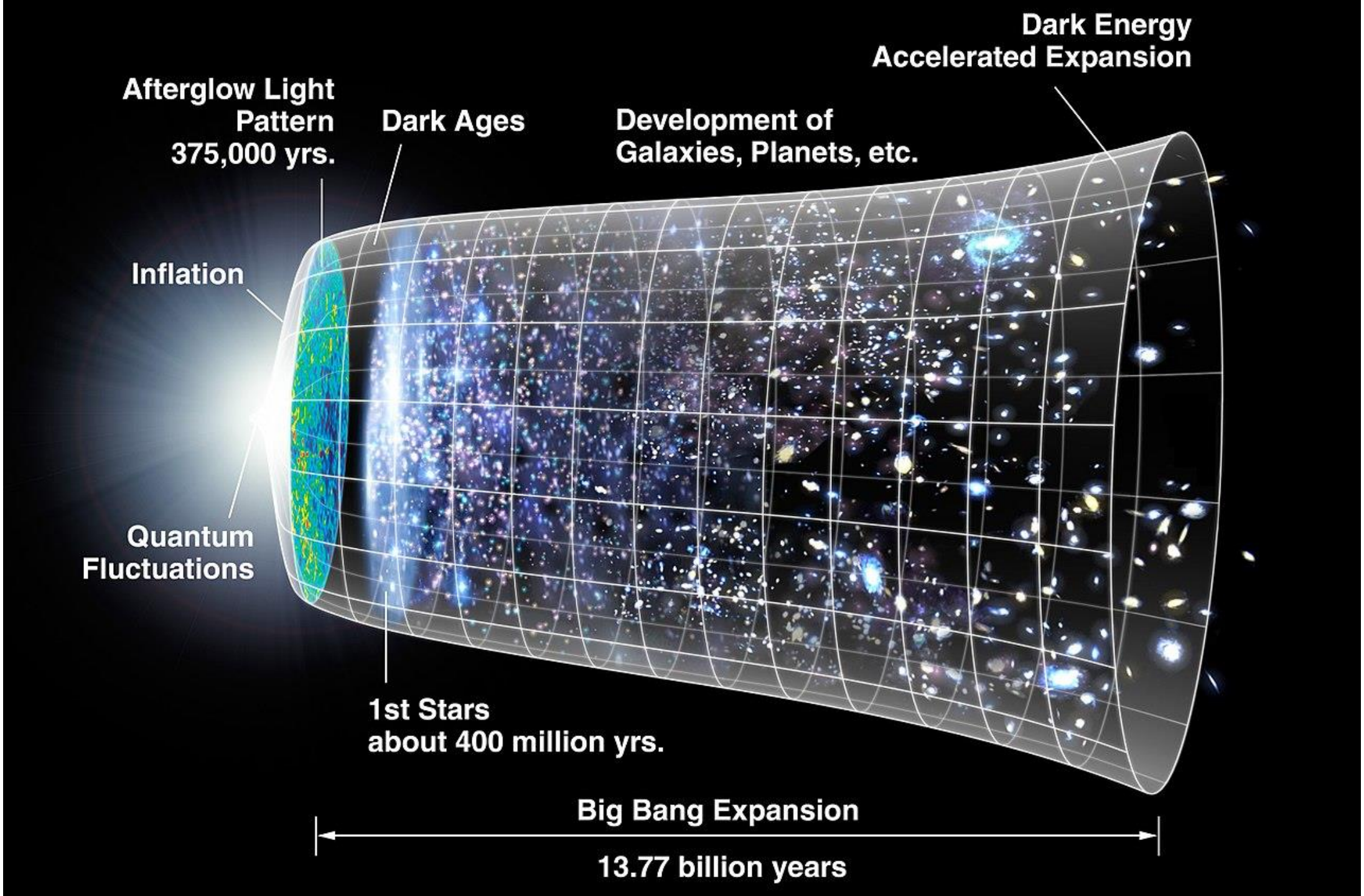
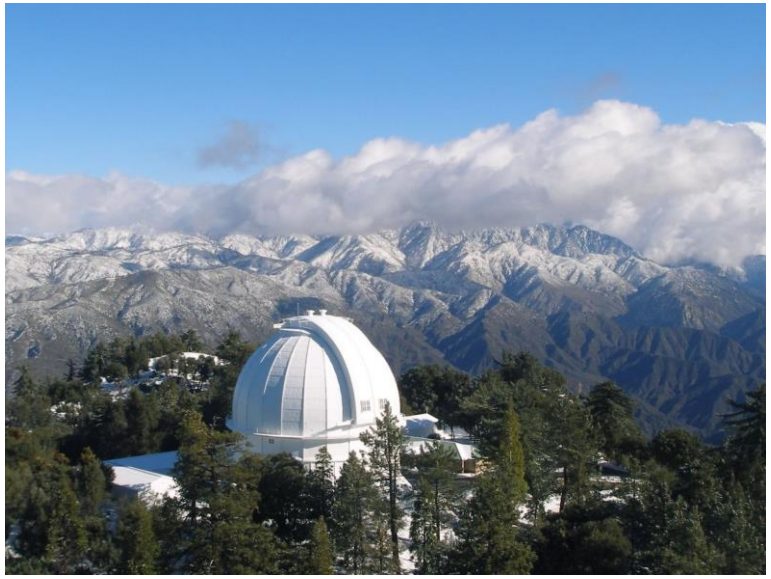
Kosmologie a zkoumání vesmíru

Jan Voldřich

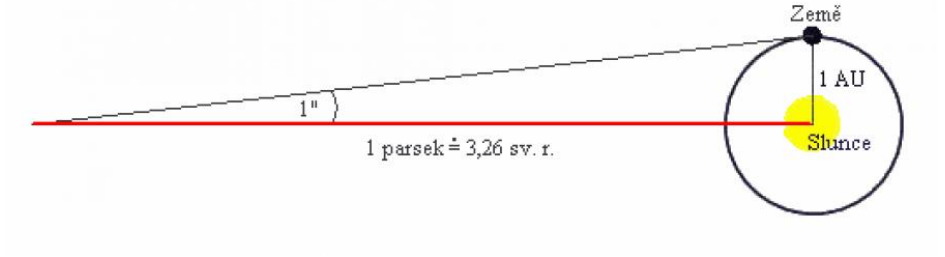
Obsah

- Dnešní představa o vývoji vesmíru
- Expanze vesmíru
- Teorie Velkého třesku
- Reliktní záření
- Temná hmota a energie
- Kvark-gluonové plasma
- Obecná teorie relativity
- „Okna“ do vesmíru
- Teorie inflace


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

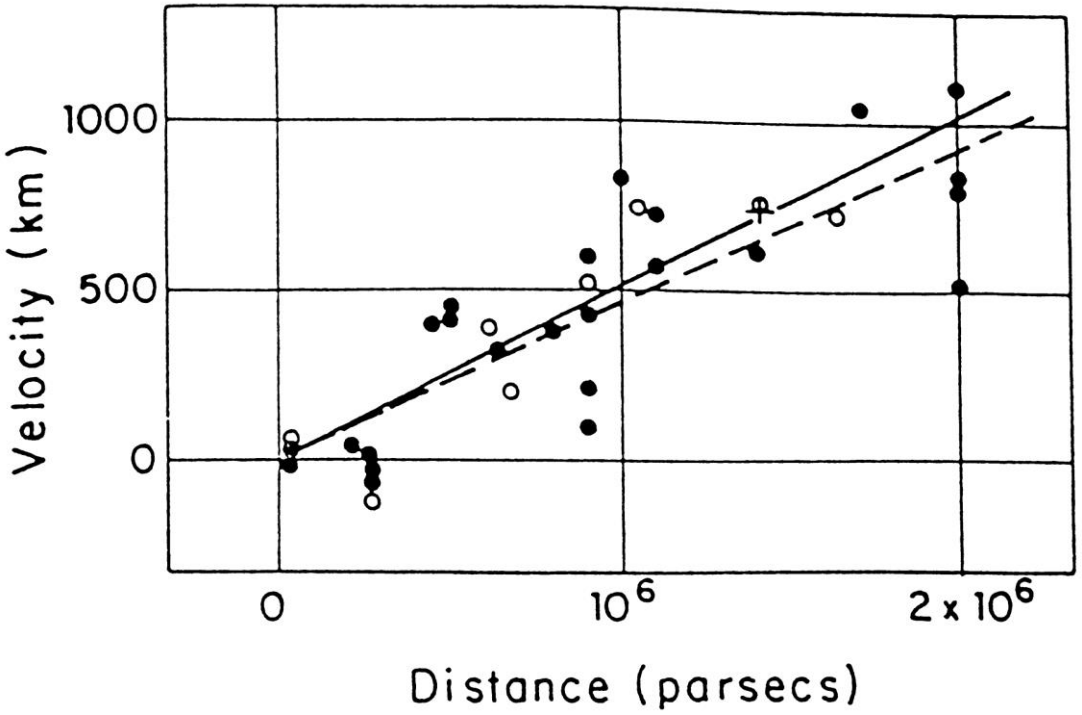


Mt Wilson

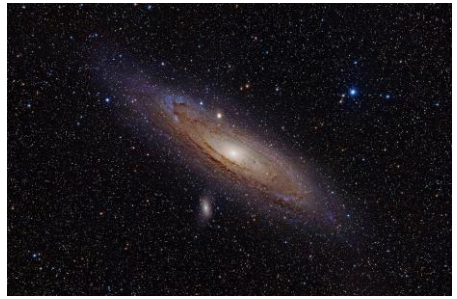


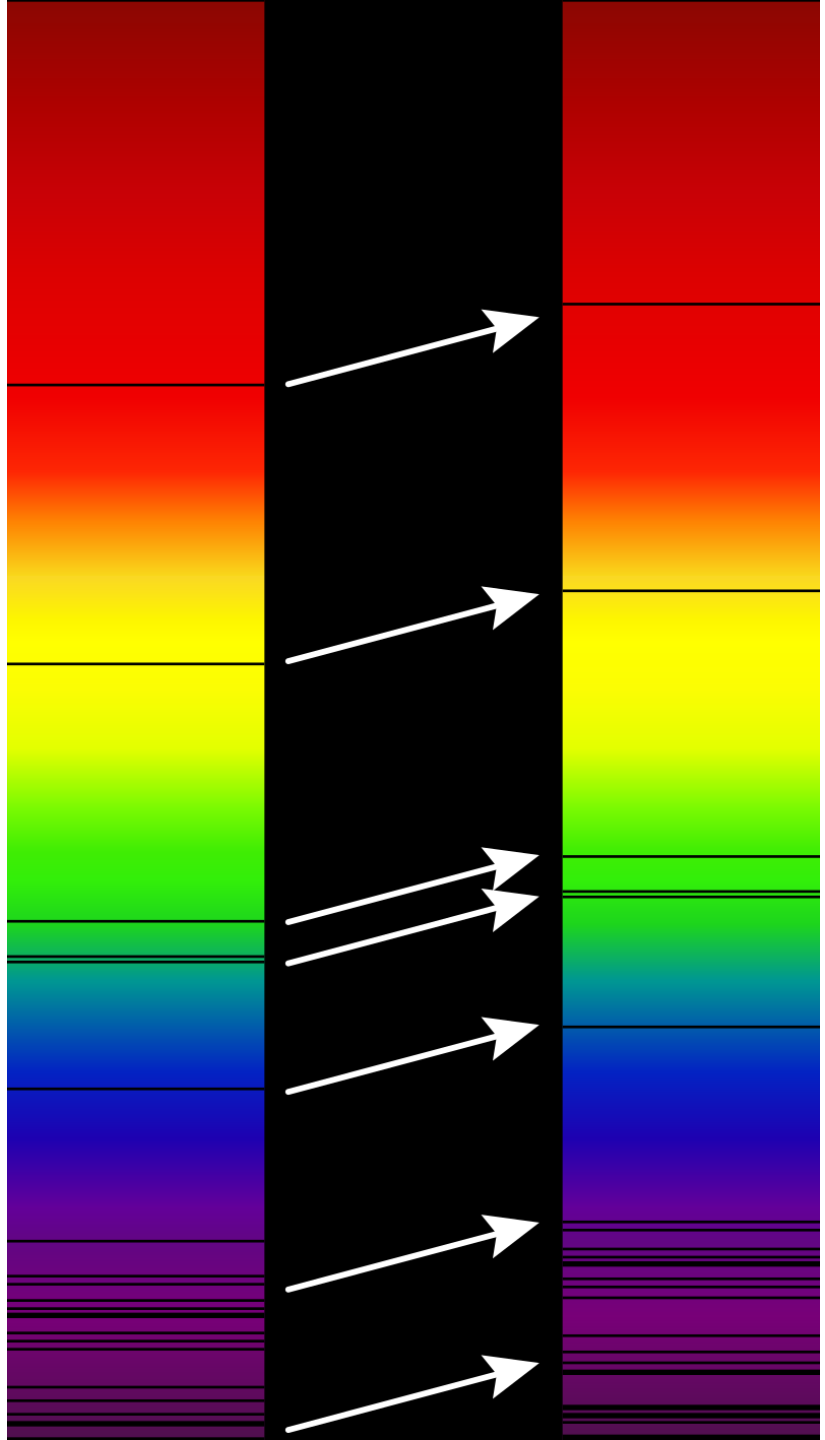
Edwin Hubble, 1929

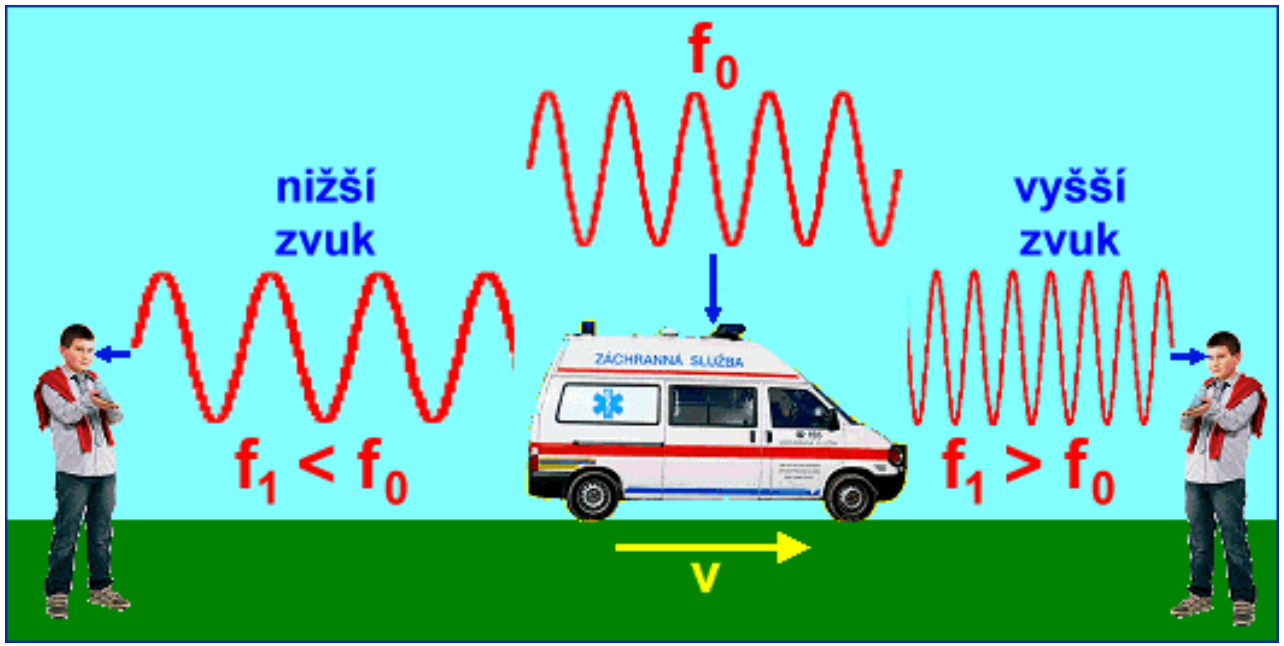
1917



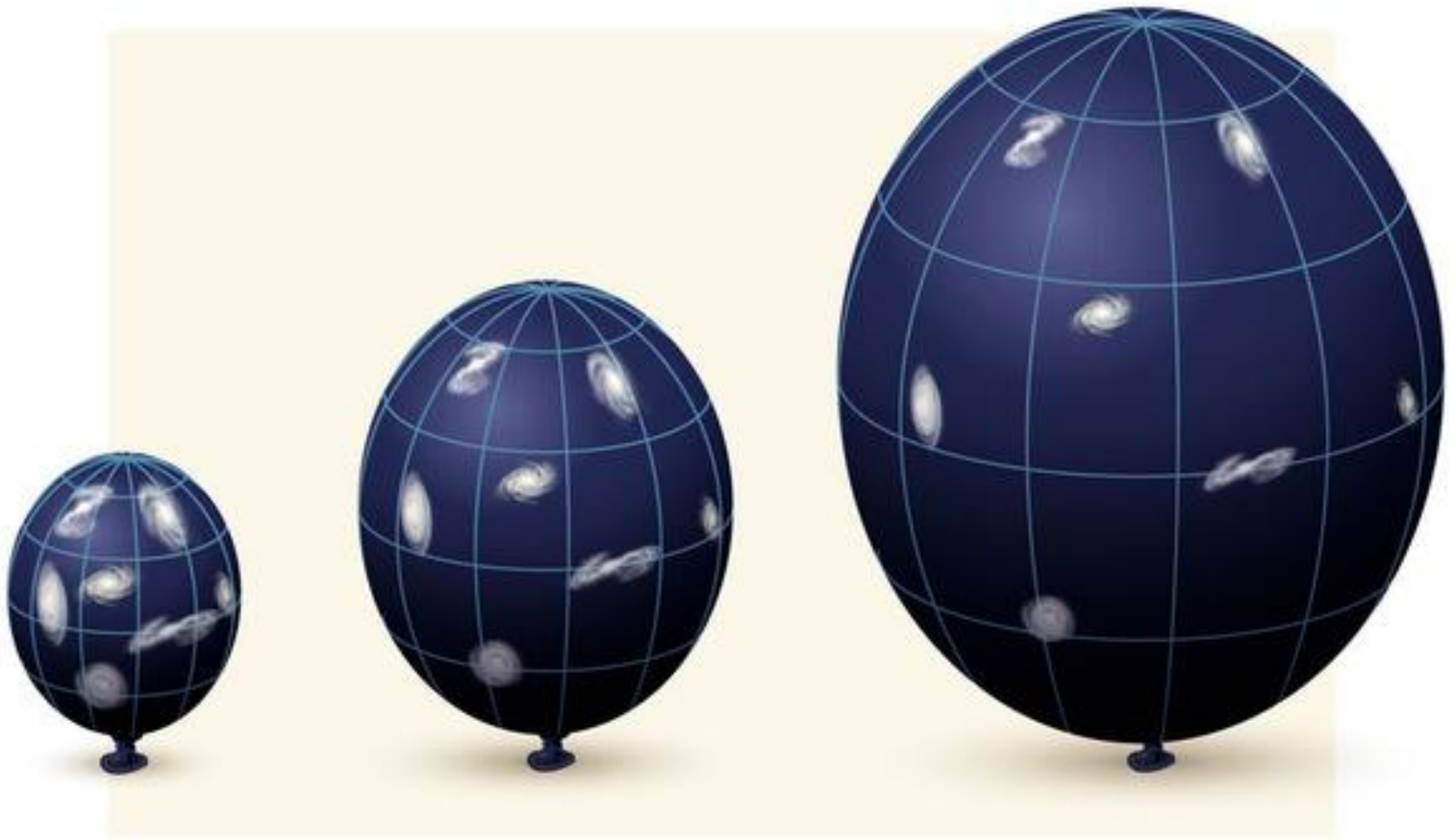
H=68 km/s/Mpc



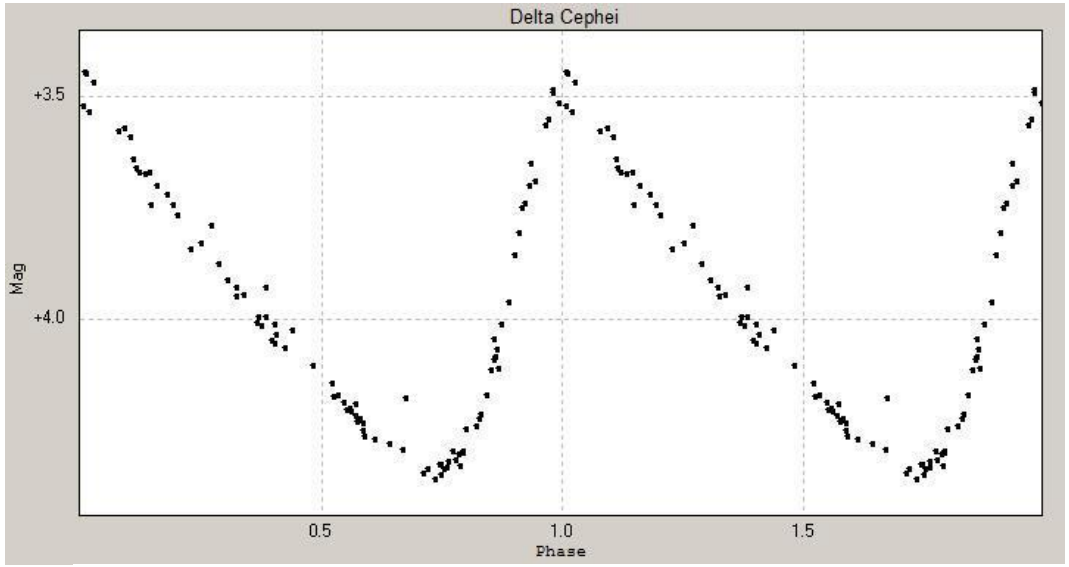


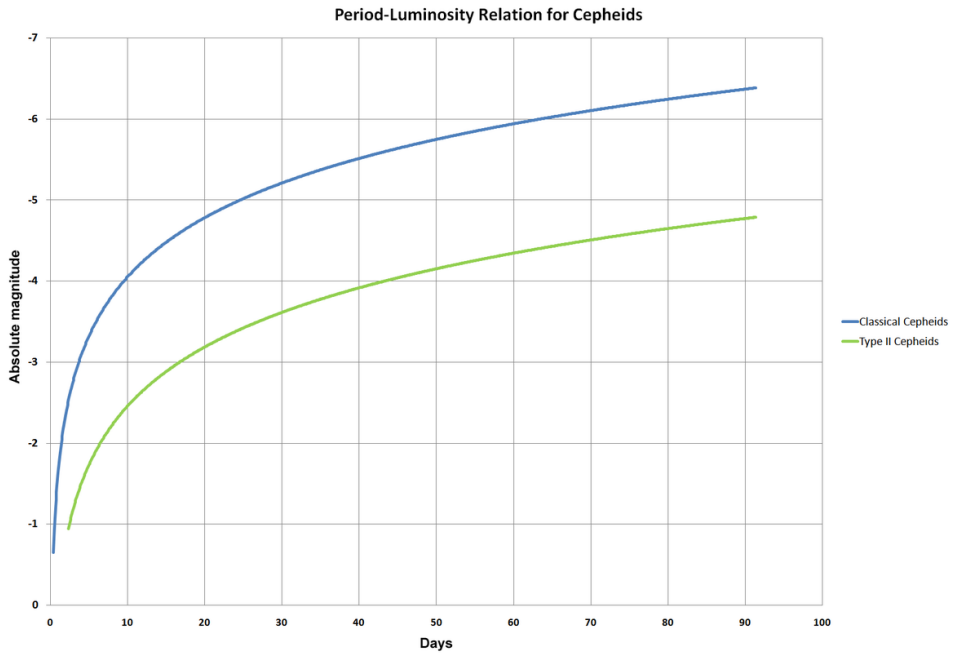

f0
nižší
zvuk
vyšší
zvuk
f1 < f0
f1 > f0
ZÁCHRANNÁ SLUŽBA
v

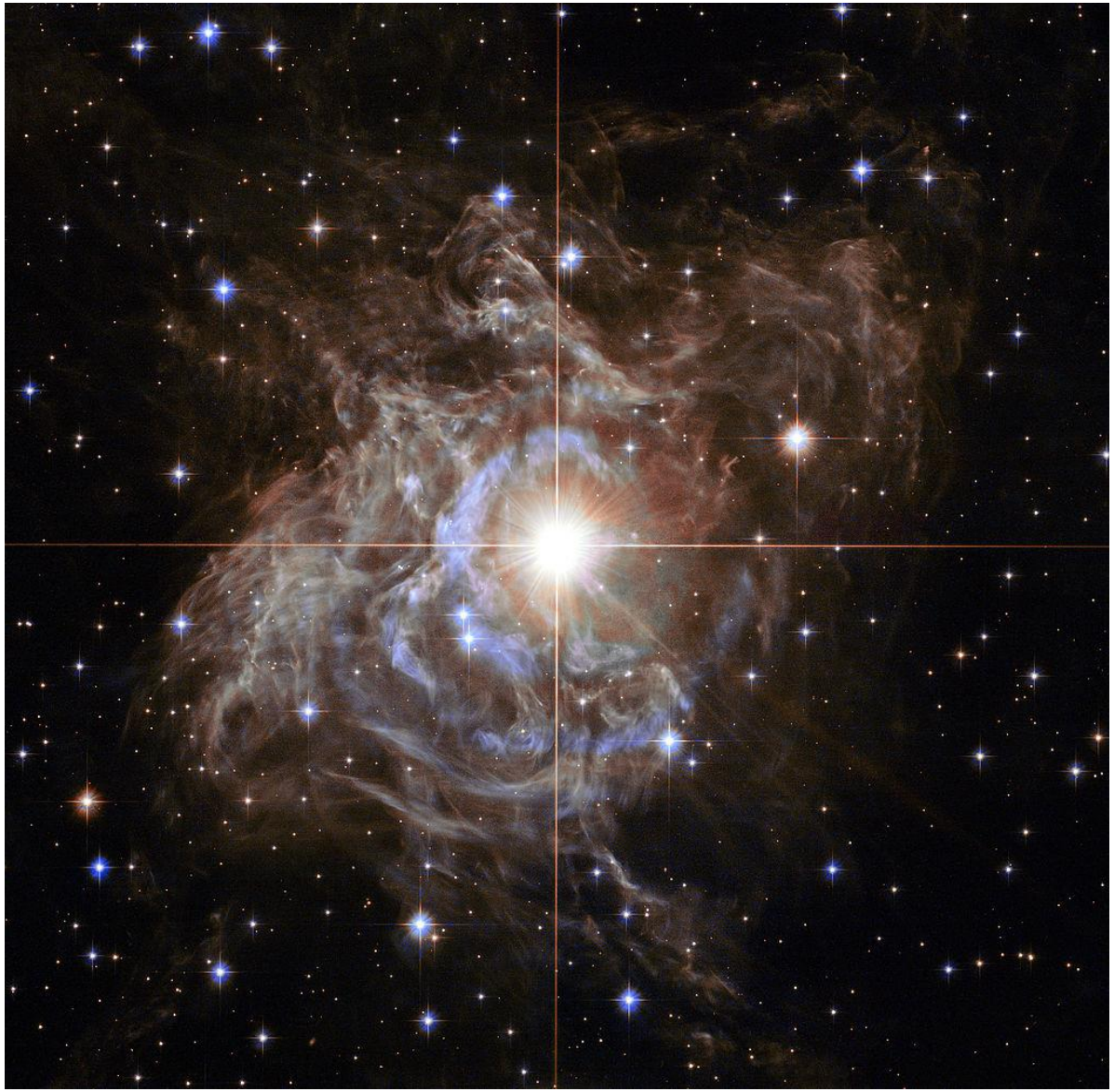
Expanze vesmíru



Cefeidy



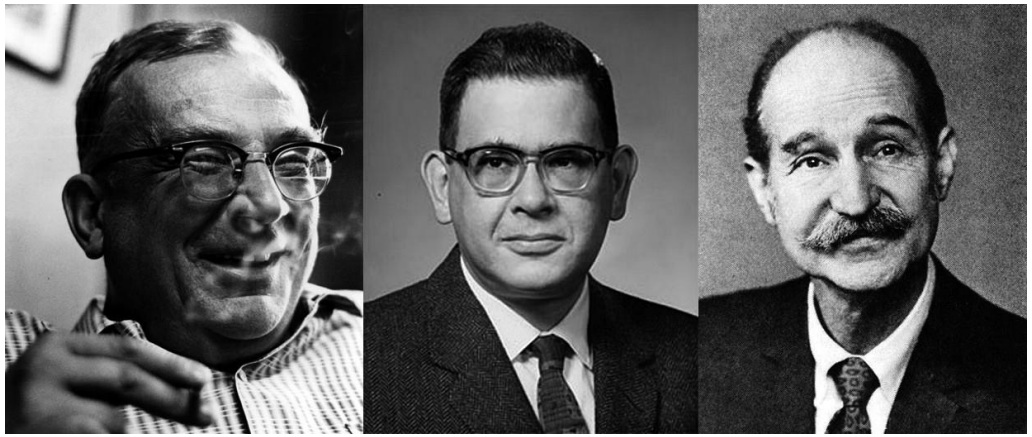




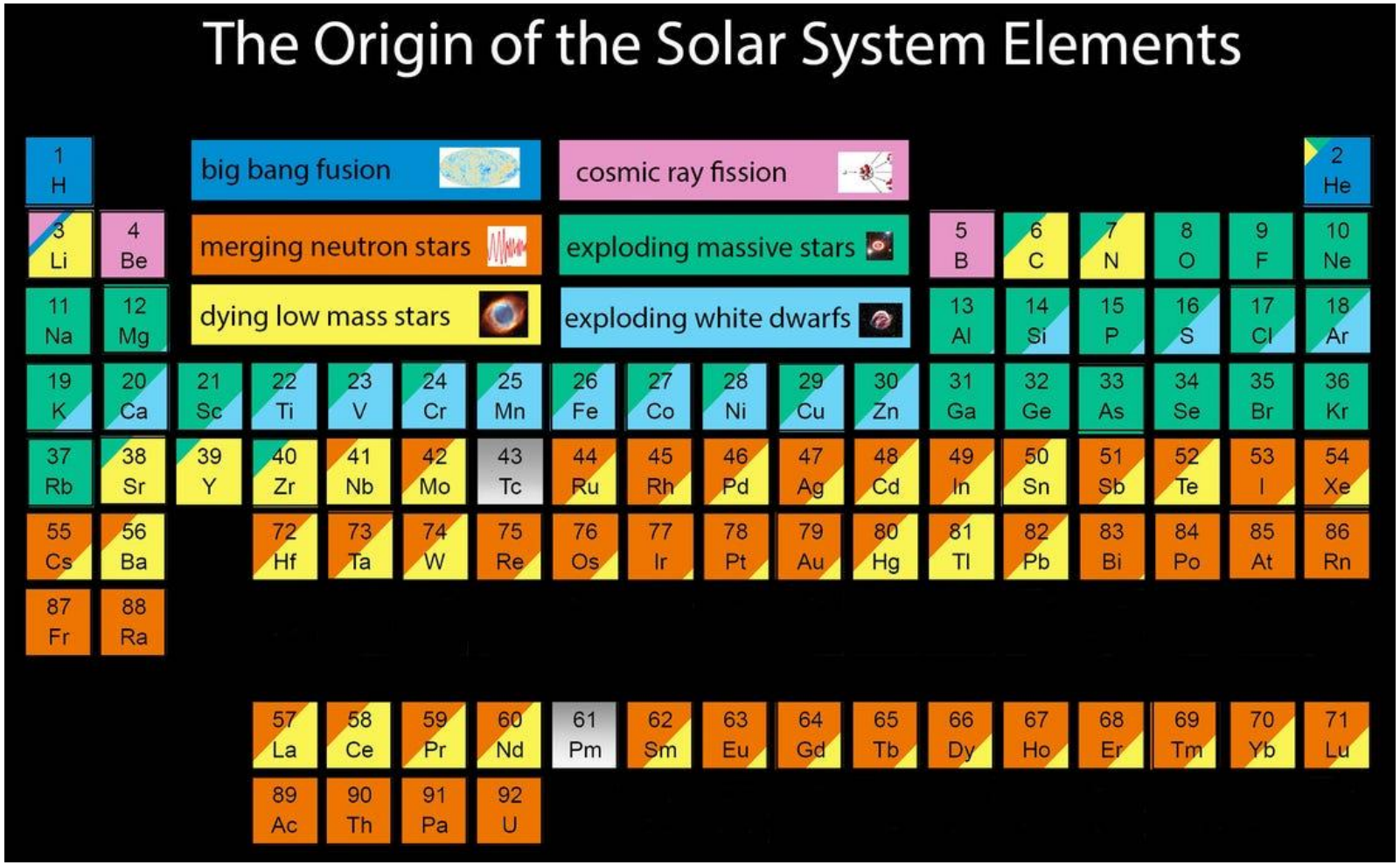
RS Puppis, Mléčná dráha, HST

αβγ teorie

- G.Gamow, R.Alpher, H.Bethe, R.Herman
- 1948 – teorie „horkého vesmíru“ – později „Velký třesk“ (F. Hoyle)
- Vznik prvků
- Předpověď reliktního záření

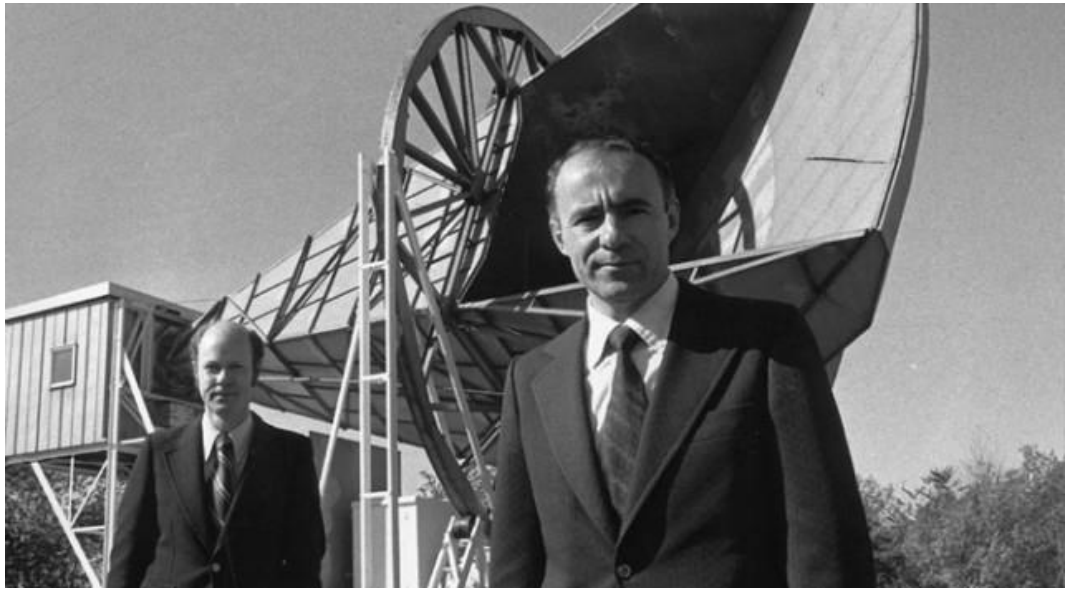


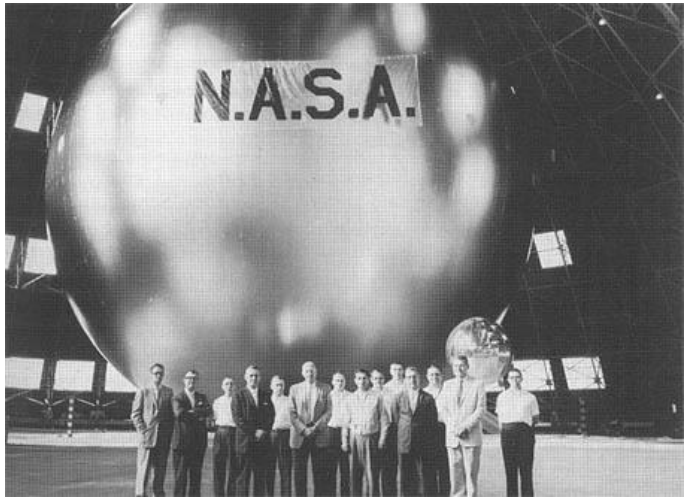
The Origin of the Solar System Elements

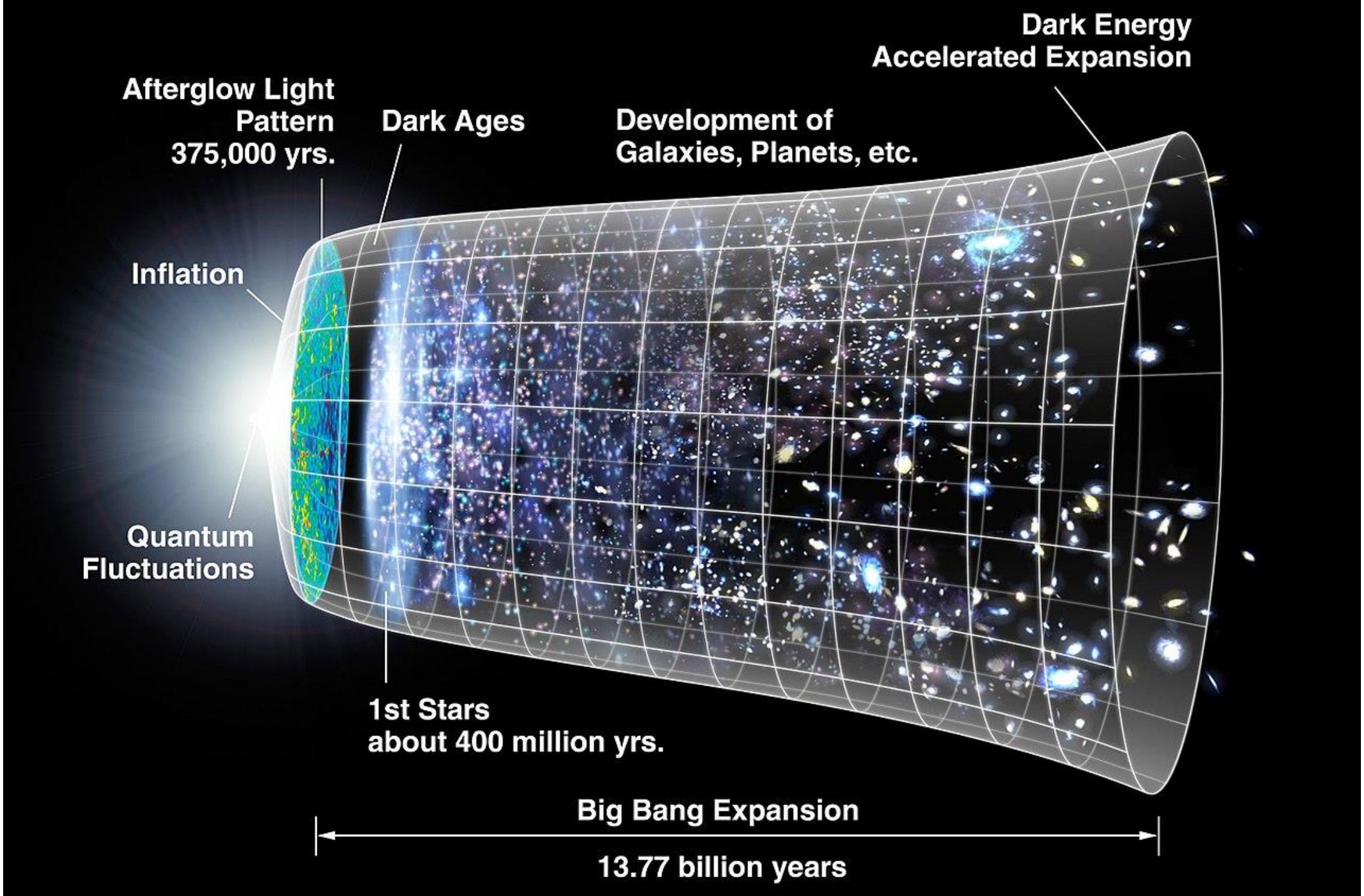


Reliktní záření

- Bellovy laboratoře
- 1960-1963 - Echo
- 1965 – přehlídka oblohy v rad. oboru
- Penzias, Wilson
- 7,3 cm



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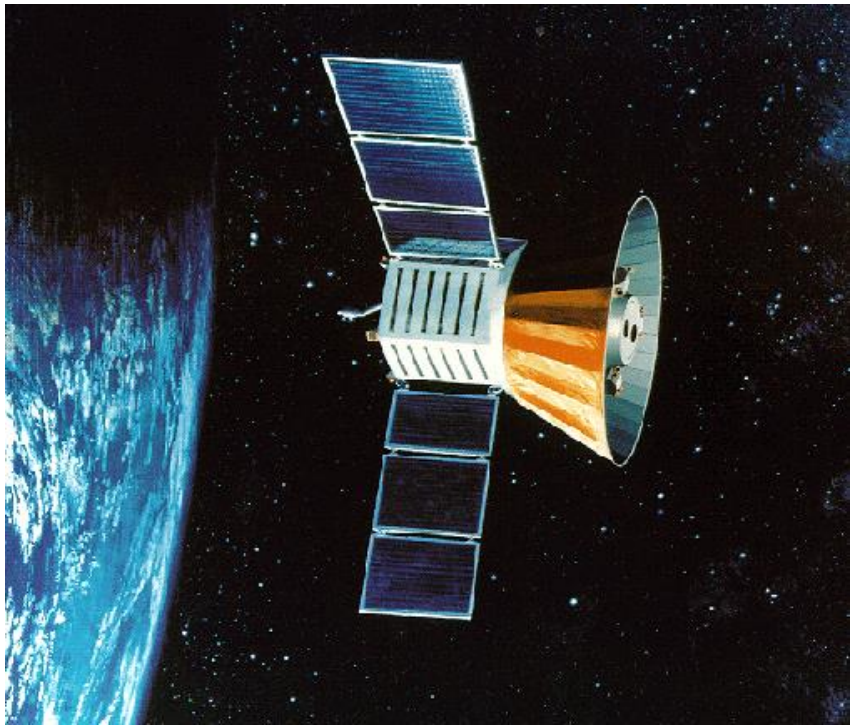
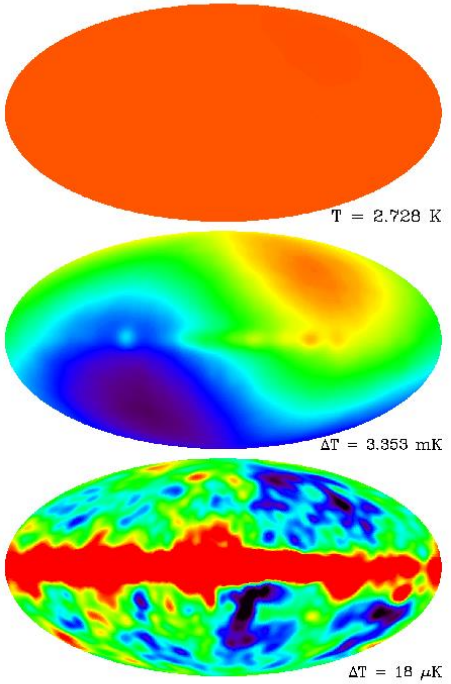
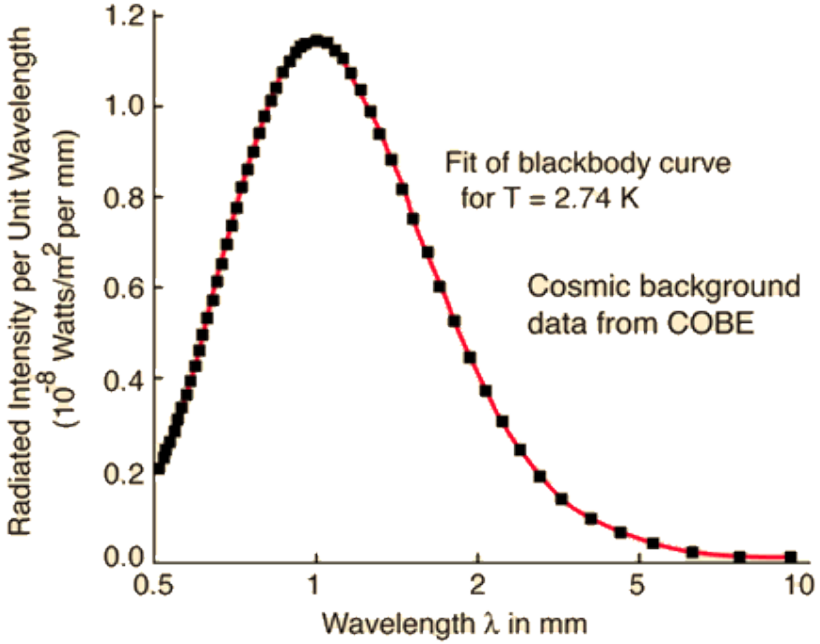
about 400 million yrs.
Big Bang Expansion
13.77 billion years

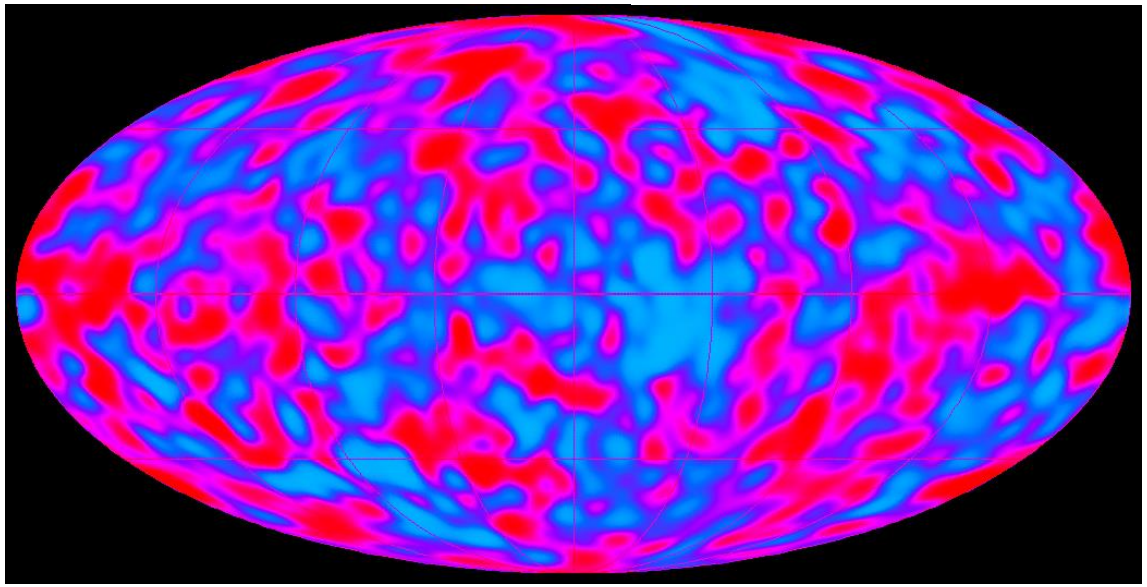
COBE

- 1989
- 8 min – splněny cíle
- T=2,73 K
- Chlazení (kap. He)
- Spektrum:

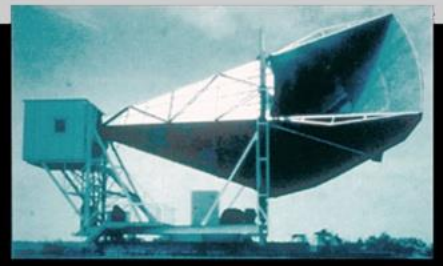


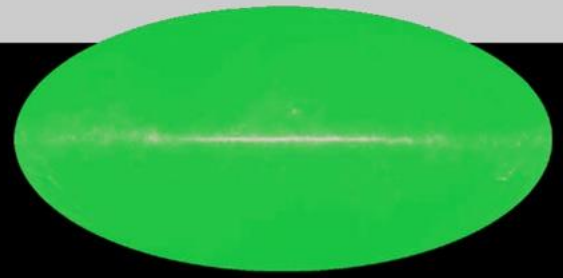






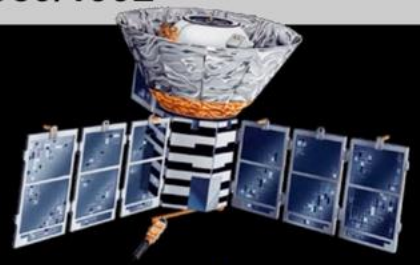
1965 — **Penzias a Wilson**

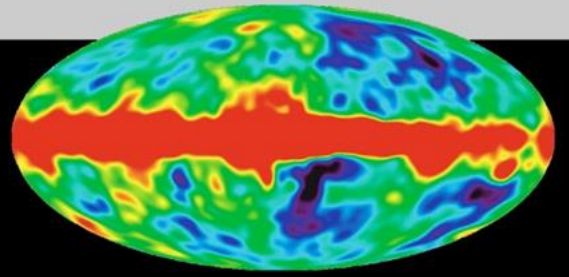




objev šumu z konce Velkého třesku
1 pásmo

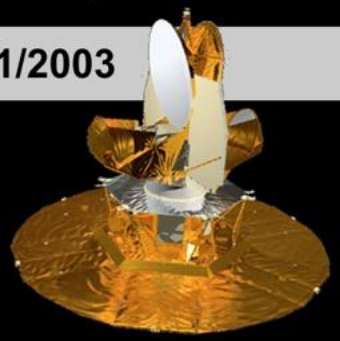
1989/1992 — **COBE**

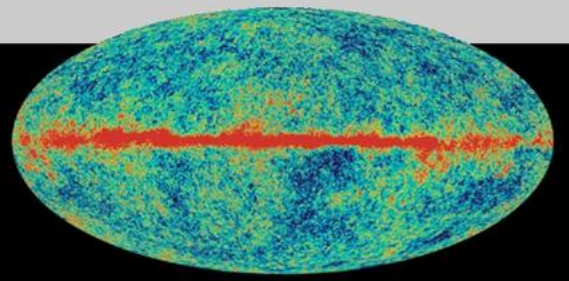




jde o záření černého tělesa T = 2,73 K
objev fluktuací (anizotropie)
ΔT = 400 μK, $\Delta \varphi = 7°$
3 pásma

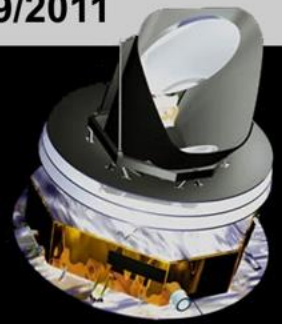
2001/2003 — **WMAP**

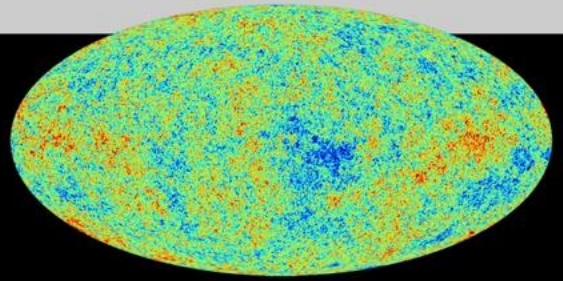




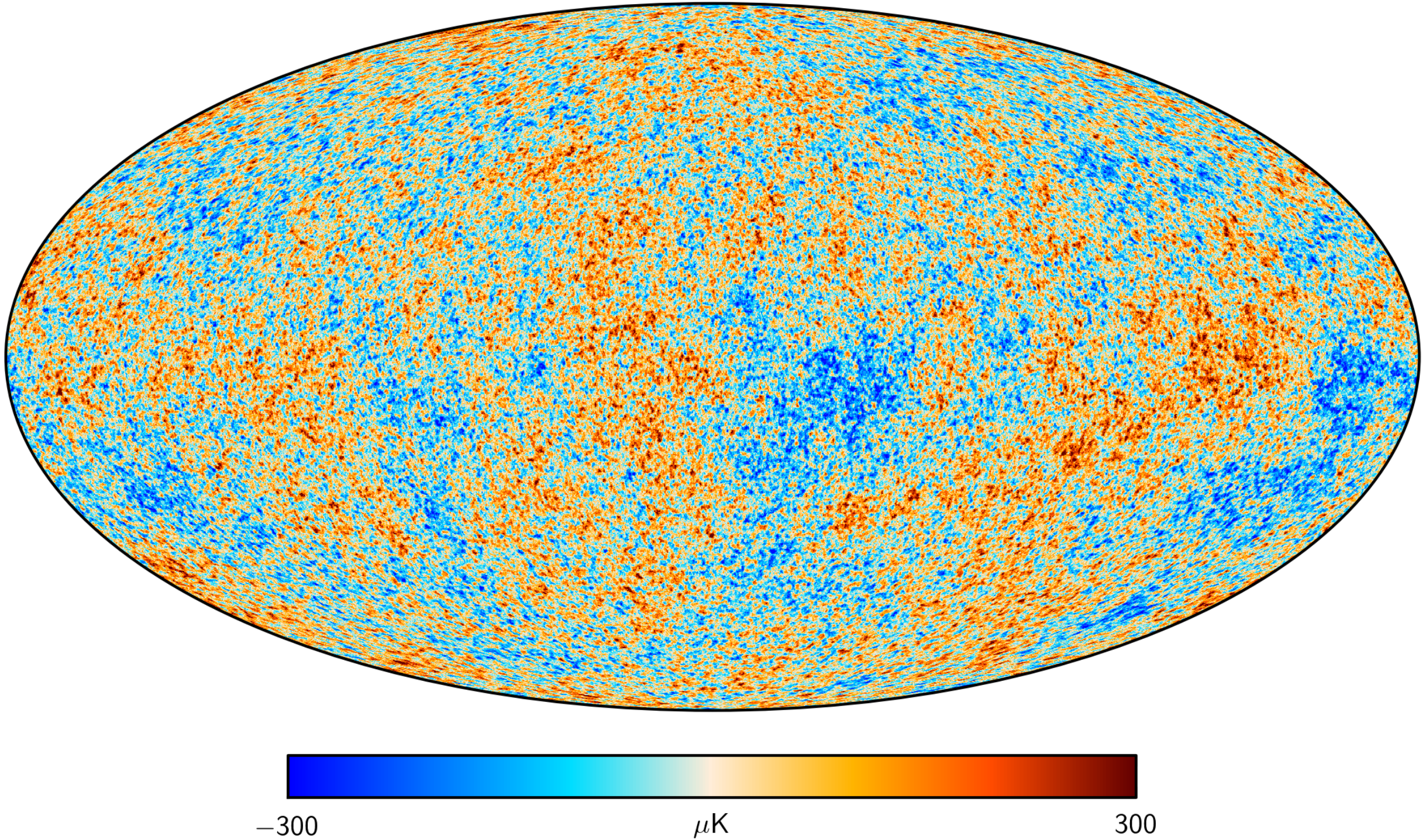
stanovení základních parametrů Vesmíru
ΔT = 20 μK, $\Delta \varphi = 15'$
5 pásem

2009/2011 — **Planck**

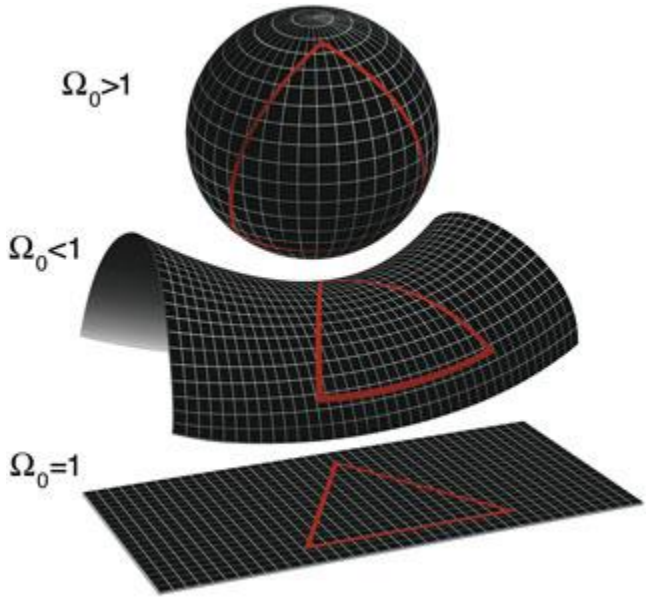


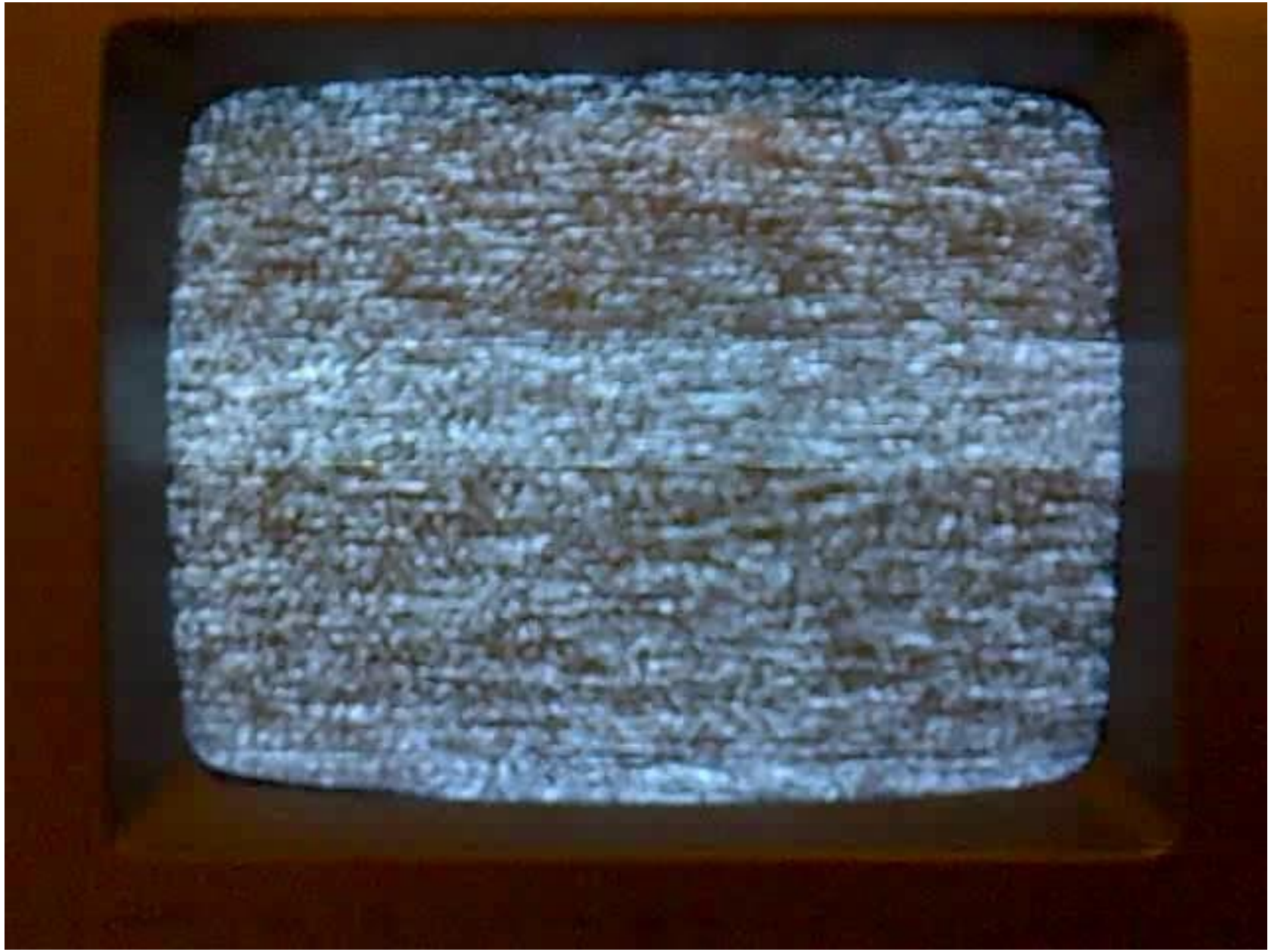


ΔT = 1 μK, $\Delta \varphi = 5'$
9 pásem

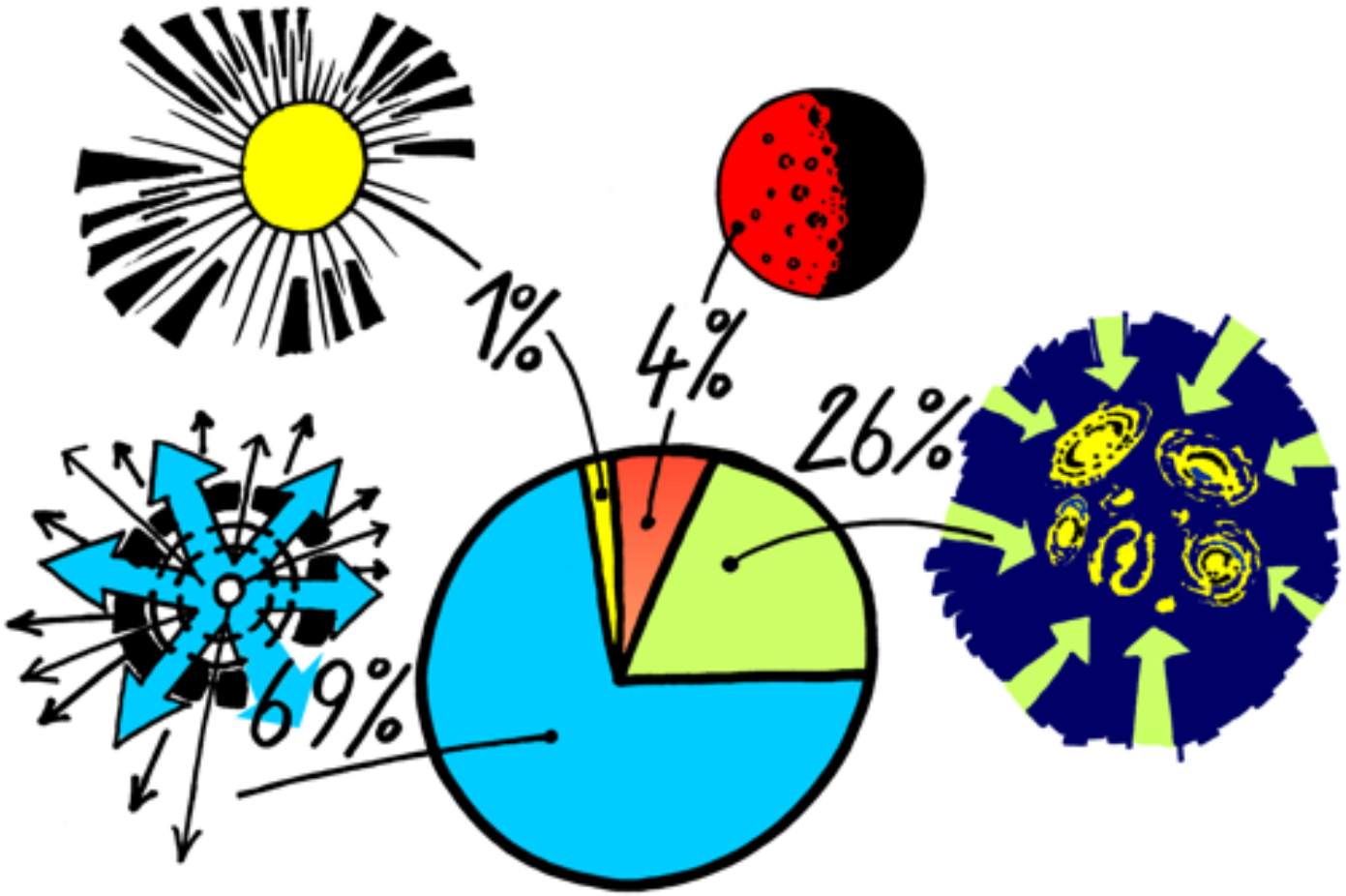

−300
μK
300

	Description	Symbol	Value
Independent parameters	Physical baryon density parameter[a]	$\Omega_b h^2$	0.022 30 ± 0.000 14
	Physical dark matter density parameter[a]	$\Omega_c h^2$	0.1188 ± 0.0010
	Age of the universe	t_0	13.799 ± 0.021 × 10^9 years
	Scalar spectral index	n_s	0.9667 ± 0.0040
	Curvature fluctuation amplitude, k_0 = 0.002 Mpc^{-1}	Δ^2_R	$2.441\ ^{+0.088}_{-0.092} \times 10^{-9}$[22]
	Reionization optical depth	τ	0.066 ± 0.012
Fixed parameters	Total density parameter[b]	Ω_{tot}	1
	Equation of state of dark energy	w	−1
	Tensor/scalar ratio	r	0
	Running of spectral index	$dn_s/d\ln k$	0
	Sum of three neutrino masses	$\sum m_\nu$	0.06 eV/c^2[c][18]:40
	Effective number of relativistic degrees of freedom	N_{eff}	3.046[d][18]:47
Calculated values	Hubble constant	H_0	67.74 ± 0.46 km s^{-1} Mpc^{-1}
	Baryon density parameter[b]	Ω_b	0.0486 ± 0.0010[e]
	Dark matter density parameter[b]	Ω_c	0.2589 ± 0.0057[f]
	Matter density parameter[b]	Ω_m	0.3089 ± 0.0062
	Dark energy density parameter[b]	Ω_Λ	0.6911 ± 0.0062
	Critical density	ρ_{crit}	(8.62 ± 0.12) × 10^{-27} kg/m^3[g]
	The present root-mean-square matter fluctuation averaged over a sphere of radius $8h^{-1}$ Mpc	σ_8	0.8159 ± 0.0086
	Redshift at decoupling	z_*	1 089.90 ± 0.23
	Age at decoupling	t_*	377 700 ± 3200 years[22]
	Redshift of reionization (with uniform prior)	z_{re}	$8.5\ ^{+1.0}_{-1.1}$[23]



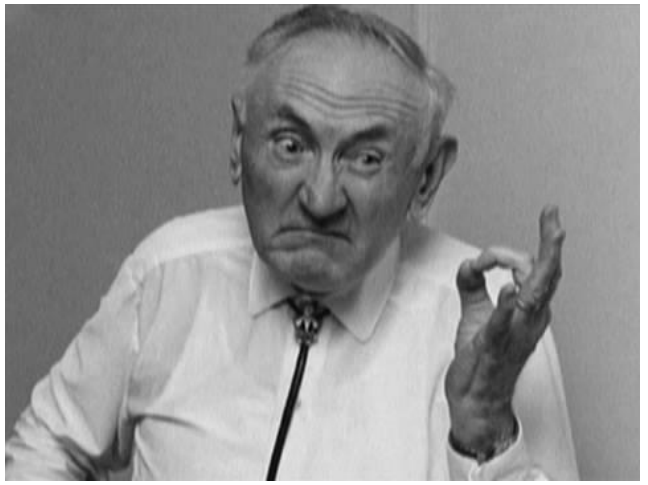


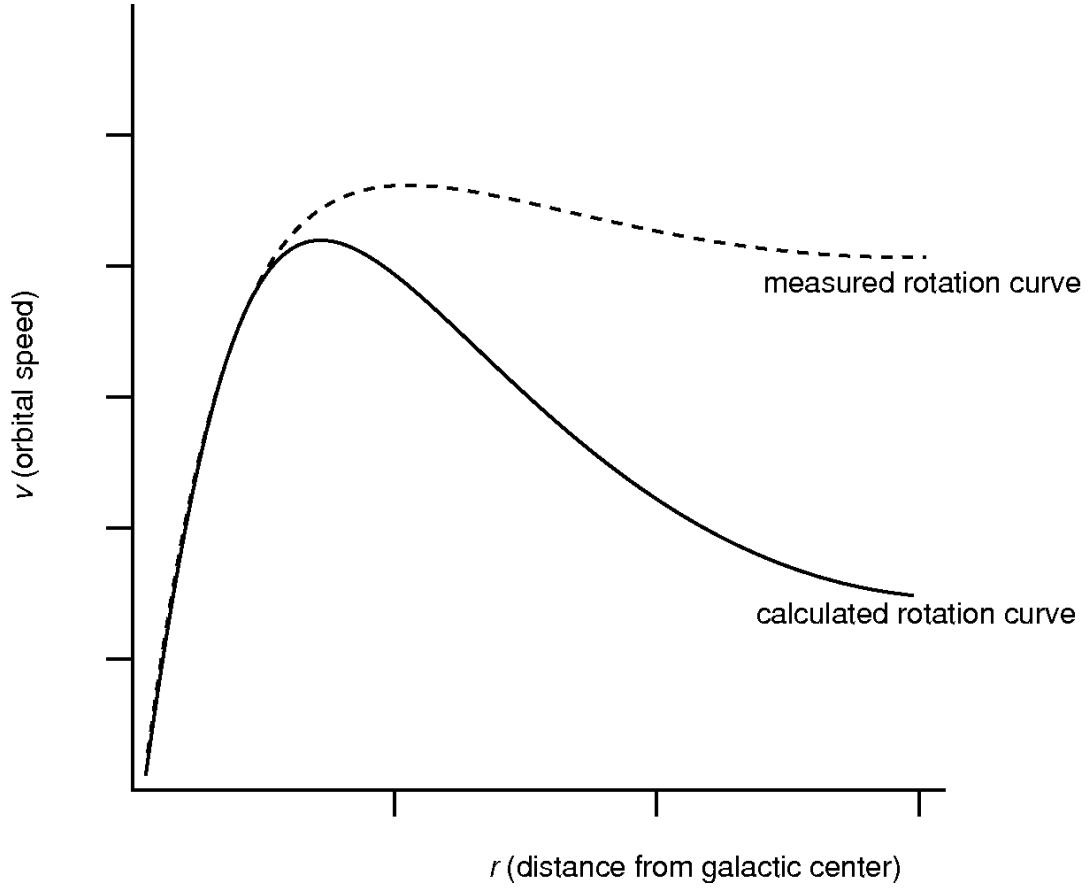
- Složení vesmíru

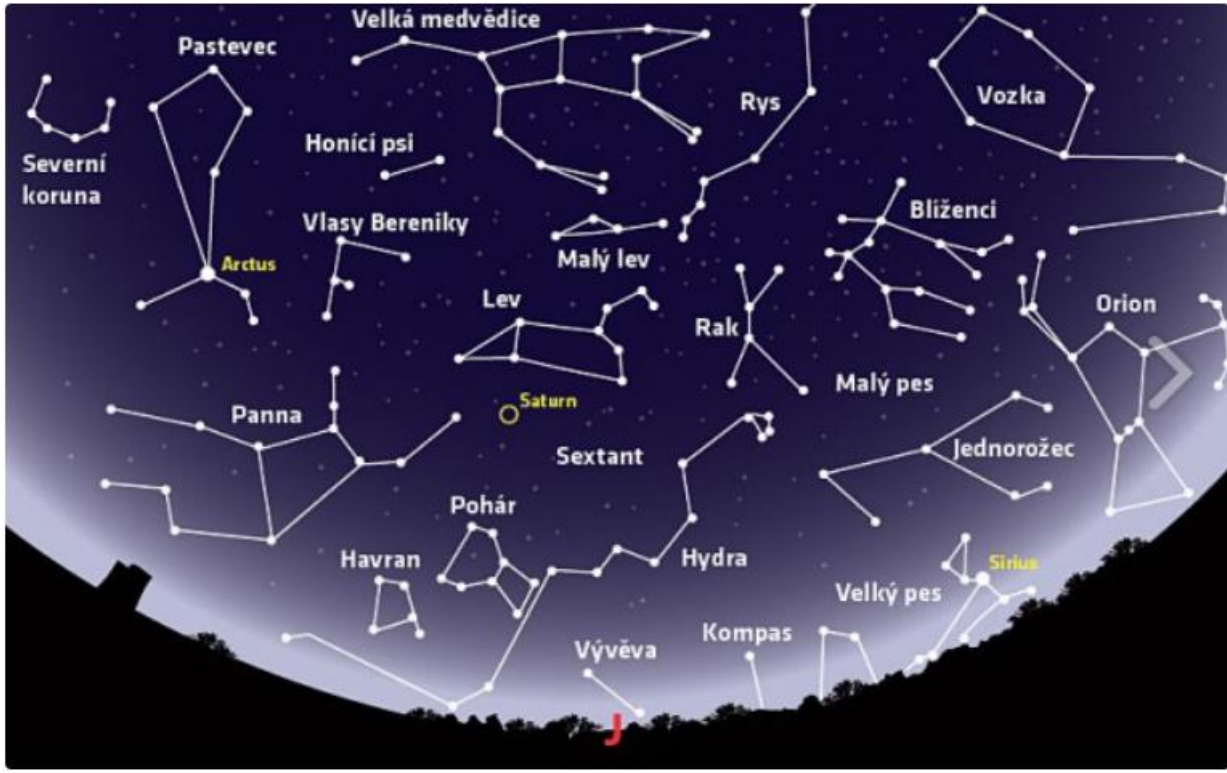


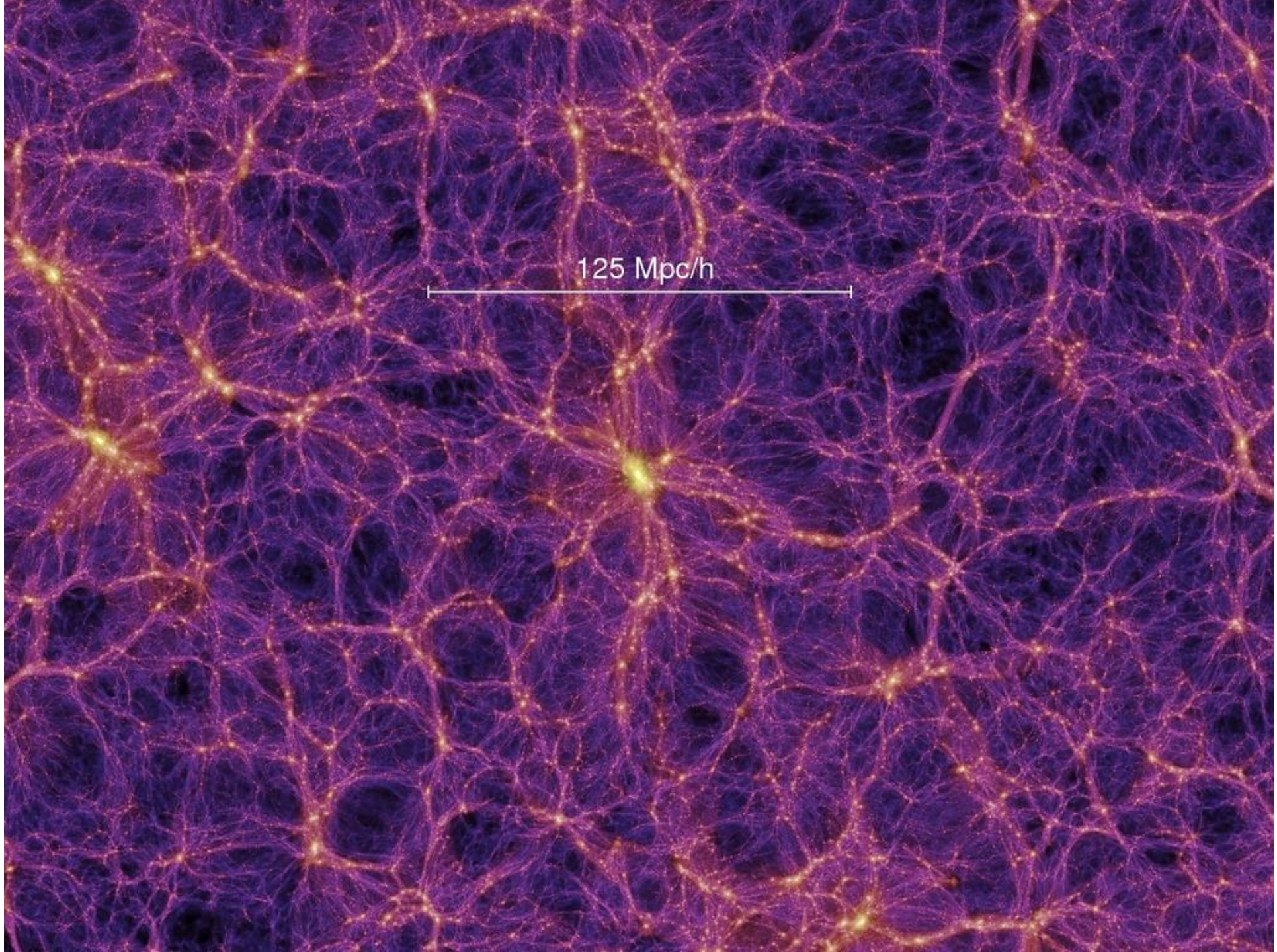
Temná hmota

- Fritz Zwicky (1934)
- Neinteraguje elektromagneticky (jako neutrina)



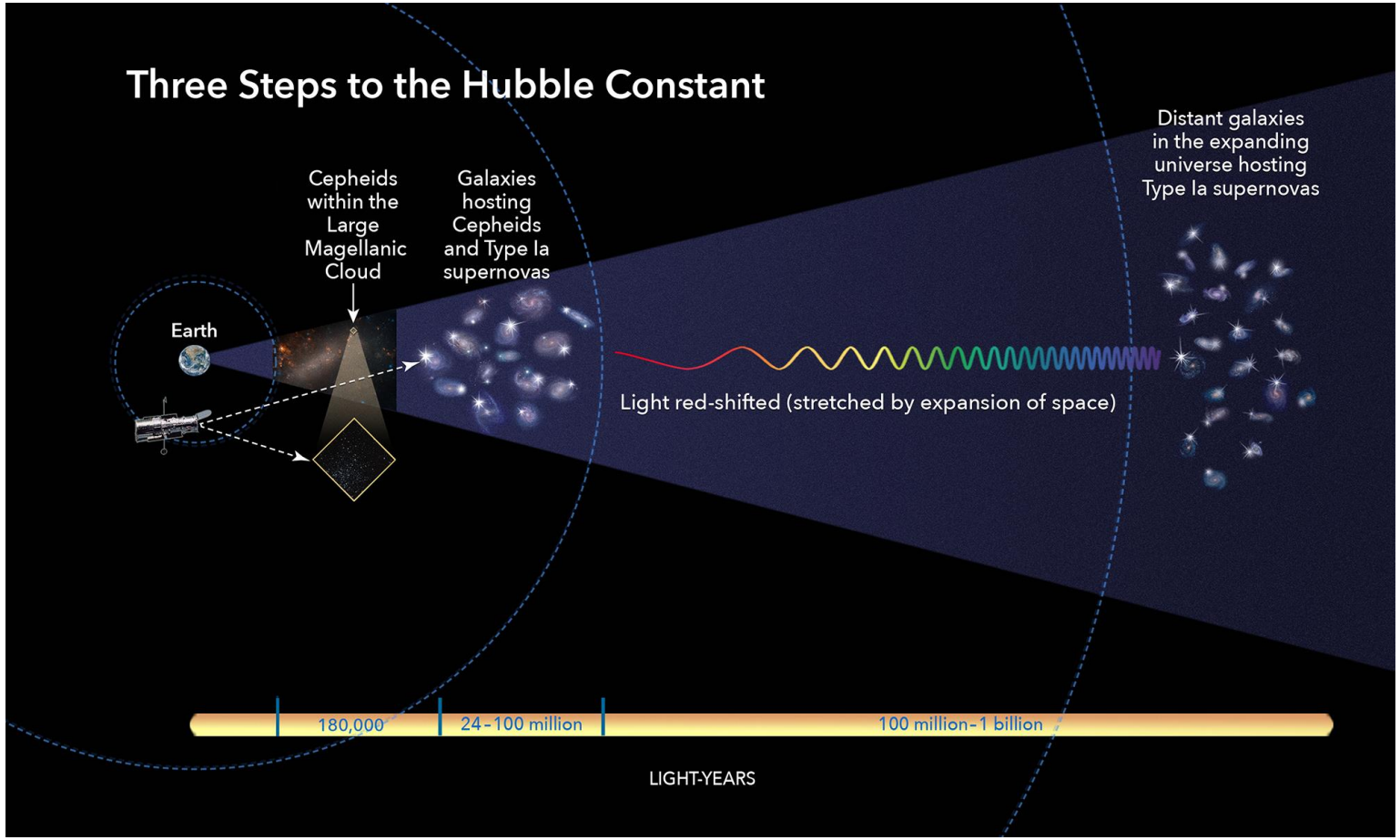


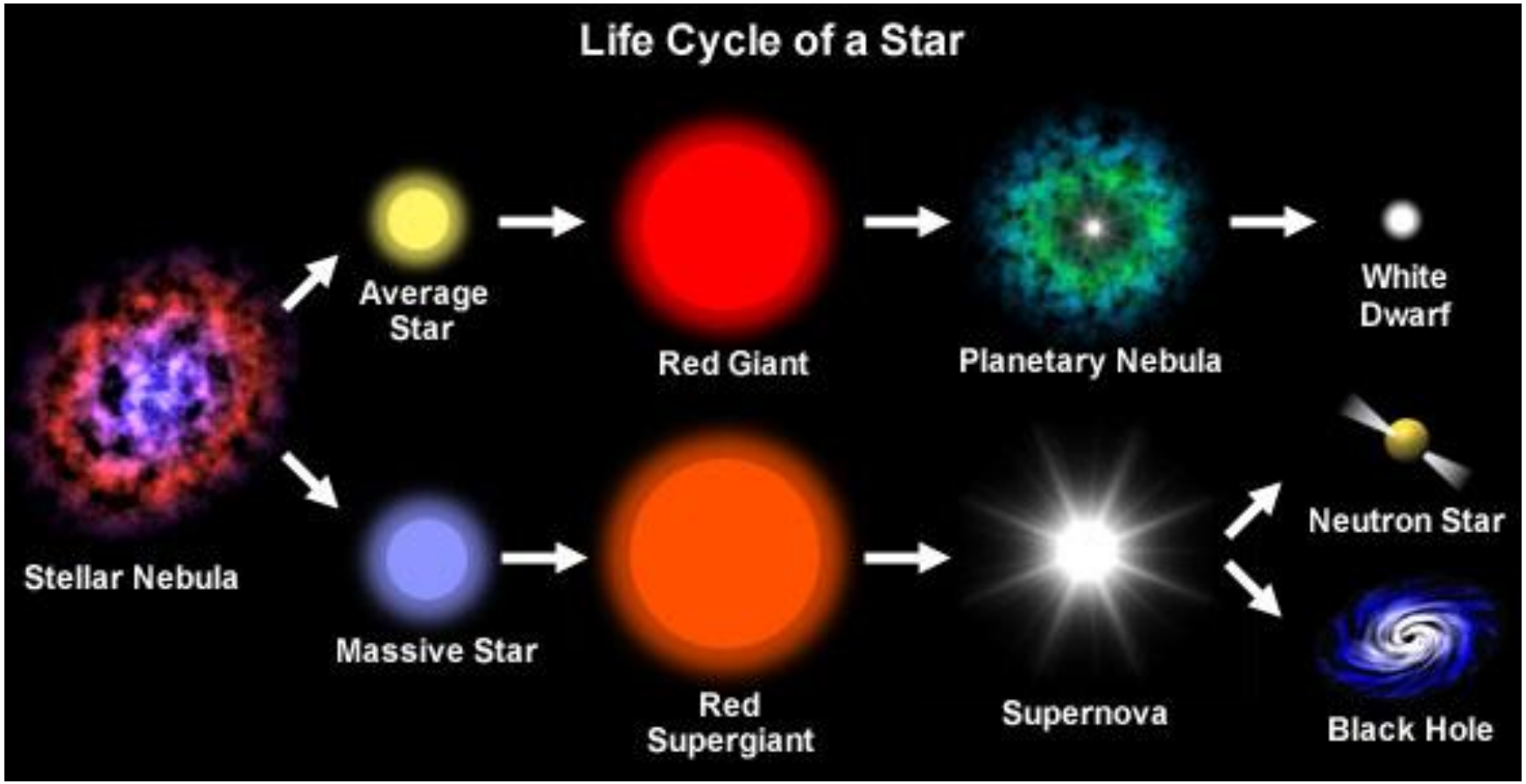


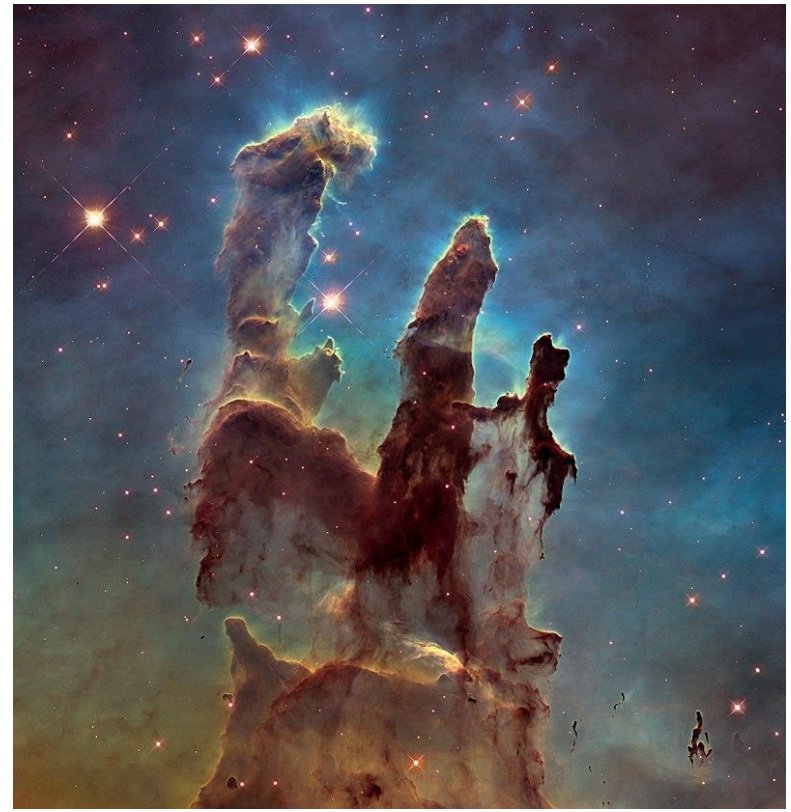

125 Mpc/h

Zrychlená expanze – temná energie?

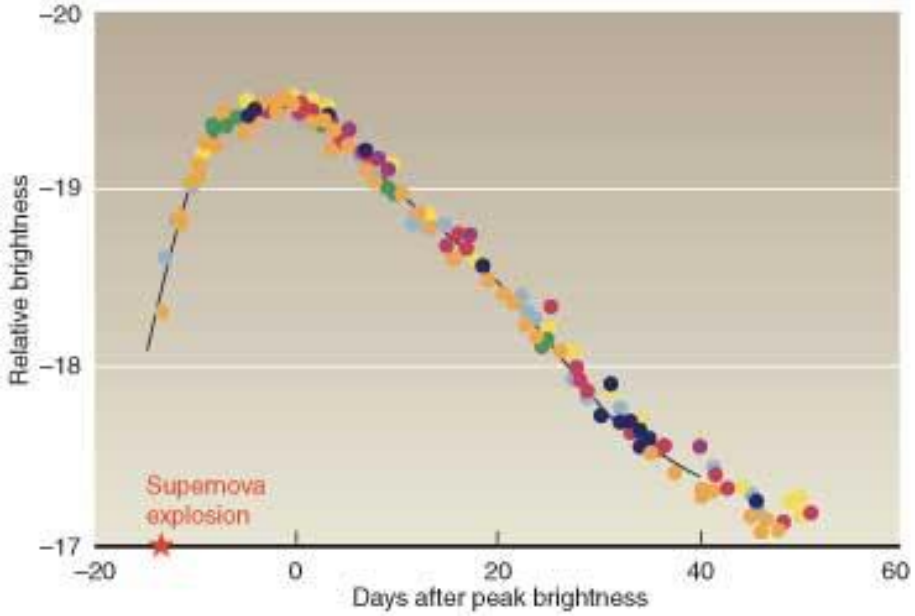
- 1998 Saul Perlmutter, Adam Riess (2011 – Nobelova cena)
- Supernova Ia



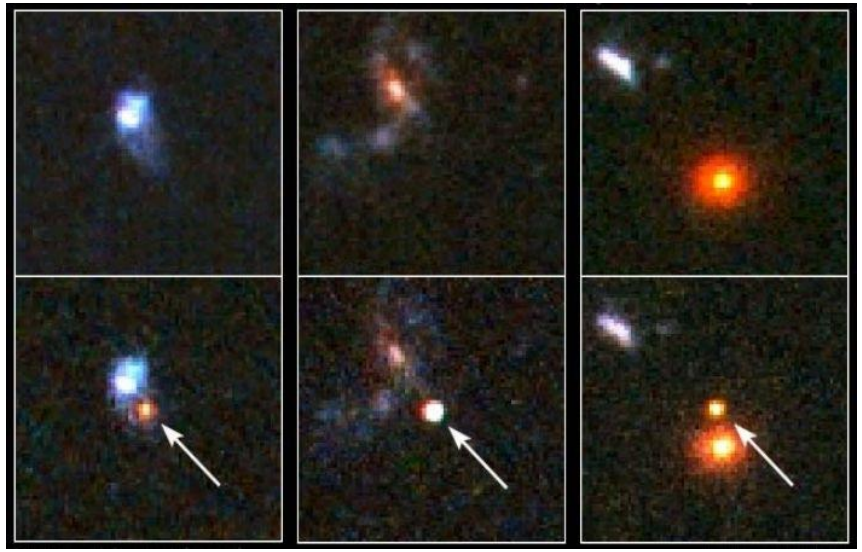

Life Cycle of a Star
Average Star
Red Giant
Planetary Nebula
White Dwarf
Stellar Nebula
Massive Star
Red Supergiant
Supernova
Neutron Star
Black Hole



Supernova Ia



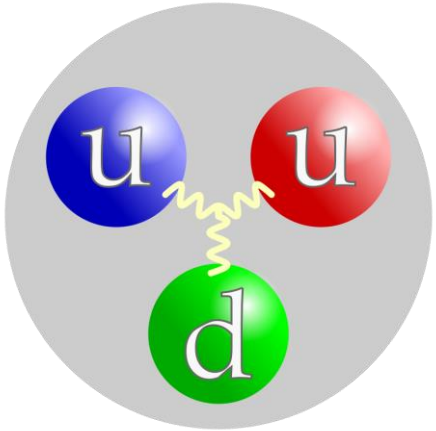
- Chandrasekharova mez

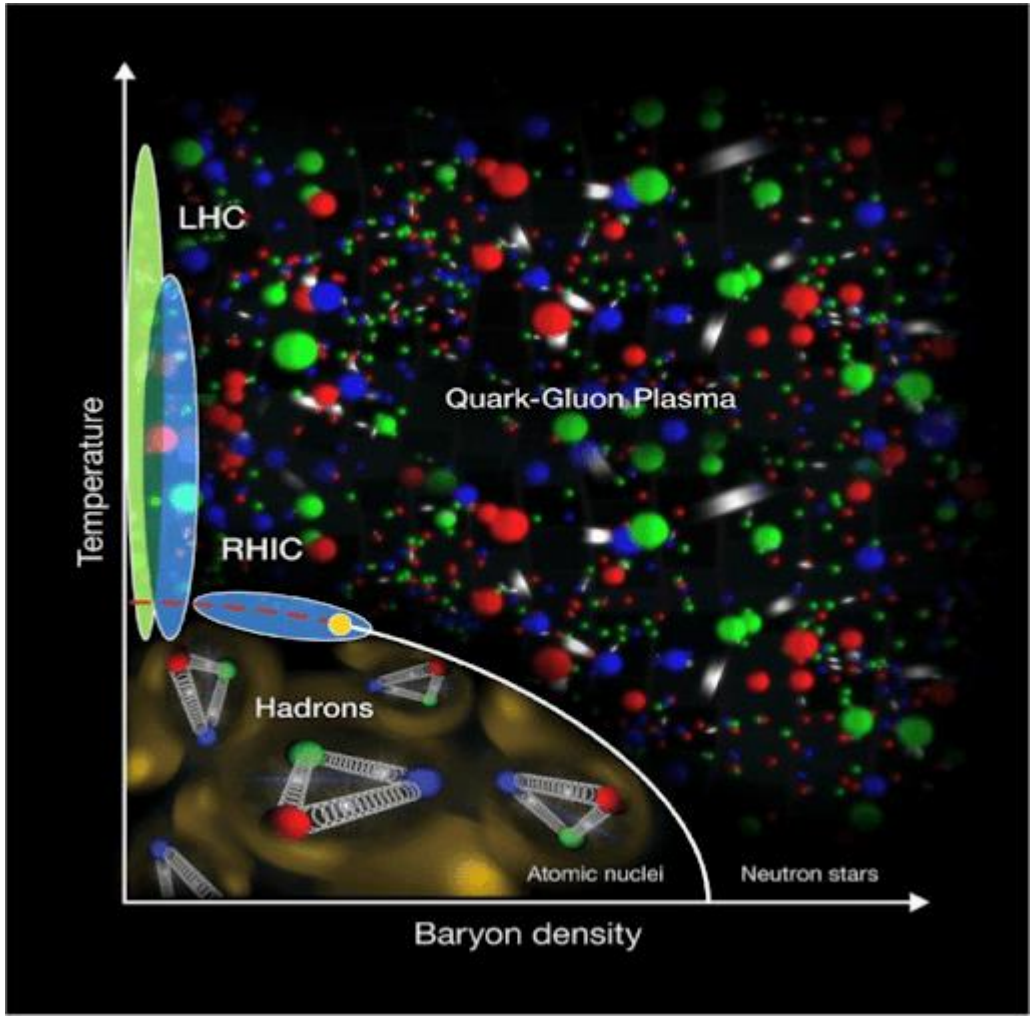


G299, před 4500 let

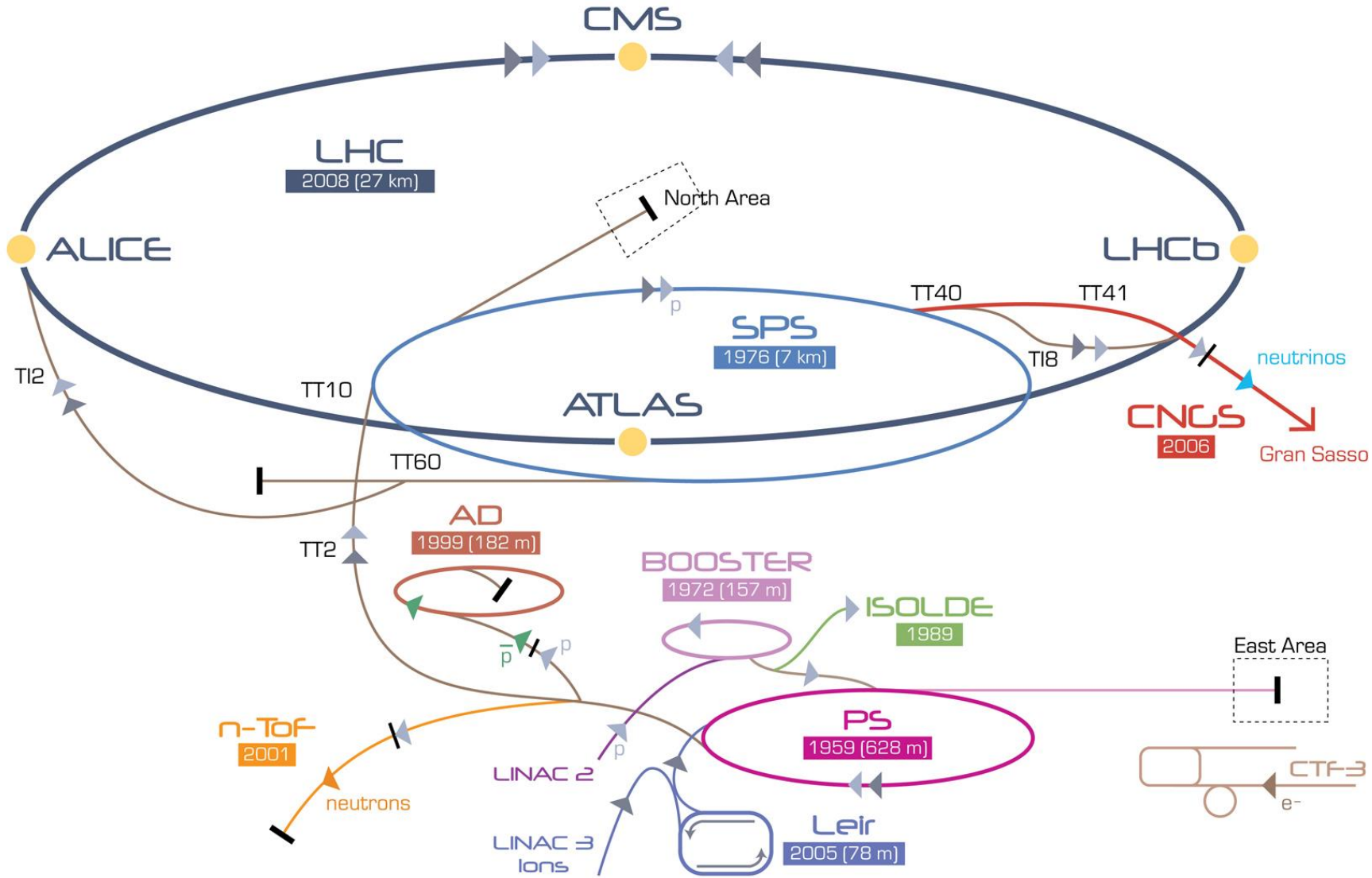
Kvark-gluonové plasma

- 10^{-5} s
- T= 10^{12} K = 100000 T_S
- Silná interakce
- 2000 – Super proton synchrotron (CERN)
- Pb-Pb





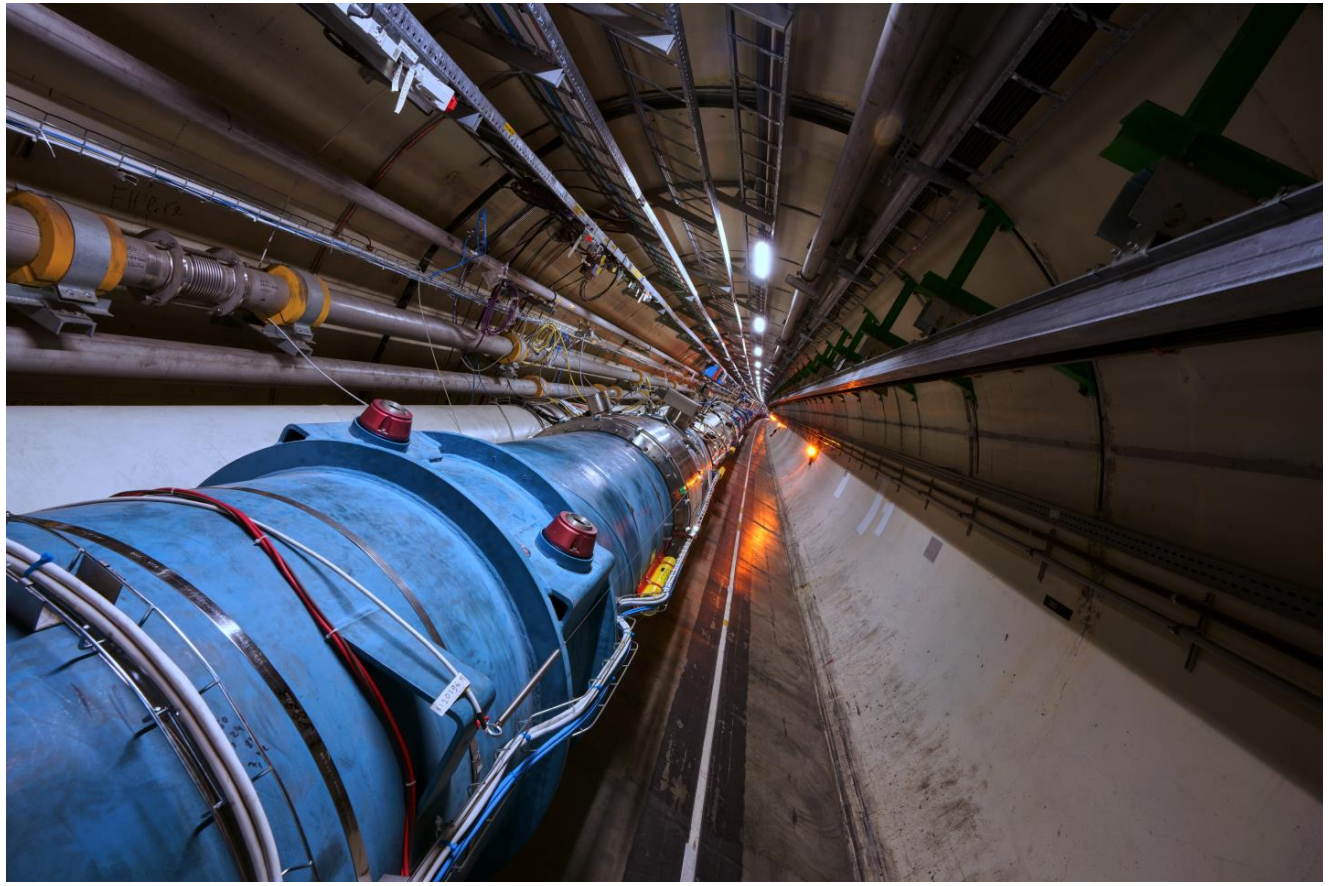

LHCb
ATLAS
CERN Meyrin
CERN Prévessin
SPS 7 km
SUISSE
FRANCE
CMS
ALICE
LHC 27 km

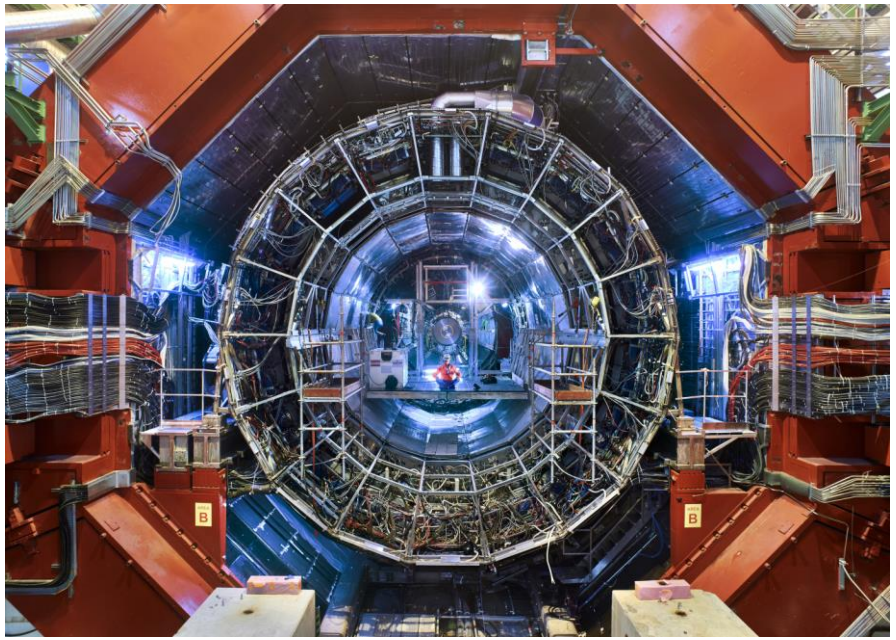


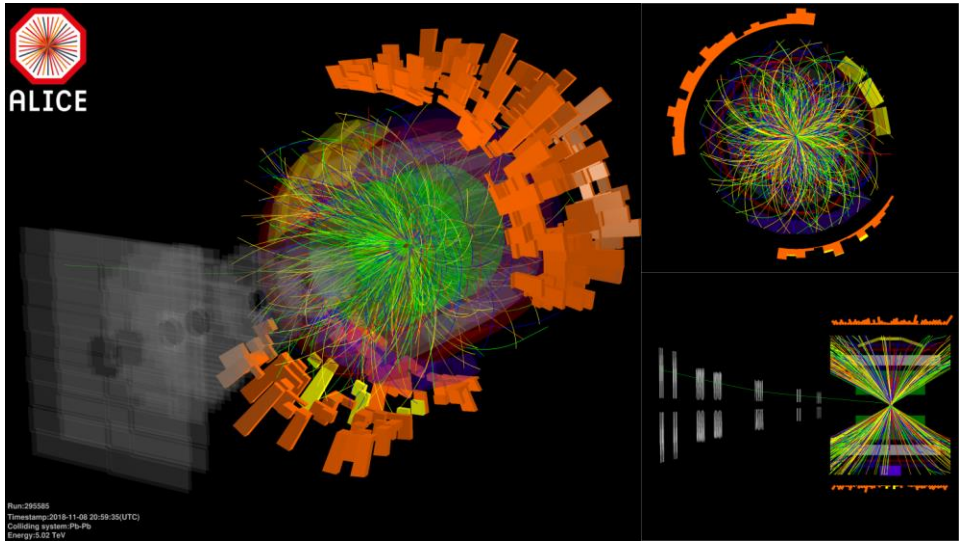
LHC Large Hadron Collider SPS Super Proton Synchrotron PS Proton Synchrotron

AD Antiproton Decelerator CTF3 Clic Test Facility CNGS Cern Neutrinos to Gran Sasso ISOLDE Isotope Separator OnLine DEvice

LEIR Low Energy Ion Ring LINAC LINear ACcelerator n-ToF Neutrons Time Of Flight



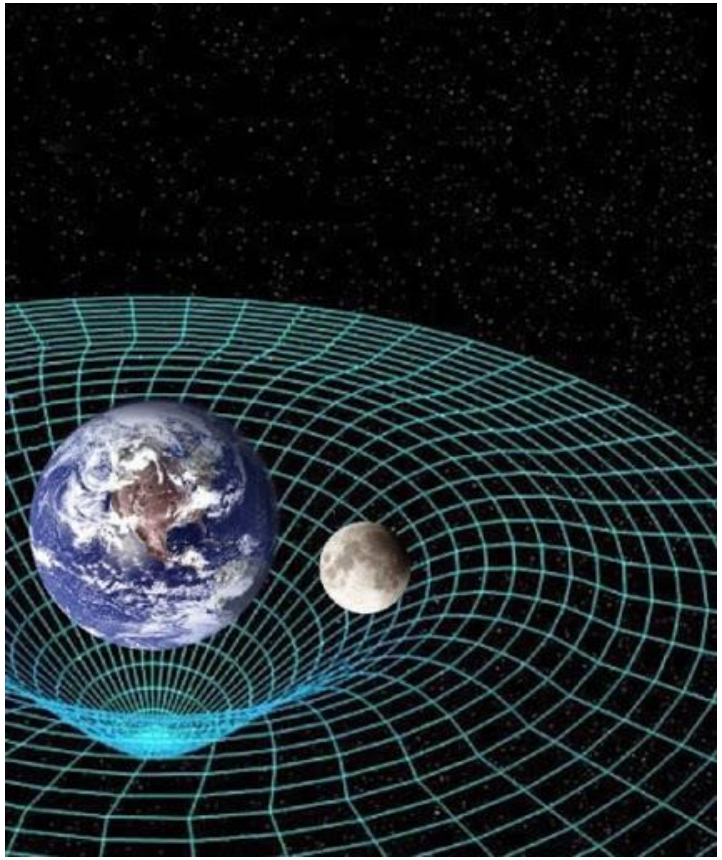



ALICE
Run:295585
Timestamp:2018-11-06 20:59:35(UTC)
Colliding system:Pb-Pb
Energy:5.02 TeV

- www


PROPRIETE CERN
CERN
This machine is a ser
DO NOT POWE
DOWN!!
PROPRIETE CERN
Information Management: A Proposal

Obecná teorie relativity (1915)



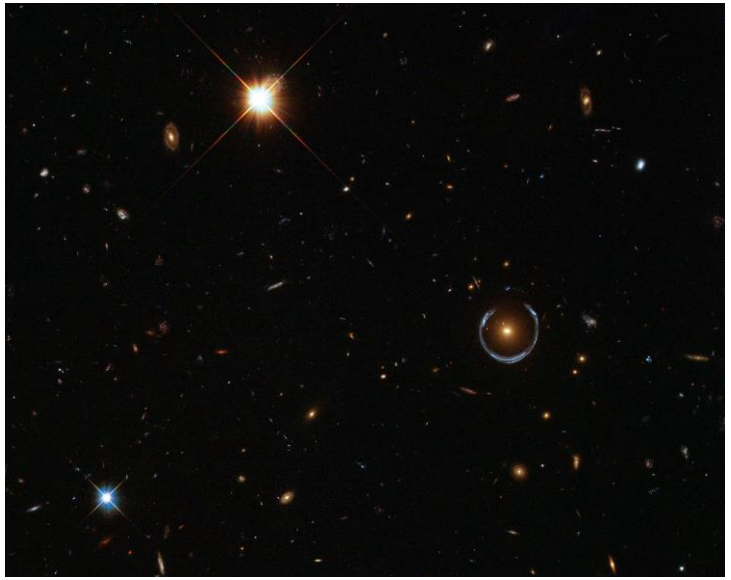
844 Sitzung der physikalisch-mathematischen Klasse vom 25. November 1915

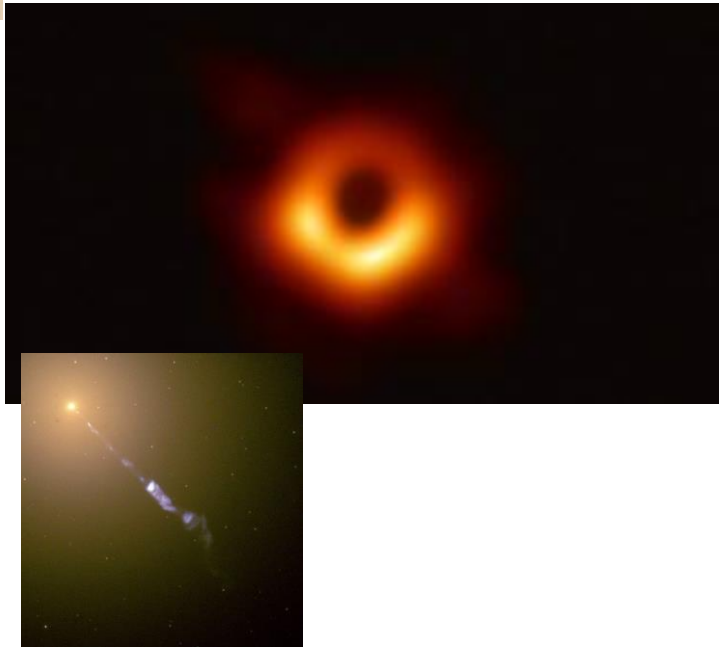
Die Feldgleichungen der Gravitation.

Von A. Einstein.

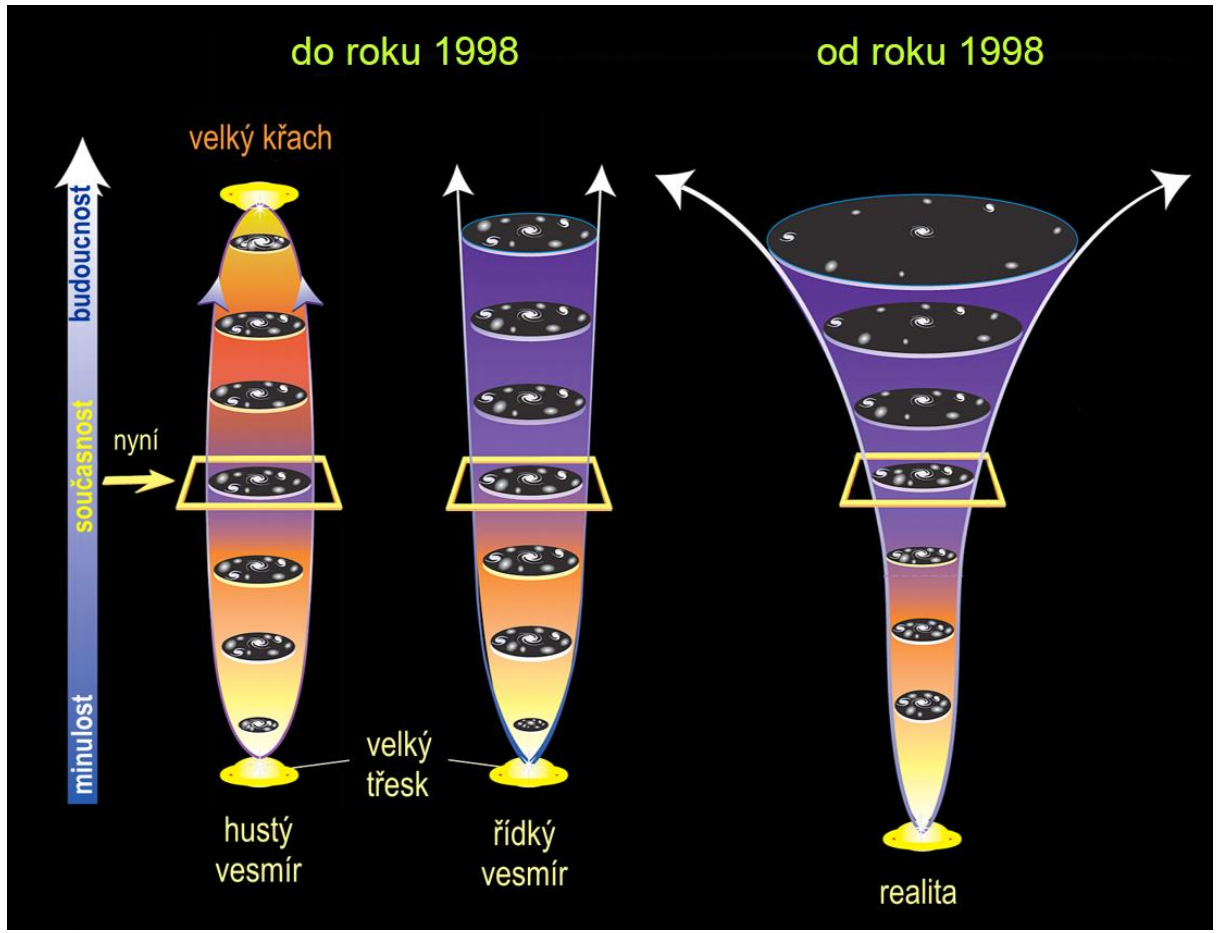
In zwei vor kurzem erschienenen Mitteilungen[1] habe ich gezeigt, wie man zu Feldgleichungen der Gravitation gelangen kann, die dem Postulat allgemeiner Relativität entsprechen, d. h. die in ihrer allgemeinen Fassung beliebigen Substitutionen der Raumzeitvariabeln gegenüber kovariant sind.

Der Entwicklungsgang war dabei folgender. Zunächst fand ich Gleichungen, welche die Newtonsche Theorie als Näherung enthalten



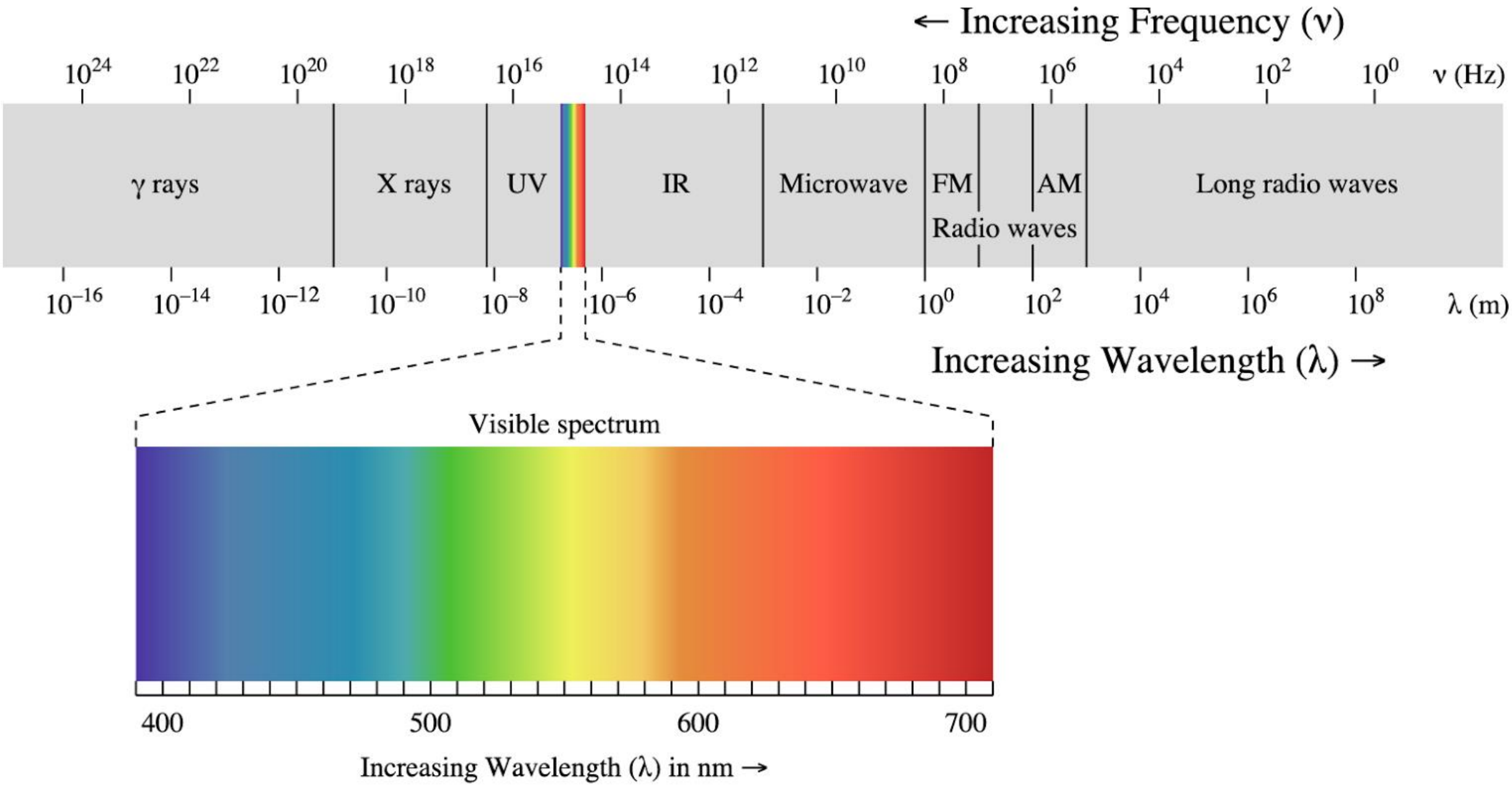


$$R_{\mu\nu} - \frac{1}{2} R\, g_{\mu\nu} + \Lambda\, g_{\mu\nu} = \frac{8\pi G}{c^4} T_{\mu\nu}$$

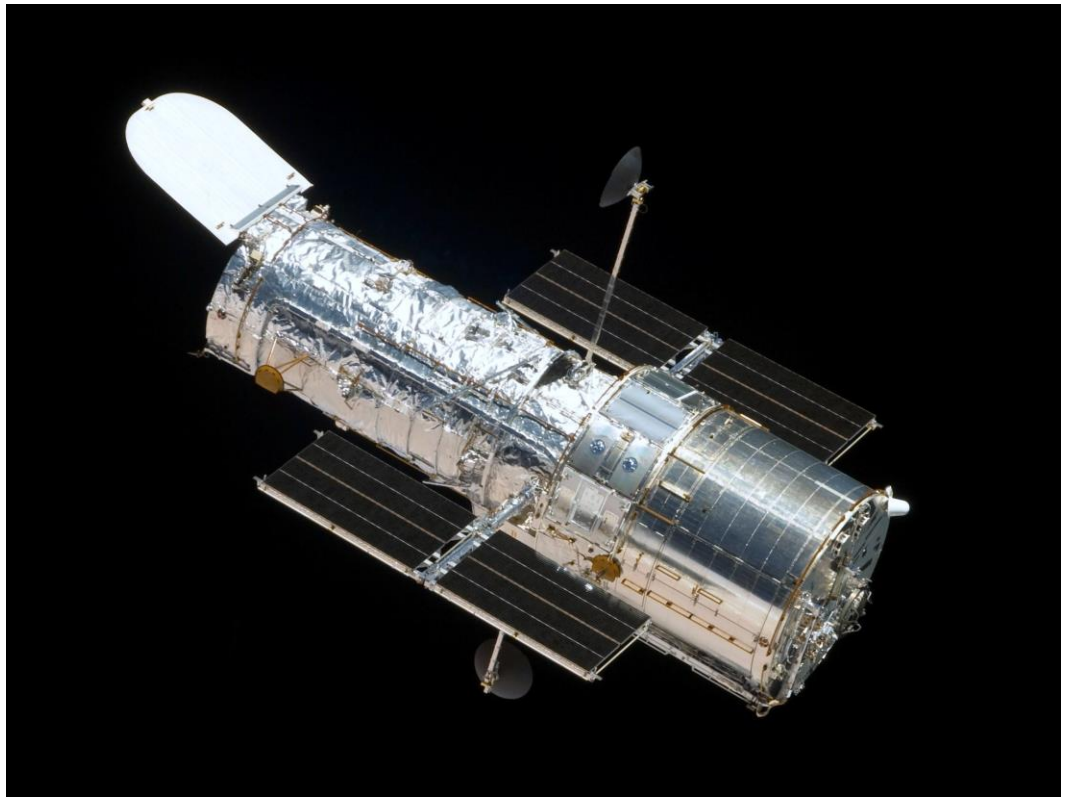


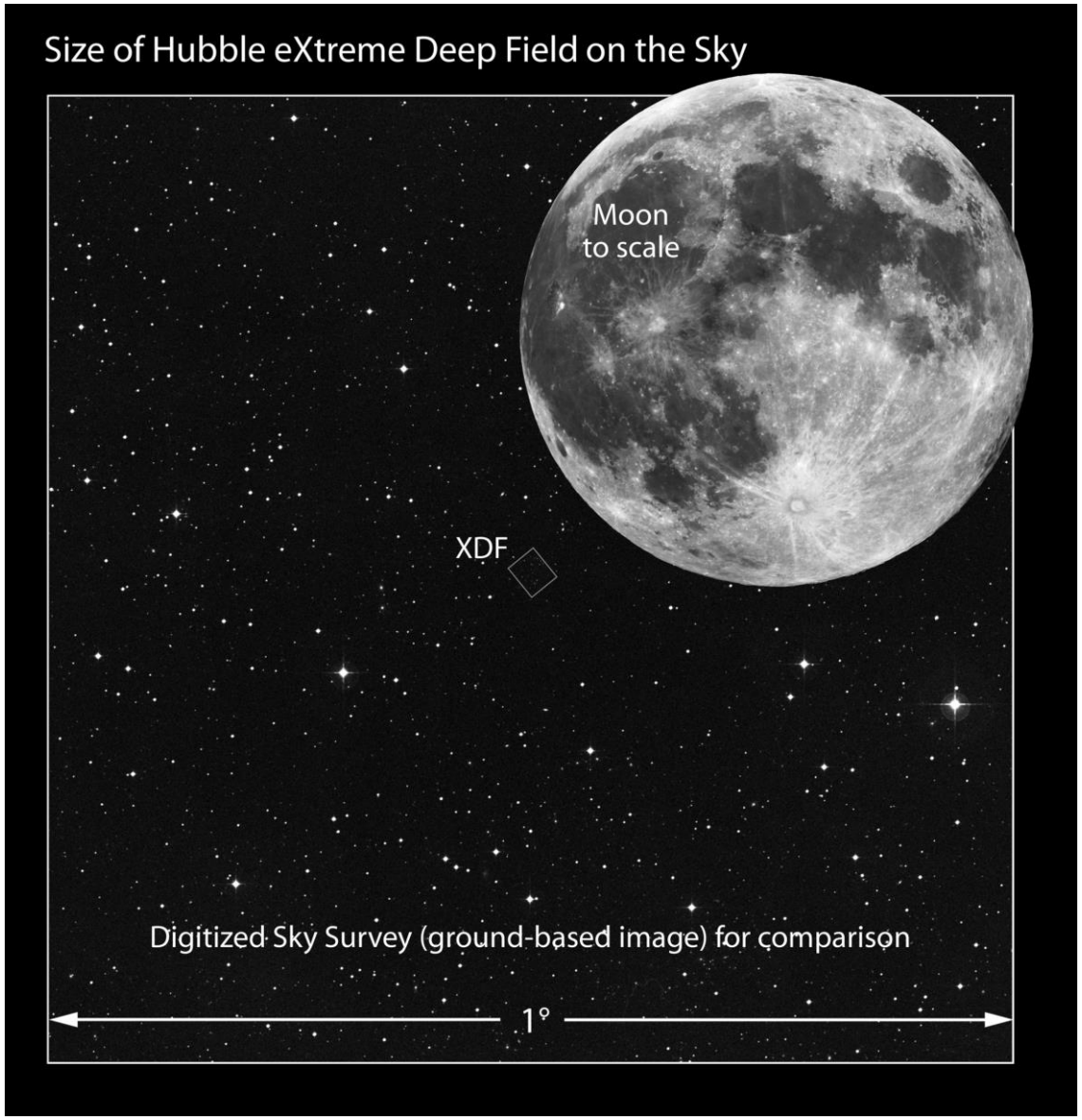
Okna do vesmíru

- Elektromagnetické (vč. reliktního záření)
- Gravitační vlny
- Reliktní neutrina

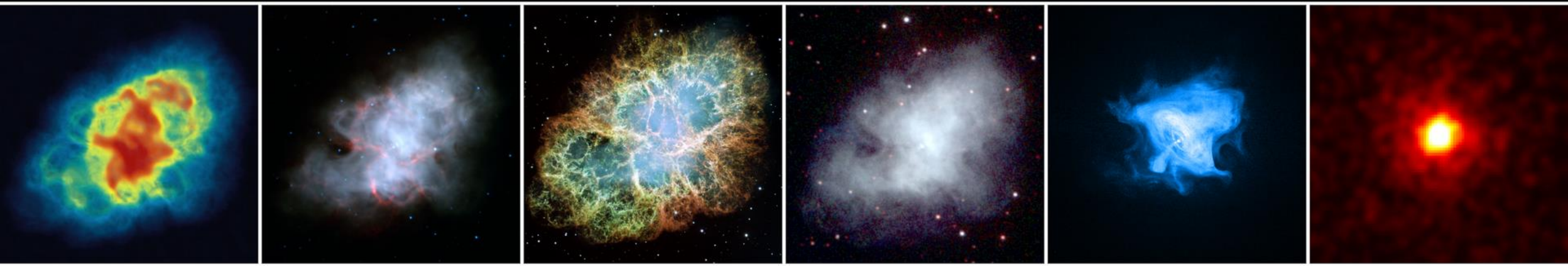

← Increasing Frequency (ν)
10^24 10^22 10^20 10^18 10^16 10^14 10^12 10^10 10^8 10^6 10^4 10^2 10^0 ν (Hz)
γ rays
X rays
UV
IR
Microwave
FM
AM
Radio waves
Long radio waves
10^−16 10^−14 10^−12 10^−10 10^−8 10^−6 10^−4 10^−2 10^0 10^2 10^4 10^6 10^8 λ (m)
Increasing Wavelength (λ) →
Visible spectrum
400
500
600
700
Increasing Wavelength (λ) in nm →

- Hubbleovo extrémně hluboké pole
- 2000 snímků
- Expozice 23 dní
- 5500 galaxií
- Nejstarší 13,2 mld LY



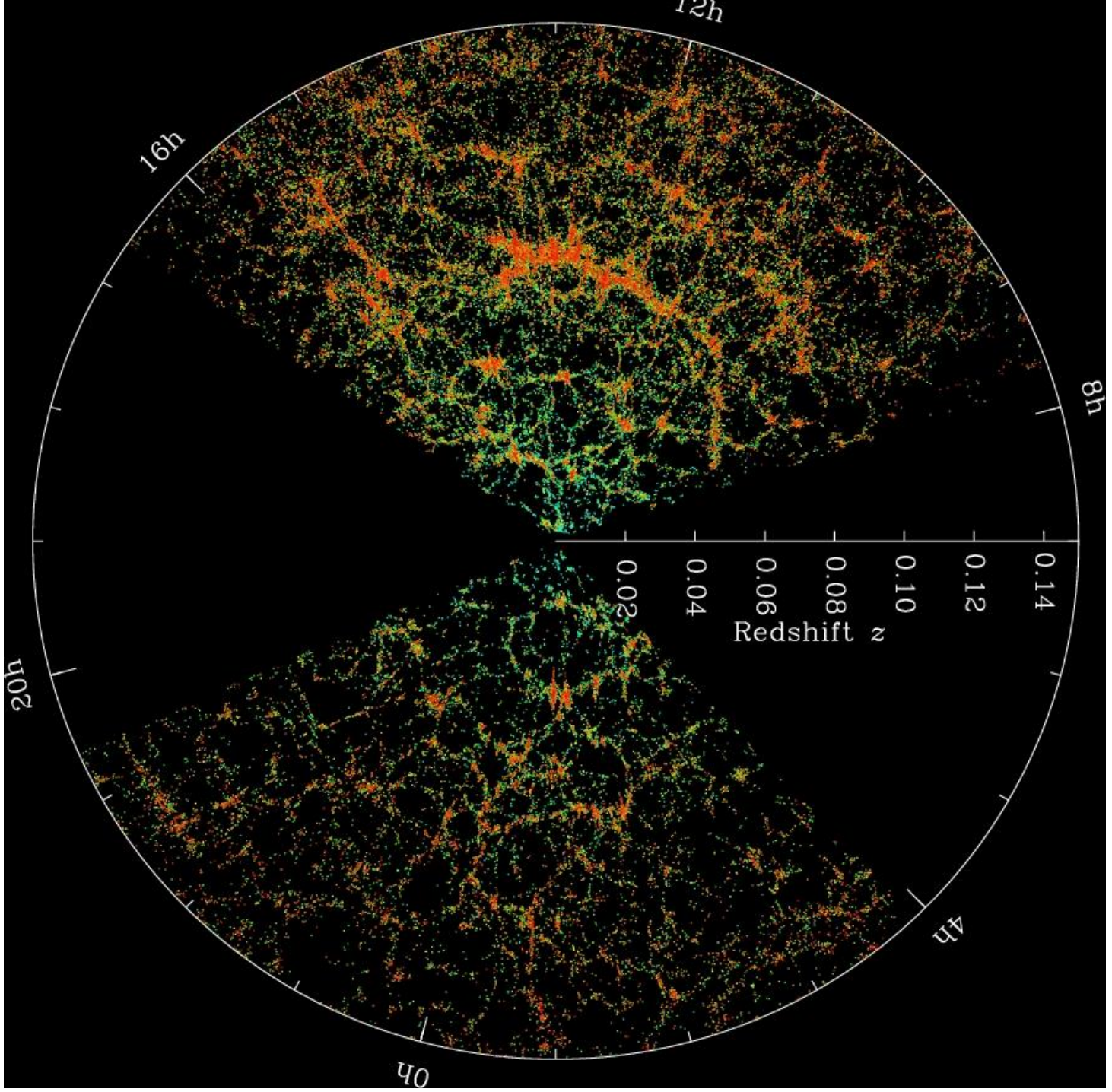


CRAB NEBULA



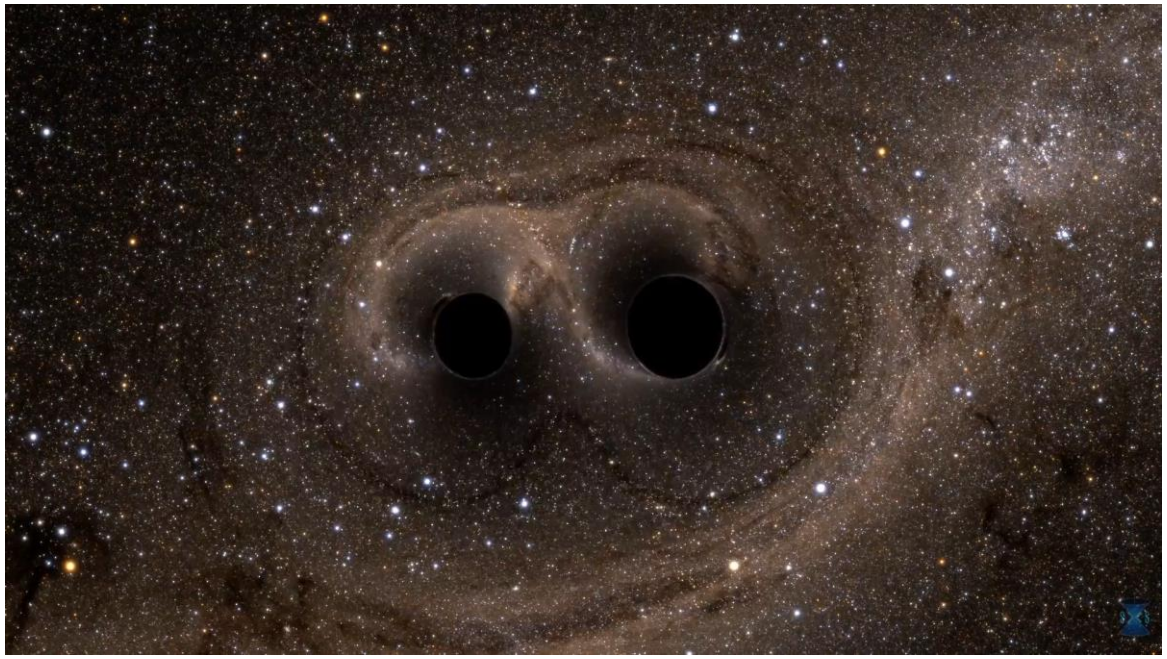
RADIO	INFRARED	VISIBLE LIGHT	ULTRAVIOLET	X-RAYS	GAMMA RAYS

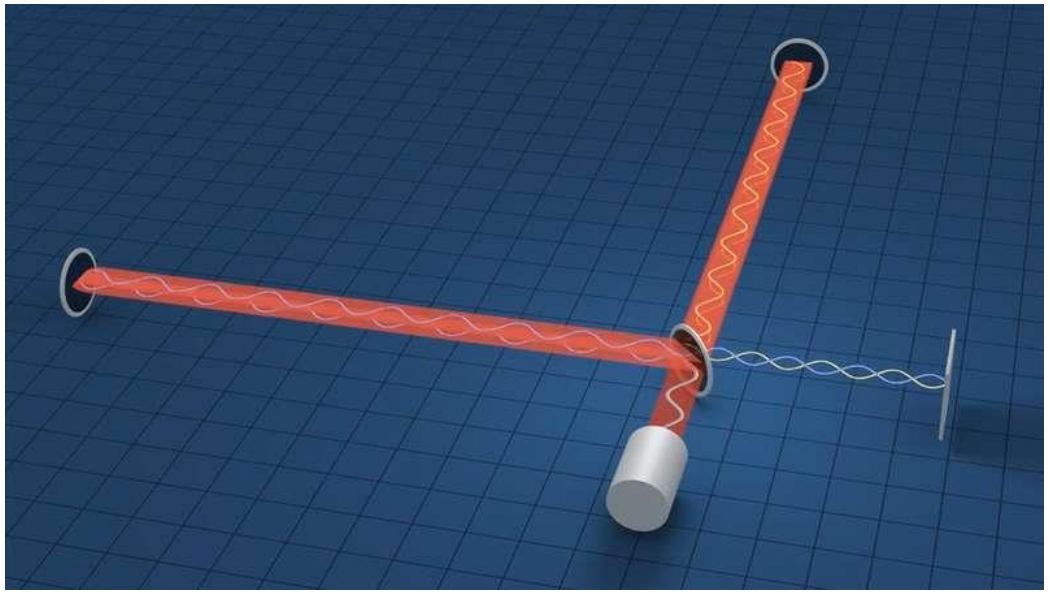
- Sloan digital sky survey

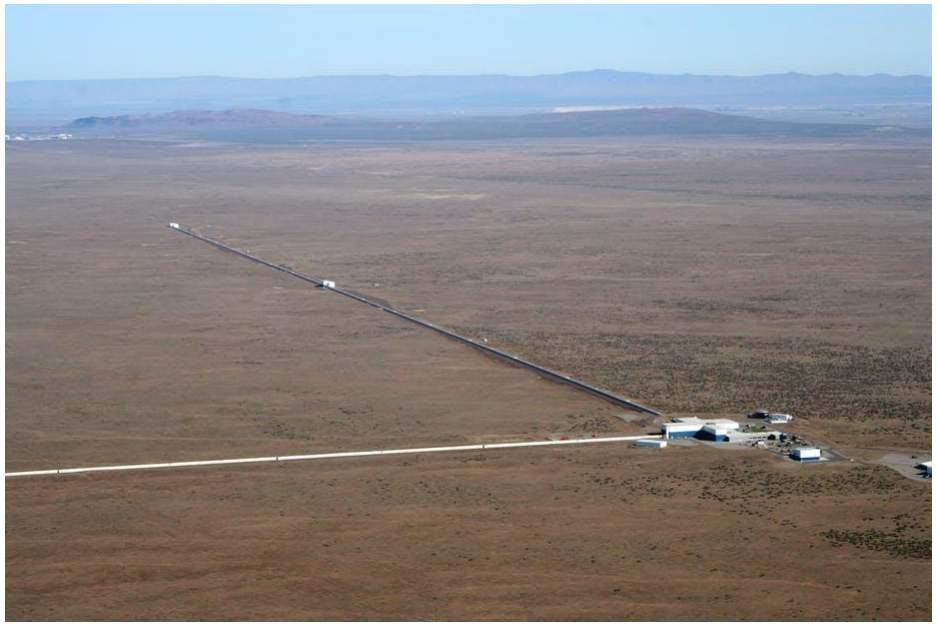


Gravitační vlny

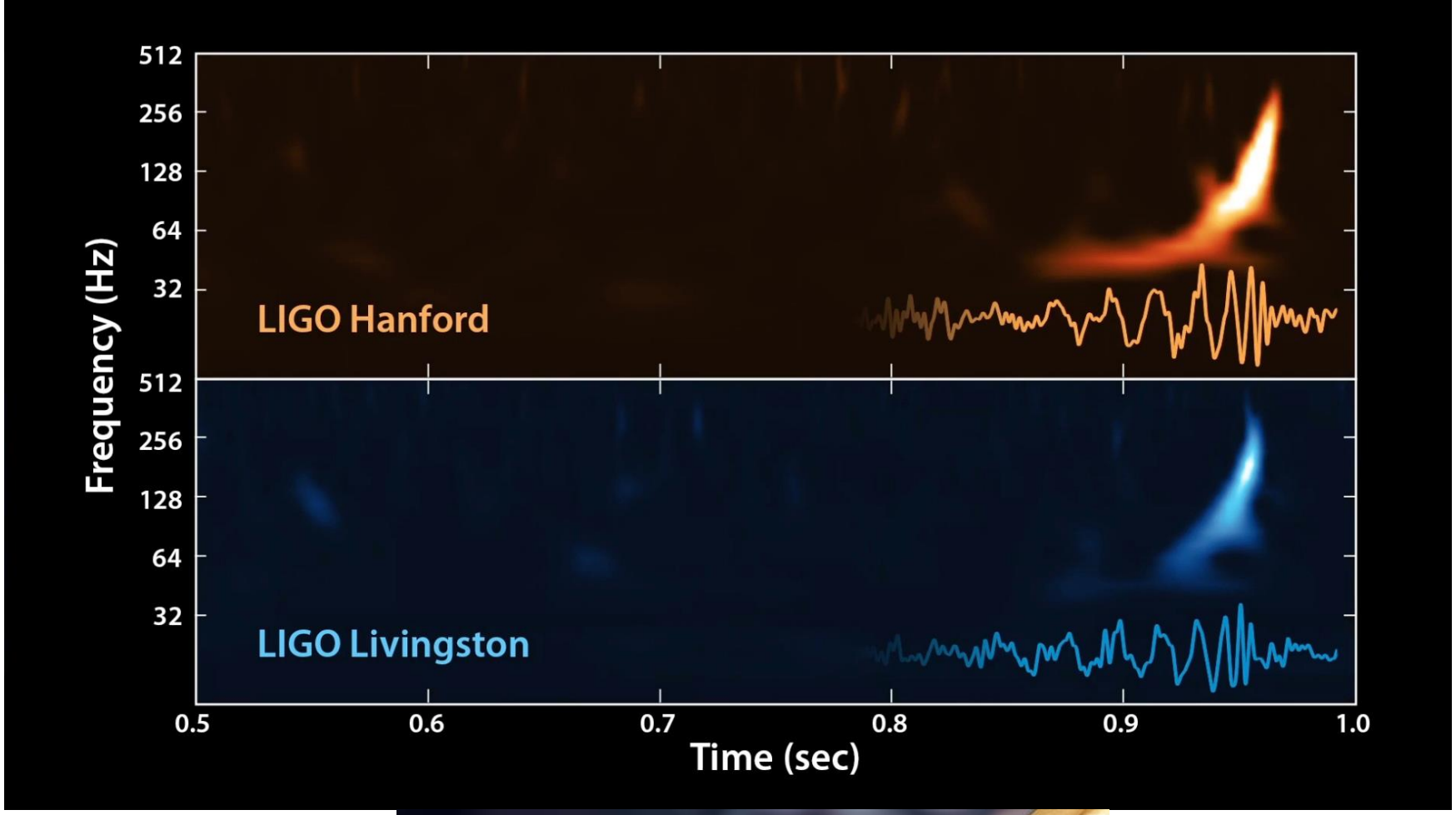
- Obecná relativita

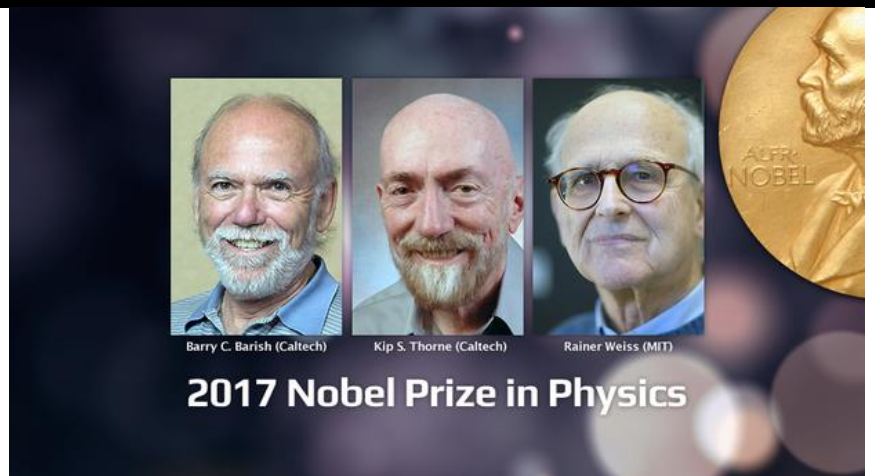




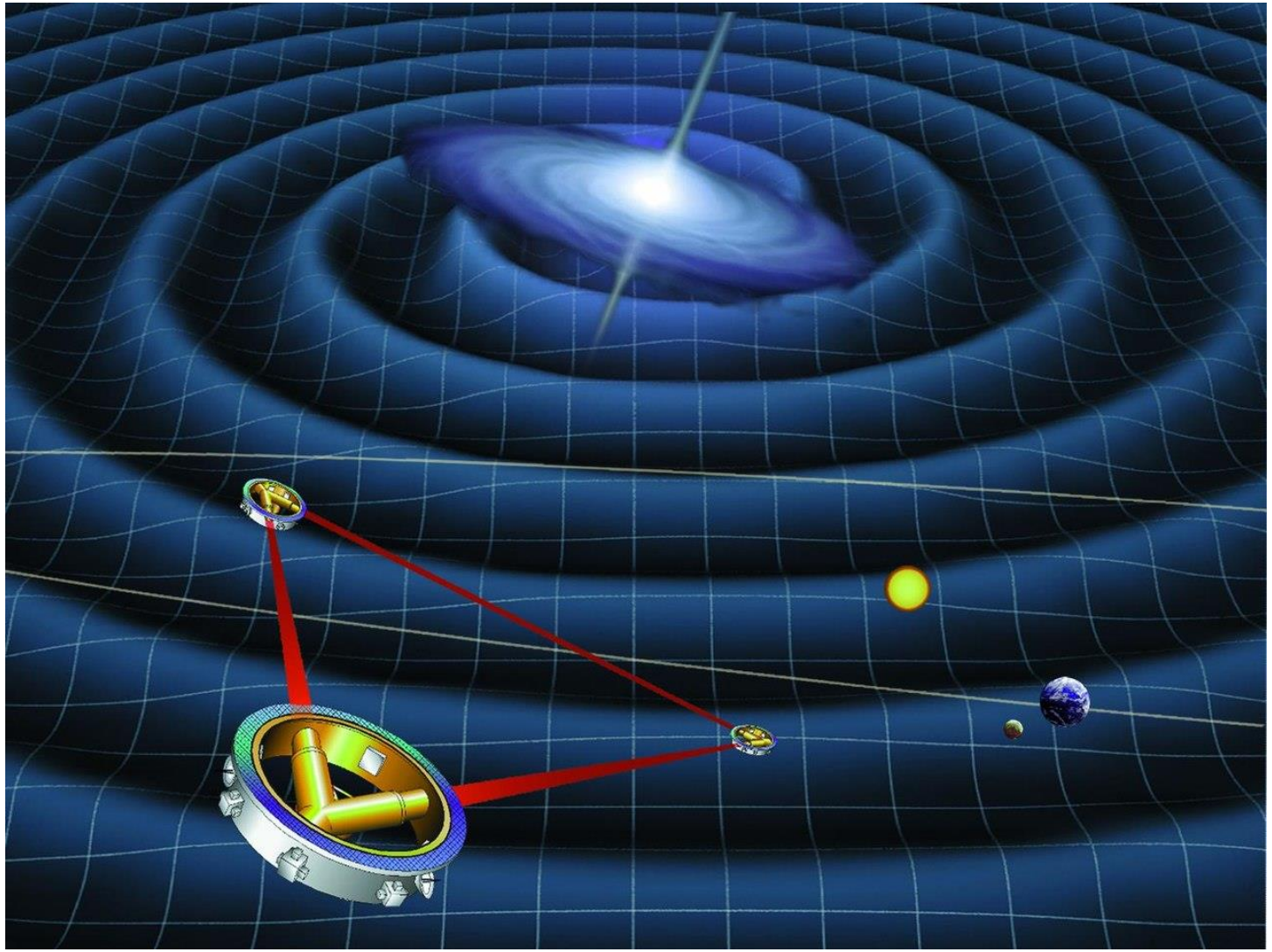


LIGO, Hanford, WA, USA

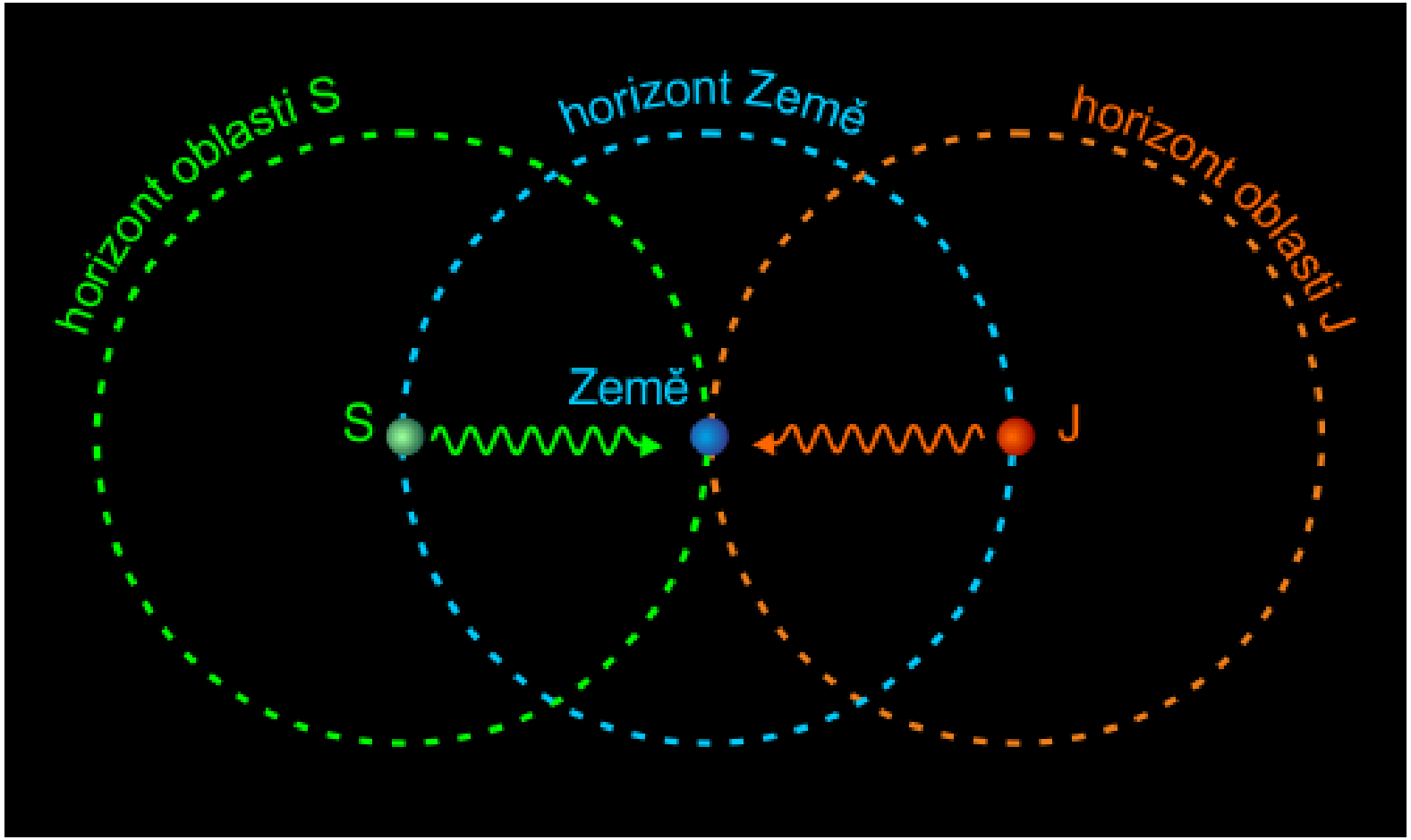

512
256
128
64
32
Frequency (Hz)
LIGO Hanford
512
256
128
64
32
LIGO Livingston
0.5
0.6
0.7
0.8
0.9
1.0
Time (sec)


Barry C. Barish (Caltech)
Kip S. Thorne (Caltech)
Rainer Weiss (MIT)
2017 Nobel Prize in Physics

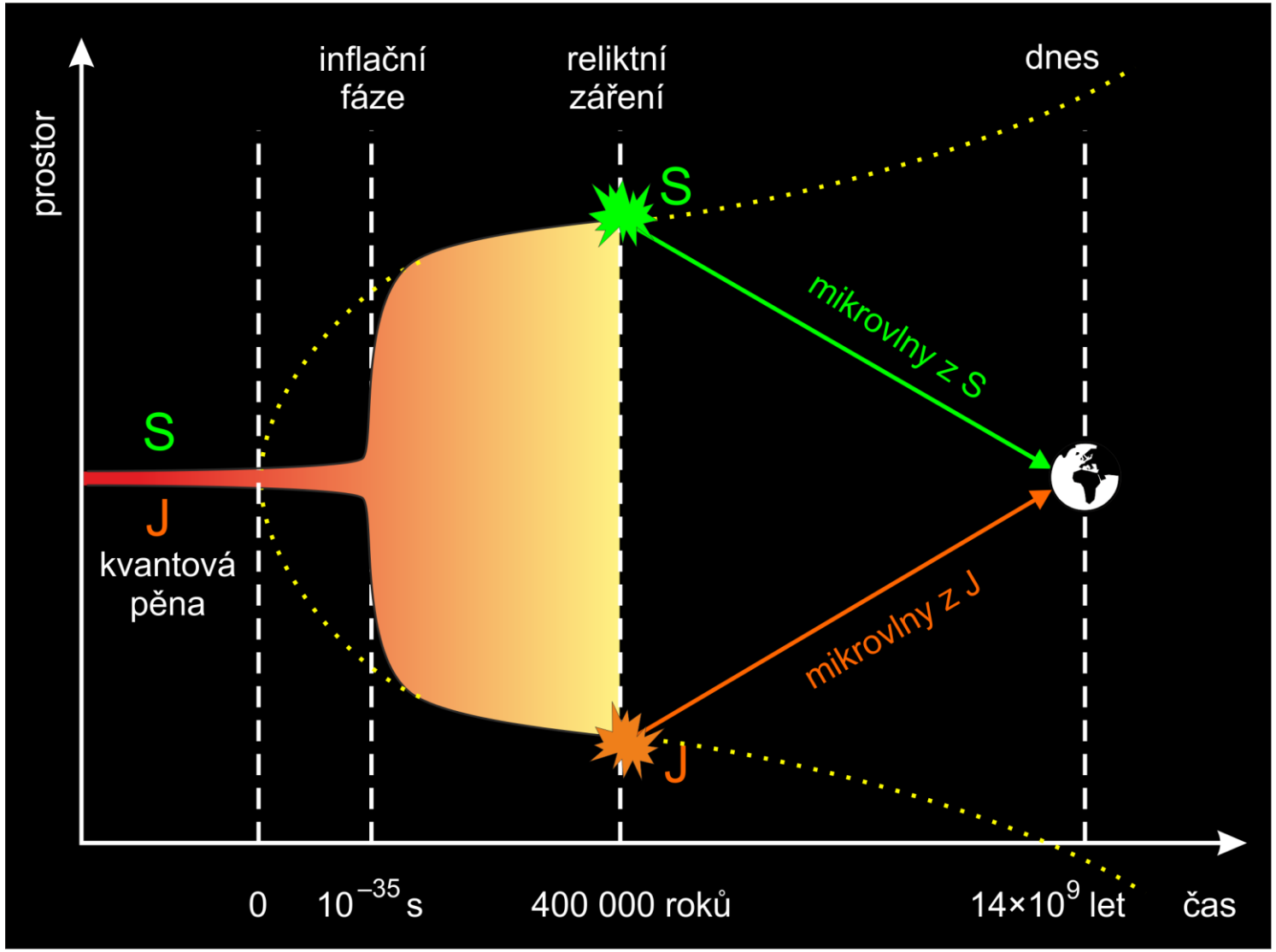
- eLISA



- Pozorovatelný vesmír



- Inflace


prostor
inflační fáze
reliktní záření
dnes
S
S
J
kvantová pěna
mikrovlny z S
mikrovlny z J
J
0
10−35 s
400 000 roků
14×109 let
čas

- Aldebaran.cz