天文学正在发现

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outline

1. 膨胀宇宙的发现

2. 暗物质的发现

3. 暗能量的发现

4. 宇宙微波背景辐射的发现

5. 中微子的发现

6. 引力波的发现

7. 脉冲星的发现

8. 宇宙第一缕曙光的“发现”

X类通识课 **新生研讨课** （注重：自己查阅文献、小组讨论、公众表达）

天文系必修、外单位选修 上课需携带笔记本电脑

8周课 / 16学时（双周）、每次讲授1学时、讨论 / 发言1学时

新生研讨课

考核方式：

平时出勤、课上表现占60%

期末论文占40%

每堂课后都会有一个论文（英文1000字）候选题目，选择其中之一

平时作业：

每堂课后都会布置，下一堂课的文献调研题目

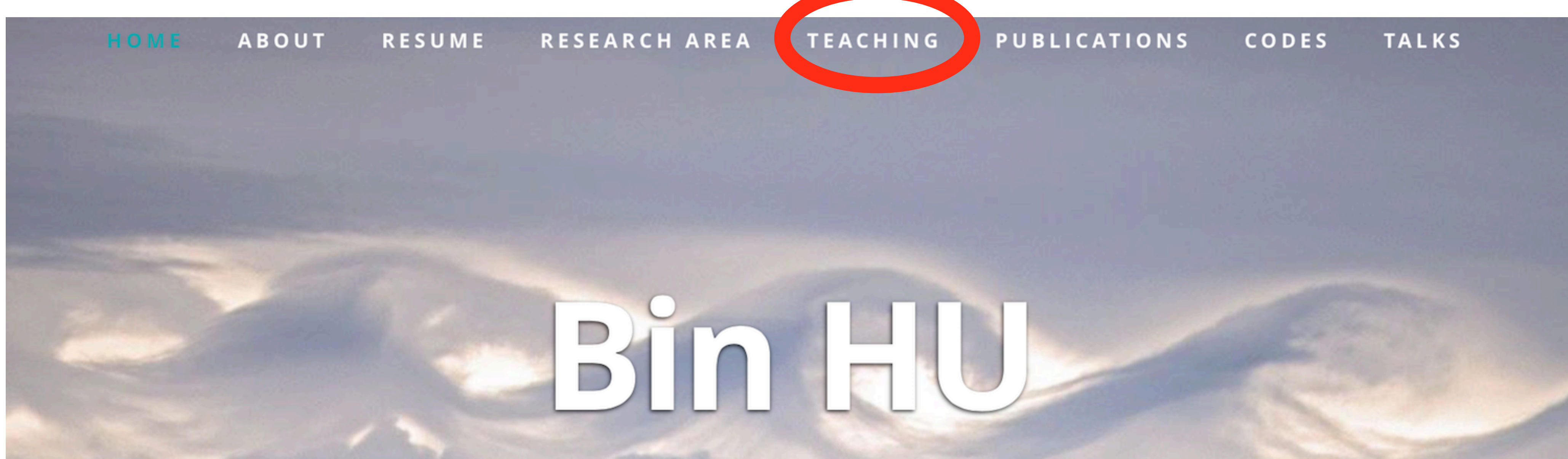
每小组200字调研论文（英文）+ 口头报告（中 / 英）

答　　疑：

有问题及时问（课下、微信群、办公室）

http://astrowww.bnu.edu.cn/sites/hubin/bh_bnu_homepage/#teach

课　　件：

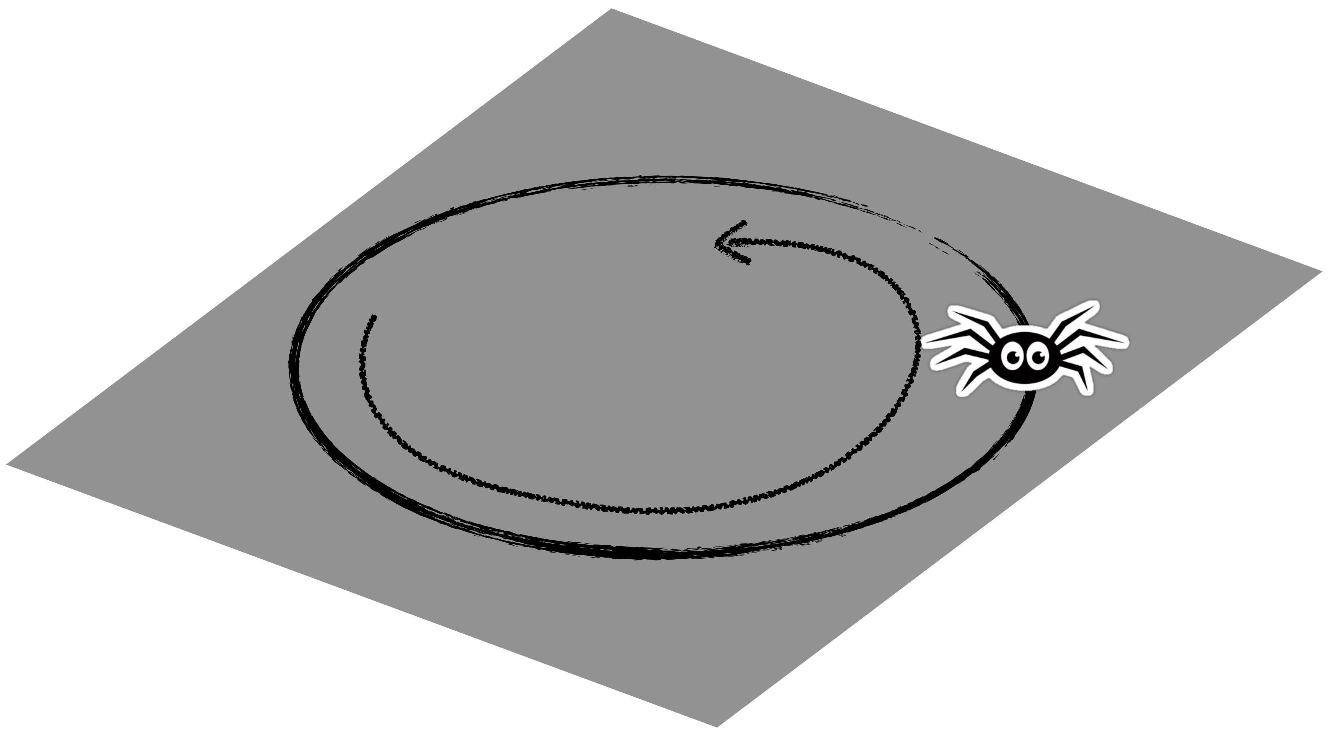


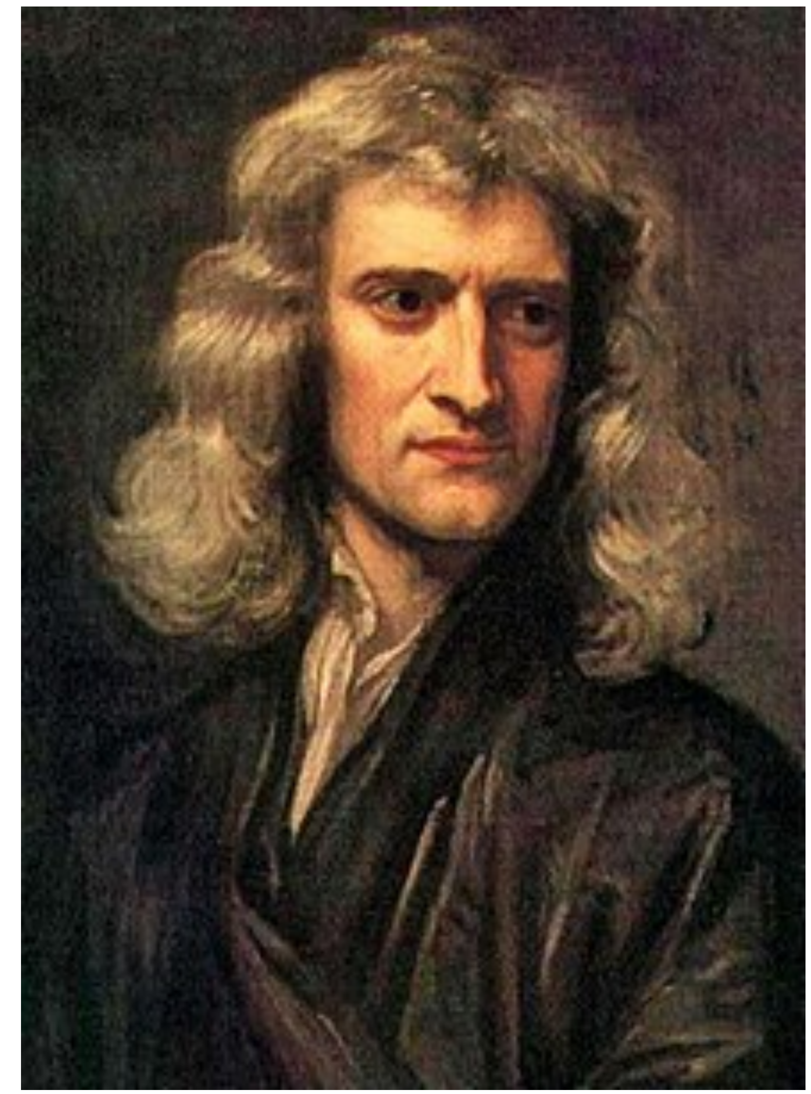

Google
Baidu 百度
Bing
YAHOO!

2018天文学正在发现
微信群2维码

助教：李四

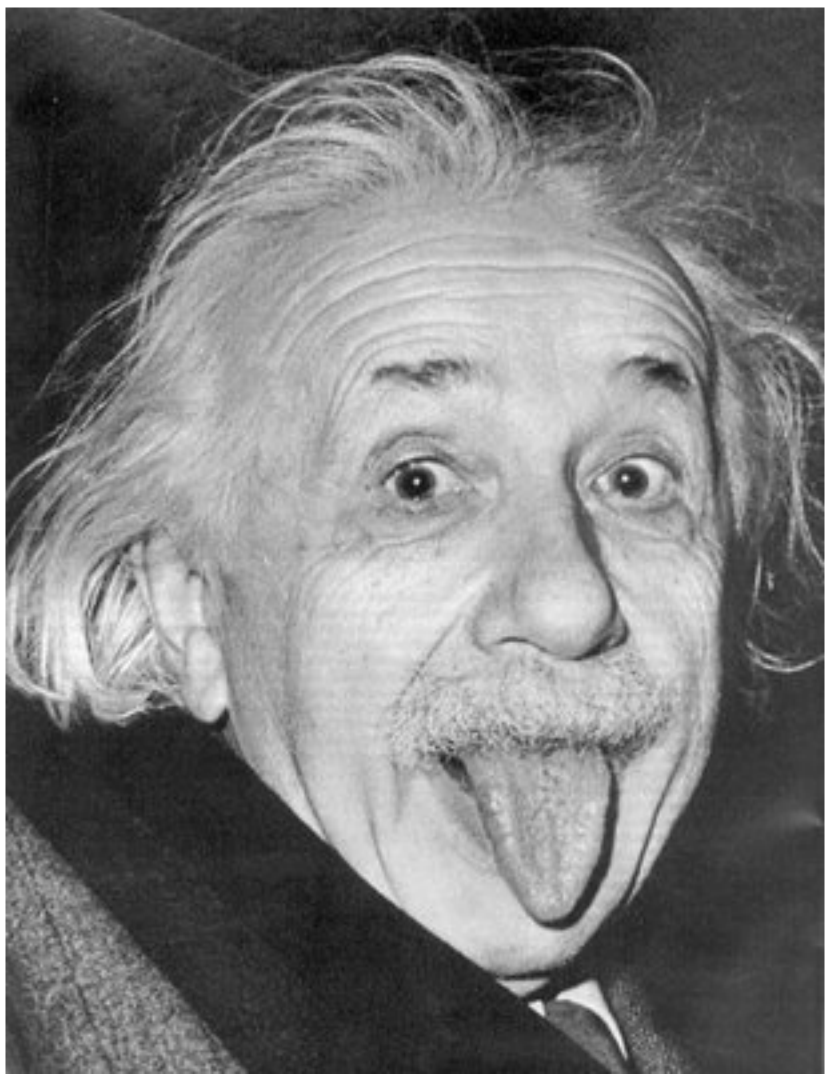
1. 4维时空观 3+1维

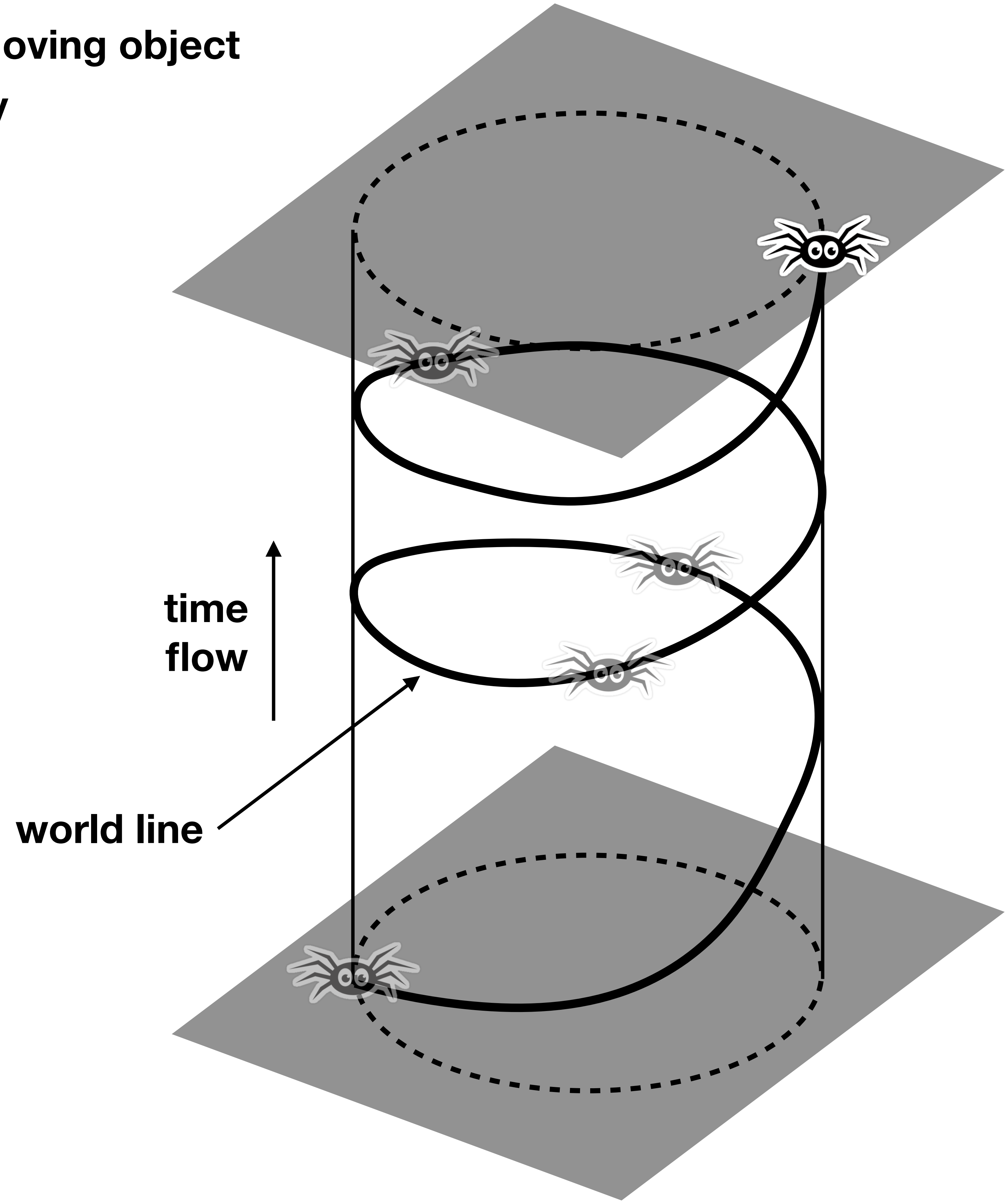




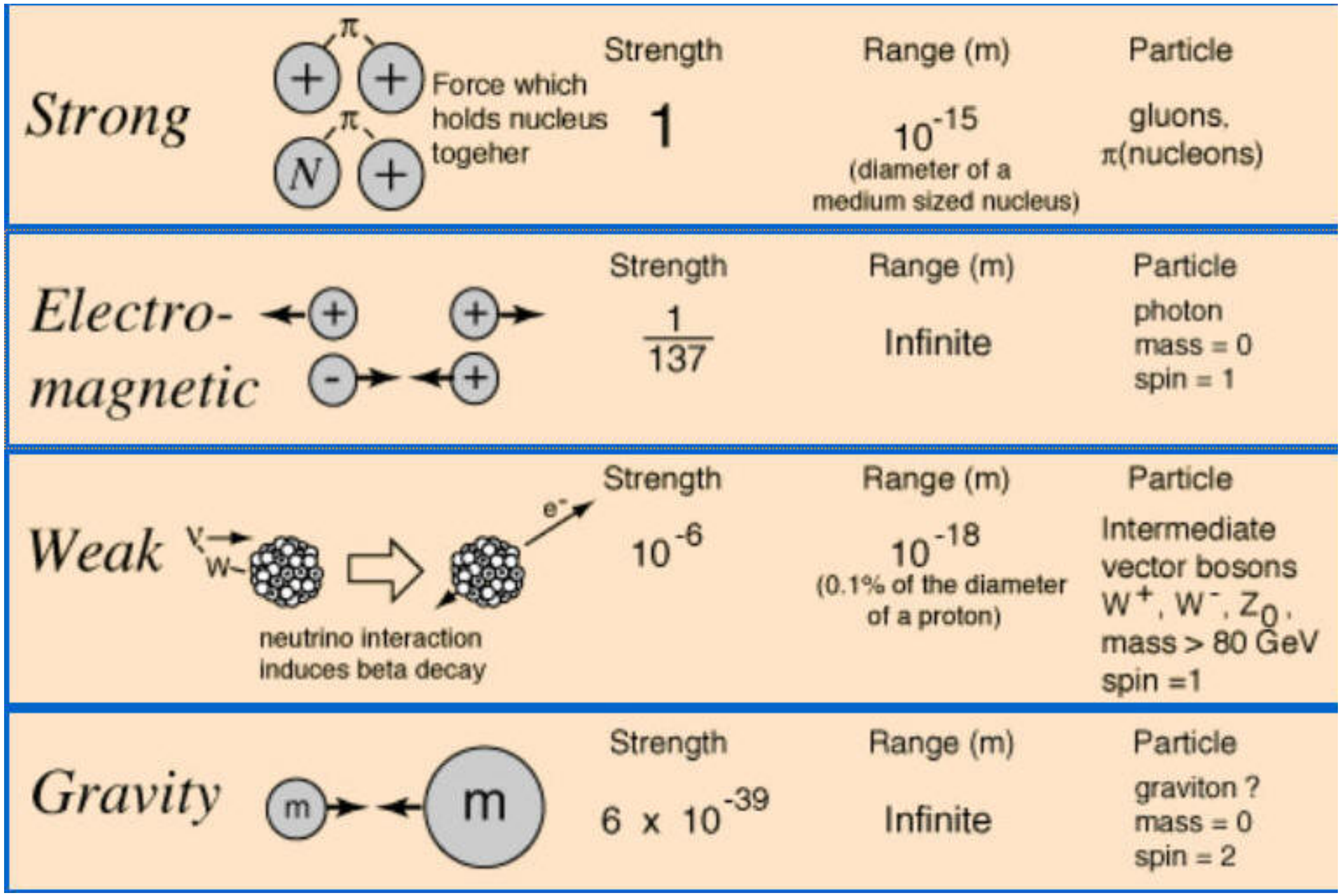
geodesic: the world line of the moving object

(最短线) under **ONLY** gravity

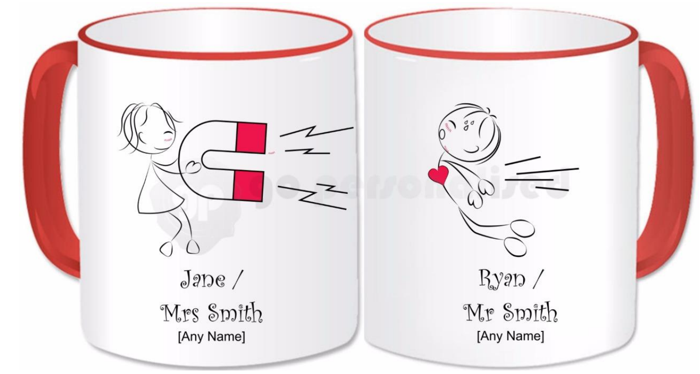


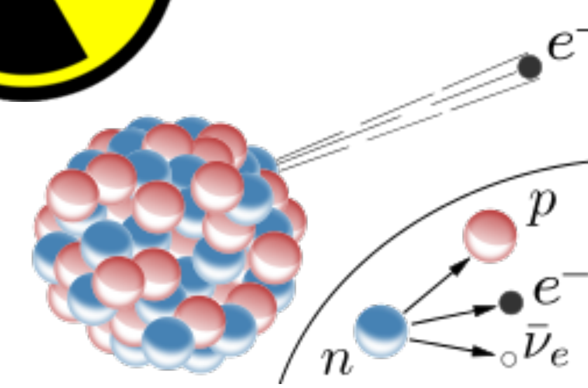


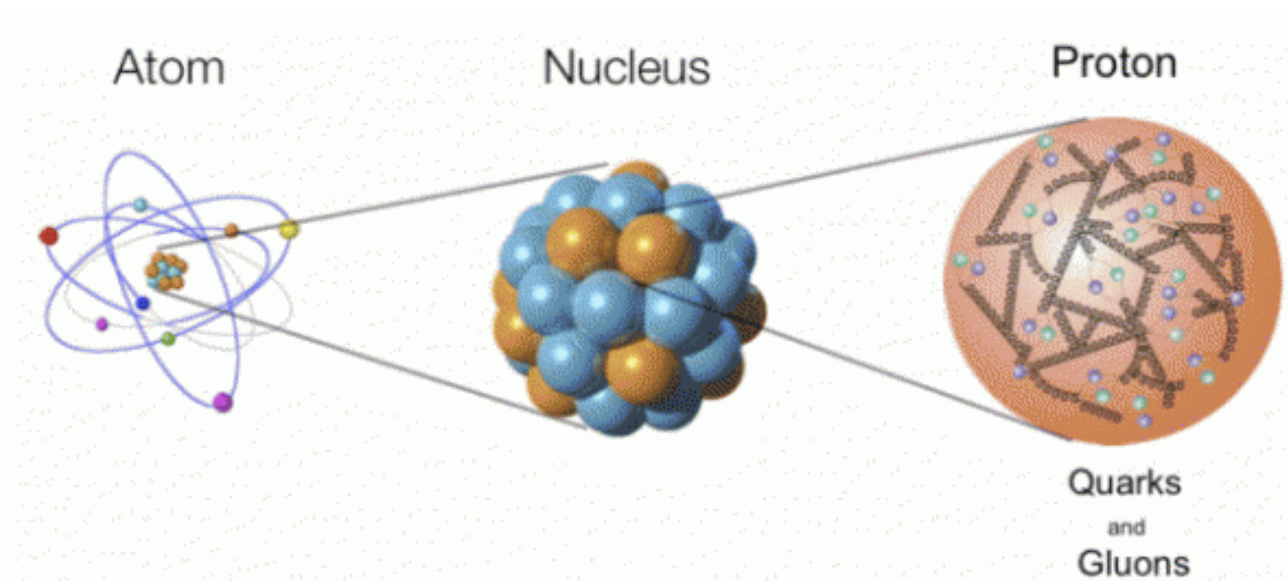
4 fundamental forces

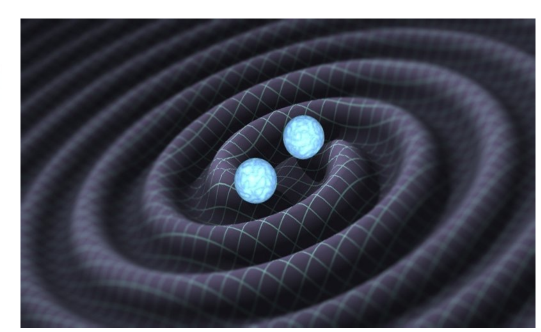


Force	Description	Strength	Range (m)	Particle
Strong	Force which holds nucleus togeher	1	10^{-15} (diameter of a medium sized nucleus)	gluons, π(nucleons)
Electro-magnetic		$\frac{1}{137}$	Infinite	photon mass = 0 spin = 1
Weak	neutrino interaction induces beta decay	10^{-6}	10^{-18} (0.1% of the diameter of a proton)	Intermediate vector bosons W^+, W^-, Z_0, mass > 80 GeV spin =1
Gravity		6×10^{-39}	Infinite	graviton ? mass = 0 spin = 2







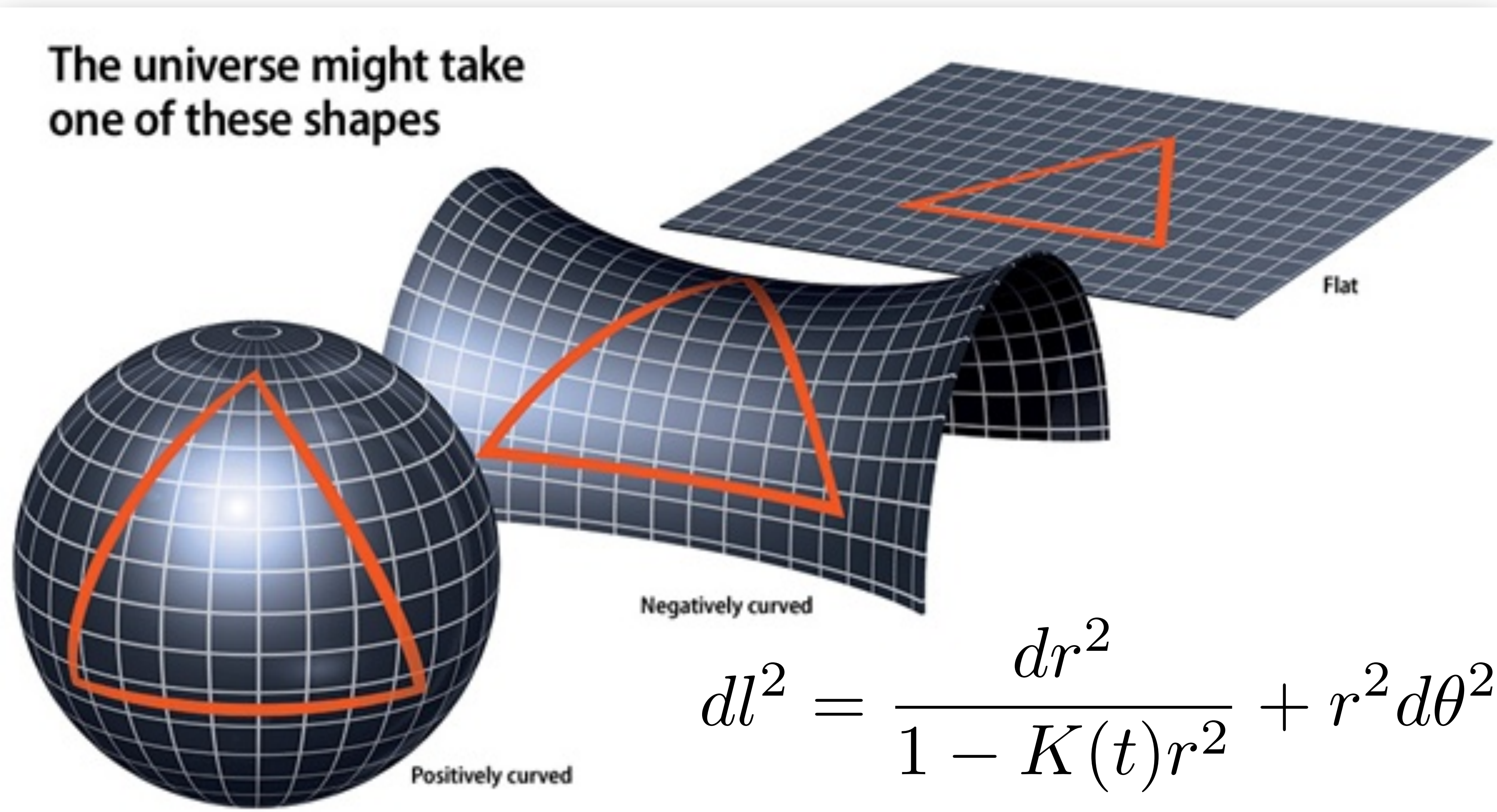


2. 时空几何

topology

$$dl^2 = dx^2 + dy^2 + dz^2$$

$$dl^2 = dr^2 + r^2 d\theta^2 + r^2 \sin^2\theta d\phi^2$$



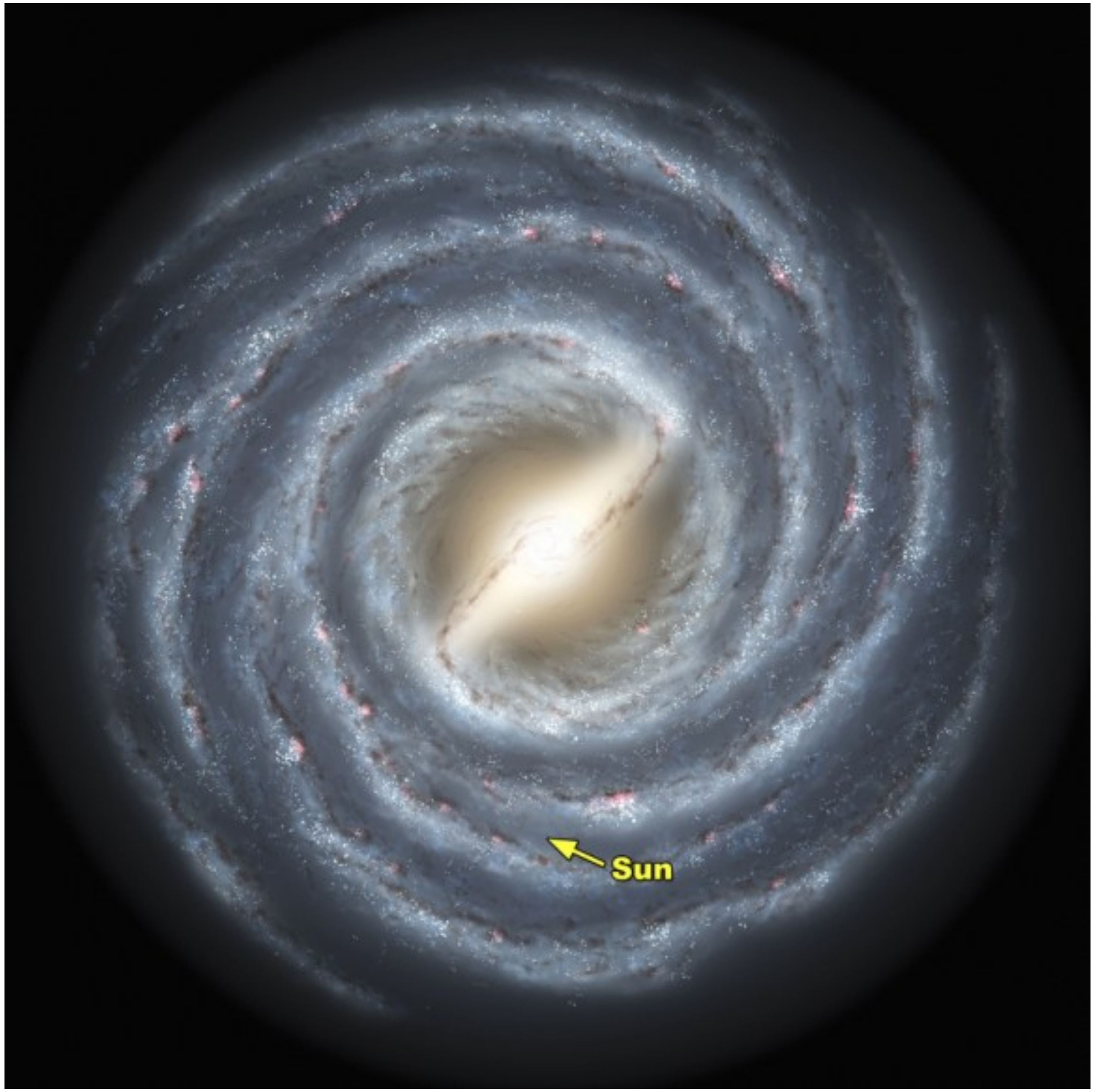
$$k = \begin{cases} +1 \rightarrow (close) \\ 0 \rightarrow (flat) \\ -1 \rightarrow (open) \end{cases}$$

$$K(t) = \frac{k}{a^2(t)}$$

$$dl^2 = \frac{dr^2}{1 - K(t) r^2} + r^2 d\theta^2 + r^2 \sin^2\theta d\phi^2$$

3. 宇宙学原理 (Copernican principle)

For a **co-moving observer**, on the **large** scale, the universe is **homogenous** and **isotropic**.

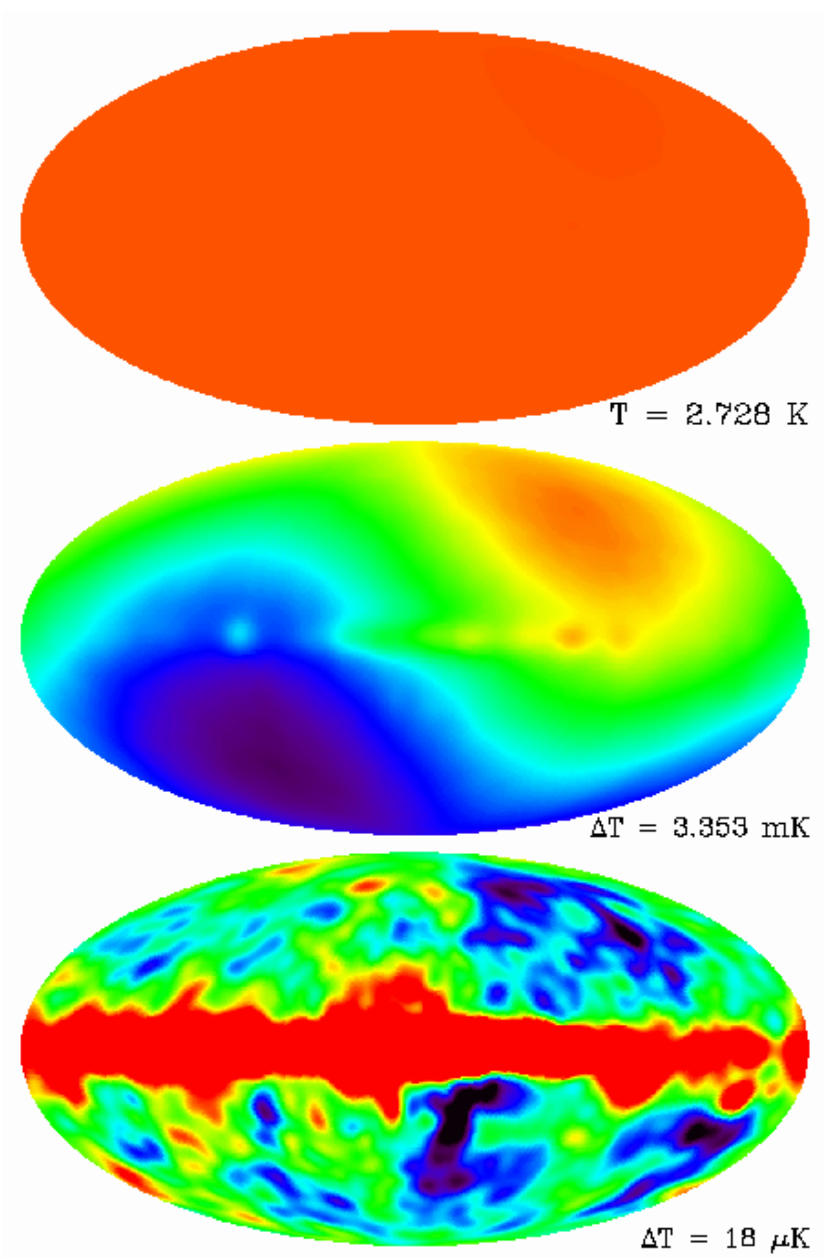


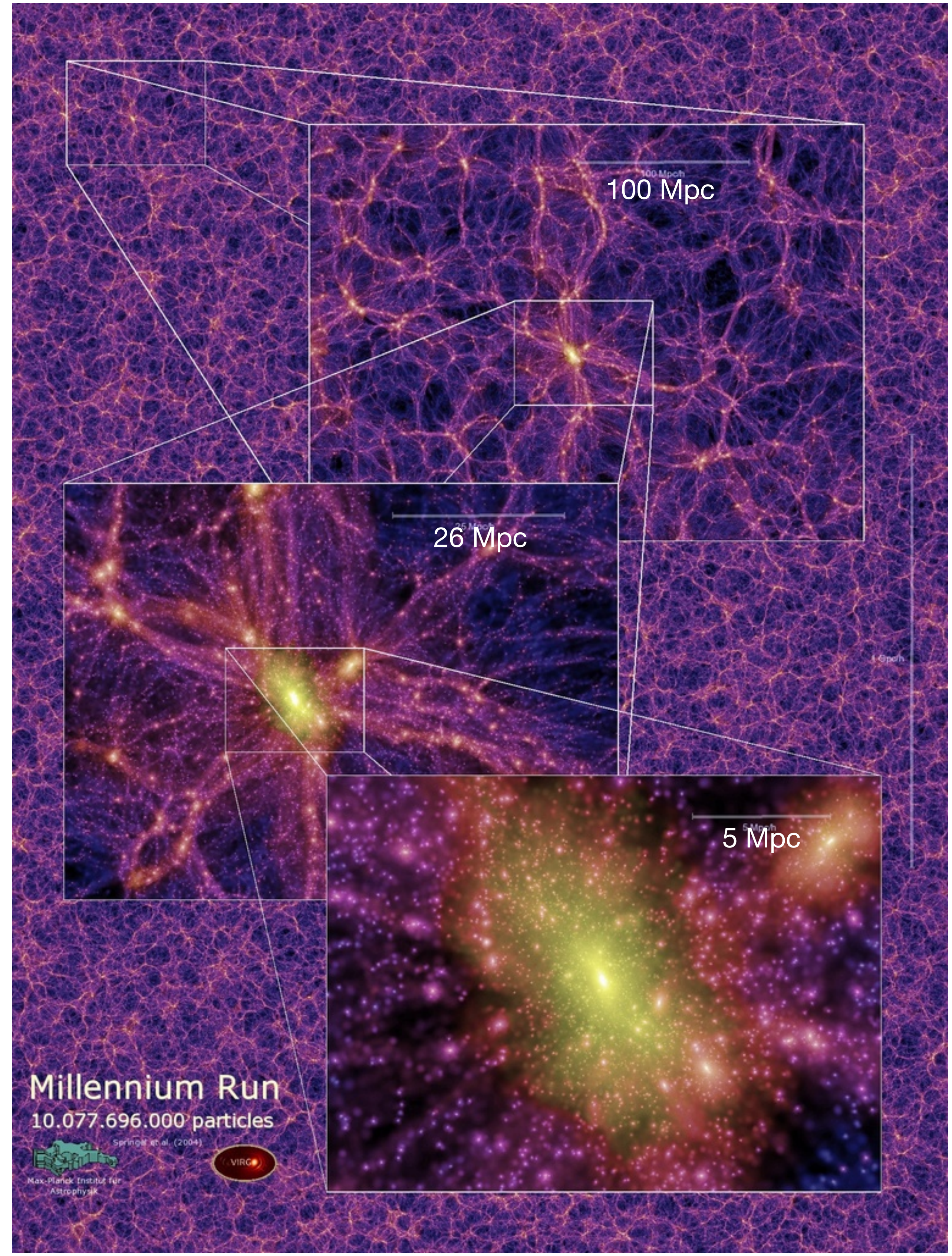
For a **co-moving observer**, on the **large** scale, the universe is **homogenous** and **isotropic**.

1. Observer: co-move with the background expansion

2. On this scale (> 1 Mpc): each galaxy is l ike a test particle

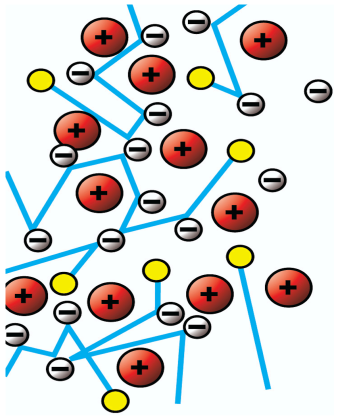
[milky way ~ 15kpc, 1pc ~ 3 ly]

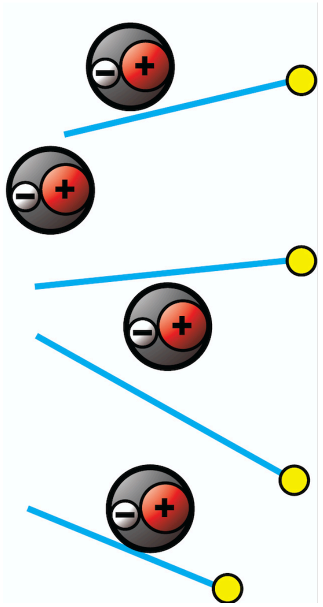


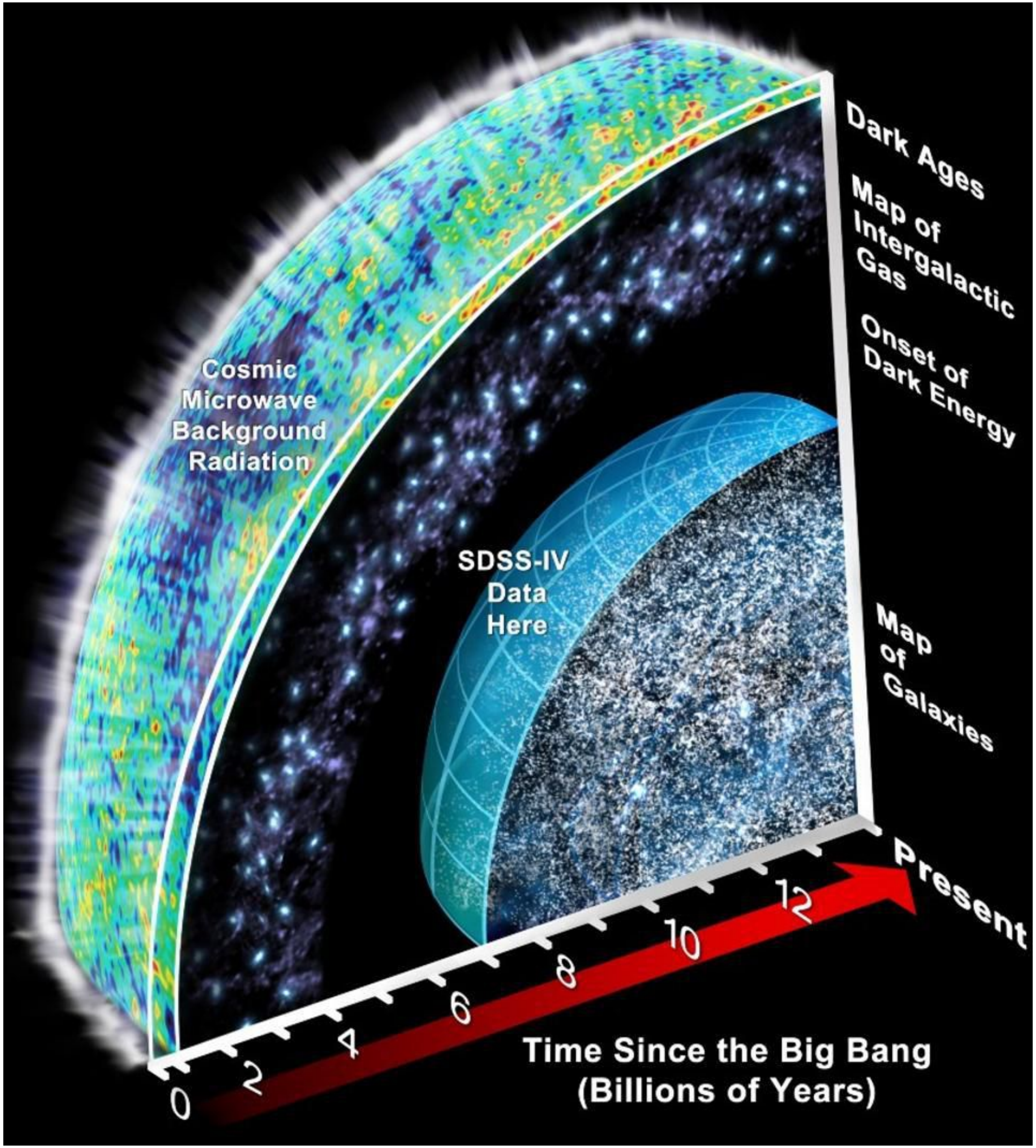


Cosmic
Microwave
Background

The **faintest** light we can ever see!







4. Hubble定律

$$H_0 \sim 70\ [km/s/\mathrm{Mpc}]$$

$$v = Hd$$

$$H(t) = \frac{\dot{a}(t)}{a(t)}$$

Edwin Hubble 1929

How Large H_0?

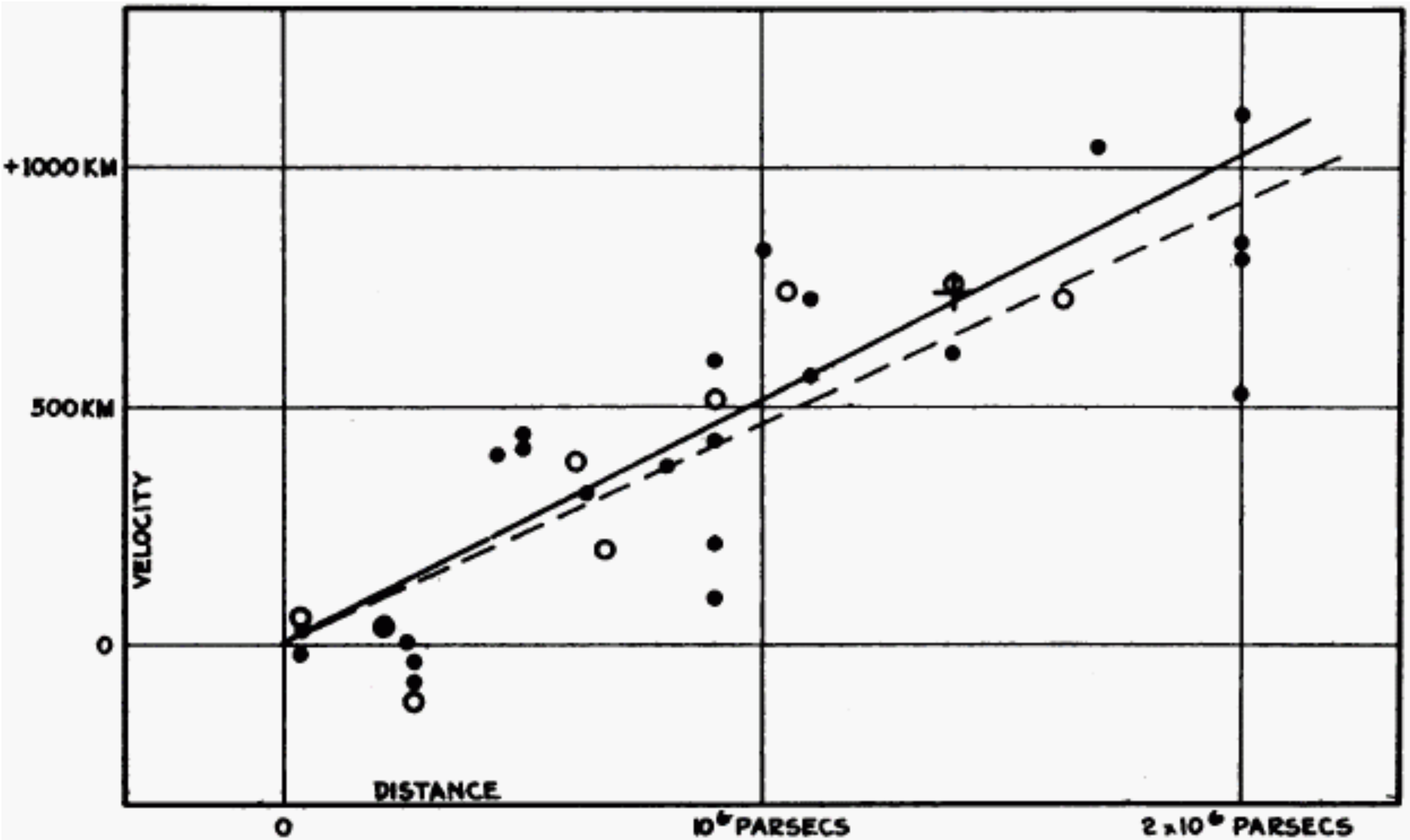
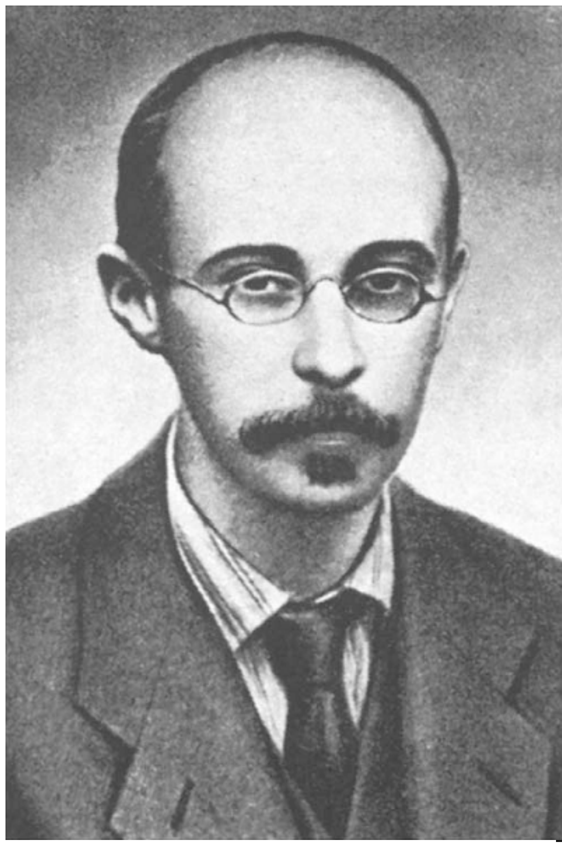


FIGURE 1

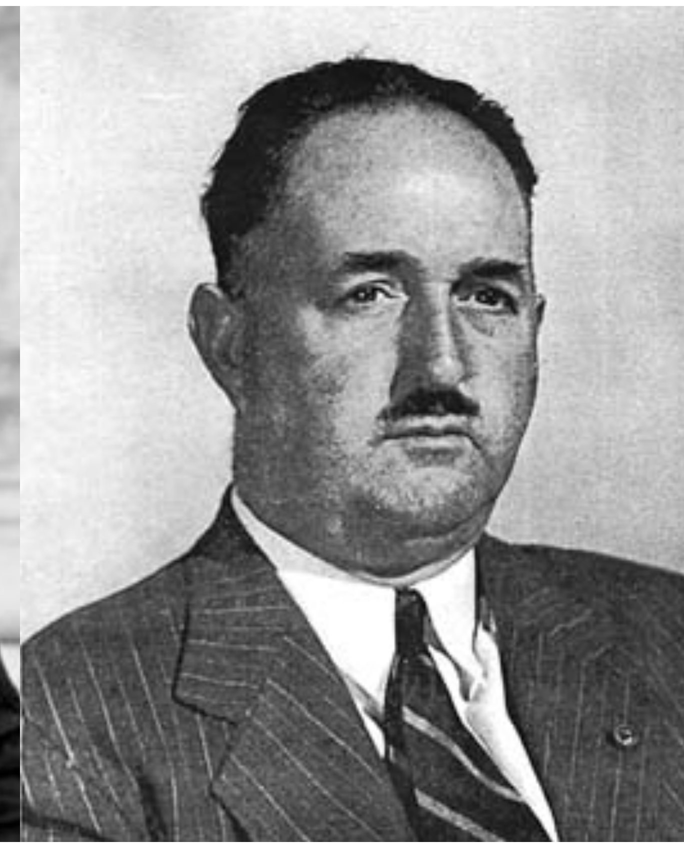
Velocity-Distance Relation among Extra-Galactic Nebulae.

5. Fridemann-Robertson-Walker-Lemaître universe



Friedmann 1920

Lemaître 1927



Robertson 1936

Walker 1936

ON GRAVITATIONAL WAVES.

BY

A. EINSTEIN and N. ROSEN.

ABSTRACT.

The rigorous solution for cylindrical gravitational waves is given. For the convenience of the reader the theory of gravitational waves and their production, already known in principle, is given in the first part of this paper. After encountering relationships which cast doubt on the existence of *rigorous* solutions for undulatory gravitational fields, we investigate rigorously the case of cylindrical gravitational waves. It turns out that rigorous solutions exist and that the problem reduces to the usual cylindrical waves in euclidean space.

1936

NAME	DATE IN	REFEREE	DATE IN	TO AUTHOR	TO N.Y.	ISSUE	REJECTED
Gregory	5/24	Zwicky 6/4	6/8				6/12
Einstein & Rosen	6/1	Robertson 7/6	7/17	7/23			
[illegible]	[illegible]				4/14	MAY 15, 1936	
[illegible]	3/28		4/16	4/8	4/17/36	JUNE 15, 1936	

Figure 5. An early extract from the *Physical Review* logbook. The Einstein–Rosen article was received by the journal on 1 June 1936. After a delay of more than a month, John Tate sent a referral to Howard Percy Robertson on 6 July, finding him in Moscow, Idaho, on vacation after a sabbatical at Caltech. Robertson returned the manuscript and his review to Tate on 17 July. Six days later the package was sent back to Einstein. (Courtesy of Martin Blume, American Physical Society.)

(EoM of gravitational d.o.f.)

$$G_{\mu\nu} = 8\pi G T_{\mu\nu}$$ → Einstein eq.

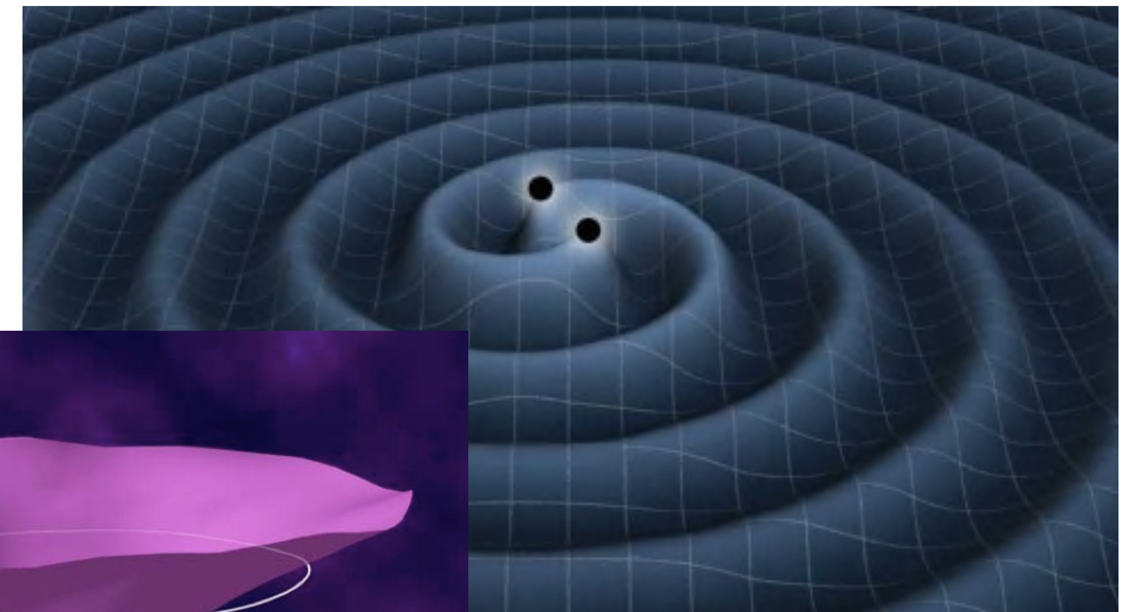
gravity sector (Geometry of space-time)

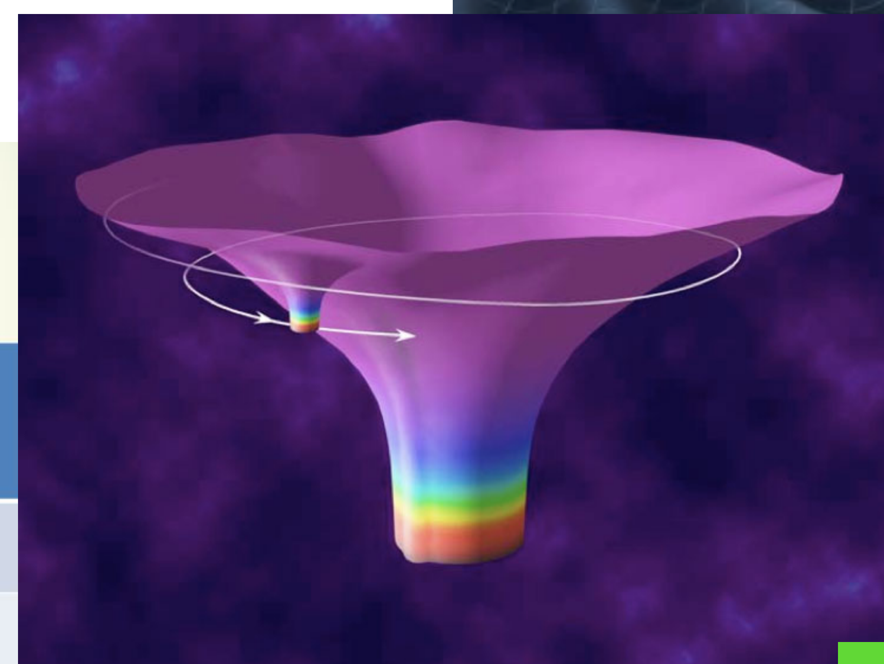
gravitational coupling constant

matter sector (stress-energy tensor)

John Wheeler

Spacetime tells matter how to move; matter tells spacetime how to curve





Gravitation and the other fundamental interactions

Fundamental Interaction	Crucial years	Fundamental constant	Normalized Intensity
Gravity	1687	$Gm_p^2/\hbar c$	5.1×10^{-39}
Weak nuclear force	1934	$G_{Fermi}(m_p c^2)^2$	1.03×10^{-5}
Electromagnetism	1864	$e^2/(4\pi\varepsilon_0\hbar c)$	$7.3\times10^{-3} \simeq 1/137$
Strong nuclear force	1935/1947	α_s	0.119

$$\begin{pmatrix} -\rho & 0 & 0 & 0 \\ 0 & +P & 0 & 0 \\ 0 & 0 & +P & 0 \\ 0 & 0 & 0 & +P \end{pmatrix}$$

model cosmic matter distribution by the fluid approach!

need a lots of energy to bend the space-time!

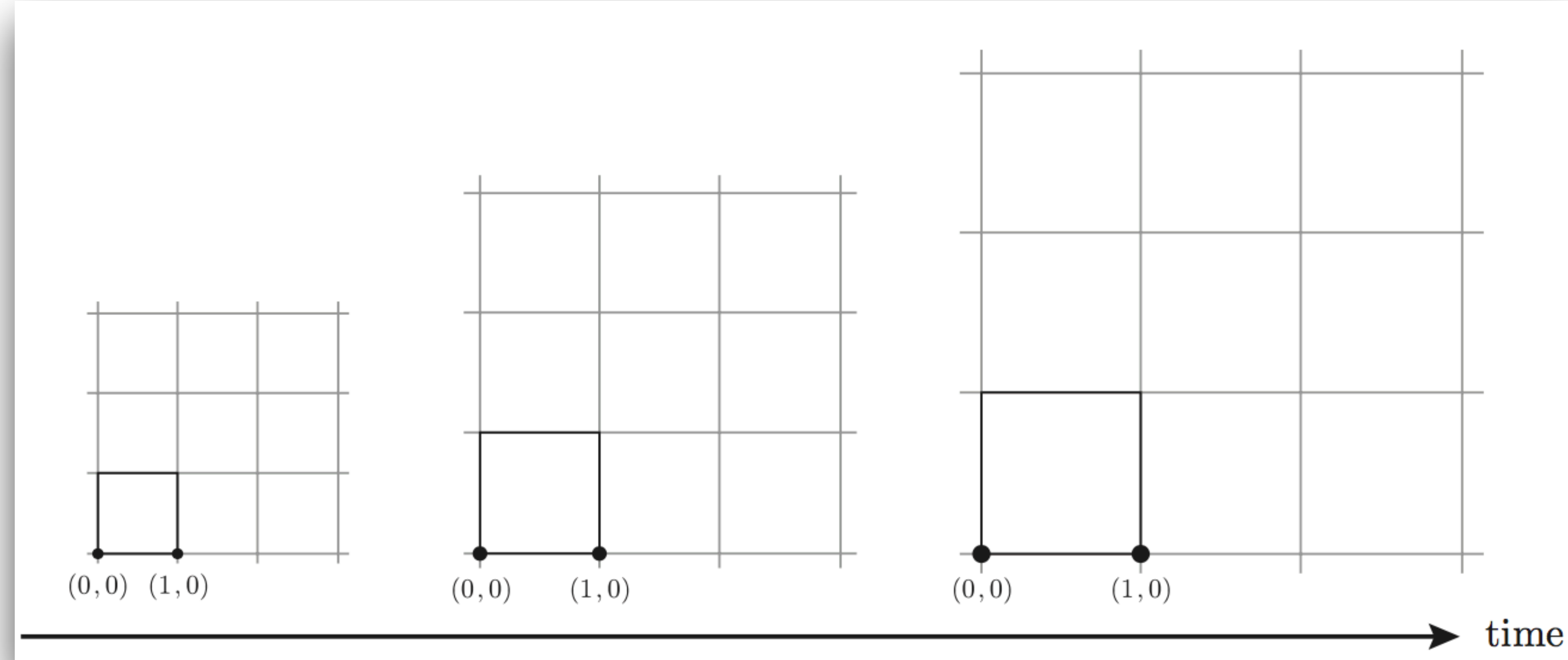
$$\nabla_\mu T^{\mu\nu} = 0$$ → energy-momentum conservation eq.

(EoM of matter)

$[ds^2 = g_{\mu\nu} dx^\mu dx^\nu]$

gravity field

$$ds^2 = -dt^2 + a^2(t) \times dl^2$$



$$ds^2 = -dt^2 + a^2(t)[\frac{dr^2}{1-K(t)r^2} + r^2 d\theta^2 + r^2 \sin^2\theta d\varphi^2]$$

dv^2 (physical)

(co-moving) du^2

dv = a du

here, du = 1, but dv increase w.r.t. time

Friedmann eq.

$$\left(\frac{\dot{a}}{a}\right)^2 = \frac{8\pi G}{3}\rho - \frac{k}{a^2} \, ,$$

$$\frac{\ddot{a}}{a} = -\frac{4\pi G}{3}(\rho + 3P)$$

Problem-1

What is the solution of a(t)?

Matter dominated epoch $P = 0 \, , \rho = \rho_0 a^{-3}$

Radiation dominated epoch $P = \rho/3 \, , \rho = \rho_0 a^{-4}$

Dark energy dominated epoch $P = -\rho \, , \rho = \rho_0 a^{0}$

Software

Wolfram
Mathematica

Problem-2

简述宇宙热历史