Holography and Quantum Error Correction

Part I:

Non-Euclidean Geometry and Black Holes

اصول موضوع هندسه اقلیدسی

یک- بین هر دو نقطه می توان یک خط راست کشید،

دو- هر خطی بین دو نقطه را می توان به میزان دلخواه امتداد داد،

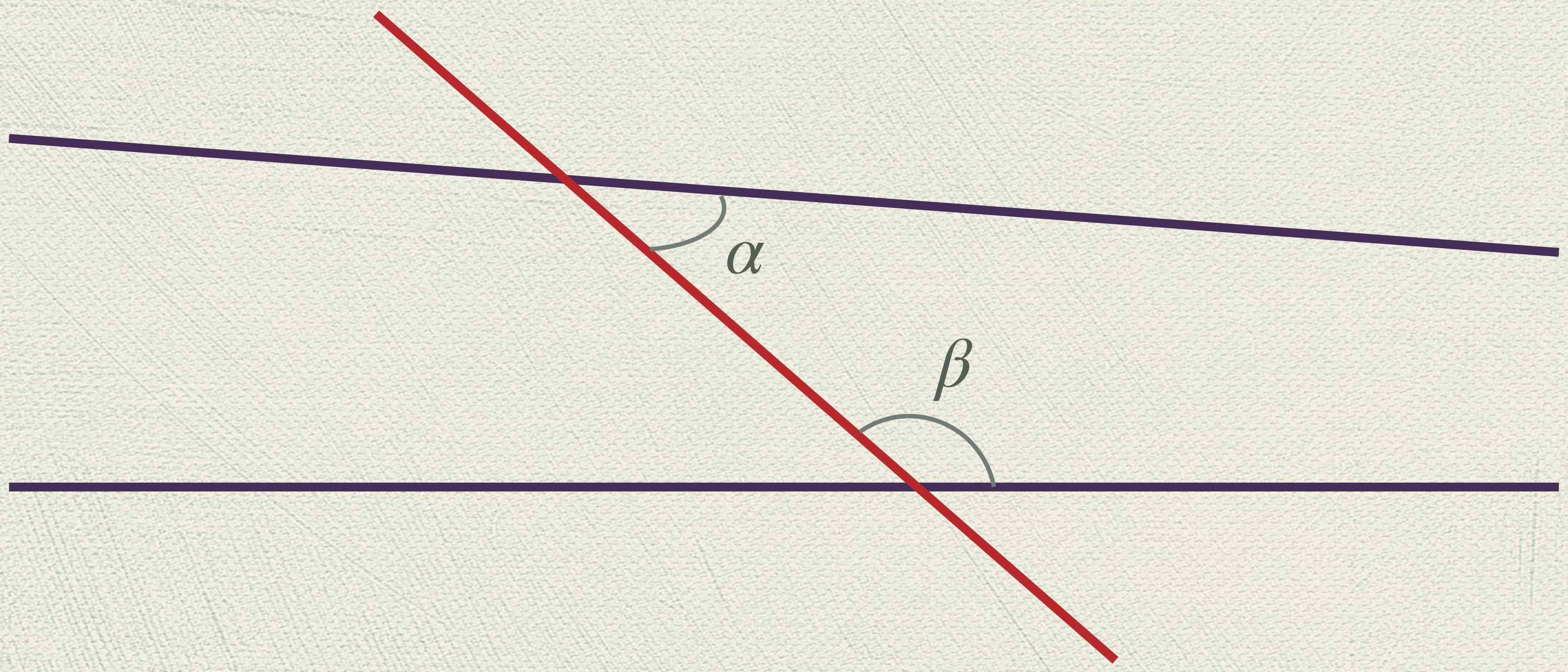
سه - می توان هر دایره ای با هر مرکزی و هر شعاعی رسم کرد،

چهار - تمام زوایای قائمه با هم مساوی هستند،

پنج - اگر خط راستی دو خط راست دیگر را قطع کند، و مجموع زوایای ایجاد شده در یک طرف از دو قائمه کمتر باشد، آن دو خط نهایتا در آن طرف به هم خواهند رسید.

The fifth postulate

The parallel postulate

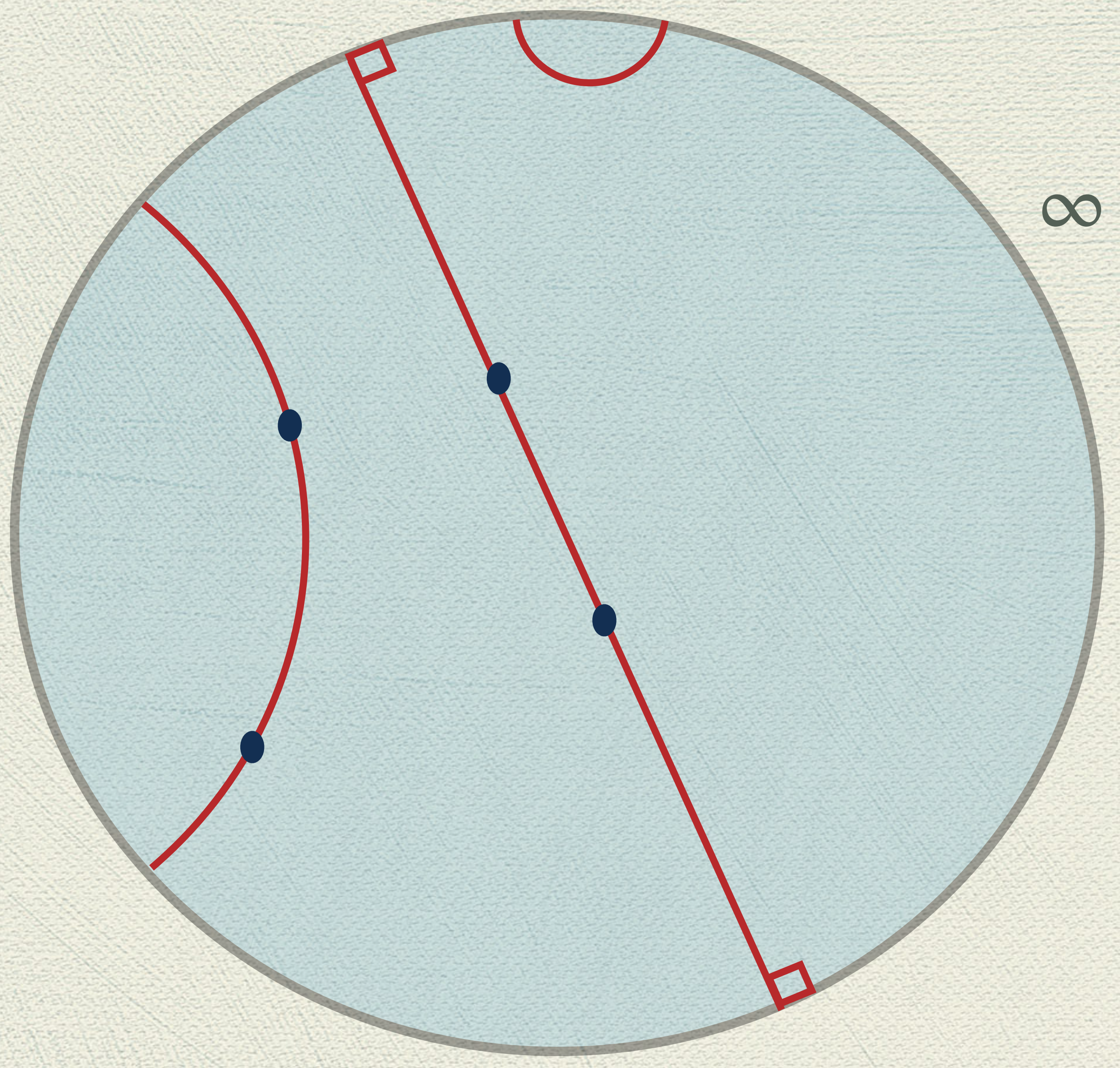


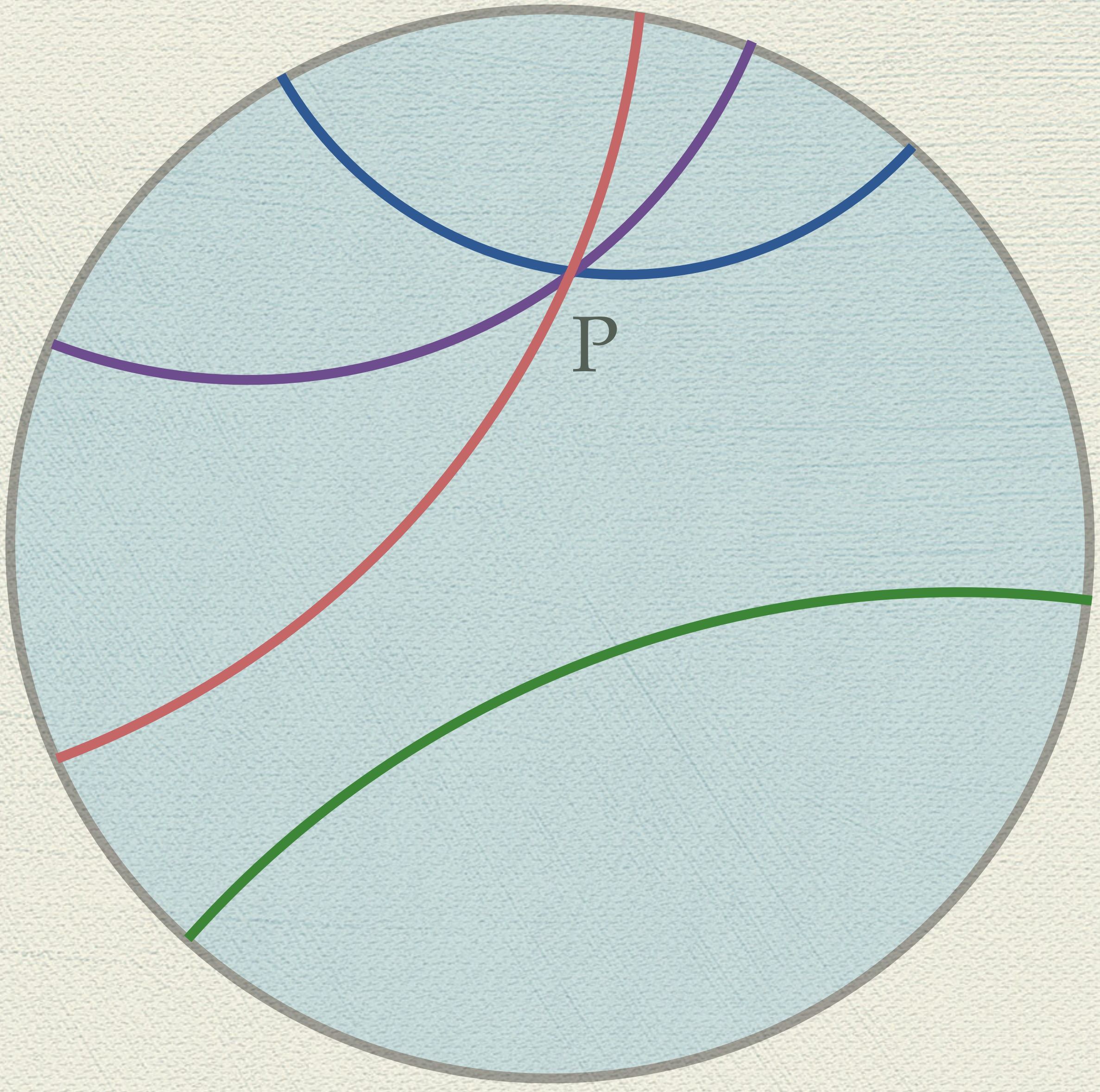
اصل موضوع پنجم در طول ۲۰۰۰ سال:

- از یک نقطه خارج یک خط تنها یک خط می توان به موازات آن رسم کرد.
- مجموع زوایای یک مثلث دو قائمه است.
- مثلثی وجود دارد که مجموع زاویه هایش دو قائمه است.
- هر مثلثی را در یک دایره می توان محاط کرد.
- مربعی وجود دارد که همه زاویه هایش قائمه هستند.
- دو خط که با خط سومی موازی باشند، خودشان با هم موازی اند.
- هیچ حد بالایی برای مساحت یک مثلث وجود ندارد.

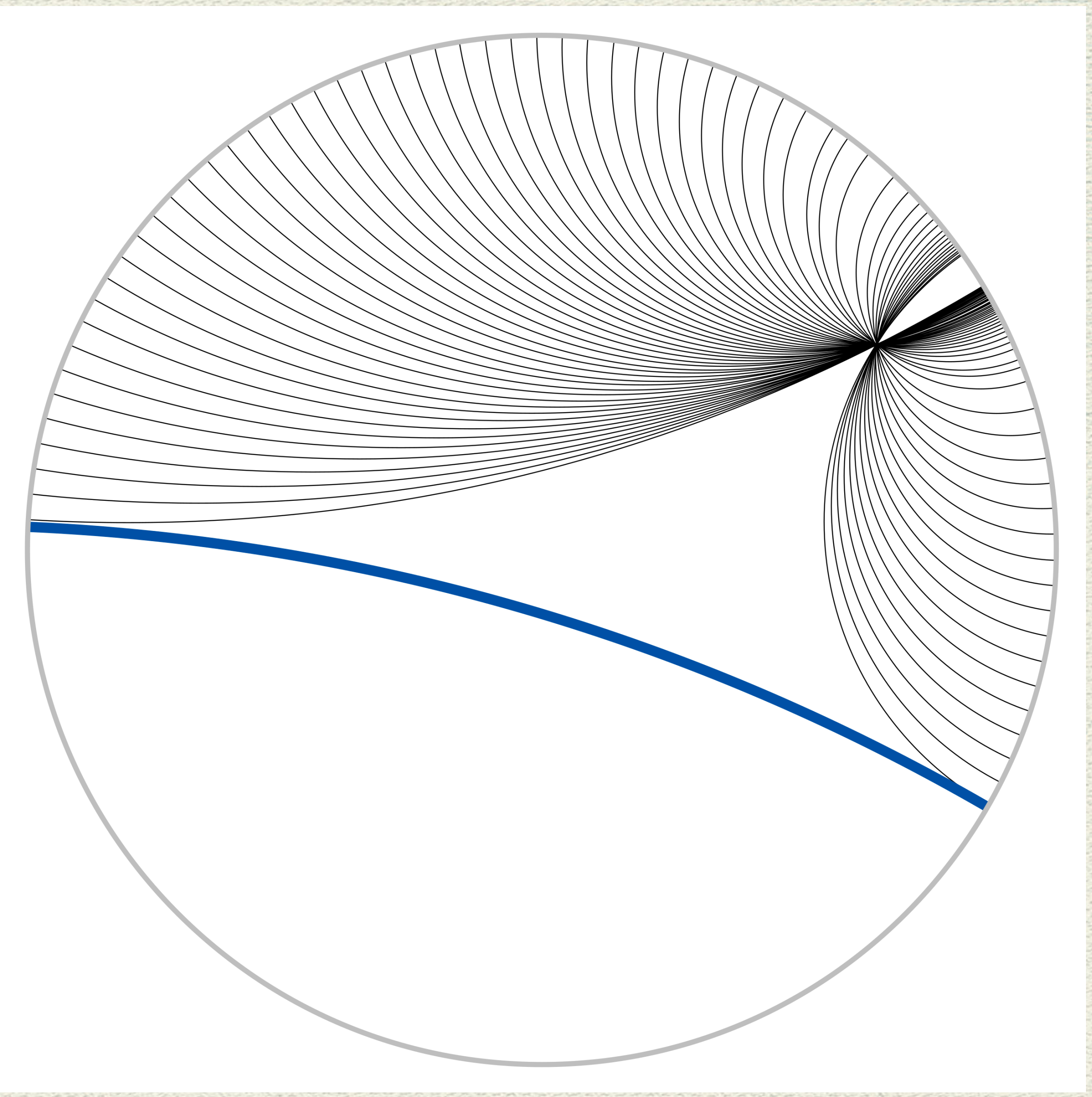
- Proclus (410-485),
- Ibn al-Heytham (965-1039),
- Omar Khayyam (1050-1123),
- Nasir al-Din Tusi (1201-1274),
- Sadr al Din (1298),
- Girolamo Saccheri (1667-1733),
- Giordano Vitale (1633-1711),
- John Lambert (1766),
- Nikolai Lobachevsky (1829),
- Janos Bolyai (1831),
- Gauss,
- Reimann,…

Hyperbolic Geometry





بر خلاف اصل پنجم اقلیدس:
از هر نقطه خارج یک خط بی نهایت خط عبور می کند که همه با آن خط موازي هستند.



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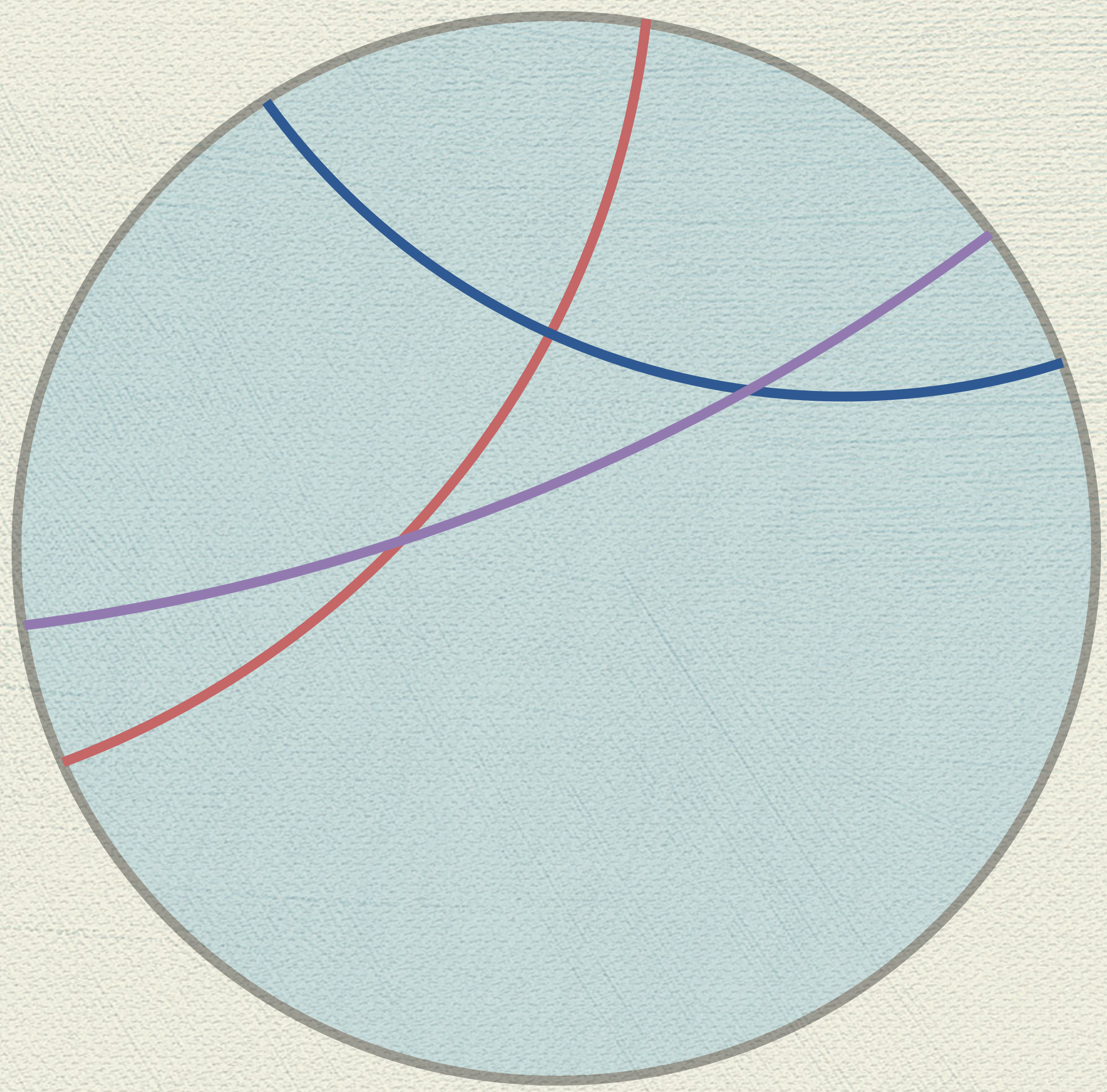
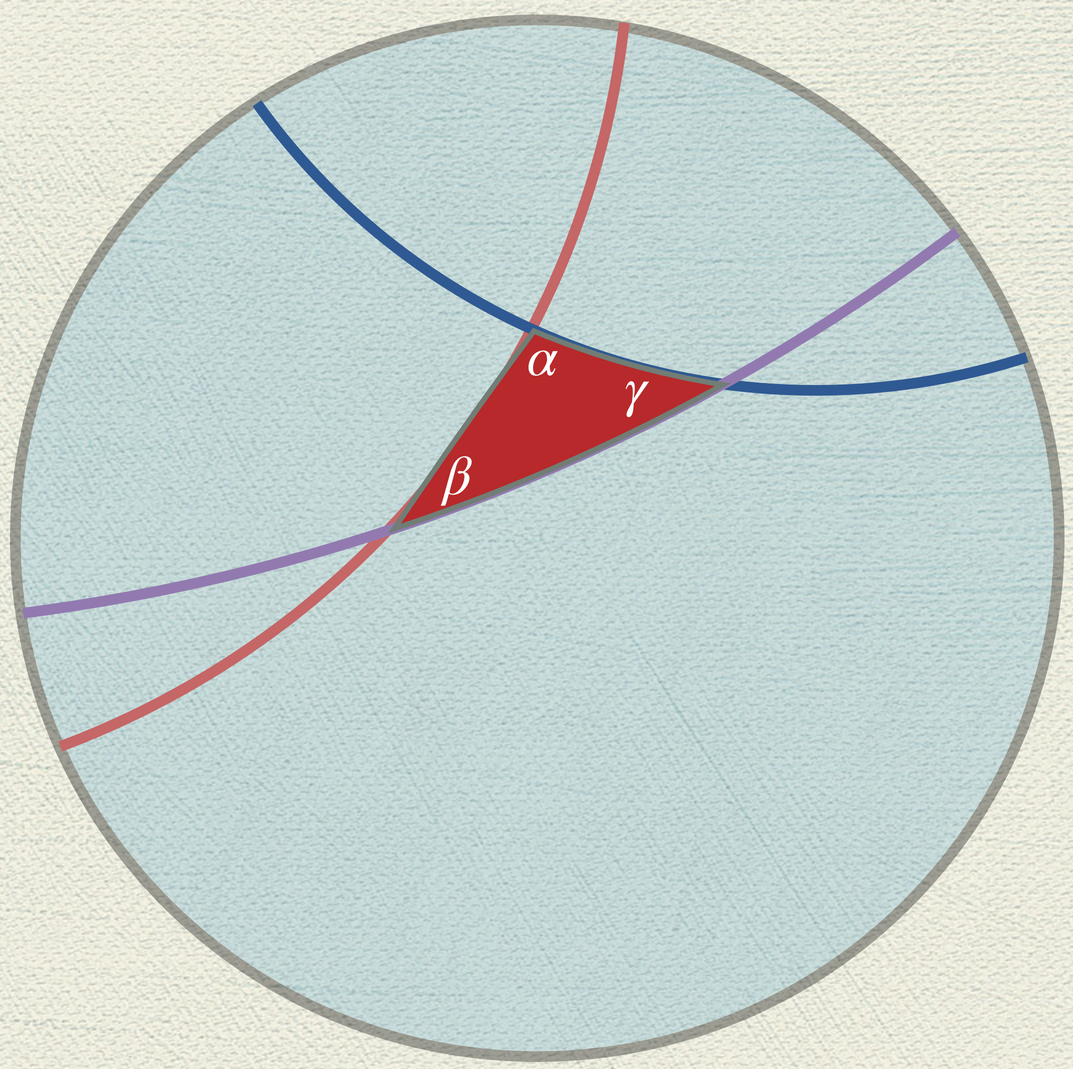


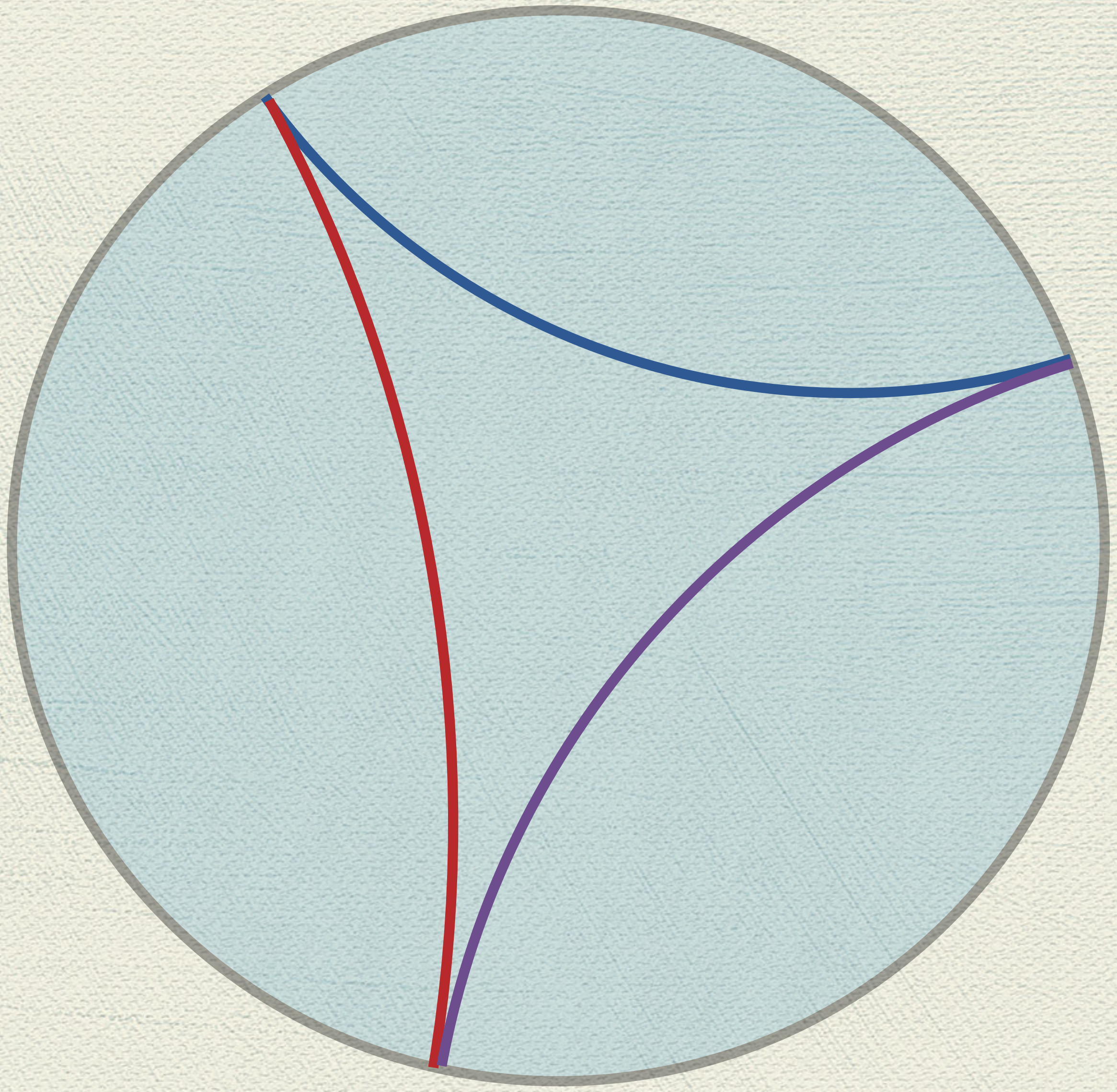
مجموع زوایای داخل یک مثلث کمتر از ۱۸۰ درجه است.



مساحت یک مثلث

$S = R^2(\pi - \alpha - \beta - \gamma)$

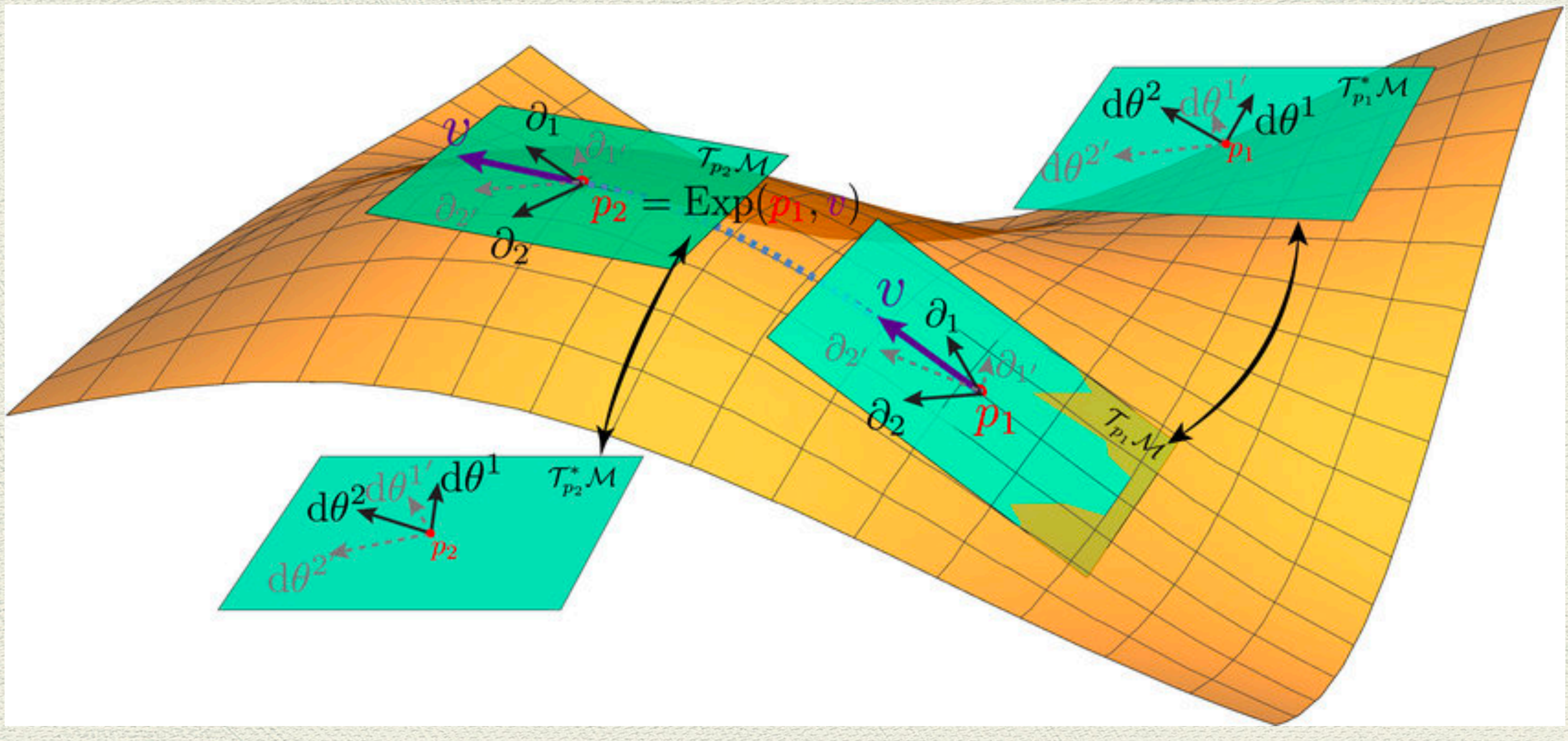
$\alpha + \beta + \gamma \leq \pi$



$$\alpha + \beta + \gamma = 0$$

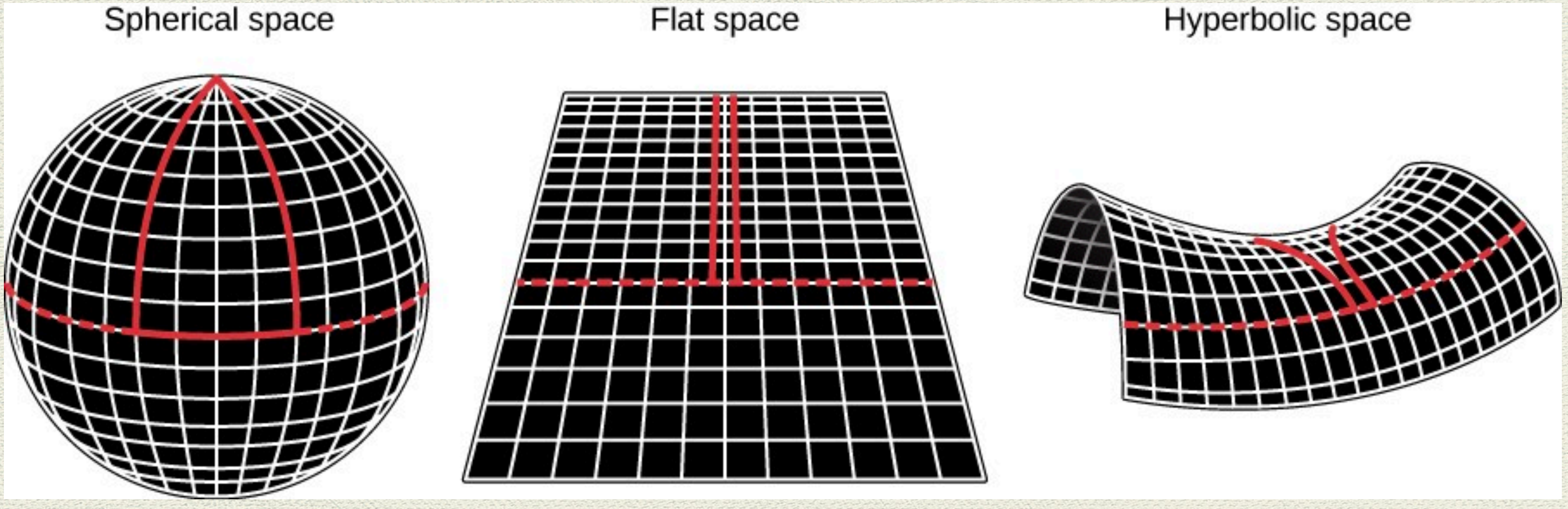
$$S = \pi R^2$$

Reimannian Geometry



$$ds^2 = g_{\mu\nu} du^\mu du^\nu$$

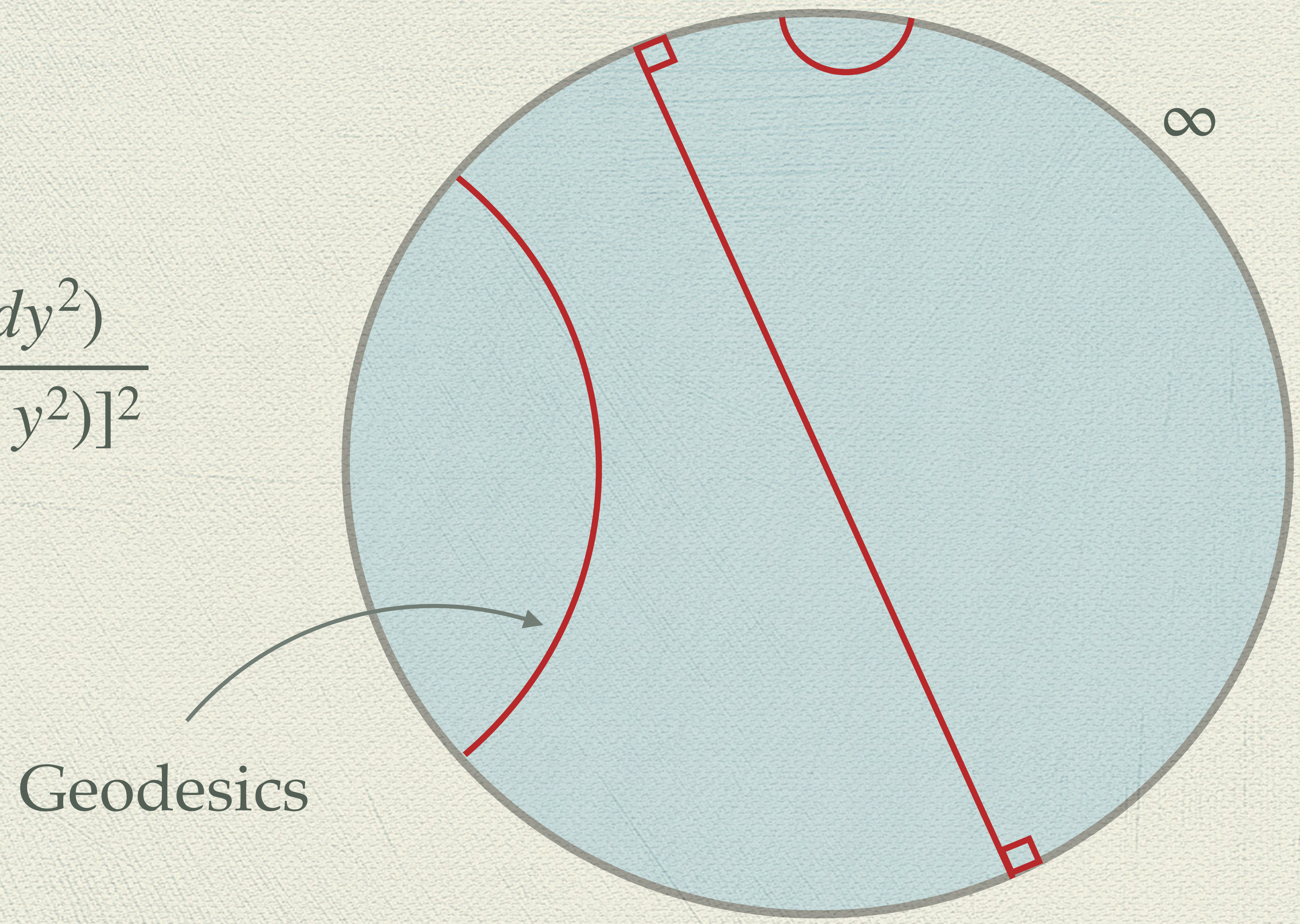
Spaces of Constant Curvature with Euclidean metric



$R > 0$ $\quad$ $R = 0$ $\quad$ $R < 0$

Poincare Disk Model

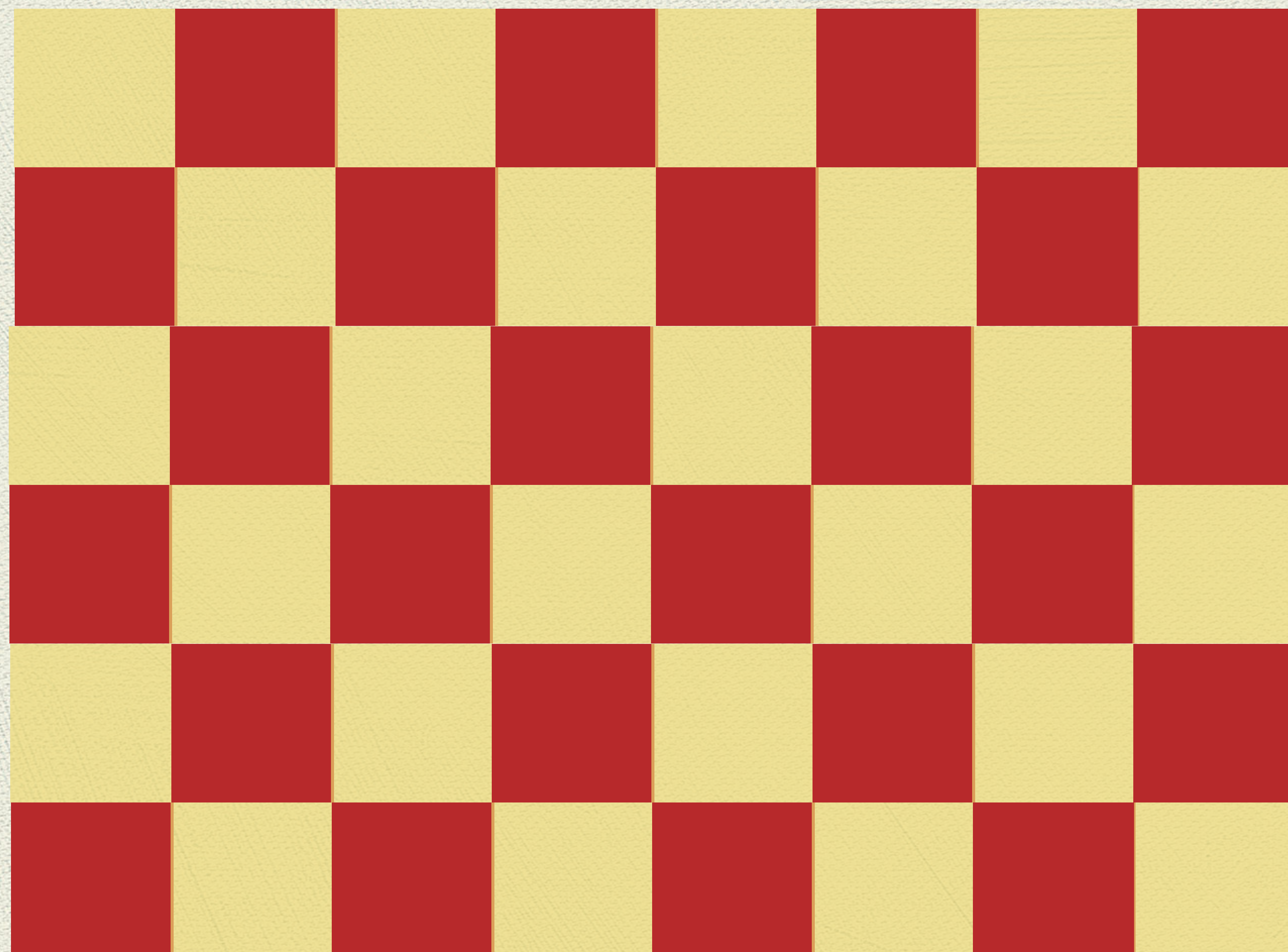
$$ds^2 = \frac{4(dx^2 + dy^2)}{[1 - (x^2 + y^2)]^2}$$



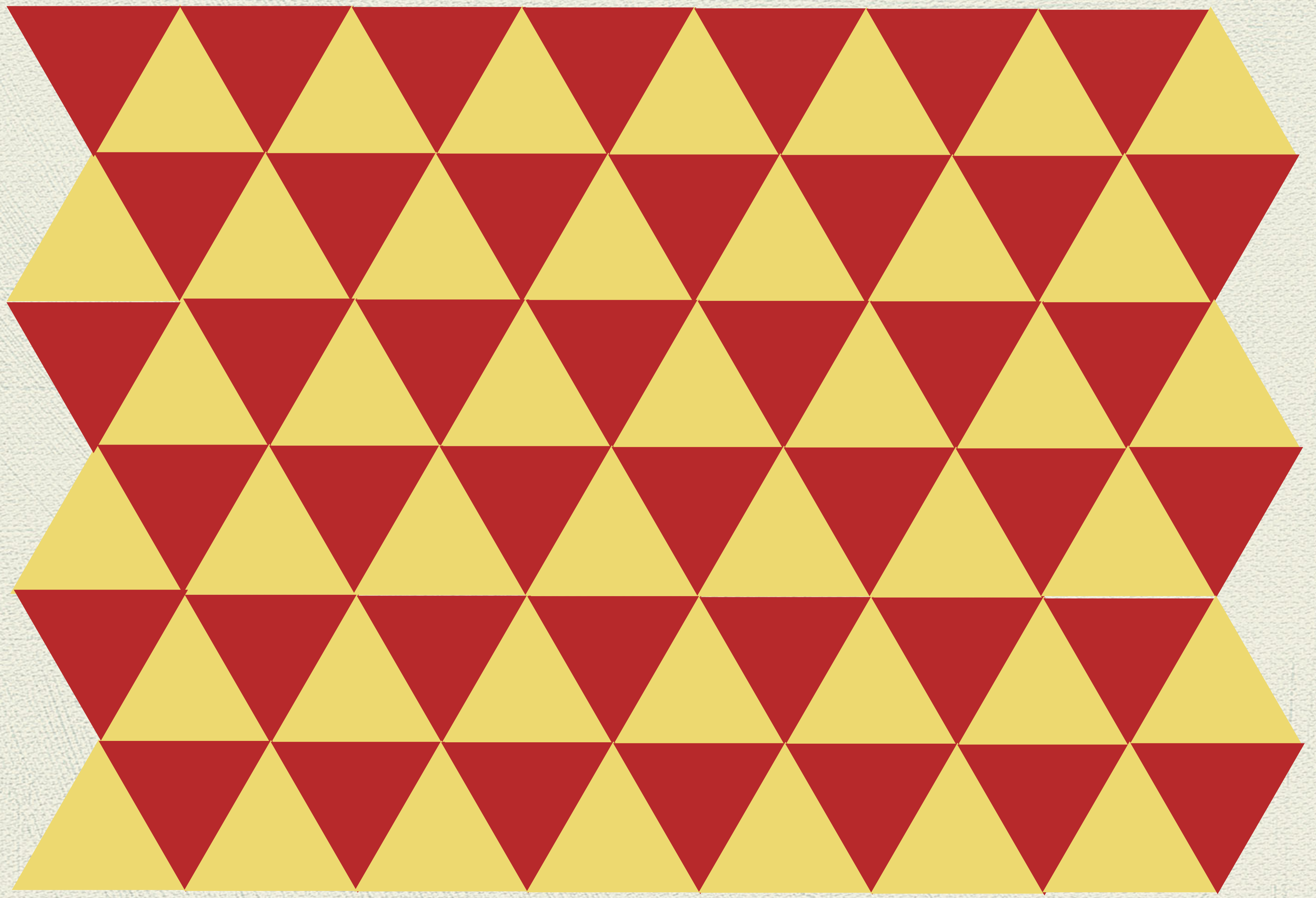
Euclidean Tesselations

یک سطح اقلیدسی را تنها به سه صورت می توان کاشی کاری کرد.

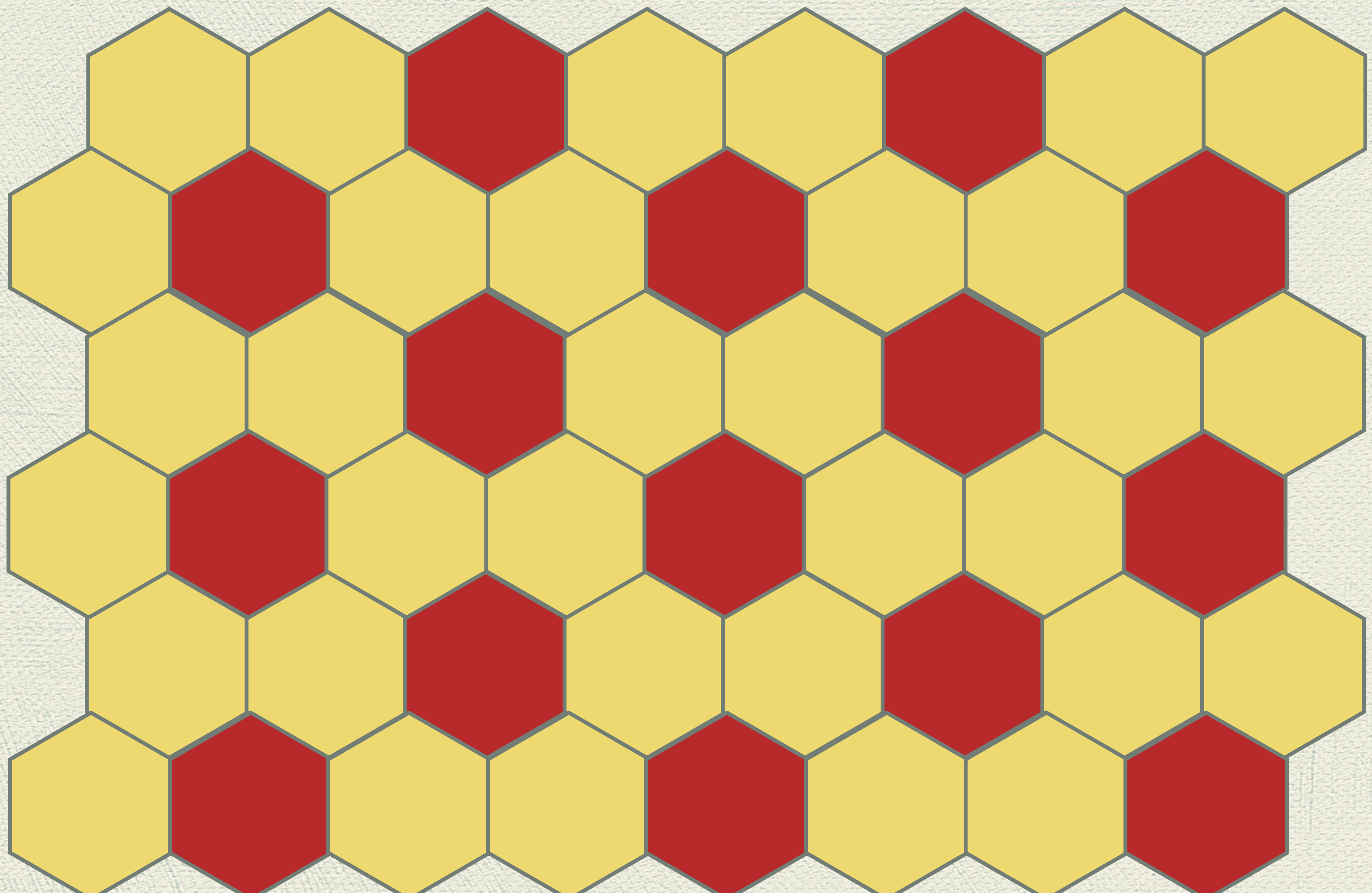
با مربع



با مثلث



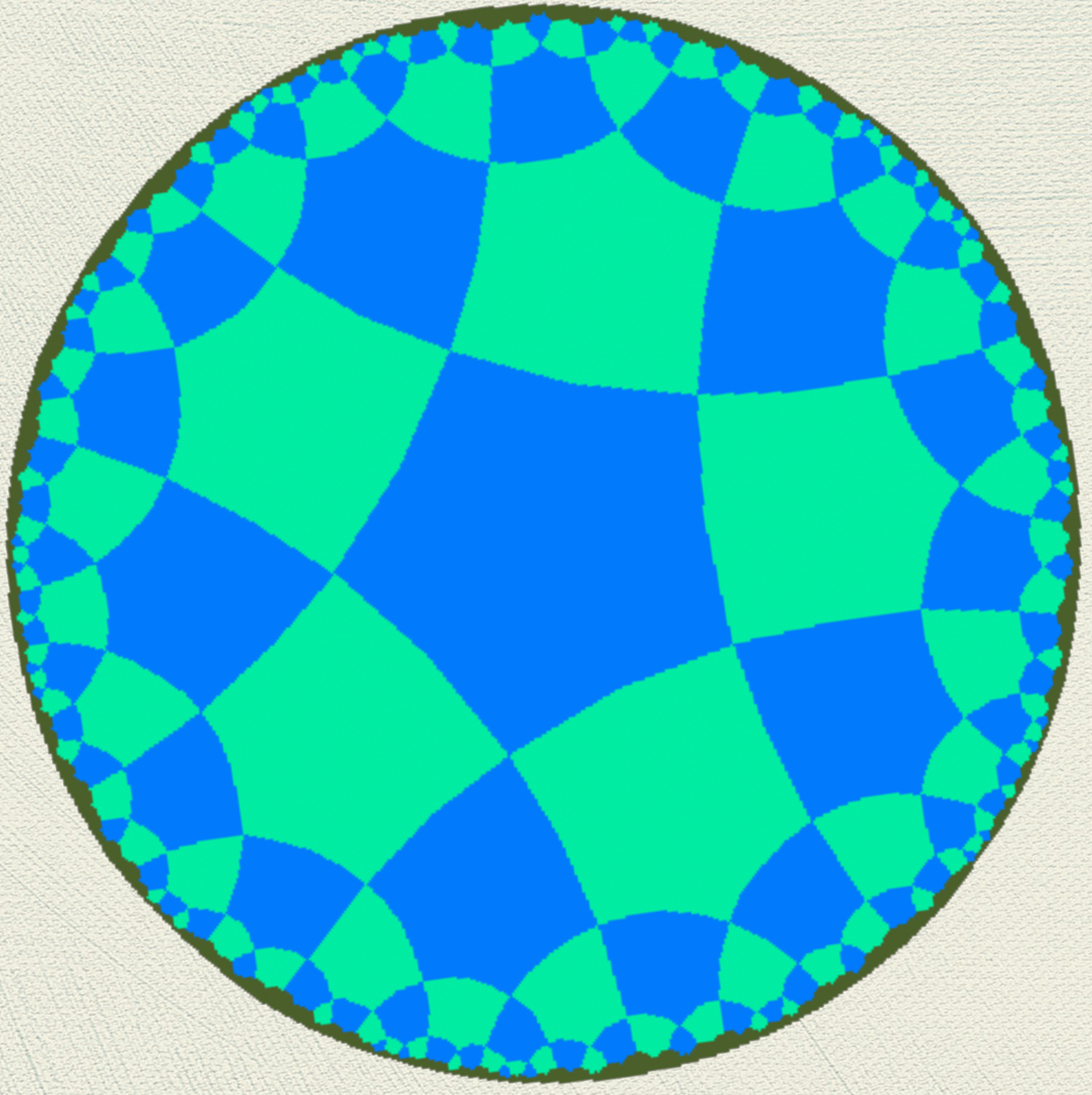
با شش ضلعی



Hyperbolic Tesselations

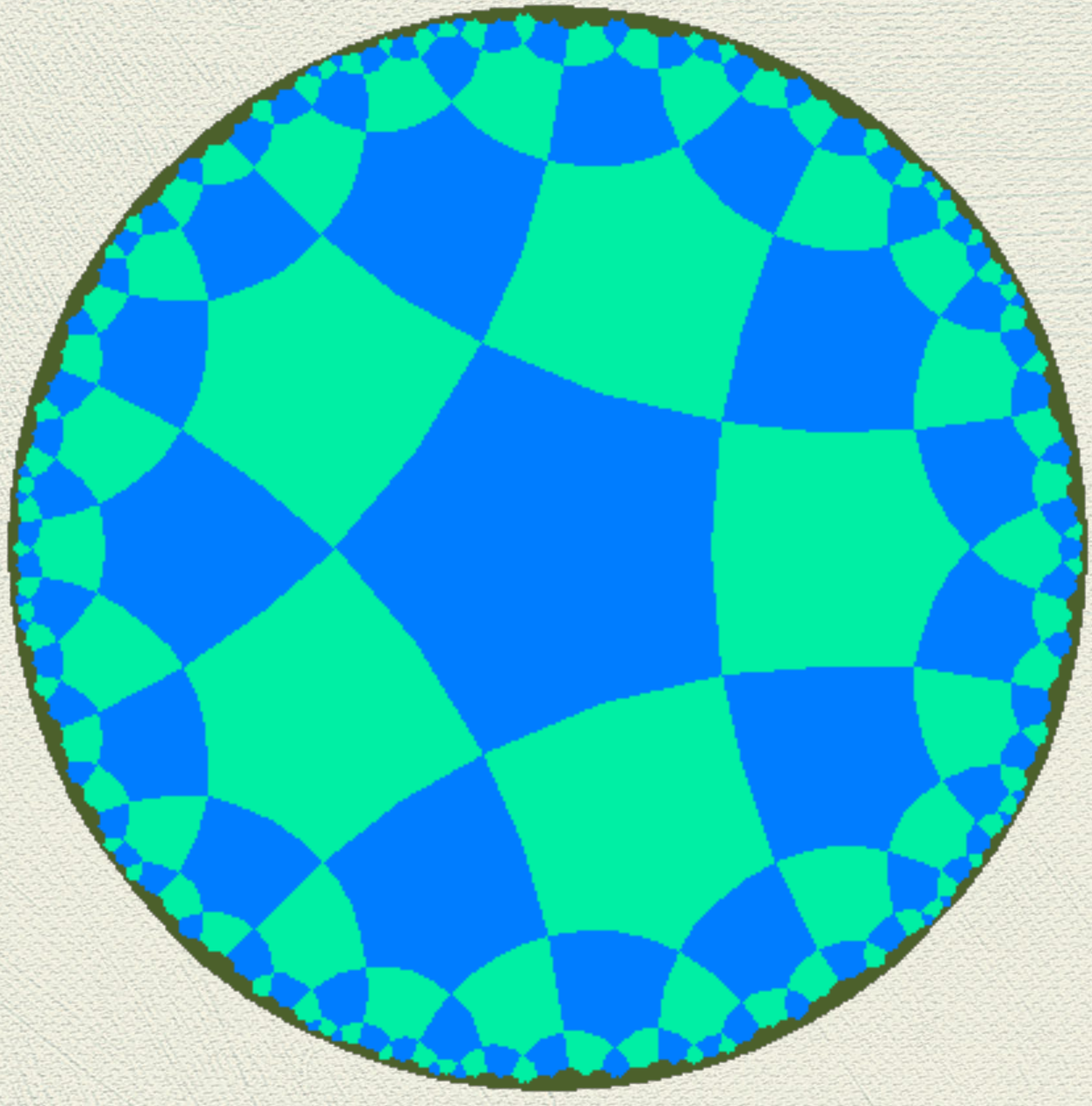
یک صفحه هذلولوی را به بی نهایت صورت می توان کاشیکاری کرد.

تمام این چند ضلعی ها یک اندازه هستند.

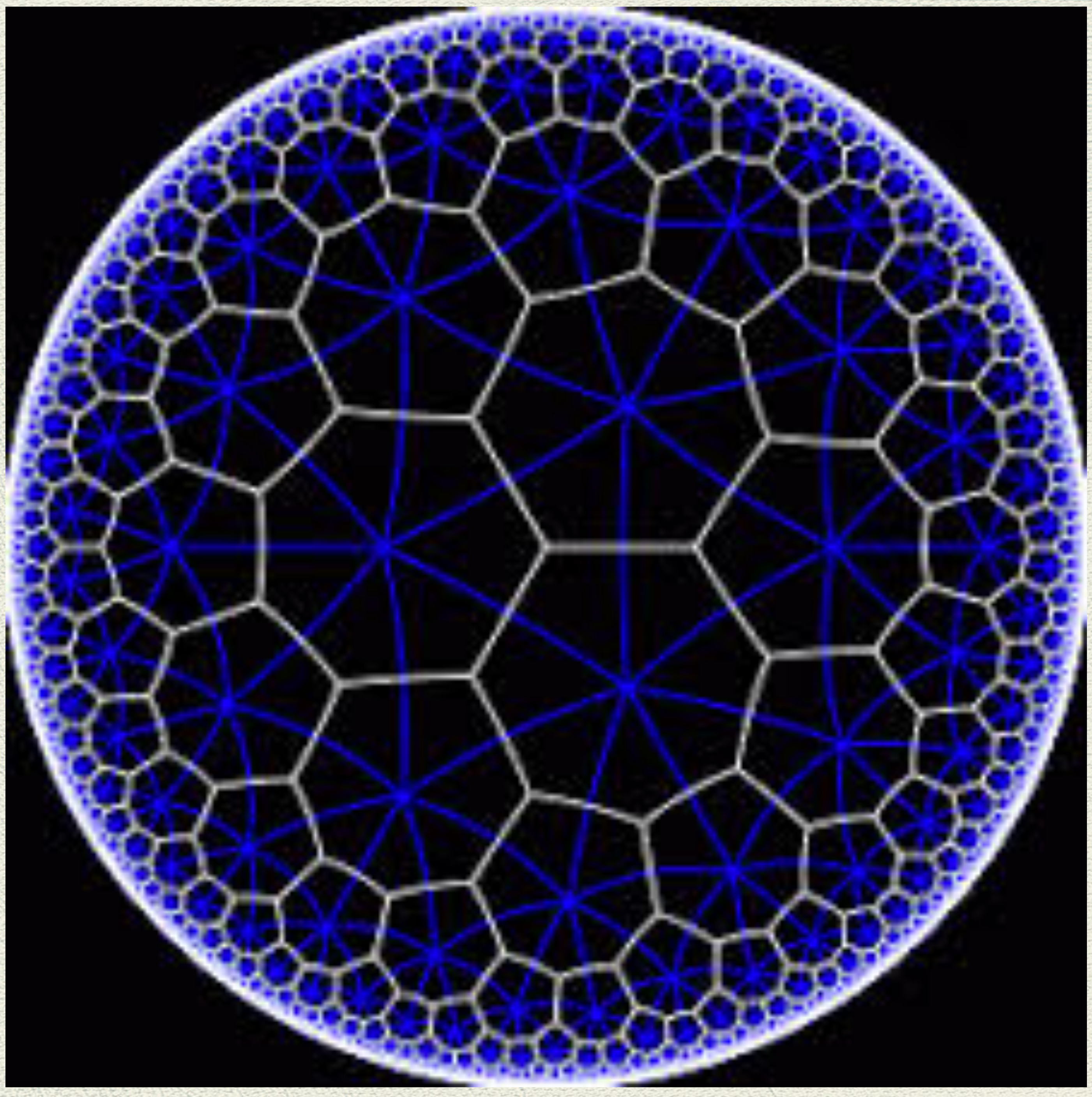


Schlaffli Symbol = (5 , 4)

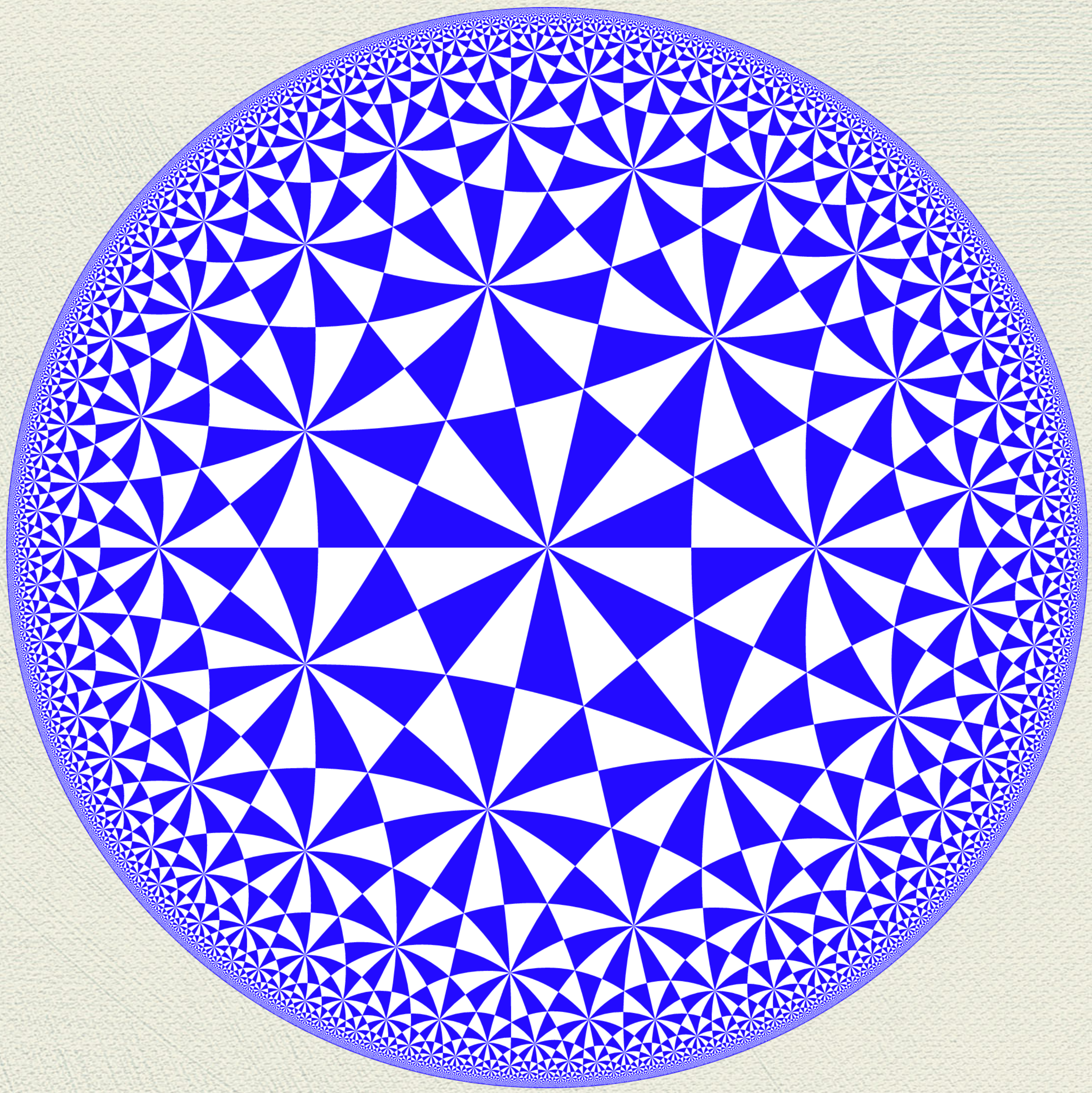
Regular Hyperbolic Tesselations



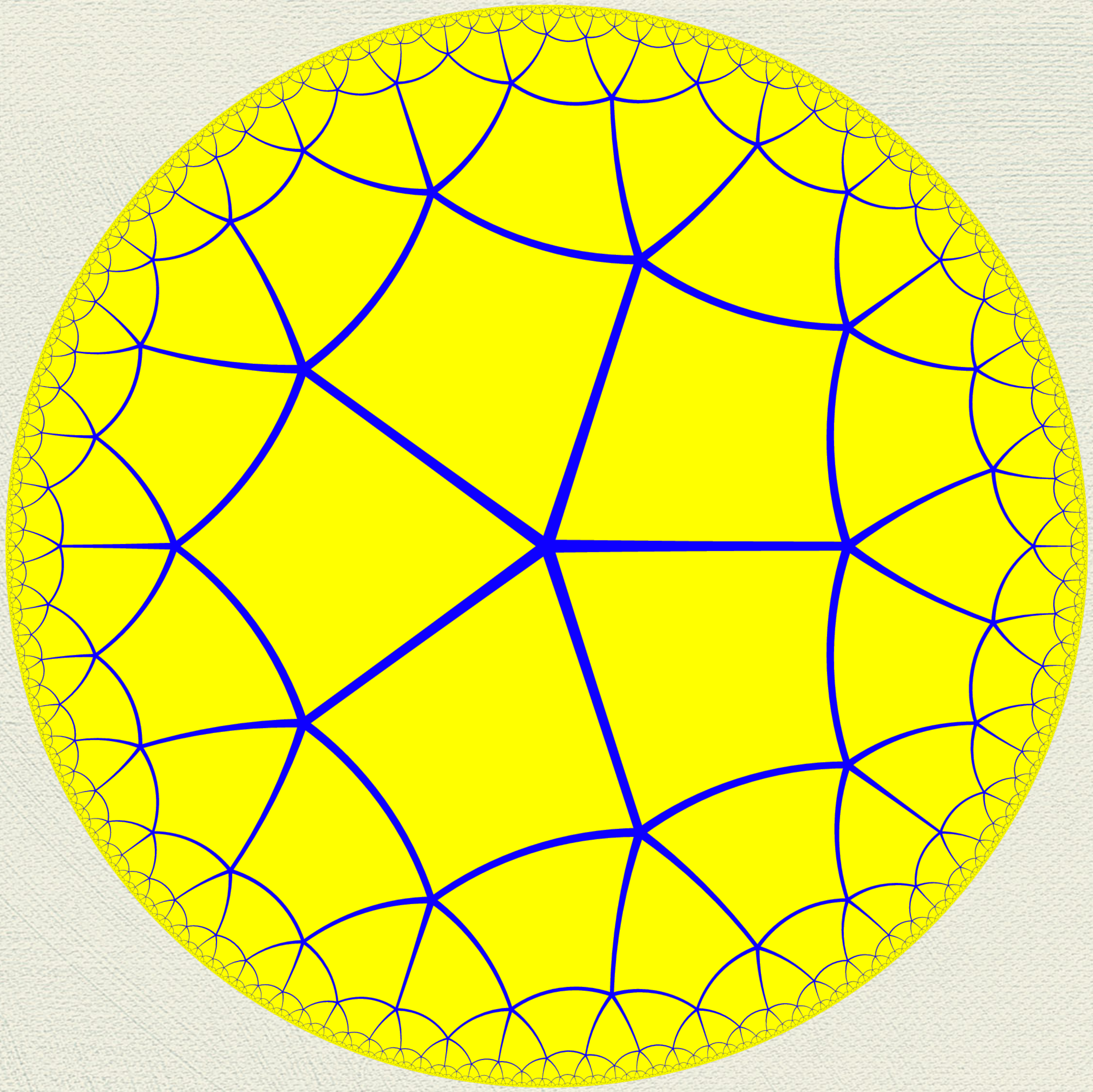
Schlaffli Symbol = (5 , 4)



Schlaffli Symbol = (6 , 3)



Schlaffli Symbol = (3, 14)



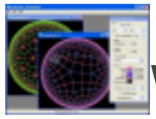
Schlaffli Symbol = (4 , 5)

Categories

- Audio 14
- Image editing / photo software 17
- Operating systems 6
- Security software 23
- Browsers 7
- Communication 8
- Data storage 7
- Download programs 4
- Education 5
- E-mail 11
- Games 6
- Hobby and read 11
- Office software 23
- Mobile apps 9
- Video 12
- Website development 26
- Business software 13

Popular programs

ADPHONE	Happy Fish
Verge	Destructivator
Smart Mouse Share	jPDF Fields
Outlook Import Wizard	QB-US States
Monkeymen Desktop Calendar	Advanced IP Address Calculator
Functor	Easy Notes
Calendar Organizer Deluxe	Real All Video Converter
Remote Mail Cleaner	RecoveryFIX for PST

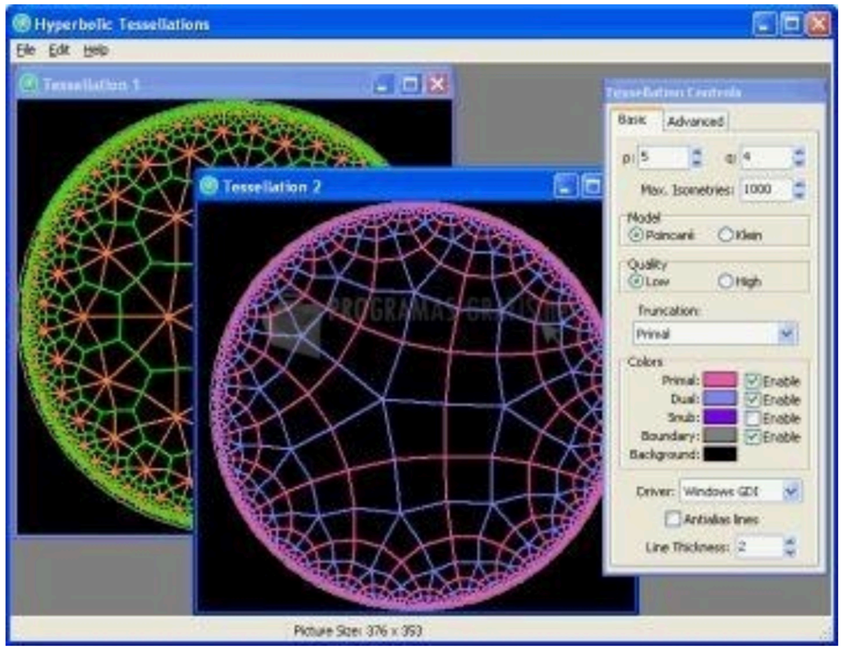


Hyperbolic Tessellations for Windows 10 32/64 download free

DOWNLOAD

With the name of. tessellations. (tessellations) we know a pattern of figures that completely covers or paves a flat surface in which there are no gaps and where the figures do not overlap. Examples: bathroom tiles, squares of linoleum on the floor of an office or street tiling.

Hyperbolic Tessellations is a tool that allows you to create an unlimited number of tessellations from the Menu, in File-> New. There you will find patterns. Choose one of them and take it through the drag and drop system to a hyperbolic space. In Hyperbolic Tessellations you can work with the right mouse button to edit the tessellations. In this way, you can specify the number of vertices to be drawn, the model, the quality, the color, and so on.



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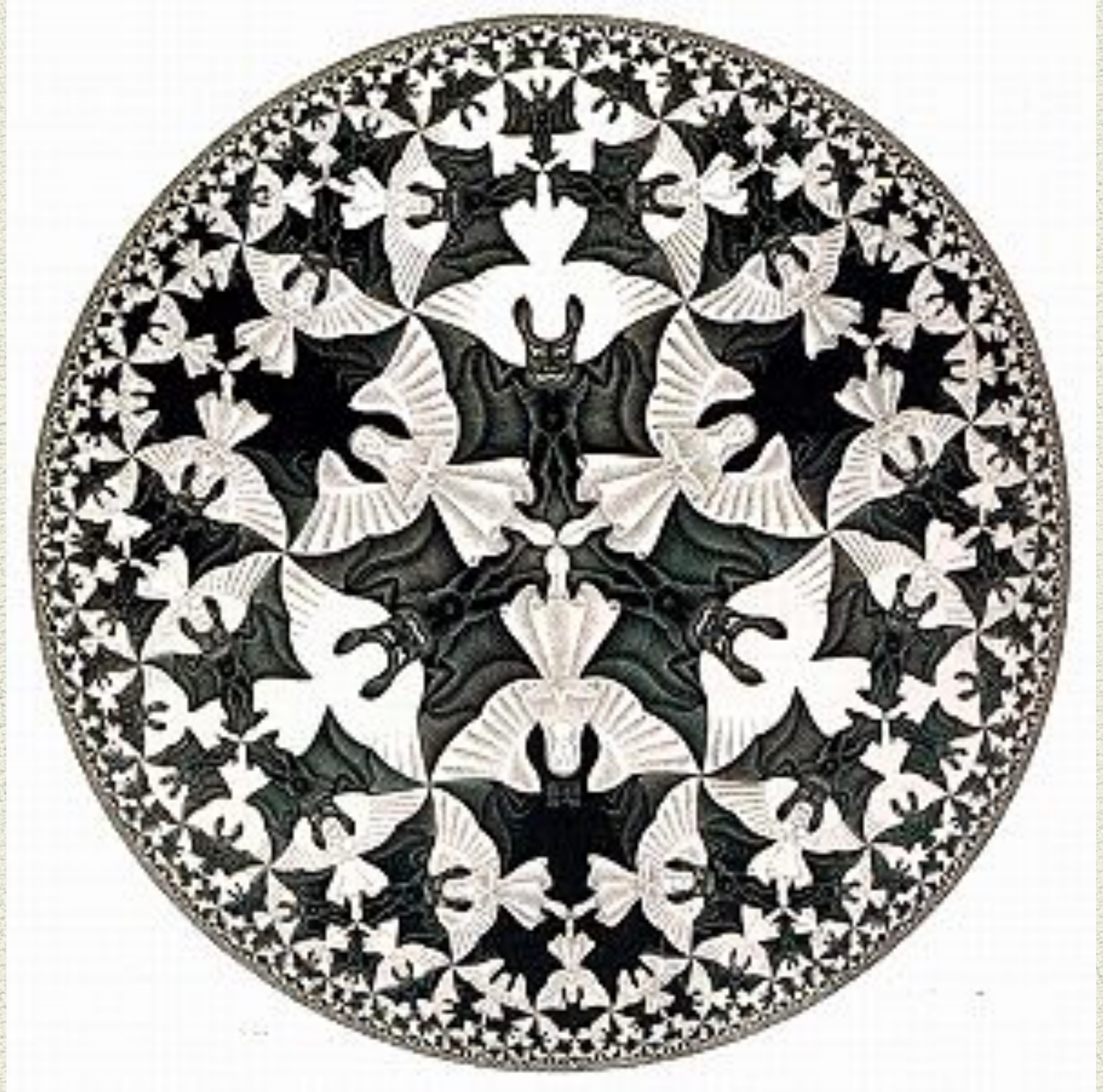
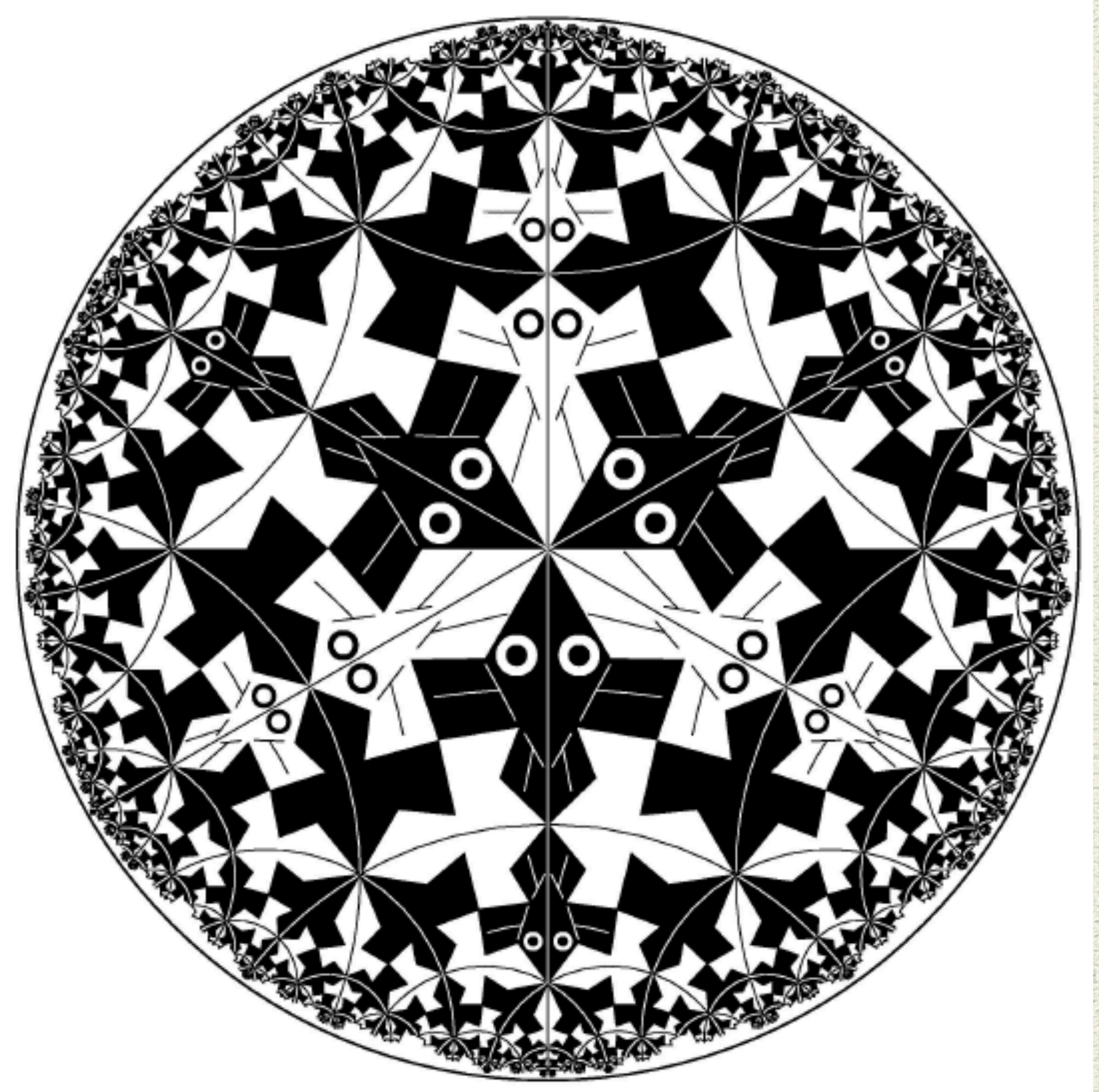
Devices: Desktop PC, Laptop (ASUS, HP, DELL, Acer, Lenovo, MSI), Ultrabook

OS: Professional, Enterprise, Education, Home Edition, versions: 1507, 1511, 1607, 1703, 1709, 1803, 1809

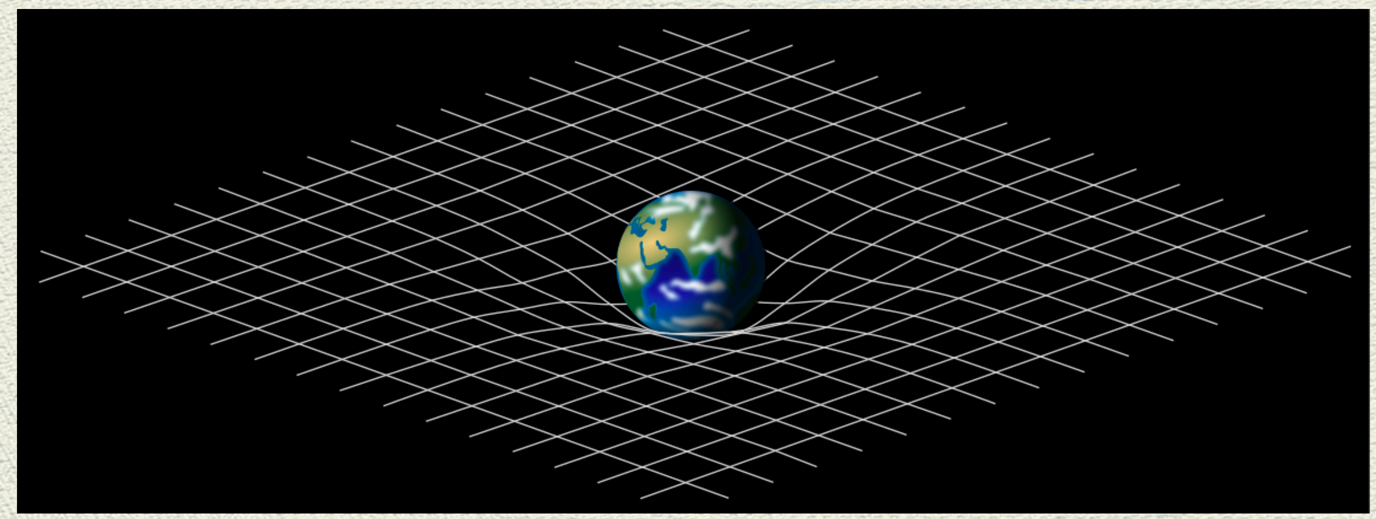
Esher Artworks





Black Holes

Einstein's Equation

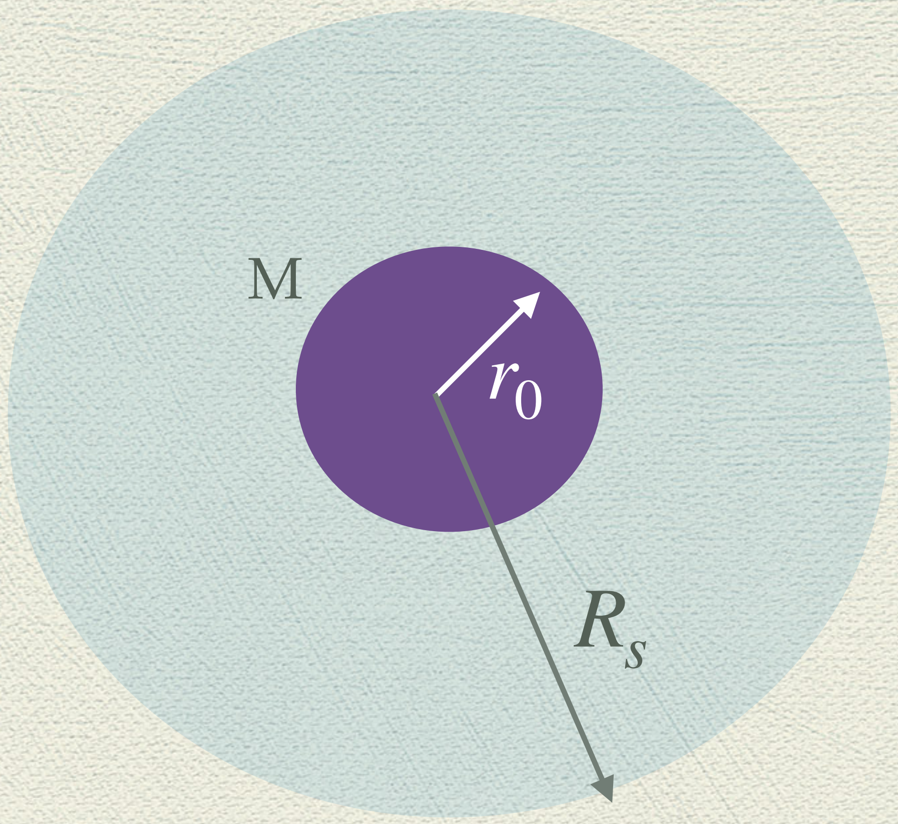


$$ds^2 = g_{\mu\nu} dx^\mu dx^\nu$$

$$G_{\mu\nu} = \frac{8\pi G}{c^3} T_{\mu,\nu}$$

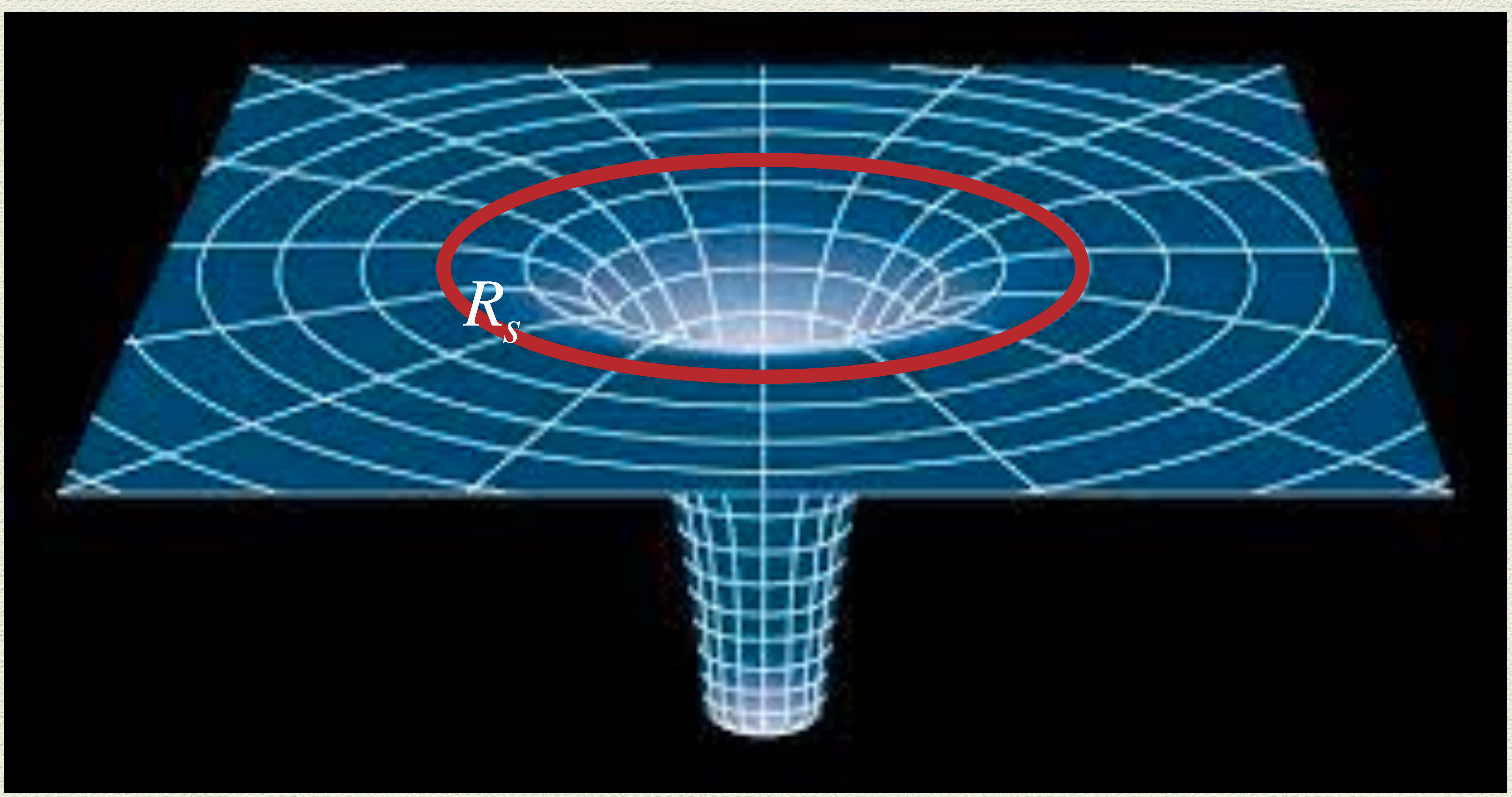
$$G_{\mu\nu} := R_{\mu\nu} - \frac{1}{2} g_{\mu\nu} R$$

Schwartzchild Solution



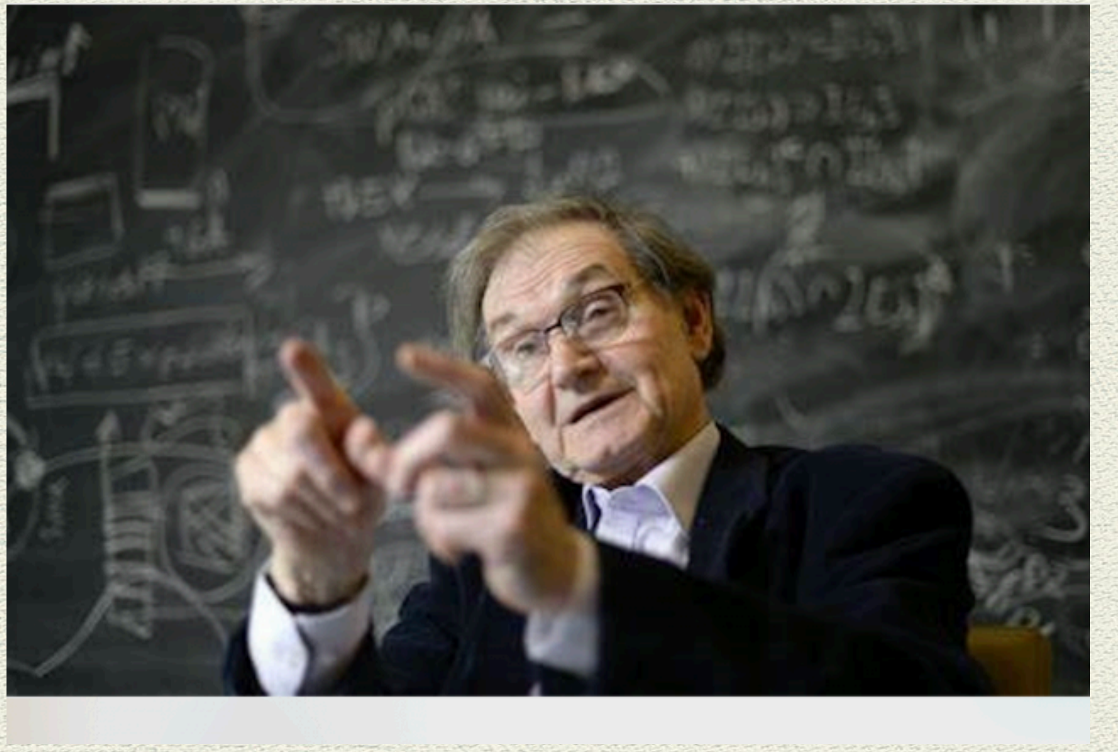
$$ds^2 = (1 - \frac{R_s}{r})c^2dt^2 - \frac{dr^2}{1 - \frac{R_s}{r}} - r^2d\Omega^2$$

$$R_s = \frac{2GM}{c^2}$$



Black hole has no matter inside it

Singularity Theorems



Roger Penrose and Steven Hawking

No Hair Theorem

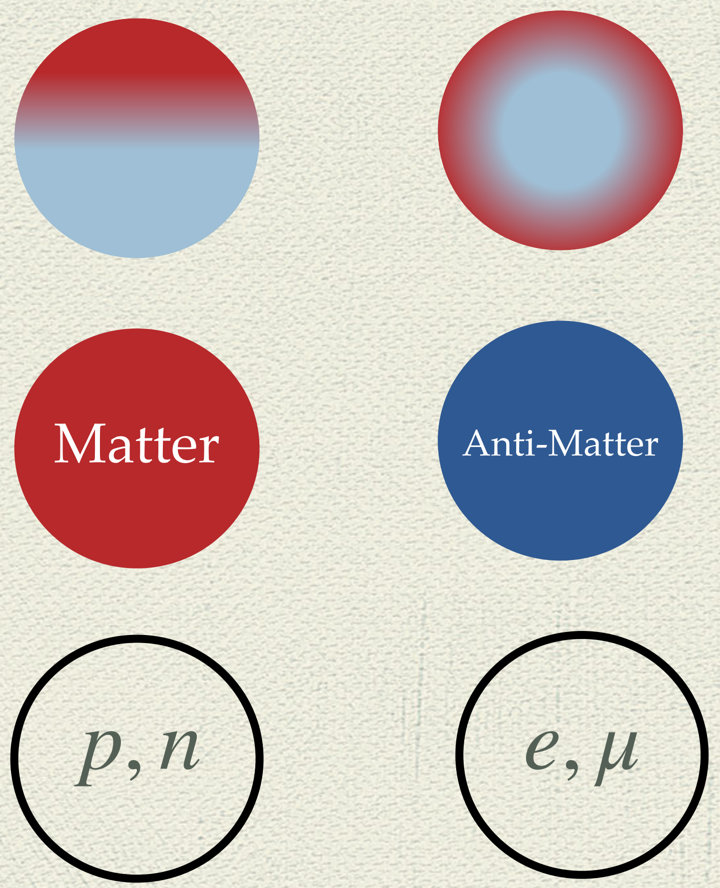
The spacetime outside horizon depends only on

Mass (M), Charge (Q) and Angular Momentum (J)

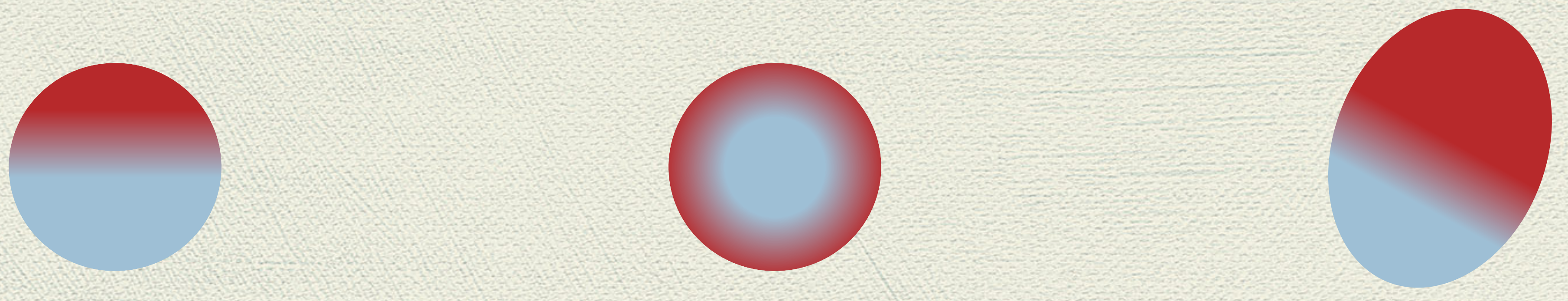
Independent of mass and charge distribution

Independent of matter or anti-matter

Independent of baryon or lepton number

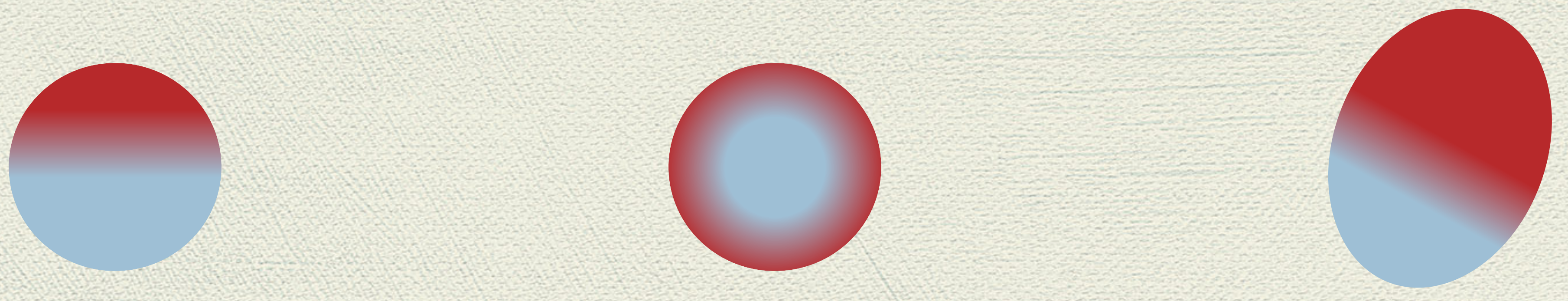


Why this is unexpected?

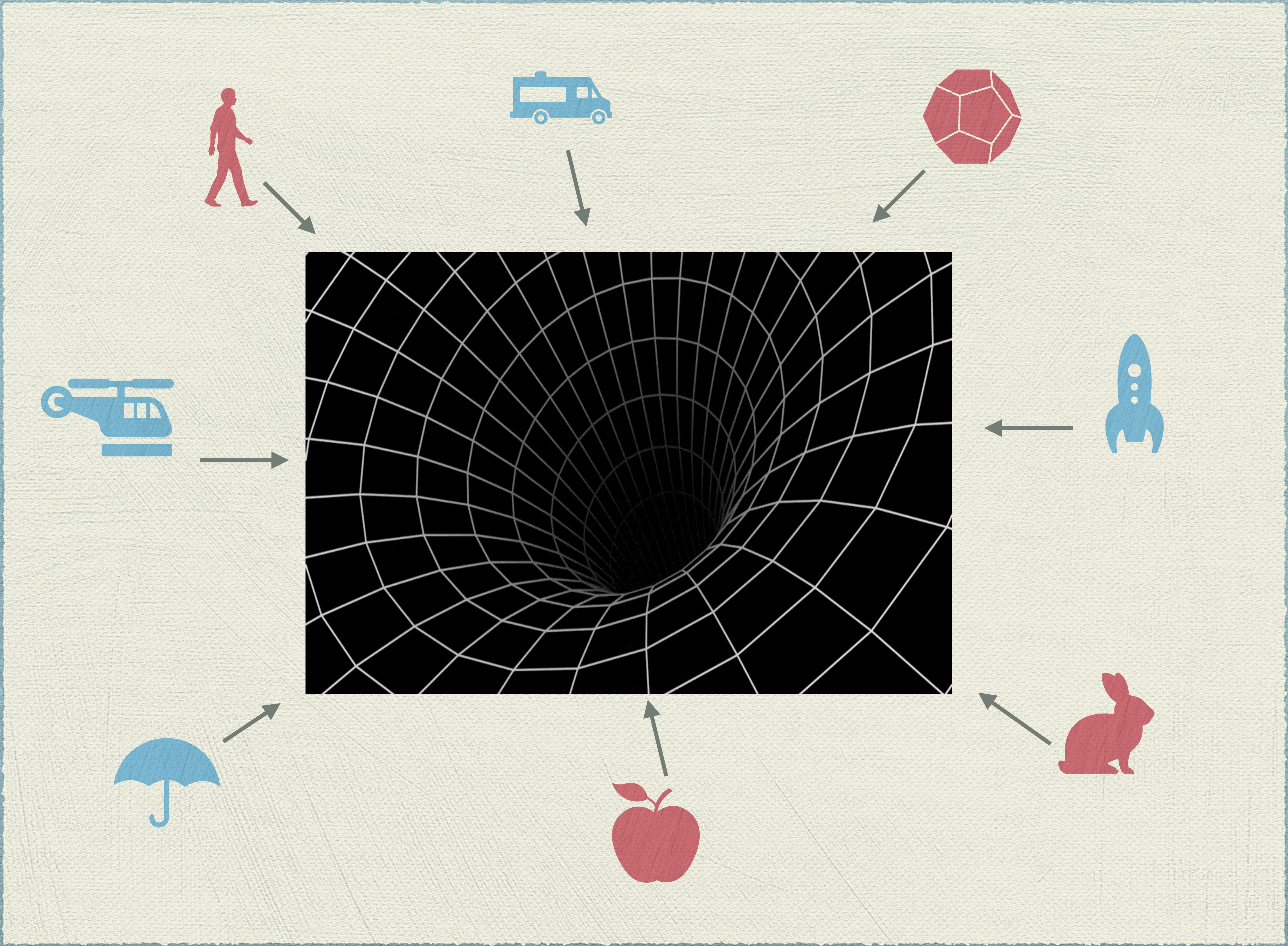


No matter how the matter collapses,
the final spacetime around the black hole does not depend on the original distribution.

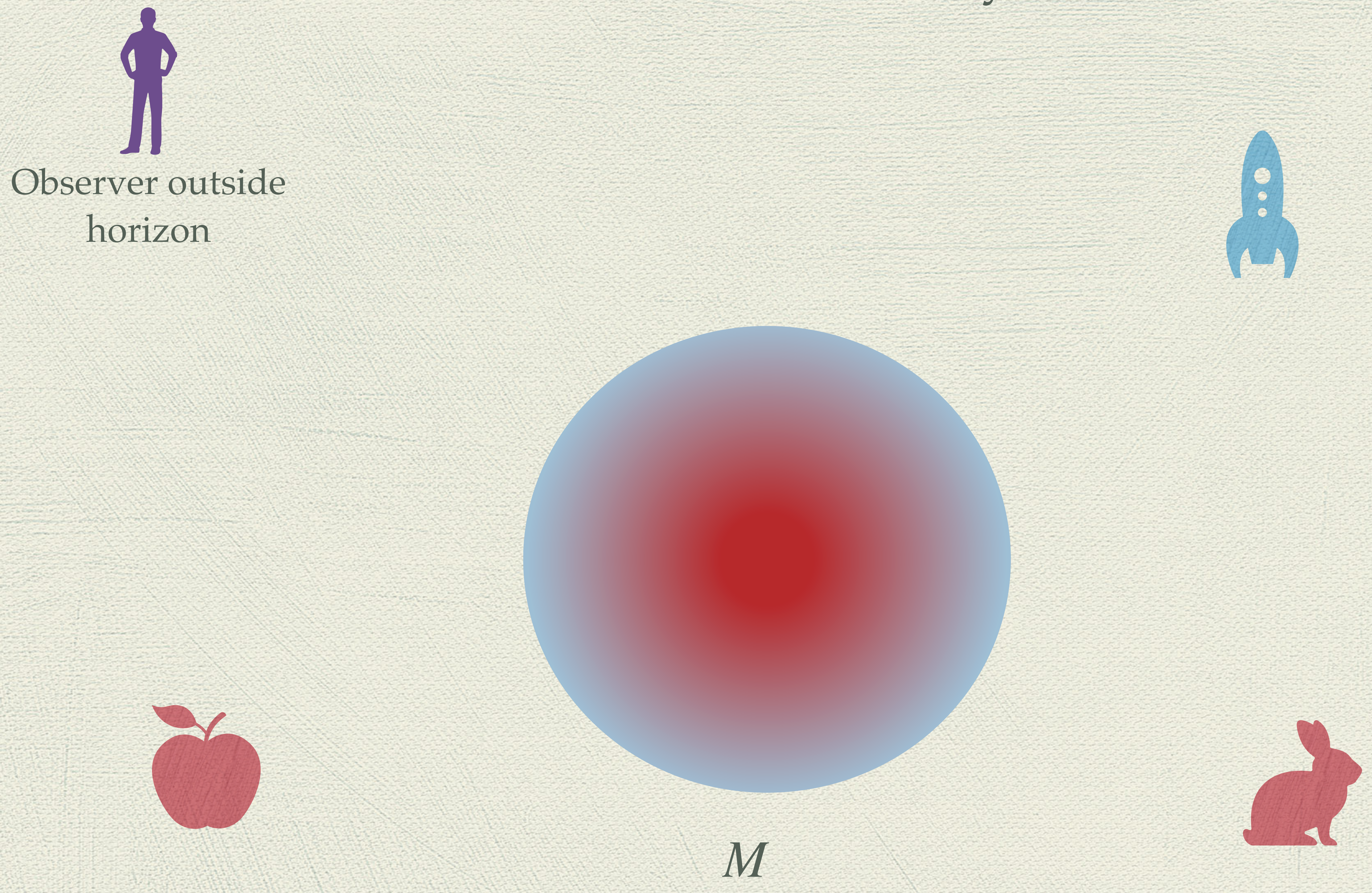
Why this is important?



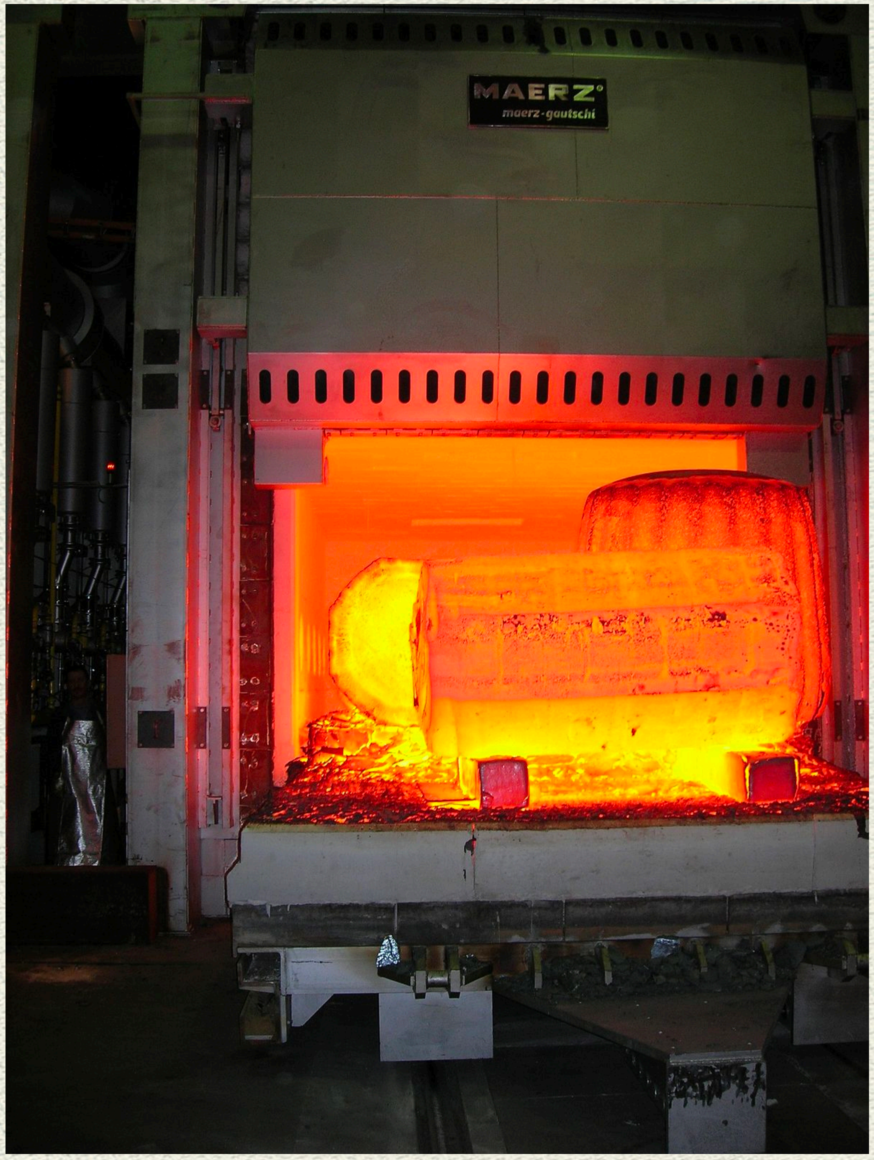
Because all the information is lost!



Conflict with Unitarity

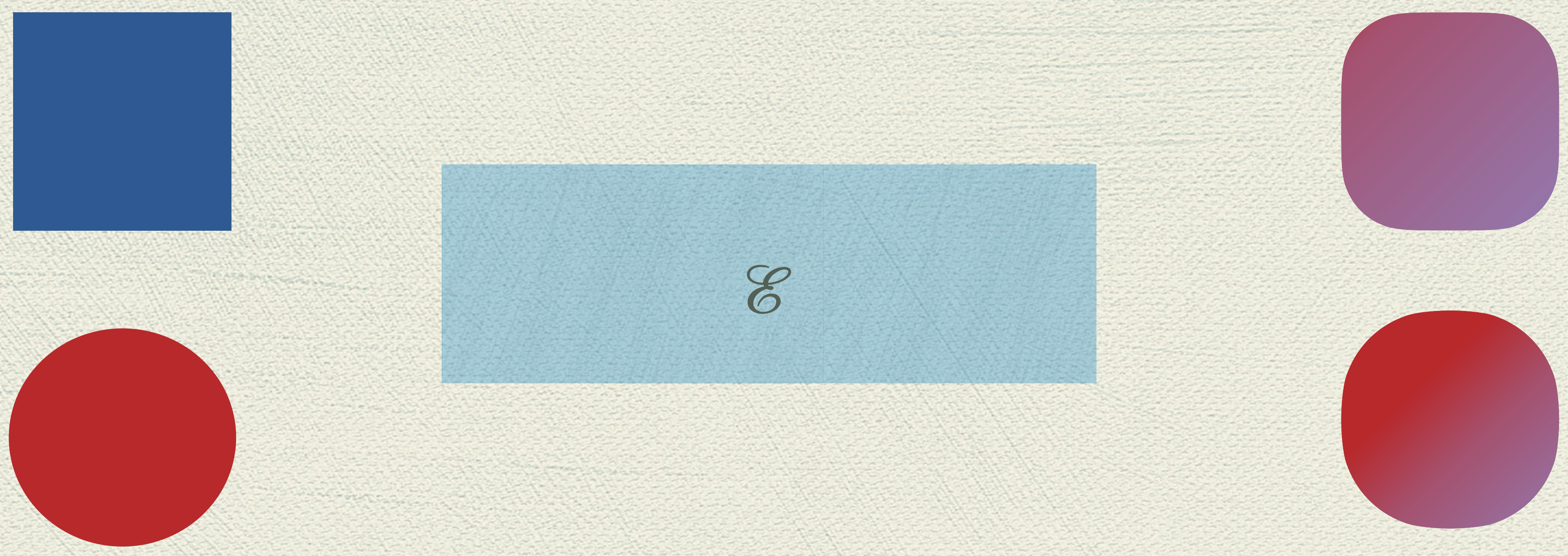


Q: Don't we have the same thing in everyday life?



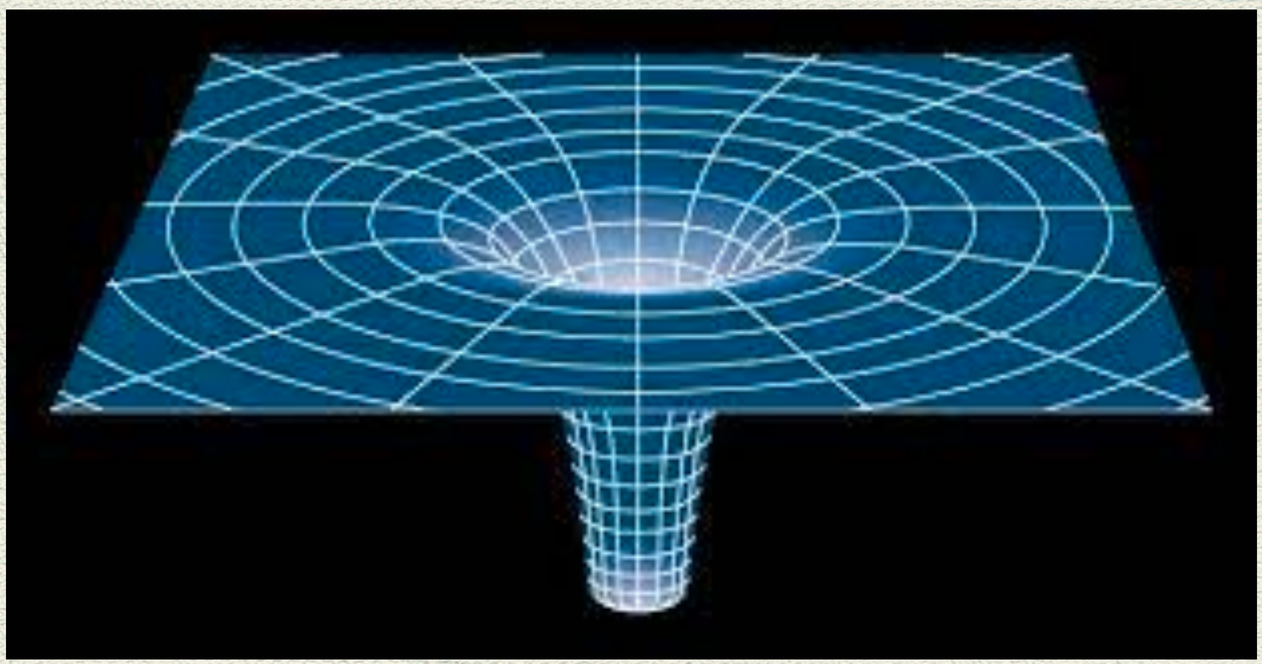
A: We are not talking about a multitude of particles.
This happens even at the microscopic level?

Q: Don't we have the same thing in quantum operations?



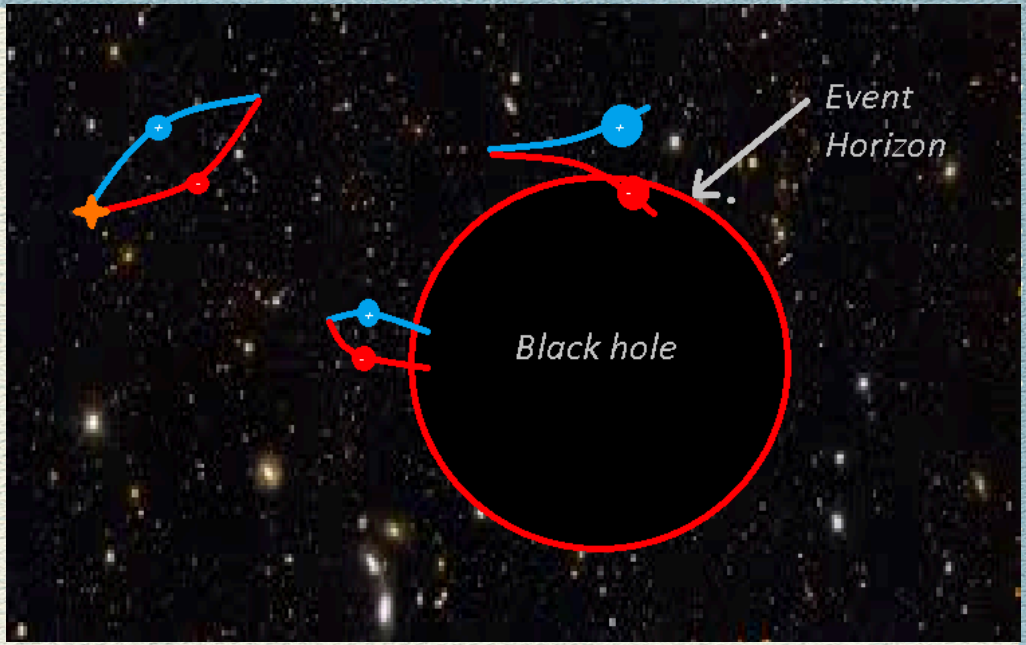
$$F(\mathcal{E}(\rho), \mathcal{E}(\sigma)) \geq F(\rho, \sigma)$$

A: Yes, but there is no environment here.



Any object + Black hole of mass m → Black hole of mass M

Moreover: Black hole evaporates!



1-Quantum Field Theory in curved space time

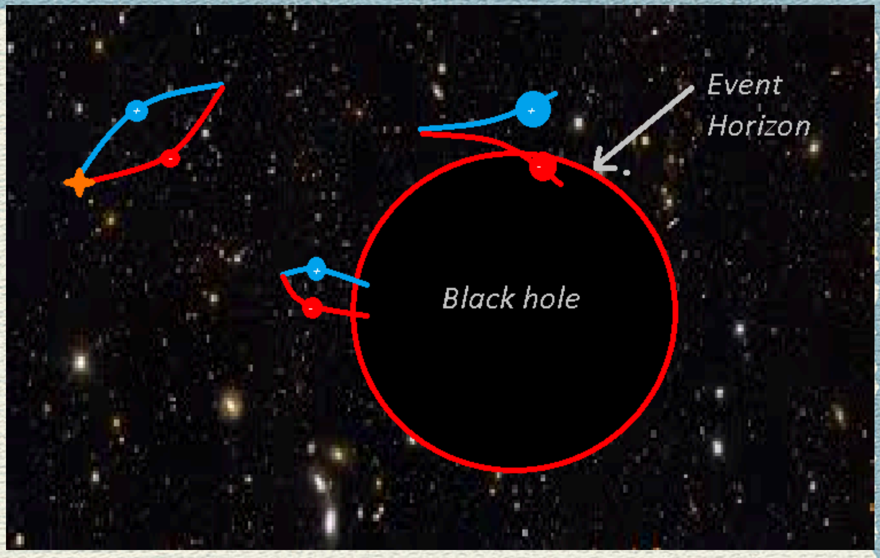
2-Extreme Gravity near the horizon
which changes virtual particles to real particles

3-Entanglement

↓

Hawking radiation

$$T = \frac{\hbar c^3}{8\pi G k\ M}$$



$$T = \frac{\hbar c^3}{8\pi G k\ M}$$

1-Large black holes are cooler

2-The black hole becomes hotter as it radiates

3-In natural units: $\hbar = c = G = k = 1$

$$T = \frac{1}{8\pi M}$$

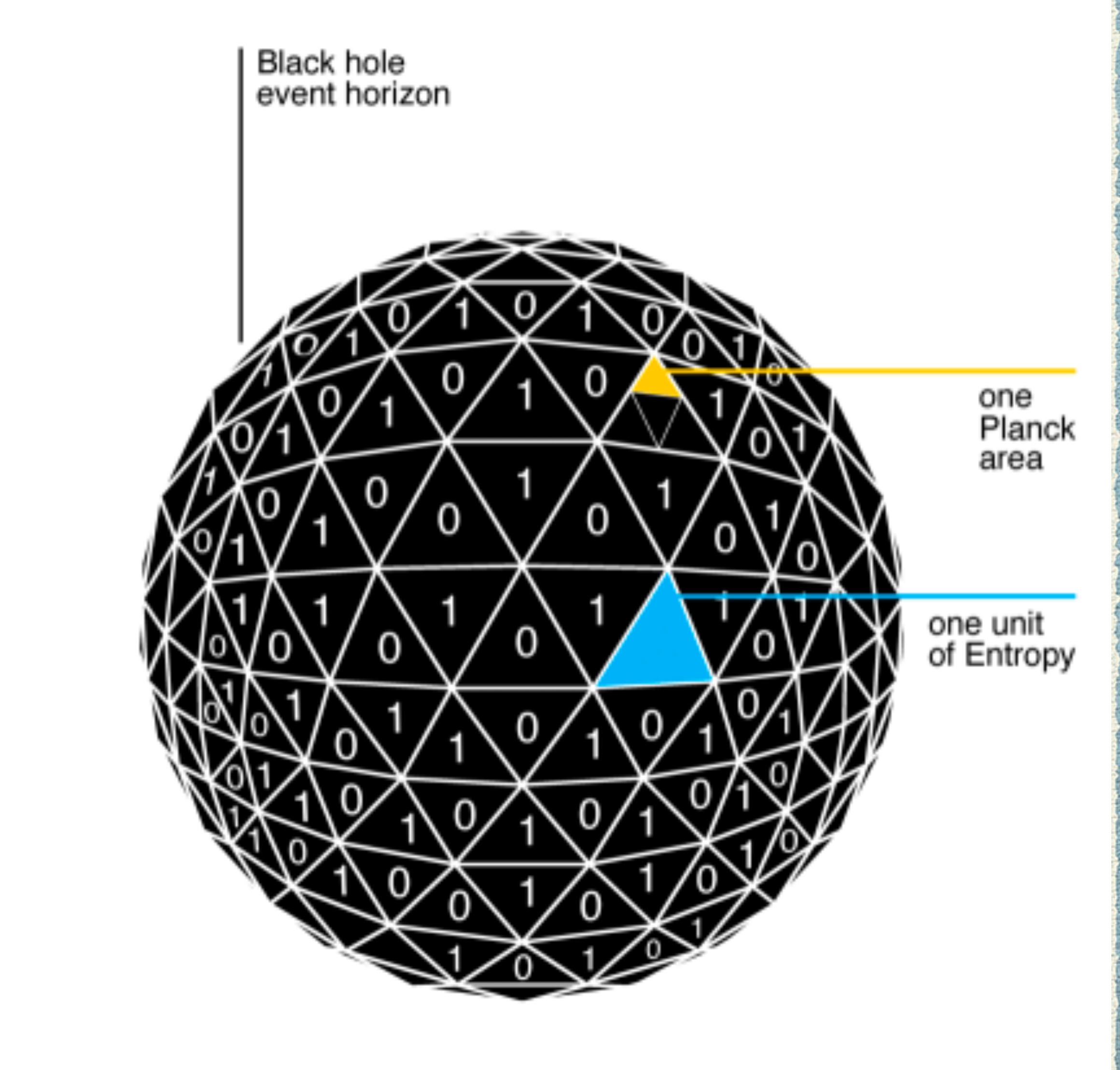
$$dS = \frac{dQ}{T} = 8\pi M\ dQ = 8\pi M\ dM$$

$$S = 4\pi M^2$$

$$S = 4\pi M^2$$

$$R_s = \frac{2GM}{c^2} \longrightarrow R_s = 2M \longrightarrow S = \pi R_s^2 \longrightarrow S = \frac{A}{4}$$

This result agrees with Beckenstein's bound



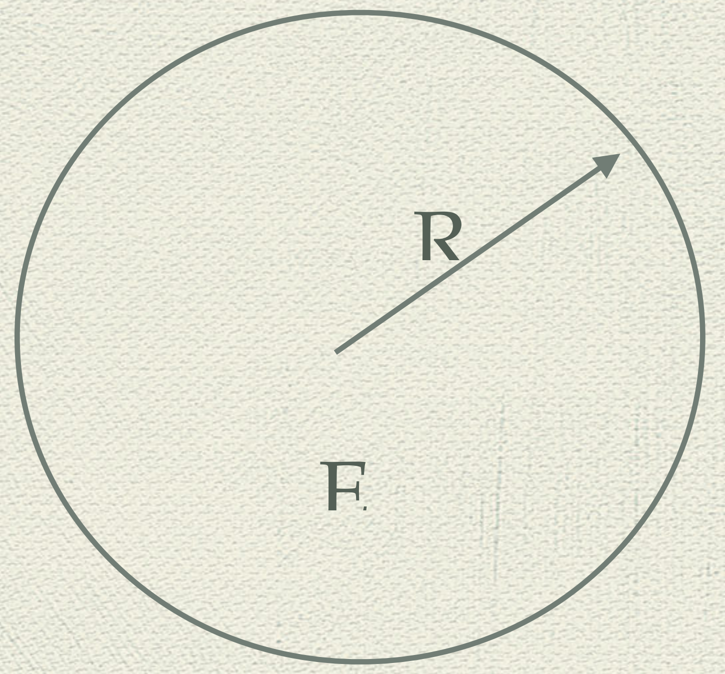
Beckenstein Bound

Quantum Field Theory in Curved Spacetime

Maximum entropy in any region of space $$S \leq \frac{2\pi k\ R\ E}{\hbar\ c}$$

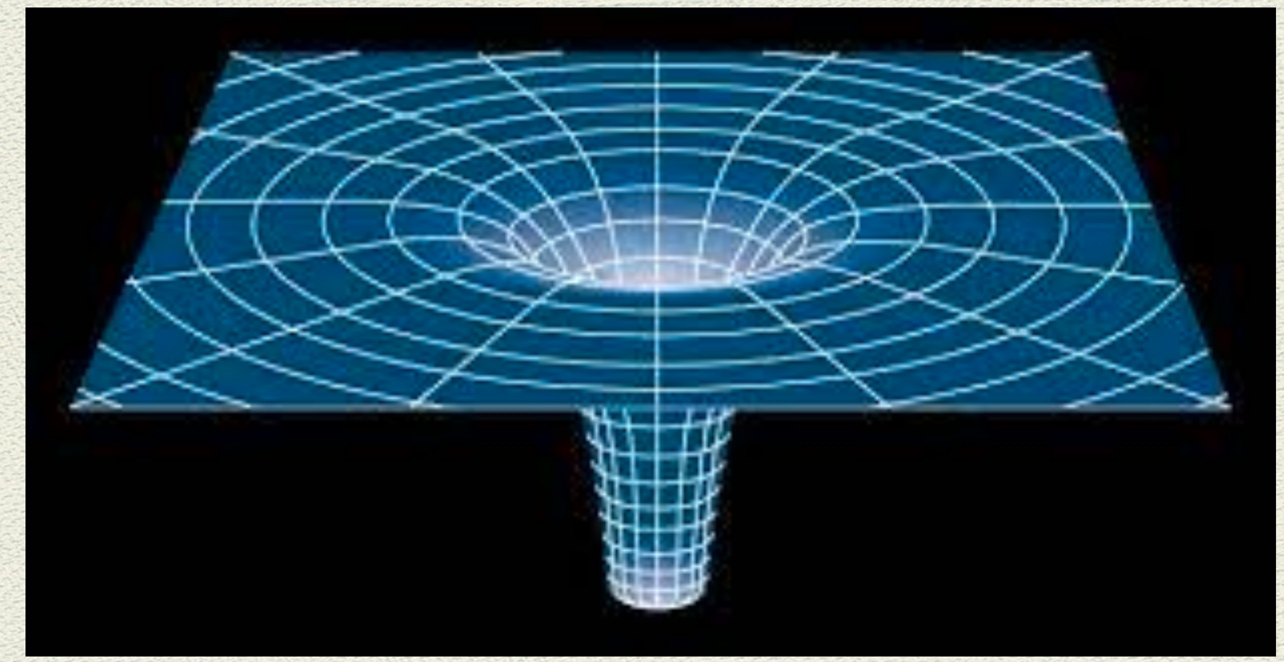
$$I = \log \Omega = \frac{\ln \Omega}{\ln 2} = \frac{k \ln \Omega}{k \ln 2} = \frac{S}{k\ \ln 2}$$

$$I \leq \frac{2\pi\ R\ E}{\hbar\ c\ \ln 2}$$



The maximum information inside a black hole

$$S \leq \frac{2\pi k \; R \; E}{\hbar \; c}$$



$$S \leq \frac{2\pi k \; R_s \; Mc^2}{\hbar \; c}$$

$$R_s = \frac{2GM}{c^2}$$

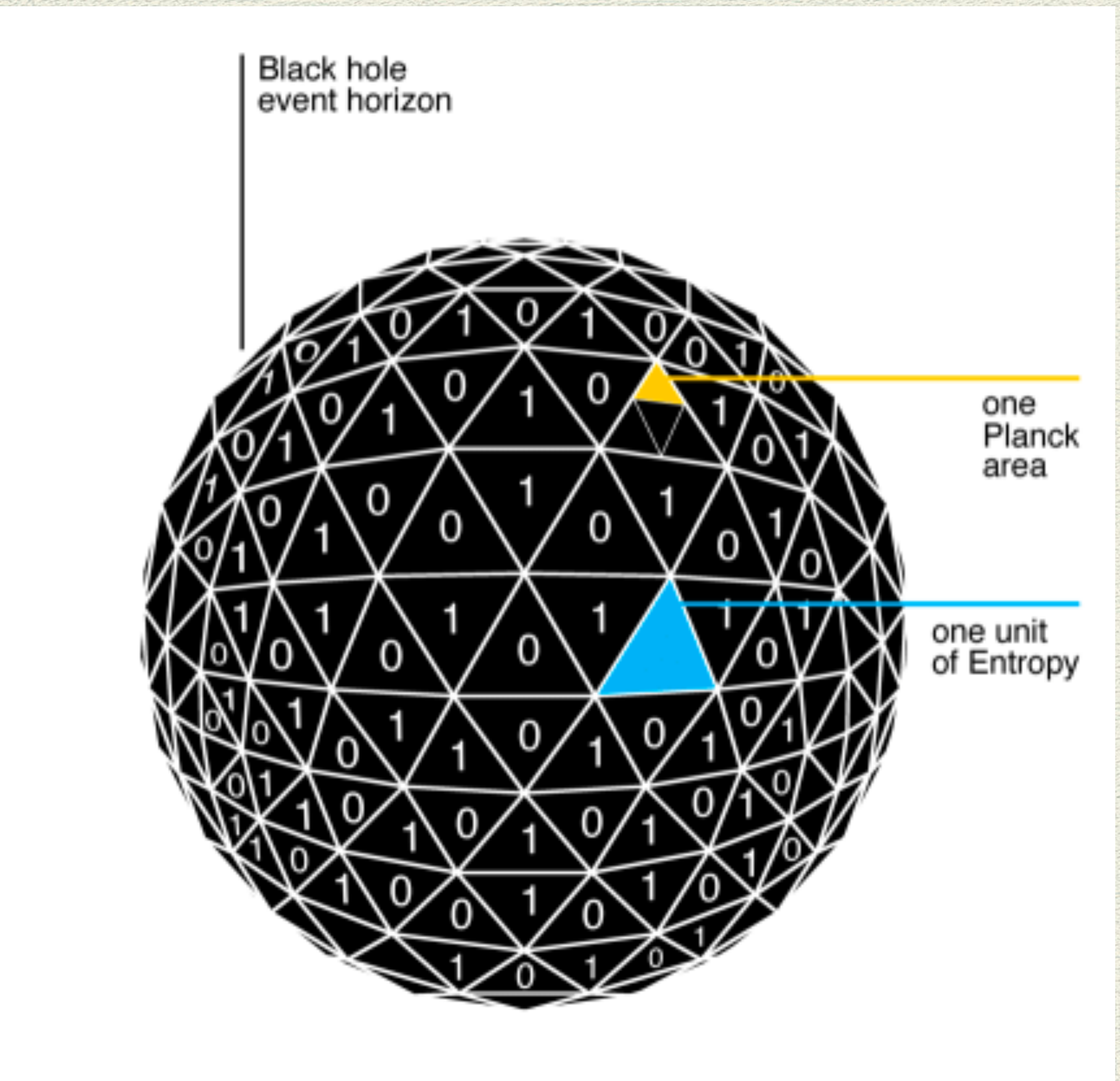
$$S \leq \frac{\pi k \; R_s^2}{\frac{G\hbar}{c^3}} \sim \frac{k \; A}{4 \; l_p^2}$$

$$I \leq \frac{A}{4 \; l_p^2}$$

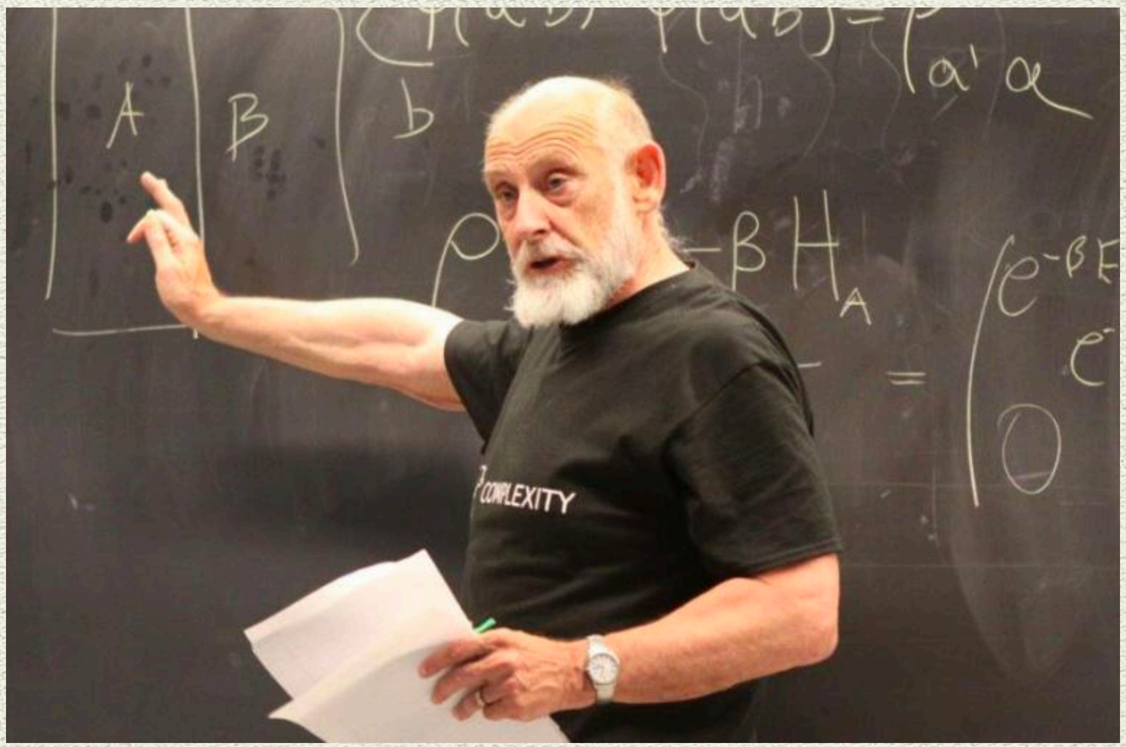
Conjecture: Information is carved on the surface of the black hole

$$S \leq \frac{\pi k \ R_s^2}{\frac{G\hbar}{c^3}} \sim \frac{k \ A}{4 \ l_p^2}$$

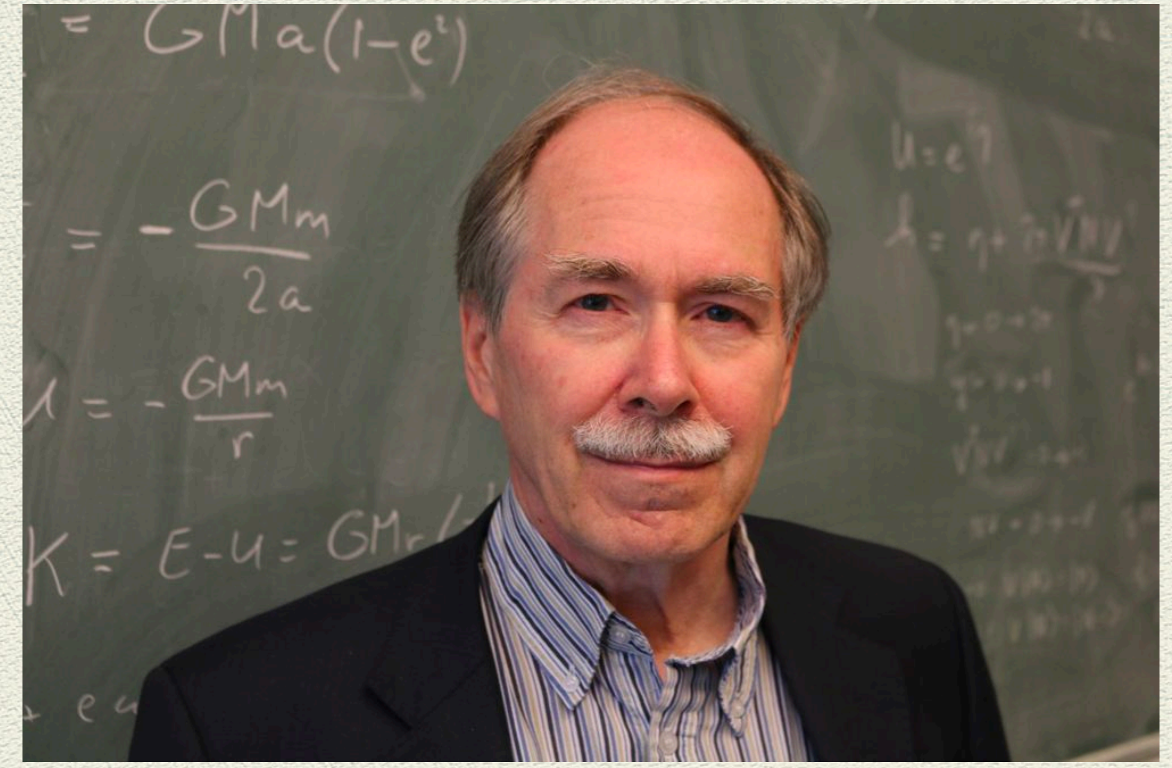
$$I \leq \frac{A}{4 \ l_p^2}$$



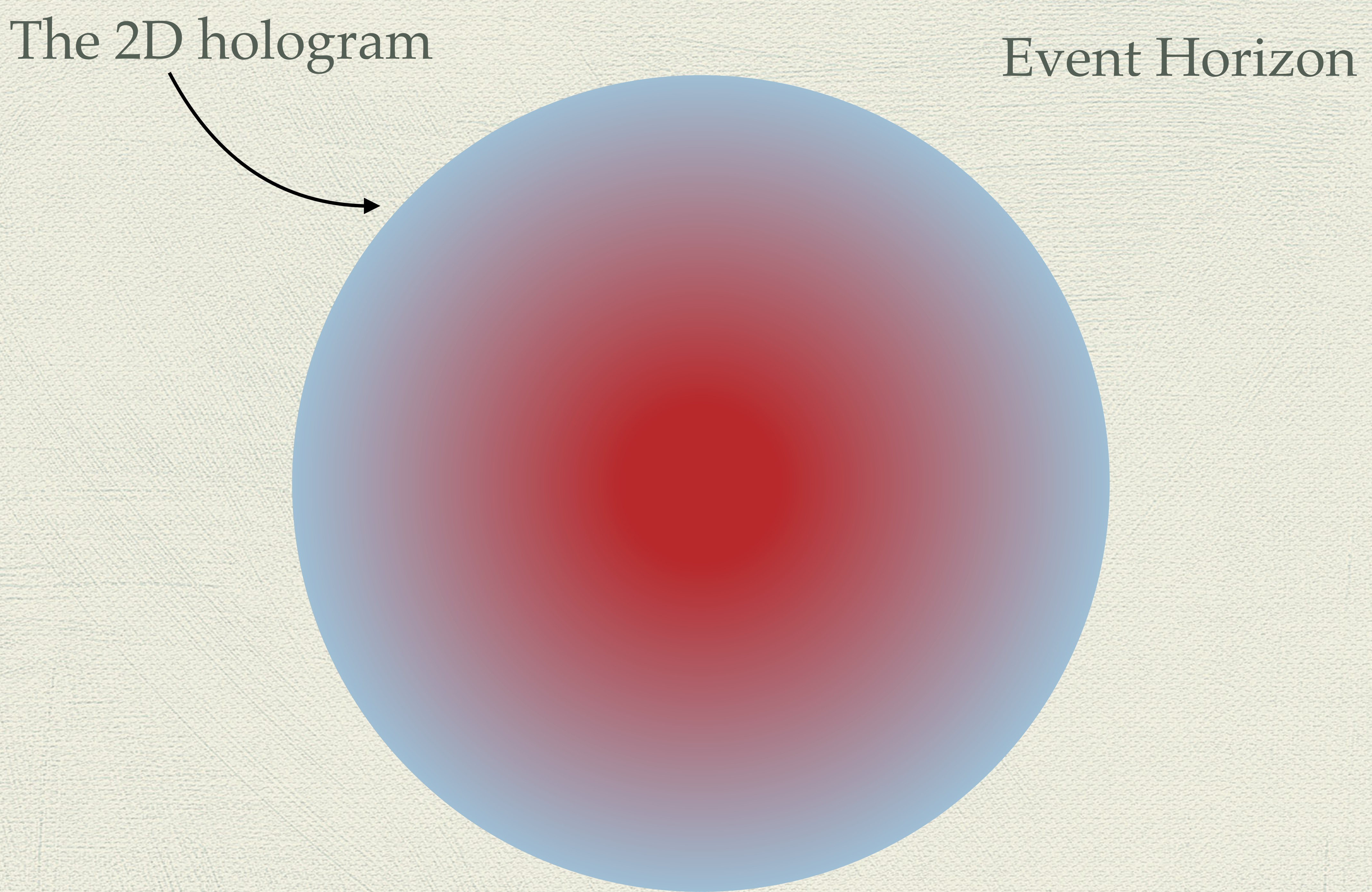
Holography



Susskind



t'Hooft



Holographic Principle

End of part I