From Einstein to Hawking : A journey through spacetime

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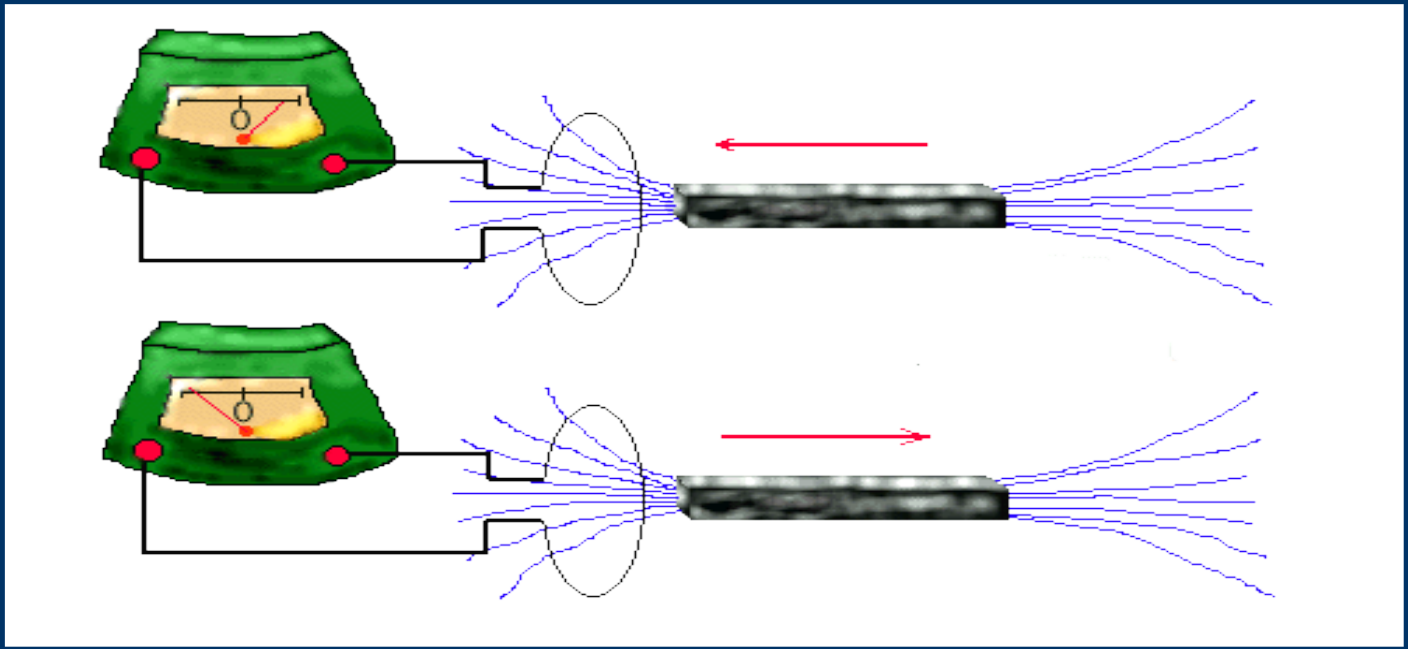
Half a century of time travel

- Special Relativity
- Light and quanta
- General Relativity
- Big Bang and Black Holes
- Quanta and Black Holes

Shrinking rods

- Current carrying loop is a magnet
- Moving magnet creates current



Relativity of motion

- Should the loop move or the magnet?
- Should charge move or the field?

Relativity of motion

- Galelio's dialogue
  - chess on a moving riverboat.

Relativity of motion

- Forced and unforced motion
- Aristotle had philosophised that uniform motion also required a “force”

Relativity of motion : shrinking rods

- Lorentz's solution
  - Fields are not directly observed
  - Acceleration is directly observed
- Fields must look different to different observers
- ... But also the length of a wire has to contract

The conservative solution

- Give up rigid lengths

$$L = L_0 \sqrt{1 - \frac{v^2}{c^2}}$$

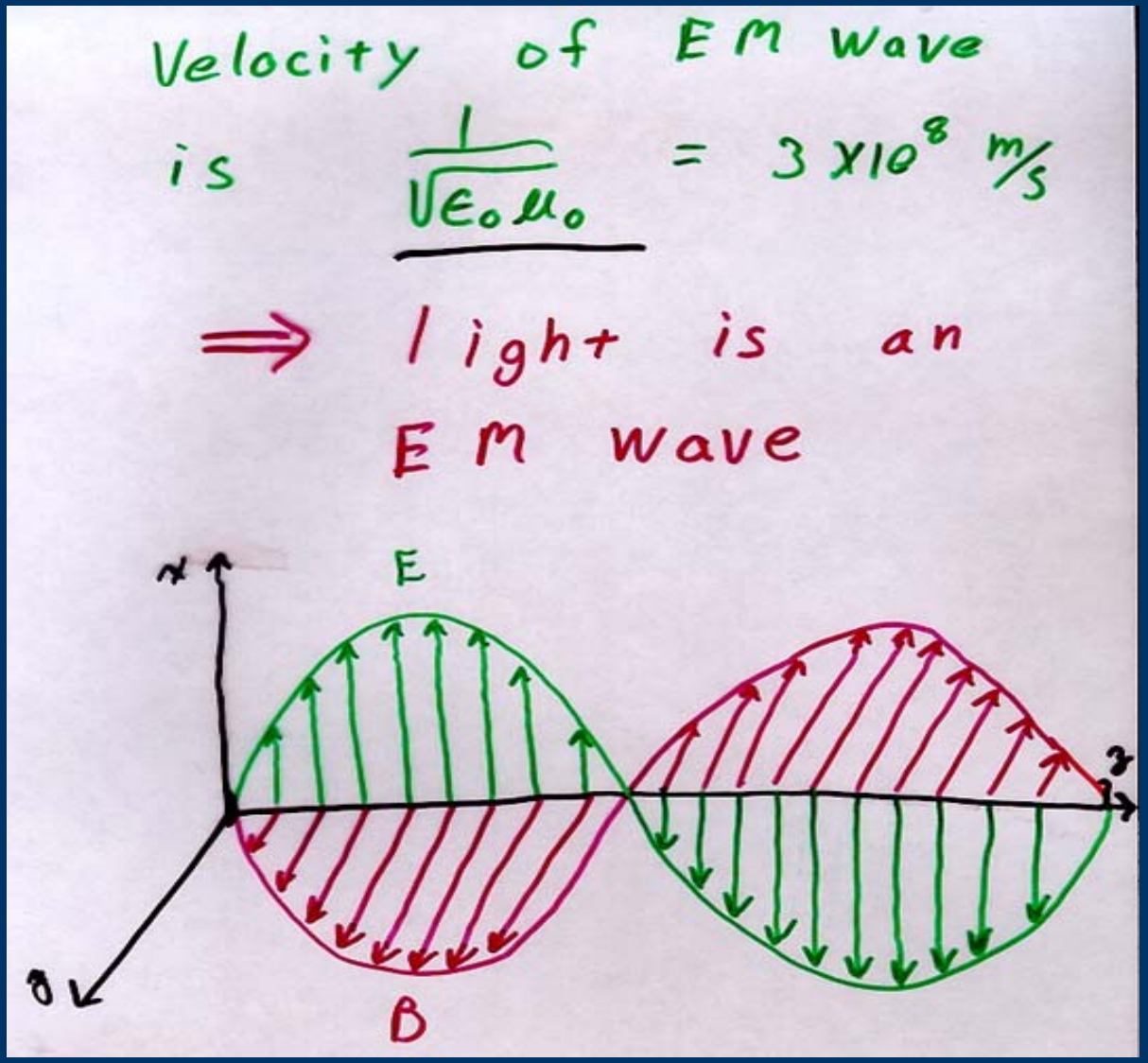
- Also give up relativity !!!

Lazy clocks

- Clocks must slow down

$$T = \frac{T_0}{\sqrt{1 - \left(\frac{v}{c}\right)^2}}$$

Electromagnetic waves (Maxwell)



Paradox !!! Paradox !!!

Electromagnetism

Relativity

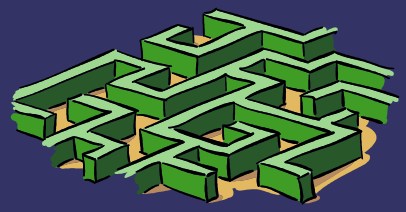
Rigid length

Einstein's solution

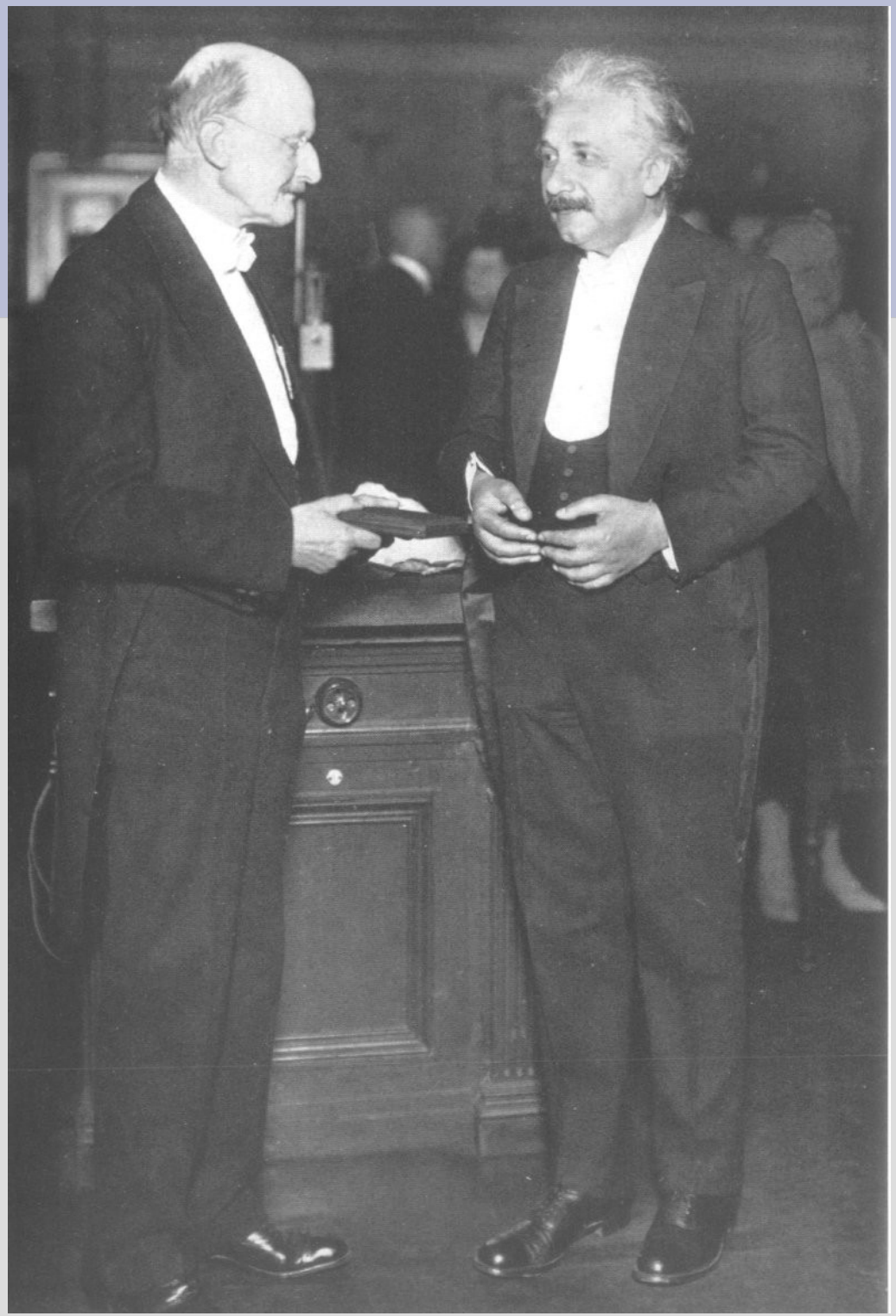
- Relativity principle must be valid
- Laws of electromagnetism must be valid
- Length does not have Pythagorean meaning
- Time does not have Newtonian universality

Einstein's solution

- The speed of light has to be independent of emitter and absorber's state of motion
- ... makes sense since the electric and magnetic constants determining its value have to be same in all frames of reference.



The inveterate adventurer



General Theory of Relativity

Precisely what it was not!!!!

It is not a “generalisation” of Special Relativity!

Or just may be Einstein was right ...

Only new effects so far unknown will decide

General Theory of Relativity

- It is a Relativistic theory of Gravity
- Much like electromagnetism ...
- painfully discovered over two centuries

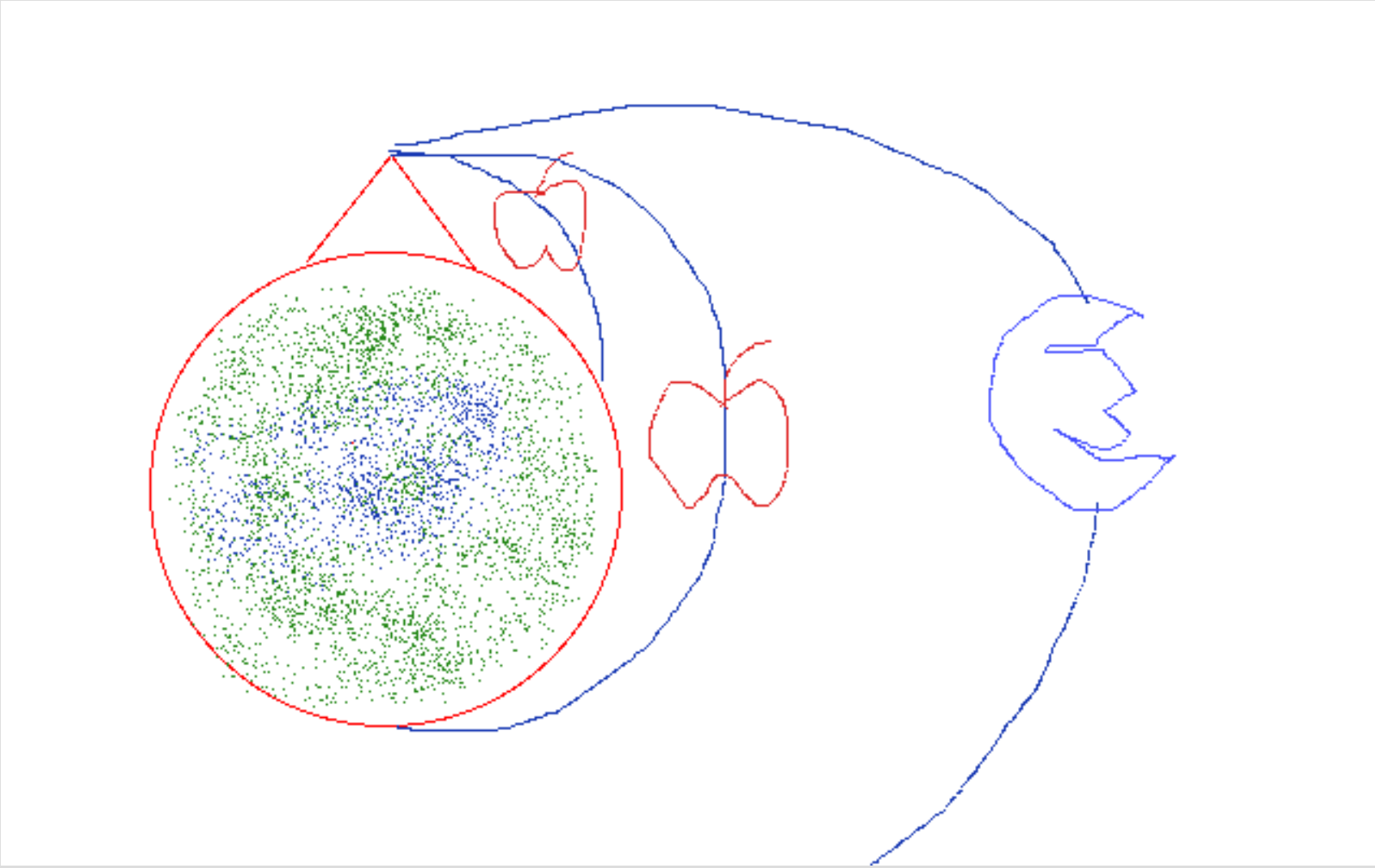
General Relativity

- Newton's Gravity was rigid
- Its effects spread over all space
- Time was universal
- Gravity effects must also be restricted by "speed of light"
- We know two more forces that obey this

General Relativity

- Why we cannot do away with Einstein's point of view
- Gravity is the only of the four forces which is universal ...

Newton : From apple to Moon



Principle of Equivalence

... of inertial and gravitational masses

$$m\,a = F = \frac{q_1 q_2}{[4\pi\epsilon_0]}\,\frac{1}{r^2}$$

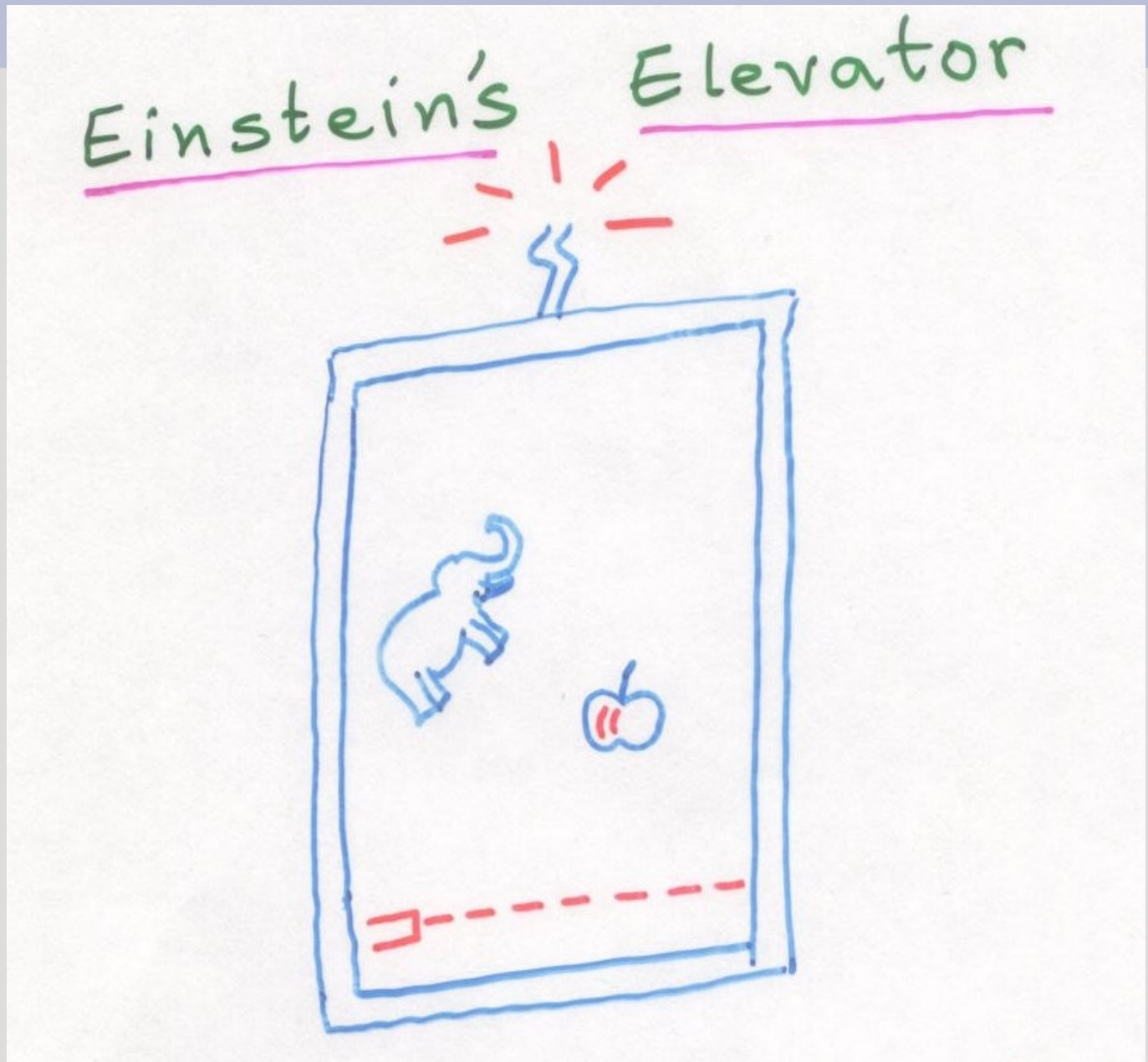
But

$$m\,a = F = G\,m\,m_2 \times \frac{1}{r^2}$$

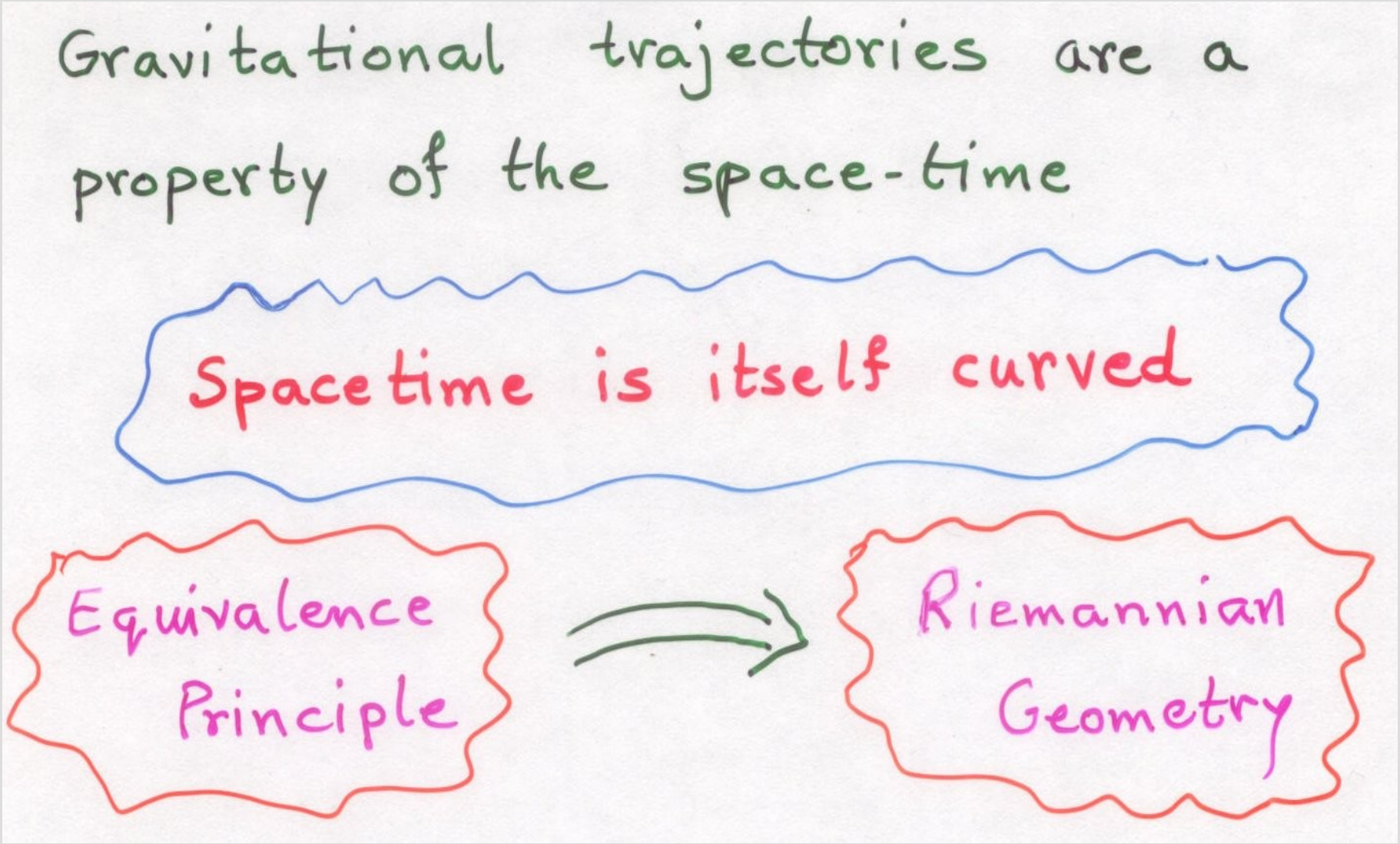
inertial mass

Gravitational "charge"

Principle of Equivalence



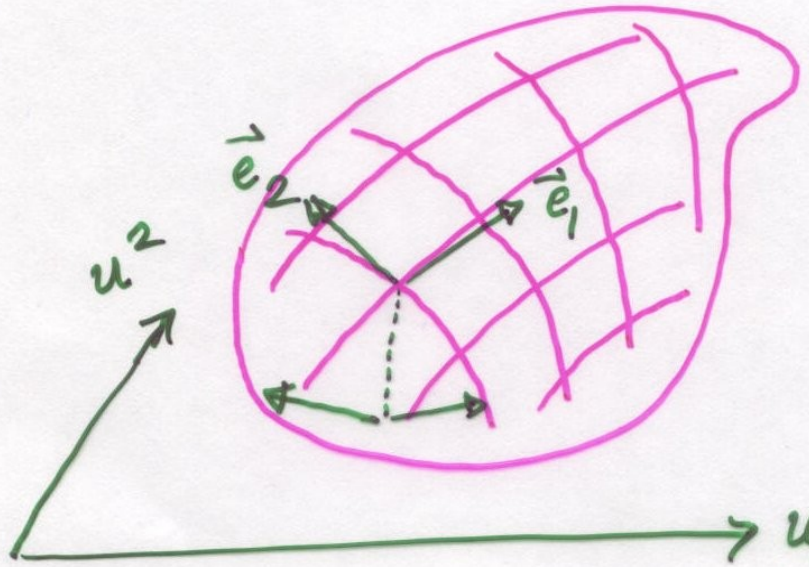
Differential Geometry



Mathematics of curved space-time

Differtial Geometry: [Gauss, Riemann, Levi-Civita]

Study of "curved" spaces using methods of differtial calculus



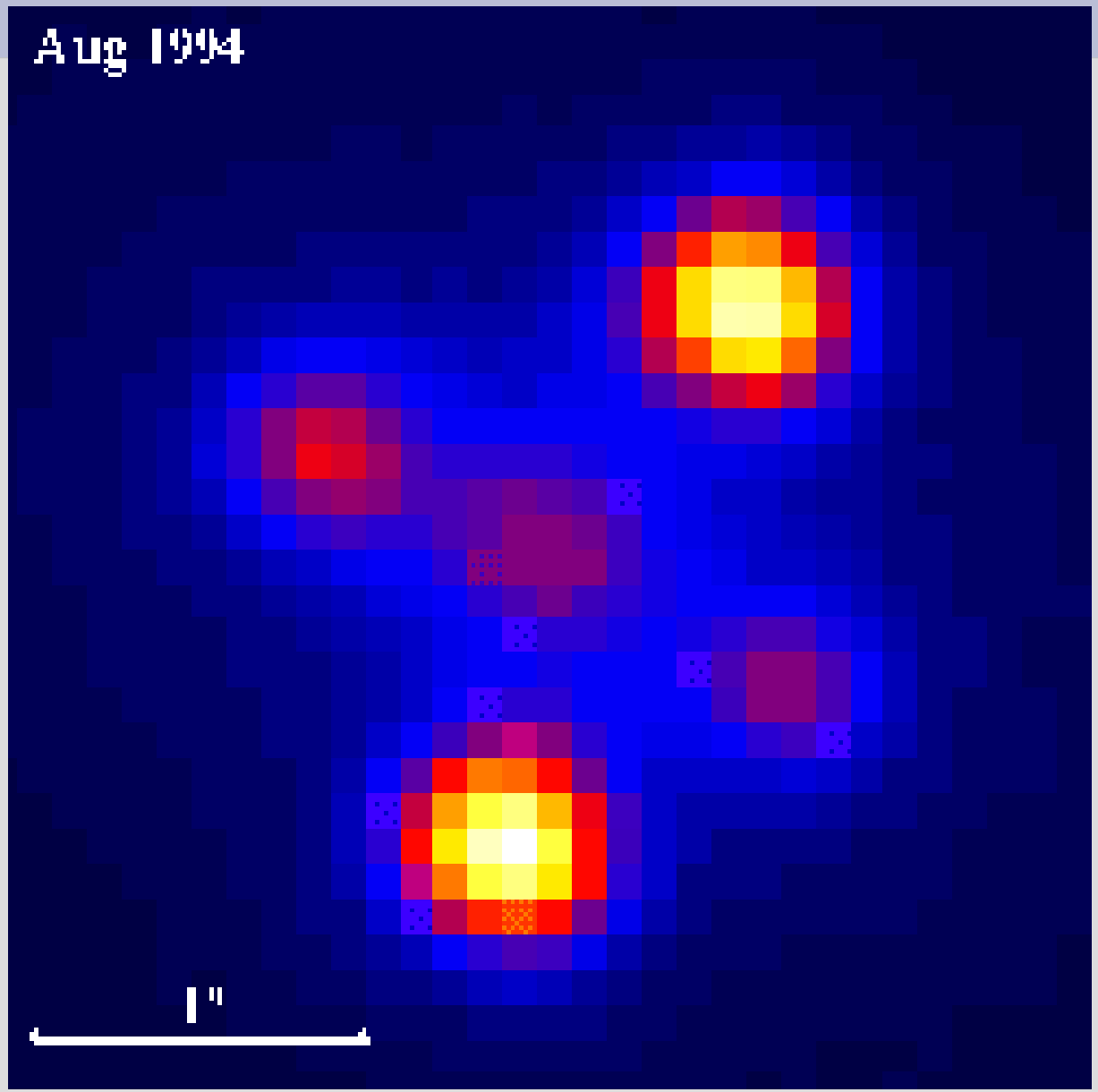
$\vec{e}_1 \cdot \vec{e}_2$ (Pythag.)

$= e_1^x e_2^x + e_1^y e_2^y + e_1^z e_2^z$

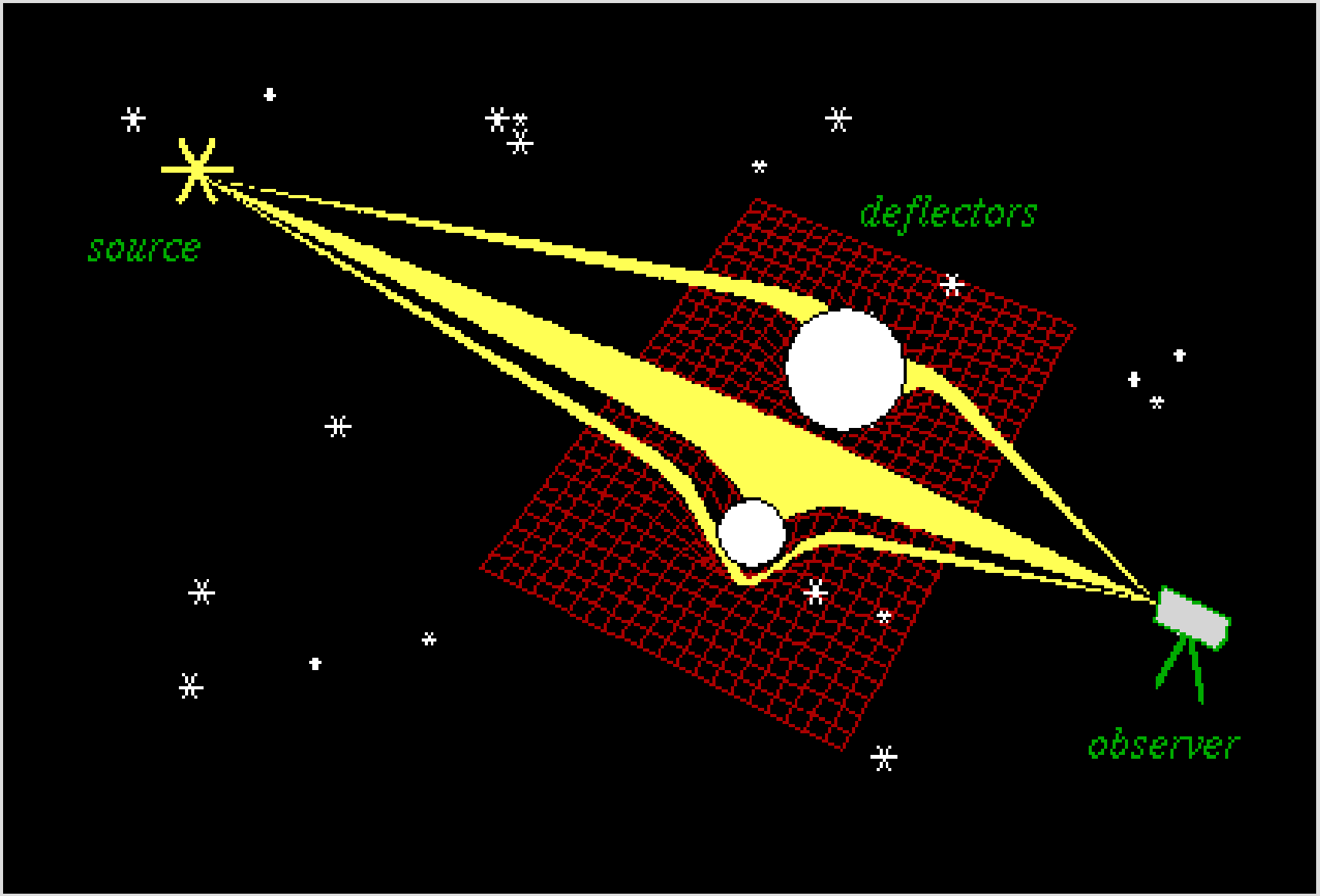
$\vec{e}_1 \cdot \vec{e}_2$ (Gauss)

$= g_{xx} e_1^x e_2^x + g_{yy} e_1^y e_2^y + g_{zz} e_1^z e_2^z$

Bending of Light



Bending of Light



New results about Black Holes

- Gravitational systems are either moving towards a collapse or emerging from a Bang. [Hawking and Penrose 1960 – 63].

Quantum Mechanics of Black Holes

- The strong gravitational field of a Black Hole can cause spontaneous radiation of particle – anti-particle pairs by quantum principles.
- Regardless of what went into the Black Hole, the emerging radiation is completely random [Information loss paradox].

Thank You!!