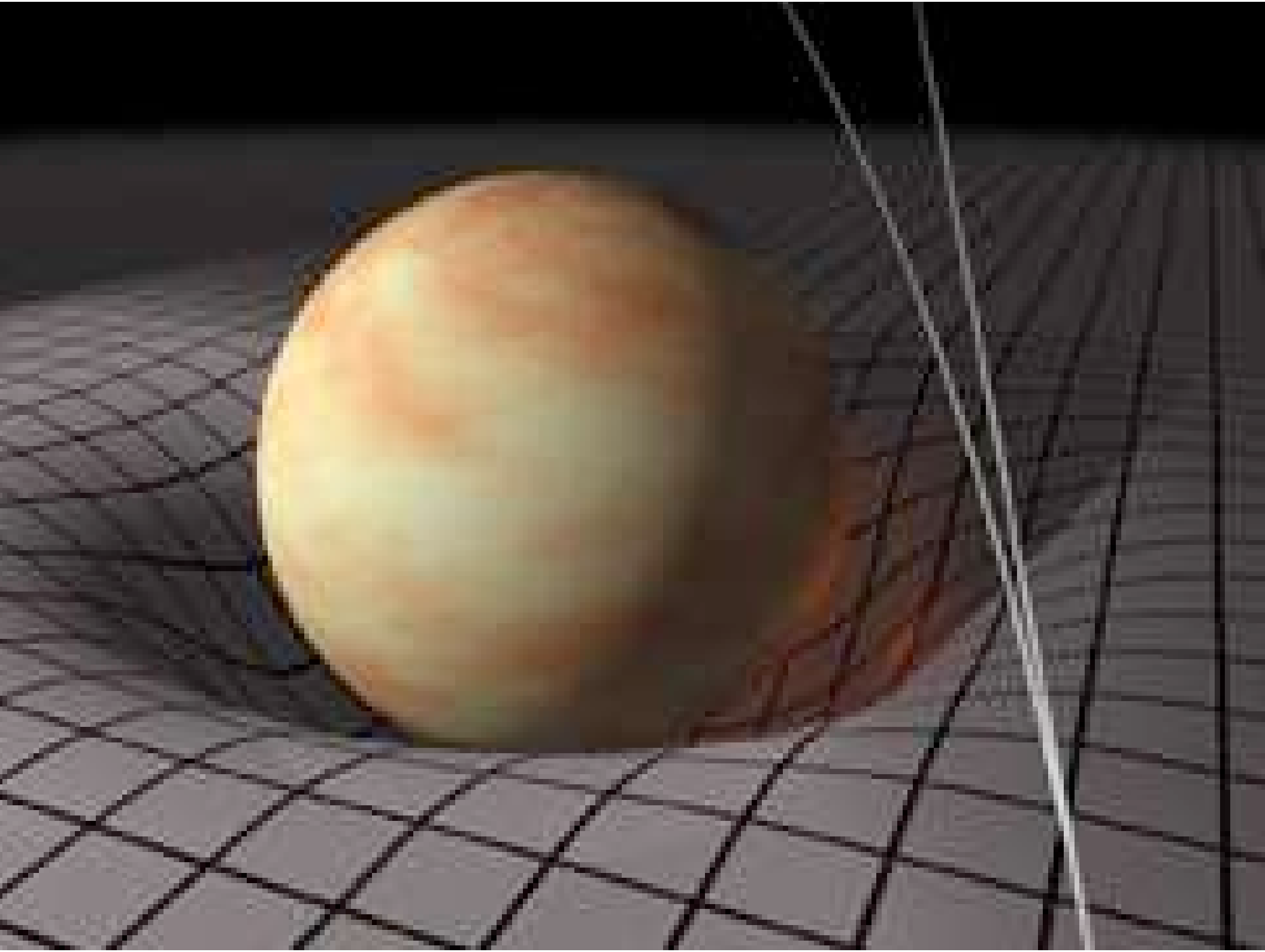
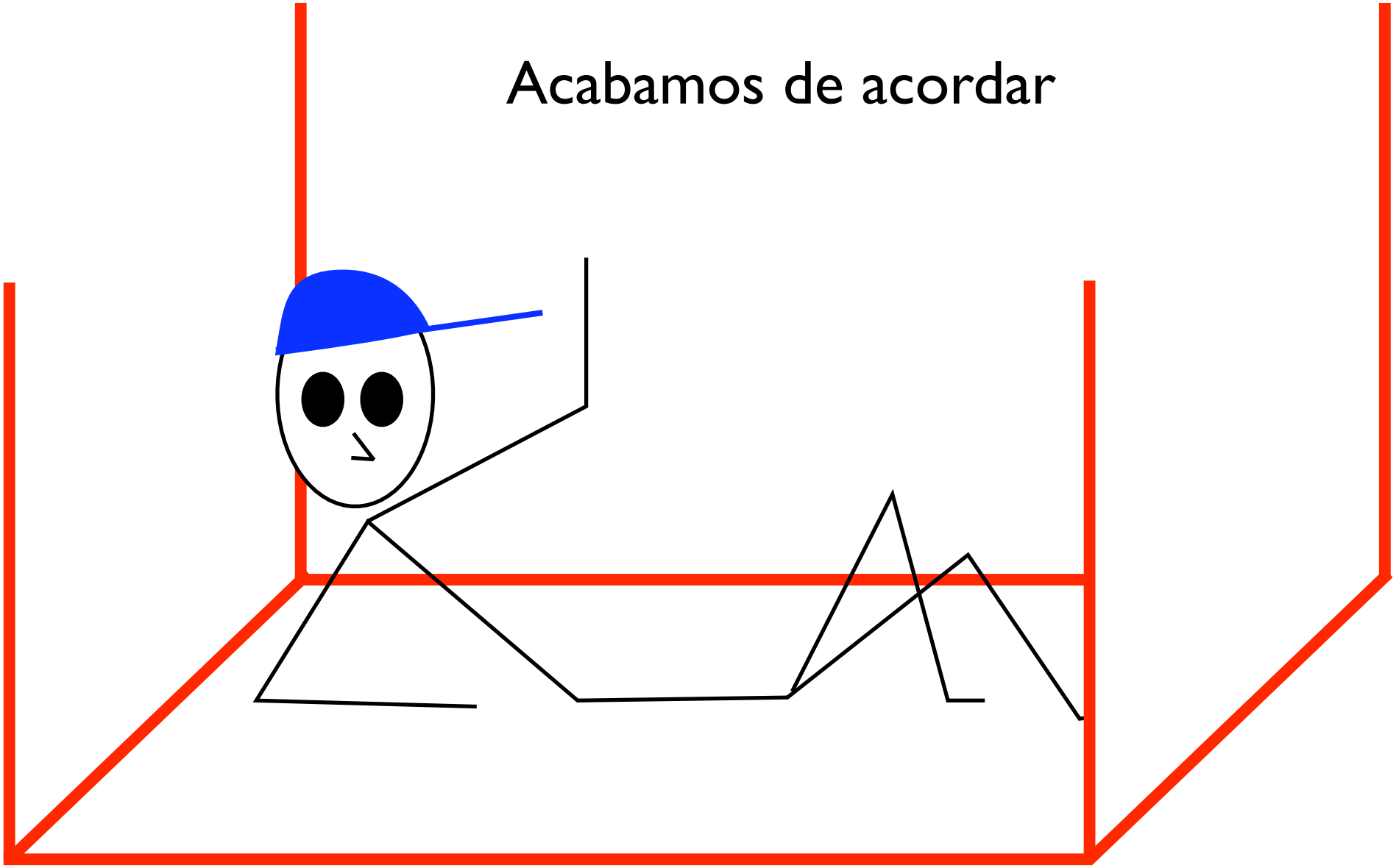
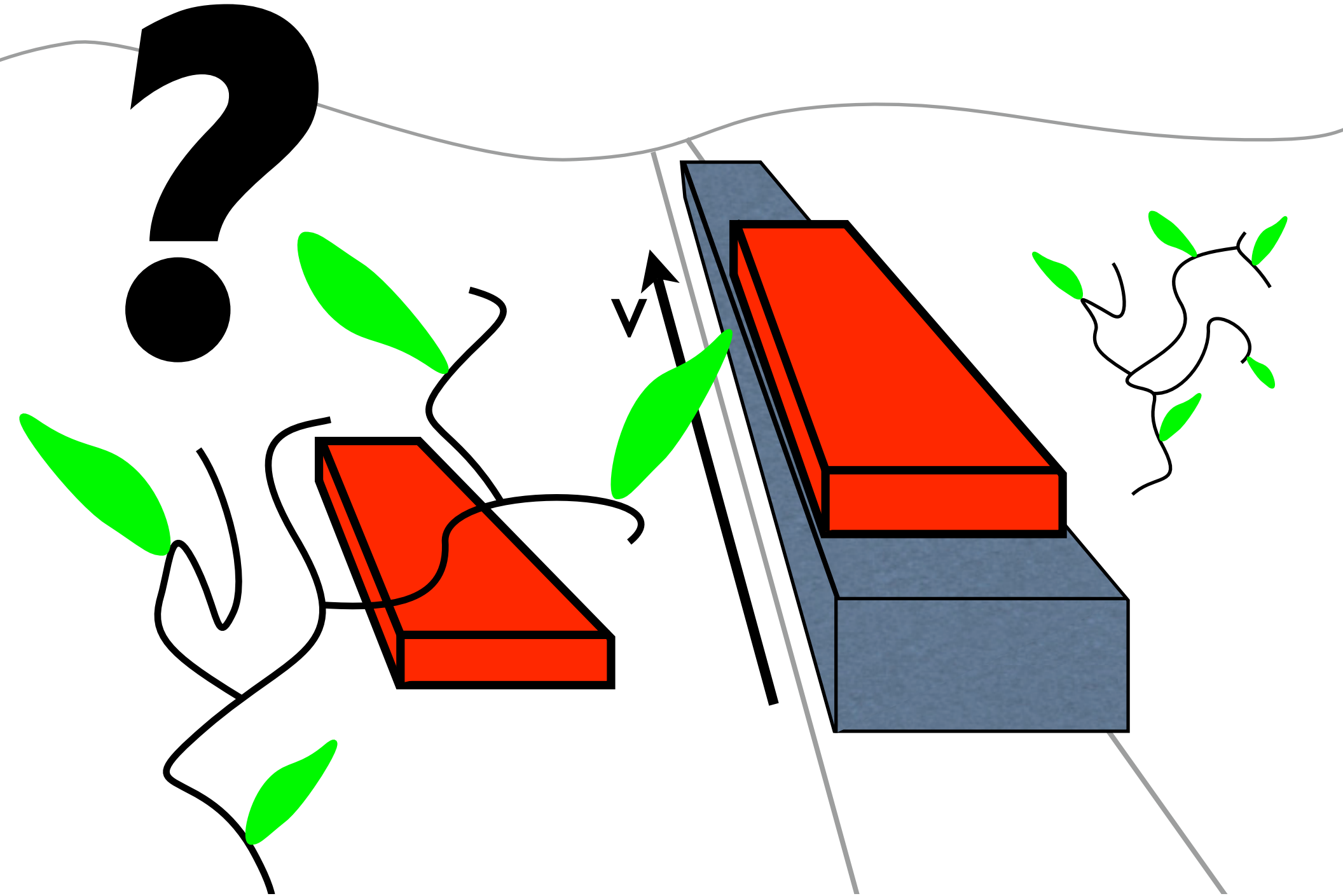
Relatividade Geral



Princípio da equivalência

Acabamos de acordar

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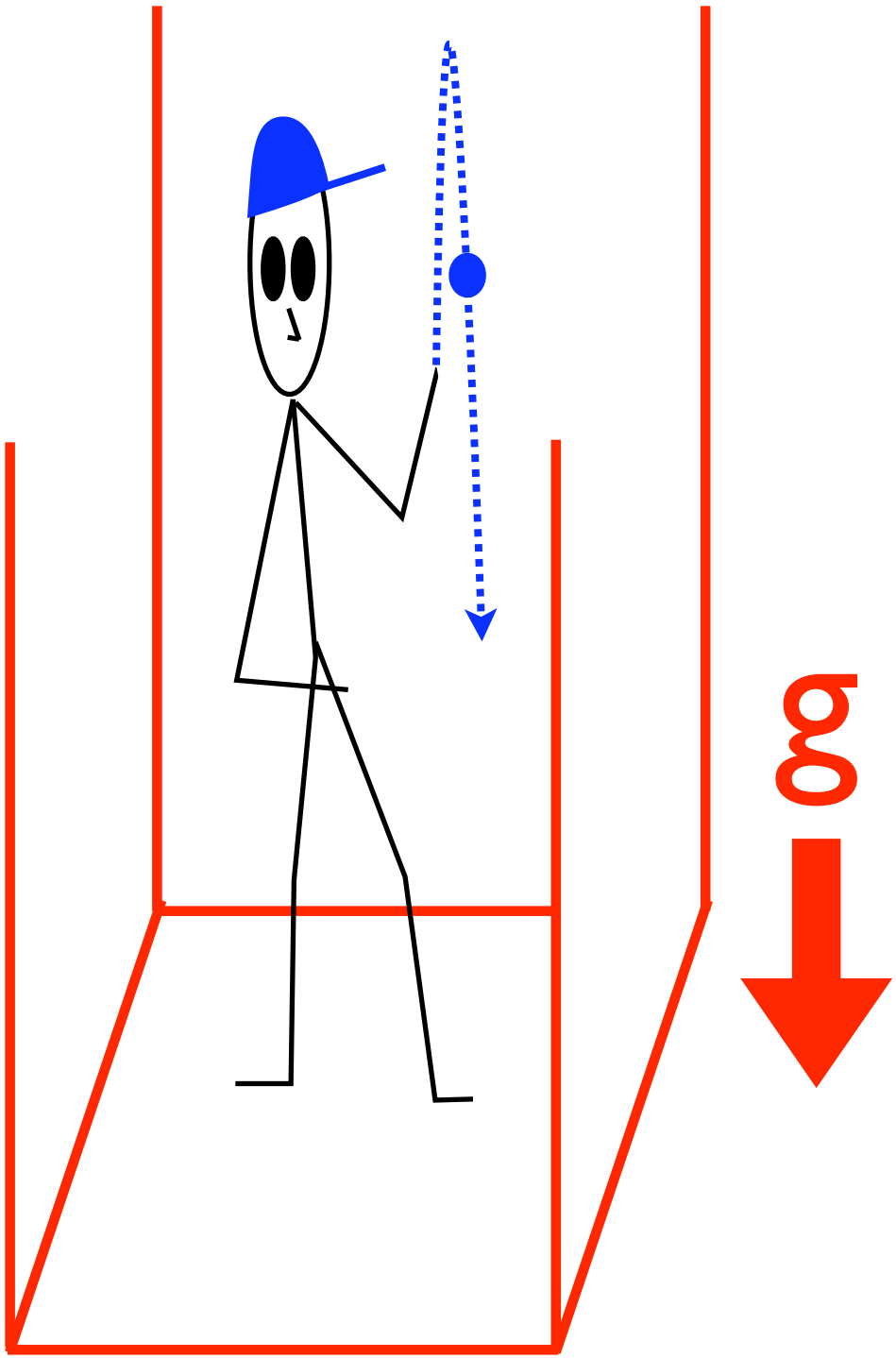
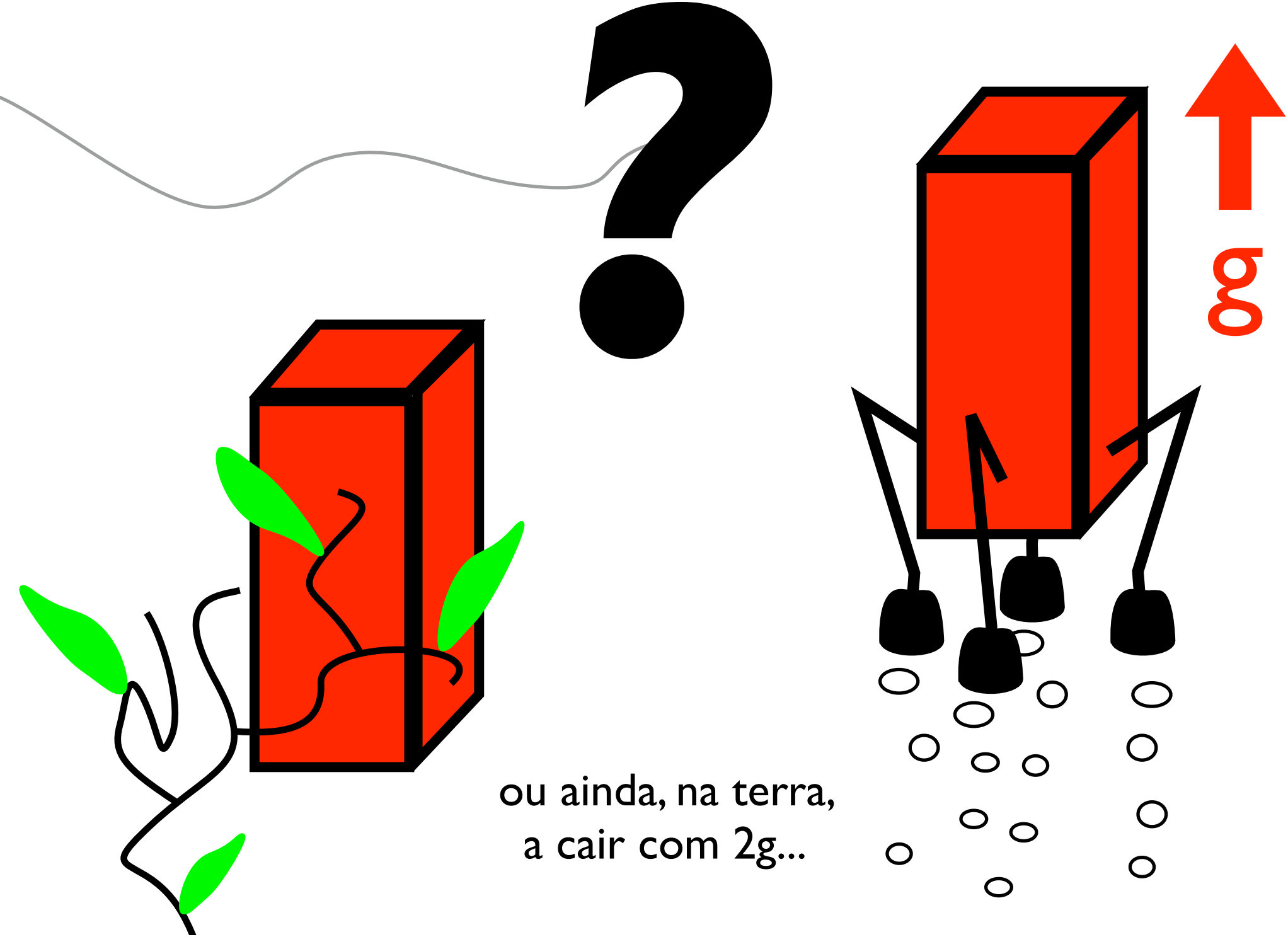
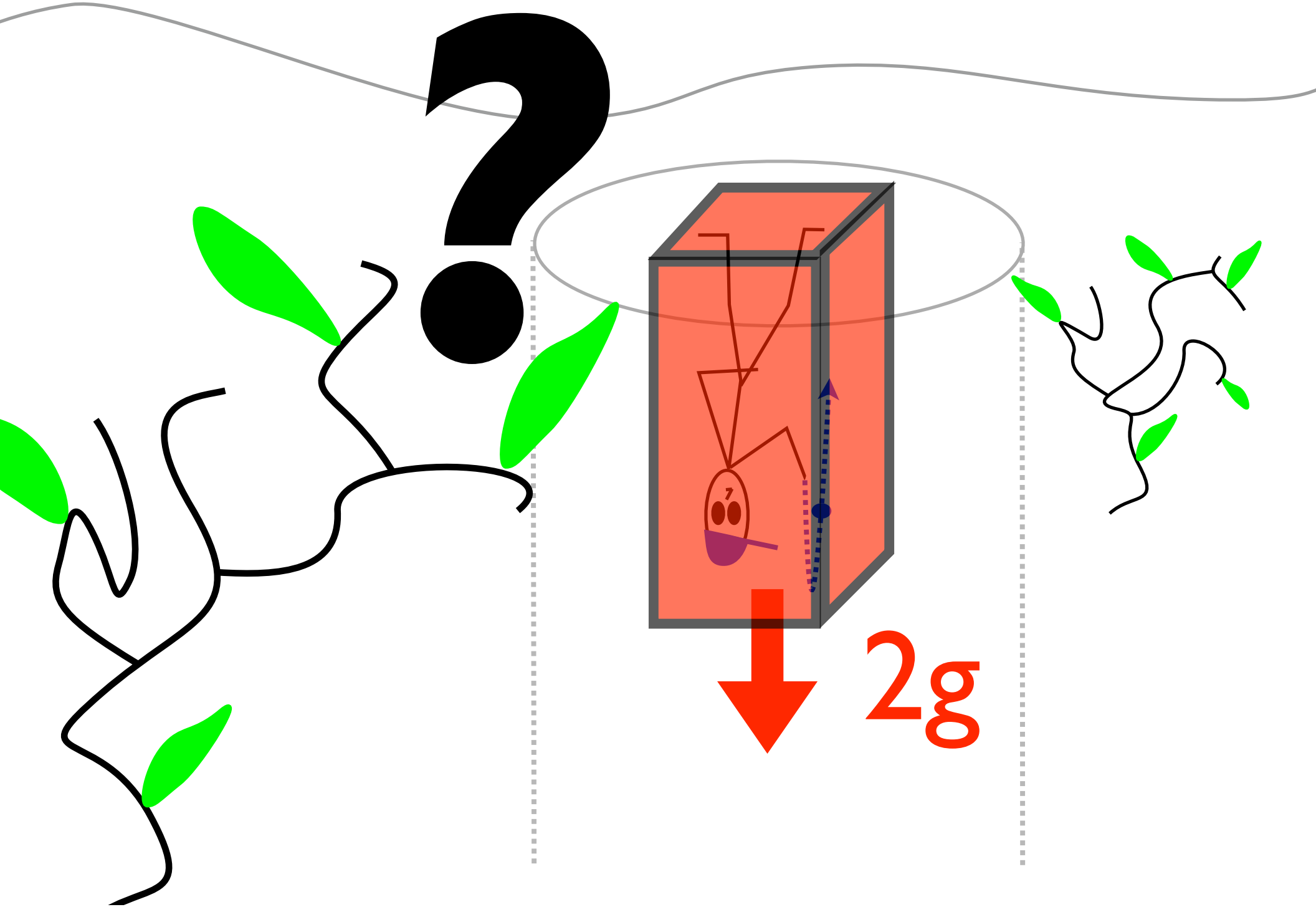


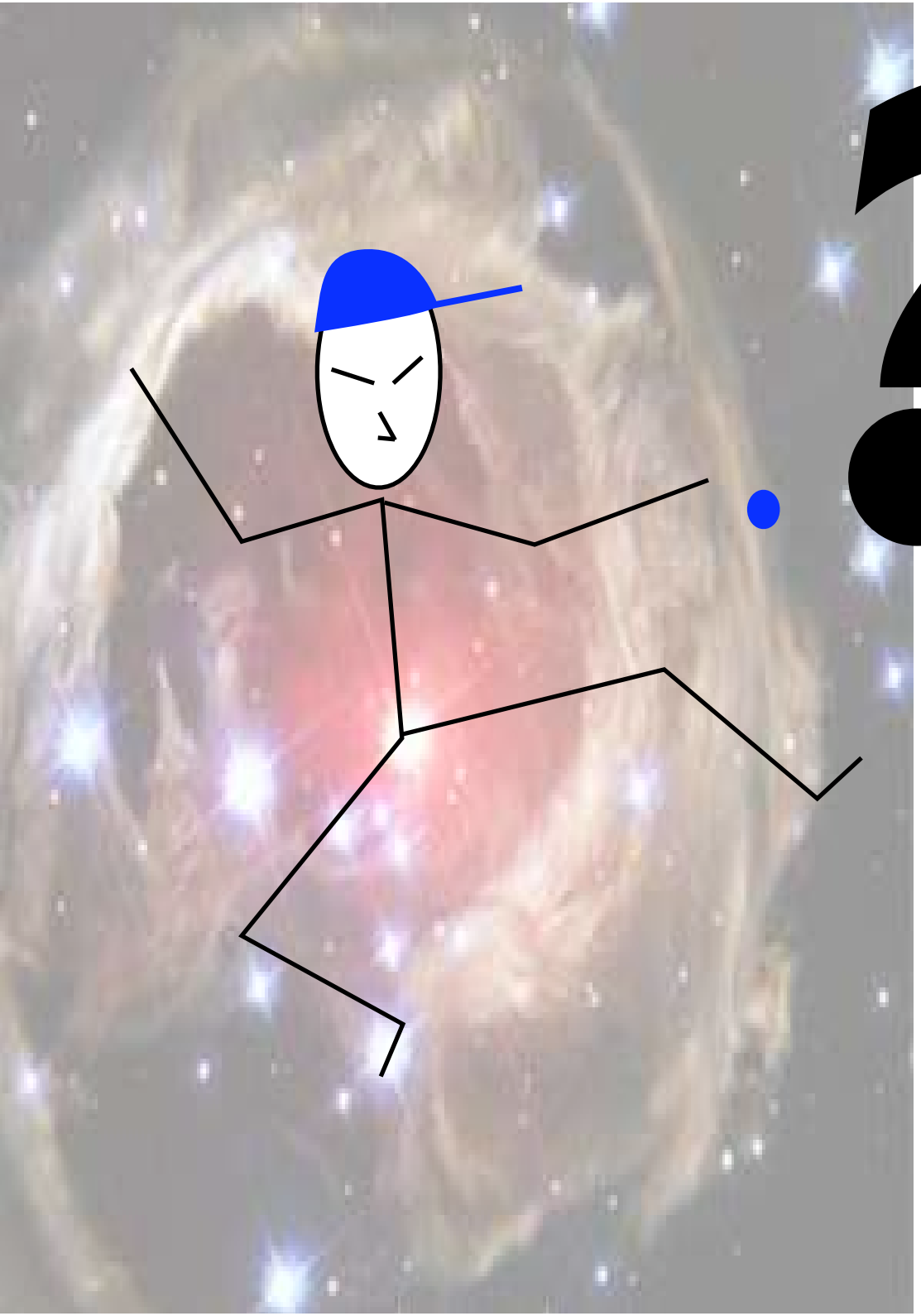
Acabamos de
acordar outra vez

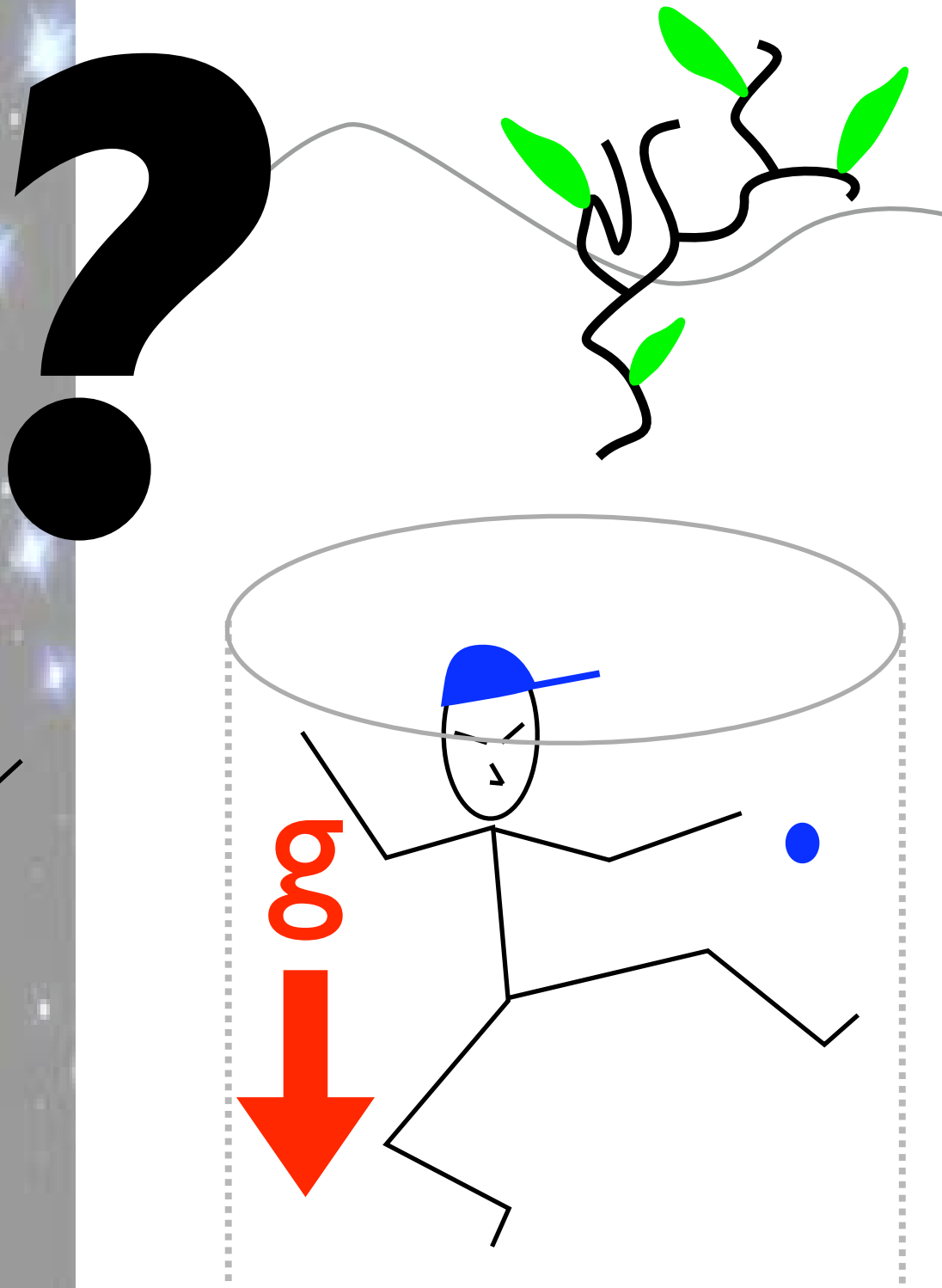


ou ainda, na terra,
a cair com 2g...


?
2g

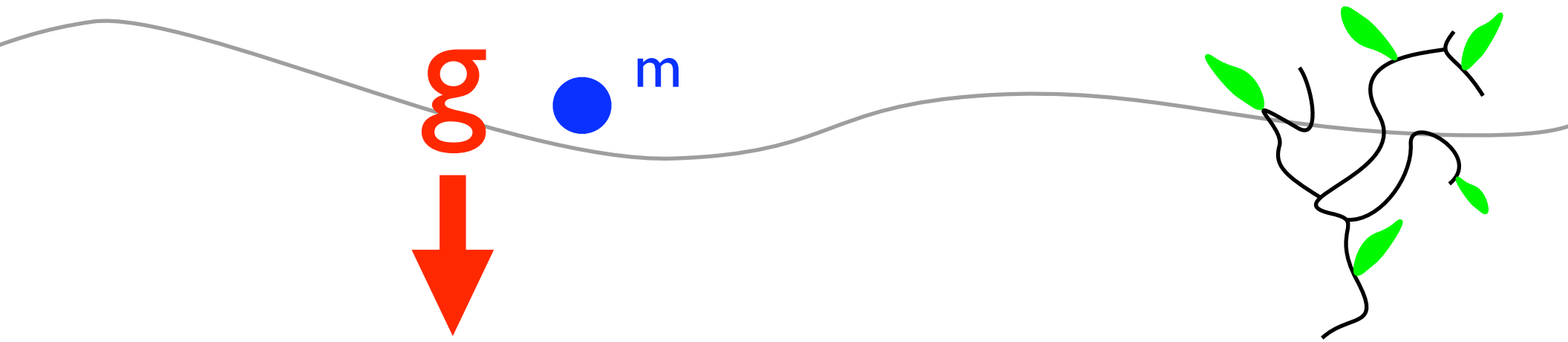
Acordamos mais uma vez




g

O ponto crucial está na bolinha azul, sempre ao nosso lado.

Vamos (re)ver como ela cai no campo gravítico da terra



A força que ela sente é o seu peso,

$$m\,g$$

A aceleração com que ela cai é dada igualando a força que ela sente à massa vezes a aceleração

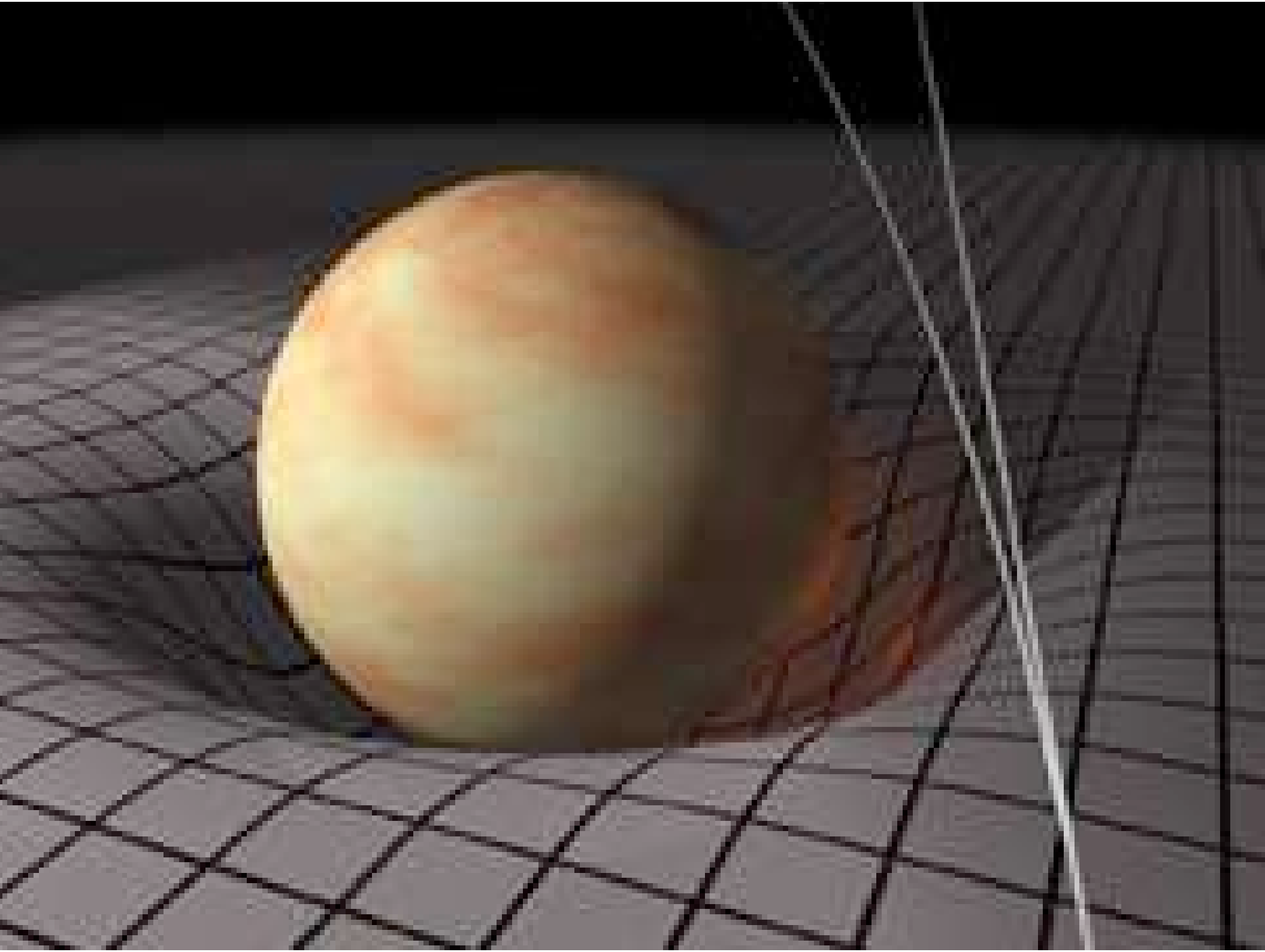
$$m\,a$$

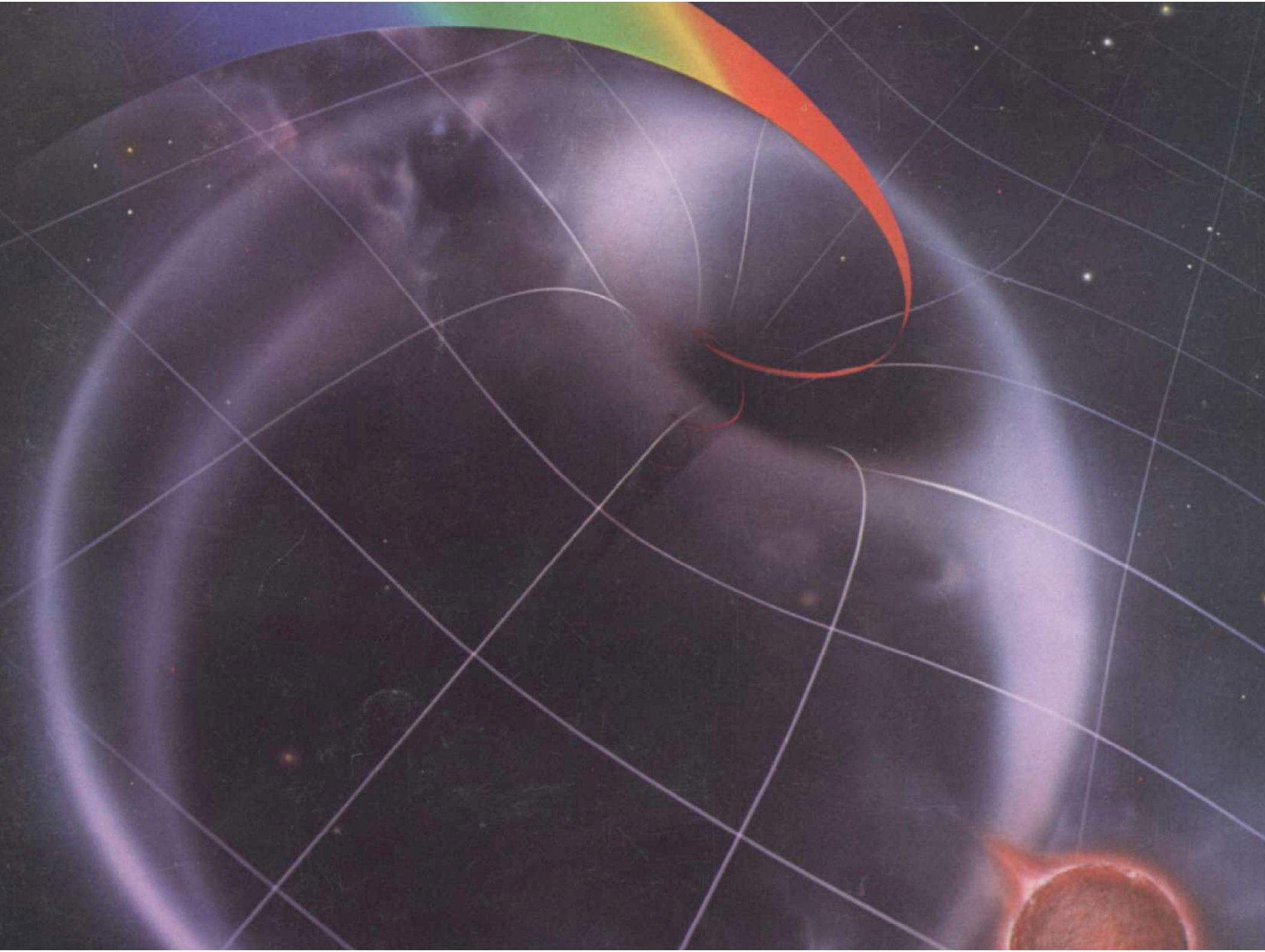
Obtemos então

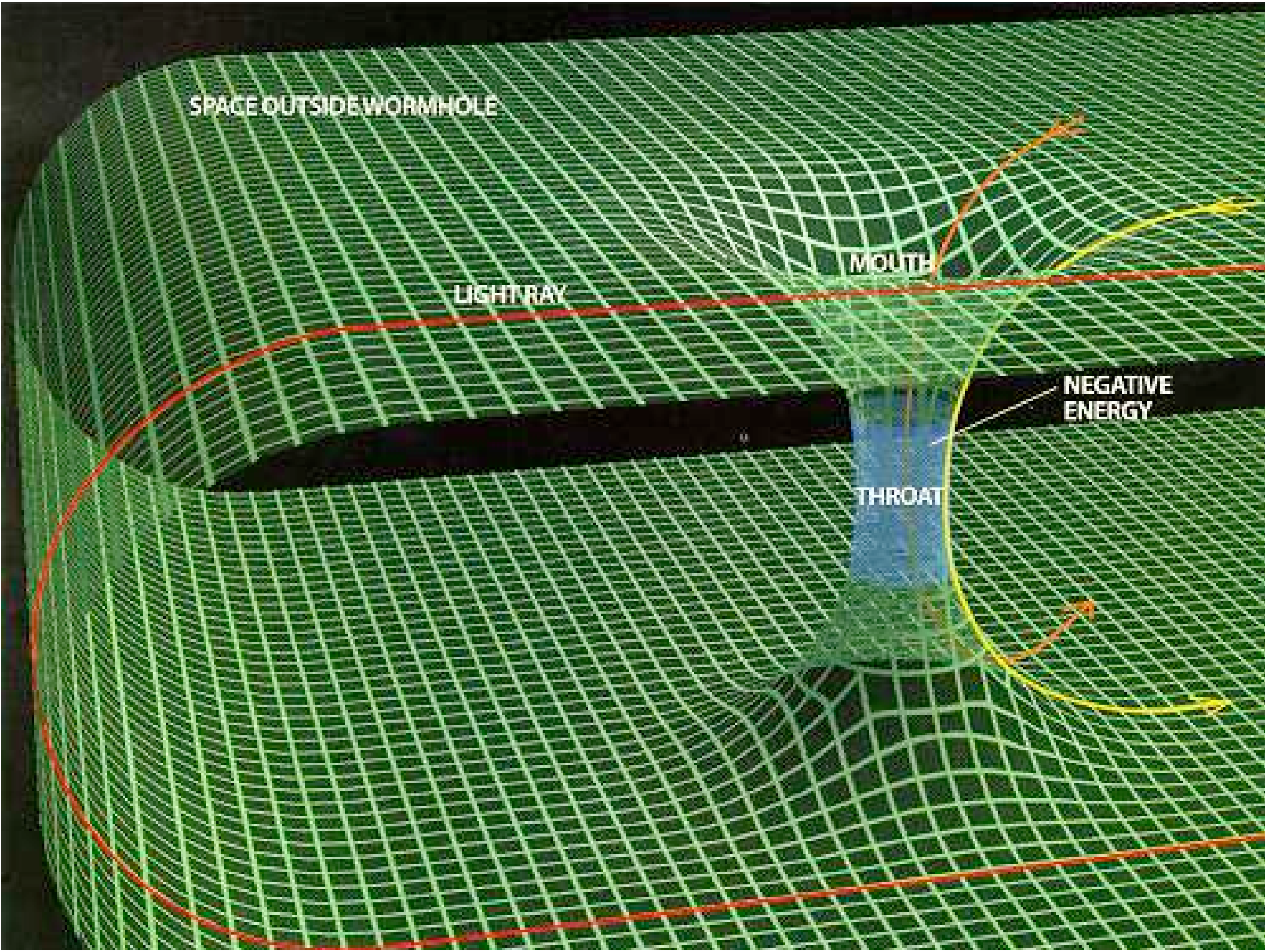
$$\cancel{m}\,a = \cancel{m}\,g$$

Por isso todos os corpos (localmente) caem da mesma forma, com a mesma aceleração.

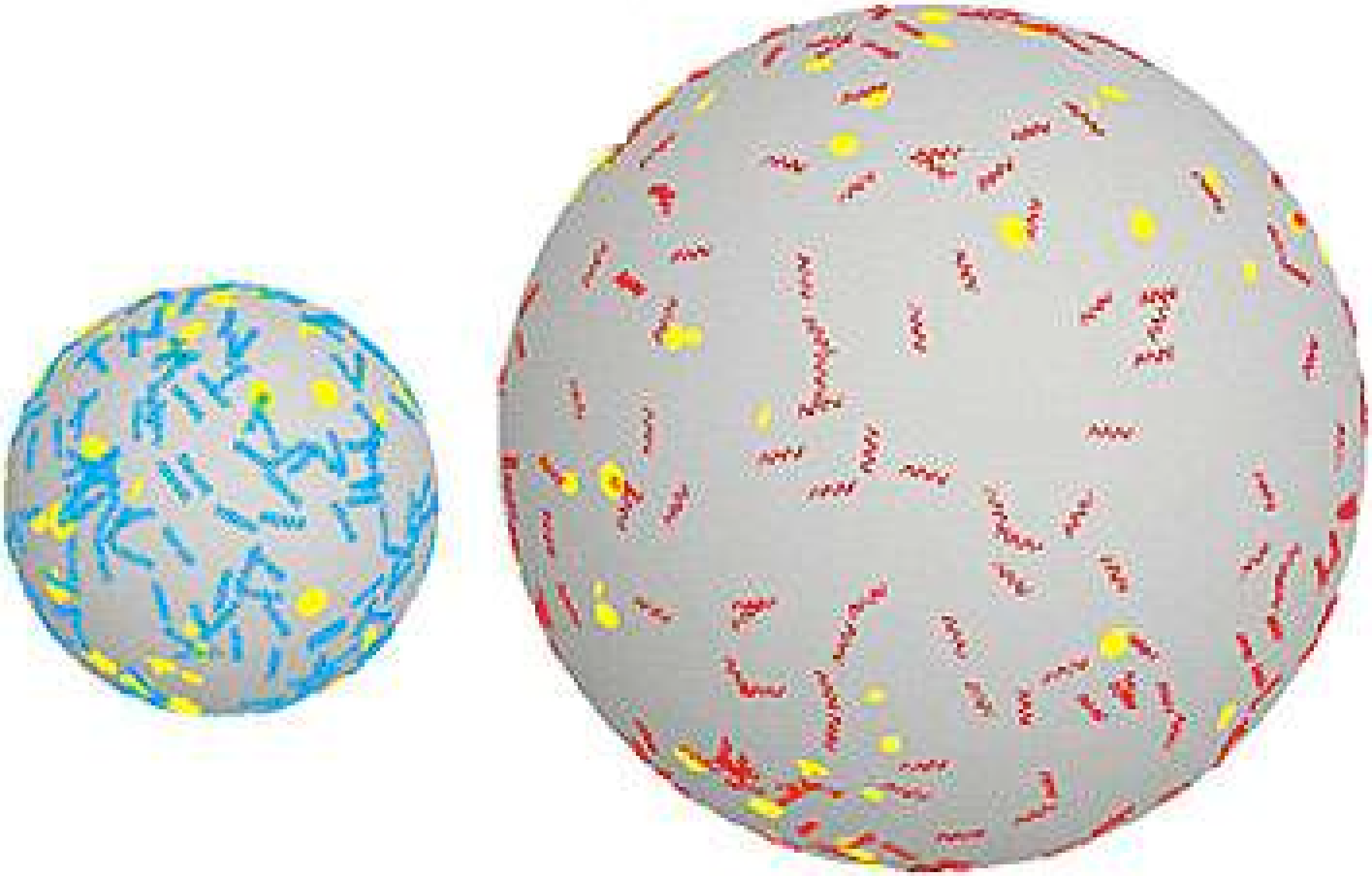
A gravidade pode por isso ser geometrizada



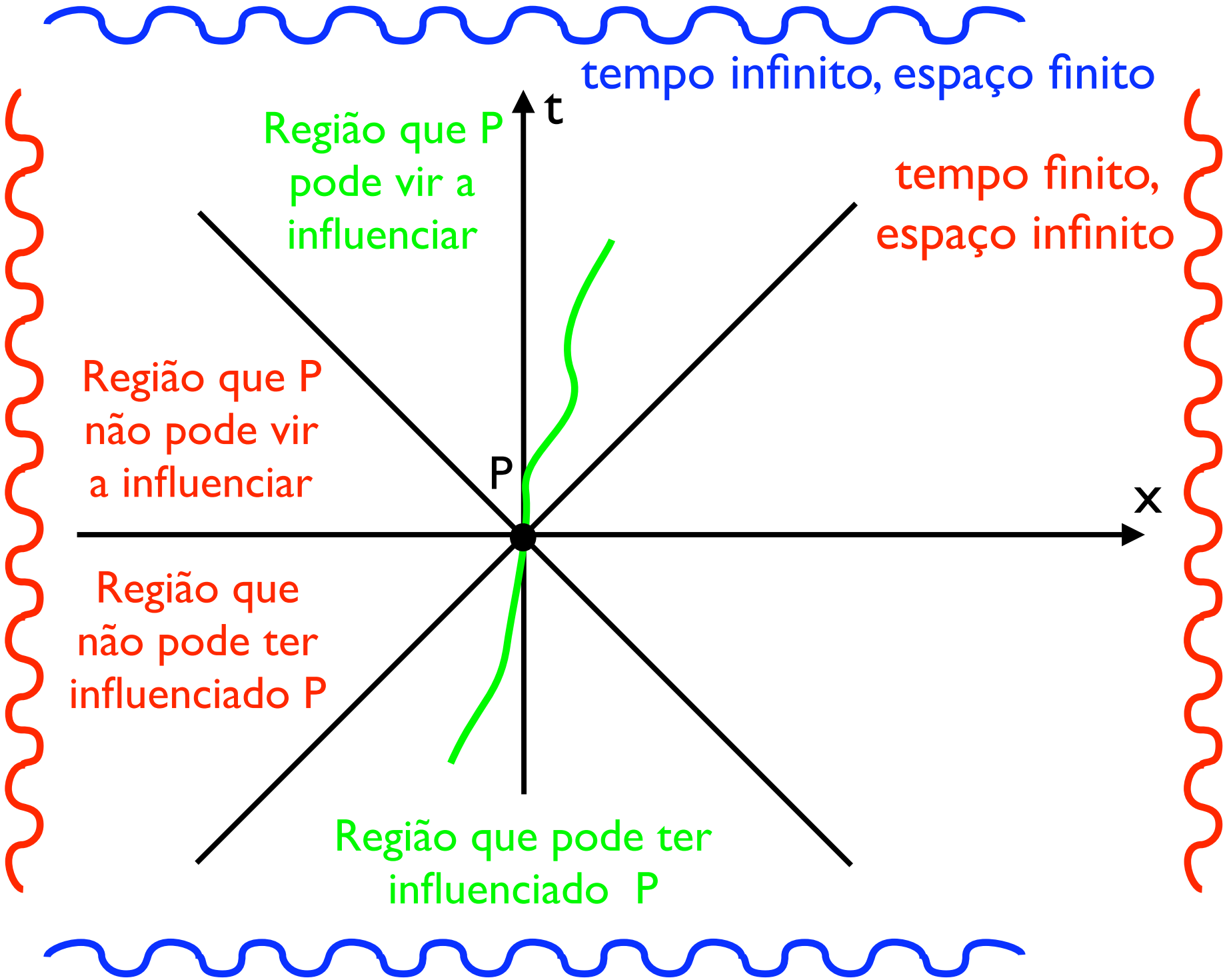



SPACE OUTSIDE WORMHOLE
MOUTH
LIGHT RAY
NEGATIVE ENERGY
THROAT

Universo em Expansão



Causalidade

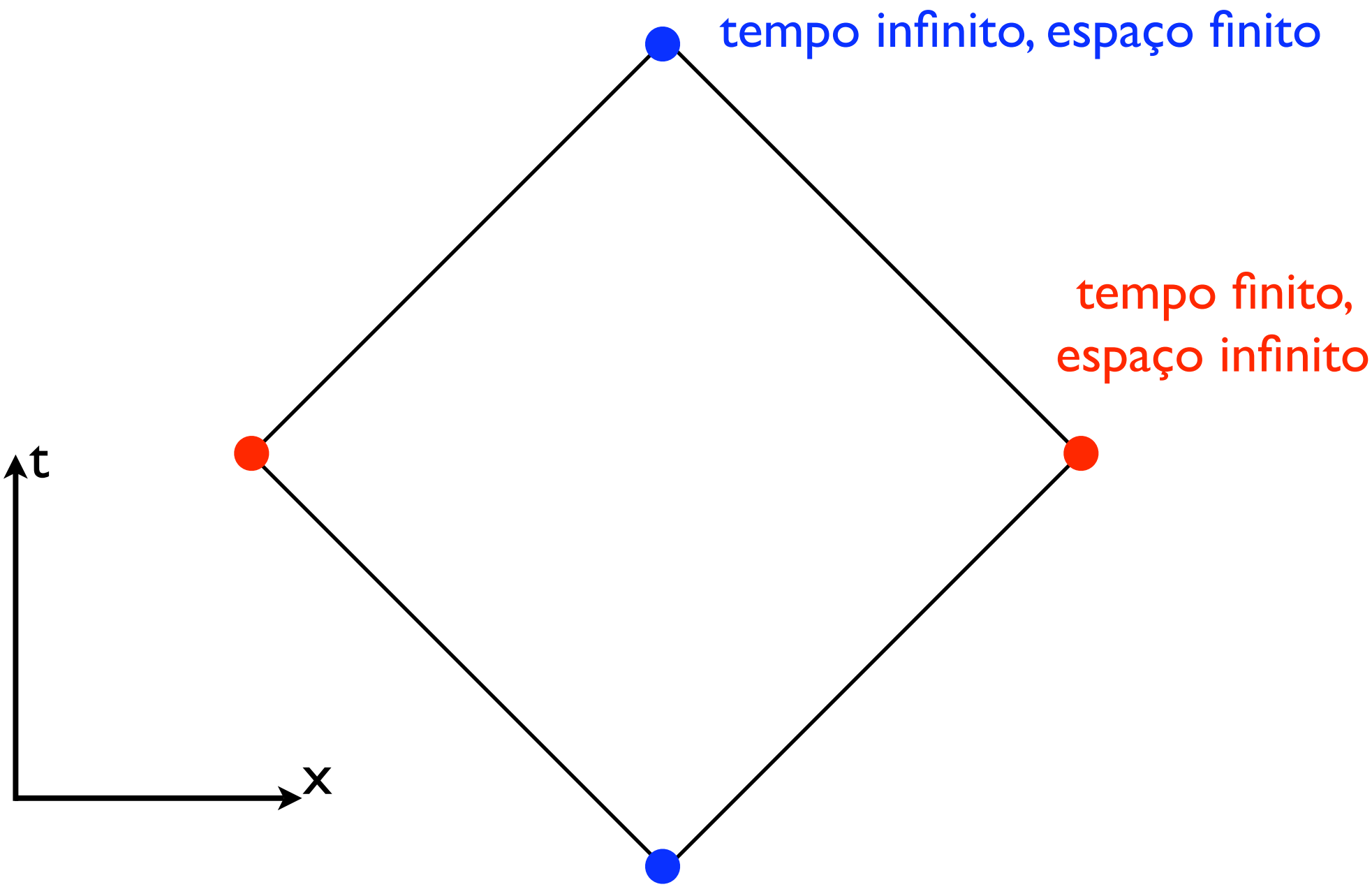

tempo infinito, espaço finito
t
Região que P pode vir a influenciar
tempo finito, espaço infinito
Região que P não pode vir a influenciar
P
x
Região que não pode ter influenciado P
Região que pode ter influenciado P

Diagramas de Carter-Penrose

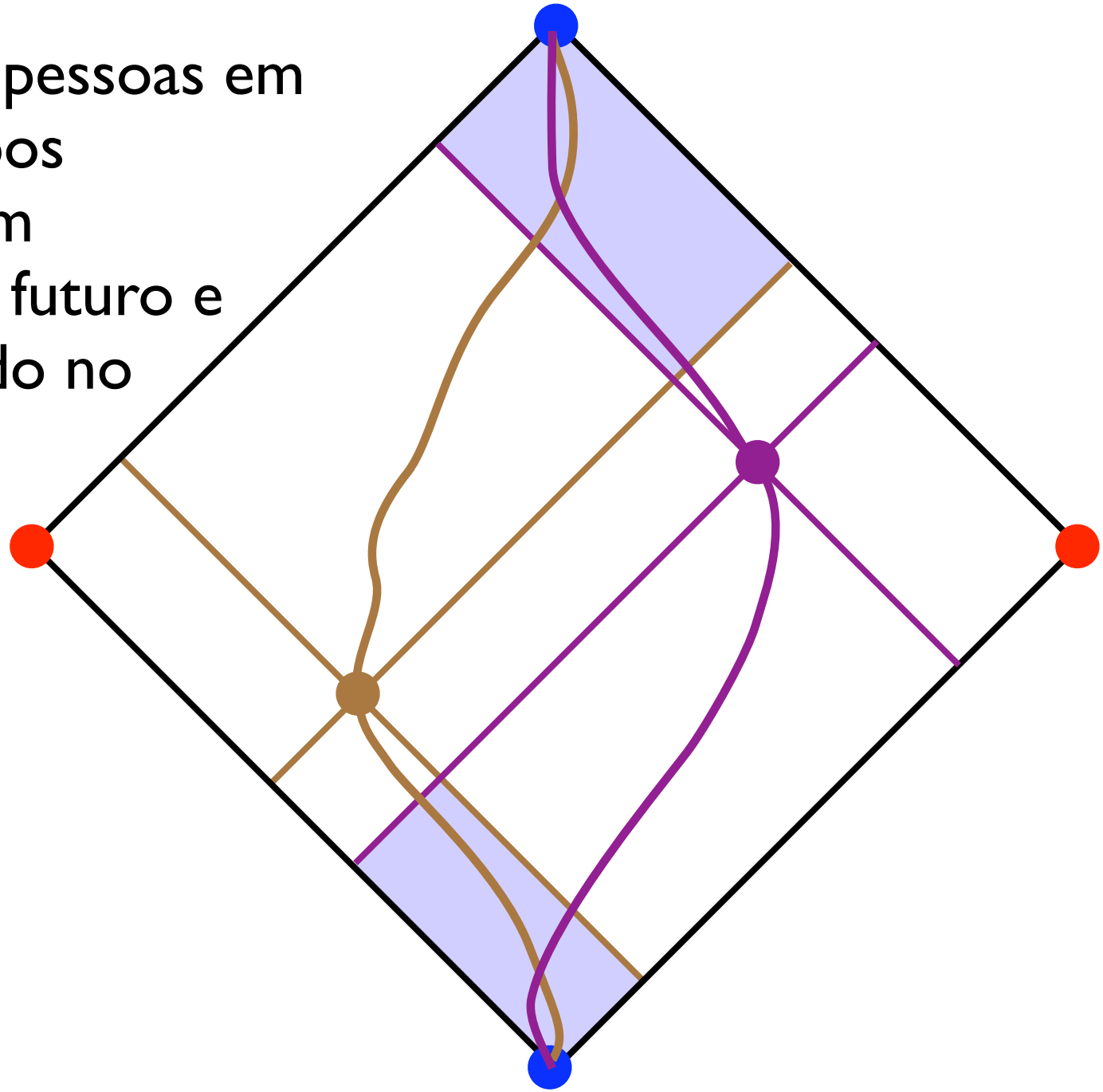
Queremos representar, num diagrama compacto, a causalidade de Espaços-Tempo

Exigimos então (e apenas) um diagrama compacto com raios de luz a 45° (para ser simples analisar a causalidade)

Espaço-Tempo Vazio ou Espaço-Tempo de Minkowski



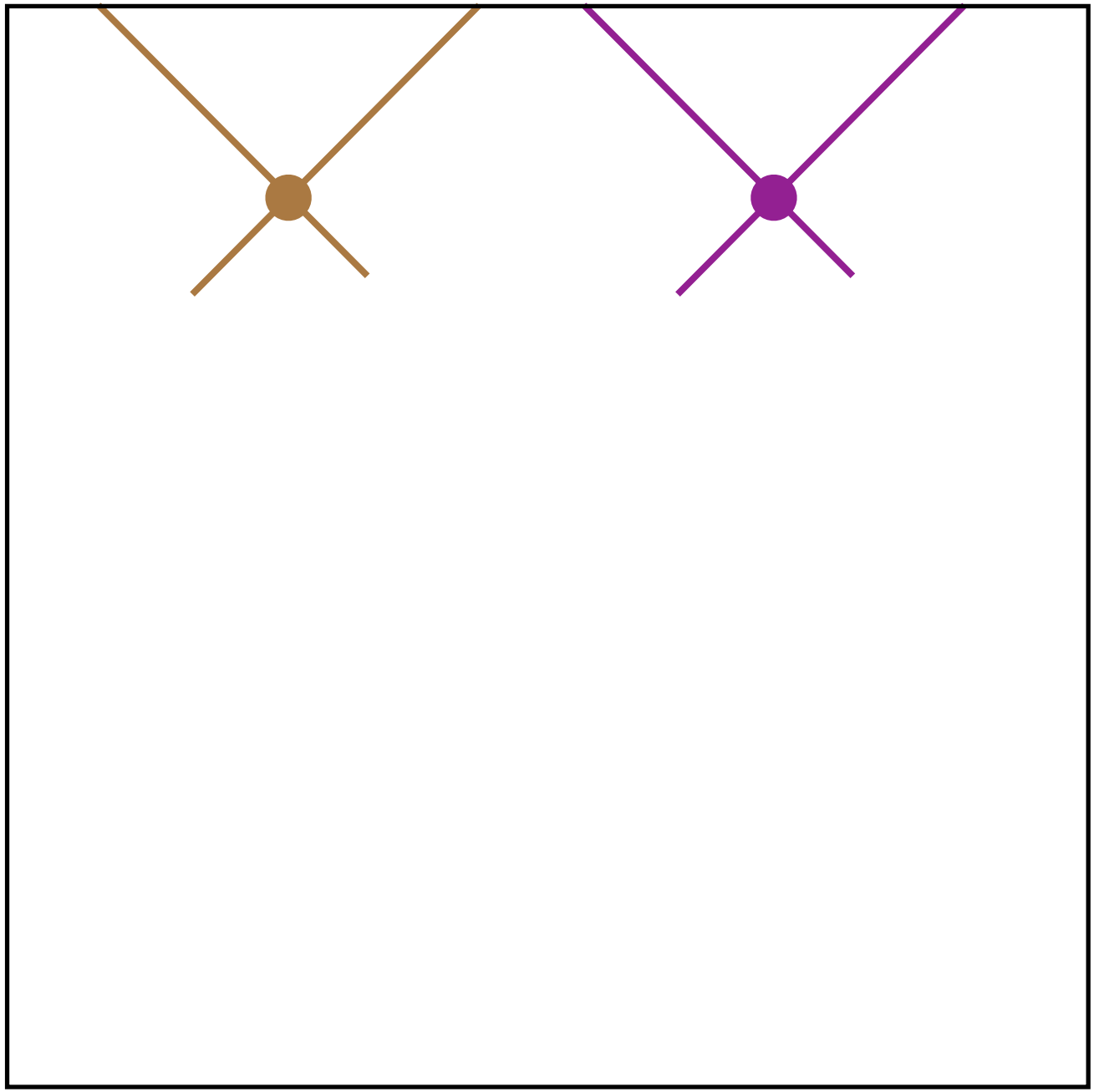
Quaisquer duas pessoas em posições e tempos diferentes podem encontrar-se no futuro e ter-se encontrado no passado



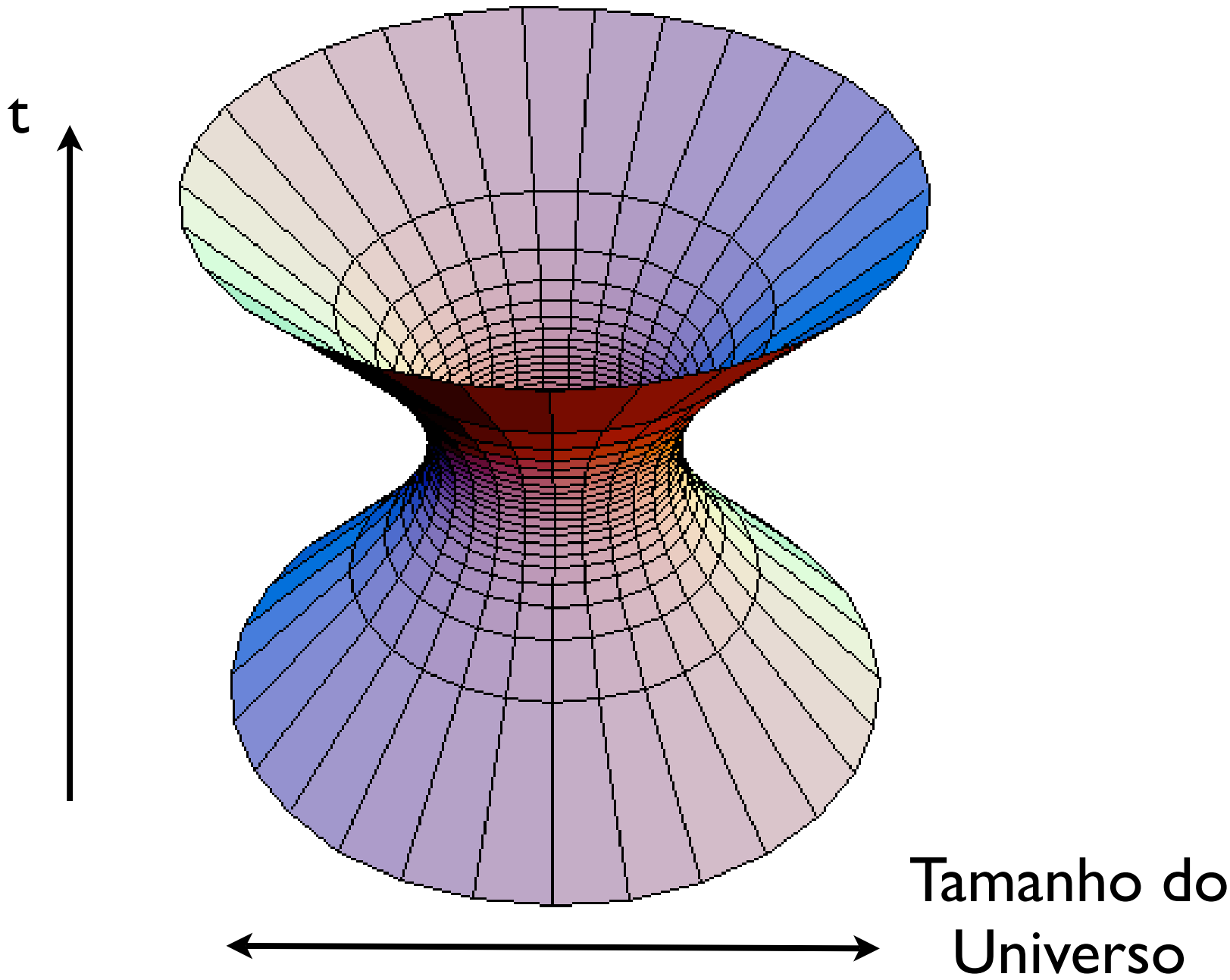
Causalidade em Espaços-Tempo Curvos

Que tipo de Espaço-Tempo?

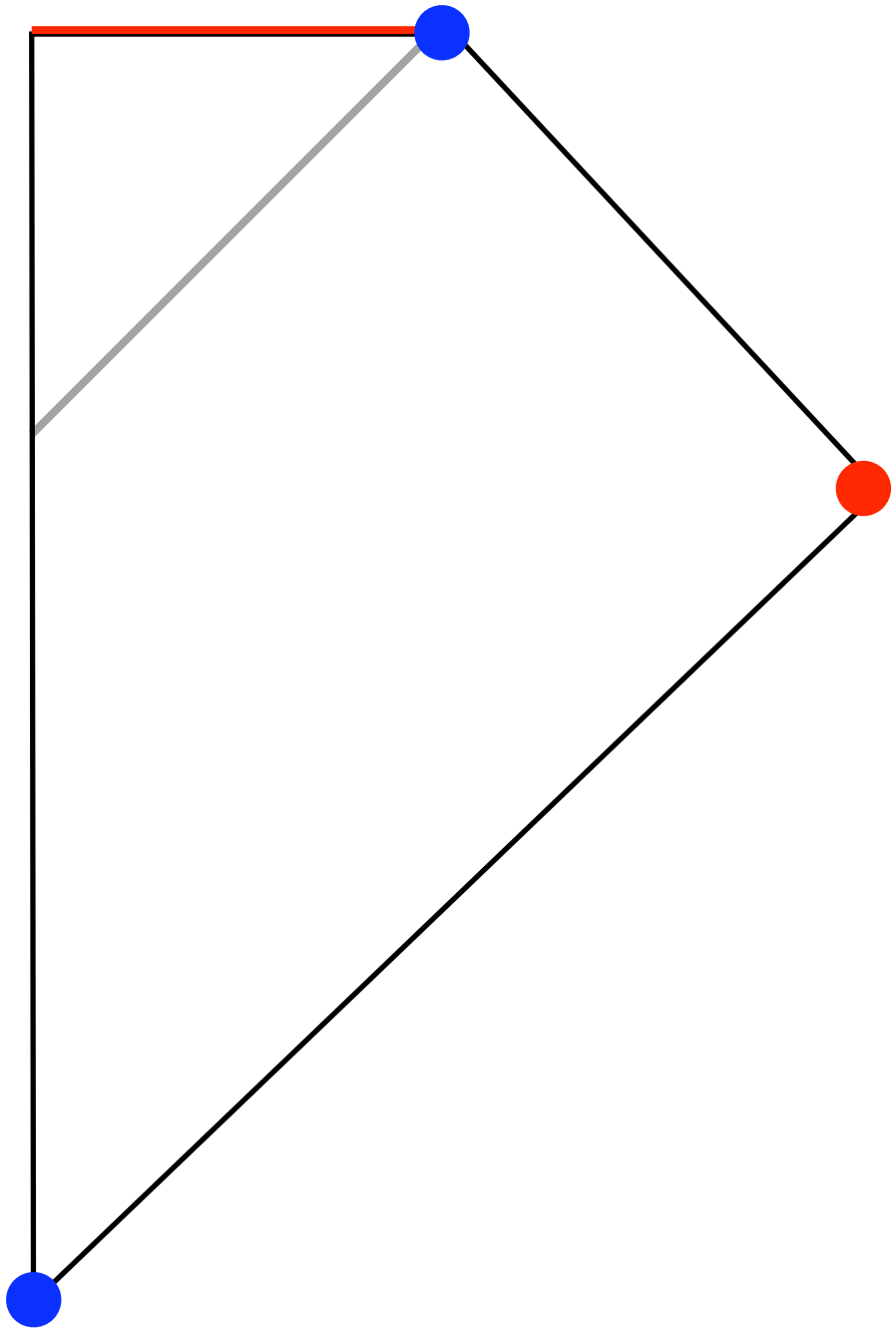
Consideremos duas pessoas bastante separadas



Podem ter-se encontrado no passado mas não se vão poder encontrar mais.


t
Tamanho do
Universo

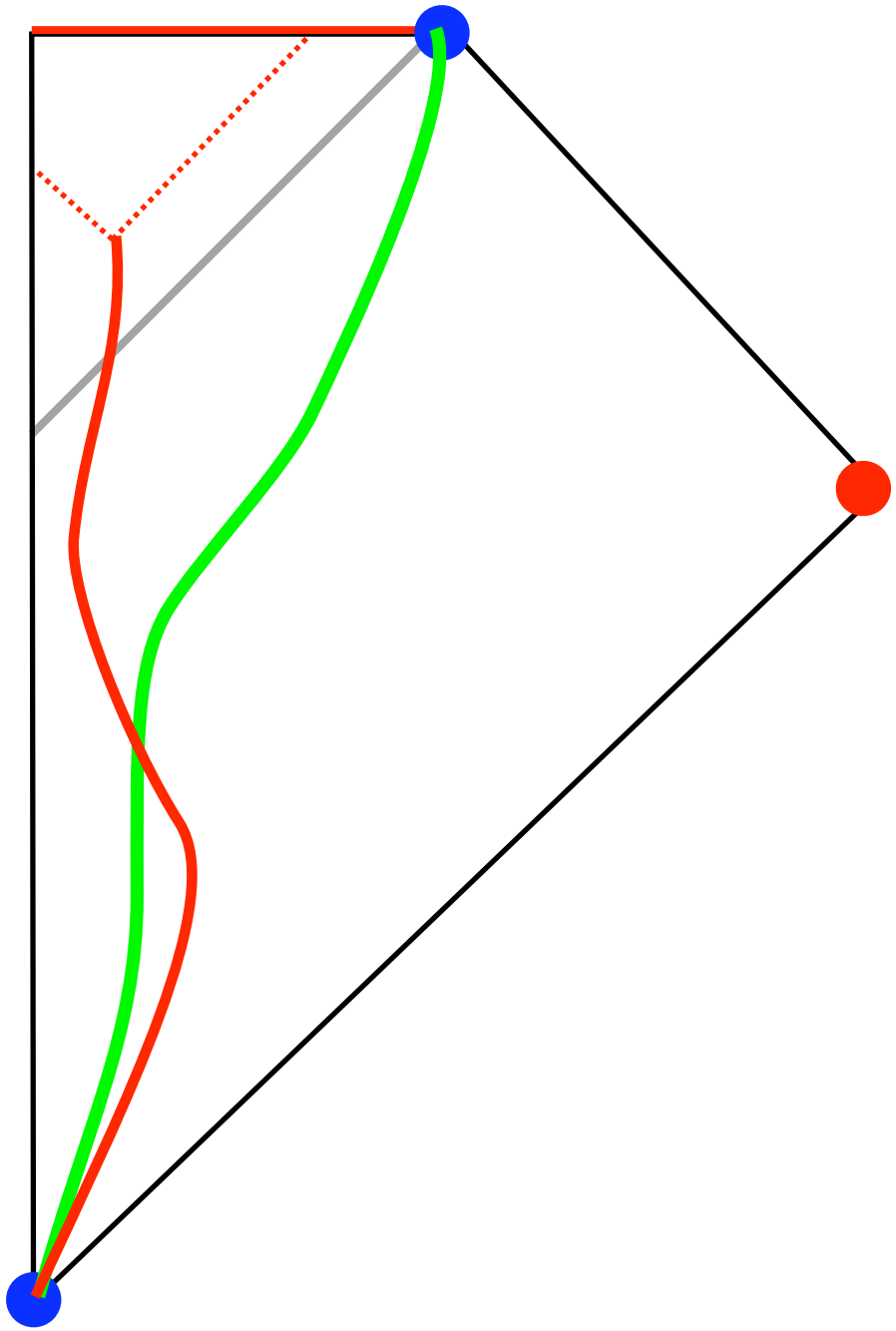
Que espaço Tempo?

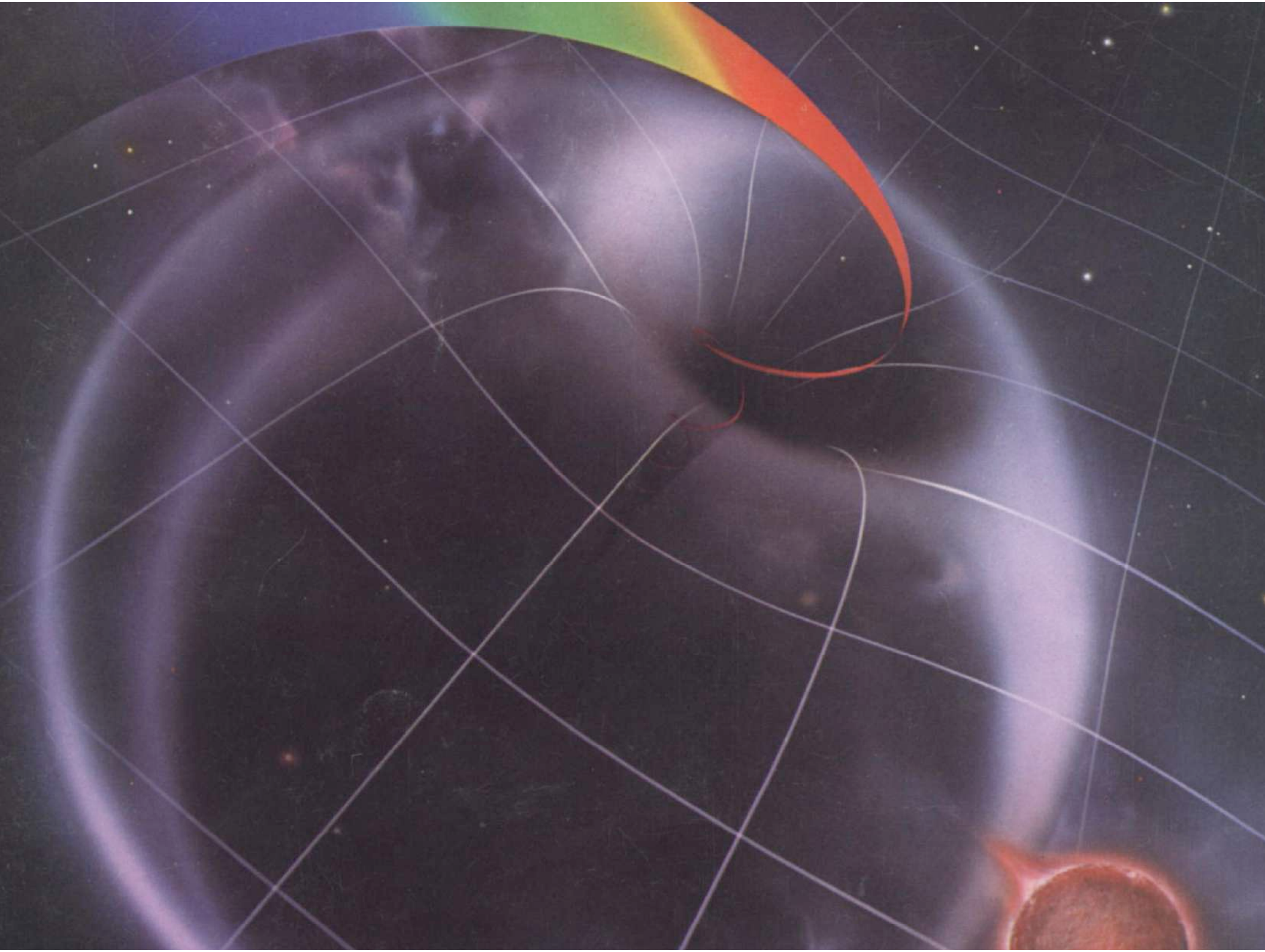


Nota: Triangulo
também representa
Minkowski

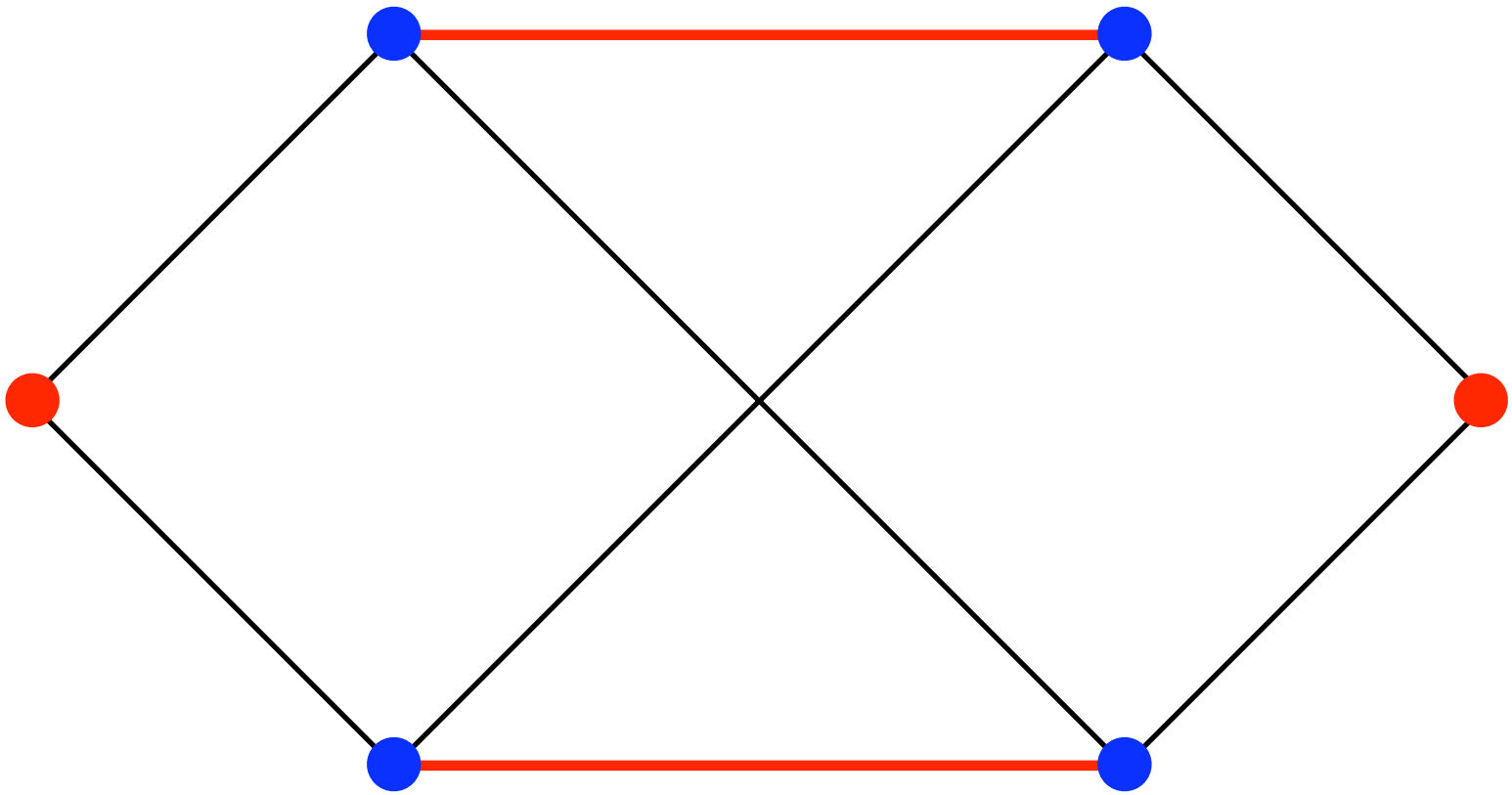
Podemos viver uma vida eterna tranquila...

... desde que não se passe a linha cinzenta! Se se passar não se sai mais.

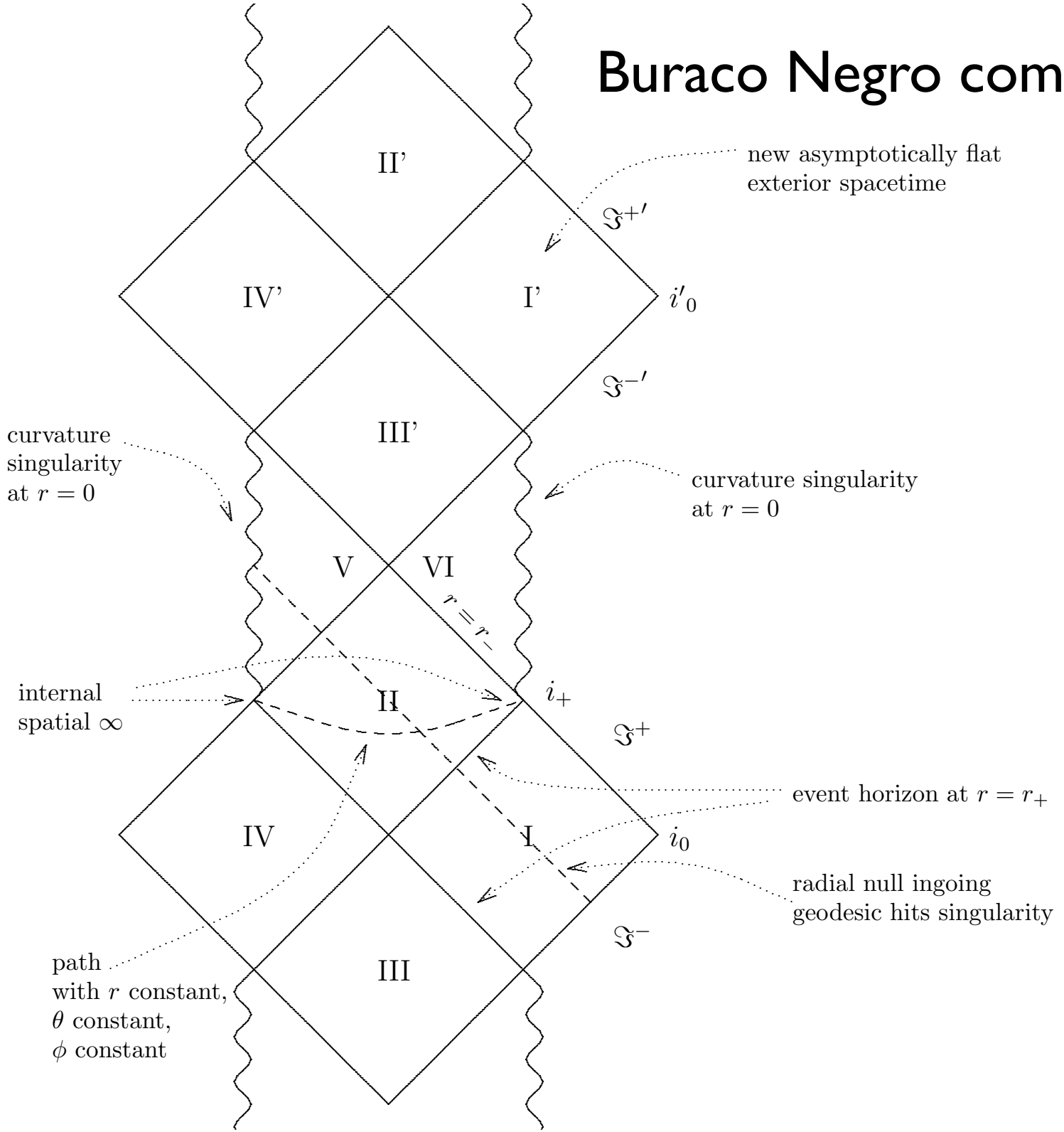




Buraco Negro Eterno de Schwarzschild



Viagens no tempo. Parênteses

...

Buraco Negro com Carga