Irreversible Relativistic Effects and Spacetime Curvature

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Gravity and Entropy

- Deriving the Einstein field equations using BH entropy and Unruh temperature; Jacobson 1995.

- Quantum gravity from BH entropy, Verlinde 2010; Susskind 1994.

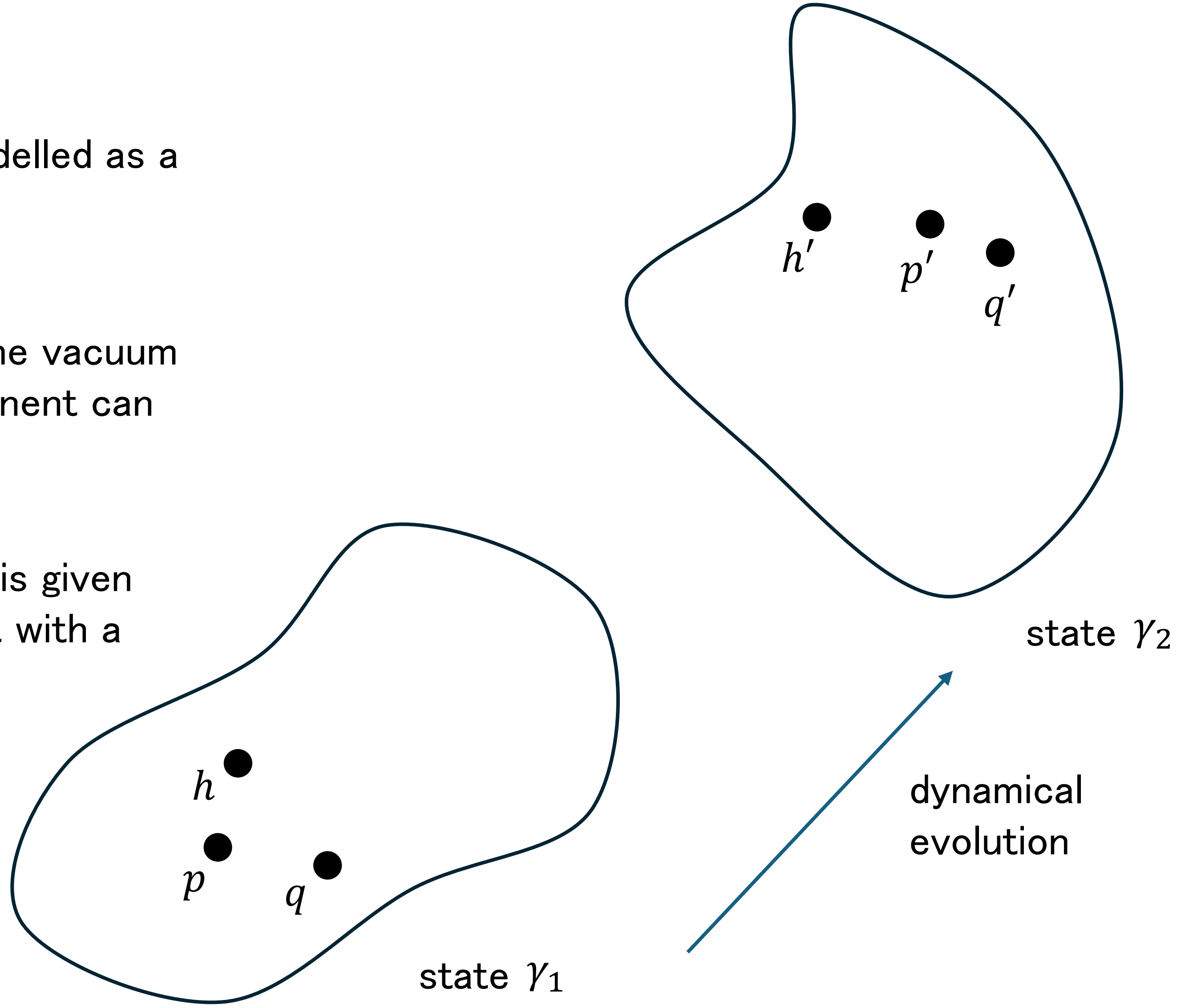
- Deformations of space observed in a moving frame; Cosserat 1912, Cartan 1922&1926

The vacuum as a Medium

- The vacuum being a medium modelled as a 4–dimensional manifold.

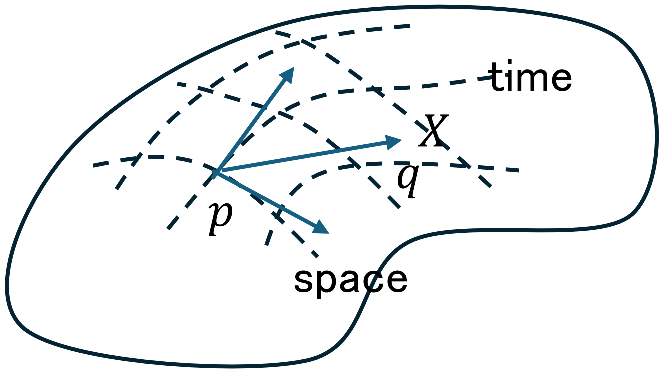
- Particles come in contact with the vacuum at a point where the local component can interact with the particle.

- A physical state of the universe is given where each particle is in contact with a unique point.



Local Frames of Reference

- At a point, a local frame of reference will resolve the neighbourhood of contact points into displacements of space and time



$$X = \vartheta^{\mu}(p; dx)\boldsymbol{e}_{\mu}$$

$$dp^{\mu} = F^{\mu}(dx)$$

$$dv^{\mu} = \frac{F^{\mu}_{\nu}(dx)}{m}\, v^{\nu}$$

- We assume that all clocks are equivalent, and that for a change of the physical state of the universe, all clock carries by each particle displace by the same unit of time.

The Equivalence Principle

- Galileo: There is no experiment that can be done to distinguish two observers (inertial!) – Einstein's special theory of relativity.

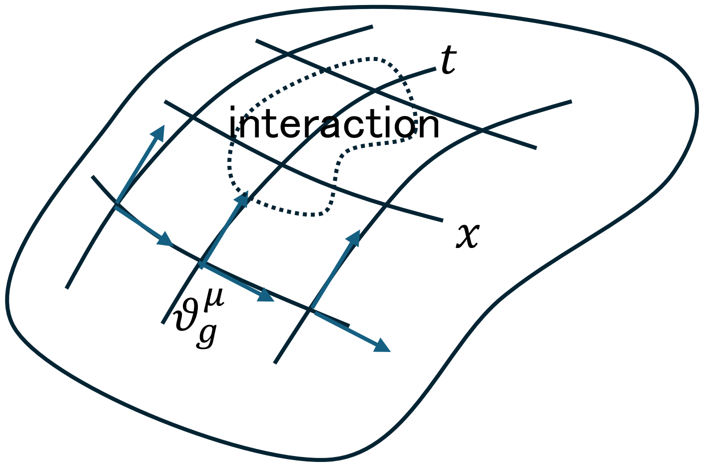
- From the equivalence of inertial and gravitational mass, uniformly accelerating observers can be considered to be at rest albeit detecting a gravitational field, Einstein 1907.

- Einstein: since gravitational fields should depend on the distribution of mass, then if inertial motion would correspond to gravitational fields, then a generalisation of the principle of relativity is a theory of gravity (General Relativity.)

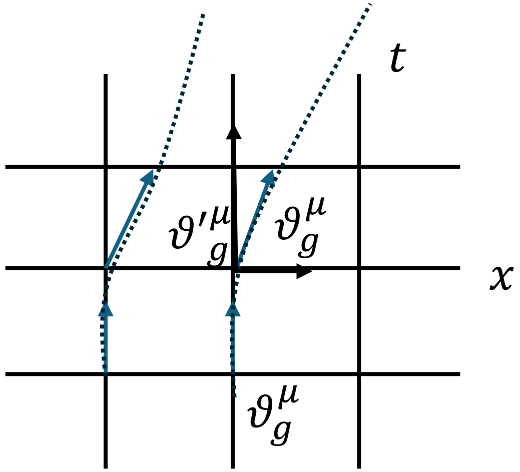
- Re-interpretation: Any particle along its worldline, is always at rest – having the same 4-velocity (the geodesic equation.)

Motion of Galilean Frames and Spacetime

- Imagine a neighbourhood when the vacuum is active, and collection of Galilean frames [Cartan 1922]

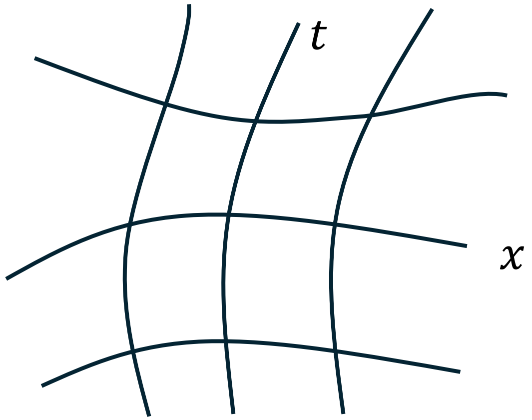


- We decelerate the Galilean frame to keep it on track



$$dv^\mu = \frac{F_\nu^\mu(dx)}{m}\, v^\nu$$

- The track of events recorded by these accelerated frames give spacetime



$$\vartheta^\mu(x; dx)$$

$$d\vartheta^\mu + \Gamma_\nu^\mu(x, dx) \wedge \vartheta^\mu(x; dx) = 0$$

$R_{\mu\nu} = 0$; Einstein 1940

Configuration Entropy

- If we consider a configuration of particles in a Galilean background at spatial infinity

Entropy generated per particle

$$\sigma = m \oint dv$$

- Analogously, we can define the entropy per particle as

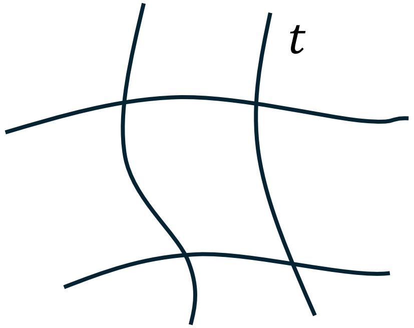
$$d\sigma = m\, dv$$

- This implies that the requirement that the amount of entropy generation is to be maximised would require gravity to be attractive.

Entropy at the Centre of Mass of a Particle

- If we calculate the total entropy generated for a frame moving along constant time coordinate

$$S = S_{cg}\sqrt{1 - v^2}$$



- According to the Galilean background at spatial infinity, the vacuum is pumping energy to the rest frame of the particle, yet the particle is always at rest.

$$dS_{cg} = d\sigma_{cg} = \; m\, dv_{cg}$$

- Then, the energy would be expected to appear in the rest frame of the particle as heat with a temperature

$$T = \frac{dE_{cg}}{dS_{cg}} = \frac{dv_{cg}}{2}$$

- This will give the following unit

$$\eta = \frac{\pi c k}{\hbar}$$

Summary

- The vacuum can be described as a medium where particles come in contact with the vacuum where they can interact locally with the vacuum.

- The Einstein field equation in vacuum seem to be a consistency condition on the possible spacetimes.

- We can define entropy by comparing configurations for some observer.

- This entropy seems to be related to time dilation and the temperature of the vacuum.

- How can we model the interaction between the vacuum and particles? model the vacuum as an elastic medium?

- Apply such concepts to problems in cosmology.

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