UiO : Fysisk institutt

Det matematisk-naturvitenskapelige fakultet

Lecture 16

This week

- **Monday:** Hyperbolic motion (Spaceship Navigation 101). Relativistic energy and momentum, the energy-momentum relation. (Sections 7.1-7.3)
- **Wednesday:** Doppler effect with photons, relativistic scattering. (Sections 7.4-7.7)
- **Problem session:** Problem set 7, exercise your four-vectors + old exam question (2006).
- **Mid-term exam:** problem set available Monday 19th of March. Deadline: Friday.

Recap

- We define four-velocity and four-acceleration in terms of the proper time τ

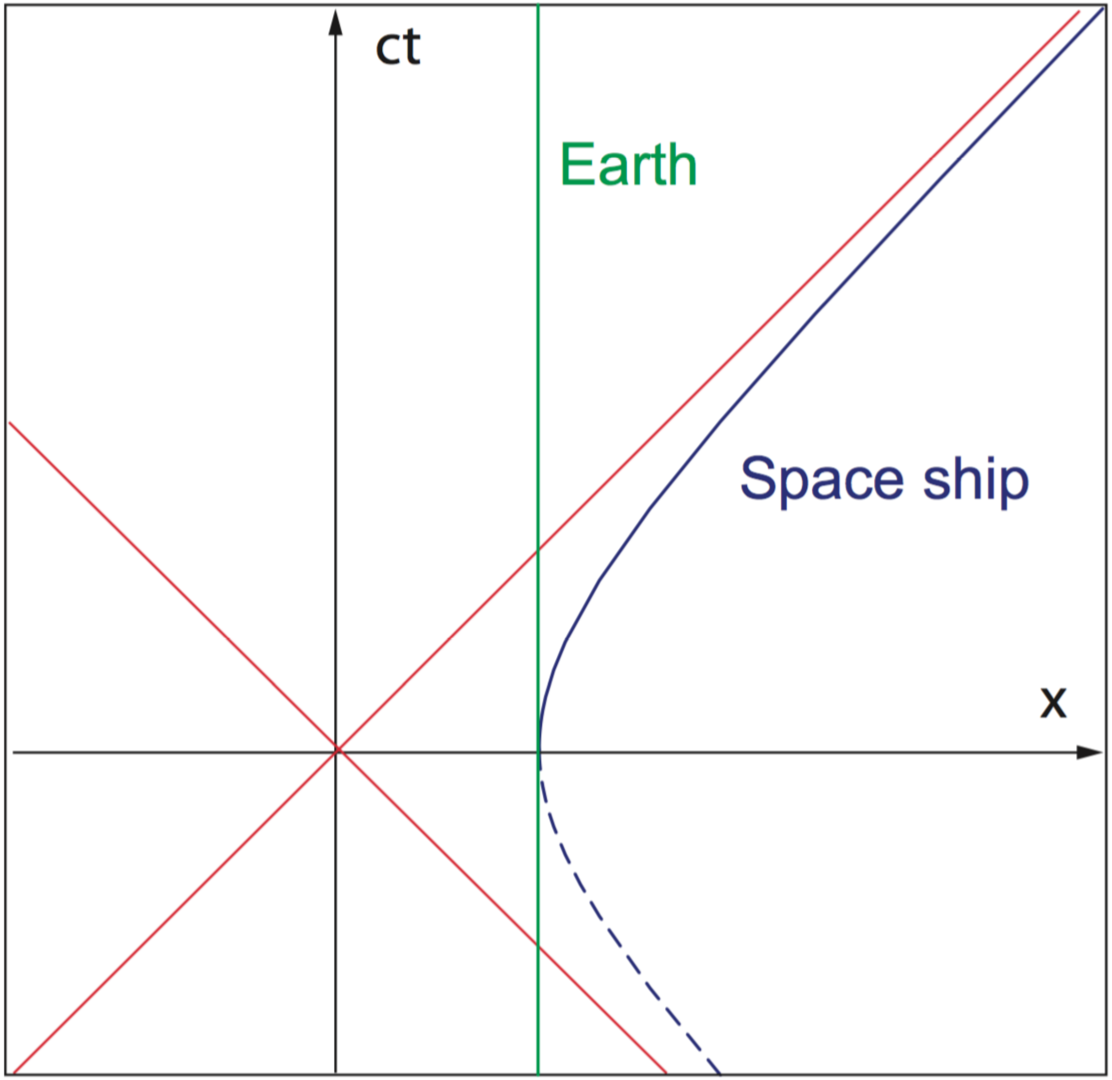
$$U^{\mu} \equiv \frac{dx^{\mu}}{d\tau}; \qquad A^{\mu} \equiv \frac{d^2 x^{\mu}}{d\tau^2}$$

- The **proper acceleration** is defined as the acceleration in the instantaneous inertial RF (the changing RF where v = 0).
  - This is the acceleration measurable with an accelerometer (so not free fall).

Today

- Spaceship Navigation SF101
  - Velocity, position and time for a spaceship.
  - Hyperbolic motion.
  - A very very strange constant.
- Relativistic energy and momentum
  - The energy-momentum relation.
- Spaceship economics SF102
  - The practical issues in theoretical spaceship travel.

Spaceship Minkowski diagram



Mid-term evaluation

- Please take five minutes and try to respond to the following points (in English or Norwegian):
  - How do you feel about the level of the lectures: too fast and confusing, or too detailed and boring?
  - Are there particular topics where you have trouble understanding the math, or relating to the math/physics you've learned in other courses?
  - Concerning the problem sets: To little work? Too much work? Too easy? Too hard? Do the problem classes work? Suggestions for improvements?
  - Any other comments or suggestions for the course.

Summary

- Relativistic four-momentum p^μ is defined as

$$p^\mu = mU^\mu = (\gamma mc, \gamma m\vec{v}) = (E/c, \vec{p})$$

where E and p is the relativistic energy and momentum. These reduce to ordinary kinetic energy plus rest energy, and to ordinary momentum in the non-relativistic limit.

- These lead to the energy-momentum relation

$$E^2 = p^2c^2 + m^2c^4$$

which allows massless particles with E = pc.