

Time dilation and spacetime diagrams

Exercise 1

In the galactic year 2125, you undertake the Sun-Sirius voyage to study this binary stellar system.

After 8 years in your spaceship, you land on an exoplanet around Sirius A.

In what galactic year are we then, and what was the speed of your ship?

In 2128, three years after you left, the earthlings send you a radio message.

When do you receive this message?

When you arrive on the planet, you send a picture of your new home. When will they receive it?

Draw a Minkowski diagram that shows the various worldlines.

Sun-Sirius distance in the galactic frame of reference: 9 ly.

Exercise 2

Carlos, 40, has to travel, for a secret mission, to the star *Kappa Ceti*, 30 ly away in the equatorial constellation of *Cetus*. The Carlos' vessel is a $\beta 95$ model. When he left, his daughter Maria, is 15 years old. Maria sends a letter each month to her father with an electromagnetic wave. How often does Carlos receive letters during his trip to *Kappa Ceti*?

Just arrived at *Kappa Ceti*, Carlos came back to the Sun. Show the Minkowski diagram.

When they meet again, how old are the daughter and the father?

$\beta 95$ model: $\beta = 3/\sqrt{10}$

Exercise 3

In Japan, the Shinkansen train takes 3 hours to travel from Tokyo to Shin-Aomori, 675 km away. Initially, two atomic clocks are synchronized at Tokyo. One remains on the station, and the other makes a round trip to Shin-Aomori on the train. Back to Tokyo, what is the desynchronization between the two clocks? Is it measurable? The atomic clocks accuracy is 0.5 ns/day.

The terrestrial reference frame is supposed inertial.

Exercise 4

A plane flies around the Earth straight on the equator toward the east, covering 40,000 km at 1000 km/h ground speed. At the beginning, two atomic clocks at rest are synchronized. One remains on the ground, and the other makes the round trip on the plane around the world. Back to the initial point, what is the desynchronization between the two clocks? What if the plane travels toward west?

Altitude variations are ignored. Geocentric frame considered inertial.

Exercise 5

What is the probability for a muon created at 15 km with a vertical velocity of $0.995c$ to reach the sea level? Chacaltaya, 5240m? Plot a spacetime diagram with the muon worldline.

Muon mean life at rest: $2.2 \mu\text{s}$