

Lecture 13

Newton's Cosmology III: Relativity before Einstein

What is an event ?

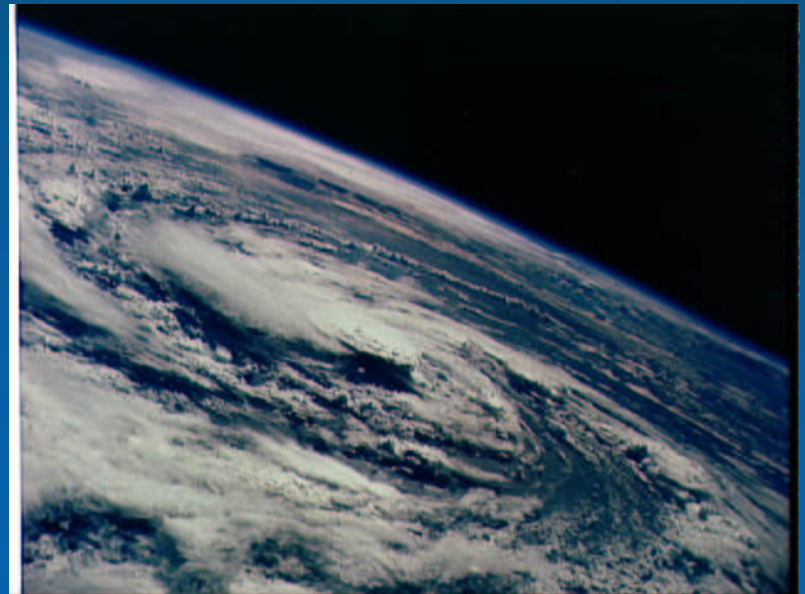
- When is it happening \Rightarrow time t
- Where is it happening \Rightarrow position (x, y, z)
- What reference frame

\Rightarrow coordinate (t, x, y, z) measured with respect to a particular observer at $(0, 0, 0, 0)$

\Rightarrow frame of reference

Inertial reference frame

- An **inertial reference frame** is a reference frame at rest or in constant motion (i.e. constant speed, constant direction).
- Non-inertial frames \Rightarrow fictitious forces
 - centrifugal force
 - Coriolis force

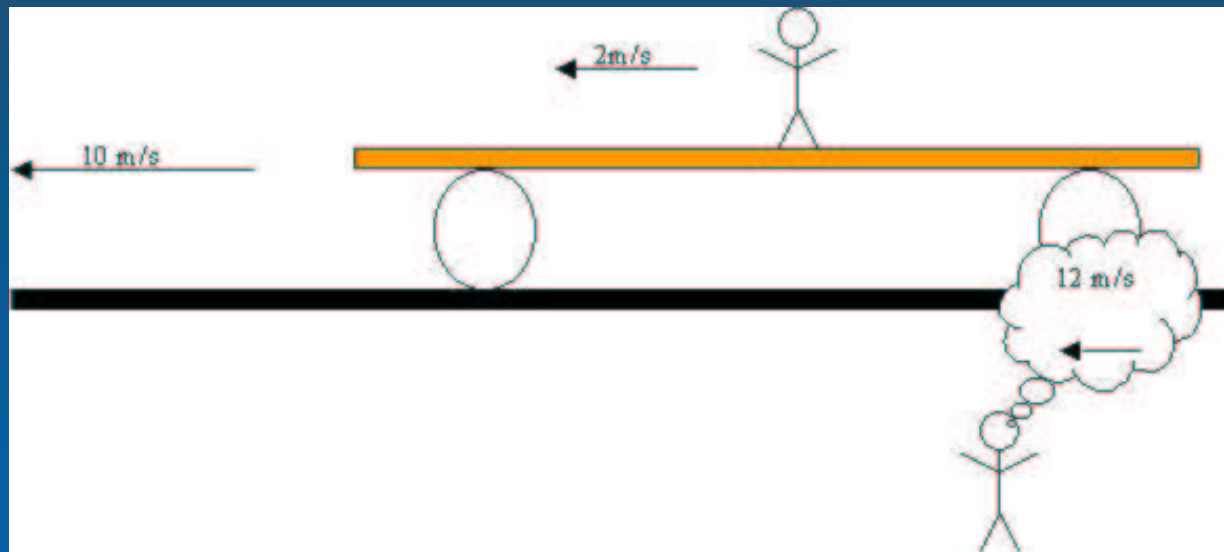


A few definitions ...

- **Inertial Observer:** An **inertial observer** is an observer whose rest frame is inertial
- **Invariance:** A quantity is said to be **invariant** if all inertial observers would obtain the same result from a measurement of this quantity
- **Relativity:** A quantity is said to be **relative** if different inertial observers obtain different results from their measurement.

Examples

- **invariant:** time, mass, acceleration, force
- **relative:** velocity, position



⇒ Galilean relativity

What does Galilean relativity (Galilean invariance) exactly mean ?

- There is no absolute standard of rest. Newton's laws work equally well, and in the same manner, in all inertial (i.e. unaccelerated) frames.
- **Conclusion:** By no experiment within a closed lab one can prove whether the lab is moving at a constant speed or whether the lab is at rest.
- **Example:** airplane, window shades down, no turbulence — is it flying ?

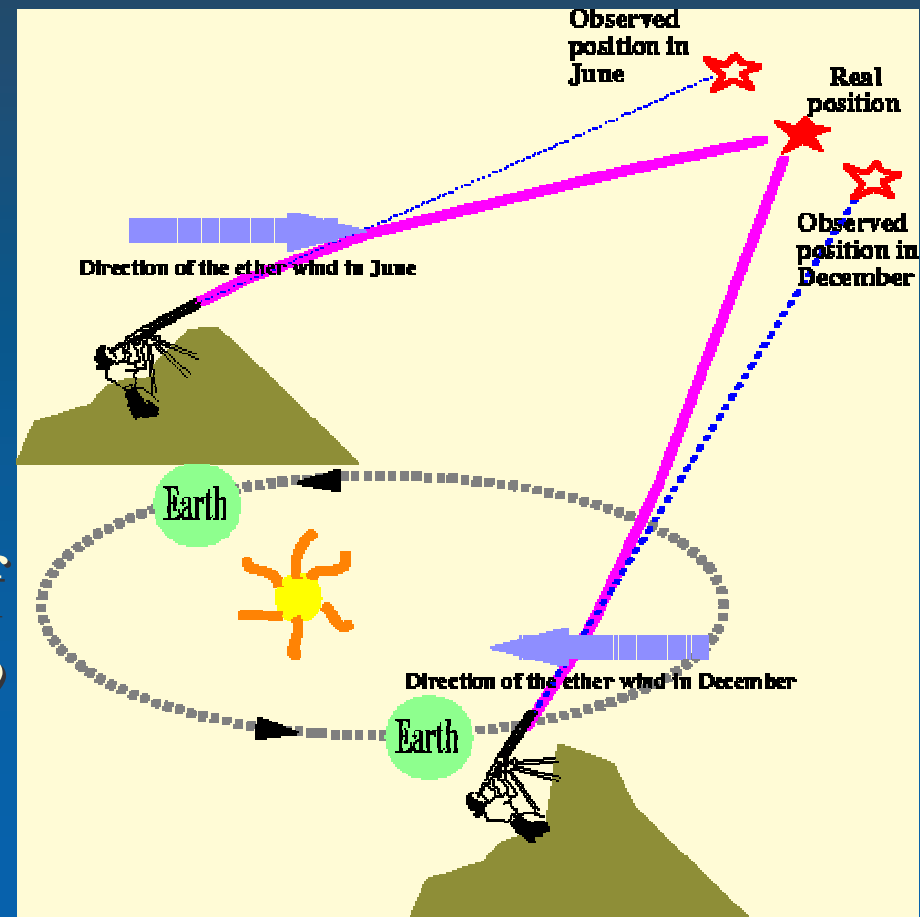
Developments in physics:

Electromagnetism

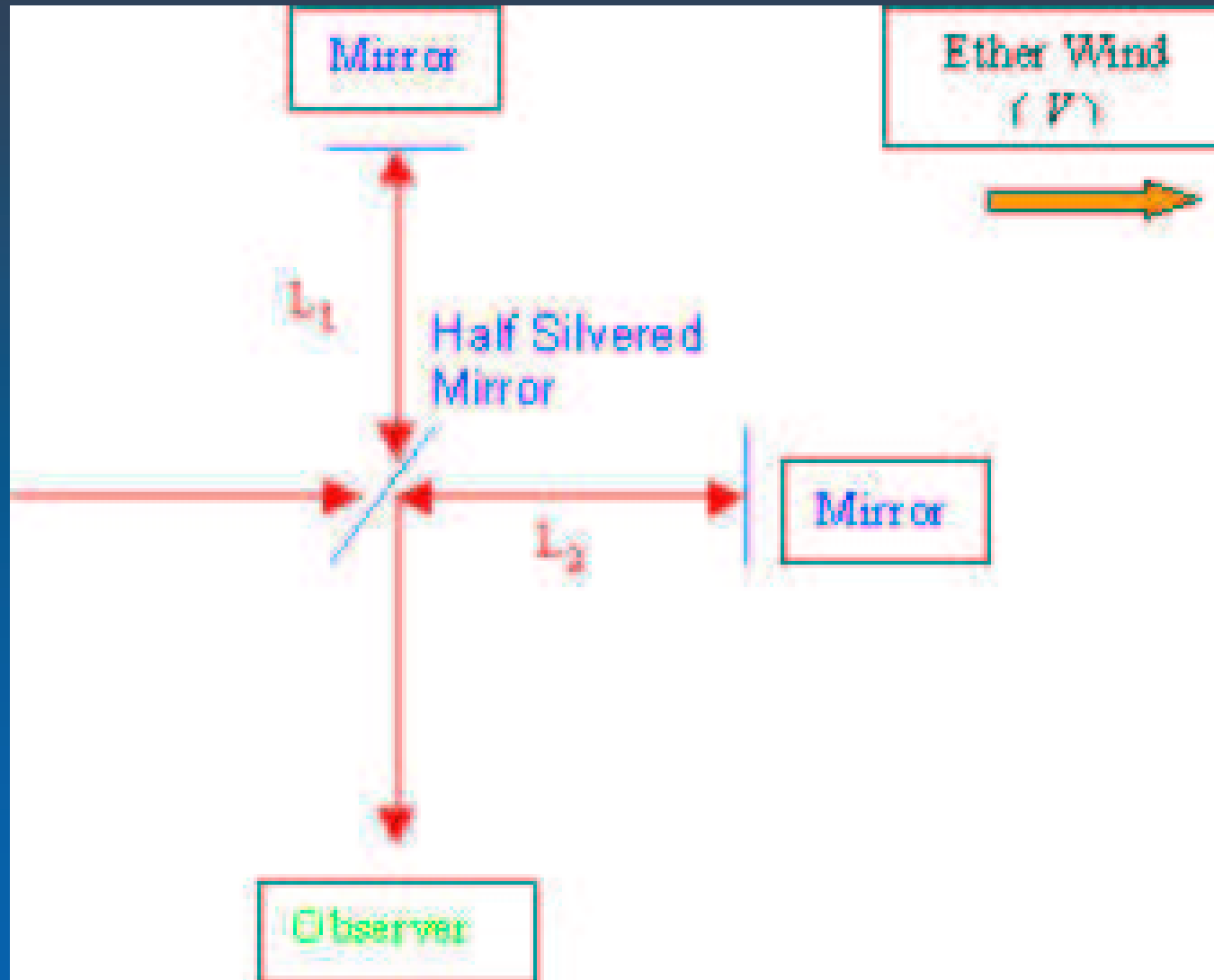
- 1860s: James Clerk Maxwell develops a theory of electricity and magnetism: manifestation of one electromagnetic force
- prediction of electromagnetic waves
 - traveling through space at the speed of light
 - examples: light, radio waves
- Problems:
 - speed of light c is the same in all inertial frames, i.e. c is invariant and not relative
 - what medium “carries” those EM waves ?

The ether is back !! — or is it ??

- **Idea:** electromagnetic waves travel through the **luminiferous ether** (similar to sound waves traveling through air)
⇒ rest frame of the ether is a preferred reference frame
- Can the existence of this ether be tested ?
- Sure it can !



The Michelson-Morley experiment



Result of the Michelson-Morley experiment: the big surprise

- **Expectation:**
 - only in the reference frame of the ether, the speed of light should be
$$c = 299\,792\,458 \text{ m/sec}$$
 - in other reference frames, the velocity should be different (e.g. by 30 km/sec, the speed with which the Earth orbit the Sun)
- **Observation:**
 - the velocity of light was the same to less than 5 km/sec \Rightarrow **there is no ether !!!**

Two clouds on the horizon of 19th century physics

- Michelson-Morley result
- thermal radiation of hot bodies (so-called black body radiation)

Two hurricanes result

- Theory of relativity
- Quantum mechanics