Relativity

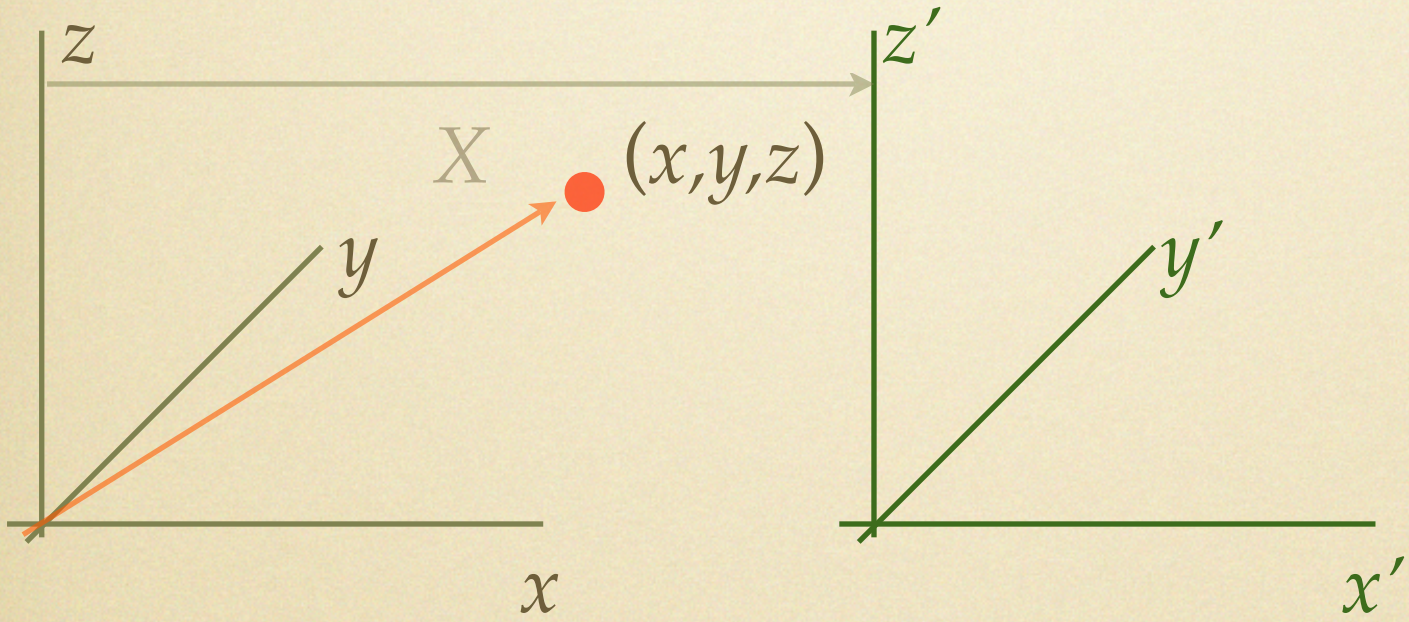
Galileo and Einstein

Time dilation

Length contraction

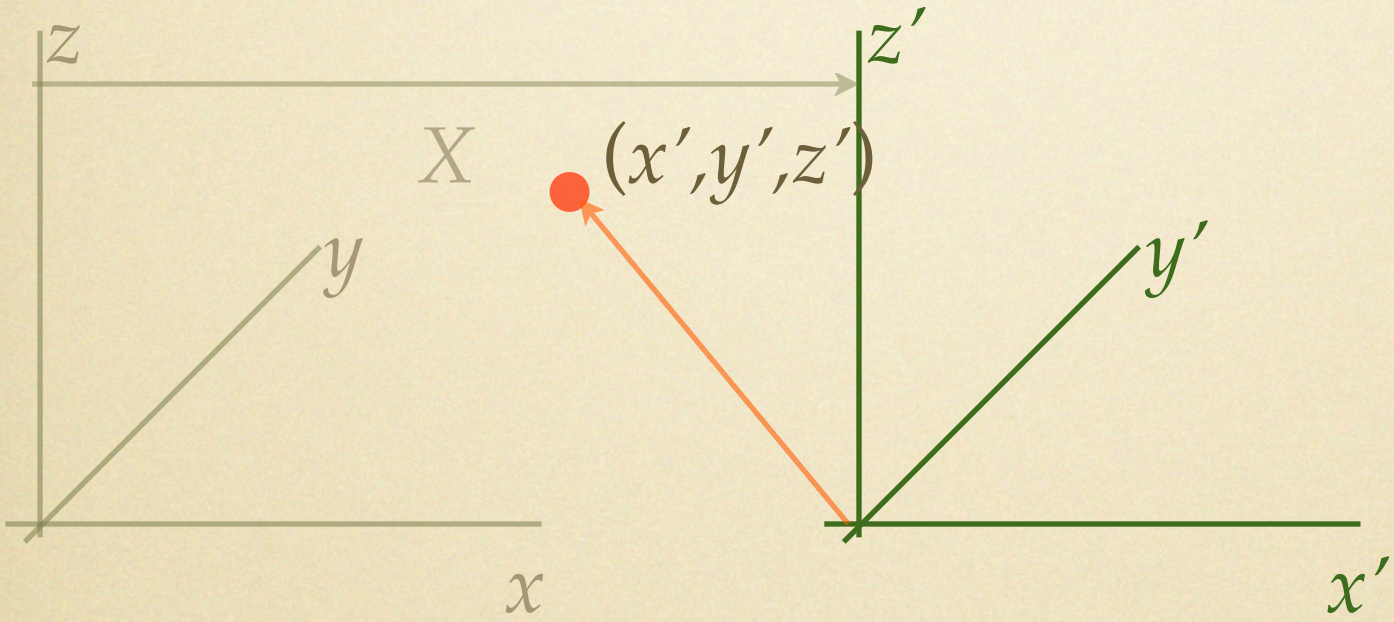
Two coordinate systems

$x'y'z'$ displaced by $\mathbf{X} = X\hat{\imath}$



Two coordinate systems

$x'y'z'$ displaced by $\mathbf{X} = X\hat{\mathbf{i}}$



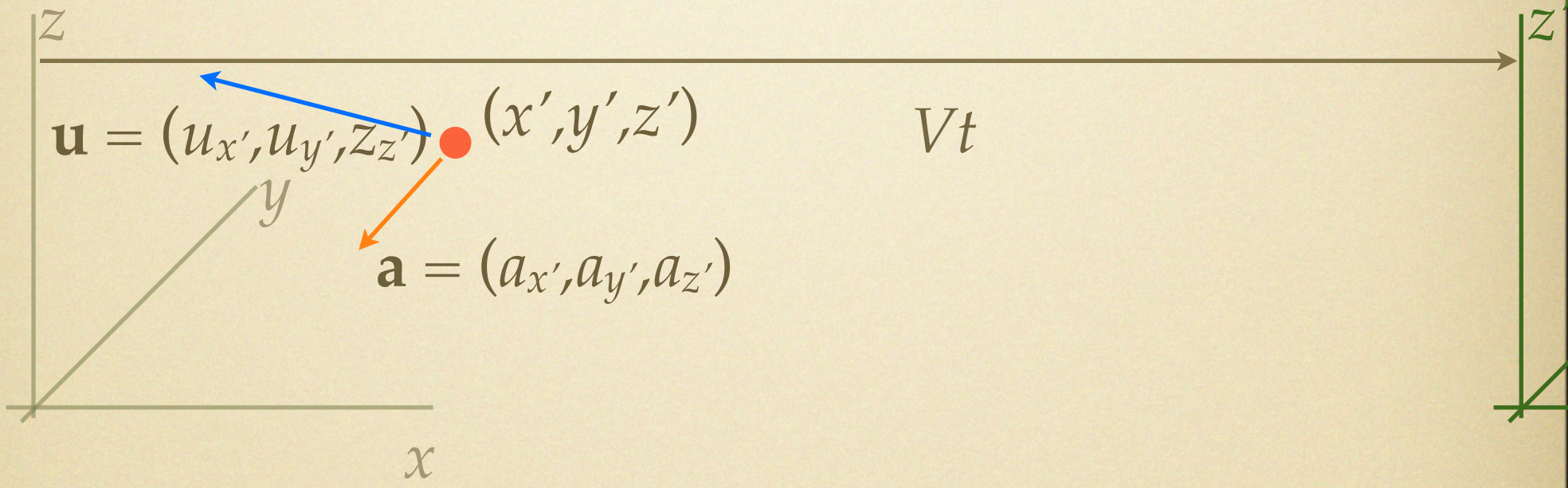
$$x' = x - X$$

$$y' = y$$

$$z' = z$$

Two coordinate systems

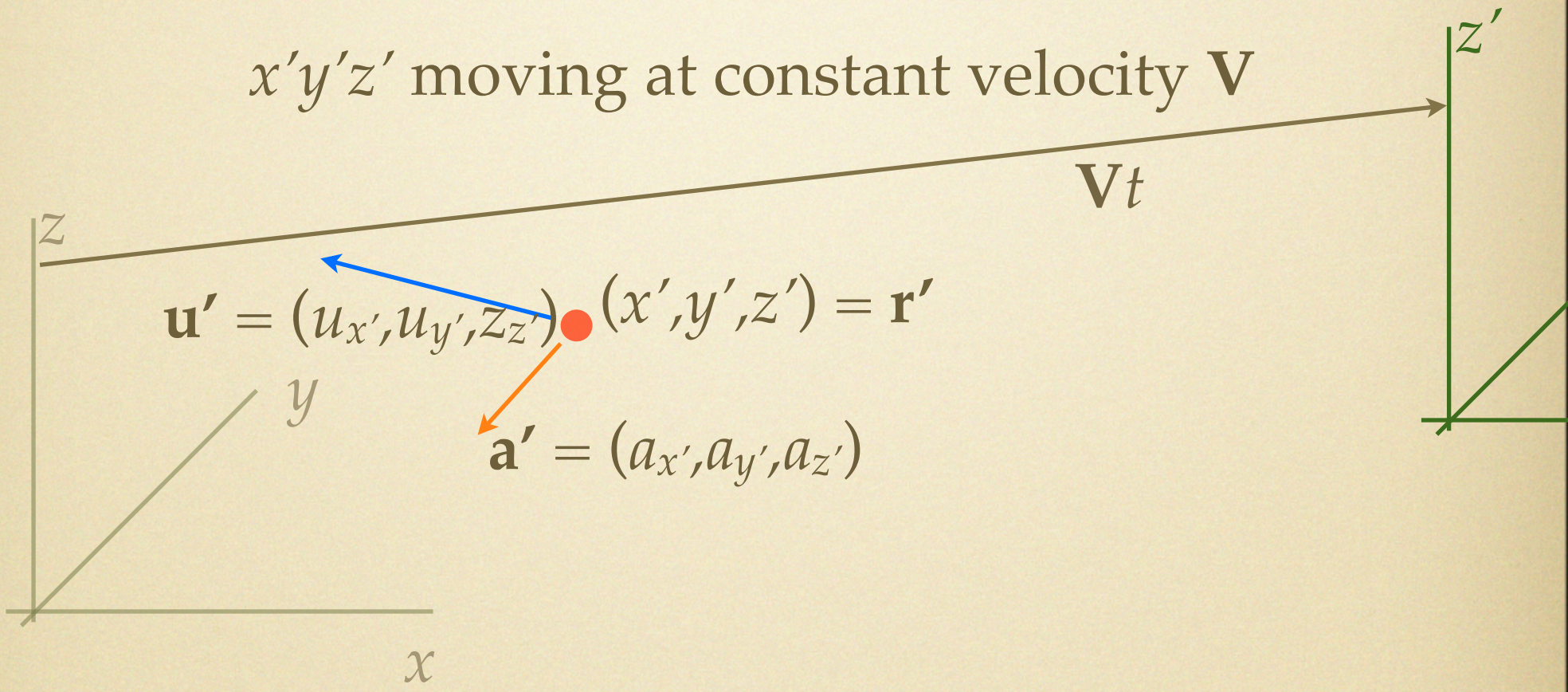
$x'y'z'$ moving at constant velocity $\mathbf{V} = V\,\hat{\mathbf{i}}$



$$a_{x'} = a_x \qquad u_{x'} = u_x - V \qquad x' = x - Vt$$
$$a_{y'} = a_y \qquad u_{y'} = u_y \qquad y' = y$$
$$a_{z'} = a_z \qquad u_{z'} = u_z \qquad z' = z$$

Galilean Transformation

In General



$$a' = a \qquad \mathbf{u}' = \mathbf{u} - \mathbf{V} \qquad \mathbf{r}' = \mathbf{r} - \mathbf{V}t$$

Galilean Transformation

Galilean Relativity

- If one coordinate system moves with respect to another then accelerations are the same in both
- Forces and their effects on acceleration do not change if you change to another frame of reference which is moving at constant velocity with respect to the first.

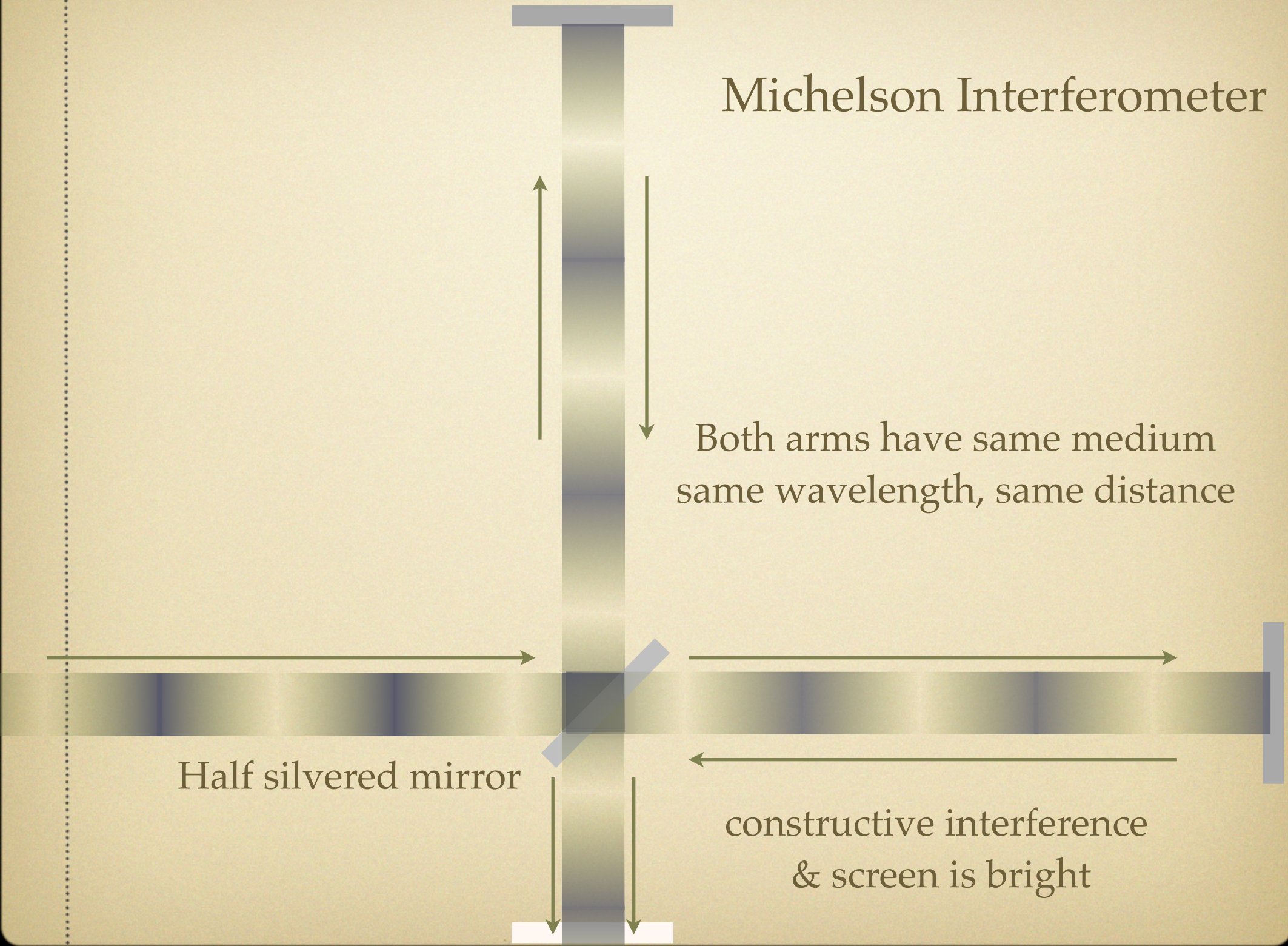
All inertial frames of reference are equivalent

- "Galilean principle of relativity"
  - Newton's laws are valid
  - all masses, forces and accelerations are the same.

Fly in the ointment

- Theory of light and radio waves doesn't obey Galilean Relativity
  - light and radio signals are waves
  - in what medium? aether! (universal jello)
  - What's the speed of the earth through it?

Michelson Interferometer

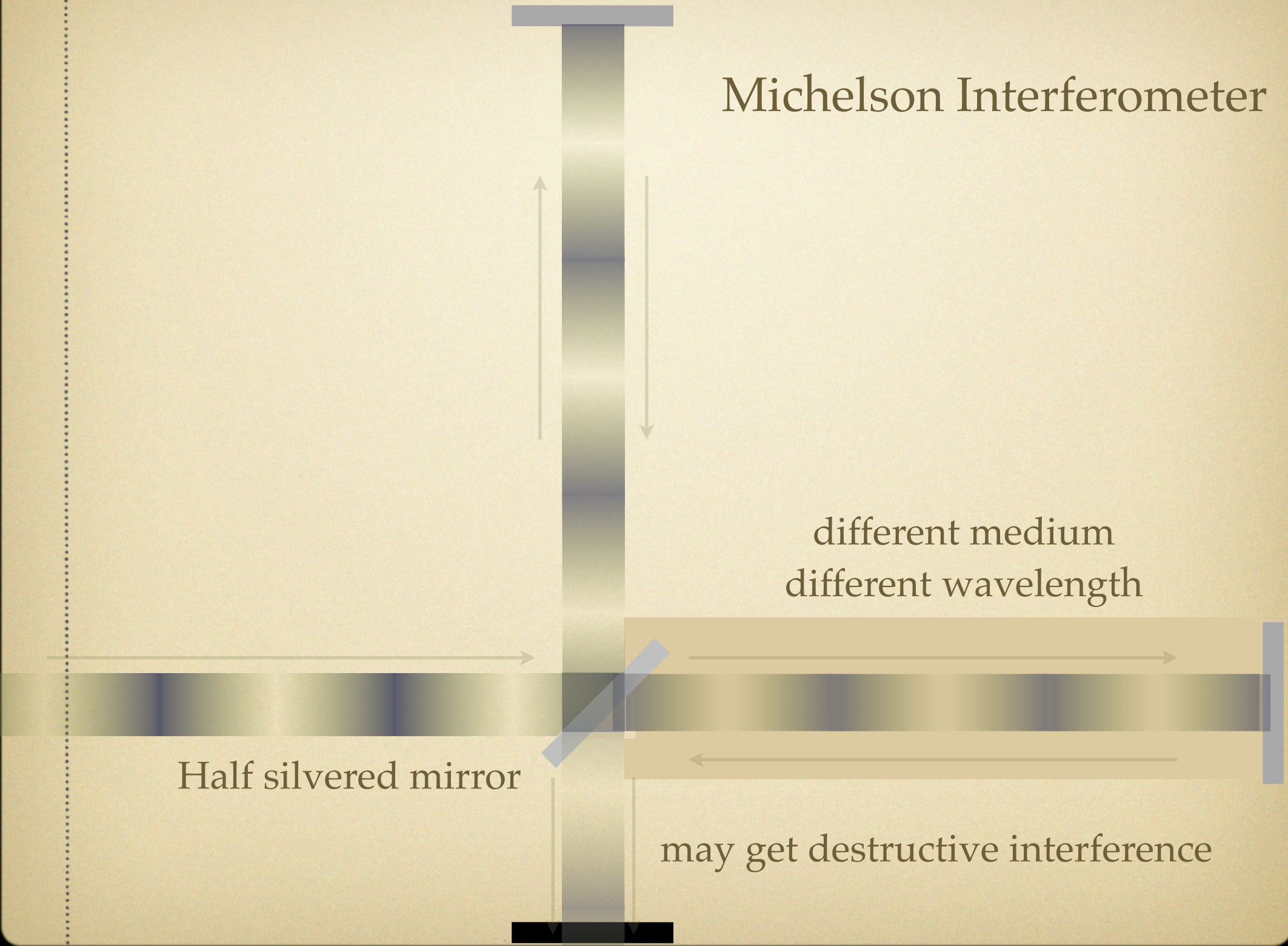


Both arms have same medium
same wavelength, same distance

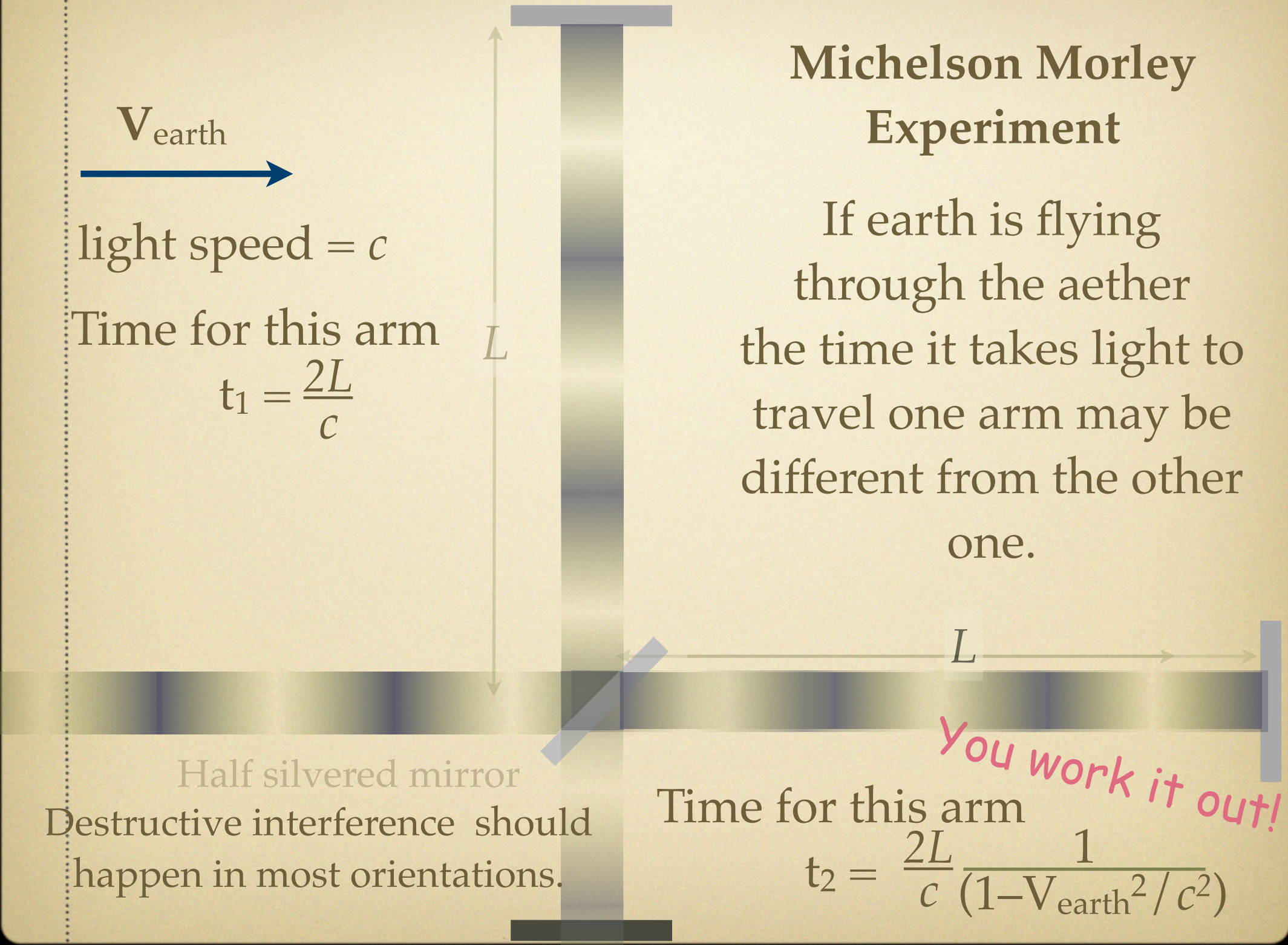
Half silvered mirror

constructive interference
& screen is bright

Michelson Interferometer



Michelson Morley Experiment



Experiment Results

- No interference between the two beams
- The speed of the earth through the aether could not be measured.
- But every 6 months earth changes direction in its motion around the sun.
  - $V_{earth} = 0$ all the time, from M-M expt.
  - But, $\Delta V_{earth} = 60000$ m/s, every 6 months

Conclusion

- From this experiment and others
- The speed of light must be the same in all inertial reference frames.
- Einstein modifies Galileo's relativity
  - Note: History was not quite so simple
  - The logical consequences are unbelievable

$$x' = \gamma(x - vt)$$
$$y' = y$$
$$z' = z$$
$$t' = \gamma(t - vx/c^2)$$

where

$$\gamma = \sqrt{1 - v^2/c^2}$$

The Lorentz Transformation