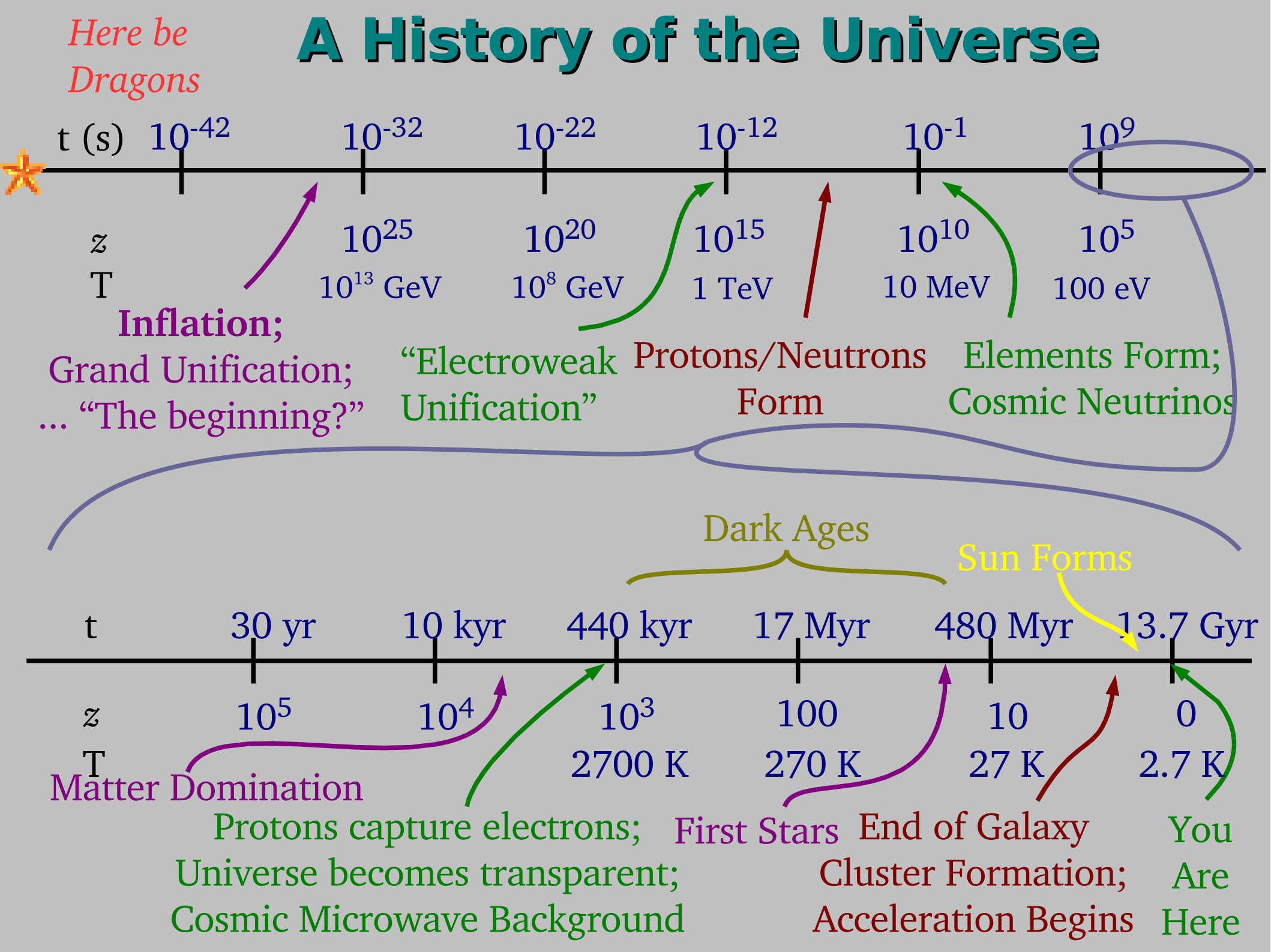
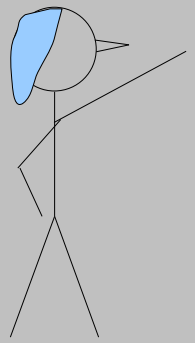
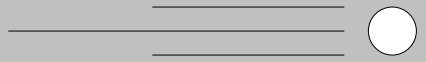
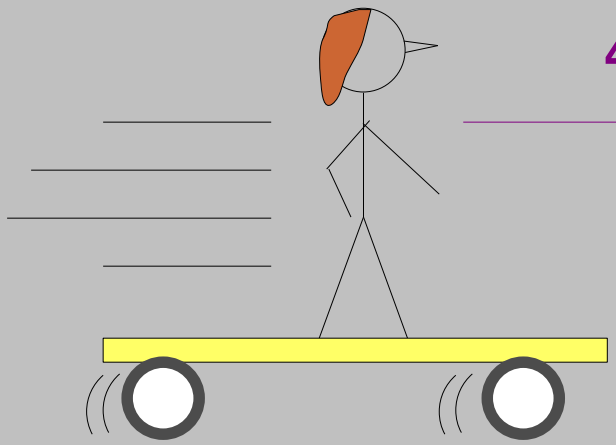

Here be Dragons
A History of the Universe
t (s)
10-42
10-32
10-22
10-12
10-1
109
z
T
1025
1013 GeV
1020
108 GeV
1015
1 TeV
1010
10 MeV
105
100 eV
Inflation;
Grand Unification;
... "The beginning?"
"Electroweak Unification"
Protons/Neutrons Form
Elements Form;
Cosmic Neutrinos
Dark Ages
Sun Forms
t
30 yr
10 kyr
440 kyr
17 Myr
480 Myr
13.7 Gyr
z
T
105
10
4
103
2700 K
100
270 K
10
27 K
0
2.7 K
Matter Domination
Protons capture electrons;
Universe becomes transparent;
Cosmic Microwave Background
First Stars
End of Galaxy
Cluster Formation;
Acceleration Begins
You
Are
Here



80 mph





40 mph

What is the speed of the baseball relative to the skateboard dude?

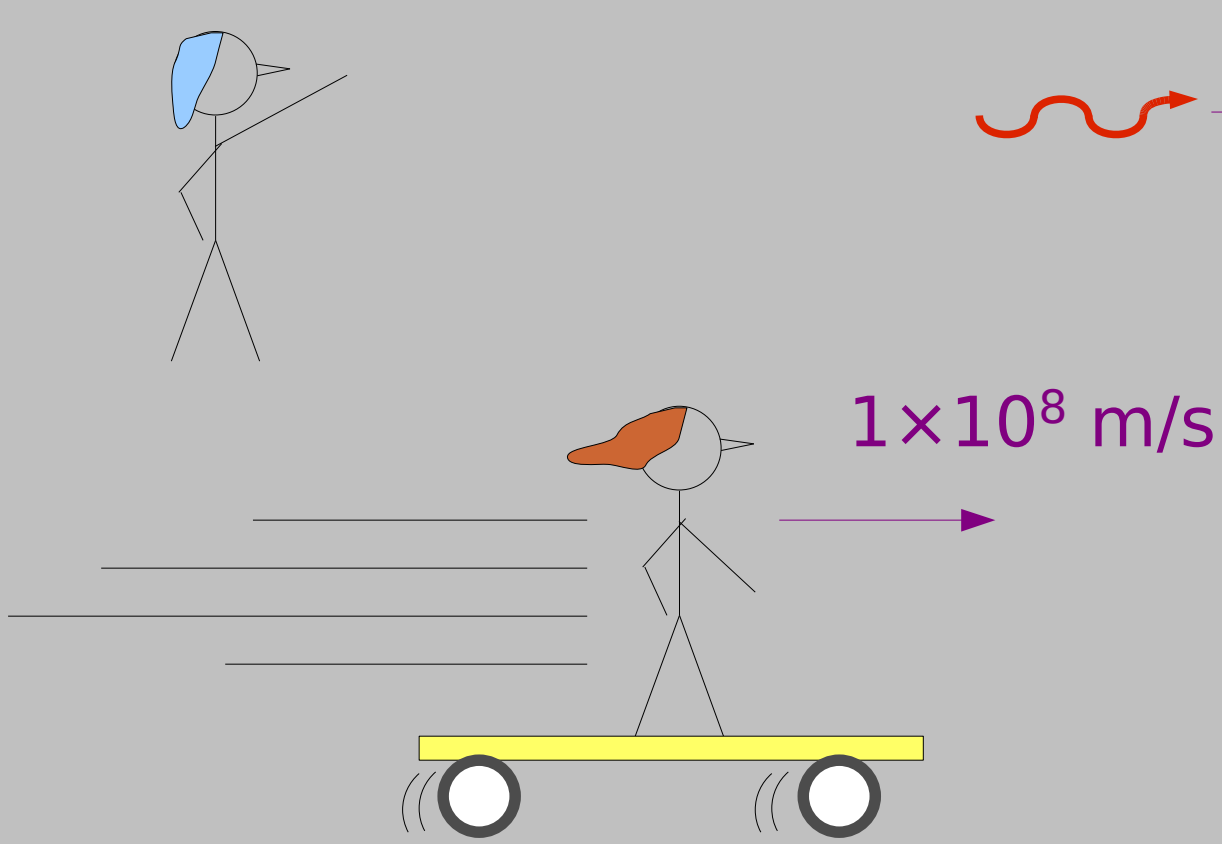
A 2 mph

B 20 mph

C 40 mph

D 80 mph

E 120 mph



What is the speed of the photon relative to the skateboard dude?

A 2 m/s

B 1×10^8 m/s

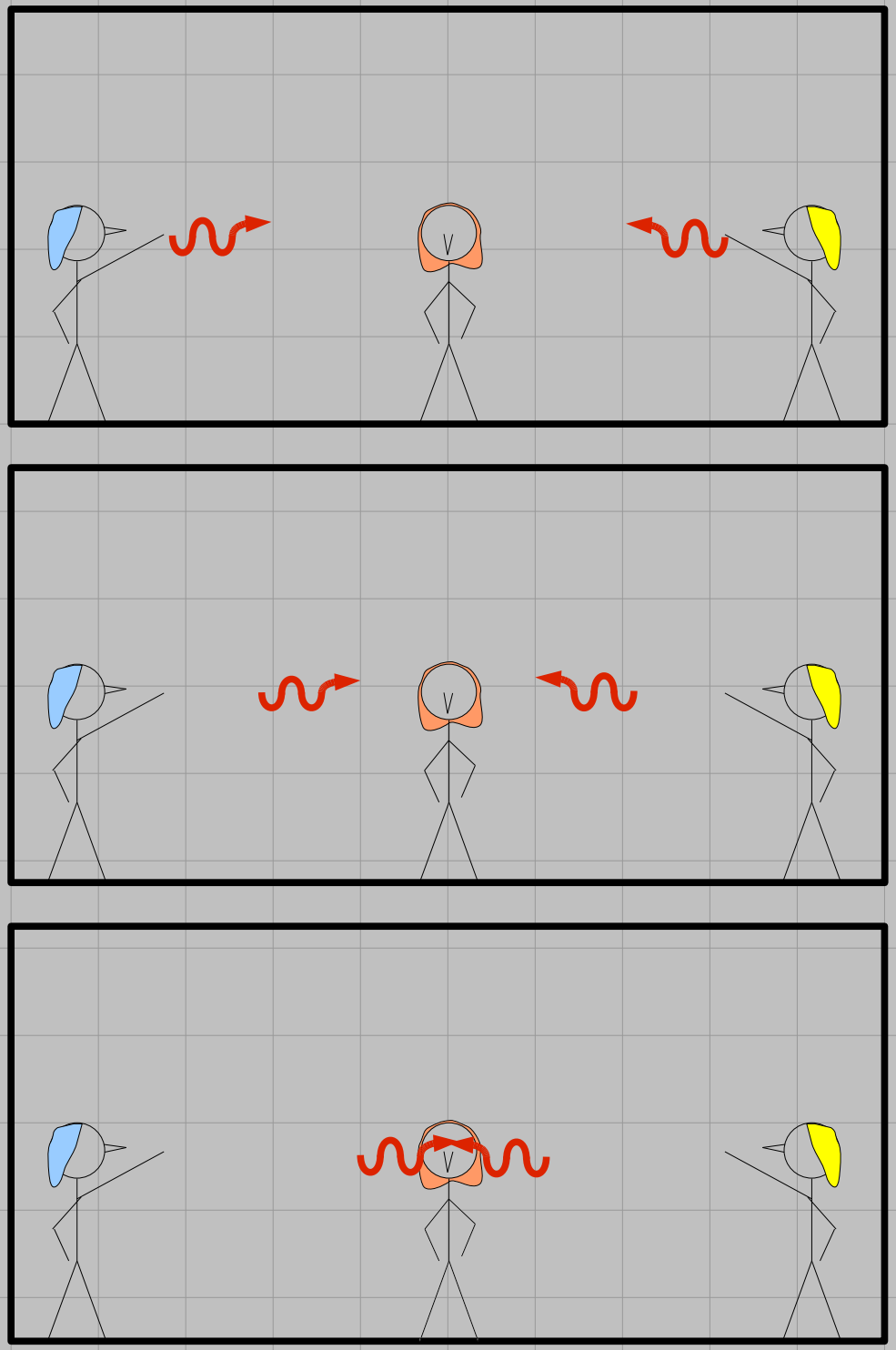
C 2×10^8 m/s

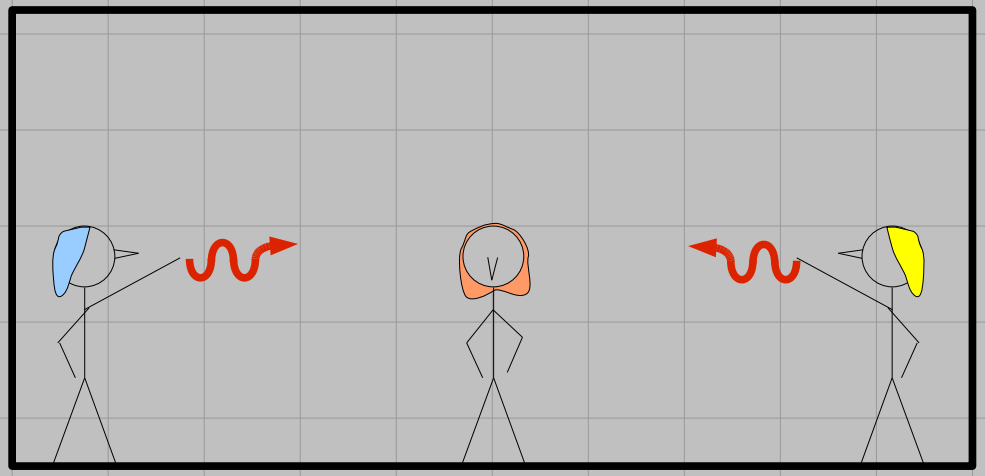
D 3×10^8 m/s

E 4×10^8 m/s

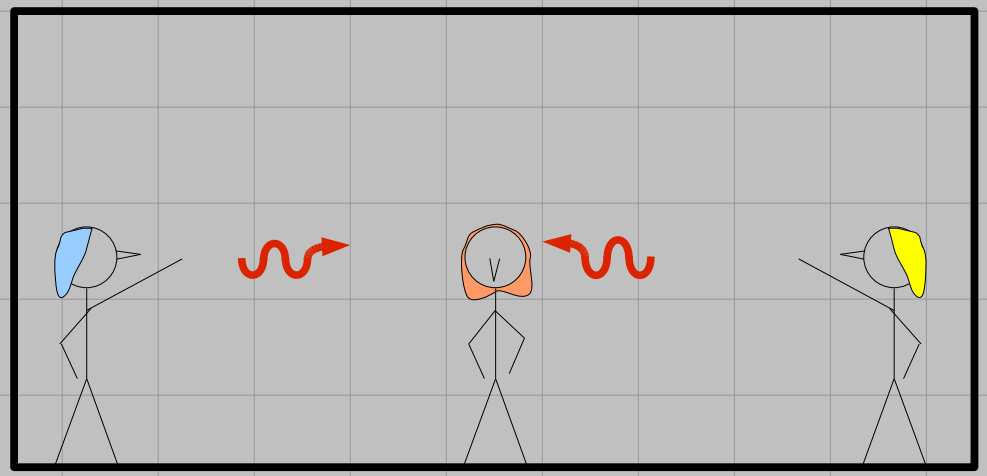
Postulate of Special Relativity:

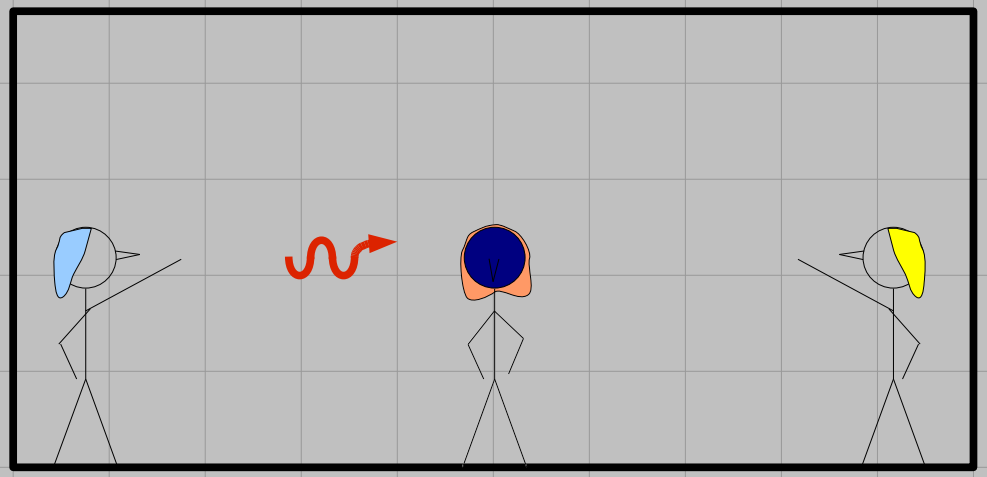
The laws of Physics – including the speed of light – are the same for every observer.



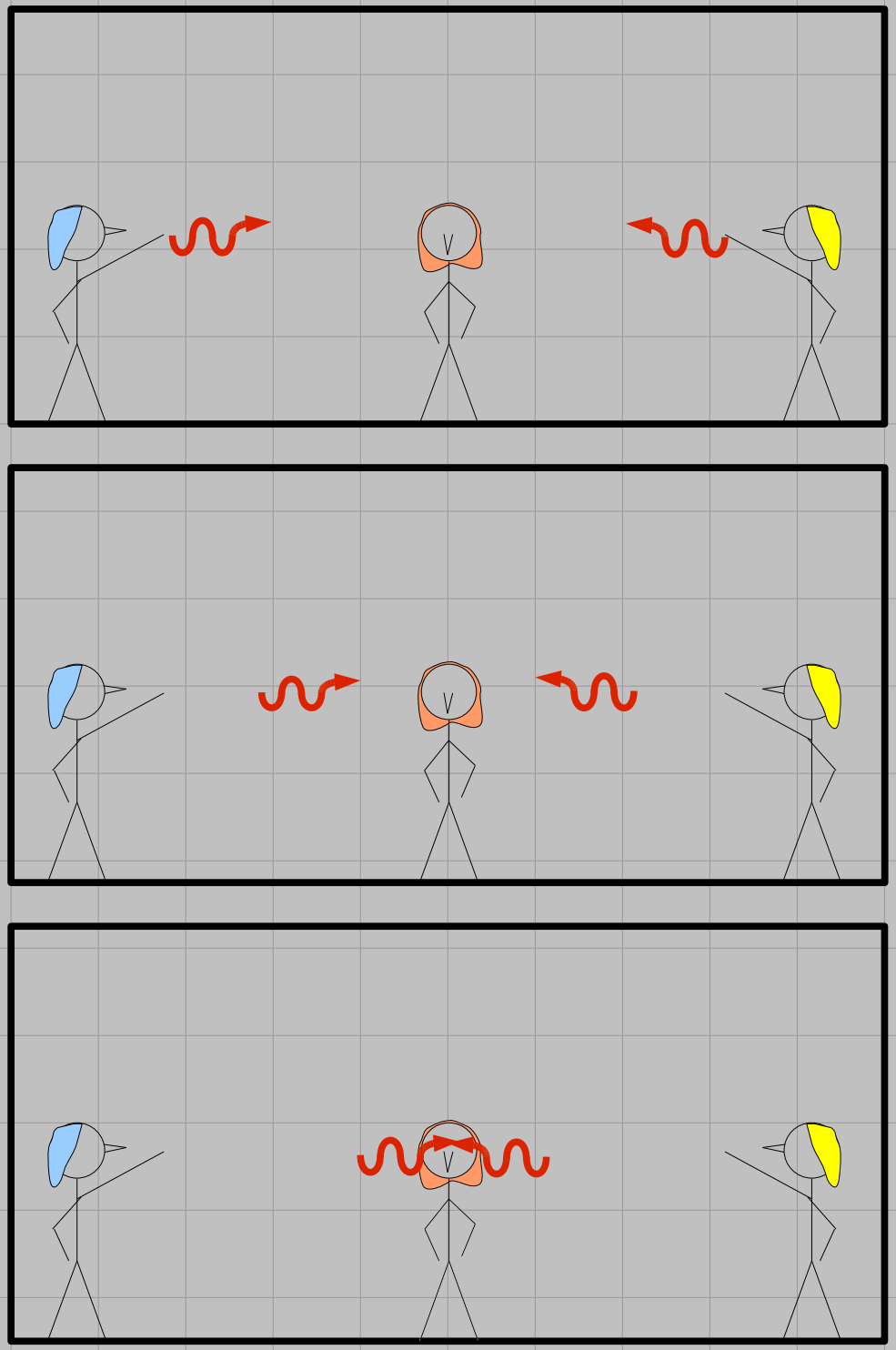


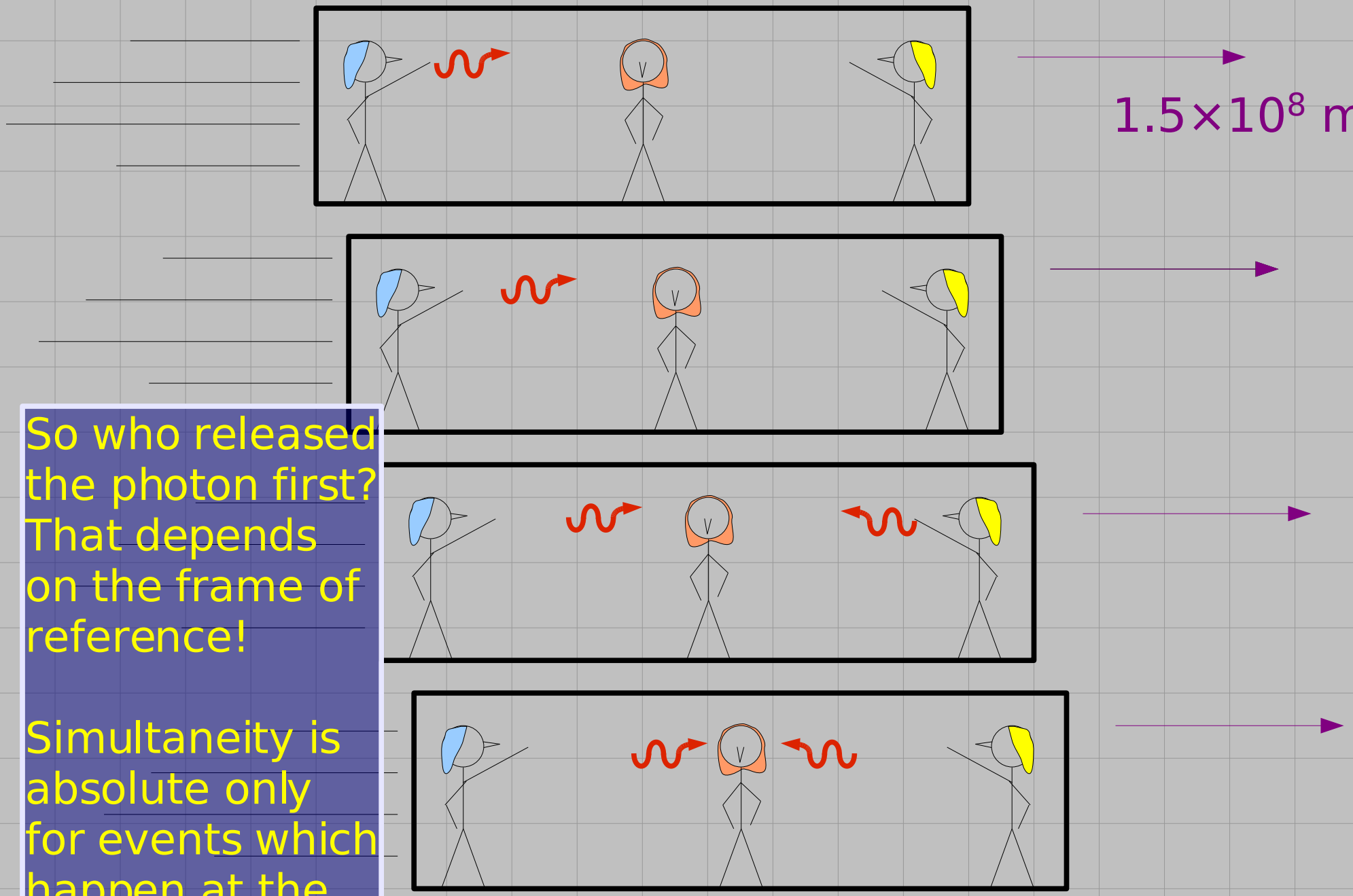
1.5×10^8 m/s





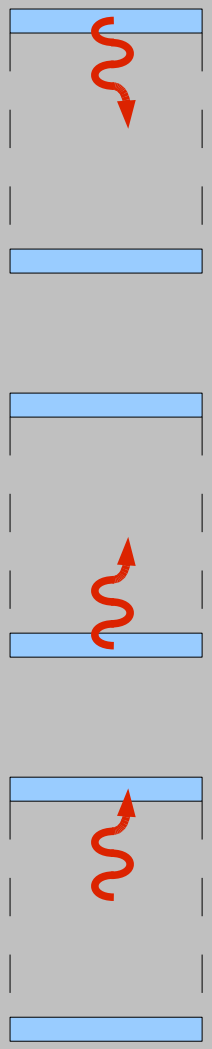
Not the same experiment as on the last slide!





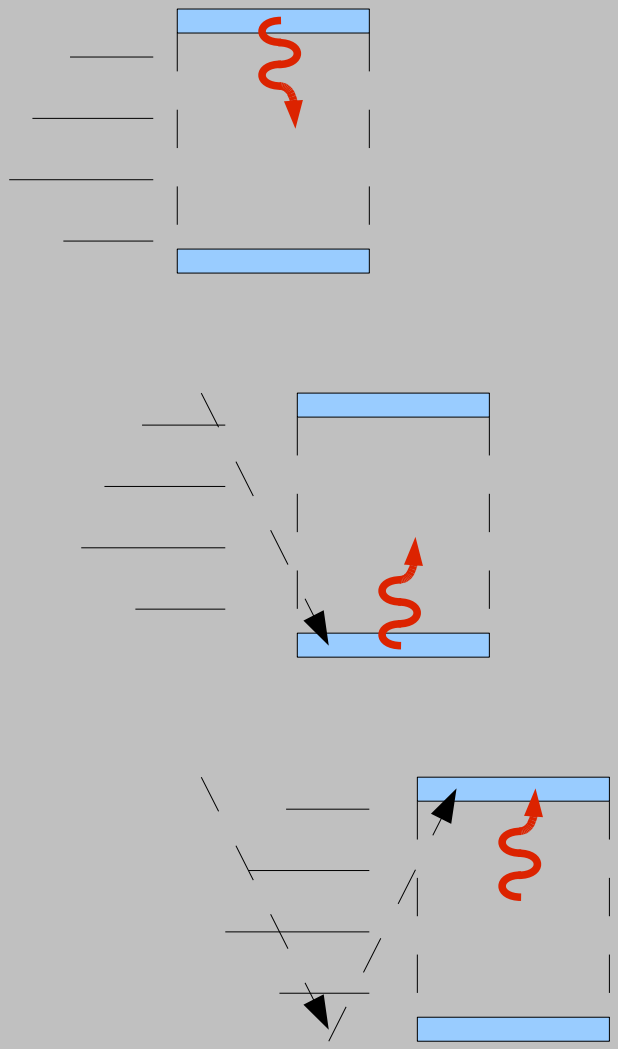
So who released the photon first? That depends on the frame of reference!

Simultaneity is absolute only for events which happen at the same point in space!



Case A:

1 Second Elapsed



Case B

How much time has elapsed for Case B?

A < 1 second

B 1 second

C > 1 second

Moving clocks run slow!

Special Relativity tells us that space and time are mixed up with each other.

General Relativity

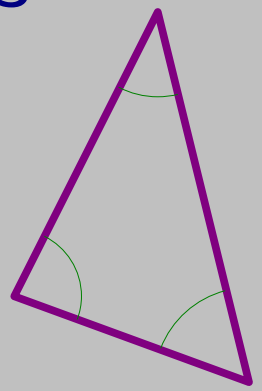
Our modern theory of gravity, originally developed by Einstein.

- Gravity is not a “force,” it is the *curvature of spacetime*.
- Particles move in as straight of lines as possible through spacetime.
- The presence and distribution of mass, energy, and pressure determines the curvature of spacetime.
- Yields identical results to Newton's gravity when “far” from something very massive.

How do you determine if spacetime is curved???

Flat (Euclidean) Space:

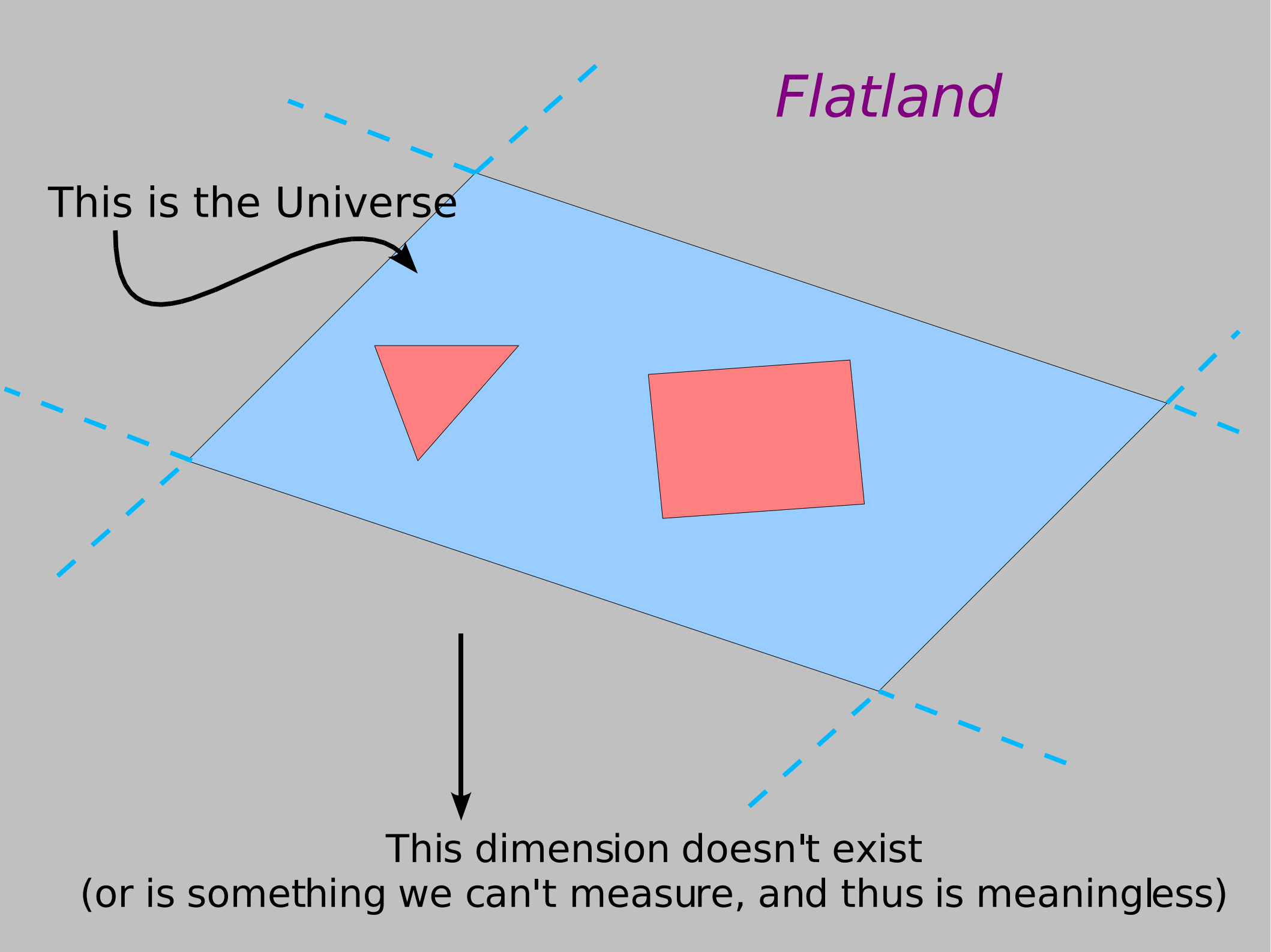
Any triangle, three interior angles add to 180°



0 Curvature : angles sum to 180°

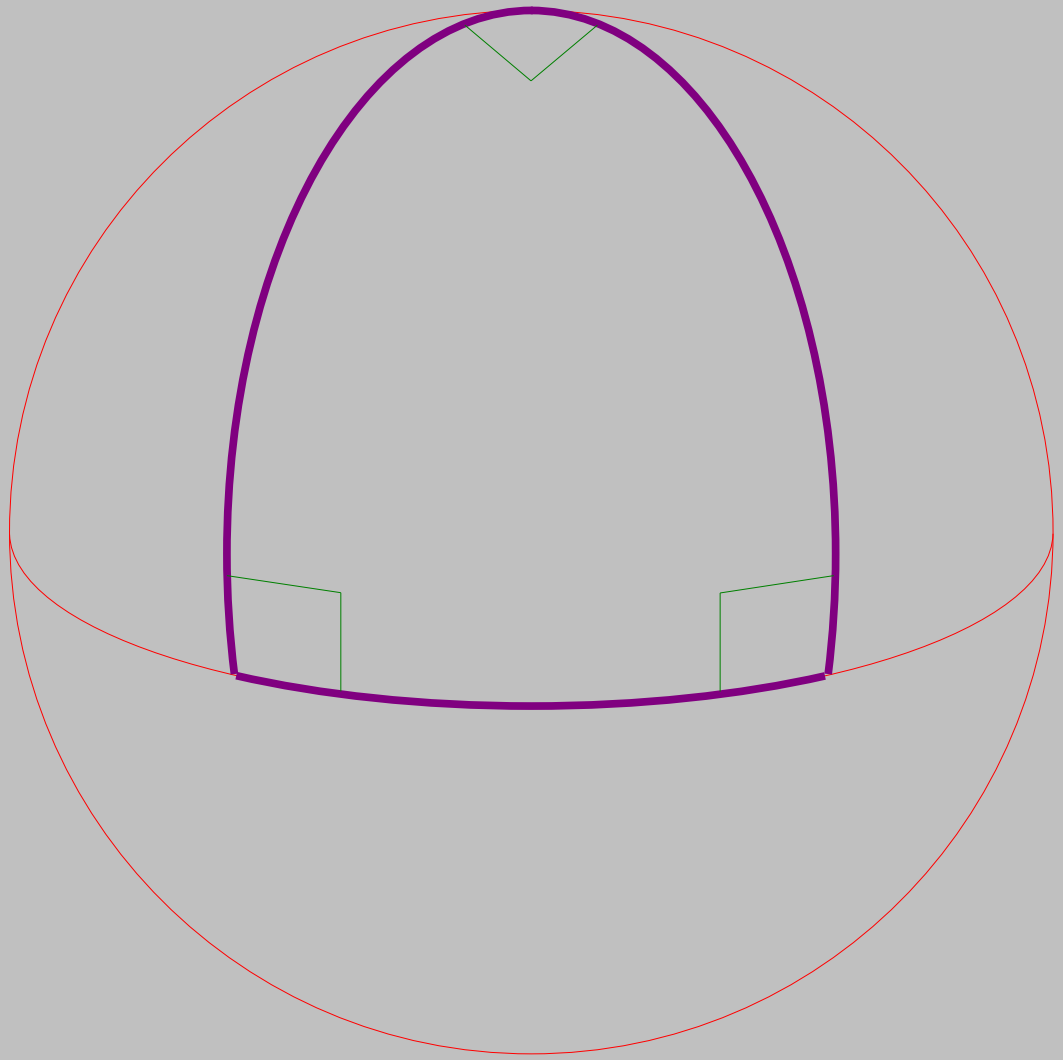
Positive Curvature : angles sum to > 180°

Negative Curvature : angles sum to < 180°


Flatland
This is the Universe
This dimension doesn't exist
(or is something we can't measure, and thus is meaningless)

Example curved 2d space :
The *surface* of a sphere

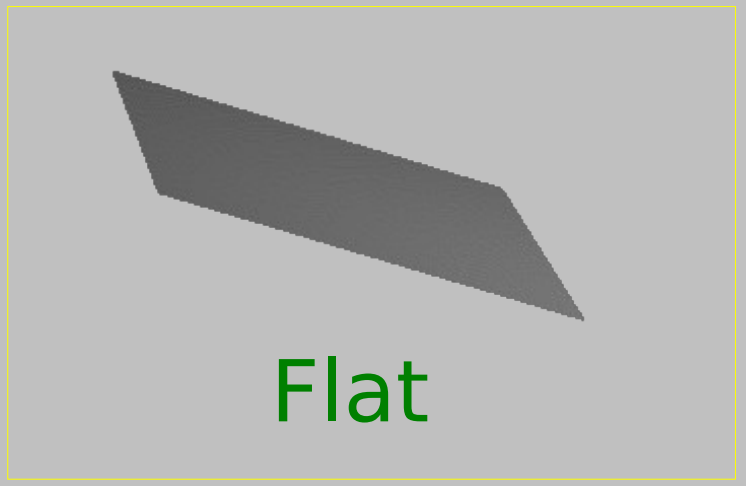
(positive curvature)

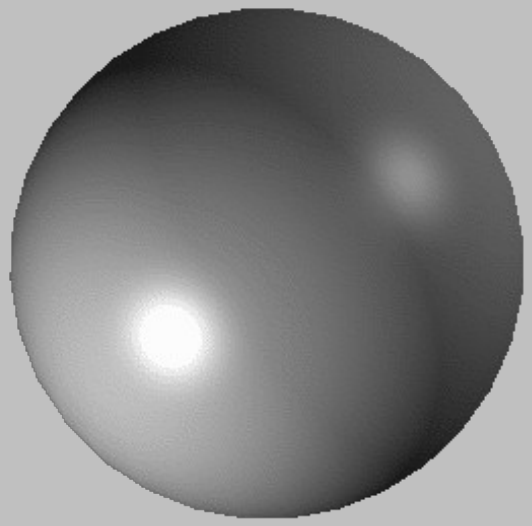


Flatland (2-dimensional) creatures could measure this curvature without reference to the third dimension we use to describe this here!

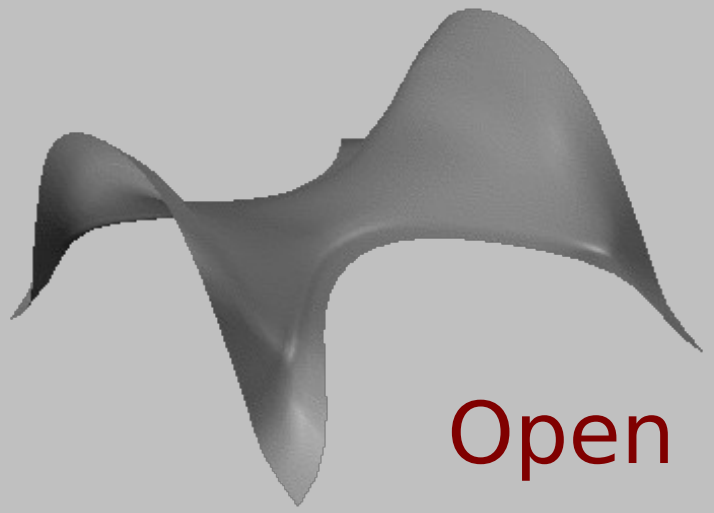
Angles sum to 270°...!

Possible Shapes of the Universe





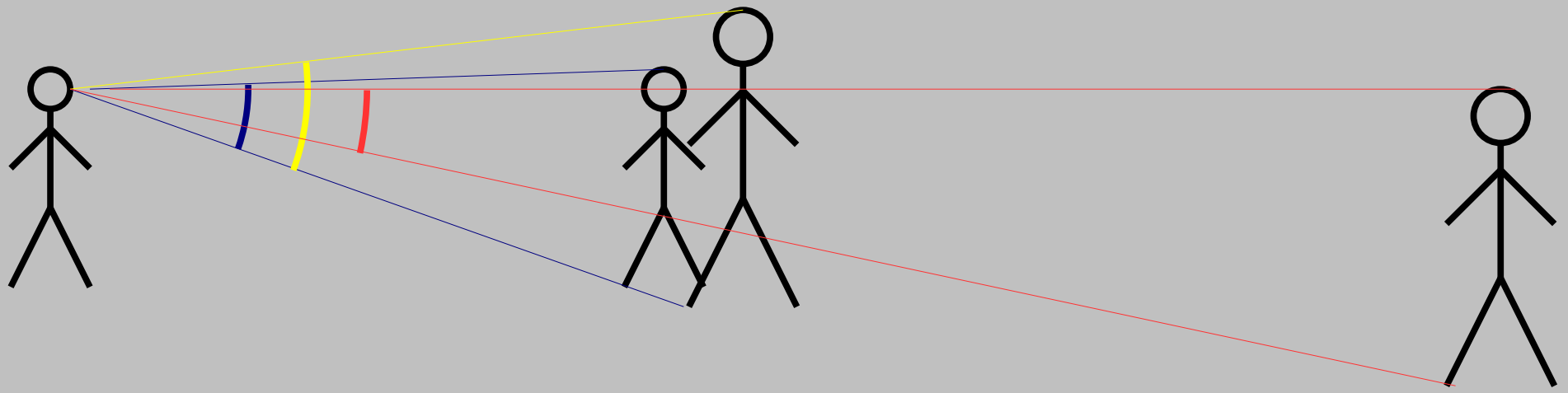
Closed

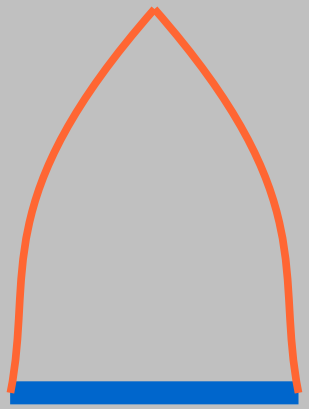


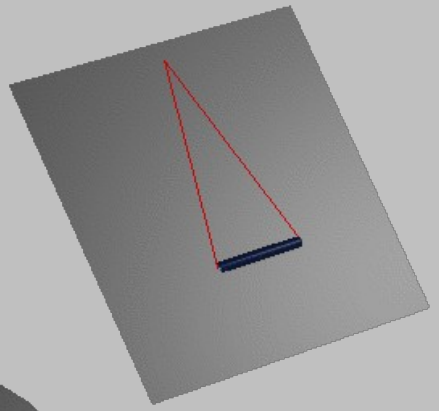
Open

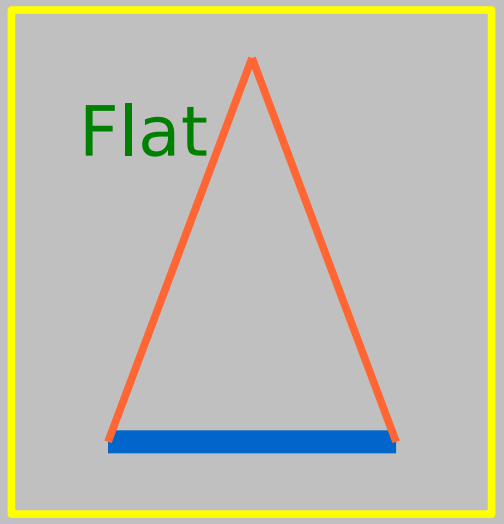
What do we mean when we
say how big something looks?

The angle that it *subtends*.

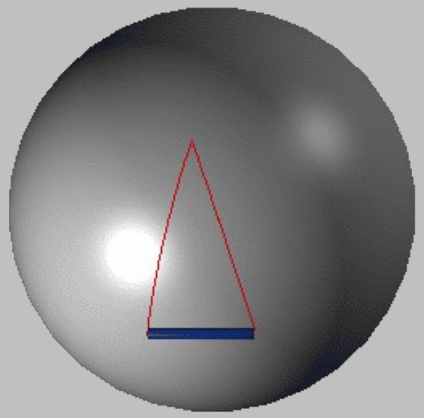


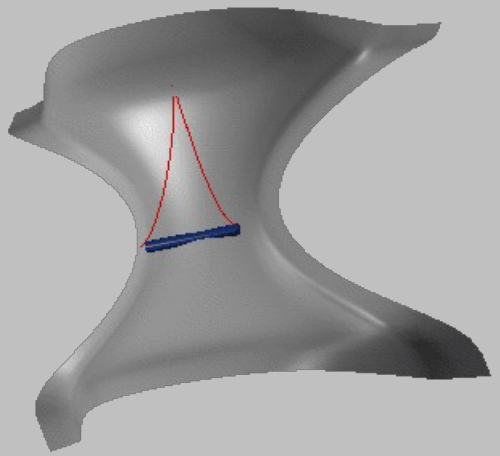




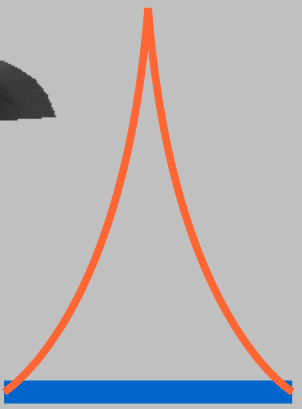


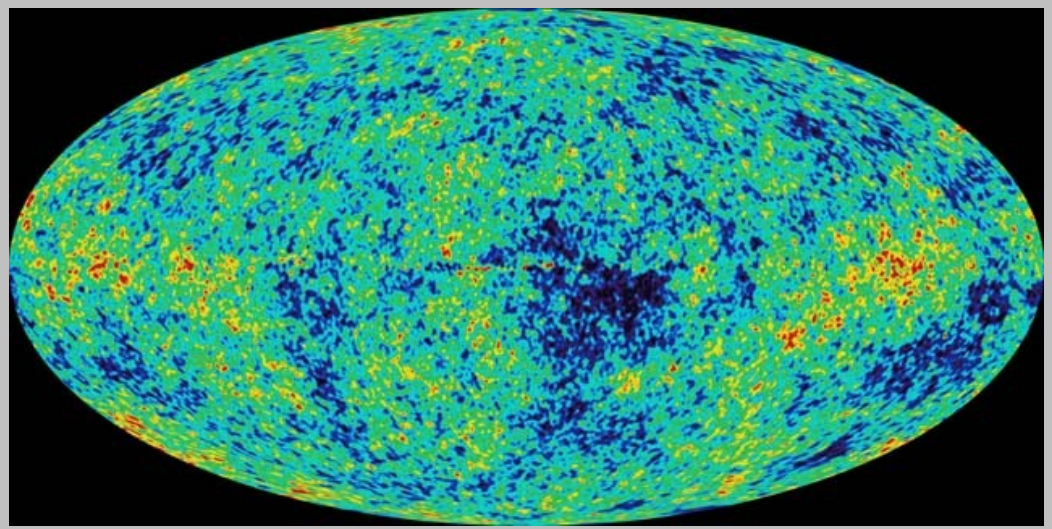
Closed:
Looks Bigger

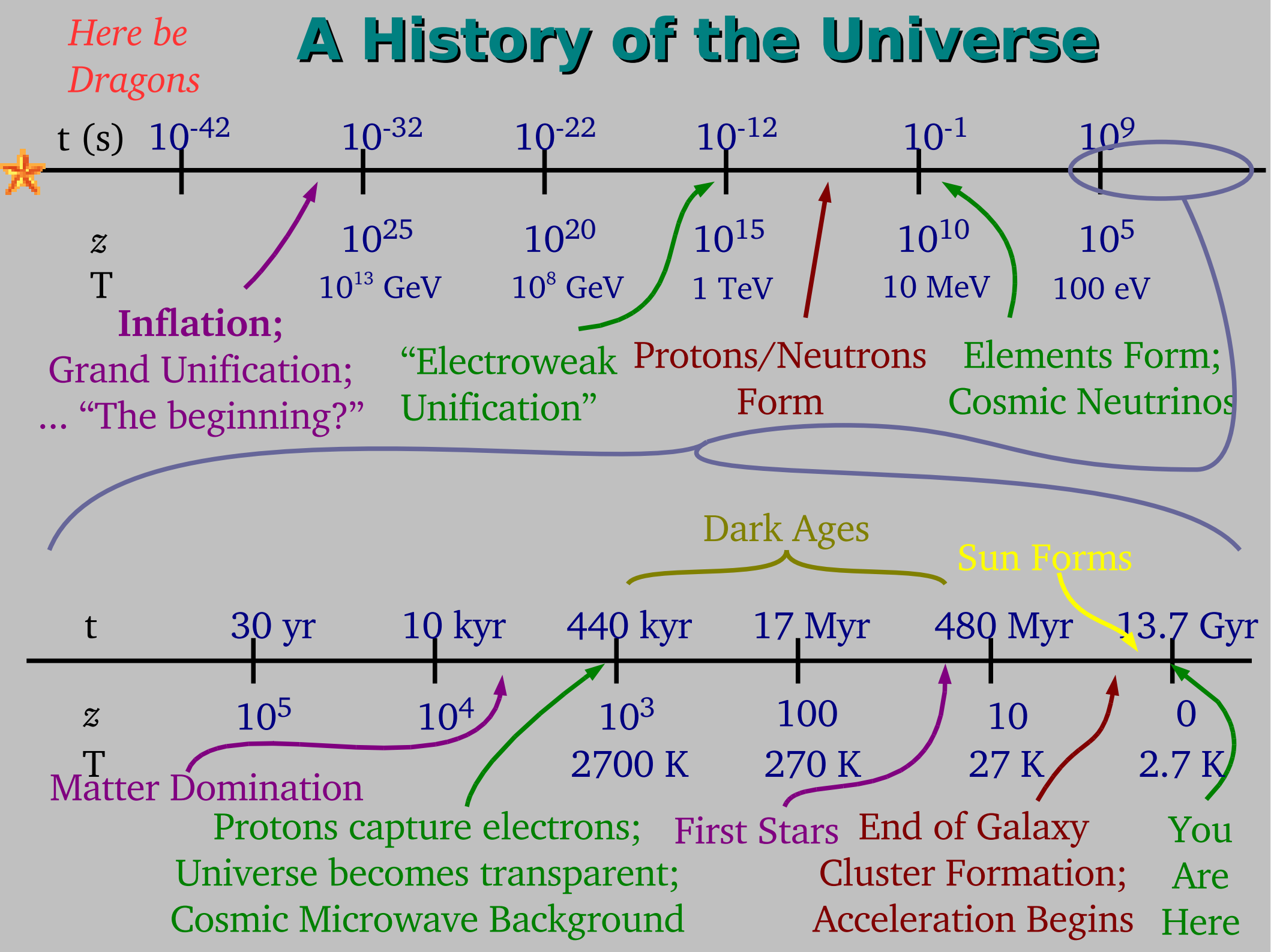




Open:
Looks Smaller



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