Relativity for Poets

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The Albuquerque Astronomical Society

June 2nd, 2012

Agenda

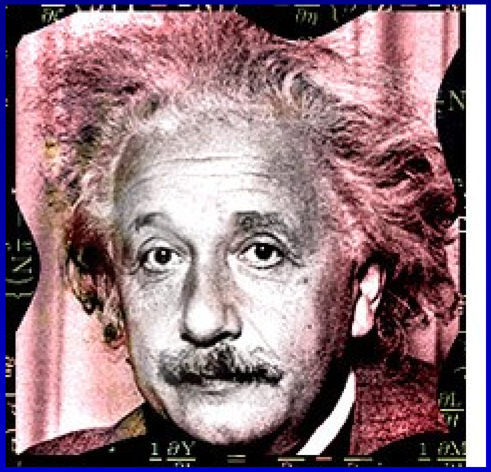
- **Intro**
- **Special Relativity**
- **The Twin Paradox**
- **Resistance to Relativity**
- **Space Travel Difficulties**

What is "Relativity"?

Speed of Light

Mass/Energy Equvalence

Time Dilation



Length Contraction

$$\frac{\partial^2 u}{\partial t^2} = c^2 \nabla^2 u,$$

Physics of Motion

Mass Increase

Let's get Started…

Required Math – Radar Ranging

- A Pulse is Emitted...
- It travels through space at a fixed speed...
- It bounces off of some Object, and comes back at the same speed...
- Upon its return, you measure the elapsed time since the pulse was launched.
- The Distance to the Object is half the elapsed time, multiplied by the speed of the Pulse...

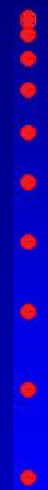
Special Relativity is based on Two Principles…

- The Laws of Physics are the *Same* in all inertial reference frames

- The Speed of Light is *Independent* of the motions of either the Source or the Observer

The Laws of Physics are the Same in all Inertial Reference Frames*

* Imagine Cruise Control on Steroids



$$\vec{F} = m\vec{a}$$

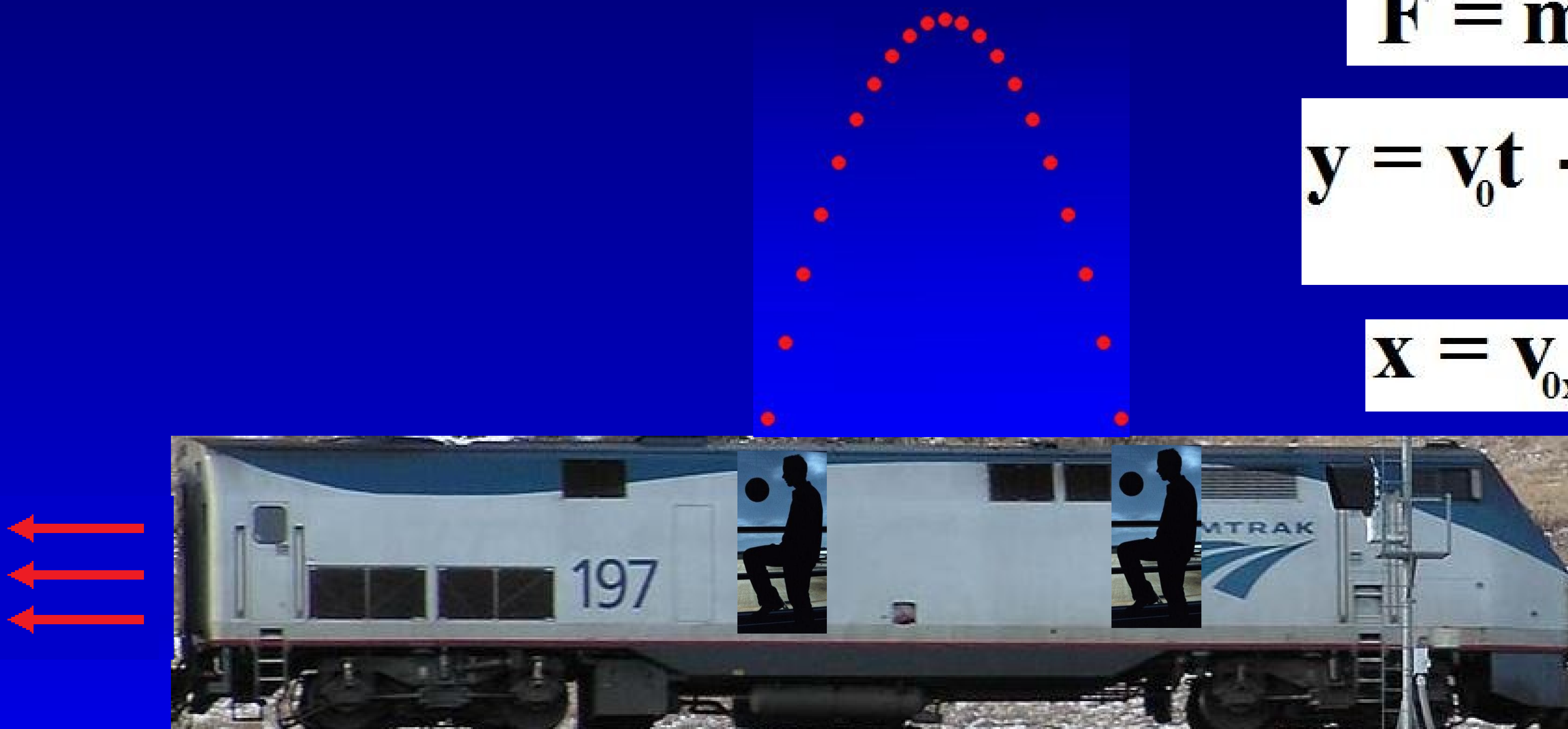
$$y = v_0 t - g\frac{t^2}{2}$$

The Laws of Physics are the Same in all inertial reference frames

$$\vec{F} = m\vec{a}$$

$$y = v_0 t - g\frac{t^2}{2}$$

$$x = v_{0x} t$$



Lightspeed is *Independent* of motions of Source or Observer

But ordinary objects aren't like that!

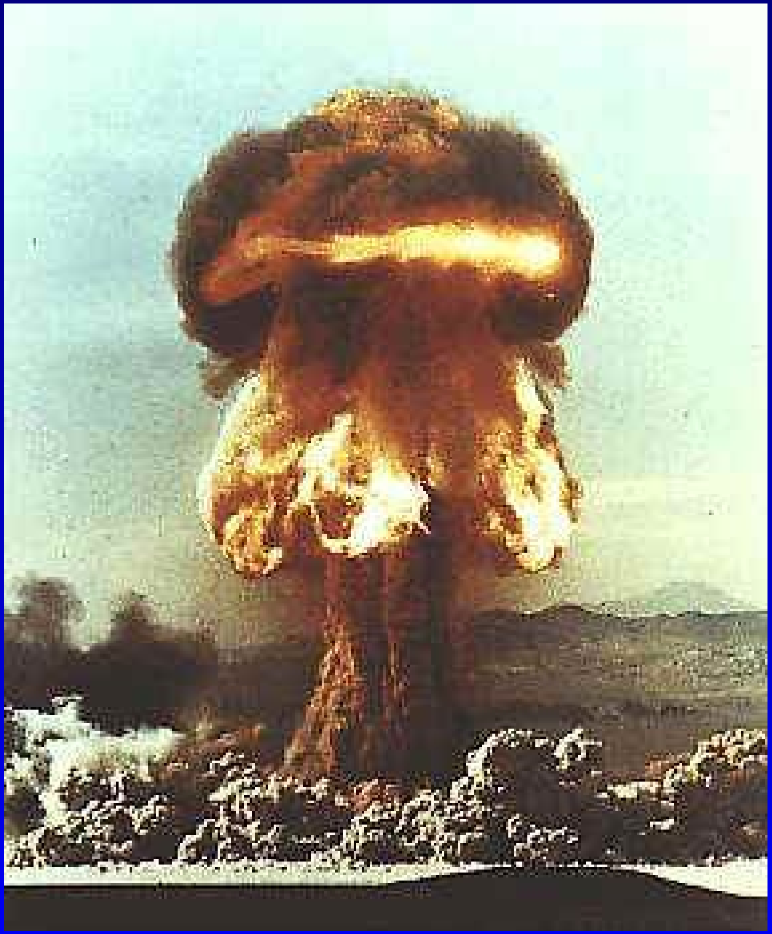
Lightspeed is *Independent* of motions of Source or Observer

This Time, with a Speeding Train!

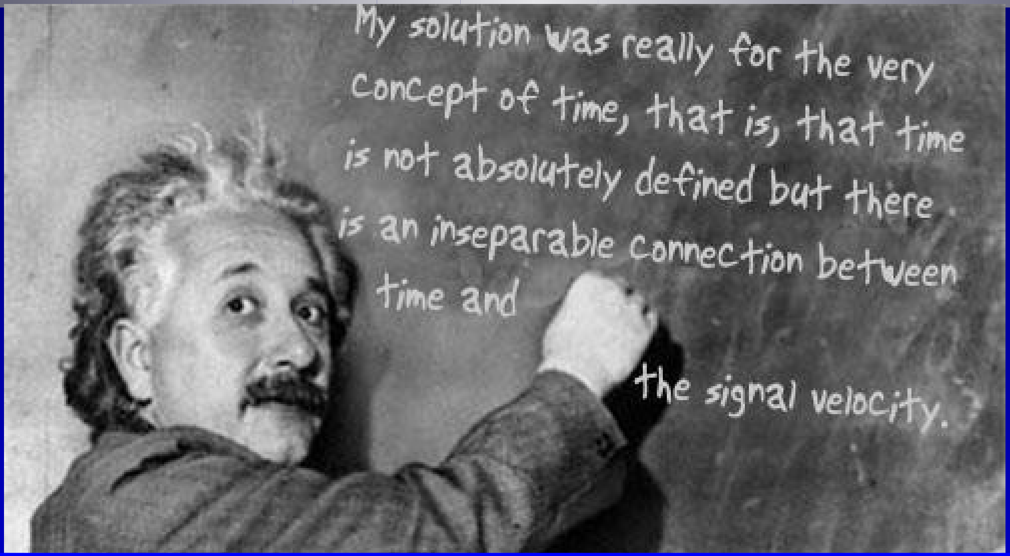
What are the Consequences?

- Time Dilation (Events take “longer” in frames seen as moving)
- Length Contraction (Distances appear “shorter” in frames seen as moving)
- Mass/Momentum Increase (masses appear “greater” in frames seen as moving)
- Inability to accelerate *anything*, even a tiny electron, past the Speed of Light, 3×10^8 m/s.

Oh yeah, and $E = mc^2$



The Big One…
Time is not Absolute!



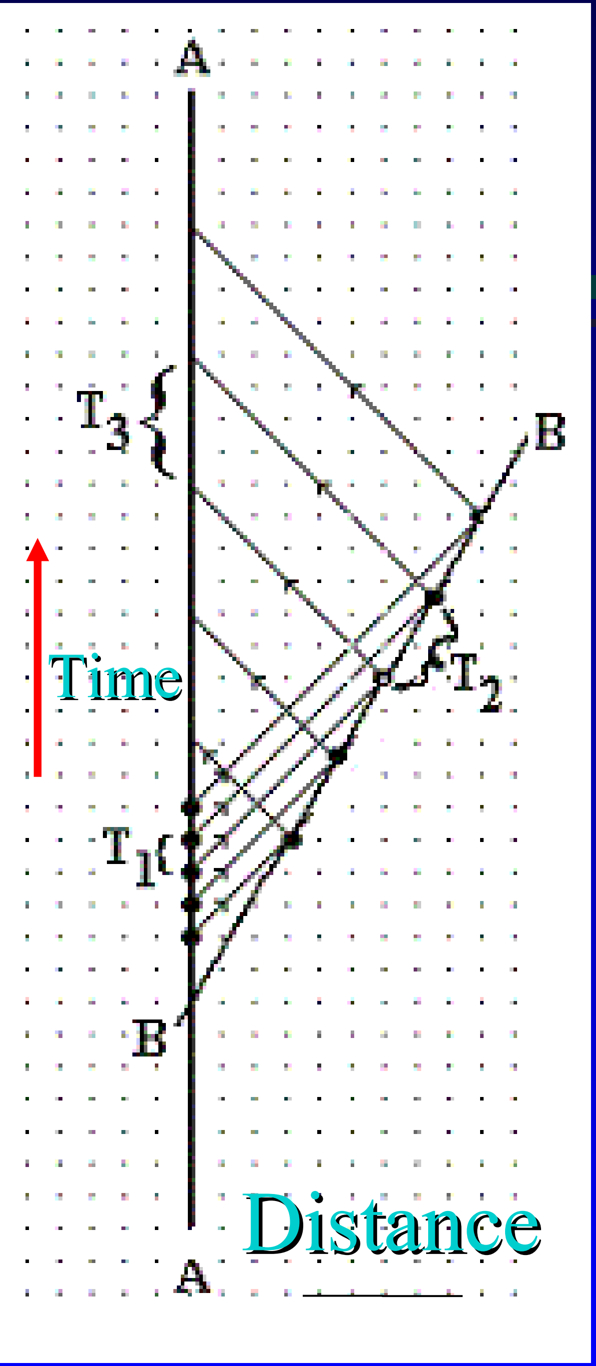
"My solution was really for the very concept of time, that is, that time is not absolutely defined but there is an inseparable connection between time and the signal velocity."

Time Dilation?

In this Minkowski Space-Time diagram, Sender A "Blips" every T_1 units (seconds, minutes, years)…

Receiver B will get these pulses every T_2 units, where $T_2 > T_1$ (as the distance between A and B *increases with time*)

If B sends new blips out with every reception, i.e. every T_2 units of B-time, then A will receive blips at T_3 units apart, where $T_3 > T_2$ (again, as the distance between A and B *increases with time*)



Some Radar Ranges...

- Object at 3 Light Years Away: there will be 6 years between emission and reception, for signals traveling at the speed of light.

- Object at 6 Light Years Away: there will be 12 years between emission and reception, for signals traveling at the speed of light.

Time Dilation?

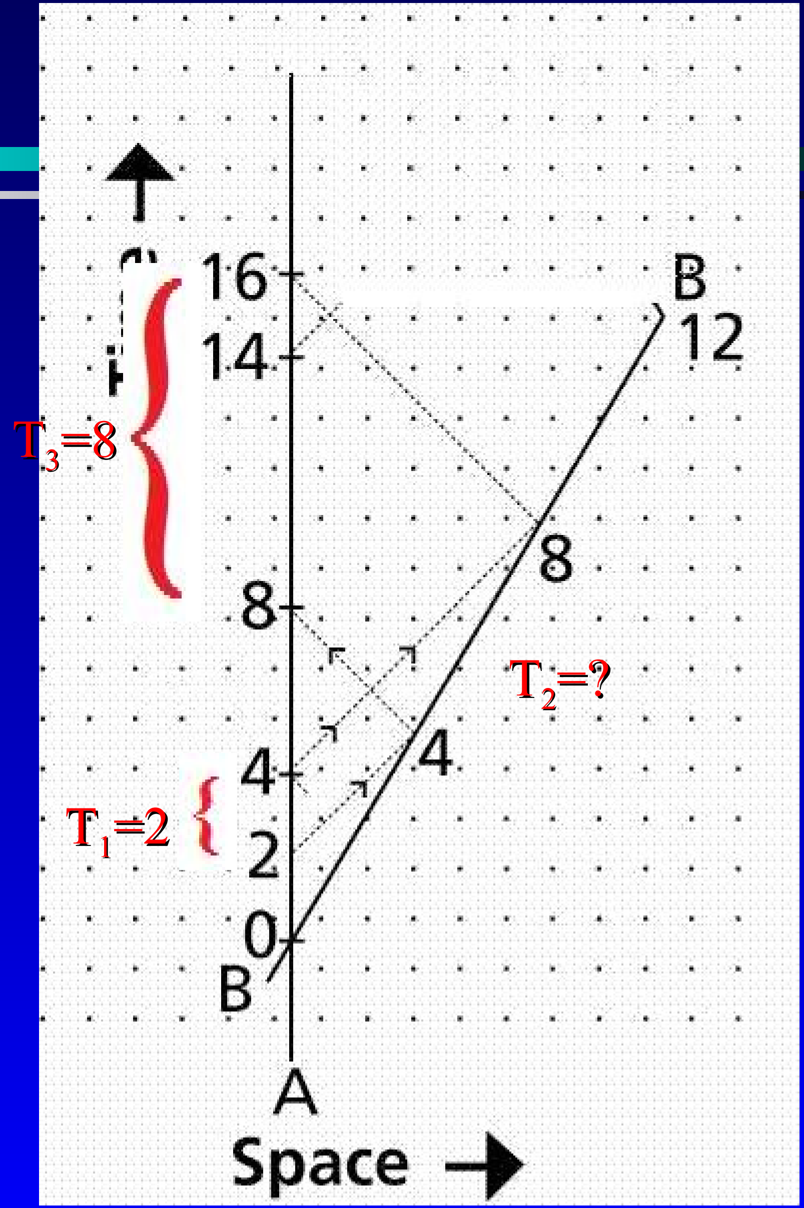
By Symmetry, the delay B observes for A's signals , $T_2 / T_1 > 1$, *must* equal the delay A sees for B's signals, $T_3 / T_2 > 1$

If B is traveling at 0.6c, 3/5 of the Speed of Light, and if A sends blips every 2 years, $T_1 = 2$, and $T_3 = 8$.

$$\frac{T_3}{T_2} = \frac{T_2}{T_1}$$

$$T_3 x T_1 = 8x2 = 16 = T_2 x T_2$$

$$\Rightarrow T_2 = 4$$



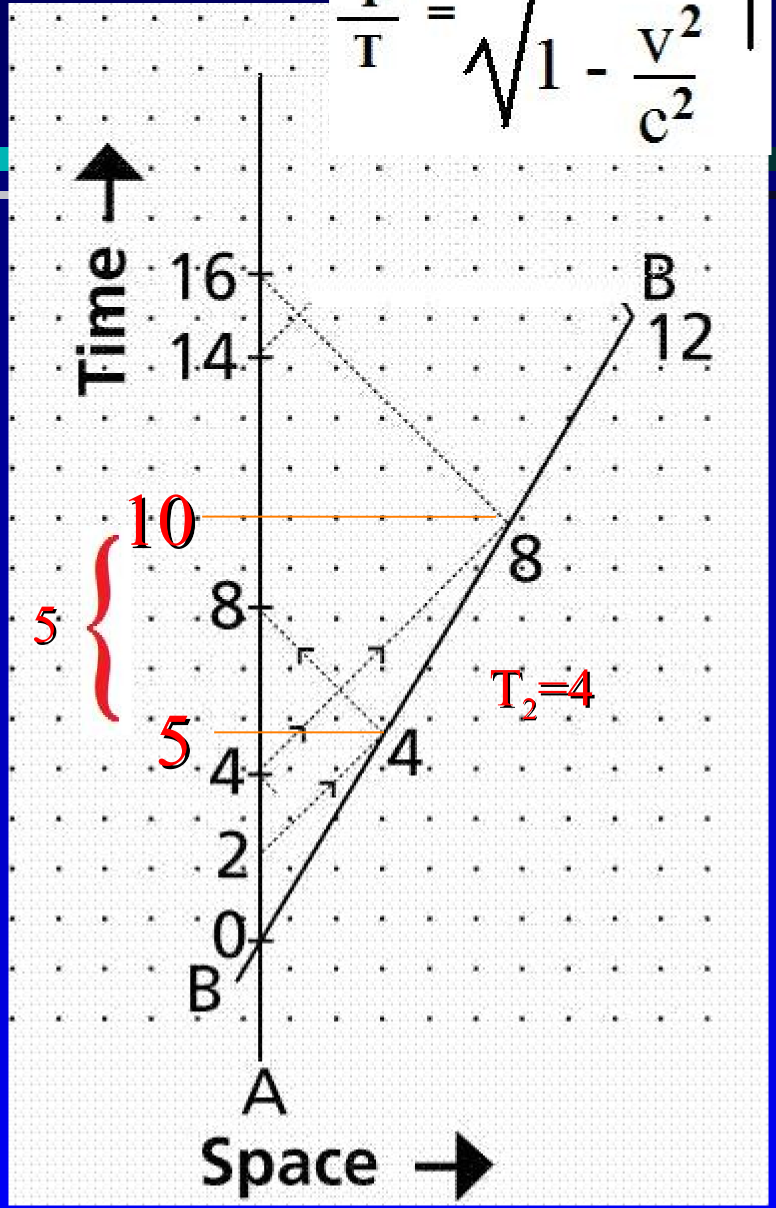
So, where's the Dilation?

$$\frac{T'}{T} = \frac{1}{\sqrt{1 - \frac{v^2}{c^2}}}$$

The pulses A sends and receives from B are like Radar Ranging: the outbound beam takes as long to reach B as it does to return, and travels the same distance both ways.

The time of the "bounce" is the average of send/receive times: (4+16)/2 = 10 years, while (2+8)/2 = 5 years.

What B measured as 4 years, A measures as 10-5=5 years:*Dilation!*



In Summary…

This little animation shows the First Blip in Red (Launches at 2 years, bounces at 5 years, returns at 8 years)

versus

the Second Blip in *Blue* (Launches at *4* years, bounces at *10* years, returns at *16* years)

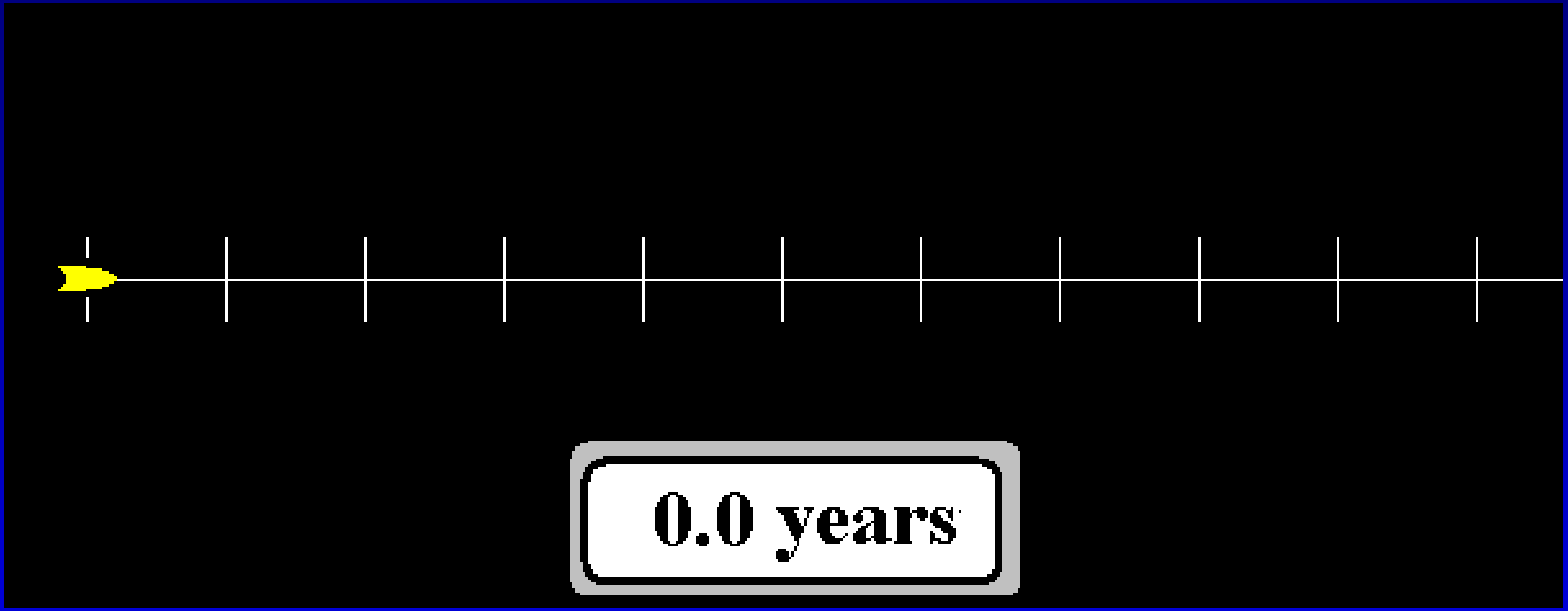
$$\frac{(2+8)}{2} = 5$$

$$10\text{-}5=5$$

$$\frac{(4+16)}{2} = 10$$

$$\frac{(16-8)}{(4-2)} = 4 = 2^2,\ (4-2)\text{x}2=4$$

Here we go!



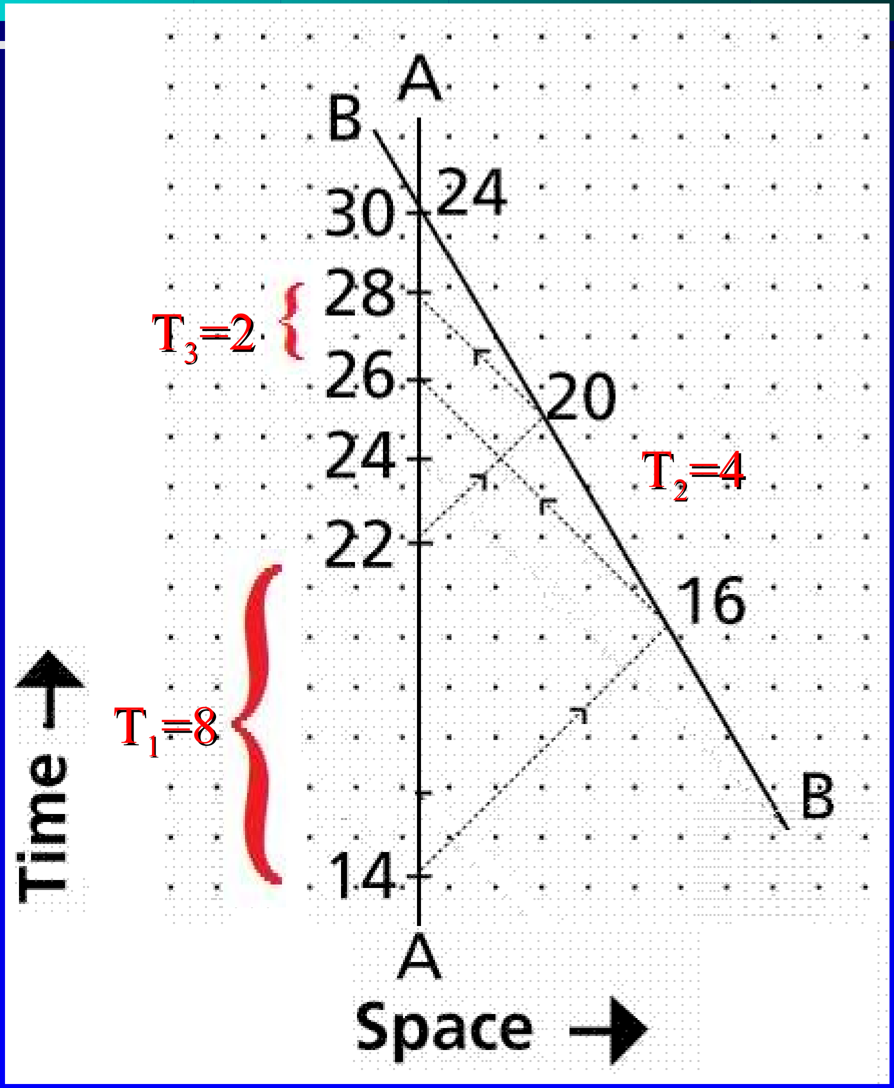
Click for Animated Movie!

http://www.passcal.nmt.edu/~dthomas/relativity_movies/movie.gif

What if B was *Approaching* A?

If B is traveling at 0.6c *toward* B, at 3/5 of the Speed of Light, and if A sends blips every 2 years, T_1 =8, and T_3 =2.

In this case, B *again* finds that T_2 =4, and that his pulses are *speeded up* by a factor of 2 (8/2= 4 = "half the time"). Likewise, A's reception of B's pulses are speeded up by a factor of 2 as well (4/2 = 2).

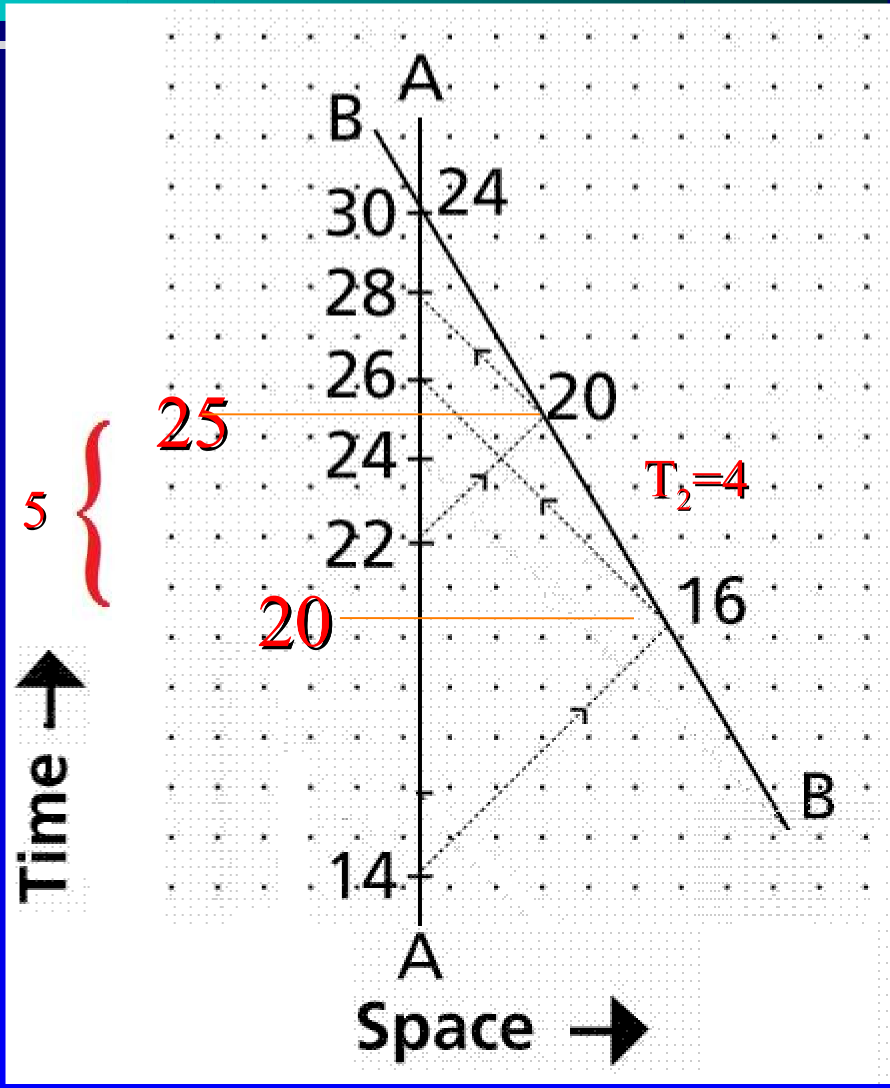


Time Dilation, *Approaching…*

Again, the time of the "bounce" is the average of send/receive times: (14+26)/2 = 20 years, while (22+28)/2 = 25 years.

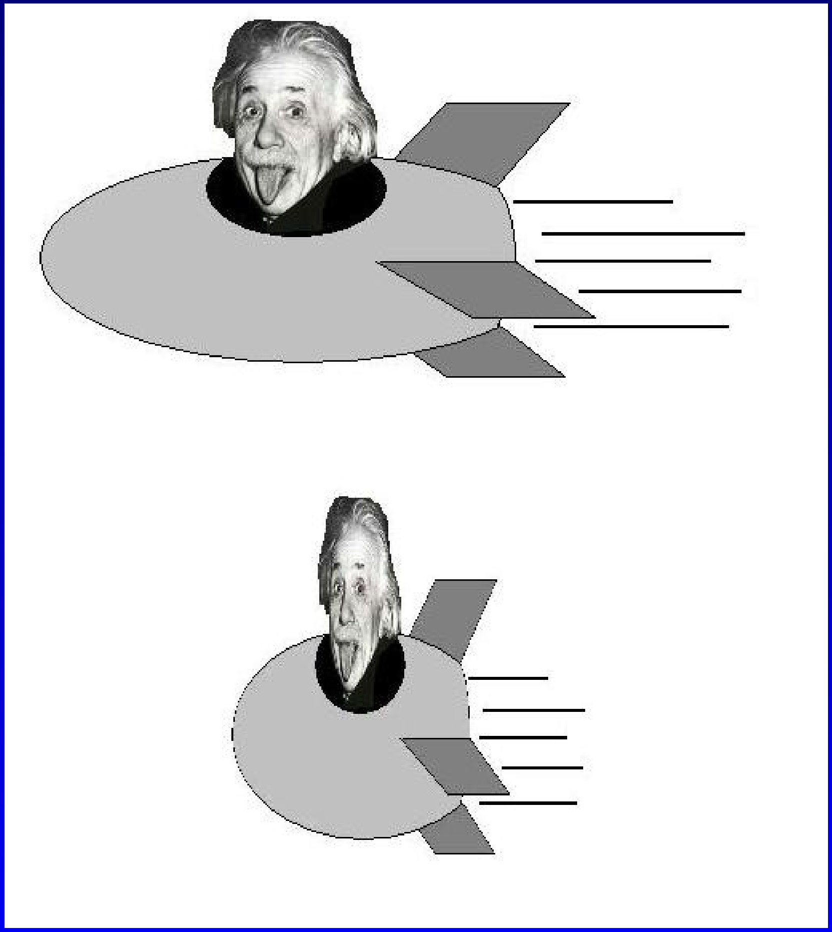
What B measured as 4 years, A measures as 10-5=5 years: *Dilation! (Again! Or Still!)*

If B is considered "at home," and A is the traveler, the same results apply (*Symmetry*).



Length Contraction?

$$\frac{L'}{L} = \sqrt{1 - \frac{v^2}{c^2}}$$



If we were to observe a spaceship traveling very fast, its length would appear to be contracted along the direction of travel. But, this effect is very hard to measure.

Length *Contraction*…

If *we* were speeding through some neighborhood, however, the dimensions of that neighborhood would appear to be contracted to us, along the direction of our motion. This length, which is just the distance we have traveled, is *easy* to measure.

Observed Dilation & Contraction: Muon Decay (1.56 μsec), v=0.98*c*

Space, 10 km up

μ μ μ

$\Delta T = \dfrac{10\text{km}}{3\text{x}10^5\text{km/s}} \cong 34\ \mu\text{s}$

Ground level

Classical: 10 km, 34 μs, 22 half-lives, 0% reaches ground

Muon Reference: 2 km, 7 μs, 4 half-lives, 5% (Length Contraction)

Earth Reference: 10 km, 34 μs, 4 half-lives, 5% (Time Dilation)

Observed Dilation & Contraction: Muon Decay (1.56 μsec), v=0.98*c*

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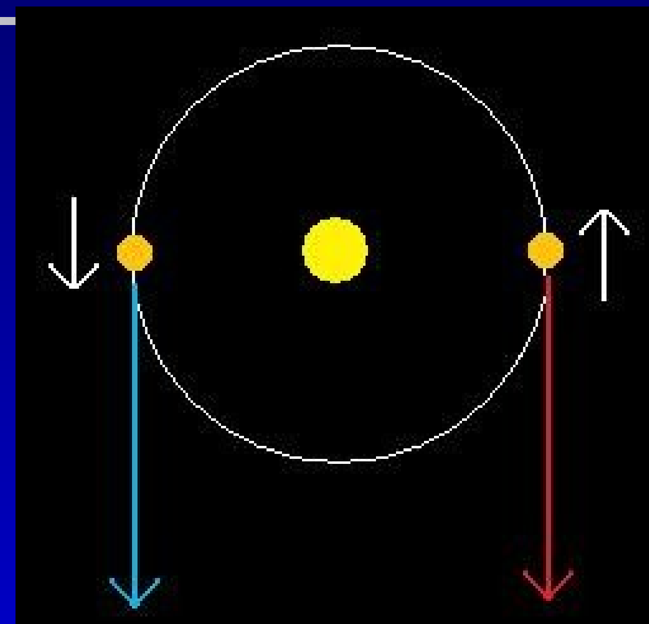
But, how can two observers in relative motion *both* see length contraction/time dilation in the other?

The effects of length contraction and time dilation do not occur in one's own rest frame, but only in observed *moving* frames.

A common diverging lens *allows two people to each see each other as smaller*.

They have not changed size; they only *appear* to be smaller.

Verification that Light Velocities are not *Additive*….

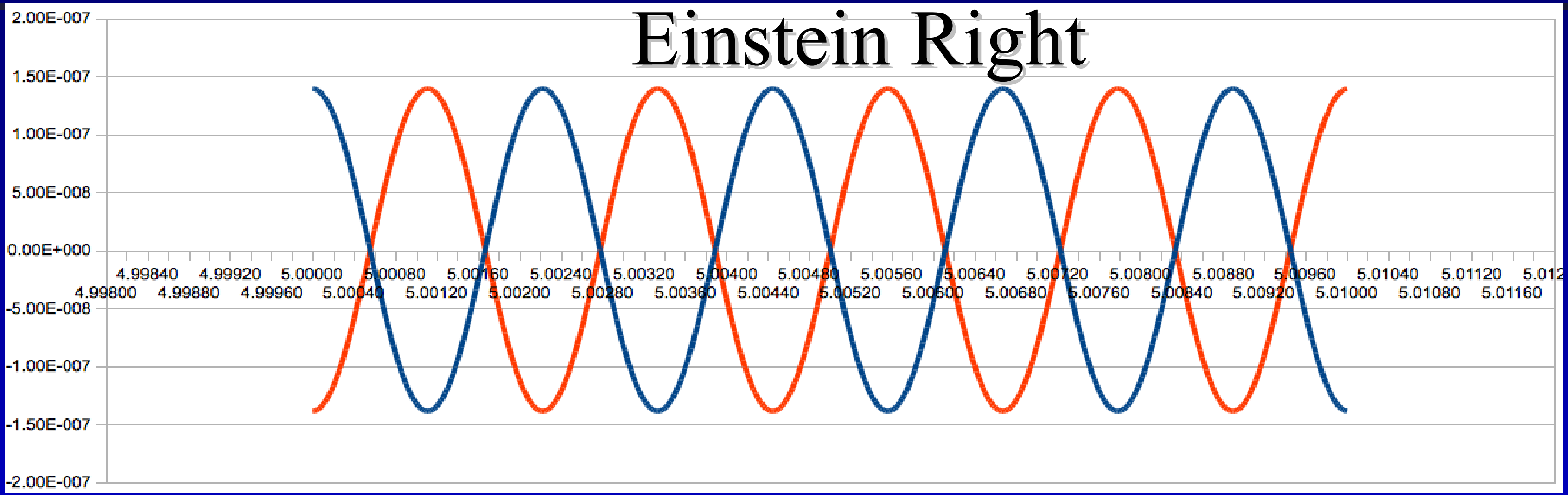


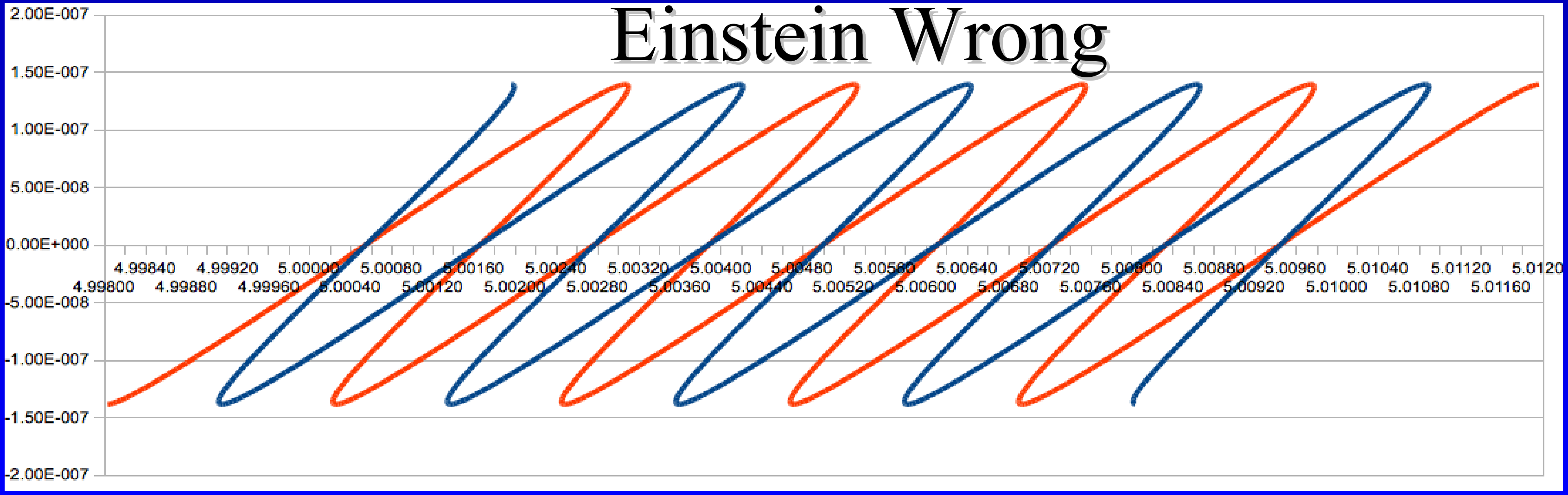
Expected Time/Velocity Curve of Stars of Castor C (Binary System), if Einstein was RIGHT (Light travels at 299,792,458 meters/sec), and if Einstein was WRONG.

Are Light Velocities *Additive*?

Expected Time/Velocity Curve of One Star of Castor C (Binary System), if Einstein was WRONG (Light travels at c=299,792,458 m/sec ± motion of source); here, "Castor C" is just 5 light-years away. At orbital speeds of 0.0004c, transit times will vary from
5 lightyears/(1-.0004)lightyears/year = 5.002 years = 1827.0 days, to 5 lightyears/(1+.0004)lightyears/year = 4.998 years = 1825.5 days, or about 1+1/2 days.

Castor C @ only 5 LightYears

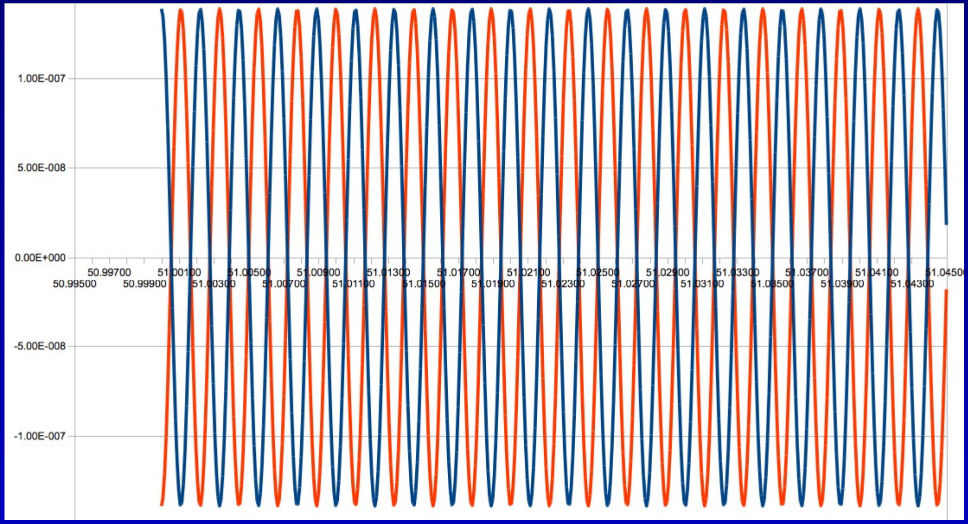




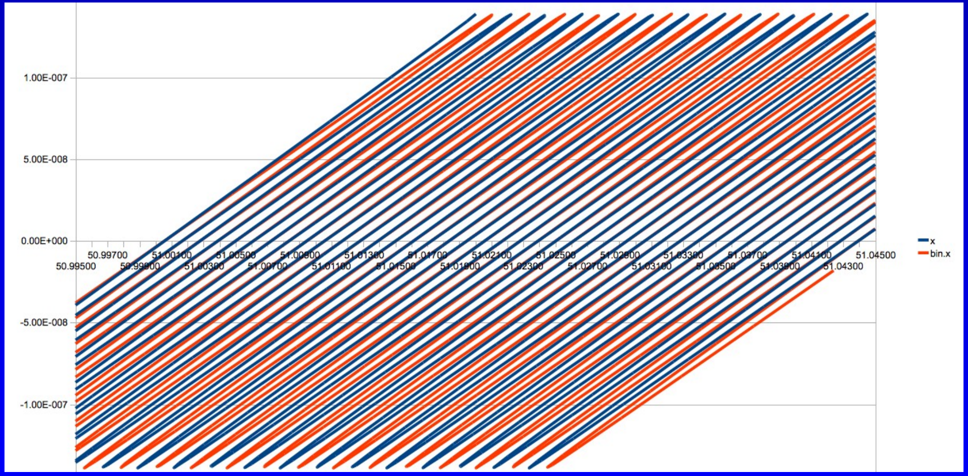
Are Light Velocities *Additive*?

Expected Time/Velocity Curve of One Star of Castor C (Binary System), if Einstein was WRONG (Light travels at c=299,792,458 m/sec ± motion of source); here, Castor C is 50 light-years away (*about actual*). At orbital speeds of 0.0004c, transit times will vary from 50 lightyears/(1-.0004) lightyears/year = 50.02 years = 18270 days, to 50 lightyears/(1+.0004)lightyears/year = 49.98 years = 18255 days, or about 15 days.

Castor C @ 51 LightYears



Einstein
Right

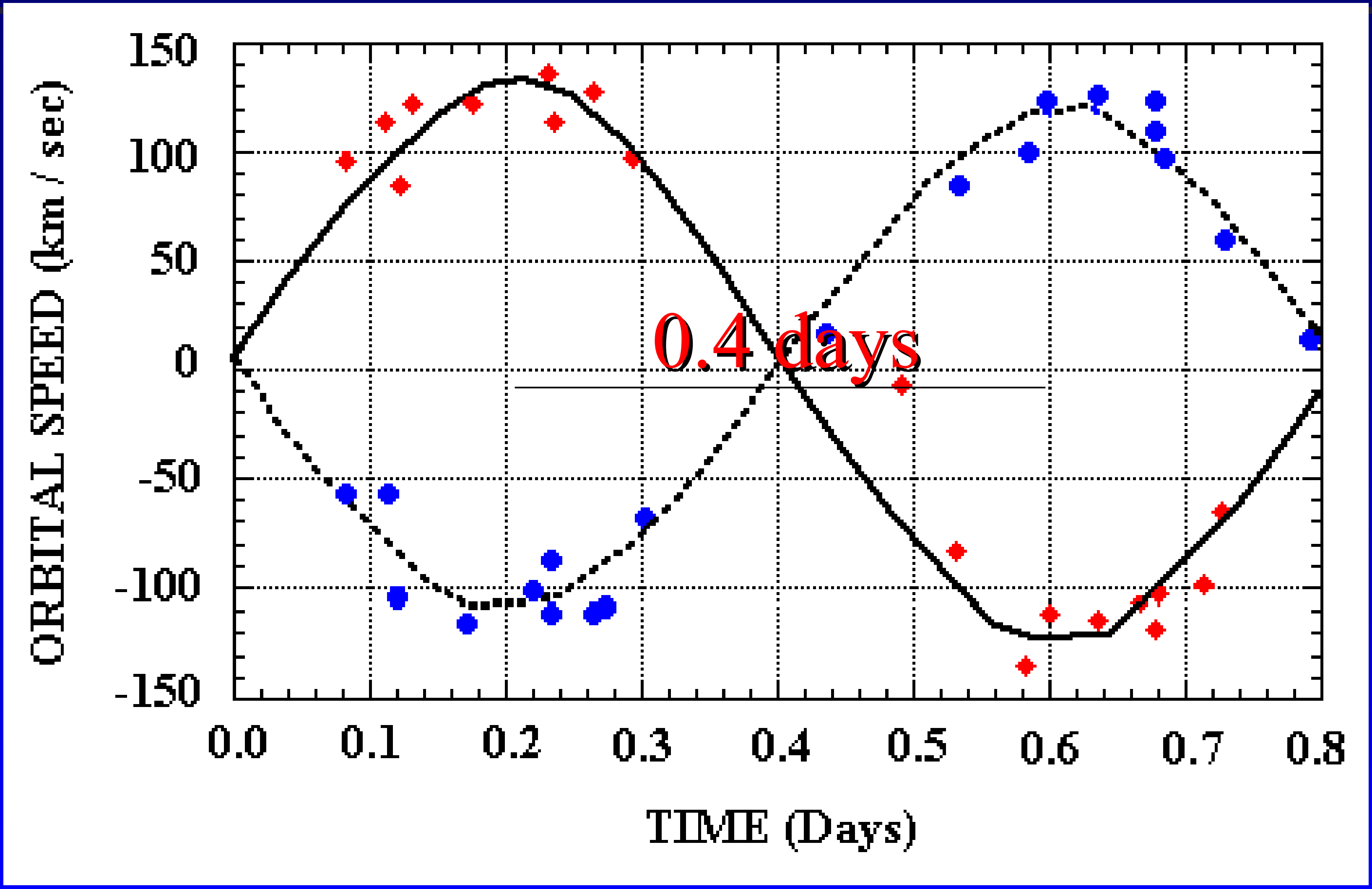


Einstein
Wrong

Light Velocities are *Not* Additive! Real Data from Castor C

The actual measurements of both of Castor C's binary stars look decidedly like the first graph, and demonstrate very strongly that Einstein was right. At the binaries' relatively small speeds, the differences in calculated velocities between classical and Einsteinian Doppler shifts is insignificant - only a few miles per hour out of hundreds of times the speed of sound.

Light Velocities are *Not* Additive! Real Data from Castor C



OK, but *How* would it LOOK??

$$f(t+\Delta t)=R\cos(\omega t)$$

$$\text{where } R=0.8\,million\,miles\,,\ \omega=\frac{2\pi}{0.8\ days},$$

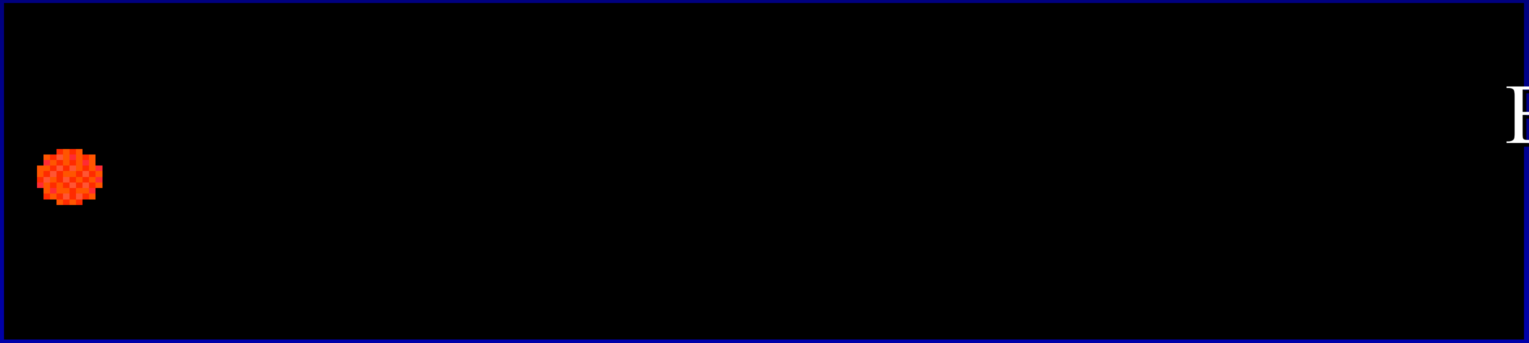
$$\text{and } \Delta t=\frac{D+R\sin(\omega t)}{WaveSpeed}$$

$$WaveSpeed=c(Einstein),\text{or } c-v\cos(\omega t)(Wacky)$$

$$with\ v=\omega R$$

$$So\ WaveSpeed=c(Einstein),\text{or } c-\omega(R\cos(\omega t))(Wacky)$$

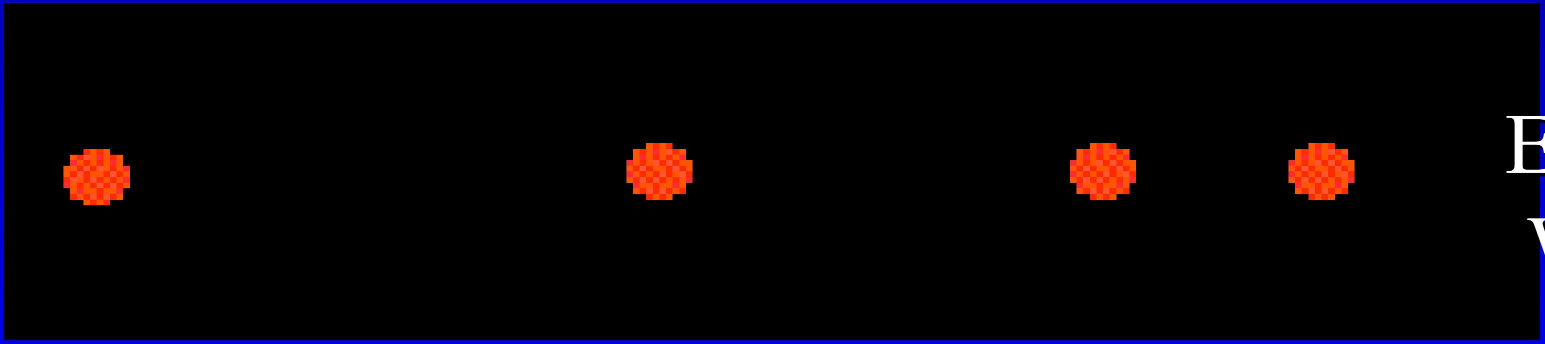
Castor C @ 5 LightYears



Einstein Right

Click for Animated Movie!

http://www.passcal.nmt.edu/~dthomas/relativity_movies/redBinaryReal.gif

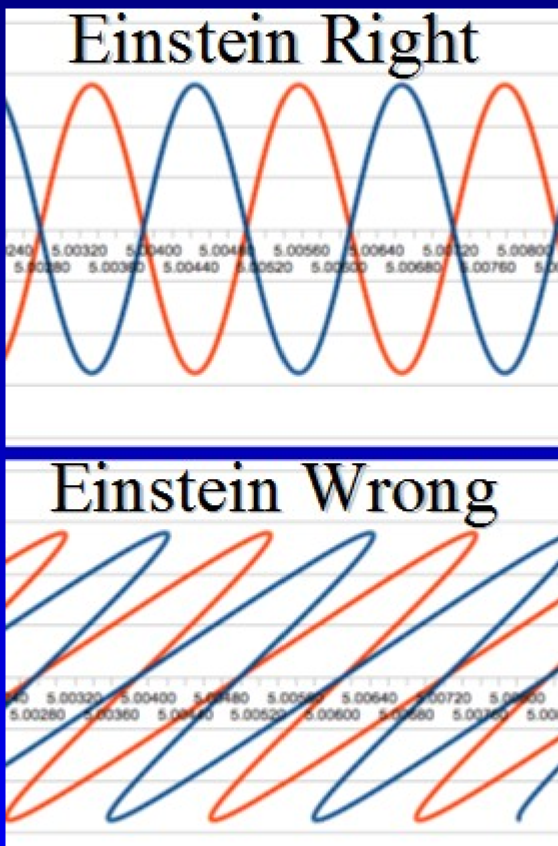


Einstein Wrong

Click for Animated Movie!

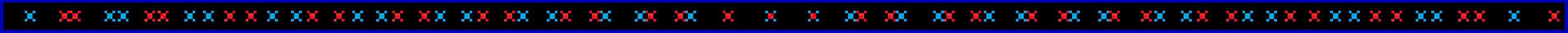
http://www.passcal.nmt.edu/~dthomas/relativity_movies/redBinary.gif

Castor C @ 5 LightYears



In the Einstein=Wrong world, WHY doesn't the binary star ever move from left to right?
It's because time is messed up so badly, even when the star *should* appear to move left, it moves to the right!

Castor C @ 51 LightYears



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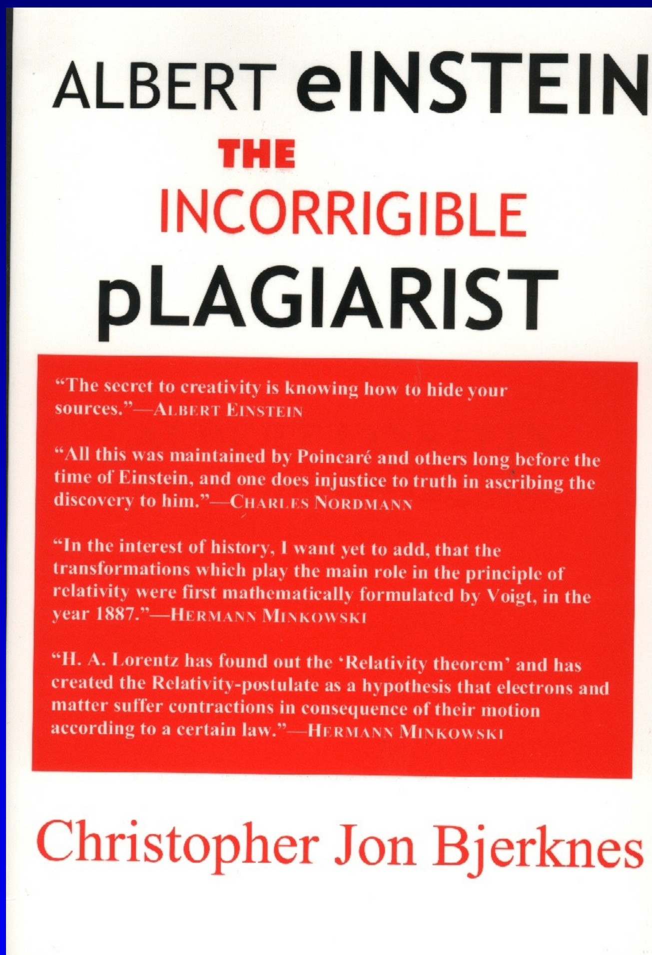
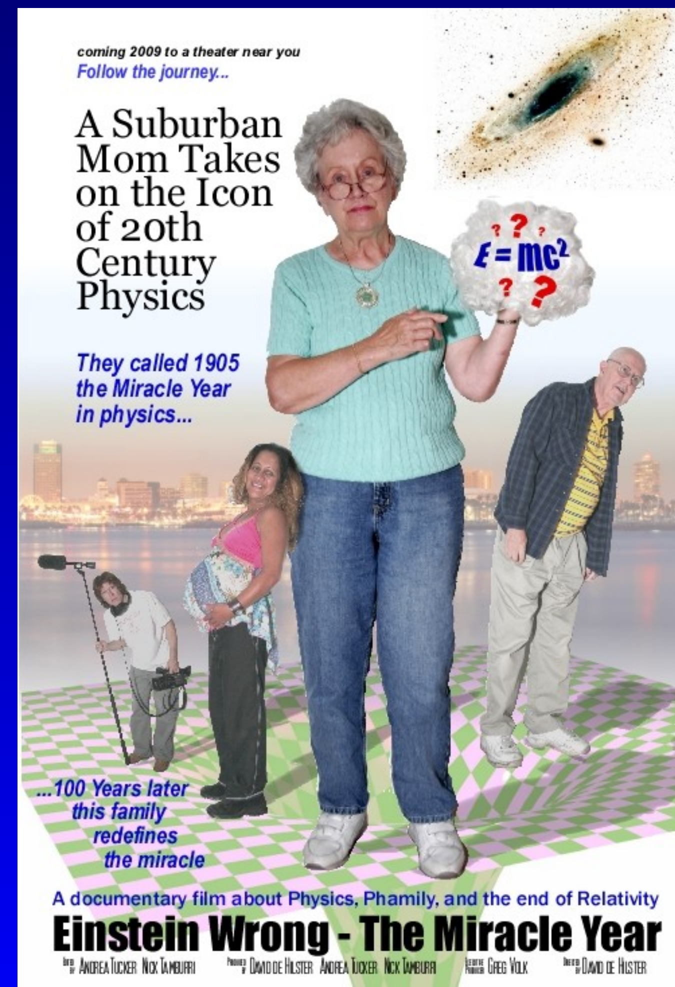
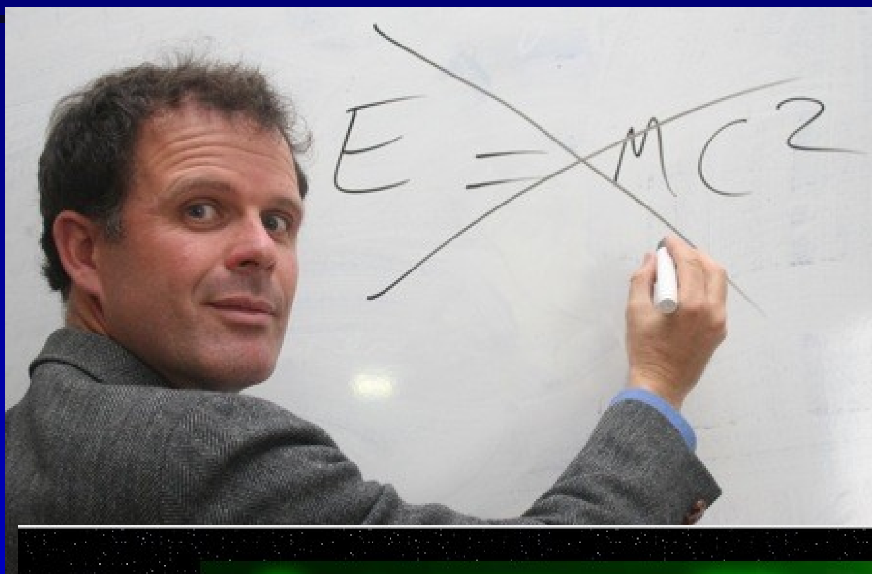
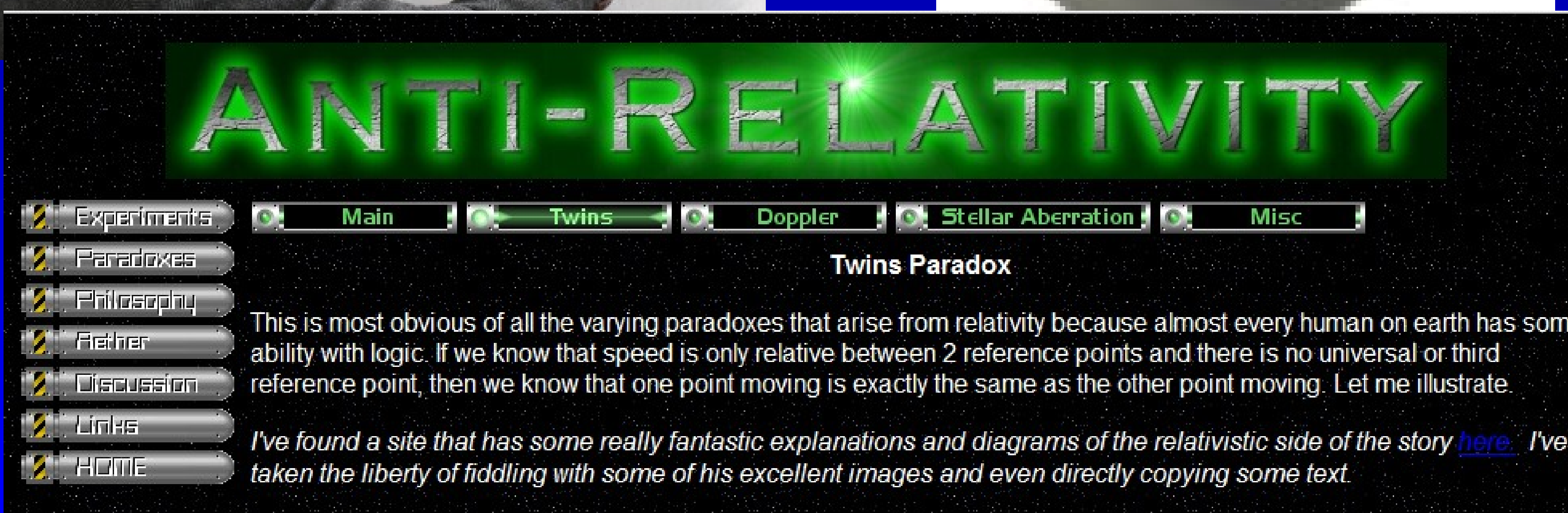
Relativity Protests





Relativity Protests





Relativity Protests

Christos A. Tsolkas

PHYSICS-MATHEMATICS

PHYSICS

THE "NEW PHYSICS"

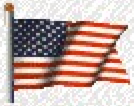
GALILEO,NEWTON,EINSTEIN,QUANTUM MECHANICS ARE WRONG!

MATHEMATICS

THE "NEW MATHEMATICS"

(see, Greek version)

Greek/Ελληνικά



English/Αγγλικά

41,922 Visitors

Since September 17, 2001

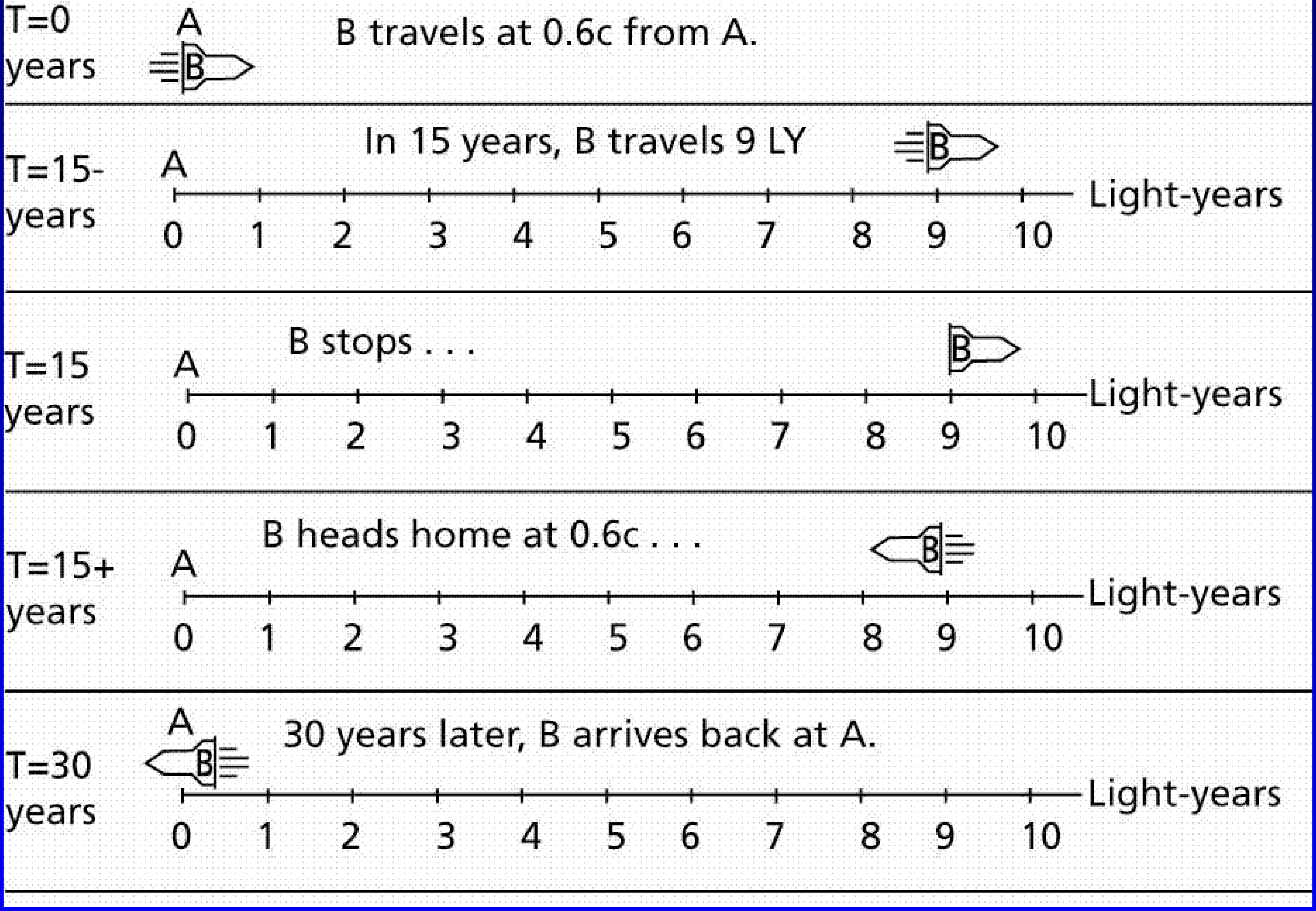
What is the “Twin Paradox?”

No, not a twin pair o’ Docs…

What is the “Twin Paradox?”

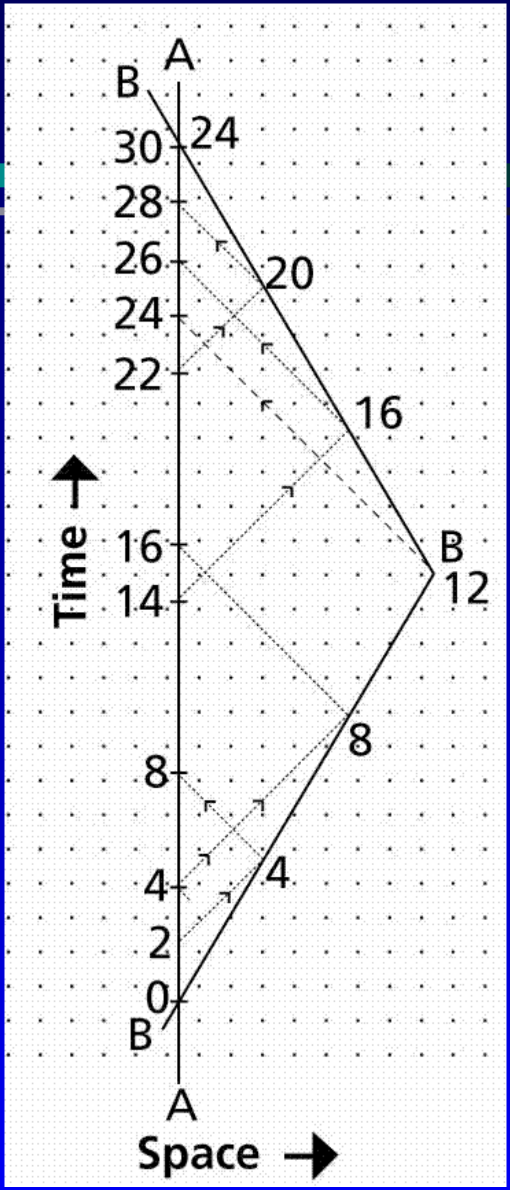
Einstein’s “Twin Paradox” is a thought experiment involving two twins, one of whom sets out on a journey into space and back. Because of the time dilation effect of relativity, the twin who left is observed to have a slowing down of time, and will actually end up younger than the twin that stayed behind. But, *can’t either twin can be considered at rest*, with the *other twin* moving? *Who is older?*

Brother B takes a little Trip…



What Brother A Sees :

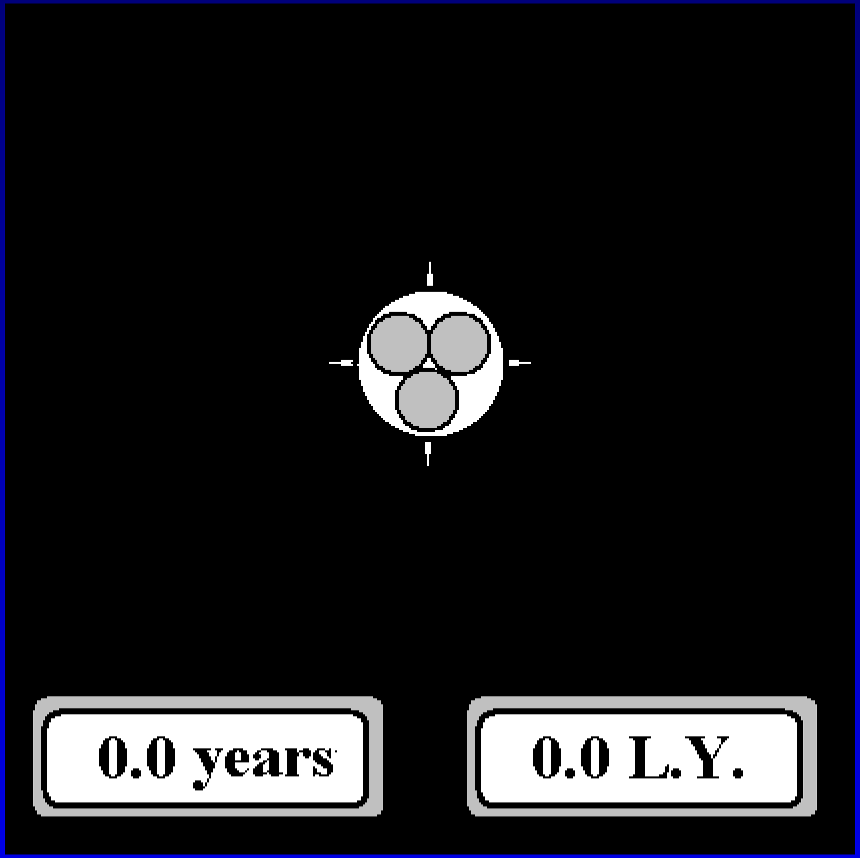
From Brother A's point of view: Brother B speeds away for 24 years, turns around, and arrives back home just 6 years later, for a total of 24+6=30 years.



What Brother A Sees :

The Movie Version

What Brother A Sees :

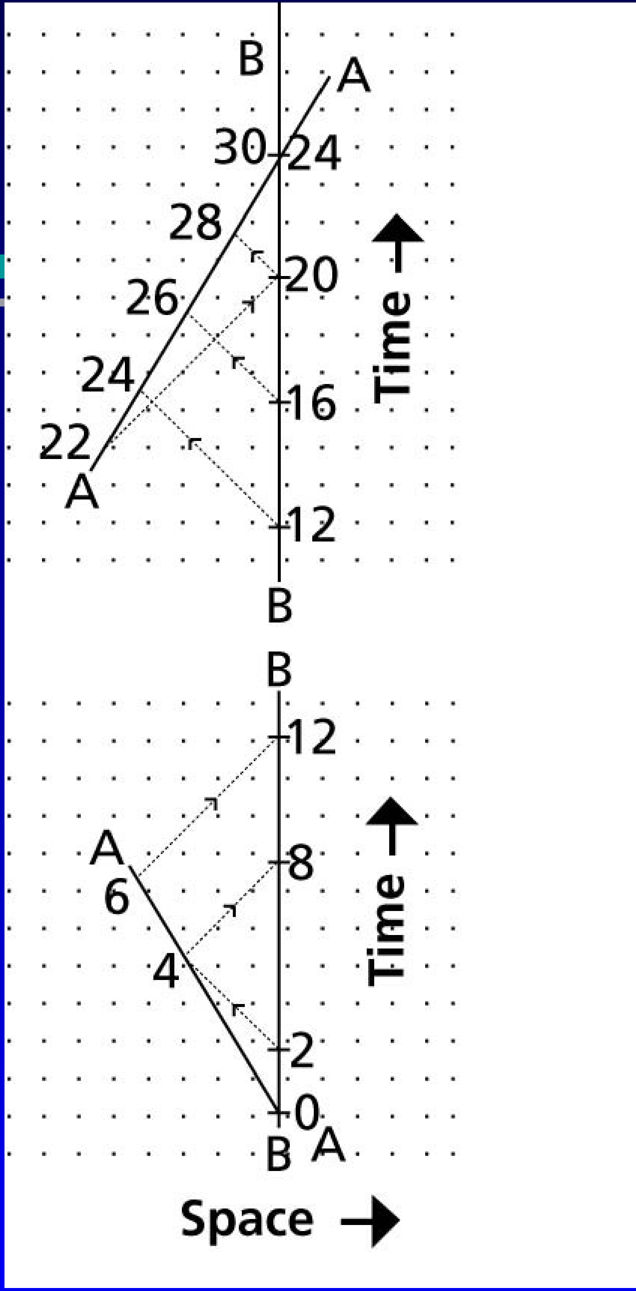


Click for Animated Movie!

http://www.passcal.nmt.edu/~dthomas/relativity_movies/A_views_B.gif

What Brother B Sees

From Brother B's point of view, he speeds away for 12 years, *stops, turns around, accelerates again to 0.6c*, and arrives back home in another 12 years, for a total of 12+12=24 years.



What Brother B Sees :

The Movie Version

What Brother B Sees :

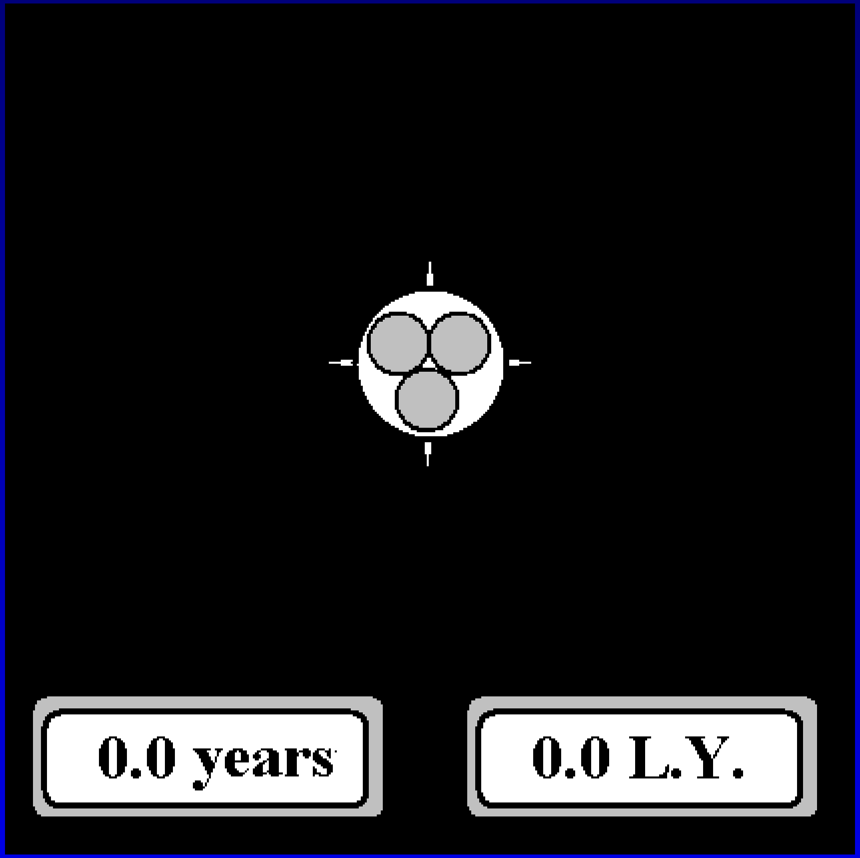
Click for Animated Movie!

http://www.passcal.nmt.edu/~dthomas/relativity_movies/B_views_A.gif

If Light Velocities were *Additive…*

The Movie Version,
from Twin A's
Point of View

If Light Velocities were *Additive…*



Click for Animated Movie!

http://www.passcal.nmt.edu/~dthomas/relativity_movies/WackyWay.gif

But, *WHY?*

Maxwell's Equations

$\oint\!\!\oint \vec{E} \cdot \hat{n}\, dS = \frac{q}{\varepsilon_o}$ — Gauss's Law

$\oint\!\!\oint \vec{B} \cdot \hat{n}\, dS = 0$ — (no monopoles)

$\oint \vec{B} \cdot d\vec{l} = \mu_o \left(i + \varepsilon_o \frac{d}{dt} \Phi_E \right)$ — Ampère's Law

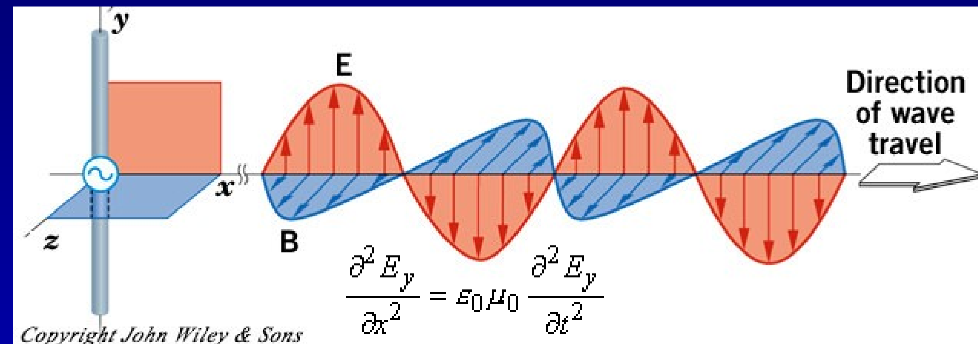
$\oint \vec{E} \cdot d\vec{l} = -\frac{d}{dt} \Phi_B$ — Faraday's Law

$\vec{\nabla} \cdot \vec{E} = \frac{\rho}{\varepsilon_o}$ $\qquad$ $\vec{\nabla} \times \vec{B} = \mu_o \left(\vec{j} + \varepsilon_o \frac{\partial \vec{E}}{\partial t} \right)$

$\vec{\nabla} \cdot \vec{B} = 0$ $\qquad$ $\vec{\nabla} \times \vec{E} = -\frac{\partial \vec{B}}{\partial t}$

(Differential Forms)

$\nabla^2 E = \varepsilon_0 \mu_0 \frac{\partial^2 E}{\partial t^2}$ $\qquad$ $\nabla^2 B = \varepsilon_0 \mu_0 \frac{\partial^2 B}{\partial t^2}$



$$c = \frac{1}{\sqrt{\mu_0 \epsilon_0}}$$

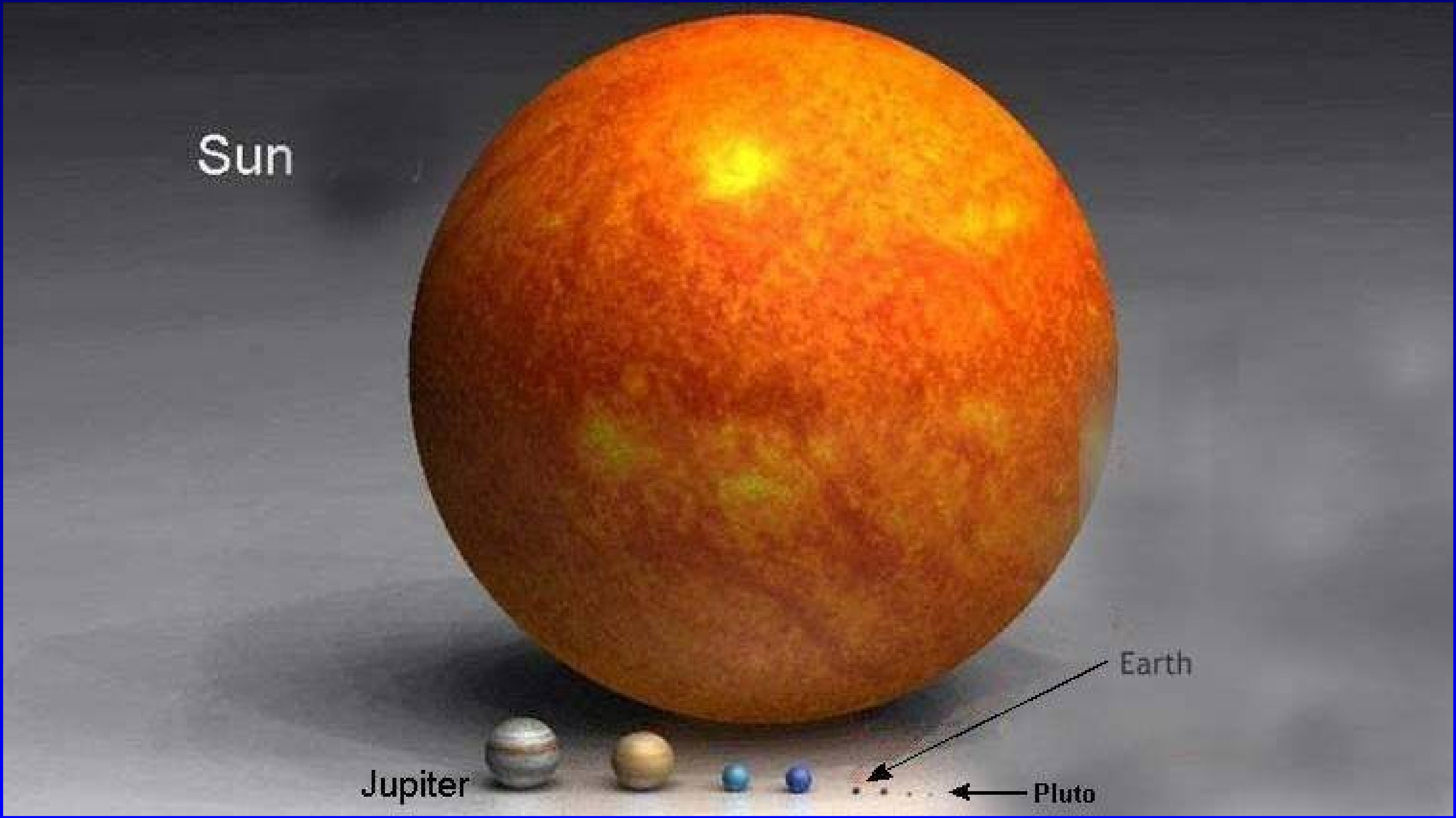
If *The Flash* could catch up to a light wave…?!?

Space Travel will be *HARD*…

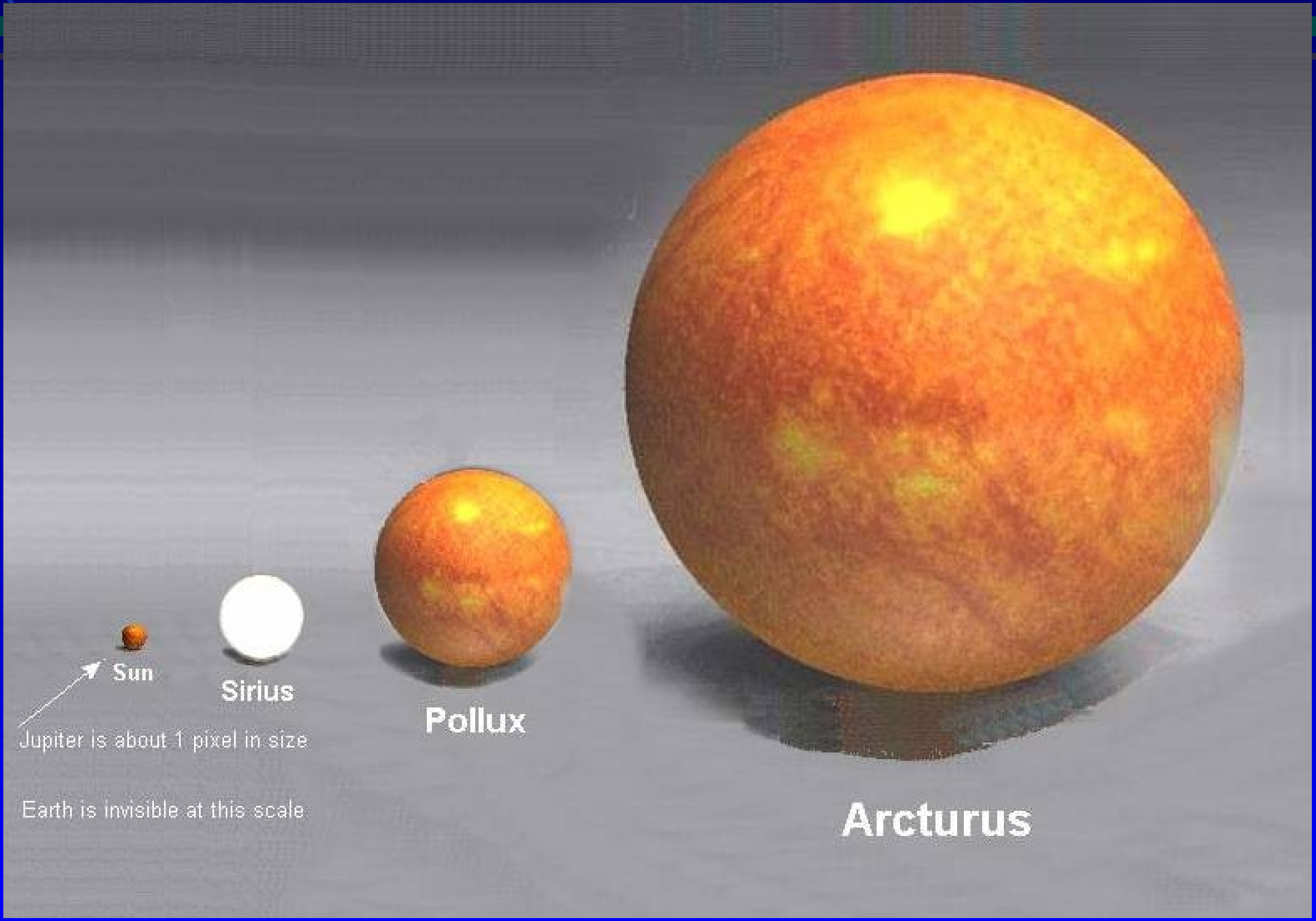
1 micron (μm) diameter silicon grain (0.00004 inches)

If *we* were traveling through interstellar space at 90% of the Speed of Light, the grain would appear to have a kinetic energy of about 170 Joules – or, about the energy of a 22-caliber bullet (40 grains, 64.8 mg/grain) traveling over the speed of sound (about 1200 feet per second, or 366 meter/second)

Space is BIG



Space is BIG


Sun
Sirius
Pollux
Arcturus
Jupiter is about 1 pixel in size
Earth is invisible at this scale

Energy Budget for Space Travel

Total Human Production

$E \sim 5 \times 10^{20}$ J / year (80-90% fossil fuel)

***200 years (industrial age)**

$E \sim 10^{23}$ J

Energy Budget for Space Travel

Sun

- **$E = 3.83 \times 10^{26}$ J/s**
- **Converts 4.26 Billion kg of H to He per second**
- **Or 91.6 Billion 1 Mt Bombs/s**
- **Or 9907 Times Total Human Production/*second***

Energy Budget for Space Travel

Small Ship – Cruise Liner

~ 140 Million kg (*No Fuel*)

~ 340m x 56m x 63m

Fuel to accelerate to fraction X of c

4x - If wish to Come Home

Accelerate-Decelerate-Accelerate-Decelerate

Fuel-to-Payload Ratio: *Large*

How Big a Ship?

Freedom of the Seas is the largest luxury cruise ship in the world, owned by Royal Caribbean.

This cruise ship weighs 160,000 tons, it is 1,112 feet long, 184 feet wide and it has 15 passenger decks holding 3,634 guests double-occupancy. Freedom of the Seas towers 208 feet tall, approximately the same height as two of the Statue of Liberty, placed head to toe.

How Big a Ship?

$$160{,}000 \text{ tons} \times \left(2000\ \frac{\text{pounds}}{\text{ton}}\right) \times \left(\frac{1}{2.205}\ \frac{\text{kg}}{\text{pound}}\right) =$$

1.4×10^{8} kg

Energy Budget for Space Travel

For 0.10c, weightless fuel

$E = 6.3 \times 10^{22}$J

Or 508 Times Total Human Production/Year; < 1 millisec of sun

For 0.99c, weightless fuel

$E = 3.1 \times 10^{26}$J

Or 614,000 Times Total Human Production/Year; 0.8 seconds of sun

Energy Budget for Space Travel

For 0.10c, fuel-to-payload ratio = 100

$E = 1.8 \times 10^{29}$ J

Or 363 *million* Times Total Human Production/Year; ~ 8 hours of sun

For 0.99c, fuel-to-payload ratio = 100

$E = 2.2 \times 10^{32}$ J

Or 438 *billion* Times Total Human Production/Year; ~6.6 days of sun

Energy Budget for Space Travel

That's a huge expenditure, dwarfing modern budgets by orders of magnitude.

And for what?

To abduct

Betty & Barney Hill?

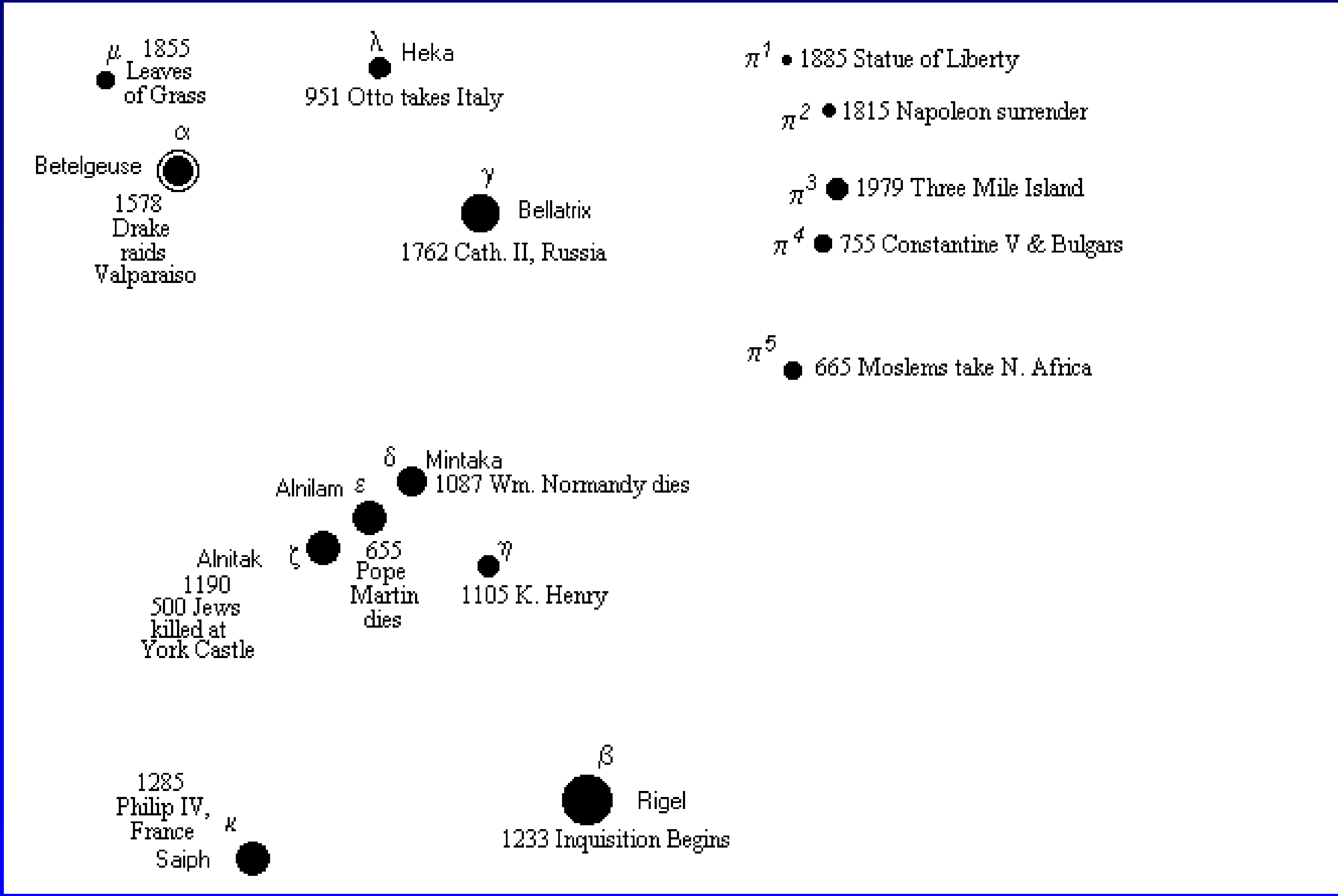
About the Transit of Venus...

Halley explained the importance of transits before his death in 1742. Observations (at > 100 locations) of the 1761 and 1769 transits, combined with the principle of parallax, provided the first precise estimates of the distance between the Sun and the Earth.

Parallax helps to find the distance to the Moon (background stars), but the Sun is too bright.

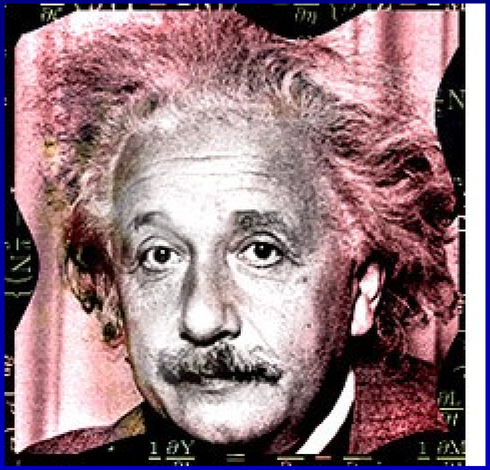
The Annular Eclipse of 5-20-12

The Speed of Light Affects Everything We See…



It's the Law

670 *million* miles per hour…



It's not just a good idea, it's the **LAW**!