Classroom computer animations of relativistic objects

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Abstract

This is a short note to announce the availability of some movies that may be useful in classroom discussions on the photographic appearance of objects moving at relativistic speeds. The images are based on special relativity with no account taken of (other than to ignore) the effects of doppler shifts, intensity shifts or gravitational effects.

Motivation

First encounters with Special Relativity can be quite daunting for many students: time dilation, length contraction, twin paradoxes and the like all tend to send their minds into a state of neural meltdown. This is not a favorable outcome. But they do respond well to colour and movement – in particular to computer simulations of special relativistic effects such as the apparent change in shape, as revealed by a photograph, of an object moving close to the speed of light. I have made a series of movies for a number of common situations using a (slightly) modified version of the standard ray-tracing package, POV-Ray(tm) 3.5. Though there is nothing new in this, I have found it to be a useful teaching tool. I have put the movies and other material on the web at this address

`http://users.monash.edu/~leo/research/movies/sr/index.html`

The first point that must be stressed before taking the students through these movies is that the process of taking a photograph in Special Relativity

is fundamentally different from what we normally call making an observation. Photography entails the collection of photons by one person at one instant in time (in the camera's frame) while an observation is the detection of a single event. Furthermore, an observer (or a frame) is the infinite arena in which all possible events can be detected.

I found the material in these movies sufficient to occupy approximately two one hour tutorials. The students can be asked to study the movies and then to explain, both in mathematical and descriptive terms, why the images are as they are. In doing so they will have to have a firm understanding of the principle of relativity and of relativistic aberration. My aim was to get the students to formulate a simple principle that would help them predict how an object's shape might appear when photographed at relativistic speeds.

I have not included the effects of redshift nor the changes in intensity. I was interested only in the apparent change in the shape rather than changes in colour and brightness (perhaps at later time, any volunteers?).

The changes to the POV-Ray(tm) package were quite simple. I added a few routines to allow Lorentz transformations between the camera and object frames. The camera was allowed to move relative to all other objects in the scene. All of the photons were created in the rest frame of the camera. These were then Lorentz transformed into the scene frame at which point the normal POV-Ray(tm) routines takeover. This idea has been used before (see for example the code by Andrew Howard `andrbh@cs.mu.oz.au` though I believe there are errors in his Lorentz routines).

I have included the movies and the modified POV-Ray(tm) source at the above website. Note, as part of the POV-Ray(tm) licence I am required to declare that my modifications do not form part of the official POV-Ray(tm) release and that I take full responsibility for all alterations. Furthermore, if you wish to use this version you must read and accept the legal conditions as set out in povlegal.doc (the latest version of which can be found at `http://www.povray.org/povlegal.html`)

Forward motion - The Triffid Nebula

Here are two (computer generated) images (Fig1a.jpg, Fig1b.jpg) of the Triffid Nebula. Both were taken with identical cameras. The only difference is that one of the images was taken in a frame moving at $\beta = 0.75$ towards the Nebula. The images were taken at the instant the two cameras passed each other. Which image is which? Compare this with the familiar images from Startrek when the warp drive is engaged.
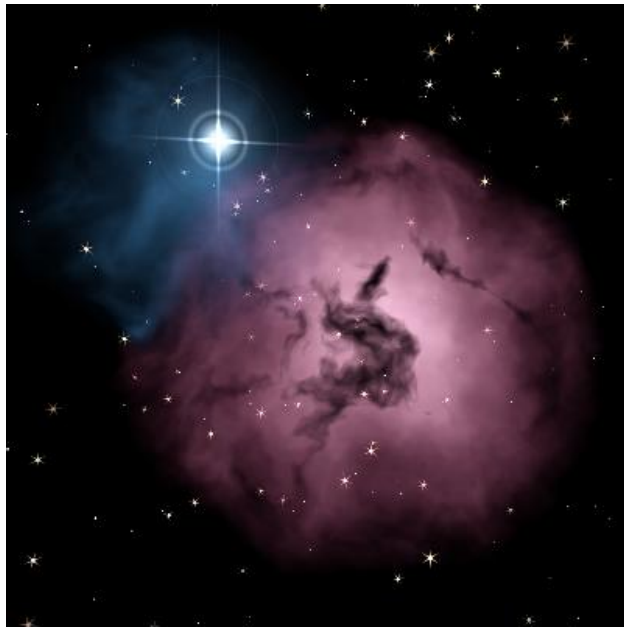
Forward motion - The TARDIS

Here are another two stills (Fig2a.jpg, Fig2b.jpg), this time of a cube (Dr Who's *TARDIS = Time and Relative Dimensions in Space*) moving directly towards the observer. The cubes appear to bulge outwards. Why? They also appear to be smaller (or are they further away?). Why?
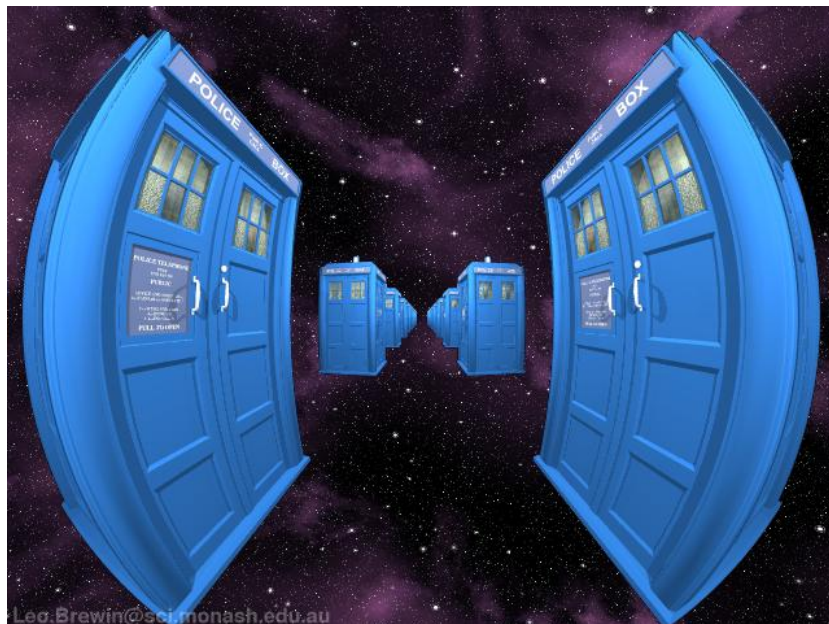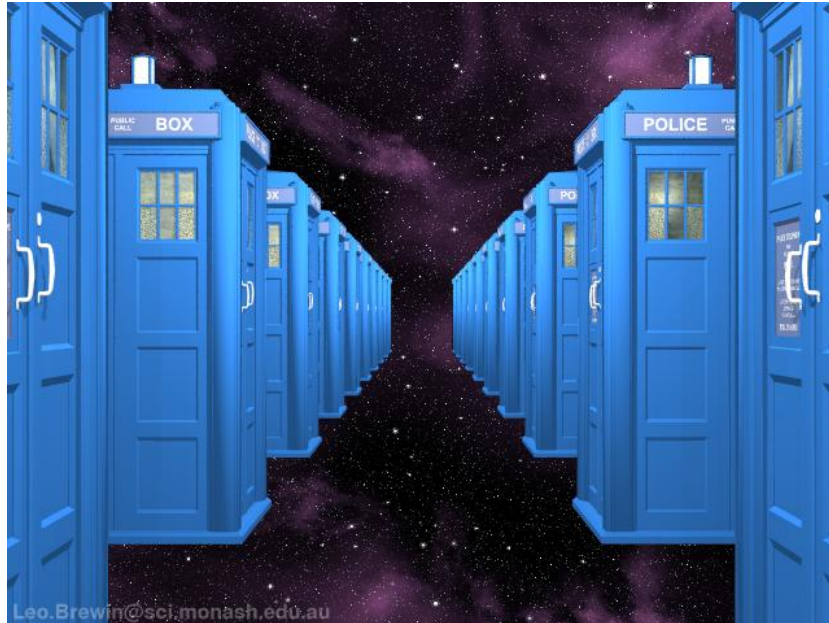
Transverse motion - The Albert Einstein Steam Railway

Here are two images of a train moving across the line of sight of a single observer. The top image (Fig3a.jpg) is of a train moving at $\beta = 0.05$ while the lower (Fig3b.jpg) image has $\beta = 0.95$.

The students should be able to explain why speed of the train appears to slow down as it moves from left to right. The train also appears to shorten in length as it moves left to right. Why? The train also appears to rotate, but that is harder to explain (bonus marks?)