BINARY STARS IN ORBIT : OPTICAL EFFECTS

by ETF, 23rd March 2013

Einstein's special & general theories of relativity have perplexed people for years because there are alleged to be time dilation and length contraction effects. These have been (and continue to be) severely counter-intuitive to lots of people. Personally, I think these effects are probably real but I want to be able to verify them for myself.

A fundamental premise of special & general relativity (immensely counter-intuitive to the lay person) is that the incoming velocity of light arriving at an observer in empty space is always c and does NOT depend on the velocity of the source towards or away from the observer, nor on the velocity of the observer towards or away from the source. The only effect is supposed to be that the received photons are blue- or red-shifted. If the source recedes at c (or faster) the photons are black-shifted and have zero energy, hence no photons would be observed.

But suppose that photons were actually like bullets that travel at speed c ± v , where ± v is the velocity of the source towards/away from the observer. The Open University 'disproved' it by showing a vacuum storage ring in which relativistic electrons emitted pulses of light, at a sharp bend in the ring, through a glass diaphragm into the laboratory. Elementary electronic timing measured the pulses crossing the lab at c, despite the electrons themselves travelling at 0.8 c.

But my objection to the 'disproof' was this: it is well known that photons travel at less than c in a dielectric because they are absorbed by the atoms and get re-radiated after small time delays. So I assert that the light might indeed hit the glass diaphragm at 1.8 c but the atoms of the dielectric would re-radiate the photons into the laboratory at c.

Willem de Sitter (1872-1934) was a Dutch cosmologist who said that a crucial test of this would be to study binary-star pairs. If the light from each star travelled to Earth at c ± v (rather than c) where ± v was the positive or negative velocity component of the star as seen relative to Earth, some bizarre optical effects should be seen. From time to time, ghost images of the stars would wink in and out. Sometimes we should see only the two stars, but at other times three or four stars, at various places all within their orbit radius. The Open University displayed a computer simulation of these ghosts and asserted that they are never actually seen, hence de Sitter's method has 'verified' relativity. There was no mention of how far away the binary stars would have to be. I presumed they would be a few hundred light-years away.

I did some computations on a hypothetical pair of binary stars whose orbits would have very high velocities at their closest approach (at 'periastron'). I chose a blue star of 10 solar masses co-orbiting a red star of 10 solar masses in 7 years. They would reach a maximum spatial separation of 16 Astronomical Units (AU) at 'apastron', where the orbit velocities would be at a minimum of 10.4 km/sec. They would reach a minimum separation of 4 AU at periastron, where the orbit velocities would be at a maximum of 42.1 km/sec.

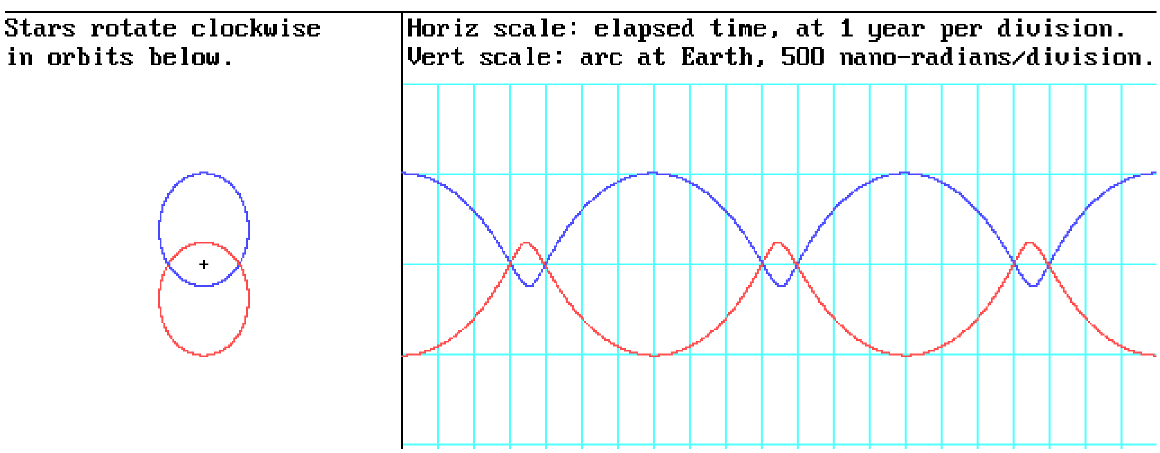
In the three diagrams that follow (Binary*LY.gif) the elliptical orbits are plotted as if viewed from above their plane.

To understand my Binary*LY.gifs you have to assume that you are observing the orbit plane edge-on as seen from the right, so that the maximum velocity of the blue star is 42.1 km/sec away from Earth and of the red star is 42.1 km/sec towards Earth , occurring at periastron. At the Earth you would see the stars moving back and forth along a vertical straight line. The vertical grid on the graph are lines of constant time, so looking down any vertical line you would see whether the binary system appears at Earth as two stars, or four, and so on. The plotting grid extends to the right for 21 years (three full orbits). The star positions (they orbit clockwise) are projected onto the grid. The vertical lines are in pale blue, at yearly intervals.

Up to a distance of 250 light-years there would be no discernible optical anomalies. The effect of c ± v at this distance leads to maximum time-of-arrival anomalies of 13 days late for the blue star's light and 13 days early for the red star's light, which have negligible effect upon the quasi-sinusoidal curves. No 'ghost' images would be seen.

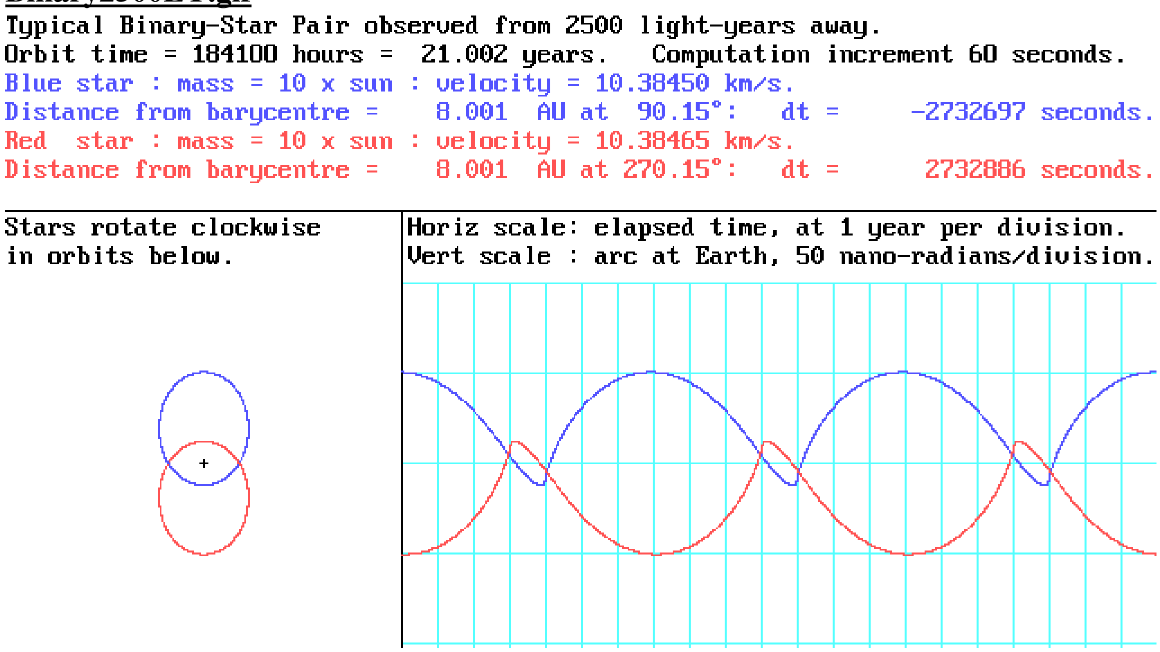
Binary250LY.gif

Typical Binary-Star Pair observed from 250 light-years away.
Orbit time = 184100 hours = 21.002 years. Computation increment 60 seconds.
Blue star : mass = 10 x sun : velocity = 10.38450 km/s.
Distance from barycentre = 8.001 AU at 89.98°: dt = -273269 seconds.
Red star : mass = 10 x sun : velocity = 10.38450 km/s.
Distance from barycentre = 8.001 AU at 269.98°: dt = 273288 seconds.



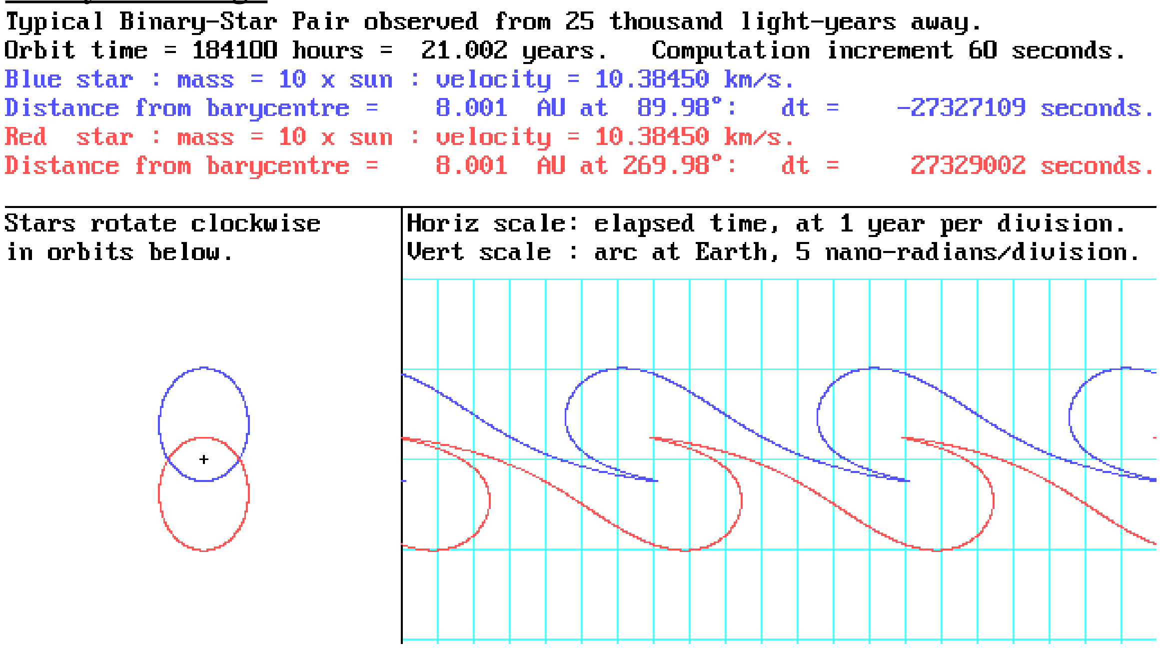
At a distance of 2,500 light-years the distortions to the sinusoidal light curves become noticeable, reaching maximum time-of-arrival anomalies at periastron of 128 days late for the blue star and 128 days early for the red star. Nevertheless, no ghost images would yet be seen.

Binary2500LY.gif



At a distance of 25 thousand light-years (one quarter of the way across our Galaxy) the effects of c ± v are to create maximum time-of-arrival anomalies of 3.5 years late for the blue star and 3.5 years early for the red star, occurring at periastron. So the red star's light sometimes arrives one full orbit period ahead of the blue star's light, at periastron. Assuming your telescope had enough resolving power you would sometimes see only the two stars, but more often you would see four simultaneously (3 red + 1 blue, or 3 blue + 1 red) during any 7-year orbit period.

<u>Binary25000LY.gif</u>



Now we have to consider the limiting resolution of optical telescopes to separate the individual star images. A perfect objective lens or parabolic mirror of diameter D, not having any optical blocking by sub-mirrors and their support struts (and assuming perfect eyepiece lenses) could separate two star images whose angular spacing is roughly 2.5 W/D in radians, where W is the wavelength, say 500 nanometres near the peak of the human night vision response:-

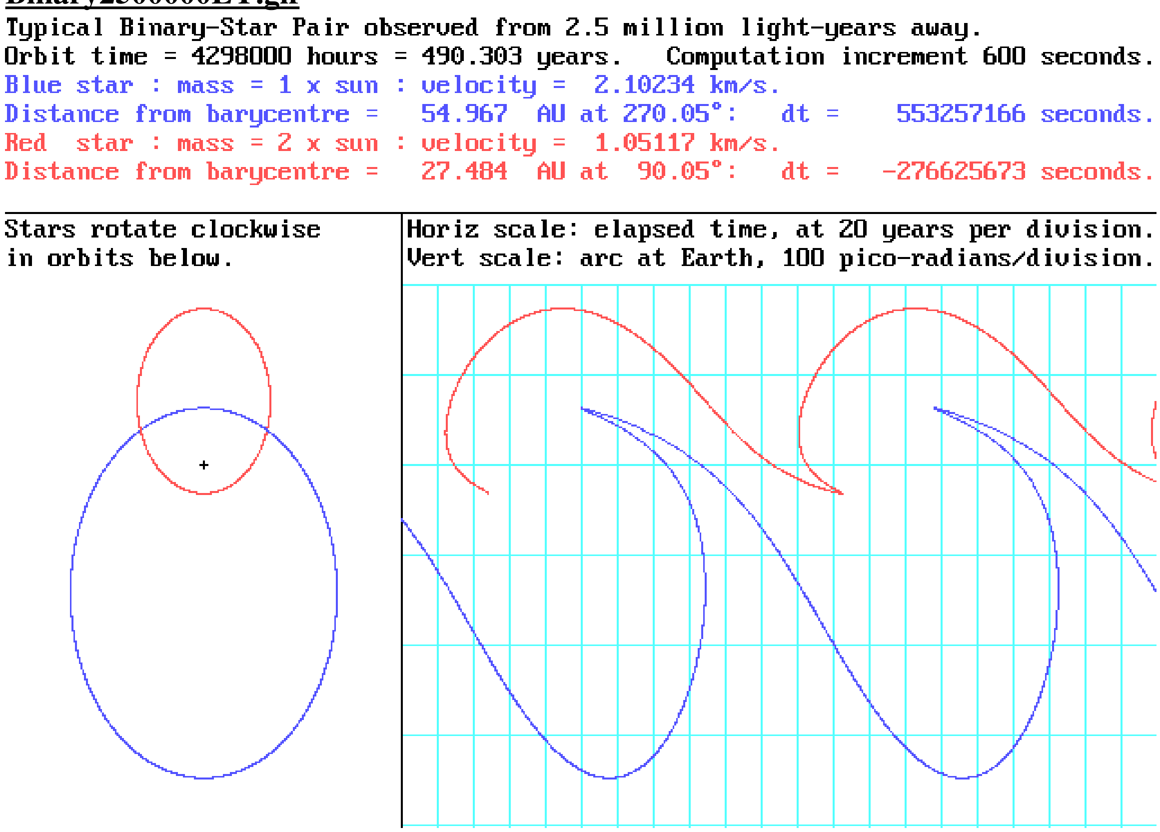
7 x 50 mm binoculars	**== 25 micro-radians ==**	**5 arc-seconds**
250 mm amateur telescope	**== 5 micro-radians ==**	**1 arc-second**
Mount Wilson 100-inch Hooker	**== 500 nano-radians ==**	**100 milli-arc-seconds**
Mount Palomar 200-inch Hale	**== 250 nano-radians ==**	**50 milli-arc-seconds**
Subaru (Hawaii) 8.3-metre dish	**== 150 nano-radians ==**	**30 milli-arc-seconds**
Keck (Hawaii) 10-metre dish	**== 125 nano-radians ==**	**25 milli-arc-seconds**

To resolve star images 10 nano-radians apart would require interferometry, such as by the use of the Keck Observatory's twin 10-metre mirrors that are separated by 85 metres, but this would not produce a directly-photographed optical image.

Unfortunately, my binary system's orbits subtend only 10 nano-radians at the Earth, beyond any single-mirror telescope to resolve. Even binary pairs a hundred AU apart would appear as a smeared blob at that distance. But, if there were superimposed ghost images, there would be more than two superimposed spectra having different shifts because they would emanate from different velocity components in the orbits. I presume these are not actually seen.

The light from distant galaxies (2.5 million LY +) would be utterly bizarre. The galactic spectra would be smeared right out. Obviously this doesn't happen. De Sitter, who died in 1934, proposed his method at a time before spacecraft. But, presumably by now, the precision tracking of transponders on spacecraft in rendezvous with Venus, Mars, Jupiter, Saturn, Uranus and Neptune would easily have revealed any c ± v effect. For instance, a spacecraft velocity of five km/sec would delay the radio signals by 21 milliseconds in a 375-gigametre journey.

Binary2500000LY.gif



I feel disappointed to discover that de Sitter's method could only be verified spectroscopically. It could not be demonstrated visually to the human eye except at distances where no existing ground-based or orbiting telescope could resolve the negligible separation angle between the binary stars anyway. Looking through my binoculars, or through an amateur telescope or a modern 8-metre or 10-metre instrument, I shall not be able to confirm the presence or absence of binary 'ghosts' in our galaxy.