Computed radial velocity curves for the figure-eight orbit

by S Edgeworth

If hypothetically there are any real figure-eight triple star systems out there, what would their radial velocity curves look like?

The figure-eight orbit was modelled using n-body integration software, which included added code to enable the star system's orbital major axis to be oriented at various angles relative to the hypothetical observer, and to output the radial velocity data.

This article presents computed radial velocity curves for hypothetical triple star systems with the figure-eight orbit.

The shape of the radial velocity curve is determined by the viewing angle, which is the angle between these two lines:
(a) the line connecting the observer (a telescope on or near Earth) and the barycentre of the triple star system,
and
(b) the line of the major axis of the figure-eight orbit of the triple star system.

Diagram 1 shows the orientation of the orbit, relative to the direction to the observer (labelled “sol”), for the first radial velocity curve (0 degrees).

Diagram 2 shows the orientation of the orbit for the second radial velocity curve (22.5° degrees).

The orientations for the remaining radial velocity curves continue in the same pattern, at successive intervals of 22.5°.

Diagram 1: Orientation 0°

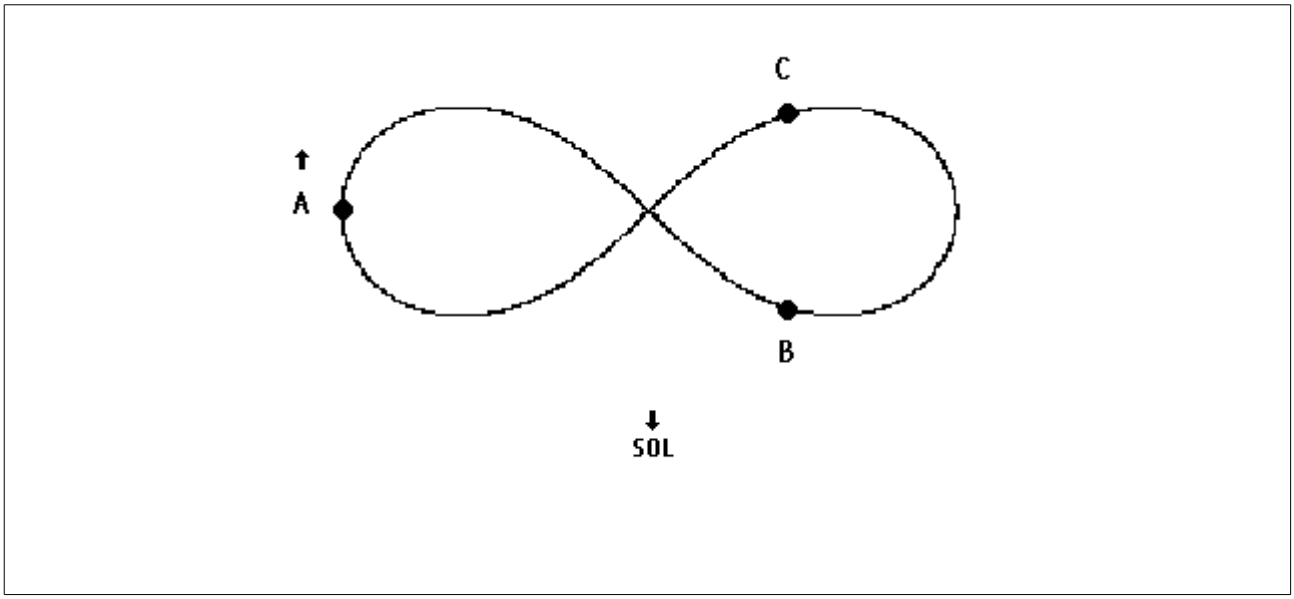
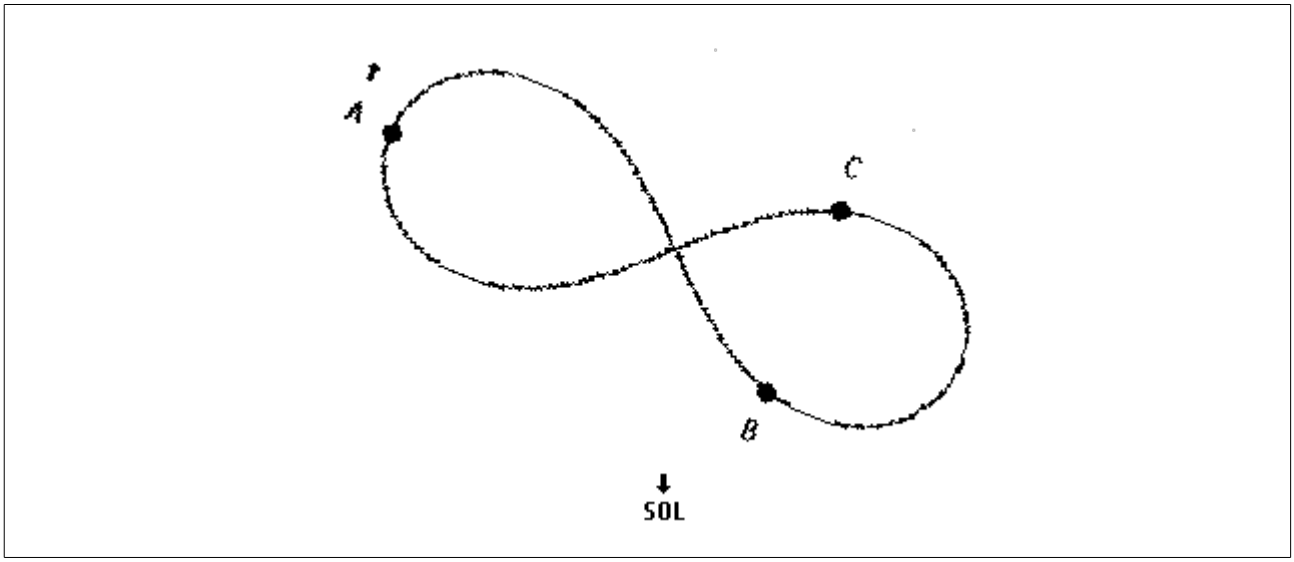


Diagram 2: Orientation 22.5°



In the radial velocity curves, the horizontal axis is time. Each curve shows exactly one orbital period. The vertical axis represents radial velocity. Up represents motion away from the observer, and down represents motion towards the observer.

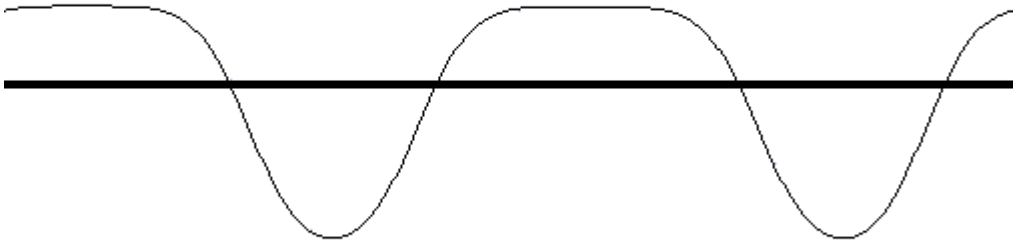
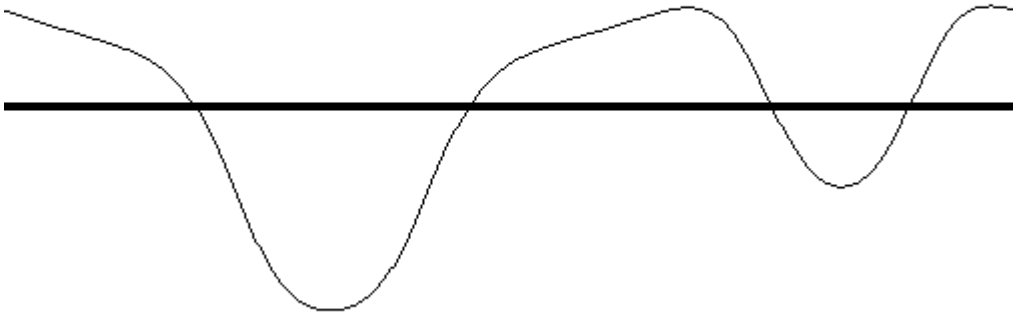
The curves represent the radial velocity curve of just one of the three stars. The curves for the other two stars are identical but shifted in phase by exactly one-third and two-thirds of the orbital period respectively.

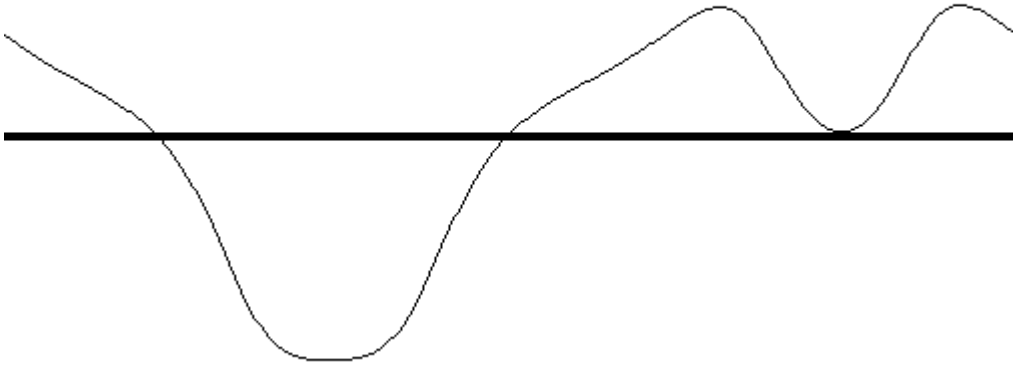
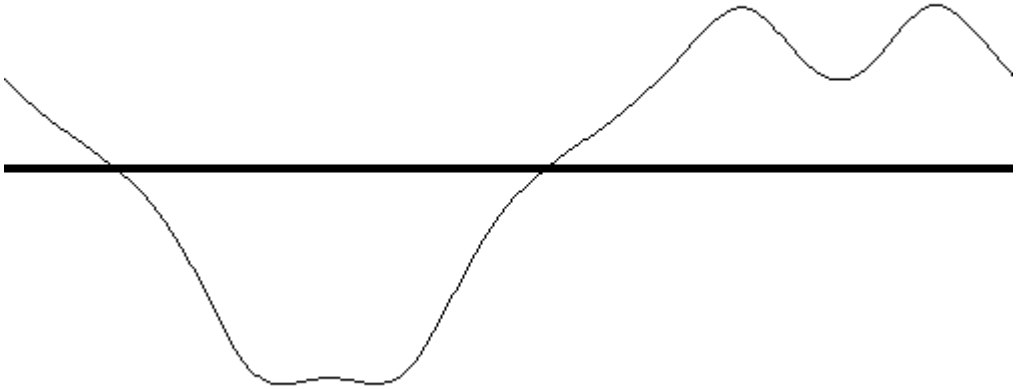
Units have been deliberately omitted, as the curves are scalable to any perfect figure-eight orbit. Orbits on an orbital plane which is inclined relative to the viewing point would yield the same shape curves (but with amplitude reducing to zero if the relative inclination is perpendicular).

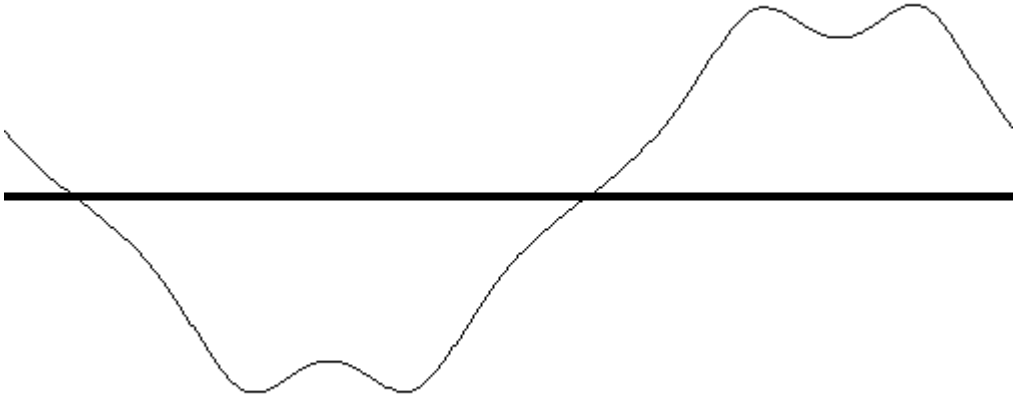
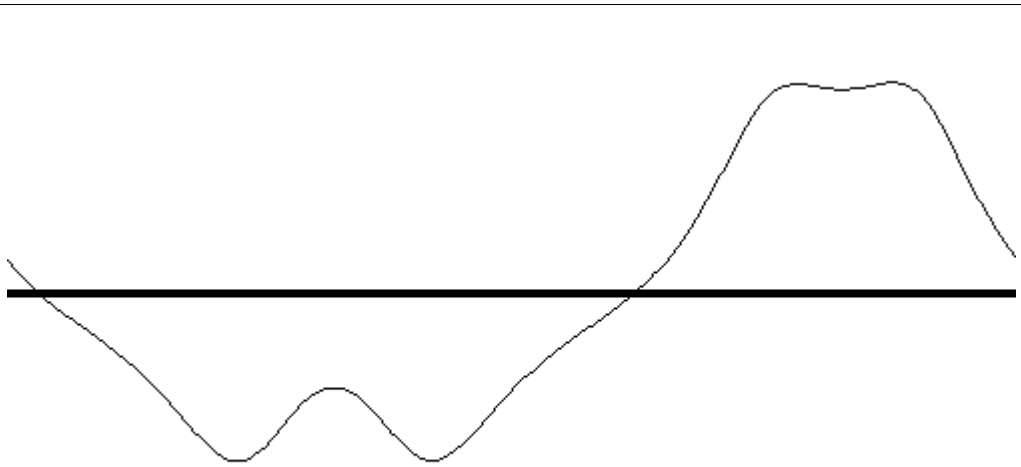
Note that each radial velocity curve has two or three maxima and two or three minima per orbital period. This is significantly different to the radial velocity curves of binary stars, which have only one maximum and one minimum per orbital period.

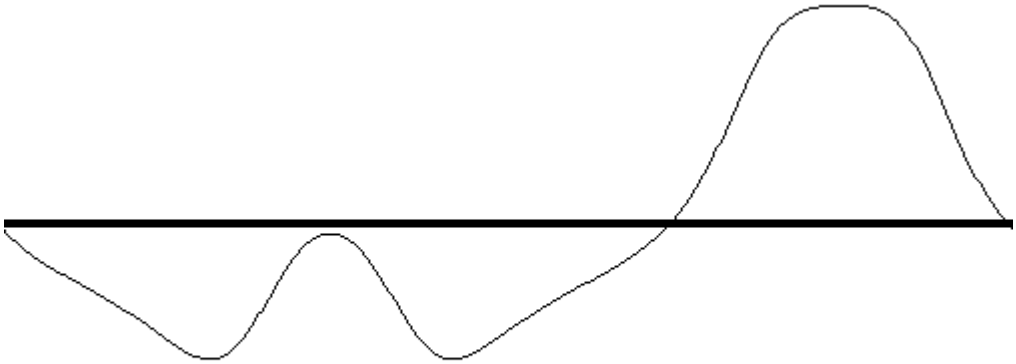
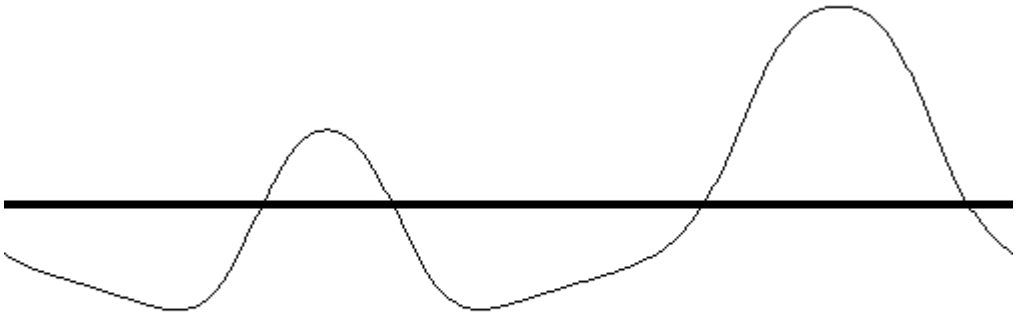
Each curve shows radial velocity for exactly one orbital period.

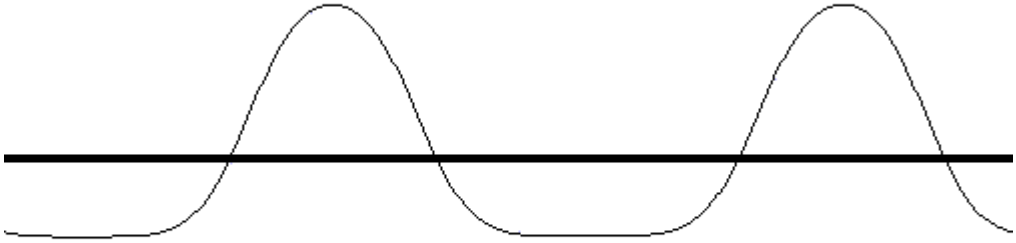
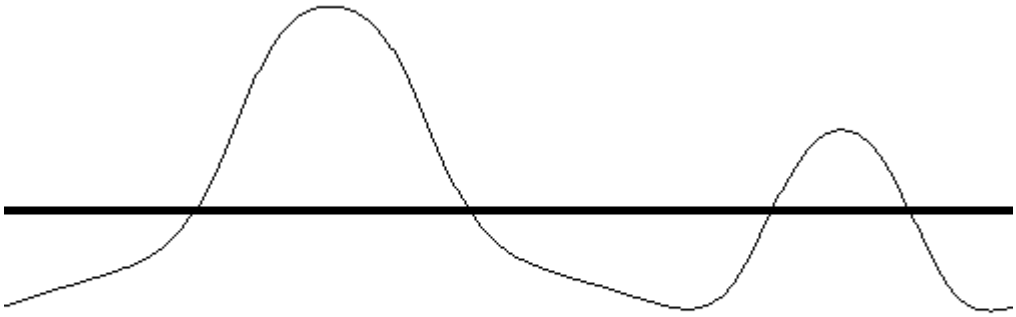
Diagrams 2-19: Computed radial velocity curves at various orientations

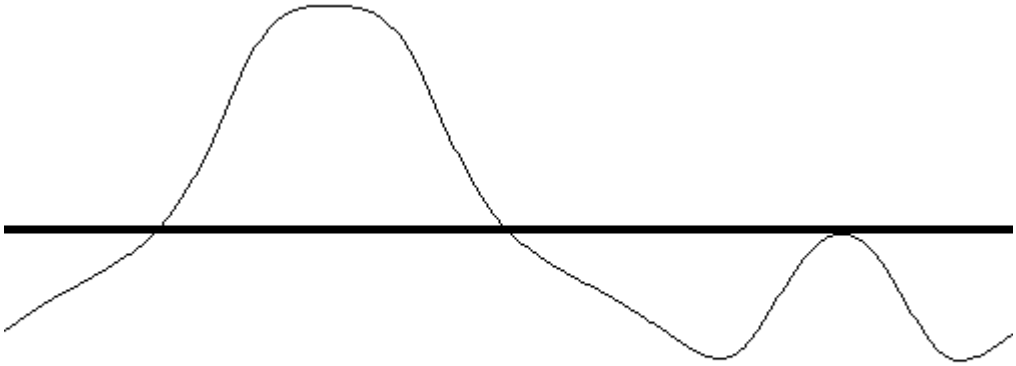
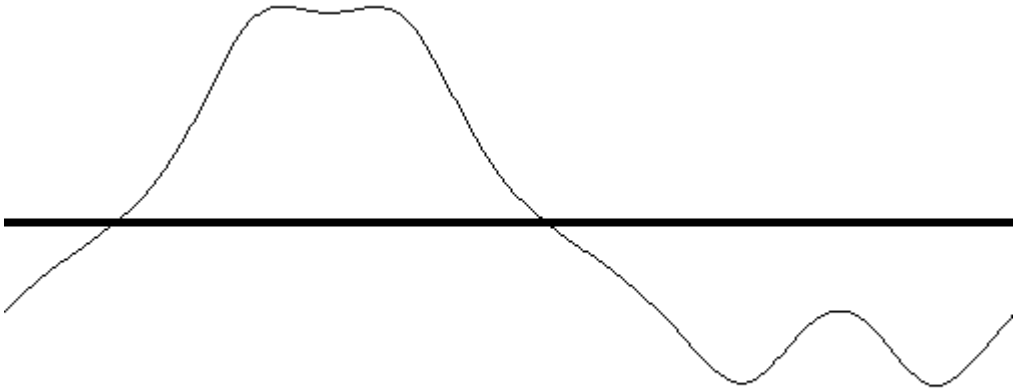
0°	
22.5°	

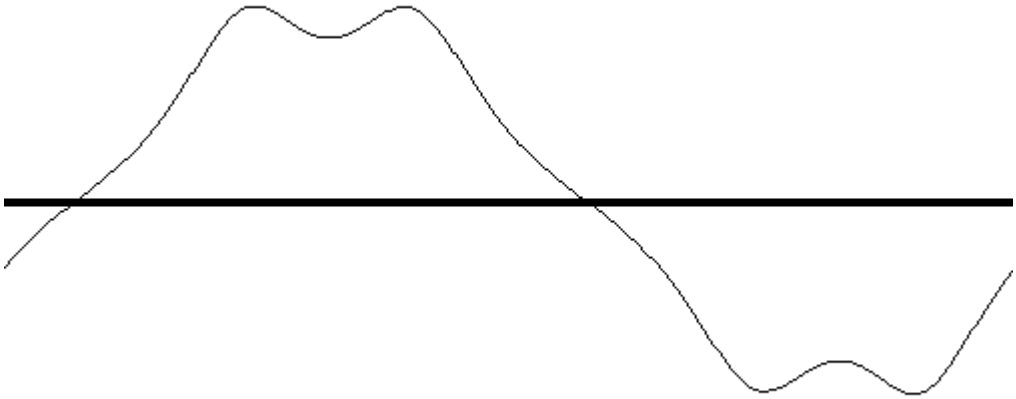
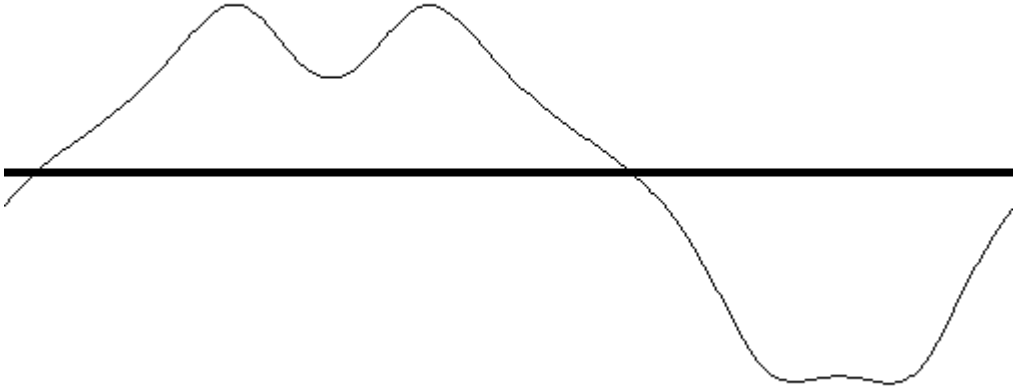
45°	
67.5°	

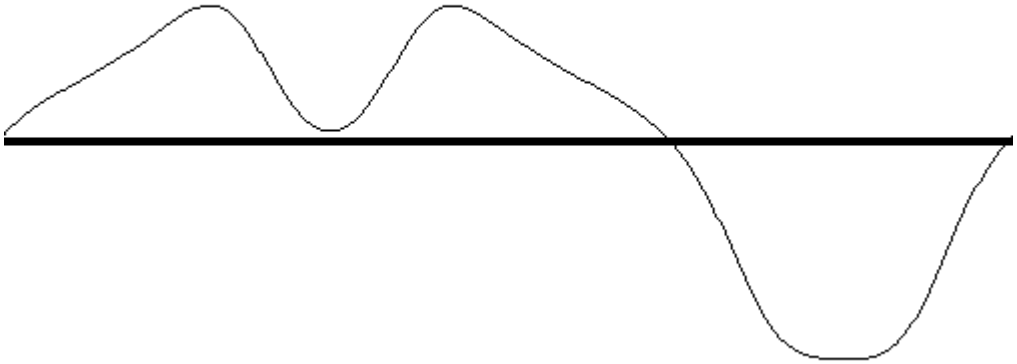
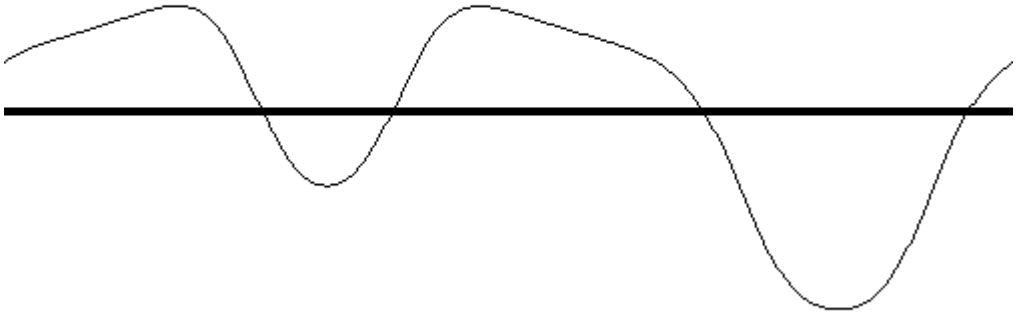
90°	
112.5°	

135°	
157.5°	

180°	
202.5°	

225°	
247.5°	

270°	
292.5°	

315°	
337.5º	

These radial velocity curves are for the perfect figure-eight orbit. There are also some interesting variations of the orbit in which one of the starting parameters is altered slightly, for example by giving one star a slightly different mass, or a slightly different starting position, or slightly different starting velocity. Some of these variations are stable, and would produce slight variations of the radial velocity curves described above.

In some of those variations, the orientation of the major axis of the orbit precesses continuously, This would give a radial velocity curve which gradually changes over time, progressing gradually through the illustrated curves.

In other variations, the major axis of the orbit oscillates back and forth through an angle of about 90 degrees. This would give a radial velocity curve which gradually changes over time, oscillating gradually back and forth through an approximate 90 degrees range of the illustrated curves.

Conclusion:

If triple star systems with figure-eight orbits exist, they may be identifiable from their radial velocity curves. The radial velocity curve of each star will have 2 or 3 maxima and 2 or 3 minima per orbital period (instead of the 1 maximum and 1 minimum of binary star systems), and the curve will be similar to one of the curves illustrated above. It may also be possible to estimate the orientation of the orbit, relative to Earth, from the shape of the radial velocity curve.

References

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A remarkable periodic solution of the three-body problem...
A.Chenciner and R.Montgomery