It has been estimated that half of all stars are components of binary or multiple systems. Yet the number of known orbits for astrometric and spectroscopic binary systems together is less than 7,000 (including redundancies), almost all of them for bright stars. A new generation of deep all-sky surveys such as Pan-STARRS, Gaia, and LSST are expected to lead to the discovery of millions of new systems. Although for many of these systems, the orbits may be poorly sampled initially, it is to be expected that combinations of new and old data sources will eventually lead to many more orbits being known. As a result, a revolution in the scientific understanding of these systems may be upon us.

The current database of visual (astrometric) binary orbits represents them relative to the “plane of the sky”, that is, the plane orthogonal to the line of sight. Although the line of sight to stars constantly changes due to proper motion, aberration, and other effects, there is no agreed upon standard for what line of sight defines the orbital reference plane.

Furthermore, the computation of differential coordinates (component B relative to A) for a given star must be based on the binary system’s direction at that date. Thus, a different “plane of the sky” is appropriate for each such date, i.e., each observation. However, projection effects between the reference planes, differential aberration, and the curvature of the sky are generally neglected in such computations. Usually the only correction applied is for the change in the north direction (position angle zero) due to precession (and sometimes also proper motion). This paper will present an algorithm for a more complete model of the geometry involved, and will show that such a model is necessary to avoid errors in the computed observables that are significant at modern astrometric accuracy. The paper will also suggest where conventions need to be established to avoid ambiguities in how quantities related to binary star orbits are interpreted.

**Ambiguous Aspects of the Orbital Parameters**

Because OR86 is a collection of orbits determined by different investigators, it is a heterogeneous source of information. Several aspects of the data in OR86 are not well defined and therefore present an obstacle to precise computations. About 1/3 of the orbits do not have the epoch E specified (most of the specified E’s are 2000). Orbital elements P and T, which are times, are often expressed as a year + fraction, in units of Besselian years, but the conversion to more standard time units is not given. Also, a significant issue is that the plane by which the right hand side of the equation is the north direction is relative to the “equinox, if any, to which the node (O) refers”. That is, the north direction, at the position of the binary system on the celestial sphere, is toward the north celestial pole of date E.

**Geometry Usually Considered**

In computing observables from orbital elements, we can take the solution of the two-body problem for binary stars as given. Standard texts such as Alken (1964), The Binary Stars, then advise computing for the change in the north direction, due to precession, between the epoch of the orbit (E) and the epoch of observation, and similarly for the change in north direction due to the star’s proper motion (although aberration is usually a larger effect). Simple formulas are provided. Some texts also give corrections for change of scale and change of light-time, for those systems with significant radial velocities.

**Other Geometry To Consider**

The algorithm adopted for the NOVAS double star algorithm can be summarized as follows. Some details (such as change of units) are omitted, and for practical reasons the order of computations in the software is somewhat different.

1) Using standard astrometric parameters (e.g., from the Hipparcos catalog) for component A, or the system’s center of mass, compute:
   - \( a_o \), the mean place direction vector of A at epoch \( E \) (epoch of orbit),
   - \( \alpha_o \), the mean place direction vector of A at the time of observation, where both vectors are in barycentric and with respect to the ICRS axes.
2) Compute the 3x3 transformation matrix between the plane-of-the-sky coordinate system defined by \( a_o \) and the ICRS.
3) Compute the change in scale and light-time between epoch \( E \) and the time of observation, due to the radial velocity of the system.
4) Using standard Keplerian-orbit algorithms, applied to the orbital elements given in OR86, compute \( \delta \), the 3-vector displacement of component B w.r.t. component A, at the time of observation (corrected for the change in scale and light-time in the plane-of-the-sky coordinate system defined by \( \alpha_o \)).
5) Correct \( \delta \) for change of scale, and transform to the ICRS using the matrix from step 2. Call the result \( \delta' \).
6) Using \( \delta' \), the mass ratio \( i/C \) known, and other set \( o = C \), compute:
   - \( a' \), the mean place direction vector of A at the time of observation, in the ICRS.
7) Compute the apparent place direction vectors \( a'' \) for A and B components, starting with \( a' \) and \( b' \), apply parallax, gravitational light bending, and aberration. Obtain apparent \( a' \) and \( b' \) for both components.
8) Compute differential apparent coordinates (position angle \( i' \) and separation \( b' \)) between A and B.