RELATIVISTIC REFERENCE FRAMES IN ASTROMETRY

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Astrometry can be defined as the measurement of space-time coordinates of photon events. For example, in principle, in classical optical astrometry, we measure the components of velocity, and hence the direction, of an incoming photon with respect to an instrumental coordinate system, and the clock time, at the instant of detection. The observer's coordinate system at any instant can be identified with a local inertial frame. In the case of interferometric observations, the measurements are of clock times of arrival of a wavefront at two detectors whose spatial coordinates are specified with respect to instantaneous inertial frames.

On the other hand, the motions of celestial objects, and in particular of the photons which enable us to observe them, can only be described completely in a fully relativistic context, by means of coordinates referred to a global reference frame. These coordinates, while satisfying the relativistic equations of motion, are otherwise purely mathematical entities whose numerical values depend entirely on the particular choice of coordinate system or metric. It has been pointed out elsewhere (eg Murray 1981,1985) that the light deflection in the gravitional field of the Sun differs by a numerically significant amount according to whether it is described in terms of the Schwarzschild standard or isotropic metrics.

It is therefore clearly of the utmost importance that coordinate frames used in astrometry, and the transformations between them, be precisely defined.

The coordinates of the observer with respect to the global reference frame are continually changing. Even if the global frame could be identified with an inertial frame in the special relativistic sense, the transformation between this frame and the observer's frame would give rise to the phenomenon of aberration which is rigorously described by a Lorentz transformation. The problem is that, in general relativity, there is no such thing as a global inertial frame; it is therefore necessary to introduce the concept of an intermediate frame

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which is at rest with respect to the global frame and which is locally inertial. Elsewhere I have given the transformation from the coordinates in the general spherically symmetric metric to the so-called "natural frame" which can then be transformed rigorously to the observer's local inertial frame by an appropriate Lorentz transformation (Murray,1983). The concept of the natural frame has been further developed by Fukushima et al. (1985). By means of the natural frame the apparent ambiguity in light deflection as described by different forms of the coordinate metric is resolved.

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