PARALLAXES WITH LARGE REFLECTORS

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ABSTRACT

Reflecting telescopes designed to do astrometry can obtain parallaxes essentially free of systematic errors. Improvements in detection and mensuration now make it possible to produce parallaxes of unprecedented accuracy without undue cost or effort.

Traditionally, stellar trigonometric parallaxes have been obtained with long-focus photographic refractors with apertures of one meter or less. Reflecting telescopes are generally designed with other objectives in mind and therefore are usually not suitable for high-precision astrometry unless special precautions are taken in the observations and reductions. To be sure, there have been programs that have used large aperture reflectors to obtain parallaxes for stars fainter than those accessible with refractors. The van Maanen series with the Mount Wilson 2.5-meter and 1.5-meter telescopes is well known, and that effort was reasonably successful in those instances in which the reference frame was kept within the coma-free field. More recently, there have been astrometric efforts with the Kitt Peak 4.0-meter and the Isaac Newton 2.5-meter reflectors, but instruments of this class generally have too many demands to be devoted to systematic parallax programs.

There are a few reflectors that have been designed for the primary purpose of doing astrometry. These include the USNO 1.55-meter astrometric reflector, built in the early 1960's under the guidance of Kaj Strand, the 1.56-meter reflector at Shangi, the Turin 1.0-meter copy of the USNO instrument, and the McCormick 1.0-meter of somewhat different design. The USNO instrument has produced a significant body of parallax and proper motion data, having generated over 800 parallaxes from more than 50,000 plates over a 20-year period.

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One feature that makes the USNO instrument (and similar ones) particularly suitable for astrometry is that it has a folded prime-focus; that is, it has a flat secondary. Being flat, the secondary is large, with a diameter of 0.9-meters. This significant obstruction limits the light gathering power of the telescope to that of an instrument with an apertaure of 1.25-meters, but it eliminates the distortions caused by hyperpolic secondaries.

Such a system promised to be free of the systematic errors so common to refractors, and in 1971, at the Fourth Astrometric Conference at the University of Virginia, Atkinson (1971) had the audacity to go on record suggesting such a possibility. By 1978, with 485 parallaxes available to us, we felt we had enough data to test this assertion, and the analysis of the systematic errors of the telescope was presented by Harrington et al (1978).

The primary approach was that employed by van Altena (1971), which was to examine the distribution of relative parallaxes of the reference stars. The dispersion of reference star parallaxes derived at that time was 0".0041. Adopting an intrinsic dispersion from the mean correction to absolute parallax of 0".0019, we deduced a formal external standard error of 0".0036, a value identical to the mean internal standard error.

It would be too bold to suggest that the systematic errors of this instrument are identically zero, but they are obviously small, probably below the milli-arc-second level. More importantly, at our current level of precision, our internal error estimates are probably realistic estimates of the true errors, and therefore the growth of weight of a parallax with increased material may follow Gaussian statistics. Thus, parallaxes with true precisions at or below the milli-arc-second level are obtainable, and efforts to increase the weights of the individual positions may produce significant dividends.

The are several possibilities for increasing these weights. Assuming that the photographic plate remains the detector (at least for the next few years), there are the new, very high signal-to-noise emulsions, such as the Kodak IIIa emulsions. Experiments at USNO and elsewhere have shown that a weight increase by a full factor of two is easily obtainable with no increase in the exposure time required to achieve a specified limiting magnitude. Along with the new emulsions, USNO is also introducing the capability of magnitude compensation. Filters with neutral density occulting spots of a variety of densities will make it possible to obtain parallaxes of stars up to first magnitude.

The plate measuring can now also be improved. USNO has used a single semi-automatic measuring machine (SAMM) throughout its program, which is free of personal bias and imprecision, but which is an intensity scanning machine. Some form of "pixellating" density scanning machine is to be preferred, and the PDS microdensitometer

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has been used in several places for this purpose. Experiments with the Lowell and Berkely PDS's have indicated an increase in weight by almost a factor of two, which suggests an increase of more than two may be possible with newer machines. (However, USNO exposure times must be increased to obtain images with optimum densities.) Thus, with new emulsions and new machines, milli-arc-second parallaxes should be obtainable with our present level of effort.

However, the non-linear, inefficient, grainy photographic plate is not an optimum detector. The plate holder could be replaced by some sort of direct electronic detector, such as the instruments in use at Allegheny, Lick, and McCormick. USNO is using a CCD detector on the 1.55-meter reflector, and Dahn describes this effort elsewhere in these proceedings.

The combination of a large specialized reflector with improved techniques for detection and mensuration can lead to parallaxes of unprecedented accuracy without undue cost or effort. The future for imaginative ground-based parallax astrometry is indeed bright.

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van Altena, W. F.: 1971, Astron. J. 76, 932.

Discussion:

MURRAY: Do you use filters with your IIIa-J plates?
HARRINGTON: Yes, we do.
UPGREN: How did you determine the cosmic error?
van ALTENA: I expect that once you begin using the IIIa-J and IIIa-F emulsions with the 61-inch reflector and measure them with the PDS-like measuring machine that the standard errors of your parallaxes will be about 0".001 for the same number of plates.
HARRINGTON: We certainly want better than one milliarcsecond, and we could do it now with 16 times the material. We are now down to 0".0014 on our longest series. We certainly hope to get to one milliarcsecond without much effort with these weight increases.