Observational Model for Precision Astrometry with the Space Interferometry Mission (SIM)

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Abstract

The Space Interferometry Mission (SIM) is a space-based long-baseline optical interferometer for precision astrometry. The SIM architecture uses a 10-m Michelson interferometer in Earth-trailing solar orbit to provide 4 microarcsecond (μas) precision absolute position measurements of stars down to 20 magnitude. SIM is expected to achieve a proper motion accuracy of about 2 μas/yr during its 5-year lifetime.

One of the primary objectives of the SIM instrument is to accurately determine the directions to a grid of stars, together with their proper motions and parallax, improving a priori knowledge by nearly three orders of magnitude. The SIM instrument does not directly measure the angular separation between stars, but the projection of each star direction vector onto the interferometer baseline vector by measuring the pathlength delay of starlight as it passes through the two arms of the interferometer. Because the a priori baseline vector is only known to arcsec accuracy through on-board attitude information, the interferometer baseline vector must also be estimated in an *it a posteriori* manner in addition to the astrometic parameters. A consequence of this is that in order to generate a consistent set of equations from which to determine the astrometric parameters, multiple measurements of each star with different baseline orientations must be made, and dually multiple star measurements must be made with each baseline.

SIM makes the pathlength delay measurement by a combination of internal metrology measurements to determine the distance the starlight travels through the two arms of the interferometer and a measurement of the white light stellar fringe to find the point of equal pathlength. Because this operation requires a non--negligible integration time to accumulate enough photons to measure the stellar fringe position, the baseline vector is not stationary over this time period as its absolute length and orientation are time--varying. This conflicts with the requirement that a single baseline vector measures a set of stars.

This paper addresses how the time-varying baseline is "regularized" so that it may act as a single baseline vector for multiple stars. The notion of the regularized baseline is fundamental to the extraction of the astrometric parameters. It has been used extensively in a number of grid simulation studies to plan observation sequences for the mission, etc. We present theory of guide interferometers angle feedforward and discuss implications for the SIM instrument design and simulations.

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