SIM Astrometric Measurement

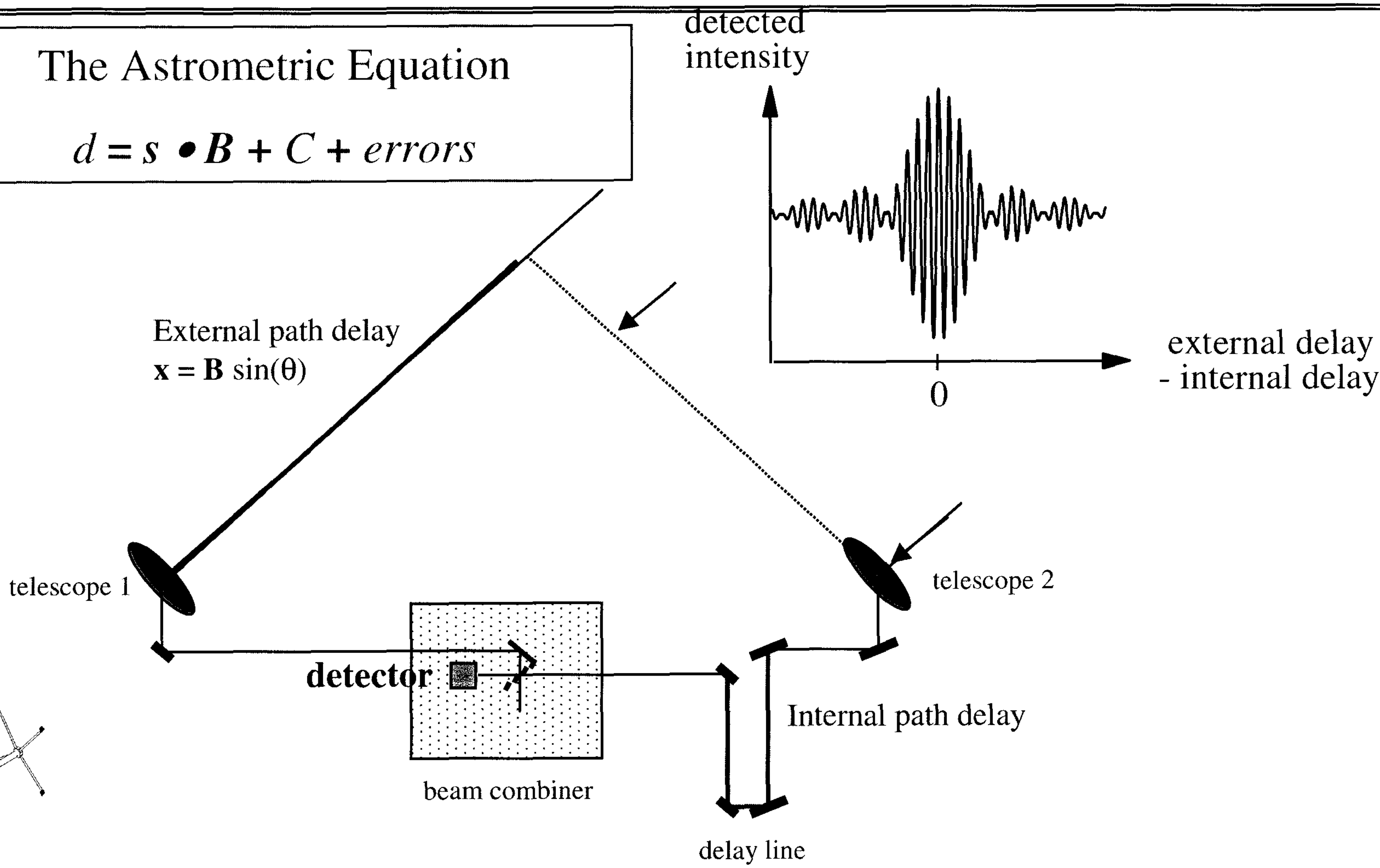
Space Interferometry Mission

SIM

A NASA Origins Mission

The Astrometric Equation

$$d = s \bullet B + C + errors$$



The peak of the interference pattern occurs when the internal path delay equals the external path delay

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Primary Goal

Achieve a 4 μas wide-angle (1 μas narrow-angle) 4π astrometric grid to act as a global instrument calibration and a set of "surveyor's points" for science measurements

Standard Scientific Problem: Using our uncalibrated instrument to measure not-sufficiently-known quantities to perform a precise instrument calibration.

By having a set of standard "surveyor's points" on the sky, we can use these points to determine spacecraft orientation and baseline length for each set of observations.

Why A Grid?

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Some basic design characteristics of SIM:

- Observations limited to 15° field-of-regard without reorienting spacecraft
- Attitude control system does not give instrument baseline orientation precisely enough for required science precision (need 100 μas)
- 60° Solar exclusion angle
- Measurements are all one-dimensional *optical path delays*
- System tracks metrology (baseline length and optical path lengths) changes from an initial *unknown* value

Accumulating Grid Observations

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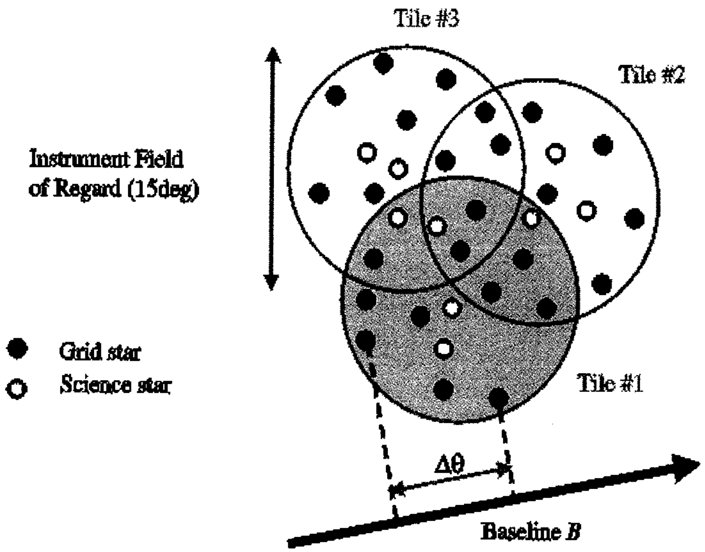

- O(3000) Stable Astrometric Objects
- Individual Measurements are 1-d delays, *not separations*
- About 1/2 tile offset
- ~1000 total 15° tiles per scan (solar exclusion of 60°)
- ~12-15 grid objects per tile
- Scan the whole sky (minus solar exclusion) ~4.5 times/year

➔ Common Baseline Orientation during a tile ties delay measurements together for that tile

➔ Objects in tile overlap regions tie adjacent tiles together for the 4π Grid

➔ Celestial Sphere surveyed twice per scan with Orthogonal Baseline Projections to obtain Isotropic Position Errors.

➔ Simultaneous fit of instrument and stellar parameters. This resulting Grid Catalog will then be used as instrument calibration during science observations

Solving The Grid

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We are currently simulating the grid with a Monte Carlo grid catalog and a simple instrument model to make instrument design decisions.

- The nominal 5 year mission will generate 23k tiles & 300k observations
- The resulting design matrix is sparse (1% filled) and large (343k x 100k)
- For our current simulations of the grid, we solve it using the method of Conjugate Gradients on the Normal Equations, looking at the difference vector between a parameter-based model and the measurements.
- The solution takes ~8 hours on a Sun Ultra 30 workstation
  - Some parts of the process operate in parallel on a farm of ~20 workstations

Grid Object Requirements

- Sufficient stars for grid
- Small enough angular diameter to remain unresolved
- Bright enough to be observed quickly
- Astrometric Stability
  - Large starspots
  - Binaries
  - Ground knowledge

At first, two populations seem to fit these requirements

- Close (60 pc) G dwarfs
- Farther (1kpc) K giants

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SIM Grid Candidate Populations

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G dwarfs

- 9th magnitude @ 60 pc
  - 1000 - 1500 stars
  - Starspots not an issue
  - Need radial velocity measurements of 1 (10) m/s to detect Jupiter (Neptune) at 2 AU.
- 12th magnitude
  - enough for full grid
  - could measure 4-40 m/s radial velocity, but larger distance means Neptunes stop being an issue.
  - Would need close proxy sample to understand contamination fraction

K giants

- 12th magnitude reaches 5 kpc (but 1kpc is more representative)
  - enough stars for the whole grid
  - More massive stars & larger distance means there is less sensitivity to wobble from planet-sized companions.
  - Conversely, since these stars are farther away, it is more difficult to measure for close stellar companions with prior ground-based measurements, so ground-work is harder
  - More surface convection
  - More likely to have large starspots, but distance means less problem from them
  - Need close proxy sample to study populations

The Road Ahead

- Observational programs are currently operating to identify K giant Grid candidates in both hemispheres
- Simulation using detailed instrument models
  - Observations Scenarios
  - Effects of Instrument design decisions
  - Grid contamination effects