Space Interferometry Mission

An Introduction

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What is SIM ?

SIM is NASA's first space-based long-baseline interferometer designed for precision astrometry. SIM will extend the reach of precision astrometry to cover the entire Galaxy, and will address a diverse set of topics in stellar astrophysics and Galactic astronomy, and will be an extraordinary tool for discovering planets. The principal science topics for SIM include:

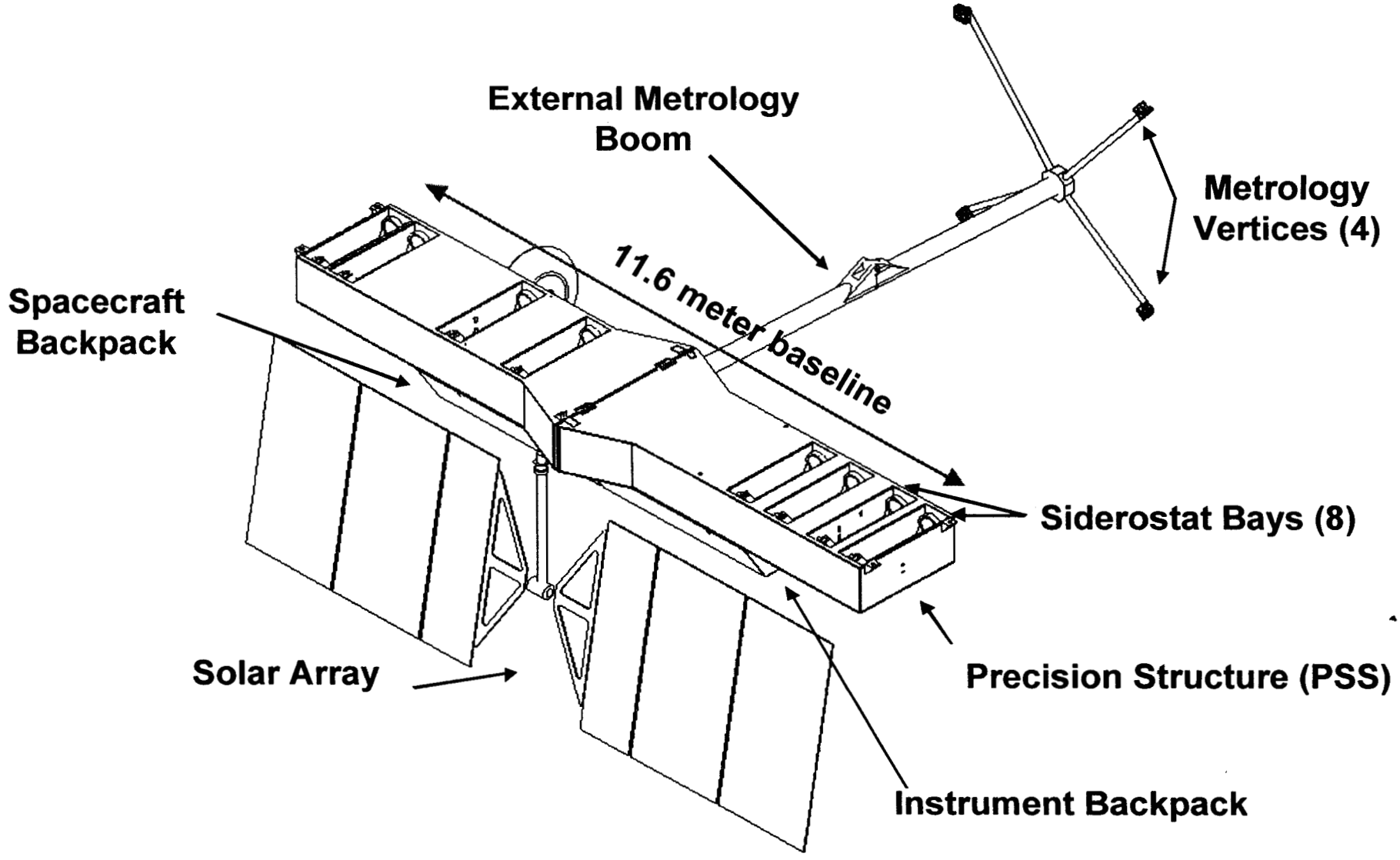
- Astrometric search for planets with masses as small as a few Earth masses around the nearest stars
- Characterization of planetary systems: mass distribution; planet frequency; multi-planet systems
- Ages of globular clusters
- Calibration of the cosmic distance scale using Cepheids and other indicators
- Stellar Dynamics of the Galaxy
- Accurate masses for sub-stellar companions
- Orbits of globular clusters an satellite galaxies
- Dynamics and evolution of binary stars
- Astrophysics of luminous stars
- Rotational parallaxes to spiral galaxies
- Dynamics of the local universe

The mission is currently in Formulation Phase ('Phase A/B'). Implementation Phase will start in 2002, with launch expected in mid-2006. In October 1999, the Project selected one of two major architectures under consideration for the SIM design. JPL is now busy developing this design in more detail, in partnership with TRW and Lockheed Martin.

The SIM Instrument

SIM comprises three Michelson interferometers on a 10-m structure. Collectors at each end of the structure contain afocal telescopes which compress the input beam from a diameter of 0.3 m. Two telescope pairs observe bright guide stars, to stabilize the optical system, and a third pair observes the science target. The instrument will be launched into an Earth-trailing solar orbit (like SIRTF).

The CCD camera on SIM is designed to detect the exact position of the white-light envelope of the interference fringes between the two 33-cm entrance apertures. A laser metrology system measures the **internal delay** - the optical path difference (OPD) between the two arms of the instrument. This internal delay, measured repeatedly over the 5-year mission, allows us to calculate the 5 basic astrometric parameters of each target star: Position (RA and dec); proper motion (in RA and dec); and parallax.


External Metrology Boom
Metrology Vertices (4)
11.6 meter baseline
Spacecraft Backpack
Siderostat Bays (8)
Solar Array
Precision Structure (PSS)
Instrument Backpack

SIM Observing Modes

Global astrometry

SIM will achieve an accuracy of **4 microarcseconds** in absolute position for stars as faint as 20 magnitude. It will set up and maintain an **astrometric grid** (*see below*) of approximately 3000 stars down to about 12 mag, as a reference system for astrometry of science targets.

Narrow-angle (local) Astrometry

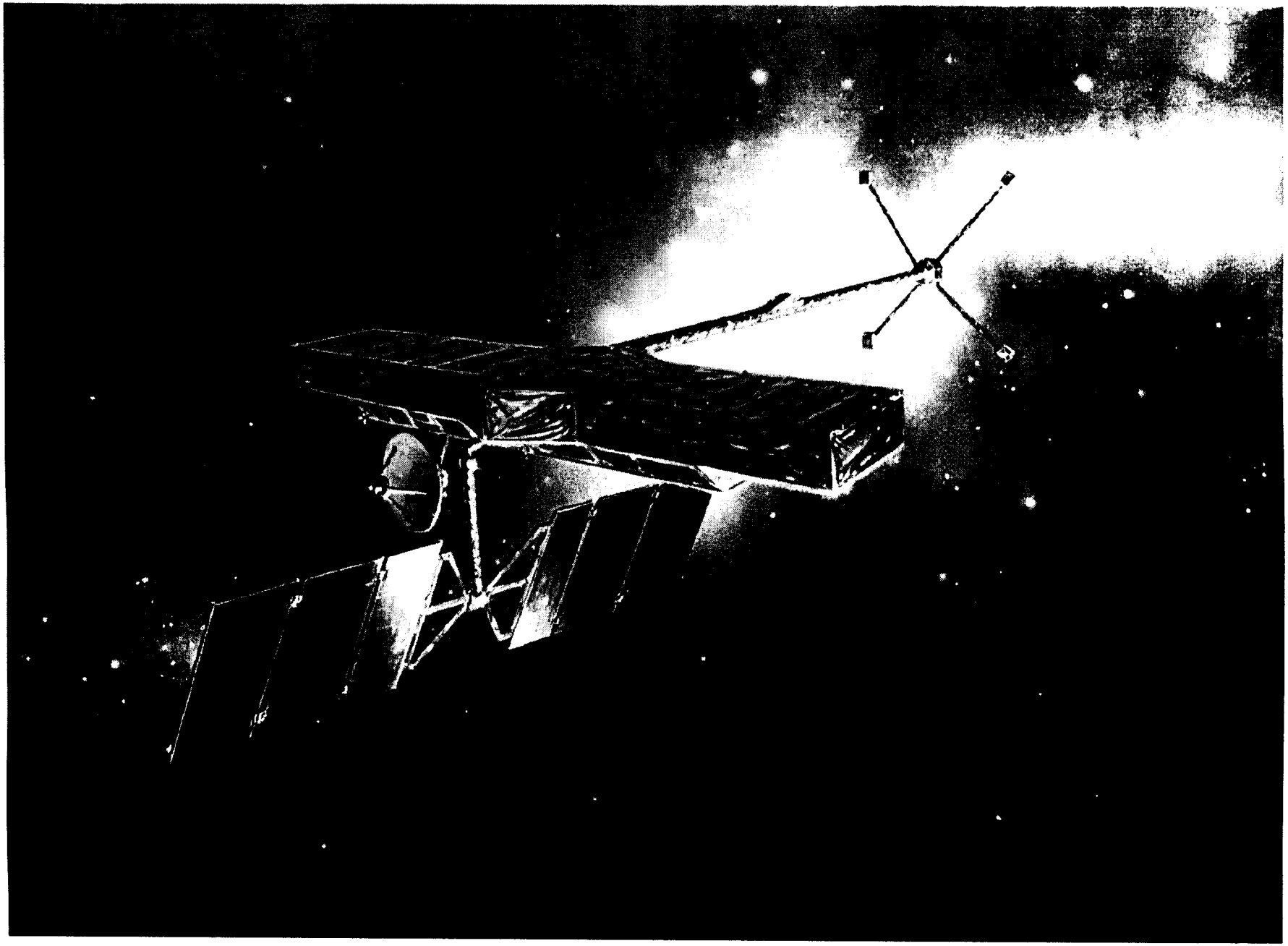
In this more, the instrument measures relative positions between the target star and several reference stars within a radius of 0.5 deg. These nearby stars define a local reference in which the SIM accuracy will be **1 microarcsecond** in a 1-hour observation, cycling between target and references stars.

Synthesis Imaging

SIM operates as an aperture synthesis imager, provide a fully diffraction-limited aperture of 10m in the optical band. The mission is required to demonstrate this capability for future imaging missions, such as the *Terrestrial Planet Finder* (TPF). By rotating the instrument, the (u,v) coverage will allow SIM to make **10-milliarcsec resolution** images of relatively complicated targets, with high dynamic range. An example of an imaging target for SIM could be a nearby active galactic nucleus with strong H-α line emission near its center. By imaging the line-emitting gas, SIM will measure the mass distribution in the nucleus.

Nulling

This capability is a technology demonstration for a the *Terrestrial Planet Finder* . In nulling mode, the light paths through the instrument are adjusted to place a dark fringe (or 'null') on the detector. This cancels most of the light from the bright central star, allowing off-axis light from a planet close to the star to be detected. SIM will be required to demonstrate on-axis suppression on a bright star, to a level of **1 part in 10^4**.



Artist's impression of SIM in Earth-trailing solar orbit

Performance Summary

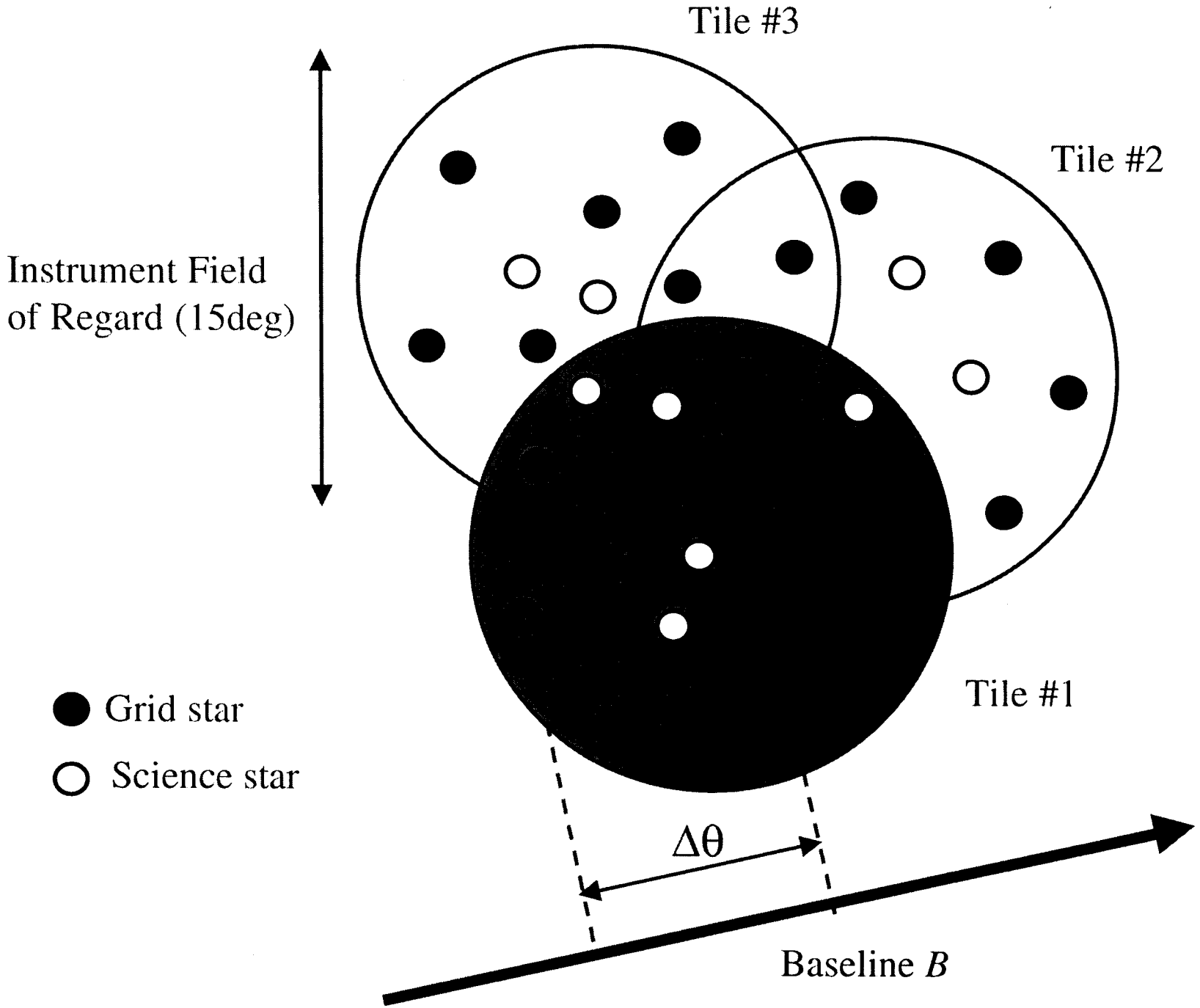
Wide Angle astrometric accuracy (1-D, 1-σ)	4 μas (end of 5-yr mission)
Narrow Angle astrometric accuracy (1-D, 1-σ)	1 μas (in 1 hour)
Instrument Field of Regard	15 deg
Instrument throughput (photon noise contribution to single 1-D measurement, 1-σ)	7.3 μas in 50 minutes
Synthesis Imaging resolution	10 mas (at 0.7 μm)
Aperture plane (u,v) coverage, evenly distributed	400 points
Nulling depth (on-axis suppression)	10^{-4}

SIM Astrometric Grid

SIM global astrometry requires an all-sky reference grid, to which positions of target objects are referenced. SIM observes and maintains this grid by observing a set of overlapping 'tiles', akin to a plate survey. The major parameters of the grid are:

Number of reference stars	3000
Mean star magnitude	$V < 12$
Accuracy of star positions	4 microarcsec RMS in RA and dec at end of 5 year mission
Estimated number of quasars	50 (tie to inertial frame)
Average number of stars per tile	12
Average number of (1-D) visits	112 (per star)
Sky coverage	All sky

Assembling a catalog with these characteristics will be a major challenge. See the **SIM posters in Session 46** for details of the astrophysical approaches currently under consideration. The hardest requirement is the elimination of perturbations due to binary companions; 4 microarcseconds requires eliminating not only stellar companions, but also sub-stellar companions below the brown-dwarf mass range.


Tile #3
Tile #2
Instrument Field
of Regard (15deg)
Grid star
Science star
Tile #1
Δθ
Baseline B

Research Opportunities with SIM

Announcement of Opportunity (AO) for the SIM Science Team

NASA expects to release in February 2000 an AO for participate in the SIM Science Team. A draft is available on the SIM web site, or at the **SIM Display (Grand Hall).** The Science team will comprise the leaders of Key Projects, which are expected to use about 50% of the available SIM observing time, and individual scientists with a strong commitment to working with the SIM Project on the development of the instrument and data analysis tools.

SIM Grid Star Workshop

A Grid Star Workshop will be held in Pasadena, January 20-21, 2000. Late registration for this workshop is still possible - please ask at the SIM Display (Grand Hall). The Workshop is focused on the problem of selection of reference stars for the SIM astrometric grid (see above). More details can also be found on the SIM web site :

`http://sim.jpl.nasa.gov/grid_workshop/`

SIM Preparatory Science Program

Awards are expected to be announced in January from the second year of the Preparatory Science Program (a NASA Research Announcement). This NRA is focused primarily on selection of stars for the SIM astrometric grid. NASA expects to issue a NRA for a third year, in late 2000.

Michelson Interferometry Summer School

A third Michelson Summer School on Interferometry will be held in Berkeley, California, August 21-25, 2000. Details will be available on the SIM web site. As in previous years, students and researchers new to the field will attain a solid base in the principles and applications of optical and infrared interferometry. Materials from the second Summer School are available at:

`http://sim.jpl.nasa.gov/michelson/viewgraphs.html`

Michelson Fellowship Program

Fellowships are offered annually to young researchers with the goal of developing expertise in optical interferometry and its astrophysical applications. Graduate student fellowships support students at US universities and research institutions for three years. Postdoctoral Fellowships are awarded normally for two years with an extension to three years. Application details are available on the SIM web site.

Visit the SIM Display in the Grand Hall

- Pick up a copy of the book "Space Interferometry Mission - Taking the Measure of the Universe" is available which describes the science, the instrument, and the mission.

- View a preprint copy of *"Working on the Fringe"*, an International Conference on Optical/IR Interferometry (Dana Point, May 1999). The book will be published by the Astronomical Society of the Pacific (display in Grand Hall).

- Sign up (on the web site) for the **S I M N e w s l e t t e r** distributed by e-mail about every 2 months.

- Or visit the SIM web site: **`http://sim.jpl.nasa.gov/`**

Poster Session 46
Space Interferometry Mission

46.01 Astrometric Modeling for the Space Interferometry Mission
S. G. Turyshev, M. H. Milman (Jet Propulsion Laboratory)

46.02 An Introduction to Astrometry with the Space Interferometry Mission
S. C. Unwin (Jet Propulsion Laboratory, California Institute of Technology)

46.03 The Grid Giant Star Survey for the SIM Astrometric Grid
R.J. Patterson, S.R. Majewski, A. Kundu (UVa), W.E. Kunkel (LCO), K.V.Johnston (Wesleyan U.), D.P. Geisler, W. Gieren, R. Muñoz (U.Concepciòn)

46.04 Selection of Stars for the SIM Astrometric Grid
B.D. Mason, A.R. Hajian, S.E. Urban (U.S. Naval Observatory)

46.05 Toward a Microarcsecond Extragalactic Frame Tie for SIM: HST Positions and Motions of Possible Grid Stars
A.A. Polak, E.P. Bozyan, P.D. Hemenway (University of Rhode Island), HST Astrometry Science Team

46.06 Selecting Reference Grid Stars for SIM: Some Practicalities
R.A. Wade (Penn State U.)

46.07 Surveying the SIM Grid Stars for Duplicity

S. Urban, B. Mason (USNO), E. Horch (RIT), E. Holdenried, T. Rafferty, W. Hartkopf (USNO), W. van Altena (Yale)

46.08 Microarcsecond Astrometry As A Probe Of Circumstellar Structure

T. Velusamy, S.G Turyshev (Jet Propulsion Laboratory (CALTECH))

46.09 Planet Detection with SIM in Narrow Angle Mode

J.H. Catanzarite (Infrared Processing and Analysis Center, California Institute of Technology), S.C. Unwin, M. Shao (Jet Propulsion Laboratory, California Institute of Technology), S. Loiseau (Observatoire de Paris - Meudon), D. Pourbaix (Universite Libre de Bruxelles), SIM Science Planning Team

46.10 Imaging with SIM: A Software SIMulator

J. Rajagopal, T. Boeker, R.J. Allen (STScI)

46.11 Imaging with SIM - Instrument errors and image quality

O. Guyon (U.Hawaii), J. Rajagopal, R.J. Allen (STScI)

46.12 The Influence of Massive Companions on the SIM Celestial Reference Frame

C. Jacobs, S. Turyshev (JPL)

Acknowledgement

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