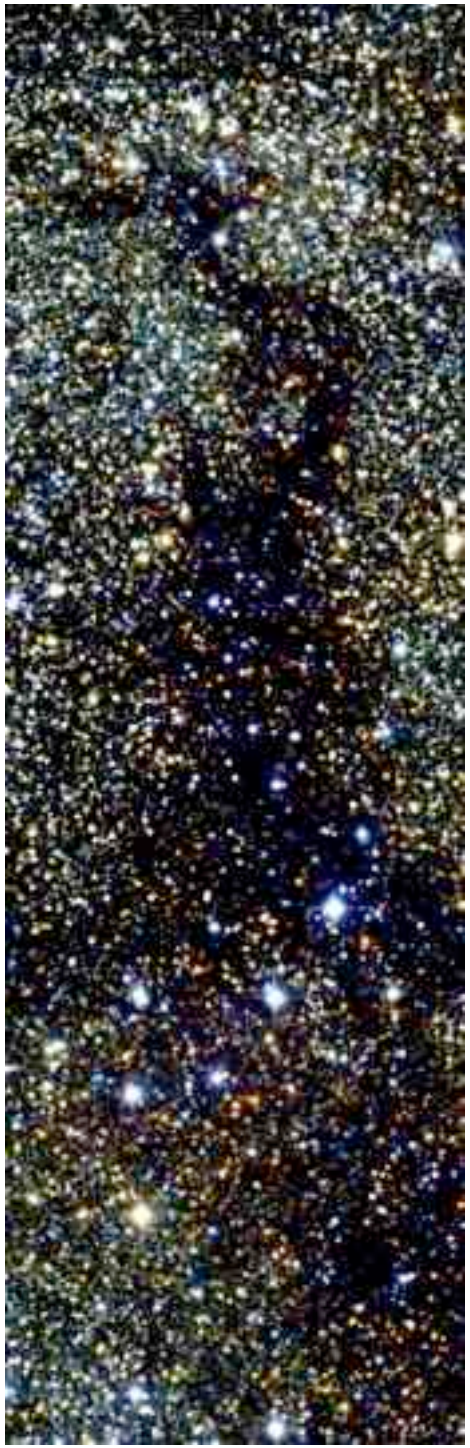


SIM Science Studies Workshop

Welcome

Steve Unwin, SIM Science Office

and

Dawn Gelino, NASA Exoplanet Science Institute

September 24 - 25, 2008

Welcome and Introduction

- Why are you here?
  - to learn about SIM Lite so you can effectively execute your SIM Science Study
- What should you expect of us?
- What do we expect of you?

Agenda - day 1

Wednesday, September 24

9:00 AM Welcome (Beichman/Unwin)
9:10 AM SIM Science Studies Construct: Why are you here?
What do we expect of you? What do you expect of us? (Unwin)
9:30 AM Project Introduction & Description (Marr/Shao)
10:00 AM How does SIM work 1?: Hardware (Goullioud)

10:40 AM Coffee Break

11:05 AM How does SIM work 2?: Operations (Unwin)
11:25 AM How does SIM work 3?: Data Analysis (Meier/Murphy)
11:45 AM How does SIM work 4?: Grid & Reference Frames (Makarov)

12:05 PM Lunch (on own)

1:40 PM Summary of Key Projects: Planets (Marcy) (Coffee & snacks available)
2:25 PM S. Gaudi (Ohio State) – Measuring the Astrometric Signature of Transiting Planets with SIM
2:40 PM M. Kaplinghat (UC Irvine) – Determining the Nature of Dark Matter Using Proper Motions of Stars in the Milky Way Satellites
3:10 PM Leave for JPL testbed tour
~5:15 PM Return to Sheraton

Agenda - day 2

Thursday, September 25

9:00 AM Summary of Key Projects: Stellar Astrophysics (Boden)

9:45 AM J. Holberg (U of Arizona) – A Novel SIM-Based Technique for the Precise Determination of Absolute Stellar Fluxes

10:00 AM A. Kraus (Caltech) – The Dynamical Legacy of Star Formation

10:15 AM S. Ridgway (NOAO) – Stellar Astrophysics with SIM and Optical Long Baseline Interferometry

10:30 AM W.-C. Jao (Georgia State U) – Parallax Observations of Local Supergiants

10:45 AM Coffee Break

11:05 AM D. Gelino (Caltech/NExScI) – Determining How the True Reflex Motions and Dynamical Orbits for Interacting Binaries Depend on Photocenter Contamination

11:20 AM J. Tomsick (UC Berkeley) – How Well Can SIM Measure Parameters of Neutron Star and Black Hole Binaries?

11:35 AM R. Peterson (UCO/Lick Obs) – NGC 6791: SIM Plans for Binaries, Colors, and Parallaxes

11:50 AM S. Dhital (Vanderbilt U) – Planets in Binary Star Systems: A Catalog of Wide, Low- mass Binaries for the SIM Science Community

12:05 PM R. Olling (U of Maryland) – 1% Luminosity-Independent Distances to Nearby Galaxies with the Rotational Parallax Technique

12:20 PM R. Olling (U of Maryland) –Searching for Solar System Giant Analogs with SIM

12:35 PM Lunch (on own)

Agenda - day 2

Thursday, September 25

2:00 PM Summary of Key Projects: Extragalactic (Shaya)

2:45 PM E. Ford (U of Florida) – Detection and Characterization of Resonant Planetary Systems with SIM

3:00 PM A. Tanner (JPL) – Detecting Terrestrial Mass Planets Around M-dwarfs: Is SIM Competitive?

3:15 PM J. Subasavage (Georgia State U) – SIM's Search for Planets Orbiting White Dwarfs

3:30 PM Coffee Break

4:00 PM M. Kuchner (GSFC) – Sizes & Shapes of Kuiper Belt Objects and Centaurs with SIM

4:15 PM G. Anglada-Escude (DTM/Carnegie) – Gaia-SIM Legacy Project

4:30 PM Concluding Remarks & Action Plan (Gelino)

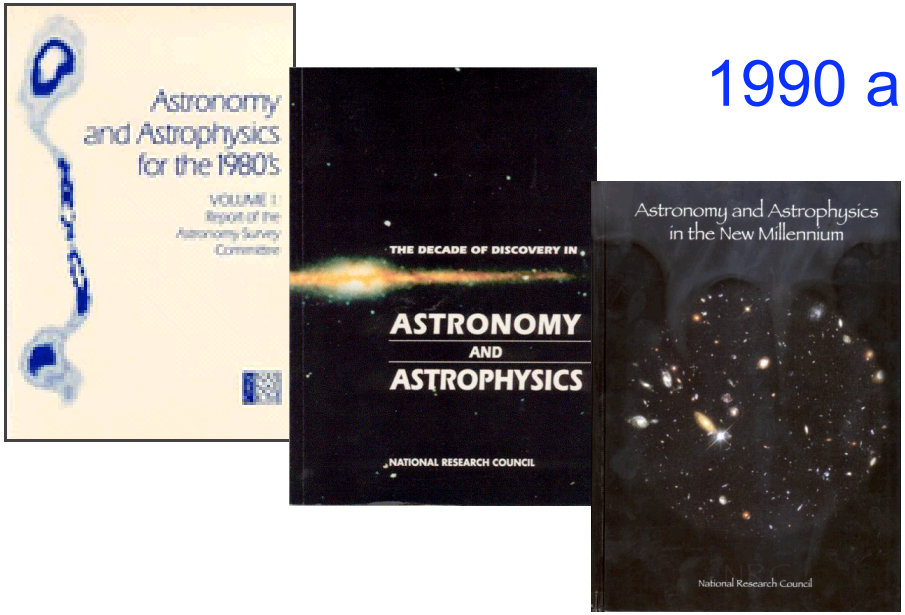
Why SIM Science Studies ?

- NASA wants the best possible science from every mission
- SIM Lite has been delayed significantly, so NASA is interested in what (scientifically) has changed since the project began
- NASA's objective for the SIM Science Studies:
  - To ensure NASA's SIM Lite investment is supported by best the possible science portfolio
  - Provide opportunity for broader science participation; developing new, innovative theoretical and observational SIM science concepts; and providing a conduit for advances in understanding to impact the SIM science program
  - Improve science community understanding for making effective use of SIM (i.e. using interferometry and astrometry and their unique characteristics compared to more traditional imaging and spectroscopic observations)
  - Enhance SIM science impact by broadening the mission's science base and community awareness

O, be some other name! What's in a name? That which we call SIM …

- SIM - the **Space Interferometry Mission** has gone though many name changes
- They all share the same fundamental concept:
  - Michelson interferometry in the optical waveband
  - Precision (~microarcsecond-level) astrometry of stars
- First mention is "**Space based optical interferometer**" in "Astronomy and Astrophysics for the 1980's", George Field – Chair (1982)
- **Astrometric Interferometer Mission (AIM)** in "The Decade of Discovery in Astronomy and Astrophysics", John Bahcall – Chair (1991)
- JPL studied the **Orbiting Stellar Interferometer (OSI)** starting in 1991
- OSI was renamed **Space Interferometry Mission (SIM)** and entered NASA pre-phase-A in 1996
- **SIM** endorsed by "Astronomy and Astrophysics in the New Millennium, C. McKee and J. Taylor" – Co-chairs (2001)
- **PlanetQuest** added to the SIM name in Nov 2004, to emphasize the significance of its ability to detect terrestrial planets
- **SIM PlanetQuest** is now **SIM Lite** (2008)

Recommended by the National Academy of Sciences



1990 and 2000 NRC Decadal Reviews

"…emphasized the *dual capability* of SIM, noting that this capability would enable "…both… detecting planets and … mapping the structure of the Milky Way and other nearby galaxies."

Worlds Beyond: Report of the ExoPlanet Task Force

Astronomy and Astrophysics Advisory Committee

1 Executive summary

This is a 15 year strategy for the detection and characterization of extrasolar planets ("exoplanets") and planetary systems, requested by NASA and the NSF to the Astronomy and Astrophysics Advisory Committee. The charge to the Task Force is given in the Appendix. The strategy is an outgrowth of the efforts underway for two decades to detect and characterize extrasolar planets–in which over 260 planets and dozens of multiple planet systems have been found and studied. It is informed by a variety of technological studies within the astronomical community, industry, NASA centers and NSF-funded facilities that point the way toward techniques and approaches for detection and characterization of Earth-sized (0.5–2 times Earth's radius) and Earth-mass (0.1–10 times the mass of the Earth) planets in the solar neighborhood. The raw material for the strategy was provided in the form of invited briefings and 85 white papers received from the community.

The strategy is intended to address the following questions, given in priority order:

1. **What are the physical characteristics of planets in the habitable zones around bright, nearby stars?**
2. **What is the architecture of planetary systems?**
3. **When, how and in what environments are planets formed?**

Astrometric planet search endorsed by the Exoplanet Task Force (AAAC 2008)

"The only technique appropriate to survey the nearest hundred or so bright sun-like stars in the mid-term is space-based astrometry, and this is one cornerstone of the Task Force recommendations."

SIM PlanetQuest is now *SIM Lite*

- Effort in the past year to find a capable lower-cost precision astrometry mission resulted in *SIM Lite*
- Complexity, mass, and cost are reduced compared to SIM PlanetQuest
  - Among other things, the baseline is reduced to 6m, but the collector diameter increased to 50cm
- Science Team's evaluation of science impact:
  - For planet searching, accuracy will be tailored to each target (according to star distance) by increasing the integration time per visit to a star
    - Systematic noise floor is very low
  - For faint astrophysics targets, in photon-limited regime, larger collecting area mostly compensates for shorter baseline
    - Where necessary, re-balance target list, to use fewer targets, or accept less accuracy
    - Re-optimization depends on the details of each specific study

SIM Lite science is SIM science

- *SIM Lite* science has received endorsement from numerous community peer review committees
- It accomplishes the *same* broad-ranging science objectives that have been evaluated and endorsed by independent committees:
  - Greatly exceeds the objectives of the *1990 (Bahcall) Decadal Survey*
  - Exceeds the objectives of the *2000 (McKee/Taylor) Decadal Survey*
  - Meets the objectives for extrasolar planet detection laid out by the *2008 (Lunine) Exoplanet Task Force*

The SIM Lite Science Team: 1991-2008

- SISWG - Space Interferometry Science Working Group (Steve Ridgway, Chair)
  - Advised NASA on space interferometry 1991-1995 (POINTS - OSI downselect)
- SIMSWG - Science Working Group (Deane Peterson, Chair)
  - Advised NASA on space interferometry 1996-1999
- SIM project science office at JPL
  - In place since 1996 when SIM formally selected by NASA for pre-phase A study, led by JPL
- **SIM Science Team** (formal selection)
  - Competitively selected via NASA Announcement of Opportunity in 2000
  - 10 Key Projects
  - 5 Mission Scientists (selected for specific expertise of value to SIM)
- SIM Science Studies
  - 19 studies, selected in 2008

SIM Science Team

Key Science Projects

Dr. Geoffrey Marcy	U. California, Berkeley	Planetary Systems
Dr. Michael Shao	NASA/JPL	Extrasolar Planets
Dr. Charles Beichman	MSC/Caltech	Young Planetary Systems and Stars
Dr. Andrew Gould	Ohio State University	Astrometric Micro-Lensing
Dr. Edward Shaya	Univ. of Maryland	Dynamic Observations of Galaxies
Dr. Kenneth Johnston	U.S. Naval Observatory	Reference Frame-Tie Objects
Dr. Brian Chaboyer	Dartmouth College	Population II Distances & Globular Clusters Ages
Dr. Todd Henry	Georgia State University	Stellar Mass-Luminosity Relation
Dr. Steven Majewski	University of Virginia	Measuring the Milky Way
Dr. Ann Wehrle	Space Science Institute	Active Galactic Nuclei

Mission Scientists

Dr. Guy Worthey	Washington State University	Education & Public Outreach Scientist
Dr. Andreas Quirrenbach	Leiden University	Data Scientist
Dr. Stuart Shaklan	NASA/JPL	Instrument Scientist
Dr. Shrinivas Kulkarni	MSC/Caltech	Interdisciplinary Scientist
Dr. Ronald Allen	Space Telescope Science Inst.	Synthesis Imaging Scientist

Only Principal Investigators listed. Including co-investigators the SIM Science Team has 86 members.

What should you expect of us?

- The SIM Project and members of the Science Team are here for 2 days to answer your questions about SIM Lite
- We will provide summaries of the Science Team's 15 Key Projects
- You will hear about most of the 19 selected Science Studies
- You will hear about the development of the instrument so far, and (briefly) the testbeds and the technology program
  - More information can be obtained on the SIM testbed tour at JPL later today
- You will learn how SIM Lite makes measurements, and how the data are analyzed
- You will learn how to plan and design a SIM Lite experiment
  - Suitable target selection criteria, observing cadence, reference stars, integration times, chopping, integration with other targets, etc.

- Please, ask as many questions as you like, about SIM Lite, and we'll try to answer them!

What do we expect of you? Participation

- You will be a member of the broader SIM Lite Science Team:
  - SIM Science Team - 15 members
  - SIM Project Science Office - Shao, Unwin, Edberg, Pan, Catanzarite, plus fractions of several others
  - SIM Science Studies PIs - 18 members, plus co-Is
- Your help is actively needed to communicate the importance of SIM Lite to the astronomical community
  - NASA has made a very significant investment in SIM Lite and its technology
  - This investment can be fulfilled and the science promise realized - *but only if the mission goes ahead*
  - SIM Lite is under review - both internally by NASA, and by the upcoming Decadal Survey
- Your job is to explore the opportunities for new science discoveries that SIM Lite offers
- Your job is *also* to tell your colleagues about the scientific importance of this mission
  - Refereed papers
  - Presentations at conferences and workshops
    - We can provide useful materials to help you - performance estimators, design memos, template viewgraphs etc.

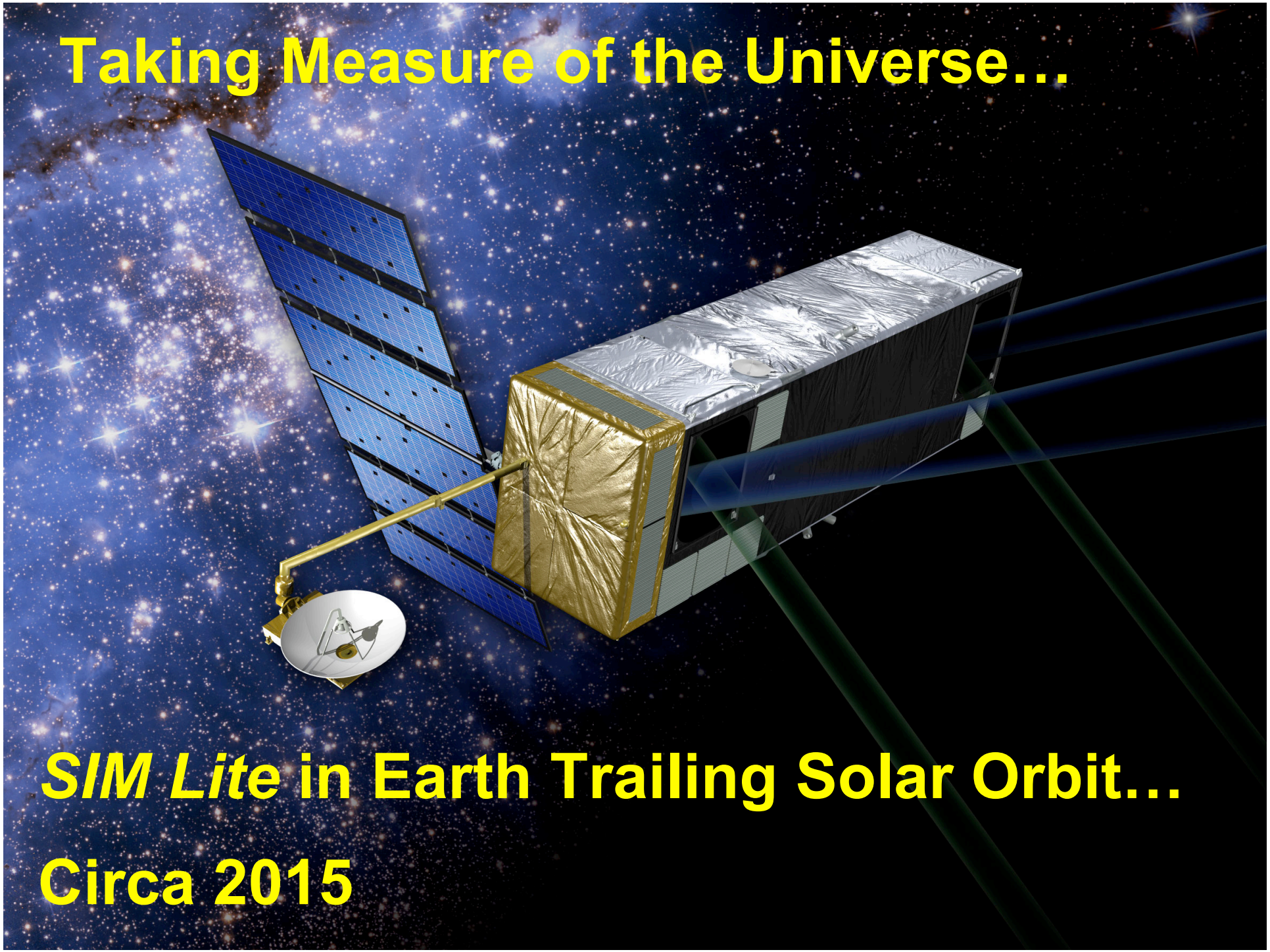
What do we expect of you? Papers and talks

- **AAS 213th Meeting in Long Beach, CA - January 4-9, 2009**
  - We expect *every* SIM Science Study to present a poster or a 10-minute talk on your Study plans and any results to date
  - Deadline for abstracts is Wednesday, 1 October 2008, 9:00 pm PST
  - We will coordinate with the AAS to group the posters (and talks) into a dedicated session:
    - 34. Instrumentation: Space Missions
    - Comment field: "SIM Science Studies"
  - Please be sure to copy Stephen Unwin Stephen.Unwin@jpl.nasa.gov and Dawn Gelino dawn@ipac.caltech.edu on your submission so we can look out for your abstract

- **AAS 214th Meeting in Pasadena, CA - June 7-11, 2009**
  - We expect *every* SIM Science Study to present a paper at this conference
  - This paper will be considered the major part of your *Final Report*
  - We will arrange for a dedicated session on SIM Lite at this meeting
    - Most likely a one full day 'Meeting-in-a-Meeting'

- **Refereed papers**
  - You should plan on writing up your SIM Science Study final report for a refereed journal
  - This is good for you - publication is always good
  - This is good for SIM Lite - wider community learns about science opportunities
  - Remember, your Final Report will be placed on the NExScI website

Taking Measure of the Universe…



SIM Lite in Earth Trailing Solar Orbit…

Circa 2015

End

What's in a name?

From Shakespeare's *Romeo and Juliet*, 1594:

JULIET

O Romeo, Romeo! Wherefore art thou Romeo
Deny thy father and refuse thy name;
Or, if thou wilt not, be but sworn my love,
And I'll no longer be a Capulet.

ROMEO.

[Aside.] Shall I hear more, or shall I speak at this?

JULIET:

'Tis but thy name that is my enemy;
Thou art thyself, though not a Montague.
What's Montague? It is nor hand, nor foot,
Nor arm, nor face, nor any other part
Belonging to a man. O, be some other name!
What's in a name? That which we call a rose
By any other name would smell as sweet;
So Romeo would, were he not Romeo call'd,
Retain that dear perfection which he owes
Without that title. Romeo, doff thy name,
And for that name which is no part of thee
Take all myself.

SIM Meets National Academy Performance Goals

Report Name	Wide-Angle Astrometry (end of mission)		Narrow-Angle Astrometry (single measurement)				
	Requirement	Goal	Requirement	Goal	Magnitude Limit (V)	Nulling	Rotational Synthesis Imaging
1982 Decadal Survey	Space Optical Interferometer (SOI) with resolutions of 1 to 10 μas by early part of next century						
1991 Decadal Survey ('AIM')	30 μas	3 μas	not specified	not specified	20	No	No
2001 Decadal Survey ('SIM')	10 μas	4 μas	3 μas	1 μas	20	Yes	Full uv-plane from 1m to 10m
2002 CAA Letter Assessment of SIM	10 μas	4 μas	3 μas	1 μas	20	No	10m baseline
SIM-PQ Performance	2.4 μas *		0.7 μas *		20	No	9m and 6m baselines
Planet Hunter	none		1 μas *		10	No	6m baseline
SIM-Lite	**4 μas ***		**1 μas ***		**19-20**	**No**	**6 m baseline**

* Performance is Current Best Estimate (CBE) prediction, without margin, based upon SIM's completed technology development program and mature flight design