Extrasolar Planet Inferometric Survey (EPIcS)

Principal Investigator: Michael Shao (JPL)

Team Members:
Sallie Baliunas (Harvard-Smithsonian CfA), Andrew Boden (JPL), Shrinivas Kulkarni (Caltech), Douglas N. C. Lin (UCSC), Tom Loredo (Cornell Univ), Didier Queloz (Observ de Geneve), Stuart Shaklan (JPL), Scott Tremaine (Princeton Univ Obs), Alexander Wolszczan (Penn State)

The discovery of the nature of the solar system was a crowning achievement of Renaissance science. The quest to evaluate the properties of extrasolar planetary systems is central to both the intellectual understanding of our origins and the cultural understanding of humanity's place in the Universe; thus it is appropriate that the goals and objectives of NASA's breakthrough Origins program emphasize the study of planetary systems, with a focus on the search for habitable planets. We propose an ambitious research program that will use SIM—the first major mission of the Origins program—to explore planetary systems in our Galactic neighborhood. Our program is a novel two-tiered SIM survey of nearby stars that exploits the capabilities of SIM to achieve two scientific objectives: (i) to identify Earth-like planets in habitable regions around nearby Sun-like stars; and (ii) to explore the nature and evolution of planetary systems in their full variety. The first of these objectives was recently recommended by the Astronomy and Astrophysics Survey Committee (the McKee-Taylor Committee) as a prerequisite for the development of the Terrestrial Planet Finder mission later in the decade. Our program combines this two-part survey with preparatory and contemporaneous research designed to maximize the scientific return from the limited and thus precious observing resources of SIM.

Our first objective demands measurements with the highest possible astrometric accuracy ($\sim 1\ \mu$as) and thus requires long observing times for each target. Thus a survey addressing only this objective should focus on relatively few (~ 75) nearby stars. In contrast, our second, broader objective is best accomplished with reduced astrometric accuracy ($\sim 4\ \mu$as) and shorter integration times, allowing us to survey thousands of stars of many different types throughout a larger volume. We have juggled SIM's operational constraints to develop an optimized hierarchical observing strategy capable of achieving both objectives in a single, coordinated survey. The survey is designed to hedge our bets in the face of the current near-total uncertainty in the frequency and diversity of planetary systems. Our strategy virtually guarantees important and exciting scientific returns regardless of whether planetary systems like our own are typical features of most stars or rare and precious ornaments.

We will use SIM for a two-tiered Extrasolar Planet Interferometric Survey (EPIc survey, or EPIcS). The *Tier 1* survey is designed primarily to address our first objective, the detection of Earth-like planets around nearby stars. The Tier 1 targets will consist of ~ 75 main-sequence (MS) stars within 10 pc of the Sun. About a third of these will be G dwarfs resembling the Sun; this sample is large enough that even the absence of terrestrial planets would be an extremely significant—if discouraging—result. The remainder of the Tier 1 targets will be inactive MS stars of other spectral types: mostly K and M, but including ~ 10 A and F stars to provide a preliminary survey of planets around young, massive stars. The *Tier 2* targets will consist of ~ 2100 stars from the following diverse classes: all MS spectral types, in particular early types; binary stars; stars with a broad range of age and metallicity; stars with dust disks; evolved stars; white dwarfs; and stars with planets discovered by radial-velocity surveys. Each class addresses specific features of the planet-formation process (are metals necessary for giant planet formation? does the number of planets decline slowly with time due to dynamical evolution? what is the relation between dust disks and planets?), and will contain >100 targets to ensure that our findings are statistically robust.

The observing strategy is crafted for maximum efficiency and accuracy. We will observe each Tier 1 target $\sim$ 70 times over the course of the mission, with each observation comprised of $\sim$ 20 1-min integrations (10 each on a science target and a reference) that will be averaged to provide astrometry with $\sim$ 1 μas accuracy. Within the 15° radius Field of Regard (FOR) associated with each Tier 1 target, we will identify $\sim$ 28 Tier 2 targets that are bright (R $<\sim$ 12), and usually within 25 pc. We will observe Tier 2 targets with single 1-min integrations, aiming for $\sim$4 μas accuracy. This "piggybacking" of Tier 2 observations on Tier 1 pointings saves pointing overhead, provides some redundancy within each FOR, and decreases the systematic errors in Tier 1 observations. We also propose a preparatory research program to maximize the scientific return from our survey, involving both target selection and the development of analysis pipelines. An important aspect of this program is the focus on identifying stable reference stars in each Tier 1 FOR, and developing analysis software that can handle the complications introduced by possible acceleration of the reference stars.

Our preparatory program includes radial velocity (RV) and adaptive optics (AO) imaging observations to help us select the best science targets and reference stars. For science targets, the main goal of these observations is to ensure that the targets do not have companion stars that would preclude the existence or detection of low-mass planets. For reference stars, the goal is to identify one or two reference stars within 1.5° of each Tier 1 target (Tier 2 targets can use more distant grid stars as references). We will study two classes of candidates: bright ($\sim$ 10 mag) MS stars in binary systems (chosen to have orbits that scour out any planets that could complicate the astrometry)and distant K giants at a distance of 1 Kpc. Because we can't rule out the possibility of planetary companions to K giants, two references are needed to unambiguously assign a planet to the target or one of the reference stars.

To maximize the return from SIM, we must analyze complex and scarce astrometric data with the highest possible reliability and efficiency. Traditional tools such as the Lomb-Scargle periodogram (LSP) and its variants must be sharpened. We have already created new methods that promise significant improvements over the LSP. A goal of our preparatory research is to have a tunable data analysis pipeline before mission start implementing a variety of methods for such tasks as delay calibration, planet detection, and estimation of orbital parameters.

Once the mission is underway, we anticipate that significant analytical and observational work will be needed to supplement the SIM observations. We will undertake important parts of this research ourselves, but also will adopt a policy of early data release to focus the attention and resources of the community on SIM and on extrasolar planets, to encourage independent analysis, to receive suggestions for revisions in our observing and sampling strategy, and to display our progress in time to justify an extended mission.