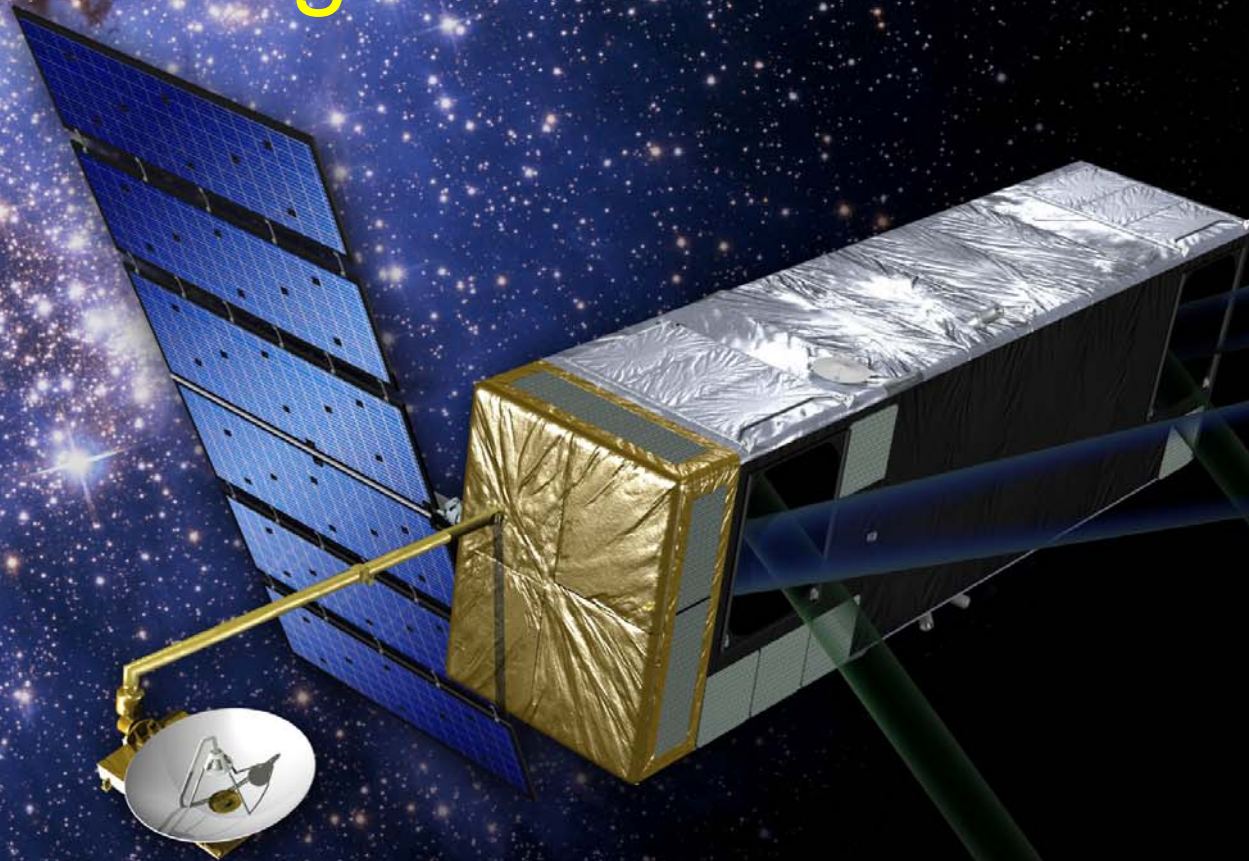


# Looking for Planets With *SIM*



C. Beichman, MSC/Caltech/JPL

With help from the SIM Science Team, incl.

M. Shao, G. Marcy, S. Unwin, A. Tanner, J. Catanzarite

# Key Science Goal for SIM: Deep and Broad Search for Planets

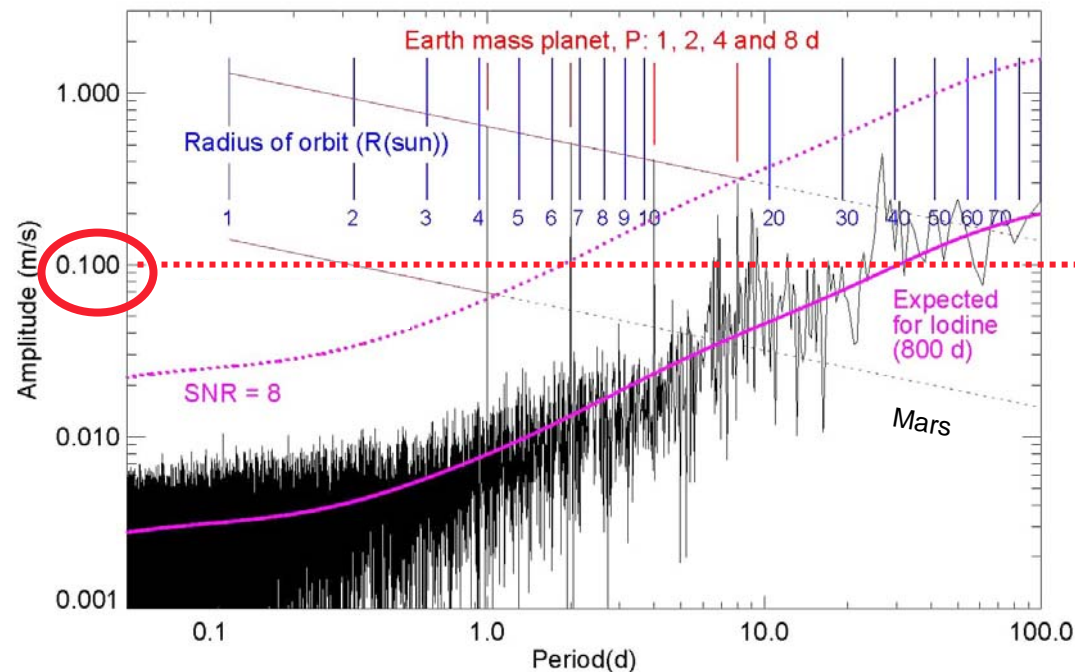
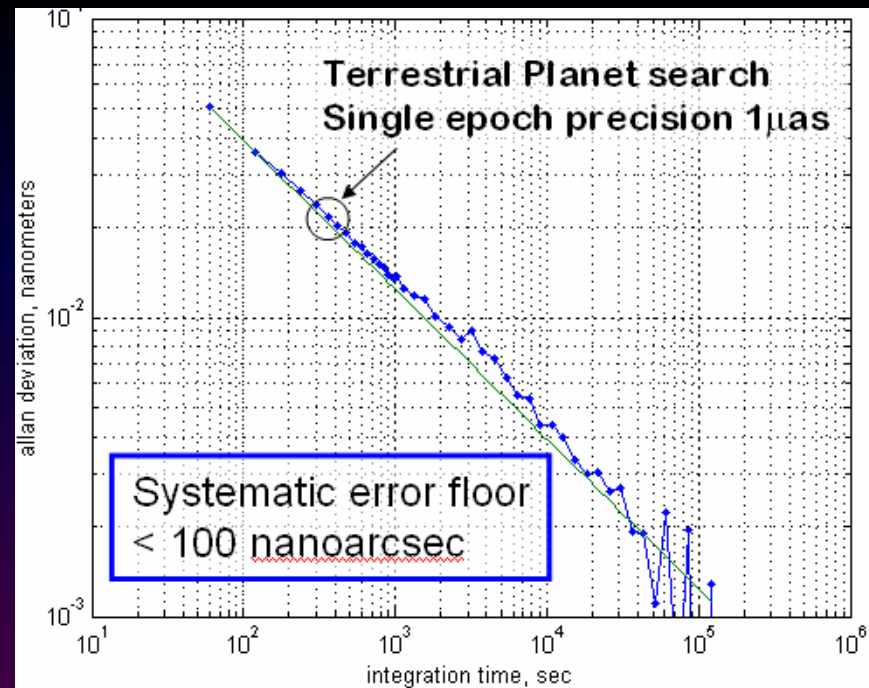
- Earth analogs in Habitable Zones of solar type stars
- Explore thousands of stars, complementing RV studies, to reveal diversity of planetary systems
  - Planets around early type stars (A, F), white dwarfs, etc.
  - Planets around young stars
- Complete characterization of RV and Transiting systems
- Determine planetary masses, inclinations, coplanarity for all systems

***SIM represents the initial step toward finding and characterizing “habitable planets” around nearest stars***



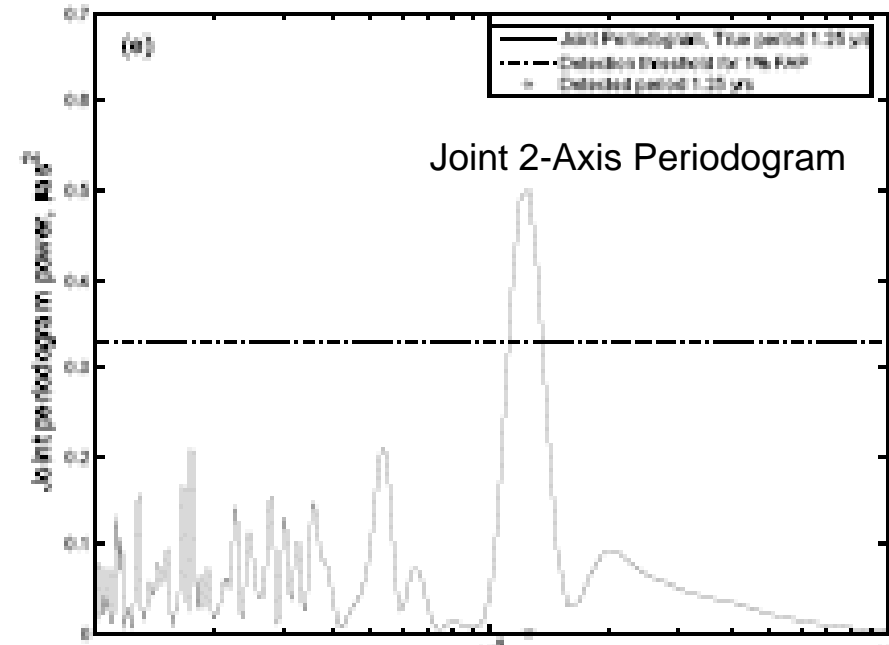
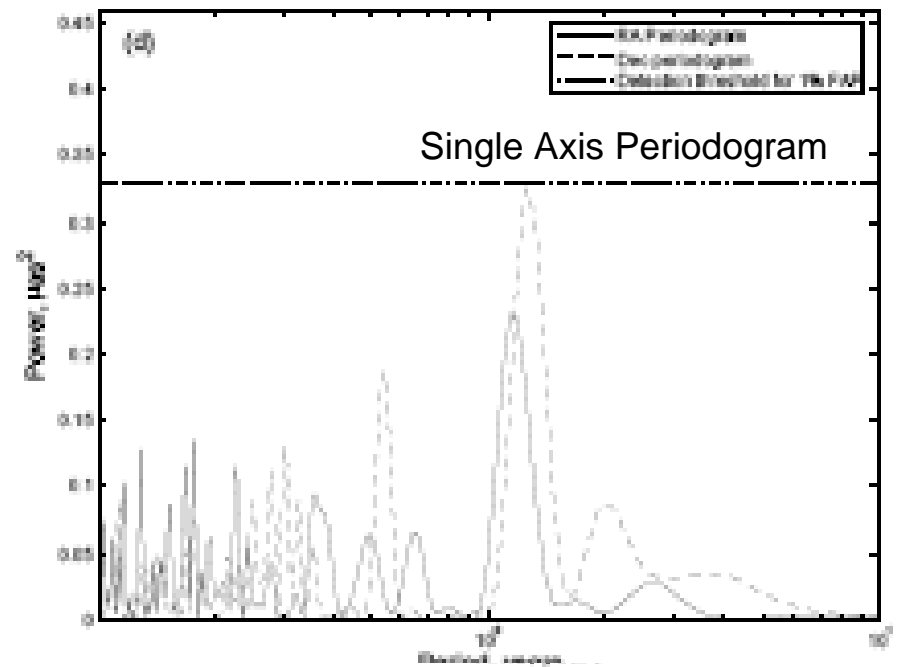
# SIM Can Find Earth Analogs

- SIM's *differential* astrometry precision ( $\leq 0.05 \mu\text{as}$ ) can find Earth Analogs ( $1-3 M_E$ ) around 65-230 stars
  - $0.3 (M_p/M_{\text{Earth}}) (a/1\text{AU}) (10\text{pc/d}) \mu\text{as}$
  - $a(\text{Habitable Zone}) = 1 (L/L_o)^{0.5} \text{AU}$
  - Noise  $\sim 1 \mu\text{as}/\sqrt{(\#\text{visits})} \rightarrow$  few 100 visits to reach SNR 5 for 1% false alarm probability
  - White light starspot jitter  $< 0.1 \mu\text{as}$  for 10 pc G star
- Line jitter of  $0.2 \text{ m/s}$   $\rightarrow$  very difficult for RV to find Earth analogs in HZ around solar type stars

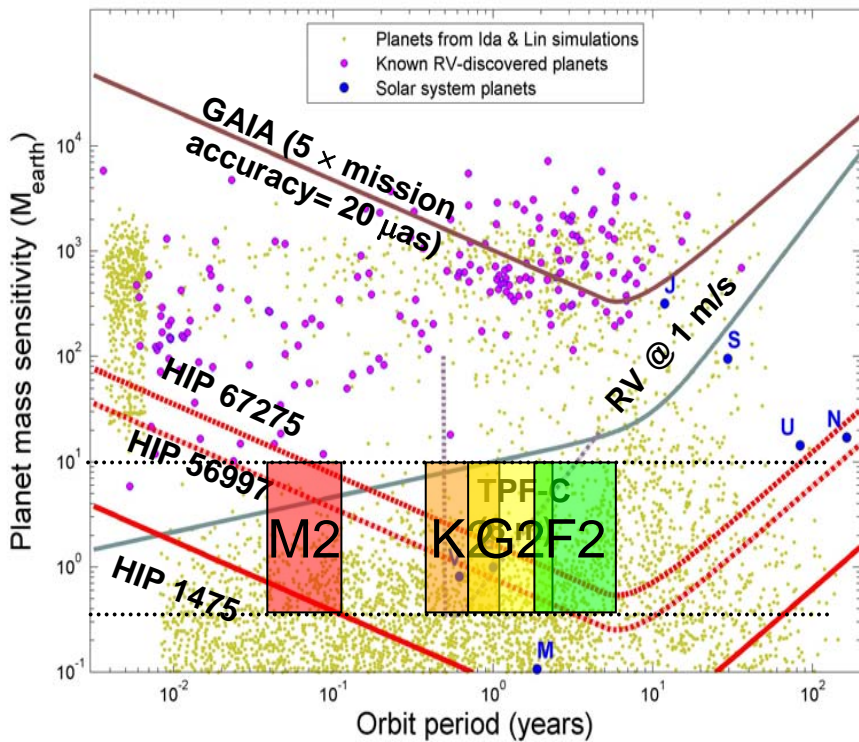


# SIM Planet Observing Technique

- Perform 200 individual observations (100x2D each at  $\sim 1 \mu\text{as}$ ) of a  $1.5 M_{\oplus}$  planet orbiting a  $1 M_{\odot}$  star at 10 pc
- After 5 years, detection at  $< 0.1 \mu\text{as}$  has false alarm probability of  $< 1\%$
- Sufficient information to detect multiple planets



## Exoplanet Discovery Space



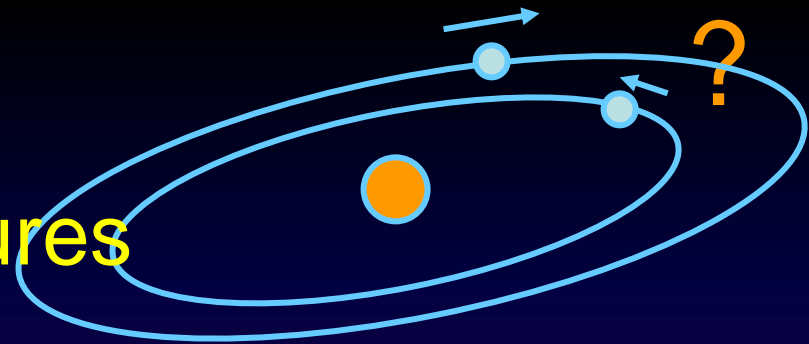
# SIM Earth Analog Survey Will Search Closest Stars

## Deep Survey for Terrestrial Planets in the Habitable Zone

Mass sensitivity at mid-habitable zone	$1 M_{\oplus}$	$2 M_{\oplus}$	$3 M_{\oplus}$
# of target stars that can be surveyed <sup>1</sup>	65	150	230

<sup>1</sup>Using 40% of SIM-Lite mission time (five years).

# Complete Understanding of Planetary System Architectures



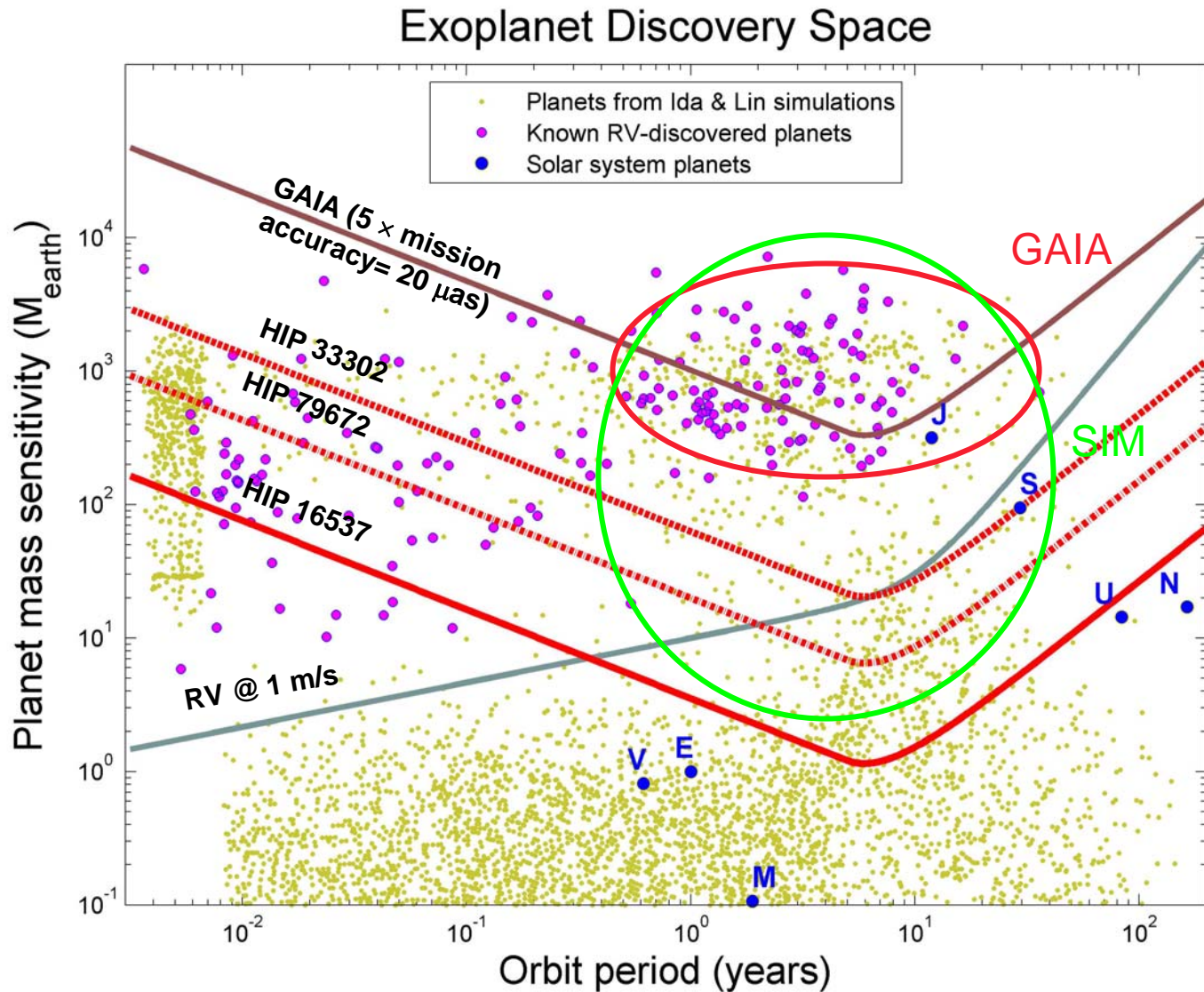
- Full orbital solutions including masses, inclination & co-planarity for all RV systems (+250) and stars with transits (ground, CoRoT, Kepler)
- Survey ~1000 stars to explore metallicity, spectral type, absence/presence of debris disks, and presence in binary systems.
  - Search to  $<10 M_E$  level (rocky/icy transition)
  - Search for planets around stars not probed by RV (star types O, B, A, early F, white dwarfs).

Mass Range	$0.3$ to $10 M_{\oplus}$	$0.1$ to $10 M_{Jup}$
# planets detected in survey of 1000 stars	50 (7%)	150 (87%)

*Based on Cumming 2007 with terrestrial planet incidence increased by x5*

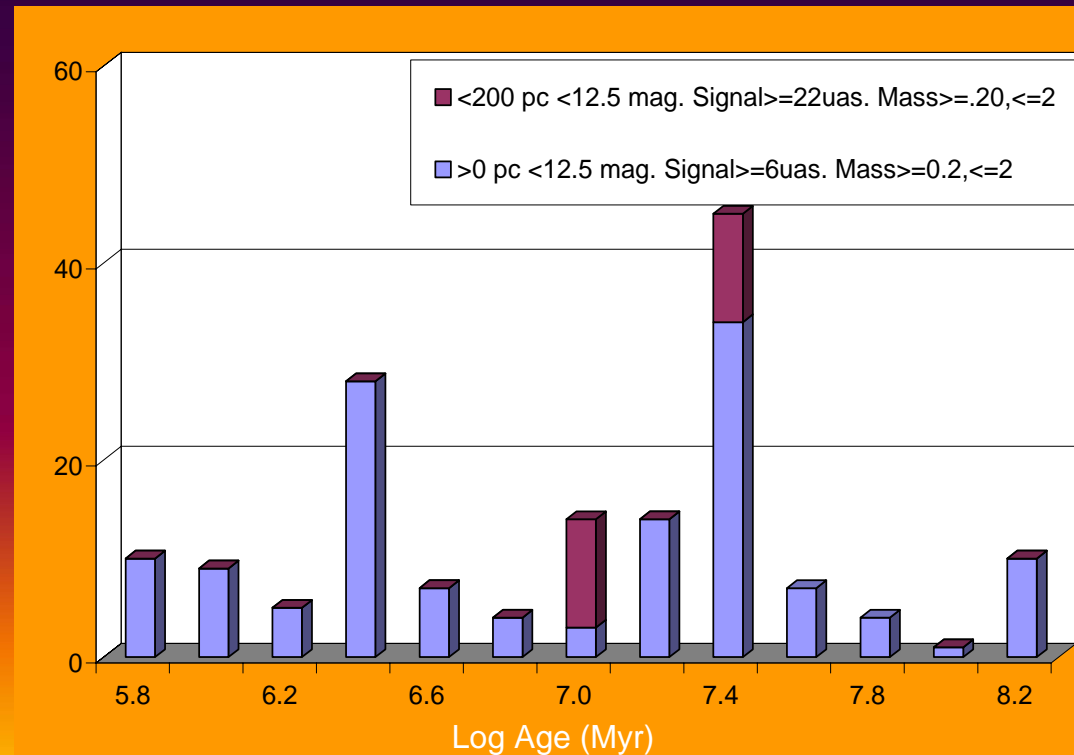


# Scope of Broad Survey



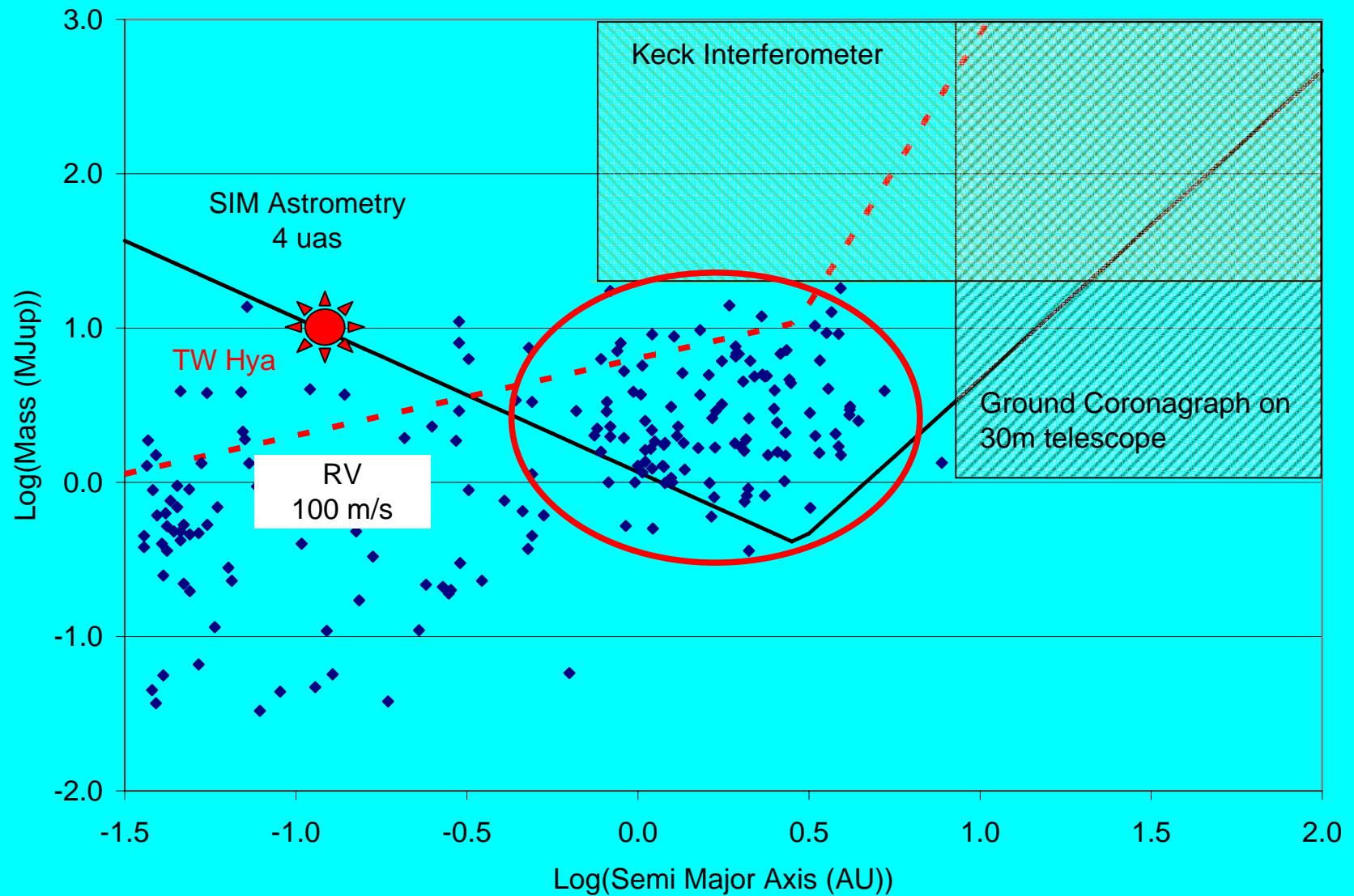
# How Do Planetary Systems Form & Evolve?

- What fraction of young stars have gas-giant planets?
- Do gas-giant planets form at the “water-condensation” line?
- Does the incidence, distribution, and orbital parameters of planets change with age and protostellar disk mass?
- How does orbital migration affect where, when, and how terrestrial planets form ?
- Only astrometry can find planets down to Saturn-Jupiter mass within 1-10 AU of parent stars at 25-150 pc
  - Line jitter and rotation at 100 m/s precludes (most) planet detection via RV
  - White light jitter of few  $\mu\text{as}$  consistent with astrometric detection of gas giants





# SIM Will Find Gas-Giants Orbiting Young Stars



# SIM(-Lite) and GAIA Planet Search Comparison

	<i>SIM Deep Survey</i>	<i>SIM Broad Survey</i>	<i>GAIA</i>
<i>Single/Mission Measurement Accuracy</i>	1 $\mu\text{as}$ / 0.1 $\mu\text{as}$ in 100 2D obs.	4 $\mu\text{as}$ / 0.4 $\mu\text{as}$ in 2D 100 obs.	70 $\mu\text{as}$ / 7 $\mu\text{as}$ in 100 obs.
<i>Target Mag Range</i>	-1 to 7 mag	-1 to 15 mag	7 to 15 mag <7 mag at <i>reduced</i> sensitivity
<i>Science Goals</i>	Survey for HZ Earth Analogs around 65-230 closest, bright stars (1-3 $M_E$ )	Survey of 1000 stars for icy/gas giants Uranus- Jupiter	All sky survey for gas giants, Saturn/Jupiter

# SIM As Part of Planet Search Program: Proven, Timely, & Synergistic

- Demonstrated sub-microarcsecond precision
  - This laboratory demonstration lies at the heart of the mission
- The SIM Project has met all Technical Milestones
- SIM has been validated by two decadal reports, and two roadmap studies, & most recently an astrometric approach to planet finding has been endorsed by ***ExoPlanet Task Force***
- SIM is ready to fly as early as 2013.
- SIM could make 2013-2023 the decade of extra-solar planets
  - SIM & COROT and Kepler
  - SIM & GAIA
  - SIM & JWST
  - SIM & TPF-C, TPF/Darwin