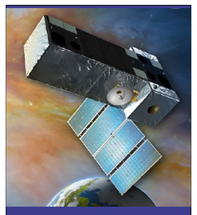
Searching for Solar System Analogs with SIM Lite



SIM Lite ASTROMETRIC OBSERVATORY

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- **Solar System Analogs, SOASAs**, have a "Jupiter" &/or "Saturn"
- To determine orbit: $P_{ORBIT} <\sim 2x\ T_{MISSION}$
- All outer planets have $P_{ORBIT} > 2x\ T_{MISSION}$

Planet	a [AU]	Period [yr]	Mass [M_{JUP}]
Jupiter	5.2	11.9	318
Saturn	9.5	29.4	95
Uranus	19.2	84.0	15
Neptune	30.1	164.0	17

- **SOSAs & Heavy SOSAs**

SOSAs: $P \in [11.9, 165]$ yr, $M \in [0.05, 1]\ M_{JUP}$

HOSAs: $P \in [11.9, 165]$ yr, $M \in [1, 13]\ M_{JUP}$

- Fraction of Plan. Systems:
  [Tabachnik & Tremaine (2002) or Cumming et al (2008)]
  - **SOSAs: 13 %**
  - **HOSAs: (17 ± 3)%**
    - **8% of Sun-like stars**

Migration Theories predict

- Inward migration (known "RV" planets)
- Outward migration (Uranus & Neptune)
  - Outer edge: 50-100 AU (350 – 1,000 yr) [Ida & Lin, 2004]
- Predict massive long-period planets
- requires massive disks

– Without migration: 30-40 AU (165-250 yr)

– MUCH, MUCH, MUCH longer than $2T_{MISSION}$

Expected values for size, velocity & acceleration

$$a_0 = 95/d_{10pc}\ (P^{+2}\ M_{TOT}^{-2})^{1/3}\ M_{C;J}\ [\mu as]$$
$$|\mu| = 600/d_{10pc}\ (P^{-1}\ M_{TOT}^{-2})^{1/3}\ M_{C;J}\ [\mu as/yr]$$
$$|d\mu/dt| = 3800/d_{10pc}\ (P^{-4}\ M_{TOT}^{-2})^{1/3}\ M_{C;J}\ [\mu as/yr^2]$$

10	$M_{JUPITER}$ @	20 pc		
Period [yr]	a_0 [μas]	|μ| [μas/yr]	|dμ/dt| [μas/yr²]	Comment
10	2,191	1,376	864.9	5 yr; Std. Orbit Fitting
20	3,478	1,093	343.2	
40	5,521	867	136.2	
80	8,763	688	54.1	
160	13,911	546	21.5	GAIA 5yr (3-σ_{acc}= 14.5 μas/yr²)
320	22,082	434	8.5	SIM 5yr (3-σ_{acc}= 7.5 μas/yr²)
640	35,053	344	3.4	
1,280	55,644	273	1.3	S+G 5yr (3-σ_{acc}= 1.5 μas/yr²)

Standard method:

Proper-motion difference between epochs

SIM vs. Hipparcos?? $3x\varepsilon_{\mu}$(HIPP) ~ 3 mas/yr ==> ☹

Next-Gen Astrometry missions:

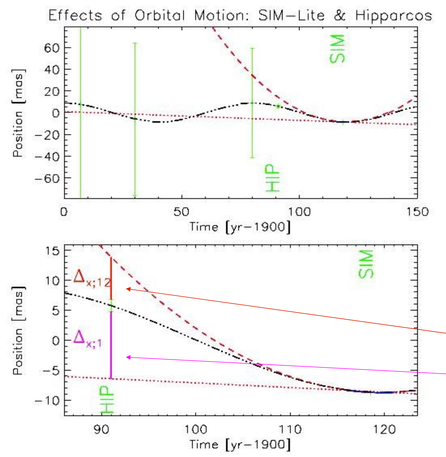
Detection of acceleration down to:

~160 yr: GAIA only

~320 yr: SIM only

~1,280 yr: GAIA + SIM data

M=10 M_{JUP}, P=80 yr, D=20 pc, a_0=8.8 mas, μ_{ORBIT}=0.69 mas/yr



Our Approach:

Extrapolate SIM astrometry to earlier (Hipparcos) epoch and compare positions [Olling, 2007]

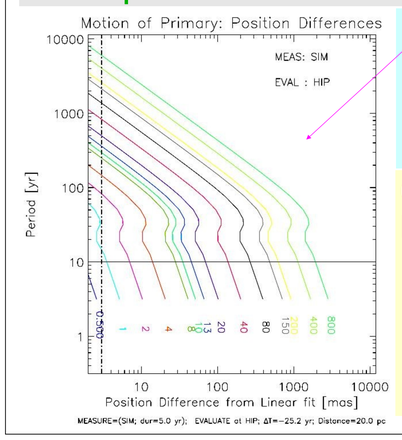
Difference between backtrapolations:

Quadratic: $\Delta_{x;12}$

Linear: $\Delta_{x;1}$

tells Period & Mass

Extrapolate SIM astrometric model to HIPPARCOS position



LINER FITS:
Position Differences are degenerate: multiple Masses & Periods at given pos.dif

QUADRATIC FITS:
Lift Degeneracy
Analytically proven (face-on, circular)
PD depends only on orbital motion:
center-of-mass motion drops out