Astrometry

Future Directions for Interferometry

Tucson

Nov. 13-15, 2006

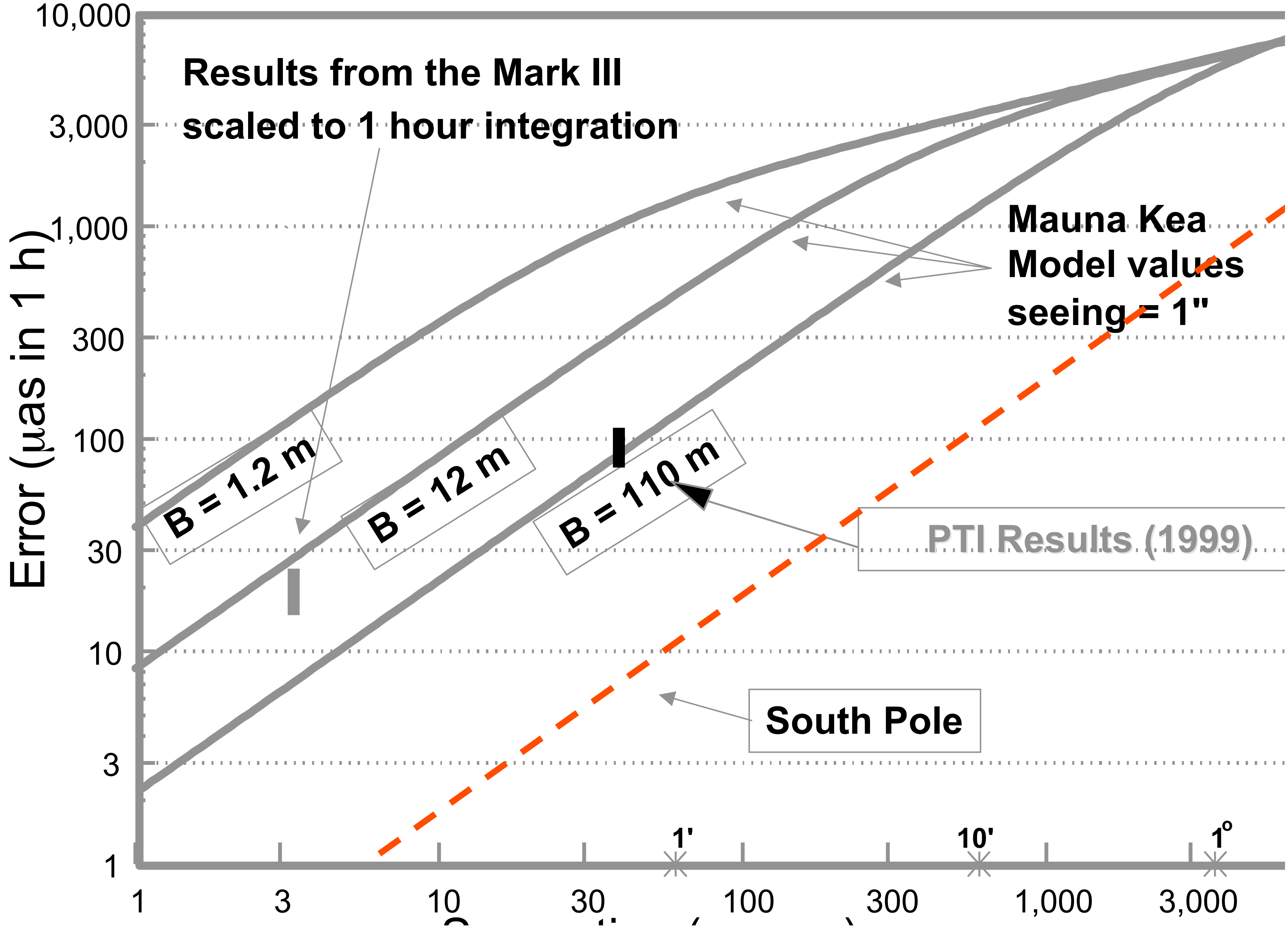
An answer in search of a Question?

- Astrometry provides unique lever on many important astrophyscal questions. Some examples:
  - Exoplanets
  - Galactic Center
  - Stellar Mass, Distance & Luminosity
- Interferometry is particularly well-suited to astrometry. In fact, it may be what interferometers do best…

Types of Astrometry

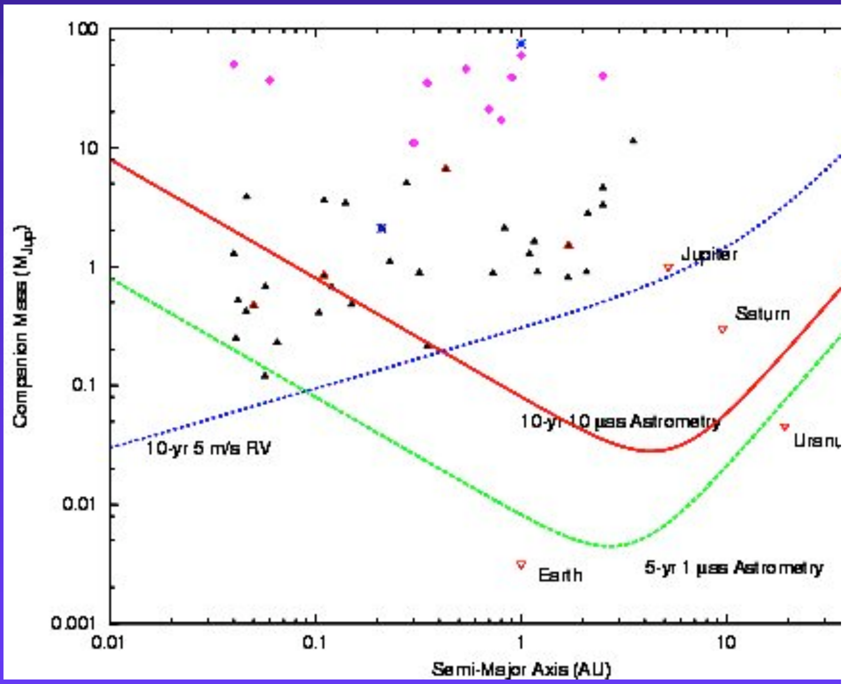
- “Wide-Angle”: Over entire sky, atmospheric effects are uncorrelated.
  - ~1-5 milli-arcsecond performance.
- “Narrow-Angle”: Less than ~1 arc-minute, atmospheric errors subtract out (mostly)
  - 20 micro-arcsecond performance.
- “Very Narrow Angle”:Targets are close enough to be in FOV of single beam combiner, though at different delays. Atmosphere stabilized with fringe tracking.
  - 5-20 micro-arcsecond performance for 0.1-1 arcsecond separations.

Atmospheric limits to a narrow angle measurement



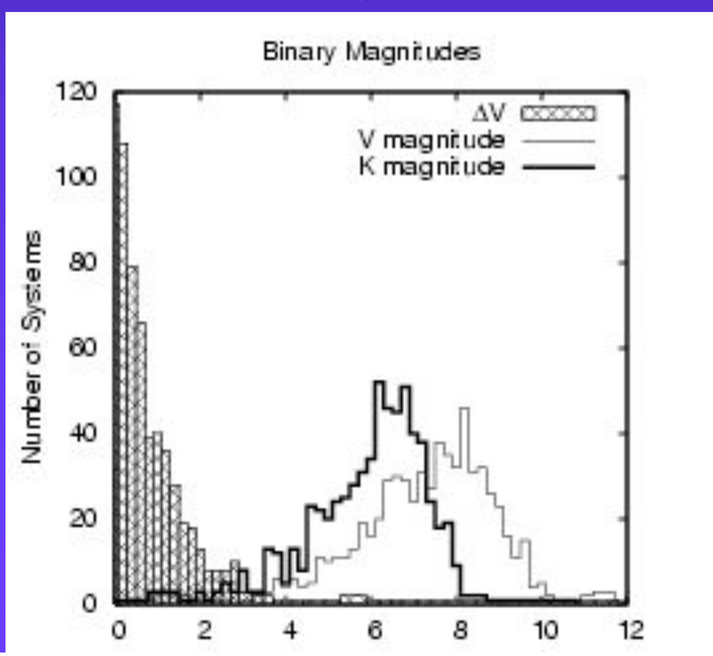
Narrow-Angle Astrometry: Exoplanets

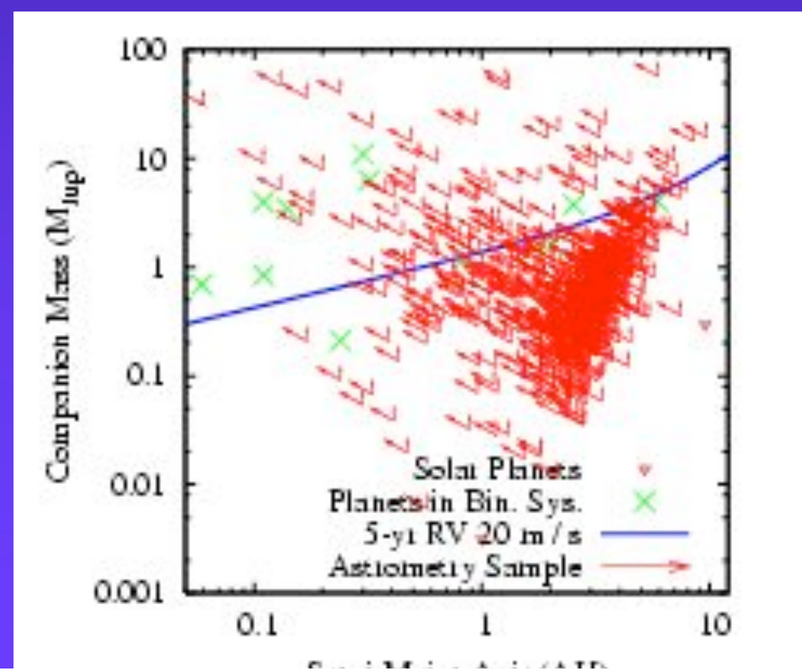
- Astrometry is complementary to RV - better at longer periods.
- Provides inclination, mass.
- Need ~10 micro-arcseconds to be competitive with RV.
- Traditionally these have been the targets for "dual-star" systems (PRIMA, KOA)



Very Narrow-Angle Astrometry: Exoplanets in Binaries

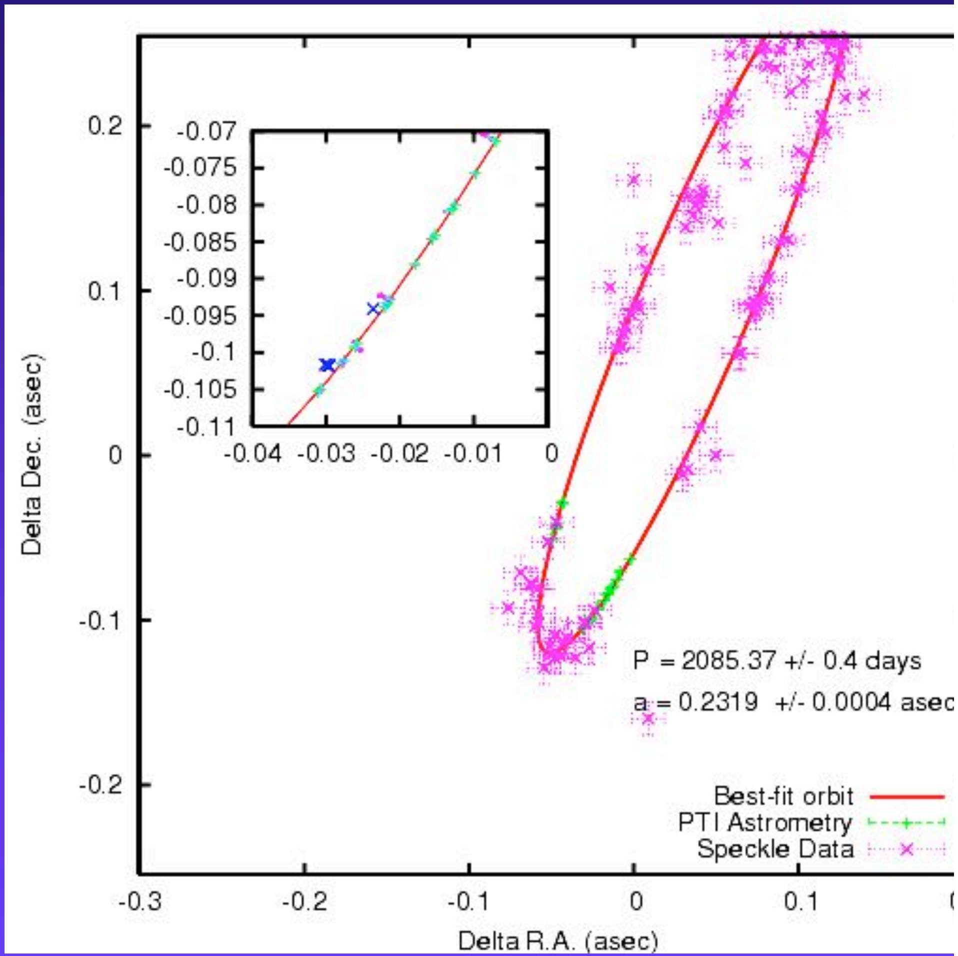
- Very narrow angle astrometry could be applied on one of several arrays, with ~500 targets in a representative sample (here assuming 1.8-m apertures).
- Targets would all be speckle binary systems brighter than mK ~ 8
  - Allows higher precision in shorter time than using background references.





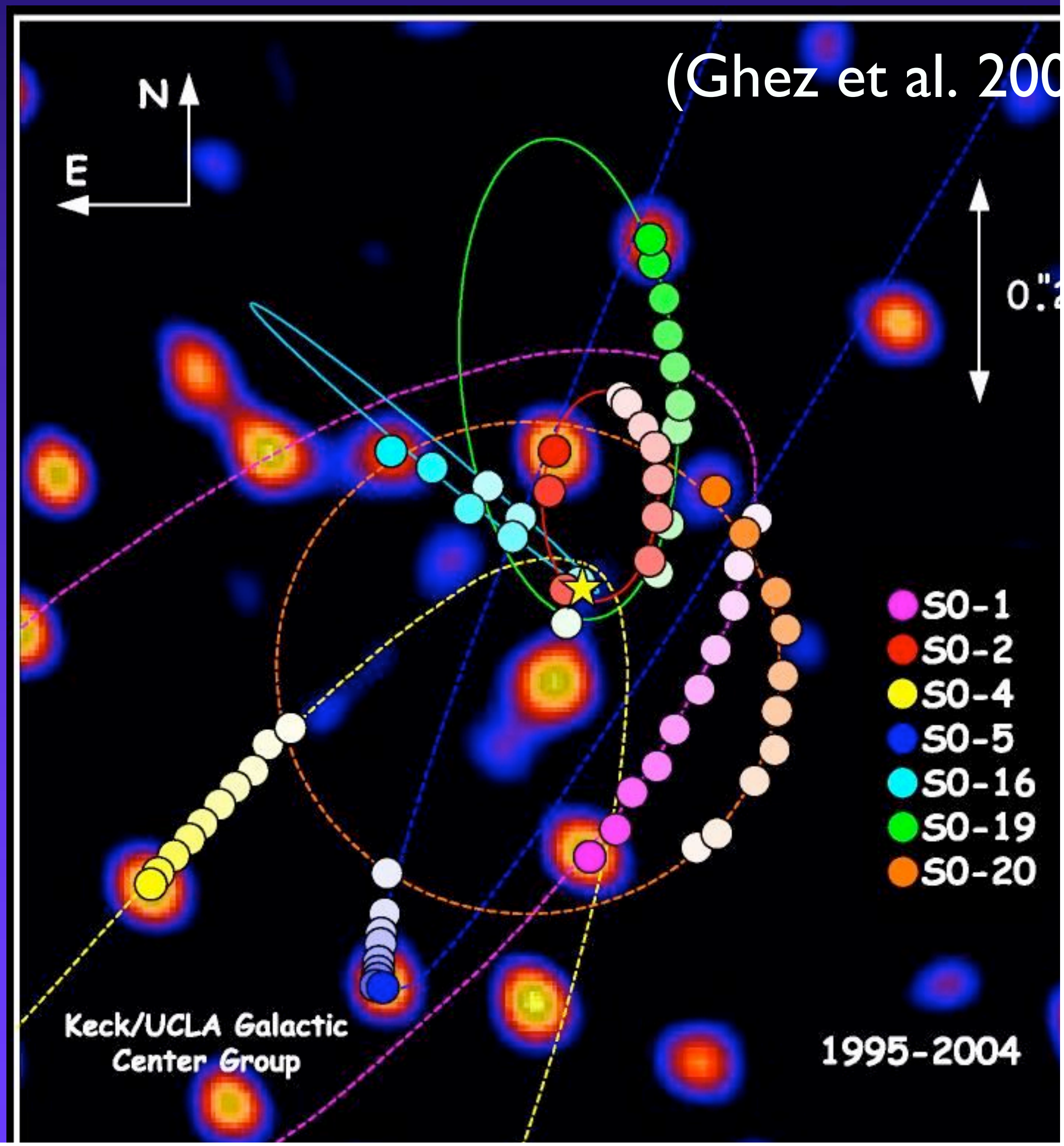
Binary Orbits

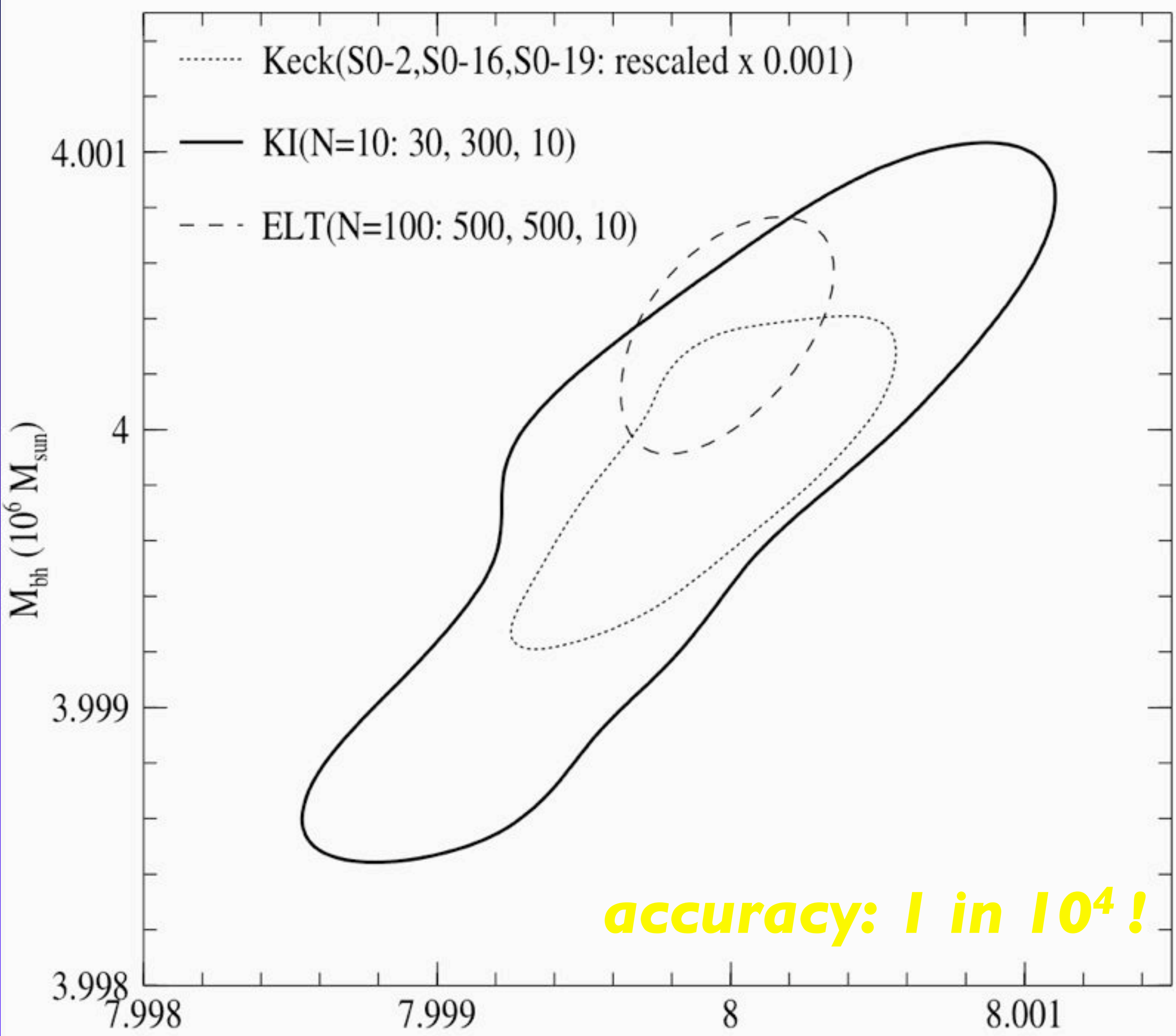
- With 20 micro-arcsecond astrometry on 0.2 arcsecond binaries we have the precision to revolutionize stellar astronomy (0.01%).
- At PTI, we have begun to observe several known “speckle” binary systems (e.g. HD 202275).
- Results compare favorably with previous data.
- Can determine apparent orbital geometry to ~0.2 % with ~20 points, 1/5th of the orbit.
- a=0.2319 ±0.0004 arcseconds.



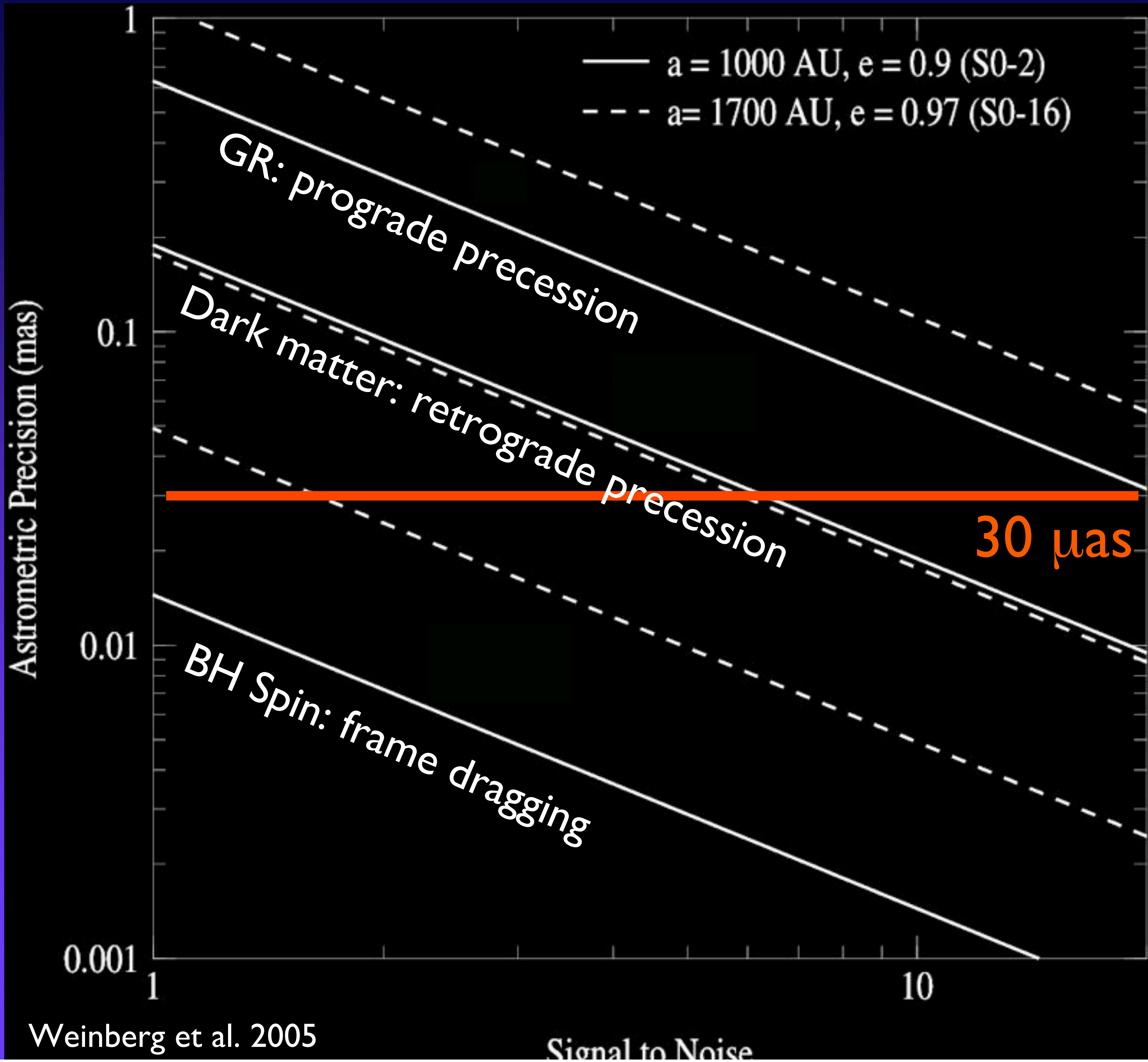
Young Stars in the GC

- orbits constrain BH, DM, GR,...
- current state of the art: ~0.25 mas astrometry
- KI/VLTI: ~30 μas astrometry





Weinberg, Milosavljevic, & Ghez 2005



Weinberg et al. 2005

Other GC Science

- Dark matter detection via orbital perturbations: IMBHs?
- Astrometry of SgrA* flares
- Eventually... black hole spin

Dome C Location
Interferometer Sensitivity

- **Astrometry (~20 x – if free air turbulence ~0)**
  - Depends ~ int($h^2 C_N^2$) so low elevation seeing helps.
  - Extremely Long baselines possible.
  - Large isoplanatic angle required to avoid photon limit.
- **Differential Phase (~20 x @ 2 µm)**
  - Water vapor limited sensitivity ~ σ_{PWV}/SNR ~ 25/SNR.
  - photon limited with phase referencing ~ 20 µrad
    (K_{magn} = 5, 10 min int, 1.8 m telescope, 10% throughput)..
- **Background limited sensitivity (~75x @ 2 µm)**
  - improvement ~ $NEP_{T1} NEP_{T2} \times$ sqrt(τ_0) ~ 4.7 K_{magn} , 2.5 N_{magn}

All interferometer modes are dramatically improved!

The Importance of the Free Air Turbulence

- Ordering of scientific priorities.
  - Which is the most important observing mode?
  - If potential for astrometric accuracy < 1 μ" then astrometry might be the top priority.
- Profound effect on instrument design.
  - ~ 1 μ" class astrometry may require siderostats.
  - Telescope pivot error tolerances become ~ 1 μm for

    ~ 1 μ" astrometry.

Antarctica?

Site	r_0 (500nm)	f_c	θ_0	σ_δ (100m, 1', 1hr)
Mauna Kea	20 cm	80 Hz	1.6"	60 μas
South Pole	6 cm	35 Hz	34"	8 μas
Dome C	20 cm	2.5 Hz	380"	0.5 μas

Impact of Recent NASA Actions

- With the Outrigger Array gone, there is currently no astrometric facility planned for the Northern Hemisphere.
- With SIM delays there is an opportunity to get the jump on some very interesting science from the ground.