How Astrometry Will Contribute to the Future of Indirect Detection

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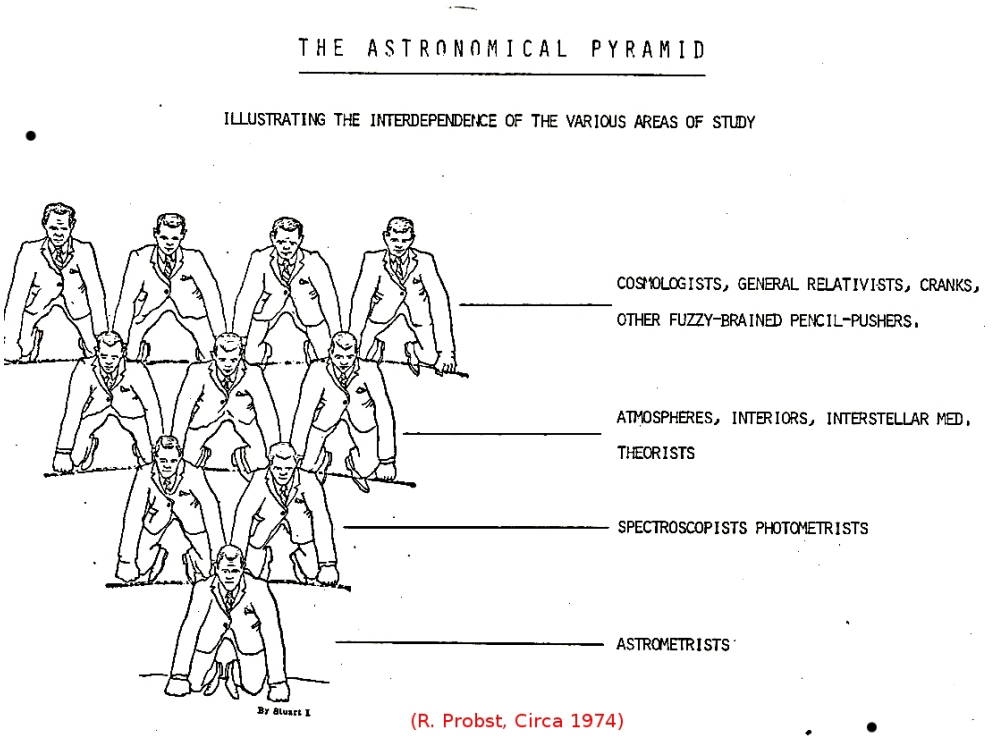
Exploring Strange New Worlds: From Giant Planets to Super Earths

Preamble

Astrometry?

- *Boring* part of astronomy dealing with star positions & reference frames!

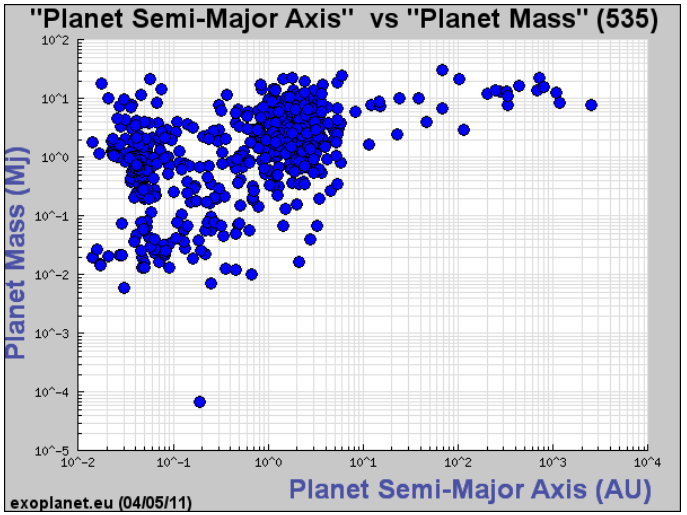


(R. Probst, Circa 1974)

- Absence of pretty pictures. Agreed, nobody is perfect!

Debate over?

Why astrometry in the context of extrasolar planets?



Keep in mind that i is floating everywhere!

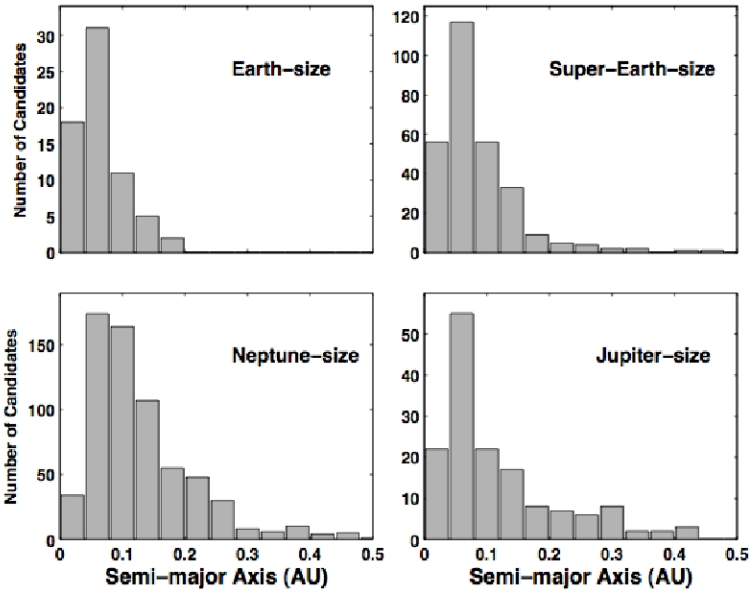
$$f(M) = \frac{(a_1 \sin i)^3}{P^2} = \frac{M_2^3 \sin^3 i}{(M_1 + M_2)^2}$$

Coplanarity!

OK, for transiting planets, $i \sim \frac{\pi}{2}$.

What about M_1?

In case of Kepler, M_1 is derived from the KIC ... which required the parallax of the object!

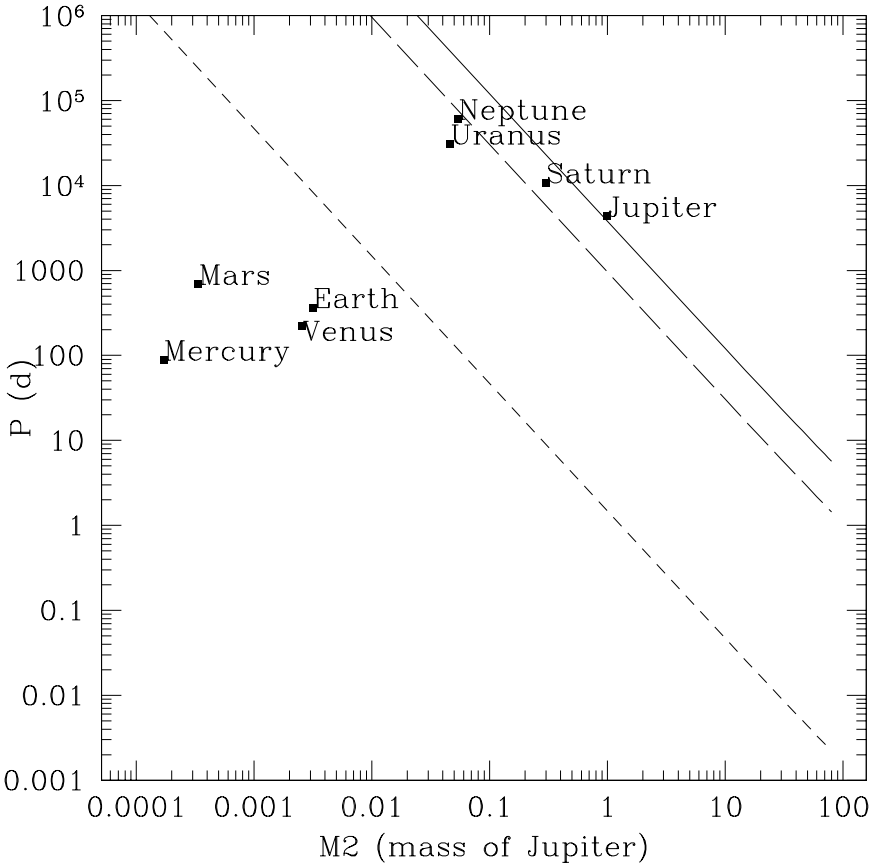


(Borucki et al., 2011)

Main weakness

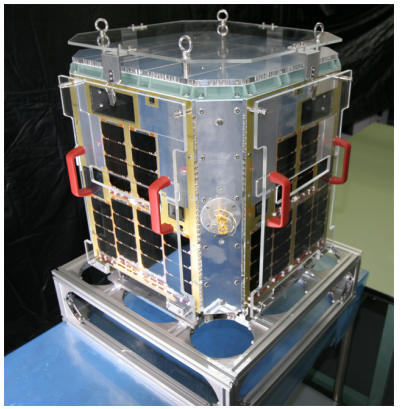
The further away a unit length, the smaller the sustained angle.

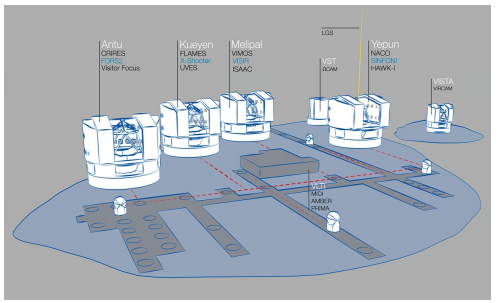
Orbit reconstruction for a central solar-type star located at 250pc, 100pc, or 1.3pc ($\sigma = 10\mu$as, S/N=1.9).

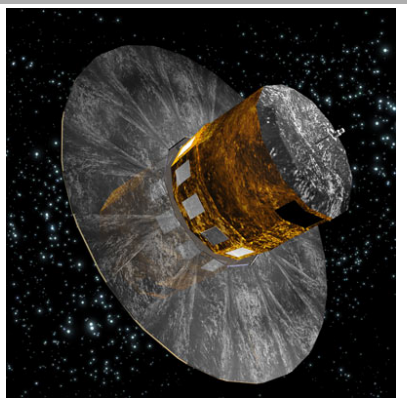


This explains, alone, why the technique has had a limited success so far.

Past, present and future

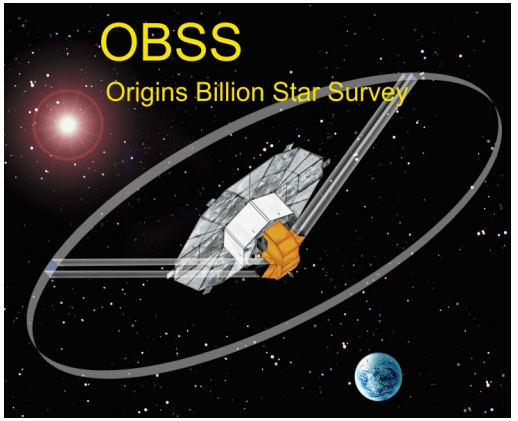


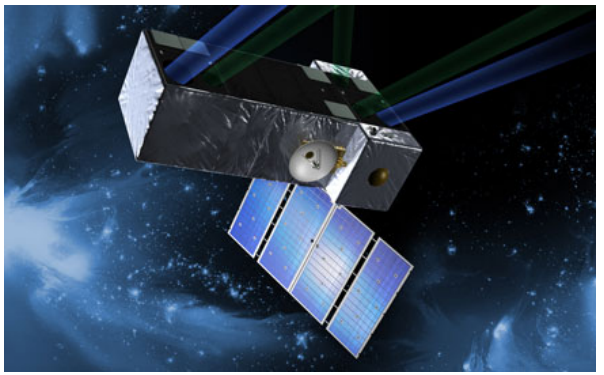




- Hipparcos: 8 mas (ESA, 1989)
- HST: 1 mas (NASA, 1990)
- Nano-Jasmine: 3 mas in IR (Japon, 2011)
- PRIMA: 30 μas (ESO, 2012+, 100μas)
- Gaia: 30 μas (ESA, 2013)

Has this become a European *exclusive domain*?





Casualties of the war on budget! RIP

Will Keck interferometer and ASTRA be the next ones? 100% sure according to Chas (Monday).

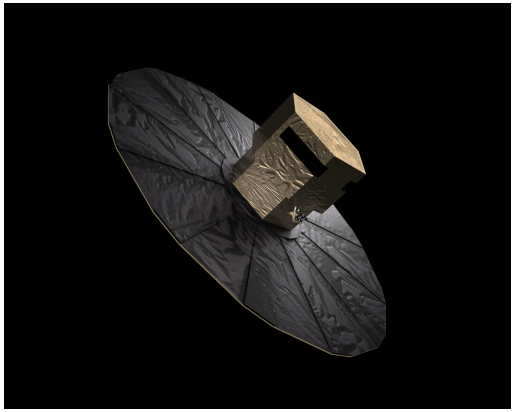
J-MAPS (USNO DoD, 5mas) still alive but as a DoD project, public access to the raw data remains unsettled.

2 on-going astrometric projects:

- CAPScam (Carnegie):long term observation (10y) of about 100 nearby M, L, T dwarfs;
- RIPL (Berkeley): 3y observation of 29 nearby M dwarfs.

What is Gaia?

- European Space Agency cornerstone mission
- Launched by Soyuz Fregat in March 2013
- Five-year mission
- Located at L2 point
- All sky survey down to 20th mag. ($\sim 10^9$ stars)
- Astrometry is primary goal



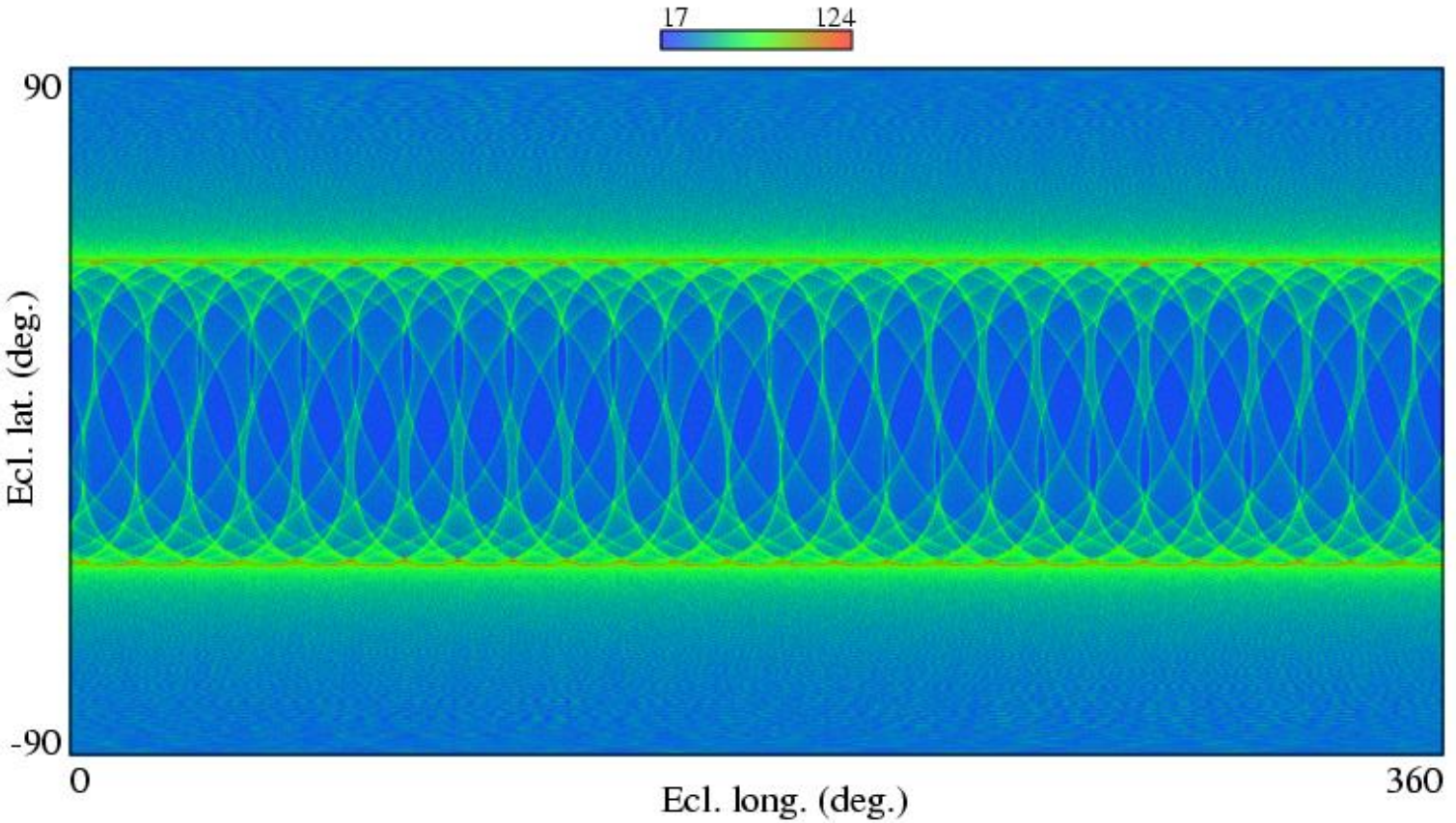
End-of-mission

Star	V mag	σ_ϖ (μas)
B1V	< 10	5.2
	15	20.6
	20	262.9
G2V	< 10	5.1
	15	19.4
	20	243.4
M6V	< 10	5.2
	15	8.1
	20	83.9

- Photometry with low resolution spectra
- Radial velocity down to 17th mag ($R = 11500$), precision of ~ 15 km/s for several millions stars

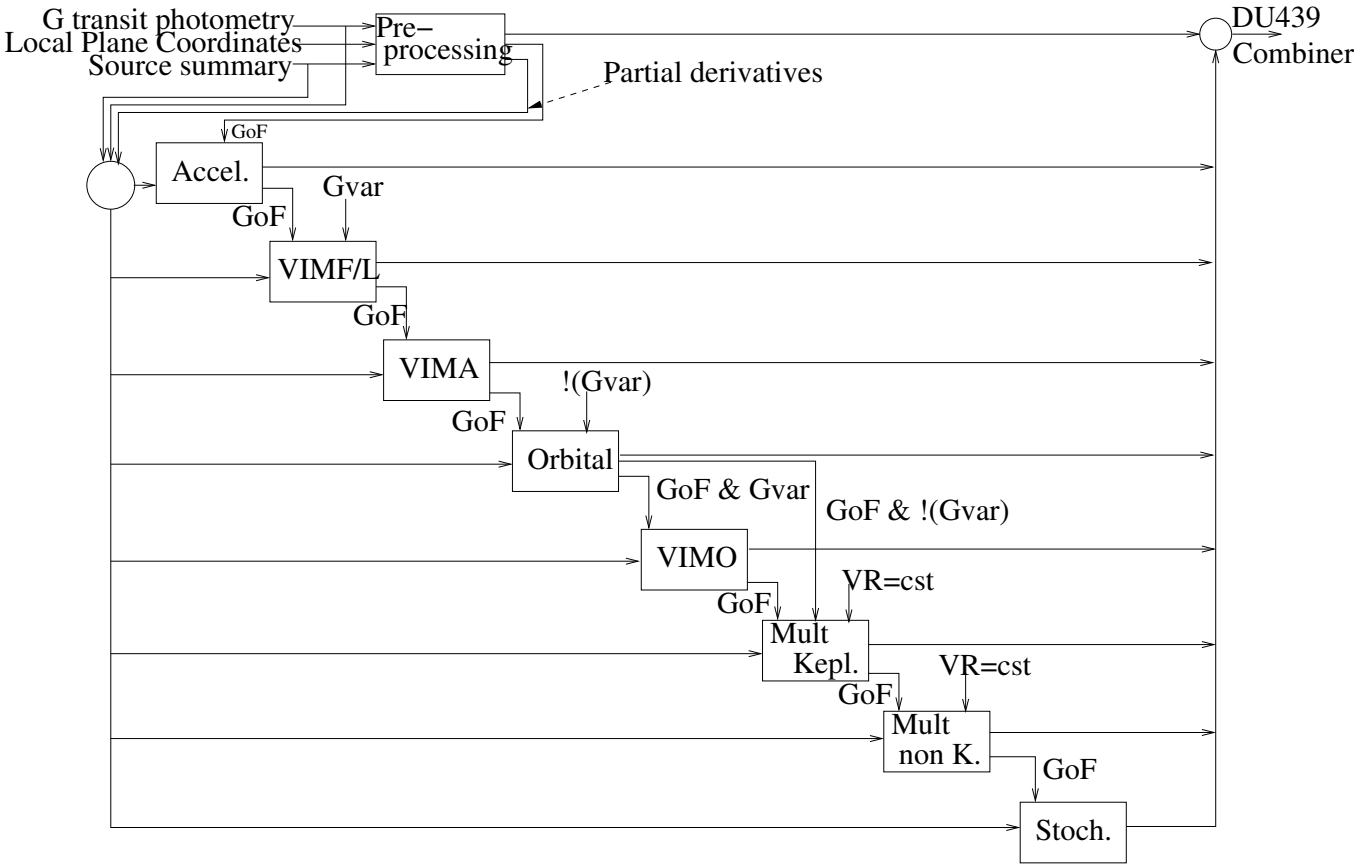
What Gaia is not

Unlike HST and JWST, Gaia is not a pointing instrument!!



On average, 80 1D-observations, not uniformly distributed. Typical epoch precision for bright star $\sim$ $30\mu as$.

Gaia Unresolved Non-Single Star Pipeline



No genuine planet pipeline but several efficient orbit fitting ones. Benefit from photometric and spectroscopic Gaia complementary data to segregate stellar and substellar companions (60M orbital NSS, 5k for extrasolar planets).

Conclusions

- Astrometry **does** provide distance to the target star and **does** complement RV data;
- Coplanarity cannot be fully studied with transiting systems only;
- Success of astrometry rather limited so far but with Gaia, one finally reaches the precision required for detection/discovery;
- Due to sparse and limited time series, orbits might not be definitive yet
  - PRIMA will help . . . but for a limited sample (10 stars/night)
  - Could ASTRA (Keck) stay alive a bit longer?
  - How dead SIM really is?

Please, do not repeat with Gaia what Han et al. did with Hipparcos!

There should be no debate, astrometry complements RV!