Orbital Inclinations, True Masses, and System Architectures of Long-Period Giant Planets

New Constraints with Hipparcos-Gaia Astrometry

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Context

- Hundreds of exoplanets have been detected using the radial velocity technique, but this only provides a minimum companion mass $m \sin i$.
- The true mass m can only be determined by measuring the orbital inclination i with data from other techniques, which is challenging for planets with long orbital periods.
- The ongoing *Gaia* mission will measure inclinations and true masses for many of these planets through astrometry, but the data will not be made available until *Gaia* DR4, still years away.
- However, proper motion data from *Gaia* can be combined with those from the older *Hipparcos* mission to produce long-timespan astrometric measurements that can be used to **measure orbital inclinations and true masses of long-period giant planets**.
- I highlight here some examples of how *Hipparcos-Gaia* astrometry can be used to explore the long-period giant planets and the architectures of planetary systems.

Wide Components in Transiting Systems

Hipparcos-Gaia astrometry is highly sensitive to long-term accelerations caused by wide companions, ranging from planets to stars. The nature of these companions cannot be determined from astrometry alone, but combining data from other observational techniques allows for robust constraints on their masses. Several hundred TESS Objects of Interest (TOIs) have *Hipparcos-Gaia* astrometry available, allowing for the **discovery of wide companions in known transiting systems.**

One such example is HD 15337 (TOI-402), a 2-planet system with orbital periods of 5 and 17 days discovered by TESS that additionally displays a radial velocity trend and a significant astrometric acceleration. This is consistent with anything from a giant planet at several AU to a wide stellar companion. Very recently, a candidate stellar companion to this star has been discovered at 65 AU separation [5]. If this candidate can be confirmed as a bound companion, the radial velocity and astrometric data can be combined to determine the orbit of the binary, allowing for exploration of the alignment of orbits in the system at large scales.

Similar analyses can be performed for other visual binaries with transiting planets, giving us a picture of the orbital alignments, dynamics, and formation histories of planetary systems in compact (< 200 AU separation) binaries.

References

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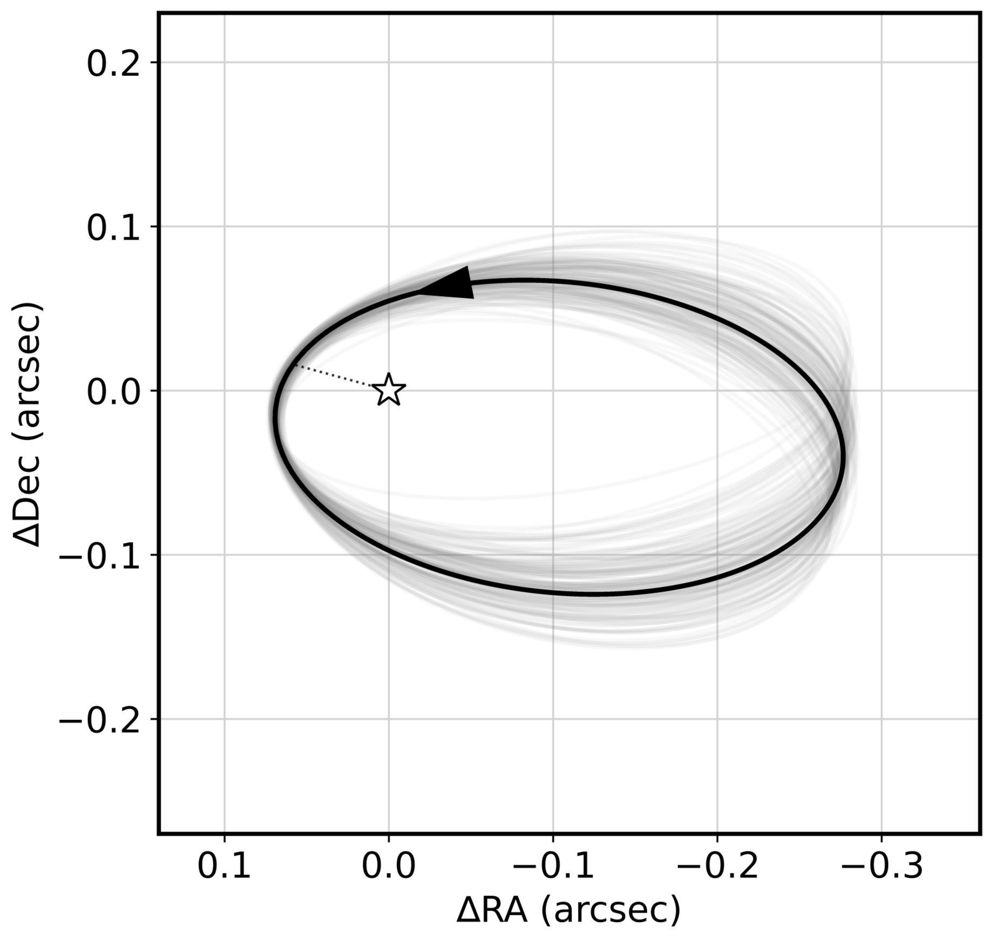
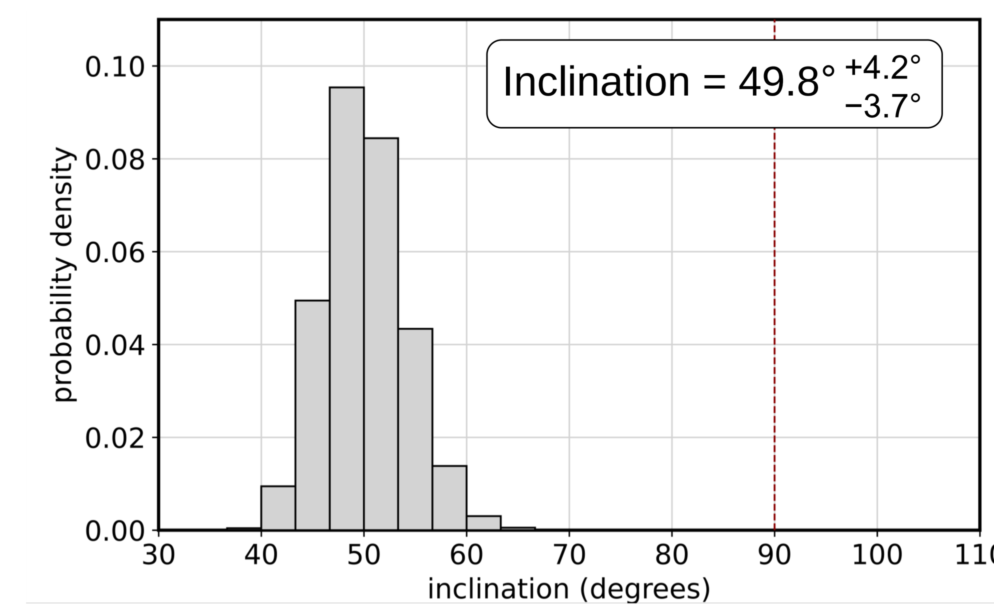
Mutual Inclinations in Transiting Systems

A number of long-period giant planets have been discovered in systems that also contain short-period transiting planets, and astrometry allows us to measure the **difference in orbital inclinations** in these systems.

A good example is π Mensae, a nearby system with a transiting Neptune on a 6-day orbit and a massive giant planet on a 6-year orbit. Several studies have already used *Hipparcos-Gaia* astrometry to investigate the mutual inclination between the two planets, establishing that the system is significantly misaligned. [1,2,3]

With the recent release of updated *Hipparcos-Gaia* astrometry [4] I show here updated results for the orbit of π Men b. Parameter precision has increased significantly over past results, and the giant planet b is confirmed to be strongly misaligned with the transiting planet. The upper plot shows the projected orbit of π Men b while the lower plot shows the distribution of orbital inclinations.

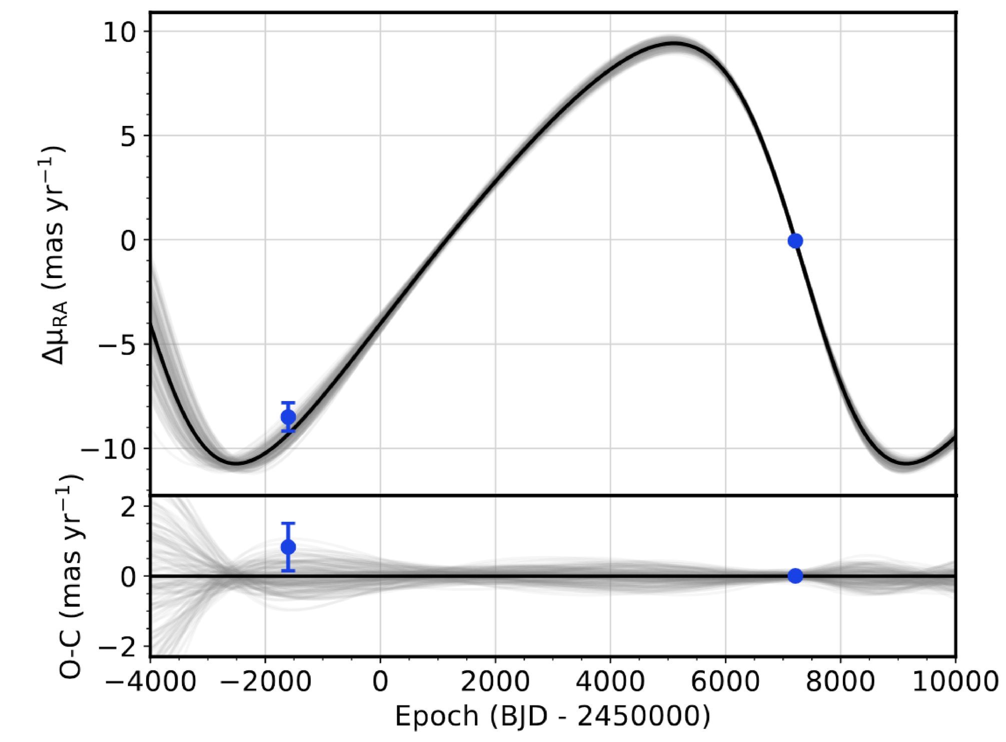


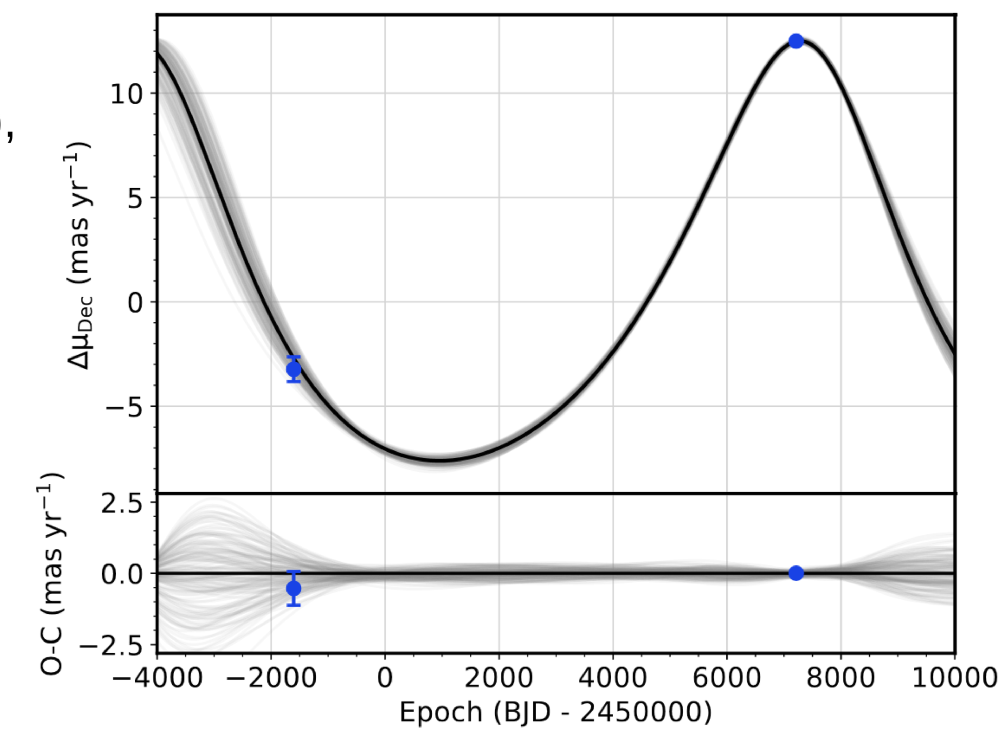


False Positive Planets on Long-Period Orbits

Due to the unknown true mass of radial velocity companions, some giant planet candidates **may actually be stars or brown dwarfs observed at near-polar orbital inclinations**. I have explored this possibility in the known sample of long-period giant planets and identified two examples of this.

One is HD 92987 B, a companion with a minimum mass of 17 M_J which we find to have a true mass of 268 M_J (0.26 $M_\odot$), making this companion a low-mass star instead of a substellar object. The *Hipparcos-Gaia* data in both co-ordinates is shown on the right, showing the large astrometric signal (10 mas yr^{-1} ≈ 2 km s^{-1}), far larger than the amplitude of radial velocity variations. The other example is HD 221420 b, a planet candidate with a minimum mass of 6 M_J that has a true mass of 23 M_J, which can be understood as a high-mass planet or a low-mass brown dwarf.





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