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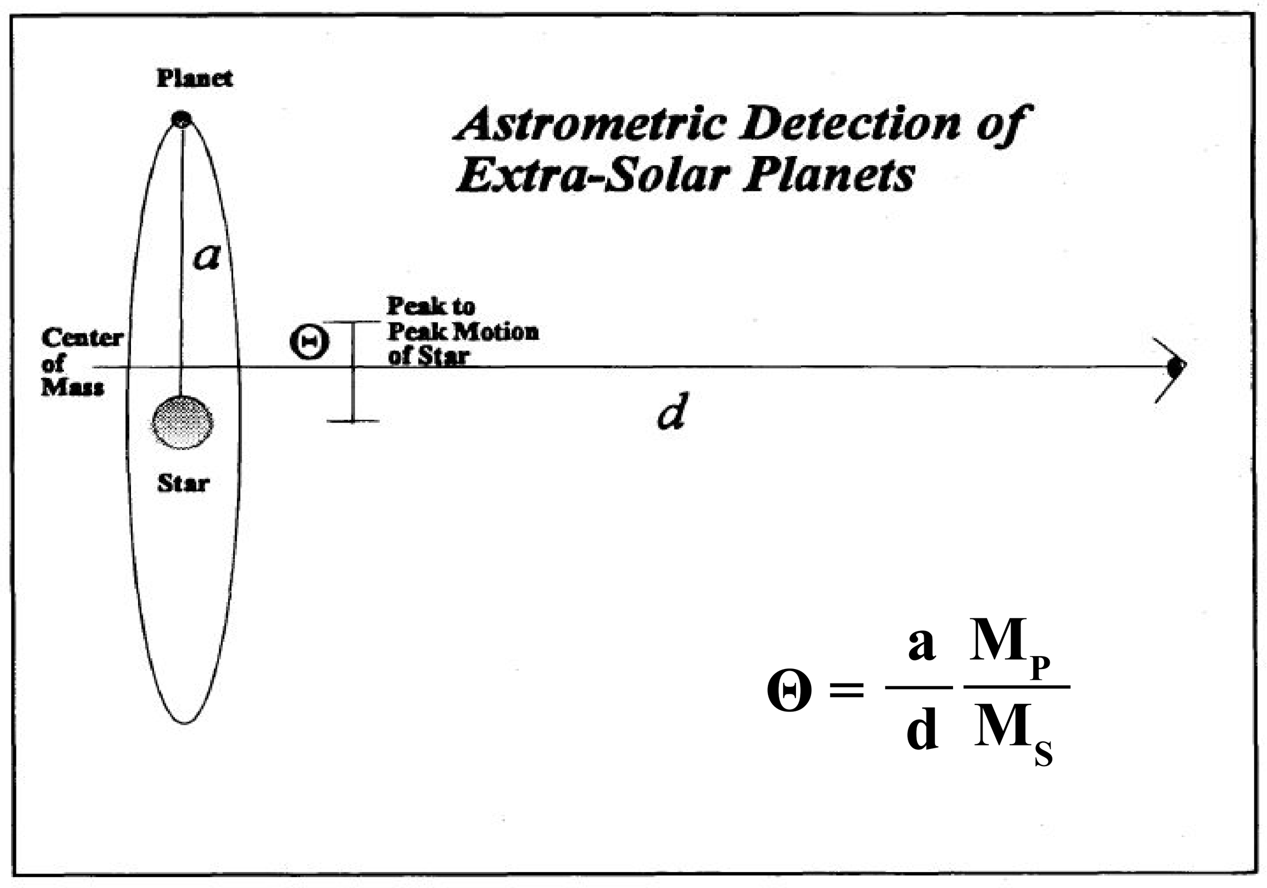
ASTROMETRY OF BINARIES WITH ADAPTIVE OPTICS

A WAY FOR FINDING EXOPLANETS?

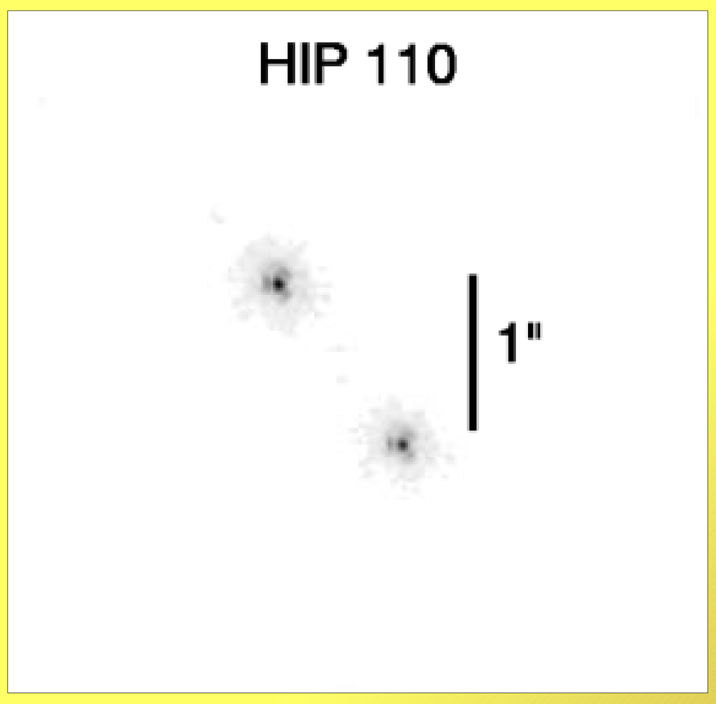
Astrometry (measuring position of a star) is one of many methods of searching for extrasolar planets (exoplanets). It bases on fact, that a star and a planet are orbiting around common center of mass. The physical movement of the star manifests in periodical changes in star's position on the sky. The scale of those changes depends on many things, such as: masses of star and planet, semi-major axis of planet's orbit, or the distance to the system, but usually reaches tenths or hundreds microarcseconds [μas] for most massive planets. In many cases such precision can be achieved with largest telescopes with Adaptive Optics facilities. A very promising objects for this type of research are visual double and multiple stars. They allow us to make astrometry in smaller fields than single stars, which makes the research more precise.

This paper presents the method and the results of our study of the astrometric ability of Hale (Mt. Palomar) and Keck II (Mauna Kea) telescopes to find exoplanets in some visual double or multiple stellar systems.



←
In astrometric studies we look for small-scale, periodical motion of a star. This "wobbling" is caused by gravitational influence of orbiting planet. The scale of star's motion (astrometric signal - Θ) depends on semi-major axis (a), distance to the system (d) and masses of star (M_S) and planet (M_P) [1,2].

Astrometry works best for massive planets on far orbits around close stars.



WHY VISUAL BINARIES?

Firstly, because most of stars are in double or multiple systems, but most of already known planets are hosted by single stars. It's because we don't have good methods which we can use for binaries.

Secondly, we can use one of our stars as a reference star. It gives us an opportunity to make images in much smaller fields than for single stars. The smaller field, the higher precision of position measurements.

And finally, we don't have to worry about paralaxes and proper motions of stars, field distortions, aberrations, etc [1, 2, 3]...

DETECTION LIMITS

To make precise measurements we have to use "stable" telescope. It means that single measurements (from image to image) should have small dispersion and be random (gaussian statistic). Any statistical contributions to the measurements, especially derived from optical and mechanical effects, should be corrected.

The precision of astrometrical measurements of a particular telescope determine how massive planets on how distant orbits can be found with that telescope. We can detect planet if the astrometric signal i higher than 3σ, where σ is the uncertainty of a measurement for a given epoch, which we can understand as the astrometrical noise. Knowing mass and distance to the star, we can determine the minimum product of mass and semi-major axis of a planet that we are able to detect:

$$a\, M_P > 3\, \sigma\, d\, M_S$$

Degeneration of mass and semi-major axis can be eliminated with 3rd Keplerian law, but we have to know orbital period [1,2].

ADAPTIVE OPTICS – A KEY TO THE SUCCESS!

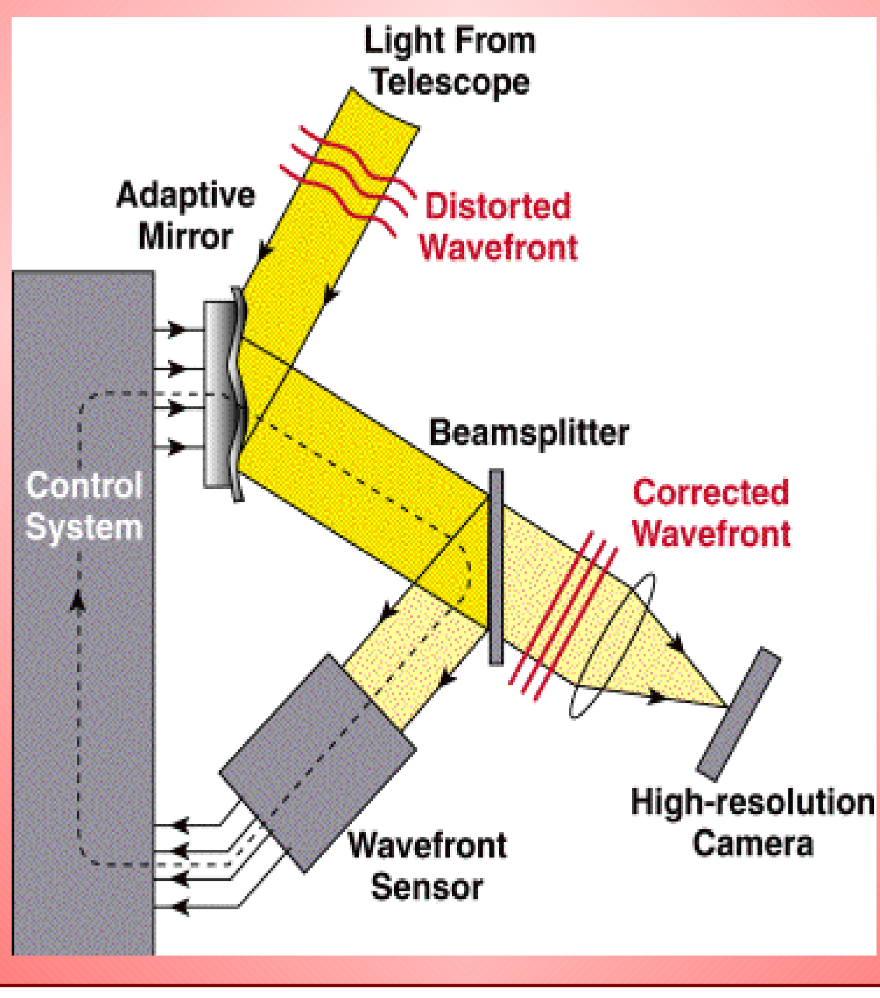
In perfect telescope a star should be seen, because of diffraction, as so called "Airy disc". Its size depends on telescopes aperture *D* and wavelength *λ* as *1.22 λ/D*. Unfortunately it works only in space. Our atmosphere is built of many turbulent regions, all of which can have different refraction index (dependent on temperature, density and humidity) and refracts light in different ways. In telescope we get bigger, blurred image with smaller maximum of intensity. Adaptive Optics (AO) is a facility, that compensates this blurring (called *seeing*) and makes diffraction-only limited images [4]. Astrometric measurements of such images are much more accurate than seeing-limited.

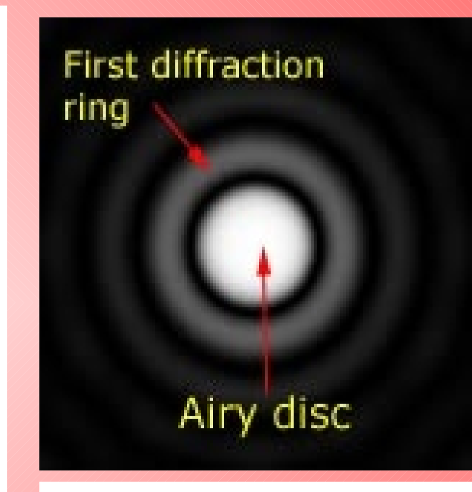
<u>Main components of AO systems</u> [5]:

WAVEFRONT SENSOR – a device that measures distortion of the wavefront.

ADAPTIVE MIRROR – a mirror which surface can be deformable. It corrects the distortion of the wavefront and makes it flat. Surface of the mirror can be changed 100 – 1000 times per second. Usually it is an additional mirror "behind" the telescope but sometimes secondary mirror of a telescope plays that role.

CONTROL SYSTEM – analyzes wavefront measurements and plans mirror deformation.





← *Image of a star in a "perfect" telescope*

↓ *Image of a tight binary without (left) and with AO correction.*

RESULTS:

For those binaries, which masses (at least one component) are known or can be estimated, results of astrometric stability studies are presented. In column 2 the lowest achieved σ is given. Presented results confirm that it is possible to achieve precision good enough for searching Jupiter type exoplanets around nearby visual binaries using telescopes with AO. Astrometry can be a way for finding another worlds.

Star	Lowest σ [mas]	Distance [pc]	Mass A [M_{SUN}]	Limit for A [AU M_{JUP}]	Mass B [M_{SUN}]	Limit for B [AU M_{JUP}]	Telescope
GJ 195	0.22	13.89	0.53	2.53	0.19	0.51	Hale
GJ 352	1.7	10.53	0.44	12.31	0.41	11.47	Hale
GJ 458	0.5	15.32	0.40	4.79	0.37	4.43	Hale
GJ 507	0.7	13.16	0.46	6.57	0.37	5.33	Hale
GJ 569 B	0.11	9.81	0.071	0.0116	0.054	0.088	Keck II
GJ 661	0.07	6.32	0.379	0.29	0.34	0.28	Hale
GJ 767	0.21	13.35	0.44	1.93	0.40	1.75	Hale
GJ 860	0.1	4.01	0.34	0.17	0.271	0.11	Hale
GJ 873	1.3	5.05	0.36	2.55	???	???	Hale
GJ 9071	0.6	13.89	0.53	6.66	0.49	6.16	Hale

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