The new algorithm of study extrasolar planatary systems

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Introduction

About two hundreds years ago people began to organize the first steps in study of one of the most oldest and the most exciting questions in a history of mankind - are we alone in the universe?

Of course the majority of initial experiments had no significant results, but nowadays things have changed.

In the middle of the last century, astronomers are very close to discovery of planets outside our solar system. Today we called them *exoplanets.*

Now we have discovered around 4500 exoplanets , of which more than 1550 confirmed and 3500 unconfirmed (candidates) [1].

It's interesting that in our Solar system the number of satellites is extremely larger than the number of planets, and it's paradoxically, that the first discovery of so-called "exomoon" is still expected.

Actuality of the project

Detection the first satellites of exoplanets is one of the most important task of modern astronomy.

It has a great importance in the field of understanding the structure of planetary systems.

Major satellites of gas planets located in the habitable zone are potentially suitable place for the life development.

Main tasks

Currently, our observation equipment came very close to the discovery of small bodies in extrasolar systems: asteroids and planetary satellites.

Numerous estimates show that the problem of discovering large planetary satellites (comparable to the Moon) in exoplanet systems can be solved using existing astronomical equipment [2].

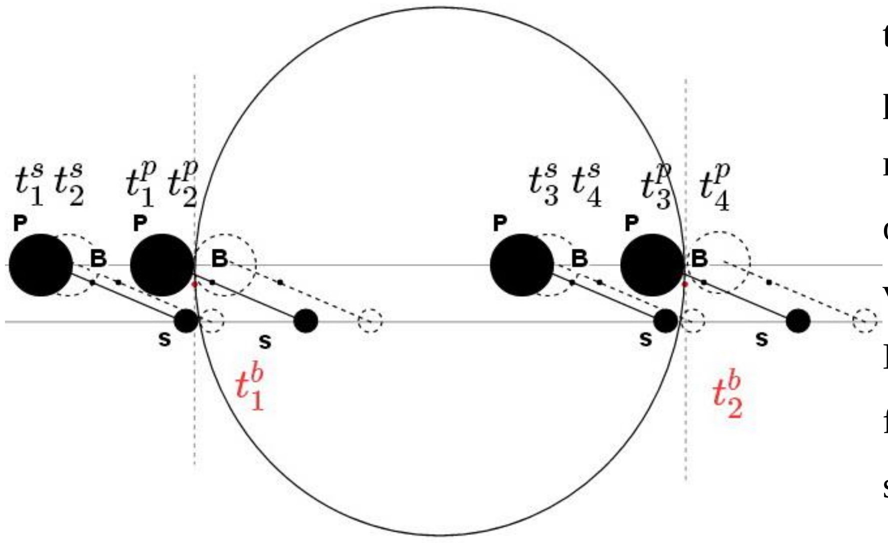
At the basis of modern methods of satellites detection lies deep processing of observational data [2].

The goal of the real project is to study the possibility of discovering the planetary satellites in the transit system, where the planet periodically eclipses the star disk, causing a slight decrease in brightness. It is shown that even in a cases when exoplanet's transit lies below the error level of the modern telescopes (in brightness of star measurements) satellites transit can be detected by statistical processing of photometric data of the brightness of the star before or after the transit and variations in time transit caused by gravitational influence of the satellite to the planet.

Methods and structure

The structural basis of the new method was the TTV effect (transit timing variation) - change in transit time due to the movement of the components of the planet-satellite system around a center of mass (barycenter) [3].

Due to TTV effect a remote spectator can detect the shift in time of the beginning / end of the planetary transit compare to his ephemerids. The characteristic value of the transit time has is about 10-100 seconds, and decreases with increasing mass of the planet, with decreasing in the planet's period around the host star [4]. Individual use of TTV does not detect planets satellite due to the lack of precision in measurements of time variations [2].



Let's assume a faraway spectator observes a planetary system of a certain star. So his visual ray is located accurate in the plane of the system. Our spectator could make ephemerides for transits of one chosen planet. In the case, the time of begining and ending of every new transit will shift comparing with the ephemerides. The difference between observed and predicted times of a transit is known as transit timing variation or TTV . The variation of the overall transit time is known as time duration variation or TDV .

Actually, such variations of the planet may be caused by variety of things. First of all, we can observe a perturbing planet with an unstable orbit. Different effects were studied as an effective sources of timing variations.

On the other hand, one of the reasons of such behaviour would be the existence of exomoons around this planet. Due to this fact, TTV and TDV occur. The structure of the transit is presented in (Figure 1) .

Figure 1.

In Figure 1, we illustrate the main stages of the transit of an exoplanet system with one satellite. Here, the big white circle denotes the star, the middle circle denotes the planet (p) and small circle denotes the satellite (s). The barycenter (b) of the planet - satellite system is shown as the small dot on the line connecting the planet and satellite.

The satellite influences the transit in two ways: (i) it changes the moments of transit's beginning and end (causes transit timing variation), and (ii) decreases the star's flux beyond the planetary transit.

To increase the sensitivity of the method (in addition to time transit variation) were used the integration of brightness of the star **J1 (J2)** in the selected interval T seconds before / after the main (planetary) transit.

If the transit timing variation caused by the movement of the planet-satellite system around the barycenter, the satellite will be located on the star disk before or after the main transit, and will have an influence on the brightness of the stars at this time. Negative (positive) variation of transit time lead to the entry of satellite on star disc before the planetary transit (and remaining on stellar disc after the main transit). Thus, there is a negative correlation in possessing a companion between the ratio J2 / J1 and transit timing variation. In other words, the calculation the correlation coefficient between these two variables allows us to make a conclusion about the existence of satellites on the orbit around extrasolar planet.

Numerical simulation. Earth -moon system.

To demonstrate the possibilities of applying this new method the following tests were made.

The most effective test of this method was made on Earth-moon systeCalculated the correlation coefficient between the time transit variation and the variation of the brightness relationship in the Earth-Moon system. The program for the experimant was developed, which simulates the motion of the system planet-satellite and simulates the brightness curve of the star during the transit of the planet. Movement system planet-satellite is modeled within two-body problem, without taking into account the effects of other planets. A study on the impact of errors in determining the correlation coefficient Δ (J2 / J1) and Δt.

Errors of measurement variation and the brightness of a star transit time taken for the photometric data observatory «Kepler».

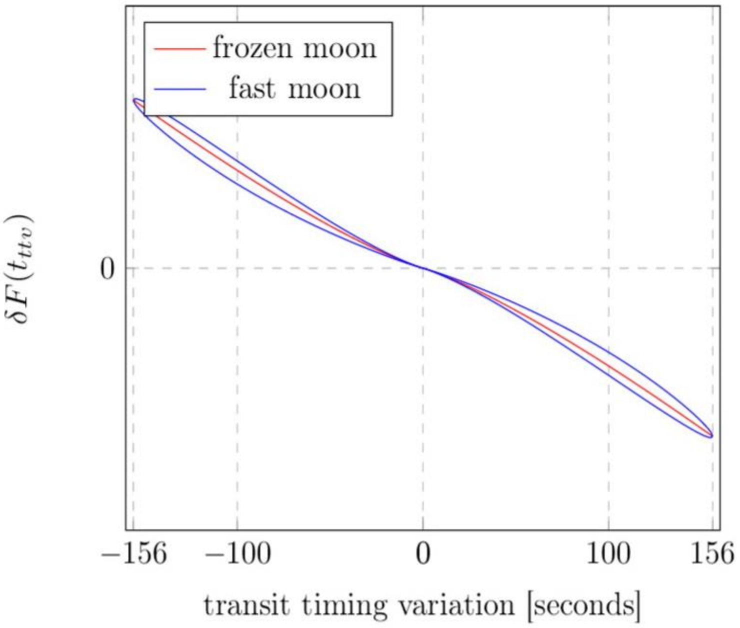


Figure 2.

Analysis of the results.

As a result of the testing method developed at the Earth-Moon system has been obtained high correlation coefficient of TTV and brightness variations. The correlation coefficient is high even with accounting errors.

The main advantage of the method is that its accuracy increases with increasing of the number of satellites around the planet (because TTV and BF are additive values). With the introduction of an additional moon at a distance greater than or smaller than the radius of the Moon's orbit, the shape of the curve changes insignificantly and the accuracy of satellite detection multiplies. Even with an artificial increase in the speeds of the satellites (to velocities close to the speed of the planet), the shape of the curve remains the same.

Literature

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