Search for extrasolar planets around White Dwarfs

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Introduction

Search for extrasolar planets around other stars is one of the most topical areas in astrophysics presently. There are various search methods and the most productive of them is the transit method, which is based on photometric observations. Already more than 2600 exoplanets were discovered by this method.

The matter of the transit method: it is possible to interpret registered variability of a star as its planet passing through the star disk (transit phenomenon) in case of light curve of certain form and high precision periodicity. The main requirement for a transit observation: the planet orbit plane is oriented nearly along the line of sight. Probability of such planet orbit orientation is proportional to the ratio of planet radius to star radius.

The most simple variant is to search planets of Jovian radii on the short period orbits (from several days to several weeks). At the moment, the largest number of exoplanets were discovered around stars with F-G spectral classes with masses close to Solar mass. Most of planets discovered around other stars has orbital period from 1 to 100 days.

THE MAIN SCIENTIFIC GOAL OF THE PROJECT

We present a project aimed at **detection of exoplanets orbiting around white dwarfs** using the method of transit, i.e., passing of a giant planet through the star disk of small diameter.

The transit method requires high photometric precision. For example, transit of a giant planet (R ≈ 11 Earth radii) leads to brightness drop of a Sun-like star of about 1%.

Nowadays there are about 20 thousand known white dwarfs brighter than 19 mag [1]. In the case if a white dwarf has a transiting exoplanet we will definitely register significant brightness decrease of the central star, even if the eclipse is not total, since the size of the giant planet is comparable with the size of the white dwarf. Characteristic sizes of white dwarf diameters have values close to the Earth diameter (0.8% - 2% of Solar diameter).

According to our estimates the transit phenomena for close star-planet systems (< 1 AU) range from minutes to tens of minutes.

PRECONDITIONS

We consider the following arguments for the possible presence of planets in systems of white dwarfs:

1. One of the first exoplanets was discovered in the system "pulsar + white dwarf" [2].
2. Presence of planet remnants in systems of white dwarfs [3], [4].
3. Discovery of planets in two systems of subdwarfs V391 Pegasi and Kepler-70 (KOI-55), that experienced a stage of red giants [5], [6].
4. Discovery of disintegrating minor planets orbiting the white dwarf WD1145+017 [7].

Advantages of extrasolar planet search around white dwarfs:

1. Prevalence of white dwarfs (3-10% of all stars number)
2. Easy to detect (full or partial eclipse). It significantly reduces the requirements for the photometric precision.

Factors that complicate the extrasolar planets searching around white dwarfs:

1. Very low luminosity of white dwarfs (absolute values are in the range 10^m - 15^m).
2. Quite small duration of eclipse (minutes).

Most of extrasolar planets have masses similar or greater than Jovian mass and are at distances less than 0.5 AU from host stars. This increases the probability of finding extrasolar planets around white dwarfs.

We calculated this probability (1) for 1140 exoplanets with known radii and orbits, assuming a white dwarf (mass = 0.6 $M_\odot$) instead of their parent stars. The duration of the eclipse was also calculated (Fig.1).

$$\sigma = \sigma_p \underbrace{\left(\frac{R_p}{2\pi a_p}\right)}_{\sigma_1} \underbrace{\left(\frac{2R_p}{\pi a_p}\right)}_{\sigma_2} = \sigma_p \frac{1}{\pi^2}\left(\frac{R_p}{a_p}\right)^2 \quad (1)$$

σ_1 - probability of planet presence
σ_2 - ratio of eclipse time to the rotation period
σ_p – probability of successful orbital inclination

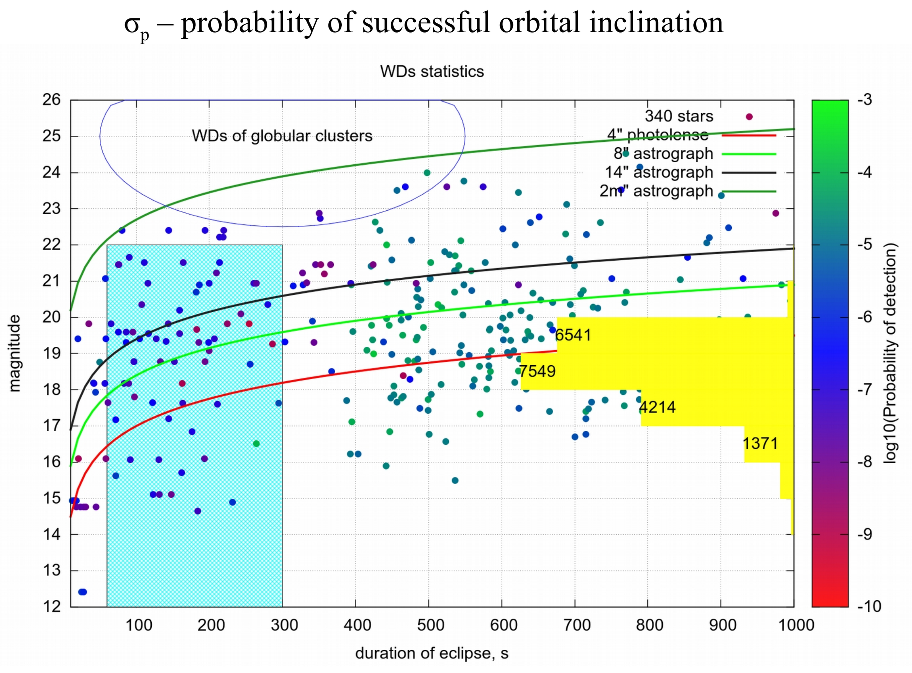


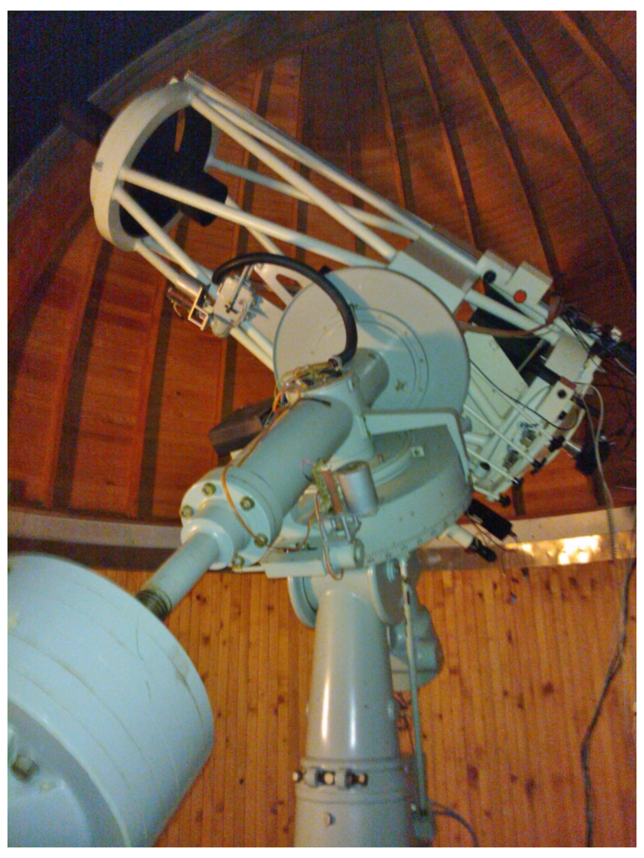
Fig.1. The probability of detection for 1140 exoplanets with known radius and orbital period.

Instruments

Observatory at peak Terskol, Northern Caucasus

Observatory in Hurbanovo, Slovakia

Observatory in Lisnyky, Ukraine



Stará Lesná Observatory, Slovakia

MAO NASU, Ukraine

Skalnaté Pleso Observatory, Slovakia

Fig. 3. Available small telescopes

Tab.1. The main characteristics of available telescopes

Observatory \ Features	Telescope	Focal Length (mm)	Aperture (cm)	Camera	CCD size	FoV (arcmin)
Lisnyky (Ukraine)	Schmidt - Cassegrain Celestron - 14"	3910	35	Rolera MGi	512 × 512	7 × 7
Stará Lesná Observatory (Slovakia)	Cassegrain	7500	60	FLI ML 3041	2048 × 2048	14 × 14
Skalnaté Pleso Observatory (Slovakia)	Nasmyth-Cassegrain	10800	130	MI G4-9000	3056 × 3056	12 × 12
Hurbanovo (Slovakia)	Schmidt-Cassegrain	3905	35.5	SBIG ST 10 XME,	2184 × 1472	13 × 9
MAO (Ukraine)	Schmidt - Cassegrain Celestron - 14"	3500	35	SBIG STL-1301	1280 × 1024	18 × 14
Terskol (Russia)	Cassegrain Zeiss-600	7800	60	SBIG STL-1001	1024 × 1024	10×10

OBJECTS

For our research we used data from SDSSDR7WD - Sloan Digital Sky Survey DR7 White Dwarf Catalog, containing 20 thousand white dwarfs.

We collected information on the magnitudes of the white dwarf, obtained in the filters u, g, r, i, z, and calculated the values of u-g, g-r, g-i, and g-z. Figure 2 shows that some white dwarfs are far from the main group of objects.

In our opinion such value excess may be due to the fact that during the object observation, using one of the filters, the white dwarf was eclipsed, possibly, by an exoplanet.

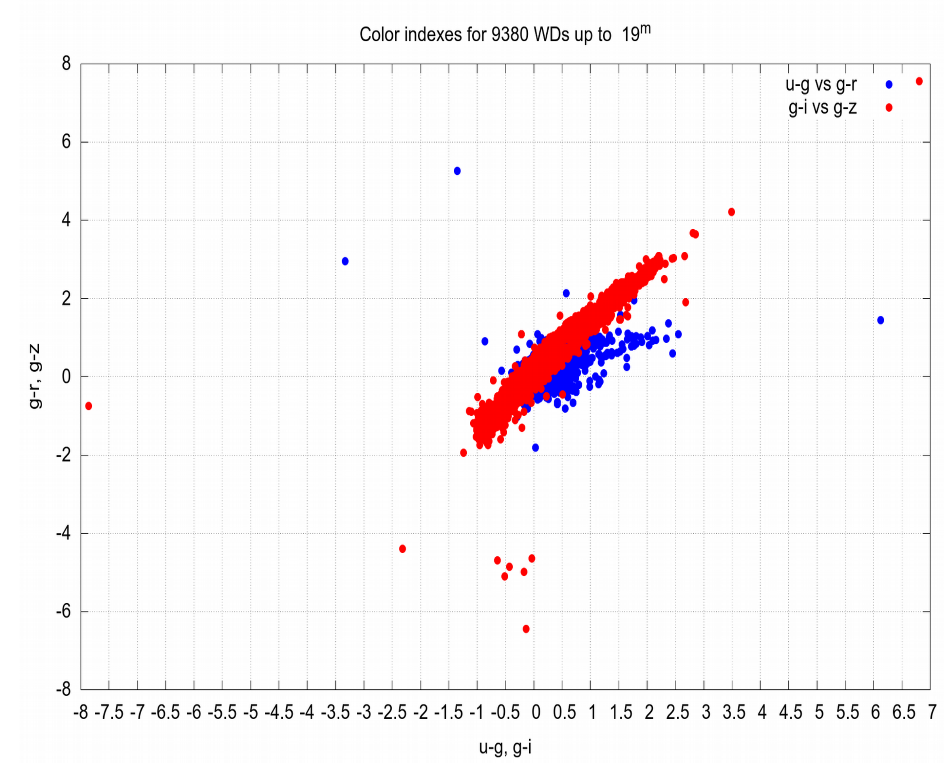


Fig.2. Distribution of white dwarfs by color index.

We have already started the long-term photometric observations using some telescopes that are noted in Tab.1 An overview of these telescopes are in Fig.3.

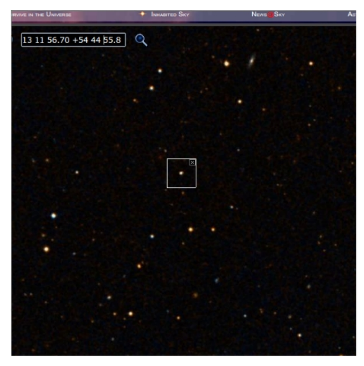
We have selected several objects that are visible in the northern latitudes and whose observations are possible with telescopes of MAO NASU and Astronomical institute of SAS.

Candidate №1 SDSS J070546.78+393453.4

|gmag |umag |rmag |imag |zmag |gmag_extinction
|16.51 |16.11 |16.67|24.37|17.25 | 0.292130
Constellation: Auriga
RA: 07h05m46.63s
Dec: +39∘35'00.0"
Apparent magnitude: 15.15

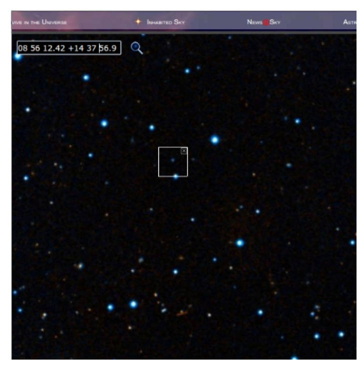
Candidate №2 SDSS J220823.66-011534.0

|gmag |umag |rmag |imag |zmag |gmag_extinction
|21.75 |18.42 |18.79|19.07|19.84 | 0.351438
Constellation: Aquarius
RA: 22h08m23.67s
Dec: -01∘15'33.2"
Apparent magnitude: 18.15



Candidate №3 SDSS J131156.70+544455.8

|gmag |umag |rmag |imag |zmag | gmag_extinction
|18.52 |24.65 |17.07|16.05|15.49 | 0.087918
Constellation: Ursa Major
RA: 13h11m56.95s
Dec: +54∘44'54.1"
Apparent magnitude: 16.5



Candidate №4 SDSS J085612.42+143756.9

|gmag |umag |rmag |imag |zmag | gmag_extinction
|25.08 |23.73 |19.81|18.27|17.52 | 0.165427
Constellation: Cancer
RA: 08h56m12.42s
Dec: +14∘38'00.1"
Apparent magnitude: 18.2

PRELIMINARY RESULTS

At the moment analysis of our obtained observational data shows some effects likes to eclipses. The most striking example of this phenomenon was observed on 17.04.2018 for white dwarf SDSS J131156.70+544455.8 and it is shown in Fig.4. We can see a brightness decreasing of 2 magnitudes with a duration of about 10 minutes. This may well be due to the eclipse of the white dwarf by planet. It is necessary to analyze periodograms as well as to obtain new observations to confirm or refute this statement.

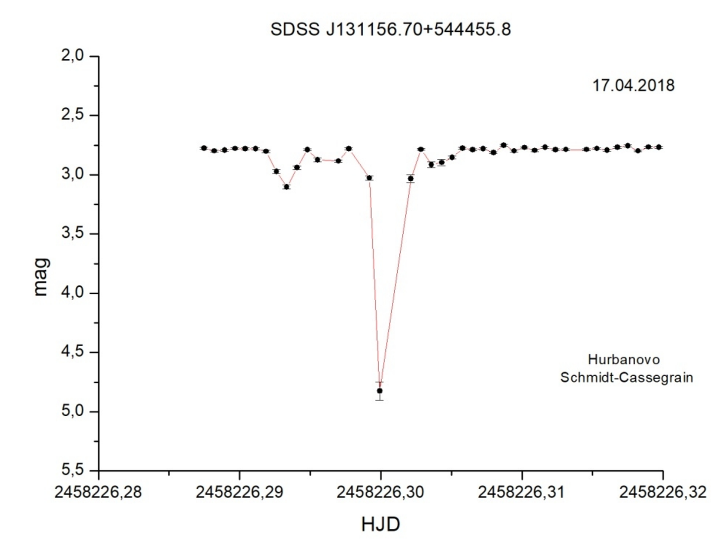


Fig.4. Light curve with eclipse-like minima of SDSS J131156.70+544455.8

CONCLUSIONS

The development of this method and its testing will allow to discover new exoplanets or estimate the limits of distribution probability of giant planets in systems of white dwarfs. Observational data obtained using meter-class telescopes fully satisfy the requirements of the task. In the near future we also plan to use the data from astronomical catalogues.

We will be happy to everyone who is interested in this problem and who wants to join our team for work within the framework of this project.

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