1999JAVSO..27...77W

MONITORING NEARBY STARS FOR TRANSITS BY EXTRASOLAR JOVIAN PLANETS, II: TRANSITS OF M-TYPE (RED) DWARF STARS BY CLOSE EXTRASOLAR GIANT (JOVIAN) PLANETS

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Presented at the 86th AAVSO Annual Meeting, October 25, 1997; revised August 30, 1998.

Abstract

Probabilities are estimated for the occurrence and observation of transits of 849 red dwarfs brighter than visual magnitude 12.0 by their close extrasolar giant (70,000 km radii) planets. The special cases of Gliese 876 and the red dwarf eclipsing binaries CM Draconis and YY Geminorum are also discussed.

1. Introduction

West (1996) showed that transits of a Jupiter-size (70,000 km radius) planet could dim red dwarf stars by 0.08 to 0.37 magnitude; such transits could be detected visually by amateur observers using small- to medium-aperture telescopes. Transits of red dwarfs would be much easier to detect than transits of solar-type stars, which would dim by only about 0.01 magnitude.

The probability P_{tr} for the occurrence of transits of the disk of a star with radius R_s by a planet orbiting it at the mean distance "a" is, assuming random orbit orientation,

$$P_{tr} = (R_s/a), \qquad (1)$$

and, if transits occur, the probability P_{obs} that an observer will observe the planet transiting its star would for a circular orbit, be

$$P_{obs} = (R_s/\pi a). \qquad (2)$$

Equations (1) and (2) show that the transit (photometric) method for detecting extrasolar giant planets favors the discovery of planets orbiting close to their stars.

2. Procedure

We now know of five giant planets orbiting solar-type stars at mean distances from 0.045 a.u. to 0.23 a.u. (Marcy and Butler 1998), which were discovered through precise radial velocity measurements of their stars. Marcy and Fischer (1998) used this method to discover a giant (1.9 Jupiter masses or more) planet orbiting the nearby red dwarf Gliese 876 (spectral type M3.5V) in a close (a = 0.20 a.u.) elliptical (e = 0.37) orbit with a 61-day period, thus demonstrating that extrasolar giant planets also orbit close to red dwarfs. For R_s = 150,000 km, which is typical for a red dwarf, and $0.045 \le a \le 0.23$ a.u., equations (1) and (2) give the range of values $0.00436 \le P_{tr} \le 0.0223$, and $0.0014 \le P_{obs} \le 0.0071$.

A full transit of Gliese 876 by its planet of 70,000 km radius will dim it by 0.27 magnitude, which a visual observer can easily detect. A transit should last from one to three hours.

A search of Gliese and Jahreiss (1991) yielded a total of 1,945 red dwarfs. Their distribution in apparent visual magnitude is shown in Table 1. The 849 red dwarfs brighter than visual magnitude 12.0 can be monitored by many amateur observers, while the 1,096 fainter stars will probably require monitoring by professional astronomers with large telescopes and special equipment.

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Table 1. Apparent visual magnitude distribution of red dwarfs in Gliese and Jahreiss (1991).

Apparent Visual Magnitude (V)	*Number of Stars*
brighter than 7	1
7–8	8
8–9	28
9–10	145
10–11	283
11–12	384
fainter than 12	1,096

3. Results and discussion

One expects that extrasolar planets orbiting red dwarfs in the range of mean distances considered above will have periods of revolution between 200 and 2,000 hours. If giant planets orbit 5% of red dwarfs at the mean distances considered, one expects about 100 nearby red dwarfs to have such close giant planets. The values of P_{tr} found above lead one to expect that one or more such extrasolar giant planets will transit a red dwarf. The small corresponding values for P_{obs} indicate that from 50,000 to 4,000,000 hours of observing time might be needed to monitor thoroughly the selected set of red dwarfs for transits by extrasolar giant planets.

Thus an enormous amount of observing time will be needed to monitor adequately the set of red dwarfs selected above for transits of close giant planets. Moreover, one may reasonably expect to discover only one or a few new extrasolar giant planets. Therefore, an observing program to monitor these nearby red dwarfs for transits by extrasolar giant planets will need the exclusive use of at least one automatic patrol telescope.

Much less observing time may be needed to detect transits by the recently-discovered giant planet of Gliese 876, if they occur, since the intervals at which they might occur during its 1,460-hour orbital period can be found from its radial velocity curve. A full transit by the planet should dim it by about 0.2 magnitude. Also, the P_{tr} values for CM Draconis (Gliese 630.1A) and YY Geminorum (Gliese 278C) could be much larger than predicted by equation (1); this conjecture is based on the coplanarity argument that holds for our solar system, wherein the planes of the planetary orbits are not oriented randomly, but lie in a disk that also contains the Sun's equator. Guinan *et al.* (1996) have already reported a possible transit detection for CM Draconis, which is an eclipsing binary consisting of two red dwarfs that are each similar to Gliese 876 in size, luminosity, and probably mass. The existence of this possible planet may soon be verified by photometric monitoring of this red dwarf binary.

4. Conclusions

(a) A reasonable probability exists that transits of one or more nearby red dwarf stars by their close extrasolar giant planet(s) can be observed.

(b) An enormous amount of observing time (from 50,000 hours to 4,000,000 hours) might be needed to detect a transit of one red dwarf by its extrasolar giant planet.

(c) Much less observing time may be needed to detect transits of Gliese 876 by its giant planet or by giant planets of the red dwarf eclipsing binaries CM Draconis and YY Geminorum.

References

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