# The Planets Found Are the Planets There, Multiplied by How Easy They Are to Find

— The probability of seeing a transit across a Sun-like star is **0.465047** % for an Earth-like planet at **1** AU, **0.089363** % for a Jupiter-like planet at **5.204** AU and **9.300935** % for a hot Jupiter at **0.05** AU — the separator is whether the selection is a cut or a weight — [Paper 781]

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*— From thinking to syncing. —*

**Abstract**

**Lining up the planets found so far, large planets orbiting close to their stars stand out. It is tempting to read that as the lineup of planets in the universe.What weight the transit and stellar-wobble (radial velocity) methods put on the lineup is counted.No new theorem or law is claimed. First, the probability of seeing a transit is inversely proportional to orbital radius——0.465047 % at 1 AU, 0.089363 % at 5.204 AU, 9.300935 % at 0.05 AU** (Section 2). **Second, transit depth is set by size alone——0.008386 % for the Earth-like planet, 1.009827 % for both the Jupiter-like planet and the hot Jupiter** (Section 2). **Third, and this is the core. Without cutting anything away, the lineup changes——the share inside 0.1 AU is 0.150515 in the universe and 0.505051 among transit detections (3.355483 times)** (Section 3). **Fourth, distant planets almost vanish from the lineup——beyond 1 AU, from 0.349485 to 0.040404** (Section 3). **Fifth, a different method puts a different shape of weight——orbital radii reachable at a stellar wobble of 1 m/s are 0.008003 AU for an Earth mass, 2.353218 AU for a Neptune mass and 807.629045 AU for a Jupiter mass** (Section 2). **Sixth, the separator is whether the selection is a cut or a weight ——"the lineup of planets found tells us the lineup of planets in the universe" has no truth value until one says what weight the method applied** (Section 4). **Keywords**: exoplanets, transit method, radial velocity method, selection effect, detection probability, observational bias.

**Scope of this paper (scope note)**: No new theorem or law is claimed——transit depth being the square of the radius ratio, transit probability being the ratio of stellar radius to orbital radius, the formula for the stellar wobble speed, and detected planets being biased by method are all known (Seager, ed., 2010; Perryman 2018).A trial universe is set up——orbital radii uniform in logarithm from $0.05$ to $5$ AU is an arrangement for showing the weight; the real lineup of planets is not claimed.No noise is included——photometric noise, stellar activity and details of observing periods are not treated; for transits only the condition of three transits in four years is included.Orbits are circular——eccentricity and edge effects from planet size are left out.No survey is evaluated——the results or missed counts of real surveys are not treated.Relation to earlier papers: Paper 364 showed that selection alone raises the mean by $1.52$ standard deviations and shrinks the spread to $0.45$——its scope note stated that it worked on standard normal random numbers with the explicit condition of the top $16$ percent. There selection was a cut. Here nothing is cut away, and the lineup is counted as changing merely by applying the weight of detection probability. Selection by cut, and selection by weight.What is added is deriving depth, transit probability, transit duration and wobble speed as a set for three planets, deriving the share of each interval in a trial universe two ways, by formula and by random numbers, showing factors of $\mathbf{3.355483}$ and $\mathbf{0.115610}$, deriving the orbital radii reachable at a wobble threshold for each mass, showing that the shape of the weight differs by method, and placing the separator on cut or weight.

## 1. Notation and the Question

Setting: let the star have radius $R_*$ and mass $M_*$, the planet radius $R_p$ and mass $M_p$, and the orbital radius be $a$. With random orientation, the probability of seeing a transit is $R_*/a$.

$$\delta = \left(\frac{R_p}{R_*}\right)^2, \qquad p_{\mathrm{tr}} = \frac{R_*}{a}, \qquad K = \sqrt{\frac{G(M_* + M_p)}{a}}\,\frac{M_p}{M_* + M_p}$$

In a trial universe with orbital radii uniform in logarithm from $0.05$ to $5$ AU, the share of an interval $[a_1, a_2]$ in the universe and among transit detections is as follows.

$$S_{\mathrm{univ}} = \frac{\ln(a_2/a_1)}{\ln 100}, \qquad S_{\mathrm{tr}} = \frac{1/a_1 - 1/a_2}{1/0.05 - 1/5}$$

Question: does the lineup of planets found reflect the lineup of planets in the universe?

## 2. How Easy Three Planets Are to Find

Computation 2.1: for three planets around a Sun-like star, period, transit depth, transit probability, transit duration and stellar wobble speed were derived. The wobble speed was derived two ways, from orbital speed and from period, agreeing to a relative difference of $3.331 \times 10^{-15}$.

| planet | period | depth | transit probability | duration | wobble speed |
|---|---|---|---|---|---|
| Earth-like (1 AU) | 365.256350 d | 0.008386 % | 0.465047 % | 12.976492 h | 0.089458 m/s |
| Jupiter-like (5.204 AU) | 4334.082456 d | 1.009827 % | 0.089363 % | 29.588156 h | 12.457684 m/s |
| hot Jupiter (0.05 AU) | 4.081749 d | 1.009827 % | 9.300935 % | 2.904440 h | 127.092804 m/s |

> **Observation 2.2**
>
> **visibility of a transit is set by nearness, depth by size.The same Jupiter size gives a transit probability of 9.300935 % at 0.05 AU and 0.089363 % at 5.204 AU, with depth 1.009827 % in both——the same planet becomes about a hundred times harder to find by placement alone.**

**Computation 2.3**: **taking a stellar wobble of 1 m/s as the detection threshold, and using that the wobble speed scales as $a^{-1/2}$, the upper limit of reachable orbital radius was derived for each mass.**

| planet mass | upper orbital radius reachable at 1 m/s |
|---|---|
| Earth mass | 0.008003 AU |
| Neptune mass | 2.353218 AU |
| Jupiter mass | 807.629045 AU |

> **Observation 2.4**
>
> **a different method puts a different shape of weight.Transits weight nearness and size; wobble weights nearness and mass. At the wobble threshold an Earth mass is reached only inside 0.008003 AU, while a Jupiter mass is reached out to 807.629045 AU——the two methods light up different corners of the lineup.**

## 3. The Weighted Lineup

**Computation 3.1**: **in the trial universe, the share of three intervals was derived by formula and also counted with random numbers (400,000 planets given orientation and orbital radius; 8255 showed transits).**

| interval | share in universe | among transits (formula) | same (random) | factor |
|---|---|---|---|---|
| 0.05 to 0.1 AU | 0.150515 | 0.505051 | 0.508904 | 3.355483 |
| 0.1 to 1 AU | 0.500000 | 0.454545 | 0.452816 | 0.909091 |
| 1 to 5 AU | 0.349485 | 0.040404 | 0.038280 | 0.115610 |

**Observation 3.2**

**this is the core: without cutting anything away, the lineup changes.Every planet has some chance of showing a transit, yet the near interval that is 0.150515 of the universe becomes 0.505051 among transit detections ( 3.355483 times)——half the planets found lying inside 0.1 AU does not mean half the universe's planets lie there.**

**Observation 3.3**

**distant planets almost vanish from the lineup.Beyond 1 AU, 0.349485 of the universe falls to 0.040404 among detections (0.115610 times). Requiring three transits in four years sets an upper limit of 1.211414 AU, so 0.307839 of the universe cannot be seen at all, and the share inside 0.1 AU among detections rises to 0.521525——when an observing window overlaps the weight, the lineup shifts still closer in.**

**Observation 3.4**

**the random count agreed with the formula within fluctuation.Per-interval deviations are 0.700, 0.315 and 0.980 standard deviations. The overall fraction showing transits was 2.063750 % in this random sequence (formula 1.999476 %), 2.904 standard deviations off, but pooling 2,000,000 planets from another 20 random sequences gave 2.007550 %, 0.816 standard deviations off——the pooling was done so as not to mistake the scatter of one random sequence for an error in the formula.**

## 4. The Separator

**Observation 4.1**

**the separator is whether the selection is a cut or a weight.With a cut, the lineup of what remains is set by the threshold. With a weight, nothing is discarded, yet the shape of the detection probability is multiplied straight onto the lineup——“the lineup of planets found tells us the lineup of planets in the universe” has no truth value until one says what weight the method applied.**

**Observation 4.2**

**beside Paper 364.Paper 364 kept the top 16 percent by a cut and showed the mean rising by 1.52 standard deviations——here nothing is cut, and the $1/a$ weight alone is counted as multiplying the near interval’s share by 3.355483.**

**Observation 4.3**

**what is not said.The trial universe is an arrangement, and neither the real lineup of planets, nor noise and stellar activity, nor the results of real surveys are treated——what is shown is that the lineup found is the product of the universe’s lineup and the weight.**

## 5. Roll Call and Closing

1. **transit probability 0.465047 %** (Computation 2.1): **Earth-like at 1 AU.**
2. **9.300935 % and 0.089363 %** (Observation 2.2): **the same Jupiter, placed differently.**
3. **depth 1.009827 %** (Computation 2.1): **set by size.**
4. **0.150515 in the universe** (Computation 3.1): **the near interval.**
5. **0.505051 among detections** (Observation 3.2): **the core.**
6. **factor 3.355483** (Computation 3.1): **the size of the weight.**
7. **0.349485 to 0.040404** (Observation 3.3): **distant planets vanish.**
8. **0.521525 with three transits** (Observation 3.3): **a window overlaps.**
9. **Jupiter mass 807.629045 AU** (Computation 2.3): **the wobble’s weight.**

10. **cut or weight** (Observation 4.1): **the separator; Paper 364.**

**Closing**: **The planets found are the planets there, multiplied by how easy they are to find.The probability of seeing a transit across a Sun-like star is 0.465047 % for an Earth-like planet at 1 AU, 0.089363 % for a Jupiter-like planet at 5.204 AU and 9.300935 % for a hot Jupiter at 0.05 AU, inversely proportional to orbital radius——depth is set by size, visibility by nearness.In a trial universe with orbital radii uniform in logarithm from 0.05 to 5 AU, the share inside 0.1 AU rises from 0.150515 of the universe to 0.505051 of detections (3.355483 times), and the share beyond 1 AU falls from 0.349485 to 0.040404. Nothing is cut away, yet the shape of detection probability is multiplied straight onto the lineup——searching by stellar wobble moves the weight to mass and $a^{-1/2}$, lighting a different corner of the lineup.The separator is whether the selection is a cut or a weight.Placed among the earlier papers——Paper 364 counted selection by cut; this counts selection by weight.To be honest——the trial universe is an arrangement, and neither the real lineup of planets, nor noise, nor survey results are treated.**

## References


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