White Paper Roman's Core Community Surveys

Combining transits with microlensing

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Abstract

Introduction
Among the detection methods of exoplanets microlensing and transits give complementary results. The microlensing detection gives the mass of the planet, but only the project semi-major axis at a given epoch of the orbital revolution and not the radius. The transit method gives the radius and, through the directly observed orbital period, the semi-major axis, but not the mass without the help of amplitude of the radial velocity variation or astrometry of the star. The latter are sometimes not possible because of the stellar activity and/or faintness.
Here I show that the Nancy Grace Roman Telescope will improve the mass determination with the combination of the two methods.

The combination of microlensing and transits.
Let's start from the sample of planets detected by microlensing. Some of them could also make a planetary transit. Here I estimate the number of transiting planet in the sample of planets detected by microlensing with the Nancy Grace Roman Telescope.

Consider a microlensing event consisting in the observation of the amplification of a background star by a foreground star and its planet. From the analysis of the lightcurve one infers the masses and of the planet and its parent star and the the projection of the planet orbit semi-major axis at the time of the microlensing event.

Suppose that the inclination of the planet orbit is close to 90° so that it transits its parent star at some point of its orbital revolution. The transit event will be characterized by its time internal ΔT with respect to the microlensing event. As shown in Figure 1, ΔT is related to the orbital period P by the relation

$$\Delta T = P\beta/2\pi \qquad (1)$$

for the lensing configuration (1) or , for the configuration (2), by

$$\Delta T = P(\pi - \beta)/2\pi \qquad (2)$$

It is also clear from Figure 1 that the planet semi-major axis a is related to projected star-planet separation a_{Pr} at the time of microlensing by the expression

$$a = a_{Pr}/\cos\beta \qquad (3)$$

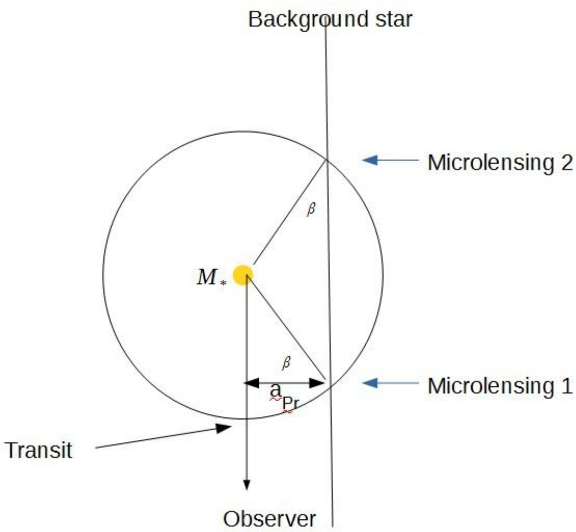

Figure 1 Microlensing of the background star and transit of the parent star by the planet

Then, using the Kepler law $P=2\pi\sqrt{a^3/GM_*}$, one finds after some algebra, that the period P can be inferred from the observables ΔT , a_{Pr} and the mass M_* of the foreground lensing star by

$$P=\frac{2\pi\Delta T}{\alpha}=\frac{2\pi\Delta T}{\frac{\pi}{2}-\arccos[(\frac{4\pi^2 a_{Pr}^3}{GM_*\Delta T^2})^{1/3}]} \qquad (3)$$

Since is a_{Pr} necessarily smaller than a, the period P is necessarily larger than $P=2\pi\sqrt{a_{Pr}^3/GM_*}$.

The transits may be detected by Roman itself, by Cheops, Euclid or later by Plato.

Probability of transits

For a single star-planet system, the geometric probability p of a transit

$$p=R_*/a \qquad (4)$$

The probability that, among N microlensing events, at least one leads to a transit is

$$p=1-\prod_{1}^{N}(1-p_i) \qquad (5)$$

where p_i is the probability of transit of the i^{th} event.
The mean expected number of transits is then, for a mean 2 AU for planets detected by microlensing (Figure 2), and assuming a one solar radius for the parent star,

$$p = 1 - \prod_{1}^{N} (0.9977) \qquad (6)$$

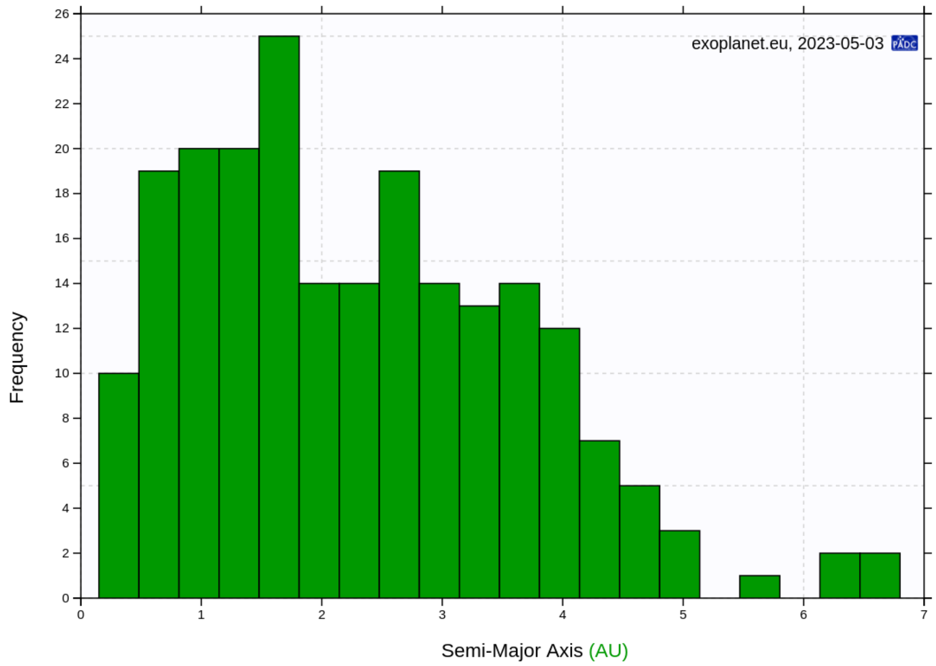

Figure 2 Distribution of semi-major axis for microlensing planets

From the 238 planets detected by microlensing as of May 1st 2023, one gets p = 0.42 .

The expected number of transits is then given by

$$N_{transit} = \sum_{1}^{N} p_i = 0.0023\, N$$

If Roman detects 5000 microlensing planets with a semi-major axis distribution similar to Ogle, MOA and KMT campaigns, 13 of them should present a transit.

References

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