Circumbinary planets: detection limits and occurrence rates

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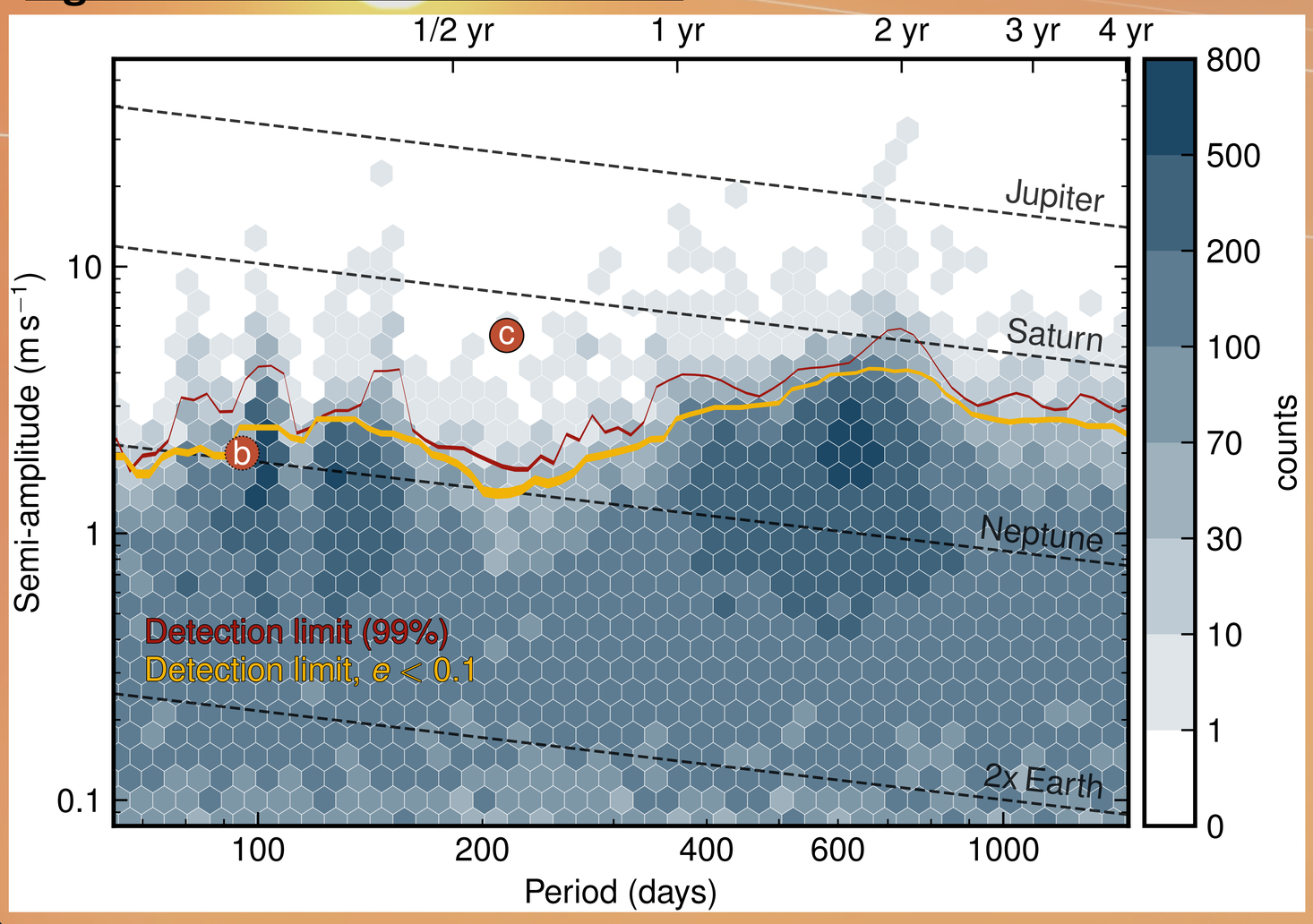
Overview: Circumbinary planets orbit around both stars of a binary star system and challenge our understanding of planet formation and orbital evolution. Planet formation was thought to be difficult in these binary star systems, yet now 15 circumbinary planets have been discovered in 13 systems. The BEBOP survey discovered the first CBP with radial-velocity (RV) observations alone, BEBOP-1c [1] (scan QR code). Detection limits are commonly calculated using injection and recovery tests. This is computationally heavy and time consuming, therefore circular orbits are commonly assumed. Here I present an **alternative method to calculate detection limits** using Bayesian nested sampling which is fast to compute, robust, and requires less assumptions. I apply this method to the entire BEBOP South sample and calculate preliminary occurrence rates for the survey.

Fig 1. BEBOP-1 detection limit[1]

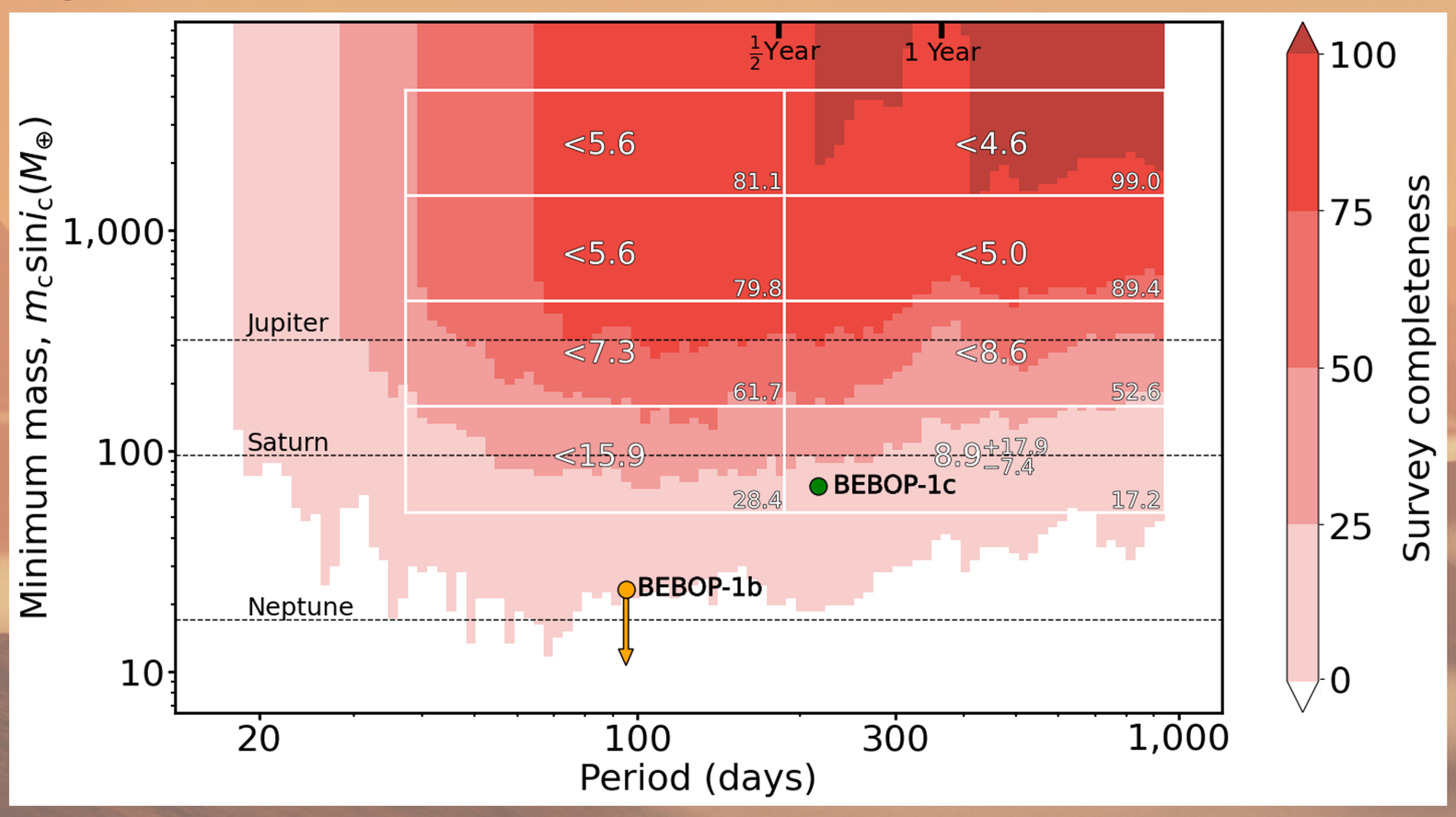


To calculate detection limits using *kima* [2], a nested sampling algorithm which fits Np Keplerian signals simultaneously, we:

1. Subtract the highest-likelihood posterior sample corresponding to Np detected planets from the data.
2. Fit for an additional planetary signal in the data, this gives posterior samples that correspond to undiscovered signals still compatible with the data.
3. Calculate the 99% upper limit on the semi-amplitude in period bins to obtain the detection limit.

We find that **using only samples with e<0.1 provides overoptimistic detection limits by 20-40%** and we therefore **advise against assuming circular orbits for calculating detection limits** [3].

Fig 2. Completeness and occurrence rates for BEBOP



Calculating detection limits for the entire BEBOP survey South sample (65 systems) allows us to calculate our survey's "completeness", or our sensitivity to certain regions of parameter space (the red regions in Fig 2).

With this completeness we calculate the preliminary occurrence rates as in [4] for circumbinary planets for our Southern sample (the white boxes in Fig 2).

These circumbinary planet occurrence rates agree with [5,6], and those of gas giants around single stars [7,8]. More details can be found in [9]. With observations ongoing, more robust occurrence rates will be available soon.

References

[1] Standing, M.R. et al. (2023) NatAstro [2] Faria, J.P. et al. (2018) JOSS [3] Standing, M.R. et al. (2022) MNRAS [4] Martin, D.V. et al. (2019) A&A
[5] Armstrong, D.J. et al. (2014) MNRAS [6] Asensio-Torres, R. et al. (2018) A&A [7] Cuming, A. et al. (2008) PASP
[8] Wittenmyer, R.A. et al. (2020) MNRAS [9] Standing, M.R. (2022) Thesis

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