The Influence of Photometry on Deconfusion of Directly Imaged Multi-Planet Systems

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1. The Confusion Problem

- Directly imaged multi-planet systems (with future observatories like HWO, ELTs, or Roman) are likely to introduce a "confusion" problem, making it difficult to differentiate between Earth-like and non-Earth-like planets[1]
- Confusion arises from not knowing which detection in a set of images belongs to which planet (see Fig. 1), due to lack of prior knowledge about orbital parameters or planetary characteristics[1, 2].

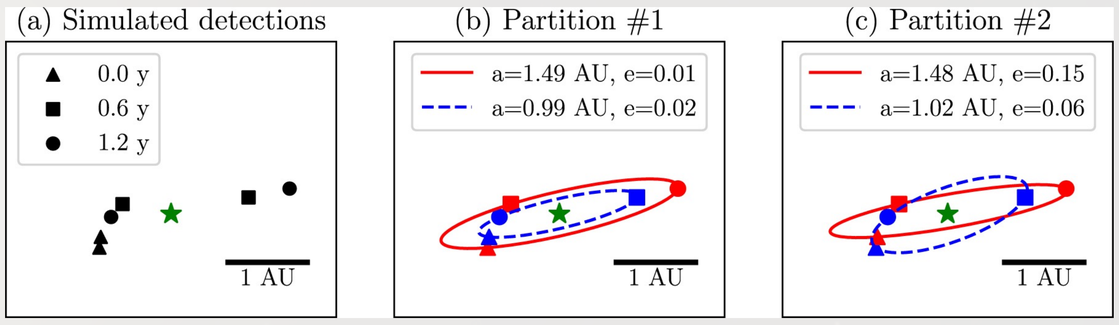


Fig. 1. The confusion problem from [1]. Three simulated detections of a 2-planet system over a period of 1.2 years (left). Orbits can be assigned (partitioned) in multiple different ways, resulting in substantially different orbit fits for the system (center and right).

- The "deconfuser" was developed to address confusion by:
  - Deconfusing directly imaged planetary systems
  - Predicting confusion rates of simulated planetary systems
- MC simulations with the deconfuser indicate higher probability of confusion for high-inclination systems[1]. High-*i* systems offer the greatest potential for reducing confusion with the addition of photometric considerations.

2. Deconfusion with Photometry

- We developed a method to augment the deconfuser's ranking metrics and incorporate planetary phase information.
- We developed a photometry model, noise model, and likelihood ranking scheme to expand the existing orbit ranking scheme
- The flow of the expanded ranking scheme is shown in Figure 2:
  1. Accept orbital geometry of the planet detections as determined by the deconfuser
  2. Calculate the expected flux ratio and photon count rate at the detector for each observation
  3. Add detector properties (e.g., read noise, dark current) to simulate noisy detection
  4. Calculate likelihood of each detection given measured photometry
  5. Calculate likelihood of each orbit
  6. Compare orbit options

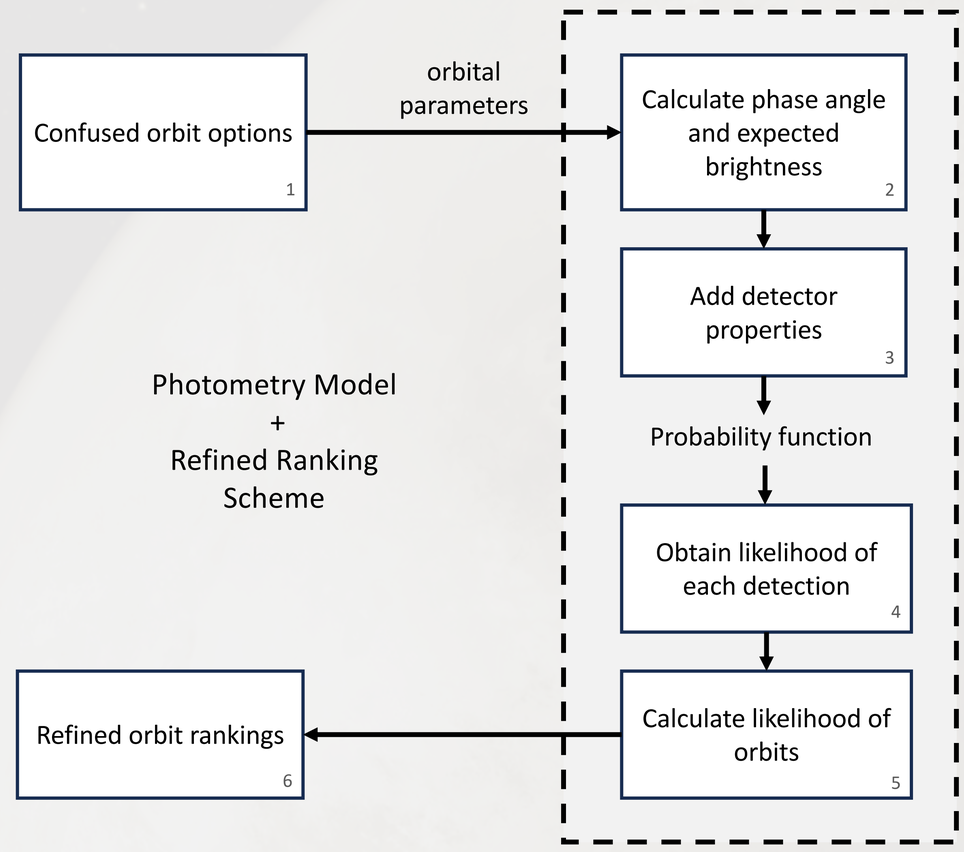
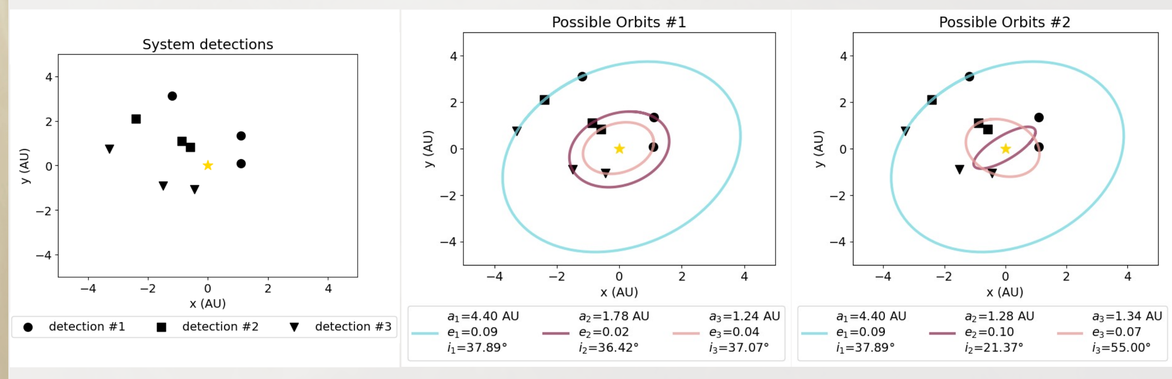


Fig. 2. Flow of the photometry ranking algorithm as it fits within the deconfuser.

3. Analysis of a Confused System

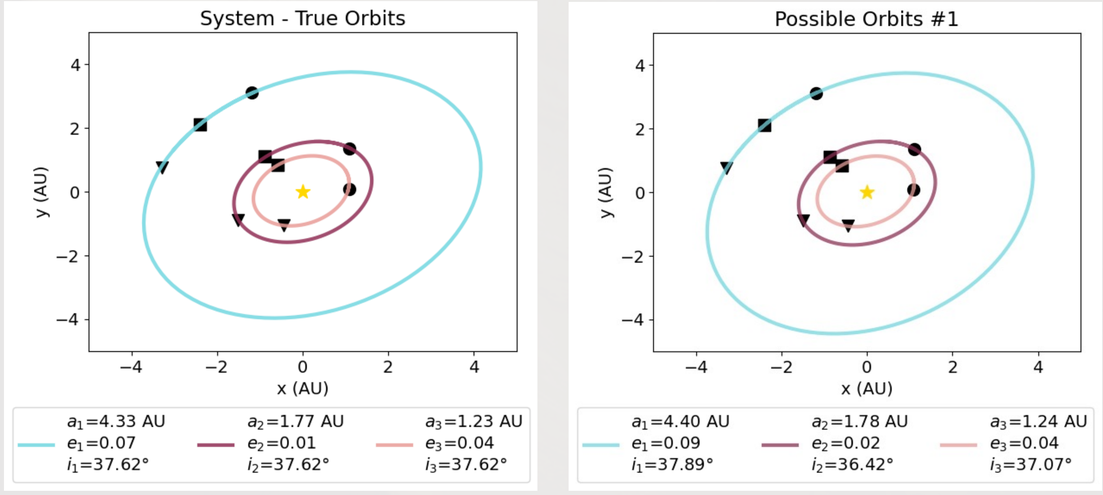
With only astrometry



? ?

With astrometry + photometry

L_option 1 > L_option 2



Deconfused!

Stay tuned for Hasler et al. with full photometry analysis, coming soon!

Acknowledgements
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References

[1] Pogorelyuk, L., Fitzgerald, R., Vlahakis, S., Morgan, R., and Cahoy, K. (2022). ApJ, 937(2):66.
[2] Keithly, D. R. and Savransky, D. (2021). ApJL, 919(1):L11.