Searching for triple-detection Planet Nine candidates using FIR all-sky survey data

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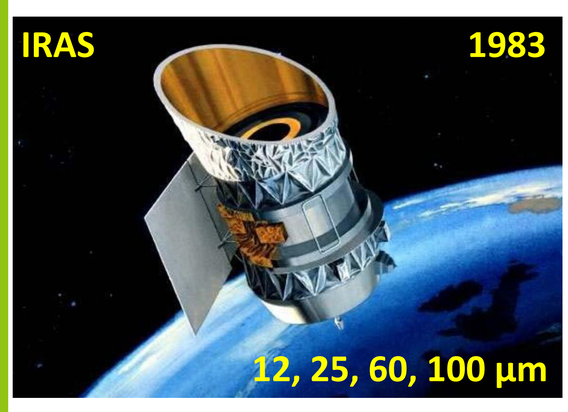
Introduction

The outer solar system is theoretically predicted to harbor an undiscovered planet, often referred to as Planet Nine (P9). Simulations suggested that its gravitational influence could explain the unusual clustering of Kuiper Belt Objects [1]. However, there has been no observational evidence for the existence of P9 so far, since its predicted orbit is distantly beyond Neptune's, where it reflects only a faint amount of Sunlight. As a result, P9 was expected to be very faint in optical. Such a large distance led to the need for far-infrared (FIR) all-sky surveys to detect the thermal radiation from P9. Extended from our recent study [2], this work aims to search for triple-detection P9 candidates in data of two FIR surveys based on the expected orbital motion and parallax motion of P9.

Data & Method

Far-Infrared All-Sky Surveys



Credit: NASA/JPL-Caltech

Credit: ISAS/JAXA

- Use IRAS catalogs and a dedicated source list for P9 search called "AKARI Monthly Unconfirmed Source List" (AKARI-MUSL) including sources moving over months.
- Estimate flux and orbital motion of P9 by assuming the black-body radiation with $7M_{\oplus} \leq M_{P9} \leq 17M_{\oplus}$; 280 AU $\leq d_{P9} \leq$ 700 AU; and T = 50 K [3].
- First, search for sources moving slowly from an IRAS position to an AKARI one over 23 years within $42' \leq \theta_1 \leq 166'$ (pairs).
- Then, continue to search for sources moving from the above AKARI position to another AKARI one over 6 months due to parallax motion within $10.2' \leq \theta_2 \leq 25.5'$ (triplets).

Flowchart of P9's Selection Process

Above detection limits	Remove too bright/identified sources	Exclude the Galactic plane/bulge regions	Search for pairs	Search for triplets	Visual image inspection
AKARI: 996,342 sources IRAS: 1,385,202 sources		AKARI: 42,261 sources IRAS: 2,911 sources	4470 pairs	242 triplets	

Result & Future Work

Requirements for a good candidate

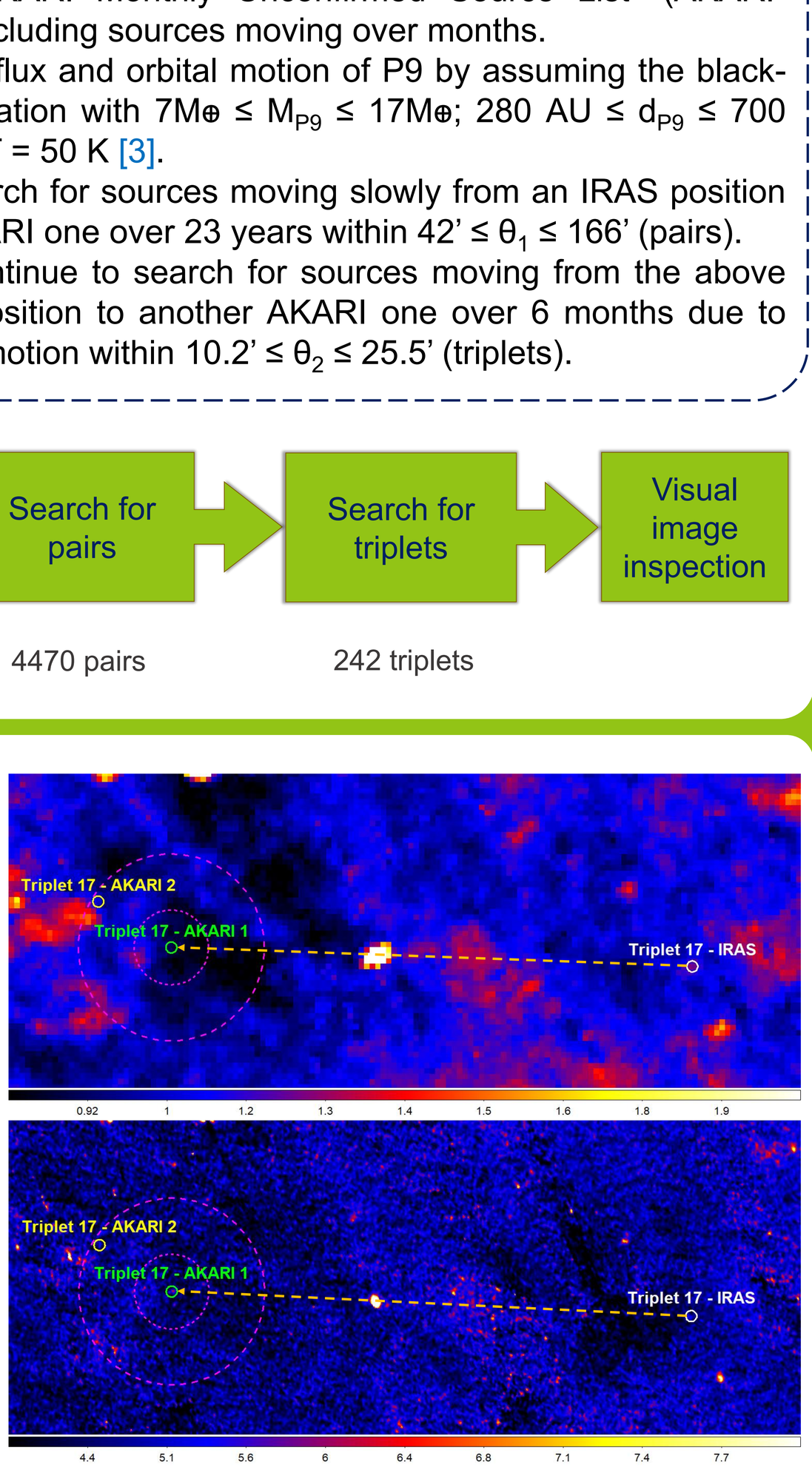
- Both IRAS and AKARI images do not contain the cirrus region
- IRAS source is absent from the same position in AKARI image and vice versa.
- IRAS and AKARI positions do not include pixel-missing regions in both images.

Any good candidates?

- After manually checking images of the first 60 triplets, we found one good candidate (see the figure).
- θ_1 = 142.7' and θ_2 = 23.5', indicating that 304 AU $\leq d_{P9} \leq$ 310 AU.

What's next?

- Check images of remaining triplets.
- AKARI detection probability maps are necessary for detection epochs of AKARI 1 and AKARI 2 components.



Top panel: IRAS image, Bottom panel: AKARI image

Reference

1. Konstantin Batygin and Michael E. Brown 2016 *AJ* **151** 22 (DOI: 10.3847/0004-6256/151/2/22)
2. Terry L. Phan *et al* 2025 *PASA* **42** e064 (DOI: 10.1017/pasa.2025.10024)
3. Nicolas B. Cowan *et al* 2016 *ApJL* **822** L2 (DOI: 10.3847/2041-8205/822/1/L2)