Finding Planet 9 In the AKARI Image

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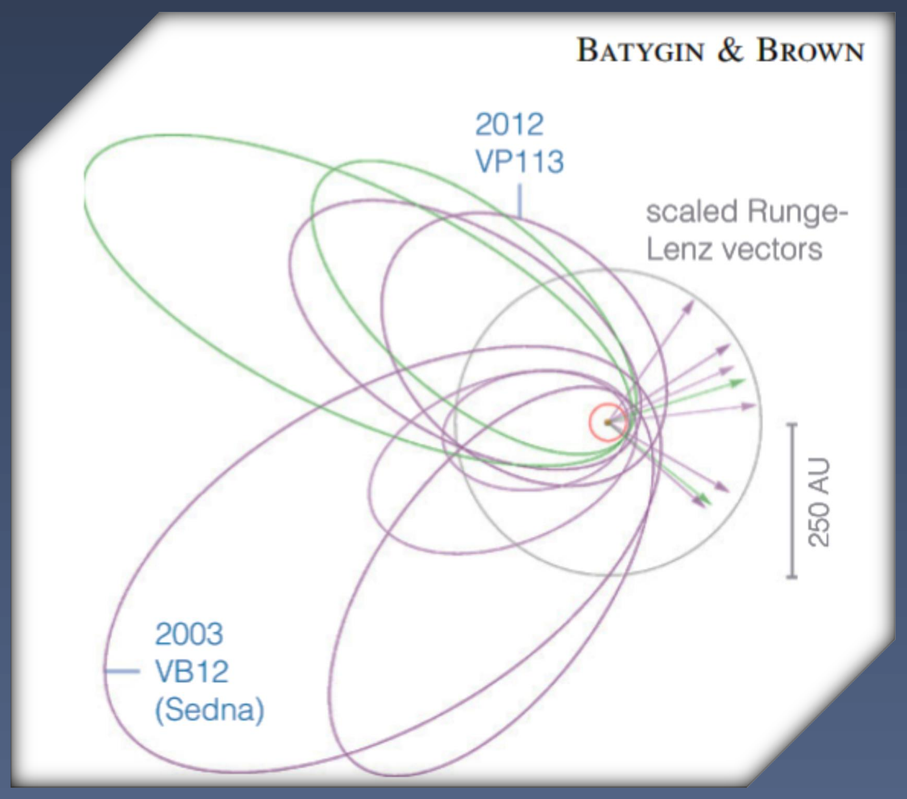
Why we believe P9 exist

The clustering of many distant Kuiper Belt Objects (KBO) has been considered as the evidence of a giant planet called Planet 9 (P9) for a long time (Batygin & Brown 2016), thus we believe there is another giant planet outside the Neptune's orbit.

There are various works that search for P9 (e.g, Cowan et al. 2016; Brown & Batygin 2022; Sedgwick & Serjeant 2022) in different catalogs.



This figure shows the clustering of KBOs.

Each ellipse represents one KBO's orbit.

AKARI

The reflected Sun light from P9 is too faint, so we aim to detect grey body radiation from P9 in the infrared.

Space telescope AKARI is developed by JAXA/ISAS , launched in 2006 and completed the operation in 2011. It was designed to make an all-sky survey in the infrared band (1.7~180μm).

In this work, we selected P9 candidates from AKARI's Test Source Catalog (Yamamura et al. 2010). This catalog is made of sources rejected from Bright Source Catalog, which represent it contains moving sources. Since the most sensitive band is 90μm, so we selected candidates based on sources' 90μm flux density.

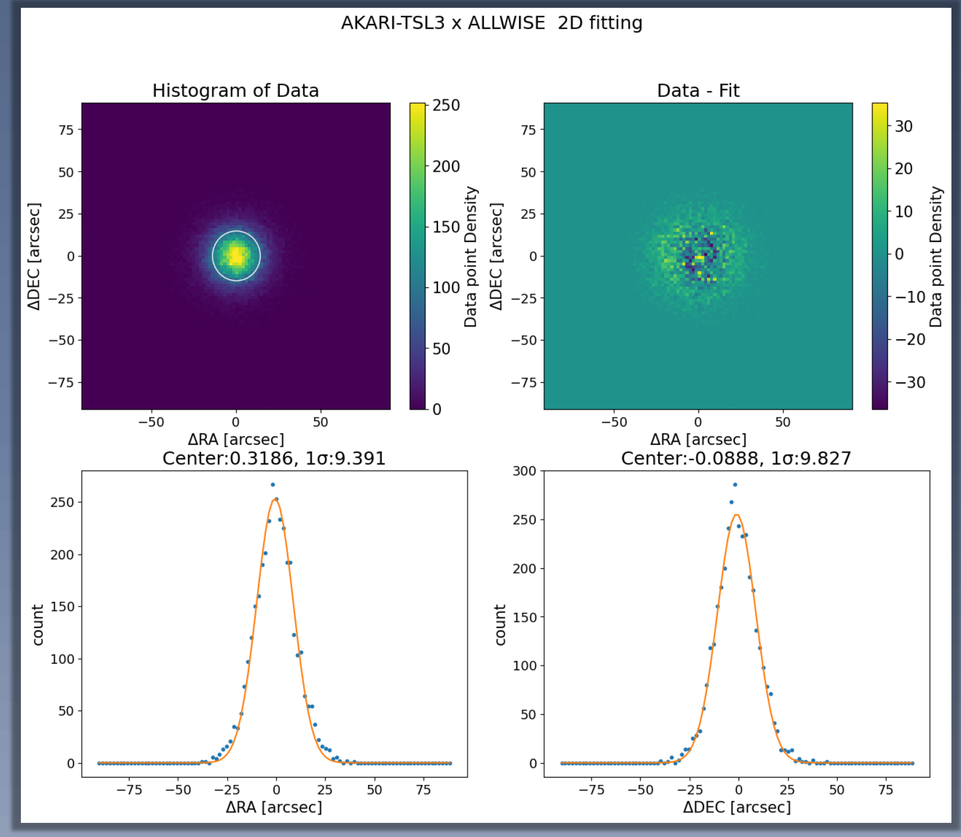
Method

We cross-match AKARI Test Source Catalog with these 11 catalogs.

Table 2. The 2D-Gaussian fitting result of the (ΔRA, ΔDEC) in unit of arcsecond. $(\Delta RA_C, \Delta DEC_C)$ is the center of the 2D Gaussian fitting, which means the overall shift of that catalog with AKARI

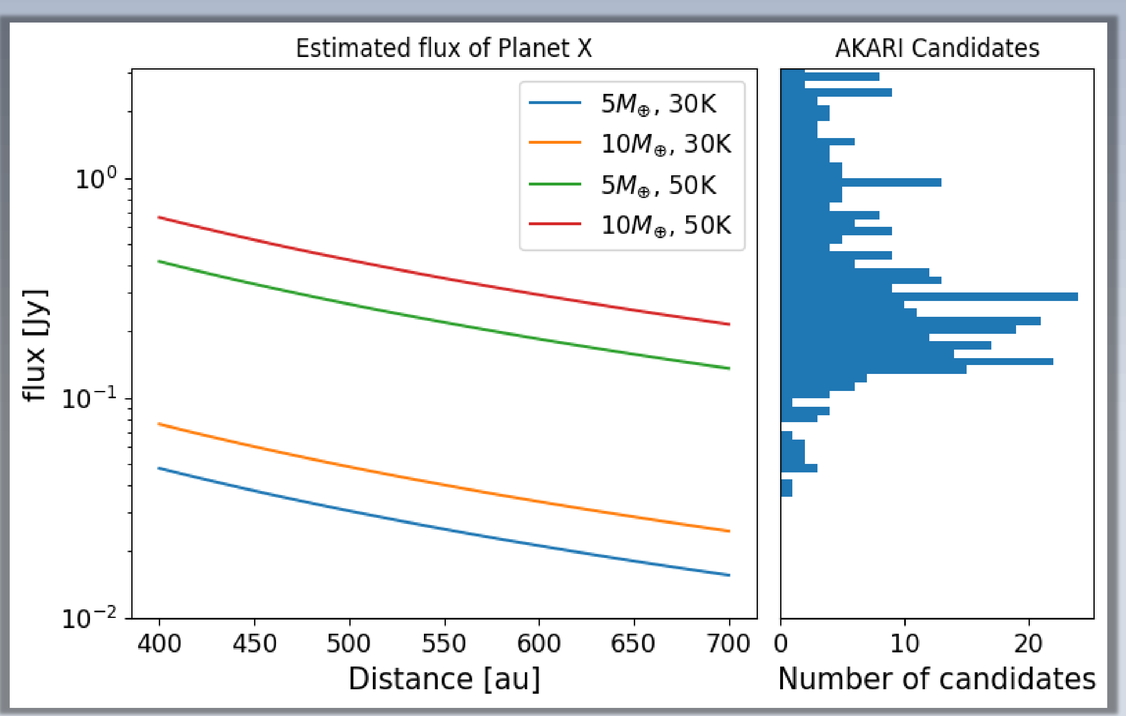
Catalog Name	$\sigma_{\Delta RA}$	$\sigma_{\Delta DEC}$	$(\Delta RA_C, \Delta DEC_C)$
2MASS	5.872	7.429	(0.6890, -0.5711)
NOMAD	12.354	12.812	(0.2555, -0.4098)
PS1	9.257	9.388	(0.1348, -0.0560)
WISE	11.216	11.561	(0.3079, -0.1642)
ALLWISE	9.793	10.032	(0.2153, -0.0679)
CatWISE	7.244	7.195	(0.0943, -0.0667)
unWISE	7.151	7.184	(0.1289, -0.0526)
SIMBAD	4.451	5.515	(0.8619, -0.5320)
SDSS DR16	7.162	7.174	(0.0706, -0.0460)
IRAS PSC	7.390	5.163	(1.0773, -0.7455)
IRAS FSC	11.367	6.594	(1.0551, 0.0243)

1. Select sources with low background flux to refrain from the cirrus contamination.
2. Based on the simulation result (Millholland & Laughlin 2017), we select candidates in the region 30°<RA<50° and -20°<DEC<20°.
3. Cross-matching AKARI with other catalogs to exclude the known sources. This criteria is determined by applying Gaussian fitting to the displacement of all AKARI sources and consider sources with that larger than 2σ as unknown sources.
4. These unknown sources can be the P9 candidates if they agree with expected motion of P9.



Example of step 3's fitting. This is the case cross matching with ALLWISE.

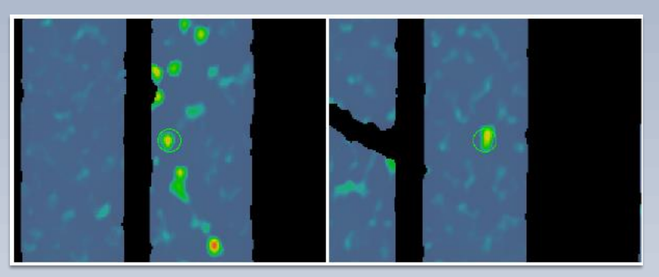
Candidates



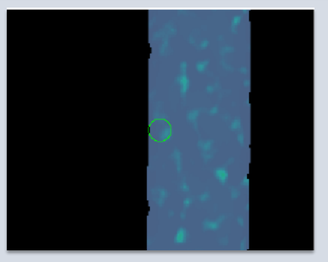
Up to step 3, we selected 413 P9 candidates from the Test Source Catalog and will filter out more in step 4.

In the left figure, we calculate the expected flux of P9 in the 90μm wavelength with different mass and temperature. This parameter range is inferred by different simulations (Batygin & Brown 2016, Cowan et al. 2016). The candidates histogram is shown left and they are able to cover the 10 Earth mass parameter space.

Good candidate



Detected in the same day 2006/07/29



No detection at the same place 2007/01/26