Astrophysical artefact in the astrometric detection of exoplanets?

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Work in progress

- Dynamical and brightness astrometry
- Astrophysical sources of excess brightness
  - Simulations
  - Observations
- Conclusion
Context

Ultimate goal: the precise physical characterization of Earth-mass planets in the Habitable Zone (~ 1 AU) by direct spectro-polarimetric imaging

It will also require a good knowledge of their mass.

Two approaches (also used to find Earth-mass planets):

- Radial Velocity measurements
- Astrometry
Radial Velocity and Astrometric mass measurements have both their limitations.

Here we investigate a possible artefact of the astrometric approach for the Earth-mass regime at 1 AU.

==> not applicable to Gaia or PRIMA/ESPRI

Very simple idea:

can a blob in a disc mimic the astrometric signal of an Earth-mass planet at 1 AU?
Dynamical and brightness astrometry

- Dynamical astrometry

- Brightness (photometric) astrometry

**Question:** can $\Delta \alpha_{ph}$ be > $\Delta \alpha_B$?

\[
\Delta \alpha_B = \frac{M_C a}{M_* D}
\]

\[
\Delta \alpha_{ph} = \frac{l_2 a}{l_1 D} - \Delta \alpha_B = \left( \frac{l_2}{l_1} - \frac{M_C}{M_*} \right) \frac{a}{D}
\]
Dynamical and brightness astrometry

\[ \Delta \alpha_B = \frac{M_C}{M_*} \frac{a}{D} \sim 3 \times 10^{-6} \frac{a}{D} \]

for a 1 Earth-mass planet

\[ \Delta \alpha_{ph} = \frac{l_2}{l_1} \frac{a}{D} - \Delta \alpha_B \sim \frac{l_2}{l_1} \frac{a}{D} \]

Can \( \frac{l_2}{l_1} \) be > \( 3 \times 10^{-6} \)?
Dynamical and brightness astrometry

\[ \Delta \alpha_B = \frac{M_c}{M_* D} \sim 3 \times 10^{-6} \frac{a}{D} \]

\[ \Delta \alpha_{ph} \sim \frac{l_2}{l_1 D} = \frac{A}{4} \left( \frac{R_C}{a} \right)^2 \frac{a}{D} = \frac{A}{4} \frac{R_C^2}{aD} \]
Dynamical and brightness astrometry

- \( \Delta \alpha_B = \frac{M_C}{M_*} \frac{a}{D} \sim 3 \times 10^{-6} \frac{a}{D} \)
- \( \Delta \alpha_{ph} \sim \frac{l_2}{l_1} \frac{a}{D} = A \left( \frac{R_C}{a} \right)^2 \frac{a}{D} = A \frac{R_C^2}{4 aD} \)

Can \( \Delta \alpha_{ph} \) be larger than \( \Delta \alpha_B \) at 1 AU?

Condition: \( A/4(R_C^2/1AU) > 3.10^{-6} \sim 100 R_{jup}^2 \quad \Rightarrow \quad AR_C^2 > 50 R_{jup}^2 \)

Explore sources of low mass objects brighter than 50 Jupiter at 1 AU

Past experience: Anything can happen in exoplanetology
Astrophysical sources of brightness excess

- Simulations

Astrophysical sources of brightness excess

- Observations
  - Earth's dust ring (Reach, Icarus, 209, 848, 2011)

About \( N = 10 \) blobs \( 0.1 \text{ AU} \times 0.1 \text{ AU} \)

\[ = 200 \times 200 \ R_{jup}^2 \]

Assuming a dust albedo 0.01,

\[ AR_C^2 > \sim 10^3 R_{jup}^2 \]

for each blob and at 1 AU:

\[
\Delta \alpha_{ph} \sim \frac{1}{\sqrt{N}} \frac{A}{4} \left( \frac{R_C}{a} \right)^2 \frac{a}{D} = \frac{A}{12} \frac{R_C^2}{aD} = 0.015 \frac{R_{jup}}{D}
\]

\[ \sim \Delta \alpha_B \text{ for } 1M_{Earth} \text{ at } 1 \text{ AU} \]
Astrophysical sources of brightness excess

• Observations
  – Fomalhaut b

Companion 400 brighter than a Jupiter at 100 AU

Interpretation: dust cloud around a planet

Open question: Can such dust clouds exist at 1 AU?
Conclusion

The photocenter variation can possibly be larger than the 1 Earth mass astrometric signal at 1 AU.

To measure terrestrial planet masses at 1 AU, astrometric measurements must be combined with high contrast high angular resolution imaging.