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

Context

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.

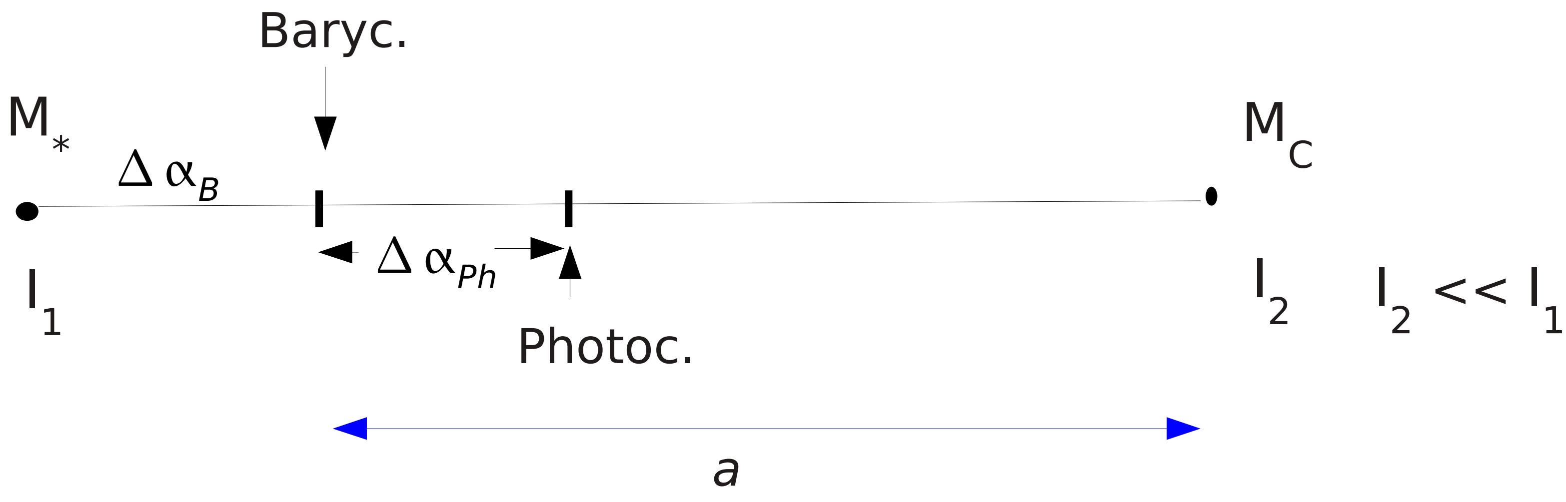
==> **not applicable to Gaia or PRIMA/ESPRI**

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

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

- Brightness (photometric) astrometry

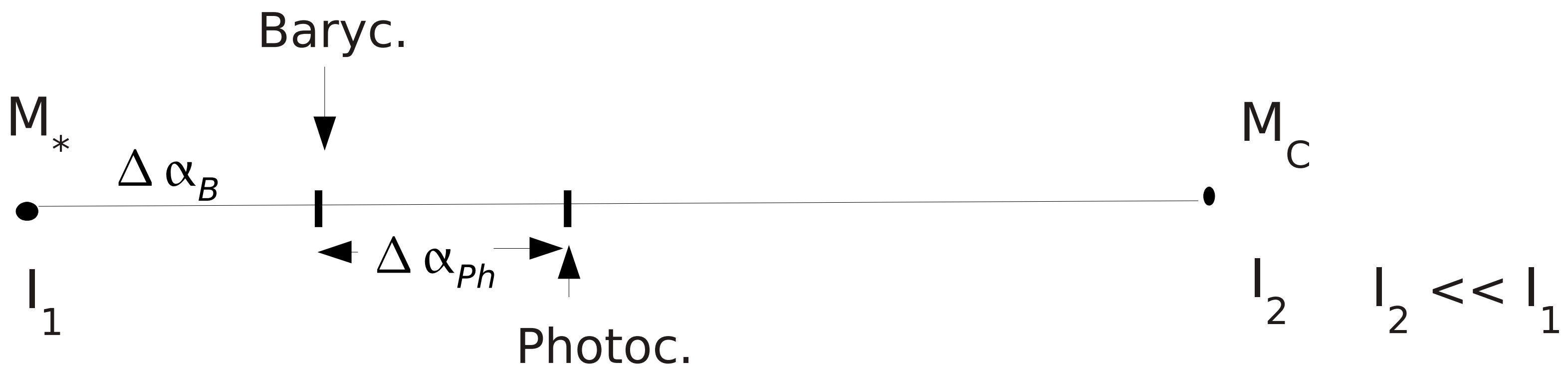
$$\Delta\alpha_{Ph} = \frac{I_2}{I_1}\frac{a}{D} - \Delta\alpha_B = \left(\frac{I_2}{I_1} - \frac{M_C}{M_*}\right)\frac{a}{D}$$

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

Dynamical and brightness astrometry

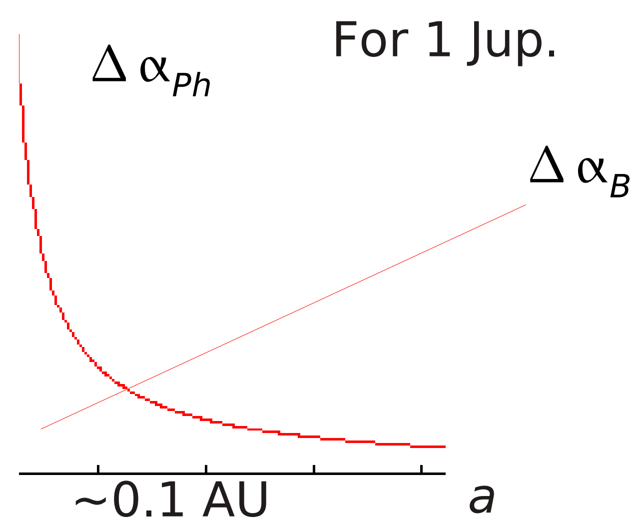
- $\Delta\alpha_B = \frac{M_C}{M_*}\frac{a}{D} \sim 3\,x\,10^{-6}\frac{a}{D}$ for a 1 Earth-mass planet
- $\Delta\alpha_{Ph} = \frac{I_2}{I_1}\frac{a}{D} - \Delta\alpha_B \sim \frac{I_2}{I_1}\frac{a}{D}$ **Can I_2/I_1 be > $3x10^{-6}$?**

Dynamical and brightness astrometry



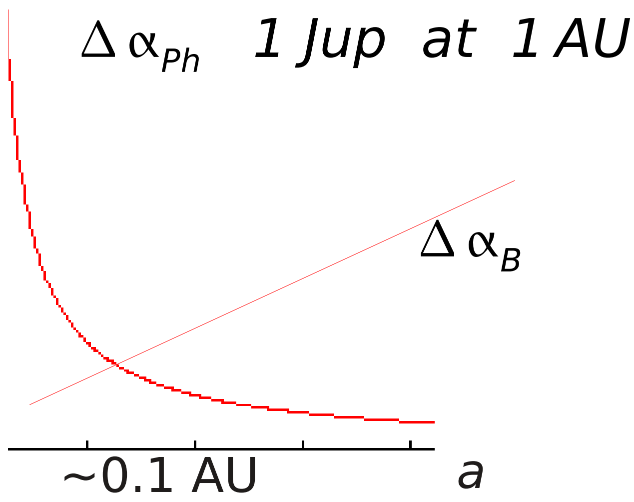
- $$\Delta\alpha_B = \frac{M_C}{M_*}\frac{a}{D} \sim 3\,x\,10^{-6}\frac{a}{D}$$

- $$\Delta\alpha_{Ph} \sim \frac{l_2}{l_1}\frac{a}{D} = \frac{A}{4}\left(\frac{R_C}{a}\right)^2\frac{a}{D} = \frac{A}{4}\frac{R_C^2}{aD}$$



Dynamical and brightness astrometry

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



Can $\Delta\alpha_{Ph}$ be larger than $\Delta\alpha_B$ at 1 AU ?

Condition: $A/4(R_C^2/1AU) > 3.10^{-6} \sim 100\,R_{Jup}^2$ ==> $AR_C^2 > 50\,R_{Jup}^2$

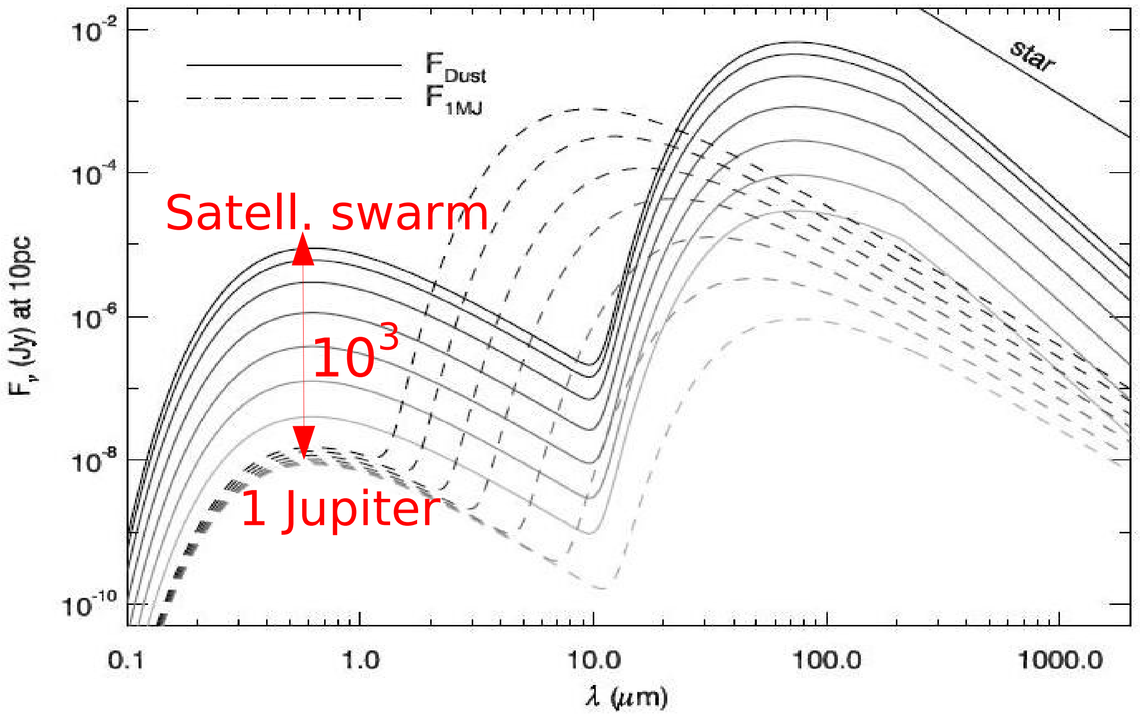
Explore sources of low mass objects brighter than 50 Jupiter at 1 AU

Past experience: Anything can happen in exoplanetology

Astrophysical sources of brighness excess

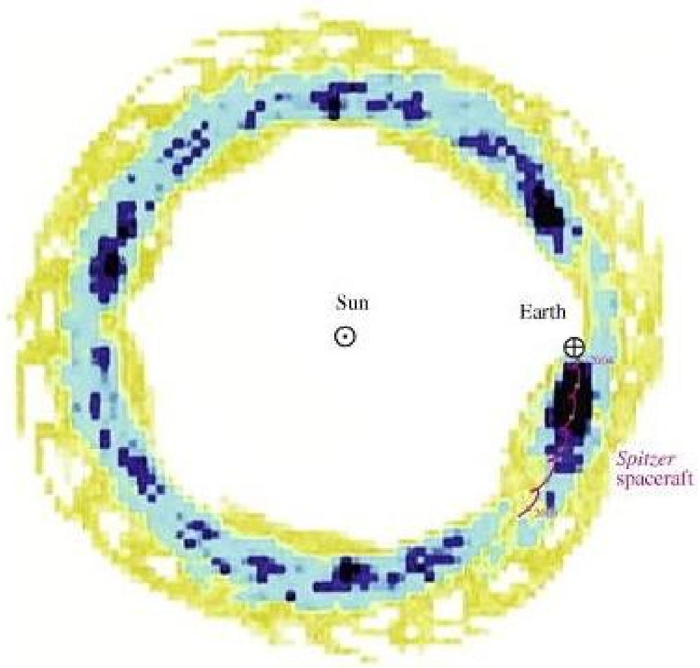
- Simulations

''Irregular Satellite Swarms: Detectable Dust around Solar System and Extrasolar Planets'' Kennedy & Wyatt, MNRAS, 412, 2137, 2011



Astrophysical sources of brighness excess

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



About N = 10 blobs 0.1 AU x 0.1 AU

$= 200 \times 200\ R_{jup}^2$

Assuming a dust albedo 0.01,

$$A R_C^2 > \sim 10^3 R_{Jup}^2$$

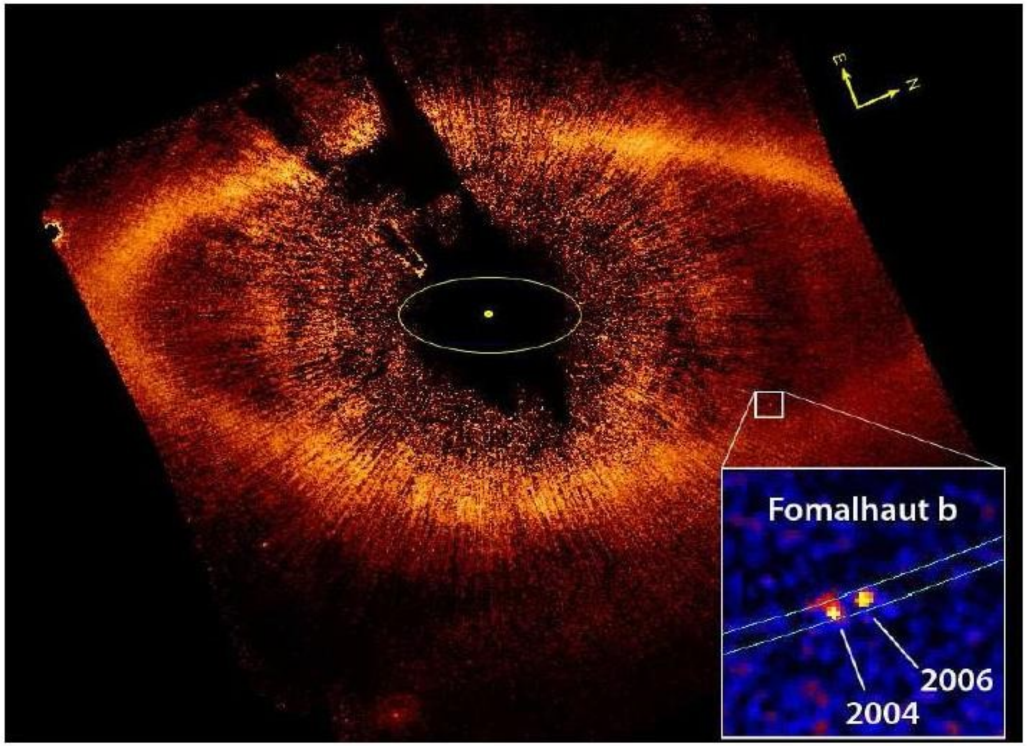
for each blob and at 1 AU:

$$\Delta\alpha_{Ph} \sim \frac{1}{\sqrt{N}} \frac{A}{4} \left(\frac{R_C}{a}\right)^2 \frac{a}{D} = \frac{A}{12} \frac{R_C^2}{aD} = 0.015 \frac{R_{Jup}}{D}$$

$$\sim \Delta\alpha_B \ \ for \ \ 1 M_{Earth} \ \ at \ \ 1 \ \ AU$$

Astrophysical sources of brighness 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