Making the most of Gaia Raw Data:

Sub-pixellic CrossMatch of Gaia Observations.

Describing a dual space transformation as a preprocess to cluster observations with large error in one direction.

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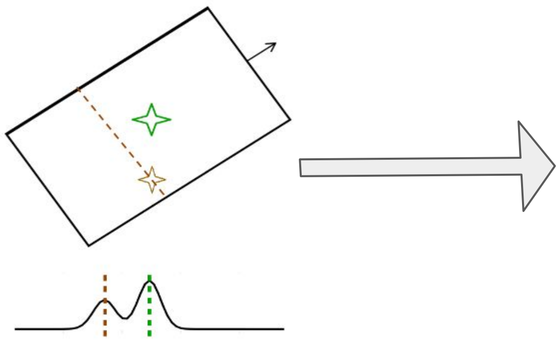
EXCELENCIA MARÍA DE MAEZTU

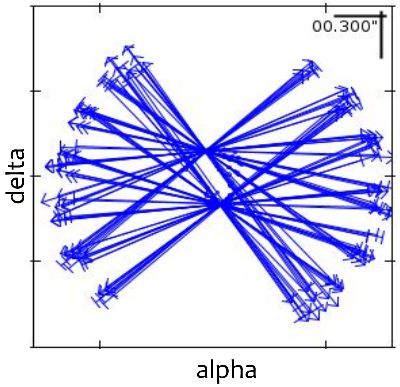
Gaia Observation Cross-Match (XM)

- Gaia data processing pipeline requires a Cross-Matching (XM) of observations, which clusters point-like observations from the onboard detection algorithm and defines the source list.

- In some cases, such as crowded areas or close pairs of sources, the onboard detection can be shifted from the actual photometric peak. This can generate confusions in the source assignment, leading to sub-optimal astrometric and photometric resolution. To avoid this, we can consider a XM algorithm based on the on-ground peak determination or centroid.

- Faint observations centroids (G > 13mag) have only one-dimensional information (in the Along-Scan direction), so the point-like position used by the XM must include a large error bar in the normal direction (Across-Scan).





Line Dual Space

- Clustering the lines according to their intersection pattern presents several drawbacks, mainly for moving sources and crowded regions.
- Therefore, we transform the lines into points in the dual space

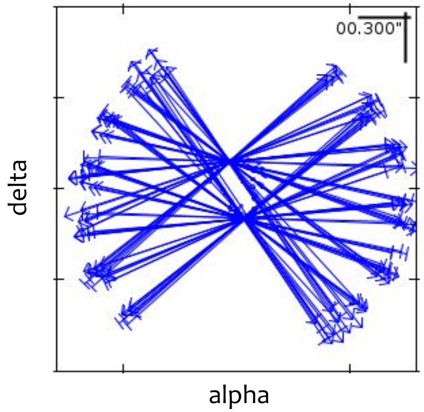
$$
\begin{array}{rcl}
\mathbb{R}^2 & \longrightarrow & \mathbb{R}^2 \\
p = (a,b) & \mapsto & D(p) = p^* : y = ax - b \\
l : y = mx + n & \mapsto & D(l) = l^* = (m, -n)
\end{array}
$$

which maintains the collinearity, i.e. collinear points dualise into lines sharing a common intersection point (and vice versa).

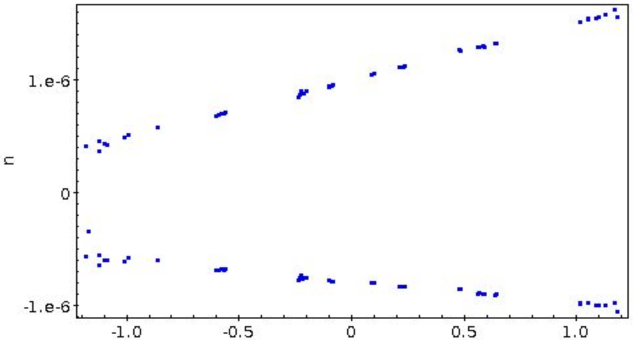
Primal Space		Dual Space
Line Observations	⟺	*Punctual Observations*
Punctual Sources	⟺	*Line pattern, i.e. linear trend of observations*

Results - Sources with no motion

- Sources with a clear intersection pattern are transformed into linear trends.

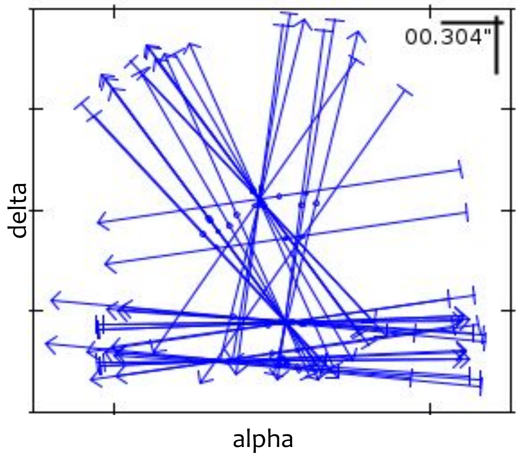


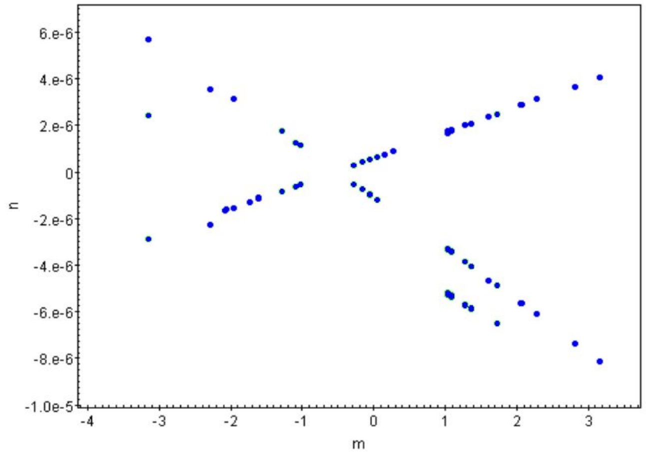
$$y = m_i x + n_i \quad \forall i = 1 \dots N$$



$$n_i = -\hat{x} m_i + \hat{y} \quad \forall i = 1 \dots N$$

- For cases with more than two sources, e.g., close sources in crowded regions, the property is maintained.

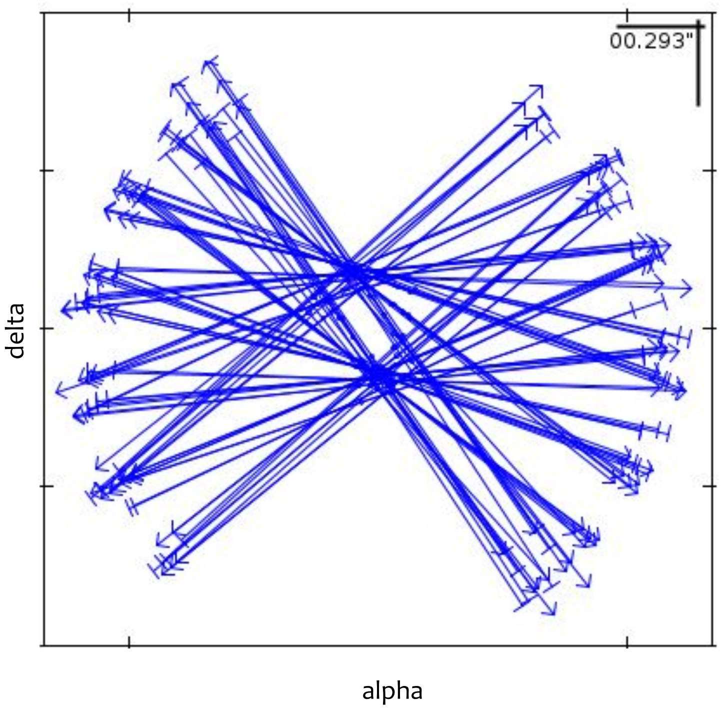


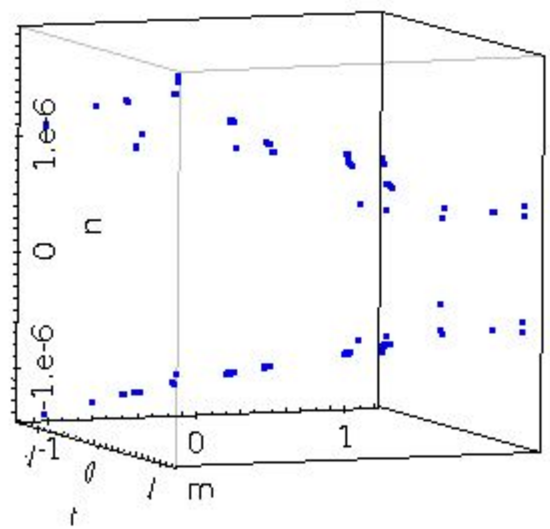


Results - Moving Sources

- For moving sources, the source model can be extended to include motion parameters. The dual points from the same source observation follow a quadratic trend in the (m,t,n) 3d-space.

$$
\begin{aligned}
n_i &= -\hat{x} m_i + \hat{y} = -(x_0 + \mu_x t_i) m_i + (y_0 + \mu_y t_i) \\
&= y_0 - x_0 m_i + \mu_y t_i - \mu_x m_i t_i \qquad \forall i = 1 \ldots N
\end{aligned}
$$





Impact

- Using this transformation, we can implement different methods to cluster these point trends.
- For the moment, we are testing a refined Random Sample Consensus (RanSaC) algorithm and a novel Integer Linear Programming model.
- This resolution improves the performance of the Gaia observation XM in a large variety of complex scenarios, such as crowded fields and visually close pairs of sources.