Exoplanet search with astrometry

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Introduction

My aim is to identify giant exoplanets and brown dwarfs as anomalies in the population of Gaia sources within a 100 pc radius from the Solar System. I employ deep learning algorithms to determine low-mass outliers in the population of Gaia DR3 single and non-single sources.

Objective

Deep-learning based identification of substellar companions as outliers in astrometric surveys.

Method

Astrometric input data source:
GDR3 tables from Gaia Archive (gaia_source, nss_two_body_orbit, binary_masses) and PMa catalog (J/A+A/657/A7/).

Constraints:
G $<$ 13 mag & parallax $>$ 10 mas.

Sample A:
81402 sources
(13 features from Gaia DR3).

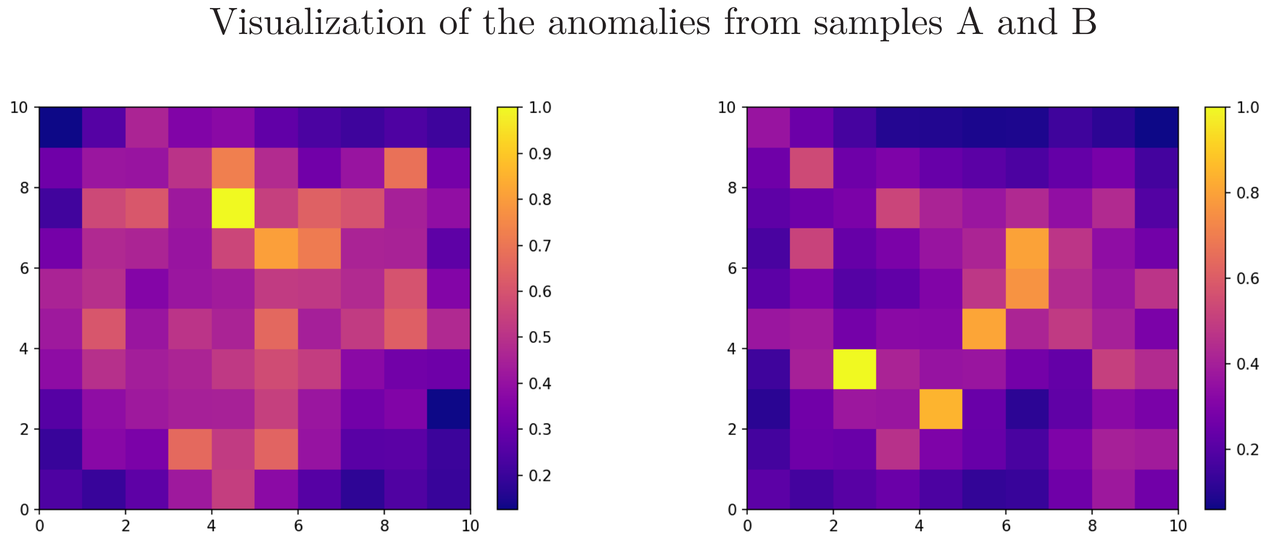
Sample B:
20977 sources
(35 features from PMa catalog $\cap$ Gaia DR3).

I exploited Self-Organizing Maps (Kohonen's Self Organizing Feature Maps, or SOMs), an unsupervised neural network useful to obtain a low dimensional representation of the data for feature and anomaly detection.

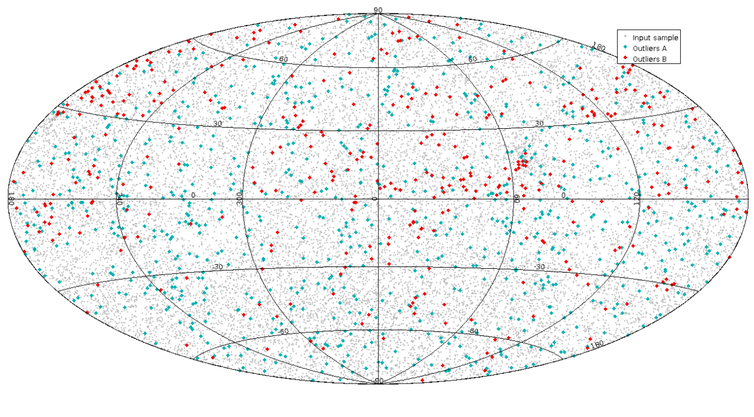
Each 100-neurons SOM returned a matrix of mean inter-neuron distances (MID) for all winning nodes in the model.
Their coordinates were then mapped to the input data to retrieve the sources' identifiers.
For visualization purposes, lighter neurons in the pseudocolor grid include the outliers.

Results

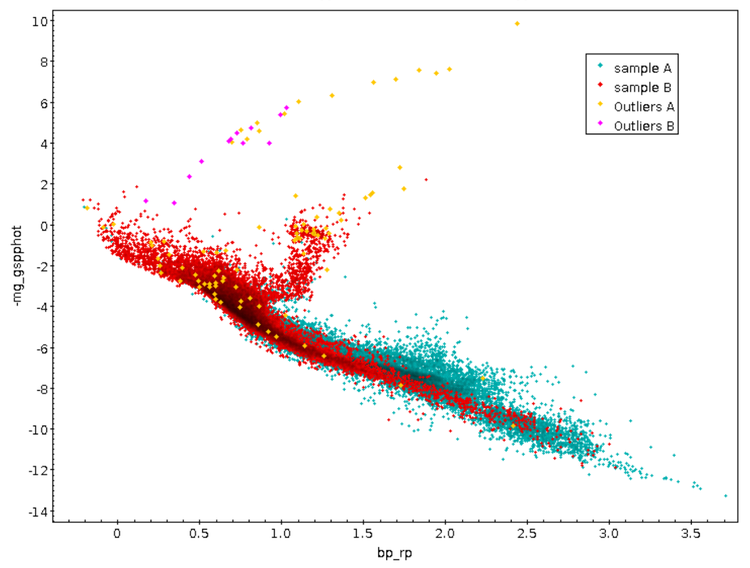
Visualization of the anomalies from samples A and B



All-sky map in Aitoff projection



Color-Magnitude Diagram



Conclusion

238 sources in sample A and 367 sources in sample B can most likely be considered outliers. Further work will aim to assess the likelihood for those outliers to be substellar companions, and to identify those systems hosting extrasolar planets.
This preliminary research explores the potential of deep learning algorithms for the detection of exoplanets.

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This work has made use of the following open-source Python packages: `numpy`, `matplotlib`, `pandas`, `astropy`, `scikit-learn`, `astroquery`. The SOM has been implemented using the `MiniSOM` library.

References

Thebault, P., Bonanni, D. (2025), A&A, Forthcoming article
Sahlmann, J., Gómez, P. (2025), MNRAS, 537, 2
Gaia Collaboration, Arenou, F., et al. (2023), A&A 674, A34
Holl, B., et al. (2023), A&A 674, A10
Gaia Collaboration, Vallenari, A., et al. (2023), A&A 674, A1
Kervella, P., Arenou, F., & Thévenin, F. (2022), A&A, 657, A7
Brandt, T., D. (2021) ApJS 254 42
Vettigli, G. (2018), MiniSom. https://github.com/JustGlowing/minisom/
Gaia Collaboration, Prusti, T.. et al. (2016), A&A 595, A1