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The use of Multiple large-scale Surveys in Astrocladistics: The Jovian Trojans

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Abstract

Cladistics is a multivariate analysis technique most often used in the biological sciences. Recent advances have brought this method to Astronomy, forming a new discipline, Astrocladistics. The technique uses clustering analysis to link closely related objects, and presents the resulting hypothetical relationships based on their characteristics. We apply Astrocladistics to the Jovian Trojans, a population known to contain at least six collisional families, to further demonstrate the technique in the planetary sciences. Through this analysis, we can incorporate dynamical information, as well as datasets from three surveys, *WISE*, *SDSS* and *Gaia* DR2, without truncating datasets. The resulting dendritic trees identify members of existing collisional families, and can be compared with other taxonomic systems. This is preparation for the future datasets, including the release of *Gaia* DR3 and other next generation surveys, such as *LSST*.

1. Introduction

Modern cladistics began in the mid 20th century [4] and rapidly became the methodology of choice for biological taxonomy. Today, the discipline has expanded to include genetic analysis, with large datasets giving us a clear understanding of the 'Tree of Life' [6]. There have been recent efforts to expand the cladistical technique into Astronomy, collectively called 'Astrocladistics' [1]. These works include investigations into the satellite systems of Jupiter and Saturn [5]. In order to expand the use of Astrocladistics in planetary sciences, we chose the Jovian Trojans as a test case for the technique. The Jovian Trojans are a population of approximately 7000 known small bodies, located at the L4 and L5 Lagrange points of Jupiter. Within the two swarms, six collisional families have been identified [10], four in the L4 swarm and two in the L5 swarm.

2. Astrocladistical methodology

Astrocladistical methodology begins with the creation of a 2D matrix. In the rows are the objects of interest, in this case the Jovian Trojans, with each column representing a specific characteristic. The characteristics are the dynamical proper elements (Δa, e & sin-i) [8], calculated librations, geometric albedo and colors from three surveys, *WISE* [3], *SDSS* [7] and *Gaia* DR2 [12]. Characteristics for each Trojan are binned and coded, with incomplete data accounted for with a ?. In total there are 349 L4 Trojans and 351 L5 Trojans analysed, selected for having data in at least one of the surveys. Once constructed, a block of 10,000 equally parsimonious trees are generated using TNT [2]. A consensus of the trees [9] then represents the hypothesised relationships between the Jovian Trojans.

3. L4 and L5 Trees

In each of the L4 and L5 consensus trees, the respective identified families can be seen. We show the example of the extended Eurybates family in figure 1. The core family is identified, with the rest of the extended family shown. Within this extended family, new groupings may be seen, for example around 9817 Thersander, that have not been previously identified.

4. Future Work

Astrocladistics can be used to combine the analysis of disparate survey databases. As we move into the new era of large sky surveys, the technique could be used to analyse even larger datasets. *Gaia* DR3, which is to be released in late 2021, will incorporate more colors and a wider range of Solar system objects. *LSST* [11], which is to gain first light in 2020 will provide a plethora of information regarding estimations of millions of Solar system objects. Astrocladistics, being parallelizable on HPC systems [2], is well suited to these large forms of data analysis.

5. Summary and Conclusions

Cladistics is traditionally used to study the relationships between organisms. We expand the use of the technique in the planetary sciences, specifically the Jovian Trojans, adding to the field of Astrocladistics. By incorporating data from three surveys, *WISE* [3], *SDSS* [7] and *Gaia* DR2 [12] we can improve our understanding of these objects. This work establishes a framework for the technique that could be used in the next generation of surveys, including *LSST* [11].

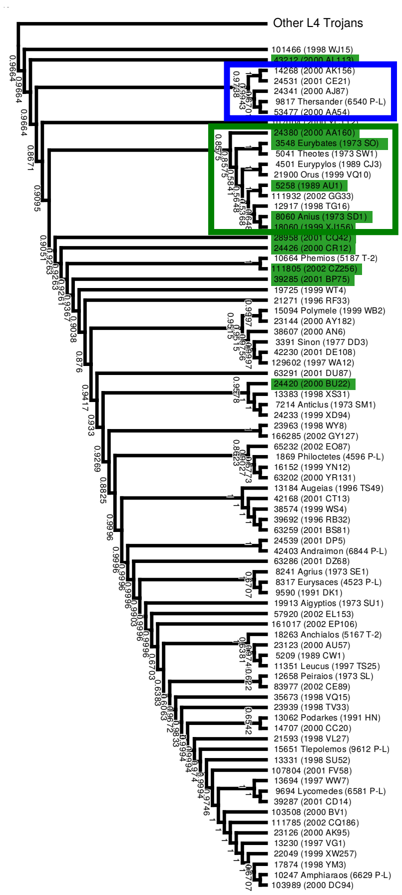

Figure 1: Consensus tree showing extended Eurybates family. Identified members shown in green, with the core family highlighted. A potential Thersander group is highlighted in blue. Numbers at each node represent the frequency of the branch in the tree block.

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References

[1] Fraix-Burnet, D. et al.: Multivariate approaches to classification in extragalactic astronomy. Frontiers in Astronomy and Space Sciences, 2, 3. 2015

[2] Goloboff, P. A., and Catalano, S. A. TNT version 1.5, including a full implementation of phylogenetic morphometrics. Cladistics, 32(3), 221–238. 2016

[3] Grav, T. et al.: WISE/NEOWISE observations of the Jovian Trojan Population: Taxonomy. The Astrophysical Journal, 759(1), 49. 2012

[4] Hennig, W.: Phylogenetic systematics. Annual Review of Entomology, Vol. 10(1), 97–116, 1965

[5] Holt, T. R. et al.: Cladistical Analysis of the Jovian and Saturnian Satellite Systems. The Astrophysical Journal, 859(2), 97. 2018

[6] Hug, L. A. et al.: A new view of the tree of life. Nature Microbiology, 1(5), 16048. 2016

[7] Ivezic, Z. et al.: SDSS Moving Object Catalog V3.0. EAR-A-I0035-3-SDSSMOC-V3.0. NASA Planetary Data System, 2010.

[8] Knežević, Z., and Milani, A. AstDys: Synthetic proper elements 5553 numbered and multiopposition Trojans. Retrieved from http://hamilton.dm.unipi.it/ astdys2/propsynth/tro.syn. 2017

[9] Maddison, W. P., and Maddison, D. R. : Mesquite: a modular system for evolutionary analysis. Version 3.20. 2017

[10] Nesvorný, D. et al.: Identification and Dynamical Properties of Asteroid Families. In P. Michel, F. E. DeMeo, and W. F. Bottke (Eds.), Asteroids IV. University of Arizona Press. 2015

[11] Schwamb, M. E. et al.: Large Synoptic Survey Telescope Solar System Science Roadmap. Retrieved from http://arxiv.org/abs/1802.01783 2018

[12] Spoto, F. et al.: Gaia Data Release 2: Observations of solar system objects. Astronomy & Astrophysics, 616, A13. 2018