Cladistical Analysis of the Jovian Satellites. T. R. Holt[1], A. J. Brown[2] and D. Nesvorny[3], [1]Center for Astrophysics and Supercomputing, Swinburne University of Technology, Melbourne, Victoria, Australia holt.t.astro@gmail.com, [2]SETI Institute, Mountain View, California, USA, [3]Southwest Research Institute, Department of Space Studies, Boulder, CO. USA.

Introduction: Surrounding Jupiter there are multiple satellites, 67 known to-date. The most recent classification system [1,2], based on orbital characteristics, uses the largest member of the group as the name and example. The closest group to Jupiter is the prograde Amalthea group, 4 small satellites embedded in a ring system. Moving outwards there are the famous Galilean moons, Io, Europa, Ganymede and Callisto, whose mass is similar to terrestrial planets. The final and largest group, is that of the outer Irregular satellites. Those irregulars that show a prograde orbit are closest to Jupiter and have previously been classified into three families [2], the Themisto, Carpo and Himalia groups. The remainder of the irregular satellites show a retrograde orbit, counter to Jupiter's rotation. Based on similarities in semi-major axis (*a*), inclination (*i*) and eccentricity (*e*) these satellites have been grouped into families [1,2]. In order outward from Jupiter they are: Ananke family (a 2.13x10^7 km ; i 148.9°; e 0.24); Carme family (a 2.34x10^7 km ; i 164.9°; e 0.25) and the Pasiphae family (a 2:36x10^7 km ; i 151.4°; e 0.41). There are some irregular satellites, recently discovered in 2003 [3], 2010 [4] and 2011[5], that have yet to be named or officially classified.

The aim of this project is to investigate the validity of the groupings and taxonomic relationships amongst these satellites, using a technique called cladistics.

Cladistics: This technique is traditionally used to examine the relationships between biological groups, though it has been used to classify Galaxies [6]. This work is the first usage of cladistics in a planetary science context. Cladistics uses a multivariate analysis to examine the relationships between groups, in this case the Jovian satellites. The advantage of this method over other, bivariate analysis systems is the inclusion of multiple orbital and physical characteristics, thus more detailed relationships can be inferred. The resulting branching taxonomic tree is then a hypothesis for the relational groups.

Methods: To construct a taxonomic tree, a taxon-character matrix is required. A taxon-character matrix is a table consisting of the individual satellites (taxa) in the rows, and the orbital (5), physical (2) and compositional (29) characteristics in each column. The data was gathered from [2,7-14]. The resulting matrix is analyzed using the Mesquite software package [15]. A strict consensus of the 100 most parsimonious trees is presented in figure 1.

Results:

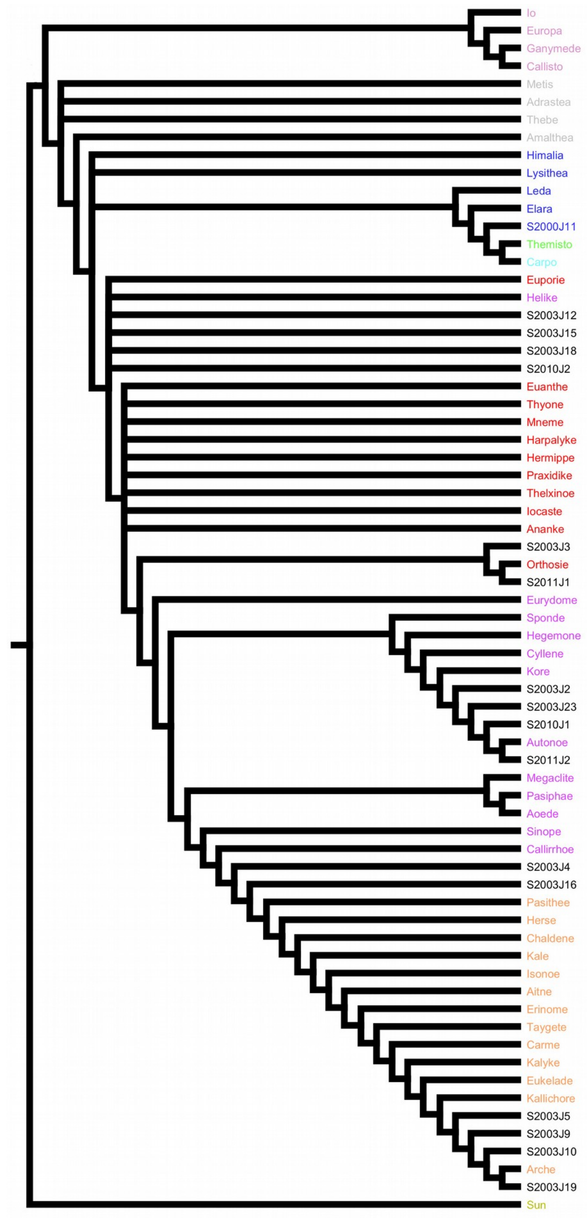

Figure 1: A strict consensus taxonomic tree of the Jovian satellites. Colors indicate families [1,2]: Amalthea family; Galileans; Themisto group; Himalia family; Carpo group; Anake family; Carme family; Pasiphae group; Sun outgroup; Uncatagorised and yet to be named

Satellite groups:

The taxonomic tree confirms earlier classification systems [1,2] with each of these groups exemplified by a large type satellite. Some of the newer, unnamed irregular satellites can also be confidently assigned to these groups.

Amalthea Inner Regular family: These satellites form a sister group to the irregular satellites, suggesting a common origin. The icy composition of Amalthea [15] supports this hypothesis. The association with the Himalia family also indicates a similar mechanism of capture.

Galilean: The Galilean satellites form a sister group to all other satellites. This agrees with the theory that they formed locally through disk accretion [17] and survived planetary encounters of the jumping-Jupiter model [18].

Himalia Prograde Irregular family: This is a well supported group. Themisto and Carpo were proposed as their own groups [1], but this analysis supports a larger family with the type satellite being Himalia. The Himalia family forms a distinct group to the other irregular satellite groups (Anake family, Carme family and Pasiphae group). This would suggest a common origin, but perhaps not a common mechanism of capture.

Anake Irregular family: The Anake family is upheld and expanded to include new members. Heike is moved from the Pasiphae group. Some of the unclassified members can also be assigned to this family; S2003J3/12/15/18, S2010J2 & S2011J1. The Anake family form a super-family with the other irregular satellites.

Carme Irregular family: This family is also upheld and expanded. It is expanded to confidently include S2003J5/9/10/19. Possible other members include Sinope, Callirrhoe and S2003J4/16.

Pasiphae Irregular group: This group is problematic. Pasiphae itself forms a small group with Megaclite and Aoede, but is separate from the others. There is another group with Sponde, Hegemone, Cyllene, Kore, Autone, S2003J2/23, S2010J1 and S2011J2. This groups is well supported, but does not contain a large type member. The other large member of the group, Sinope, could possibly belong to the Carme family. This suggests that the Pasiphae group is the result of multiple interactions, with multiple originator objects.

Origins: With the groups outlined, the multiple origins of the Jovian satellites can begin to be determined. Each family, except the Galileans, is composed of a large, type satellite. With the prograde Amalthea and Himalia families forming a sister group to the other irregular families, this would support a different origin mechanism. Nebular drag theory has been proposed as this mechanism for the Himalia Family [19] and could explain the orbital mechanics of the Amalthea as well.

It has been theorized that the irregular satellites were captured during planetary interactions, involved with the jumping-Jupiter model [20]. The progenerators of the families proposed would be consistent with this model.

Further work: The composition of the small satellites is still theoretical. This leads to a bias towards orbital characteristics in analysis. This study and others [1,2] link them to larger type satellites that have known compositions. As technology improves, spectral imaging, using a large infra-red space telescope, such as the James Webb Space Telescope, may be undertaken on these smaller bodies. This would provide the missing compositional information and could help resolve several families.

Using a similar cladistical technique, the type satellites of the families can be compared with other solar system bodies. This would help resolve the origin of the Jovian satellites and relationships between solar system bodies.

References:

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