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# TESTING THE HYPOTHESIS OF AN UNKNOWN PLANET USING THE MOID ANALYSIS

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MOID values for 1156 long-periodic comets with aphelion distances greater than 250 AU and slightly hyperbolic orbits relative to the assumed planet X are calculated. It was found that in 51 of them, these values do not exceed the radii of the spheres of influence of the planets. This is approximately 25 percent more than the background value and cannot be considered random. The obtained result can be considered as an additional argument in favor of the hypothesis under discussion.

**Keywords:** comets–planets–MOID.

## 1. INTRODUCTION

This work is a logical continuation of the paper that shows the existence of families of long-period and periodic comets of giant planets. Recall that in the cited works, an array of MOID (minimal orbital intersection distance) values was analyzed and their redundancy relative to giant planets was proved. In particular, [5] shows that the number of long-period comets with small MOID values is 1.4-1.7 times higher than the background values.

In this paper the question will be studied for the assumed Planet X with parameters:

$$a = 339\,AU(\pm 34), e = 0.16(\pm 0.02), \omega = 57^\circ(\pm 15^\circ), \Omega = 272.7^\circ(\pm 3^\circ), i = 86^\circ(\pm 2^\circ). \tag{1}$$

The hypothesis of the existence of such a planet belongs to one of the authors. The most complete review of the hypothesis and its main arguments is given in [4].

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## 2. DATA USED AND RESEARCH METHODOLOGY

To analyze the MOID values of known comets relative to the putative planet, the algorithms given in [3] are used.

In this task, the values of the radius of the sphere of action, which are determined by the formula [2] are used as the limit distances for analyzing MOID values for the planet X:

$$h = a_p \sqrt[5]{\left(\frac{M_p}{M_S}\right)^2} \tag{2}$$

Where, $a$ – planet's semi-major axis, $M_p$ - mass of planet, $M_S$ – mass of Sun.

The subjects of this study are 1156 slightly hyperbolic and long-period comets with aphelion distances greater than 250 AU. The compiled list covers comets up to 2020. The last comet in it is C/2009 Y1. Their data is grabbed from JPL HORIZONS.

As an example for testing, we give the MOID values of two comets (elliptical and hyperbolic) with respect to (1):

C/2012 L1; $r = 0.48$ and C/1980 E1; $r = 1.14$

## 3. CALCULATION RESULTS

The Guliyev hypothesis assumes that the mass of an unknown planet does not exceed 10 earth masses. This means that the analysis should select comets with MOID values up to 6 AU.

As a result of calculations, 51 comets with this characteristic were found in the considered list. Their list is given in table 1. Comets are characterized by relatively large perihelion distances (aver. 2.200 AU). Among them, objects with straight orbits dominate (31 vs. 20). 10 of them have slightly hyperbolic eccentricities.

The table also shows the values of the latitudes of the perihelion ($B'$) of comets relative to the motion of the planet plane. 16 of the 51 values of this parameter are within 30 degrees of the plane. Consequently, the small MOID values of the selected comets are not always associated with this factor.

Table 1 shows the calculated values of the inclinat ions ($I'$) of the selected comets relative to the plane of motion of planet X. There is a slight dominance of the values of this parameter near 0° and 180°. In particular, the regions $I' < 17°$ and $I' > 163°$ correspond to 8 and 5 values. Although their number exceeds the random norm, however, this does not mean that the assumed excess of MOID values is associated with this factor.

**Table 1.** Data on 51 long-period comets and calculated MOID values

| comet | $q$ (AU) | $e$ | $i$ | $\Omega$ | $\omega$ | MOID | $B'$ | $I'$ |
|---|---|---|---|---|---|---|---|---|
| C/1911 O1 | 0.489 | 0.997 | 33.81 | 294.21 | 153 | 0.28 | 0.5 | 55.4 |
| C/2010 A4 | 2.738 | 0.99 | 96.73 | 346.69 | 271.69 | 0.36 | -7.18 | 75.6 |
| C/2019 J2 | 1.727 | 0.997 | 105.14 | 25.47 | 98.7 | 0.42 | 5.63 | 113.9 |
| C/2012 L1 | 2.262 | 0.997 | 87.22 | 271.77 | 140.29 | 0.48 | 0.69 | 1 |
| C/2008 E3 | 5.531 | 0.998 | 105.08 | 105.67 | 218.08 | 0.49 | -4.21 | 162.3 |
| C/2012 V2 | 1.455 | 0.997 | 67.18 | 262.17 | 217.32 | 0.73 | 3.57 | 21.1 |
| C/2011 C1 | 0.883 | 0.997 | 16.83 | 192.44 | 84.47 | 0.82 | -3.6 | 83.3 |
| C/1997 A1 | 3.157 | 1.002 | 145.07 | 135.77 | 40.01 | 0.96 | 10.23 | 117.7 |
| C/1850 Q1 | 0.566 | 1 | 40.06 | 208.11 | 243.2 | 1 | -7.97 | 70.4 |
| C/1980 E1 | 3.364 | 1.057 | 1.66 | 114.56 | 135.09 | 1.14 | 22.11 | 87.7 |
| C/2005 N1 | 1.125 | 0.998 | 51.18 | 3.24 | 80.04 | 1.15 | -6.04 | 88.8 |
| C/2012 H1 | 1.296 | 1 | 27.74 | 125.98 | 137.99 | 1.2 | 5.29 | 109 |
| C/1914 M1 | 3.747 | 1.003 | 71.04 | 271.51 | 14 | 1.21 | -3.4 | 15.1 |
| C/2010 B1 | 2.941 | 0.999 | 101.98 | 277.21 | 211.52 | 1.24 | -3.48 | 16.7 |
| C/2010 D2 | 3.917 | 1 | 59.17 | 314.89 | 129.12 | 1.54 | 10.69 | 48.8 |
| C/2016 M1 | 2.212 | 1 | 91 | 92.19 | 209.77 | 1.77 | -1.79 | 177.1 |
| C/2004 U1 | 2.659 | 0.999 | 130.62 | 112.55 | 20.13 | 1.85 | 8.12 | 138.7 |
| C/1925 F2 | 1.633 | 0.995 | 26.98 | 7.04 | 259.28 | 1.91 | 4.27 | 89 |
| C/2013 E2 | 1.414 | 0.997 | 21.85 | 182.49 | 95.84 | 2.03 | -5.1 | 86.2 |
| C/2002 O4 | 0.776 | 1.001 | 73.13 | 321.04 | 105.94 | 2.16 | 5.02 | 50.1 |
| C/1954 O2 | 3.87 | 1.001 | 100.39 | 265.34 | 144.67 | 2.24 | 2.9 | 15.6 |
| C/2006 K1 | 1.752 | 0.992 | 144.26 | 243.81 | 143.46 | 2.26 | 4.23 | 62.6 |
| C/1885 N1 | 2.507 | 1 | 80.62 | 93.9 | 178.52 | 2.29 | -1.82 | 166.6 |
| C/2014 G1 | 5.467 | 0.992 | 165.64 | 337.94 | 77.02 | 2.38 | 11.02 | 88 |
| C/1955 G1 | 4.496 | 1.003 | 123.93 | 321.33 | 73.75 | 2.49 | 10.78 | 60 |
| C/2016 A5 | 2.947 | 0.998 | 40.32 | 136.22 | 321.61 | 2.51 | 10.61 | 114.2 |
| C/2003 T4 | 0.85 | 1 | 86.76 | 93.9 | 181.65 | 2.61 | -2.36 | 172.6 |
| C/1748 K1 | 0.625 | 1 | 67.08 | 36.64 | 245.67 | 2.66 | 4.51 | 120 |
| C/1998 K3 | 3.547 | 1 | 160.21 | 307.96 | 47.84 | 2.8 | 10.51 | 77.9 |
| C/1846 B1 | 1.481 | 0.992 | 47.43 | 113.27 | 337.99 | 2.93 | 4.92 | 129.7 |
| C/1988 F1 | 1.174 | 0.998 | 62.81 | 288.77 | 326.51 | 3.06 | -2.06 | 28.5 |
| C/1988 J1 | 1.174 | 0.998 | 62.81 | 288.76 | 326.52 | 3.08 | -2.05 | 28.5 |
| C/1898 V1 | 2.285 | 1 | 22.5 | 97.24 | 4.64 | 3.31 | 9.88 | 108.6 |
| C/1890 O1 | 0.764 | 1 | 63.35 | 15.83 | 85.66 | 3.44 | 5.44 | 100.8 |
| C/2007 J1 | 5.368 | 1.002 | 89.84 | 65.52 | 93.7 | 3.67 | 5.59 | 153.5 |
| C/1871 L1 | 1.083 | 1 | 101.98 | 213.7 | 96.32 | 3.7 | 4.62 | 59.8 |
| C/1822 N1 | 1.145 | 0.996 | 127.34 | 95.24 | 181.11 | 3.73 | -2.88 | 146.3 |
| C/1920 X1 | 1.148 | 0.994 | 22.03 | 108.83 | 340.89 | 3.96 | -1.18 | 107.2 |

**Table 2.** continuation table 1

| | | | | | | | | |
|---|---|---|---|---|---|---|---|---|
| C/2004 G1 | 1.202 | 1 | 114.49 | 228.38 | 110.49 | 3.98 | 5.66 | 50.8 |
| C/1932 M1 | 1.647 | 1.001 | 78.39 | 246.09 | 69.79 | 4.03 | 2.33 | 26.6 |
| C/1975 X1 | 0.864 | 1.001 | 93.96 | 281.49 | 215.47 | 4.61 | 3.42 | 12.5 |
| C/1897 U1 | 1.357 | 1 | 69.61 | 33.49 | 65.91 | 4.9 | -7.03 | 118 |
| C/2006 S3 | 5.131 | 1.003 | 166.03 | 38.37 | 140.13 | 5.18 | 14.75 | 102 |
| C/1980 L1 | 2.584 | 1 | 73.15 | 279.52 | 334.96 | 5.24 | -1.61 | 15.1 |
| C/1785 A1 | 1.143 | 1 | 70.24 | 267.21 | 205.63 | 5.26 | 2.71 | 16.5 |
| C/1877 G1 | 0.95 | 0.999 | 121.15 | 318.33 | 63.12 | 5.27 | 2.26 | 56.5 |
| C/1958 R1 | 1.628 | 1 | 61.26 | 323.78 | 100.74 | 5.34 | -4.93 | 55.2 |
| C/2010 J3 | 2.249 | 1 | 14.63 | 101.07 | 180.37 | 5.37 | -9.67 | 100.6 |
| C/1954 M2 | 0.746 | 1 | 88.54 | 75.57 | 254.73 | 5.59 | -0.84 | 163 |
| C/2014 M1 | 5.545 | 1 | 160.16 | 234.77 | 337.63 | 5.63 | 15.12 | 78 |
| C/1975 T1 | 1.604 | 0.997 | 91.61 | 278.68 | 246.24 | 5.77 | -2.17 | 8.8 |

In addition, table 1 shows the calculated inclinations ($I'$) of the selected comets relative to the motion of planet X plane. There is a slight dominance of the values of this parameter near 0° and 180°. In particular, the regions $I' < 17°$ and $I' > 163°$ correspond to 8 and 5 values. Although their number exceeds the random norm, however, this does not mean that the assumed excess of MOID values is associated with this factor.

The possibility of determining the randomness measure of such comets was discussed in [6]. For a uniform or random distribution of MOID values, the number of MOIDs within an interval of 6 AU should be:

$$N = 2 \times 1156 \times 6/339 = 40.9$$

If the interval is limited to 5.77 AU (the extreme value in table 1), there should be 39 of them. This means that there is a significant advantage of the real value of MOIDs over the expected one (by about 25 percent).

## 4. CONCLUSION

Analysis of the MOID values of 1156 long-period comets relative to the assumed planet with orbital parameters (1) and identification of 51 comets among them allows us to draw a conclusion about the reality of the existence of such a planet. The obtained data can be considered as another argument in favor of the discussed hypothesis.

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