A Fruit of a Different Kind: 2015 BP\textsubscript{519} as an Outlier among the Extreme Trans-Neptunian Objects

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Keywords: minor planets, asteroids: individual (2015 BP\textsubscript{519})
The presence of one or more planets orbiting the Sun between the orbit of Neptune and the Oort Cloud has been investigated multiple times for many decades, but all the efforts to observe them have so far been unsuccessful. This subject found new significance in the wake of the discovery of 2012 VP_{113} (Trujillo & Sheppard 2014), when a number of intriguing patterns were identified in the distributions of the orbital elements of the known extreme trans-Neptunian objects —those with semimajor axis greater than 150 au and perihelion distance greater than 30 au—or ETNOs (de la Fuente Marcos & de la Fuente Marcos 2014; Trujillo & Sheppard 2014). The patterns were tentatively explained as caused by one (Trujillo & Sheppard 2014) or more (de la Fuente Marcos & de la Fuente Marcos 2014) trans-Plutonian planets. Further evidence in the form of theoretical and numerical analyses was presented —Planet Nine hypothesis— by Batygin & Brown (2016). However, the causality in which a perturber induces a peculiar orbital architecture on the ETNOs has been dismissed by some researchers (Shankman et al. 2017), who claim that observational biases in the data are the true cause. The announcement of the discovery of 2015 BP_{519} (Becker et al. 2018), unofficially known as Caju, has been hailed by some as a consistent piece of robust evidence for the existence of a yet-to-be-discovered massive planet far beyond the trans-Neptunian belt. Here, we use the latest data available from JPL’s Small-Body Database (Giorgini 2015) to show that 2015 BP_{519} is a statistical outlier within the 29 known ETNOs; therefore, it cannot be used as a reference to further support the trends perhaps present for other ETNOs.

The orbit determination of 2015 BP_{519} (epoch JD 2458200.5, 23-March-2018, solution date 31-May-2018) is based on 30 observations for a data-arc span of 1176 days and has semimajor axis, \( a = 430 \pm 24 \) au, eccentricity, \( e = 0.918 \pm 0.005 \), inclination, \( i = 54^\circ.1173 \pm 0^\circ.0003 \), longitude of the ascending node, \( \Omega = 135^\circ.192 \pm 0^\circ.005 \), and argument of perihelion, \( \omega = 348^\circ.39 \pm 0^\circ.07 \); Becker et al. (2018) already mentioned the unusual value of \( i \). The patterns present in ETNO orbital parameter space produce clustering in the location of perihelia and poles, and the study of the distributions of pole and perihelion separations (between each pair, see de la Fuente Marcos & de la Fuente Marcos 2016; de la Fuente Marcos et al. 2017) can help in identifying features inconsistent with the overall behavior. Figure 1 shows such distributions (in gray) computed considering the errors in the values of the orbital parameters involved.

Following de la Fuente Marcos & de la Fuente Marcos (2016) and using the criteria discussed by Tukey (1977), we searched for outliers in the distributions of pole and perihelion separations. Here, outliers are observations that fall below \( Q_1 - 1.5 \text{IQR} \) (lower limit) or above \( Q_3 + 1.5 \text{IQR} \) (upper limit), where \( Q_1 \) is the first quartile, \( Q_3 \) is the third quartile, and IQR is the interquartile range. The upper outlier limit in \( i \) is 42° (in blue in Figure 1, bottom panel), but the inclination of 2015 BP_{519} is above 54°. If the other ETNOs reached their current orbital inclinations as a result of the same process (be it due to massive perturbers or any other), it is difficult to claim that whichever mechanisms are responsible for the current orbital organization of most of the ETNOs could also be behind the present-day orbit of 2015 BP_{519}. A different origin for the orbit of 2015 BP_{519} is further supported by the fact that its orbital pole is well away from those of the others (pairs including 2015 BP_{519} in pink in Figure 1). Having relatively well-aligned orbital poles is indicative of a fairly consistent direction of orbital angular momentum, which in turn suggests that the objects are subjected to the same type of background perturbation. Figure 1, middle panel, shows the upper outlier limit for the pole separations, 60° (in green); all the pairs with separations above this value include 2015 BP_{519}, i.e. the overall orientation in space of 2015 BP_{519} is rather different from those of the other known ETNOs. In addition and following de la Fuente Marcos & de la Fuente Marcos (2017), the nodal distances of 2015 BP_{519}, in red in Figure 1, bottom panel, also suggest an outlier nature.

In this Note, we have provided evidence against 2015 BP_{519} having followed the same dynamical pathway that placed the ETNOs where they are now. Asteroid 2015 BP_{519} represents a case of extreme dynamical anticorrelation within the ETNO orbital realm; the objects discussed by de León et al. (2017) and de la Fuente Marcos et al. (2017) represent the opposite side, that of well-correlated pairs of ETNOs.

We thank A. I. Gómez de Castro for providing access to computing facilities. This work was partially supported by the Spanish MINECO under grant ESP2015-68908-R. In preparation of this Note, we made use of the NASA Astrophysics Data System and the MPC data server.

REFERENCES

Batygin, K., & Brown, M. E. 2016, AJ, 151, 22
Becker, J. C., Khain, T., Hamilton, S. J., et al. 2018, AJ, 156, 81
Figure 1. Distributions of the angular separations between perihelia, $\alpha_q$ (top panel, the bin size is 1°), and orbital poles, $\alpha_p$ (middle panel, 0.22°), upper outlier limit in green. The black curve/gray bins are the result of the analysis of $4\times10^6$ random pairs of ETNOs with synthetic orbits based on the mean values and dispersions of the orbital elements of real ETNOs. The bin width has been computed using the Freedman-Diaconis rule (Freedman & Diaconis 1981): $2 \text{IQR} n^{-1/3}$, where $n$ is the number of data points. In red/pink we show the distributions of pairs including 2015 BP$_{519}$. Distribution of nodal distances (bottom panel, descending nodes in solid color, ascending empty), in red 2015 BP$_{519}$, upper outlier limit in blue.
de la Fuente Marcos, C., & de la Fuente Marcos, R. 2014, MNRAS, 443, L59
de la Fuente Marcos, C., & de la Fuente Marcos, R. 2016, MNRAS, 462, 1972
de la Fuente Marcos, C., & de la Fuente Marcos, R. 2017, MNRAS, 471, L61
de la Fuente Marcos, C., de la Fuente Marcos, R., & Aarseth, S. J. 2017, Ap&SS, 362, 198
de León, J., de la Fuente Marcos, C., & de la Fuente Marcos, R. 2017, MNRAS, 467, L66

Freedman, D., & Diaconis, P. 1981, Z. Wahrscheinlichkeitstheor. verwandte Geb., 57, 453
Giorgini, J. D. 2015, IAU General Assembly, 22, 2256293
Shankman, C., Kavelaars, J. J., Bannister, M. T., et al. 2017, AJ, 154, 50
Trujillo, C. A., & Sheppard, S. S. 2014, Nature, 507, 471
Tukey, J. W. 1977, Addison-Wesley Series in Behavioral Science: Quantitative Methods, Reading, Mass.: Addison-Wesley