Making Dwarf Planets as Planets Without Violating Current Definition of A Planet

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Abstract

The definition of a planet by the International Astronomical Union (IAU) is still ambiguous because the IAU resolution B5 did not clearly define the third criterion of clearing the neighborhood. So, we try to propose a new definition of planets that adopts planets so that it can be applied to all spherical bodies, covering exoplanets as well as planets in the solar system. To do this, we adopt a definition of a planet without violating current definition of a planet.

1 Introduction

The International Astronomical Union (IAU) defines a planet as a body that orbits the Sun, achieves hydrostatic equilibrium, and clears its orbital neighborhood. The last criterion, an orbital clearing, has been formalized by many authors. Stern and Levison [6] introduce a dynamical parameter Λ, Soter [5] proposes a parameter μ, and Margot [3] presents a general formulation that yields a discriminant Π.

Here, we propose a mass-based definition of a planet. In the definition, A planet must be greater than lower limit of mass ratio.

2 Existing Metric

Tremaine [7] develops the formation of Oort-type comet clouds, considering that the ejection of comets by the mass of a single planet is M_p, the semi-major axis a_p, and the mass of the central star $M_\star$. The ejection process is a diffusion or random walk process in the orbital energy of a comet, with the energy described by the variable $x = 1/a$, where a is the semi-major axis of the comet's orbit. The diffusion coefficient $D_x = \left\langle (\Delta x)^2 \right\rangle^{1/2}$ is the root mean squared change in x per orbit, resulting from the gravity kicks of an associated planet. Tremaine [7] finds that

$$D_x = \frac{10}{a_p}\frac{M_p}{M_\star} \tag{1}$$

and t_{diff} is

$$t_{diff} = P\frac{x^2}{D_x^2} \tag{2}$$

Later, Margot [3] argues that the clearing timescale should be a main sequence lifetime. However, Margot et al. [4] argues that the timescale based on a main-sequence lifetime of hydrogen-fusing stars must be abandoned and defines the clearing mass is

$$m_{clear} = C^{3/2}\ m_{central}^{5/8}\ \left(\frac{t_{clear}}{1.1\times 10^5 y}\right)^{-3/4} a^{9/8} \tag{3}$$

3   Proposed Metric

In a planetary mass m, central mass M, planetary semi-major axis a, A planetary hill sphere is $R_H = a\left(\frac{m}{3M}\right)^{1/3}$, a planetary orbital velocity is $v_{orb} = \sqrt{\frac{GM}{a}}$, and a planetary escape velocity in the C times hill radii is $v_{esc} = \sqrt{\frac{2Gm}{CR_H}}$. If the planetary escape velocity must be greater than 0.00025 times of planetary orbital velocity, and C must be $2\sqrt{3}$ (Gladman [2]) the following equation is induced like below:

$$m > m_{clear} = 2.056 \times 10^{-11} m_{central} \tag{4}$$

In the Solar System, $m_{central}$ is $1.989 \times 10^{30} kg$, and therefore minimum mass to be a planet is about $4.1 \times 10^{19} kg$. There is no profound lower mass limit to be a planet.

4   Proposed Improvements to IAU Resolution B5 (2006)

Because it is relatively straightforward to apply a quantitative orbit-clearing criterion to exoworlds, it is possible to extend the 2006 IAU planet definition to brown dwarfs and stars other than the Sun and to remove ambiguity about what it means to clear an orbital zone. Likewise, it is possible to use a specific mass threshold to replace a vague and impractical prescription regarding roundness. We hope that these considerations will help start the conversation about making planetary taxonomy both quantitative and useful. One possible IAU-aligned formulation is as follows:

A planet is celestial body that

(a) orbits one or more stars, brown dwarfs, stellar remnents

(b) has a true mass below the limiting mass for thermonuclear fusion of deuterium (currently calculated to be 13 Jupiter masses for objects of solar metallicity); and

(c) has a mass ratio with the central object below the L4/L5 instability and above lower mass limit to dynamical dominance i.e., $2.056 \times 10^{-11} < m/m_{central} < 0.04$.

In this formulation, clause (c) follows the recommendations from the working definition of IAU Commission F2 (Lecavelier des Etangs and Lissauer [1]).

5 Experiment of A Dynamical Dominance

The new having cleared its orbit conditions must also be confirmed experimentally. We confirmed so with the dwarf planet 2002 UX25 and an experimental comet in Figure 1. That implies 2002 UX25 has a dynamical dominance. Therefore, the eight planets and five dwarf planets and Orcus, Quaoar, Gonggong, Sedna, Mani, Salacia, 2002 UX25, 2002 AW197, 2003 AZ84, and many large dwarf planet candinates must be planet.
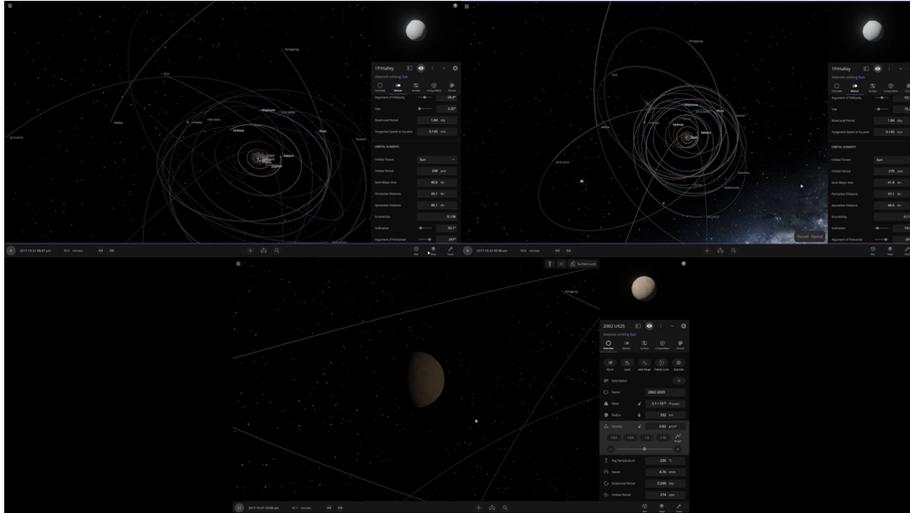

Figure 1: For example, 2002 UX25 has a dynamical dominance because it changed orbit of a experimental comet.

6 Conclusions

Precise definitions are needed to communicate and organize thoughts. The IAU definition of "planet" has been criticized with good reason since 2006. In this work, we examined the results of Solar System bodies to propose this

definition. This analysis revealed the presense of groupings among Solar System bodies.

7   Acknowledgments

References

[1] Lecavelier des Etangs, A., and Lissauer, J. J. 2022, The IAU working definition of an exoplanet, "New Astronomy Reviews", 94, 101641, doi: 10.1016/j.newar.2022.101641

[2] Gladman, B. 1993, Dynamics of systems of two close planets, Icarus, 106, 247, doi: 10.1006/icar.1993.1169

[3] Margot, J. (2015). "A Quantitative Criterion for Defining Planets," *The Astronomical Journal*, 150(6): 1-7, doi: 10.1088/0004-6256/150/6/185

[4] Margot, J., B. Gladman, and T. Yang (2024). "Quantitative Criteria for Defining Planets," *The Planetary Science Journal*, 5(7): 1-10, doi: 10.3847/PSJ/ad55f3

[5] Soter, S. (2006). "What is a planet?" *The Astronomical Journal*, 132(6), 2513–2519, doi: 10.1086/508861

[6] Stern, S. A., and H. Levison (2002). Regarding the criteria for planethood and proposed planetary classification schemes. *Highlights of Astronomy*, 12, 205–213

[7] Tremaine, S. (1993). "The Distribution of Comets around Stars," *ASP Conference Series*, 36: 335-344.