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Pluto: A Planet or a Trans-Neptunian Object?

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Abstract. The purposes of classification and taxonomy are reviewed. Using examples from fields ranging from paleontology to planetology, I argue that non-exclusive classifications, which allow Pluto to be considered both a planet and a TNO, provide the most desirable approach to progress in our science.

1. Introduction

Scientists classify things in order to find patterns that will help explain how things are related or how they evolved. In some sciences, such as paleontology and meteoritics, considerable effort goes into taxonomy. Much less effort goes into taxonomy and classification in most of planetary science. Nevertheless, discussion of the classification of Pluto in 1998-99 was surprisingly vigorous. There are lessons to be learned from looking at other examples of classification that are analogous to the case of Pluto. Analogies are never perfect, but they can lead to useful insights.

2. Archaeopteryx

Although an ancient (145 Ma) fossil may appear to have little relevance to Pluto, there are lessons to be learned from its classification. Archaeopteryx was first discovered by von Meyer (1861a, b) shortly after publication of Darwin's Origin of Species. It was immediately recognized as unusual and likely to provide insight into the evolutionary relationship, if any, between birds and dinosaurs. Further study of archaeopteryx fossils has shown that it had characteristics both of dinosaurs and of birds (see, e.g., Ostrom 1975). Distinctive bird-like features included the existence of both feathers and a furcula (wishbone). Furthermore, the hind limbs were much more bird-like than dinosaur-like. On the other hand, distinctive dinosaur-like features included the existence of teeth and a pelvis that was much more like those of other dinosaurs than like those of modern birds. The fore limbs and the vertebrae were also more dinosaur-like than bird-like but the differences were not so distinctive. Should it be classified as a dinosaur, as a bird, or as the ancestral bird?

For more than 50 years there was strong disagreement and consensus only began to emerge after the analysis by Heilmann (1926). Even after almost a century the paleontologists still argued the details. Ostrom (1975) argued that there was no evidence against the direct evolution of birds from archaeopteryx but also noted the arguments of other paleontologists who had claimed that there was no relation between birds and theropod dinosaurs (a large class of dinosaurs including archaeopteryx). Sereno (1999) argues that the immediate ancestor of modern birds was confuciusornis, a species very closely related to archaeopteryx in his phylogenetic tree, and that both are aves. All of the above dinosaurs are theropods, generally thought to be the direct ancestors of birds, but some paleontologists (Jones et al. 2000) have argued that the origin of birds lies much earlier than any theropods, and perhaps with longisquama insignis at 220 Ma.

The classification of Pluto has been an issue for much less than a decade, only since enough TNOs were discovered to recognize Plutinos as a sub-class. If TNOs, and specifically Plutinos, had been known before the discovery of Pluto, our thought processes might have been different but the history of archaeopteryx suggests that even then the disagreements might have lasted many decades. Pluto certainly has planetary characteristics. It is nearly spherical indicating that self-gravity has overcome structural strength. It has an atmosphere, at least seasonally, although Trafton et al. (1997) have argued that it may be in hydrodynamic escape and thus like a comet while Meech and Belton (1990) demonstrated a bound atmosphere around Chiron. Pluto also has dynamical characteristics of the Plutinos including a moderate eccentricity, a high inclination and a libration with Neptune. If we spend the next several decades disputing the classification we will be distracted from the entire point of classification. The important point is that Pluto should be looked at from both sides since, like archaeopteryx, it is on or near the boundary between two classes and thus can shed unique light on the relationship between the groups. In particular, if we want to understand how icy planets work, then Pluto should be included as a planet in such a study. If we want to understand how some TNOs reached their present libration with Neptune (Malhotra 1995), then Pluto should be included as a TNO in such a study. The key lesson from archaeopteryx is to look at Pluto from both sides and not spend decades, or even centuries, disputing the classification.

3. Defining a Planet

Efforts to define a planet have been approached by two very different groups of researchers in different contexts. The planet-formation theorists and the observers of extra-solar planets are concerned about the separation of the largest planets from brown dwarfs. Cometary, asteroidal and planetary scientists all are concerned about the separation of planets from smaller bodies.

As discussed by Oppenheimer et al. (2000), theorists who study the formation of planets often make the distinction that planets formed in disks around stars while brown dwarfs in orbit around other stars formed by fragmentation of the originally collapsing cloud. Regrettably, although this is in some sense the most valuable classification in terms of understanding formation processes, it is not at all useful in a practical sense because it is not based on an observable quantity. All useful classifications must be based on observable data. Other researchers have argued that one should consider a brown dwarf to be anything that was large enough to burn deuterium and a planet to be anything smaller. This places the boundary near 0.013 solar masses. Since the mass, or at least $m \sin i$, is an observable quantity in most of the cases of interest, the deuterium burning at least becomes an observable criterion. The boundary is likely to be similar to the one based on formation mechanism according to current theory, but that is a fortunate coincidence.

At the small end of planets, the origin of the body would lead to classifying planets dynamically as bodies that dominate (by mass) their region of the Solar System, whereas the theory of how planets work would lead to classifying them physically, e.g., as bodies in which self-gravity dominates structural strength. Unlike the case for large planets and brown dwarfs, both criteria are observable and for many small bodies the mass dominance is more directly observable than the shape. This might argue for mass dominance as the better criterion but either is available. For this we might look at another, closely related case.

Our traditional definition of a satellite is a purely dynamical one – something orbiting a planet, but there are clearly different classes of satellites. There are generally considered to be 4 terrestrial planets, but for decades it has been common to treat Luna as a 5th terrestrial planet, increasing the size of the sample and thus better showing the patterns of how rocky planets work (e.g., Lowman 1975). Earth's moon does have enough self-gravity to overcome most of its structural strength and by that definition is a planet, but in terms of formation, we have to consider it a satellite. In this regard it is not like the Galilean satellites but probably the first example of a class of satellites that must have been formed in a collision between its planet and another planetesimal (e.g., Cameron and Benz 1991). Charon is likely another example. Similarly, it only makes sense to think of Pluto as a typical icy planet if we consider it together with some of the Galilean satellites of Jupiter and Titan and Triton. We can consider them all together as icy planets if we are thinking of the internal structure and retention of atmospheres, but we must think of them separately (as regular satellites or anomalous satellites or TNOs) if we are considering the formation process. (One might also ask whether D/Shoemaker-Levy 9 should not have been classed as a satellite rather than as a comet!) From these analogies we note that planetary scientists are not always consistent in choosing between formation scenarios and internal properties or between dynamical properties and physical properties.

4. Dual Classification

After cometary activity was discovered on Chiron (Tholen et al. 1988) and more particularly after a coma was seen by Meech and Belton (1990), the IAU via the Minor Planet Center was forced to consider the classification of Chiron, a long-established minor planet (2060) in a system which, until then, had mutually exclusive catalogs of minor planets and comets. After some discussion, it was decided that 95P/Chiron = (2060) Chiron, i.e., putting Chiron in both catalogs, was the most sensible approach. This meant that it automatically turned up in catalogs used both by observers of asteroidal physico-chemical properties and observers of cometary physico-chemical properties. Since this example, two other examples have been discovered, 107P/Wilson-Harrington = (4015) Wilson-Harrington and 133P/Elst-Pizarro = (7968) Elst-Pizarro. These three examples are very different physically from one another but they all test the boundaries of our understanding of physical properties. Consideration of all three in both ways has led to a better understanding of the range of phenomena that comets exhibit and has contributed to the realization that many near-Earth asteroids may be dormant comets. Dual classification helps in this case because it highlights the boundaries between categories that may represent either a single continuum or two slightly-overlapping populations.

Dual classification is also valuable when the criteria for classification in two different ways are nearly orthogonal. Classification of people by their nationality and by their height leads to nearly orthogonal classifications. Although there are obvious correlations between height and nationality, the range of heights for a given nationality is so large that the two systems show only a weak correlation in classification and there is a huge overlap of people from different nationalities in any bin of height. This example may be even closer to the case of Pluto in that dynamical classifications are only weakly correlated with classification by physical properties.

5. Summary

Examples from other fields, some close to the question of classifying Pluto and some rather remote, all point to the value of focusing our attention on the problems we are trying to solve. That focus leads me to argue that dual classification, whether by orthogonal criteria or for boundary cases in otherwise mutually exclusive categories, is a valuable tool. Perhaps in 50 years it will be perfectly clear just how Pluto is related both to planets like Neptune and to TNOs like the Plutinos. In the meantime, the most important thing is to recognize that it shares characteristics with both and we do not have sufficient information to exclude it from either category.

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