A DEFENCE OF PLURALISM IN THE DEBATE ABOUT NATURAL KINDS: CASE STUDY FROM THE CLASSIFICATION OF CELESTIAL OBJECTS

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Abstract. I reconsider the monism/pluralism debate about natural kinds. Monism claims that there is a privileged division of reality into natural kinds, while pluralism states that there are many ways of classifying objects according to different purposes. I compare three different monistic accounts of natural kinds with the pluralism advocated by promiscuous realism. The analysis of some examples of the classification of celestial objects suggest that there are indeed different legitimate ways of classifying things according to different purposes; contrary to monism, the boundaries between kinds are not fixed. These results show that promiscuous realism is a better account of natural kind.

I. Introduction

Classifications are an important component of science. Often the first step towards the formulation of a scientific theory is the invention of a classification scheme that subdivides the observational stuff in suitable bins and organizes the large quantity of empirical information. The philosophical analysis of classifications is closely connected with the debate about natural kinds. A natural kind is a class whose members share many important scientific properties and about which it is possible to formulate substantial inductive generalizations. Examples of natural kinds are biological species (e.g. cats, dogs), chemical elements (e.g. hydrogen, gold), chemical compounds (e.g. water), elementary particles (e.g. electrons, protons). It is easy to find examples of classes that are not natural kinds: the class of things weighing less than 3 kg or the stars belonging to a particular constellation. Members of these classes share only the defining property, and no reliable inductive generalization can be formulated about them.

There is a lack of agreement about the status of classifications and natural kinds. Two broad families of philosophical theories can be identified: monism and pluralism. Monism claims that there is only one natural way of distinguishing kinds, according to their essential intrinsic properties, although there could be different ways of classifying objects, because someone could decide to ignore certain real differences in order to better suit his or her aims. For example, in some contexts drinkable water can be classified as a mixture of several kinds (viz. water, sodium, calcium, potassium, carbon dioxide), and in other contexts simply as water. However, there is a unique privileged classification, the one that recognizes the real essence of a kind. The real essence of water is expressed by its chemical formula: water is H_2O, and nothing else is water. Thus drinkable water is not water, but for some purposes we can classify it as water. As a metaphysical theory, monism requires the uniqueness of boundaries between kinds; as a theory about classifications, monism is compatible with classificatory pluralism, although it requires the existence of a privileged classification scheme.

Pluralism claims that there is more than one legitimate way of dividing kinds, and thus there are many different legitimate ways of classifying objects, according to many legitimate purposes. The boundaries between kinds are not fixed. Even a chemical formula is not sufficient to trace a boundary: are two isotopes of an element (e.g. deuterium and hydrogen) of the same kind? Is heavy water, where hydrogen is replaced by deuterium, water? Pluralism states that the answer is not determined once and for all; it depends on many factors: the purpose of the classification, the context, historical reasons, and so forth. As a metaphysical theory, pluralism denies the uniqueness of boundaries between kinds; as a theory about classifications, pluralism predicts a plurality of classifications depending on the theory in which they are formulated and on the interests and aims of scientists.

Among the two families of monism and pluralism it is possible to distinguish various accounts of natural kinds. In the present paper I will be interested in the following four: the essentialist account (natural kinds must be identified using essential intrinsic properties), the nomological account (natural kind terms feature in scientific laws), the causal account (there is a causal mechanism that explains why members of a natural kind share scientifically relevant properties), and promiscuous realism (there are many legitimate ways of classifying things according to different purposes).

Essentialism is the best known example of a monistic account of natural kinds. It has a long established tradition, from Aristotle, who held that members of a kind share a common essence, to Locke, who theorized an unobservable microstructure for explaining the shared properties. Contemporary essentialism, mainly associated with Kripke (1971, 1972) and Putnam (1975), claims that essential intrinsic properties define necessary and sufficient conditions for belonging to a natural kind. For example, the natural kind 'water' can be defined by means of an essential intrinsic property, namely the chemical formula: water is H_2O. The essentialist viewpoint goes along with some sort of realism: the world is objectively constituted of natural kinds whose boundaries are independent of our purposes. The primary aim of scientific classification is to reproduce the real segmentation of things into natural kinds.

The nomological account (Collier 1996) holds that natural kind terms feature in scientific laws, that is in unrestricted statements supporting counterfactuals. Natural kinds are connected by causal relations. A natural kind cannot be a proper subclass of a class that preserves these causal relations. According to Collier (Collier 1996), biological species and chemical elements, which are usually regarded as paradigmatic natural kinds, are not natural kinds, because their causal relations can be abstracted to more general classes. Collier considers natural kinds as very abstract classes defined by scientific laws that specify necessary relations and that set a unique classification.

> Whatever the natural kinds are, they must be very abstract. Perhaps masses and intervals are natural kinds. [...] [N]ecessary relations [...] among natural kinds are given by the laws that relate them [...] [T]here is a unique classification into natural kinds (Collier 1996, pp. 4-5).

Monism is expressed by the requirement of a unique classification based on necessary relations formulated by scientific laws; these necessary relations are a substitute for essences.

According to the causal account (Boyd 1991) members of the same natural kind tend to share similar properties because of a causal mechanism. This account can be characterized by the following definition.

> A class C of entities is a natural kind if and only if there is a large set of scientifically relevant properties such that C is the maximal class whose members tend to share these properties because of some causal mechanism (Machery 2005, pp. 447-448).

Not every member of a natural kind must have all the properties that characterize the kind. This is a fundamental difference from the essentialist account, which regards the characteristic properties of a natural kind as necessary and sufficient conditions possessed by all members of the kind. Another important point is that the previously mentioned definition is intentionally fuzzy: expressions such as „a large set" and „tend to share" occur in it. A plurality of causal mechanisms is allowed (e.g. essences, intrinsic or relational properties, homeostasis, or a common origin). The causal account can be restated via the following three requirements: (1) members of a kind tend to share a large set of scientifically relevant properties; (2) members of a kind share these properties because of some causal mechanism; (3) these properties are specific to the kind (Machery 2005, p. 449).

Essentialist, nomological and causal accounts have in common an important characteristic: a natural kind cannot be a subclass of a larger class whose members share the same relevant properties. Thus, for every kind, there is a point beyond which no further subdivision is admissible. Consider, for example, the kind dog. The class of white dogs is not a natural kind, because every relevant property possessed by white dogs is also possessed by dogs – except the property 'white'. There are thus infimic kinds (Slater 2005, pp. 30-31), i.e. the most specific kinds; it is impossible to subdivide an infimic kind into other kinds, because there are no relevant differences between its members. The classification system based on infimic kinds is the most complete one, in which no relevant difference is ignored.

Promiscuous realism belongs to the pluralist family. It asserts that there is no unique way of classifying things, and that every classification depends on both the properties of the objects and the purposes of the classification.

> My thesis is that there are countless legitimate, objectively grounded ways of classifying objects in the world. And these may often cross-classify one another in indefinitely complex ways. Thus while I do not deny that there are, in a sense, natural kinds, I wish to fit them into a metaphysics of radical ontological pluralism, what I have referred to as 'promiscuous realism' (Dupré 1993, p. 18).

The word 'realism' points out that the arbitrariness of classification is limited by the properties of the objects and thus a good classification is objectively grounded. The word 'promiscuous' points out that there is no privileged way of classifying things, but that there are different legitimate ways.

> [M]y position is realist, in that I insist that there is something that legitimates a good set of classifications [..] But the position also recognizes an ineliminable role for human classifiers in selecting a particular classification scheme [...] This selection will of course depend crucially on the purposes for which the classification is intended (Dupré 2002, p. 54).

Biology has provided examples supporting Dupré's viewpoint. In this paper I will show that astronomy supports promiscuous realism. There are many legitimate ways of classifying celestial objects in natural kinds according to many different legitimate purposes. These purposes can be very different. Sometimes astronomers are searching for a larger sample or for a sample that allows more accurate measurements, or they are interested in finding an overlap between two different kinds in order to study their correlations; sometimes astronomers' primary purpose is to keep pace with technological advances , and in other situations they need to explain the exact meaning of a scientific term.

II. Classification schemes in astronomy

The examples I will examine are the classification of variable stars, Chiron's dual classification as comet and asteroid, the definition of planets, and some aspects of the classification of supernovae, Cepheids, and galaxies. We will see that different accounts of natural kinds are compatible with the actual scientific practice regarding variable stars, which thus cannot be used as a test case for the monism/pluralism debate. The case of Chiron poses a serious problem for the essentialist account, but it is compatible with the causal account. The classification of planets proves that monism is untenable. Finally, the classification of supernovae, Cepheids, and galaxies illustrates the different purposes of classifications, giving support to promiscuous realism.

II.1 Variable stars

The General Catalogue of Variable Stars (GCVS) classifies variable stars according to a plurality of criteria, e.g. the physical mechanism of the variability, spectral type, length of the period, light curve shape, and the amplitude of the variability. Six major kinds of variable stars are recognized: eruptive, pulsating, rotating, cataclysmic, eclipsing, and X-ray variables. These kinds are divided into subclasses.

> All of these classes include objects of a dissimilar nature that belong to different types of light variability. On the other hand, an object may be variable because of almost all of the possible reasons or because of any combination of them (Samus, Durlevich 2004, par. 1 – GCVS Variability Types).

The classification of variable stars contains two threats to the essentialist account of natural kinds. First, a kind of variables could include stars which are different in nature as well as in observational properties; thus members of a kind could have different intrinsic and extrinsic properties. Second, a variable star can belong to many different kinds, thus destroying the clear-cut distinction between kinds required by essentialism. As an example of the first point I will consider the classification of eclipsing variables; for the second point I will consider the variable star named WZ Sge.

A plurality of classification criteria can be found in the classification of eclipsing systems; hence this kind of variables includes stars with very different physical and observational properties.

> We adopt a triple system of classifying eclipsing binary systems: according to the shape of the combined light curve, as well as to physical and evolutionary characteristics of their components. The classification based on light curves is simple, traditional, and suits the observers; the second and third classification methods take into account positions of the binary-system components in the (MV, B-V) diagram and the degree of inner Roche lobe filling (Samus, Durlevich 2004, par. 5 – Close Binary Eclipsing Systems).

In this case the same kind is classified in three different ways in conformity with different purposes. The first type of classification is suitable for observational studies; the second takes into consideration mass, luminosity, colour, and spectral type, and is correlated with the physical evolution of stars – therefore is congenial for studies concerning star formation and evolution; the third is based on the actual physical mechanism that produces the variability, and thus is suitable for studies dedicated to the explanation of every detail of the variability. You can see a true case of promiscuous realism at work in science. Is this situation problematic for essentialism? The answer is no, for two reasons. The first reason is that essentialism is compatible with a plurality of classification schemes: „Classificatory pluralism does not entail metaphysical pluralism." (Slater 2005, p. 30). Essentialism requires that a privileged classification scheme exist, but it does not require that scientists use only the privileged classification scheme. Scientists can decide to ignore differences between kinds in order to better satisfy certain purposes. The second reason is that essentialism can claim that the classification of binary eclipsing systems mixes intrinsic and extrinsic properties. To be an eclipsing system is not an essential intrinsic property of stars, because it depends on the line of sight of the observer. Of the three classification schemes recognized by GCVS, the first one, based on the light curve shape, is strongly influenced by the relative position of the stars and the observer. It can be useful for certain purposes but, for the study of the true physical properties of stars, it is superseded by the other two methods of classification. The method based on an (MV, B-V) diagram classifies an eclipsing binary system according to the physical characteristics of the components, viz. the presence of certain emission lines in the spectra and the nature of the components (whether they are giant stars, white dwarfs, or the nuclei of a planetary nebula). These physical properties are very general ones, in the sense that every star can be classified using them; thus they do not capture all the relevant features of a binary system. This type of classification ignores specific differences between binary systems; it can be useful from a scientific point of view but, from an essentialist viewpoint, is an incomplete classification scheme. On the contrary, the classification based on the degree of inner Roche lobe filling seems more complete, because it captures an essential property of binary systems, namely the relative distance between the components. It can be considered an example of the privileged classification scheme required by essentialism; the other two schemes, which add more complexity to the classification, are based on extrinsic properties and ignore certain pertinent distinctions.

An example of the second threat is the star WZ Sge, which is classified as belonging to the classes labelled UGSU (cataclysmic variable stars characterized by the presence of short normal outbursts and longer brighter outbursts), E (eclipsing binary systems), and ZZ (pulsating white dwarfs). To what kind does WZ Sge belong? It is a cataclysmic variable star as well as a binary eclipsing variable star as well as a pulsating variable star. Thus it belongs to three different higher level kinds in the hierarchy of variable stars. This situation is very different from the case of my dog, which belongs to many kinds (e.g. dogs, mammals, vertebrates, and animals) which are hierarchically organized. In biology, classification schemes are represented by a tree, and an organism belongs to one and only one path of the tree. On the contrary, WZ Sge belongs to three different paths. Essentialism requires sharp boundaries between natural kinds, but WZ Sge cannot be forced into only one country; it continually crosses the boundaries.

Essentialism can reply to these considerations by claiming that the GCVS classification is incomplete. It is necessary to recognize the existence of more specific kinds in order to account for stars having many mechanisms responsible for the variability; in the case of WZ Sge, it is possible to define a kind, say UGSU+E+ZZ, whose members are eclipsing binary systems in which a component is a pulsating star subjected to normal and longer outbursts. WZ Sge belongs – so essentialism could claim – to a new kind of variable stars. Although the real history of the observations of WZ Sge was not so straightforward, the outcome of the studies of this star is that WZ Sge is the prototype[1] of a new class of variable stars, called WZ Sge-type dwarf novae. The definition of this new kind, far from being an *ad hoc* move to save a metaphysical theory, was a necessary step in the direction of more comprehensive scientific studies of variable stars.

The classification of variable stars shows that many different classification schemes are used in real scientific practice, according to many different purposes; from a methodological viewpoint, all these classification schemes are legitimate, on a par. This is the situation predicted by promiscuous realism. However, as shown above, essentialism can be defended with success. What about the causal account? Consider for example the kind 'WZ Sge-type white dwarf'. Is there a large set of scientifically relevant properties that the members of this kind tend to share? Yes, e.g. some physical characteristics of the binary system as well as of the components, the mechanism of the variability, the presence of longer brighter outbursts. Do the members of the kind share these properties because of some causal mechanism? Yes. The exact mechanism is not known, but many theoretical hypotheses have been proposed. Are the shared properties specific to the kind? Yes. This kind of variable has been defined in order to group stars with peculiar characteristics. Hence the causal account is compatible with the classification of variable stars.

The nomological account requires the existence of unrestricted laws supporting counterfactuals in which natural kind terms occur. In the simplest cases these laws can be formulated. The dynamics of the simplest eclipsing binary system are controlled by the laws of mechanics, which explain very well the regularity of the period and of the light curve shape. More complex systems present more difficulties. Stars such as WZ Sge experience unpredictable outbursts, and there is a lack of agreement about the theoretical model that can explain their behaviour. However, the histo-

[1] Note that in classification of variable stars the prototype has a role similar to Putnam's stereotype (Putnam 1975).

ry of astronomy shows that the search for laws explaining the features of variable stars has sometimes been crowned with success. Hence we cannot rule out the nomological account because of the lack of known scientific laws governing every detail of every kind of variable star, especially if we recognize that these laws have been formulated at least for some kinds.

The classification of variable stars cannot be used as a test case for the monism/pluralism debate, because different accounts of natural kinds are compatible with actual scientific practice regarding variable stars.

II.2 Dual classification

The best known example of a celestial object with a dual classification is Chiron, the prototype of a class of small bodies orbiting between Jupiter and Neptune called Centaurs, originally classified as an asteroid. Later, when cometary activity was discovered, it was classified as a comet without removing it from the catalogue of asteroids. Thus Chiron belongs to two kinds that were mutually exclusive before its reclassification. A dual classification can suggest relations between two different kinds that were previously unrelated. Chiron's dual classification as asteroid and comet hinted that near-Earth asteroids might be dormant comets. A dual classification has been proposed also for Pluto: „As with [...] Chiron [...], where the choice of the 'minor planet' or 'comet' designation depends on the context, we are proposing that Pluto would have dual status as a 'major' and a 'minor' body" (Marsden 1999). A benefit of Pluto's dual classification is that it would expand both the sample of icy planets and the sample of Trans Neptunian Objects (TNOs) in libration with Neptune (A'Hearn 2001).

This situation is interesting from a philosophical point of view. It reminds us that there are many different ways to construct a classification, and that there is no absolutely correct method, rather, every classification depends on the context. If an astronomer is interested in the study of comets, he can determine certain criteria according to which celestial bodies are classified as comets. With respect to these criteria, Chiron is a comet. If an astronomer is interested in asteroids, she can determine certain criteria according to which celestial bodies are classified as asteroids. With respect to these criteria, Chiron is an asteroid. In the same way, if someone is interested in the physics of icy planets, then he can treat Pluto as an icy planet; if someone is interested in the dynamics of TNOs, then she can treat Pluto as a TNO. Sharp distinctions are not always possible, and not always desirable.

The case of Chiron poses a serious problem for the essentialist account. Is it a comet or an asteroid (or perhaps a Centaur)? There is no reason to prefer one kind to the other, and thus there is an overlapping classification between asteroids and comets. While cases of dual classification can be a source of concern for the essentialist account, they are of primary scientific interest. They[2] have linked together two kinds which were considered to have no common members, and have encouraged the formulation of relevant scientific hypotheses (A'Hearn 2001).

The nomological account suffers from the same problem we will examine in the case of planets: there is no law in which natural kind terms for asteroids and comets occur.

Chiron's dual classification is easily understandable by the causal account, which does not require that an object belong to one and only one natural kind (this is a consequence of the fact that the causal account does not require that every object belonging to a kind possess all relevant properties).

II.3 Planets

The need for an explicit and exact definition of 'planet' has arisen out of the growing rate of discovery of TNOs with physical and orbital properties comparable with those of Pluto. The discovery of Eris (formerly known by the name 2003UB313), a TNO greater than Pluto, announced in July 2005, has precipitated the need for such a definition. Astronomers agreed on a definition of 'planet' at the 26th General Assembly of the International Astronomical Union (IAU) held in Prague, August 2006. A planet has been defined as a celestial body that orbits the Sun, has a round shape due to its gravity, and has an orbital dominance, i.e. has cleared the neighbourhood around its orbit. According to this definition, Pluto is removed from the list of planets because it lacks orbital dominance (near Pluto there are many objects with physical characteristics comparable to those of Pluto). The known planets in the Solar system are eight: Mercury, Venus, Earth, Mars, Jupiter, Saturn, Uranus, and Neptune.

The case of the classification of planets is an example of an explication, in the sense described by Carnap (Carnap 1950, p. 4). An explication deals with the meaning of an already given expression (*explicandum*), and provides an expression (*explicans*) that explains, by means of linguistic and empirical methods, the meaning of the explicandum. The explicandum is used in science and natural language, sometimes as a self-evident expres-

[2] Four other objects have a dual classification as asteroid and comet.

sion, but really its meaning is not clearly stated. A problem of explication is not well-defined. We cannot decide, in an exact way, whether a proposed explication is correct. „Strictly speaking, the question whether the solution is right or wrong makes no good sense because there is no clear-cut answer" (Carnap 1950, p. 4). Carnap discusses four requirements for an explication: similarity to the explicandum, exactness, fruitfulness, and simplicity (Carnap 1950, p. 5). According to Carnap, the last three requirements are the most important, while the first one is probably too strong, and it is often not in agreement with actual scientific procedure. Exactness means that the definition must be stated in exact terms and must be applicable without uncertainties. Fruitfulness means that the explicans must be useful for the formulation of scientific laws. Simplicity means that the definition must be based on properties that are easily ascertainable.

A problem for monism is that there is no natural limit to the possible distinctions between planets. There are no infimic kinds. The most complete classification of planets is a classification in which every planet is a separate kind. The eight planets can be divided into at least two classes: terrestrial and gaseous planets. Terrestrial planets (Mercury, Venus, Earth, and Mars) are so different (cf. Table 1) that there are many ways for dividing them into different kinds.

Table 1 – Characteristics of terrestrial planets, from Sosio (1998, p. 378)

Planet	**Density** (water=1)	**Gravity** (Earth=1)	**Inclination** (degree)	**Rotation period** (Earth=1)
Mercury	5.4	0.38	0	58.7
Venus	5.2	0.90	2	243
Earth	5.5	1.0	0	231
Mars	3.9	0.38	24	1.03

According to density, terrestrial planets can be classified in two groups, one including the first three planets, the other including Mars. If they are classified according to gravity, the distinction is between Earth and Venus on one side and Mars and Mercury on the other. If they are classified according to inclination, we found that Earth and Mars form a group which is very different from that of Mercury and Venus. The rotation periods of Earth and of Mars are almost identical. Earth is the only terrestrial planet with a large satellite. There are many ways of dividing terrestrial planets in kinds, and no one of them is privileged; there is no limit to the discrimination process. The lack of definite boundaries between groups of planets is a serious problem for monistic accounts. If there are no definite boundaries then every class of planets is artificial, and the classification of planet cannot be based on natural distinctions. This analysis is confirmed by the fact that planet, as defined by IAU, cannot be recognized as a natural kind by monistic accounts. From the essentialist viewpoint, planet is not a natural kind because it is defined in terms of relational properties, not in terms of intrinsic properties. Orbital dominance depends not only on the physical properties of the planet but also, mainly, on the physical properties of the neighbouring celestial objects. Although astronomers have defined necessary and sufficient conditions for membership of the kind 'planet', these conditions are not derived from essential intrinsic properties, they are merely an explication of a scientific concept whose range of applicability had become uncertain. Carnap's observations on explication, with the four requirements of similarity, exactness, fruitfulness, and simplicity, are sufficient to explain what has happened in the astronomical community, without the need for essential intrinsic properties.

According to the nomological account, natural kind terms feature in scientific laws. In the case of planets, the relevant laws could be Kepler's laws. However, there is a problem: the class of planets is a subset of a larger class about which the same laws can be formulated. Not only planets satisfy Kepler's laws, but also asteroids, satellites, and comets. According to the nomological account, a natural kind is not a proper subclass of a class about which the same laws can be formulated, and thus we are forced to conclude that planet is not a natural kind, because it is too specific.

The causal account is also forced to recognize that 'planet' is not a natural kind. Are there scientifically relevant properties which planets tend to share? Yes. For example, planets are cold and dim; they can have an atmosphere (planets have an orbital dominance and thus can be large enough to maintain an atmosphere); they can have water on their surface (because they are neither too hot nor too small); thus they can – at least in principle – sustain life. Are the properties of planets shared because of some causal mechanism? Probably yes, due to their common origin, but contemporary knowledge is not sufficient to give a definite answer. Finally, is the class of planets a subset of a larger class with the same scientifically relevant properties? The answer is yes. Several satellites are spherical due to their gravitational pull, and have enough mass to maintain an atmosphere and possibly water. In the Solar system, the physical properties of the largest satellites are similar to the physical properties of the terrestrial planets; really, there is more similarity between terrestrial planets and the largest satellites than between terrestrial planets and giant planets. Thus, according to the causal account, 'planet' is not a natural kind. The classification has been pushed beyond infimic kinds.

Promiscuous realism is in a better position. It can recognize the legitimacy of the various definitions which have been proposed and which are motivated by different aims. Consider, for example, the definition proposed by the Working Group on Extrasolar Planets (WGESP) of IAU: A planet is an object with a mass below 13 Jupiter masses that orbits a star; the lower mass for a planet should be the same as that used in our solar system. This definition leaves the lower mass indeterminate, while the IAU definition leaves the upper mass indeterminate. The two definitions differ because they try to resolve different problems, and thus their purposes are different. The WGESP definition has been formulated by a group interested in extrasolar planets, where many candidate planets have a mass greater than Jupiter; therefore the definition must determine the upper mass but can leave the lower mass indeterminate. The IAU definition has been formulated to resolve a problem relative to the Solar System, where the upper mass is not problematic, but the lower mass is a much discussed issue. There are different legitimate ways of defining a planet according to different purposes.

II.4 Supernovae and Cepheids[3]

The first studies did not recognize the existence of different types of supernovae. It was supposed that supernovae were homogeneous with a dispersion of the absolute luminosity at peak of about 1.1 magnitudes; thus supernovae were considered reliable distance indicators. Later researches showed that supernovae were not as homogeneous as supposed; the dispersion of the absolute luminosity at peak was greater than hitherto believed. This discovery, which would have rendered supernovae ineffective as distance indicators, caused a modification in their classification: two subclasses, called Type I and Type II supernovae, were defined. Type I supernovae are more uniform than generic supernovae, with a dispersion of absolute luminosity at peak of about 0.8 magnitudes, and thus they are more reliable

[3] For a brief description of the role of supernovae in astronomy see Riess, Press, and Kirshner (1996, pp. 88-90). For a historical review of Cepheid observation see Fernie 1969.

distance indicators. By means of spectral analysis astronomers discovered three subclasses of Type I supernovae, identified by the labels Ia, Ib, and Ic. Type Ia supernovae are very homogeneous, with a dispersion of the absolute luminosity at peak of about 0.6 magnitudes, and can serve as better distance indicators. Today Type Ia supernovae are used as standard candles to measure extragalactic distances and to verify cosmological hypotheses.

What is the philosophical moral of this story? The purpose of the classification of supernovae is to find a class of supernovae whose members have, with known approximation, the same absolute luminosity at peak, in order to use them as precise distance indicators. Astronomers are not searching for a classification schema based on essential intrinsic properties of supernovae; they are searching for standard candles, and the criteria used for classifying supernovae are subsidiary to this goal. When the goal changes the classification also changes: GCVS does not recognize subtypes Ia, Ib, and Ic, but only the distinction between Type I and Type II, because it is not interested in extragalactic distances. The classification is instrumental, in the sense that it is a tool devised for a particular purpose – a different purpose produces a different classification. However, the classification is not arbitrary, because it is constrained by the properties of supernovae, which are independent of the aims of astronomers – a different classification would not satisfy the purpose for which it has been conceived.

This situation is not peculiar to supernovae. The case of Cepheids is similar. Astronomers assign Cepheids to different classes (W Virginis and Delta Cephei types) because they obey different period-luminosity relations, and thus the separation in different classes is indispensable in order to use Cepheids as distance indicators.

These examples thus show that the classification of supernovae and Cepheids is not based on essential properties, but on properties that serve certain objectives external to the nature of the classified objects, but essential for astronomy.

II.5 Galaxies

The Hubble classification of galaxies[4] is based on a few morphological characteristics observed through the visual inspection of photographic images. Galaxies are divided into five main classes, namely ellipticals, ordi-

[4] For a description of the Hubble schema see Sandage 1975 and Sandage 2005.

nary spirals, barred spirals, lenticulars, and irregulars. There are important correlations between Hubble classification and the physical properties of galaxies[5]. It is by means of these correlations that the classification acquires a deep theoretical significance and can be used to verify theoretical frameworks about star formation and evolution. Different theories can be investigated with the aid of computer simulations, confronting the outcome of the simulation with the known properties of the Hubble classification.

Although Hubble classification has proved very useful, there is an important reason for trying to supersede it: astronomical surveys produce thousands of images of galaxies whose classification via the Hubble schema, which is based on human visual inspection of photographic images, is impossible. For example, we can compare a very large traditional catalogue such as de Vaucouleurs (1991), which includes data on 23.000 galaxies, with the Sloan Digital Sky Survey that, at the completion of its first part in 2005, had detected about 200 million objects and measured the spectra of more than 675.000 galaxies[6]. The only way to deal with such a wealth of data is the automated classification of galaxies. Roughly speaking, systems of automated classification make use of machine learning and image standardization and compression. It is not my intention to describe the techniques and the results of the automated classification of galaxies. The important point, at least from a philosophical viewpoint, is that the greater push for a revision of Hubble classification originates from technological progress. Modifications and additions to the Hubble classification are suggested by technological advancements producing too many data to analyse, not by theoretical developments and new observations.

The main problem for monism is that this role of technology is ignored. Monism points out that a good classification reproduces the real boundaries between kinds; thus a classification can be criticized because it does not match the division of reality into natural kinds. Monism, with its insistence on essential properties, cannot explain why a successful classification can be criticized on the ground that it does not allow the use of computer-aided classification systems. This situation is an unexpected one, and monism lacks the theoretical instruments to provide an explanation.

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[5] See Kennicutt 1998 and Sandage 1986.

[6] See the description of the Sloan Digital Sky Survey at http://www.sdss.org/.

Conclusion

The observation that in real scientific practice there are many different ways of classifying objects is not decisive in rebutting monism. Classificatory pluralism is compatible with monism, which can explain the existence of different classifications by recognizing that sometimes scientists decide to ignore certain real differences in order to satisfy specific aims. The observation that some objects have a dual classification is also not a conclusive rebuttal of monism. While its most restrictive interpretation (i.e. essentialism) does not recognize the possibility of an object belonging to more than one natural kind (apart from the case of hierarchically ordered kinds), the more liberal form of the causal account can accommodate such a situation. The best strategy for a rebuttal of monism is to show that there is no end point in the division of natural kinds and thus that the infimic kinds required by monism do not exist[7]. A common belief of astronomers seems to be that an end point in classification does not exist: „The process of discrimination seems never to be carried so far that it cannot be carried further; that is, the discrimination process can never be considered complete." (Morgan 1988, p. 8).

Planetary astronomy can show that there is no stopping point in the classification of planets. Every class of planets can be divided into many different smaller classes according to many different criteria based on scientifically relevant intrinsic properties such as mass, density, gravity, rotation period, and inclination. Therefore the infimic kinds do not exist. Hence monism is untenable. After recognizing that monism is not a viable option in astronomy, we can use the classification of supernovae, Cepheids and galaxies to show the plurality of purposes that are at the base of various classification systems.

A last question I want to analyse is concerns the objectivity of natural kinds and of scientific classifications. Traditional realism about natural kinds is grounded on the fact that membership of a particular kind is determined by the possession of essential properties; in this sense, there is a unique answer to the question to what kind a given thing belongs. The aim of sci-

[7] This is the strategy used by Slater 2005 to show that chemistry is not a monist-friendly domain. A similar idea has been expressed with respect to biology: „[...] divisions can be found well below what is generally taken to be the species level [...] Indeed, it is not entirely clear how we should motivate any stopping point in constructing genealogies until we reach the individual organism." (Duprè 1993, p. 49).

ence is to determine these essential properties, and therefore to determine the natural kinds defined by them. Natural kinds are thus imposed by nature. A good classification is based on those real natural kinds; therefore it is objectively grounded. On the other hand, the analysis of real scientific practice shows that natural kinds are inquiry-relative, in the sense that scientists recognize different natural kinds according to different purposes. Classifications depend on particular investigative ends. Thus a question arises: are natural kinds and classifications arbitrary and purely conventional? I think that some sort of realism can be successfully defended. Classifications are constrained by nature; given a particular classificatory question, the set of possible answers is limited by nature. Consider, as an example, the question „Is Pluto a planet?". The answer is not unequivocally determined. If we adopt the definition of planet that requires orbital dominance, then Pluto is not a planet; if we do not require orbital dominance but, for instance, require that a planet be a round object directly orbiting the Sun, then Pluto is a planet. It seems that the answer is determined by our free will; a planet is not definable by means of essential intrinsic properties, but only by using more or less arbitrary conventions. However, nature imposes some constrains. It is a matter of fact that Pluto does not have an orbital dominance and is round due to its gravitational pull. Thus, it is a matter of fact that if we adopt the definition according to which a planet is a round object directly orbiting the Sun, then Pluto is a planet, the Moon is not a planet, and Ceres is a planet. We have some freedom in choosing a particular classificatory scheme; but the consequences of such decision are determined and imposed upon us by nature. We can freely choose the kind of question we want to pose to nature; but the answer is determined by nature itself.

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