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Another earth: An astronomical concept of the planet for the environmental humanities

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ABSTRACT

Since the notion of the Anthropocene entered the discourse of environmental humanities, it has prompted multiple conceptual innovations. This paper focuses on one such case: the term planetary – and the adjacent genre of planetary thinking – theorized by a broad range of scholars. The original contribution of this paper lies in developing an astronomical concept of the planet, derived from the definition agreed by resolution 5A 2006 of International Astronomical Union, which defines planets based on their dynamical context. By means of philosophical interpretation of the definition's underlying assumptions, this paper articulates standalone philosophical implications of the astronomical concept: the contextualization of the planet in expanded ecology of the solar system, paired with the understanding of the planet as a structure of phase gradients and as a historical natural kind. Furthermore, I position the astronomical concept alongside theorizations of the planet by Latour, Stengers, Clark & Szerszynski as well as Chakrabarty, touching upon the Gaia hypothesis or the concept of geological history. Finally, I encourage deeper disciplinary interaction between astronomy and environmental humanities. The benefits of this interaction are highlighted in the concluding discussion concerning the multiplicity of planetary narratives and applications of the astronomical concept of the planet.

KEYWORDS

Astronomy; planets; planetary thinking; evolution; geological history; historical natural kinds; cosmic ecology

1. Introduction

In his recent collection of essays that rethink the relation between planetary sciences and the concept of history, Dipesh Chakrabarty (2021) demonstrates the potentiality of deep engagement between astronomy and environmental humanities when he articulates the maxim of planetary thinking: '*keeping other planets always in view even if only implicitly*' (Chakrabarty 2021, 79). This maxim suggests thinking about planets in a generic, cosmic view, which situates them as objects emerging from the broader context of the evolution and architecture of their home solar systems, and their relation to the host stars. This paper seeks to expand the gesture of Chakrabarty's maxim by introducing an *astronomical concept of the planet* – the conceptualization of the planet as a category of astronomical objects with distinct qualities and a degree of identity over time, which directly

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follows from how planets are defined in contemporary astronomy. While doing so, this paper urges the readers to imagine: What if the foundations of the planetary perspective in contemporary environmental thinking did not lie in the Anthropocene debate, visual references on Earth photographs or metaphors borrowed from Earth system science, but instead in the astronomical legacy of thinking about planets as members of a specific category of celestial bodies? What would such an account look like? The motivation to explore these questions stems from conviction that although planetary thinking may engage with multiple modes of conceptualizing the planet, each of these comes with some set of commitments. By uncovering the philosophical implications of the astronomical concept of the planet, this paper thus seeks to expand the theoretical basis of planetary thinking, and to parcel out potential common ground for further discussion between different philosophical articulations of the planetary. Beyond that, I also argue that the astronomical concept may function as a tool of disciplinary crosspollination, leading to the theorization of environmental problematics in larger cosmic context (mainly in relation to the role of cosmic history, including evolution of solar systems and biospheres).

I proceed in the following fashion. Section 2 reviews some entry points into contemporary planetary thinking, characterized by its tendency to build planetary perspective upon the unique affordances of the Earth (with respect to emergence of life), as well as via disciplinary translation from natural sciences to humanities (as exemplified by concepts such as *Gaia* or *symbiogenesis*). This exposition is followed by a deep dive into the definition of a planet as agreed by 5A 2006 resolution of International Astronomical Union (IAU), which presents the cornerstone of the astronomical concept of the planet (Section 3). By means of philosophical interpretation of the underlying assumptions behind IAU's definition, I then proceed with articulating the philosophical implications of the astronomical concept (Section 4): structural understanding of planets as heterogeneous stacks of *phase gradients* (Section 4.1), contextualization of planets in *expanded ecology of the solar system* (Section 4.2) and categorization of planets as *historical natural kinds* (Section 4.3). After explaining these implications, the argument of the paper proceeds with a bit of positioning (Section 7): the astronomical concept of the planet is discussed alongside theorizations of the planet by Clark and Szerszynski (2021) and Chakrabarty (2021) that both touch upon the concept of history. In this discussion, the central commitment of the astronomic concept of the planet is articulated: the commitment to the singularity of geological history, as opposed to plurality of planetary temporalities. In conclusion (Section 8), I discuss applications of the astronomical concept by briefly returning to general epistemological and methodological takeaways. It encourages deeper interdisciplinary interaction between astronomy and environmental humanities, and it highlights the benefits of such interaction in discussions concerning the multiplicity of planetary narratives.

2. Planetary thinking today

Planetary thinking has recently moved to the forefront of the agenda in environmental humanities, largely as an offspring of Anthropocene discourse, which positions human interventions into the Earth system as planetary both in their scope and in their consequences. Despite not committing to think about planets in purely natural-scientific terms (since it many times opposes scientism that would reduce philosophical takes on the planetary to mere footnotes to natural sciences), planetary thinking has been strongly influenced by Earth system science (ESS), which treats the Earth as a scientific object analysable in terms of theory of complex adaptive systems, thermodynamics, biogeochemical cycles, physics of gases, fluid dynamics, etc. (Pierrehumbert 2011). Another scientific discipline that has always been present on the background of this genre of thinking is *astronomy*, although its contribution has been seldom acknowledged in its own terms. Nevertheless, references to the cosmic context of the concept of the planetary are scattered through the literature (Spivak and Winterling 2015; Latour 2017; Clark and Szerszynski 2021), and the deeper exploration of this astronomical dimension has been conducted by anthropologists of outer space such as Lisa Messeri (2016) – who explains how astronomy comes to view planets as concrete places endowed with meaning – or more recently by historian Dipesh Chakrabarty (2021). Chakrabarty's contribution may be interpreted as a proposal to adopt a cosmic viewpoint in environmental humanities and to infuse astronomical concepts into planetary thinking. He backs this view by his explanation of how ESS can be viewed as a special case of astronomy, focused on the case of one planet, the Earth. As Pierrehumbert (2011) puts it elsewhere, '[t]he discovery of global warming is a great triumph of two centuries of developments in fundamental physics and chemistry' (60) – and by extension, of astronomy as a discipline that applies these fundamental insights into the study of celestial bodies in general, Earth included.

However, when it comes to environmental concerns that motivate contemporary planetary thinking, most of the literature focuses on the unique case of Earth, and its specific coupling with living matter, human actors included. While crafting their concept of a 'planetary social thought', Clark and Szerszynski (2021) introduce a range of key questions that exemplify this tendency:

> What kind of planet is this on which we find ourselves? What has our planet done in the past and what might it be capable of doing in the future? … [W]hat kind of creature or being are we? How have 'we' inhabited and made use of this planet in the past, and what might we find ourselves doing with the Earth and all its shifting, changeable processes in the future? (Clark and Szerszynski 2021, 3)

According to their recollection, these questions are indicative of the role that the concept of the Anthropocene has played in 'opening up broader matters of concern about human relationships with the Earth', brought about by an increasing likelihood of overshooting planetary tipping points due to anthropogenic climate change, such as irreversible loss of glaciers and polar ice sheets or runaway acidification of the oceans (Clark and Szerszynski 2021, 2–3). The aim of planetary social thought is then to 'identify clear pathways out of the current predicament', and in general to carve out a space of imagination in humanities and social sciences for possible futures of human inhabitation of this planet, while using the 'knowledge about how our planet works' as a base of this work of imagining (Clark and Szerszynski 2021, 4). As the authors claim, the new kind of planetary thinking becomes an imperative today, as it gives us a framework to address political issues related to climate change, including environmental injustice or climate colonialism (see also Keucheyan 2016, 20–46). Planetary social thought brings into our attention how the political issues that human societies immediately deal with sit in a larger terrain of 'the contact zone of human and non-human processes' (Clark and Szerszynski 2021, 4), or as Clark puts it elsewhere, it highlights 'the consequences of the earth mobilizing itself, of the collisions of its own temporalities and spatialities with the times and spaces of human life' (Clark 2011, 2). Ultimately then, the question of how 'we could live our lives otherwise' comes always already with question of 'how a planet becomes other than it is' (Clark and Szerszynski 2021, 4).

After all, different Earth-centred modalities of planetary thinking appear in wide range of disciplines ranging from cultural geography (Cosgrove 2001) and post-colonial studies (Spivak 2003) through media theory (Bratton 2015, Gabrys 2016) to continental philosophy (Thacker 2011, Woodard 2013, Connolly 2017, Hui 2020). Some authors, such as Savransky (2023), draw heavily on Deleuze and Guattari's (1994) *geophilosophy*, which provides a leeway to highly speculative reading of our planet and its affordances. Here, the precedence is given to poetic descriptions of 'contingencies and excesses of planetary dynamics, geological disjunctures and Earth-historical trajectories that we can never hope to control' (Savransky 2023, 3–4). Such descriptions lead to at once metaphysical, epistemological and political insights: the Earth is an unpredictable process of chaotic becoming, rather than a relatively stable and coherent entity. Hence, the planet is represented as principally unknowable, and impossible to tame by technoscientific apparatuses. Some of these ideas – especially the processual perspective on the planet implicit in the Deleuzian prose – may find analogous formulations in the astronomical concept of the planet. However, the astronomical conceptualization also significantly departs from one-sided preference of pure becoming, multiplicity and planetary otherness in favour of a philosophical position that would think Earth (and in fact any planet in the universe) in closer proximity to the astronomical understanding of planets. Such a position, however, does not render the astronomical insights with a sense of superiority – instead, it simply points at an expanded field of available philosophical conceptualizations that may yield implications which would otherwise stay unarticulated.

Besides Anthropocene discourse, planetary thinking finds important point of reference also in some earlier disciplinary translations between environmental humanities and natural sciences, especially ESS (*Gaia hypothesis*), evolutionary biology (*symbiogenesis*) and theory of complex adaptive systems (*autopoiesis*) (Margulis 1999, Clarke 2020). When it comes to the Gaia hypothesis, it brings an urgent need to scale-up conceptual tools of environmental humanities to capture systemic realities on the planet-wide level. Additionally, it serves as a great example of how astronomy becomes relevant for ecological theories: James Lovelock originally used the Gaia hypothesis to conceptualize potential biosignatures detectable by remote sensing of atmospheres of other planets in our Solar System, especially Mars (Latour 2017, 91). The hypothesis suggests that our planet's biotic and abiotic components interact in a unique and tightly integrated manner, maintaining conditions conducive to life (which makes Earth different from all other planets in our Solar System). The Earth system thus exhibits a form of *homeostasis* – an active regulation of environmental conditions (Clarke 2020, 38–39). Although the idea of Earth as a homeostatic system remains controversial in the ESS community, the emergent interplay between living organisms and the planetary ecology posited by the Gaia hypothesis enables thinkers such as Lynn Margulis (1999, 141–161) to question the view of organisms as discrete, separate entities, promoting instead an entangled perspective on organism–environment coupling. Hence, Latour (2018) has recently proposed to talk about organisms as *Lovelockian agents*, i.e. as composite actor-ecologies (75). Together, they coalesce into a patchwork of 'multiple, controversial, mutually entangled loops' situated within what he calls the 'critical zone' of Gaia – the thin envelope of Earth's upper crust that constitutes the primary environment of living organisms (Latour 2017, 140–141).[1]

These ideas are inspired by Latour's earlier work on *actor-network theory* (ANT). In his exploration of the political ecology of Gaia, Latour fuses the ontological standpoint of ANT – which privileges the diffusion of agency within the relational webs of *mediators* and *intermediaries* (Latour 2005, 38) – with Gaia's holistic perspective on Earth's life-support system, conditioning the existence of both human and non-human actors. Within this networked perspective, Gaia becomes a stage where diverse entities negotiate and shape environmental realities. This leads Latour to the postulation of *Gaiapolitics* as a new mode of normative practice based on the fluid, dynamical reality of the Earth. The planet becomes understood not as a static backdrop for human affairs, but as an active party in the negotiation of the affairs relevant to all Earthlings. Such a modality of political undertaking thus emphasizes the active, generative nature of planetary spatiality, which according to Latour side-tracks the political-ecological relevance of the notion of history:

> It is this deep shift from a destiny based on history to an exploration of what, for want of the better term, could be called *geo*graphy (actually *Gaiagraphy*) that explains the rather obsolete character of any philosophy of history. Historicity has been absorbed by *spatiality*, as if philosophy of history had been subsumed by a strange form of spatial philosophy – accompanied by an even stranger form of *geo*politics (actually *Gaiapolitics*). (Chakrabarty and Latour 2020, 431)

The key influence for such political conceptualization of Gaia comes from the work of an author closely allied to Latour's project, Isabelle Stengers. Stengers (2011) emphasizes the political work of ecology as a practice of dynamical and evolving shaping of the conditions of mutual existence, the process of 'collectively inventing what the world we all have in common will be' (349). Just as in the case of Deleuzian thinking, her approach stands in contrast to static and fixed notions of the planet, encouraging a view that considers the continuous becoming of the Earth and its composite nature, with the pivotal role of biosphere.

The Earth-centric and biocentric approach thus stands out as a shared heritage of a much of contemporary planetary scholarship. At the same time, this heritage may present a crucial limitation to such conceptual endeavour. Beyond the role of pure chance in maintaining habitable planetary environment, Gaian perspectives may neglect abiotic ecological factors, including the influence of cosmic ecologies – the role of Sun, Moon and other celestial bodies in shaping the orbital context of the Earth, as well as the conditions on the Earth surface (think about the tidal forces caused by the Moon or convection of molecules in atmosphere propelled by solar radiation). Following Chakrabarty (2021), planetary perspective requires a certain degree of genericity – it should be applicable to the case of any planet, thus seeing our Earth as a particular permutation of cosmic matter that temporarily takes upon the shape of a celestial body which fulfils the definitional criteria for being a planet. In turn, such a generic, cosmic view, may be better suited to provide a unified framework to address heterogeneous planetary ecologies, where networks of technical objects mix up with biological or geological assemblages. Such a framework may be instructive in reconceptualizing the situation of Anthropocene not as an unwanted historical aberration, but as a critical point in the long durée of evolution of terrestrial planets, which paves the way towards new negotiation of metabolic transactions between social, economic, infrastructural and biogeochemical feedback loops (Frank, Carroll-Nellenback, Alberti and Kleidon 2018). For this reason, the argument of this paper brackets off the just reviewed entry points into planetary thinking, posing instead the question of planetary perspective anew, from the vantage point of astronomy. Only after distilling the substantial philosophical insights from the astronomical definition of the planet, this fresh material can be channelled back into the vernaculars of the ongoing planetary discourse in environmental humanities, which will cash out by reinvigorating the discussions that still firmly orbit around references to Gaia hypothesis or Anthropocene.

3. An astronomical concept of the planet

As a distinct group of astronomical objects, planets are surprisingly common and diverse (Snellen et al. 2022). Today, we know about many solar systems around different classes of stars, and we distinguish several types of planets, including *hot Jupiters* (gas giants with large mass orbiting extremely close to stars), *sub-Neptunes* (ice giants with gaseous envelopes smaller than Neptune or Uranus), *super-Earths* (rocky planets up to 10 times Earth's masses) or *terrestrial planets* (including Earth, Venus or Mars). In the last three decades, the classification of planets – and the related definition of what a planet is – has been vividly debated with respect to discoveries of first star-orbiting exoplanets, beginning in 1995 with the discovery of 51 Pegasi b (Mayor and Queloz 1995). Since 51 Pegasi b turned out to be more massive than any planet in our solar system, it opened the question of the upper mass limit for a planet. This issue was later reinforced by discoveries of substellar star-orbiting objects known as *brown dwarfs* ('failed stars', see Basri and Brown 2006, 194). For this reason, the definition of a planet in exoplanet astronomy emphasizes two features: (1) that a planet is a body that orbits a star, and (2) that the upper mass limit – which lies at 13 Jupiter masses – is the demarcation line between planets and other celestial objects (Murzi 2007, 371). Beyond this threshold, the conditions in the object's core are sufficient for kickstarting of thermonuclear fusion, at least for a limited time (Seager 2010, 5–6).

However, the problems also lie on another end of the spectrum of potential masses. Since the early 2000s, discoveries of trans-Neptunian Kuiper Belt objects (KBOs) – especially 2003 UB 313 (also known as Eris) – problematized how planets in the Solar System had been understood up to then. Thus, at the edge of our Solar System, we begun encountering a new population of Pluto-like objects difficult to distinguish from the 'official' planets (Dick 2020, 506). To prevent uncontrollable explosion of the number of the planets, delegates at the annual congress of IAU held in Prague in August 2006 made a pragmatic move. They demoted Pluto to the status of 'dwarf planet' and adopted the resolution 5A IAU 2006, which defined a planet as follows:

> A 'planet' is a celestial body that (a) is in orbit around the Sun, (b) has sufficient mass for its self-gravity to overcome rigid body forces so that it assumes a hydrostatic equilibrium (nearly round) shape, and (c) has cleared the neighbourhood around its orbit. (IAU General Assembly 2006, 4)[2]

In this paper, this definition will be treated as a paradigmatic astronomical definition of a planet. Compared to the definitions in exoplanet astronomy, it offers deeper granularity, as it can filter out objects at the low mass threshold that may fail to be planets due to criterion (c). Beyond that, it has a great explanatory potential, since it offers valuable insights into the nature of many planetary features, mainly concerning relationship to the evolutionary history of solar system. In turn, it also encapsulates up-to-date knowledge about the formation of planets, and it allows to make predictions about their characteristic behaviour. Furthermore, by means of employing the three criteria, 5A IAU 2006 resolution fulfils a general requirement for the definition of the planet formulated by Alan Stern and Harold Levinson. They argue that if we were to define a planet based on a single sufficient feature, we would run into inevitable troubles, since there is no single property unique to a planet (Stern and Levinson 2002, 206–207). Think about criteria (a) and (b) in the IAU definition. As for (a), other objects orbit the Sun too, such as asteroids or comets. When it comes to (b), it simply states what kind of shape an object we call planet must have, although stars, pulsars or even some asteroids (e.g. Ceres) rest in hydrostatic equilibrium too. Hence, Stern and Levinson propose instead to focus on multi-criteria approach, 'a *classification algorithm*, a sieve, that allows one to test any given body and determine if it is or is not a planet' (Stern and Levinson 2002, 207).

Beyond its multi-criteria aspect, the most intriguing feature of the definition is criterion (c), which can be translated into simpler language as a criterion stating that a planet must be *gravitationally dominant* within its vicinity. It means that during early evolutionary history of the Solar System, each of the eight planets 'did a good job' in clearing out their neighbourhood, and so they 'earned' the status of the planet. This criterion finds its more technical articulation by Steven Soter:

> […] some bodies in the solar system are dynamically important enough to have cleared out most of the neighboring planetesimals in a Hubble time,[3] while lesser bodies, unable to do so, occupy transient unstable orbits or are preserved in mean motion resonances or satellite orbits. (Soter 2006, 2513)

A planet becomes a planet by virtue of undertaking a certain evolutionary pathway; what then makes planets truly distinguishable is their position in the overall architecture of a mature solar system. This position is linked to their gravitational influence on other bodies around the host star and determined by their evolutionary history. As Soter puts it, planets 'occur only in highly evolved (old) systems, which have reached the final cleanup phase of accretion, with the major bodies in stable nonintersecting or resonant orbits' (Soter 2006, 2518). They are thus 'symptoms' of a particular stage of the evolution of the given solar system.

IAU definition also highlights fundamental distinction between two kinds of criteria used for a definition of a planet: those based on *intrinsic properties* (e.g. mass, radius or physical processes sustained by the object, such as nuclear fusion) and those based on *dynamical context* (e.g. the stellar or galactic environment). The criterion (c) of IAU's definition is exactly the case of the latter – it is a *time-dependent* property that arises from the object's relation to its cosmic neighbourhood. To illustrate this point, consider some other salient feature of many planets, such as having a population of orbiting satellites. These satellites have not been in their orbits since forever, but the planet acquired them by gravitational capture, or they formed out of accretion after a catastrophic event (such as in case of Earth's Moon, formed after a collision between young Earth and a Mars-sized object, see Stern and Levinson 2002, 206). And just as a planet may acquire a satellite, it may lose it over time. The same holds for the presence of atmosphere: some planets have it, some do not, and some – such as Mars – lost it almost entirely (Seager 2010, 82). Similarly, the feature of gravitational dominance is time dependent since planets acquire and lose their position in their solar system's architecture over time (Soter 2006, 2517). What we encounter here is a classification of an object based on its history, which ultimately boils down to the changing context of the object's existence – hence the definition is based on *dynamical* context. Any solar system is such a dynamically evolving context wherein its different sub-components appear as standalone objects that are the manifestations of its maturation.

4. Philosophical implications of the astronomical definition

In the astronomical definition as codified by IAU, the meaning of the concept of the planet is linked to the evolutionary history of the object being conceptualized (Basri and Brown 2006, 211–212), which allows us to see the planets as transitory phases of cosmic matter featuring time-sensitive properties and oscillating between relative dependency on the context of their cosmic origin on the one hand (e.g. the energy dependence on the host star) and a degree of organizational autonomy on the other hand (gravitational role in the final phase of solar system's accretion, when asteroids or satellites are being formed). However, this autonomy is less an insulation from the outside, and more a constant negotiation of the planet's relative separation from the extraneous forces, meaning that the planet still needs – in the last instance – the context of the solar system for its existence. For that reason, it is important to maintain the viewpoint of a planet as a sort of cosmic exteriority – it arises out of the cosmic context as a temporary manifestation of gravitationally bound cosmic matter with emergent internal dynamics. Features of planets, such as the presence of atmosphere or its habitability, are conditioned by the series of contextual, ecological factors binding the planet to its extra-planetary environment. The strict separation between the planetary and the cosmic thus remains ontologically fragile.

4.1. Planets as structures of phase gradients

At this point, we also cross the boundary between the astronomical concept and its philosophical elaboration. What we encounter is a kind of thinking about a planet as a particular modality of cosmic exteriority. In case of small rocky planets such as Earth, it begins its existence by accretion of planetesimals into a compact object that assumes a stable, spherical shape (hydrostatic equilibrium), once the force of gravity overcomes the material strength of the proto-planetary body (Basri and Brown 2006, 197). By passing another milestone, when the gravitational energy of the body is strong enough to trigger solid state convection and chemical reactions in the object's interior, the object begins to alter its initial composition. This bootstraps a cascade of internal processes conditioning the emergence of new planetary layers, such as atmosphere and biosphere. Thus one can say that any planet's structure is a non-linear, heterogeneous stack of *phase gradients of matter*, ranging from metallic through solid or liquid to gas and vapour (plus its potential complex assemblages, such as carbon-based organic matter). Figure 1 illustrates this case in a visual diagram that stacks phases of different chemical elements in intermixed layers, starting with planetary cores and extending to uppermost portions of their atmospheres.

Evolutionary pathways of rocky planets in our Solar System may also help to understand what it means for a planet to be composed of different *phases* of matter. A particularly striking demonstration offers the history of Venus. Roughly 1 billion years ago, as the Sun's luminosity gradually increased, the ancient ocean of Venus transformed into a thick layer of water vapour in the atmosphere, which caused a runaway global heating followed by the atmospheric escape of water vapour due to photodissociation of hydrogen from oxygen, leaving the atmosphere of the planet rich in CO_2 (Gillmann et al. 2022).

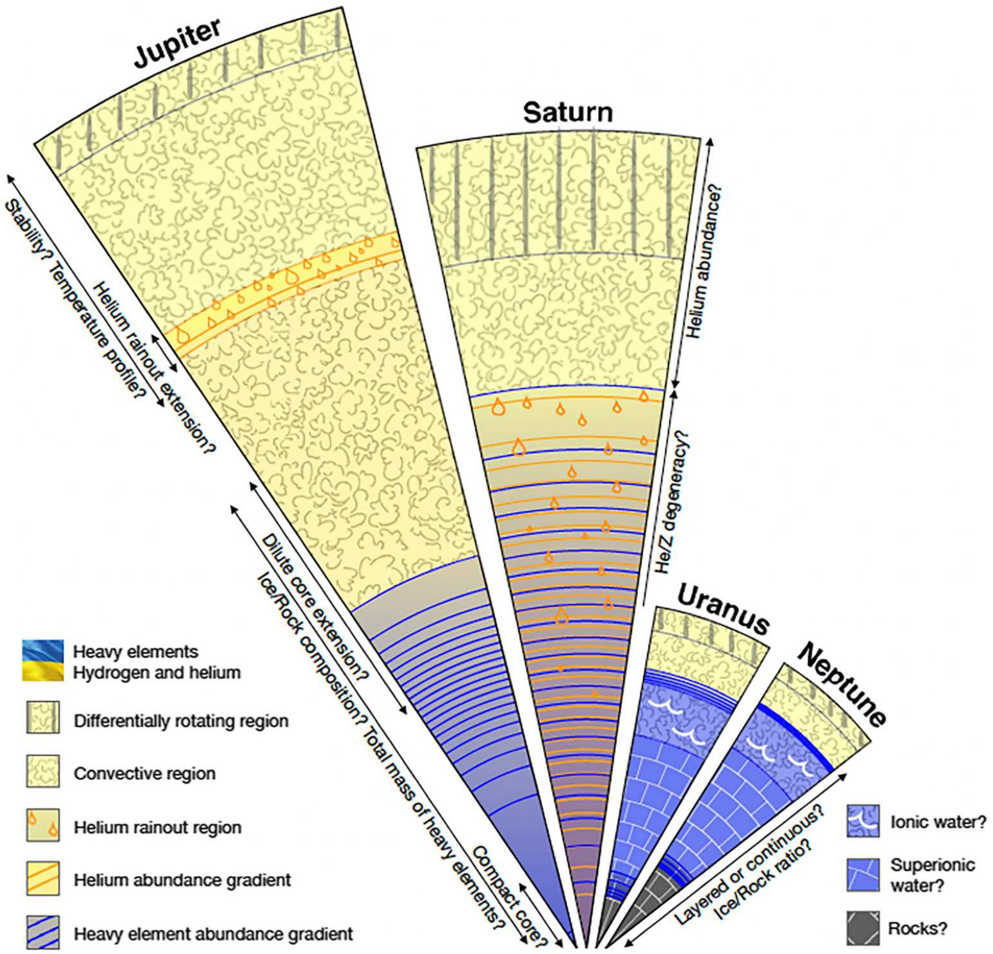

Figure 1. Vertical diagrams of the internal composition of our Solar System's gas giants (Jupiter and Saturn) and ice giants (Uranus and Neptune). Taken from Guillot et al. (2022, 3). The image contains vertical diagrams of the internal structure of Jupiter, Saturn, Uranus and Neptune. These diagrams look like sections of a palette or a fan, and each of them is composed of distinct layers that represent different phases of chemical elements that the planet consists of.

The phase transition of the significant portion of matter from which the planet had been composed led to an abrupt change in the planet's overall character. One can also think about these phase transitions in terms of the fundamental lesson from physics of gases: the relation between density, pressure and temperature. Where the pressure or the temperature on the Earth different, we would not be looking – as observers on its surface – at the atmosphere with clouds up in the sky, but for instance, on a giant planet-wide ocean (us located at its very bottom) or on an ice ceiling (just as the frozen crust of Jupiter's moon Europa).

4.2. Planets in expanded ecologies

As such, the presence of atmospheres is a great sign of the multiple interlocking procedures and phase transitions that planets sustain. An atmosphere is essential for clearly separating surface from the outer space by a layer of temperature gradient. It allows for the retention of incoming energy from the stellar flux, thus using the energy to warm up the planet, and it channels this energy into complex geophysical and geochemical phenomena such as winds, clouds, rock formation, hydrological cycle and so on. A special role in the creation of atmosphere is played by *greenhouse gases* such as CO_2, water vapour or methane, since these gases trap the outcoming radiation in the atmosphere and heat the planet (Pierrehumbert 2011, 5). The planet–stellar interaction mediated by the atmosphere thus can be interpreted in terms of an *expanded ecology* of the solar system: the planet interacts with its stellar context by maintaining and channelling the star's energy in the complex internal dynamics of atmospheric processes, approximated as a web of cosmic-ecological feedback loops.[4] The planet–star ecological relationship extends beyond the energy inputs: the host star is also the primary sculptor of its planetary system in gravitational terms, and it influences the planets by space weather phenomena including magnetic storms, stellar winds, changes in sunspots and coronal mass ejections (Aiapetian et al. 2020, 138–148). Since planets are formed from the same cloud of cosmic matter, the chemical composition of the star is also telling of what kinds of planets are likely to orbit it, as in the case of the correlation between the star's metallicity – i.e. the abundance of heavy elements relative to hydrogen or helium – and the occurrence of gas giants (Turrini et al. 2022, 236).

In case of rocky planets such as Earth, it is important to emphasize that the atmosphere must be actively maintained by the planet – the geological processes (tectonism, volcanism) must generate enough outgassing from the interior to keep the atmospheric heating machine running. Moreover, the production of the atmosphere must be complemented by the regulation of greenhouse gas concentrations by absorption processes such as carbonate–silicate weathering (Kasting, Whitmire and Reynolds 1993, 109–110). And what is more, an additional driver of atmosphere's composition and maintenance can be the presence of biosphere. As for Earth, the first evolved bacteria caused an increase in methane concentrations in its atmosphere. Later, when the first photosynthesizing microorganism appeared in Proterozoic, the series of oxygenation events transformed the composition of Earth's atmosphere close to its present state (Pierrehumbert 2011, 10–11). The existence of biosphere thus brings us to the question of planet's *habitability* for Earth-like life, which nicely dovetails with the expanded ecological vision of the solar system. Whether a planet is habitable is conditioned by a host of clearly determinable factors in terms of planet–stellar interaction, as well as in terms of organizational capacities and resources of the planet (atmosphere maintenance, temperature, the presence of rotating metallic core that generates magnetic field, existence of tidal forces, gravity, etc. – see Kasting, Whitmire and Reynolds 1993, 113–125; Kaltenegger 2017, 5–18). Moreover, consistently with the astronomical concept of the planet, habitability turns out to be a time-dependent, evolving feature. Each planet's habitability is just 'a snapshot in time' (Kaltenegger 2017, 447–449), conditioned by the series of contextual, ecological factors.

An additional factor that influences the categorization of any planet as habitable is of course the definition of life itself. Given the aim of this paper is to take a step towards a philosophical attitude on the planet imbued with a degree of genericity, it is crucial to adopt a sufficiently broad definition of life capable of accounting for unorthodox forms of living matter unlike anything we can encounter in terrestrial ecologies. For example, one can think about metabolic, reproductive and evolutionary aspects of organic matter through the prism of information theory as a process consuming and archiving information to pass it on. Hence, while constructing their generic definition of *lyfe* – a concept specifically intended to broaden the understanding of possible forms of life beyond the confines of terrestrial-based biology (and hence also terrestrially-*biased* biology) – Wong, Bartlett, Chen and Tierney (2022, 5–6) suggest to focus on information storage as one of the three pillars of lyfe's emergence, together with the presence of energetic driving force and combinatorial diversity of lyfe's basic building blocks. Such definition remains agnostic to the concrete chemical substrate of 'lyving matter' – it can be a carbon-based entity as well as silicon-based – and it allows the authors to articulate the key notion of *genesity*, designed to generalize Earth-centric definition of habitability. What type of substrates for the genesis of lyfe is available at the given planet is of course largely dependent on the cosmic-ecological factors – the chemical composition of accretion disc, the class of host star, etc. After all, a narrow definition of life is one of the principal limitations of any planetary perspective built around Gaia hypothesis mentioned earlier – it sits at the intersection of Earth-centric and life-centric viewpoints, thus disqualifying alternative, non-terrestrial planetarities, which are nevertheless indispensable for generic, cosmic ramification of the concept of the planet.

4.3. Planets as historical natural kinds

The interplay of the extraneous forces of the star and the emergent intrinsic dynamics of the planet leads to the kickstarting of multiple feedback loops that wrap up the planet into an environment gaining increasing degrees of autonomy from the outer space – the planet becomes less and less determined by the outside factors, and more and more governed by the processes of its making. This gradual separation of the planet's interiority from the cosmic exteriority is in fact the last step in the evolution of the planet as a standalone object in the architecture of the solar system. It marks the beginning of the phase when the planet exercises sovereign influence over its 'home turf' (its atmosphere, its surface, the gravitational neighbourhood). Just as the cell gradually separates itself from its immediate surroundings and develops a complex web of metabolic interactions with the environment (Rosslenbroich 2014, 39), the planet may be imagined as undergoing a similar kind of envelopment, led by the tendency to negotiate a stable set of interactions with the outside. Accordingly, recent publications in the astronomical community indicate such an evolutionary reading of the planetary history. Furukawa and Walker (2018) have adopted the language of *major transitions* employed in the context of evolutionary biology and applied it to the case of the emergence of new layers of the planet's system, such as biosphere and technosphere. Elsewhere, Frank, Grinspoon and Walker (2022) developed an evolutionary perspective that places intelligent life into the *long durée* of planetary history, wherein the primary unit of evolution is not species or life in general, but the planet itself.

Although thinking about planets in evolutionary terms may be for good reasons deemed problematic – especially because evolution can mean here at best change over time, not strictly speaking Darwinian evolution – we may distil one key insight from this approach: planets are not *natural kinds* defined by intrinsic properties (since their definition based solely on intrinsic properties is insufficient),[5] but *historical natural kinds* (Cleland, Hazen and Morrison 2021) – entities defined by extrinsic properties relative to evolutionary processes that create them. The analogy with a distinction between 'meteoroid' and 'meteorite' may be instructive here. While the former is a small rocky object orbiting Sun, the latter is a small rocky object of extraterrestrial origin that landed on the surface of our planet (Soter 2006, 2518). Although they can be the same object, their context clearly differs. What is more, there is an element of history, or of object's *lineage*, to be highlighted here. A meteorite needs to undergo a specific pathway to become one, which can be labelled as vaguely speaking 'evolutionary' – the meteorite 'evolved out' of a meteoroid as it changed the context of its existence by landing on Earth's surface. In a similar vein, a process of organism's growth (ontogenesis) follows a path-dependent trajectory that involves clear milestones determined by the changing context of the organism's existence, which in turn influences the categorization of an individual organism – as illustrated in case of mammals by the transformation of foetus to new-born individual, characterized by 'major transition' from internal environment before the birth to external environment after the birth. Defining an object based on the dynamical context – as 5A IAU 2006 resolution does – thus means to focus on the time-dependent properties which are endowed to the object by virtue of the environment the object occurs in.

That we arrive at such a historical-evolutionary perspective on a planet is not a small feat. First, it testifies to the role of history frequently attributed to ESS, where '[…] nonlawlike historical contingencies play an outsized role in the inductive reasoning' (Cleland, Hazen and Morrison 2021, 2). Second, it also means that one can think about astronomy as historical science that deals with long timespans way beyond human historical scales. The ultimate historical context of astronomy than may be cosmic evolution – *cosmogony* – with *planetogeny* and furthermore *biogeny* as its subchapters:

> […] the universe began in the Big Bang ∼13.8 billion y ago and subsequently went through an *ordered sequence* of many physicochemical stages, each of which added chemical and structural complexity to the cosmos, eventually producing planetary environments supporting the emergence of the first living things. (Cleland, Hazen and Morrison 2021, 7 [emphasis mine])

It is the long cosmic timespans that the notion of geological time invoked by the Anthropocene discourse is dealing with, and for that reason, we can stipulate that geological time is derivative from the cosmic perspective of the astronomical definition of the planet. In this definition, the planet is treated as an occurrence in the ordered sequence of singular historical context that contains the evolution of the solar system. This evolved system in turn presents the authentic environment that conditions the planet's being so and so. For this reason, there is a deep linkage we can stipulate between historical (dynamical) and ecological (contextual) dimension of the planet's astronomical conceptualization, captured by identifying the 'dynamical context' as the main factor that determines what a planet is.

5. Discussion: Planetary history in environmental humanities

The historical dimension implied by the astronomical concept of the planet has been recently spotted also by authors in environment humanities. For example, in his exposition of the theoretical implications of the removal of Pluto from the category of planets, Bronislaw Szerszynski observes that planets are path-depended, historical entities (2021, 219), and he compellingly narrates the evolution of planets as a story of Simondonian ontogenesis (Szerszynski 2021, 217). Elsewhere, he also discusses the motif of major transitions in planetary evolution with respect to the underlying idea of 'the combination of formerly distinct individuals into stable new evolutionary and ecological individuals', as illustrated in biology by 'the fusion of unrelated prokaryotes into the eukaryotic cell' (Szerszynski 2017, 96–7). Applying this approach to understand the ongoing energetic and material recombinations within biosphere and technosphere, he proposes to treat the major transition of the Anthropocene as a new kind of coupling between humans, non-humans, and technological infrastructures. Beyond these remarks, Szerszynski's collaborative work with Nigel Clark also shows motivation to engage with astronomy and ESS (Clark and Szerszynski 2021, 14–32; 77–81). Based on their recollection of the historical developments and key concepts in ESS's narrative of the Earth's geological past (Clark and Szerszynski 2021, 14–32), the authors nod at the contingent historicity of the Earth's evolution, citing Jan Zalasiewicz that 'the Earth seems to be less one planet, rather a number of different Earths that have succeeded each other in time' (Zalasiewicz cited in Clark and Szerszynski 2021, 6). This motivates the authors to think about the Earth through their concept of *planetary multiplicity*, which captures the planet's becoming otherwise, alongside with changing modes of its human inhabitation (Clark and Szerszynski 2021, 33). Echoing the above-discussed takes by Savransky or Deleuze and Guattari, this 'becoming otherwise' is further specified as the self-differentiating and transformative capacity of the Earth, which is moreover not exclusive to the Earth, but represents the specific mode of being of any planet (Szerszynski 2021, 205).

However, the difference between the astronomic concept of the planet and the treatment in Clark and Szerszynski lies in the underlying assumptions about the nature of history. According to them, planetary multiplicity brings 'a wide range of rhythms, intervals, periodicities and singularities' (Clark and Szerszynski 2021, 171), but these are in their view already the *products* of the temporalizing labour of the planetary multiplicity, which is not itself understood as an existence *within* history, cosmic or other: 'we conceive of planetary multiplicity not so much as acting in time, but as actively temporizing or *making* time', meaning that the 'planets generate their own futurity by breaking out of their past states – at every scale from the smallest molecular rearrangements to entire Earth system shifts' (Clark and Szerszynski 2021, 173). This means that with planetary multiplicity comes also relativization of geological time: it is no longer the temporality that pertains to the planet's evolutionary history, mobilized to pinpoint Earth's specific identity. Instead, the planet's evolutionary history is broken down into incommensurable temporal orders. That may not be problematic per se, but seen from the vantage point of the astronomical concept of the planet, it is exactly the singularity of any planet's evolutionary history in the dynamical context of its solar system – i.e. its unique lineage, expressed in cosmic and geological time – that determines the phase space of the planet's possible past, present and future states. In this sense, the layered composition of the planet diagrams a relation of past to the present, hinting at a limited range of trajectories of the planet's evolution based on its history. This relation is best visible in the dependency of the Earth's biosphere on pre-biotic conditions, as stated in Section 4.2: the planet's continuous presence in the habitable zone, relative stability of Sun's luminosity, the presence of magnetic field, sufficient gravity, tidal forces, atmosphere etc. As it were, the biosphere – the 'evolutionary younger' layer – emerges from the interplay of older planetary layers – lithosphere, atmosphere, magnetosphere, etc.

The astronomic concept of the planet thus leads to the full appreciation of any planet's *evolutionary path-dependency*, or in other words, of the *generative entrenchment* of the present and future conditions of the planet in the past evolutionary steps.[6] The sequence of the planet's states may remain in such reading contingent (e.g. there is no guarantee a planet in habitable zone with favourable set of basic parameters will develop a biosphere), but the range of its possible states is limited (e.g. a rocky planet with a mass of Mercury is only hardly capable to maintain rich atmosphere, given its weak gravity; therefore, the planet's possible states are limited to unstable, primitive atmospheres).[7] Beyond the case of Earth's evolutionary layers, another good illustration of such generative entrenchment represents the hierarchy of three phases of accretion in the formation of solar system (Soter 2006, 2517): *primary accretion* (formation of star), *secondary accretion* (formation of planets by accretion of planetesimals or gas condensation, see Basri and Brown 2006, 205–206; Turrini et al. 2022, 225–228), and *tertiary accretion* (formation of planetary satellites, asteroids, comets – see Soter 2006, 2513). In each of these three stages, the architectonics of solar system are gradually locked-in, and certain developmental pathways are ruled out. For example, if the primary accretion results in a birth of star with a very short Main sequence period (the period of star's energy production by nuclear fusion), it may not allow enough time for the evolution of biosphere on any of its planet. In a similar vein, the gravitational interplay of planets influences tertiary accretion, by means of parcelling out available space for formation of dwarf planets or asteroids.

While presenting his account of what does it mean to think in planetary terms, Dipesh Chakrabarty underscores how the cosmic perspective on the planet leads to a new understanding of history, albeit he does not phrase it in evolutionary terms: '[…] this planet reveals itself as an object of astronomical and geological studies and as a very special case containing the history of life—all of these dimensions vastly out-scaling human realities of space and time' (Chakrabarty 2021, 69–70). By distinguishing the category of the planet from the notion of *globality* associated with geopolitical historicity of colonial modernity, thinking about the planet as a historical entity means to decisively orient one's inquiry towards astronomy and ESS as the primary contexts of reference. Seen from the vantage point of the planet as a historical natural kind, Chakrabarty's intuition about the deep link between planetarity and the new register of history is thus certainly warranted. As previously mentioned, he underscores this viewpoint by the maxim of always already assuming the cosmic context of any philosophical inquiry regarding our planet, which he explicates in a following way:

> The [climate] science is not even specific to this planet; it is part of what is called planetary science. It does not belong to an earthbound imagination. […] Our current warming is an instance of planetary warming that has happened both on this planet and on other planets, humans or no humans, and with different consequences. It just so happens that the current warming of the earth is of human doing.
>
> The scientific problem of climate change thus emerges from what may be called *comparative planetary studies* and *entails a degree of interplanetary research and thinking*. The imagination at work here is not human centered. (Chakrabraty 2021, 67 [emphasis mine])

Let me underscore some parts of Chakrabarty's thinking in this quote. He talks about comparative planetary studies, or *comparative planetology*, which is an actual subfield of astronomy comparing different planets in terms of their chemical composition, mass, atmosphere or habitability (Kaltenegger 2017, 433–434). Yet, such a comparative endeavour can be flipped into humanities register – one can think about comparative planetology as a study of different planetary arrangements in terms of geopolitical architecture, socio-economic regimes, technological development, or philosophical and cultural imagination (Likavčan 2019), effectively comparing different versions of Earth resulting from alternating value systems guiding human individual and collective behaviour. Clark and Szerszynski also describe their project as a '*comparative and speculative planetology*' (2021, 93), but they do not provide more detailed account of what such a project means in their case. Chakrabarty's comments thus seem to be more useful in framing the consequences of a project of comparative planetology, by means of his suggestion to expand planetary thinking to the interplanetary context. Following the argument of this paper, such expansion may mean to enlarge the theoretical grounds of planetary thinking in environmental humanities by borrowing insights from contemporary astronomical research. The astronomical concept of the planet serves this purpose, which leads to the appreciation of any planet's historicity, its expanded ecological dependencies and the complex, layered nature of different matter-phase gradients that compose planetary atmospheres and interiors.

6. Conclusion

Even though different philosophical conceptualizations of the planet are possible, each of them comes with a baggage of basic commitments that render them useful in specific contexts. One can think about this position as a kind of pragmatic relativism, which allows to narrate the story of the planet from multiple angles without lessening their consequentiality. The story of the Earth as told by ESS and astronomy is just one among many, but stories exist in plural because they respond to different needs of communities that craft them.[8] When it comes to scientific narratives of the geological and cosmic time, these narratives respond to the urgency of finding the common ground for ecological action of all relevant actors combined. These narratives thus may prove to be useful in everyday struggles of climate scholars or activists, by locating them in larger historical context. The intention of this paper is to underscore that one of the useful functions of history is not just to assert change and difference – it comes with a promise that historical change can be explained and narrated, and that although it remains contingent, it does not mean it is impossible to pinpoint factors that influence and drive it. In my reading, it is exactly the question of evolutionary genealogy and mechanisms of planet's history, as well as the possibility of constructively placing human interventions within this history (e.g. by maintaining habitability of the Earth, as proposed by Chakrabarty 2019, 21–22), that the astronomical concept of the planet brings to the fore, and that justifies its place in environmental humanities alongside more speculative philosophical ramifications of the planet reviewed in Section 2 and Section 5. The astronomical concept of the planet thus works as a reminder of Chakrabarty's maxim that any invocation of the planetary potentially gestures towards astronomy.

Given these remarks, what are the possible uses of the astronomical concept of the planet? How may it influence the debate in contemporary environmental humanities? One of the central features of planetary thinking is that it marries the knowledge base of natural sciences with normative dimension of ethics and politics.[9] Astronomy can reinforce this normative traction by grounding planetary thinking in theoretical commitments designed to guide speculative propositions. Beyond the main commitment to the singularity of geological history, as discussed in detail above, another commitment lies in identifying basic geophysical and geochemical properties of planets as conditions of possibility of higher-order phase gradient layers – biospheres and technospheres. Here, the suggestion is to trace the deep history of life and technology back to their initial planetary site conditions, pre-biotic (in case of biospheres, see Spitzer 2021) and pre-technological (in case of technospheres, see Haff 2013). This would mean to treat life and technology as *symptoms* of planetary evolution, rather than as separate domains of existence, and to work on the projections of the pathways for their future viable evolution, including the limits imposed on them. Some philosophers, such as Stiegler (2018), have already developed foundational contributions that explicate technosphere–biosphere interactions on the crossroads of philosophy of technology, heterodox economic theories (e.g. Georgescu-Roegen's (1975) bioeconomics) and thermodynamics (as emphasized by Stiegler's neologism *Neganthropocene*). In turn, we may expect renewed interest of astronomers in the 'matters of concern' (Latour 2005) implicit in their scientific practice, and in the exploration of the environmental consequences of relevant astronomical disciplines, such as exoplanet astronomy, astrobiology or SETI (search for extraterrestrial intelligence). This would mean to engage in recursive 'gestures of cosmic relations' (Messeri 2017, 327): learning new things about our Earth and its adequate modes of human inhabitation by studying other planets in the universe. Such gestures may lead to especially valuable political and ethical propositions in environmental humanities, prompted by speculations on the possible fates of other intelligent creatures in the universe, or by the enlarging the scope of multispecies ecologies to extraterrestrial forms of life (Haqq-Misra and Baum 2009, Wong and Bartlett 2022).

To wrap up, we can rephrase the main insights of the astronomic concept in the following terms: planets are historical natural kinds, which can be characterized in terms of their structure as heterogeneous phase gradients of (cosmic) matter. Their evolution, features and dynamics are embedded in the larger context of their host solar system, and they maintain only a relative degree of separation from the cosmic exterior. For this reason, they can be treated as involutions of cosmic exteriority, which remain highly dependent on the solar system's expanded ecology, in terms of planet–stellar interaction involving energy transfers or solar weather. Beyond that, the astronomic concept of the planet leads us to appreciate astronomy as a science deeply aware of the historicity of its objects. Chakrabarty underscores this by recalling words of Oxford philosopher Robin Collingwood: 'modern astronomy … gives us a celestial history' (Collingwood cited in Chakrabarty and Latour 2020, 446). Furthermore, being contextually sensitive is astronomy's epistemic virtue, since paying attention to the environment of planet's formation is a decisive factor in understanding the mode of existence of this astronomical object. Hence, we can claim that planets are historical natural kinds with singular – albeit contingent – genealogy, embedded in the evolutionary history of their host solar system. What we achieve by such reading is a coherent picture of what a planet is, spelled out through commitments that allow us to construct philosophy *of*, *for* and *with* the planet, with potential to develop new normative framework to tackle the interlocking emergencies of the Anthropocene.

Notes

1. In a different context, one could also refer to the wave of vitalist tendencies in new materialist philosophies (e.g. Bennett 2010).
2. Dwarf planets – such as Pluto – do not fulfil criterion (c), see Messeri (2010, 189).
3. *Planetesimals* are the initial aggregates of cosmic matter that coalesce in the proto-planetary disc around the young star. *Hubble time* is the time the universe needed to expand to its present state. This rather long timescale allows to account for different possible lifespans of host stars (Stern and Levinson 2002, 208).
4. This expanded understanding of ecology echoes remarks of some environmental humanities authors that have ventured into the realm of outer space studies, see Helmreich (2017, 304–305).
5. For detailed explanation of why intrinsic criteria are not sufficient, see Stern and Levinson (2002, 206). Additional arguments against treating planets as natural kinds have been formulated in Murzi (2007, 368–371).
6. For explanation of generative entrenchment, see Schank and Wimsatt (1986).
7. Analogously, we can think about stellar evolution as contingent historical process with limited set of recognizable and repeatable pathways. *Hertzsprung–Russell diagram* (H-R diagram) represents a plot of stars categorized according to their luminosity and colour spectrum, diagramming at the same time a virtual space of their possible evolutionary forms (Pierrehumbert 2011, 22–24). Applied to the case of planets, one can then speculate about H-R diagram of possible planetary states and their sequences.
8. Compare to Bawaka Country (2015).
9. This is well exemplified by Spivak (2012, 340–343), who treats the planet as an enigma of *alterity*, an ethical-political Other that confronts humans with imperatives and obligations. Her proposition works well in the context of the astronomical concept of the planet since it maintains the planet in the register of cosmic exteriority.

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